Cosmological Results from the SNLS
(and some connections with host galaxies)

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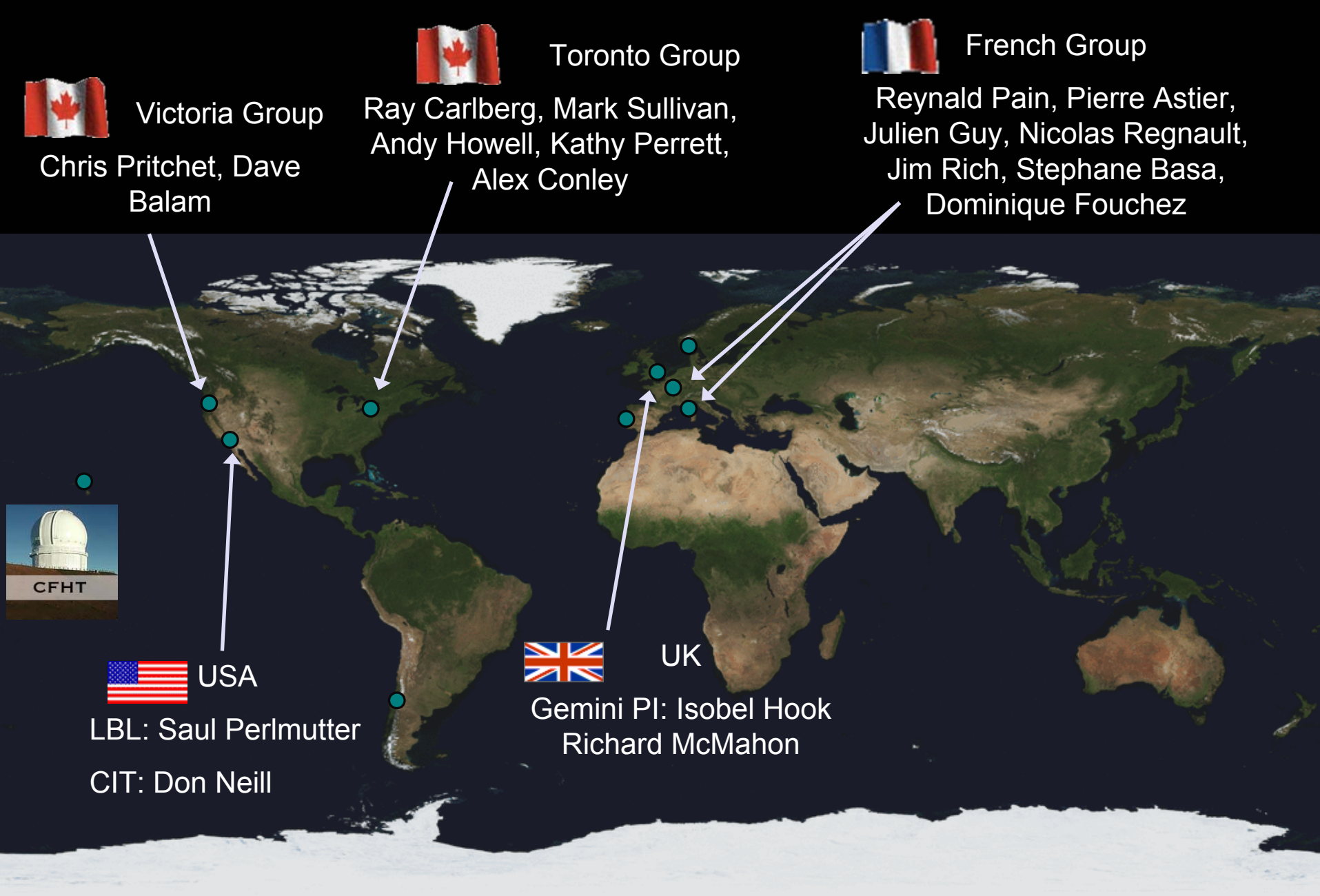
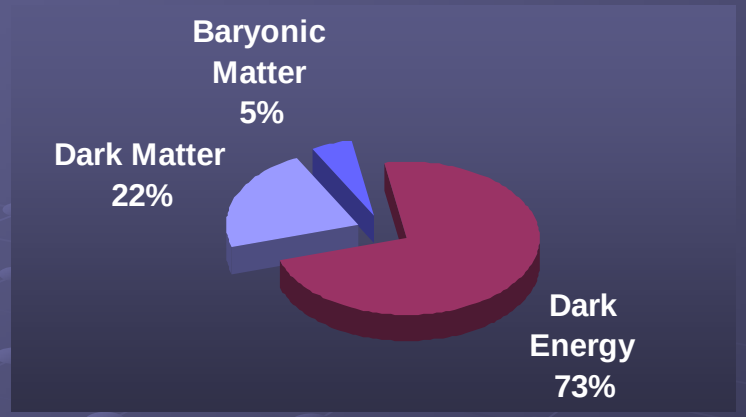


Full list of students and associates at: http://cfht.hawaii.edu/SNLS/

How do we measure dark energy?

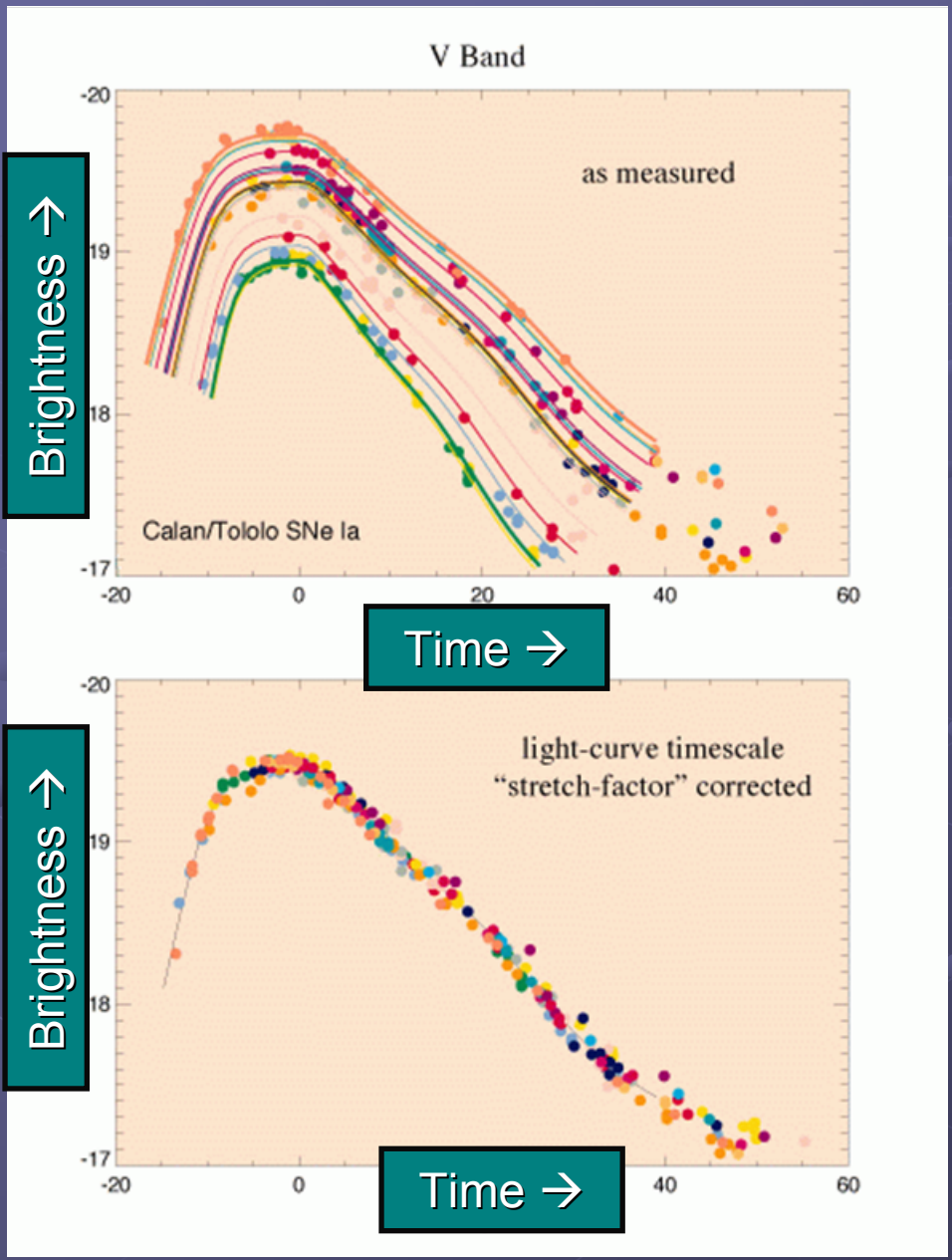
$$H^2(a) = H_0^2\left[\Omega_m a^{-3} + \Omega_k a^{-2} + \Omega_X a^{-3(1+w)}\right]$$

Matter component | Curvature | **Dark energy component**



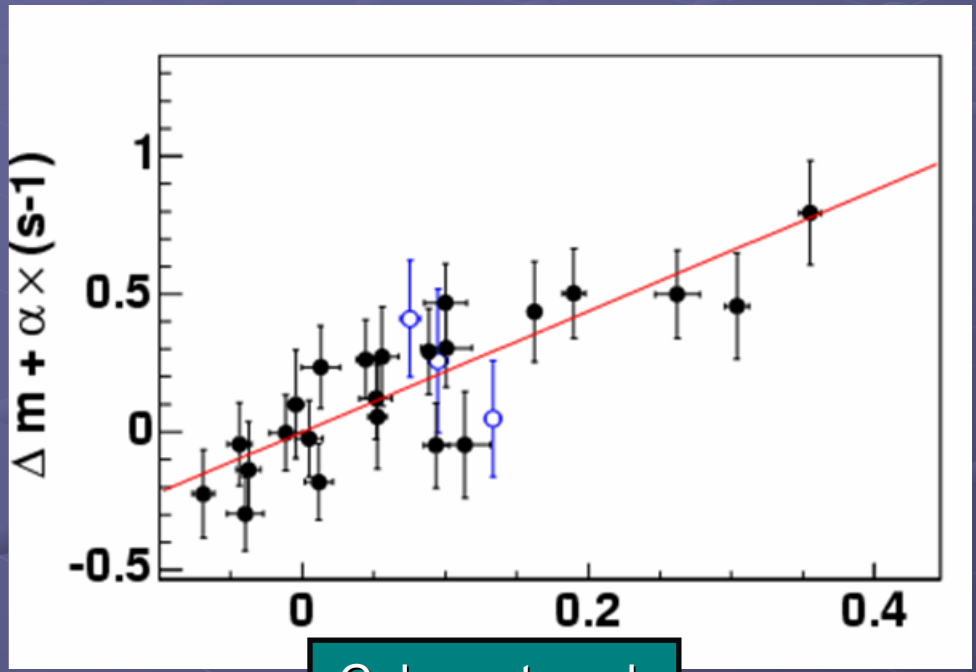
- w=P/ρ
- Broad possibilities for Ω_X or dark energy
  - "Cosmological constant": w=-1 across space and time
  - "Quintessence" class models: w>-1
  - "Phantom energy": w<-1 *(GR incomplete?)*
- Determine w(a) for dark energy component
  1. Is <w> consistent with -1 ?
  2. Is w constant?
  3. What is w(a) ?

Making a standard candle



1. "*Phillips relation*": A correction to SN Ia light-curves based on light-curve shape drastically improves the quality of the standard candle.

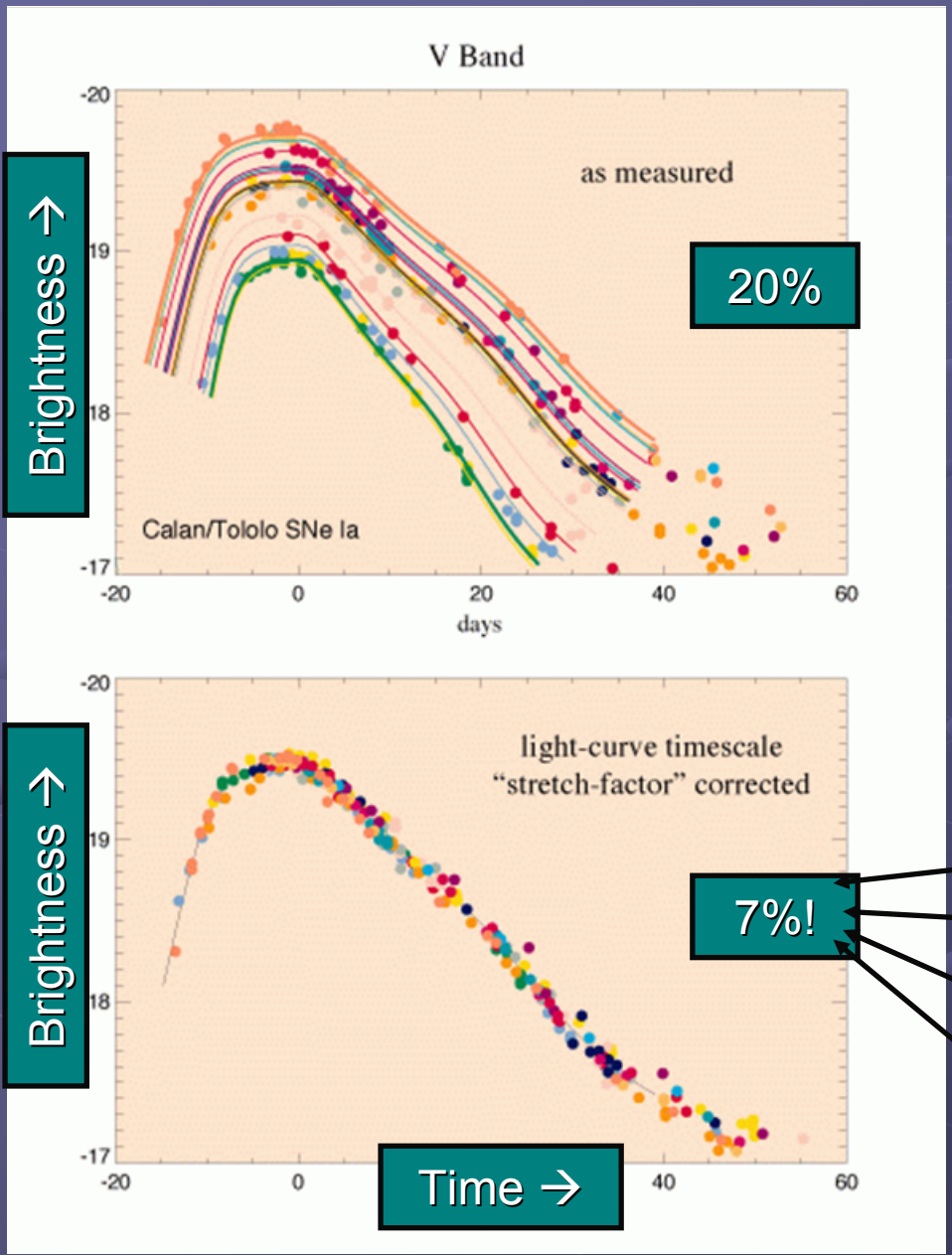
Making a standard candle



1. "*Phillips relation*": A correction to SN Ia light-curves based on light-curve shape drastically improves the quality of the standard candle.

2. SN colour: A correction to the SN luminosity based on the SN colour

Making a standard candle



1. "*Phillips relation*": A correction to SN Ia light-curves based on light-curve shape drastically improves the quality of the standard candle.

2. SN colour: A correction to the SN luminosity based on the SN colour

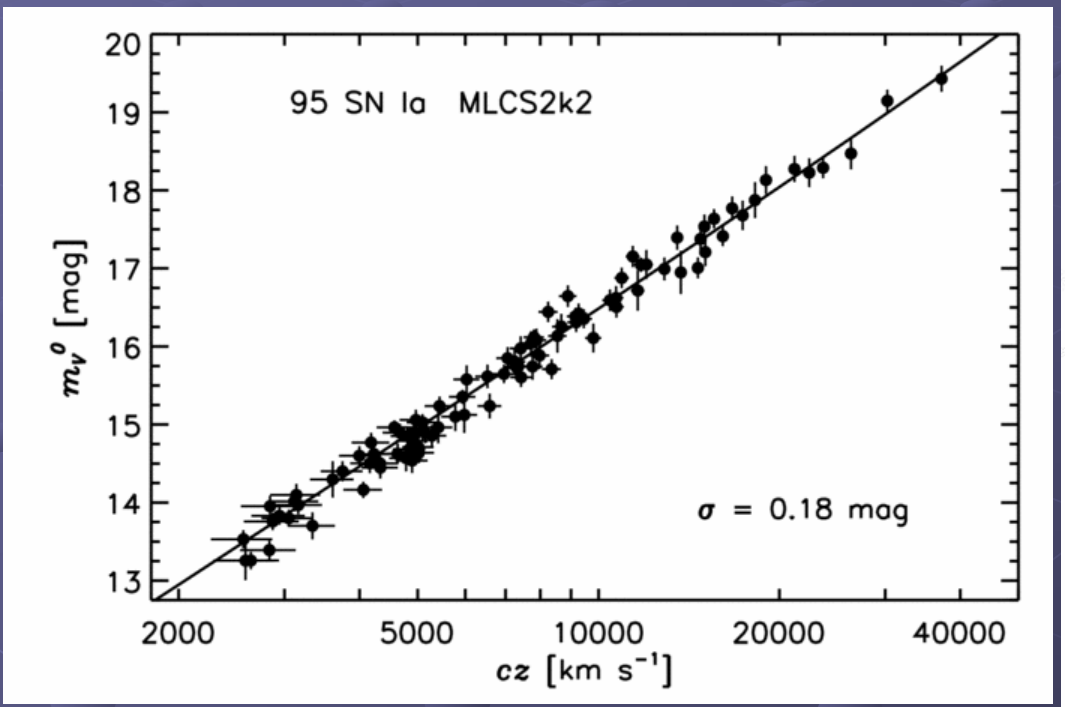
Many methods:

- Stretch – Perlmutter 97, 99
- (M)LCS(2k2) – Riess, 95,96, Jha 07
- SALT(2) – Guy 05, 07
- CMAGIC – Wang et al., Conley et al.
- Δm_{15} – Phillips 93; Hamuy 95; Prieto 06

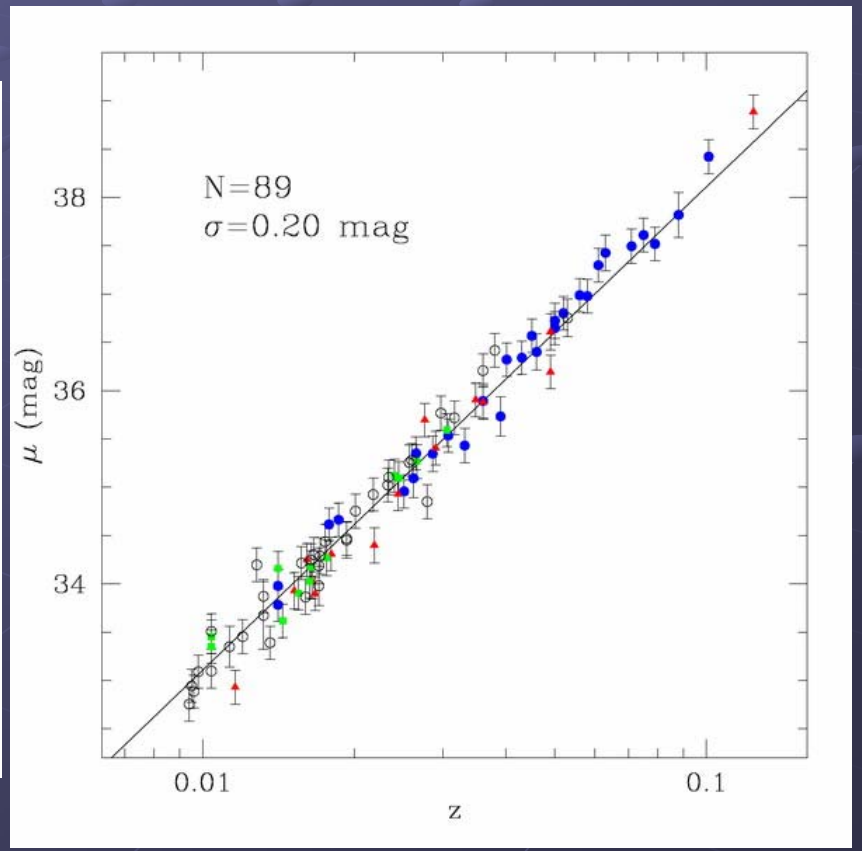
“Local” SN Ia Hubble Diagrams

Most light-curve fitting techniques fare equally well

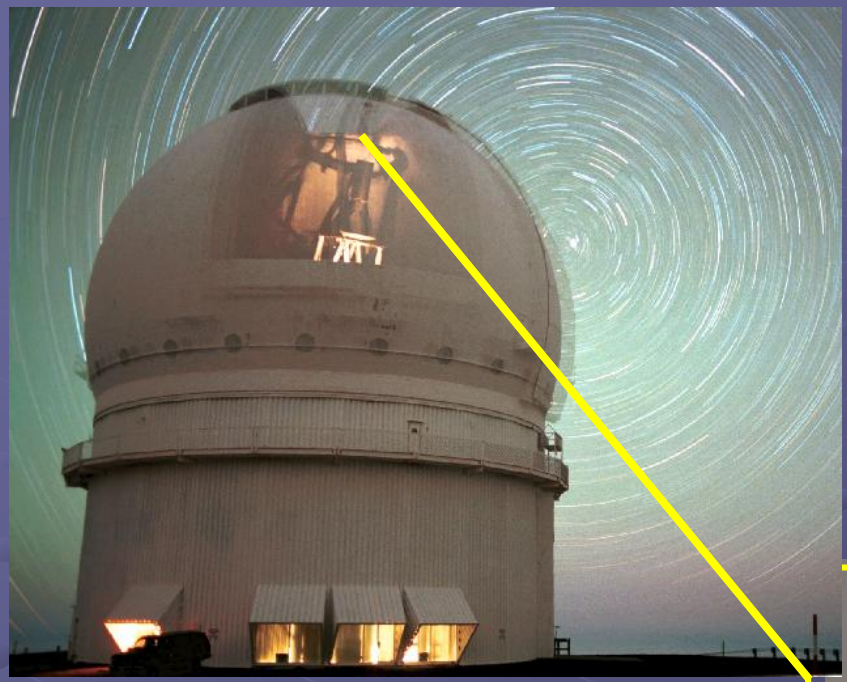
Jha et al. 2007



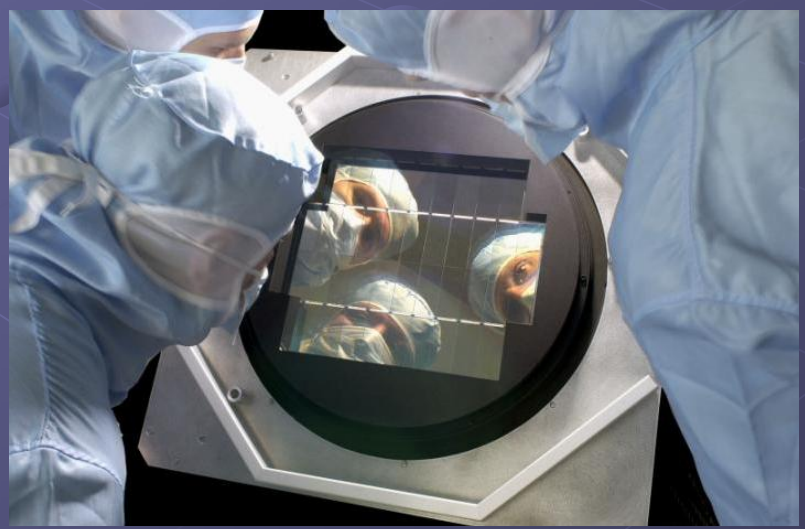
Prieto et al. 2006

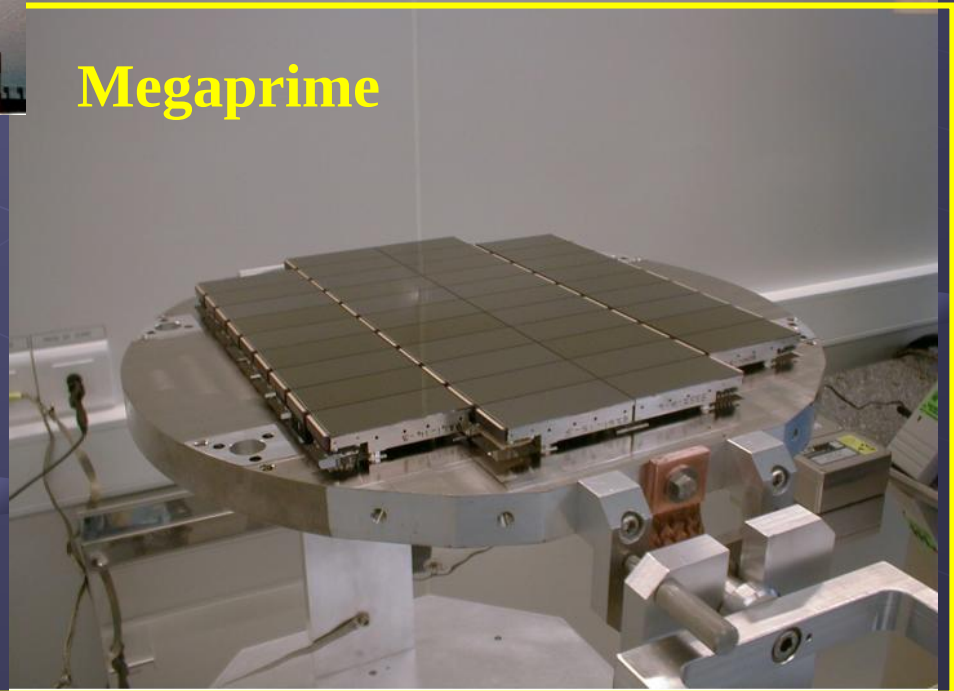


Supernova Legacy Survey (2003-2008)



- 5 year survey, goal: 500 distant SNe Ia to measure “w”
- Uses CFHT/“Megacam”
- 36 CCDs, good blue response
- 4 filters for good k-corrections and color measurement

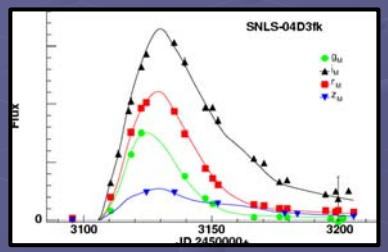




Supernova Legacy Survey

Imaging

Distances from light-curves

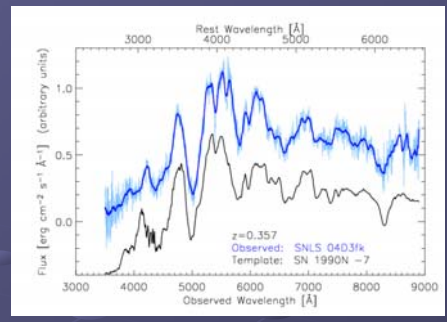


Discoveries **Lightcurves**

g'r'i'z' every 4 days during dark time

Spectroscopy

Redshifts ➔ Distances from cosmological model



Gemini N & S (120 hr/yr)

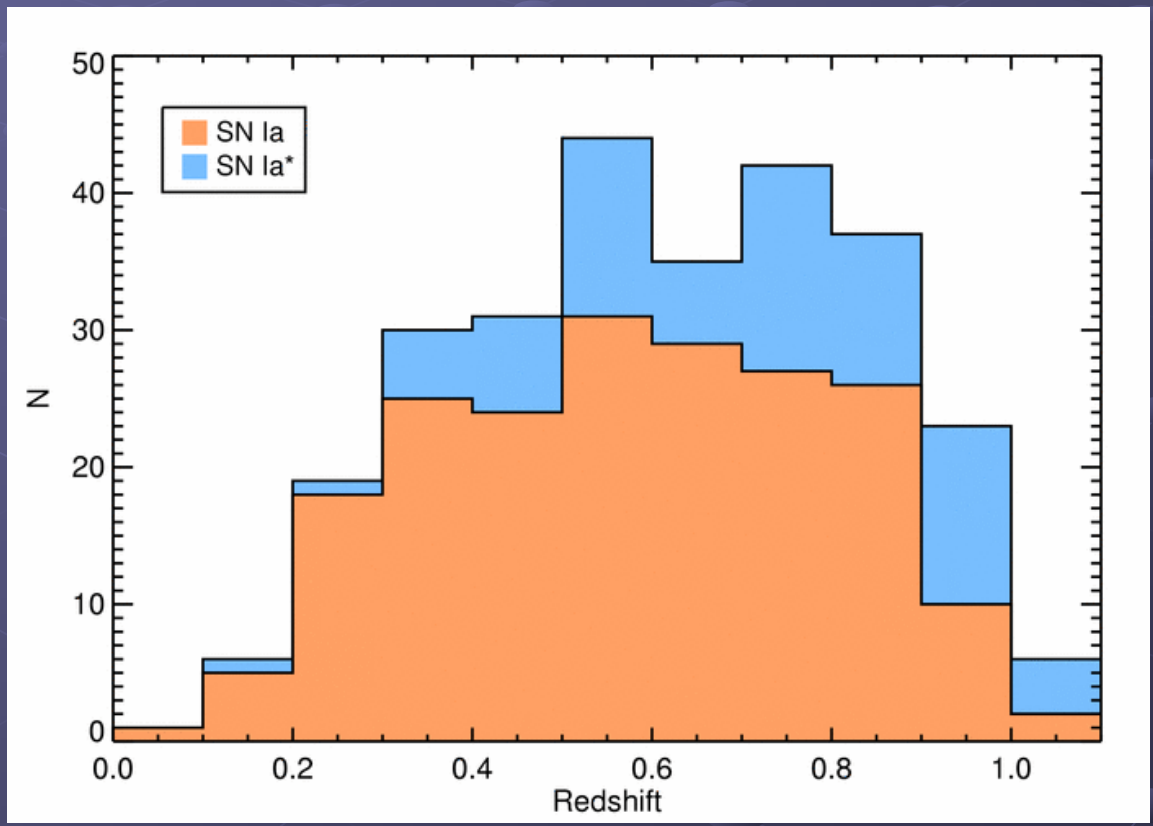
VLT (120 hr/yr)

Keck (8 nights/yr)

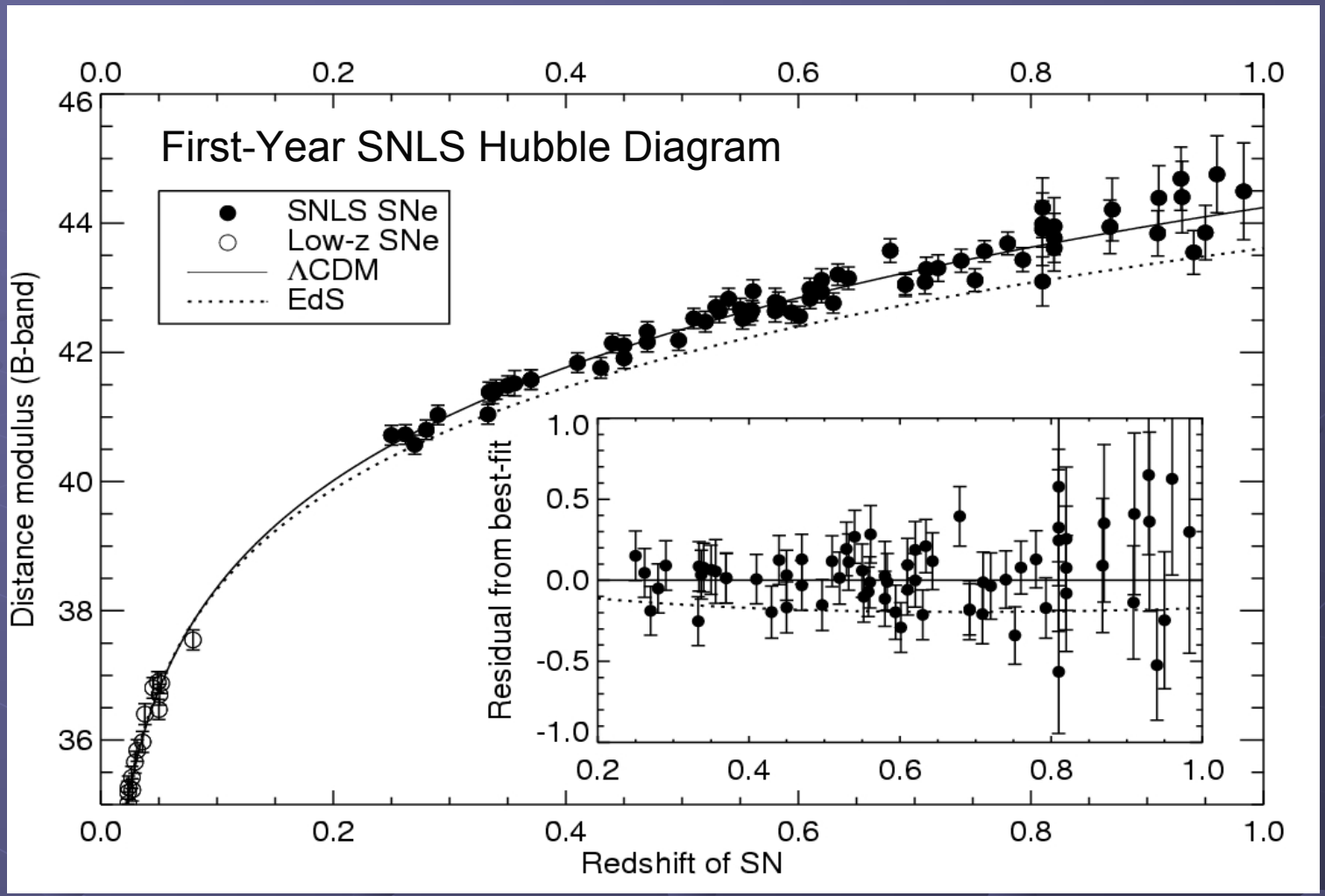
Magellan (Host galaxies)

Current status

- Survey running for 3.5 years
- >300 confirmed distant SNe Ia
  - Largest single telescope sample of (high-z ?) SNe Ia
  - “On track” for 500 **spectroscopically confirmed** SNe Ia by survey end (2000 in total)



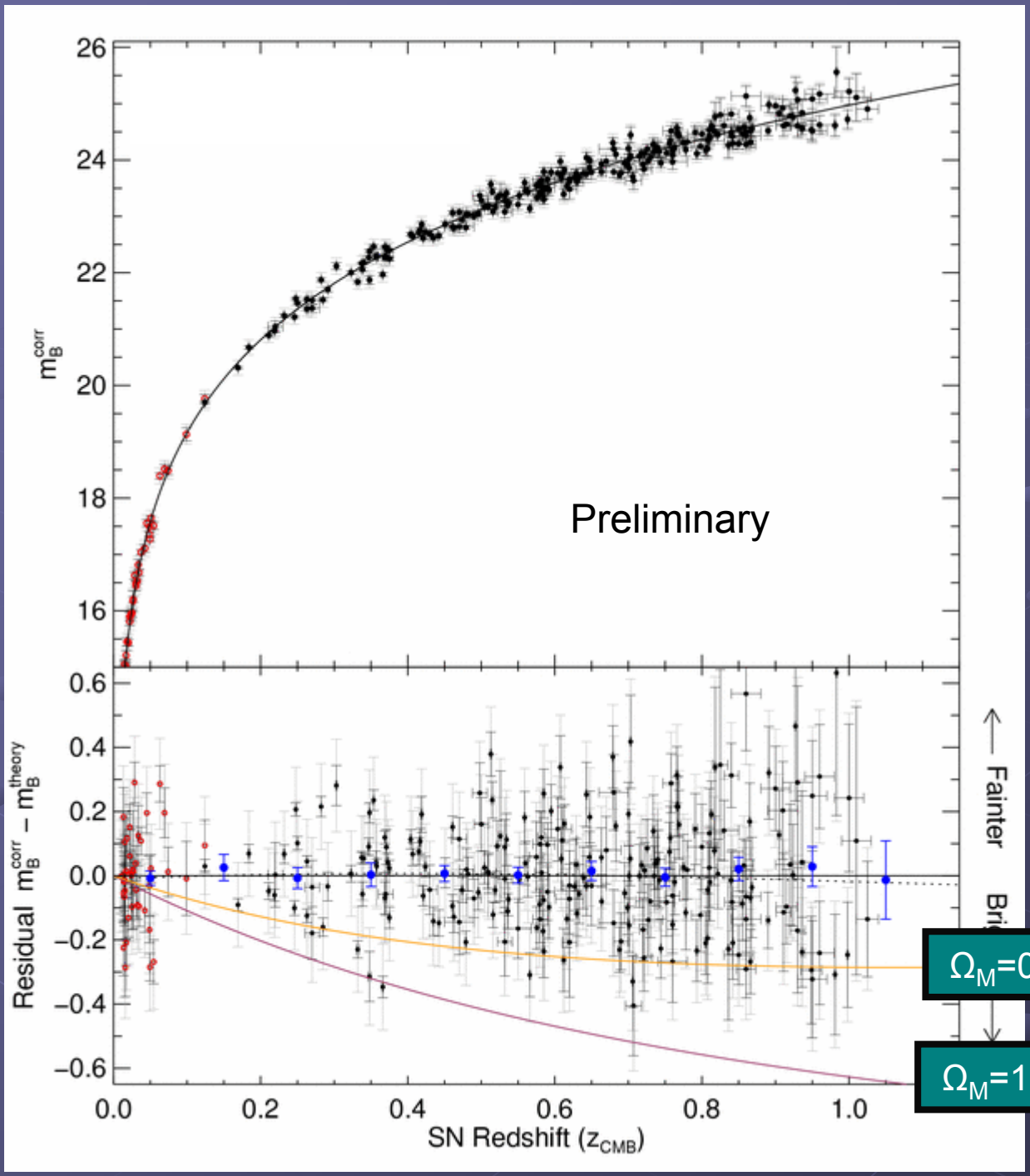
SNLS 1st year



$$\mu_B = m_B - \mathrm{M}_B + \alpha(s-1) - \beta \times c$$

Astier et al. (2006)

"Third year" SNLS Hubble Diagram (**preliminary**)



250 High-z SNe Ia

Independent analysis and calibration to A06

Best-fit for SNLS+flatness

$$\Omega_M = 0.26^{+0.03}_{-0.03}$$

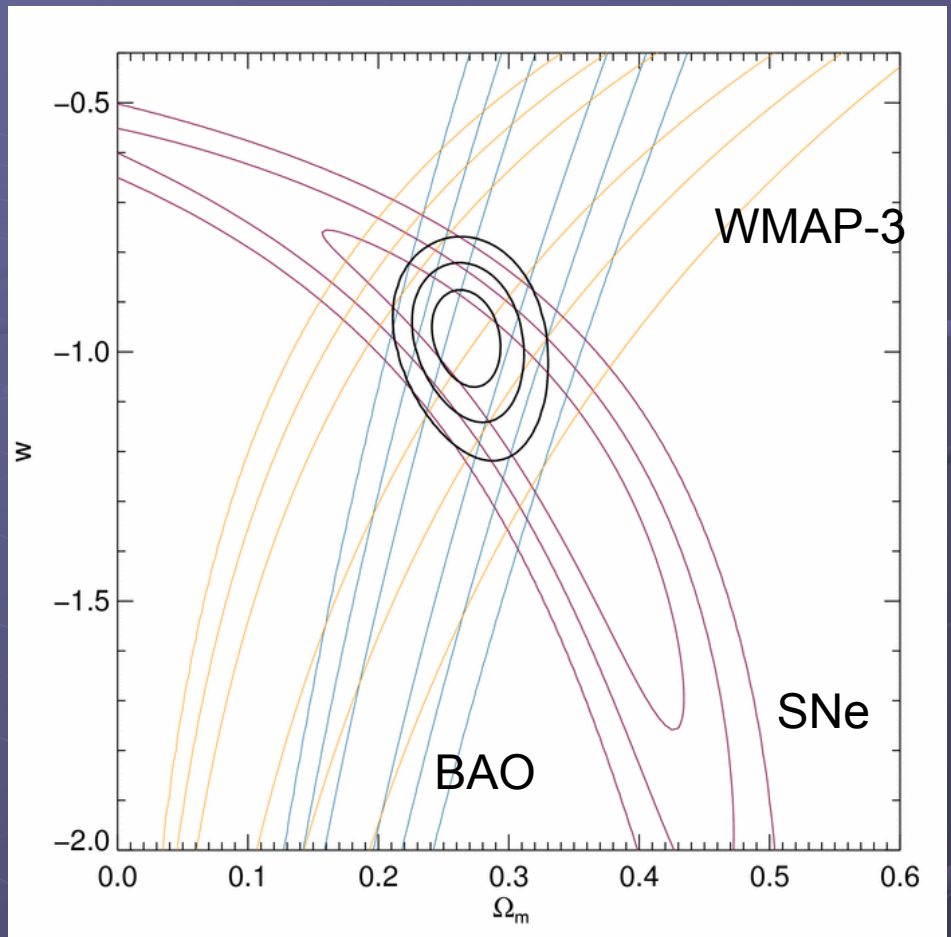
Ω_M=0.3, Ω_λ=0

Ω_M=1.0, Ω_λ=0

Sullivan et al. 2007

Cosmological Constraints (**Preliminary**)

SNLS + BAO + simple WMAP + Flat



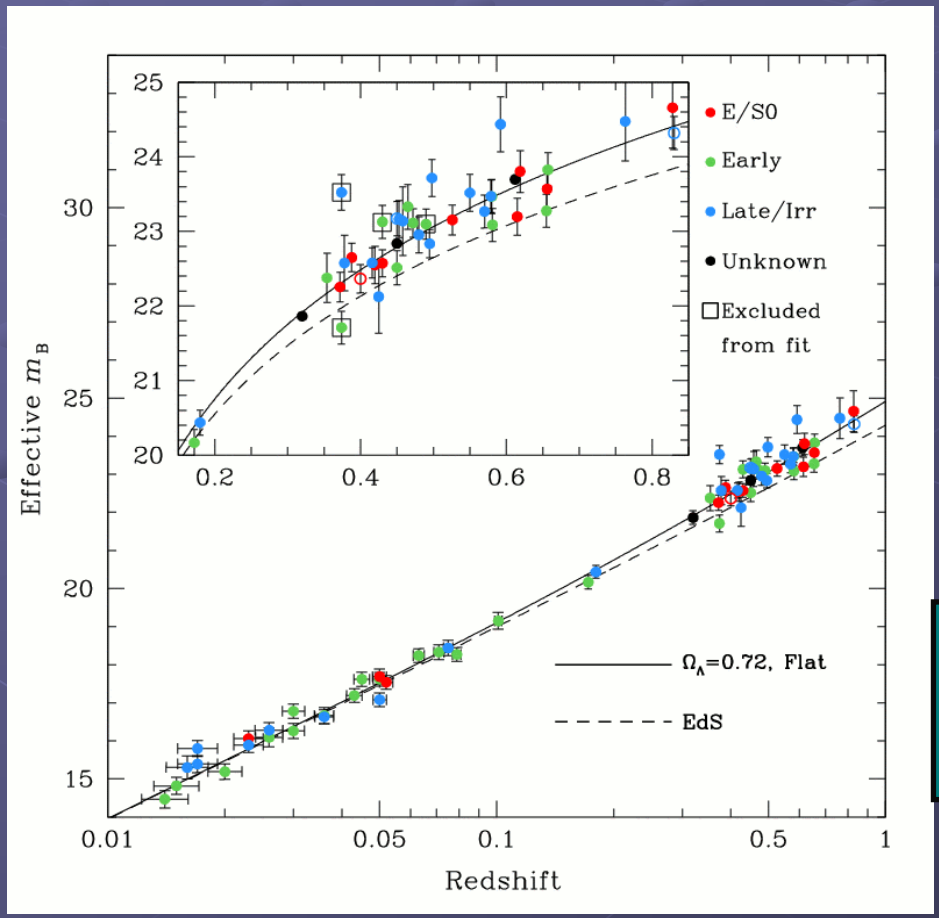
7% measure of w

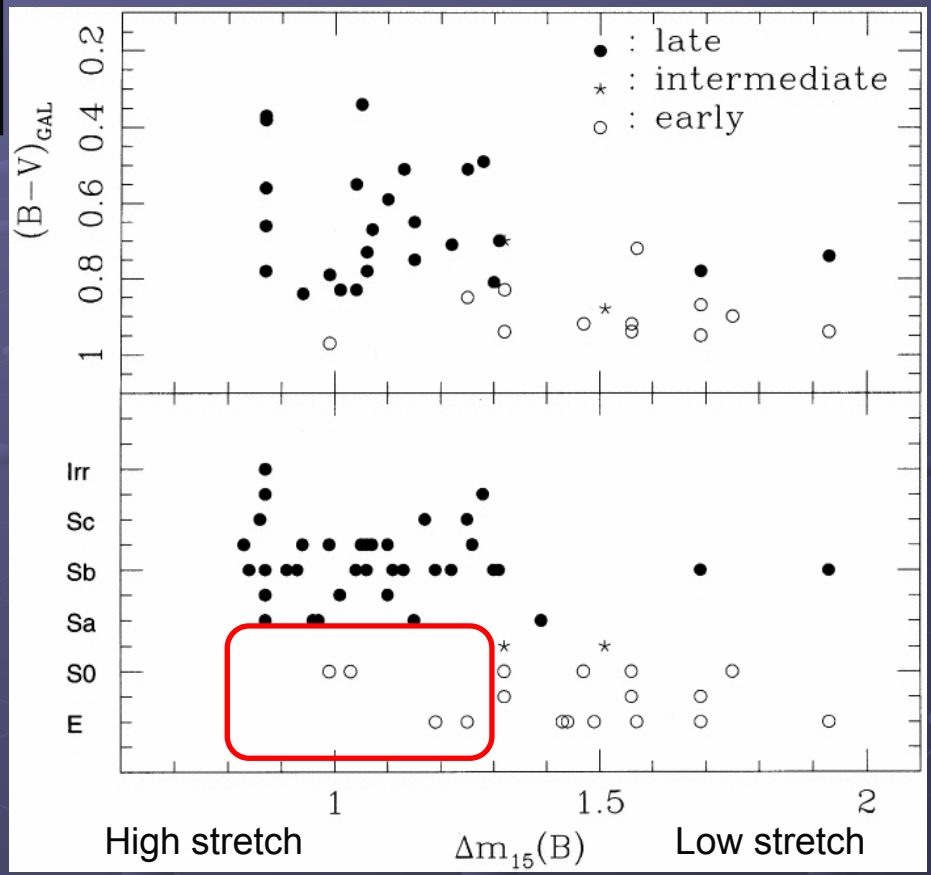
Coming soon: w(a); <w> in a non-flat Universe; Full WMAP-3 analysis (CosmoMC); Riess et al. (2007) added in

Host galaxies impact SN properties

SN Ia Light-curve shape depends on morphology

e.g. Hamuy et al. (2000)

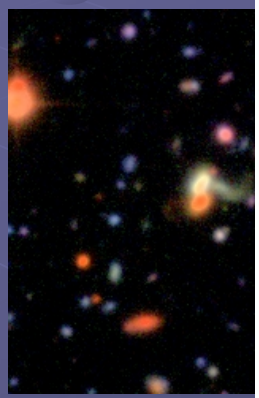


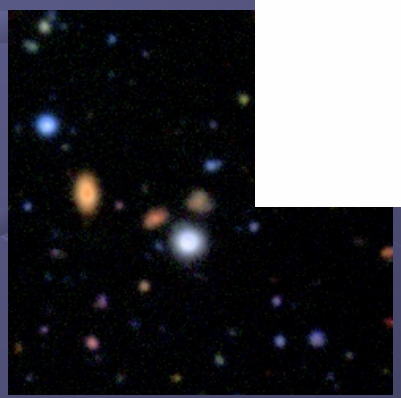


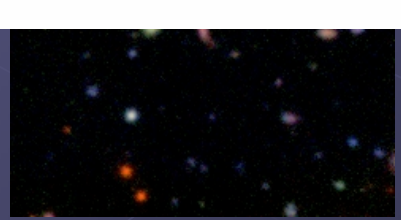
Some evidence that SNe Ia in ellipticals show smaller scatter

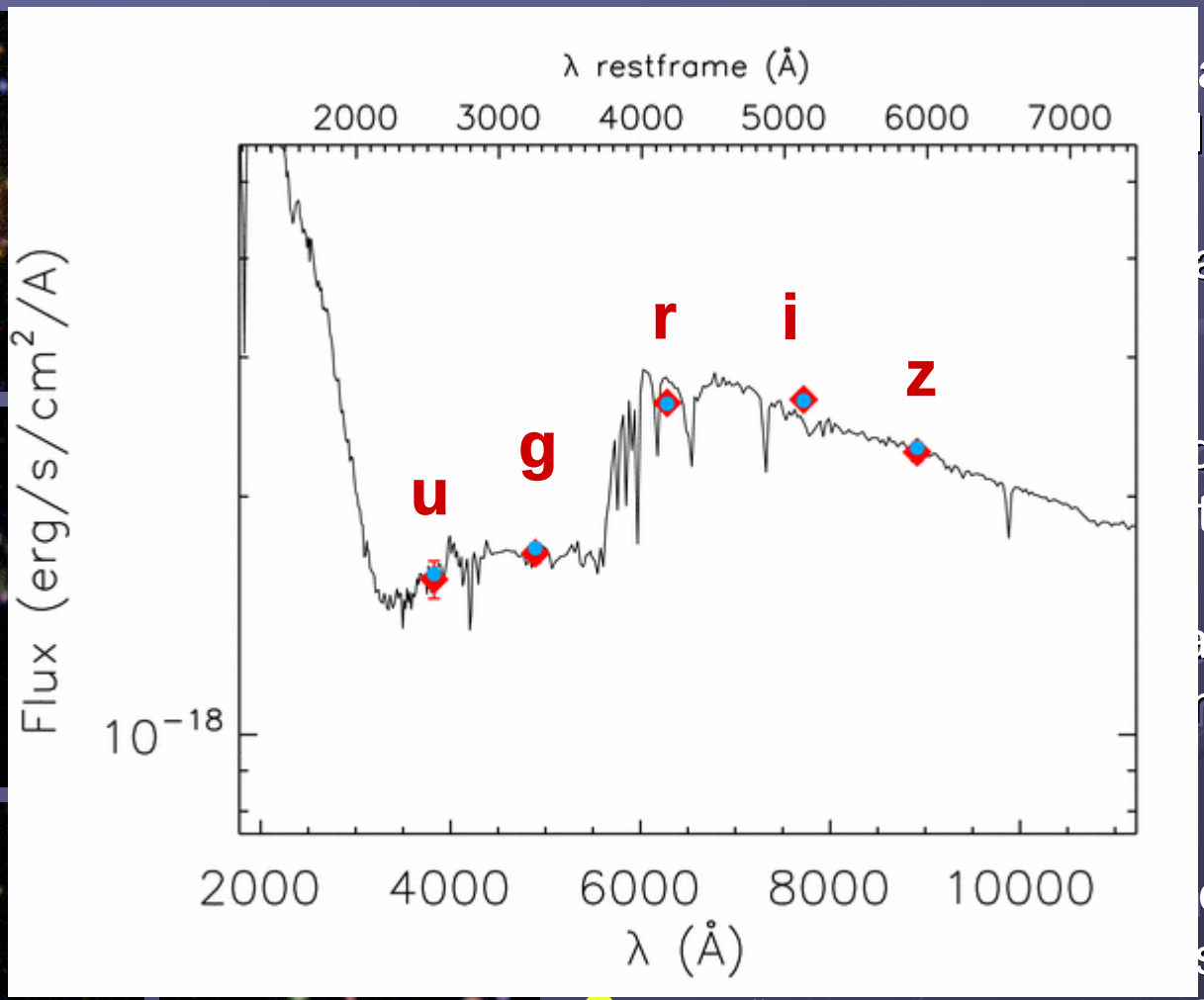
Sullivan et al. (2003)

Typing of SNLS SN Ia hosts









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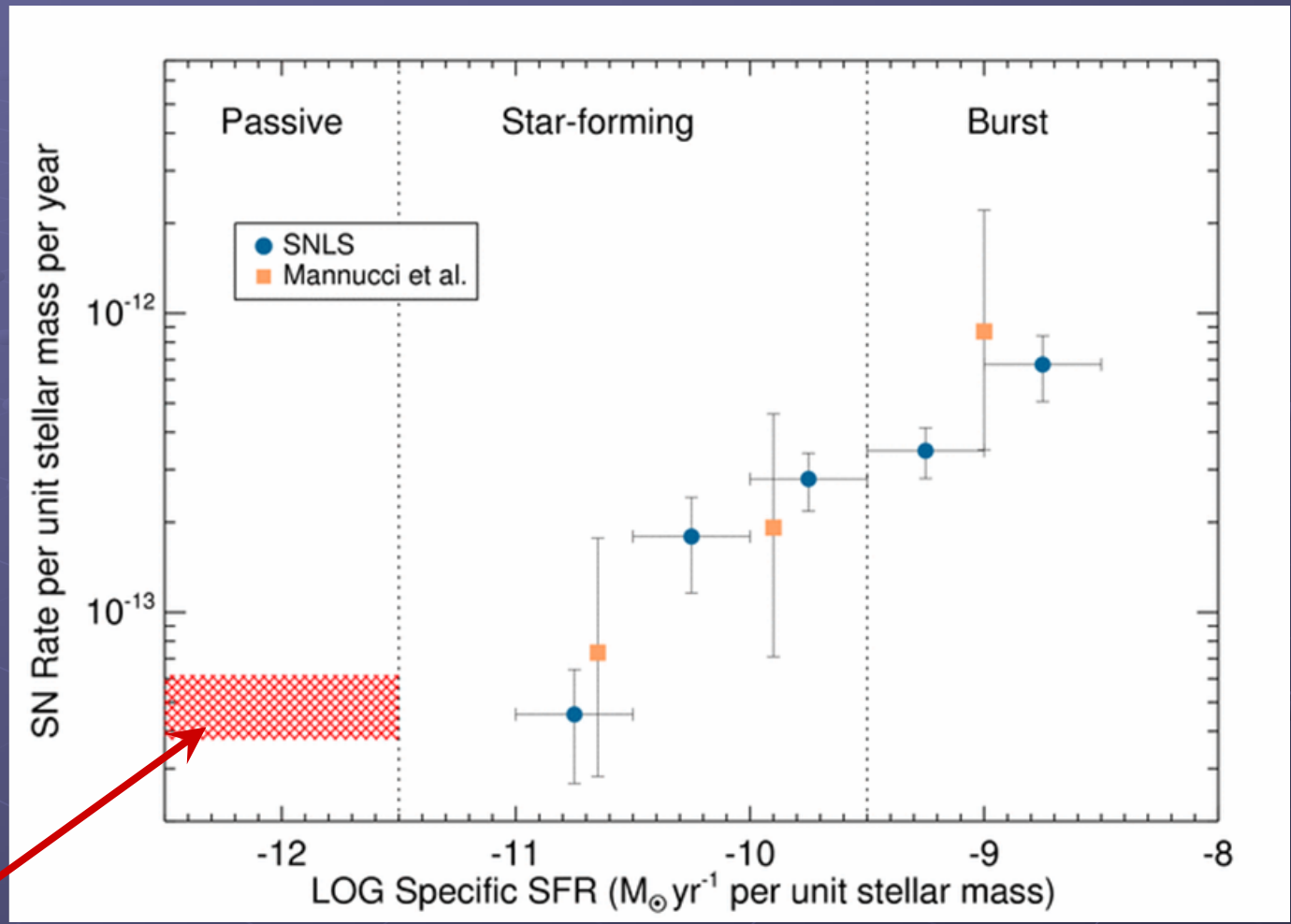
Starb

Sullivan et al. (2006)

SNLS: SN rate as a function of sSFR

SN Ia hosts classified by star-formation activity

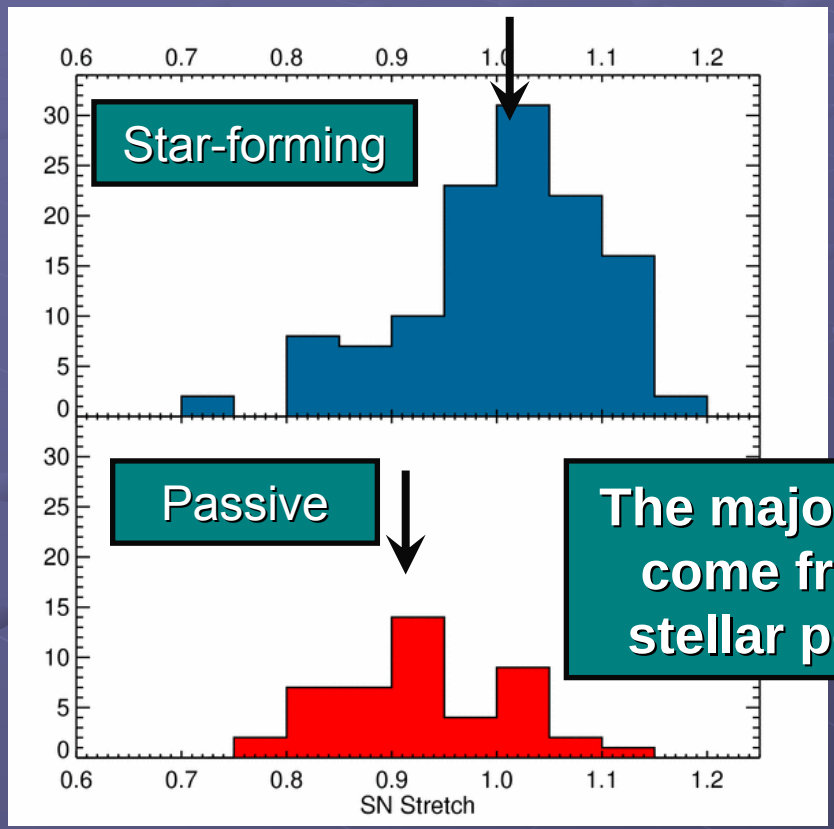
Per unit stellar mass, SNe are at least an order of magnitude more common in more vigorously star-forming galaxies



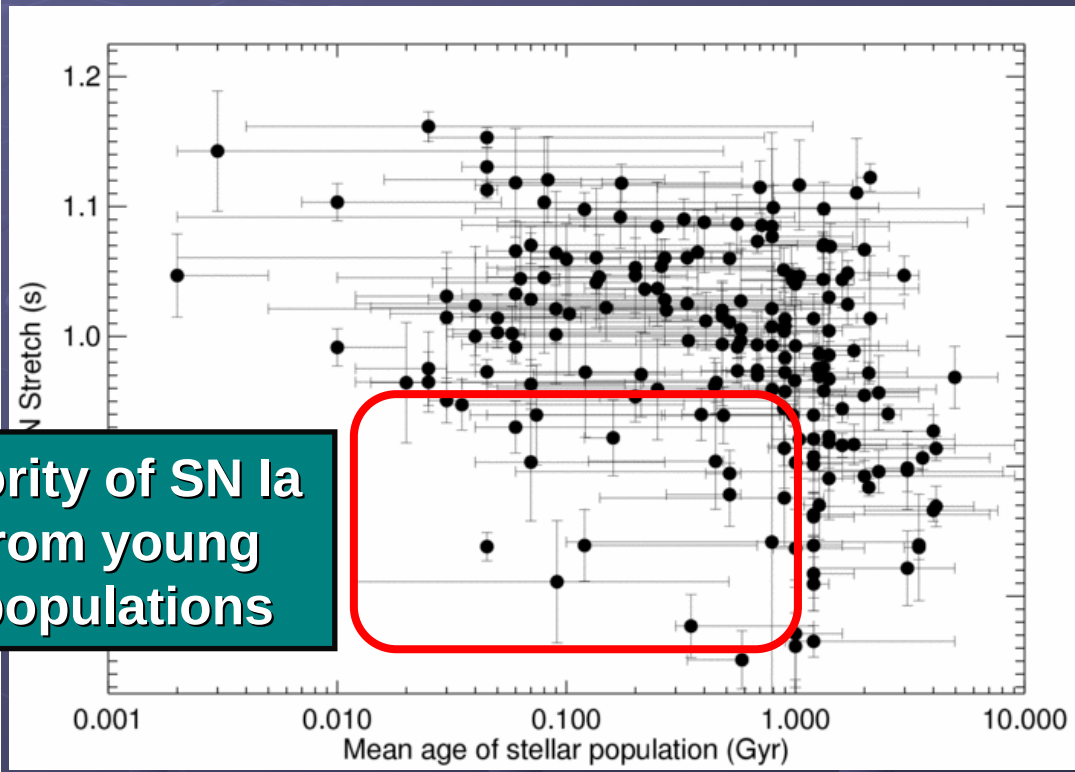
SNLS "passive" galaxies

SN Ia Stretch dependencies

Stretch by galaxy star-formation activity



Stretch versus mean age



The majority of SN Ia come from young stellar populations

170 SNe Ia

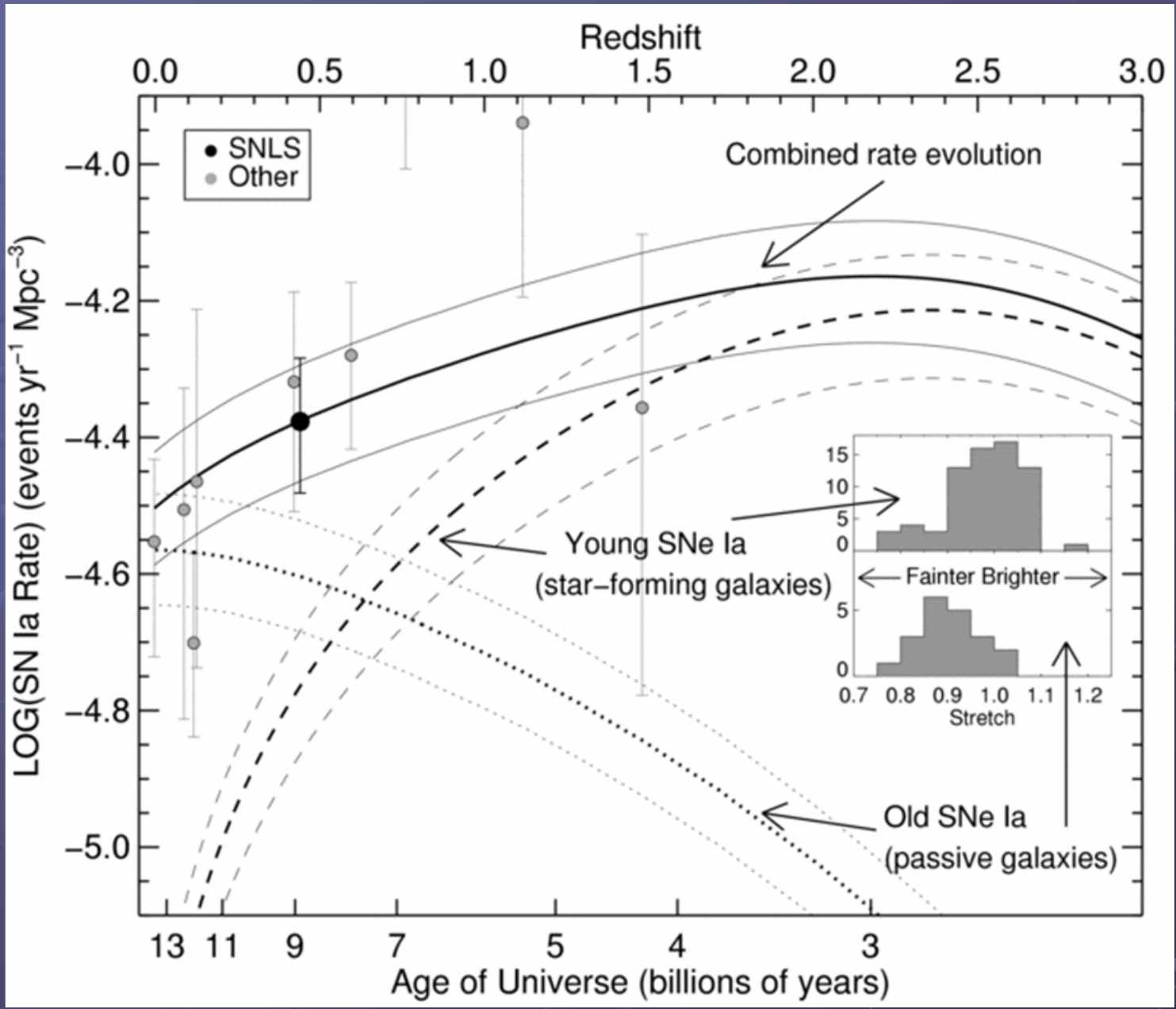
(Update from Sullivan et al. 2006; better zeropoints, host photometry, more SNe)

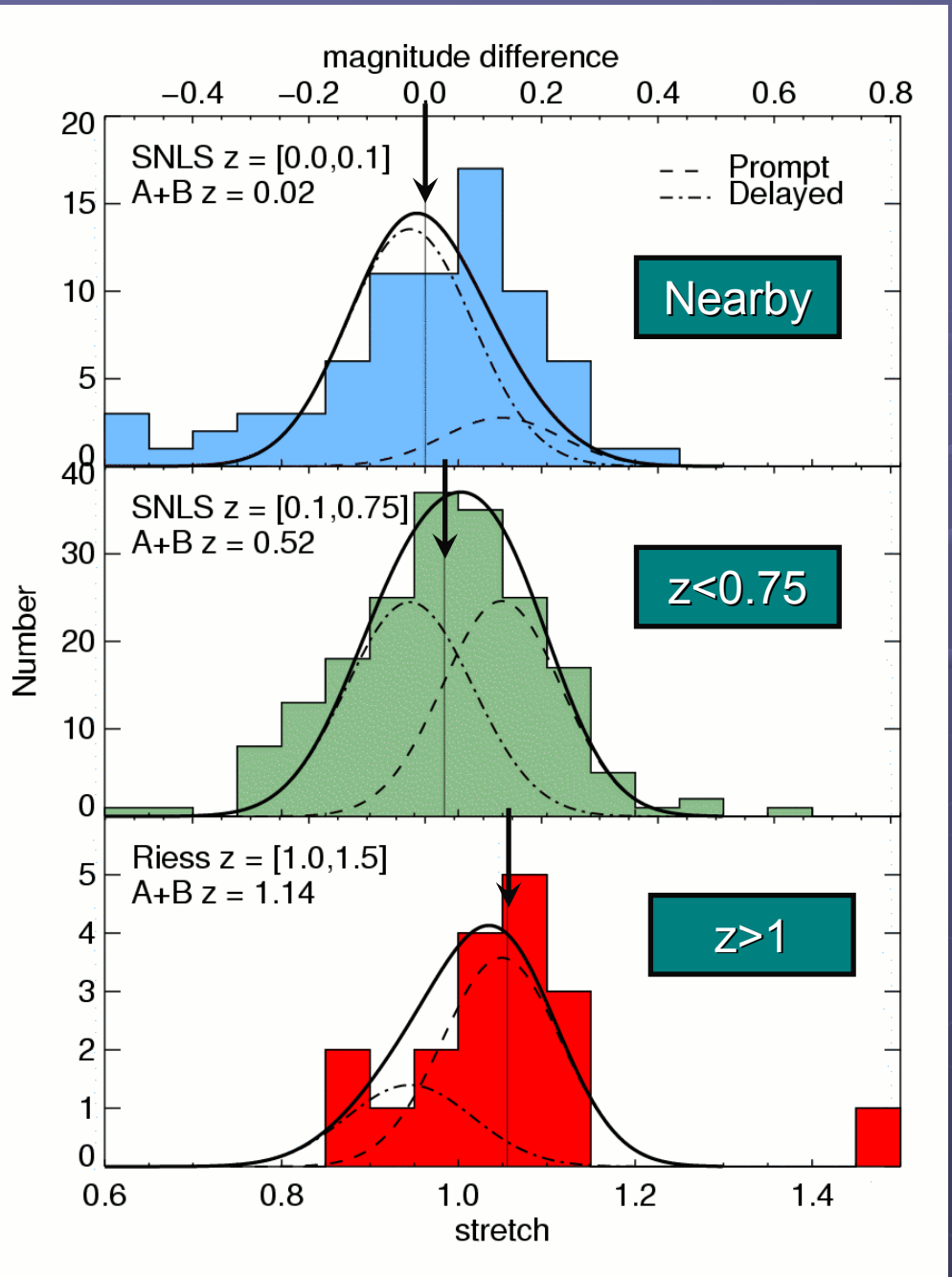
SN population drift?

Relative mix of evolves with redshift

A+B predictions, but similar for any two component model

Sullivan et al. 2006





Evolution in Stretch?

Gaussians – predicted evolution from A+B model

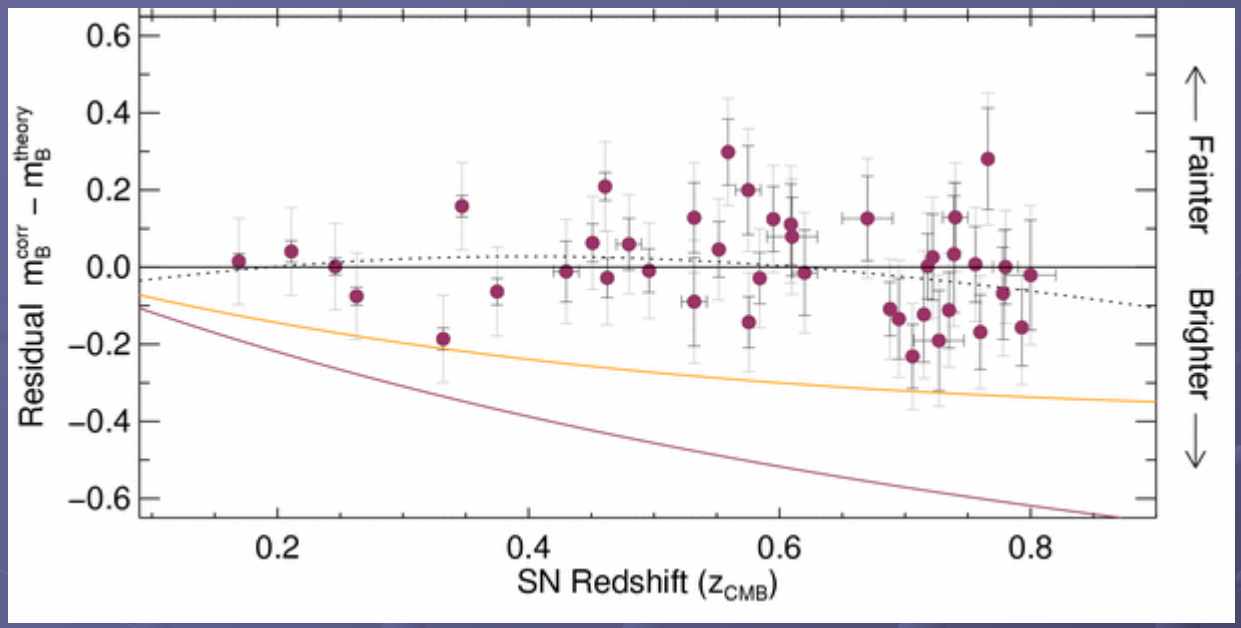
Average stretch, and thus average *intrinsic* brightness of SNe Ia evolves with redshift

but

if stretch correction works perfectly, this should not affect cosmology

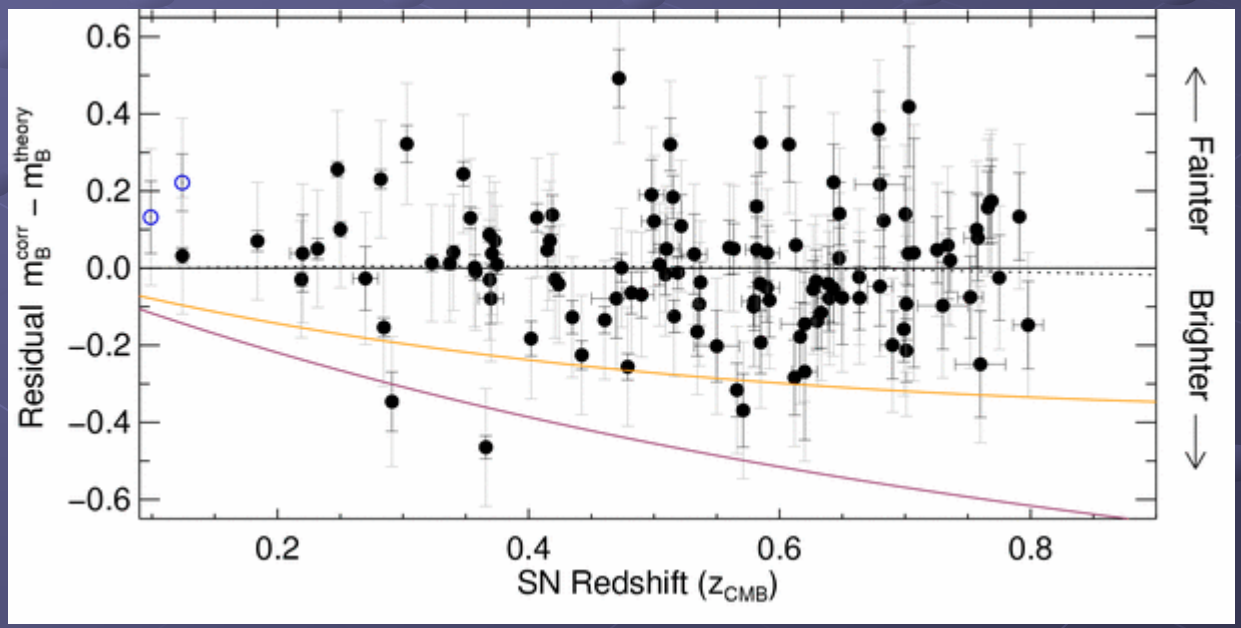
Howell et al. 2007

SN Subsets



Passive

α~1.6 ± 0.2
β~1.7 ± 0.2
σ~0.10 mag



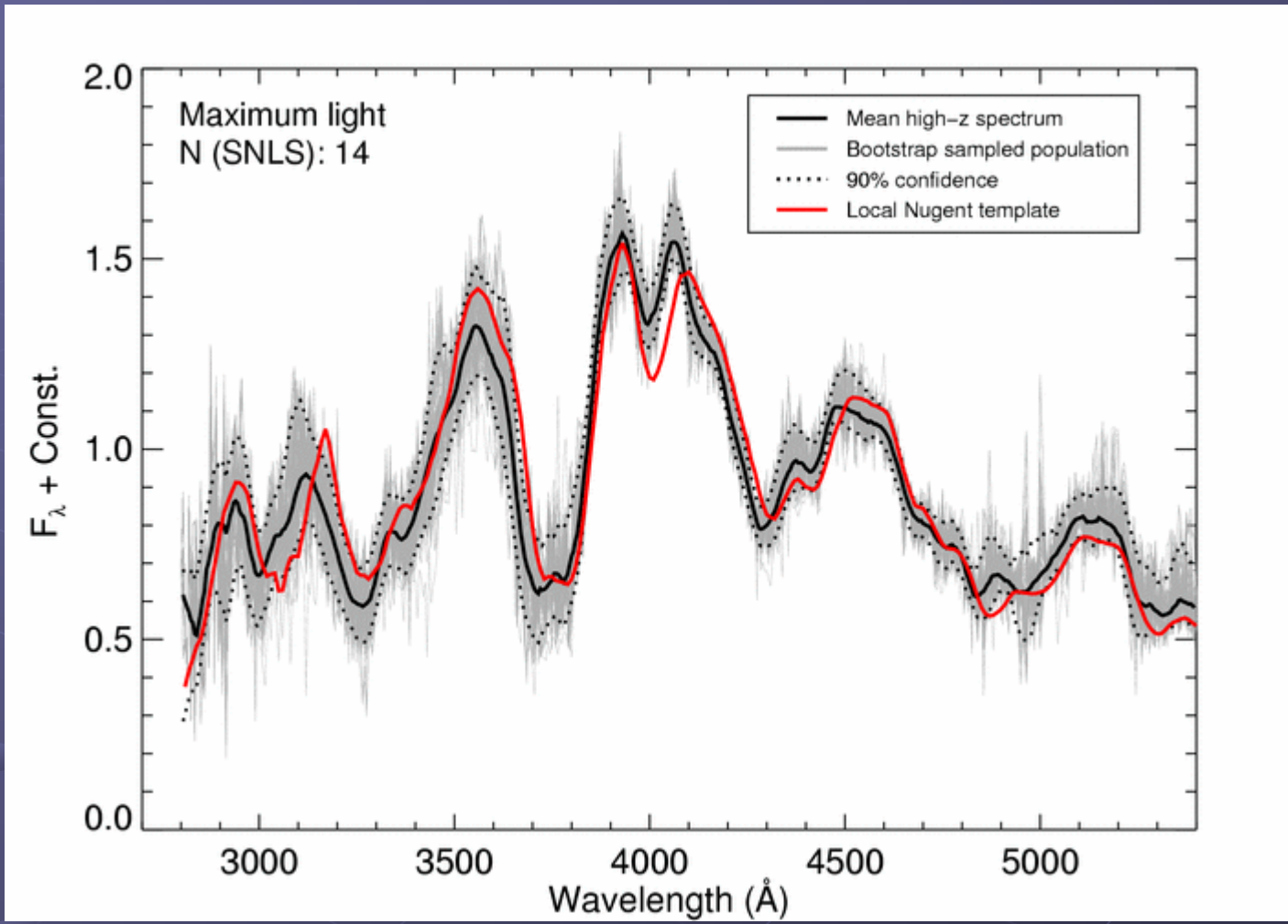
Star-forming

α~1.6 ± 0.2
β~2.4 ± 0.2
σ~0.16 mag

(No) Evolution in mean spectrum?

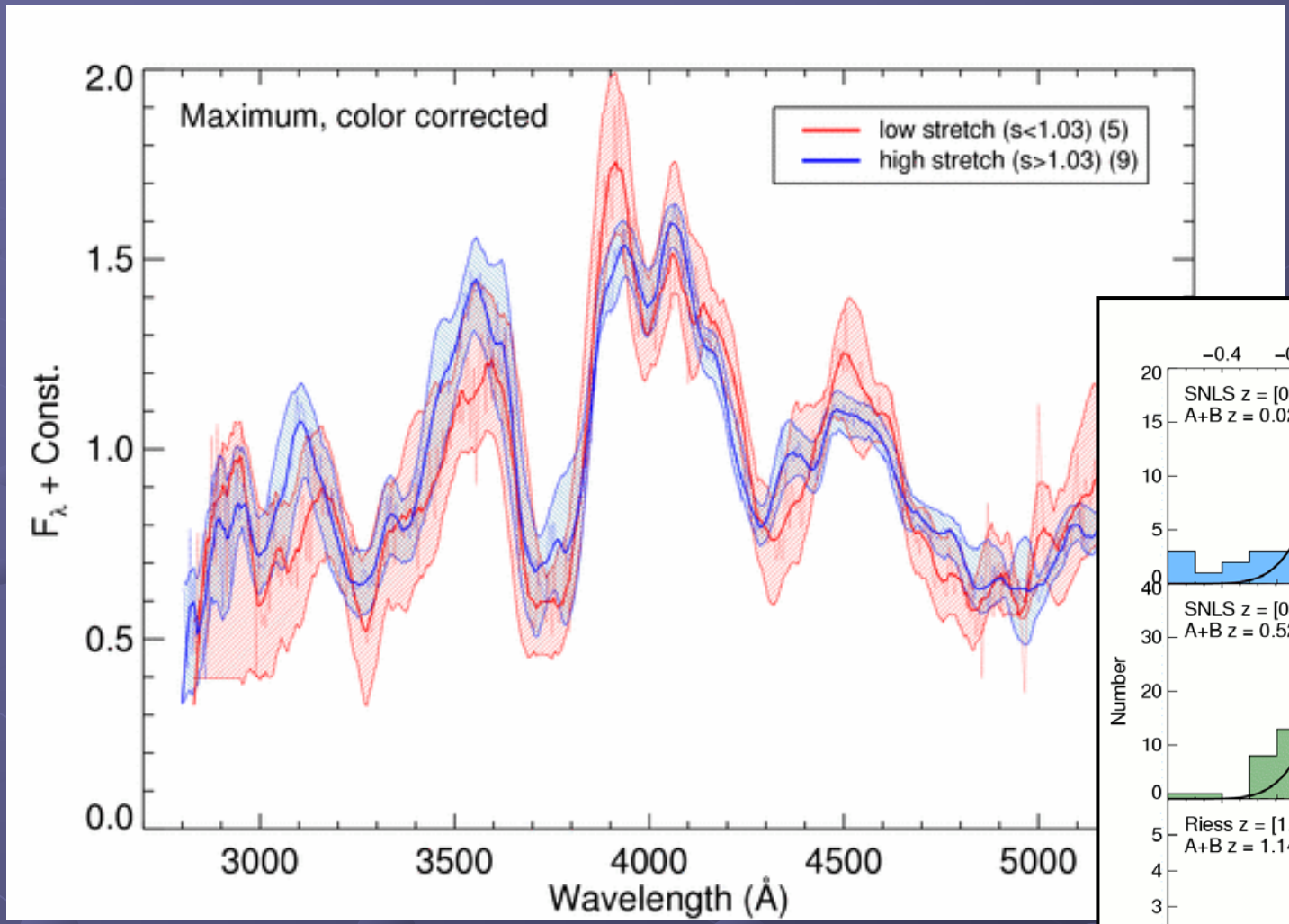
Intensive Keck/LRIS study of SNLS SNe Ia

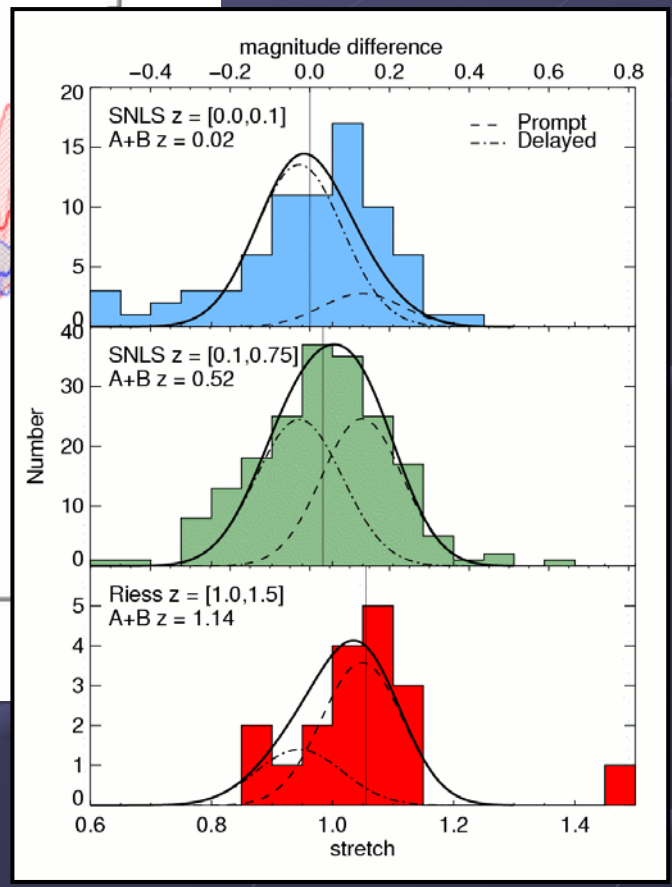
z=0 (red) compared to z=0.5 (black)



Ellis et al. in prep

Light-curve width dependence





Mean SNLS spectra split by s

(Ellis et al. 2007)

Future Prospects with SNLS

- Current constraints on <w>: <w>=-1 to ~ 6-7% (stat)
  - <w> >-0.8 excluded at 3-sigma level
- At survey end a 4-5% statistical measure will be achieved:
  - 500 SNLS + 200 SDSS + z>1 + new local samples
  - Improved external constraints (BAO, WMAP, WL)

- Progenitor age appears an important factor affecting stretch/Δm_{15}
  - Stretch depends on host SFR/Age – **WHY??**

- SNe in passive galaxies are better standard candles
  - More homogeneous progenitors? or dust?