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Jonathan Mackey

Jorick S. Vink

Nicole St-Louis

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COVER ILLUSTRATION:

Hubble Space Telescope image of the cluster of massive stars, Pismis 24, and part of the emission nebula NGC 6357 (Credit: NASA/ESA/Hubble and Jesús Maíz Apellániz) overlaid on an image of the Poul nabrone Dolmen in the West of Ireland

Credit: Steve Ford Elliott. Poster credit: Morgan Fraser, Sophie Murray.

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Chief Editor

JOSÉ MIGUEL RODRIGUEZ ESPINOSA, General Secretariat

Instituto de Astrofísica de Andalucía

Glorieta de la Astronomía s/n

18008 Granada

Spain

IAU-general.secretary@iap.fr

Editor

DIANA WORRALL, Assistant General Secretary

HH Wills Physics Laboratory

University of Bristol

Tyndall Avenue

Bristol

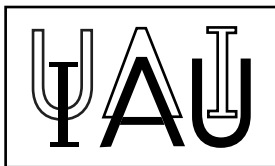
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IAU-assistant.general.secretary@iap.fr

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MASSIVE STARS NEAR AND FAR

PROCEEDINGS OF THE 361st SYMPOSIUM OF
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BALLYCONNELL, REPUBLIC OF IRELAND
8–13 MAY 2022

Edited by

JONATHAN MACKEY

Dublin Institute for Advanced Studies, Ireland

JORICK S. VINK

Armagh Observatory and Planetarium, Northern Ireland

and

NICOLE ST-LOUIS

Université de Montréal, Canada



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Preface to the Proceedings

The organisers of IAU Symposium 361, “Massive Stars Near and Far”, were delighted to finally welcome participants to Ireland from 8-13th May 2022. This was the first IAU Symposium hosted in Ireland since IAUS 230: “Populations of High-Energy Sources in Galaxies” in 2005, and followed a milestone event for the development of Astronomy research in Ireland: the accession of Ireland to the European Southern Observatory (ESO) in 2018. The conference was originally scheduled for May 2020 but was among the first wave of meetings that had to be postponed indefinitely following the outbreak and global spread of the COVID-19 pandemic in February and March 2020. At the time we couldn’t imagine that all of our lives would be so fundamentally changed in the intervening period, or that it would take so long just to reschedule an international conference! During this time the LOC had two PhD graduations, one retirement, babies born and many career paths changed.

The Symposium was the latest in the long-standing series of Massive Star conferences, taking place roughly every four years since the first one in 1971 in Buenos Aires, Argentina (IAU Symposium 49: “Wolf-Rayet and High-Temperature Stars”). The last meeting in this series was the very successful IAU Symposium 329 in Auckland, NZ in 2016, “The lives and death-throes of massive stars”. The Ireland meeting was originally to take place in Puerto Rico but, following the devastating hurricane that hit the island, the organisers realised it would be impossible to host the conference, and so a call went out in January 2018 from IAU Commission G2 for expressions of interest proposing a new venue. Once Ireland was selected as the host, we set up an all-island LOC including researchers from the Republic and Northern Ireland, and chose the Slieve Russell Hotel and Country Club, near the border in Ballyconnell, Co. Cavan, as the meeting hotel. The SOC was drawn from a diverse group of researchers from all over the world. Little did the LOC and SOC members expect that they would be serving for 4 years, through planning for two in-person meetings (the first one postponed) and one virtual preview meeting, including 3 calls for abstracts that had to be reviewed by the SOC. We are very grateful to the enthusiastic and committed members of the LOC and SOC, who remained engaged and contributed hugely to making the meetings a success.

The short-notice postponement of the conference in May 2020 was difficult for both organisers and participants as many costs had already been paid for or committed. We are grateful to the vast majority of participants for their support and patience as we refunded registration fees. As it became clear that the pandemic would continue for some time, we decided to host a Virtual Preview Meeting in the week of 3-7 May 2021, so that the early career researchers with invited and contributed talks could finally present their research to the community. This virtual meeting was a great success, regularly having 180-200 participants logged-on for the talks, with an archive of talks on a private youtube channel for those in timezones that prevented live participation. A standout memory is Dylan Kee giving his talk live from Hawaii in the small hours of the morning, and still being awake enough to ask questions to the other speakers in the session.

The organisers are grateful to the IAU for allowing us to schedule the in-person meeting for 8-13 May 2022 and renewing the travel grant offers, enabling 35 researchers from 19 countries to come to the meeting in-person who otherwise would not have had the resources to participate. In total we had 211 participants from 32 countries representing all continents except Antarctica. The meeting venue, the Slieve Russell Hotel in Ballyconnell, Co. Cavan, Ireland, is located in a rural setting with almost all participants staying at the meeting hotel, ensuring plenty of informal interaction during the week over meals and walking on the extensive grounds. The excellent conference facilities

helped with social distancing and ventilation - high ceilings and a room that holds over 500 allowed us to seat everyone classroom style with generous spacing between tables, and with a large space for posters at the back of the hall.

The Symposium brought together observational and theoretical astrophysicists to discuss all aspects of massive stars: their formation, evolution, demise as supernovae and GRBs, and (for the first time in this series of Massive Stars Symposia!) gravitational waves from mergers of stellar-remnant neutron stars and black holes. The special focus for this meeting was on massive stars in the Early Universe, how they were born, lived and died, how they compare with massive stars in our Galaxy, how we can observe them and their imprint on the cosmos, and what we can learn from very low-metallicity galaxies in the local Universe. The scientific sessions were:

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|--|---------------------------|
| 1. Observations of massive stars near and far | (Chair: Jorick Vink) |
| 2. Stellar Atmospheres and Winds | (Chair: Nicole St Louis) |
| 3. Physical Processes in Massive Stars | (Chair: Dany Vanbeveren) |
| 4. Stellar Multiplicity | (Chair: Alceste Bonanos) |
| 5. Stellar Structure and Evolution of Single Stars | (Chair: Paco Najarro) |
| 6. Cool Supergiants | (Chair: Lidia Oskinova) |
| 7. Unsteady Mass Loss | (Chair: Morgan Fraser) |
| 8. Wolf-Rayet Stars and Stellar Feedback | (Chair: Raman Prinja) |
| 9. Massive Star Formation Near and Far | (Chair: Asif Ud-Doula) |
| 10. Stellar End-Points and Gravitational Waves | (Chair: Heloise Stevance) |
| 11. Future Instrumentation and Facilities | (Chair: Jonathan Mackey) |

“Massive stars: Near & Far” offered the opportunity for researchers working on massive stars in the Local Universe to interact with those working on massive stars at cosmological distances. After an opening by Prof Langer on the key outstanding questions from the birth to death of massive stars, Paul Crowther discussed the HST UV Legacy Project ULLYSES that targets local massive stars in nearby low metallicity galaxies, such as the LMC and the SMC.

After this introduction to massive stars in the local Universe (“Near”), we moved up in redshift, where the rest-frame UV is shifted towards higher wavelengths. Allison Strom started her talk explaining the relevance of “Cosmic Noon” where star formation in the Universe peaked, and massive stars look very different from those nearby. The speakers on the remainder of the first day intermittently discussed observations Near & Far. The final discussion was very lively, as it became clear that the combination of projects such as ULLYSES and CLASSY will be critical for understanding the data from the first generations of massive stars with JWST (first results had not yet come out at the time of the meeting, although there was great excitement and anticipation among the community).

The second & third day focused on the physics and evolution of single & binary massive stars nearby. One highlight was the discovery of a huge Mega-Gauss interior magnetic field at the core-envelope boundary from asteroseismology, by Dominic Bowman and collaborators. It is clear that multi-dimensional simulations are helping to progress our understanding of stellar interiors and surface layers, and promise significant advances in this decade. For studying populations of massive stars and identifying unusual objects, new surveys producing huge quantities of data, together with machine learning and other analysis tools, are rapidly expanding our knowledge of stellar diversity.

On Thursday the focus shifted to the formation of massive stars, both locally and in the early Universe, including a very informative overview talk by Ralf Klessen on “The First Stars”. As if massive stars and very massive stars (VMS), with masses over 100 solar masses, are not sufficiently spectacular, the discussion moved on to the formation

and existence of supermassive stars of order 100,000 Solar masses, which seem to be required to explain the formation of supermassive black holes already at very early times in the Universe.

It is an exciting time for transient science, with new discoveries from ongoing surveys and new facilities coming online in the next few years. Strategies for dealing with the deluge of data so that they can be dealt with by humans was a recurring theme of the session on stellar end-points and gravitational waves on Thursday. On Friday morning Ana Gomez de Castro told us about the planned future UV observatories, a key waveband for observations of massive stars and currently covered only by HST.

The week ended, like the life of a massive star, but this time not as a supernova or direct collapse to a Black Hole but with a golf analogy by Alex de Koter. The Summary was both informative and entertaining and participants departed in good spirits with huge amounts of energy and new ideas, after talking to old and new colleagues and friends after a 2 year delay.

Despite the limitations imposed on us by COVID-19, we still were able to run some of our planned public engagement and education activities related to massive stars. Deirdre Kelleghan (artist, amateur astronomer and educator) visited 4 primary schools in the Cavan area on the 9th and 10th of May, talked to them about astronomy, stars, telescopes including JWST, and the beauty of our Universe through painting and drawings. The Armagh Observatory and Planetarium generously donated their mobile planetarium and staff time for school visits on the 11th of May, a fabulous experience for the students.

There were two conference excursions, one to the Marble Arch Caves and the Cuilcagh Lakelands UNESCO Global Geopark, and the other to the seaside surfing town of Bundoran on the Wild Atlantic Way. The organisers got great feedback on both tours. The weather had not been great for the first two days, and so everyone appreciated a fresh and windy outdoor afternoon with a good walk in the hills or along the coastal cliffs, and even (for the brave few) sea swimming and surfing lessons.

During and after the meeting we received a lot of mostly positive feedback, mainly about how great it was for people to finally meet up again in-person with colleagues and friends from around the world. The conference facilities of the Slieve Russell Hotel were excellent and many people expressed surprise and delight that the B&B room rates were so reasonable for such facilities. Despite the Covid-precautions we took, we could not escape it completely with so many participants from many different countries at different stages of the pandemic. Quite a few of the participants reported to have tested positive for COVID after the end of the conference; thankfully most people had mild symptoms and as far as we know all made a complete recovery. There is no doubt that the meeting benefited from the feel-good factor of people being at a face-to-face meeting for the first time in more than 2 years, and this was reflected in the overwhelmingly positive spirit pervading the discussions, questions and answers, and social interaction throughout the week. The secluded location with a large residential conference hotel also contributed to this.

It bears repeating that we are especially grateful to the long-serving SOC and LOC who in the end planned two in-person meetings and one virtual meeting, and to the Organising Committee of Commission G2 and divisions G, B and C who supported us. The SOC went through nearly 500 abstracts over the 3 years of their service for the original meeting, the virtual preview, and the rescheduled meeting. Significant in-kind support for administration and finances from the Dublin Institute for Advanced Studies (DIAS) is also greatly appreciated. Local organisation was a marathon team effort from researchers and students at DIAS, Armagh Observatory and Planetarium, University College Dublin, Maynooth University and Trinity College Dublin.

In the months since the meeting took place we have seen the first spectacular results from JWST, fully justifying the investment of time and resources that this observatory required, and surpassing the hopes and expectations of the community with new discoveries about massive stars in our Galaxy and at the highest redshifts. Similarly, the first results from ULLYSES and related surveys are out and are enabling new discoveries about the low-metallicity population of massive stars in the local Universe. With the new Gravitational Wave observing runs starting in mid-2023, it is an exciting time to be working in our field. We look forward with great anticipation to the next Massive Stars Symposium in a few years time, and wish the organisers a successful meeting.

The Editors: Jonathan Mackey, Jorick S. Vink, Nicole St-Louis

Editors of the Proceedings

- Jonathan Mackey (Dublin Institute for Advanced Studies, Ireland)
- Jorick S. Vink (Armagh Observatory and Planetarium, Northern Ireland)
- Nicole St-Louis (Université de Montréal, Canada)

Scientific Organising Committee

- | | |
|------------------------------|--|
| • Paula Benaglia | Instituto Argentino de Radioastronomía, Argentina |
| • Alceste Bonanos | National Observatory of Athens, Greece |
| • Alex Carciofi | Universidade de São Paulo, Brazil |
| • Sylvia Ekström | University of Geneva, Switzerland |
| • Ana Gómez de Castro | Universidad Complutense de Madrid, Spain |
| • Jose Groh | Trinity College Dublin, Ireland |
| • Claus Leitherer | Space Telescope Science Institute, USA |
| • Emily Levesque | University of Washington, USA |
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| • Fabrice Martins | CNRS, France |
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| • Nicole St-Louis | Université de Montréal, Canada |
| • Jorick S. Vink (co-chair) | Armagh Observatory and Planetarium, Northern Ireland |
| • Daniel Whalen | University of Portsmouth, UK |
| • Naoki Yoshida | University of Tokyo, Japan |

Local Organising Committee

- | | |
|--------------------|--|
| • Ioana Boian | Trinity College Dublin, Ireland |
| • Seán Brennan | University College Dublin, Ireland |
| • Morgan Fraser | University College Dublin, Ireland |
| • Anne Grace | Dublin Institute for Advanced Studies, Ireland |
| • Samuel Green | Dublin Institute for Advanced Studies, Ireland |
| • Erin Higgins | Armagh Observatory and Planetarium, Northern Ireland |
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| • Sophie Murray | Dublin Institute for Advanced Studies, Ireland |
| • John Regan | Maynooth University, Ireland |
| • Gautham Sabhahit | Armagh Observatory and Planetarium, Northern Ireland |
| • Jorick S. Vink | Armagh Observatory and Planetarium, Northern Ireland |

List of Participants

Abdellaoui, Slah	de Wit, Stephan
Abdul-Masih, Michael	de Wit, Willem-Jan
Aghakhanloo, Mojgan	Derkink, Annelotte
Agliozzo, Claudia	Dhouib, Hachem
Aguilera-Dena, David R.	Dorda, Ricardo
Allan, Andrew	Drout, Maria
Andrassy, Robert	Dsilva, Karan
Antoniadis, Konstantinos	Ekström, Sylvia
Araya, Ignacio	Fabry, Matthias
Arias, Lorena	Farrell, Eoin
Arora, Bharti	Fitzpatrick, Beth
Arrieta, Anabel	Fraser, Morgan
Backs, Frank	Frost, Abigail
Banyard, Gareth	Gagnier, Damien
Barron, James	Garcia, Miriam
Beasor, Emma	Gilkis, Avishai
Berg, Danielle	Goetberg, Ylva
Bernini Peron, Matheus	Goldberg, Jared
Bestenlehner, Joachim	Gomez de Castro, Ana
Björklund, Robin	González-Torà, Gemma
Blanchard, Peter	Gordon, Kathryn
Blomme, Ronny	Gormaz Matamala, Alex
Bodensteiner, Julia	Graefener, Goetz
Bonanos, Alceste	Grasha, Kathryn
Bordier, Emma	Grassitelli, Luca
Bostroem, Azalee	Green, Samuel
Bowman, Dominic	Gull, Maude
Brands, Sarah	Haemmerle, Lionel
Brennan, Sean	Hamann, Wolf-Rainer
Britavskiy, Nikolay	Hawcroft, Calum
Broekgaarden, Floor	Heap, Sara
Brose, Robert	Henneco, Jan
Burssens, Siemen	Herrington, Nicholas
Burton, Michael	Higgins, Erin
Byrne, Robert	Hillier, John
Cannon, Emily	Hirschi, Raphael
Castellanos Sánchez, Raúl	Ho, Anna
Chene, Andre-Nicolas	Holgado, Gonzalo
Christodoulou, Evangelia	Hossein-zadeh, Griffin
Cooke, Jeff	Hussaini, Maryam
Costa, Guglielmo	J. Santos, Wilton
Crowther, Paul	Jacobson-Galan, Wynn
Davies, Ben	Janssens, Soetkin
de Burgos Sierra, Abel	Jiménez Martínez, Irene
de Koter, Alex	Jiménez-Hernández, Palmira
de la Fuente Guillen, Diego	Johnson, Rachel
de Mink, Selma	Johnston, Cole

Jung, Moo-Keon	O'Brennan, Hannah
Kamp, Keefe	O'Grady, Anna
Karamehmetoglu, Emir	O'Neill, David
Kee, N. Dylan	Oey, Sally
Kehrig, Carolina	Oliva, G. Andre
Keszthelyi, Zsolt	Olivier, Grace
Klement, Robert	Omand, Conor
Klencki, Jakub	Omukai, Kazuyuki
Klessen, Ralf	Oskinova, Lidia
Kolaczek-Szymanski, Piotr	Oudmaijer, Rene
Kotysz, Krzysztof	Owocki, Stanley
Kravtsov, Ihor	Pantaleoni, Michelangelo
Kremer, Kyle	Parsons, Timothy
Kummer, Floris	Patrick, Lee
Labadie-Bartz, Jonathan	Pauli, Daniel
Langer, Norbert	Pauwels, Tinne
Lanthermann, Cyprien	Penny, Laura
Laplace, Eva	Pistinner, Shlomi
Larkin, Cormac	Pledger, Joanne
Lazzarini, Margaret	Poniatowski, Luka
Lefever, Roel	Prentice, Simon
Leitherer, Claus	Prinja, Raman
Lenoir-Craig, Guillaume	Quintana Isasi, Alexis
Lorenzo, Marta	R. Aguilera-Dena, David
Lyman, Joe	Ramachandran, Varsha
Mackey, Jonathan	Regan, John
Madura, Thomas	Ren, Yi
Mahy, Laurent	Renzo, Mathieu
Maíz Apellániz, Jesús	Reyero Serantes, Sabela
Maravelias, Grigoris	Rickard, Matthew
Marchant, Pablo	Ricker, Paul
Marco, Amparo	Rieutord, Michel
Martinet, Sébastien	Rivinius, Thomas
Maryeva, Olga	Rizzuti, Federico
Massa, Derck	Roberti, Lorenzo
McDonald, Sarah	Rodriguez Berlanas, Sara
McQuinn, Kristen	Røed Ødegaard, Knut Jørgen
Mehner, Andrea	Rosen, Anna
Moens, Nicolas	Rosu, Sophie
Moriya, Takashi	Rubio Díez, Maria del Mar
Morris, Patrick	Rübke, Klaus
Moutzouri, Maria	Sabhahit, Gautham
Munoz Sanchez, Gonzalo	Sanchez, Julieta
Murphy, Laura	Sander, Andreas
Murray, Sophie	Schneider, Fabian
Najarro, Francisco	Schootemeijer, Abel
Nandal, Devesh	Schultz, William
Nazarenar Rodriguez, Cinthya	Schürmann, Christoph
Naze, Yael	Sen, Koushik
Negueruela, Ignacio	Senchyna, Peter
Nikolaeva, Evgeniia	Shenar, Tomer

Shenton, Robert	Vargas-Salazar, Irene
Shishkin, Dmitry	Villasenor, Jaime
Simón-Díaz, Sergio	Vink, Jorick S.
Sixtos, Andres	Wade, Gregg
Smartt, Stephen	Wang, Chen
Smith, Keith	Weßmayer, David
Smith, Nathan	Williamson, Marc
St-Louis, Nicole	Winch, Ethan
Stacey, Erik	Wofford, Aida
Stanway, Elizabeth	Woods, Paul
Stevance, Heloise	Woods, Tyrone
Stoop, Mitchel	Yarovova, Anastasiya
Strom, Allison	Yoon, Sung-Chul
Sushch, Iurii	Zapartas, Manos
Tanaka, Kei	Zsíros, Szanna
Teja, Rishabh Singh	Sana, Hugues
Telford, Grace	Humphreys, Roberta
Tinyanont, Samaporn	A.J., Nayana
Toonen, Silvia	Dorn-Wallenstein, Trevor
Tramper, Frank	Wei, Dandan
Tsiatsiou, Sophie	Massey, Philip
Tuquet, Selin	Neugent, Kathryn
ud-Doula, Asif	Cantiello, Matteo
van Son, Lieke	
Vanbeveren, Dany	

