Improving the Cosmological Utility of Type Ia Supernovae Using the Color–Magnitude Diagram

Supernova Cosmology Project

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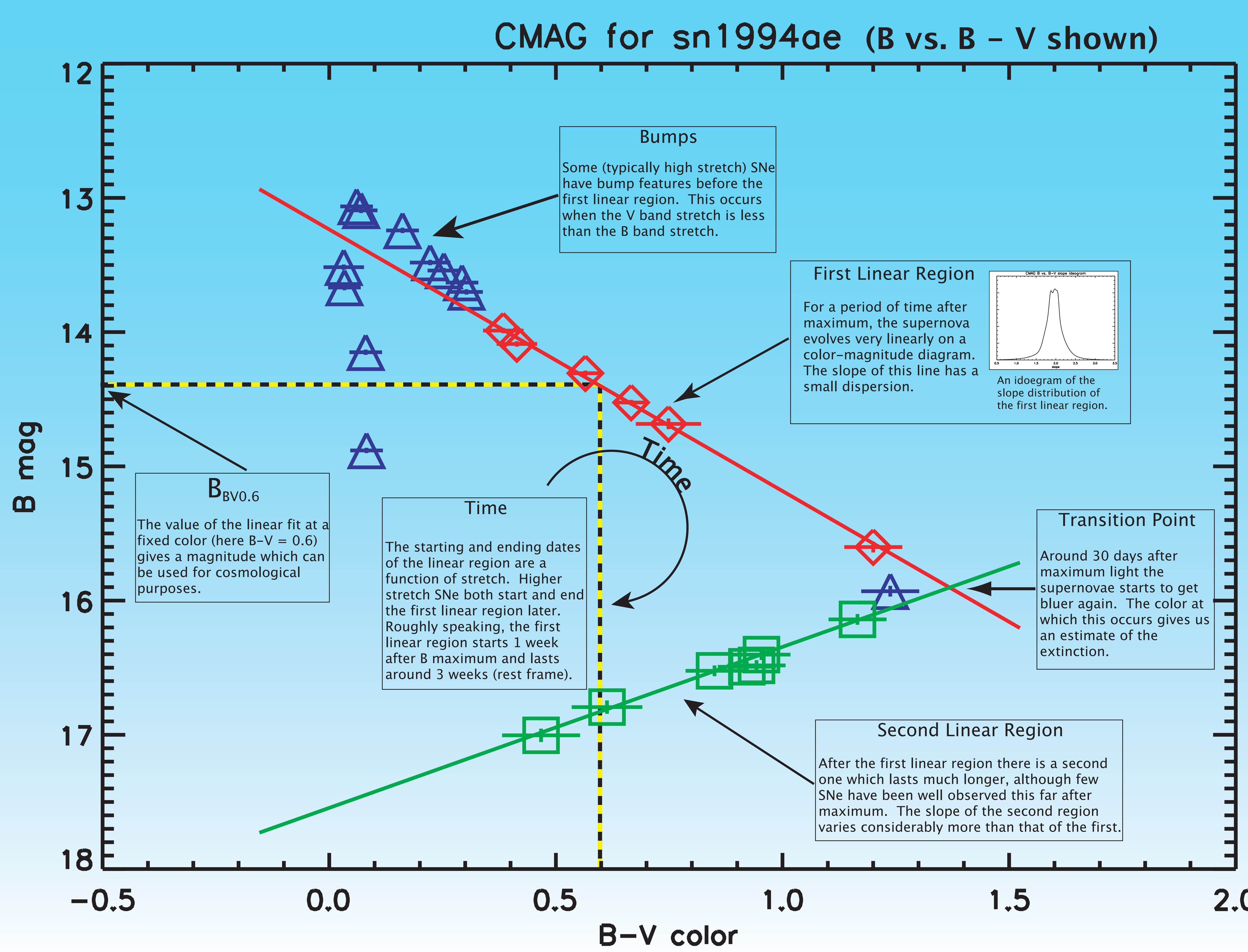
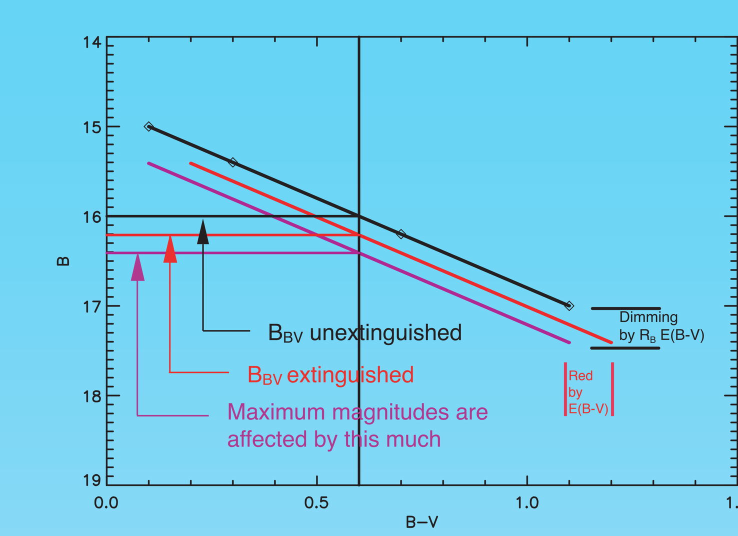
What is CMAGIC?

Type Ia supernovae display a remarkably simple evolution on a Color–Magnitude diagram. Starting about a week after maximum they evolve in an almost perfectly linear fashion in color–magnitude space. A technique that takes advantage of this simplicity is known as CMAGIC (for Color MAGnitude Intercept Calibration). CMAGIC works in many colors. To the right we show the B vs. B–V case for a nearby SNe Ia.

Current lightcurve templates (stretch, MLCS) do not fully reproduce this observed behavior.



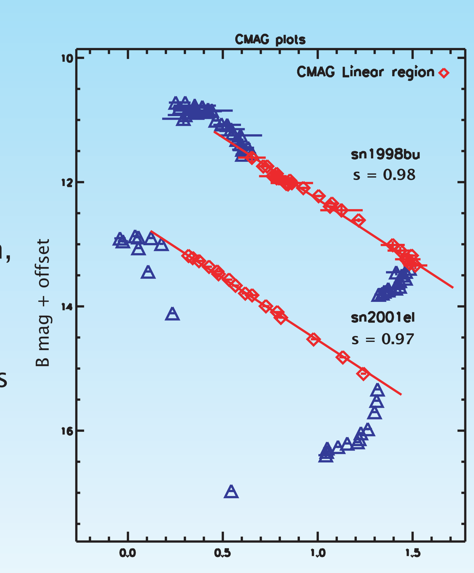
Dust Extinction



Because of the linear relationship, CMAGIC magnitudes are less affected by dust extinction than maximum magnitudes. For standard Milky–Way dust B_{BV} is half as much affected.

Ia's are not a one parameter family

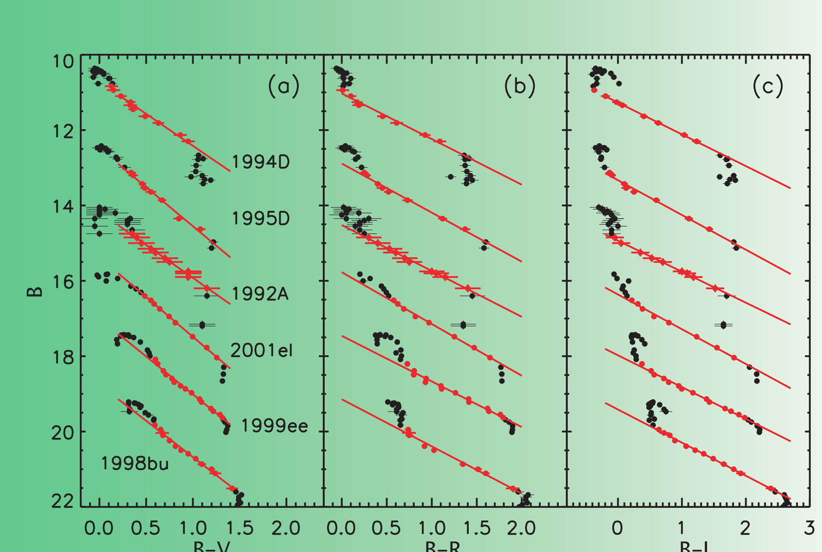
Bumps tell use that Type Ia supernovae do not constitute a 1 parameter family. Shown on the right are two SNe with virtually the same stretch, only one of which has a bump. If SNe Ia were a one parameter family in stretch or Δm_{15}, then this would not be possible.



CMAGIC in Other Colors

There are CMAGIC relations in several other colors as well. To the right we show B vs. B–V, B vs. B–R and B vs. B–I for several Type Ia supernovae. The slope distribution in B–I is particularly tight.

We are attempting to determine the optimum combination of information from all of these colors that minimizes the scatter of SNe Ia around the Hubble line. This will increase the scientific yield of large scale multicolor supernova surveys such as the SNFactory and SNAP.

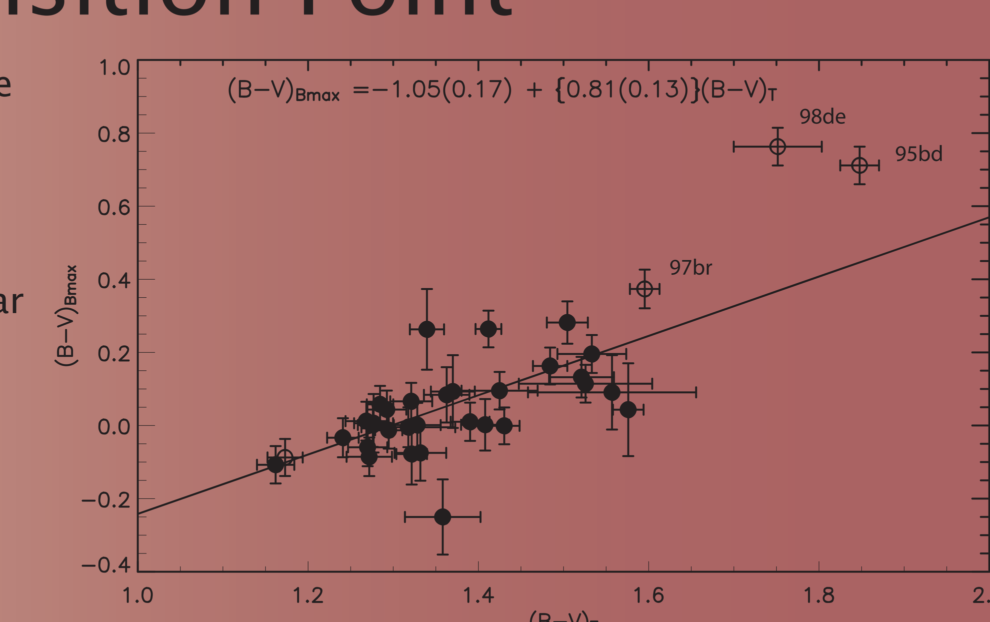


CMAGIC diagrams in several additional colors.

Transition Point

The transition point from the first to the second linear region is interesting for several reasons. It occurs as the SNe transitions to the nebular phase. We define the transition magnitude and color as the point at which the two linear fits intersect.

The color at transition is a measure of the amount of extinction. An unextinguished SNe Ia has a transition color of around B–V=1. The transition magnitude can be converted into a transition date. This date is a linear function of stretch.

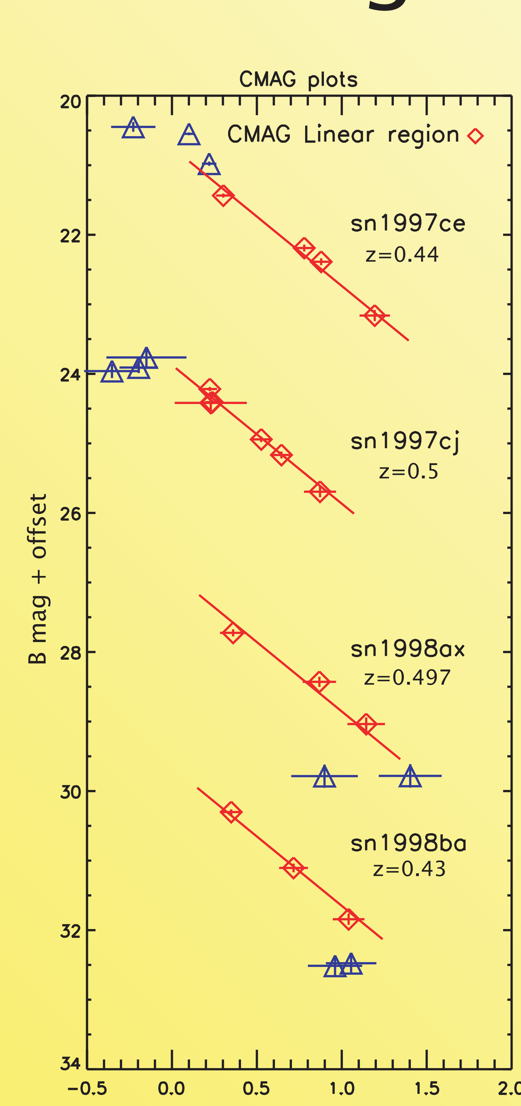


The color at the transition point versus the color at B maximum, another estimator of extinction.

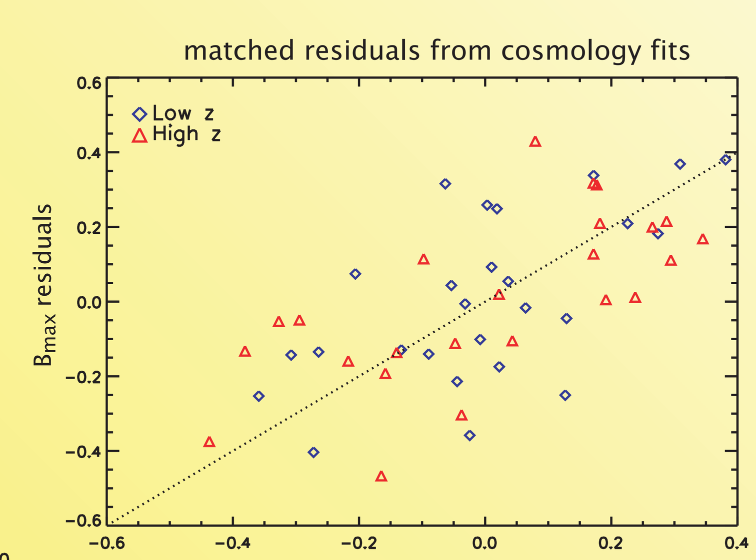
CMAGIC at High Redshift

We are performing a blind analysis of currently existing supernova data sets using CMAGIC. For theoretical reasons we expect CMAGIC to be affected differently by some potential systematics than maximum magnitude fits. Therefore, by comparing the CMAGIC results with maximum magnitude based analyses we can determine if previous cosmological measurements are contaminated by these effects. For example, as shown above, CMAGIC is less affected by host galaxy dust extinction than maximum magnitudes, independent of assumptions about R_V, so if the same results are obtained this will demonstrate that host galaxy dust is not a serious issue with current data sets.

On the right we show some examples of well–observed high redshift SNe Ia. These clearly display the linear behavior that characterizes CMAGIC. Also note that sn1997ce clearly displays a bump.



Comparing the residuals of CMAGIC cosmology fits and maximum magnitude fits argues that extinction from host galaxy dust is not significant in the current high or low redshift sample. If there were significant amounts of dust we would expect the line of correlation to have a slope of 2 rather than the slope of 1 shown here.

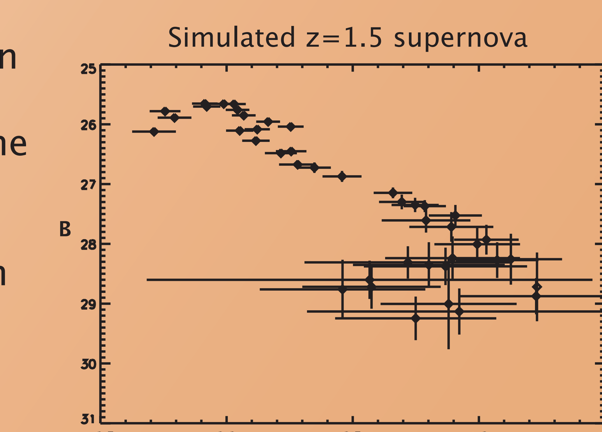


CMAGIC with SNAP

SNAP will excel at CMAGIC. By design it will obtain multicolor photometry with dense time coverage for all of the supernovae it discovers. Here we show simulated light curves at high redshift as SNAP would observe them in B vs. B–V. The first diagram is based on sn1998bu moved to z=1.5 and the second on sn1999ac moved to z=1. The bump feature is clearly discernible even at z=1.5. These simulated data points are not binned.

CMAGIC will both increase the scientific impact of SNAP and provide a means to cross–check various systematic effects. The SNAP data set will be a dramatic improvement over any other current or planned high redshift supernova sample for CMAGIC.

Simulated z=1.5 supernova



Simulated z=1.0 supernova