The Environments of High and Low Luminosity SNe Ia

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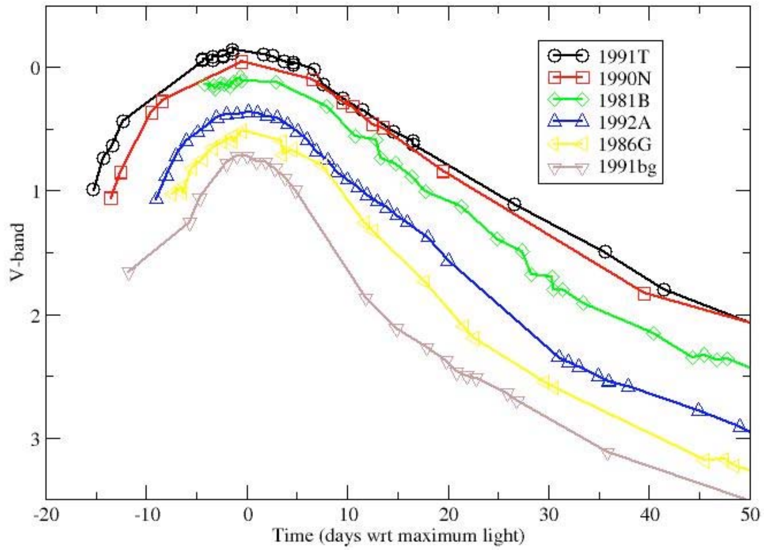
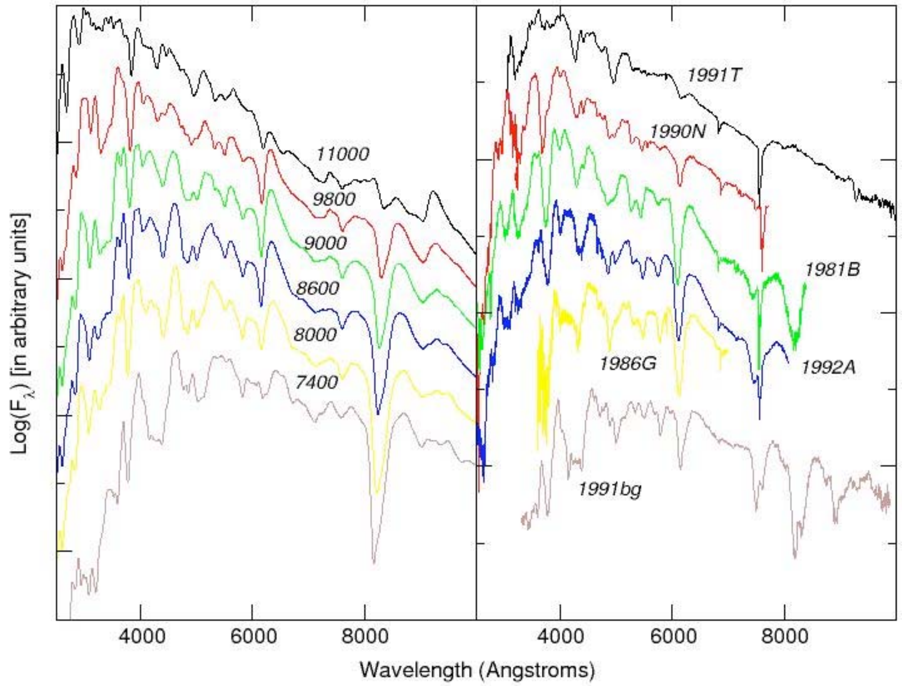
Lightcurves and Spectra

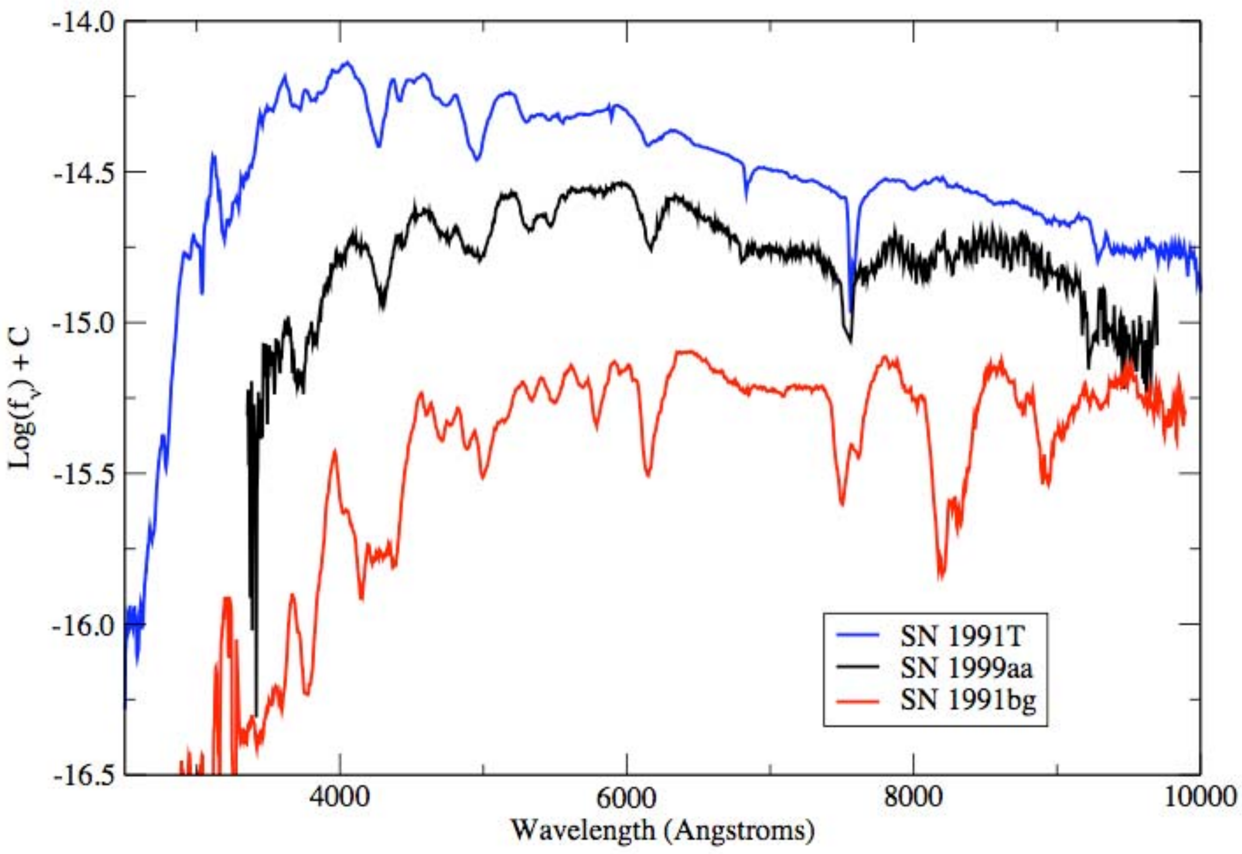


LCS: Broader are brighter

Spectral Sequence:
Brighter are hotter



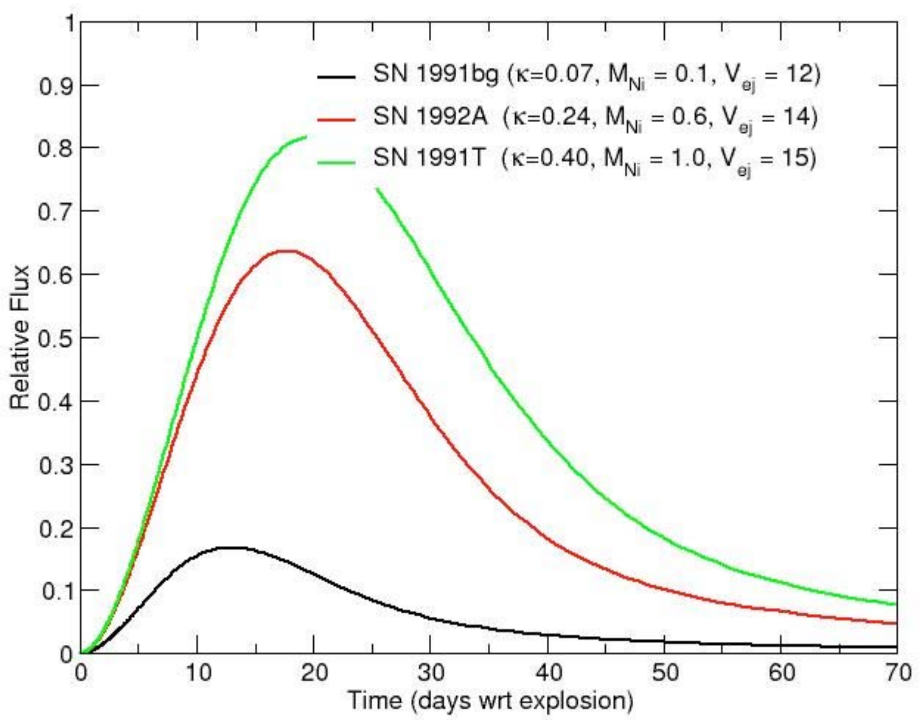
The Extremes



Fe III @ peak
t_{rise} ~ 22 d.

Ti II @ peak
t_{rise} ~ 12 d.

Lightcurves and Spectra



Brighter SNe Ia are hotter due to more Ni^{56}. This increases the opacities due to Fe-peak lines. This increase in opacity makes the lightcurves broader as the SN can trap photons more effectively.

SN Ia Energetics

Where does a SN get its velocity from?

Three sources and sinks of Energy in a SN Ia are balanced by the following equation,
Kinetic Energy = Nuclear Energy - Binding Energy

Or:

$$\frac{1}{2} M_{WD} V_{KE}^2 = E_{nuc} - E_{bin}$$

SN Ia Energetics

Some interesting results from this:

For $V_{KE} > 0$ then $E_{nuc} > E_{bin}$.

$E_{bin} \sim 0.5$ foe (foe = 10^{51} ergs) for a WD with $M = M_{CH}$

Thus, $E_{nuc} > 0.5$ foe to have an explosion

$E_{nuc} = 1.55$ foe/$M_{\odot}$ of ^{56}Ni and 1.18 foe/$M_{\odot}$ for Si-group

So we need to make at least 0.3 $M_{\odot}$ of ^{56}Ni, or some combination of Ni and IME material, to get an explosion.

SN Ia Energetics

Subluminous SNe Ia:

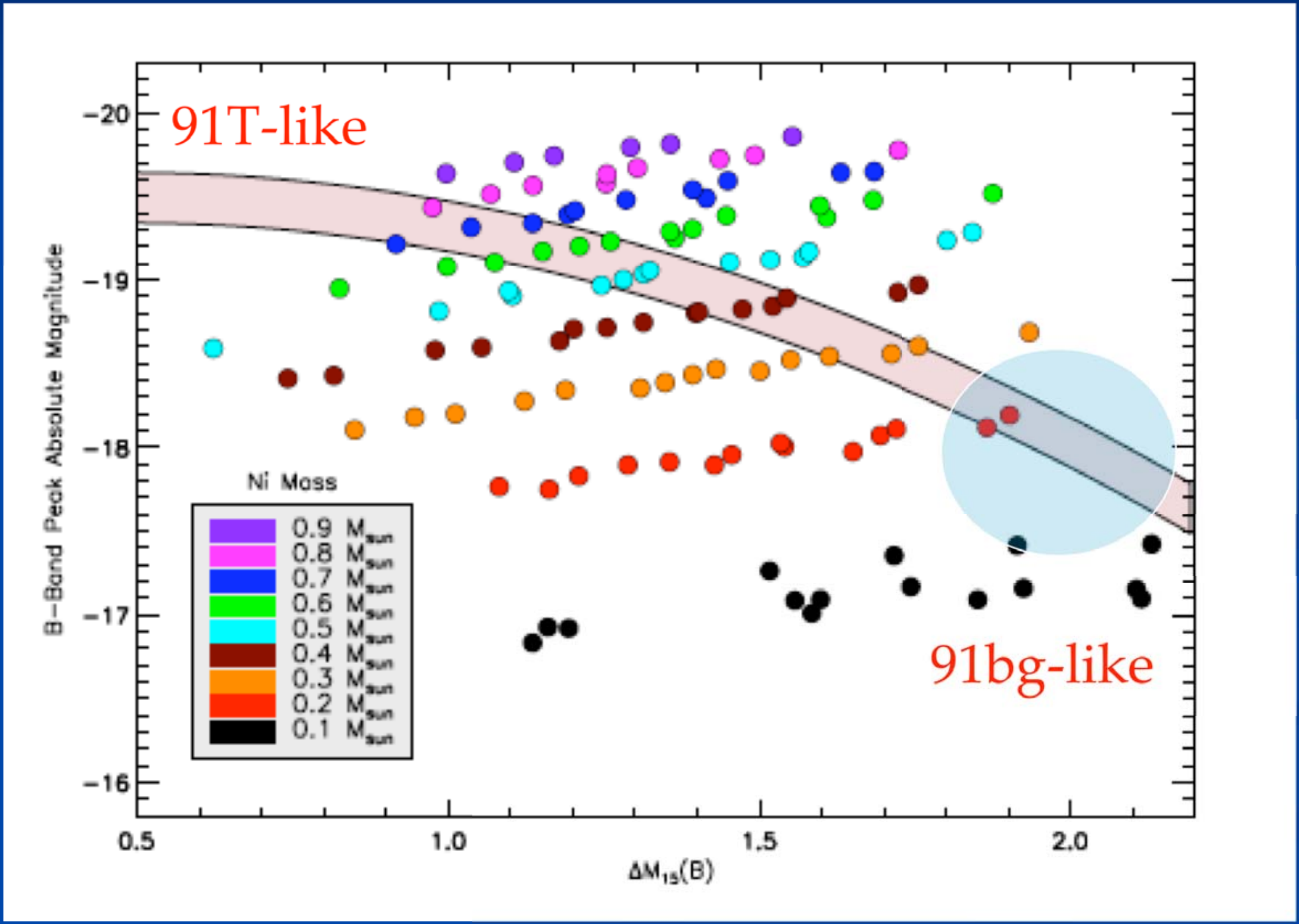
SN 1991bg has M_B = -17.25 and a rise time of only 12 days (stretch = 0.6 for this class of SN Ia). This implies that it made ~0.07 $M_\odot$ of ^{56}Ni.

How much of the rest of the star was burned?

Just to have it reach a positive velocity we need an additional 0.4 foe from the Si-group. This means > 0.3 $M_\odot$ of IME material was made.

Since the velocities seen in these SNe are ~20% less than the average SN Ia, it is likely that around 1.0 $M_\odot$ is burned.

SN Ia Energetics



Kasen *et al.* (2006)

Biases in Searches Low-z

ALL searches are biased in one way or another. This is fine so long as you fully understand what they are…

Pointed searches/Catalog-based: KAIT, amateurs, etc.

- Problems - will not cover low-luminosity hosts
- Advantages (KAIT) - go very deep, catch them early and will find faint SNe in bright hosts

Pointless Searches: SN Factory

- Problems - Faint SNe on bright hosts are not detected/followed-up
- Advantages - Sample the low-luminosity hosts quite well, much more similar to high-z sample

Biases in Searches High-z

Past searches: SCP, HZSST

- Flying by the seat of our pants. Most SN found at detection limit, incorporated cuts like % increase over the host
- Never bother with impossible spectra - faint targets on bright hosts
- Not rolling

Present searches (0.1 < z < 1.0): SDSS, Essence, SNLS

- Spectroscopically tend not to target low-%increase targets
- Though can use color to extract nature of SN after-the-fact
- Rolling

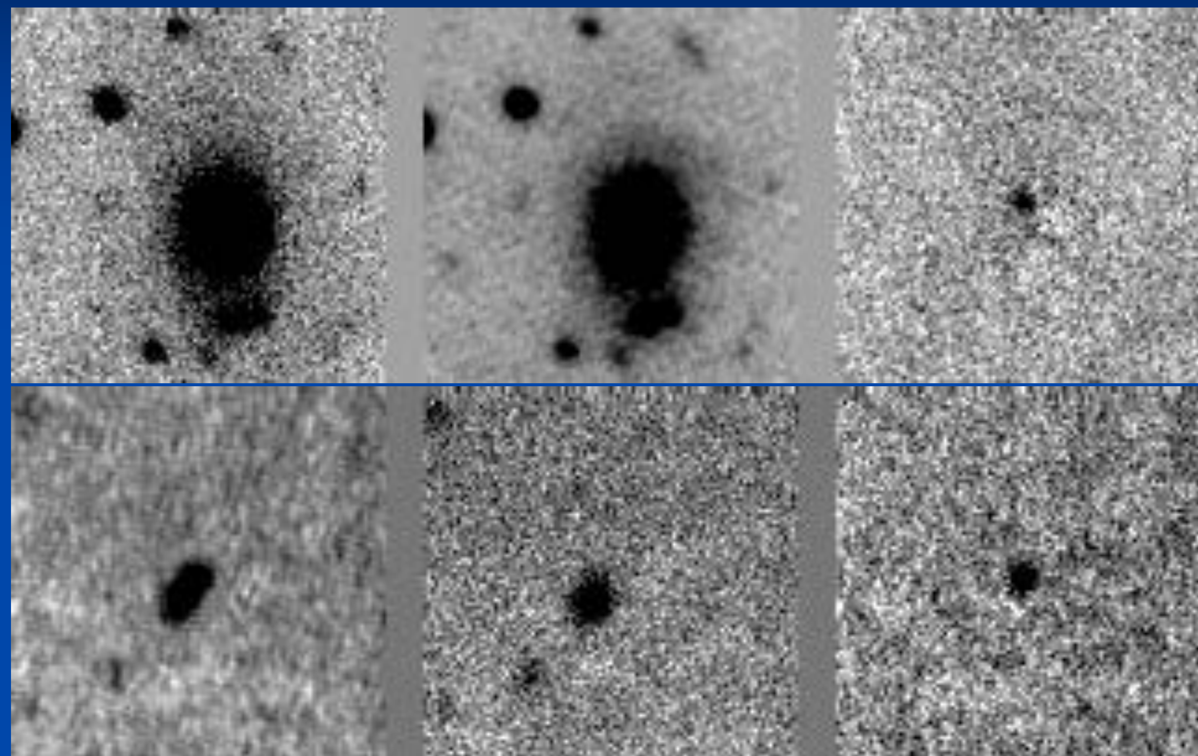
Present searches (z > 1.0): HST

- GOODS's search uses color info to select targets
- Cluster search - pointed
- Coarsely rolling

SNLS & Keck

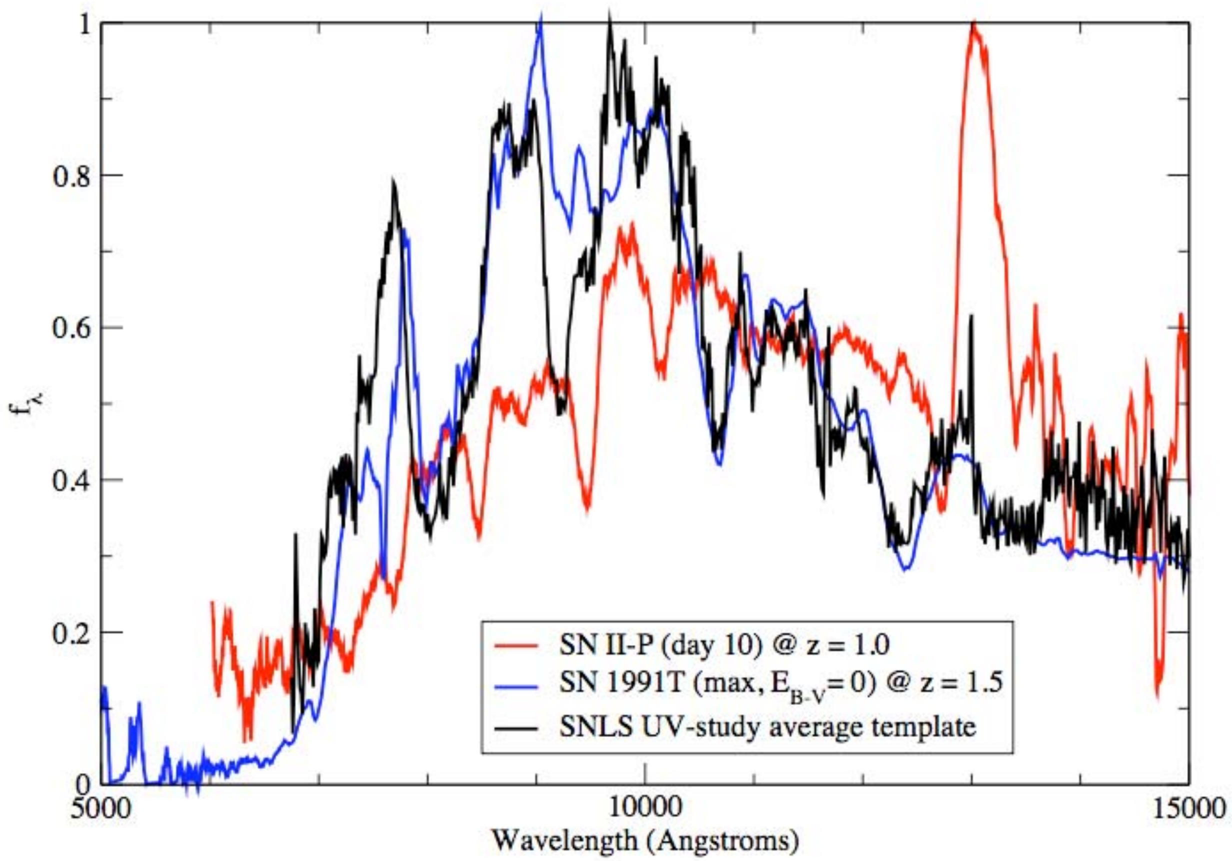
Nearby

Hi-z



In general the high-z supernovae are much harder to take spectra of due to both their faintness and the fact that the separation from their host galaxy is comparable to the seeing.

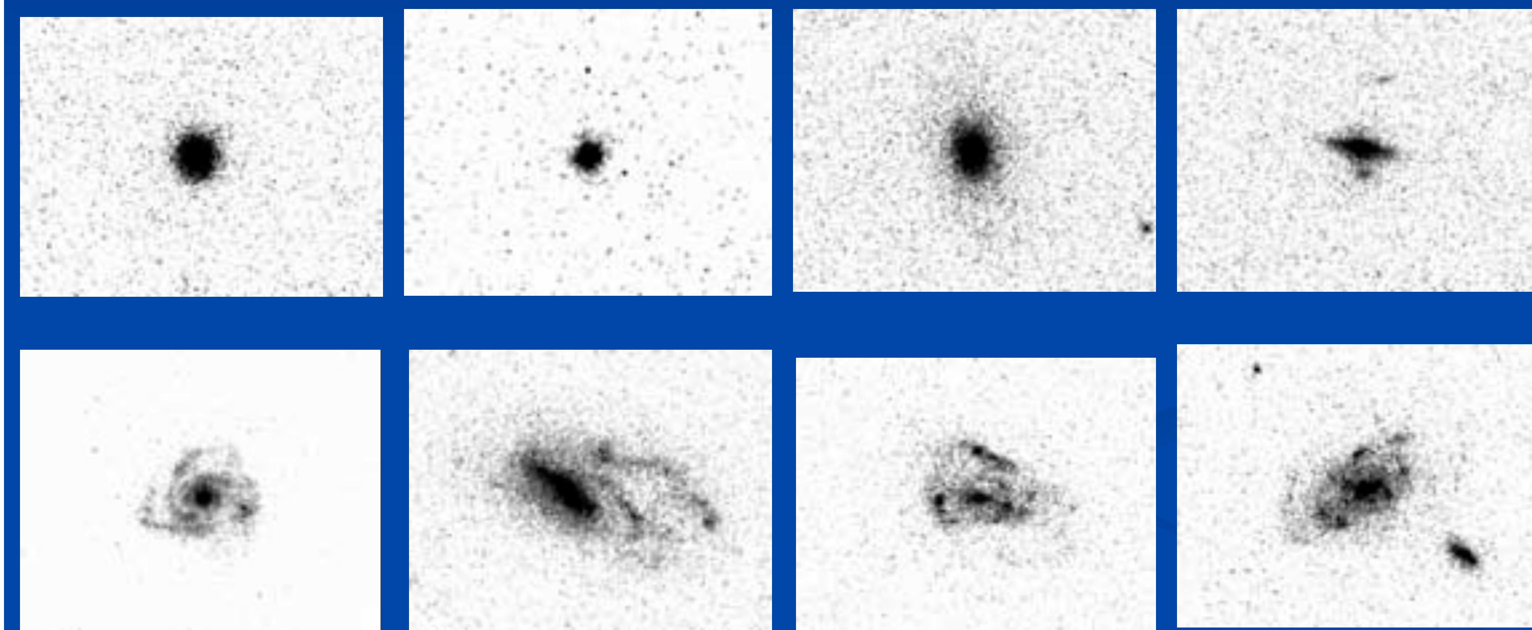
Color's at High-z



Need much better understanding of UV nature of all SNe (and their extinction distributions) in order to constrain the rates at high-z.

Host Galaxy Studies

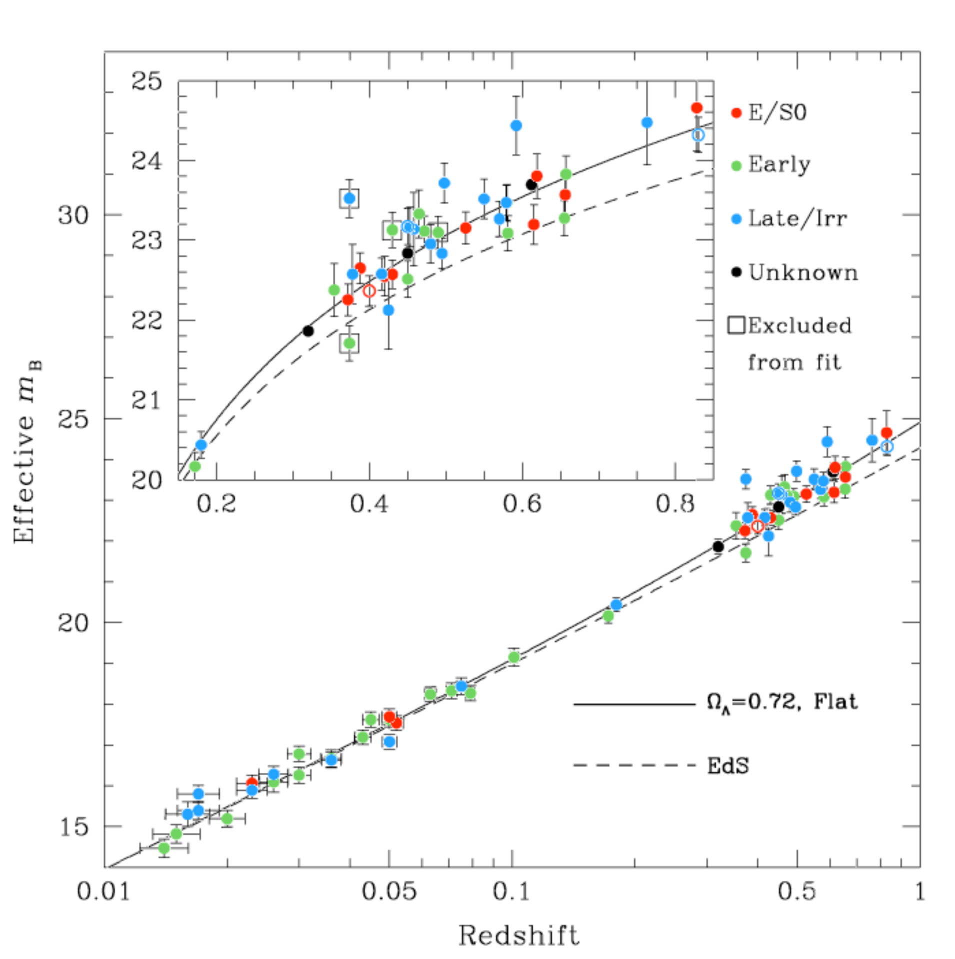
Sullivan *et al. (2003)*

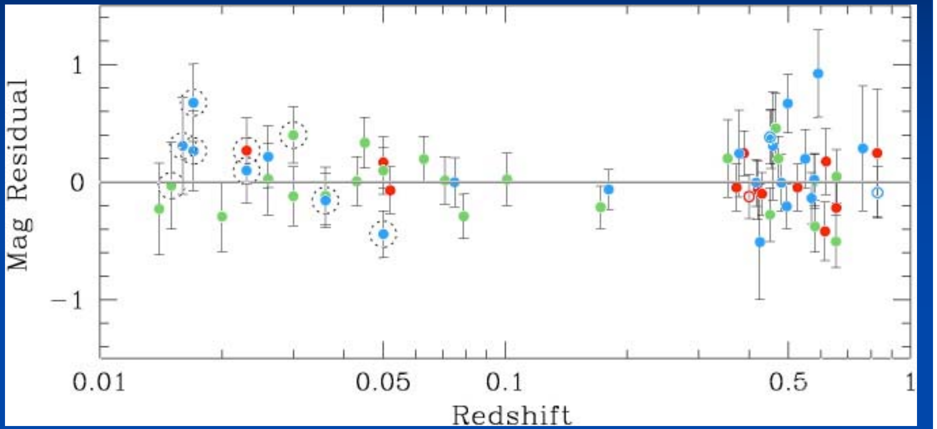


Ellipticals
&
Spirals

Over 30 SNe Ia host galaxies at high-z observed with HST/STIS photometry and with spectroscopy taken at Keck.

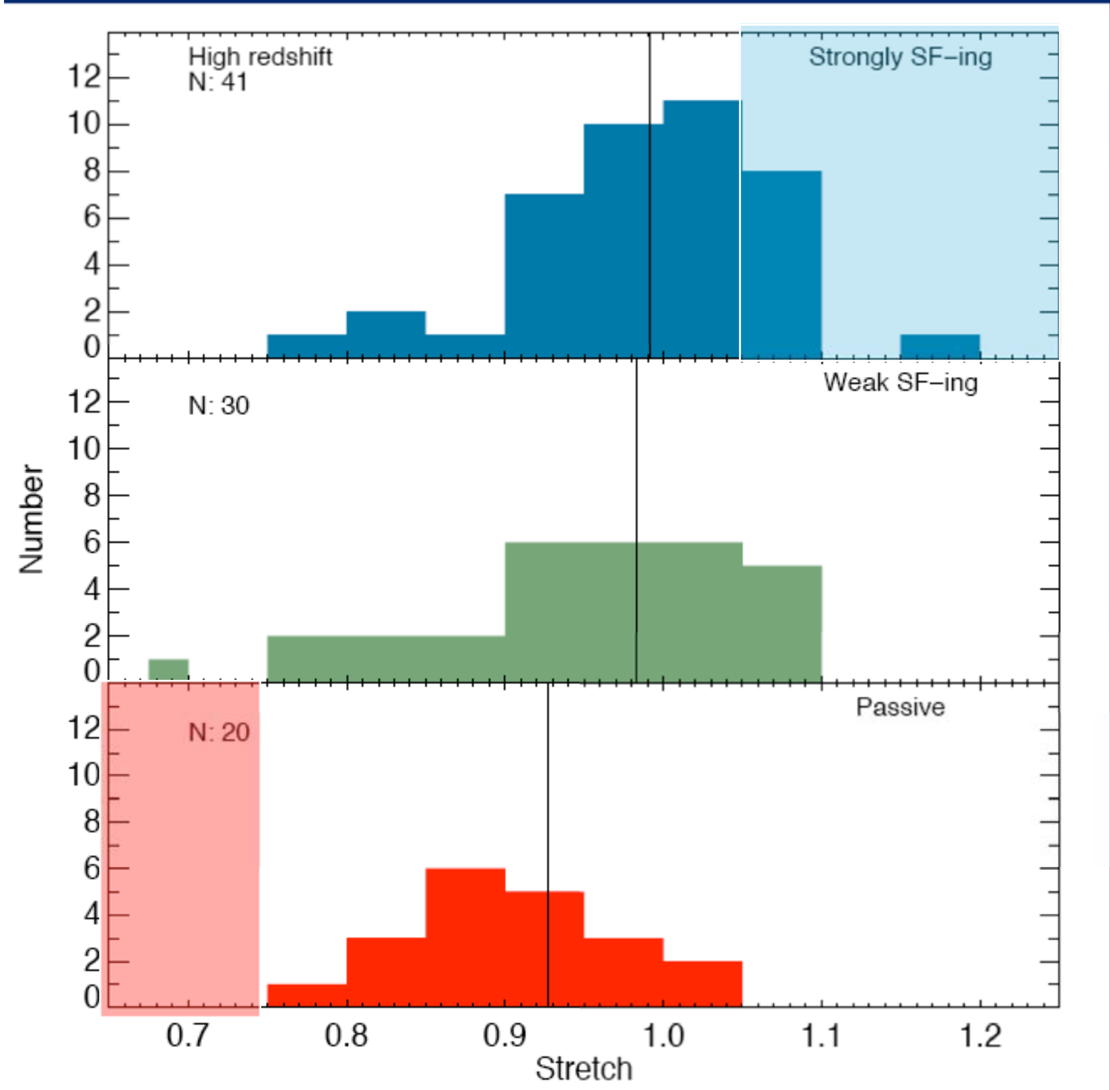
Differences are small





Scatter about the Hubble line was less in the E/S0 galaxies, and they were, on average, ~0.1 magnitudes brighter than their spiral counterparts.

SNLS Host-Stretch



The SNLS data in Sullivan et al. (2006) was broken down by host properties. Crudely speaking we have those in active SF galaxies, weakly SF galaxies and passive galaxies.

Clear signature that environment effects the SN Ia explosion mechanism / progenitor.

SN 91bg's & 91T's

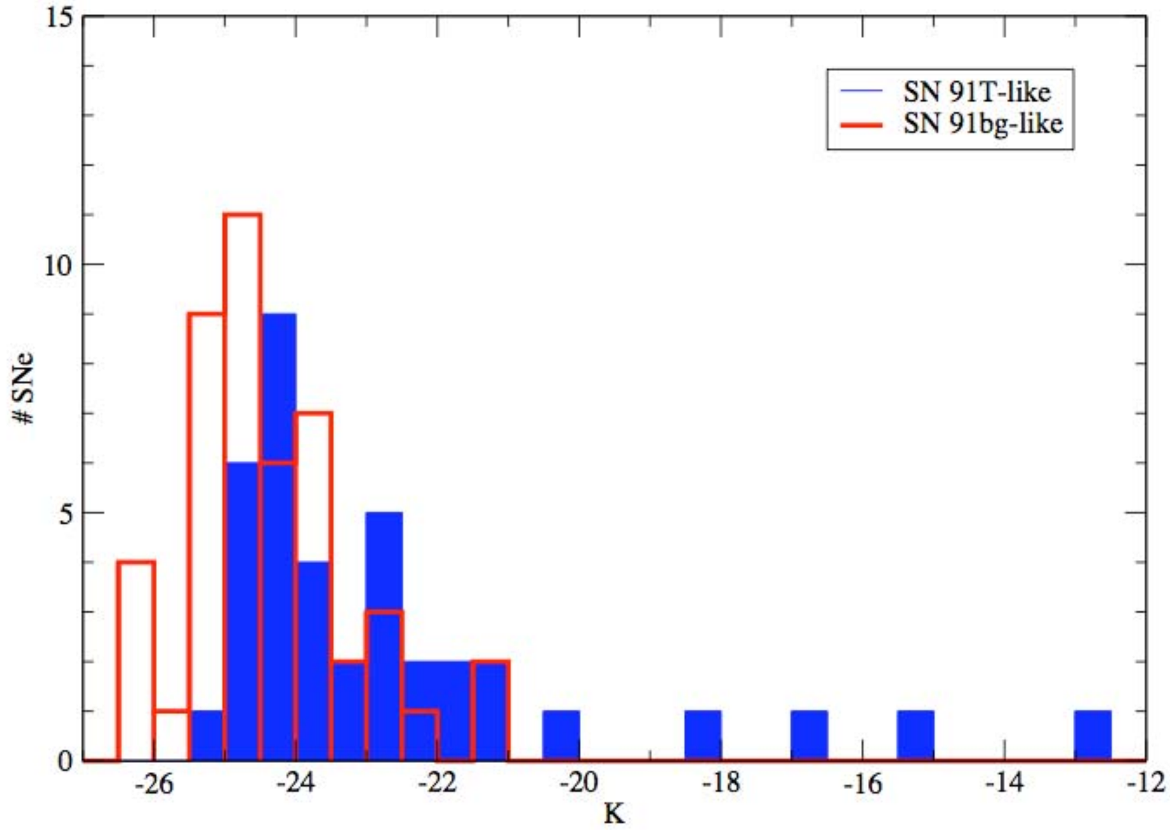
Branch, Fisher & Nugent (1993): 91bg=3 & 91T=1
Li *et al*. (2000): 91bg=6 & 91T=11
As of last night in the IAUC's: 91bg= 53 & 91T= 41

Of Note:

NGC 2841 had 2 confirmed 91bg-like SNe and 2 other SN I.
NGC 1275 had a confirmed 91bg-like SN and another SN I.

All SN 91T-like objects (not 99aa-like) that I have had access to the spectroscopy or are unequivocal in the telegrams as to their nature (no Ca II H&K) also mention the presence of large amounts of extinction or a conspicuous Na I D line at the redshift of the host galaxy. Certainly there must be some without but I have yet to see them….

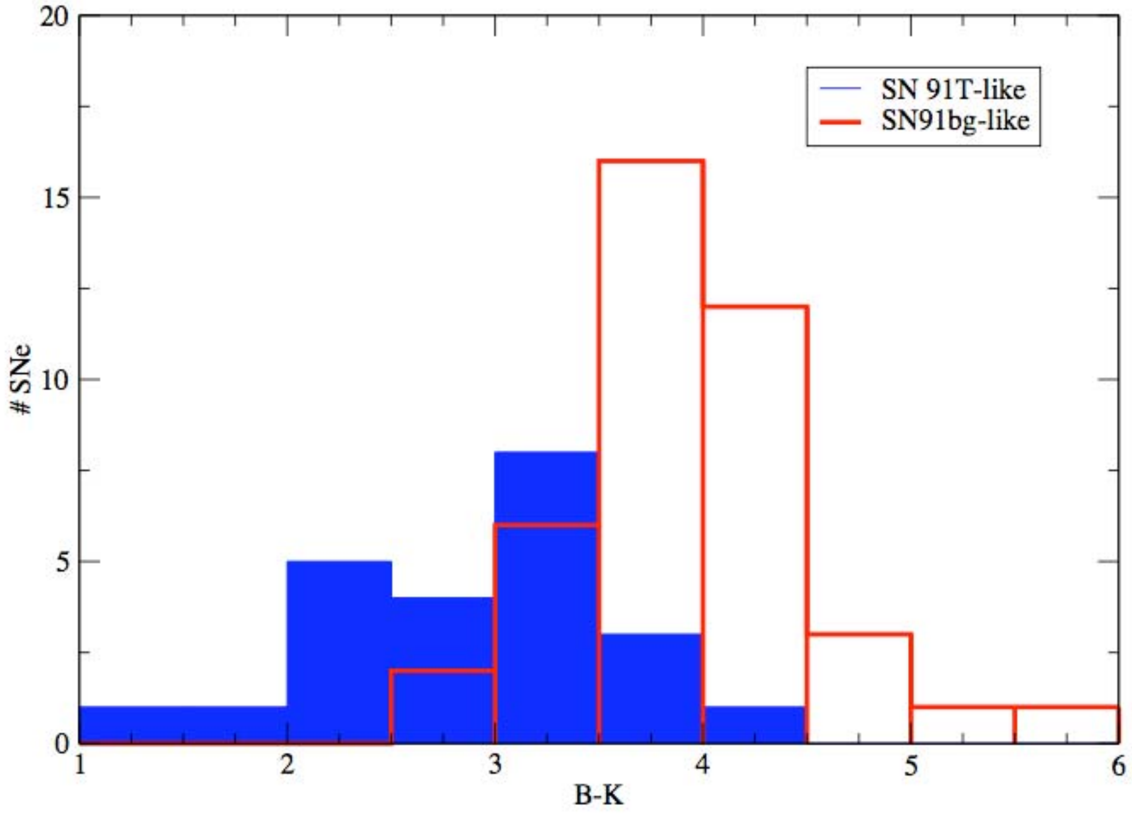
Hosts of SN 91bg's & 91T's



Remember that E/S0's are overrepresented in the RC3 catalog by an order of magnitude.

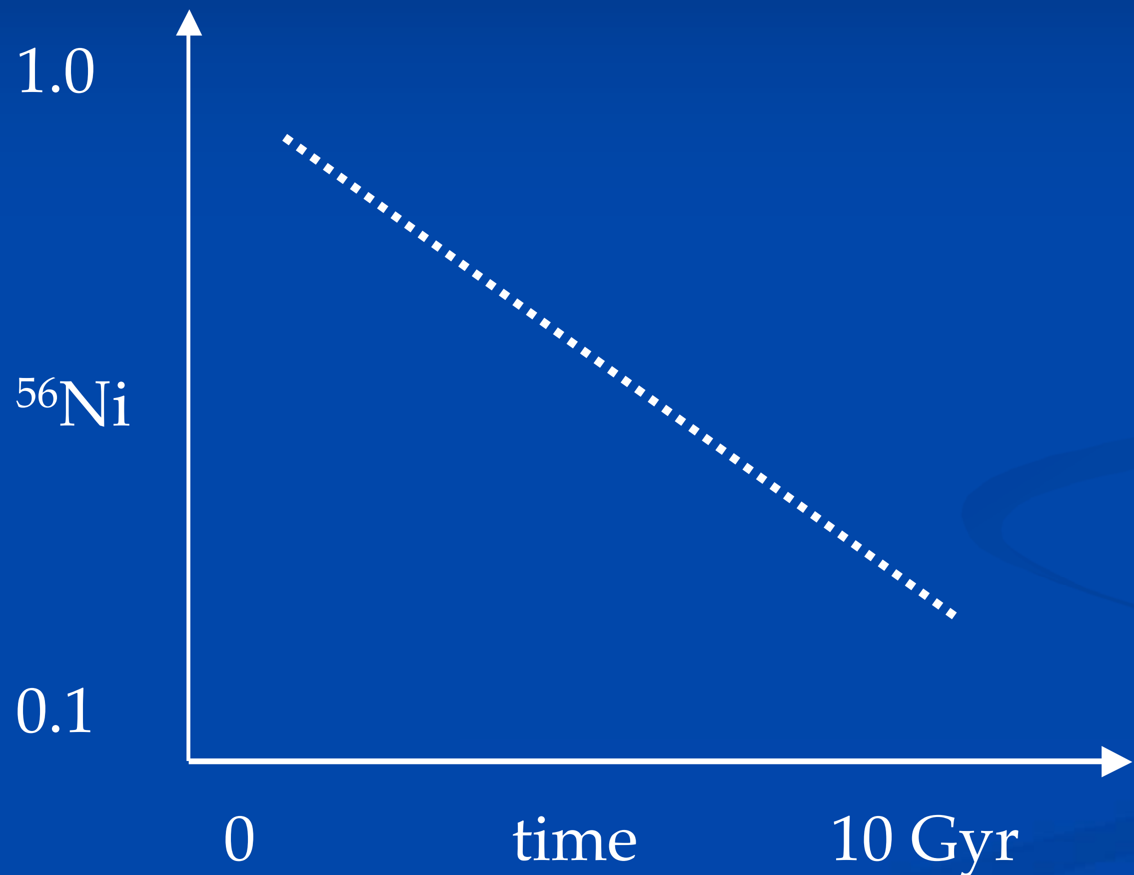
SFR -> SNe Ia

Hosts of SN 91bg's & 91T's



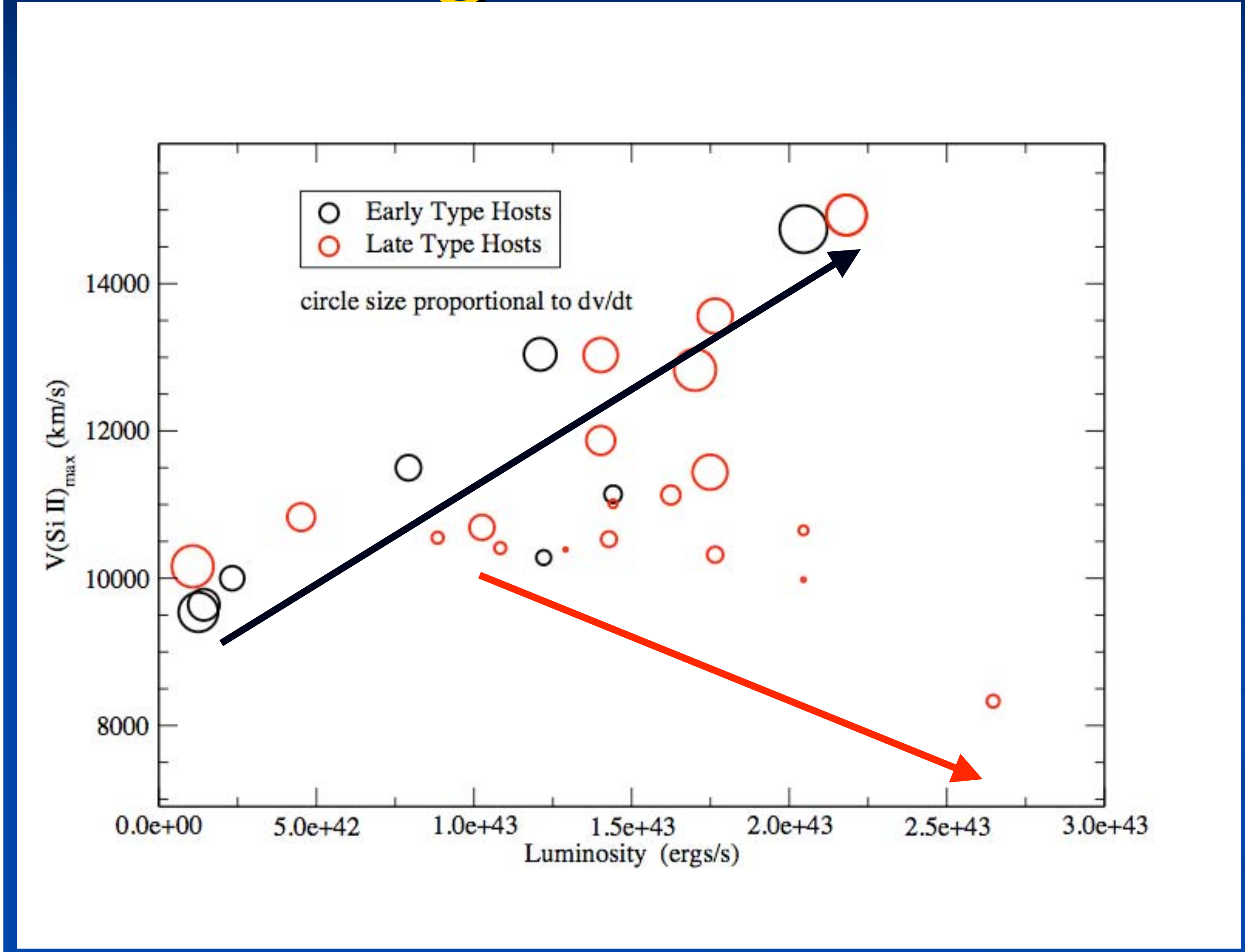
There are very few hosts that produce both types.

Time is a factor



Simple view but very likely.

Progenitor Differences?



Two separate progenitor paths revealed???

The old and young populations also show a different relationship between KE and Ni…

Conspiracy

If there is more than one progenitor system (say something following the A+B model) then you must explain the relative populations of subluminous, overluminous and normal SNe Ia and their evolution accordingly.

If there is one basic progenitor system then how does age tie itself directly to ^{56}Ni production?

Homework

Theorists:

- Come up with a mechanism that nicely ties age to ^{56}Ni (perhaps as Ken Nomoto suggested)
- How low/high can we go? $0.01 < M_{Ni} < 1.38$? And why does it seem that no matter what most of the rest of the star always gets burned.
- Rule-in or rule-out progenitor systems based on the rates and whether or not they would likely be able to follow the age-luminosity effect.

Observers:

- Work hard to determine the rates of subtypes of SNe Ia as a function of z. Photometrically id everything in the rolling searches and get their host redshifts.
- Work hard to determine the rates at z >>1