Exploring SNe Lightcurves and Environments with CLASP

Joe Lyman†, David Bersier & Phil James
Astrophysics Research Institute,
Liverpool John Moores University

CLASP (Create Lightcurves with Alignment, Subtraction and Photometry) comprises two pipelines developed to automate data reduction and lightcurve creation from transient imaging, through template subtraction based on the ISIS code (Alard 2000, A&A Supp, 144, 363). With CLASP, a large catalogue of core collapse supernova (CCSN) multicolour lightcurves is being produced.

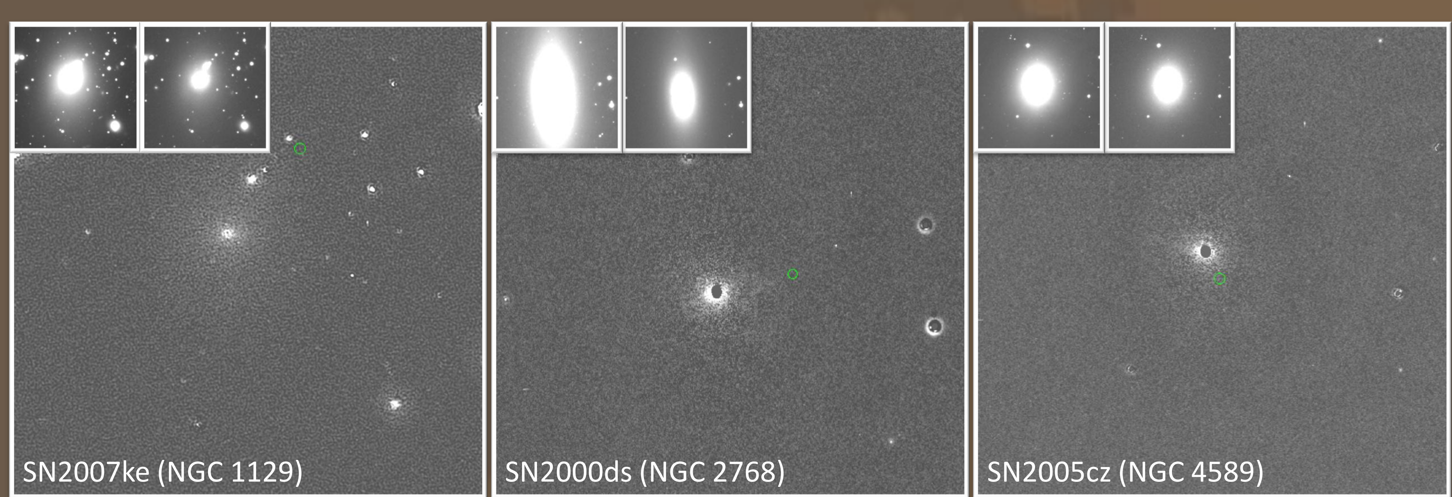
At the end of a massive (>8$M_{\odot}$) star's life, it undergoes core collapse and we observe a CCSN. Massive stars are very short lived on galaxy dynamical timescales and to a good approximation (notwithstanding runaway stars) the CCSNe is observed at the birth place of its progenitor. This makes CCSNe valuable tracers of recent star formation and probes of the upper end of the initial mass function (IMF), as they can be observed at much greater distances than we can resolve stars to directly probe the stellar population. Utilising the potential of CCSNe in this manner, however, requires knowledge of the progenitor stars and how these translate to the various CCSN types we observe. The underlying question of what the progenitors of CCSNe are across various types remains poorly understood.

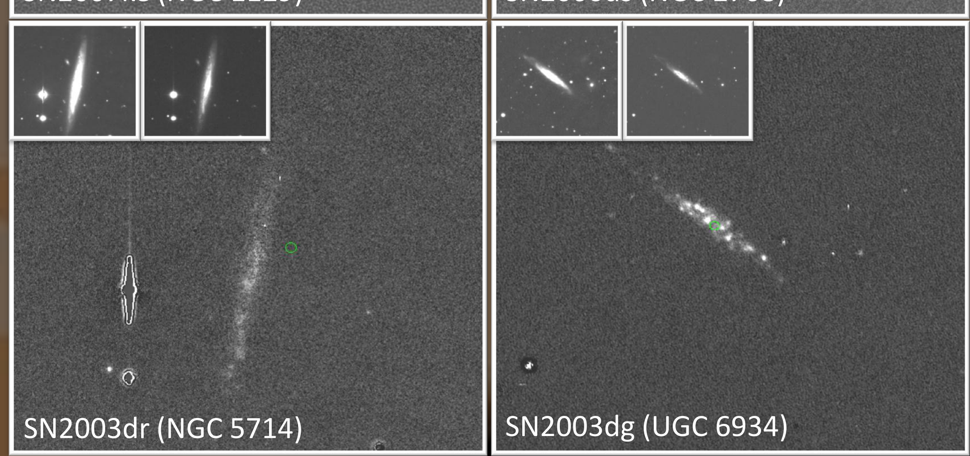
It is the aim of this study to produce a lightcurve catalogue of Palomar Transient Factory (PTF) CCSNe discoveries using the 2.0m robotic Liverpool Telescope (LT), situated on La Palma. This catalogue will provide a statistically significant sample of CCSNe lightcurves across all types, unhindered by biases introduced in other, host targeted supernovae searches. Analytical modelling of the lightcurves will discern information about their explosion to characterise the progenitors. This work will complement current and previous work of CCSNe environments following the method carried out by Anderson & James (2008, MNRAS, 390, 1527; 2009, MNRAS, 399, 559), which utilises Hα emission brightness at the location of the supernova as a proxy inferring mass/metallicity relations between CCSNe types.

CLASP procedures and applicability

Currently CLASP performs all steps between receiving a basic CCD reduced exposure and its template, and producing a subtracted image and (if desired) a magnitude and associated error for plotting on a lightcurve. The program requires only a few CCD header definitions and has coped with data from a variety of instruments data so far, spanning FOVs from 5' to >1 degree. Naturally this method of template subtraction lends itself to observations of transient events such as supernovae (SNe), GRB afterglows, novae etc., but has also been able to readily perform R band continuum subtraction of Hα images of galaxies to investigate the environments of peculiar SNe.

Subtractions performed with CLASP. *Top to bottom* – R band template image, R band (Hα narrowband in last two columns) science image, CLASP subtracted image. *Left to right* – PTF10fps, PTF10hjw, PTF10hmc (LT+RATCam), SN2008ip (WISE 40 inch Telescope), SN2011fe (SkycamZ at LT), NGC3690, NGC4303 (Isaac Newton Telescope+WFC).





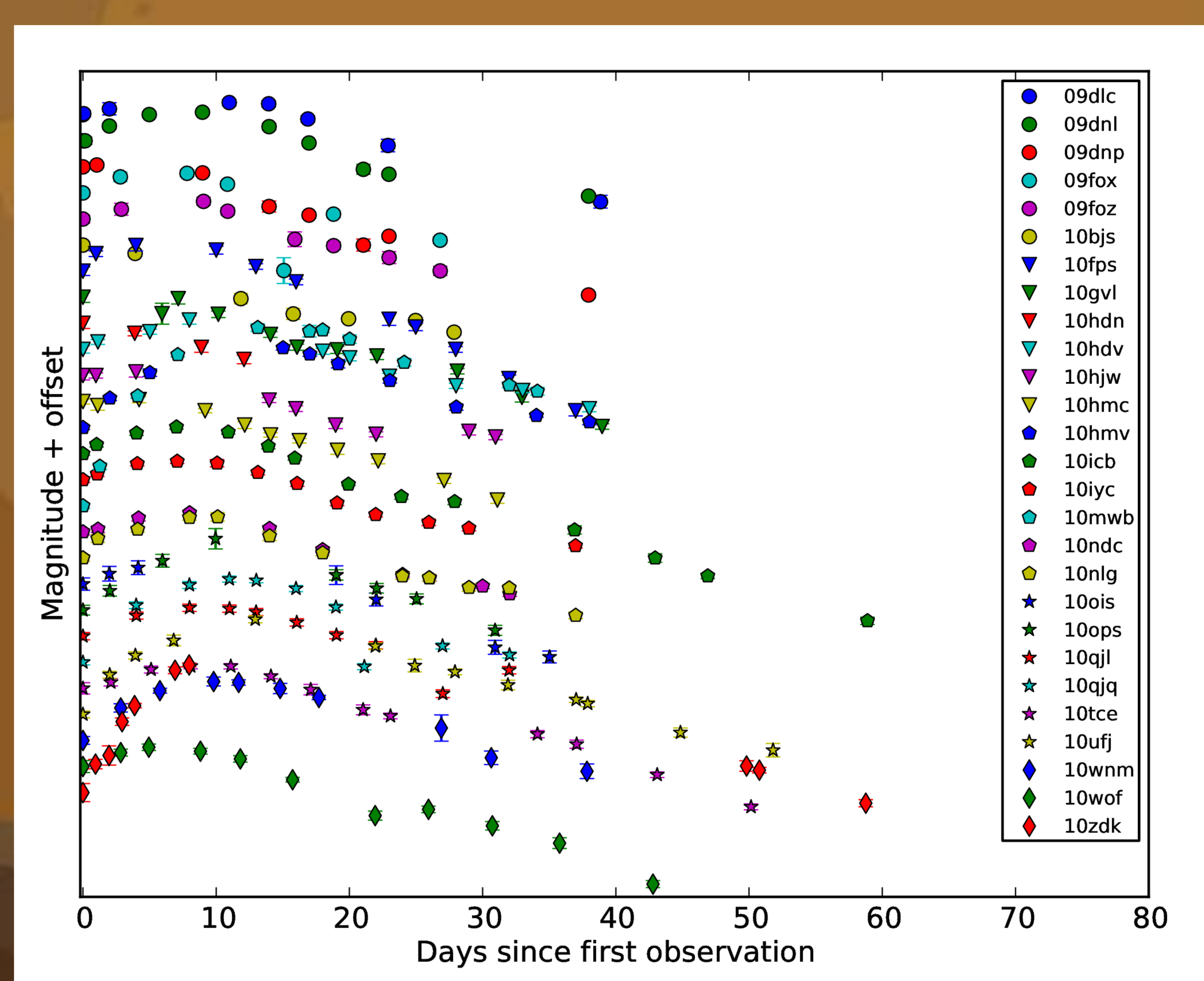
Peculiar SNIb host Hα emission after continuum subtraction with CLASP. The SN location is marked by a circle. Only 1 of the 5 shows any Hα at the location of the SN. *Inset left* – R band image, *inset right* – Hα narrow band image.

The origin of peculiar SNIb

Peculiar SNIb similar to SN2005cz are faint and calcium rich. These SNe have gathered a lot of interest as they are spectroscopically similar to traditional SNIb, who are of massive star origin, but are observed to explode in early type galaxies, traditionally thought to contain very little, if any, current star formation or, consequently, massive stars. Perets et al. (2010, Nature, 465, 322) argue for a helium-rich white dwarf explosion as the progenitor of these SNe (akin to SNIa), whilst Kawabata et al. (2010, Nature, 465, 326) argue for a traditional CCSNe massive star origin. Here we utilise Hα as a tracer of recent star formation in 5 hosts of this class of SNe by using CLASP to subtract the R band continuum after flux and psf matching. The locations of 4 out of 5 of the SNe reveal no detectable Hα emission, indicating a lack of massive stars at their locations, arguing strongly that they arise from an older stellar population as claimed by Perets et al.

Multicolour lightcurve catalogue and explosion parameters of CCSNe

The initial creation of the lightcurve catalogue will be performed by CLASP *(right)*. From multicolour lightcurves for an individual CCSNe, a pseudo-bolometric lightcurve can be constructed, after applying corrections for the missed NIR contribution, by converting magnitudes to monochromatic fluxes at the effective wavelength of each filter, and interpolating the SED between these points. A pseudo-bolometric lightcurve allows direct analysis of the explosion (Arnett 1980, ApJ, 237, 541 & Arnett 1982, ApJ, 253, 785). This will reveal parameters of the explosion: the mass of the ejecta, the mass of ^{56}Ni synthesised and the kinetic energy of the explosion. Statistically significant samples of these parameters do not exist currently and are restricted to single objects from detailed modelling or a small handful using Arnett's analytical method. With a large number across different CCSN types, these parameters will provide insights into the nature of the progenitor systems and, through correlation with other environment tracing techniques, allow investigations of their dependence on host environment to be established, ultimately enhancing our understanding of CCSNe, and their use in other areas of astrophysics.



Example r band lightcurves for a selection of SNe (including Ia, whose templates are more readily available from a related proposal) constructed using CLASP to demonstrate its use. Magnitude scale is arbitrary as points have been offset for clarity. As is clear, the majority of events are followed for ~1-2 months with a cadence of around a few days, enough for construction of the pseudo-bolometric lightcurve.

†jdl@astro.livjm.ac.uk