INTERNATIONAL UNION OF CRYSTALLOGRAPHY

IUCr Newsletter

Volume 31 · Issue 2

Collected archival edition
Original article text and available illustrations

Contents

Letter from the President

So long ... till Melbourne! 4

Letter to the President

Continuing support for Ukrainian scientists 6

Editorial

Editorial 8

Letter to the President

Who owns crystallography? 10

Feature article

Golden Oldies and their continued role in education 12

Editorial

AlphaFold and the future of structural biology 15

Crystal structure prediction: achievements and opportunities 19

Fourth-generation light sources 23

IUCr journals news

New Section Editor of Acta Crystallographica, Section B 26

Introduction to the virtual thematic issue on room-temperature biological crystallography 27

Commentary

Mapping structural correlations in real space 31

How much do molecular shapes matter? 34

The study of mineral behavior at low and high temperatures and their properties using a combination of different methods has not become routine yet 41

Unravelling the secrets of multi-domain lytic polysaccharide monooxygenases (LPMOs) 44

Continuous development in macromolecular crystallography with CCP4 47

Feature article

Pauling's rules revisited 49

IUCr Congress

IUCr 2023 – virtual registration now open 52

Women in Crystallography project 53

Regional news

Recent news from the European Crystallographic Association 56

Meeting report

24th Heart of Europe Bio-Crystallography meeting 58

Meeting report (IUCr supported)

19th BCA/CCG Intensive Teaching School in X-ray Structure Analysis 60

Meeting report

Third International SAXS excites 2023 Symposium 65

Meeting report (IUCr supported)

Hot Topics in Contemporary Crystallography 5 (HTCC5) 67

Eighth International School on Biological Crystallization 70

58th Course of the International School of Crystallography – Structural Drug Design 2023: Biology, Chemistry and Computers 79

Meeting report

29th Slovenian–Croatian/Croatian–Slovenian Crystallographic Meeting 82

Notice

CCDC news and updates 84

History of crystallography

A hall of fame of crystallographers and related scientists 86

Awards and prizes

Erwin Félix Lewy Bertaut Prize for 2023 96

ECA SIG4 Publication Award for 2023 97

Obituary

Uri Shmueli (1928–2023) 99

Jimpei Harada (1931–2023) 102

André Authier (1932–2023) 106

David G. Watson (1934–2023) 108

Aldo Félix Craievich (1939–2023) 110

Carles Miravitlles (1942–2023) 115

Book review

How Science Runs – Impressions from a Scientific Career. By Eric J. Mittemeijer 121

Press release

Kirara service for high-quality protein crystal growth in microgravity 123

IUCr supported events

IUCr supported meetings 126

Meetings calendar

Meetings calendar 127

LETTER FROM THE PRESIDENT

So long ... till Melbourne!



Hanna Dąbkowska

It is summer already and, at the time of writing this Letter, we are only 50 days from the beginning of the 26th IUCr Congress in Melbourne. I often visit the Congress website and smile back at Michael Parker, the Chair of the Organizing Committee, and Brendan Kennedy, the Program Chair. They both look relaxed and in a very good mood, but it is well understood how much work and stress lies behind the organization of such an event. Unlike all the other IUCr Congresses, the Melbourne teams had only two years to prepare the venue, usually prepared in three. It is a very big difference and the effort is very much appreciated.

This is my eighth and last Letter. I am grateful to those of you who have commented on my Letters and encouraged me to continue. In these Letters I have tried to highlight what has been happening in different parts of our community. Staying positive is not easy in these challenging times – but now I realize that it never was. Natural cataclysms and man-made wars and conflicts add to the stress we all have to deal with. Fortunately, with COVID-19 now in the back mirror, we can concentrate on implementing the vision for the future. This is what the IUCr Commissions will be suggesting during their discussions with the IUCr Executive Committee (EC) in Melbourne. This is what the IUCr General Assembly (GA) will be discussing as well.

To understand what is happening around us, the EC will also be listening to the reports of IUCr Representatives to other organizations (ISC, CODATA, COSPAR, IOCG, IUPAC, ICTNS, ISO). All these organizations face similar challenges to those faced by the IUCr – we all have to promote new, emerging science and embrace different ways to approach research, learning and teaching. We have to encourage the inevitable change of generations and the important fact that many more people from around the world are making their input ... . There is a lot of unknown in the future: How should ethical problems be addressed? Will artificial intelligence help in solving today's questions? Are we creating a better world for the future of humanity? Are we moving too fast? Too slow? For sure crystallography is in the background of many innovations. Are we only solving the imposed problems or are we being really creative like our Prize winners, proposing new questions (and answers) for science? How are we dealing with new (and old ...) challenges? How can we stop “for-profit” journals (and travel sites!) taking a bite from our income or some pseudo-scientific groups announcing “crystallographic” meetings in suspiciously attractive places? No President or EC or even GA can answer these questions. But we all have to be aware of them and not be misled.

Fortunately, the IUCr is blessed with an active, international community of leaders in many corners of science, a loyal staff and an excellent reputation. Our schools, conferences, workshops and OpenLabs teach new generations of structural scientists, providing a good background and understanding of crystallography for future leaders in such diverse areas as solid-state physics, materials science,

chemistry, structural biology and pharmaceutical research. We are well positioned to be successful in the near future and in the next 75 years of this organization.

Of course to achieve it all, the IUCr needs a lot of support from all of us volunteers: teachers, lecturers, organizers, leaders. Aside from our “day jobs”, we work to prepare meetings, schools, congresses. We dedicate our time assessing applications, refereeing papers, attending meetings around the world.

Being a scientific union we try to be as non-political as possible but at the same time we have to declare our position in addressing injustice in the world and promoting a better and safer environment for our meetings and well beyond. We have no direct influence over devastating forest fires or tornadoes around the world but we can actively help to develop vaccines and cures for known and not so well known diseases. We are essential in the search for new, technologically important materials, assessing resources and in investigating the behavior of materials in extreme conditions – opening the door for limitless future explorations. We understand our own strengths, but more action is needed. We need to project our values to other communities, so the name Crystallography means something. It meant a lot 75 years ago, it meant progress. Now it is time to decide – are we sticking to this name or are we changing it to something more appealing to the new generation – like Structural Science perhaps?

To be able to proceed and promote our research we need to actively support IUCr Journals. This means publishing our best results in these journals, citing the published papers and confirming that they are available in our universities and company libraries. I stressed many times that unlike our main competitors, all the surplus income generated by our journals goes to supporting future crystallographers to attend schools and meetings.

I apologize for not visiting as many conferences and meetings as some of my predecessors. This was partially because of the lingering COVID threat at the beginning of my term. Despite many invitations I did not manage to attend any African meetings in person, but I am extremely happy to be the President connecting the African Crystallographic Association (AfCA) to the IUCr. And I am immensely grateful to the many of you who worked so hard to achieve it. I am very sorry that Professor Claude Lecomte, Chair of the Steering Committee for the IUCr Crystallography in Africa initiative, is not able to join us in Melbourne. I hope he will come and celebrate the African success with us at the next Congress in Calgary.

And here I would like to end my Letters. I want to thank you all for trusting me with this fascinating job and I am also very grateful to a long line of people who helped me over these two years and who helped this Union to flourish.

I am looking forward to seeing many of you in Melbourne, please stay safe.

LETTER TO THE PRESIDENT

Continuing support for Ukrainian scientists



Marek Konarzewski

Dear Professor Dabkowska

I would like to express our sincere thanks for your continued cooperation with our Academy. We are particularly grateful for your support of our programs for Ukrainian researchers fleeing war zones.

The Polish Academy of Sciences has taken a number of steps to support scientists from Ukraine. As early as 1 March 2022, we launched a short-term program to enable scientists who had left Ukraine to conduct research in the institutes of the Polish Academy of Sciences. In total, we hosted 192 Ukrainian fellows for up to 10 months. The total expenditure for this purpose amounted to 5.8 M PLN. Nearly 84% of PAS fellows were women scientists, which makes our programs one of the most notable endeavors also in this respect.

Throughout the year, we organized 9 training opportunities in English and Ukrainian addressed to Ukrainian scientists. In total, nearly 600 participants attended these workshops.

All of the above would not be possible without intensive cooperation between the academies and international scientific organizations in Europe and beyond. We thank you for all your support and assure you that in 2023 our Academy will continue to pay our membership dues as we always did in the past.

Yours sincerely,

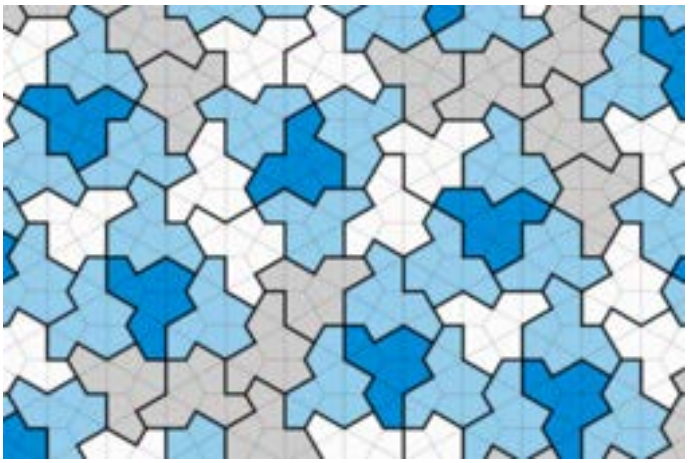


Marek Konarzewski


PAN
President
Polish Academy of Sciences

EDITORIAL

Editorial



Mike Glazer

As we are now in summer here in Europe, we are turning our thoughts to the IUCr Congress to be held in August in Melbourne, Australia, where it will be winter. Our international congresses take place every three years and always attract a large number of participants. The IUCr Congress is a great place to be as this is where you can hear about the vast range of topics covered by crystallography, meet others, and often form valuable collaborations. Despite its time of year, the Melbourne arrangements look great, and I look forward to attending. I intend on the way to spend three days in Singapore, one of my favourite stopovers, before flying on to Melbourne, first of all for the IUCr Finance Committee meeting. By the time this issue of the *IUCr Newsletter* appears, the Congress will almost be in full swing.

Our subject, crystallography, one of the oldest of scientific disciplines, continues to throw up surprises. For most of the time, it was accepted that what defines a crystal is connected with the concept of periodicity, namely that groups of atoms repeat in an ideal crystal in much the same way as one can tile a floor with single shapes (or monotiles). This concept of periodicity led crystallographers long ago to believe that the symmetries of these shapes must be confined to two-, three-, four- and sixfold rotations (the so-called Crystallographic Restriction Theorem). Then, along comes Dan Shechtman, who spoilt all our cherished views when he found that crystals do exist with five- or tenfold symmetries, a discovery that earned him the Nobel Prize in 2011. This discovery, which is now accepted, but admittedly after some resistance, raised the question of how you can tile a floor without leaving gaps using local fivefold symmetries. The famous Penrose tiling is an example where this problem is solved by using two shapes. The result is what is called an aperiodic array, *i.e.* one that never repeats but becomes periodic in a higher-dimensional space.

Mathematicians are quite happy with that, even though we may find it challenging to get our heads around higher-dimensional space! Now since then, mathematicians have been wondering if it is possible to have a tiling still consisting of a single shape that is infinitely aperiodic. Such a shape has been labelled the “Einstein” shape. But then, to everyone’s surprise, just last year, a retired print technician, David Smith, discovered such a shape based on divisions of a hexagonal periodic array. This shape has now been called the “Hat”. Symmetry enthusiasts have become so excited by this discovery that they have convened a special conference in Oxford, UK, in July called the “Hatfest”, celebrating the discovery of an aperiodic monotile. The conference will include some of the world’s leading authorities on symmetry. I hope to have a report on the meeting in the next issue of the *Newsletter*.

Why is this important for us humble crystallographers? Well, the existence of aperiodic crystals found by Shechtman meant that we have had to revise our long-held understanding of crystals. So, is it possible that genuine aperiodic crystals may exist out there with symmetry using monotiles? That an amateur can make such a discovery shows that we don’t have to be experts in crystallography to make important

contributions to mathematics and science. It even made the national press! By the way, you can experiment with the “Hat” yourself here.

In this issue of the *Newsletter*, we have a number of contributions. Mohan Bhadbhade considers the importance of molecular shapes and how they stack together in a crystal. Piero Macchi raises an interesting question in a letter about who actually “owns” crystallography – well worth a read. Do send in any thoughts yourself.

David Brown, well known for his work on bond valence theory, has provided an article explaining the concept and how it relates to the so-called first rule of bonding due to Linus Pauling. Also, as has become something of a tradition now, the Hargittais have submitted another nice article, this time on the wonderful Earth Science Museum based within Moscow State University. Do take a look at their introductory comments on the terrible situation right now between Russia and Ukraine.

Also, take a look at the “Golden Oldies” where 10 significant past publications in crystallography have been highlighted.

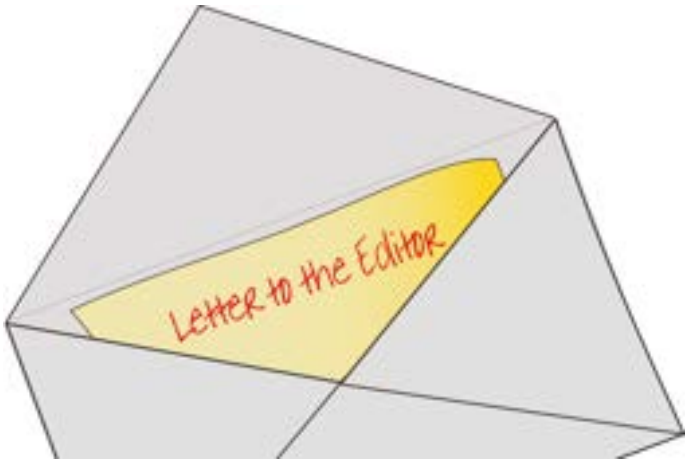
As usual, I have the sad task of reporting on the deaths of several colleagues, well known to many of us. Uri Shmueli (Israel) was a good friend of mine. We first met at a European Crystallographic Meeting, and we spent the day together, walking and chatting. He told me the story of his childhood during the Second World War in his home city of Kraków, Poland, and how he experienced concentration camps such as KZ Mauthausen (see his memoir here). I recall saying to him that he should return to Poland to see how it had changed, but his bad experiences from that time were such that he was afraid of doing that. However, several years later, when we had the European Crystallographic Meeting in Kraków, there I saw him in a restaurant, beaming from ear to ear. He had taken my advice and had been visiting all his old haunts, including where he used to live. He found everyone to be kind and welcoming, and he was generally having a great time.

We also have an obituary for Jimpei Harada (Japan), well known for his work on diffuse scattering from materials undergoing phase transitions. Because of a common interest in the structures of perovskites, I first came to know him when he was working on electron diffraction with the great Goro Honjo in Japan. The formidable André Authier (France), one-time President of the IUCr, was one of the world’s leading greatest experts in the dynamical theory of diffraction. Much decorated, he was especially proud of his achievement in receiving the Légion d’Honneur. His book on the history of crystallography, *Early Days of X-ray Crystallography*, is a significant contribution and I strongly recommend it to you.

Others who have left us and are commemorated in this issue are Aldo Craievich (Argentina/Brazil), Carles Miravitlles (Spain) and David Watson (UK), all well known in our community.

LETTER TO THE PRESIDENT

Who owns crystallography?



Piero Macchi

This, to me surprising, question was asked during an ECA lunch webinar by the lecturer. The lecture was thought-provoking, and this was the first provocation. However, the true shocks were the answers. Many people wrote that it belongs to “everybody” (the answer expected by the lecturer). Few, including myself, wrote “nobody”. Some started kidding, with answers like “Mike Glazer”! I have a long-term strong admiration for Mike, as a scientist and intrepid aviator, and I found myself thinking that if he really owned it, crystallography would probably be in a much better state.

Others wrote “Lawrence Bragg”. Not so sure if that was also a joke, in keeping with the common misconception of considering crystallography synonymous with X-ray diffraction and therefore recognizing Bragg as the father of crystallography, whereas he certainly was not. There is an additional misconception, which is that the science produced by someone belongs to that person.

Let us come back to “everybody” and “nobody”, though. While the lecturer answered me that this is basically the same, I strongly disagree. Saying that everybody owns crystallography means that none has a *golden* share. Saying that nobody owns it means that none has a share.

So the question is: can anyone own (a) science?

No!

The United Nations Educational, Scientific and Cultural Organization (UNESCO) has included in the list of Intangible Cultural Heritage a number of arts and techniques, but has not included any science and will not include it even though the list is growing at a rapid pace.

Why?

Because there is an enormous difference between paternity/maternity and ownership. To me, saying that someone owns science is almost like saying that someone owns a human being. Nonetheless, every human being has a mother/father. When a mother or a father says “my son/daughter” does not imply his/her possession (and when this unfortunately occurs, it is a crime). To avoid the ambiguity, though, it would not help saying that the son/daughter is owned by everybody!

Similarly, to avoid the ambiguity in the pronouns (I, we, our group did this research…) or in the adjectives (my, our science…) it does not help saying that the science is owned by everybody.

While this could be merely semantic, the next step in the lecturer’s presentation was that “taxpayers” could be science owners because of their financial contribution. Now it becomes clear that it is not just semantics. Apart from the fact that “everybody” and “taxpayers” are not synonymous…. the implication of taxpayers owning science is extremely dangerous.

Let us see it from a different perspective. Taxpayers in some (developed) countries contribute with their taxes to the national health system. Does it mean that they own the national health? No, at most, they collectively own hospitals, medicines, and instruments, but not the health.

The same holds true for culture. Thanks to taxpayers, we build schools, libraries, research centers and universities; we buy books, instruments, chemicals, and software. This does not mean that taxpayers own the culture, the ideas exposed in those books, the knowledge produced with those items, in other words, the science. If that were so, research would no longer be free, the worst sin that scientists could commit (see Bertold Brecht, Lebens des Galilei).

This is the reason why I think that messages like that launched in the ECA webinar, and often proposed by politicians and decision-makers, strongly and negatively affect scientific research, in crystallography as well as in any other science. I am surprised that many colleagues do not realize this threat, and I sincerely hope that they would reconsider their answers (or better that they would consider the title question to be not acceptable at all).

Science progresses because research is free, and research is free because nobody owns science.

I thank A. Guagliardi, N. Masciocchi, V. Meille, and A. Sironi for helpful discussion.

FEATURE ARTICLE

Golden Oldies and their continued role in education



Chiara Massera, John R. Helliwell

Acta Crystallographica Section E: Crystallographic Communications has recently launched a special virtual issue on *Modern approaches and tools for teaching crystallography* (edited by G. Diaz de Delgado and S. Perkin), introducing a new category of articles aiming at education matters, including "*experiences of teaching in a pandemic and accessing diffraction equipment remotely, as well as practical advice on all aspects of crystal structure determination*" (read the Foreword here). Whereas *Acta E*'s education articles focus particularly on chemical crystallography, our paper, which highlights ten seminal crystallographic articles, is obviously much broader, being across the science disciplines and also including the philosophy of science (Massera & Helliwell, 2023).

We should explain first why we wrote this Golden Oldies article. Quoting from it: "*One of us (CM) had the idea and invited JRH to join in. We had already discovered our similar approaches to our science, of using multiple methods to move beyond the precision of one method alone (crystallography) and reach accuracy when we both taught at the European Crystallography School 6 ('ECS6 Budapest'). Yet our areas of science were distinctly different, smaller and bigger molecules, respectively, and thereby nicely complementary for this article. The choices of these publications are inevitably our personal ones. We first opted for those authored only by individuals who are no longer with us. This is a neat mechanism to minimize the risk of losing our friends. Secondly, a maximum of ten articles is going to be woefully inadequate, so we foresee a series of future articles from colleagues who will make their own top ten selections. As our overall aim is education, with a historical focus, we draw attention to the article by Jenny Glusker (1998) 'The teaching of crystallography: A historical survey'; her selection of references provides an independent suite of examples*". For each of our choices, we created a new title that emphasizes how the paper's importance worked out from a present-day perspective and added a brief biographical sketch of the authors. We dedicated our paper to the memory of Olga Kennard for her contributions to disseminating quality data in structural science.

It became clear to us from the reactions of the editor, Graciela Diaz de Delgado of the Universidad de Los Andes Mérida in Venezuela, and the referees that they rather liked our article. That said, we did have to respond to some obviously learned comments from all three! Also, as one of us is on Twitter (@HelliwellJohn), the tweets about our article coming online attracted a lot of likes (>100) and views (>9000). Then there was an enthusiastic note about it on LinkedIn. At this point, thanks are due to the *IUCr Newsletter* Editor, Mike Glazer, for inviting us to write a short note to highlight our paper.

The ten articles we selected, following a historical timeline, are as follows:

Ewald (1969, but which is really 1912 to 1914) *Reciprocal space and Ewald's sphere*

W. L. Bragg (1913) *The first X-ray crystal structures*

Lonsdale (1929) *The determination of the planar structure of benzene*

Banerjee (1933) *The first description of a direct method of phasing*

Megaw (1934) *The nature of ice and the importance of collecting crystals in their mother liquor*

Bernal & Crowfoot (1934) *The initiation of protein X-ray crystallography*

Hughes (1941) *The first least-squares refinement of a crystal structure against its X-ray diffraction data*

Bijvoet *et al.* (1951) *Determination of the absolute configuration of optically active compounds by means of X-rays*

Okaya & Pepinsky (1956) *Solution of the phase problem by altering the X-ray wavelength*

Coppens (1977) *Charge density analysis to elucidate the nature of chemical bonding*

It proved a very interesting commission to write this article. Overall, we sought to describe where in the philosophy of science each article fitted. A paradigm shift, maybe? We assigned this accolade to W. L. Bragg and his 1913 paper on the alkali halide crystal structures (Fig. 1).

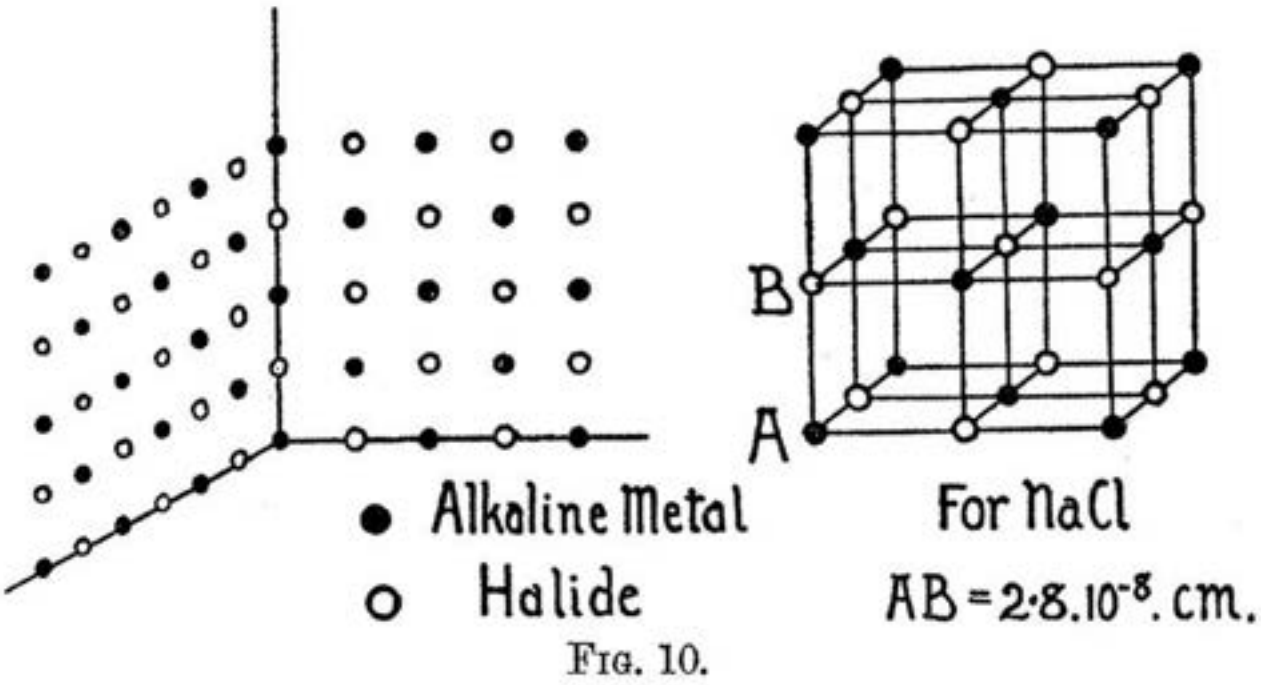


Figure 1. The three-dimensional structure of the alkali halides (Fig. 10 in Bragg, 1913).

Mainly we thought our chosen articles were examples of incremental science, although rather large increments and maybe even leaps forward. They were articles that were examples of science pull, even well ahead of their time, as well as technology push. We tried to convey the scientific context in which all this crystallographic research was conducted, and we also noticed the importance of community agreed standards, *i.e.* consensus, such as the IUCr *checkCIF* and the PDB Validation Report procedures. These had been developed by extensively discussing topics and challenges together in the IUCr Journals and the IUCr Commissions, as well as the PDB's Expert Advisory Groups.

Suffice to say we hope that you enjoy our article.

References

Banerjee, K. (1933). *Proc. R. Soc. London Ser. A*, **141**, 188–193.

Bernal, J. D. & Crowfoot, D. C. (1934). *Nature*, **133**, 794–795.

Bijvoet, J. M., Peerdeman, A. F. & van Bommel, A. J. (1951). *Nature*, **168**, 271–272.

Bragg, W. L. (1913). *Proc. R. Soc. London Ser. A*, **89**, 248–277.

Coppens, P. (1977). *Angew. Chem. Int. Ed. Engl.* **16**, 32–40.

Ewald, P. P. (1969). *Acta Cryst*. A**25**, 103–108.

Glusker, J. P. (1998). *Acta Cryst*. A**54**, 707–715.

Hughes, E. W. (1941). *J. Am. Chem. Soc.* **63**, 1737–1752.

Lonsdale, K. (1929). *Proc. R. Soc. London Ser. A*, **123**, 494–515.

Massera, C. & Helliwell, J. R. (2023). *Acta Cryst*. E**79**, 580–591.

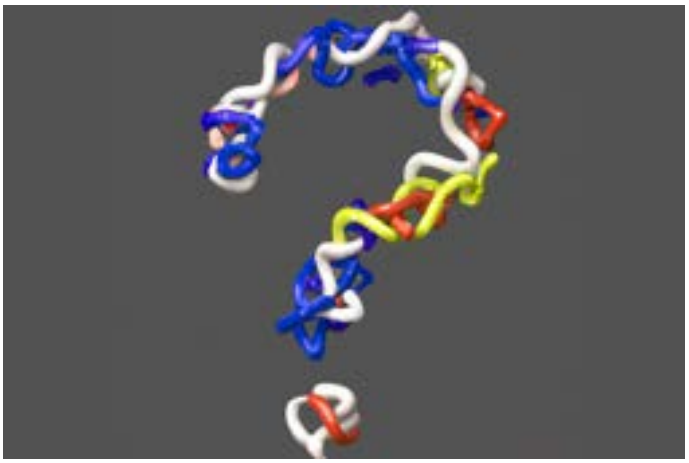
Megaw, H. D. (1934). *Nature*, **134**, 900–901.

Okaya, Y. & Pepinsky, R. (1956). *Phys. Rev*. **103**, 1645–1647.

Chiara Massera is at the Dipartimento di Scienze Chimiche, della Vita e della Sostenibilità Ambientale, Università di Parma, Italy (chiara.massera@unipr.it), and John R. Helliwell is at the Department of Chemistry, University of Manchester, UK (john.helliwell@manchester.ac.uk).

EDITORIAL

AlphaFold and the future of structural biology



Randy J. Read, Edward N. Baker, Charles S. Bond, Elspeth F. Garman, Mark J. van Raaij

The landscape of structural biology changed dramatically in 2020 with the emergence of the second version of the *AlphaFold* protein structure-prediction program (Jumper *et al*., 2021). Since then, structural biologists, and the many other scientists whose research is informed by knowledge of macromolecular structure, have scrambled to adapt. Much of the hype in both the scientific literature and popular media has indeed been justified: the current version of *AlphaFold* is astonishingly powerful, and it would be foolish not to make full use of it. Unfortunately, recent anecdotal reports suggest that some scientists reviewing grants and papers believe that *AlphaFold* is so powerful that it has made experimental structural biology redundant. There is clearly still a need for education about the strengths and weaknesses of current machine-learning methods for protein structure prediction, and the essential role that remains for experiment.

The advance in *AlphaFold* was unveiled at CASP14, the 14th edition of the Critical Assessment of protein Structure Prediction. For the first time in the history of CASP, the best models of protein targets were judged as being competitive with experimental structures in their backbone accuracy, almost independent of the difficulty of the modelling problem (Kryshtafovych *et al.*, 2021). Since then, other powerful machine-learning algorithms for structure prediction have emerged, including the first (Baek *et al.*, 2021) and second (Baek *et al*., 2023) versions of *RoseTTAFold*, *ESMfold* (Lin *et al.*, 2023) and *OpenFold* (Ahdritz *et al.*, 2022), an open-source reimplementation of *AlphaFold* including training code.

Within half a year of CASP14, the *AlphaFold* algorithm was made freely available through Google Colab notebooks, including a community-developed version (Mirdita *et al.*, 2022). Pre-calculated structures of a large collection of proteins from important genomes were made available through the AlphaFold Database at the European Bioinformatics Institute (Tunyasuvunakool *et al*., 2021), which has since been expanded to include about 200 million proteins representing most of the UniProt database (Varadi *et al*., 2022).

Structural biologists quickly embraced the advantages that these models bring (Perrakis & Sixma, 2021), including insights into improved construct design, the generation of compelling hypotheses about interacting proteins or domains, and the acceleration of structure solution by molecular replacement (Millán *et al*., 2021) for crystallography or docking for electron cryo-microscopy (cryo-EM). A particularly notable example was integrative modelling of the nuclear pore complex by combining *AlphaFold* (Jumper *et al*., 2021) and *RoseTTAFold* (Baek *et al.*, 2021) models with cryoelectron tomography and complementary data (Mosalaganti *et al.*, 2022).

Most structural biologists are aware that the models are not actually as accurate as experimental structures. The backbone accuracy measured in CASP does not ensure the accuracy of all coordinates including side chains. An objective evaluation of how well different models explain experimental diffraction data showed that experimental structures from alternative crystal forms (in spite of different crystal-packing interactions) are generally better than *AlphaFold* models (Terwilliger *et al.*, 2023). It has also been reported that *AlphaFold* models perform less well than experimental structures as targets for the computational docking algorithms used in drug design (Karelina *et al.*, 2023).

It is also important to remember that multi-domain targets in CASP are subdivided into 'evaluation units' when predictors fail to predict their relative orientations (Kinch *et al.*, 2021). Many *AlphaFold* models, including those submitted to CASP14, indeed have large errors in the relative orientations of domains.

The authors of *AlphaFold* acknowledge its limitations, and one of the great strengths of *AlphaFold* is its ability to assess its own accuracy: the predicted aligned error (PAE) matrix presents clear warnings when relative domain orientations are uncertain, and the predicted value of the local distance difference test or LDDT (Mariani *et al.*, 2013) statistic (pLDDT) correlates rather well with the actual local model accuracy (Jumper *et al.*, 2021).

The most serious limitations of *AlphaFold* and other machine-learning algorithms for structure prediction arise from the fact that they are based on learning patterns and know almost nothing about physics and chemistry. They can generate a single structure that is most consistent with the patterns they know about, but not a collection of alternative conformations that are influenced in their relative stability by factors such as pH, temperature or the binding of ions, other ligands or other proteins. For the foreseeable future, we will certainly need experiments to assess these effects. In addition, variants with amino-acid substitutions will satisfy the same patterns, even though such substitutions may destabilize the protein or change its conformation. Nonetheless, other algorithms exist that can use the *AlphaFold* model to predict the effects of variants on stability as accurately as with an experimental structure (Akdel *et al.*, 2022).

One of the most powerful aspects of experimental structural biology is the discovery of the unexpected, including the discovery of obligate cofactors and specific metal ions in structures, as well as structurally important post-translational modifications, including various kinds of spontaneous chemical cross-linking such as is observed in fluorescent proteins. Crystallography and cryo-EM will also give an answer to the question of stoichiometry of a homomer (or heteromer), while *AlphaFold*, despite valuable developments in multimer prediction (Evans *et al.*, 2022), still requires hypothetical stoichiometries to be tested.

Papers describing macromolecular structure-prediction algorithms and their use are welcome in the relevant IUCr journals: *Structural Biology* (*Acta Crystallographica Section D*), *Structural Biology Communications* (*Acta Crystallographica Section F*) and *IUCrJ*. For new structures, authors should bear in mind that the use of predicted structures as molecular-replacement models has already become standard practice, and papers describing the resulting structures must make new contributions to our biological understanding.

The field of structural biology and the nature of its challenges has, for the second time this century, undergone a major change. The resolution revolution in cryo-EM has allowed previously intractable systems to be studied at resolutions permitting '*de novo*' model building, but it has not made X-ray crystallography or NMR spectroscopy redundant (Kühlbrandt, 2014). In the same way, the major leap in structure prediction that *AlphaFold* has spawned does not mean that experimental techniques have suddenly become meaningless. As other commentators have said (Perrakis & Sixma, 2021; Kleywegt & Velankar, 2022), this change is accelerating progress and bringing us more power to address deeper questions, and we should embrace the new possibilities.

References

Ahdritz, G., Bouatta, N., Kadyan, S., Xia, Q., Gerecke, W., O'Donnell, T. J., Berenberg, D., Fisk, I., Zanichelli, N., Zhang, B., Nowaczynski, A., Wang, B., Stepniewska-Dziubinska, M. M., Zhang, S., Ojewole, A., Guney, M. E., Biderman, S., Watkins, A. M., Ra, S., Lorenzo, P. R., Nivon, L., Weitzner, B., Ban, Y.-E. A., Sorger, P. K., Mostaque, E., Zhang, Z., Bonneau, R. & AlQuraishi, M. (2022). *bioRxiv*, 2022.11.20.517210.

Akdel, M., Pires, D. E. V., Pardo, E. P., Jänes, J., Zalevsky, A. O., Mészáros, B., Bryant, P., Good, L. L., Laskowski, R. A., Pozzati, G., Shenoy, A., Zhu, W., Kundrotas, P., Serra, V. R., Rodrigues, C. H. M., Dunham, A. S., Burke, D., Borkakoti, N., Velankar, S., Frost, A., Basquin, J., Lindorff-Larsen, K., Bateman, A., Kajava, A. V., Valencia, A., Ovchinnikov, S., Durairaj, J., Ascher, D. B., Thornton, J. M., Davey, N. E., Stein, A., Elofsson, A., Croll, T. I. & Beltrao, P. (2022). *Nat. Struct. Mol. Biol.* **29**, 1056–1067.

Baek, M., Anishchenko, I., Humphreys, I. R., Cong, Q., Baker, D. & DiMaio, F. (2023). *bioRxiv*, 2023.05.24.542179.

Baek, M., DiMaio, F., Anishchenko, I., Dauparas, J., Ovchinnikov, S., Lee, G. R., Wang, J., Cong, Q., Kinch, L. N., Schaeffer, R. D., Millán, C., Park, H., Adams, C., Glassman, C. R., DeGiovanni, A., Pereira, J. H., Rodrigues, A. V., van Dijk, A. A., Ebrecht, A. C., Opperman, D. J., Sagmeister, T., Buhlheller, C., Pavkov-Keller, T., Rathinaswamy, M. K., Dalwadi, U., Yip, C. K., Burke, J. E., Garcia, K. C., Grishin, N. V., Adams, P. D., Read, R. J. & Baker, D. (2021). *Science*, **373**, 871–876.

Evans, R., O'Neill, M., Pritzel, A., Antropova, N., Senior, A., Green, T., Žídek, A., Bates, R., Blackwell, S., Yim, J., Ronneberger, O., Bodenstein, S., Zielinski, M., Bridgland, A., Potapenko, A., Cowie, A., Tunyasuvunakool, K., Jain, R., Clancy, E., Kohli, P., Jumper, J. & Hassabis, D. (2022). bioRxiv, 2021.10.04.463034.

Jumper, J., Evans, R., Pritzel, A., Green, T., Figurnov, M., Ronneberger, O., Tunyasuvunakool, K., Bates, R., Žídek, A., Potapenko, A., Bridgland, A., Meyer, C., Kohl, S. A. A., Ballard, A. J., Cowie, A., Romera-Paredes, B., Nikolov, S., Jain, R., Adler, J., Back, T., Petersen, S., Reiman, D., Clancy, E., Zielinski, M., Steinegger, M., Pacholska, M., Berghammer, T., Bodenstein, S., Silver, D., Vinyals, O., Senior, A. W., Kavukcuoglu, K., Kohli, P. & Hassabis, D. (2021). *Nature*, **596**, 583–589.

Karelina, M., Noh, J. J. & Dror, R. O. (2023). *bioRxiv*, 2023.05.18.541346.

Kinch, L. N., Schaeffer, R. D., Kryshtafovych, A. & Grishin, N. V. (2021). *Proteins*, **89**, 1618–1632.

Kleywegt, G. J. & Velankar, S. (2022). *IUCrJ*, **9**, 399–400.

Kryshtafovych, A., Schwede, T., Topf, M., Fidelis, K. & Moult, J. (2021). *Proteins*, **89**, 1607–1617.

Kühlbrandt, W. (2014). *Science*, **343**, 1443–1444.

Lin, Z., Akin, H., Rao, R., Hie, B., Zhu, Z., Lu, W., Smetanin, N., Verkuil, R., Kabeli, O., Shmueli, Y., dos Santos Costa, A., Fazel-Zarandi, M., Sercu, T., Candido, S. & Rives, A. (2023). *Science*, **379**, 1123–1130.

Mariani, V., Biasini, M., Barbato, A. & Schwede, T. (2013). *Bioinformatics*, **29**, 2722–2728.

Millán, C., Keegan, R. M., Pereira, J., Sammito, M. D., Simpkin, A. J., McCoy, A. J., Lupas, A. N., Hartmann, M. D., Rigden, D. J. & Read, R. J. (2021). *Proteins*, **89**, 1752–1769.

Mirdita, M., Schütze, K., Moriwaki, Y., Heo, L., Ovchinnikov, S. & Steinegger, M. (2022). *Nat. Methods*, **19**, 679–682.

Mosalaganti, S., Obarska-Kosinska, A., Siggel, M., Taniguchi, R., Turoňová, B., Zimmerli, C. E., Buczak, K., Schmidt, F. H., Margiotta, E., Mackmull, M.-T., Hagen, W. J. H., Hummer, G., Kosinski, J. & Beck, M. (2022). *Science*, **376**, eabm9506.

Perrakis, A. & Sixma, T. K. (2021). *EMBO Rep.* **22**, e54046.

Terwilliger, T. C., Liebschner, D., Croll, T. I., Williams, C. J., McCoy, A. J., Poon, B. K., Afonine, P. V., Oeffner, R. D., Richardson, J. S., Read, R. J. & Adams, P. D. (2023). *bioRxiv*, 2022.11.21.517405.

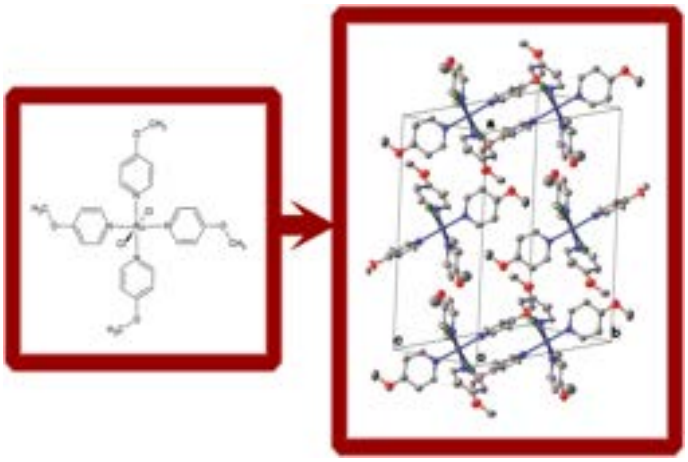
Tunyasuvunakool, K., Adler, J., Wu, Z., Green, T., Zielinski, M., Žídek, A., Bridgland, A., Cowie, A., Meyer, C., Laydon, A., Velankar, S., Kleywegt, G. J., Bateman, A., Evans, R., Pritzel, A., Figurnov, M., Ronneberger, O., Bates, R., Kohl, S. A. A., Potapenko, A., Ballard, A. J., Romera-Paredes, B., Nikolov, S., Jain, R., Clancy, E., Reiman, D., Petersen, S., Senior, A. W., Kavukcuoglu, K., Birney, E., Kohli, P., Jumper, J. & Hassabis, D. (2021). *Nature*, **596**, 590–596.

Varadi, M., Anyango, S., Deshpande, M., Nair, S., Natassia, C., Yordanova, G., Yuan, D., Stroe, O., Wood, G., Laydon, A., Žídek, A., Green, T., Tunyasuvunakool, K., Petersen, S., Jumper, J., Clancy, E., Green, R., Vora, A., Lutfi, M., Figurnov, M., Cowie, A., Hobbs, N., Kohli, P., Kleywegt, G., Birney, E., Hassabis, D. & Velankar, S. (2022). *Nucleic Acids Res*. **50**, D439–D444.

This article was originally published in *Acta Cryst.* (2023). D**79**, 556–558; *Acta Cryst*. (2023). F**79**, 166–168; and *IUCrJ* (2023). **10**, 377–379.

EDITORIAL

Crystal structure prediction: achievements and opportunities



C. Richard A. Catlow

The role of computational modelling in structural science was discussed in an Editorial in 2020 (Catlow, 2020). The field is, however, evolving rapidly and it is timely to return to the theme of structure prediction, starting with the celebrated quotation from the News and Views article of John Maddox, Editor of *Nature*, published in 1988:

One of the continuing scandals in the physical sciences is that it remains impossible to predict the structure of even the simplest crystalline solids from a knowledge of their composition.

The statement was of questionable accuracy but provided a powerful stimulus to the growing field of crystal structure modelling and prediction, with a response by the present author and Price, published in *Nature* two years later (Catlow & Price, 1990). The field was then reviewed twenty years after Maddox's article (Woodley & Catlow, 2008), and more recently by Oganov (2018) and Woodley *et al.* (2020). But how far has the community responded to the 'Maddox Challenge' over thirty years after it was first issued?

It is first necessary to recall the distinction between 'modelling' and 'prediction'. The ability to model crystal structures has a long history including the early work of Pauling. Then in the 1980s, it became clear that relatively simple interatomic potential models coupled with energy minimization procedures could model accurately the structures of a wide range of solids including silicates (Catlow *et al.*, 1982) and zeolites (Henson *et al.*, 1994); similar success was enjoyed in modelling molecular crystals. However, this was not prediction: it showed that transferable potentials would generate an energy minimum structure that was close to that experimentally observed; and this capability could help in refining structures. But prediction requires a search of the configurational space spanned by the structural variables to identify regions, which may correspond to stable structures, and which can then be refined by minimization of the energy calculated either using an interatomic potential model or using quantum mechanical techniques.

The exploration of energy landscapes is a major field of theoretical and computational science with crystal structure prediction being one key area. Notable progress was made in structure prediction for inorganic materials by Jansen and Schön who explored energy landscapes using simulated annealing techniques, reviewed by Schön & Jansen (2009). In a series of studies, Woodley and co-workers have shown the power of Genetic Algorithm methods in structure prediction (Lazauskas *et al.*, 2017). Successful predictions have been made in several cases by the simple expedient of generating a large number of random configurations which are then subjected to energy minimization with the resulting

lowest energy structure being the predicted structure [see, for example, Pickard & Needs (2011)]. The approach is compared with search methods by Woodley & Sokol (2012).

Different types of crystal structure may need different methods. For network and framework structures, topological principles may be used – an approach that has a long history going back to the early work of Wells (1954). It has enjoyed considerable success in the field of structure prediction in microporous materials as illustrated by Bell, Klinowski, Treacy and co-workers [see, for example, Foster *et al.* (2004) and Treacy *et al.* (2004)]. While the very active area of molecular crystal structure prediction explores structural possibilities using packing algorithms. Recent developments in the field are reviewed by Price (2018), with the prediction of the structures of polymorphs of pharmaceutical compounds being of particular interest and importance.

This editorial cannot do justice to a large and increasingly diverse field and the interested reader should consult the articles cited and references therein. But what is the current status of the field and where are the opportunities and challenges?

Structure prediction methods can, of course, be extended to other areas of structural science, notably nano-particle structures, where recent illustrations include the work of Escatllar *et al.* (2019) using GA methods coupled with DFT refinement, which predicted the structures of magnesium silicate nano-particles of relevance to the study of the chemistry of cosmic dust grains.

The field continues to benefit from methodological developments. A major limitation of most methods used for CSP is the lack of information that they provide about the global structure of the lattice energy landscape: the pathways and energy barriers between predicted structures, and how structures group into superbasins. A recent article by Yang & Day (2022) analysing energy landscapes of molecular crystals applied a Monte Carlo approach to approximate energy barriers between crystal structures of known polymorphic molecules, showing how the results help us to understand the kinetic stability of high-energy structures.

Another interesting technical development is reported by Dickson *et al.* (2022), who examined systems with variable composition and were able to implement variable compositions within the runs while searching a space of compositions.

A further fascinating recent development is the work of Price & Price (2022), which offers insight into the sensitivity of organic crystal packing to the substituents, based on an analysis of 232 crystal structures of 'chalcones' with only one small substituent on each phenyl ring. Although most of each molecule was the (chalcone) molecular scaffold, remarkably there were over 170 different packings. The only large isostructural group was of 15 molecules with all substituents, mainly halogens, in the *para* position. How can such structural diversity be compatible with the molecules all having the same chalcone scaffold? This diversity is closely mirrored by the structures generated by a crystal structure prediction study of the unsubstituted chalcone. Hence the packing is dominated by the core, but since this has a wide variety of packings of similar stability, the packing changes required by the substituents produce a wide range of observed structures. There is little evidence for any crystal engineering principle of preferred chalcone scaffold packing beyond close packing of the specific molecule.

Some of the most important recent developments in the field relate to the application of machine learning (ML) techniques. ML can be used to reduce the computational cost associated with energy evaluations by using energies calculated from *e.g.* DFT as training sets to enable ML calculations of energies as a function of geometry: essentially ML potentials. More ambitiously, ML can be used in direct structure prediction by using known structural databases as a training set as in the work of Ryan *et al.* (2018). The use of these methods will continue to grow, and they will be increasingly used together with the simulation methods discussed above. Another possible development will be the increased use of potential-based methods in energy evaluations, including, of course, ML potentials, but also high-quality 'classical' potentials based on analytical functions. There remain, of course, many challenges including modelling of disorder where there is a recent intriguing contribution from Dittrich (2021) who discusses

the inclusion of restraints from theory in disorder refinement.

Over thirty years after the Maddox challenge, structure prediction is an exciting and rapidly developing field. **IUCrJ** welcomes articles in this and related areas.

References

Catlow, C. R. A. (2020). *IUCrJ*, **7**, 778–779.

Catlow, C. R. A. & Price, G. D. (1990). *Nature*, **347**, 243–248.

Catlow, C. R. A., Thomas, J. M., Parker, S. C. & Jefferson, D. A. (1982). *Nature*, **295**, 658–662.

Dickson, R. C., Manning, T. D., Raj, E. S., Booth, J. C. S., Rosseinsky, M. J. & Dyer, M. S. (2022). *Phys. Chem. Chem. Phys.* **24**, 16374–16387.

Dittrich, B. (2021). *IUCrJ*, **8**, 305–318.

Escatllar, A. M., Lazaukas, T., Woodley, S. M. & Bromley, S. T. (2019). *ACS Earth Space Chem.* **3**, 2390–2403.

Foster, M. D., Simperler, A., Bell, R. G., Friedrichs, O. D., Paz, F. A. A. & Klinowski, J. (2004). *Nat. Mater.* **3**, 234–238.

Henson, N. J., Cheetham, A. K. & Gale, J. D. (1994). *Chem. Mater.* **6**, 1647–1650.

Lazauskas, T., Sokol, A. A. & Woodley, S. M. (2017). *Nanoscale*, **9**, 3850–3864.

Oganov, A. R. (2018). *Faraday Discuss.* **211**, 643–660.

Pickard, C. J. & Needs, R. J. (2011). *J. Phys. Condens. Matter*, **23**, 053201.

Price, L. S. & Price, S. L. (2022). *Cryst. Growth Des.* **22**, 1801–1816.

Price, S. L. (2018). *Faraday Discuss.* **211**, 9–30.

Ryan, K., Lengyel, J. & Shatruk, M. (2018). *J. Am. Chem. Soc.* **140**, 10158–10168.

Schön, J. C. & Jansen, M. (2009). *Int. J. Mater. Res.* **100**, 135–152.

Treacy, M. M. J., Rivin, I., Balkovsky, E., Randall, K. H. & Foster, M. D. (2004). *Microporous Mesoporous Mater.* **74**, 121–132.

Wells, A. F. (1954). *Acta Cryst.* **7**, 842–848.

Woodley, S. M. & Catlow, R. (2008). *Nat. Mater.* **7**, 937–946.

Woodley, S. M., Day, G. M. & Catlow, R. (2020). *Phil. Trans. R. Soc. A.* **378**, 20190600.

Woodley, S. M. & Sokol, A. A. (2012). *Angew. Chem. Int. Ed.* **51**, 3752–3754.

Yang, S. & Day, G. M. (2022). *Commun. Chem.* **5**, 86–98.

This article was originally published in *IUCrJ* (2023). **10**, 143–144.

EDITORIAL

Fourth-generation light sources



Henry N. Chapman

On the northern summer solstice of 2016, Max IV opened in Lund, Sweden, the first of a new generation of synchrotron radiation facilities based on the multibend achromat (MBA). This new innovation provides a way to control the trajectories of giga-electron-volt electrons to micrometre precision. The X-ray beam generated from such an improved ‘fourth generation’ storage ring, measured at the experiment 50 m away, is largely spatially coherent because the angular width of the source, as seen from this distance, is exceedingly small – the same reason why starlight is spatially coherent. Basically, the difference between the distances of paths that rays take to reach the observer from one side of the source or the other is less than a wavelength, such that an optical instrument (including diffraction from the eponymous Young’s double slit or its generalization to a macromolecular crystal) does not yield a result any different to that obtained with a single point emitter. Such can easily be the case when the Young’s ‘slits’ or scatterers are placed very close together. Indeed, the coherence of beams from a laboratory source was adequate for von Laue, Friedrich and Knipping to observe the first diffraction from zinc sulfide and for Rosalind Franklin to create Photograph 51 of the B-form of DNA. (Periodic structures allowed many coherence ‘patches’ to contribute to produce a measurable signal.) The new MBA sources fulfil this condition for scatterers placed at any spacing within the entire microradian extent of the beam (thereby dropping the need for periodicity in the sample). In some new source designs and for photon energies softer than about 10 keV, the entire beam is coherent – referred to as diffraction limited. This implies that the source itself is exceedingly bright. And it is brightness (or brilliance as some call it) that truly defines these sources and provides opportunities in all fields of research that synchrotrons cater to today.

The brightness of a source describes how much light it emits per second and unit area into each solid angle and over a particular bandwidth. Given the above definition of spatial coherence, brightness is seen to be proportional to the number of photons per second passing through a ‘coherence volume’ of phase space (of position and momentum). One can strip away unwanted coherence modes by limiting the solid angle and area of the source that contributes to an experiment, such as by collimating the beam as Friedrich and Knipping first did, but it is a fundamental theorem of optics that one can never increase the number of rays per phase space volume. There are many ways to make things worse, but the source brightness dictates the upper limit on how quickly one can undertake a diffraction experiment, measure a spectrum, collect an image or tomogram, or expose a wafer. Brightness thus forms the basis of the comparison of sources, and the user meeting of every synchrotron radiation facility features one or more graphs of this quantity to boast the preeminence of their source or to justify the need for the next upgrade. What is astounding is the plot of the progression of the average brightness of sources since the discovery of X-rays by Röntgen in 1895. Not much happened until 1947 when synchrotron radiation was observed at the General Electric Research Laboratory in Schenectady, New York (Robinson, 2001). Since the late 1970s there has been a steady exponential growth that has brought 11 orders of magnitude

increase in that time. This represents a doubling every 1.4 years, which can be compared with Moore's law of a doubling of the number of transistors on a chip about every 2 years. Sirius, at the Brazilian Synchrotron Light Laboratory, is currently under commissioning and the ESRF in France has completed its upgrade to its Extremely Brilliant Source (EBS), giving a 30 times increase in brightness (Raimondi *et al*., 2023). Other facilities such as the Advanced Photon Source and the Advanced Light Source in the USA, SPring-8 in Japan, Diamond Light Source in the UK, and PETRA in Germany, are soon to follow, with even larger gains in brightness. As in the fields of microlithography (driving Moore's law) and high-power optical lasers, the exponential growth of the performance of accelerator-based X-ray sources has relied on considerable effort and ingenuity to fuel progress punctuated by breakthroughs such as the MBA. Another key invention, the undulator, combined with optimized storage ring designs in the 'third-generation' synchrotron facilities that have served us for the last 30 years. The periodic magnetic structure delivers constructive interference of emission as the electron traverses each period [scaled from centimetres down to ångstroms by virtue of a double whammy of special relativity (Hwu & Margaritondo, 2021)]. X-ray free-electron lasers built upon this remarkable device by using enough periods that the radiation field influences the trajectories of the electrons (travelling at near light speed) and imprints itself onto their distribution, so that they all radiate in phase. This sets up a positive feedback that amplifies the FEL pulse and gains us yet another huge jump in peak brightness (and coherence) – both due to the increased number of photons, but also now because the X-rays are generated in femtosecond-duration pulses. Once also labelled as fourth-generation sources, current XFELs are more of a bifurcation that coexists with storage rings to expand X-ray science.

What new capabilities will fourth-generation synchrotron radiation sources bring? There is a clear benefit for imaging and tomography, where the speed at which an image is acquired is directly proportional to brightness. Thus, larger volumes (brains, computer chips) can be imaged in reasonable times, and if the sample can handle it, movies of processes in batteries, materials formation and processing, or energy harvesting can be made. Faster detectors and high-resolution X-ray optics are needed. The full coherence of the beam brings to fruition an idea first expressed by David Sayre, of utilizing the ability of crystallography to phase the wavefield scattering from a sample in order to synthesize an image of any object placed in the beam (Sayre, 1980). The method of ptychography, first developed in the electron microscope, provides an optimal way to recover the wavefield (Pfeiffer, 2018). These ideas could be driven all the way to atomic resolution – again, if the sample can handle it, or if information can be combined from many objects. The imaging of biological structures such as cells and macromolecules remains limited by radiation damage, and higher brightness just achieves the inevitable degradation sooner, for the same recorded diffraction information. Nevertheless, highly automated sample delivery methods enable rapid surveys of sensitive structures to be conducted over large parameter spaces, including time-resolved measurements, or to capture rare events, as needed to investigate relationships between structure and function.

Unlike previous transitions, many of the challenges faced by fourth-generation synchrotron facilities have solutions developed at the XFELs. Thirty years ago, the performance of beamlines was often limited by the speed of detectors. XFELs were such a startling jump of a billion times in peak brightness that large investments were necessary in high-speed integrating detectors. These are now a great match for the upgraded synchrotrons (Chapman, 2018) and can consume photons faster than a storage-ring-based source can provide them (Allahgholi *et al.*, 2015). These detectors produce vast amounts of data, which is recognized as too large to fully archive and in need of new expertise to turn it into knowledge. Techniques such as serial crystallography, born out of the necessity to work with destructive X-ray pulses, are already being adopted at synchrotron facilities to make full use of the source output and provide a paradigm for high-throughput automated experiments (Standfuss & Spence, 2017). A strong connection between these different 'fourth generation' facilities is needed to tackle what are becoming joint challenges. Looking even further ahead, a higher diversity of sources including energy-recovery linacs (Shen, 2001), and compact accelerators utilizing high-power laser technologies (Graves *et al*., 2017), may benefit from such synergies and serve the needs of structural science with both specialized instrumentation for particular types of measurements or test beds for further development. **IUCrJ** will

continue to chart the exciting outcomes emerging from this and future generations of sources.

References

Allahgholi, A., Becker, J., Bianco, L., Delfs, A., Dinapoli, R., Goettlicher, P., Graafsma, H., Greiffenberg, D., Hirsemann, H., Jack, S., Klanner, R., Klyuev, A., Krueger, H., Lange, S., Marras, A., Mezza, D., Mozzanica, A., Rah, S., Xia, Q., Schmitt, B., Schwandt, J., Sheviakov, I., Shi, X., Smoljanin, S., Trunk, U., Zhang, J. & Zimmer, M. (2015). *J. Instrum*. **10**, C01023.

Chapman, H. N. (2018). *Nat. Methods*, **15**, 774–775.

Graves, W. S., Chen, J. P. J., Fromme, P., Holl, M. R., Kirian, R., Malin, L. E., Schmidt, K. E., Spence, J., Underhill, M., Weierstall, U., Zatsepin, N. A., Zhang, C., Hong, K.-H., Moncton, D. E., Limborg-Deprey, C. & Nanni, E. A. (2017). *Proceedings of the 38th International Free Electron Laser Conference (FEL2017)*, 20–25 August 2017, Santa Fe, NM, USA, pp. 225–228. https://doi.org/ 10.18429/JACoW-FEL2017-TUB03.

Hwu, Y. & Margaritondo, G. (2021). *J. Synchrotron Rad*. **28**, 1014–1029.

Pfeiffer, F. (2018). *Nat. Photon.* **12**, 9–17.

Raimondi, P., Benabderrahmane, C., Berkvens, P., Biasci, J. C., Borowiec, P., Bouteille, J.-F., Brochard, T., Brookes, N. B., Carmignani, N., Carver, L. R., Chaize, J.-M., Chavanne, J., Checchia, S., Chushkin, Y., Cianciosi, F., Di Michiel, M., Dimper, R., D'Elia, A., Einfeld, D., Ewald, F., Farvacque, L., Goirand, L., Hardy, L., Jacob, J., Jolly, L., Krisch, M., Le Bec, G., Leconte, I., Liuzzo, S. M., Maccarrone, C., Marchial, T., Martin, D., Mezouar, M., Nevo, C., Perron, T., Plouviez, E., Reichert, H., Renaud, P., Revol, J.-L., Roche, B., Scheidt, K.-B., Serriere, V., Sette, F., Susini, J., Torino, L., Versteegen, R., White, S. & Zontone, F. (2023). *Commun. Phys*. **6**, 82.

Robinson, A. L. (2001). In: *X-ray data booklet*, edited by A. C. Thompson & D. Vaughan, Section 2.2. Berkeley: Lawrence Berkeley National Laboratory. https://xdb.lbl.gov/Section2/Sec_2-2.html.

Sayre, D. (1980). *Prospects for long-wavelength X-ray microscopy and diffraction*. In: *Imaging processes and coherence in physics*, Lecture Notes in Physics, Vol. 112, pp. 229–235, edited by M. Schlenker, M. Fink, J. P. Goedgebuer, C. Malgrange, J. C., Vieénot & R. H. Wade. Berlin, Heidelberg: Springer.

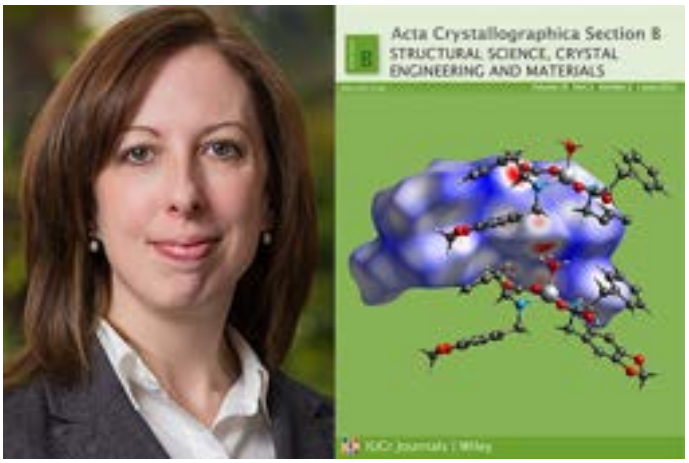
Shen, Q. (2001). *X-ray flux, brilliance and coherence of the proposed Cornell energy-recovery synchrotron source*. Technical Memo 01– 002, Cornell University CHESS, USA.

Standfuss, J. & Spence, J. (2017). *IUCrJ*, **4**, 100–101.

This article was originally published in *IUCrJ* (2023). **10**, 246–247.

IUCR JOURNALS NEWS

New Section Editor of Acta Crystallographica, Section B



Louise Dawe, the new Section Editor of *Acta Cryst. B*.

Alexander J. Blake, Marc de Boissieu, Ashwini Nangia

Professor Louise Dawe of the Department of Chemistry and Biochemistry, Wilfrid Laurier University, Waterloo, Ontario, Canada, has recently been appointed as a Section Editor for *Acta Crystallographica*, *Section B*.

Louise holds a Master's in Science (Chemistry) from the University of Utah (USA), as well as Bachelor's degrees in Chemistry and Education, and a PhD in Chemistry from Memorial University of Newfoundland (Canada). She took up her current position in 2013 and is currently associate professor. With over 140 peer-reviewed publications to her credit, Louise is recognized for her expertise in small molecule X-ray crystallography. Her research group specializes in designing, synthesizing, and characterizing novel ligands that enable the simultaneous coordination of Lewis acids and anions.

In addition to her academic pursuits, Louise holds several leadership positions within the scientific community. She serves as the chair of the Canadian National Committee for Crystallography, co-chair of the International Program Committee for the 27th Congress and General Assembly of the International Union of Crystallography and is a member of the IUCr Meeting Support Committee. Furthermore, since 2019 Louise has taken on the role of organizer for the Canadian Chemical Crystallography Workshops, fostering knowledge exchange and collaboration.

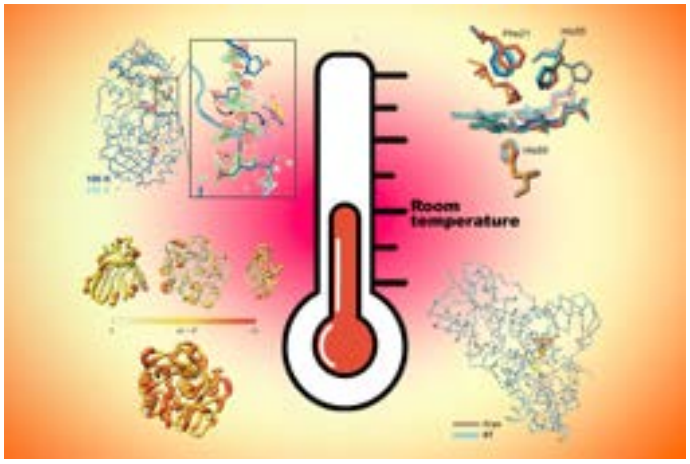
Since 2020, Louise has been a co-editor for *Acta Crystallographica*, *Section C*. In 2022, she assumed the role of Teaching and Education co-editor for *Journal of Applied Crystallography* and will continue in this role in parallel with her new Section Editor one.

Her unwavering passion for the science and community of crystallography drives her commitment to supporting the publication of high-quality research. She aims to enable the publication of superior work related to the fundamental understanding of structure, crystal growth, and the development and application of new molecules and materials. Moreover, Louise is enthusiastic about welcoming new authors and providing emerging researchers with a strong publishing community.

The three existing Section Editors (Sandy Blake, Marc de Boissieu and Ashwini Nangia) are delighted to welcome Louise to the team and look forward to working with her on the further development of the journal.

IUCR JOURNALS NEWS

Introduction to the virtual thematic issue on room-temperature biological crystallography



Roberto A. Steiner

After many years in which the use of cryogenic conditions (typically around 100 K) represented an almost ubiquitous approach to biological crystallographic studies, there has been a recent resurgence in room temperature (RT) or (near-)physiological temperature experimentation. One of the main advantages of measuring diffraction data at low temperatures is the possibility of mitigating the detrimental effects of radiation-induced damage in macromolecular crystals (Garman & Schneider, 1997). Although cryo-conditions do not completely abolish global and specific radiation damage (Bui *et al.*, 2014; Garman, 2010; Ravelli & McSweeney, 2000; Weik *et al.*, 2000), their use, together with judicious instrument choices, often allow the collection of complete diffraction data from a single crystal without significant loss in resolution. Nowadays, whilst the 'one crystal, one data set' experimental format afforded by cryo-temperatures remains popular and practically convenient, advances in multi-crystal serial data collection approaches (SFX and SSX for serial femtosecond and serial synchrotron X-ray crystallography, respectively) and detectors with extremely fast read-out rates allow the measurement of complete datasets at RT with modest radiation-induced damage. These developments offer exciting opportunities as there is an increasing realization that RT or multi-temperature measurements, represent a valid approach to study functionally important conformations that may be hidden at cryogenic temperatures (Fraser *et al*., 2009; Keedy *et al*., 2018; Keedy *et al*., 2015; Keedy *et al*., 2014; Fenwick *et al*., 2014). Also, temperature-dependent differences in protein–ligand interactions including unique binding poses and new binding sites (Skaist Mehlman *et al*., 2023) make RT crystallographic studies very relevant for a more complete understanding of protein–ligand interactions that might be important for drug discovery (Fischer *et al*., 2014; Fischer *et al*., 2015). Importantly, RT studies on microcrystals coupled with suitable mixing and/or activation methods can also allow the visualization of reaction intermediates (Olmos *et al*., 2018; Butryn *et al*., 2021; Gruhl *et al*., 2023).

This virtual thematic issue (see https://journals.iucr.org/special_issues/2022/RT/) presents a collection of articles recently published in *IUCrJ*, *Acta Cryst. D Structural Biology* and *Acta Cryst. F Structural Biology Communications*, some of which have been commissioned specifically, that highlight topics and trends in modern RT biological crystallography.

In a review paper, Thorne provides an overview of the key advantages and physical principles of, and methods for, crystallographic data collection at non-cryogenic temperatures (Thorne, 2023). The paper also discusses some factors relevant to interpreting the resulting data. This review complements another excellent review on practical methods for RT data collection and analysis published recently in *Quarterly*

Reviews of Biophysics (Fischer, 2021).

A series of original research articles then discuss RT crystallographic work in the context of different biological systems. Metal centres in proteins can be very sensitive to radiation damage thus making standard single-crystal RT experiments particularly challenging. Moreno-Chicano and co-workers explored the complementarity of several diffraction techniques to study the multifunctional heme-containing dehaloperoxidase B (DHP-B) globin (Moreno-Chicano *et al*., 2022). Aumonier and colleagues used RT time-resolved oscillation crystallography coupled with *in crystallo* UV–Vis absorption spectroscopy to look at the slow relaxation of a reaction intermediate – a thio-ether covalent bond between the chromophore and a cysteine residue – in the photoreaction of the LOV2 domain of phototropin 2 from *Arabidopsis thaliana* (Aumonier *et al.*, 2022). Ebrahim and co-workers performed a multi-temperature experiment on the SARS-CoV-2 main protease (M^{pro}), a promising target for the development of novel antiviral therapeutics (Ebrahim *et al*., 2022). Using multi-copy ensemble models they highlight conformational heterogeneity at various sites including a key substrate-binding loop that may inspire new strategies for antiviral drug development. Sharma and co-workers further explored the theme of conformational variability and allosteric coupling in protein tyrosine phosphatase 1B (PTP1B) by solving its SSX structure in the unliganded state (Sharma *et al*., 2023) whilst Schneps and colleagues employed SSX on the circadian photoreceptor cryptochrome (CRY) revealing regions of enhanced mobility in loops that have functional importance within this protein family and whose atomic displacement parameters correlate well with those predicted from molecular-dynamics simulations (Schneps *et al.*, 2022). The theme of ligand-binding discrepancies between cryo-cooled and physiological temperature structures is discussed by Huang and co-workers by looking at the interaction of TL00150, a 175.15 Da fragment, with endothiapepsin using a ‘temperature-resolved’ approach (Huang *et al*., 2022). Some aspects of radiation damage are considered by Yabukarski and colleagues who employed a panel of well known model systems, to show that radiation damage only modestly increases conformational heterogeneity at RT, suggesting that dynamic information can be obtained from single crystals at near-physiological temperature (Yabukarski *et al.*, 2022). Båth and co-authors employed lipidic cubic phase (LCP) microcrystallization applied to the photosynthetic reaction centre of *Blastochloris viridis* (Båth *et al*., 2022). Using X-ray free electron laser (XFEL) radiation they obtained its structure at the 2.25 Å resolution that allowed the visualization of the mobile ubiquinone potentially facilitating time-resolved diffraction studies of electron-transfer reactions to this cofactor. Finally, Zielinski and co-workers discussed efficient RT SSX experiments carried out on three different proteins of biological relevance using the CFEL TapeDrive, a conveyor-belt-based sample-delivery system (Zielinski *et al*., 2022).

The issue also includes a few articles that are a bit more ‘technical’ in their nature. Greisman and colleagues discuss native single anomalous diffraction (SAD) phasing at RT (Greisman *et al*., 2022) whilst Doukov and co-workers show how high-quality anomalous signal can be collected from single-crystal diffraction data with relatively low occupancy at and above RT (Doukov *et al*., 2023). In the field of synchrotron instrumentation, increasingly more sophisticated developments are happening at sites worldwide. One example is discussed by Okumura and colleagues in their presentation of the setup for *in situ* crystal data-collection and ligand-screening available at SPring-8 (Okumura *et al*., 2022).

Hopefully, this virtual thematic issue will encourage the reader to explore additional published work on the topic of RT biological crystallography and, importantly, facilitate the conception and execution of relevant experiments.

References

Aumonier, S., Engilberge, S., Caramello, N., von Stetten, D., Gotthard, G., Leonard, G. A., Mueller-Dieckmann, C. & Royant, A. (2022). *IUCrJ*, **9**, 756–767.

Båth, P., Banacore, A., Börjesson, P., Bosman, R., Wickstrand, C., Safari, C., Dods, R., Ghosh, S., Dahl, P., Ortolani, G., Björg Ulfarsdottir, T., Hammarin, G., García Bonete, M.-J., Vallejos, A., Ostojić, L., Edlund, P., Linse, J.-B., Andersson, R., Nango, E., Owada, S., Tanaka, R., Tono, K., Joti, Y., Nureki, O., Luo, F., James, D., Nass, K., Johnson, P. J. M., Knopp, G., Ozerov, D., Cirelli, C., Milne, C., Iwata, S., Brändén, G. & Neutze,

R. (2022). *Acta Cryst*. D**78**, 698–708.

Bui, S., von Stetten, D., Jambrina, P. G., Prangé, T., Colloc'h, N., de Sanctis, D., Royant, A., Rosta, E. & Steiner, R. A. (2014). *Angew. Chem. Int. Ed.* **53**, 13710–13714.

Butryn, A., Simon, P. S., Aller, P., Hinchliffe, P., Massad, R. N., Leen, G., Tooke, C. L., Bogacz, I., Kim, I. S., Bhowmick, A., Brewster, A. S., Devenish, N. E., Brem, J., Kamps, J., Lang, P. A., Rabe, P., Axford, D., Beale, J. H., Davy, B., Ebrahim, A., Orlans, J., Storm, S. L. S., Zhou, T., Owada, S., Tanaka, R., Tono, K., Evans, G., Owen, R. L., Houle, F. A., Sauter, N. K., Schofield, C. J., Spencer, J., Yachandra, V. K., Yano, J., Kern, J. F. & Orville, A. M. (2021). *Nat. Commun.* **12**, 4461.

Doukov, T., Herschlag, D. & Yabukarski, F. (2023). *Acta Cryst.* D**79**, 212–223.

Ebrahim, A., Riley, B. T., Kumaran, D., Andi, B., Fuchs, M. R., McSweeney, S. & Keedy, D. A. (2022). *IUCrJ*, **9**, 682–694.

Fenwick, R. B., van den Bedem, H., Fraser, J. S. & Wright, P. E. (2014). *Proc. Natl Acad. Sci. USA*, **111**, E445–E454.

Fischer, M. (2021). *Q. Rev. Biophys*. **54**, e1.

Fischer, M., Coleman, R. G., Fraser, J. S. & Shoichet, B. K. (2014). *Nat. Chem*. **6**, 575–583.

Fischer, M., Shoichet, B. K. & Fraser, J. S. (2015). *ChemBioChem*, **16**, 1560–1564.

Fraser, J. S., Clarkson, M. W., Degnan, S. C., Erion, R., Kern, D. & Alber, T. (2009). *Nature*, **462**, 669–673.

Garman, E. F. (2010). *Acta Cryst*. D**66**, 339–351.

Garman, E. F. & Schneider, T. R. (1997). *J. Appl. Cryst.* **30**, 211–237.

Greisman, J. B., Dalton, K. M., Sheehan, C. J., Klureza, M. A., Kurinov, I. & Hekstra, D. R. (2022). *Acta Cryst*. D**78**, 986–996.

Gruhl, T., Weinert, T. & Rodrigues, M. J. (2023). *Nature*, https:// doi.org/10.1038/s41586-023-05863-6.

Huang, C.-Y., Aumonier, S., Engilberge, S., Eris, D., Smith, K. M. L., Leonarski, F., Wojdyla, J. A., Beale, J. H., Buntschu, D., Pauluhn, A., Sharpe, M. E., Metz, A., Olieric, V. & Wang, M. (2022). A*cta Cryst*. D**78**, 964–974.

Keedy, D. A., Hill, Z. B., Biel, J. T., Kang, E., Rettenmaier, T. J., Brandao-Neto, J., Pearce, N. M., von Delft, F., Wells, J. A. & Fraser, J. S. (2018). *eLife* **7**, e36307.

Keedy, D. A., Kenner, L. R., Warkentin, M., Woldeyes, R. A., Hopkins, J. B., Thompson, M. C., Brewster, A. S., Van Benschoten, A. H., Baxter, E. L., Uervirojnangkoorn, M., McPhillips, S. E., Song, J., Alonso-Mori, R., Holton, J. M., Weis, W. I., Brunger, A. T., Soltis, S. M., Lemke, H., Gonzalez, A., Sauter, N. K., Cohen, A. E., van den Bedem, H., Thorne, R. E. & Fraser, J. S. (2015). *eLife* **4**, e07574.

Keedy, D. A., van den Bedem, H., Sivak, D. A., Petsko, G. A., Ringe, D., Wilson, M. A. & Fraser, J. S. (2014). *Structure*, **22**, 899–910.

Moreno-Chicano, T., Carey, L. M., Axford, D., Beale, J. H., Doak, R. B., Duyvesteyn, H. M. E., Ebrahim, A., Henning, R. W., Monteiro, D. C. F., Myles, D. A., Owada, S., Sherrell, D. A., Straw, M. L., Šrajer, V., Sugimoto, H., Tono, K., Tosha, T., Tews, I., Trebbin, M., Strange, R. W., Weiss, K. L., Worrall, J. A. R., Meilleur, F., Owen, R. L., Ghiladi, R. A. & Hough, M. A. (2022). *IUCrJ*, **9**, 610–624.

Okumura, H., Sakai, N., Murakami, H., Mizuno, N., Nakamura, Y., Ueno, G., Masunaga, T., Kawamura, T., Baba, S., Hasegawa, K., Yamamoto, M. & Kumasaka, T. (2022). *Acta Cryst*. F**78**, 241–251.

Olmos, J. L. Jr, Pandey, S., Martin-Garcia, J. M., Calvey, G., Katz, A., Knoska, J., Kupitz, C., Hunter, M. S., Liang, M., Oberthuer, D., Yefanov, O., Wiedorn, M., Heyman, M., Holl, M., Pande, K., Barty, A., Miller, M. D., Stern, S., Roy-Chowdhury, S., Coe, J., Nagaratnam, N., Zook, J., Verburgt, J., Norwood, T., Poudyal, I., Xu,

D., Koglin, J., Seaberg, M. H., Zhao, Y., Bajt, S., Grant, T., Mariani, V., Nelson, G., Subramanian, G., Bae, E., Fromme, R., Fung, R., Schwander, P., Frank, M., White, T. A., Weierstall, U., Zatsepin, N., Spence, J., Fromme, P., Chapman, H. N., Pollack, L., Tremblay, L., Ourmazd, A., Phillips, G. N. Jr & Schmidt, M. (2018). *BMC Biol.* **16**, 59.

Ravelli, R. B. & McSweeney, S. M. (2000). *Structure*, **8**, 315–328.

Schneps, C. M., Ganguly, A. & Crane, B. R. (2022). *Acta Cryst*. D**78**, 975–985.

Sharma, S., Ebrahim, A. & Keedy, D. A. (2023). *Acta Cryst*. F**79**, 23–30.

Skaist Mehlman, T., Biel, J. T., Azeem, S. M., Nelson, E. R., Hossain, S., Dunnett, L., Paterson, N. G., Douangamath, A., Talon, R., Axford, D., Orins, H., von Delft, F. & Keedy, D. A. (2023). *eLife* **12**, e84632.

Thorne, R. E. (2023). *Acta Cryst*. D**79**, 78–94.

Weik, M., Ravelli, R. B., Kryger, G., McSweeney, S., Raves, M. L., Harel, M., Gros, P., Silman, I., Kroon, J. & Sussman, J. L. (2000). *Proc. Natl Acad. Sci. USA*, **97**, 623–628.

Yabukarski, F., Doukov, T., Mokhtari, D. A., Du, S. & Herschlag, D. (2022). *Acta Cryst.* D**78**, 945–963.

Zielinski, K. A., Prester, A., Andaleeb, H., Bui, S., Yefanov, O., Catapano, L., Henkel, A., Wiedorn, M. O., Lorbeer, O., Crosas, E., Meyer, J., Mariani, V., Domaracky, M., White, T. A., Fleckenstein, H., Sarrou, I., Werner, N., Betzel, C., Rohde, H., Aepfelbacher, M., Chapman, H. N., Perbandt, M., Steiner, R. A. & Oberthuer, D. (2022). *IUCrJ*, **9**, 778–791.

This article was originally published in *Acta Cryst.* (2023). D**79**, 268–270; *Acta Cryst*. (2023). F**79**, 79–81; and *IUCrJ* (2023). **10**, 248–250.

COMMENTARY

Mapping structural correlations in real space

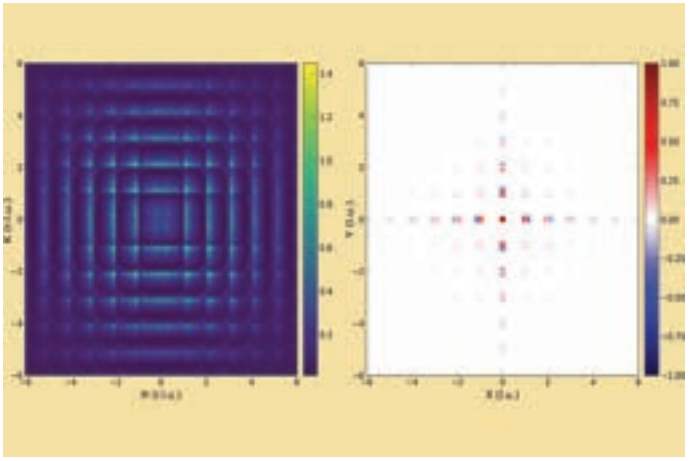


Figure 1. (Left) Diffuse scattering in **Q**-space from equal concentrations of two different atomic species with differing ionic radii occupying random sites on a square lattice. (Right) Three-dimensional difference pair distribution function (3D-ΔPDF) map in real space showing peaks with both positive (red) and negative (blue) intensities representing the change in the probabilities of their respective interatomic vectors compared with the average structure. The 3D-ΔPDF transforms reveal both the size of the local relaxations and the length scale over which those relaxations are correlated (P. Upreti, private communication).

Ray Osborn

The very first issue of *Acta Crystallographica* contained an article by Kathleen Lonsdale on single-crystal diffuse scattering (Lonsdale, 1948). Admittedly, her focus was on thermal diffuse scattering, but it illustrates the fact that the value of understanding the scattering between the Bragg peaks was recognized from the earliest days of X-ray diffraction. Since then the power of diffuse scattering, whether of X-rays or neutrons, in probing disorder within crystalline materials has been demonstrated by measurements on a wide range of materials from metallic alloys to molecular solids. An excellent introduction to the subject is provided by one of Lonsdale's last students, Richard Welberry (Welberry, 2022). Nevertheless, in spite of this long history, I think it is fair to say that diffuse scattering is not as widely used as might be expected, given the importance of local structural correlations in the functionality of so many materials. In the past, this was due to two major challenges, the challenge of measuring scattering that was several orders-of-magnitude weaker than Bragg peaks over large three-dimensional volumes of reciprocal space and the challenge of modeling the results. With advances in the power of both X-ray and neutron sources as well as the more widespread availability of large area detectors, high-quality diffuse scattering data is now much easier to collect, but the second challenge is still a deterrent to non-specialists, in spite of the existence of a number of software tools for atomistic modeling (Proffen & Neder, 1997; Paddison, 2019).

The relatively recent development of three-dimensional difference pair distribution function (3D-ΔPDF) analysis may encourage some scientists to give diffuse scattering another look. Patterson maps, *i.e.* 3D maps of interatomic vector probabilities produced by the Fourier transformation of S(**Q**), have long been used by crystallographers as a tool in solving crystal structures. What Thomas Weber and colleagues at ETZ Zürich realized is that if it were possible to eliminate scattering from the long-range ordered structure before performing the transform, the resulting maps would only contain interatomic vectors whose probabilities differ from the average (Weber & Simonov, 2012). These are difference Patterson

maps, hence the Δ in 3D-ΔPDF. This is accomplished by removing the Bragg peaks at integer (*hkl*) values and replacing them with interpolations of the surrounding diffuse scattering, a procedure known as 'punch-and-fill.' 3D-ΔPDF maps filter out the average structure entirely, allowing us to focus on the changes in site occupations and atomic relaxations caused by local disorder. This is not possible with polycrystalline PDF data, in which there is no way to separate Bragg and diffuse contributions without sophisticated modeling. In 3D-ΔPDF maps, the smoothly varying distributions of intensity in **Q**-space are transformed into discrete spots in real space, with both positive and negative intensities reflecting increases or decreases in their respective vector probabilities compared with the average crystal structure (see Fig. 1).

The beauty of this method is that 3D-ΔPDF maps are relatively easy to interpret even without any modeling. The article by Schmidt *et al.* (2023) in this issue demonstrates this with an analysis that combines new neutron and X-ray data from yttria-stabilized zirconia (YSZ). The diffuse scattering in YSZ is extremely strong because of a high concentration of oxygen vacancies. This, coupled with the commercial availability of large single crystals produced as artificial diamonds, has encouraged several diffuse scattering investigations using both neutrons and X-rays over the past forty years. These have used increasingly sophisticated instrumentation as it became available, from the initial raster scans of a single **Q**-plane using a neutron triple-axis spectrometer that I once participated in (Osborn *et al.*, 1986) to more complete reciprocal space volumes collected with neutron and X-ray area detectors (Welberry *et al.*, 1995; Goff *et al.*, 1999). However, the results have been somewhat qualitative even after employing a variety of modeling methods. In the new study by Schmidt *et al.* (2023), shifts in interatomic vectors are determined directly from the 3D-ΔPDF maps, producing more definitive values of the relaxations of both anions and cations around vacancies. The authors also performed atomistic simulations to reproduce the PDF peak intensities but these only served to confirm their original interpretations. Intriguingly, the size of the relaxations they observe are significantly greater than those derived from Bragg peak analysis, but the consistency between the neutron and X-ray data suggests the numbers are reliable.

The observed relaxations of nearest neighbors around a vacancy do not yield many surprises. More controversial is whether the vacancies tend to form pairs along the unit-cell diagonals, with or without cation interstitials. By contrasting the neutron PDFs, which are sensitive to oxygen pairs, with X-ray PDFs, which are less so, Schmidt *et al.* (2023) concluded that there was an increased probability of ⟨½½½⟩ vacancy pairs, but not between cation interstitials. They also found no evidence of longer-range correlations, which would have provided evidence of extended vacancy complexes. This is somewhat surprising as, with 18 mol% Y_2O_3, there are quite sharp diffuse peaks in **Q**-space, indicating that correlations extend to 15 Å or more (Osborn *et al.*, 1986; Goff *et al.*, 1999). One of the strengths of 3D-ΔPDF maps is that they allow correlations to be determined over a much greater range of length scales than polycrystalline PDFs. In our own work on sodium-intercalated V_2O_5, we were able to measure the growth of structural correlations in the sodium substructure with decreasing temperature from 10 Å to 200 Å (Krogstad *et al.*, 2020). The new X-ray measurements were performed with a laboratory source, so synchrotron studies to look for very weak PDF signals at longer distances might be worth considering.

In the latest edition of his book, Welberry points out that 3D-ΔPDF vector probabilities 'are simply related to the Warren–Cowley short-range order parameters that have frequently been used to parametrize diffuse scattering models' (Welberry, 2022). In other words, 3D-ΔPDF maps can, if properly interpreted, provide as much, if not more, information than can be derived by atomistic modeling in reciprocal space. Some modeling might still be necessary in multicomponent systems, in which there is ambiguity about the origin of each PDF peak, but the problem is considerably simplified by the dimensionality reduction produced by transforming S(**Q**) to a discrete set of vector probabilities. This presupposes that the original data is of high enough quality and completeness that the transforms are numerically robust and that care is taken not to introduce spurious Fourier artifacts in the 'punch-and-fill' process. Exploring methods of improving the reliability of 3D-ΔPDF maps could help to stimulate the surprisingly undeveloped field of three-dimensional spectral analysis. Nevertheless, there are an increasing number of 3D-ΔPDF results

appearing in the literature each year, and this new work illustrates why it is becoming so popular and promises soon to become a commonly used tool in characterizing disordered materials.

Acknowledgements

I am grateful to Puspa Upreti for providing the calculations used in the figure. Work by RO is supported by the US Department of Energy, Office of Science, Office of Basic Energy Sciences, Division of Material Sciences and Engineering.

References

Goff, J. P., Hayes, W., Hull, S., Hutchings, M. T. & Clausen, K. N. (1999). *Phys. Rev. B*, **59**, 14202–14219.

Krogstad, M. J., Rosenkranz, S., Wozniak, J. M., Jennings, G., Ruff, J. P. C., Vaughey, J. T. & Osborn, R. (2020). *Nat. Mater.* **19**, 63–68.

Lonsdale, K. (1948). *Acta Cryst.* **1**, 12–20.

Osborn, R., Andersen, N. H., Clausen, K. N., Hackett, M. A., Hayes, W., Hutchings, M. T. & MacDonald, J. E. (1986). *Mater. Sci. Forum*, **7**, 55–62.

Paddison, J. A. M. (2019). *Acta Cryst.* A**75**, 14–24.

Proffen, Th. & Neder, R. B. (1997). *J. Appl. Cryst.* **30**, 171–175.

Schmidt, E. M., Neder, R. B., Martin, J. D., Minelli, A., Lemée, M.-H. & Goodwin, A. L. (2023). *Acta Cryst.* B**79**, 138–147.

Weber, T. & Simonov, A. (2012). *Z. Kristallogr.* **227**, 238–247.

Welberry, T. R. (2022). *Diffuse X-ray Scattering and Models of Disorder*. Oxford University Press.

Welberry, T. R., Withers, R. L. & Mayo, S. C. (1995). *J. Solid State Chem.* **115**, 43–54.

This article was originally published in *Acta Cryst.* (2023). B**79**, 99–100.

COMMENTARY

How much do molecular shapes matter?



Mohan Bhadbhade

Polymorphism, a phenomenon where the same chemical entity yields different crystal modifications, has been known since the discovery of the phenomenon in benzamine (Wohler & Liebig, 1832). In recent years, polymorphism has become an intensively researched area because of its direct impact on the behaviour of industrial organic materials, particularly pharmaceutical solids, and to some extent dyes, pesticides and explosives (Brittain, 2016; Bernstein, 2020). In the case of pharmaceutical solids, the impetus came from real situations when problems faced with the large-scale crystallizations of drug compounds produced polymorphs with properties affecting the efficacy of the drug (solubility and bioavailability) (Bauer *et al.*, 2001).

Polymorphism is just part of the story of molecules crystallizing in unwanted, uncontrollable forms. Another layer to this area is the study of the growth of crystals containing crystallization solvents (or water) in the crystal structure, a phenomenon with many terms: solvates, solvatomorphs, pseudo-polymorphs, inclusion compounds and clathrates. Research efforts in this area seem to be ever growing, in part because of the promise of improving solubility and the shelf life or avenues to grow molecular cocrystals incorporating other bioactive components. Therefore, it is not surprising that this research area has become an indispensable part of R&D programs of several large multi-national pharmaceutical companies and has also seen engagement from chemists and chemical engineers worldwide. Of course, this research has both a strong commercial angle in the form of protecting new formulations through patents and a research angle deepening our understanding of crystal nucleation and growth and the intermolecular interactions that hold these crystals together. There have been several books, reviews and monographs on these topics (see Griesser, 2006; Cruz-Cabeza *et al.*, 2015; Healy, 2017) and the research interest in this field is likely to continue growing, as shown by one very recent example in which the journal *Pharmaceutics* will publish a special issue in 2023 entitled *Polymorphism and Pseudopolymorphism of Pharmaceutical Substances*.

Therefore, the article *Exploring the thermal behaviour of the solvated structures of nifedipine* by Jones *et al.* (2023) is a timely and important contribution to this research area. Their research has thoroughly investigated solvates of nifedipine (NIF), a dihydropyridine drug [Fig. 1(*a*)] developed as an L-type calcium channel antagonist (Tang *et al.*, 2016). The authors, after a wide screening of solvents, reported crystal structures of seven solvates studied using differential scanning calorimetry and thermogravimetric analysis and by variable-temperature X-ray powder diffraction to understand their desolvation behaviour, stability and structural changes during these processes. The structure of nifedipine without any solvent (the stable α form) was reported by Triggle *et al.* (1980) and there have been several publications on other polymorphs and solvates of this drug (Caira *et al.*, 2003; Klimakow *et al.*, 2010; Gunn *et al.*, 2012). However, the paper by Jones *et al.* (2023) supplies a much broader landscape on the behaviour of solvated forms of this drug. Studies such as these are valuable in many ways, providing experimentally observed conformations of the drug molecule in different crystalline environments, enriching our understanding of the roles played by solvents in crystal growth and providing an insight into crystal engineering principles by analysing intermolecular interactions in different crystal forms.

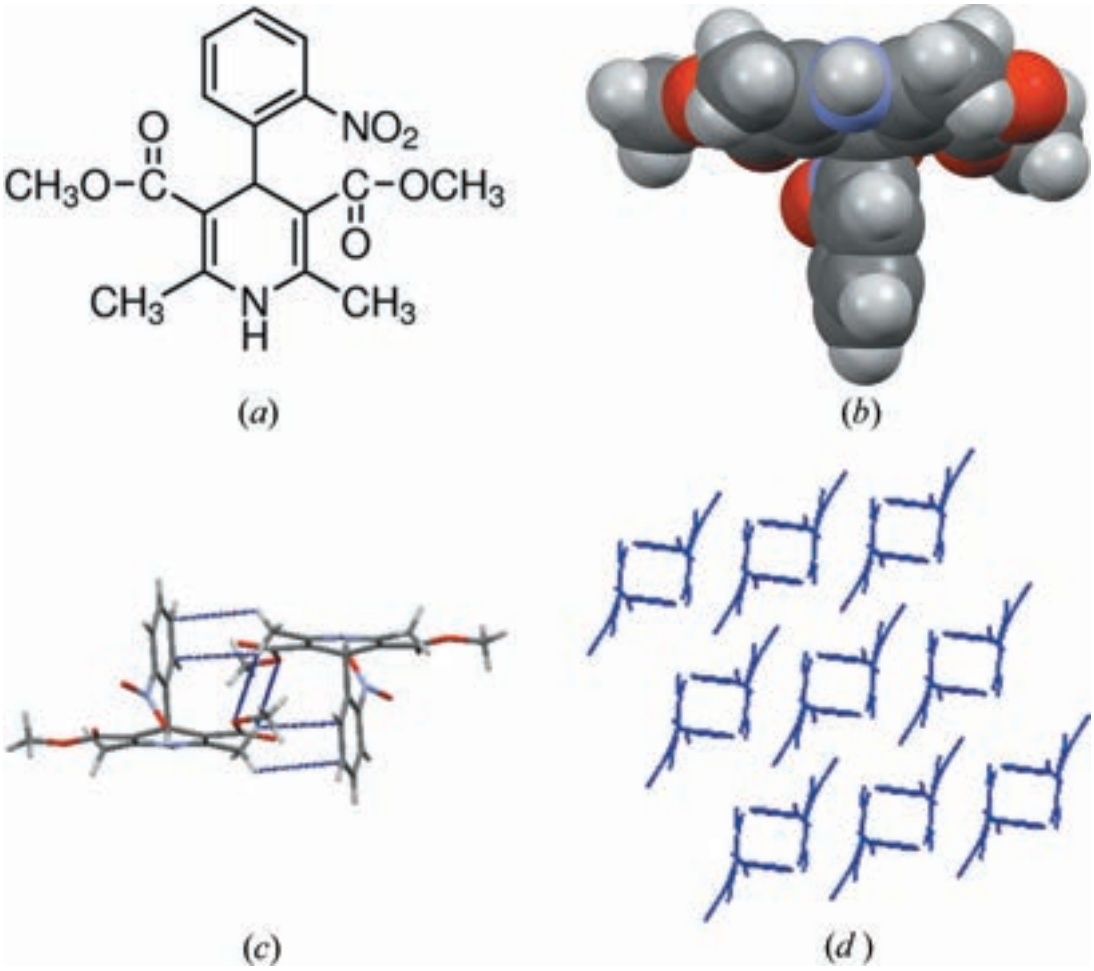


Figure 1. (*a*) Molecular structure of NIF, (*b*) T-shaped molecule, (*c*) packing in the stable form of NIF and (*d*) centrosymmetric dimer (in 1,4-dioxane solvate).

It is intriguing that all seven solvates (including those with significantly different motifs, such as the THF solvate) desolvate to the thermodynamically stable α form. This implies that there would be a conserved stable framework of NIF molecules to which all solvated forms return once the solvent molecules leave the crystal lattice! It is worth exploring what (if any) commonalities may exist in the patterns of molecular packing. The NIF molecule resembles a T shape [Fig. 1(*b*)] and interlocks itself with its centrosymmetric counterpart forming a dimeric pair which form layers [Fig. 1(*d*)], as seen in the original unsolvated crystal structure of NIF (α form). Could this centrosymmetric dimer making C—H···O and C—H···π contacts [Fig. 1(*c*)] be a synthon (Desiraju, 1995) in the family of structures of this molecule?

The category 1 system of NIF packing can be seen in the zoomed-out views in Fig. 2. The NIF (in blue) adopts similar structures incorporating 1,4-dioxane, morpholine, DMSO and DMA (orange, orange, green and orange, respectively). Despite containing different solvents, the host molecular association bears a close relationship with that seen in the α-NIF structure.

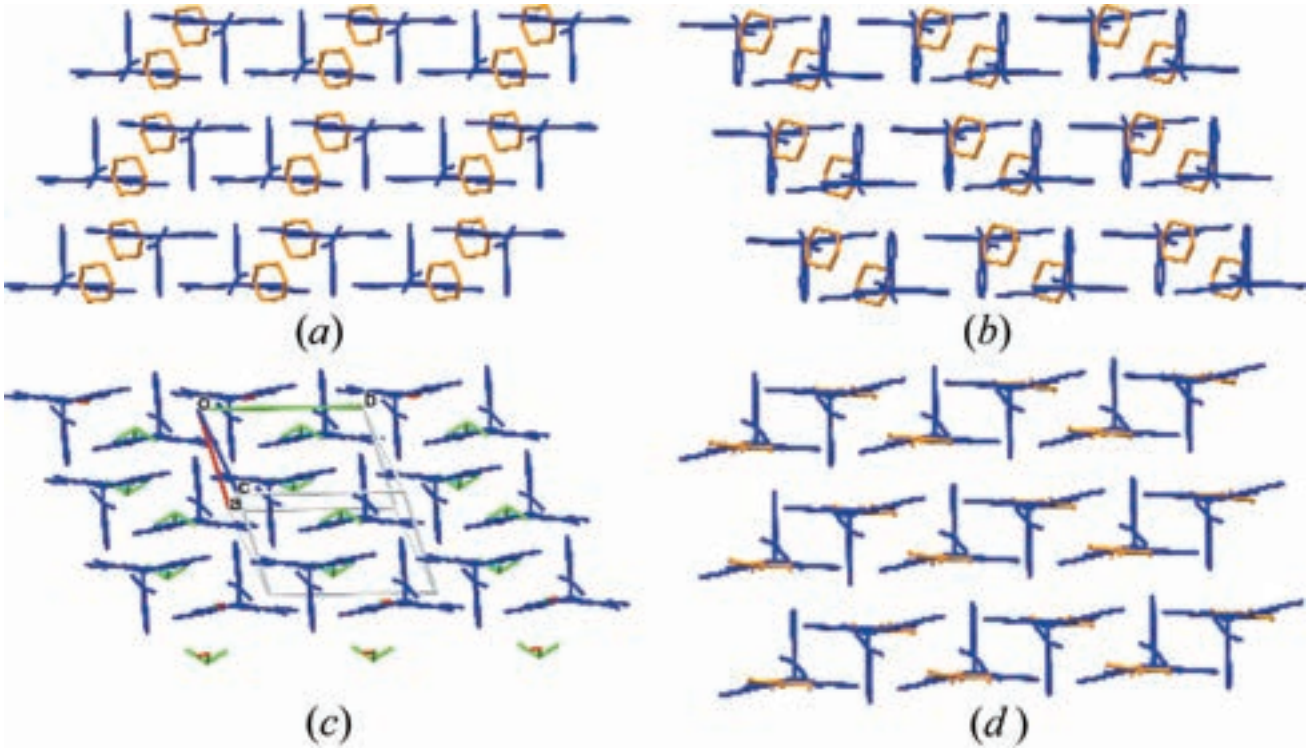


Figure 2. View of molecular packing in structurally similar solvates of (*a*) 1,4-dioxane, (*b*) morpholine, (*c*) DMSO and (*d*) DMA.

What is interesting is the packing of the molecules in the second category, which yield different structures (Fig. 3). As discussed in detail by the authors, solvents interact with the NIF molecule quite differently compared to the first category; also, the conformation of the NIF molecule is *cis–cis* in Figs. 3(*b*) and 3(*c*). But the pattern of host molecular packing, although with more modulations, is seen to exist in all three solvates. An intriguing case is that of pyridine solvate which has added complexity of crystallizing in a chiral space group. In this case, the two molecules of the asymmetric unit (light blue and dark blue) form this dimeric embrace, whereas in the other solvates it is the association of centrosymmetrically-related molecules.

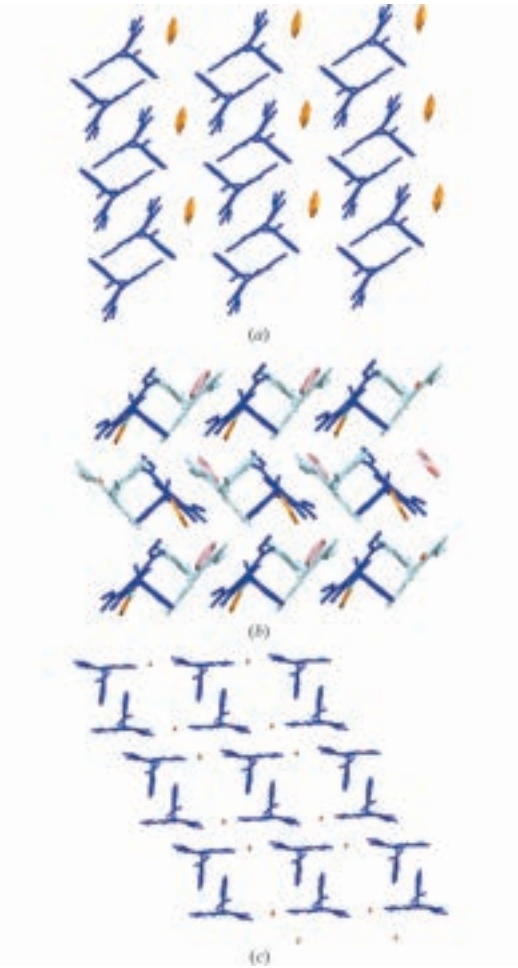


Figure 3. NIF with solvates (*a*) THF, (*b*) pyridine and (*c*) MeOH. For clarity, all views are down arbitrary orientations.

Therefore, it is conceivable to trace the possible mechanistic pathways for desolvation that converge to the stable α form with the least molecular movement. This case study of conserved packing patterns is of interest for crystal engineering purposes and reminds us of the geometrical approaches discussed years ago by Kitaigorodsky (1961). Do angled frameworks of molecules exhibit these isostructuralities during their molecular packing in forming crystals? Many solvates formed from L-shaped host molecules (Alshahateet *et al.*, 2015; Bishop *et al.*, 2018) were also noted to form a centrosymmetric dimeric association. Host molecule organization governed by relatively weaker interactions creates a well conserved layered framework allowing intercalations of several solvents that form stronger hydrogen bonds with the host.

Jones *et al.* (2023) also state an interesting use of the seeding technique to produce a δ form of NIF using crystals of a similar molecule, felodipine, that produces a *cis–cis* conformation for the NIF molecule (felodipine is not a symmetric molecule, but it does show this packing feature). Could this form a co-crystal, and would such studies lead us to the complementary 'fitting' in producing multicomponent molecular crystals? It is very likely that in future we will see fascinating multi-component crystals, as creatively combined as fishes with birds and fishes with horses by the legendary artist Escher (Fig. 4).

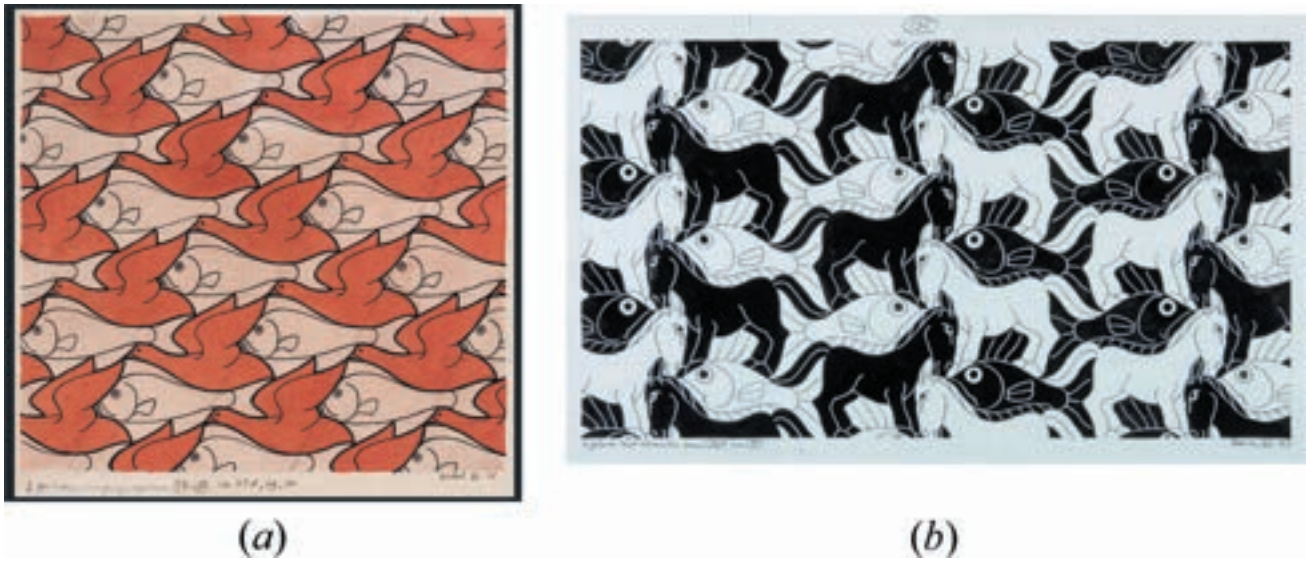


Figure 4. M. C. Escher (1898–1972) tessellations: (*a*) fish and bird (https://artdocents.wordpress.com/tag/mc-escher/) and (*b*) fish and horse (https://www.pinterest.com/pin/397794579557584028/).

References

Alshahateet, S. F., Bhadbhade, M. M., Bishop, R. & Scudder, M. L. (2015). *CrystEngComm*, **17**, 877–888.

Bauer, J., Spanton, S., Henry, R., Quick, J., Dziki, W., Porter, W. & Morris, J. (2001). *Pharm. Res.* **18**, 859–866.

Bernstein, J. (2020). *Polymorphism in Molecular Crystals,* 2nd ed. Oxford University Press.

Bishop, R., Bhadbhade, M. M., Scudder, M. L. & Gao, J. (2018). *Cryst. Growth Des.* **18**, 4880–4889.

Brittain, H. G. (2016). *Polymorphism in Pharmaceutical Solids,* 2nd ed. Boca Raton: Taylor & Francis.

Caira, M. R., Robbertse, Y., Bergh, J. J., Song, M. & De Villiers, M. M. (2003). *J. Pharm. Sci.* **92**, 2519–2533.

Cruz-Cabeza, A. J., Reutzel-Edens, S. M. & Bernstein, J. (2015). *Chem. Soc. Rev.* **44**, 8619–8635.

Desiraju, G. (1995). *Angew. Chem. Int. Ed. Engl.* **34**, 2311–2327.

Griesser, U. J. (2006). *Polymorphism in the Pharmaceutical Industry*, edited by R. Hilfiker, pp. 211–230. Weinheim: Wiley-VCH.

Gunn, E., Guzei, I. A., Cai, T. & Yu, L. (2012). *Cryst. Growth Des.* **12**, 2037–2043.

Healy, A. M., Worku, Z. A., Kumar, D. & Madi, A. M. (2017). *Adv. Drug Deliv. Rev.* **117**, 25–46.

Jones, E. C. L., Goldsmith, K. E., Ward, M. R., Bimbo, L. M. & Oswald, I. D. H. (2023). *Acta Cryst.* B**79**, 164–175.

Kitaigorodsky, A. I. (1961). *Organic Chemical Crystallography.* New York: Consultants Bureau.

Klimakow, M., Rademann, K. & Emmerling, F. (2010). *Cryst. Growth Des.* **10**, 2693–2698.

Wöhler, F. & Liebig, J. (1832). *Ann. Pharm.* **3**, 249–282.

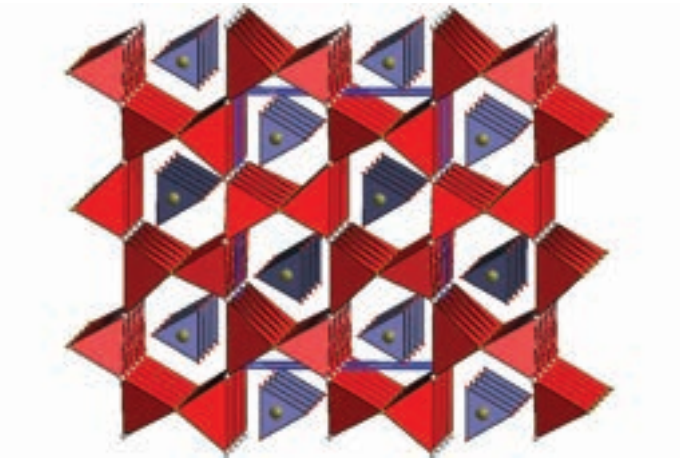
Tang, L., Gamal El-Din, T. M., Swanson, T. M., Pryde, D. C., Scheuer, T., Zheng, N. & Catterall, W. A. (2016). *Nature*, **537**, 117–121.

Triggle, A. M., Shefter, E. & Triggle, D. J. (1980). *J. Med. Chem.* **23**, 1442–1445.

This article was originally published in *Acta Cryst.* (2023). B**79**, 101–103.

COMMENTARY

The study of mineral behavior at low and high temperatures and their properties using a combination of different methods has not become routine yet



Sergey M. Aksenov

The complex study of the temperature behavior of natural and synthetic compounds (both inorganic and organic) has become quite common due to the widespread use of modern laboratory equipment. The development of powder diffractometers makes it possible to obtain reliable data from a small amount of pure substance, which can be heated (cooled) to very high (low) temperatures. Nevertheless, studying the features of the crystal structures of rare minerals is still rather challenging because the amount of available material for further measurements is not just small, but very small and could be limited to only a few grains. In this case it is always very interesting to read papers about complete characterization of rare minerals which contain not only structural data, but also the measurement of physical properties.

Synthetic compounds of the ludwigite-type structure, which is characterized by the general formula $M^{2+}_2M^{3+}O_2(BO_3)$, attract interest because of their magnetic properties in particular (Medrano *et al.*, 2015; Moshkina *et al.*, 2016; Sottmann *et al.*, 2018; Sofronova & Nazarenko, 2017). However, the study of natural samples is often difficult because of the complex chemical composition and the presence of magnetic impurity ions (Aleksandrov & Troneva, 2008) which have an influence on the observed properties. Hence the need to use additional techniques to study the distribution of the elements over crystallographic sites and for a better understanding of the physical properties on the cation arrangement.

Biryukov *et al.* (2022) presented a complex study of azoproite, a rare mineral from Tazheran Massif, with the idealized chemical formula $Mg_2[(Ti,Mg),Fe^{3+}]O_2(BO_3)$ (Konev *et al.*, 1971). It is interesting to note that the sample of azoproite was provided for the investigation by its discoverer, A. A. Konev (1928–2009). The empirical formula of the studied sample is $(Mg_{1.81}Fe^{2+}_{0.19})_{\Sigma 2.00}(Fe^{3+}_{0.36}Ti_{0.26}Mg_{0.26}Al_{0.12})_{\Sigma 1.00}O_2(BO_3)$ and the Fe^{2+}/Fe^{3+} ratios and the distribution of ferric and ferrous iron over crystallographic sites were determined using Mössbauer spectroscopy data both for the natural sample and for the sample calcined at 1023 K. The crystal structure was studied using single-crystal X-ray diffraction analysis, while *in situ* low- and high-temperature behavior in the temperature range 93–1373 K was studied using powder X-ray diffraction analysis. Magnetometry studies were performed in the temperature range 5–300 K. Based on differential scanning calorimetry (DSC) it was shown that azoproite melts at temperatures higher than 1600 K and it does not decompose due to the $Fe^{2+} \rightarrow Fe^{3+}$ oxidation process. DSC, Mössbauer

spectroscopy, magnetometry, and LT- and HT-XRD data clearly indicate the absence of phase transitions in the temperature range 5–1650 K. It was found that, unlike other studied borates and oxoborates [vonsenite, hulsite, synthetic $Fe_3(BO_4)O_2$ and $FeBO_3$ (Biryukov *et al.*, 2021, 2020)], no sharp anomalies in the unit-cell parameters were present in azoproite. This was explained by the magnetostriction or magnetoelastic effects due to the absence of magnetic phase transitions. The ludwigite-type structure is based on the dense heteropolyhedral framework which is formed by [MO_6]-octahedra and [BO_3]-triangles. However, it also can be represented in terms of anion-centered polyhedra (Krivovichev *et al.*, 2013), where [OM_4] and [OM_5] polyhedra form a microporous framework and [BO_3] triangles fill the wide channels. This approach for the description of the crystal structure is better for the interpretation of high-temperature behavior. The thermal expansion of azoproite is slightly anisotropic in the whole temperature range due to the arrangement of the oxocentered [OM_4] and [OM_5] polyhedra, while the thermal oscillations of [BO_3] triangles contribute the most to the anisotropy of the expansion.

The study of azoproite continues the authors' systematic investigation of the crystal structures, *in situ* low- and high-temperature behavior and magnetic properties of natural oxoborates (Biryukov *et al.*, 2021, 2020). It is clearly shown that accurate interpretation of crystal structure data needs a combination of not only diffraction analysis (single-crystal and powder), but also additional methods. In particular, the interpretation of the low-temperature behavior could be rather difficult without magnetic measurements, while the behavior at high temperature could be speculative without a contribution from DSC data and a comparison of Mössbauer spectroscopy data from both initial and calcined samples. This approach can be applied for different types of materials (Volkov *et al.*, 2023, 2022) and demonstrates significant advantages for the deep understanding of a materials' properties; however, the downside is the time which is required to complete the study.

References

Aleksandrov, S. M. & Troneva, M. A. (2008). *Geochem. Int.* **46**, 800–813.

Biryukov, Y. P., Zinnatullin, A. L., Bubnova, R. S., Vagizov, F. G., Shablinskii, A. P., Filatov, S. K., Shilovskikh, V. V. & Pekov, I. V. (2020). *Acta Cryst.* B**76**, 543–553.

Biryukov, Y. P., Zinnatullin, A. L., Cherosov, M. A., Shablinskii, A. P., Yusupov, R. V., Bubnova, R. S., Vagizov, F. G., Filatov, S. K., Avdontceva, M. S. & Pekov, I. V. (2021). *Acta Cryst.* B**77**, 1021–1034.

Biryukov, Y. P., Zinnatullin, A. L., Levashova, I. O., Shablinskii, A. P., Cherosov, M. A., Bubnova, R. S., Vagizov, F. G., Krzhizhanovskaya, M. G., Filatov, S. K., Shilovskikh, V. V. & Pekov, I. V. (2022). *Acta Cryst.* B**78**, 809–816.

Konev, A. A., Lebedeva, V. S., Kashayev, A. A. & Ushchapovskaya, Z. F. (1971). *Int. Geol. Rev.* **13**, 1183–1188.

Krivovichev, S. V., Mentré, O., Siidra, O. I., Colmont, M. & Filatov, S. K. (2013). *Chem. Rev.* **113**, 6459–6535.

Medrano, C. P. C., Freitas, D. C., Sanchez, D. R., Pinheiro, C. B., Eslava, G. G., Ghivelder, L. & Continentino, M. A. (2015). *Phys. Rev. B*, **91**, 054402.

Moshkina, E., Sofronova, S., Veligzhanin, A., Molokeev, M., Nazarenko, I., Eremin, E. & Bezmaternykh, L. (2016). *J. Magn. Magn. Mater.* **402**, 69–75.

Sofronova, S. & Nazarenko, I. (2017). *Cryst. Res. Technol.* **52**, 1600338.

Sottmann, J., Nataf, L., Chaix, L., Pralong, V. & Martin, C. (2018). *J. Phys. Chem. C*, **122**, 17042–17048.

Volkov, S. N., Charkin, D. O., Arsentev, M. Y., Aksenov, S. M., Manelis, L. S., Krzhizhanovskaya, M. G., Sinelshchikova, O. Y., Ugolkov, V. L., Povolotskiy, A. V., Shilovskikh, V. V., Antonov, A. A. & Bubnova, R. S. (2022). *CrystEngComm*, **24**, 4174–4179.

Volkov, S. N., Charkin, D. O., Firsova, V. A., Manelis, L. S., Banaru, A. M., Povolotskiy, A. V., Yukhno, V. A., Arsent'ev, M. Y., Savchenko, Y., Ugolkov, V. L., Krzhizhanovskaya, M. G., Bubnova, R. S. & Aksenov, S. M. (2023). *Inorg. Chem.* **62**, 30–34.

This article was originally published in *Acta Cryst.* (2023). B**79**, 196–197.

COMMENTARY

Unravelling the secrets of multi-domain lytic polysaccharide monooxygenases (LPMOs)

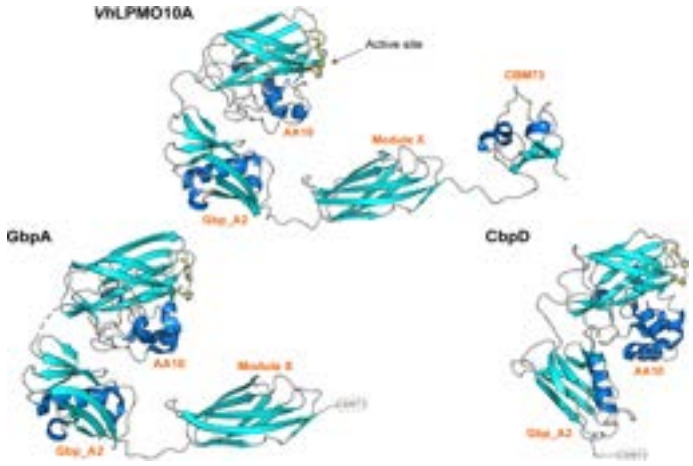


Figure 1. Structure of V*h*LPMO10A and two similar multi-domain LPMOs. The side chains of the catalytically crucial, copper-binding histidines are shown with yellow carbons and the copper (only shown for V*h*LPMO10A) appears as an orange sphere. Dashed lines in the structures of GbpA and CbpD indicate structural elements (linker and CBM73 module) that could not be modelled due to protein truncation (GbpA) or insufficient electron density (CbpD).

Gustav Vaaje-Kolstad, Vincent G. H. Eijsink

The discovery of enzymes known as lytic polysaccharide monooxygenases (LPMOs; Vaaje-Kolstad *et al.*, 2005, 2010), which catalyze the oxidative cleavage of glycosidic bonds in polysaccharides, has changed our understanding of how nature deals with recalcitrant polysaccharide-rich co-polymeric structures such as plant cell walls. LPMOs have received ample attention in the context of their use for more efficient enzymatic saccharification of chitin- or cellulose-rich biomass (Chylenski *et al.*, 2019). Interestingly, these abundant enzymes are also encountered in environments where degradation of biomass does not seem pertinent. Furthermore, multiple studies have revealed links between LPMOs and microbial pathogenicity (Vandhana *et al.*, 2022), for example GbpA in *Vibrio cholerae* (Kirn *et al.*, 2005; Stauder *et al.*, 2012; Wong *et al.*, 2012) and CbpD in *Pseudomonas aeruginosa* (Askarian *et al.*, 2021).

These latter LPMOs are multi-domain enzymes, starting with a catalytic LPMO domain and ending with a chitin-binding module belonging to family CBM73. In between, they have one or two additional domains with essentially unknown function, the first one of which is called Gbp_A2. The second of these domains resembles the FimC chaperone involved in pili formation in Gram-negative bacteria and is here referred to as Module X. Many carbohydrate-active enzymes, such as cellulases and chitinases, comprise a catalytic domain and one or more substrate-binding domains that are connected by flexible linkers. Crystal structures of such intrinsically flexible multi-domain proteins are very rare.

In this issue, Zhou *et al.* (2023) present the crystal structure of a complete four-domain GbpA homologue, *Vh*LPMO10A, produced by *Vibrio campbellii* (also known as *Vibrio harveyi*), an abundant pathogen in marine ecosystems (Zhang *et al.*, 2020). The previously published structure of GbpA (Wong *et al.*, 2012) lacks the C-terminal CBM73, whereas the structure of CbpD (Dade *et al.*, 2022) lacks both Module X (which is absent in this protein) and the CBM73. Important structural features that cannot be easily predicted by state-of-the-art AI algorithms are for example the multimerization state and inter-domain orientations in multi-domain structures. By combining X-ray data with SEC and SAXS data, Zhou *et al.*

provide insights in these matters that may give hints to protein function. Based on the data presented, the authors conclude that *Vh*LPMO10A is a monomeric protein with an elongated form, similar to what has been observed for GbpA and CbpD, also using SAXS analysis. Of note, the paper also provides the first crystal structure of a CBM73, for which, so far, only an NMR structure was available (Madland *et al.*, 2021).

The linkers connecting the domains are rather short (10, 8 and 18 residues, respectively) and contain few glycines (one, zero and two, respectively), suggesting that they are not very flexible, which may have helped in obtaining crystals. The longest linker, connecting the CBM73 to the other three domains, has typical features of an extended linker, with low sequence complexity and abundance of proline (four) and glutamate (four). Indeed, based on various observations, including lacking electron density for the CBM73 in one of the *Vh*LPMO10A monomers in the asymmetric unit, Zhou *et al.* conclude that the CBM moves rather freely and independent of the rest of the protein, as has also been observed in NMR studies of a CBM-containing cellulose-active LPMO (Courtade *et al.*, 2018). The other three domains may have more fixed orientations relative to each other and their orientation is also similar to that observed for GbpA. Still, for both proteins, SAXS data show a solution structure that is more elongated than the crystal structure, suggesting that the observed relative domain orientations in the crystals are affected by crystal contacts.

Importantly, Zhou *et al.* have gone a long way in the further characterization of their LPMO domain, thus providing important information for the LPMO field. In particular, their data on binding of various metal ions are unique and shed light on the binding potential of the unique copper-binding histidine motif in LPMOs. As a point of warning, the pH and temperature optima for 'LPMO activity' described in the paper are based on measuring H_2O_2 production resulting from an off-pathway oxidase reaction of the LPMO with molecular oxygen (Stepnov & Eijsink, 2023). While interesting, the catalytic features of the oxidase reaction do not say much about the reaction that leads to oxidation and cleavage of polysaccharide substrates.

Zhou *et al.* suggest that *Vh*LPMO10A might be useful in industrial processing of chitin, which indeed may be the case. However, looking at available functional data for GbpA, it seems likely that proteins such as *Vh*LPMO10A (also?) have a role in the pathogenicity-related physiology of *Vibrio* species. The novel, complete crystal structure of *Vh*LPMO10A and the adjacent functional data provide an excellent starting point for digging deeper into the true biological role of these enzymes. Importantly, GbpA, *Vh*LPMO10A and several other LPMOs with putative roles beyond biomass processing (*e.g.* Askarian *et al.*, 2021; Zhong *et al.*, 2022) are all active on chitin, *i.e.* a polymer of a sugar, *N*-acetylglucosamine, that is abundant in carbohydrate-containing microbial structures, such as cell walls. It needs to be questioned whether chitin is the true substrate of these LPMOs. In this respect, it is worth noting that the topology of the substrate-binding surfaces of the LPMO domains of GbpA and *Vh*LPMO10A is somewhat different from those of LPMOs known to play a key role in chitin degradation, such as *Sm*LPMO10A [also known as CBP21; see arrows in Figure 3 in Zhou *et al.* (2023)].

Despite the structural and functional insights provided by Zhou *et al.*, the biological function of proteins such as *Vh*LPMO10A and GbpA remains largely enigmatic. From work on GbpA, it seems certain that these proteins are important mediators of the interaction between *Vibrio* and relevant host surfaces (Kirn *et al.*, 2005; Wong *et al.*, 2012). Indeed, for GbpA it has been shown that the LPMO domain binds to both chitin and intestinal mucin and the CBM73 domain binds to chitin, whereas the combined Gbp_A2 domain and Module X mediate binding of the secreted GbpA protein to the surface of the *Vibrio* cells. Interestingly, the GbpA ortholog of the non-pathogenic bacterium *Aeromonas veronii* Hm21 stimulates epithelial cell proliferation in Zebrafish (Banse *et al.*, 2023). Most intriguingly, these known biological roles do not explain why these proteins have LPMO activity. Perhaps, degradation of chitin for nutritional and/or invasive purposes is in fact the key role of the LPMO domains. Alternatively, proteins such as *Vh*LPMO10A may have substrates that are yet to be discovered.

References

Askarian, F., Uchiyama, S., Masson, H., Sørensen, H. V., Golten, O., Bunaes, A. C., Mekasha, S., Røhr, A. K., Kommedal, E., Ludviksen, J. A., Arntzen, M. Ø., Schmidt, B., Zurich, R. H., van Sorge, N. M., Eijsink, V. G. H., Krengel, U., Mollnes, T. E., Lewis, N. E., Nizet, V. & Vaaje-Kolstad, G. (2021). *Nat. Commun.* **12**, 1230.

Banse, A. V., VanBeuge, S., Smith, T. J., Logan, S. L. & Guillemin, K. (2023). *Gut Microbes*, **15**, 2183686.

Chylenski, P., Bissaro, B., Sørlie, M., Røhr, K., Várnai, A., Horn, S. J. & Eijsink, V. G. H. (2019). *ACS Catal.* **9**, 4970–4991.

Courtade, G., Forsberg, Z., Heggset, E. B., Eijsink, V. G. H. & Aachmann, F. L. (2018). *J. Biol. Chem.* **293**, 13006–13015.

Dade, C. M., Douzi, B., Cambillau, C., Ball, G., Voulhoux, R. & Forest, K. T. (2022). *Acta Cryst.* D**78**, 1064–1078.

Kirn, T. J., Jude, B. A. & Taylor, R. K. (2005). *Nature*, **438**, 863–866.

Madland, E., Forsberg, Z., Wang, Y., Lindorff-Larsen, K., Niebisch, A., Modregger, J., Eijsink, V. G. H., Aachmann, F. L. & Courtade, G. (2021). *J. Biol. Chem.* **297**, 101084.

Stauder, M., Huq, A., Pezzati, E., Grim, C. J., Ramoino, P., Pane, L., Colwell, R. R., Pruzzo, C. & Vezzulli, L. (2012). *Env. Microbiol. Rep.* **4**, 439–445.

Stepnov, A. A. & Eijsink, V. G. H. (2023). *Methods Enzymol.* **679**, 163–189.

Vaaje-Kolstad, G., Horn, S. J., van Aalten, D. M. F., Synstad, B. & Eijsink, V. G. H. (2005). *J. Biol. Chem.* **280**, 28492–28497.

Vaaje-Kolstad, G., Westereng, B., Horn, S. J., Liu, Z. L., Zhai, H., Sørlie, M. & Eijsink, V. G. H. (2010). *Science*, **330**, 219–222.

Vandhana, T. M., Reyre, J. L., Sushmaa, D., Berrin, J. G., Bissaro, B. & Madhuprakash, J. (2022). *New Phytol.* **233**, 2380–2396.

Wong, E., Vaaje-Kolstad, G., Ghosh, A., Hurtado-Guerrero, R., Konarev, P. V., Ibrahim, A. F. M., Svergun, D. I., Eijsink, V. G. H., Chatterjee, N. S. & van Aalten, D. M. F. (2012). *PLoS Pathog.* **8**, e1002373.

Zhang, X. H., He, X. X. & Austin, B. (2020). *Mar. Life Sci. Technol.* **2**, 231–245.

Zhong, X., Zhang, L., van Wezel, G. P., Vijgenboom, E. & Claessen, D. (2022). *mBio*, **13**, e00456–22.

Zhou, Y., Wannapaiboon, S., Prongjit, M., Pornsuwan, S., Sucharitakul, J., Kamonsutthipaijit, N., Robinson, R. C. & Suginta, W. (2023). *Acta Cryst.* D**79**, 479–497.

This article was originally published in *Acta Cryst.* (2023). D**79**, 444–446.

COMMENTARY

Continuous development in macromolecular crystallography with CCP4

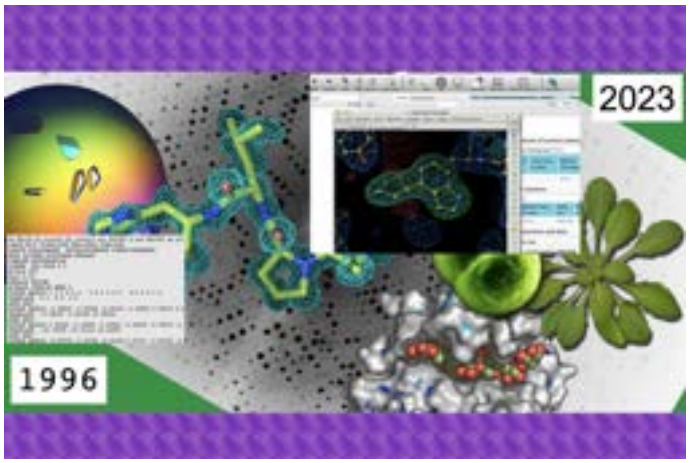


Figure 1. The evolution of CCP4 from 1996 to the present day.

Martín Martinez-Ripoll, Armando Albert

People engaged in X-ray crystallography since the early 1970s have been spectators and beneficiaries of the contributions of many colleagues who dedicated a significant part of their professional careers to the development of computational methodology for X-ray crystallography. Indeed, from the earliest standalone programs for processing experimental measurements extracted from Weissenberg diagrams, to the handling of the resolution and refinement programs and the earliest graphic representation programs, crystallographers will always be grateful to this community effort. But over the years, small-molecule crystallographers benefited from the great advances made in the development of integrated systems, such as the *XRAY*76 System, which for the first time offered a full collection of tools for full resolution of small-molecule structures from single-crystal X-ray diffraction data.

The field of macromolecular crystallography also underwent a development equivalent to that of small molecules, although somewhat later. The establishment of the Collaborative Computational Project No. 4 (known as CCP4) in 1979 represented a spectacular qualitative advance in the field. CCP4 is a public resource for producing and supporting a world-leading, integrated suite of programs that allows researchers to determine and analyze macromolecular structures by X-ray crystallography. Indeed, the CCP4 project has evolved in line with structural biology advancements, becoming an essential resource for researchers and scientists worldwide (Fig. 1).

Nowadays, the CCP4 initiative is not merely a collection of programs, it includes a graphical interface that guides less experienced users through the resolution pathway to the structural analysis and provides traceability of jobs. In addition, CCP4 supports various educational projects around the globe. These initiatives extend beyond self-promotion and include an open mailing list that anyone can join to share conference and workshop announcements, questions and discussions, that sometimes turn into debates, and information about job offers.

The article by Agirre *et al.* in this issue (Agirre *et al.*, 2023), provides a thorough review of the *CCP*4 suite of programs. It constitutes a long-awaited initiative intended to review the current state of the CCP4 project and future developments. In addition, it offers an up-to-date literature citation for the suite, which has had multiple references in the past, and for each of the individual programs. The review aligns with the idea that the complexity of macromolecular crystallography should be accessible to both non-expert

and advanced users and should offer computing tools regardless of the difficulty of the project. The article also provides a critical analysis of the challenges and opportunities that the field of macromolecular crystallography faces now and in the future.

References

Agirre, J., Atanasova, M., Bagdonas, H., Ballard, C. B., Baslé, A., Beilsten-Edmands, J., Borges, R. J., Brown, D. G., Burgos-Mármol, J. J., Berrisford, J. M., Bond, P. S., Caballero, I., Catapano, L., Chojnowski, G., Cook, A. G., Cowtan, K. D., Croll, T. I., Debreczeni, J. É., Devenish, N. E., Dodson, E. J., Drevon, T. R., Emsley, P., Evans, G., Evans, P. R., Fando, M., Foadi, J., Fuentes-Montero, L., Garman, E. F., Gerstel, M., Gildea, R. J., Hatti, K., Hekkelman, M. L., Heuser, P., Hoh, S. W., Hough, M. A., Jenkins, H. T., Jiménez, E., Joosten, R. P., Keegan, R. M., Keep, N., Krissinel, E. B., Kolenko, P., Kovalevskiy, O., Lamzin, V. S., Lawson, D. M., Lebedev, A. A., Leslie, A. G. W., Lohkamp, B., Long, F., Malý, M., McCoy, A. J., McNicholas, S. J., Medina, A., Millán, C., Murray, J. W., Murshudov, G. N., Nicholls, R. A., Noble, M. E. M., Oeffner, R., Pannu, N. S., Parkhurst, J. M., Pearce, N., Pereira, J., Perrakis, A., Powell, H. R., Read, R. J., Rigden, D. J., Rochira, W., Sammito, M., Sánchez Rodríguez, F., Sheldrick, G. M., Shelley, K. L., Simkovic, F., Simpkin, A. J., Skubak, P., Sobolev, E., Steiner, R. A., Stevenson, K., Tews, I., Thomas, J. M. H., Thorn, A., Valls, J. T., Uski, V., Usón, I., Vagin, A., Velankar, S., Vollmar, M., Walden, H., Waterman, D., Wilson, K. S., Winn, M. D., Winter, G., Wojdyr, M. & Yamashita, K. (2023). *Acta Cryst.* D**79**, 449–461.

This article was originally published in *Acta Cryst.* (2023). D**79**, 447–448.

FEATURE ARTICLE

Pauling's rules revisited



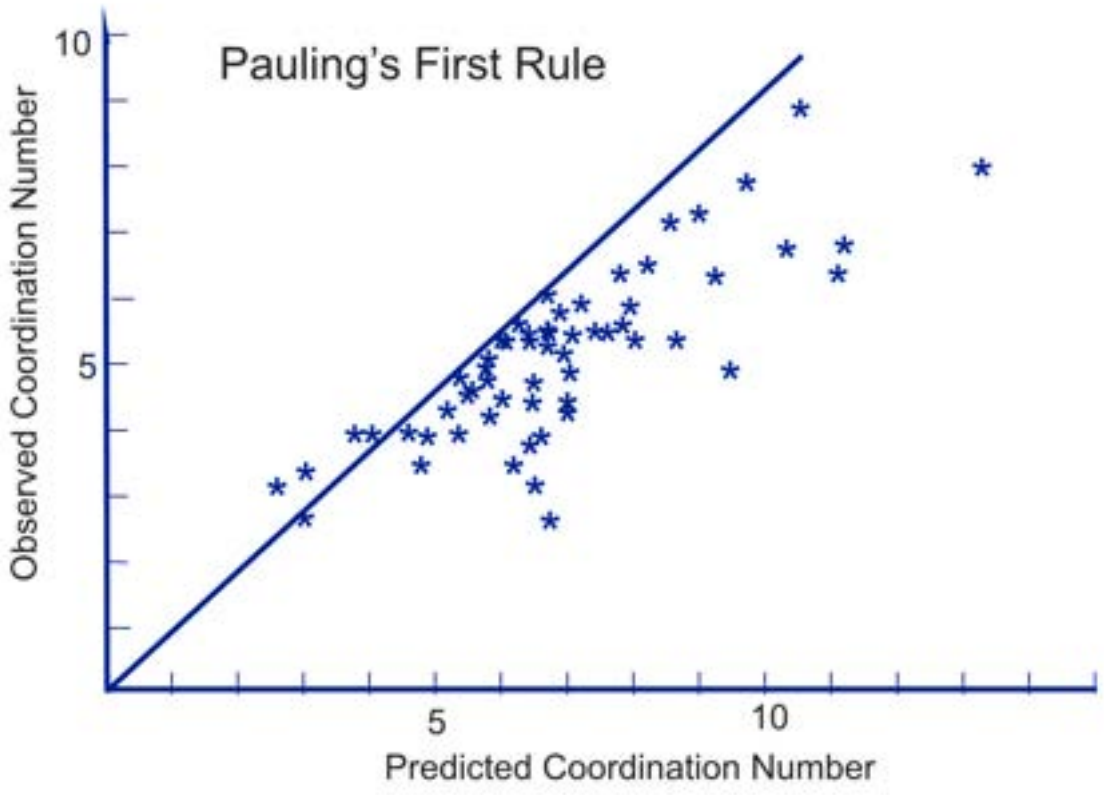
I. David Brown

Almost a century ago, Linus Pauling (1929) proposed a set of rules governing the structural chemistry of inorganic crystals. The rules were a tentative step toward creating a valence theory for inorganic compounds. Unfortunately, the new quantum mechanics that promised to answer all of chemistry's questions appeared at the same time, and Pauling's rules were soon forgotten. They are worth a second look because they point to a simple but rich theory of valence that describes the chemistry of both organic and inorganic compounds using only the simple concepts of valence, atoms and bonds.

Curiously, for all its success, quantum mechanics has never provided definitions for either bonds or valence, or even for atoms once they are incorporated into a molecule. The reason for this failure is simple. Quantum mechanics calculates the energy and other physical properties using the electric field that connects electrons to nuclei, but any calculation using a force field is a mathematical integration that requires a set of initial conditions, such as the spatial coordinates of the nuclei. This restricts each calculation to a single spatial arrangement of atoms. Valence theories are more flexible because they do not use atomic coordinates. Instead, they define the location of an atom by its place within the network of bonds that links the atom to its neighbours. Chemical properties such as molecular structure and reactivity are determined by how the network distributes the valences of the atoms among its various bonds. By not having to specify atomic coordinates, valence theories are simpler and more intuitive, but at the cost of being unable to calculate energies. It follows that quantum and valence approaches provide complementary descriptions of the same compound. Quantum theory describes the physics of electrons bound to nuclei, valence theory describes the chemistry of atoms linked by bonds. In the past, when the atom was still just a hypothesis, valence theory brought order to organic chemistry where it is still widely used, but finding a comparable theory of inorganic chemistry has proved elusive.

Pauling presented his rules in an early attempt to formulate an inorganic valence theory. His first two rules are visionary because they express the idea that structural chemistry is largely determined by the sizes and valences of the atoms, concepts that serve as surrogates for the quantum picture of the core and the valence shell, respectively. Hidden unnoticed within these rules lie the clues to a unified theory of valence, one that provides an enriched description of the structure and properties of both organic and inorganic compounds.

Pauling's first rule states that the coordination number of a cation depends on the ratio of the cation to anion radii, but all attempts to define the radius of an atom or ion have failed because atoms do not behave like hard spheres. What has hitherto been overlooked is that the proper measure of atomic size in chemistry is not the radius of the atom, which is undefinable, but the coordination number that the atom adopts in different chemical contexts. The elemental property that best characterizes the size of an atom is the average of its observed coordination numbers.



Pauling's second rule defines the bond strength of a cation as its valence divided by its coordination number. The rule states that the valence of an anion is approximately equal to the sum of the bond strengths it receives from its cation neighbours. This rule introduces four important ideas:

Even though the ionic model uses an electric force field to link cations to anions, Pauling assumes that this field can be transformed into a network of localized bonds. A formal derivation shows that while such a transformation is possible, it is not reversible because the atomic coordinates are lost in the process.

The most important chemical property of an atom is neither its valence nor its coordination number, but its bond strength which indicates its preferred bond partners.

Two atoms contribute equal valences to form a bond.

The bond strength, being a ratio, is not restricted to integral values. The traditional association of valence with an electron has no physical basis. Valence and electrons can never be measured at the same time: the valence of an atom can only be measured when it is part of a compound, but an individual electron can only be observed when it is an isolated particle.

A unified theory of valence is possible if non-integral valences are allowed. It describes the chemical structures of both organic and inorganic compounds by a network of localized bonds that obey a number of simple rules. Elements are characterized by their observed properties of valences and average coordination number, but their most important property is their bonding strength, equal to the ratio of their valence to average coordination number. Bonds are found to form only between atoms whose bonding strengths differ by less than a factor of two, though atoms with lone pairs, such as anions, can form stronger bonds by making their lone pairs stereoactive, thus accounting for the different chemistries of anions and cations. The ionicity of a bond is the difference between the electronegativities of its bonded atoms, where the electronegativity can be shown to be equal to the bonding strength of the element in its highest valence state. Organic molecules are formed by atoms with bonding strengths close to 1.0, allowing them to form bonds of low ionicity in many different ways. Hydrogen and fluorine

necessarily terminate the bond network to form discrete molecules.

The resulting unified valence theory (Brown, 2023) is quantitative and can predict which atoms will form bonds, as well as the bond lengths, geometries and chemical properties of the resulting compound. The structure and chemistry of hydrogen bonds, and likely also of halogen bonds, are predicted from atomic valences and sizes. The theory describes solubilities and the species present in aqueous solutions at various pHs. Where practical considerations often limit quantum mechanical calculations to isolated clusters of atoms, valence theory incorporates a knowledge of the chemical environment and its influence on the internal structure of a molecule. Even though valence theory cannot determine physical properties, its simplicity makes it an ideal way to introduce students to chemistry, and for those who later graduate to quantum mechanics, it provides a way of selecting a structure for a more comprehensive quantum investigation.

References

Pauling, L. (1929). The principles determining the structure of complex ionic crystals. *J. Am. Chem. Soc.* **51**, 1010–1026.

Brown, I.D. (2023). A rigorous theory of valence. *Struct. Chem.* **34**, 361–389.

I. David Brown is Professor Emeritus at Brockhouse Institute for Materials Research, McMaster University, Hamilton, ON, Canada; idbrown@mcmaster.ca.

IUCR CONGRESS

IUCr 2023 – virtual registration now open



We have launched additional ways for you to participate in and benefit from the Congress.

In-Person Attendance

We are encouraging as much in-person interaction and collaboration as possible. The full in-person registration provides an all-access pass to everything the Congress has on offer, with over 700 specialised oral sessions, microsymposia award lectures and posters to be delivered; IUCr 2023 is a truly global representation of crystallography and related structural science expertise. The Congress's social functions complement the scientific program to facilitate your networking needs and your culinary tastebuds! All this knowledge and access to industry under one roof in Melbourne, Australia. It will be a magnificent event.

Day Pass Attendance

For those who don't have the time to spare, we have introduced a one-day or two-day pass. This is now available for delegates to purchase. The pass includes admission to the sessions in person. And access to the exhibition on the day of attendance. The pass also includes all catering on-site during the day but does not include the Congress social functions.

Virtual Attendance

However, we also appreciate there are many factors that prohibit some of our community from attending IUCr 2023 physically. Therefore, we are introducing a virtual registration option for those delegates who would love to be with us in person but can't make it to Melbourne. If you register as an in-person delegate between now and the Congress, you will automatically receive access to the virtual program.

Virtual registration entitlements include live streaming of recordings of selected Virtual Congress sessions, including the Opening Ceremony, four award lectures, all three plenary presentations, all keynote presentations, the 75th-anniversary symposia, the Congress Closing Ceremony and access to the digital poster gallery. We promise an inspiring and innovative program showcasing keynote speakers and plenary speakers from across the globe.

For details on all attendance options, please see here.

We urge you to join over 1,700+ crystallographers representing 72 countries, who will contribute to the strengthening of the global crystallography community. We promise you it will be worth the journey.

IUCR CONGRESS

Women in Crystallography project



Annalisa Guerri

For the third time since its launch in Oviedo, Spain, at ECM31, and with a more international scope, the “Women in Crystallography” project is in the limelight again – this time in a different continent, with a very special host: our colleagues from down under in Melbourne. We thank all the crystallographers for the hospitality, and we hope we will be able to keep up with the tradition of making this T-shirt fundraising event a fabulous success. The T-shirts will be available at the Dectris, IUCr and STOE exhibition booths, all of which are supporting and sponsoring this initiative along with the ECA.

The money collected will be used to support more and more female crystallographers to attend congresses and schools around the world.

Take a picture of yourself wearing your T-shirt and post it on Twitter with the hashtags #Womenincrystallography #IUCr2023.

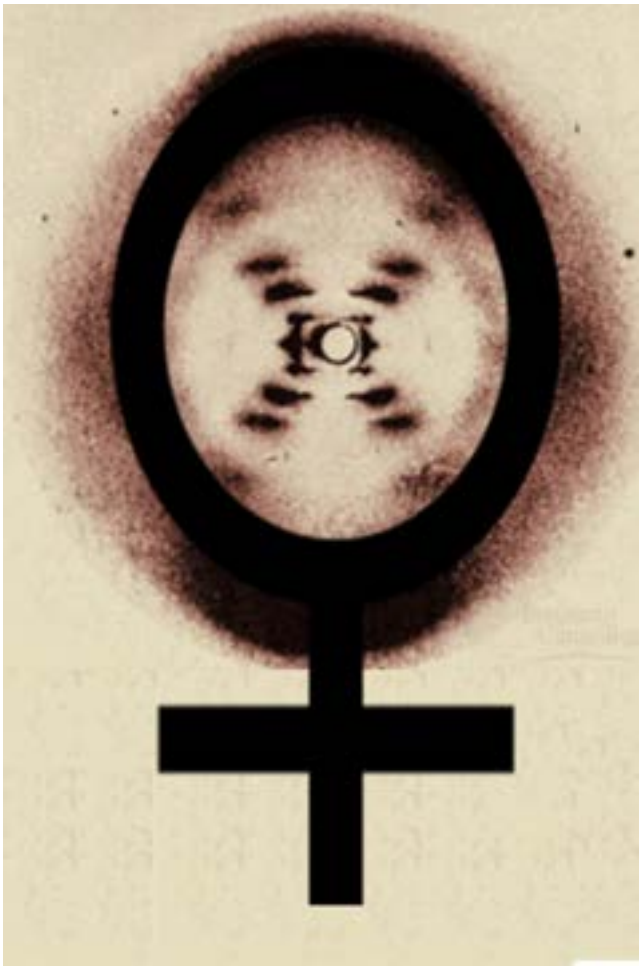
See you in Melbourne!

History of the “Women in Crystallography” logo

The “Women in Crystallography” project was launched in 2018 during the ECM31 in Oviedo thanks to the first organized microsymposium on Women in Crystallography (MS45). The Chairs of the microsymposium (Julia Contreras García and Annalisa Guerri) were asked to provide a logo and a motto for the MS to be shown at the beginning of the session.

The logo originated from the worldwide famous “Photo 51”, the X-ray fiber diffraction image of DNA taken by Raymond Gosling, a graduate student working under the supervision of Rosalind Franklin. This pattern is an iconic symbol for crystallographers and represents female scientists in crystallography.

After a short email exchange, the following picture and wording below came to light for the introduction of the MS45:



Starting from this idea, Laura Roches Fernández and Julia Contreras García elaborated the logo and gave birth to the one used to print the T-shirts. After a first draft, the logo was refined at the University of Oviedo as it appears below:



The idea was also inspired by another project born in 2015: the “women under high pressure” movement with the aim to improve the participation of women, especially young scientists, at events around the world and to create a balanced attendance among participants and also among the speakers.

“*N'oubliez jamais qu'il suffira d'une crise politique, économique ou religieuse pour que les droits des femmes soient remis en question. Ces droits ne sont jamais acquis. Vous devrez rester vigilantes votre vie durant.*"

“*Never forget that a political, economic, or religious crisis is enough to cast doubt on women’s rights. These rights will never be vested. You have to stay vigilant your whole life.*”

— Simone de Beauvoir

REGIONAL NEWS

Recent news from the European Crystallographic Association



From left to right: Andy Maloney, Klaudia Hradil, Arie van der Lee, Marijana Daković, Antonia Neels, Angela Altomare (IUCr representative), Consiglia Tedesco. Photo taken by Gilberto Artioli in front of the building of the Dipartimento di Geoscienze of the University of Padova.

Arie van der Lee

Future event planning

After the very successful European Crystallographic Meeting in Versailles (ECM33), France, in August 2022, activities moved along at a slower pace but were not completely absent. The ECA Executive Committee met in Padova, Italy, from 17 to 19 February 2023, where we were hosted by the chair of the 34th European Crystallographic Meeting (ECM34), Gilberto Artioli, and visited Padova's brand new Congress Center, where the meeting will take place in 2024. Progress in the organization of future ECA events (ECM35, Lviv; ECS8, Berlin, July 2023; ECS9, Nancy, June 2024) was discussed also with the different organizers. A bid for the organization of a European Crystallography School in North Macedonia in 2025 will probably be submitted so that it can be discussed and voted on during this year's annual Council Meeting, which will be held virtually in September 2023.

ECA Prizes

The ECA Executive Committee also considered the way the ECA's prizes are attributed and how to increase the attractiveness of the prizes. We had discussions with the Council, the young crystallographers in Versailles and colleagues of the boards of the American Crystallographic Association (ACA) and the European Neutron Scattering Association (ENSA). Following these discussions, new guidelines will be drafted and presented at the forthcoming Council Meeting. We will also announce the birth of one or two new prizes.

2023 Erwin Félix Lewy Bertaut Prize

The 2023 Erwin Félix Lewy Bertaut Prize was awarded to Dr Matilde Saura-Múzquiz, currently at Department of Materials Physics, Universidad Complutense de Madrid, Spain. The ECA and ENSA jointly award the Bertaut Prize in memory of the scientific achievements of the late Erwin Félix Lewy Bertaut, representing cornerstones in both crystallography and neutron scattering. Dr Saura-Múzquiz has impressive early-career contributions in the field of the crystallography of functional materials. The Bertaut Prize ceremony took place in Garching, Germany, during the European Conference on Neutron Scattering 2023.

For more information, please see the article in this *Newsletter* here.

2023 ECA SIG4 Publication Award

The ECA's Special Interest Group 4 (Electron Crystallography) has introduced recently a publication award in order to facilitate the advancement of electron crystallography methods and to encourage the exploration of innovative applications. The first awardees are Meng Ge, Taimin Yang, Hongyi Xu, Xiaodong Zou and Zhehao Huang (Department of Materials and Environmental Chemistry, Stockholm University, Sweden) for their paper "*Direct Location of Organic Molecules in Framework Materials by Three-Dimensional Electron Diffraction*", published in the *Journal of the American Chemical Society*. The prize was announced at the Electron Crystallography Workshop held in Antwerp, Belgium, on 30–31 May 2023.

For more information, please see the article in this *Newsletter* here.

Gender balance and equity statement

Work is in progress to establish a gender balance and equity statement by the ECA, which should be taken not only into consideration for the ECA's own events, such as ECMs and ECSs, but also as a condition to receive financial support for non-ECA events. The ECA's General Interest Group 3 (Education in Crystallography) is making a proposal that will be edited by the Executive Committee before discussion at the Council Meeting in September 2023.

Lunchtime webinars

The successful series of ECA lunchtime webinars has, at the time of writing (May 2023), reached its 21st edition. The ECA's young crystallographers organize this series, and it will continue to be held after the summer. Another series of webinars, Distinguished Lectures on Quantum Crystallography and Complementary Fields, initiated by the ECA's Special Interest Group 2 (Quantum Crystallography) and the IUCr Commission on Quantum Crystallography, continued as well: seven webinars have taken place since April 2022, usually with two lectures during the same webinar.

Crystallography in Africa

The ECA continues to support the development of crystallography in Africa. The African Crystallographic Association (AfCA) was established in 2021. With respect to National Membership, AfCA and ECA have decided that the ECA's African National Members may remain ECA National Members as long as they wish. The ECA was represented by its secretary, Andy Maloney, at the 3rd African Conference on Crystallography in Nairobi, Kenya, from 17 to 21 January 2023. The ECA's National Member Officer, Delia Haynes, was, of course, also present in Nairobi in her role as AfCA's Executive Committee president.

ECA members are also involved in the AFRAMED/Remote labs project led by its past president Claude Lecomte who has initiated this exciting development aiming to train African crystallographers in the techniques of single-crystal diffraction in laboratories equipped with single-crystal diffractometers elsewhere and to give them the opportunity to run their own experiments by remote access to the diffractometer in the distant laboratory. This project was launched in Nancy, France, on 31 August 2022.

MEETING REPORT

24th Heart of Europe Bio-Crystallography meeting



Participants at the 24th Heart of Europe Bio-Crystallography meeting in Dolni Vltavice, Czech Republic.

Milton T. Stubbs

The 24th Heart of Europe Bio-Crystallography meeting (HEC24) took place in September 2022 on the shores of the beautiful Lake Lipno in the South Bohemian village of Dolni Vltavice, Czech Republic. Organized in collaboration with the Czech and Slovak Crystallographic Association by Ivana Kutá Smatanová and her team from the University of South Bohemia in České Budějovice, HEC24 received financial support from seven companies, the European Crystallographic Association (ECA) (which awarded twelve bursaries for young scientists), as well as IUCr Journals who provided two copies of *State of the Art of Macromolecular Crystallization* as prizes for student presentations.

This first post-COVID-19 meeting was attended by 109 structural biologists from 22 research groups in central Europe (Austria, the Czech Republic, Germany and Poland), and opened with the introduction of new HEC group Przemek Grudnik (Jagiellonian University, Krakow). Over the next three days, 26 PhD students and four young postdocs presented current topics of their research. The quality of the talks was excellent, making it hard for the HEC Prize committee to reach its decision. After much deliberation, Elżbieta Wątor (Jagiellonian University, Kraków, Poland) was awarded the prize for her presentation “Half way to hypusine. Molecular basis of (deoxy)hypusination”. Ten flash talks, introduced for the first time at HEC23, were also presented, and Jakub Hrubý (CTU Prague, Czech Republic) was awarded for his presentation “Effects of the Zn^{2+} to Cd^{2+} Exchange on the Structure and Activity of S1 Nuclease”. The HEC lecture, presented each year by a prominent scientist outside the HEC community, was delivered by Kay Diederichs (University of Konstanz). His talk “A better understanding of X-ray data quality indicators” was truly inspirational, reminding participants young and old (!) of the importance of statistics.



This year’s HEC prizes were awarded to Elżbieta Wątor (second from left) of the Jagiellonian University, Kraków, Poland, for her talk “Half way to hypusine. Molecular basis of (deoxy)hypusination” and Jakub Hrubý (second from right) from the CTU Prague, Czech Republic, for his flash talk “Effects of the Zn^{2+} to Cd^{2+} Exchange on the Structure and Activity of S1 Nuclease”. Each was awarded a copy of *State of the Art of Macromolecular Crystallization*, edited by Howard Einspahr and kindly sponsored by IUCr Journals. The awards were presented by Ivana Kutá Smatanová (left) and Manfred Weiss (right).

Interspersal of the programme with short company-sponsored presentations served to introduce new technologies to the participants, and the hearty Bohemian food and drink fostered a warm atmosphere for both formal and informal discussion. The afternoon boat ride provided time for relaxed discussions over a Czech beer or two, and the last-night disco was thoroughly appreciated.

Ivana and her team are to be thanked for the excellent organisation of HEC24, which ended with an (almost) impromptu live sing-along of the HEC song that was penned for HEC23 during lockdown. The next Heart of Europe Bio-Crystallography meeting (HEC25), organized by Michael Lammers of the University of Greifswald, will also be lakeside, taking place on the shores of Lake Kummerow in Salem, Mecklenburg-Vorpommern (Germany), from 21 to 23 September 2023.

MEETING REPORT (IUCR SUPPORTED)

19th BCA/CCG Intensive Teaching School in X-ray Structure Analysis



Natalie Pridmore

The 19th BCA/CCG Intensive Teaching School in X-ray Structure Analysis was back in person, for the first time since 2019, and held at Trevelyan College, Durham, UK, from 25 March to 2 April 2023. The school was once again heavily oversubscribed due to its national and international reputation for providing a good basis in crystallography, and this year we welcomed almost 80 students from the UK, Ireland, Germany, Hungary, Malta, Croatia, Poland, Spain, Italy and Australia. The variety of nationalities, academic backgrounds and crystallographic experience created a great environment for both learning and meeting new people, with many students and staff commenting on the positive and friendly atmosphere.

As a result of feedback from students and staff over the years, the format of the biennial course has evolved. It currently consists of a mixture of lectures and tutorials designed to help students improve their understanding of the lecture material. As the name suggests, the course is intensive with a full timetable across the seven days providing the students with the opportunity to gain a good theoretical understanding of various aspects of crystallography from a single-crystal perspective. Beginning with an introductory lecture shortly after arrival on Saturday evening, the lectures given by Professor Richard Cooper, Dr Lukas Palatinus, Dr Claire Hobday, Dr Helena Shepherd, Dr Andrew Bond and Dr Mark Senn covered Maths, Symmetry, Data collection, Fourier/Patterson, Electron Diffraction, Direct Methods, Charge Flipping and Superspace, Parameterisation, Least Squares, Refinement, Twinning, and Derivation of Results. An introduction to databases was also given by Dr Chris Kingsbury and the use of Synchrotron and Neutron facilities was highlighted by Dr Mark Warren and Dr Amber Thompson.

Attendees were assigned to a tutor group, consisting of one tutor and up to eight students, and worked together throughout the week to tackle a series of problems related to the lecture material. This year we welcomed new tutors Dr Natalie Johnson, Dr Carsten Lenczyk and Dr Natalie Pridmore (as a floating tutor), and welcomed back Dr Samantha Chong, Dr Matic Lozinsek and Dr Jeremiah Tidey, who were tutoring in person for the first time, and Dr Andrew Cairns, Dr Iain Oswald, Dr Amber Thompson, Dr Mark Warren and Dr Hamish Yeung. The lectures and tutorials were once again held in the Sir James Knott Hall, which enabled us to switch easily between formal lectures and tutorial work with minimal disruption. The accommodation and meals were provided in Collingwood College, which is less than a 5-minute walk away but provided a pleasant chance for some fresh air and brief exercise during the day.

As is traditional at the school, apart from the Maths lecture on the first day, the evening activities are designed to be more relaxed and provide an opportunity for the students to mix with each other through a combination of educational and fun activities. On the Sunday evening, a successful bar quiz, organised

by Richard Cooper, was enjoyed by all those in attendance (including the bar staff) whereas Monday evening's session was a chance for the students to get to know some of the lecturers and tutors better with a panel question session, which included a discussion of the favourite or most difficult structure they have solved and their favourite space group.

This year's student presentations, on the Friday evening, were organised by Dr Jeremiah Tidey and Dr Mark Warren. Each of the tutor groups put together a 5-minute presentation on a crystallographic topic, drawn from a hat earlier in the week, and performed it in a style that was also chosen at random. This year, this included Crystal Growth and Selection in the style of Shakespearean Theatre, asking the age-old question to measure or not to measure; Disorder as a Public Service Announcement/Breaking News, which warned of the dangers of using squeeze routinely, and The Lab Diffractometer in the style of a Pantomime (oh yes they did!). As with previous years the scientific quality, thematic accuracy and entertainment value of each presentation was assessed by our elite panel of judges, the lecturers, who were very impressed by all the entries.

The conference dinner, held in Trevelyan College, on the Saturday evening provided the chance to thank all the people who had contributed to the success of this year's school including the local staff, organisers, lecturers, tutors and students. The hard work and positive attitude from the staff and students alike helped to create a very friendly school. After this year's school, Dr Hazel Sparkes, who did not attend this year's school but was instrumental in its organisation, is stepping back from her role as local organiser, and Dr Claire Wilson is stepping down from preparing the notes for the course. We would like to thank them both for their contributions for over a decade; their organisation, enthusiasm and drive have enabled the course to run and helped maintain its high standards. We are delighted that Dr Natalie Pridmore and Dr Andrew Cairns have agreed to take over as local organiser and note preparer, respectively.

Following on from the school, an optional hands-on *Olex2* workshop was held on the Sunday, run by Dr Oleg Dolomanov, Dr Florian Kleemiss, Florian Meurer and Dr Toby Blundell. This was well received by the over 45 registered participants, who had the opportunity to use *Olex2* to apply concepts that they had learnt on the course to test both structures and their own data.

I would like to finish by saying thank you to all the sponsors of this year's school: IUCr, ECA, CCG, ICG, Bruker, Rigaku, Almac and CCDC. Without the financial support from these organisations, we would not have been able to help as many students attend the school, or run it so successfully, and we are very grateful for their continued support.

Reports from two bursary recipients

Sourav De (Research Centre for Natural Sciences, Budapest, Hungary)



Graduating from a different field of chemistry, I did not have first-hand experience with the X-ray diffractometer. However, preparing crystals and providing the sample to our crystallographer was a part of my work during my PhD and I was always amazed by the vast amount of information that could be obtained from a crystal structure. This motivated me to enter the field of crystallography as my post-doc research at the Research Centre for Natural Sciences, Budapest. Our research group performs crystal engineering, *e.g.* fine-tuning of crystal architecture requires the recognition, understanding and application of supramolecular interactions, crystallographic and in case of occurrence, non-crystallographic symmetries with the emphasis on the relationship of secondary interactions and polymorphism. I work mainly on reporting novel polymorphs, solvatomorphs, cocrystals of biologically active substances and study their properties using the SXRD. I am grateful to all my colleagues, who helped me to learn the operation of the diffractometer and how to handle the necessary software. Very soon, I kind of started feeling myself like a detective who eagerly used to wait for the mysteries to come, *i.e.* the crystals to grow and the secrets a crystal structure offers. However, in the longer term, I felt that even though I had the working knowledge, I lacked some of the fundamental knowledge behind the structure solution. Knowing this, my caring supervisor, Dr Petra Bombicz, suggested attending the 19th BCA/CCG Intensive Teaching School in X-ray Structure Analysis, being able to learn from interactions, lectures and discussions with eminent scientists and excellent teachers in the cradle of crystallography in the UK. I am highly grateful to the organizers and the sponsors as their support with the bursary made my participation possible.

The school was extremely well-organized and it even exceeded my expectation. The organizers ensured a comfortable stay for all participants and the meals served were of high quality. The school focused on delivering comprehensive theoretical and practical knowledge related to X-ray structure analysis

techniques. The program encompassed lectures, discussions, hands-on tutorials, and interactions with distinguished scientists and educators. Throughout the school, I had the privilege of learning extensively from esteemed scientists and excellent teachers. The lectures were informative and covered a wide range of topics, including the principles of X-ray crystallography, data collection, structure determination, refinement techniques, and advanced applications. The discussions provided valuable insights into current research trends and challenges in the field. This did not only expand my theoretical knowledge but also helped me to understand the latest advancements in crystallography. The following *Olex2* workshop was also helpful in acquiring new skills and tricks for solving the structures.

Outside the classroom, interacting with young researchers from multiple countries and exchanging ideas on various approaches of addressing everyday crystallography problems was a valuable experience generating a possibility to establish a new professional network in future. Overall, I found this school to be beneficial, and I strongly recommend it to any researcher who is new to the field of crystallography.

Luca Sironi (Università degli Studi di Milano, Italy)



The 19th BCA/CCG Intensive Teaching School in X-ray Structure Analysis in Durham was an amazing experience. It was my first international School and I must say it exceeded my expectations. We were about 80 participants coming from different countries and backgrounds, among them synthetic chemists, crystallographers, material scientists, and engineers.

We were arranged in 10 tables with 8 people each and every group was assigned a tutor. The lectures were often interspersed with individual or group tutorials, coordinated by the tutors. I have really appreciated this lecture mode because it really helped solidify the concepts while interacting with others. Lecturers and tutors were very well prepared and available to answer any questions, allowing us to solve any doubts immediately. Both the slides and the teaching materials we have been given were very clear, despite the complexity of some topics, and covered a wide variety of content, including a Maths refresher.

At first glance, the timetable might seem very intense, from 9 am to 9 pm, and in fact it was. However, it was also well balanced: there were many opportunities to unwind and socialise with other participants, such as coffee and tea breaks and during meals. Also, while frontal lectures were held during the day, several fun activities were planned after dinner, including a quiz, a question time session, and a group presentation. The quiz, which focused on logic and general knowledge, took place in the friendly atmosphere of the college bar, and it was a perfect opportunity to play as a team. The question time was very inspiring: the lecturers could tell about themselves, their careers as crystallographers, and also their hobbies. As for the group presentation, we had to talk about a crystallographic topic in an unconventional way: my group had to explain the least squares refinement through a true crime style, which wasn't easy at all but was really fun. In the middle of the week, after the morning lesson, we had some free time and had the chance to relax and visit the centre of Durham, its cathedral, castle and old town, or take a walk in the nature along the river, enjoying the peaceful atmosphere.

The whole School was very well organised, allocating the appropriate amount of time for lectures, tutorials, breaks, and group activities. In addition, the lecture hall, dining room, and dormitories were all within walking distance from one another.

In conclusion, I would definitely recommend the Durham School to all those who wish to approach crystallography and structure analysis starting from scratch and to all young crystallographers like me who already have some experience in the field and want to extend their network of contacts.

MEETING REPORT

Third International SAXS excites 2023 Symposium



Andreas Keilbach

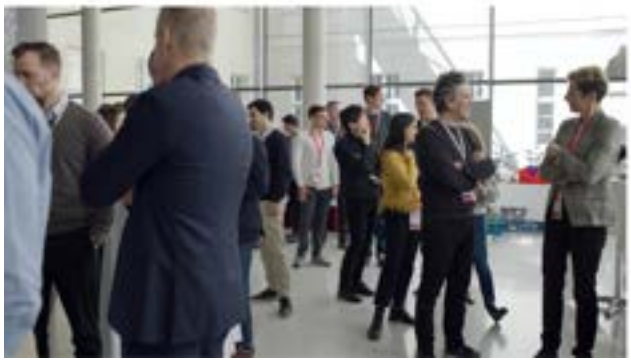
In April 2023, Anton Paar and the Institute of Inorganic Chemistry at Graz University of Technology successfully hosted the third edition of the SAXS excites Symposium series. More than 80 participants from over 18 countries gathered in the Austrian city of Graz – home to many key figures in the field of small-angle scattering, such as Otto Kratky, Günther Porod and Otto Glatter.

The event connected to that history and brought together an array of users from the field of SAXS, with the aim of encouraging multidisciplinary cooperation and an open exchange of experience between renowned scientists, young scientists and industry. In this unique setting, researchers with different scientific backgrounds – ranging from biology to materials science – got together, learned about their individual progress and challenges in the application of small-angle scattering, and sparked new ideas for their own experiments.

The symposium featured 21 high-level presentations from keynote speakers such as Jan Ilavsky (Argonne National Lab) on the new age of (U)SAXS applications in metallurgy, Denise Erb (Helmholtz-Zentrum Dresden-Rossendorf) on GI-SAXS observations of spontaneous nanopattern formation on crystal surfaces under extreme conditions, Stefan Salentinig (University of Fribourg) on SAXS-guided engineering of antimicrobial nanomaterials, and Cy Jeffries (EMBL Hamburg) on the significance of small-angle X-ray scattering with regard to biological materials for structure determination in the age of *AlphaFold*.

A poster session offered an opportunity to discuss the latest scientific findings in more detail and initiate possible future collaboration projects between the participants.




It wasn’t all work though! A short Anton Paar company tour ended with a visit to the Anton Paar Sudhaus brewery, where head brewmaster Gebhard Sauseng explained the details of the brewing process. And no brewhouse tour would be complete without the option to also sample and taste the beers fresh from the tap. From there, it was only a few steps to the conference dinner.

With this third SAXS excites Symposium, Graz University of Technology and Anton Paar – together with all the participants – again placed impressive emphasis on SAXS in a city that has a long, strong connection to the field.

Positive feedback

"*The scope and quality of the scientific presentations were impressive.*"

"*The discussed topics allow me to look beyond the horizon of my own research.*"

"*The organization of the conference was very professional.*"

"*The scientific meeting as well as the company tour and conference dinner were awesome!*"

For more information please click here.

Contact: Andreas Keilbach.

MEETING REPORT (IUCR SUPPORTED)

Hot Topics in Contemporary Crystallography 5 (HTCC5)



Aleksandar Višnjevac

After his visit to Dubrovnik in 1929, George Bernard Shaw wrote "These who look for paradise on earth should come and see Dubrovnik”. Since then, the unique beauty of this medieval city has not changed, but it has, to the delight of many crystallographers from across and beyond Europe, become home to a series of advanced crystallography workshops organized by the Croatian Association of Crystallographers called Hot Topics in Contemporary Crystallography. The fifth edition (HTCC5) of this series took place on 16–21 April 2023 in the enchantingly picturesque village of Mlini, a mere 9 km from the old city gates of Dubrovnik. The venue was the luxury Sheraton Dubrovnik Riviera hotel and conference center which, in mid-April, is smoothly embedded into this drowsy place. The venue is ideally suited for many reasons, one of them being the Dubrovnik International Airport situated a “stone’s throw” away (but far enough to avoid disturbance from the roaring engines of many landing and taking-off iron birds).

HTCC5 was entirely dedicated to macromolecular crystallography (as was its predecessor, HTCC4, held at the same location back in 2019). During the four working days, four topics were thoroughly tackled: crystallization (HT1), processing (HT2), databases (HT3) and visualization (HT4). This was achieved through a balanced number of lectures (15), tutorials (14) and demo-sessions (2). An absolute delight for the students and HTCC5’s *fil rouge* of a kind, was the 'Bring your own sample' activity, with three formal sessions and many informal gatherings, permitting students to bring their ill-crystallizing samples, analyse them by means of Dynamic Light Scattering (Xtal Concepts) and improve the crystallization conditions using microseeding techniques with the help of an on-site installed Douglas Instruments crystallization robot.





(Left) Patrick Shaw Stewart (Douglas Instruments) with Ivana Nikšić-Franjić, and Arne Meyer (Xtal Concepts) in the background. (Right) Rob Nicholls and Eugene Krissinel running a tutorial at the Processing HT.

I could not be prouder of the list of lecturers that we gathered at HTCC5. Crystallization was masterfully presented by (in alphabetical order) Areej Abuhammad, Terese Bergfors, Martin Caffrey and Elspeth Garman. The students practiced 'crystal fishing' with the aid of a video microscope that projected onto the main screen, allowing everyone in the audience to see exactly what was happening, and to applaud when the 'fisher' was successful. Processing was introduced by two delightful introductory lectures by Edward Lowe, and continued through a whole day with a series of alternating lectures and tutorials delivered by the people who create and develop one of the most popular packages, *CCP*4: Eugene Krissinel and Rob Nicholls. We had contributors from both PDBe and the CCDC (David Armstrong, Rupesh Chikhale and Fabio Montisci) who demonstrated the hottest features of these databases with a particular emphasis on the zones where small-molecule and macromolecular structures intertwine (docking). Hands-on sessions introduced students to the practical use of PDB-KB and the CCDC's *CSD-CrossMiner* and *GOLD*. The visualization topic was short and sweet. Masterminded by Zoran Štefanić, this acquainted students with the techniques of visualizing allosteric pathways in oligomeric enzymes using a variety of the most popular programs. The cherry on top was the interactive and competitive web-based game in which students were tasked to explore symmetry in two dimensions and compete with others in the search for the right “crystal” packing; the scoreboard was regularly updated and displayed on the screen, which created a cheerful and positively competitive atmosphere.



A student crystal `fishing' using a video microscope.

The workshop, which was largely supported by the Croatian Science Foundation through project calixDNA (PI: Aleksandar Višnjevac), and generously sponsored by Bruker, Douglas Instruments, Formulatrix, Mitegen, Anton Paar, Oxford Cryosystems, Dectris and Rigaku, gathered 52 registered participants from 16 countries (Algeria, Austria, Croatia, Czech Republic, France, Germany, Italy, Ireland, Jordan, Poland, Serbia, Sweden, Slovenia, Turkey, UK and Ukraine) with 28 students and 11 lecturers. Thirteen students received bursaries to cover (partially or entirely) their registration fees, accommodation and travel expenses. The bursary scheme was generously funded by the IUCr, Croatian Association of Crystallographers and European Crystallographic Association.

The students presented 19 posters and 15 short discussion-triggering presentations (DTPs). The best presentations were rewarded with a €100 award generously provided by Dectris (best DTP) and the Croatian Association of Crystallographers (best poster). The best poster prize was awarded to Daniel Mokos (University of Graz, Austria) for his poster entitled 'Crystal structure and proposed mechanism of A622 homologues from the nicotine biosynthesis pathway', whereas Marika Majerová (Masaryk

University, Czech Republic) was awarded for the best DTP for her presentation entitled 'An extant enzyme with dual dehalogenase–luciferase function'.

More information about HTCC5 is available here and on the Croatian Association of Crystallographers Facebook page, the Croatian Crystallographers Instagram platform and on Twitter: @hrvukris. We are very much looking forward to HTCC6 and we invite you to keep an eye on our social networks.



(Left) Martin Caffrey's live demo on lipidic cubic phase crystallization. (Right) Areej Abuhammad presenting the award for the best DTP to Marika Majerová.

MEETING REPORT (IUCR SUPPORTED)

Eighth International School on Biological Crystallization



One of the lively poster sessions during ISBC2023.

Juan Manuel García-Ruiz

The Laboratory of Crystallographic Studies (CSIC-UGR) has successfully organised the 8th International School on Biological Crystallization (ISBC2023) under the auspices of the IUCr through the Commissions on Crystal Growth and Characterization of Materials, Biological Macromolecules and Crystallographic Teaching, with the support of the International Doctoral Summer School Programme of the School of Science, Technology and Engineering (University of Granada), the Spanish Royal Society of Chemistry (RSEQ) and the Spanish Specialized Group of Crystallography and Crystal Growth (GE3C). The School was held at Hotel Abades Nevada Palace close to the centre of the beautiful city of Granada, an ideal place to promote close scientific and social interactions between attendees.

ISBC2023 attracted the interest of postgraduate/postdoctoral students as well as research scientists from industry and academia who deal routinely with crystallization processes but seek fundamental knowledge on the crystallization phenomena and the behaviour of crystallizing solutions. The participants came to Granada to learn from top-quality international speakers, to hear case study presentations, to watch practical hands-on demonstrations and to present their research results in the purposely dedicated poster sessions.

ISBC2023 delivered five days of lectures and practical demonstrations related to the crystallization of biological macromolecules, including large crystals for neutron diffraction and tiny crystals for XFEL or EM. One day was fully devoted to case studies on the crystallization of membrane proteins, viruses and large macromolecular complexes, and sample preparation for cryoEM.

As in previous editions, the Demonstration Fair was very successful with much positive feedback from the participants. A round-table discussion on “Teaching Crystallography” was also highly appreciated among tutors, academics, students and industrial representatives.

Attendance

The turnout of the School was excellent having a total of 113 participants from 19 different countries, most of whom were students (41%), speakers (24%) and academics (17%), the rest being composed of industrial representatives (1) and exhibitors (7). The participants were supported by a team of four people from the organization. We achieved our goal of gender balance, having 53% female participants and 47% male.

Considerable effort was also made to provide financial support to as many students as possible. All of the 39 applicants were awarded a bursary to attend the School, including all 24 students coming from outside Spain.

Programme

The first day, Monday, started with an introduction to the School and was fully dedicated to explaining the whole process of crystallization “From solution to protein crystals”, from the purification and preparation of protein solutions to the basic concepts of crystallization, nucleation, phase diagrams, crystal growth kinetics and the different crystallization techniques (Fig. 1).



Figure 1. Professor Bernhard Rupp showing how to optimize protein crystal growth.

Tuesday was devoted to special hot topics, including femtosecond crystallography, microseeding, microfluidics, how to grow crystals for neutron diffraction, the crystallization of membrane proteins and large macromolecular complexes (Fig. 2).



Figure 2. “Femtosecond Crystallography, a New Era in Structural Biology”, a talk given by Professor Petra Fromme.

On Wednesday there were sessions on especially relevant topics such as optimization of crystal growth for neutron diffraction, SAXS and EM (Fig. 3).



Figure 6. Professor Lars Redecke impresses the audience with his lecture "Overview of protein crystallization in living cells".

Thursday was dedicated to the very popular ‘Demonstration Fair’, at which specialists offered 23 short (20–40 minutes) practical sessions periodically at scheduled times. Participants were free to choose what sessions they wanted to attend and in the order they wished, so that they selected their own learning programme “*a la carte*”. The Demonstration Fair proved to be an excellent teaching tool as it provided students with plenty of opportunities to interact on a personal basis with the teachers and to watch closely how to perform crystallization experiments (Fig. 4).



Figure 4. Upper picture shows Professor Rupp on the left with Dr Crissy Tarver behind preparing her second round. On her right is Professor Fromme who is showing how to crystallize the membrane protein PSI *in situ*. In the bottom picture Dr Janet Newman is describing tips and tricks for vapour-diffusion (hanging and sitting drops) experiments, catching the attention of many students.

The last day of the School started with a very appealing lecture given by Professor Bernhard Rupp titled “The Chemistry of Mushroom Magic (Why you should not lick toads)” followed by the round-table discussions on “Teaching Crystallography” driven by Professor JuanMa Garcia-Ruiz on how to present the successful story of the “Crystallization Competition” with the help and presentations of Dr Ivana Kuta Smatanova and Dr Janet Newman (Fig. 5). There were also 5-min talks given by the poster winners.



Figure 5. Round-table discussion on “Teaching Crystallography” driven by Professor Garcia-Ruiz with the help of Dr Ivana Kuta Smatanova (left) and Dr Janet Newman (middle).

Poster sessions

The students made a great contribution to the success of the School with 41 posters. There were poster sessions on Monday, Tuesday and Wednesday coffee breaks, proving to be a very valuable time in order to discuss the scientific work. The six poster winners (Fig. 6), who were selected by an international panel of lecturers composed of Bernhard Rupp, Crissy Tarver, Christian Biertümpfel, Lata Govada, May Marsh and Joe Ng, gave a 5-min presentation on Friday morning.

Student	Affiliation	Prize
Filipa Engrola	UCIBIO (Portugal)	IUCr
Uxía Pérez de José	CSIC-IQFR (Spain)	IUCr
Yevgeniya Karibjanova	Génie Chimique Toulouse (France)	IUCr
Markéta Šoltysová	IOCB (Czech Republic)	AUSE/LEC
Ángela Fernández García	CSIC-IQFR (Spain)	AUSE/LEC
Aumonier Sylvain	Paul Scherrer Institut (Switzerland)	B. Rupp



Figure 6. Poster prize winners.

Social events

In addition to the scientific course, there was a parallel social programme, which consisted of a welcome cocktail on Sunday, a night guided walk of Albaicín and Sacromonte on Wednesday (Fig. 7) and a Flamenco Dinner Party on Thursday in the traditional district of Albayzin (Fig. 8), which is known worldwide for its flamenco music.



Figure 7. A picture of the attendees during their night guided walk of Albaicín and Sacromonte.



Figure 8. A picture of the Flamenco Party on Thursday evening.

Evaluation and conclusions

Overall, the School was deemed to be very successful as judged by the majority of positive comments written by the participants. The attendees were asked about three major items: the quality of the scientific programme, the Demonstration Fair and the organisation. These are some of the comments:

“I really enjoyed my time, learned a lot, met some really enthusiastic students and thankfully didn't have much of a hangover from the sangria on Thursday night.” (Martin Caffrey, speaker).

“It was my great pleasure to be a part of your School... you did super job and I am looking forward to the 9th run:)... (Ivana Smatanova, speaker).

“Was a pleasure and honour to be a part of ISBC2023. The meeting, the talks, the posters were all of such high standard. This year we got to experience 'the Rain in Spain on the plains' for the first time 😀. Thank you once again for everything”. (Lata Govada, academic).

“It was wonderful to see everyone again in 3D after such a long time! Thank you Gavi, JuanMa and team for organizing such a wonderful workshop again. I know it is a lot of work, but everyone one of us including students and instructors, appreciate everyone's effort, energy and enthusiasm.” (Joseph Ng, speaker).

“Yes, indeed – thanks to all of the organisers for putting together a wonderful course for the students and participants.” (Tom Peat, speaker).

“It really was a pleasure to be a part of ISBC2023! I enjoyed the science, time in Spain, and time with friends. Thank you and your team for everything.” (Crissy L. Tarver, academic).

“MUCHAS GRACIAS to you and to all the school organisers. It was a great pleasure to take part in ISBC2023 and to have the opportunity to meet the biological crystal grower community again after such

a long time for such a high quality event in Granada." (Monica Spano, speaker).

"Thank you very much for hosting us for such a great meeting! I enjoy the energy of teachers and students, active discussions, and exchanges of ideas. I am glad that everybody is well after 4 years. Take care and see you again!" (Naoko Mizuno, speaker).

"Thank you so much for organizing such a great event! I am really grateful for the opportunity to contribute and meet you all in person! Muito obrigada :) (Filipa Castro, speaker).

"Thanks very much for organizing this wonderful meeting/workshop. As always, everything was superb. The talks very exciting; the students, very talented and had great posters. Thanks also to everyone for this effort." (Guillermo Calero, speaker).

"Thank you to you and your team for organizing the workshop again, and making it run so smoothly. It brings together many old friends and helps creates new ones. It also showcases the amazing beauty of Spain. I love Granada and I love the country. I will say it once more – Thank you." (Edward H. Snell, speaker).

There was a general feeling among the participants that the School had been very valuable partly because of the quality of the programme and partly due to the contribution of some of the best lecturers for the wide range of topics covered.

All in all, the ISBC2023 was an enriching experience for all of those involved triggering several fruitful scientific discussions. The positive approach, the openness and active participation of each of the participants made it a wonderful experience worthwhile to be repeated in the future.

Finally, we would like to express our gratitude to all of the participants; to the teachers for their full commitment and to the students and colleagues from academic and industrial background for believing in these Crystallization Schools. We also wish to express our heartfelt thanks to the Members of the Organizing Committee for their substantial contributions to the Schools. We are very grateful to all the people who have worked very hard in preparing the Schools to make it successful. Last but not least, we would also like to express our special gratitude to the Sponsors and Exhibitors for their great support.

MEETING REPORT (IUCR SUPPORTED)

58th Course of the International School of Crystallography – Structural Drug Design 2023: Biology, Chemistry and Computers



Group photo.

Annalisa Guerri

The Course, the 58th edition of the International School of Crystallography, was held at the Ettore Majorana Foundation and Centre for Scientific Culture from 2 to 10 June 2023. The Centre is situated in the old pre-mediaeval city of Erice, Italy, where four restored monasteries provide an ideal setting for scientific and professional exchanges. The event was initially scheduled for 2020 but postponed because of the COVID-19 pandemic.

The number of participants was limited to 83; in addition there were 28 lecturers and workshop presenters, and the organizers of the conference. The participants, from 23 countries, were largely from university (PhD students, postdoctoral and young researchers), with some industry participants. IUCr funds were used to support the attendance of three female and four male young scientists, from Belgium, the Czech Republic, Greece, Mexico, Norway, Poland and South Africa.

The schedule for a typical day included a morning session with four 45-minute lectures, followed by a lunch break. The afternoon session included different workshops/tutorials.

The aim of the organizers was to provide the students with an overview of the current structural and biophysical techniques and informatic tools used in the field and their applications in different areas. The program was subdivided by topic, each day covering a particular theme: introduction to the general techniques (crystallography, cryo-EM, machine learning), biophysics and binding (computing and measuring binding affinity, conformational and allosteric landscapes), informatics (machine learning, docking, FEP, molecular dynamics), small-molecule chemistry (compound design, compound optimization, crystal structure prediction), biologics (rational design, and developability) and case studies describing the many steps in the process of drug discovery, from initial library screening to back-up studies. After each lecture, some time was set aside for discussion.

Nine workshops were offered to the participants in the afternoons, providing hands-on experience in a diverse set of techniques necessary in drug discovery from ligand fitting into electron density maps, to cryo-EM data processing, to *in silico* drug discovery and optimization using different software to biologics design. Each workshop was repeated at least twice, to give the participants more opportunity to attend.

Two poster sessions were held in the evening, giving the young participants a chance to showcase their work and discuss with the lecturers and more senior participants. Sixty-six posters were presented in total, half in each session. Each poster session was preceded by a poster preview session (at lunchtime), to increase the time for poster viewing and informal discussions.

During the last afternoon, two talks, one describing the trials and tribulations of starting a new company and one offering a vision of where structural biology and drug discovery could be in 10 years, provided ground for a final discussion.

The lecturers and workshop organizers were a mix of individuals from pharmaceutical companies and academia, all with a very high level of expertise and that represented the different branches of science required to meet the diverse challenges of drug design.

Awards and participant feedback

Sixty-six abstracts were submitted for poster presentation, among these, ten were selected for a short oral presentation (12 minutes + 3 minutes question time).

During the closing ceremony, several awards were presented. For the posters, the first place was assigned to Zuzanna Kozicka (University of Basel, Switzerland), the second place to Francesca Vallese (Columbia University, New York, NY, USA) and the third to Dennis Peter Stegmann (Swiss Light Source, Villigen PSI, Switzerland).



From left to right: the three winners of the poster prizes, Dennis Peter Stegmann (third prize), Francesca Vallese (second prize) and Zuzanna Kozicka (first prize), Course Executive Secretary, Annalisa Guerri (University of Florence, Italy) and Course Director, Giovanna Scapin (NanoImagingServices, USA).

The Lodovico Prize (acknowledging the most active student inside and outside the lecture hall) was given to Kristýna Adámková (Institute of Biotechnology of the Czech Academy of Sciences, Prague, Czech Republic).



Winner of the Lodovico Prize, Kristýna Adámková (center), with Giovanna and Annalisa.

At the end of the Course, participants were asked to participate in a survey to judge and comment on the quality of the Course. Their responses indicate that a similar meeting should be held at least in 3–4 years' time and that the course had been successful in most of its objectives (score 85/100).

Special event

During the course a special Icebreaker event was organized to further promote socialization and interaction outside the lecture and workshop halls. Eight groups were formed (each including a lecturer) and given the objective of identifying one aspect of the Course they most enjoyed, and then presenting the outcome in a 5-minute presentation at the end of the last day. The presentations were very creative and extremely entertaining and provided a nice introduction to the Course final remarks.

MEETING REPORT

29th Slovenian–Croatian/Croatian–Slovenian Crystallographic Meeting



Marta Počkaj

The 29th Slovenian–Croatian/Croatian–Slovenian Crystallographic Meeting (SCCM 2023) was held on 14–18 June 2023 in Topolšica, Slovenia. There were 60 registered participants from Austria, France, Germany, Morocco, Ukraine, UK, Croatia and Slovenia.

Four plenary lectures were presented: '*Crystal engineering of organic and metal-organic multicomponent halogen-bonded solids*' by Dominik Cinčić, University of Zagreb, Croatia; '*Order from disorder: towards molecular architecture of the muscle Z-disk assembly*' by Kristina Djinović-Carugo, EMBL Grenoble, France; '*High-pressure phase transitions in molecular crystals*' by Simon Parsons, University of Edinburgh, UK; and '*DFT modelling of materials and crystal structures using periodic-boundary conditions*' by Anton Kokalj, Jožef Stefan Institute, Slovenia.

In addition, 45 short oral presentations were given, which addressed contemporary topics in crystallography: structure determination of organic, inorganic and coordination compounds, crystal architecture, engineering and design, phase transitions, structure–property relationships, synergy of diffraction and complementary techniques *etc*. One of the advantages of the Slovenian–Croatian meetings is that all participants present their work as short oral contributions, which is especially important for young scientists who therefore have the possibility to deliver their results in a friendly but professional atmosphere. At this year's meeting, the young scientists were offered the possibility to enter the best presentation award competition – it turned out that there were 28 competitors in three different categories (MSc students, PhD students and postdoctoral researchers who defended their theses not more than five years ago). Although all presentations were excellent, the jury unanimously awarded the following presentations:

MSc student Lea Čolakić (University of Zagreb, Croatia) for '*Picky halogen bonding in isocyanate-based Werner complexes*'; PhD student Erik Uran (Jožef Stefan Institute, Slovenia) for '*Salts, adducts and cocrystals formed in reactions of SO_2 with organic amines*'; and postdoc researcher Ivica Cvrtila (Ruđer Bošković Institute, Croatia) for '*Chiral crystallization of hippuric acid from carvone*'.



From left: Ilaria Gimondi (CCDC); best presentation award winners Ivica Cvrtila, Erik Uran, Lea Čolakić and Klemen Motaln; and the chairs of the meeting, Professor Anton Meden and Professor Marijana Đaković. Photograph taken by Mirela Dragomir.

Another special award for an outstanding presentation on contemporary topics in chemical crystallography and advances in small-molecule crystallographic information sponsored by the CCDC was awarded to Klemen Motaln (Jožef Stefan Institute, Slovenia) for '*The elusive crystal structure of* $XeOF_2$'.

The representatives of the CCDC also held a hands-on workshop focusing on *Mercury* and its new features, such as *CSD-Particle*.

The meeting was co-organized by the Faculty of Chemistry and Chemical Technology at the University of Ljubljana, and the Croatian Crystallographic Association under the auspices of the University of Ljubljana and promoted by the Slovenian Chemical Society. There was no registration fee; therefore, we thank the sponsors and advertisers: CCDC, Renacon, Rigaku, Aparatura, Mettler-Toledo, Vigor, Mitegen, Technobis, Dectris, Optik Instruments, Lek-Sandoz, Krka and Scan.

More information about the meeting can be found here.

NOTICE

CCDC news and updates



The IUCr was delighted to welcome members of the CCDC team to its offices in Chester, UK, recently. Front row, l-r: Suzanna Ward (CCDC Head of Database and Community), Natalie Johnson (CCDC Data Integrity Research Scientist), Alex Stanley (IUCr CEO); back row, l-r: Jürgen Harter (CCDC CEO), Ian Bruno (CCDC Director of Data Initiatives), Peter Strickland (IUCr Executive Managing Editor), Mike Hoyland (IUCr Systems Developer). Photo by Ed Morgan.

Blog – Boosting Research Efficiency in Industry with FAIR Data

In this blog (based on the webinar "Boosting Research Efficiency in Industry with FAIR Data") we discuss the FAIR data principles and their potential. Topics include how these principles are applied at the CCDC and how the chemical industry can benefit from them. Read more.

New CSD-Particle Online Training Courses

We have six online training courses to help you learn the basics of how to use the CSD software. The latest course added to the collection is "Surface Analysis with CSD-Particle", presented in a "watch, try, test" format, allowing you to receive a completion certificate for your efforts.

Alongside these free courses, if you want to learn more about *CSD-Particle*, we have two new self-guided workshops: "Surface Analysis with CSD-Particle Tools in Mercury" and "Investigation of New Plastic and Elastic Properties Tools in Mercury." In these workshops, you can explore the chemical and topological properties of particle surfaces and slip planes in crystals using a step-by-step workshop guide.

New How-To Videos

Discover how *Mercury* makes it easy to explore symmetry in crystal structures and how *Mogul* can be used as a structure validation tool during crystal structure refinement. Watch the videos to learn more.

Upcoming Events

In 2023 we are attending and sponsoring many events worldwide and delivering free virtual workshops and webinars. Visit our events page here for the full list.

13–17 August 2023: ACS Fall – Harnessing the Power of Data

Join the CCDC talk on Algorithm Development and Data Analysis in Chemical Space (CINF), presented by Jeff Jeff Lengyel, Materials Scientist. Find out more.

22–29 August 2023: Meet us at the IUCr Congress 2023

The CCDC is exhibiting, holding workshops, presenting and chairing talks and running the CSD leaderboard. Don’t miss this opportunity to meet our team. Find out more.

If you would like to suggest topics for our workshops and webinars email us at hello@ccdc.cam.ac.uk.

Follow us on social media

Want to learn more about CCDC events, blogs, case studies and software updates? Follow us on LinkedIn, Facebook and Twitter.

HISTORY OF CRYSTALLOGRAPHY

A hall of fame of crystallographers and related scientists



Istvan Hargittai, Magdolna Hargittai

This hall of fame, the Earth Science Museum at Lomonosov Moscow State University, is part of our universal scientific and cultural values. In the current tragic situation in 2023, we are moved to dedicate this account to those brave men and women who are being persecuted in Russia for protesting and condemning the ruthless and unjustified war by their country against Ukraine.

Floors 24−28 of the famous high-rise building of Lomonosov Moscow State University house the Earth Science Museum. It was established around 1950, at the time of the inauguration of this building, where much of the university relocated from downtown Moscow. The building has a magnificent location in the Vorobyovi Hills, which were called the Lenin Hills at the time. After the collapse of the Soviet Union, their name was changed back to their pre-Soviet name, Vorobyovy Hills, but the official address of the university remained 1 Lenin Hills.



The tower of Lomonosov Moscow State University. The Earth Science Museum is in the top rectangular portion of the tower, floors 24−28.

Layout of the museum

The top round portion of the tower houses the Rotunda, which is a festival hall. The top rectangular portion consists of five floors, and that is the museum. The museum also functions as an extended study room for students of various subjects, such as crystallography, geography, geology, anthropology, biology, environmental science, soil science *etc.*

When the university was moving from downtown to the new location, considerable funds were devoted to an almost luxurious interior, which has, over the decades, considerably degraded as a result of use and neglect. Still, the museum has kept much of its old glitter. A substantial part of its elegance comes from the large number – at least 75 − of busts of scientists. They were all created at the time of the museum's establishment by many of the best sculptors in the Soviet Union at the time.



A classroom exercise in Hall 8 in 2016.

The five floors of the museum comprise 24 exhibition halls totaling an area of 25 hundred square meters (27 thousand square feet). On descending from Floor 28, the numbering of the halls increases, and each floor has a specific topic. Our recent book about science in Moscow [1] presents this museum floor by floor, hall by hall and bust by bust, and there are many of them (as mentioned above), including a few commemorating international scientists. In this contribution, we single out a few busts and indicate the names of the sculptors. The date of erection of the busts was uniformly around 1950. All photographs in this article were taken by the authors, unless indicated otherwise.

In this account, six of the memorials are presented, including Charles Darwin, who is mentioned for his general importance. The other five were crystallographers or closely related mineralogists and geologists. The careers of two of the scientists, Evgraf S. Fedorov and Vladimir I. Vernadsky, are presented in more detail.



In Hall 7, focusing on the methods of geological research. Here is a Charles Darwin (1809−1882) statue sculpted by the internationally renowned artist Sergey T. Konenkov.



A bust of Nikolai I. Koksharov (1818−1893) by M. A. Gritsuk. Koksharov described the morphology of many minerals, and his bust stands in Hall 11, focusing on the occurrence of non-metallic ores.

Eduard Suess

Eduard Suess (1831−1914) was an Austrian geologist of international fame and a professor at the University of Vienna. He was born in London, and the Geological Society of London has commemorated his birthplace with a commemorative plaque. His family moved from London, first to Prague, then to Vienna, where he completed his studies. He researched the geography of the Alps and was a pioneer in considering the issues of ecology in scientific discussions.



From left to right: the Suess plaque at 4 Duncan Terrace, N1, London [2]; his bust (1928) in Schwarzenberg Square in Vienna; and his bust by B. D. Korolev in Hall 5 of the Earth Science Museum.

Evgraf S. Federov

Evgraf S. Fedorov (1853−1919) was a crystallographer and mathematician [3]. He was born in Oranburg, Russia, lived most of his life in St. Petersburg, and died in Petrograd (but it was the same city). The name of St. Petersburg was changed in 1914 to Petrograd as an expression of nationalism. In 1924, it was changed to Leningrad, and today it is once again St. Petersburg, following a 1991 referendum. Fedorov's father was a high-ranking engineer-general who died when Fedorov was 14 years old. His mother brought up her four children alone. Soon, Fedorov studied in military schools and began military service. In 1874, he left that and started attending medical school lectures, without being officially enrolled because of his lack of a proper high school (secondary school) diploma. After one year, he switched to the Institute of Technology to study chemistry. After another year, he changed again and embarked on a tour of Western Europe. He worked in typography and, upon his return to Russia, he published newspapers.

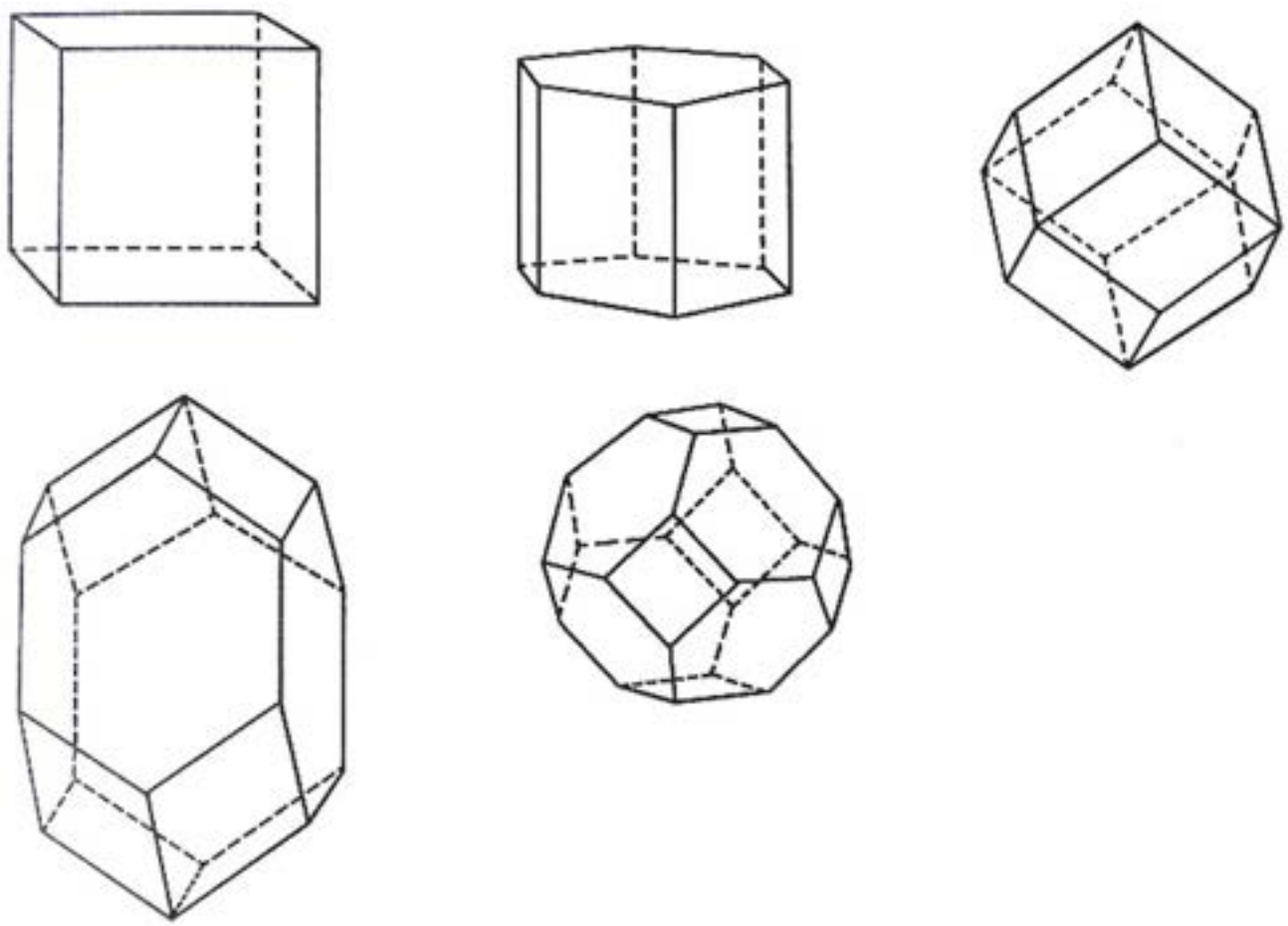
Fedorov became interested in crystallography and, in 1880, he enrolled at the Mining Institute, from which he graduated in 1883. He participated in geological expeditions in the Ural Mountains and, for a while, he and his family moved to the region in these mountains to ease their financial situation. His scientific contributions helped his advancement. He was appointed to professorships in St. Petersburg and Moscow. In 1901, at Vladimir Vernadsky's recommendation, he was awarded the degree of Doctor of Mineralogy and Geognosy, the latter being the science of the origin and distribution of minerals in the earth's crust – by now, an obsolete term, which has given way to a broader meaning of geology. During the 1905 revolution, he was elected to be the director of the Mining Institute. No such elections have taken place before or since. His appointment was terminated in 1910 and he continued at the institute as a Professor of Crystallography and Petrography. His highest recognition was his election to the Academy of Sciences in 1919. However, in the same year, he died of pneumonia, caused at least in part by lack of food and heating in revolutionary Petrograd.



A bust of Evgraf S. Fedorov by A. V. Grubbe in Hall 8 and his photograph from about 1900 (Evgraf Fedorov Mondadori.jpg, Wikimedia Commons, public domain).

Fedorov's significant scientific production centered around crystallography. His most famous contribution is the derivation of the 230 three-dimensional space groups of symmetry. At about the same time, the English William Barlow (1845−1934) and the German Arthur Schoenflies (1853−1928) also derived the 230 space groups. The simultaneity of this discovery by the three authors, operating independently of each other, does not diminish the importance of their individual contributions. Of the three, Barlow's achievement is rather peculiar as his approach was largely intuitive. He considered oriented motifs: he hung pairs of gloves on a rack, thereby making space group models. We know from Marjorie Senechal about his empirical approach: "He bought gloves by the gross, so the story goes, mystifying the sales lady by answering '*I don't care*' to her first question, '*What size, sir?*'" [4].

Fedorov's lesser-known studies included a systematic investigation of space-filling parallelohedra. He determined all five that can fill the space in parallel orientation without gaps or overlaps: the cube, the hexagonal prism, the rhombic dodecahedron, an elongated rhombic dodecahedron with eight rhombic and four hexagonal faces, and the truncated octahedron. They are shown here from Marjorie Senechal [5].



Fedorov’s five polyhedra, which can fill space in parallel positions. From Marjorie Senechal [5]; reproduced with permission.

Vladimir I. Vernadsky

Vladimir I. Vernadsky (1863−1945) was an internationally renowned geochemist, crystallographer and geologist, and a contributor to many other fields of science. He was also a science historian and an organizer of scientific institutions. His father was a descendant of the Zaporozhye Cossacks and his mother came from a Russian noble family. Vernadsky was born in St. Petersburg, studied in a Kharkov gymnasium from 1873, and completed his high school education back in St. Petersburg in 1880. During 1881−1885 he studied at the Physics and Mathematics Faculty of St. Petersburg University. He participated in soil science expeditions and was a student of the soil scientist Vasily V. Dokuchaev. Dmitry I. Mendeleev was among Vernadsky’s professors.

Vernadsky was actively engaged in mineralogy during and after his university studies. He traveled to Italy, France and Germany as part of his education. From 1890, he held professorial appointments in crystallography and mineralogy at the Imperial Moscow University. Many future well-known mineralogists were among his students. He became full professor in 1902. In 1911, he resigned along with many of his colleagues, to protest the ministerial policy of considerably curtailing university autonomy.



Interior of the museum, Hall 9, with the busts of Aleksandr E. Fersman (by A. V. Babichev) (left) and Vladimir I. Vernadsky (by E. M. Vilensky) (right) highlighted.

Vernadsky moved from Moscow to St. Petersburg and worked in the Geological Museum. For years he drew ever closer to the Academy of Sciences. Following the revolutions, he was among the founders of the Ukrainian Academy of Sciences and served as its first president. He did not stay long in Ukraine and returned to St. Petersburg. The next few years were turbulent in his life, as they were for the entire country, which in the meantime had become the Soviet Union. At one point, he was arrested and jailed but soon freed because of protests by various leading scientists.

Vernadsky was involved in creating institutions dealing with the new science of radioactive materials and he participated in expeditions to uncover sources of radioactive minerals. In 1922−1926 he often lectured in Paris and published a text on geochemistry in the French language. He became engaged in studies of improved utilization of natural resources and in drafting plans for the electrification of the Soviet Union, called GOELRO. He was active in building up the network of scientific institutions in Moscow after they had been moved there in 1934 from St. Petersburg. He and his closest colleagues, Aleksander E. Fersman among them, quietly survived the years of Stalinist repressions during the second half of the 1930s [1].

However, Vernadsky was not blind to the lawlessness of the tyranny and condemned its supporters among scientists. We can mention one example. Vasily R. Vilyams (1863−1939) was among the founders of soil science in Russia. Under the Soviet system, however, he concocted unscientific plans causing harm to agriculture in the Soviet Union (also in Eastern Europe after World War II, when Vilyams had long been dead but his teachings had survived) [6]. Scientists who disagreed with Vilyams may have faced tragic consequences, even execution. A few years after Vilyams' passing, Vernadsky wrote that Vilyams left behind a bad and distorted school, and that he used inaccurate data that often contradicted reality. Vernadsky noted that Vilyams having joined the communist party did not make him a better scientist and predicted that he would soon be forgotten. Vernadsky's assessment of Vilyams' activities was correct,

but not his prediction that Vilyams would soon be forgotten [6]. To this date, there is a conspicuous cult of Vilyams in Russia, complete with his large statue in Moscow and other measures to commemorate him and his teachings, including a bust in the Earth Science Museum. To be fair, however, Vernadsky also has a cult, deservedly, with memorials in numerous places, both in Russia and Ukraine. There is a magnificent Vernadsky Geological Museum at 11 Mikhovaya Street in downtown Moscow.



A detail of the front of a Ukrainian banknote, 1000 Hryvnia, with Vernadsky's portrait and his words: "Я вірю у величне майбутнє Україну" (I believe in the great future of Ukraine).

Aleksandr E. Fersman

Aleksandr E. Fersman (1883−1945) was a mineralogist, crystallographer and geochemist. The author Aleksey Tolstoy called him "the Poet of stones" [7]. Fersman completed his studies at Moscow University and was among Vernadsky's disciples. From 1917 to the end of his life, he was the director of what is today the Fersman Mineralogical Museum at 18 Leninsky Avenue in Moscow. During World War II, he was responsible for the evacuation of the most valuable minerals from the museum and for their safe return in 1944.

Visiting the museum

The Earth Science Museum is, in principle, open to the public, and there is no entrance fee. In practice, it is not easy to be admitted, and already entering the tower of the university is possible by permission only, and entering the museum is by appointment only. Unfortunately, we cannot offer any information on how one goes about getting the necessary paperwork for such a visit (we mean under peaceful conditions; under the current war, it is meaningless to contemplate such a visit). However, if one succeeds in getting through the red tape, such a visit offers a unique and unforgettable experience, both for experts of earth sciences and crystallographers, and for laypersons as well. Our last visit was in 2019, and the visit during which we photographed all the busts in the museum took place in 2016. On both occasions, our visits were arranged through personal connections rather than through official channels. The associates of the museum are most helpful in assisting the visitor; they are exceptionally knowledgeable and display obvious pride in presenting the riches of their institution.

Literature references

[1] Hargittai, I. & Hargittai, M. (2019). *Science in Moscow: Memorials of a Research Empire*, ch. 3, pp. 101-129. World Scientific.
[2] Hargittai, I. & Hargittai, M. (2021). *Science in London: A Guide to Memorials*, ch. 5, pp. 238-239. Springer Nature.
[3] Evgraf Stepanovich Fedorov, Wikipedia.
[4] Senechal, M. (1990). *Historical Atlas of Crystallography*, edited by J. Lima-de-Faria, p. 49. Dordrecht: Kluwer Academic Publishers.
[5] Senechal, M. (2013). *Shaping Space: Exploring Polyhedra in Nature, Art, and the Geometrical Imagination*, p. 105. Springer.
[6] Hargittai, I. & Hargittai, M. (2019). *Science in Moscow: Memorials of a Research Empire*, ch. 6, pp. 247-248. World Scientific.
[7] Alexander Evgenievich Fersman, Wikipedia.

AWARDS AND PRIZES

Erwin Félix Lewy Bertaut Prize for 2023



Arie van der Lee

The 2023 Erwin Félix Lewy Bertaut Prize was awarded to Dr Matilde Saura-Múzquiz, currently at the Department of Materials Physics, Universidad Complutense de Madrid, Spain. The ECA and the European Neutron Scattering Association (ENSA) jointly award the Bertaut Prize in memory of the scientific achievements of the late Erwin Félix Lewy Bertaut, representing cornerstones in both crystallography and neutron scattering. The laureate is expected to be a young scientist (up to eight years after finishing their PhD thesis) having a clear affiliation with the ECA/ENSA region in recognition of notable experimental, methodological or theoretical contributions to the investigation of matter using crystallographic or neutron scattering methods.

Dr Saura-Múzquiz has impressive early-career contributions in the field of the crystallography of functional materials, in particular those related to the studies of magnetic and non-magnetic complex oxide structure (scheelites, fergusonites, perovskites, pyrochlores, …) and those on nanoparticle morphology, nuclear and magnetic texture and magnetic performance of sintered materials, while combining neutron and X-ray diffraction methods. The Bertaut Prize ceremony took place in Garching, Germany, during the European Conference on Neutron Scattering 2023.

AWARDS AND PRIZES

ECA SIG4 Publication Award for 2023



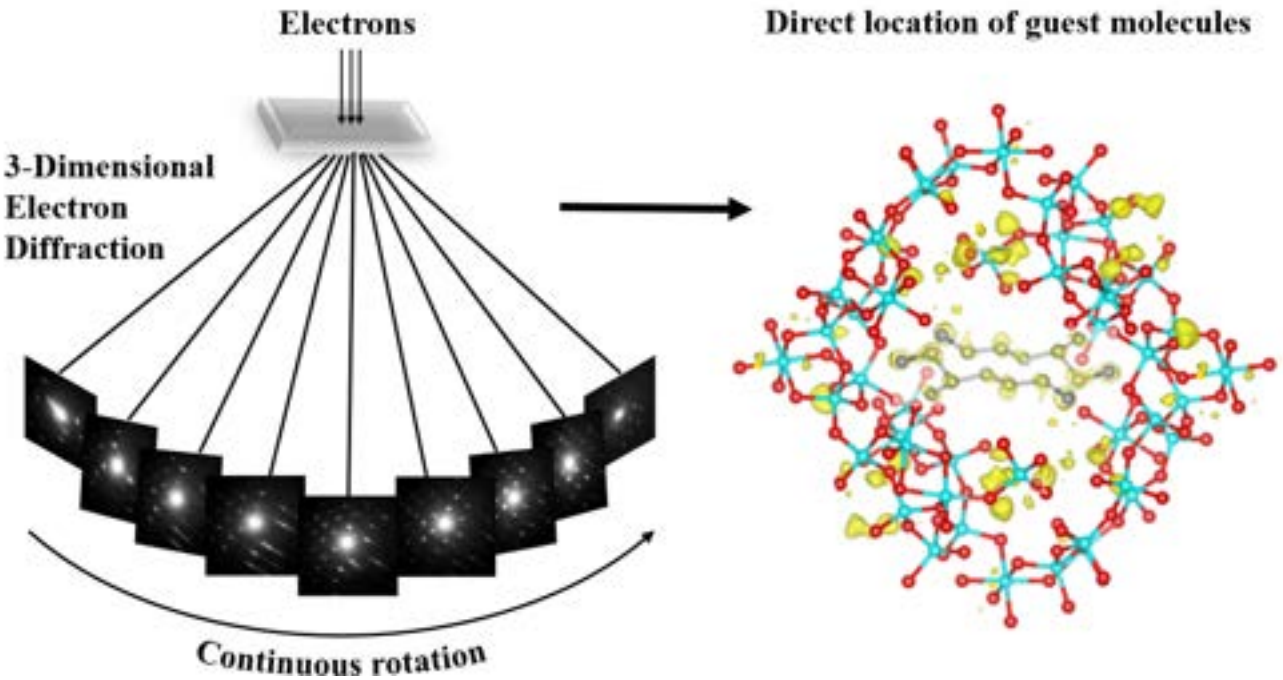
Meng Ge, the first author of the awarded publication.

Tatiana E. Gorelik

Electron crystallography (3D ED/MicroED) has experienced significant growth in recent decades as a powerful method for structure determination. Many crystal structures that were previously challenging to determine using classical crystallographic techniques can now be elucidated with the aid of electron diffraction. Recognizing the importance of this field, the flagship journal of the IUCr, **IUCrJ**, has introduced a dedicated section on electron crystallography.

To further support method development and encourage innovative applications of this technique, the Special Interest Group for Electron Crystallography (SIG4) of the European Crystallographic Association (ECA) has established a distinguished publication award in the field of electron crystallography. The award committee consists of internationally renowned scientists, including established electron diffraction experts and newcomers to the electron crystallography field. The involvement of diverse committee members ensures an unbiased evaluation of the submitted nominations.

After carefully evaluating the nominated publications, the committee unanimously decided to present the SIG4 Distinguished Publication Award for 2023 to the paper titled "*Direct Location of Organic Molecules in Framework Materials by Three-Dimensional Electron Diffraction*" by Meng Ge, Taimin Yang, Hongyi Xu, Xiaodong Zou and Zhehao Huang, published in the *Journal of the American Chemical Society* [Ge *et al*. (2022). **144**, 15165−15174].



The presented research is driven by the application of electron crystallography to framework materials. It clearly delivers a number of important structures that illustrate the power of the technique. The authors provide ample detail regarding the structure solution process, refinement and a careful analysis of the factors influencing the outcome. This work illustrates to a wider, more applied audience that some of the promise of electron diffraction is now possible, *i.e.* the location of hydrogen atoms, and provides a basis by which others may follow. This paper ‘moves the dial’ in terms of demonstrating the power of electron crystallography while giving an empowering feeling that others can achieve the same kind of results. The chemistry that this paper presents, made possible by electron crystallography, is both exciting and indicative of the promising future of this technique. Consequently, this publication surpasses being perceived as "just another demonstration of the power of electron crystallography" and stands as much more than that.

We extend our heartfelt congratulations to the authors of this publication and wish them continued success in their future endeavours. Furthermore, we eagerly anticipate the publication of other exciting research in the field of electron crystallography in the years to come.

Tatiana E. Gorelik is chair of ECA SIG4.

OBITUARY

Uri Shmueli (1928–2023)



Photo courtesy of Alicja Rafalska-Łasocha.

Carolyn P. Brock

Uri was born on 13 May 1928 in Kraków, Poland. His parents, Moshe Szmulewicz and Nina Seidenfrau Szmulewicz, both of whom were Hebrew teachers and Zionists, named their only child Uriel. He did not become Uri Shmueli until 1954.

In his memoirs dated 2013, Uri described his childhood as happy. There were skiing vacations in the winter and two months in a family camp each summer. But Jews in Poland were also subject to increasing harassment. Walking to school could be dangerous.

Starting in September 1939, life for the Szmulewicz family became difficult (see his memoirs). When it became illegal for him to attend school, Uri's mother taught him Hebrew, Bible and German, and arranged lessons for him in Polish, history, Latin, mathematics, geography, natural history and English. The lessons continued after the family moved to the nearby town of Wieliczka, where much of his mother's family lived. At 13, Uri had his Bar Mitzvah, necessarily in a private house because the synagogues had been closed. Later he found he was unwelcome for prayers in two different minyans (a quorum of ten Jewish adults required for certain religious obligations in Judaism) because at home his family spoke Hebrew, the holy language, and because he knew no Yiddish.

The family was separated in August 1942. Uri and his father were sent to a work camp in Płaszów, where they were still allowed to wear their own clothes; somewhat later, they were relocated for a time to the Kraków ghetto. Because their factory made electrical cables and Bakelite sockets, they were protected as essential workers. Uri made friends in the camp and, because of his skills, became an informal apprentice to his department's mechanic. He remembered that there were supervising Poles at the camp who were kind to him. One sneaked him a book about the theory of sets.

In January 1944, Płaszów was converted into a concentration camp. That August, Uri and his father were among the 4500 put on a train for KZ Mauthausen, where they were separated. Uri ended up at the subcamp KZ Linz III, located on an island in the river Traun, where conditions became steadily worse as the end of the war approached. In May 1945 Uri finally became free, eight days before his 18th birthday. Shortly thereafter he learned that his father had perished. Of his whole extended family only a few cousins had survived.

From August 1945 to November 1947, Uri was in Italy, first in a youth camp near Bari and later in Rome. He managed to learn enough on his own to pass, in Italian, the exams for an external, scientific high-school degree.

Uri had many gifts, one of them being for languages. He learned Hebrew and Polish as a child and had good training in German, English and Latin. In KZ Linz III, he learned Russian because it was the language spoken by most prisoners in his block. While in Italy, he learned, in addition to Italian, Yiddish, which during his childhood his parents had retained as their private language.

Using false papers, Uri entered Palestine in November 1947. He settled in Tel Aviv, where he first worked as a salesman of oil products but then apprenticed as a grinder of optical lenses. He was, to his regret, found unfit for military service. In Tel Aviv, he met Miriam Ajzenfeld, and they were married in 1954. She encouraged him to continue his studies and then worked to support them both while he did.

At 28, Uri started university at the Technion. He described the first year as being incredibly difficult because of all he had forgotten while grinding lenses, but he succeeded, earning a BSc in physics in 1960 and an MSc in 1961. From there, he went to the Weizmann Institute for graduate studies in polymer crystallography. By late 1961, Uri and Miriam were secure enough to start a family. Their son Rami was born in 1962, and their daughter Yael in 1967.

After completing his PhD in 1966, Uri joined the teaching staff of Tel Aviv University. There he set up the Laboratory of Chemical Crystallography. That lab was later taken over by one of his students, the late Professor Israel Goldberg, who became Uri's longtime collaborator and very good friend. The Cambridge Structural Database includes 35 structures from Uri's work in that lab.

Uri published papers about crystal packing and thermal motion in donor–acceptor compounds, and on the effects of molecular vibrations on NMR spectra. His 1974 paper *Libration of 9,10-Anthraquinone at 5 Temperatures* with Peter Kroon in *Acta Crystallographica* Section A was pioneering in its analysis of thermal motion in a crystal studied at multiple temperatures. He was one of the eight authors of the 1996 publication in *Acta A* titled *Atomic Displacement Parameter Nomenclature – Report of a Subcommittee on Atomic Displacement Parameter Nomenclature*. That 12-page report has been cited a surprising 284 times.

Towards the end of the 1970s, Uri became interested in structure-factor statistics, which remained his focus until and beyond retirement. His last paper was published in *Journal of Applied Crystallography* in 2016. Altogether there were more than 80 publications that have been cited nearly 1700 times.

In 1982 Uri started his long service as Editor of Volume B (*Reciprocal Space*) of *International Tables for Crystallography*. (Volume B is the successor to Volume II of the earlier 'red' series *International Tables for X-ray Crystallography*.) He edited the 1993, 2006 and 2010 editions and wrote more than a few of the included articles. The staff at the IUCr in Chester very much appreciated his diligent and careful work, and they remember him very fondly as a friend and as a pleasure to work with. He was always polite and kind, and always very tactful.

Uri retired in 1996. The next few years were marred by the passing of his wife Miriam in 1997 after a long illness. Later, however, Uri enjoyed the long, productive and happy retirement that he so deserved. He wrote a book (*Theories and Techniques of Crystal Structure Determination*, Oxford University Press, 2007), and continued editing Volume B of *International Tables*.

In his later years, Uri reconnected with Magda Leuchter, whom he had first known in 1947 while in Rome. They shared 25 years together and enjoyed their combined four children and eleven grandchildren.

In 2001 and 2003, Uri returned to Poland after an absence of more than 60 years. The first trip was to deliver a plenary lecture at the European Crystallographic Meeting; the second was to show his family the places where he had grown up. Later Uri became involved in projects to remember the Jewry of Wieliczka (see https://www.youtube.com/watch?v=C4bzb2wut0I, especially minutes 9:30–16:30).



With the 70th anniversary plaque, Wieliczka, 2012 (courtesy of P. Zarychta).

No remembrance of Uri can be complete without mention of his remarkable personal qualities. I first met him in 1981 in Tel Aviv and was immediately struck by his humanity. He was gentle and kind, but also tough. I remember him as surprisingly hopeful and optimistic about mankind. At Tel Aviv University, he was recognized year after year as a beloved instructor whose door was always open. His memoir shows that he made friends easily with all kinds of people, learning their language if necessary. People were drawn to Uri. While he described himself as secular, he shone with a kind of inner light that was appropriate for somebody who had been given the name of an archangel.

I am very grateful for Yael Shmueli-Friedland's help with this remembrance.

This obituary has also been published in *Acta Cryst*. (2023). A**79**, 387–389.

For a list of papers by Professor Shmueli appearing in IUCr journals click here.

OBITUARY

Jimpei Harada (1931–2023)



Masaki Takata

Thirty-five years ago, Professor Jimpei Harada told me, ‘If you understand diffraction, that’s enough.’ He employed me as his Assistant Professor and opened the door to my becoming a crystallographer. On 9 February 2023, at the age of 92, he passed away. Just recently, though, I heard he was still energetically working beyond the age of 90, and I still find it hard to believe that he is no longer with us. Professor Harada had a deep appreciation for art and good food, and, most of all, had a deep passion for crystallography.

Professor Jimpei Harada devoted himself to advancing crystallography in Japan and the Asia-Pacific region. He served as the President of the Crystallographic Society of Japan in 1992 and was an active member of the Executive Committee of the International Union of Crystallography (IUCr) from 1990 to 1996. Along with Professor Sydney Hall of the Crystallography Centre at the University of Western Australia, he established the Asian Crystallographic Association (AsCA) through the collaboration of Japan and Australia. He also led the management of the organization as its Treasurer.

In 1989, owing to the international isolation of the People’s Republic of China following the Tiananmen Square incident, there were concerns about holding the 16th IUCr Congress in Beijing in 1993. However, Professor Harada persuaded Western countries that the Beijing Congress was an important milestone in promoting crystallography in the Asian region and the IUCr Congress was successfully held in Beijing, hosted by the Chinese Crystallographic Society.

In addition, in 1993, Professor Harada worked with Dr Steve Wilkins (1946–2013) of CSIRO to realize the Australian National Beamline Facility at the Photon Factory of KEK (High Energy Accelerator Research Organization). The importance of his contributions was evident when news of his passing was announced, as messages of condolence were immediately received from, among others, Dr Andrew Stevenson (ANSTO Australian Synchrotron), Dr Zwi Barnea (University of Melbourne), Professor Dudley Creagh (University of Canberra), Dr David Cookson (ANSTO) and Dr Richard Garrett (ANSTO).

Jimpei Harada graduated from the Department of Physics at the Tokyo University of Science in 1953 and then went on to graduate school at the Tokyo Institute of Technology, where he obtained a PhD in science in 1964. After that he held various positions, including Assistant Professor at the Tokyo Institute of Technology, researcher at the University of Melbourne, senior researcher at Brookhaven National Laboratory, and Assistant and then full Professor at the Department of Applied Physics, Faculty of Engineering, Nagoya University. After retiring in 1994, he became an Emeritus Professor at Nagoya University, a Professor in the Natural Science Department at the University of Electro-Communications and, in 1996, the Director of the X-ray Research Laboratory at Rigaku Corporation. He also served as a member of the Radiation Facility Committee at KEK. He dedicated himself to education and research for

many years.

Over his half-century of research, Professor Harada maximized the use of quantum beams, such as electron beams, X-rays, neutron beams and synchrotron radiation, as tools for crystallography research. He led the way in establishing the fundamental principles of crystallography, developing measurement devices, and promoting and applying crystallography in industry. Professor Harada was at the forefront of the transformation of crystallography brought about by technological innovations in light sources.

Professor Harada initially started studying crystallography by developing a sample rotation device inside an electron microscope with Professor Goroh Honjo. While observing Si single crystals from various crystallographic orientations using electron diffraction, they discovered diffuse scattering. This phenomenon was later observed in X-ray diffraction as well. On the basis of these findings, Professor Harada proposed a theory on the existence of low-frequency transverse waves (phonons) that are strongly dependent on the crystal structure. This theory was established through the diffuse scattering of $BaTiO_3$, which provided experimental evidence for the existence of soft phonons, as previously suggested by Cochran in 1959. This achievement had a significant impact both domestically and internationally at the time, as $BaTiO_3$ was being recognized as a cutting-edge material. At the IUCr Congress held in Melbourne in August 1965, Professor Harada was highly praised by Kathleen Lonsdale (then the Vice President of the IUCr), M. Blackman and Professor Guinier of France. As a result, he was invited to work as a researcher at ATNSE in Australia from 1966 to 1968.

While in Australia, Professor Harada worked with Professor J. M. Cowley’s research group and developed a new analysis method that complementarily utilized neutron and X-ray diffraction data. This method resolved the problem of the arbitrariness of structural analysis results due to the strong correlation between structural parameters in the tetragonal phase of BaTiO3, which had been considered to be essentially unsolvable at the time (Harada *et al*., 1970). From 1968–1970, he worked as a member of Dr Gen Shirane’s neutron inelastic scattering group at Brookhaven National Laboratory, researching perovskite crystal phase transitions and soft modes. His work on the atomic level elucidation of the displacement-type ferroelectric phase transition in $BaTiO_3$ was considered a pioneering achievement in materials structure science [see for example Harada *et al.* (1971)].



Professor Harada then achieved significant progress in the field of crystallography that led to the creation of the area of research that concerns dynamics in materials. He established correction formulas for thermal diffuse scattering with Professor Makoto Sakata, determined short-range order by quantitative measurements of diffuse scattering with Dr Kenichi Oshima, solved surface and interface structures by crystal truncation rod scattering, and performed precise structure analysis, including anharmonic thermal vibrations, by neutron scattering.

Throughout that time, Professor Harada worked on developing ‘bright’ X-ray sources for observing weak diffuse scattering intensities. To achieve long-term operation of rotating anode X-ray generators, which are powerful X-ray sources used in laboratory settings, he introduced magnetic seals to the vacuum-holding mechanism of the target rotation section. As a result, the average operating lifetime of a rotating anode was extended from 100 h to over 1000 h, and they are still in use today. In 1986, he also collaborated with many other researchers to install a large six-axis diffractometer at the Photon Factory BL4C beamline, laying the foundation for advancing materials structure science.

Professor Harada repeatedly told Professor Sakata, who was then an Assistant Professor at Nagoya University, ‘Professor Norio Kato works on dynamical theory, I work on scattering, and you should find your own area of research’, which led Professor Sakata to start researching the maximum-entropy method. At the pub that Professor Harada nicknamed ‘upstairs’, he often shared this story with others, including myself. I believe that he taught us that having our own unique research area is what makes us competent researchers.

Professor Harada was like a father figure to me, always showing concern and checking up on me when I transferred from Nagoya University to Shimane University and later on when I moved to Tohoku University to work on the realization of the next-generation synchrotron radiation facility, NanoTerasu. It is my utmost regret that he was not able to make the visit to NanoTerasu that Professor Michiyoshi Tanaka and I had planned for him.

To conclude this account of Jimpei's life and achievements, I would like to borrow the final words of Professor Dudley Creagh's message of condolence: 'Vale Jimpei ... a true friend and colleague.'

References

Harada, J., Axe, J. D. & Shirane, G. (1971). *Phys. Rev. B*, **4**, 155–162.

Harada, J., Pedersen, T. & Barnea, Z. (1970). *Acta Cryst*. A**26**, 336–344.

This obituary has also been published in *J. Appl. Cryst.* (2023). **56**, 1306–1307.

For a list of papers by Professor Harada appearing in IUCr journals click here.

OBITUARY

André Authier (1932–2023)



André Authier speaking at the 21st IUCr Congress in Osaka, Japan, in 2008.

Yves Epelboin

It was with great sadness that we heard that Professor André Authier had passed away on 7 March 2023, at the age of 90.

Most scientists will remember foremost André's huge contribution to crystallography, which was at an international level. He was a founder of the European Crystallographic Association, of which he became the first President in 1972, in 1975 he became Chair of the IUCr's Commission on Crystal Growth and Characterization of Materials, and in 1978 he became Chair of the IUCr's Commission on Crystallographic Teaching. He was then elected as a member of the IUCr's Executive Committee in 1984 and became IUCr President in 1990. After these achievements he did not stop: he was Editor of *Acta Crystallographica Section A* from 1993 to 2011 and also the Editor of Volume D (*Physical Properties of Crystals*) of *International Tables for Crystallography*. An active member and a leader of various international and French committees, he was also involved in organizing many different conferences, including as Chair of the Programme Committee for the 15th IUCr Congress in Bordeaux in 1990.

André first studied physics at the prestigious Ecole Normale Supérieure Ulm from 1951. After that he moved to the USA and, in 1955, became a visiting scientist at MIT. He defended his Doctorate of Sciences at Sorbonne University in 1961 under the supervision of Professor Hubert Curien in the old laboratory of crystallography (which was founded in 1809). After his thesis André had various responsibilities at Sorbonne University, both in research and teaching. When Professor Curien left the laboratory to take on responsibilities for research at a national level, he asked André to lead the group on the study of defects in crystals. André himself became a Professor of the lab in 1965.

A full description of his work and activities would run to many pages. Here I note that his contribution to the dynamical theory of X-ray diffraction, his studies of the influence of defects on quasi-perfect crystals, from both experimental aspects and the theoretical viewpoint, allowed him to build a research group that was visited by many impressive scientists, including S. Takagi, N. Kato and P. P. Ewald. André was also a specialist in X-ray topography. He was the first to make a direct observation of the propagation of X-ray fields in a crystal in the Bragg reflection condition and was one of the first contributors to the theory of X-ray diffraction by deformed crystals. He analysed and explained the imaging of defects in X-ray topography, and applied this approach to the study of crystal defects, growth defects in synthetic crystals as well as in natural minerals, ferroelectric domains and electrical defects in semiconductors.

André received many honours during his life: he was an honorary member of the German Science Academy (Leopoldina), and chevalier then officier de la légion d'honneur in France, along with many

other awards and titles, national and international.

After his retirement in 1996, he worked on the history of crystallography (his book *Early Days of X-ray Crystallography* was published by the IUCr in association with Oxford University Press in 2013) and also finished his book *Dynamical Theory of X-ray Diffraction*, which is considered to be the definitive reference work for the field (*IUCr Monographs on Crystallography*, No. 11, 2001). I have personal recollections about this latter book: when I had the privilege of being hired as a member of his group in 1968, I learned about dynamical theory through a copy of his manuscript (in French at that time). In fact, André was so keen to describe all aspects of diffraction in his monograph that he revised the manuscript throughout his professional life. A revised edition was published in 2003.

The staff at the IUCr, with whom he worked for many years as an encouraging and supporting President and a conscientious Editor, remember him with great respect but also as a good friend: he regularly sent photos of the beautiful gardens at his home in Limousin. He is survived by his wife Irena and his two daughters, Isabelle and Sophie.

This obituary was originally published in *Acta Cryst*. (2023). A**79**, 385–386.

For a list of papers by Professor Authier appearing in IUCr journals click here.

OBITUARY

David G. Watson (1934–2023)



David Watson at the ACA Annual Meeting in Atlanta, GA, USA, in 1994. Photo contributed to the IUCr gallery by W. L. Duax.

William Clegg

I first met Dr David Watson when I was a postgraduate student doing research for my PhD under the supervision of Dr Peter Wheatley in Cambridge in the early 1970s. I was in a small laboratory in the short mezzanine corridor sandwiched between ground and first floors behind two large lecture theatres in the Lensfield Road Chemistry Departments, and the still rather young Cambridge Crystallographic Data Centre occupied offices in the same corridor, developing the Cambridge Structural Database. At the time I remember the staff included the Director Olga Kennard (herself recently deceased), Frank Allen and Sam Motherwell, all of whom I got to know. I remember David as a quiet, unobtrusive but dedicated and efficient scientist and I think he was effectively Olga's second-in-command. David joined the CCDC when it was first founded in 1965 and contributed to its growth for over 30 years, during which he became head of the database team and moved with them to their new purpose-built home in 1992.

The CCDC has published an obituary focusing on David's work there (https://www.ccdc.cam.ac.uk/discover/blog/obituary-dr-david-g-watson/), with tributes from some of his former colleagues. Gill Heale, CCDC Scientific Editor 1988–2007, adds: 'David undertook my initial crystallographic training and it was a privilege to have such an excellent, methodical and patient teacher. We worked together on the data deposition scheme and it was a landmark day when we issued the first CCDC number. As our database group manager, David was kind, fair and approachable and I liked him very much.' These are qualities he brought to the publishing activities of the IUCr.

Our paths next crossed in 2000, when the IUCr was planning the launch of its first non-print journal, *Section E* of *Acta Crystallographica*. The venture was strongly supported by the CCDC, represented mainly by Frank Allen. As this project would involve many new features and approaches, it was felt that *Section E* would benefit from having two Section Editors rather than the usual one. With a few years of experience as a Co-editor of *Section C* and a strong authorship record, I was invited to take up one role, and David was recommended by Frank for the other. We met for discussion in the editorial offices in Chester and quickly found we could work well together, having complementary backgrounds and common aims and standards. The journal was launched in 2001 and we served together until the 2008 IUCr Congress in Osaka, when the work was taken over by a team of three Section Editors. By then we had recruited a large and very international team of Co-editors.

David had an eye for detail, an excellent grasp of scientific writing style, and a desire for accuracy and consistency. These served him well in an editorial capacity. His proof-reading of articles was meticulous

but also rapid, usually with a turnover of just hours for a large daily batch of manuscripts. He contributed enormously to the early success and productivity of *Section E* and to its establishment and development. When we both stepped down in 2008, I was glad of the released time for other activities, but David chose to continue in the team as a Co-editor, which helped with continuity under the new leadership. He finally stepped down from the Editorial Board, after 12 years with the journal, in 2012.

He is remembered with great affection by the editorial staff in the IUCr's Chester Offices. Peter Strickland, who was IUCr Managing Editor during the period that David was on the *Section E* board, noted: 'David was a meticulous planner and played a huge part in the setting up of *Section E* and making fellow crystallographers aware of the new journal. He was kind and friendly to all the staff at the IUCr, and we will miss him.'

David was one of the gentlest and most reliable scientists with whom I have ever had the privilege and pleasure of collaborating. I have fond memories of our shared experiences in this editorial work and I was saddened by the news of his death. His scientific legacy, both at the CCDC and for the IUCr, is exceptional and greatly valued.

This obituary was originally published in *Acta Cryst*. (2023). E**79**, 578–579.

For a list of papers by Dr Watson appearing in IUCr journals click here.

OBITUARY

Aldo Félix Craievich (1939–2023)



Diego G. Lamas

On 24 April 2023, we received the very sad news of the passing of Professor Dr Aldo Félix Craievich at the age of 84. He was a brilliant Argentine–Brazilian crystallographer who not only had the remarkable vision to create the first synchrotron in the southern hemisphere but also played a leading role in the construction of the Brazilian Synchrotron Light Laboratory (LNLS) in Campinas, São Paulo, Brazil, serving as its first deputy director and head of the scientific department. He coordinated the projects of the LNLS beamlines and the construction of the first seven of them, but also he put in a lot of effort to create the user community of LNLS. He organized and gave by himself numerous courses and conferences on synchrotron light techniques throughout Latin America, becoming a mentor and great teacher for many crystallographers in the region.



Aldo was born in 1939 in the city of Zavalla, in the Province of Santa Fe, Argentina, and lived in this country until age 34, except for when he resided in France to conduct the research work for his PhD thesis. He graduated in Physics in 1964 at the Balseiro Institute of the National University of Cuyo (San Carlos de Bariloche, in the Argentine Patagonia), where he received a highly advanced education that profoundly impacted his future career as a researcher. In 1965, he joined the Institute of Mathematics, Astronomy and Physics (IMAF, currently FaMAF) of the National University of Córdoba (UNC, Córdoba City), where he was tasked with creating a laboratory of X-ray techniques. To gain a deeper understanding of these techniques and complete his training in experimental physics, he decided to undertake a PhD. In mid-1966, he moved to the Laboratoire de Physique des Solides (LPS, Laboratory of Solid-State Physics) in Orsay, France, which at that time was part of the University of Paris and later became part of the newly established University Paris-Sud or University Paris XI (nowadays University Paris-Saclay). Thanks to the support of the authorities at IMAF and of another Argentine who had worked there, Alberto Bonfiglioli, Aldo was able to join the research group of the renowned crystallographer André Guinier, widely known for his contributions to small-angle X-ray scattering (SAXS) among others. Aldo presented his PhD thesis at the Balseiro Institute in early 1969, and from that moment on he resumed the establishment of the X-ray laboratory at IMAF, installing X-ray diffraction and SAXS instruments. In he case of the latter, this was the second one in the country, following the facility implemented by Bonfiglioli at the Constituyentes Atomic Center of the National Atomic Energy Commission (CAC-CNEA) in Buenos Aires. Unfortunately, both SAXS facilities were discontinued some years later when both researchers left their institutions, and Argentina did not have similar instruments for decades. This situation only started to change a few years ago, largely thanks to Aldo’s work in teaching and promoting X-ray techniques and crystallography.

Aldo worked at IMAF for a few years and published the first papers using the equipment from the laboratory he established. However, in 1973 he accepted an invitation from Professor Yvonne Mascarenhas to work at the Institute of Physics and Chemistry of São Carlos (IFQSC, now IFSC) in São

Carlos, São Paulo State, Brazil. There, he set up the first SAXS instrument in Brazil, making again a valuable contribution to the region. He initially planned to stay at IFQSC for only one year, but, because of the serious political situation in Argentina, he extended his stay, and years later, when the Argentine democracy was restored, he led the very important project to create a synchrotron facility. As a result, Aldo resided in Brazil for the rest of his life. In relation to this, it is worth mentioning that Aldo never forgot his home country: he was always grateful for the education he received and returned many times to visit family, colleagues, teachers and friends. Furthermore, he made significant contributions to the progress of science in Argentina.

At IFQSC, Aldo continued his previous work on glassy materials using SAXS experiments, but after a few years he decided to align his research work with the institute's trend of studying biological systems and started by exploring organic molecular crystals. To deepen his knowledge in this area, he embarked on a postdoctoral stay at the LPS in 1976, returning to IFQSC the following year to initiate this new line of research, which also relied on SAXS experiments.

In 1980, Aldo decided to leave São Carlos to undertake a new challenge in Rio de Janeiro: the creation of an X-ray laboratory at the Brazilian Center for Research in Physics (CBPF), an institution that had a reputation for excellence in theoretical research. Since he had to wait approximately a year for the purchase of the instruments, he decided to do another stay in Orsay, but this time at the recently established Laboratoire pour l'Utilization du Rayonnement Electromagnétique (LURE, Laboratory for the Use of Electromagnetic Radiation). At that time, synchrotron radiation sources were still in their early development stages, and the LURE laboratory, being one of the first facilities open to users, played a crucial role in expanding the use of techniques based on this radiation. During Aldo's stay at LURE from 1981 to 1982, which was aimed primarily at conducting *in situ* SAXS experiments on glassy materials and exploring extended X-ray absorption fine-structure (EXAFS) spectroscopy, the idea of creating the first synchrotron radiation source in Brazil emerged. This initiative gained strength when Aldo organized a visit to LURE by the president of the National Council for Scientific and Technological Development (CNPq) of Brazil in early 1982. Shortly after, the Synchrotron Radiation Project (PRS) of CNPq was established. This was developed from 1982 to 1985, with Aldo serving as the director of its executive committee from 1983. This role led him to promote the project and the importance of synchrotron radiation techniques in Brazil and other countries in Latin America. Additionally, Aldo coordinated a CNPq scholarship program for human resource development in these techniques. Finally, in 1985, it was decided to create the Brazilian Synchrotron Light Laboratory (LNLS) in Campinas, São Paulo State, and in 1986 CNPq designated Cylon Gonçalves da Silva, a professor at the Institute of Physics of the University of Campinas, as the director of LNLS, while Aldo served as the deputy director.

The construction of LNLS took ten years and had unique characteristics. Particularly noteworthy is the fact that most of the components needed for the first source, called UVX, and the beamlines were manufactured either at LNLS itself or by Brazilian industry. Undoubtedly, this project can be considered one of the most important milestones in science and technology in Latin America. While the UVX source construction project was led by Antonio Ricardo D. Rodrigues, Aldo took charge of leading the projects for the beamlines and the construction of the first seven, which were made available to users in July 1997. Additionally, Aldo recognized the vital importance of building a user community, the true 'owners' of an open facility like LNLS, and, to achieve this, he taught courses and lectures not only in Brazil but also in many other Latin American countries, including Argentina, Chile, Colombia, Cuba, Mexico, Peru, Uruguay and Venezuela. In 1989, long before the laboratory was opened to users, he organized the First LNLS User Meeting, an activity that has continued every year and still takes place with increasing interest.

It is worth noting that Aldo believed that in order to successfully fulfill his important role at LNLS he needed to stay updated with advances in synchrotron radiation instrumentation and techniques. Therefore, every year he returned to the LURE synchrotron as a user for at least one or two weeks. He continued conducting experimental work, particularly in the study of nanomaterials and glassy materials using SAXS techniques, and publishing the results of his high-level scientific research work.

Towards the end of 1997, after many years of intense work and with LNLS operating successfully, Aldo decided to leave the institution and dedicate himself fully to research and university teaching. Therefore, in January 1998, he joined the Institute of Physics at the University of São Paulo (IF-USP) in São Paulo city, where he obtained a position as a full-time professor. However, he never distanced himself from LNLS. He not only remained a frequent user but also continued to work on building the user community. Aldo continued to deliver courses and lectures, and promoted scientific collaborations with groups sharing similar research interests. It was during this time that I had the honor of collaborating closely with Aldo, sharing 20 years of scientific challenges, teaching activities, crystallography outreach and friendship.

In 2009, upon reaching the age of 70, Aldo was forced to retire, as mandated by Brazilian law. However, he continued as a senior professor at IF-USP until the end of his days. He never stopped travelling the world to teach and learn, always with great enthusiasm. He followed with great interest the creation of LNLS's second source, Sirius, whose characteristics were discussed with users in the same year of Aldo's retirement. Construction began in 2013, and the first users were welcomed in 2020. Much earlier than its operational start-up, it was understood that Sirius would be one of the most advanced synchrotron sources in the world, a fourth-generation source, and that the user community needed to prepare itself to match such advancements. Aldo accompanied us in this process and encouraged us to continue growing as researchers. The COVID-19 pandemic and subsequent health issues prevented him from further travels, but he remained engaged in all LNLS activities and the numerous scientific societies that interested him, including the International Union of Crystallography (IUCr), the Brazilian Crystallographic Association (ABCr), the Argentine Crystallographic Association (AACr), the Latin American Crystallographic Association (LACA), the Brazilian Society for Materials Research (SBPMat), the Argentine Association of Materials (SAM) and the Argentine Physical Association (AFA), among others. Regarding the IUCr, it is worth mentioning that Aldo served as co-editor of the *Journal of Synchrotron Radiation* from 2009 to 2020.



Photograph taken during the VIII Annual Meeting of the Argentinian Association of Crystallography, in Santa Fe City, in 2012. Professor Dr Aldo Félix Craievich was recognized as a guest of honor of the National University of the Littoral.

Aldo received numerous awards and distinctions throughout his career. In 1980, he became a full member of the São Paulo Academy of Sciences (Brazil) and, since 2015, also of the Brazilian Academy of Sciences. He received recognition from the LNLS (staff and users), ABCr, AACr, SBPMat, the National University of the Littoral and the Balseiro Institute. Additionally, he received the Mercosur Science and Technology Prize twice (2004 and 2010), jointly with colleagues from Argentina and Brazil, in the 'integration' category, awarded by UNESCO and the Network of Science and Technology of Mercosur (RECyT).

Working with Aldo was a fascinating experience, not only for me but also for many other colleagues. Whenever there was something we didn't understand, Aldo would take a pencil and start reasoning deeply, not letting go of the subject until the issue was resolved. He always encouraged us to comprehend the phenomena we were studying in great detail, believing that any question could be solved with enough effort. By sharing scientific activities with him, we discovered that we had so much more to offer as scientists if we did not settle for superficial answers or quick solutions. Another aspect I want to highlight is that Aldo was incredibly generous and open with his knowledge, a quality that unfortunately is not always found and one we truly appreciated. Furthermore, Aldo was a person of great culture, and when he shared anecdotes of his experiences he always left us with valuable lessons.

The first LNLS source, UVX, ceased operation in 2019 after 22 years. However, Sirius is now fully operational, and the construction of new beamlines shows a bright future ahead. In addition, after 40 years since the initiation of the PRS-CNPq project, the large Latin American user community, which was created through Aldo's generous teaching efforts, is now embarking on new challenges in the development of Sirius. The renovated synchrotron facility at LNLS and its well established user community are the main legacies of Professor Dr Aldo Félix Craievich, who had the vision to recognize the tremendous importance of creating the first multi-user synchrotron radiation laboratory in the southern hemisphere and dedicated most of his scientific life to turning that vision into a reality. At the same time, he promoted the fundamentals of crystallography and many of its techniques. In recent years, his SAXS courses in Argentina led to the establishment of two advanced instruments dedicated to this technique, both of them being opened to the scientific community. Following Aldo's example, the leading researchers of these SAXS facilities continue to disseminate the fundamentals and applications of the technique he learned from Guinier. We will deeply miss Aldo, our dear friend, teacher and mentor.

This obituary has also been published in *J. Synchrotron Rad.* (2023). **30**, 856–858.

For a list of papers by Professor Dr Craievich appearing in IUCr journals click here.

OBITUARY

Carles Miravitlles (1942–2023)



Carles Miravitlles at ICMAB.

Xavier Obradors, Elies Molins, Jordi Rius, Anna May-Masnou

We are deeply saddened to announce the death of our dear friend and colleague Professor Carles Miravitlles, founder of ICMAB in 1986 and director of the center for 21 years, from 1986 to 2008. Carles passed away on 16 April 2023, at the age of 80.

The legacy and memory left by Carles Miravitlles, who was born in Barcelona on 9 September 1942, is extraordinary, for both his human and his professional qualities. He was a key figure in the creation of the Institute of Materials Science of Barcelona of the Spanish National Research Council (ICMAB–CSIC) and in the promotion of research in Catalonia.



From left: Enric Banda, Carles Solà and Carles Miravitlles.

Carles, a visionary man

Carles was a person who loved science, undoubtedly influenced by the figure of his father, Lluís Miravitlles Millé (Professor of Applied Geology at the University of Barcelona, UB, Spain). Carles received his PhD in pharmacy under the supervision of Manuel Font-Altaba (Professor of Crystallography of the UB) and undertook several stays in the Dpt. de Chimie-Physique et Crystallography of the University of Leuven (Belgium). There he came into contact with Dr Gabriel Germain, who, together with Professor Michael Woolfson and Dr Peter Main, was one of the leading scientists in direct methods, which were emerging as a powerful technique for solving crystal structures. In 1974, he was appointed as Scientific Researcher at the Institute of Earth Sciences 'Jaume Almera' (now GeoSciences Barcelona) of the CSIC and contributed decisively to the popularization of this methodology in Catalonia. During this time, his research interest focused on structural crystallography and X-ray diffraction, mainly on organic compounds of pharmacological interest. In 1980, he organized the European Crystallographic Meeting (ECM-6) in Barcelona. He became Full Professor of the CSIC in 1986 and, in the same year, was nominated Director of ICMAB.

Apart from his interest in scientific research, in the second half of the 1980s he combined a very successful vision and a great capacity for work to create and promote ICMAB at the forefront of materials science research. He was able to mobilize this emerging discipline, anticipating it within the CSIC, achieving the creation of four new Materials Science Institutes in Spain and later promoting the existence of a 'National Materials Science Plan'. He was also very active in promoting the international collaboration of ICMAB with many research centers and institutions, mainly around Europe. The debt we owe him goes far beyond the ICMAB community and extends to this field's scientific community.



Inauguration of the ICMAB building in 1991.

On the other hand, Carles Miravitlles' wisdom in promoting a new CSIC research center in the Bellaterra Campus of the Autonomous University of Barcelona (UAB) was the seed that later turned this campus into one of the largest research concentrations in southern Europe. Carles' ability to attract diverse talent and to convince political and institutional leaders to launch large-scale operations was exceptional. And this is the legacy he has left to all of us at ICMAB: the passion for excellence, internationalization and scientific ambition that has led us to be recognized twice as Severo Ochoa Excellent Centre in the area of advanced functional materials.



From left: Jaume Casabó, Carles Miravitlles and Andreu Mas-Colell.

Carles Miravitlles not only contributed to building the basic skeleton of the ICMAB, he was also determinant in other areas of management of the CSIC and his beloved Catalonia: first, as CSIC Delegate in Catalonia (from 1987 to 1992), where he was able to promote institutional relationships with the Generalitat de Catalunya; and later, by encouraging the CSIC to create a new research center in Nanoscience and Nanotechnology that eventually became the current Catalan Institute of Nanoscience and Nanotechnology (ICN2). He also managed to collaborate with companies with the capacity to carry out research on the campus, creating the MATGAS Economic Interest Group, with the participation of the company Carburos Metálicos (now, part of Air Products), the CSIC and the UAB. Once released from the direction of ICMAB, he agreed to become the Director of the 'Eduardo Torroja' Institute in Madrid (2008–2009) to modernize and reorganize the center. Finally, Carles Miravitlles returned to ICMAB, and until a few months before his death, he was still regularly coming to the Institute.

In addition to these positions at CSIC, Carles Miravitlles was president of the Spanish Committee of Crystallography and, since 1993, a full member of the Royal Academy of Arts and Sciences of Barcelona, of which he was also Vice Secretary. He was a member of the Chemistry Section of the European Academy, President of the Expominer Fair, and an academician of the Royal Academy of Pharmacy of Catalonia since 2016. In 1992 he received the Narcís Monturiol Medal in scientific merit from the Generalitat de Catalunya, for his dedication to the study of new materials and for contributions to the field of crystallography.



Crystallography research group at ICMAB in 2012: (bottom, left to right): Oriol Vallcorba, Joan Esquiu and Xavier Campos; (top, left to right): Anna Crespi, Noelia García, Joana Martínez, Elies Molins, Muling Zeng, Ignasi Mata, Carles Miravitlles, Anna Laromaine, Jordi Rius, Anna Roig, Cosmin Cotet, Marta Vendrell and Xavier Torrelles.

Carles Miravitlles' human qualities and bonhomie were hallmarks that accompanied him throughout his life and were recognized by everyone. He distinguished himself by being very positive, being kind to everyone, whether they shared his opinion or not, and always keeping a certain degree of irony and sarcasm about the research and administration management structures, both state and autonomous. His mastery of human relations at all levels and of political structures made him an undisputed leader among research managers.

To preserve his memory, the conference room of the ICMAB has been named after him.



ICMABers, when Carles Miravitlles was director of the center.

What they say about Carles ...

"*Carles is the person who has most influenced my scientific and professional career. He first encouraged me to move to ICMAB in 1989 when I was a young Full Professor at the Faculty of Physics of the University of Barcelona. His support and that of the president of the International Scientific Committee, Prof. Manuel Cardona, were decisive in creating a powerful research team in Magnetism and Superconductivity. Later, in 2002, he proposed me to be the deputy director of ICMAB and, finally, the 2008 director. I always thanked him for his trust in me and for the unconditional support, help and expertise I received from him when I took on the tasks of directing the center*". Xavier Obradors, director of the ICMAB between 2008 and 2023.

"*Carles Miravitlles brought the Institute into being; we already know that he made a very wise choice of researchers from the beginning and guided the expansion of the Institute throughout the 21 years that he was its director. His dynamism, intelligence, and creativity allowed ICMAB to grow both in size and quality. His mark was indelible, and those of us who have been able to interact with him know what a great loss his passing means. In the broadest sense, he had a significant influence on research in Catalonia and Spain. He will be greatly missed".* David Amabilino, current director of ICMAB.

"*Carles was a nice person. He was generous, honest, respectful, funny and creative (his head was buzzing with ideas) but at the same time, like a good scientist, he was rational, that is, sensitive to arguments. I guess that's why we never argued once in over 40 years. He also had a remarkable global and future vision. At the beginning of my research career I had him by my side and later on when I needed him he always helped me. He was also a person who knew how to listen and give advice, something that was very useful to him, later, during his more than twenty years as Director of the Institute of Materials Science in Barcelona. I will miss you.*" Jordi Rius, Research Professor of ICMAB.

"*Carles Miravitlles 'took me in' at ICMAB at a complicated time for me; it was 1992. This determined my professional career. From the beginning, we had a trusted relationship. Carles was an intuitive, social person; he had a visionary point of view and a humor that was not always politically correct. He was a tireless and tremendously restless worker with the ambition and obsession to make ICMAB a modern research center of reference. He used to head his e-mails with a 'benvolgut amic i company'".* Anna Roig, Research Professor at ICMAB.

"*Of Carles I can say that he had an advanced vision, both scientifically and technically. He had the virtue of knowing how to surround himself with good or very good people in his field. He had an idea of the future (I am talking about the late 80s) of ICMAB of scientific and technical excellence, and obviously also in the field of computer science. For example, by making proposals ahead of his time, such as the idea of making a kind of Virtual Institute (he said without walls), where you could work remotely securely as if everyone was in the same institution. At that time, talking about Virtual Private Networks was a very advanced idea, which led ICMAB to have a world-class Computer Network in the following years, being a computing reference, both at the CSIC and at the UAB campus*". Joan Figuerola, Head of Computer Science Department at ICMAB for many years.

"All those who were lucky enough to know Carles recognize his affable and conciliatory nature. Everyone was happy when they found him. He always had some anecdote to tell or some news that no one else knew. His smile was encouraging and his story charmed you. In the CSIC he has been considered as the director of the Institute that all researchers would have liked to have. Tireless worker, rooted in his land, empathetic and generous. No sports lover, except for dominoes. Spartan in tastes, although a good gourmet. He left us just two days after losing his wife. He started by doing complicated crystallography calculations when there were no computers, and became an excellent promoter and manager of research and science, always looking for excellent researchers. We will remember him for his eternal affability, firm commitment to a job well done and knowing how to enjoy the little things. We will never be able to appreciate the great influence he had on the people with whom he came in contact. Sometimes exceptional people make this world a little better. Despite the moments of sadness, we will always be proud of having known him." Elies Molins, Head of the Advanced Structural and Functional

Crystallography Department of ICMAB and Co-president of the FMTS-WFSW.



From left: Marta Vendrell, Joan Figuerola and Carles Miravitlles in December 2022 for the ICMAB Christmas party.

A shorter version of this obituary has been published in *J. Appl. Cryst.* (2023). **56**, 1304–1305.

For a list of papers by Professor Miravitlles appearing in IUCr journals click here.

BOOK REVIEW

How Science Runs – Impressions from a Scientific Career. By Eric J. Mittemeijer



Mike Glazer

Springer Nature, 2022. Pp. 266. Price EUR 31.64, ISBN 978-3-030-90094-6 (hardcover), ISBN 978-3-030-90097-7.16.75 (softcover). Price EUR 24.60 (eBook), ISBN 978-3-030-90095-3.

This is a fascinating book that should appeal to anyone wanting to have a view of the life of a typical academic scientist. The author, Eric Mittemeijer, is an internationally well known and distinguished materials scientist with considerable experience within university academia. In this book, he takes us on a series of journeys through 14 separate chapters, describing his own experiences in making his career. The book is quite long, at 266 pages, and is packed through with anecdotes about famous scientists that he has met during his career. Some of these are amusing, while others are highly critical of the behaviour of others and of certain aspects of academic life. The author does not hold back! He begins with the statement ‘Science is not an abstract activity performed by flawless gods’, which I think sums up the philosophy behind this book.

Professor Mittemeijer was born in the Netherlands and spent several years at the Delft University of Technology, holding the chair of the world-famous W. G. (Willy) Burgers, but then moved to Germany to become a Max Planck Director of the Institute for Metals Research in Stuttgart (today Max Planck Institute for Intelligent Systems) and Full Professor of Metallurgy at Stuttgart University (since 1998). He retired in 2016.

I will not go through each of the chapters in turn, but to give a flavour of what is presented, we see chapters beginning with his parents, on growing up, his school years and becoming a scientist. But then we also get chapters of a more technical nature, such as a polemic on the vexed question of publish or perish, the growth and progress of science, the discovery of quasicrystals, and discussions of so-called ‘tarnished’ science: mistakes, deceit and fraud in science. He ends with a description of his years in Stuttgart and how, being Dutch, he fitted in with the German system.

One slightly disconcerting aspect, although eventually one to which one becomes inured, is his switching from time to time between expressing himself in the first person and the third person. Nonetheless, there are many little snippets of information that I was unaware of and which the author points out. For instance, I never knew before that in the Netherlands, generally thought of as a very liberal country, women in government jobs and younger than 45 were obliged by a law of 1924 to give up their job the moment they married! This persisted until 1958.

Mittemeijer talks about his experiences with meeting other scientists in several places. For instance, he describes his attending presentations by William (Bill) Parrish, the father of the vertical Philips powder diffractometer. He is described as a person with a loud voice and an impressive, intimidating personality that it was not easy to confront critically in a (public) discussion. This is what the author writes:

Bill Parrish was there [at a conference]. Our work was not really criticizing Parrish but also not supporting his approach. Mentally I was prepared for a question, also a possible critical one, by Parrish after my lecture. I had not even completely finished speaking when the massive body of Parrish already rose from his seat. Before the chairman could have given Parrish the opportunity to pose his question, I loudly said, actually it gushed spontaneously out of me: 'Oh, oh, here it comes!' The audience laughed, recognizing the confrontation of an established, famous, much older scientist with a relatively unknown young man. Parrish was at once unarmed, and the stress I felt relaxed. His following question was easy to respond to.

I recall having a similar experience myself with Bill when I gave a talk at a conference on synchrotron radiation.

In the chapter entitled *Young versus old* Mittemeijer discusses the story of the discovery of quasicrystals and the problems the later Nobel prize winner Dan Shechtman had in convincing the crystallographic world that it was possible to find crystals that showed tenfold (or fivefold) symmetries, something that was totally against accepted ideas about crystals at the time. Apparently, the head of the laboratory where Shechtman worked urged him to leave, saying, 'you are a disgrace to my group'. The first publication on Shechtman's work after a previous one had been rejected was a short paper submitted to *Physical Review Letters*, which was immediately accepted. Mittemeijer suggests that this was probably because of the listing of the great John W. Cahn as a co-author.

In discussing the case of Willy Burgers, the author explains that there is some tragedy in the recognition that the famous Burgers vector used in the theory of dislocations was the achievement of his brother Jan. There is a story that an honorary doctorate was granted to Willy Burgers in France, but when the French eulogist mentioned that science owed the Burgers vector to Willy Burgers, Burgers immediately interrupted and shouted 'c'est le vecteur de mon frère, c'est le vecteur de mon frère!!'.

In another section, the author has some criticism about the famous Rietveld method in powder diffraction. He points out that the original idea for this method was put forward by Bert O. Loopstra, who later discussed the idea of whole-pattern fitting with Bob van Laar. In order to create a computer program to carry out the method, they hired the computer-savvy Hugo M. Rietveld. The first paper by Loopstra and Rietveld was published in *Acta Crystallographica* in 1969, having been submitted in 1968. A later paper published in 1969 by Rietveld alone in *Journal of Applied Crystallography* is the one that is always quoted and led to the name 'Rietveld method' or 'Rietveld refinement'. Mittemeijer points out that this did grave injustice to the originator of the method, Bert Loopstra. Rietveld later left science to become a librarian: Mittemeijer says the notion that he left science because he was disappointed that the method had not found wide acceptance at the time is just a 'fairy tale'. Thus, according to the author, the profile refinement method should more justly be called the 'Loopstra method', concluding that this story has a sad ending.

Summing up, I think this book is thought provoking and should be of interest to anyone already working in science, especially those intending to work in science. There are many warnings and, at the same time, delights to be found in the numerous anecdotes and descriptions provided by the author. It is a generally good and entertaining read.

This book review was originally published in *J. Appl. Cryst.* (2023). **56**, 908–909.

PRESS RELEASE

Kirara service for high-quality protein crystal growth in microgravity



Kirara#5 call for samples

Greetings from space!

We are happy to share that Kirara#4 recently returned from its mission to the International Space Station (ISS) and that we are already planning and preparing for the upcoming mission. Read more about the samples flown so far by the Kirara service.

Kirara#5 is already under preparation! And so we are calling for samples for the upcoming missions, and these are not strictly limited to proteins, as shown through the examples of previous missions.

In case you missed it, Space Commerce Matters, together with ICE Cubes and the Japan Manned Space Systems Corporation (JAMSS), organized a webinar focused on "Crystal Growing in Microgravity". The keynote speaker, Dr Anne Wilson from Butler University, Indianapolis, IN, USA, presented her project on a meta-analysis of Crystals Grown in Microgravity. The recorded webinar can be viewed here.

What is Kirara? A low-cost crystallization service in space, providing the opportunity to take advantage of the unique microgravity environment on board the International Space Station (ISS) for crystal growth in support of many applications, such as drug discovery. The service uses an original small incubator unit developed by JAMSS and accommodated inside the ICE Cubes Facility on the ISS.



Why space? The microgravity environment on-board the ISS has been proven beneficial to enable and study complex molecule crystallization processes. In space, gravity and convective forces do not get in the way of crystal formation, allowing crystals to grow larger, with a more rigid, ordered, near-perfect structure compared with those produced on Earth. The unique microgravity laboratory and environment of the ISS can therefore be used to support, for example, the investigations for the development of novel drugs that could treat viral outbreaks or antibiotic-resistant bacteria.

Why Kirara? Because it offers a unique end-to-end service where microgravity and crystallization experts determine the ideal crystallization conditions for the user. Several options are available to users to analyze their crystals once returned to Earth. These include support to crystal testing with the same experts also helping in the set up and performance of post-flight analysis (*e.g.* X-ray diffraction of the crystals), as requested. All the deliverables and intellectual property rights obtained belong to the customers.

Previous missions

The Kirara crystallization service has had four successful missions so far. During the first mission in December 2019, seven pharmaceutical companies and research centers participated and the first ever cellulose synthesis by enzyme in microgravity took place. On Kirara#2 in December 2020, the Kirara service was used to investigate Veklury, a redemsivir-based medicament for treating COVID-19, from InnoStudio Inc. and CycloLab Cyclodextrin C&D Laboratory Ltd. In December 2021, Kirara#3 exposed to microgravity the research of five different customers from Pharma/AgBio companies and research institutes from three different continents – Asia, US and Europe. Recently, Kirara#4 hosted samples for drug R&D (COVID-19 related research) and academic research (life sciences and agriculture), as well as educational and inspirational projects.

ICE Cubes/Space Applications Services contacts:

Leonardo Surdo: leonardo.surdo@spaceapplications.com

Dr Miguel Ferreira: miguel.ferreira@spaceapplications.com

Learn more here.

Find out how microgravity can boost research in a variety of sectors and fields of activity.

IUCR SUPPORTED EVENTS

IUCr supported meetings

These forthcoming meetings are supported by grants from the IUCr Calendar Committee.



11th Oct 2026 - 16th Oct 2026

Indaba10

Skukuza, Kruger National Park, South Africa



5th Dec 2026 - 10th Dec 2026

African Materials Research Society (AMRS 2026)

Nairobi, Kenya

MEETINGS CALENDAR

Meetings calendar

This is a list of meetings of interest to crystallographers occurring within the next twelve months, as recorded in the IUCr Calendar of Events. Please let us know of any that are missing by completing this form or sending an email to forthcoming.meetings@iucr.org.



Indaba10 South Africa 11th Oct 2026 - 16th Oct 2026



Synchrotron Radiation: Science, Knowledge, Innovations, Future (SKIF-2026) Russian Federation 18th Oct 2026 - 23rd Oct 2026



CCP-EM/Diamond Icknield Workshop United Kingdom 9th Nov 2026 - 13th Nov 2026



Instruct-ERIC hands-on workshop on Advanced cryo-FIB-SEM methods Germany 9th Nov 2026 - 13th Nov 2026



Crystal36-AXAA 2026 Meeting Australia 26th Nov 2026 - 2nd Dec 2026

African Materials Research Society (AMRS 2026) Kenya 5th Dec 2026 - 10th Dec 2026

Joint Polish-German Crystallographic Meeting 2027 Germany 15th Feb 2027 - 18th Feb 2027