Present and Future
Large Optical Transient Surveys

Supernovae Rates and Expectations

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Transients Seminar

Weds 12th December 2007

- Many surveys designed to find type Ia SNe (dark energy)

  - it's good to know what else they (will) contain (Lars)
- What will they do for SNe studies?

  SNe rates – and their evolution

- Discussion of SNe rates – almost all literature is on Ia's...
- Overview of surveys: area, depth, cadence, etc etc
- One upcoming local survey: PTF (Mansi)
- Watch out for glimpses of CC SN rates...

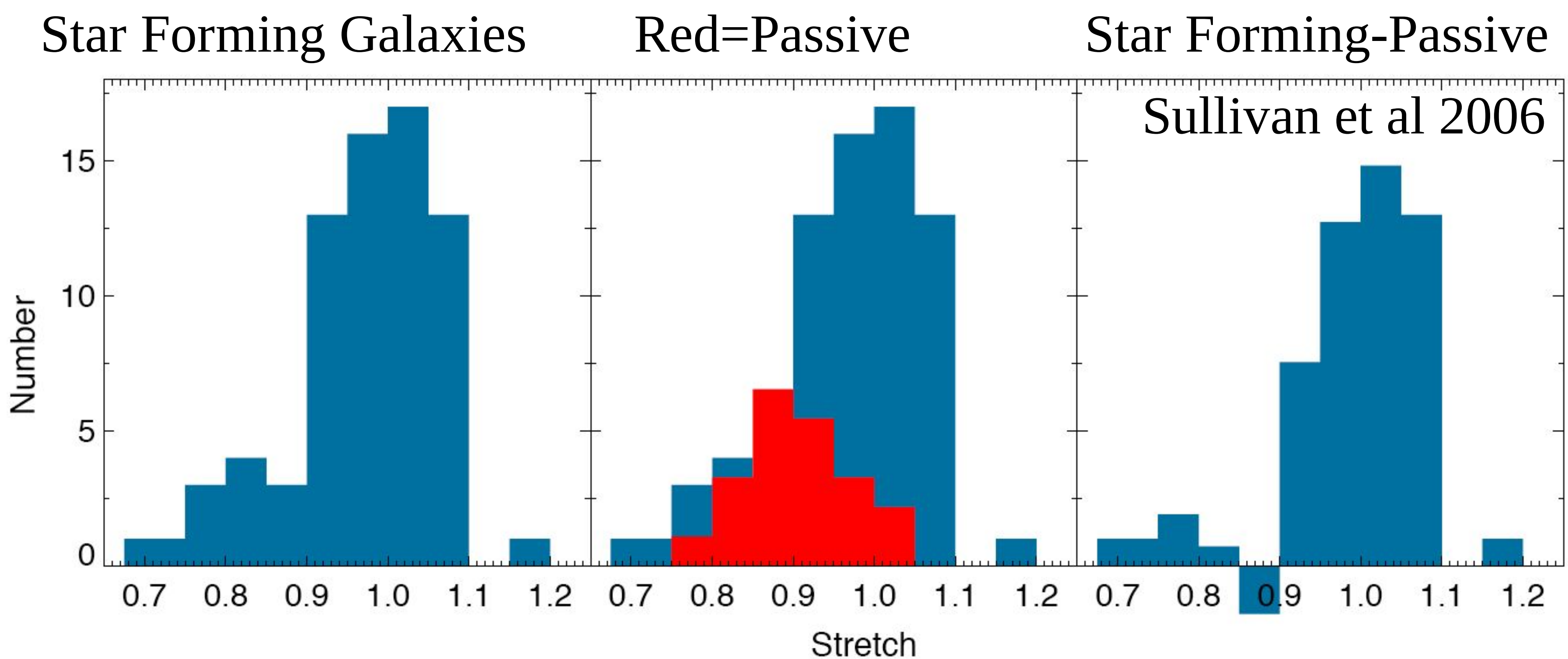
Type Ia Supernovae Dependence on Galaxy Type and Cosmic Rates

There are observed trends in Ia properties with galaxy type (no evidence yet for metallicity effects):

- Brightest (e.g. 1991T) events occur preferentially in young stellar environments (hence mostly spiral and irregular galaxies)
- Sub-luminous (and peculiar, eg. 1991bg) Ia's dramatically prefer old stellar populations . . (Elliptical and S0 Galaxies)
- Rates track BOTH the stellar mass and the star formation rate

These are likely the result of Ia SNe occurring in *both old and young stellar populations:* this motivated Scannapieco & Bildsten's (2005) simple explanation for the observed cosmic Ia rate.

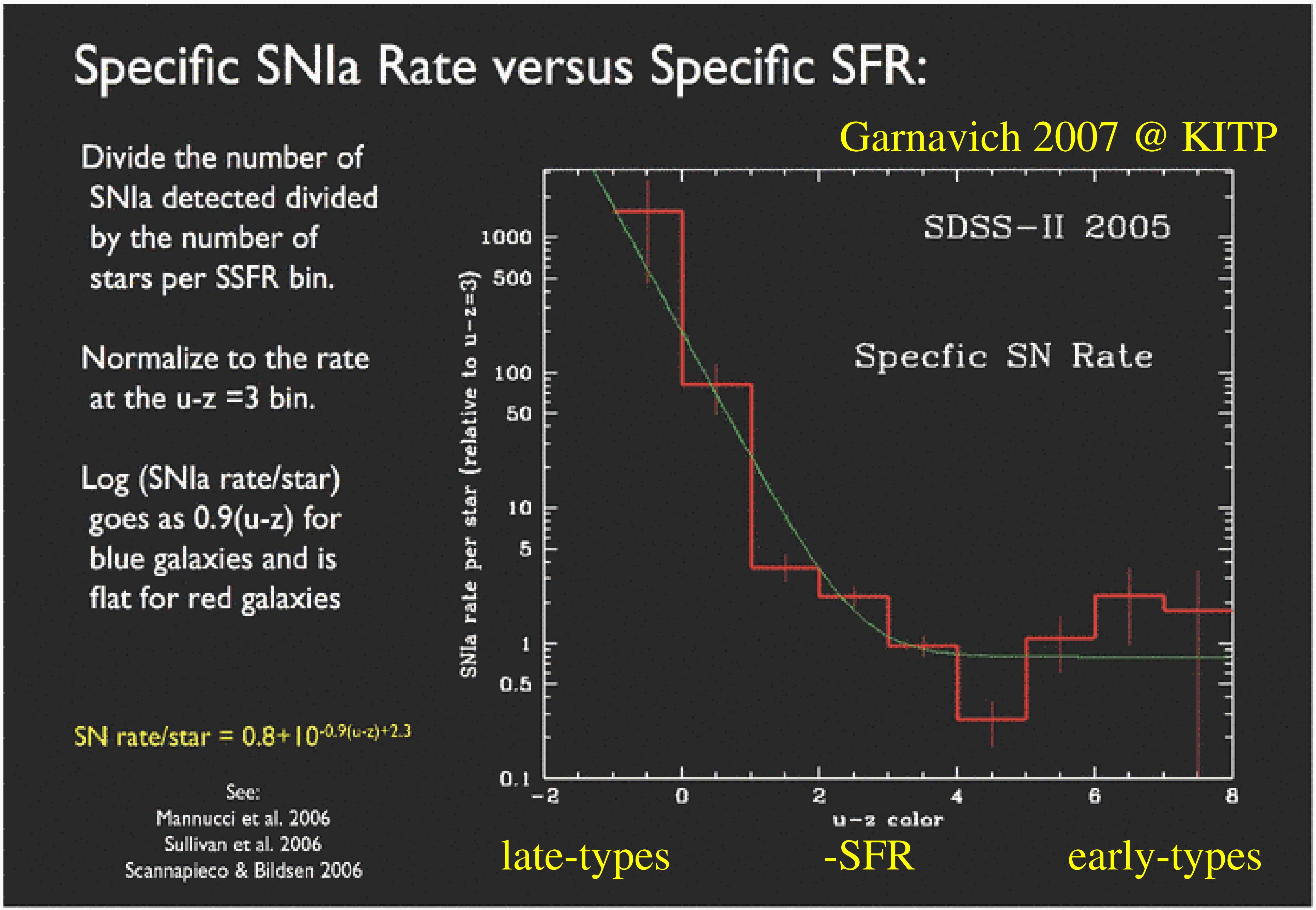
CFHT Supernovae Legacy Survey (SNLS)



The number of faint (small stretch) Ia's in spirals is consistent with the old stellar population in the spiral galaxy.

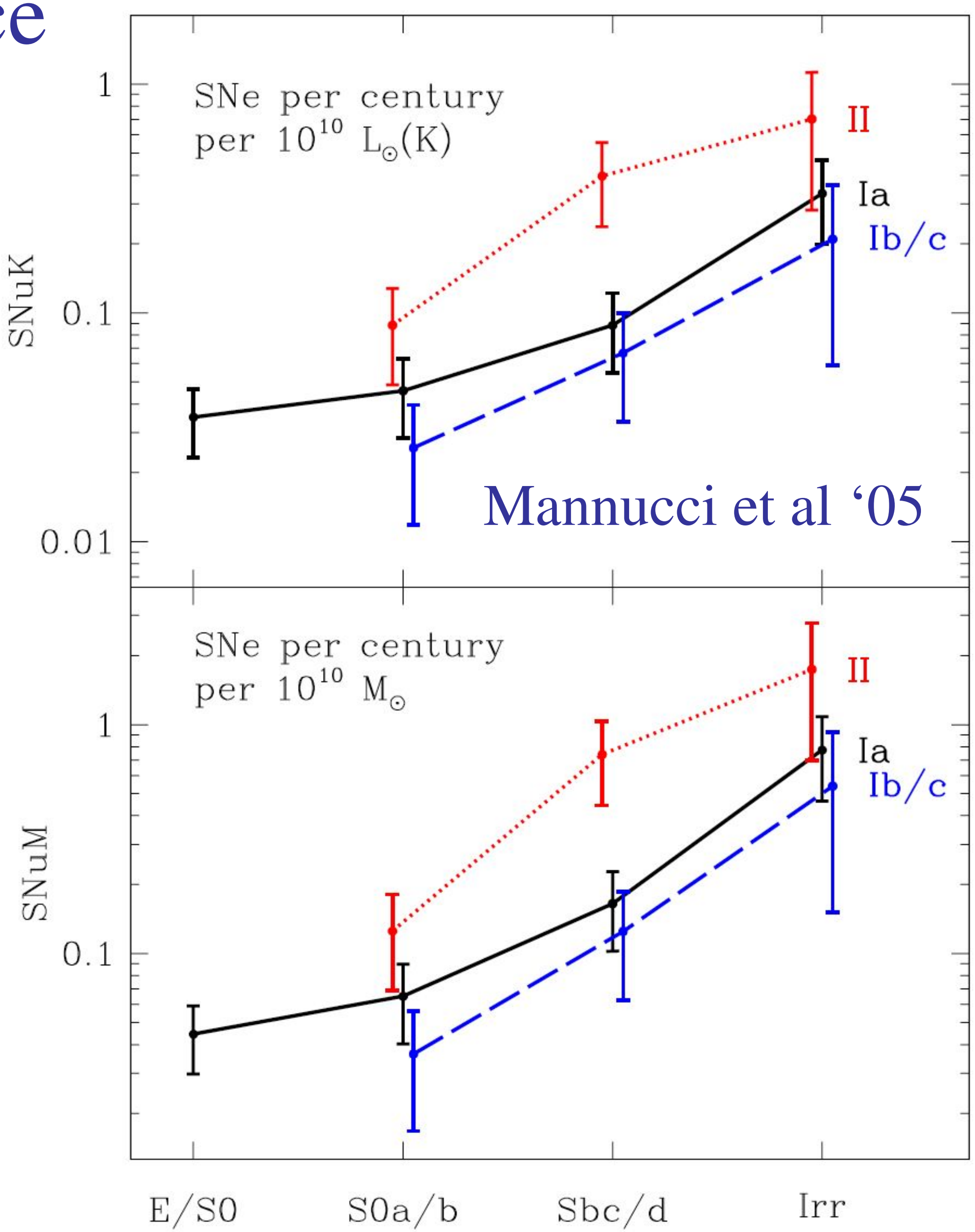
The two populations are distinct!

SDSS Supernova Survey



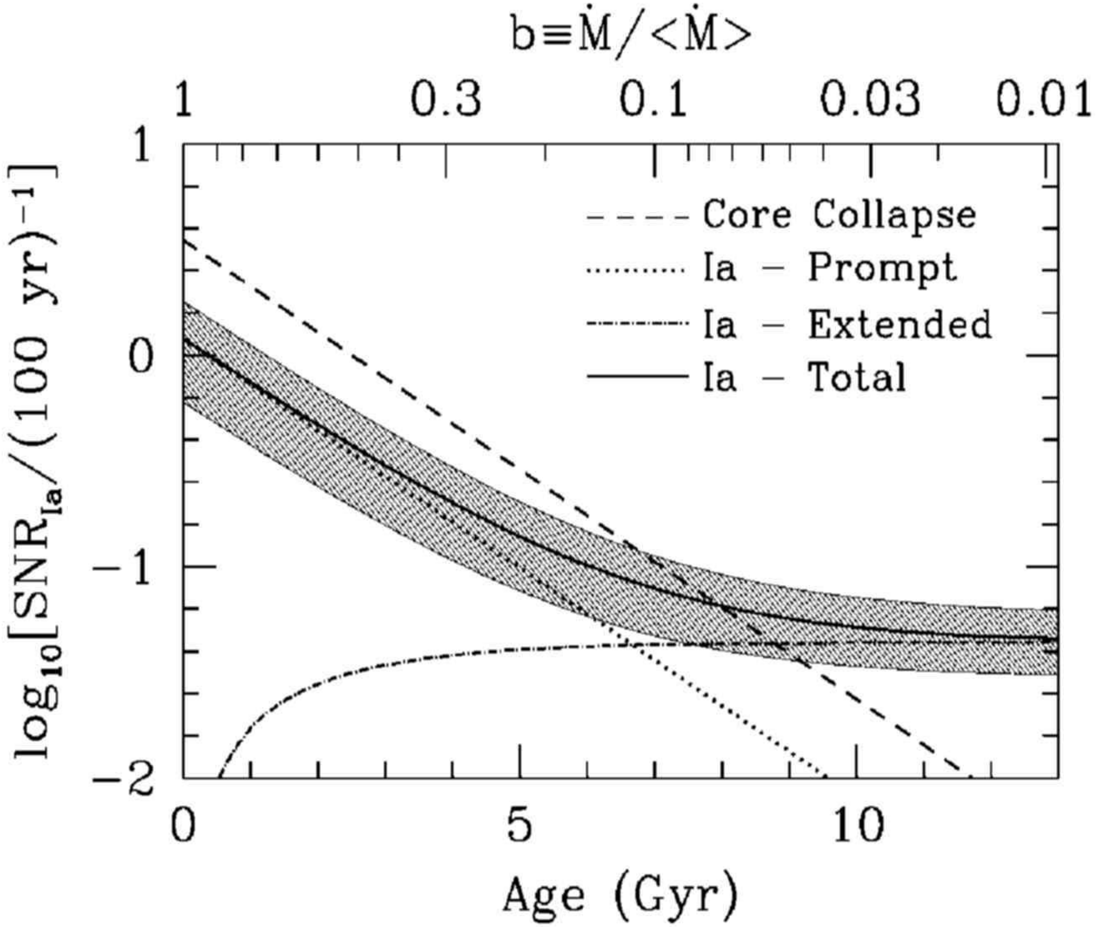
SN Rate Dependence on Galaxy Type

- Infrared luminosity used to determine the stellar mass
- Part of the Ia rate tracks the SFR, and is 1/3 the Core Collapse (mostly type II) rate
- Ia data can be “fit” with one term that depends on mass (confirmed in clusters: Sharon et al ‘06) and another that is 40% of the core collapse rate
- Roughly one Ia every 400 years for 1 solar mass per year of star formation.



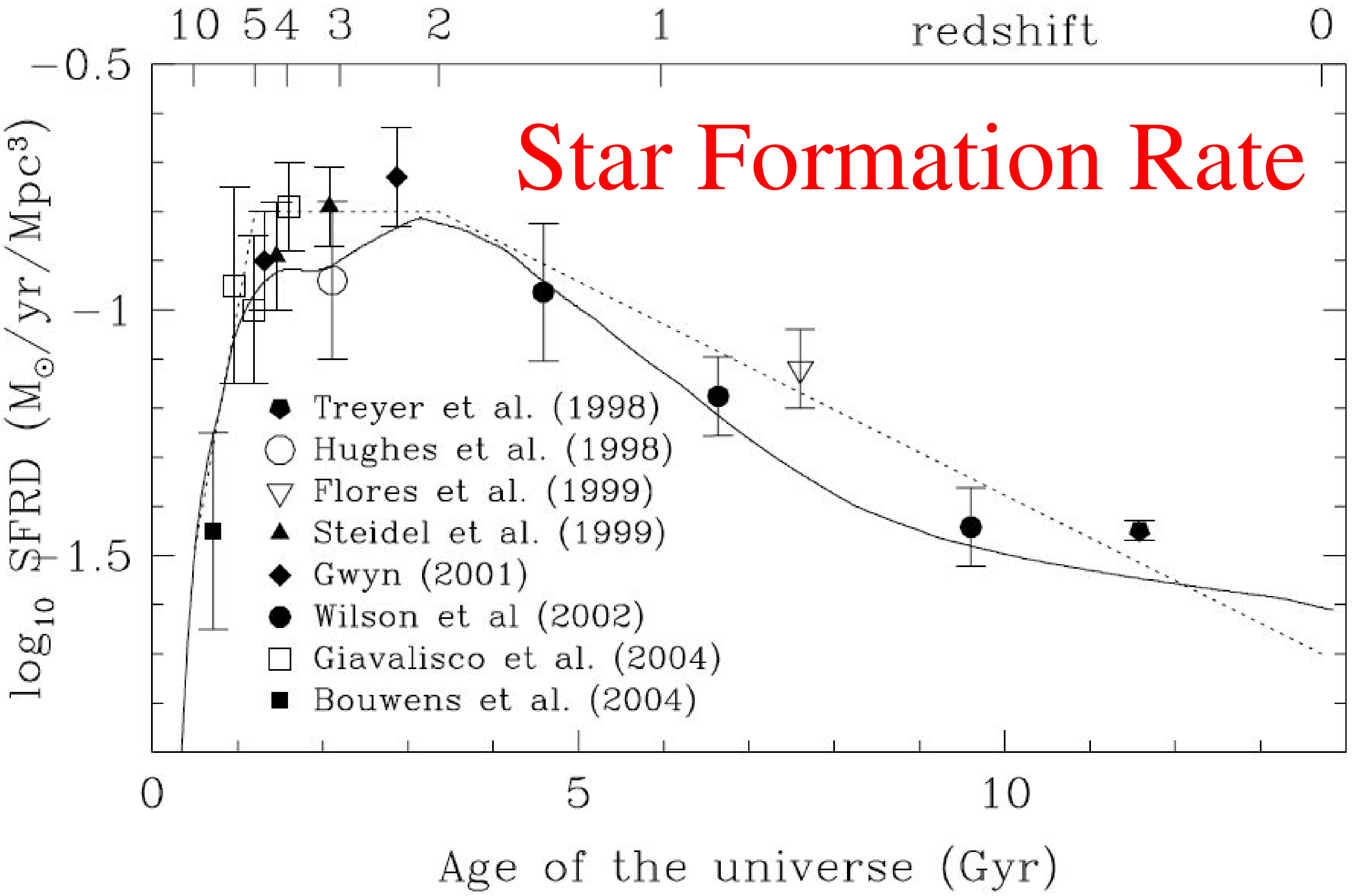
SB05 assumed that the Ia rate tracks the stellar mass and star formation rate as measured by Mannucci et al, then measured the constants from local galaxies to get:

$$\frac{\text{Ia Rate}}{(100\text{yr})^{-1}} \approx 0.4\left(\frac{M_*}{10^{11}M_\odot}\right) + 2.6\left(\frac{\dot{M}_*}{10^{10}M_\odot\text{Gyr}^{-1}}\right)$$



This example shows the outcome when the galaxy's SFR drops exponentially on a 2 Gyr timescale

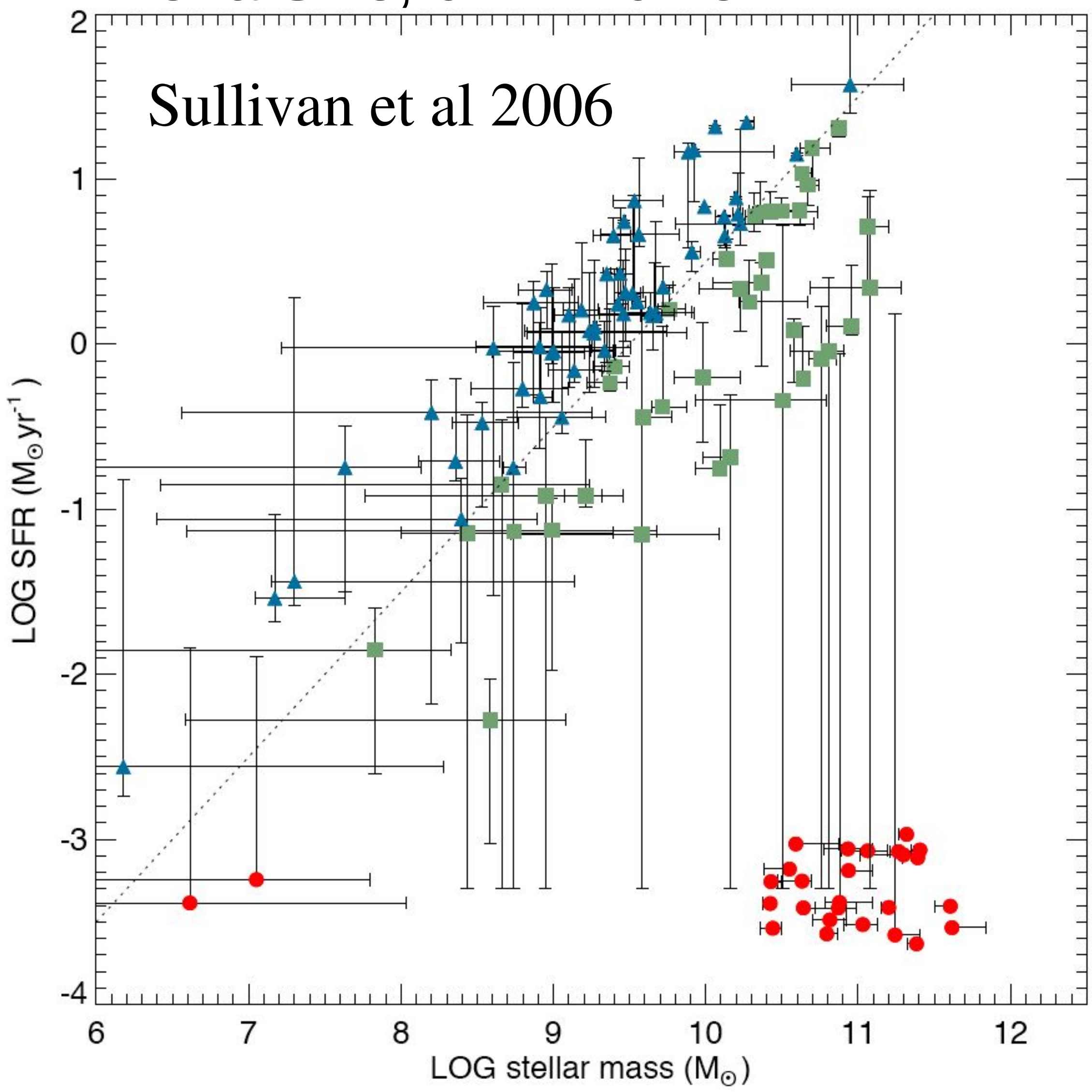
- 80% of the Ia SN over a galaxy's lifetime come from the prompt contribution (see Oemler & Tinsley 1979).
- Fe production from Ia's is 3 times that from CC



$$\frac{\text{Ia SN}}{\text{yr Mpc}^3} = 2 \times 10^{-5} + 2.5 \times 10^{-4} \left(\frac{SFR}{0.1 M_\odot \text{yr}^{-1}\ \text{Mpc}^{-3}} \right)$$

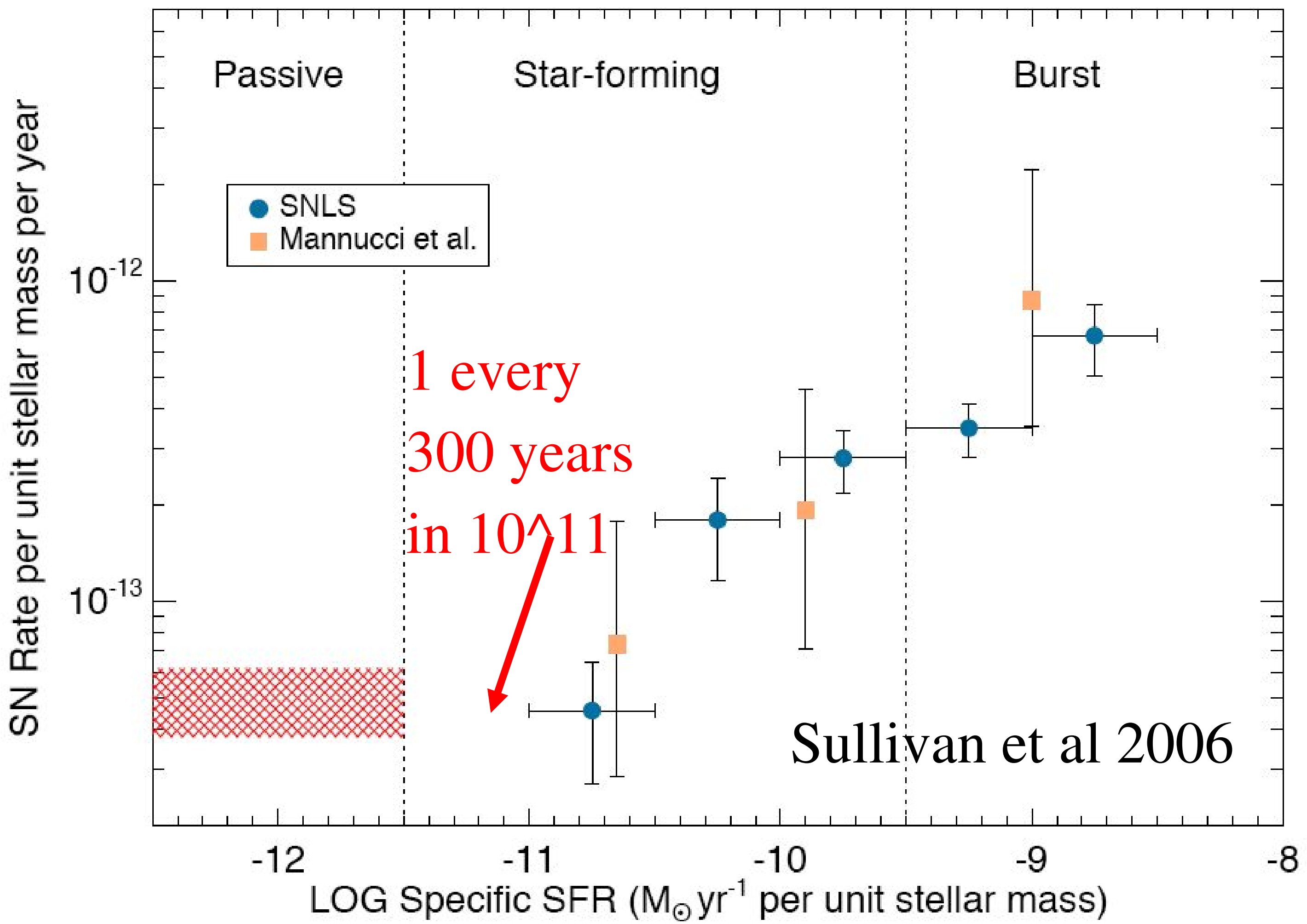
Canada-France-Hawaii Telescope SuperNova Legacy Survey (SNLS)

125 Ia SNe, 0.2<z<0.75

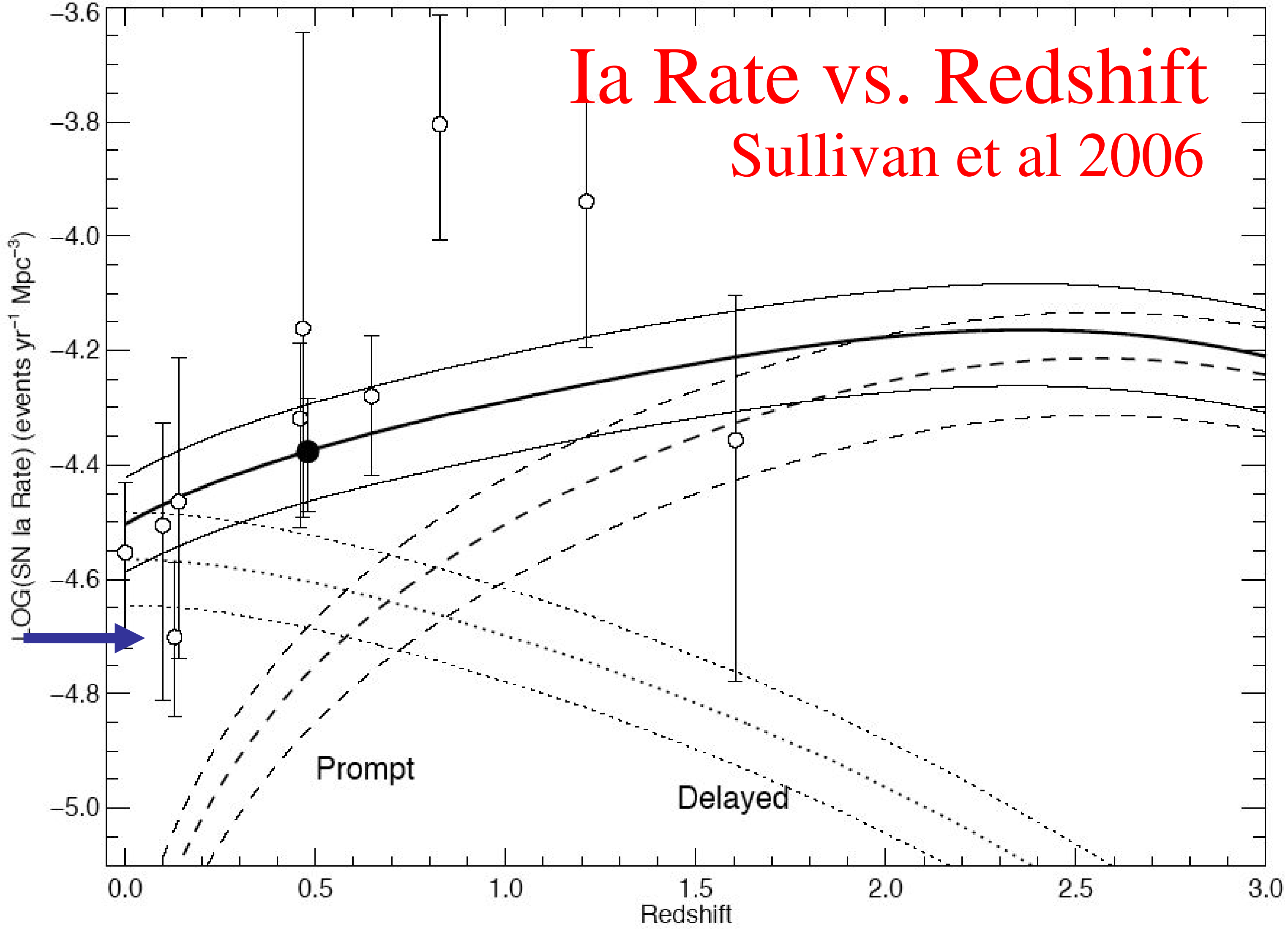


- Galaxies identified from the CFHT survey. All Ia's are spectroscopically confirmed
- For the clear counterparts (some are ambiguous), the galaxies were classified via colors as vigorous star formers, star-forming, and passive.
- When SNLS is done, this list should be ~500

Scalings with Star Formation Rate

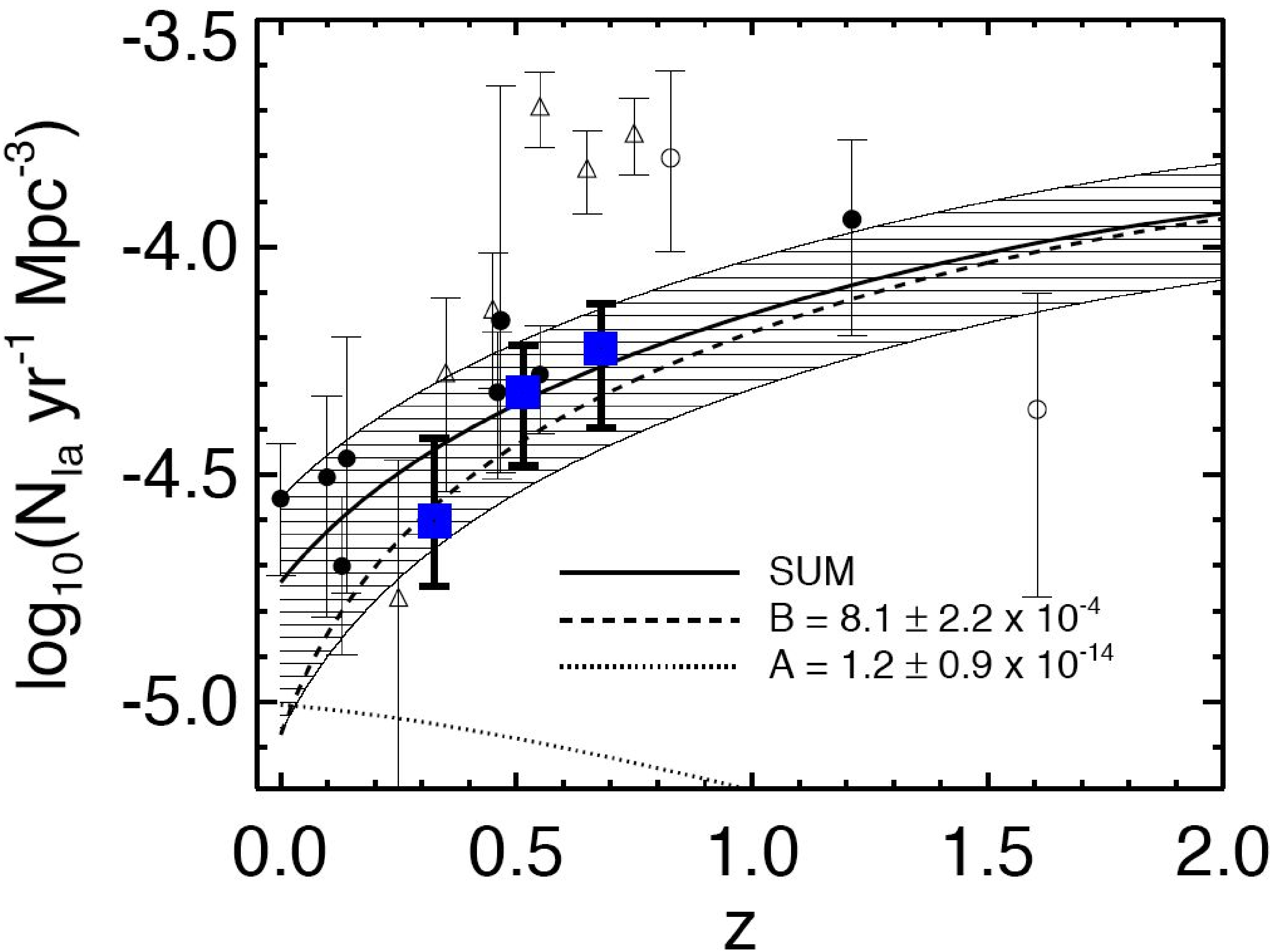


Confirmation of the mass specific rate of Manneucci et al for passive galaxies, and confirmation of the linear Ia rate dependence on star formation rate!



Their normalization with the SFR is 3 times smaller than Scannapieco and Bildsten 2005, giving a different evolution with z.
Note that they enforced normalisation to the new SNLS Ia volume point at z=0.47 (Neill et al 2006).

Another CFHT Legacy Survey fit – SDSS-SN point?



Neill et al. 2007 astroph-0701161 – note odd units of SFR/M*

Hopkins & Beacom 2006

Flexible model for fitting SFH – now industry standard

Use to predict SN rates via Mannuecci model – but including delay times as well!

$$\dot{\rho}_{\rm SNIa}(t) = A\dot{\rho}_*(t - t_{Ia}) + B\rho_*(t)$$

Fits all* data points with A = 1.15×10^{-3} M_o^{-1} and t_{Ia} = 2.7Gyr

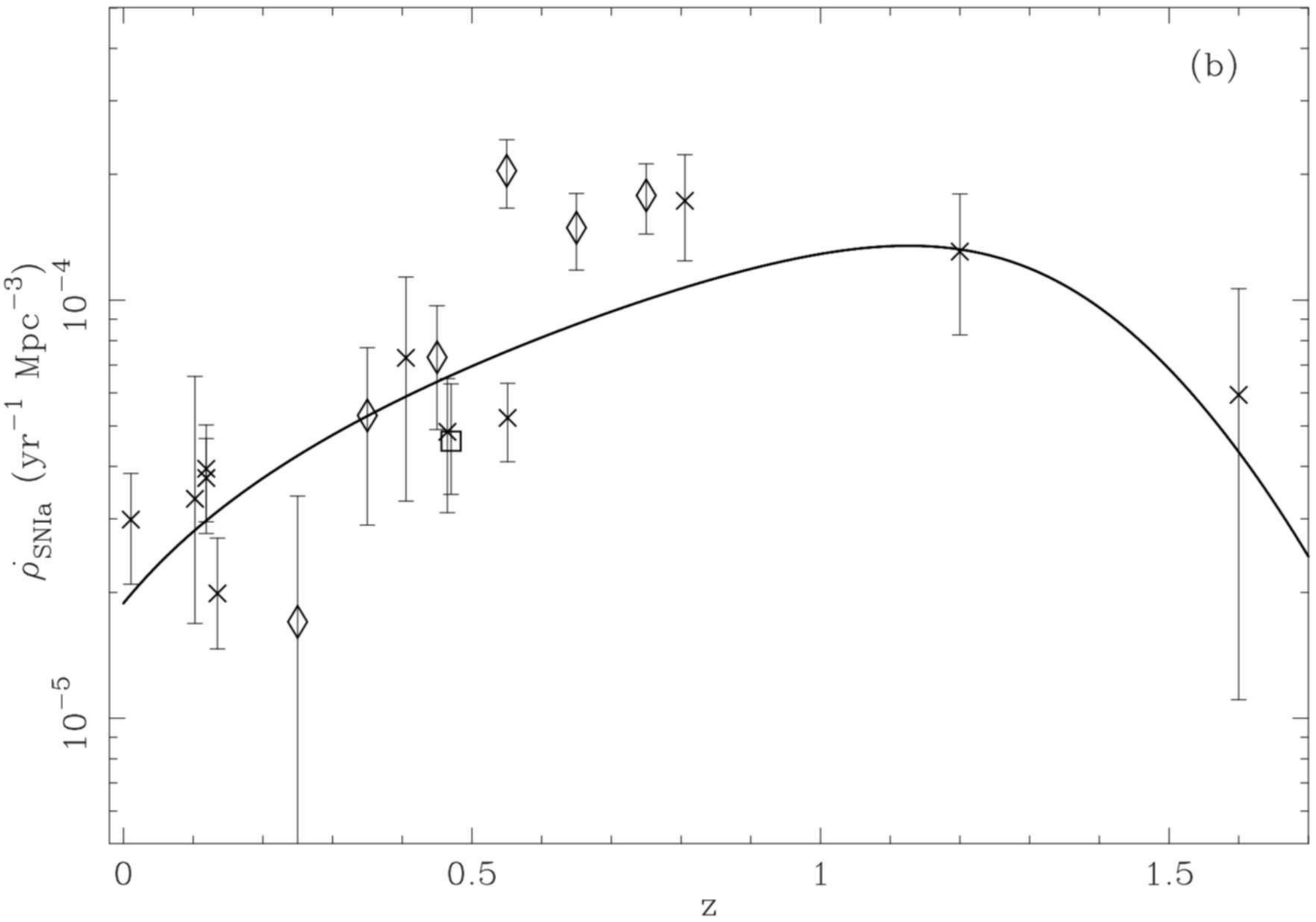
– and B=0! No tracking of M*? Ignores bimodality that got us started on this in the first place... Need spatially-resolved SN rates? Or just ignore delay time? Being driven by high-z data point...

Hopkins & Beacom 2006 $\dot{\rho}_{\rm SNIa}(t) = A\dot{\rho}_*(t - t_{Ia}) + B\rho_*(t)$

Fits all* data points with $A = 1.15\times10^{-3}\,M_o^{-1}$ t_{Ia} = 2.7Gyr B=0

while ignoring noted differences in host galaxy types

Predicts low rate at high z – need more data here...



High Redshift SN surveys: GOODS, SDF

GOODS ACS survey found 23 type Ia SNe at z > 1

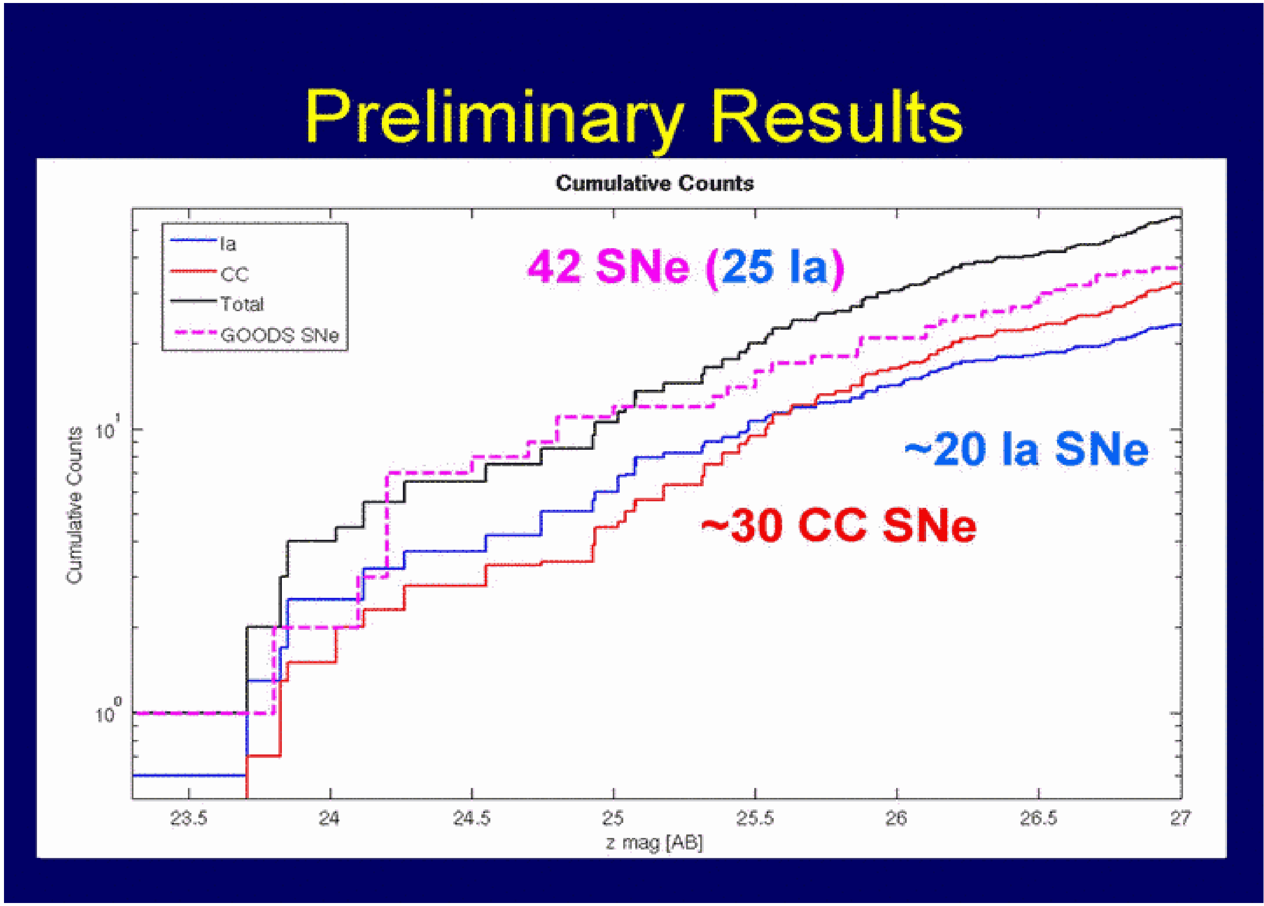
Can get similar numbers from re-imaging the Subaru Deep Field

(Poznanski et al 2007)

Two epochs – photometric typing (no light curve!)

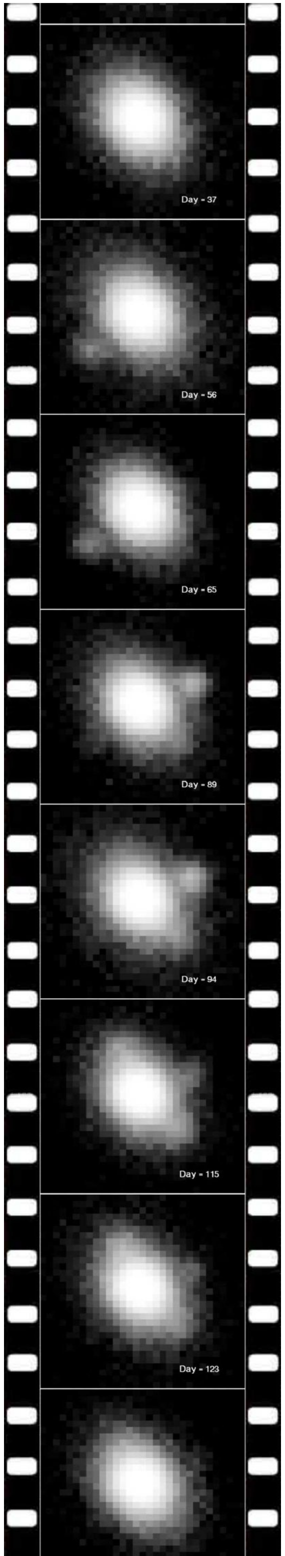
Also seems to be seeing few objects at high z...

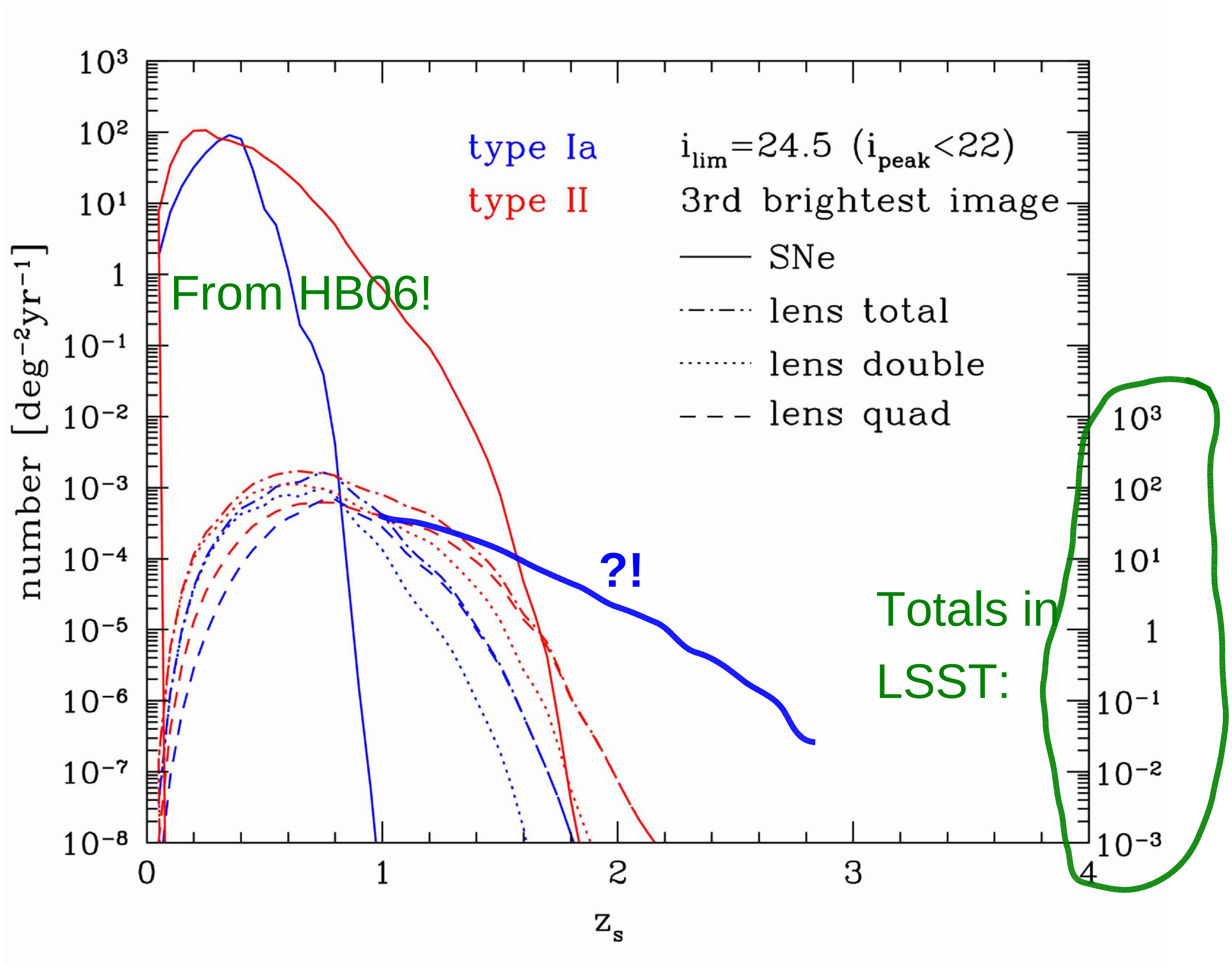
Analysis still preliminary...



Gravitational Lensing – increases ***observability*** of high z SNe:

(plot from M. Oguri / LSST strong lensing science collaboration)





Designing a SN survey:

Required cadence – depends on redshift...

eg SDSS 3 days, CFHTLS 6 days,

GOODS 45 days!

Discovery survey need not be finely-sampled

Depth/Area trade-off – important number is

limiting magnitude per visit...

Current SN surveys:

LOSS (KAIT, Lick)
Supernova Factory (Palomar)
SDSS
ESSENCE (CTIO)
SNLS (CFHT)

Future SN surveys:

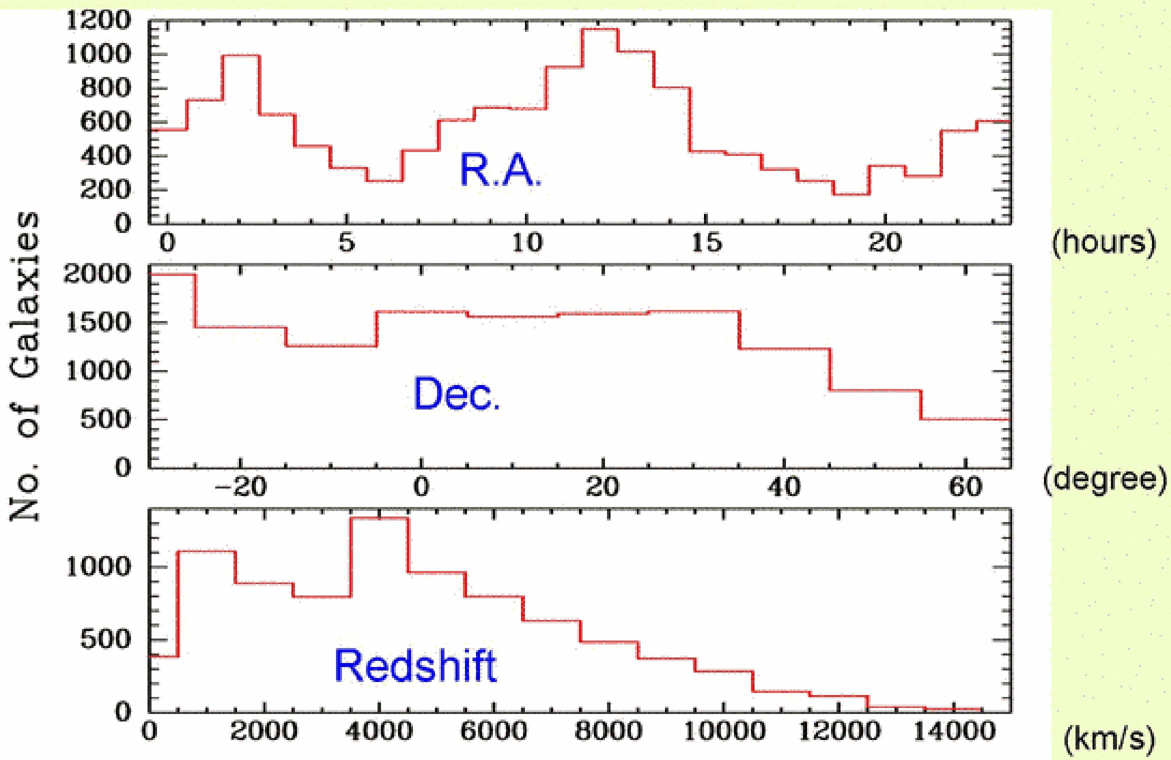
PTF (Mansi)
PS1
SKYMAPPER
DES
LSST

LOSS (survey) with KAIT (telescope)

- Monitoring ~13,000 nearby galaxies
- BVRI imaging (for 20% of objects), limiting magnitude ~ 18
- 2-3” typical seeing
- 2-12 day cadence
- 10 years so far
- Typing from light curves
- <z> ~ 0.01
- Phot. and spec. follow-up

LOSS sample galaxies

- Selected from RC3, UGC, ESO-Uppsala
- Limits on DEC, redshift
- Limits on brightness, diameter of the galaxies
- 14,000 fields, ~20,000 galaxies



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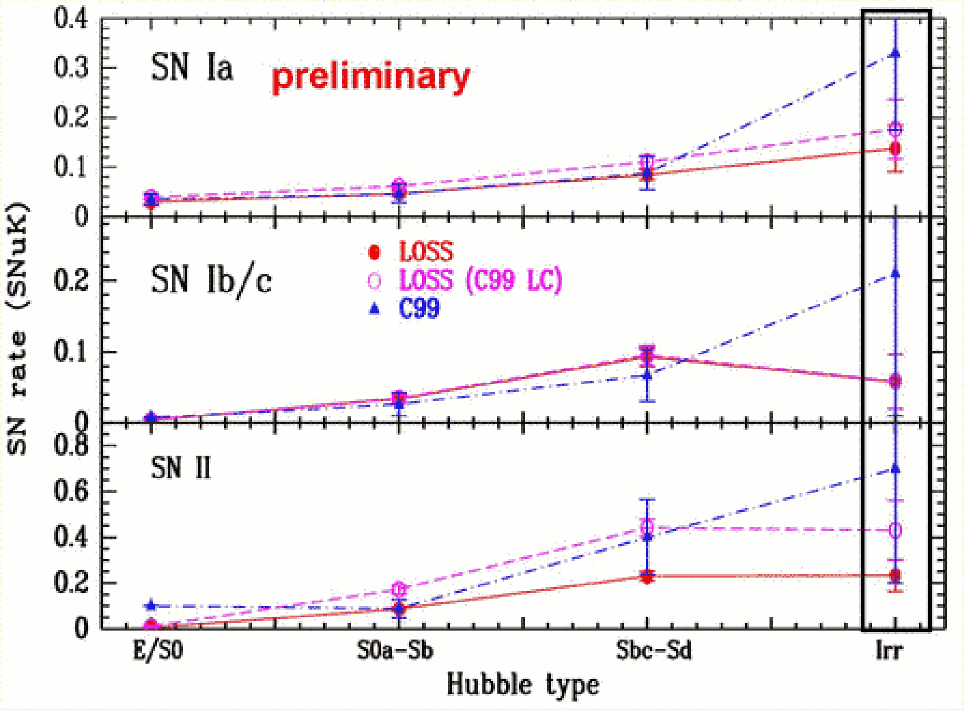
- 10 years so far
- Typing from light curves
- <z> ~ 0.01
- Phot. and spec. follow-up
- 566 SNe so far
- Including CC SNe!

SN rate vs. Hubble type

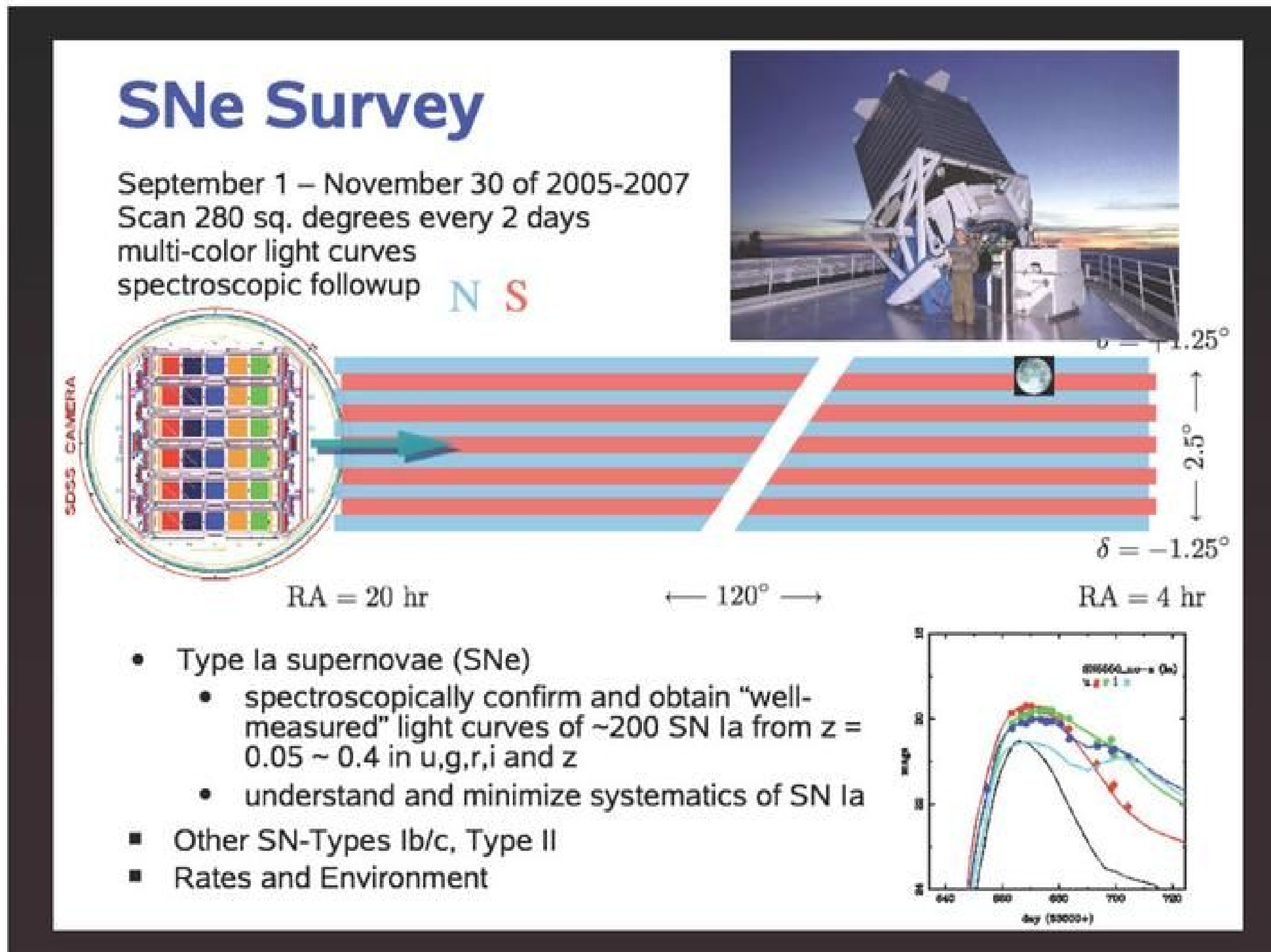
K-band luminosity normalization



An increasing trend for SN Ia rate from early to late-type galaxies
M05 values in irregular galaxies are too large

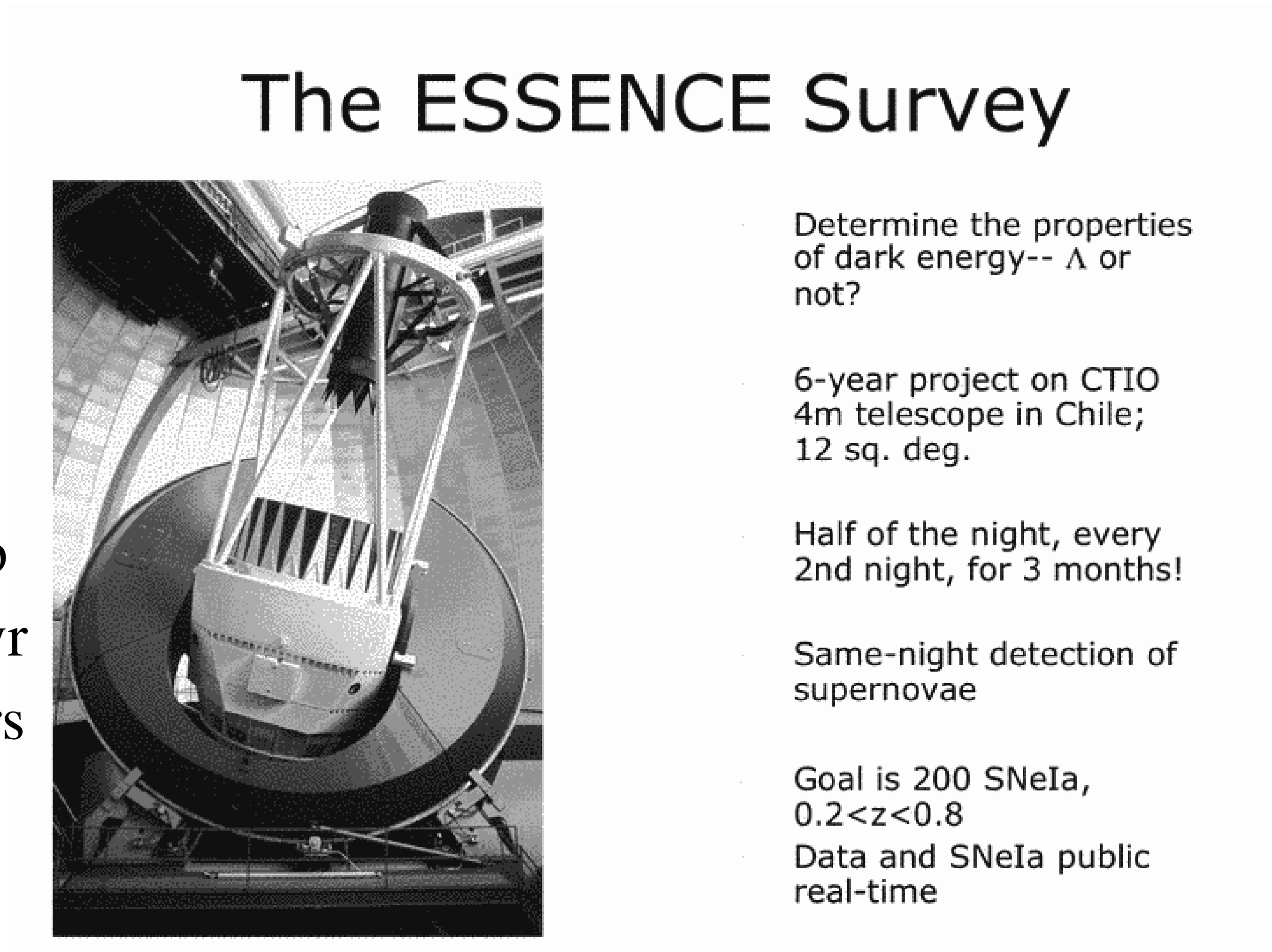
SDSS-SN

- 300 sq deg (2.5deg-wide "stripe 82") at celestial equator, RA -60:60 deg
- ugriz imaging, S/N = 10 at r = 21.5 in 54-sec exposure
- 1.2" typical seeing
- 4-day cadence
- 3 x 3-month seasons
- Optimised for Ia
- <z> ~ 0.2
- 90% Photometric typing
- Massive spec. follow-up
- c. 450 SNe Ia
- 50+25 core-collapse SN interlopers...



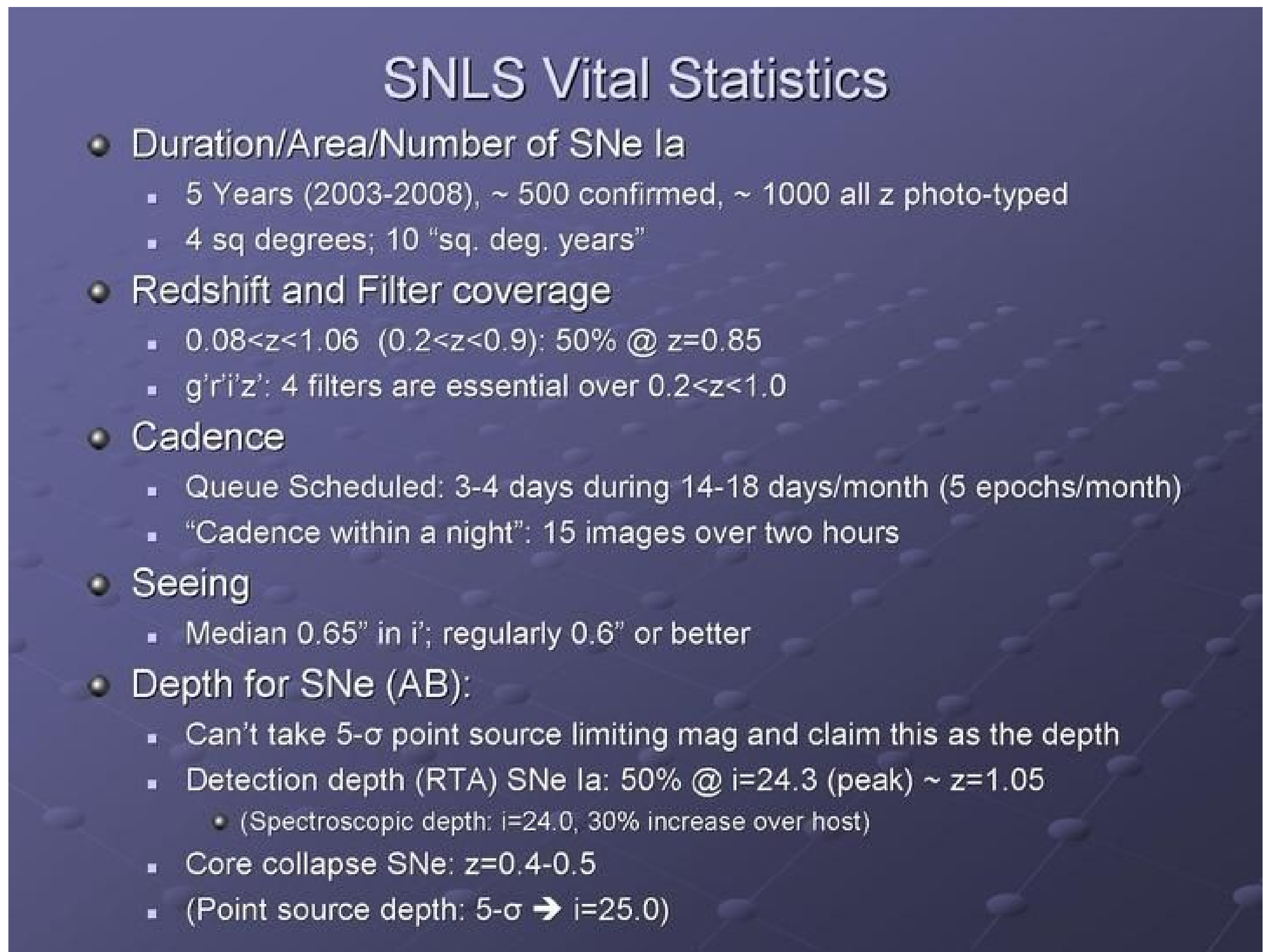
ESSENCE

- 12 sq deg (36 x 0.36 sq deg CTIO Blanco MOSAIC fields)
- r+i imaging, 200-sec exposure,
- typical seeing?
- 4-day cadence
- 6 x 3-month seasons
- 2002-2008
- Optimised for Ia
- <z> ~ 0.5
- 70% photometric typing
- Late time spec. follow-up
- c. 100 SNe Ia from 1st 3 yr
- Few 10s of CC interlopers



SNLS (CFHTLS)

- 4 sq deg (4 x 1 sq deg MegaCam pointings)
- ugriz imaging, limiting mag i = 25.6 in 30-min exposure
- 0.65” median seeing (i)
- 6-day average cadence
- 5 x 6-month seasons
- Finish in 2008
- <z> ~ 0.6
- “depth” = 24.3 in i
- Massive spec. follow-up
- c. 500 SNe Ia
- 50+25 core-collapse SN interlopers...



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SNLS (CFHT)

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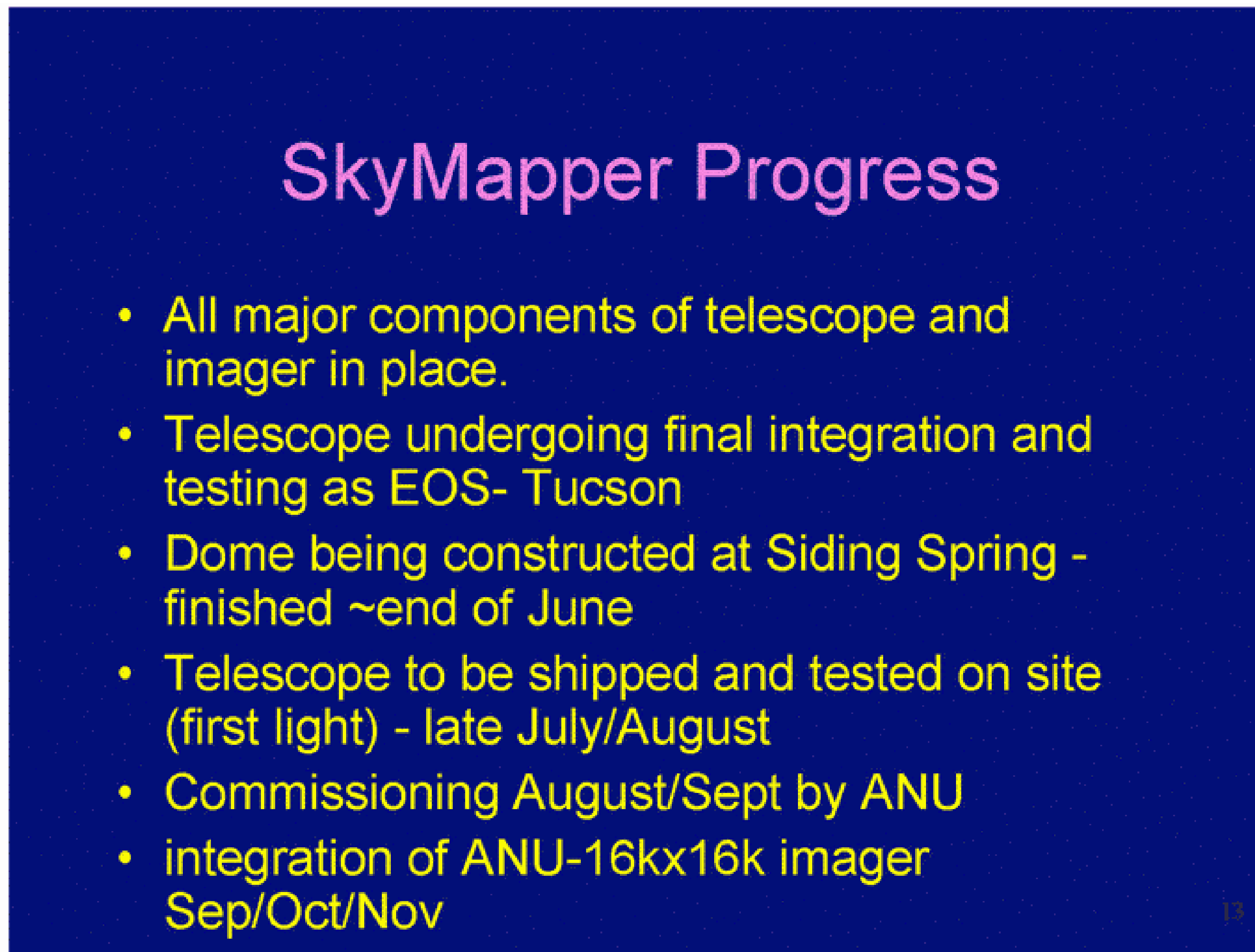
DES
LSST

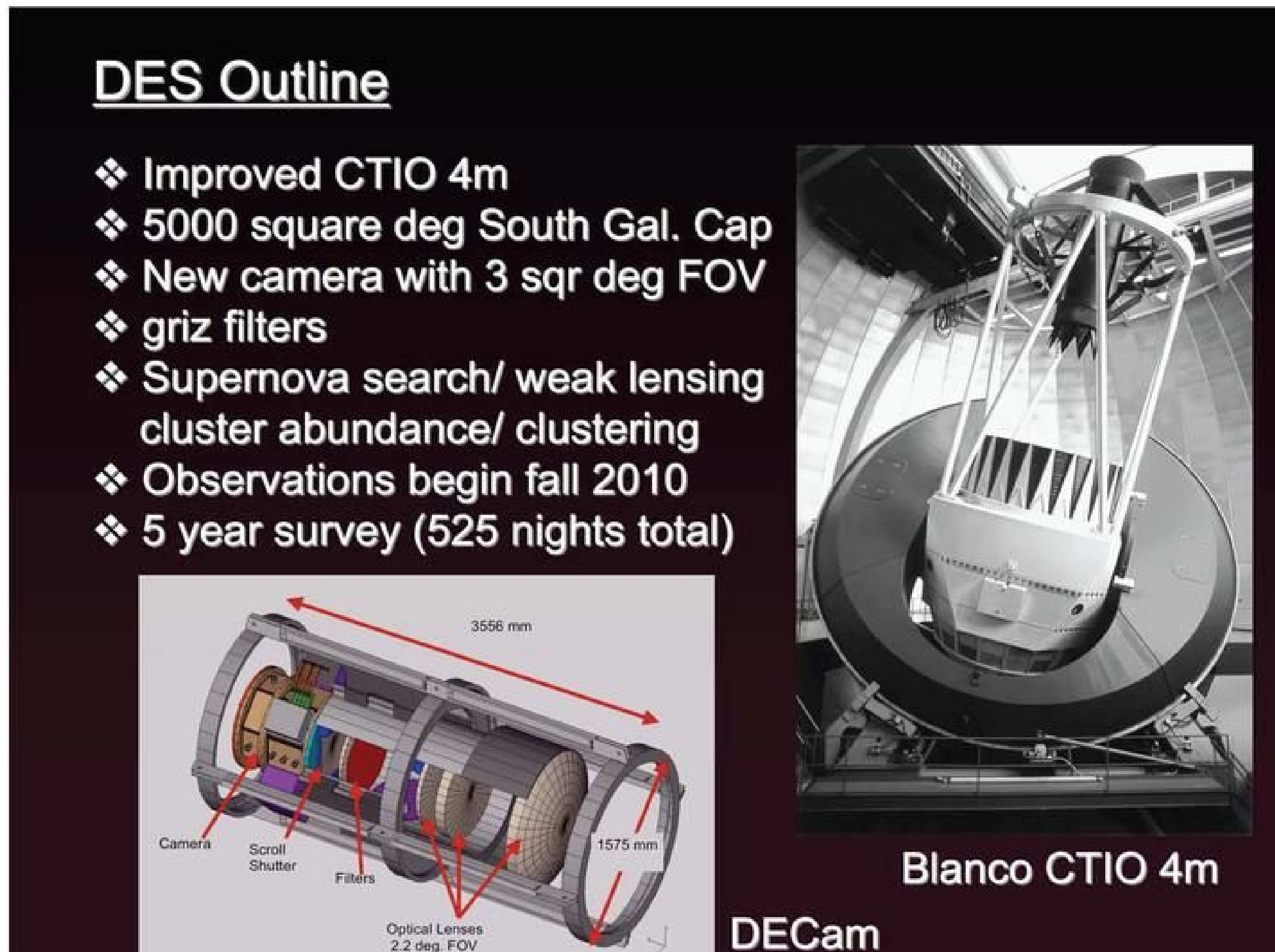
SkyMapper

- 20,000 sq deg (new 1.35m telescope with 5.7sq deg imager!)
- uvgriz imaging, limiting mag i = 19.1 in 30-sec exposure
- 1.7” = “good” seeing
- 2-10 day cadence
- unknown survey length
- First light August 2008
- c. 200 SNe per year
- <z> ~ 0.02 - 0.1
- Strength is in wierdos



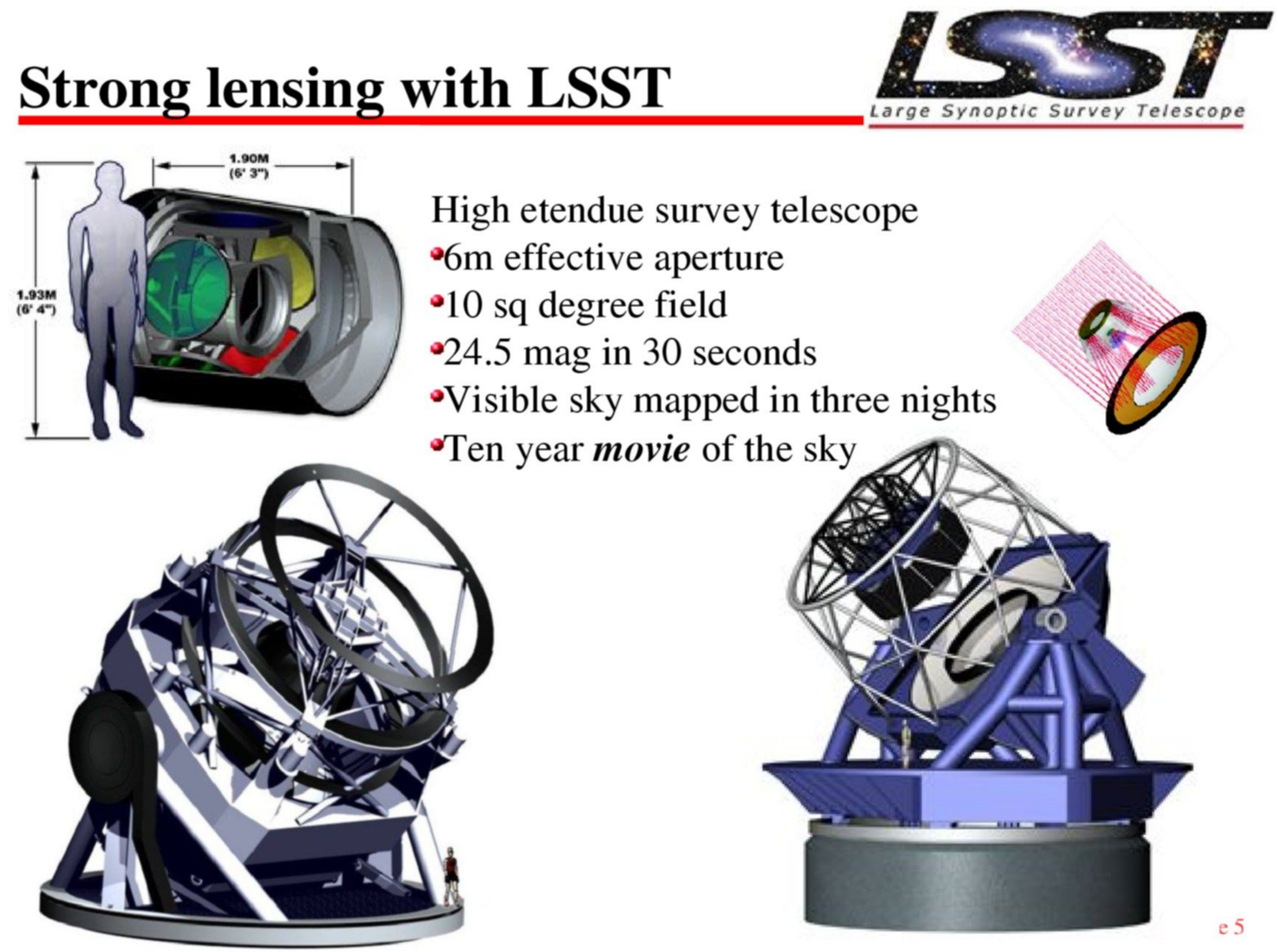
DES (Dark Energy Survey)

- 9 sq deg (Refitted CTIO 4-m telescope with 3sq deg imager!)
- griz imaging, obs strategy?
- Seeing? Depends on camera... no ESSENCE data... Schecter optimistic!
- 4-6 day cadence
- First light Fall 2010
- c. 1400 SNe in 5 years
- c. 1100 with good LCs
- c. 500 spec. follow-up
- <z> ~ 0.6



LSST (Large Synoptic Survey Telescope)

- 20,000 sq deg (6.4m effective area, 10sq deg imager)
- grizY imaging
- Seeing? Cerro Pachon median = 0.7", 10% < 0.4?! or something
- 4 day average cadence
- 20 day average cadence for each filter...
- "First light" mid 2015
- Commissioning 2016-18



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		Parameter	Required Value (units)	Goal Value (units)	Origin and Comments	Group 3 Supernovae	Group 4 Optical Transients	Group 5 NEA, Solar System	Group 6 Weak lensing	Group 7 Strong Lensing
1	a	Sky coverage	15,000 sq.deg for |Galactic Latitude| > 20o in less than 10 years	20,000 sq.deg for |Galactic Latitude| > 300 at zero Long., > 150 at 180 Long., in less than 10 years at airmass <1.5.	Dark Energy – Weak Lensing and Wide-Area Supernova Search	*			*	*
1	c	Sky coverage	500 sq.deg in >5 locations for |Galactic Latitude| > 20 deg	1000 sq.deg in > 10 locations for |Galactic Latitude| > 15 deg	Deep Supernova Search	*				
2	a	Total Filter complement	0.4-1.1 micron in 5 filters grizY	0.33-1.1 microns in 7 filters ubgrizY	5 filters required for accuracy in photometric redshifts. Y filter for extending accurate photo-z's to higher redshift.					
4	a	Number of visits in each filter over 10 years in each sky patch	150 in 5 filters	200 in 6 filters	Weak Lensing				*	
4	b	Number of visits in each filter over 10 years in each sky patch	230 in 4 filters	600 in 6 filters	Deep Supernova	*				
4	e	Number of visits in each filter over 10 years in each sky patch	500 in 1 filter	1000 in 2 filters	Transient lensing		*			
5	a	Depth and dynamic range of single exposure	17-24 AB mag, 10 σ	16-25 AB mag, 10 σ	Must be sky background noise limited.	*	*	*	*	*
6	a	Depth of final stacked image	29 mag/arcsec2, 10σ	29.5mag/arcsec2, 10σ	Weak lensing	*			*	*
7	a	Required image quality in each band per exposure	<0.8" FWHM	<0.6" FWHM	Weak Lensing – for shape measurement in r and i. Improvement in quadrupole moment to go as sqrt of number of exposures.	*	*	*	*	*

Notes: WL and SN surveys likely most useful, NEA stripe has useful cadence though.
Cadences need clarifying for the dim. Assume mag limits correspond to 0.7” seeing

Supernova Surveys/Rates

http://online.kitp.ucsb.edu/online/sncadence_c07/

Survey	SDSS	PS1	SNLS	PTF	SKY	DES	LSST
Depth(i)	21.5	~24	25.6	~21	~19	~25?	~24
Deg^2	280	150	4	7000	20000	9	20000
Cad (d)	4	4	3	5	2-10	4-6	4
Seeing	1.5	0.8?	0.65	1.5	>1.8	~0.7	0.7
Ia/yr	600	c. 6000	400	1400	>200	~400	c. 10^6
.Ia/yr							
91bg/yr							
-15d/yr							