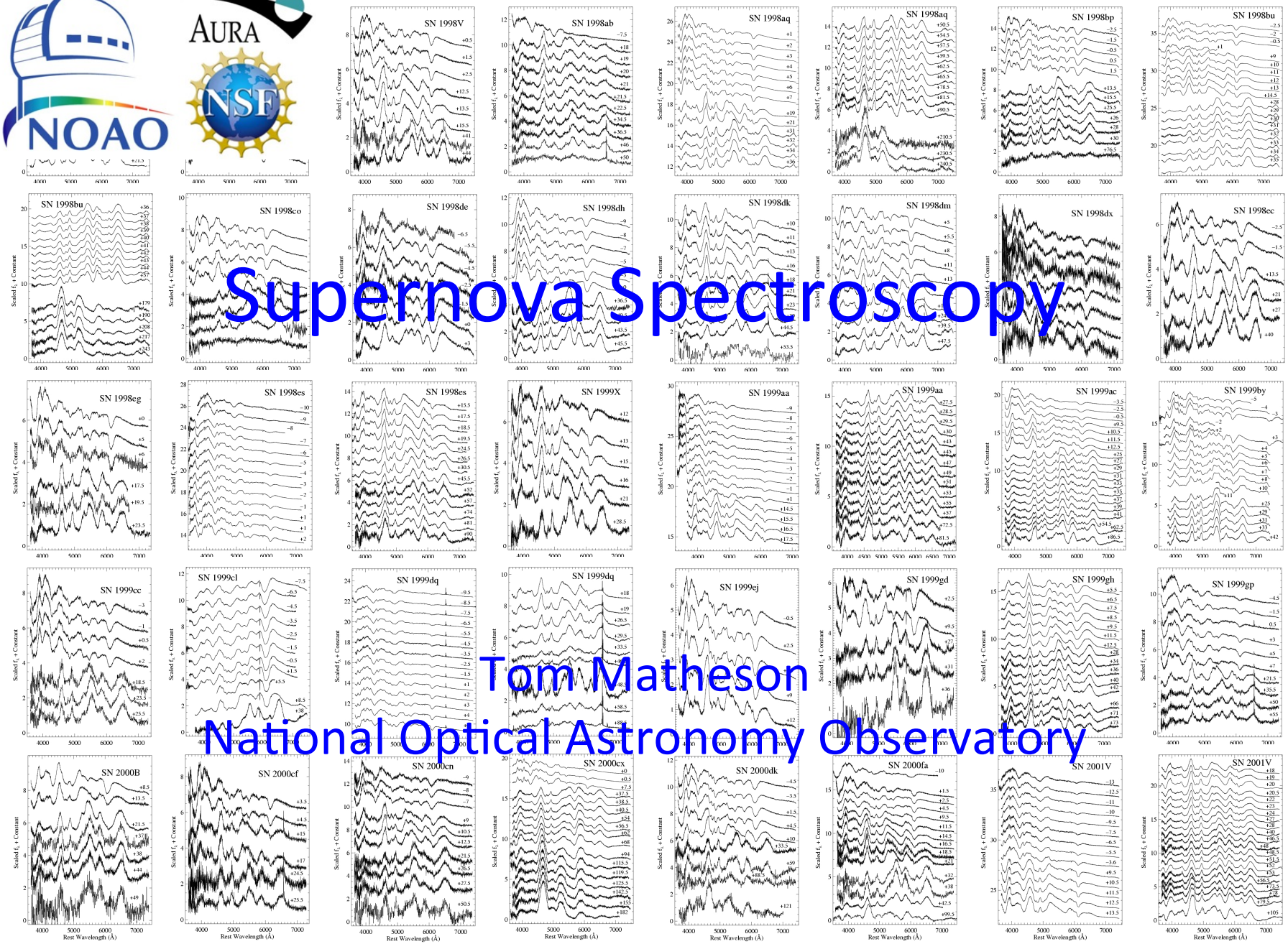
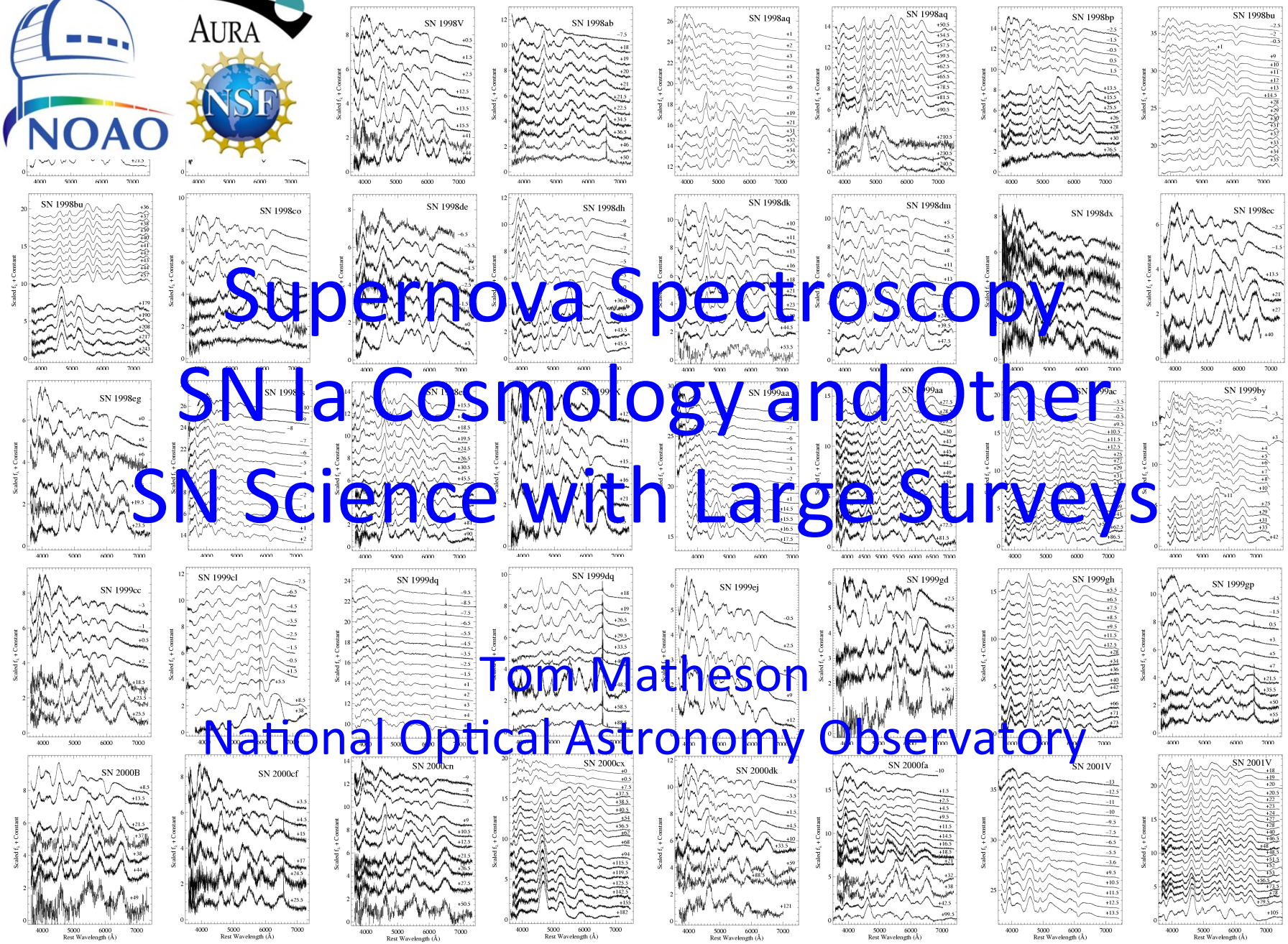
Supernova Spectroscopy

Tom Matheson
National Optical Astronomy Observatory



Supernova Spectroscopy
SN Ia Cosmology and Other
SN Science with Large Surveys

Tom Matheson
National Optical Astronomy Observatory



SNe Ia Are All the Same

Since 1941, we saw SNe Ia as essentially uniform objects spectroscopically.

From Alex Kim's talk, we can see how easy they are as standard candles

The meetings were concluded Friday by a trip to Palomar Mountain, where the members were taken on a complete tour of the 200-inch dome and the two Schmidt telescopes, a privilege not ordinarily accorded visitors.

Abstracts of the papers presented which are available at this time, and which have not already been printed in the June number of the *Publications*, follow, their order being dictated simply by convenience.

SPECTRA OF SUPERNOVAE

By R. Minkowski

(*Abstract*)

Spectroscopic observations indicate at least two types of supernovae. Nine objects (represented by the supernovae in IC 4182 and in NGC 4636) form an extremely homogeneous group provisionally called "type I." The remaining five objects (represented by the supernova in NGC 4725) are distinctly different; they are provisionally designated as "type II." The individual differences in this group are large; at least one object, the supernova in NGC 4559, may represent a third type or, possibly, an unusually bright ordinary nova.

Spectra of supernovae of type I have been observed from 7 days before maximum until 339 days after. Except for minor differences, the spectrograms of all objects of type I are closely comparable at corresponding times after maxima. Even at the earliest premaximum stage hitherto observed, the spectrum consists of very wide emission bands. No significant transformation of the spectrum occurs near maximum. Spectra of type II have been observed from maximum until 115 days after. Up to about a week after maximum, the spectrum is continuous and extends far into the ultraviolet, indicating a very high color temperature. Faint emission is suspected near $H\alpha$. Thereafter, the continuous spectrum fades and becomes redder. Simultaneously, absorptions and broad emission bands are developed. The spectrum as a whole resembles that of normal novae in the transition stage, although the hydrogen bands are relatively faint and forbidden

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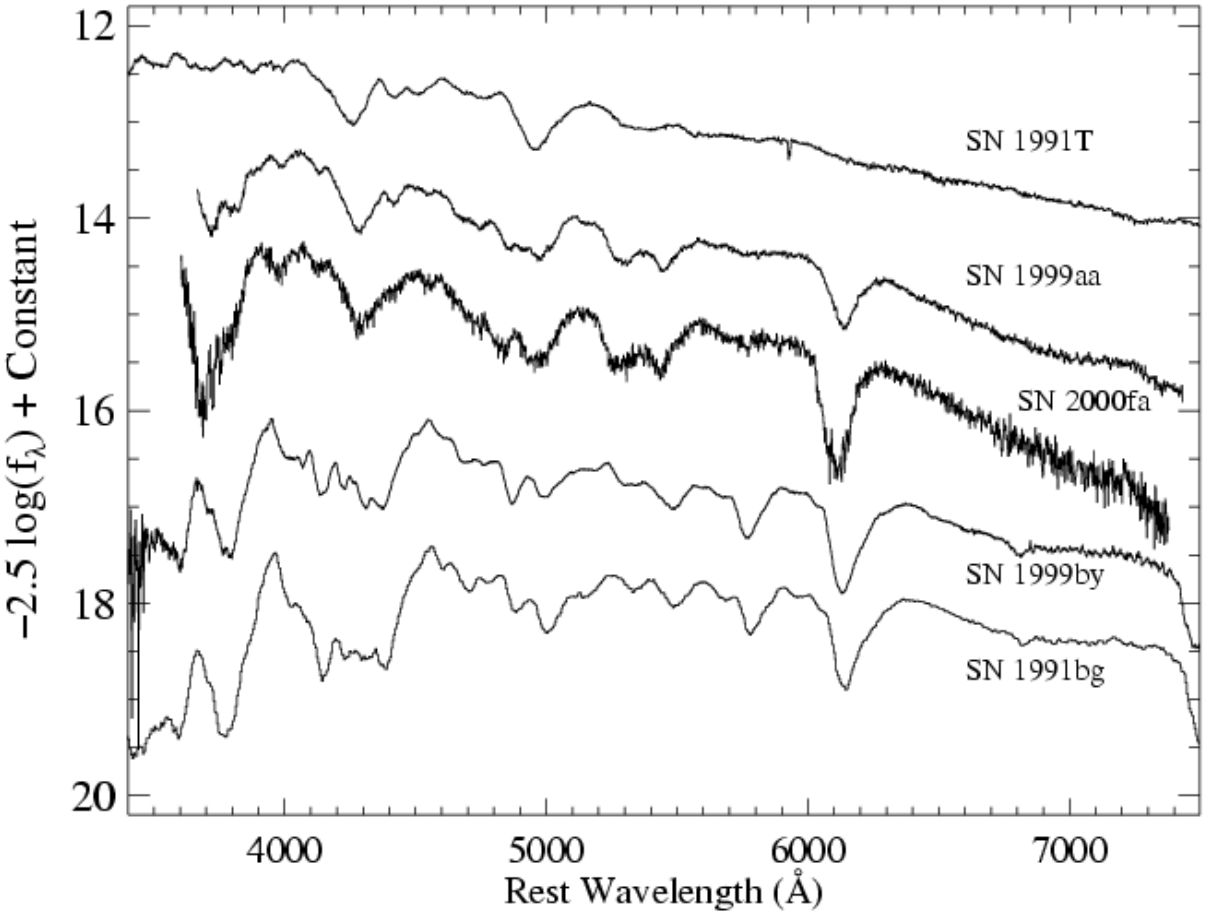
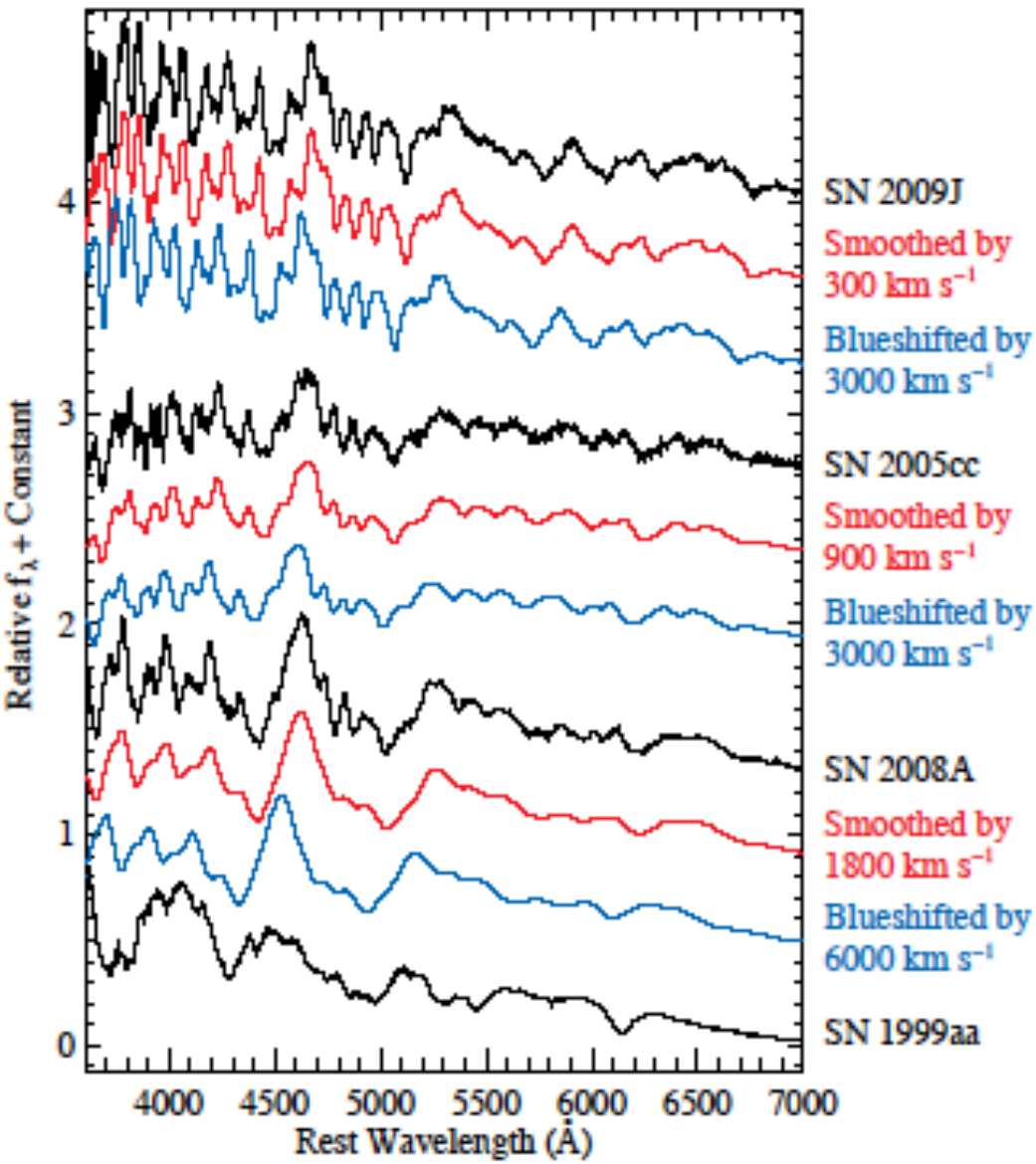
SNe Ia Are Not All the Same



Calibrateable by using any of the light-curve shape methods

Even SNe with same LC shape parameters can have different spectra (Alex Kim's talk)

Bizarre SNe: Type Iax

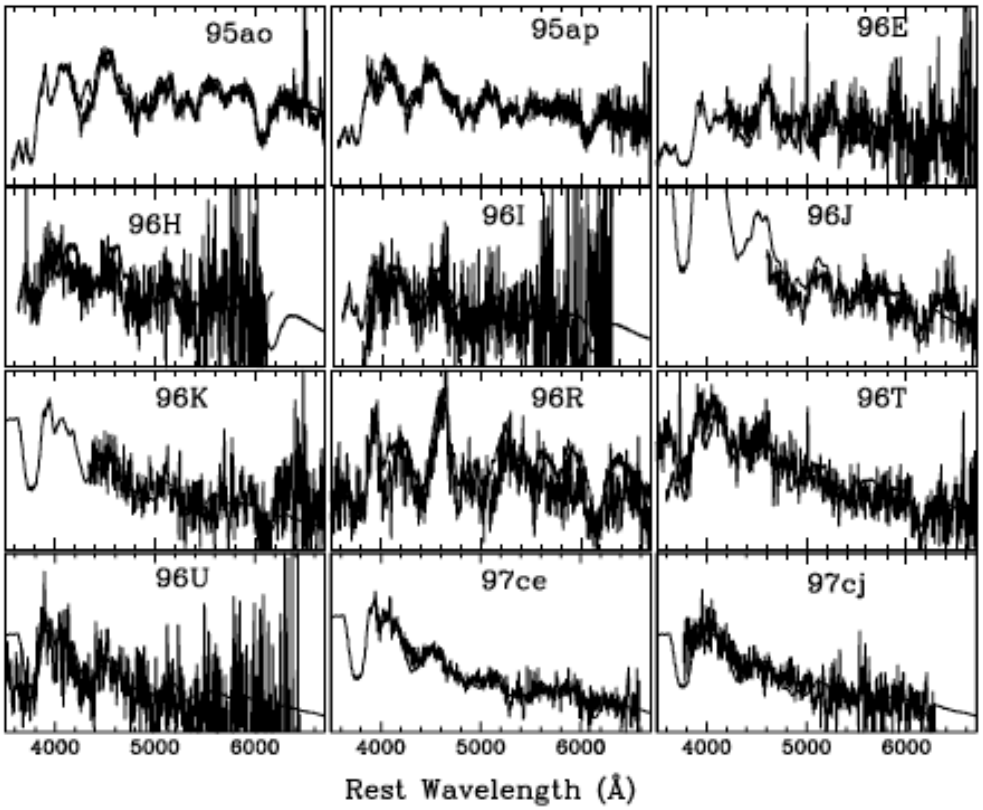


Different progenitor?

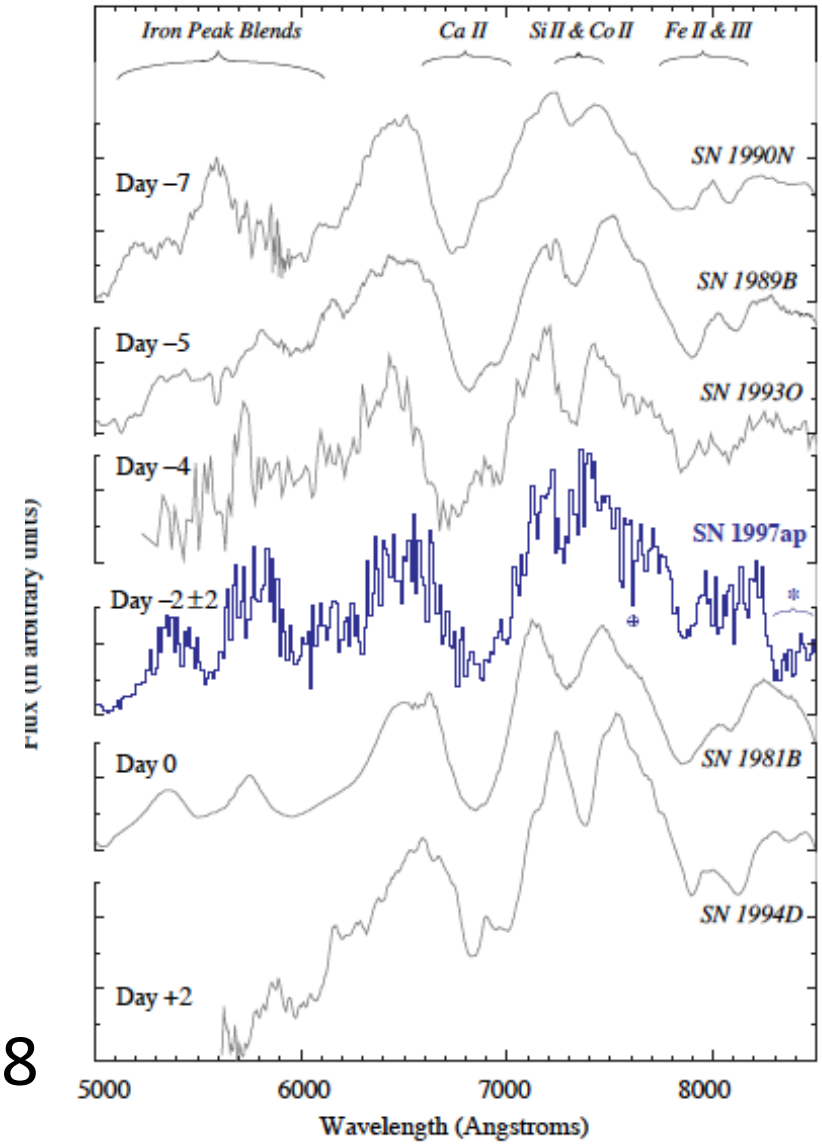
Possible C/O WD accreting from He star

Foley et al. 2013

Proof That We Were Looking at SNe Ia

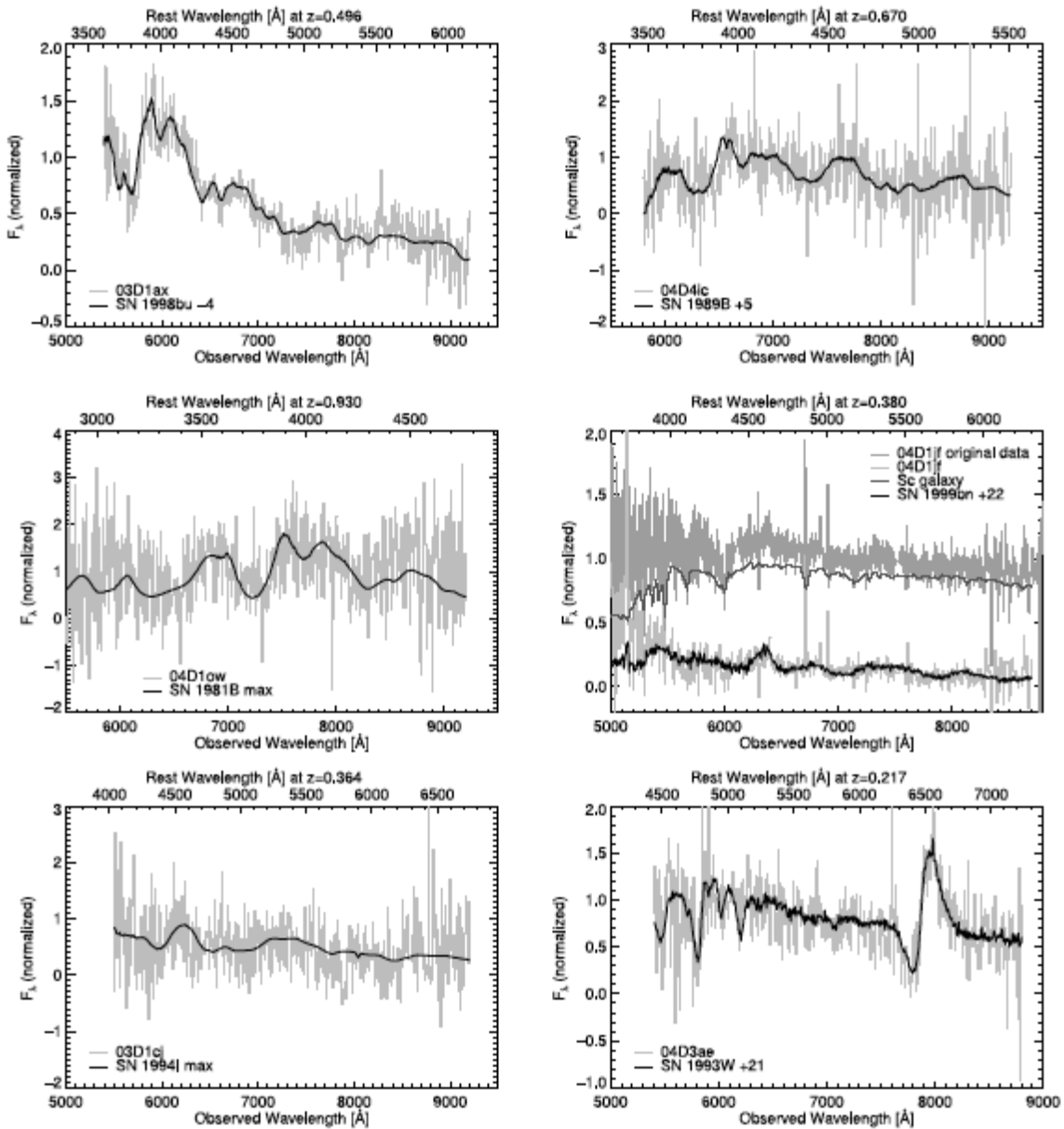


Riess et al. 1998



Perlmutter et al. 1998

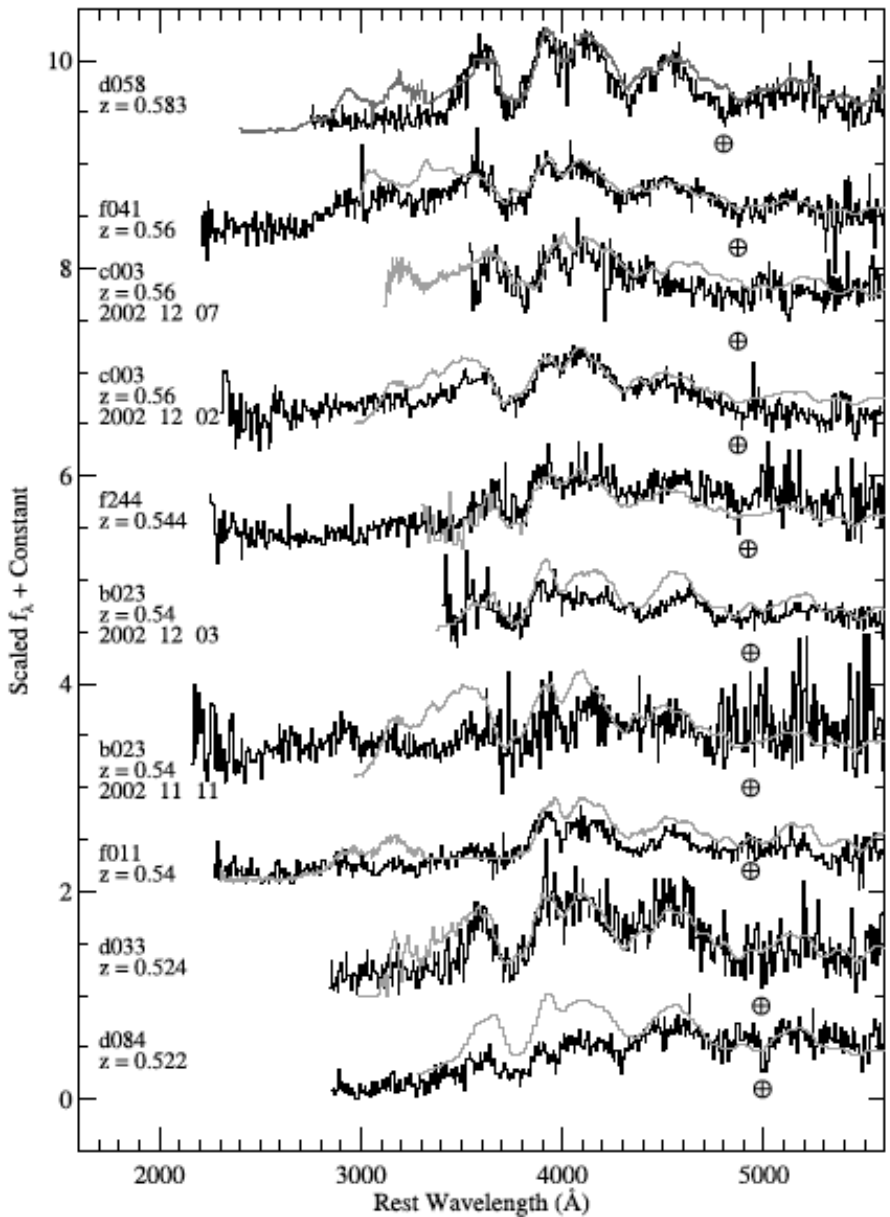
Follow-On Cosmology Surveys: Redshifts & SN Systematics



Supernova Legacy Survey has ~500 spectra of high-redshift SNe Ia

Howell et al. 2005

Follow-On Cosmology Surveys: Redshifts & SN Systematics

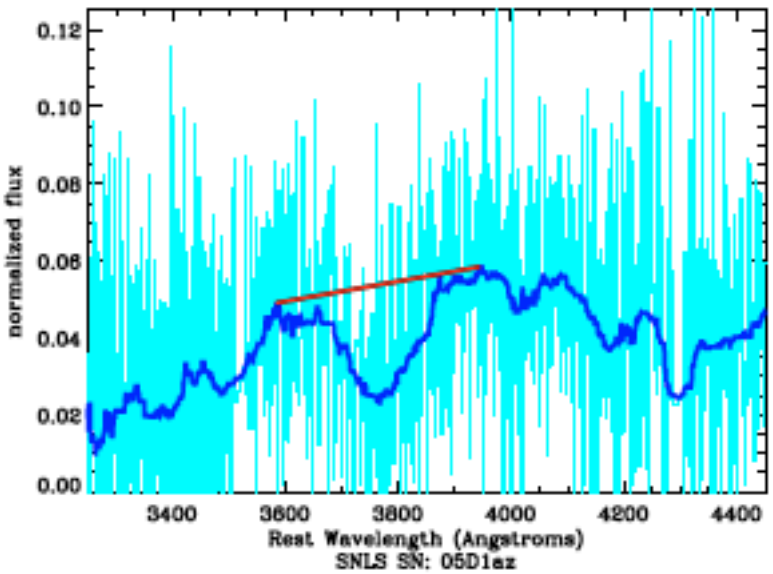


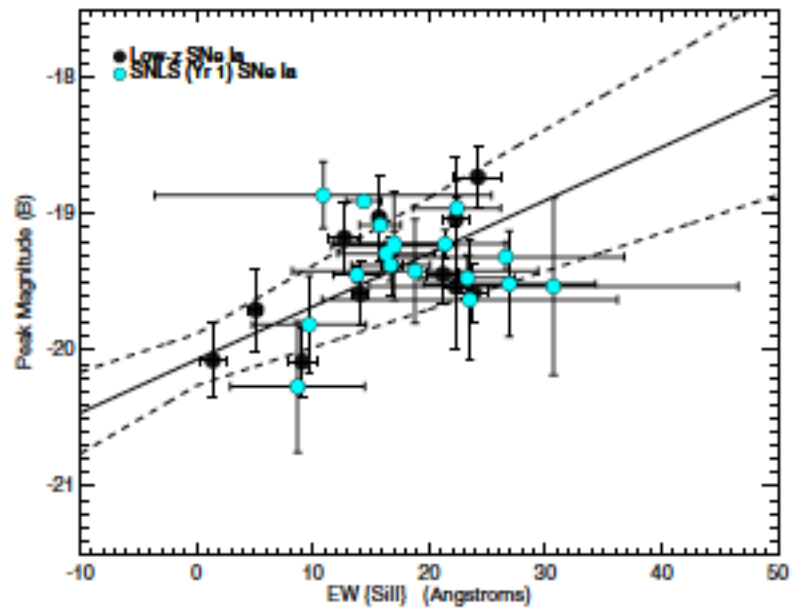
ESSENCE Survey has ~200 spectra of high-redshift SNe Ia

Matheson et al. 2005
Foley et al. 2009

Large low-redshift samples: CfA, Berkeley, SN Factory, Carnegie

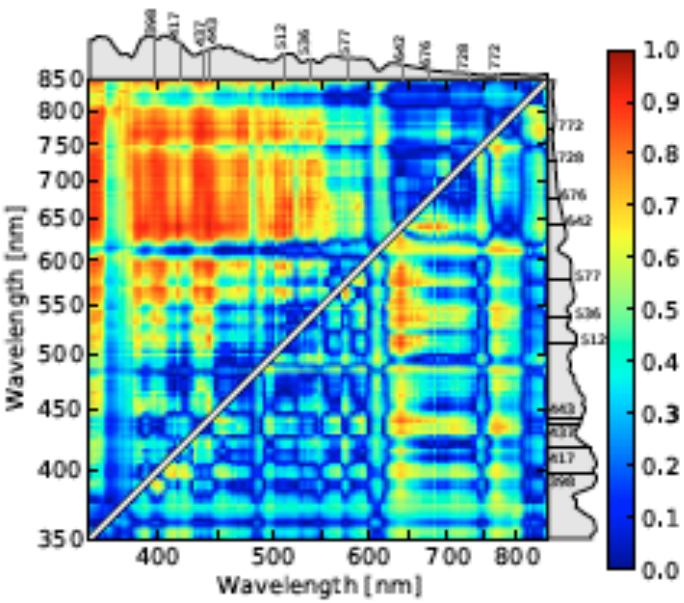
Use These Large Data Sets to Find Spectroscopic Clues to Luminosity

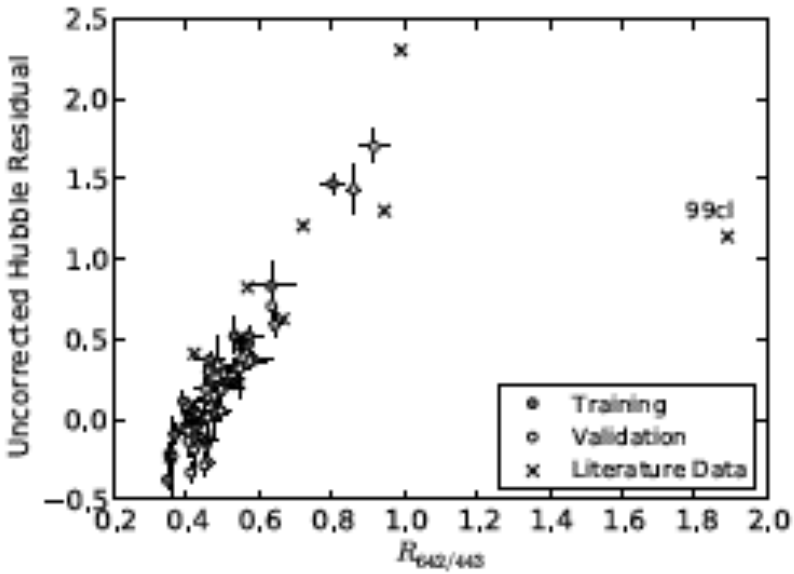




Nugent et al. 1995
Bronder et al. 2008

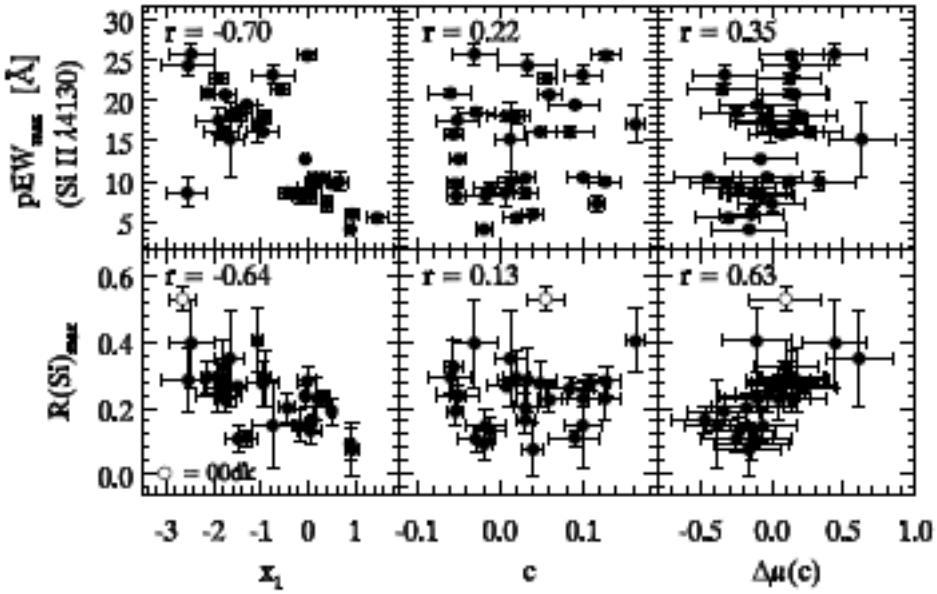
Nearby SN Ia Sample Provides Even More Data to Explore





Bailey et al 2009

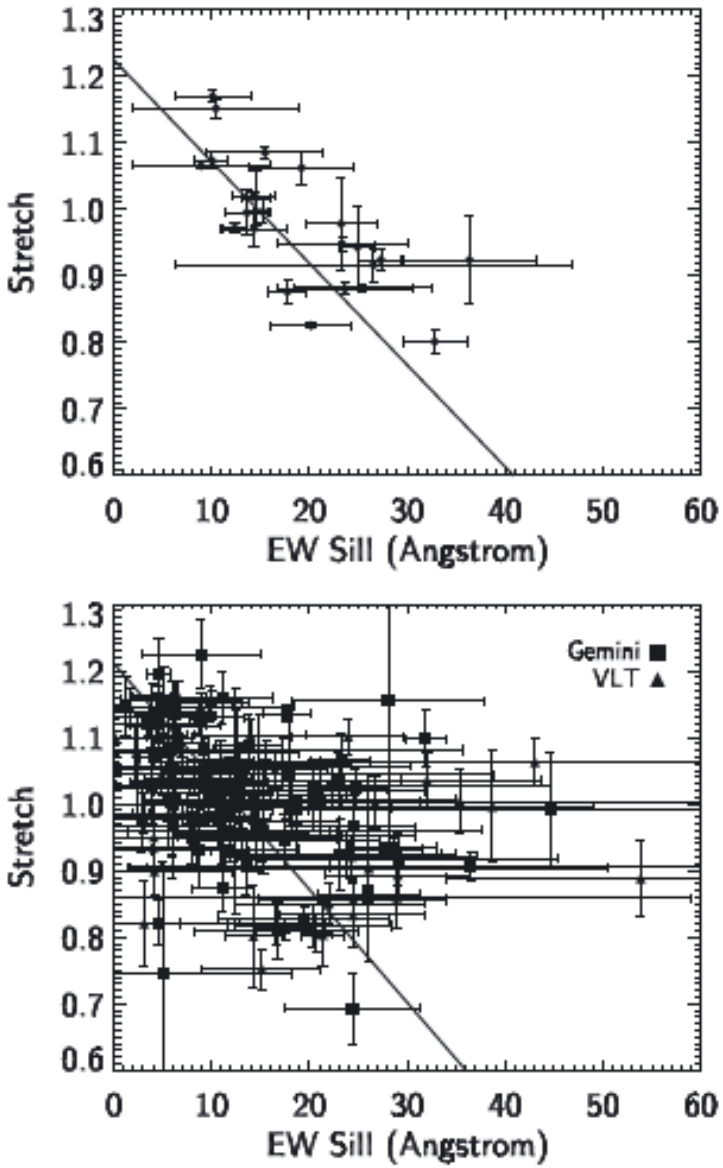
Spectral Features Correlate with Photometric Parameters



Blondin et al. 2010

"Do spectra improve distance measurements of SN Ia? Yes, but not as much as we had hoped."

Spectral Features Get Harder to Measure

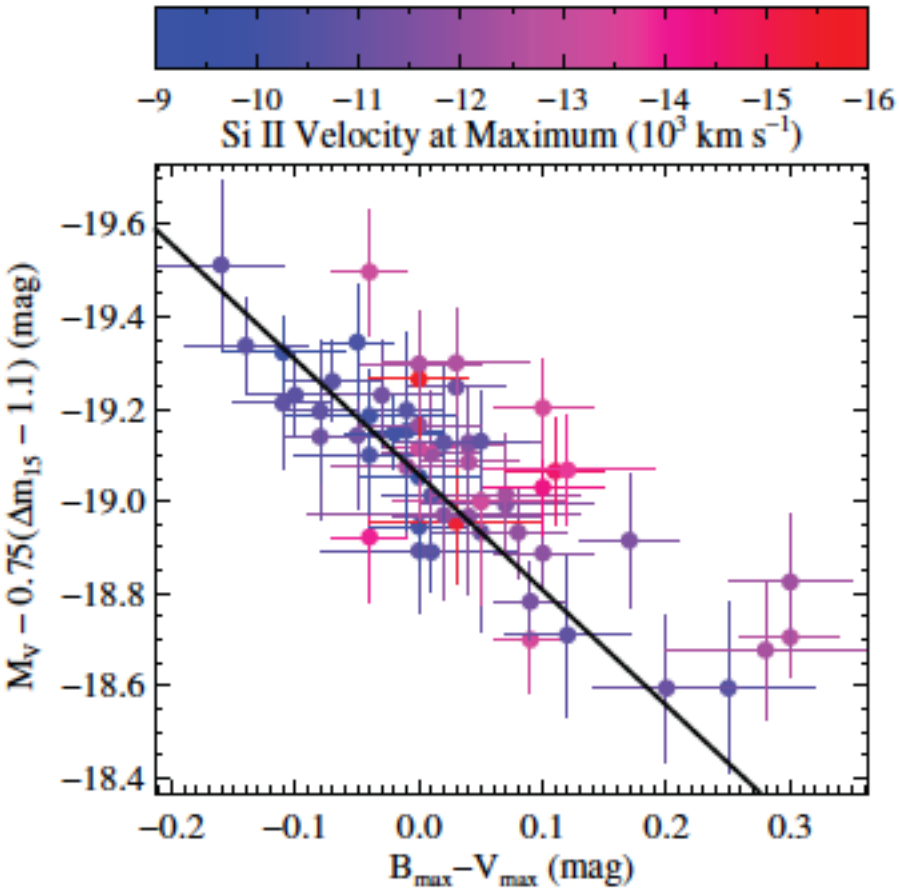


Spectra of high-redshift SNe Ia are generally not of the same high signal-to-noise ratio as the low-redshift sample

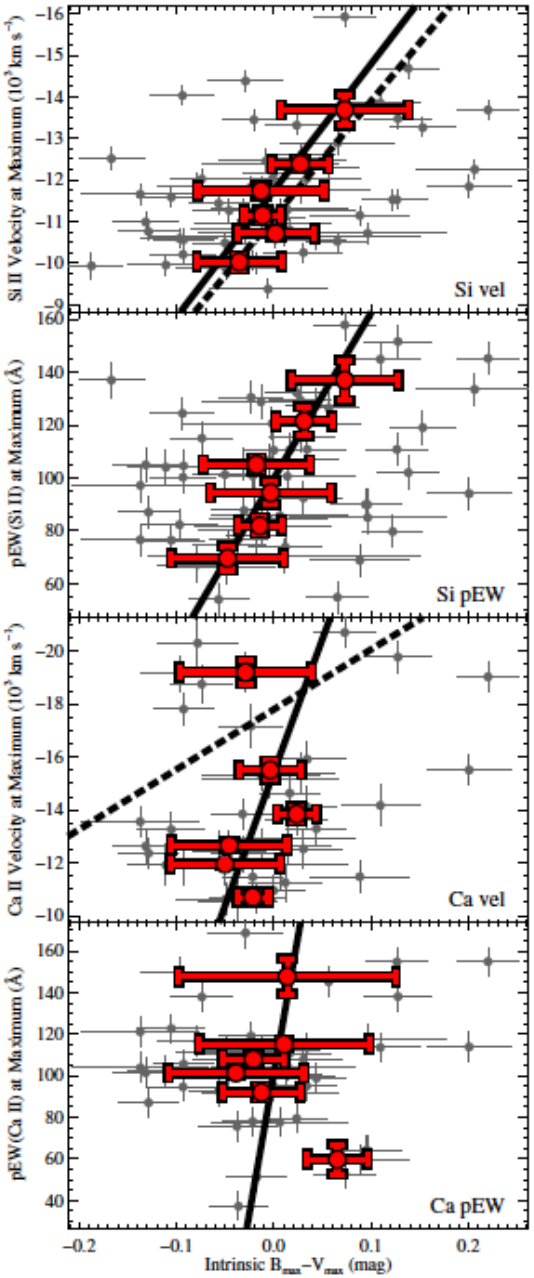
Walker et al. 2011

Velocities from Spectra May Provide Clues about Intrinsic Color

Ryan Foley: Sample SNe Ia over many redshift bins to calibrate this effect



Foley & Kasen 2011
Foley, Sanders, Kirshner 2011
Mandel, Foley, Kirshner 2014



LSST Strawman Plan

Michael Wood-Vasey, Spectroscopy in the Era of LSST workshop report

Spectra of ~10,000 supernovae at given phases. These spectra will be distributed from $0.1<z<0.9$. R~100-1000.

Set A) 5,000 for spectra at maximum light.

Set B) 2,500 to follow all SN-like events to explore contamination and classification

Set C) 2,500 (5x500) repeated coverage to map out full coverage around peak.

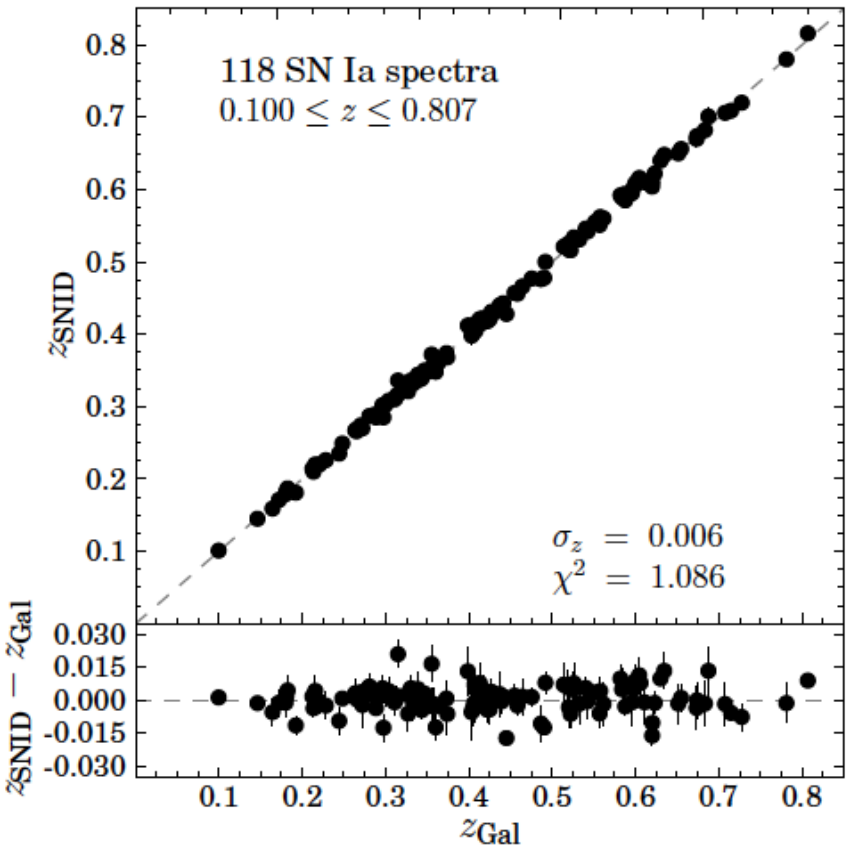
Spectra of 100,000 host galaxies from $0.1<z<0.9$.

R~4000 for the host galaxies is to obtain sufficient information on emission and absorption lines to characterize the gas-phase metallicity of the host galaxies and to split the O[II] doublet.

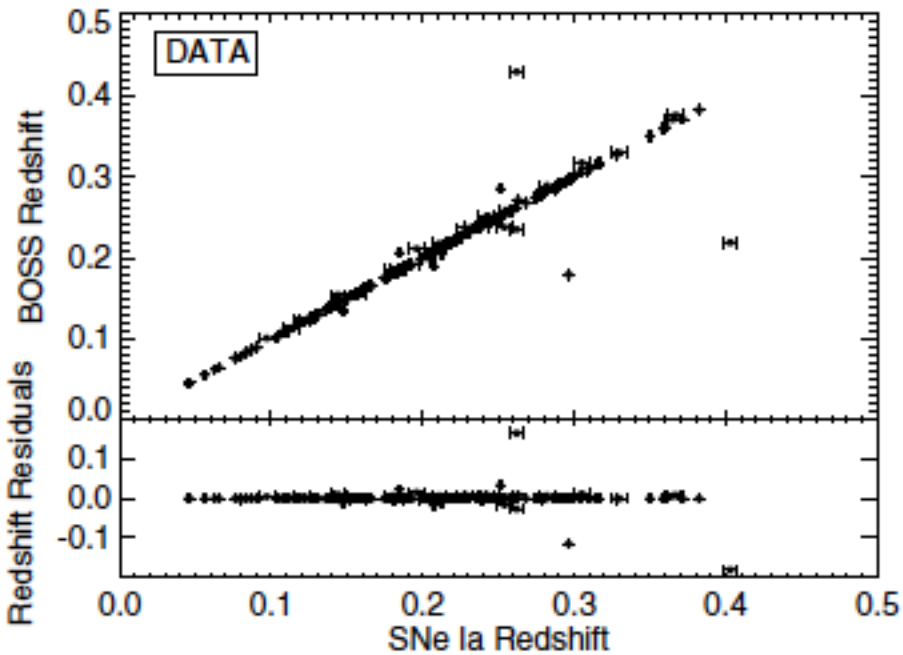
Improve photo-typing (e.g., Olmstead et al. 2014).

Redshifts from SNe Alone are Quite Good

Only viable redshift for low-surface brightness hosts?

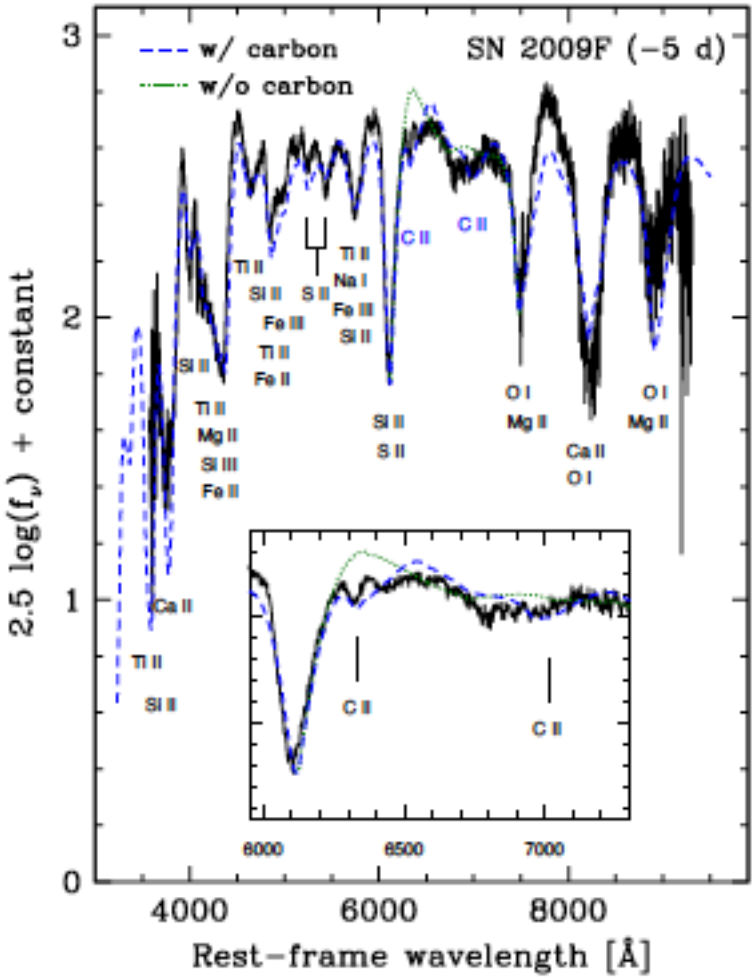


Narayan et al., in prep



Campbell et al. 2013

Do We Care What SNe Ia Are?

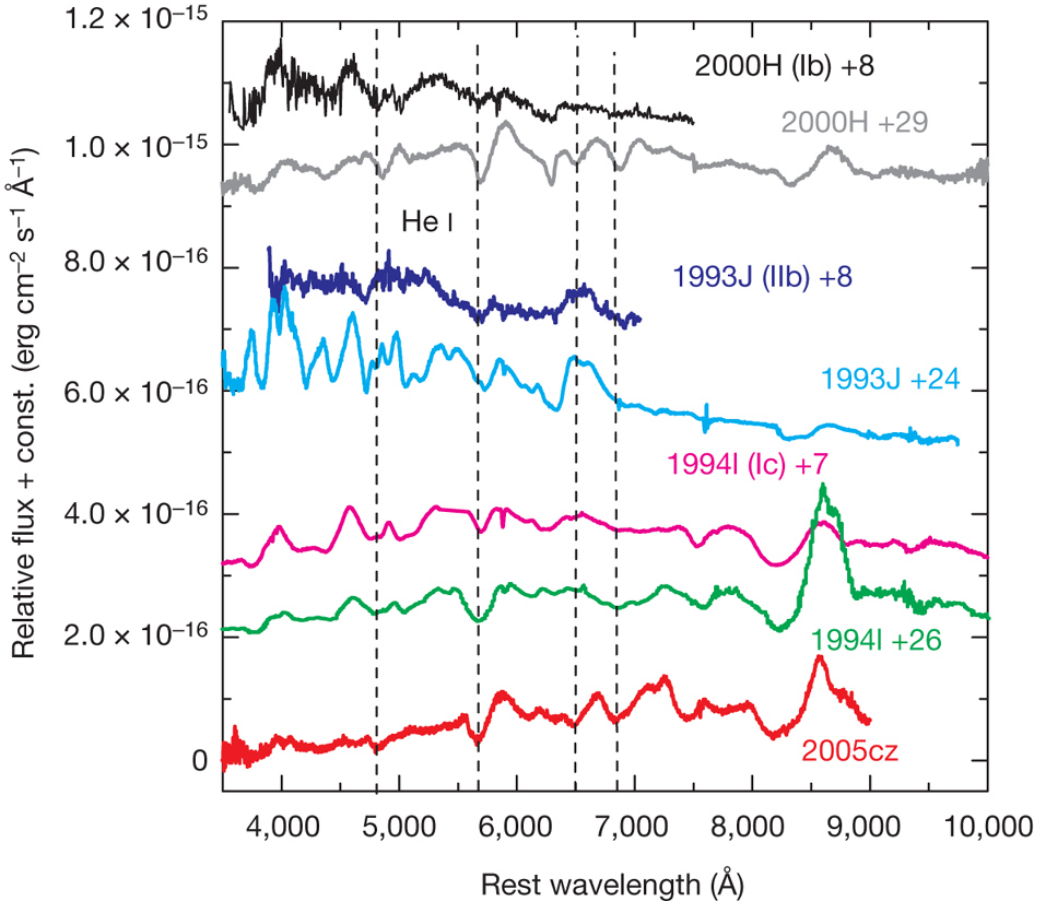


Low-redshift objects are best candidates for detailed studies

Potential clues to progenitor systems

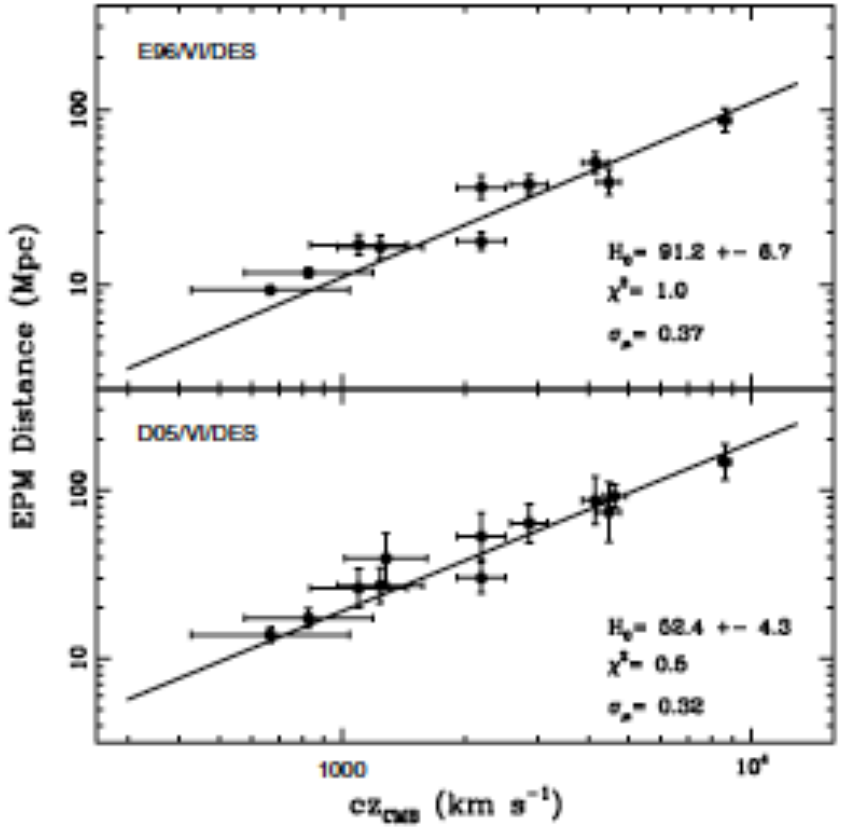
Thomas et al. 2011; Parrent et al. 2011; Folatelli et al. 2012

Core-Collapse SNe Are Even Worse



Kawabata et al. 2010

Core-Collapse SNe Distances



Jones et al. 2009

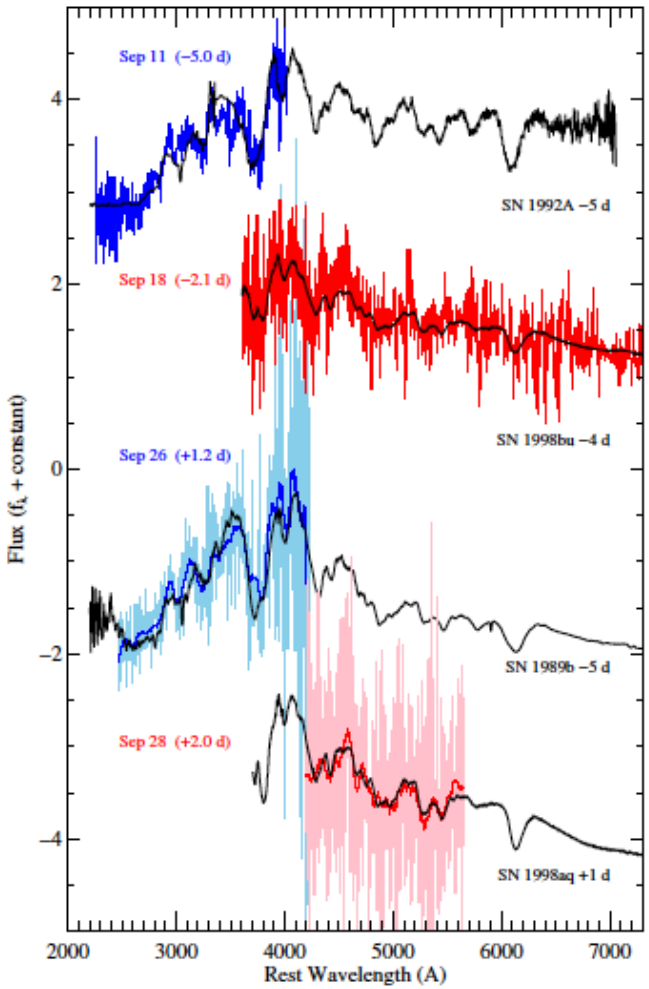
Expanding photosphere method (e.g., Schmidt et al. 1992

Standard candles (e.g., Hamuy et al. 2003)

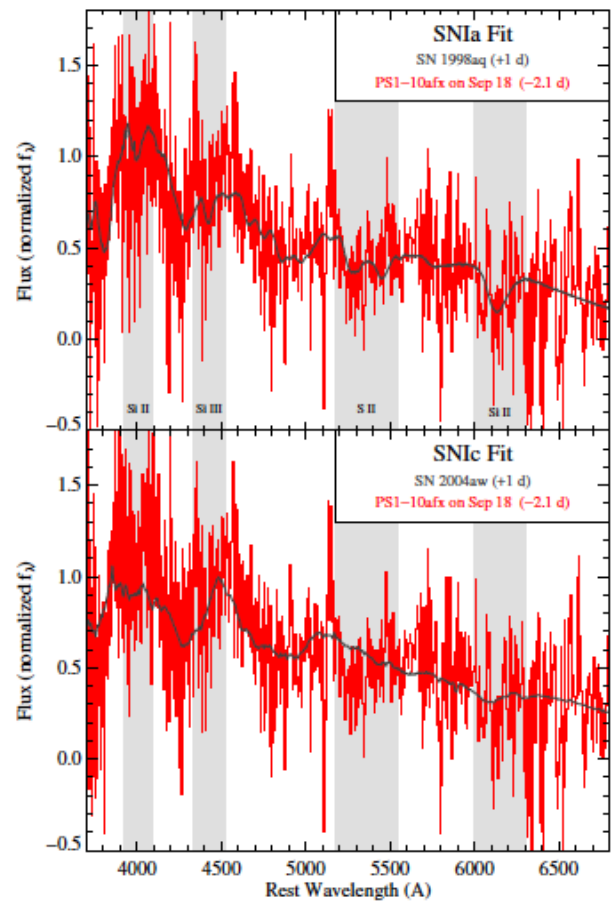
The Advantage of Wide, Deep Surveys

Very High Redshift SNe Ia from the Ground

The Case of PS1-10afx

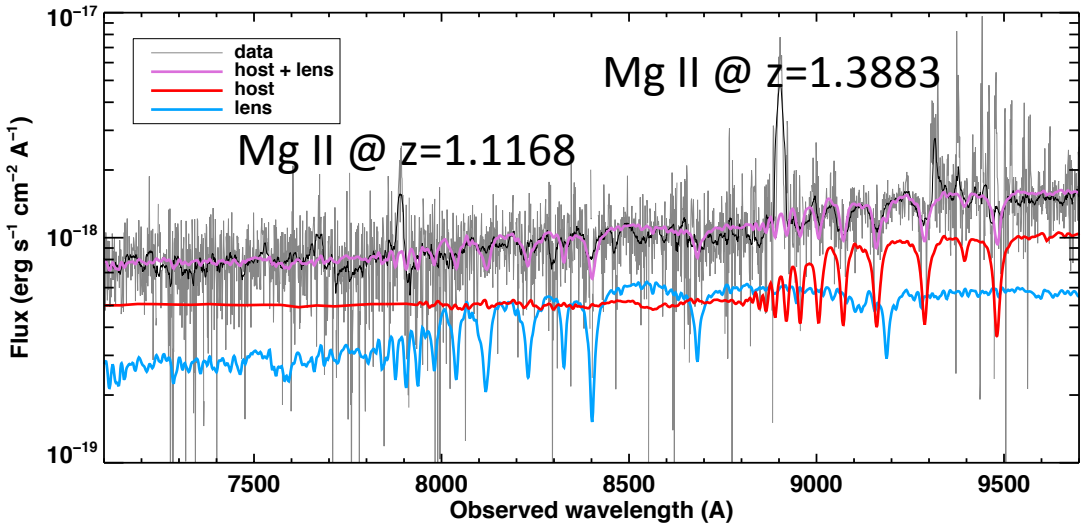


New type of Superluminous SN?
Chornock et al. 2013

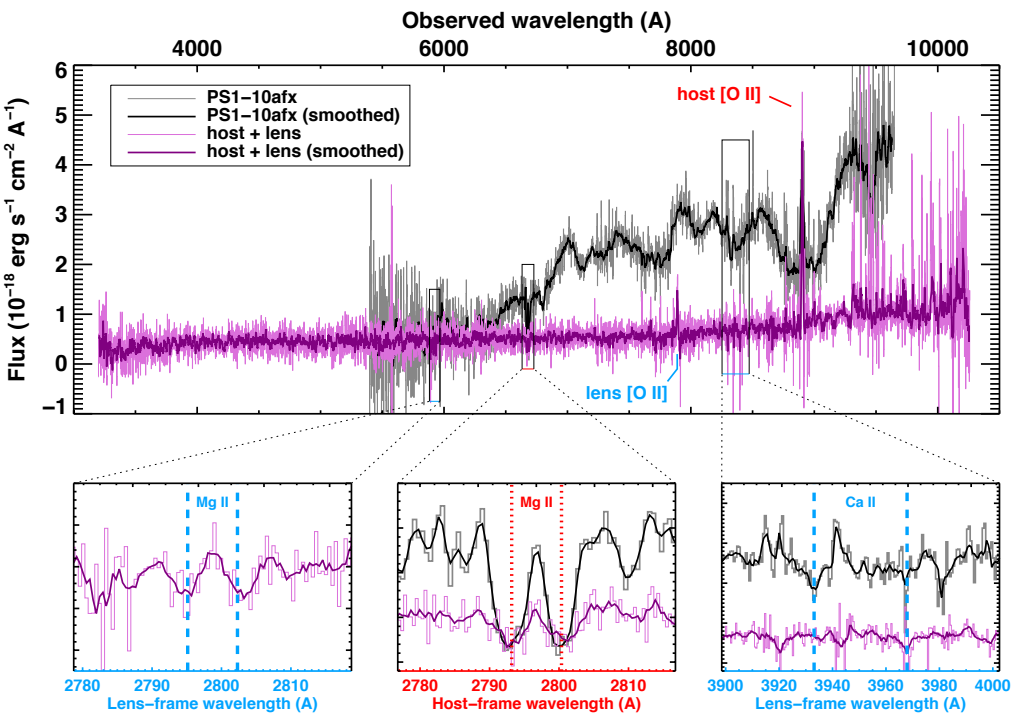


Lensed SN Ia at z=1.3883?
Quimby et al. 2013

The Case of PS1-10afx

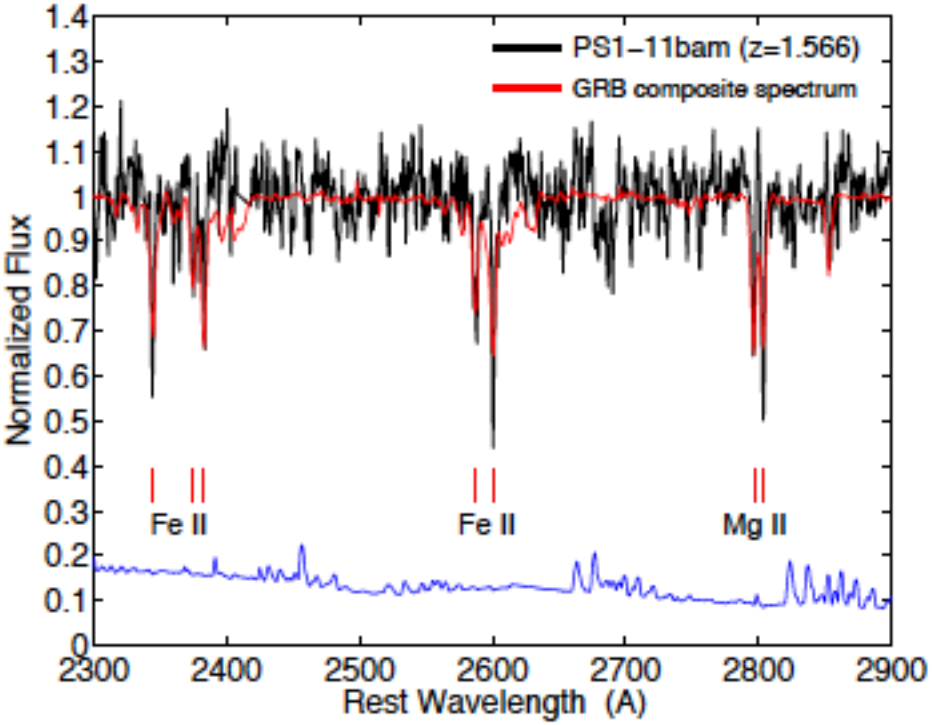


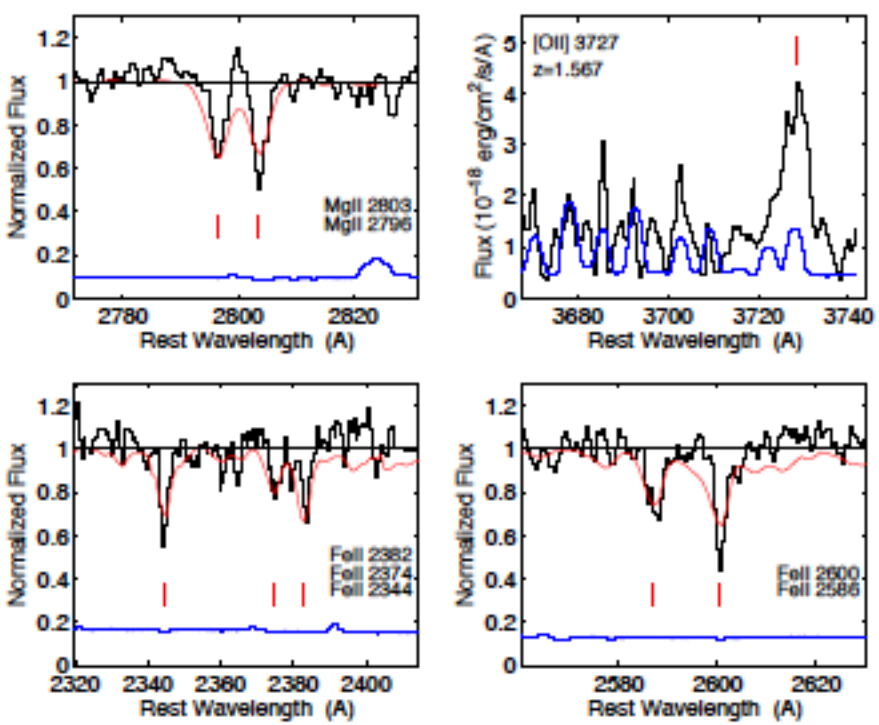
Implies a 30-fold magnification of the lensed SN Ia



Quimby et al. 2014

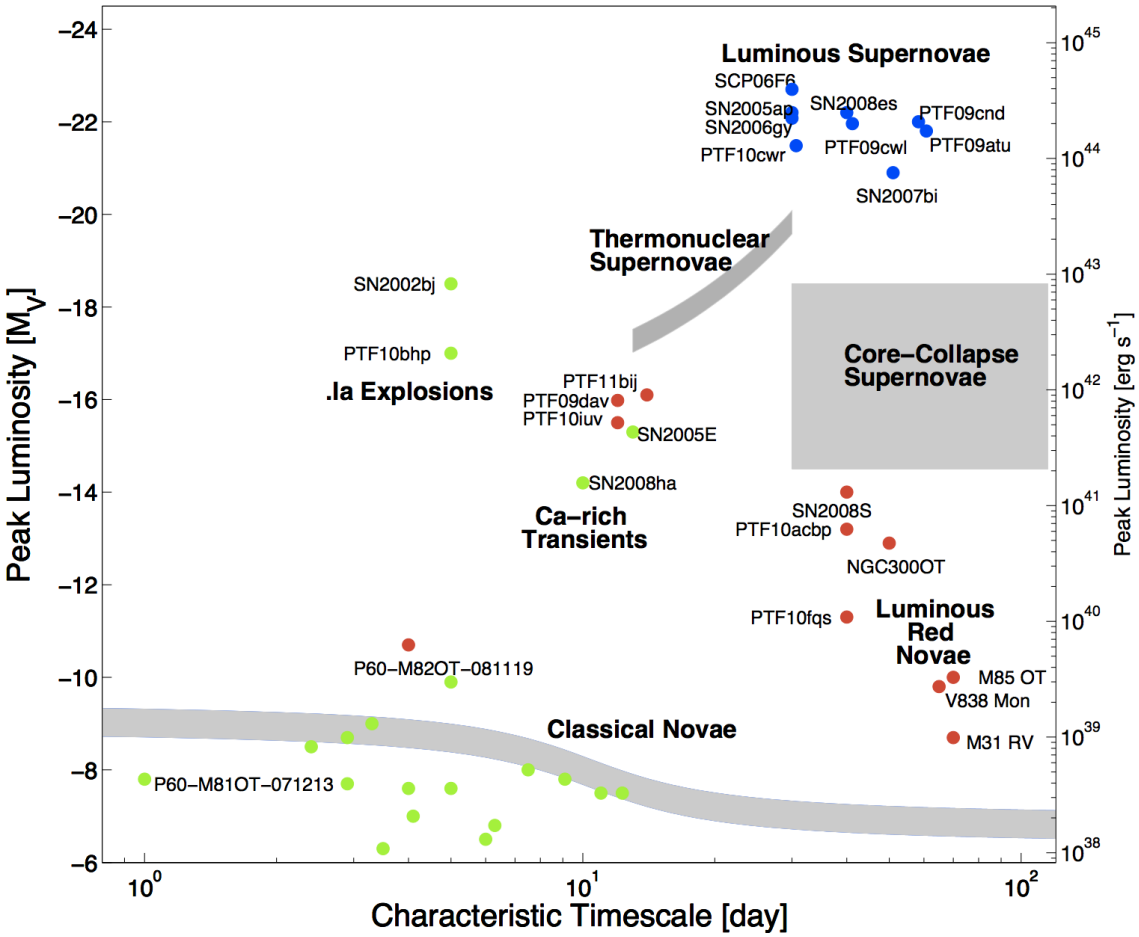
Superluminous SNe: Another High-z Probe





Berger et al. 2012

What Are We Missing?



Variety abounds with all kinds of interesting and extreme conditions

Spectra provide access to the underlying physics that photometry cannot

Kasliwal 2012

Will we have the resources to follow SNe?

Report available, astro-ph 1311.2496 (Matheson et al.)

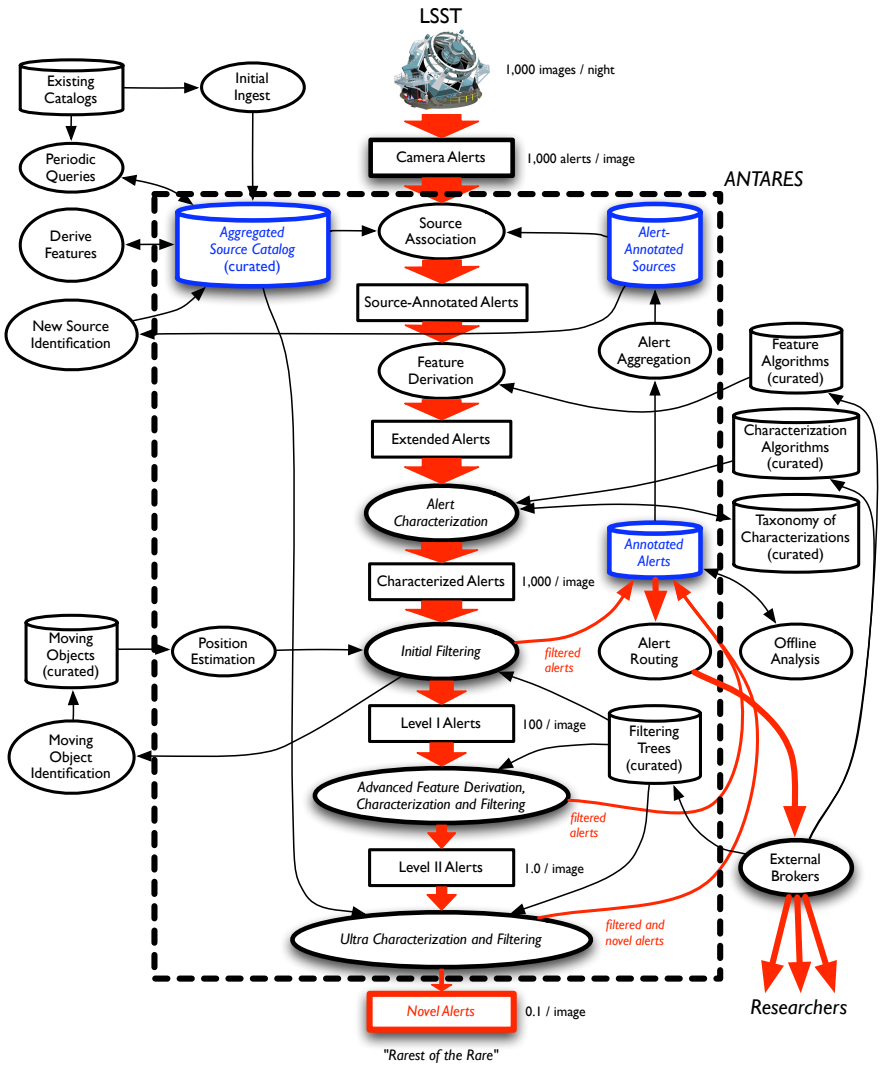
Will we have the resources to follow SNe?

What We Will Not Get

Will we have the resources to follow SNe?

No Gemini instrument currently in development to meet LSST needs.

Will we be able to distinguish SNe in a massive alert stream?



PTF: Bloom et al. 2012

Skyalert.org

ANTARES:
The Arizona-NOAO Temporal Analysis and Response to Events System

NSF funded project to build an event broker (INSPIRE CISE AST-1344024).

Tom Matheson, NOAO
Abhijit Saha, NOAO
Richard Snodgrass, Arizona, Computer Science
John Kececioglu, Arizona, Computer Science

Conclusions

- Spectroscopy of SNe Ia helps cosmology, but expensive
- Spectroscopic redshifts of hosts important
- Spectra necessary to sort out progenitors
- SNe Ia, core-collapse SNe, and explosive transients in general need spectroscopy to study explosion physics
- Large surveys will find rare objects where spectroscopy is critical
- Need to start now to develop follow-up resources (Gemini, SOAR)
- Need to distinguish among alerts to find the best objects to follow