Near Infrared Studies of Type IIP SNe and their Explosion Parameters

Kate Maguire[1], Stephen J. Smartt[1], Andrea Pastorello[1], Elisa Di Carlo[2], Stefano Benetti[3]

[1]Astrophysics Research Centre, Queen's University Belfast, UK. [2]INAF - Osservatorio Astronomico Collurania-Teramo, Italy. [3]INAF - Osservatorio Astronomico di Padova, Italy.

1. Introduction

- SN 2004et is one of the best studied type IIP SNe, with extensive optical and near infrared (NIR) photometry and spectroscopy.
- The affect of the addition of NIR JHK band photometry to the bolometric light curve is investigated and is seen to be significant.
- The explosion parameters of type IIP SNe are determined using hydrodynamical modeling and these values are compared to the masses obtained using pre-explosion imaging.
- We also investigate the use of NIR photometry to improve estimates of cosmological distances using the Standard Candle Method (SCM).

2. NIR data of SN 2004et

Bolometric light curve (UBVRIJHK)

The UBVRIJHK bolometric light curve of SN 2004et is compared to the bolometric light curves of other IIP SNe (including NIR data where available) in Figure 1. Figure 2 shows the contribution made by the NIR bands to the total optical and NIR flux. The NIR is seen to contribute a significant percentage to the total flux, which highlights the importance of obtaining NIR as well as optical data.

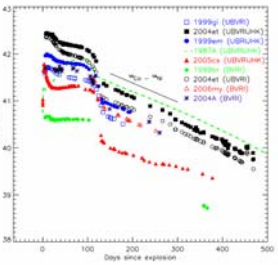

Figure 1. Comparison of UBVRIJHK bolometric light curve of SN 2004et with other type IIP SNe.

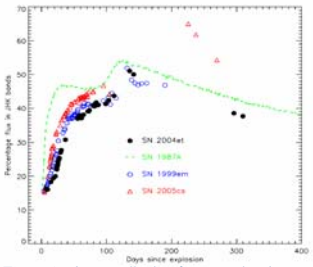

Figure 2. Flux contribution from NIR bands as a percentage of the total flux from optical and NIR bands for a selection of type IIP SNe.

Near Infrared Spectroscopy

Figure 3 shows the extensive photospheric phase NIR spectra of SN 2004et that were obtained with the AZT-24+SWIRCAM at Campo Imperatore Observatory, Italy.

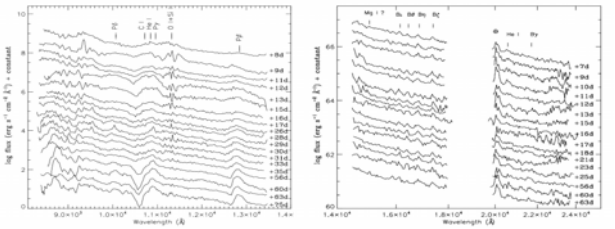

Fig. 3 (a) IJ NIR spectra of SN 2004et from + 8 to + 75 days post explosion. **(b)** HK NIR spectra of SN 2004et from + 7 days to + 63 days post explosion. The prominent spectral features are marked.

3. Comparison of type IIP SNe

Hydrodynamical modeling of Type IIP SNe

The hydrodynamical equations of Litvinova & Nadyozhin (1983, 1985) use the observational properties of IIP SNe (plateau length, plateau duration and V band magnitude mid-plateau) to estimate the explosion energy, pre-explosion radius and ejected mass. Table 1 shows these parameters for a sample of well studied type IIP SNe.

SN	D (Mpc)	A_v	Δt	vel_{ph} (km/s)	M_V	Energy ($\times 10^{51}$ erg)	Radius ($R_\odot$)	Mass ejected ($M_\odot$)	Direct Mass ($M_\odot$)
1999br	14.1 ± 2.6	0.06 ± 0.06	100 ± 15	1541 ± 150	-13.16 ± 0.45	0.20 ± 0.09	31 ± 19	20 ± 10	< 15
1999em	11.7 ± 1.0	0.31 ± 0.16	120 ± 10	3046 ± 150	-16.68 ± 0.27	0.84 ± 0.29	437 ± 173	18 ± 7	< 15
1999gi	10.0 ± 0.8	0.65 ± 0.16	115 ± 10	2717 ± 150	-15.67 ± 0.26	0.64 ± 0.25	183 ± 69	21 ± 9	< 14
2003gd	9.3 ± 1.8	0.43 ± 0.19	113 ± 20	3210 ± 200	-16.06 ± 0.47	1.04 ± 0.49	179 ± 122	24 ± 13	7^{+6}_{-8}
2004A	20.3 ± 3.4	0.19 ± 0.09	107 ± 20	3200 ± 200	-16.33 ± 0.39	0.68 ± 0.37	328 ± 197	15 ± 9	7^{+6}_{-2}
2004dj	3.3 ± 0.3	0.53 ± 0.06	105 ± 20	2957 ± 150	-16.16 ± 0.23	0.65 ± 0.30	277 ± 107	16 ± 9	15 ± 3
2004et	5.9 ± 0.4	1.3 ± 0.2	110 ± 15	3462 ± 150	-17.15 ± 0.27	0.88 ± 0.31	631 ± 251	14 ± 6	9^{+3}_{-2}
2005cs	7.1 ± 1.2	0.16 ± 0.1	118 ± 15	1500 ± 150	-14.66 ± 0.39	0.17 ± 0.08	208 ± 123	13 ± 6	8 ± 2
2006my	22.3 ± 2.6	0.08	120 ± 20	2953 ± 300	-16.26 ± 0.28	0.86 ± 0.44	274 ± 135	22 ± 12	< 13
2006ov	12.6 ± 2.4	0.07 ± 0.2	118 ± 30	1410 ± 200	-15.12 ± 0.47	0.12 ± 0.09	465 ± 363	9 ± 7	< 10

Table 1. Type IIP SNe parameters, calculated using the equations of Litvinova & Nadyozhin (1985).

Progenitor mass estimates

Figure 4 shows the progenitor masses obtained from the equations of Litvinova & Nadyozhin (1983, 1985) for a sample of 10 recent nearby IIP SNe against the progenitor masses/mass limits obtained from pre-explosion imaging (Smartt et al. 2009). The model is seen to give consistently higher main sequence masses than the direct masses/mass limits.

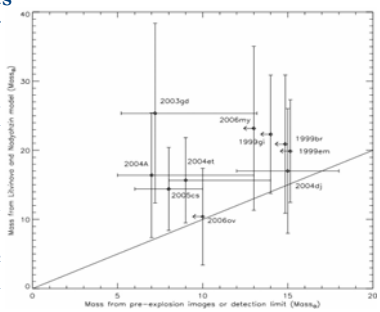

Figure 4. The progenitor masses obtained from hydrodynamical modeling versus those obtained from pre-explosion images. A one-to-one correspondence line is shown.

4. NIR distance estimates

Standard Candle Method using NIR photometry

Hamuy & Pinto (2001) introduced a method for determining distances to type IIP SNe, which is based on the correlation they found between the luminosity and expansion velocity during the plateau phase. Nugent et al. (2006) and most recently Poznanski et al. (2009) have improved and simplified this method for a larger sample of type IIP SNe. Another method that uses type IIP SNe for a estimating distances is the spectral fitting expanding atmosphere method (SEAM) (e.g., Baron et al. 2004, Dessart & Hillier 2006).

Using a sample of type IIP SNe with NIR data, we investigate the use of NIR instead of optical photometry to improve the dispersion of the Hubble diagram due to the smaller extinction in the NIR compared to optical bands. Figure 5 shows a comparison between optical and NIR bands for plots of the luminosity against redshift. For this preliminary sample, the scatter in the NIR bands appears to be smaller than in the optical.

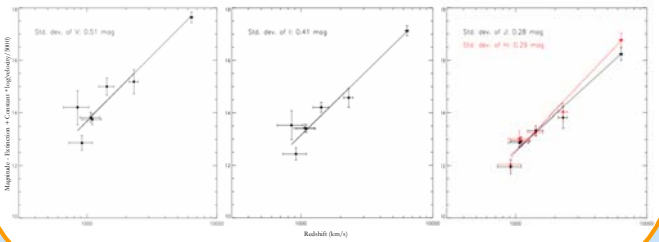

Figure 5. Hubble diagram of luminosity against redshift using (a) V band data, (b) I band data and (c) J band data. The scatter of each data set is also shown.

5. Conclusions

- We present a large set of data for SN 2004et, which includes extensive NIR photometry and spectroscopy. The NIR flux contribution to the bolometric light curve is seen to be significant.
- Using hydrodynamical models, the explosion parameters of a sample of 10 recent type IIP SNe were calculated and compared. The models are seen to consistently overestimate the main-sequence mass of the progenitor star compared to the mass obtained from direct imaging.
- The standard candle method for distance measurements is extended to the NIR. The scatter in the Hubble diagram for our sample of IIP SNe is seen to be smaller in the NIR J and H bands compared to optical V and I bands. Future work will include expanding this preliminary sample to include more type IIP SNe with NIR data.

Baron E. et al., 2004, ApJ, 616, L91
Dessart L. & Hillier D. J., 2006, A&A, 447, 691
Hamuy M. & Pinto P. A., 2002, ApJ, 566, L63
Litvinova I. Y. & Nadyozhin D. K., 1983, Ap&SS, 89, 89
Litvinova I. Y. & Nadyozhin D. K., 1985, SAVL, 11, 145
Nugent P. et al., 2006, ApJ, 645, 841
Poznanski D. et al., 2009, ApJ, 694, 1067
Smartt S. J. et al., 2009, MNRAS,395,1409