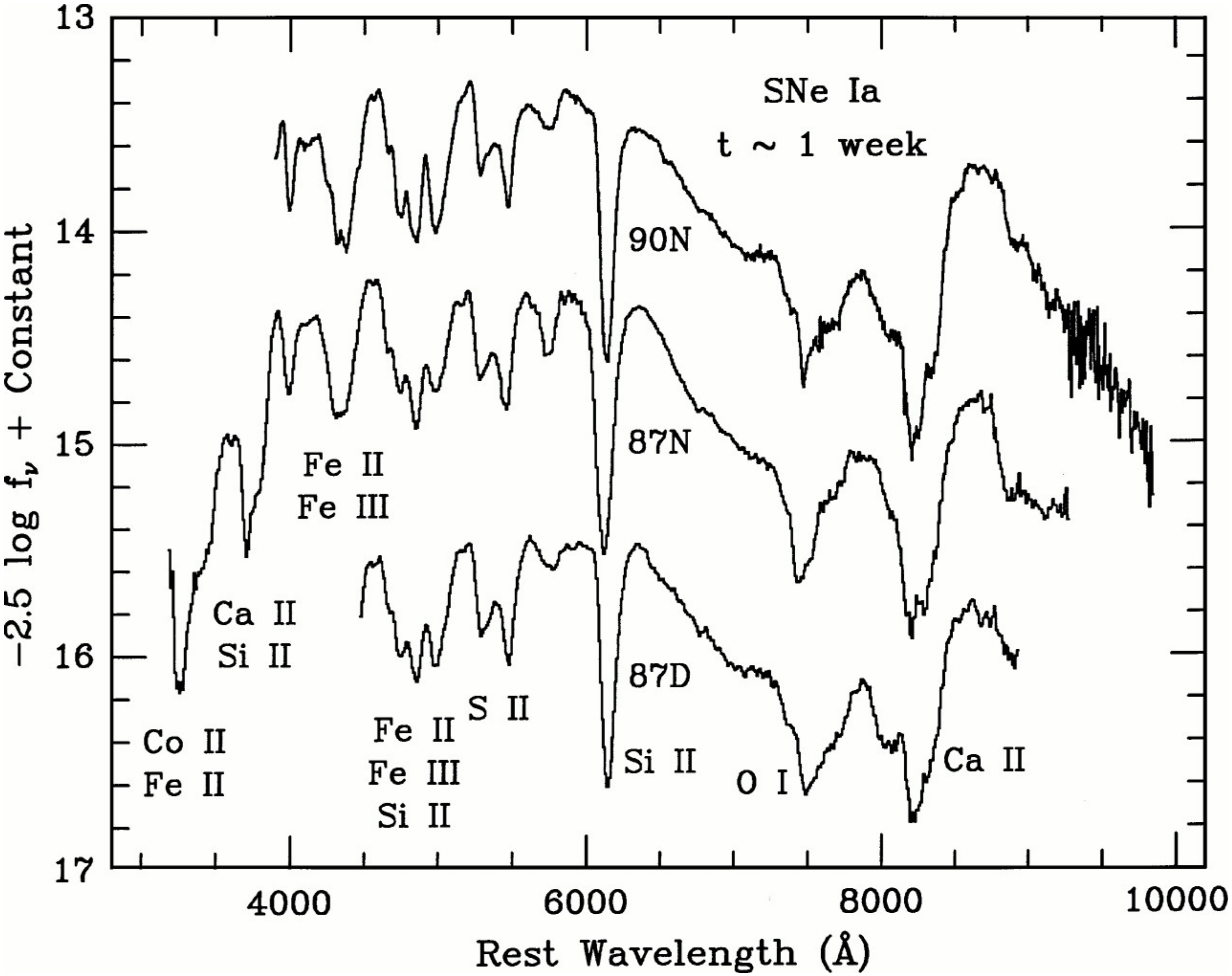
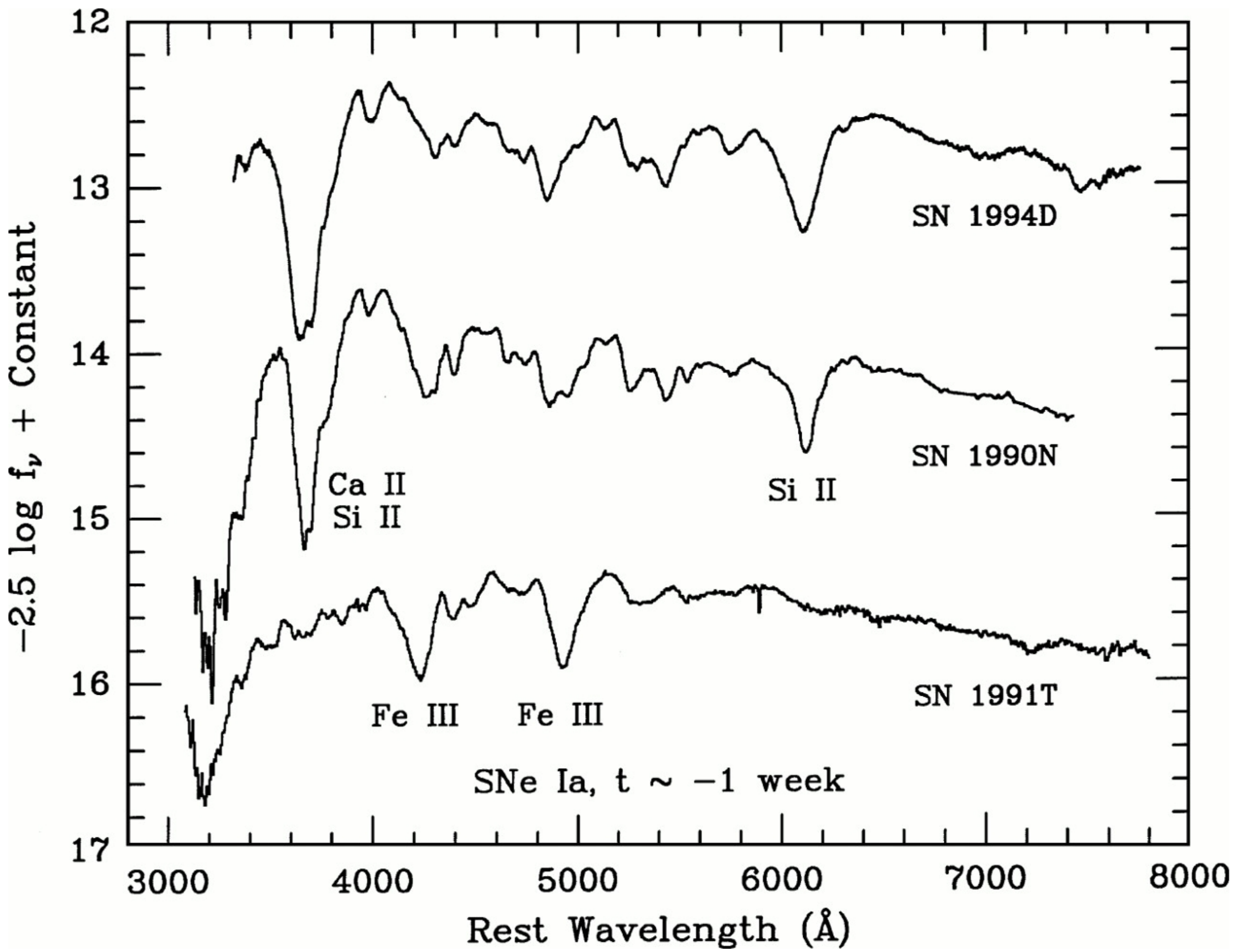
Type Ia supernovae = thermonuclear explosions

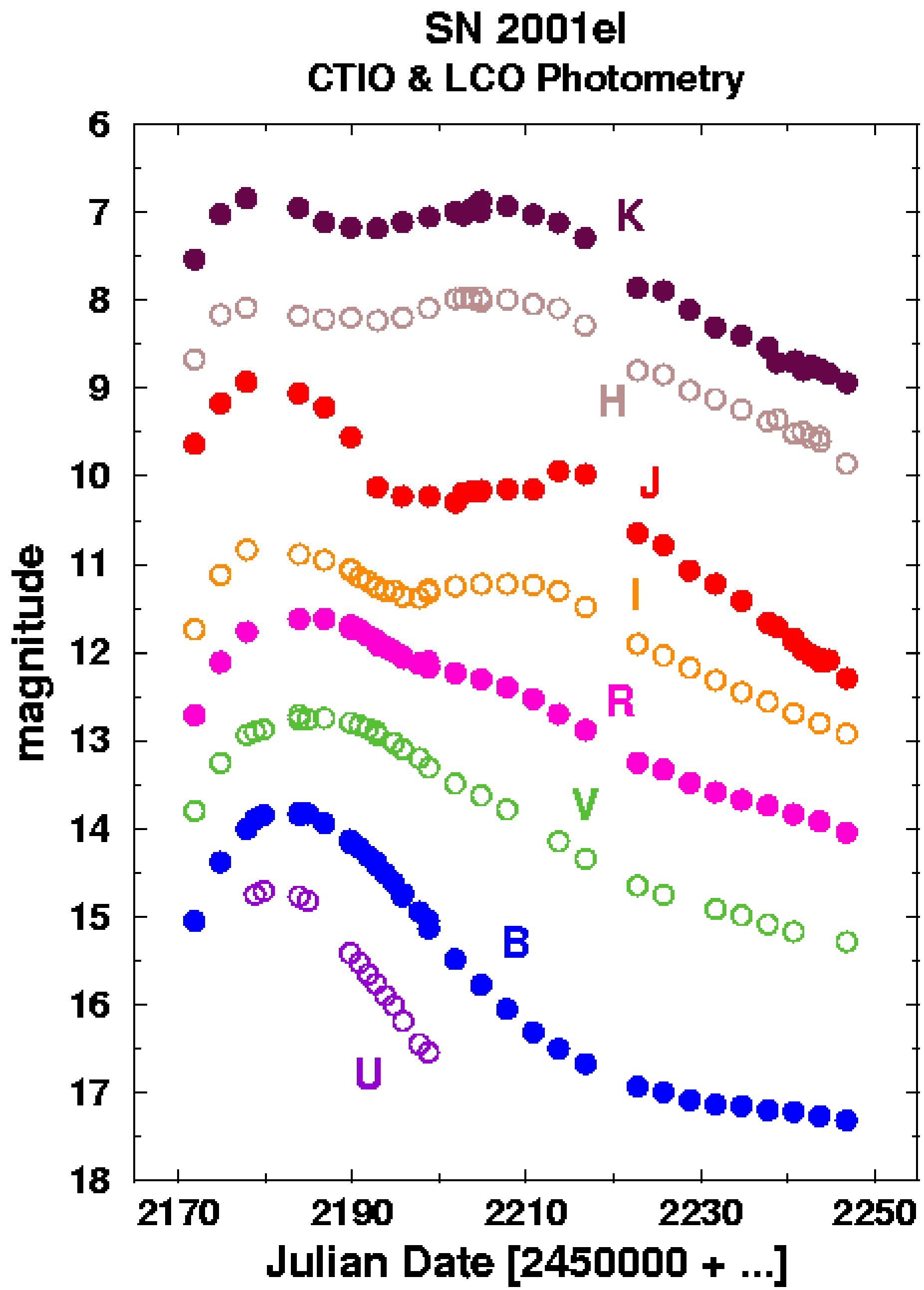
Homogeous spectra



Exceptions



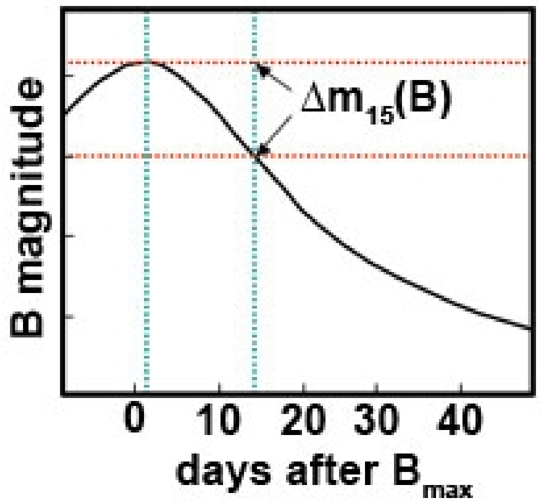
SN 1994D
SN 1990N
SN 1991T
Ca II
Si II
Si II
Fe III
Fe III
SNe Ia, t ~ −1 week
−2.5 log f_ν + Constant
Rest Wavelength (Å)
12
13
14
15
16
17
3000
4000
5000
6000
7000
8000



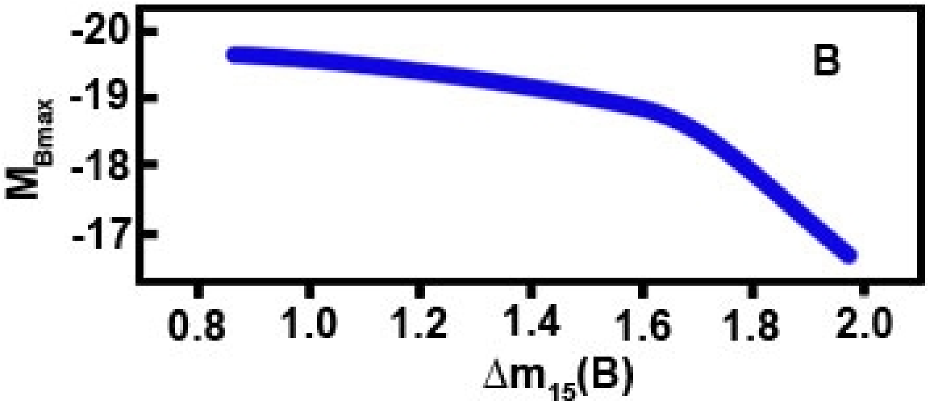
SN 2001el
CTIO & LCO Photometry
magnitude
Julian Date [2450000 + ...]
6
7
8
9
10
11
12
13
14
15
16
17
18
2170
2190
2210
2230
2250
K
H
J
I
R
V
B
U

Bump in IR

Delta m_{15}

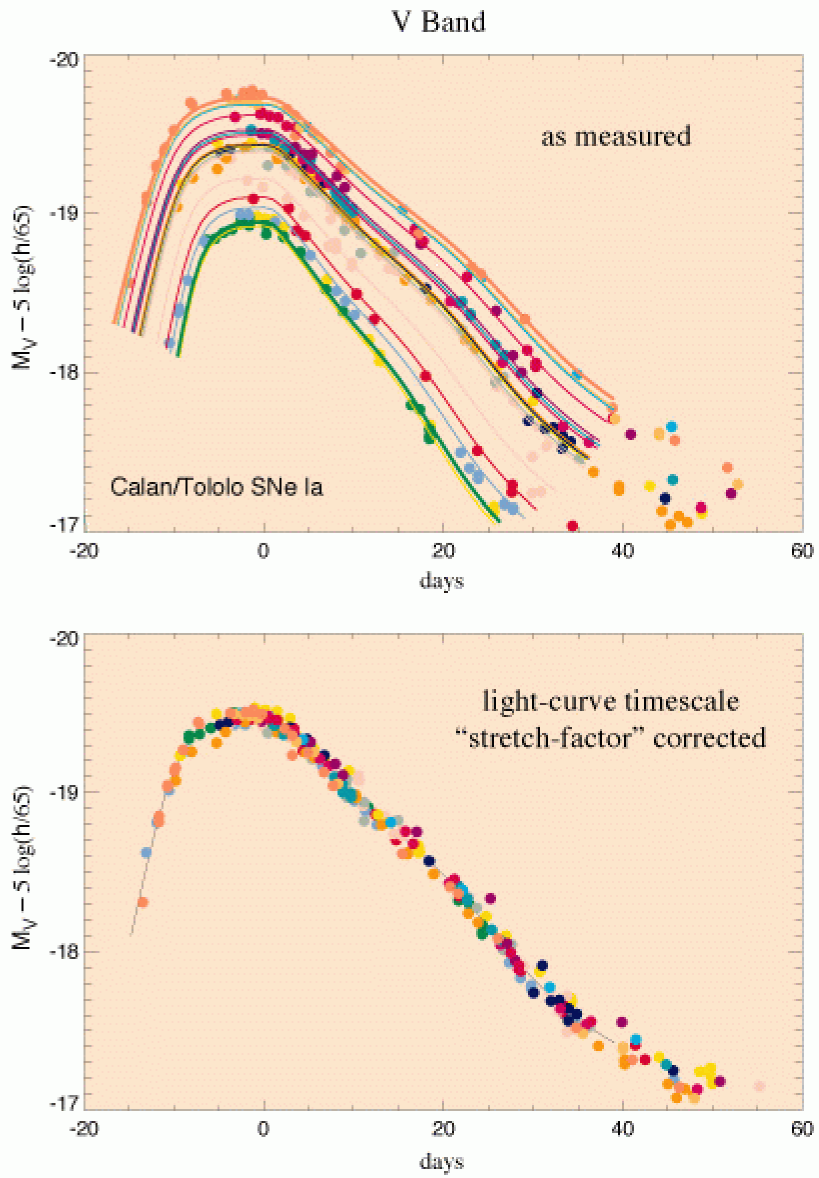


B magnitude
Δm15(B)
0
10
20
30
40
days after Bmax



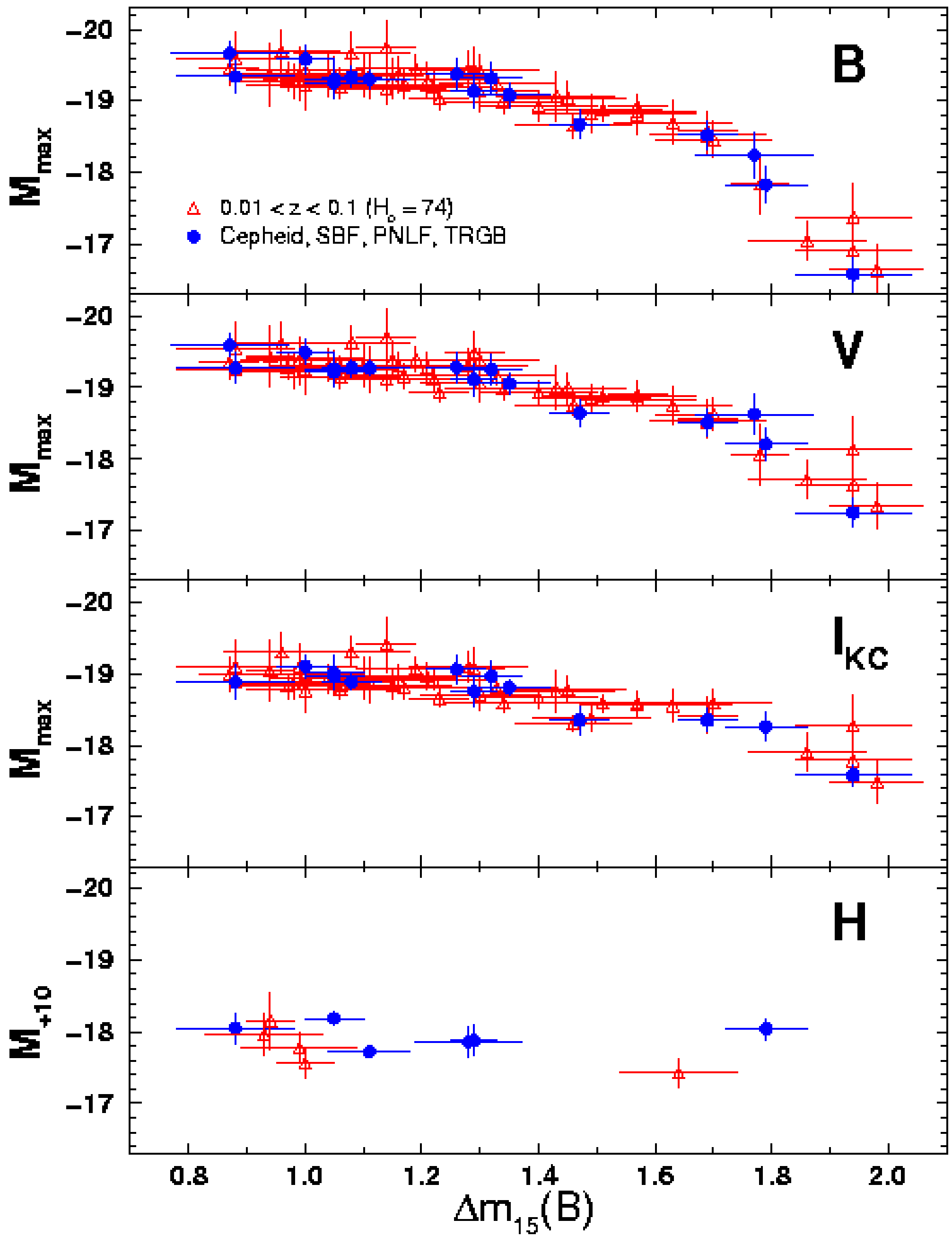
MBmax
-20
-19
-18
-17
B
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Δm15(B)

Low Redshift Type Ia Template Lightcurves

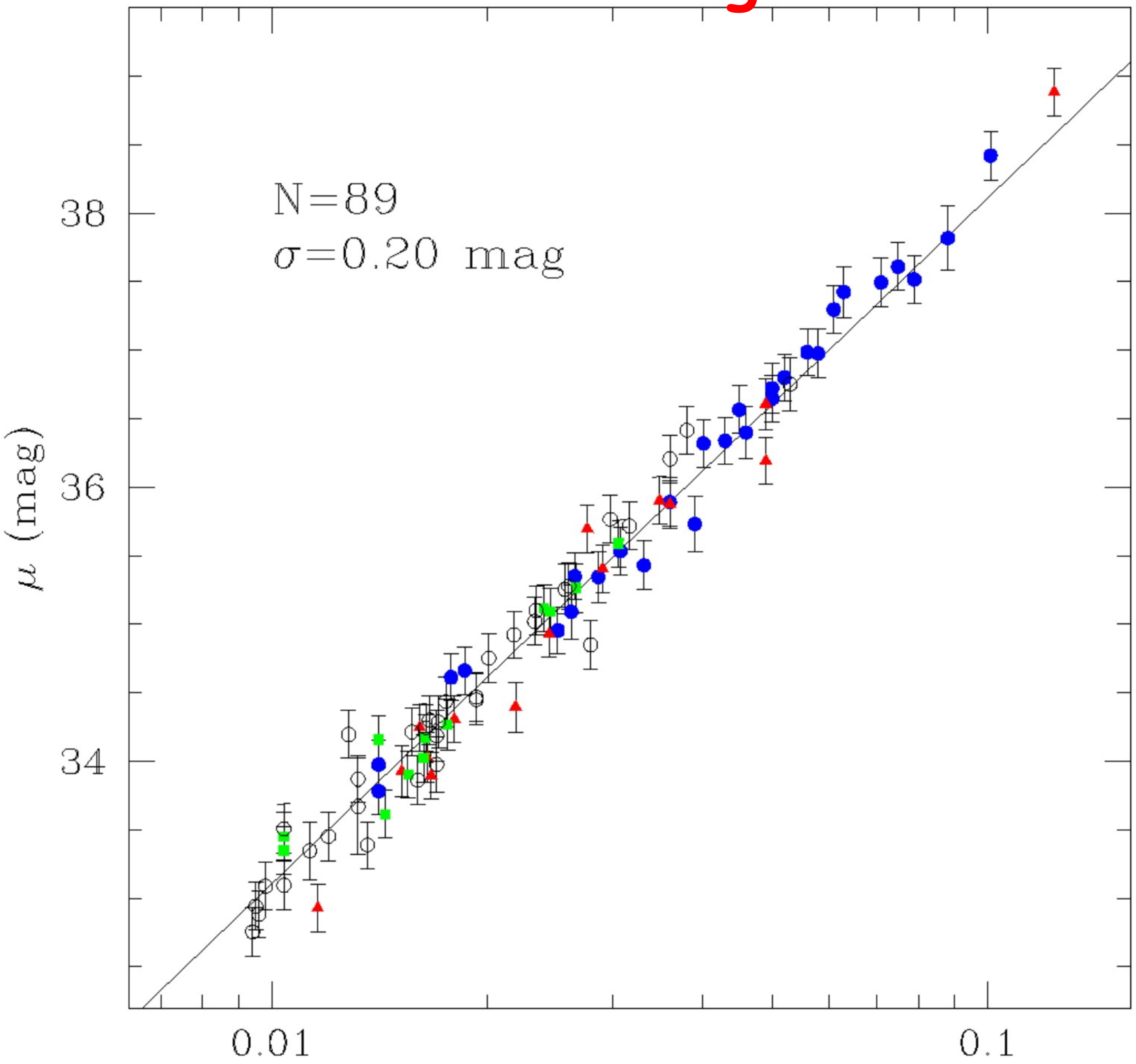


Stretch factor
Delta m15
MCLC

Philips relation



Hubble diagram



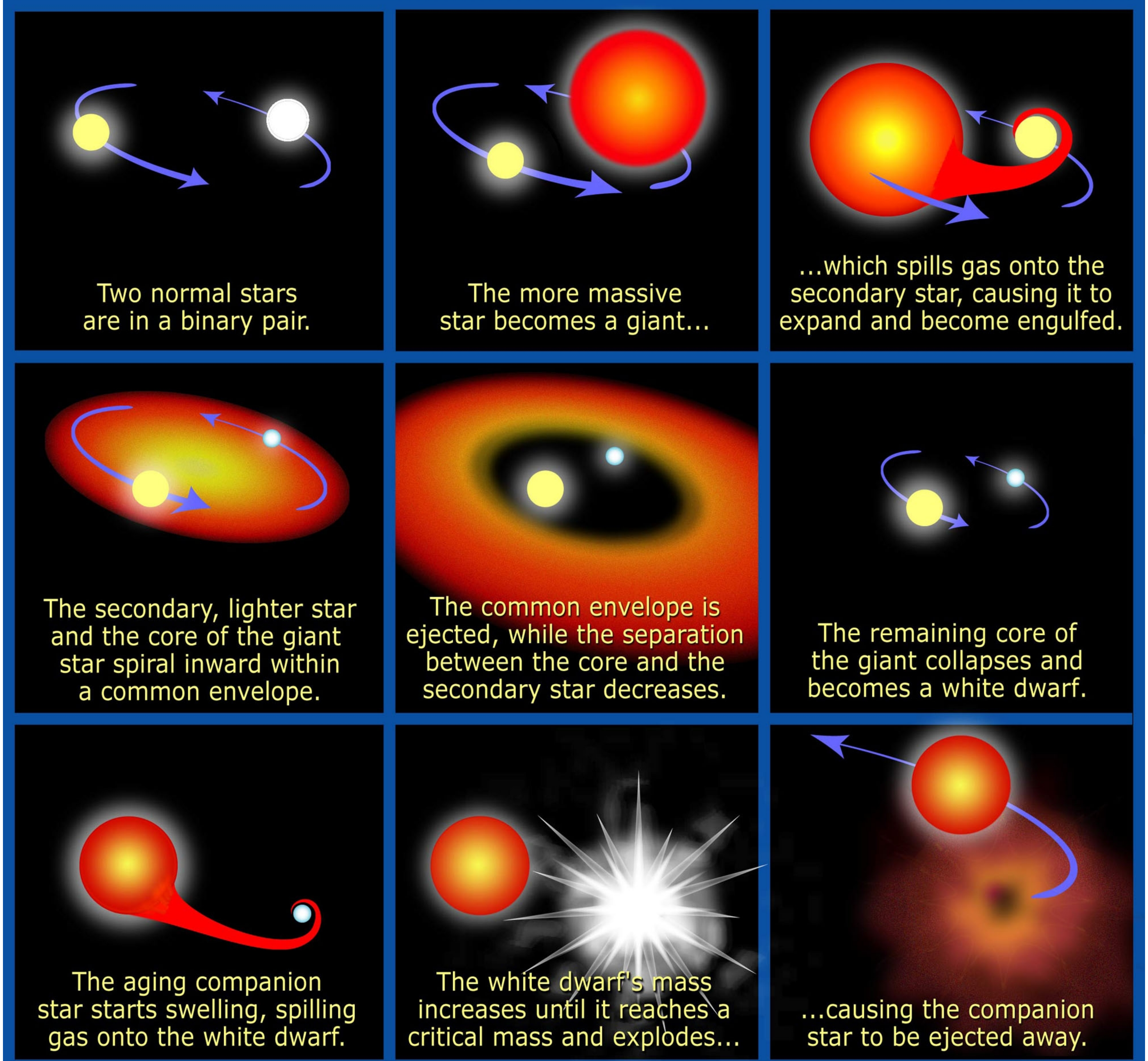
Type Ia progenitors

I. Double degenerate = merging binary white dwars

II. Single degenerate = white dwarf + MS or red giant

Only one progenitor known = Tycho

The progenitor of a Type Ia supernova



Explosion mechanism

Thermonuclear burning of C/O white dwarf as $M > M_{Chandra}$

Burning to NSE = ^{56}Ni

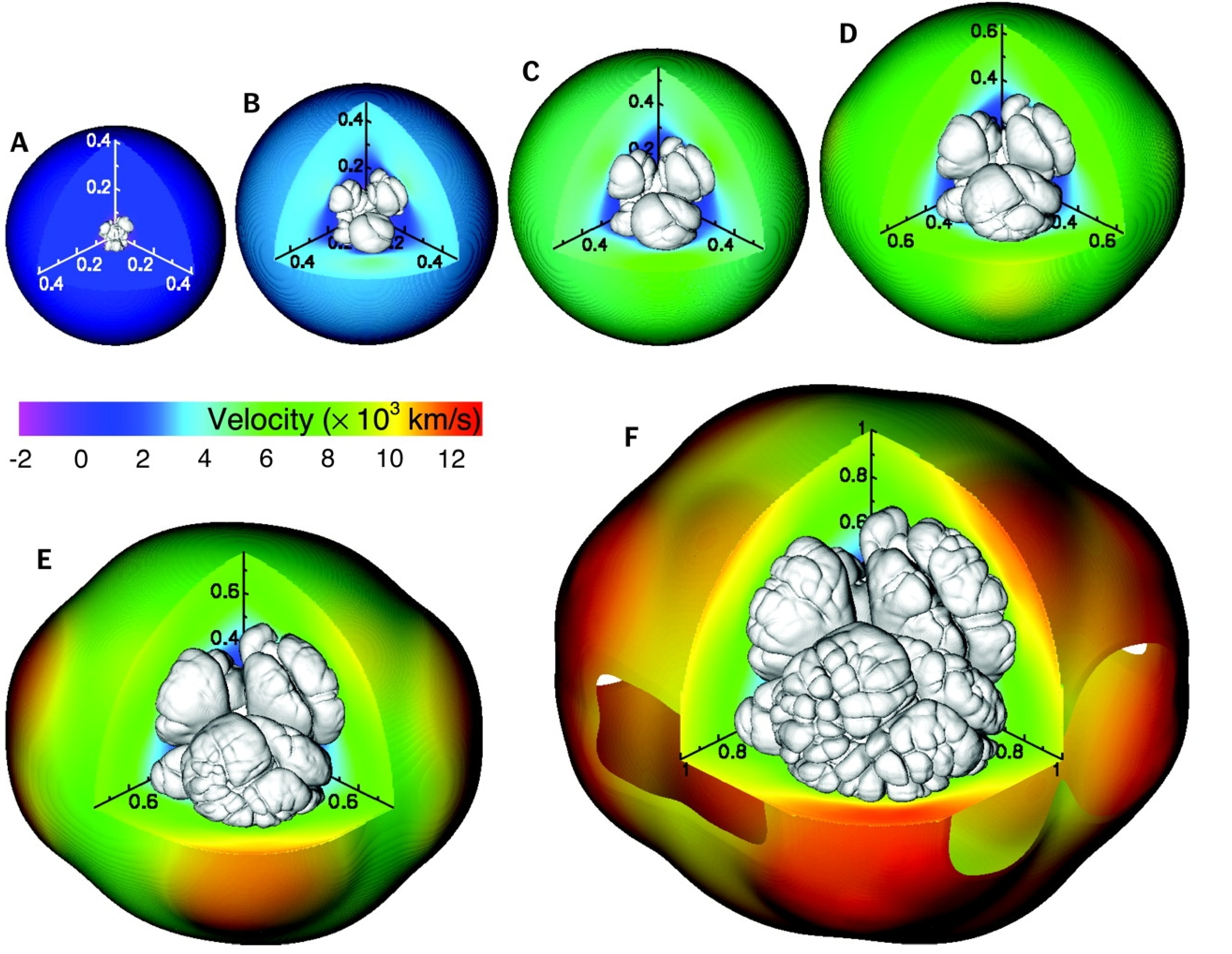
I. Deflagration = subsonic burning front. WD expands $\Rightarrow$ density decreases $\Rightarrow$ only center to NSE $\Rightarrow$ C, O, Mg, Si, Ca on outside

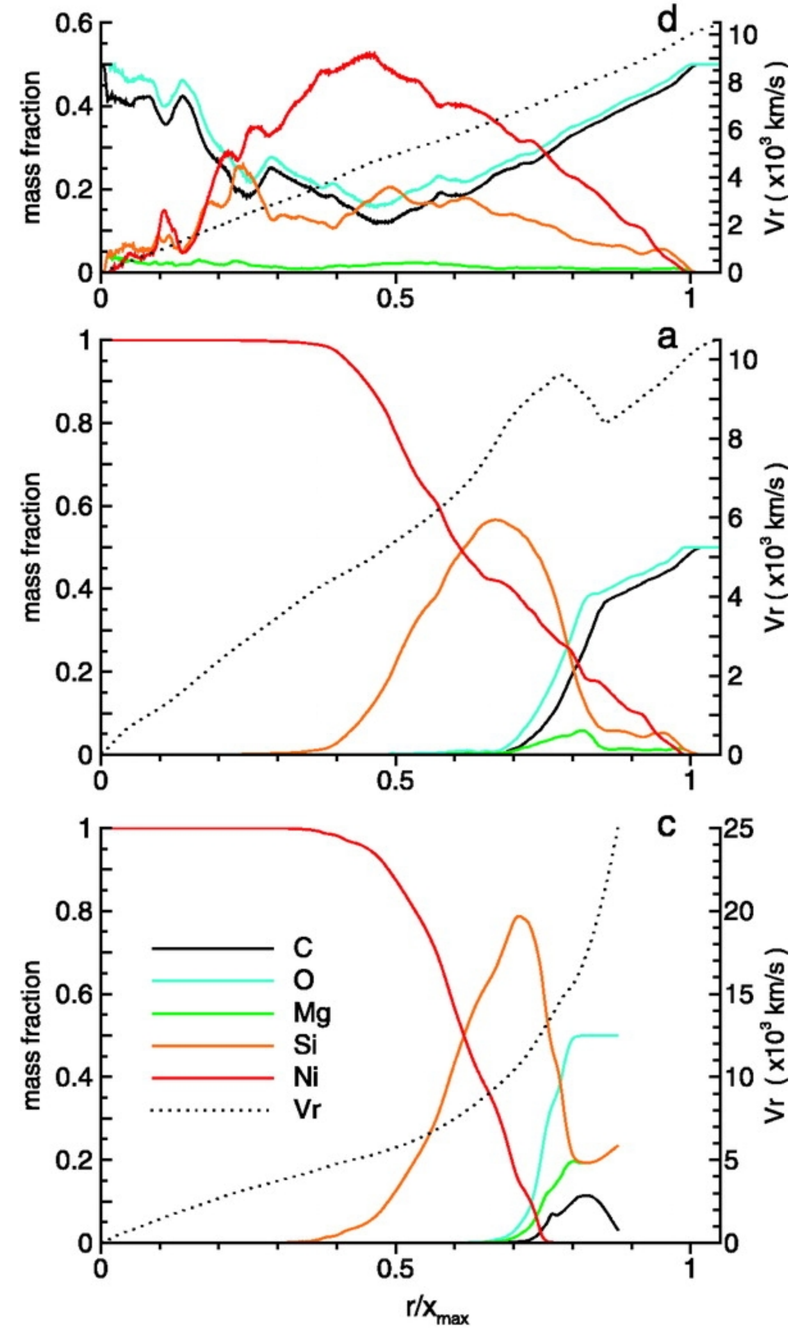
II. Detonation = supersonic burning front. WD does not have time to expand $\Rightarrow$ whole star to NSE $\Rightarrow$ ^{56}Ni only

Observations: Lines of Si, Mg, ... at high velocity

No C/O at low velocity

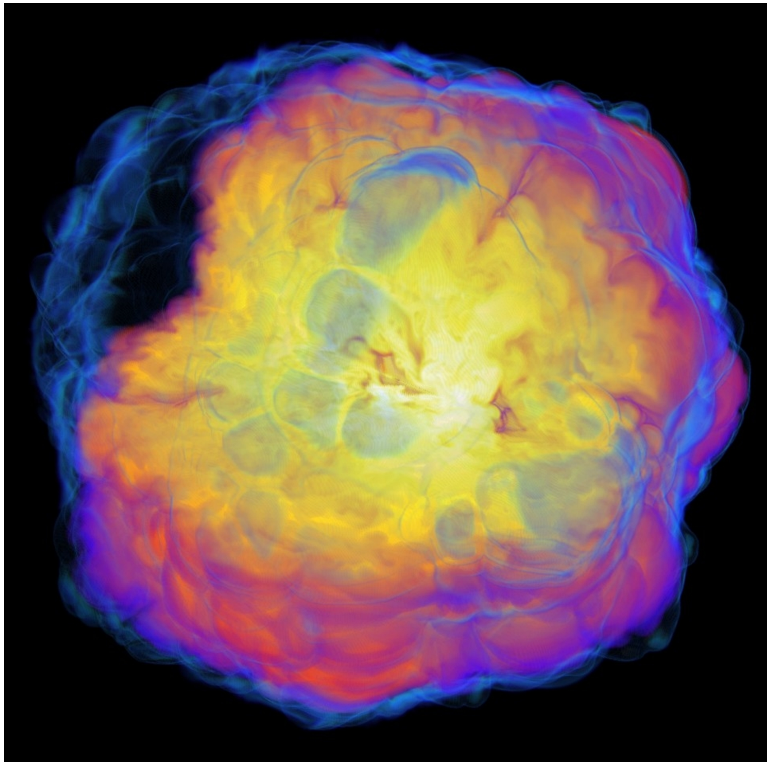
Delayed detonation

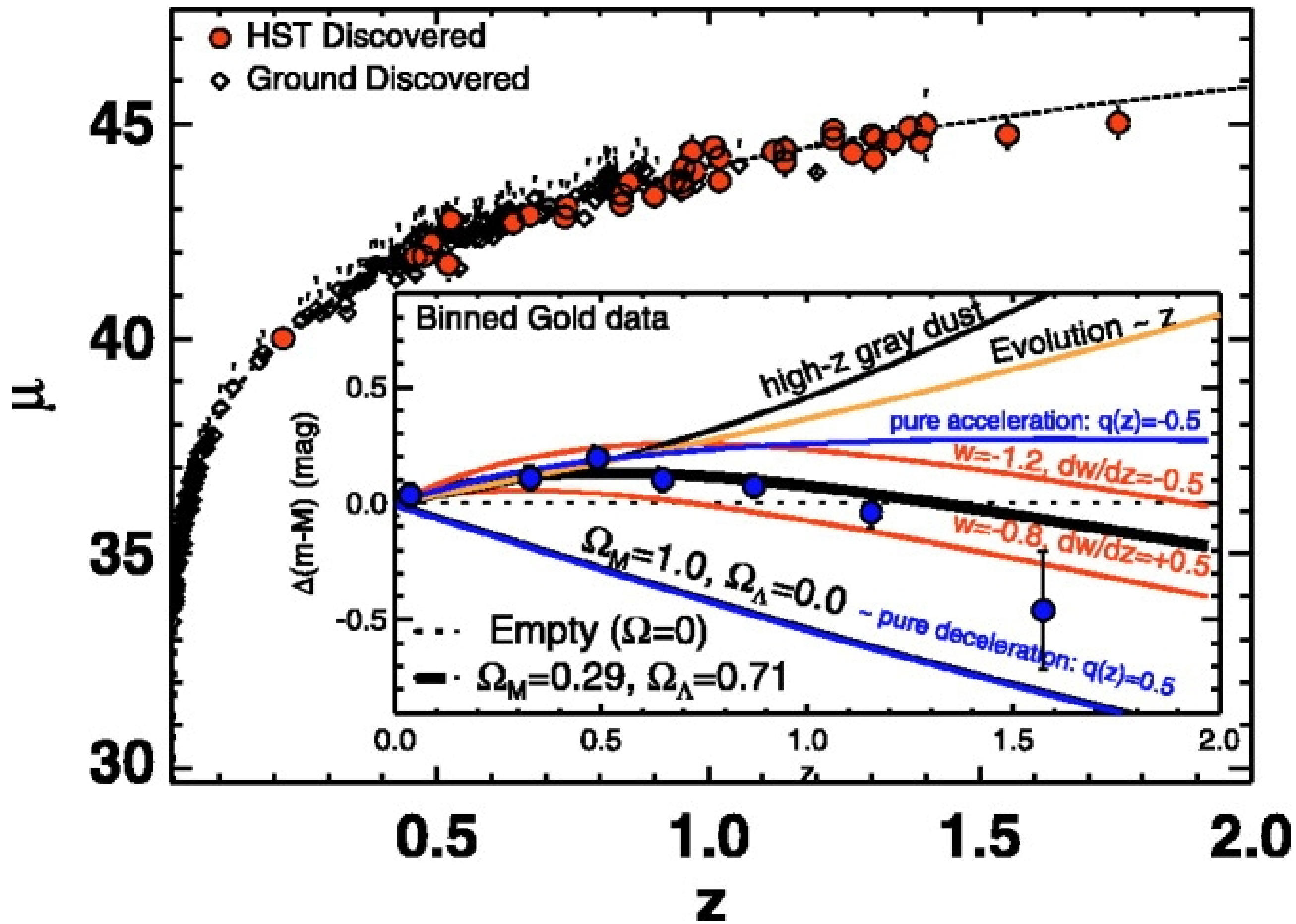

A
B
C
D
E
F
Velocity (× 10^3 km/s)
-2 0 2 4 6 8 10 12
0.2
0.4
0.6
0.8
1



Deflagration

Delayed det.





Riess et al 2006

Systematic effects?

1. Dust extinction. Use IR and elliptical galaxies

2. Evolutionary effects: C/O ratio depends on metallicity.
   Explosion energy depends on C or O.

3. Different progenitors? Some in star forming galaxies,
   some in ellipticals.

4. Contamination by Type Ib/c SNe

No strong indications of evolutionary effects are found

Hubble diagram in IR

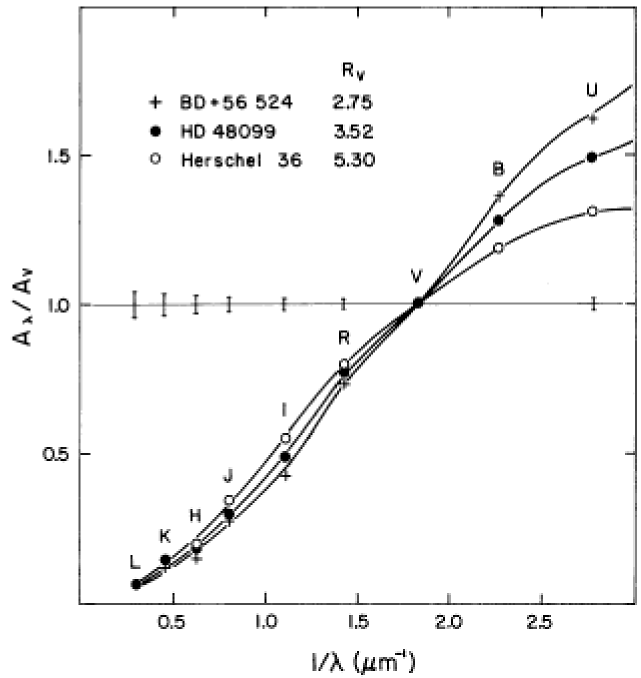
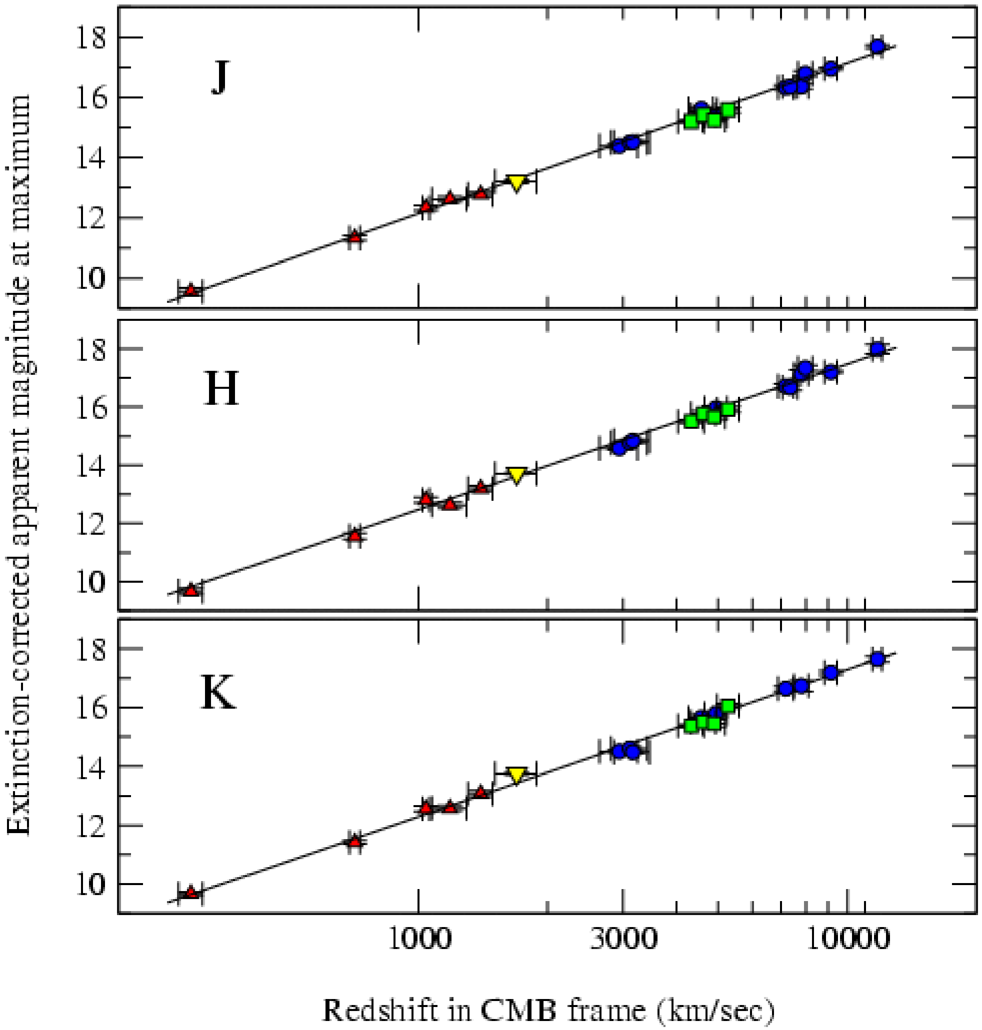


FIG. 3.—Comparison between the mean optical/NIR R_V-dependent extinction law from eqs. (2) and (3) and three lines of sight with largely separated R_V values. The wavelength position of the various broad-band filters from which the data were obtained are labeled (see Table 3). The "error" bars represent the computed standard deviation of the data about the best fit of $A(\lambda)/A(V)$ vs. R_V^{-1} with $a(x) + b(x)/R_V$ where $x \equiv \lambda^{-1}$. The effect of varying R_V on the shape of the extinction curves is quite apparent, particularly at the shorter wavelengths.



Conclusions

1. We do not know the progenitors
2. We do not understand the explosion mechanism
3. Type Ias are still good standard candles