Optical Observations of Type II Supernovae

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Abstract. I present an overview of optical observations (mostly spectra) of Type II supernovae. SNe II are defined by the presence of hydrogen, and exhibit a very wide variety of properties. SNe II-L tend to show evidence of late-time interaction with circumstellar material. SNe IIn are distinguished by relatively narrow emission lines with little or no P-Cygni absorption component and (quite often) slowly declining light curves; they probably have unusually dense circumstellar gas with which the ejecta interact. Some SNe IIn, however, might not be genuine SNe, but rather are super-outbursts of luminous blue variables. The progenitors of SNe IIb contain only a low-mass skin of hydrogen; their spectra gradually evolve to resemble those of SNe Ib. Limited spectropolarimetry thus far indicates large asymmetries in the ejecta of SNe IIn, but much smaller ones in SNe II-P. There is intriguing, but still inconclusive, evidence that some peculiar SNe IIn might be associated with gamma-ray bursts. SNe II-P are useful for cosmological distance determinations with the Expanding Photosphere Method, which is independent of the Cepheid distance scale.

INTRODUCTION

Supernovae (SNe) occur in several spectroscopically distinct varieties; see reference [1], for example. Type I SNe are defined by the absence of obvious hydrogen in their optical spectra, except for possible contamination from superposed H II regions. SNe II all prominently exhibit hydrogen in their spectra, yet the strength and profile of the Hα line vary widely among these objects.

The early-time ($t \approx 1$ week past maximum brightness) spectra of SNe are illustrated in Figure 1. [Unless otherwise noted, the optical spectra illustrated here were obtained by my group, primarily with the 3-m Shane reflector at Lick Observatory. When referring to phase of evolution, the variables $t$ and $\tau$ denote time since maximum brightness (usually in the $B$ passband) and time since explosion, respectively.] The lines are broad due to the high velocities of the ejecta, and most of them have P-Cygni profiles formed by resonant scattering above the photosphere. SNe Ia are characterized by a deep absorption trough around 6150 Å produced by blueshifted Si II λ6355. Members of the Ib and Ic subclasses do not show this
The presence of moderately strong optical He I lines, especially He I $\lambda 5876$, distinguishes SNe Ib from SNe Ic.

Figure 1: Early-time spectra of SNe, showing the main subtypes.

The late-time ($t \sim 4$ months) optical spectra of SNe provide additional constraints on the classification scheme (Figure 2). SNe Ia show blends of dozens of Fe emission lines, mixed with some Co lines. SNe Ib and Ic, on the other hand, have relatively unblended emission lines of intermediate-mass elements such as O and Ca. At this phase, SNe II are dominated by the strong H$\alpha$ emission line; in other respects, most of them spectroscopically resemble SNe Ib and Ic, but with narrower emission lines. The late-time spectra of SNe II show substantial heterogeneity, as do the early-time spectra.

To a first approximation, the light curves of SNe I are all broadly similar [2], while those of SNe II exhibit much dispersion [3]. It is useful to subdivide the majority of early-time light curves of SNe II into two relatively distinct subclasses [4,5]. The light curves of SNe II-L (“linear”) generally resemble those of SNe I, with a steep decline after maximum brightness followed by a slower exponential tail. In contrast, SNe II-P (“plateau”) remain within $\sim 1$ mag of maximum brightness for an extended period. The peak absolute magnitudes of SNe II-P show a very wide
dispersion [6], almost certainly due to differences in the radii of the progenitor stars. The light curve of SN 1987A, albeit unusual, was generically related to those of SNe II-P; the initial peak was very low because the progenitor was a blue supergiant, much smaller than a red supergiant [7]. The remainder of this review concentrates on SNe II.

**Figure 2**: Late-time spectra of SNe. At even later phases, SN 1987A was dominated by strong emission lines of Hα, [O I], [Ca II], and the Ca II near-infrared triplet.

**SUBCLASSES OF TYPE II SUPERNOVAE**

Most SNe II-P seem to have a relatively well-defined spectral development, as shown in Figure 3 for SN 1992H (see also reference [8]). At early times the spectrum is nearly featureless and very blue, indicating a high color temperature (∼10,000 K). He I λ5876 with a P-Cygni profile is sometimes visible. The temperature rapidly decreases with time, reaching ∼5000 K after a few weeks, as expected from the adiabatic expansion and associated cooling of the ejecta. It remains roughly constant at this value during the plateau (the photospheric phase), while the hydrogen recombination wave moves through the massive (∼10 M☉) hydrogen ejecta and releases the energy deposited by the shock. At this stage strong Balmer lines
and Ca II H&K with well-developed P-Cygni profiles appear, as do weaker lines of Fe II, Sc II, and other iron-group elements. The spectrum gradually takes on a nebular appearance as the light curve drops to the late-time tail; the continuum fades, but Hα becomes very strong, and prominent emission lines of [O I], [Ca II], and Ca II also appear.

Figure 3: Montage of spectra of SN 1992H in NGC 5377. Epochs (days) are given relative to the estimated time of explosion, February 8, 1992.

Few SNe II-L have been observed in as much detail as SNe II-P. Figure 4 shows the spectral development of SN 1979C [9], an unusually luminous member of this subclass. Near maximum brightness the spectrum is very blue and almost featureless, with a slight hint of Hα emission. A week later, Hα emission is more easily discernible, and low-contrast P-Cygni profiles of Na I, Hβ, and Fe II have appeared. By \( t \approx 1 \) month, the Hα emission line is very strong but still devoid of an absorption component, while the other features clearly have P-Cygni profiles. Strong, broad Hα emission dominates the spectrum at \( t \approx 7 \) months, and [O I] \( \lambda\lambda 6300, 6364 \) emission is also present. Several authors [10–12] have speculated that the absence
of Hα absorption spectroscopically differentiates SNe II-L from SNe II-P, but the small size of the sample of well-observed objects precluded definitive conclusions.

Figure 4: Montage of spectra of SN 1979C in NGC 4321, from reference [9]; reproduced with permission. Epochs (days) are given relative to the date of maximum brightness, April 15, 1979.

The progenitors of SNe II-L are generally believed to have relatively low-mass hydrogen envelopes (a few $M_\odot$); otherwise, they would exhibit distinct plateaus, as do SNe II-P. On the other hand, they may have more circumstellar gas than do SNe II-P, and this could give rise to the emission-line dominated spectra. They are often radio sources [13]; moreover, the ultraviolet excess (at $\lambda \lesssim 1600$ Å) seen in SN 1979C and 1980K may be produced by inverse Compton scattering of photospheric radiation by high-speed electrons in shock-heated ($T \approx 10^9$ K) circumstellar material [14,15]. Finally, the light curves of some SNe II-L reveal an extra source of energy: after declining exponentially for several years, the Hα flux of SN 1980K reached a steady level, showing little if any decline thereafter [16,17]. The excess almost certainly comes from the kinetic energy of the ejecta.
being thermalized and radiated due to an interaction with circumstellar matter [18,19].

The very late-time optical recovery of SNe 1979C and 1980K [17,20,21] and other SNe II-L supports the idea of ejecta interacting with circumstellar material. The spectra consist of a few strong, broad emission lines such as Hα, [O I] λλ6300, 6364, and [O III] λλ4959, 5007. A *Hubble Space Telescope (HST)* ultraviolet spectrum of SN 1979C reveals some prominent, double-peaked emission lines with the blue peak substantially stronger than the red, suggesting dust extinction within the expanding ejecta [21]. The data show general agreement with the emission lines expected from circumstellar interaction [22], but the specific models that are available show several differences with the observations. For example, we find higher electron densities \(10^5\) to \(10^7\) cm\(^{-3}\), resulting in stronger collisional de-excitation than assumed in the models. These differences can be used to further constrain the nature of the progenitor star. Note that based on photometry of the stellar populations in the environment of SN 1979C (from *HST* images), the progenitor of the SN was at most 10 million years years old, so its initial mass was probably 17–18 \(M_\odot\) [23].

During the past decade, there has been the gradual emergence of a new, distinct subclass of SNe II [11,24,25,19] whose ejecta are believed to be strongly interacting with dense circumstellar gas, even at early times (unlike SNe II-L). The derived mass-loss rates for the progenitors can exceed \(10^{-4}\)\(M_\odot\) yr\(^{-1}\) [26]. In these objects, the broad absorption components of all lines are weak or absent throughout their evolution. Instead, their spectra are dominated by strong emission lines, most notably Hα, having a complex but relatively narrow profile. Although the details differ among objects, Hα typically exhibits a very narrow component (FWHM \(\lesssim 200\) km s\(^{-1}\)) superposed on a base of intermediate width (FWHM \(\approx 1000\)–2000 km s\(^{-1}\); sometimes a very broad component (FWHM \(\approx 5000\)–10,000 km s\(^{-1}\)) is also present. This subclass was christened “Type IIn” [25], the “n” denoting “narrow” to emphasize the presence of the intermediate-width or very narrow emission components. Representative spectra of five SNe IIn are shown in Figure 5, with two epochs for SN 1994Y.

The early-time continua of SNe IIn tend to be bluer than normal. Occasionally He I emission lines are present in the first few spectra (e.g., SN 1994Y in Figure 5). Very narrow Balmer absorption lines are visible in the early-time spectra of some of these objects, often with corresponding Fe II, Ca II, O I, or Na I absorption as well (e.g., SNe 1994W and 1994ak in Figure 5). Some of them are unusually luminous at maximum brightness, and they generally fade quite slowly, at least at early times. The equivalent width of the intermediate Hα component can grow to astoundingly high values at late times. The great diversity in the observed characteristics of SNe IIn provides clues to the various degrees and forms of mass loss late in the lives of massive stars.
Figure 5: Montage of spectra of SNe IIn. Epochs are given relative to the estimated dates of explosion.

**TYPE II SUPERNOVA IMPOSTORS?**

The peculiar SN IIn 1961V ("Type V" according to Zwicky [27]) had probably the most bizarre light curve ever recorded. (SN 1954J, also known as "Variable 12" in NGC 2403, was similar [28].) Its progenitor was a very luminous star, visible in many photographs of the host galaxy (NGC 1058) prior to the explosion. Perhaps SN 1961V was not a genuine supernova (defined to be the violent destruction of a star at the end of its life), but rather the super-outburst of a luminous blue variable such as η Carinae [29,30].
A related object may have been SN II in 1997bs, the first SN discovered in the Lick Observatory Supernova Search (LOSS) that we are conducting with the 0.75-m Katzman Automatic Imaging Telescope (KAIT) at Lick Observatory [31]. Its spectrum was peculiar (Figure 6), consisting of narrow Balmer and Fe II emission lines superposed on a featureless continuum. Its progenitor was discovered in an HST archival image of the host galaxy [32]. It is a very luminous star ($M_V \approx -7.4$ mag), and it didn’t brighten as much as expected for a SN explosion ($M_V \approx -13$ at maximum). These data suggest that SN 1997bs may have been like SN 1961V — that is, a supernova impostor. The real test will be whether the star is still visible in future HST images obtained years after the outburst.

![Figure 6: Spectrum of SN 1997bs, obtained on April 16, 1997 UT.](image)

**LINKS BETWEEN TYPE II AND TYPE Ib/Ic SUPERNOVAE**

Filippenko [33] discussed the case of SN 1987K, which appeared to be a link between SNe II and SNe Ib. Near maximum brightness, it was undoubtedly a SN II, but with rather weak photospheric Balmer and Ca II lines. Many months after maximum brightness, its spectrum was essentially that of a SN Ib. The simplest interpretation is that SN 1987K had a meager hydrogen atmosphere at the time it exploded; it would naturally masquerade as a SN II for a while, and as the expanding ejecta thinned out the spectrum would become dominated by emission from deeper and denser layers. The progenitor was probably a star that, prior to exploding via iron core collapse, lost almost all of its hydrogen envelope.
either through mass transfer onto a companion or as a result of stellar winds. Such SNe were dubbed “SNe IIb” by Woosley et al. [34], who had proposed a similar preliminary model for SN 1987A before it was known to have a massive hydrogen envelope.

![Figure 7: Early-time spectral evolution of SN 1993J. A comparison with the Type Ib SN 1984L is shown at bottom, demonstrating the presence of He I lines in SN 1993J. The explosion date was March 27.5, 1993.](image)

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The data for SN 1987K (especially its light curve) were rather sparse, making it difficult to model in detail. Fortunately, the Type II SN 1993J in NGC 3031 (M81) came to the rescue, and was studied in greater detail than any supernova since SN 1987A [35]. Its light curves [36] and spectra [37–39] amply supported the hypothesis that the progenitor of SN 1993J probably had a low-mass (0.1–0.6 $M_\odot$) hydrogen envelope above a ∼ 4 $M_\odot$ He core [40–42]. Figure 7 shows several early-time spectra of SN 1993J, showing the emergence of He I features typical of SNe Ib.
Considerably later (Figure 8), the Hα emission nearly disappeared, and the spectral resemblance to SNe Ib was strong. The general consensus is that its initial mass was $\sim 15 M_\odot$. A star of such low mass cannot shed nearly its entire hydrogen envelope without the assistance of a companion star. Thus, the progenitor of SN 1993J probably lost most of its hydrogen through mass transfer to a bound companion 3–20 AU away. In addition, part of the gas may have been lost from the system. Had the progenitor lost essentially all of its hydrogen prior to exploding, it would have had the optical characteristics of SNe Ib. There is now little doubt that most SNe Ib, and probably SNe Ic as well, result from core collapse in stripped, massive stars, rather than from the thermonuclear runaway of white dwarfs.

SN 1993J held several more surprises. Observations at radio [43] and X-ray [44] wavelengths revealed that the ejecta are interacting with relatively dense circumstellar material [45], probably ejected from the system during the course of its pre-SN evolution. Optical evidence for this interaction also began emerging at $\tau \gtrsim 10$ months: the Hα emission line grew in relative prominence, and by $\tau \approx 14$ months it had become the dominant line in the spectrum [38,46,47], consistent with models [22]. Its profile was very broad (FWHM $\approx 17,000$ km s$^{-1}$; Figure 8) and had a relatively flat top, but with prominent peaks and valleys whose likely origin is Rayleigh-Taylor instabilities in the cool, dense shell of gas behind the reverse shock [48]. Radio VLBI measurements show that the ejecta are circularly symmetric, but with significant emission asymmetries [49], possibly consistent with the asymmetric Hα profile seen in some of the spectra [38].

*Figure 8:* In the top spectrum, which shows SN 1993J about 7 months after the explosion, Hα emission is very weak; the resemblance to spectra of SNe Ib is striking. A year later (bottom), however, Hα was once again the dominant feature in the spectrum (which was scaled for display purposes).
SPECTROPOLARIMETRY OF TYPE II SUPERNOVAE

Spectropolarimetry of SNe can be used to probe their geometry [50]. The basic question is whether SNe are round. Such work is important for a full understanding of the physics of SN explosions and can provide information on the circumstellar environment of SNe. We have obtained spectropolarimetry of one object from each of the major SN types and subtypes, generally with the Keck-II 10-m telescope.

![Figure 9: Polarization data for SN 1998S, obtained with Keck-II on March 7, 1998. (a) Total flux, in units of $10^{-15}$ ergs s$^{-1}$ cm$^{-2}$ Å$^{-1}$. (b) Observed degree of polarization. (c,d) The normalized $q$ and $u$ Stokes parameters, with prominent narrow-line features indicated. (e) Average of the (nearly identical) 1σ statistical uncertainties in the Stokes $q$ and $u$ parameters. See reference [51] for details.](#)

We have completed our analysis of the peculiar Type IIn SN 1998S [51]. The data consist of one epoch of spectropolarimetry (5 days after discovery) and total flux.
spectra spanning the first 494 days after discovery. The SN is found to exhibit a high degree of linear polarization (Figure 9), implying significant asphericity for its continuum-scattering environment. Prior to removal of the interstellar polarization, the polarization spectrum is characterized by a flat continuum (at $p \approx 2\%$) with distinct changes in polarization associated with both the broad (symmetric, half width near-zero intensity $\gtrsim 10,000 \text{ km s}^{-1}$) and narrow (unresolved, FWHM $< 300 \text{ km s}^{-1}$) line emission seen in the total flux spectrum. When analyzed in terms of a polarized continuum with unpolarized broad-line recombination emission, however, an intrinsic continuum polarization of $p \approx 3\%$ results, suggesting a global asphericity of $\gtrsim 45\%$ from the oblate, electron-scattering dominated models of H"oflich [52]. The smooth, blue continuum evident at early times is inconsistent with a reddened, single-temperature blackbody, instead having a color temperature that increases with decreasing wavelength. Broad emission-line profiles with distinct blue and red peaks are seen in the total flux spectra at later times, suggesting a disk-like or ring-like morphology for the dense ($n_e \approx 10^7 \text{ cm}^{-3}$) circumstellar medium, generically similar to what is seen directly in SN 1987A, although much denser and closer to the progenitor in SN 1998S.

The Type IIn SN 1997eg also exhibits considerable polarization [50]; there are sharp polarization changes across its strong, multi-component emission lines, suggesting distinct scattering origins for the different components. Based on our rather small sample, it appears as though SNe II-P are considerably less polarized than SNe IIn, at least within the first month or two after the explosion. Leonard et al. [50] show some spectropolarimetric evidence of asphericity in the ejecta of SN II-P 1997ds, but it does not match the degree of polarization of SNe IIn 1998S and 1997eg. Moreover, SN II-P 1999em does not reveal significant polarization variation across the strong Balmer lines shortly after its explosion [53].

**SUPERNOVAE ASSOCIATED WITH GAMMA-RAY BURSTS?**

At least a small fraction of gamma-ray bursts (GRBs) may be associated with nearby SNe. Probably the most compelling example thus far is that of SN 1998bw and GRB 980425 [54–56], which were temporally and spatially coincident. SN 1998bw was, in many ways, an extraordinary SN; it was very luminous at optical and radio wavelengths, and it showed evidence for relativistic outflow. Its bizarre optical spectrum is often classified as that of a SN Ic, but the object should be called a “peculiar SN Ic” if not a subclass of its own; the spectrum was distinctly different from that of a normal SN Ic.

As discussed by several speakers at this meeting, models suggest that SNe associated with GRBs are highly asymmetric. Thus, spectropolarimetry should provide some useful tests. In particular, perhaps objects such as SN 1998S, discussed above, would have been seen as GRBs had their rotation axis been pointed in our direction. That of SN 1998S was almost certainly not aligned with us [51]; both the
spectropolarimetry and the appearance of double-peaked Hα emission suggest an inclined view, rather than pole-on.

![Figure 10: Spectral evolution of SN 1999E](image)

The case of GRB 970514 and the very luminous SN IIn 1997cy is also interesting [57,58]; there is a reasonable possibility that the two objects were associated. The optical spectrum of SN 1997cy was highly unusual, and bore some resemblance to that of SN 1998bw, though there were some differences as well. SN 1999E, which might be linked with GRB 980910 but with large uncertainties [59], also had an optical spectrum similar to that of SN 1997cy [60,61]; see Figure 10. The undulations are very broad, indicating high ejection velocities. Besides Hα, secure line identifications are difficult, though some of the emission features seem to be associated with oxygen and calcium. Perhaps SN 1999E was produced by the highly asymmetric collapse of a carbon-oxygen core.

 Shortly before this meeting, SN IIn 1999eb was discovered with KAIT [62], and Terlevich et al. [63] pointed out that it might be associated with GRB 991002. However, KAIT data show that the optical SN was visible at least 10 days before
the GRB occurred, making it very unlikely that the two were linked. If SN 1999eb ends up showing double-peaked Hα emission at late times, as did SN 1998S, it will be another argument against the SN/GRB association in this particular case, since our view will not have been pole-on.

THE EXPANDING PHOTOSPHERE METHOD

Despite *not* being anything like “standard candles,” SNe II-P (and some SNe II-L) are very good distance indicators. They are, in fact, “custom yardsticks” when calibrated with the “Expanding Photosphere Method” (EPM); see [64]. A variant of the famous Baade-Wesselink method for determining the distances of pulsating variable stars, this technique relies on an accurate measurement of the photosphere’s effective temperature and velocity during the plateau phase of SNe II-P.

Briefly, here is how EPM works. The radius \( R \) of the photosphere can be determined from its velocity \( v \) and time since explosion \( t - t_0 \) if the ejecta are freely expanding: 

\[
R = v(t - t_0) + R_0 \approx v(t - t_0),
\]

where we have assumed that the initial radius of the star \( R_0 \) at \( t = t_0 \) is negligible relative to \( R \) after a few days. The velocity of the photosphere is determined from measurements of the wavelengths of the absorption minima in P-Cygni profiles of weak lines such as those of Fe II or, better yet, Sc II. (The absorption minima of strong lines like Hα form far above the photosphere.)

The angular size \( \theta \) of the photosphere, on the other hand, is found from the measured, dereddened flux density \( f_\nu \) at a given frequency. We have

\[
4\pi D^2 f_\nu = 4\pi R^2 \zeta^2 \pi B_\nu(T),
\]

where \( D \) is the distance to the supernova, \( B_\nu(T) \) is the value of the Planck function at color temperature \( T \) (derived from broadband measurements of the supernova’s brightness in at least two passbands), and \( \zeta^2 \) is the flux dilution correction factor (basically a measure of how much the spectrum deviates from that of a blackbody, due primarily to the electron-scattering opacity).

The above two equations imply that \( t = D(\theta/v) + t_0 \). Thus, for a series of measurements of \( \theta \) and \( v \) at various times \( t \), a plot of \( \theta/v \) versus \( t \) should yield a straight line of slope \( D \) and intercept \( t_0 \). This determination of the distance is independent of the various uncertain rungs in the cosmological distance ladder; it does not even depend on the calibration of the Cepheids. It is equally valid for nearby and distant SNe II-P.

An important check of EPM is that the derived distance be *constant* while the SN is on the plateau (before it has started to enter the nebular phase). This has been verified with SN 1987A [65] and a number of other SNe II-P [66,67]. Moreover, the EPM distance to SN 1987A agrees with that determined geometrically through measurements of the brightening and fading of emission lines from the inner circumstellar ring [68]. It is also noteworthy that EPM is relatively insensitive
to reddening: an underestimate of the reddening leads to an underestimate of the color temperature \( T \) [and hence of \( B_\nu(T) \) as well], but this is compensated by an underestimate of \( f_\nu \), yielding a nearly unchanged value of \( \theta \). Indeed, for errors in \( A_V \) [the visual extinction, or \( \sim 3.1E(B-V) \)] of 0–1 mag, one incurs an error in \( D \) of only \( \sim 0–20\% \) [66].

Of course, EPM has some caveats or potential limitations. A critical assumption is spherical symmetry for the expanding ejecta, yet polarimetry shows that SN 1987A was not spherical [69], as do direct \( HST \) measurements of the shape of the ejecta. As discussed above, the few other SNe II-P that have been studied don’t show very much polarization, though it is possible that deviations from spherical symmetry could be a severe problem for some SNe II-P. On the other hand, the average distance derived with EPM for many SNe II-P might be almost unaffected, given random orientations to the line of sight. (Sometimes the cross-sectional area will be too large, and other times too small, relative to spherical ejecta.) Indeed, comparison of EPM and Cepheid distances to the same galaxies shows agreement to within the expected uncertainties for a sample of 6 objects (\( D_{\text{Cepheids}}/D_{\text{EPM}} = 0.98 \pm 0.08; \) [64]).

Another limitation of EPM is that one needs a well-observed SN II-P in a given galaxy in order to measure its distance; thus, the technique is most useful for aggregate studies of galaxies, rather than for distances of specific galaxies in a random sample. Finally, knowledge of the flux dilution correction factor, \( \zeta^2 \), is critical to the success of EPM. Fortunately, an extensive grid of models [64] shows that the value of \( \zeta^2 \) is mainly a function of \( T \) during the plateau phase of SNe II-P; it is relatively insensitive to other variables such as helium abundance, metallicity, density structure, and expansion rate. Also, it does not differ too greatly from unity during the plateau. There are, however, some differences of opinion regarding the treatment of radiative transfer and thermalization in expanding supernova atmospheres [70]. The calculations are difficult and various assumptions are made, possibly leading to significant systematic errors.

The most distant SN II-P to which EPM has successfully been applied is SN 1992am at \( z = 0.0487 \) [71]. The derived distance is \( D = 180_{-25}^{+30} \) Mpc. This object, together with 15 other SNe II-P at smaller redshifts, yields a best fit value of \( H_0 = 73 \pm 7 \) km s\(^{-1}\) Mpc\(^{-1}\), where the quoted uncertainty is purely statistical [67,64]. A systematic uncertainty of \( \sim \pm6 \) km s\(^{-1}\) Mpc\(^{-1}\) should also be associated with the above result. The main source of statistical uncertainty is the relatively small number of SNe II-P in the EPM sample, and the low redshift of most of the objects (whose radial velocities are substantially affected by peculiar motions). My group is currently trying to remedy the situation with EPM measurements of additional nearby SNe II-P (at Lick Observatory), as well as with Keck spectra of SNe II-P in the redshift range 0.1–0.3.
ACKNOWLEDGMENTS

My recent research on SNe has been financed by NSF grant AST–9417213, as well as by NASA grants GO-6584, GO-7434, AR-6371, and AR-8006 from the Space Telescope Science Institute, which is operated by AURA, Inc., under NASA Contract NAS5-26555. The Committee on Research (U.C. Berkeley) provided partial travel support to attend this meeting. I am grateful to the students and postdocs who have worked with me on SNe over the past 14 years for their assistance and discussions. Tom Matheson and Doug Leonard were especially helpful with the figures for this review.

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