The Nearby Supernova Factory

Michael Wood-Vasey, UC Berkeley/LBNL

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The Nearby Supernova Factory Collaboration

- Lawrence Berkeley National Lab
  - G. Aldering, B. C. Lee, S. Loken, P. Nugent, S. Perlmutter, J. Siegrist, R. C. Thomas, L. Wang, W. M. Wood-Vasey
- Laboratoire de Physique Nucleaire et de Haute Energies de Paris
  - P. Antilogus, P. Astier, E. Barrelet, G. Garavini, L-A. Guevara, S. Gilles, D. Hardin, D. Imbault, C. Juramay, R. Pain, K. Schmaneche, R. Taillet, D. Vincent
- Centre de Recherche Astronomique de Lyon
  - G. Adam, R. Bacon, C. Bonnaud, L. Capoani, D. Dubet, F. Hénault, B. Lantz, J-P. Lemmonier, A. Pécontal, E. Pécontal
- Institut de Physique Nucleaire de Lyon
  - N. Blanc, G. Boudoul, S. Bongard, A. Castera, Y. Copin, E. Gangler, G. Smadja
- CfCP, University of Chicago
  - R. Kessler

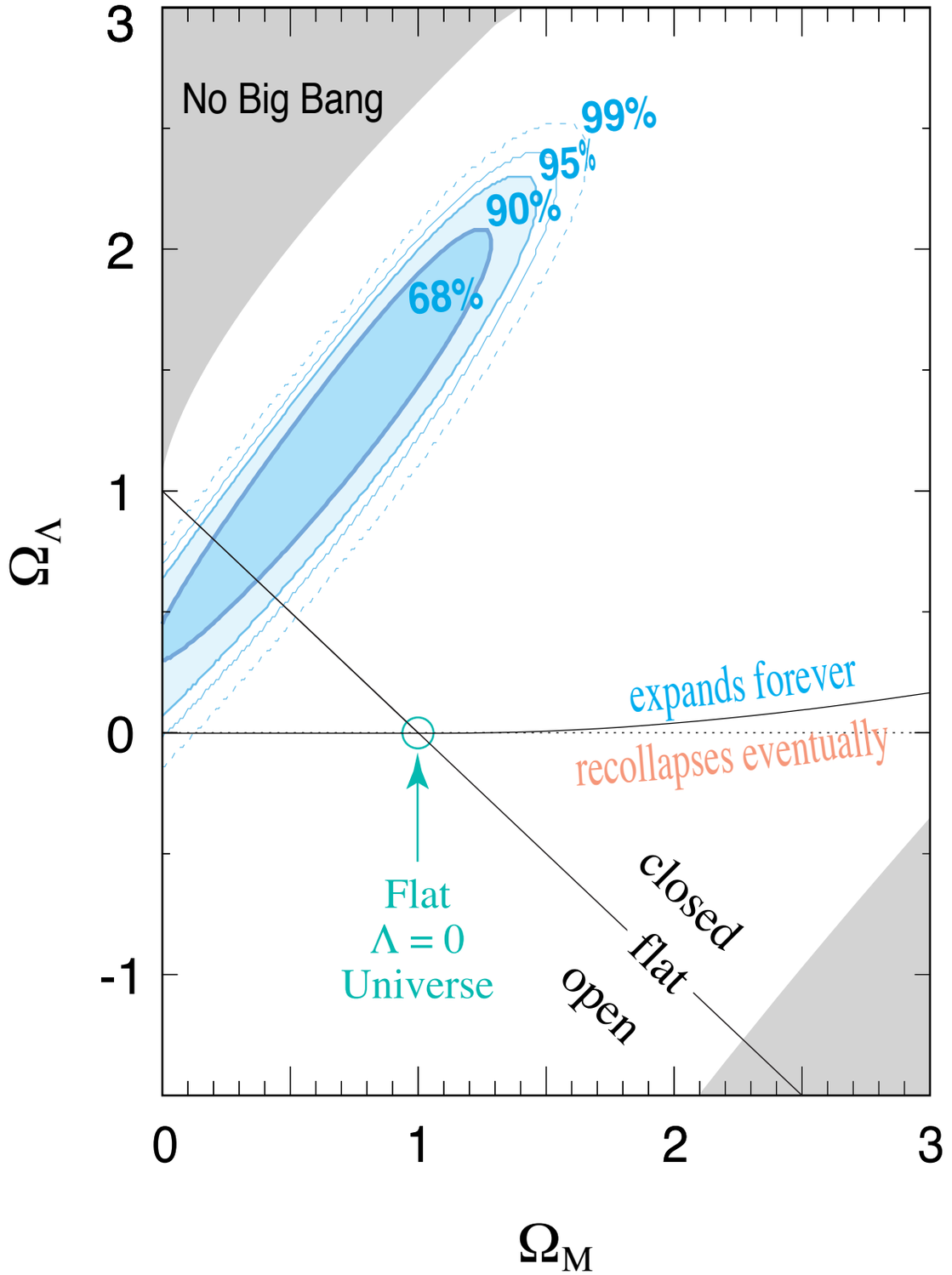
The Nearby Supernova Factory Science Goals

- Anchor low-z portion of Hubble diagram
- Definitive SNe Ia template lightcurves
- Refine K-corrections
- New parameters to standardize SNe Ia
- Supernova rates
- Test for host-galaxy extinction effects
- Local velocity map
- New understanding of SNe Ia

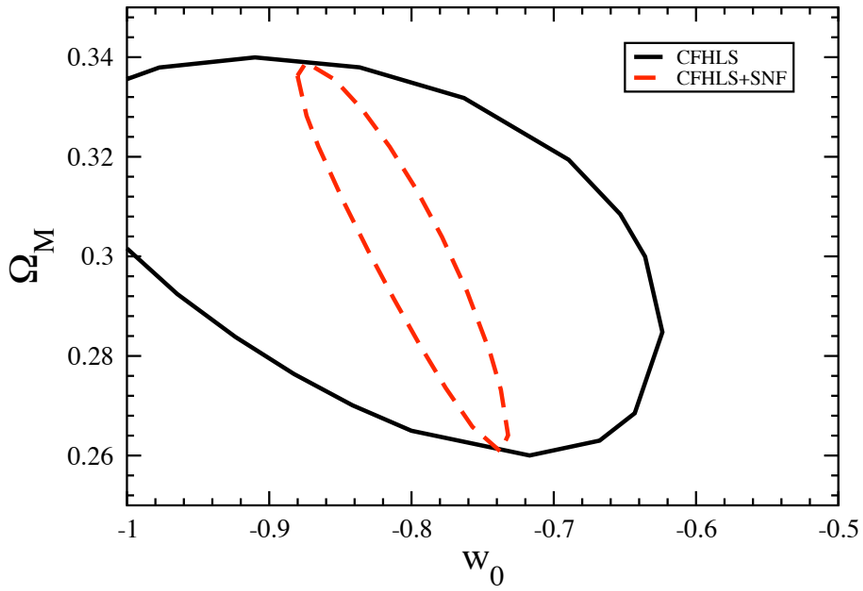
The Nearby Supernova Factory Baseline Program

- Discover and study 300 Type Ia supernovae over 3 years
- Discovery via blind, wide-field CCD search
- Concentrate on nearby smooth Hubble-flow
- Early discovery, 10 to 15 days before maximum
- Flux-calibrated optical spectroscopy every 3-7 days
- Follow-up from -15 to +50 days; more for nearer SNe
- Lightcurve follow-up for 0.03<z for peculiar velocities
- UV spectroscopy for small subset using HST
- Near-infrared lightcurves and/or spectra for small subset

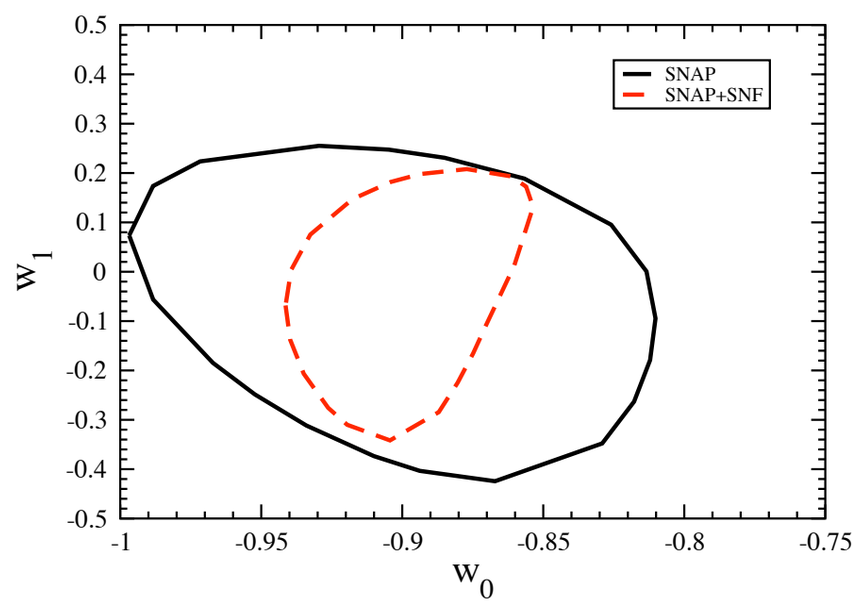
Improve Measurements of Cosmological Parameters



Perlmutter *et al.* 1999

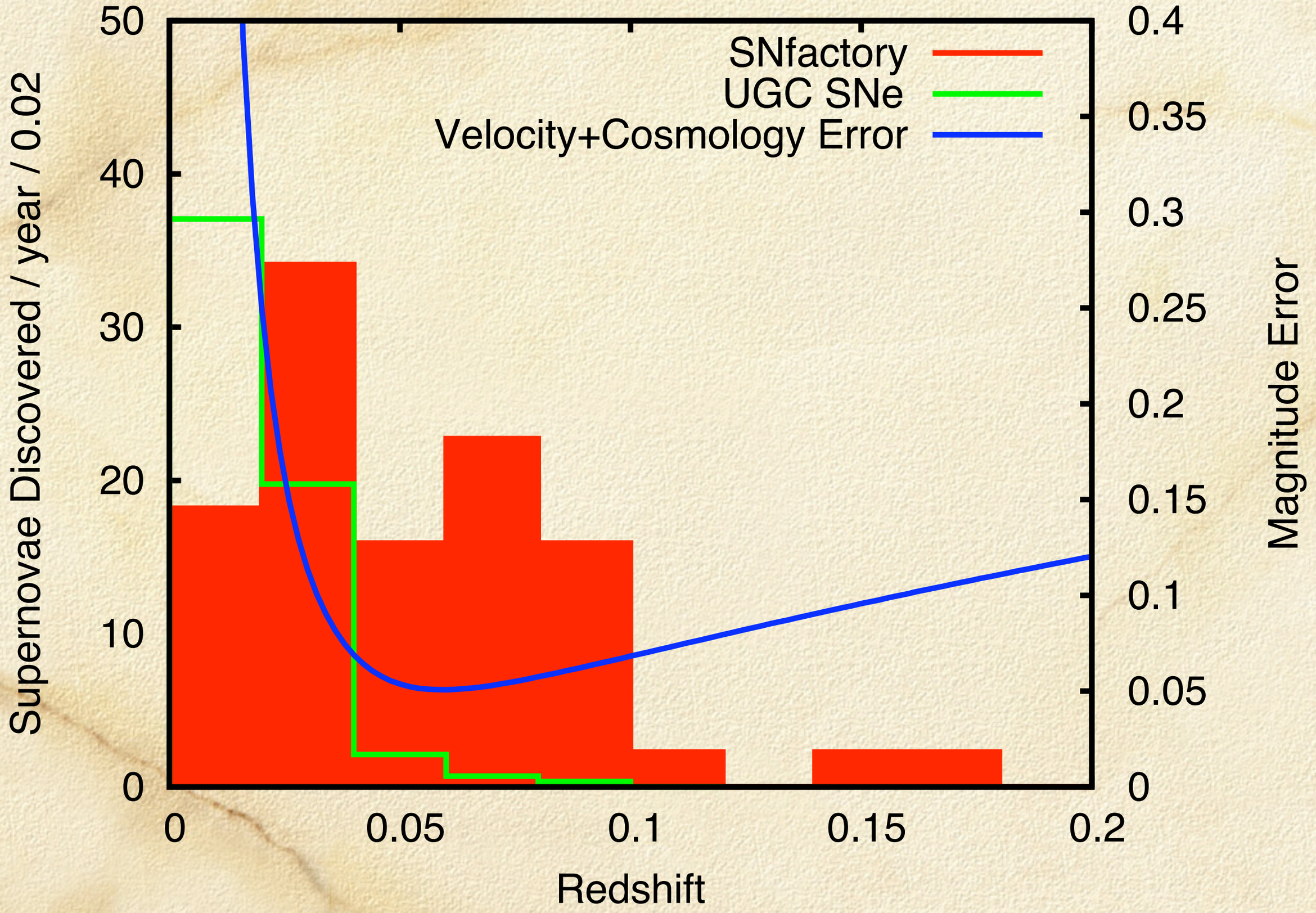


Low-z SNe Ia greatly improve SNAP & SNLS results

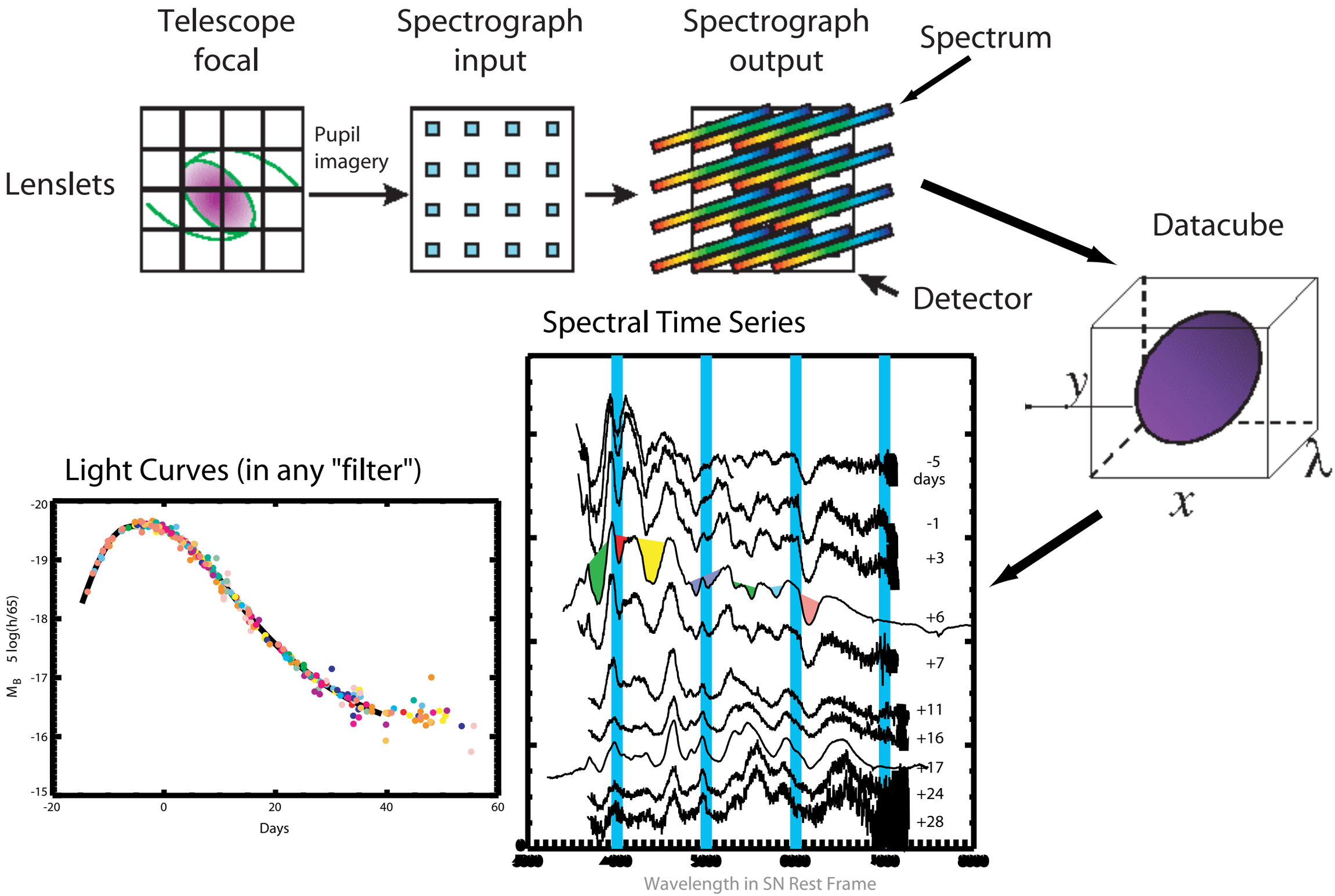


SNAP/SNLS figures courtesy Eric Linder

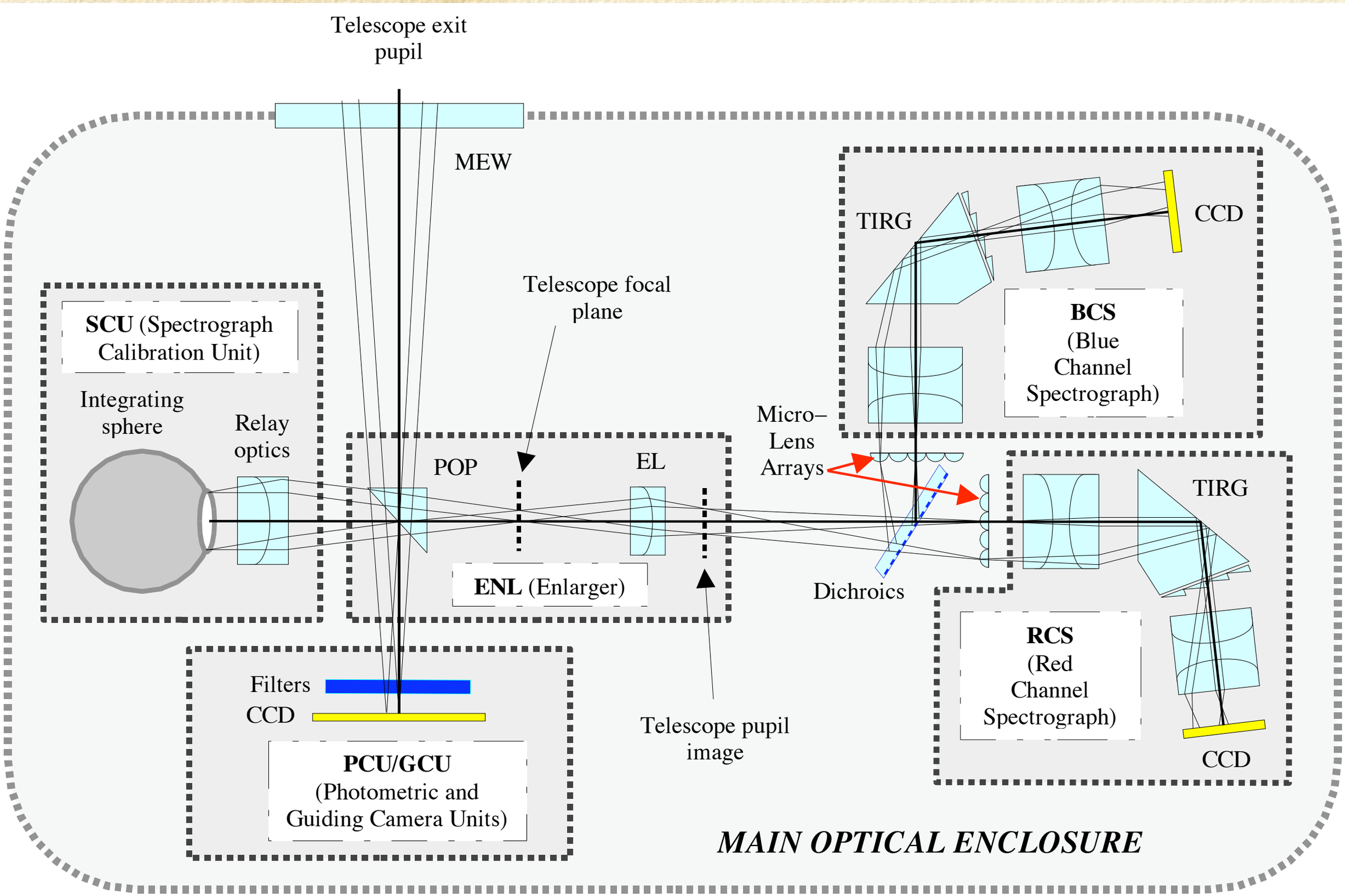
Choice of Redshift Range



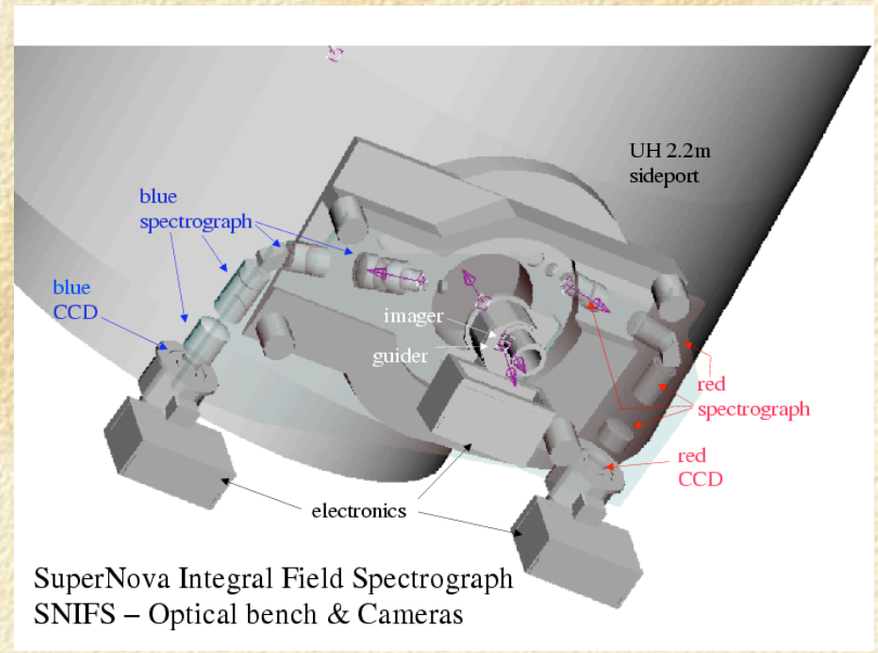
IFU Essential for Spectrophotometry

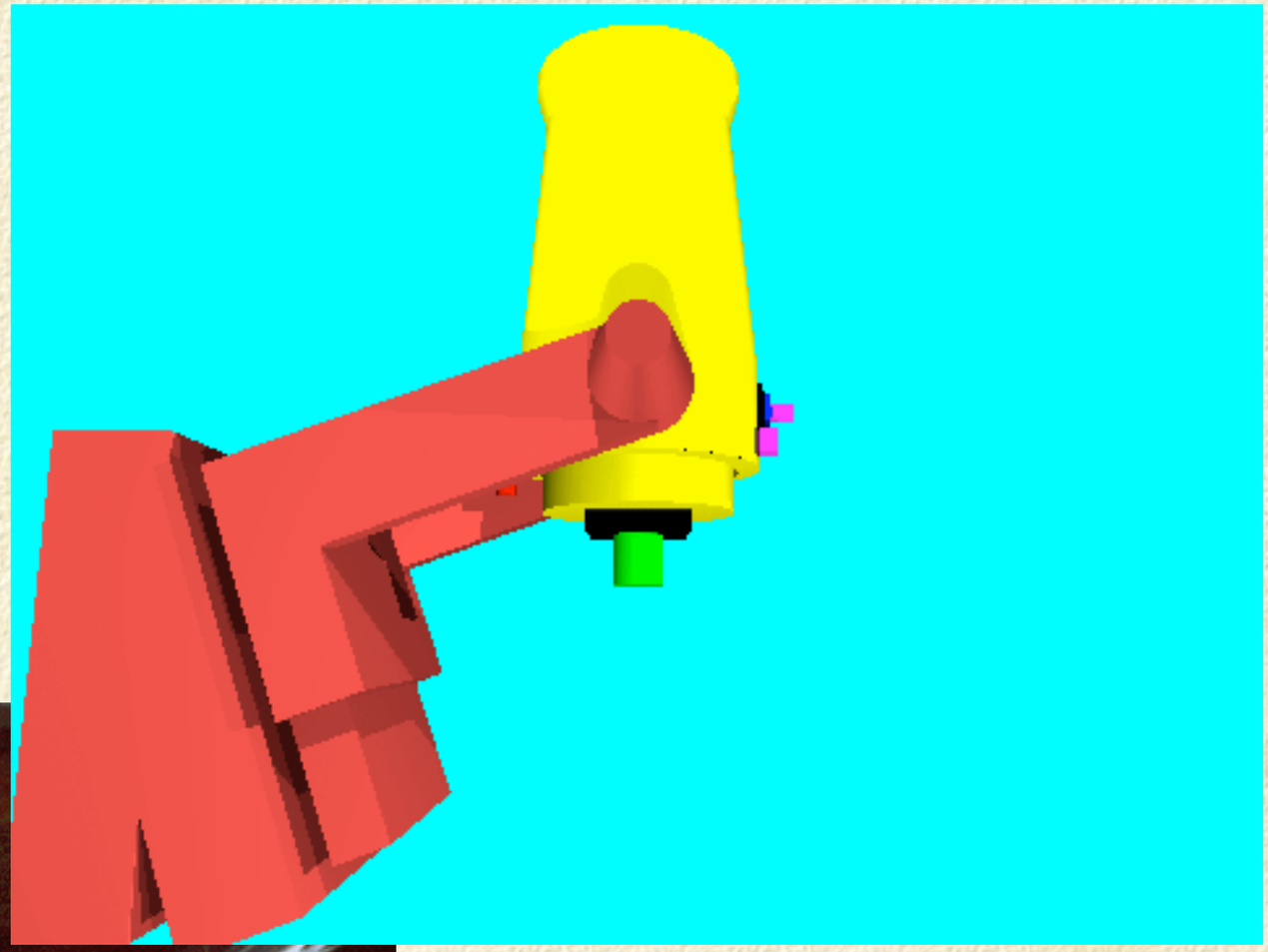


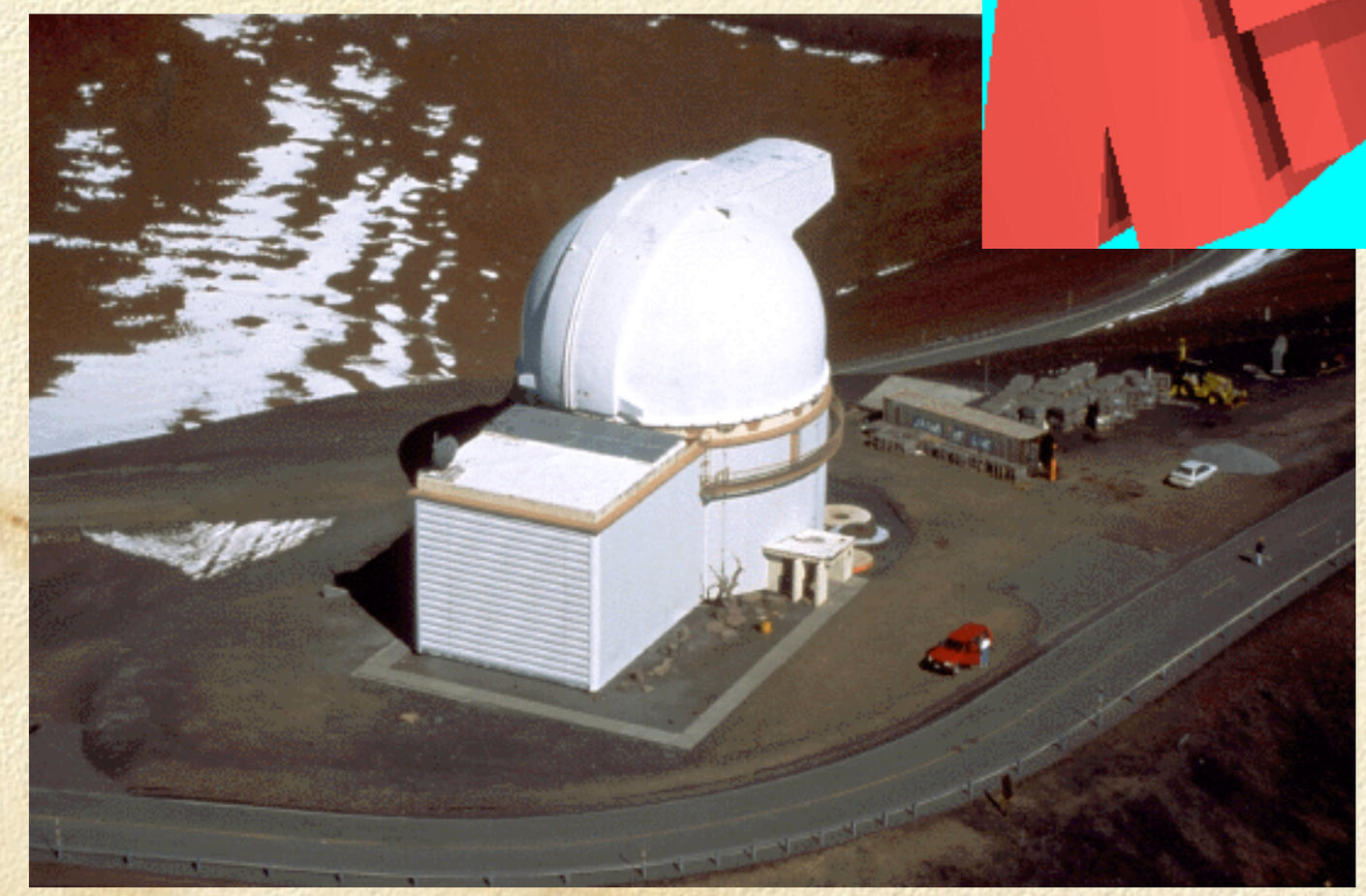
SNIFS Optical Layout



SNIFS will be side-mounted on UH 2.2-m







SuperNova Integral Field Spectrograph Specifications

Channel	Blue	Red
Collimator	70 mm focal length	70 mm focal length
Camera	140 mm focal length	140 mm focal length
Output f/#	f/7	f/7
Coverage	3200-5400 Å	5200-10,000 Å
Dispersion	2.4 Å/pixel	3.0 Å/pixel
Grism	300 l/mm @ λ_B= 3800 Å	200 l/mm @ λ_B= 7250 Å
Detector	Marconi 2k × 2k	E2V-DD 2k × 4k
Calibration	He/Hg/Cd + flat	Ne/Ar/Xe + flat

SuperNova Integral Field Spectrograph Specifications

Integral Field Unit

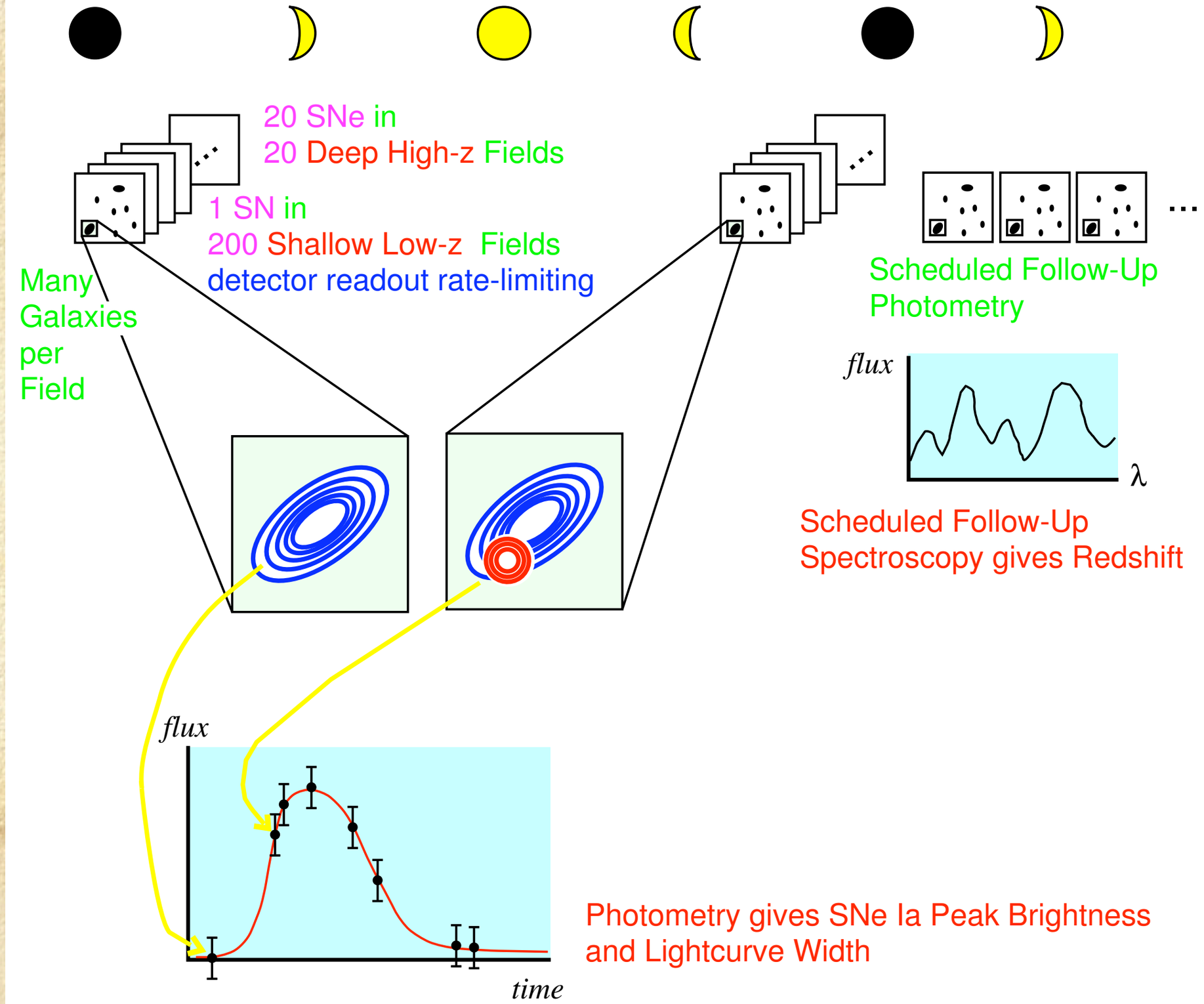
Lens specifications	1 mm diam, f/3.5, fused silica
Size	15×15 1 mm diameter lenslets
Angular Scale	0.4″/lens
Field of View	6″ × 6″

Auxiliary Camera & Guider Camera

Scale	0.14″/pixel
Field of View	two 4.7′ × 9.4′ regions
Detectors	E2V 2k × 4k
Filters	BVugriz + extinction monitor

But first you've got to find them . . .

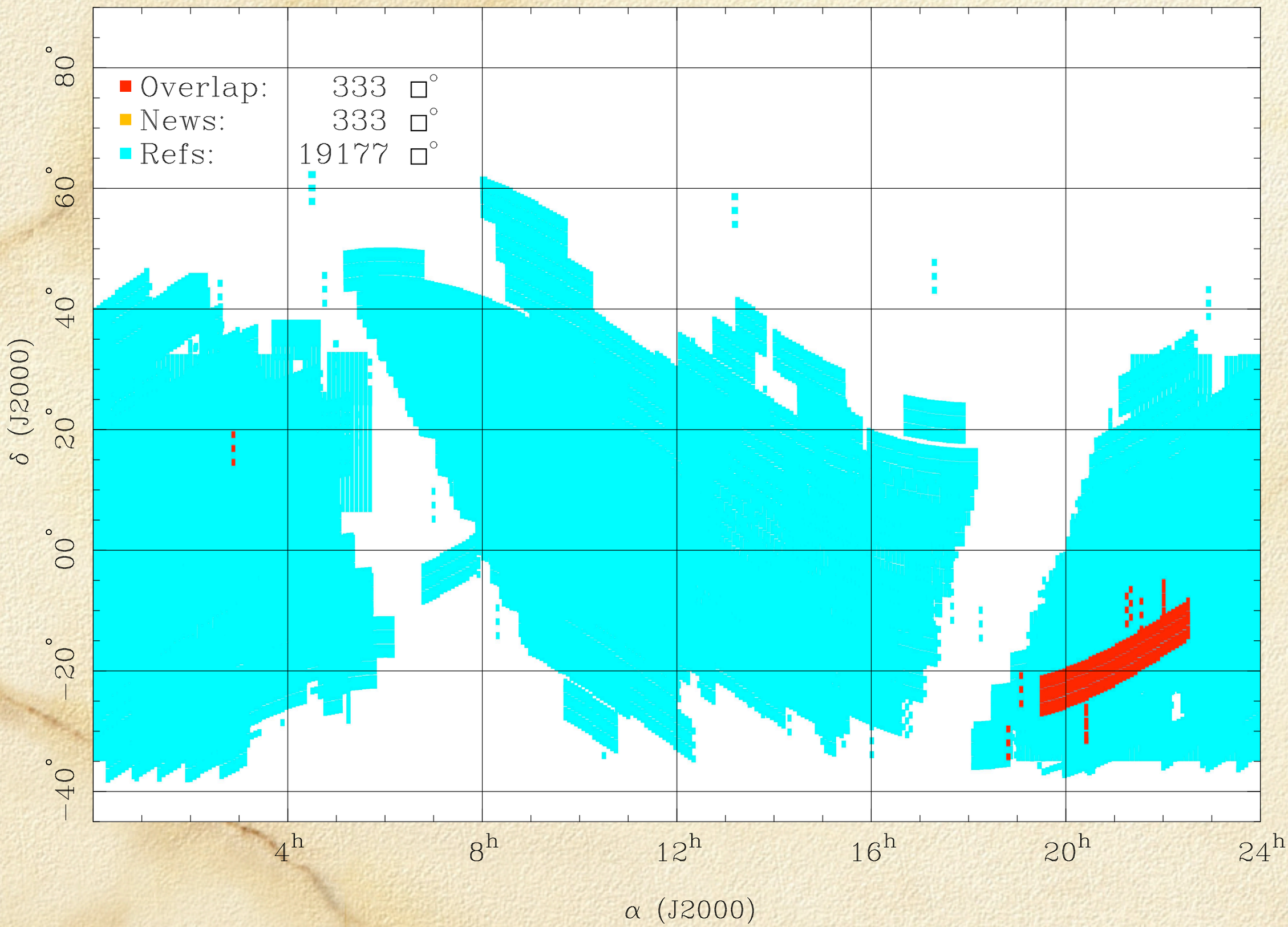
What's so hard about finding low-z SNe?



Search Facilities

	NEAT Haleakala	Palomar 3-CCD	Palomar 112-CCD	
Aperture	1.2-m	1.2-m	1.2-m	
Imager Format	4k × 4k	3 × 4k × 4k	112 × 2.4k × 0.6k	
Imager Scale	1.33″/pixel	1.0″/pixel	0.87″/pixel	
Field of View	1.5° × 1.5°	1.1° × 3.4°	2.3° × 4.1°	
Filters	open	open	RG 610	UBRI
Exposures	3 × 20 sec	3 × 60 sec	3 × 60 sec	140 sec
Readout	20 sec	20 sec	40 sec	N/A
Nightly Coverage	300 sq. deg.	500 sq. deg.	500-800 sq. deg.	
Start	March 2000	April 2001	August 2003	
Data (compressed)	12 GB / night	40 GB / night	60 GB / night	

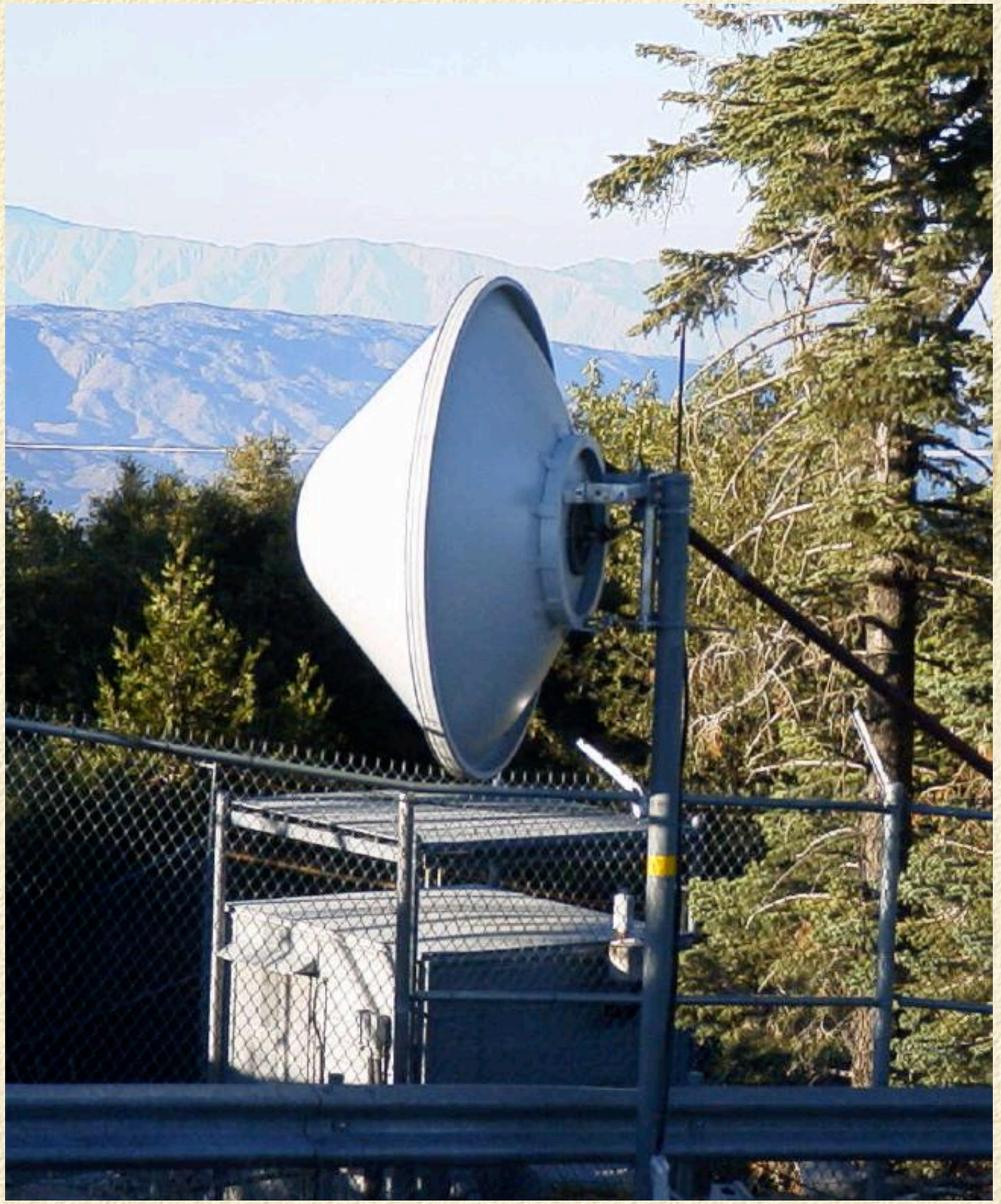
Palomar NEAT Overlap: New = 08/08/2002; Gap = 0–1000 Days



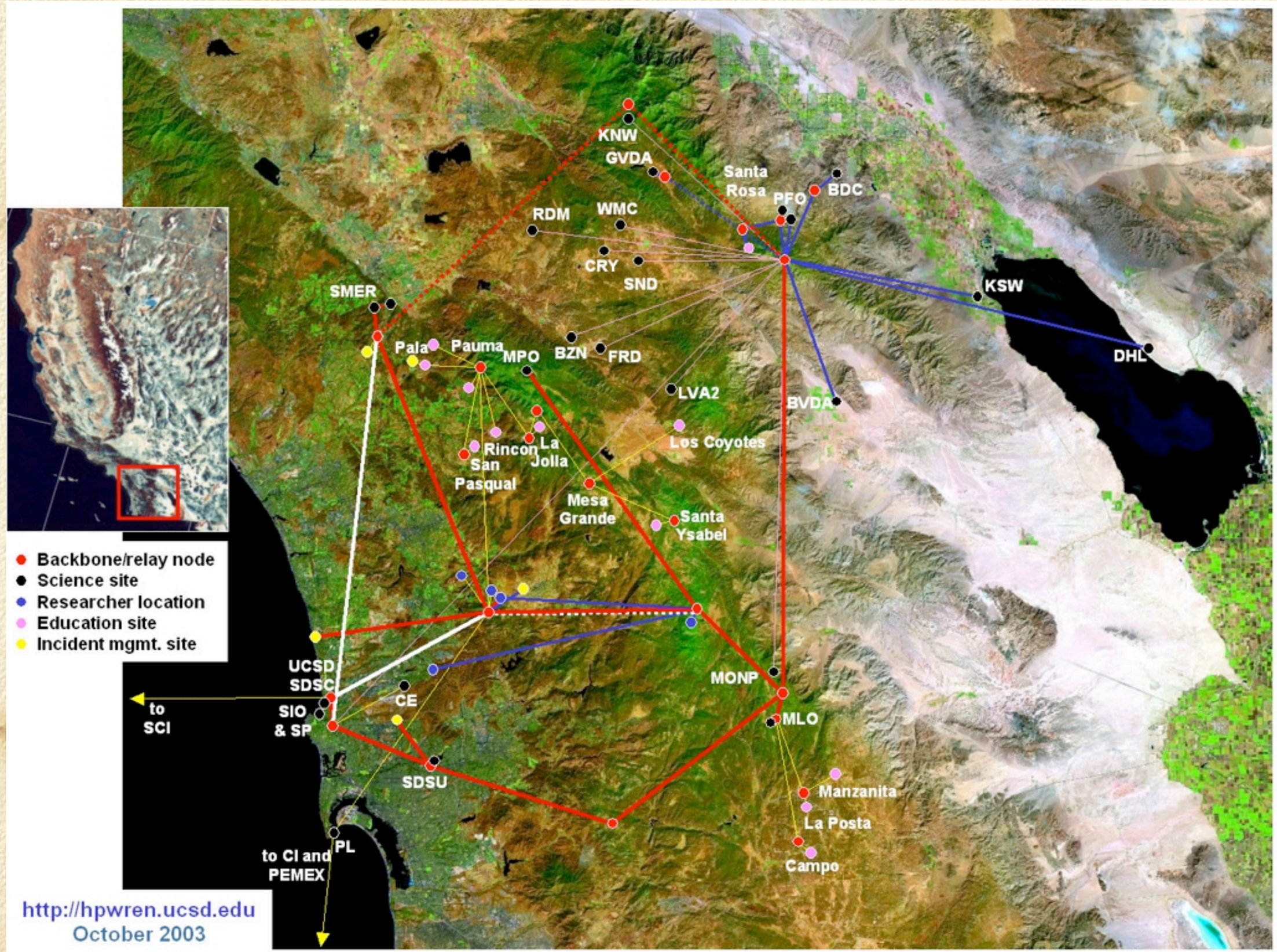
Automated Supernova Discovery

- Necessary for the SNfactory or any large-scale study of nearby supernovae
- Requires automated data processing
  - Data transfer
  - Image processing and cleaning
  - Subtraction of matching image stacks
  - Identification of objects on subtracted frame
- Hard part: supernova discrimination
  - Supernova? Asteroid? Variable Star? Artifact?

Data is sent from the Palomar 48″



along the HPWREN wireless network



and up to LBL/NERSC.

- Archived on NERSC High-Performance Storage System (HPSS)
  - Massive robotic tape vault
  - 100 petabyte capacity
  - Transfer rates of 10 Mb/s from Palomar→HPSS
- Images processed and subtracted on the NERSC Parallel Distributed Systems Facility (PDSF)
  - 400-CPU workstation cluster
  - 2 TB local storage for SNfactory processing
  - Automated job submission and queuing system processes and subtracts images with no human action

The Challenge is in the Numbers

- Each night transfer and process
  - 21,000 images (CCD frames)
  - 50-60 gigabytes
- Compare with previous observations
  - 20 terabytes of reference data
  - Database of millions of images
  - Automate
    - Image Processing
    - Candidate Identification
    - Quality Control

Automated Image Processing

- Processing continuous throughout the night
  - Download images
  - Group according to dark calibration frame and CCD
  - Clean and process images
    - Bias correct
    - Dark subtract
    - Flatfield *(this is the tricky one)*
    - Load into image database
- Final run at 8:30 am every morning
  - All processing finished by noon

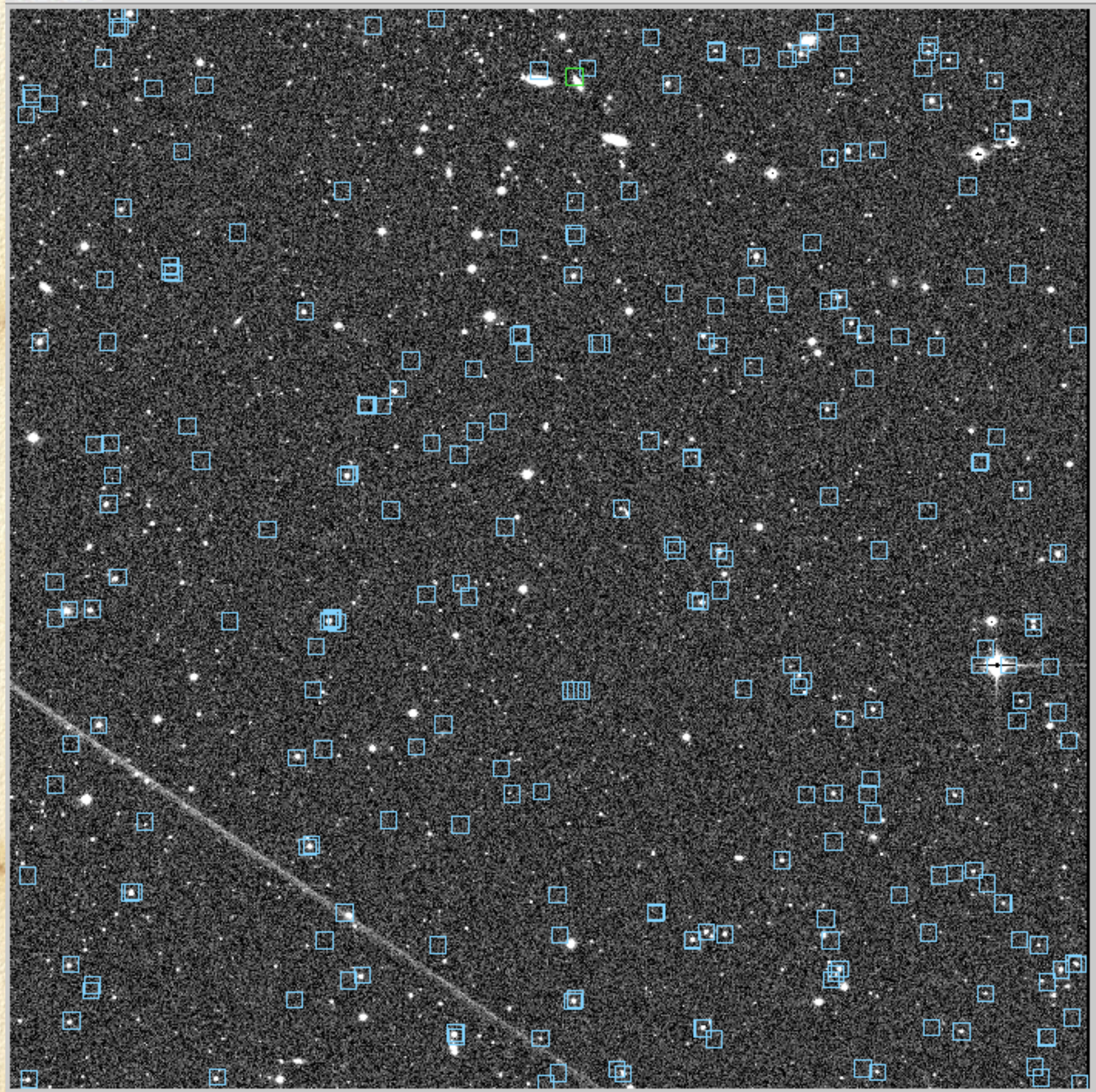
Image Database

- PostgreSQL database stores information for all of the images processed from search telescopes
- Currently holds several million images
- Used for matching search and reference images
- Examples of some of the database tables:
  - Image quality information (on all 2,935,265 images)
  - Transformations between images (4,560,472 pairs)
  - Subtractions of images (260,718)

Image subtraction to find SNe

- Query database for matching images
- Verify images quality and USNO star catalog match
- Calculate transformations between images
- Move all images to the same coordinates and sum
- Generate separate reference and search image stacks
- Calculate point spread function convolution to image stack with the worst seeing - difficult to do well
- Subtract image stacks: SUB = NEW - REF
  - After adjusting by proper flux ratio

submay122002oschinbd43225_25_9_s_6 quickscan



Exit

Box In

Box Out

Zoom Box

Full View

Pass+Unmasked

Pass+Masked

Fail+Unmasked

Fail+Masked

Redraw

Zero: -63.7350

Span: 318.675

Redraw

---

age Shown:

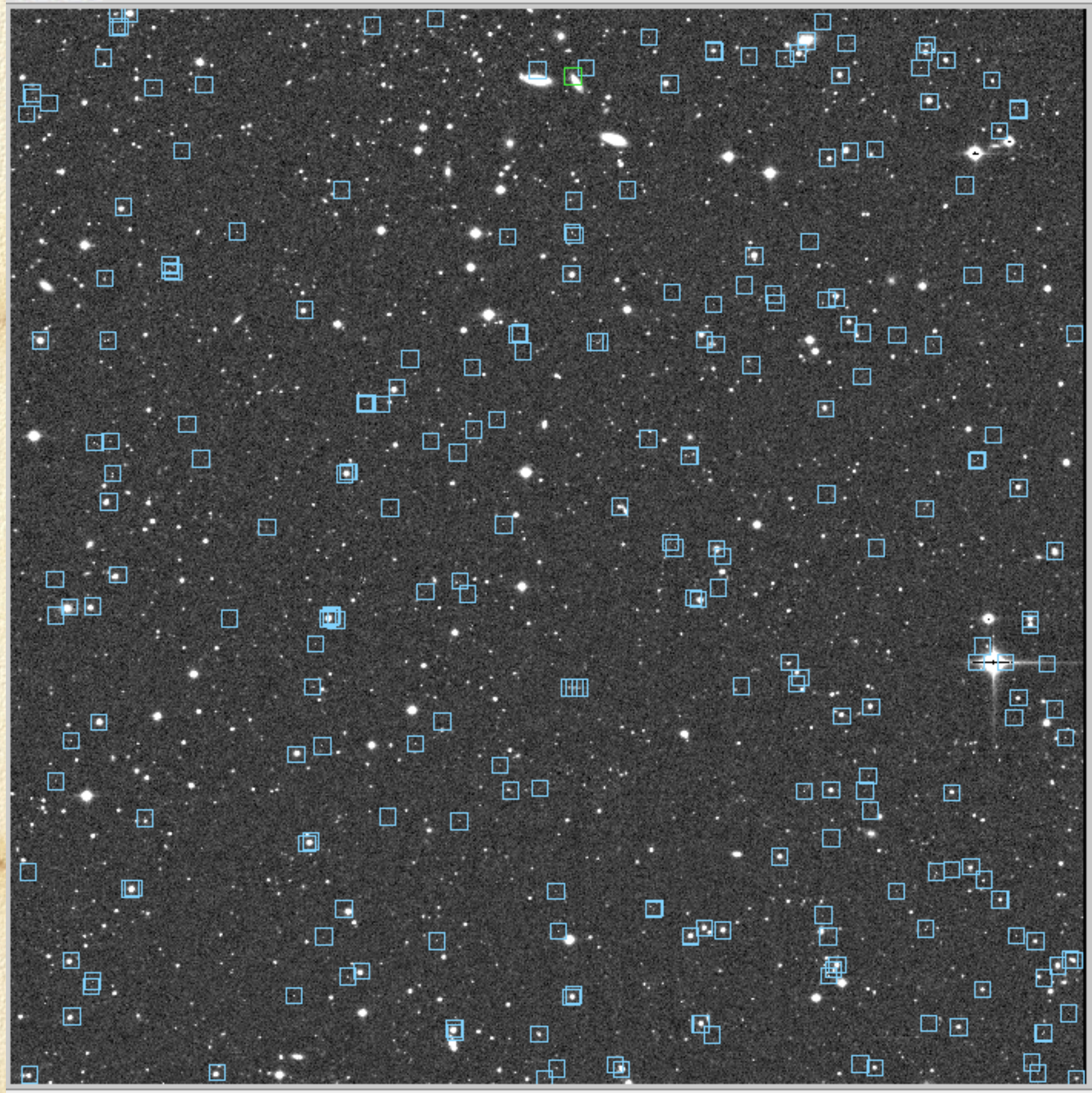
sub
ref
new
new1
new2

Candidates: 1

Subtraction Unusable

Subtraction Usable

submay122002oschinbd43225_25_9_s_6 quickscan



Exit

Box In

Box Out

Zoom Box

Full View

Pass+Unmasked

Pass+Masked

Fail+Unmasked

Fail+Masked

Redraw

Zero: -63.7350

Span: 318.675

Redraw

Image Shown:

new

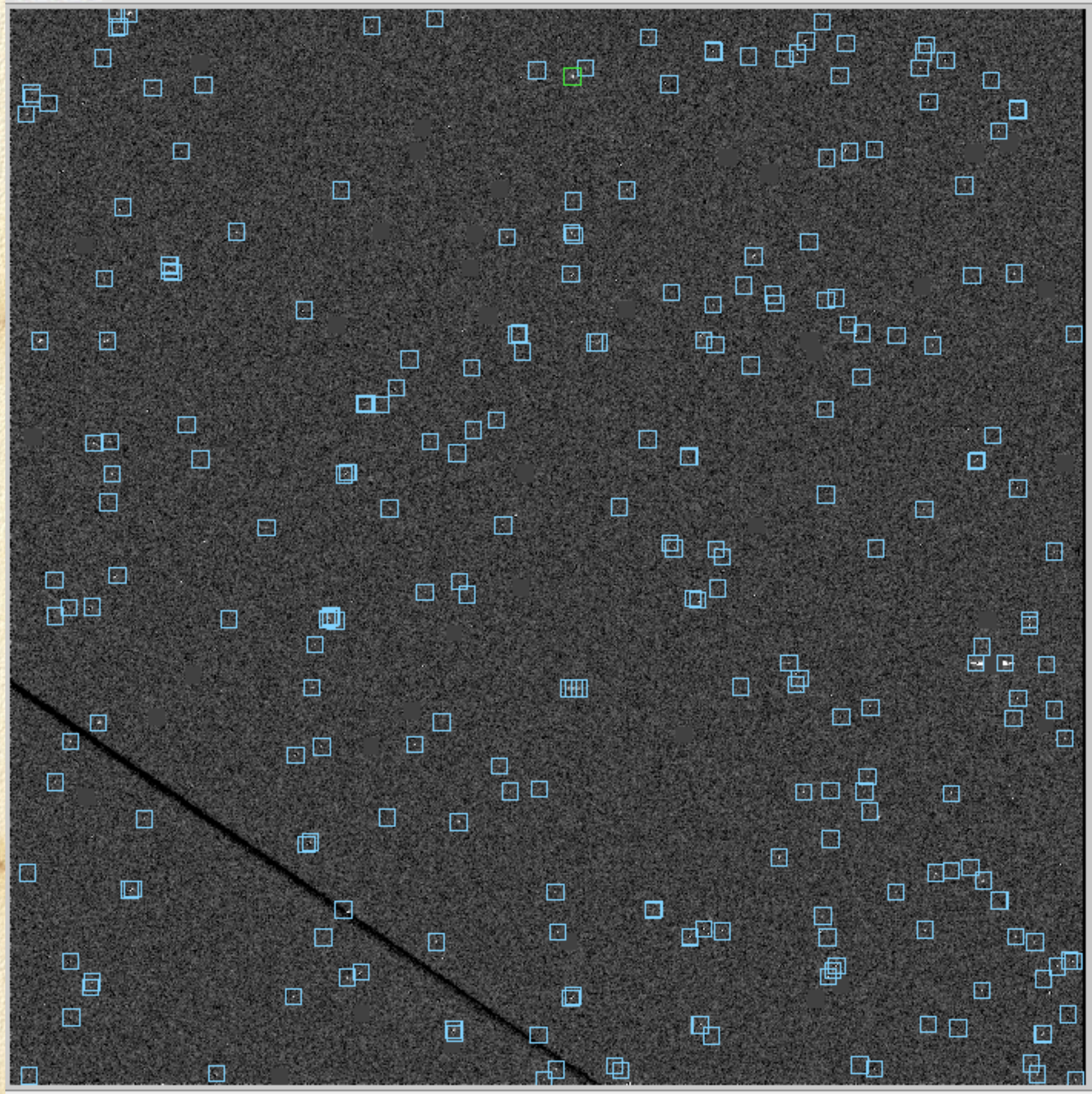
Objects: 252

Candidates: 1

Subtraction Unusable

Subtraction Usable

submay122002oschinbd43225_25_9_s_6 quickscan



Exit

Box In

Box Out

Zoom Box

Full View

Pass+Unmasked

Pass+Masked

Fail+Unmasked

Fail+Masked

Redraw

Zero: -63.7350

Span: 318.675

Redraw

Image Shown:

sub

Objects: 252

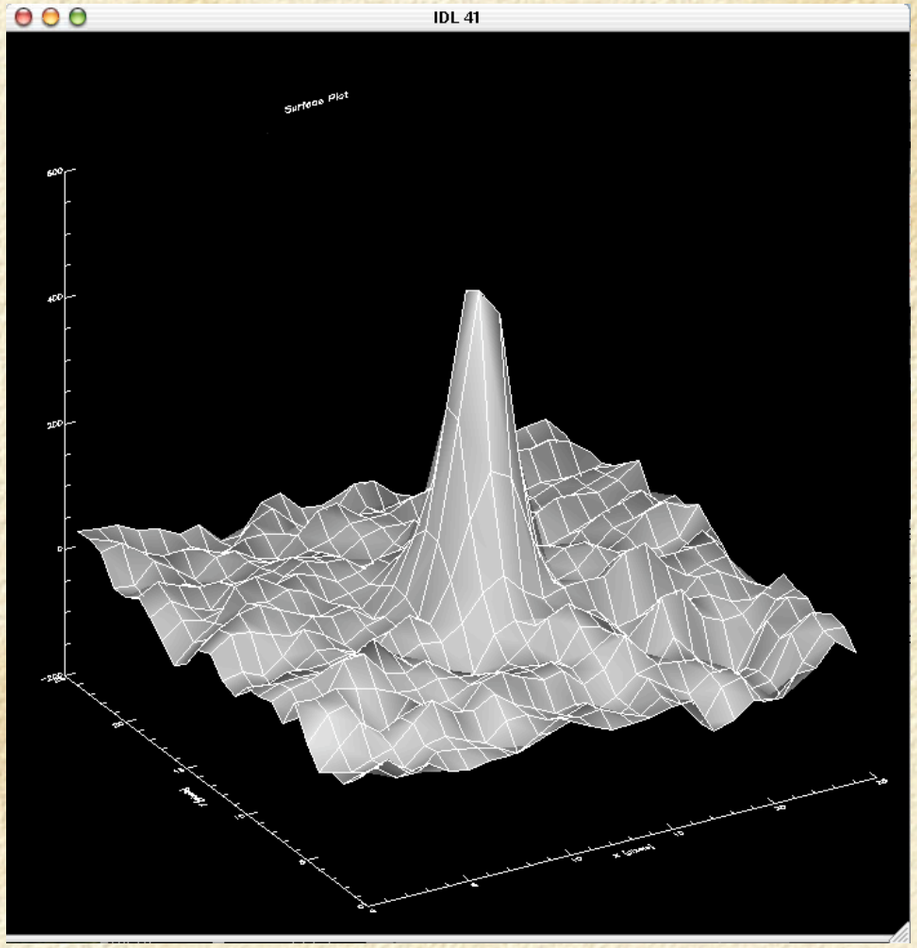
Candidates: 1

Subtraction Unusable

Subtraction Usable

SN Candidate Identification

- Scan subtracted image, SUB, for objects
- Object identification
  - star, galaxy, cosmic ray, artifact, etc.
- SN candidate must be consistent in all frames
- Quantitative score cuts select only interesting objects
- Our current automated screening leaves us with 1% of the images to scan for supernova candidates
- Takes one person < 2 hours to scan a night's data



Discovery of 2002cx

submay122002oschinbd43225_25_9_s_6 tiles

NEW1 14992. | NEW2 15645. | NEW 15264. | REF 9191.3

5800.7 | 6454.0 | 6073.2 | 9191.3

First | Prev | Next | Last | Candidates | Keep | Show Full Image | Slice Plot | Surface Plot | Exit

Redraw | apr232002oschinbd51226.fts | Show Grey | Show Contours | Crosshairs | Unconvolved

Zero: -1 Span: 4 Cont. Min: 2 Cont. Step: 2

Lightcurve | DSS | Mark as Variable Star | Mark as Asteroid

Ap.Sig	=	16.68
%Inc	=	66.08
PCyg.Sig	=	5.539
MXY	=	1.109
FWX	=	3.317
FWY	=	3.184
NeighDist	=	14.64
NeighMag	=	16.85
Mag	=	18.91
Theta	=	333.5
New1Sig	=	57.44
New2Sig	=	45.74
Sub1Sig	=	15.01
Sub2Sig	=	15.34
Sub2-Sub1	=	1.144
DSub1Sub2	=	0.1117
HoleInRef	=	18.80
BigApRatio	=	-0.1281

Candidate 1 of 1 :unscanned

Position on refsys: 1070.2 , 1892.6
RA(1950)= 13:11:18.58
Dec(1950)= +07:13:24.34
RA(2000) = 13:13:49.76
Dec(2000) = +06:57:31.98

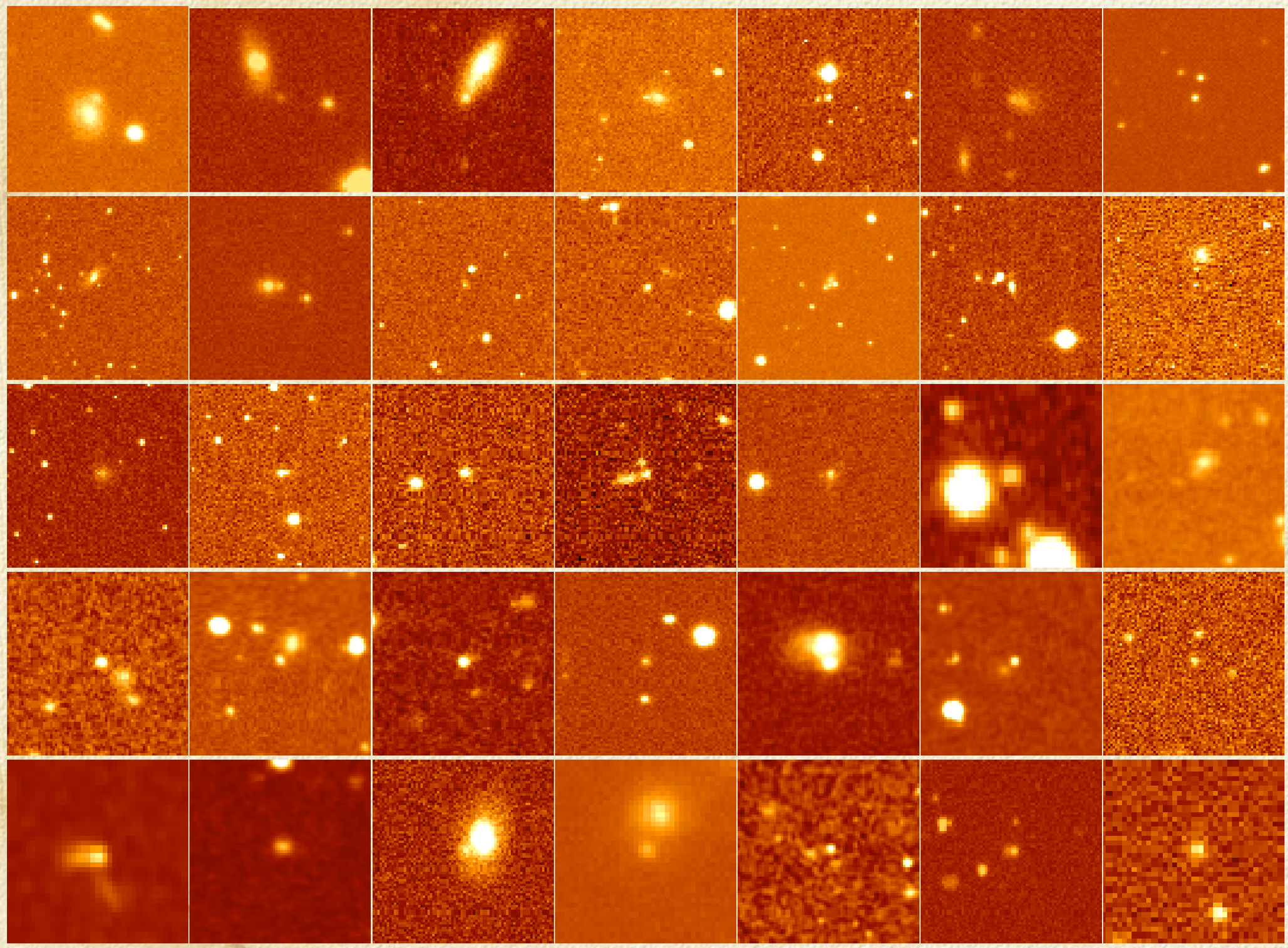
Database candidates within 15" :
S2002-070 (cand0079) : 0.0"

RA: 13:11:18.58
DEC: +07:13:24.34
X: 1070.24
Y: 1892.63

SNfactory Prototype Search

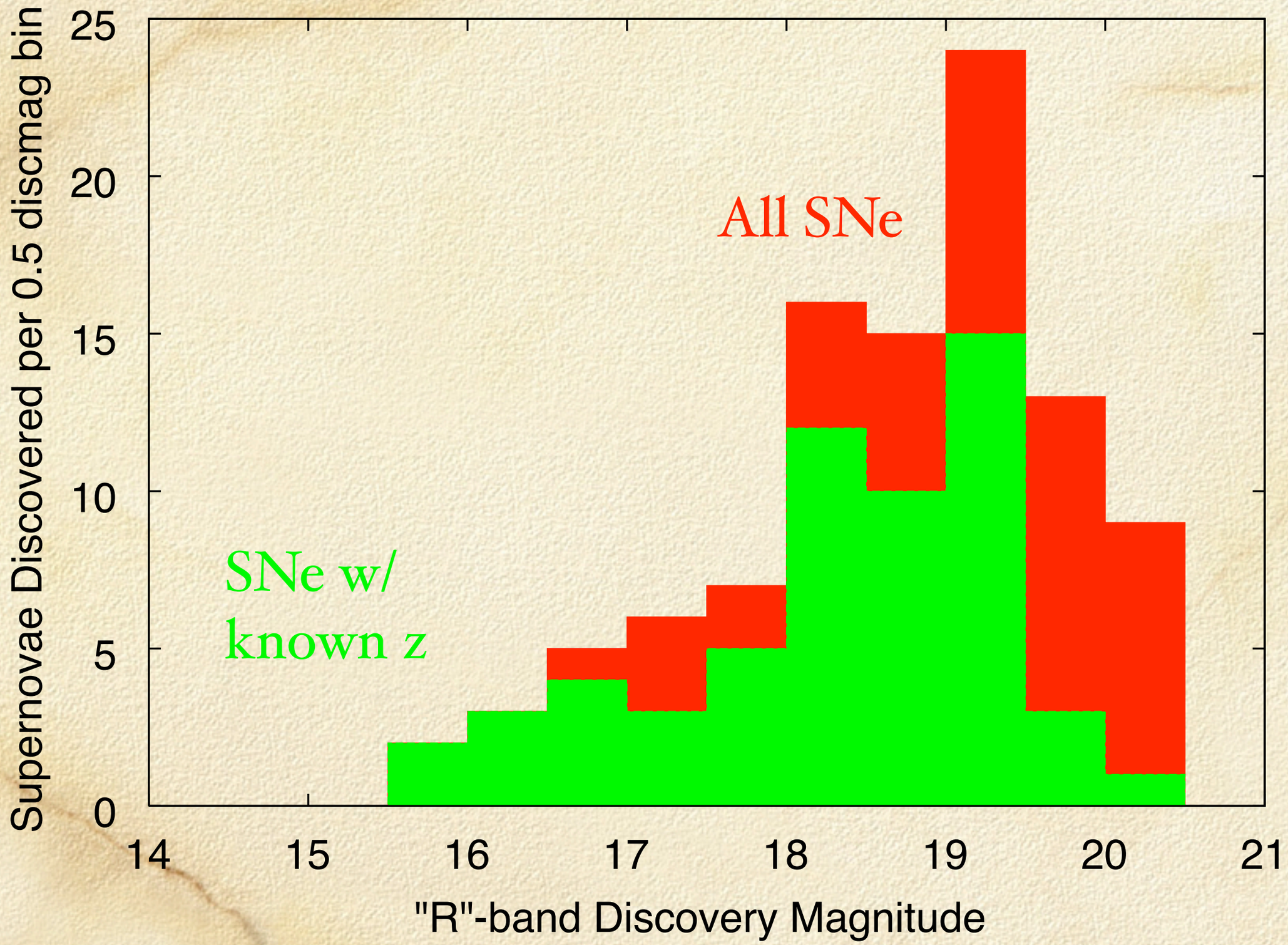
- Fall 2002 - Spring 2003, I carried out a prototype search to verify the SN discovery pipeline.
- 78 SNe SNe found in ~6 months
  - 69 SNe found first by us
  - 9 SNe reported first by other groups
- 45 SNe spectroscopically classified
  - 30 Ia, 2 Ib/c, 13 II
- Discovery rate: ~12.5 SNe/month ⇒ 150 SNe/year
  - 2/3 Ia fraction ⇒ ~100 SNe Ia / year
- Conclusion: Search pipeline verified as a success!

Successful test of Search Pipeline

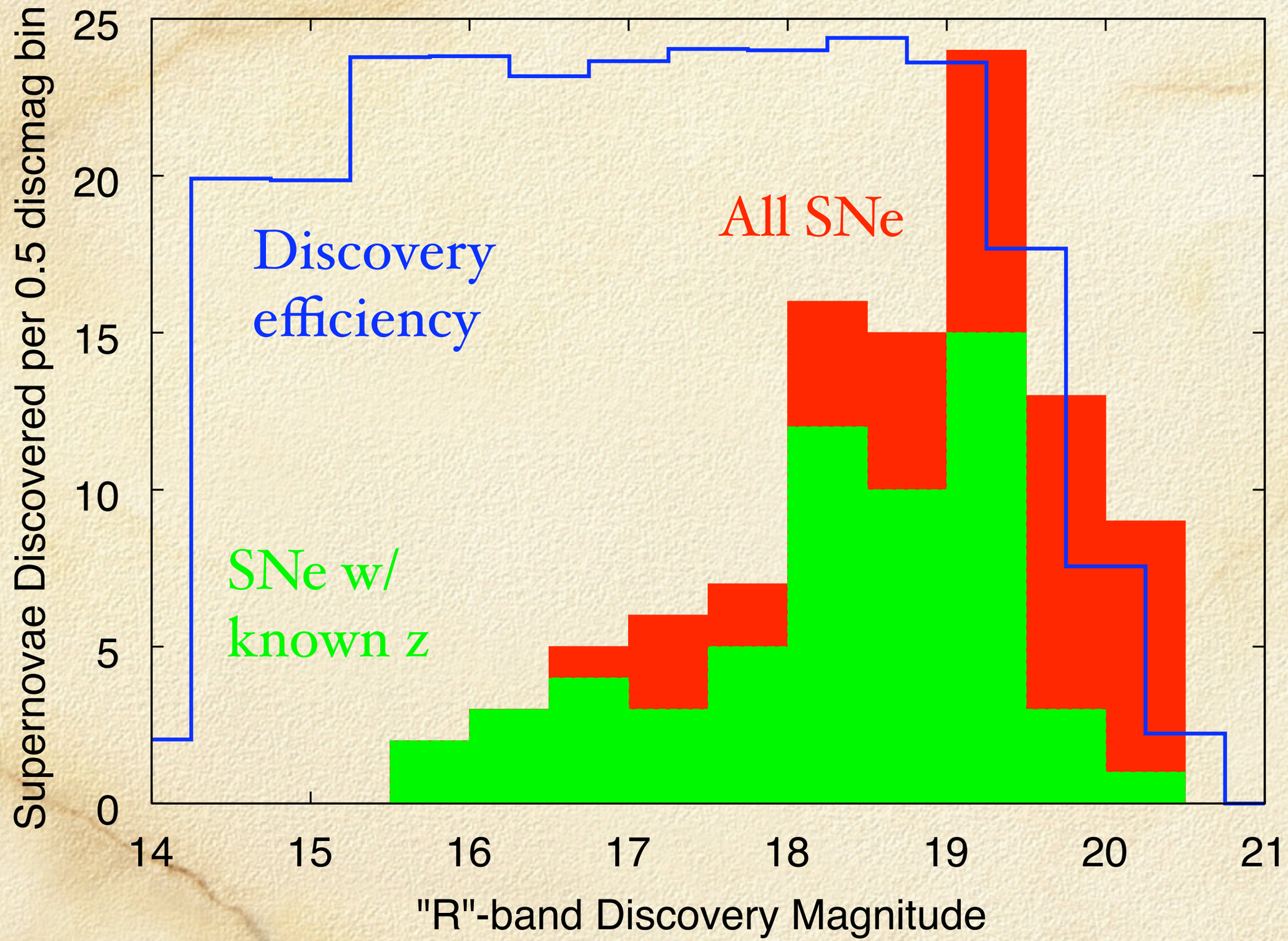


some of our 83 SNe discoveries reported in the IAUC

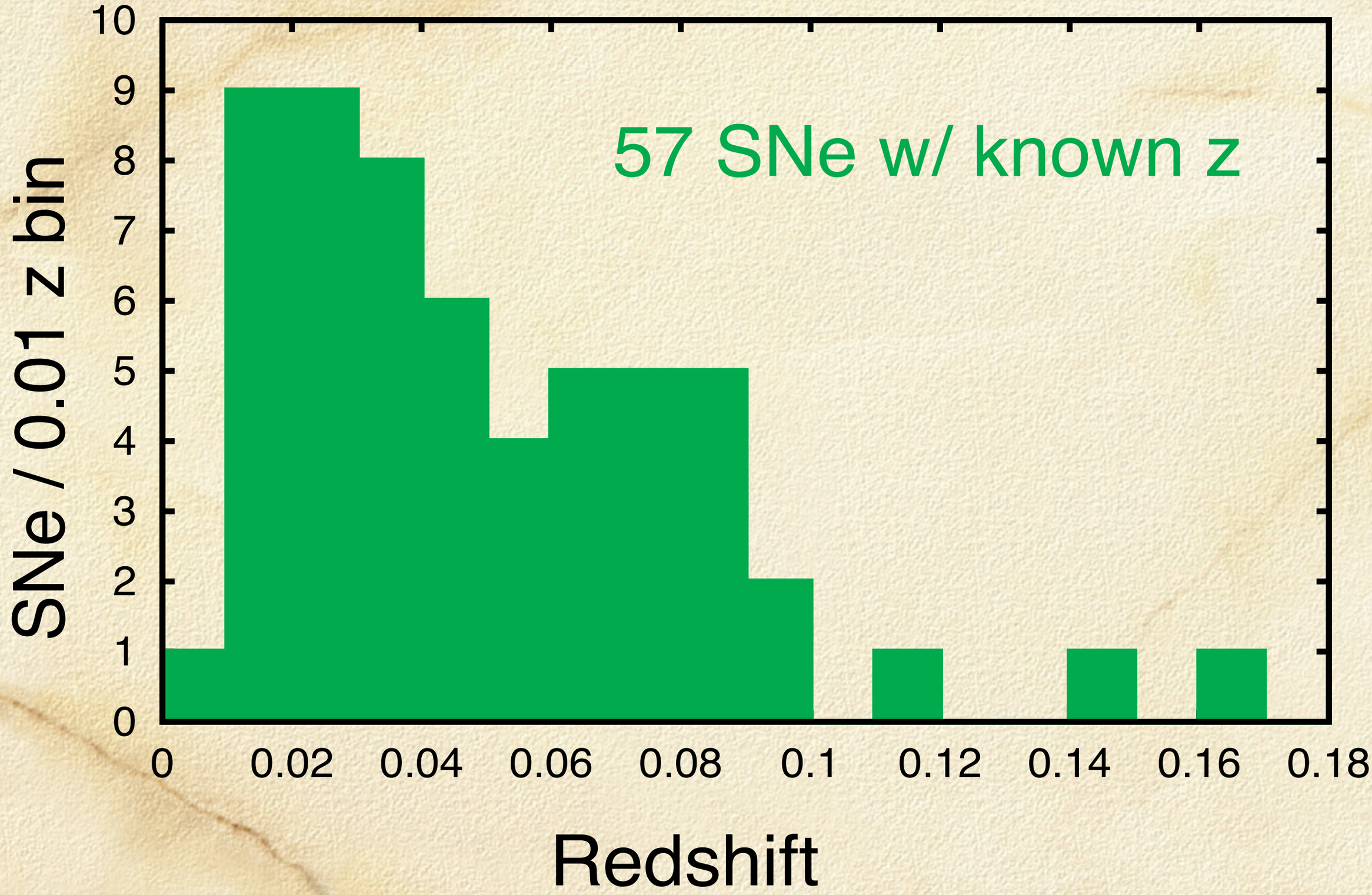
Discovery Mag of SNe in Search



Discovery Mag of SNe in Search



Redshift of SNe from prototype search



The Nearby Supernova Factory will

- be the largest nearby supernova search yet.
- be the only long-term, blind, CCD-based nearby SN search.
- implement a unique instrument optimized for automated SN studies.
- obtain the most extensive set of SN Ia spectra ever.
- Provide improved statistical constraints on cosmological parameters.
- greatly improve current SN Ia standardization methods.
- offer the possibility of new and improved methods of standardizing SNe Ia.
- provide new insights into the physics of SNe Ia.
- begin in earnest in spring 2004.