Memo 2.3.1:
Cosmology from
Type II Supernovae

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1 Introduction

The detailed study of SNe Ia is the driving science behind the SNAP satellite proposal. However, there are a number of other interesting scientific measurements that will be carried out with the proposed facility. Here we highlight one of these methods, the use of Type II Supernovae to construct a Hubble diagram and determine the cosmological parameters.

2 EPM & Type II Supernova

The expanding photosphere method (EPM) was developed by Baade (1926) for use with variable stars and has been applied to SNe II (Kirshner & Kwan 1974; Branch et al. 1981; Schmidt et al. 1992; Eastman et al. 1996) in order to estimate the value of H_0. For a particularly lucid description of the empirical application of the EPM to supernovae see Branch (1987).

These previous applications of the EPM have all been semi-empirical in nature in the sense that the supernova is assumed to emit radiation as a blackbody or as a diluted blackbody. Then one simply needs to determine the color temperature and the velocity of expansion in order to determine the total luminosity. For the most recent application of this method see Hamuy *et al.* (2001, astro-ph/0105006). They observed SN 1999em both spectroscopically and photometrically from the UV through IR at several epochs with high signal-to-noise, arriving at a distance to this supernova with uncertainties comparable to those of well observed SNe Ia.

3 SEAM & Type II Supernova

However, it should be noted that EPM is plagued by the fact that supernovae are not dilute blackbodies, as well as by uncertainties in the absolute value of the "dilution factor" (Schmidt et al. 1992; Baron et al. 1995). Hamuy (2001, private communication) has pointed out that for other SNe II in the Hubble flow, EPM has not generated consistent distances. This leads one to consider more detailed modeling of individual supernovae.

With the use of the detailed spectral modeling one has been able to overcome this difficulty and make the method much more precise (Baron et al. 1993, 1994, 1995; Nugent et al. 1995; Baron et al. 1996). In the Spectral-fitting Expanding Atmosphere Method (SEAM) one uses observed spectra and photometry combined with detailed theoretical modeling of the observed spectra to determine distances to both SNe Ia and II. It is unnecessary to make any assumptions about the intrinsic luminosity of the supernova. While previous use of the EPM has involved using observed colors to determine a temperature and then assuming the supernova is a dilute black body, one needs to make no such assumptions. It has already been demonstrated that the SEAM method gives accurate distances for SN 1993J (Baron et al. 1993, 1994, 1995), which was a peculiar Type II supernova, and SN 1994I (Baron et al. 1996), a SNe Ic, normal SNe IIP should both be easier to model and give more reliable distances. Preliminary results on SN 1993W and SN 1999em (observed in the UV with HST) confirm that this is indeed the case. Figure 1 shows our current best fit for a typical plateau-type SN II. The agreement is remarkable.

It has also been shown (Mitchell et al. 2001; Baron et al., in preparation) that with accurate radiation hydrodynamical models an exceptionally precise match to the spectra of SN 1987A can be achieved. Here, they are able to fit a long time series of spectra that have unprecedented coverage in both time and wavelength which will allow us both to assess the uncertainties in the method and to independently determine a distance to the LMC, which is still one of the major uncertainties in the *HST* measurements of Cepheids and hence in the Hubble constant. This method is likely to rival Cepheid based distances in quality and has a much greater distance range.

4 Conclusions

Clearly, with the thousands of SNe II to be discovered with SNAP we will be unable to perform detailed modeling of nearly 10,000 supernovae. However, our preliminary results on individual spectra already show that the method is extremely accurate. By detailed modeling of several selected well observed SNe, we should be able to produce a grid of theoretical models which, combined with Monte-Carlo simulations, will allow us to use the SNe II as independent distance indicators. This last point is in fact the most important aspect of the use of SNe II and the SEAM method for determining cosmological distances, i.e. the physics and astronomy is completely independent of that of the SNe Ia and hence the statistical and systematic errors are also uncorrelated with those of the SNe Ia search. This is a crucial check on the cosmological parameters determined by the SNe Ia search.

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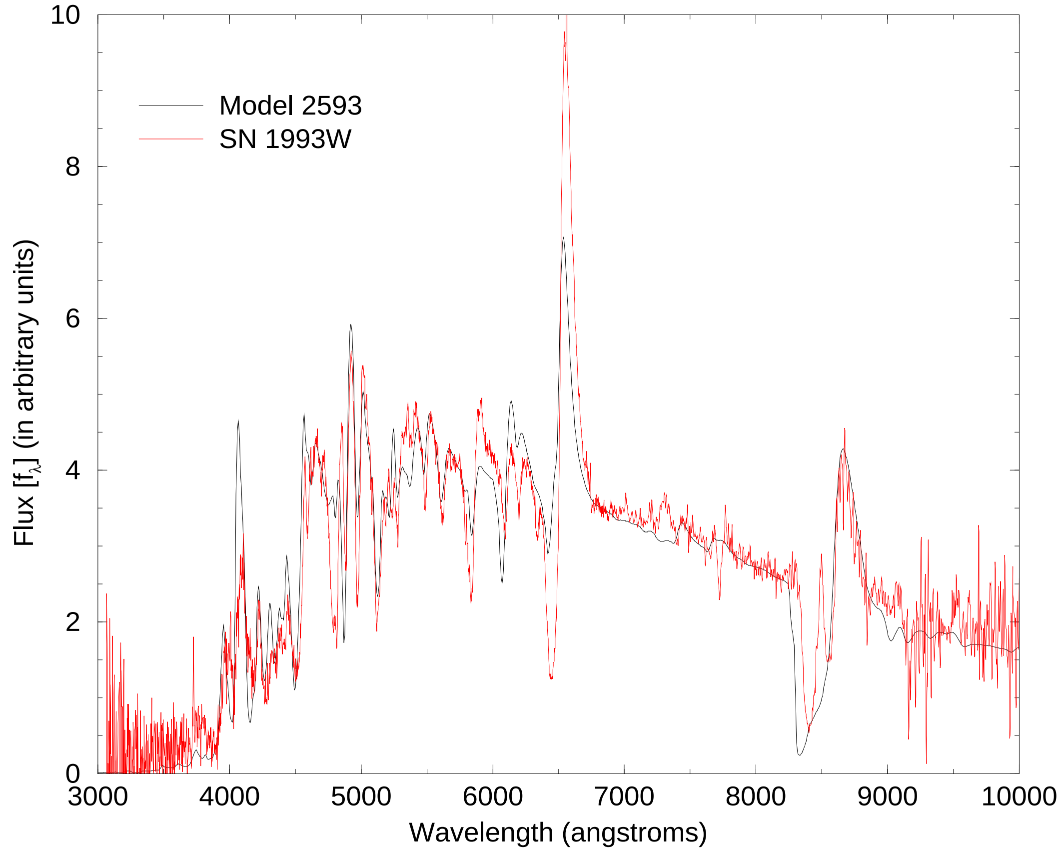

Figure 1: A fit to SN 1993W (courtesy D. Leonard) at roughly 40 days after max.