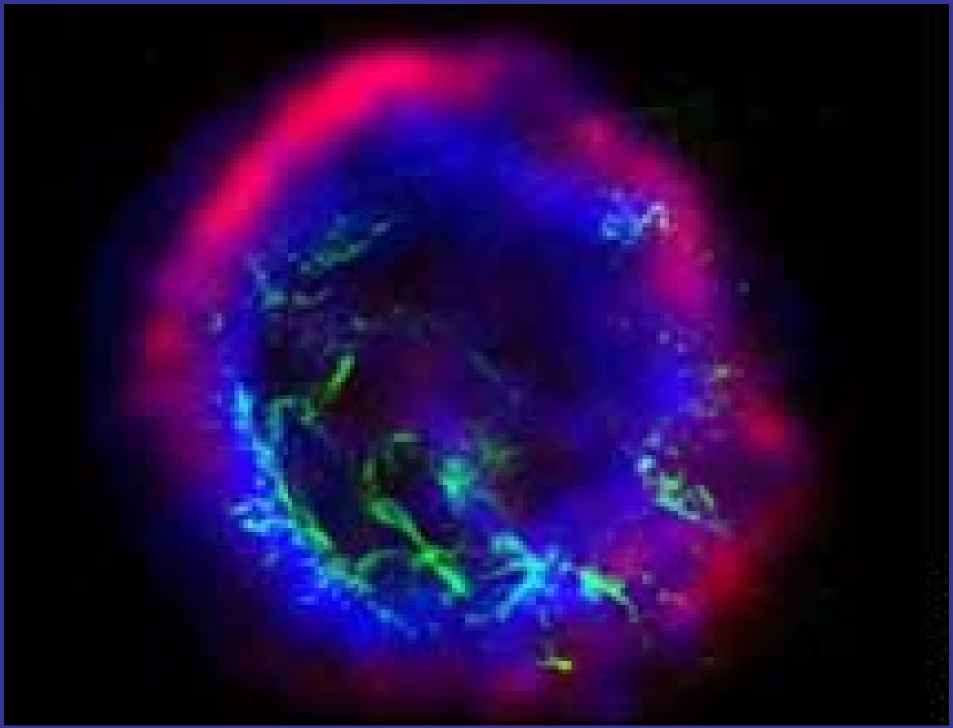
# The Carnegie Supernova Project: A Status Report



Wendy Freedman

Carnegie Observatories, Pasadena, CA

COSMO05: Bonn, Germany

August, 2005

# Carnegie Supernova Project (CSP)

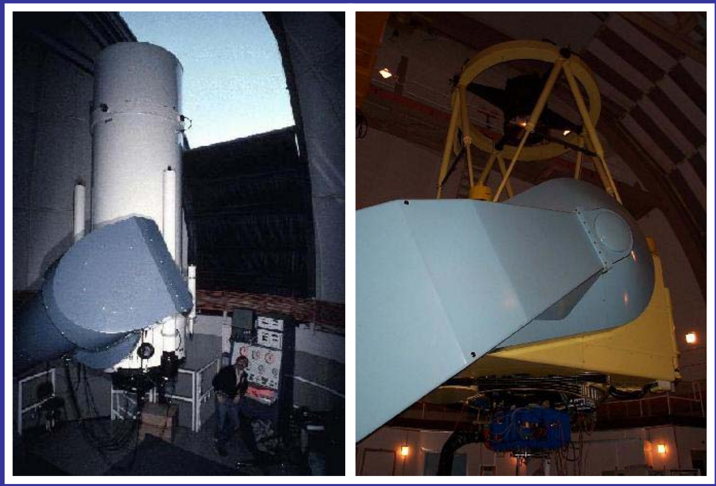
- Restframe I-band Hubble diagram

  - Infrared observations of Type Ia & II supernovae
  - 'Low' ($z < 0.1$) and 'high' ($0.1 < z < 0.6$) redshifts
  - Minimize and control systematics
  - Improved constraints on $d_L(z)$ [ultimately w, w']

# Carnegie Supernova Project (CSP)

## Low z:

- 10-color (u'BVg'r'i'YJHK) photometry
- 1.0 and 2.5-meter telescopes
- well-sampled light curves
- spectroscopy with time coverage
- wide range of galaxy environments
- accurate k- and spectral corrections



## High z:

- Magellan (6.5-meter) telescopes
- I restframe (YJ) photometry
- ugriz or VRI photometry (CFHT/Tololo)
- good sampling at peak brightness
- VLT, Gemini, Keck spectroscopy

# Carnegie Supernova Project (CSP)

## CSP Carnegie col's, PI's:

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Gaston Folatelli

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Mario Hamuy

Barry Madore

Nidia Morell

Eric Persson

Mark Phillips

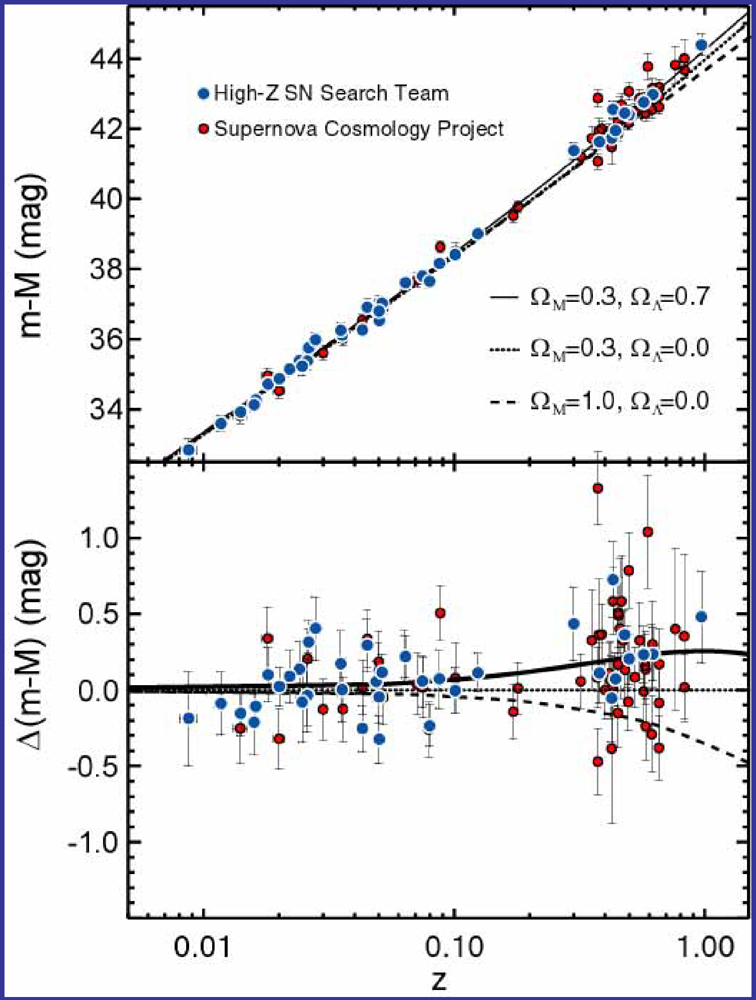
Miguel Roth

Nick Suntzeff

Pamela Wyatt

Ray Carlberg, Chris Pritchet, Mark Sullivan, Kathy Perrett, Andy Howell (CFHT Legacy)
Alex Filippenko, Weidong Li (KAIT)
Nick Suntzeff (ESSENCE)

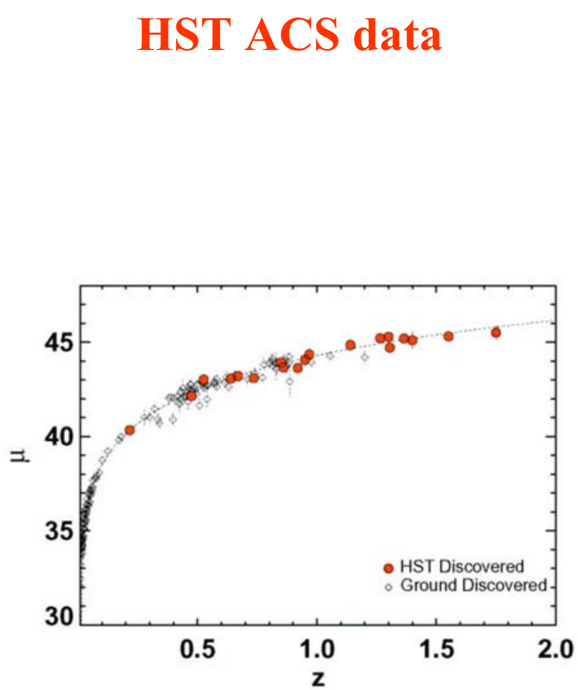
# Type Ia Supernovae for Cosmology



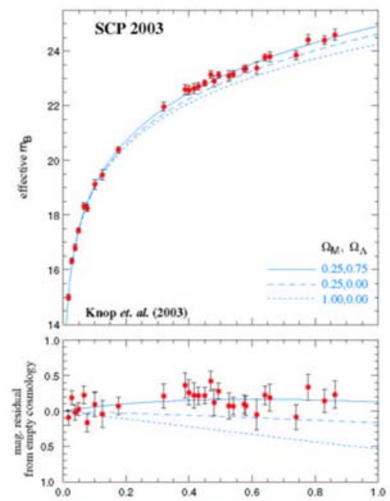

**Riess et al. 1998**
**Perlmutter et al. 1999**

**First evidence for acceleration**

# State of the Art




Riess et al. 2004




Knop et al. 2003

# Type Ia supernovae as distance indicators

# Type Ia Supernovae for Cosmology

**Advantages:**

- small dispersion
- single objects (simpler than galaxies or clusters of galaxies)
- can be observed over wide z range

**Challenges:**

- dust (grey dust)
- chemical composition
- evolution
- photometric calibration (e.g., Vega)
- environmental differences
- lensing

**Next step: Improved Systematics**

# Luminosity Distances

$$d_L = \left(\frac{L}{4\pi F}\right)^{\frac{1}{2}}$$

L : intrinsic luminosity of the supernova
F : observed flux of the supernova

**Distance modulus:**

$\mu_0 = m - M = 5 \log d_L + 25$ where $d_L$ is in Mpc

# Characterizing the Equation of State

Equation of state: $w = P/\rho c^2$

P : pressure
$\rho$ : energy density

$$d_L = cH_0^{-1}(1+z)\int_0^z dz[(1+z)^3\Omega_m + (1-\Omega_m)(1+z)^{3(1+w)}]^{-1/2}$$

For $w(z) = w_0 + w'z$ :

$$d_L = cH_0^{-1}(1+z)\int_0^z dz[(1+z)^3\Omega_m + (1-\Omega_m)(1+z)^{3(1+w_0-w')}e^{3w'z}]^{-1/2}$$

For example,
W = -1 simplest model; cosmological constant
W ≥ -1 quintessence models, dynamical scalar field; generally w' ≠ 0

Critical to determine if w =-1 or not; very different fundamental physics.
Does w vary with time – is the dark energy dynamical?

# Recent Estimates of w

W = -1 +/- 0.2 +/- 0.1 (Knop et al. 2003; Riess et al. 2004)

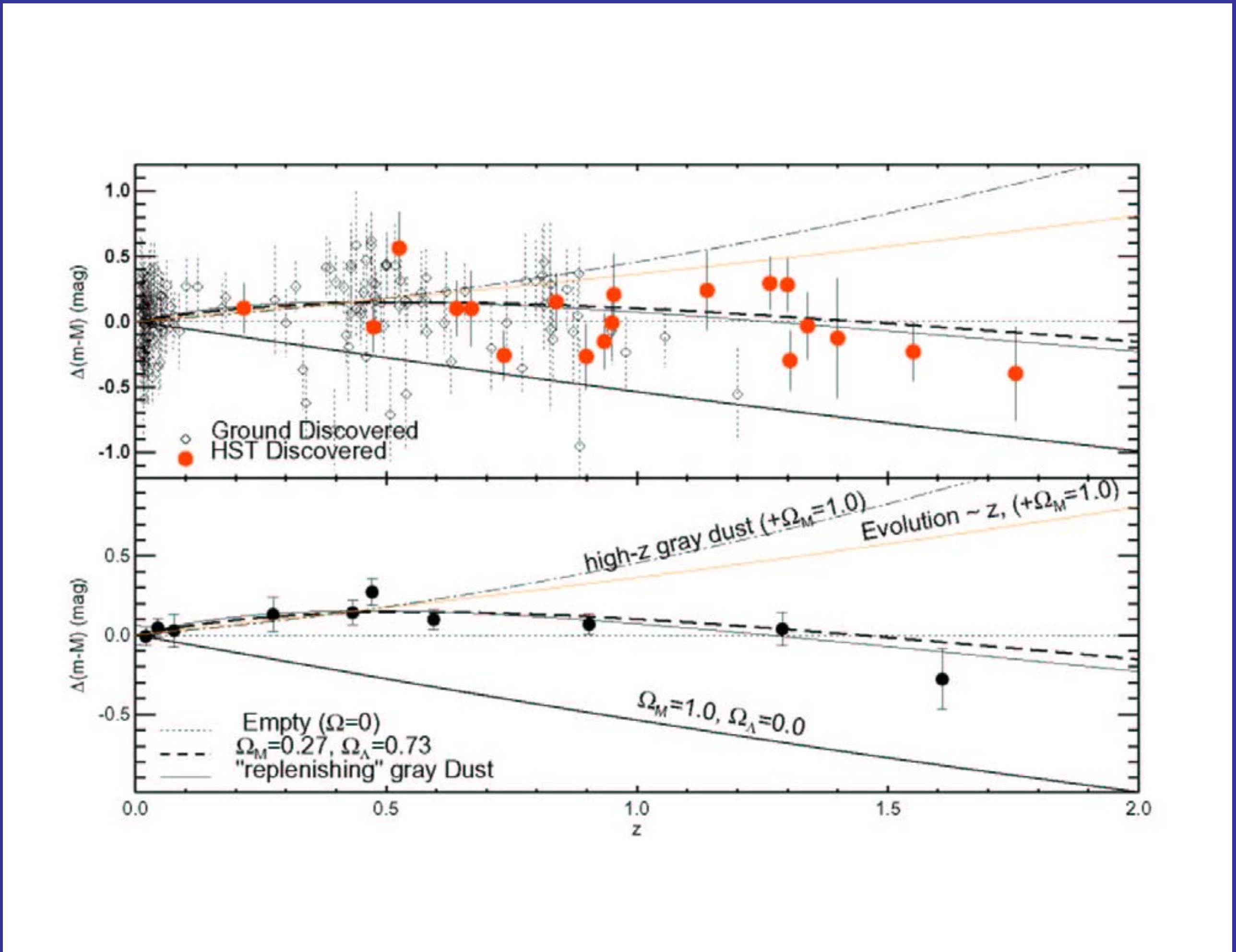
**Assumptions:**

- flatness: $\Omega_0 = 1$
- $\Omega_m = 0.3 \pm 0.04$

# Minimizing Systematics in era of precision cosmology

- Dust absorption and scattering
- Chemical composition effects
- Evolutionary effects

# Gray Dust?

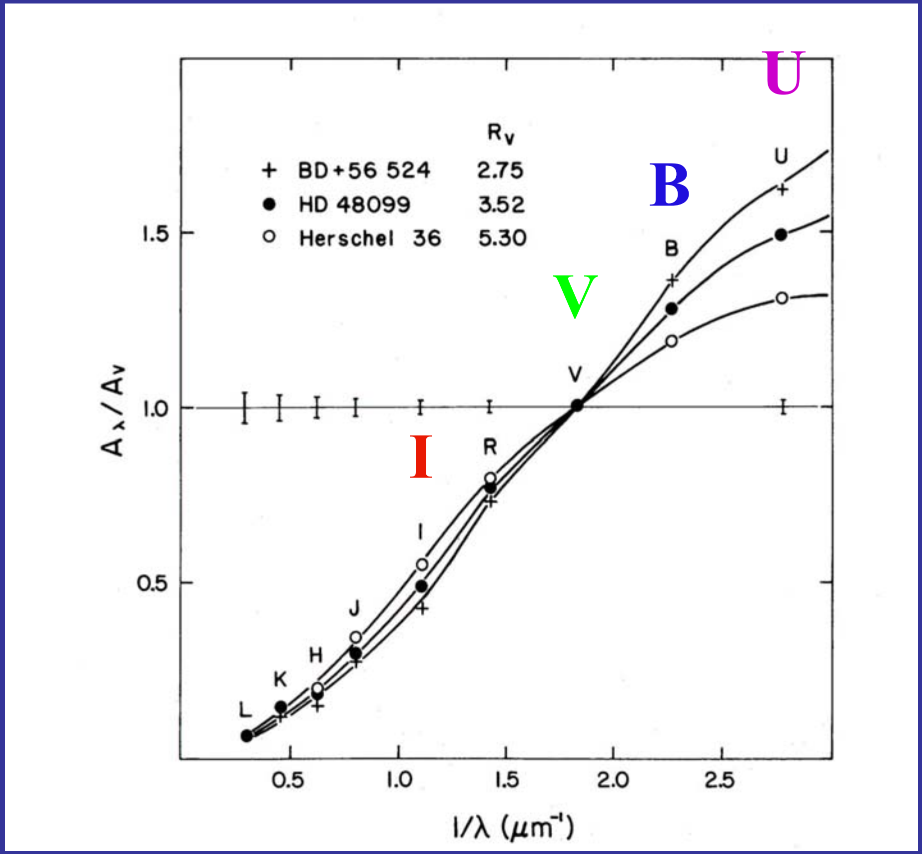



Riess et al. 2004

There is no evidence to date for gray dust.

The data are consistent with the presence of dark energy.

# Galactic Extinction Law




A

A

A

R

*C*

# Supernova Ia Metallicities

•L

O

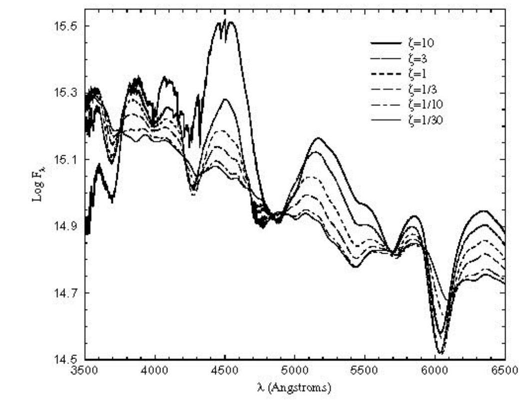


FIG. 3.—Expansion of optical region of Fig. 1

•V

U

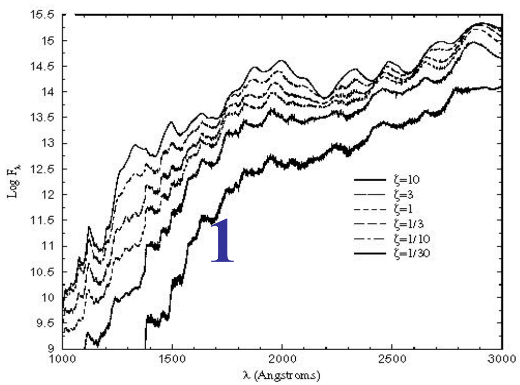


FIG. 2.—Expansion of ultraviolet region of Fig. 1

IR

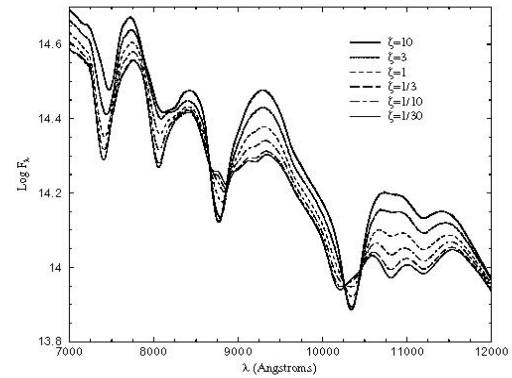


FIG. 4.—Expansion of infrared region of Fig. 1

L

# Present/Future Supernova Projects

**High z:**

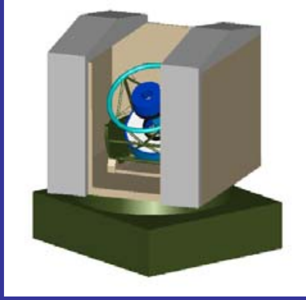
- CFHT Legacy Survey
- ESSENCE
- Carnegie Supernova Project (CSP)
- Supernova Cosmology Project (SCP)
- GOODS

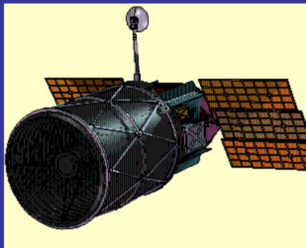
**Low/Intermediate z:**

- LOTOSS (KAIT)
- SN Factory
- SDSSII
- CSP

**Future Supernova Projects:**

- LSST, Panstarrs
- Giant Magellan
- JDEM

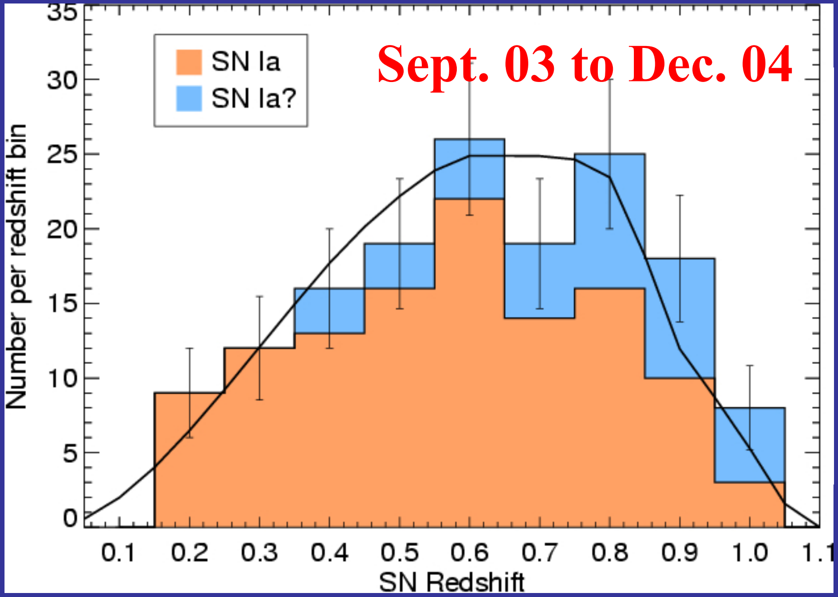




# Current Type Ia supernovae searches

# CSP target selection

# 1. CFHT Legacy Survey (SNLS)

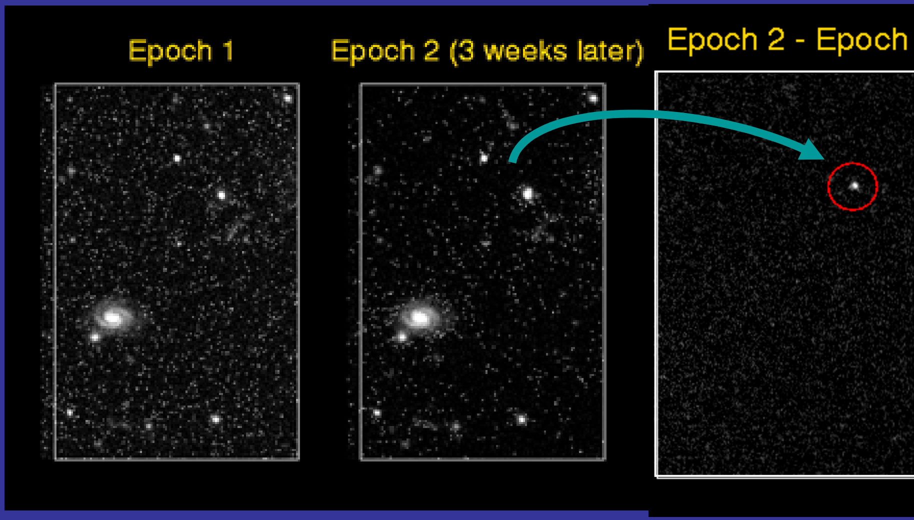



- u'g'r'I'z' light curves
- observations to I' ~ 28 mag
- CFHT MegaCam (1 sq. deg.)
- spectroscopy: VLT, Gemini, Keck
- 2000 SN over 5 years
- 0.1 < z < 1

CFHT Poor weather
2003, 2004, 2005!

# 2. ESSENCE

- VRI light curves
- CTIO 4m Mosaic Imager
- 200 SN over 5 years
- share nights with Supermacho project
- observe each field every 4 nights
- $0.1 < z < 0.8$



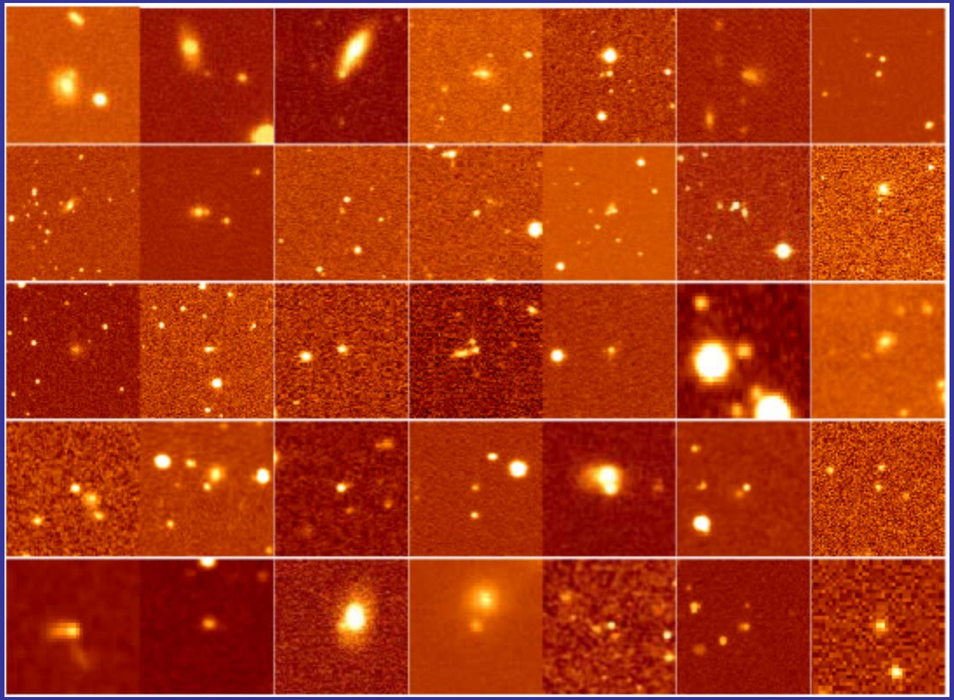

High z Supernova Team

NOAO Science Archive:
**http://archive.noao.edu/nsa/**

# 3. LOTOSS / KAIT

- Automated supernova search
- UBVRI light curves
- Lick Observatory
- 0 < z < ~0.15

# 4. Supernova Factory



Wood – Vasey et al 2004

- spectrophotometry
- Univ. Hawaii
- 0.32 – 1 μm
- NEAT, Palomar (search)
- ~150 SNae per year
- 3 years

**Same search techniques as distant searches**

# 5. Sloan Digital Sky Survey II (SDSSII)

- 5-band Sloan photometry
- observing cadence: every 2$^{nd}$ night
- Sept. thru Nov. observations
- $0.05 < z < 0.35$
- followup spectroscopy
- 3 years NSF funding

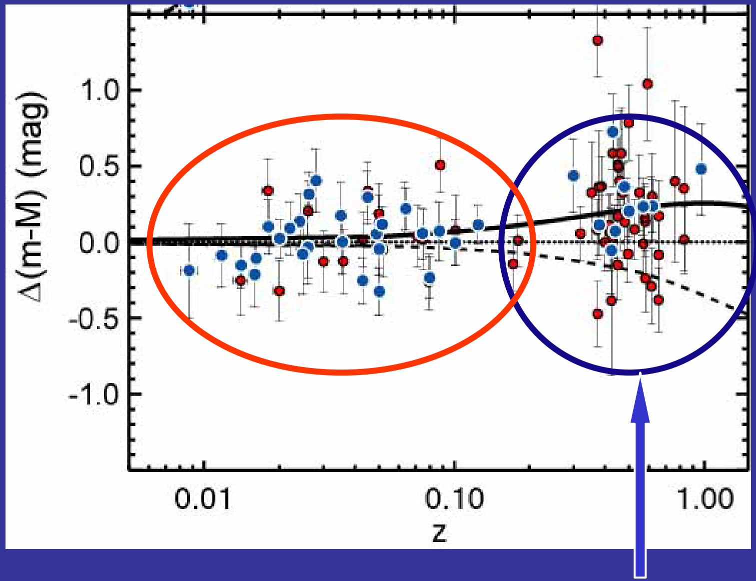
# Carnegie Supernova Project (CSP)

**An I-band Hubble diagram**

- **Advantages:**

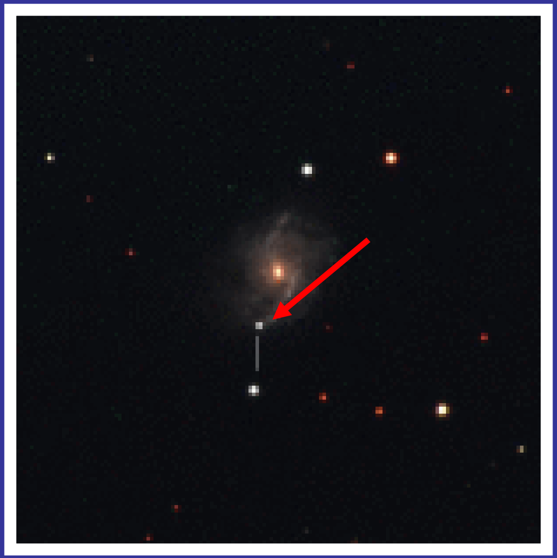
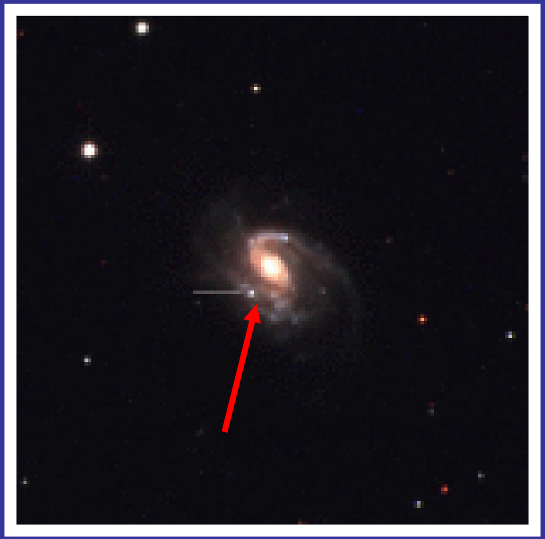
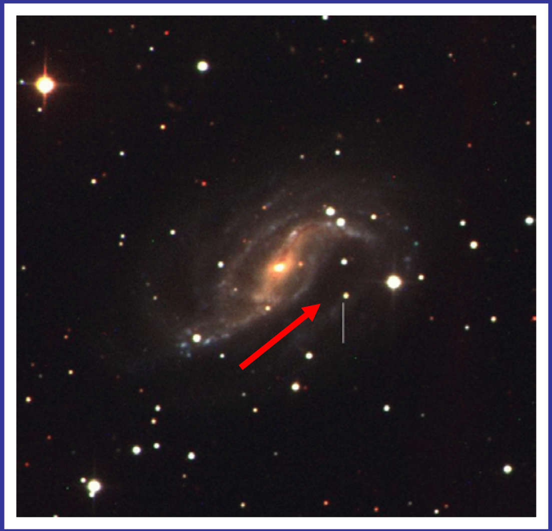
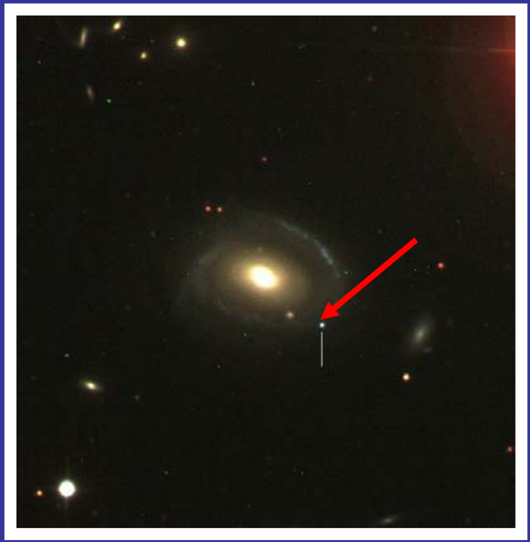
  - dust
  - chemical composition
  - low dispersion

=> reduce systematics




[Why hasn't this been done? HARD! IR detectors on large telescopes]

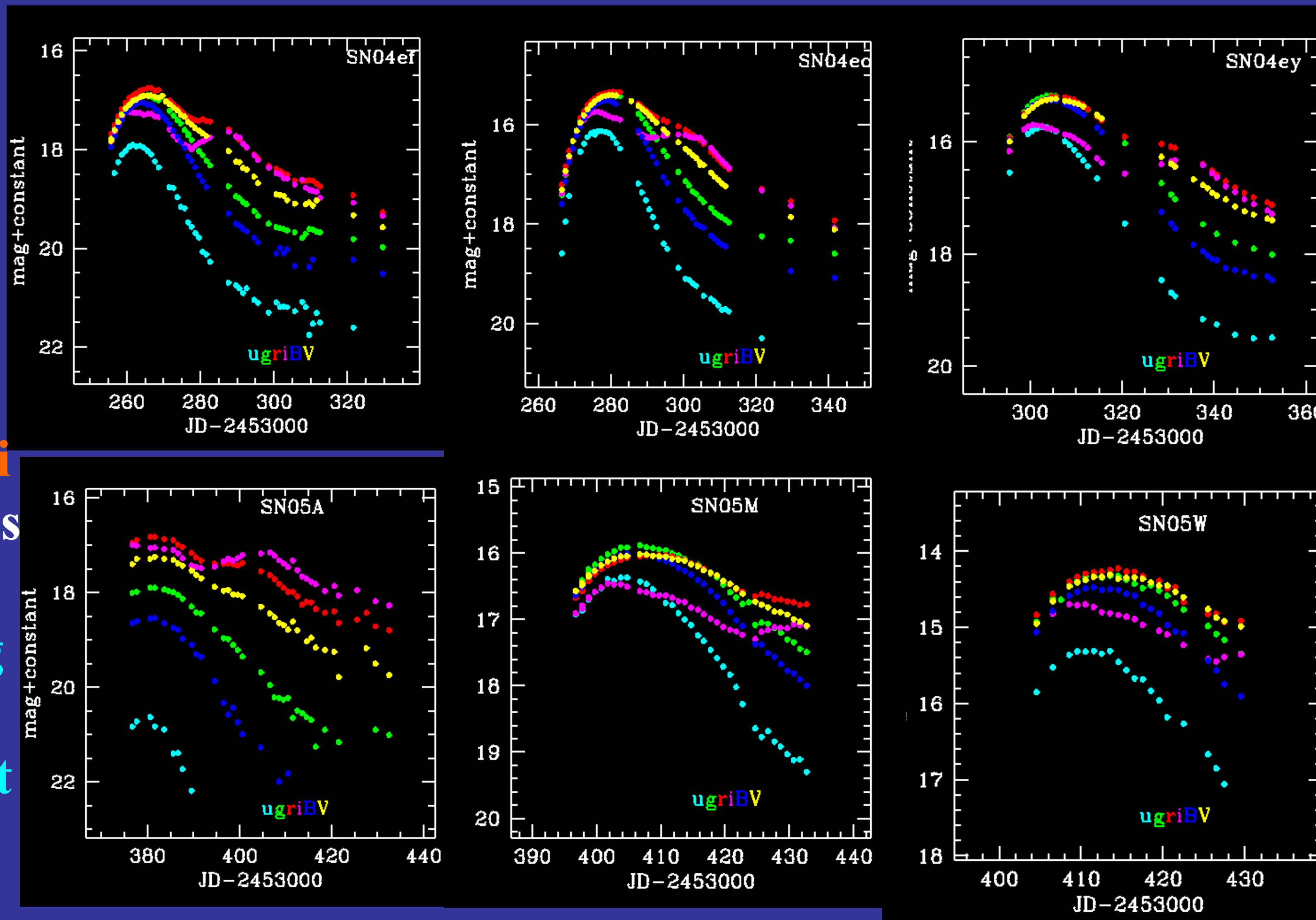
# CSP Low z Targets

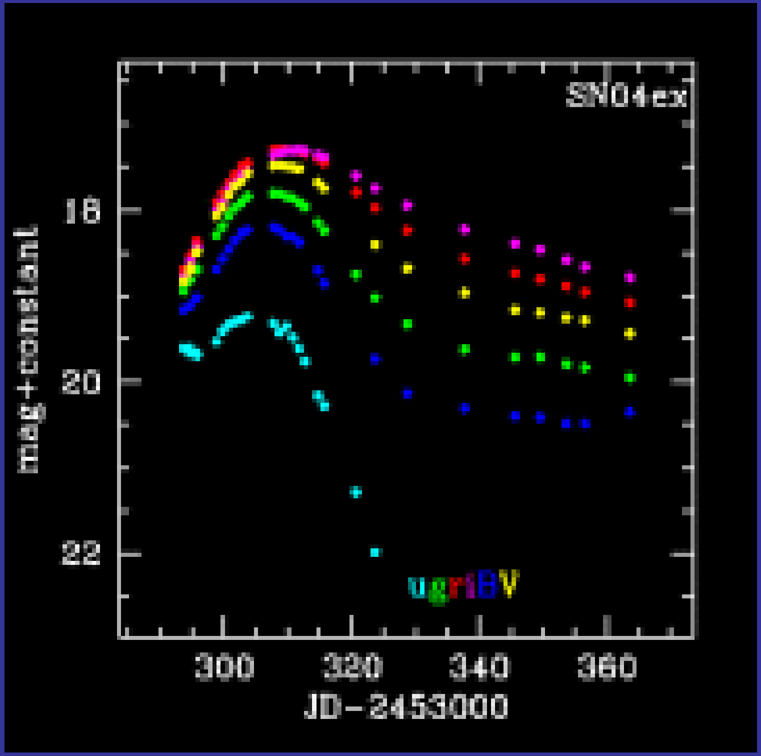
# Carnegie Supernova Project

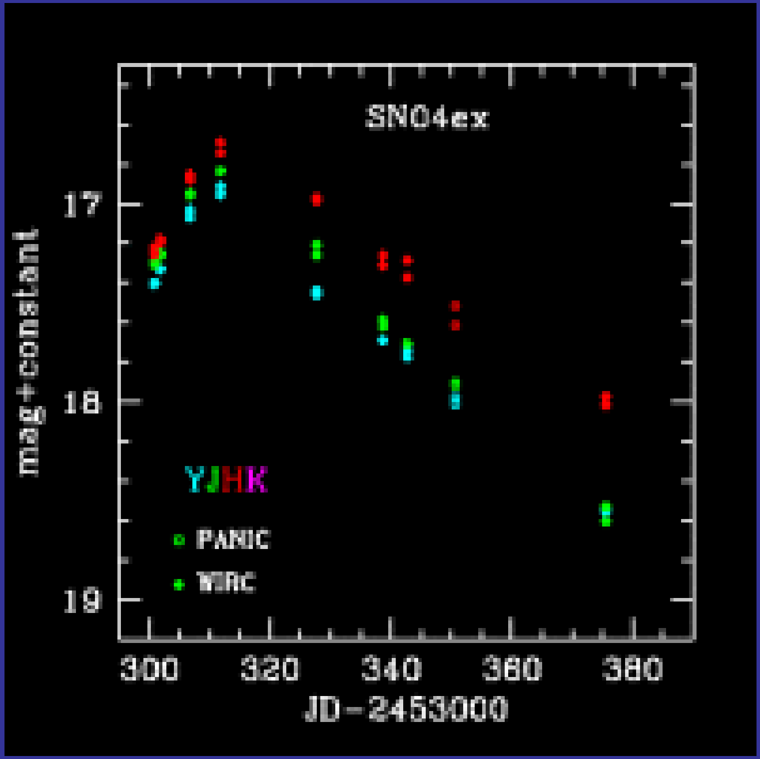
## Type Ia Supernovae

- 31 observed to date
- u’BVg’r’i light curves
- excellent sampling
- Hamuy et al. 2005, in prep.

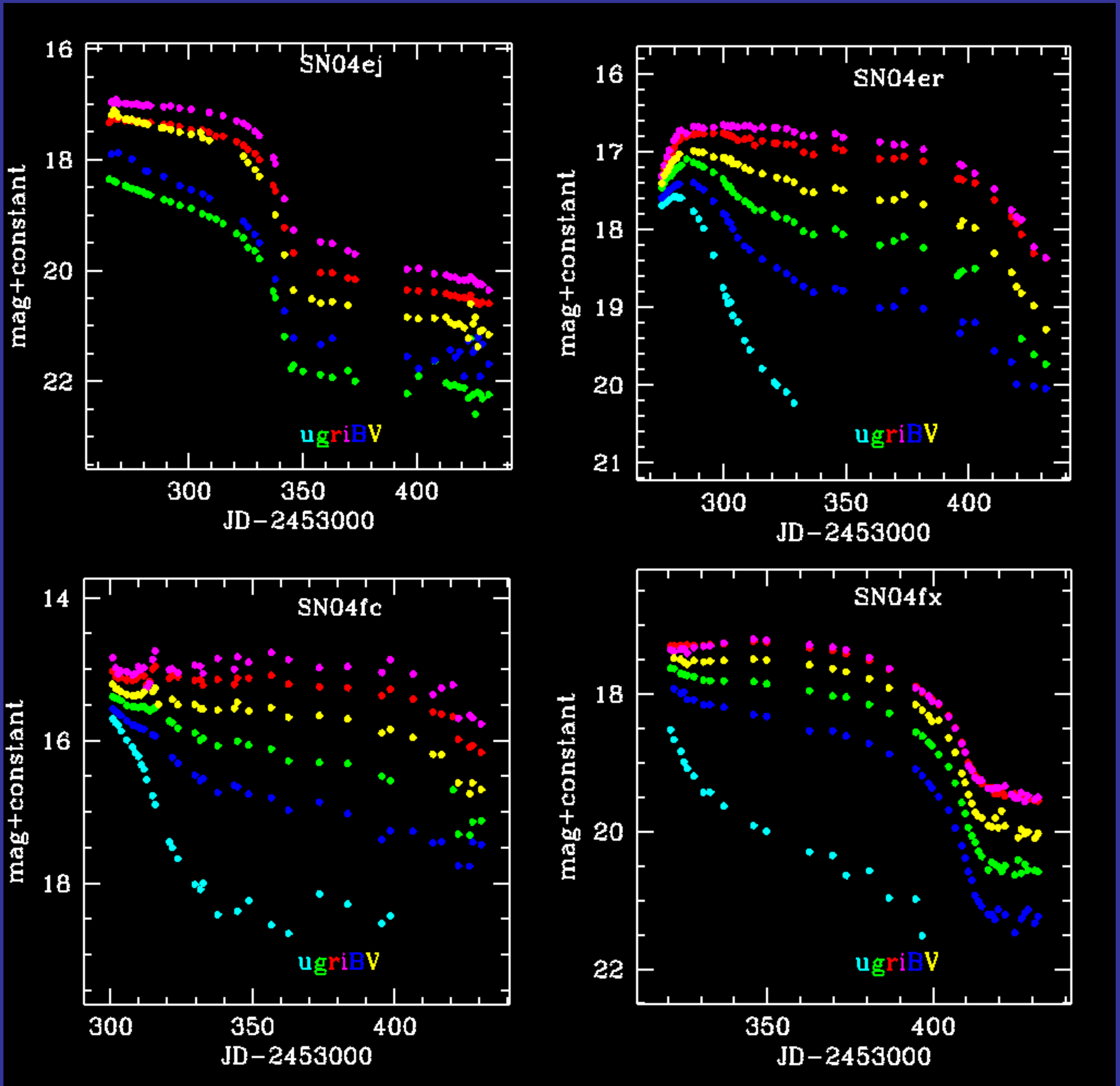


# CSP low z: optical / IR

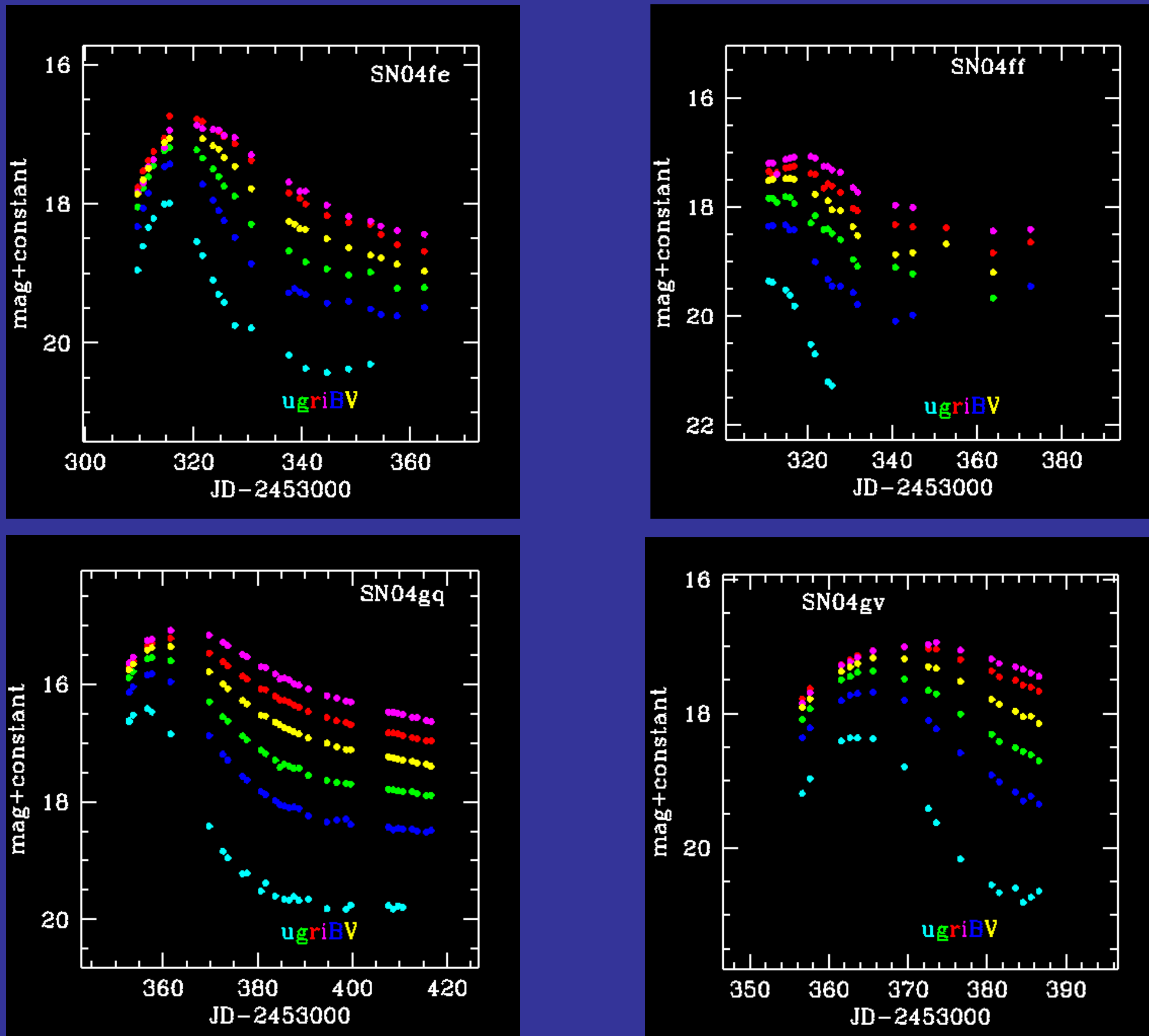


# Light curves (Type II)

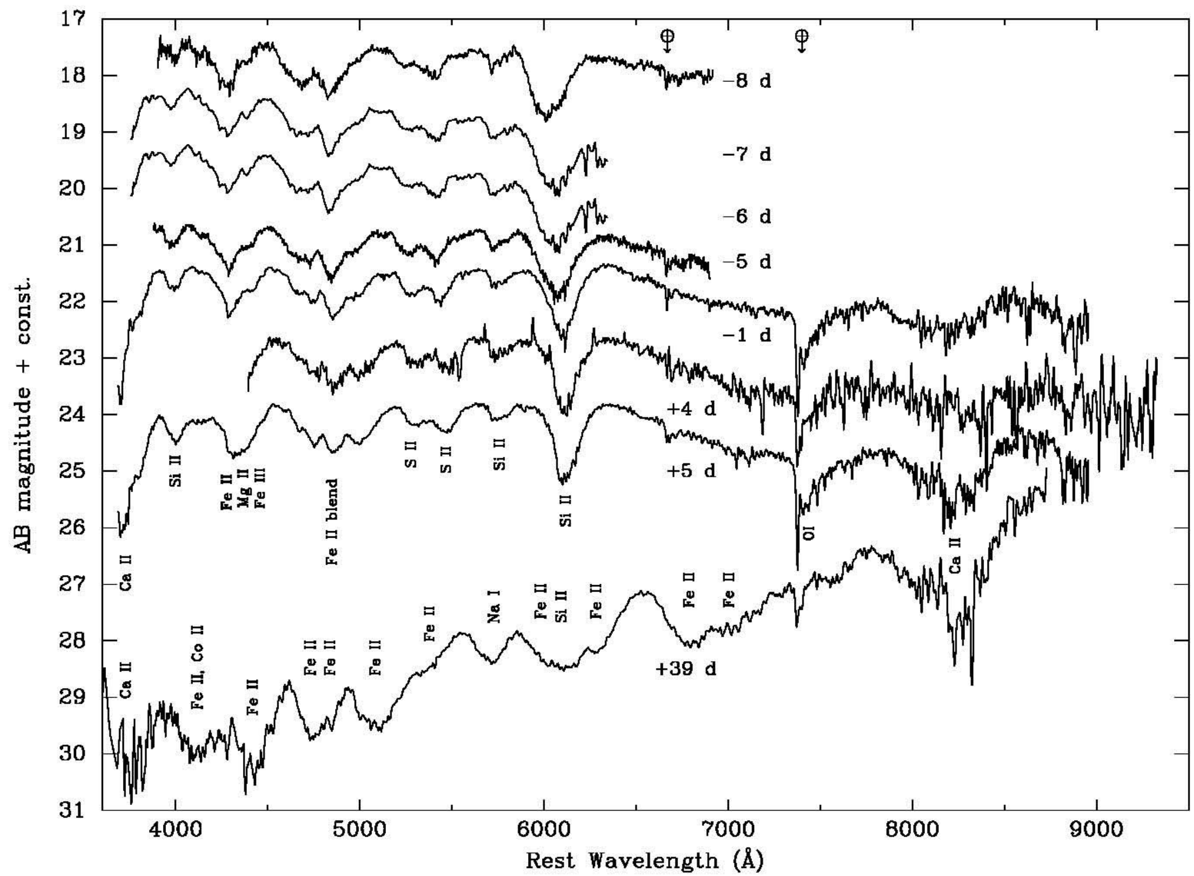


# Light curves (Type Ibc)



# Carnegie Supernova Project

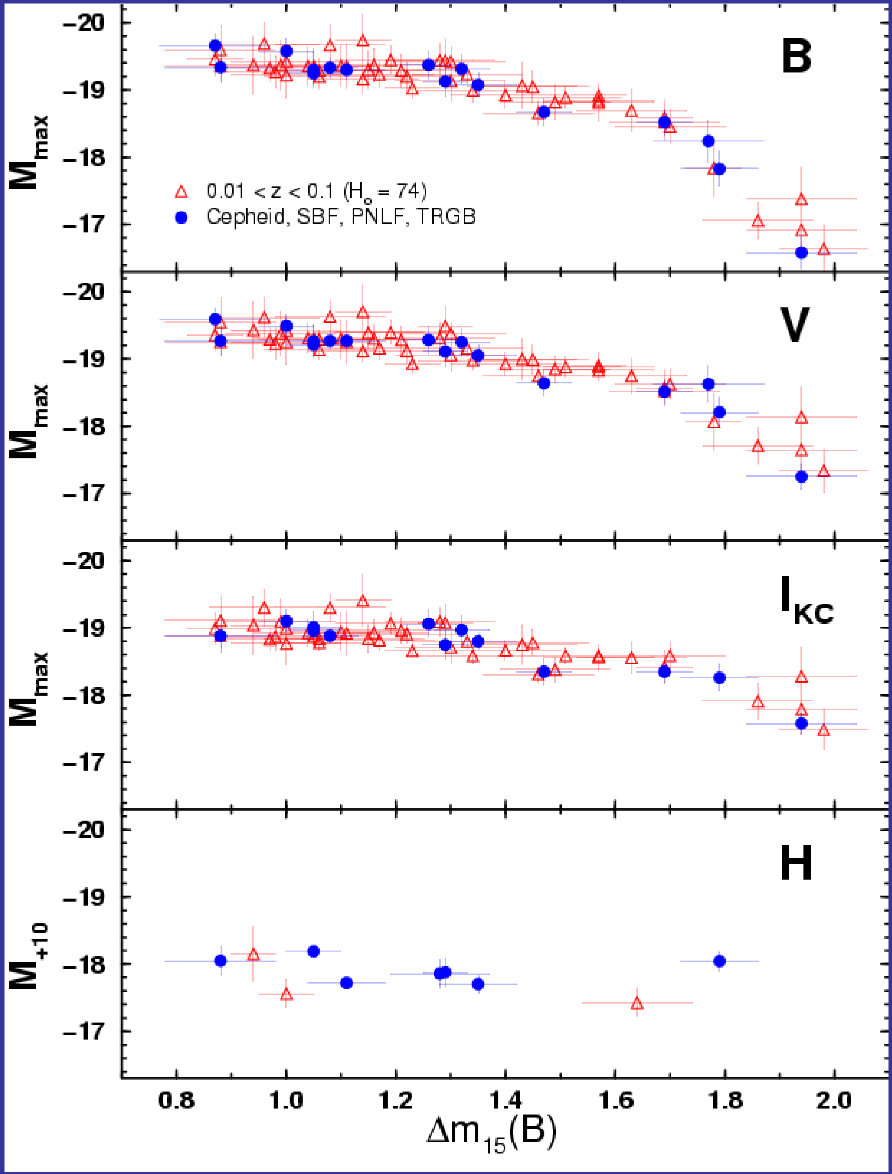
- SN 2004ef
- Type Ia
- spectra from
  C100 and
  Magellan /
  LDSS2




Nidia Morell

# Carnegie Supernova Project

- decline rate versus magnitude
- BVIH
- H-band promising as distance indicator

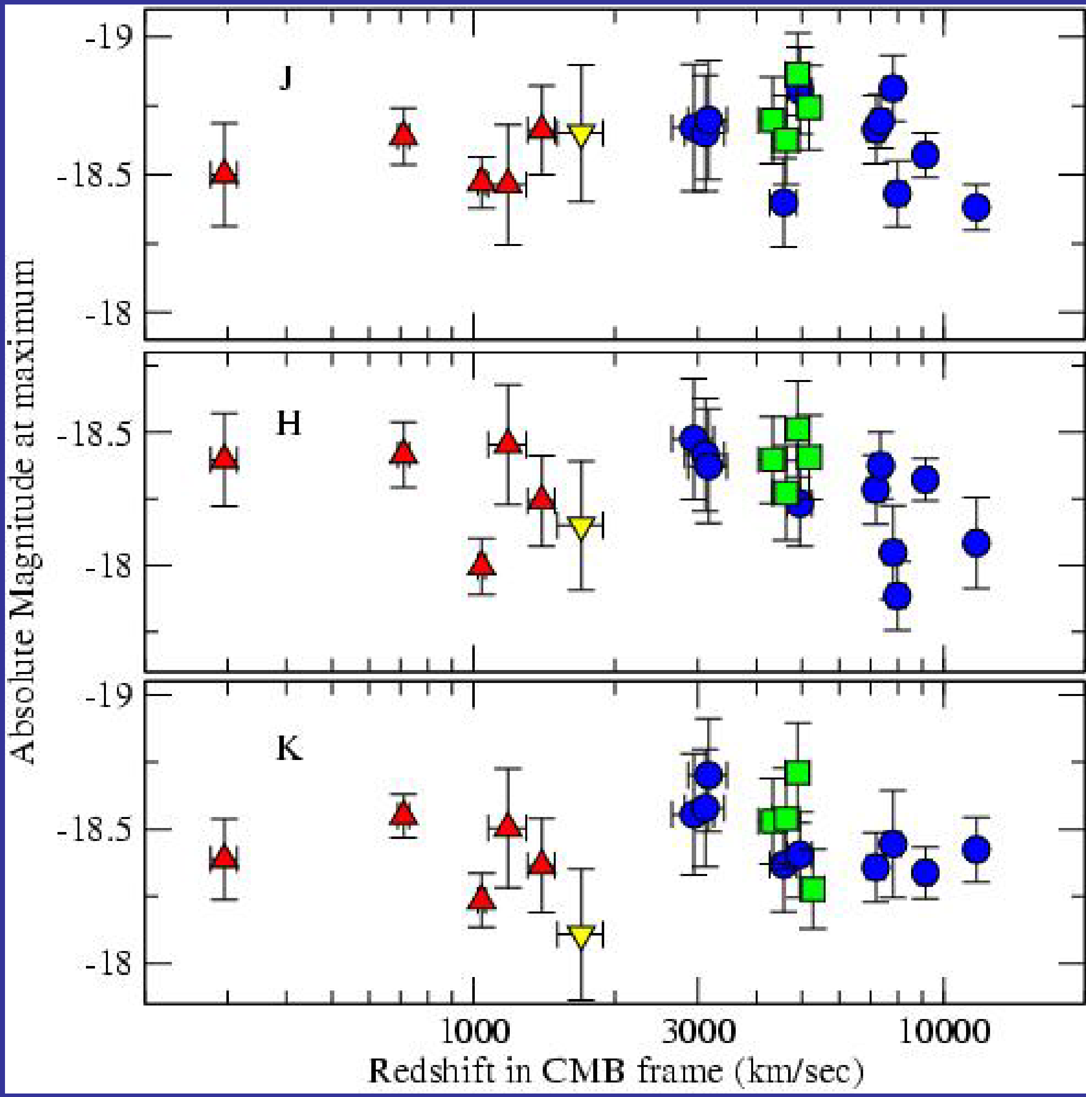



Krisciunas et al. (2002)

# Carnegie Supernova Project

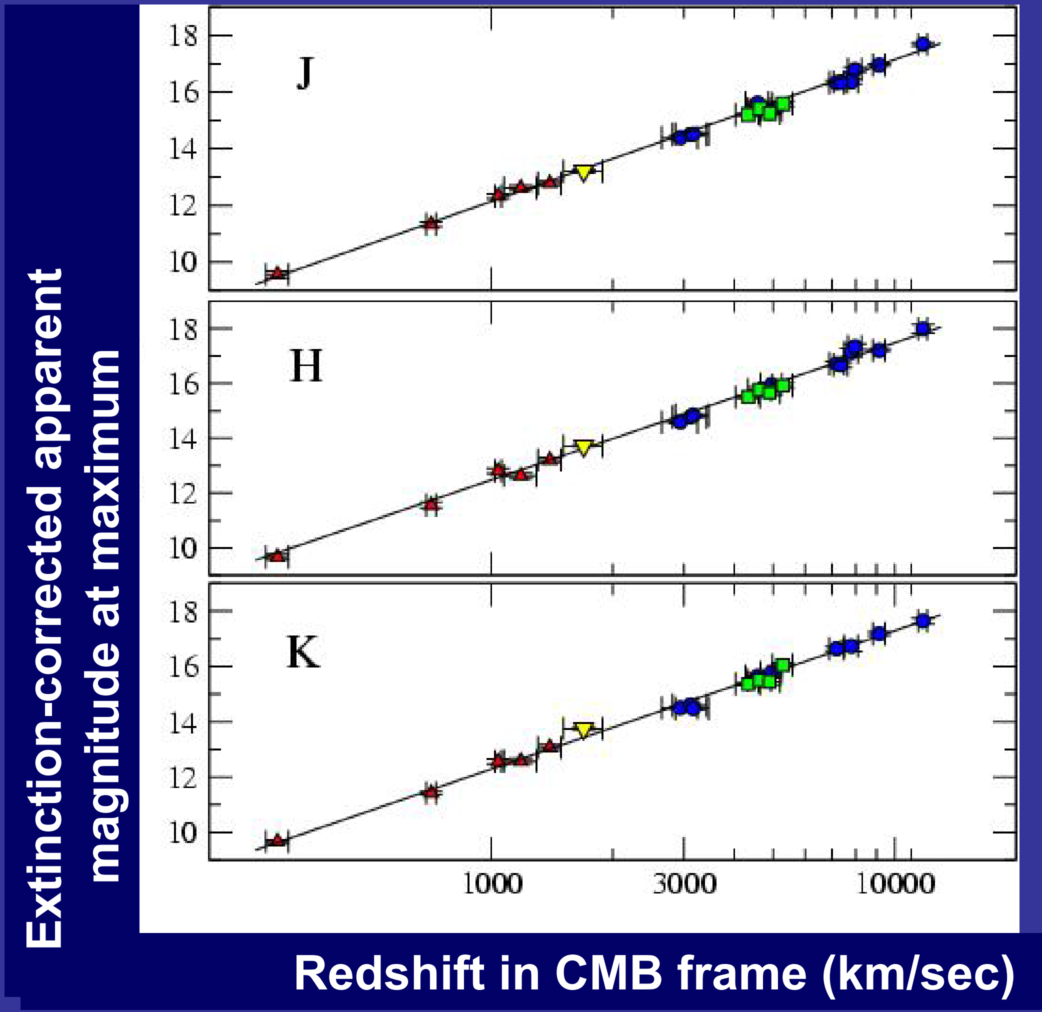
- decline rate versus magnitude
  JHK

Krisciunas et al. (2004)



# Carnegie Supernova Project

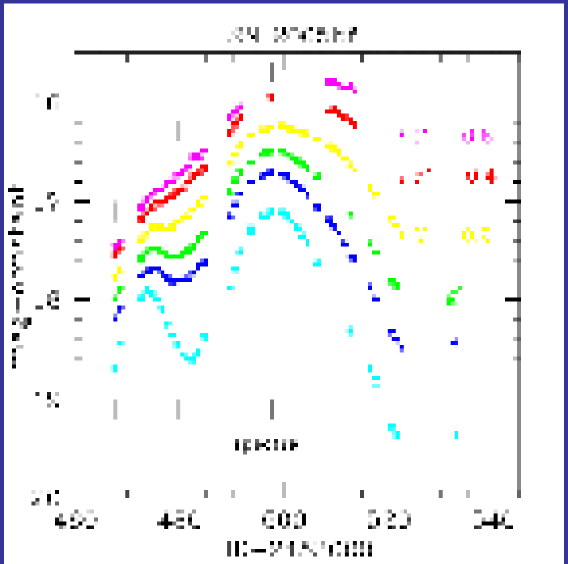
**JHK Hubble diagrams**

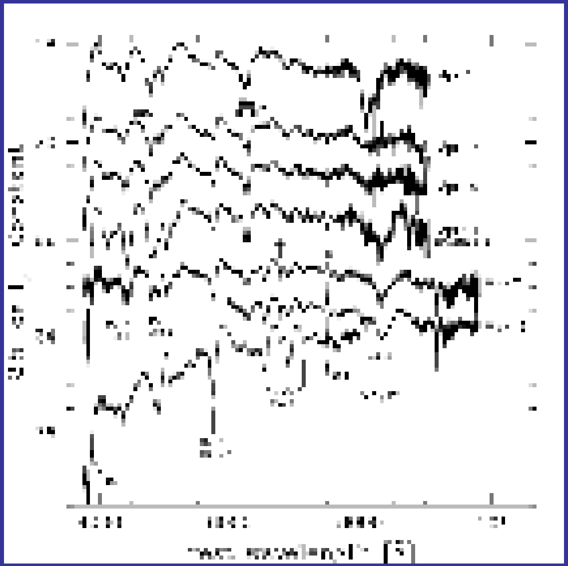



Krisciunas et al.

# SN 2005bf

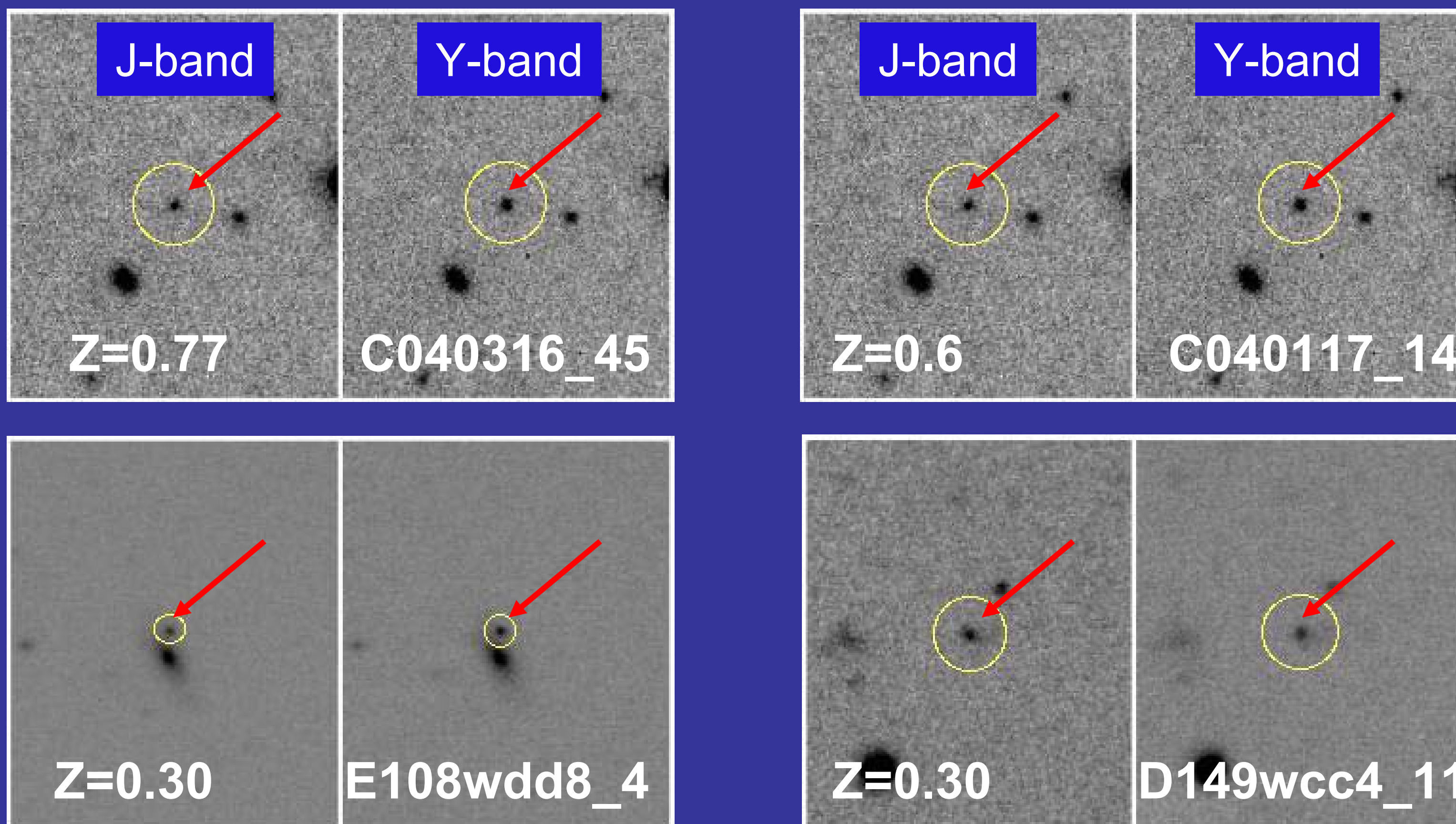
- Type Ib / c
- originally classified as Type Ic and transformed to Type Ib
- Type Ib and Ic supernovae associated with massive stars and core collapse
- GRBs: some associated with Type Ic supernovae
- initial peak 25 days before maximum light
- these behaviors never observed previously



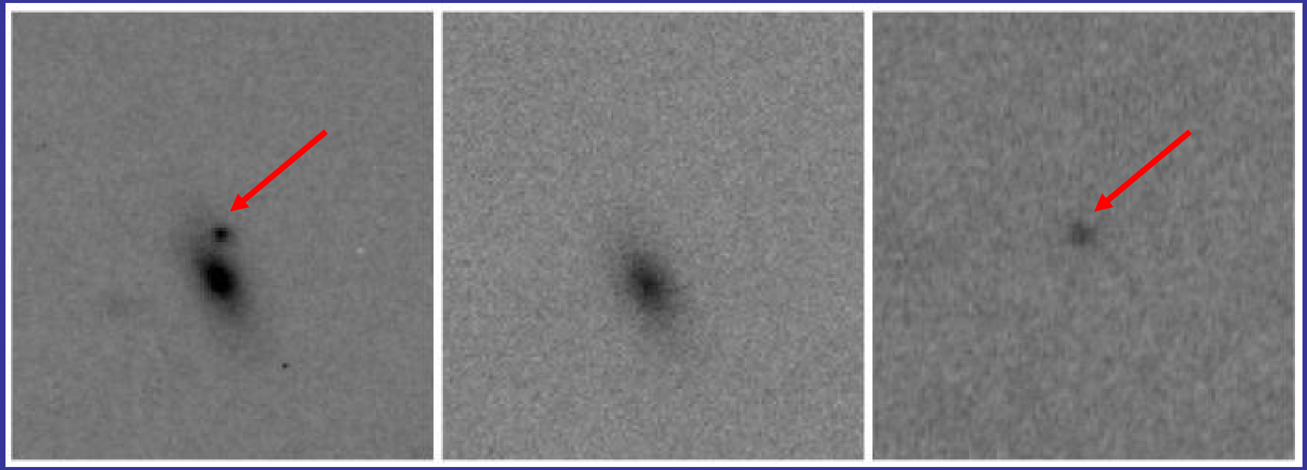


Folatelli et al. 2005, in preparation

# Magellan PANIC Supernova Images



# Magellan High-z IR Observations



Target image

Template

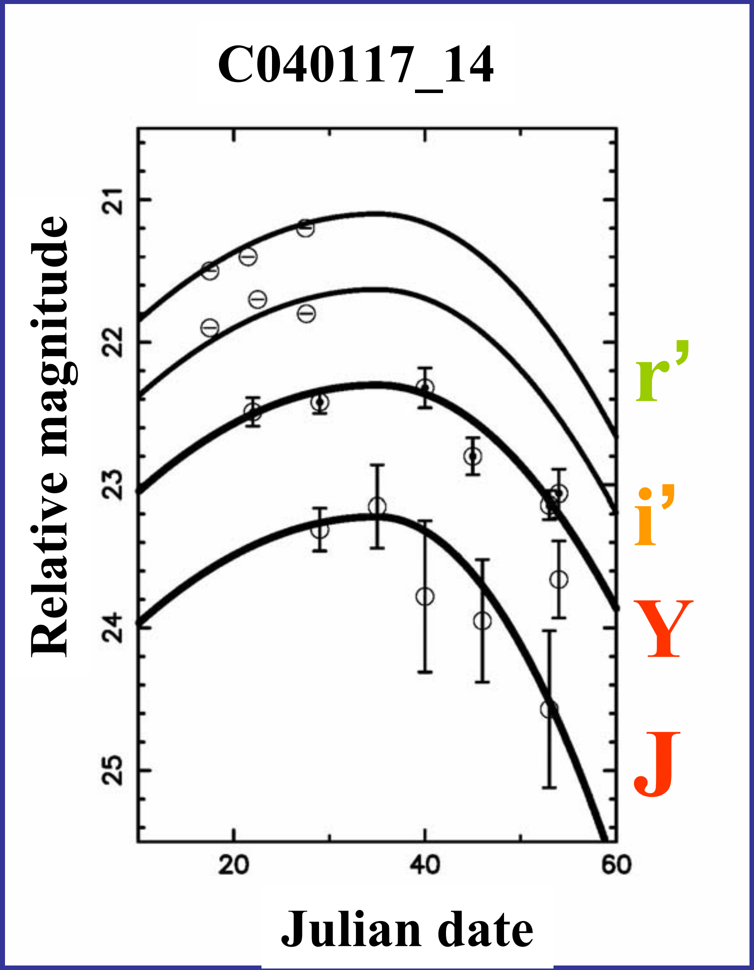
Difference image

D149wcc411

Y band

z = 0.3 ESSENCE object

# Magellan High-z Observations




Stay tuned…

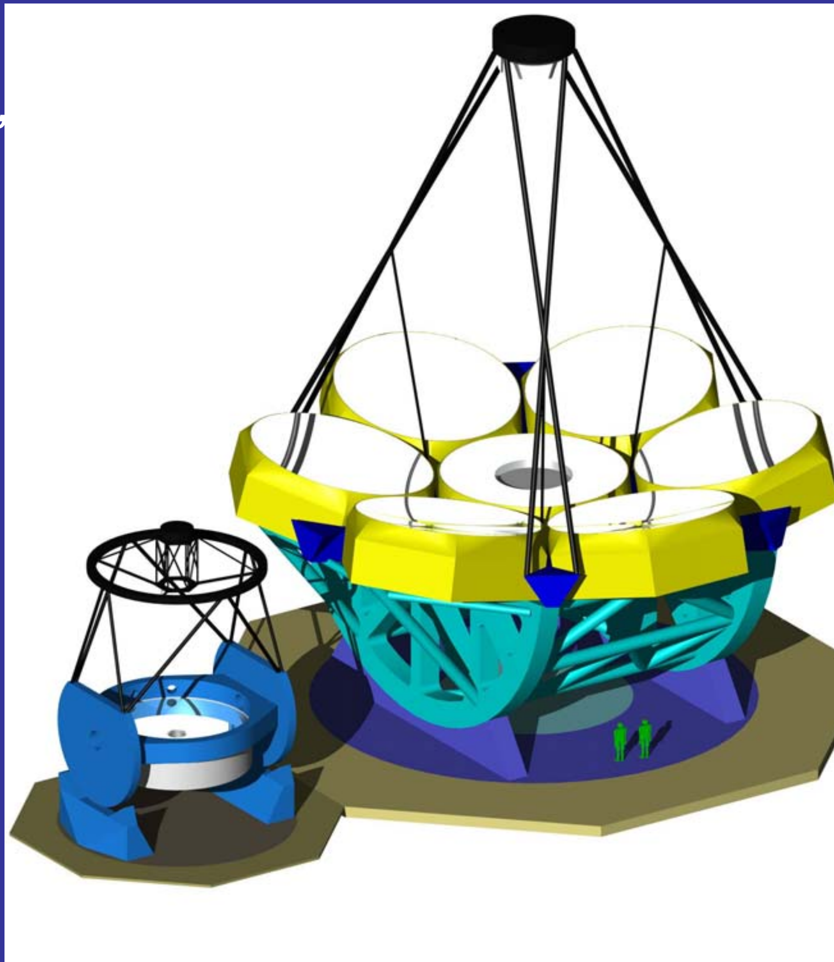
z = 0.6 SNLS object

# Future Plans (Carnegie High z)

## *The Giant Magellan Telescope (GMT)*

Supernovae 1<z<2

- *Roger Angel mirrors*
- *Seven 8.4-meter mirrors; f/0.7*
- 21.5-meter aperture, 25.3-meter baseline
- *A consortium of partners currently including Carnegie, Harvard/Smithsonian, University of Arizona, Texas A&M, University of Texas Austin, MIT and the University of Michigan*
- *Funds are in place for the 18-month conceptual design phase*



*Highest Priority Capabilities:*

1. Narrow field, high dynamic range AO

2. Wide field, optical spectroscopy

*Dark Matter (lensing) and dark energy studies.*