Luminosity Distances to 129 SN-Ia in the SDSSII Supernova Survey

Hubert Lampeitl, STScI

Zheng (Poster) Mon *Exhibit Hall DE*
Lampeitl (Oral) Wed 10:45am *Exhibit Hall C*
Dilday (Oral) Thurs 2:30pm *Telus 111*

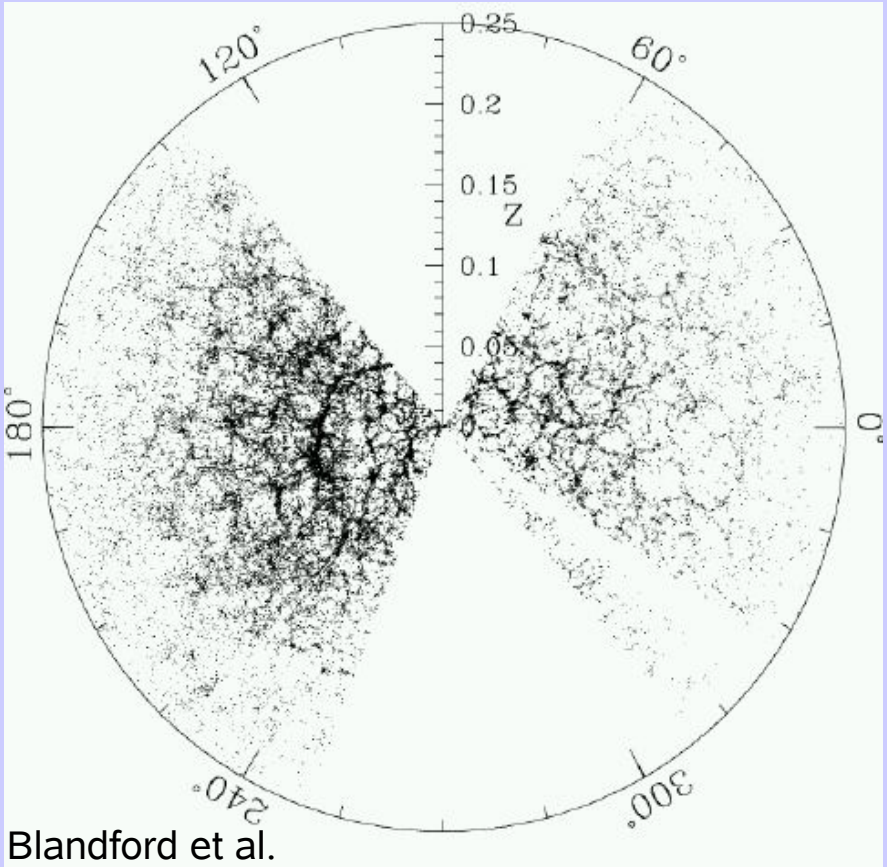
Special Session Thurs *"LSS in the SDSS"*

Calgary,June 2006

SDSS Phase-II

(Sloan Digital Sky Survey / www.sdss.org)

- Legacy Survey: complete spectroscopy
- SEGUE: galactic structure
- Supernova Survey



Blandford et al.

American Museum of Natural History
Astrophysical Institute Potsdam
University of Basel
Cambridge University
Case Western Reserve University
University of Chicago
Drexel University
Fermi National Accelerator Laboratory
Institute for Advanced Study, Princeton
Japan Participation Group
Johns Hopkins University
Joint Institute for Nuclear Astrophysics
Michigan State/Notre Dame/Chicago
Kavli Institute for Particle
Astrophysics and Cosmology
Stanford/SLAC
Korean Scientist Group
LAMOST
Los Alamos National Laboratory
Max-Planck-Institute for Astronomy Heidelberg
Max-Planck-Institute for Astrophysics Garching
New Mexico State University
Ohio State University
University of Pittsburgh
University of Portsmouth
Princeton University
US Naval Observatory
University of Washington

Funding: Sloan Foundation, NSF
and participating institutions

Apache Point Observatory
Southern New Mexico

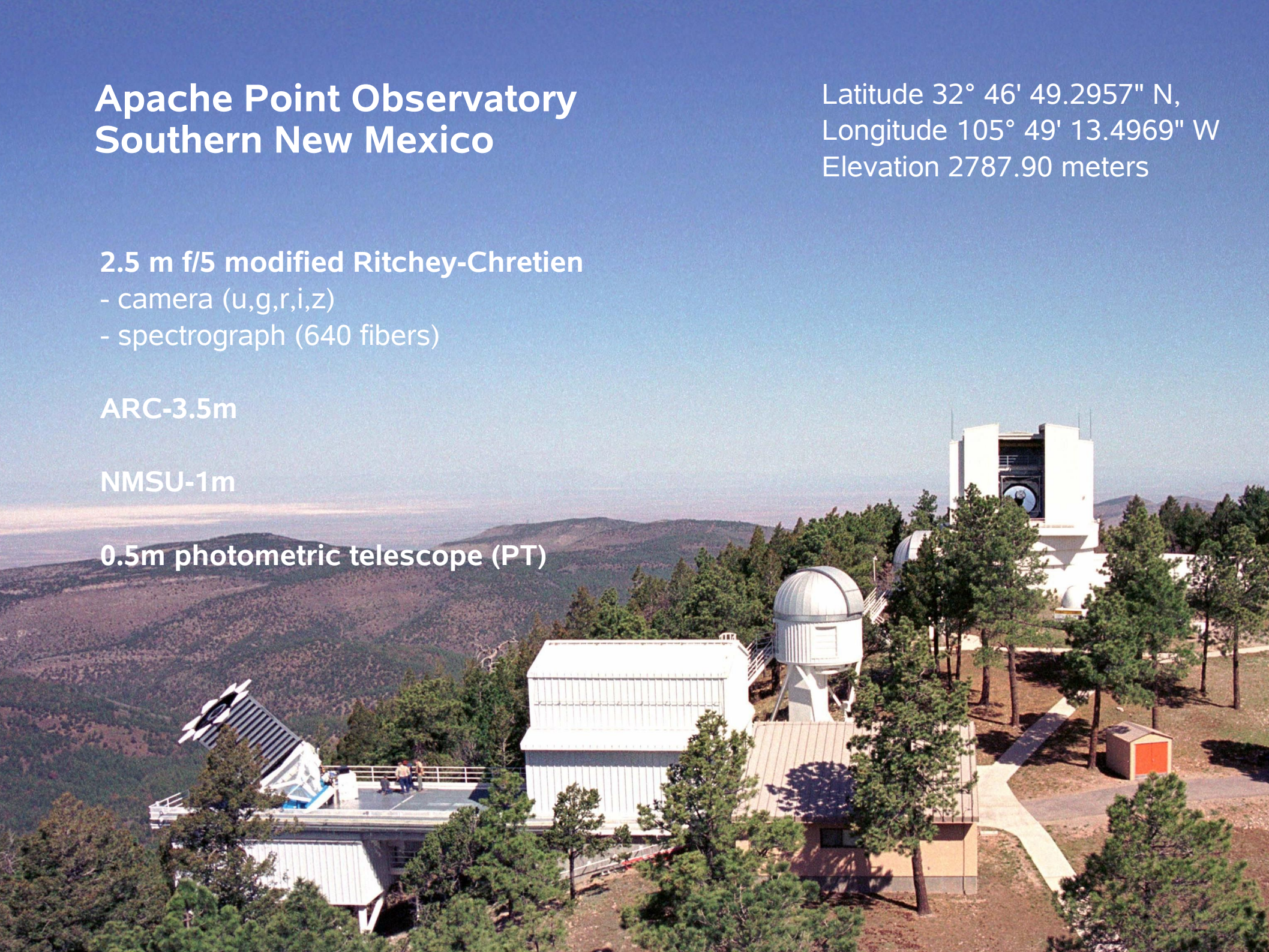
Latitude 32° 46' 49.2957" N,
Longitude 105° 49' 13.4969" W
Elevation 2787.90 meters

2.5 m f/5 modified Ritchey-Chretien
- camera (u,g,r,i,z)
- spectrograph (640 fibers)

ARC-3.5m

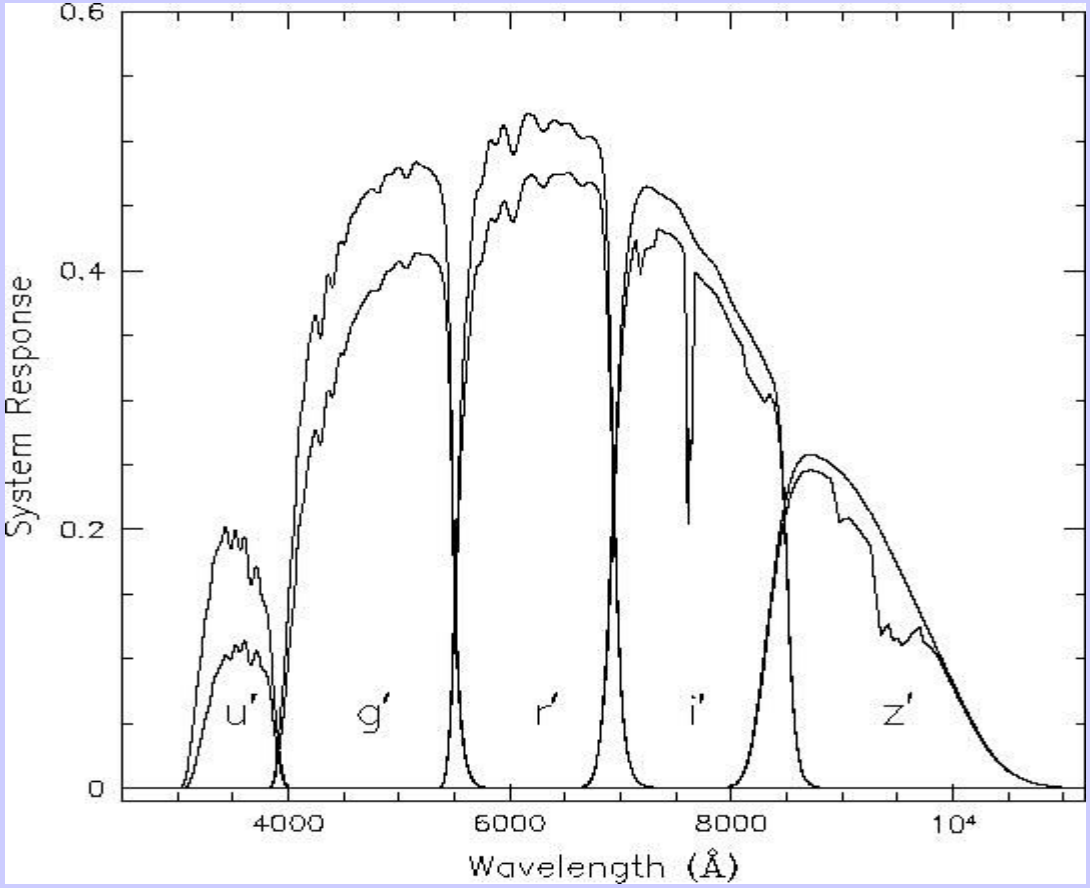
NMSU-1m

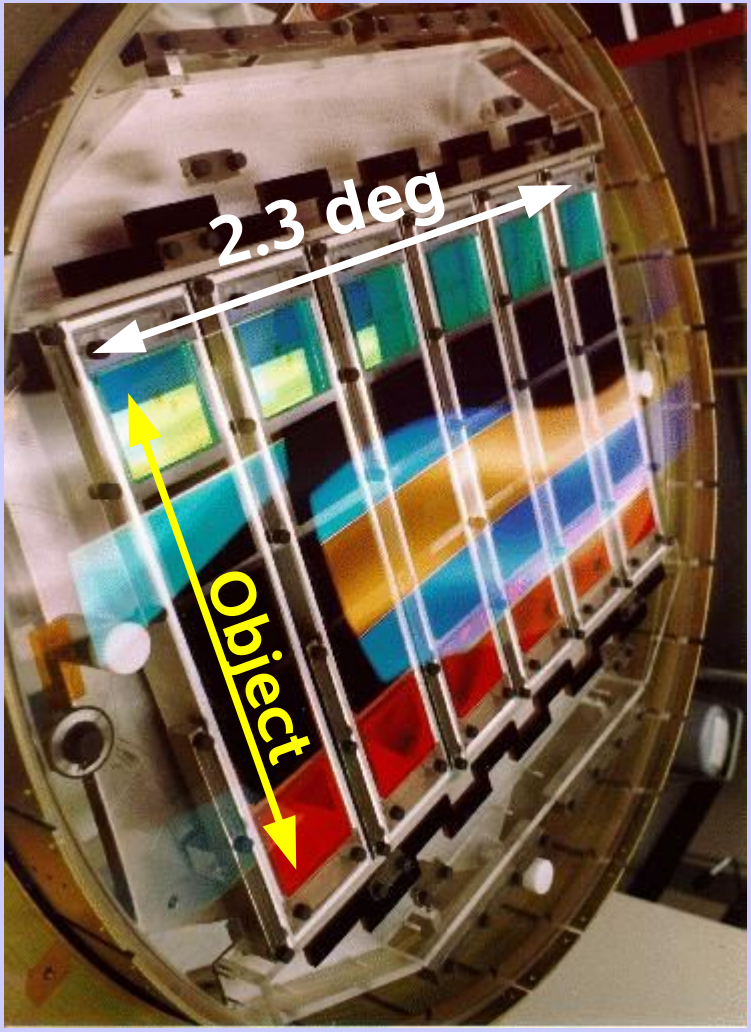
0.5m photometric telescope (PT)



SDSS-2.5m Imaging Camera

- drift scan camera
  (30 2048 x 2048 TectronixCCDs)
  5 filters in r i u z g
- siderial scan rate
- integration time 56 s





u	g	r	i	z
22.0	22.2	22.2	21.3	20.5

(56s, 95%, stars)

SDSS II SN Development/Operations

Fermilab: J. Adelman-McCarthy, F. DeJongh, G. Miknaitis, H. Lin,
J. Marriner, C. Stoughton, D. Tucker, D. Lamenti (SF State) J. Frieman

U. Chicago: B. Dilday, R. Kessler, D. Cinabro (Wayne State), M. SubbaRao

U. Washington: A. Becker, C. Hogan, Z. Ivezic JINA: P. Garnavich

Portsmouth: R. Nichol, M. Smith, B. Bassett NMSU: J. Holtzman, T. Gueth

APO: J. Barentine, H. Brewington, J. Dembicky, M. Harvanek, J. Krzesinski,
B. Ketzeback, D. Long, O. & V. Malanushenko, R. McMillan, K. Pan, S. Snedden

JPG: M. Doi, N. Yasuda, N. Takanashi, K. Konishi, K. Tokita

Stanford: R. Romani, M. Sako, C. Zheng, R. Blandford, S. Kahn, J. Kaplan

Ohio State: D. DePoy, J. L. Prieto, J. Marshall JHU/STScI: A. Riess, H. Lampeitl

Penn State: D. Schneider

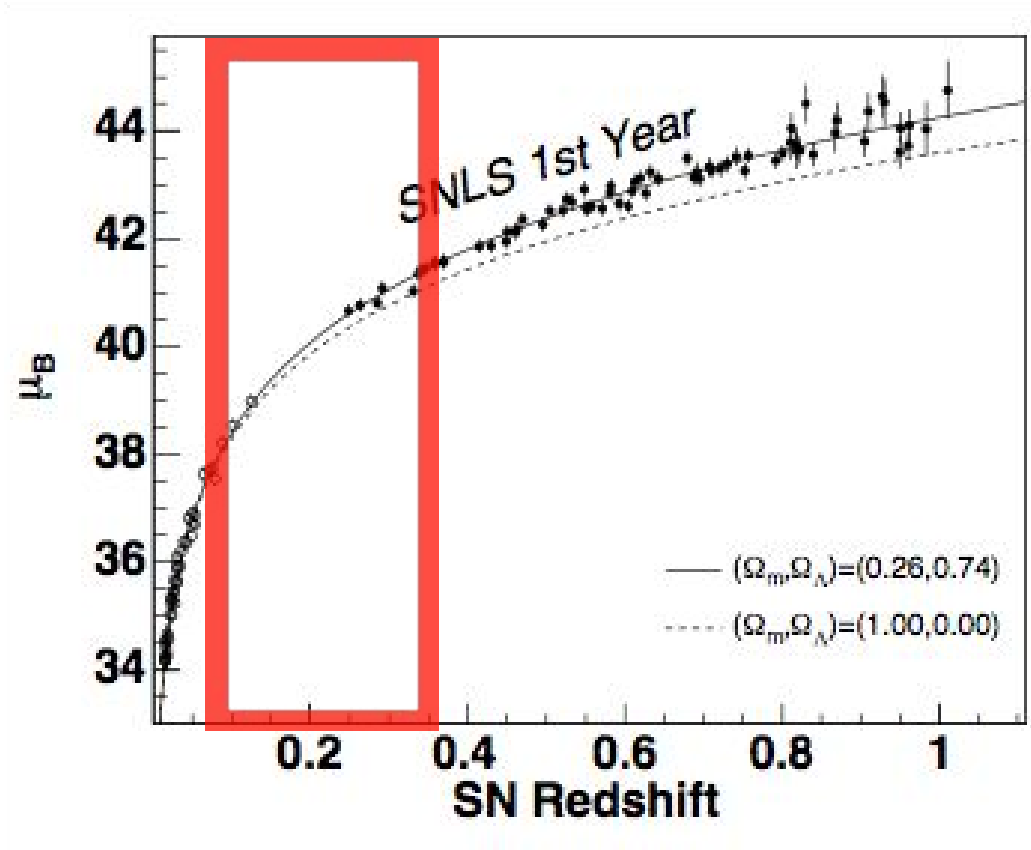
External Collaborators: M. Richmond (RIT), E. Elson (SAAO), B. Bassett (SAAO),
K. van den Heyden (SAAO), S. Jha (Berkeley),
L. Wang (LBL), R. Foley (UCB), A. Filippenko (UCB)
Additional collaborators on spectroscopic follow-up

SDSSII SNe Survey

Exploring DE & SNe at an epoch when DE dominates

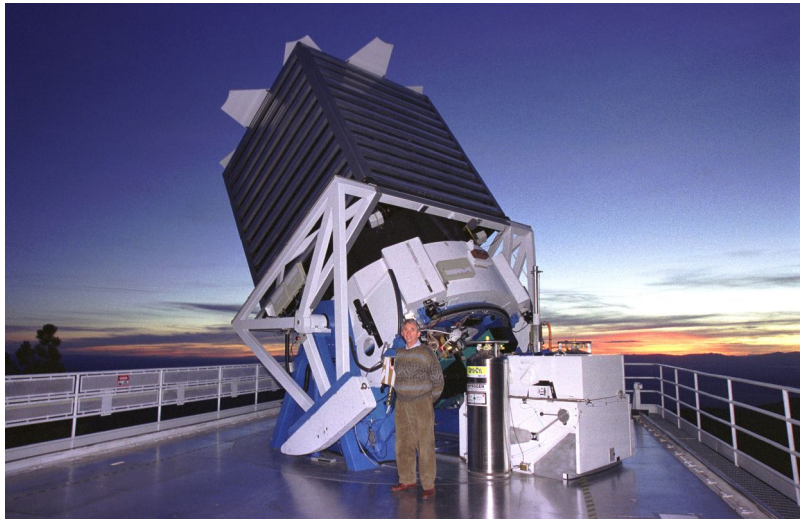
- Type Ia supernovae (Sne)
  - spectroscopically confirm and obtain “well-measured” light curves of ~200 SN Ia from z = 0.05 ~ 0.4 in u,g,r,i and z
  - bridge low-z (z<0.05; and high-z (0.3<z<1.0; ESSENCE, SNLS) sources
  - understand and minimize systematics of SN Ia as distance indicators

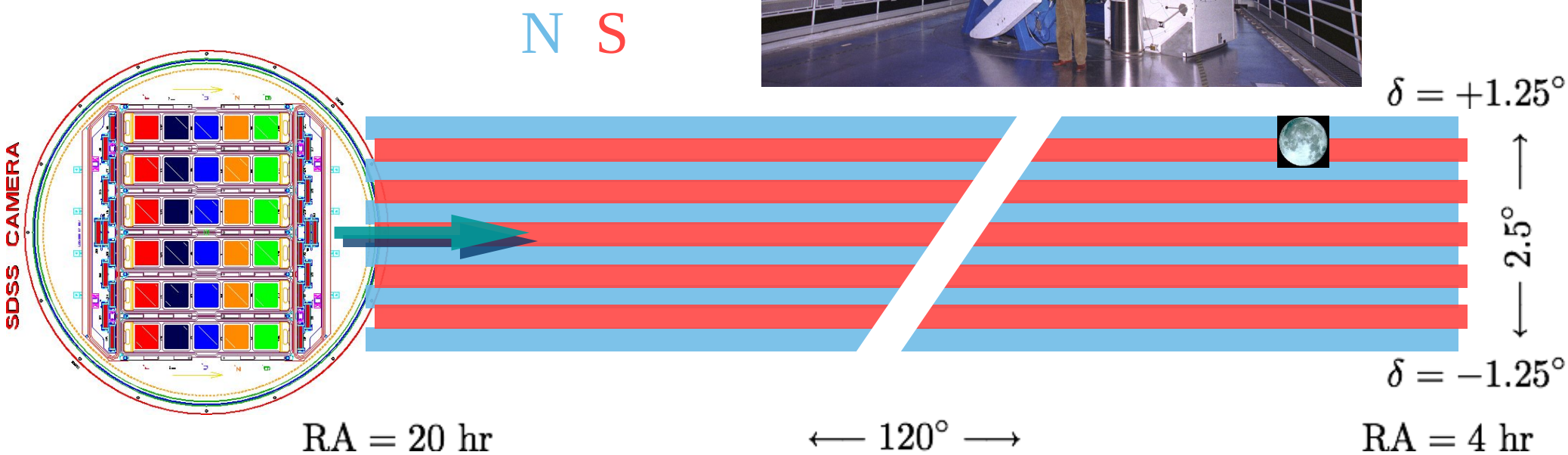
- Other SN-Types Ib/c, Type II
- Rates and Environment
- Other Transients



Astier et al. (2005)

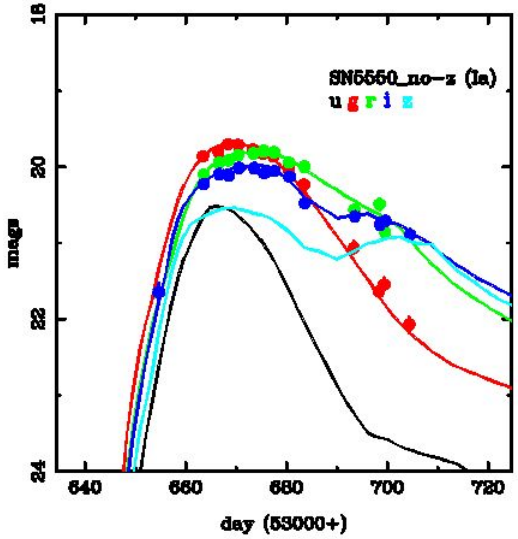
SNe Survey





Use the SDSS 2.5m telescope

- September 1 - November 30 of 2005-2007
- Scan 280 square degrees every 2 days
- on site 24 h data reduction (~200 GByte/night)
- Obtain multi-color light curves
- >90% efficiency after ~2 - 4 epochs
- spectroscopic follow-up



Data Processing

Dedicated computer cluster (20 CPUs @ APO) + 1 Server @ Fermilab

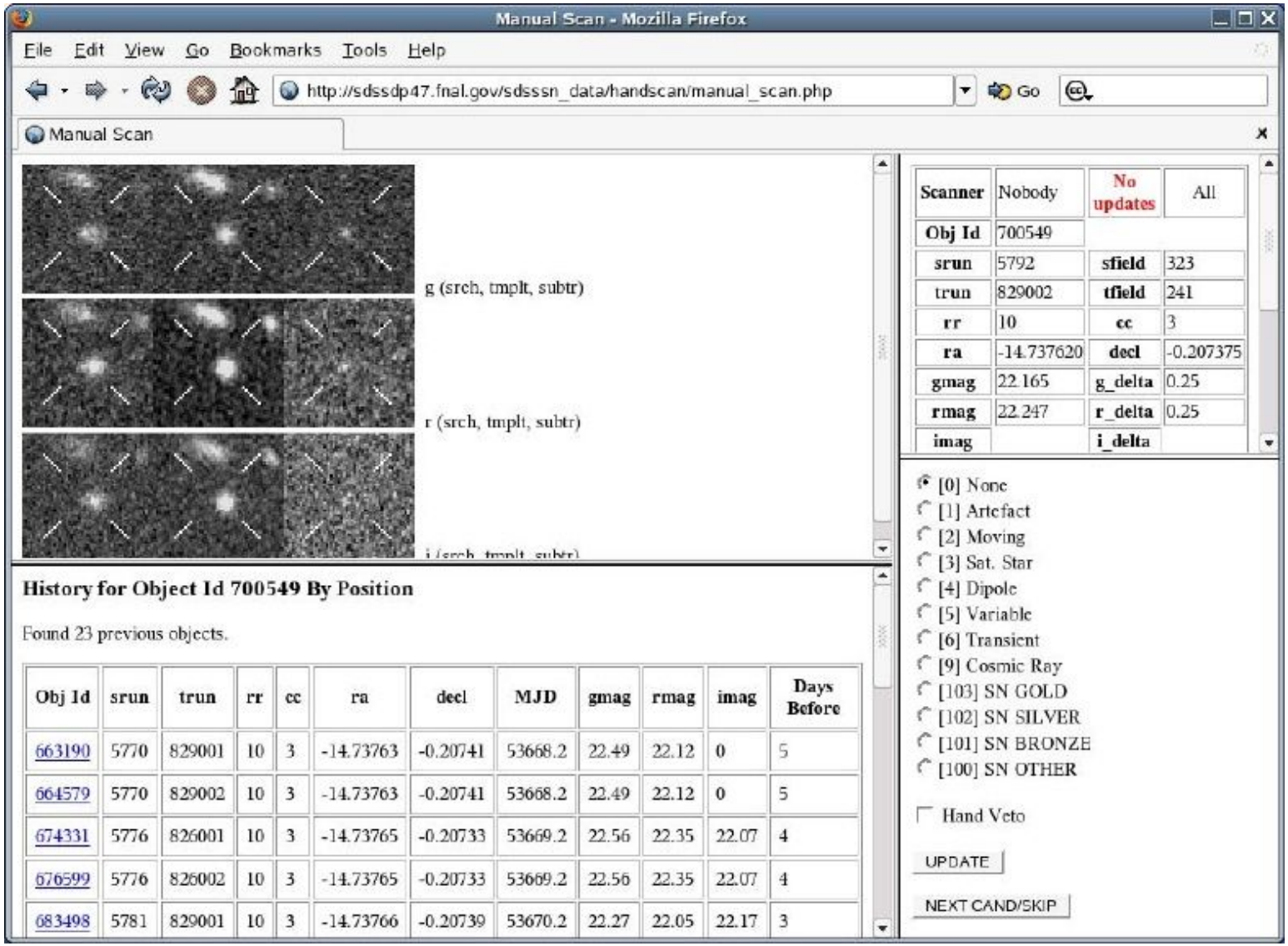
- **SDSS standard reduction** (photo)
  + *artificial SN*
- **image subtraction in g,r and i**
  coadded templates (~10 images)
  similar code as ESSENCE
- **rejection of false positives**
  - detection in two filters within <0.8”
  - veto cataloges of previous variable objects
- **visual inspection of objects**
  using a web based interface
  -> *candidates*
- **photometric typing**
  to select candidates for spectroscopic follow-up

ca. 200 Gbyte in long night turn around 24 h

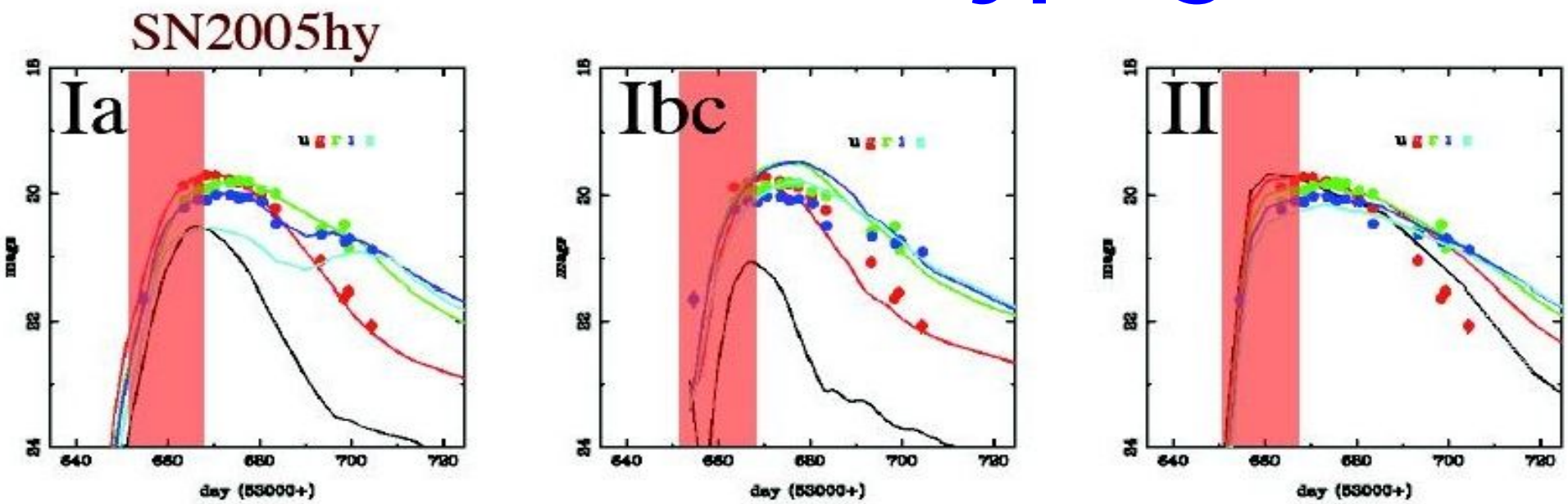
Visual Inspection

www-based interface

scan results captured in database



Photometric Typing



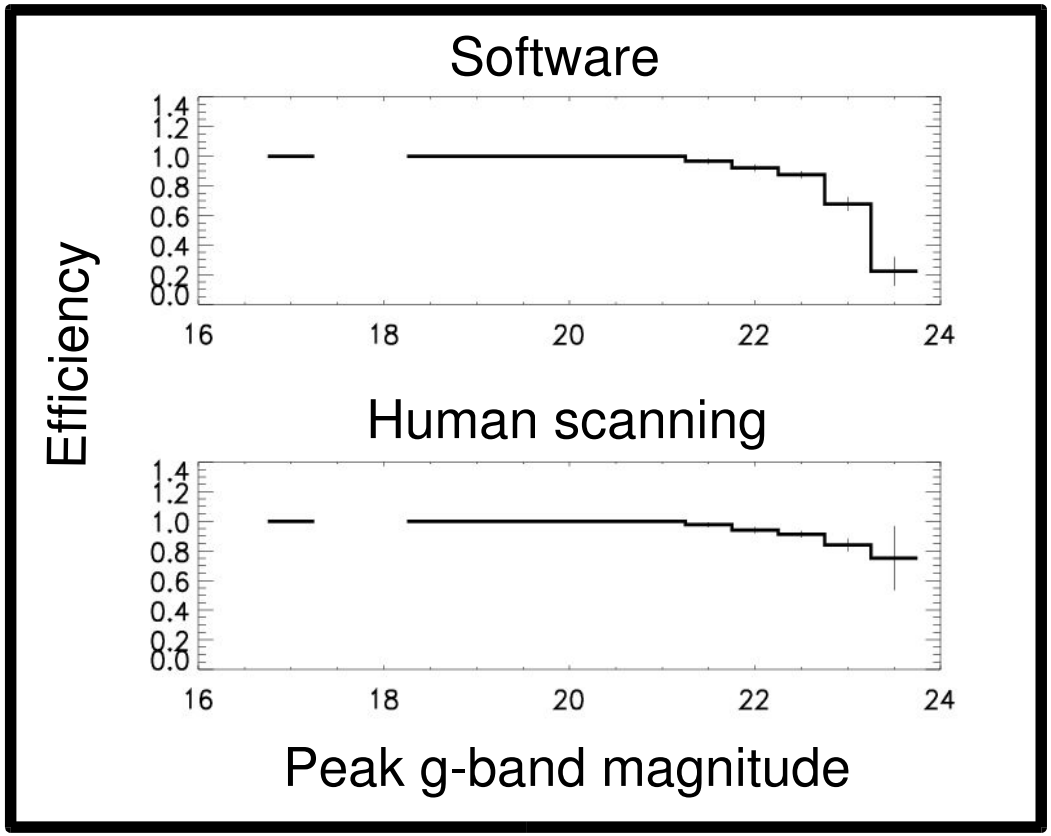
- color typing using gri-data
- comparison with precompiled Ia, Ia-pec, II-P, II-L, IIb, Ibc, Ibc-hypernova light curves
- fit for redshift, extinction, stretch
- >90% efficency after 2-4 epochs
- ~ 5-10% accurate SN redshift

Statistics:

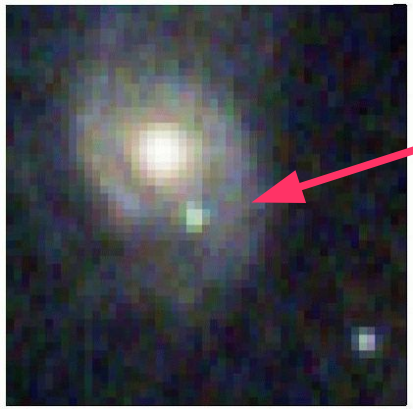
Objects scanned by scientists	**160,000 (~4000/night)**
SN tags	**12,000**
reasonable SN like LC	**300**
observed spectra	**~200**
confirmed Ia	**129**
premaximum image	**116**

Testing Survey Efficiency with Simulated SNe (fakes) -> see also B. Dildays talk tomorrow

Insert ~1000 fakes with realistic light-curves into the data stream to test software/human scanning efficiencies



PSF estimate from SDSS photo pipeline



Fakes with peak Sept1-Nov30

~ 88% software efficiency

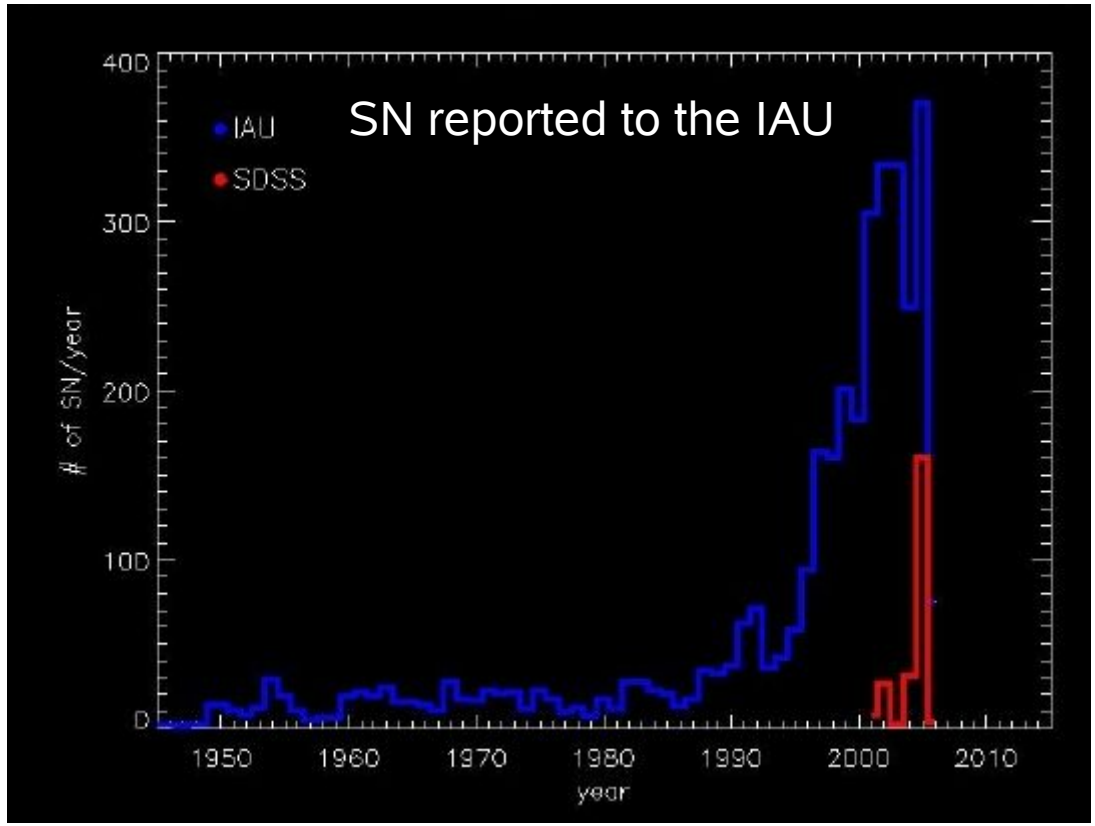
~ 94% human scanning efficiency

Fakes generated assuming no extinction

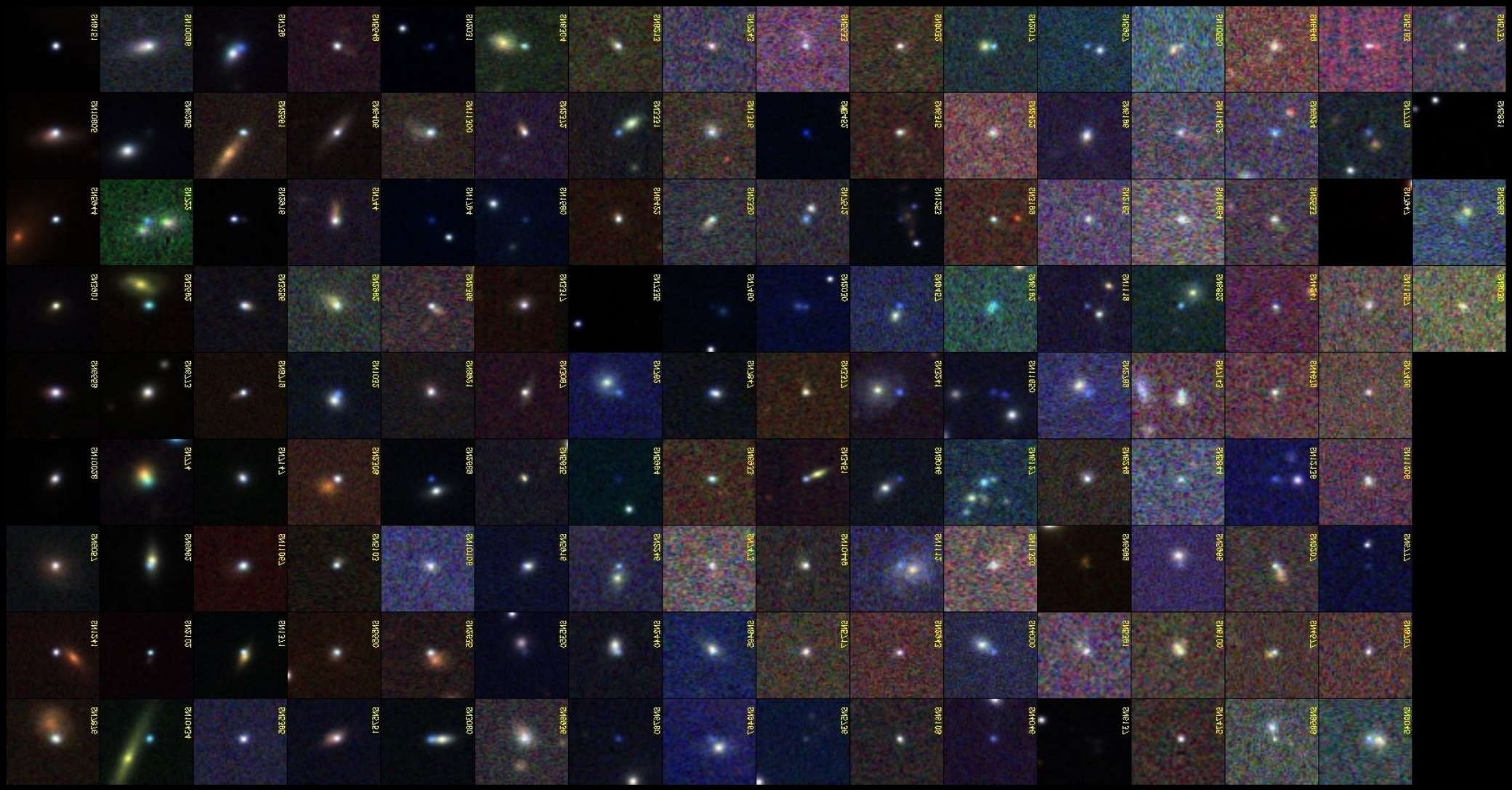
Fall 2005 Campaign

in total 53 imaging nights, over 200 SN spectra obtained

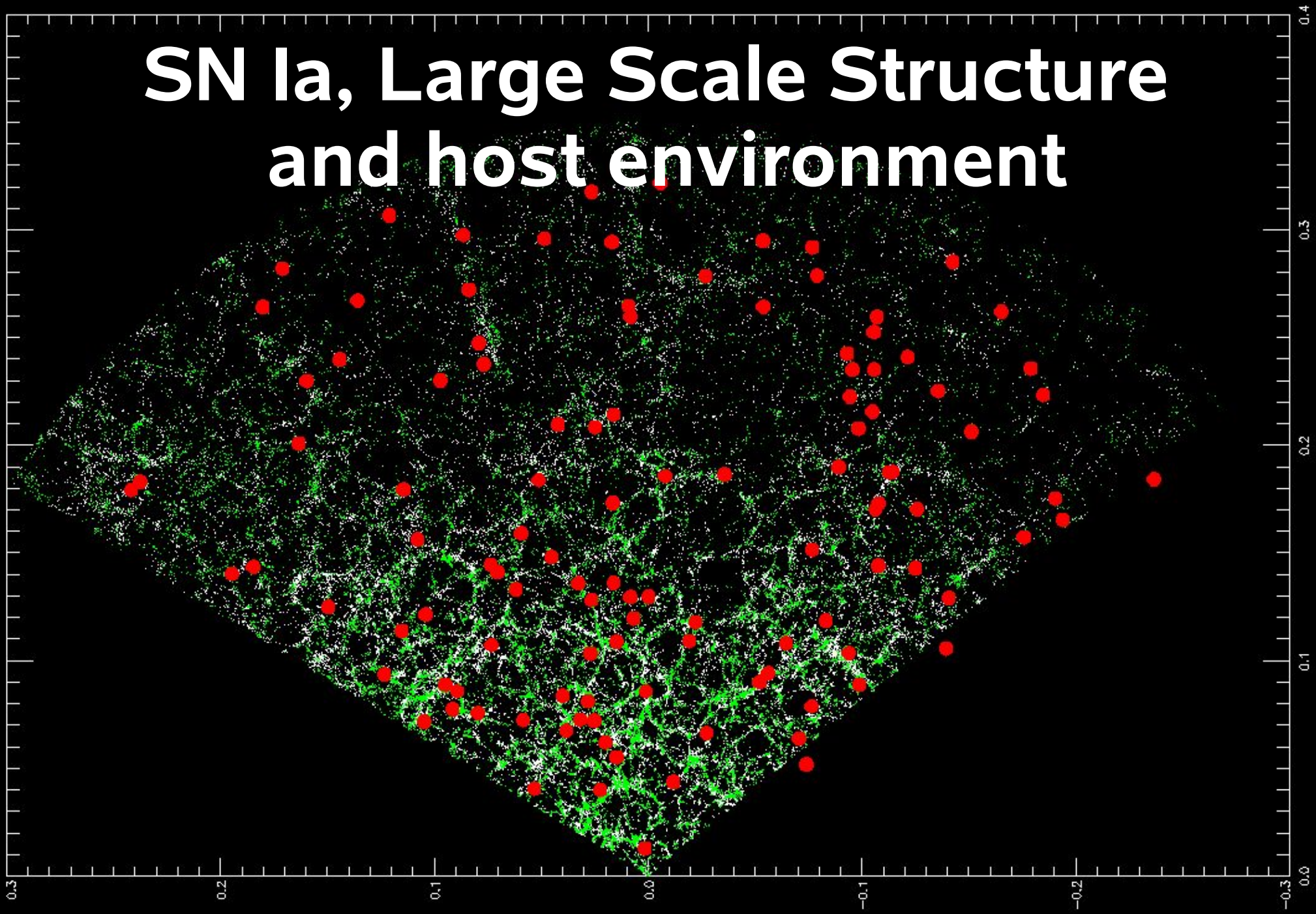
129 spectroscopically confirmed SN Ia ($0.05 < z < 0.4$)
(+16 SNIa from 2004)
13 spectroscopically probable SN Ia
6 SN Ib/c
10 SN II
5 AGN
~ hundreds of uncon-firmed Sne with good Lightcurves



Spectroscopic Confirmed Ia in 2005



SN Ia, Large Scale Structure and host environment

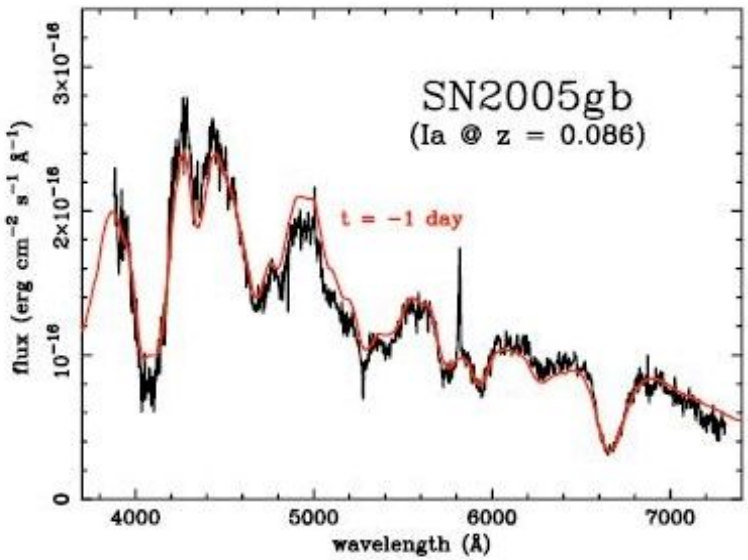


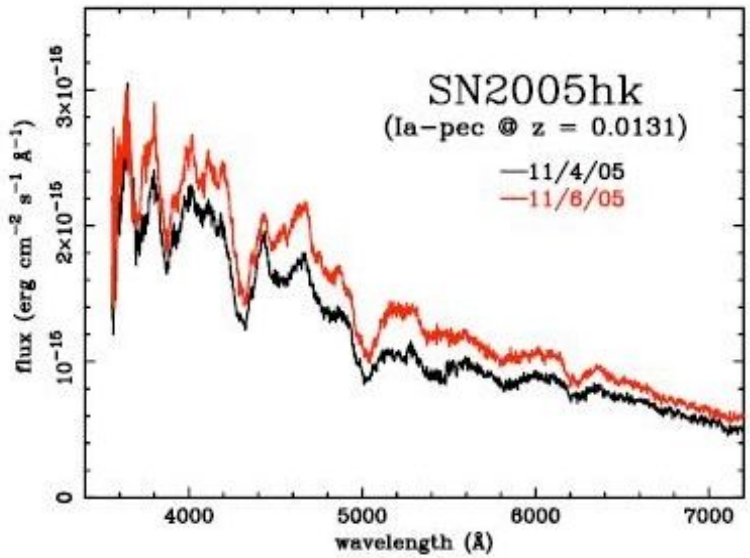
Follow-up program

- Spectroscopic - confirm type and measure redshift
  - ARC (3.5m) - 33 half nights; HET (9.2m) - 90 hours of queue time; MDM (2.4m) - 40 nights; WHT (4.2m) - 6 nights; Subaru (8.2m) - 6 half nights; [Keck (10m) - 1 night]

- Imaging - fill in/out light curves
  - MDM (2.4m) - 40 nights; NMSU (1m) - many nights; UH88 - 5 nights; VATT (1.8m) - 7 nights; WIYN (3.5m) - 2 half nights; [CSP (IR @ 6.5m Magellan) - several targets]

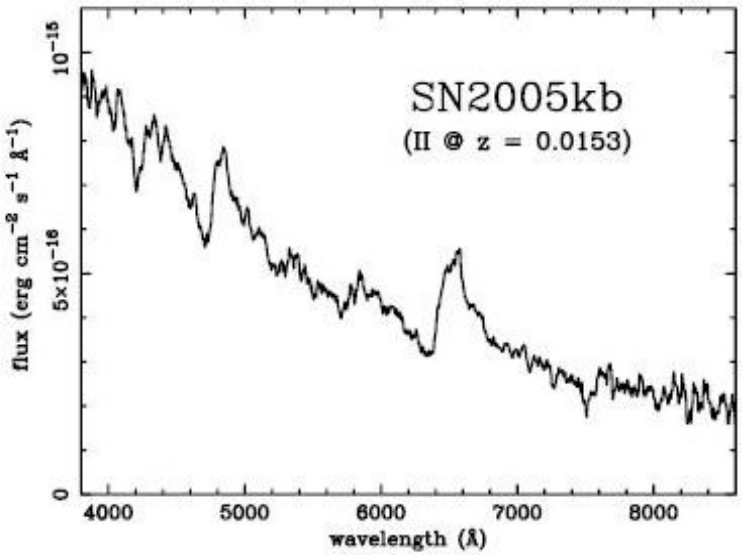
MDM

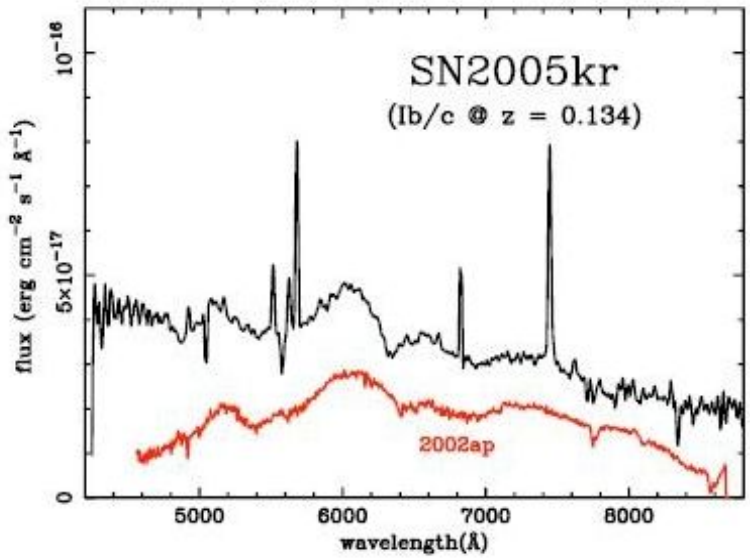




ARC

ARC





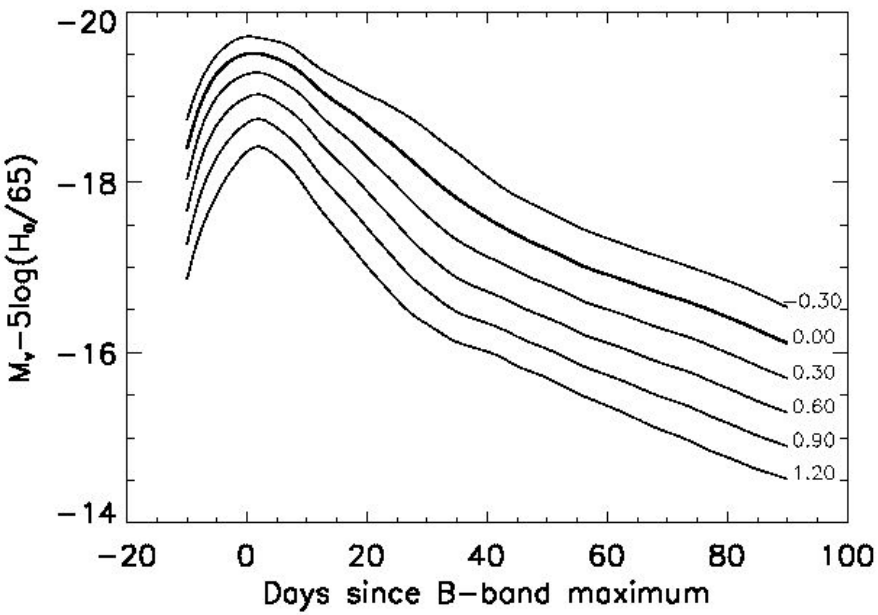
HET

MLCS2k2 (S. Jha, 2002, Riess, ApJ 473,1996)

Multicolor Light Curve Shape Method / Bayesian Approach

$$m_x(t-t0) = M_x^0 + \mu_0 + \xi(\alpha_x + \beta_x / R_V) A_v + P_x \Delta + Q_x \Delta^2$$

galactic extinction
k-correction
time dilation z



Set of light curves in UBVRI

Training Set of 30 SNIa:

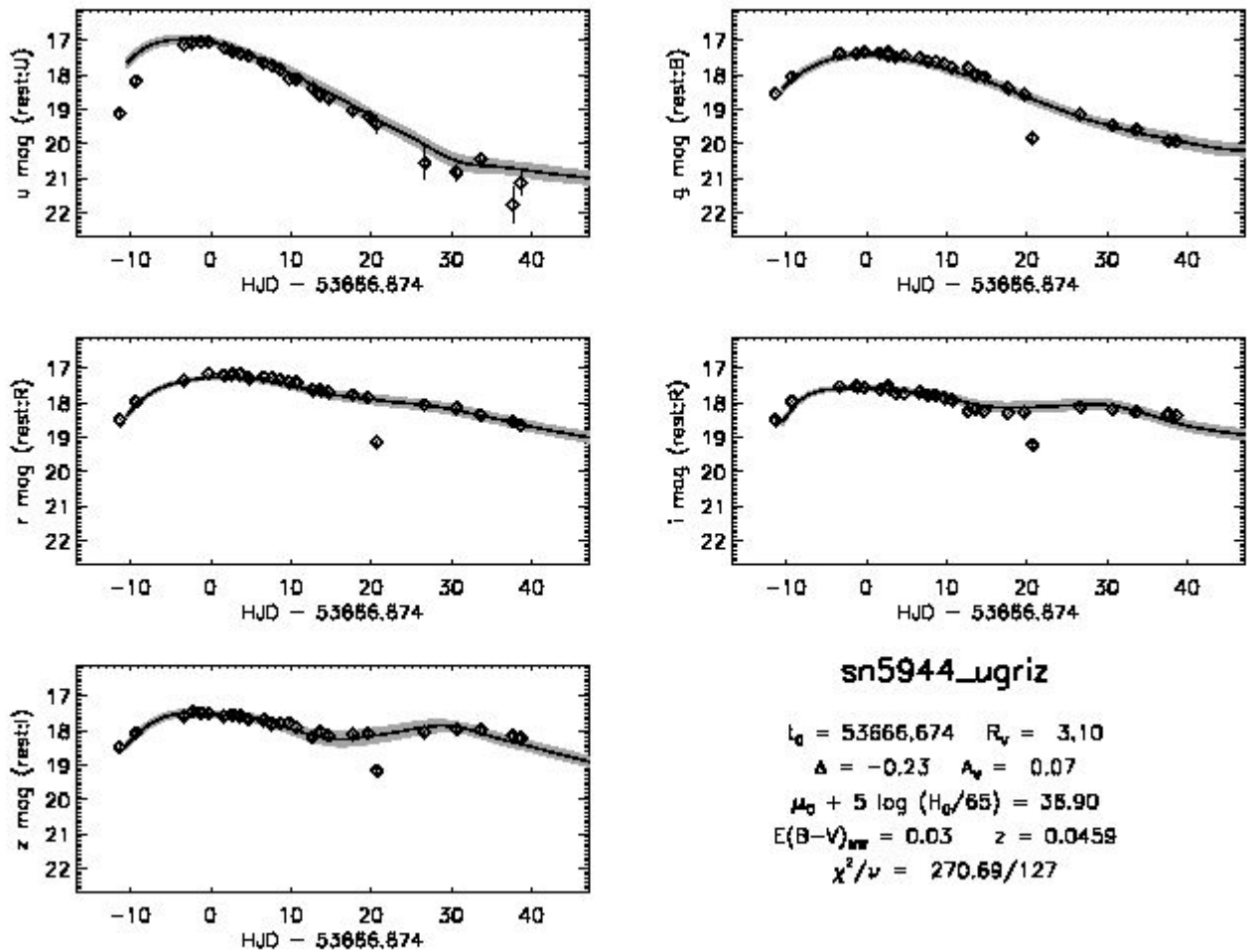
$$M_x^0, P_x, Q_x$$

Simultaneous fit for:

$$t_0, \mu_0, R_V, A_V^0, \Delta$$

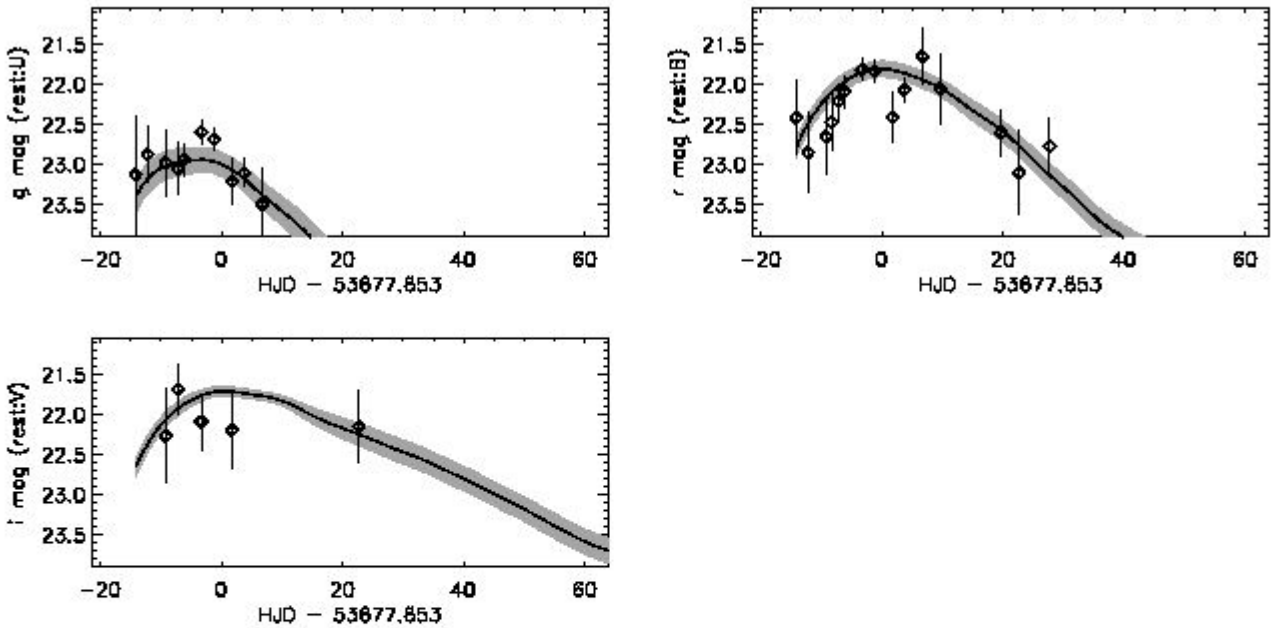
Representative Light Curves

z = 0.046



Representative Light Curves

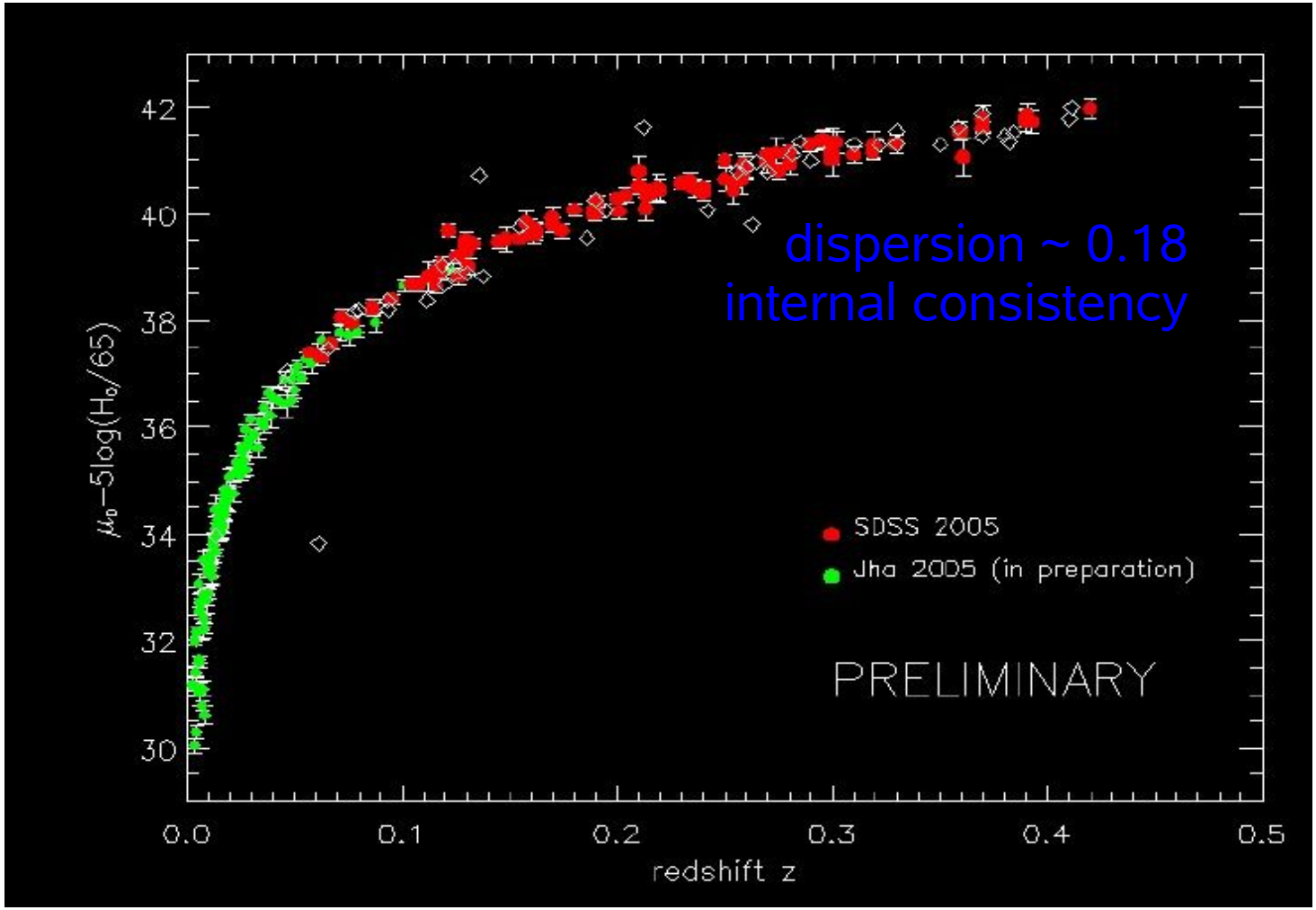
z = 0.420



sn8030_ugriz

t_0 = 53677.653 R_V = 3.10
Δ = −0.30 A_V = 0.18
$\mu_0 + 5 \log (H_0/65)$ = 41.88
$E(B-V)_{MW}$ = 0.04 z = 0.4200
χ^2/ν = 16.25/26

Preliminary Hubble Diagram



- Combination of SDSS and high redshift data leads to improved constraints, due to broader redshift leverage.
- SDSS can probe w = -1 in the low redshift range (z ~ 0.2)

Current Status and Plans

2005 - finalize on photometric reduction
- LC fitting and comparison of different methods (MLCS, dm15, etc.)
- host properties & rates
- investigation of photometric typing for cosmology

2006 - find and follow up other types of SNe (IIP, Ibc, hypernovae ...)
- multi epoch spectroscopy of SNe

2007 ...