6th International School of Crystallisation
(Granada, Spain, May 20th-25th)

The Laboratory of Crystallographic Studies (CSIC-UGR) has organised the 6th International School of Crystallization: Drugs, Foods, Agrochemicals, Minerals, New Materials (ISC2018, http://www.iscgranada.org/) under the auspices of the International Union of Crystallography through the Crystal Growth and Characterization of Materials Commission and the Teaching Commission, with the support of the International Doctoral Summer School Programme of the School of Science, Technology and Engineering of the University of Granada, the Spanish Specialized Group of Crystallography and Crystal Growth (GE3C) and the Excellence Network of Crystallography and Crystallization "Factoría de Cristalización". The event took place in the Centre of the beautiful City of Granada, an ideal place to promote close scientific and social interactions between the attendees.

The School gathered postgraduate/postdoctoral students as well as research scientists from industry and academia that deal routinely with crystallisation processes but seek fundamental knowledge on the crystallisation phenomena and the behaviour of crystallising solutions. Students from all over the world were invited 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.

ISC2018 covered five days of lectures and practical demonstrations related to the field of the crystallization of foods, drugs and agrochemical compounds.

Organising Committee

Prof. Juan Manuel Garcia-Ruiz, Director of the School
Dr. Jaime Gómez Morales, co-Director of the School
Dr. Duane Choquesillo Lazarte, co-Director of the School
Dr. Alfonso Garcia Caballero
Dr. Cristóbal Verdugo Escamilla
Prof. Giuseppe Falini
Prof. Ulrich Griesser

Attendance

The turnout of the School was excellent having with 104 participants from 17 different countries, most of which were students (50 students, 48.1 %) and tutors (29 speakers & demonstrators, 27.9 %), being the rest composed of academics (11 academics, 10.6 %), industrial representatives (12, 11.5 %) and exhibitors (2, 1.9 %) (Figure 1). The participants were supported by 29 speakers and demonstrators (26.8 %).

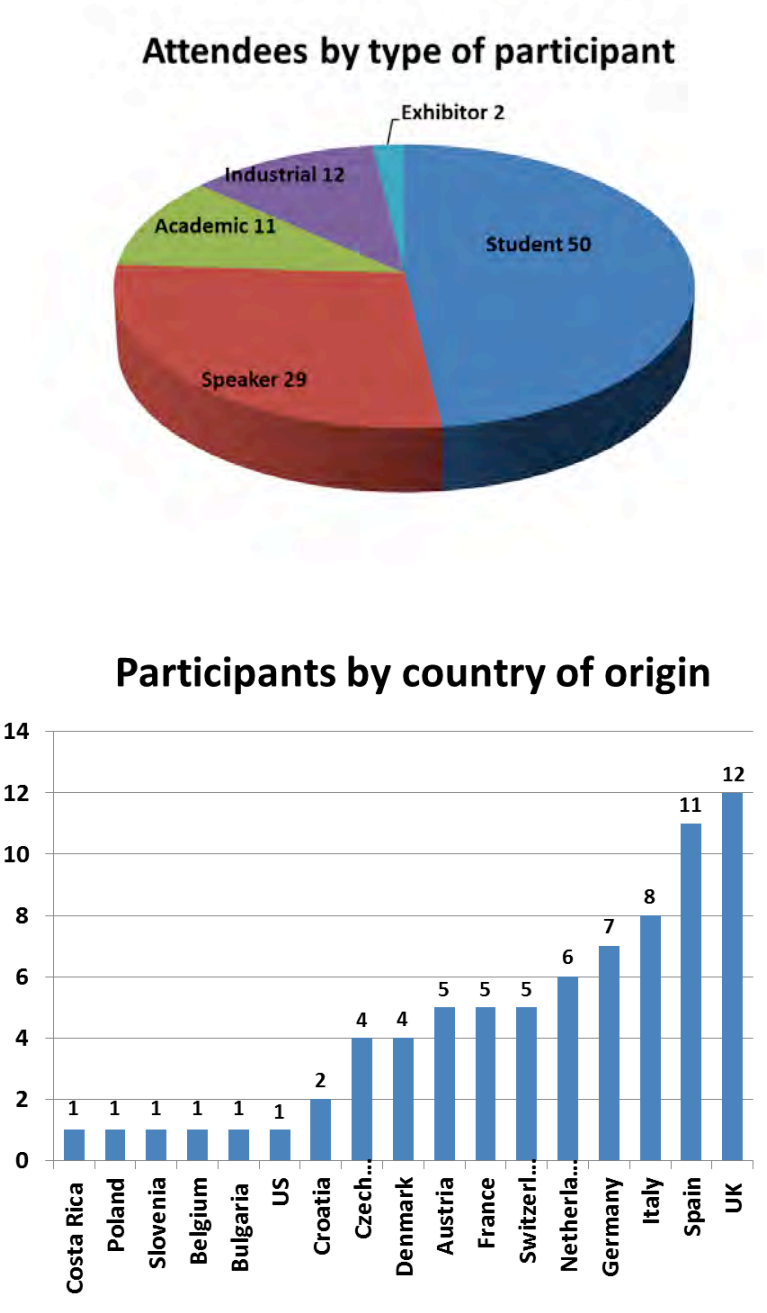


Figure 1. Top: Distribution of the type of participants in the ISC2018; Down: Number of participants in the ISC2018 by country of origin, excluding speakers (17 different countries).

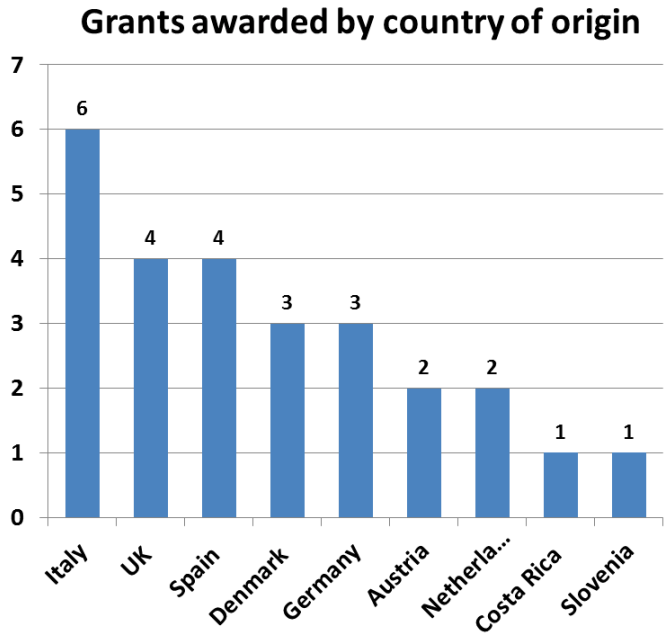


Figure 2. Country of origin of the students that received a grant to attend ISC2018.

A considerable effort was made to provide financial support to as many students as possible. In fact, all grant applications were accepted for funding (Figure 2). Remarkably, most of the granted students were coming from outside Spain (22, accounting for 84.6 % of all the granted students).

Programme of ISC2018

ISC2018 covered five days of lectures and practical demonstrations carried by 29 selected experts in fields directly related to crystallisation.

Main topics of ISC2018

- Solution properties.
- Nucleation: classical and non-classical approaches.
- Crystal growth kinetics and mechanisms.
- Crystallization routes.
- Crystallization techniques.
- Crystal morphology.
- Mineral textures.
- Polymorphism.

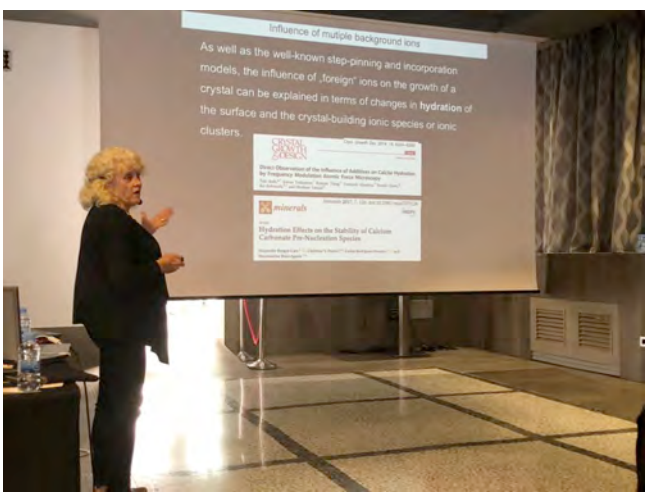
- Hydrates and solvates.
- Crystallization screening.
- Industrial (mass) crystallization.
- Crystallization in microfluidics.
- Chirality.
- Biomineralization.
- Mesocrystals.
- Nanocrystals.
- Co-crystals.

List of Speakers during ISC2018

- **Alain Ibanez,** Institut NEEL, CNRS/UJF, France.
- **Alejandro Rodríguez Navarro**, University of Granada, Spain.
- **Andrew Putnis**, University of Munster, Germany.
- **Bart Kahr**, NYU, USA.
- **Carlos Rodríguez Navarro**, University of Granada, Spain.
- **Christine Putnis**, University of Munster, Germany.
- **Denis Gebauer**, University of Konstanz, Germany.
- **Dierk Wieckhusen**, Novartis Pharma, Switzerland.
- **Fermin Otálora**, CSIC-University of Granada, Spain.
- **Gan Zhang**, Weizmann Institute, Israel.
- **Giuseppe Falini**, University of Bologna, Italy.
- **Heike Lorenz**, Max Planck Institute, Germany.
- **Helmut Cölfen**, University of Konstanz, Germany.
- **Isaac Rodríguez Ruiz**, CEA Marcule, France.
- **Jordi Benet-Buchholz**, ICIQ, Spain.
- **Joel Bernstein**, NYU, Abu Dhabi.
- **Jaime Gómez Morales**, CSIC-University of Granada, Spain.
- **Jim de Yoreo**, Pacific Northwest National Laboratory, US.
- **Juan Manuel García-Ruiz**, CSIC-University of Granada, Spain.
- **Jurg Hulliger**, University of Bern, Switzerland.
- **Lia Addadi**, Weizmann Institute of Science, Israel.

- **Lourdes Fernández**, Universidad Complutense Madrid, Spain.
- **Marc McKee**, McGill University, Canada.
- **Michael Zaworotko**, University of Limerick, Ireland.
- **Mike Ward**, NYU, USA.
- **Ulrich Griesser**, University of Insbruck, Austria.
- **Zoltan Nagy**, Purdue University, USA.

The first day of the School dealt with the fundamentals of crystallisation from solution encompassing a revision structure and properties of crystallizing solutions, nucleation theories, crystal growth kinetics and mechanisms, morphology and structural defects (Figure 3).



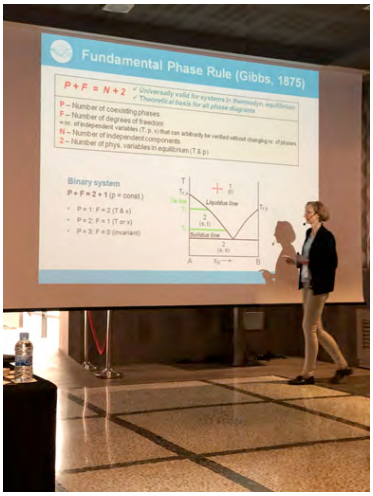


Figure 3. Left) "Nanoscale imagen of crystal growth using AFM", talk given by Dr. Christine Putnis. Right) Prof. Heike Lorenz talking about Solutions, solutions equilibria and solubility.

The second day of the School focused on both classical and novel crystallization techniques including solution *vs* gel growth, crystallization from melts and crystallization in microfluidic systems. There were also lectures on hollow crystals, mesocrystals and nanocrystallization (Figure 4).

Figure 4. Left) Dr. Zoltan Nagy giving an overview on new directions on crystallization control. Rigth) Dierk Wieckhusen talking about development of robust pharmaceutical crystallization processes.

On Wednesday there were two markedly different sessions on special topics. While the morning session was devoted to discuss the fundamentals of polymorphism, cocrystallization and chiral crystallization, the afternoon was dedicated to biological crystallization (Figure 5). The afternoon was dedicated to biological crystallization (Figure 6). In the evening, there was a special talk given by Prof. Juan Manuel Garcia-Ruiz on the symmetry of the Alhambra prior to the night visit to the Alhambra palaces.

Figure 5. left) Prof. Bart Kahr talking about chiral crystals; right) Prof. Joel Bernstein talking about facts and fictions on polymorphism.

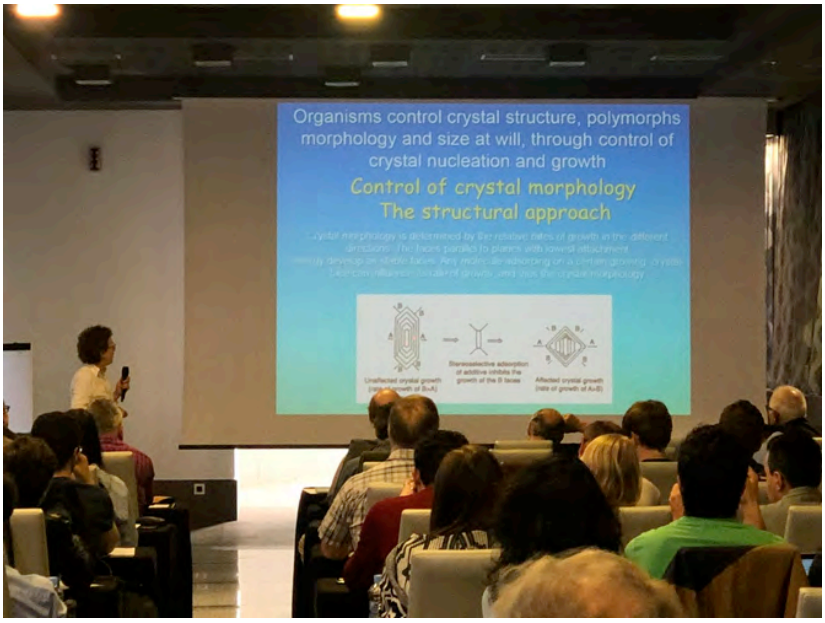


Figure 6. Prof. Lia Addadi talking about polymorphism in biological environments.

Thursday was entirely dedicated to a 'Demonstrations Fair', at which 18 specialists offered short (20-40 minutes) practical sessions periodically at scheduled times. Participants could 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 Demonstrations' Fair proved to be an excellent teaching tool as it provided students with plenty of opportunities to interact on a personal basis with tutors and to watch closely how to perform crystallisation experiments (Figure 7).

Figure 7. Demonstrations Fair: Left) Dr. Jürg Hulliger explaining "crystal growth equipment for controlled growth from solution: temperature difference and evaporation technique". Rigth) Helmut Cölfen and Denis Gebauer explaining how to analyse prenucleation cluster and synthesize mesocrystals.

On the last day there were lectures on special hot topics, including crystal engineering of task-specific materials, mineral assembly and analysis of the structural organization of mineralized tissues. In addition, it took place a round table on "Classical *vs* non-classical nucleation", one of the most debated topics in crystallization nowadays. The round table was moderated by Lourdes Fernández Díaz and counted with specialists such as Helmut Cölfen, Denis Gebauer, Jim de Yoreo and Christine Putnis and Guisseppe Falini (Figure 8). The School was closed with the presentation of prizes offered by the International Union of Crystallography and the Crystallization Factory of la Laboratory of Crystallographic Studies.

Figure 8. Round table discussion on Classical Nucleation *vs* Non-Classical Nucleation with Prof. Jim de Yoreo, Dr. Denis Gebauer, Prof. Christine Putnis and Prof. Giusseppe Falini.

Poster Sessions

Poster sessions rounded out each of the days and proved to be a very valuable time in order to discuss the scientific work. Students made a great contribution by presenting 44 posters (Figure 9). Student teams from the Netherlands, Italy, Germany, Austria and UK were honoured by an international panel of lecturers, who decided to award 5 prizes for the best poster presentations (Table 1, Figure 10). Two prizes were given by the IUCr (the books "A Little Dictionary of Crystallography" and "Symmetry Aspects of M.C. Escher's Periodic Drawings") and three prizes by The Crystallization Factory (the

documentary of The Mystery of the Giant Crystals and 2 books of the exhibition "CRISTALES": A World to Discover).

Table 1. List of students awarded with a prize for their poster presentation.

Granada ISC2018 Poster Prizes			
Prize	**Beneficiary**	**Affiliation**	**Country**
IUCr	Mr. Hans Hendrikse	AMOLF	Netherlands
IUCr	Ms. Francesca Carella	Istec-CNR	Italy
La Factoria	Mr. Panayiotis Klitou	University of Leeds	UK
La Factoria	Ms. Cristina Ruiz-Agudo	University of Konstanz	Germany
La Factoria	Mr. Fabian Kurzeman	University of Innsbruck	Austria

Figure 9. The poster sessions were dynamic and very lively.

Figure 10. Students receiving their poster prizes. Mr. Hans Hendrikse (IUCr prize), Ms. Francesca Carella (IUCr prize), Mr. Panayiotis Klitou (La Factoria prize), Ms. Cristina Ruiz-Agudo (La Factoria prize), Mr. Fabian Kurzeman (La Factoria prize, collected by Pr. Ulrich Griesser).

Social events

In addition to the scientific course, there was a parallel social programme which consisted of a welcome cocktail on Sunday (Figure 11), a night tour to the Nazaries palaces of The Alhambra on Wednesday (Figure 12) and a Flamenco dinner party on Thursday in the Carmen de la Victoria of the Albayzin district (Figure 13).

Figure 11. A group of students and teachers during the welcome reception on Sunday 20th May.

Figure 12. A group of students and teachers inside the Alhambra Palaces.

Figure 13. The Flamenco dinner took place at Carmen de la Victoria, including the performance of a flamenco dancing group.

Evaluation

Overall, the School was deemed to be very successful as judged by the majority of positive comments written in the evaluation form by the participants. The attendees were asked about three major items: the quality of the scientific programme, the demonstrations Fair, and the organisation (see Figure 14).

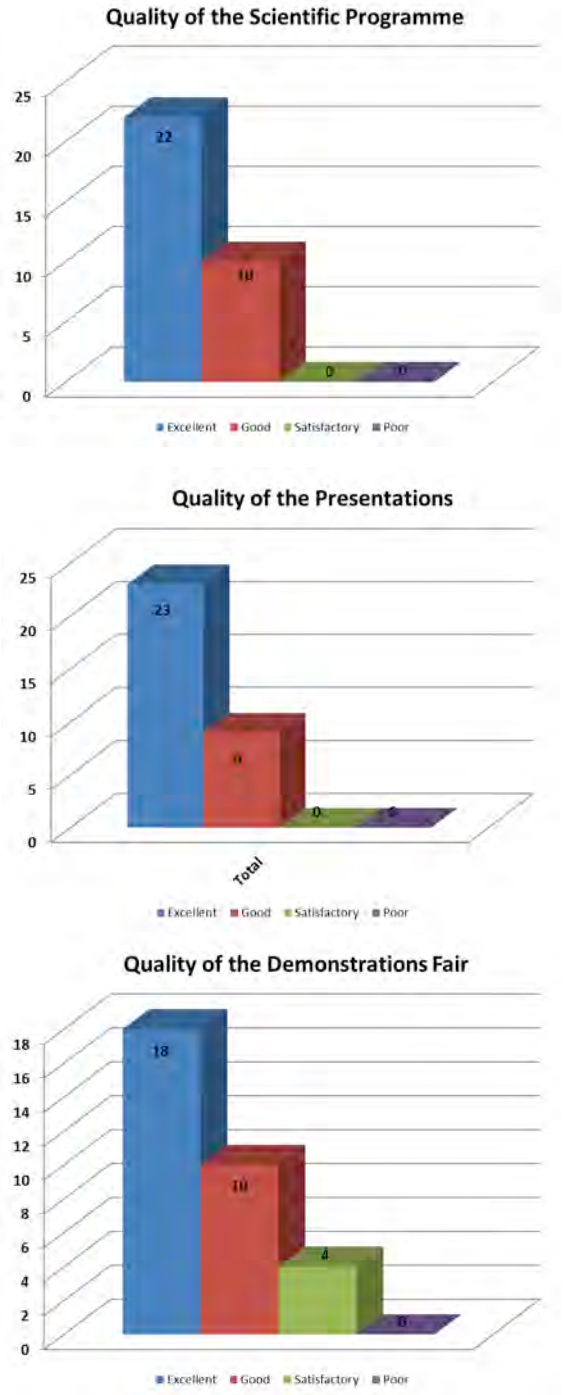


Figure 14. Top: Opinion of the delegates about the quality of the scientific programme; Middle: Opinion of the delegates about the quality of the presentations fair; Bottom: Opinion of the delegates about the quality of the demonstrations fair.

Conclusions

According to the evaluation forms, the school was considered very valuable by the participants, 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 ISC2018 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 Crystallisation 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 gratitude to the Sponsors and Exhibitors for their great support.