Excellence Cluster Universe

MIAPP Munich Institute for Astro- and Particle Physics

2-26, May 2017

Superluminous Supernovae in the Next Decade

- ABSTRACTS -

WEEK 1 Tuesday, May 2

Stephen Smartt

Progenitors - Review of the constraints

I will review the various constraints we now have on the progenitor stars of SLSNe. They are mostly H and He free and likely to be massive carbon oxygen cores. There are now a range of ejecta masses and core mass estimates from light curve and nebular spectral modelling. We know that many, if not all, have strong shock breakout signatures, which implies an extended envelope of material around the compact carbon-oxygen core. They appear to be exclusively produced in low metallicity galaxies, and are approximately 1 in 10,000 core-collapse events by volume. Their light curves are rather homogeneous, although the explosions may be asymmetric as judged by the one polarisation result. This talk will review the evidence as a whole, drawing from the results presented in the literature to date and try to sketch the structure of the progenitor stars.

Alessandro Chieffi

The evolution of massive stars as a function of mass, metallicity and initial rotational velocity

I will discuss the key properties of our latest set of massive stars extending in mass between 13 and 120 Msun, in metallicity between [Fe/H] = −3 and [Fe/H] = 0 and for three initial rotational velocities, 0, 150 and 300 km/s. This is the more complete set of models presently available in the community. All the models were followed from the pre main sequence up to final collapse. Rotating models have been computed by taking into account two instabilities connected with rotation, namely meridional circulation and shear. I will briefly discuss them. I will also briefly comment on the calibration of the free parameters that enter in the determination of both the transport of the angular momentum and the chemicals. Several sets of explosive burnings were determined for different calibrations of the explosion: set F was computed by imposing that all stars eject 0.07 Msun of ^{56}Ni, set M considers the mixing and fall back plus a mass cut imposed again by requiring the ejection of 0.07 Msun of ^{56}Ni, while set R was computed as set M but assuming that all stars more massive 25 Msun fully collapse in a remnant returning to the interstellar medium only the wind. Rotation lowers the minimum mass that becomes a WR star from 20 to 13 Msun at solar metallicity while at [Fe/H] = −1 such a minimum mass drops from 80 to 30 Msun (for vini = 300 km/s). Also the supernova type is strongly affected by rotation. Without rotation, at subsolar metallicities basically all stars show up as Type IIP supernovae while most of the rotating models of M > 30 or so show up as Type Ib supernovae. I will discuss this point in some detail. As far as the yields are concerned, rotating models DO produce a large amount of N, F and s-process nuclei due to the interplay between the central He burning and the H burning shell. At low metallicities also nuclei of the strong component (Like Ba, Cs, La) and even Pb are produced in large amount for vini = 300 km/s. Some of the most massive models actually enter in the pair instability regime. Though we cannot compute such a dynamical phase, I will try to make some general consideration about the yields that one can expect from the explosion of these very massive stars.

WEEK 1 Wednesday, May 3

Peter Brown

Comparing superluminous supernovae in the ultraviolet across the history of the Universe

The redshifting of light makes observations at different wavelengths necessary to compare objects in the same rest-frame energies. Ultraviolet observations of nearby superluminous supernovae can be compared with optical, near-infrared, and infrared observations of supernovae at increasingly higher redshifts. I will discuss a framework for comparing the spectral energy distributions of these objects even when the rest-frame wavelengths do not cleanly match up. These spectral energy distributions can also be used to predict the detectability of superluminous and other types of supernovae as a function of redshift, observer-frame band, and depth.

Avishay Gal-Yam

Spectroscopy of Type I superluminous supernovae and possible relations to other stripped supernovae

I will briefly review the spectroscopic evolution of Type I (H poor) superluminous supernovae (SLSNe-I). I will then review recent attempts to model the spectra at various phases in the optical and UV range. I will present a method to simple understand spectra of SLSNe-I at early phases, that is based on minimal assumptions, and is consistent with more complex numerical methods. I will discuss the implications from recent analysis on the progenitors of SLSNe-I and on possible explosion models. Finally, I will try to relate these results to early spectra of other types of stripped supernovae.

WEEK 1 Thursday, May 4

Peter Hoeflich

An alternative model for superluminous thermonuclear explosions

Bright thermonuclear supernovae are commonly attributed to merging of two massive WDs, which may produce ^{56}Ni masses well in excess of 1.3 Mo, which is well in excess of even detonation models of sub-, and M(Ch) with its production of up to 0.9 Mo. However, the merger scenario may be at odds with the low continuum polarization observed in several objects. As alternative model, we suggest a modified core-degenerate scenario similar to (Yoon 2008, Raskin et al. 2010, Ilkov & Soker, 2013), in which a detonation is triggered. The simulations of the setup are based on Mesa, and the non-LTE LCs and spectra are calculated using our code HYDRA including molecule formation. The resulting LCs show a very slow rise and decline with a continuum from superluminous to normal-bright SNe Ia, and spectra with expansion velocities similar to very subluminous SN1991bg-like objects but narrow Si/S layers and a low UV flux. This class of models would predict superluminous SNe Ia to fill a continuum from normal bright to superluminous SNe Ia. We will discuss the underlying physics of the LC and spectral formation, the 'knobs and wiggles' and its current limits and challenges.

Takashi Moriya

How magnetars can make 'SLSN–R' / How can magnetars mimic the ^{56}Ni decay?

Many slowly declining SLSNe have decline rates that are consistent with the ^{56}Co decay, leading to a model that they are powered by ^{56}Ni. However, ^{56}Ni models are not often preferred in terms of spectral properties. I discuss what kind of magnetar properties are required to make slowly declining SLSNe by magnetars and constrain magnetar properties possibly powering these SLSNe.

WEEK 1 Friday, May 5

Lin Yan

CSM around SLSNe–I: H–poor SLSNe with late–time H–alpha emission

We present observations of two new hydrogen–poor superluminous supernovae (SLSN–I), iPTF15esb and iPTF16bad, showing late–time H–alpha emission. Including the previously published iPTF13ehe, this makes up a total of three such events to date. iPTF13ehe is one of the most luminous and the slowest evolving SLSNe–I, whereas the other two are less luminous and fast decliners. The H–alpha lines are as luminous as 1–3 x 10^{41} erg s^{-1} with FWHM widths of 4000–6000 km s^{-1}. We interpret this as a result of the ejecta running into a neutral H–shell located at a radius of several times 10^{16} cm. This implies that an episode of violent mass loss must have occurred several decades before the supernova explosion. Such a short time interval suggests that eruptive mass loss could be common prior to the death of a massive star as a SLSN. This also implies that helium is unlikely to be completely stripped off the progenitor stars and could be present in the ejecta, although helium features are not detected in our data. At late times (+240 d), our spectra appear to have intrinsically lower [OI] 6300 luminosities than that of SN2015bn and SN2007bi, possibly an indication of smaller oxygen masses (< 10–30 M_solar). In addition, for all three events, the broad Halpha lines are initially blue–shifted relative to the host galaxies. This result is in tension with the binary star model proposed for iPTF13ehe. Finally, iPTF15esb has a peculiar LC with semi–periodic undulations with a time scale of 22 days, and higher amplitudes in bluer bands. One possible explanation is eject–CSM interaction. Together with late–time H–alpha emission, these observations imply the presence of both H–poor and H–rich CSM shells in iPTF15esb.

Jeff Cooke

High redshift superluminous supernova surveys

I will present an overview of three ongoing surveys searching for z > 2 superluminous supernovae (SLSNe) and highlight some of the active follow–up deep spectroscopy by presenting some z ~ 2–4 SLSN spectra taken near maximum light. These searches have been very successful in detecting a large number of z ~ 2–4 SLSNe and have the capability to detect events to z ~ 6 that can be followed up with JWST. The total number of z > 2 SLSN photometric candidates already exceeds that found at low redshift, with those having spectra potentially exceeding the number at low redshift by the launch of JWST. Because these SLSNe are detected and classified in the far–UV, and because SLSNe can be detected to z ~ 20 with JWST, there is an urgent need for low redshift programs that target far–UV SLSN light curves and spectra, as well as efforts to connect and classify z > 2 SLSNe by their restframe optical and far–UV. In addition, the data point to an immediate need for high–resolution models of their far–UV spectra.

Chris Curtin

DECam detection and Keck spectroscopy of ongoing high redshift superluminous supernovae

We have collected deep u-band imaging of a number of southern fields using the DECam at CTIO as part of the Survey Using DECam for Superluminous Supernovae (SUDSS). Using color selection, enhanced by the large wavelength range of the available data, including our deep u-band contribution, we have generated large catalogs of high redshift (z ~ 2-4) Lyman Break Galaxies (LBGs). Our LBG selection and monitoring technique enables the efficient identification of high redshift transients, namely superluminous supernovae (SLSNe). When taking spectra, we search for rising, or near peak supernova candidates (less than a few weeks old, restframe). At present, in fields with regular ongoing coverage, we can select ~10 candidates per field at short notice that meet our criteria. This is a lower limit on the detection rate, though our spectroscopic follow-up campaign will enable a measurement of the ratio of SLSNe to candidates. The deep, Keck spectra also enable SLSN classification and offer a wealth of information on the physics of the individual events. In addition, the data are useful toward determining SLSN rates at different redshifts, linking SLSN types to their far-ultraviolet light curve behaviors for both past and future photometric identification, and possibly identifying other types of superluminous, high redshift transients, such as tidal disruption events.

Janet Ting-Wan Chen

A sub-solar metallicity is required for superluminous supernova progenitors

Host galaxy properties provide strong constraints on the stellar progenitors of superluminous supernovae. By comparing a sample of 18 low-redshift superluminous supernova hosts to a volume-limited galaxy population in the local Universe, we show that sub-solar metallicities seem to be a requirement. All superluminous supernovae in hosts with high measured gas-phase metallicities are found to explode at large galactocentric radii, indicating that the metallicity at the explosion site is likely lower than the integrated host value. We also confirm that high specific star-formation rates are a feature of super-luminous supernova host galaxies, but interpret this as simply a consequence of the anti-correlation between gas-phase metallicity and specific star-formation rate and the requirement of on-going star formation to produce young, massive stars greater than ~10-20 M_solar. Based on our sample, we propose an upper limit of ~0.5 Z_solar for forming superluminous supernova progenitors (assuming an N2 metallicity diagnostic and a solar oxygen abundance of 8.69). Finally, we show that if magnetar powering is the source of the extreme luminosity then the required initial spins appear to be correlated with metallicity of the host galaxy. This correlation needs further work, but if it holds it is a powerful link between the supernova parameters and nature of the progenitor population.

Additional 5-minute presentation

The list of superluminous supernovae and their host galaxies

We have collected the most comprehensive list of superluminous supernovae and their host galaxies. The website includes basic information of SLSNe, their light curves and spectrum series, also main physical parameters of their host galaxies, such as stellar mass, star-formation rate and metallicity.

WEEK 2 Tuesday, May 9

Alexander Heger

The deaths of very massive and supermassive stars

Whereas stars with masses of more than 100 solar masses are very rare in the present universe, they may have been more common among the first generation of stars. Some scenarios exist that would even allow the formation of stars in excess of 100,000 solar masses. But how massive can stars actually get before they collapse to black holes? And what would we be able to see? I will discuss the deaths of stars in the mass range from very massive to supermassive stars, stars from 100 to beyond 100,000 solar masses. This comprises energetic supernova that may be powered by accretion onto a black hole as well as unexpected and surprisingly powerful thermonuclear explosions. The case of pulsational pair instability at the low-mass end shows that a very bright display can just be the result from efficient conversion of energy rather than vast energy.

Daniela Carollo

Supernovae and Population III surveys: SkyMapper

The SkyMapper Southern Sky Survey is a comprehensive wide-area digital survey of the entire southern sky, run from the robotic 1.3-m SkyMapper telescope at Siding Spring Observatory in Australia. Two main research goals of the survey are: 1) the search for supernovae and other transients and, 2) the search for the most metal-poor stars in the Milky Way. The supernovae search is optimized for the discovery and follow-up of low-redshift type Ia supernovae to constrain cosmic expansion and peculiar velocities (total footprint area of 2000 deg^2 with a cadence of < 5 days). The metal-poor stars candidates are identified by adopting a unique SkyMapper filter set that allows for estimation of stellar atmospheric parameters. In this talk I will briefly describe SkyMapper and I will give an overview of the supernova search activities. The state-of-the-art of extremely metal-poor stars discovery both in the halo system and in the bulge will be also summarized.

WEEK 2 Wednesday, May 10

Charlotte Angus

SLSNe within the Dark Energy Survey

The Dark Energy Survey (DES) supernova program has completed the 4 of its 5 years of observations. This multi-colour, cadenced search for high redshift supernova has already discovered over 1500 likely type Ia supernova (SNIa) candidates. With NIR light-curves, spectroscopy and deep stacks providing photometric redshifts and detailed environmental information for every transient, the DES dataset is unrivalled in its potential to study SLSNe. I will present the DES SLSN sample from the first 4 years of the survey, including the highest spectroscopically confirmed supernova at z ~ 2.

Ragnhild Lunnan

An observational view of SLSNe as pair-Instability supernovae

I will discuss PS1-14bj, the only observed SLSN with the long rise time predicted by PISN models, as well as other candidates from the literature such as SN2007bi, and I will review the general case of slowly-evolving SLSNe ('Type R') as pair-instability candidates.

WEEK 2 Thursday, May 11

Andy Fruchter

Energetics of the jets associated with GRBs and the ultra-long GRB/SLSN 2011kl

Supernova 2011kl, associated with the ultra-long gamma-ray burst (ULGRB) 111209A, exhibited a higher-than-normal peak luminosity, placing it in the parameter space between regular supernovae and super-luminous supernovae. Its light curve can only be matched by an abnormally high fraction of Ni-56 that appears inconsistent with the observed spectrum, and as a result it has been suggested that the supernova, and by extension the gamma-ray burst, are powered by the spin-down of a highly magnetised millisecond pulsar, known as a magnetar. We investigate the broadband observations of ULGRB 111209A, and find two independent measures that suggest a high density circumburst environment. However, the light curve of the GRB afterglow shows no evidence of a jet break (the steep decline that would be expected as the jet slows due to the resistance of the external medium) out to three weeks after trigger, implying a wide jet. Combined with the high isotropic energy of the burst, this implies that only a maximally rotating magnetar with a spin period of ~ 1 ms can provide enough energy to power both ULGRB 111209A and Supernova 2011kl. Interestingly, had the observations continued on for a while longer, as could have been done by Chandra, for instance, either the light curve or the magnetar model would have clearly broken.

Matt Nicholl

Fitting the multi-band light curves of SLSNe

Many SLSN studies (and SN studies in general) rely on fits to the bolometric light curves and chi^2 minimisation. Here, I present a new open-source light curve modelling code, "MOSFiT" with a number of improvements over the status quo. These include: MCMC fitting to understand error distributions; modelling the multicolour data to remove systematics between different methods of estimating the bolometric light curve, and to retain temperature information; a modular framework to 'plug and play' with different power sources and ejecta models; interacting directly with the Open Supernova Catalog to maximise the sample size and enable easy sharing of both data and models. I will also show some new results from applying this code to the current SLSN sample.

WEEK 2 Friday, May 12

Giorgos Leloudas

ASASSN-15lh

ASASSN-15lh was claimed to be the most luminous supernova ever discovered. Despite some initial similarities with the class of SLSNe I, our study showed that ASASSN-15lh is instead an extreme Tidal Disruption Event (TDE). This is mainly supported by the UV spectrum, the temperature evolution and the location/environment of the event, as well as other evidence, which are inconsistent with a SLSN but compatible with a TDE.

Luc Dessart

Radiative transfer models of SLSNe powered by a magnetar, ^{56}Ni power and interaction with circumstellar-material: Light curve and spectral properties

I will present results from radiation hydrodynamics and radiative transfer simulations for ejecta that owe their extraordinary luminosities from the injection energy by a central engine (i.e., a magnetar), from the decay power of a greater-than-average mass of ^{56}Ni, or from the interaction of an ejecta with a dense and extended CSM. I will discuss the light curve and spectroscopic signatures associated with each context, and confront the observations of super-luminous supernovae.

WEEK 3	Monday, May 15

Ragnhild Lunnan

The PS1/MDS SLSN sample

I will provide an overview of the SLSN sample from the Pan-STARRS Medium Deep Survey, which with its multi-band light curves and wide redshift range ($0.3 < z < 1.6$) offers an excellent view into the UV emission for future high-z searches. With 16 objects all from a single survey with a well defined footprint and cadence, there are interesting statistics on the properties of SLSNe as a class.

Dan Perley

Superluminous supernova host galaxies in context

The host galaxies of hydrogen-free superluminous supernovae are quite different from those of other supernovae derived from massive stars: they're smaller, have lower stellar masses, and a remarkable fraction of them are in the middle of an intense starburst episode. (The hosts of hydrogen-rich SLSN also appear to be unusual, but in ways that defy simple generalizations.) How can we quantify these differences, and how can we interpret them in a meaningful way that helps us better understand what sort of progenitor actually produces them? Currently we are faced with two major challenges in interpreting SLSN host observations. First, the dwarf-galaxy regime that (hydrogen-poor) SLSNe seem to favor is the least well studied by comparison galaxy surveys, and so comparison samples are sparse and often biased. Second, because galaxy properties often correlate (low-mass galaxies tend to have smaller sizes, greater star-formation rate densities, higher metallicities, and so on) it is not always easy to distill which specific parameter or parameters are fundamentally responsible. New observations of not only SLSNe but also of ordinary supernovae are helping to resolve these difficulties.

WEEK 3	Tuesday, May 16

Ken'ichi Nomoto

Pulsational pair-Instability models for UV bright superluminous supernovae

We have calculated many models of pulsational pair instability and associated mass ejection. Based on those results, we have calculated circumstellar interaction models for some SLSNe, and will present a new model for a UV bright SLSN.

Cosimo Inserra

Superluminous supernovae in cosmology and/or as high redshift probes

The last five years have seen the surprising discovery of new classes of ultra-bright 'superluminous' supernovae, some 100 times brighter than classical supernova types, offering new probes of the high redshift universe and the potential for a new class of standard candle. I will provide a summary of the attempts done until now trying to use them as cosmological probes. I will focus on the potential shown and the challenges that we have to face in order to understand if they can or cannot use in cosmology. In doing so, I will also present the rate of SLSNe for low redshift surveys (e.g. PTF) together with those at high redshift (e.g. Euclid). Hence, I will also focus on what dark energy surveys like DES, LSST and Euclid can give in terms of SLSN astrophysics up to high redshifts.

WEEK 3	Wednesday, May 17

Giorgos Leloudas

SLSN polarimetry (with a bit of SUSHIES)

Polarimetry is a valuable tool to probe the geometry of unresolved sources, such as SN explosions. I will present the first such studies performed on SLSNe, including LSQ14mo, SN 2015bn, PS15br and PS17bek. Constraining the geometry of these events can help determine the mechanism behind their extreme luminosity. While the first results are not conclusive, at least in the case of the nearby SN 2015bn there is a significant increase of polarisation with time, supporting a two-layered ejecta model. Finally, I will present the latest constraints on SLSNe from the study of their host galaxies, from our SUSHIES survey.

Paolo Mazzali

Extracting information from the spectra of Type Ib/c SNe (including SLSNe)

I will discuss how the spectra of SNe Ib/c (including SLSNe) can be used, in combination with radiative transfer codes, to extract physical information about the properties of the SN (masses, energetics, composition, morphology).

WEEK 3	Thursday, May 18

Chiaki Kobayashi

SLSN in galactic chemical evolution

Despite more than ten years of observational surveys, no star has been discovered that shows a signature of the enrichment from a pair-instability supernova in the Milky Way. Such a star should show high [(Si,S)/(O,Mg)] ratios. Using the same abundance fitting approach, I will present a couple of stars that may be enriched by a super-luminous supernova (SLSN). I will also discuss the contribution of SLSNe on the Galactic and cosmic chemical evolution, and the properties of the host galaxies in cosmological hydrodynamical simulations.

Anders Jerkstrand

Modelling and interpretation of nebular spectra of SLSNe

Several scenarios remain viable as explanation of SLSNe based on bolometric or blackbody light curve fitting. Progress in the next few years will likely come from spectral modelling and analysis: we need to know what these SNe consist of. The composition of emitting gas can be analyzed in the nebular phase. I describe recent work on modelling the spectral appearance of several different ejecta classes, and results of comparison of these models with observed nebular spectra, of which we now have 3 good-quality data sets (SN 2007bi, LSQ14an, and SN 2015bn). One of the main results so far is that very large oxygen masses appear to be present in the ejecta, although not distributed as in pair-instability explosions.

WEEK 3 Friday, May 19

Peter Blanchard

A search for superluminous supernovae from Pan-STARRS

The latest generation of time-domain optical surveys have led to the discovery of superluminous supernovae, but few such events are being discovered at low redshift where they can be studied in great detail in the optical, radio, and X-rays. We are undertaking a program to increase the discovery rate of these rare transients by following up carefully selected events from the Pan-STARRS Survey for Transients. We are utilizing a combination of FLWO, MMT, Magellan, and Gemini observations to classify and monitor nearby SLSNe, supplemented with radio and X-ray observations. In the first year of operation we have substantially increased the rate of discovery over previous surveys. In this talk I will highlight results from some of the interesting SLSNe that we have found.

Elena Pian

SLSNe, core-collapse SNe and GRBs: Can analogies and diversities bring us closer to the mechanisms and progenitors

I will report on some recent observational facts about core-collapse stripped-envelope SNe, H-poor SLSNe, GRBs and their afterglows that may be relevant for determining their progenitors and the relationship among these apparently different phenomena.

WEEK 4 Monday, May, 22

Dan Whalen

Superluminous supernovae and JWST

Primordial SNe could be ideal probes of the properties of the first stars because they can be detected at cosmic dawn, $z \sim 20$, and because the properties of their progenitor stars can be inferred from their light curves, since those of PISNe are very different from CC SNe LCs. Population III (Pop III) SNe and GRBs can also probe cosmic star formation rates at the earliest epochs. I will review Pop III SNe, their light curves in the NIR, and prospects for their detection by JWST, the ELTs, Euclid and WFIRST.

Jeff Cooke

Are high redshift galaxy interactions factories for very massive stars?

It is believed that some superluminous supernovae (SLSNe) and long gamma-ray bursts (LGRBs) are related. I will present evidence for an unusually high fraction of SLSN and LGRB host galaxies showing morphological and/or spectroscopic interactions with respect to typical galaxies. At least 2/3rds of $z > 2$ SLSN-I-like host galaxies show evidence for pair interaction from ground-based imaging or spectroscopy. Of the larger number of LGRB hosts with HST imaging, ~55% show close companions and/or disturbed morphology, with the remaining being too faint ($m > 27$) to determine. Interestingly, 5 LGRB afterglow spectra show 'pair' absorption. Using basic geometric arguments, the 5 pair absorbers detected in 40 LGRB host spectra imply a 50-100% close/interacting pair fraction - a lower limit due to spectral resolution of the data and the adopted pair absorber definition. All evidence points to an interaction/merger fraction of >50% (and potentially 100%). As a result, the interaction process may provide important clues on the production of massive stars at high redshift.

WEEK 4 Tuesday, May, 23

Daniela Carollo

The chemical signature of the first stars in the Milky Way halo system

The halo system of the Milky Way is a precious laboratory because it provides unique elemental abundance and kinematic information on the first objects formed in the Universe, and this information can be used to tightly constrain models of galaxy formation and evolution. In this talk I will summarize the current view of the Galactic stellar halo, its architecture (diffuse components, structures), its age structure, and the emerging chemical patterns (metallicity, CEMP stars) and the connection with first stars. Possible formation scenarios of the Galaxy based on these results will be discussed.

Jeremy Mould

The DECamERON project

An interesting transient has been detected in one of our three Dark Energy Camera deep fields. Observations of these deep fields take advantage of the high red sensitivity of DECam, a Cerro Tololo Interamerican Observatory 4m telescope instrumental development that the principal investigator has been following to fruition for over a decade. The survey includes the Y band with rest wavelength 1430 Å at $z = 6$. Survey fields (the Prime field 0555-6130, the 16hr field 1600-75 and the SUDSS New Southern Field) are deeper in Y than the VISTA and related infrared surveys. They are circumpolar, allowing all night to be used efficiently, exploiting the moon tolerance of 1-micron observations to minimize conflict with the Dark Energy Survey. As an *i*-band dropout (meaning that the flux decrement shortward of Lyman alpha is in the *i* bandpass), the transient we report here is a $z \sim 6$ supernova candidate, with a luminosity comparable to the brightest known current epoch superluminous supernova (i.e., $\sim 2 \times 10^{11}\ L_\odot$).

Melina Bersten

Hydrodynamic effect of magnetar models

Magnetars have been proposed as one of the possible sources to power the light curve of super-luminous supernovae. We have included the energy deposited by a hypothetical magnetar in our one-dimensional hydrodynamical code and analyzed the dynamical effect on the supernova ejecta. We present the LC modelling for some interesting SLSNe as e.g. SN~2011kr, the first object associated with an ultra-long-duration GRB, or ASASSN-15lh claimed to be the most luminous SN ever discovered.

Janet Ting-Wan Chen

The evolution of superluminous supernova LSQ14mo and its interacting host galaxy system

We present and analyse an extensive dataset of the superluminous supernova (SLSN) LSQ14mo (z = 0.256), consisting of a multi-colour light curve from −30 d to +70 d in the rest-frame and a series of 6 spectra from PESSTO covering −7 d to +50 d. This is among the densest spectroscopic coverage, and best-constrained rising light curve, for a fast-declining hydrogen-poor SLSN. The bolometric light curve can be reproduced with a millisecond magnetar model with ~4 M_sol ejecta mass, and the temperature and velocity evolution is also suggestive of a magnetar as the power source. Spectral modelling indicates that the SN ejected ~6 M_sol of CO-rich material with a kinetic energy of ~7 x 10^{51} erg, and suggests a partially thermalised additional source of luminosity between −2 d and +22 d. This may be due to interaction with a shell of material originating from pre-explosion mass loss. We further present a detailed analysis of the host galaxy system of LSQ14mo. PESSTO and GROND imaging show three spatially resolved bright regions, and we used the VLT and FORS2 to obtain deep (five-hour exposure) spectra of the SN position and the three star-forming regions, which are at a similar redshift. The FORS spectrum at +300 days shows no trace of SN emission lines and we place limits on the strength of [O I] from comparisons with other Ic SNe. The deep spectra provide a unique chance to investigate spatial variations in the host star-formation activity and metallicity. The specific star-formation rate is similar in all three components, as is the presence of a young stellar population. However, the position of LSQ14mo exhibits a lower metallicity, with 12 + log(O/H) = 8.2 in both the R23 and N2 scales (corresponding to ~0.3 Z_sol). We propose that the three bright regions in the host system are interacting, which thus triggers star-formation and forms young stellar populations.

WEEK 4 Thursday, May, 25

Ke-Jung Chen

Multidimensional simulations of superluminous supernovae

Recent all-sky transient searches have discovered new and unexpected explosion types that fall outside traditional SN classification schemes. These exotic outliers in many cases are due to the deaths of massive stars and therefore may have been prevalent in the primordial universe because the Pop III IMF is thought to be top-heavy. Depending on the mass of the progenitor, these outliers may be faint, magnetar-powered, pair-instability, or general relativistic instability SNe, all of which have unique observational signatures. Some of these events are superluminous, 10-100 times brighter than normal supernovae, and may produce energetic UV, X-ray, or gamma-ray bursts. Their extreme luminosities enable their detection at z > 10 and they are ideal probes of the primordial universe at cosmic dawn, prior to the advent of the first galaxies. Here, we examine these exotic explosions with state of the art 3D radiation-hydro simulations that bridge all spatial scales from the central engine to breakout into the IGM, where observational signatures can be computed. We discuss the coevolution of radiation and turbulent mixing in SN ejecta and present realistic light curves for these explosions for JWST and the coming generation of extremely large telescopes (ELTs).

Cosimo Inserra

Diversity and complexity in superluminous supernovae observables

SLSNe come in many flavours. A small group of the newly discovered SLSNe show broad and slowly evolving light curves. In these objects semi-forbidden and forbidden emission lines appear surprisingly early at 50-70 days and remain visible with almost no variation up to 400 days. The spectra remain blue out to 400 days. There are small, but discernible light curve fluctuations in all of them. The light curve of each shows a faster decline than ^{56}Co after 150 days and it further steepens after 300 days. These features are quite distinct from the faster evolving superluminous supernovae, which represent the bulk of SLSNe, and are not easily explained in terms of only a variation in ejecta mass. While a central engine is still the most likely luminosity source, it appears that the ejecta structure is complex, with multiple emitting zones and at least some interaction between the expanding ejecta and surrounding material. In addition, I will also present SLSNe showing a distinct, broad H feature during the photospheric phase with no clear sign of interaction in their early spectra. These transients show a slow decline at later times, and we detect strong, multi-component H emission after 200 days past maximum which we interpret as an indication of interaction of the ejecta with an asymmetric, clumpy circumstellar material. The spectra and photometric evolution of the objects are similar to some bright type II (or type IIL) supernovae, although they have much higher luminosity and evolve on slower timescales. This comparison is qualitatively similar to how SLSN I compare with normal Ic in that the former are brighter and evolve more slowly.

WEEK 4 Friday, May, 26

Panel

Superluminous supernovae in the next decade