CAASTRO
ARC CENTRE OF EXCELLENCE
FOR ALL-SKY ASTROPHYSICS

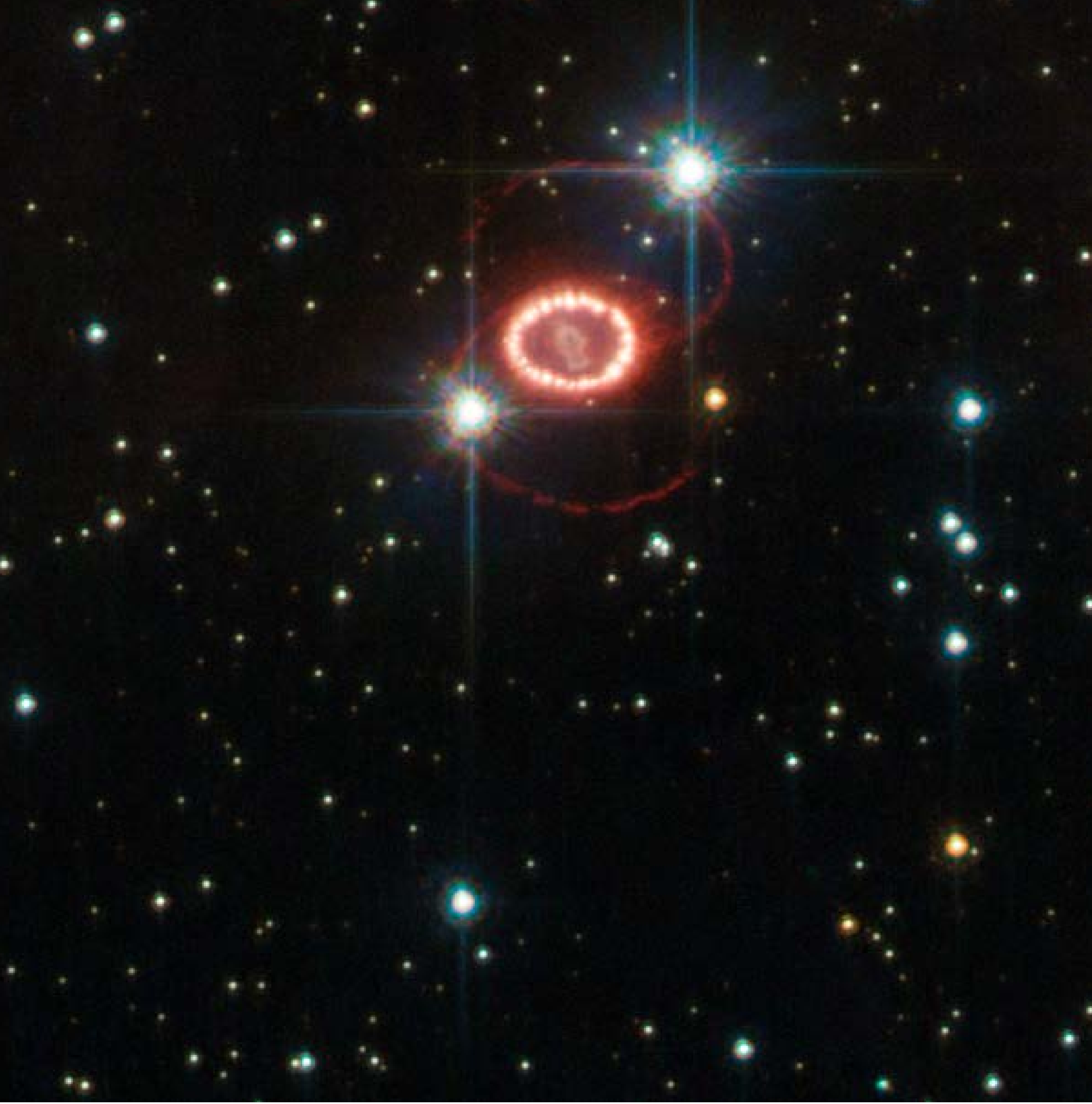
The Centre of Excellence for All-sky Astrophysics

2014 CAASTRO Annual Scientific Conference

Supernovae in the Local Universe:

Celebrating 10,000 days of Supernova 1987A

11th -15th August 2014, Coffs Harbour, NSW, Australia



CAASTRO
ALL-SKY ASTROPHYSICS

PROGRAM

2014 ANNUAL SCIENTIFIC CONFERENCE

Supernovae in the Local Universe:
Celebrating 10,000 days of Supernova 1987A

10th-15th August
Coffs Harbour, NSW, Australia

SUNDAY 10 AUGUST 2014

Time	Item
3:00pm	Registration Desk Opens Jetty Harbour Room
5:00pm	Welcome Drinks Charlie's Decks
	Dinner Delegates own choice Options: • Charlie's Restaurant • Room Service • Coffs Harbour City Centre (Taxi at own cost)

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

MONDAY 11 AUGUST 2014

Time	Item
6:30am	*Optional Activity* Walk – Charlesworth Bay to Korora Bay
7:00am	**Breakfast** *Charlie's Restaurant*
7:30am – 8:50am	**Registration Desk Open**
Welcome	
9:00am	**Welcome/Acknowledgement of Country** *Jetty Harbour Room*
9:05am – 9:15am	**Welcome and Conference Overview** Bryan Gaensler
Session I: 10,000 Days of Supernova 1987A **Session Chair: Bryan Gaensler**	
9:15am – 9:40am	Dick McCray (invited talk) *Supernova 1987A at 10,000 days* (25 min presentation)
9:40am– 10:05am	Josefin Larsson (invited talk) *The ejecta of SN 1987A at 10,000 days* (25 min presentation)
10:05am – 10:20am	Giovanna Zanardo *Spectral & morphological analysis of the remnant of Supernova 1987A with ALMA & ATCA* (15 min presentation)
10:20am – 10:35am	Mikako Matsuura *Herschel and ALMA observations of supernova 1987A* (15 min presentation)
10:35am – 11:00am	Claes Fransson (invited talk) *Physical Conditions in the SN 1987A Ejecta at 10,000 days* (25 min presentation)
11:00am – 11:20am	Group questions and discussions (20 min Q&A)
11:20am – 11:50am	**Morning Tea** **Island Courtyard**

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

Session II: Unusual & Unique Objects Session Chair: Stuart Ryder	
11:50am – 12:20pm	Raffaella Margutti (invited talk) *Supernova 2009ip: Supernova or imposter?* (25 min presentation & 5 min Q&A)
12:20pm – 12:35pm	Fang Yuan *Locations of Peculiar Supernovae as a Diagnostic of Their Origins* (12min presentation & 3 min Q&A)
12:35pm – 1:05pm	Nathan Smith (invited talk) *Pre-Supernova Eruptions and the Fates of Massive Stars* (25 min presentation & 5 min Q&A)
1:05pm – 2:30pm	**Lunch Charlies Restaurant**
Session III: Unique Measurements Session Chair: Jeremy Mould	
2:30pm – 3:00pm	Avishay Gal-Yam (invited talk) *Supernova flash spectroscopy: a new observational window into stellar death* (25 min presentation & 5 min Q&A)
3:00pm – 3:15pm	Nadejda Blagorodnova *Gaia: A Supernova Discovery Machine* (12 min presentation & 3 min Q&A)
3:15pm- 3:30pm	Brad Tucker *KEGS - The Kepler Extra-Galactic Survey* (12 min presentation & 3 min Q&A)
3:30pm	**Afternoon Tea Island Courtyard**
3:35pm – 5:30pm	Poster Session & Social Gathering/Supernova Bingo
6:30pm	**Dinner** *Buffet Dinner – Charlie's Restaurant*

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

TUESDAY 12 AUGUST 2014

Time	Item
6:30am	*Optional Activity* Beach Volley Ball
7:00am	**Breakfast** *Charlie's Restaurant*
8:55am – 9:00am	**Announcements**
Session IV: Nearby Core Collapse Supernovae **Session Chair: Christina Thöne**	
9:00am – 9:30am	Stephen Smartt (invited talk) *Observational constraints on progenitors of nearby supernovae* (25 min presentation & 5 min Q&A)
9:30am – 9:45am	Ori Fox *Uncovering the Putative B-Star Binary Companion of the SN 1993J Progenitor* (12 min presentation & 3 min Q&A)
9:45am – 10:00am	Melina Bersten *The First Evidence of a Binary Progenitor for a Type Ib Supernova* (12 min presentation & 3 min Q&A)
10:00am – 10:15am	Michael Bietenholz Two Newly-Resolved Supernovae: SN 2011dh and SN 1996cr (12 min presentation & 3 min Q&A)
10:15am – 10:30am	Isaac Shivvers *Young Type IIn Supernova 1998S in High Resolution* (12 min presentation & 3 min Q&A)
10:30am – 11:00am	**Morning Tea** **Island Courtyard**
Session V: Stellar Populations, Core Collapse and Progenitors **Session Chair: Kate Maguire**	
11:00am – 11:30am	Paul Crowther (invited talk) *Observations of massive star populations in nearby galaxies* (25 min presentation & 5 min Q&A)
11:30am – 12:00pm	Joe Anderson (invited talk) *Statistical studies of supernova environments* (25 min presentation & 5 min Q&A))

12:00pm - 12:15pm	Ben Davies *How Cool Are Red Supergiants? Obtaining accurate masses for SN-IIP progenitors* (12 min presentation & 3 min Q&A)
12:15pm - 12:30pm	Maryam Modjaz *CfA Spectra of 73 Stripped Supernovae & Implications for the Spectroscopic SN-GRB Connection* (12 min presentation & 3 min Q&A)
12:30pm – 2:00pm	**Lunch** **Charlies Restaurant**
Session VI: Stellar Populations, Core Collapse and Progenitors (continued) **Session Chair: Schuyler Van Dyk**	
2:00pm – 2:30pm	Selma de Mink (invited talk) *Binary Interactions: Theory And Population Synthesis* (25 min presentation & 5 min Q&A)
2:30pm – 3:00pm	Sung-Chul Yoon (invited talk) *Progenitors of Type Ib/c supernovae* (25 min presentation & 5 min Q&A)
3:00pm – 3:15pm	John Eldridge *Unveiling the progenitors of type Ib/c Supernovae* (12 min presentation & 3 min Q&A)
3:15pm – 3:30pm	Frederica Bianco *Probing the progenitors channels of stripped SN with the CfA SN sample* (12 min presentation & 3 min Q&A)
3:30pm – 4:00pm	**Afternoon Tea** **Island Courtyard**

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

Session VII: Stellar Populations, Core Collapse and Progenitors (continued) **Session Chair: Maryam Modjaz**	
4:00pm – 4:15pm	Anders Jerkstrand *Progenitor masses of Type IIb supernovae from nebular phase spectral modelling* (12 min presentation & 3 min Q&A)
4:15pm – 4:30pm	Alceste Bonanos *A survey of dusty, evolved, massive stars in the nearby Universe* (12 min presentation & 3 min Q&A)
4:30pm – 4:45pm	Morgan Fraser *Solving the red supergiant problem?* (12 min presentation & 3 min Q&A)
4:45pm – 5:15pm	Thierry Foglizzo (invited talk) *The explosion mechanism of core collapse supernovae* (25 min presentation & 5 min Q&A)
6:30pm	**Dinner** *BBQ by the Pool*

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

WEDNESDAY 13 AUGUST 2014

Time	Item
6:30am	*Optional Activity* Tennis
7:00am	Breakfast Charlie's Restaurant
8:55am – 9:00am	**Announcements**
Session VIII: 10,000 Days of Supernova 1987A (continued) **Session Chair: Lister Staveley-Smith**	
9:00am – 9:15am	Ivo Seitenzahl *The Light Curve of SN 1987A Revisited: Constraining Production Masses Of Radioactive Nuclides* (12 min presentation & 3 min Q&A)
9:15am – 9:30am	Dick Manchester *9999 Days of Radio Observations of SN 1987A* (12 min presentation & 3 min Q&A)
9:30am – 9:45am	Kari Frank *New Chandra ACIS Observations of SN 1987A* (12 min presentation & 3 min Q&A)
9:45am – 10:00am	Paul Lasky *Gravitational waves from a possible neutron star in the supernova remnant 1987A* (12 min presentation & 3 min Q&A)
10:00am – 10:30am	**Morning Tea** **Island Courtyard**
Session IX: Unusual & Unique Objects (continued) **Session Chair: Chris Lidman**	
10:30am – 11:00am	Ferdinando Patat (invited talk) *Spectropolarimetry and Asphericity of Supernovae* (25 min presentation & 5 min Q&A)
11:00am – 11:15am	Maria Drout *Rapidly-Evolving and Luminous Transients from Pan-STARRS1* (12 min presentation & 3 min Q&A)
11:15am - 11:30am	Io Kleiser *Rapidly Fading Supernovae from Massive Star Explosions* (12 min presentation & 3 min Q&A)

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

11:30am – 11:45am	Alexandra Kozyreva *Observational properties of low-redshift pair instability supernovae* (12 min presentation & 3 min Q&A)
11:45am -12:00pm	Andy Howell *Superluminous supernovae from SNLS* (12 min presentation & 3 min Q&A)
12:00pm -12:15pm	Iair Arcavi *Transients in the SN - SLSN Gap* (12 min presentation & 3 min Q&A)
12:15pm – 2:00pm	**Lunch** **Charlies Restaurant**
2:15pm	**Free Afternoon** Social Program – optional activities: Muttonbird Island Tour (Cost TBC) Big Banana ($15/person) Golf ($27/person) Coffs CBD Visit
	Dinner *Own Choice* *A bus will take delegates into Coffs Harbour* *(depart 6:00pm and return 9:00pm)*

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

THURSDAY 14 AUGUST 2014

Time	Item
6:30am	*Optional Activity* Early Morning Beach Walk
7:00am	**Breakfast** Charlie's Restaurant
8:55am – 9:00am	**Announcements**
Session X: Type Ia Supernovae and Their Progenitors **Session Chair: Ken'ichi Nomoto**	
9:00am – 9:30am	Fritz Roepke (invited talk) *Type Ia supernova models compared to local events* (25 min presentation & 5 min Q&A)
9:30am – 10:00am	Ashley Ruiter (invited talk) *White Dwarf Binaries and Type Ia Progenitors* (25 min presentation & 5 min Q&A)
10:00am – 10:15am	Ken Shen *Double detonation Type Ia supernovae from double white dwarf progenitors* (12 min presentation & 3 min Q&A)
10:15am – 10:30am	John Hillier *Time-dependent Radiative Transfer Modelling of Supernovae Spectra* (12 min presentation & 3 min Q&A)
10:30am – 11:00am	**Morning Tea** **Island Courtyard**
Session XI: Type Ia Supernovae and Their Progenitors (continued) **Session Chair: Noam Soker**	
11:00am – 11:15am	Marten van Kerkwijk *Normal type Ia supernovae from white dwarf mergers* (12 min presentation & 3 min Q&A)
11:15am – 11:30am	Richard Scalzo *The Range of Ejected Masses in Type Ia Supernovae* (12 min presentation & 3 min Q&A)
11:30am – 11:45am	Kate Maguire *Searching for progenitor signatures in Type Ia supernova spectra* (12 min presentation & 3 min Q&A)

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

11:45am - 12:00pm	Michael Childress *SN 2012fr and High-Velocity Features in Type Ia Supernovae* (12 min presentation & 3 min Q&A)
12:00pm - 12:15pm	Ryan Foley *Extensive Multi-wavelength Observations of SN 2014J in M82 Indicate Reddening and Circumstellar Scattering by Typical Dust* (12 min presentation & 3 min Q&A)
12:15pm - 12:30pm	Curtis McCully *The Progenitor System of the Type Iax SN 2012Z* (12 min presentation & 3 min Q&A)
12:30pm – 2:00pm	**Lunch** **Charlies Restaurant**
Session XII: Supernova Remnants and Historical Supernovae **Session Chair: Margarita Rosado**	
2:00pm – 2:30pm	Carles Badenes (invited talk) *The Physics of Young Supernova Remnants* (25 min presentation & 5 min Q&A)
2:30pm – 2:45pm	You-Hua Chu *Type Ia Supernova Remnants in the Large Magellanic Cloud* (12 min presentation & 3 min Q&A)
2:45pm – 3:00pm	Wolfgang Kerzendorf *Companions of Supernovae* (12 min presentation & 3 min Q&A)
3:00pm – 3:15pm	Brian Williams *Spitzer Observations of the Type Ia Supernova Remnant N103B: A Type Ia with CSM Interaction?* (12 min presentation & 3 min Q&A)
3:15pm – 3:30pm	Kazimierz Borkowski *Non-uniform Expansion of the Youngest Galactic Supernova Remnant G1.9+0.3* (12 min presentation & 3 min Q&A)
3:30pm – 4:00pm	**Afternoon Tea** **Island Courtyard**

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

Session XIII: Supernova Remnants and Historical Supernovae (continued) **Session Chair: Alceste Bonanos**	
4:00pm – 4:30pm	Armin Rest (invited talk) *An Astronomical Time Machine: Light Echoes from Historic Supernovae and Stellar Eruptions* (25 min presentation & 5 min Q&A)
4:30pm – 5:00pm	Haley Gomez (invited talk) *Dust in Young Supernova Remnants* (25 min presentation & 5 min Q&A)
5:00pm – 5:15pm	Tea Temim *Supernovae as drivers of dust evolution in the Magellanic Clouds* (12 min presentation & 3 min Q&A)
6:30pm	**Conference Dinner** **Marine Harbour Room** Dinner Speaker - Brian Schmidt

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

FRIDAY 15 AUGUST 2014

Time	Item
7:30am	*Optional Activity* Pilates
7:00am	**Breakfast** *Charlie's Restaurant*
9:25am – 9:30am	**Announcements**
Session XIV: 10,000 Days of Supernova 1987A; 23,741 Days of Bob **Session Chair: You-Hua Chu**	
9:30am – 9:50am	Robert Kirshner (invited talk) *Hot Spots and Shock Stops in SN 1987A* (20min presentation)
9:50am – 10:30am	Supernova 1987A Panel Session chaired by Robert Kirshner (40 min general discussion and Q&A)
10:30am-11:00am	**Morning Tea** **Island Courtyard**
Session XV: Future Instruments and Techniques **Session Chair: TBC**	
11:00am – 11:20am	Bernhard Mueller (invited talk) *Neutrinos and Gravitational Waves - What will we learn from a Galactic Supernova?* (17 min presentation & 3 min Q&A)
11:20am – 11:40am	Kate Scholberg (invited talk) *Neutrinos from Supernovae: what the Next Burst will Bring* (17 min presentation & 3 min Q&A)
11:40am – 11:55am	Sarah Gossan *Observing Gravitational Waves from the Next Nearby Core-Collapse Supernova* (12 min presentation & 3 min Q&A)
11:55am - 12:15pm	Tara Murphy (invited talk) *Explosive Variables and Transients with MWA, ASKAP and SKA* (17 min presentation & 3 min Q&A)
12:15pm – 1:45pm	**Lunch** **Charlies Restaurant**

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

Session XVI: Future Instruments and Techniques (continued) **Session Chair: TBC**	
1:45pm – 2:05pm	George Sonneborn (invited talk) *Nearby Supernovae and the James Webb Space Telescope* (17 min presentation & 3 min Q&A)
2:05pm – 2:20pm	Russell Cannon *The next 1987A* (12 min presentation & 3 min Q&A)
2:20pm – 2:50pm	Conference Summary Emily Levesque and Stuart Sim (30 mins)
2:50pm	**CLOSE**

ABSTRACTS

Session I: 10,000 Days of Supernova 1987A

Mr Richard McCray
University of California Berkeley

Supernova 1987A at 10,000 days

Since its discovery, SN 1987A has been observed intensively by virtually every kind of telescope on the ground and in space. After a brief overview of the physical model that has been constructed by interpretation of these multi-wavelength observations, describe what we are learning about the structure of the reverse shock from observations with HST and about molecules in the interior debris from observations with ALMA.

Dr Josefin Larsson
Royal Institute of Technology & Oskar Klein Centre

The ejecta of SN 1987A at 10 000 days

The ejecta of SN 1987A have been extensively observed by HST and VLT since early epochs. I will review what we have learnt from these observations in terms of the energy output of the ejecta as well as the three-dimensional structure and composition. After fading for about 5000 days after the explosion, the ejecta are now in a new evolutionary phase where they are brightening due to energy input from the X-rays from the equatorial ring. The X-ray input can also explain the edge-brightened morphology with a 'hole' in the centre seen in the HST images. Combined imaging and spectral observations further show that the three-dimensional geometry is highly asymmetric, with clumps of material distributed near the plane of the ring. These asymmetries probe the conditions at the time of the explosion.

Ms Giovanna Zanardo
International Centre for Radio Astronomy Research

Spectral and morphological analysis of the remnant of Supernova 1987A with ALMA & ATCA

Radio supernovae result from the collision between a supernova (SN) shock and the progenitor’s circumstellar medium (CSM). Supernova 1987A in the Large Magellanic Cloud, as the only nearby core-collapse supernova observed to date, has allowed unique studies on the stages of the SN-CSM interaction and the complex structure of the emission. High-frequency radio observations of the

supernova remnant (SNR) are particularly effective in probing both the nonthermal and thermal components of the emission, while providing constraints to its physical origin. Nonthermal emission from the outer shock and, possibly, from a pulsar or pulsar wind nebula, can be expected in conjunction with thermal emission from plasma and from newly-forming dust grains. To investigate the nature of the emission detected across the transition from radio to far-infrared, we present a comprehensive spectral and morphological analysis of the SNR with the Australia Telescope Compact Array (ATCA) and the Atacama Large Millimeter/submillimeter Array (ALMA). The emission components in images from 94 to 672 GHz (3.2 mm to 450 m) are separated with the assistance of a synchrotron template from the ATCA high-resolution observations at 44 GHz, and a dust template from the ALMA observations at 672 GHz. The emission morphology and the spectral index distribution are discussed before and after subtraction of the synchrotron and dust models. To explain the emission residuals, the scenario of possible particle flux injection by a pulsar situated in the inner regions of the remnant is explored.

Dr Mikako Matsuura
University College London

Herschel and ALMA observations of supernova 1987A

Supernovae (SNe) have been proposed to play a key role on galaxy evolution, including a major source of dust found in galaxies. The hypothesis of SNe as a major dust factory requires measurements of dust masses in supernovae. We have observed SN 1987A at far-infrared and submillemeter wavelength, using Herschel Space Observatory and ALMA. Herschel thermal emission of dust towards SN 1987A in 2011, with an inferred dust mass of 0.4-0.7 solar masses. This is about 1,000 larger mass of dust than the previously reported mass in this SN in early days. The only possible explanation of this large mass of dust is that refractory elements, which were ejected by SN explosion, efficiently condensed into dust grains in short time scale (<25 years). In order to elucidate this explanation, we have carried out further Herschel and ALMA observations. Herschel follow-up imaging observations confirmed previous far-infrared photometry. Moreover, Herschel spectroscopic observations ruled out a possibility that line contamination into the Herschel broad-band may distort the dust mass, confirming that far-infrared emission is due to thermal emission from a large mass of dust. ALMA high angular resolution image isolated the location of dust to be in the ejecta, demonstrating dust grains were freshly formed from elements ejected by SN explosion. Our Herschel and ALMA observations have opened up a new era of dust studies in supernovae, with future prospects of more precise studies of chemistry and dynamics within SNe.

Dr Claes Fransson
Oskar Klein Center, Stockholm University

Physical Conditions in the SN 1987A Ejecta at 10,000 days

The radioactive input from 56Ni, 57Ni and 44Ti provided the energy source during the first ~5000 days. Models of the spectrum and light curve provide an accurate estimate of the masses of these

isotopes, as well as the masses of the most important nucleosynthesis products. The rise of the light curve after day 5000 needs an extra energy source and I will discuss the energy deposition from the X-rays and its effects on the ejecta. Finally I will discuss the modelling of the molecular CO and SiO emission from the first years until the recent ALMA observations, and what these tell us about the present ejecta conditions. A few words of the ongoing interaction with the ring will also be added.

Session II: Unusual and Unique Objects

Dr Raffaella Margutti
Harvard University- Institute for Theory and Computation

Supernova 2009ip: Supernova or imposter?

The double re-brightening of SN2009ip in 2012 raised questions about our understanding of the late stages of massive star evolution. Here I present a review of the observational properties of this remarkable explosion and I offer an overview of the possible explanations that have been put forward in the last months. Irrespective of whether the explosion was terminal, SN 2009ip brought to light the existence of new channels for sustained episodic mass-loss in massive stars, the physical origin of which has yet to be identified.

Dr Fang Yuan
Australian National University

Locations of Peculiar Supernovae as a Diagnostic of Their Origins

One of the key questions for understanding supernovae is the nature of their progenitors. For very nearby core-collapse supernovae, direct identifications of pre-explosion progenitor stars have led to the tightest constraints on their physical characteristics - but this is only possible in a handful of cases. Recently, an increasing number of unusual transients occurring far away from galaxies have been discovered by wide-field transient surveys, e.g. a class of peculiar sub-luminous

---

Dr Nathan Smith
University of Arizona

Pre-Supernova Eruptions and the Fates of Massive Stars

Session III: Unique Measurements

Prof. Avishay Gal-Yam
Weizmann Institute of Science

Supernova flash spectroscopy: a new observational window into stellar death

I will present the technique of flash spectroscopy: rapid spectroscopic observation of supernovae, shortly (hours) after they explode. Strong shock breakout radiation flash-ionizes any surrounding circumstellar material (CSM) distributed around the exploding star, and the resulting recombination emission lines enable a direct measurement of the CSM composition. As the ejecta expand they sweep up the CSM, so a series of spectra tracking the emission line evolution will allow to constrain the physical distribution of gas around each event. The CSM around massive stars is a probe of their evolution during the final year prior to explosion, a critical period not easily accessible till now. We have demonstrated the efficacy of this technique with recent studies from the iPTF survey that can regularly detect SNe hours after they explode.

Ms Nadejda Blagorodnova
Institute of Astronomy

Gaia: A Supernova Discovery Machine

Gaia is ESA's global space astrometry satellite, which launched in Dec 2013, to embark on its full-sky 5 year mission. During early summer 2014 it is expected to complete its commissioning phase. It will then carry out an Ecliptic Pole Scanning Mode set of observations for initialisation and validation purposes. The full-sky nominal operation mode will then commence. In this talk I will present the potential of Gaia for transient discovery, and in particular how Gaia will detect a significant number of supernovae. I will detail Gaia's expected capabilities with special attention to: its ability to localise nuclear transients (Blagorodnova et. al., in prep.); the performance of GS-TEC (Blagorodnova et. al, 2014), the automated realtime classification of low-resolution Gaia spectro-photometry; status of the ground based follow-up and validation campaigns and the first performance results from the Ecliptic Pole Scanning Phase.

Dr Brad Tucker
Australian National University / University of California, Berkeley

KEGS - The Kepler Extra-Galactic Survey

Kepler's unique technical capabilities are not only well suited for finding and studying exo-planets, but also supernovae. I will give an overview of the Kepler Extra-Galactic survey - a program using

Kepler to search for supernovae, active galactic nuclei, and other transients in galaxies. To date we have found two type Ia supernovae and two core-collapse supernovae. The 30-minute cadence of Kepler has revealed subtle features in the light-curves of these supernova not detectable with any other survey. With a high-cadence, high precision survey, shock break-out in a large number of SN can be found, improving our understanding of supernova progenitors. We can also search in nearby galaxies for very fast and faint transients, filling in a previously unaccessible parameter space. Lastly, the precision data of any discovered type Ia supernova combined with ground based data can dramatically improve our use of type Ia for determining distances and measuring the properties of dark energy.

Session IV: Nearby Core Collapse Supernovae

Prof. Stephen Smartt
Queen's University Belfast

Observational constraints on progenitors of nearby supernovae

The nearest supernovae are discovered in galaxies closer than about 10 - 20 Mpc and these galaxies often have images taken with either the space telescopes or large ground telescopes. These archival images predate the supernova explosion and are often of high enough resolution and depth that the massive star that exploded can be identified. The last decade has seen successful identification of progenitor stars and even the subsequent disappearance in some cases. It is now routine practice to search for progenitor star identification for all nearby supernovae to estimate luminosity and a mass through application of stellar evolutionary models.This talk will review the results in this area and the implications for stellar evolution, the explosion mechanism and nucleosynthesis.

Dr Ori Fox
University of California, Berkeley

Uncovering the Putative B-Star Binary Companion of the SN 1993J Progenitor

Type IIb supernova (SN IIb) models typically invoke H envelope stripping by mass transfer in a binary system. Located in M81, at a distance of only 3.6 Mpc, SN 1993J offers one of the best opportunities to test such models. Already, 93J is one of only four SNe IIb with the progenitor primary star directly identified in pre-explosion images. Resulting models suggest that the 93J progenitor companion grew to 22 M_solar and became a source of ultraviolet (UV) excess, but the direct detection of continuum emission from the predicted companion has proven difficult. In 2002, an excess flux in the near-UV and B bands suggested the possible presence of the hot companion. In 2004, Keck optical spectra showed evidence for absorption lines consistent with a hot (B2 Ia) star, but the field was crowded and dominated by flux from the SN. In 2012, the SN flux finally faded below the expected continuum level of the companion star. Here I present recently published Hubble Space Telescope (HST) Cosmic Origins Spectrograph (COS) far- and near-UV spectra, along with Wide-Field Camera 3 (WFC3) photometry of SN 1993J observed in 2012. These observations provide the best opportunity yet for uncovering the UV continuum properties from the putative companion.

Dr Melina Bersten
Kavli Institute for the Physics and Mathematics of the Universe

The First Evidence of a Binary Progenitor for a Type Ib Supernova

Determining the nature of the progenitor of core-collapse supernovae (SNe) is a crucial problem in astrophysics. For hydrogen-deficient SN(Types Ib and Ic) this is particular controversial, single

massive stars and close binary systems are the most appealing alternatives. Direct detections of hydrogen-deficient SN progenitors in deeppre-explosion images so far have not been successful. Recently, a luminous blue object was identified for the first time in archival images of the Type Ib SN iPTF 13bvn. I will show that the hydrodynamical modelling of iPTF 13bvn implies that the progenitor was low-mass helium star, suggesting a binary scenario. I will show close-binary evolution calculations that provide a self-consistent picture for the light-curve shape, the absence of hydrogen, and the pre-SN photometry. In this work we predict that the remaining companion is a luminous O-type star. A future detection of such star may be possible and would represent the first robust progenitor identification for a Type-Ib SN.

Dr Michael Bietenholz
Hartebeesthoek Radio Astronomy Observatory

Two Newly-Resolved Supernovae: SN 2011dh and SN 1996cr

We present 8.4-GHz VLBI results on two recent and nearby supernovae, which are resolved with VLBI. These add two to the only five supernova with ages less than 30 yrs for which we have so far obtained a well-resolved image. The first is SN 1996cr in Circinus Galaxy, at a distance of only 3.7 Mpc. It is one of the brightest radio supernova ever observed, but was not discovered till a few years after the explosion, using radio observations. Our VLBI data from 2013 with the Australian LBA allow us to determine a source size and show that the average expansion speed is ~8000 km/s. The second is SN 2011dh, a bright type IIb supernova in the nearby (8.4 Mpc) galaxy M51. We obtained High Sensitivity Array VLBI observations of it in 2012 August, and our new VLBI image shows that it has fairly circular shell structure. It is expanding rapidly, with an average speed of ~20000 km/s. We discuss the implications of the results on these two newly resolved examples for our understanding of supernova.

Mr Isaac Shivvers
University of California, Berkeley

Young Type IIn Supernova 1998S in High Resolution

The nearby Type IIn Supernova (SN) 1998S persists as one of the best-studied examples of its type. It provided a unique opportunity to study the progenitor star from within as the explosion lit up a dense circumstellar material (CSM) launched from the progenitor star before it underwent core collapse. Modern studies of SN spectra very soon after shock breakout (i.e. “SN flash spectroscopy”) provide remarkable parallels to the SN 1998S system, and a thorough understanding of SN 1998S will further enable these and future studies. In this presentation I present a Keck HIRES spectrum of SN 1998S taken on 1998 March 4.46 UT, within a few days of shock breakout. This spectrum indicates that the inner CSM displays qualitatively different properties from the outer CSM, perhaps due to a change in the wind properties off of the progenitor ∼10 y before core collapse. I will discuss this complex spectrum in detail and describe the properties of the SN 1998S system at this early stage in its development.

Session V: Stellar Populations, Core Collapse and Progenitors

Prof. Paul Crowther
University of Sheffield

Observations of massive star populations in nearby galaxies

I will review massive star populations in nearby galaxies, including OB stars, Wolf-Rayet stars and Red Supergiants, and their parent clusters. Recent VLT and HST observations of the massive stars within the LMC 30 Doradus nebula permit its use as a template for extragalactic giant HII regions, including the significance of massive binaries. I will consider the significance of differing degrees of association of H-rich and H-deficient ccSNe with HII regions, and implications for their progenitor masses.

Dr Joseph Anderson
European Southern Observatory, Chile

Statistical studies of supernova environments

Mapping the diversity of supernovae (SNe) transient behaviour back to specific progenitors is key to our understanding of the paths taken by stellar evolution before explosive stellar death. Investigations of the immediate environments of SNe allow statistical constraints to be made on progenitor properties such as mass and metallicity. In this talk I will review the progress that has been made in this field. Pixel statistics using tracers of e.g. star formation within galaxies have shown intriguing differences in the explosion sites of in particular SNe types II and Ib/c, suggesting statistical differences in population ages. In addition, such studies have shown (unexpectedly) that the interacting SNe IIn do not explode in regions containing the most massive stars, and has hence constrained at least a significant fraction of their progenitors to arise from the lower end of the core-collapse SN mass range. Host HII region spectroscopy has been obtained for a significant number of core-collapse events, however definitive conclusions on differences between distinct SN types have to-date been elusive. Stellar evolution models predict that the relative fraction of SN Ib/c to SN II should increase with increasing metallicity, due to the dependence of mass-loss rates on progenitor metallicity. However, current data show no clear separation in the environment metallicities of these SN types. Environment studies are also being undertaken for SN Ia, where constraints can be made on the shortest delay times of progenitor systems, and the preference of different SNe types for different environments within galaxies. Environment studies are evolving to different resolutions, and the use of different wavelengths and techniques (e.g. IFU observations in the near-IR), which promise to bring additional fruitful results. I will end this review suggesting that the next stage in this field is to combine environmental information together with more specific SN observed characteristics (such as decline rates, absolute magnitudes, spectral line profiles), and I will show some preliminary intriguing results in that direction.

Dr Ben Davies
Liverpool John Moores University

How Cool Are Red Supergiants? Obtaining accurate masses for SN-IIP progenitors

There are now numerous examples of SNe II-P with Red Supergiant (RSG) progenitors identified in pre-explosion imaging. Using the brightness and colour of the progenitor, in combination with models of stellar structure and atmospheres, it is possible to estimate of the progenitor's initial mass. Analysis of a sample of such events has led to the surprising claim that the SNe from RSGs with initial masses >17Msun are somehow 'missing'. A crucial step in the derivation of progenitor mass from pre-explosion photometry is the conversion from magnitude/colour to bolometric luminosity. This requires knowledge of the shape of RSG spectral energy distributions (SEDs) to infer bolometric corrections. The widely-used calibration for this comes from the optical-based temperature scale of Levesque et al. However we have shown recently that these calibrations greatly overestimate the NIR flux and substantially underestimating the level of circumstellar extinction, with obvious implications for estimating of bolometric luminosities. Using continuous optical-NIR spectrophotometry of RSGs in metallicity environments ranging from Solar to 1/10 Solar, we have reappraised the temperature scale of RSGs, and present new calibrations for obtaining L_bol of RSGs from broad-band photometry.

Prof. Maryam Modjaz
New York University

CfA Spectra of 73 Stripped SN and Implications for the Spectroscopic SN-GRB Connection

The study of Stripped-Envelope Core-Collapse SNe (stripped SNe) is vital for a number important areas in astrophysics, from understanding the diverse deaths of massive stars, to the connection between SNe and Long-duration Gamma-ray bursts (GRBs) to quantifying and excluding contaminants in high-z SNe Ia searches for cosmology. However, their study has been confined to a handful of well-observed individual objects that happened to be nearby or peculiar. While the SNe Ic-bl associated with GRBs have been studied in detail, the full range of properties of normal or broad-lined SNe is not known, nor their dominant progenitor channel and the productions conditions that lead to different kinds of explosions in massive stars. Here I will present optical spectra of 73 stripped SNe (SNe IIb, Ib, Ic and Ic-bl) collected at the Harvard-Smithsonian Center for Astrophysics (CfA) from 1994-2009, as published in Modjaz et al. (2014), doubling the world-supply of well observed SESNe. Forty-four of these 73 SESNe have a date of maximum light from either our companion paper (Bianco et al. 2014) or from the literature. I will discuss pertinent features of this homogeneous and densely time-sampled data set, as well as the large number of re-classifications of SN subtypes (mostly from SN Ic to SN Ib) and improved SNID templates. In addition, I will attack the SN-GRB connection question by investigating what sets apart the spectra of SN Ic-bl with GRBs from those without GRBs. Here, we present the first statistical analysis of the largest set of spectra and expansion velocities of 10 SN-GRBs, 15 SNe Ic-bl and 24 SNe Ic, based on both the CfA data set and the literature. I will show evidence that implies that the progenitor stars of SN-GRBs are most likely not only H- but also fully He-free, putting strong constraints on the stellar evolutionary paths needed to produce H-free and He-free GRB progenitor stars at low metallicity.

Session VI: Stellar Populations, Core Collapse and Progenitors (continued)

Dr Selma de Mink

Binarity and the deaths of massive stars: a population synthesis viewpoint

Extensive observing campaigns of young massive stars are now providing strong constraints on the primordial binary fraction, the distribution of separations and mass ratios. These results imply that for each 10 explosions marking the death of a massive star, 7 of these result from a massive star that has experienced severe binary interaction, i.e. stripping by its companion or has accreted mass and angular momentum, or has even coalesced with its companion. In particular the mass gainers are typically the secondary star. They may have traveled 100 pc or more from their birth place after their companion exploded. I will review the observational constraints and discuss ongoing efforts to quantify the impact and various implications using population synthesis simulations

---

Prof. Sung-Chul Yoon
Seoul National University

Progenitors of Type Ib/c supernovae

Type Ib/c supernovae (SNe Ibc) are characterized by the lack of hydrogen lines in the spectra, and believed to originate from hydrogen-deficient massive stars. They can be produced as a result of strong mass-loss from massive single stars and/or mass transfers in close binary systeMs Recent observations nowadays provide important constraints on the nature of SNe Ib/c progenitors. First, the ejecta masses of SNe Ibc appear to be systematically lower than what stellar evolution models predict within the single star scenario. Second, the optical luminosities of SNe Ibc progenitors at the pre-supernova stage seem to be fairly low, given that direct identification of SNe Ib/c progenitors in the pre-explosion optical images has not been successful so far even with some very deep searches. These new constraints seem to imply that the nature of SN Ib/c progenitors is very different from that of luminous Wolf-Rayet stars, and that the majority of SNe Ib/c has a binary star origin. However, theoretical models of SNe Ib/c considering binary interactions still have difficulty in addressing several important questions like: which physical conditions make SNe Ib progenitors different from SNe Ic progenitors, and why relatively low-mass helium stars produced in binary systems as SNe Ibc progenitors have not been discovered yet. In this talk, I will review which theoretical predictions on SNe Ibc progenitors are available, and how they should confront future observations.

Dr John Eldridge
University of Auckland

Unveiling the progenitors of type Ib/c Supernovae

Currently for type Ib/c supernovae nearly all pre-explosion images of the supernova site with 20Mpc reveal no observed progenitor other than the recent case of iPTF13bvn. From these and by considering the relative rates of core-collapse supernovae there is growing evidence that large numbers of type Ib/c supernova come from helium stars made via binary interactions that are of a lower initial mass (approx. 20Msun) than the expected progenitors, Wolf-Rayet stars. However this is at odds with other evidence such as the distribution of type Ib/c in their host galaxies being strongly associated with active star-forming regions indicates that Wolf-Rayet stars are the most common progenitors. We will discuss our recent work modelling to predict the distribution of supernovae in their host galaxies taking full account of the contribution of interacting binary stars. We will show that we are able to produce a consistent picture that type Ib/c supernova arise from both progenitor channels and that we are able to derive their relative rates. If time allows we will also discuss the trends of the Ib/Ic channels and how this varies with metallicity of the progenitor.

Federica Bianco
New York University

Probing the progenitors channels of stripped SN with the CfA SN sample.

Stripped envelope supernovae (stripped SN) arise from the spectacular death of massive stars which have lost their outer layers of Hydrogen and Helium in the late stages of their lives. While they have been studied less than SN Ia, they are intrinsically as common. The scarcity of data has thus far impaired the detailed study of their photometric differences, and of the characteristics of their progenitor channels. The CfA produced the largest stripped SN sample to date, and the first to include photometric coverage in optical and NIR bands (Bianco et al. 2014), as well as spectroscopy (Modjaz et al. 2014). Our photometry is produced from template subtracted images for over 90% of the objects in our sample, removing galaxy contamination and allowing us to accurately measure peak brightness and decline rates, while the NIR coverage helps constraining extinction and reddening. We will discuss how the use of both photometry and spectra from the CfA data set allows us to derive accurate bolometric light curves, and measure ejecta velocities in a consistent, homogeneous fashion for the entire sample. We thus set constraints on the ejecta masses of SN IIb, Ib, Ic and Ic-BL, in a Bayesian framework. We will discuss differences in the explosions and the progenitor channels for different subtypes of stripped SN.

Session VII: Stellar Populations, Core Collapse and Progenitors (continued)

Dr Anders Jerkstrand
Queen's University Belfast

Progenitor masses of Type IIb supernovae from nebular phase spectral modelling

Type IIb supernovae are a transitional class between hydrogen-rich and hydrogen-poor explosions, which includes famous SNe in the local Universe such as Cas A and SN 1993J. The IIb class is quite common (~10-15% of the core-collapse rate), and significant progress in understanding these explosions has lately been made from progenitor detections, light curve modeling, and nebular phase spectroscopy. The nebular phase, in which the deepest layers of the ejecta become visible, offers a particularly good opportunity to determine the mass, composition and morphology of the ejecta. I discuss recent spectral modelling of Type IIb SNe in this phase using NLTE spectral synthesis calculations of stellar evolution/explosion models. The modeling shows that the three best observed events in this class (the nearby SN 1993J, SN 2008ax, and SN 2011dh) are all well described by ejecta from M_ZAMS = 12-15 Msun progenitors, which suggests that Type IIb supernovae predominantly come from low/intermediate mass stars stripped of their hydrogen envelopes by binary companions. I also discuss the significance of strong [N II] 6548, 6584 A lines predicted by the models (which can be confused with H-alpha), the nucleosynthesis yields of various elements (in particular oxygen and magnesium), and signatures of molecule and dust formation in the ejecta of SN 2011dh. I also compare the results of this class to previous nebular phase modelling of Type II SNe, including SN 1987A.

Dr Alceste Bonanos
Institute of Astronomy, Astrophyscis, Space Application sand Remote Sensing, National Observatory of Athens

A survey of dusty, evolved, massive stars in the nearby Universe

We have undertaken a systematic survey of rare, luminous, dusty massive stars in nearby (D<10 Mpc) galaxies, which correspond to progenitors of future core-collapse supernovae and possibly transients. In this talk, we describe the survey and our first results. The goal is to understand the importance of such stars in massive star evolution and to provide spectroscopic classification for progenitors of future supernovae. We take advantage of the abundant mid-IR imaging data of nearby galaxies from the Spitzer archive to identify the luminous mid-IR population of stars in the star-forming spiral and dwarf irregular galaxies of the Local Group and in more distant galaxies, such as M83. Follow-up spectroscopy has so far revealed several candidate luminous blue variables, red supergiants and yellow supergiants. The role of mass loss from massive stars, especially episodic mass loss in evolved massive stars, is one of the outstanding open questions facing stellar evolution theory, and the results of our survey will provide crucial data on the properties and statistics of systems mostly obscured by their own mass loss.

Dr Morgan Fraser
Institute of Astronomy, University of Cambridge

Solving the red supergiant problem?

Direct detections of the progenitors of Type II SNe in nearby galaxies have shown that they are red supergiants between 8 and 16 solar masses. The absence of Type II SN progenitors with a mass greater than 16 solar masses is puzzling, given that we observe red supergiants with masses of up to ~30 solar masses. One possible explanation is that higher mass RSGs do not explode as optically bright SNe, but rather undergo a weak explosion with fallback, and so go undetected. Evidence for this scenario could come from the identification of a massive red supergiant in images of a nearby galaxy, which is then no longer present in subsequent years, and with no reported coincident SN. In this talk, I present the first results of a search for such events using archival images from the Hubble Space Telescope.

Dr Thierry Foglizzo
CEA-Saclay

The explosion mechanism of core collapse supernovae

Numerical simulations suggest that the explosion mechanism of massive stars is sensitive to hydrodynamical instabilities which break the spherical symmetry in the inner 400km, during the first second after the collapse of the stellar core into a proto-neutron star. Some of these processes can be illustrated experimentally using a simple fountain, based on the analogy between the dynamics of the shock in the stellar core and a hydraulic jumps in shallow water. I will review the theoretical progress to understand this mechanism and its consequences on the birth conditions of neutron stars.

Session VIII: 10,000 Days of Supernova 1987A (continued)

Dr Ivo Seitenzahl
Australian National University

The Light Curve of SN1987a Revisited: Constraining Production Masses of Radioactive Nuclides

We revisit the evidence for the contribution of the long-lived radioactive nuclides 44Ti, 55Fe, 56Co, 57Co, and 60Co to the UVOIR light curve of SN 1987A. We show that the V-band luminosity constitutes a roughly constant fraction of the bolometric luminosity between 900 and 1900 days, and we obtain an approximate bolometric light curve out to 4334 days by scaling the late time V-band data by a constant factor where no bolometric light curve data is available. Considering the five most relevant decay chains starting at 44Ti, 55Co, 56Ni, 57Ni, and 60Co, we perform a least squares fit to the constructed composite bolometric light curve. For the nickel isotopes, we obtain best fit values of M(56Ni) = (7.1+-0.3) x10-2 M⊙ and M(57Ni) = (4.1+-1.8)x 10-3 M⊙. Our best fit 44Ti mass is M(44Ti)=(0.55 +-0.17) 10-4 M⊙, which is in disagreement with the much higher (3.1+-0.8) x 10-4 M⊙ recently derived from INTEGRAL observations. The associated uncertainties far exceed the best fit values for 55Co and 60Co and, as a result, we only give upper limits on the production masses of M(55Co) < 7.2 x 10-3 M⊙ and M(60Co) < 1.7 x 10-4 M⊙. Furthermore, we find that the leptonic channels in the decay of 57Co (internal conversion and Auger electrons) are a significant contribution and constitute up to 15.5% of the total luminosity. Consideration of the kinetic energy of these electrons is essential in lowering our best fit nickel isotope production ratio to [57Ni/56Ni] = 2.5+-1.1, which is still somewhat high but in agreement with gamma-ray observations and model predictions.

Dr Dick Manchester
CSIRO

9999 Days of Radio Observations of SN 1987A

Radio emission from SN 1987A was detected on February 25, 1987, one day after the optical discovery. Observations at frequencies between 840 MHz and 2.3 GHz using several instruments detected the radio SN peaking at about 100 mJy a day or two after the initial detection and then decaying with a timescale of about 10 days. After three years of quiescence, it was again detected at Molonglo in July 1990 and a month later with the Australia Telescope Compact Array. These detections signalled the birth of a radio supernova remnant. Regular observations at frequencies between 840 MHz and 9 GHz since then show an increasing flux density which now exceeds that of the initial radio burst. Since 1995, the increase was well described by exponential growth with an e-folding time of about 2500 days but recent observations suggest a lengthening of the timescale. From the initial detection of the radio remnant, the spectrum has been accurately power-law, but with a spectral index that has varied between -0.7 and -1.0. Some implications of these results are described.

Dr Kari Frank
Penn State

New Chandra ACIS Observations of SN 1987A

We present results from the latest Chandra ACIS observations of SN 1987A and compare them to past observations. The soft X-ray light curve is updated and examined for evidence of a break which would indicate the forward shock has passed through the equatorial ring. We also calculate the expansion rate and investigate evolution in the radial expansion of the remnant.

Dr Paul Lasky
University of Melbourne

Gravitational waves from a possible neutron star in the supernova remnant 1987A

The possible existence of a neutron star in the supernova remnant 1987A presents an exciting possibility to directly detect continuous gravitational waves using ground-based interferometers such as the Laser Interferometer Gravitational Wave Observatory (LIGO). Semipermanent asphericities in the neutron star caused by thermoelastic or hydromagnetic deformations allow for ellipticities $< 10^{-4}$; a deformation that would easily be detectable with Advanced LIGO. In this talk, we will i) provide an overview of the theoretical work going in to understanding potential neutron star deformations and ii) describe ongoing efforts within LIGO to search for periodic gravitational waves from a neutron star in SNR 1987A, focussing our attention on the semi-coherent cross-correlation search.

Session IX: Unusual and Unique Objects (continued)

Dr Ferdinando Patat
European Southern Observatory

Spectropolarimetry and Asphericity of Supernovae

In my talk I will review the results of Supernova Spectropolarimetry and their implications on our understanding of the SN phenomenon.

Ms Maria Drout
Harvard University

Rapidly-Evolving and Luminous Transients from Pan-STARRS1

In the past decade, several rapidly-evolving transients have been discovered whose timescales and luminosities are not easily explained by traditional supernovae (SN) models. The sample size of these objects has remained small due, at least in part, to the challenge of detecting short timescale transients with traditional survey cadences. Here we present the results from a search within the Pan-STARRS1 Medium Deep Survey (PS1-MDS) for rapidly-evolving and luminous transients. We identify 10 new transients with a time above half-maximum of less than 12 days and -16.5 > M > -20 mag. This increases the number of known events in this region of SN phase space by roughly a factor of three. The median redshift of the PS1-MDS sample is z=0.275 and they all exploded in star forming galaxies. In general, the transients possess faster rise than decline timescale and blue colours at maximum light (g - r < -0.2). Best fit blackbodies reveal photospheric temperatures/radii that expand/cool with time and explosion spectra taken near maximum light are dominated by a blue continuum, consistent with a hot, optically thick, ejecta. We find it difficult to reconcile the short timescale, high peak luminosity (L > 10^43 erg/s), and lack of UV line blanketing observed in many of these transients with an explosion powered mainly by the radioactive decay of Ni-56. Rather, we find that many are consistent with either (1) cooling envelope emission from the explosion of a star with a low-mass extended envelope which ejected very little (<0.03 M_sun) radioactive material, or (2) a shock breakout within a dense, optically thick, wind surrounding the progenitor star. After calculating the detection efficiency for objects with rapid timescales in the PS1-MDS we find a volumetric rate of 3000 - 5500 events/yr/Gpc^3 (1-6% of the core-collapse SN rate at z=0.2).

Ms Io Kleiser
California Institute of Technology

Rapidly Fading Supernovae from Massive Star Explosions

Transient surveys have recently discovered a class of supernovae (SNe) with extremely rapidly declining light curves. These events are also often relatively faint, especially compared to Type Ia SNe. The common explanation for these events involves a weak explosion, producing a radioactive outflow with small ejected mass and kinetic energy (M ~ 0.1 Msun and E ~ 0.1 B, respectively), perhaps from the detonation of a helium shell on a white dwarf. We argue, in contrast, that these events may be Type Ib/c SNe with typical masses and energies (M ~ 3 Msun, E ~ 1 B), but which ejected very little radioactive material. In our picture, the light curve is powered by the diffusion of thermal energy deposited by the explosion shock wave, and the rapid evolution is due to recombination, which reduces the opacity and results in an "oxygen-plateau" light curve. Using a radiative transfer code, we generate synthetic spectra and light curves and demonstrate that this model can reasonably fit the observations of one event, SN 2010X. Similar models may explain the features of other rapidly evolving SNe such as SN 2002bj and SN 2005ek. SNe such as these require stripped-envelope progenitors with rather large radii (R ~ 20 Rsun), which may originate from a mass loss episode occurring just prior to explosion.

Dr Alexandra Kozyreva

Observational properties of low-redshift pair instability supernovae

So-called superluminous supernovae have been recently discovered in the local Universe. It appears possible that some of them originate in stellar explosions induced by the pair instability mechanism. Recent stellar evolution models also predict pair instability supernovae from very massive stars at fairly high metallicities (i.e., Z ∼ 0.004). We provide supernova models and synthetic light curves for two progenitor models, a 150 $M_\odot$ red supergiant and a 250 $M_\odot$ yellow supergiant at a metallicity of Z = 0.001, for which the evolution from the main sequence to collapse and the initiation of the pair instability supernova (PISN) itself has been previously computed in a realistic and self-consistent way. We use the radiation hydrodynamics code STELLA to describe the supernova evolution of both models in a time frame of about 500 days. We describe the shock-breakout phases of both supernovae, which are characterized by higher luminosity, longer duration, and a lower effective temperature than those of ordinary Type IIP supernovae.We derive the bolometric, as well as the U, B, V, R, and I, light curves of our pair instability supernova models, which show a long-lasting plateau phase with maxima at Mbol ≃ −19.3 mag and −21.3 mag for our lower and higher mass models, respectively. While we do not produce synthetic spectra, we also describe the photospheric composition and velocity as a function of time. We conclude that the light curve of the explosion of our initially 150 $M_\odot$ star resembles those of relatively bright type IIP supernovae, whereas its photospheric velocity at early times is somewhat lower. Its 56Ni mass of 0.04 $M_\odot$ also falls well into the range found in ordinary core collapse supernovae. The light curve and photospheric velocity of our 250 $M_\odot$ models has a striking resemblance to that of the superluminous SN 2007bi, strengthening its interpretation as pair as pair instability supernova. We conclude that pair instability supernovae may occur more frequently in the local universe than previously assumed.

Prof. Andy Howell
Las Cumbres Observatory / University of California, Santa Barbara

During the course of the Supernova Legacy Survey, several superluminous supernovae were discovered. Two have spectra and are two of the highest redshift Type I SLSNe: SNLS-07D2bv (z=1.5) and SNLS-06D4eu (z=1.588). Because they are at such high redshift, these SNe give us our most complete look at SLSNe in the UV, where they radiate most of their energy. I also show the first radiative transfer calculations applied to SLSNe, and show that they are consistent with being the explosions of Carbon-Oxygen stellar cores of a few solar masses. The magnetar spin-down model is consistent with the lightcurves and spectra. We have also discovered new SLSN candidates in the SNLS data set, and these will be discussed. Finally, I will present on overview of the Las Cumbres Observatory Global Telescope Network and the supernova key project, which aims to observe 450 low-redshift supernovae over 3 years.

Dr Iair Arcavi
LCOGT and KITP, UC Santa Barbara

Transients in the SN - SLSN Gap

The peak luminosities of novae, supernovae (SNe) and superluminous SNe (SLSNe) span a wide and seemingly discontinuous range. The gap between novae and SNe has been a target of intensive observational campaigns in recent years. The gap between SNe and SLSNe (i.e. transients with peak magnitudes between -19 and -21 which are not obviously powered by interaction), however, is less explored. Such a gap, if real, would be an important clue as to the origin of some classes of SLSNe. I will present the results of a search for transients in this luminosity range using the Palomar Transient Factory (PTF) archive, focusing on events originally classified as core-collapse SNe. We find six events with peak absolute magnitudes around -20 but with no clear signs of interaction (i.e. not SNe IIn or Ia-CSM). Three of these events are located in the centers of their hosts, and we consider them to be tidal disruption flares resulting from the close encounter of a star and a super-massive black hole. The other three events in our sample are likely SNe of intriguing new types.

Session X: Type Ia Supernovae and Their Progenitors

Prof. Friedrich Roepke
University of Wuerzburg

Type Ia supernova models compared to local events

Observations of Type Ia supernovae (SNe Ia) provide strong evidence that these events are due to thermonuclear explosions of white dwarf stars. The exact nature of the progenitor system, however, is still enigmatic. Systematic searches in the local Universe over the past decade have confirmed the existence of various sub-classes with diverging characteristics. The possibility that different progenitor systems and explosion mechanisms are at work in SNe Ia challenges their theoretical modeling but also makes them a fascinating part of astrophysical transients. Thus, progress can only be made when comparing models to individual, well-observed nearby supernovae. I will discuss how recent developments in three-dimensional simulations allow to associate different explosion scenarios to certain sub-classes of SNe Ia. This strategy relies on assumptions of the progenitor system and follows explosion hydrodynamics, nucleosynthesis and radiative transfer in a consistent approach. On the basis of examples I will argue that events in the Local Universe are particularly important in scrutinizing such models. Although some open questions still remain, a combined effort in theoretical model building and observation holds promise for shaping a comprehensive picture of the physics of SNe Ia. This is an important step towards a theoretical foundation of the use of these objects as cosmological probes as well as for understanding their role in galactic chemical evolution.

Dr Ashley Ruiter
RSAA Mount Stromlo Observatory, Australian National University

White Dwarf Binaries and Type Ia Progenitors

The progenitor systems of Type Ia supernovae are still unknown, though recent theoretical works have shown that none of the commonly addressed progenitor channels can be completely ruled out. Delayed detonations (single degenerate scenario), various flavours of WD mergers (double degenerate scenario), and double detonations (via slow or fast accretion) all appear to be viable scenarios, though it is still unclear as to what fraction of each (if all) channel(s) contributes to the overall SN Ia population. The most realistic progenitor model in terms of accounting for the rates, delay time distribution, and distribution in peak brightness is that of the (violent) WD merger, whereby two WDs merge and immediately explode. Since these progenitors consist of a range of (sub-Chandra) primary WD masses, their light-curves exhibit a range of peak luminosities that has been found to match fairly well with the peak luminosities of locally-observed SNe Ia. I will discuss the evolution, properties, and fate of WD mergers in more detail, and highlight what I believe will be useful for the advancement of our understanding of SN Ia progenitors from a binary evolution perspective.

Dr Ken Shen
University of California, Berkeley

Double detonation Type Ia supernovae from double white dwarf progenitors

Mounting evidence suggests that the standard single degenerate scenario cannot produce the bulk of Type Ia supernovae. One promising alternative is the double detonation scenario, in which helium-rich mass transfer from a low-mass white dwarf onto a C/O white dwarf results in a helium detonation, which triggers a subsequent core detonation. I will present recent work that establishes the theoretical viability of this scenario, explains observations of the circumstellar environment around SNe Ia, and makes unique, testable predictions.

Prof. D. John Hillier
University of Pittsburgh

Time-dependent Radiative Transfer Modeling of Supernovae Spectra

Utilizing the radiative transfer code CMFGEN, we are undertaking time-dependent radiative transfer calculations of Type Ia SNe, Type Ibc SNe, and Type II SNe that simultaneously compute multi-band light curves and spectra from approximately one day after the explosion through the photospheric phase, and into the nebular phase. The calculations are non-LTE, and allow for a multitude of atomic processes (bound-bound, bound-free, free-free, collisional, and charge exchange), and for non-thermal excitation and ionization from non-thermal electrons created by the degradation in energy of high energy (MeV) gamma-rays. In this presentation we discuss our work on modeling of Type Ia SNe. Standard WD explosion models, with a range of nickel masses, can match observations of Type Ia SNe at maximum. We explored one theoretical model in detail, and have shown that, except for the earliest times, it provides a reasonable match to the light curve and spectral evolution of the Ia SN 2005cf. Initial modeling showed large discrepancies with observations, and a good match was only obtained when we used detailed non-LTE modeling, and included all the necessary physics. With standard 1D explosion models, extensive mixing is required to explain the rapid rise and blue colors of Type Ia SNe at early times. Since the early-time properties are very dependent on the progenitor properties, other models need to be pursued. For example, pulsational-delayed detonations are better able to produce the blue colors at early times without extensive mixing.

Session XI: Type Ia Supernovae and Their Progenitors (continued)

Prof. Marten van Kerkwijk
University of Toronto

Normal type Ia supernovae from white dwarf mergers

Type Ia supernovae are known to reflect explosions of white dwarfs, but it remains unclear what triggers the explosion. The standard model, in which white dwarfs approach the Chandrasekhar mass, now seems more likely to lead to SN 2002cx-like transients, while normal type Ia supernova are better reproduced with sub-Chandrasekhar models. The latter include mergers of white dwarf, and I will discuss both recent insights from numerical simulations, where our results with the new moving mesh AREPO code are qualitatively different from earlier ones based on SPH codes, and expectations and predictions, in particular for the occasional presence of large amounts of circumstellar medium from the common-envelope phase and for late-time nebular spectra. I will also present the results of our radio and optical searches for late-time interaction of the ejecta of type Ia supernovae with possible common-envelope remnants.

Mr Richard Scalzo
Australian National University

The Range of Ejected Masses in Type Ia Supernovae

Type Ia supernovae, the thermonuclear explosions of carbon-oxygen white dwarfs, have been used for over a decade as precision tools for studying the expansion history of the universe. However, the evolutionary pathways to supernova explosion and the physics of the explosion remain uncertain. The total mass ejected in the explosion is a powerful discriminant between different theoretical explosion scenarios. The bolometric light curve of a SN Ia is sensitive to the ejected mass, and moreover can be reliably modelled using simple semi-analytic techniques. I will discuss my ongoing work using bolometric light curves from several type Ia supernova datasets, comparing to contemporary numerical explosion models and interpreting the results in the light of binary population synthesis models for type Ia supernova progenitors. While the Chandrasekhar limit is a commonly accepted typical mass scale for type Ia supernovae, their bolometric light curves are best explained if a range of ejected masses and explosion mechanisms are realized in nature. Ongoing and future surveys at low and high redshift, such as SkyMapper and the Dark Energy Survey, will continue to improve statistical constraints on the mass distribution of type Ia supernovae and the contribution of astrophysical systematics to the error budget for the dark energy equation of state.

Dr Kate Maguire
European Southern Observatory

Searching for progenitor signatures in Type Ia supernova spectra

There is increasing observational evidence that there are at least two distinct populations of SNe Ia. I will present recent results from a search for narrow blueshifted Na I D absorption lines, interpreted as evidence of circumstellar material (CSM) surrounding the progenitor system. The link between the presence of CSM in some SNe Ia and the properties of their light curves, spectra and host galaxy environments will be shown. In particular, I will discuss the connection to high-velocity features in early-time SN Ia spectra. The significance of these findings and other recent observational evidence on the diversity of SNe Ia will be highlighted.

Dr Michael Childress
Australian National University

SN 2012fr and High-Velocity Features in Type Ia Supernovae

Many Type Ia supernovae (SNe Ia) exhibit features in their spectra whose velocities highly exceed that of the majority of spectroscopic features. We examined these high-velocity features (HVFs) in the Ca IR triplet from maximum-light spectra of a sample of ~60 nearby SNe Ia and found that strong HVFs are present almost exclusively in SNe Ia with slow declining light curves and low photospheric velocities. The most extreme example is SN 2012fr, which was discovered 15 days before maximum light in the nearby galaxy NGC 1365. Daily (and at very early epochs sub-daily) pre-max spectra show dramatic evolution in velocity and strength of the HVFs in Ca IR and Si 6355, and the evolution of the HVF central velocities argue for them originating from material contiguous to the exploding progenitor star. HVFs thus represent an important new observational dimension for SN Ia explosion physics.

Prof. Ryan Foley
University of Illinois

Extensive Multi-wavelength Observations of SN 2014J in M82 Indicate Reddening and Circumstellar Scattering by Typical Dust

Dust along the lines of sight to Type Ia supernovae (SNe Ia) appears to be very different from that of the Milky Way. Circumstellar scattering of the SN light could account for the odd observations. SN 2014J in M82 is extremely close and highly reddened, providing an excellent opportunity to study dust properties and circumstellar scattering. I will present an extensive set of observations of SN 2014J including 10 epochs of HST UV spectroscopy, multiple optical/NIR light curves, and high-resolution optical spectroscopy. Neither dust reddening or circumstellar scattering alone can account for all observations. I will argue that the wide range of observed properties for SN 2014J are

caused by a combination of dust reddening, likely originating in the interstellar medium of M82, and scattering off circumstellar material. For this model, roughly half of the extinction is caused by reddening from typical dust (R_V = 2.6) and roughly half by scattering off LMC-like dust in the circumstellar environment of SN 2014J.

Dr Curtis McCully
Rutgers, The State University of New Jersey

The Progenitor System of the Type Iax SN 2012Z

We present the detection of a luminous, blue source coincident with the type Iax SN 2012Z from deep HST pre-explosion imaging of NGC 1309. This is likely the first time the progenitor system of a white dwarf supernova has been observed. We explore some of the possible scenarios that are consistent with our observations; based on its luminosity, colors, and environment, as well as a similarity to the pre-outburst Galactic helium nova system V445 Puppis, our favored model of SN 2012Z is the explosion of a WD accreting from a helium-star companion. Future HST observations, after SN 2012Z has faded, could test this hypothesis, or else show that this supernova was actually the explosive death of a massive star.

Session XII: Supernova Remnants and Historical Supernovae

Prof. CarlesBadenes
University of Pittsburgh

The Physics of Young Type Ia Supernova Remnants

I will discuss recent observational developments on Type Ia Supernova Remnants (SNRs). A decade and a half of modern X-ray observations of SNRs with Chandra, XMM-Newton, and Suzaku, have allowed us to collect large samples of objects with excellent spectra. New methods have been proposed to differentiate Type Ia from core collapse explosions and model the emission and dynamics of young SNRs, furthering our knowledge of both the explosions that originated them and their progenitors. I will discuss the implications of our advanced understanding of young Type Ia SNRs for the physics of Type Ia SNe and the identity of their progenitors.

Prof. You-Hua Chu
University of Illinois

Type Ia Supernova Remnants in the Large Magellanic Cloud

About a dozen Type Ia supernova remnants (SNRs) are known in the Large Magellanic Cloud (LMC). These Type Ia SNRs are in a variety of interstellar environments, and the evolved ones have been diagnosed by the high Fe/O ratios derived from their X-ray spectra. We have obtained Hubble Space Telescope images of 7 Type Ia SNRs in H-alpha and continuum bands for the following purposes: (1) search for surviving companions of the SN progenitors, (2) determine star formation history to probe the delay time of these Type Ia SNe, and (3) study the physical structure of the SNRs per se. We have carried out photometry of stars in the continuum bands and compared the locations of stars with the post-impact evolution tracks of surviving companions modelled by Pan et al. (2013). While surviving He-star and main-sequence companions can be rules out in the youngest Type Ia SNRs, candidates of surviving companions are present in some SNRs and they need follow-up spectroscopic observations to confirm/reject their status. The H-alpha images reveal not only fine filaments delineating the SNR shells, but also small knots near shell centers or behind shocks along shell riMs Preliminary results of our analysis will be presented.

Dr Wolfgang Kerzendorf
University of Toronto

Companions of Supernovae

Most supernovae should occur in binaries. Massive stars, the progenitors of core collapse supernovae (SN II/Ib/c), have a very high binarity fraction of 80% (on average, they have 1.5 companions), and binaries are required to produce thermonuclear supernovae (SN Ia). Theory suggests that in many cases we expect a surviving unusual energized companion, which can be a powerful probe to study the progenitor system. While recent studies have been unable to detect (partly due to vague theoretical predictions) any companions in nearby Type Ia supernova remnants, there has been much less effort for finding companions in core-collapse remnants. We have designed a survey around a panchromatic dataset of Magellanic Cloud supernova remnants, resulting in optical Gemini spectra of 140 companion candidates, many hundreds of comparison stars and spectra of the remnant itself for 22 remnants. We deliberately chose both Type Ia/core collapse remnants to answer the question: What are the companions of supernovae? What features does a companion exhibit after being blasted by a supernova? In this talk, I will introduce our survey and discuss stellar parameter analysis and outliers found in the this new dataset.

Dr Brian Williams
NASA Goddard Space Flight Center

Spitzer Observations of the Type Ia Supernova Remnant N103B: A Type Ia with CSM Interaction?

A small but growing subclass of Type Ia supernovae show signs of interaction with material in a circumstellar medium (CSM), likely the result of significant pre-supernova mass loss from the progenitor system. Among Type Ia supernova remnants (SNRs), only the remnant of Kepler's supernova has been shown to be interacting with a dense CSM. We report results from Spitzer observations of SNR 0509-68.7, also known as N103B, a young Type Ia supernova remnant in the Large Magellanic Cloud that shows interaction with a dense medium in its western hemisphere. Our images show that N103B has strong IR emission from warm dust in the post-shock environment. The post-shock gas density we derive, 45 cm^-3, is much higher than in other Type Ia remnants in the LMC, though a lack of spatial resolution may bias measurements towards regions of higher than average density. This density is similar to that in Kepler's SNR. Optical images show Hα emission along the entire periphery of the western portion of the shock, with [O III] and [S II] lines emitted from a few dense clumps of material where the shock has become radiative. The dust is silicate in nature, though standard silicate dust models fail to reproduce the ``18mum'' silicate feature that peaks instead at 17.3mum. We propose that the dense material is circumstellar material lost from the progenitor system, as with Kepler. If the CSM interpretation is correct, this remnant would become the second member, along with Kepler, of a class of Type Ia remnants characterized by interaction with a dense CSM hundreds of years post-explosion. A lack of N enhancement eliminates symbiotic AGB progenitors. The white dwarf companion must have been relatively unevolved at the time of the explosion.

Dr Kazimierz Borkowski
North Carolina State University

Non uniform Expansion of the Youngest Galactic Supernova Remnant G1.9+0.3

G1.9+0.3 is the youngest known Galactic supernova remnant (SNR), most likely the result of an asymmetric Type Ia supernova explosion. Its age has been estimated at only about 100 yr by measuring its overall expansion at X-ray and radio wavelengths. A long (980 ks) Chandra observation in 2011 together with shorter 2007 and 2009 observations allowed for spatially-resolved studies of its expansion over a 4.3 yr time baseline. We used the multiscale partitioning method of Krishnamurthy, Raginsky, & Willett (2010) to arrive at a smoothed 2011 image. This model image was then fit to unsmoothed images from the earlier epochs, allowing for expansion and image shifts. The measured expansion rates strongly deviate from uniform expansion. Expansion rates increase inward by about 60% along the X-ray bright SE-NW axis, ranging from 0.52% +- 0.03% per yr to 0.84% +- 0.06% per yr. This corresponds to undecelerated ages of 120 - 190 yr, confirming the young age of G1.9+0.3, and implying a significant (deceleration parameter $m < 0.6$) deceleration of the blast wave. The spatially-integrated X-ray flux, strongly dominated by the synchrotron emission, increases at a rate of 1.9% +- 0.7% per year, in agreement with previous, less accurate measurements. G1.9+0.3 is the only Galactic SNR increasing in brightness at X-ray and radio wavelengths. The presence of Si- and S-rich ejecta in the NW inner rim suggests that the rapidly-expanding inner rims mark the location of the reverse shock. The more slowly-expanding outer rims farther out can be identified with the blast wave. The large spread in expansion ages between the reverse shock and the blast wave rules out slowly varying density distributions in both the ejecta and the ambient medium. Sudden large density gradients either in the ejecta or the ambient medium are required in order to suddenly decelerate the reverse shock or the blast wave. (A less likely explanation involves the presence of highly-clumped ejecta.) The blast wave could have been decelerated recently by an encounter with a modest (factor of several) density discontinuity in the ambient medium, such as found at a wind termination shock. If this were true, the SN progenitor must have been losing mass in a strong stellar wind prior to the explosion. Alternatively, the reverse shock might have encountered a larger (factor of 10 or more) density discontinuity within the SN ejecta, such as found in pulsating delayed-detonation Type Ia SN models. Through one-dimensional hydrodynamical simulations, we demonstrate that the blast wave is much more decelerated than the reverse shock in these models for young remnants at ages similar to G1.9+0.3. The presence of strong density gradients in the outer ejecta of Type Ia SNe has significant implications for the interpretation of their early-time spectra and for understanding how white dwarfs explode. Our one-dimensional models do not account for the asymmetry of G1.9+0.3, so a complete understanding of its dynamics must await the confrontation of present and future observations with more realistic three-dimensional Type Ia models.

Session XIII: Supernova Remnants and Historical Supernovae (continued)

Dr Armin Rest
STScI

An Astronomical Time Machine: Light Echoes from Historic Supernovae and Stellar Eruptions

Tycho Brahe's observations of a supernova in 1572 challenged the dogma that the celestial realm was unchanging. Now, 440 years later we have once again seen the light that Tycho saw as simple reflections from walls of Galactic dust. These light echoes, as well as ones detected from other historical events such as SN 1987A, Cas A and Eta Carinae's Great Eruption, give us a rare opportunity in astronomy: the direct observation of the cause (the explosion/eruption) and the effect (the remnant) of the same astronomical event. But we can do more: the light echoes let us look at the explosion from different angles, and permit us to map the asymmetries in the explosion. I will discuss how the unprecedented three-dimensional view of these exciting events allows us to unravel some of their secrets.

Dr Haley Gomez
Cardiff University

Dust in Young Supernova Remnants

In the last decade (and particularly in recent years), SCUBA, the Herschel Space Observatory and now, ALMA observations in the infra-red and submillimetre regime have revealed that core-collapse supernovae are prolific dust factories, with evidence of 0.1 - 0. 7$M_\odot$ of dust formed within the ejecta. Here I will discuss our changing view on supernovae as interstellar dust sources based on recent studies of the following supernova remnants, Cassiopeia A, the Crab Nebula, SN1987A, Tycho and Kepler. Although there is little evidence (as yet) for significant dust production in Type Ia supernova ejecta, there is no longer any question that dust (and molecule) formation is efficient after some supernova events, though it is not clear how much of this survives over longer timescales.

Dr Tea Temim

Supernovae as drivers of dust evolution in the Magellanic Clouds

The presence of dust in galaxies has a profound effect on their spectral appearance and on the many processes that determine the physical, chemical, and thermal state of their interstellar medium (ISM). The understanding of the dust destruction rate by supernova shocks in particular is extremely important for understanding its origin. The amount of grain destruction determines whether the

dust budget can be balanced by dust formation in stellar sources, or whether dust growth in molecular clouds is required. Due to the extensive wavelength coverage and known distance, the Magellanic Clouds offer a unique opportunity for studying a complete sample of supernova remnants (SNRs), the environments into which they expand, and how much dust they destroy and inject into the ISM. I will present new estimates of dust destruction rates by SNRs in the Magellanic Clouds and discuss their implications for dust evolution models.

Session XIV: 10,000 Days of Supernova 1987A; 23,741 Days of Bob

Prof. Robert Kirshner

Hot Spots and Shock Stops in SN 1987A

Observations of SN 1987A's inner ring began with spectra from the International Ultraviolet Explorer and have been carried forward with imaging from the Hubble Space Telescope since its launch in 1990. The images acquired by the SINS and the SAINTS programs (for which I have served as the PI) provide a high-resolution view of the debris and of the interaction of the shock with the inner ring of circumstellar material. I will present measurements of the evolution of the hot spots on the ring, which first erupted in 1995, up to our most recent observations in June 2014. Many of the two dozen hotspots have now passed their peak brightness. A simple physical picture of the hot spots as the locus of interaction between stalactites of gas and an oblique shock explains some, but not all, of their properties.

Session XV: Future Instruments and techniques

Dr Bernhard Mueller
Monash Centre for Astrophysics, Monash University

Neutrinos and Gravitational Waves -- What will we learn from a Galactic Supernova?

SN 1987A inaugurated a new era in astroparticle physics with the detection of some two dozen neutrinos emitted directly from the optically opaque supernova core. Despite the small number of detection events, this first observation gave us a rough understanding of what the supernova engine and the newly-born neutron star looked like. In this talk, I shall demonstrate how modern numerical simulations of the supernova engine in multi-D and better detectors will help to extract detailed, time-dependent information about the evolution of the neutron star, the supernova shock, and hydrodynamic instabilities like convection and shock sloshing from prospective observations of neutrinos as well as gravitational waves from a Galactic supernova.

Prof. Kate Scholberg
Duke University

Neutrinos from Supernovae: What the Next Burst will Bring

The twodozen neutrinos observed from SN1987A had enormous impact. The next nearby core-collapse supernova will yield orders of magnitude more data in neutrino detectors worldwide. This talk will cover the expected signal, supernova neutrino detection techniques in general, current supernova neutrino detectors, prospects for specific future experiments, and how we can prepare to get the most from the next supernova neutrino burst.

Ms Sarah Gossan
California Institute of Technology

Observing Gravitational Waves from the Next Nearby Core-Collapse Supernova

The next galactic core-collapse supernova has already exploded, and its electromagnetic waves, neutrinos, and gravitational waves may arrive at any moment. We discuss the theoretical pre-dictions for gravitational wave signal morphology produced by multi-dimensional, state-of-the-art simulations of core-collapse supernovae for a broad range of emission models. We present a method for detecting gravitational waves from core-collapse supernovae with a network of ground-based laser interferometers, considering both untriggered searches and searches triggered by electromag- netic or neutrino observations. Using such triggers, the uncertainty in the signal arrival time is greatly reduced and the source's sky position is constrained, reducing the non-Gaussian

detector noise background. We demonstrate the improvement in search sensitivity achieved due to reduc- ing the duration of search intervals and increasing the size of the detector network. Employing an excess-power search algorithm, X-Pipeline, we present sensitivity estimates for gravitational wave signals predicted by multiple different emission models, in the context of the second-generation of ground-based gravitational wave detectors, scheduled to come online by 2015-2020.

Dr Tara Murphy
University of Sydney

Explosive Variables and Transients with MWA, ASKAP AND SKA

Session XVI: Future Instruments and Techniques (continued)

Dr George Sonneborn
NASA Goddard Space Flight Center

Nearby Supernovae and the James Webb Space Telescope

The James Webb Space Telescope (JWST) is a large aperture, cryogenic, infrared-optimized space observatory under construction by NASA for launch in 2018. The European and Canadian Space Agencies are mission partners. JWST will find and study the first galaxies that formed in the early universe, peer through dusty clouds to see star and planet formation at high spatial resolution. The unprecedented sensitivity and angular resolution of JWST in the near and mid IR will enable studies of new and recent supernovae, including dust formation, in galaxies throughout the local universe. JWST will have a 6.5m-diameter segmented primary mirror and will be diffraction-limited at 2 microns. JWST's instrumentation provides imaging, coronagraphy, and spectroscopy (R<3000) over the wavelength range 1-29 microns. The Target of Opportunity response time can be as short as 48 hours. The JWST observatory will be placed in an Earth-Sun L2 orbit by an Ariane 5 launch vehicle provided by ESA. The observatory is designed for a 5-year prime science mission, with consumables for 10 years of science operations. The first call for proposals for JWST observations is scheduled to be released in 2017.

Dr Russell Cannon
AAO

The next 1987A

Are we prepared for the next naked-eye supernova? How quickly will we be able to react? SN1987A had an unusually slow rise to maximum light which gave astronomers time to think about unique observational opportunities, modify existing instruments and even develop new ones. It would be prudent to have an idea of what observations might be most critical, and which instruments can best take advantage of a brief opportunity to take extremely high S/N data at short notice.

POSTER ABSTRACTS

Topic 1: 10,000 Days of Supernova 1987A

1. Ms. Antonia Bevan
UCL

Modelling late-time red-blue line asymmetries in the spectra of core-collapse supernovae

Spitzer mid-IR observations of core-collapse supernovae have revealed dust formation to be common during the first 1000 days after explosion, while Herschel far-IR observations of supernova remnants such as Cassiopeia A, SN 1987A and the Crab Nebula have measured up to 0.1-0.5 solar masses of cool dust to be present in their ejecta (Barlow et al. 2010, Matsuura et al. 2011, Gomez et al. 2012). These estimates are based on fitting the observed infrared continuum emission. However, the completion of the Herschel mission means that there will now be a long wait for comparable or better space borne thermal infrared facilities to become available. The absorption of optical or near-IR radiation by newly-formed dust within the ejecta of supernovae can result in an asymmetry between the red and blue shifted components, with the redwards emission from the far side of the ejecta undergoing greater absorption (Lucy et al. 1989). Such red-blue asymmetries are frequently observed in the late-time (T>400d) spectra of supernova ejecta and there is a large database of such observations available. We present here a new Monte Carlo code that models factors affecting the red-blue asymmetry, including smooth or clumped dust distributions, in order to assess the utility of line profile fitting for quantifying the masses of dust formed in supernova ejecta. We also present some examples of preliminary line profile fits for SN1987A.

---

2. Dr. Mario Manuel
University of Michigan

Ring Formation in SN1987a: Proposed Laboratory Experiments to Investigate Fast- and Slow- Wind Interactions

Ring nebulae are often observed in the final evolutionary stages of blue supergiant stars, as in the case of SN1987a. The generally accepted formation paradigm for these systems typically consists of a sparse, fast wind interacting with a previously ejected denser, slow wind [Blondin ApJ 405 (1993)]. Numerical codes have demonstrated that such an interaction may explain observed ring nebulae around blue supergiants [Chita AA 488 (2008)]. We propose a novel set of laboratory-astrophysics experiments to investigate the interaction of these two fluids and provide a controllable system to benchmark numerical calculations. The experimental platform and nominal parameters will be discussed. Support for this work was provided by NASA through Einstein Postdoctoral Fellowship grant number PF3-140111 awarded by the Chandra X-ray Center, which is operated by the Astrophysical Observatory for NASA under contract NAS8-03060. This work is funded by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-NA0001840.

---

3. Ms. Katia Migotto
Department of Astronomy, Stockholm University

Time evolution of the emission lines from the inner circumstellar ring of SN 1987A

We present the results from our analysis of the time evolution of emission lines from the inner circumstellar ring of supernova (SN) 1987A, obtained from high resolution UVES/VLT spectra from 2002 - 2013. The emission lines arise from the interaction of the SN outer ejecta with the ring, and their time evolution is discussed in this context. In addition, the optical light curves are compared with the time evolution of HST narrow band imaging. We find that the widths of low ionization lines have increased, which is likely to be the result of shocks with increasing velocities becoming radiative as the gas cools. We also find that the fluxes of the emission lines have decreased since 2007, of both shocked and un-shocked components. We interpret these results as the beginning of the end of the inner circumstellar ring, which is being disintegrated by the shocks. These observations provide an opportunity to study the evolution of the radiative shocks up to more than 500 km/s in real time.

Topic 2: Nearby Core Collapse Supernovae

4. Mr. Subhash Bose
Aryabhatta Research Institute of observational Sciences (ARIES)

Photometric and spectroscopic study of type IIP SN 2013ab.

We present densely-sampled UBVRI/gri photometric and low-resolution (6-10Å) optical spectroscopic observations from 2 to 190 days after explosion of a recently discovered type II SN 2013ab in a nearby (~24 Mpc) galaxy NGC 5669. The SN has been photometrically monitored almost daily using 1m telescopes of the Las Cumbres Observatory Global Telescope (LCOGT) network and ARIES telescopes in India. Spectroscopic observations have also been carried out almost every week from telescopes across the globe. The light curve and spectra suggests that the SN is a normal type IIP event, however with a steeper decline in comparison to other archetypal SNe of similar brightness. The velocity profile of SN 2013ab shows striking resemblance with that of SNe 1999em and 2012aw. Following the Rabinak & Waxman (2011) prescription, the progenitor radius estimate from early temperature measurements, shows that the SN is possibly from a large RSG having radius ~800 R_sun. The distance to the SN and hence to its host galaxy is estimated by applying EPM, which yields a distance of 24.3 Mpc. From tail bolometric luminosity, the mass of synthesized nickel in the explosion is found to be 0.065 M_sun. We also plan to present the estimated progenitor properties from detailed hydrodynamical modelling.

---

5. Dr. Cristina Romero-Canizales
Institute of Astrophysics, Pontifical Catholic University of Chile

Radio supernovae in Arp 299

Arp 299 is a luminous infrared galaxy (LIRG; L_IR ~ 6.7E+11 L_sun) whose nuclear and circumnuclear regions harbour a very prolific supernova factory. In this talk I will present results based on radio observations, which have led to the direct and indirect detection of core collapse supernovae in this LIRG, and which represent a stepping-stone for the study of similar systems in the local Universe.

---

6. Dr. Firoza Sutaria
Indian Institute of Astrophysics

Optical and multi waveband studies of recent, bright, type-IIP supernovae

Type-IIP supernovae are among the most common type of core collapse SNe, with progenitors with an extended H-envelope. It may be possible to use them as "standard candles" for cosmological distance estimates, if the physical processes underlying the transfer of energy from the shock to the expanding photosphere (among other factors) was better understood. I report here on our program

to study optically bright, type-II SNe, with particular emphasis on the optical, and multwaveband observations of the recent type -IIP SNe, e.g. SN2012aw, SN2012A and SN2013ej. Combining the optical coverage with our own data in X-ray bands (for SN2012aw) and archival data in UV and other bands (wherever available) for the other sources, and comparing with other archetypal SNe-IIP, we estimate the time evolution of photospheric properties, (e.g. the expansion velocity), as well as the mass, and mass-loss rate and other properties of the progenitor. Finally, since our program has also covered optical observation of other sub-classes of SNe-II (e.g. the SN-IIn SN2010jl and the SN-IIb SN2011dh), I compare and contrast across the subclasses, the nature of the CSM, and the shock interaction with it.

---

7. Dr. Péter Székely
University of Szeged

Chemical Composition of the Ejecta of the Rare Type IIb Supernova 2013df

SN 2013df, appeared in the nearby galaxy NGC 4414 at a distance of ~17 Mpc, is a rare type IIb supernova. Members of this subclass are intermediate between the hydrogen-rich type II-P SNe and the hydrogen-poor, stripped envelope Type Ib/c explosions. Their progenitors are thought to be massive (~20 MSun) stars, which may have interacting binary companions. Up to now, detailed analysis have been published on only a few type IIb SNe, thus, it is important to study well-observed individual objects as thoroughly as possible. Our team collected a sample of high-quality data on SN 2013df. Here we present the results of our spectroscopic analysis based on 6 optical spectra obtained between June 13 and July 8, 2013 with the 9.2m Hobby-Eberly Telescope (HET) Marcario Low Resolution Spectrograph (LRS) at McDonald Observatory, Texas. We applied the SYNAPPS spectral synthesis code to get information on the chemical composition and physical properties of the ejecta. The spectral evolution, based on the comparison with other type IIb SNe 1993J and 2011dh, is also presented and discussed

---

8. Dr. Katalin Takats
Universidad Andres Bello

On the diversity of Type II-P Supernovae: the case of SN 2009ib

Type II-P supernovae represent the most numerous group among the core-collapse SNe. An interesting subgroup is that of the subluminous events, which are typified by fainter absolute magnitudes, lower expansion velocities and lower Ni-masses than the majority of SNe II-P. Recently, by studying of intermediate events falling in between the normal and subluminous SNe populations as well as by analysing samples of SNe light curves it has been confirmed that the observed properties of SNe II-P have continuous distributions instead of forming discreet groups. We present optical and near-infrared photometric and spectroscopic observations of SN 2009ib in NGC 1559, which represents another link connecting different SNe II-P. Through this object we study the diversity of the observed properties of SNe II-P. We estimate the physical parameters of the

progenitor at the explosion via hydrodynamical modelling of the main observables, and compare them to those of other SNe.

---

9. Mr. Giacomo Terreran
INAF-OAPd, QUB

Luminous type II supernovae

I present the photometric and spectral analysis of two luminous Type II Supernovae (SNe): SN2013fs and SN2014G. Both of them presented early-time spectra characterized by the presence of narrow H lines in emission, resembling those seen in young type IIn SNe. However the subsequent spectral evolution of the two objects revealed a more canonical nature for these two objects. SN2013fs presented, in the redder bands, a relatively short plateau of less than 80d (compared to a typical plateau duration of a hundred or so days) which led to classify this event as a type II-P. The briefness of the plateau can be due to a smaller hydrogen envelope or to a higher rate of the recombination front. The light curve of 2014G, instead, after a 20d-rise shows a linear decay that addresses to a II-L classification. Though, in the redder bands, after ~50d, a change of steepness can be notice and a hint of plateau appears in the light curve. This is then followed by a more dramatic drop after ~30d, in a way that resembles the behaviour of a type II-P SN. The former SN appears to be one of the most luminous type II-P SNe known so far, with a peak luminosity of log L = 42.8 erg s^−1 (which is twice the brightness of SN1999em) and a 56Ni mass of 0.06 solar masses. On the other hand, although 2014G presented a comparable peak luminosity of log L = 42.5 erg s^−1, such brightness is not unusual in type II-L events (e.g. SN1979C was twice more luminous). Despite the different classification of SN2013fs and SN2014G, these two objects are more similar to each other than their light curves suggest. In fact, the spectral evolutions and the luminosities are pretty much resembling, pointing to analogous chemical composition but with different mass of the residual hydrogen envelope. In this scenario, these two SNe could be two intermediate objects between traditional SNe II-P and II-L. Finally, several authors suggested that the observables of classical type II SNe are tightly correlated. However, the samples analyzed so far still lack of a significant number of luminous sources, since bright canonical type II SNe are quite rare. In this context, the study of the physical parameters of SN2013fs and SN2014G is of the uttermost importance in order to verify the reliability of these relations extended to the most energetic H-rich events.

---

10. Dr. Schuyler Van Dyk
Caltech

A Potpourri of Progenitors and Echoes

I will present recent results on the direct identification and characterization of several nearby core-collapse supernova (CCSN) progenitors, as well as on scattered light echoes around two CCSNe.

---

11. Mr. Naveen Yadav
Tata Institute of Fundamental Research

Electron Cooling In A Young Bright Radio Supernova

SN 2012aw is a optically bright type IIP supernova which exploded in the nearby galaxy Messier 95 (M95) at a distance of 10 Mpc. We will present the radio observations carried out by Jansky VLA and their modeling. We calculated the spectral index values using C, X & K bands and found them to be smaller than the values expected for optically thin regime. This is also the time when the optical bolometric luminosity stays in the plateau phase. We interpret the observed low spectral index values to be resulting due to electron cooling. We find that inverse Compton cooling process dominates over synchrotron cooling process, on the basis of comparison between Compton cooling timescale and Synchrotron cooling timescale. We model the radio emission as synchrotron emission from a relativistic electron population with a cut off at high energy. The cut off is determined by comparing the electron cooling time scale and the acceleration time scale. The radio data is fitted to the model. We constrain the mass loss rate in the wind. We also estimate the equipartition factor between relativistic electrons and the magnetic field. We find that the radiating plasma is far from equipartition (relativistic electrons have more energy than the magnetic fields).

Topic 3: Stellar Populations, Core Collapse and Progenitors

12. Dr. Joseph Anderson
ESO Chile

Characterizing the V-band light-curves of hydrogen-rich type II supernovae

We present an analysis of the diversity of V-band light-curves of hydrogen-rich type II supernovae. Analyzing a sample of 116 supernovae, several magnitude measurements are defined, together with decline rates at different epochs, and time durations of different phases. It is found that magnitudes measured at maximum light correlate more strongly with decline rates than those measured at other epochs: brighter supernovae at maximum generally have faster declining light-curves at all epochs. We find a relation between the decline rate during the 'plateau' phase and peak magnitudes, which has a dispersion of 0.56 magnitudes, offering the prospect of using type II supernovae as purely photometric distance indicators. Our analysis suggests that the type II population spans a continuum from low-luminosity events which have flat light-curves during the 'plateau' stage, through to the brightest events which decline much faster. A large range in optically thick phase durations is observed, implying a range in progenitor envelope masses at the epoch of explosion. During the radioactive tails, we find many supernovae with faster declining light-curves than expected from full trapping of radioactive emission, implying low mass ejecta. It is suggested that the main driver of light-curve diversity is the extent of hydrogen envelopes retained before explosion. Finally, a new classification scheme is introduced where hydrogen-rich events are typed as simply 'SNII' with an 's2' value giving the decline rate during the 'plateau' phase, indicating its morphological type

---

13. Dr. Joseph Anderson
ESO Chile

Analysis of blue-shifted emission peaks in type II supernovae

In classical P-Cygni profiles, theory predicts emission to peak at zero rest velocity. However, supernova spectra exhibit emission that is generally blue shifted. While this characteristic has been reported in many supernovae, it is rarely discussed in any detail. Here we present an analysis of H-alpha emission-peaks using a dataset of 95 type II supernovae, quantifying their strength and time evolution. Using a post-explosion time of 30d, we observe a systematic blueshift of H-alpha emission, with a mean value of -2000kms-1. This offset is greatest at early times but vanishes as supernovae become nebular. Simulations of Dessart et al. (2013) match the observed behaviour, reproducing both its strength and evolution in time. Such blueshifts are a fundamental feature of supernova spectra as they are intimately tied to the density distribution of ejecta, which falls more rapidly than in stellar winds. This steeper density structure causes line emission/absorption to be much more confined; it also exacerbates the occultation of the receding part of the ejecta, biasing line emission to the blue for a distant observer. We conclude that blue-shifted emission-peak offsets of several thousand kms-1 are a generic property of observations, confirmed by models, of photospheric-phase type II supernovae.

14. Dr. Antonio de Ugarte Postigo
IAA-CSIC

Constraining the GRB/SN relation with the 10.4m GTC telescope

In this talk I will review the latest advances on the relation between gamma-ray bursts (GRBs) and their associated SNe. I will highlight the observations that, in this line have been performed with our program at the 10.4m GTC telescope. Our program is aimed at the follow-up of all the SNe related to GRBs up to a redshift of z=1.0 using imaging and up to z=0.6 with spectroscopy. Since 2010 we have detected 8 new GRB/SNe (out of a total of 11), of which 6 were discovered by our program. Among these, we have discovered an exceptionally faint SN associated to GRB 100418A, and the extremely blue SN associated with the very peculiar ultra-long GRB 101225A (the Christmas burst) at a redshift of 0.8. Both point towards the existence of a broad variety of SNe associated to GRBs. We have recently produced a detailed study of GRB120422A/SN 2012bz that lies in the gap between low-luminosity and high-luminosity GRBs. In 2013 we discovered the SN associated with the ultra-luminous GRB 130427A/SN 2013cq, showing that SNe are produced independently of the energetics of the gamma-ray emission. Finally the spectroscopic study of GRB 130215A/SN 2013ez, at z=0.6 revealed an exceptionally low expansion velocity for a GRB/SN. Within our program we have also looked for the possible SN emission associated with short gamma-ray burst, produced during the merger of compact objects. I will describe the case of GRB 130603B, observed by our program and for which a kilonova component was detected for the first time using the HST.

---

15. Dr. Gaston Folatelli
Kavli IPMU

A Newly Identified Family of Flat-Velocity Type IIb Supernovae

Intensive observations of supernovae (SN) has allowed the identification transitional objects between SN subtypes, which in turn has shed light on their physical properties. I will introduce a small group of stripped-envelope objects characterized by the following spectroscopic peculiarities: weak helium lines that develop with time, low expansion velocities with a flat evolution, and small but firmly detected amounts of hydrogen. These events, which we named "flat-velocity Type IIb SN", tend to appear in high-metallicity environments. Their flat velocity evolution suggests the presence of a dense shell in the ejecta, although the origin of such shell is unclear. Despite the spectroscopic similarities, these objects show very diverse luminosities, which might be due to a projection effect in an asymmetric ejecta.

---

16. Mr. Christopher Frohmaier
University of Southampton

The Volumetric Supernova Rate in the Local Universe from PTF

We present preliminary results on the volumetric supernova rate in the local Universe (z<0.08). An accurate rate determination places constraints on stellar evolution models and may help in understanding supernova progenitor types. Data were analysed from two years of Palomar Transient Factory (PTF) observations, and detection efficiencies calculated through the addition of fake supernovae into the PTF discovery pipeline. The fake supernovae comprehensively sample the parameter space of PTF observations and dictate the weighting for each real supernova. We also present an investigation into the detectability of the new class of "Calcium rich or "faint and fast"" supernovae and place constraints on their origin."

---

17. Dr. Lluis Galbany
DAS U. Chile

PCA of type II supernova light-curves

We present a Principal Component Analysis (PCA) of the light-curves of a sample of more than 200 Core-collapse supernovae (SNe) from several sources, and most of them previously unpublished. We used different reference epochs in order to extract the common properties of these light-curves and searched for correlations to some physical parameters such as the burning of Ni56, amount of Hydrogen, and morphological parameters such as the length of the plateau, the stretch or the light-curve, and the decrements in brightness after maximum and after the plateau. We also used these similarities to produce SNe II light- curve templates that will be used in the future for standardize these objects and determine cosmological distances.

---

18. Dr. Lluis Galbany
DAS U. Chile

Integral Field Spectroscopy of supernova host galaxies

We used optical Integral Field Spectroscopy (IFS) of nearby supernova (SN) host galaxies (0.005 < z < 0.03) with the goal of finding correlations in the environmental parameters at the location of different SN types. We used those galaxies provided by the Calar Alto Legacy Integral Field Area (CALIFA) Survey, together with previous observations obtained with the same instrument. This approach provides with spatially resolved 2D spectroscopic information of the whole field of the galaxy. After subtracting the stellar continuum emission, we produced intensity maps of several ionized gas emission lines and stellar population parameters. We measured the velocity field of the galaxies from the Hα emission line shift, and computed the rotational parameters needed to deproject the galactic disc. We found differences in the galactocentric distances distributions among SN types, being SNe Ibc/IIb more centered than SNe Ia, and SNe II in the middle of those. Assuming the presence of metallicity gradients in galaxies, distance can be used as a proxy of the metallicity at the explosion site. Our findings would mean that SNe Ibc/IIb can be found in metal-richer environments than SNe II. We also determined aggregations of HII regions from the extinction-corrected Hα emission 2D maps, and measured the distance from the SN to the nearest HII clump. We found that a sequence in association to these star-forming regions, from SNe Ibc/IIb to SNe II, being SNe Ia practically not correlated to them. This can be explained by differences in ages and masses among the parent stellar populations of the progenitors of different SN types. This approach is an improvement over the previous efforts based on photometry or on spectroscopy of the galaxy core.

---

19. Mr. Avishai Gilkis
Technion

Intermittent Accretion Disk Production in Core Collapse Supernovae

We derive a simple approximation for stochastic angular momentum in convective regions of stars. This approximation is applied for evolved massive stars at core-collapsing epoch, utilizing the assumptions of mixing length theory. We show that some convective regions have sufficient stochastic angular momentum to form intermittent accretion disks around the newly formed neutron star or black hole (BH). Such accretion disks may form jets that can explode the star even after BH formation.

---

20. Dr. Patrick Kelly
University of California, Berkeley

The Exceptional Host Galaxies of Fast-Ejecta Core-Collapse Supernovae

Spectra of broad-lined Type Ic supernovae (SN Ic-BL), the only kind of SN observed at the locations of long-duration gamma-ray bursts (LGRBs), exhibit wide features indicative of high ejecta velocities (~0.1c). I will discuss our recent study the host galaxies of a sample of 245 low-redshift ($z < 0.2$) core-collapse SN, including 17 SN Ic-BL, that were discovered by galaxy-untargeted searches, and 15 optically luminous and dust-obscured $z < 1.2$ LGRBs. We show that, when compared with SDSS galaxies having similar stellar masses, the hosts of low-redshift SN Ic-BL and $z < 1.2$ LGRBs have high stellar-mass and star-formation-rate densities. Core-collapse SN having typical ejecta velocities, in contrast, show no preference for such galaxies. Moreover, SDSS spectroscopy shows that the hosts of SN Ic-BL, unlike those of SN Ib/Ic and SN II, exhibit high gas velocity dispersions for their stellar masses. The patterns likely reflect variations among star-forming environments, and suggest that LGRBs can be used as probes of conditions in high-redshift galaxies. They may be caused by efficient formation of massive binary progenitors systems in densely star-forming regions, or, less probably, a higher fraction of stars created with the initial masses required for a SN Ic-BL or LGRB. Finally, we show that the preference of SN Ic-BL and LGRBs for galaxies with high stellar-mass and star-formation-rate densities cannot be attributed to a preference for low metal abundances, and must instead reflect the influence of a separate environmental factor.

---

21. Ms. Hyun-Jeong Kim
Seoul National University

Observational Properties of Type Ibc Supernova Progenitors in Binary Systems

The progenitors of Type Ibc supernovae (SN Ibc) have been believed to be massive Wolf-Rayet (WR) stars, formed either through stellar wind mass loss or Roche-lobe outflow in a binary system. But observations indicate that ordinary SN Ibc have relatively low ejecta masses (~ 2 Msun), which is not compatible with the WR scenario for SN Ibc progenitors. On the other hand, relatively lower-/intermediate-mass helium stars in a binary system which can be produced via mass transfer are also suggested as a possible candidate for SN Ibc progenitors. Binary star evolution models predict that SN Ibc progenitors having final masses of 3 - 7 M_sun can be produced, but their observational properties are not well understood. In this study, we present the preliminary results of the parameter study on the observational constraints of a helium star of ~4.4 M_sun in a binary system using evolutionary models and atmospheric radiative transfer code CMFGEN. We present the predicted magnitudes in optical bands for different wind velocity profiles, mass loss rates, and clumping factors. We also present a composite spectrum of the progenitor binary system considering different companion stars like O- and B-type stars. Based on the results, we discuss the expected observational properties of SN Ibc progenitors in binary systems and the possible use of these observables in future SN Ibc progenitor surveys.

---

22. Dr. Hanindyo Kuncarayakti
Millennium Institute of Astrophysics

Optical/NIR view of SN explosion sites with IFU spectroscopy

We present an IFU view of nearby SN sites, combining both optical and near-IR observations. This unique dataset enables us to probe the parent stellar populations of SN progenitor stars and derive constraints on the age and metallicity of the explosion site, which in turn give the estimates for the initial mass and metallicity of the progenitor. The AO-assisted NIR observations provide near diffraction-limit IFU spectroscopy strengthens the optical results, resolving the stellar populations at the SN sites and provide clues on the star formation history at the site. Here we present the preliminary results of this ongoing campaign.

---

23. Dr. Emily Levesque
University of Colorado at Boulder

Red Supergiants as Supernova Progenitors

Red supergiants (RSGs) are a key mass-losing phase in the lifetimes of moderately massive (10-25 Mo) stars. Pre-explosion observations of Type II-P supernovae have confirmed that lower-mass RSGs are these events' immediate predecessors, while the more massive RSG population may undergo direct collapse to a black hole or mark an intermediate evolutionary stage prior to the stars' final

explosion as blue supergiants or Wolf-Rayet stars. Our recent observations of RSGs samples throughout the Local Group and comparisons with the latest generations of stellar evolutionary models have made great strides in understanding these stars' physical properties and mass loss behaviors across natal environments that span a factor of 20 in metallicity. This talk will discuss recent work utilizing our current sample of Local Group RSGs to answer outstanding questions regarding their roles as supernova progenitors. These include examination of the notorious "red supergiant problem", metallicity-dependent evolution and transient behavior in RSGs, and the role of RSG binary evolution in SN 1987A-like events and other more exotic end products such as Thorne-Zytkow objects. These recent strides emphasize the importance of ongoing extragalactic stellar astrophysics endeavors in understanding core-collapse supernovae progenitors.

---

24. Mr. Sergey Lisakov
Observatoire de la Côte d'Azur

Simulations of Type II-P supernovae and their progenitors

All stars with an initial mass of 8 solar masses or more, but not massive enough to encounter the pair-production instability, eventually form a degenerate core and collapse to form a compact object, either a neutron star or a black hole. Most of these are believed to produce the so-called core-collapse supernovae (CCSN). We try to map the relationship between the resulting CCSN types and the properties of their progenitors (initial mass, rotation rate and metallicity; single vs binary; mass loss through wind and mass exchange; binary separation and mass ratio), using advanced stellar structure and stellar atmosphere codes.

---

25. Ms. Yuqian Liu
New York University

Analyzing the Largest Spectroscopy Data Set of Stripped SNE to Improve SN Identification and to Constrain their Progenitors

Dozens of Stripped-Envelope Core-Collapse Supernovae (SESNe) are discovered every year but only a few of them have good spectra and photometry. Given the difficulty of collecting data of many SESNe, people usually focus on a specific SN. The latest paper that statistically compared spectra of different SESNe subtypes was conducted in 2001 by Matheson et al., using spectra of 28 SESNe among which many didn't have a good light curve to determine phases of spectra. Recently, Modjaz et al. (2014) published optical spectra of 73 SESNe collected at the Harvard-Smithsonian Center for Astrophysics (CfA), doubling world-supply of well observed SESNe. Forty-four of these 73 SESNe have a date of maximum light. Besides the above data, we have collected the spectra of most of the literature SESNe, thus we can analyze spectra of our very large sample of about 80 SESNe with a well-defined maximum and type. It's time to understand different subtypes of SESNe in a statistical way. By comparing the strength of He I λ5876 with respect to that of H-α in Type Ib SNe (SNe Ib) and Type IIb SNe (SNe IIb), we found that there is a continuum of hydrogen envelope in their progenitors. The strength and velocity of He I lines are different in SNe Ib and SNe IIb especially when the spectra were taken around three weeks after the date of maximum light, enabling us to differentiate SNe Ib from SNe IIb even without spectra taken around maximum date. We quantified

the diversity within each SESNe subtype by constructing average spectra for SNe of the same subtype and analyzing line strength evolution of individual SN. We also found that O I λ7774 line is stronger in Type Ic SNe (SNe Ic) than in SNe Ib. This is consistent with the measurements done by Matheson et al. (2001), but contradicts the predictions made by Dessart et al. (2012) using a model that SNe Ib and SNe Ic have the same progenitors but different level of 56 Ni mixing.

---

26. Dr Joe Lyman
University of Warwick

Bolometric light curves and explosion parameters of 38 stripped-envelope core-collapse supernovae

The SN discovery rate is already well beyond the regime where most events can be followed up with spectroscopic and photometric monitoring to fully characterise the explosion. Therefore the maximum science value of a SN must be extracted from relatively little follow up coverage. Bolometric light curves are a valuable tool for the study of SNe, although have been traditionally observationally expensive. Utilising bolometric corrections from previous work, a large sample of literature stripped-envelope CCSN bolometric light curves are constructed. T hese are modelled with a simple analytical prescription to obtain explosion parameters of each event - modelling results agreeing well with more detailed studies. With these distributions of parameters, the characteristics of the various subtypes are investigated and the nature of the progenitor stars probed.

---

27. Ms. Athira Menon
Monash University, Melbourne

Pop III Presupernova models: Stellar evolution and nucleosynthesis of rotating and magnetic massive stars

The first stars of the Universe, referred to as Population III (Pop III) stars, began their lives with an initial composition of pristine big bang nucleosynthesis material. The initial mass function (IMF) of these stars is expected to be skewed towards the high mass end, with inital masses between 10-100 Ms (Bromm & Larson (2004), Abel, Bryan & Norman (2000)). The first heavy elements (heavier than helium), were synthesised in these stars, which were ejected through supernova explosions and became the seeds for forming the next generation of stars. Ionizing radiation released from these stars during their lifetime, are considered to be responsible for reionizing the Universe. The imprints of the first generation of stars, are expected to be left on the observed class of Ultra-Metal Poor stars (UMPs) with [Fe/H] <-5 (Venn & Lambert (2008)). Thus, simulating Pop III stars provides important clues in understanding the evolution of the early Universe. In the past, stellar evolution studies of Pop III massive stars have been done by authors such as Chieffi & Limongi (2002) and Heger & Woosely (2010). However, these works were exempted from the use of rotation and magnetic fields. Rotation and magnetism, can have a significant impact on the evolution of the internal structure of the star, due to angular momentum transport and enhanced mixing (Heger et al. (2000), Hirschi (2006)). We present results of simulations of presupernova evolution models of Pop III massive stars, with rotation and magnetic fields, in the mass range between 10-100 Ms. We

study the complete evolution of their stellar structural properties, from the Zero Age Main Sequence (ZAMS) upto core-collapse, along with their detailed nucleosynthesis yields, using the 1-D hydrodynamic code 'KEPLER'. The models are initiated with a zero-metallicity, big bang nucleosynthesis composition and rotation rates between 0.1-0.9 of the critical angular velocity of the star. Nucleosynthesis yields are calculated in parallel by the code, using a co-processing network consisting of a vast number of chemical species.

---

28. Dr. Attila Meszaros
Charles University

Number of the Types of the Gamma-Ray Bursts: Two or Three?

Practically with a certainty it can be said that there are two physically different types of the gamma-ray bursts: the short/hard and the long/soft ones. The relation of the long/soft bursts with supernovae is well stated, but the physics of the short/hard bursts is not clear yet. In addition, the author - with his collaborators - did in the last years a great effort to clarify, if there exist either only these two types, or there exists also a third one. A brief survey of these efforts is presented here.

---

29. Dr. Felipe Olivares E.
Universidad Andrés Bello

Multiwavelength analysis of GRB-SNe in the context of the full sample

After the discovery of the first connection between GRBs and SNe almost 15 years ago, more than two dozen SN-like rebrightenings and seven solid spectroscopically-confirmed associations have been discovered to date. The luminosity, evolution, and origin of four SN rebrightenings in GRB afterglow light curves are determined along with accurate determinations of the host-galaxy extinction via afterglow SED analysis. For this purpose, we employed GROND optical/NIR data and Swift X-ray/UV data. We constructed quasi-bolometric light curves, which were corrected for the contribution of the NIR bands using the available data for SNe 1998bw and 2006aj and modelled by means of Arnett's analytic approach to obtain the physical parameters of the explosion, such as synthesized nickel mass, total ejected mass, and kinetic energy. The SNe 2009nz, 2010ma, 2010bh, and 2008hw observed by GROND exhibit about 1.1, 1.7, 0.7, and 0.8 times the optical luminosity of SN 1998bw, respectively. The modelling resulted in nickel masses of around 0.2-0.5 M_{sun}, which are larger than for local type-Ic SNe and resemble those of other GRB-SNe. From a sample of GRB-SNe, we utilized the SN and GRB parameters to assess the nature of the connection statistically. The average brightness for 27 GRB-SNe is $M_V = -19.46(\pm 0.12$ RMS) mag. Only 7% of all GRB-SNe are significantly brighter than SN 1998bw.

---

30. Mr. Oded Papish
Technion

Exploding Core-Collapse Supernovae by Jets-Driven Feedback Mechanism

We present new numerical results of the jittering-jets model for the explosion of core collapse supernovae (CCSN). These results show that the jittering jets model is able to explode CCSNe. We compare our results to observations of the SNR Cassiopeia A. In the jittering jets model part of the collapsing gas possesses local angular momentum as a result of stochastic processes and instabilities (e.g., SASI) and forms an intermediate accretion disk. This accretion disk launches two opposite jets. Due to the rapid change in the disk's axis, the jets can be intermittent and their direction can be rapidly varying.

---

31. Dr. Dovi Poznanski
Tel Aviv University

An emerging Coherent Picture of Red Supergiant SN explosions

Computer simulations of core-collapse have difficulty exploding. Very few observational clues constrain directly the parameters of the exploding star. However, I will show that three lines of evidence indicate that in the most common type of core-collapse supernovae, the energy deposited in the ejecta by the exploding core is approximately proportional to the progenitor mass cubed. This result stems from an observed uniformity of light-curve plateau duration, a correlation between mass and ejecta velocity, and the known correlation between luminosity and velocity. This result ties in analytical and numerical models together with observations, providing us with clues as to the mechanism via which the explosion of the core deposits a small fraction of its energy into the hurled envelope. I will further show recent measurements that strengthen these results.

---

32. Dr. Stuart Ryder
AAO

The First Supernova Discovered with GeMS/GSAOI

Luminous Infrared Galaxies (LIRGs) are believed to be forming stars at a rate that should yield on average one core-collapse supernova (CCSN) event per year, and yet hardly any have been found. Our search for core-collapse supernovae in LIRGs with adaptive optics on Gemini North has enabled us to place the first empirical constraints on the fraction of supernovae missed by optical surveys. We have commenced a search with the powerful new GeMS/GSAOI facility on Gemini South, and our first epoch images of the LIRG IRAS 18293-3413 already reveal a new supernova not seen in any optical survey.

33. Prof. Noam Soker
Technion

The jittering-jets model for core collapse supernovae

I will present the motivation for considering the jittering-jets model for the explosion of CCSNe, and new results that we are working on now. Our 2D and 3D simulations show that the jittering-jets model can account for the explosion of CCSNe.

---

34. Dr. Akihiro Suzuki
Kyoto University

Relativistic radiation-hydrodynamical calculations of supernova shock breakout

Supernova shock breakout is a bright UV or X-ray flash that occurs at the birth of a core-collapse supernova. Since the phenomena occurs when the radiation decouples from the matter, it is necessary to treat the propagation of the shock in the framework of radiation-hydrodynamics. I have developed a two-dimensional radiation-hydrodynamics code taking into account special relativity. In this presentation, I introduce the code and results of some test calculations including supernova shock breakout.

---

35. Dr. Christina Thöne
IAA - CSIC

The SN Ib factory NGC 2770 in high resolution

NGC 2770 at 30 Mpc hosted 3 Type Ib SNe between 1999 and 2008. The last of those, SN 2008D, was the first SN to have a shock-breakout observed in X-rays, thus marking the exact explosion time of the SN. We obtained VIMOS-IFU data of the galaxy as well as narrow-band tunable filters from GTC/OSIRIS of NII, Halpha and SII. These data allow us to make maps of metallicity, shocked regions, stellar population ages and more of the entire galaxy. All three SNe lie in the outer spiral arms of the galaxy and lie at the edge or outside the major star-forming regions. Their metallicities are all around half solar and their ages (directly related to their progenitor mass) higher than necessary for single massive progenitors. This could imply that the progenitors had to be binary systems, in line with some previous studies on SN Ib regions. It is also interesting to note that none of the three SNe lie in regions with enhanced SF, low metallicity or age but two of them next to some more extreme regions. Those strong local variations throughout the galaxy make it clear that we need resolved information to determine the properties of different SN progenitors.

---

36. Ms. Stephanie Bernard
University of Melbourne

Detecting z ~ 1 type Ia supernovae at large separations from their hosts

Searching for supernovae in the early universe is often motivated by the possible discovery of the deaths of first stars, termed Population III stars. We have developed a method to find z > 3 core-collapse supernovae that may have Population III progenitors. I will discuss our program that focuses on z ~ 3 - 5 supernovae have no visible host galaxies (called "orphan "supernovae). Our method is also sensitive to "lower redshift" z ~ 1 type Ia and some core-collapse supernovae at large separations from their host galaxies. In this talk, I will present results from this work, including the detection of UV shock breakout signature in an intermediate-redshift supernova candidate.

---

37. Prof. Ryan Foley
University of Illinois

Type Iax Supernovae: Progenitors, Explosions, and Remnants?

I will overview the Type Iax class of supernovae, which are low-energy, likely thermonuclear, stellar explosions that are similar to, but physically distinct from, SN Ia. The best model for their progenitor system is a C/O WD accreting from a He-star companion. Observations suggest, and theory predicts, that at least some SN Iax do not completely disrupt their WD progenitor stars, leaving behind a battered, bruised, and possibly very luminous remnant star. I will also present deep post-explosion HST images of SN 2008ha, the least luminous member of the class, which reveal a luminous star at the position of the SN possibly the companion star or the predicted remnant.

---

38. Ms. Ragnhild Lunnan
Harvard University

Staring Into the Beast's Lair: Host Environments of Superluminous Supernovae

The advent of wide field optical time-domains surveys are providing opportunities to discover and decipher new types of transients. One of the most unexpected results to come out of surveys like Pan-STARRS and PTF is the discovery of super-luminous supernovae (SLSNe), with bolometric luminosities up to 100 times that of normal core-collapse, Type Ia SNe, and even GRB-SNe and with spectra that do not match any known SN classes. These SLSNe represent a new challenge to our understanding of the death of massive stars, the standard core-collapse picture, and the mechanism for powering optical emission in SNe. Progress in our understanding will come from both studying the properties of the SNe themselves, as well as studying their galactic and sub-galactic environments. In this talk, I will present results from an extensive study of ~30 SLSN host galaxies, spanning a redshift range of 0.1 < z < 1.6. Our data includes optical and NIR photometry and optical spectroscopy, allowing us to determine stellar masses, star formation rates and metallicities, as well as resolved HST imaging allowing us to study the host morphologies and the locations of the SLSNe relative to the overall host light distribution. I will show that SLSNe are preferentially found in low-luminosity, low-mass, low-metallicity and high specific star formation rate host galaxies. They are statistically inconsistent with coming from the same galaxy population as ordinary core-collapse SNe, but share many similarities with the host galaxies of long gamma-ray bursts.

---

39. Dr. Joe Lyman
University of Warwick

The progenitors of Ca-rich transients

Ca-rich transients represent a peculiar class of optical transients with luminosities intermediate between novae and SNe. These Ca-rich transients exhibit spectra similar to type I SNe at maximum light but quickly evolve to the nebular phase to reveal spectra dominated by calcium. Their host morphologies are diverse, with a large fraction of early type galaxies, and within their hosts their environments appear extreme, often at offsets of tens of kpc. Many progenitor models have been proposed ranging from massive stars to various white dwarf binary configurations. Here I present work that rules out a young age for these progenitors by comparing their environments to ongoing and recent star-formation tracers. Additionally, deep limits at the locations of some proximate examples rule out the presence of underlying faint host systems, inferring Ca-rich transients are not formed in situ. High-velocity, kicked systems thus provide a potential progenitor model.

---

40. Dr. Jon Mauerhan
University of California Berkeley

Spectropolarimetry of SN2009ip's 2012 explosion: direct evidence for aspherical circumstellar material

We present spectropolarimetry of SN 2009ip throughout the evolution of its 2012 outburst, including the initial 2012a explosion and the subsequent 2012b phase of interaction with circumstellar material (CSM). The polarization measurements indicate a substantially aspherical geometry for the 2012A outflow. The peak of the 2012b CSM-interaction phase exhibits a significantly higher degree of asphericity than 2012a and, interestingly, an orthogonal axis of symmetry on the sky. The results are consistent with a potentially bipolar explosion expanding into a toroidal distribution of CSM (i.e., a disk or ring). It is thus likely that only a small fraction of the SN ejecta participated in CSM interaction and contributed to the 2012B luminosity. Previous calculations that have assumed spherical symmetry for the CSM must have significantly underestimated the explosion energy. A kinetic energy of ~1e51 erg is difficult to avoid, supporting the interpretation that the 2012 outburst of SN2009ip was the result of a terminal core-collapse explosion.

---

41. Dr. Takashi Moriya
University of Bonn

Electron-capture supernovae exploding within super-AGB wind

Electron-capture supernovae (ecSNe) are explosions triggered by electron-degenerate O+Ne+Mg cores. The progenitors are super-AGB stars when they explode if they are single stars. Super-AGB stars are known to have high mass-loss rates (~ 1e-4 Msun/yr) and slow wind velocities (~ 10 km/s), making the CSM very dense. Thus, the observational properties of ecSNe can be strongly affected by the dense CSM. We performed numerical LC modeling of ecSNe exploding within the super-AGB wind by using realistic ecSN progenitor models. We find that the early LCs during the plateau phase in which the recombination in the H-rich envelope occurs does not affected by the wind but the later LCs are strongly affected by the wind and ecSNe will be observed as Type IIn SNe. We compare our LC models to the LC of SN 1054 (Crab Nebula), which has been suggested to be an ecSN. We show that the LC properties can be explained by an ecSN exploded within the super-AGB wind without any other extreme mass loss suggested to be necessary to explain the LC. We also find that our LCs can explain the Type IIn SNe with the LC plateau (so-called Type IIn-P) and suggest that they are ecSNe exploded within the super-AGB wind. We also discuss other observational properties of ecSNe exploded within the super-AGB wind.

42. Dr. Andrea Pastorello
INAF - Padova Astronomical Observatory

The heterogeneous type Ibn supernova family

Type Ibn supernovae are core-collapse events whose ejecta interact with He-rich and H-poor circumstellar material. A major stellar outburst was observed in 2004 in the galaxy UGC 4904, and was followed 2 years later by a terminal core-collapse explosion of the famous SN Ibn 2006jc. As a consequence of this amazing discovery, the astronomical community increased its interest toward this rare supernova type, and dedicated wide follow-up campaigns aimed to obtain high-quality data for a few of type Ibn supernovae. Including recent discoveries, a dozen of type Ibn events have been studied so far, showing an unexpected variety in the observational parameters and the explosion sites. I will review our current knowledge on SN 2006jc-like events.

43. Ms. Maria Pruzhinskaya
Sternberg astronomical institute of Lomonosov Moscow State University

Fast radio bursts, kilonovae and MASTER synoptic survey

Wide field transients' surveys allow us to discover numerous numbers of transients including transients of unknown nature. The recently reported discovery of fast radio bursts (FRBs) in the framework of the neutron star-neutron star (NS+NS) or neutron star-black hole (NS+BH) binary merger model will be discussed. It is shown that there is no discrepancy between NS merger rate and observed FRB rates in the framework of the Scenario Machine population synthesis - for a kick velocity of 100-150 km s-1 an average NS merger rate is 1/500-1/2000 yr-1 per galaxy up to z = 0.5-1.

The other part of presentation will be devoted to the MASTER robotic network. This network is designed for studies of the prompt optical emission of gamma-ray bursts (GRBs; optical emission synchronous with the gamma-ray radiation) and surveys of the sky aimed at discovering uncatalogued objects and photometric studies for various programs. More than 200 alert observations of gamma-ray bursts were made (optical emission were found for 16 objects) and more than 500 optical transients (supernovae, novae, flashes of quasars and BL Lac objects, potentially hazardous asteroids etc.) were discovered by MASTER.

---

44. Dr. Steve Schulze
Institute for Astrophysics, Pontificia Universidad Catôlica de Chile

The SUSHIES Project - Unraveling the Host Galaxies of Super-luminous Supernovae

Recent SN surveys revealed the existence of a family of super-luminous SNe (SLSNe) with peak magnitudes exceeding Mpeak < -21 mag. With the emergence of this new family of SNe, it became clear that their progenitors are very different from normal core-collapse SNe. To place constraints on their progenitors and their explosion mechanisms, our team has initiated the SUSHIES (SUper-luminous SN Host galaxY) survey to characterize the hosts of 30 SLSNe between z~0 and z~0.5, using optical and NIR imaging and host spectroscopy. In this talk I will present our findings on these galaxies that give rise to some of the most brilliant explosions in the Universe. We find that SLSNe explode in faint (M=-17.5 mag) dwarf galaxies with star-formation rates of 0.5-3 M/yr. One of our key results is that the majority of H-poor SLSN hosts are similar to extreme emission-line galaxies, in their mass and luminosity distributions and in that they often show equivalent widths > 100 AA in [OIII]-5007. Furthermore, I will discuss the host offsets of these explosions and put the host properties in the context of GRB host galaxies and other populations of star-forming galaxies.

---

45. Dr. Hideyuki Umeda
University of Tokyo

Possible Type Ic Super Luminous SNe from metal-poor pulsational pair-unstable massive stars

It is now well known that stars slightly less massive than the mass range for pair instability SNe experience "pulsational pair-unstable (PPU)" stage just before Fe core-collapse. In our previous paper in Yoshida, Okita, Umeda (2014), we investigated metal poor massive star evolution mainly to study the core-collapse explosion and nucleosynthesis of most massive CO stars. Although the stars studied in the paper, with mass of 120-250Msun and metallicity Z~ 0.001~0.004 enter into the PPU stage, we did not consider the mass-loss effects during this stage. Here we extend the previous work and calculate full evolution of those stars including the mass loss during PPU. We show that number of pulses, ejected mass, kinetic energy, and interval of pulses depend on the stellar mass. In most cases these pulses collide and shine a few months to ten years before core-collapse and may become precursors of main collapse. If the final core collapse causes stellar explosion with 10^51 ergs or more, collision between the ejecta and previously ejected mass generates light curves with a range of luminosity, from faint SNe to those as bright as Super Luminous SNe

Topic 5: Type Ia Supernovae and Their Progenitors

46. Dr Alceste Bonanos

High-cadence monitoring of the optical light curve of SN 2014J

SN 2014J offered the opportunity to search for microvariability in its light curve, given the proximity of M82 and brightness of the supernova. We used the 2.3 m Aristarchos telescope at Helmos Observatory, Greece, to obtain B and V-band time-series photometry of SN2014J over 4 consecutive nights in February 2014, with a cadence of ~2 minutes in each band. We present the light curves and a preliminary analysis of the results.

---

47. Mr. Peter Brown
Texas A&M

An Ultraviolet View of Supernova Progenitors

The ultraviolet flux of supernovae is strongly affected by many properties of the progenitor and its environment including metallicity, asymmetries, density gradients, dust extinction, and interaction with companions or circumstellar material. Disentangling these different effects requires large samples of supernovae observed in the ultraviolet and detailed studies of the nearest objects. I will show the ability of UV observations to constrain the progenitor systems using Swift UV observations of supernovae, including very early observations of the very nearby SN2011fe. UV observations also constrain the nature of the dust extinction, using our growing sample of moderately reddened supernovae and the extremely close and extremely reddened SN2014J. I will also give a summary of the nearly three hundred supernovae observed to date and the Swift Optical/Ultraviolet Supernova Archive (SOUSA).

---

48. Mr. Georgios Dimitriadis
University of Southampton

Late time data of PTF Supernovae Type Ia

We present late time ($200<t<1000$ days) data of low-redshift Type Ia Supernovae (SNe Ia) discovered and monitored by the Palomar Transient Factory, a rolling survey over 2009-2012 of the Northern sky. We identify a sample of slowly declining events ("high stretch") that show an excess in the light curve, compared to the well-observed normal SNe Ia, (e.g., SN2011fe), at these late epochs. These outbursts may indicate interaction of the SN Ia ejecta with circumstellar material around the progenitor star, resembling less extreme versions of SN Ia-CSM such as PTF11kx. We discuss the implications of our study regarding the nature of the progenitor systems of SNe Ia.

---

49. Mr. Robert Firth
University of Southampton

The Rising Light Curves of Type Ia Supernovae

The very early light curves of Type Ia Supernovae (SNe Ia) are one of the most direct windows onto the physics of the ejecta. The shape and speed of the rise are key to understanding this environment, and by fitting the rising light curves, constraints can be placed on the 56Ni distribution and the contribution of shock emission. We use such early-time SN Ia data from the Palomar Transient Factory (PTF) and the La Silla Quest variability survey (LSQ), and find that the rise is best fit as a power-law tn, with mean = 2.36 ± 0.13, discrepant from the commonly assumed value of n = 2. We find the sample mean uncorrected rise time of 18.83 ± 0.48 days, and also show that the speed of the early (t < 7 days) light curve is uncorrelated with the speed of the late-time light curve (t > 7 days), the latter commonly used in the standardisation of SNe Ia for their cosmological use. We discuss the implications of this both for the use of SNe Ia in cosmology, and for understanding the physics of SNe Ia.

---

50. Dr. Melissa Graham
University of California, Berkeley

Twins for Life? A Comparative Analysis of the Nearby SNe Ia 2011fe and 2011by to Late Times

The nearby SNe Ia 2011fe and 2011by were twin-like in their optical photospheric spectra and light curve shapes, but 2011by exhibited a relatively depressed flux in the near-ultraviolet (NUV) and was intrinsically fainter by ~0.6 magnitudes (a factor of 1.7 in synthesized 56Ni mass) at maximum light. Foley & Kirshner (2013) argued that this was a result of significantly higher metallicity in the progenitor star of 2011by. As both SNe Ia are nearby and well observed, we extend the comparison to 10 days before and 300 days after maximum brightness, including one earlier epoch of HST NUV spectra, two epochs of nebular phase optical spectra, and late-time photometry. We find that the disparity in NUV flux between 2011fe and 2011by is even stronger before maximum light, as expected by progenitor metallicity models. SNe 2011fe and 2011by are even more twin-like in their nebular phase spectra, which suggests they formed more similar amounts of 56Ni than inferred from peak brightness. At late times, 2011by appears to experience a slower decline and have the same intrinsic magnitude as 2011fe. In our comparative analysis of these two nearby SNe Ia, we attempt to converge on a single physical model that can explain both the general similarity and few specific differences of 2011fe and 2011by, including progenitor metallicity, density gradient, mixing of nucleosynthetic products, ejecta mass, viewing angle, explosion asymmetry, companion type, and environment.

---

51. Dr. Yi Chi Eric Hsiao
Aarhus University/Las Campanas Observatory

Near-infrared spectroscopy of Type Ia supernovae

At optical wavelengths, reducing the scatter and systematics of SN Ia luminosity has proven difficult. Observations in the NIR offers a way forward. In the NIR, SNe Ia have smaller intrinsic scatters and require smaller dust/color corrections. A key ingredient for improving SN Ia in the NIR as distance indicators is to obtain NIR spectroscopy to determine precise k-corrections. Carnegie Supernova Project II is a four year program dedicated to obtaining NIR observations of a definitive sample of SNe Ia. With the newly-commissioned high-throughput NIR spectrometer on the 6.5-m Magellan Telescope, we are beginning to gather a large enough sample of high-quality NIR spectra, not only to improve SN Ia cosmology, but also to probe the explosion physics and unprocessed materials from the progenitors. I will describe our progress to date.

---

52. Mr. Naveh Levanon
Technion, Israel

The unavoidable observational effects of circumstellar matter in the double degenerate scenario for Type Ia supernovae

We follow the mass blown during the WD-WD merger process in the Double-Degenerate (DD) scenario for type Ia supernovae (SN Ia), and find that the interaction of the SN ejecta with this wind affects the early (<1 day) light curve in a way that contradicts observations, if the detonation occurs during or shortly after the merger (<1 year). The main source of the blown mass is a disk-wind, or jets that are launched by the accretion disk around the more massive WD. This disk-originated matter (DOM) will be shocked by the SN ejecta and kinetic energy will be channeled to thermal energy and then to extra radiation. The extra radiation could be interpreted as an explosion originating from progenitor having a radius of one solar radius or more, contradicting observations of SN 2011fe and SN 2014J.

---

53. Prof. Ken'ichi Nomoto
Kavli IPMU, The University of Tokyo

Final Evolution of Spinning White Dwarfs and their Companions in Single Degenerate Models for Type Ia Supernovae

We will present the evolution of uniformly rotating, mass-accreting white dwarfs (WDs) and their companion stars in the single degenerate model for Type Ia supernovae. For certain ranges of binary parameters (the companion's mass and the binary separation), the WD increases its mass through the "effective" Chandrasekhar mass of the uniformly rotating WD, M(Ch, rot), and undergoes "prompt" carbon ignition. For nearby ranges of binary parameters, the WD mass exceeds the Chandrasekhar mass of the non-rotating WD but does not reach M(Ch, rot). Such a WD undergoes

spin-down evolution and "delayed" carbon ignition. During the spin-down phase, the companion would evolve to become a He WD or a low mass star. We will discuss if the missing companion problem of some Type Ia supernovae can be reconciled.

---

54. Dr. Jeffrey Silverman
University of TX at Austin

High-Velocity Features in the Spectra of Type-Ia Supernova

Optical spectra of Type-Ia supernovae (SNe Ia) obtained before maximum brightness sometimes show high-velocity features (HVFs). They are most often seen in Si II and Ca II and in the most obvious cases appear as a second, separate absorption feature at about 6000-13,000 km/s higher expansion velocity than the more normal photospheric velocity features (PVFs). We explore how to determine the presence or absence of HVFs and how to accurately measure these two components. We investigate how often HVFs occur, at what epochs, and how they evolve with time using a large sample of low-resolution, optical spectra of nearby SNe Ia. Our work indicates that HVFs are quite common in SNe Ia during the weeks leading up to maximum brightness. Correlations between photometric observables and the strengths and expansion velocities of both HVFs and PVFs are currently being searched for. Various explanations for the existence and behavior of the HVFs are being considered, with possibilities including a density enhancement in the outer portion of the SN ejecta or low levels of interaction with circumstellar material.

---

55. Prof. Noam Soker
Technion

The core-degenerate scenario for SN Ia

I will present the core-degenerate scenario for SN Ia. This is an alternative to the DD and SD scenario, and seems to do well with some specific SN Ia (e.g., SN 2011fe, and PDF 11kx). I will present new results from 2014 obtained by my research group.

Topic 6: Supernova Remnants

56. Mr. Baha Dincel
Astrophysical Institute and University Observatory Jena

Discovery of an OB Runaway Star inside SNR S147

We present first results of a long term study: Searching for OB-type runaway stars inside supernova remnants (SNRs). We identified spectral types and measured radial velocities (RV) by optical spectroscopic observations and we found an OB runaway star inside SNR S147. HD 37424 is a B0.3V type star with a peculiar velocity of 74.0+/-7.5 km/s. Tracing back the past trajectories via Monte Carlo simulations, we found that HD 37424 was located at the same position as the central source PSR J0538+2817 30+/-4 kyr ago. This position is only ~4 arcmin away from the geometrical center of the SNR. So, we suggest that HD 37424 was the presupernova binary companion to the progenitor of the pulsar and the SNR. We found a distance of 1333 (+103/-112) pc to the SNR. The age is 30+/-4 kyr and the total visual extinction towards the center is 1.28+/-0.06 mag. The zero age main sequence progenitor mass should be greater than 13 Msun. We calculated the presupernova binary parameters for different progenitor masses. The values found for the Roche Lobe radii suggest that it was an interacting binary in the late stages of the progenitor.

---

57. Prof. David Burrows
Penn State University

Chandra observations of RCW 103

We present analysis of Chandra observations of RCW103 with a combined exposure time of 99 ks, based on X-ray and equivalent width images, plus spectral analysis of 28 regions. We find strong variations in absorption across the remnant that is stronger in the north and west. The electron temperature is fairly uniform at 0.58 keV. Metal abundances are inhomogeneous and vary from 0.3 - 1.4 solar from region to region, but likely include significant contributions from both the CSM, with subsolar abundances, and ejecta, with abundances that are above solar. Preliminary comparison with predictions for core-collapse nucleosynthesis models suggest a low progenitor mass of 13-15 solar masses.

---

58. Prof. Bryan Gaensler
CAASTRO

The supernova remnant W50: understanding the magnetic fields in a unique outflow-driven object

We present new radio observations of the nebula W50 (G39.7-2.0), using the Australia Telescope Compact Array (ATCA). Our understanding of this enigmatic object has previously been hindered by the large angular extent of the nebulae (2 x1 degrees), with the Western edge dipping into the Galactic plane. Such large objects are typically poorly studied due to the considerable number of separate pointings required for full imaging. The nebula is also entirely unique in that it appears to be interacting with the central compact source and first known Galactic microquasar, SS433. Our mosaiced, spectropolarimetric ATCA observations of this field are centred at 2.1 GHz, using a large bandwidth of 2 GHz. This allows us to measure the polarised fraction, rotation measure, depolarisation, and spectral index of W50's emission, and to detect diffuse linearly polarised emission which 'lights up' the large-scale ordered magnetic fields in the object. The challenge of processing such wide-field, wide-band, spectropolarimetric observations is a significant technical issue that is currently being faced by the upcoming Square Kilometre Array (SKA) pathfinders and will be faced by the SKA itself. We therefore analyse the data using techniques that are fundamental to understanding cosmic magnetism - such as Rotation Measure Synthesis - and that allow us to probe Faraday rotation along the line of sight towards W50. Through these methods it is possible to distinguish between magnetic effects arising in the nebula itself, and those arising along the line of sight in intervening Faraday screens. While W50 is typically considered to be a supernova remnant, the contribution from the initial explosion that presumably preceded formation of the compact object SS433, has not previously been convincingly distinguished from the impact of the jet and wind activity of the central system. We shall discuss how we are able to put constraints on the formation of the object through our discovery of a 'ring' of ordered magnetic fields that surrounds SS433 - consistent with field compression from a shock wave, and evidence in favour of the supernova remnant hypothesis.

---

59. Dr. Parviz Ghavamian
Towson University

The Age and Distance of the Galactic Supernova Remnant G156.2+5.7

The Galactic supernova remnant G156.2+5.7 is a prominent and large (~ 50') X-ray source which is surprisingly little understood and poorly studied. X-ray spectroscopy of non-radiative shocks in the remnant with ASCA and Suzaku revealed soft thermal X-ray emission from a thin thermal plasma of temperature ~ 0.5 keV, but with hard X-ray components consistent with synchrotron radiation. Although Sedov models of the X-ray emission have suggested an age ~ 15,000 years and a distance of 1.3 kpc for G156.2+5.7, more recent analyses have noted an apparent association between radiative shocks in the SNR and the Taurus-Auriga molecular cloud, which is located only 300 pc away. Such a distance would imply an age of only 400 years for the SNR, possibly making it a contemporary of SN 1604. To shed light on the kinematics and age of G156.2+5.7, we present spectra of the Balmer-dominated shocks in G156.2+5.7 acquired with the Blue Channel spectrograph at the 6.5m telescope of MMT observatory. The high spectral resolution and signal-to-noise of the

data allow us to detect the broad component Halpha lines, critical for determine the shock speed and degree of postshock electron-ion equilibration. The shock velocities derived from this data will enable the most accurate determination of the age, distance, SN type and explosion energy of G156.2+5.7, and will help settle whether this remnant is nearby and young, or far away and old.

---

60. Dr. Jonay Gonzalez-Hernandez
Instituto de Astrofísica de Canarias

Origin of Galactic type-Ia Supernovae

Type Ia supernovae (SNe Ia) are the best known cosmological distance indicators at high redshifts. Their use led to the discovery of the currently accelerating expansion of the universe (see e.g. Perlmutter et al. 1999). These SNe are thought to occur when a white dwarf made of carbon and oxygen accretes sufficient mass to trigger a thermonuclear explosion. The explosion could occur via accretion from a companion star (single-degenerate (SD) channel) or via merging of two white dwarfs (double-degenerate (DD) channel). Therefore, a companion star will survive the explosion only in the SD channel (see e.g. Maoz et al. 2013). Both channels might contribute to the production of type Ia supernovae but the relative proportions of their contributions remain a fundamental puzzle in astronomy. While in Type II SNe we have the advantage that the explosion leaves a compact star to which surviving companions (if they exist) often remain bound, thus enabling a large number of studies (see e.g. González Hernández et al. 2006 ApJ Letters; 2008 A&A; 2011 ApJ; 2012 ApJ Letters; 2014 MNRAS Letters), in SNe Ia the explosion almost certainly does not produce any compact object. However, the possible companion star (if it exists) would probably have peculiar properties, like a relatively large proper-motion, over-luminosity, anomalous abundances. The increase in the empirical knowledge of SNe Ia has led to an enormous advance in their cosmological use, the understanding of the explosion mechanism still requires careful evaluation (Howell 2011). One way to investigate this is by performing direct survey of the field of historical SNe Ia. Depending on the date of the SN event and the distance to the SN remnant, we are able to define the region where to find the possible companion star, close to the geometrical center of the SN remnant (see e.g. Ruiz-Lapuente 1997 Science; Ruiz-Lapuente 2014). There are only four know historical Galactic type Ia supernova events: SN 1572 (Tycho Brahe's supernova), SN 1006, SN 1604 (Kepler's supernova) and the recently identified SN 185. Our group have been investigating these Galactic historical SNIa, trying to search for the companion stars of the progenitor of historical Galactic type-Ia supernova with the aim of clarifying the origin of these cosmological candles. We have identified a very promising candidate companion for SN 1572 (see e.g. Ruiz-Lapuente et al. 2004 Nature; González Hernández et al. 2009 ApJ; Bedin et al. 2014 MNRAS) but we have not found any candidate companion for SN 1006, suggesting for the latter that the SN event occurred in 1006, the brightest stellar event ever registered in our galaxy, could have been the result of the merging of two white dwarfs (González Hernández et al. 2012 Nature). I this talk I will present the details of the work we have done so far in SN 1572 and SN 1006, and I will introduce our next target, the Johannes Kepler's SN 1604.

---

61. Prof. Bon-Chul Koo
Seoul National University

Phosphorus and Supernova Nucleosynthesis in Cassiopeia A

Phosphorus (31P), which is an indispensable ingredient for life, is mainly formed in massive (~> 8 M⨀) stars by neutron capture on silicon in hydrostatic neon-burning shells in the pre-supernova (SN) stage and also in explosive carbon and neon burning layers during SN explosion. We report on near-infrared spectroscopic observations of the young supernova remnant Cassiopeia A where we detect strong [P II] emission lines. We have obtained medium-resolution JHK (0.94-2.46 μm) long-slit spectra of eight positions around the main SN ejecta shell using the TripleSpec spectrograph mounted at the Palomar 5-m Hale telescope. By analyzing the spectra, we identified 63 knots and, for each knot, we measured the radial velocities and fluxes of emission lines from H, He, and heavy-element ions. The knots are classified into three categories based on their spectroscopic and kinematic properties: He-rich circumstellar knots, S-rich SN knots, and Fe-rich SN knots. The S-rich SN ejecta knots show [P II] lines as strong as [S II] and [Fe II] lines. We show that the abundance ratio of P to Fe in these knots is up to 100 times the average ratio of the Milky Way (1.1x10-2) and that it is compatible with predictions from SN nucleosynthetic models but not with the scenario in which the chemical elements in the inner SN layers are completely mixed by hydrodynamic instabilities during the explosion. We discuss the practical use of [P II] lines as a probe of SN nucleosynthesis.

---

62. Dr. Roland Kothes
Dominion Radio Astrophysical Observatory

A Thorough Investigation of Distance and Age of the PWN 3C58 (SN1181?)

A growing number of astronomers present evidence that the pulsar wind nebula 3C58 is much older than predicted by its proposed connection to the historical supernova of A.D. 1181. I have derived a new more reliable distance estimate of 2 kpc for 3C 58. Based on this new distance I re-evaluate evidence presented in the literature against the historical connection between 3C58 and the Guest Star of A.D. 1181. I show that the new distance changes some of the PWN's characteristics quite dramatically. This leads once more to a higher probability for its historical connection.

---

63. Dr. Margarita Rosado
Universidad Nacional Autónoma de México, Instituto de Astronomía

A kinematical catalogue of HII regions and superbubbles in the Large Magellanic Cloud.

We report the results of a kinematical Hα survey of the Large Magellanic Cloud presented in the form of a kinematical and photometrical catalogue of 210 HII regions in the LMC and the radial velocity field of the ionized Hydrogen in this galaxy. These data were obtained aimed at

understanding the LMC HII regions, bubbles and superbubbles in a global (galactic) scale so that we could have a 3D view of the LMC HII regions and can separate its rotation due to gravitational potential from other motions such as expansions. As a first result we find a bimodal distribution of the radial velocities of the catalogued HII regions in agreement with the proposed two large-scale components derived from the HI work of Luks & Rohlfs (1992) and from stellar kinematics studies.

---

64. Dr. Nozomu Tominaga
Konan University

Distribution of ejected iron masses and remant masses in the early universe

We derive the supernova properties in the early universe from the elemental abundances of extremely metal-poor stars by abundance profiling. The extremely metal-poor stars record the abundance ratios of elements produced from population III supernovae. The observations of the increasing number of extremely metal-poor stars have made it possible to statistically constrain the explosion properties of population III supernovae, in particular the distribution of ejected iron masses and remant masses. The distribution of the ejected Fe mass of population III supernovae has the same peak as that of the present day supernovae but shows an extended tail down to \sim10^{-2}-10^{-5}M_sun. The discrepancy in the fractions could stem from the observational bias in the nearby Universe due to the dimness of faint Type Ibc SNe and the bias that the extremely metal-poor stars are enriched from SNe of more massive stars that in the nearby Universe. On the other hand, although it is difficult to constrain the remnant masses from the observations of nearby SNe because of the uncertainty in the fallback mass, the distribution of the mass of the compact remnant of population III supernovae is as wide as that of the present day stellar-mass black holes which is constrained from the observations of X-ray binary systems. This is a unique method clarifying the difference between the explosion properties in the early Universe and in the nearby Universe.

---

65. Mr. Danny Tsebrenko
Technion, Israel

Type Ia Supernovae inside Planetary Nebulae

Using 3D numerical hydrodynamical simulations, we show that jets launched prior to Type Ia supernova (SN Ia) explosion in the core-degenerate (CD) scenario can account for the appearance of two opposite lobes ('Ears') along the symmetry axis of the SN remnant (SNR). In the double-degenerate (DD) and CD scenarios the merger of the two degenerate compact objects is very likely to lead to the formation of an accretion disc, that might launch two opposite jets. In the CD scenario, these jets interact with the envelope ejected during the preceding common envelope phase. If explosion occurs shortly after the merger process, the exploding gas and the jets will collide with the ejected nebula, leading to SNR with axisymmetric components including 'Ears'. We also explore the possibility that the jets are launched by the companion white dwarf prior to its merger with the core. This last process is similar to the one where jets are launched in some pre-planetary nebulae. The SNR 'Ears' in this case are formed by a spherical SN Ia explosion inside an elliptical planetary nebula-like object. We compare our numerical results with two SNRs – Kepler and G1.9+0.3

Topic 7: Future Instruments and Techniques

66. Dr. Assaf Horesh
Weizmann institute of science

Exploring the dynamical radio sky

The field of time domain is going through a revolution. Not only that the current large optical transient surveys allow the discovery of a plethora of supernovae, but an increasing number of supernovae are discovered at a young age, a few hours to a day after explosion. Combined with the new capabilities of radio observatories such as the Jansky Very Large Array, this enables a comprehensive pan-wavelength study of supernovae at an early stage. I will review results from radio observations of supernovae in the last few years. In short, through our campaign, we were able to rule out a subset of type Ia supernova progenitors, learn about the microphysical parameters of type IIb supernova shockwaves and discover a fast evolving radio supernova. These latest results bode well for future studies of young supernovae.

---

67. Dr. Atish Kamble
Harvard-Smithsonian Center for Astrophysics

Radio Supernovae in the Local Universe and the next Galactic Supernova

In the last three decades, about 50 radio supernovae (SNe) have been detected as against over 6000 in the optical. Despite this relatively small number a rich diversity among them has already been identified which is an indication of the underlying bounty of radio SNe waiting to be discovered. With the advent of sensitive, wide-field instruments operating at radio frequencies (EVLA, ASKAP, Apertif, MeerKAT etc. and ultimately the SKA) the SN research is on the brink of revolution where several tens of SN could potentially be discovered annually in an unbiased way. This presents an unprecedented opportunity for new discoveries as well as for improving our fundamental understanding of the SNe, their environments, progenitors and central engines. Besides, radio SNe contribute uniquely to our knowledge of fundamental physics, for instance, in terms of particle acceleration and energy equipartition. We will summarize our current state of knowledge about radio emission in various types of SNe and leverage it to propose strategies for maximizing radio SNe detections and scientific returns. It is astonishing that not one Galactic SN has been discovered ever since Galileo turned the telescope to the sky. The culprit responsible for blocking our views in the Galactic plane is the dust. This, however, is no hindrance to the radio waves which travel through it practically unscathed. By modelling observability across the electromagnetic band, we show that the next electromagnetic discovery of a Galactic SN will most likely be through its radio emission. And, in terms of the wealth of information to unravel, it will be a watershed event just as SN 1987A was.

---

68. Prof. Jeremy Mould
Swinburne

Observing High Redshift Supernovae

What is the highest redshift type Ia supernova imaginable? Were the supernovae of Population III physically different from those we observe today? These are questions that require widefield infrared surveys. For massive star supernovae the spectral energy distribution peak transits the K band window in the epoch of reionization. The Kunlun Infrared Sky Survey is a 2 micron sky survey from Dome A, Antarctica with an 85 cm telescope designed and built by the Nanjing Institute of Astronomical Optics & Technology. It is a precursor for the 2.5-m Kunlun Dark Universe Survey Telescope, whose limiting survey magnitude will be competitive with the Euclid and WFIRST space missions of the next decade. Our current high z supernova search is DECamERoN, the Dark Energy Camera Epoch of Reionization survey, which takes advantage of the high sensitivity of DECam at 1 micron. DECamERoN's goal is AB = 25 mag in grizY with deeper cuts at gr over a 10 sq degree area. It is a complementary project to OzDES and SUDSS.

Topic 8: Surveys/Cosmology

69. Dr. Chris Lidman
AAO

OzDES

OzDES is a five-year program using 2dF and AAOmega to target the ten deep fields of the Dark Energy Survey. In addition to using thousands of Type Ia supernovae to constrain the evolution in the dark energy equation-of-state parameter, OzDES will measure the growth of supermassive black holes over the last 12 billion years.

---

70. Dr. Santiago Gonzalez
Universidad de Chile

Type Ia cosmology with CMAGIC

Type Ia supernovae (SNe Ia) have been successfully used as standardizable distance indicators for cosmology providing primary evidence for the accelerated expansion of the universe. Traditional SN Ia standardization methods use the known relations between lightcurve-shape and brightness, as well as color and brightness, to correct for peak luminosity and reduce the intrinsic luminosity scatter. We present here a method based on post-maximum color-magnitude relations (CMAGIC, Wang et al. 2003, Conley et al. 2006), which reveal a linear regime where the luminosity scatter is small and the effects of host extinction by dust are less important. We apply this technique to a mutli-redshift dataset from the literature and obtain first Hubble diagrams.

---

71. Dr. Or Graur
New York University

Results from 3 Multi-Cycle Hubble Space Telescope Supernova Surveys: CLASH, CANDELS, and the Frontier Fields

I will present the results of high-redshift supernova surveys that have been conducted as part of three multi-cycle treasury Hubble Space Telescope programs. The first two - CLASH and CANDELS - are complete, while the third - the Frontier Fields - is ongoing. I will present the Type Ia supernova rates measured by these surveys and discuss what these rates (which, for the first time, are probing Type Ia supernovae beyond redshift 2) tell us about the progenitor stellar systems of Type Ia supernovae. I will also present three strongly-lensed supernovae that were discovered behind three of the CLASH galaxy clusters and show how they can be used to probe the distribution of dark matter in the clusters. Finally, I will show first results from the ongoing Frontier Fields Supernova Survey.

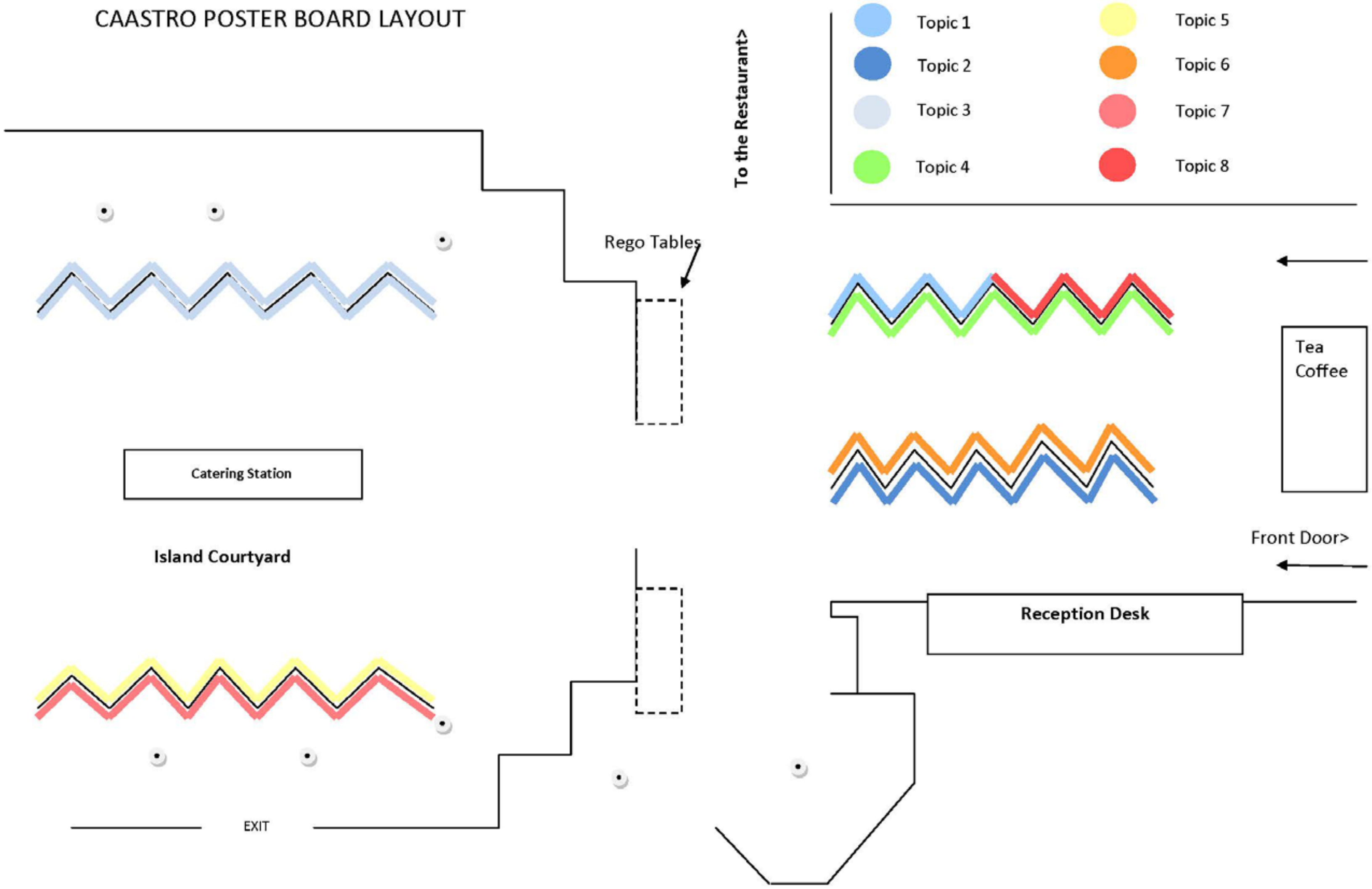
---

72. Ms. Bonnie Zhang
Australian National University

SkyMapper Supernova Search

SkyMapper is a 1.3m wide-field robotic optical telescope located at Siding Spring Observatory in Australia, dedicated to carrying out a 6-filter digital survey of the southern sky. Alongside the main survey, the telescope will carry out a supernova search that aims to obtain high-quality type Ia supernova light curves for cosmology, constraining both cosmic expansion and peculiar velocities. Over the next five years, SkyMapper will provide a low-redshift ($z < 0.1$) sample of approximately 500 type Ia supernovae to complement the Dark Energy Survey sample at $0.2 < z < 1.2$. We aim to utilise the overlap of DES and SkyMapper fields to obtain millimag-level calibration, which combined with the unprecedentedly large sample size will result in much tighter cosmological constraints.

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A



Poster Abstracts

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

Title	Given Name	Family Name	Institution	Country	Email
Dr.	Joseph	Anderson	ESO Chile	Chile	janderso@eso.org
Dr.	Iair	Arcavi	LCOGT and KITP, UC Santa Barbara	United States	arcavi@gmail.com
Prof.	Carles	Badenes	University of Pittsburgh	United States	badenes@pitt.edu
Ms.	Stephanie	Bernard	University of Melbourne	Australia	sbernard@student.unimelb.edu.au
Dr.	Melina	Bersten	Kavli IPMU	Japan	melina.bersten@ipmu.jp
Ms.	Antonia	Bevan	UCL	United Kingdom	antonia.bevan@googlemail.com
Dr.	Frederica	Bianco	New York University	United States	fb55@nyu.edu
Dr.	Michael	Bietenholz	Hartebeesthoek Radio Astronomy Observatory	South Africa	michael@hartrao.ac.za
Ms.	Nadejda	Blagorodnova	Institute of Astronomy	United Kingdom	nblago@ast.cam.ac.uk
Dr.	Alceste	Bonanos		Greece	bonanos@noa.gr
Dr.	Kazimierz	Borkowski	North Carolina State University	United States	kborkow@ncsu.edu

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

Mr.	Subhash	Bose	Aryabhatta Research Institute of observational Sciences (ARIES)	India	email@subhashbose.com
Mr.	Peter	Brown	Texas A&M	United States	pbrown@physics.tamu.edu
Prof.	David	Burrows	Penn State University	United States	burrows@astro.psu.edu
Dr.	Russell	Cannon	AAO	Australia	rdc@aao.gov.au
Dr.	Daniel	Castro	MIT	United States	castro@mit.edu
Dr.	Michael	Childress	Australian National University	Australia	michael.childress@anu.edu.au
Prof.	You-Hua	Chu	University of Illinois	United States	yhchu@illinois.edu
Prof.	Paul	Crowther	University of Sheffield	United Kingdom	Paul.Crowther@sheffield.ac.uk
Dr.	Ben	Davies	Liverpool John Moores University	United Kingdom	b.davies@ljmu.ac.uk
Dr.	Selma	de Mink		Australia	demink@obs.carnegiescience.edu
Dr.	Antonio	de Ugarte Postigo	IAA-CSIC	Spain	adeugartepostigo@gmail.com
Mr.	Georgios	Dimitriadis	University of Southampton	United Kingdom	G.Dimitriadis@soton.ac.uk
Mr.	Baha	Dincel	Astrophysical Institute and University Observatory Jena	Germany	baha.dincel@uni-jena.de

Ms.	Maria	Drout	Harvard University	United States	mdrout@cfa.harvard.edu
Dr.	John	Eldridge	University of Auckland	New Zealand	j.eldridge@auckland.ac.nz
Mr.	Robert	Evans		Australia	bobevans@exemail.com.au
Mr.	Robert	Firth	University of Southampton	United Kingdom	ref1g12@soton.ac.uk
Dr.	Thierry	Foglizzo	CEA-Saclay	France	foglizzo@cea.fr
Dr.	Gaston	Folatelli	Kavli IPMU	Japan	gaston.folatelli@ipmu.jp
Prof.	Ryan	Foley	University of Illinois	United States	rfoley@illinois.edu
Dr.	Ori	Fox	University of California, Berkeley	United States	ofox@berkeley.edu
Dr.	Kari	Frank	Penn State	United States	kafrank@psu.edu
Dr.	Claes	Fransson	Oskar Klein Center, Stockholm University	Sweden	claes@astro.su.se
Dr.	Morgan	Fraser	Institute of Astronomy, University of Cambridge	United Kingdom	mf@ast.cam.ac.uk
Mr.	Christopher	Frohmaier	University of Southampton	United Kingdom	cf5g09@soton.ac.uk
Prof.	Bryan	Gaensler	CAASTRO	Australia	bryan.gaensler@sydney.edu.au

Dr.	Lluis	Galbany	DAS U. Chile	Chile	lgalbany@das.uchile.cl
Prof.	Avishay	Gal-Yam	Weizmann Institute of Science	Israel	avishay.gal-yam@weizmann.ac.il
Dr.	Parviz	Ghavamian	Towson University	Australia	pghavamian@towson.edu
Mr.	Avishai	Gilkis	Technion	Israel	agilkis@tx.technion.ac.il
Dr.	Haley	Gomez	Cardiff University	United Kingdom	haley.gomez@astro.cf.uk
Dr.	Santiago	Gonzalez	Universidad de Chile	Chile	gongsale@gmail.com
Dr.	Jonay	Gonzalez-Hernandez	Instituto de Astrofísica de Canarias	Spain	jonay@iac.es
Ms.	Sarah	Gossan	California Institute of Technology	United States	sarah.gossan@tapir.caltech.edu
Dr.	Melissa	Graham	University of California, Berkeley	United States	melissagraham@berkeley.edu
Dr.	Or	Graur	New York University	United States	orgraur@nyu.edu
Ms.	Kate	Gunn	CAASTRO	Australia	kate.gunn@sydney.edu.au
Prof.	D. John	Hillier	University of Pittsburgh	United States	hillier@pitt.edu
Dr.	Assaf	Horesh	Weizmann institute of science	Israel	horesh@gmail.com

Prof.	Andy	Howell	Las Cumbres Observatory / University of California, Santa Barbara	United States	ahowell@lcogt.net
Dr.	Yi Chi Eric	Hsiao	Aarhus University/Las Campanas Observatory	Denmark	yichi.hsiao@gmail.com
Dr.	Anders	Jerkstrand	Queen's University Belfast	United Kingdom	a.jerkstrand@qub.ac.uk
Dr.	Atish	Kamble	Harvard-Smithsonian Center for Astrophysics	United States	akamble@cfa.harvard.edu
Dr.	Patrick	Kelly	University of California, Berkeley	United States	pkelly@astro.berkeley.edu
Dr.	Wolfgang	Kerzendorf		Canada	wkerzendorf@gmail.com
Ms.	Hyun-Jeong	Kim	Seoul National University	South Korea	hjkim@astro.snu.ac.kr
Prof.	Robert	Kirshner	Harvard University	United States	kirshner@cfa.harvard.edu
Ms.	Io	Kleiser	California Institute of Technology	United States	ikleiser@caltech.edu
Prof.	Bon-Chul	Koo	Seoul National University	South Korea	koo@astro.snu.ac.kr
Dr.	Roland	Kothes	Dominion Radio Astrophysical Observatory	Canada	roland.kothes@nrc-cnrc.gc.ca

Dr.	Alexandra	Kozyreva		Germany	sasha.kozyreva@gmail.com
Dr.	Hanindyo	Kuncarayakti	Millennium Institute of Astrophysics	Chile	hanin@das.uchile.cl
Dr.	Josefin	Larsson	Royal Institute of Technology & OKC	Sweden	josla@kth.se
Dr.	Paul	Lasky	University of Melbourne	Australia	paul.lasky@unimelb.edu.au
Mr.	Naveh	Levanon	Technion, Israel	Israel	naveh.levanon@gmail.com
Dr.	Emily	Levesque	University of Colorado at Boulder	United States	Emily.Levesque@colorado.edu
Dr.	Chris	Lidman	AAO	Australia	clidman@aao.gov.au
Mr.	Sergey	Lisakov	Observatoire de la Côte d'Azur	France	lisakov57@gmail.com
Ms.	Yuqian	Liu	New York University	United States	yl1260@nyu.edu
Ms.	Ragnhild	Lunnan	Harvard University	United States	rlunnan@cfa.harvard.edu
Dr.	Joe	Lyman	University of Warwick	United Kingdom	J.D.Lyman@warwick.ac.uk
Dr.	Kate	Maguire	ESO	Germany	kate.maguire@eso.org

Dr.	Dick	Manchester	CSIRO	Australia	dick.manchester@csiro.au
Dr.	Mario	Manuel	University of Michigan	United States	mmanuel@umich.edu
Dr.	Raffaella	Margutti	Harvard University- Institute for Theory and Computation	Australia	rmargutti@cfa.harvard.edu
Dr.	Jon	Mauerhan	University of California Berkeley	United States	mauerhan@astro.berkeley.edu
Mr.	Richard	McCray	U. California Berkeley	United States	mccrayr@me.com
Dr.	Curtis	McCully	Rutgers, The State University of New Jersey	United States	cmccully@physics.rutgers.edu
Prof.	Don	Melrose	The University of Sydney	Australia	melrose@physics.usyd.edu.au
Ms.	Athira	Menon	Monash University, Melbourne	Australia	athira.menon@monash.edu
Dr.	Attila	Meszaros	Charles University	Czech Republic	meszaros@cesnet.cz
Ms.	Katia	Migotto	Department of Astronomy, Stockholm University	Sweden	katia.migotto@astro.su.se
Prof.	Maryam	Modjaz	New York University	United States	mmodjaz@nyu.edu
Dr.	Takashi	Moriya	University of Bonn	Germany	moriyatk@astro.uni-bonn.de

Prof.	Jeremy	Mould	Swinburne	Australia	jmould@swin.edu.au
Dr.	Bernhard	Mueller	Monash Centre for Astrophysics, Monash University	Australia	bernhard.mueller@monash.edu
Dr.	Tara	Murphy	University of Sydney	Australia	tara@physics.usyd.edu.au
Prof.	Ken'ichi	Nomoto	Kavli IPMU, The University of Tokyo	Japan	nomoto@astron.s.u-tokyo.ac.jp
Dr.	Felipe	Olivares E.	Universidad Andrés Bello	Chile	f.olivares.e@gmail.com
Mr.	Oded	Papish	Technion	Israel	papish@tx.technion.ac.il
Dr.	Ferdinando	Patat	European Southern Observatory	Germany	fpatat@eso.org
Dr.	Dan	Patnaude		Australia	dpatnaude@cfa.harvard.edu
Dr.	Dovi	Poznanski	Tel Aviv University	Israel	dovi@tau.ac.il
Ms.	Maria	Pruzhinskaya	Sternberg astronomical institute of Lomonosov Moscow State University	Russia	pruzhinskaya@gmail.com
Dr.	Armin	Rest	STScI	United States	arest@stsci.edu
Prof.	Friedrich	Roepke	University of Wuerzburg	Germany	friedrich.roepke@astro.uni-wuerzburg.de

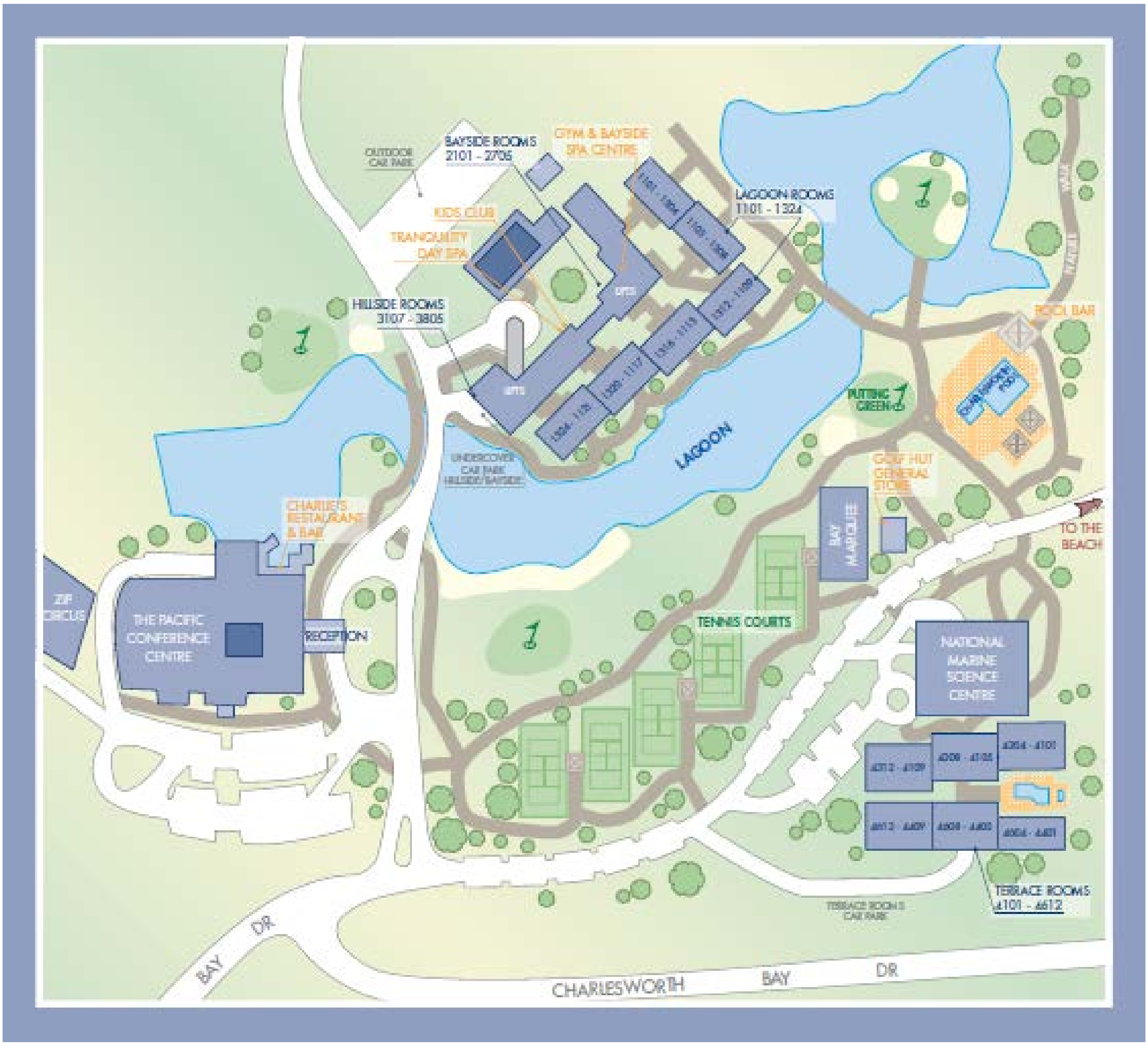
Dr.	Cristina	Romero-Canizales	Institute of Astrophysics, Pontifical Catholic University of Chile	Chile	cromero@astro.puc.cl
Dr.	Margarita	Rosado	Universidad Nacional Autónoma de México, Instituto de Astronomía	Mexico	margarit@astro.unam.mx
Dr.	Ashley	Ruiter	RSAA Mount Stromlo Observatory, ANU	Australia	ashley.ruiter@anu.edu.au
Dr.	Stuart	Ryder	AAO	Australia	sdr@aao.gov.au
Mr.	Richard	Scalzo	Australian National University	Australia	richard.scalzo@anu.edu.au
Prof.	Brian	Schmidt	ANU	Australia	denise.sturgess@anu.edu.au
Prof.	Kate	Scholberg	Duke University	United States	schol@phy.duke.edu
Dr.	Steve	Schulze	Institute for Astrophysics, Pontificia Universidad Católica de Chile	Chile	sschulze@astro.puc.cl
Dr.	Ivo	Seitenzahl	ANU	Australia	ivo.seitenzahl@anu.edu.au
Dr.	Ken	Shen	UC Berkeley	United States	kenshen@astro.berkeley.edu

Mr.	Isaac	Shivvers	UC Berkeley	United States	ishivvers@berkeley.edu
Dr.	Jeffrey	Silverman	University of TX at Austin	United States	jsilverman@astro.as.utexas.edu
Dr.	Stuart	Sim		United Kingdom	s.sim@qub.ac.uk
Prof.	Stephen	Smartt			
Dr.	Nathan	Smith	University of Arizona	United States	nathans@as.arizona.edu
Prof.	Noam	Soker	Technion	Israel	soker@physics.technion.ac.il
Dr.	George	Sonneborn	NASA Goddard Space Flight Center	United States	george.sonneborn@nasa.gov
Prof.	Lister	Staveley-Smith	UWA	Australia	lister.staveley-smith@uwa.edu.au
Dr.	Hyun-Il	Sung	Korea Astronomy & Space science Institute (KASI)	South Korea	hisung@kasi.re.kr
Dr.	Firoza	Sutaria	Indian Institute of Astrophysics	India	fsutaria@iiap.res.in
Dr.	Akihiro	Suzuki	Kyoto University	Japan	asuzuki@kusastro.kyoto-u.ac.jp
Dr.	Péter	Székely	University of Szeged	Hungary	pierre@physx.u-szeged.hu
Dr.	Katalin	Takats	Universidad Andres Bello	Chile	ktakats@gmail.com
Dr.	Tea	Temim		United States	tea.temim@nasa.gov

Mr.	Giacomo	Terreran	INAF-OAPd, QUB	Italy	giacomo.terreran@oapd.inaf.it
Dr.	Christina	Thöne	IAA - CSIC	Spain	cthoene@iaa.es
Dr.	Nozomu	Tominaga	Konan University	Japan	tominaga@konan-u.ac.jp
Mr.	Danny	Tsebrenko	Technion, Israel	Israel	ddtt@tx.technion.ac.il
Dr.	Brad	Tucker	ANU / UC Berkeley	Australia	brad@mso.anu.edu.au
Dr.	Hideyuki	Umeda	University of Tokyo	Japan	umeda@astron.s.u-tokyo.ac.jp
Dr.	Schuyler	Van Dyk	Caltech	United States	vandyk@ipac.caltech.edu
Prof.	Marten	van Kerkwijk	University of Toronto	Canada	mhvk@astro.utoronto.ca
Dr.	Alkiviadis	Vlasis	Observatoire de la Cote d'Azur	France	Vlasis.Alkiviadis@oca.eu
Dr.	Roger	Wesson	European Southern Observatory	Chile	rwesson@star.ucl.ac.uk
Dr.	Brian	Williams	NASA Goddard Space Flight Center	United States	brian.j.williams@nasa.gov
Ms.	Kylie	Williams	CAASTRO	Australia	k.williams@physics.usyd.edu.au
Mr.	Naveen	Yadav	Tata Institute Of Fundamental Research	India	naveen.phys@gmail.com
Prof.	Sung-Chul	Yoon	Seoul National University	South Korea	yoon@astro.snu.ac.kr

Dr.	Fang	Yuan		Australia	fang.yuan@anu.edu.au
Ms.	Giovanna	Zanardo		Australia	giovanna.zanardo@gmail.com
Ms.	Bonnie	Zhang	Australian National University	Australia	bonnie.zhang@anu.edu.au

RESORT PLAN


OUTDOOR CAR PARK
BAYSIDE ROOMS 2101 - 2706
GYM & BAYSIDE SPA CENTRE
KIDS CLUB
TRANQUILITY DAY SPA
LAGOON ROOMS 1101 - 1324
HILLSIDE ROOMS 3107 - 3805
LIFTS
LAGOON
UNDERCOVER CAR PARK HILLSIDE/BAYSIDE
PUTTING GREEN
POOL BAR
GOLF HUT GENERAL STORE
CHARLIE'S RESTAURANT & BAR
BAY MARQUEE
TO THE BEACH
ZIP CIRCUS
THE PACIFIC CONFERENCE CENTRE
RECEPTION
TENNIS COURTS
NATIONAL MARINE SCIENCE CENTRE
TERRACE ROOMS 4101 - 4612
TERRACE ROOMS CAR PARK
BAY DR
CHARLESWORTH BAY DR


RESORT MAP
Pacific Bay Resort
COFFS HARBOUR
and
The Bay Golf Course
Wyndham Time Share
CARPARK
VILLAGE CENTRE
CARPARK
GENERAL STORE & GOLF SHOP
PARKING
BAY DRIVE
CHARLESWORTH BAY DRIVE
PACIFIC HIGHWAY
① RECEPTION
② CHARLIE'S RESTAURANT AND BAR
③ TERRACE POOL AND SPA
④ NATIONAL MARINE SCIENCE CENTRE
⑤ CONFERENCE CENTRE
⑥ TERRACE ROOMS
⑦ BAYSIDE SPA CENTRE & GYM
⑧ GOLF SHOP and RESORT STORE
⑨ CHARLESWORTH POOL AND BAR
⑩ DOLFI KIDS CLUB
⑪ LAGOON ROOMS
⑫ BAYSIDE ROOMS
⑬ HILLSIDE ROOMS
⑭ CHILDREN'S PLAYGROUND
⑮ HILLSIDE POOL
⑯ TRANQUILITY DAY SPA & HAIR STUDIO
⑰ DAVID CONNERS WALKING TRAIL (START)
⑱ TENNIS COURTS
⑲ ZIP CIRCUS

Supernovae in the Local Universe: Celebrating 10,000 days of Supernova 1987A

Social Program

Day 1: Sunday 10th

3pm Registration Desk opens
Jetty Harbour Room

5pm Welcome Drinks
Charlie's Decks

Day 2: Monday 11th

6:30 am **Early Morning Walk: Charlesworth Bay to Korora Bay**
** There is NO cost for this activity
Enjoy an early morning walk along this picturesque coast line
Note: please remember to wear warm clothing – it will still be quite cold as it is winter.

Day 3: Tuesday 12th

6:30am **6:30am** **Beach Volley Ball**
** There is NO cost for this activity
Note: please remember to wear warm clothing – it will still be quite cold as it is winter.

Day 4: Wednesday 13th

6:30am **Tennis**

** There is NO cost for this activity

Novotel Pacific Bay Resort, Tennis courts

Enjoy a friendly game of non-competitive tennis to start the day

Note: please remember to wear warm clothing – it will still be quite cold as it is winter.

2:00pm **Option 1: Tour the Big Banana**

***** There is an additional cost for this activity***

Learn everything you ever wanted to know about bananas on the interesting and interactive tour. Followed by the opportunity to purchase some truly amazing memorabilia to remember your trip to Australia.

2:00pm **Option 2: Golf**

***** There is an additional cost for this activity***

Enjoy the Resort's 9 hole, par 3 golf course

2:30pm **Option 3: Muttonbird Island Walk/CBD Visit**
***** There is an additional cost for this activity***

Muttonbird Island, also known as Giidany Miirlarl, is a precious seabird rookery in Coffs Harbour's heart. It boasts spectacular views from coast to islands.

Muttonbird Island is a great spot for watching birds up close; it's one of the only easily-accessible places in NSW where the migratory wedge-tailed shearwater nests. It is also an important Aboriginal place, harbouring stories of the Dreaming and a wealth of traditional resources.

It's a great place to take a short walk, and the unforgettable views will be well worth your effort. The best way to find out more about the Aboriginal stories of Muttonbird is on an award-winning guided Discovery tour conducted by local Gumbaynggirr rangers.

There will also be time to visit the city centre for some shopping and exploring.

Day 5: Thursday 14th

6:30am **Early Morning Beach Walk**

** There is NO cost for this activity

Enjoy an early morning walk along this picturesque coast line

Note: please remember to wear warm clothing – it will still be quite cold as it is winter.

Day 6: Friday 19th

7:00am **Pilates**

** There is NO cost for this activity

Note: please remember to wear warm clothing – it will still be quite cold as it is winter.