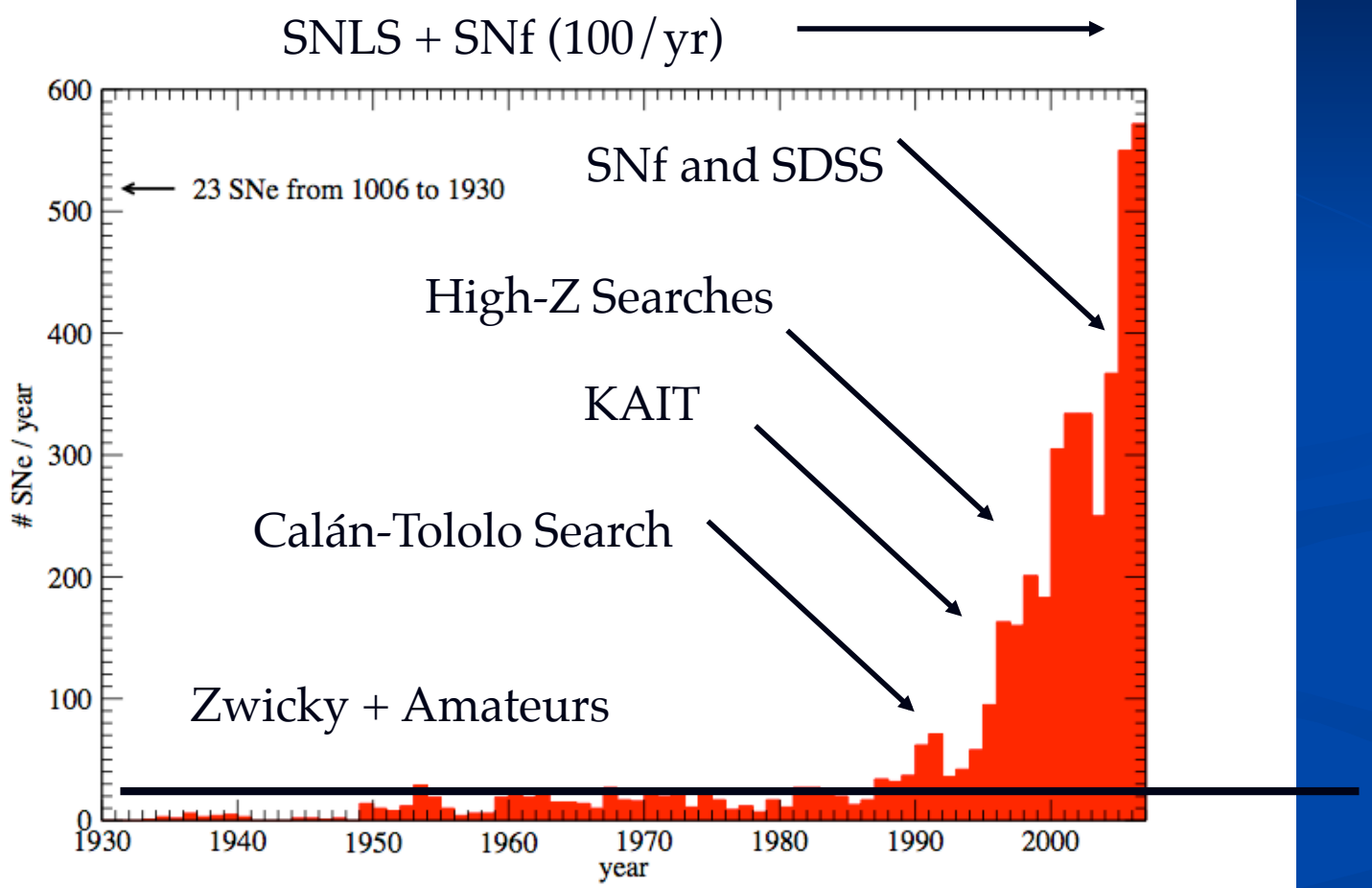
SNe 1999as & 2007bi
Twin Pair Production SNe?

Peter Nugent (LBNL)

Steady up to 1990…



How was SN 1999as found?

Spring 1999 SNe Survey:

- Follow-up of 40 SNe in one semester using a wide variety of programs to generate SNe discoveries. EROS, KITP, NEAT...

- Goal was to find SNe Ia at low-redshift in a similar fashion as one finds them at high-redshift. Thus don't target galaxies, but do a wide field search a la the Calán Tololo program, but with CCDs.

- Target was to obtain 20 SNe Ia in the smooth Hubble flow ($0.03 < z < 0.10$) caught before peak brightness. Thus limiting magnitude was R~20. (Kowalski *et al.*, 2008)

It became the largest and deepest search for nearby SNe.

Sky Coverage

Nearby Supernova Campaign: Survey Parameters

Search	Type	Aper (m)	FOV (deg^{-2})	Scale ("/pixel)	Exp (sec)	Time (hrs)	Filter	Coverage (deg^2)	Ia	II	Ic	Untyped (faint)
EROS	Staring	1.0	1.00	0.60	300	125	B & R	~450	11	3	0	10
MOSAIC/CTIO	Staring	0.9	1.00	0.43	240	48	R	~175	6	2	0	1
NEAT	Staring	1.0	2.54	1.40	60	15	open	~425	3	1	1	0
Spacewatch	Drift Scan	0.9	$0.57\times t$	1.05	430	140	OG515	~150	3	0	0	2
QUEST	Drift Scan	1.0	$2.30\times t$	1.00	550	4	V	~140	0	0	0	1
Other Searches	IAUC								6	2	0	0
Totals								~1340	29	8	1	14

Follow-up

Photometry:

- Lick 1-m
- YALO 1-m
- CTIO 0.9-m, 1.5-m
- Danish 1.5-m
- and all the search facilities

Spectroscopy:

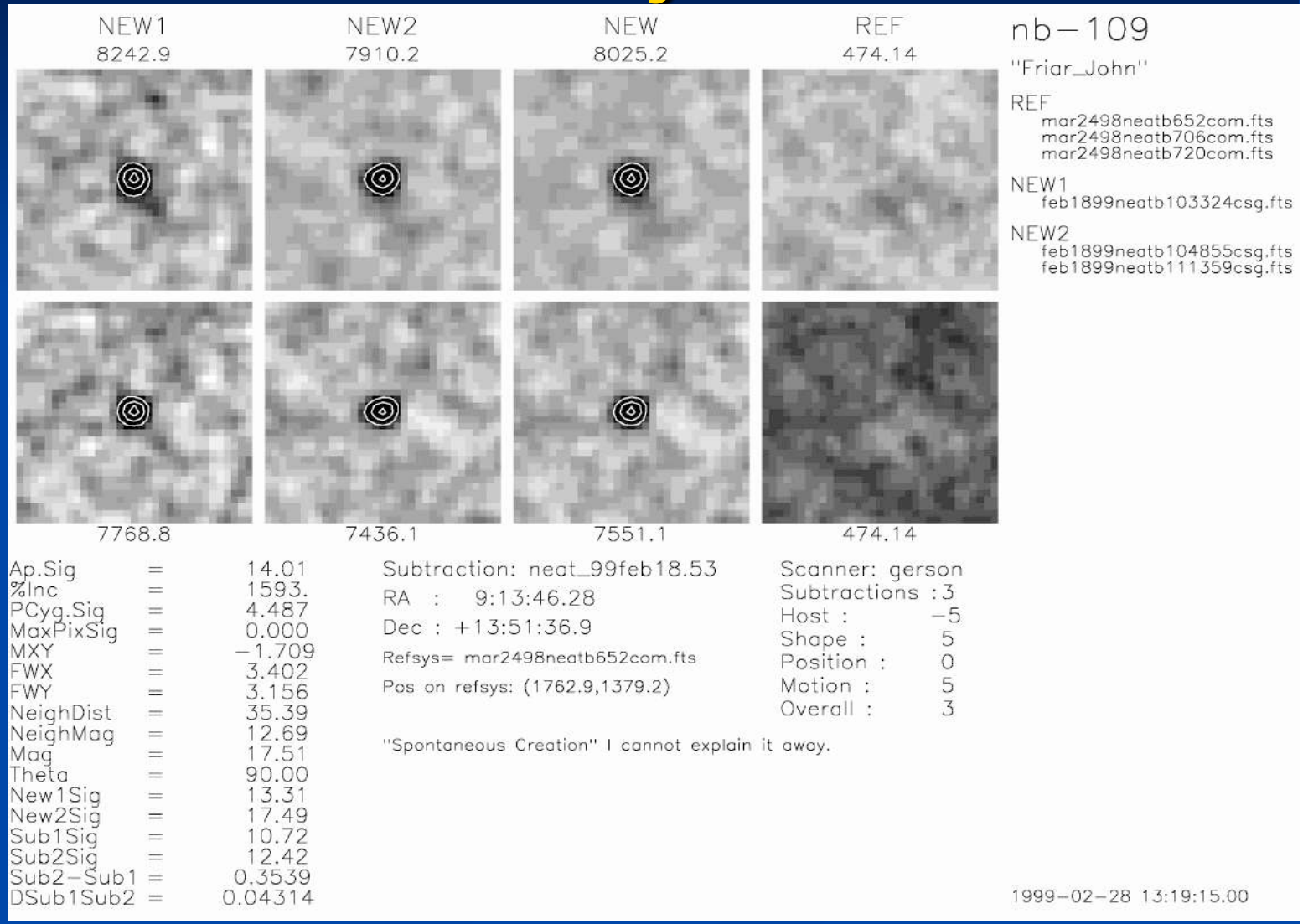
- Lick 3-m
- KPNO 4-m, 2.1-m
- CTIO 4-m, 1.5-m
- ES0 3.6-m

Discovery

Date:
Feb 18.43

Magnitude:
R~17.5

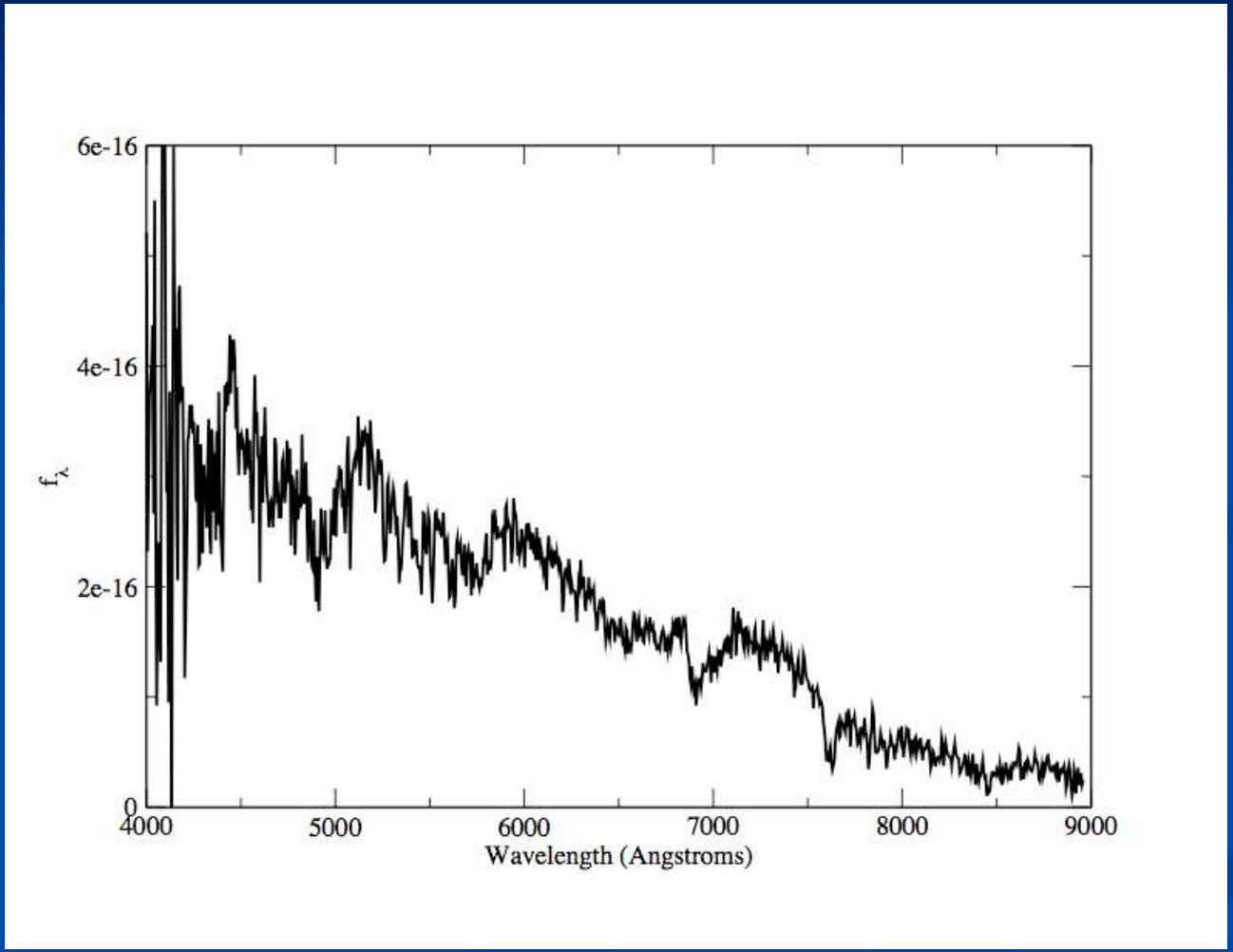
Host:
zip



First Spectrum

Mar 6.4 was the first spectrum.

MDM

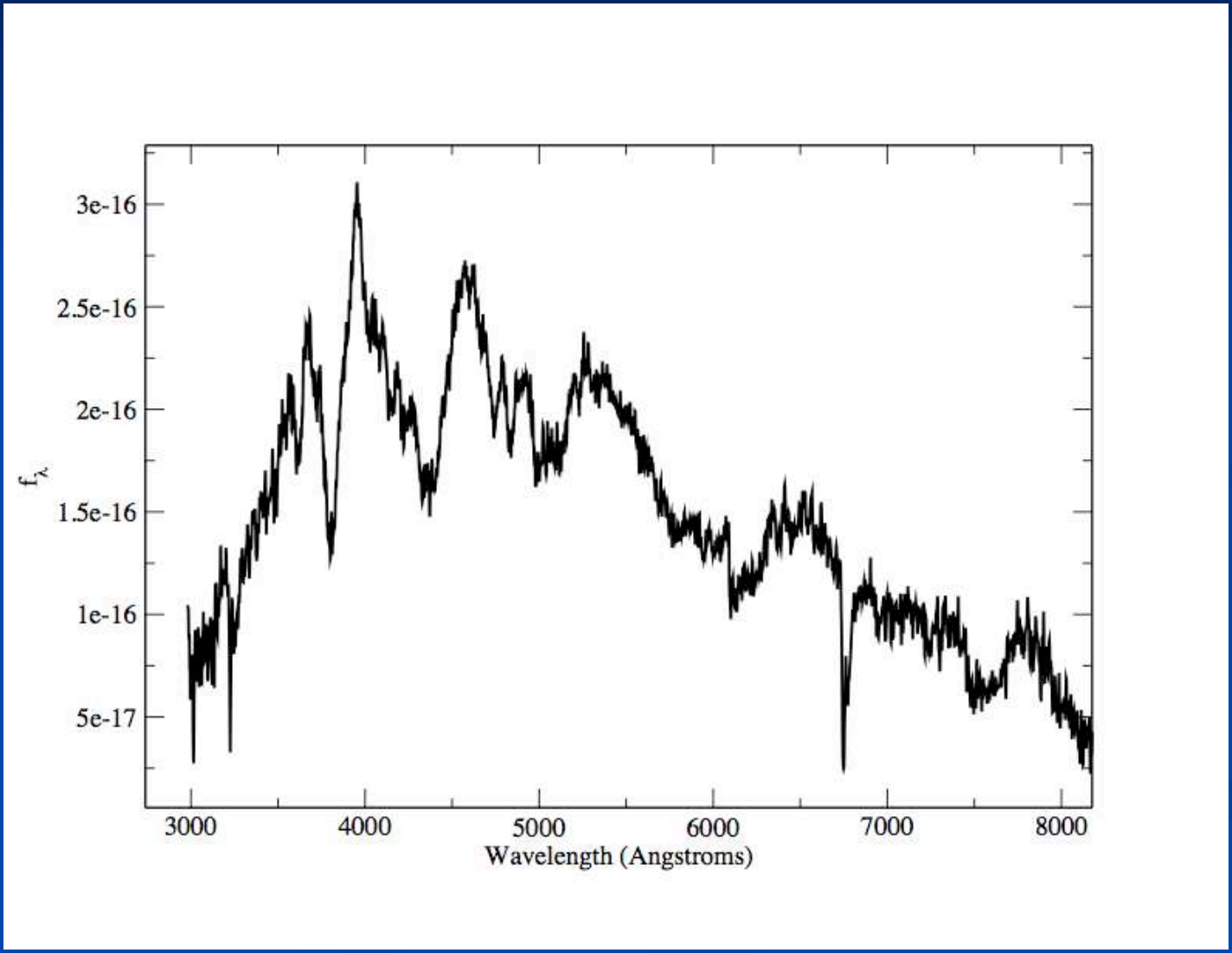


First Interesting Spectrum

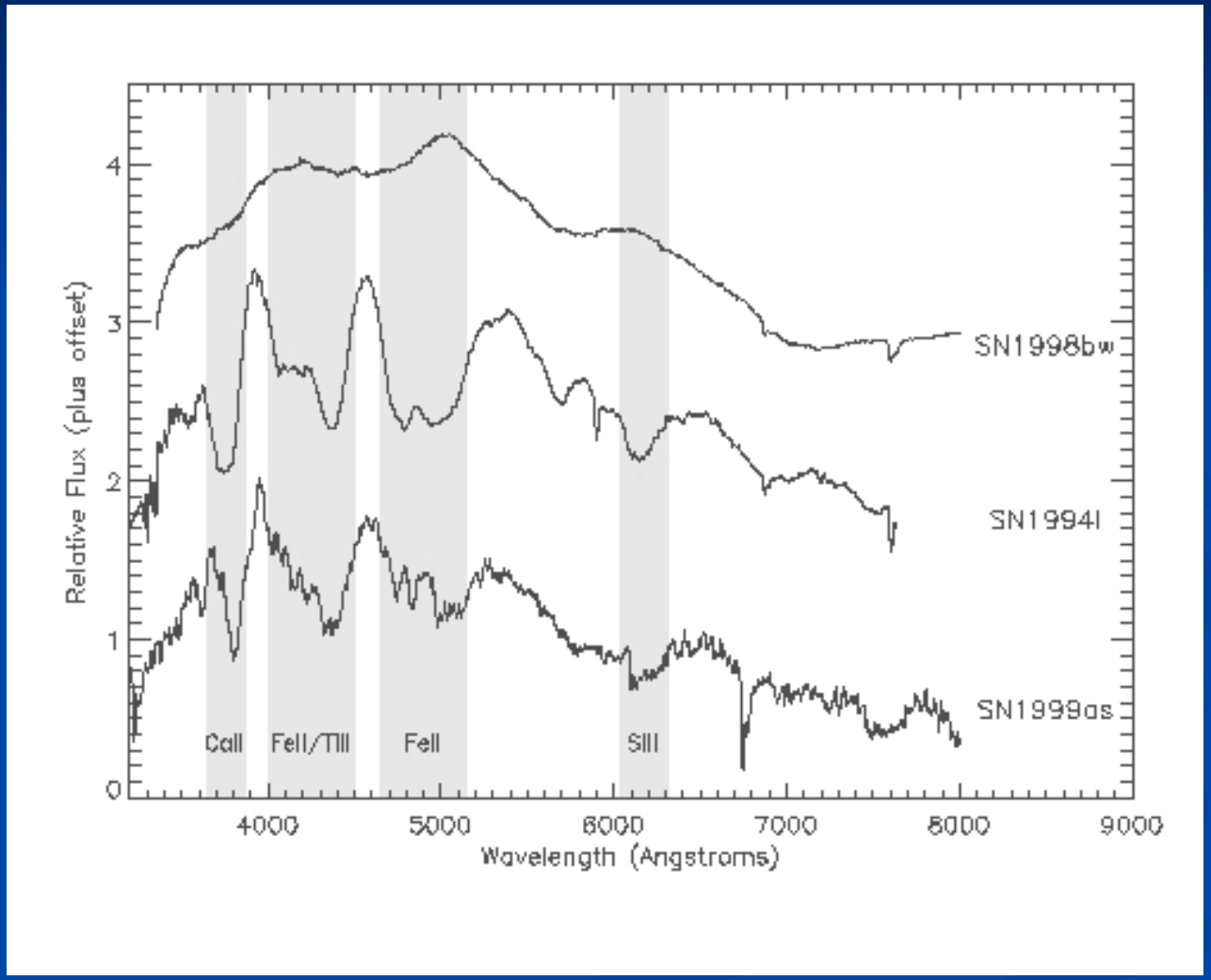
Mar 16.4 was the first good spectrum.

Clearly a Ib/c but with some very interesting narrow features.

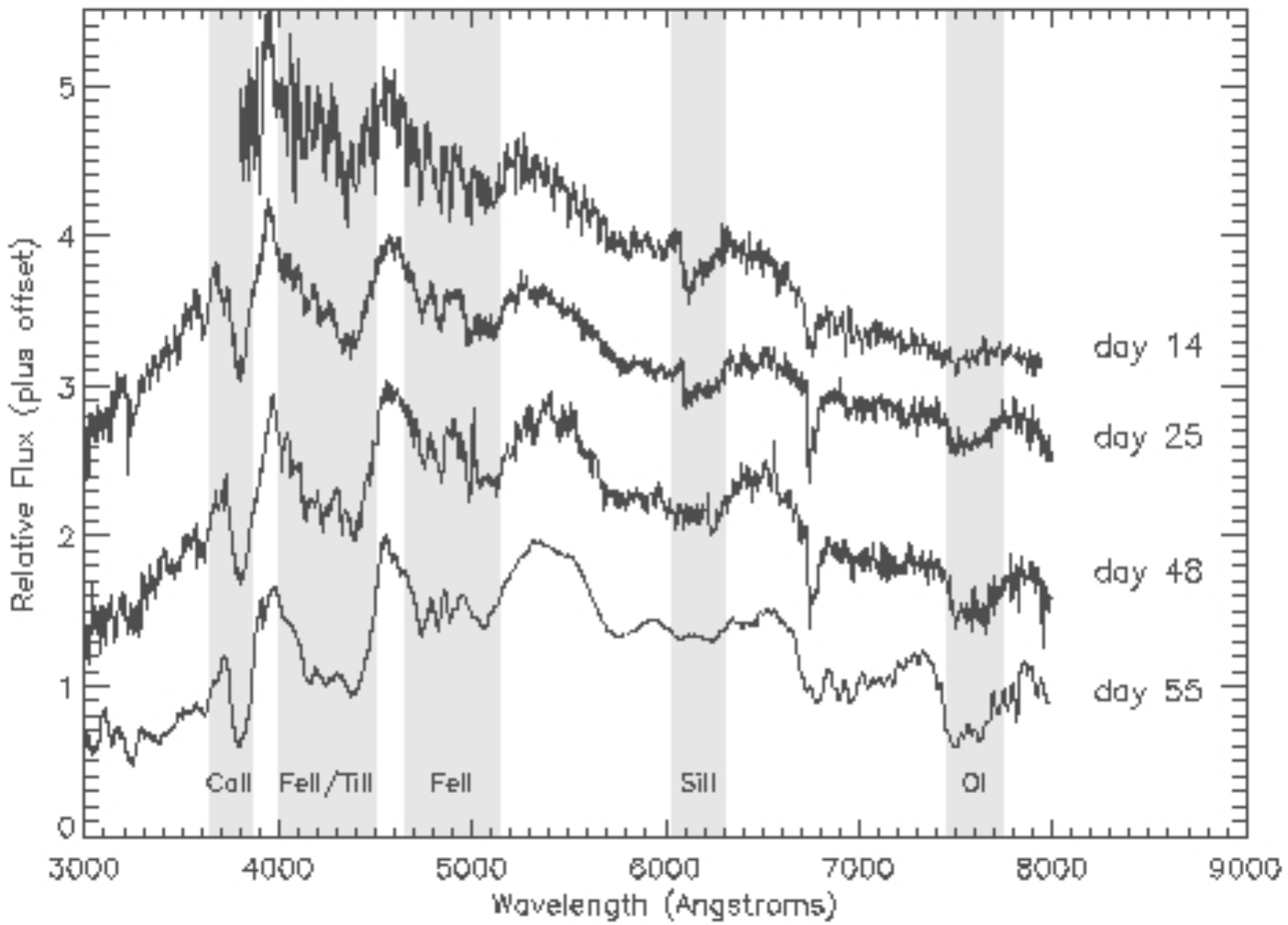
Redshift
z=0.127
M_V=-21.2



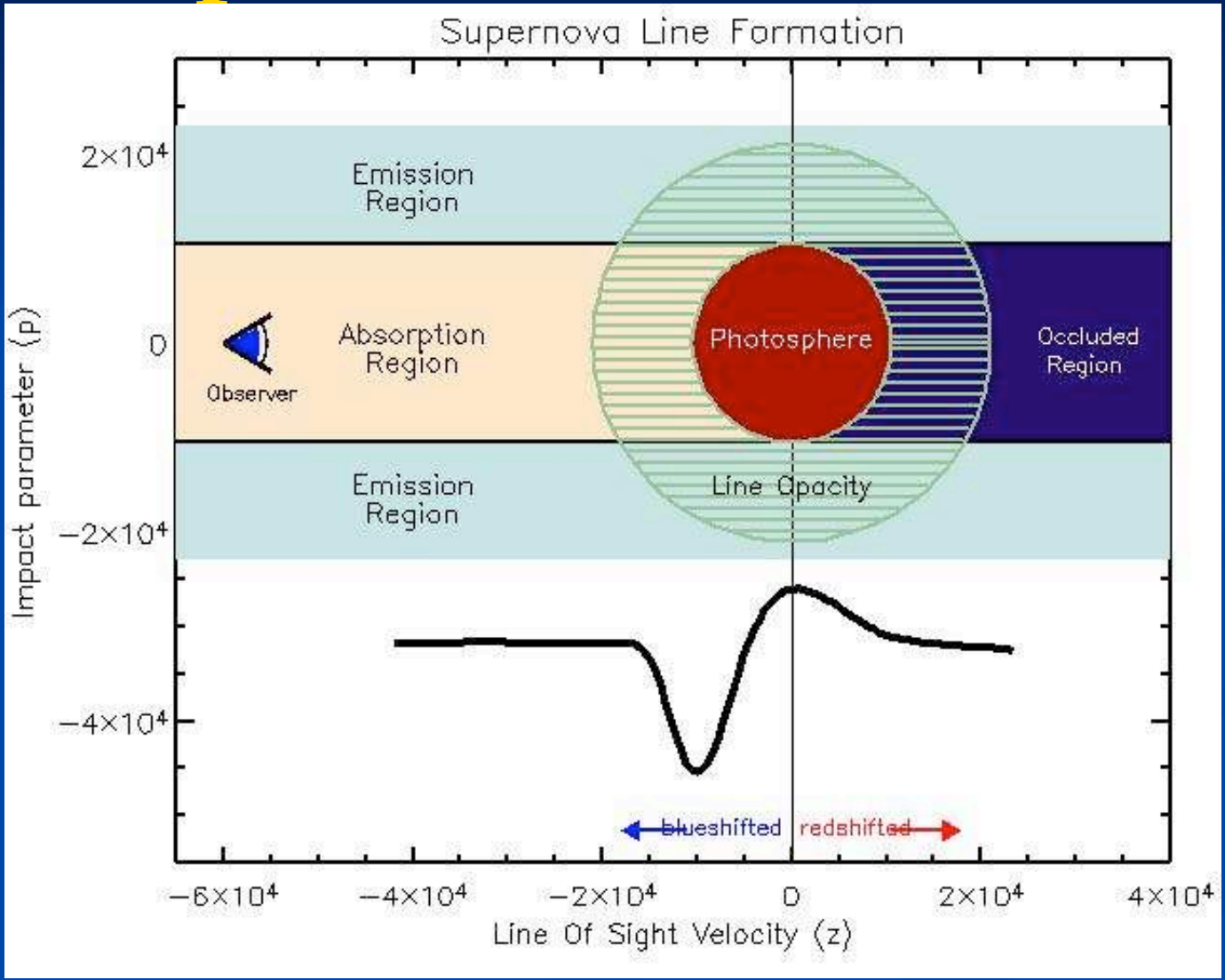
Comparison Spectra



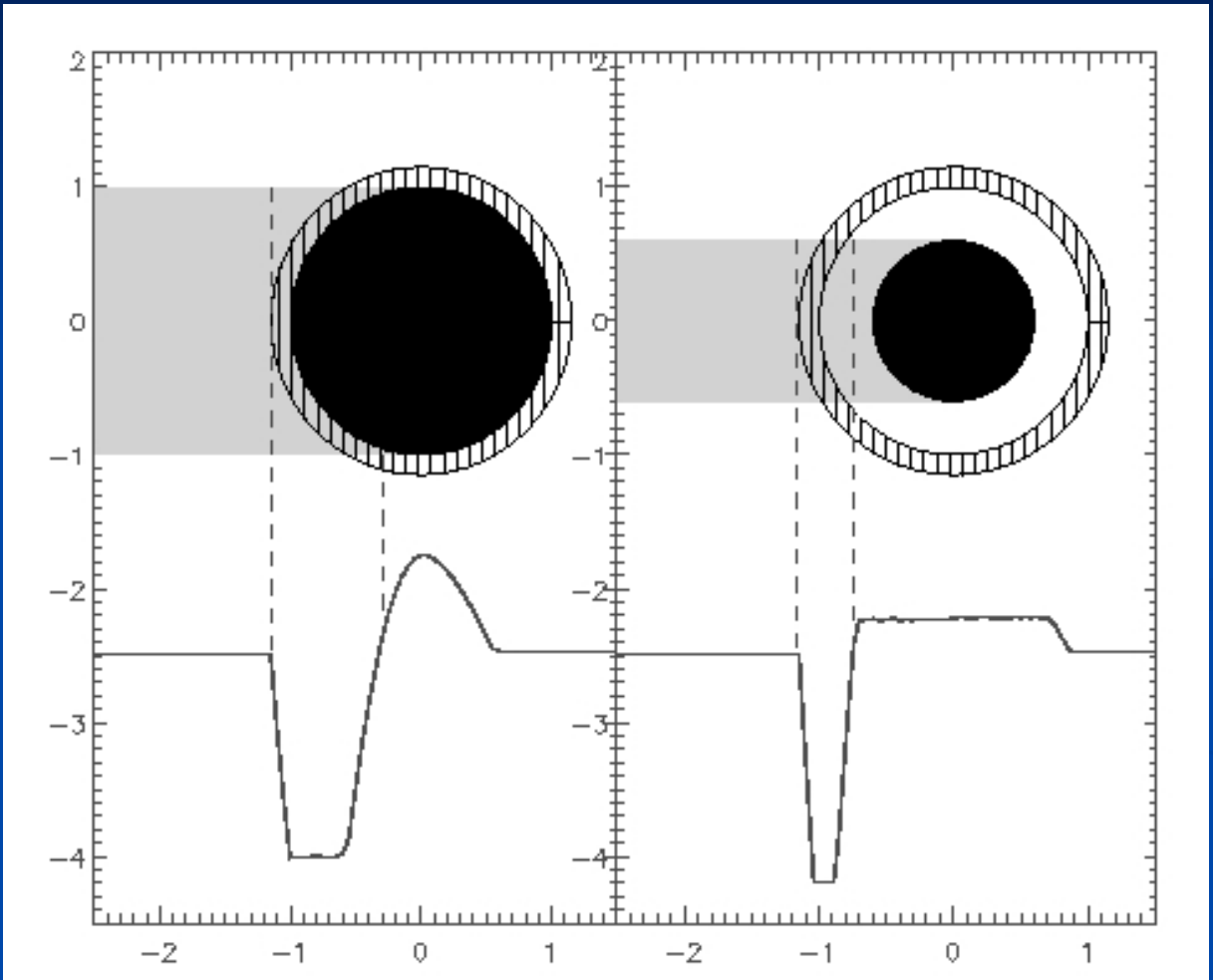
Spectral Evolution



Spectrum Formation

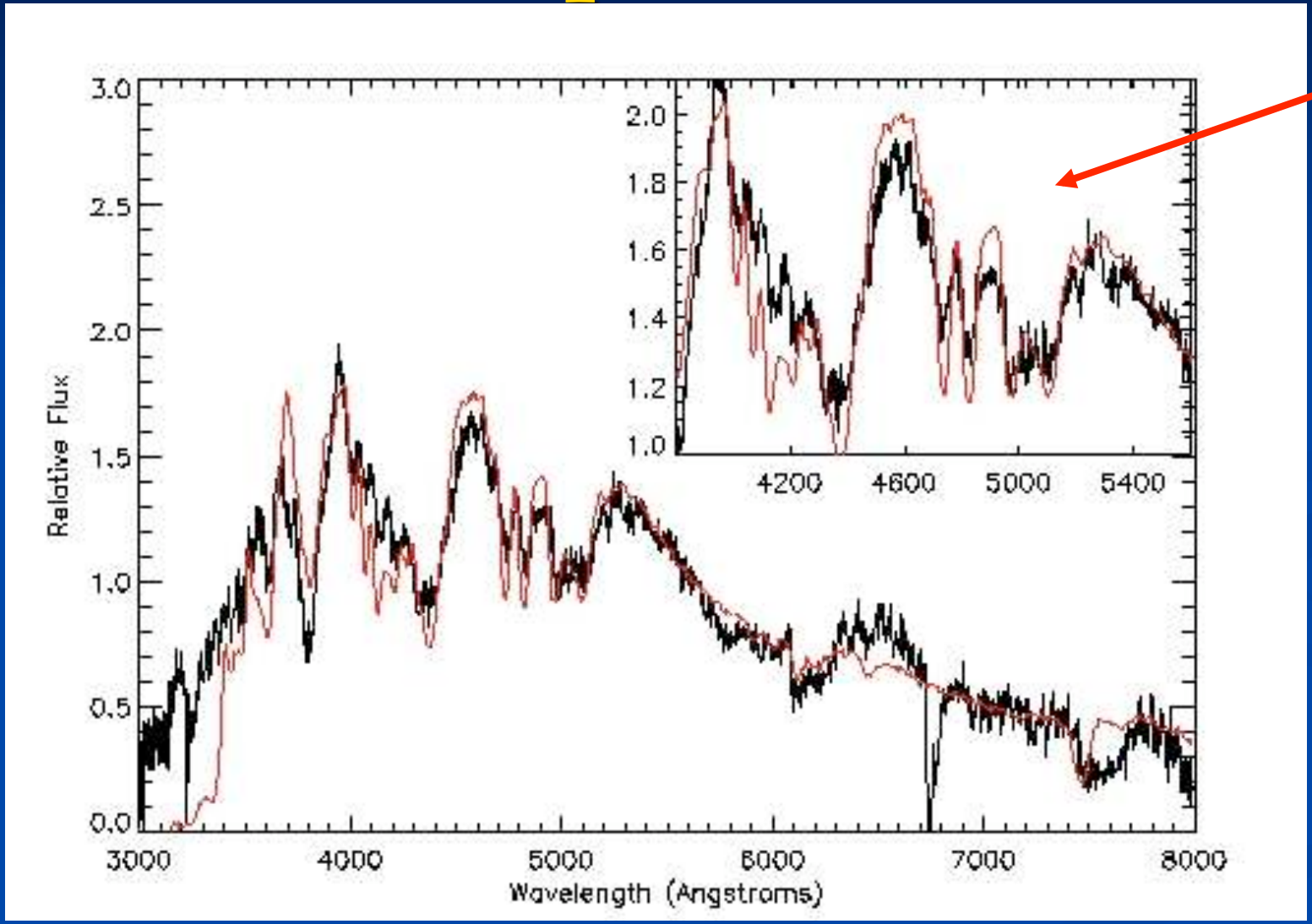


Shell Model

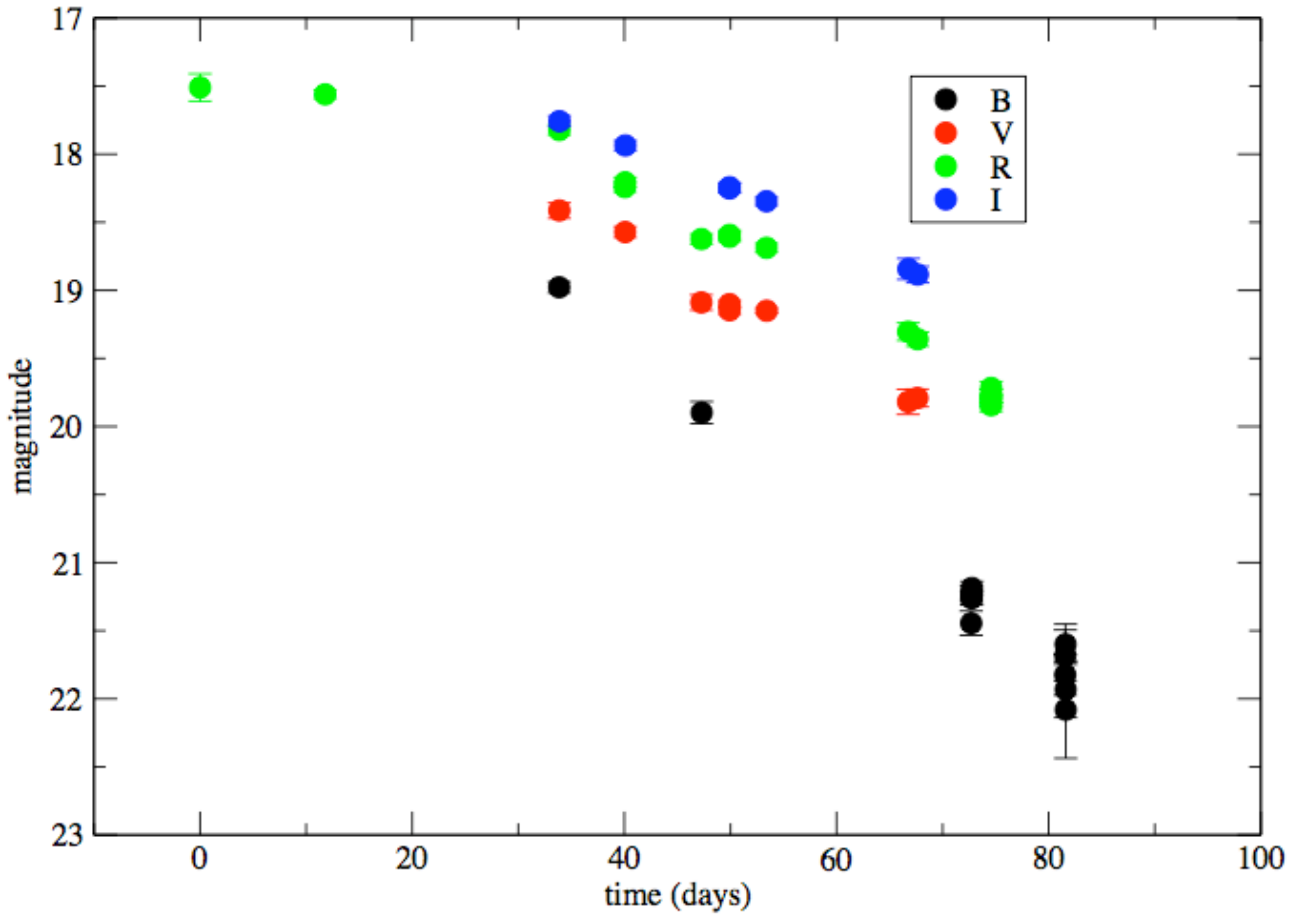


A detached shell is the only way to explain the narrow lines.

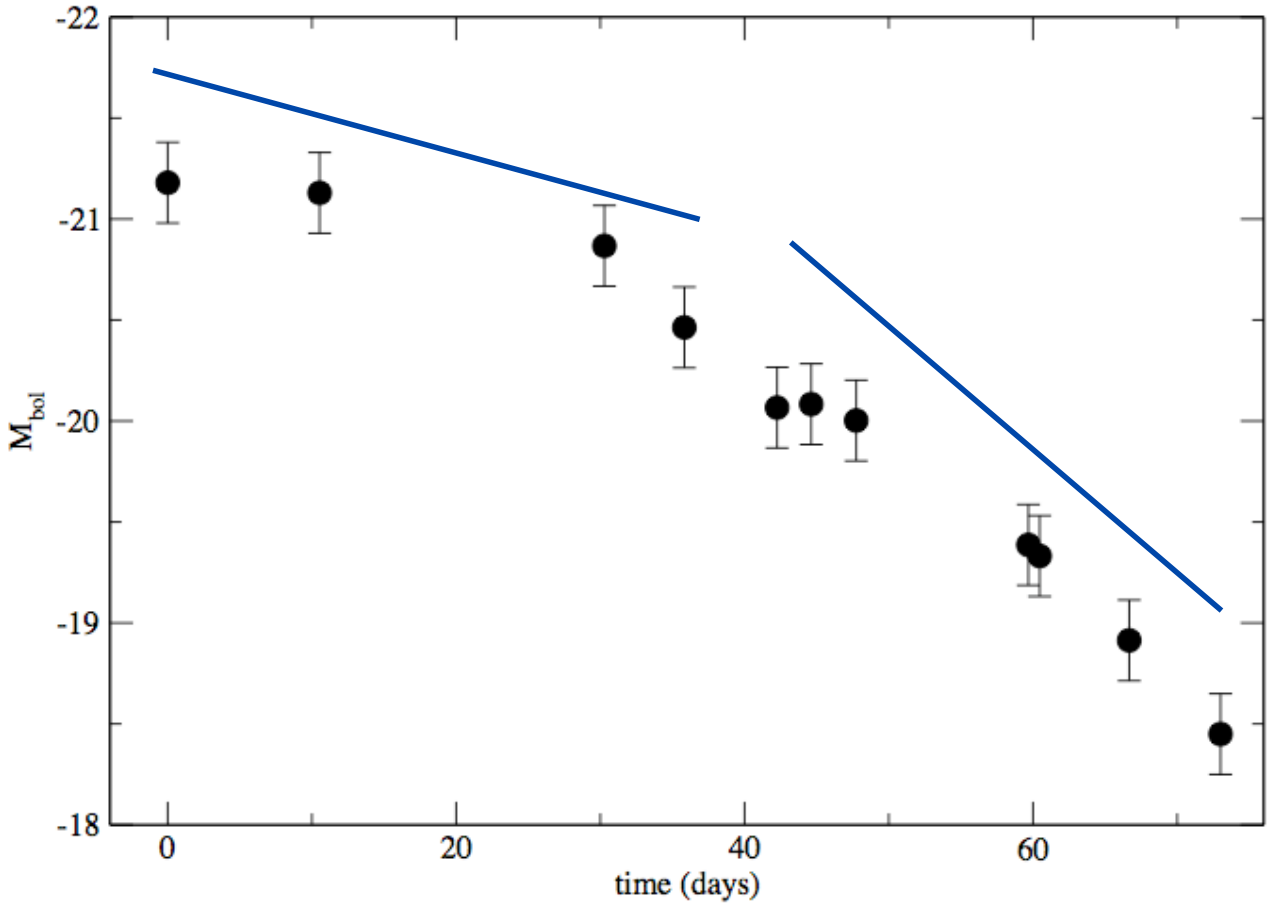
Spectral Fits



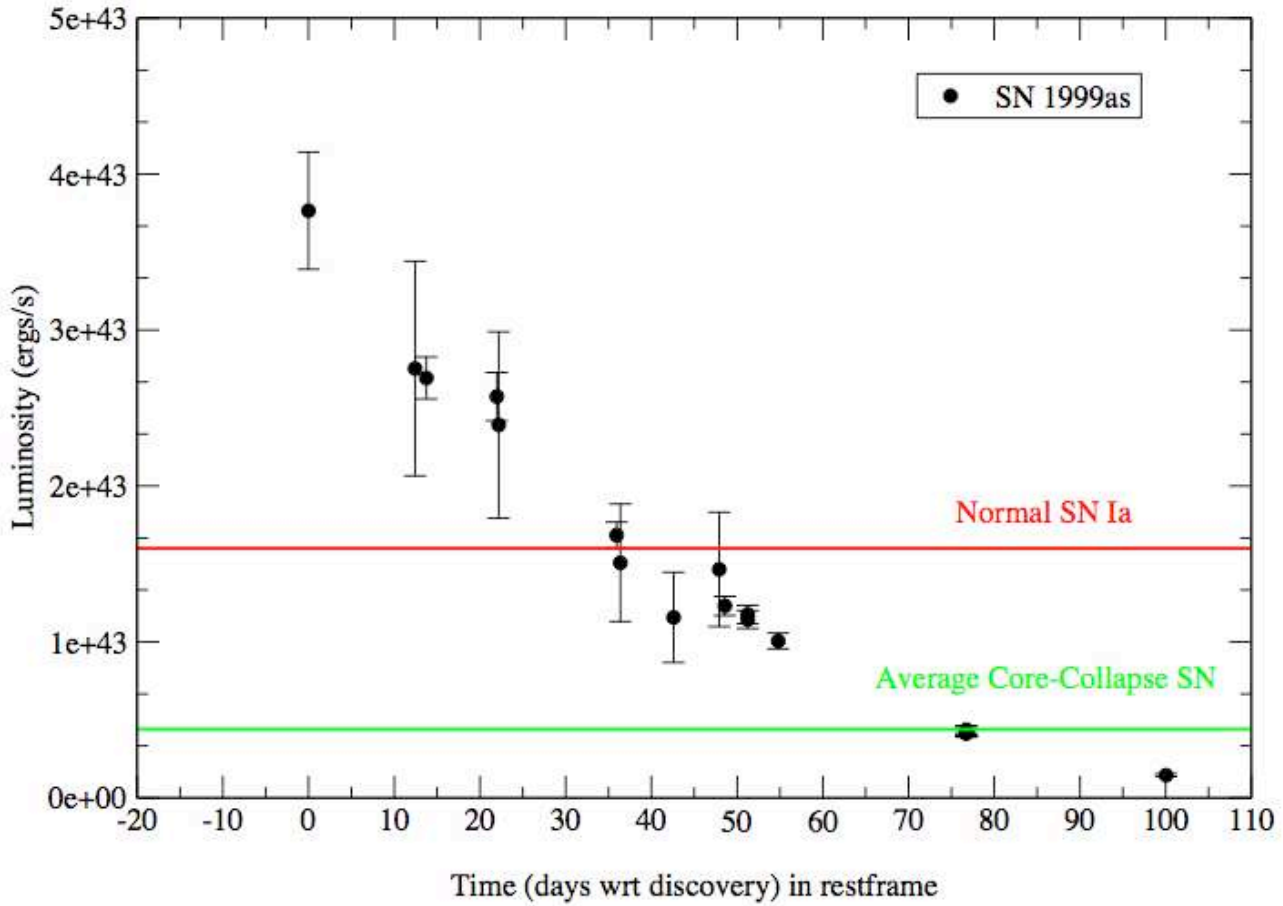
Lightcurve



Bolometric LC

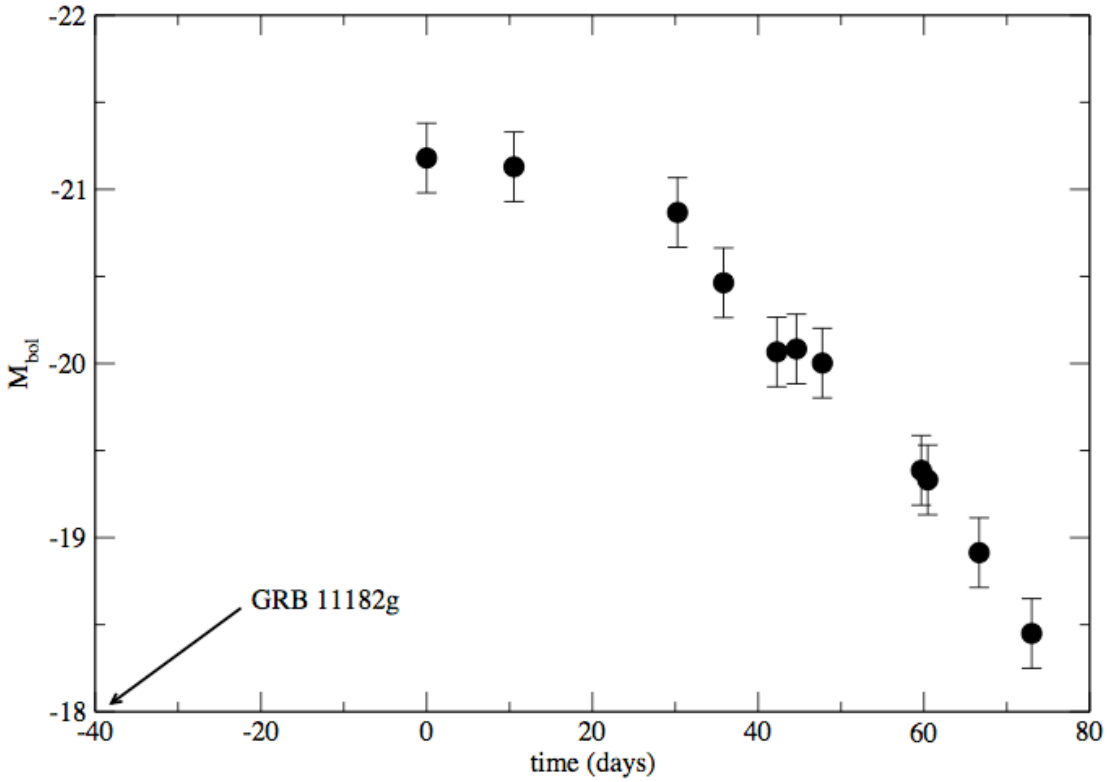


LC Comparison

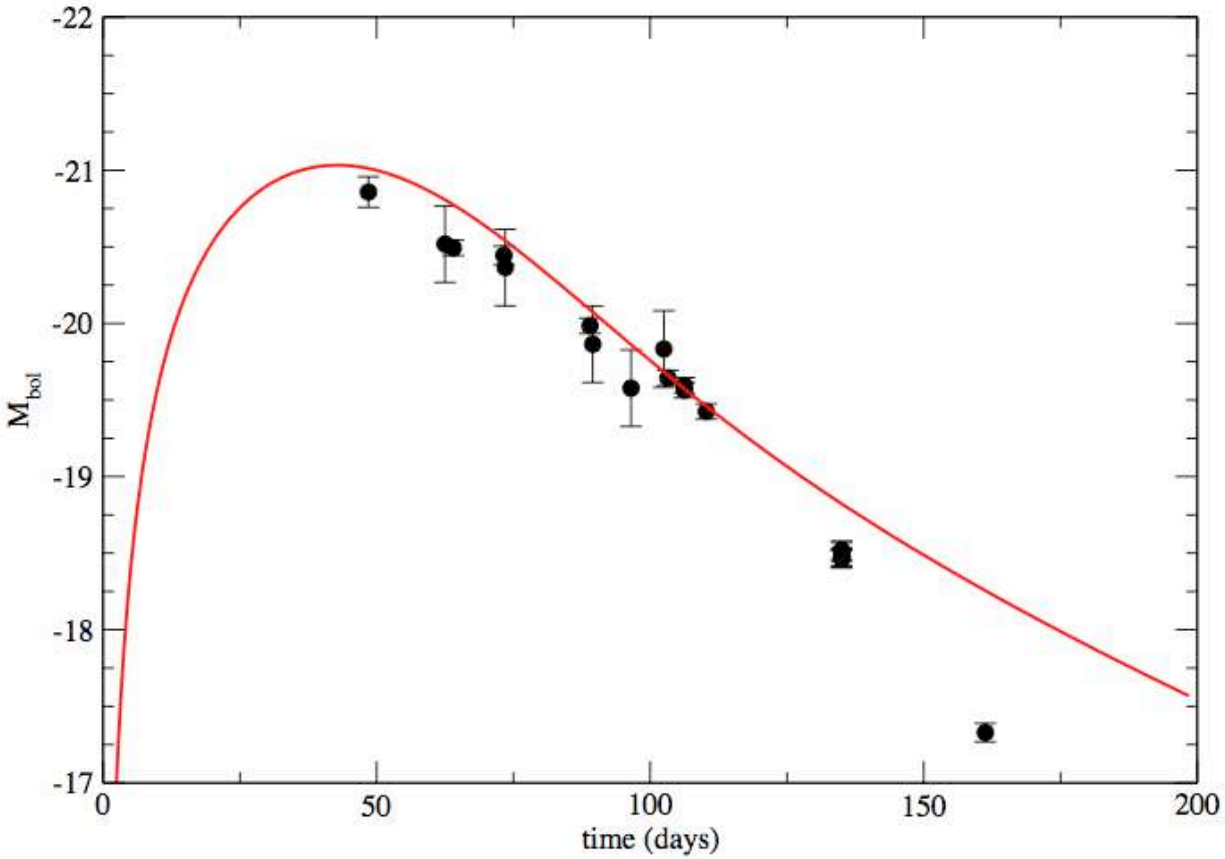


Possible GRB….

Name	TJD	Peak Flux	RA	Dec	sig(deg)
11182g	85552.	0.236	131.7	3.5	30.9



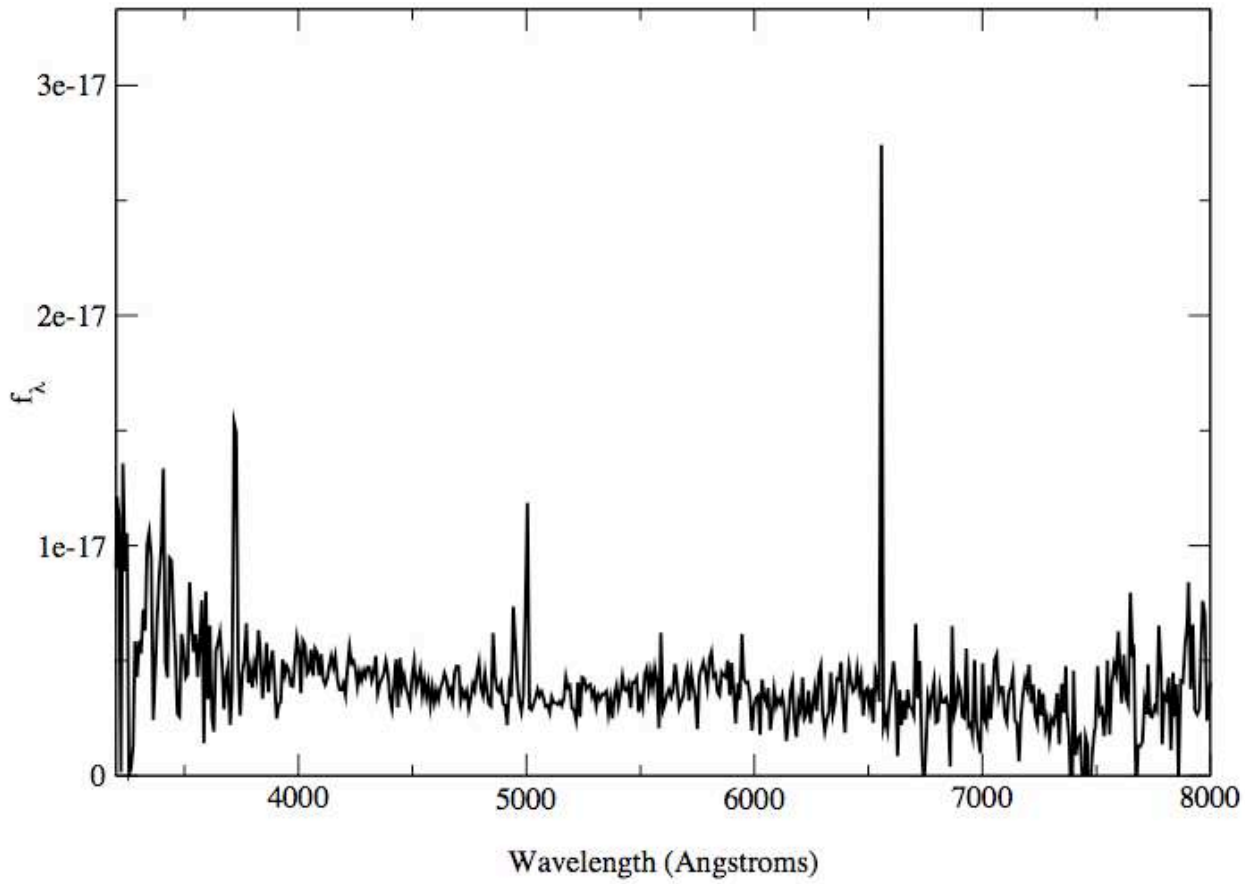
Models



Some degeneracy:

$M_{Ni} = 5\ M_{\odot}$
$M_{tot} = 50\ M_{\odot}$
KE = 50 foe

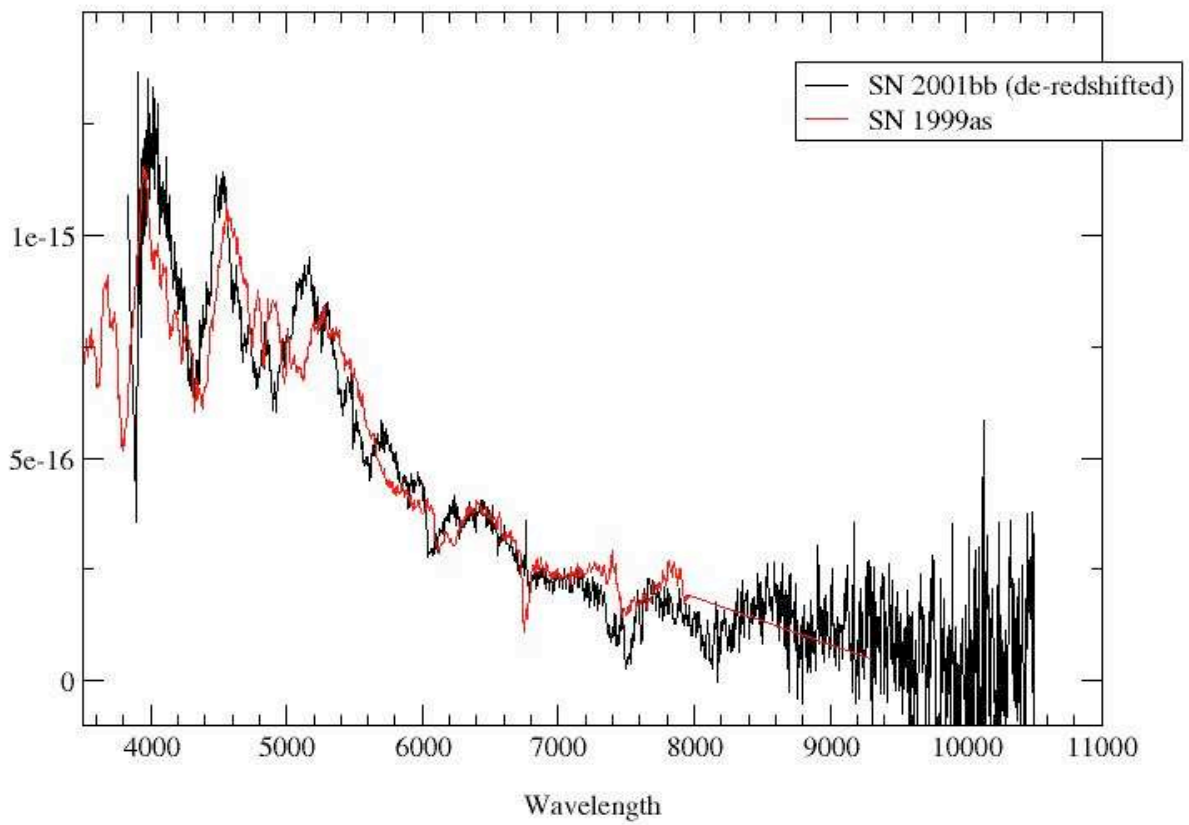
Host Spectrum



Preliminary measurement of the host has the metallicity at < 1/3 solar.

$M_V = -17.8$

Other SNe like this?



SN 2001bb was caught < 5 days after explosion.

But then faded by 2 magnitudes in the next 20 days.
$M_V = -17.8$

Other SN 1999as events

No event like SN 1999as has been found in over ~200 SCP high-z supernovae, ~500 SNLS supernovae.

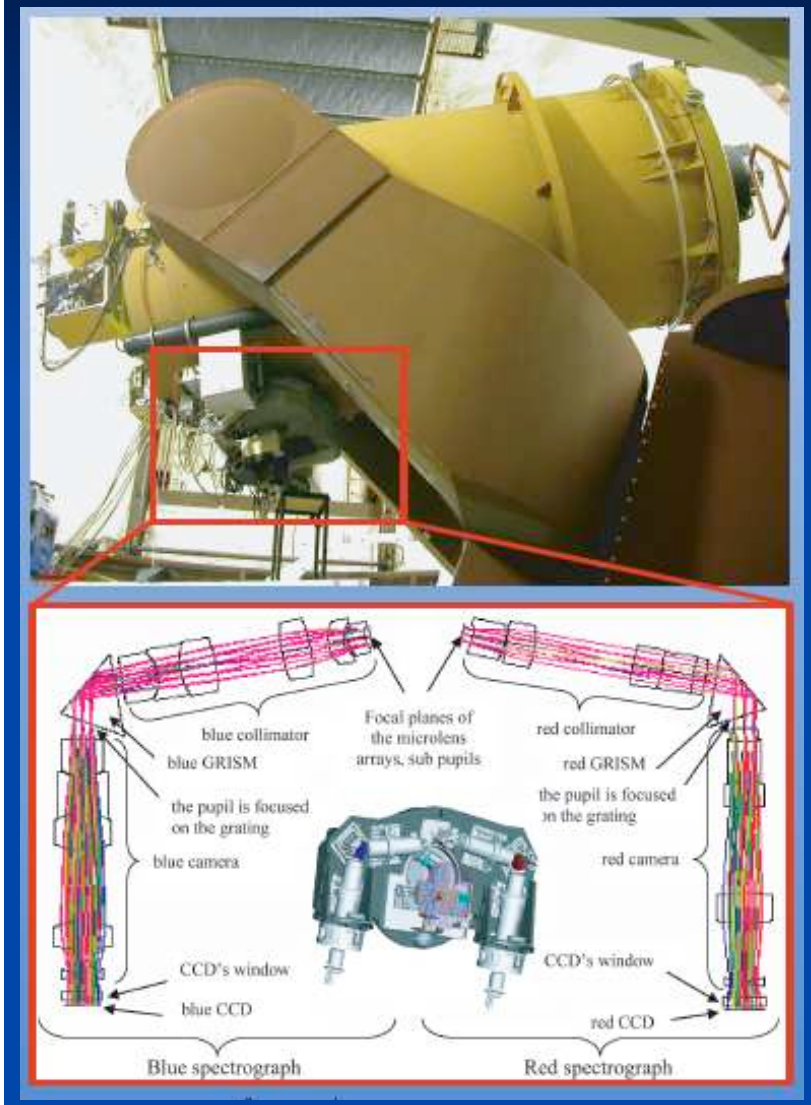
Even though the effective volume for finding these objects and the length of it lightcurve make it much more easy to discover.

It is a very rare event to find…. until 2007.

SN Factory

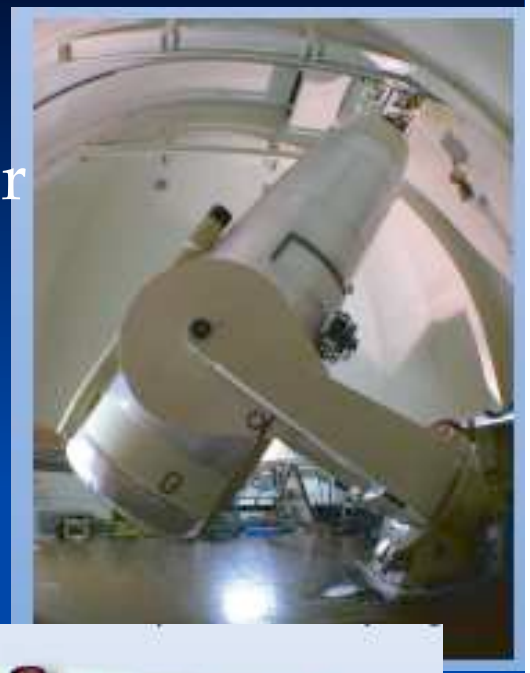
- Redshift Range is in a sweet spot for nearby SNe ($0.03 < z < 0.09$)
- Spectrophotometric follow-up from 0.35 - 1.00 microns
- Discovered 150+ well studied SNe Ia (with >8 epochs) caught at or before peak brightness
- Unbiased* discovery in that one does not target particular galaxies (though what criteria were used to initiate spectroscopic confirmation will lead to some biases)
- Well placed to find "second" parameters via spectral features and their evolution
- Eliminates K-correction systematics

Nearby SN Factory



Searching on Palomar Oschin Schmidt

Spectrophotometric Follow-up w/ UH 2.2-m



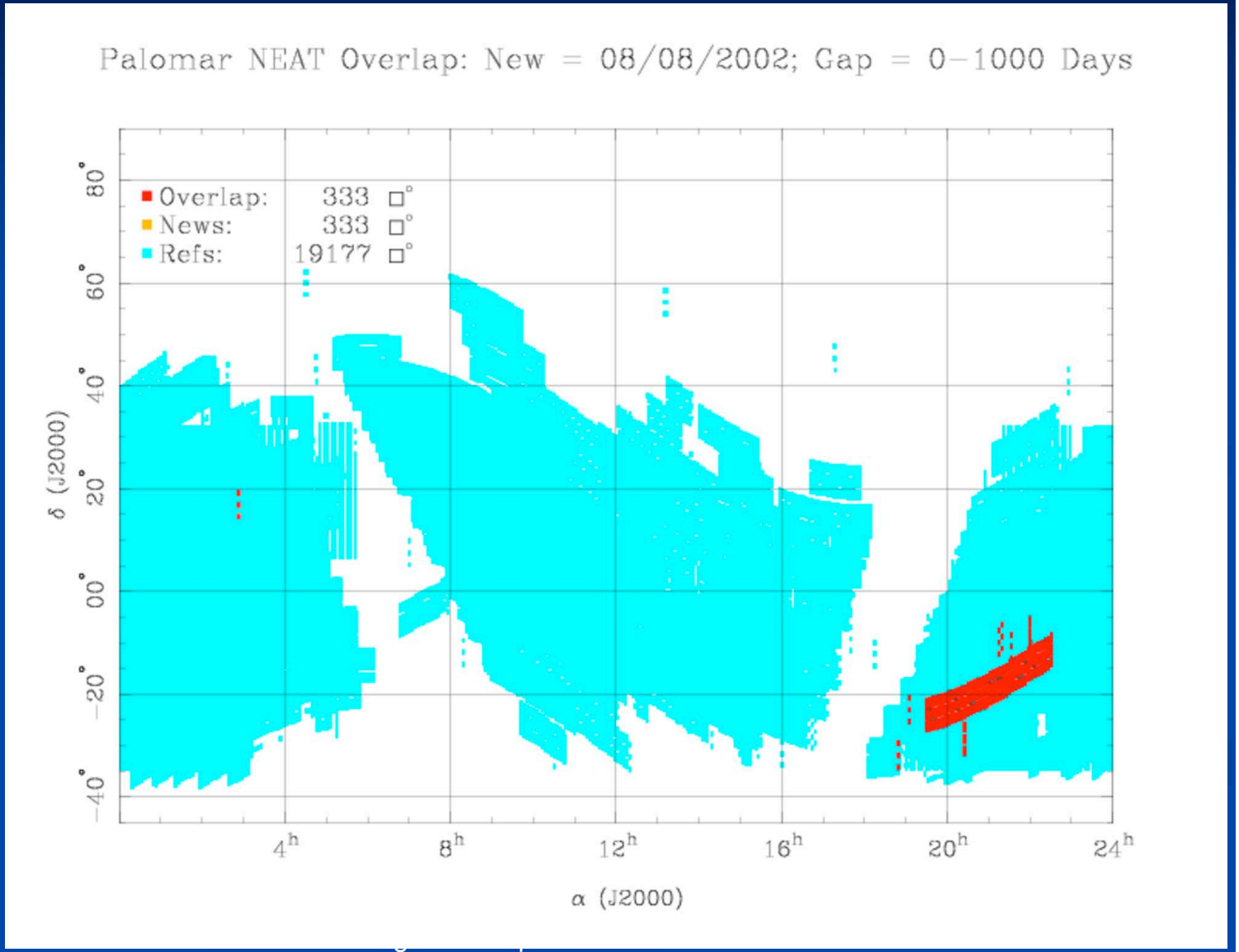
(artist's concept)

Search & Goals

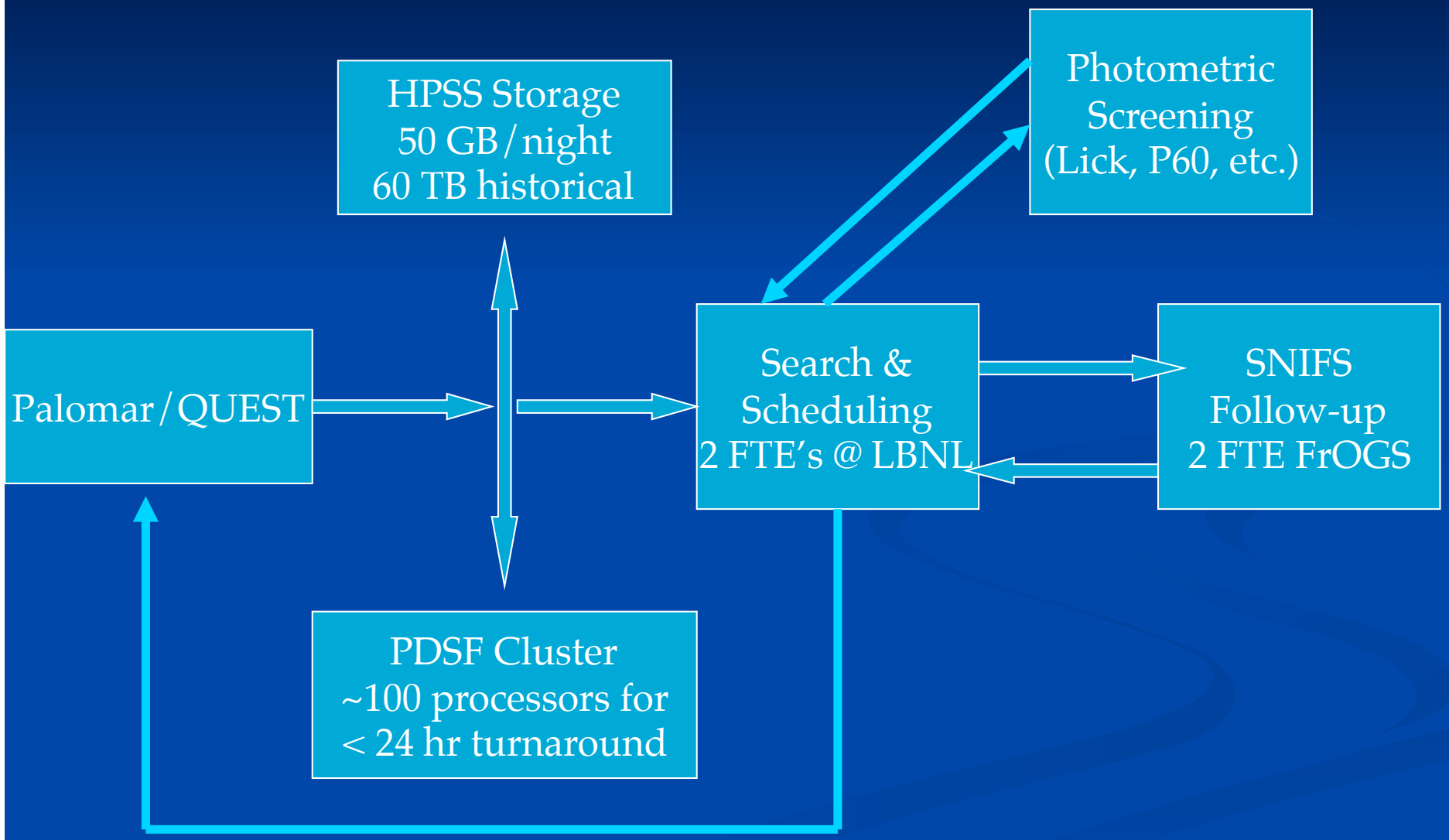
Asteroids: One person's garbage is another's gold!

Pave the sky each night, ~600 sq. deg. to mag 21.5 -> 2 SNe/night

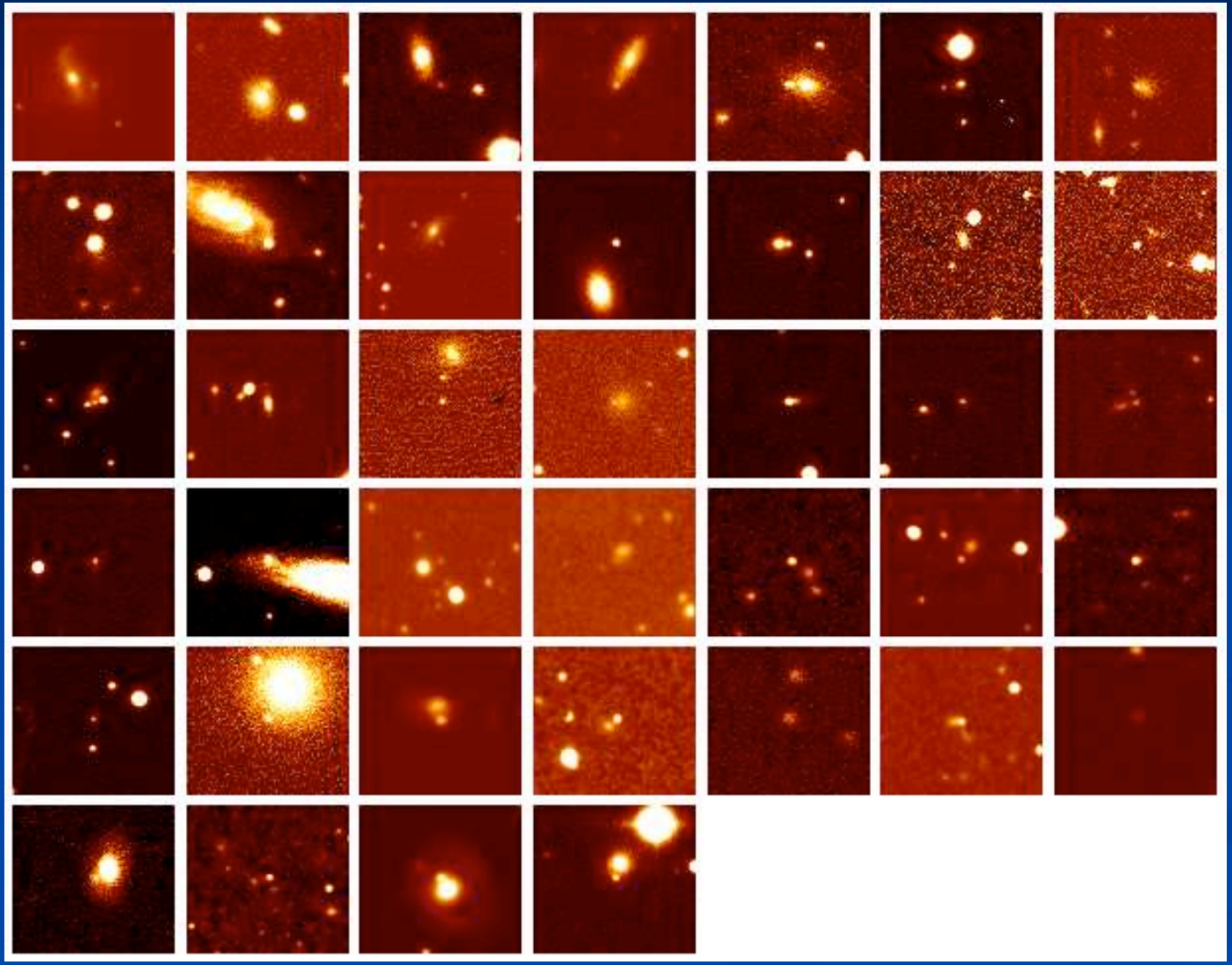
150 SNe Ia in the Hubble flow over the project lifetime.



Data Flow…


HPSS Storage
50 GB / night
60 TB historical
Photometric
Screening
(Lick, P60, etc.)
Palomar / QUEST
Search &
Scheduling
2 FTE's @ LBNL
SNIFS
Follow-up
2 FTE FrOGS
PDSF Cluster
~100 processors for
< 24 hr turnaround

Supernovae



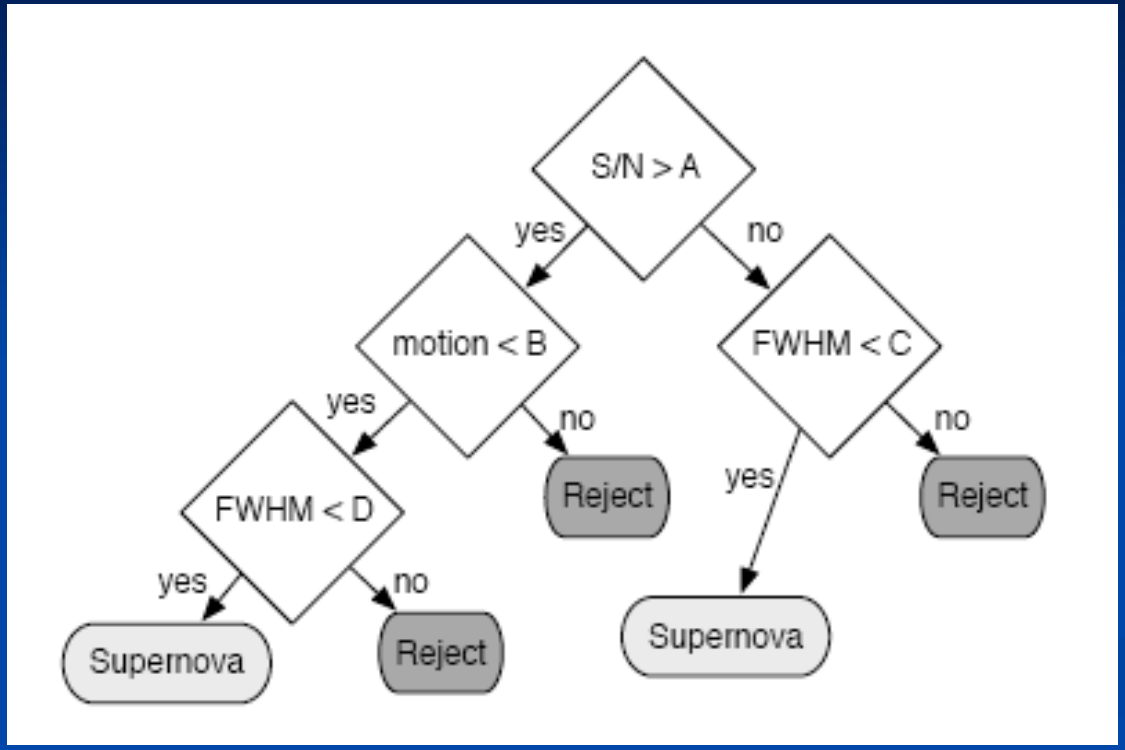
The last month's SN Ia discoveries.

Searching the data

When the SN-only search was going on the Palomar-schmidt we covered about 110 pointings of the QUEST camera a night. These pointings consist of 2 images in one filter (RG610) separated by 1 hour. S/N ~7 to R of 20.0 during full moon and 21.5 during new moon. This results in an effective area of ~600 sq. deg.

This generated about 10,000 image-pairs in a night. 10% of those had 5-sigma detections on them. Since 1000 subtractions is too much to scan, we used a boosted decision tree to knock it down to a more reasonable number < 100.

Boosted Decision Tree

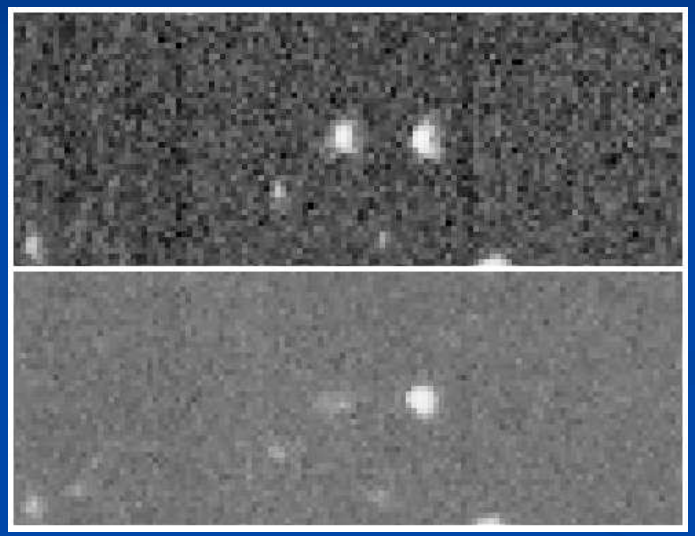


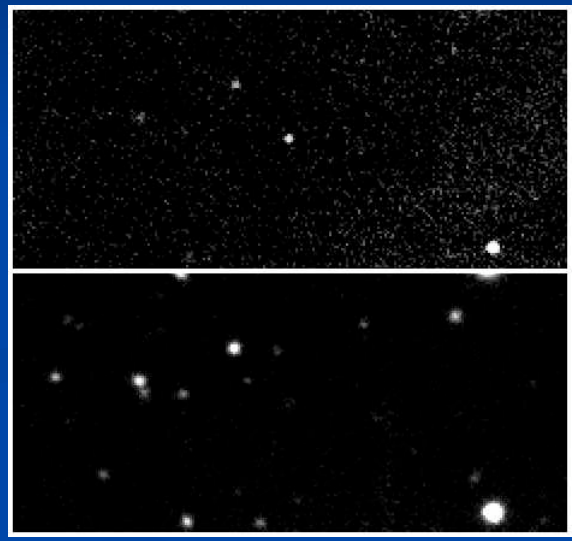
The SN Factory decision tree incorporates between 20 and 30 variables and is 85% effective. It cuts the scanning load by an order of magnitude. It has been trained on fake and historical SN.

Example decision tree that would treat high S/N objects differently than low S/N objects. In practice a real decision tree has many more branches and the same variable can be used at many different branches with different cut values (Bailey *et al.* , 2007)

Nugent Decision Tree

new

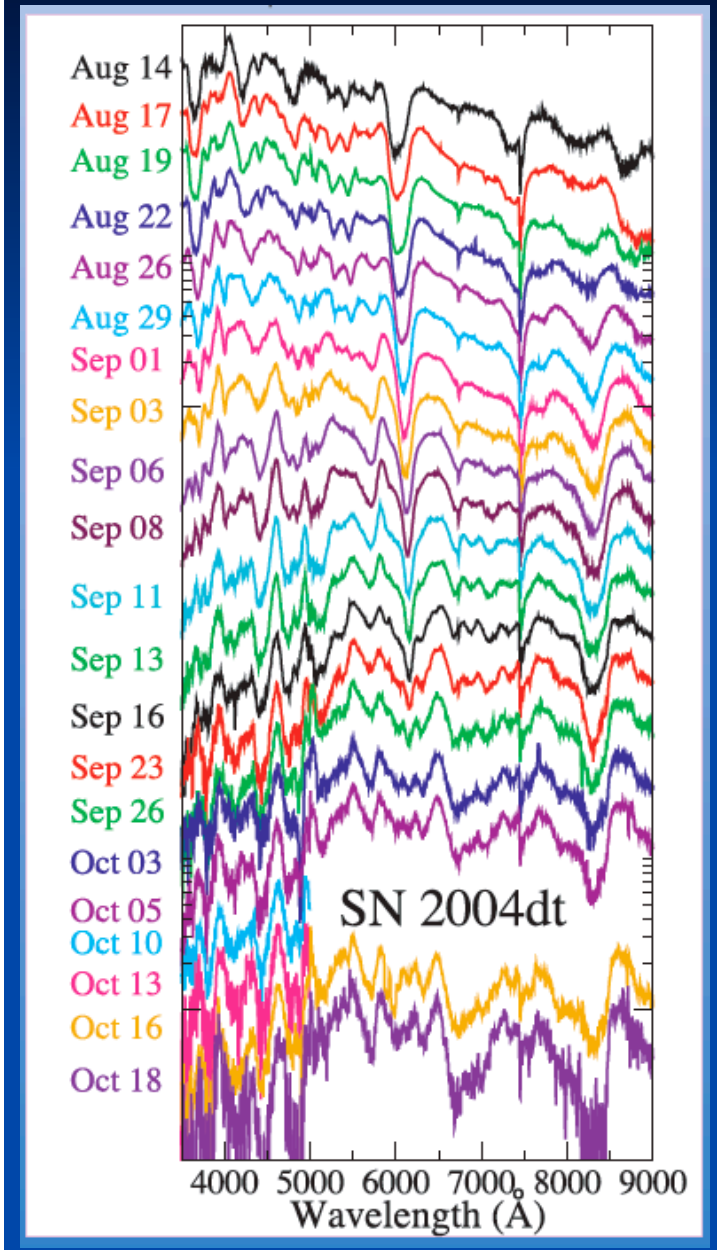


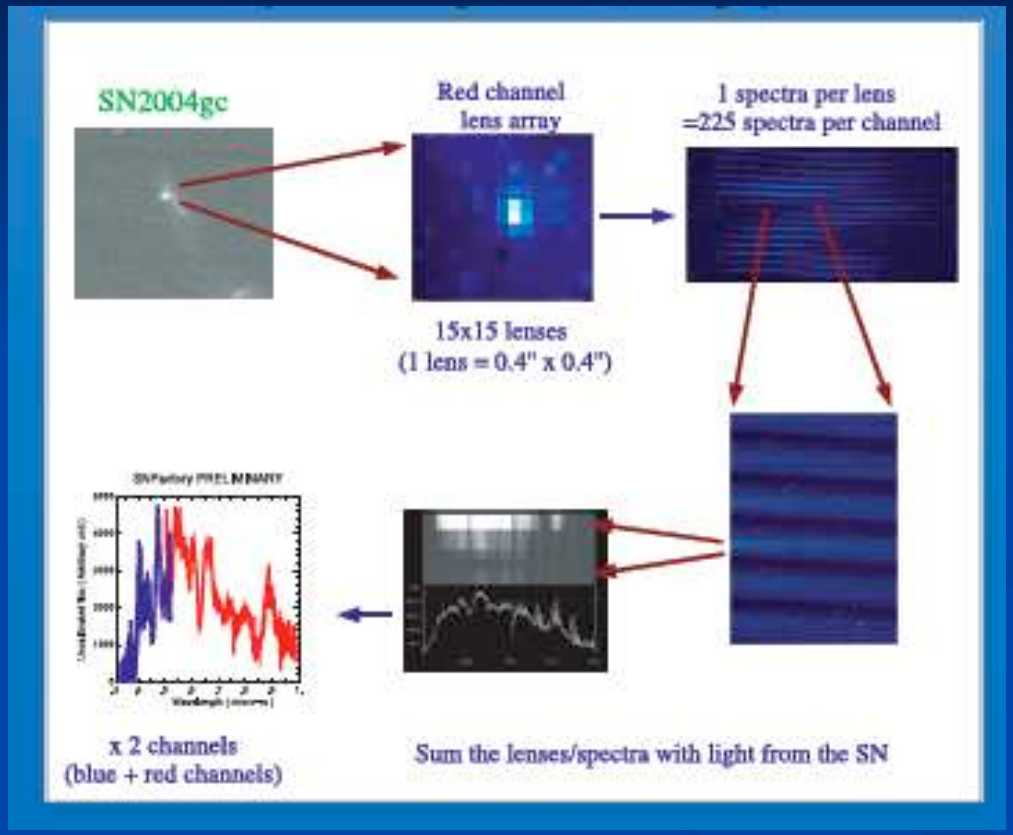


ref

What do you send to the scope? Especially when you find 10 good candidates and only have space for 5...

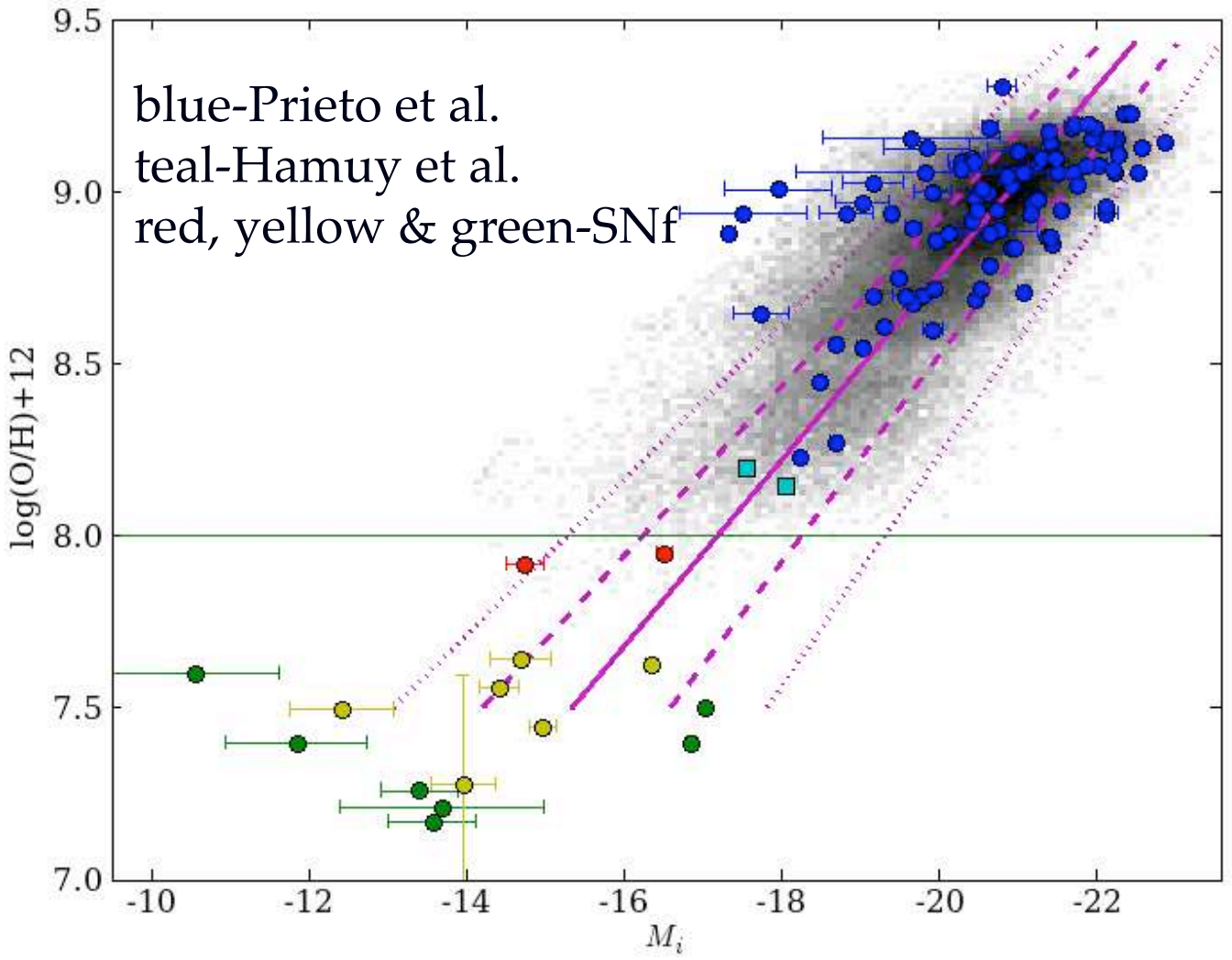
SNIFS



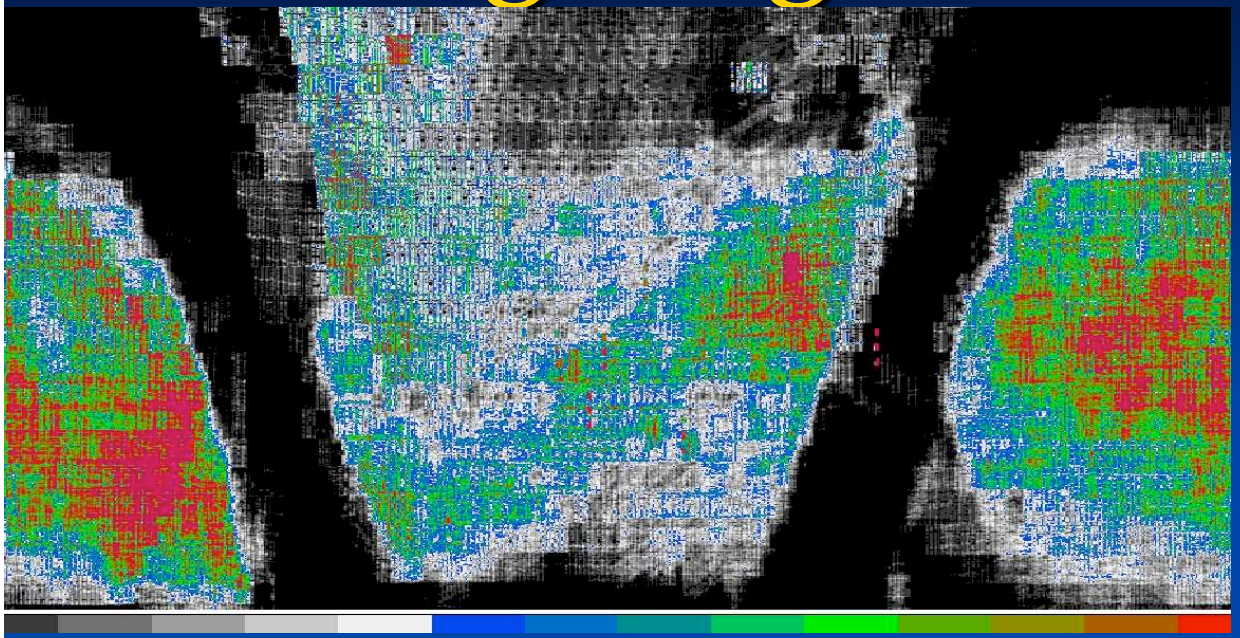


Automated follow-up, overheads ~4min:
Leads to about 20 science spectra night down to mag 20.0 on an 88" telescope.

SNf - SN Ia Hosts



Targeting Aid…DeepSky



Having DeepSky lets us to do something other SNe searches can ill afford to do: go after SNe without apparent hosts.

The historical lightcurves allow us to strongly rule out distant AGN and variable stars in favor of SNe.

This data spans 9 years and almost 20,000 square degrees, half from the NEAT 3-banger and half from the Palomar-QUEST camera on the Palomar Oschin schmidt telescope (RG610/Open). The entire dataset is 90 TB and will create both a temporal and static catalog of astrophysical objects. NERSC is re-processing and hosting this data on spinning disk (30% complete as of 1 hr ago - 2 months to go). Several historical pre-discoveries already!

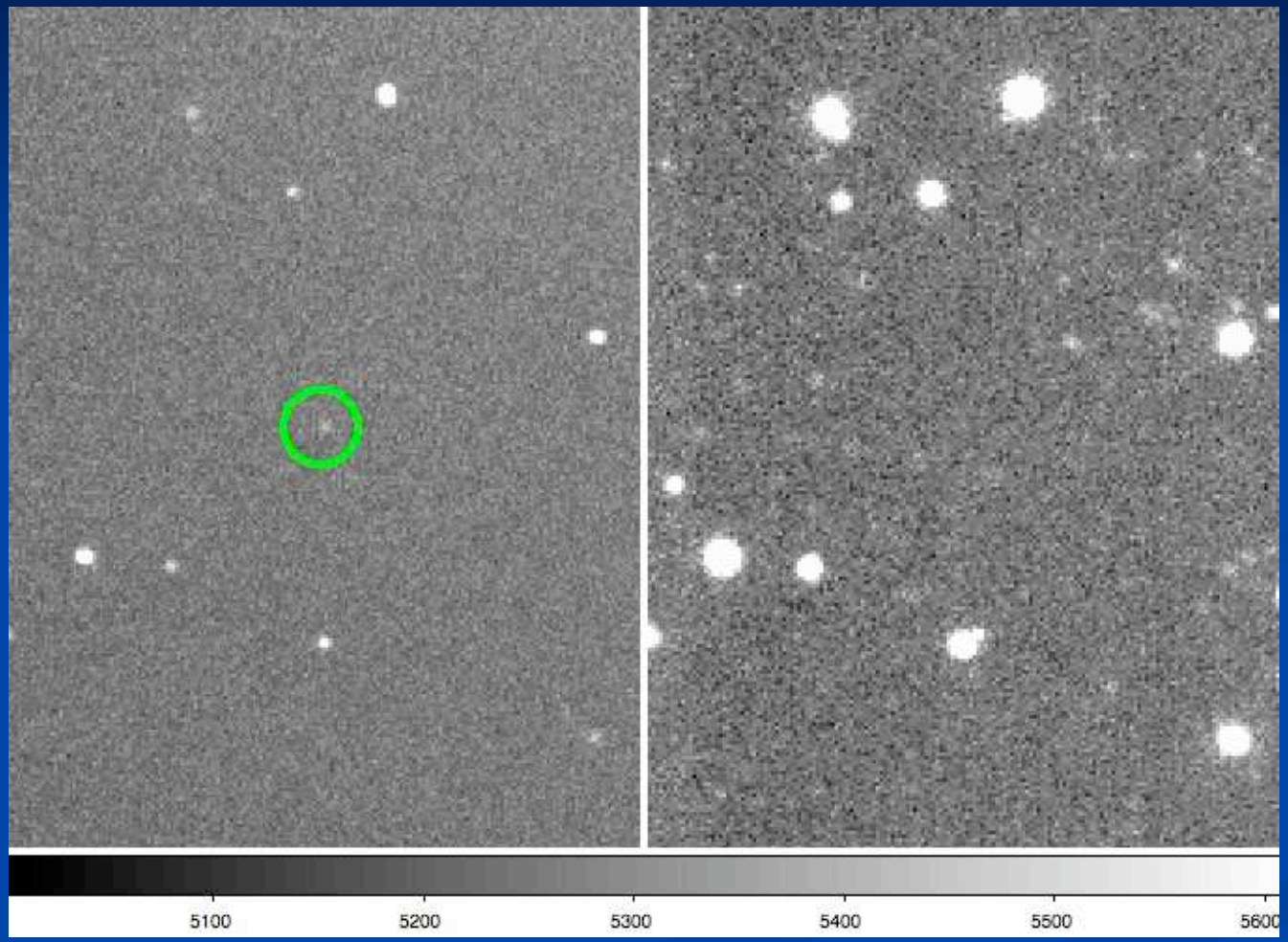
See: http://supernova.lbl.gov/~nugent/deepsky.html

SN 2007bi Discovery

Found Apr 6th, 2007

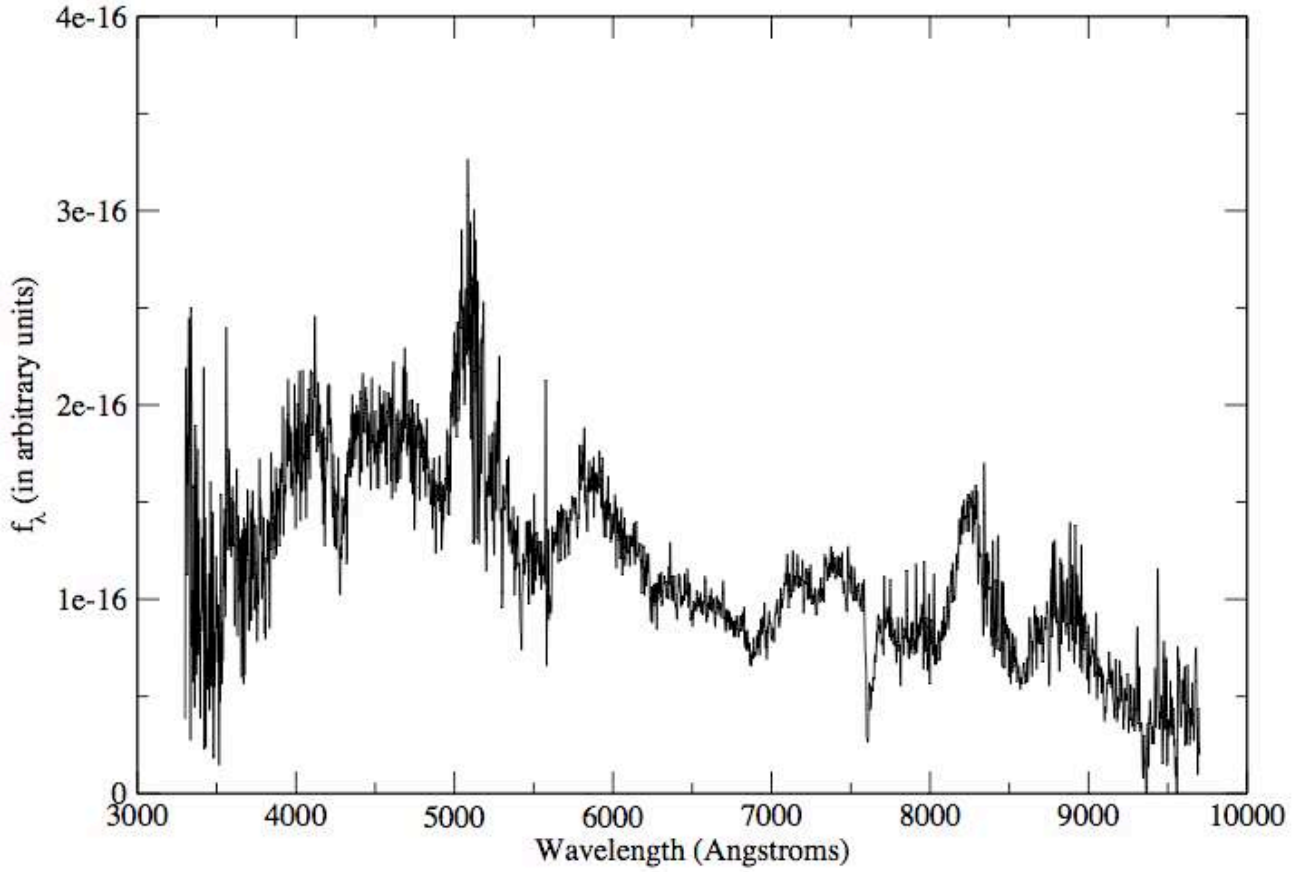
Host has M_g= -16.4
@ z = 0.127

M_V = -20.5

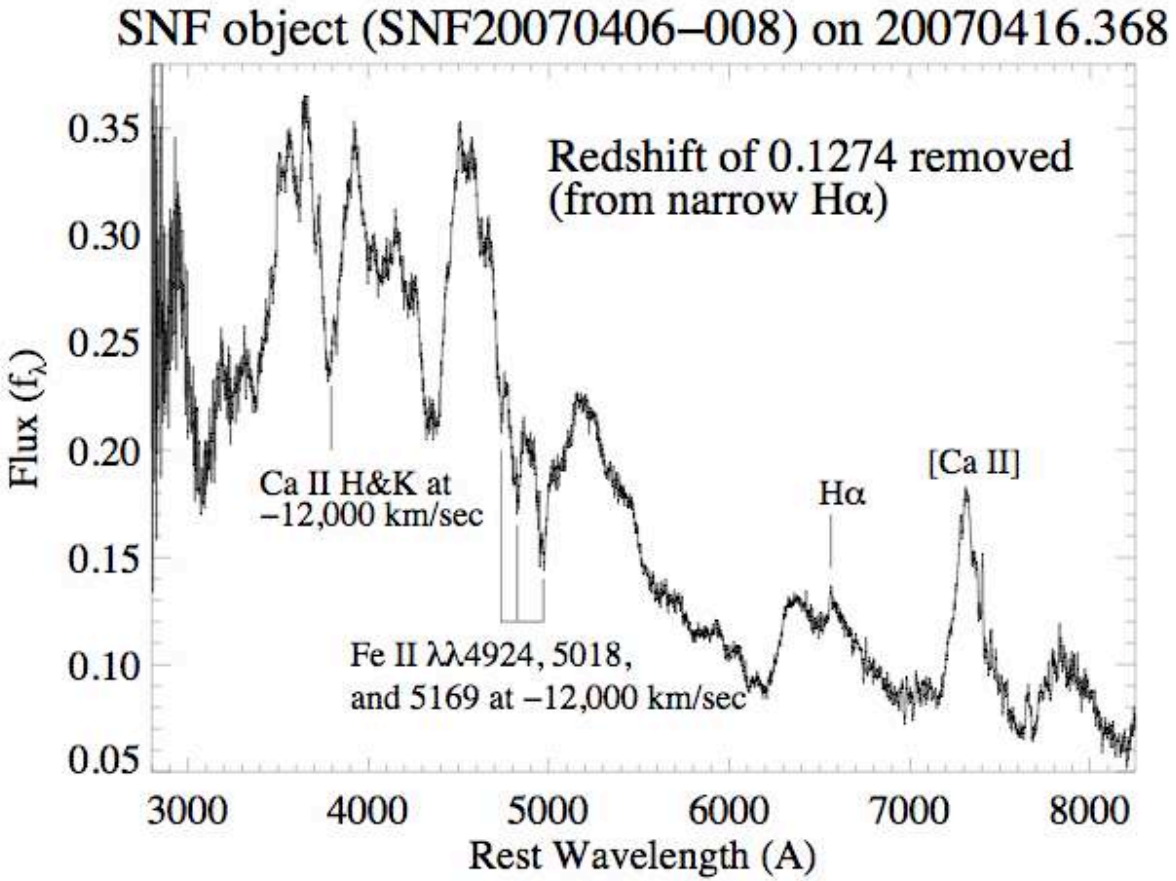


SN 2007bi Spectrum

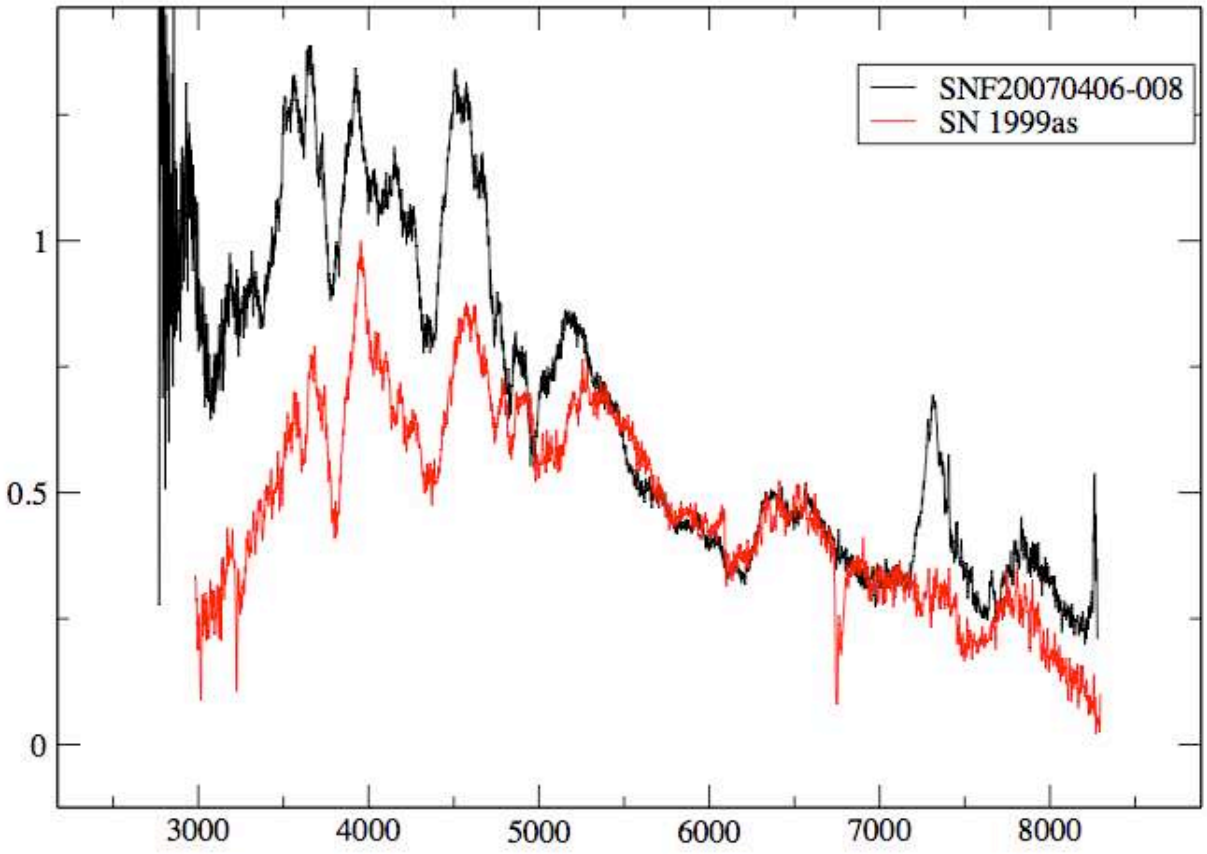
Spectrum Apr 6th.



SN 2007bi confirmation

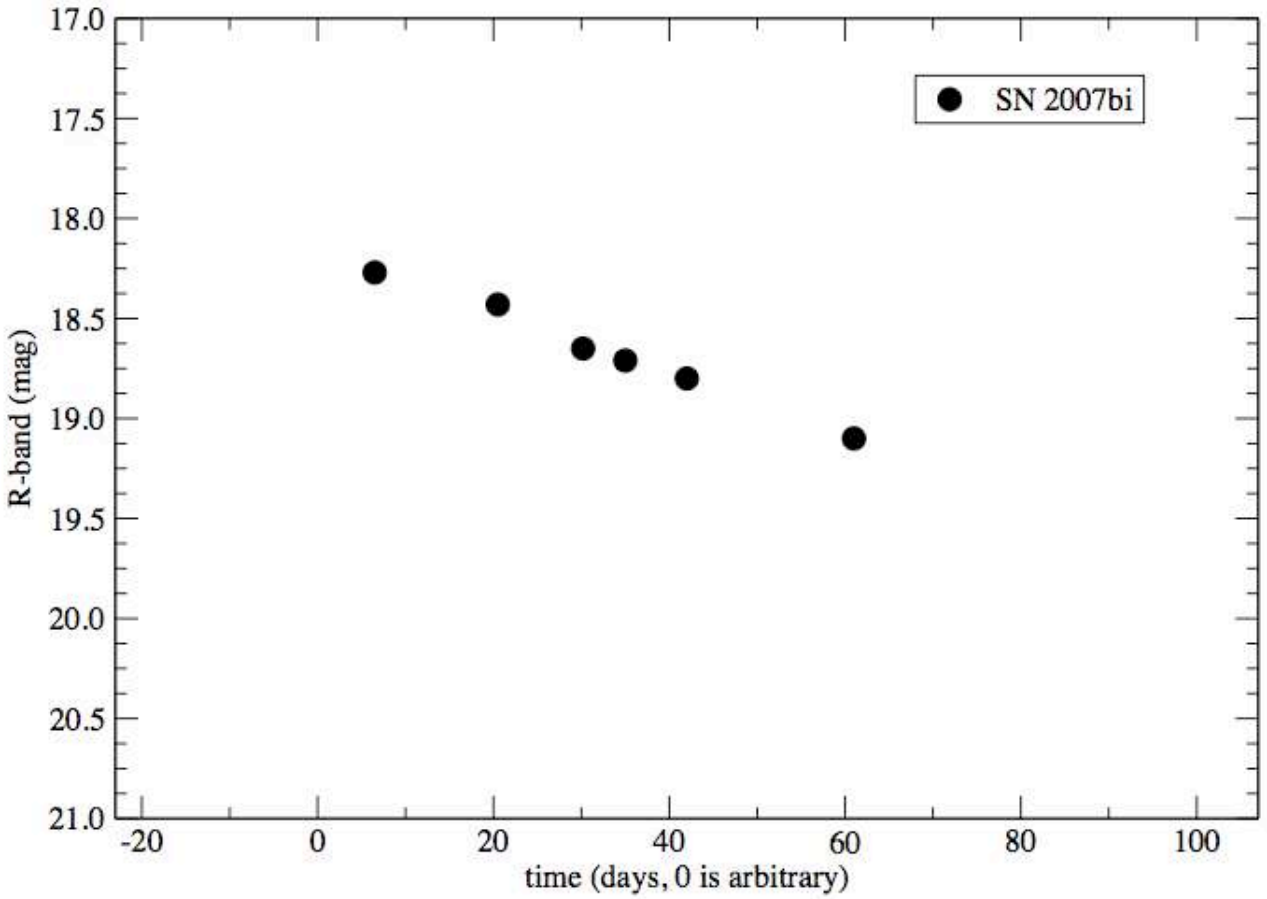


SNe 2007bi & 1999as



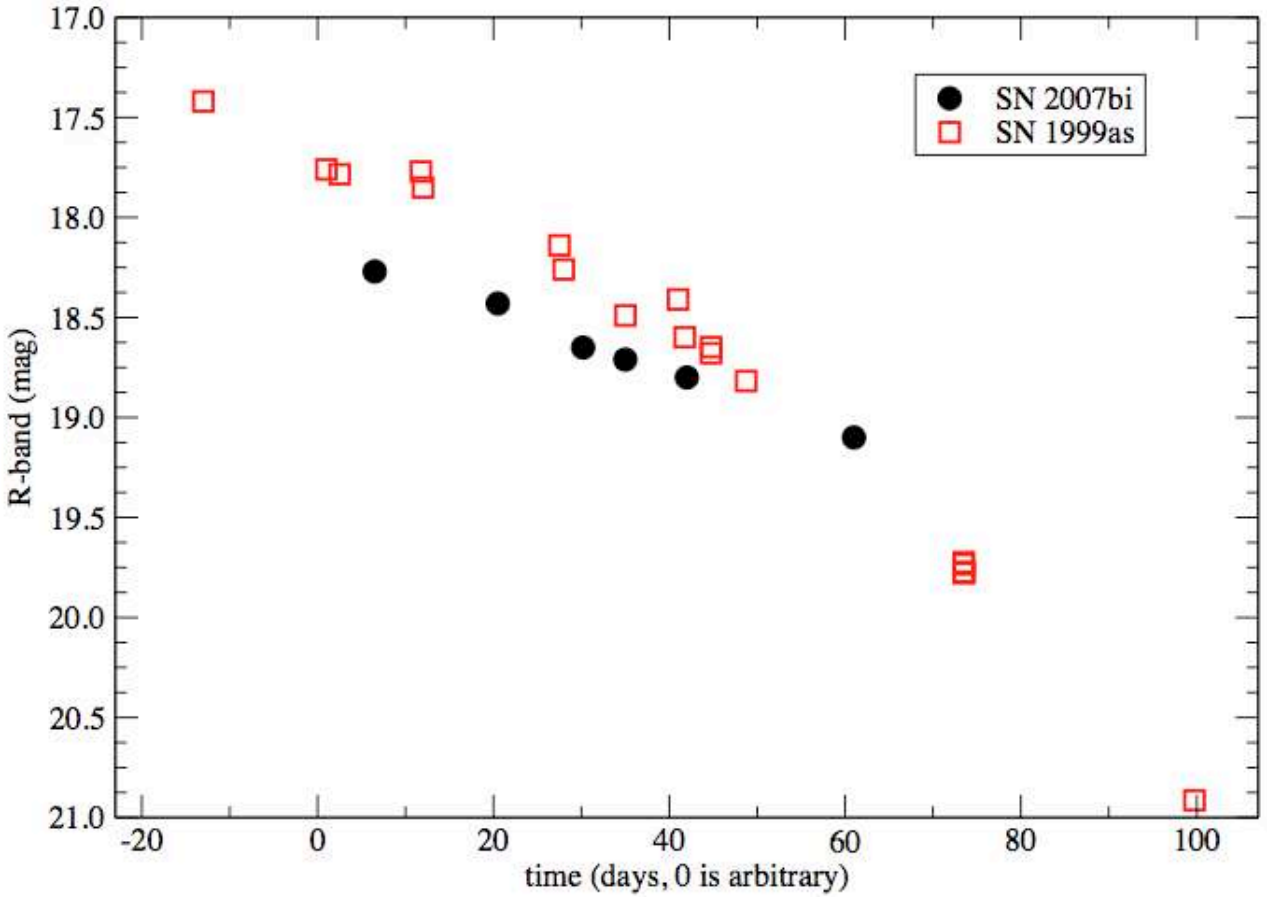
SN 2007bi

The lightcurve decayed by only 0.8 mag. over the first 2 months.



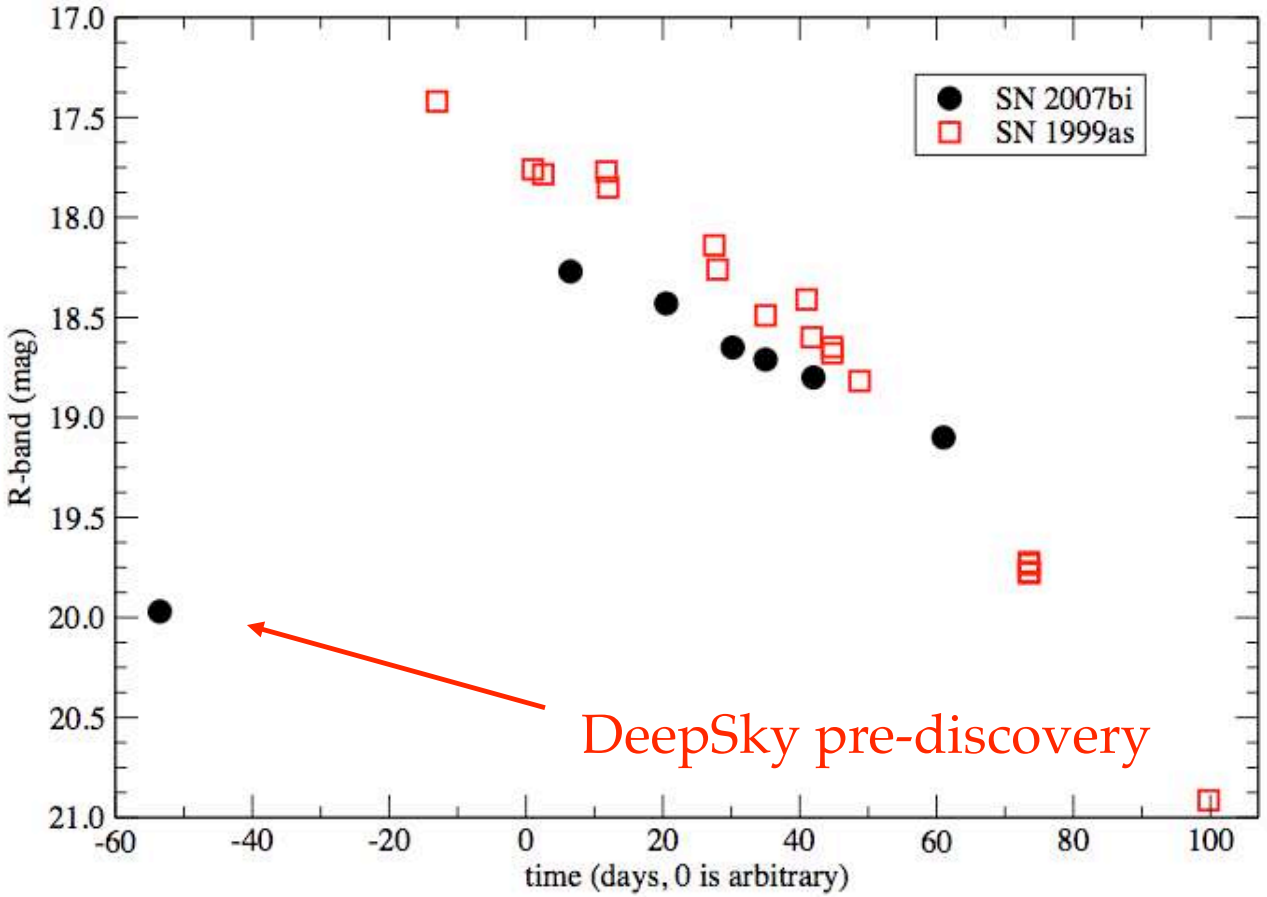
SN 2007bi

Comparable to, but not completely the same as SN 1999as



SN 2007bi

Comparable to, but not completely the same as SN 1999as



Pair Production

Why Consider Pair Production SN?

- Large amount of Ni^{56} - too much for "standard" CC mechanism
- Large total Mass
- Large KE
- Low metallicity environment

What else could it be?

- CSM interaction - but would have to be something new…
- Something else entirely

Conclusions

What you find is what you get.

IMHO we have missed many of these over the years.

Why did we find these at the start of a search? Desperation.

How many have we missed?

Anything that just missed detection in previous epochs that doesn't look like a Ia on the rise would be dropped.