Supernovae with Euclid

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Thanks to R. Nichol, M. Della Valle, F. Mannucci, A. Goobar, P. Astier, B. Leibundgut, A. Ealet

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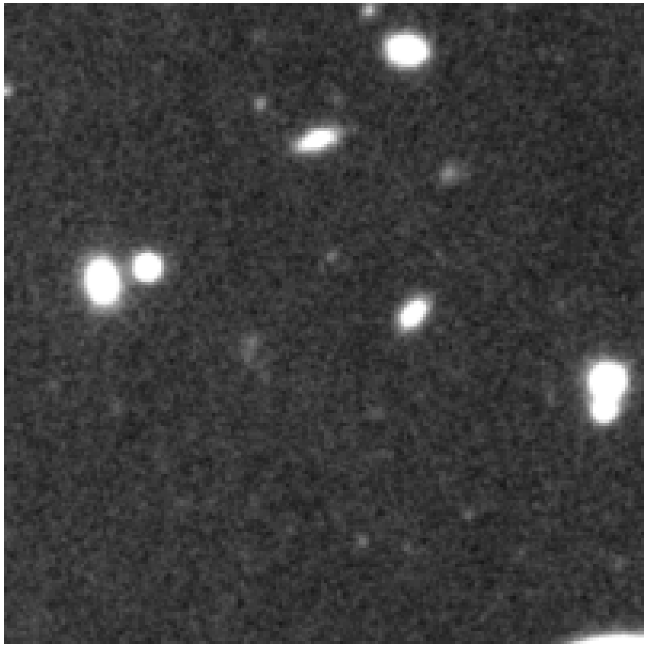
Outline

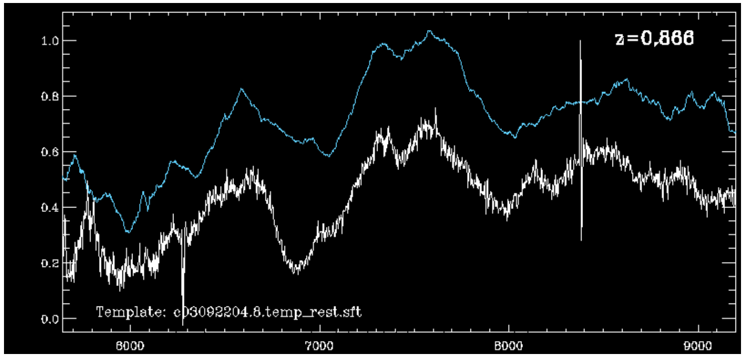
- Introduction
- Parameters of a Euclid Supernova survey
- Cosmology with Type Ia SNe
- Astrophysics with SNe (all types)

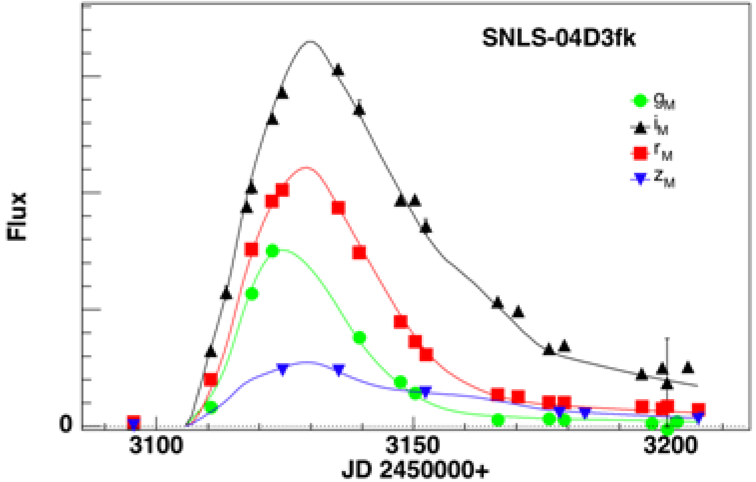
Finding & Using Supernovae

- Need to know for each SN
  - Type
  - Redshift
  - For cosmology: distance (from corrected peak magnitude)
    - in turn requires colours and good sampling of the lightcurve



Example images from the High-z team (Schmidt et al)





Example spectrum and multi-colour light-curve from SNLS

Parameters of a Euclid SN survey
(i) Imaging

- Deep survey (repeat observations)
  - Lightcurves in J, H, K, (R+I+Z)
  - photo-zs for most host galaxies
  - spatial location of the SN within its host
- Details TBD (matched to primary science requirements)
  - FOV > 40 sq deg in at least two patches of > 10 sq deg
  - ~40 visits : Cadence TBD

	Depth Each Visit (AB mag)	**Final Depth (AB mag)**
J, H, K (5σ point source)	24	26
R+I+Z (10σ extended source)	24.5	26.5

Above: Euclid deep survey parameters: imaging

Parameters of a Euclid SN survey
(ii) Spectroscopy

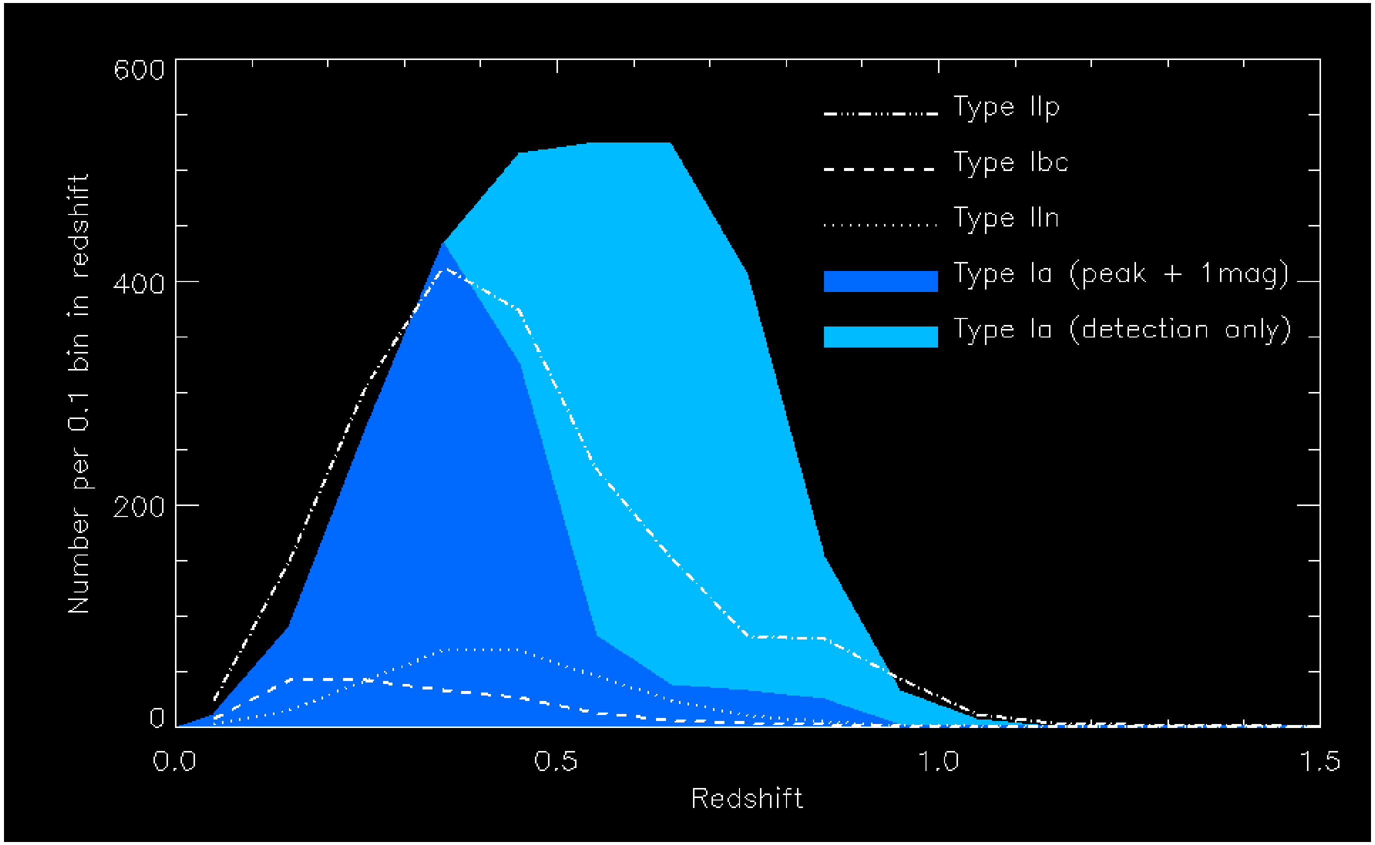
- Deep survey
  - spectroscopic z for brighter host galaxies
  - some spectroscopic SN types. Photo typing needs to be investigated
- Details TBD

	Depth Each Visit (AB mag)	**Final Depth (AB mag)**
Slitless spectroscopy (continuum)	H~19.5	H~21.5
DMD spectroscopy (continuum)	H~22	H~24

Above: Euclid deep survey parameters: spectroscopy

Potential for valuable SN survey: Deep (esp NIR), wide area, stable

Expected Euclid SN counts in J band



N(z) for SNe detected 1 mag fainter than peak, estimated by A. Goobar based on assumptions in Goobar et al arXiv:0810.4932 (SN Ia rates from Dahlen et al 2004). "Detection-only" curve is an estimate (IH) of total number of detectable SNeIa (no lightcurves)

Counts for a 5 year survey assuming 10 sq deg monitored at any time.

Produces 1000-2000 SNeIa to z<0.7

Plus a further 1000-2000 to z<1 (detections only)

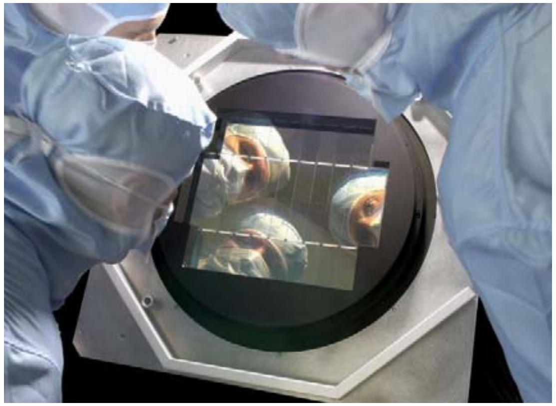
Comparable number of CC SNe

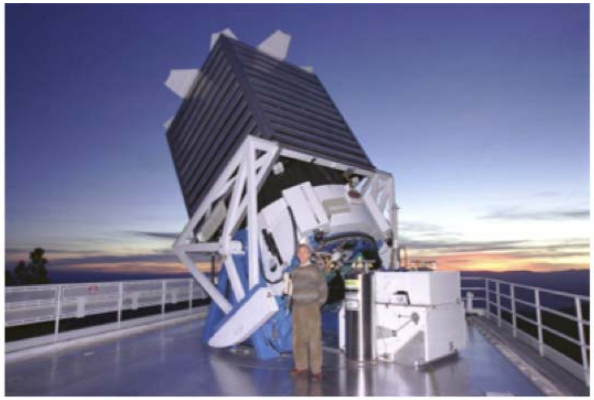
Cosmology with Type Ia SNe

- Type Ia SNe are standardisable candles that can be used as distance indicators
  - Corrected peak magnitude vs z depends on cosmology
- A powerful and proven method for measuring cosmological parameters
- SNe Ia provide independent constraints from WL and BAO

(Some) Current and Future SN Surveys

SN Legacy Survey	~450 SNe 0.1< z <0.9
ESSENCE survey	~200 SNe 0.1< z <0.8
HST + GOODS	z >1 SNe
KAIT search	~50 Ia/yr at v. low z (<0.03)
Carnegie Supernova Project	low and high-z, includes NIR
SN factory	300 nearby SNe (0.03-0.08)
SDSS SN search	0.1< z < 0.4
High-z cluster SN search	z > 1 SNe “dust free”
Palomar Transient Factory	> 600 nearby SNe
Skymapper	up to 50000 SNe over 5 years
PAN-Starrs	> 10^4 SNe
DES + VISTA	~2000 SNe (~100 with NIR)
LSST	~10^6 SNe in 10 years
JWST + ELTs	SNe Ia to z~4





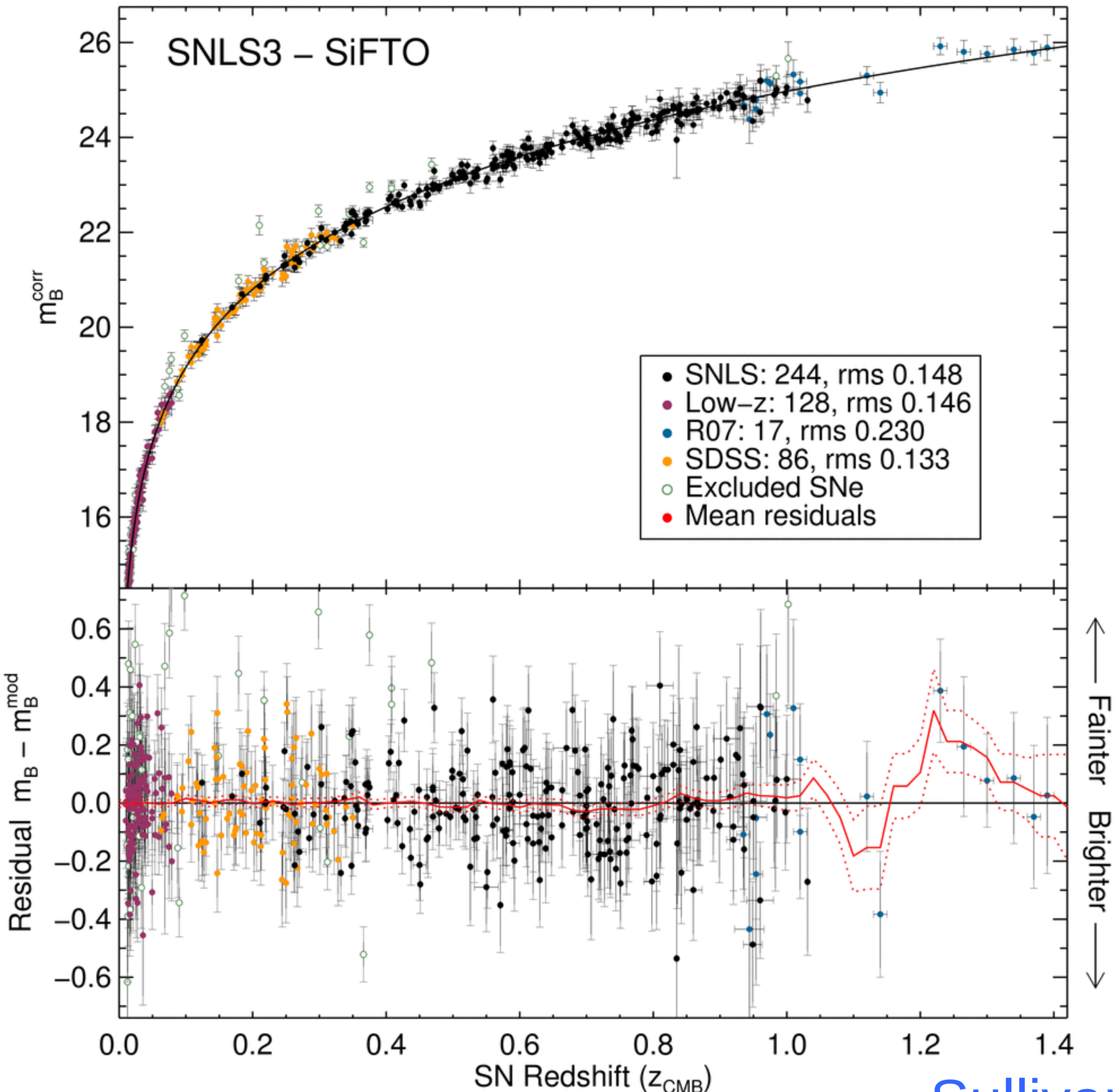
SNLS

- 5 year survey at CFHT
- 4 x 1 sq deg
- (u),g,r,i,z
- ~450 SNeIa confirmed with 8m spectra 0.1<z<0.9
- Astier et al (2006) ++

Both use "Rolling Search"

SDSS-II

- Sep-1 – Nov 30 2005-2007
- 300 sq deg every 2 days
- u,g,r,i,z
- 500+ SNeIa confirmed with spectra 0.1 < z < 0.4
- Frieman et al (2008); Sako, et al (2008), Kessler, et al 09; Lampeitl et al 09; Sollerman et al 09

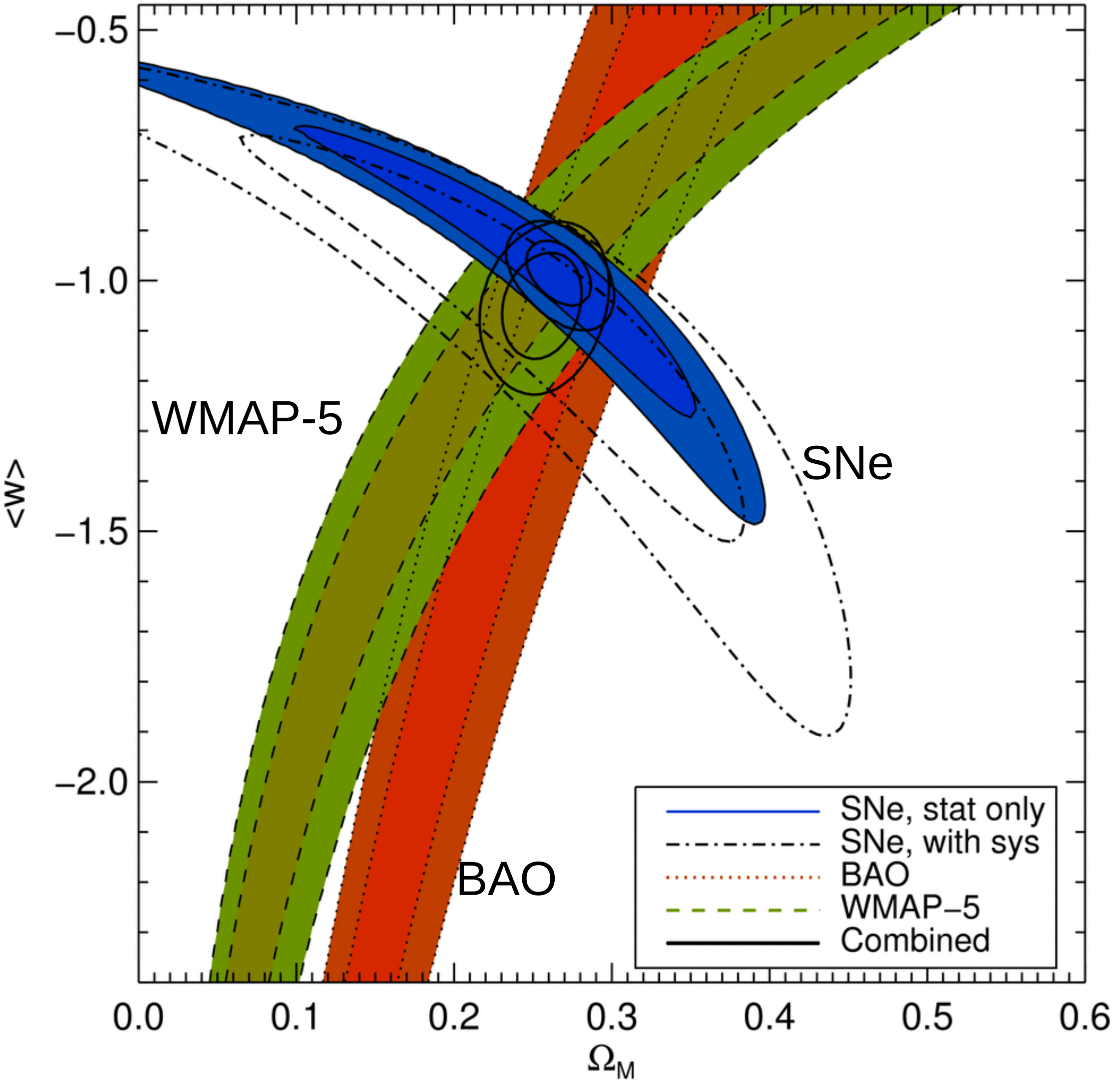


SNLS3 Hubble Diagram (**preliminary**)

244 distant SNLS SNe Ia
128 local SNe Ia
86 SDSS-SN Ia
17 from HST
476 SNe total

Sullivan et al., Conley et al, Guy et al in prep

SNLS3 Cosmological Constraints (**Preliminary**)



SNLS3 + BAO + WMAP5 “shifts” + **Flat**

$$\langle w \rangle \approx -1$$

4.5% statistical errors

~5% systematic errors

~7% stat + sys errors

No evidence for departures from w=-1

Sullivan et al. in prep

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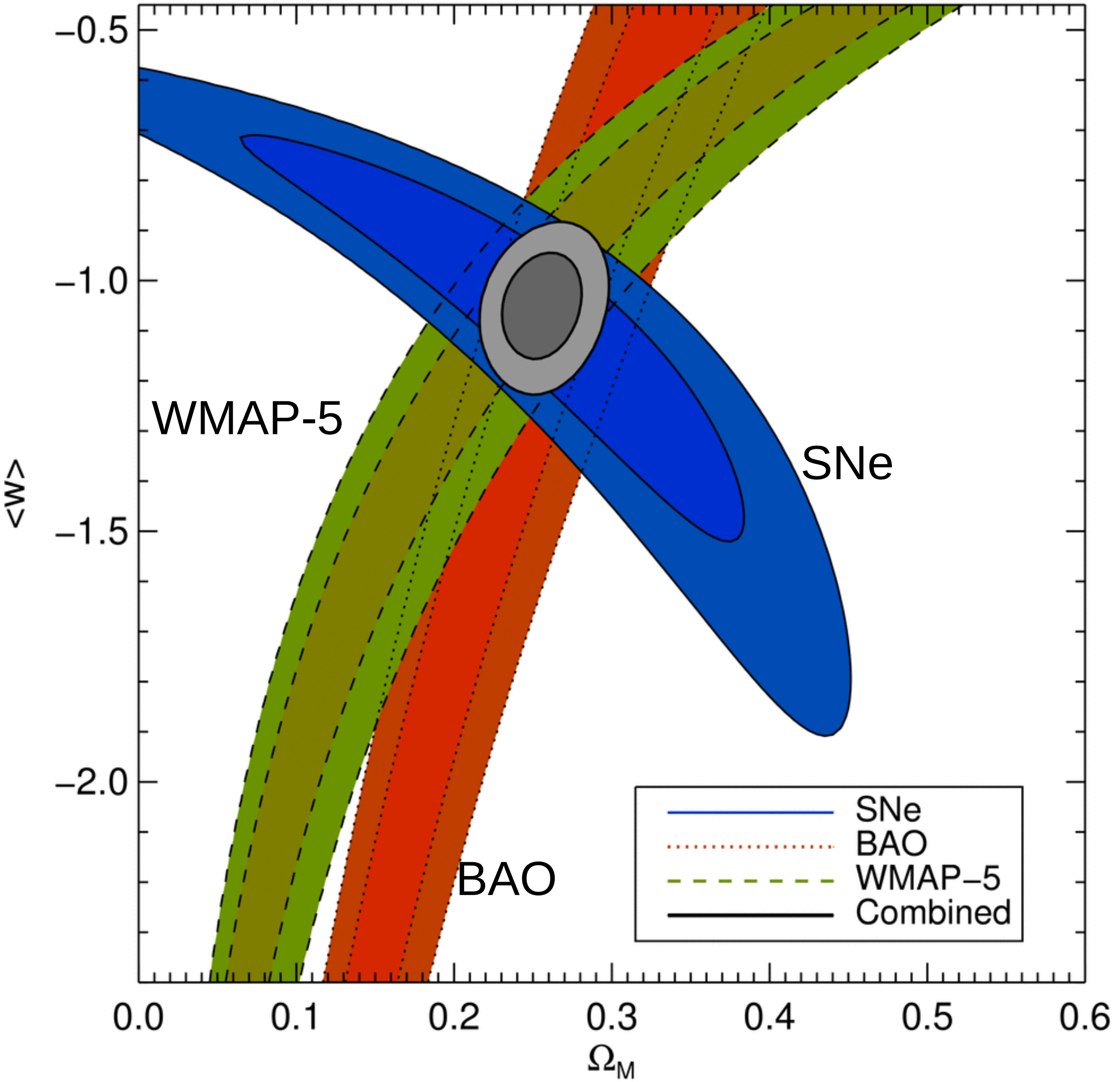

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Identified systematics in SNLS3 (preliminary)

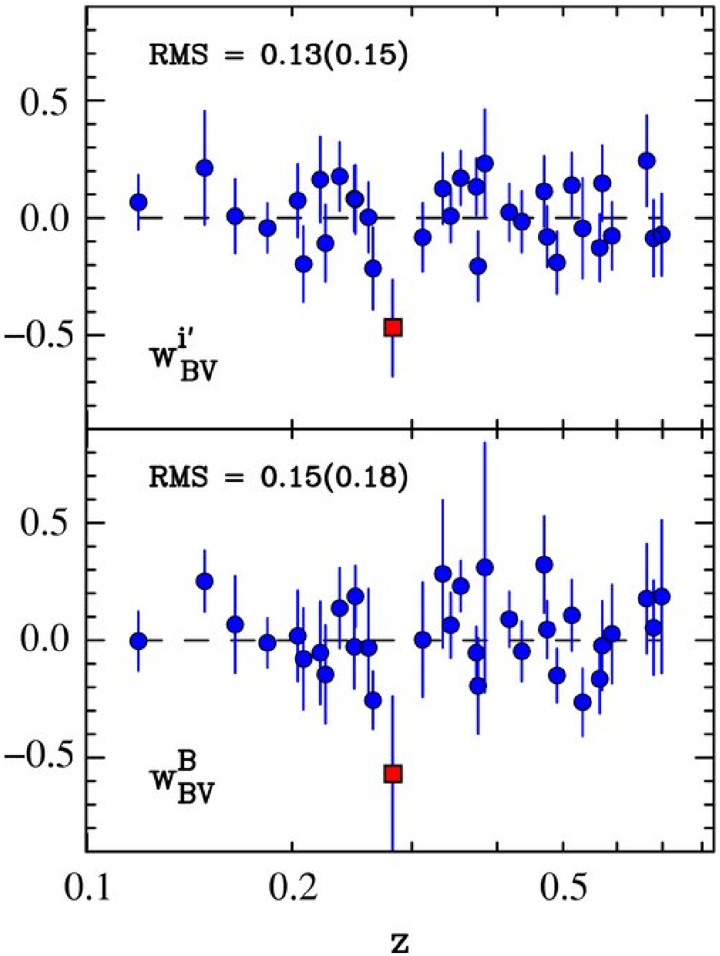
- Brightness-colour relation is complex
- Different R_V cf our Galaxy?
- SN show intrinsic colour-L relation (β)
- Possible *z* variation of β
- Euclid NIR photometry will disentangle these effects

Systematic	**% <w> error**	**Extra**
Statistical only	4.3	…
SNLS zero points	4.5	1.3
SNLS filters	4.4	0.6
External zero points	4.7	1.9
External filters	4.5	0.8
SN colour relation	5.0	2.5
BD+17 colours	5.1	2.6
BD+17 SED	4.4	0.4
Peculiar velocities	4.4	0.5
Malmquist bias	4.4	0.7
Nicmos non-linearity	4.4	0.7
Non-Ia contamination	4.4	0.7
All systematics	**6.8**	**5.0**

Conley et al. in prep

Rest-frame I-band Hubble diagram

Carnegie Supernova Project (Freedman et al 2009)



- Magellan 6.5m YJ data near maximum light of SNeIa from SDSS-II, SNLS, ESSENCE
- Smaller intrinsic dispersion in rest-frame I than B

DES + VISTA

A few thousand SNe in optical + a few hundred with NIR colours at <z> ~ 0.2

- 500 Mpix CCD camera for CTIO 4m
- 5 year survey, starting 2011
- g,r,i,z
- SN component:
- Repeat ~15 sq deg
- 2000 SNe
- 0.3< z < 0.8

- 67 Mpix NIR camera on 4m VISTA telescope
- Surveys start early 2010
- Z,Y,J,H,K
- SN component:
- Repeat imaging ~15 sq deg
- 250 CC and 100 SNeIa
- <z> ~ 0.2

Euclid’s role in SN cosmology

- Large sample
  - 1000 - 2000 SNeIa z<0.7
- Deep, stable IR photometry
  - Control of dust extinction
  - Smaller scatter in Hubble diagram at longer rest-frame wavelengths
- Benefit of coordinated ground-based optical campaign
  - measure standard rest-frame B-band and I-band distances to the *same supernovae*

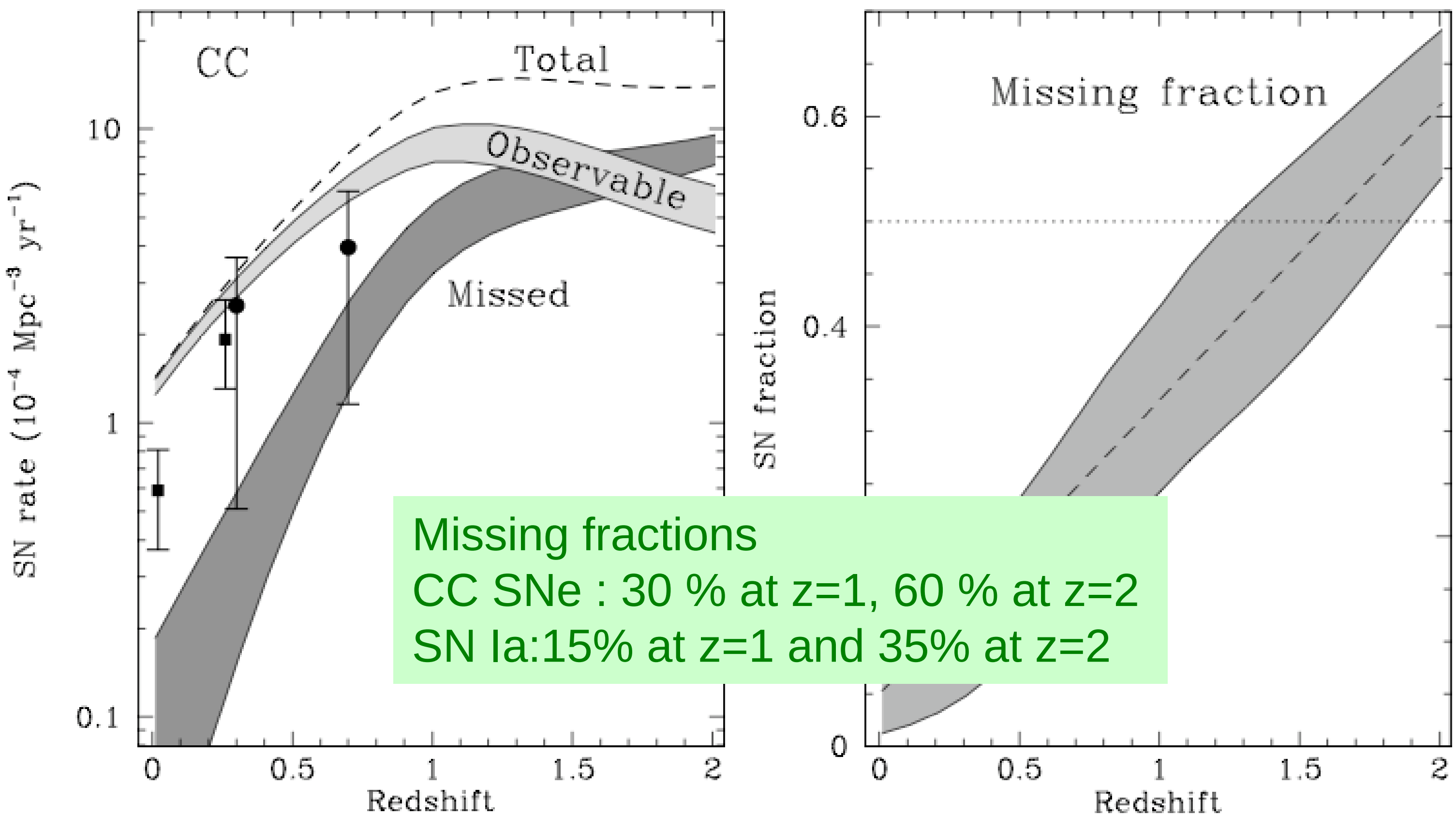
Astrophysics with SN rates

- Metal enrichment of the Universe
  - SNe are main producers of heavy elements and dust in the Universe
- Star formation history of the Universe
  - SNII rate is tied to star formation rate
- Galaxy evolution
  - A galaxy's chemical enrichment history depends on SN rate
  - SNe produce feedback effects in galaxy formation
- Progenitors
  - SN rates(z) constrain progenitor models (via 'delay time')
  - Additional information from rates vs galaxy morphology
  - Location of SN in its host (spiral arms etc?)

Artists impression by David A.Hardy/www.astroart.org & PPARC

Missing fraction from optical SN searches

(Mannucci, Della Valle & Panagia 2007)



Missing fractions
CC SNe : 30 % at z=1, 60 % at z=2
SN Ia:15% at z=1 and 35% at z=2

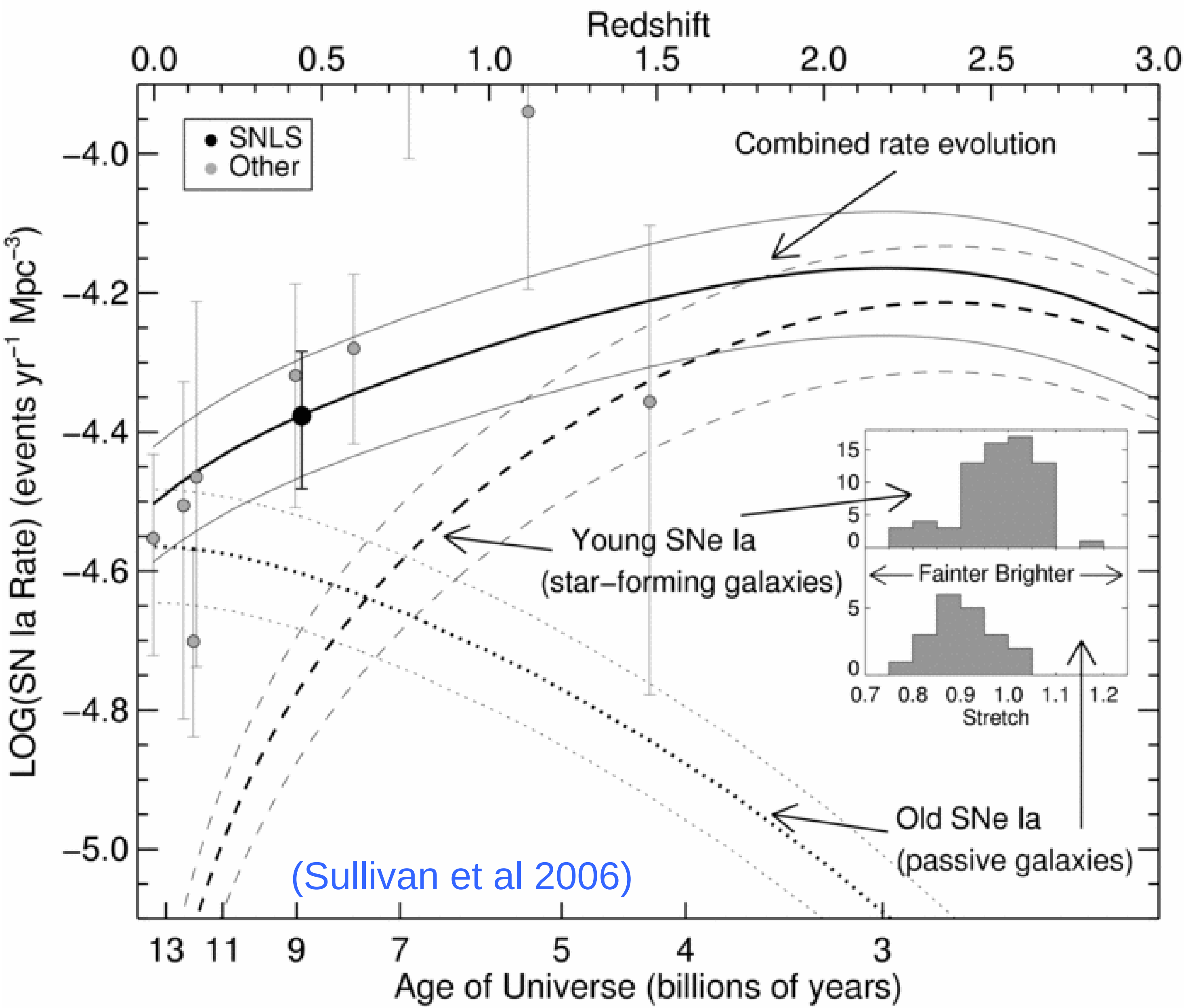
Intrinsic total SN rate is derived from the SF density. The expected SN rate in optical searches is shown in light grey, and is compared with the data points from Cappellaro et al. (2005) (squares), and Dahlen et al. (2004) (circles).

SNIa rates and progenitors

- Type Ia progenitors not known
  - WD in binary system? What is companion?
- Constrain progenitor model by comparing predicted delay times with observations
  - SFH * DTD = SN Rate
- Current rate measurements favour a "two component" model

SN Ia mix vs redshift

Relative mix of young+old evolves strongly with redshift

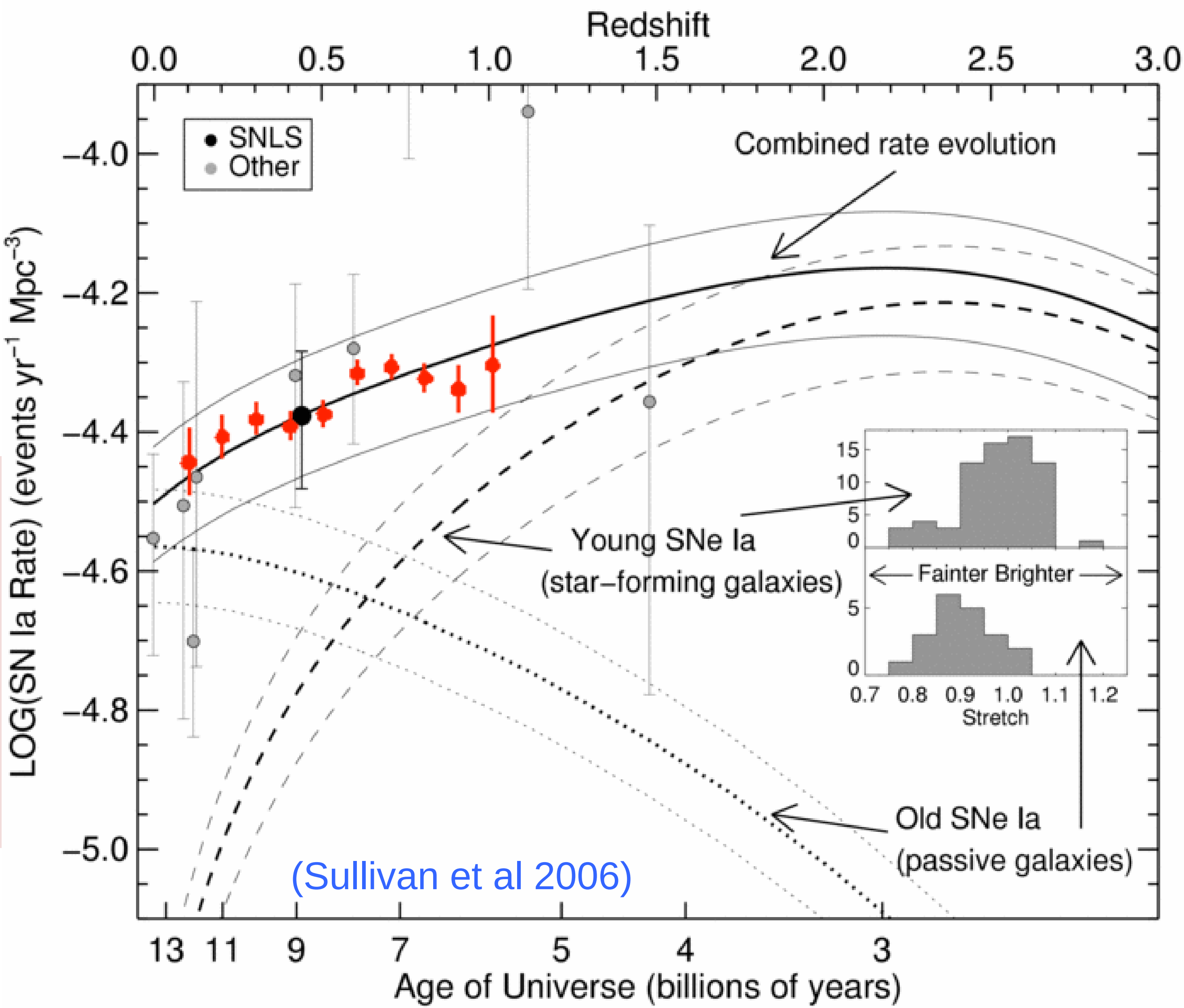


SN Ia mix vs redshift

Relative mix of young+old evolves strongly with redshift

Euclid rate measurement accurate to ~ 5% in Δz=0.1 bins

Less affected by dust



SNe with Euclid : Summary

- Euclid deep surveys can provide (“for free”) -
- SNIa cosmology
  - much-improved extinction corrections
  - Rest-frame I-band Hubble diagram with thousands of objects to z ~ 0.7
- Accurate SN rates
  - Including extincted SNe
  - Use to constrain progenitor models, models of feedback processes, SFH, better understanding of SNeIa for cosmology

The end