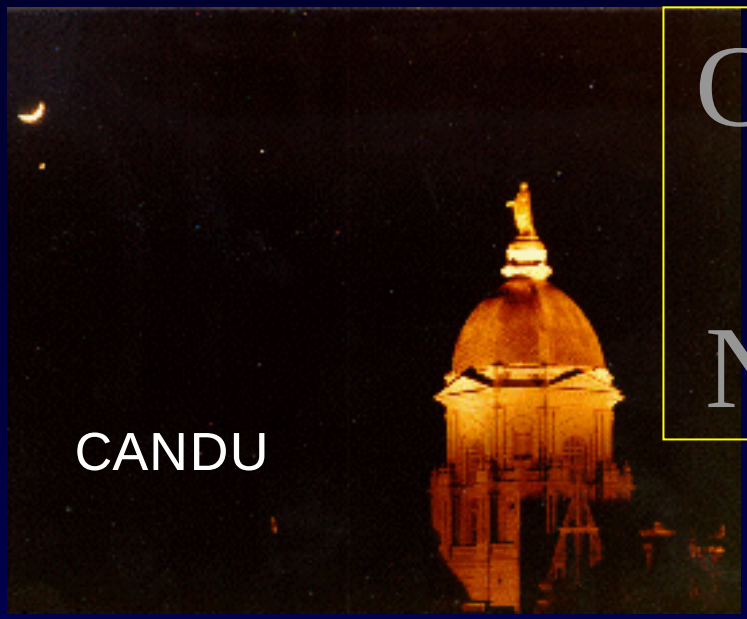


Center for Astrophysics at Notre Dame University

Peter Garnavich
Joseph Gallagher

Properties of Type Ia Supernovae Host Galaxies

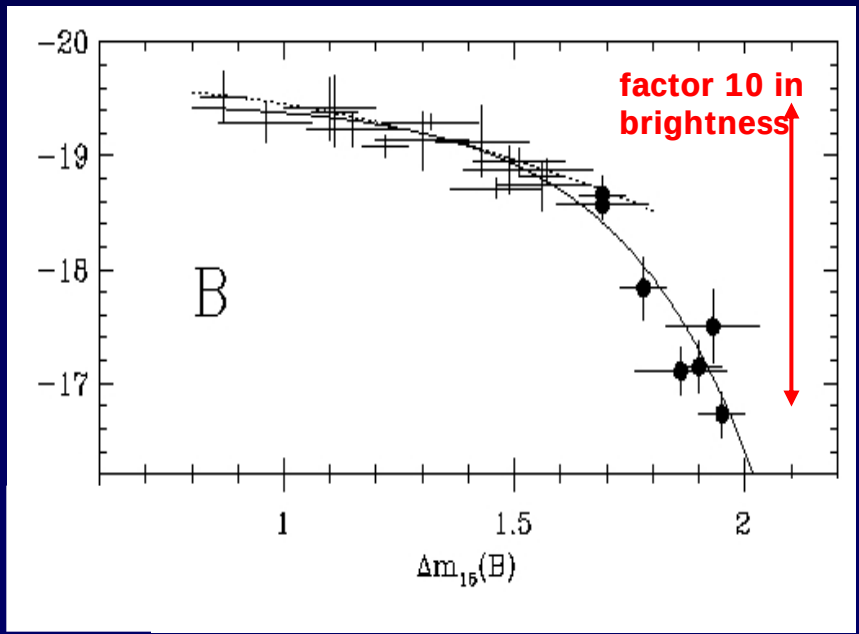
Saurabh Jha – UC Berkeley
Robert Kirshner – CfA

Type Ia Supernovae are NOT Standard Candles

Wide range of peak brightness
=> range of ^{56}Ni produced

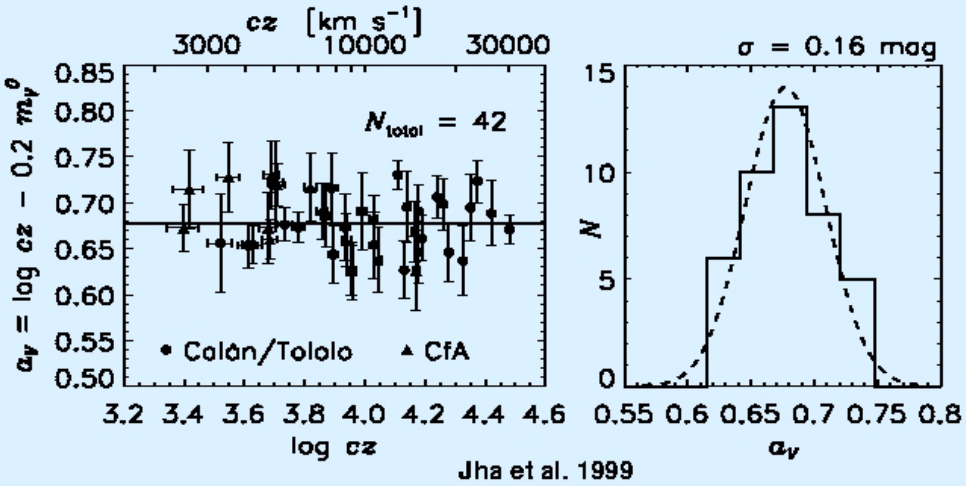
Brightness and color correlates with light curve decay rate

What is the source of the diversity?



Phillips et al. 1999; Garnavich et al 2004

1st Parameter – Light Curve Shape (Ni mass?)
2nd Parameter – Color (standard extinction law)

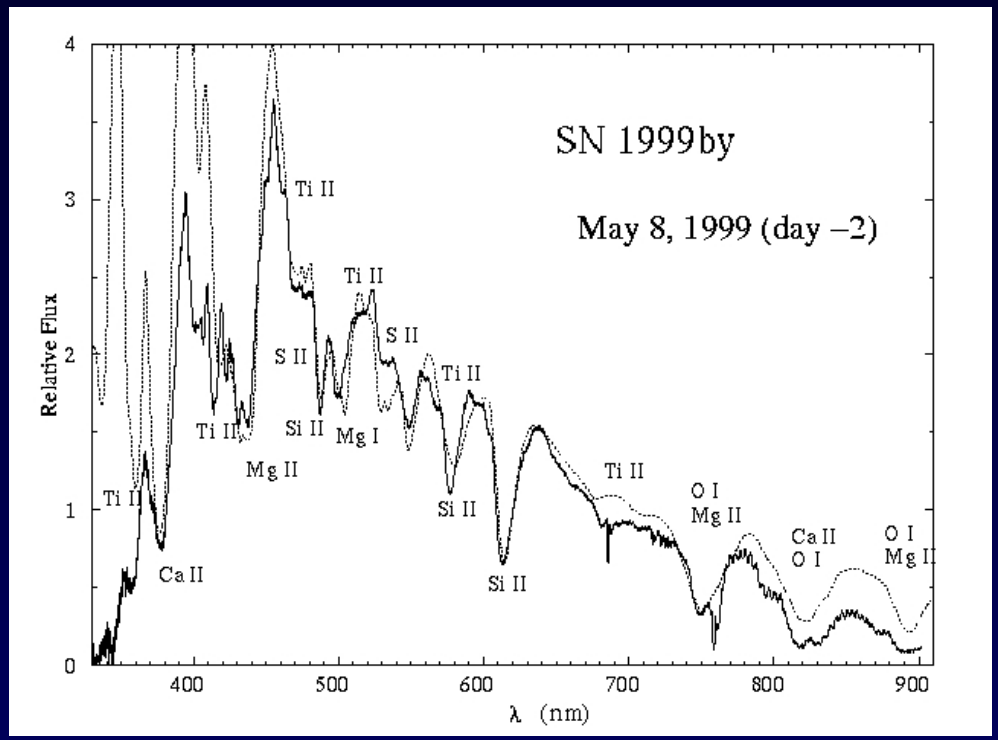


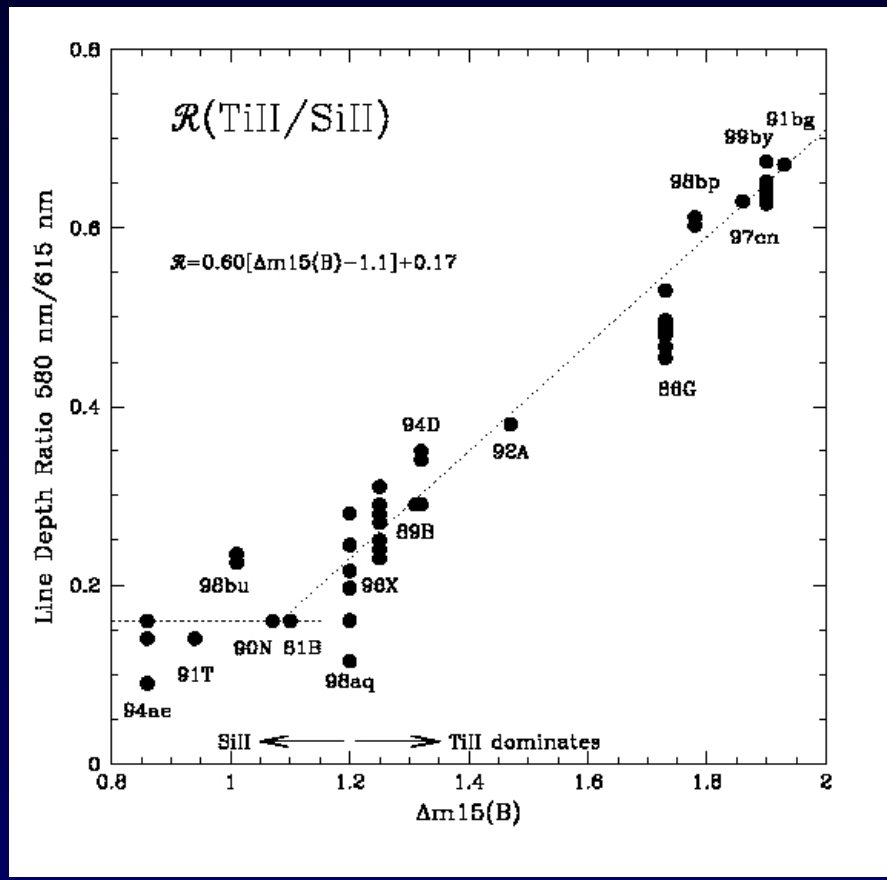
After correction, there remains a scatter of 15%

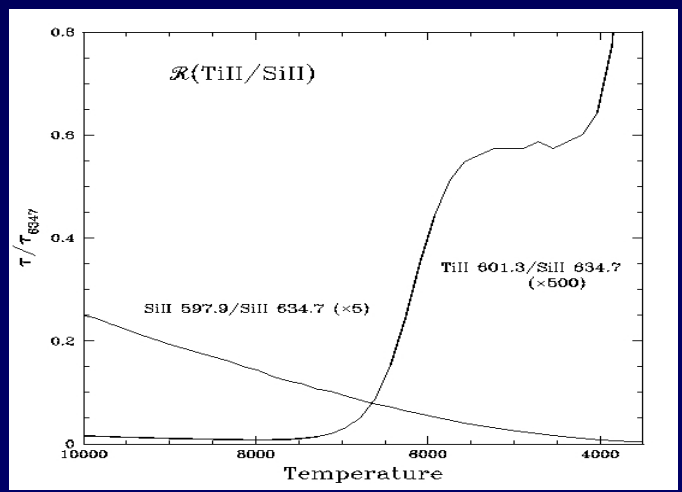
⇒ Is this random (weather or asymmetry?)

⇒ Is this a sign of a "third parameter"?

SNIa Make a Single Continuous Family







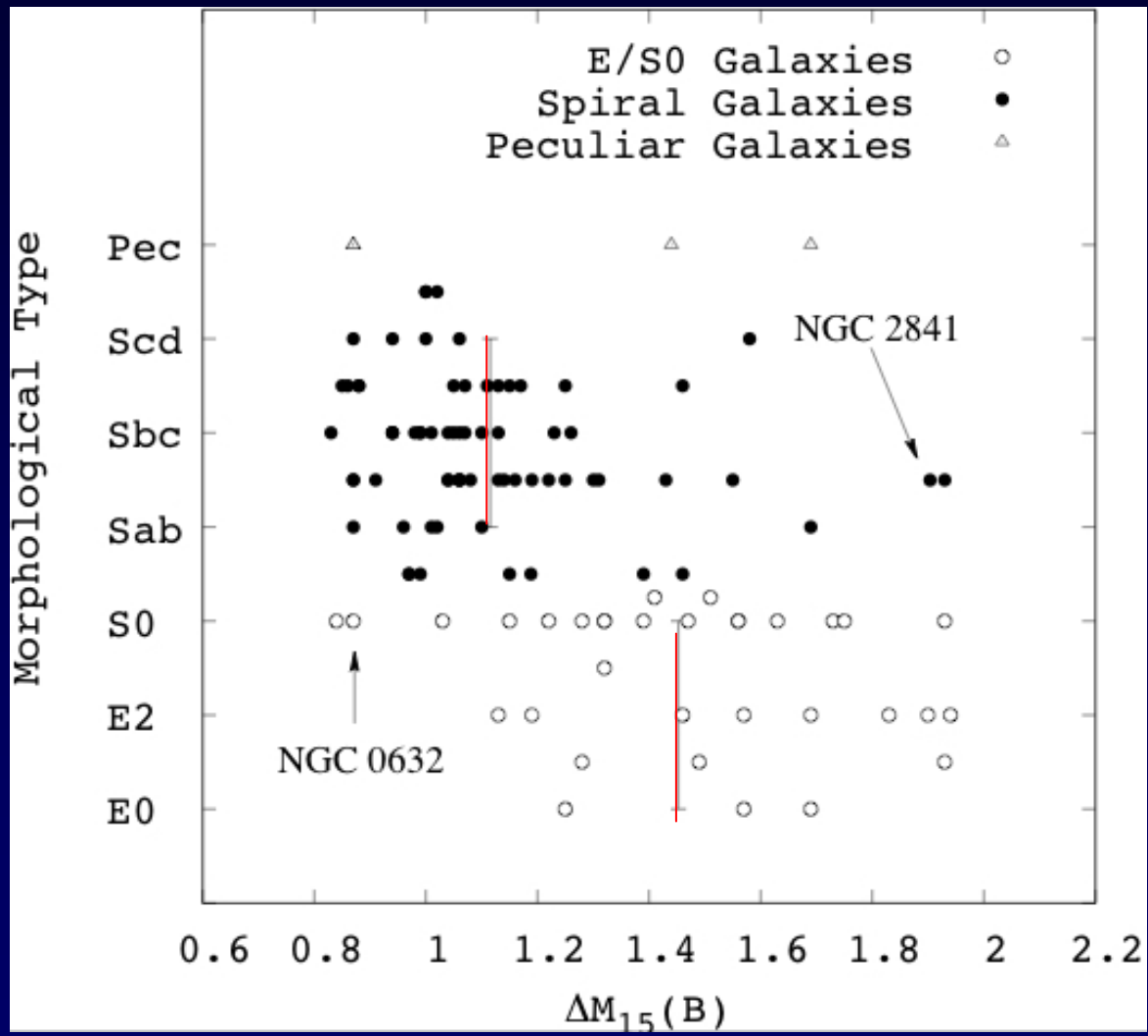
Hatano et al. => TiII comes in quickly with slightly lower temperature.
Line blanketing the blue.

Clue to the SN Ia Diversity

Hamuy et al. (1996) noted a trend between host morphology and SNIa decline rate in Calan/Tololo set

Adding all SNIa available now:
See even stronger division between morphological types.

Fast (faint) SNIa like E/S0 galaxies while Slow (bright) events prefer Spirals



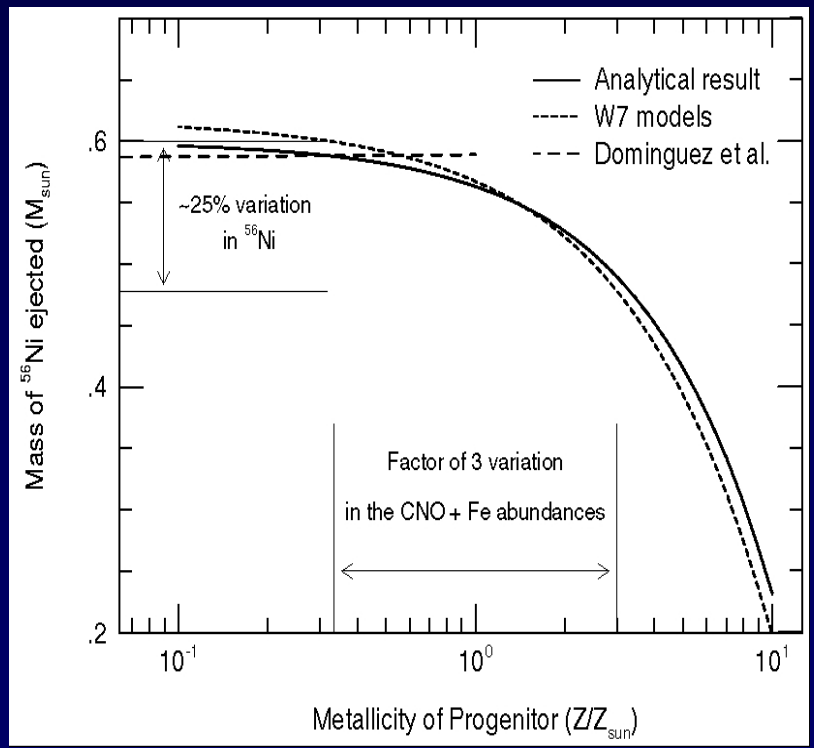
Diversity: Metallicity or population age?

Model: Brightness – Metallicity Relation?

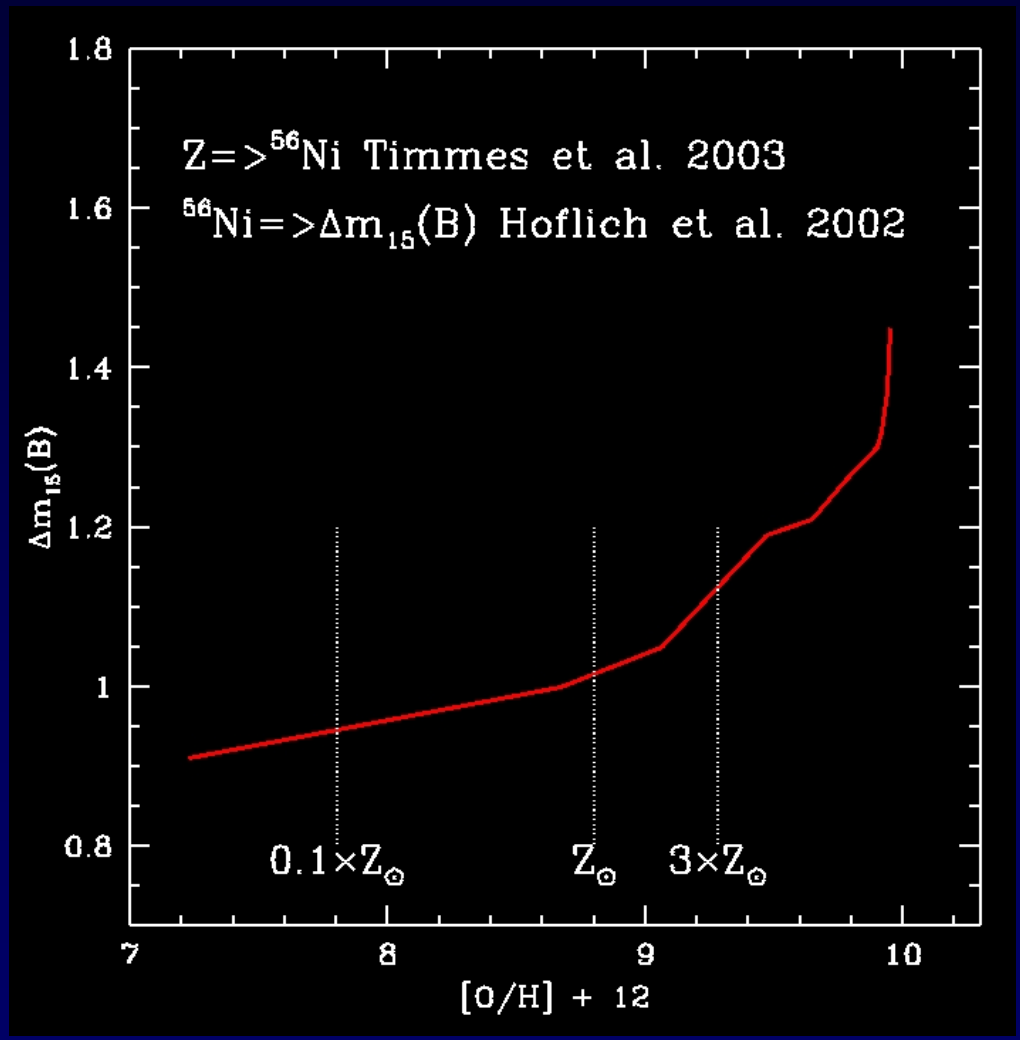
Progenitor metallicity influences the C/O ratio in the resulting WD

C/O ratio effects ^{56}Ni production

Small effect for Z<Solar



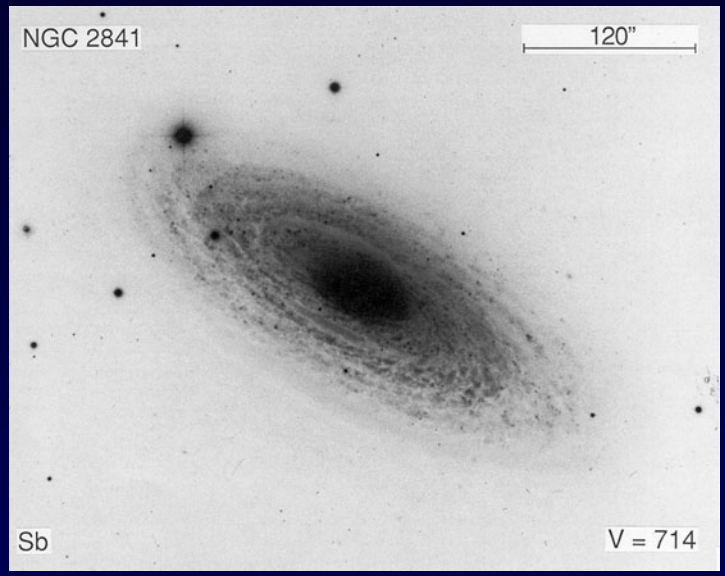
Timmes, Brown & Truran 2003

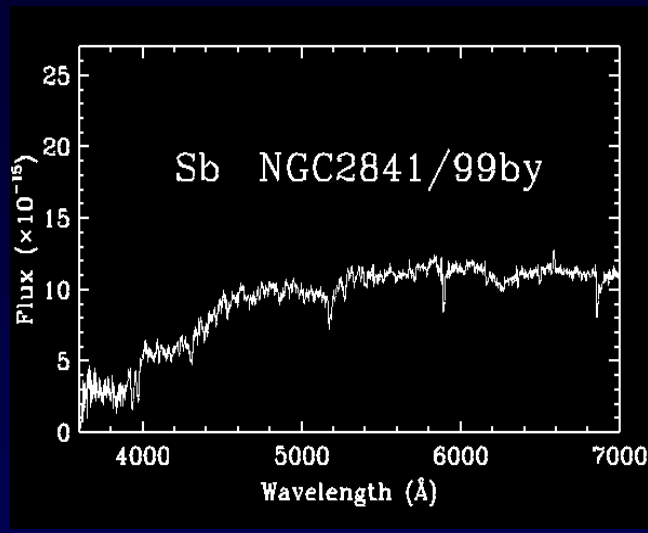


Morphology is Not Enough

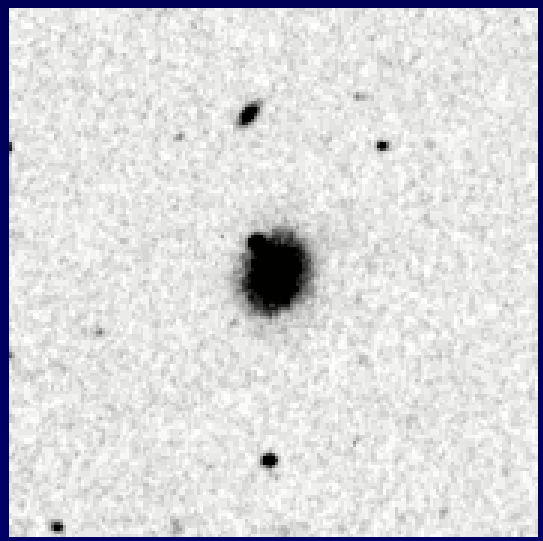
Exceptions:

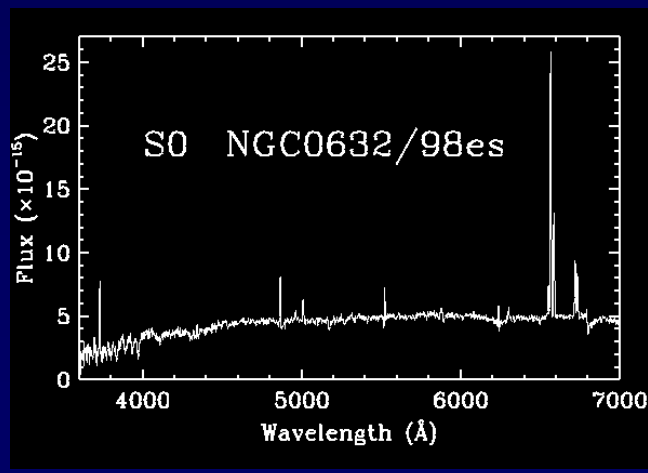
1999by in NGC2841
Sb galaxy with an extreme fast decliner
=> very little emission indicating a low star-formation rate .





1998es in NGC 632
an extreme slow decliner in an early type galaxy
=> very large emission indicating rapid star formation – a central star burst.





Integrated Spectroscopy

Spectra of 57 type Ia hosts

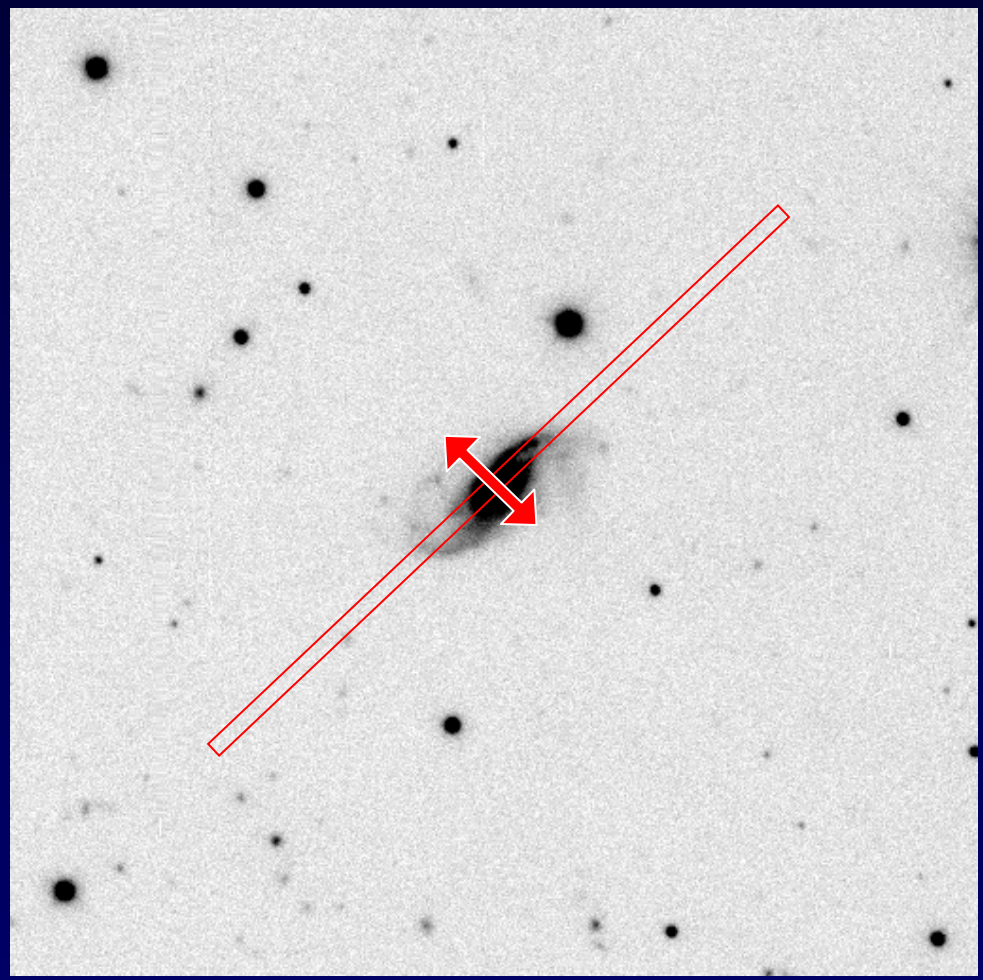
Mt. Hopkins 1.5m Tillinghast telescope + FAST spectrograph

3” slit scanned across the galaxies

Integrated spectrum gives average properties of the galaxies – not biased by central region

Good match to spectra of hosts at high redshift.

Host of SN 2000cf



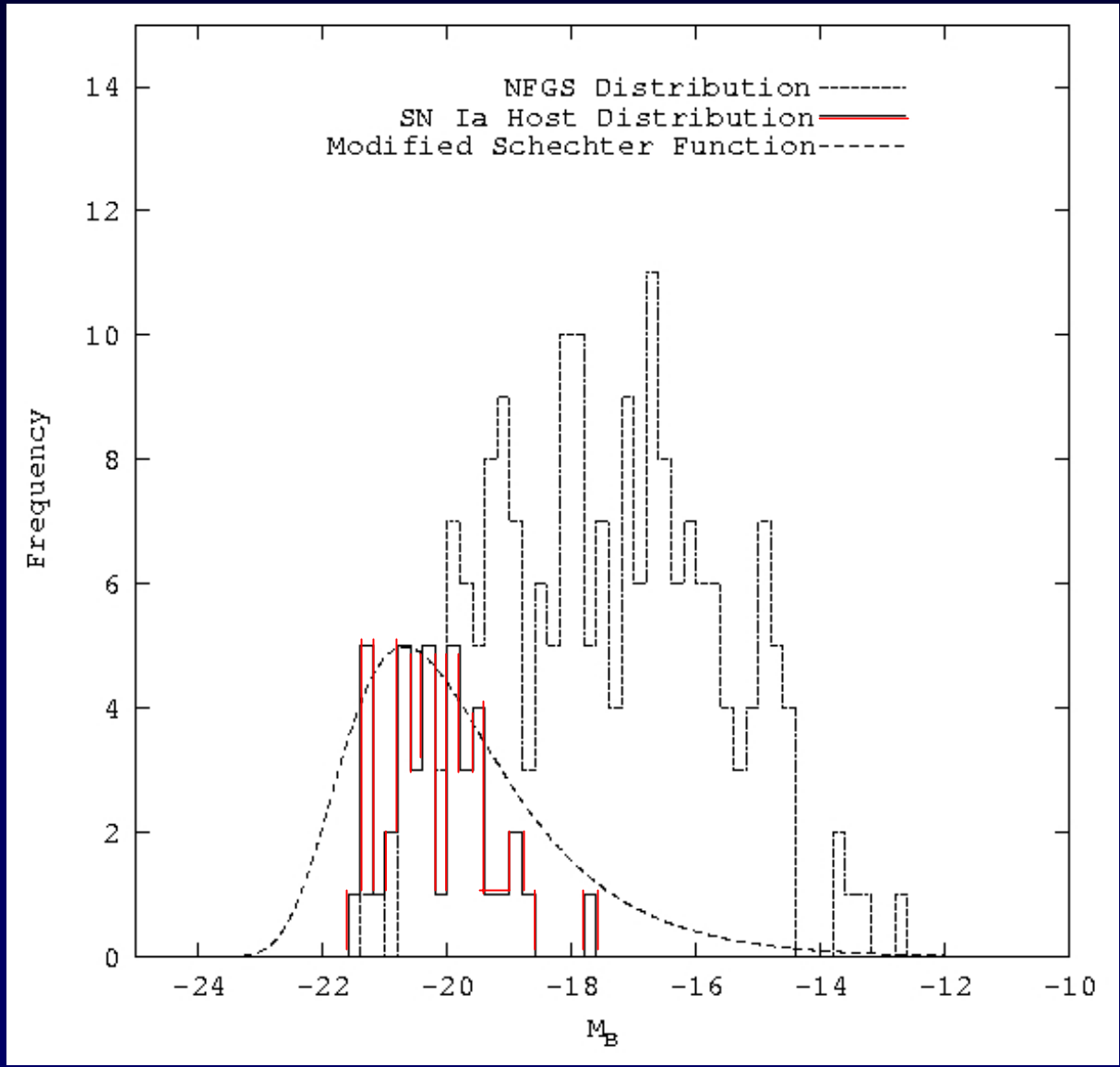
Comparison between SNIa Hosts & NFGS

Near Field Galaxy Survey (Jansen 2000) and SDSS used to see if SNIa hosts are "normal" galaxies.

But SNIa hosts only selected by a SN discovery.

Consider: the chance of a supernova in a galaxy depends on the number of stars in the galaxy–

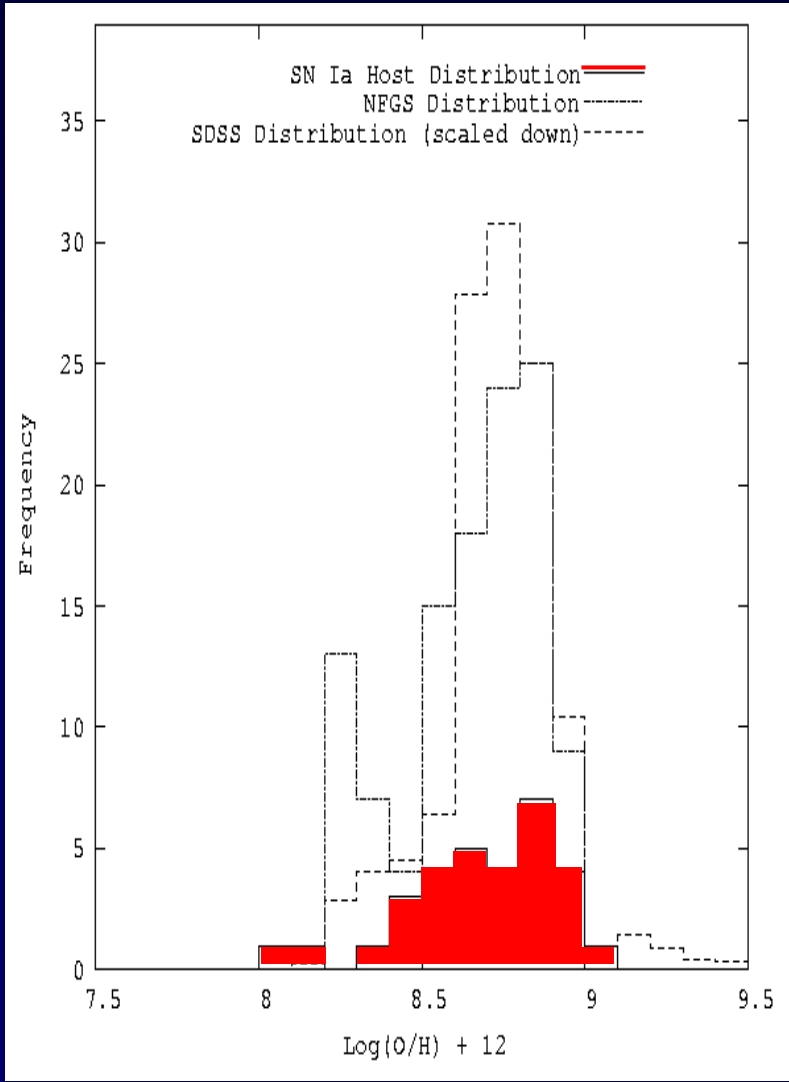
A Schechter function weighted by the number of stars gives a good match to the SN host luminosity distribution.

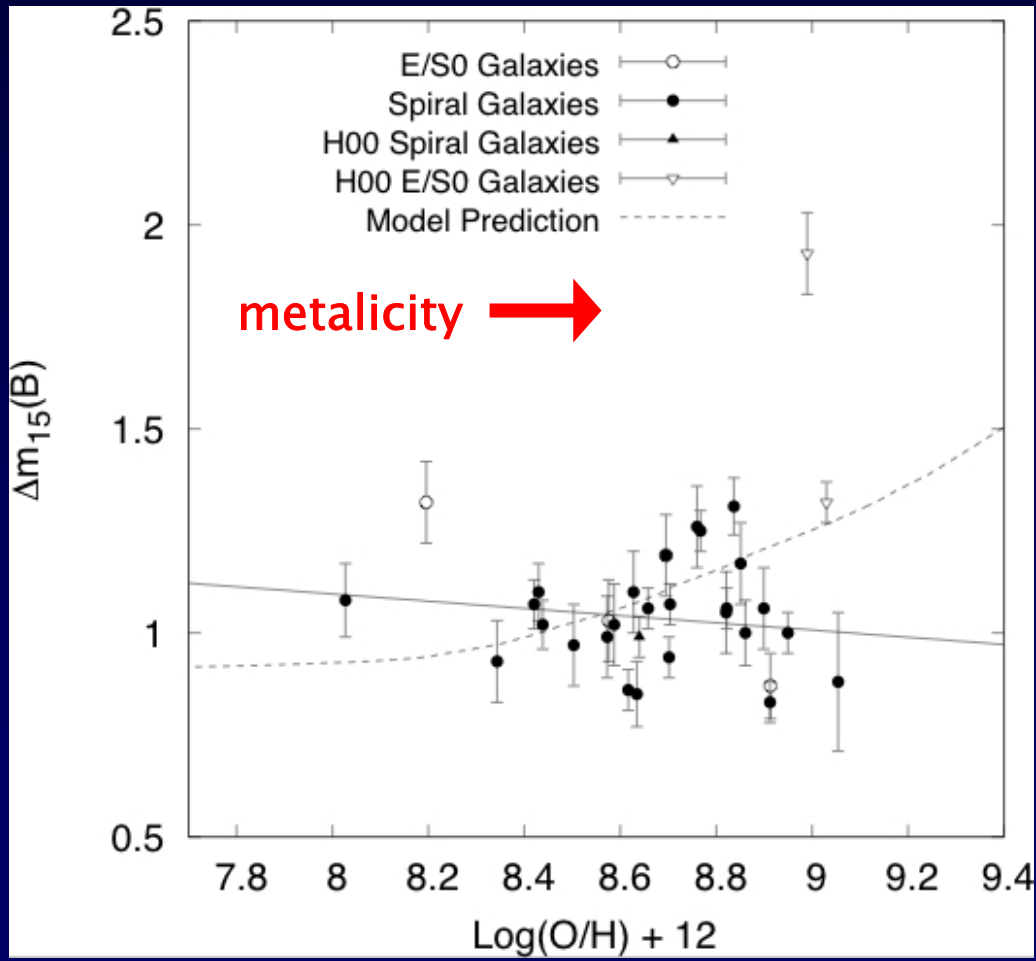


Host Metalicity

O/H ratio from emission line fluxes (Kewley & Dopita 2002)

No clear trend between host metallicity and decline rate. Early-type galaxies (Hamuy et al) have the same metallicity as some spirals, but a wide range of decline rate.





Distance from Galaxy Center

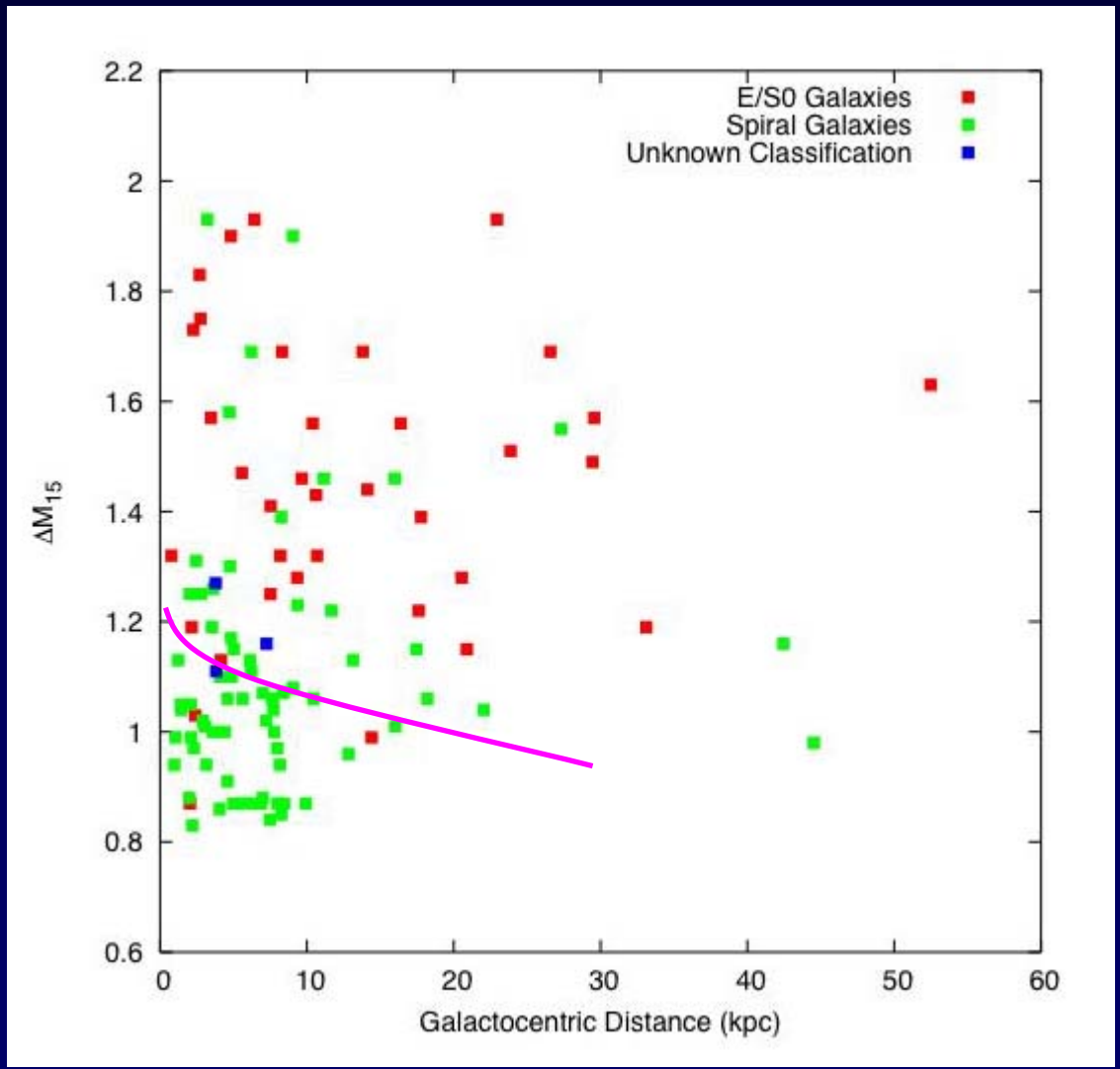
Spirals show metallicity gradients that may show up in SNIa variation with galactocentric distance.

Trend: high metal abundance at small distances and decreasing metals outward.

In Milky Way, the variation is a factor of 8 in metallicity between 4 kpc and 16 kpc.

Using Timmes, Brown & Truran (2003) would expect fainter SNIa near the center of spirals, but see the opposite.

>100 SNIa



Check of Systematics

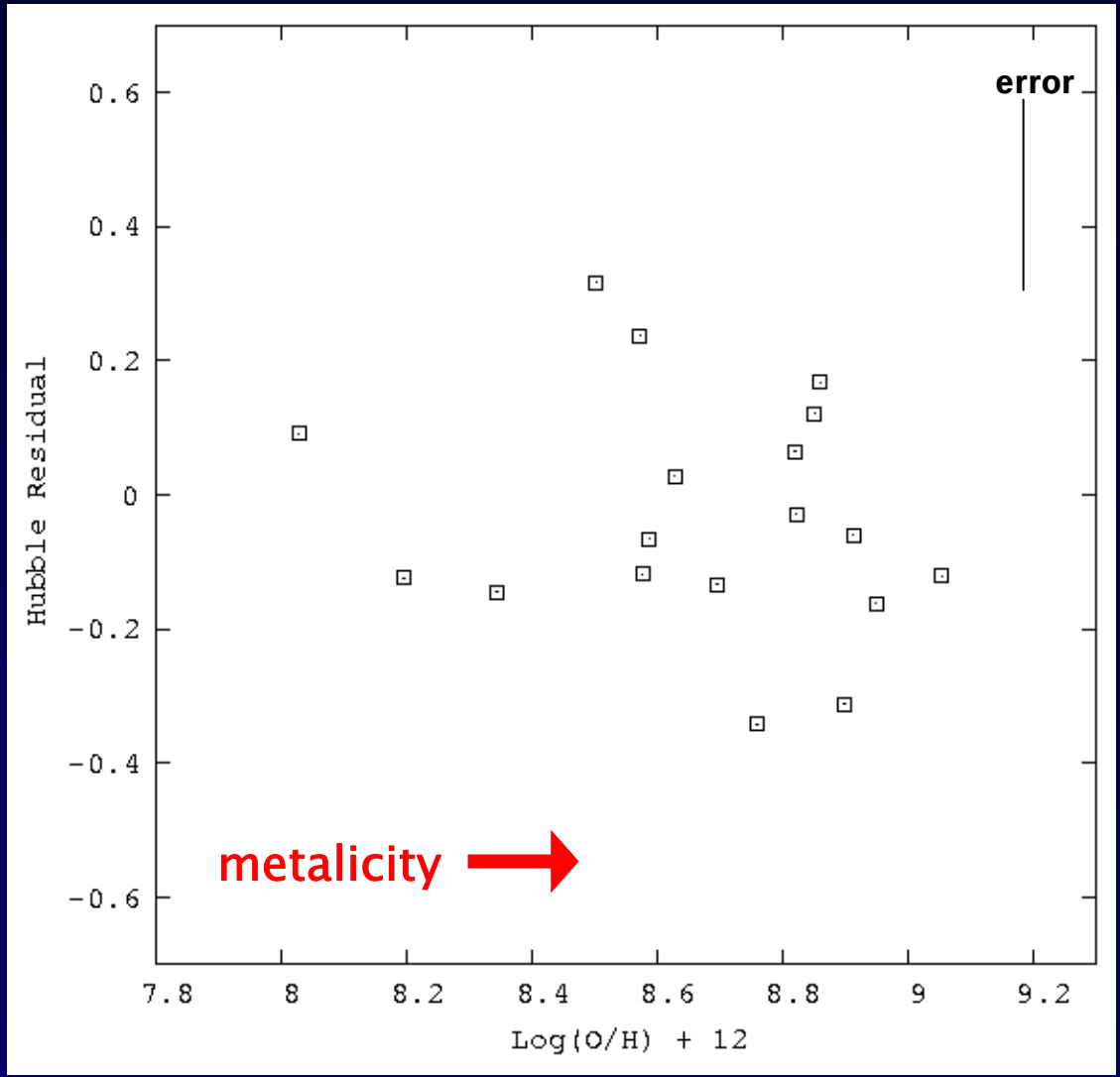
Hubble Flow RMS ~0.16 mag

Is the 3rd parameter a metal dependence?

Residuals to the Hubble diagram show no significant correlation with Oxygen abundance.

Galaxies span only one decade of metalicity

Need many more Hubble flow supernovae to really tell if there is a correlation.



Star Formation Rate

Current Star Formation Rate is estimated from the Hα Luminosity.

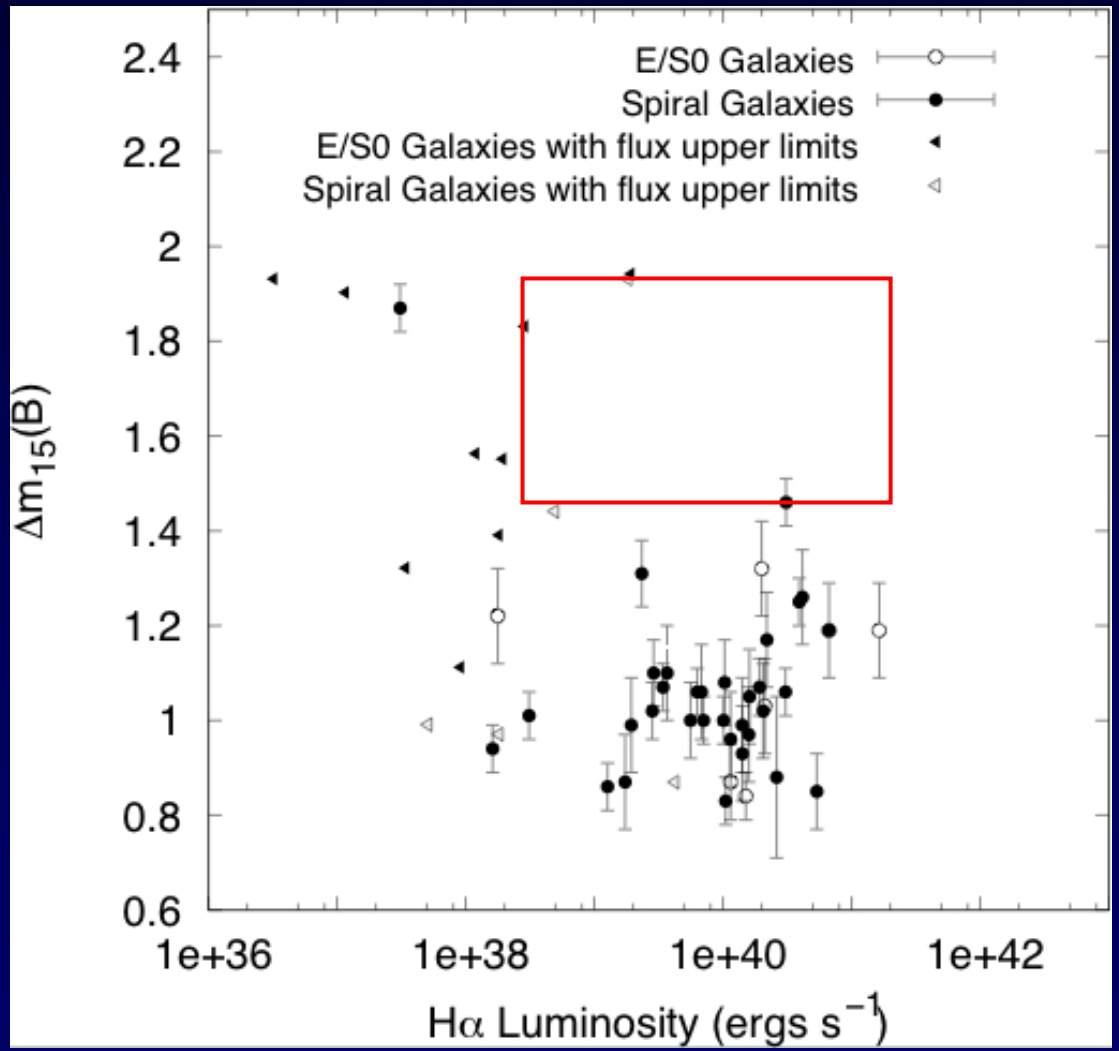
Galaxies with no detected Hα flux are shown as upper limits.

For galaxies with star formation there is no correlation with decline rate.

But only galaxies with insignificant star formation host SNIa with $\Delta m_{15}(B) > 1.5$

Zone of Avoidance

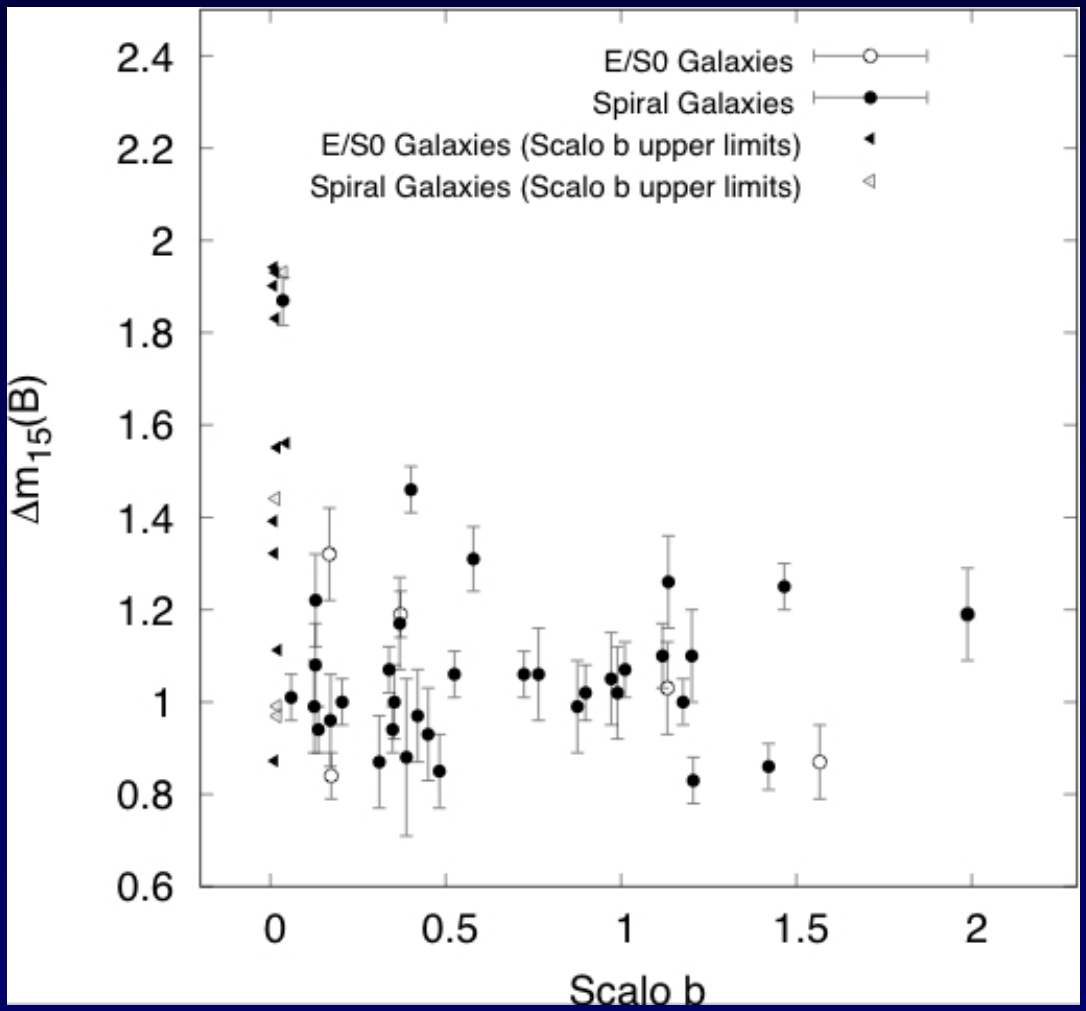
Current Star formation rate →

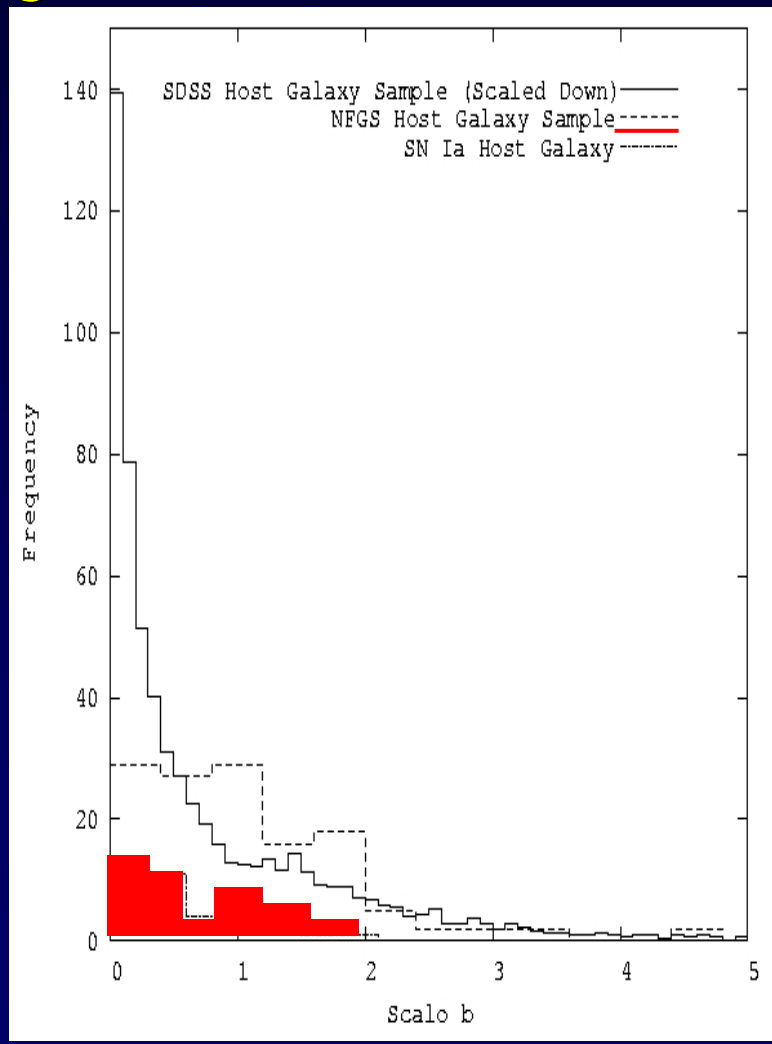


Star Formation History

Hα equivalent width is a measure of the current star formation rate compared to the average in the past – Scalo "b" parameter.

Fast SNIa found in hosts with lower than average SFR (b<1)





Model: Luminosity-Age Relation

Simple model from Umeda et al. 1999

Binary drawn randomly from steep IMF. Toss if either star has $M>8M_{sun}$

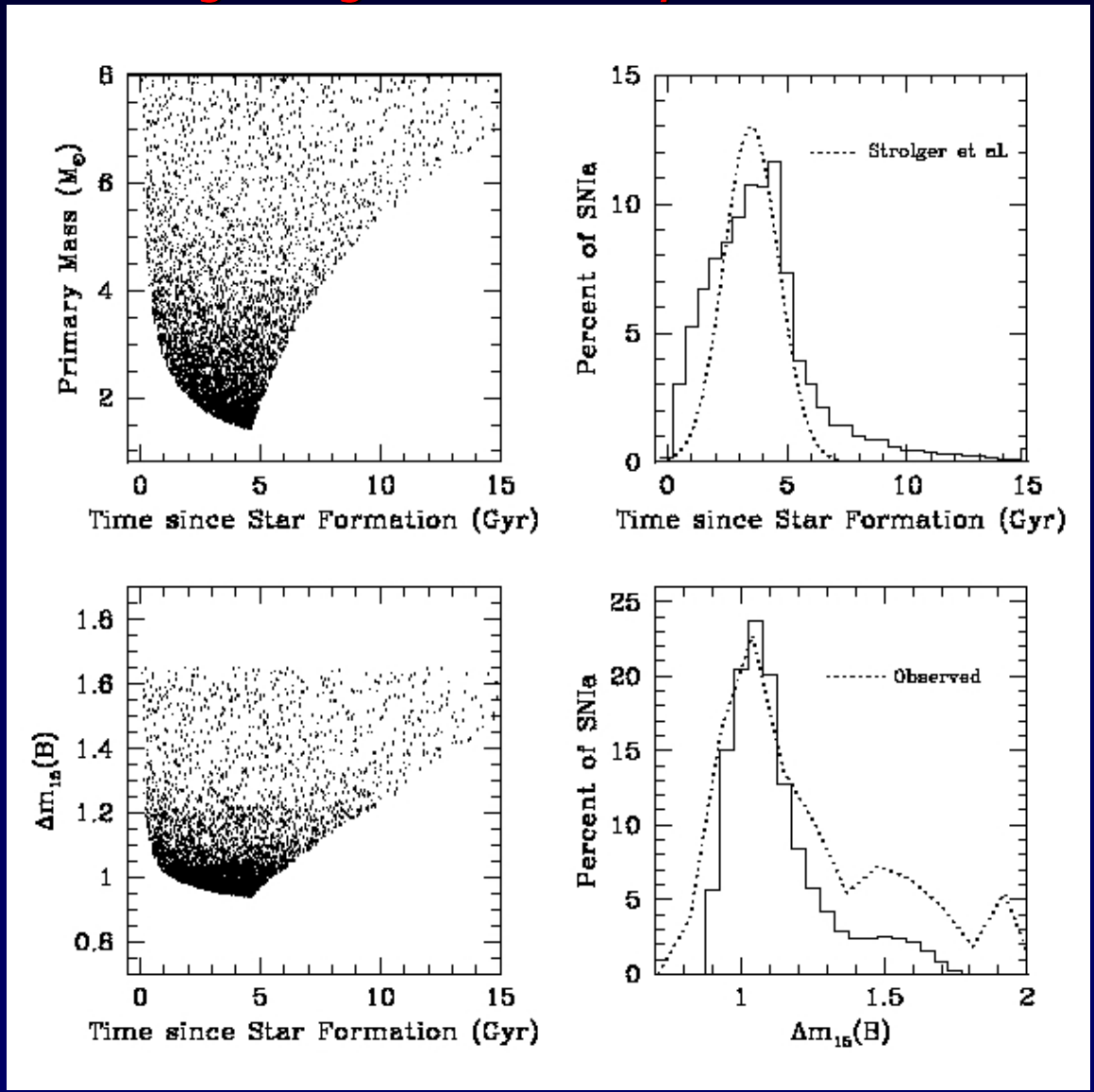
Estimate masses of WD stars: toss if mass lost by secondary can't get primary WD $>1.4\ M_{sun}$

Explodes when secondary leaves main sequence age$=10/M^{2.3}$ Gyr

"Old population" of SNIa from massive progenitors

Add: assume primary mass correlates with ^{56}Ni mass

Single Degenerate Binary



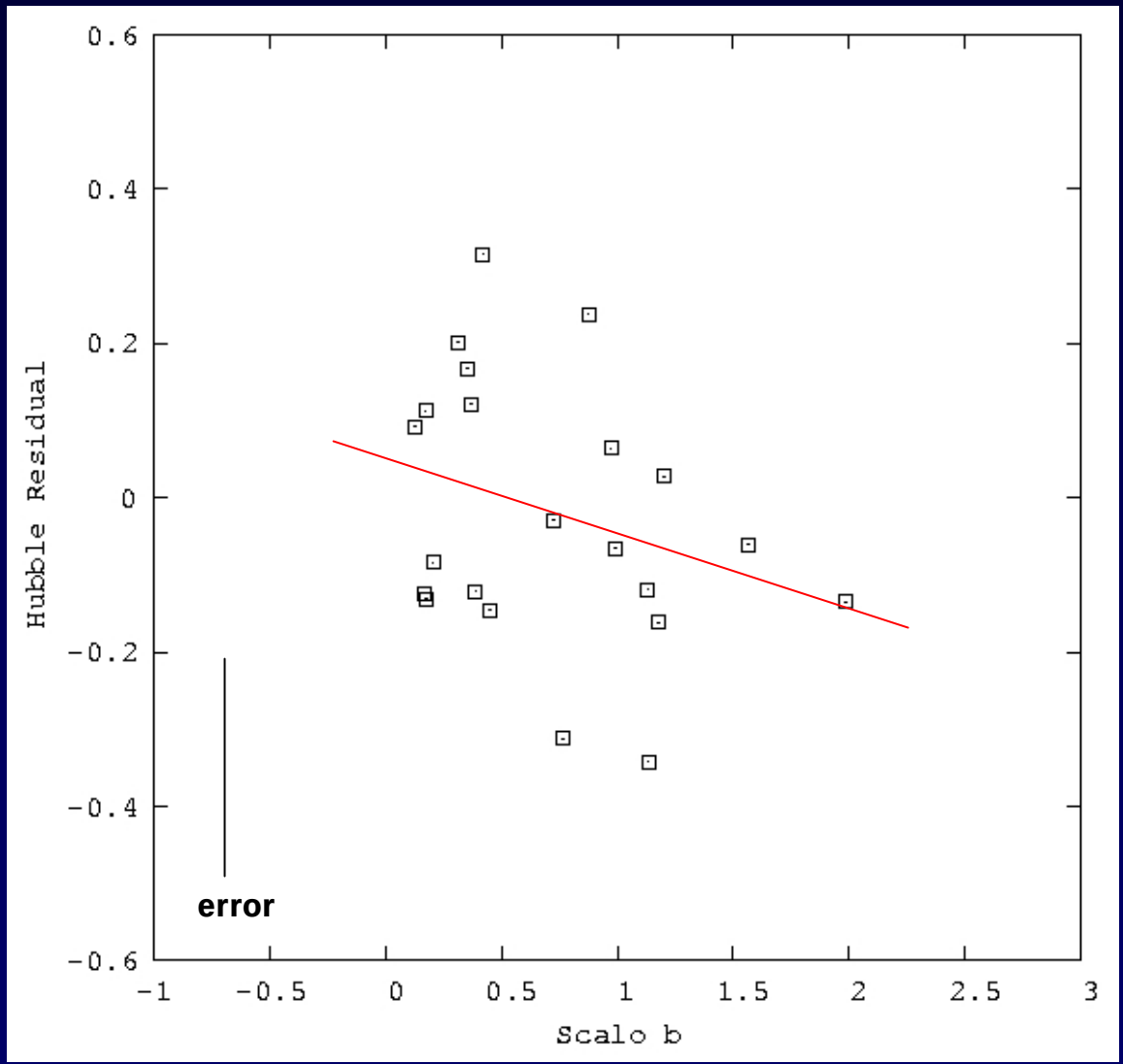
Check for Systematics: Star Formation

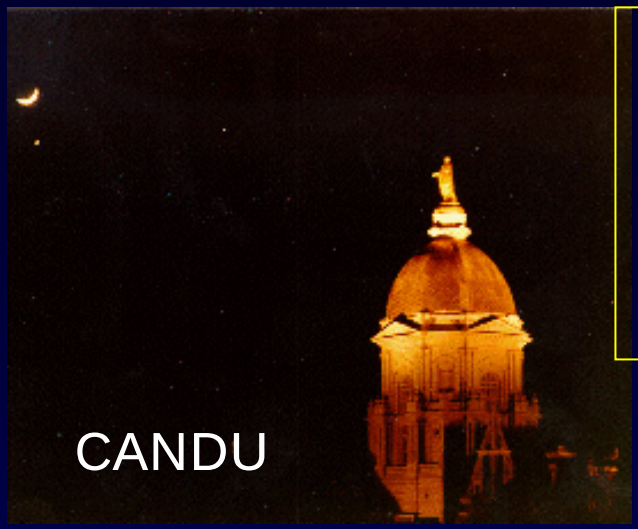
Hubble residuals compared with Scalo b parameter show a hint of correlation.

Galaxies with higher than normal current star formation lack low luminosity supernovae.

Only a 2-sigma significance

May indicate some bias at high redshift where star formation rates were higher than now.





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Summary

- There appears no relation between host metallicity and SN Ia brightness
- All fast declining SNIa with $\Delta m_{15}(B)>1.4$ occur in galaxies with extremely low star formation rates and Scalo b values.
- The variation of $\Delta m_{15}(B)$ is a result of the main sequence progenitor mass (population age) and not metallicity
- There is no strong correlation between residuals to the Hubble flow and host metalicity, but there is a weak correlation with star formation history.