The Deaths *&* Afterlives *of* Stars

22–24, April 2019

STScI

The stellar evolution lifecycle ends with a dramatic transformation of stars from their equilibrium state. Stellar deaths involve violent and often rapid expulsions of matter and energy, a process that itself represents an initial condition for many astrophysical topics. The rich diversity of stellar outcomes, their connections to progenitor properties, and the influence of these afterlife processes on shaping galaxies remain among the most exciting fields of astrophysics today and has been further sparked by the discovery of new classes of transients and the first detections of gravitational waves.

The Space Telescope Science Institute is excited to host the 2019 STScI Spring Symposium, "The Deaths and Afterlives of Stars". The symposium will bring together leading experts that are pushing new research in this exciting field of astrophysics. The discussion will include,

- The thresholds for stellar evolution that culminate in different types of stellar deaths
- The physical effects that control stellar death
- The processes through which stars die
- Astrophysical influences from the afterlives of stars


The Deaths & Afterlives of Stars
22–24, April 2019
Agenda
STScI

Monday, April 22, 2019

Welcome

8:00 – 8:45	**Registration/Breakfast**	**STScI Rear Lobby/Café Azafran**
8:45 – 8:50	Nancy Levenson	Welcome
8:50 – 9:00	Martha Boyer	Introduction

Session 1 – Which Stars Explode?

9:00-10:15	Chair: Emily Levesque	Which Stars Explode?
9:00 – 9:30	Stephen Smartt	*Which Stars Explode?*
9:30 – 10:00	Stan Woosley	*The Deaths of Massive Stars*
10:00 – 10:15	Carolyn Doherty	*Impact of Rotation on the Low-mass/High-mass Star Divide*
10:15 – 11:00	**Coffee Break + Posters**	**Café Azafran**
11:00 – 12:30	Chair: Ori Fox	Which Stars Explode?
11:00 – 11:30	Tuguldur Sukhbold	*Missing Red Supergiants and Carbon Burning*
11:30 – 11:45	Ashley Chrimes	*Exploring Progenitor Pathways for Long Duration Gamma-ray Bursts in Binary Stellar Evolution Models*
11:45 – 12:00	Jeremiah Murphy	*Toward Predicting and Constraining the Explosions of Massive Stars*
12:00 – 12:15	Jose Groh	*The Surprising Look of Massive Stars before Death*
12:15 – 12:30	Jeffrey Cummings	*The Transition Mass for Core-Collapse Supernovae Derived From the Initial-Final Mass Relation*
12:30 – 1:40	**Lunch**	

Session 2 – What Are the Physical Effects Controlling Stellar Death?

Invited Reviews – 22+8 min
Contributed Talks – 10+5 min

1:40 – 3:10	Chair: Craig Wheeler	What Are the Physical Effects Controlling Stellar Death?
1:40 – 2:10	Maryam Modjaz	*Impact of Metallicity on the Diverse Deaths of Massive Stars*
2:10 – 2:25	Eva Laplace	*The Size of Stripped-envelope Supernovae Progenitors and Its Impact on Gravitational Waves Events*
2:25– 2:55	Jen Andrews	Mass Loss and Eruptions in Core Collapse Supernova Progenitors
2:55 – 3:10	Emily Levesque	*Rotation and Mass Loss in Luminous Blue Variables*
3:10 – 4:00	**Coffee Break + Posters**	**Café Azafran**
4:00 – 5:30	Chair: Stuart Ryder	What Are the Physical Effects Controlling Stellar Death?
4:00 – 4:15	Jennifer Hoffman	*Leaving Traces: How Polarized Lines Reveal Properties of CCSN Progenitors*
4:15 – 4:45	JJ Eldridge	*EM and GW Transient with BPASS & CURVEPOPS*
4:45 – 5:00	Trevor Dorn-Wallenstein	*Stellar Population Diagnostics of the Massive Star Binary Fraction*
5:00 – 5:15	Niharika Sravan	*A Comprehensive Population-scale Modeling of Type IIb Supernova Progenitors*
5:15 – 5:30	David R. Aguilera-Dena	*Progenitors of Type I SLSNe and Long GRBs*
5:30 – 7:00	**Welcome Reception + Posters**	**Café Azafran**

Tuesday, April 23, 2019

8:15 – 9:00	**Registration/Breakfast**	**STScI Rear Lobby/Café Azafran**

Session 3 – How Do Stars Die?

9:00 – 10:15	Chair: Suvi Gezari	How Do Stars Die?
9:00 – 9:30	Sofia Ramstedt	*Stellar Winds with ALMA*
9:30 – 9:45	Raghvendra Sahai	*Binarity and the Formation of Bipolar and Mutipolar Pre-Planetary and Planetary Nebulae*
9:45 – 10:15	Ragnhild Lunnan	*What Powers Superluminous Supernovae?*

Invited Reviews – 22+8 min
Contributed Talks – 10+5 min

10:15 – 11:00	**Coffee Break + Posters**	**Café Azafran**
11:00 – 12:30	Chair: Tuomas Kangas	How Do Stars Die?
11:00 – 11:30	Iair Arcavi	*New Discoveries of Extreme Supernovae*
11:30 – 11:45	Nathaniel Roth	*The Aspherical Cow: Interpretation of Multi-Wavelength Observations of AT2018cow*
11:45 – 12:00	Anna Ho	*A Ic-BL Supernova with Shock-cooling Emission, Discovered as a Fast Optical Transient*
12:00 – 12:15	Andy Howell	*Connecting SNe to their Progenitors with the Global Supernova Project*
12:15 – 12:30	Jacob Jencson	*Uncovering Hidden Stellar Explosions with Spitzer*
12:30 – 1:40	**Lunch**	
1:40 – 3:25	Chair: Ryan Foley	Which Pathways Lead to Destruction of Stellar Remnants?
1:40 – 1:55	Eric Hsiao	*Observational Clues on the Origins of "Super-Chandrasekhar" Type Ia Supernovae*
1:55 – 2:10	Andreas Floers	*Constraints On the Explosion Mechanisms of Type Ia Supernovae from Optical and NIR Nebular Phase Spectroscopy*
2:10 – 2:25	Sumit K. Sarbadhicary	*Local Group Delay Time Distributions (DTDs): A New Perspective on Progenitor Models Using Resolved Stellar Populations*

Session 4 – Which Pathways Lead to Destruction of Stellar Remnants?

2:25 – 2:55	Ken Shen	*The Current View of Type Ia SN Progenitors*
2:55 – 3:10	Melissa Graham	*Identifying Non-Degenerate Companions in SNeIa via CSM Interaction*
3:10 – 3:25	Georgios Dimitriadis	*Early and Late-time Observations of Kepler's Brightest Supernova SN 2018oh*
3:25 – 3:30	**Group Photo**	***Front of Muller Building***
3:30 – 4:15	**Coffee Break + Posters**	**Café Azafran**
4:15 – 5:15	Chair: Ken Nomoto	Which Pathways Lead to Destruction of Stellar Remnants?
4:15 – 4:45	Selma de Mink	*Progenitors of GW Detected Black Holes*
4:45 – 5:00	Nicola Giacobbo	*Stellar Deaths As the Birth of Double Neutron Stars*
5:00 – 5:15	Carl-Johan Haster	*Gravitational Wave Observations of a Population of Stellar Mass Black Holes*
6:00	**Small Group Dinners**	**Various Locations**

Invited Reviews – 22+8 min
Contributed Talks – 10+5 min

8:00 – 9:00	Dan Milisavljevic	*Public Lecture - Multi-messenger Autopsies of Stellar Death*

Wednesday, April 24, 2019

8:15 – 9:00	**Registration/Breakfast**	**STScI Rear Lobby/Café Azafran**

Session 5 – What Happens in the Aftermath of Stellar Death?

9:00 – 10:30	Chair: Andy Fruchter	What Happens in the Aftermath of Stellar Death?
9:00 – 9:30	Nora Troja	*Electromagnetic Emission from NS Mergers*
9:30 – 9:45	Ben Gompertz	*The Diversity of Kilonova Emission in Short Gamma-Ray Bursts*
9:45 – 10:15	Enrico Ramirez-Ruiz	*R-Process Kilonova Optical/Infrared Emission*
10:15 – 10:30	Charlie Kilpatrick	*Constraints on Long-lived Radioisotopes from the Gravitational Wave Counterpart AT 2017gfo*
10:30 – 11:15	**Coffee Break + Posters**	**Café Azafran**
11:15 – 12:15	Chair: B. Sargent	What Happens in the Aftermath of Stellar Death?
11:15 – 11:45	Jennifer Johnson	*Origin of the Elements*
11:45 – 12:00	Paola Marigo	*Carbon Star Formation in the Milky Way as Seen through the Initial-final Mass Relation*
12:00 – 12:15	Aldana Grichener	*Tying SN Remnants to SN Progenitors*
12:15 – 1:25	**Lunch**	

Session 5 - What Happens in the Aftermath of Stellar Death? (Continued)

1:25 – 3:20	Chair: Erin Smith	What Happens in the Aftermath of Stellar Death?
1:25 – 1:55	Ambra Nanni	*Dust from Stellar Deaths*
1:55 – 2:10	Eli Dwek	*The Evolution of Dust in SN Ejecta*
2:10 – 2:25	Guido De Marchi	*Polluting in Time and Space*
2:25 – 2:55	Jay Farihi	*Pandemonium in the Planetary Graveyard*

Invited Reviews – 22+8 min
Contributed Talks – 10+5 min

2:55 – 3:10	John Debes	*Finding Warm Dust Around a 3 Gyr White Dwarf via Citizen Science*
3:10 – 4:00	**Coffee Break + Posters**	**Café Azafran**
4:00 – 5:35	Chair: Armin Rest	What Happens in the Aftermath of Stellar Death?
4:00 – 4:30	Laura Lopez	*Tying SN Remnants to SN Progenitors*
4:30 – 4:45	Brian Williams	*The Expansion of the Young Supernova Remnant 0509-68.7 (N103B)*
4:45 – 5:00	Wolfgang Kerzendorf	*The Siblings of Cas A*
5:00 – 5:30	Tim Heckman	*Supernova-Driven Galactic Winds*
5:30 – 5:35	Gautham Narayan	*A Look Forward to the Upcoming Workshop*

Electronic Booklet may be found here: http://www.stsci.edu/institute/conference/spring2019

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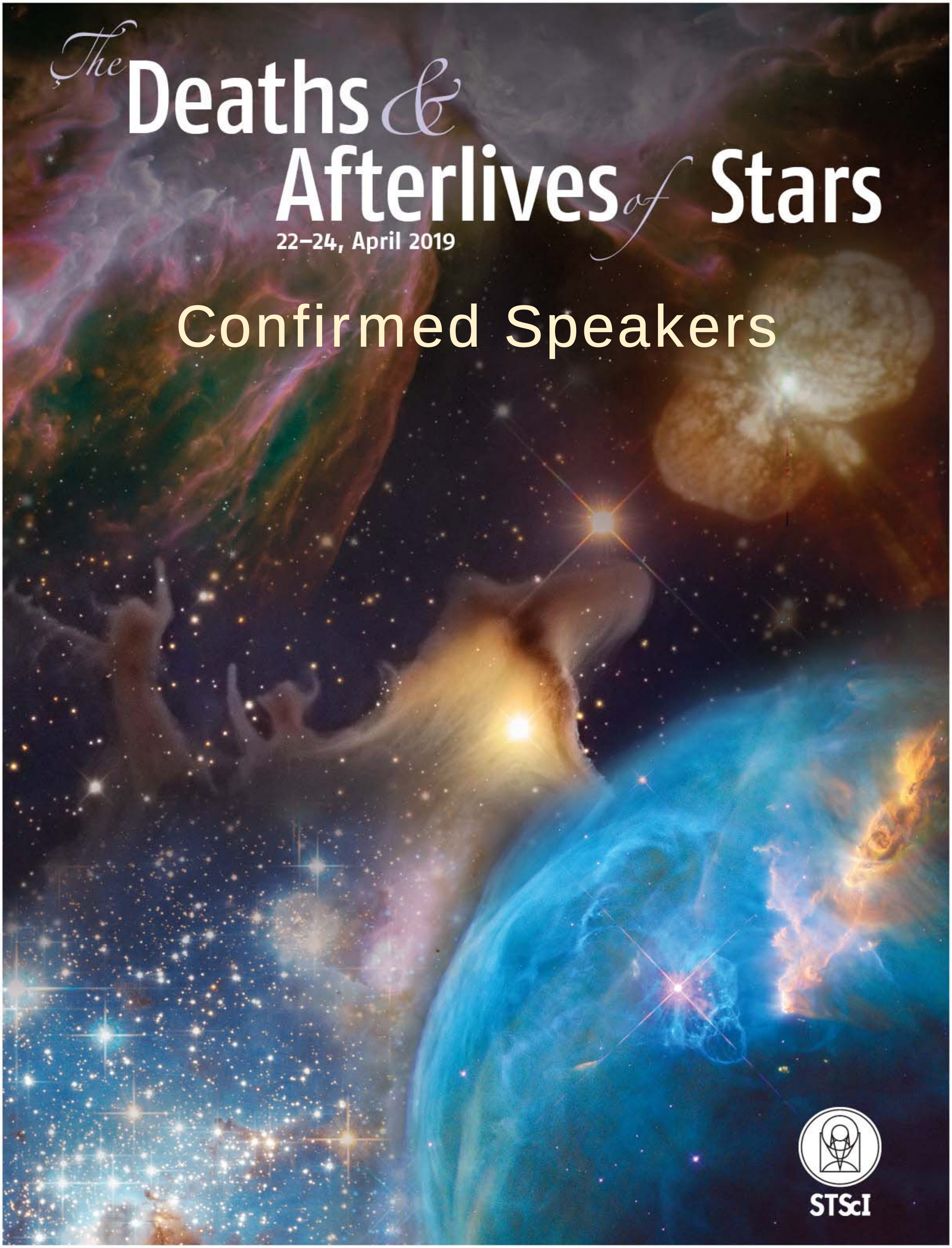
Invited Reviews – 22+8 min
Contributed Talks – 10+5 min


The Deaths & Afterlives of Stars
22–24, April 2019
Confirmed Speakers
STScI

Confirmed Speakers

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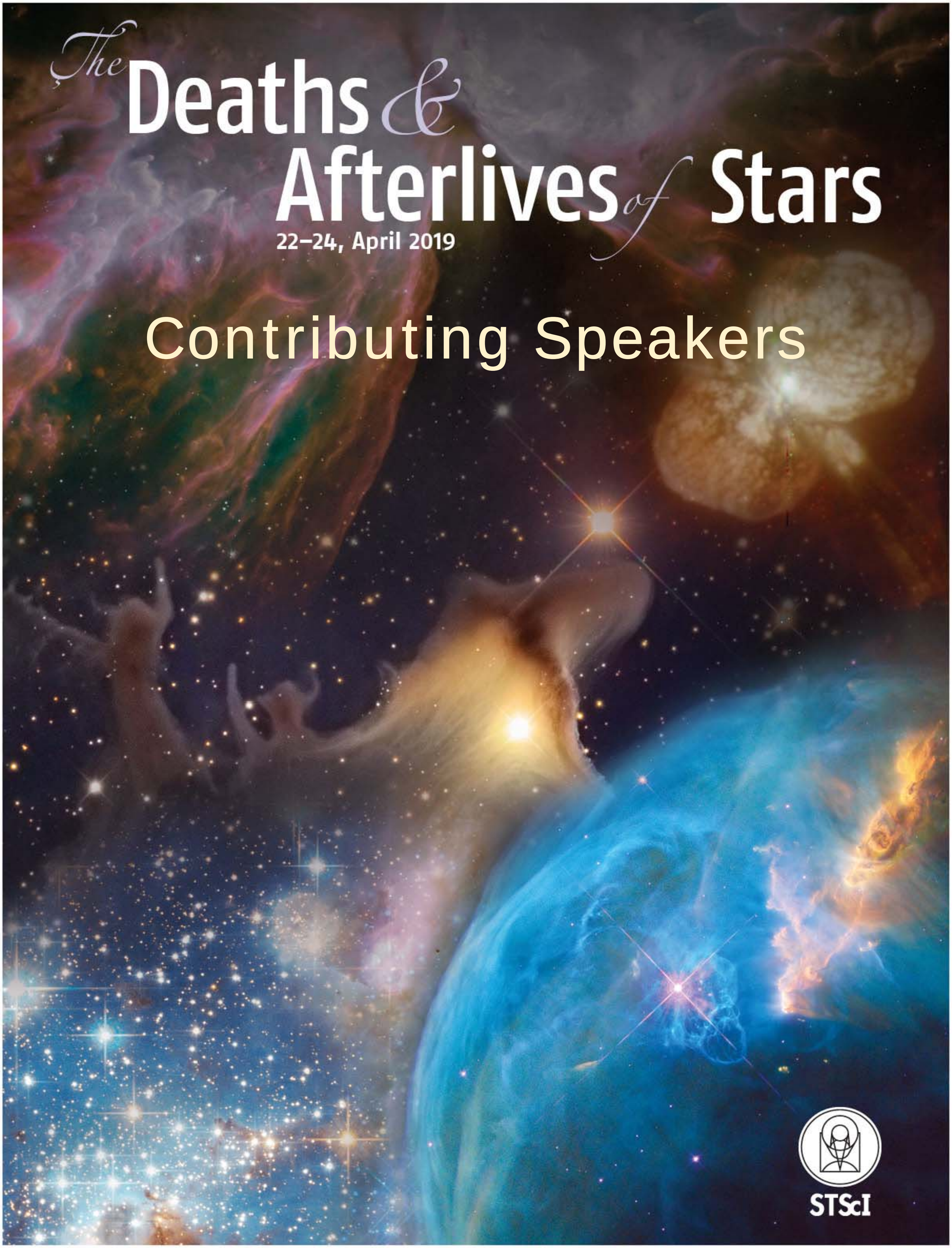
The Deaths & Afterlives of Stars
22–24, April 2019
Contributing Speakers
STScI

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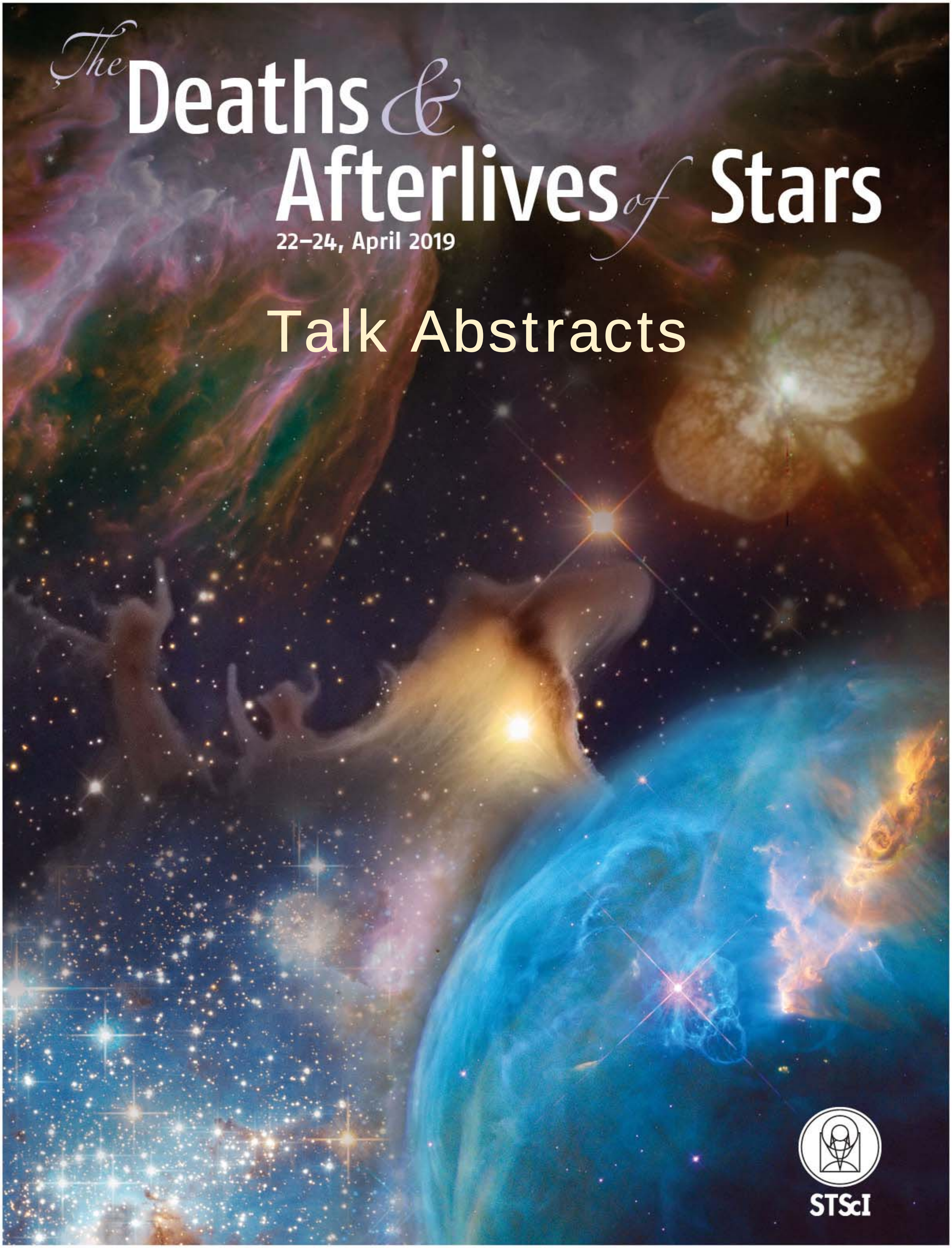
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Talk Abstracts
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David R. Aguilera-Dena (AIfA - Universität Bonn)

Progenitors of Type I SLSNe and Long GRBs

Modeling the evolution and mass loss history of rapidly rotating massive stars at low metallicity, we found that chemically homogeneously evolving stars with enhanced rotational mixing could be suitable candidates for both SLSNe in the magnetar-driven scenario and for lGRBs in the collapsar scenario. They retain a high angular momentum in their cores, enough to power these types of explosions, and have masses, magnetic fields and abundances that could also be consistent with observations of SLSNe and the hypernovae associated with lGRBs; particularly with the lack of He in their envelopes. The outcome of core collapse is determined by whether core collapse results in the formation of a fast spinning neutron star or a black hole. We analyze the evolution of these progenitors, as well as the parameter space where NS formation might favored over BH formation, and properties of their cores and of their CSM at core collapse.

Jennifer Andrews (Steward Observatory)

Mass Loss and Eruptions in Core Collapse Supernova Progenitors

The photometric and spectral evolution zoo of core collapse supernovae can be better understood if the mass loss histories of their progenitors are taken into context. While single massive star winds may explain some of the more benign and common CCSN explosions, other stronger forms of mass loss need to be invoked for higher luminosity or downright strange events. Further complicating matters is the high binary fraction among O stars which can play a role in the densities and geometries of mass loss. CCSN events powered by strong circumsteller medium interaction result from massive stars undergoing strong mass loss events in the months to years prior to explosion. The most luminous events may require mass loss rates consistent with eruptive episodes of LBVs, while the less extreme may be the result of periodic eruptions from YHGs, BSGs, or RSGs. Even normal Type IIP explosions show signs of enhanced or asymmetric mass loss from their RSG progenitors. In this talk I will discuss how mass loss and eruptive events in evolved massive stars impact the behavior of the terminal core collapse supernova.

Iair Arcavi (Tel Aviv University)

New Discoveries of Extreme Supernovae

I will review some recent discoveries of unusual and extreme supernovae and how they are pushing the limits of our understanding of supernova explosion physics and their progenitor properties.

Ashley Chrimes (The University of Warwick)

Exploring Progenitor Pathways for Long Duration Gamma-ray Bursts in Binary Stellar Evolution Models

The evolutionary pathways which lead to long-duration gamma-ray burst (GRB) progenitors are still uncertain. Any GRB progenitor must have a stripped envelope, be sufficiently massive, and have a rapidly rotating core. Pathways which have received attention in the literature include single star evolution with strong winds, or the spin-up of star by accretion from its binary companion and subsequent quasi-homogeneous evolution (QHE), leading to Wolf-Rayet type progenitors,. However, these pathways struggle to explain the presence of GRBs at solar metallicities, due to angular momentum loss through line-driven winds. We explore the impact of including binary tidal interactions in the BPASS (Binary Population and Spectral Synthesis) stellar evolution models, given an assumed initial rotation rate for massive stars. We find that tides will tend to spin-down massive stars while on the main sequence. We then investigate common envelope evolution, and determine which systems produce stars that end their lives with sufficient angular momentum for GRB production, due to the combination of initial spin, accreted angular momentum, the action of tides, mass loss and other dissipative processes. We discuss ongoing work, which includes a full prediction for the observed long-GRB rate based on BPASS progenitor pathways, for both primary and secondary stars and given reasonable distributions of initial mass function and binary distribution parameters.

Guido De Marchi (European Space Agency)

Polluting in Time and Space

Through a detailed study of the extinction properties in the Tarantula Nebula at ultraviolet, optical, and infrared wavelengths, we show that massive stars exploding as supernovae (SN) deeply alter the local interstellar medium (ISM) in regions where they have been forming over extended periods of time (~20 Myr). Compared to the diffuse Galactic ISM, the observed properties of the extinction curve include: a flattening at optical wavelengths, corresponding to a ratio of total-to-selective extinction Rv=Av/E(B-V) exceeding 4.5 and requiring fresh injection of big grains into the ISM; a steepening at wavelengths shorter than 2000 Å, requiring a larger fraction of small grains; and no appreciable variations in the fraction of very small carbonaceous particles (including possible graphitic grains and policyclic aromatic hydrocarbons) traditionally associated with the 2175 Å feature. In environments such as the Tarantula nebula, where formation of massive stars has been ongoing for over 10 Myr, a process able to naturally account for the injection of new grains is the explosion of massive stars as type-II SN. This modification is only temporary, lasting less than 100 Myr, because shattering will eventually affect the newly injected grains, breaking bigger grains, and shocks will ultimately destroy them and increase the abundance of small grains. However, this is the only time when star-forming regions are detectable as such in starburst and high-redshift galaxies. Improperly correcting the observed magnitudes using the standard Galactic extinction law will result in severely underestimated luminosities and masses for young massive stars, typically by a factor of 1.5 or more.

Selma E. de Mink (University of Amsterdam)

Progenitors of GW Detected Black Holes

Gravitational wave detections have started to reveal an emerging population of binary black holes. What does this population teach us about the physics of the lives and deaths of their progenitors, massive stars. I will try to review the main formation scenarios that are currently being discussed and highlight some recent results.

John Debes (STScI)

Finding Warm Dust Around a 3 Gyr White Dwarf via Citizen Science

Infrared excesses due to dusty disks have been observed orbiting white dwarfs with effective temperatures between 7200 K and 25000 K, suggesting that the rate of tidal disruption of minor bodies massive enough to create a coherent disk declines sharply beyond 1 Gyr after white dwarf formation. We report the discovery that the candidate white dwarf LSPM J0207+3331, via the Backyard Worlds: Planet 9 citizen science project and Keck Observatory follow-up spectroscopy, is hydrogen-dominated with a luminous compact disk ($L_{IR}/L_{\star}$=14%) and an effective temperature nearly 1000 K cooler than any known white dwarf with an infrared excess. The discovery of this object places the latest time for large scale tidal disruption events to occur at ∼3 Gyr past the formation of the host white dwarf, making new demands of dynamical models for planetesimal perturbation and disruption around post main sequence planetary systems. Curiously, the mid-IR photometry of the disk cannot be fully explained by a geometrically thin, optically thick dust disk as seen for other dusty white dwarfs, but requires a second ring of dust near the white dwarf's Roche radius.

Georgios Dimitriadis (University of California, Santa Cruz)

Early and Late-time Observations of Kepler's Brightest Supernova SN 2018oh

We will present detailed photometric and spectroscopic observations of SN 2018oh, a normal Type Ia supernova with exquisite photometric coverage from Kepler. The Kepler light curve shows an unusual two-component shape, where the flux rises with a steep linear gradient for the first few days, followed by a quadratic rise, as seen for typical SNe Ia. SN 2018oh is especially blue during the early epochs, belonging in the emerging class of SNe Ia with early blue flux excesses. Comparing the K2 light curve to several models that may provide additional heating at these early times, we slightly favor the interaction scenario with a 1-6 solar mass Roche-lobe-filling companion star, at a distance of ~2x10^12 cm. At the same time, nebular spectra of SN 2018oh show no signs of stripped Hydrogen and/or Helium in the ejecta, a direct prediction of the ejecta/companion collision scenario. Finally, we will discuss the implications of our early and late-time studies on the progenitor problem of SNe Ia.

Carolyn Doherty (Konkoly Observatory)

Impact of Rotation on the Low-mass/High-mass Star Divide

Super-AGB stars reside in the mass range ~ 6-10 Msun and bridge the divide between low/intermediate-mass and massive stars. They undergo off-centre carbon ignition prior to a thermally pulsing phase which can consist of many 10-1000s of thermal pulses. With their high luminosities and very large, cool, red stellar envelopes, these stars may appear seemingly identical to their slightly more massive red supergiant (RSG) counterparts and may act as massive star imposters. Important for both of these classes of star is rotation, and in particular its impact to the surface composition relative to the process of second dredge up. The chemical surface enrichment may result in a clear nucleosynthetic signature to differentiate between super-AGB stars and (massive star) RSGs. The refining of this mass boundary has important implications for the energetics and chemical enrichment of galaxies. Here we present a grid of rotating and non-rotating super-AGB star and low-mass massive star models either until the end of the thermally pulsing phase or until the point of core collapse.

Trevor Dorn-Wallenstein (University of Washington)

Stellar Population Diagnostics of the Massive Star Binary Fraction

A crucial ingredient in understanding stellar deaths is understanding the underlying population of stars that explode as supernovae. The distribution of supernova progenitors depends critically on the frequency of interacting binaries. In this work, we utilize custom synthetic stellar populations from the Binary Population and Stellar Synthesis (BPASS) code to determine the effect of stellar binaries on number count ratios of different evolutionary stages in both young massive clusters and galaxies with massive stellar populations as a function of the binary fraction. The BPASS populations include confirmed and proposed core-collapse progenitors such as red supergiants, yellow supergiants, classical Wolf-Rayet stars, and low-mass Wolf-Rayets whose outer layers have been shed via binary interactions. This allows us to examine the role of massive binary evolution in open questions such as the red supergiant problem and the production of stripped-envelope supernova progenitors. Comparisons between our predictions and observed data in the Milky Way and the Local Group also suggest a possible correlation between the massive star binary fraction and metallicity.

Eli Dwek (NASA Goddard Space Flight Center)

The Evolution of Dust in SN Ejecta

Supernova are very efficient producers of interstellar dust. Infrared (IR) observations of SN1987A show the presence of 0.5-1.0 Msun of dust 20 years after the explosion. Theoretical calculation of the chemical reactions and nucleation processes following the explosion suggest the rapid formation of dust in the ejecta. Dust formation models suggest that most of the dust is formed within 2-3 years after the explosion. In contrast, IR observations of SN1987A and several other SNe around that time period show the presence of only a small fraction, about 0.001, of the total mass of the condensible elements in the ejecta at that time.

In this talk I will address the origin of this discrepancy, and the ultimate fate of dust in expanding SN ejecta.

JJ Eldridge (University of Auckland)

EM and GW Transient with BPASS & CURVEPOPS

The Binary Population and Spectral Synthesis (BPASS) code is not an established tool for studying stellar populations in the Universe in the full variety of possible avenues. In this talk we will summarize our current results, findings and data products concerning supernovae and gravitational wave events. This will include presenting the our new supernova lightCURVE POPulation Synthesis project that attempts to gain further insight into the nature of supernova progenitors.

Jay Farihi (University College London)

Pandemonium in the Planetary Graveyard

Defying the notion of the silent graveyard, planetary systems refuse to die quietly. Instead, a significant fraction show one or more signs of dynamical reanimation, with strong indications of general mayhem during the last stages of stellar evolution. I will give a brief tour of these evolved and active planetary systems, which provide major insights into rocky planetary bodies in particular. These descendants of intermediate-mass stars reveal characteristics of their former planetary systems in ways unattainable by conventional methods using main-sequence stars. In particular, the metal pollution observed in white dwarf stars reveals the bulk chemistry of entire planetesimals or planetary fragments, including compelling evidence for Earth-like chemistry, planetary differentiation, and believe it or not - water. This talk will cover some of the highlights of the active planetary graveyard, including variability and transient behavior.

Andreas Floers (Max-Planck Institute for Astrophysics)

Constraints On the Explosion Mechanisms of Type Ia Supernovae from Optical and NIR Nebular Phase Spectroscopy

Even though Type Ia supernovae (SNe Ia) are widely used in cosmology, the debate about their progenitors remains unsettled. Many viable progenitor systems and explosion mechanisms have been proposed so far. Nucleosynthetic yields of neutron-rich iron group elements are the fingerprints of the explosion mechanism. Significant amounts can only be produced if the explosive burning occurs at high densities or metallicities.

In the nebular phase (t > 150d) when the outer layers of the supernova become transparent we can observe the core of the explosion which contains the iron-group elements. Until recently, SNe Ia in the nebular phase have been observed mainly in the optical. I will discuss how near-IR observations can help us constrain the excitation conditions of the iron core several hundred days after the explosion through non-LTE modelling of the first and second ionization stages of iron, cobalt and nickel. Furthermore, I will show that we can use these constraints to infer the abundances of neutron-rich iron group elements for a large sample of ~60 SNe Ia that only have optical nebular phase spectroscopy. Finally, I will link the results from the statistical analysis of the nucleosynthetic yields to theoretical explosion model predictions and argue implications on the progenitor system.

Nicola Giacobbo (Università di Padova)

Stellar Deaths As the Birth of Double Neutron Stars

GW170817 is the closest gravitational-wave event detected so far, and the only one associated with a double neutron star (DNS) merger. The LIGO-Virgo Collaboration inferred a quite high merger rate density of DNSs from GW170817 (110-3840 Gpc^-3 yr^-1, within 90% credible level), which cannot be easily explained with theoretical models. On the other hand, there is an increasing number of observational evidences that not all neutron stars are born with a large natal kick, as previously thought. For these reasons, I revised the treatment of natal kicks in my population-synthesis code MOBSE. In this talk I will discuss the results of new population-synthesis models and I will describe the crucial role played by the natal kick velocity in the formation of merging DNSs: only assuming low kicks for the NSs, it is possible to reproduce the merger rate inferred by the LIGO/Virgo Collaboration for both binary black holes and DNSs.

Ben Gompertz (University of Warwick)

The Diversity of Kilonova Emission in Short Gamma-Ray Bursts

We compare the light curve of the landmark kilonova AT2017gfo to the afterglows of all short gamma-ray bursts with a measured redshift of less than 0.5. We find several cases where a kilonova of the magnitude of AT2017gfo should have been detected (but was not), and many more where an AT2017gfo-like kilonova would have been masked beneath the bright SGRB afterglow. We also find that the current population of SGRB KN candidates were all brighter than AT2017gfo. Put together, this implies a significant diversity of kilonova emission.

Melissa L. Graham (University of Washington & LSST)

Identifying Non-Degenerate Companions in SNeIa via CSM Interaction

The nature and role of the binary companion to carbon-oxygen white dwarf stars that explode as Type Ia supernovae is not yet fully understood. Past detections of circumstellar material (CSM) that contain hydrogen for a small number of SNIa progenitor systems suggest that at least some have a nondegenerate companion. In order to constrain the prevalence, location, and quantity of CSM in SNIa systems, we performed a near-ultraviolet (NUV) HST survey to look for the high-energy signature of SNIa ejecta interacting with CSM. Our survey revealed that SN2015cp, a 91T-like overluminous SNIa, was experiencing late-onset interaction between its ejecta and surrounding CSM at 664 days after its light-curve peak. We present ground- and space-based follow-up observations of SN2015cp that reveal optical emission lines of H and Ca, typical signatures of ejecta-CSM interaction. We show how SN2015cp was likely similar to the well-studied SNIa-CSM event PTF11kx, making it the second case in which an unambiguously classified SNIa was observed to interact with a distant shell of CSM that contains hydrogen. The remainder of our HST NUV images of SNeIa were nondetections that we use to constrain the occurrence rate of observable late-onset CSM interaction. We apply theoretical models for the emission from ejecta-CSM interaction to our NUV nondetections, and place upper limits on the mass and radial extent of CSM in SNIa progenitor systems.

Aldana Grichener (Technion Institute of Technology, Israel)

R-process Nucleosynthesis in Common Envelope Jets Supernovae

We study r-process feasibility inside jets launched by a neutron star (NS) spiralling-in inside the core of a giant star, and find that such common envelope jets supernova (CEJSN) events might be a significant source of heavy r-process elements in the early Universe. We run the stellar evolution code MESA to follow the evolution of the low metallicity massive giant stars that swallow NSs and find that in many cases the NSs penetrate the core. The Bondi-Hoyle-Lyttleton mass accretion rate onto a NS as it spirals-in inside the core is sufficiently high to obtain a neutron rich ejecta as required for the strong r-process where the second and third peaks of r-process elements are synthesized. To account for the r-process abundances in the Galaxy we require that one in ten cases of a NS entering the envelope of a giant star ends as a CEJSN r-process event. We will study the mass loss episodes during the CEJSN r-process and show that we can explain the presence of r-process elements in very old stars that have very low iron abundances.

Jose Groh (Trinity College Dublin, The University of Dublin)

The Surprising Look of Massive Stars before Death

Most stars more massive than about 8 solar masses end their lives as a supernova (SN), an event of fundamental importance Universe-wide. The physical properties of massive stars before the SN event are very uncertain, both from theoretical and observational perspectives. In this talk, I will discuss recent efforts to constrain the properties of supernova progenitors based on radiative transfer modelling and numerical stellar evolution models. I will present the surprising predictions of spectral types of massive stars before death as a function of metallicity. Depending on the initial mass and rotation, the models indicate that massive stars die as red supergiants, yellow hypergiants, luminous blue variables, and Wolf-Rayet stars of the WN and WO subtypes. I will finish by discussing the latest results on the properties of early-time supernova and how they constrain the properties of stars immediately before death.

Carl-Johan Haster (LIGO Laboratory - MIT Kavli Institute for Astrophysics and Space Research)

Gravitational Wave Observations of a Population of Stellar Mass Black Holes

During the first two observation runs of Advanced LIGO and Virgo there have been 10 observations of binary black hole mergers. This enables astrophysically interesting statements about the population of stellar mass black holes in the local universe, what the global black hole merger rate is and provides new information about what stellar history this black hole population can have evolved from.

I will discuss the implications of the current gravitational wave observations on what stellar evolution models are supported, and how future black hole observations will improve them further.

Tim Heckman (Johns Hopkins University)

Supernova-Driven Galactic Winds

I will briefly review the relevant physical mechanisms by which the energy and/or momentum supplied by core-collapse supernovae drive galaxy scale outflows. I will use the nearby prototype M 82 to illustrate the multi-phase nature of these outflows, and then will summarize their systematic properties. I will conclude by describing the implications these results have on the evolution of galaxies and the inter-galactic medium

Anna Ho (Caltech)

A Ic-BL Supernova with Shock-cooling Emission, Discovered as a Fast optical Transient

Enabled by a large grasp ("etendue"), optical surveys can now probe the phase space of fast and rare transients. The richness of this phase space has been established with the discovery of over a hundred rapidly rising (<10 day) luminous transients. Here we present ZTF18abukavn (SN2018gep), discovered as a rapidly rising (1.3 mag/hr) transient only 20 minutes after first light. It is spectroscopically classified as a high-velocity stripped-envelope supernova (Ic-BL SN). The rapid rise, blue colors at peak (g-r = -0.3) and proximity (z=0.0315) establish SN2018gep as the second fast-luminous optical transient (after AT2018cow) studied up close in real time. We find that the light curve at Δt<10d is dominated by shock-cooling emission at large radii (10^14 cm), and by radioactive decay at Δt>10d. We detect no high-energy or radio emission, with limits an order of magnitude fainter than the lowest-luminosity gamma-ray bursts.

Jennifer Hoffman (University of Denver)

Leaving Traces: How Polarized Lines Reveal Properties of CCSN Progenitors

Polarized emission and absorption lines in core-collapse supernovae (CCSNe) trace detailed structures in the ejecta and surrounding circumstellar medium (CSM) that contain clues to the end stages of their progenitors' lives as massive stars. Extracting this geometrical information, however, requires careful computational modeling that takes into account the 3-D distribution of the ejecta and CSM and the potentially polarizing nature of line scattering. I present the results of such modeling for several CCSNe with multi-epoch polarization observations obtained by the Supernova Spectropolarimetry Project with the SPOL spectropolarimeter. In the cases of "interacting supernovae," time-variable line polarization can constrain the shape and density of the surrounding CSM, yielding valuable information about the progenitor's late-stage mass loss episodes. In stripped-envelope supernovae, it provides new, quantitative evidence for the asymmetric nature of the explosions and the possible role of binary companions in shaping the supernova ejecta.

Andy Howell (Las Cumbres Observatory / UCSB)

Connecting SNe to their Progenitors with the Global Supernova Project

The Global Supernova Project is a Key Project at Las Cumbres Observatory, gathering lightcurves and spectroscopy on hundreds of supernovae over several years. We use 22 robotic telescopes spread around the world to obtain rapid and sustained follow-up. I'll show recent results, highlighting the unique capabilities of the network. One set of results involves early lightcurve bumps in SNe Ia, predicted to occur when the supernova ejecta hit the companion star. LCO has played a key role in nearly every claim, including SN 2012cg, iPTF14atg, iPTF16abc, SN 2017cbv, and SN 2018oh. I'll show ten new SNe Ia with data early enough to probe such possible interaction. I'll also talk about core collapse supernovae, and attempts to infer progenitors from their properties, including modeling with MESA and other techniques. In particular I'll focus on two rare SNe with short plateaus. They aren't as stripped as SNe IIb, so what could cause serious but incomplete mass loss? They appear to arise from progenitors with ZAMS masses larger than a typical core-collapse SN.

Eric Hsiao (Florida State University)

Observational Clues on the Origins of "Super-Chandrasekhar" Type Ia Supernovae

Since the discovery of the first "super-Chandrasekhar" Type Ia supernova (SN Ia) candidate by the Supernova Legacy Survey, more objects have been identified as belonging to the same class, yet their progenitors and explosion mechanisms still remain unclear. New data from the Carnegie Supernova Project (CSP) of several candidates of this class will be presented, and they offer new clues to the origins of these "super-Chandrasekhar" SNe Ia in general. With the wide wavelength coverage of the CSP data, these objects are shown to be photometrically and spectroscopically distinct in the infrared, while in most cases their properties in the optical are largely indistinguishable from those of normal SNe Ia. I will also show that if these objects have a separate origin from the normal SN Ia population, they could have profound impact on dark energy experiments.

Jacob Jencson (Caltech)

Uncovering Hidden Stellar Explosions with Spitzer

The census of nearby core-collapse supernovae (CCSNe) and other energetic massive star outbursts is incomplete, even in the local 40 Mpc volume. Despite enormous progress enabled by wide-field transient surveys, mostly in the optical, many such events are missed due to dust obscuration. Searches at longer wavelengths offer an ideal platform to discover these missing stellar explosions. I will present results from 5 years of SPIRITS, the Spitzer Infrared Intensive Transients Survey, an ongoing search of nearby galaxies for transients in the Spitzer/IRAC 3.6 and 4.5 micron imaging bands. We have discovered a sample of 9 luminous infrared transients, of which 5 are likely heavily dust-extinguished CCSNe based on detailed, multi-wavelength characterizations. In a direct comparison to a control sample of optically discovered CCSNe in SPIRITS galaxies, we find that 38% of CCSNe are being missed in nearby galaxies due to heavy extinction. The remaining events in our sample span diverse classifications including a massive star merger, a possible electron-capture supernova of an extreme AGB star, and self-obscuring eruptions of very massive, evolved stars. These results indicate that a broad array of eruptive and explosive stellar phenomena are waiting to be uncovered by new and upcoming infrared transient searches.

Jennifer Johnson (Ohio State University)

Origin of the Elements

Wolfgang Kerzendorf (NYU/MSU)

The Siblings of Cas A

Type IIb supernovae are often thought of as the "missing link" between core-collapse supernovae that show hydrogen to those which do not. One popular interpretation for this sequence of transients is that these are collapsing massive stars with increasing amount of envelope stripped by their binary companions. This interpretation makes a prediction: a surviving companion at the sites of stripped core-collapse remnants. Several recent studies have tried to identify the remnant to Cas A - a nearby IIb remnant - without success but deep limits. One alternate explanation explaining the mass-loss is that the progenitors are extremely massive stars ejecting their envelopes via winds.

In this talk, I will show that the identification of birth clusters is a powerful probe for the progenitor of Cas A (and core-collapse remnants in general). We have identified the likely origin cluster of the progenitor Cas A within the Gaia dataset. I will present our analysis of said cluster. I will conclude with the implications on stripped envelope science.

Charlie Kilpatrick (University of California, Santa Cruz)

Constraints on Long-lived Radioisotopes from the Gravitational Wave Counterpart AT 2017gfo

The gravitational wave source GW170817 from a binary neutron star merger was associated with a transient AT 2017gfo, which is best described by theoretical models of a kilonova consisting of radioactive elements produced by rapid neutron capture (the r-process). Although the total mass of r-process elements was well-constrained by AT 2017gfo's optical and near-infrared light curves, efforts to constrain the abundance pattern of these species have been less successful. I will present new analysis of the complete radio to X-ray light curve of AT 2017gfo, including the kilonova and late-time, non-thermal afterglow arising from an off-axis jet launched by the merger. I will show constraints on the presence of late-time infrared emission that cannot be accounted for by either of these two components. I will discuss what this implies for the presence of long-lived radioisotopes such as Cf-254 and how these constraints can be used to map the abundance pattern of the AT 2017gfo ejecta and future kilonovae.

Eva Laplace (API University of Amsterdam)

The Size of Stripped-envelope Supernovae Progenitors and Its Impact on Gravitational Waves Events

Stripped-envelope and ultra-stripped envelope supernovae mark the death of massive stars that have lost their H-rich envelope and are related to exotic events such as long gamma-ray burst progenitors and to the formation of gravitational waves sources. The progenitors can result from binaries that experience one or more phases of mass transfer and lead to a variety of events, some of which are very fast and faint. New fast cadence and deep surveys are expected to dramatically increase the number of detected events in the near future.

At present, theoretical predictions for their light curves based on self- consistent binary evolutionary models are still very scarce. We present a new extended grid of full binary evolutionary models and the resulting light curves computed using hydrodynamic simulations (MESA and SNEC).

We study their properties as a function of initial mass and metallicity. At high metallicity, we find that practically all the hydrogen is removed and low-mass systems can evolve to large sizes. At low metallicity, a substantial amount of hydrogen is left and the progenitors can in principle expand to giant sizes or fill their Roche lobe a second time. In particular, we show that the prescriptions commonly used in population synthesis models underestimate the radius by up to two orders of magnitude and that this impacts the number of gravitational waves sources from double neutron star mergers.

We are planning to release a large library of theoretical light-curves of stripped-envelope supernovae in anticipation of the up-coming transient surveys such as ZTF, LSST, and Pan-STARRS.

Emily Levesque (University of Washington)

Rotation and Mass Loss in Luminous Blue Variables

Luminous blue variables (LBVs) are an intermediate stage in the evolution of extremely high mass (>40Mo) stars. They represent a crucial pre-supernova step for these stars, characterized by extreme mass loss, substantial variability, and occasional eruptions that have been mistaken for supernovae in their own right. Despite their importance there are a number of open questions regarding LBVs (even a working definition of this class of stars is still in flux). One key question concerns the physical mechanism that triggers their sporadic increases in mass loss and resulting horizontal evolution back and forth across the H-R diagram; this is the primary process by which LBVs shed mass and strongly impacts their evolution and the production of Type IIn supernovae. This talk presents new work on the role of rotation in triggering instabilities in LBVs, their subsequent mass loss and observable signatures, and implications for these stars' evolution and terminal supernovae.

Laura Lopez (Ohio State University)

Tying Supernova Remnants to Their Progenitors

Supernova remnants (SNRs), which are observed long after original SN events, provide a unique opportunity to probe progenitors. Specifically, stellar populations in the vicinities of SNRs can be used to constrain the progenitor's lifetime and mass. In this talk, I will summarize recent findings using the star-formation history (SFH) maps of Harris & Zaritsky of the Large and Small Magellanic Clouds (LMC and SMC) to probe the progenitors and explosion types of the ~75 SNRs in those galaxies. In the case of the SMC, we find that 22 out of 23 SNRs have SFHs and properties consistent with core-collapse (CC) explosions, several from high-mass progenitors. We estimate the mass distribution of the CC progenitors and find it to be similar to a Salpeter initial mass function (IMF), different from the shallower IMF found in M31 and M33 recently using a similar approach. Furthermore, we find that several SMC SNRs are located where bursts of star formation occurred 50-200 Myr ago. If the progenitors formed during that time, then the massive stars underwent delayed CC explosions as a consequence of binary interaction, rapid rotation, or low metallicity. I will compare these results to those found in M31 and M33.

Ragnhild Lunnan (Stockholm University)

What Powers Superluminous Supernovae?

Superluminous supernovae (SLSNe) are a rare class of transients discovered by untargeted surveys in the past decade, characterized by bolometric luminosities 10-100 times those of normal core-collapse and Type Ia SN. Now more than a decade after their discovery, their energy sources and progenitor stars are still debated. In this talk, I will provide a review of SLSNe, addressing their nature from two angles: 1) characterizing the explosions themselves and comparing the observed properties to model predictions, and 2) constraining the progenitor population through studies of the SLSN host galaxy environments.

Paola Marigo (University of Padova, Italy)

Carbon Star Formation in the Milky Way as Seen through the Initial-final Mass Relation

Carbon is essential to life on Earth, but its origin in the Milky Way (MW) is still debated: some studies place the major site of its synthesis in the winds of massive stars that eventually exploded as supernovae, others are in favour of low-mass stars that blew off their envelopes by stellar winds and became white dwarfs (WD). Within the latter group, the primary sources of carbon are the winds of carbon stars, characterised by a photospheric carbon-to-oxygen ratio (C/O) >1, which form during the thermally-pulsing asymptotic giant branch (TP-AGB) phase as a consequence of repeated third dredge-up episodes. To date, the range of initial masses of carbon stars and their chemical ejecta are not accurately known from theory since these quantities depend on a number of complex physical processes that are difficult to model, convection and mass loss above all.

Here we show that the initial-final mass relation (IFMR) of WDs contains the signature of carbon star formation in the MW. It manifests itself as a kink located over a range of initial masses, 1.65 <= Mi/Msun <= 2.1. The lower limit, in particular, marks the minimum initial mass for carbon stars at solar metallicity, hence it identifies the oldest age (~ 2.2 Gyr) at which carbon stars started to contribute to the chemical enrichment and to integrated light of galaxies similar to the MW.

Coupling the new IFMR data with the results of state-of-the-art dynamical atmosphere models for carbon stars, I will discuss the impact of this finding on the evolution and chemical yields of low-mass stars with solar-like metallicity, and highlight the important implications to the spectro-photometric evolution of galaxies.

The Evolution of Binaries in a Gaseous Medium: Three-Dimensional Simulations of Binary Bondi-Hoyle-Lyttleton Accretion

Andrea Antoni (University of California, Berkeley)

Binary systems in gaseous environments may evolve more quickly than via gravitational wave (GW) radiation alone. In these environments, the merger of binary black holes (BBHs) may be accompanied by electromagnetic emission. The disks of active galactic nuclei (AGN), in particular, readily trap and assemble stellar-mass BBHs. Drag forces and accretion rates dictate how these systems are transformed due to the gas. Here, we describe the results of three-dimensional hydrodynamic simulations of binaries embedded in Bondi-Hoyle-Lyttleton flows. The simulations indicate that a binary's center-of-mass motion is slowed over a shorter timescale than the pair inspirals or accretes and that the timescale for orbital inspiral is proportional to the semi-major axis to the 0.19 power. This positive scaling implies that gaseous drag forces can drive binaries either to coalescence or to the critical separation at which GW radiation dominates their further evolution. We provide the critical separation between gas- and GW-dominated inspiral and discuss the implications of these results for binaries in AGN disks and in common envelope phases.

Maryam Modjaz (New York University)

Impact of Metallicity on the Diverse Deaths of Massive Stars

I will review the observational evidence pertaining to the question of what is the impact of metallicity on the diverse deaths of massive stars, both for normal explosions such as stripped core-collapse SNe as well as for extreme explosions such as GRBs.

In particular I will discuss the question of SNe Ic-bl with and without GRBs by presenting our brand-new work on the largest host galaxy datasets from the same untargetted survey, namely the Palomar Transient Factory, which yielded some surprising and exciting results.

Jeremiah Murphy (Florida State University)

Toward Predicting and Constraining the Explosions of Massive Stars

Simulations of core-collapse supernovae (CCSNe) suggest that neutrinos and convection are important in driving explosions. Comparisons between one-dimensional and multi-dimensional simulations also suggest that this convection reduces the neutrino power required for explosion by about 30%. We develop a mean-field model for neutrino-driven convection and show that it indeed reduces the explosion condition by 30%. These derivations also indicate that turbulent dissipation plays an important role in this reduction. While multi-dimensional simulations are guiding our understanding, they are computationally expensive. For example, a resonable systematic exploration of which models explode could easily take 100s of years. To more rapidly facilitate these predictions, we include our mean-field convection model in one-dimensional simulations. These 1D+ simulations mimic the explosion conditions of the multi-dimensional simulations but are 100,000 faster. To prepare for the eventual predictions, we also constrain which stars actually explode. We age-date the stellar populations surrounding SNe and SNRs and infer their progenitor masses. To date, there are 300 progenitor mass estimates, and they place constraints on the distribution of stars that explode. For example, we find that the minimum mass for explosion is 7.3 +\- 0.1 solar masses, and the maximum mass is greater than 59 solar masses. The power law distribution between these limits is -2.95^{+0.45}_{-0.25}.

Ambra Nanni (Aix Marseille Univ, CNRS, CNES, LAM, Marseille, France/University of Padova)

Dust from Stellar Deaths

During the thermally pulsing asymptotic giant branch (TP-AGB) phase, low- and intermediate-mass stars lose mass at high rates, enriching the interstellar medium of galaxies with metals and dust. The dense environment of the circumstellar envelopes of TP-AGB stars represents the ideal site for dust condensation. Stellar pulsation triggers shock waves that lift the gas above the stellar surface where the temperature is low enough to allow solid particles to form and to accelerate the outflow if sufficient momentum is transferred. Despite the importance of TP-AGB stars as dust factories, many questions related to the dust production process and the dust properties, as well as the mass-loss mechanism, remain unanswered. In this talk I will review what we learned from observations of TP-AGB stars, as well as the most recent advancements in theoretical modelling and the challenges that lie ahead.

Enrico Ramirez-Ruiz (University of California, Santa Cruz)

Cosmic Alchemy in the Era of Gravitational Wave Astronomy

The source of about half of the heaviest elements in the Universe has been a mystery for a long time. Although the general picture of element formation is well understood, many questions about the nuclear physics processes and particularly the astrophysical details remain to be answered. Here I focus on recent advances in our understanding of the origin of the heaviest and rarest elements in the Universe.

Sofia Ramstedt (Uppsala University, Sweden)

Stellar Winds with ALMA

The deaths of stars are always preceded by more or less massive stellar winds. In the case of low- to intermediate mass stars, these winds are the means by which material from the stars is recycled in galaxies. Accurate measurements of the wind physical properties provide constraints for hydrodynamical models which study wind formation and evolution. Estimates of wind density and temperature also form the base for any further research into abundances of different elements, isotopes and molecules in the recycled material. Furthermore, to determine wind gas-to-dust mass ratios holds the key to investigations of extragalactic objects and the impact of these common stars across the Universe.

We have lately performed detailed studies of the circumstellar envelopes (CSEs) around nearby (<500 pc) stars on the Asymptotic Giant Branch (AGB) with ALMA. The properties of the wind which has created the CSE, can be derived by mapping the CO line emission. We started with a smaller sample of binary stars to investigate the formation and importance of circumstellar asymmetries and structure. To interpret the complex observations, several new analysis tools had to be assembled and tested. These tools are now put to use for the DEATHSTAR project in which we are mapping all nearby AGB stars starting in the southern sky. The goals are to provide the most accurate AGB wind properties to date, and to consistently determine the gas-to-dust mass ratios. I will present results and current status.

Nathaniel Roth (University of Maryland, College Park)

The Aspherical Cow: Interpretation of Multi-Wavelength Observations of AT2018cow

The fast blue optical transient AT2018cow has provided an unprecedented view of the extreme outcomes that may result from stellar death. Its properties pose challenges to any model of its emission, combining a remarkably fast light curve decline (flux dropping by a factor of 100 in $<$ 25 days) with a peak luminosity greater than type-I superluminous supernovae. I will present a comprehensive suite of observations across the electromagnetic spectrum, from radio to gamma rays, of the first ~100 days of the event. We interpret these as signals of an aspherical explosion, with a distinct transition in emission properties at ~20 days after discovery. Either a compact object central engine or a deeply embedded shock is required to explain the data. Our favored models include an electron capture supernova that produces a magnetar, or the failed explosion of a blue supergiant followed by black hole accretion.

Raghvendra Sahai (JPL, California Institute of Technology)

Binarity and the Formation of Bipolar and Mutipolar Pre-Planetary and Planetary Nebulae

Understanding strong binary interactions is of wide astrophysical importance. The deaths of a vast fraction of stars in the Universe that evolve in a Hubble time can be fundamentally affected by such interactions. Imaging surveys of large samples of pre-planetary and planetary nebulae with HST show that almost all objects have bipolar, multipolar and elliptical morphologies, and there is widespread presence of point-symmetric structure. This dramatic transformation of the spherical outflows of AGB stars into the extreme aspherical geometries in planetary nebulae is widely believed to be linked to strong binary interactions and is likely driven by the associated production of fast jets and central disks/torii. The key to understanding the engines that produce these jets and the jet-shaping mechanisms lies in the study of objects in transition between the AGB and PN phases. I present results from multiwavelength studies (X-Ray to radio) of key transition objects that highlight observational techniques being used to (a) determine the ages and momenta of the jet outflows which can be used to constrain the properties of the jet engines, and to (b) provide evidence for binarity during the AGB phase. The advent of large future astrophysics facilities such as Lynx and Athena (X-ray), LUVOIR (UV) and ngVLA (radio) promises to revolutionize the study of strong binarity interactions on the AGB that may be instrumental in the demise of these stars.

Sumit K. Sarbadhicary (Michigan State University)

Local Group Delay Time Distributions (DTDs): A New Perspective on Progenitor Models Using Resolved Stellar Populations

Our understanding of supernova (SN) progenitors is far from complete. For example, for Type Ia SNe, it is unclear whether the primary white dwarf interacts with a non-degenerate star, or another white dwarf prior to explosion. For core collapse SNe, it is unclear whether supergiants above 18 Msun produce visible transients, or directly collapse to black holes. Direct detection of progenitors in pre-explosion images is not always feasible, and interpreting progenitors from observations of SN light curves, spectra and/or host environments is challenging and not always unambiguous.

A promising method for discriminating SN progenitor scenarios is by measuring their delay time distribution (DTD) - the SN rate vs time-delay since a hypothetical burst of star formation. A DTD basically characterizes the formation efficiency of SNe versus the progenitor age, thus providing a direct constraint on progenitor models. While originally measured with SN surveys and the star formation histories of the surveyed galaxies, DTDs can be measured most reliably in the Local Group galaxies where stellar populations are resolved and star formation histories are not luminosity-weighted and spatially averaged over the galaxy.

In this talk, I will describe our group's efforts to measure SN DTDs in the Local Group using supernova remnant surveys. I will also demonstrate the power of the method in understanding stellar evolution by applying it to objects with independent constraints on progenitors, such as RR Lyrae and Cepheids. Finally I'll discuss our initial results on measuring DTDs of massive stellar species such as red supergiants, LBVs and Wolf Rayets, which will provide constraints on the impact of binarity and relevant pre-supernova physics of massive progenitors.

Ken Shen (University of California, Berkeley)

The Current View of Type Ia SN Progenitors

Despite the wide-ranging role Type Ia supernovae (SNe Ia) play throughout astrophysics, we lack a firm theoretical understanding of how they arise. For decades, the "single-degenerate" scenario, in which an accreting white dwarf reaches the Chandrasekhar mass, held way. However, as I will discuss, recent observational and theoretical advances have spurred researchers to explore alternative scenarios. I will highlight the successes of one of these alternative scenarios, the "Dynamically Driven Double-Degenerate Double-Detonation" (D6) scenario, which led to the first-ever discovery of surviving SN Ia companions, bringing the D6 scenario to the forefront of the field as the only known SN Ia progenitor scenario to succeed in nature.

Stephen Smartt (Queen's University Belfast)

Which Stars Explode?

I will present a broad review of our current observational constraints of supernova progenitors, with an emphasis on direct progenitor detections and the implied progenitor mass range that produces the local population of core-collapse supernovae.

Niharika Sravan (Purdue University)

A Comprehensive Population-scale Modeling of Type IIb Supernova Progenitors

The mechanisms driving removal of envelopes of stripped-envelope supernova (SE SN) progenitors is a key challenge to our understanding of massive star evolution. Type IIb SNe are particularly valuable for addressing this challenge because of the wide variety of observational constraints available for them, most notably, direct progenitor/companion identifications in several cases. We undertake an unprecedented population-scale modeling effort using MESA to test our ability to reproduce all observational constraints for Type IIb SNe. Our comprehensive grid of ~150,000 models span the full parameter space occupied by single and binary SN IIb (in progenitor mass, mass ratio, orbital separation, and mass transfer efficiency) at solar and low metallicities.

As already widely suggested, we find that Type IIb SN fractions imply that binaries comprise of the vast majority of Type IIb SNe. However, the models require significantly lower wind mass loss rates at solar metallicity and highly inefficient mass transfer. We find observational parameter spaces that are currently unprobed but highly constraining for mass loss rates due to stellar winds and eruptions. In particular, our models indicate the presence of a population of highly-compact nearly-fully-stripped progenitors and episodic mass loss in progenitors in the years leading up to core-collapse.

Tuguldur Sukhbold (Ohio State University)

Missing Red Supergiants and Carbon Burning

Recent studies on direct imaging of Type II core-collapse supernova progenitors indicate a possible threshold around Mzams~16-20 Msun, where red supergiants with larger birth masses do not appear to result in supernova explosions, and instead possibly imploding directly into a black hole. We argue that it is not a coincidence this threshold closely matches with the critical transition of central carbon burning in massive stars from convective to radiative regime, afterwich the stellar cores become significantly harder to blow up. Using the KEPLER code we demonstrate the sensitivity of this transition to the rate of 12C(alpha,gamma)16O reaction and the overshoot mixing efficiency, and we argue that the upper mass limit of exploding red supergiants could be employed to constrain uncertain input physics of massive stellar evolution calculations. Currently available observational constraints suggest that the carbon burning transition should be achieved at Mzams<20 Msun. We also provide discussions on the future prospects of observationally narrowing down this threshold, and also on recently proposed alternative explanations.

Eleonora Troja (University of Maryland)

Electromagnetic Emission from NS Mergers

Brian Williams (NASA GSFC)

The Expansion of the Young Supernova Remnant 0509-68.7 (N103B)

We present a second epoch of Chandra observations of the Type Ia LMC SNR 0509-68.7 (N103B) obtained in 2017. When combined with the earlier observations from 1999, we have a 17.4-year baseline with which we can search for evidence of the remnant's expansion. Although the lack of strong point source detections makes absolute image alignment at the necessary accuracy impossible, we can measure the change in the diameter and the area of the remnant, and find that it has expanded by an average velocity of 4170 (2860, 5450) km/s. This supports the picture of this being a young remnant; this expansion velocity corresponds to an undecelerated age of 850 yr, making the real age somewhat younger, consistent with results from light echo studies. Previous infrared observations have revealed high densities in the western half of the remnant, likely from circumstellar material, so it is likely that the real expansion velocity is lower on that side of the remnant and higher on the eastern side. A similar scenario is seen in Kepler's SNR. N103B joins the rare class of Magellanic Cloud SNRs with measured proper motions. I will discuss the implications of young SNRs interacting with a dense circumstellar medium for the progenitors of these systems.

Stan Woosley (University of California, Santa Cruz)

The Deaths of Massive Stars

The endpoints of stellar evolution for massive stars from 8 to 150 solar masses will be briefly reviewed. Common Type IIp supernovae come from isolated or detached stars that explode by neutrino transport and leave neutron star remnants. Typical main sequence masses are 12 Msun and the neutron star mass distribution and pulsar rotation rate are reasonably well reproduced by the models. Rotation is more important in heavier stars. There is no unique mass above which stars explode, but explosions of single stars above 20 Msun are rare. The average black hole mass for single stars is near 10 Msun. Mass exchanging binaries behave differently, partly because the helium core shrinks rather than growing during helium burning. Stars of a given initial mass are easier to explode in binaries and black hole production is a rarer event. A broad range of masses make Type Ib and Ic supernovae. There is a peak in the black hole birth function around 8.5 Msun and no black hole with mass between 46 and 133 Msun is produced. The heaviest CO-white dwarf made in a binary is 1.27 Msun. Some unusual types of supernovae are predicted.


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The Formation of 'Columns Crowns' by Jets Interacting with a Circumstellar Dense Shell

Mohammad Akashi {(1)Technion, IIT (2)Kinnerent College (Israel)}

We conduct three-dimensional hydrodynamical simulations of two opposite jets that interact with a spherical slow wind that includes a denser shell embedded within it, and obtain a bipolar nebula where each of the two lobes is composed of two connected bubbles and Rayleigh-Taylor instability tongues that protrude from the outer bubble and form the 'columns crown'. The jets are launched for a short time of 17 years and inflate a bipolar nebula inside a slow wind. When the bipolar structure encounters the dense shell, the interaction causes each of the two lobes to split to two connected bubbles. The interaction is prone to Rayleigh-Taylor instabilities that form tongues that protrude as columns from the outer bubble. The bases of the columns form a ring on the surface of the outer bubble, and the structure resemble a crown that we term the columns crown. This structure resembles, but is not identical to, the many filaments that protrude from the lobes of the bipolar planetary nebula Menzel 3. We discuss our results in comparison to the structure of Menzel 3 and the ways by which the discrepancies can be reconciled, and possibly turn our failure to reproduce the exact structure of Menzel 3 to a success with jets-shell interaction simulations that include more ingredients.

Hunting for Minute-timescale Extragalactic Optical Transients

Igor Andreoni (Caltech)

The sub-hour optical time domain is still largely unexplored. I will present the results of searches for fast optical optical transients using the Dark Energy Camera (DECam), a sensitive wide-field imager at CTIO. DECam allowed us to search for transients with continuous 20s exposures, for a total of 25 hours, over an area of 2.5 deg2 per pointing and at depth >23 magnitudes. The search returned hundreds of transient and variable sources, 5 of which passed our selection criteria. I will discuss the comparison of the light curves of our discovered transients with stellar flare models. An additional comparison between stellar flare models and a confirmed GRB flash suggests that light curves alone cannot discriminate between the Galactic or extragalactic nature of fast transients. Finally, I will introduce similar searches performed with the Zwicky Transient Facility, whose large field of view of 47 deg2 allows us to survey the sky in unprecedented ways.

Radial Distribution of SNe vs Star Formation Tracers

Fiona Audcent-Ross (ICRAR – UWA)

Given the limited availability of direct evidence (pre-explosion observations) for supernovae (SNe) progenitors, the location of SNe within their host galaxies can be used to set limits on one of their most fundamental characteristics, the initial mass of their progenitors. We present our constraints on the progenitors of Type Ia, Type II and stripped-envelope SNe (SE SNe), derived from comparing the radial distributions of 78 SNe in the SINGG and SUNGG surveys to the R-band, \HA{}, NUV and FUV fluxes of the 59 host galaxies. The strong correlation of SINGG Type Ia SNe with R-band fluxes is expected with progenitor models containing only low mass progenitors, such as the double degenerate model. SINGG Type Ia SNe do not trace FUV fluxes implying that the single degenerate model, which invokes a main sequence companion to the white dwarf progenitor, is an unlikely major progenitor stream for Type Ia SNe. Within smaller apertures containing 90 per cent of the total flux the radial distribution of the Type II SNe best traces FUV fluxes. This result is in line with the growing number of direct detections indicating that Type II SNe have moderately massive red supergiant progenitors. The 15 SE SNe have the strongest correlation with \HA{} fluxes, consistent with very massive progenitors (M$_{*} \gtrsim ~20$ \MS{}). This result is in contradiction with a small, but growing, number of direct detections of SE SNe progenitors revealing a predominance of moderately massive binary systems but is consistent with a recent population analysis of SE SNe locations suggesting binary progenitor masses are regularly underestimated. The SE SNe are centralised with respect to Type II SNe and there are no SE SNe recorded in the outer third of the FUV apertures and none in the outer ~20 per cent of the R-band apertures. The observed deficit of SE SNe is consistent with reduced massive star formation efficiencies in the outskirts of the SINGG galaxies.

Revealing the Evolution of High-mass Binaries Using Gravitational-wave Observations

Christopher Berry (CIERA, Northwestern University)

The binary black holes observed by LIGO and Virgo provide a new source of information regarding the end-points of stellar evolution. Multiple potential formation channels have been suggested for these binaries, and each of these have associated physical uncertainties. The details of the formation channels leave imprints on the properties of the binary black holes, such as masses and spins. From these, we can infer how binary black holes form. With 1000 detections, we can use the chirp-mass distribution and merger rate to constrain population parameters for isolated binary evolution (such as common-envelope efficiency, natal kicks and mass-loss rates) to precision of a few percent. The merger rate is expected to evolve with redshift. This can be non-parametrically reconstructed, and used to further enhance constraints on binary evolution. Combining all the information from gravitational-wave observations will provide a tough test of our best models of binary evolution.

Results from Deep Multi-Wavelength Surveys of Nearby Galaxies to Study Supernova Remnants and Their Progenitors

William P. Blair (Johns Hopkins University and STScI)

Supernova remnants (SNRs) are central to the overall cycle of star formation and evolution, depositing both energy and processed stellar ejecta back into the ISM of a galaxy. On the largest scales, the ensemble of SNRs in a galaxy thus becomes integral to the evolution of a galaxy as a whole. We will report key results from a multi-year, multi-wavelength campaign to identify and characterize the SNR populations in nearby galaxies, using observational techniques as diverse as ground-based imaging and spectroscopy, HST optical and near IR imaging in emission line and continuum bands, deep Chandra and XMM-Newton X-ray imaging surveys, and deep radio multi-frequency observations (to separate photoionized and non-thermal sources).

We have focused our efforts especially on M33, M83, and NGC 6946, all relatively nearby and nearly face-on spiral galaxies. M33 is of course the closest of these (816 kpc), so the SNR morphologies and diameters are revealed even at ground-based resolution, but the large angular size of M33 makes surveys challenging. Some 220 optical SNRs have been located, 112 of which have X-ray counterparts. At radio wavelengths (White et al., this symposium) we detect 155 of the optical SNRs, and we show that the current generation of models for the radio emission are inadequate to explain the observations. No ejecta-dominated or Crab Nebula-like SNRs have been identified.

M83 (4.6 Mpc) and NGC 6946 (6.7 Mpc) are both star-forming spiral galaxies that have hosted record numbers of historical SNe, and are close enough that HST resolution provides diameter estimates and morphology information for many of the SNRs. Despite the apparent frequency of SNe and numerous small-diameter (<10 pc) SNRs, only the remnant of SN 1957D in M83 shows evidence for ejecta in the form of broad lines exclusively from heavy elements. We have, however obtained spectra from the “old SNe” SN1980K and SN2004et, (both in NGC 6946), plus the remnant of another SN that evidently exploded in M83 in the 20th century but was not observed. The spectra from all these indicate interaction of fast shocks with circumstellar shells. Thus, we find a paucity of young ejecta-dominated SNRs which may be due to very rapid evolution of most core-collapse SNe into an ISM-dominated state.

We are using HST multi-band stellar photometry of stars adjacent to SNRs to constrain the progenitor masses of core collapse SNe. Recently, we have run this analysis on over 200 of the SNRs in M83 and compared the results with Local Group galaxies. Some progenitors are demonstrably above 20 Msol, and the progenitor mass distribution appears to be more top-heavy than found for SNRs M33 and M31.

What Can Supernovae Tell Us About Massive Stars?

K. Azalee Bostroem (UC Davis)

Massive stars, the progenitors of core-collapse supernovae (CCSNe), are not well understood, especially as they near core-collapse. Modelling multi-wavelength observations that span the photometric and spectroscopic evolution of a supernova allows us to describe the progenitor star (e.g. mass, radius, mass-loss history), as well as the explosion parameters (e.g. explosion energy, explosion asymmetry, and nucleosynthesis yields). We will discuss the progenitor models of two CCSNe: ASASSN-15oz and DLT18aq (2018ivc) as well as future work to characterize the progenitors of a sample of CCSNe through light curve and nebular spectra modeling.

Finding Millisecond Pulsars to Explain the Fermi Gamma-ray Excess

Christopher Britt (Space Telescope Science Institute)

We have performed new 1.4 GHz and 5 GHz observations of the Local Group galaxy M33 with the Jansky Very Large Array. Our survey has a limiting sensitivity of 20 µJy (4-sigma) and a resolution of 5.9 arcsec (FWHM), corresponding to a spatial resolution of 24 pc at 817 kpc. Using a novel multi-resolution algorithm, we have created a catalog of 2875 sources, including 675 with well-determined spectral indices.

Along with numerous H II regions, we detect 155 of the 217 optical supernova remnants included in the lists of Long et al. (2010) and Lee & Lee (2014). Current X-ray surveys have detected 98 of the radio-detected remnants, making this by far the largest sample of remnants at known distances with multiwavelength coverage. In M33 we can directly compare the X-ray, optical, and radio properties for a larger sample of supernova remnants at a common distance than for any other galaxy. The remnants show a large dispersion in the ratio of radio to X-ray luminosity at a given diameter, a result that challenges the current generation of models for synchrotron radiation evolution in supernova remnants. We will report the results of exploring the high-dimensional dataset using tools such as principal component analysis and t-SNE. This approach will be helpful for studies of the X-ray source population by distinguishing background AGNs from sources in M33.

Richard L. White, Knox S. Long, Robert H. Becker, William P. Blair,
David J. Helfand, & P. Frank Winkler

Ultraviolet Diversity of Standard Candles

Peter Brown (Texas A&M University)

Ultraviolet spectroscopic observations with the Hubble Space Telescope are explaining some of the diversity seen in nearby Type Ia supernovae with the Neil Gehrels Swift Observatory. We will compare the UV-bright "Super-Chandrasekhar" SN2016ccj, UV-blue normal SNe 2011fe and 2011by, the intrinsically-red and dust-reddened SN2017erp. Understanding the diversity of these "standard candles" is important to accurately and confidently use them as cosmological distance indicators through the history of the universe.

Irradiation Investigation: Exploring the Molecular Gas in Planetary Nebulae

Jesse Bublitz (Rochester Institute of Technology)

Planetary nebulae (PNe) represent the end stages of mass loss from low- to intermediate-mass stars. For some PNe, significant quantities of dense molecular gas and dust remain present in their stellar ejecta. Photodissociation and photoionization by UV and (in some objects) X-ray emission from the central stellar remnant then drive the chemical evolution. PNe with well-defined geometries and irradiation hence make ideal testbeds for models of radiation-driven heating and chemistry of molecular gas. We report the results of recent mm-wave molecular line surveys of nearby, well-studied PNe. We have obtained IRAM 30 m radio telescope observations of nine objects, and have targeted specific dense molecular knots in the Helix (NGC 7293) with the 30 m and ALMA. Among other results, these studies illustrate how the HNC/HCN abundance ratio serves as a diagnostic of UV irradiation of molecular gas. Meanwhile, our new IRAM/NOEMA maps of CO+ and HCO+ emission from the young PN NGC 7027 provide key insight into the mechanisms driving molecular ionization. These results demonstrate the potential applicability of molecule-rich PNe studies for other astrophysical environments in which molecular gas is irradiated by high-energy photons.

The Afterlife of Type Iax Supernovae

Yssavo Camacho-Neves (Rutgers University)

Type Ia Supernovae (SN Ia) have been instrumental cosmological standard candles that led to the discovery of the accelerated expansion of the Universe. Yet, the progenitors and explosion mechanism of these important and powerful transient events remain elusive. Members of the recently categorized Type Iax (SN Iax) class may be able to constrain models and progenitor systems for exploding white dwarfs. SN Iax are the largest class of “peculiar” white dwarf supernovae (>50 members). They have lower ejecta velocity, lower luminosities, and the only white dwarf supernova for which a pre-explosion progenitor system has been detected is a SN Iax. We aim to give an overview of the SN Iax class and present optical spectroscopy of SN 2014dt, a SN Iax in the nearby galaxy M61 that was the focus of extensive observations. We analyze the spectral evolution of SN 2014dt and compare it to the evolution of normal SN Ia, showing that SN 2014dt begins a “divergence phase” from normal SN Ia around 100 days after peak brightness. We also use TARDIS to generate synthetic spectra of SN 2014dt to analyze the composition of the ejecta and to probe how the physical parameters of the explosion evolve with time. We argue that SN Iax may continue to have an "afterlife" beyond the supernova explosion, with a radioactively-powered bound remnant driving an optically-thick wind.

Energy Budget and Envelope Unbinding in Common Envelope Evolution Using AMR

Luke Chamandy (University of Rochester)

Common envelope evolution (CEE) is key to understanding the fates of many binary stellar systems, including planetary nebulae and cataclysmic events involving the merger of two compact objects. We analyze four 3D high-resolution hydrodynamic simulations of CEE involving a $2\mathrm{M}_\odot$ red giant branch or asymptotic giant branch primary and a $0.25\mathrm{M}_\odot$, $0.5\mathrm{M}_\odot$ or $1\mathrm{M}_\odot$ secondary modeled as a point particle to understand the time evolution of energy transfer between various forms, the amount of unbinding of the envelope, and the influence of giant type and secondary mass. Although most of the envelope unbinding occurs during the initial plunge-in phase, most of the energy transferred to the tenuous outer envelope is compensated by tighter binding of the inner layers to the plunging secondary so that minimal net energy is transferred between the cores and envelope. Subsequently, energy is gradual transferred steadily from the cores to the envelope but not enough to unbind the remainder of the envelope. In analyzing the results, we assess the commonly used α_CE-energy formalism, and suggest an alternative that more cleanly separates core particles and gas. We discuss whether complete envelope ejection might be attained by further improvements to the numerics, without new energy sources.

High-Mass White Dwarfs in Gaia DR2: the Q Branch and WD-WD Merger Rate

Sihao Cheng (Johns Hopkins University)

Studying highmass white dwarfs WDs can shed light on the progenitors of Type Ia supernovae. Recently the unprecedented power of Gaia data has revealed an unexpected enhancement of highmass WDs on the HR diagram called the Q branch. It indicates that some WDs are experiencing a delay in their cooling. To study their origin we analyze the velocity distribution of all WDs within 250 pc and estimate their kinematic ages. We find that 7 percent of WDs have an 8 Gyr cooling delay on the Q branch in addition to the delay caused by crystallization and mergers. We propose that such a long delay may be explained by the settling of 22Ne in WDWD merger products. Our velocity analysis also allows us to show that 12 to 25 percent of all high mass WDs result from mergers, corresponding to a merger rate of 2.3 times 10 to minus 14th per solar mass per year in the mass range 1.09 to 1.27 solar masses. This is the most direct observational constraint on the rate of WDWD mergers, a promising channel of Type Ia supernova explosions,1,

The Transition Mass for Core-Collapse Supernovae Derived From the Initial-Final Mass Relation

Jeffrey Cummings (Johns Hopkins University)

The lower limit for the initial mass of stars that undergo core-collapse supernova remains difficult to measure. Besides the challenging method of observing these rare events and estimating their progenitor mass from archival observations, the white dwarf initial-final mass relation (IFMR) provides another valuable method for constraining this transition mass. Our work on the IFMR using white dwarfs in star clusters has improved our understanding of this relation and can now better estimate the initial-mass of where stellar cores reach the Chandrasekhar mass limit and undergo a supernova. Our current estimate finds that this transition mass is within 7.7 to 8.9 solar masses. More ultramassive cluster white dwarfs can constrain this further, but the primary uncertainty at these higher masses is the estimate of initial mass from progenitor evolutionary timescale. For example, these derived initial masses are very sensitive to how the adopted evolutionary model handles rotational mixing and convective-core overshoot, but we are now beginning to show that these processes can also be constrained by the trends and scatter of the IFMR.

Massive Planetary Nebula Central Stars from an Old Stellar Population

Brian Davis (Penn State University)

The [O III] 5007 planetary nebula luminosity function (PNLF) has been used as an extragalactic distance indicator for three decades. But the function is much more than a standard candle: it is also a way to probe the mass distribution of the brightest post-AGB stars in a stellar population. Such information is enormously important, as TP-AGB stars---the immediate progenitors of these post-AGB objects---are critical to our understanding of a galaxy's near-IR energy budget and its integrated stellar mass. One issue that has prevented the PNLF from being used in this way is the unknown contribution of circumstellar extinction, as one generally only observes the emergent flux from a PN, not the total unattenuated flux.

For the first time, we have determined the de-reddened PNLF of an old stellar population. By performing spectroscopy of the brightest PNe in M31's bulge and measuring the objects' Balmer decrements, we have removed the effects of circumstellar extinction and derived the true distribution of [O III] 5007 luminosities. We show that the bright PNe in the region are typically twice as luminous as what one would infer from their observed [O III] fluxes, and that even with accelerated-evolution post-AGB tracks, traditional population synthesis models cannot come close to producing the luminosities of their central stars. Since there are more than 10,000 AGB stars for every bright PN, our results show the necessity of including alternative channels of stellar evolution in population synthesis modeling.

Constraining the Progenitor Distribution of Hundreds of CCSNe

Mariangelly Diaz-Rodriguez (Florida State University)

We infer the progenitor mass distribution for 100 core-collapse supernovae. In particular, we infer the age of stellar populations surrounding 94 supernova remnants (SNRs) in M31 and M33. From these ages, we infer the progenitor mass distribution. Assuming each progenitor evolved as a single star, we find that the minimum mass is $M_{min} = 7.33^{+0.02}_{-0.16} msun$, the slope of the progenitor distribution is $\alpha = -2.96^{+0.45}_{-0.25}$, and the maximum mass is greater than $M_{max} > 38 msun$. The accuracy on the minimum mass may provide tight constraints on stellar evolution. The steep distribution suggests that the most massive stars are either not exploding with the same frequency as the stars near the minimum mass, or SNR catalogs are biased against the youngest SF regions. If there is a bias on the SNR catalogs, it will most likely only affect the slope. This bias will not affect the minimum mass or the lower limit on the maximum mass. In the future, we will infer the progenitor ages and masses for thousands of SNRs, placing unique and robust constraints on which stars explode as CCSNe.

Shock Breakout Delayed by Circumstellar Material Detected in Most Type II Supernovae

Francisco Förster (Center for Mathematical Modeling (CMM - UChile), Millenium Institute for Astrophysics (MAS))

Type II supernovae (SNe) originate from the explosion of hydrogen–rich supergiant massive stars. Their first electromagnetic signature is the shock breakout (SBO), a short–lived phenomenon which can last from hours to days depending on the density at shock emergence. We present 26 rising optical light curves of SN II candidates discovered shortly after explosion by the High cadence Transient Survey (HiTS) and derive physical parameters based on hydrodynamical models using a Bayesian approach. We observe a steep rise of a few days in 24 out of 26 SN II candidates, indicating the systematic detection of SBOs in a dense circumstellar matter (CSM) consistent with a mass loss rate $\dot{M} > 10$ −4 M yr −1 or a dense atmosphere. This implies that the characteristic hour timescale signature of stellar envelope SBOs may be rare in nature and could be delayed into longer–lived CSM SBOs in most Type II SNe.

Signatures of Circumstellar Interaction in the Unusual Transient AT2018cow

Ori Fox (Space Telescope Science Institute)

AT2018cow is a unique transient that stands out due to its relatively fast light-curve, high peak bolometric luminosity, and blue color. These properties distinguish it from typical radioactively powered core-collapse supernovae (SNe). Instead, the characteristics are more similar to a growing sample of Fast Blue Optical Transients (FBOTs). Mostly discovered at hundreds of Mpc, FBOT follow-up is usually limited to several photometry points and low signal-to-noise spectra. At only ~60 Mpc, AT2018cow offers an opportunity for detailed followup. Studies of this object published to date invoke a number of exotic interpretations for AT2018cow, including Tidal Disruption Events and Magnetars. I will present a new, recently submitted study that suggests that AT2018cow may be better described as SN undergoing significant, early-time interaction with a dense, nearby Hydrogen poor CSM shell, similar to some SNe Ibn. I show that while the spectra were dominated by a featureless blue continuum at early times, narrow lines on order of ~1000 km/s begin to emerge by day ~50. I go on to compare AT2018cow to interacting SNe Ibn and transitional IIn, finding a number of noteworthy similarities, including light-curve rise and fall times, peak magnitude, X-ray light-curves, and spectroscopic properties.

Spectropolarimetric Analysis of WR + O Binaries with SALT

Andrew Fullard (University of Denver)

Massive stars often occur in binaries, and WR stars are no exception. Interaction in binaries can affect their mass loss rates, and possibly provide the rapid rotation thought to be required for GRB production. Spectropolarimetry can help us to better characterize the CSM created by the stars' colliding winds, and thus constrain mass loss and probe wind interaction. We present spectropolarimetric results for a sample of WR+O binary systems, obtained with the Robert Stobie Spectrograph at the South African Large Telescope, between April 2017 and September 2018. We discuss our initial findings and interpretations of the polarimetric variability in several of the sampled binary systems. We analyze one system in particular, the WC8d+O8-9IV binary WR 113 (SV Ser), using archival data and radiative transfer models of the scattering structures revealed by the new observations.

Revisiting the Treatment of Common-envelope Evolution in Population Synthesis Codes

Monica Gallegos Garcia (Northwestern University)

Rapid binary population synthesis codes have been used for decades to investigate the complex evolution of compact binaries. Although these codes are widely used, they typically lack thorough calculations and prescriptions of physical processes (e.g., common-envelope, Roche lobe overflow, post main-sequence evolution) that are crucial to accurately predict the fate of these binary systems. Many of these processes, however, have been more carefully implemented in stellar evolution codes such as MESA (Modules for Experiments in Stellar Astrophysics). Motivated by this, we perform binary evolution simulations to compare results between a rapid binary synthesis code, Binary Star Evolution (BSE), and MESA. Our simulations focus on binary systems that undergo common-envelope evolution before merging. We find discrepancies between models that affect merging rates of compact binaries.

Leftover Hydrogen in Stripped Massive Stars

Avishai Gilkis (University of Cambridge)

Most massive stars evolve in interacting binary systems before exploding as core-collapse supernovae (CCSNe). Uncertainties in the efficiency of mass transfer by Roche-lobe overflow (RLOF) and the subsequent mass loss through stellar winds make it difficult to predict the material and angular momentum content in the system at its final stages. I will present binary stellar evolution simulations with decisively different assumptions for these key processes and discuss the implications for CCSNe, with special focus on the post-RLOF mass loss by stellar winds and supernovae of types IIb and Ib, for which little or no hydrogen is left in the stellar envelope. I will underscore the significant sensitivity of the stellar evolution models to the assumed mass-loss rates and the need to develop a better theoretical understanding of stellar winds.

Revisiting the Treatment of Common-envelope Evolution in Population Synthesis Codes

Roni Anna Gofman (Technion, Israel)

I will present our comparison of several binary scenarios proposed for the enigmatic core-collapse supernova (CCSN) iPTF14hls. We examine in depth the magnetar scenario and the shocked circumstellar material (CSM) scenario and explore the required properties of these scenarios for them to account for the extra radiation of iPTF14hls. We calculate the associated timescales and the required angular momentum for these scenarios. We conclude that both scenarios require a strong binary interaction. Together with the common envelope jets supernova (CEJSN) scenario, these three scenarios predict the supernova remnant to be bipolar due to jets before and/or during the explosion. Our results can serve the construction of models for future enigmatic super-luminous CCSNe.

SN 2016iet: The Pulsational or Pair-Instability Explosion of a Low Metallicity Massive CO Core Embedded in a Dense Hydrogen-Poor Circumstellar Medium

Sebastian Gomez (Harvard University)

SN 2016iet is a Type I supernova (SN) at a redshift of z = 0.0676 which shows a number of peculiar features that make it a candidate pair-instability supernovae (PISN). We present optical photometry and spectroscopy of the source obtained over a period of 2 years. The most striking features of the light curve are two distinct peaks of comparable brightness and a long separation of about 100 days, and an overall long duration, taking more than 700 days to decline by 4 magnitudes from the first peak. We interpret the long, double-peaked, light curve as being powered by interaction with a circumstellar medium (CSM). But interestingly, the spectra of the source show no evidence for the presence of hydrogen nor helium at any point during its evolution. We present a series of possible models to explain the nature of SN 2016iet. A model in which the envelope of the progenitor was ejected through episodic mass loss events, eventually leading to a SN that breaks out of a dense CSM, producing the first light curve peak, than then proceeds to interact with a CSM, powering the long lasting light curve, provides a good explanation for the SN. Our best models give an estimate of ~20 solar masses of ejecta interacting with ~30 solar masses of CSM. Another interesting feature of SN 2016iet is the fact that it is very far removed from its host, a low mass dwarf galaxy with one of the lowest metallicities observed for either Type Ic or superluminous SN. Further modeling will be required to understand the true nature of this usual SN.

An Apparent Constant LGRB Metallicity Distribution Across Redshifts z < 2.5

John Graham (Kavli Institute for Astronomy and Astrophysics, Peking University)

Recent improvements in the population of Long-duration Gamma Ray Burst (LGRB) host galaxies with measured metallicities and host masses allows us to investigate how the distributions of both these properties change with redshift. First we exclude, out to $z < 2.5$, strong redshift dependent populations biases in mass and metallicity measurements. We then find a surprising lack of evolution in the metallicity distribution of the LGRB host galaxy population. This is at odds with the general evolution in the mass metallicity relation, which becomes progressively more metal poor with increasing redshift. We further find that the LGRB host galaxy mass distribution increase with redshift is consistent with that needed to preserve the LGRB metallicity distribution as the mass metallicity relation decreases with redshift therefore the expected metallicities of the LGRB host population (given their mass and redshift) also does not evolve. However, the metallicities estimated from mass and redshift are about twice as metal rich as the population with actually measured metallicity values which resolves much of the difference between the LGRB formation metallicity cutoff of about a third solar in Graham & Fruchter 2015 with the cutoff value of solar claimed in Perley et al. 2016 in favor of the former.

Our Line-of-Sight to Eta Carinae is Changing!

Ted Gull (NASA/GSFC)

The study of Eta Carina is an effort that keeps on giving answers, yet raises still more questions. As we probe deeper and deeper into this massive binary and its complex ejecta using successive generations of new observatories and instruments, we gain insight on how massive stars may evolve, especially in the environment of other massive companions.

Specifically, the studies of Eta Carina have impact on our understanding of the many pseudosupernovae, thought to originate from massive stars in distant galaxies.

Today we know that a binary system (~100 Mo and 40 Mo) survived a major event in the 1840s even though possibly greater than 40 solar masses of material was ejected. Based upon Herschel/SPIRE measures of 12C/13C~4, that material came from a star (or stars) that initially exceeded 60 solar masses. Which companion ejected that material?

Massive amounts of dust exist in the ejecta. Yet carbon and oxygen, thought to be integral to dust formation, is greatly depleted. Many metals, such as strontium, scandium that are not seen in the ISM, are present, in addition to large amounts of iron, titanium. Is this due to complete consumption of carbon and oxygen, or is this due to a very different dust being formed in the massive eruptions?

Eta Carina has been thought to be very unstable. Yet studies of fossil winds and now of long term photometry indicate that over the past few decades, the binary and its winds are very stable. Is this an interim phase, or indicative, that Eta Carina has entered a lengthy period of relative stability before that ultimate supernova(s) event(s).

Uncovering Infrared Transients with Palomar Gattini-IR

Matthew Hankins (Caltech)

Palomar Gattini-IR is a new survey designed to undertake a ground-based wide-field search for infrared transients. We recently began full survey operations and are covering ~9,000 square degrees in J-band from Mount Palomar to a depth of 16.0 mag (AB) every night. Gattini-IR science goals include finding obscured supernovae, stellar mergers, and potential new classes of near-IR transients. We plan to present results from the first six months of survey data and discuss synergies with other ongoing transient surveys.

The Donor Star of NGC 300 ULX-1/SN2010da

Marianne Heida (Caltech)

SN2010da was a bright transient event in the nearby galaxy NGC 300. Discovered in 2010, it was initially classified as a supernova but quickly identified as a supernova impostor. After the 2010 outburst the system showed up as an increasingly bright X-ray source (Binder+2011), and it has been in the ULX regime for the past few years.

The origin of the 2010 outburst is still unclear; the dusty progenitor has been identified as a luminous blue variable (Chornock+2010, Elias-Rosa+2010), a yellow supergiant transitioning onto a blue loop (Villar+2016) or a supergiant B[e] star (Lau+2016). X-ray observations with XMM-Newton, NuSTAR and Swift revealed that the accretor is a rapidly up-spinning neutron star (Carpano+2018, Walton+2018, Binder+2018).

We have obtained deep optical through near-infrared spectra of SN2010da with X-shooter in 2018 that for the first time reveal the massive star in this system to be a red supergiant. I will discuss the implications of this discovery for the origin of the 2010 outburst and the resulting X-ray binary.

SyXB -- NS Afterlife Powered By an Evolving Low Mass Star

Kenneth Hinkle (NOAO)

X-ray symbiotic binaries (SyXB) are a rare class consisting of a neutron star (NS) with an M III companion. We have observed seven members of this class using high-resolution infrared spectroscopy. For two systems we have derived orbits. The systems are detached with orbital periods of order a decade. The best formation scenario creates the NS from a core collapse SN with the SyXB representing the few surviving high mass - low mass binary systems. For the two well studied systems the M giant has a mass in the 1 - 2 solar mass range implying an age of gigayears for the NS. NS activity is fueled by mass loss from the M III. We will review the observational material for the known members of this class and comment on the evolution of the binaries as the low mass star reaches the AGB.

Asymptotic Giant Branch Stars in the Low-Metallicity Galaxy NGC 6822

Alec Hirschauer (Space Telescope Science Institute)

The high-redshift systems in which the earliest generations of stars were formed, produced heavy elements and dust, and subsequently ended their life cycles were vastly different from the Milky Way. Nearby galaxies with low metal abundances provide important laboratories for observationally accessing the physical conditions equivalent to what had been ubiquitous throughout the early Universe. In order to more fully understand the role of dust in metal-poor environments, it is critically important to robustly identify their evolved, dust-producing asymptotic giant branch (AGB) stars. The local (~500 kpc) metal-poor ([Fe/H] ≈ -1.2; Z ≈ 30% $Z_\odot$) star-forming galaxy NGC 6822 is thought to be analogous to higher-redshift systems at the epoch of peak star formation. We present color-magnitude diagrams (CMDs) utilizing archival photometry from the Spitzer Space Telescope (Khan et al. 2015; IRAC 3.6, 4.5, 5.8, and 8.0 µm and MIPS 24 µm) and the United Kingdom Infrared Telescope (Sibbons et al. 2012; UKIRT J-, H-, and K-band) of NGC 6822. Isolating red-excess objects and carefully employing color cuts, we identify oxygen- and carbon-rich AGB star candidates. Subsequent work will entail spectral energy distribution (SED) fitting of these sources to quantify the dust mass and dust mass loss rate of this galaxy. This project was completed in anticipation of a James Webb Space Telescope (JWST) guaranteed time observation (GTO) program for this galaxy, which will probe NGC 6822 to a depth comparable to the Spitzer SAGE (Surveying the Agents of a Galaxy's Evolution; Meixner et al. 2006) surveys of the Large and Small Magellanic Clouds.

Stellar-origin Black Holes and Neutron Stars in the 2020's and Beyond: The Post Chandra and XMM-Newton Era

Ann Hornschemeier (NASA GSFC)

We present prospects for studying black hole (BH) and neutron star (NS) populations in nearby galaxies, focusing on science topics that will require next generation X-ray telescopes. Higher-throughput X-ray telescopes in the future will open up parameter space for time-domain studies of accreting stellar origin BH and NS populations. The topics are wide-ranging, from understanding gravitational wave merger progenitor populations such as Wolf-Rayet X-ray binaries to unraveling the complicated physics that allows for a population of "ultraluminous" pulsars which currently appear to defy our picture of how accretion works. We can also understand the birth of compact objects via supernova events through constraint of SN kicks in the dynamical evolution of X-ray binaries. Capabilities such as a large field of view, improved angular resolution, increased sensitivity/effective area, and timing resolution are required to answer such questions and expand our understanding of accreting BH and NS systems. We will summarize the prospects for answering these questions based on our current knowledge and simulations of Athena Wide Field Imager observations of galaxies. Athena is an ESA mission planned for launch in ~2031 and the Wide Field Imager is an example of a next generation instrument that will be excellent for studies of BH and NS populations.

Young Massive Clusters at the Galactic Center: Top Heavy Initial Mass Function and the Increased Population of Compact Objects

Matthew Hosek Jr. (UCLA)

The discovery of gravitational waves has renewed interest in the production rate and locations of stellar mass black holes. One important aspect of this problem is the stellar initial mass function (IMF), which sets the mass of the progenitor stars and hence the number of compact remnants in star clusters. We discuss the IMFs of three young clusters at the Galactic Center: The Young Nuclear Cluster, Arches Cluster, and the Quintuplet cluster. We forward model observations of these clusters to simultaneously constrain the cluster IMF and other properties (such as age and total mass) while accounting for observational uncertainties, completeness, mass segregation, and stellar multiplicity. We find that the IMFs of these clusters are either top-heavy (an overabundance of high-mass stars) or bottom-light (an under abundance of low-mass stars) relative to the standard IMF observed in local star forming regions. We investigate whether these unusual IMFs can be attributed to the Galactic Center environment or are a general property of young massive clusters, and discuss implications for the populations of compact objects that will be generated by these clusters.

Type Ibn Supernovae May Not All Come from Massive Stars

Griffin Hosseinzadeh (Center for Astrophysics | Harvard & Smithsonian)

Type Ibn supernovae are a rare class of transients whose spectra show signatures of interaction with hydrogen-poor circumstellar material. Compared to other interacting supernovae, their light curves relatively homogeneous and fast-evolving. The leading theory has been that these are the explosions of very massive Wolf–Rayet stars in which material ejected by the supernova collides with mass lost from the progenitor through winds or eruptions. These stars should have short lifetimes and thus only be found in areas with active star formation. However, one of the ~30 Type Ibn supernovae occurred in a galaxy cluster environment with no detectable star formation. I will present new HST observations of this environment, which strengthen the star formation limit below the levels of almost all known core-collapse supernovae. In light of this limit, I will discuss whether all Type Ibn supernovae can come from massive stars.

Kinematics of Mass Loss from the Outer Lagrange Point L2

Dominika Hubová (Institute of Theoretical Physics, Charles University)

We investigate the mass loss from the vicinity of the outer Lagrange point L2 of binary stars, a phenomenon that is associated with the common envelope evolutionary phase. This evolutionary stage can result in stellar merger or in formation of close binary systems. The circumstellar medium of the remnant might be significantly affected by the mass loss from the L2 point. We evaluate trajectories of test particles ejected from the proximity of the L2 point with arbitrary initial velocity and we compute the amount of energy and angular momentum these particles carry away from the system.

Discovery of Highly Blueshifted Broad Balmer and Metastable Helium Absorption Lines in Tidal Disruption Event AT2018zr

Tiara Hung (Harvard University)

Discovery of Highly Blueshifted Broad Balmer Absorption Lines in a Tidal Disruption EventRecent progress in the observations of tidal disruption events (TDEs; when stars pass too close to a black hole and is torn apart by tidal stress) have revealed an unexpected enhancement in their UV and optical emission, making the underlying emission mechanism (circularization v.s. reprocessing) a hot debate. Spectroscopy plays an important role in disentangling these scenarios as line formation is governed by the underlying physical state of the emitting gas. In this talk, I will present the discovery of a transient high-velocity outflow (~0.05c) in the TDE AT2018zr based on prominent absorption features in the UV and optical spectra in rest wavelength range of 1100-9000 angstrom. The detection of both high- and low-ionization absorption lines makes its spectrum resemble a low-ionization broad absorption line (LoBAL) QSO. Furthermore, rare hydrogen Balmer and the metastable HeI absorption lines are also detected. We conclude that these transient absorption features are likely to arise in an outflow environment, which rules in favor of the reprocessing mechanism and suggests that outflow may be ubiquitous amongst TDEs.

Gaia, White Dwarfs, and the Age of the Galaxy

Elizabeth Jeffery (Cal Poly, San Luis Obispo)

The Milky Way is composed of four major stellar populations: the thin disk, thick disk, bulge, and halo. At present, we do not know the age of any of these populations to better than one or two billion years. This lack of knowledge keeps us from answering fundamental questions about the Galaxy: When did the thin disk, thick disk, and halo form? Did they form over an extended period, and if so, how long? Was star formation continuous across these populations or instead occur in distinct episodes? The Gaia satellite is providing precise trigonometric parallaxes for a plethora of white dwarfs in each of these populations. We combine these parallaxes (and hence, distances) with photometry and analyze them using a modeling technique that relies on Bayesian statistics. This allows us to derive precise ages for individual white dwarfs and determine the age distribution and star formation history for each of the constituents of our Galaxy. We will present current progress in this endeavor, with emphasis on the ages of individual white dwarfs in two star clusters: the Hyades and Praesepe. Measuring the ages of individual white dwarfs in these well-studied clusters provides proof of concept for our technique, as well as exploration of any systematic offsets caused by timescales from main sequence models or the initial-final mass relation.

The Influence of Jets on the Light Curve of Supernovae

Noa Kaplan (Technion, Israel)

I will present results of our study of the light curve of core collapse supernovae (CCSNe) where late jets deposit energy to the ejecta. We assume that each jet deposits its kinetic energy within a small region and during a short time. The energy that each jet deposits in the ejecta is modelled to diffuse outwards through the ejecta, while the shocked jet's material expands and cools. We build a toy model where the interaction of each jet with the ejecta is modeled as a `small local explosion'. In our model the total luminosity of the CCSN is the combination of the CCSN explosion and the contributions of the late jets. Comparison of the composite light curve with observations of some CCSNe can reveal some properties of late jets in rare CCSNe.

Study of Extragalactic Supernova Remnants

Maria Kopsacheili (University of Crete/FORTH)

Studies of populations of supernova remnants (SNRs) in different galaxies provide a more representative picture of their importance for feedback and metal enrichment in a wide variety of galactic environments. We present our results on the SNRs populations in a sample of nearby spiral galaxies (NGC 7793, NGC 55, NGC 45, NGC 1313), based on deep narrow-band Hα and [S II] images. We find a total of 194 candidate SNRs. We derive the Hα and excitation distributions of the SNRs, both of which are proxies of the energy deposition on the galactic interstellar medium (ISM). In our analysis we develop methods to account for selection effects that allow us to directly compare results between different galaxies. We compare our results with similar studies in irregular galaxies and we discuss the effects of recent star-forming activity and the morphology and physical conditions in the ISM on the SNR populations and their physical properties. We also present a new, efficient, diagnostic tool for identifying SNRs and measuring their shock velocities based on narrow-band imaging. Through the effective differentiation from HII regions this diagnostic provides more complete samples of SNRs including those in later evolutionary phases with slower shocks.

Mid-IR Spectra of Carbon-Rich Post-AGB Stars Across the Decades

Kathleen Kraemer (Boston College)

Many phases of stellar evolution occur on slow timescales of millions or billions of years. The post-asymptotic giant branch (post-AGB) phase, though, when a star rapidly transitions from a cool, dust-enshrouded object to a hot white dwarf illuminating a planetary nebula (PN), lasts only 1,000-10,000 years. We have obtained 5-37 micron spectra with SOFIA's FORCAST instrument of several carbon-rich post-AGB objects in the Milky Way. We compare the new spectra to the mid-infrared spectra of the same objects that were observed at roughly 10-15 year intervals over the past 35 years with IRAS, ISO, and Spitzer. Secular changes on these timescales have already been detected in optical photometry and spectra, tracing changes in the central star. We are now in a position to investigate the corresponding changes in the circumstellar material, as it is being processed from forms found around AGB stars to those seen in PNe. These observations potentially probe the real-time evolution of circumstellar shells and the processes that occur during one of the most fleeting stages in a star's life.

Disentangling Dust Components in SN 2010jl: The First 1400 Days

Kelsie Krafton (Louisiana State University)

Our original motivation for studying dust formation in core collapse supernovae (CCSNe) was the exciting discovery that some high redshift (z > 6) galaxies were dust rich. These galaxies are less than 1 Gyr old, and so a significant fraction of the observed dust must be coming from massive stars, which evolve quickly and return their material back to the interstellar medium through supernovae (SNe). Even still, the amount of dust required per star or SN is high, with theoretical models predicting that 0.1 - 1 solar masses of dust would be needed per CCSN. Many studies by our group and others found that only about 0.0001 - 0.01 solar masses of dust have formed two or three years after the explosion. How is it that CCSNe have formed only a small amount of dust after three years, but SN 1987A has a dust mass that is several orders of magnitude larger after 25 years? To investigate the suggestion of continuous dust formation, we used two Monte Carlo Radiative transfer codes to model dust in the circumstellar medium (CSM) and ejecta of SN 2010jl. MOCASSIN fits visible and IR SEDs, while DAMOCLES fits optical emission lines. Dust located in the ejecta will preferentially extinguish emission from the far-side, red-shifted gas and result in a shift of the emission line profiles to the blue. The presence of dust also causes an infrared excess. Combining these signatures by using both models allows us to estimate the mass of dust produced by SN 2010jl. I present estimates of both new and preexisting dust masses at each epoch for SN 2010jl, over the first 1400 days of its evolution. The mass of new dust is increasing and may reach levels similar to that of SN 1987A, given enough time.

Interaction between Supernova Ejecta and Non-spherical Circumstellar Environment

Petr Kurfurst (Charles University, Prague, Czech Republic)

Progenitors of core-collapse supernovae (SN) may experience enhanced mass loss by stellar winds or outburst episodes shortly before the SN explosion. We study the hydrodynamics of spherical SN explosion into a dense circumstellar medium (CSM) with various non-spherical geometries. We calculate the evolution of thermodynamic quantities in the interaction zone with the ultimate goal of synthesizing supernova light curves and other observables.

WR DustERS: JWST-ERS Program to Resolve the Nature of Dust in Wolf-Rayet Winds

Ryan Lau (ISAS/JAXA)

Thermal infrared (IR) emission from dust is a key probe of the evolution and death of short-lived, massive stars. Dust itself is a key component of the interstellar medium; however, the dominant channels of dust production throughout cosmic time are uncertain. In this talk, I will discuss our JWST Director's Discretionary Early Release Science (DD ERS) program, where we will investigate the formation mechanism and chemical composition of dust formed in the colliding winds of a Carbon-rich Wolf-Rayet (WC) binary. With dust production rates ranging from 10^-8 - 10^-6 Msun/yr, such massive stellar binaries may have a significant influence on the dust abundance galaxies in both the local and early Universe. Dust abundances, composition and formation pathways in the hostile and luminous environment around WC+OB binaries are, however, uncertain due to observational challenges in achieving both high spatial resolution and sensitivity in the mid-IR. Our planned JWST/MIRI+MRS and NIRISS+AMI observations of the archetypal periodic dust forming Wolf-Rayet binary system WR140 will address these uncertainties and also demonstrate the utility of these observing modes for IR bright targets with faint extended emission.

Young Accreting Compact Objects in M31: The Combined the Power of NuSTAR, Chandra, and Hubble

Margaret Lazzarini (University of Washington)

Combining NuSTAR, Chandra, and the Hubble Space Telescope (HST) imaging of nearby galaxies, we are able to study both the compact object and donor star in high mass X-ray binaries (HMXBs) in the context of their local star forming environments. We infer compact object type, spectral type of the donor star, and age using multiwavelength observations from NuSTAR, Chandra, and HST. The hard X-ray colors and luminosities from NuSTAR permit the classification of accreting X-ray binary systems by compact object type, distinguishing black hole from neutron star systems. We identify UV-bright optical counterparts spatially associated with X-ray sources using high quality HST imaging. We perform spectral energy distribution (SED) fitting for the most likely optical counterparts to the HMXB candidates to infer the most likely stellar mass and temperature for the companion stars. We can also obtain high quality age estimates using spatially resolved star formation histories (SFHs). In M31, we find 15 HMXB candidates: X-ray sources spatially associated with UV-bright point source optical counterparts. To determine the quality of HMXB candidates we evaluate the SED fitting to determine if a massive, young star appears to be the donor, age estimation using spatially resolved SFHs, and compact object classification using NuSTAR hard X-ray colors and luminosities.

Ex Luna, Scientia: Probing Supernova Fundamentals in the Nuclear Gamma-ray Regime with the Lunar Occultation eXplorer (LOX)

Richard S. Miller (Johns Hopkins University Applied Physics Laboratory)

Astronomical investigations from the Moon afford new opportunities to advance our understanding of the cosmos. The Lunar Occultation Explorer (LOX) — a mature, low-risk, and high-heritage mission concept currently in development — will leverage the power of continuous all-sky monitoring and gamma-ray spectroscopy (0.1-10 MeV) to transform our knowledge of thermonuclear supernovae, the beacons of the cosmos. Gamma-ray emission is a direct consequence of the nuclear physics that governs the structure and dynamics of Type-Ia supernovae (SNeIa) and LOX will provide unprecedented new insights by monitoring and characterizing their fundamental emergent spectra and nuclear light curves. Population studies will leverage the several hundred SNeIa LOX is expected to detect over its mission lifetime to give a deeper understanding of SNeIa progenitor systems, explosion mechanisms, and diversity. LOX will reveal hidden details with far-reaching impact, and is synergistic with groundbreaking observations made at other wavelengths. Performance estimates and the development status of LOX, including in-situ validation of the observational technique from lunar orbit, will be presented along with an overview of the SNeIa analyses.

Weighing BHs with Tidal Disruption Events

Brenna Mockler (University of California, Santa Cruz)

While once rare, observations of tidal disruption events are quickly becoming commonplace. To continue to learn from these events it is necessary to robustly and systematically compare our growing number of observations with theory. Here I present a tidal disruption model (as part of the transient fitting code MOSFiT) and the results from fitting 14 TDEs. Our model uses hydrodynamical simulations to generate accretion rates and passes these accretion rates through viscosity and light reprocessing modules to create multi-wavelength light curves. It then uses an MCMC fitting routine to compare these theoretical light curves with observations. This procedure provides a robust method for measuring the masses of supermassive black holes because the shape of a TDE light curve depends strongly on the black hole's mass. In addition to describing this new black hole mass measurement method, I will discuss the implications these fits have for understanding the physics of TDEs, particularly for accretion under these extreme conditions.

RAPID: Early Classification of Explosive Transients using Deep Learning

Daniel Muthukrishna (University of Cambridge)

We present RAPID (Real-time Automated Photometric IDentification), a novel time-series classification tool capable of automatically identifying transients from within a day of the initial alert, to the full lifetime of a light curve. Using a deep recurrent neural network with Gated Recurrent Units (GRUs), we present the first method specifically designed to provide early classifications of astronomical time-series data, typing 12 different transient classes. Our classifier can process light curves with any phase coverage, and it does not rely on deriving computationally expensive features from the data, making RAPID well-suited for processing the millions of alerts that ongoing and upcoming wide-field surveys such as the Zwicky Transient Facility (ZTF), and the Large Synoptic Survey Telescope (LSST) will produce. The classification accuracy improves over the lifetime of the transient as more photometric data becomes available, and across the 12 transient classes, we obtain an average area under the receiver operating characteristic curve of 0.95 and 0.98 at early and late epochs, respectively. We have made RAPID available as a software package for machine learning-based alert-brokers to use for the autonomous and quick classification of several thousand light curves within a few seconds.

Identifying Candidate Thorne-Zytkow Objects: The Role of Variability

Anna O'Grady (University of Toronto, Dunlap Institute)

Approximately 60% of massive stars will interact with a binary companion during their lives, significantly shaping their subsequent evolution. Observational constraints on the outcomes of these interactions are therefore critical for our understanding of stellar death and the formation of close compact-object binaries. Thorne-Żytkow objects (TŻOs) are a hypothetical subclass of red giants or red supergiants (RSGs) that contain neutron stars inside their convective envelopes. Supergiant TŻOs are formed either from a close binary system undergoing common envelope evolution after one companion has exploded as a supernova, or by an asymmetric supernova kicking a neutron star into its RSG companion. Confirming the existence, frequency, and lifetime of TŻOs would provide useful constraints on binary evolution. Unfortunately, it is difficult to identify TŻOs from photometric colours alone due to their resemblance to RSGs, but one strong candidate TŻO has been identified in the Small Magellanic Cloud by Levesque et al. (2014) through spectroscopic analysis. The candidate, HV2112, has very strong photometric variability and an unusual light curve. We have carried out a systematic search for HV2112-like variability in the Magellanic Clouds, identifying ~10 new candidate systems from amongst millions of stars. In this talk we present the results from our survey, including detailed analysis of the pulsations, physical parameters, and intrinsic nature of these sources.

Constraining the TP-AGB Phase with Resolved Stellar Populations in the Small Magellanic Cloud

Giada Pastorelli (University of Padova)

The thermally-pulsing asymptotic giant branch (TP-AGB) experienced by low- and intermediate-mass stars is one of the most uncertain phases of stellar evolution. Despite the theoretical and observational efforts made so far, the impact of TP-AGB stars on some key aspects of galaxy evolution is still debated, i.e. their contribution to the integrated light of galaxies and to the interstellar dust budget.

In this work, we put quantitative constraints on the parameters that control the third dredge-up and the mass loss in TP-AGB stars by coupling high-quality observations of resolved stars in the Small Magellanic Cloud (SMC) with detailed stellar population synthesis simulations. The strength of our approach relies on the detailed spatially-resolved star formation history of the SMC, derived from the deep near-infrared photometry of the VISTA survey of the Magellanic Clouds, as well as on the capability to quickly and accurately explore a wide variety of parameters and effects with the COLIBRI code for the TP-AGB evolution.

Our work led to identify two best-fitting models that reproduce the observed star counts and luminosity functions, but differ in the efficiencies of the third dredge-up and mass loss in TP-AGB stars with initial masses larger than about 3 solar masses.

We fully characterize the TP-AGB stellar population of the SMC in terms of stellar parameters (initial masses, C/O ratios, carbon excess, mass-loss rates) and we provide extensive tables of isochrones including these improved models.

Our calibrated evolutionary tracks and isochrones will help to improve the predictive power of evolutionary population synthesis models and to interpret the upcoming data from future observing facilities.

Mass Loss, Transients, and Dust from Catastrophically Interacting Binary Stars

Ondrej Pejcha (Ondrej Pejcha)

We investigate the mass loss from the vicinity of the outer Lagrange point L2 of binary stars, a phenomenon that is associated with the common envelope evolutionary phase. This evolutionary stage can result in stellar merger or in formation of close binary systems. The circumstellar medium of the remnant might be significantly affected by the mass loss from the L2 point. We evaluate trajectories of test particles ejected from the proximity of the L2 point with arbitrary initial velocity and we compute the amount of energy and angular momentum these particles carry away from the system.

Observational Signatures of sub-Chandrasekhar Mass Type Ias

Abigail Polin (UC Berkeley)

Carbon-Oxygen white dwarfs accreting a Helium shell have the potential to explode in the sub-Chandrasekhar mass regime. Previous studies have shown how the ignition of a Helium shell can either directly ignite the white dwarf at the core-shell interface or propagate a shock wave into the center of the core causing a central ignition. I will discuss recent hydrodynamics simulations of these explosions, which exhibit an inherent relationship between SiII velocity and luminosity. This, for the first time, identifies a sub-class of Type Ia supernovae that likely result from these sub-Chandrasekhar mass progenitors.

Shock Break Out Mission

Pete Roming (SWRI)

The death of massive stars, manifested as core-collapse supernovae, critically influence how the universe evolves. Despite their fundamental importance, our understanding of these enigmatic objects is severely limited. We have performed a concept study of a space-based transient observatory that will rapidly facilitate an expansion of our understanding of these objects. By combining a very wide-field X-ray telescope with an ultraviolet telescope, and a rapidly slewing spacecraft we can constrain the poorly understood explosion mechanism of massive stars. This goal is met by observing the shock breakout of core-collapse supernovae to measure the outer envelope parameters of massive stars. A description of the observatory, mission simulation, and technology used will be provided.

Four Decades of the Type IIn Supernova 1978K

Stuart Ryder (Macquarie University)

Supernova 1978K in NGC 1313 is the oldest, and one of the closest of the class of Type IIn supernovae that explode into an unusually dense circumstellar medium. Since discovering it serendipitously in 1992 we have been following it at X-ray, optical, and radio wavelengths. Recent VLBI measurements confirm significant deceleration of the ejecta. SN 1978K is only the third evolved extragalactic supernova to be detected with ALMA, yielding important clues about dust formation in core-collapse supernovae.

SN IIb Progenitors by Fatal Common Envelope Evolution

Efrat Sabach (Technion, Israel)

Stars that do not gain angular momentum (J) by a companion along their post-main sequence evolution are termed J-isolated stars, hereafter Jsolated stars. We argue that the mass-loss rate of Jsolated stars is poorly determined because the mass-loss rate expressions on the giant branches are empirically based on samples containing stars that experience strong binary interaction, with stellar or sub-stellar companions. We follow the evolution of several observed exoplanetary systems under the Jsolated framework and show that by lowering the mass loss rate of single solar-like stars during their giant branches these stars will engulf their planets at the tip of their asymptotic giant branch phase. Under the traditional mass loss rate such stars will not engulf their planets and will not form detectable planetary nebulae (PNe), yet under the Jsolated scheme the planets will have a major role in shaping the PNe and most likely lead the stars to form elliptical PNe. We apply our scheme to several systems including a recently discovered planet detected around a subgiant star of ~ 0.97Mo for which we find that future interaction between the star and the planet might result in an observed PN.

Infrared Studies of the Variability of a Sample of Dusty Asymptotic Giant Branch Stars in the Magellanic Clouds

Ben Sargent (Space Telescope Science Institute)

The asymptotic giant branch (AGB) stars with the reddest colors have the largest amounts of circumstellar dust, which in turn suggests extremely high mass-loss rates. AGB stars vary in their brightness, and studies show that the reddest AGB stars tend to have longer periods than other AGB stars and are more likely to be fundamental mode pulsators. Such dusty AGB stars are difficult to study, as their colors are so red due to their copious amounts of circumstellar dust that they are often not detected at optical wavelengths. Therefore, they must be observed at infrared wavelengths to explore their variability. Using the Spitzer Space Telescope, my team and I have observed a sample of very dusty AGB stars in the Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC) during the Warm Spitzer mission. For each cycle, we typically observed a set of AGB stars at both 3.6 and 4.5 microns wavelength approximately monthly for most of a year. These observations reveal a wide range of variability properties. We present results from our analysis of the data obtained from these Spitzer variability programs, including light curve analyses and comparison to period-luminosity diagrams. Potentially the most interesting set of stars we observed is the sample of 13 stars from the LMC included in the set of so-called Extremely Red Objects (EROs) that were studied by Gruendl et al (2008, ApJ, 688, L9), who determined these carbon stars to have among the highest mass-loss rates of the LMC's carbon-rich AGB star population. Paradoxically, we found most of these stars to have little to no variability, perhaps suggesting these stars are reaching or have just reached the end of the AGB phase of their lives. We are also exploring the possibility of supplementing the light curves of all of our sample stars with multi-epoch photometry from the WISE mission.

Non-radiative Coronal Lines in the Shocked Ejecta of Type Ia Supernova Remnants

Ivo Seitenzahl (UNSW Canberra)

We report on our discovery of optical, broad coronal line emission from the shocked iron-rich ejecta in young Type Ia supernova (SN Ia) remnants. Deep MUSE observations reveal broad and spatially resolved coronal lines of Fe and S, most prominently [Fe XIV]5303. This indicates the progression of the reverse shock into the Fe rich layers of ejecta, allowing Fe masses to be estimated. The width of the broad lines gives us for the first time a direct determination of the reverse shock speed and hence a new observational measurement to constrain the masses and explosion energies of the progenitors.

Envelope Removal by Jets in the Grazing Envelope Evolution

Sagiv Shiber (Technion - Israel Institute of Technology)

I conduct three-dimensional hydrodynamical simulations, and show that when a secondary star launches jets while interacting with a primary giant star in a close orbit, the jets facilitate the removal of the giant envelope. I assume that the secondary star accretes mass via an accretion disk and that the accretion disk launches the jets. The results indicate that the jets eject most of the envelope gas and unbind a part of it. The jets produce high velocity outflow in the polar directions that can be as massive as the equatorial outflow. When comparing simulations with and without jets, the final orbital separation is larger and the orbit is more eccentric when jets are included. These results show that jets might solve some puzzles in the theory of common envelope evolution, namely the ejection of the envelope and the shaping of the outflow.

SOFIA 3-Micron Observations of PAHs in Planetary Nebulae

Erin Smith (NASA Goddard Space Flight Center)

Although they are less dramatic than their explosive supernova counterparts, planetary nebulae are important contributors to the chemistry of the ISM. This is especially true in the role they are believed to play in the generation of Polycyclic Aromatic Hydrocarbons (PAHs)—assemblies of benzene-like rings of carbon dust which, when excited by UV photons, relax through emission in broad bands throughout the infrared. PAHs are observed in multiple astronomical phenomena, most notably in star forming regions, which has led to their use as a marker for estimating star formation rates in distant galaxies. Understanding the formation environments of PAHs is therefore essential to multiple aspects of Astrophysics. Using ground-based (Lick) and stratospheric (SOFIA) observations of the ~3-5 micron spectra of young planetary nebulae obtained by the SOFIA instrument FLITECAM, we investigate the spatial distribution and spectral variation of the 3.3 micron PAH feature, its associated aliphatic features and set limits on the theoretical contribution of the 4.4-4.8 micron deuterated-PAH features.

The Role of Jets in the Death of Stars: Review of the Most Recent Results

Noam Soker (Technion)

I will describe recent results on the role of jets in the common envelope evolution of all types of evolved stars and in exploding massive stars, and will compare the results with the most recent observations and with other theoretical studies. I will discuss new ideas of processes that become possible by jets, such as the grazing envelope evolution, common envelope jets supernovae, and the jittering jets explosion mechanism of massive stars aided by neutrino heating. I will compare these to the most recent observations of similarities between supernova remnants and planetary nebulae, and to the most recent theoretical studies that do not include jets.

Supernova 2017eaw: The Progenitor, Circumstellar Material, and Chemical Evolution Screen Reader Support Enabled

Samaporn Tinyanont (Caltech)

The Type II-P SN 2017eaw in NGC 6946 is the most nearby core-collapse supernova (CCSN) in the recent years, providing us with an opportunity for detailed and long-term observations. We present 3 results from our infrared (IR) photometric and spectroscopic observations. First, progenitor observations in the Ks band in 4 epochs from 1 year to 1 day before the explosion reveal no significant variability in the progenitor star greater than 6% that last longer than 200 days, indicating no significant mass loss event in this period. Second, spectroscopic monitoring during the plateau phase reveals a high-velocity He I 1.083 micron absorption line, which may be results of a shock interaction with circumstellar medium or a time dependent excitation effect. Lastly, IR photometry and spectroscopy show condensation and cooling of carbon monoxide (CO), and consequently dust, in the ejecta of SN 2017eaw. The CO shows similar line profile and temporal evolution to that of SN 1987A, suggesting a common formation pathway. Spitzer photometry showed that dust started to form at ~200 days post explosion. For SN 2017eaw, we found that the evolution of dust mass is consistent with a scenario in which a large amount of ejecta dust formed early (few hundred days) but was self obscured. Such a scenario will explain the discrepancy between the small dust mass (10-4 - 10-3 solar mass) inferred from near to mid-IR observations of extragalactic SNe and the large dust mass (0.1 - 1 solar mass) inferred from far-IR and sub-millimeter observations of the nearby SN 1987A and Galactic SN remnants.

Energy Budget, Unbound Mass in Common Envelope Evolution

Yisheng Tu (University of Rochester)

Common envelope evolution (CEE) is the key to understand the formation of many planetary nebulae (such as the Hourglass Nebula). A 3D simulation is necessary to explore the full evolution of the system in enough detail, yet simulations have not ejected the envelope without adding new uncertain energy sources. We map out the energy and mass structure of CEE in space and time. We find that the asymmetry of the mass ejection leads to relative motion between the center of mass of the disrupted envelope and that of the cores. We propose this process as a mechanism to explain the offsets between the geometric centers of certain planetary nebulae and their binary central stars. Further, we explore the parameter space of the secondary mass and of the evolutionary stage of the primary (red giant branch and asymptotic giant branch).

X-ray & Submillimeter Observations of the Pulsating RV Tau Variable U Mon

Laura D. Vega (Vanderbilt University / NASA GSFC)

RV Tauri variables are post-Asymptotic Giant Branch (post-AGB) supergiants that may be a crucial stage in the evolution of low-to-intermediate mass stars with a stellar companion. The presence of a circumbinary disk also has an important impact on the orbital evolution of these systems, which is still not well understood. The association between disk, binarity, and the RV Tau variability phenomenon had remained elusive until the Kepler spacecraft's observation of the RV Tau star, DF Cyg (Vega et al. 2017). Based on modeling of the Kepler light curve, a literature radial-velocity period, and the spectral energy distribution (SED) for RV Tau variable, DF Cyg, we argued that the long-term RV Tau phenomenon (RVb) is likely to be fundamentally connected to the circumbinary disk, revealed by infrared excess, obscuring the binary system. However, as with most RV Tau variables, the lack of flux measurements long-ward of 20 microns restricts modeling of the SED and disk parameters. It is only at long wavelengths such as 800--1000 microns that the optically thin emission of the disk can be sampled and used to constrain key properties such as overall disk mass and total size for these systems. We have obtained flux measurements at 230 GHz and at 345 GHz for an RVb variable, U Mon, with the Smithsonian Submillimeter Array (SMA). The SMA fluxes will add to U Mon's SED, while the SMA images may provide direct measurements of the size of the circumbinary disk. Additionally, we have obtained XMM-Newton measurements for U Mon, which may be the first RV Tau variable to be detected in X-rays. Our XMM-Newton observations reveal hard X-ray emission which may be consistent with a close companion possibly accreting material via an accretion disk.

Black Holes & Neutron Stars in Nearby Galaxies: Insigns from NuSTAR

Neven Vulic (NASA/GSFC)

We will present results from a new technique using NuSTAR/Chandra/XMM-Newton observations to identify neutron stars (NS) and stellar-origin black holes (BH) in nearby galaxies. The end stages of massive stellar evolution may be studied via understanding the demographics of the NS and BH populations that result from supernova explosions. Such NS and BH populations are abundant in galaxies and may be well studied via X-ray emission resulting from accreting binary systems. Nearby galaxy surveys have long classified these X-ray binaries (XRBs) by the mass category of their donor stars (high-mass and low-mass). In stark contrast, the identification of XRB compact object type (the accreting object) has been limited to a handful of the brightest extragalactic sources. Using NuSTAR color-intensity and color-color diagnostics, we classified sources as candidate NS or BH and investigated the BH fraction based on specific star formation rate and X-ray luminosity. Using multiwavelength (X-ray-to-NIR) data for M31, we examined connections between XRBs and the underlying stellar populations. We will discuss the implications of our results in the context of future multiwavelength surveys in the time domain

Optimal Classification and Outlier Detection for Stripped-Envelope Core-Collapse Supernovae

Marc Williamson (New York University)

The core collapse supernovae (SNe) of massive stars offer valuable insight into one of the most active areas of supernova research: stellar progenitors. By studying the composition of the supernova ejecta, we can learn about the composition of the progenitor before the supernova. A particularly interesting subset of all core collapse supernovae are the stripped-envelope supernovae (SESNe). The spectra of these explosions indicate that the stellar progenitors were stripped of parts or all of their outer Hydrogen and Helium envelopes. In this talk, we present a novel method for classifying SESNe that is both quantitative and continuous to better reflect the physical properties of the SESNe stellar progenitors prior to explosion. We apply our method, which combines principal component analysis (PCA) with a support vector machine (SVM), to a dataset of over 150 SNe, each with spectra taken at multiple times during the SN evolution. We find that our classification method can recreate the standard class labels and naturally handles "transition SNe," in addition to yielding insight into the relationship between different SESNe types.

The Role of Convection in Determining the Ejection Efficiency of Common Envelope Interactions

Emily C Wilson (Rochester Institute of Technology)

A widely used method for parameterizing the outcomes of common envelopes (CEs) involves defining an ejection efficiency, alpha, that represents the fraction of orbital energy used to unbind the envelope as the orbit decays. Given alpha, a prediction for the post-CE orbital separation is then possible with knowledge of the energy required to unbind the primary's envelope from its core. Unfortunately, placing observational constraints on alpha is challenging as it requires knowledge of the primary's structure at the onset of the common envelope phase. Numerical simulations have also had difficulties reproducing post-CE orbital configurations as they leave extended, but still bound, envelopes. Using detailed stellar interior profiles, we calculate alpha values for a matrix of primary-companion mass pairs when the primary is likely to incur a CE, i.e. at maximal extent in its evolution. We find that the ejection efficiency is most sensitive to the properties of the surface-contact convective region (SCCR). In this region, the convective transport times are often short compared to orbital decay timescales, thereby allowing the star to effectively radiate orbital energy and thus lower alpha. The inclusion of convection in numerical simulations of CEs may resolve the ejection problem without the need for additional energy sources as the orbit must shrink substantially further before the requisite energy can be tapped to drive ejection, or convection will transport energy throughout the envelope's mass. Additionally, convection leads to predicted post-CE orbital periods of less than a day in many cases, an observational result that has been difficult to reproduce in population studies where alpha is taken to be constant. Finally, we provide a simple method to calculate alpha if the properties of the SCCR are known.

A Comparison Between Infrared and Ultraviolet Observations of Photodissociation Regions

Emily M. Witt (University of Colorado, Boulder)

Photodissociation regions (PDRs) are regions in the interstellar medium (ISM) where energetic photons, usually far ultraviolet (FUV), are actively dissociating molecules. These regions feature intense molecular line activity in both IR traced rotational-vibrational H$_2$ emission and the FUV traced electronic H$_2$ absorption. While much work has been done in the IR and UV regimes separately, it is not clear how these different wavelength regimes compare. Especially problematic is the lack of imaging resolution in the Lyman UV (1000 \AA) where the majority of H$_2$ features reside and where the powerful O VI λ1038 feature is. PDRs inform much of our understanding of how material is processed in the ISM, a mechanism that greatly influences the life cycle of stars and galaxies. This work combines archival spectroscopic measurements from the \textit{Spitzer Space Telescope} and the Far Ultraviolet Spectroscopic Explorer (\textit{FUSE}) to probe the molecular activity within these important regions. This poster presents preliminary results of a comparison between H$_{2}$ features, PAHs and other PDR diagnostics calculated from common IR and FUV relations. This archival \textit{Spitzer}/\textit{FUSE} project sets the groundwork for a future flight demonstration of the Integral Field Ultraviolet Spectroscopic Experiment (INFUSE), the first FUV integral field spectrograph (IFS), which will map energetic regions of PDRs and supernova remnants to 2" scales over a field of view of 5' x 4.3' at moderate resolving power (R $\sim$ 5000) over a 1000 - 1600 \AA\ bandpass. INFUSE is a sounding rocket borne instrument under development at the University of Colorado (CU) with a projected launch date of 2022.

The Deaths & Afterlives of Stars

22–24, April 2019

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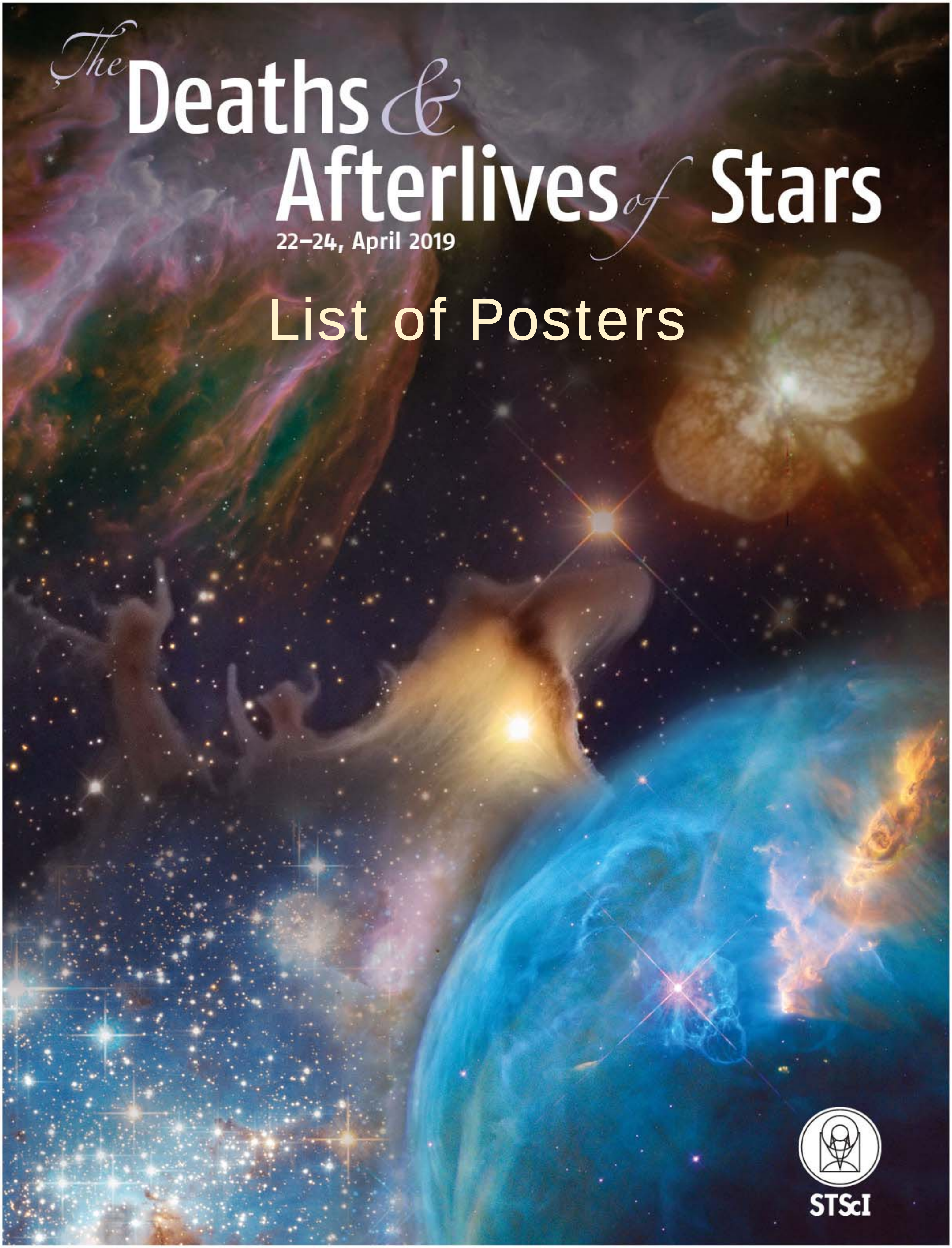

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Igor	Andreoni	andreoni@caltech.edu	Caltech	Hunting for Minute-timescale Extragalactic Optical Transients
Andrea	Antoni	aantoni@berkeley.edu	University Of California, Berkeley	The Evolution of Binaries in a Gaseous Medium: Three-Dimensional Simulations of Binary Bondi-Hoyle-Lyttleton Accretion
Fiona	Audcent-Ross	faudcentross@outlook.com	ICRAR – UWA	Radial Distribution of SNe vs Star Formation Tracers
Christopher	Berry	christopher.berry@northwestern.edu	Northwestern University	Revealing the Evolution of High-mass Binaries Using Gravitational-wave Observations
William	Blair	wblair@jhu.edu	Johns Hopkins University	Results from Deep Multi-Wavelength Surveys of Nearby Galaxies to Study Supernova Remnants and Their Progenitors
Azalee	Bostroem	abostroem@gmail.com	Univeristy of California, Davis	What Can Supernovae Tell Us About Massive Stars?
Christopher	Britt	cbritt@stsci.edu	STScI	Finding Millisecond Pulsars to Explain the Fermi Gamma-ray Excess
Peter	Brown	pbrown@physics.tamu.edu	Texas A&M	Ultraviolet Diversity of Standard Candles
Jesse	Bublitz	jtb1435@rit.edu	Rochester Institute of Technology	Irradiation Investigation: Exploring the Molecular Gas in Planetary Nebulae
Yssavo	Camacho-Neves	yic6@physics.rutgers.edu	Rutgers University	The Afterlife of Type Iax Supernovae
Luke	Chamandy	lchamandy@gmail.com	University Of Rochester	Global 3D Simulations of Common Envelope Evolution Using AMR
Sihao	Cheng	s.cheng@jhu.edu	Johns Hopkins University	High-Mass White Dwarfs in Gaia DR2: the Q Branch and WD-WD Merger Rate
Brian	Davis	bdd8@psu.edu	Penn State	An Empirical Limit on the Minimum Mass for Hot-Bottom Burning
Mariangelly	Diaz-Rodriguez	md14u@my.fsu.edu	Florida State University	Progenitor Mass Distribution for Core Collapse Supernova Remnants
Francisco	Förster	mjsepulveda@astrofisica.cl	Millennium Institute Of Astrophysics	Shock Breakout Delayed by Circumstellar Material Detected in Most Type II Supernovae
Ori	Fox	ofox@stsci.edu	STScI	Signatures of Circumstellar Interaction in the Unusual Transient AT2018cow
Andrew	Fullard	andrew.fullard@du.edu	University Of Denver	Spectropolarimetric Analysis of WR + O Binaries with SALT

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Avishai	Gilkis	agilkis@ast.cam.ac.uk	University Of Cambridge	Leftover Hydrogen in Stripped Massive Stars
Roni	Gofman	rongof@campus.technion.ac.il	Technion Institute Of Technology	The Strongly Interacting Binary Scenarios of the Enigmatic Supernova iPTF14hls
Sebastian	Gomez	sgomez@cfa.harvard.edu	Harvard University	SN 2016iet: The Pulsational or Pair-Instability Explosion of a Low Metallicity Massive CO Core Embedded in a Dense Hydrogen-Poor Circumstellar Medium
John	Graham	graham@pku.edu.cn	Kavli Institute For Astronomy And Astrophysics	An Apparent Constant LGRB Metallicity Distribution Across Redshifts z < 2.5
Ted	Gull	ted@thegulls.com	NASA-GSFC Emeritus	Our Line-of-Sight to Eta Carinae is Changing!
Matthew	Hankins	mhankins@caltech.edu	Caltech	Uncovering Infrared Transients with Palomar Gattini-IR
Marianne	Heida	mheida@caltech.edu	Caltech	The Donor Star of NGC 300 ULX-1/SN2010da
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Ann	Hornschemeier	Ann.Hornschemeier@nasa.gov	NASA GSFC	Stellar-origin Black Holes and Neutron Stars in the 2020's and Beyond: The Post Chandra and XMM-Newton Era
Matthew	Hosek	mwhosek@gmail.com	University of California, Los Angeles	Young Massive Clusters at the Galactic Center: Top Heavy Initial Mass Function and the Increased Population of Compact Objects
Griffin	Hosseinzadeh	griffin.hosseinzadeh@cfa.harvard.edu	Center For Astrophysics | Harvard & Smithsonian	Type Ibn Supernovae May Not All Come from Massive Stars
Dominika	Hubova	dominika.hubova@gmail.com	Charles University	Kinematics of Mass Loss from the Outer Lagrange Point L2
Tiara	Hung	tiarahung@ucsc.edu	Univeristy of California, Santa Cruz	Discovery of Highly Blueshifted Broad Balmer and Metastable Helium Absorption Lines in Tidal Disruption Event AT2018zr
Elizabeth	Jeffery	ejjeffer@calpoly.edu	California Polytechnic State University	Gaia, White Dwarfs, and the Age of the Galaxy
Noa	Kaplan	noa1kaplan@campus.technion.ac.il	Technion Institute Of Technology	The Influence of Jets on the Light Curve of Supernovae
Maria	Kopsacheili	mariakop@physics.uoc.gr;	University Of Crete/forth-iesl	Study of Extragalactic Supernova Remnants
Kathleen	Kraemer	kathleen.kraemer@bc.edu	Boston College	Mid-Infrared Spectra of Carbon-Rich Post-AGB Stars Across the Decades
Kelsie	Krafton	kkraft3@lsu.edu	Louisiana State University	Disentangling Dust Components in SN 2010jl: The First 1400 Days
Petr	Kurfurst	petrk@physics.muni.cz	Charles University	Interactions between Supernova Ejecta and Asymmetric Circumstellar Material
Ryan	Lau	ryanlau@caltech.edu	Isas/jaxa	WR DustERS: JWST-ERS Program to Resolve the Nature of Dust in Wolf-Rayet Winds
Margaret	Lazzarini	mlazz@uw.edu	University Of Washington	Young Accreting Compact Objects in M31: The Combined the Power of NuSTAR, Chandra, and Hubble

Richard	Miller	richard.s.miller@jhuapl.edu	Johns Hopkins University Applied Physics Laboratory	Ex Luna, Scientia: The Lunar Occultation Explorer (LOX) Transformational Population Studies of SNeIa
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Daniel	Muthukrishna	daniel.muthukrishna@ast.cam.ac.uk	University Of Cambridge	RAPID: Early Classification of Explosive Transients Using Deep Learning
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Giada	Pastorelli	giada.pastorelli@unipd.it	University Of Padova	Constraining the TP-AGB Phase with Resolved Stellar Populations in the Small Magellanic Cloud
Ondrej	Pejcha	ondrej.pejcha@gmail.com	Charles University	Mass Loss, Transients, and Dust from Catastrophically Interacting Binary Stars
Abigail	Polin	abigail@berkeley.edu	University Of California, Berkeley	Observational Signatures of sub-Chandrasekhar Mass Type Ias
Peter	Roming	proming@swri.edu	Southwest Research Insitute	Shock Break Out Explorer
Stuart	Ryder	Stuart.Ryder@mq.edu.au	Macquarie University	Four Decades of the Type IIn Supernova 1978K
Efrat	Sabach	efrats@physics.technion.ac.il	Technion Institute Of Technology	SN IIb Progenitors by Fatal Common Envelope Evolution
Beth	Sargent	sargent@stsci.edu	STScI	Infrared Studies of the Variability of a Sample of Dusty Asymptotic Giant Branch Stars in the Magellanic Clouds
Ivo	Seitenzahl	i.seitenzahl@adfa.edu.au	University Of New South Wales, Canberra	Non-radiative Coronal Lines in the Shocked Ejecta of Type Ia Supernova Remnants
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Erin	Smith	Erin.c.smith@nasa.gov	NASA/GSFC	SOFIA 3-Micron Observations of PAHs in Planetary Nebulae
Noam	Soker	soker@physics.technion.ac.il	Technion Institute Of Technology	The Role of Jets in the Death of Stars: Review of the Most Recent Results
Samaporn	Tinyanont	st@astro.caltech.edu	Caltech	Supernova 2017eaw: The Progenitor, Circumstellar Material, and Chemical Evolution Screen Reader Support Enabled
Yisheng	Tu	ytu7@u.rochester.edu	University Of Rochester	Energy Budget, Unbound Mass in Common Envelope Evolution
Gregory	Vance	gvance@asu.edu	Arizona State University	Titanium and Iron in the Cassiopeia A Supernova Remnant
Laura	Vega	laura.d.vega@vanderbilt.edu	Vanderbilt University / Nasa - GSFC	X-ray & Submillimeter Observations of the Pulsating RV Tau Variable U Mon
Neven	Vulic	neven.vulic@nasa.gov	Nasa Gsfc / Umcp / Cresst Ii	Black Holes & Neutron Stars in Nearby Galaxies: Insigns from NuSTAR
Rick	White	rlw@stsci.edu	STScI	A New, Deep JVLA Radio Survey of Supernova Remnants in M33
Marc	Williamson	mew488@nyu.edu	New York University	Optimal Classification and Outlier Detection for Stripped-Envelope Core-Collapse Supernovae*
Emily	Wilson	ecw7497@rit.edu	Rochester Institute Of Technology	The Role of Convection in Determining the Ejection Efficiency of Common Envelope Interactions
Emily	Witt	emily.witt@colorado.edu	University Of Colorado, Boulder	A Comparison Between Infrared and Ultraviolet Observations of Photodissociation Regions

The Deaths & Afterlives of Stars

22–24, April 2019

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