(1) a C+O white dwarf that accretes from a non-degenerate companion until it reaches the Chandra mass has emerged as the standard model

(2) non-red SNe Ia are excellent distance indicators, and when corrected for a correlation between luminosity and a light-curve width parameter they are even better

(3) the SN Ia diversity is multi-dimensional, so future multi-parameter luminosity corrections should make them better still

(4) SN Ia "evolution" is nothing but progenitor population drift

A CHANDRA-MASS C+O WHITE DWARF AND A NON-DEGENERATE COMPANION

(a) Chandra-mass models (with suitably parameterized nuclear flames) can account for SN Ia light curves and spectra

(b) sub-Chandra "helium ignitor" models don't give good light curves and spectra; super-Chandra white dwarf mergers may be too rare, and may collapse to form neutron stars

(c) massive accreting white dwarfs are observed (supersoft X-ray sources; recurrent novae)

(d) simulations of mass transfer in single-degenerate binary systems indicate that they can grow white dwarfs to the Chandra mass

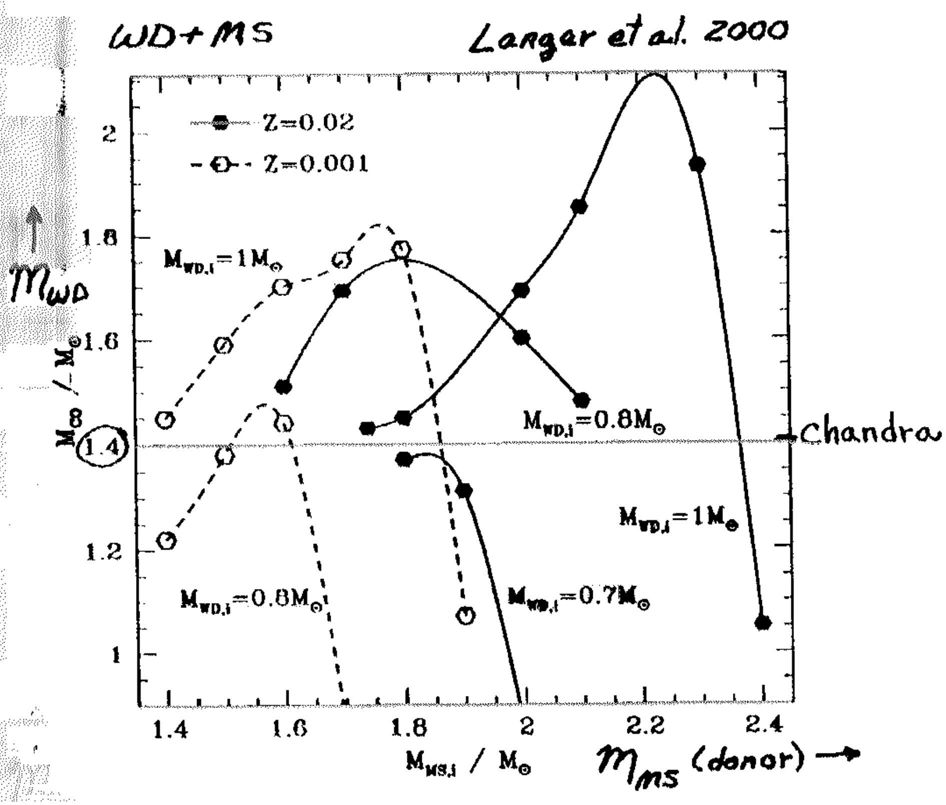
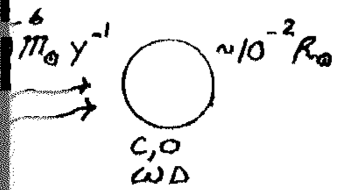


Fig. 14. Maximum achievable CO-core masses as function of the initial mass of the main sequence star, for various initial white dwarf masses and for the two metallicities considered here, as indicated (cf. also Figs. 13 and 17).

SNe Ia standard model



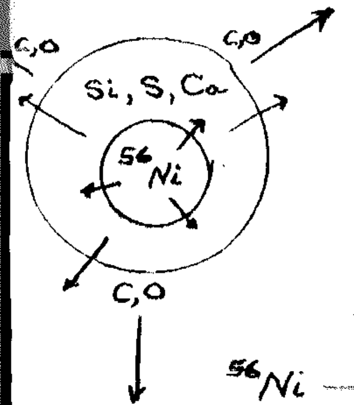
$m_{wd} \to 1.4\, m_\odot$

$\rho_c \approx 10^9\ g\ cm^{-3}$, $T_c \sim 10^9 K$

thermonuclear runaway

and nuclear flame

⇓



$v \propto r$, $v(Si) \simeq 10{,}000\ km\ s^{-1}$

$E_K = E_n - E_b \simeq 10^{51}$ erg

$T \propto R^{-1} \Rightarrow$ photon dud

but

$$^{56}Ni \xrightarrow[\gamma]{6^d} {}^{56}Co \xrightarrow[\gamma, e^+]{77^d} {}^{56}Fe$$

delayed energy input reheats the gas

fusion makes it explode,

radioactivity makes it shine,

luminosity depends mainly on m_{Ni}

Sorokina et al. 2000

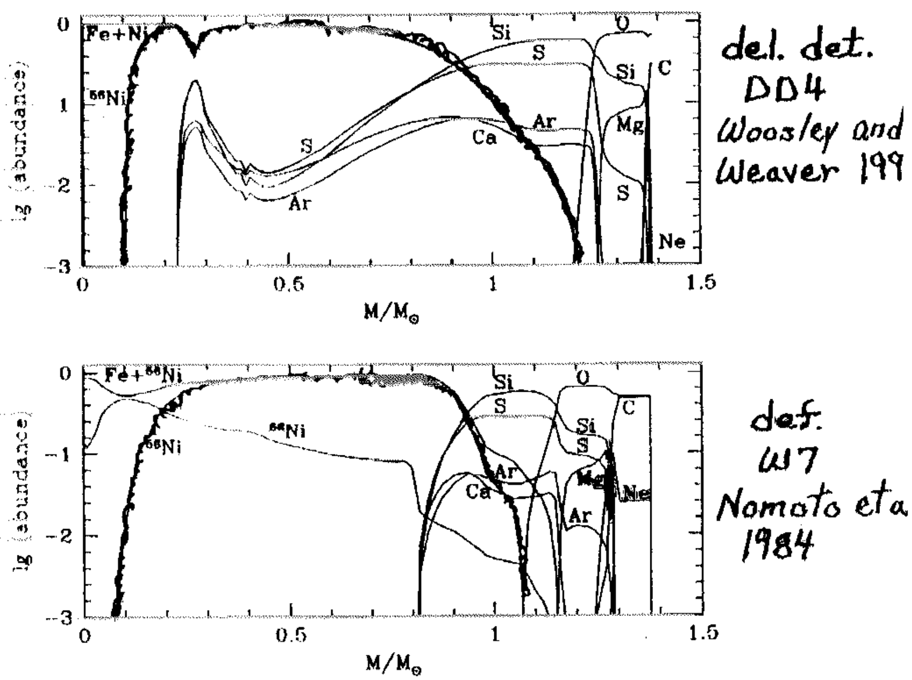


Figure 2: The distribution of the most abundant chemical elements throughout the ejecta for DD4 (top) and W7 (bottom).

SOME POSSIBLE CAUSES OF DIVERSITY

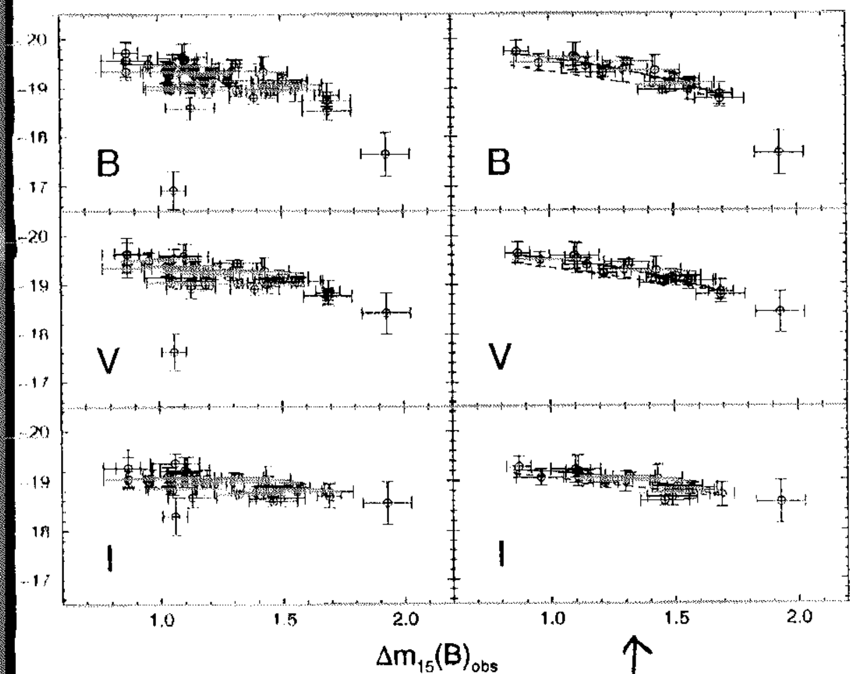
(a) the white dwarf C/O ratio depends on the main sequence mass of the white dwarf progenitor, and affects the nuclear/hydro

(b) the white dwarf central density depends on the history of the accretion rate, and affects the nuclear/hydro

(c) the white dwarf rotation rate depends on how much angular momentum is accreted, and may raise the Chandra mass and affect the nuclear/hydro

(d) the metallicity Z affects the SN line blocking

Phillips et al. 1999

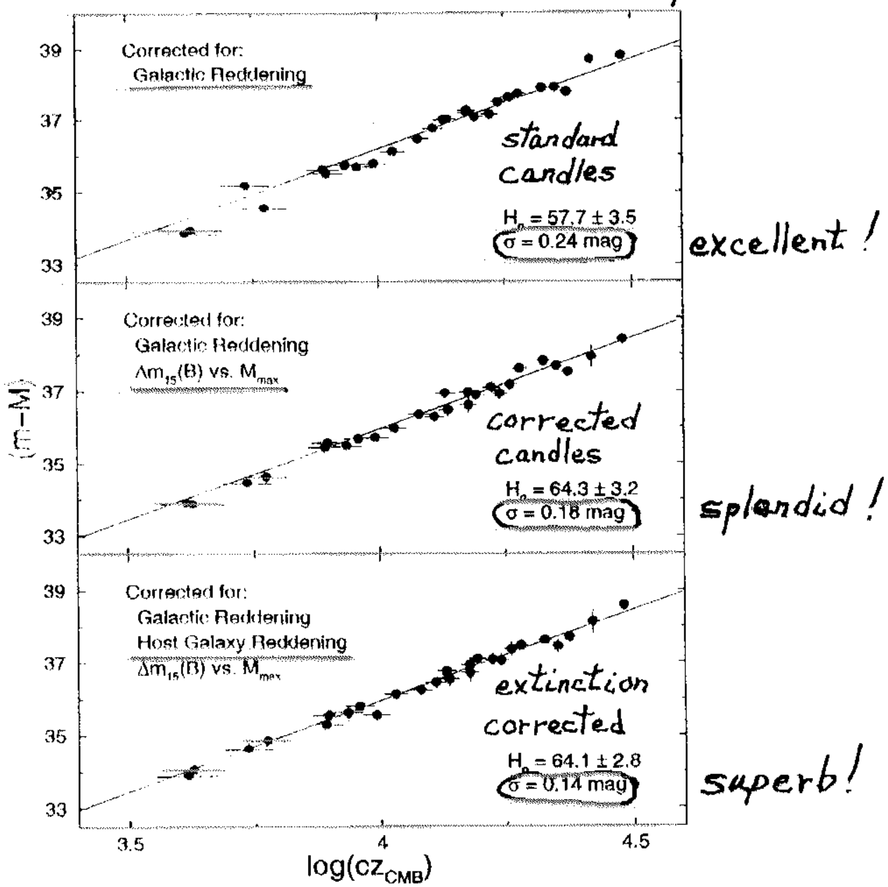


non-red SNe Ia

Phillips *et al.* Figure 8

non-red SNe Ia in the Hubble diagram

Calan/Tololo "Low Extinction" Sample Phillips et al. 1999



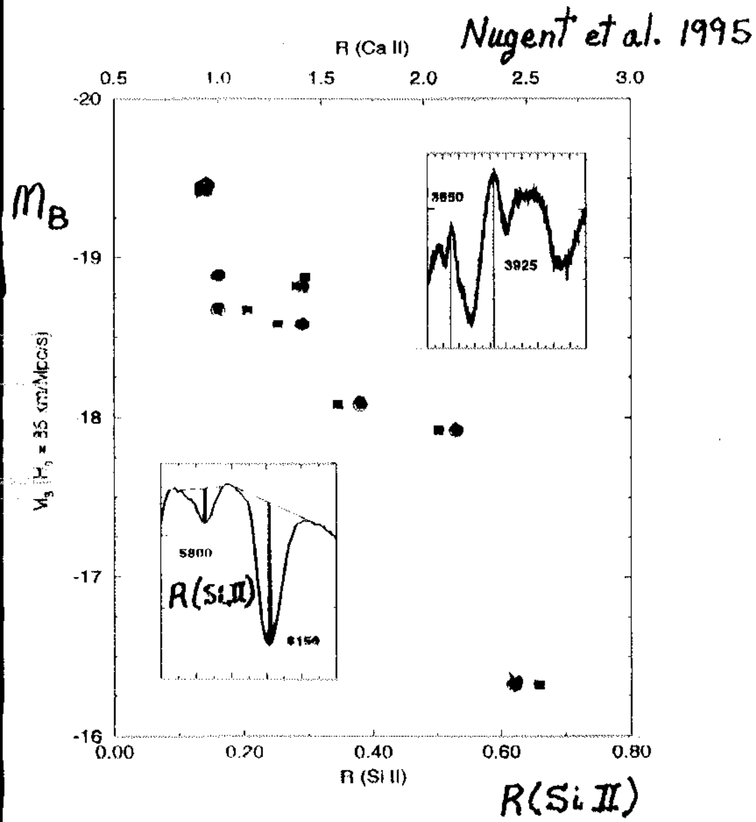
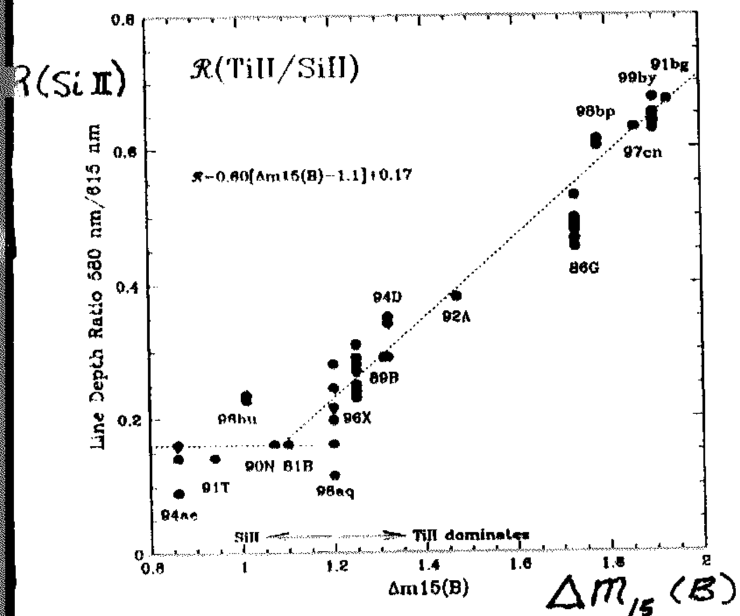


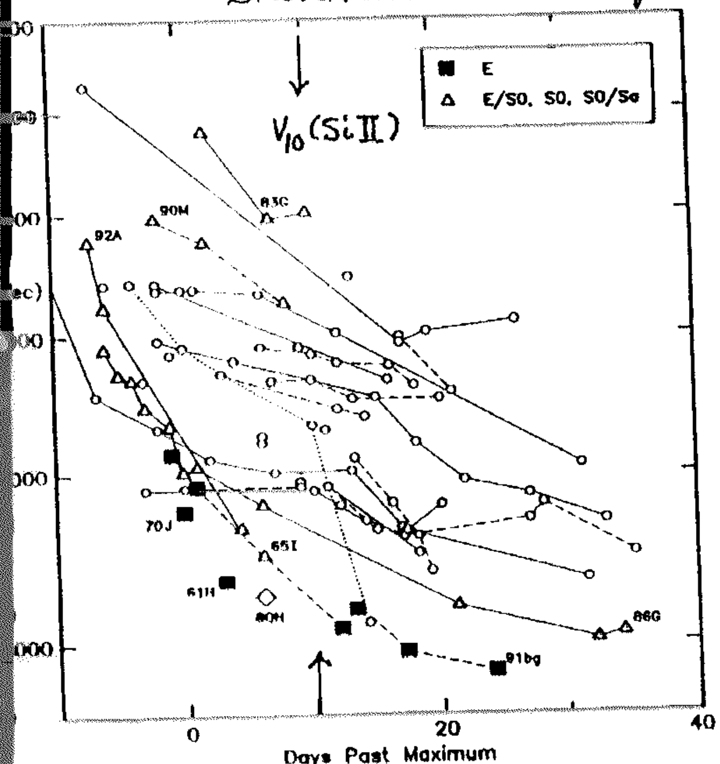
Fig. 2 — Observed M_B vs. $\mathcal{R}$(Si II) (open circles) and $\mathcal{R}$(Ca II) (filled squares). The inset graphs illustrate how the ratios were measured. Error estimates can be found in Table 1

Garnavich et al. 2002



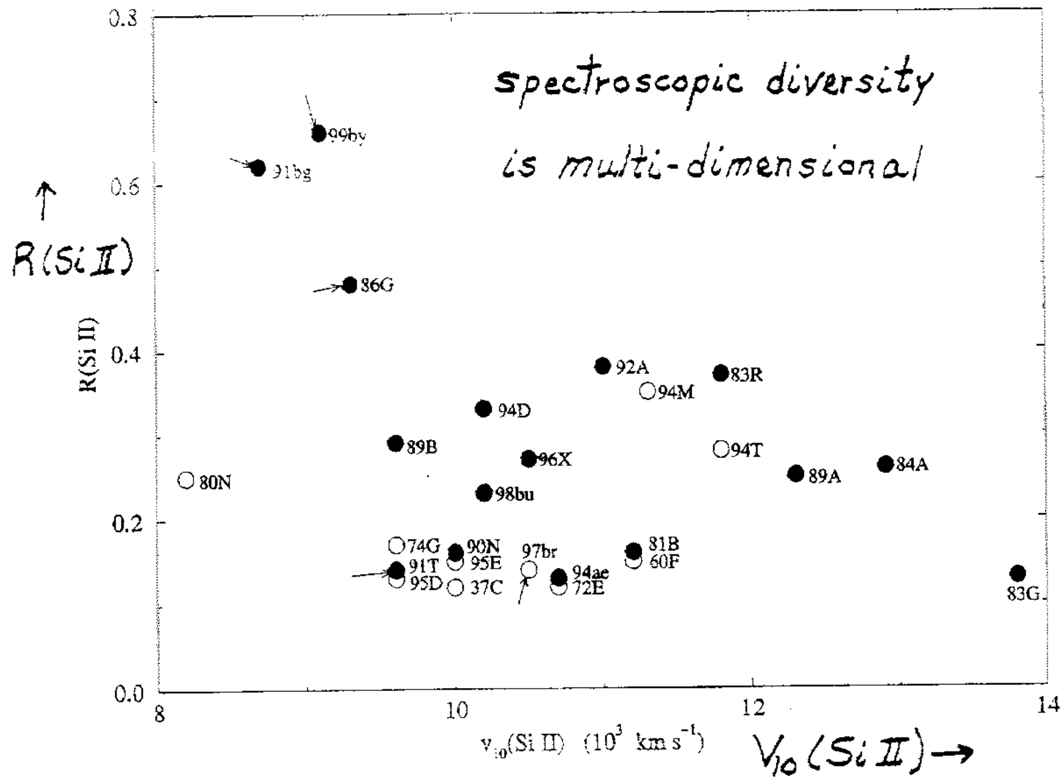
4. -- Ratio of 580 nm to 615 nm line depth for 15 supernovae. Each point represents ividual spectrum and the data is restricted to ±3 days from B_{max}. The fit applies to ovae with $\Delta m_{15}(B) > 1.2$. For $\Delta m_{15}(B) < 1.2$ the line ratio is dominated by Si II and a good indicator of luminosity, decline rate or temperature.

Branch and van den Bergh 1993



1. Plot of the blueshift of the λ6355 Si II feature vs epoch of ·vation for the supernovae listed in Table 1. Supernovae in elliptical ·ies are seen to fall along the lower edge of the observed distribu- SN 1980N, which occurred in the Sa pec galaxy NGC 1316, is ·n as an open diamond.

Hatano et al. 2001



CANDIDATES FOR MULTI-PARAMETER LUMINOSITY CORRECTIONS

The following observables have not yet been accurately measured for enough SNe Ia in the Hubble flow. Some of these (or others) may prove to be useful for making luminosity corrections.

Photometric: the rise time; the peak/tail ratio

Spectroscopic: R(Si II); V_{10}(Si II); UV features

SN Ia "EVOLUTION" IS NOTHING BUT PROGENITOR POPULATION DRIFT

Number counts, for example, evolve with time in a way that cannot be determined by making observations of the local universe.

SN Ia evolution is different, because the properties of an SN Ia depend directly on the properties of its progenitor, not on the age of the universe. Overlap in the properties of low-z and high-z progenitors is expected, so luminosity corrections established for low-z events should also apply to high-z events. SNe Ia that have the same photometric and spectroscopic characteristics should have the same luminosities.