

HST and Ground-Based Observations of SN 2008A: A Peculiar SN 2002cx-like Type Ia Supernova

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Abstract

We present HST and ground-based observations of SN 2008A. The early-time spectra and light curves show that SN 2008A is very similar to SN 2002cx and SN 2005hk, making it part of the SN 2002cx-like subclass of peculiar type Ia supernovae (Jha et al. 2006). Late-time spectroscopy of members of this class, including SN 2008A, provide evidence for significant amounts of high density, low velocity material. Even though this is a very uniform class of Type Ia supernovae, from HST imaging we find that SN 2008A is declining faster at late times than SN 2005hk. We will obtain a second epoch of HST imaging in late August 2009 to follow SN 2008A and constrain models for this subclass, including the possibility of a pure deflagration explosion.

Introduction

Type Ia supernovae (SNe Ia) have provided the precise cosmological distances that led to the discovery of the accelerating Universe (Riess et al. 1998, Perlmutter et al. 1999). While the vast majority of SNe Ia can be well described by a single parameter relating luminosity to light-curve shape (e.g., Phillips 1993) some outliers do exist. SN 2002cx (Li et al. 2003) and SN 2005hk (Phillips et al. 2007) are prototypes of a very homogeneous subclass of peculiar SNe Ia (Jha et al. 2006), which are about one magnitude fainter than normal, with early-time spectra showing expansion velocities about half those of normal SNe Ia. These low velocities persist to late times, providing a deep look into the explosion. Understanding what makes SN 2002cx-like SNe Ia different from their normal counterparts will be an important step in putting supernova cosmology on a more solid theoretical foundation.



Figure 1: Hubble Space Telescope observations of SN 2008A in NGC 634 ($z=0.016$), from February 2009 about 400 days after the B-band maximum. The supernova is very faint, with $F555W = 24.3 \pm 0.1$, $F622W = 24.2 \pm 0.1$, $F791W = 23.1 \pm 0.1$, and $F850LP = 23.6 \pm 0.3$ mag. Note the location of SN 2008A in the outskirts of a spiral galaxy.

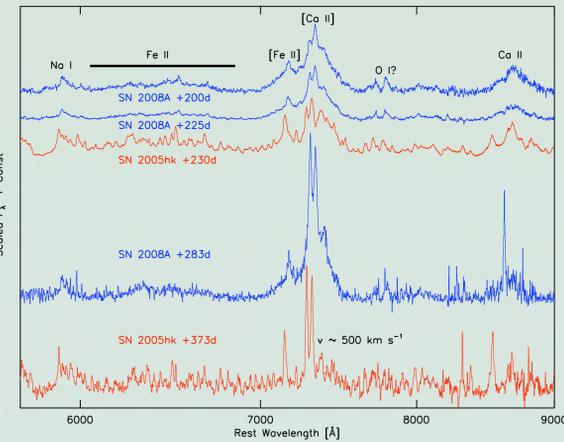
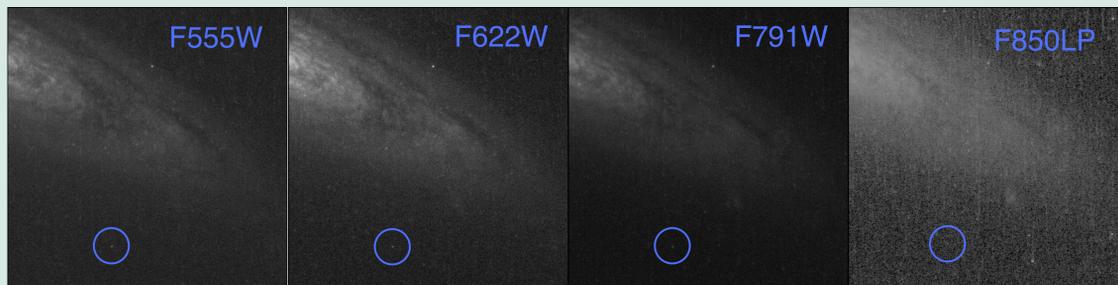


Figure 5: Late-time spectra of SN 2008A and SN 2005hk. Both spectra show permitted Fe II lines mixed with intermediate mass elements (Na, Ca) and possible unburned material (O) at low velocities. The presence of both forbidden [Ca II] and permitted Ca II at the same velocities implies a density several orders of magnitude higher than in normal SNe Ia. Both spectra also show evolution to lower density as the forbidden [Ca II] lines begin to dominate the permitted Ca II. However, some slight differences are apparent: note the lower expansion velocities in SN 2005hk (down to 500 km/s, unprecedentedly low in any SNe Ia). At these late epochs, SN 2002cx-like objects are radically different from normal SNe Ia, which in the nebular phase are dominated by forbidden iron lines with typical expansion velocities of 3000 km/s.

Discussion

★ The unique characteristics of the SN 2002cx-like subclass may be explained by models in which the explosion is a deflagration, with the nuclear burning front remaining subsonic (e.g., Kozma et al. 2005). However, these models generically predict unburned material at all layers and the emergence of strong [O I] 6300 Å emission at late times. We have not yet seen this emission, either in the late-time spectra, or the late-time photometry in the r band. As the density continues to fall, later epoch observations will severely constrain these models.

★ SN 2008A may provide evidence for the predicted, but not yet observed, "IR catastrophe" in which the dominant emission shifts from the optical bands to the far infrared as the ejecta cool below a critical temperature (e.g., Axelrod 1980; Fransson et al. 1996; Sollerman et al. 2004). The higher densities in SN 2002cx-like objects would lead to enhanced cooling and an earlier IR catastrophe. SN 2008A does appear to be declining more rapidly in the optical than other objects; if this is a signature of the IR catastrophe, we should expect a strong optical color change in our second HST epoch.

★ Understanding the physics behind this peculiar, but very homogeneous, subclass promises to also shed light on the progenitors of normal SNe Ia and how they explode (e.g., do normal SNe Ia require a deflagration to detonation transition?)

References

- Axelrod, T. 1980, PhD Thesis, UC Santa Cruz
- Fransson, C., Houck, J., & Kozma, C. 1996, in IAU Colloq. 145: SNe and SN Remnants
- Jha, S., et al. 2006, AJ, 132, 189
- Kirshner, R. P. et al. 1993, ApJ, 415, 589
- Kozma, C., et al. 2005, A&A, 437, 983
- Li, W., et al. 2003, PASP, 115, 453
- Perlmutter, S., et al. 1999, ApJ, 517, 565
- Phillips, M. M. 1993, ApJ, 413, L105
- Phillips, M.M., et al. 2007, PASP, 119, 360
- Riess, A. G., et al. 1998, ApJ, 116, 1009
- Sahu, D. K., et al. 2008, ApJ, 680, 580
- Sollerman, J., et al. 2004, A&A, 428, 555

Acknowledgments

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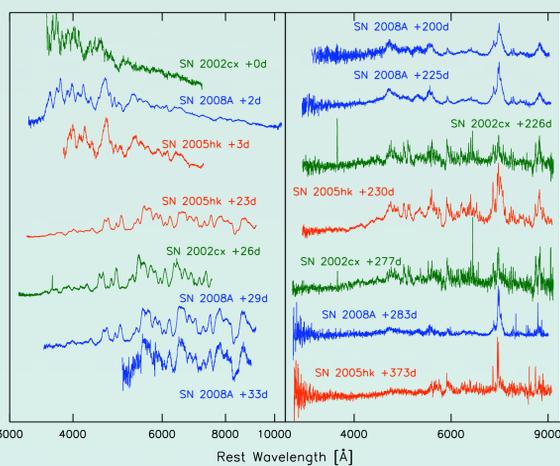


Figure 2: Spectral similarity of SN 2002cx, SN 2005hk, and SN 2008A. The SN 2002cx-like class have remarkably homogeneous spectra throughout their evolution, even more than normal SNe Ia. The SN 2008A spectra were obtained with the Lick 3m Shane telescope (+ KAST) and Keck I (+ LRIS). The SN 2002cx spectra are from Li et al. (2003), and the spectra for SN 2005hk are from Phillips et al. (2007).

Figure 3: Early time BVRI light curves of SN 2008A from Lick Observatory (KAIT and 40" Nickel) compared to SN 2002cx (Li et al. 2003) and SN 2005hk (Phillips et al. 2007), shifted to match at peak. Like the spectra, the light curves are very uniform.

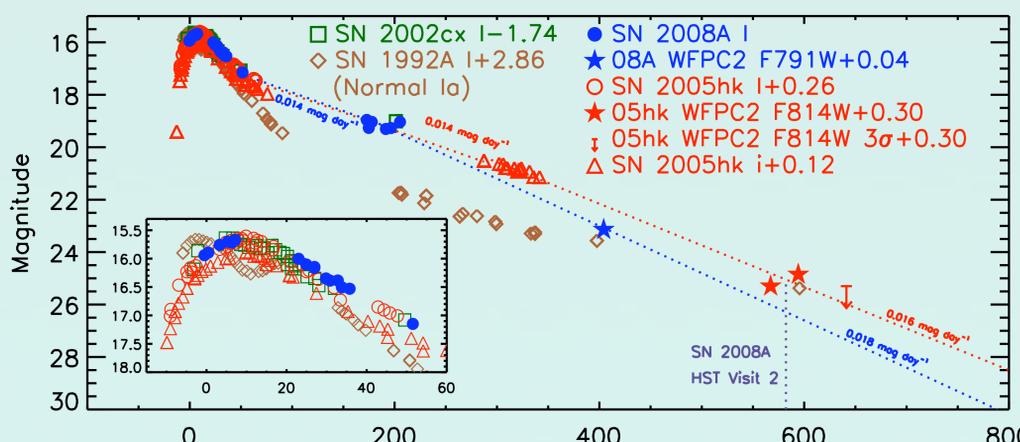
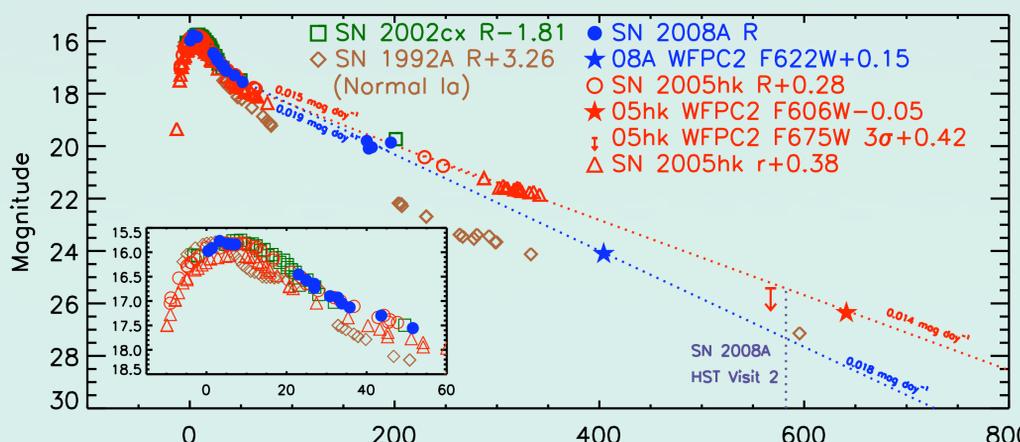
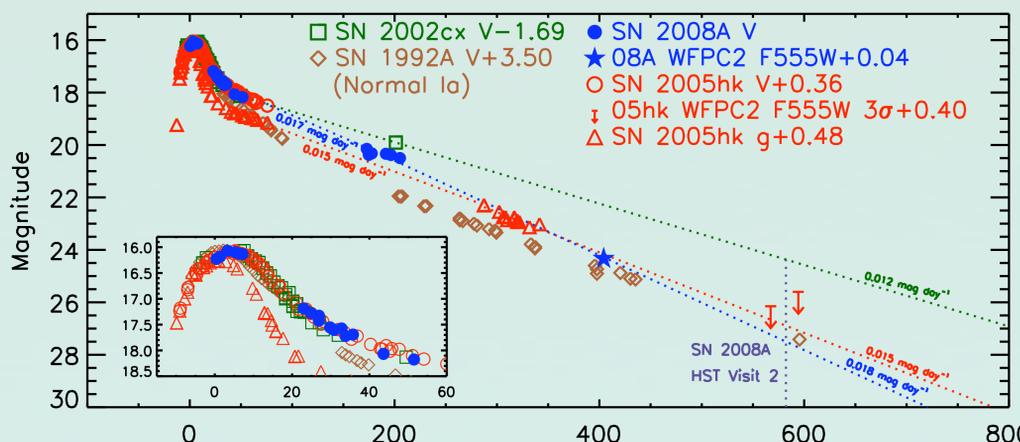
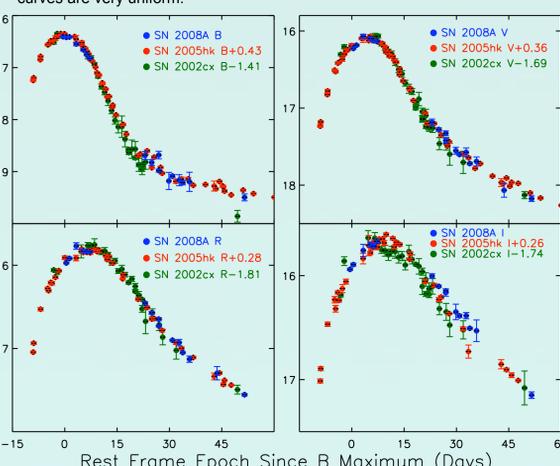


Figure 4: Late-time ground and HST photometry of SN 2008A, compared to SN 2002cx (Li et al. 2003), SN 2005hk (Phillips et al. 2007; Sahu et al. 2008), and the normal type Ia SN 1992A (Kirshner et al. 1993). The HST data show that SN 2008A is declining more rapidly at late times than its counterparts SN 2002cx and SN 2005hk. Additional HST observations of SN 2008A are scheduled for late August 2009 as marked.