The Evolution of the Cosmic SN Rate

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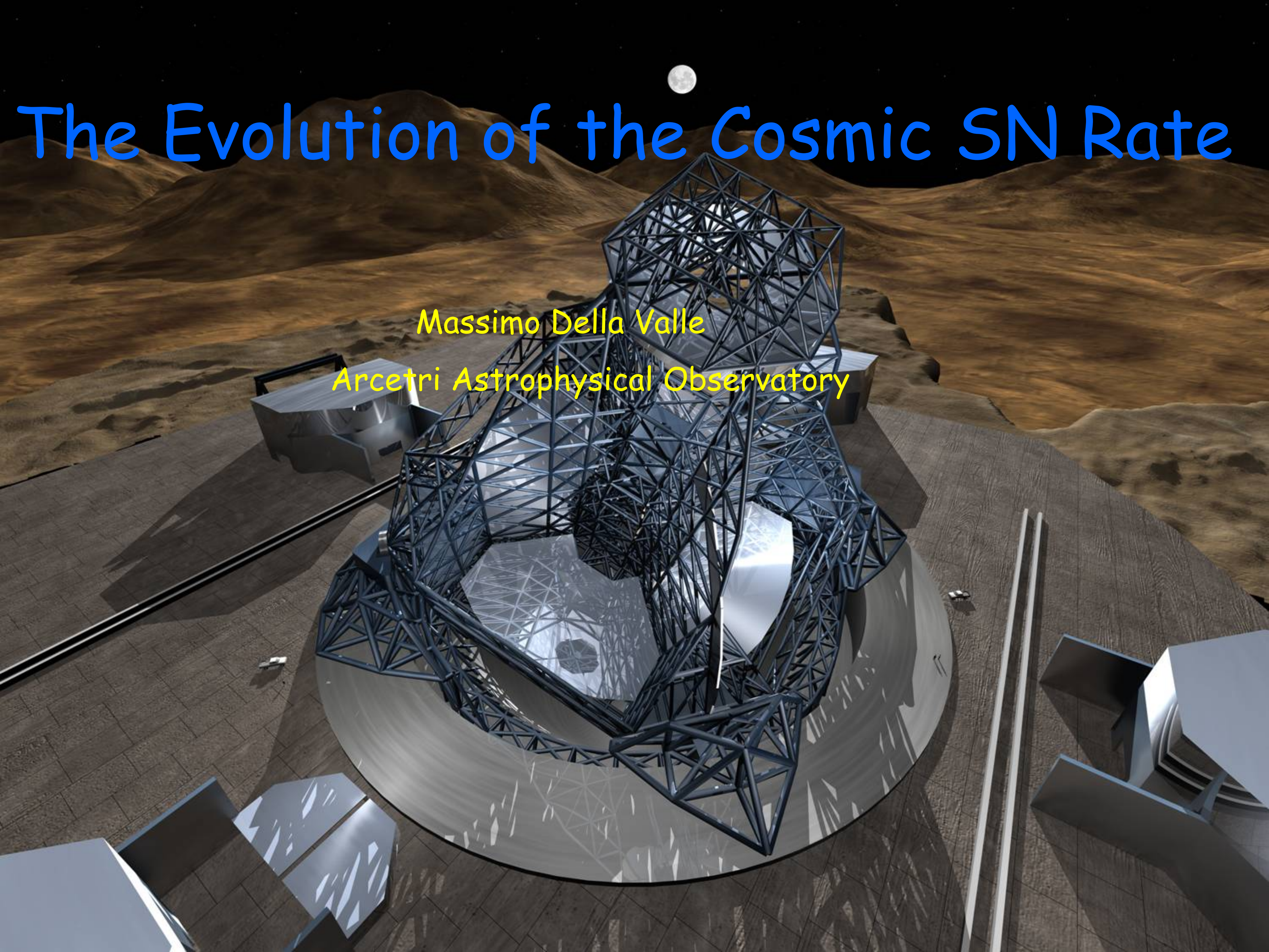

Science with ELTs

Science cases (for OWL)

- Evolution of cosmological parameters
- Large scale structure
- Galaxy formation
- (Dark?) matter distribution
- SNe at high redshift
- Star formation history
- Proto Globular Clusters
- Primordial stars (Pop III)
- Re-ionization epoch

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Patners in Crime

Roberto Gilmozzi, ESO

Nino Panagia, ESA/STScI

Jacqueline Bergeron, IAP

Piero Madau, UCSC

Jason Spyromilio, ESO

Philippe Dierickx, ESO

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Science with OWL: a practical case

The cosmic SN rate up to z ~ 10

SNe as calibrated standard candles, (SNe-Ia, Phillips 1993, SNe-II, Hamuy 2003) provide a direct measurement of q_0 at z>0.3 (Riess et al 1999;Perlmutter et al. 1998, 1999)

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Science with OWL: a practical case

The cosmic SN rate up to z ~ 10

SNe as calibrated standard candles (Phillips 1993, SNe-Ia, Hamuy 2003 Sne-II) provide a direct measurement of H_o (in the LU) and q_o at z>0.3 (Riess et al. 1999; Perlmutter et al. 1998, 1999)

The evolution of the cosmic SN rate provides a direct measurement of the cosmic star formation rate.

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SN Rate as Tracer of Star Formation Rate

a) The rate of CC SNe (II & Ib/c) is a direct measurement of the death rate of stars M>8 $M_\odot$ (>40 $M_\odot$? Normal II SNe? Normal or Peculiar Ic/b? Collapsars?)

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b) The rate of type Ia SNe provide the history of star formation of moderate mass stars, 3-8 $M_\odot$

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b) The rate of type Ia SNe provide the history of star formation of moderate mass stars, 3-8 $M_\odot$

c) The evolution of the rate can clarify the nature of the progenitors of type Ia SNe (WD+WD or WD+MS)

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SN rate→ Star formation Rate

For a Salpeter IMF with Mup=100 $M_\odot$

50% of all SN II are produced by stars with 8< $M_\odot$ <13.1 and 50% of the mass produced in SNe is in the interval 8-21.6 $M_\odot$

A 13 $M_\odot$ MS star has L=8000 $L_\odot$ and T_{eff}=22000 K, a 21.6 $M_\odot$ L=35000 $L_\odot$ and T_{eff}=27000

SN rate→ Star formation Rate

More than 50% of the stars producing SNe are poor sources of ionizing photons and of UV continuum photons

The bulk of the UV radiation both in the Balmer and in the Lyman continuum is produced by stars more massive than 40 $M_\odot$

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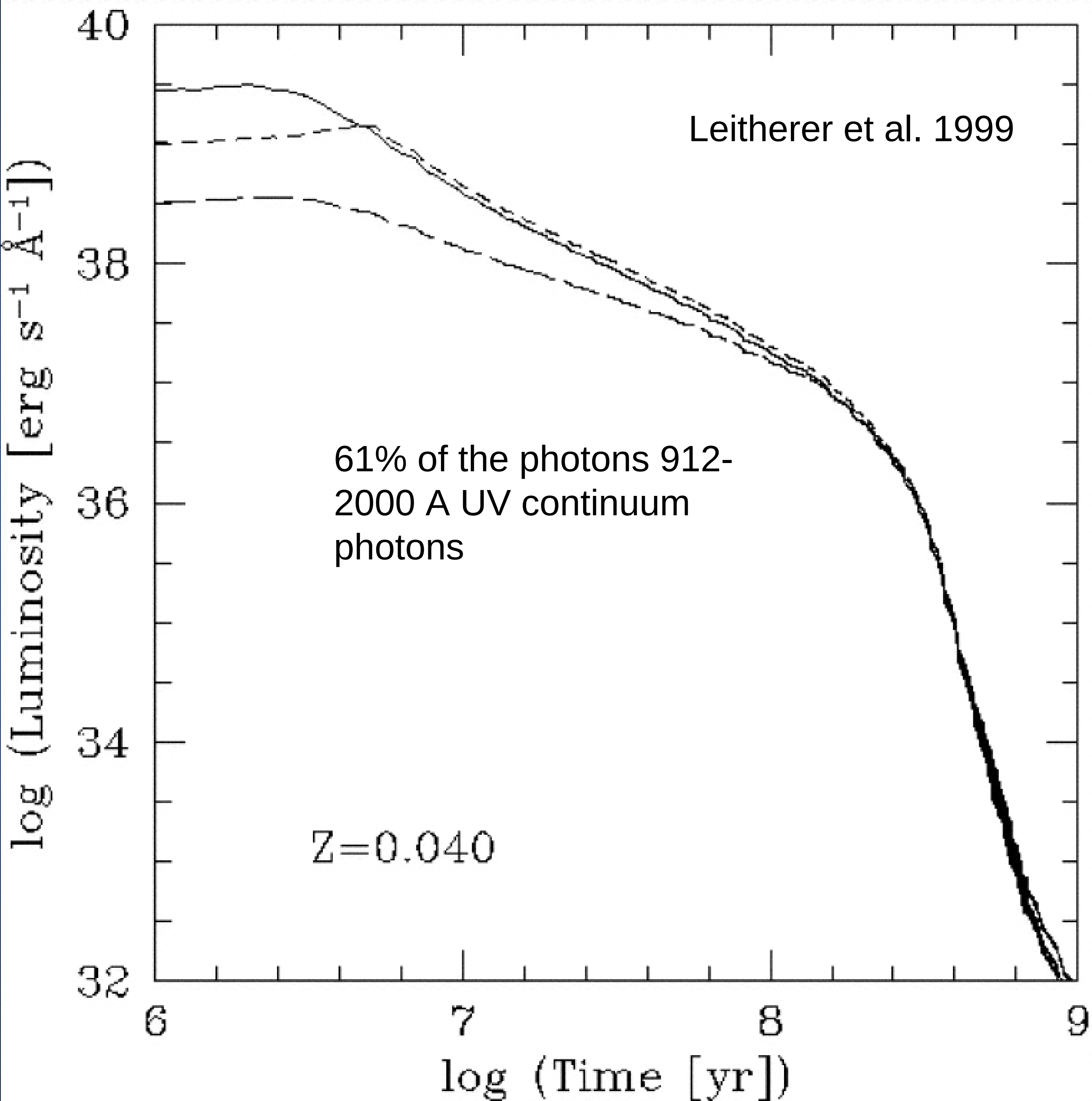
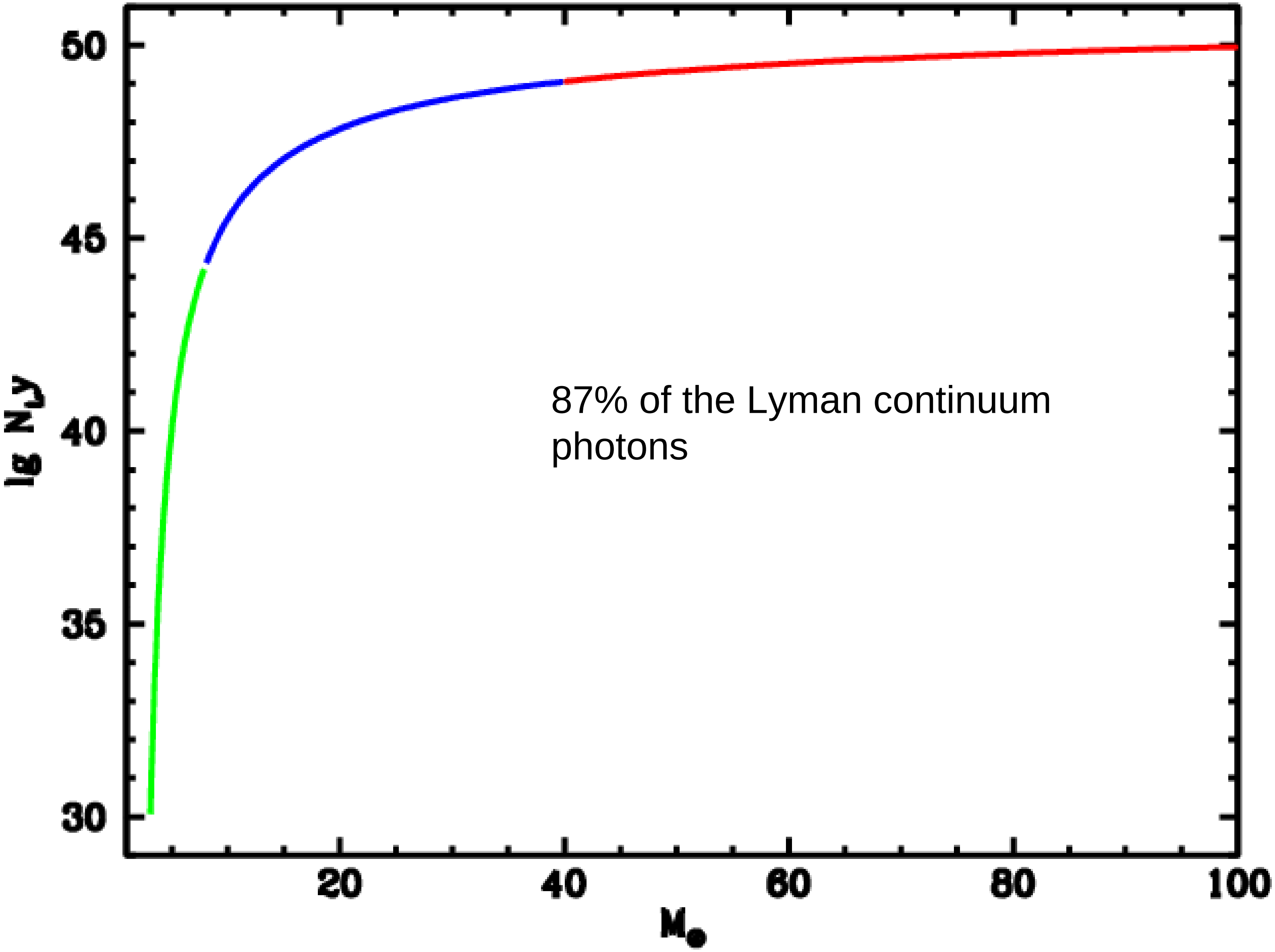



50
45
40
35
30
lg N_Ly
20
40
60
80
100
M☉
87% of the Lyman continuum photons

SN rate→ Star formation Rate

Both the Halpha fluxes and the UV fluxes Measure only the very upper part of the IMF [>40 $M_{\odot}$→ 8% ($M_{\odot}$>8)]

therefore:

SN rate→ Star formation Rate

Both the Halpha fluxes and the UV fluxes Measure only the very upper part of the IMF [>40 $M_\odot$→ 8% ($M_\odot$>8)] therefore:

They are NOT good star formation rate indicators because

a) they require a huge extrapolation to lower masses

b) the extrapolation depends on the value of Mup which is not well known and is not a constant quantity in different environment (e.g. Bressan et al. 2002)

SN rate → Star formation rate

SNe provides a measurements of the star formation rate which is:

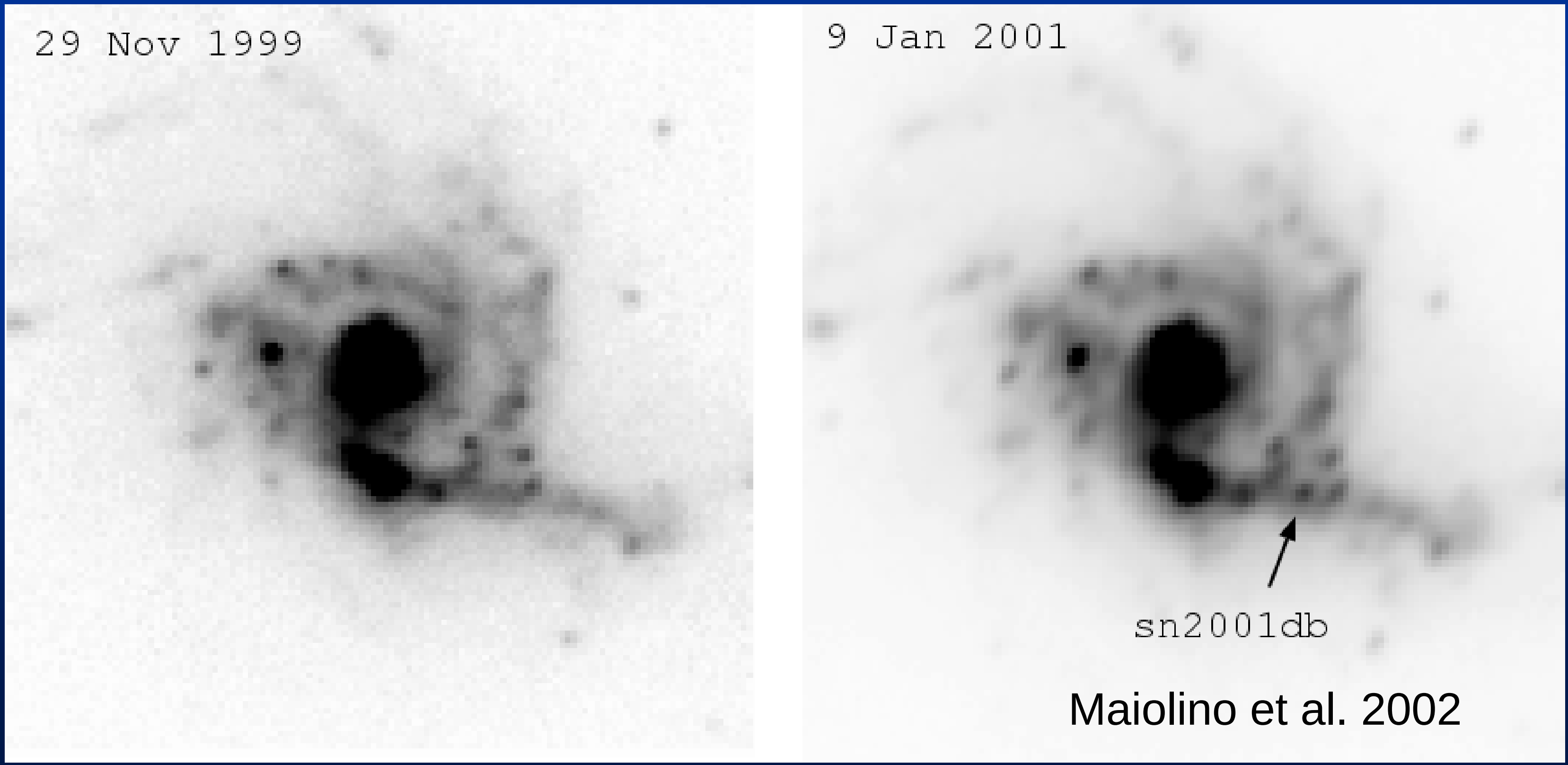
Independent of other possible determinations

More direct, because the IMF extrapolation is much smaller

More reliable because it is based on counting SN explosions rather than relying on identifying and measuring the source of ionization (if using H-alpha flux) or the source of UV continuum

Drawbacks…..

Supernovae can be missed because of the extinction



Maiolino et al. 2002

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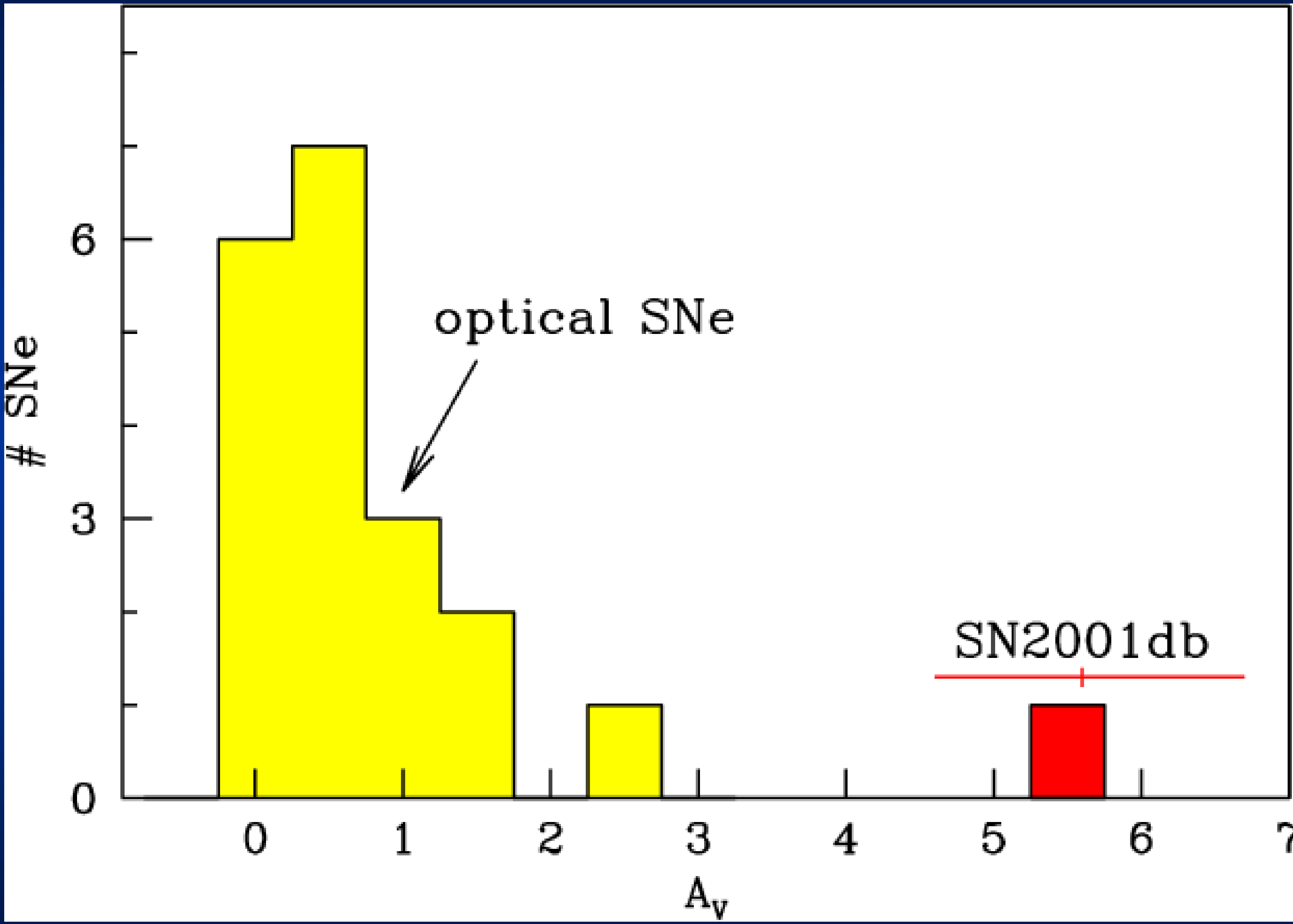

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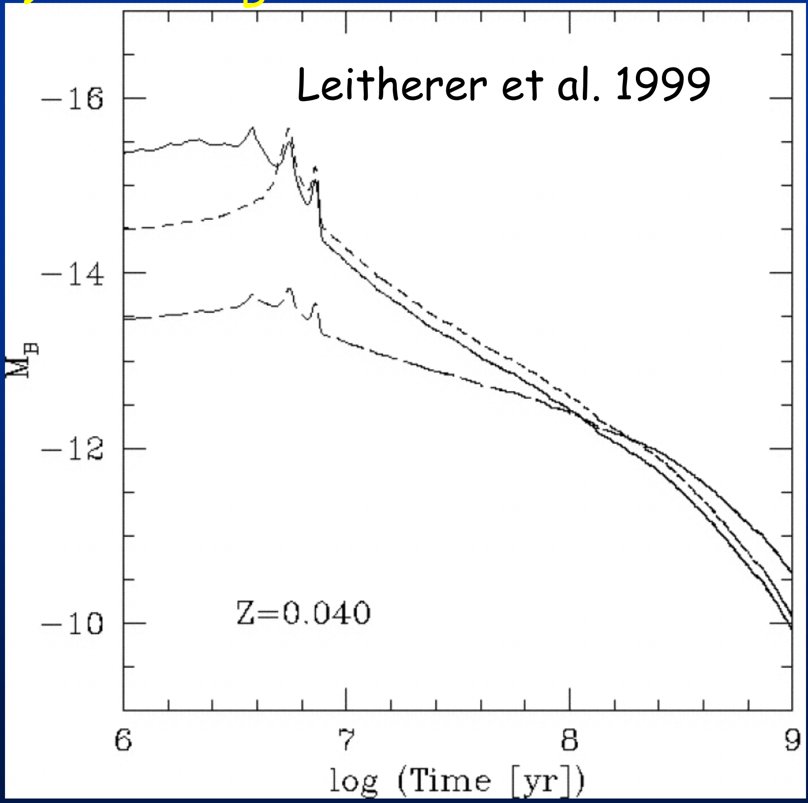
SNE CC vs. Starburst

A typical SN II has a rest-frame B magnitude= -17.5 (Patat et al. 1994)

A starburst with a mass of 10^6 $M_\odot$ which produces

1 $M_\odot$/yr (similar to the MW) has M_B=-15.4



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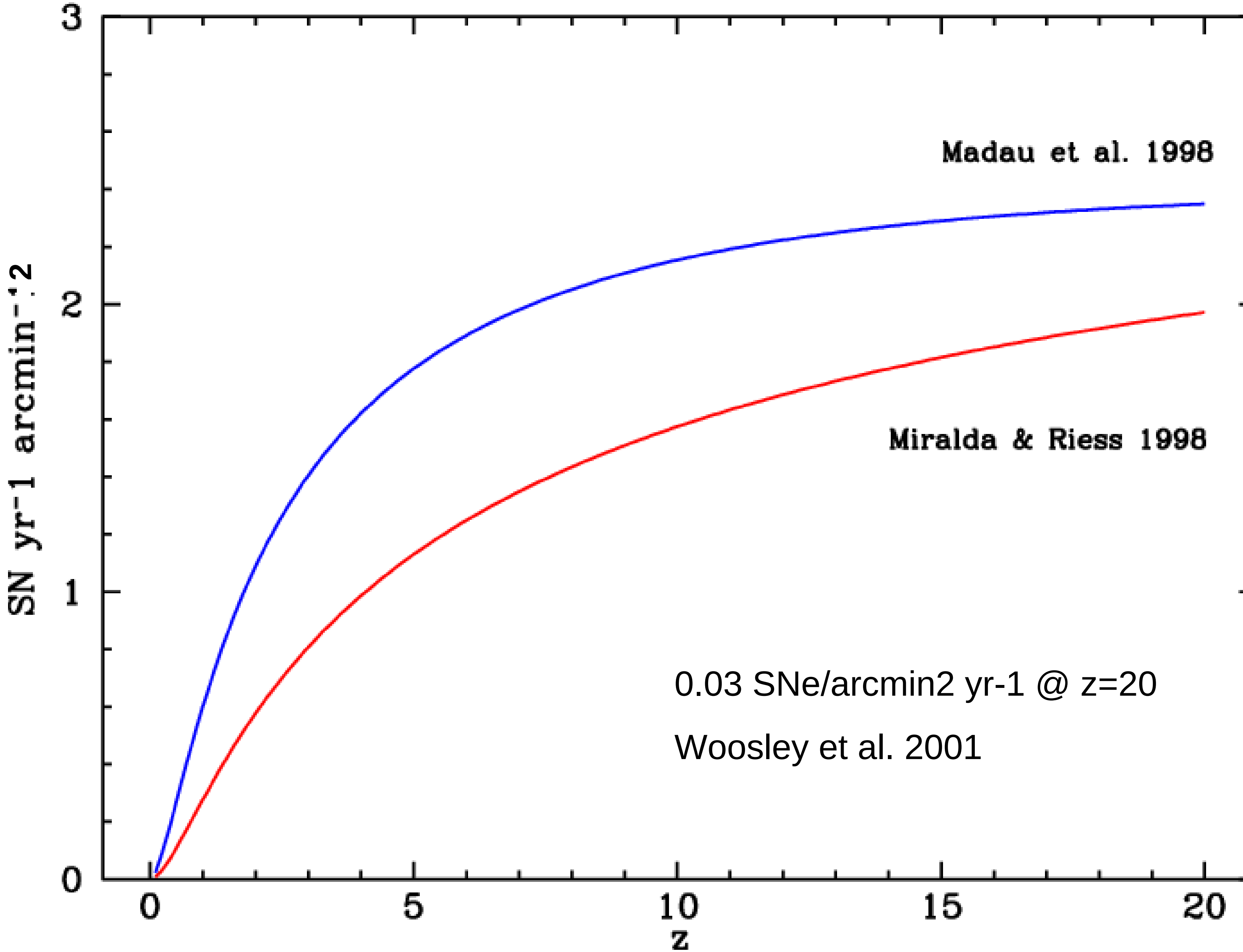
Ingredients of the simulation

Number of SNe expected in a single OWL frame (2arcmin x 2arcmin)

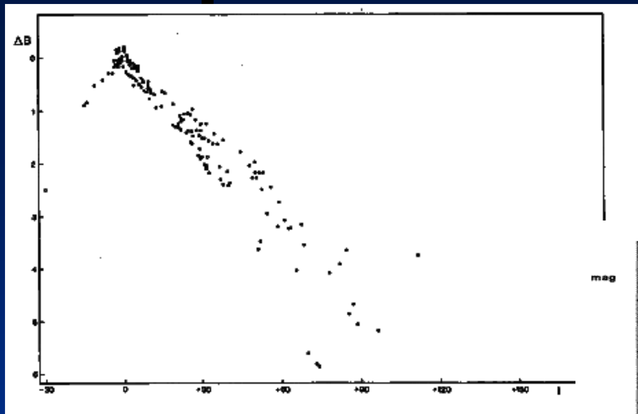

3
2
1
0
SN yr-1 arcmin-'2
0
5
10
15
20
z
Madau et al. 1998
Miralda & Riess 1998
0.03 SNe/arcmin2 yr-1 @ z=20
Woosley et al. 2001

Ingredients of the simulation

Number of SNe expected in a single OWL frame (2arcmin x 2arcmin)

8 SNe x OWL field (yr-1)

Science with



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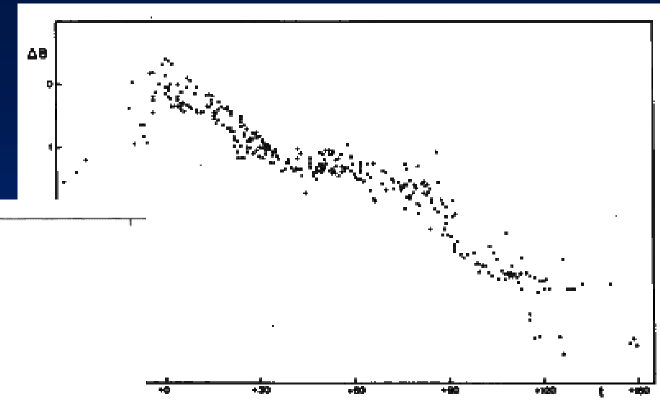

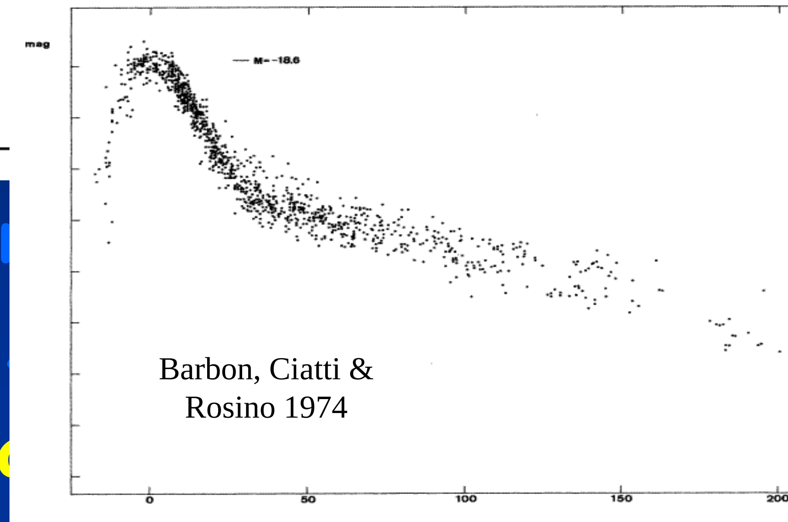

OWL f... min)

8 SNe ...

Observ... sed on the control time methodology (Zwicky 1936). The typical light curve width around maximum is 15-20 days and most SNe will occur at z<5 → light-curve width in the observer rest-frame about 100-120 days. 4 exposures at time intervals of 3 months will cover 1 year

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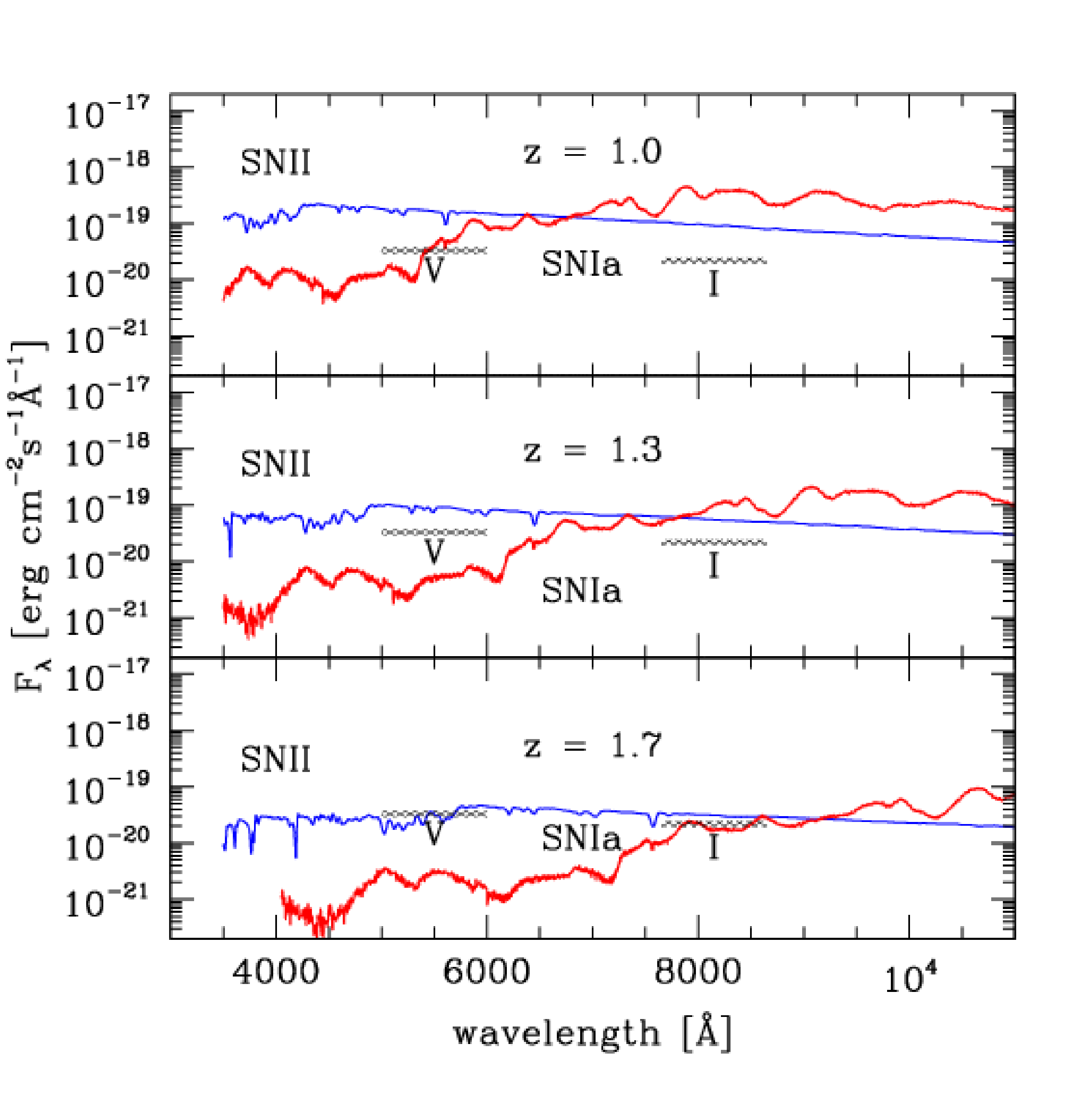
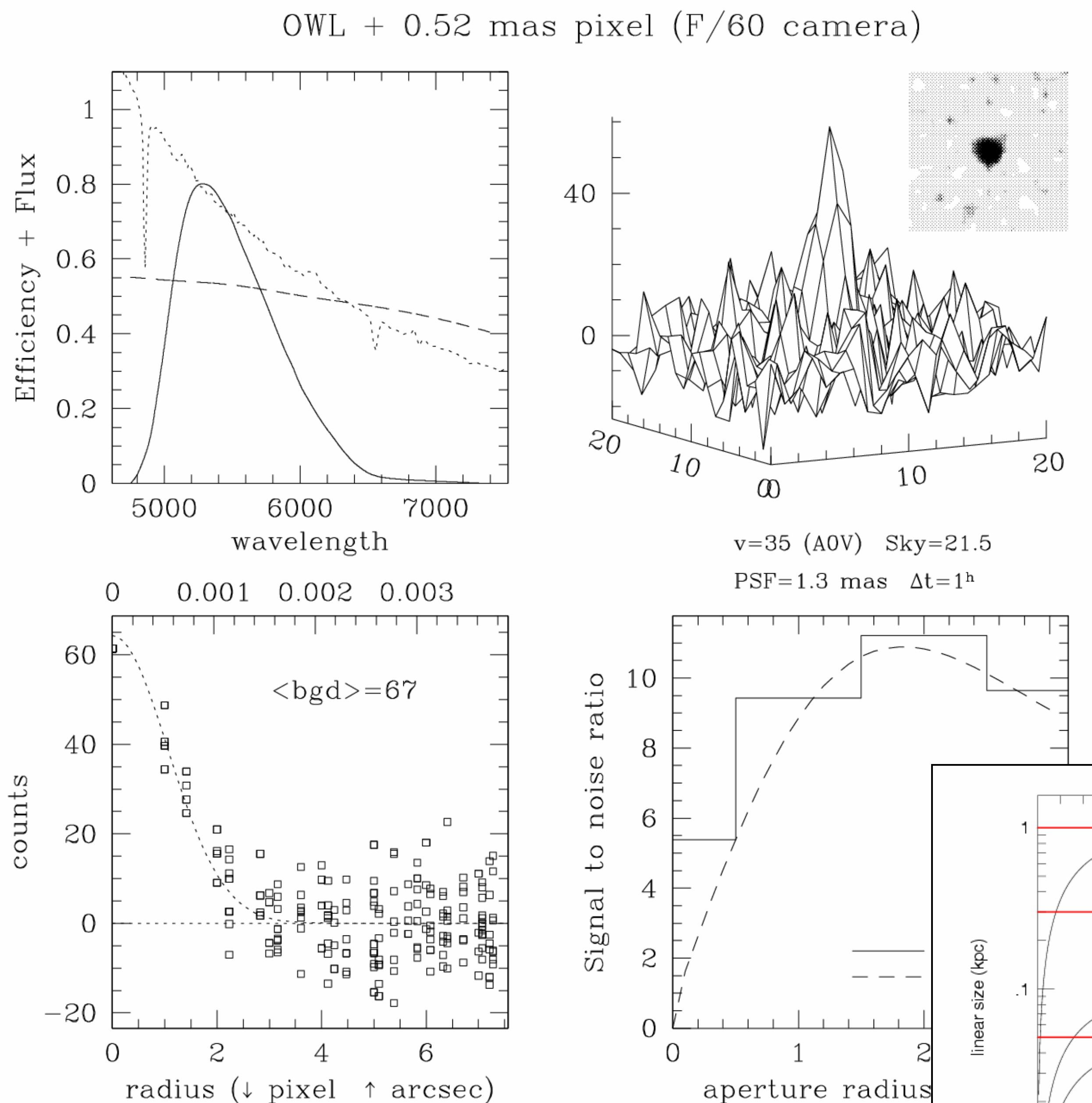
K corr

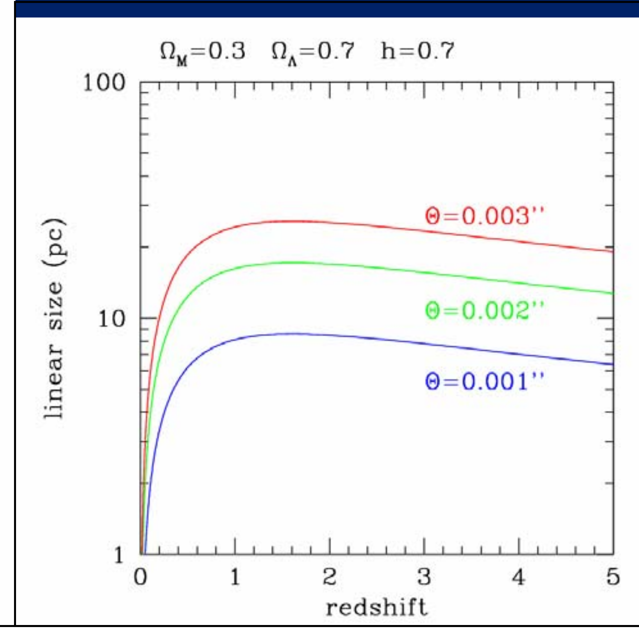
1994D &
1992A



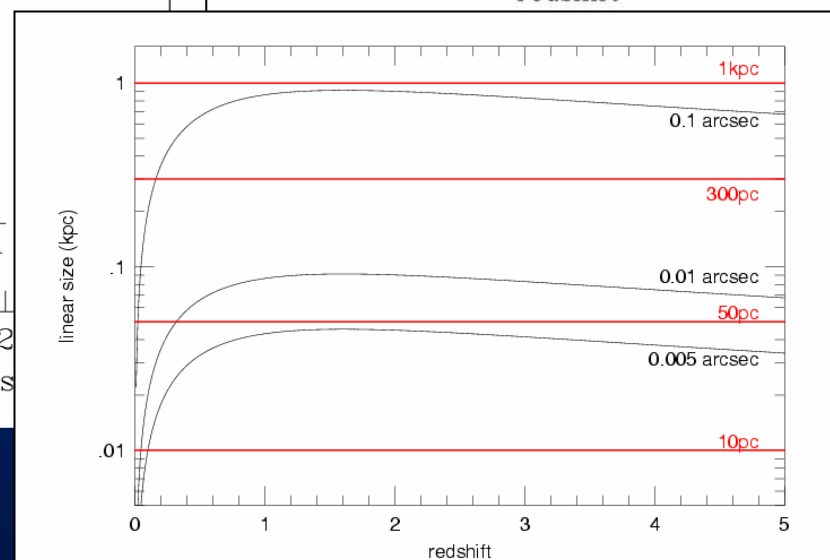
Recipe



OWL + 0.52 mas pixel (F/60 camera)
Efficiency + Flux
wavelength
5000
6000
7000
v=35 (A0V) Sky=21.5
PSF=1.3 mas Δt=1^h
counts
<bgd>=67
radius (↓ pixel ↑ arcsec)
0.001
0.002
0.003
Signal to noise ratio
aperture radius

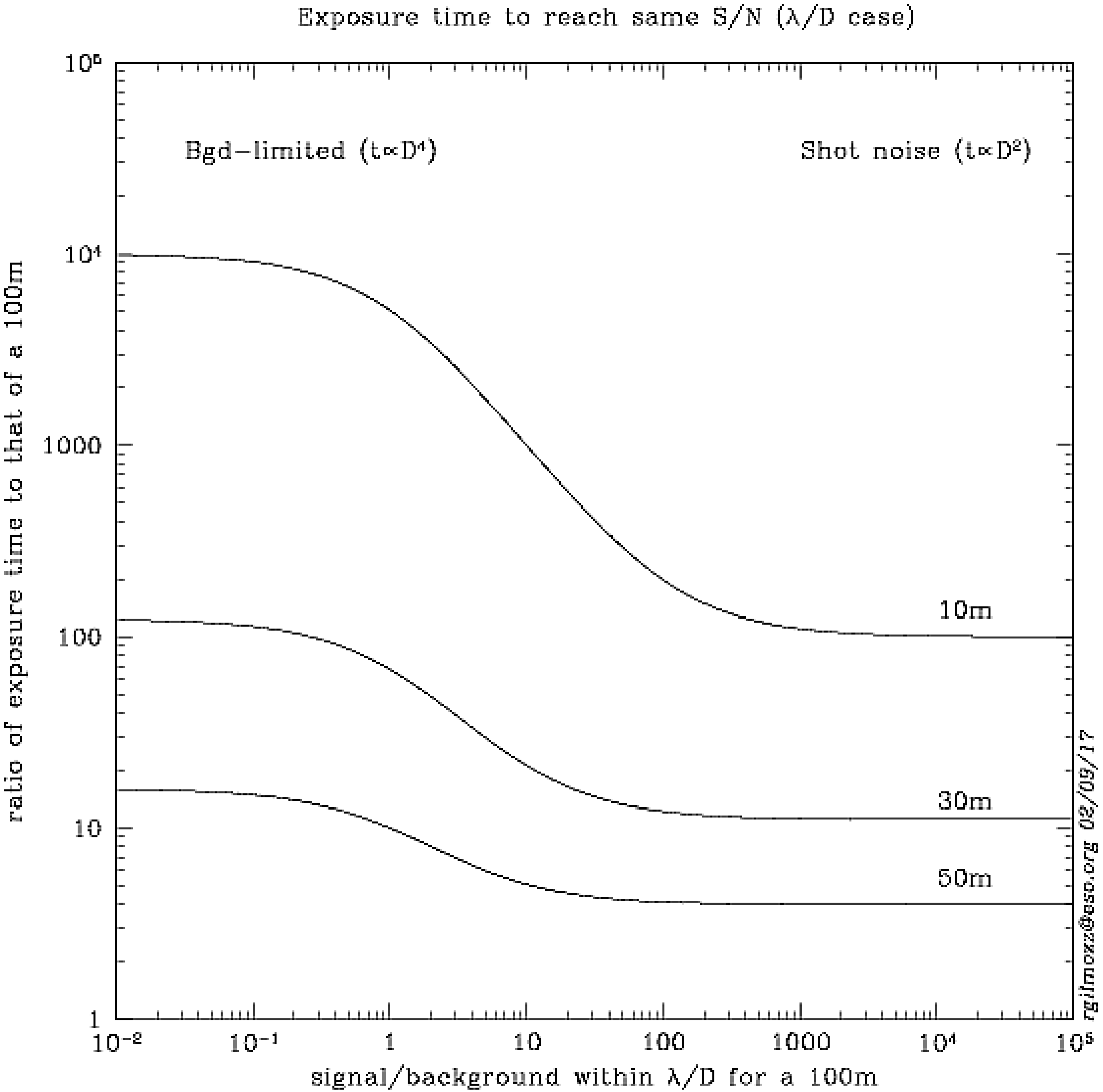


Ω_M=0.3 Ω_Λ=0.7 h=0.7
linear size (pc)
Θ=0.003''
Θ=0.002''
Θ=0.001''
redshift



linear size (kpc)
1kpc
0.1 arcsec
300pc
0.01 arcsec
50pc
0.005 arcsec
10pc
redshift

Science with ELTs



Results of the Simulation

We plane to image 50 fields in the J, H and K bands (1h each) at 4 different epochs (="SN search")

+ 3 epochs in the K band for the photometric follow-up (i.e. seven K photometric points for each SN)

+ 4h for each SN (z< 4.5-5) to get the spectroscopic classification

Grand Total=600h (search)+150h(K follow-up)+200h(spectroscopy)=950h+10%

Results of the Simulation

1050h or 130 nights to study 400 SNe up to $z = 10$

This is about twice the size of a current Treasury programme (450 orbits) and it is comparable with the UWFC, which is expected to discover about 500 SNe (at $z<1.7$) in about 6 months, or SNAP, about 2000 SNe in 2 yr ($z<1.7$).

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WHICH SN types?

SNe Ia visible up to z ~ 5

Blind below 2400A, K last useful band

SNe II visible up to z ~ 10

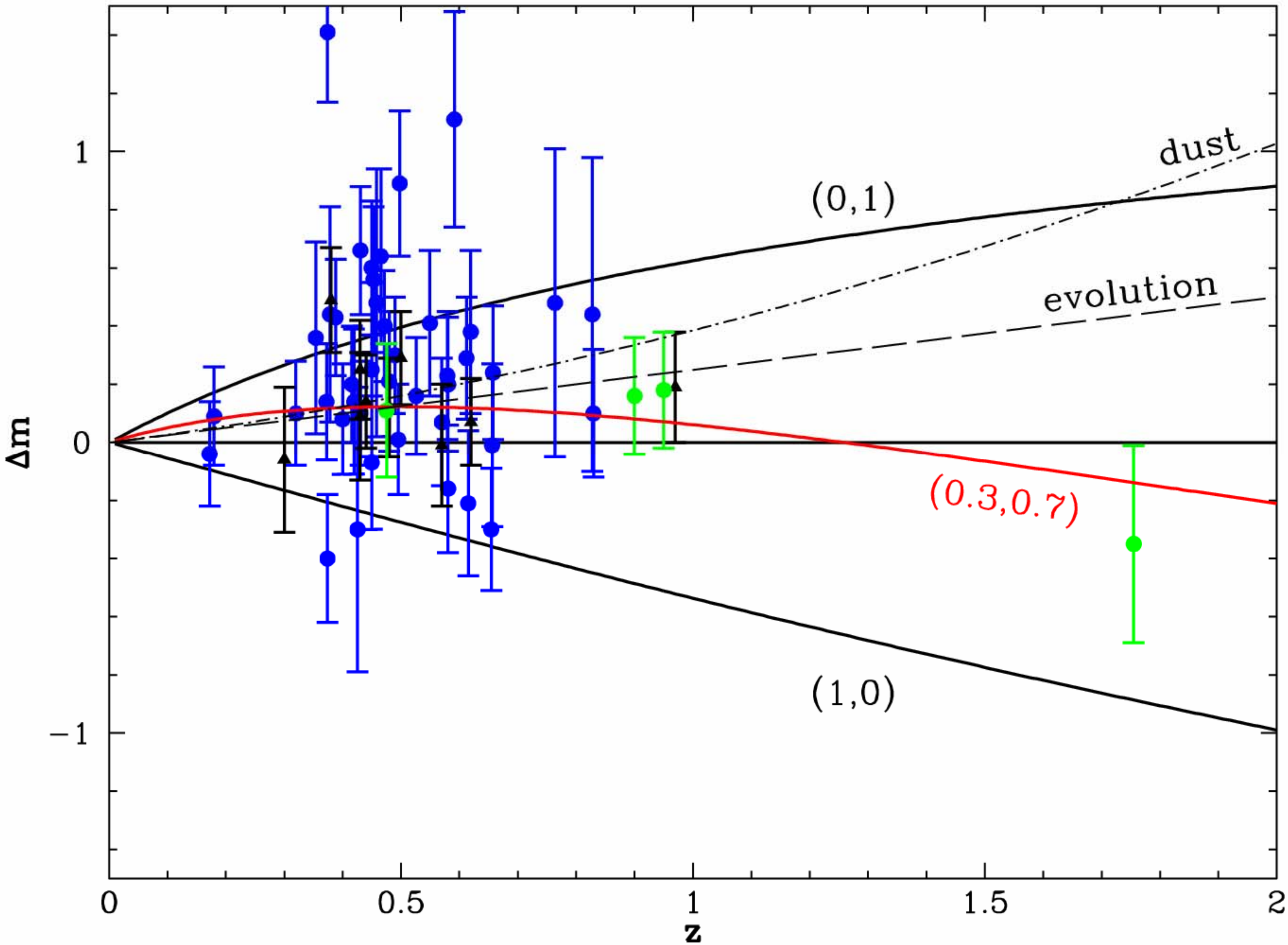
Strong UV emitters (time-dilated UV flash)

Pop III SNe (100-260 $M_\odot$)

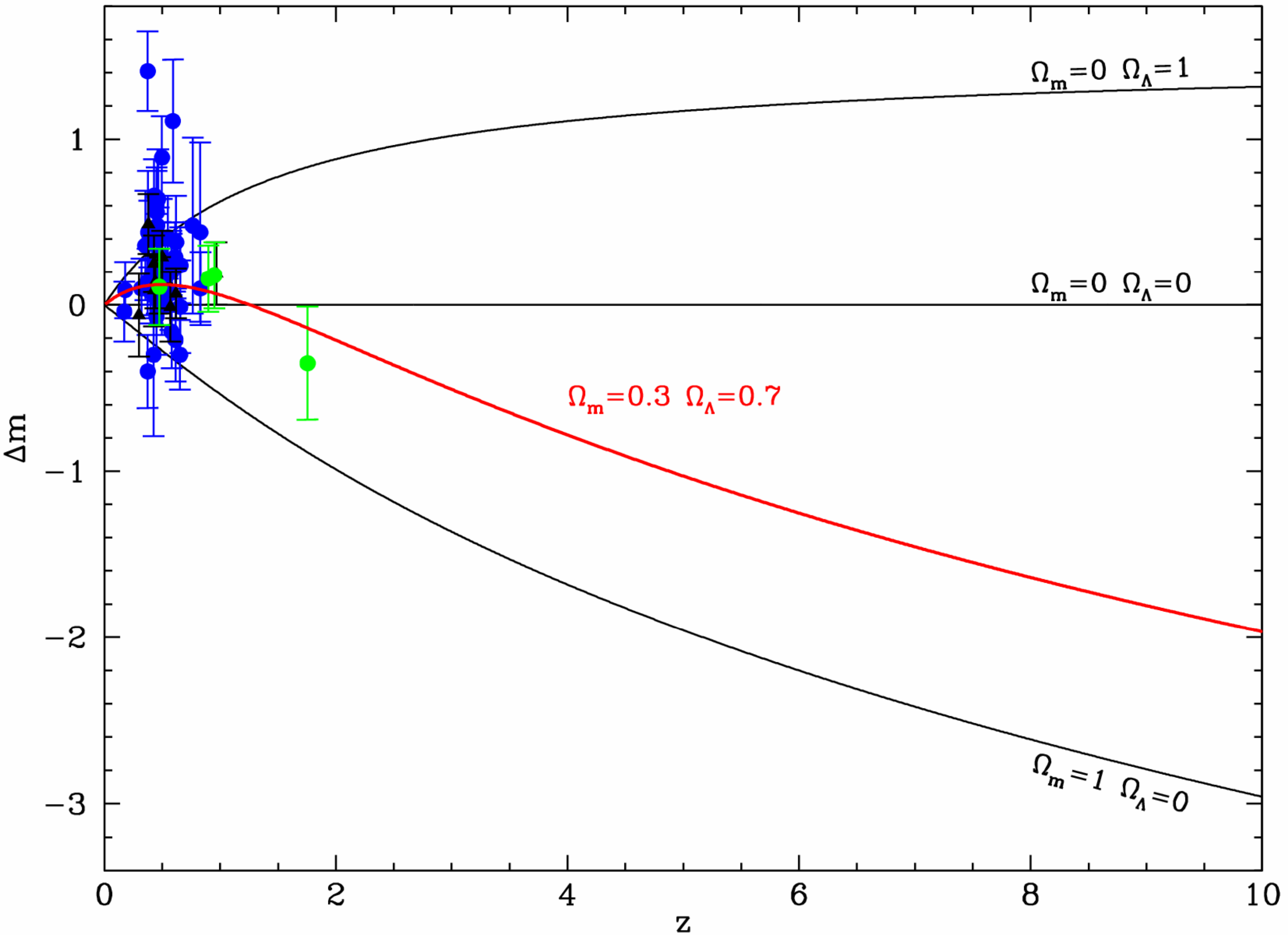
Possibly much brighter and visible to z ~20

(Heger & Woosley 2002)

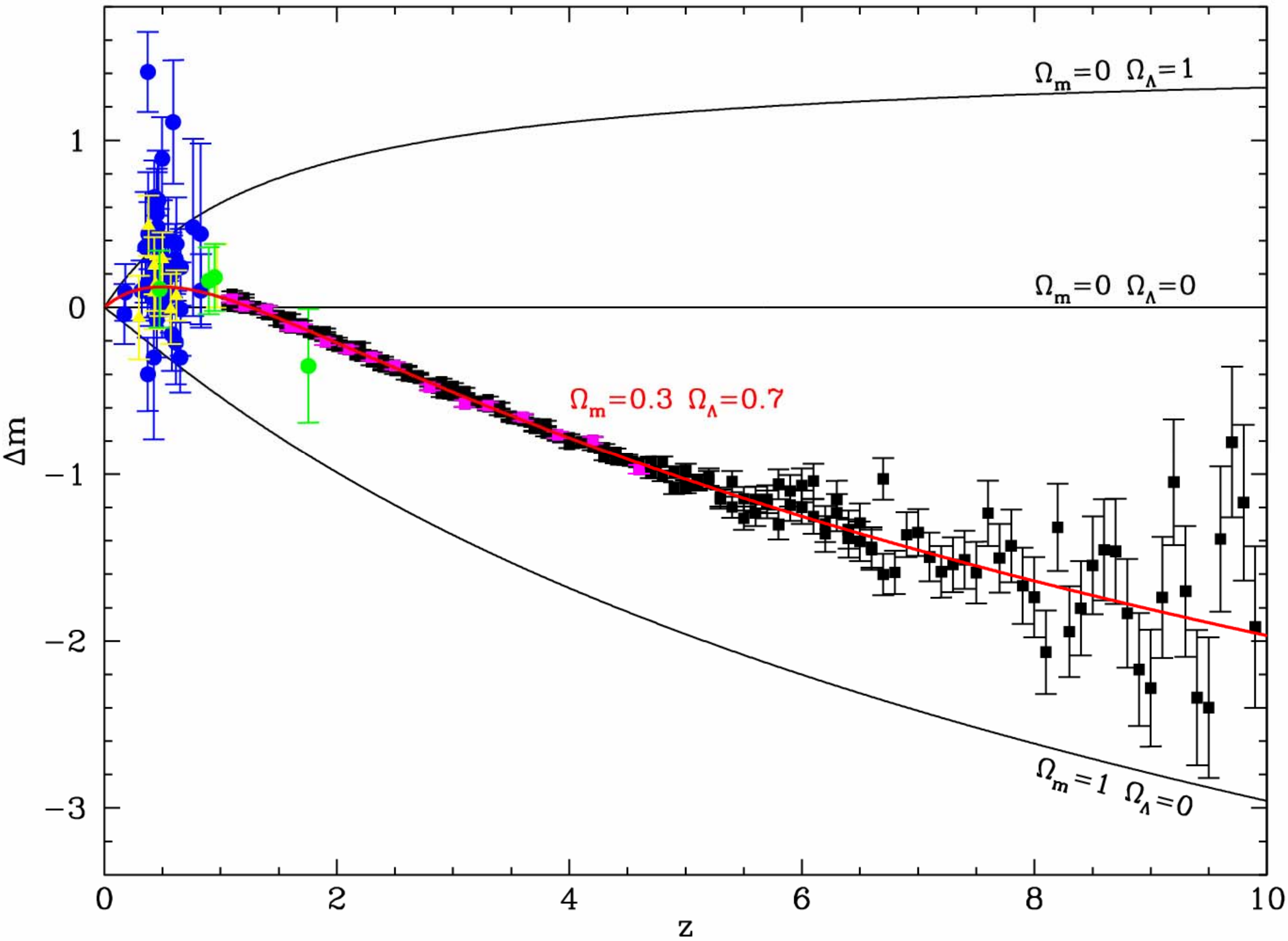
$Z_{reiz} \sim 17 \pm 5$ (Kogut et al. 2003; Spergel et al. 2003)



dust
(0,1)
evolution
(0.3,0.7)
(1,0)
Δm
z
1
0
−1
0
0.5
1
1.5
2



$\Omega_m=0\ \Omega_\Lambda=1$
$\Omega_m=0\ \Omega_\Lambda=0$
$\Omega_m=0.3\ \Omega_\Lambda=0.7$
$\Omega_m=1\ \Omega_\Lambda=0$
1
0
−1
−2
−3
Δm
0
2
4
6
8
10
z


$\Omega_m=0\ \ \Omega_\Lambda=1$
$\Omega_m=0\ \ \Omega_\Lambda=0$
$\Omega_m=0.3\ \ \Omega_\Lambda=0.7$
$\Omega_m=1\ \ \Omega_\Lambda=0$
Δm
z
1
0
−1
−2
−3
0
2
4
6
8
10

Conclusions

An ELT sample of SNe provides a measurements of the star formation rate up to z=10 which is

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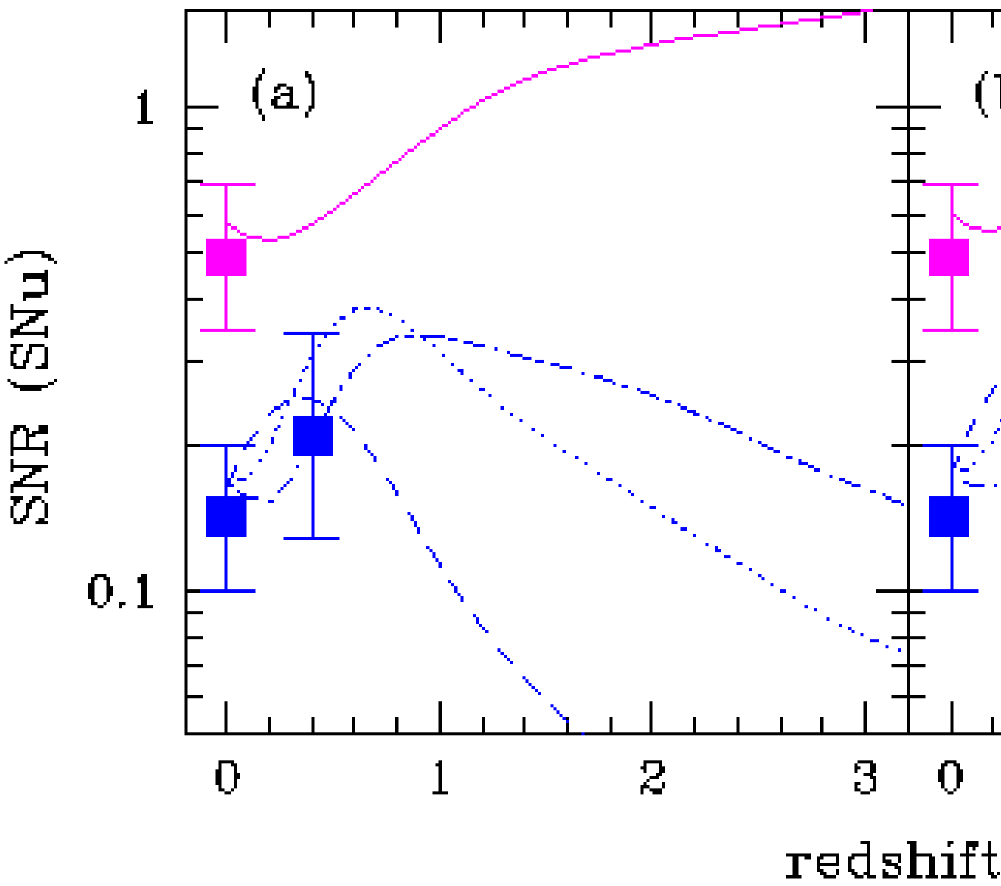
Science with ELTs

By-products

- **Disentangling models alternative to Λ**
  - Supernovae at z up to ~10: quintessence (?)
- **Also ideal probes of systematic effects**
  - Intergalactic dust
  - evolution of progenitors
- **Progenitors of type Ia SNe**

Science with ELTs



Madau, Della Valle & Panagia 1998

By-Products

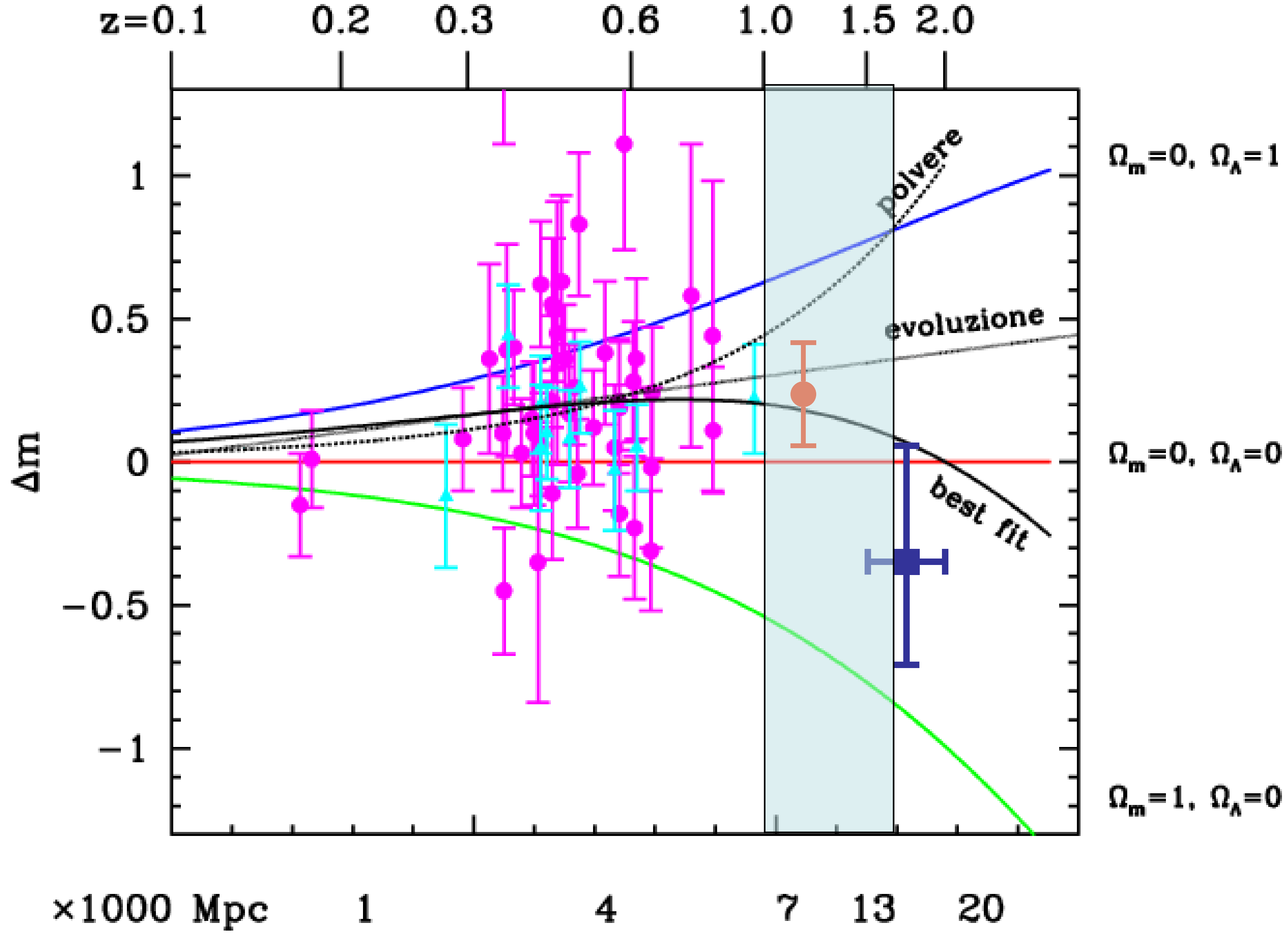
GRB/SN connection

- Hypernovae (peculiar type Ic) 1998bw, 2003dh
- Normal type Ic, 2002lt associated with GRB021211

By-Products

GRB/SN connection

- Hypernovae (peculiar type Ic)? 98bw, 03dh
- Normal type Ic? 2002lt associated with GRB021211
- What are the progenitors of high-z GRBs?



z=0.1
0.2
0.3
0.6
1.0
1.5
2.0
1
0.5
0
−0.5
−1
Δm
polvere
evoluzione
best fit
Ωm=0, ΩΛ=1
Ωm=0, ΩΛ=0
Ωm=1, ΩΛ=0
×1000 Mpc
1
4
7
13
20

Science with ELTs