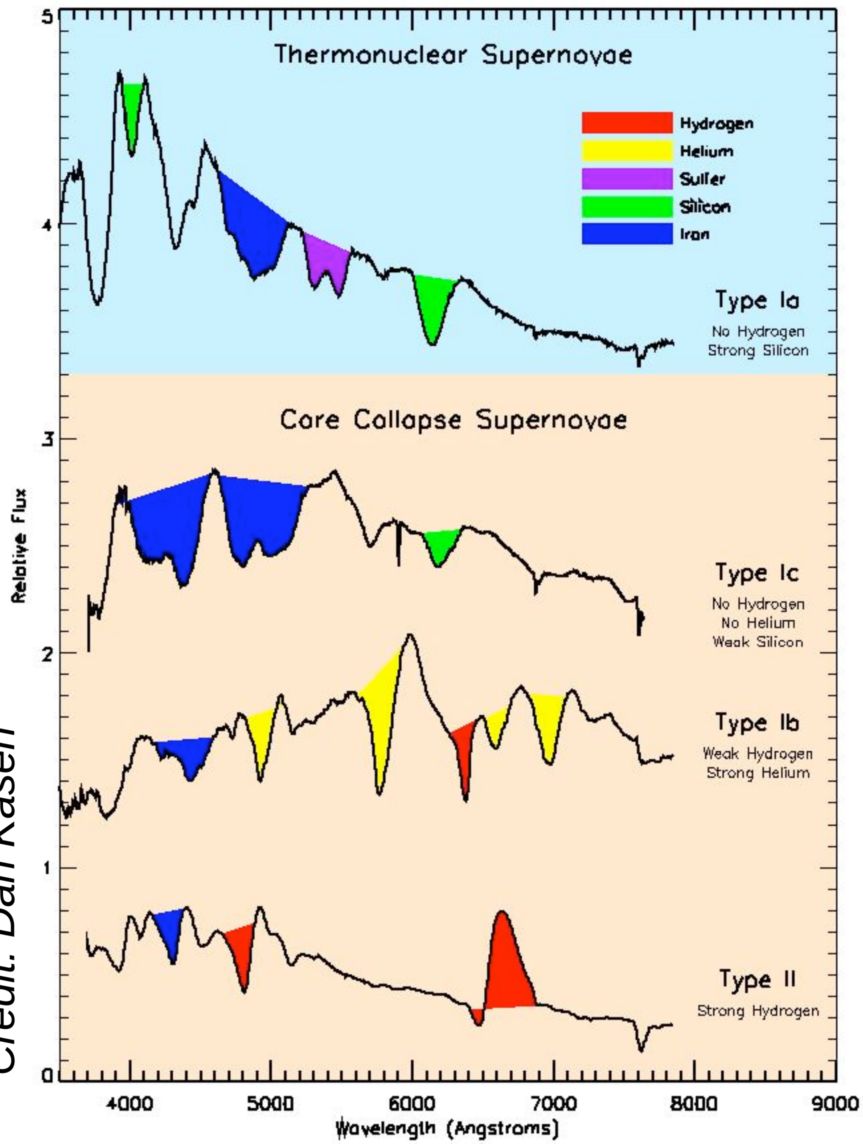
Determining the Type, Redshift, & Phase of a Supernova Spectrum



Credit: Dan Kasen

Stéphane Blondin
(CfA,KITP)

in collaboration with **John Tonry (IfA)**

Blondin & Tonry, astro-ph/0612512
Blondin & Tonry, in prep

Layout

1. Motivation
2. Supernova classification
3. Cross-correlation techniques
4. Redshift & Phase determination
5. Type determination

Layout

1. Motivation
   - classify new SNe
   - select SNe of a given type for large surveys (e.g. SN Ia)
   - cosmology with SNe Ia (redshift determination)
   - comparative studies of SN types
2. Supernova classification
3. Cross-correlation techniques
4. Redshift & Phase determination
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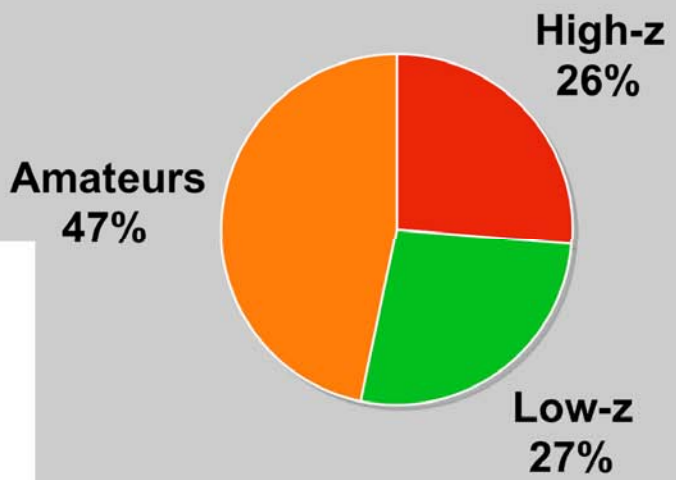
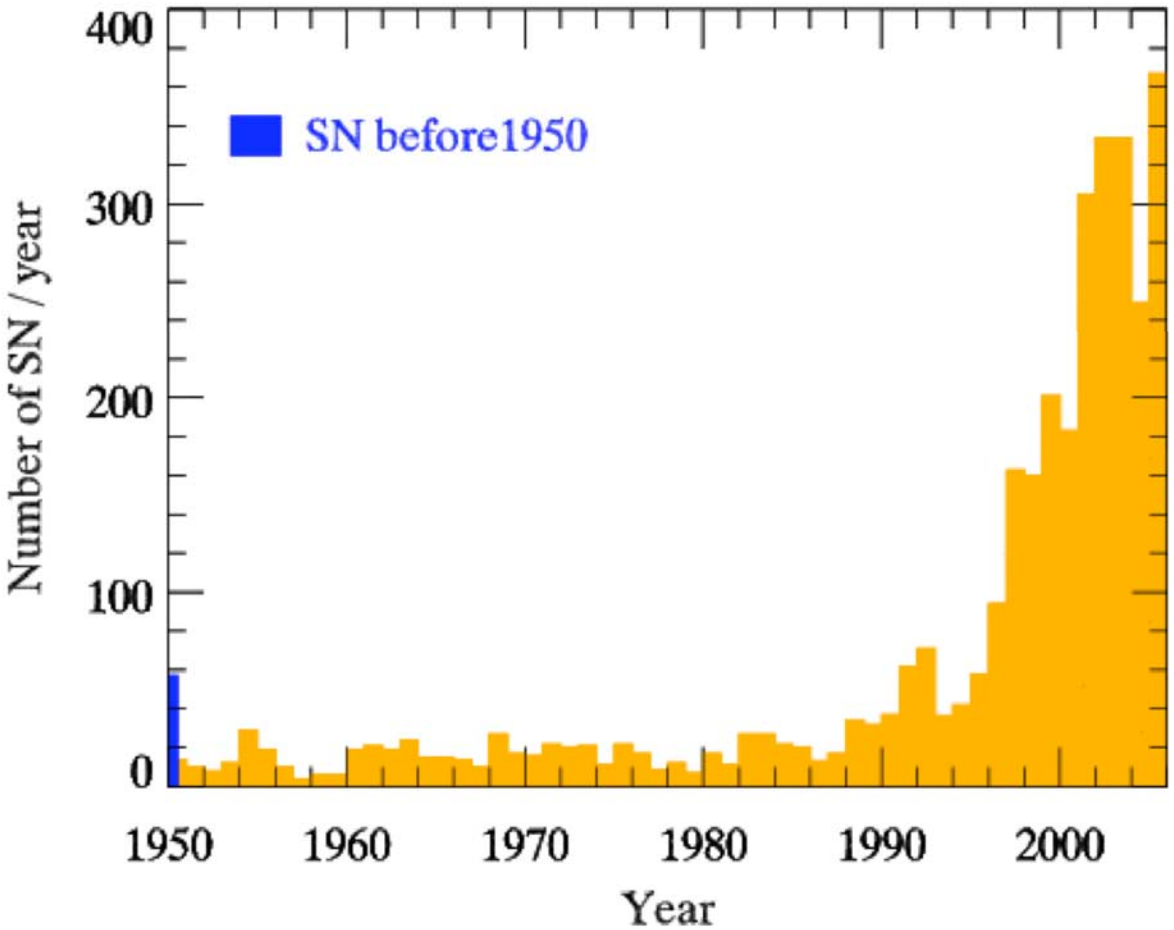
SNe by the 1000s

~3700 SNe since 1006 (50% since 2000)





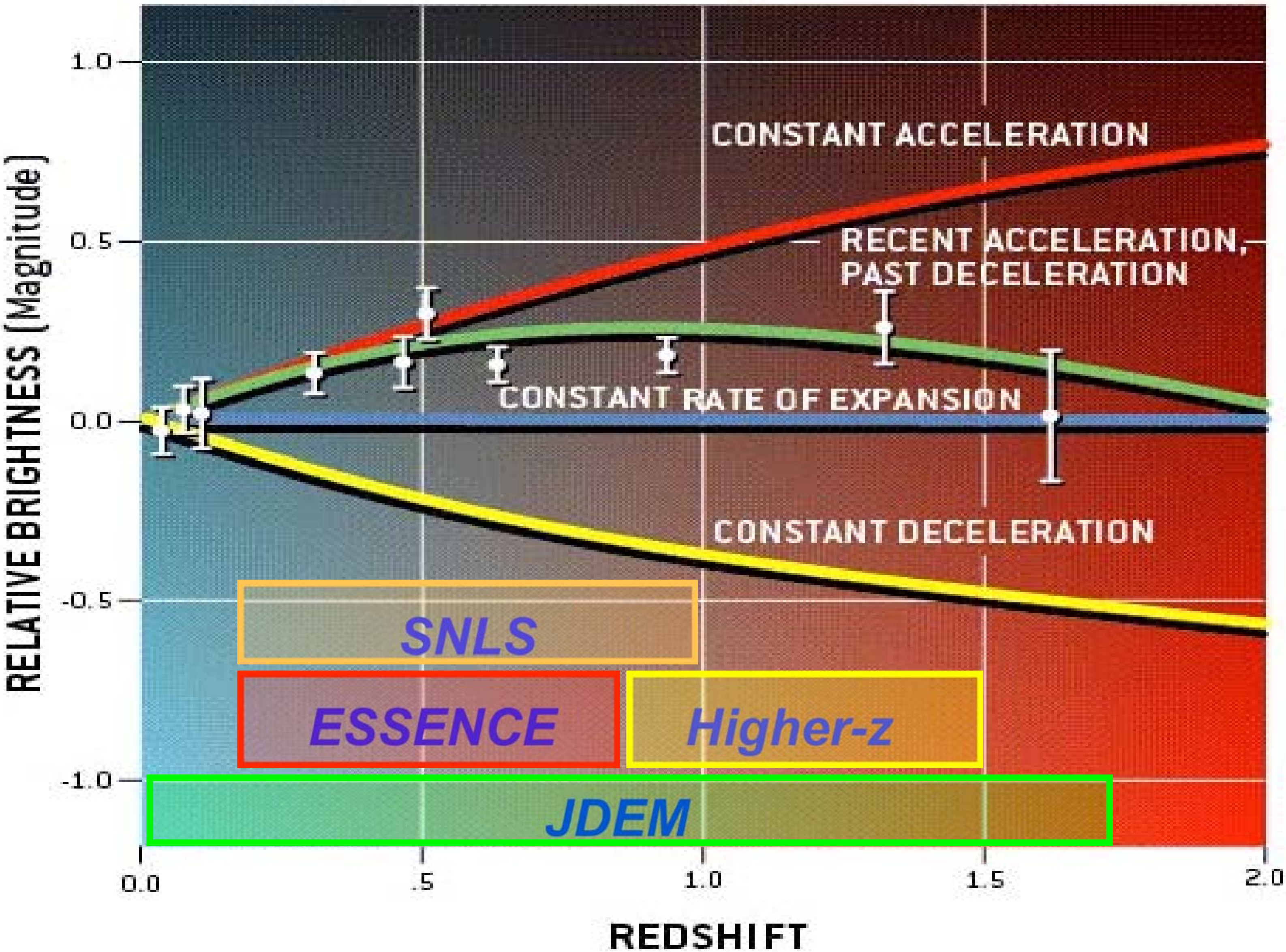
~1/2 SN is discovered by an amateur

~300+ new SNe/year

(in IAU circulars)

~40% non-securely-identified

High-z SN Ia searches

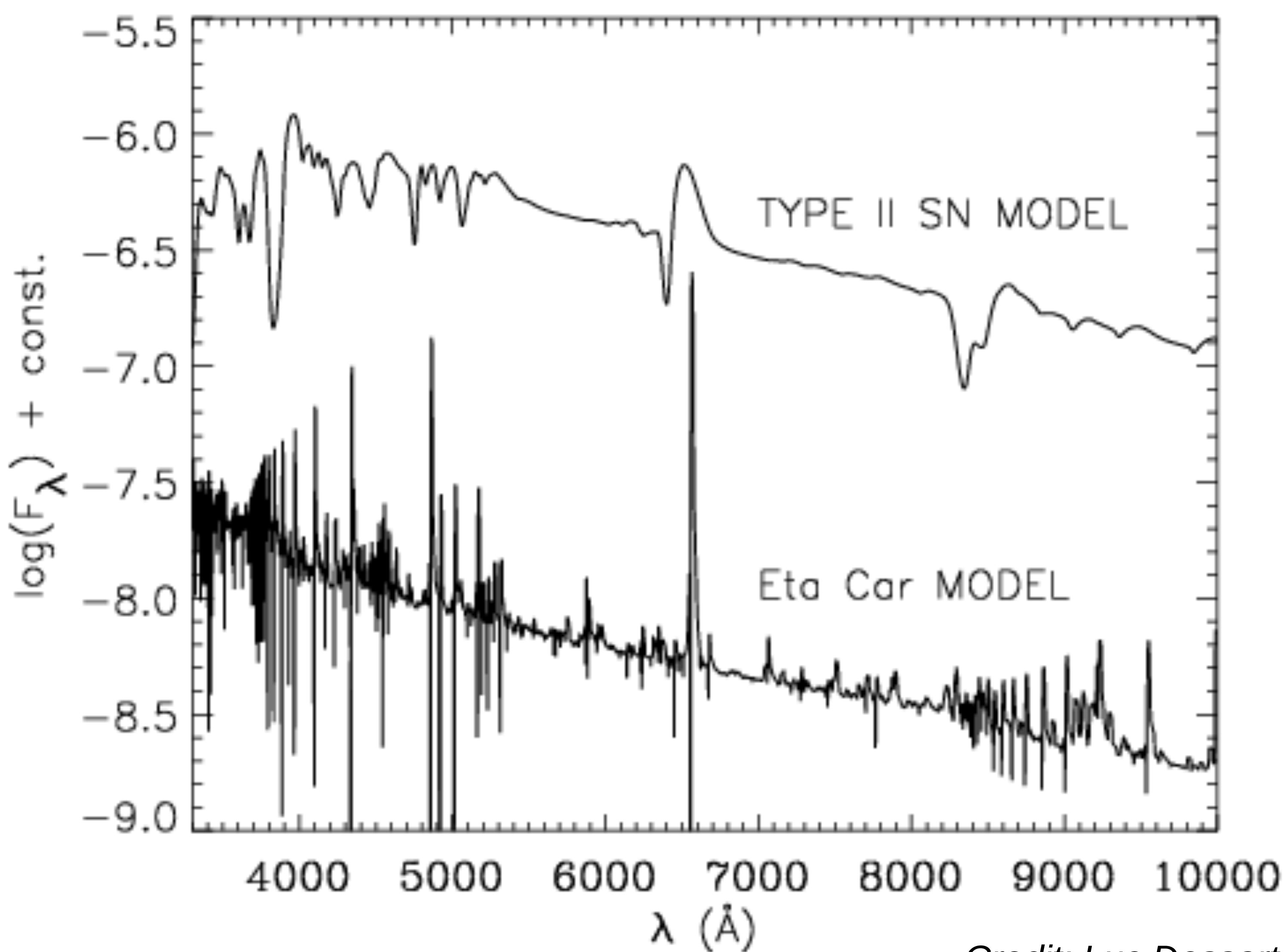


Layout

1. Motivation
2. Supernova classification
   - Type I *vs.* Type II
   - Thermonuclear (Ia) *vs.* core-collapse (Ib/c, II)
   - Line identification problem
   - Difficulty of classification at high-z
3. Cross-correlation techniques
4. Redshift & Phase determination
5. Type determination

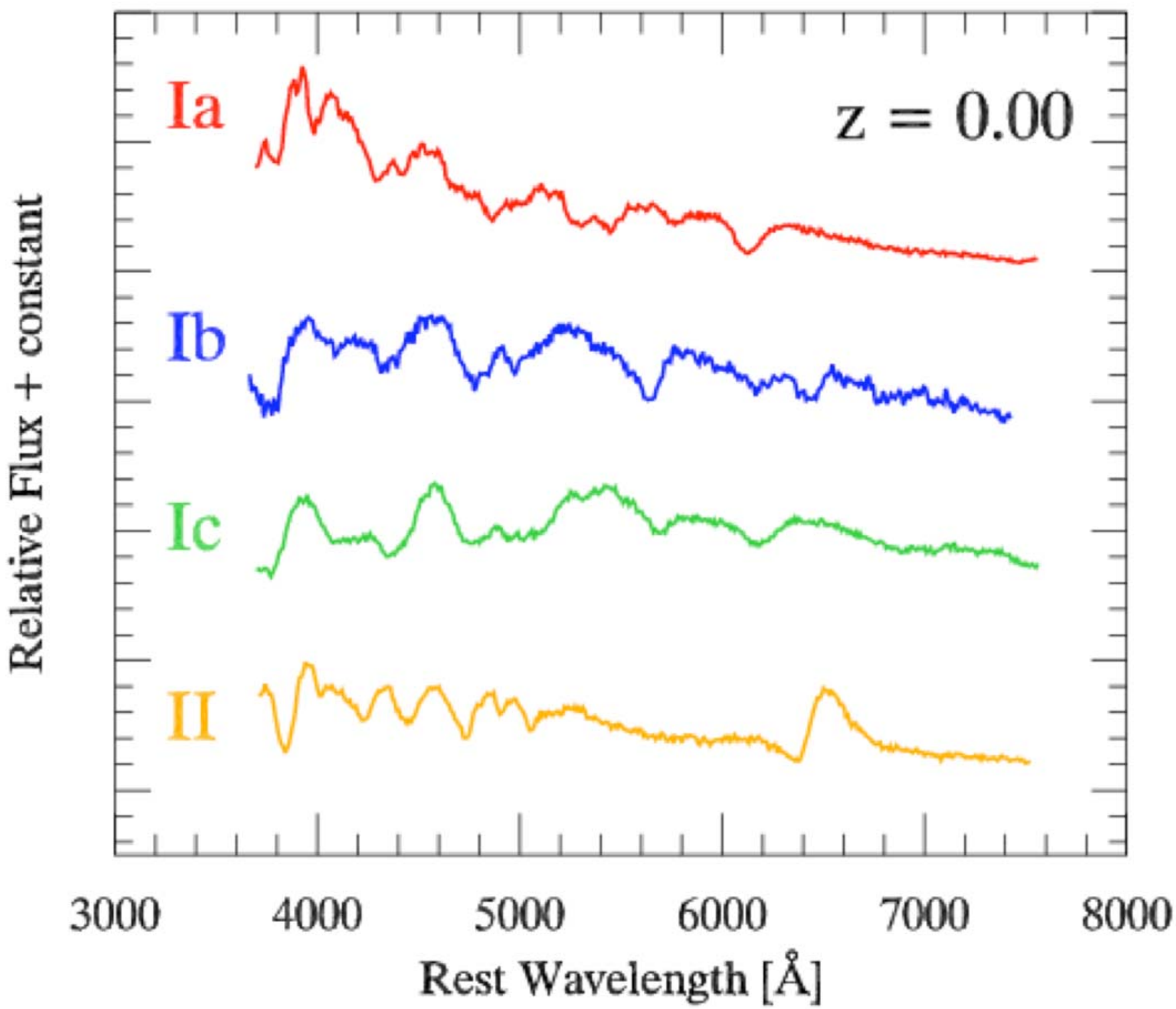
1915-1924: Annie Cannon classifies 225,300 stars (Henry Draper Catalogue)

Line identification

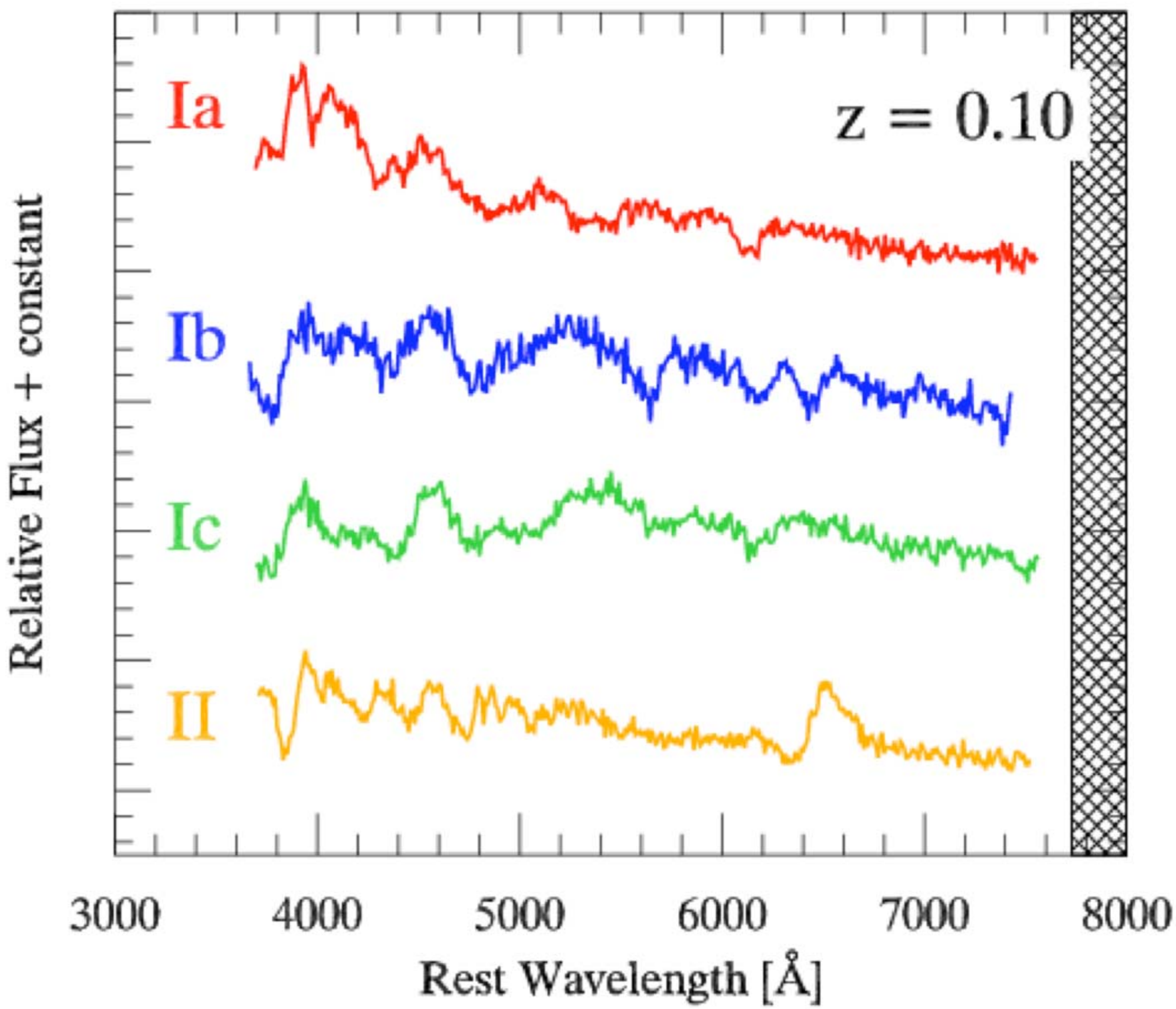


Credit: Luc Dessart

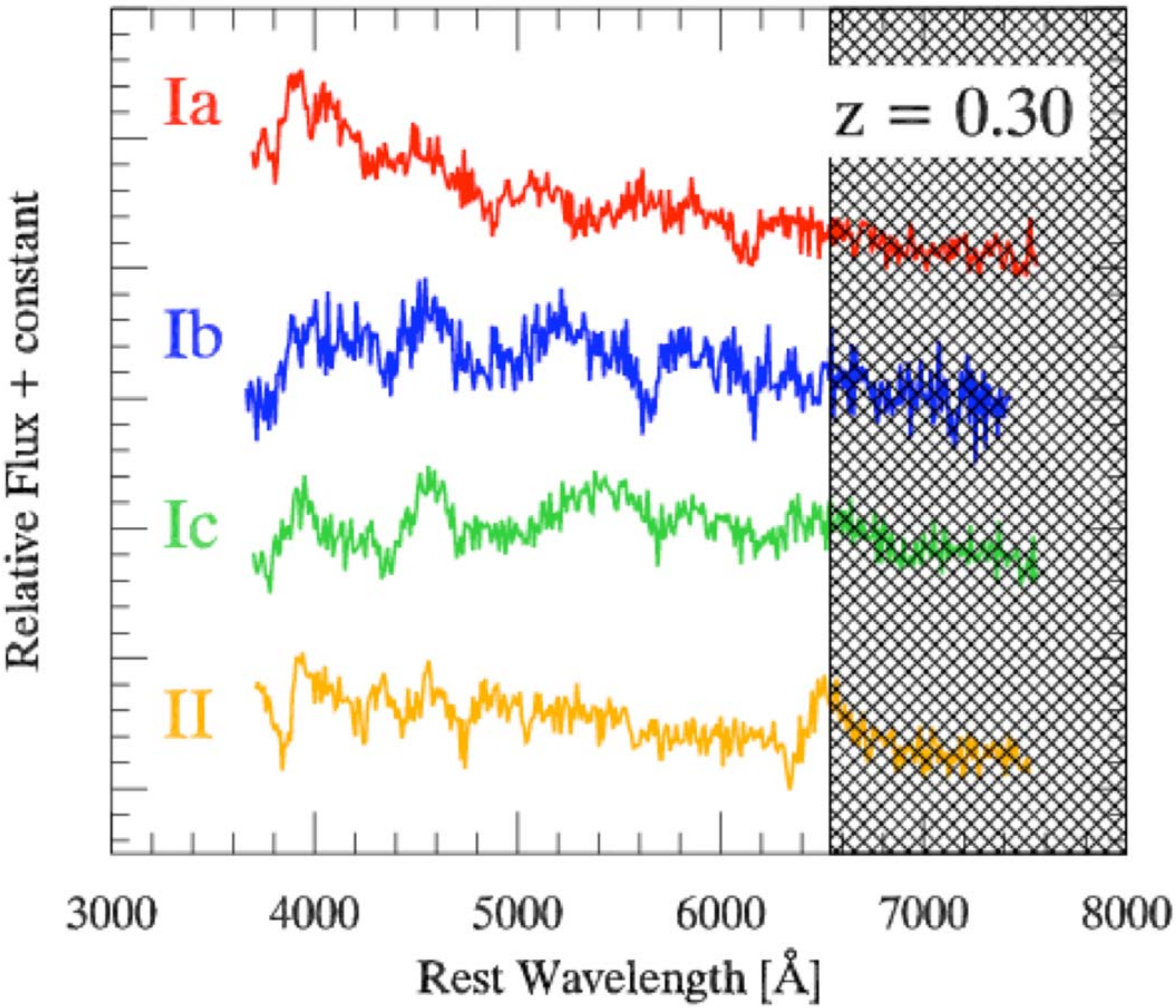
At High Redshifts…



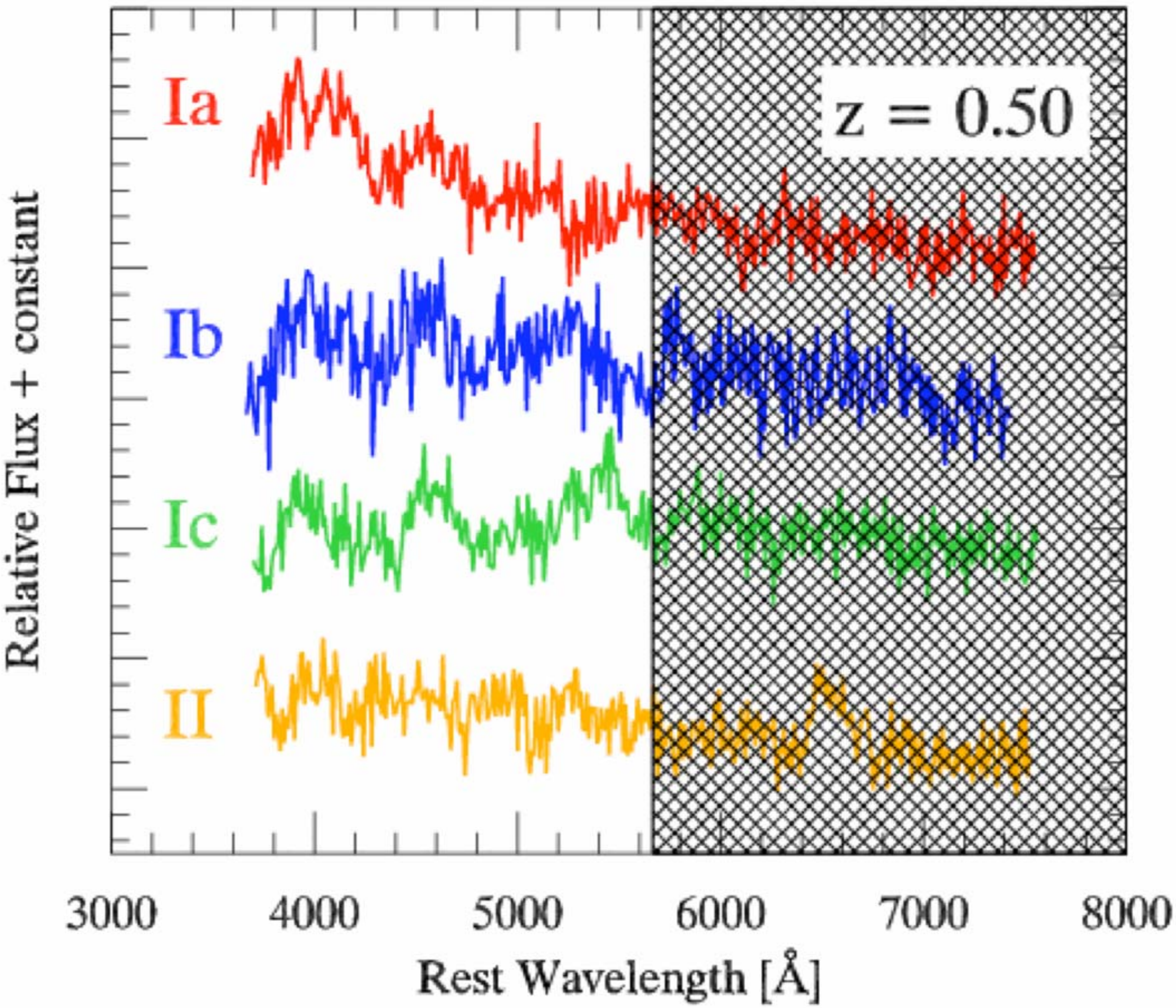
At High Redshifts…



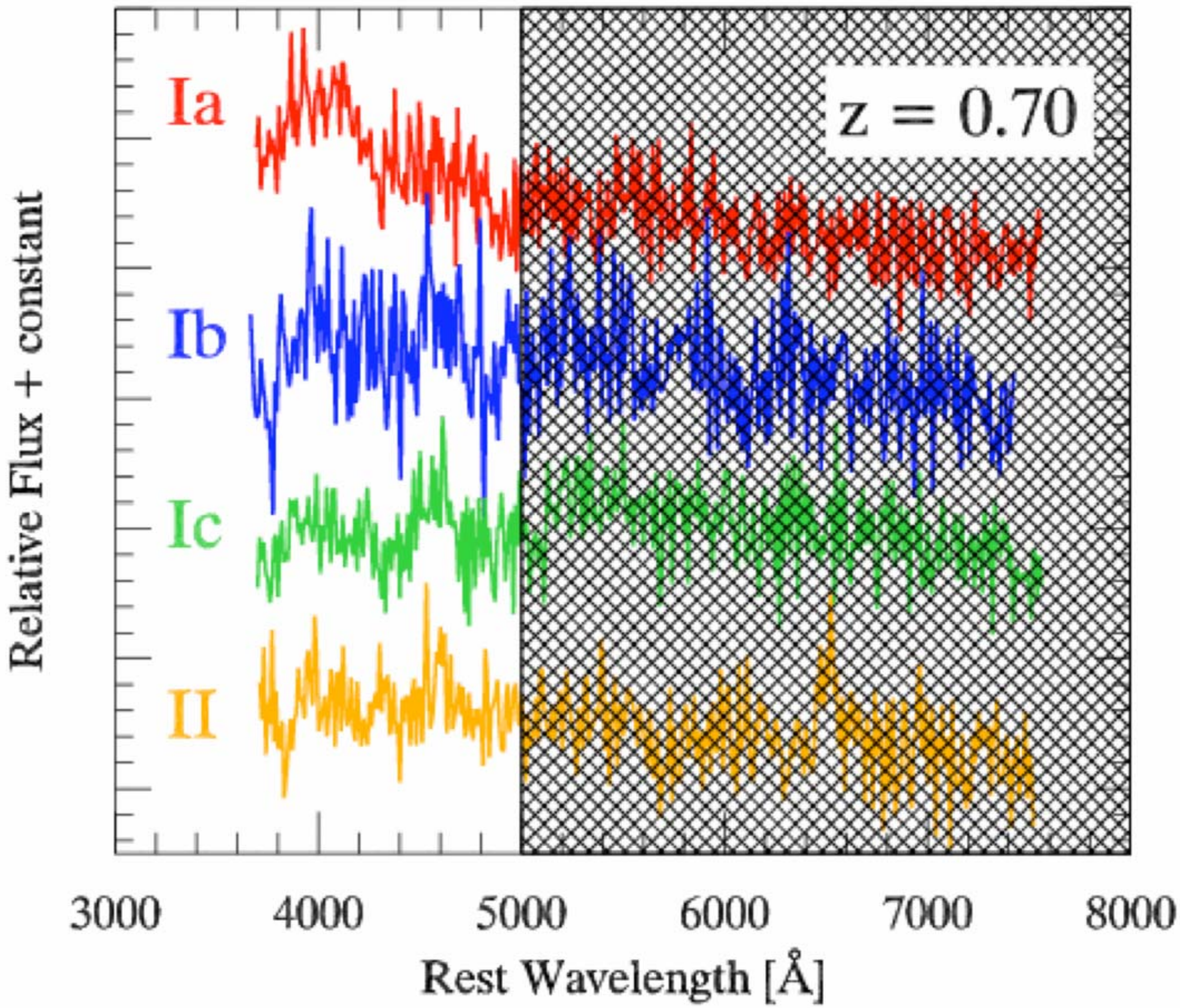
At High Redshifts…



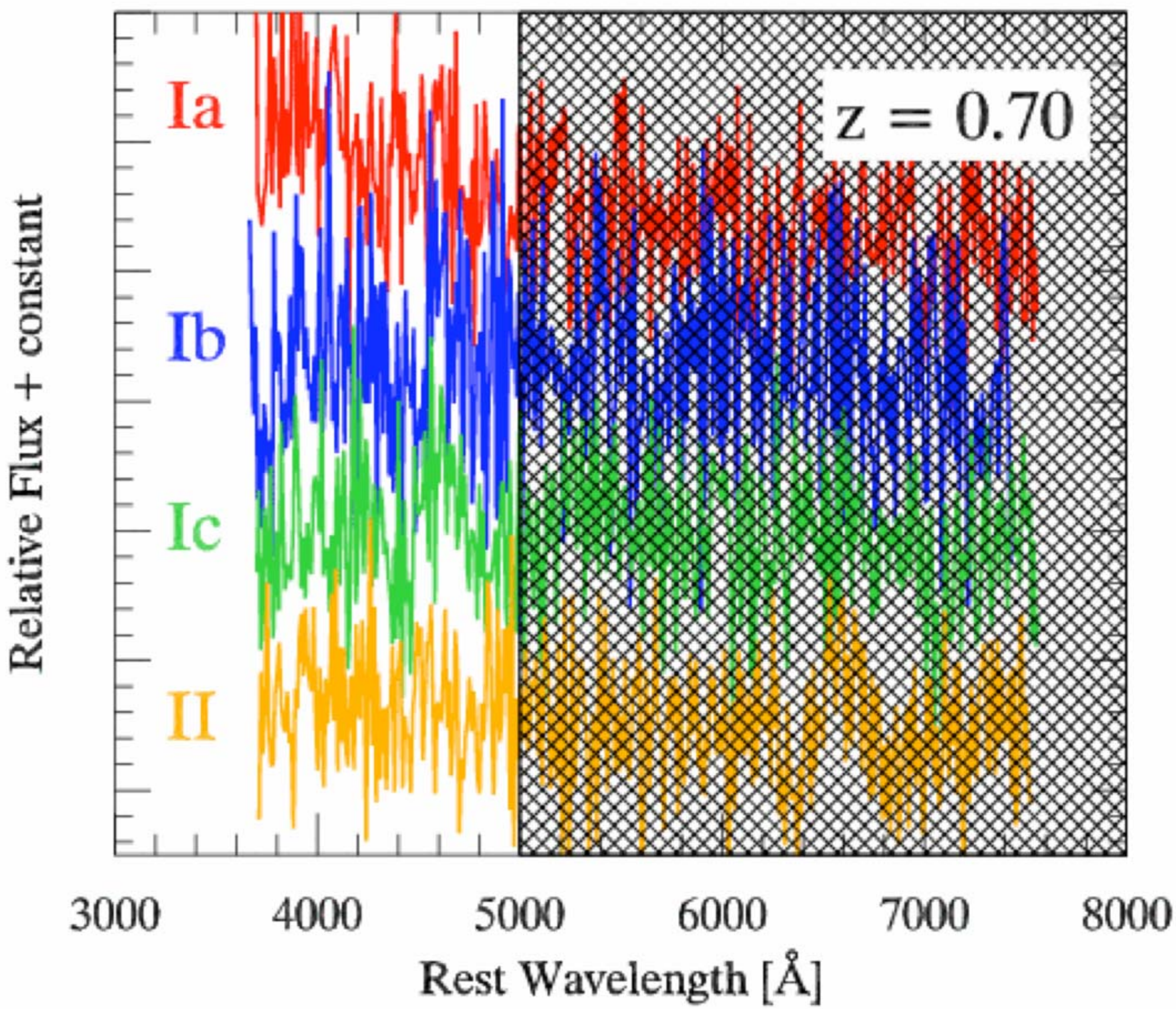
At High Redshifts…



At High Redshifts…



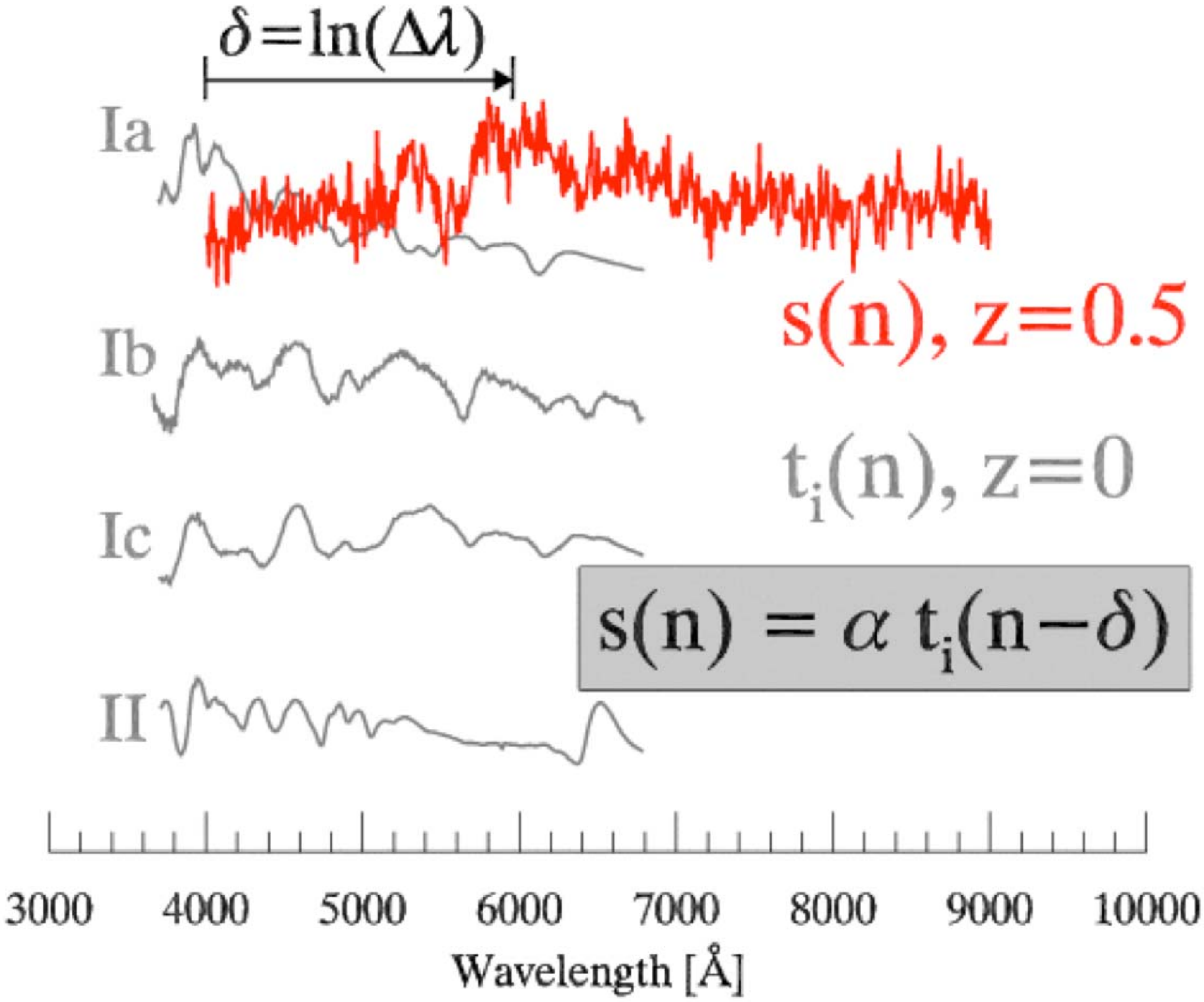
At High Redshifts…



Layout

1. Motivation
2. Supernova classification
3. Cross-correlation techniques
    - Tonry & Davis algorithm (1979)
    - SNID, the **S**uper**N**ova **ID**entification code
    - Spectrum pre-processing
    - The *rlap* diagnostic
4. Redshift & Phase determination
5. Type determination

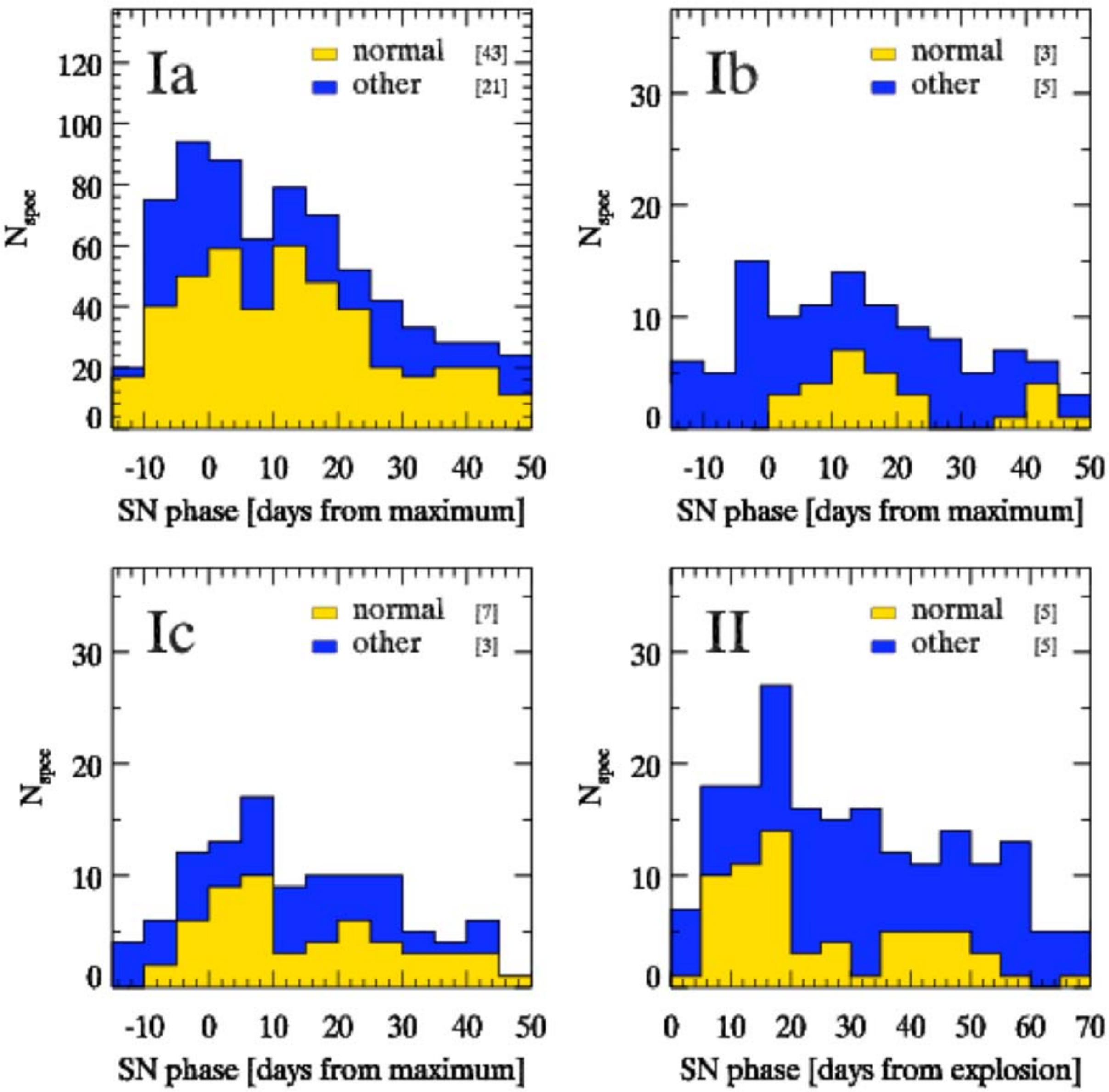
Cross-correlation basics



Input ***s****(n)*

Templates ***t****$_i$(n)*

SN spectral database



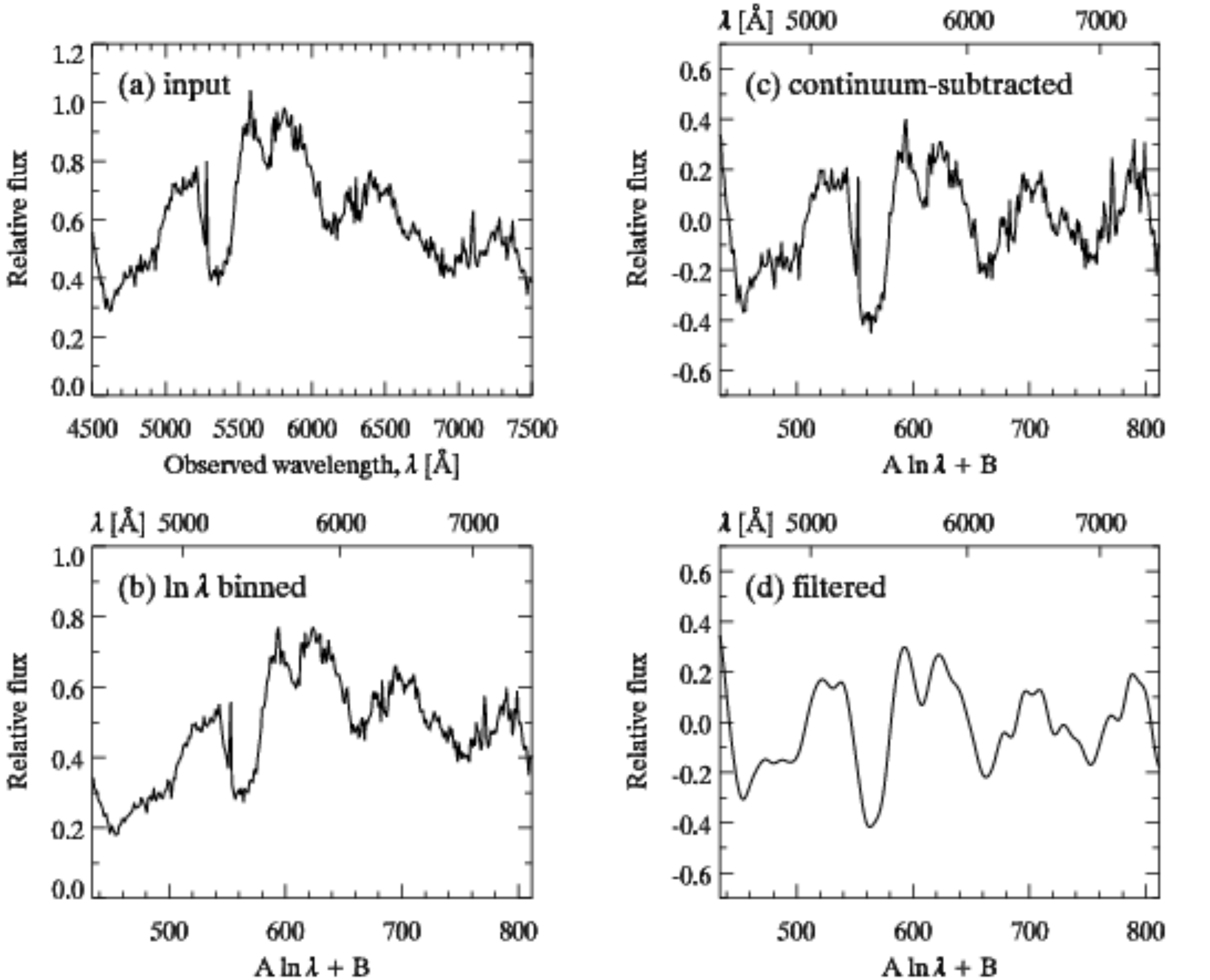
	N_{SN}	N_{spec}
Ia	64	796
Ib	8	172
Ic	9	116
II	10	353
Total	**91**	**1437**

[cf. **CfA** & **SUSPECT**]

high S/N spectra

$\lambda_{min} \leq 4000$ Å, $\lambda_{max} \geq 6500$ Å

Spectrum pre-processing

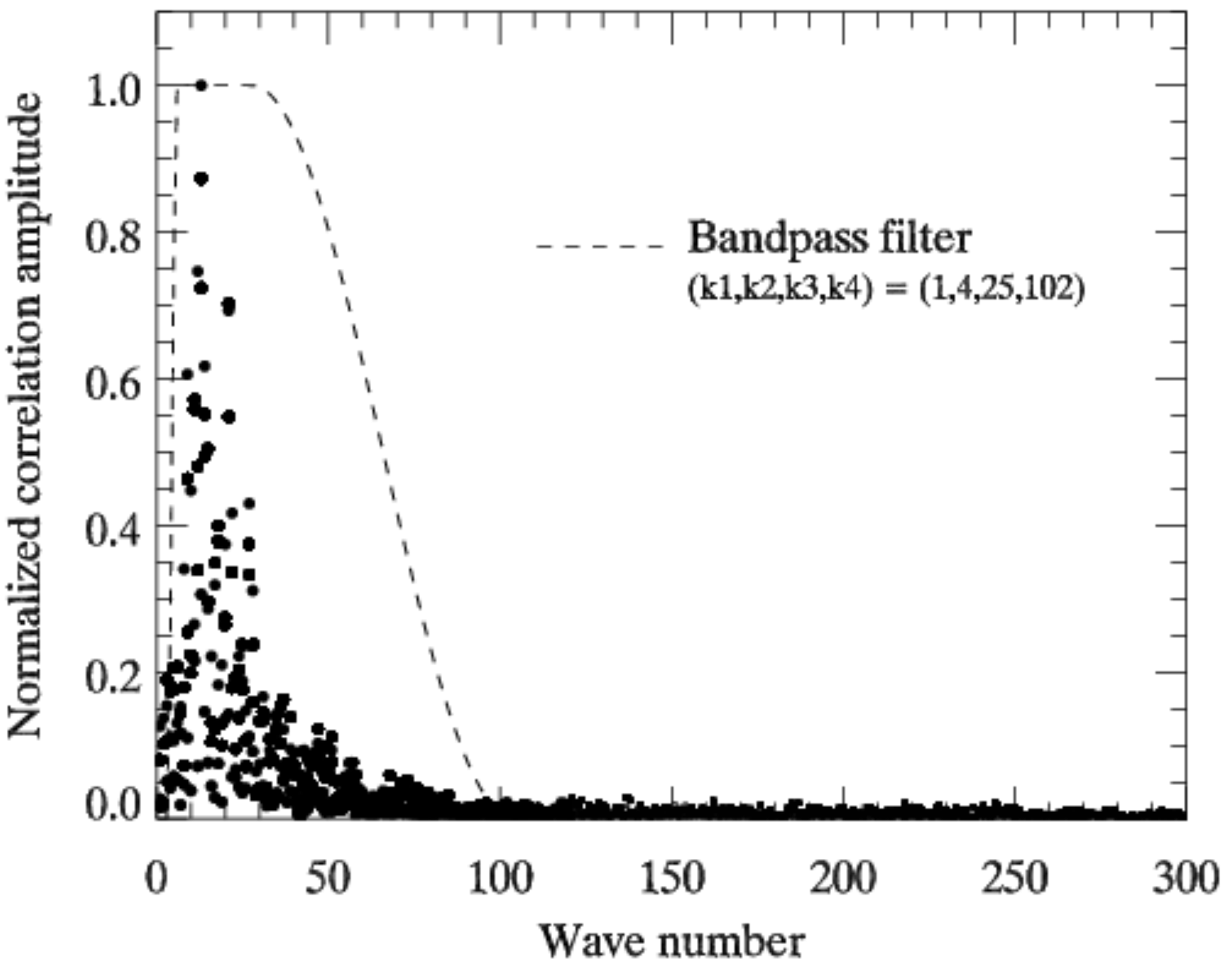


Spectra are:
(b) binned,
(c) flattened, and
(d) filtered

✔
input F_λ, F_ν, ADU, $\Re$
[*] insensitive to reddening
[*] less sensitive to galaxy contamination

✖
see [*]

Bandpass filtering

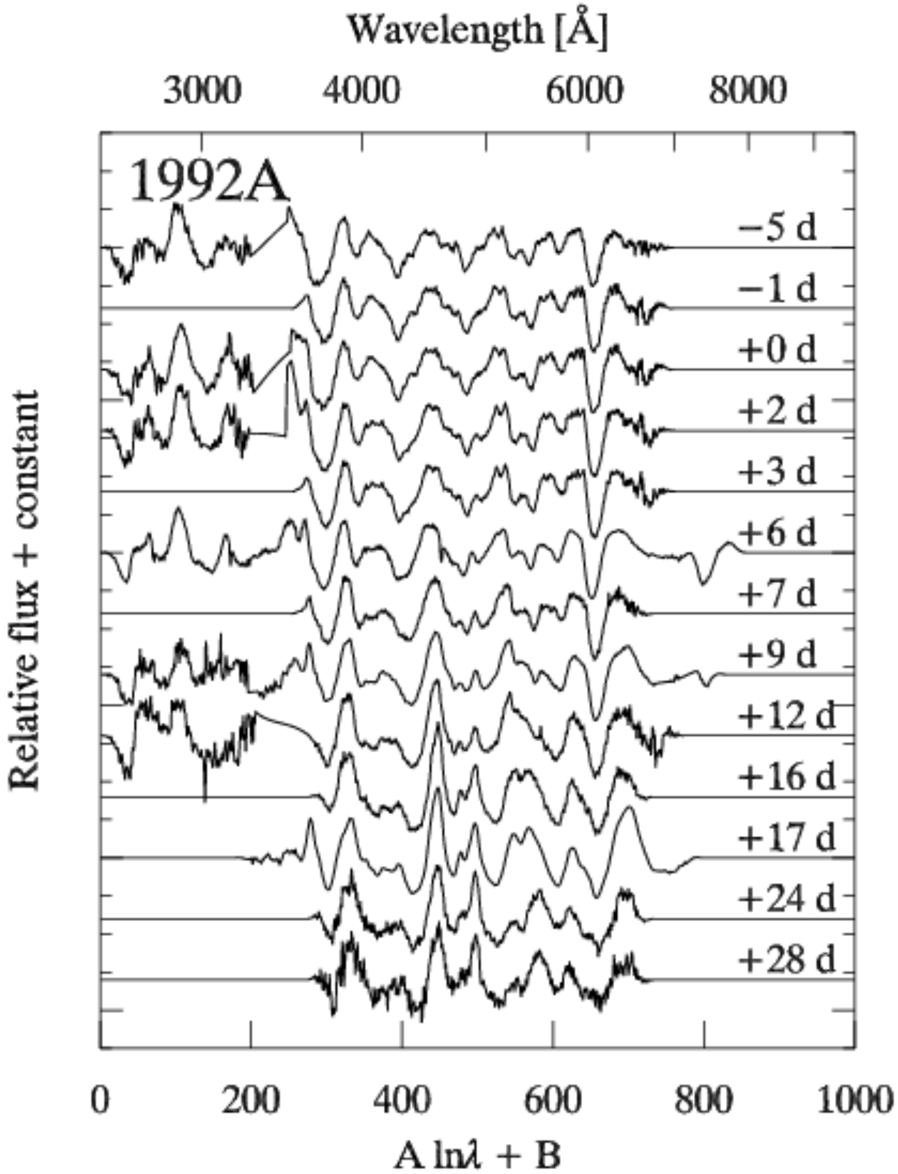


All correlation signal at **low *k*** (*k* ~ 25)

***k* > 100:**
high-freq. noise

***k* < 5:**
low-freq. residuals from continuum subtraction

A typical SN template



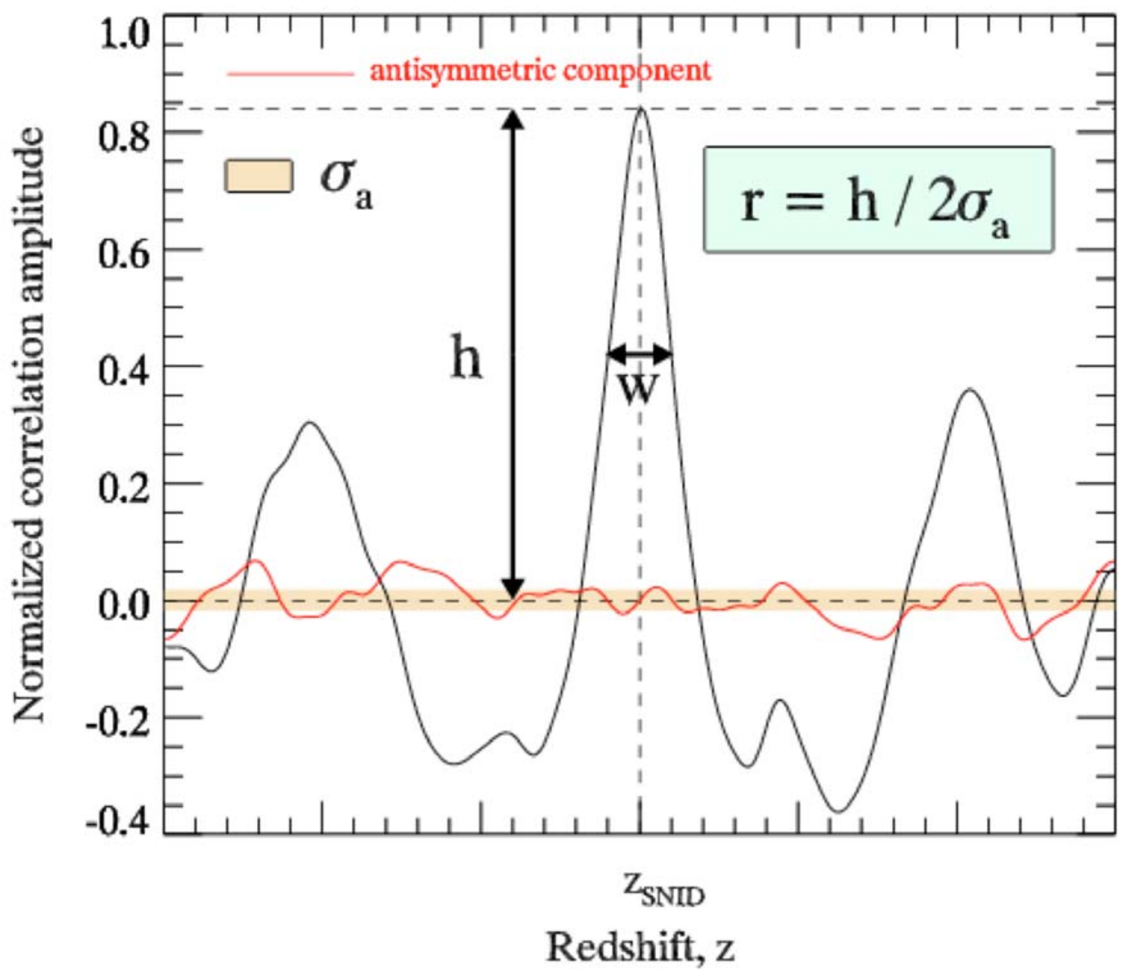
Type Ia SN 1992A

(*Kirshner et al*. 1993)

"It looks as if
Some pallid thing had squashed
its features flat…"

Robert Frost

Correlation *r*-value



Correlation parameters:

r ratio of height of correlation peak to RMS of antisymmetric component

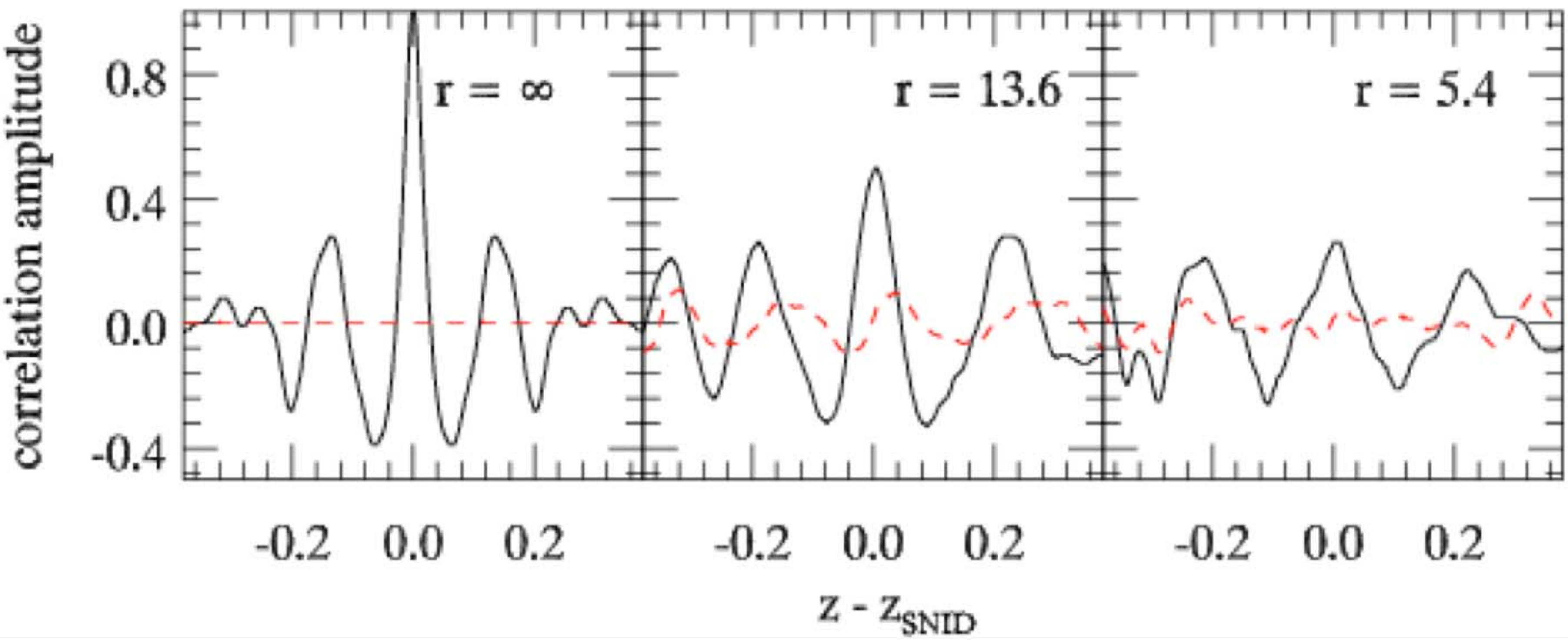
lap overlap in rest wavelength between input and template spectrum, trimmed at correlation redshift

rlap = *r* × *lap*

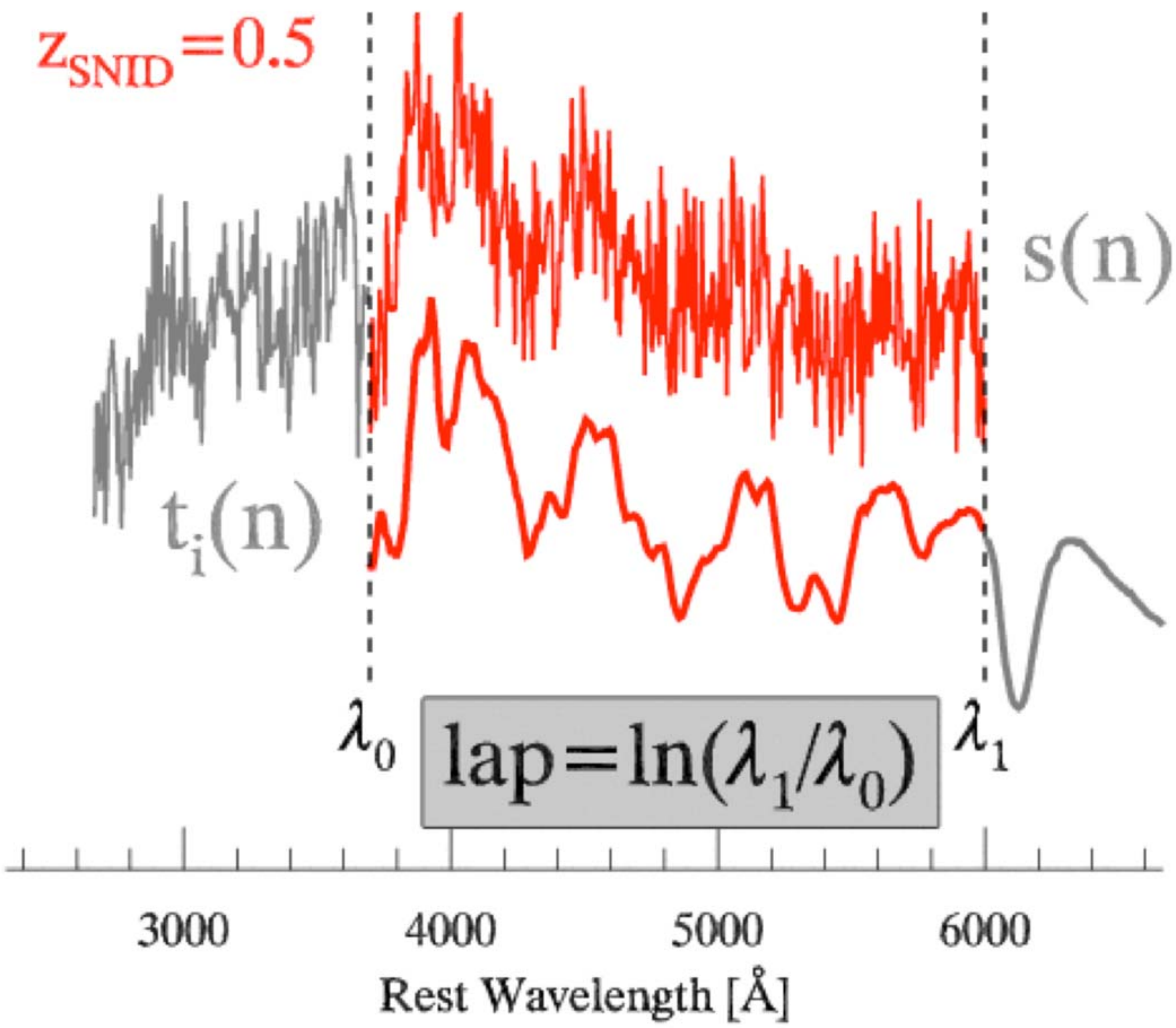
$$z_{err} \propto w \,/\, (1 + rlap)$$

Correlation functions

The ***perfect,*** the ***good,*** and the ***bad***



Spectrum over*lap*



Typically:

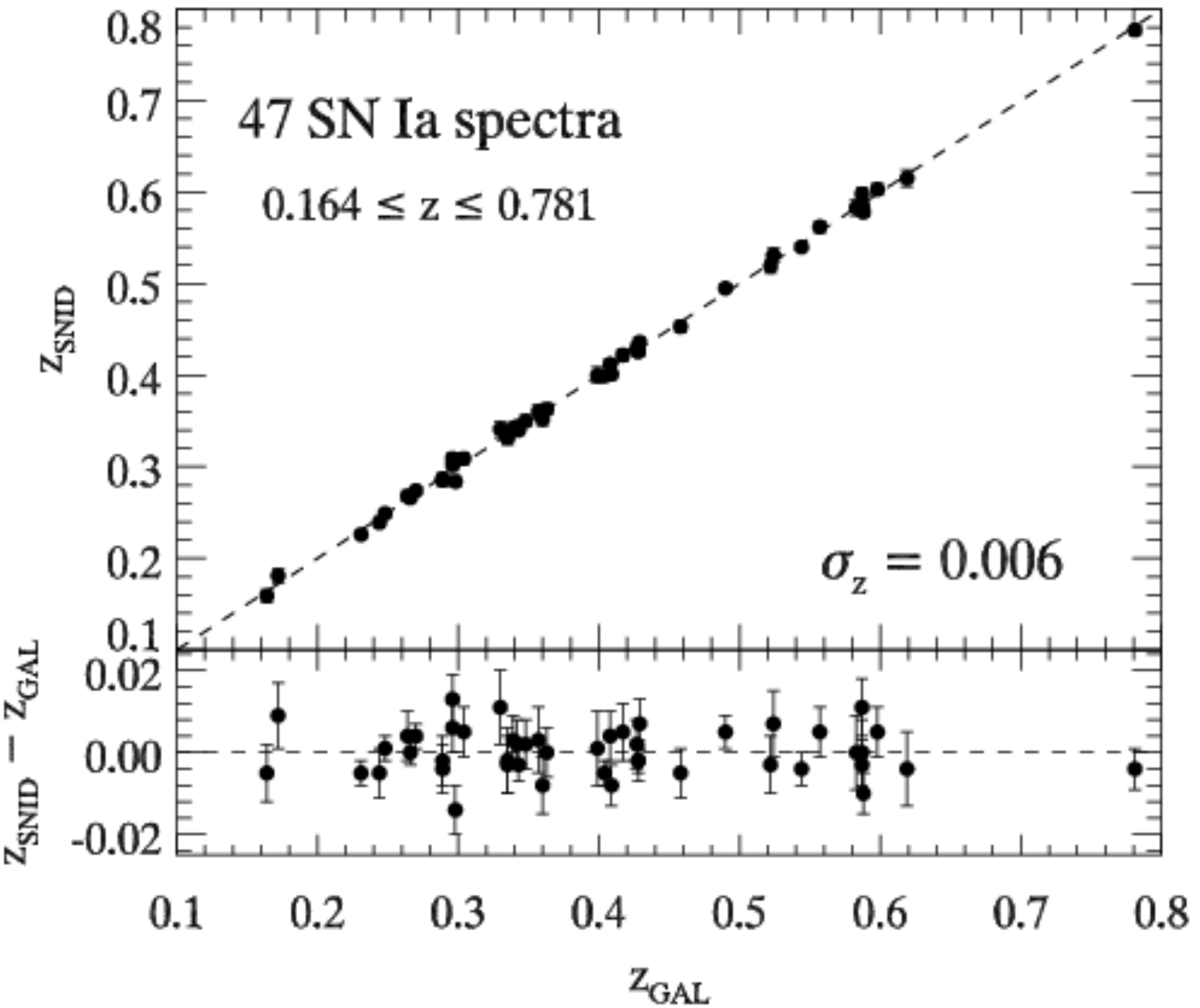
rlap ≥ 5

lap ≥ 0.40

Layout

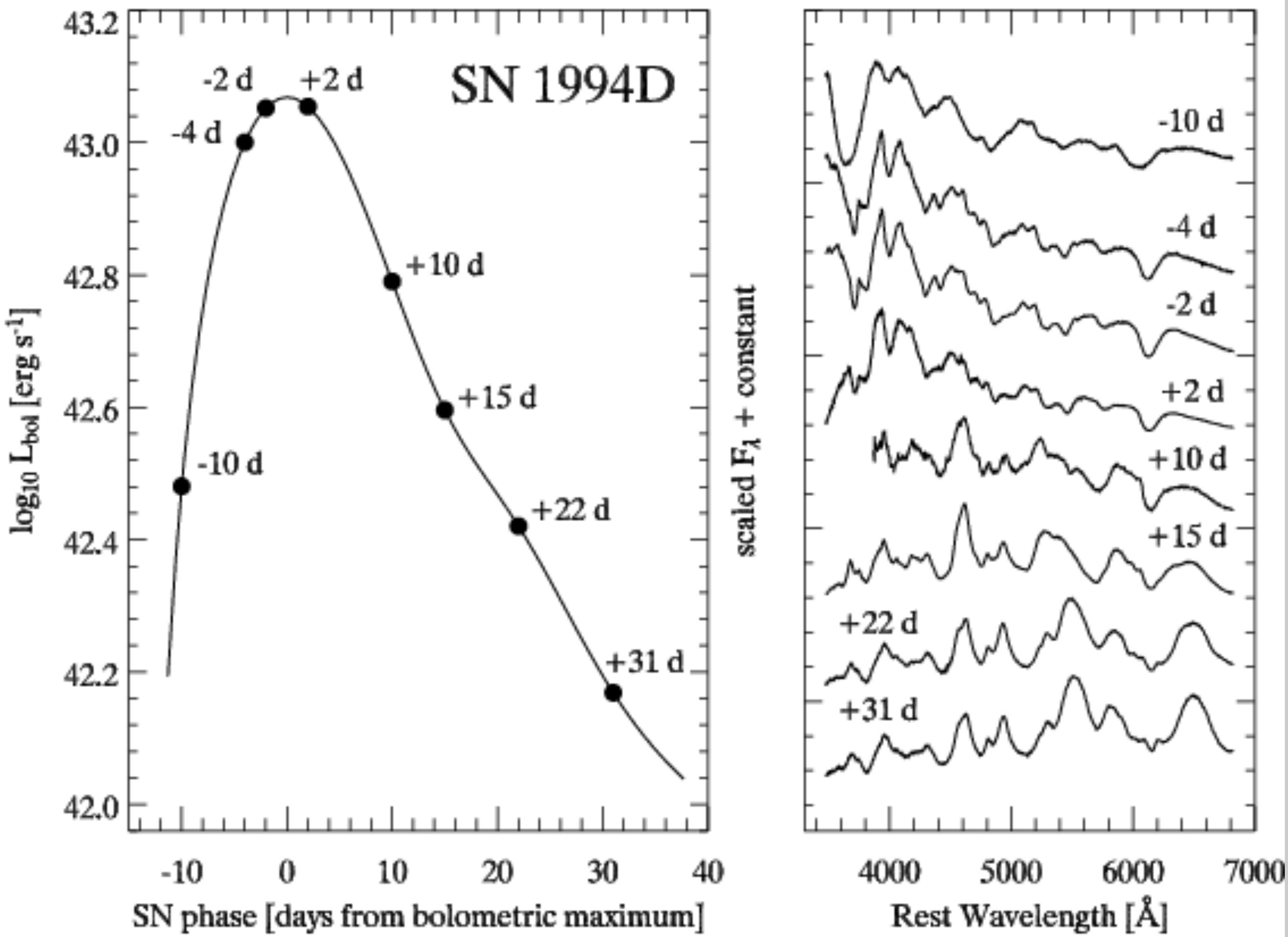
1. Motivation
2. Supernova classification
3. Cross-correlation techniques
4. Redshift & Phase determination
   - Comparison with external measurements
   - Redshift / Phase covariance
5. Type determination

SN *vs.* Galaxy redshifts

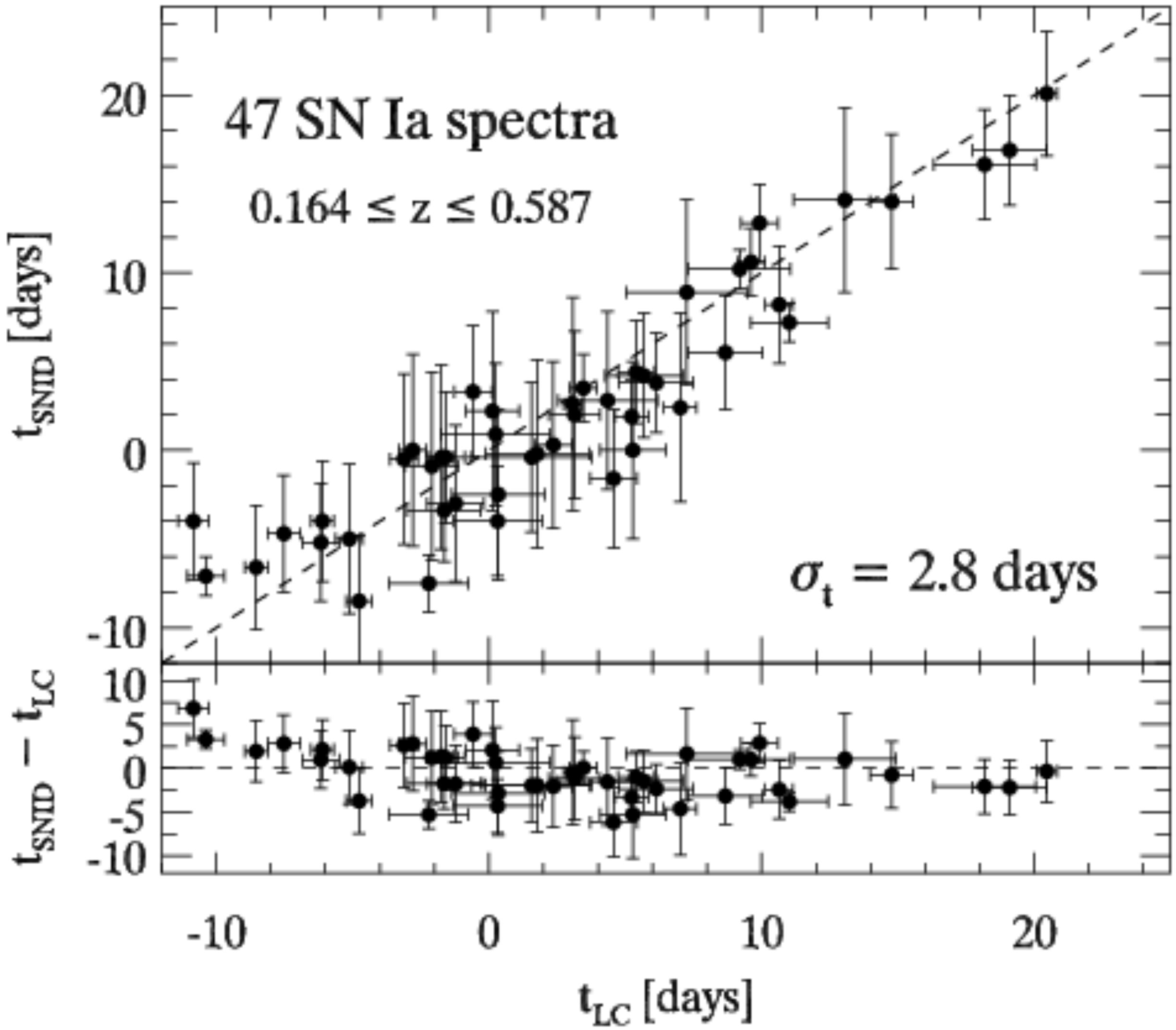


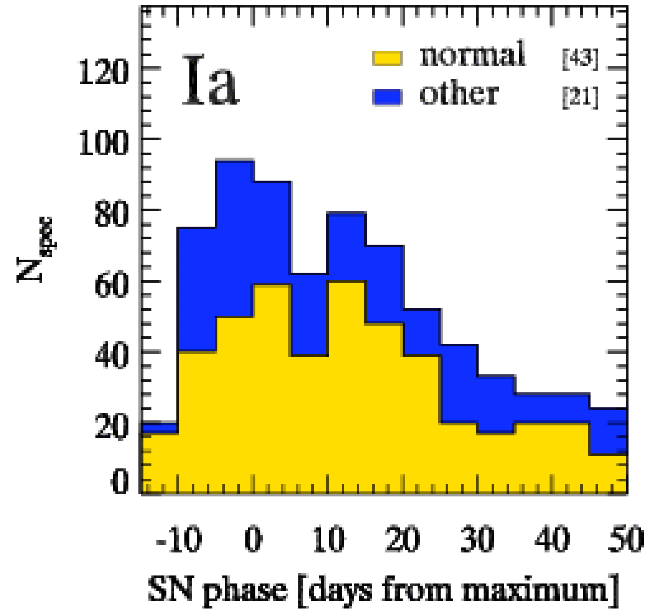
*data from **ESSENCE** (Matheson et al. 2005; Miknaitis et al. in prep)*

Phase determination



Spectrum *vs.* lightcurve phase

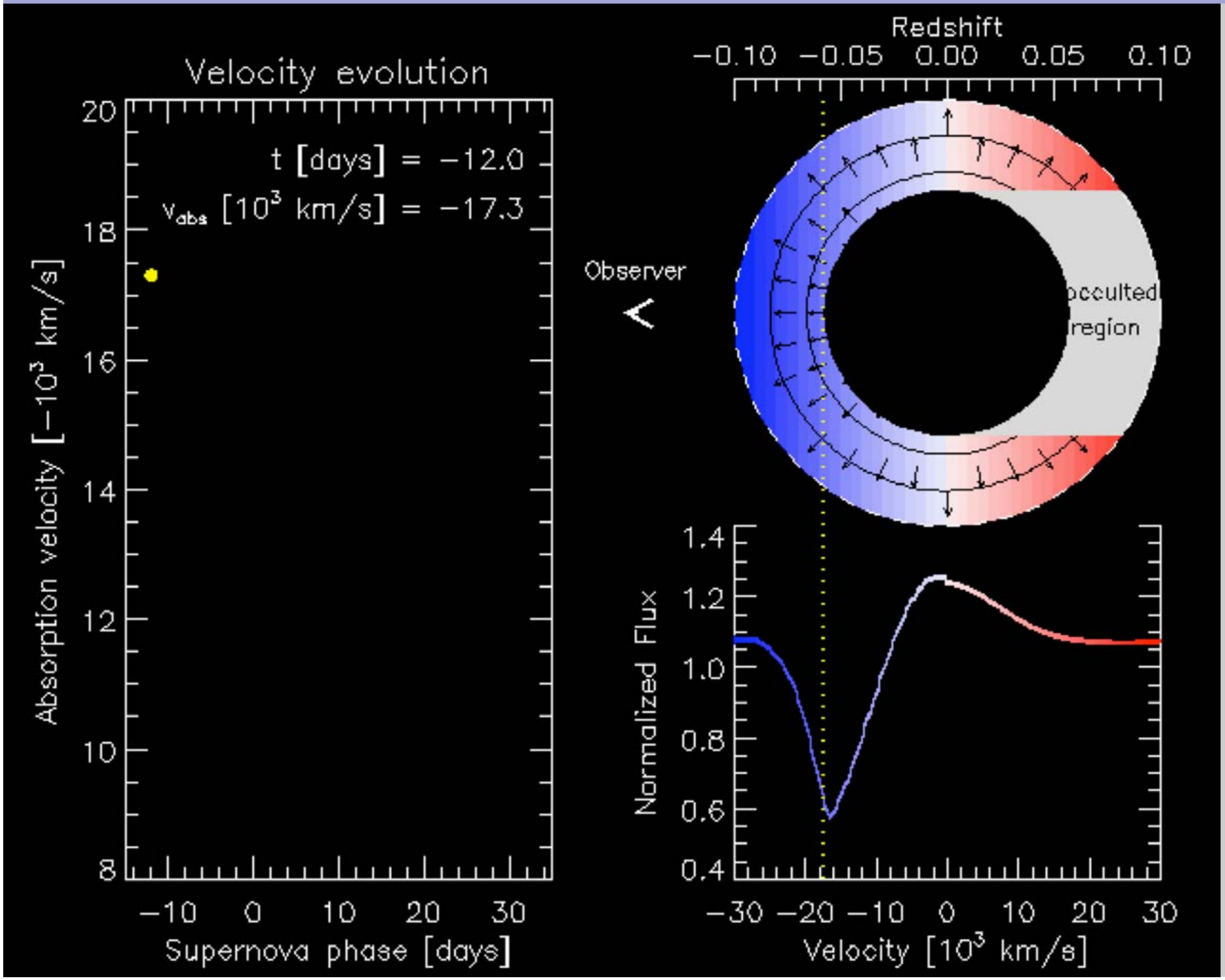




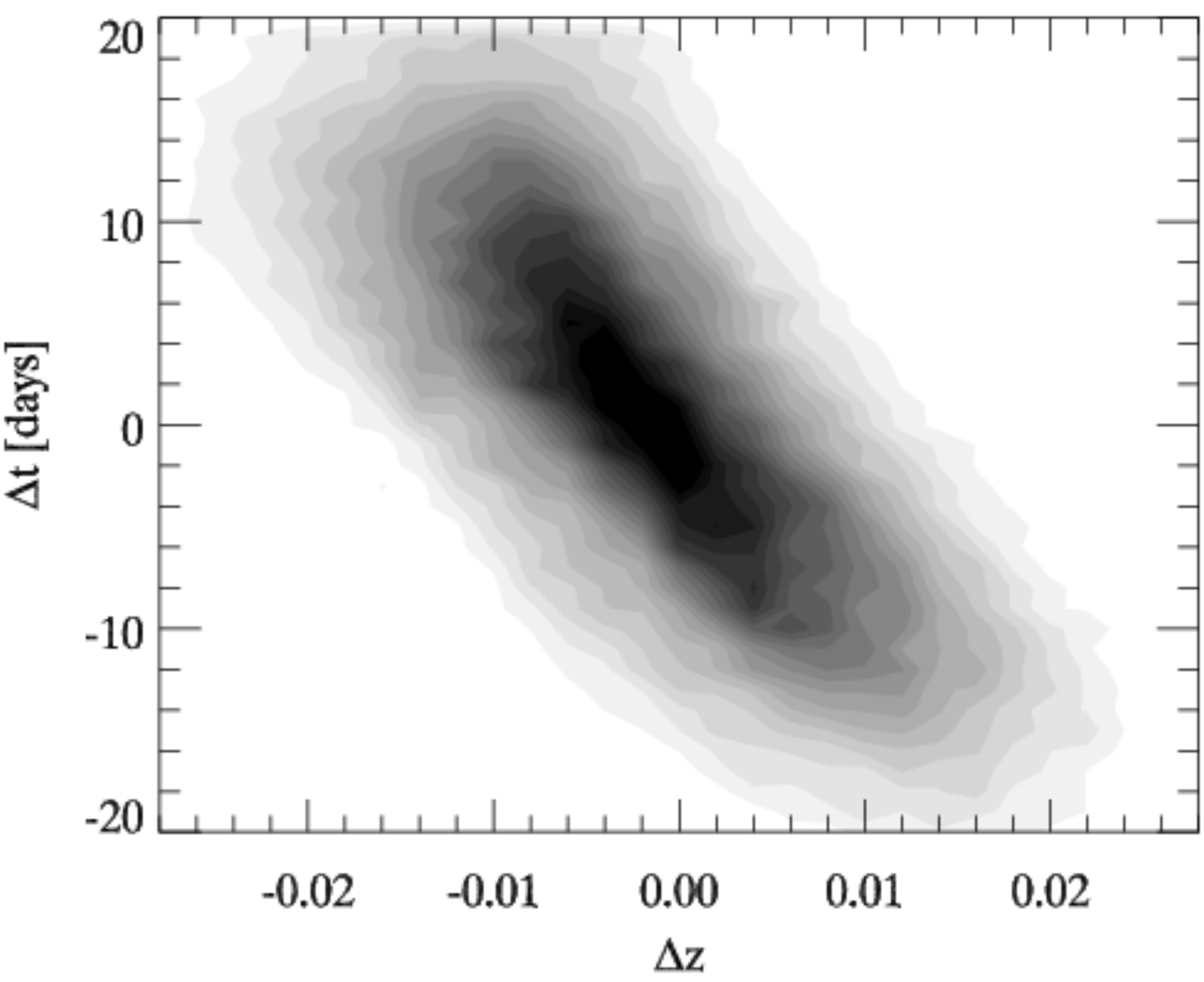
*data from **ESSENCE** (Matheson et al. 2005; Foley et al. in prep)*

t_{LC} corrected for (1+z) dilation ⇒ test for GR

Redshift/phase covariance

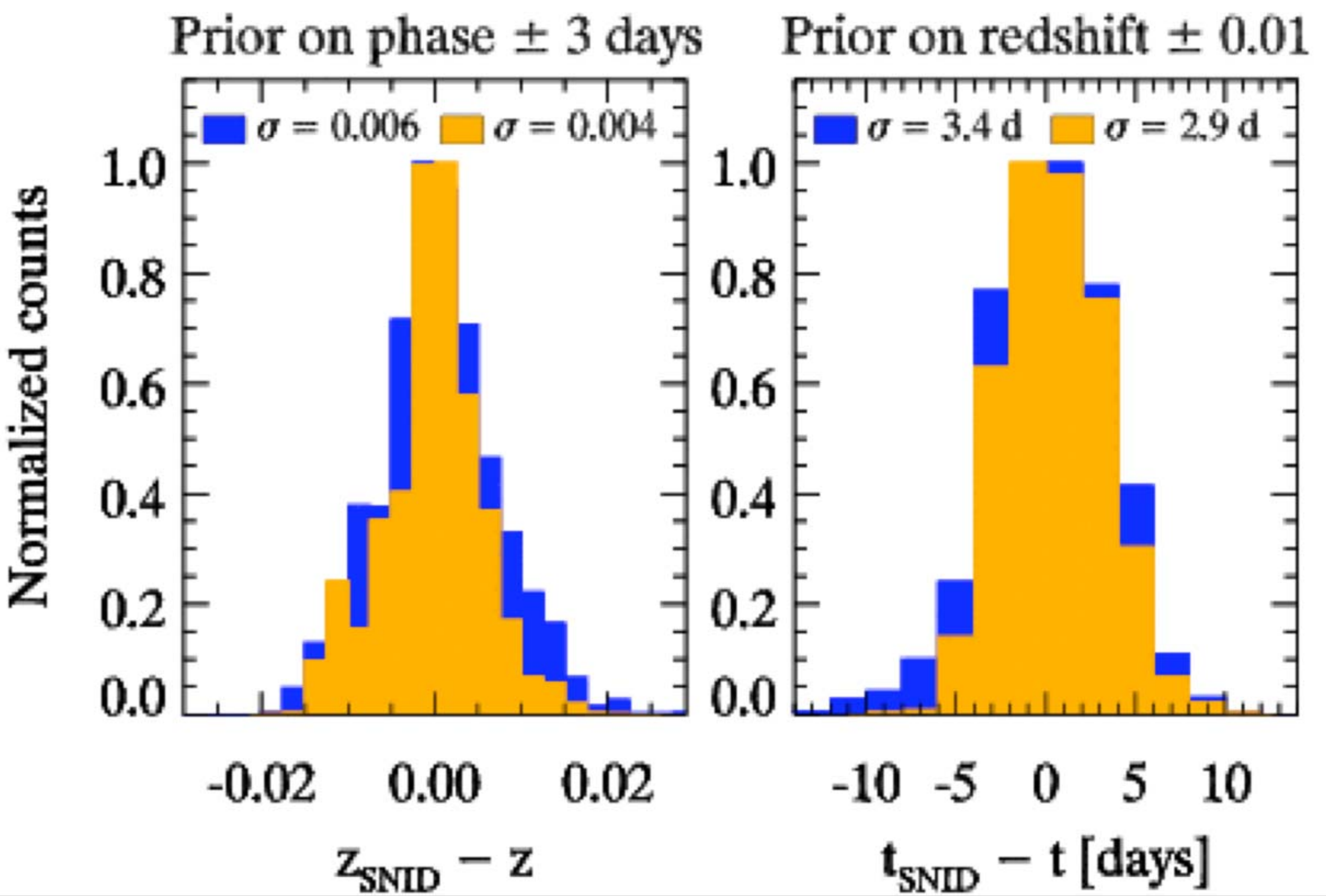


Redshift/phase covariance



Over-estimation of phase ⇒ ***Under***-estimation of redshift

Effect of *z*, *t* priors



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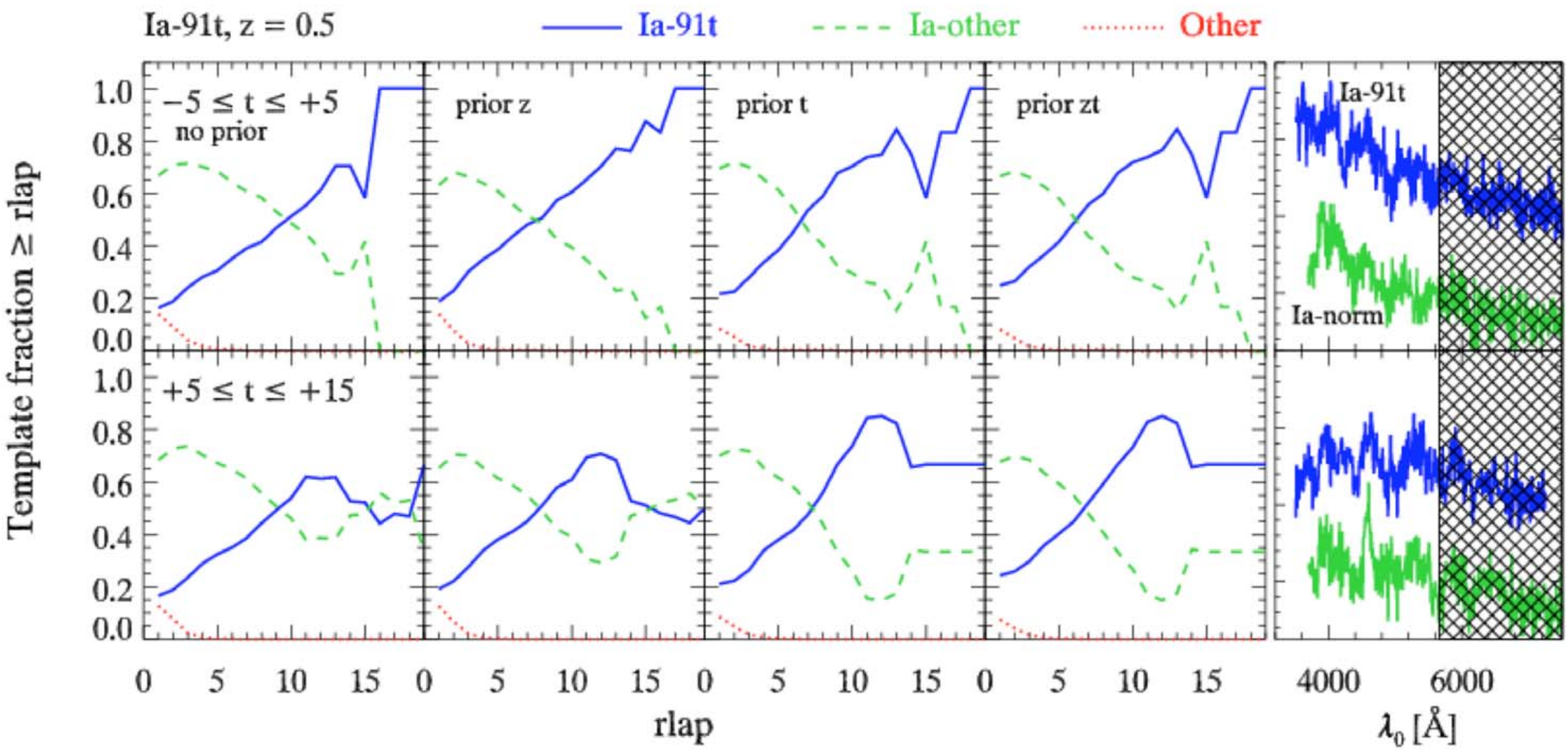
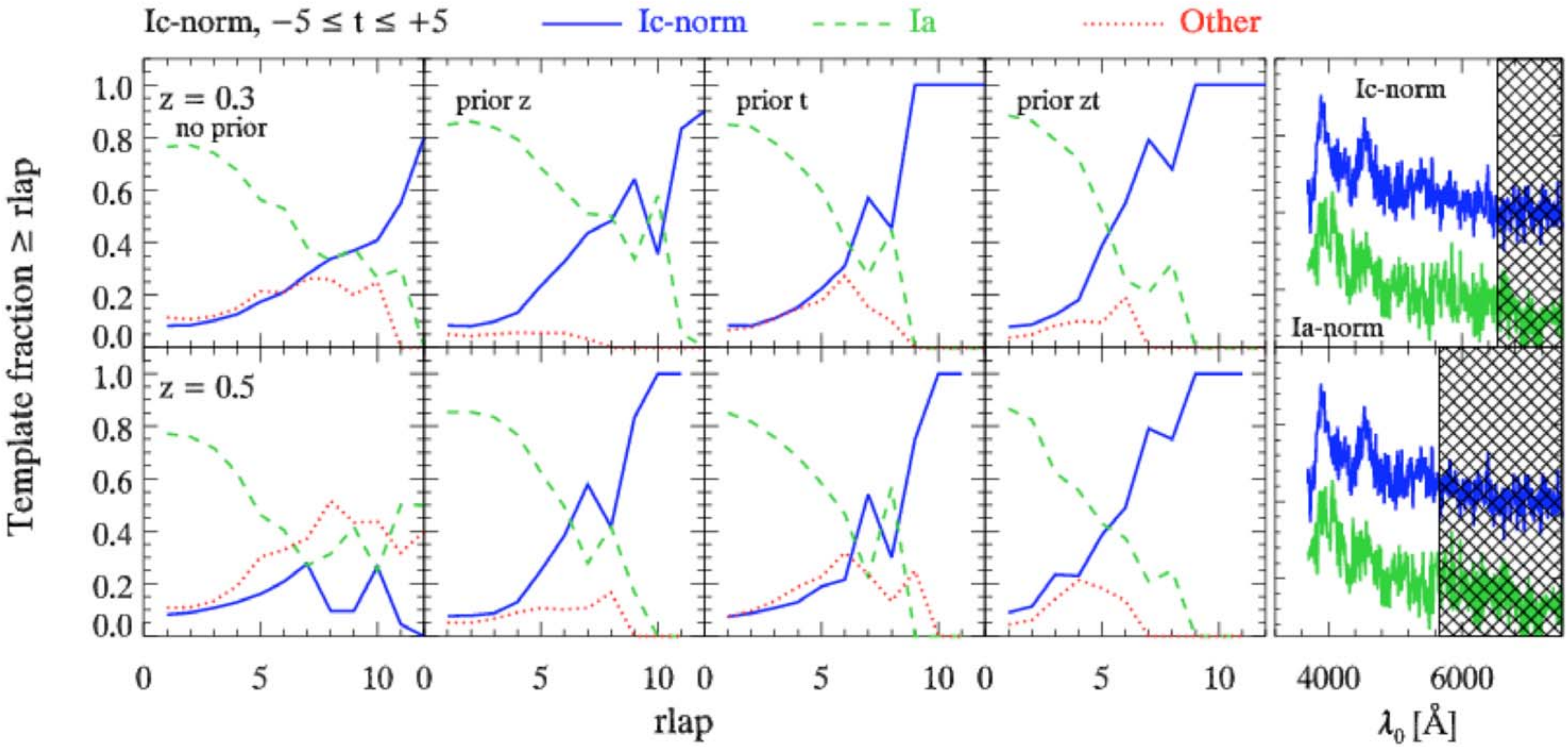
   “Peculiar” *vs.* “normal” SNe Ia at z=0.5

   Type Ic *vs.* Type Ia supernovae at z=0.5

“Peculiar” *vs.* “normal” SN Ia



SN Ia *vs.* SN Ic



Ic-norm, −5 ≤ t ≤ +5
Ic-norm
Ia
Other
z = 0.3
no prior
prior z
prior t
prior zt
z = 0.5
Ic-norm
Ia-norm
Template fraction ≥ rlap
rlap
λ0 [Å]

Conclusions

With the **S**uper**N**ova **ID**entification (SNID) code, one can:

✓ distinguish between SN **types** at high redshifts (z = 0.5)

- 91T-like SN Ia and SN Ic "contaminants"

✓ determine SN **redshifts** with $\sigma_z \leq 0.01$ out to $z \geq 0.8$

✓ determine the **phase** of a SN spectrum with $\sigma_t \leq 3$ days

…and observation / model comparisons

Coming Soon! Public release on the CfA SN webpage:

http://www.cfa.harvard.edu/oir/Research/supernovae/