1. Meeting Number: **Symposium 329**

2. Meeting Title: **The lives and death-throes of massive stars**

3. Coordinating Division: **Division G Stars and Stellar Physics**

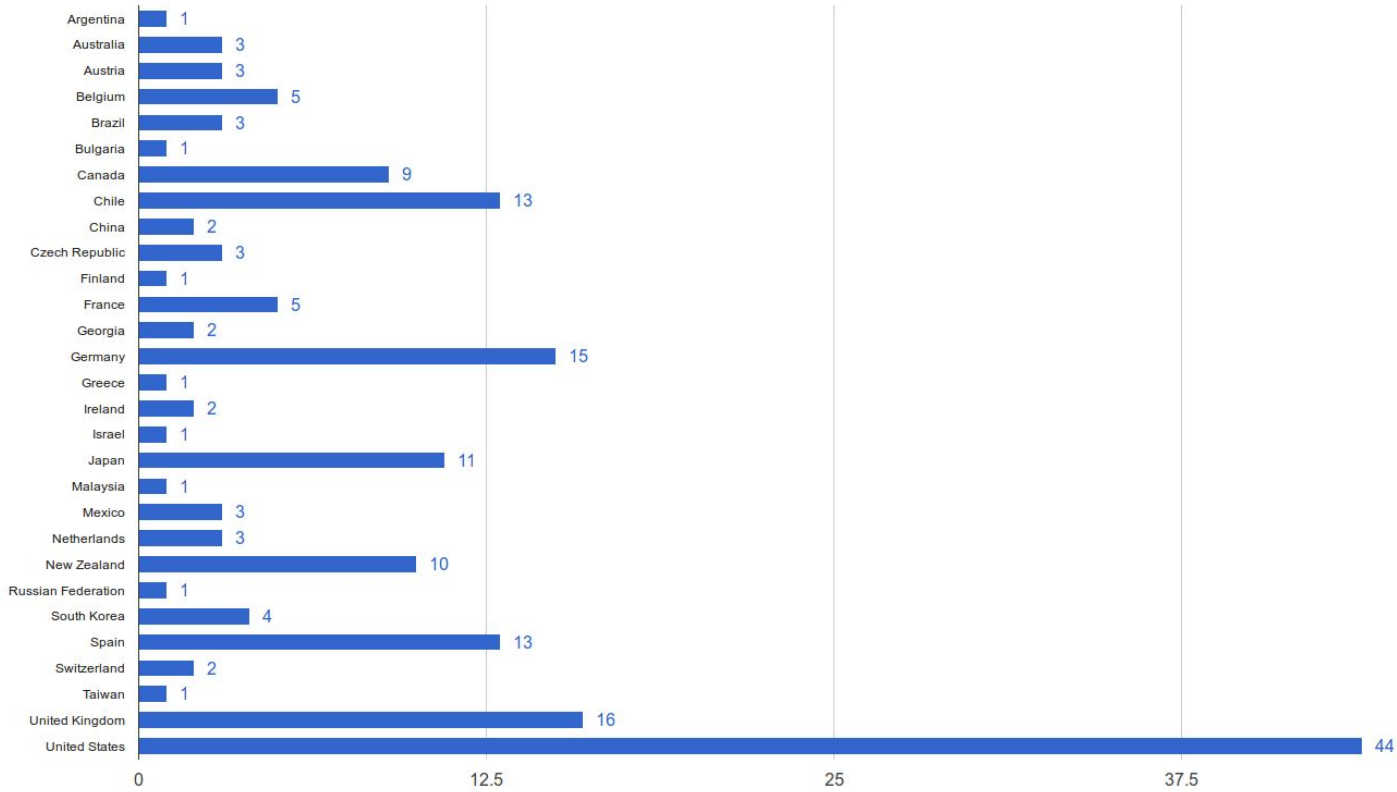
4. Dedication of meeting (if any): none

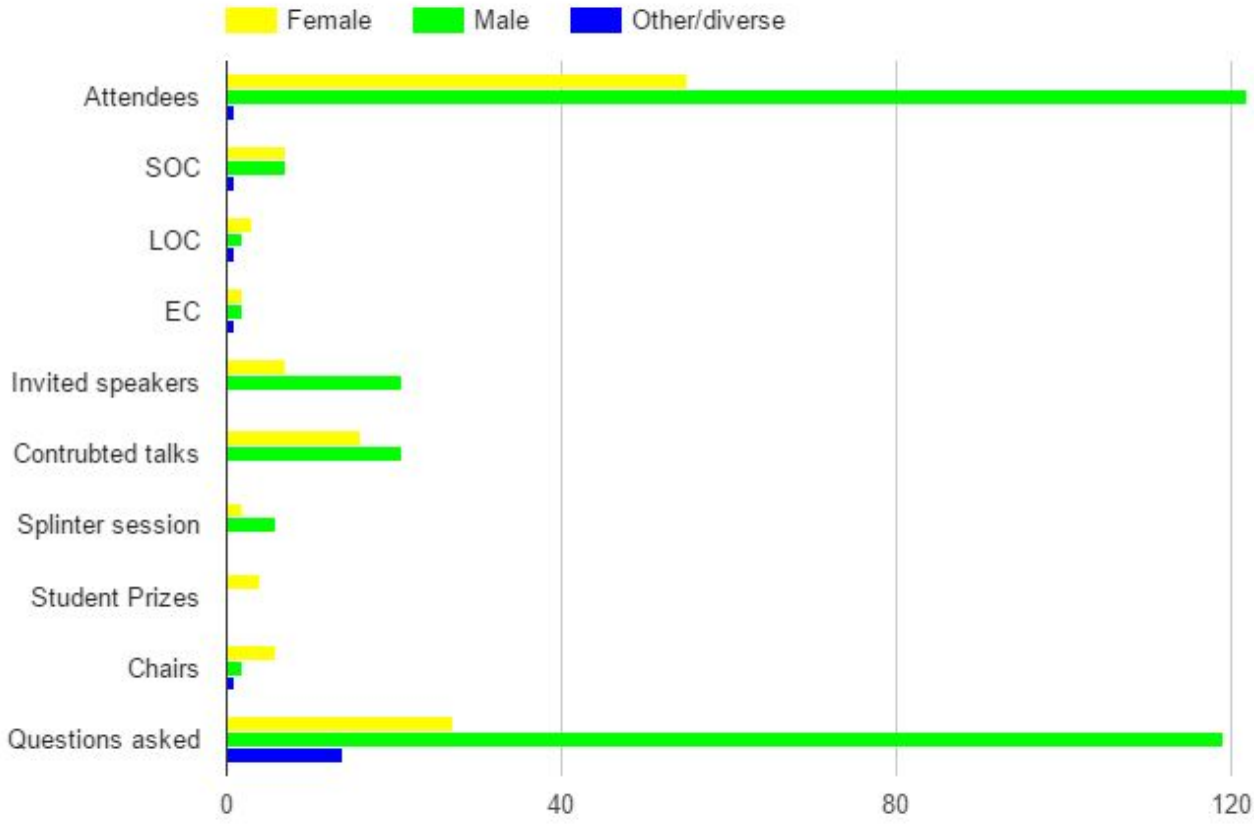
5. Location (city, country): **Auckland, New Zealand**

6. Dates of meeting: **28th November to 2nd December 2016**

7. Number of participants: 178, (M, F, D = 122, 55, 1 = 68.5%, 30.9%, 0.6%) Further equity information is included in the executive summary.

8. List of represented countries:

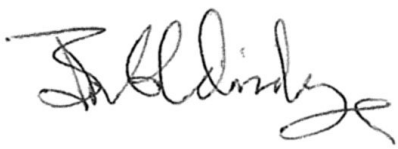





9. Report submitted by: Dr J.J. Eldridge

10. Date and place: Auckland, January 2017.

11. Signature of SOC co-chair and LOC chair



Dr JJ Eldridge

**Executive summary**

The meeting covered 4 broad areas related to massive stars and included one splinter session. The topic were:

1) Massive stars deaths in core-collapse supernova and other events.
2) Observations of massive stars.
3) Theoretical modelling of massive stars.
4) Massive stars as building blocks of galaxies through the history of the Universe.
5) Splinter session: X-ray observations of massive stars

During the week the linkage between these sessions with strong with several talks being able to be placed in any of the sessions. This reflects the growing collaborative nature of the study of massive stars. Formal discussion during the week was kept to a minimum. However long breaks were worked into the schedule to encourage informal discussion during the week. This was also further encouraged by setting the room up in a cabaret style with round tables rather than the normal lecture room format. Thus allowing people to form round table discussion groups. There was an extended discussion on Thursday run by Nathan Smith and Jose Groh concerning the best observations to test our theoretical models. In some ways bringing together all the topics of the week so far.

We are also particularly proud that our meeting from the onset worked hard to achieve an equitable meeting. Key to this was setting up an balanced SOC with 7 men, 7 women and 1 person of diverse gender. Also in selecting invited and contributed abstracts members were reminded to think about achieving an equitable balance at the meeting and to give people who don't always get a chance to speak an opportunity. Our efforts appears to pay off.

While overall 68% of the talks were by men and 32% by women. This was representative of the number of abstracts submitted and similar to the balance of attendees (Men 68.5%, Women 30.9%, Diverse 0.6%). While on the first day we were able to achieve equity with the ratio at 48% to 52%. With also good geographic diversity in speakers throughout the week in addition to this.

The meeting also had a code of conduct to make the meeting spaces safe, inclusive and free of harassment. A reporting proceeding was explained on the first day as well as identifying those on the "equity committee" who were responsible for enforcing the code. The experiment worked well but in future we recommend that the process to deal with breaches of the code of conducts be outlined before the meeting rather than being dealt with if incidents occur.

We also recorded further equity information such as the gender of those who asked questions. We are still analysing this data but of the 160 questions asked 74% were asked by men, 17% were asked by women and 9% by asked by people of diverse gender. We should note that in all the above statistics we are using the presumed gender. We only know of one gender diverse person who attended and asked those questions.

Our treatment of equity at the meeting also went beyond the talks and discussion. During the conference dinner for example we worked hard to provide entertainment that did not appropriate local culture and continue the safe inclusive environment. The result of this was to use a conference quiz (based on the "pub quiz" format common in the UK, Australia and New Zealand). It was enjoyable and some remarked it was the most enjoyable conference dinner they had attended.

In addition to IAU sponsorship for travel grants it was also sponsored by the Department of Physics from the University of Auckland as well as CAASTRO (ARC Centre of Excellence for all-sky astrophysics). Then on the day after the meeting several conference attendees contributed to a public symposium. Where the highlights of the meeting were discussed along with varied subjects from ancient astronomy, the structure of the Galaxy and science-fiction comic books.

There were two conference excursions, one to the Domain museum in Auckland the other a trip to Rangitoto island. A volcano in the bay of Auckland that erupted some 600 to 800 years ago. Surprisingly (to the tour organizer) 150 of the attendees went on the latter trip. Many enjoyed the race to the summit, exploring the lava caves afterwards and investigating a Kiwi bach (holiday home). The tour operator who organized the trips also made themselves available during the week to answer questions from attendees to plan their future travel in New Zealand after the conference.

At the end of the meeting and afterwards we received great positive feedback on our organization of the meeting. With the worst points being around trouble with the AV systems. Students and early-career researcher seems to be those who enjoyed the meeting the most and we hope that man productive collaborations will arise due to the meeting.

**Science Organizing Committee**
**Co-Chairs:** JJ Eldridge, Margaret Hanson, Artemio Herrero
Joe Anderson, Matteo Cantiello, Ben Davies, Sylvia Ekström, John Hillier, Coralie Neiner, Maria-Fernanda Nieva, Lida Oskinova, Alicia Soderberg, Nicole St-Louis, Jorick Vink, Sung-Chul Yoon

**Local Organizing Committee**
JJ Eldridge, Aimee Crawshaw, Lin Xiao, Liam McClelland, John Bray, Nicole Rodrigues

**Equity Committee**
JJ Eldridge, Margaret Hanson, Phillip Massey, Jennifer Hoffman, Liam McClelland, Lin Xiao

**Gender Breakdown Information**

| Group | Number of Male:Female:Diverse | % of Male:Female:Diverse |
|---|---|---|
| **SOC** | **7 : 7 : 1** | **47% : 47% : 6%** |
| **LOC** | **2 : 3 : 1** | **33% : 50% : 17%** |
| **EC** | **2 : 2 : 1** | **40% : 40% : 20%** |
| **Invited Speakers** | **21 : 7 : 0** | **75% : 25% : 0%** |
| **Contributed Speakers** | **27 : 16 : 0** | **63% : 37% : 0%** |
| **Splinter Session Speakers** | **6 : 2 : 0** | **75% : 25% : 0%** |
| **Student Prizes** | **0 : 4 : 0** | **0% : 100% : 0%** |
| **Chairs** | **2 : 6 : 1** | **22% : 67% : 11%** |
| **Questions asked** | **119 : 27 : 14** | **74% : 17% : 9%** |

**Science highlights**

The scientific program for the meeting was structured around 4 broad themes concerning massive stars: their supernovae, observations, theory and as constituents of galaxies. We summarize the important topics from each of these themes below.

1) **Massive stars deaths in core-collapse supernova and other events.**

Core-collapse supernovae are the final death throes of massive stars. At the meeting much was presented on recent observational surveys which are redefining our understanding of the rates of different supernova types. Especially finding more examples of the rarer types including superluminous supernova. In addition to larger samples of supernova much has been done in adding more varied observational constraints on the supernova and their progenitor stars. Especially understanding the mass-loss history of progenitors before explosion. Then there are also novel observational tests such as studying nearby stellar populations close to SN sites both by studying the stars as well as the nebula emission that arises from the population associated with the star that died. We also heard how polarization informs our knowledge of the supernova explosion mechanisms and heard our first mention that polarimeters need to be added to future plans for telescope instrumentation.

These advancements have been accompanied by great advances in understanding of the mechanisms around core-collapse and how stars explode. With there also being other ways to explode stars via jets as well as the typical core-collapse alone We also heard how that stars in interacting binaries are vital to understanding the variety and progenitors of many core-collapse supernovae.

2) **Observations of massive stars.**

The same broad lessons were repeated in this session. That of how new techniques and new spectroscopic large surveys are providing a wealth of information to refine our understanding of massive stars. Magnetic fields have been detected in many stars now, although future detections rely on more polarimeters on large telescopes being made available in future. Also while the new technique of asteroseismology is beginning to provide a window into the interior of massive stars however direct studies of massive stars are few to date. Observations of main-sequence stars in addition to revealing their intrinsic parameters are also giving us a better understanding of the number of binary stars is extremely high. And somewhat more astonishing the number of triple and higher order systems is not insignificant.

Great advances have also been made in our knowledge of red supergiants and Wolf-Rayet stars due to careful theoretical work and observational work in unison. Finally the importance of the detection of gravitational wave sources indicating massive black holes can exist in binary systems featured in many talks. Especially those concerning massive X-ray binaries which are likely to be the progenitors of such systems.

3) **Theoretical modelling of massive stars.**

The greatest advances in theory concerned first the improved understanding of binary evolution and interactions, specifically our knowledge of common-envelope evolution. Then second advances concerned the modelling of stellar atmospheres and stellar structure below the photosphere. This has led have allowed tighter constraint on Wolf-Rayet stars and their complex surfaces. The impact of magnetic fields in the surface of stars have also now been refined to a great degree.

4) **Massive stars as building blocks of galaxies through the history of the Universe.**

On the final day the conference turned to massive stars as constituents of Galaxies from our own to those at the edge of the observable Universe. Again large surveys are providing again most data to constrain our understanding and using massive stars to understand larger objects. Most interesting the case was made that in future members of the high-redshift community will being to realise more and more that to unlock further knowledge of the first galaxies it will be necessary to understand all the current uncertainties covered earlier in the week.

5) **Splinter session on X-ray observations of massive stars**

The final science session was a splinter session on the X-ray observations of massive stars. This linked strongly into other sessions of the program. Many of the talks related back to the study of magnetic fields and binary systems and thus was most complementary to the meeting.

**Final Program**

| | | | |
|---|---|---|---|
| **MONDAY** | | | **Chair: JJ Eldridge** |
| 9.15-9.30 | | | **Introduction and Mihi Whakatoa** |
| 9.30-10.10 | Meynet | Georges | Overview of recent developments in stellar theory and supernovae |
| 10.10-10.30 | Bianco | Fed | Invited: Difference between Iib/Ib/Ic/Ic-BL |
| 10.30-11 | **Morning Coffee** | | |
| 11.00-11.20 | Muller | Bernhard | Invited: Core-collapse SNe modelling - how many ways can you explode a star? |
| 11.20-11.40 | Hillier | Desmond John | Invited: Quantitative spectroscopy of supernovae |
| 11.40-11.55 | Nomoto | Kenichi | Radiation Hydrodynamics of Type I Superluminous Supernovae: Constraints on Progenitors and Explosion Mechanisms |
| 11.55-12.10 | Thöne | Christina | SN 2015bh: an LBV becomes NGC 2770s forth SN... or not? |
| 12.10-12.25 | Xiao | Lin | Emission-line diagnostics of Nearby HII Regions including Supernova host |
| 12.25-12.40 | Drout | Maria | Probing the Extremes of Pre-SN Mass Loss with the PanSTARRS1 Medium-Deep Survey |
| 12.40-14.00 | **Catered Lunch** | | |
| | | | **Chair: Margaret Hanson** |
| 14.00-14.20 | Bersten | Melina | Invited: Modelling the SN and progenitors |
| 14.20-14.40 | Fraser | Morgan | Invited: Progenitors of core-collapse supernovae |
| 14.40-15.00 | Groh | Jose | Invited: Spectroscopic evolution of supernova progenitors |
| 15.00-15.15 | Smith | Nathan | Challenges to stellar evolution from LBVs, SN Impostors, and Supernovae with Dense CSM |
| 15.15-15.30 | Podsiadlowski | Philipp | Binary Evolution and the Final Fate of Massive Stars |
| 15.30-16.10 | **Afternoon Coffee** | | |
| 16.10-16.25 | Hoffman | Jennifer | Reconstructing the Scene: New Views of Supernovae and Progenitors from the SNSPOL Project |
| 16.25-16.40 | Beasor | Emma | The evolution of red supergiants to supernovae |
| 16.40-16.55 | Menon | Athira | The quest for blue supergiants: Binary merger models for the evolution of the progenitor of SN 1987A |
| 16.55-17.10 | Yusof | Norhasliza | Very Massive Stars at Different Metallicities |
| 17.10-17.25 | Agliozzo | Claudia | The mass-loss before the end: two luminous blue variables with a collimated stellar wind |
| 17.25-17.40 | Ertl | Thomas | The progenitor-remnant connection of neutrino-driven supernovae across the stellar mass range |
| | | | |
| **TUESDAY** | | | **Chair: Sung-Chul Yoon** |
| 9.00-9.20 | Simon-Diaz | Sergio | Invited: Multi Epoch views of massive stars |
| 9.20-9.40 | Fuller | Jim | Invited: Asteroseismology of massive stars |
| 9.40-10.00 | Wade | Gregg | Invited: Magnetic fields in massive stars |
| 10.00-10.15 | Shultz | Matthew | Rotation, Evolution, Magnetic Fields, and Emission: Results from the First Population Study of Magnetic Early B-type Stars |

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| 10.15-10.30 | **Rubio** | **Maria del Mar** | Re-examining the upper mass limit of stars using an isolated ~140 Msun twin of R136's WNh5 core stars |
| 10.30-11.10 | **Morning Coffee** | | |
| 11.10-11.25 | Maíz Apellániz | Jesús | Gaia and spectroscopic surveys of O stars: the solar neighborhood in 6-D |
| 11.25-11.40 | Oksala | Mary | The evolution of magnetic fields in hot stars |
| 11.40-11.55 | **Buysschaert** | **Bram** | Magneto-asteroseismology of hot stars |
| 11.55-12.10 | Oskinova | Lidia | X-ray diagnostics of massive star winds |
| 12.10-12.25 | Gies | Douglas | Taking the Measure of Massive Stars and their Environments with the CHARA Array Long-baseline Interferometer |
| 12.25-14.30 | **Long Lunch Break to explore** | | |
| | | | **Chair: Melina Bernsten** |
| 14.30-14.50 | Nieva | Maria-Fernanda | Invited: High accuracy quantitative spectroscopy in the Galaxy |
| 14.50-15.10 | Barba | Rodlofo | Invited: OWN, a survey of O and WR stars |
| 15.10-15.30 | Ohnaka | Keiichi | Invited: Resolving the mass loss from red supergiants by high angular resolution |
| 15.30-15.45 | Massey | Philip | The Red Supergiant Content of the Local Group |
| 15.45-16.00 | Scicluna | Peter | A high-contrast imaging survey of nearby red supergiants |
| 16.00-16.40 | **Afternoon Coffee** | | |
| 16.40-16.55 | Hainich | Rainer | The metallicity dependence of WR winds |
| 16.55-17.10 | **Neugent** | **Kathryn** | The Evolutionary Status of WN3/O3 Wolf-Rayet Stars |
| | | | |
| | **SPLINTER SESSION** | | **Chair: Lida Oskinova** |
| 18.00-18.12 | Kretschmar | Peter | Studying Stellar Winds in Massive X-ray Binaries |
| 18.12-18.24 | Nazé | Yaël | X-rays from colliding winds in massive binaries |
| 18.24-18.36 | Hamaguchi | Kenji | Origin of Extremely Hard X-ray Emission from Eta |
| 18.36-18.48 | Schulz | Norbert | X-ray Emission from Massive Stars at the Core of |
| 18.48-19.00 | Russell | Chris | Modeling the Chandra observations of the Galactic Center |
| 19.00-19.12 | **Fletcher** | **Corinne** | Investigating the Magnetospheres of Rapidly |
| 19.12-19.24 | Maravelias | Grigoris | The circumstellar environment of B[e] Supergiants |
| 19.24-19.36 | **Dorn-Wallenstein** | **Trevor** | A Candidate Red Supergiant X-ray Binary in M31 |
| | | | |
| **WEDNESDAY** | | | **Chair: Yael Naze** |
| 9.00-9.20 | Caballero-Nieves | Saida | Invited: The Young and the Massive: Stars at the upper end of the Initial Mass Function |
| 9.20-9.40 | Sana | Hugues | Invited: Multiplicity of massive stars |
| 9.40-10.00 | Postnov | Konstantin | Invited: Progenitors of the black-hole binary mergers detected by LIGO |
| 10.00-10.15 | Pablo | Herbert | The Most Massive Heartbeat : Finding the Pulse of Iota Orionis |
| 10.15-10.30 | Damineli | Augusto | Eta Carinae A: a star with a hole |

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| 10.30-11.30 | **Morning Coffee - EXTENDED POSTER SESSION SPONSERED BY CAASTRO** | | |
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| **THURSDAY** | | | **Chair: Bernhard Muller** |
| 9.00-9.20 | Georgy | Cyril | Invited: Evolution models of red supergiants |
| 9.20-9.40 | Justham | Stephen | Invited: Massive binary stars |
| 9.40-10.00 | Ivanova | Natalia | Invited: Common envelope: progress and transients |
| 10.00-10.15 | Hamann | Wolf-Rainer | Massive stars in advanced evolutionary stages, and the potential progenitors of GW150914 |
| 10.15-10.30 | Sabín-Sanjulián | Carolina | Properties of the O dwarf population in 30 Doradus |
| 10.30-11.10 | **Morning Coffee** | | |
| 11.10-11.25 | Augustson | Kyle | The Magnetic Furnace: Intense Core Dynamos in B Stars |
| 11.25-11.40 | **Cristini** | **Andrea** | 3D Hydrodynamic Simulations of the Carbon Shell in a Massive Star |
| 11.40-12.00 | Gräfener | Götz | Invited: Clumping in stellar winds and interiors |
| 12.00-12.20 | Sander | Andreas | Invited: Recent advances in NLTE stellar atmosphere models |
| 12.20-12.35 | Jiang | Yanfei | 3D Radiation Magnetohydrodynamic Simulations of Massive Star Envelopes at the Iron Opacity Peak |
| 12.35-12.50 | Bard | Christopher | Effect of a Dipole Magnetic Field on Massive Star Line-Driven Winds |
| 12.50-14.30 | **Long Lunch Break to explore** | | |
| 14.00-14.30 | **LSST Transients and Variable Stars Discussion** | | |
| | | | **Chair: Jennifer Andrews** |
| 14.30-14.45 | **Erba** | **Christiana** | New Insights into the Puzzling P-Cygni Profiles of Massive Magnetic Stars |
| 14.45-15.00 | Murphy | Jeremiah | The Spatial Distribution of Massive Stars and Stellar Evolution |
| 15.00-15.15 | **Goetberg** | **Ylva** | The Elusive Population of Massive Binary Star Products: the far UV Spectra of Stripped Stars |
| 15.15-15.30 | **Keszthelyi** | **Zsolt** | The evolution of magnetic hot massive stars: implementation of the quantitative influence of surface magnetic fields in modern models of stellar evolution |
| 15.30-15.45 | Cantiello | Matteo | The Stellar Ultrasound |
| 15.45-16.00 | **McClelland** | **Liam** | Helium stars: Towards an understanding of Wolf-Rayet evolution |
| 16.00-16.30 | **Afternoon Tea** | | |
| 16.30-17.00 | | | **Discussion led by Nathan Smith & Jose Groh** |
| | | | |
| **FRIDAY** | | | **Chair: Jennifer Hoffman** |
| 9.30-9.50 | Chené | André-Nicolas | Invited: Massive infrared clusters in the Milky Way |
| 9.50-10.10 | Negureruela | Ignacio | Invited: Massive stars in Galactic clusters |

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| 10.10-10.30 | Vink | Jorick | Invited: The VLT-FLAMES Tarantula Survey |
| 10.30-11.10 | **Anti-hangover coffee** | | |
| 11.10-11.25 | Najarro | Francisco | The Massive stellar population at the Galactic Center |
| 11.25-11.40 | Crowther | Paul | The Tarantula as a template for extragalactic star forming regions from VLT/MUSE |
| 11.40-12.00 | Urbaneja | Miguel | Invited: Extragalactic supergiants |
| 12.00-12.20 | Stanway | Elizabeth | Invited: What Distant Galaxies can tell us about Massive Stars" |
| 12.20-12.40 | Herrero | Artemio | & Miriam Garcia Garcia, Invited: Winds of low metallicity OB stars |
| 12.40-14.00 | **Catered lunch** | | |
| | | | **Chair: JJ Eldridge** |
| 14.00-14.15 | Leitherer | Claus | The II Zw 40 Supernebula: 30 Doradus on Steroids |
| 14.15-14.30 | Smith | Linda | The Very Massive Star Content of the Nuclear Star Clusters in NGC 5253 |
| 14.30-14.45 | Davies | Benjamin | Red Supergiants as Cosmic Abundance Probes |
| 14.45-15.00 | Mattila | Seppo | High angular resolution infrared and radio view of optically dark supernovae in luminous infrared galaxies |
| 15.00-15.30 | **Afternoon Tea** | | |
| 15.30-16.00 | Levesque | Emily | Conference Summary & Overview |

## List of Attendees:

| First Name | Last Name | Department | Organization | Primary Address - Country | Primary Email |
|---|---|---|---|---|---|
| Michael | Abdul-Masih | Institute Of Astrophysics | Ku Leuven | Belgium | mabdul02@villanova.edu |
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|---|---|---|---|---|
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|---|---|---|---|---|
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| Víctor | Gómez-González | Astrophysics<br>Instituto Nacional De Astrofísica, Óptica Y Electrónica | Mexico | mau.gglez@gmail.com |
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| Buysschaert | Bram | Male | France | 400 |
| Camacho | Inés | Female | Spain | 400 |
| Carneiro Gama | Luiz Paulo | Male | Germany | 400 |
| Cote | Benoit | Male | Canada / USA | 400 |
| Cure Ojeda | Michel | Male | Chile | 350 |
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| Hainich | Rainer | Male | Germany | 400 |
| Haubois | Xavier | Male | CHILE | 400 |
| Hervé | Anthony | Male | czech republic | 400 |
| Higgins | Erin | Female | NI, UK | 200 |
| Hoffman | Jennifer | Female | USA | 350 |
| Holgado Alijo | Gonzalo | Male | Spain | 400 |
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| Hypolite | Delphine | Female | France | 400 |
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| Kool | Erik | Male | Australia | 400 |
| Lomax | Jamie | Female | USA | 400 |
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| Naze | Yael | Female | Belgium | 350 |
| Oksala | Mary Elizabeth | Female | USA | 350 |
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| Prat | Vincent | Male | France | 400 |
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