Astrophysical Origins: Pathways from Star Formation to Habitable Planets

Report to Europlanet

Proposing and Organizing Team:

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1. Description of Event

The program summarized here on the topic of **Astrophysical Origins: Pathways from Star Formation to Habitable Planets** was organized at the Erwin Schrödinger International Institute for Mathematics and Physics (ESI), a program-oriented research institute of the University of Vienna. ESI organizes various types of collaborative and discussion-led meetings; these range from lectures and seminars to workshops and to the largest category of "thematic programs". In 2017 we applied for a thematic program at ESI with the above title: "Astrophysical Origins: Pathways from Star Formation to Habitable Planets." The ESI "thematic programmes" are meant to bring together a large number of researchers to exchange views, participate in brainstorming sessions, initiate collaborations and/or work on publications or proposals during an extended period of time (usually several weeks). The structure of such a thematic program is left to the organizers and is maximally free, typically involving some presentation sessions and workshops, but primarily driven towards free discussions, exchange of ideas, and networking.

Our program was designed as an interdisciplinary meeting bringing together astrophysicists, geologists, atmospheric scientists, (astro-)chemists and biologists to discuss the potential places of origin of life in the universe, the emergence of habitability on planets, and the conditions that lead to such environments. Given the breadth of this topic we aimed to make the program, and the resulting list of attendees, as inclusive as possible. This scientific topic is one of the most attractive in the area of astrophysics and planetary sciences, fostered enormously by the detection of thousands of exoplanets, but also by rapid progress in the research of solar-system planets, their geology and their atmospheric evolution. The search for life, and the community's attempts to gain a better understanding of how life originated on Earth inspired us to cast a wide net when it came to the disciplines of the invited researchers. Only by successfully combining astrophysics, planetary science, (pre-biotic) chemistry and biology do we stand a chance to make progress solving this difficult problem.

This event was supported by ESI itself with 57,000 EUR awarded to us after a competitive project proposal round in 2017. This source covered exclusively the per diems (80 EUR per night) for the invited participants and two conference dinners. We applied for a Europlanet supplement of 9000 EUR for additional guests and activities, which was granted on 11 September 2018.

2. Goals

The program had the following goals:

- Bring together international scientists from many fields, nationalities and institutes to discuss an interdisciplinary approach to the question of habitability on Earth, other planets, and the conditions leading to such environments.
- Discuss astrophysical factors that determine the fate of planetary atmospheric evolution. These include stellar magnetic fields, winds, and radiation.
- Study the planetary interiors, their interaction with planetary surfaces and atmospheres, and the feedback between atmospheres and interiors such as outgassing processes.

- Discuss the chemistry from the protoplanetary disk stage to atmospheres and the early stages of life to understand its role and its preconditions in protoplanetary disks and planetary atmospheres.

3. Activities

The program was set up with the interactive proposals from the participants themselves. Before the event participants were asked to contribute ideas, plans and wishes, and were further asked to potentially give tutorial lectures about their fields that would serve as the basis for interdisciplinary discussions. The program was also structured on the spot by the participants; each week's program was put together the week before, after consulting with the participants about their plans and proposals for presentations. Several afternoons were left free for ad-hoc meetings between the entire team or any subteams, most of which were duly attended.

The program lasted for seven weeks between June 17 and August 2, 2019. In total it included 46 participants from abroad, plus a further 18 participants from Austria. Teams changed by the week, participants typically staying for 1-2 weeks, with some staying as long as 3-4 weeks (which were partially self-funded). Each week thus saw a new team composed of scientists from different but overlapping disciplines.

4. Experience and Results

The event that we hosted at ESI developed into a great success. The scheme that established itself was a daily schedule starting with a ~1.5 hour introductory/educational lecture by one participant, typically lasting from 10:00 to 11:30, with full interactive discussions in the audience. These lectures usually gave rise to additional team discussions for up to one more hour, in cases even covering the entire afternoon until 17:00. On many days, a second lecture was given by another researcher from 14:00-15:30, which would proceed in a similar manner. Some afternoons were left free for smaller group discussions, for opportunities to develop new ideas and collaborations.

We heard from many participants that they were excited by the program and the possibility to develop interdisciplinary discussions and plans. Several specific plans developed; the list below is necessarily incomplete because numerous smaller group interactions may have developed further plans. Among the most significant ones were:

- Plans to write large review articles on interdisciplinary topics that emerged from this program; specifically, we are discussing a series of papers in Space Science Reviews; the organizers are reviewing which topics were extensively discussed and would be appropriate for such reviews. One was identified already to be the conditions toward habitable planets around M dwarfs given these stars' very different evolutionary timescales and their different magnetic activity behavior compared to solar-type stars.
- Plans to continue these meetings in some ways every couple of years, at different places but involving potentially a similar audience. A possible place could be the the Munich Institute for Astro- and Particle Physics (MIAPP) that holds a planetary workshop of a similar kind in June 2020.

- Specific team efforts toward collaborations. We have heard of several initiatives that may materialize in the coming months, to carry out research projects now developed at ESI.

5. Specific highlights

Apart from many excellent presentations and discussions, a couple of special highlights should be mentioned. We had Dr. Daniel Whalen from the University of Portsmouth, presently guest professor at the University of Vienna, as a special guest from an area outside of the program, namely cosmology, teaching us about the first stars and their supernovae. This presentation led to surprising insights into the first possible synthesis of water, rocky material and therefore the first possible habitable planets in the Universe. Prof. Whalen is now preparing an ERC grant proposal partly including these aspects.

We also had a high-school student (age 17 years) participating during four weeks. He engaged in this effort to fulfil the requirement of a month of practical training outside of his school (a “Ferialpraktikum”). His tasks were, i) to follow the talks, try to understand and discuss with the participants; ii) conduct some numerical simulations of planetary atmospheric chemistry and dynamics supervised by a local expert and ESI participant; and iii) write a short report. He performed all these duties in an excellent manner and got sufficiently interested to already register for another month of practical work with the Vienna organizing group in summer 2020.

6. Social program

We installed a moderate social program in various weeks:

- A conference dinner in a typical, local Austrian restaurant in weeks 3, 4, 5, 6, 7. The first two were financially supported by ESI, for the other three we request financial support from Europlanet.
- A visit to the historical university observatory (now hosting the Department of Astrophysics) in the first week.
- A visit to the Vienna Natural History Museum with its large meteorite collection, introduced by its director, Prof. Christian Köberl, a collaborator of the organizing team, in week 4 (10 July).

7. Documentation

The meeting has been documented in the following ways:

- A private Google document was set up and made accessible to the participants to summarize the ongoing presentations and add further thoughts.
- A meeting web page, also providing access to the PDF or PPT files presented during the meeting. The address is https://www.univie.ac.at/HabitabilityESI/
- A couple of participants tweeted ongoing discussions after consent with the participants.

8. Europlanet budget

We invested the Europlanet budget as follows (see attached invoice):

- Paying for three conference dinners in different weeks, which were very appreciated by the participants as a further way to meet and discuss. Two more dinners were paid by ESI.
- Paying for the airfare for the two external organizers of this event, Dr. R. Brasser from Tokyo and Prof. S. Mojzsis from Boulder, USA.
- Paying for the airfare of a special collaborator of the Vienna ESI team, in need of support and who participated significantly in the ESI event (Prof. O. Kochukhov).
- Paying an honorary fee to the web page developer, a masters student who also participated in the meeting and helped on the organizational side.
- A modest “salary” for the high school student. He was fulfilling his tasks excellently and his interest in the topic was even further raised by this meeting. As many of his classmates would go for a one-month training in private industry and be compensated for their work, we find it appropriate to provide him analogous support. He is clearly a student who may follow a career in our fields, and we consider having attracted his interest a special outcome of this program.

9. Summary and Conclusions

The ESI program co-supported by Europlanet has raised the bar for a novel type of interdisciplinary discussions on planetary habitability and the large number of conditions leading to such environments. It has a lasting impact among the participants and has already led or will lead to novel, interdisciplinary collaborations; further meetings of this calibre are already being planned.

10. A few impressions

The following pictures give some impressions of the program setting for the lectures and discussions.

Office space for the participants

Group picture, week 7.

The lecture hall

The discussion and social room

List of participants

First Name & Surname	m/f	early career	Amateur	Europe, Russia	US/Asia/Latin America
Peter Abraham	m			y	
Vladimir Airapetian	m				y
Vitaly Akimkin	m			y	
Amanda Alexander	f	y			y
Igor Alexeev	m			y	
Michael Bartel	m	y		y	
Dmitry Bisikalo	m			y	
Bertram Bitsch	m			y	
Sudeshna Boro Saikia	f	y		y	
Ramon Brasser ORGANIZER	m				y
James Cadman	m	y		y	
Ofer Cohen	m				y
Luciano Darriba	m	y			y
Odysseas Dionatos	m			y	
Vera Dobos	f	y		y	
Caroline Dorn	f	y		y	
Rudolf Dvorak	m			y	
Georg Feulner	m			y	
Mareike Godolt	f	y		y	
Lee Grenfell	m			y	
Rodrigo Guadarrama	m	y		y	
Manuel Güdel ORGANIZER	m			y	
Anneliese Haika	f		y	y	
Nader Haghighipour	m				y
Carina Heinreichsberger	f	y		y	
Christiane Helling	f			y	
Alison Hunt	f	y		y	
Gaitee Hussain	f			y	
Meng Jin	m				y
Colin Johnstone	m	y		y	
Evgenya Kalinicheva Sergeevna	f	y		y	
Esa Kallio	m			y	
Inga Kamp	f			y	
Akos Kereszturi	m			y	

Maxim Khodachenko	m			y	
Kristina Kislyakova	f	y		y	
Christian Koeberl	m			y	
Oleg Kochukhov	m			y	
Jeffrey Linsky	m				y
Theresa Lüftinger **ORGANIZER**	f			y	
Soko Matsumura	f			y	
Yanina Metodieva	f	y		y	
Stephen Mojzsis **ORGANIZER**	m				y
Karan Molaverdikhani	m	y		y	
Sergei Nayakshin	m			y	
Athanasia Nikolaou	f	y		y	
Lena Noack	f	y		y	
Rachel Osten	f				y
Susanne Pfalzner	f			y	
Christian Rab	m	y		y	
Sudha Rajamani	f				y
Ken Rice	m			y	
Sopie Alma Schallert	f	y		y	
Marianne Schmid	f	y		y	
Maria Schönbächler	f			y	
Ildar Shaikhislamov	m			y	
Simon Scheer	m	y	y (high school)	y	
Denis Shulyak	m			y	
Sami Solanki	m			y	
Eduard Vorobyov	m			y	
Sara Vulpius	f	y		y	
Cornelia Weber	f	y		y	
Peter Woitke	m			y	
Brian Wood	m			y	

Statistics:

Total number of participants:	64	
Participants from inclusiveness states:	2	(Abraham, Dobos from HU)
Female participants:	26	
Male participants:	38	
Early-career scientists:	24	
Amateur participants:	2	(Scheer, high-school student; Haika, teacher, amateur astronomer)
European participants (incl. Russia):	53	
Participants from outside Europe:	11	