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The ESO Summer Research Programme 2020 and 2021

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The ESO summer research programme, a great success when it was first held in 2019, is now a regular event in the ESO calendar. Because of the restrictions resulting from the global pandemic, the second and third programmes were held in a virtual format without hosting the participating students in Garching. Nonetheless, both programmes attracted over 400 applicants from over 50 countries. In 2020 and 2021, 11 successful students (at BSc and MSc level) were invited to carry out scientific projects under the supervision of ESO Fellows and staff members for six weeks between July and August. The students carried out research in different fields of astronomy, from galactic structures to stellar evolution and planetary formation.

Motivation and organisation

Many top-class international universities and research institutes offer summer programmes to give undergraduate students their first taste of a research environment and an opportunity to enrich their CVs. The ESO summer research programme was born out of the ESO Fellows' desire to host a similar initiative in Garching, establishing a new way for ESO to interact with the community and allowing the Fellows to gain some experience of supervising students. The first programme, in 2019, proved to be a hit, with highly positive feedback from the students and the ESO Fellows and staff involved. In the wake of this success, the Director for Science made available funding to make the ESO summer research programme a yearly event, triggering the organisation of the second and third programmes. This involved booking ESO apartments and office space, setting up the website, organising the application process and selecting students, planning lecture series and, most importantly, designing and leading the research projects.

The response from the community was incredible. More than 400 valid applications were received in 2020 and 2021 from university students from 54 countries (Figure 1). Participants were selected by first distributing the applications amongst all potential supervisors for an initial ranking, followed by a final selection by an internal committee of Fellows. The final lists of six students (for each programme) were agreed upon to achieve the best possible gender balance and to prioritise applicants from ESO member states, our host country Chile, and ESO's strategic partner, Australia. Each selected student was then interviewed before a formal offer of a place on the programme was made. However, the chaotic events which affected the world over the past two years significantly impacted the plans for the summer research programme. The second programme in 2020 was initially advertised as being held in person at Garching, but with the sudden evolution of the global pandemic, it became necessary to move the programme entirely online. As a result, one of the selected students unfortunately had to decline the offer to attend because of incompatible timezones. The 2020 programme went forward with five projects and five students attending remotely.

The third programme, in 2021, was launched from the start as an online event, and all applicants were made aware that all activities would take place during core work hours in central European time. For both of the virtual programmes, the successful applicants were offered the opportunity to make a two-week visit to ESO in the following year if the global situation allowed it. Unfortunately, the restrictions have not yet allowed the students to travel to Garching safely.

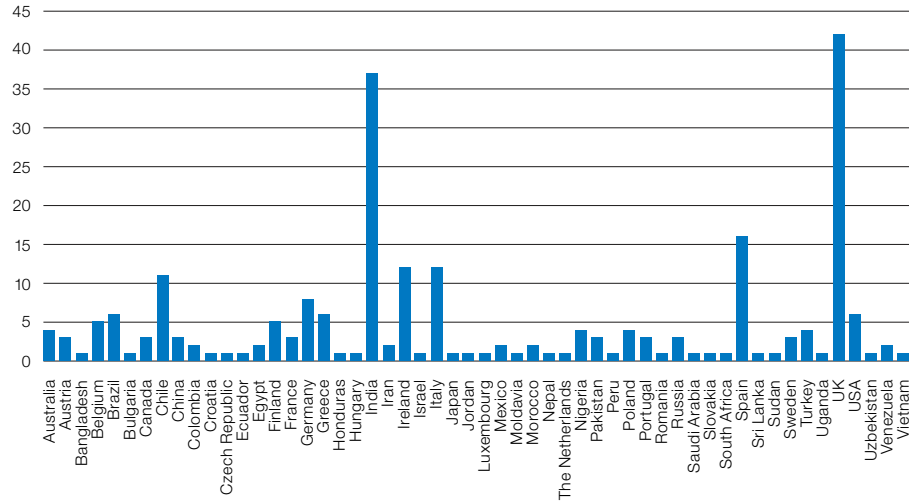

Figure 1. Number of applications per country received for the third ESRP in 2021.

Programme overview

Despite the apparent limitations of a virtual format, the second and third programmes each still had a vibrant and varied schedule. Events began with an introduction workshop, open to all ESO staff, in which the Director General welcomed the students and introduced ESO as an organisation (Figure 2). The project advisors then presented their projects, and the students were given a chance to introduce themselves. During the six weeks of the programme, most of the activities were carried out on the Microsoft Teams platform, with specific channels for each project and for specific events. While working on their research projects, under the supervision of one or more ESO Fellows, the students also attended a series of lectures spanning various astronomical topics, from instrumentation to black holes and exoplanets, given by ESO Fellows and staff members.

All students were also invited to attend the regular scientific activities of ESO (all happening online), including talks, science coffees, and informal meetings. The final event of each programme was a concluding workshop where each stu-

dent gave a 15-minute presentation of their work in front of all ESO staff in attendance. The events in 2020 and 2021 were very well attended by ESO personnel and showcased the incredible science that the students achieved during this relatively short programme (Figure 3).

Students and their research projects

Second programme: July–August 2020

Probing the atmospheres of outer worlds: transmission spectroscopy of exoplanets

Advisors: Paulo Miles-Páez & Henri Boffin
Student: Yared Reinarz (Universidad Católica del Norte, Chile)
In this project, the student embarked on the analysis of time-resolved spectroscopic data of hot Jupiters while transiting their host star. The spectra were obtained with one of the best instruments on ESO's Very Large Telescope (VLT), the FOcal Reducer and low-dispersion Spectrograph 2 (FORS2). This project looked at how the transit depth of the planet changes as a function of wavelength and thereby probes the presence of atoms and molecules, or even clouds, in the planet's atmosphere. By comparing the results obtained for several hot Jupiters, it is possible to look for correlations and to put constraints on the place where a planet formed and how it moved.

Searching for intermediate-mass black holes

Advisors: Marianne Heida & George Lansbury
Student: Zofia Kaczmarek (University of Warsaw, Poland)
This student analysed broadband optical spectra of a large sample of candidate hyperluminous X-ray sources (HLX) obtained with the Double Spectrograph on the 200-inch Hale Telescope at Palomar Observatory. Identifying the visible emission lines in the spectra allowed the determination of the redshifts of the HLX candidates. By comparing these with the redshifts of nearby galaxies the student was able to classify each source as either a bona fide HLX — possibly hosting an intermediate-mass black hole — or a foreground or background source.

Not going out quietly: variability in dying stars

Advisors: Nicola Gentile Fusillo, Anna Pala & Tommaso Marchetti
Student: Alina Vorontseva (University of Tartu, Estonia)
This project focused on large-scale data mining and combining different datasets to discover variable white dwarfs amongst the objects identified by the Gaia spacecraft. The student explored in detail the most promising candidates and attempted to uncover the origin of the observed variability though simple modelling and comparison with known objects. The student learned how to handle large datasets and utilise photometric observations from a vast array of surveys. They developed novel numerical methods to assess stellar variability and familiarised themselves with the principle of time-resolved observations as well as the basic physics of white dwarfs, both isolated and in binaries.

Comparing ground- and satellite-based climate data for atmospheric studies of astronomical relevance

Advisors: Tony Mroczkowski & Carlos de Breuck
Student: Pablo Gómez Toribio (Universitat Politècnica de Catalunya, Spain)
Atmospheric transmission is one of the most important factors in characterising a site for millimetre and submillimetre astronomy. This project focused on the study of recent, high-resolution satellite data on the climate and compared the data to those from weather stations at the Atacama Pathfinder EXperiment (APEX) and Atacama Large Millimeter/submillimeter Array (ALMA) sites. The student analysed new data from satellites monitoring the Earth to characterise

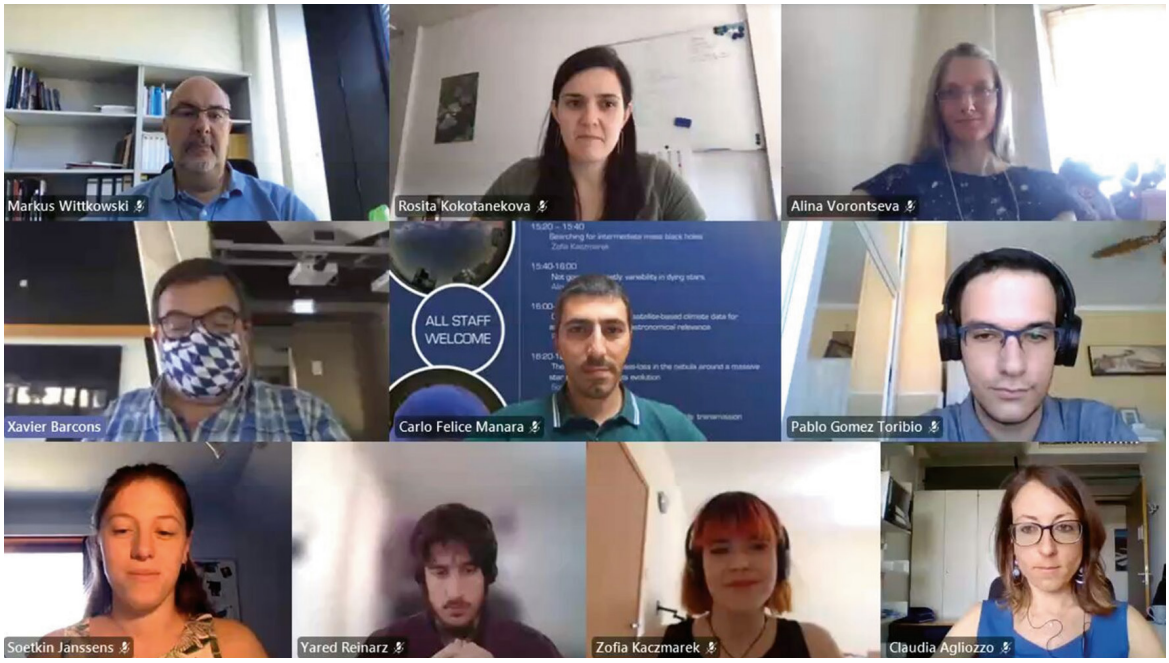

Figure 2. Screenshot taken during the welcome workshop of the second ESRP in 2020.

Figure 3. Screenshot taken during the closing workshop of the third ESRP in 2021.

the Total Precipitable Water (TPW) at 1–2 kilometres resolution and compared their measurements to weather station data from APEX and ALMA.

The fingerprints of mass-loss in the nebula around a massive star near the end of its evolution
Advisors: Claudia Agliozzo & Neil Phillips
Student: Soetkin Janssens (Katholieke Universiteit Leuven, Belgium)
This project aimed to estimate the nebular mass around a massive star near the end of its life, by evaluating different emitting components using ALMA submillimetre continuum and spectroscopic data. The student analysed integral-field-unit spectroscopic data to infer the geometry of the nebula, and thus the mass-loss mechanism, from the radial velocities of the brightest optical emission lines. These results were compared with the large mass-loss estimated from modelling of the star, and thus allowed the evolutionary state of this star to be determined. The student analysed and modelled different astrophysical emission mechanisms observed in gaseous nebulae, and learned how to derive meaningful astrophysical quantities from these. They gained familiarity with multiwavelength data from different telescopes and instruments, and learned to adopt a multiwavelength approach.

Third programme: July–August 2021

Spiral arms as drivers of chemical enrichment in galaxies
Advisors: Laura Sánchez-Menguiano & Dimitri Gadotti
Student: Anna Lena Schaible (University of Stuttgart, Germany)
In this project, the student performed a thorough analysis of the gas metallicity distribution in the galaxy NGC 4981 searching for enrichment patterns linked to its spiral structure. The student worked with high-resolution observations (part of the Time Inference with MUSE in Extragalactic Rings [TIMER] project) collected with the powerful Multi Unit Spectroscopic Explorer (MUSE) instrument mounted on the VLT. The student gained valuable experience of analysing optical spectroscopic data, performing tasks such as fitting spectra to derive the gas emission and chemical abundances, and tracing spiral arms, all aiming to answer the question of whether spiral arms are more metal-rich than the underlying galaxy disc.

Go with the flow: probing the flows and fate of gas in barred spiral galaxies
Advisors: Francesca Fragkoudi, Eric Emsellem & Adrian Bittner
Student: Rodrigo Ferrer Chávez (Autonomous University of Yucatán, Mexico)
In this project the student explored state-of-the-art numerical simulations of gas flow in barred spiral galaxies, to map a multi-dimensional view of these processes. Some of the questions the student tackled with these simulations were: i) how gas flowing into the central regions of barred galaxies builds up nuclear discs and rings; ii) what the properties of these structures are; and iii) how much of the gas is able to reach deep into the centre of the galaxy to where the supermassive black hole resides. The student also had a chance to compare these simulations with observational data of spiral galaxies taken with MUSE on the VLT.

From birth to death: the multiple faces of accretion
Advisors: Anna Pala, Carlo Manara & Nicola Gentile Fusillo
Student: Anirudh Ravishankar (Indian Institute of Science Education and Research, India)
In this project, the student investigated different accreting systems, particularly young stellar objects and accreting white dwarfs. By combining the exquisite spectroscopy obtained with the VLT and accurate photometry from the ESA Gaia space mission, the student learned to identify these two classes of objects from their fundamental observational properties. Furthermore, they used the data provided to unveil the detailed structure of the flowing material, seeing almost in real time how matter is accreted onto two different types of system, one at the start and one at end of stellar evolution. With this work the student gained insight into the physics of the accretion process and a broad understanding of the ongoing quest for a unified accretion theory.

The mysterious [CII] emission in the interstellar medium of galaxies
Advisors: Michele Ginolfi, Gergö Popping & Paola Andreani
Student: Louise Kluge (Heidelberg University, Germany)
This project aimed to compile the largest dataset of [CII] observations, at any cosmic time and for any type of galaxy, by combining existing samples with new/archival ALMA data. The student explored the redshift evolution of the [CII]-based empirical relations and used statistical methods to study their dependencies on other properties and physical quantities, such as galaxy class, stellar mass and, when possible, metallicity, dust mass and molecular gas fraction. The results obtained represent valuable information on the origin of [CII] and its link to galaxy properties, and can serve as a benchmark for modelling the physics of the interstellar medium. The student also gained valuable experience of mining the ALMA archive, handling ALMA data, and using statistical tools, as well as learning about interstellar medium physics and galaxy evolution.

Probing the building blocks of planets with ALMA
Advisors: Łukasz Tychoniec, Maria Koutoulaki & Leonardo Testi
Student: Paulina Palma (University of Chile, Chile)
This project aimed to shed light on how, when and where interstellar dust starts to stick together to form the seeds of planets. The student tackled the project by analysing ALMA data, both archival and from new observations. The student acquired valuable skills associated with the calibration, imaging, and modelling of the ALMA data and learned to extract key astrophysical results from them. The student gained a deeper understanding of interferometric techniques, which are key to the study of stars and planets in the making. In addition to acquiring these critical practical skills and valuable experience with state-of-the-art data, the student also had the opportunity to broaden their knowledge on a variety of topics covering astrophysics and astrochemistry.

Measuring IMF in high density stellar systems, i.e. relic galaxies and globular clusters
Advisors: Magda Arnaboldi, Lodo Coccato, Chiara Spiniello (Oxford) & Carlos Barbosa (University of San Paulo)
Student: Natalie Grasser (University of Vienna, Austria)
This project focused on determining the stellar initial mass function (IMF) in relic galaxies and in globular clusters (GC). The student carried out full spectral fitting of optical and near-infrared high-signal-to-noise spectra to determine the IMF slope and other stellar population parameters (age, total metallicity, [alpha/Fe]) for GCs and relics, using state-of-the-art single stellar population models. They then compared the IMF slope to the other stellar parameters, with the aim of assessing any relations or dependencies. With the inclusion of GCs the student was able to probe these relations to much lower masses, lower velocity dispersions and lower metallicity values than had been done before. This work provided a valuable contribution towards establishing whether there is a mass (or better a luminosity) threshold at which the IMF change to bottom-heavy sets in.

Feedback and future programmes

An online form was set up to allow the participating students to provide feedback on the programme. Despite the difficulties and limitations of the virtual format (particularly in 2020), the student response was overwhelmingly positive. The students were also interviewed to capture their opinions more directly, and their responses were presented in the ESOblog in 2020[1] and 2021[2]. Their words highlight how much they enjoyed their research experience and valued their time with ESO.

The repeated success of the programme has not been overlooked by ESO's management. Funding for the fourth programme has already been secured, and its organisation is well under way. We hope this time to welcome our successful applicants in person.

Acknowledgements

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Links

[1] ESO blog "A summer of astronomy" 2020: https://www.eso.org/public/unitedkingdom/blog/summer-of-astronomy/
[2] ESO blog "A summer of astronomy" 2021: https://www.eso.org/public/blog/2021-summer-research-students/