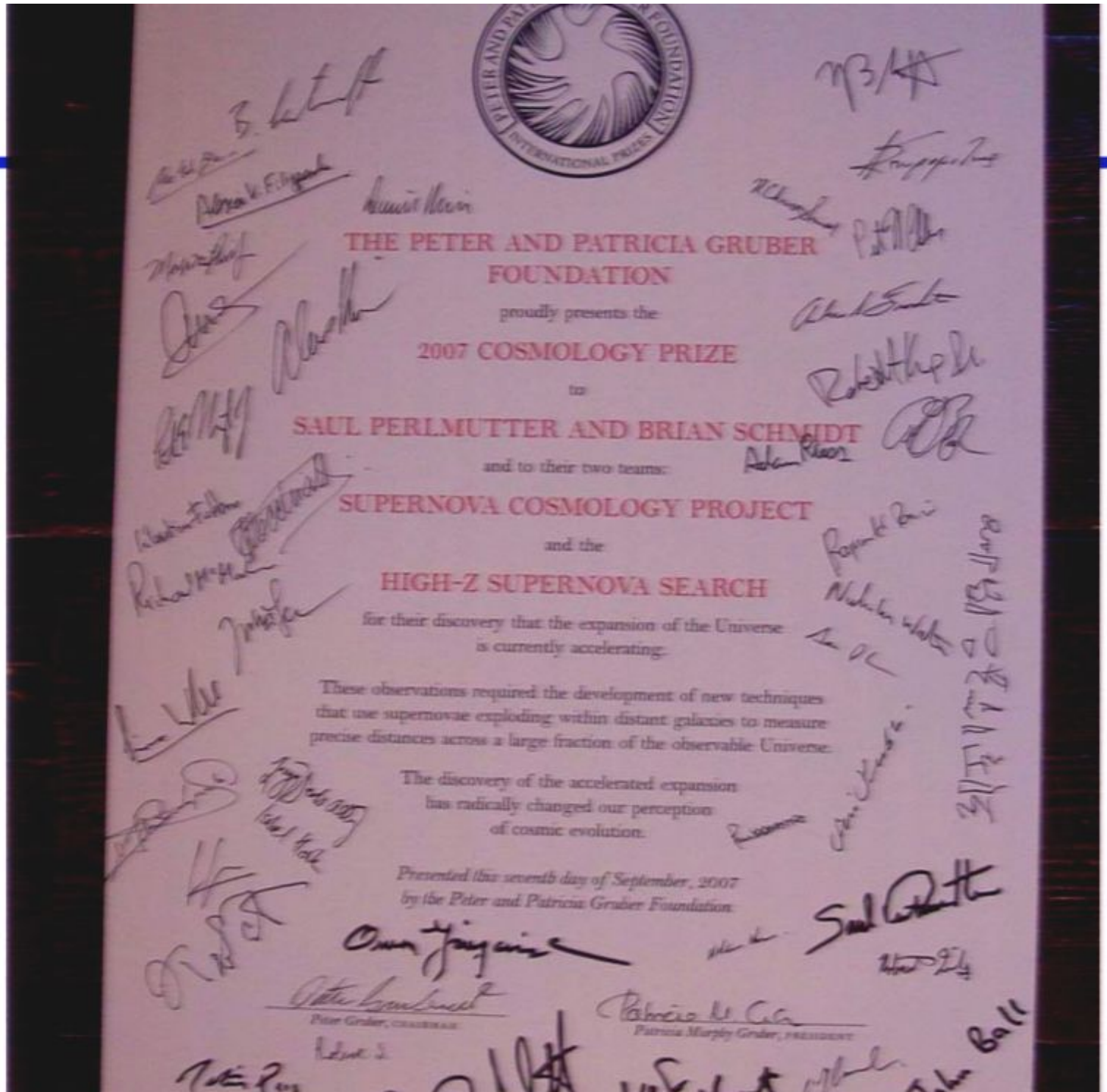
Title: Supernovae and Dark Energy

Date: Sep 13, 2007 09:30 AM

URL: http://pirsa.org/07090046

Abstract:



THE PETER AND PATRICIA GRUBER FOUNDATION

proudly presents the

2007 COSMOLOGY PRIZE

to

SAUL PERLMUTTER AND BRIAN SCHMIDT

and to their two teams:

SUPERNOVA COSMOLOGY PROJECT

and the

HIGH-Z SUPERNOVA SEARCH

for their discovery that the expansion of the Universe is currently accelerating.

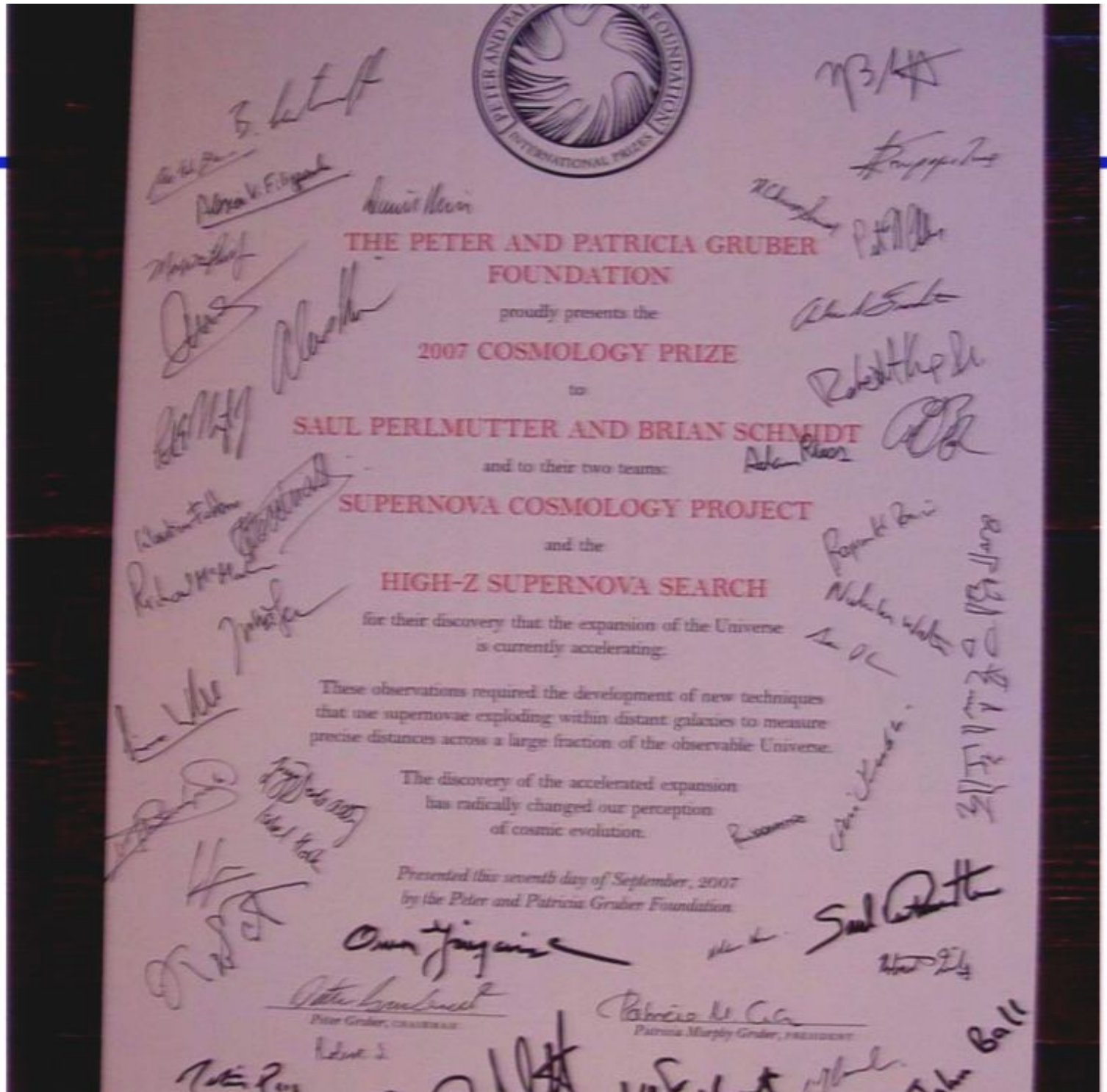
These observations required the development of new techniques that use supernovae exploding within distant galaxies to measure precise distances across a large fraction of the observable Universe.

The discovery of the accelerated expansion has radically changed our perception of cosmic evolution.

Presented this seventh day of September, 2007 by the Peter and Patricia Gruber Foundation

Peter Gruber, CHAIRMAN

Patricia Murphy Gruber, PRESIDENT



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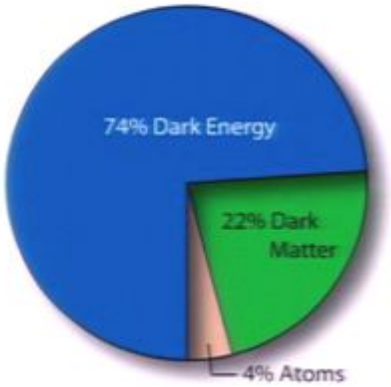
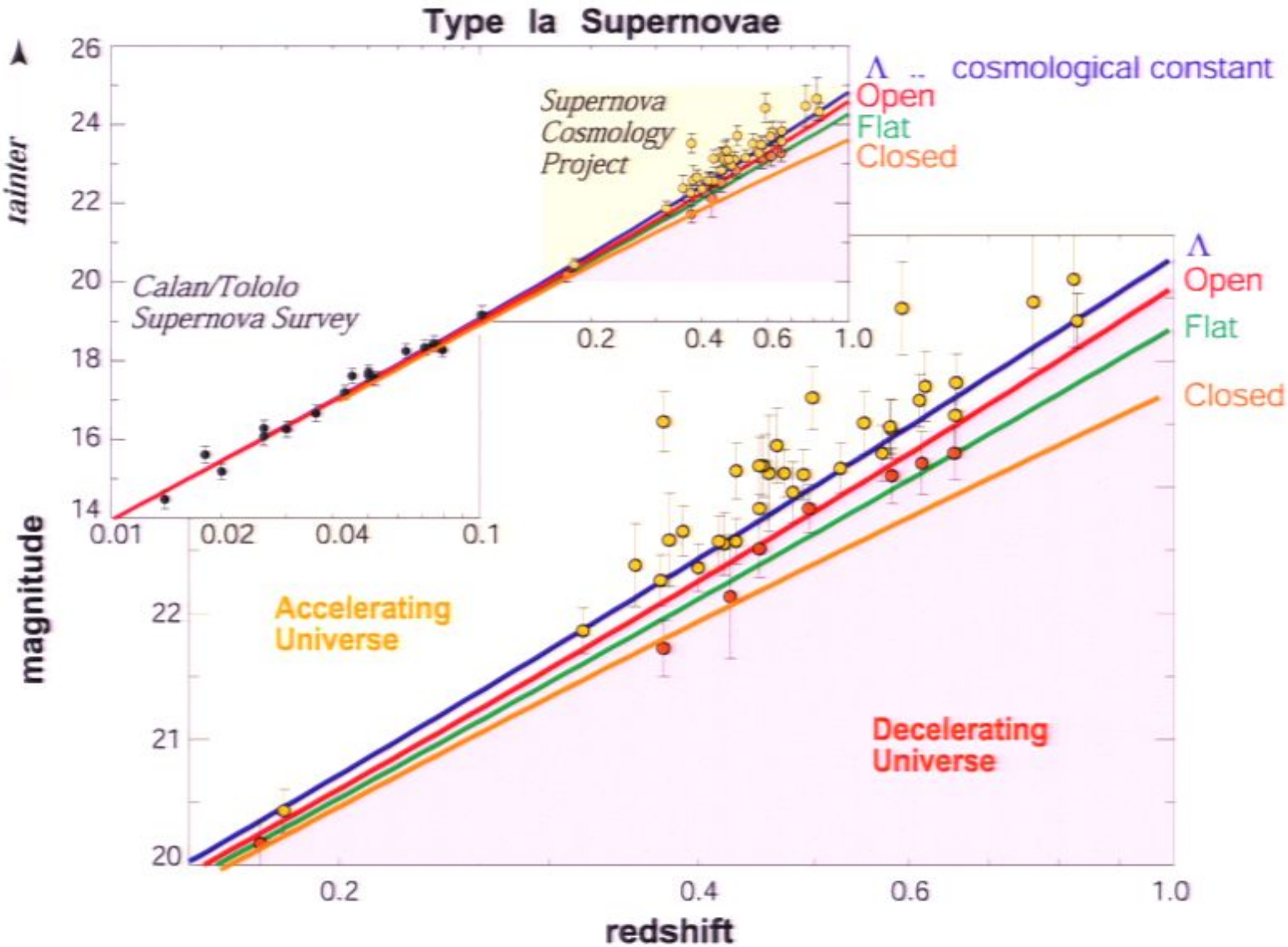
In 1998: SCP+ High-Z Team





By now many dark energy "detections"

- Type Ia supernovae
- CMB power spectrum
- Large Scale Structure
- Baryon Acoustic oscillations
- Weak gravitational lensing
- Cluster abundances
- Cluster X-ray observations (f_{gas})
- Integrated Sachs-Wolfe effect
- Age of Universe

} **dark energy signal**

- *Sunyaev-Zeldovich effect*
- *Strong gravitational lensing*
- *Core-collapse SNe*

} **Around the corner**

- *Tomography @ 21-cm (Hydrogen)*
- *Gravitational wave "sirens"*
- *Laboratory tests of gravity?*

} **Potential tools for the future**

SNIa & cosmological parameters: the luminosity distance

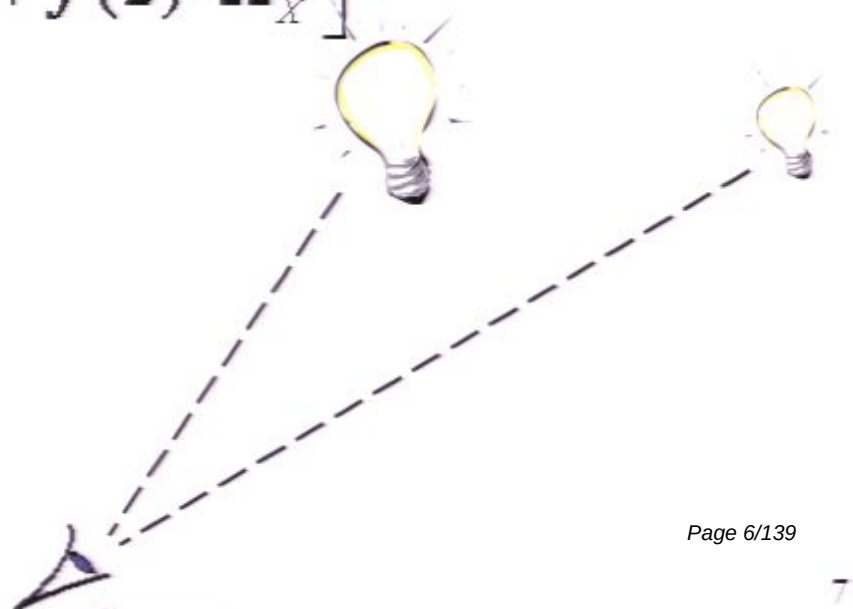
$$d_L = \frac{c \cdot (1+z_E)}{\sqrt{|\Omega_K|}} F\left(\sqrt{|\Omega_K|} \int_0^{z_E} \frac{dz}{H(z)} \right)$$

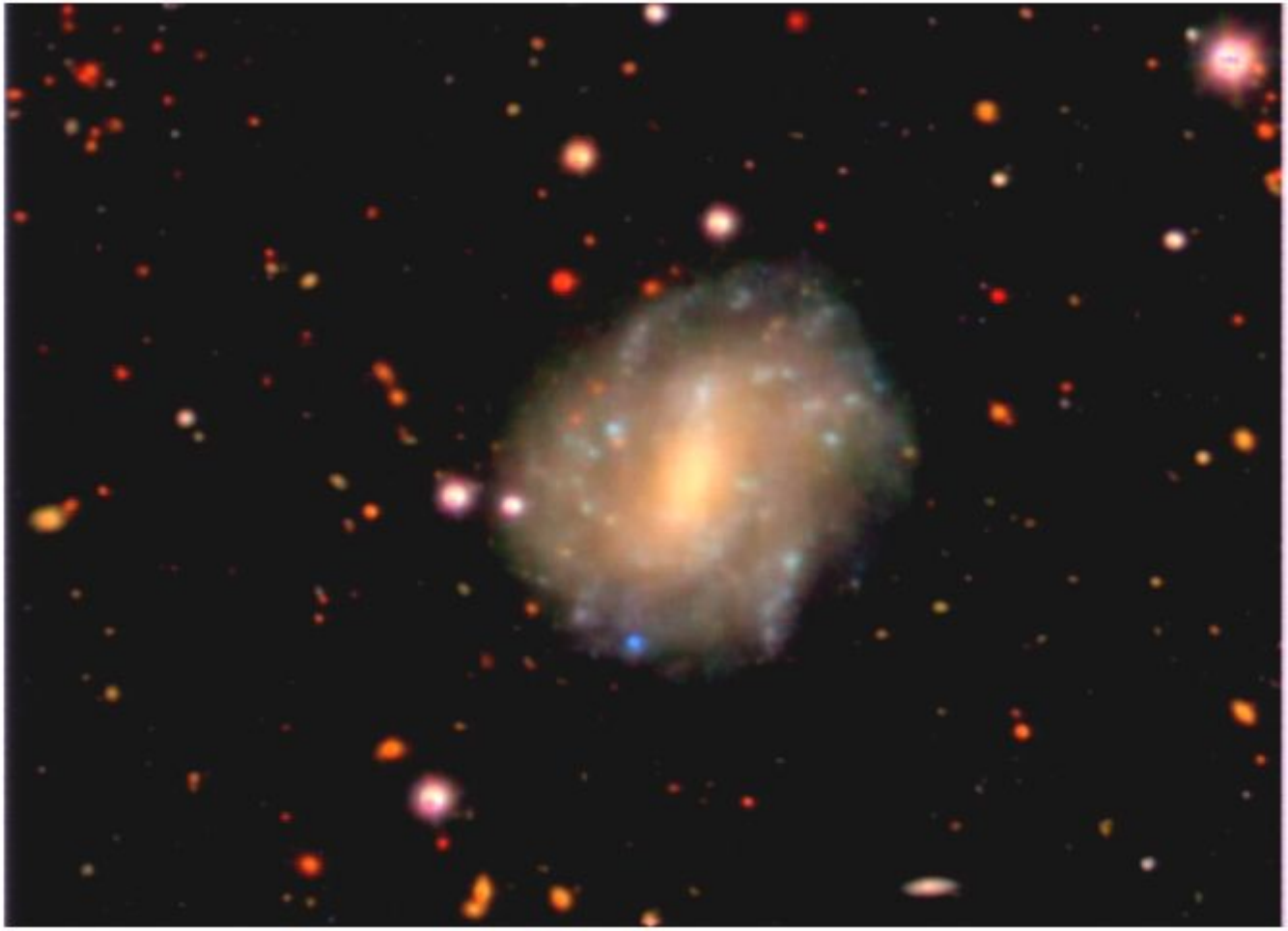
- where F(x) = sin(x) for a closed universe, sinh(x) for an open universe and x for a flat universe. In the latter case the Ω_K terms are set to 1.

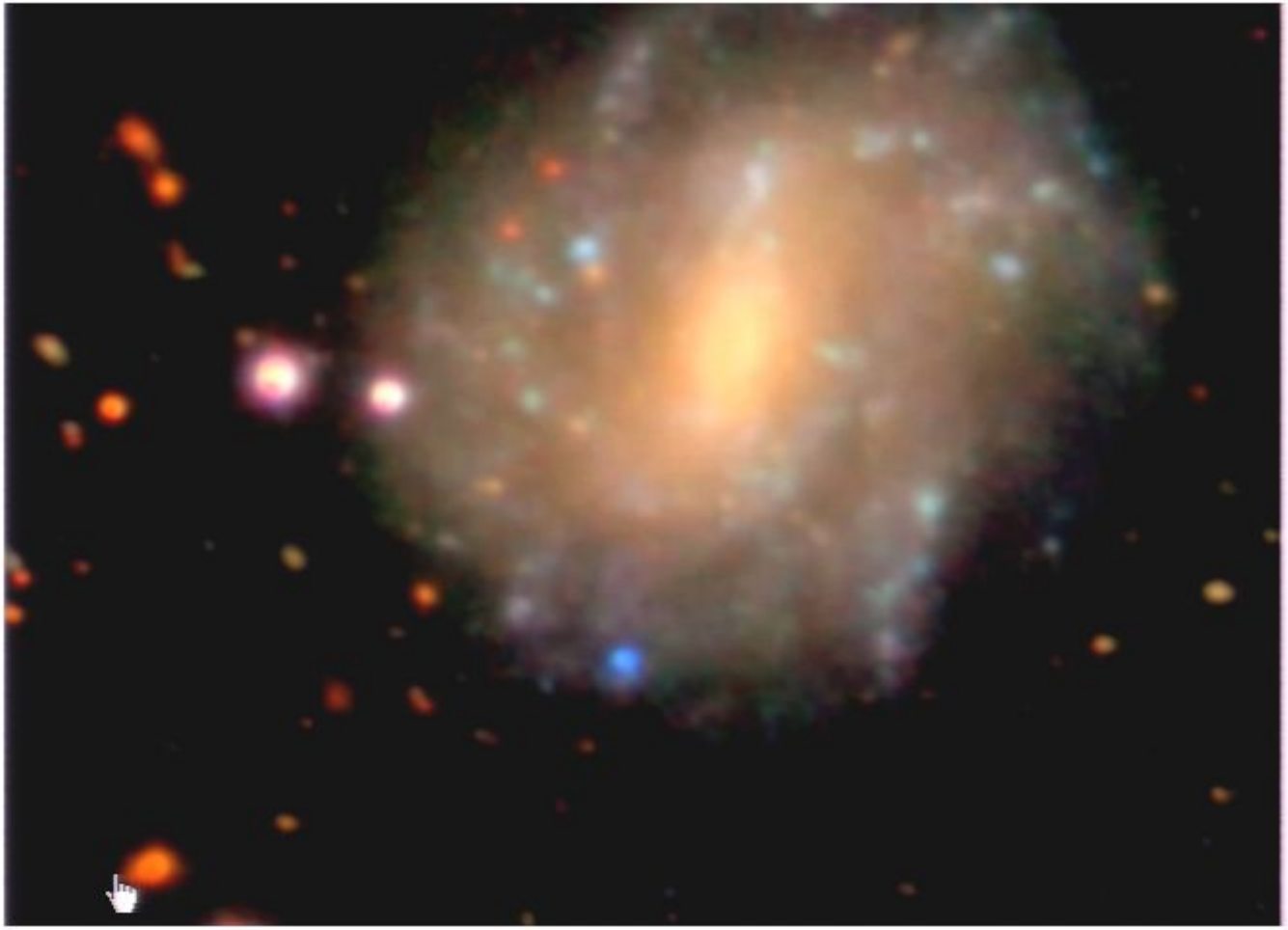
$$H^2 = H_0^2 \left[\Omega_M (1+z)^3 + \Omega_K (1+z)^2 + f(z) \cdot \Omega_X \right]$$

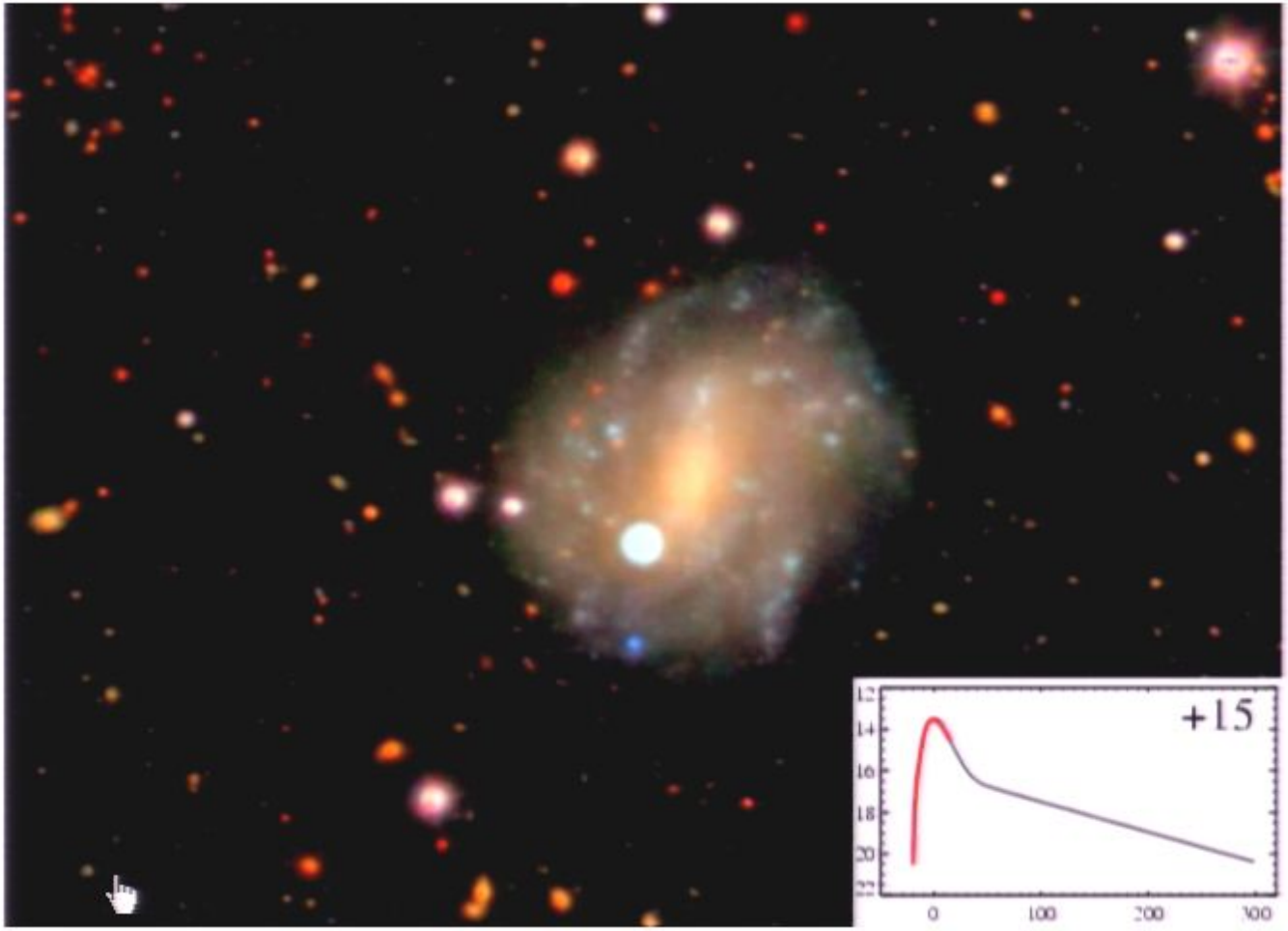
where

$$f(z) = \exp\left[3 \int_0^z \frac{1+w(x)}{1+x} dx \right]$$





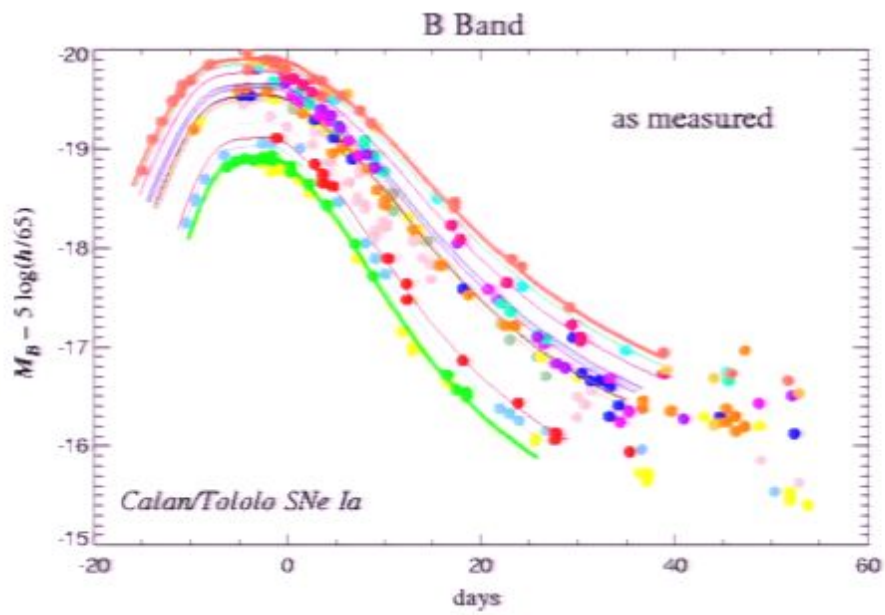


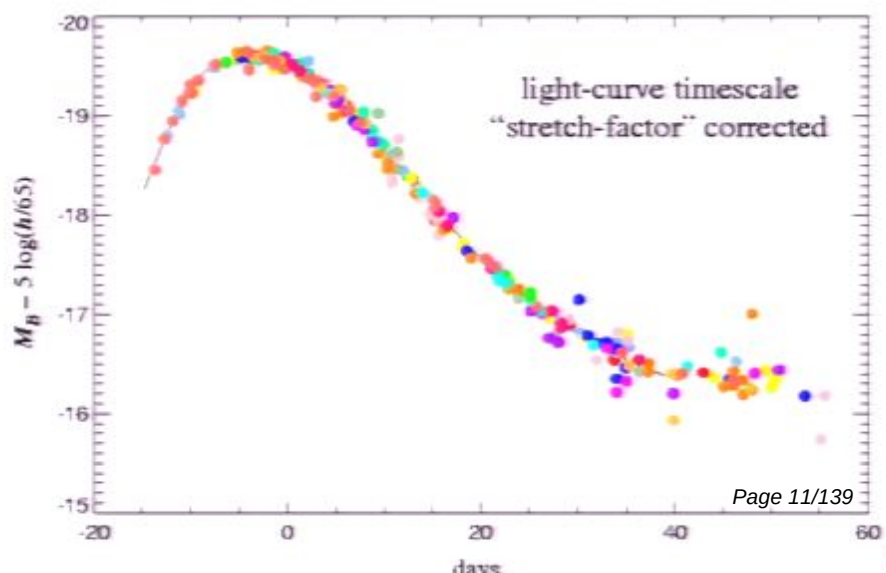

+15
12
14
16
18
20
0
100
200
300

”Standarizeable” candle

- Typical spread in Type Ia brightness is about 40%
- After shape-brightness correction, SNIa are standarized to about <15% standard deviation in brightness...

  ... Corresponding to ~7% precision in distance





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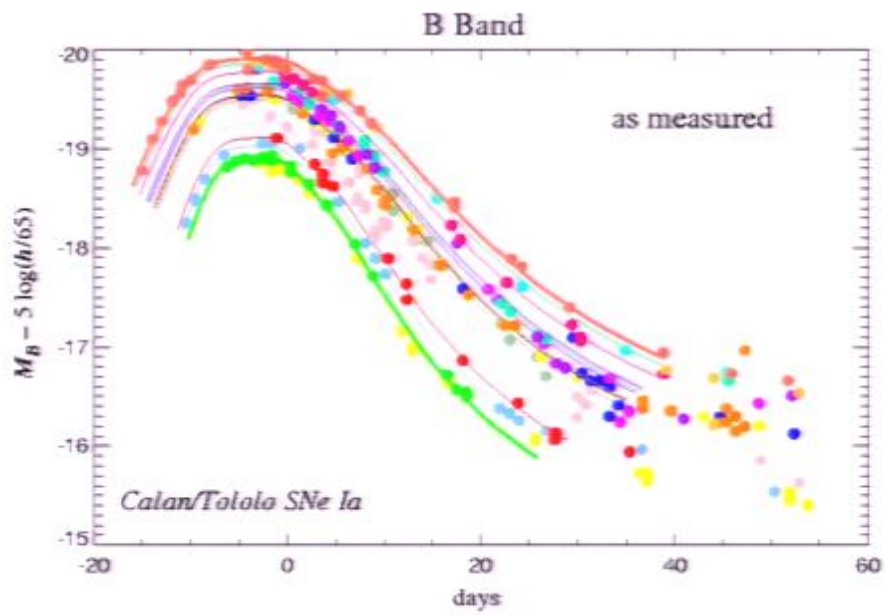

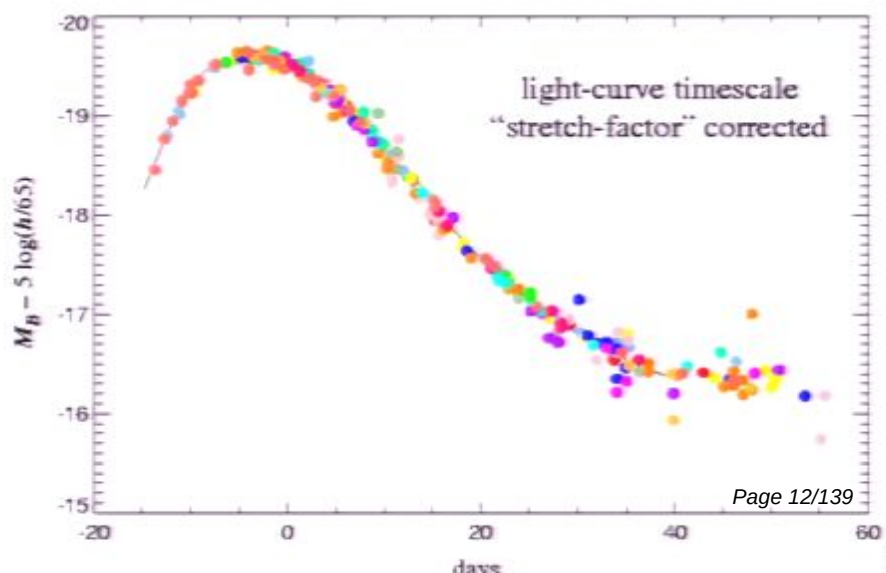

SN-cosmology tutorial

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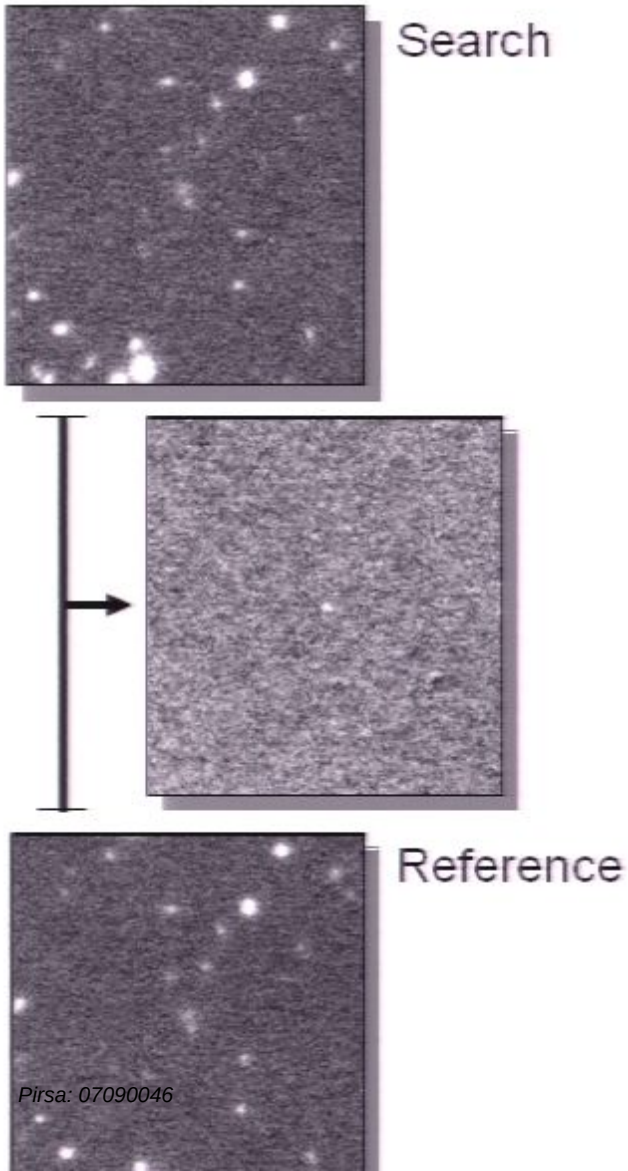

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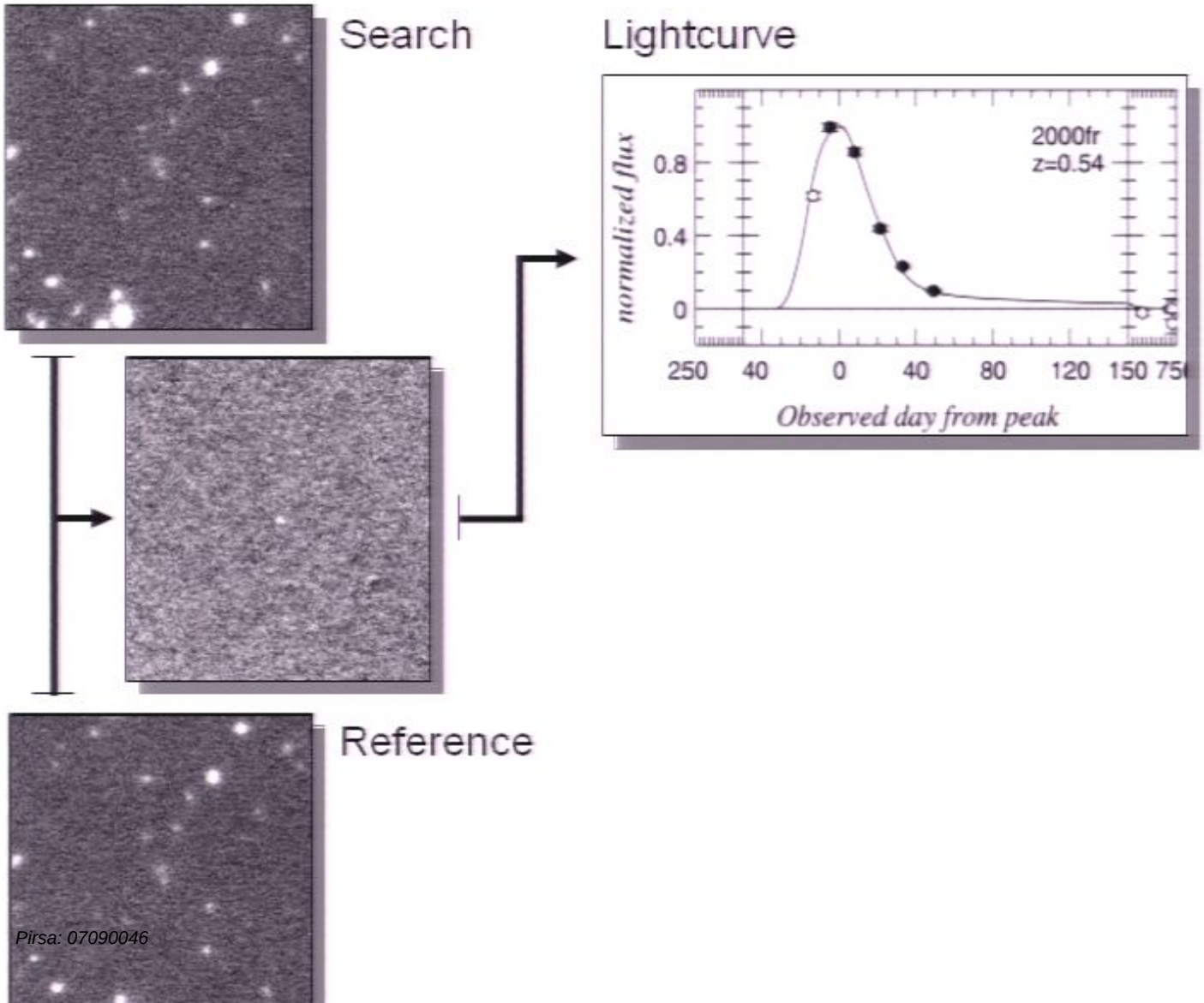

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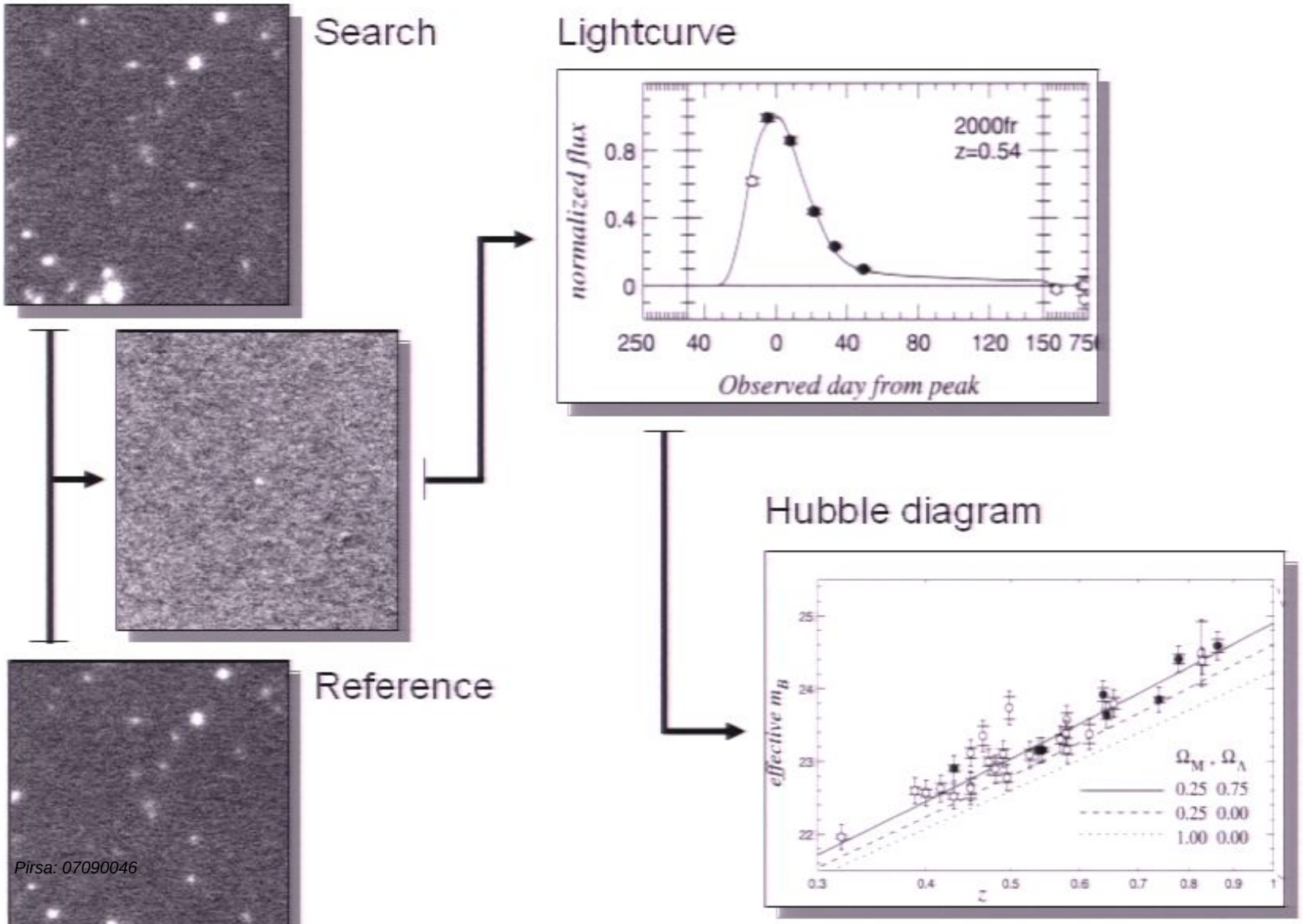

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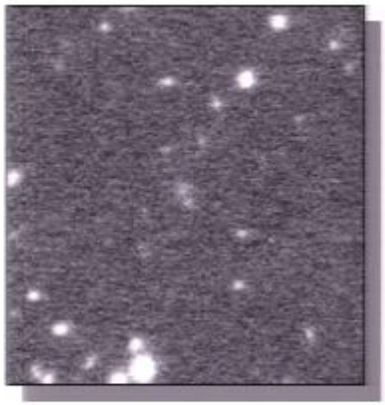
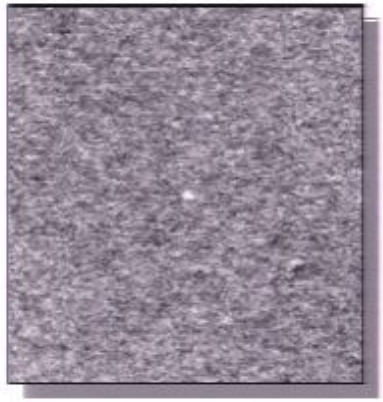
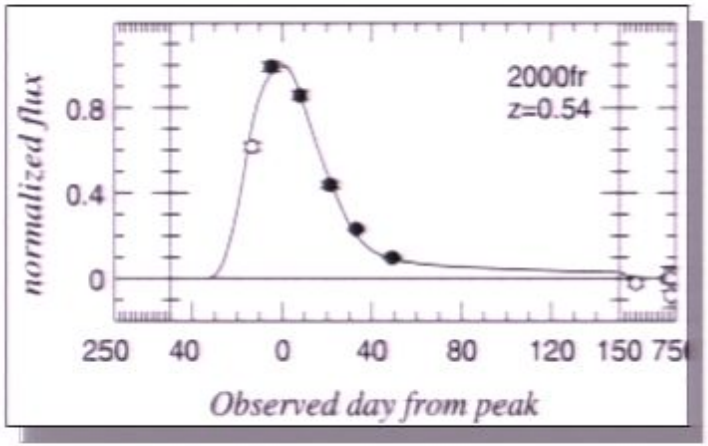


Search

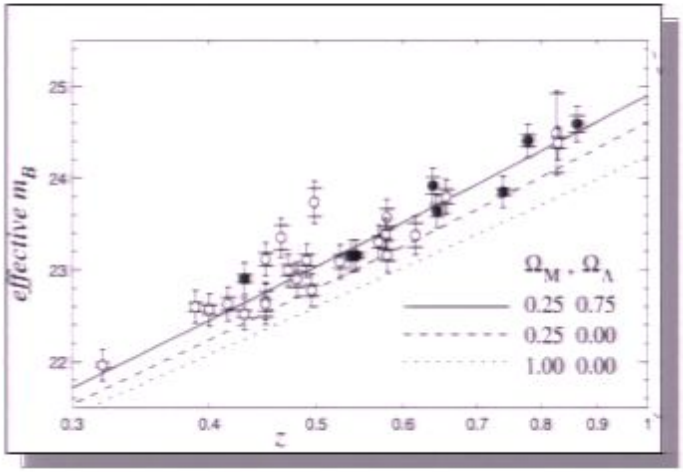


Reference

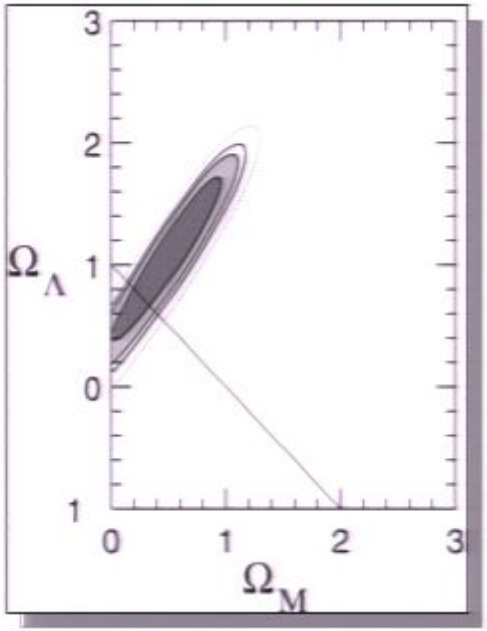
Lightcurve



Hubble diagram

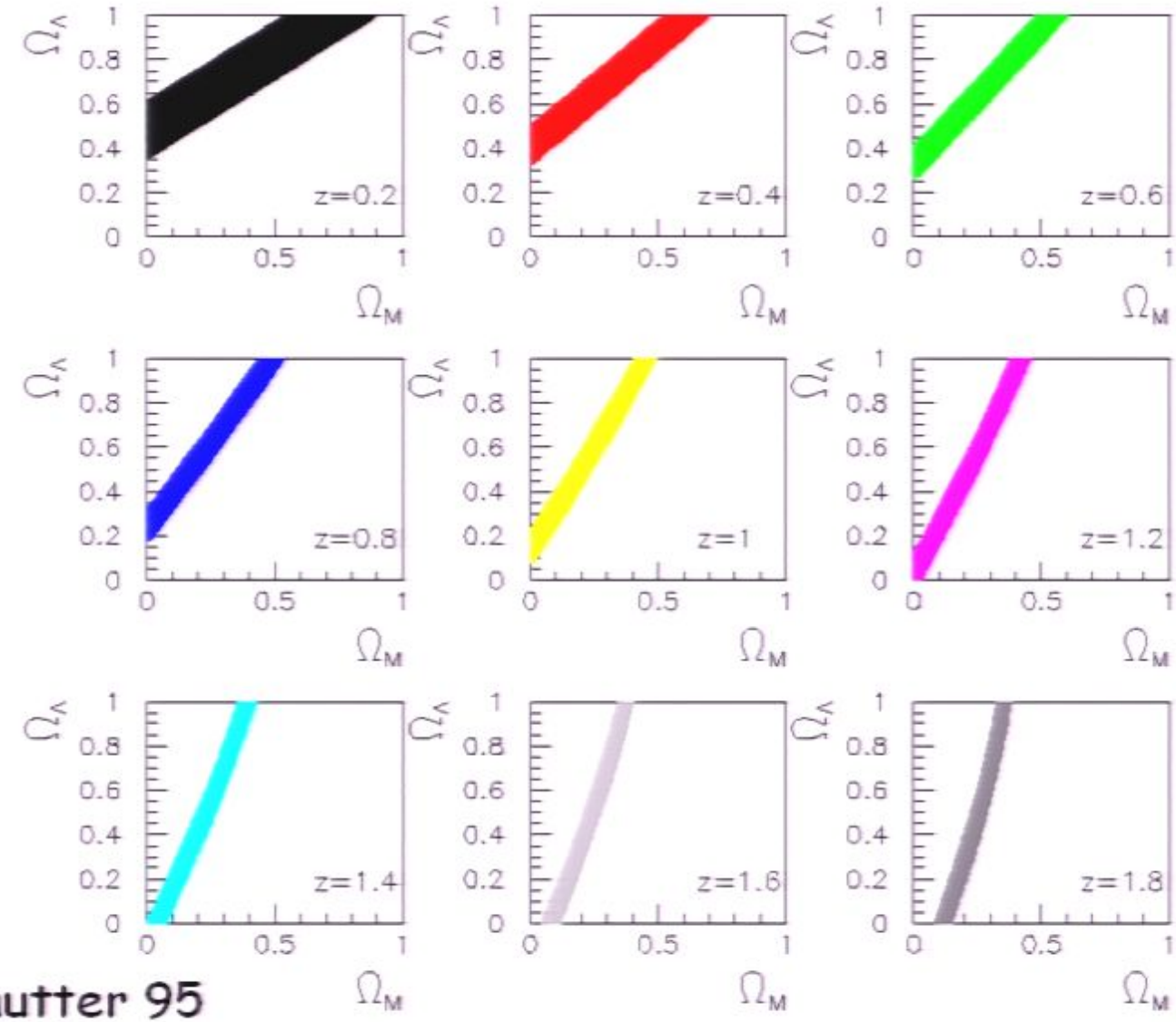


Cosmology fits



Statistical uncertainty: Redshift dependence

1σ bands at each redshift for Δm=0.02 mag



AG & Perlmutter 95

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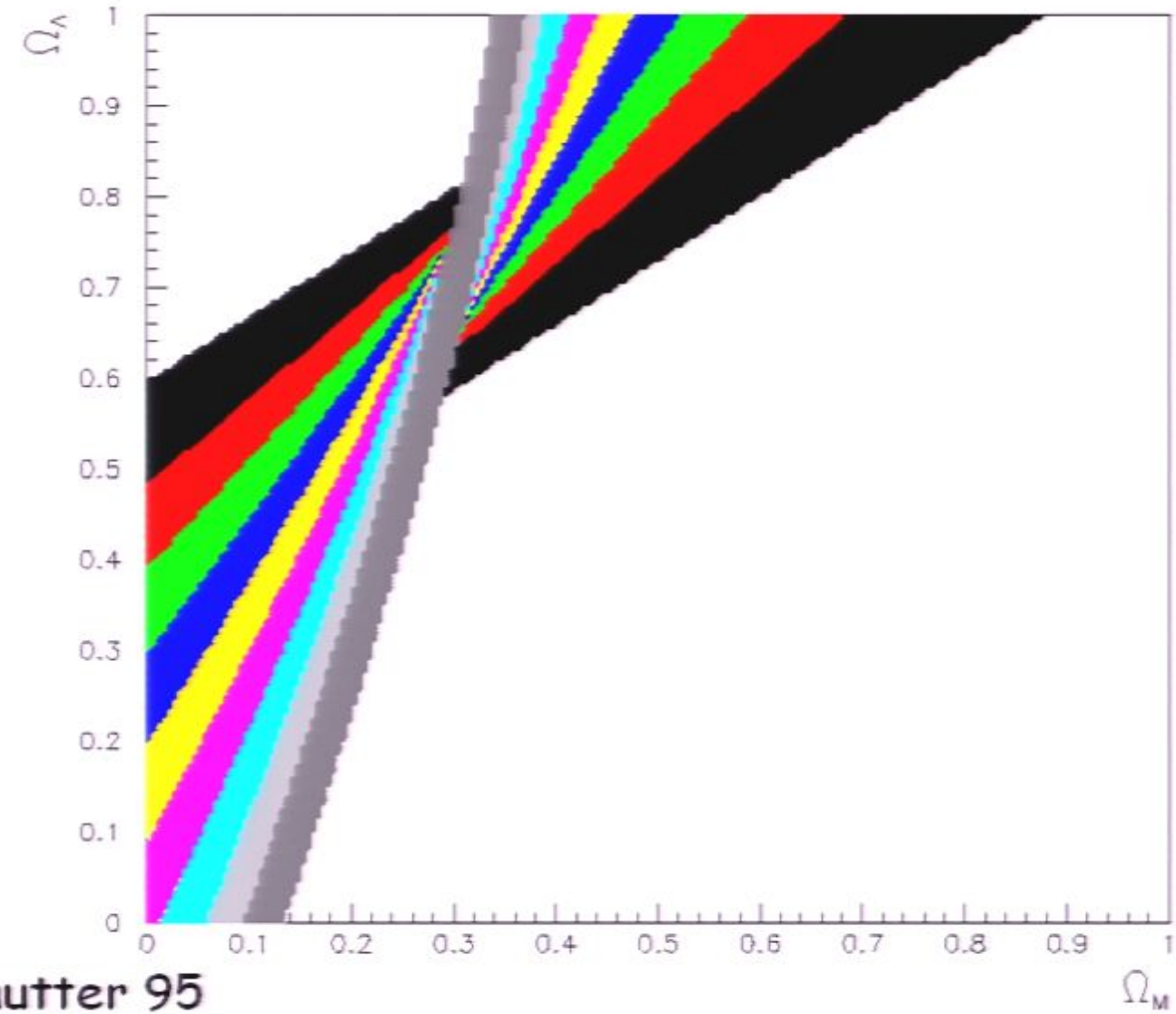


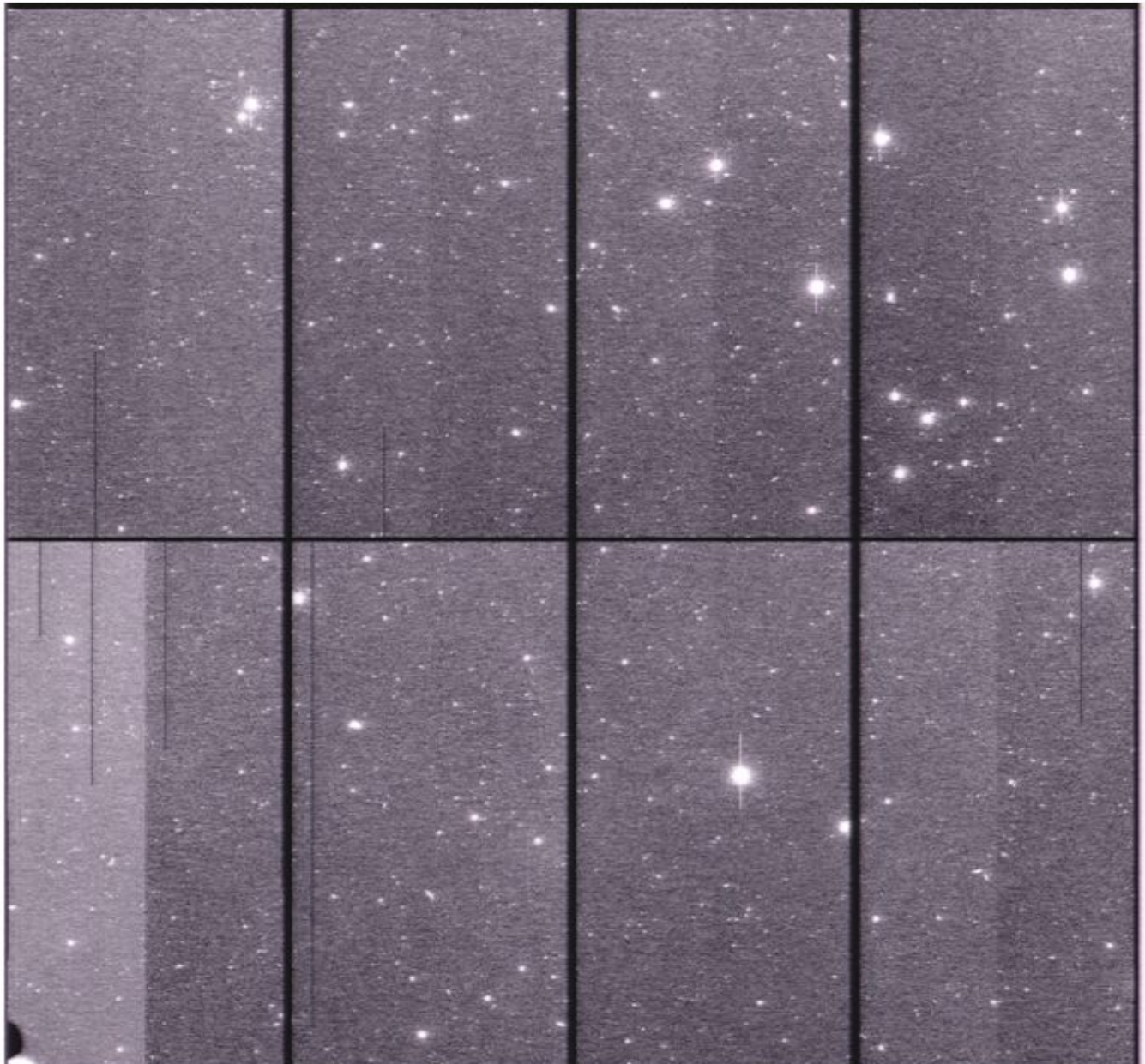
AG & Perlmutter 95

Large ongoing SNIa projects: 0.2<z<1

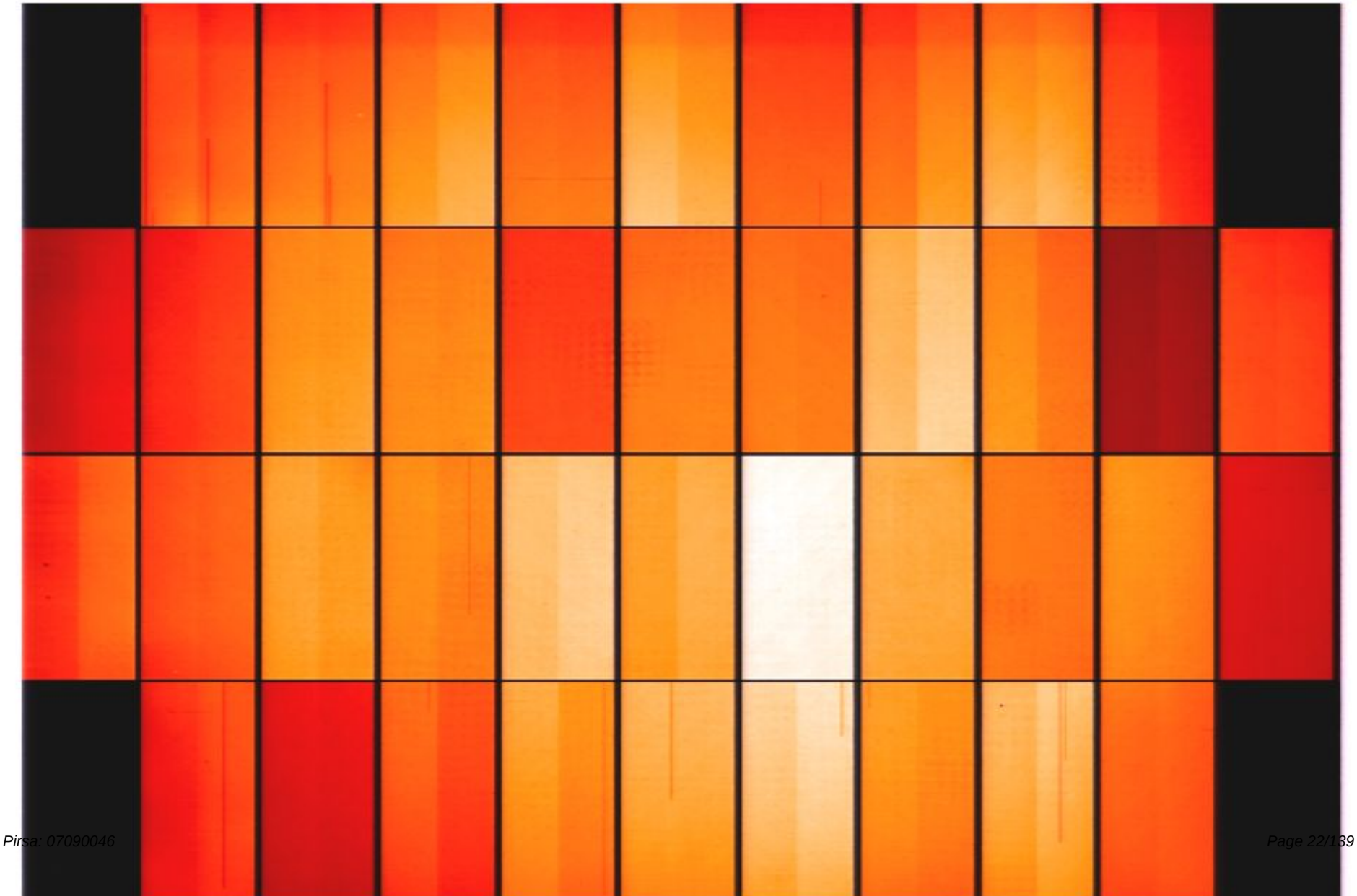
- ESSENCE at CTIO 4-m: to collect ~200 SNIa

- CFHT (3.7-m) SuperNova Legacy Survey: 5 year "rolling search"in (u)griz. By 2008 ~500 spectroscopically confirmed SNIa.

Huge Cameras! CTIO: 8 CCD's ½°x½°



CFHT-SNLS: 40 CCDs, 4 times bigger!



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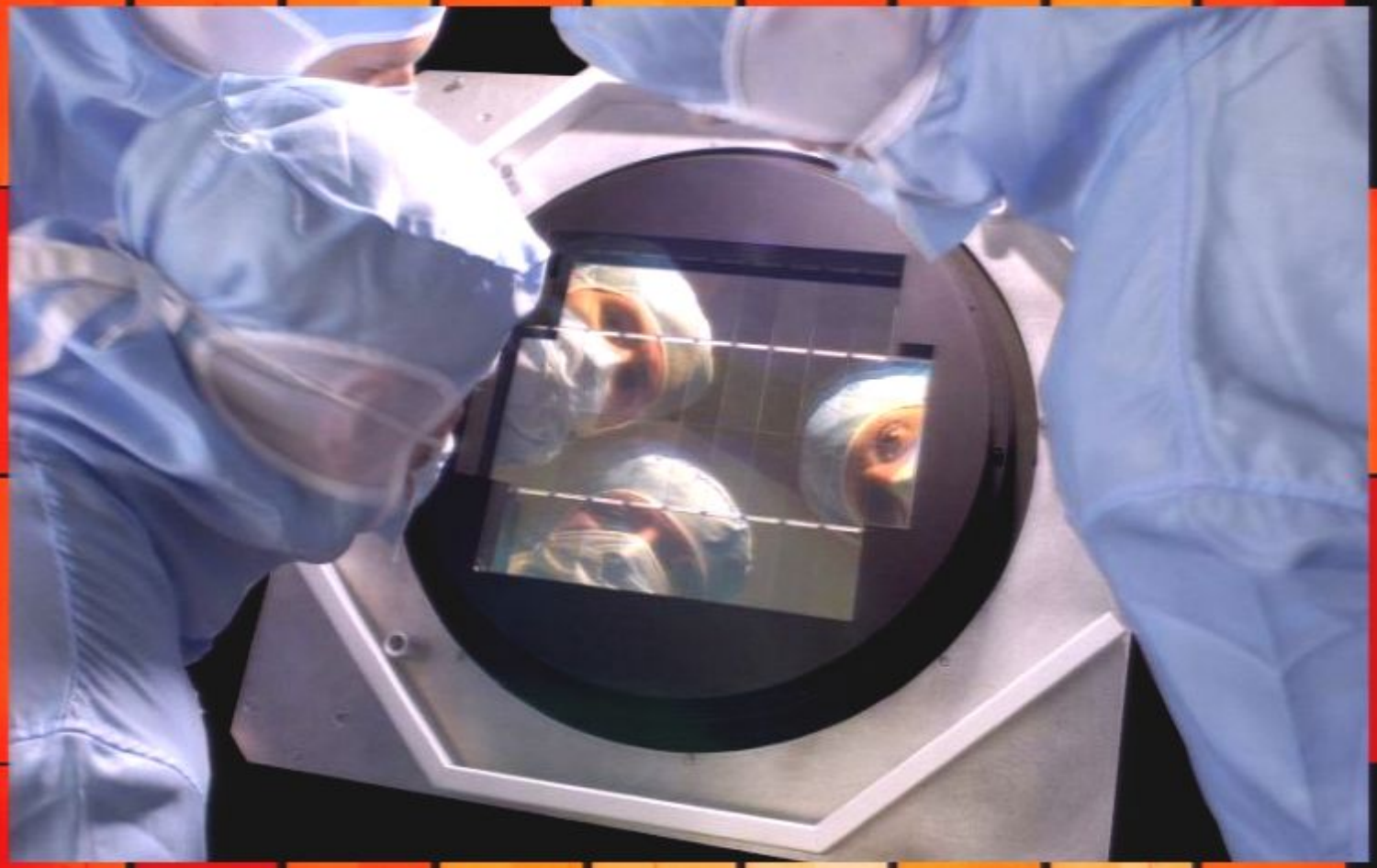
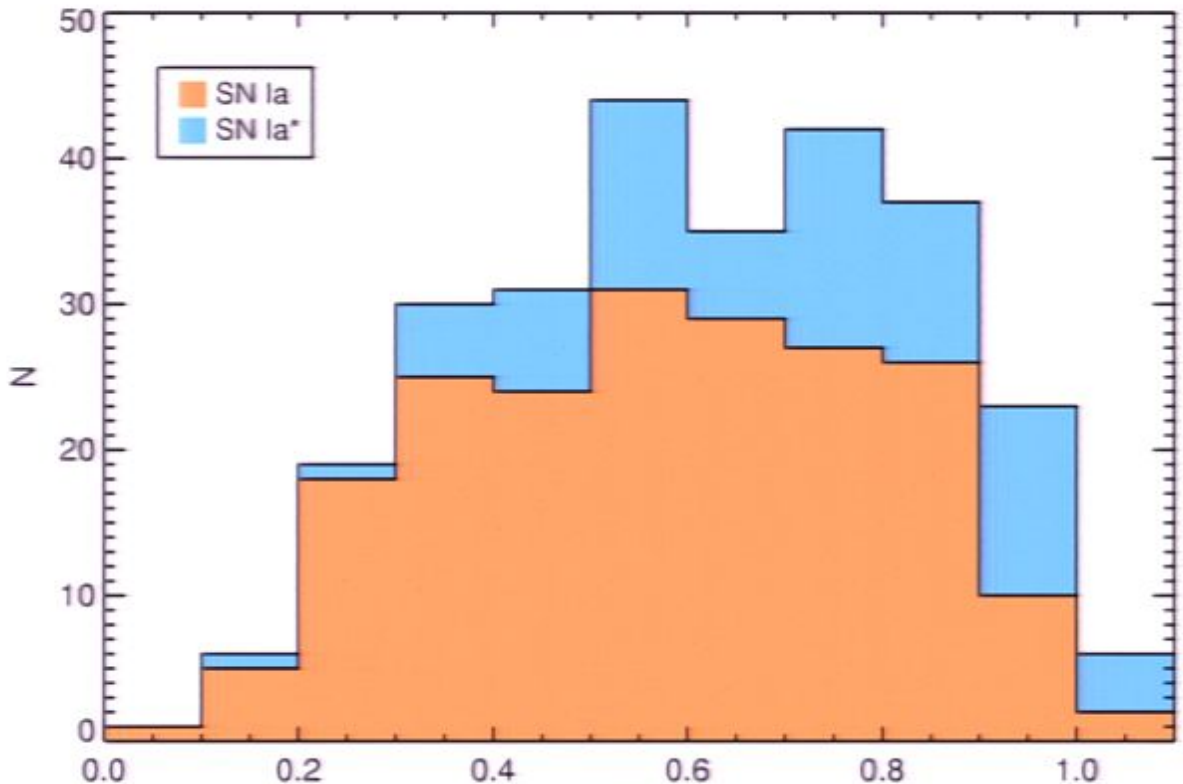
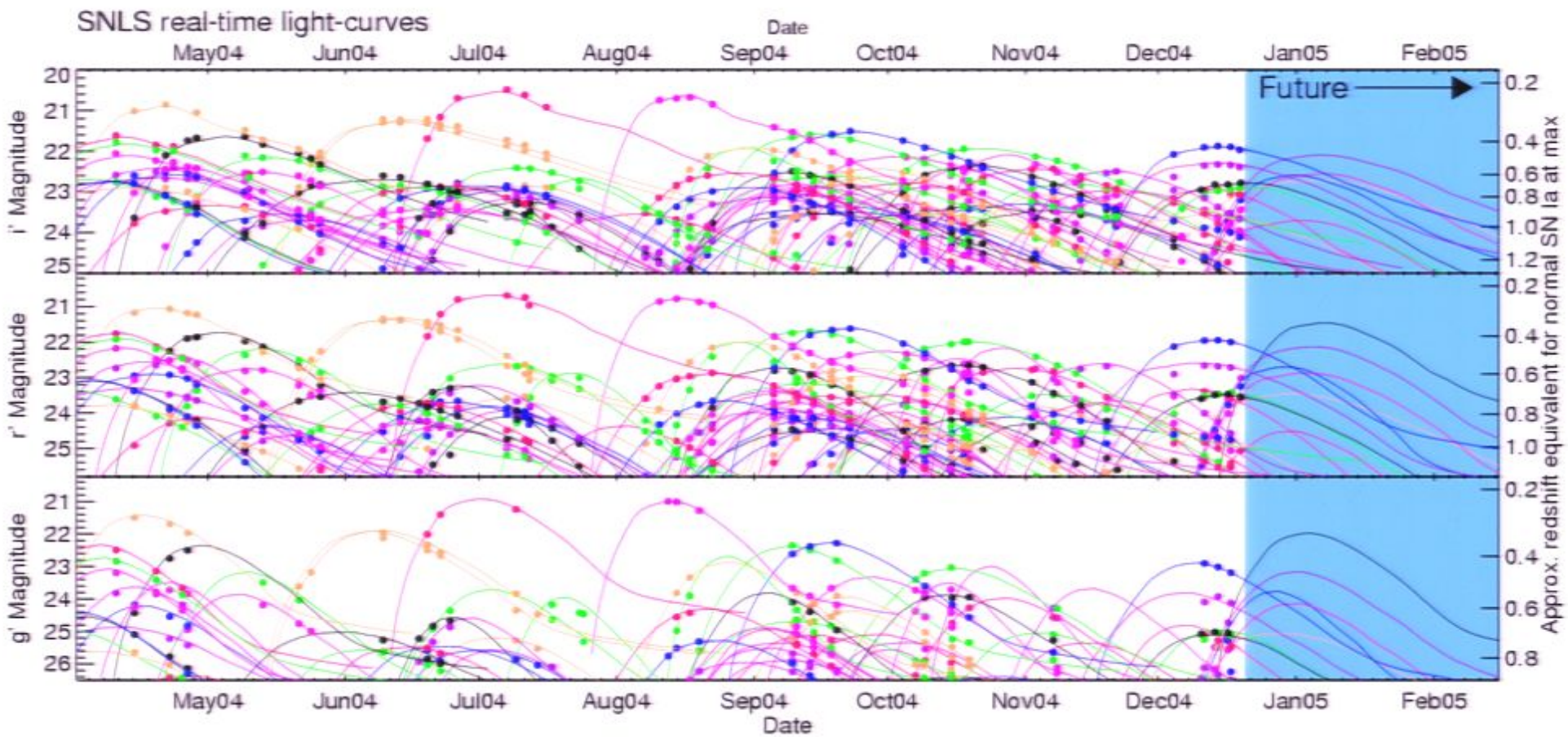


SNLS: Current status

- Survey running for nearly 4 years
- ~400 confirmed distant SNe Ia
  - La rgest single telescope sample of SNe
  - "On track" for 500 spectroscopically confirmed SNe Ia by survey end (>1000/>2000 total SNIa/All SN light-curves)



SNLS


SNLS real-time light-curves
Date
May04
Jun04
Jul04
Aug04
Sep04
Oct04
Nov04
Dec04
Jan05
Feb05
Future
i' Magnitude
r' Magnitude
g' Magnitude
Approx. redshift equivalent for normal SN Ia at max
Date

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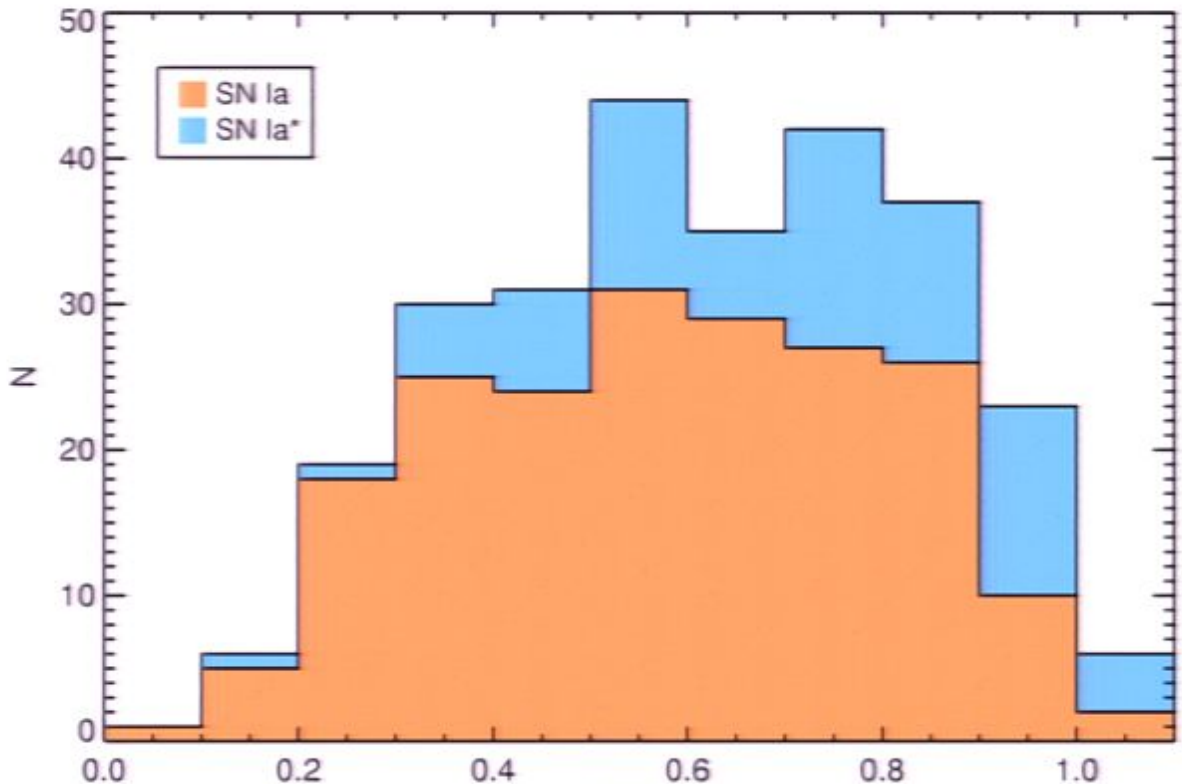

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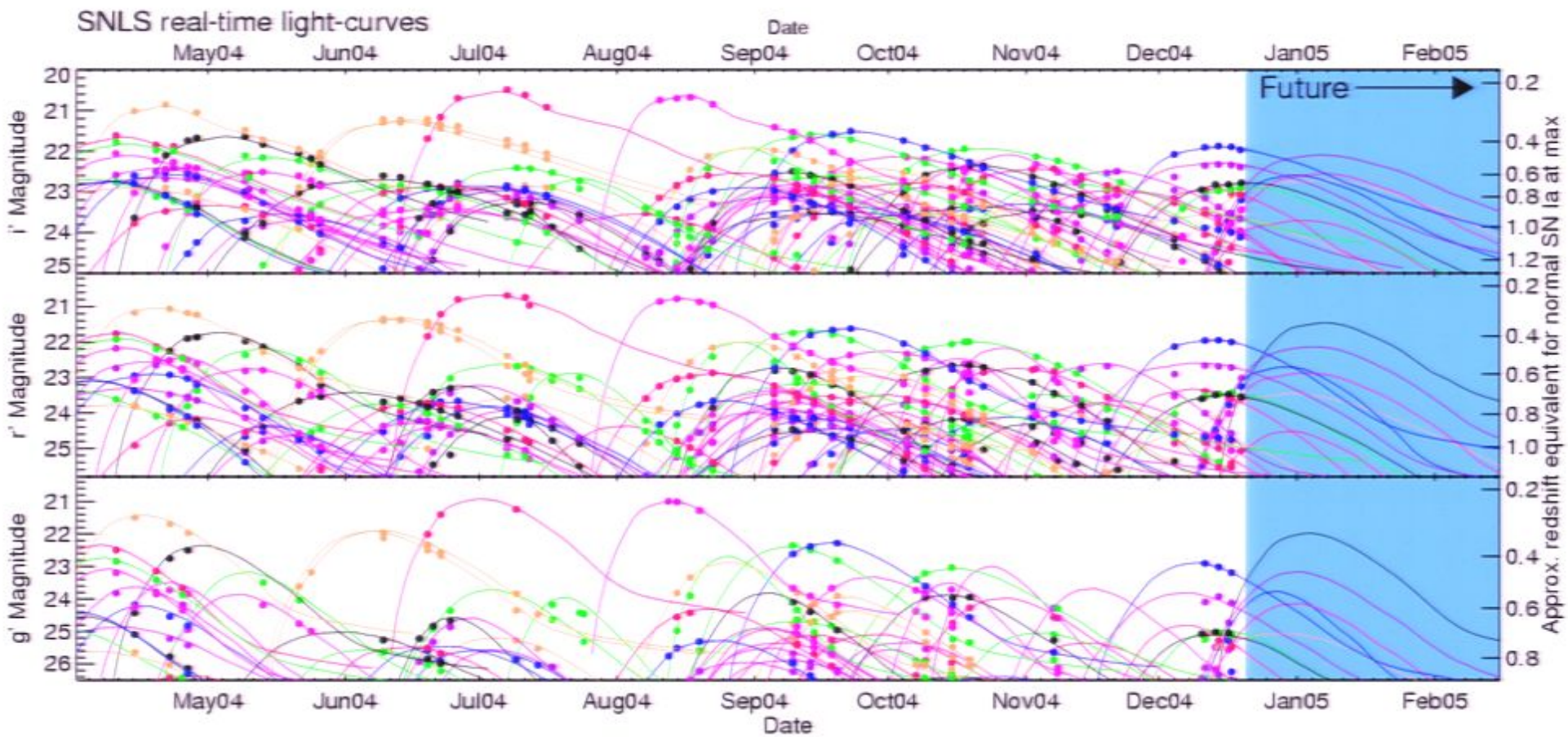
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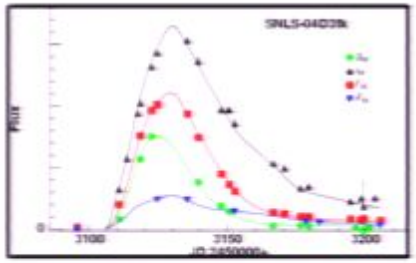
SuperNova Legacy Survey (SNLS)

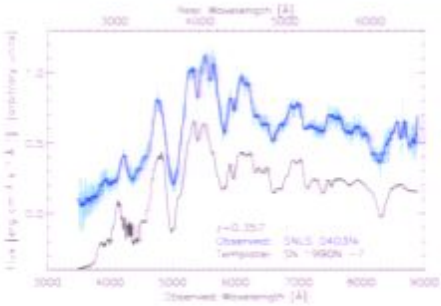
Imaging
CFHT Legacy Survey
Deep program



Discoveries Lightcurves

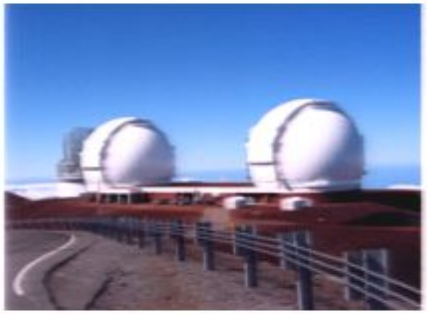
g'r'i'z' every 4 days
during dark time

Spectroscopy
Types, redshifts
from 8m-class
telescopes

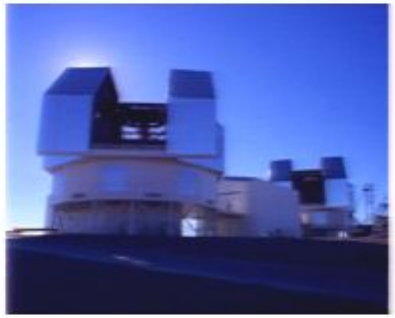


Gemini N & S (120 hr/yr)

VLT (120 hr/yr)

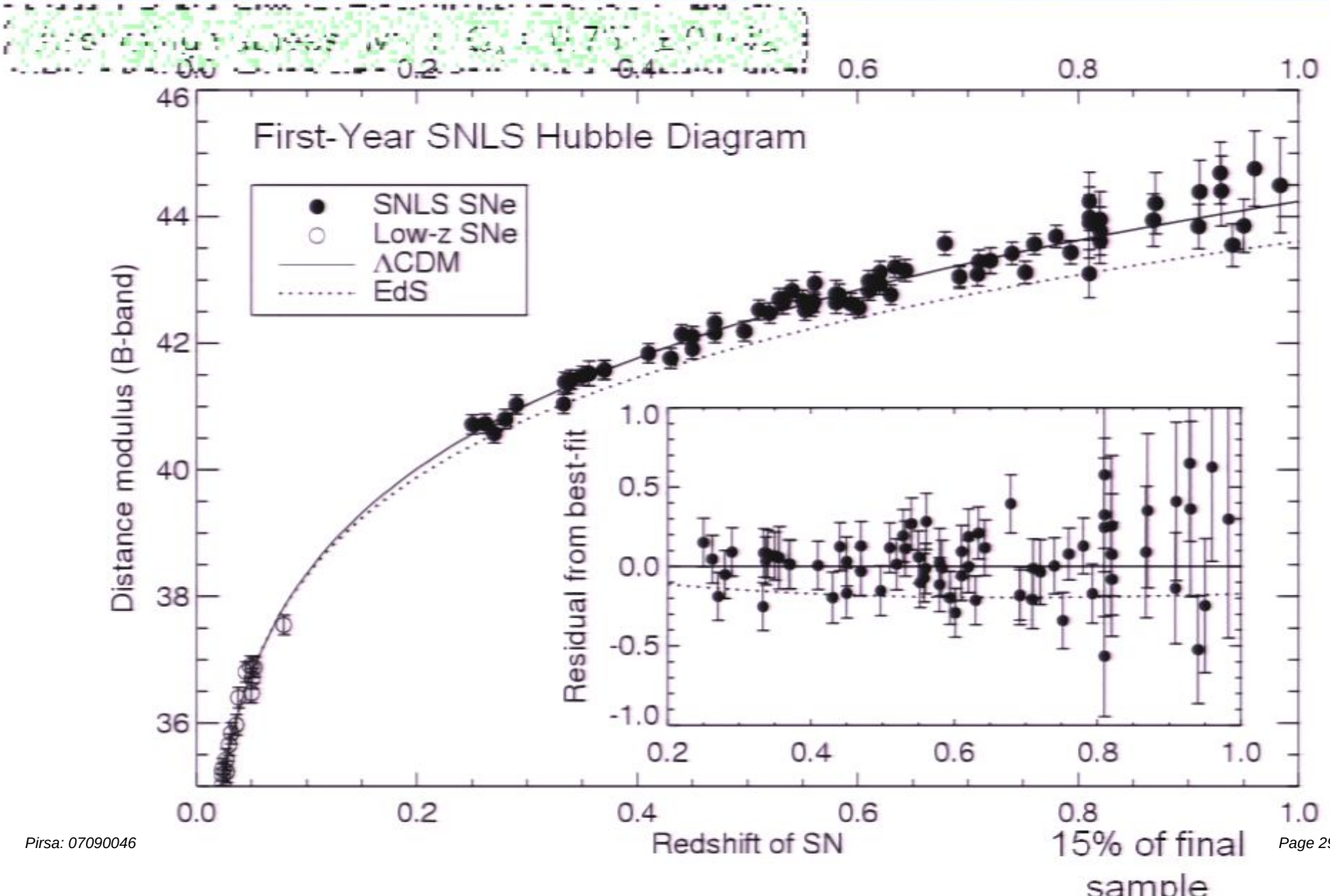


Keck (8 nights/yr)



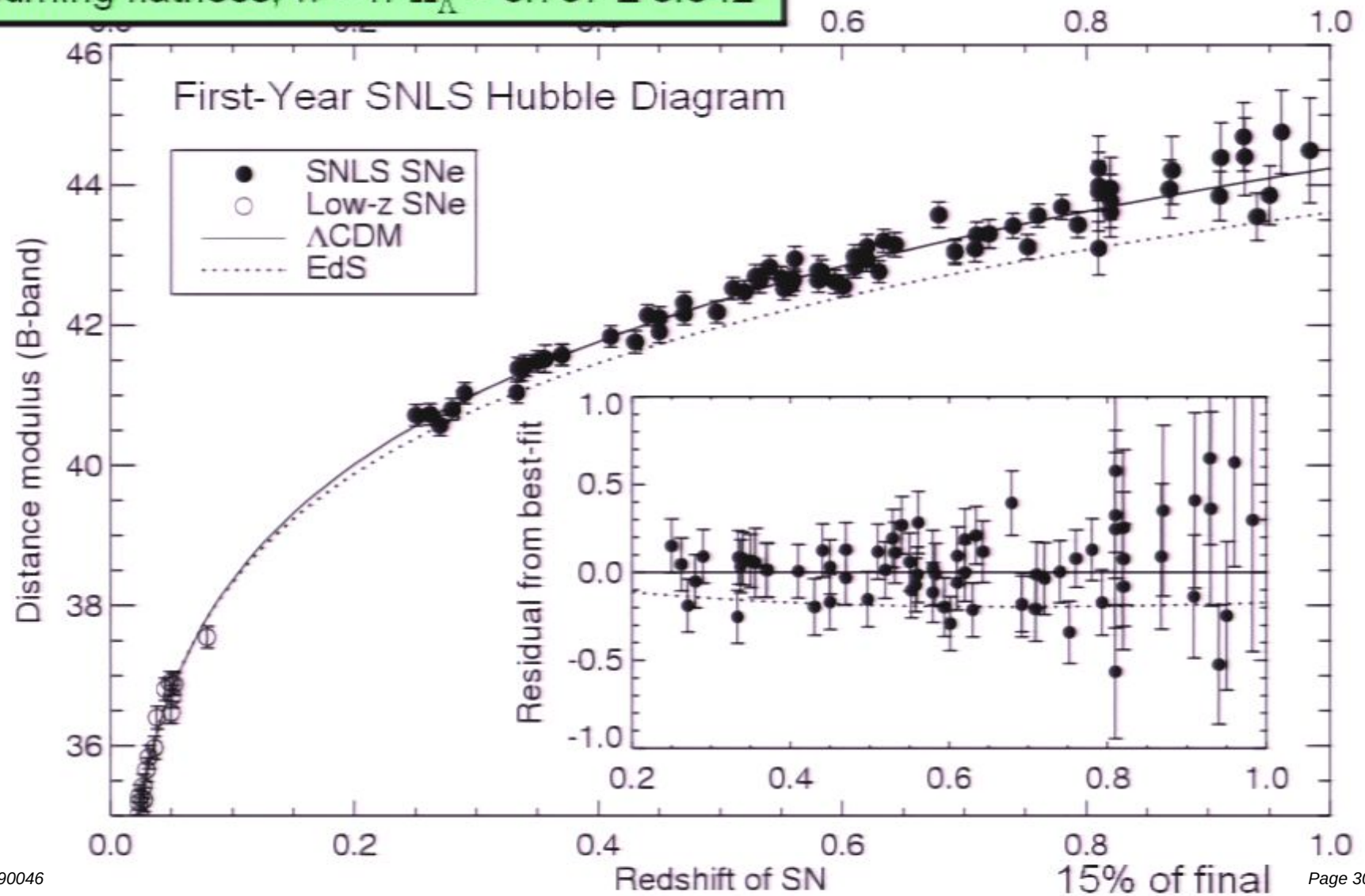
Magellan (15 nights/yr)

First Year Results (Astier et al. 2006):



First Year Results (Astier et al. 2006):

Assuming flatness, w=-1: $\Omega_\Lambda = 0.737 \pm 0.042$



15% of final sample

Baryon Acoustic Peak

THE ASTROPHYSICAL JOURNAL, 633:560–574, 2005 November 10
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SDSS z = 0.35

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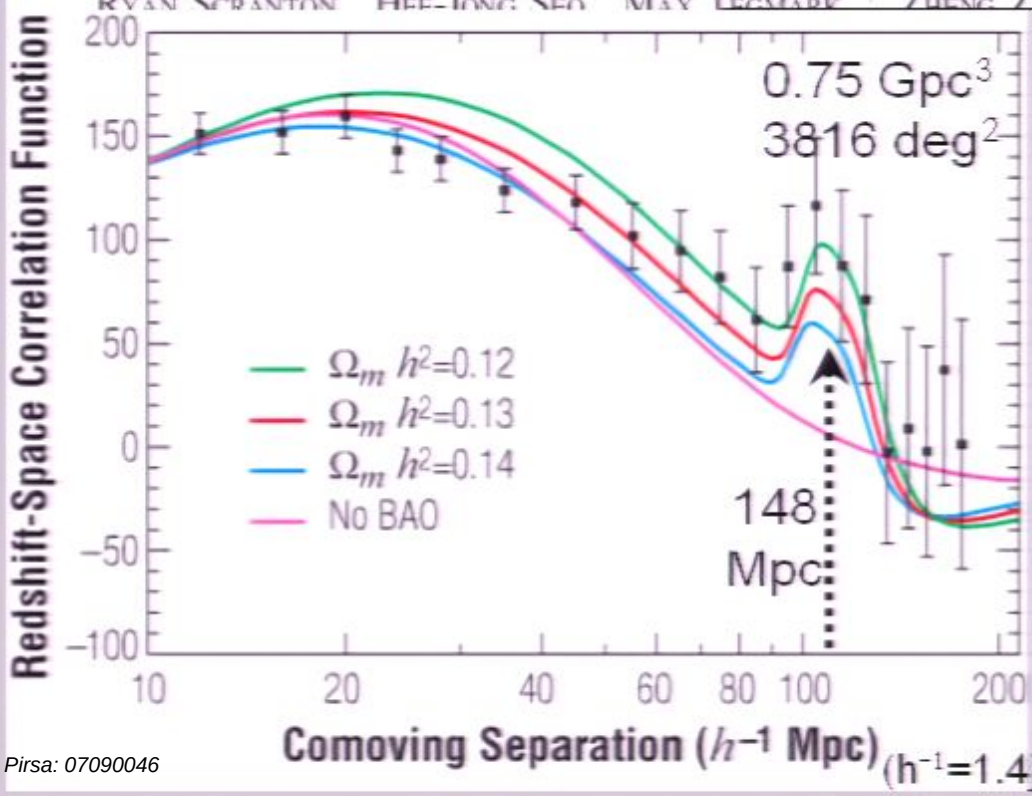

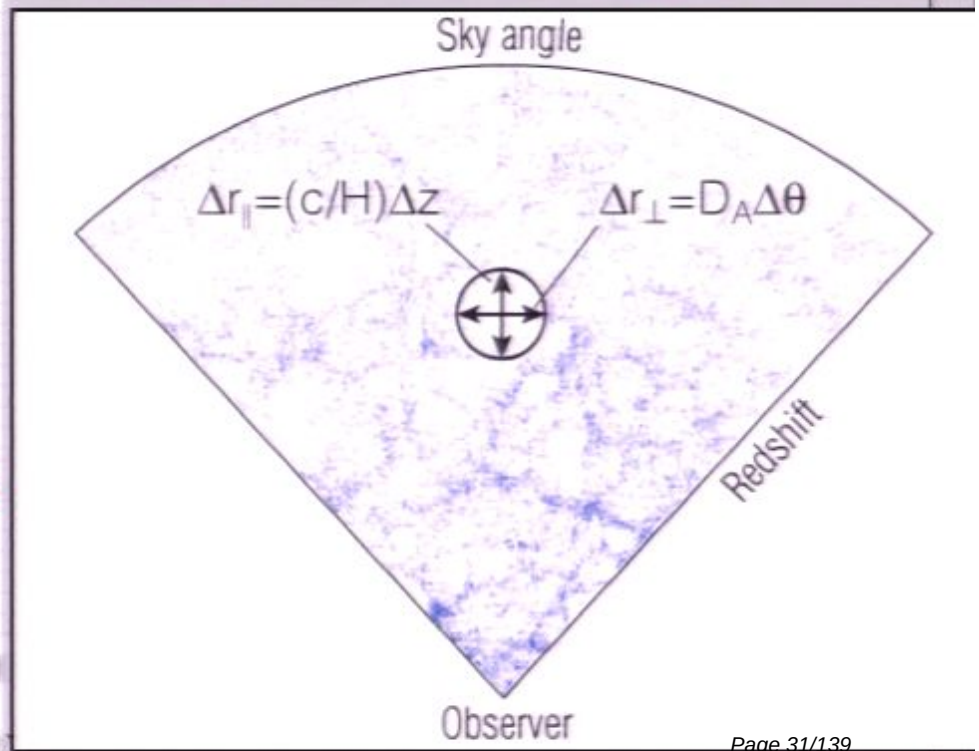

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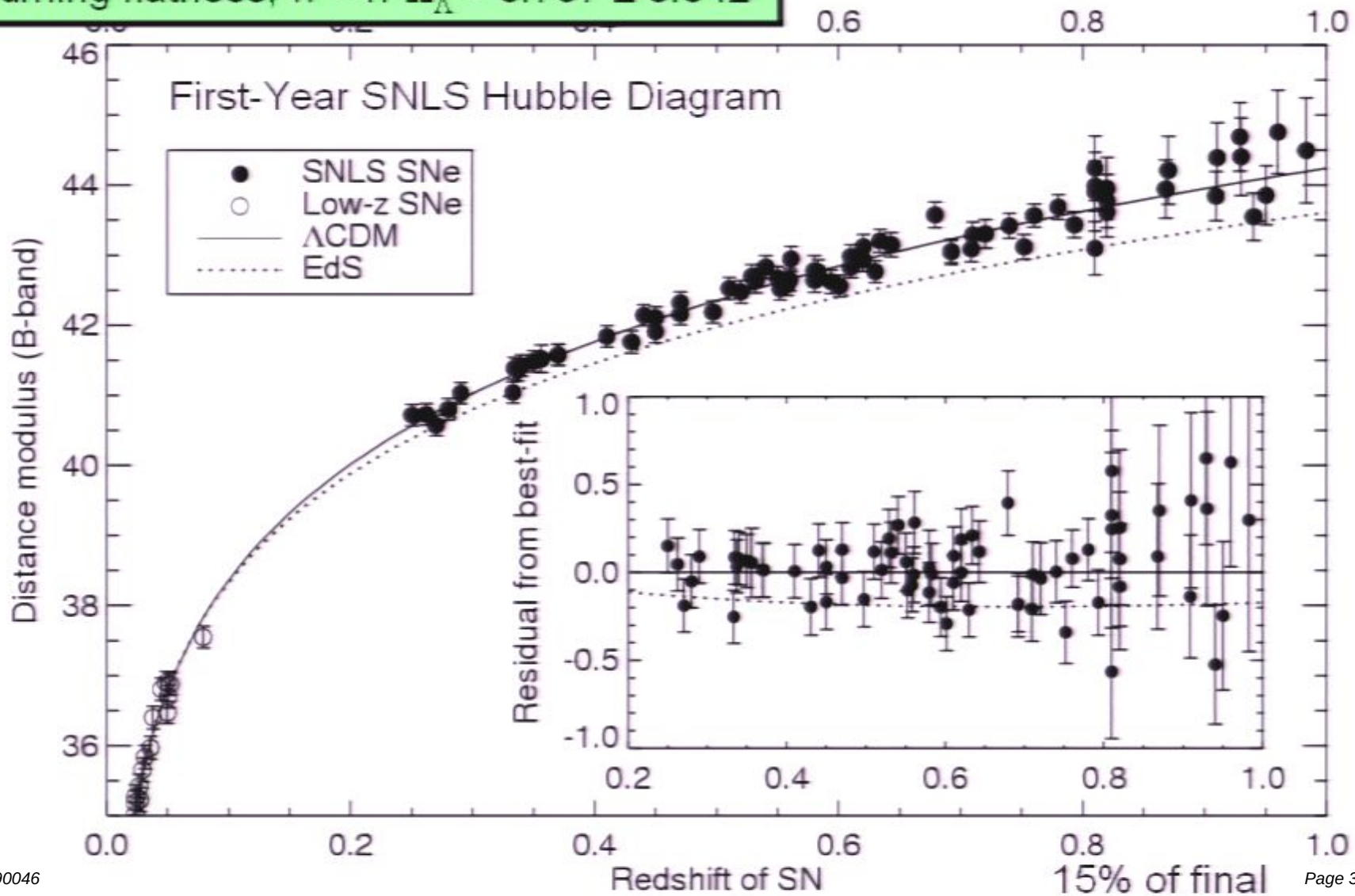

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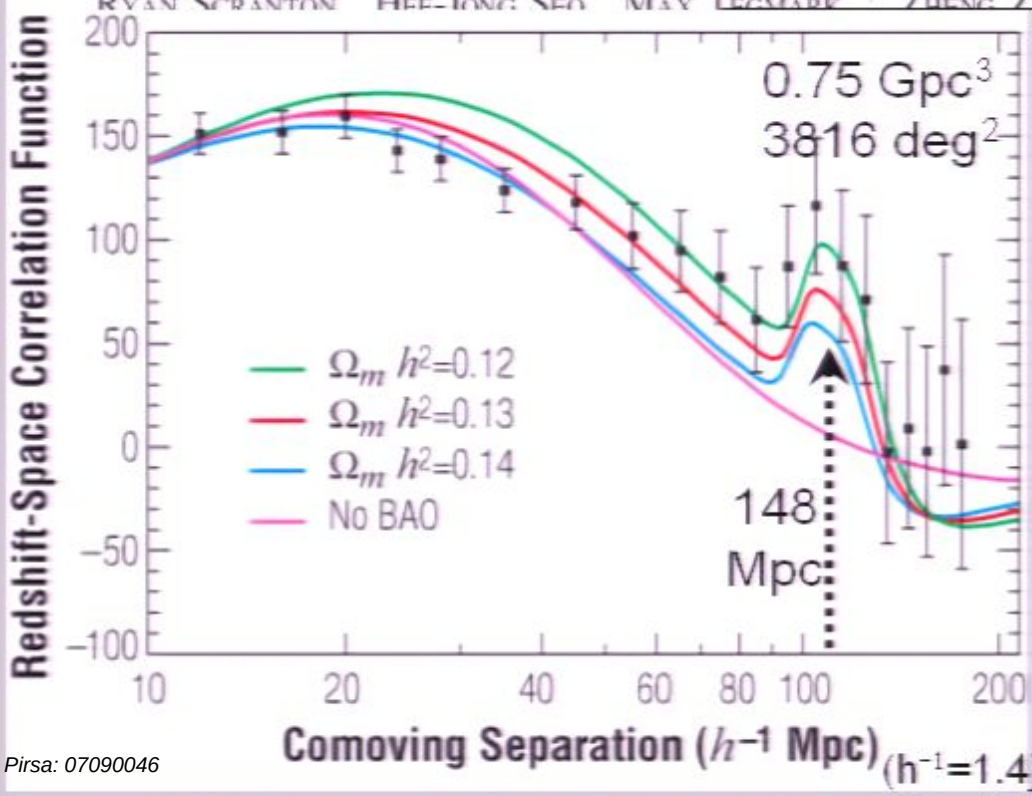
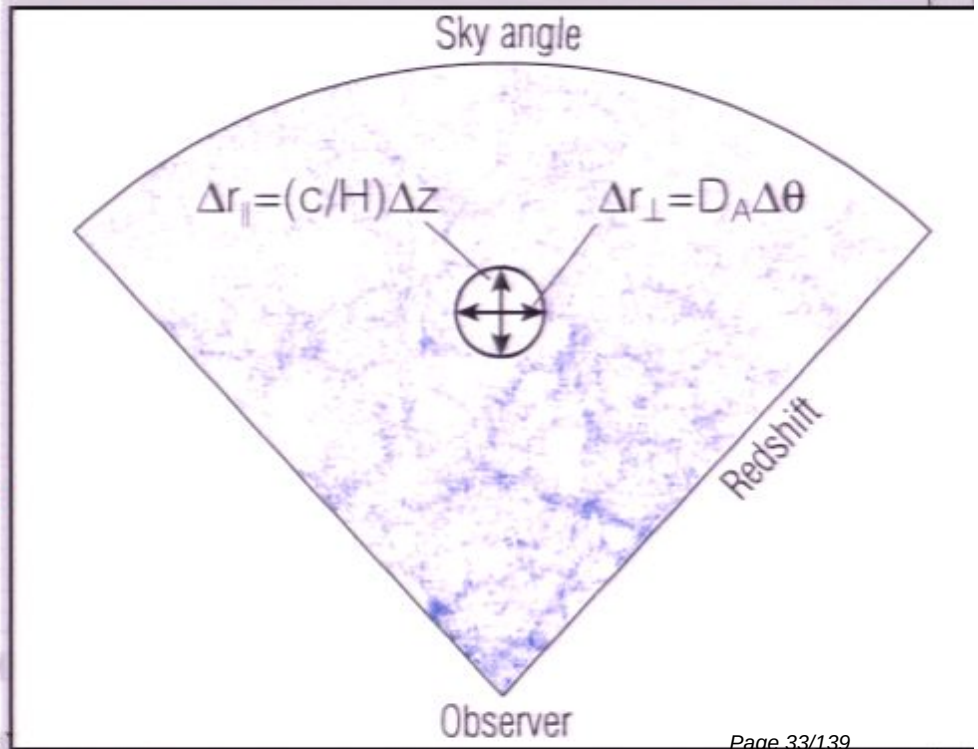
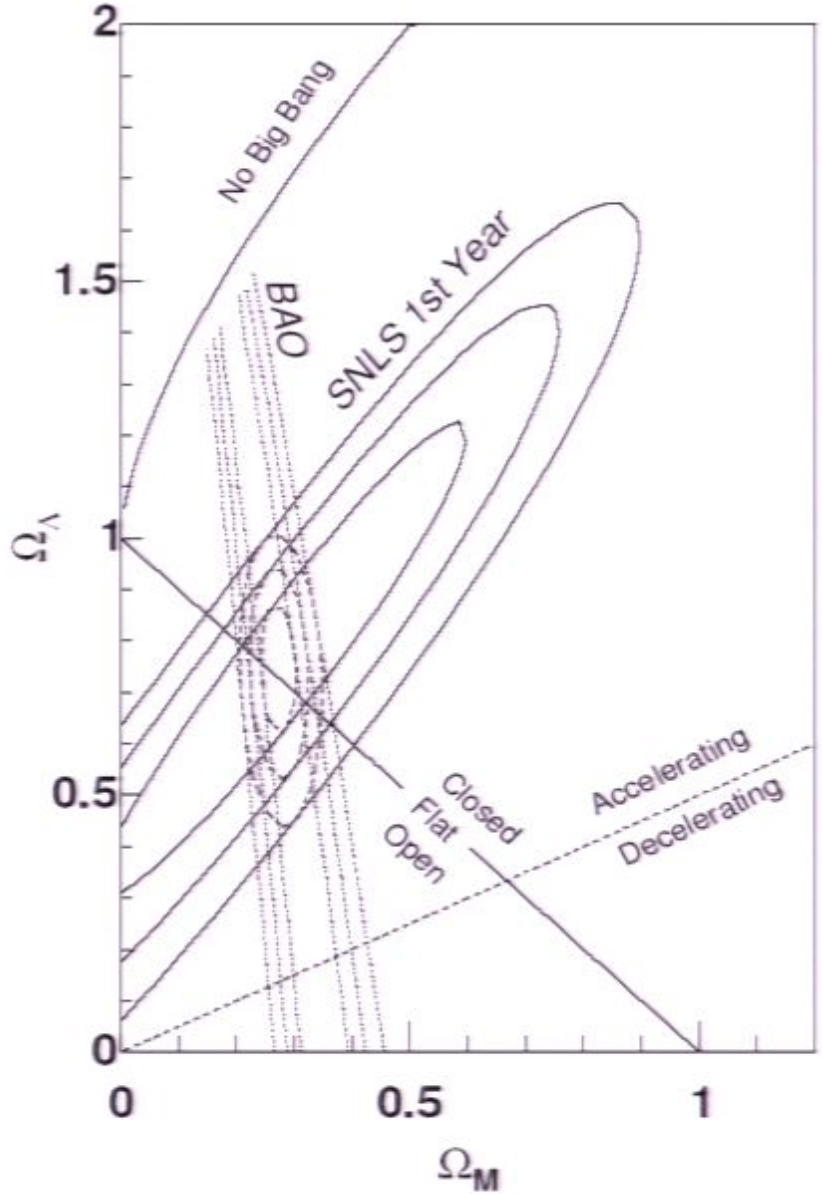
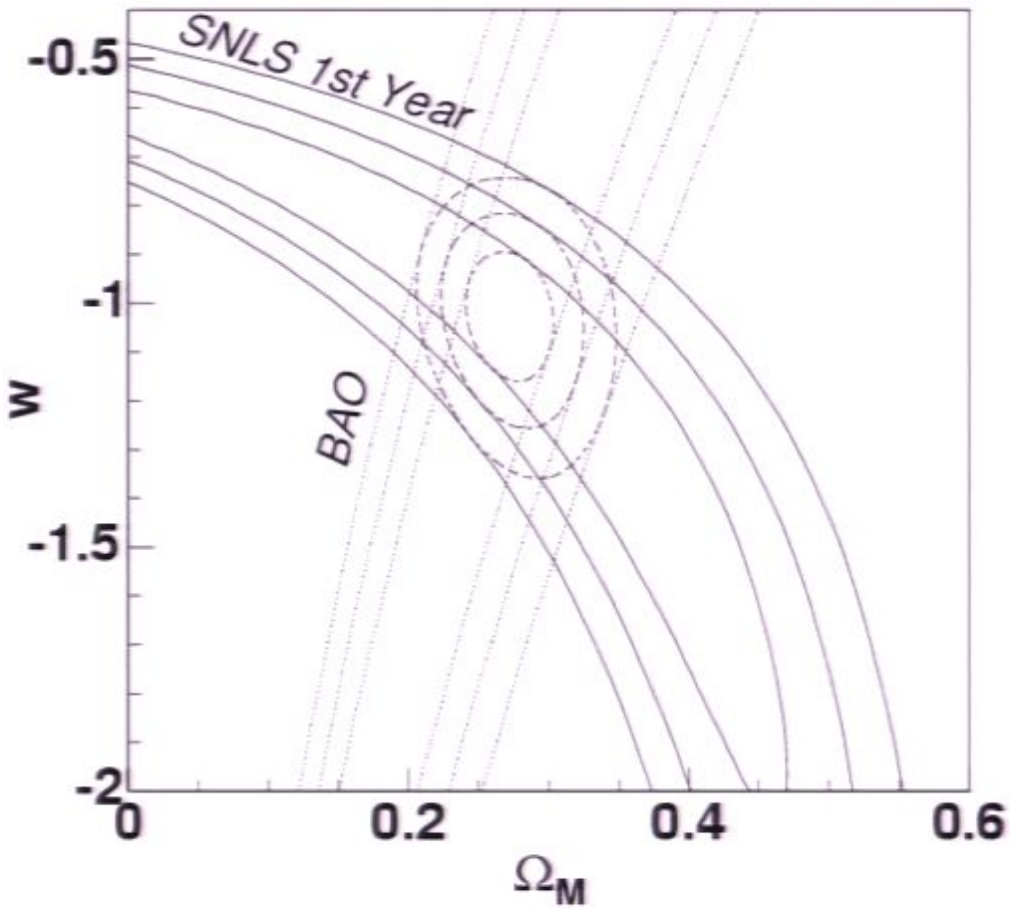


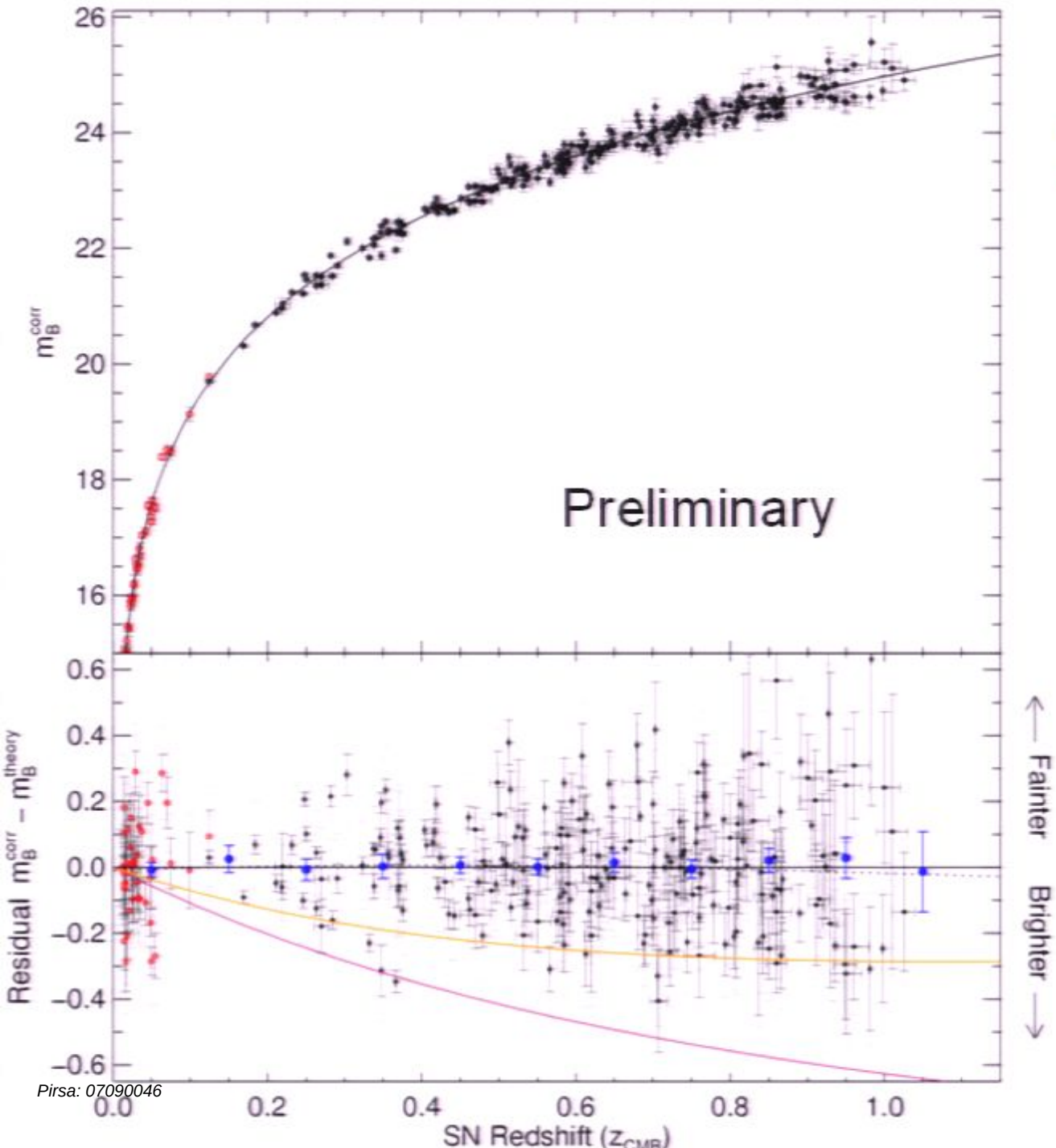


SNLS 1-yr + BAO prior (Astier et al , 2006)



SNLS 1-yr + BAO prior: w=-1.02±0.09±0.054 (Astier et al , 2006)





"Third year" SNLS Hubble Diagram (preliminary)

3/5 years of SNLS

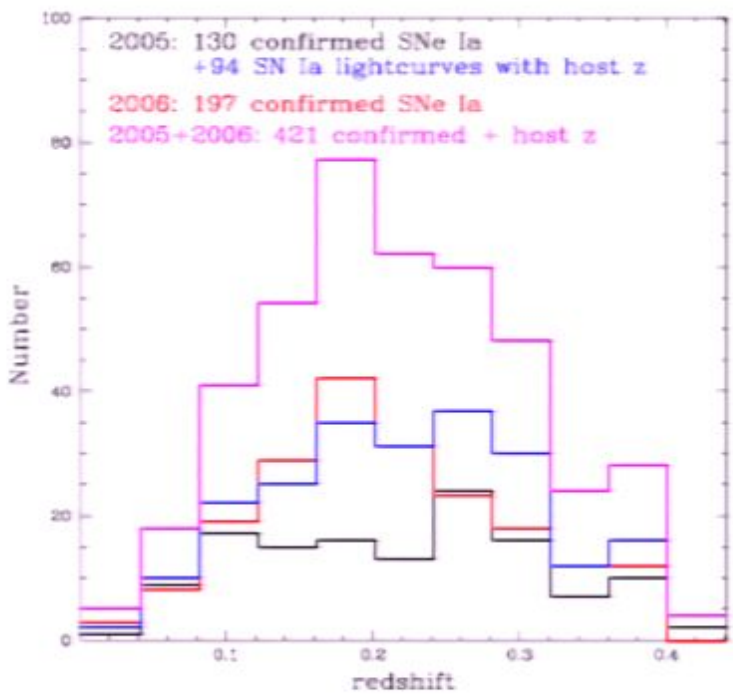
~240 distant SNe Ia

rms ~ 0.17mag

Credit: M.Sullivan

SDSS-SN

- **Rolling search completed for two years – third one started last week!**
- **300 sq.deg, 3 months/year**



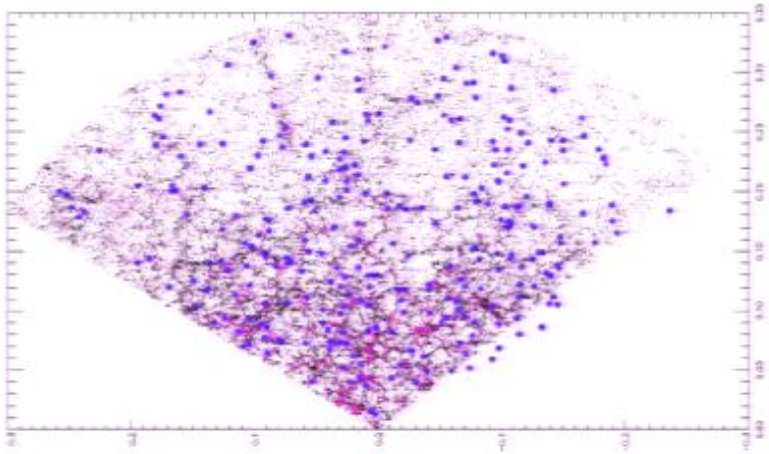
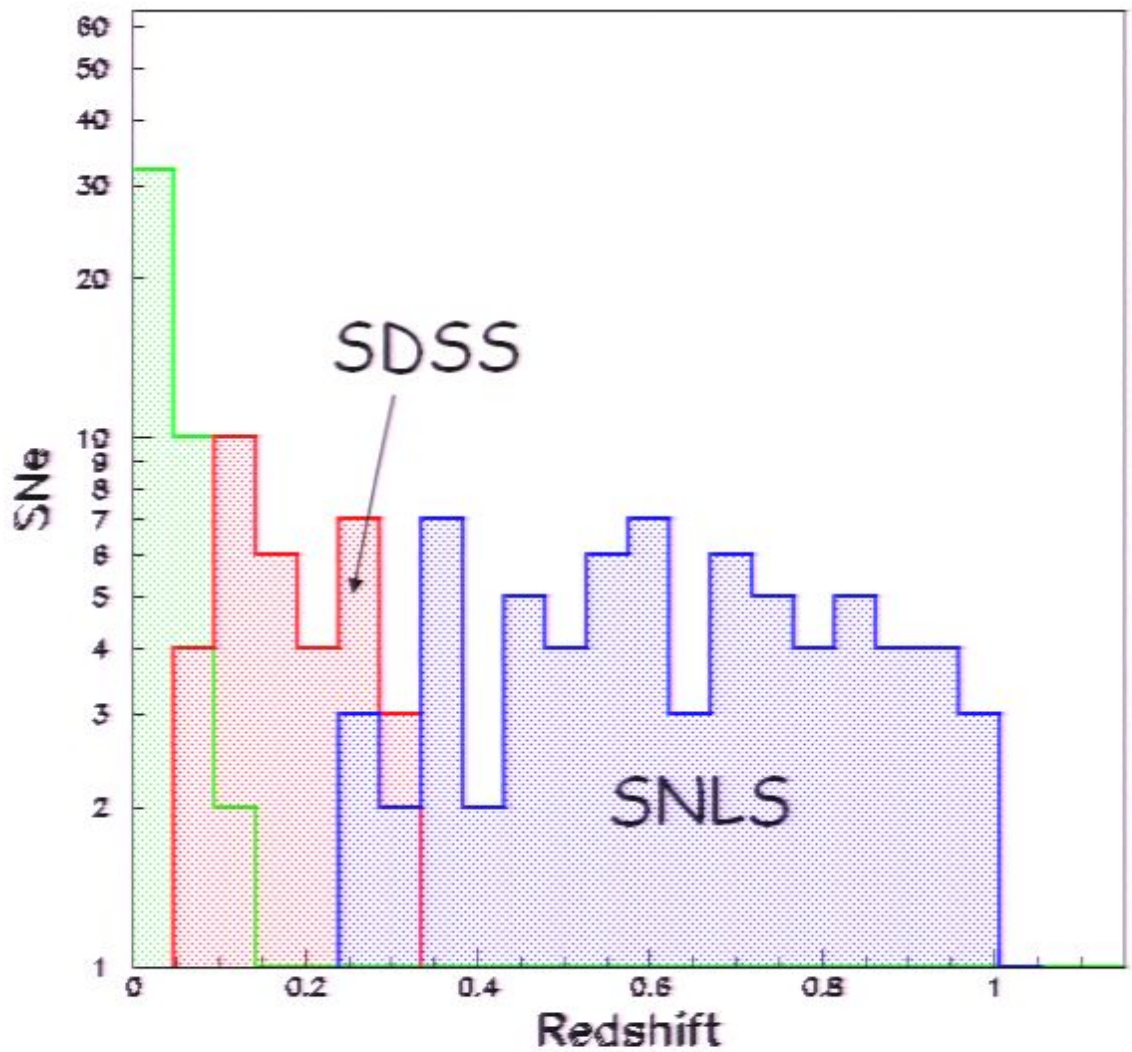


Fig. 8.— Distribution of confirmed SDSS-II SNe Ia from 2005 and 2006 in RA and redshif
blue points), superposed on the distribution of galaxies with redshifts measured by the SDSS
points in black and magenta). The SN survey extends slightly beyond the RA limits for the
survey, leading to the handful of SNe that appear "out of bounds".

Fig. 6.— Histogram of redshifts of spectroscopically confirmed SNe Ia for the 2005 (short-dashed) and 2006 (dotted) seasons. Long-dashed histogram shows the 2005 confirmed sample plus 94 objects

C-T/CfA low-z, SDSS 1-run + SNLS 1-yr



Very-high redshift supernovae from ACS/HST

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17 Nov 2006

ABSTRACT

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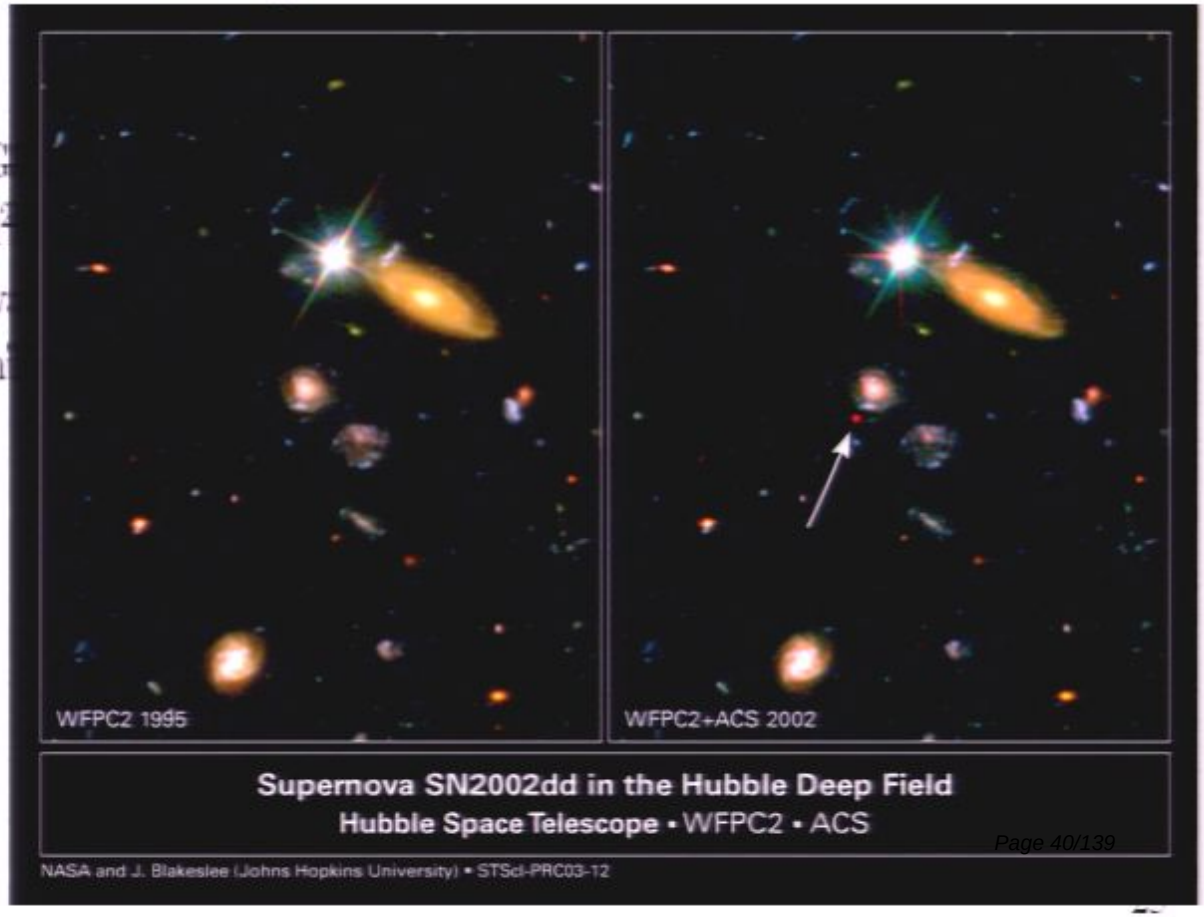
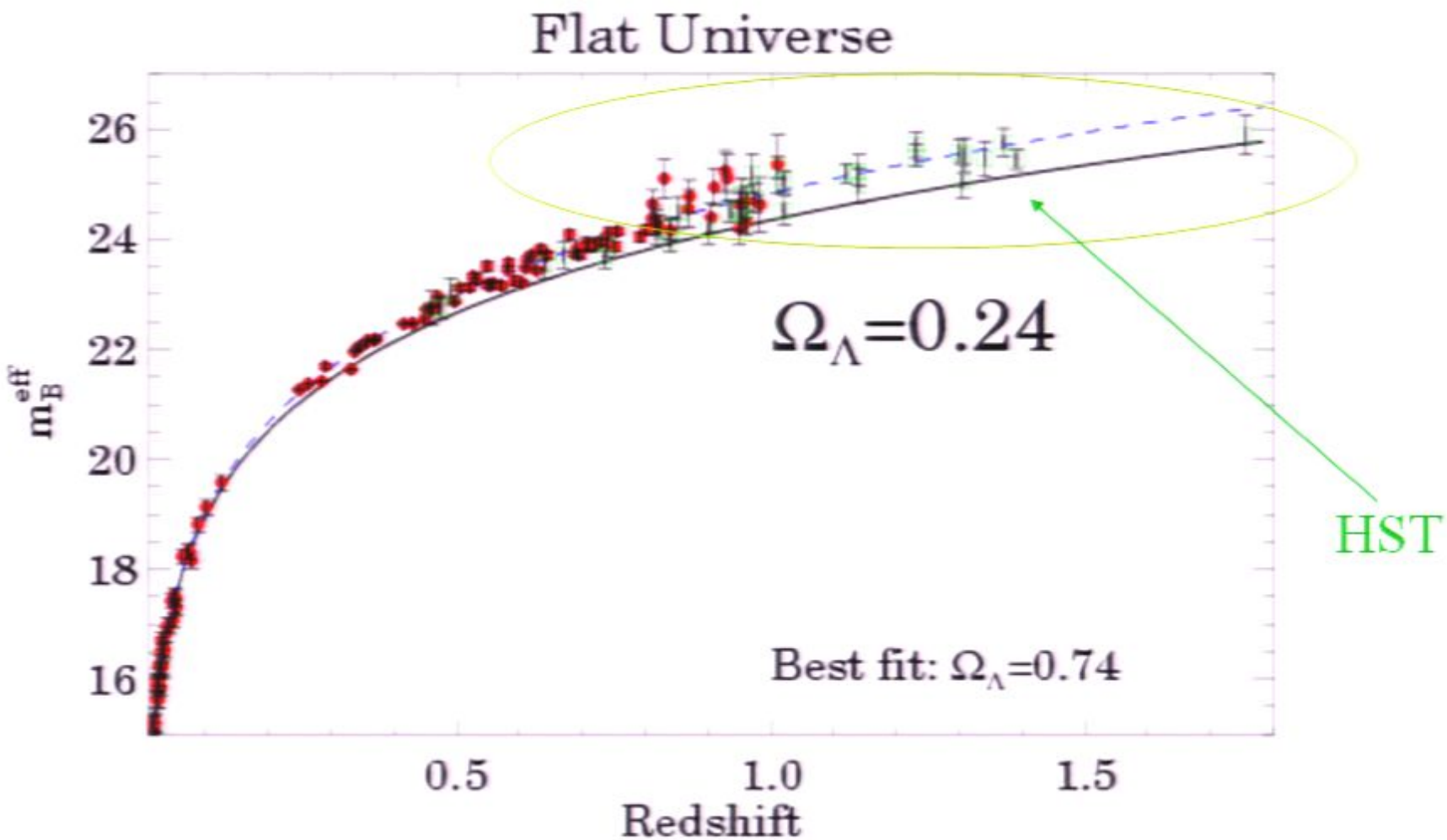


The easy part…



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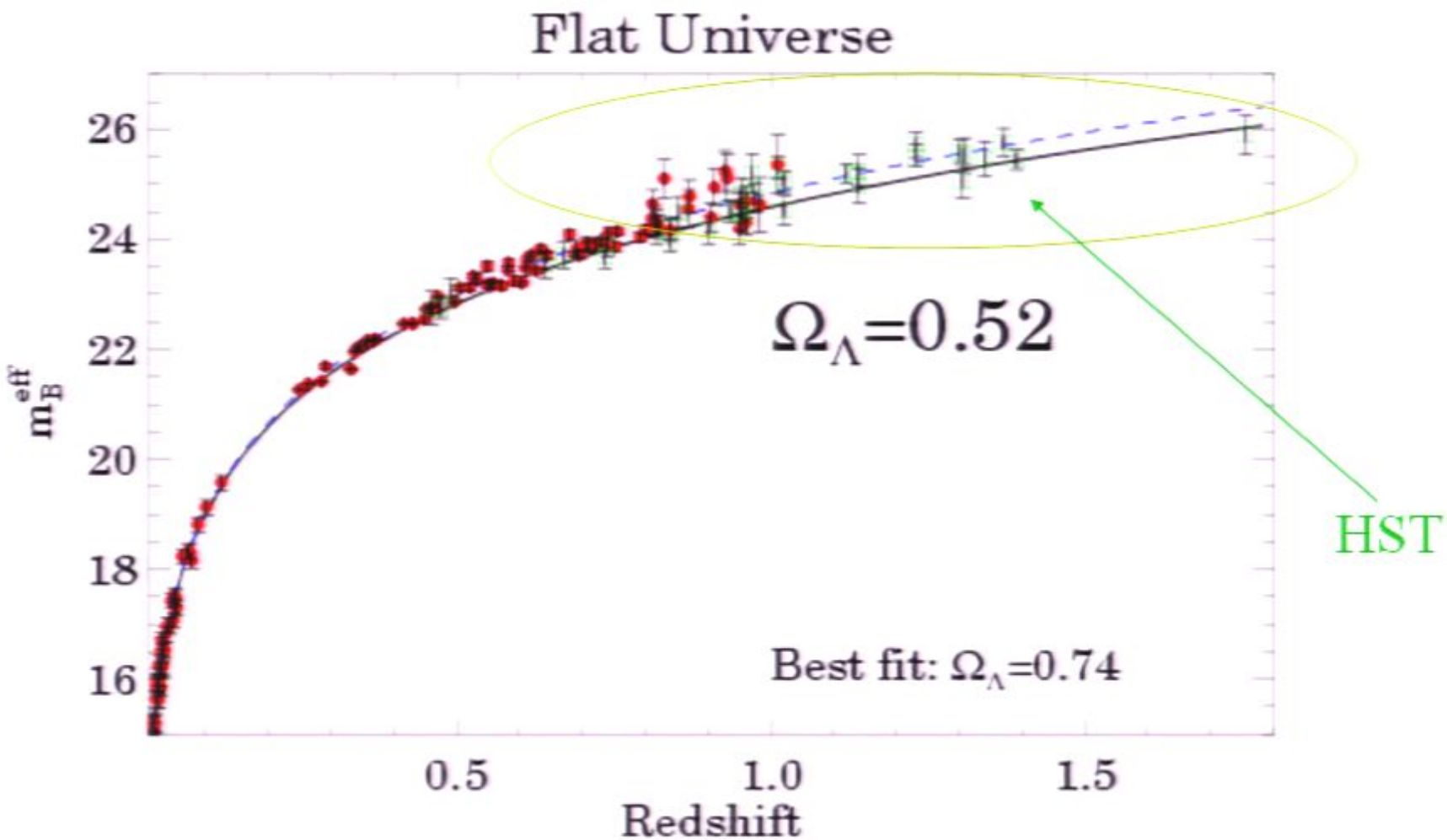

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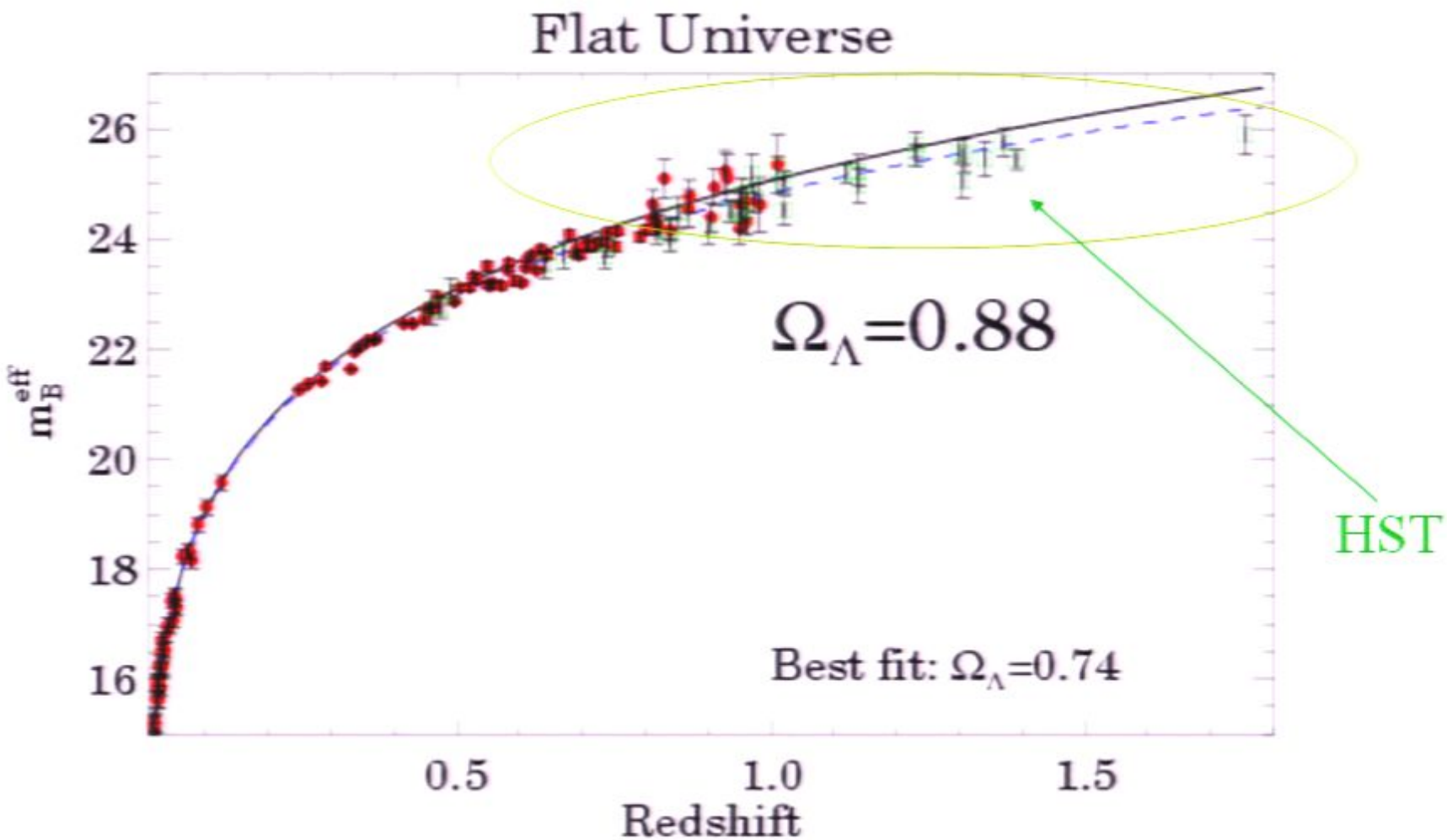

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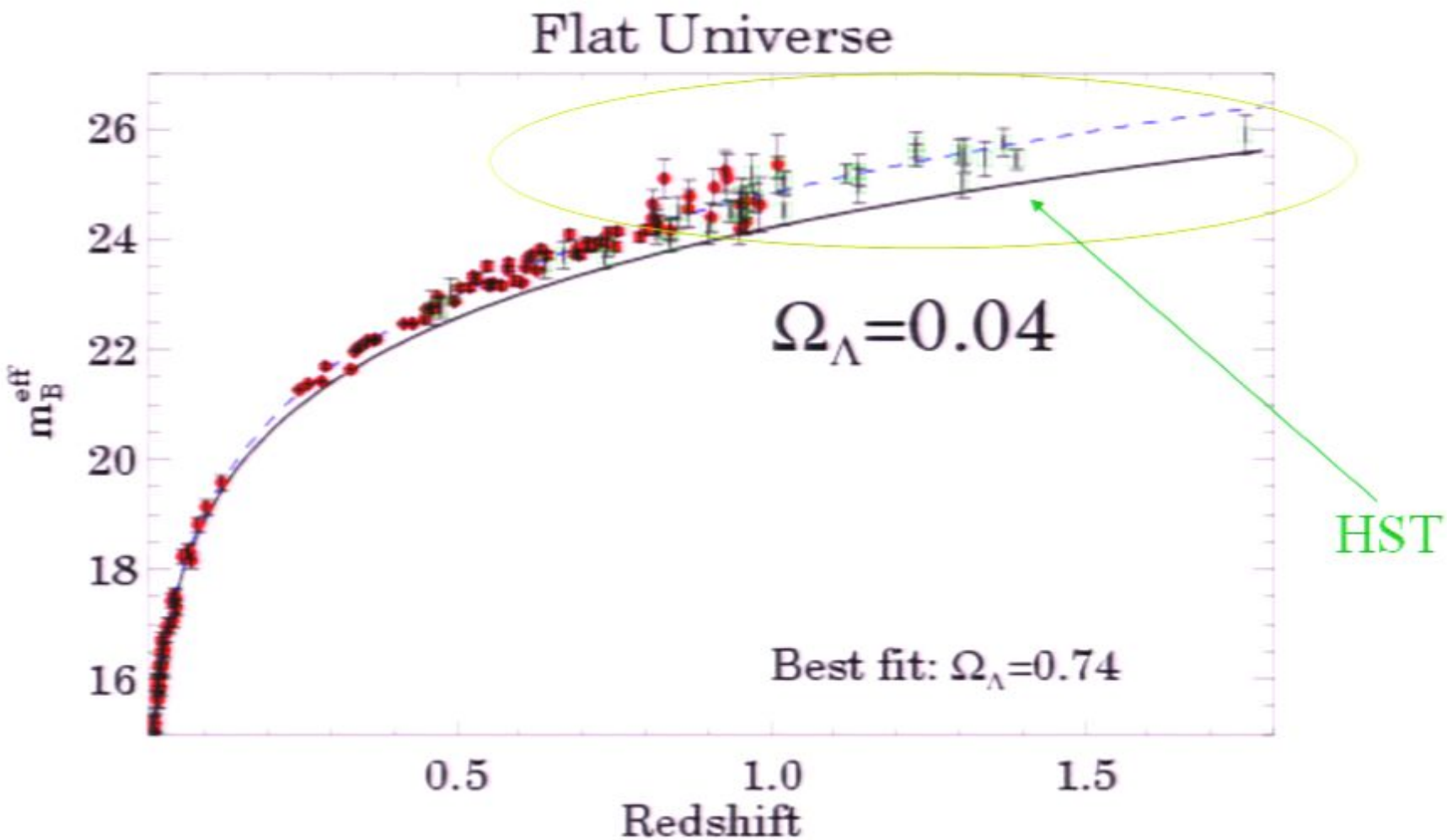

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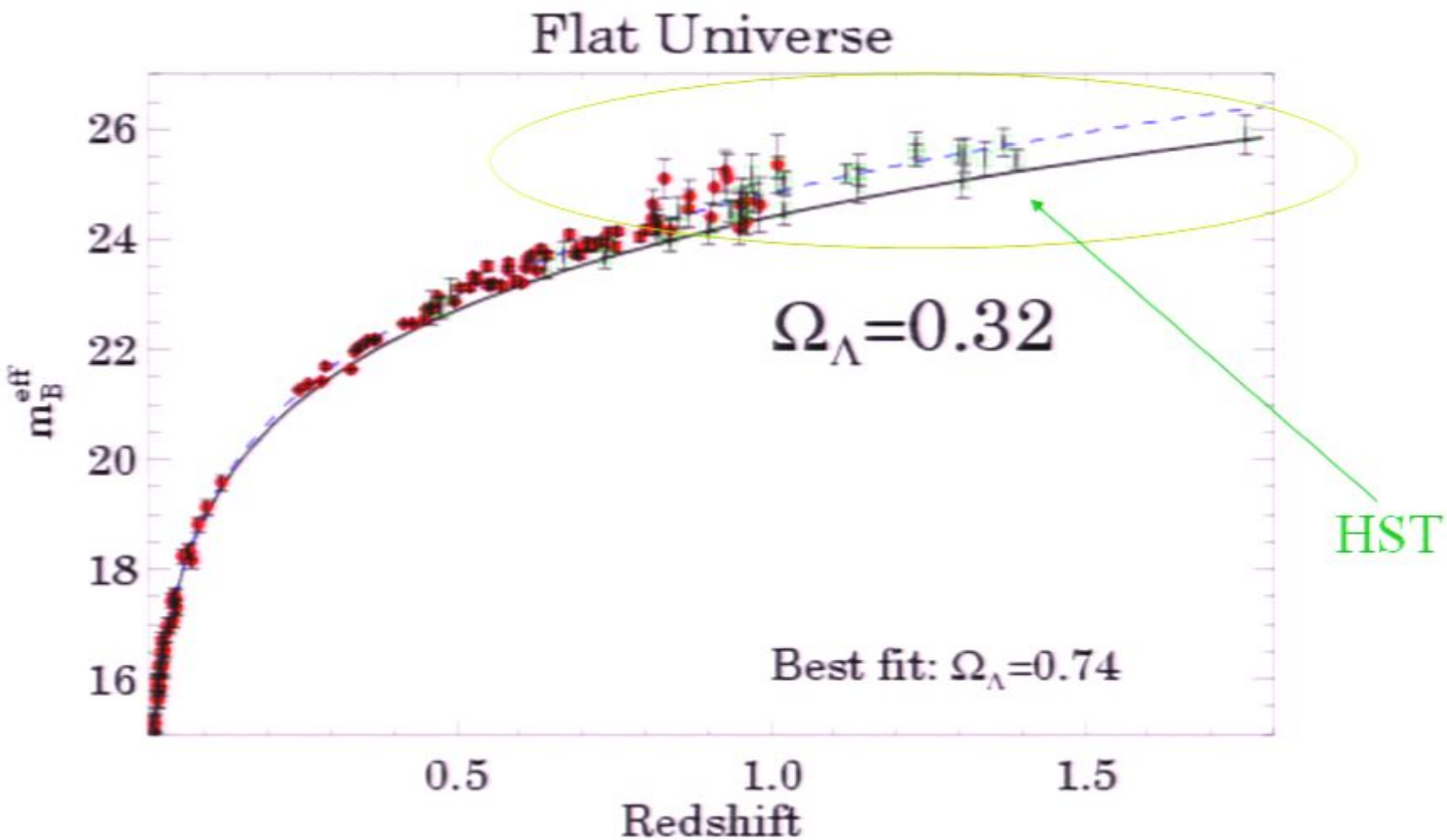

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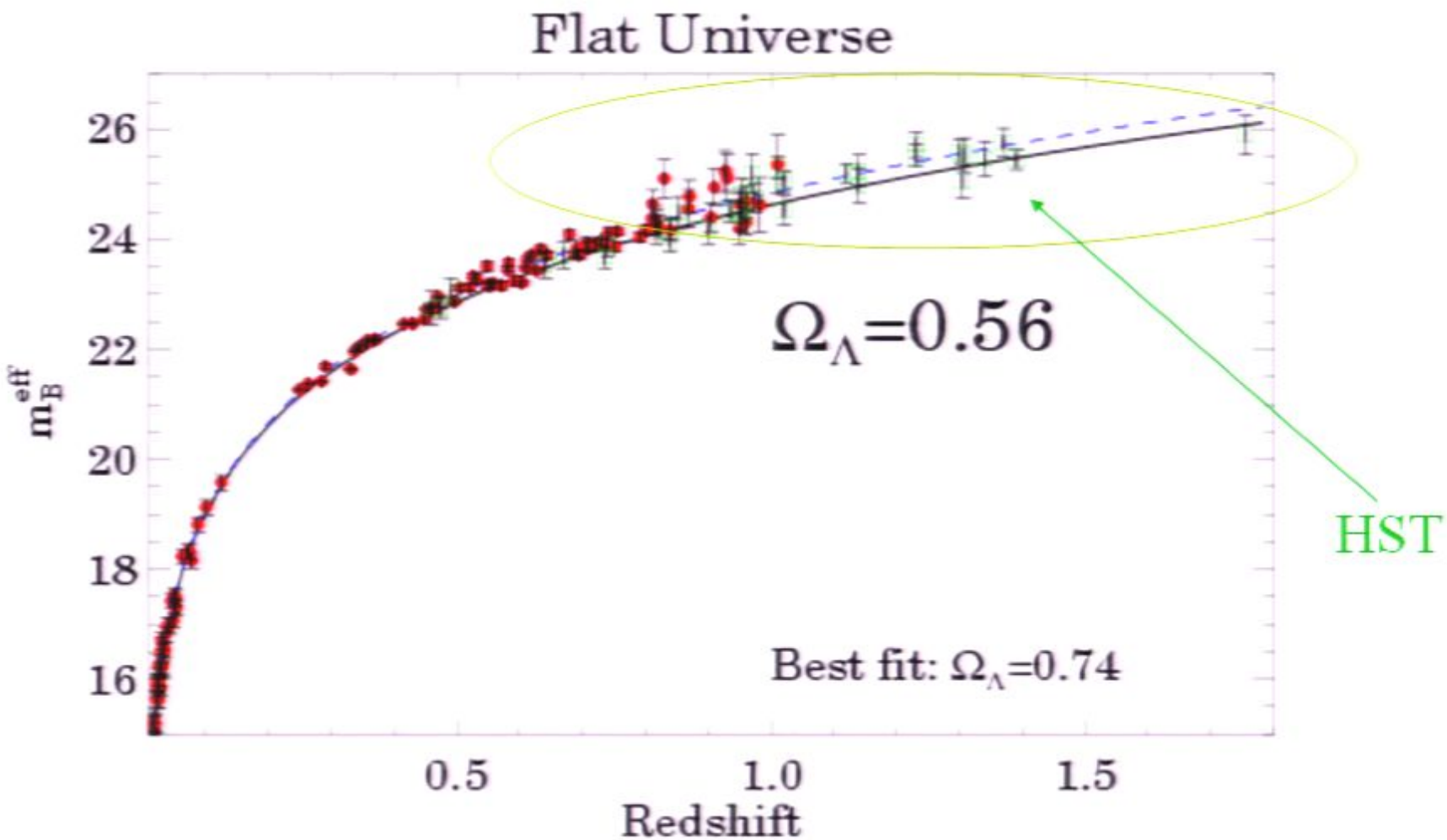

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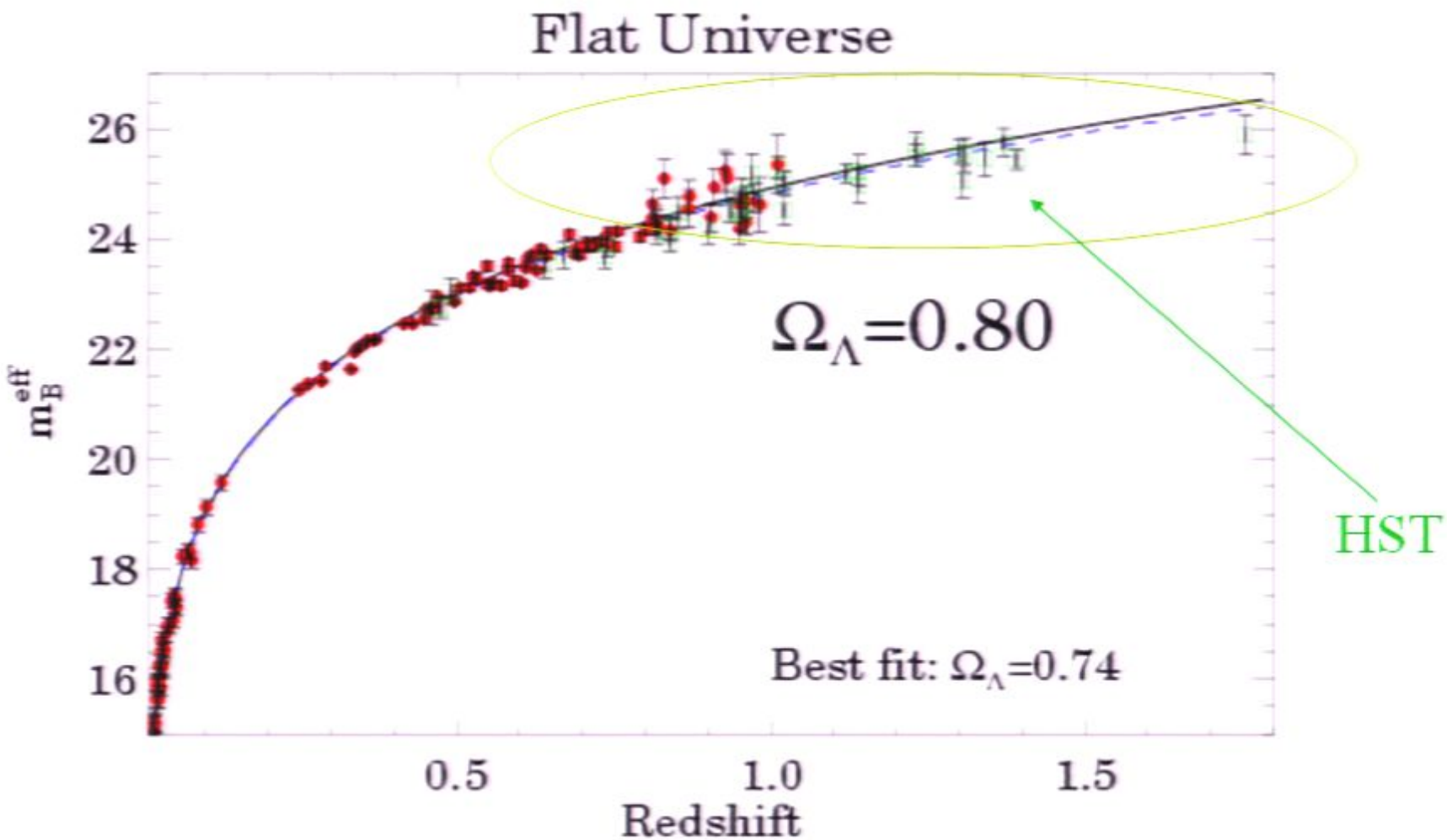

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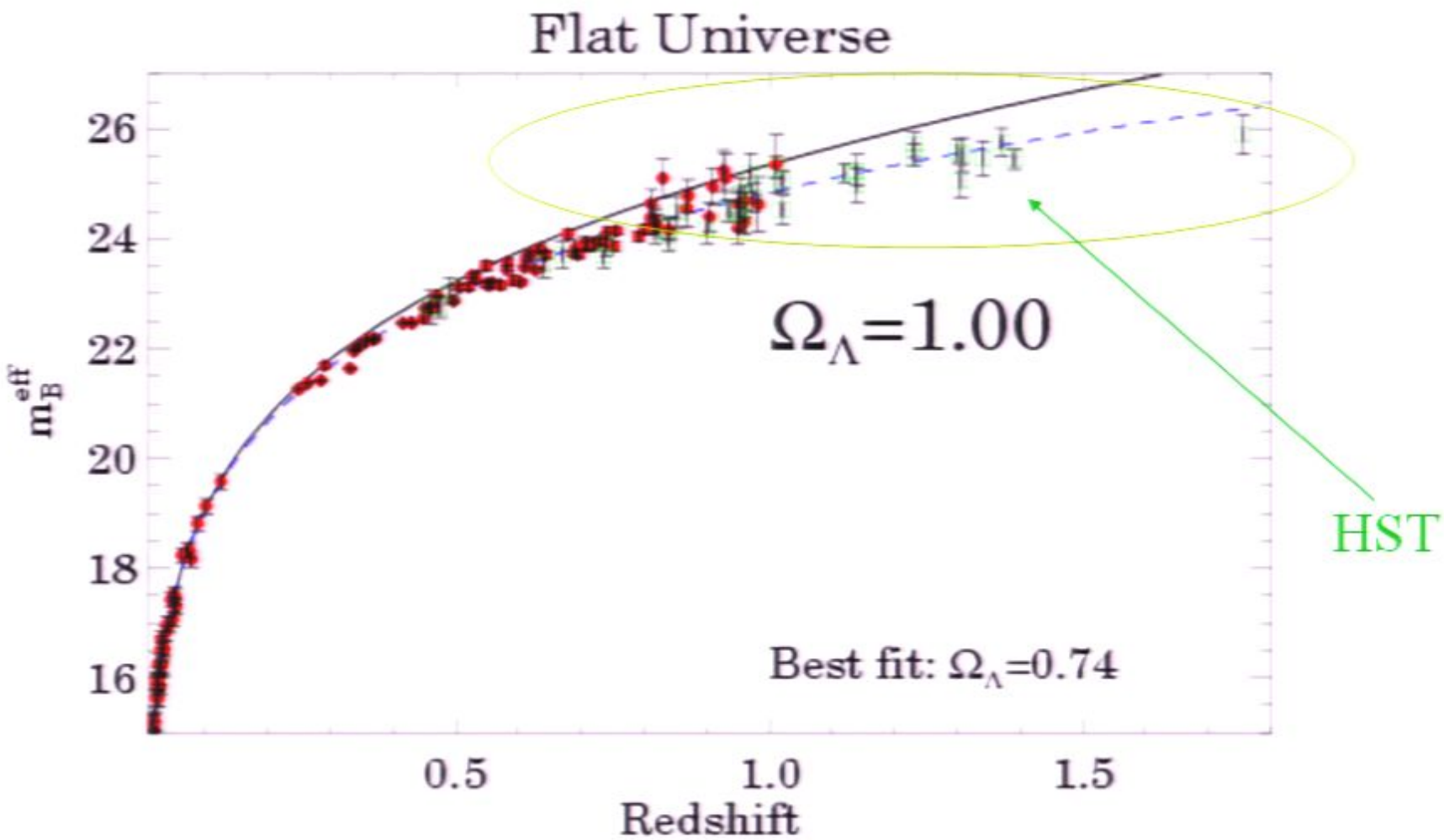
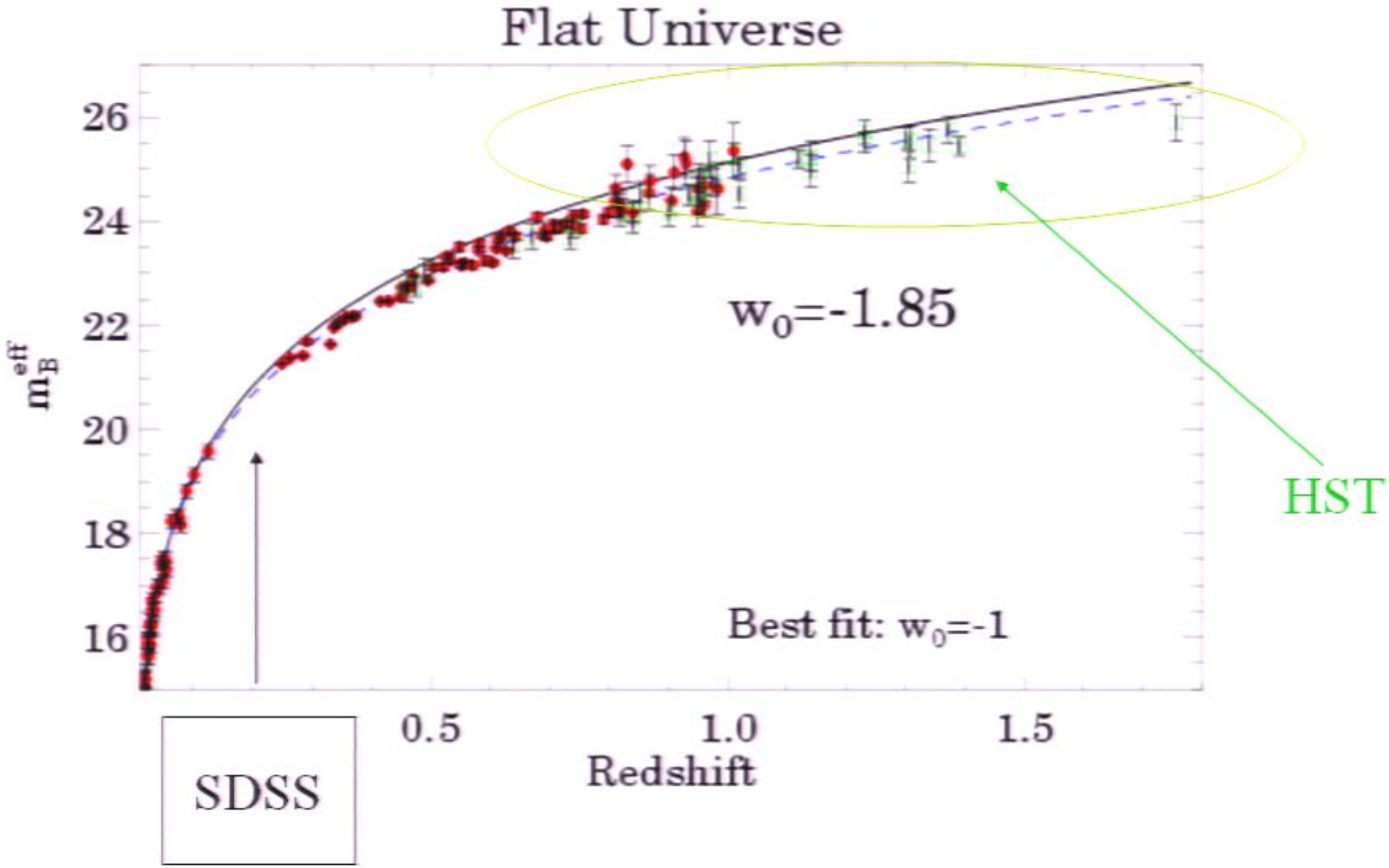


Constant dark energy



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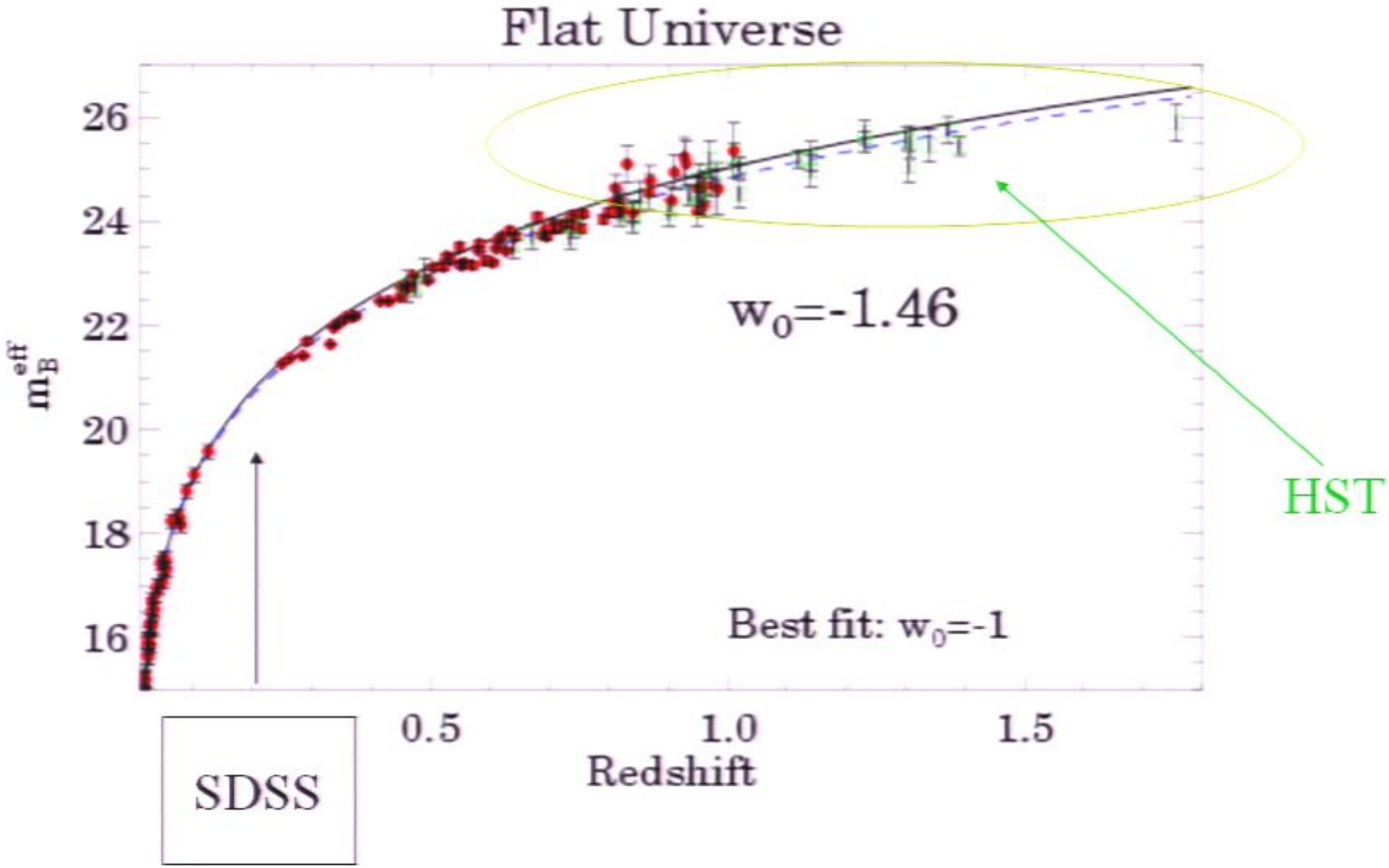

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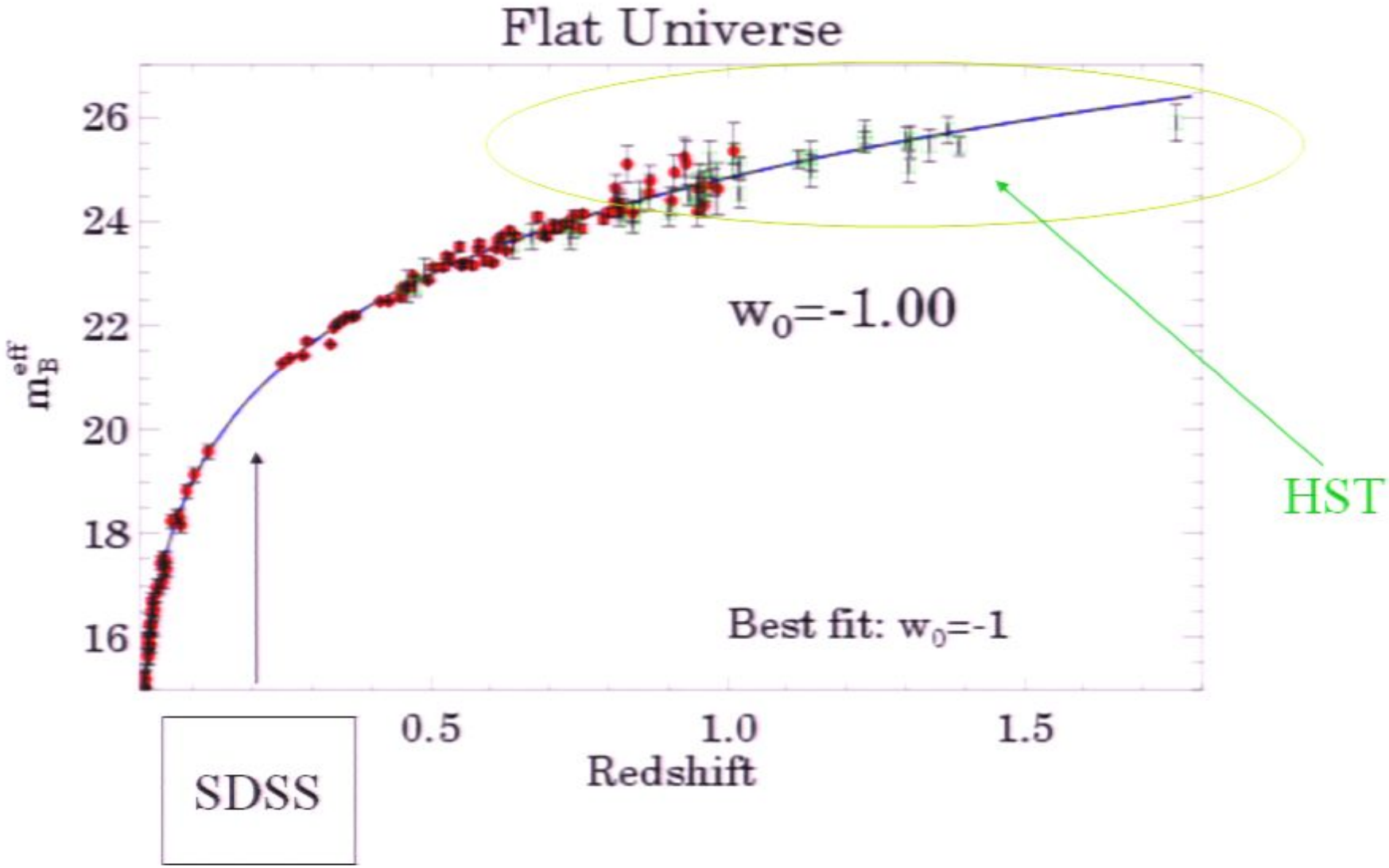

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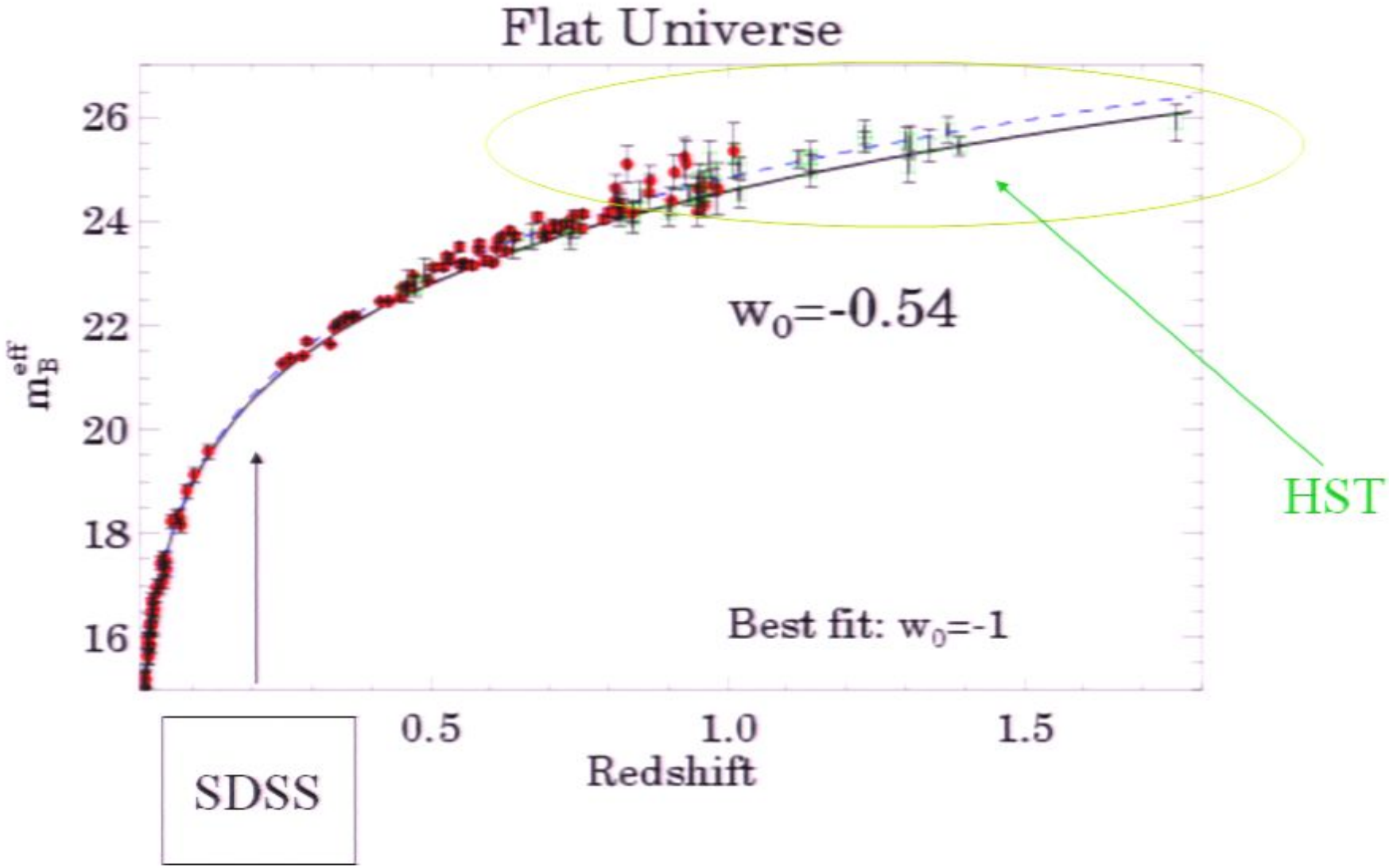

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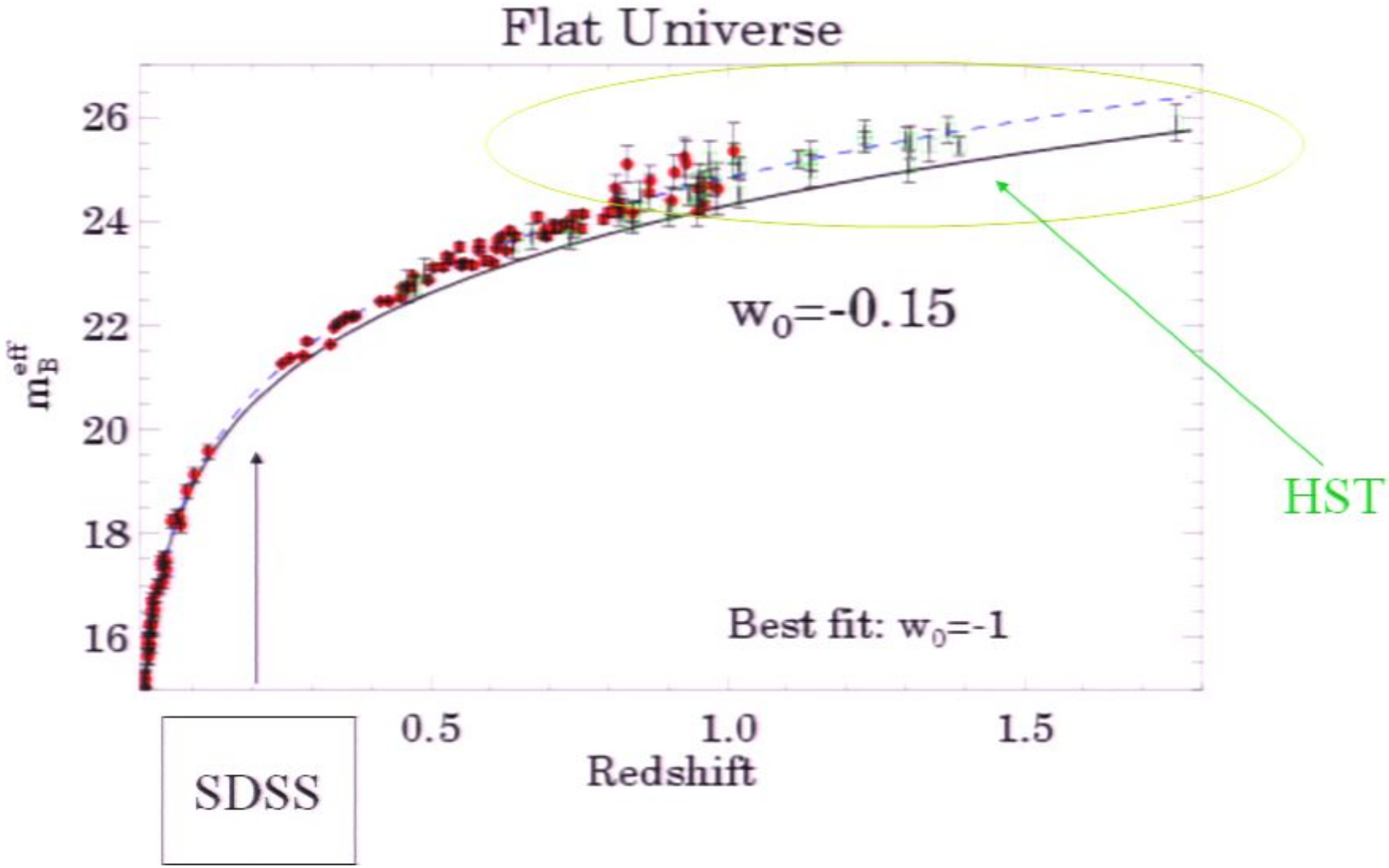

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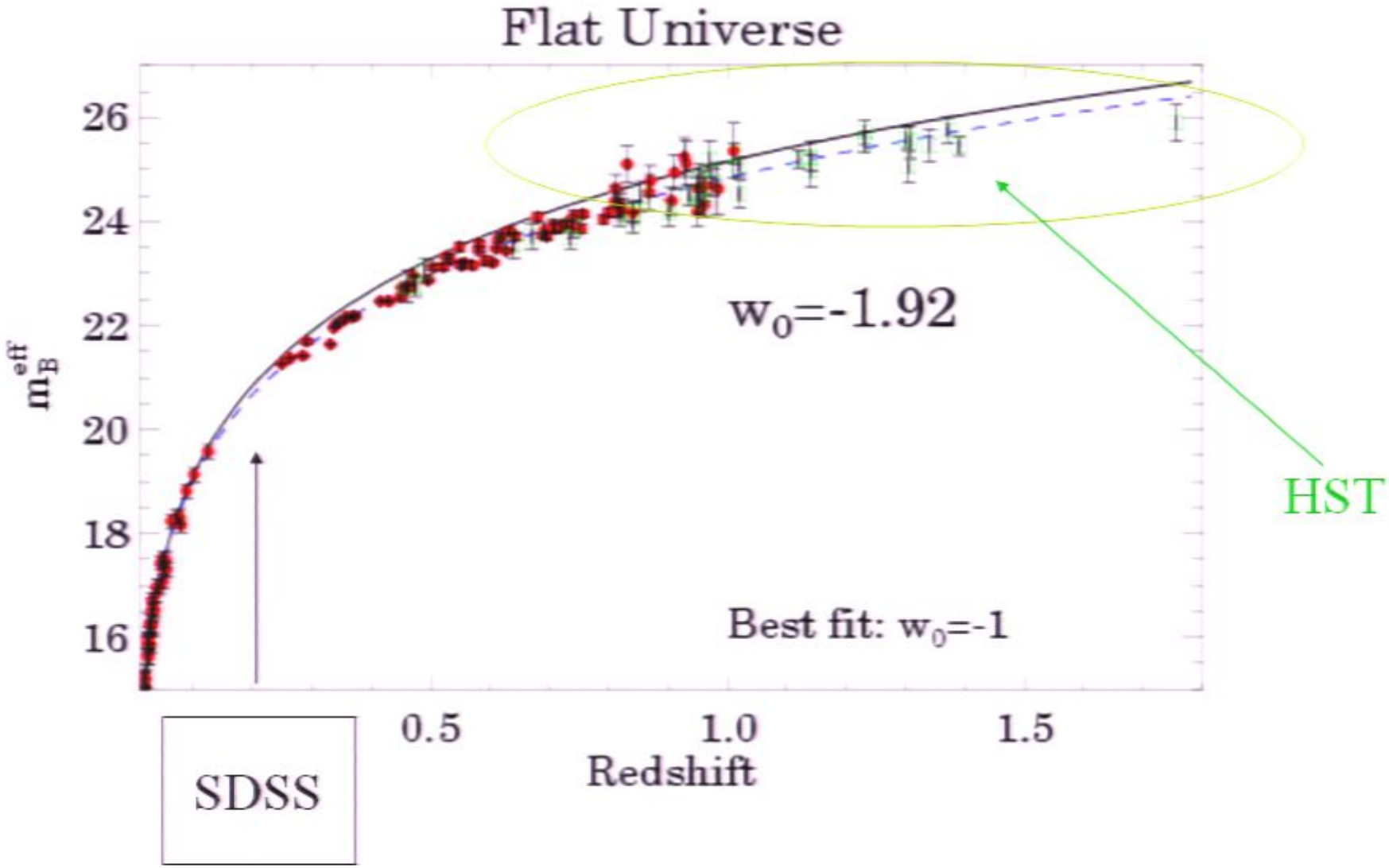
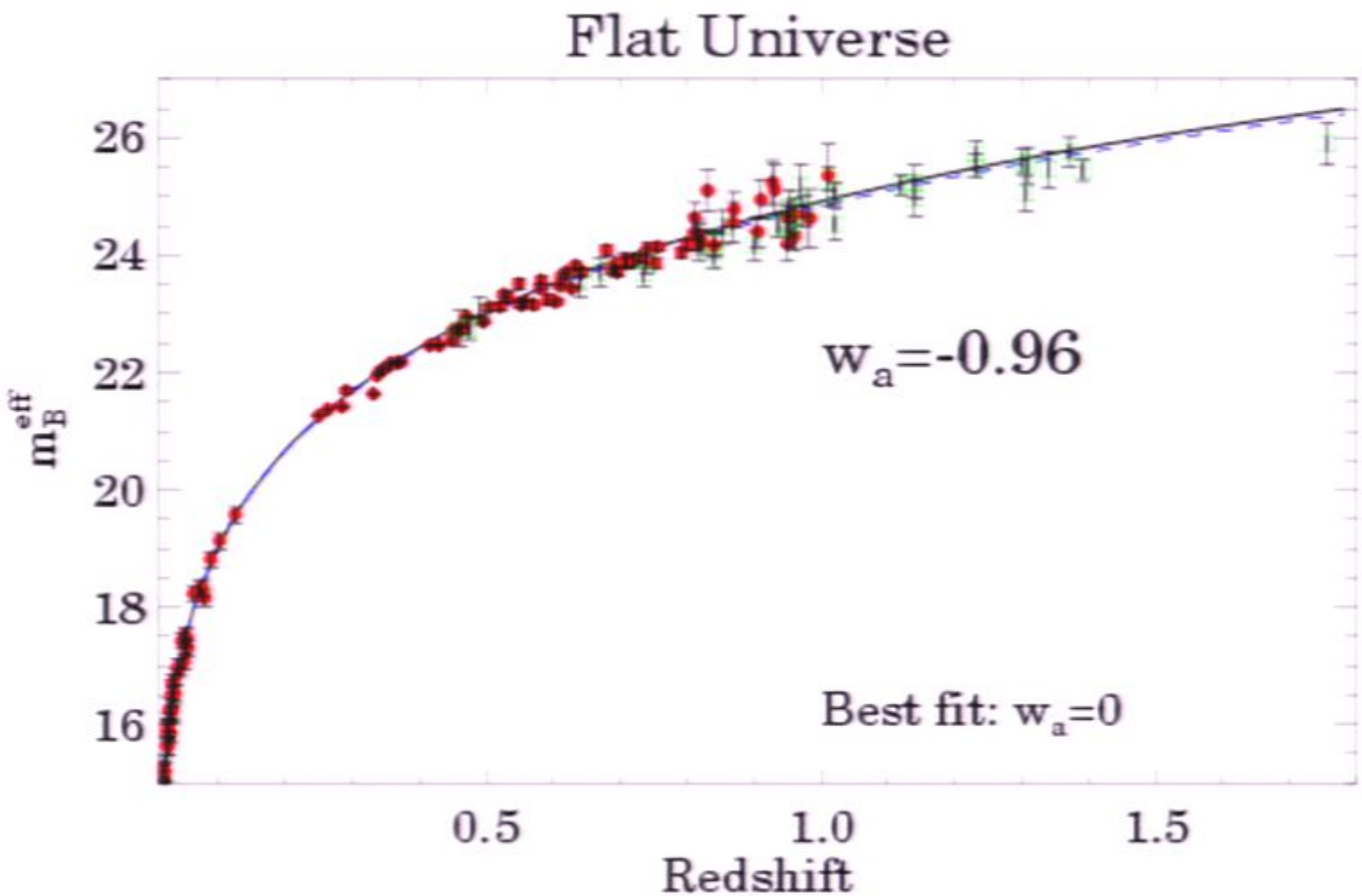


Current limits on dynamical DE are extremly weak: $w(a) = w_0 + w_a(1-a)$



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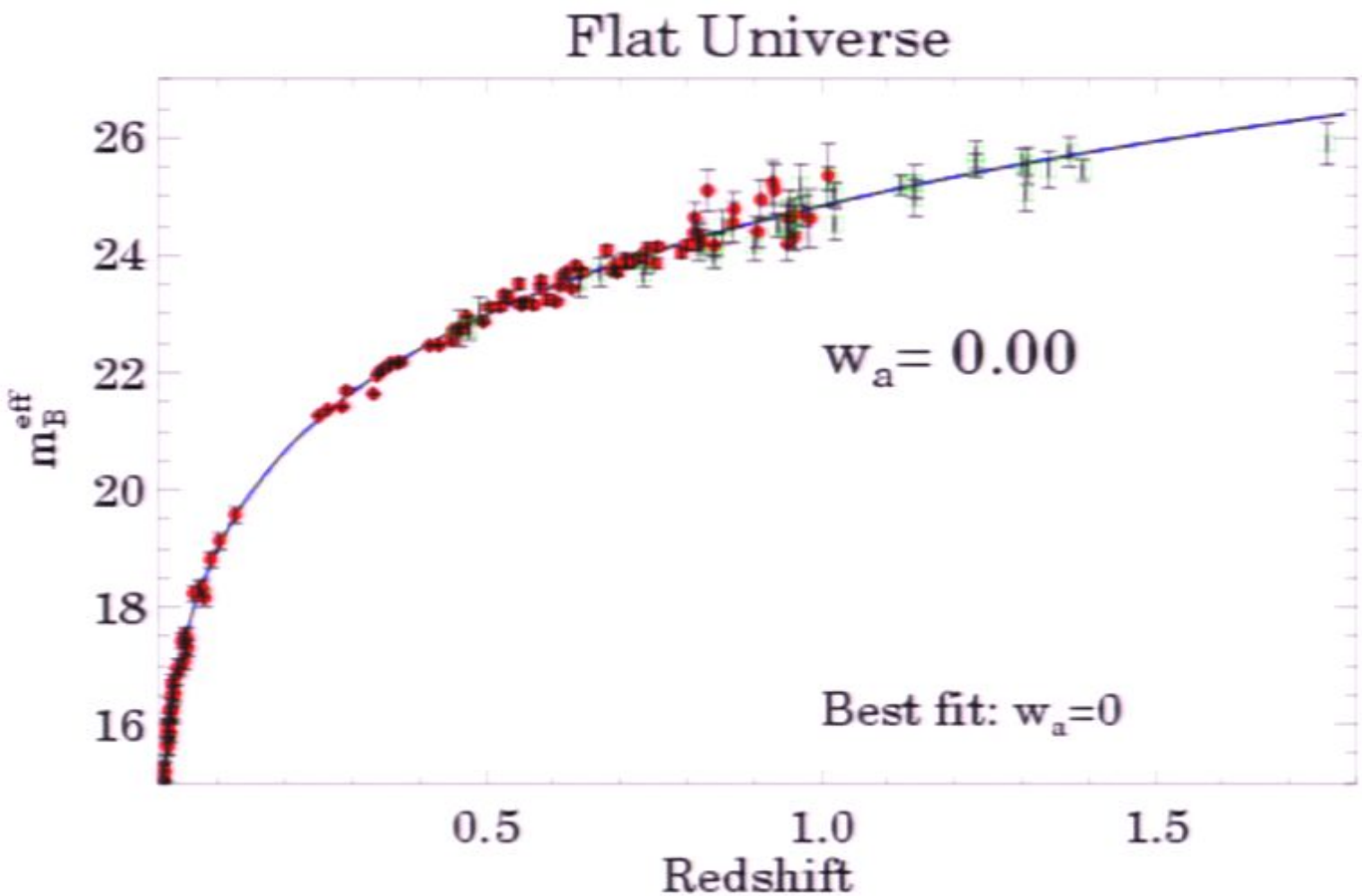

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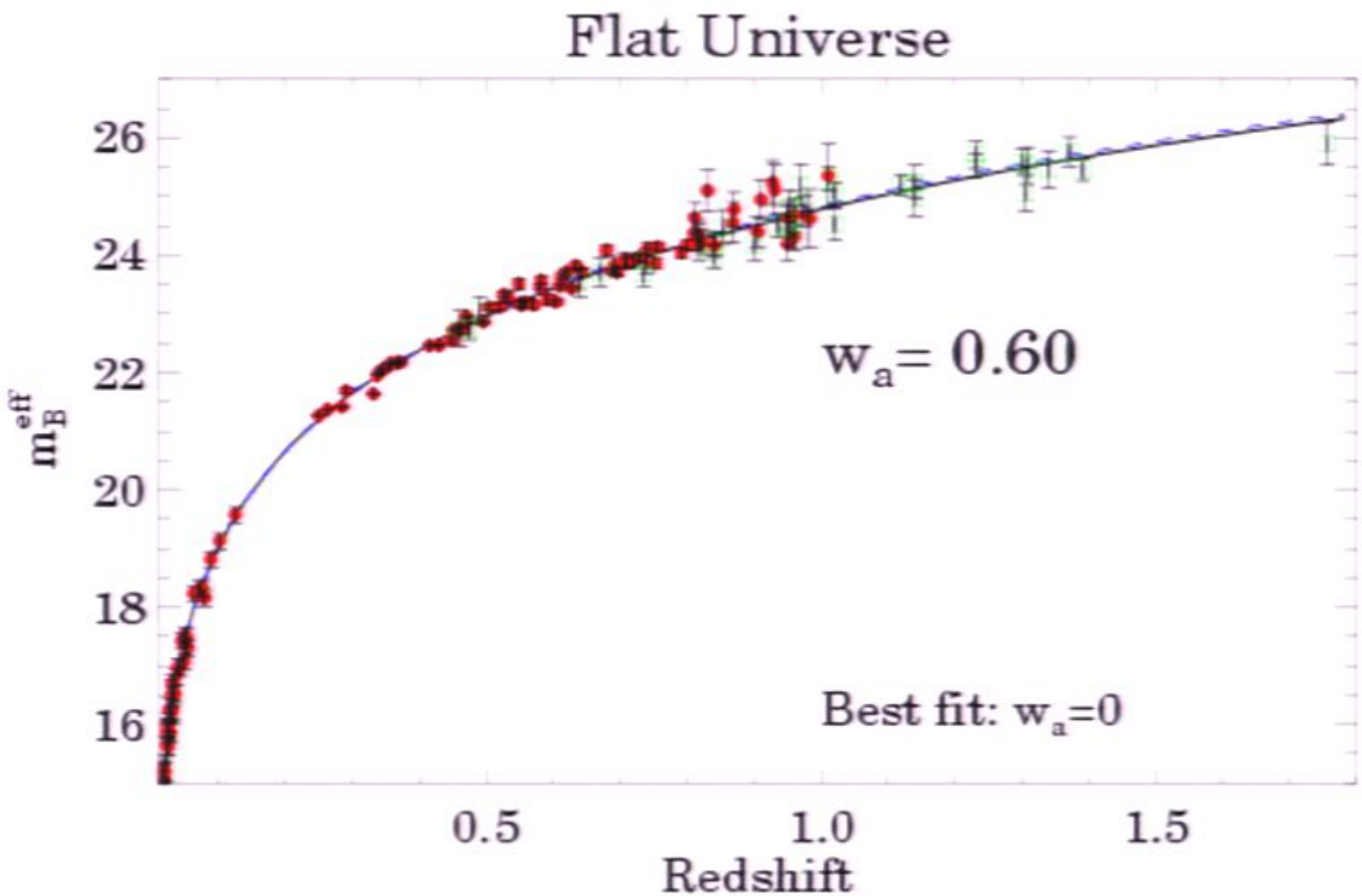

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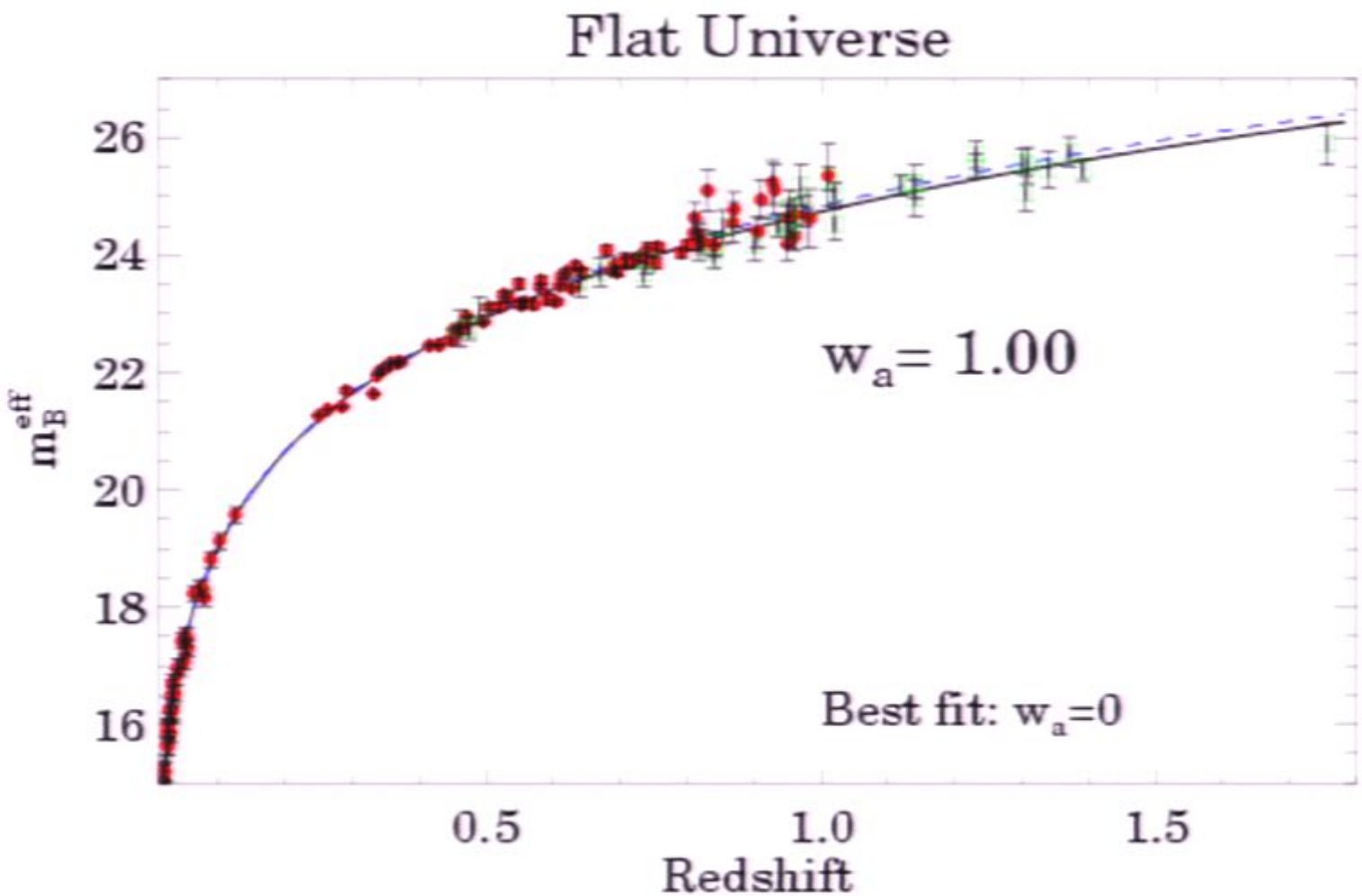

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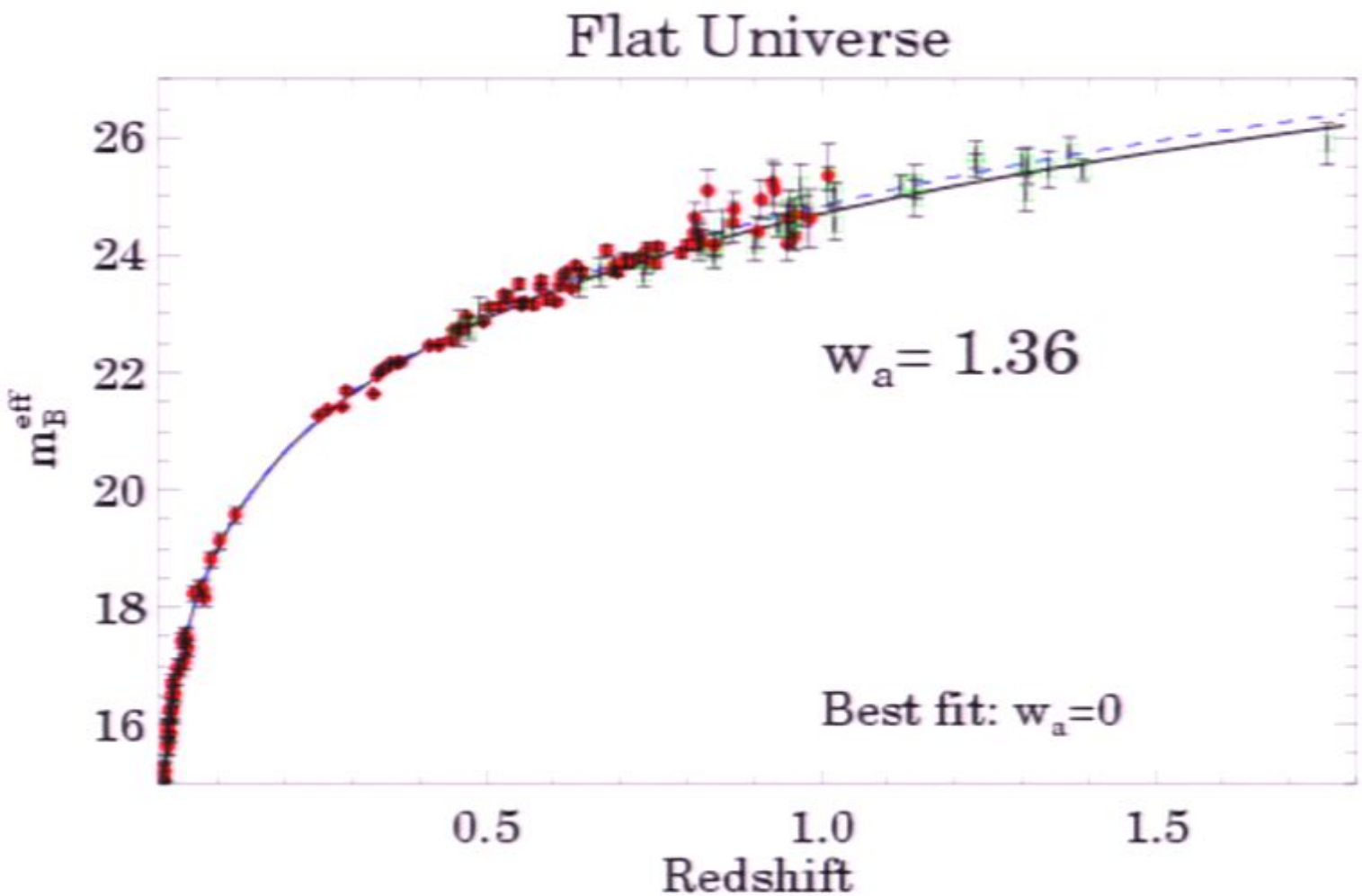
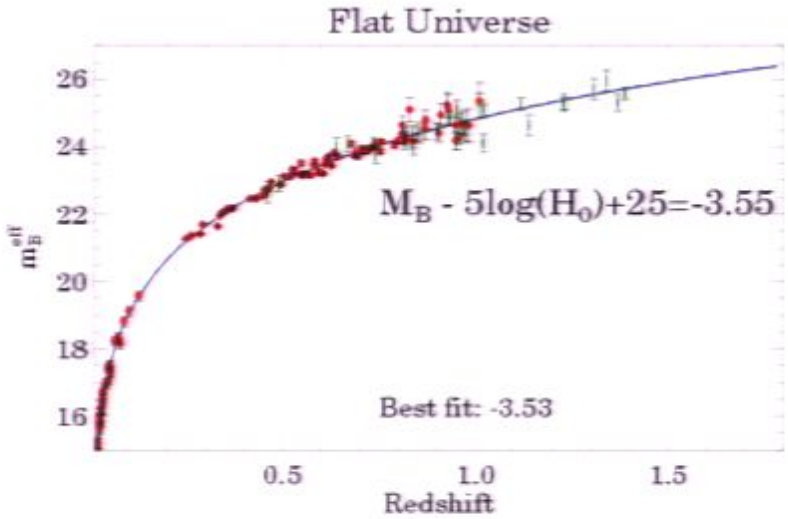
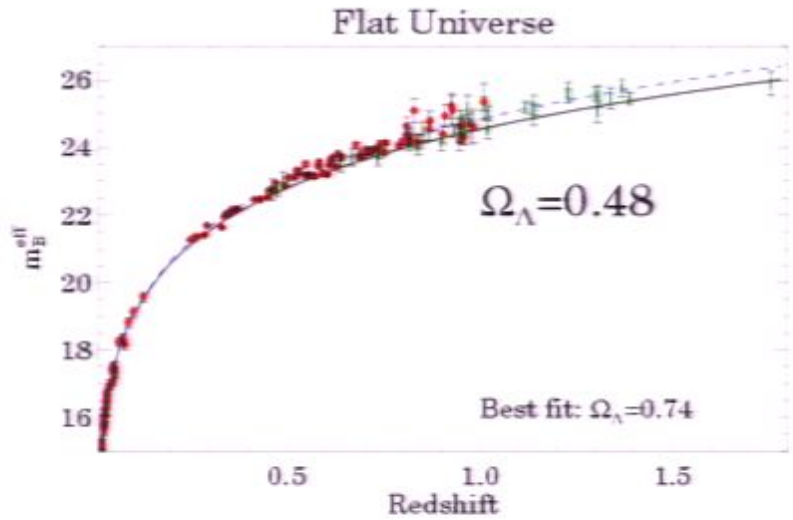
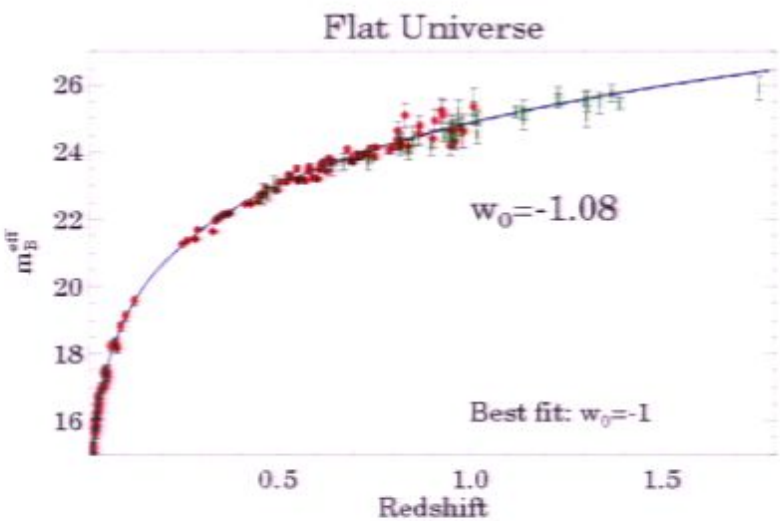
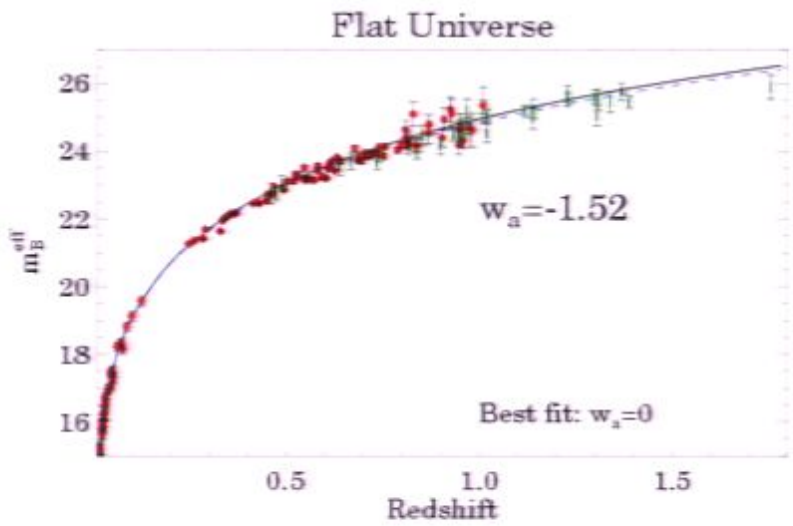


Multi-parameter problem









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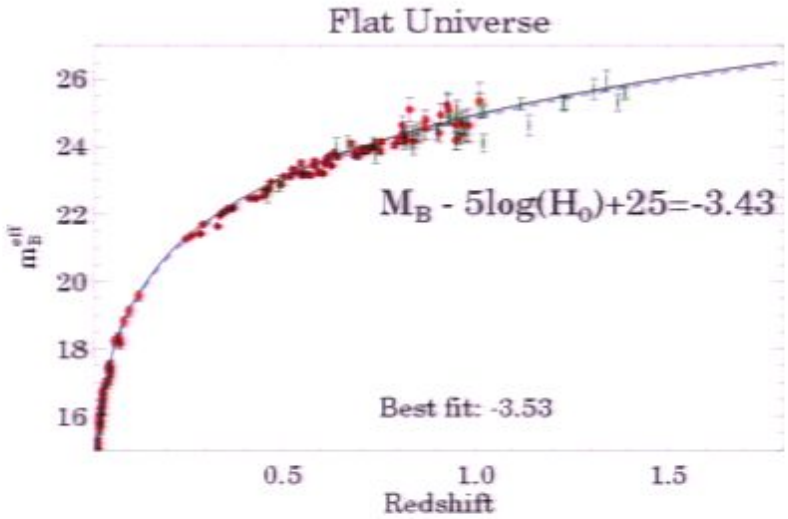

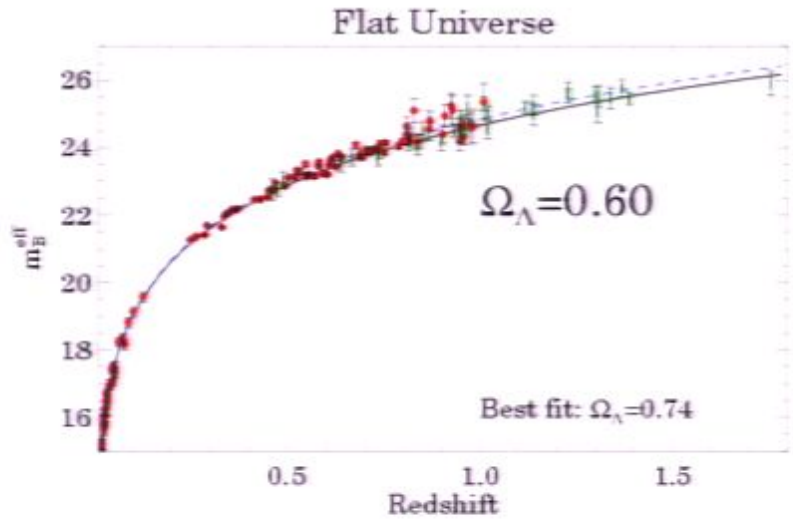

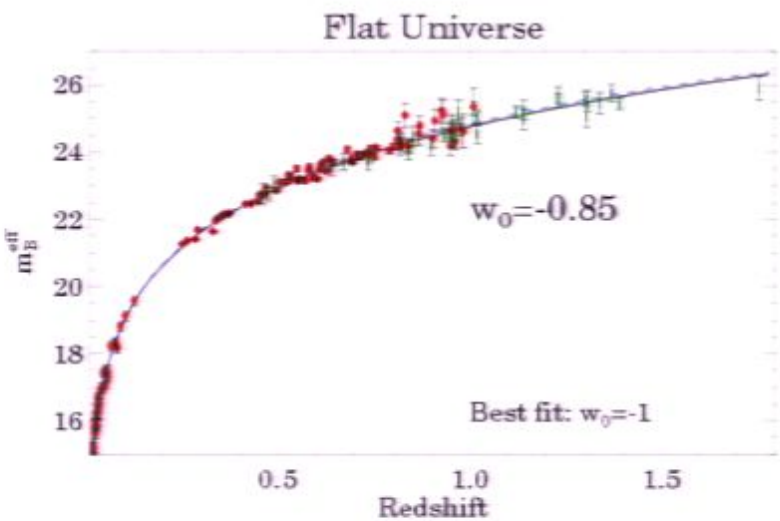

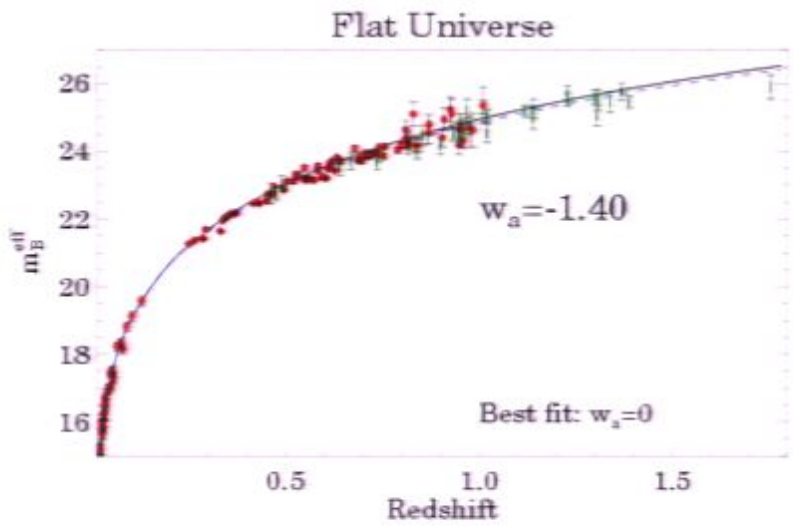

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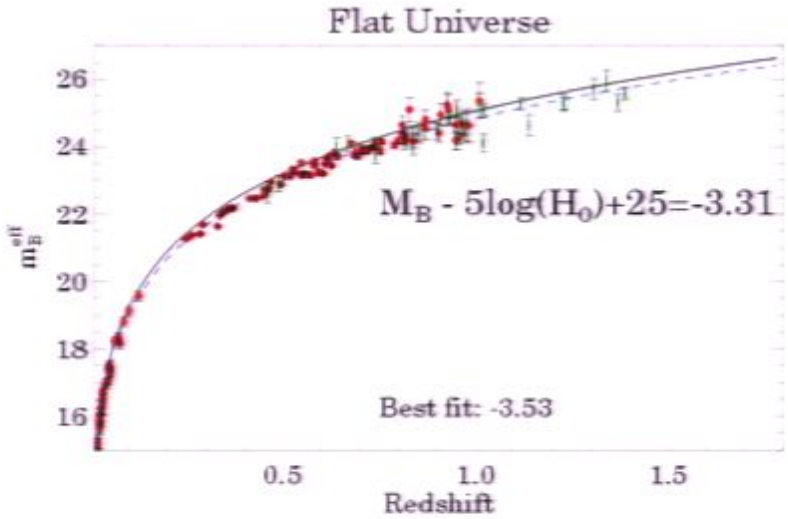

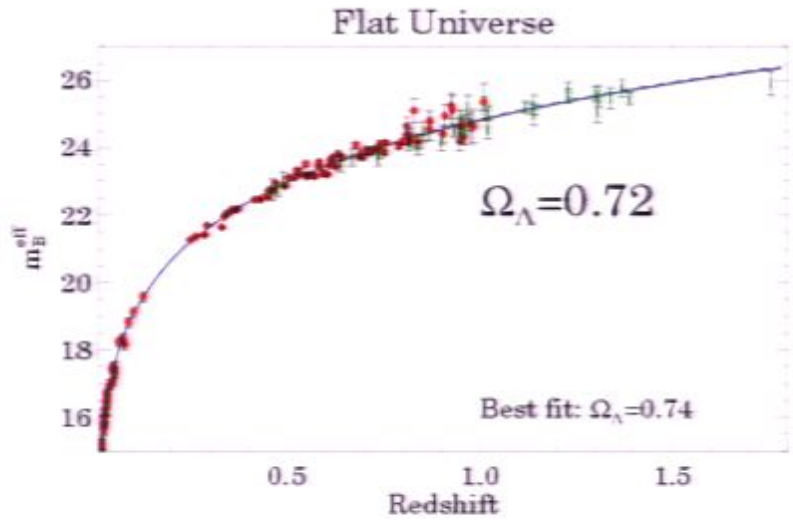

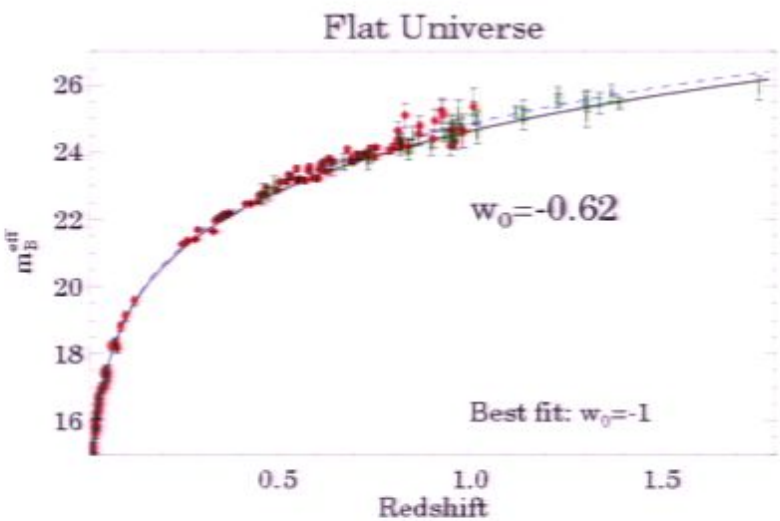

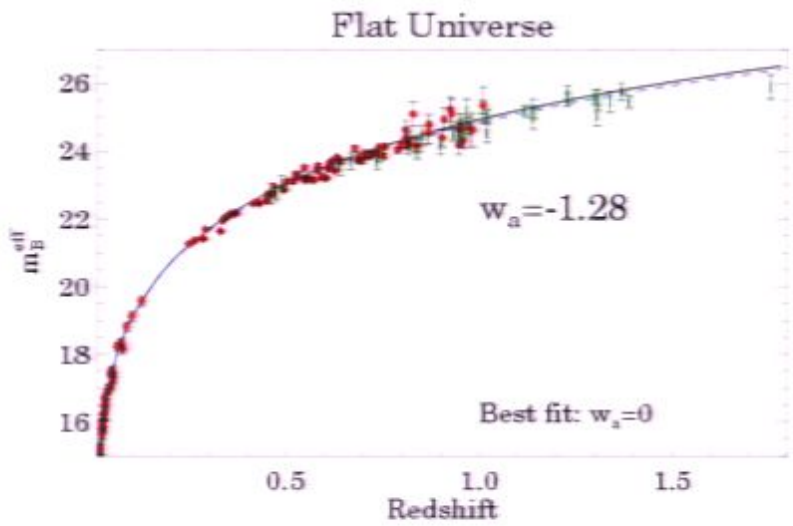

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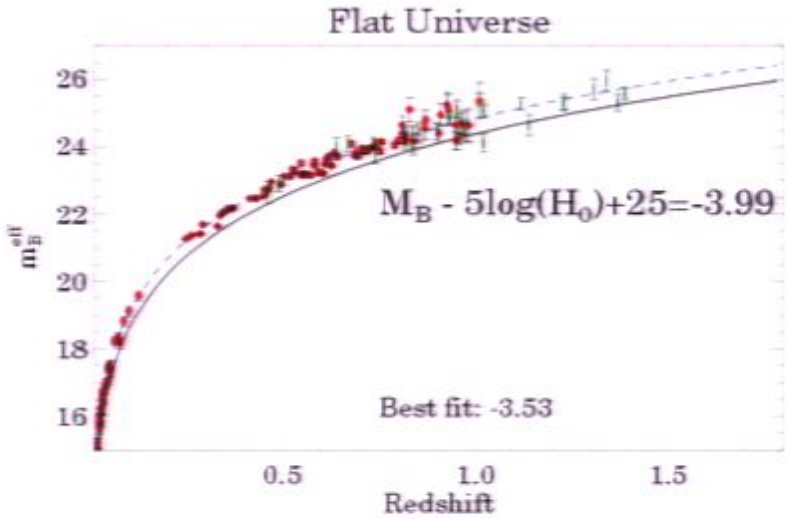

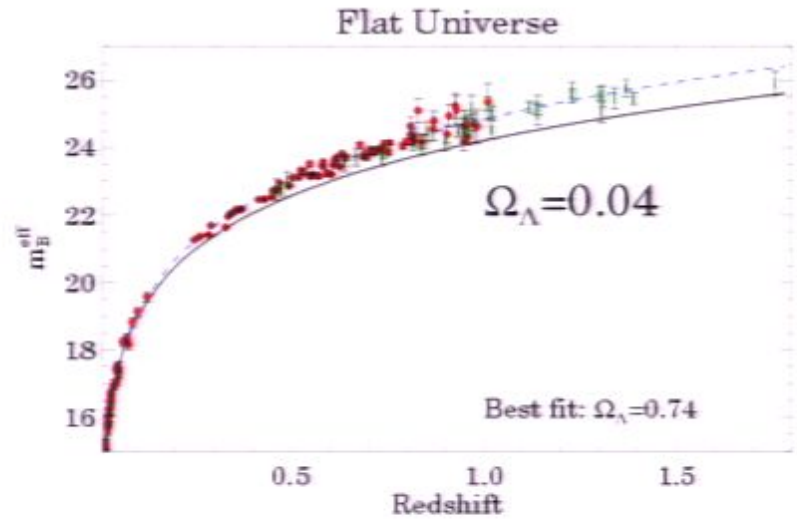

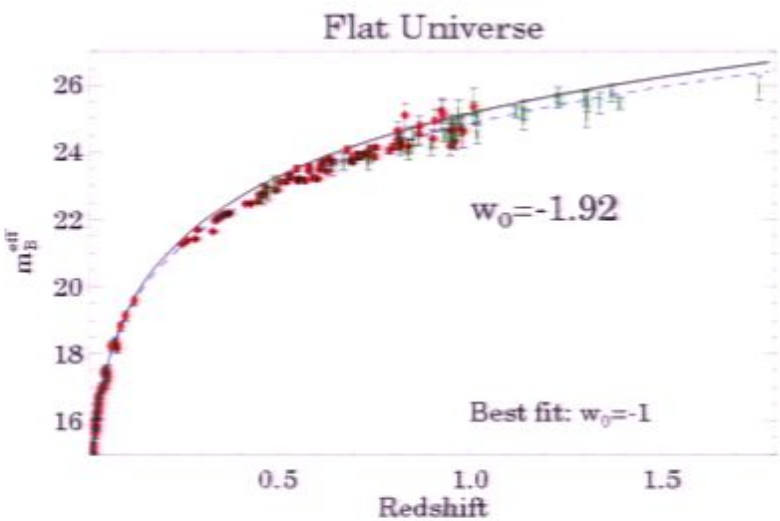

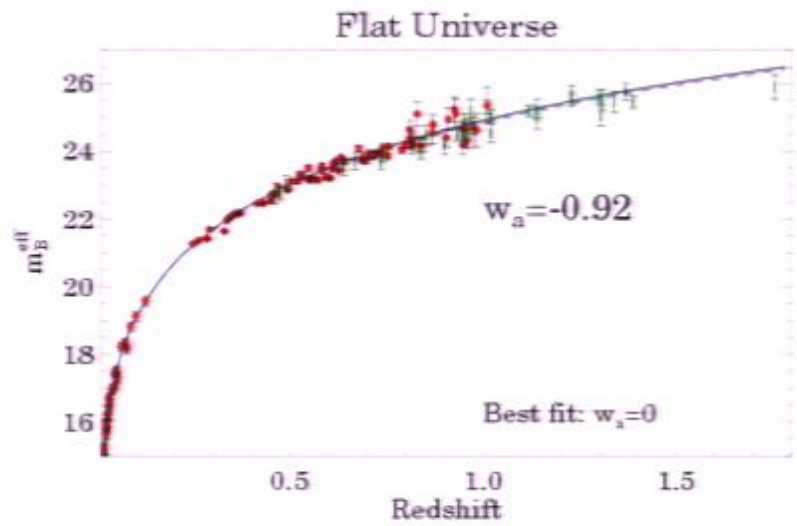

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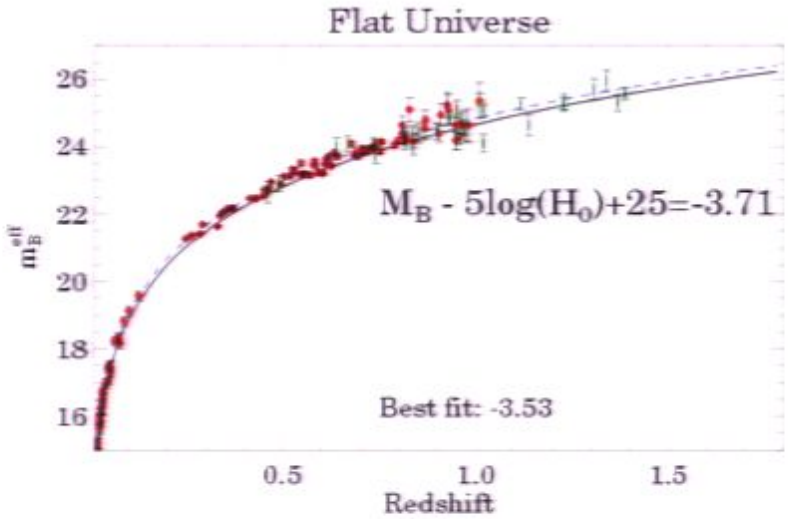

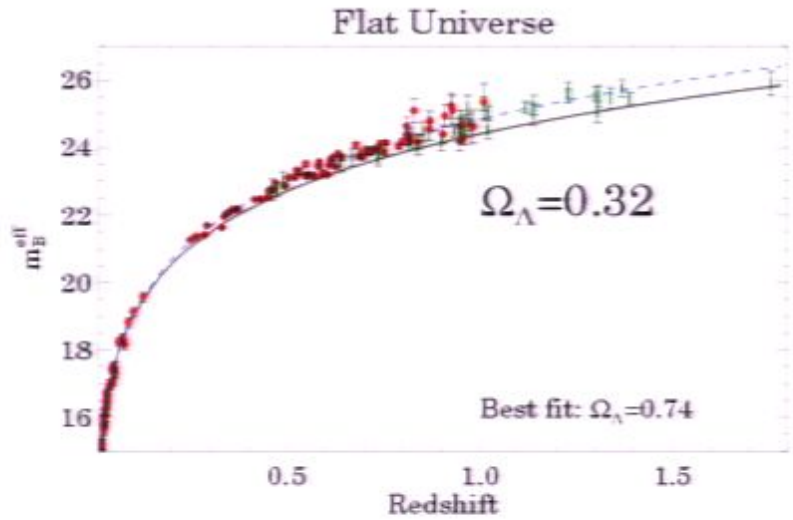

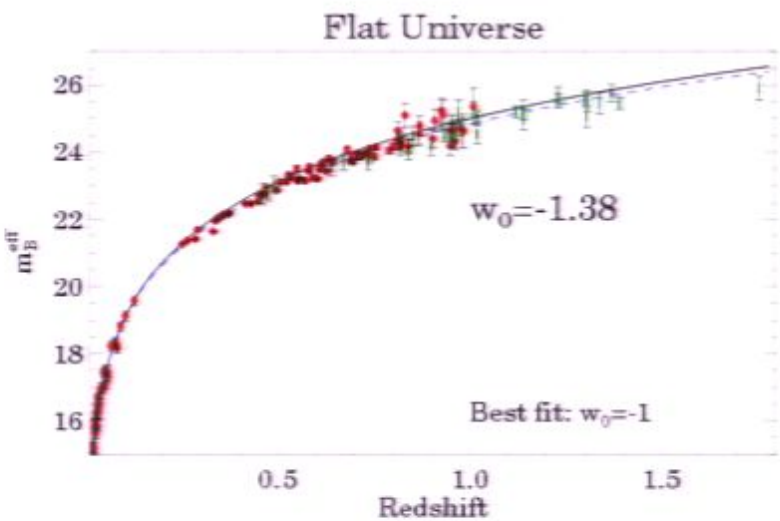

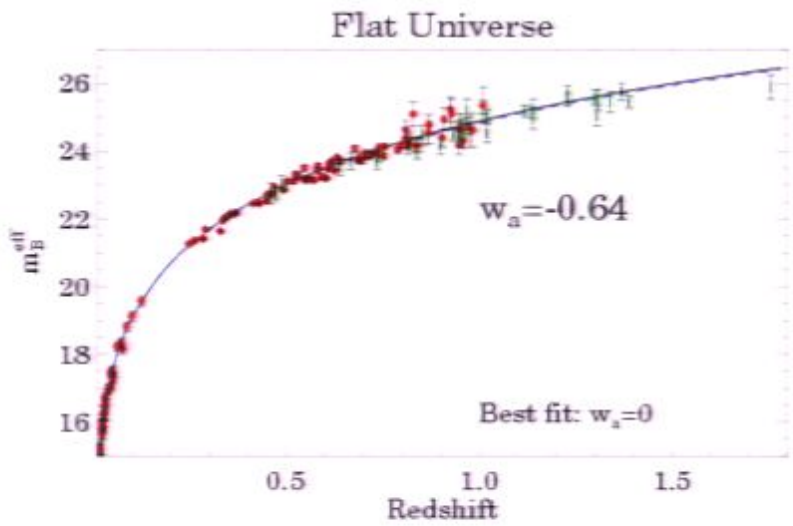

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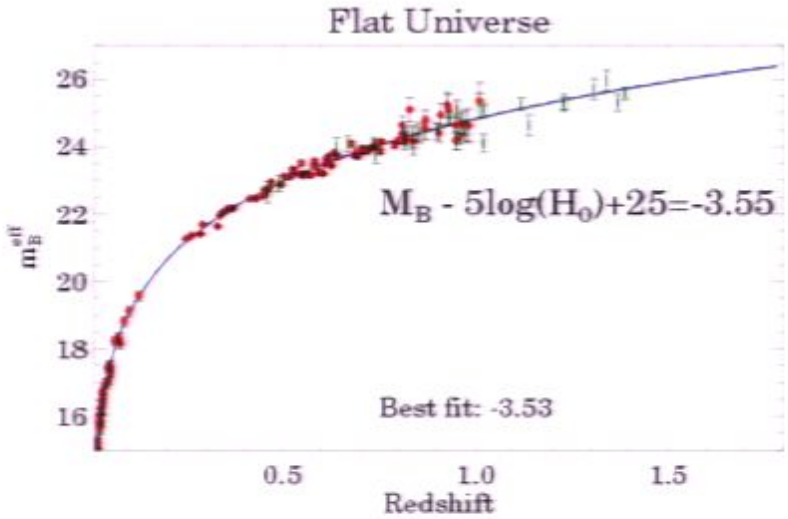

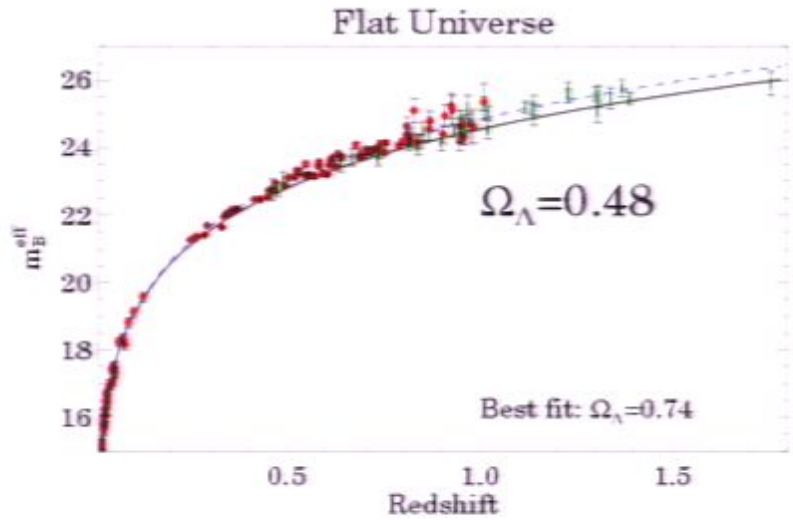

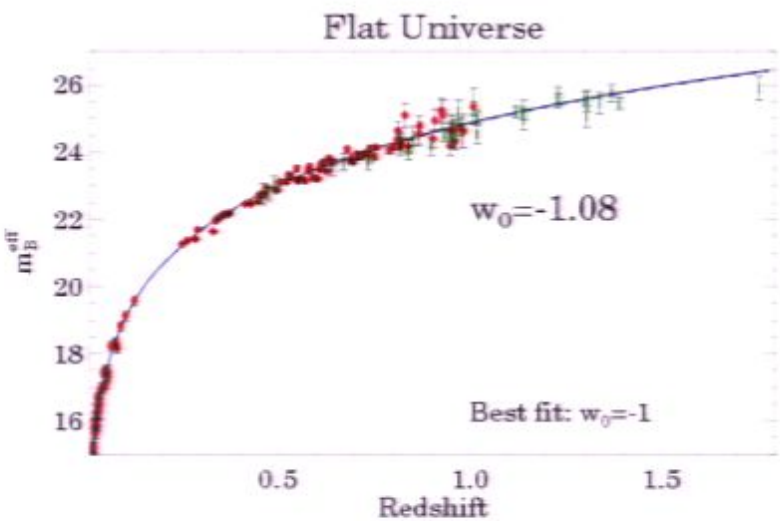

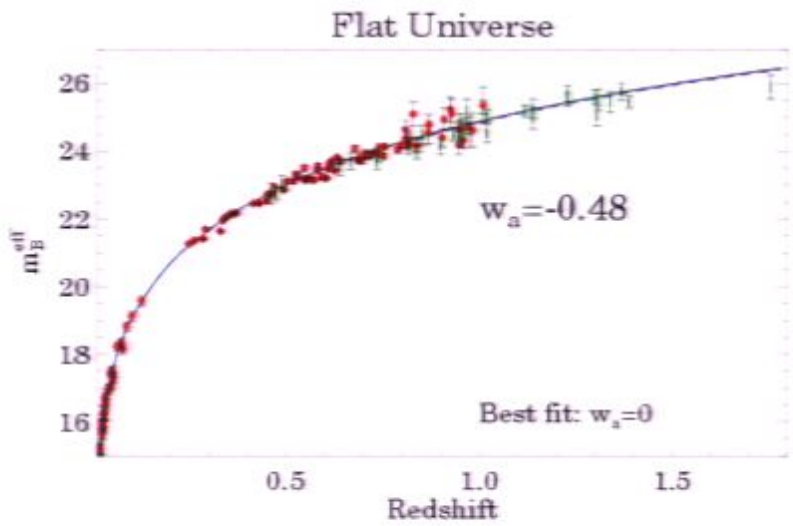

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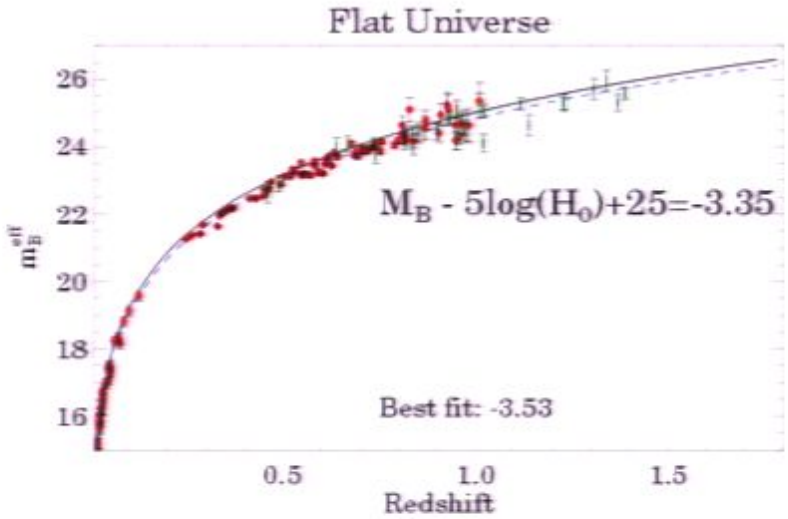

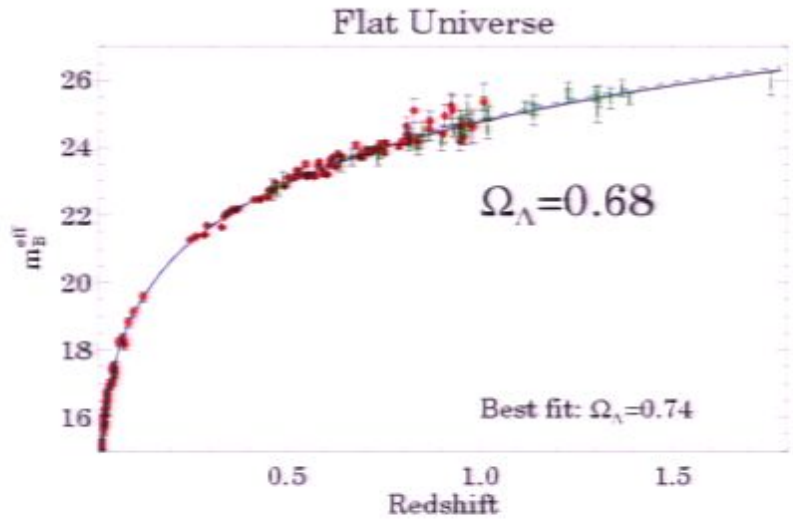

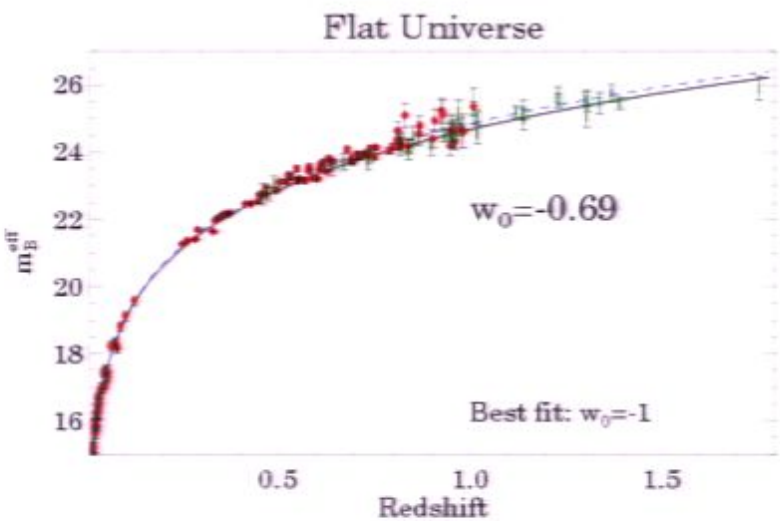

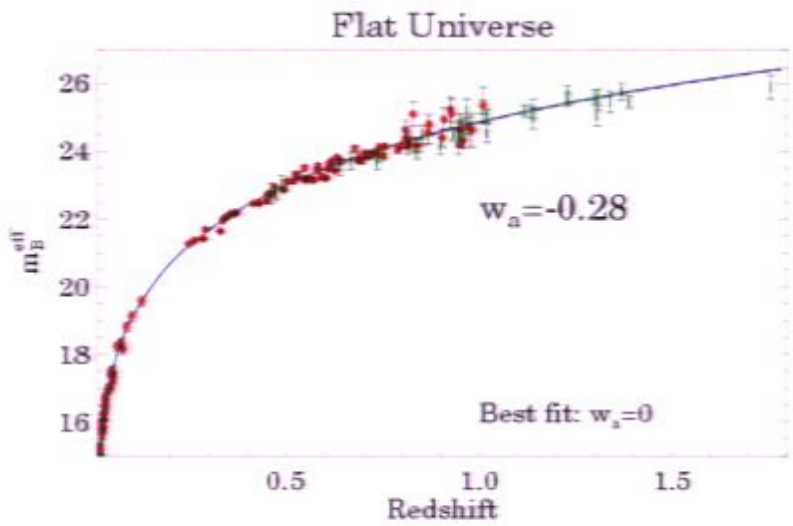

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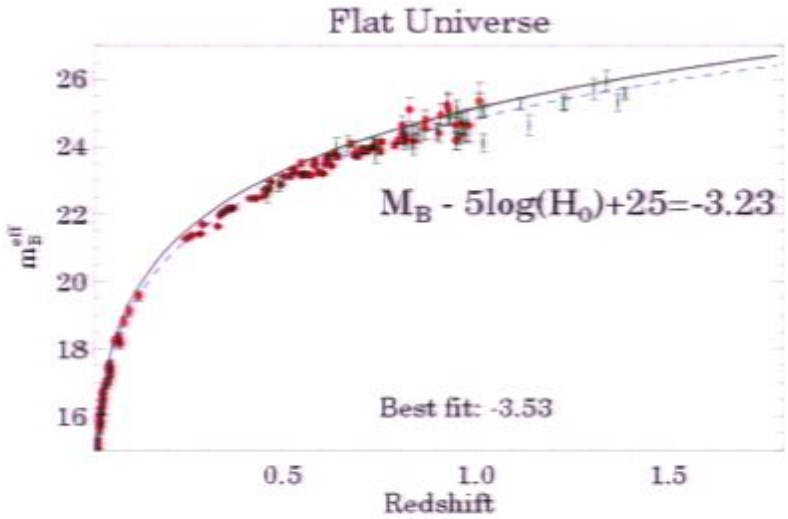

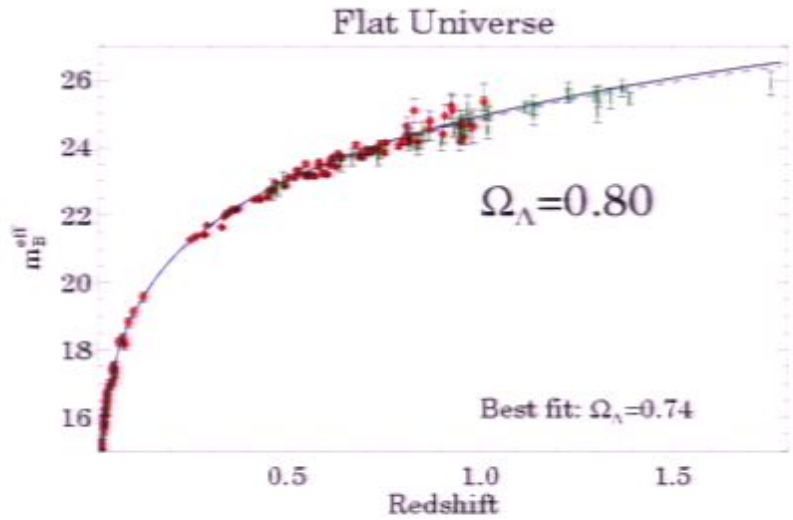

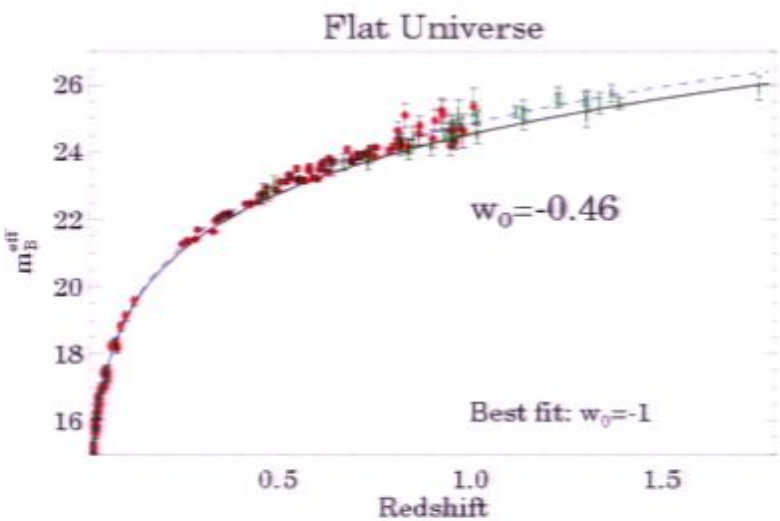

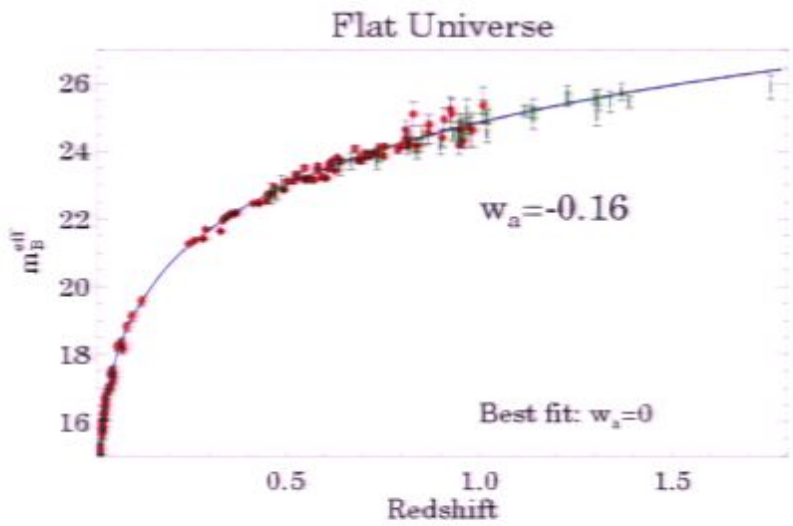

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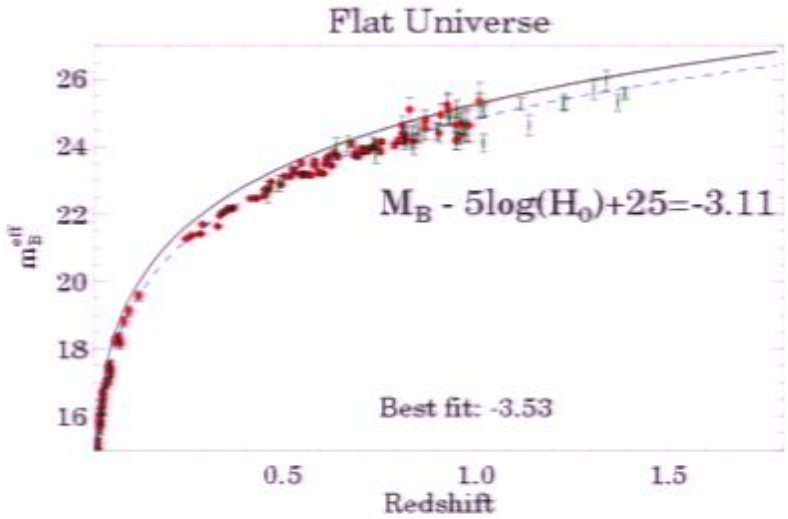

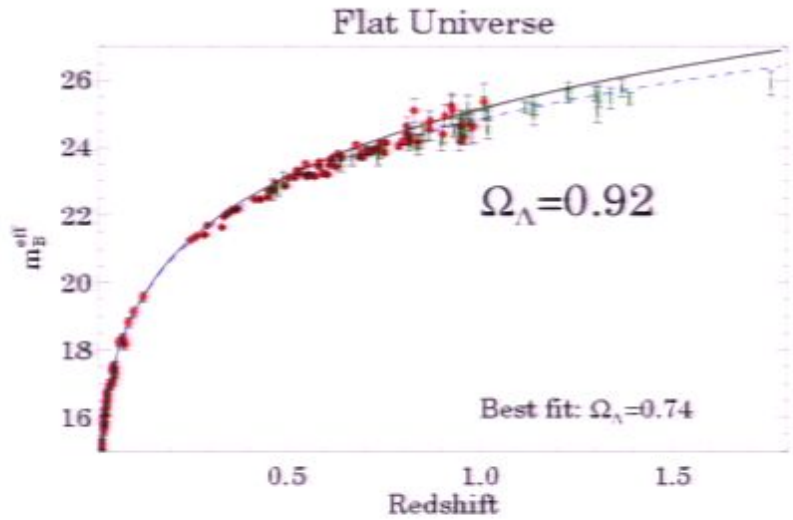

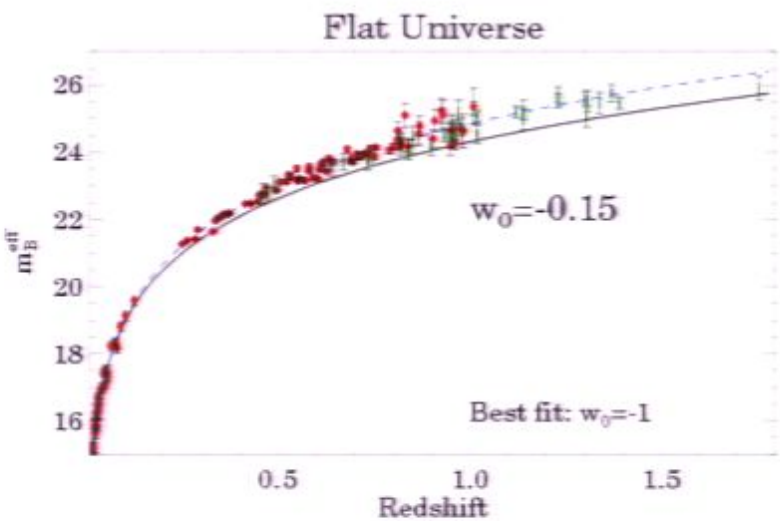

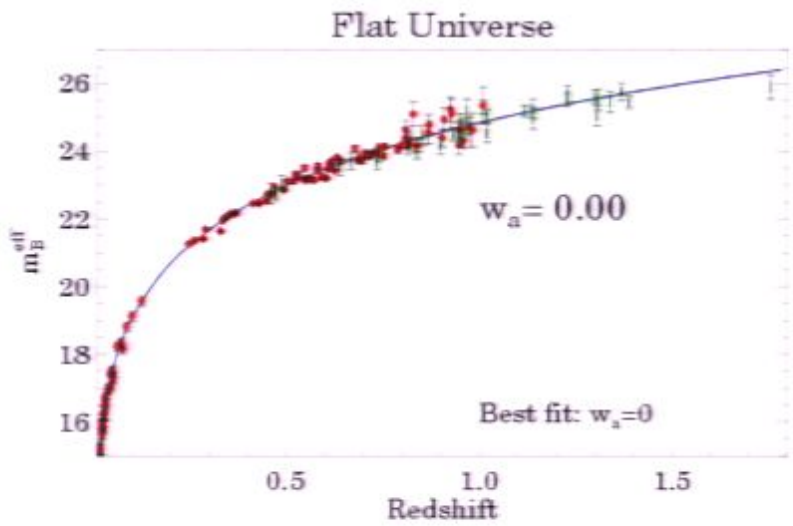

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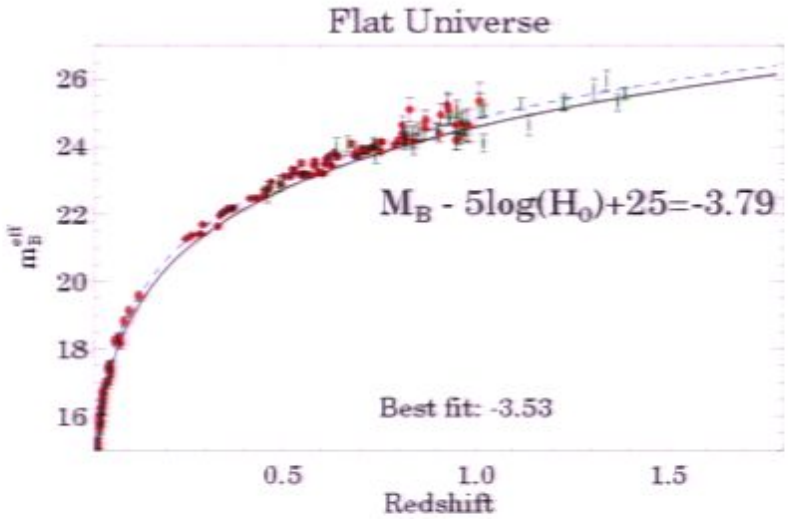

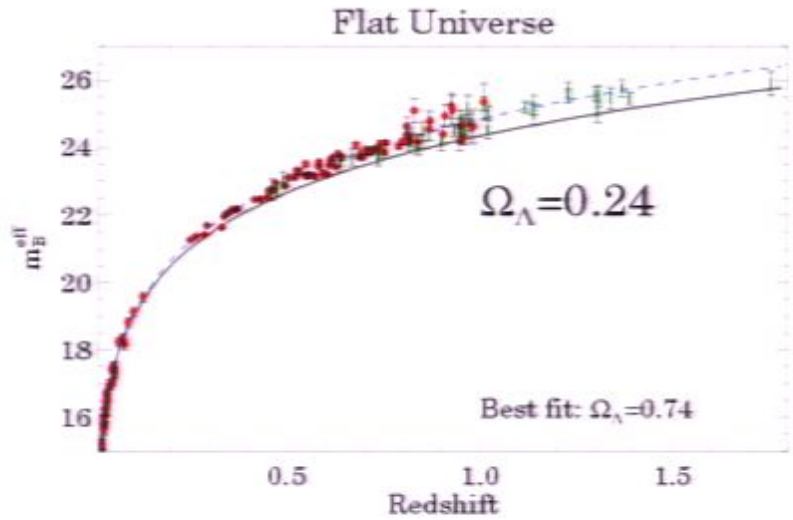

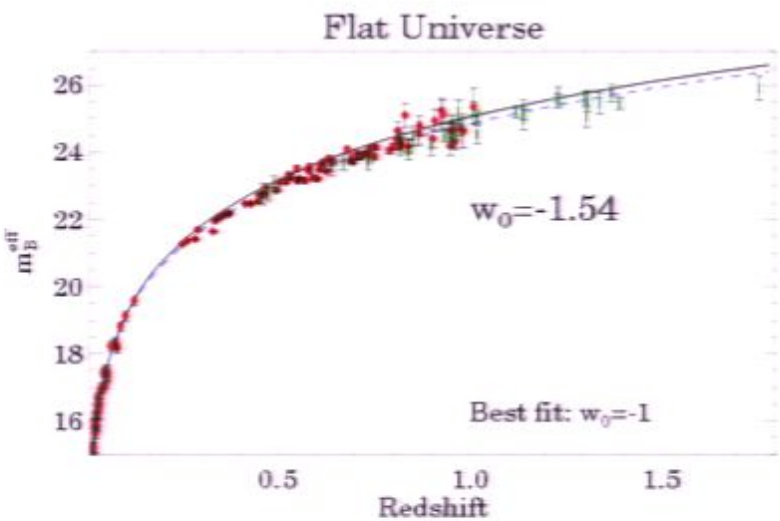

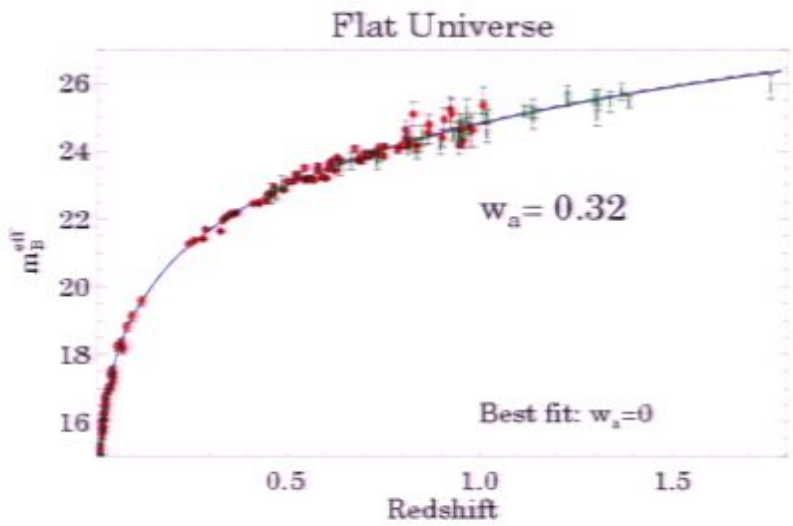

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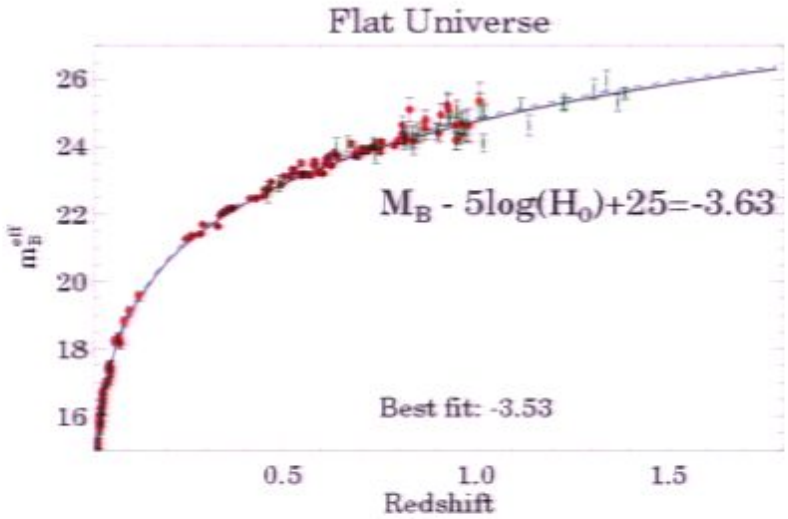

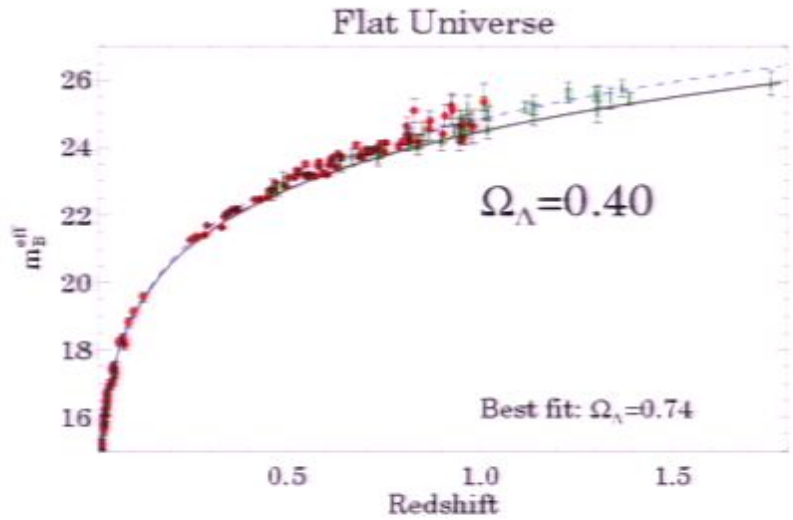

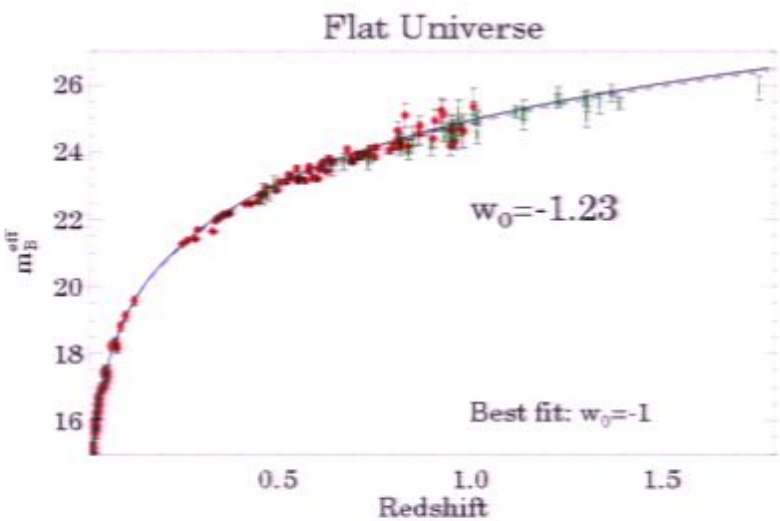

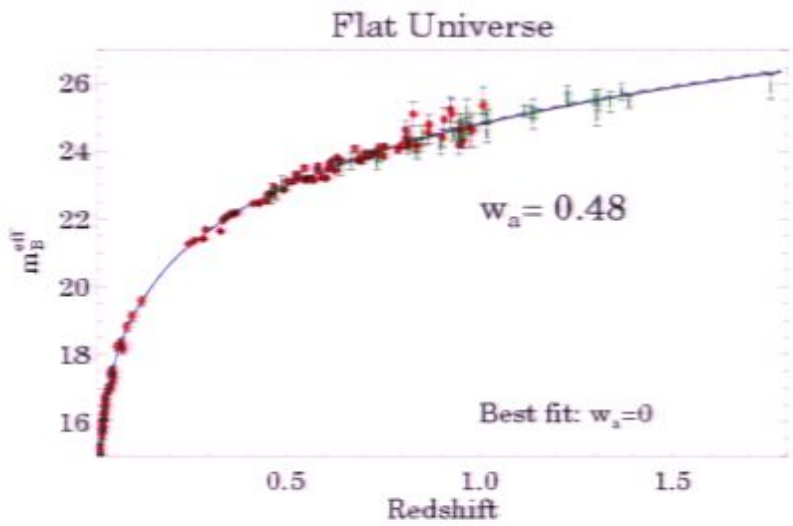

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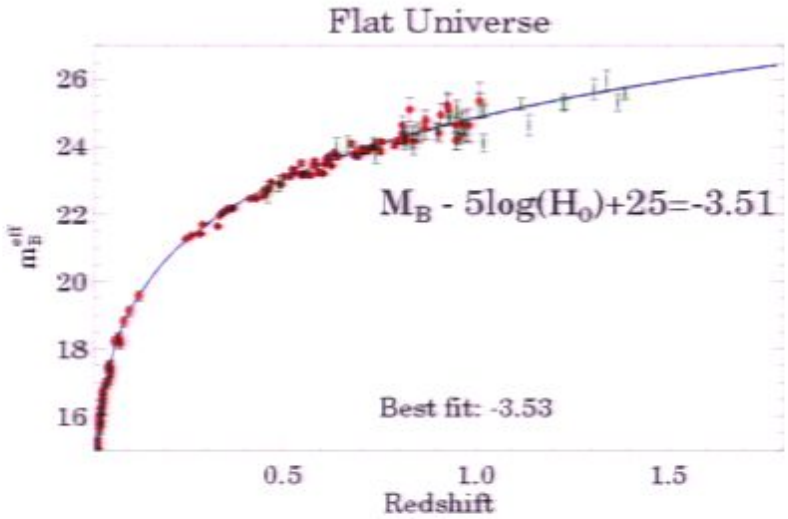

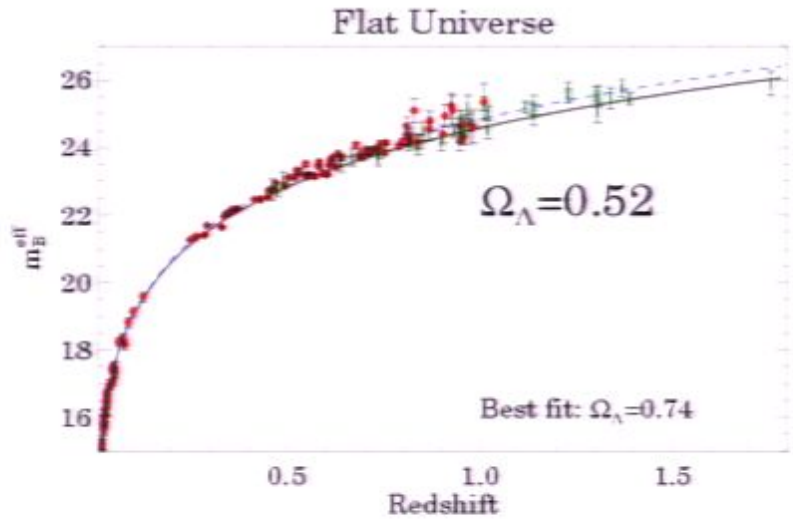

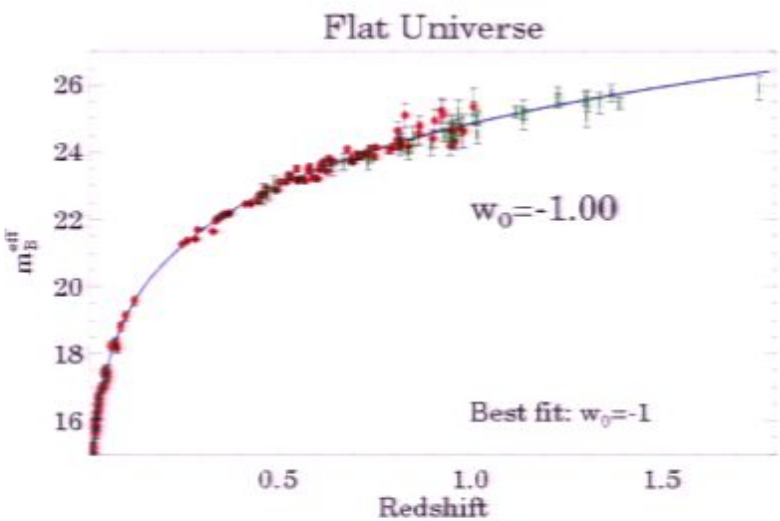

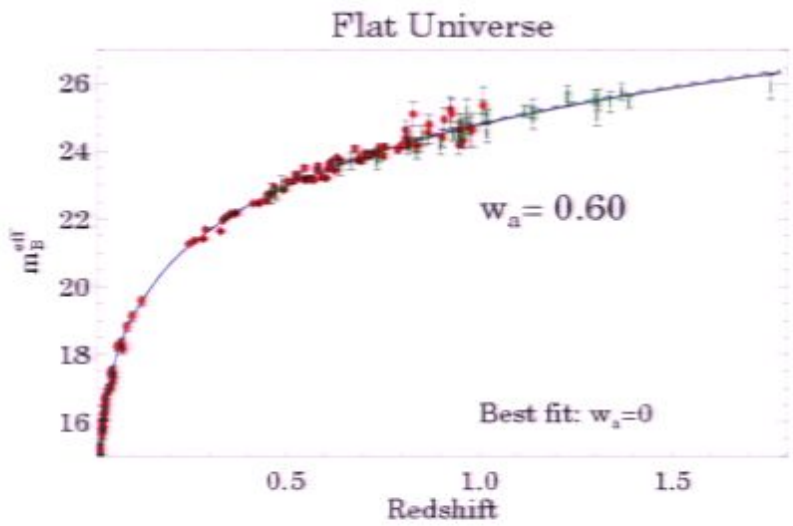

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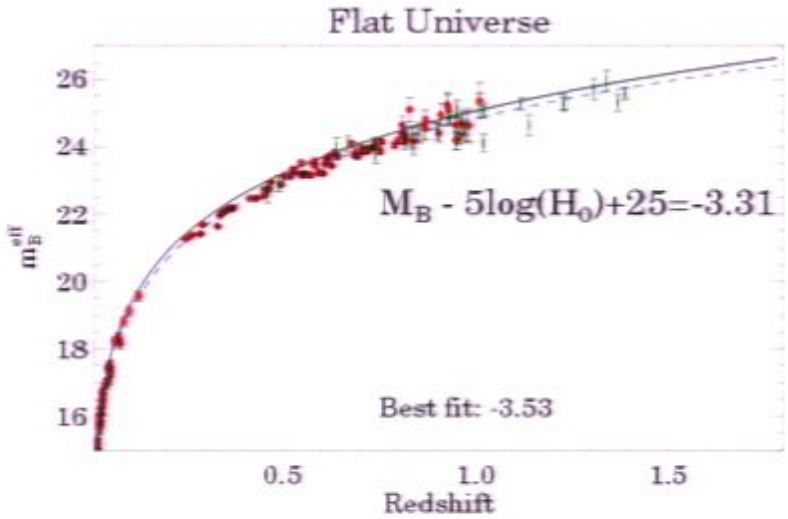

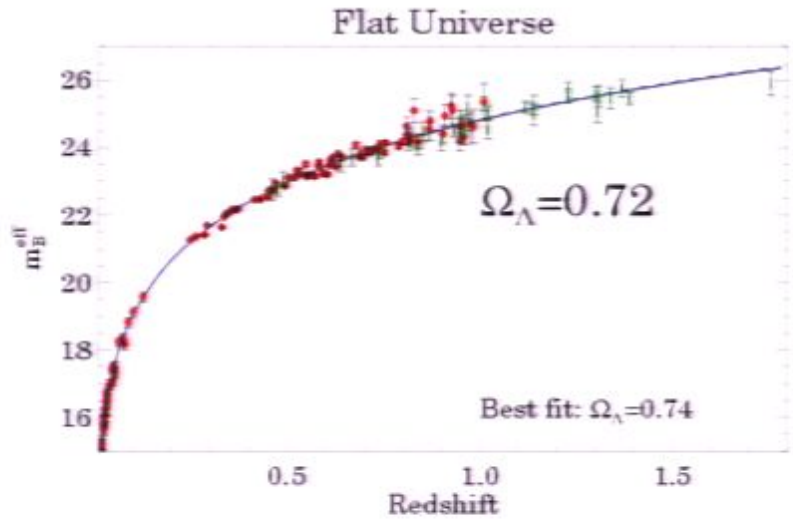

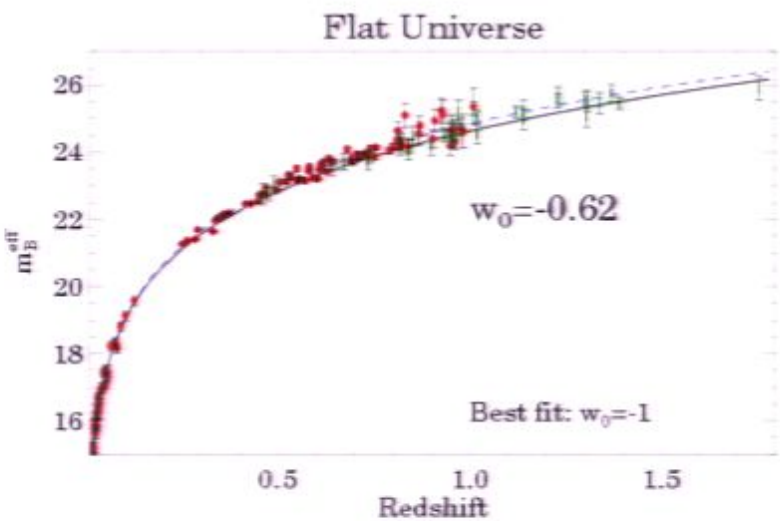

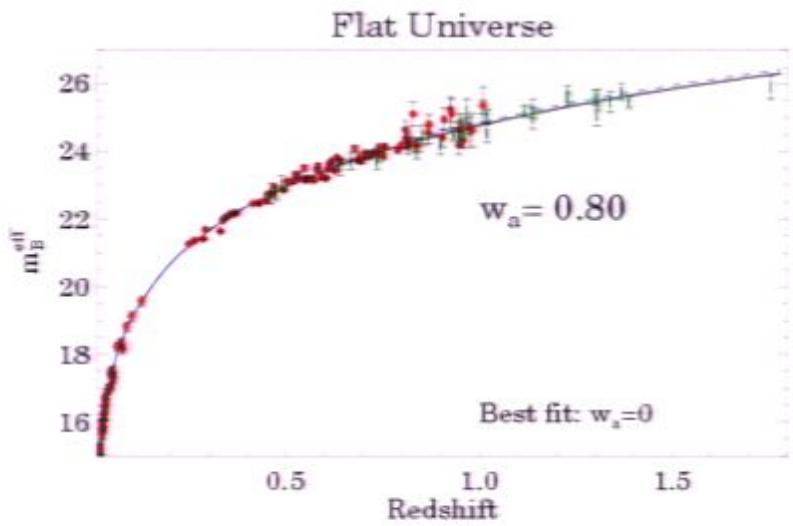

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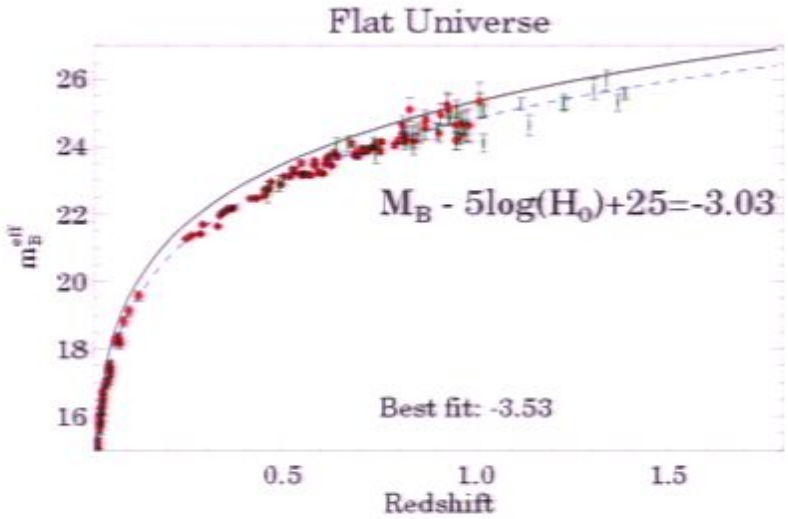

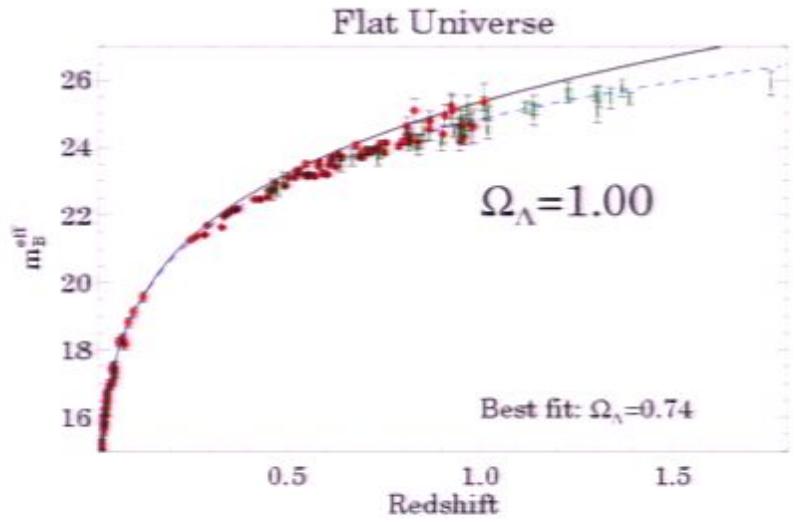

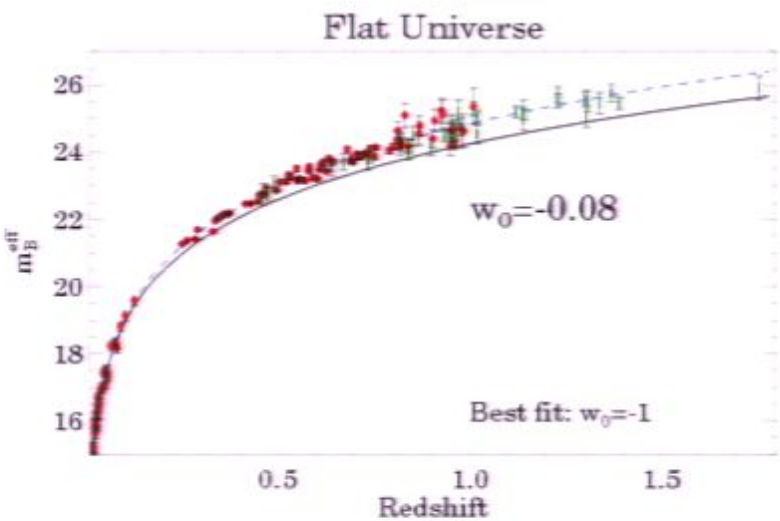

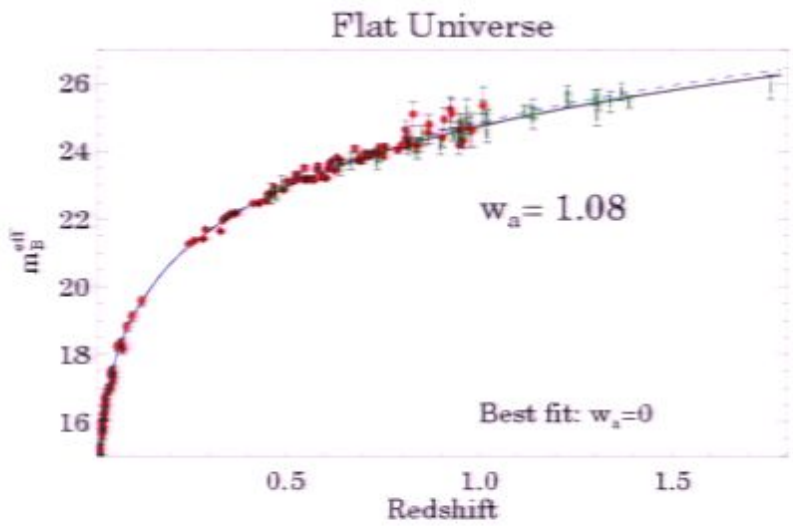

Braneworld cosmology

- Use SNLS (Astier et al 2005) + Baryon oscillations (Eisenstein et al 2005) to examine 5D extention of Friedmann eqn suggested by Dvali, Gabadadge,Porrati 2000 (DGP); Deffayet, Dvali, Gabadadze 2001.

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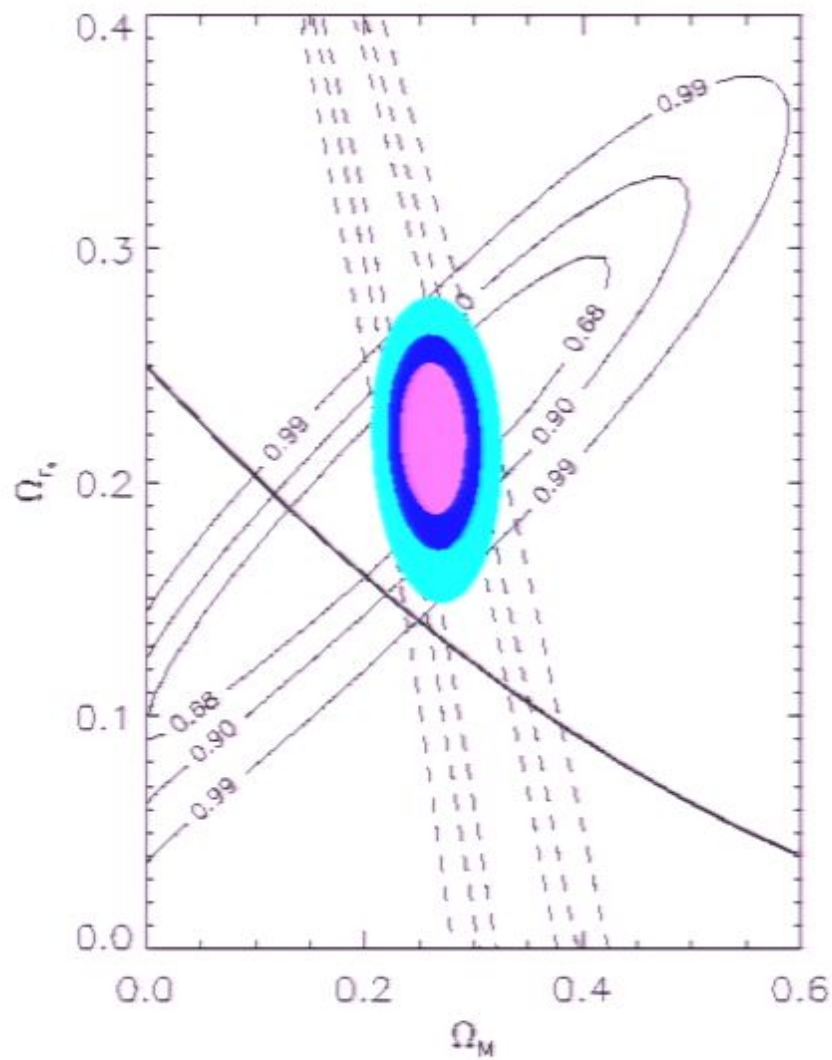

Fairbairn & AG, 2005

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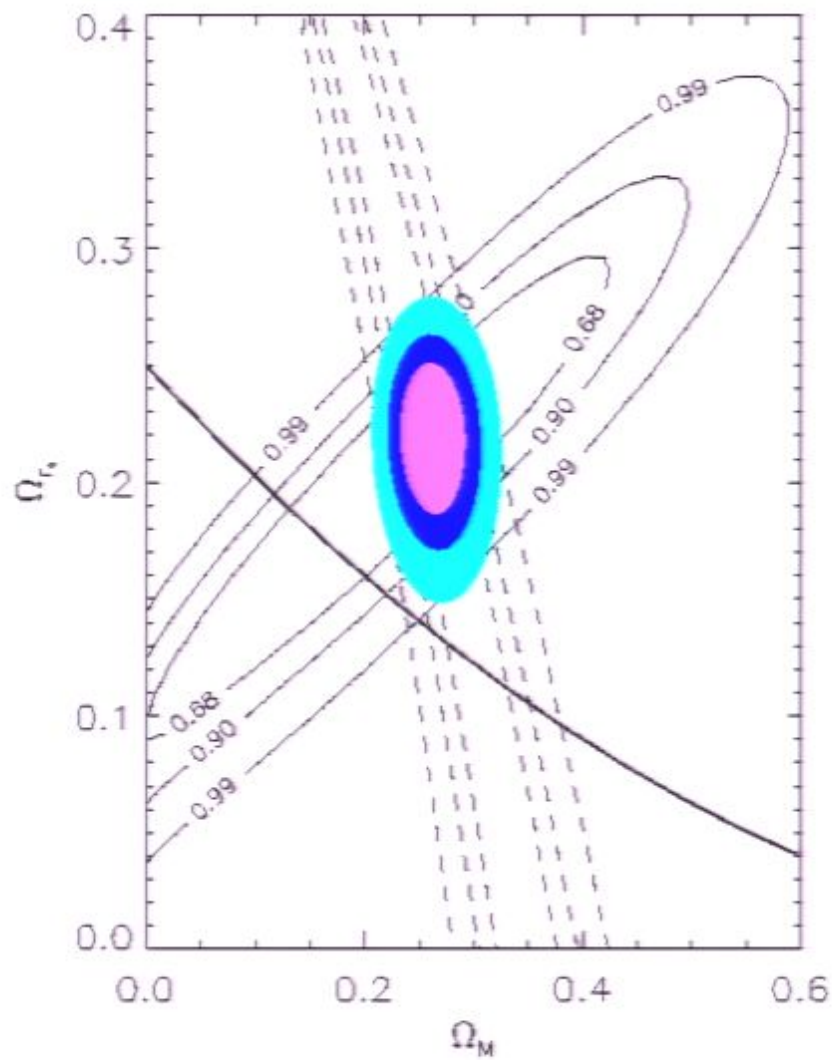

Fairbairn & AG, 2005

DGP: including ESSENCE + all data to date

6 Davis et al, 2007 ol

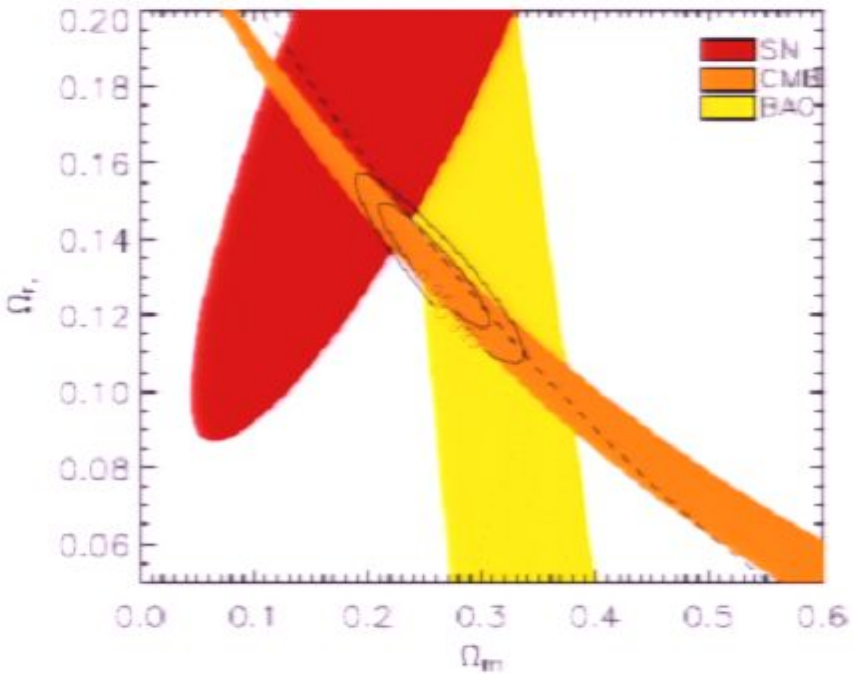

FIG. 3.— The general DGP model (Sect. 4.3.1). The dashed line shows the flat model. Here the contours from the different observational constraints disagree and the model is thus strongly disfavored.

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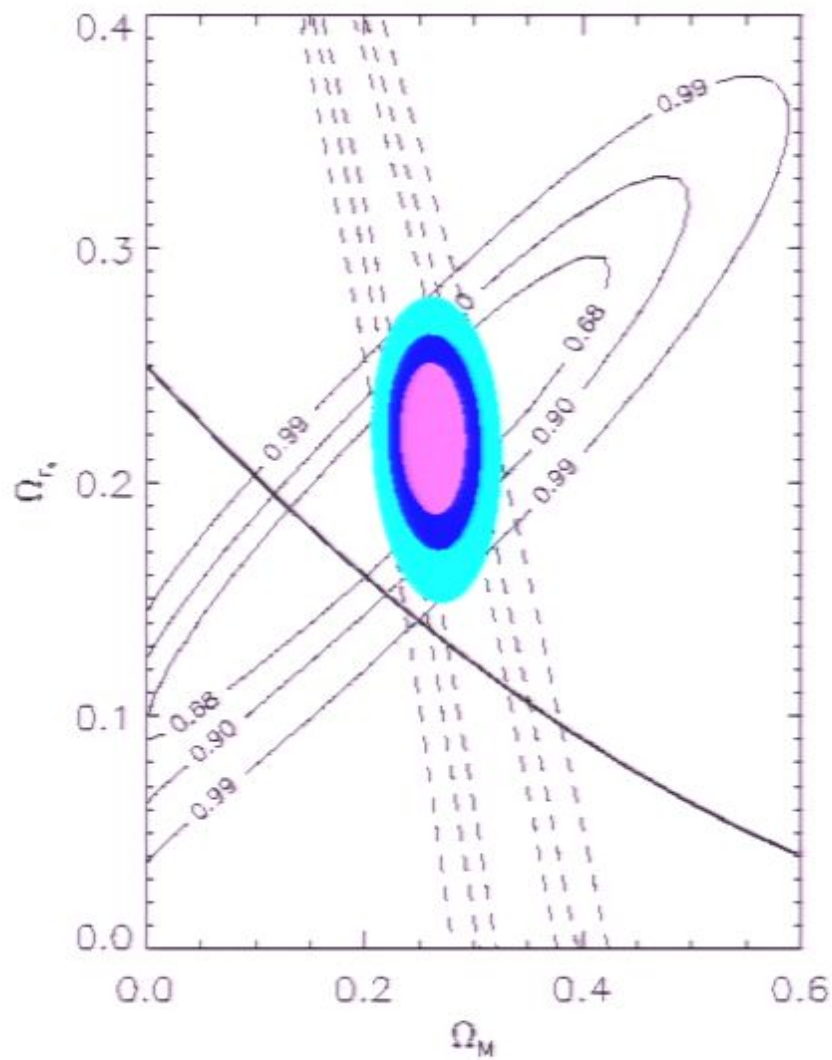
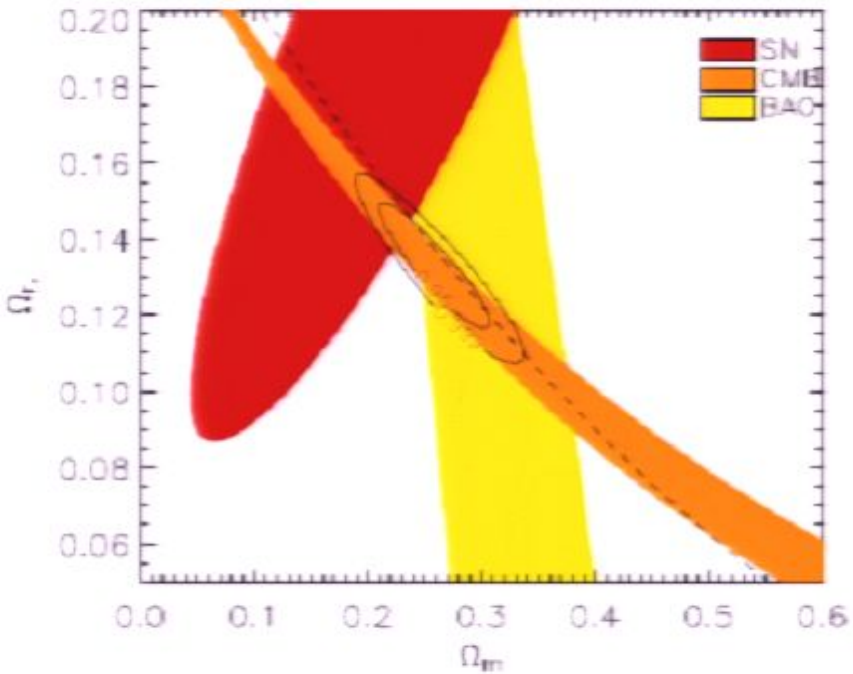


Fairbairn & AG, 2005

DGP: including ESSENCE + all data to date

6 Davis et al, 2007 ol



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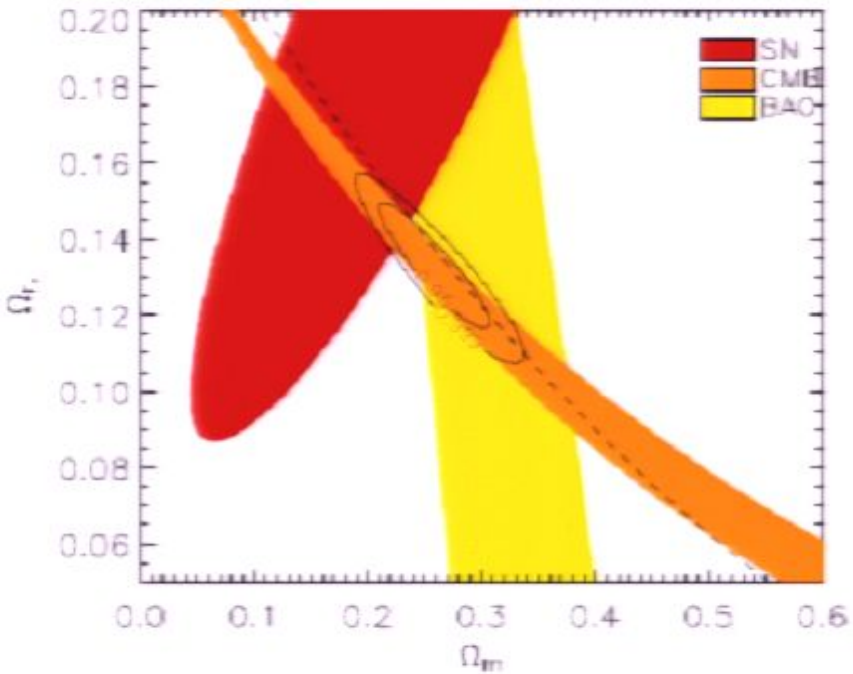

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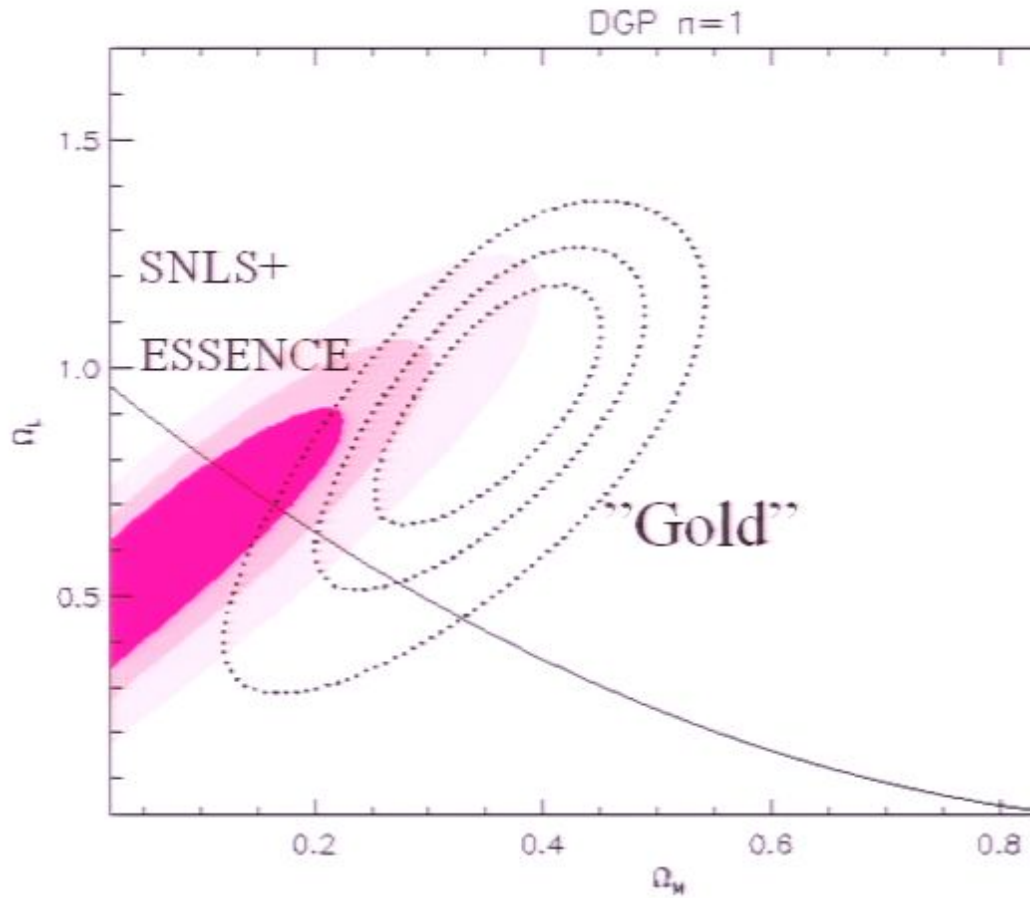


Rydbeck, Fairbairn & AG, 2007

Need to worry about systematics!

(Known) systematic effects

- SN brightness evolution
- Shape-brightness relation
- K-corrections and SN colors

Astrophysics of supernovae

- Non-Type Ia contamination
- Malmquist bias

Selection effects, contamination

- Host galaxy dust properties
- Intergalactic dust
- Gravitational lensing
- Bulk motions
- Exotica: axion-photon oscillations, etc

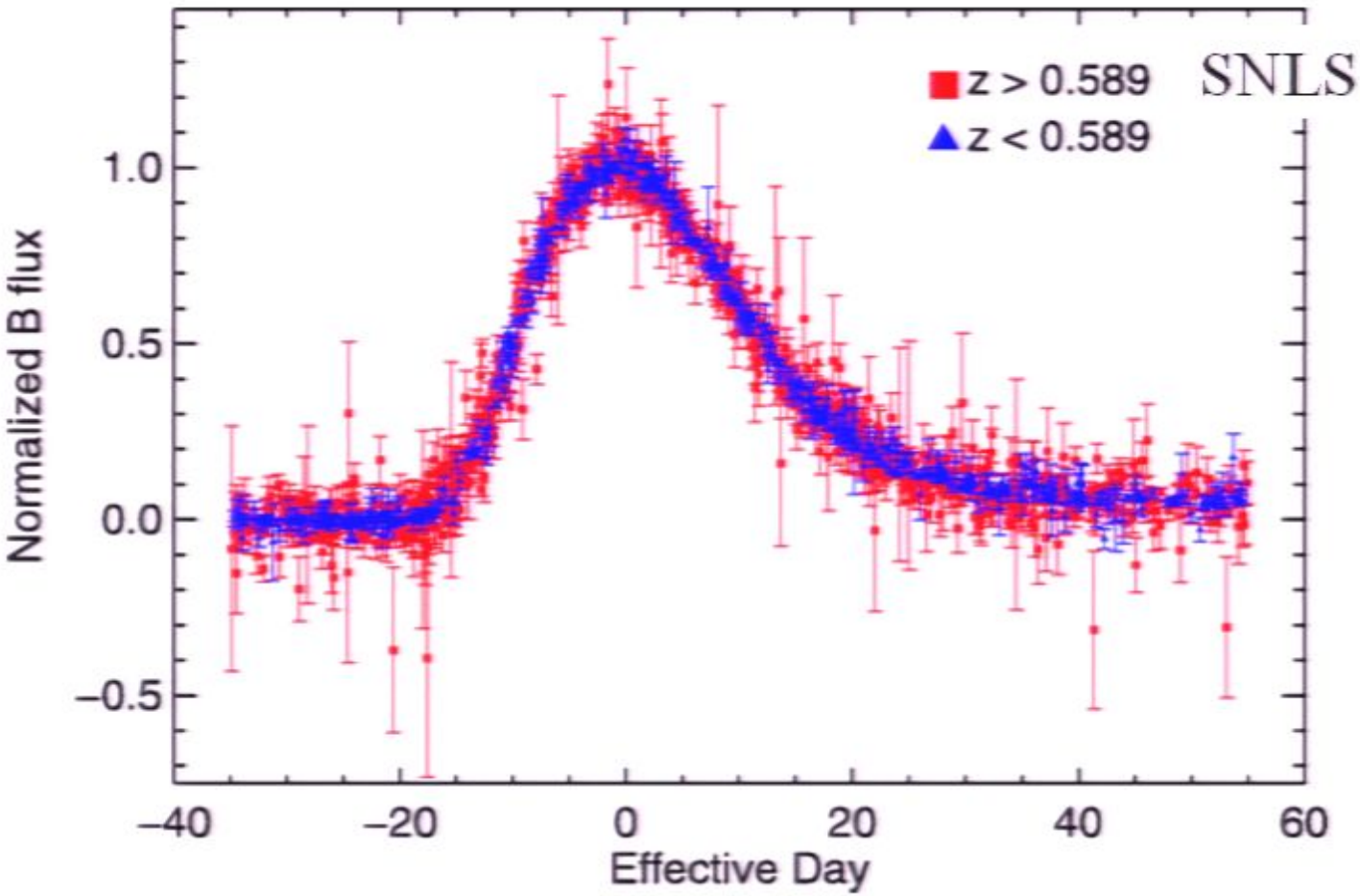
Line of sight effects

- Instrumental corrections
- Absolute calibration
- Lightcurve fitting technique/host galaxy subtraction

Measurement issues

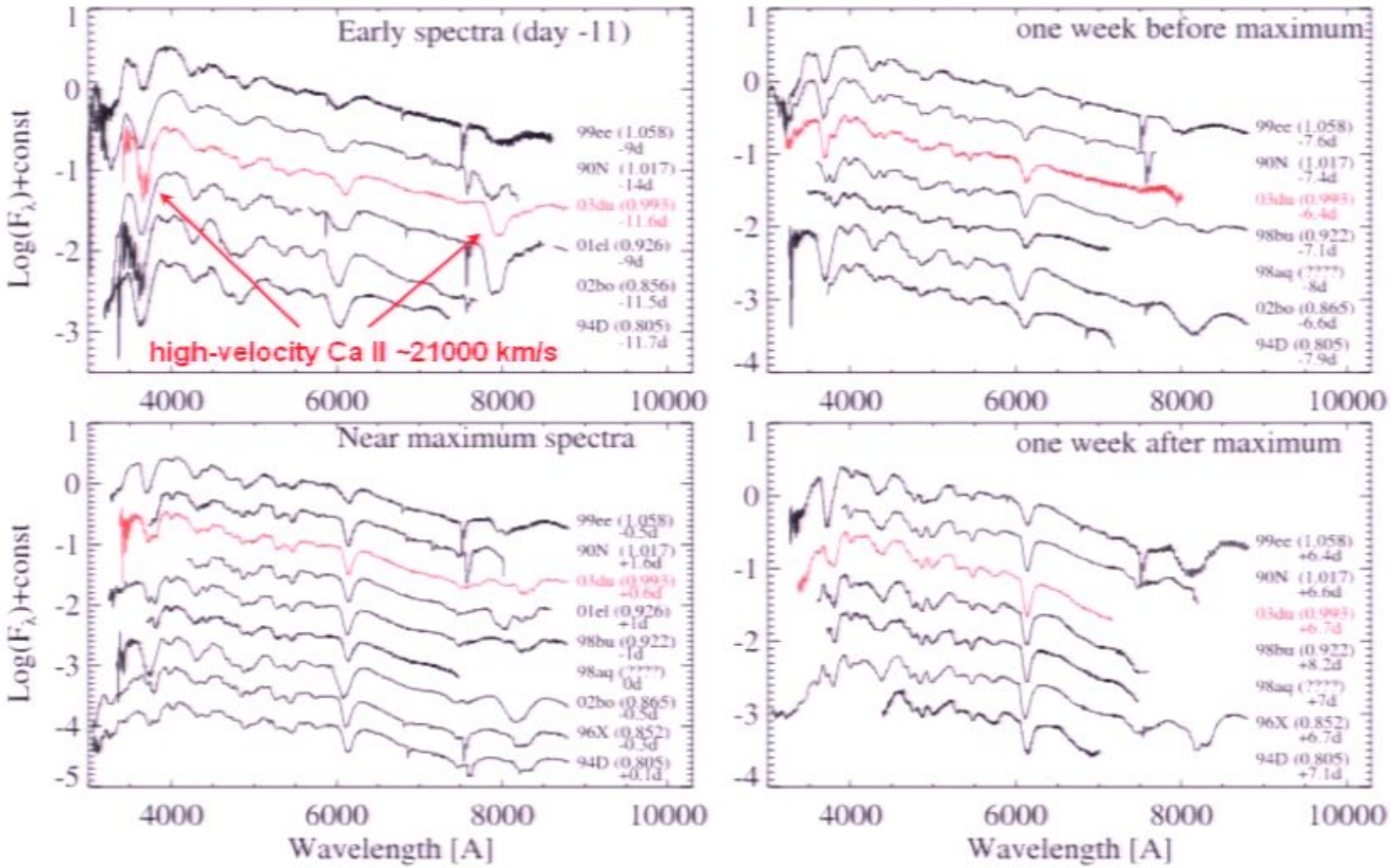
Exploring the ”Standard Candle”

Checking the standard candle: redshift dependence?



Conley el al 2006

Spectral diversity: could be used to sharpen "standard candle"?



Ongoing high-statistics low-z projects

- KAIT/LOSS: > 500 SNe (all types) discovered since 1998
- Supernova Factory: search + optical spectrophotometry of a few hundred SNe. (Search at Palomar, IFU follow-up at UH2.2m). Spectrophotometry of up to 200 SNe (?)
- Carnegie Supernova Project: high precision optical and NIR lightcurves of ~200 SNe (z<0.07). About ½ SNIa.
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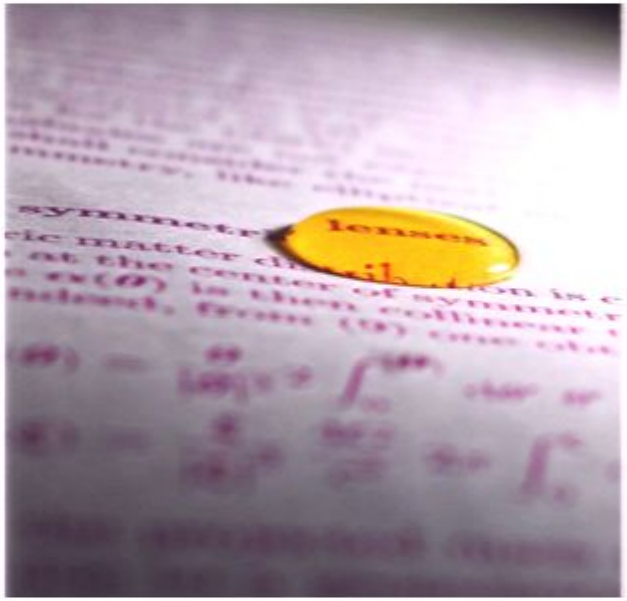
- THIS IS PROBABLY NOT ENOUGH FOR PRECISION COSMOLOGY!

Rolling search with spectroscopy of signal + background events.

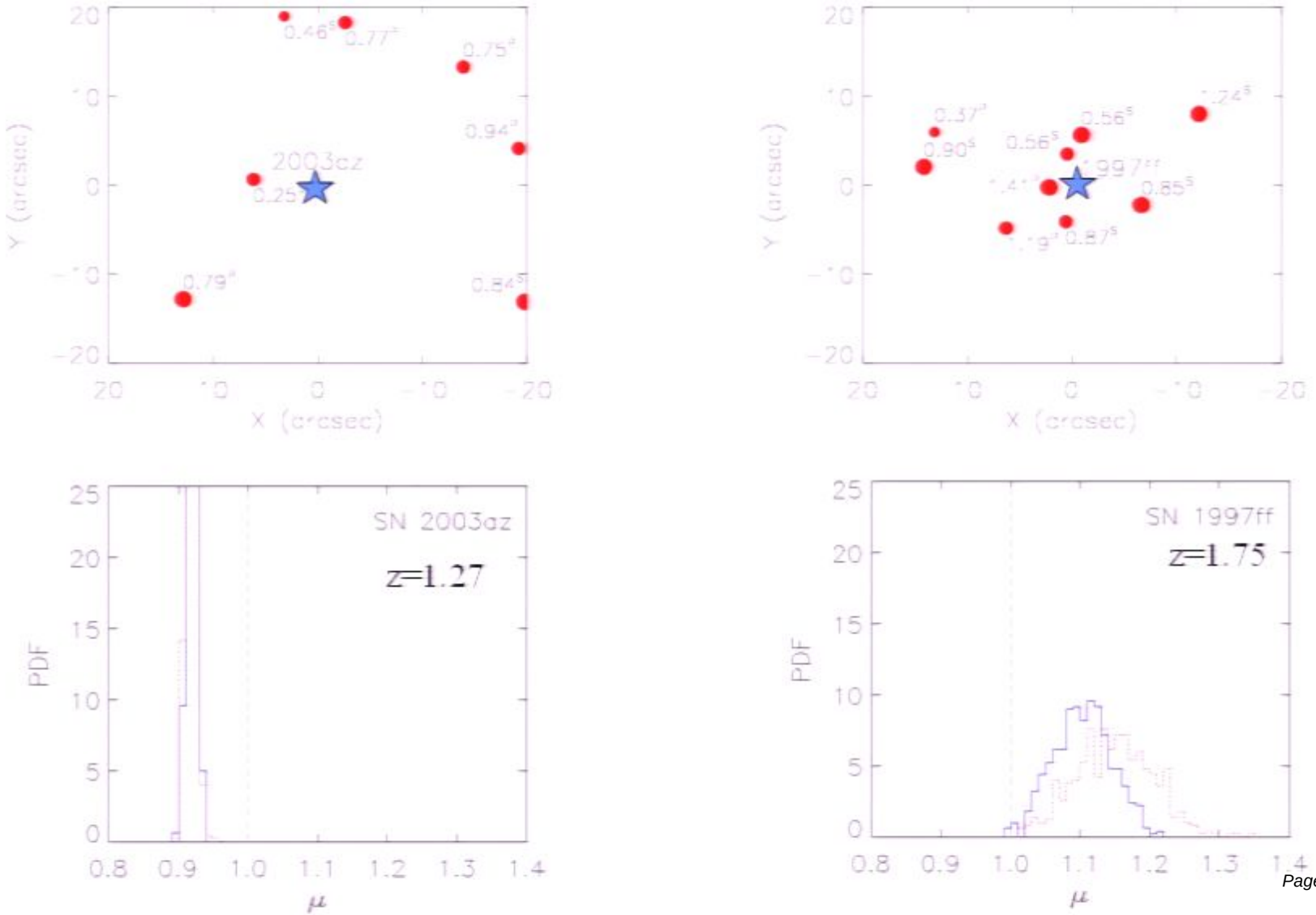
High-z SNe

Potential systematics

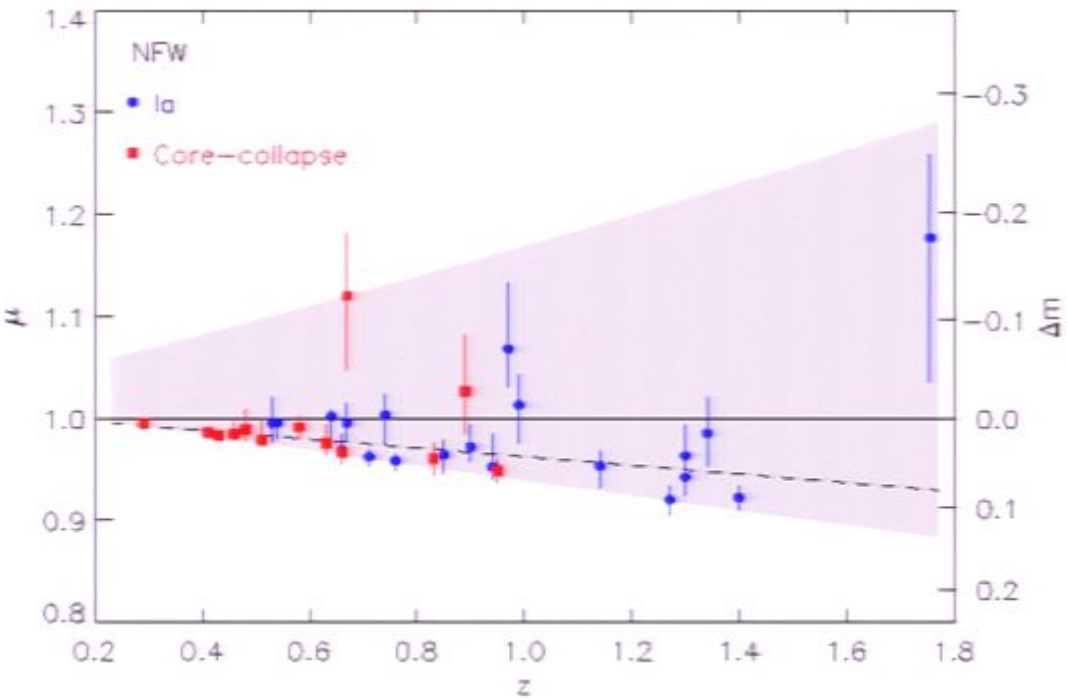
Could gravitational lensing affect the very high-z SN results?

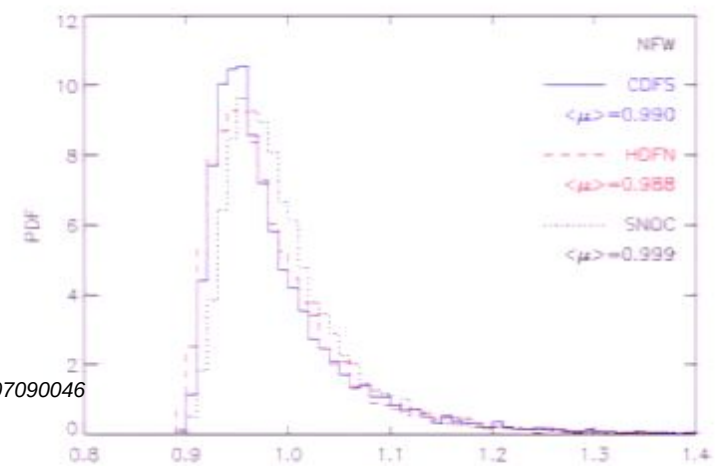


Lensing (de)magnification in the GOODS SN survey: a study case



Lensing PDFs for GOODS SN-sample

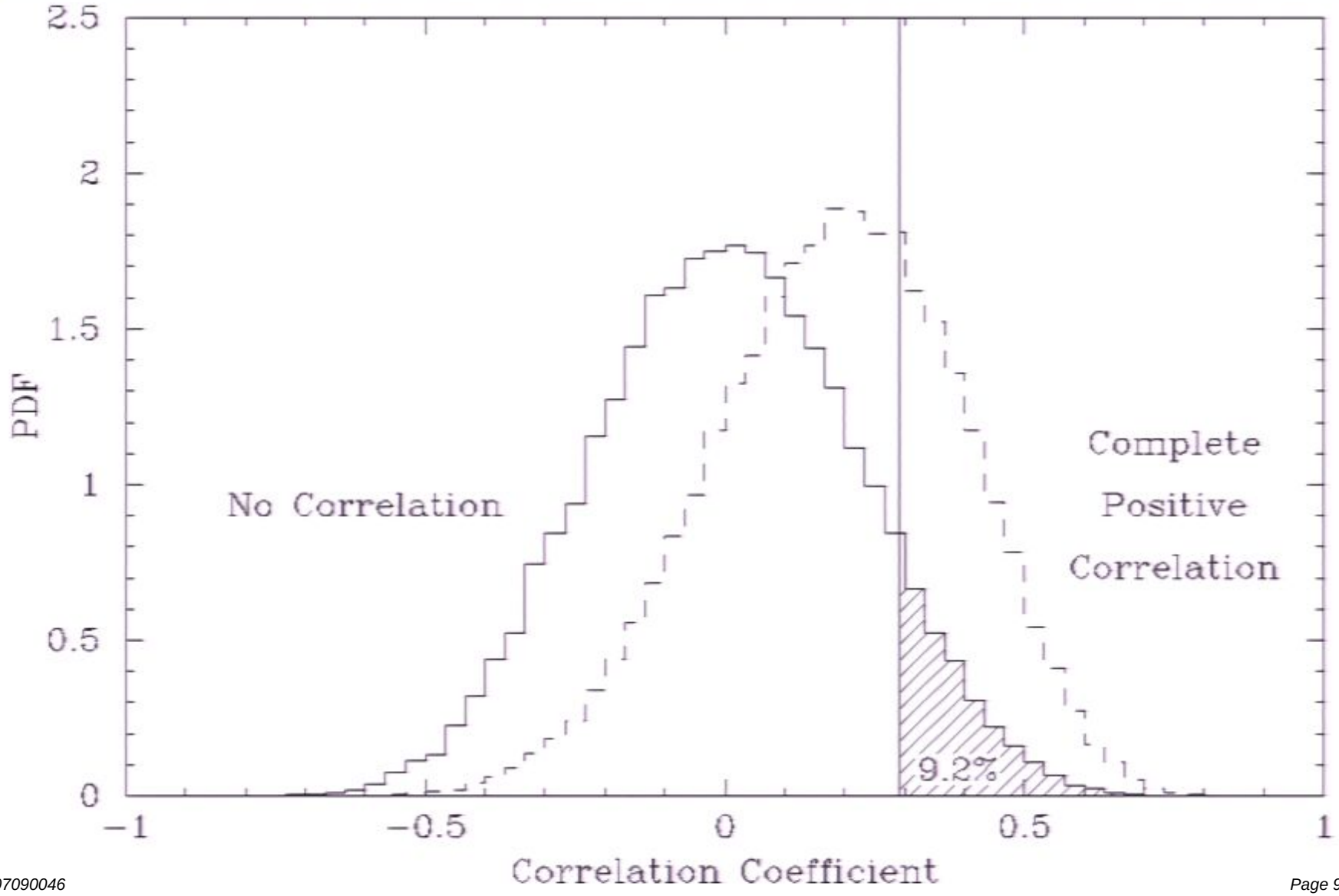




- We found NO evidence for selection effects due to lensing in the GOODS SN sample. Negligible corrections to Ω's & w.
- Expected lensing bias on SNLS results is also small: $|\delta\Omega_M|$ ~0.01 in Ω_M-Ω_Λ plane. Added uncertainty on w_0 is σ_w~0.014 for BAO prior (SNOC simulation)

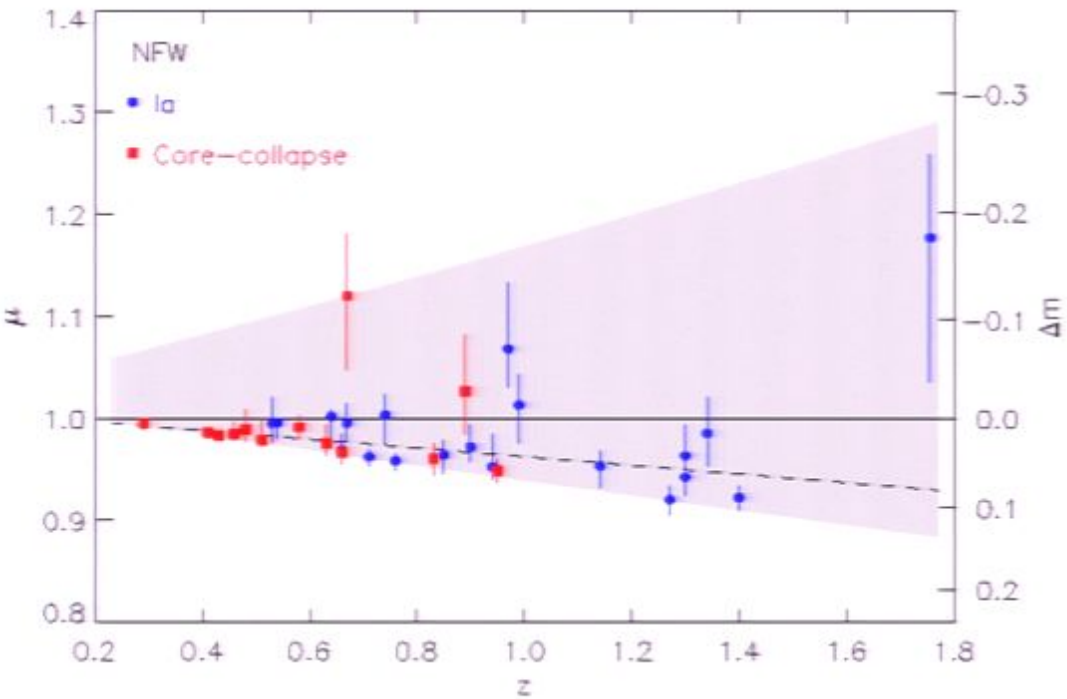
Jönsson et al. 2006

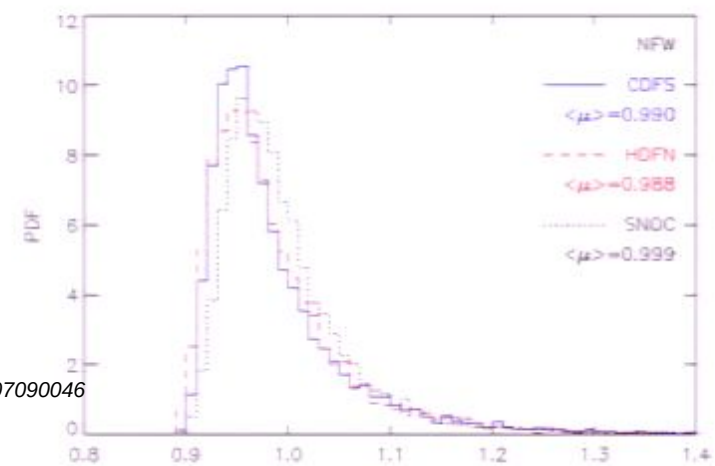
Tentative detection of correlation with residuals in Hubble diagram



Jönsson,Dahlen,AG,Mörtsell & Riess, 2007

Lensing PDFs for GOODS SN-sample

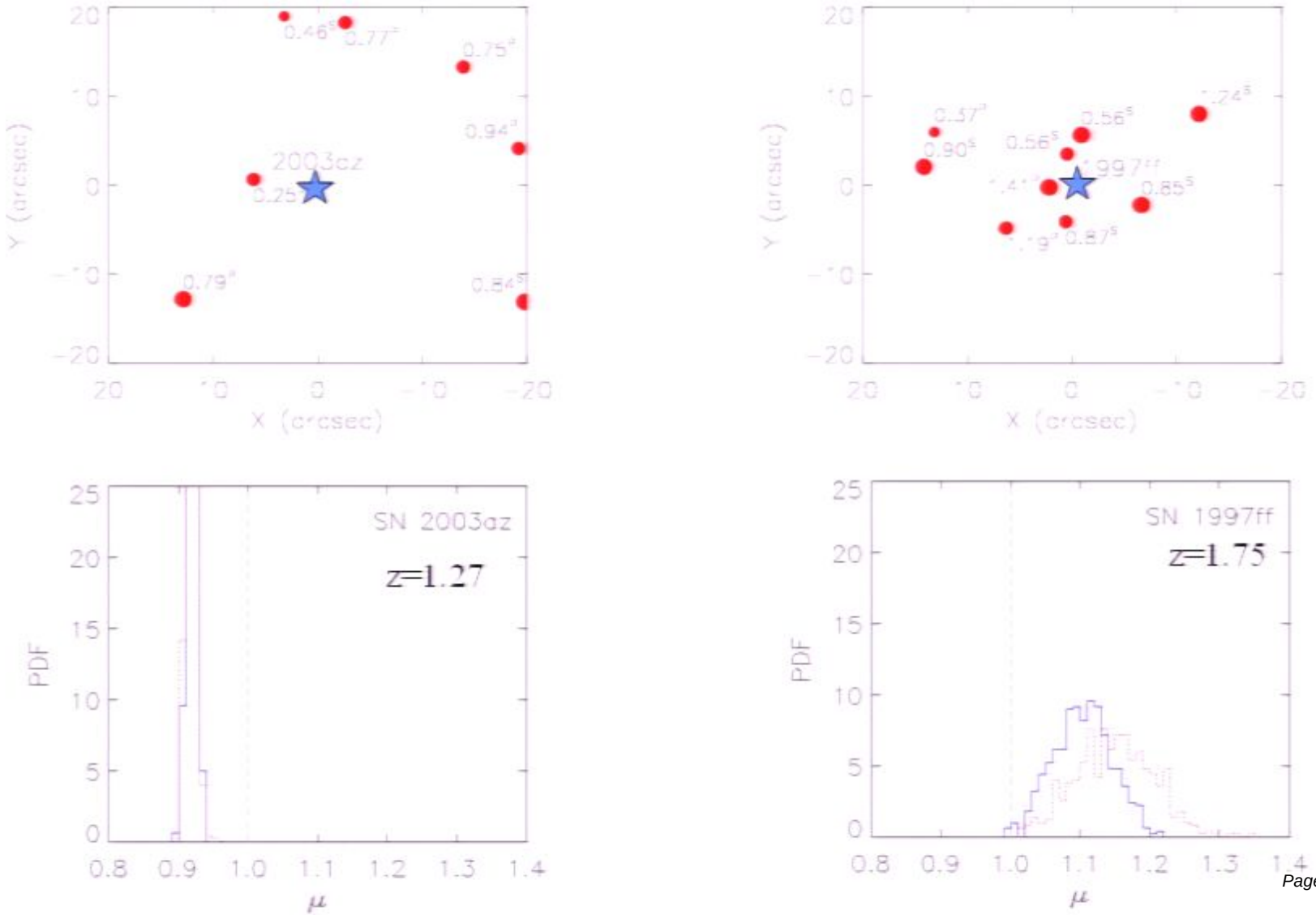




- We found NO evidence for selection effects due to lensing in the GOODS SN sample. Negligible corrections to Ω's & w.
- Expected lensing bias on SNLS results is also small: $|\delta\Omega_M|$ ~0.01 in Ω_M-Ω_Λ plane. Added uncertainty on w_0 is σ_w~0.014 for BAO prior (SNOC simulation)

Jönsson et al. 2006

Lensing (de)magnification in the GOODS SN survey: a study case



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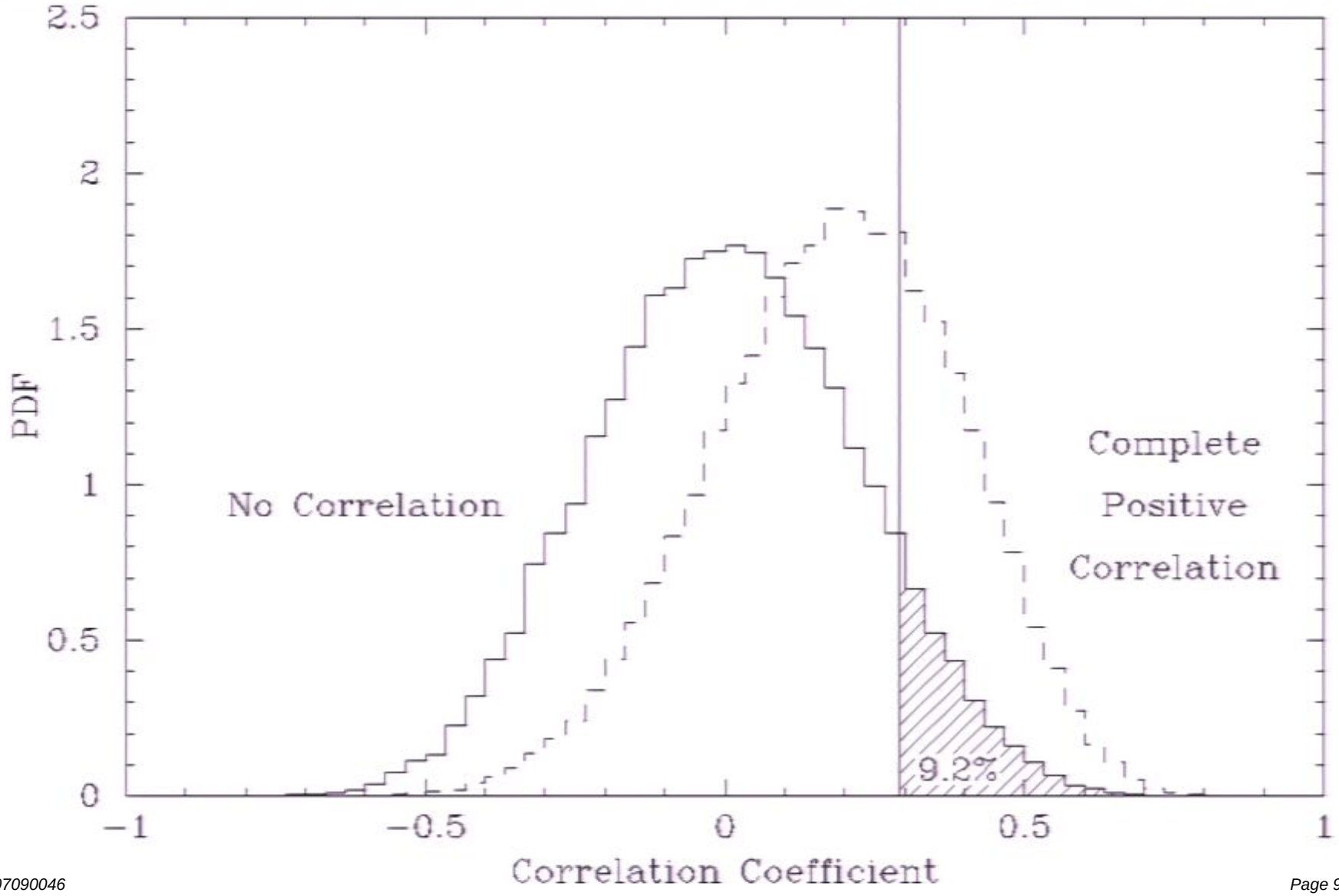

Jönsson,Dahlen,AG,Mörtsell & Riess, 2007

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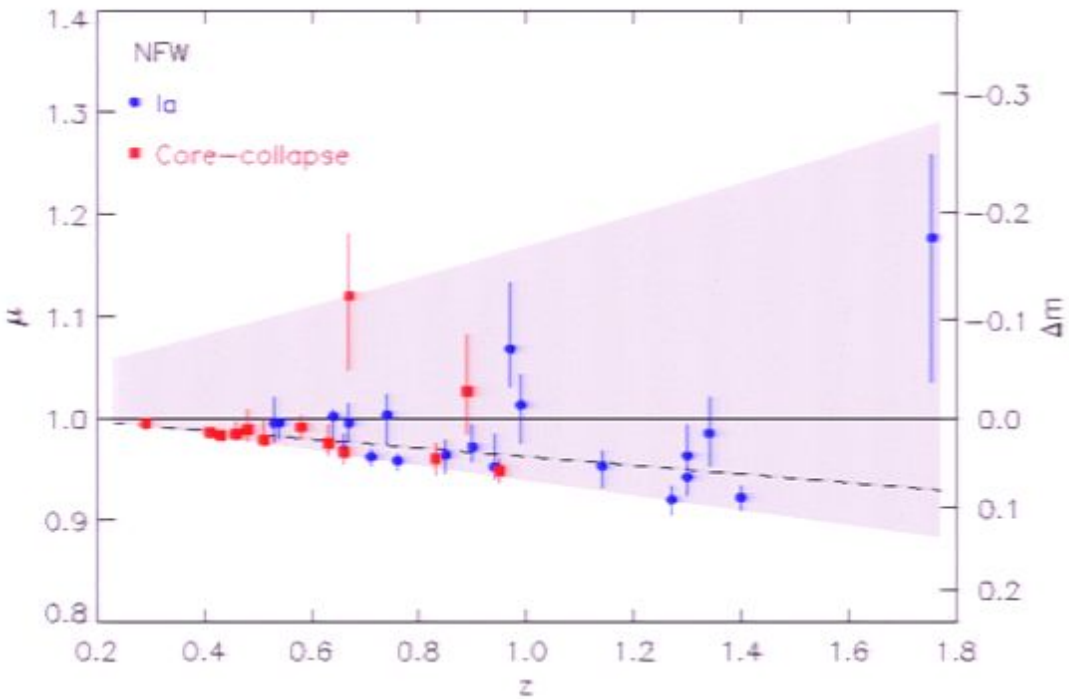

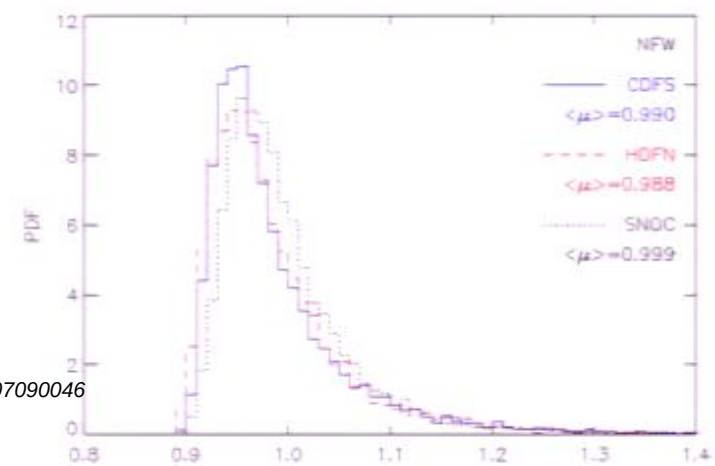

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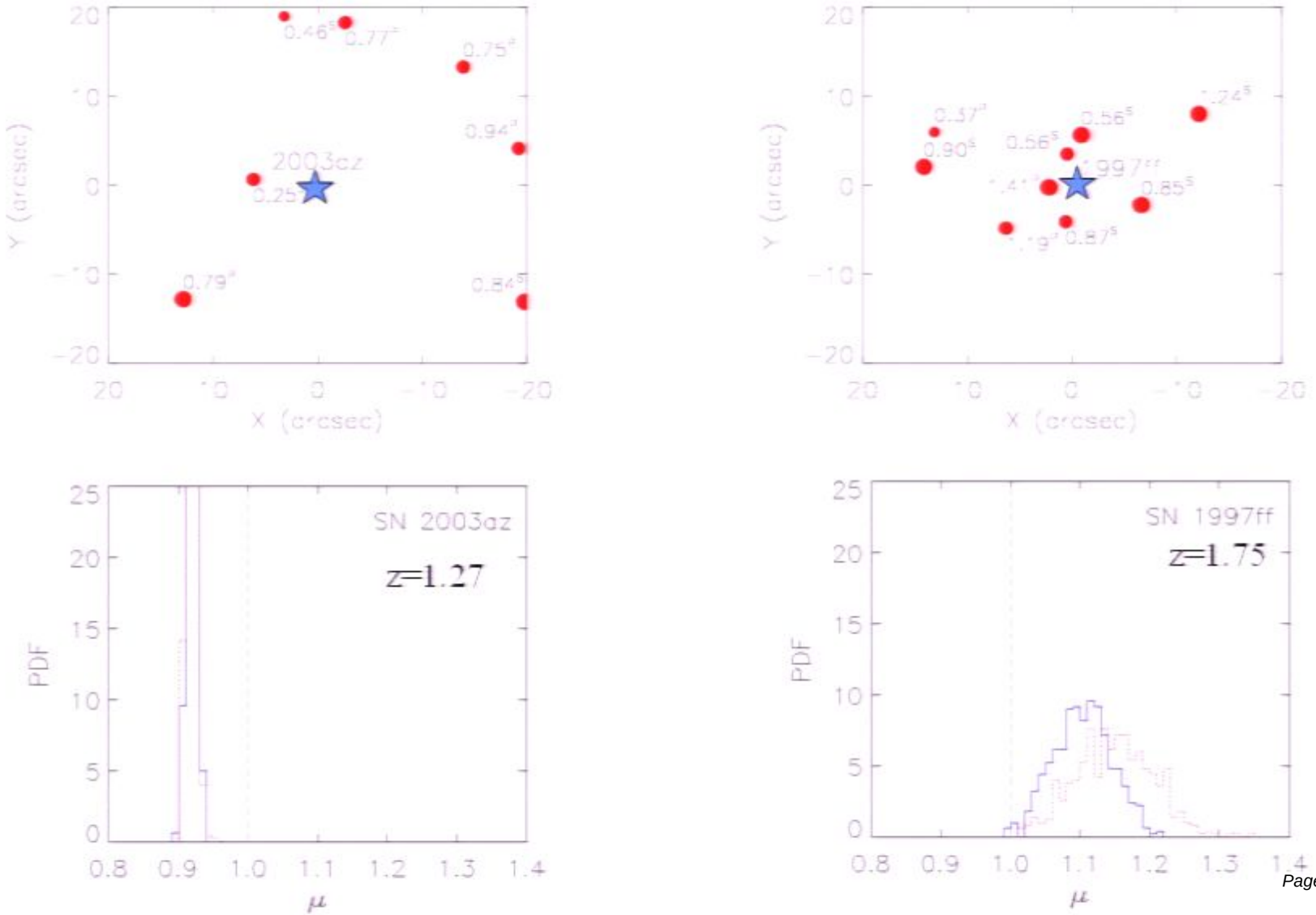
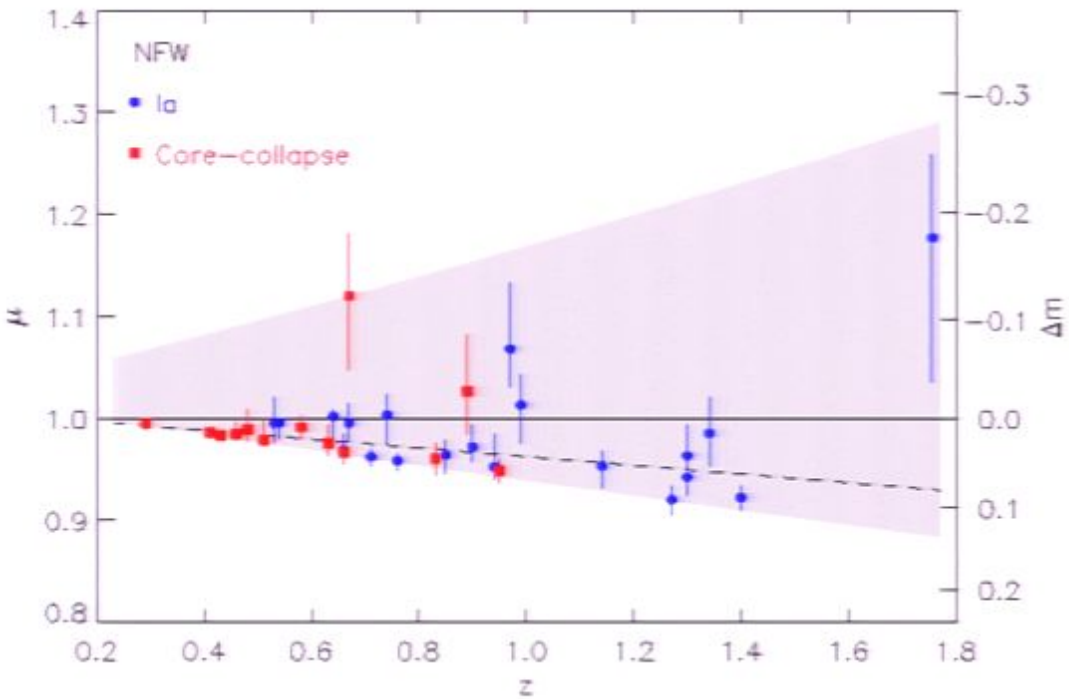
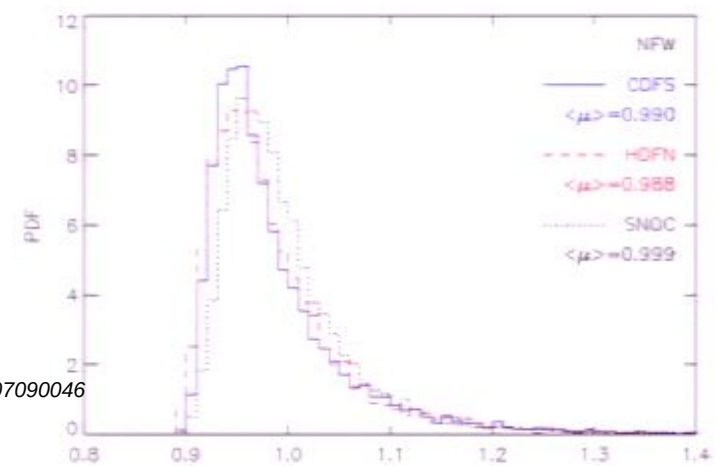


Lensing PDFs for GOODS SN-sample





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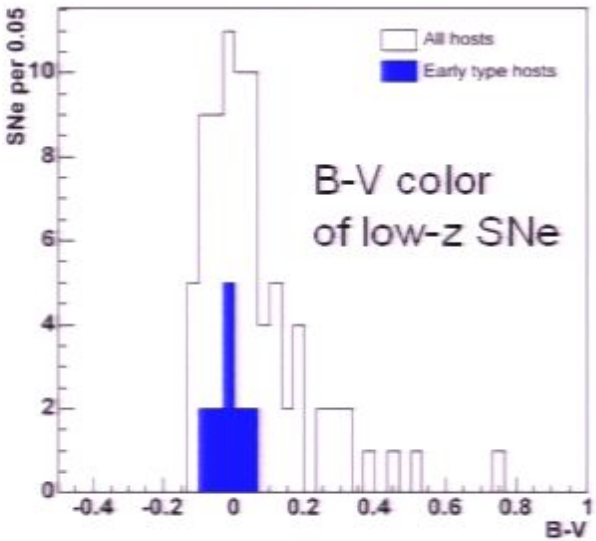
Jönsson et al. 2006

Dust/reddening: a real problem!



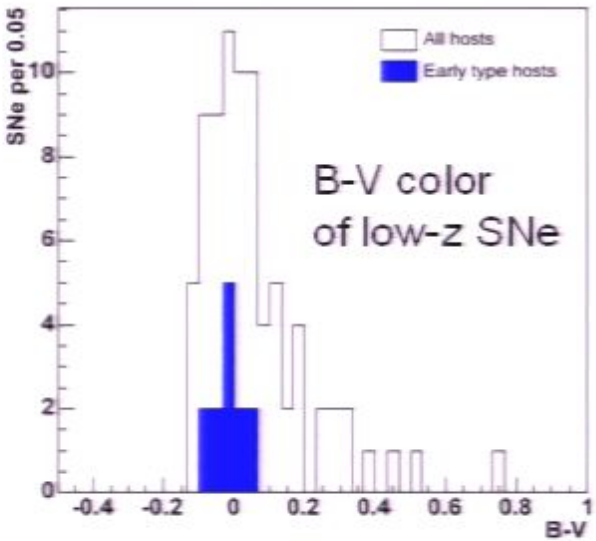
- Dust in SN host galaxy (or along line of sight)

Extinction:

$\Delta M_B = R_B \cdot E(B-V)$ with $R_B \sim 2 - 5$

Extinction correction dominates measurement error!

Dust/reddening: a real problem!



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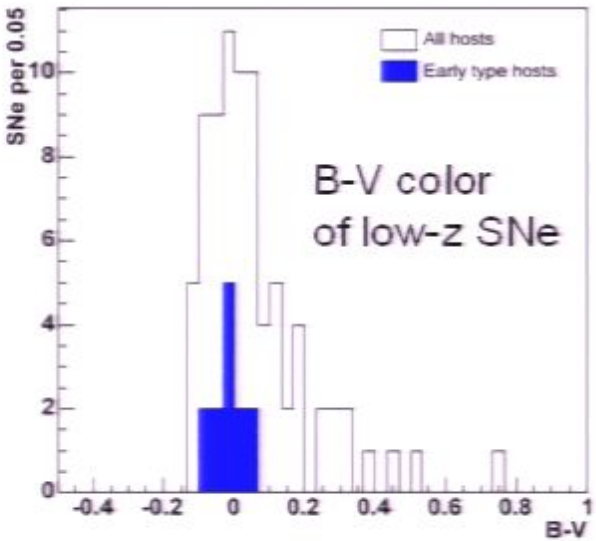

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  b) good knowledge of intrinsic "color" of SNe
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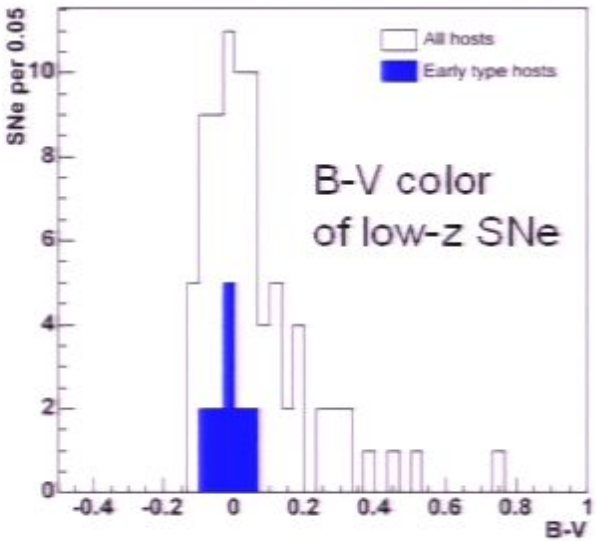

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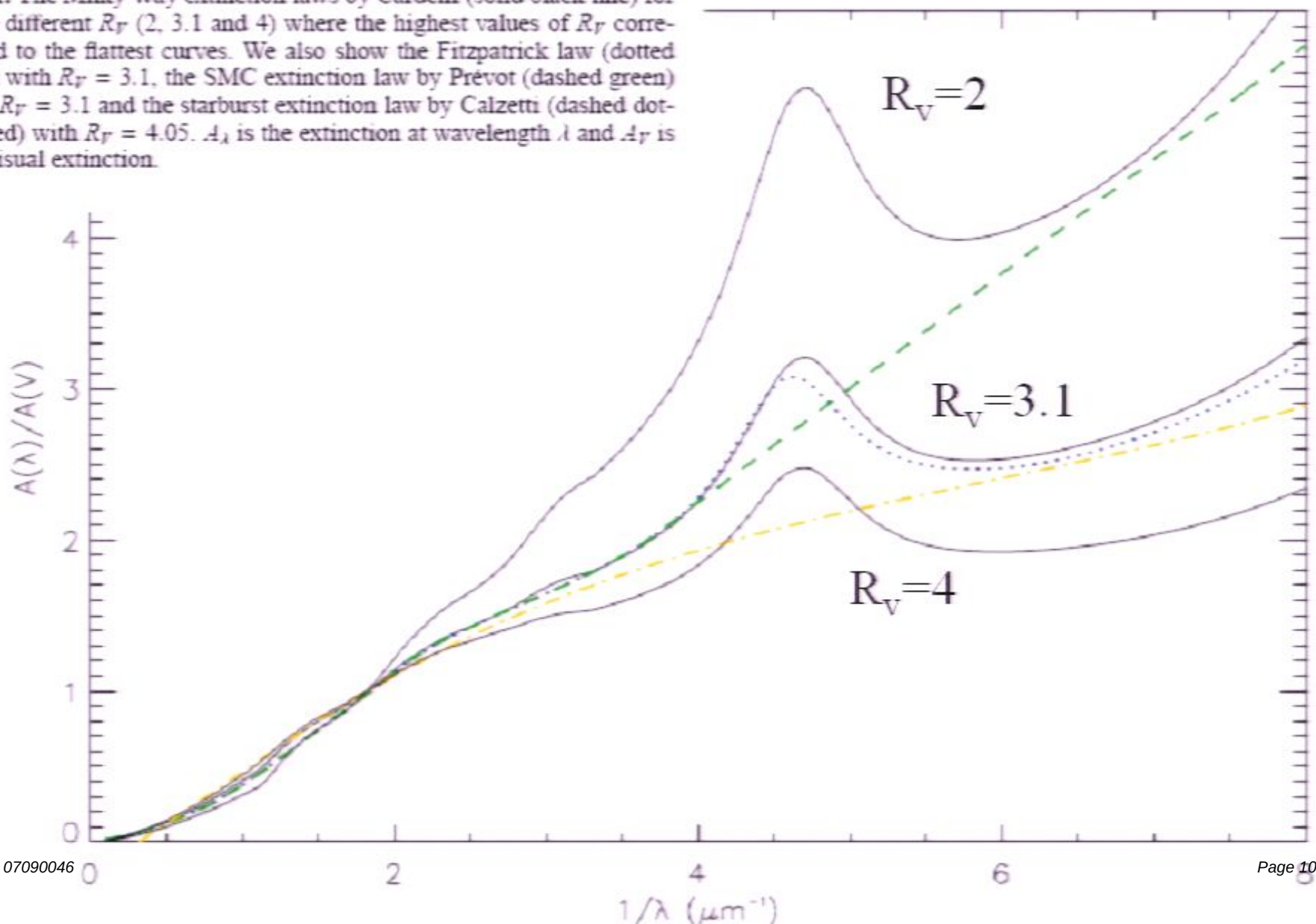
$\Delta M_B = R_B \cdot E(B-V)$ with $R_B \sim 2 - 5$

Extinction correction dominates measurement error!

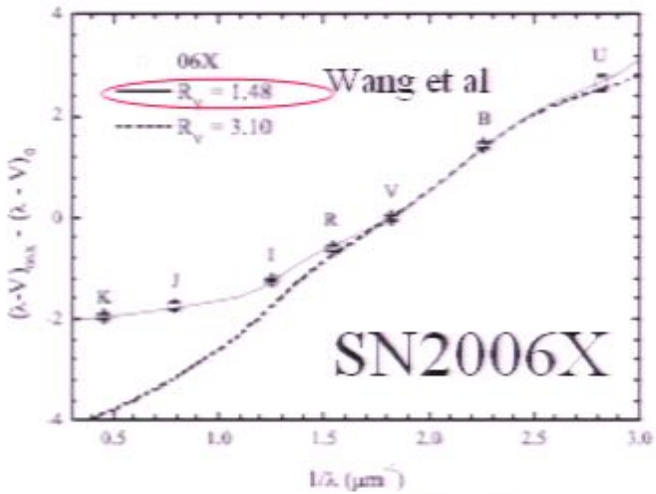
Exception: Elliptical galaxies (E/S0) have little star-formation & dust.

Extinction laws

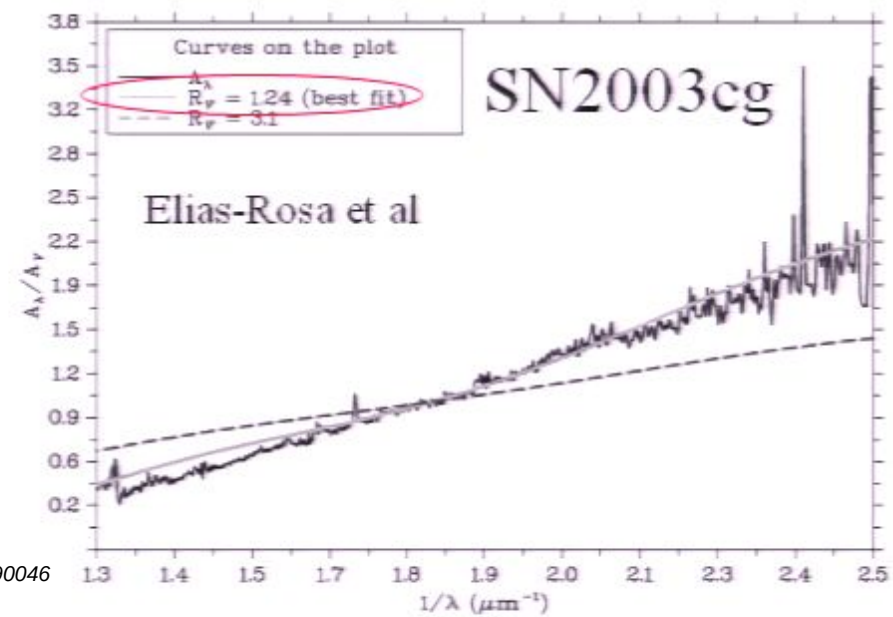
Fig. 1. The Milky Way extinction laws by Cardelli (solid black line) for three different R_V (2, 3.1 and 4) where the highest values of R_V correspond to the flattest curves. We also show the Fitzpatrick law (dotted blue) with R_V = 3.1, the SMC extinction law by Prévot (dashed green) with R_V = 3.1 and the starburst extinction law by Calzetti (dashed dotted red) with R_V = 4.05. A_λ is the extinction at wavelength λ and A_V is the visual extinction.

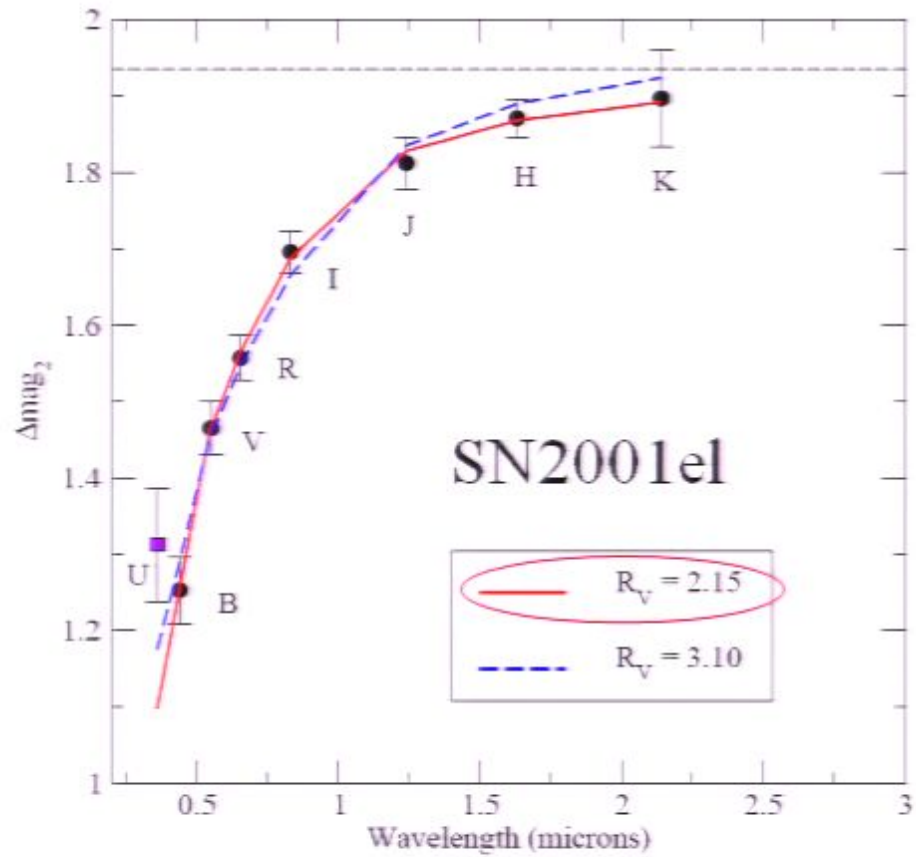


Varying dust properties in near-by SN hosts



Extinction curve





Krisciunas *et al.* Fig. 14

But for high-z SNe it is assumed all SNe hosts have same dust properties!

What is the impact of various sources of error on cosmological parameters for any given data-set?

Code in prep: allows for study of *correlated, non-gaussian* sources of error affecting groups of SNe.

Full chain of error propagation!

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Anteckningar... Övergång Formgivning Ny bild

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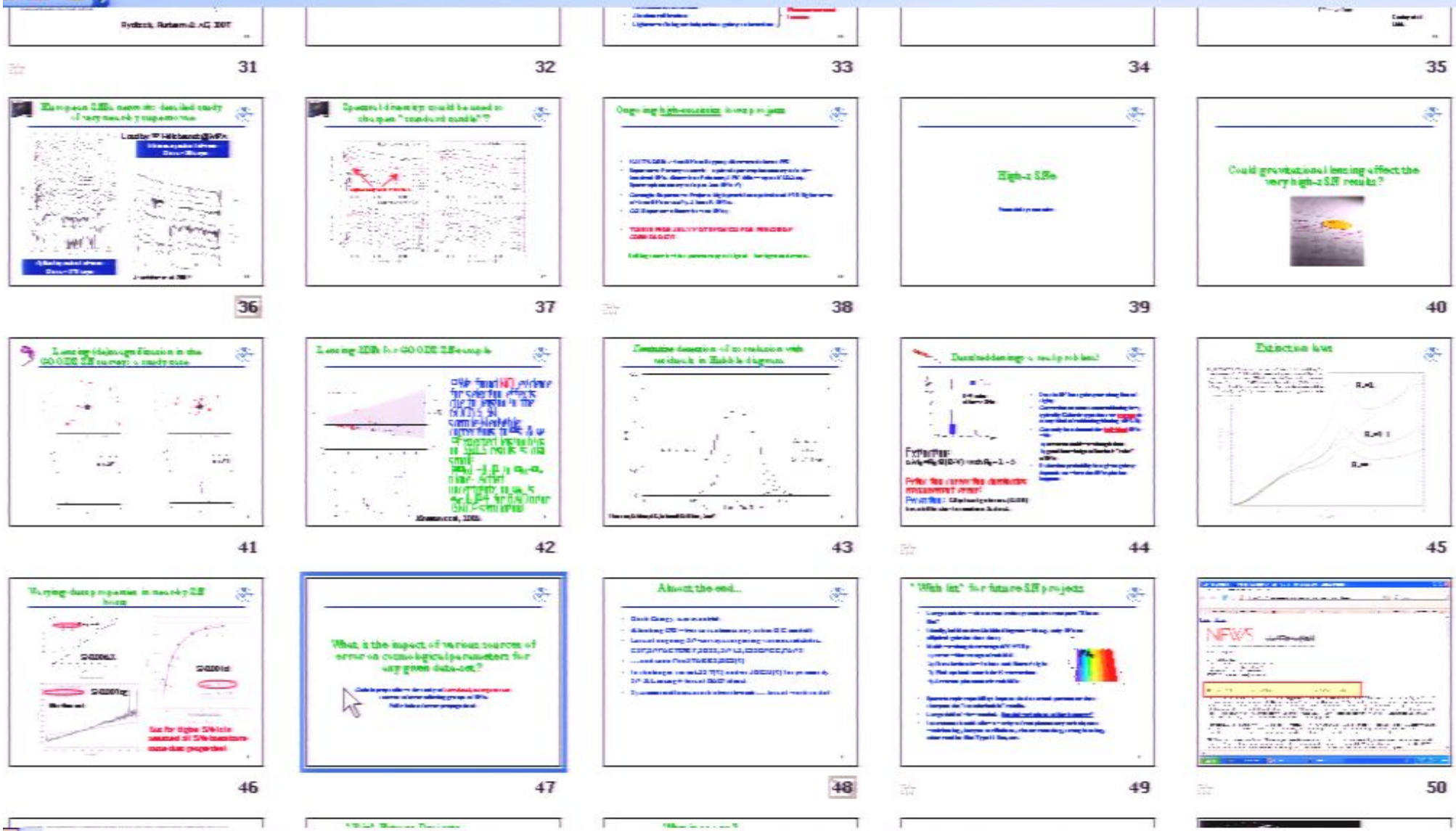

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Anteckningar... Övergång Formgivning Ny bild

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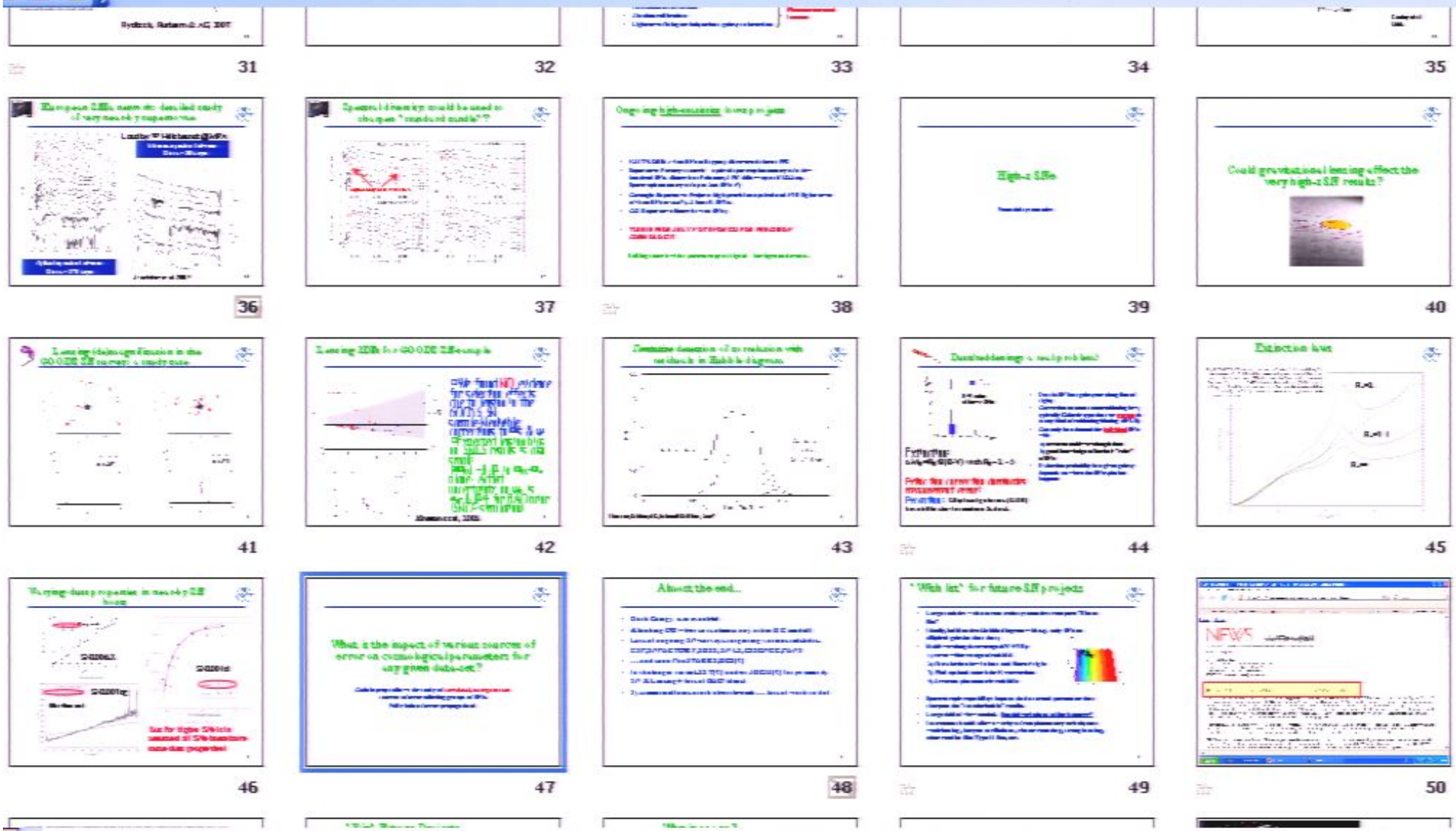

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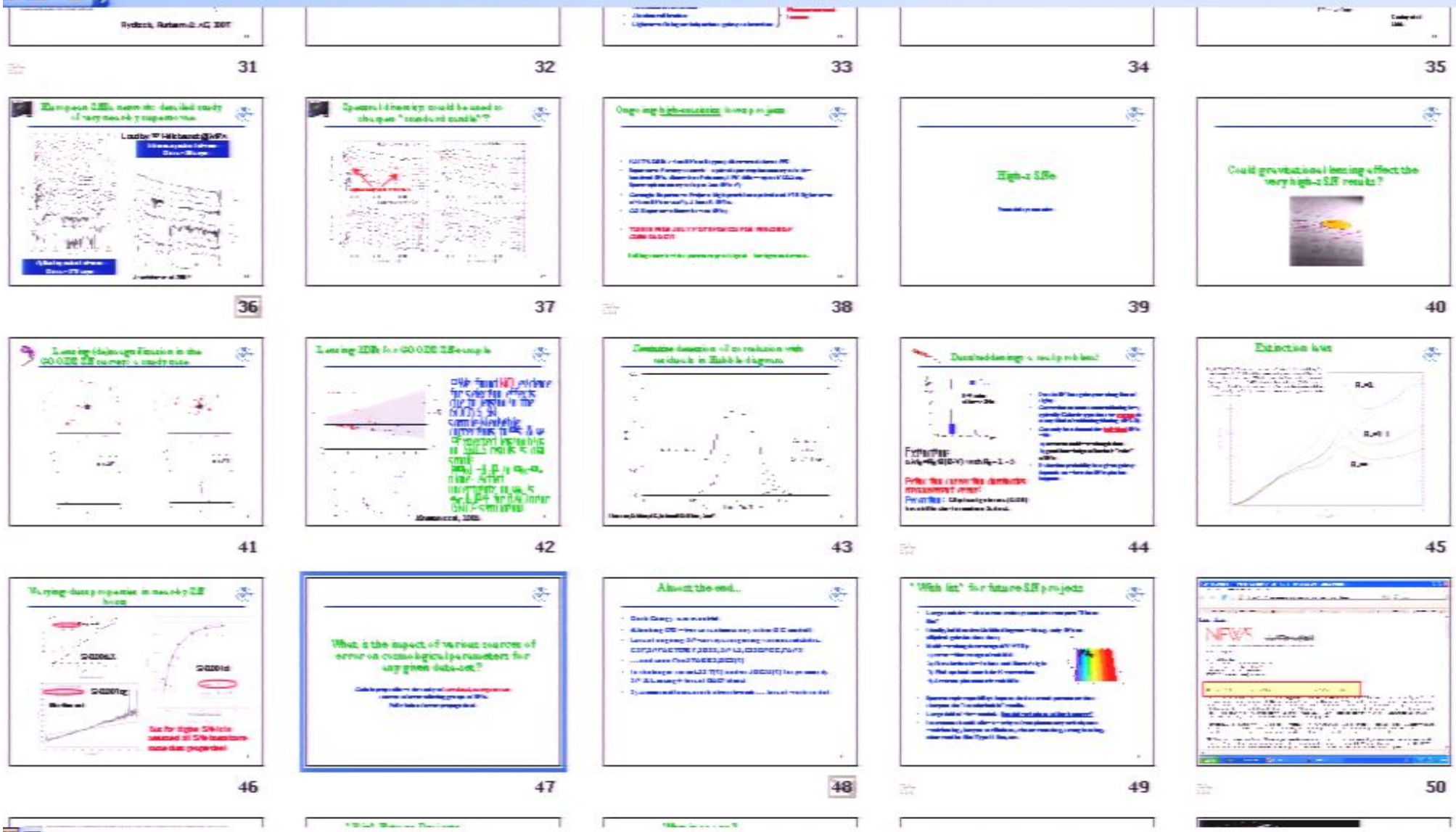

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Anteckningar... Övergång Formgivning Ny bild

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Tktest

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Bias	0	0	0
Col.spread	0	0	0
Rv_bias	3.1	3.1	3.1
Rv.spread	0	0	0
Spread	0	0	0

Lensing

Template

- Salt2(0)
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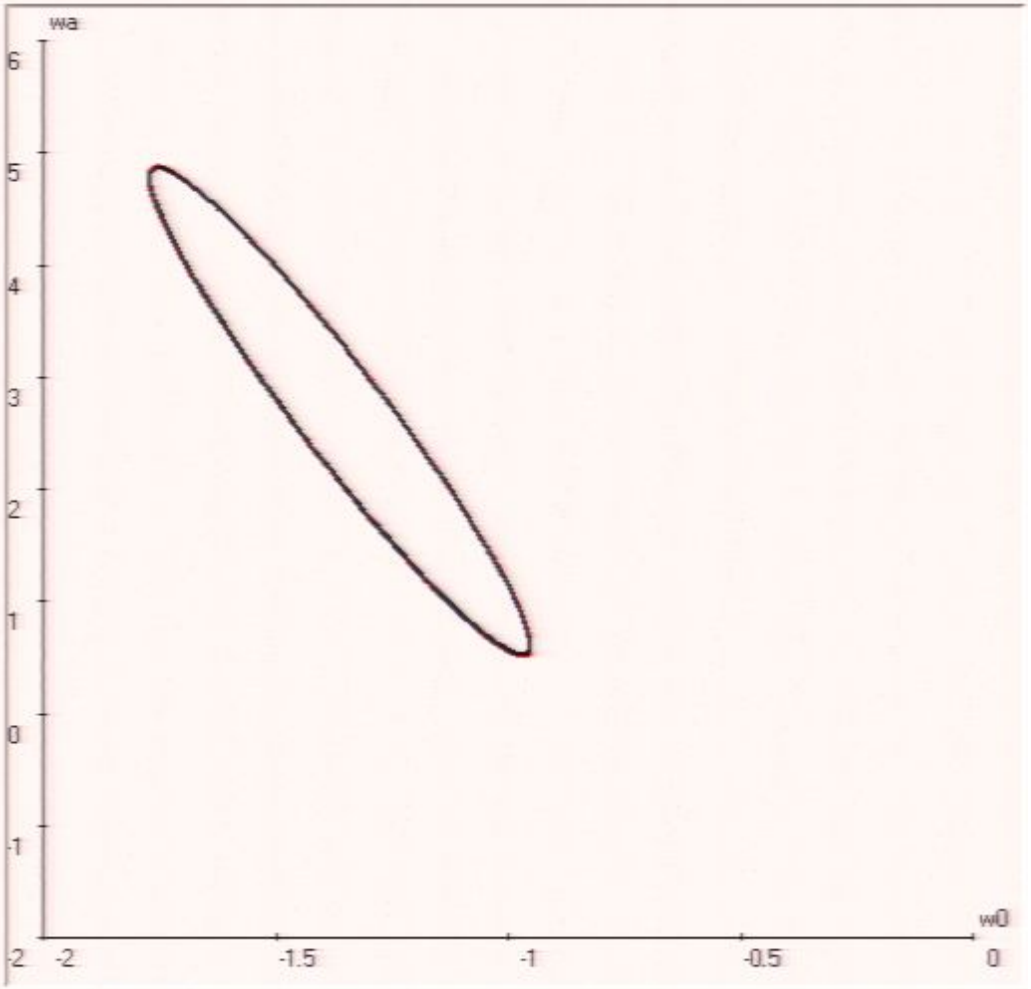

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Anteckningar... Övergång Formgivning Ny bild

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Z_spread	0	0	0
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Bias	0	0	0
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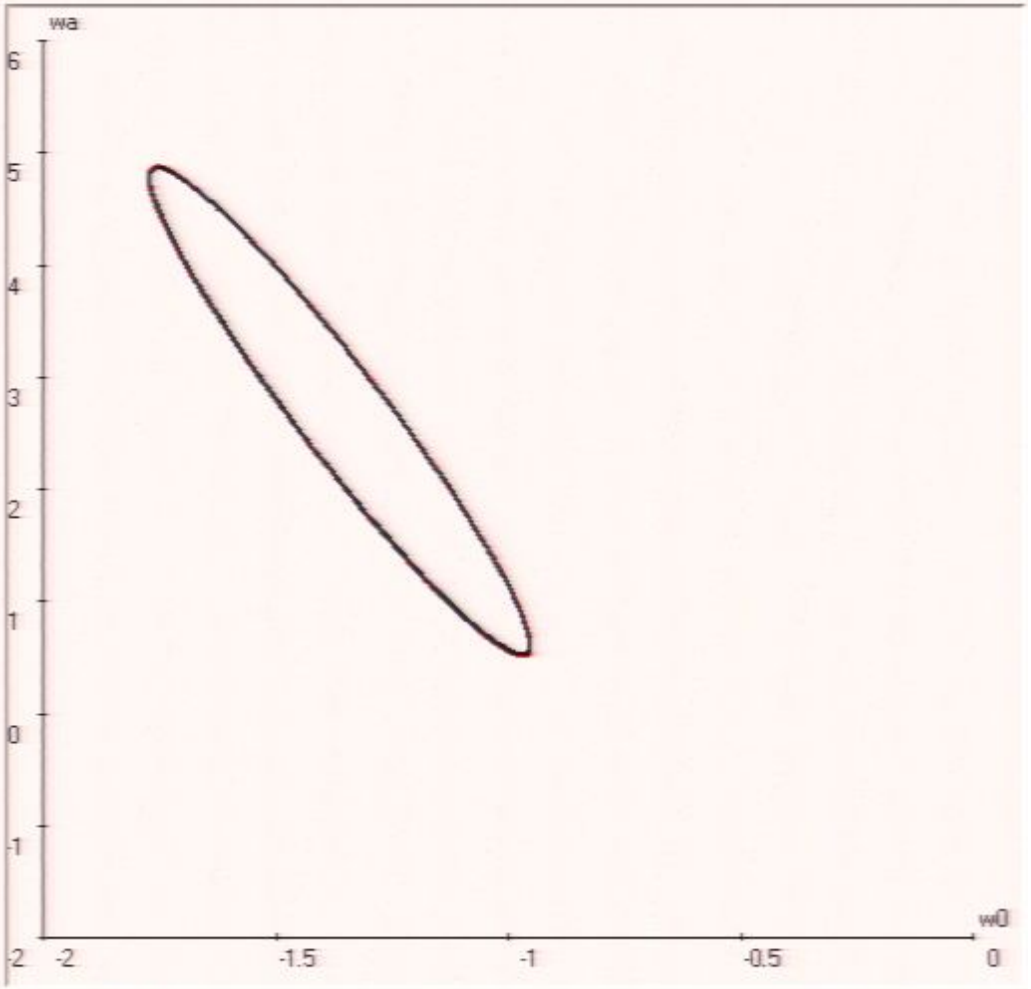

Quit Reset w0min -2

Wireless Network Connection is now connected

Connected to: GuestPass
Signal Strength: Excellent

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Bias	0	0	0
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Rv_bias	3.1	3.1	3.1
Rv.spread	0	0	0
Spread	0	0	0

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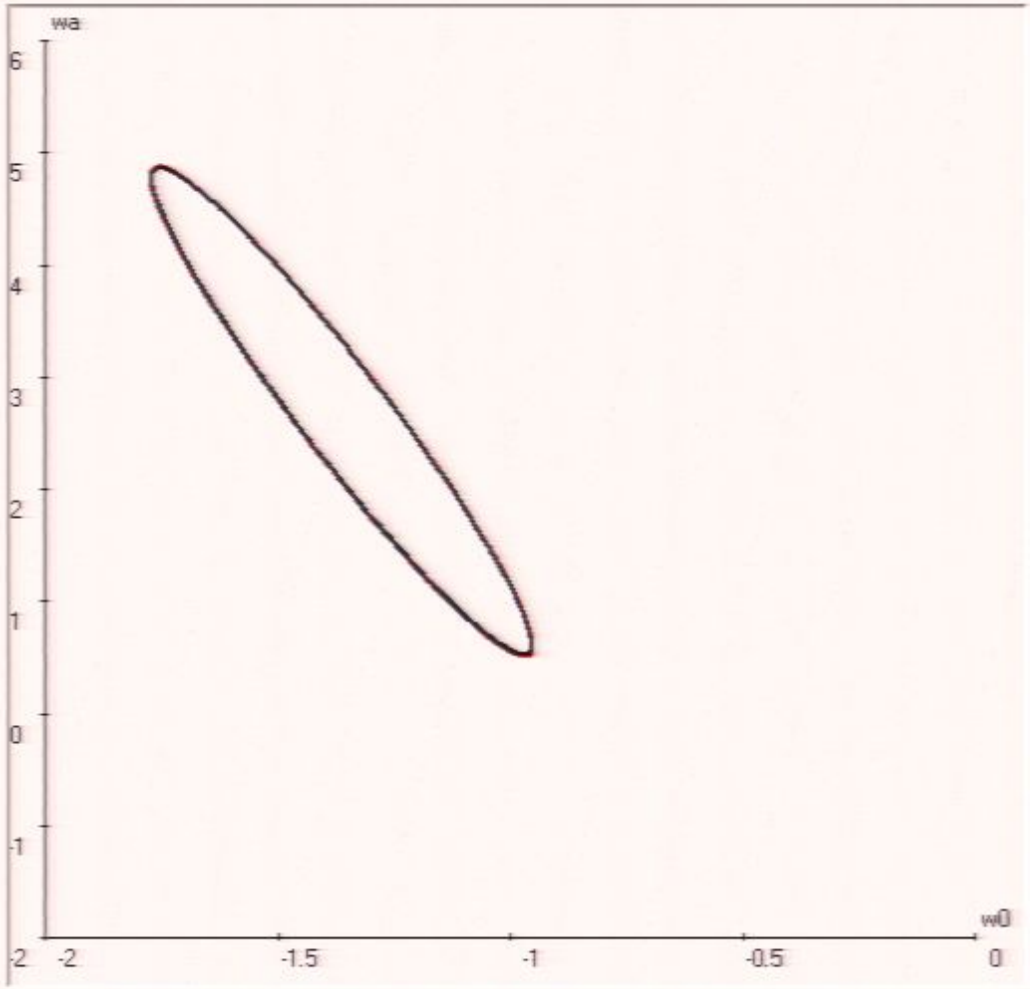

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Bias	0	0	0
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Spread	0	0	0

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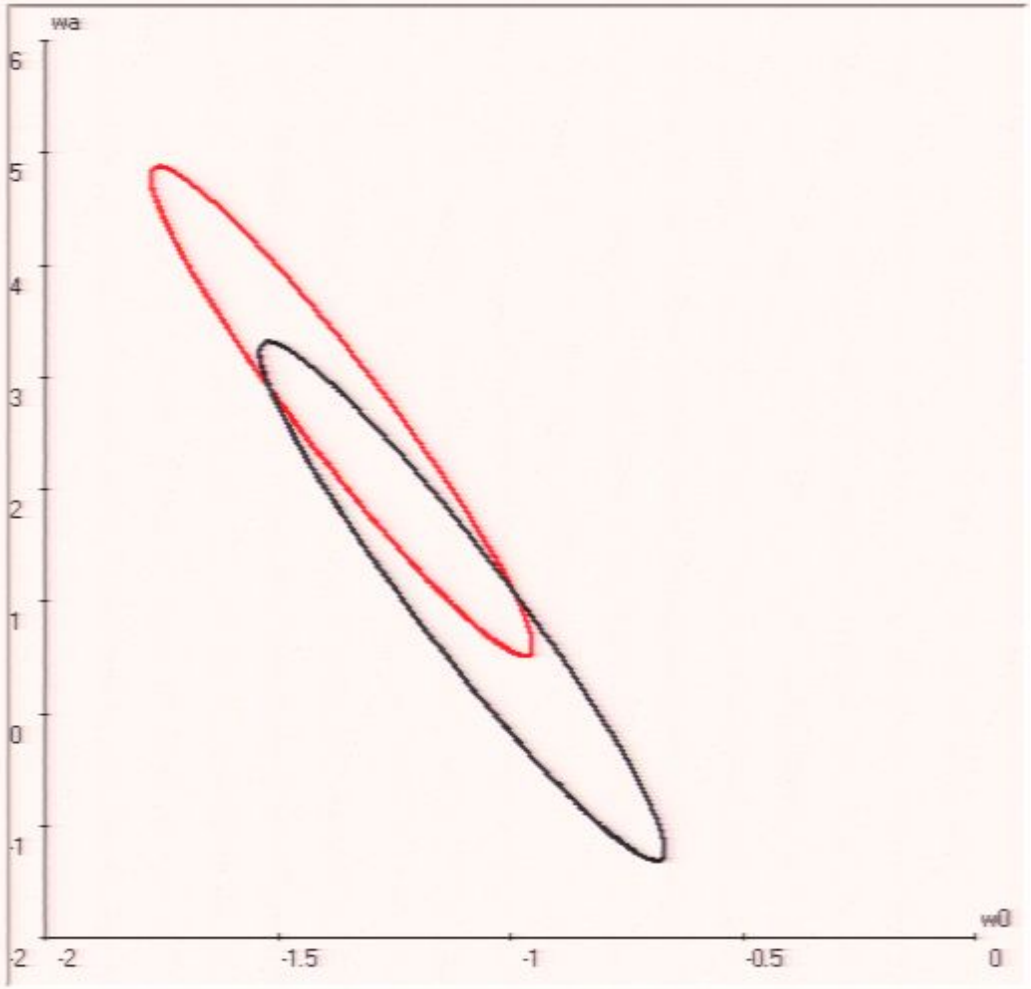

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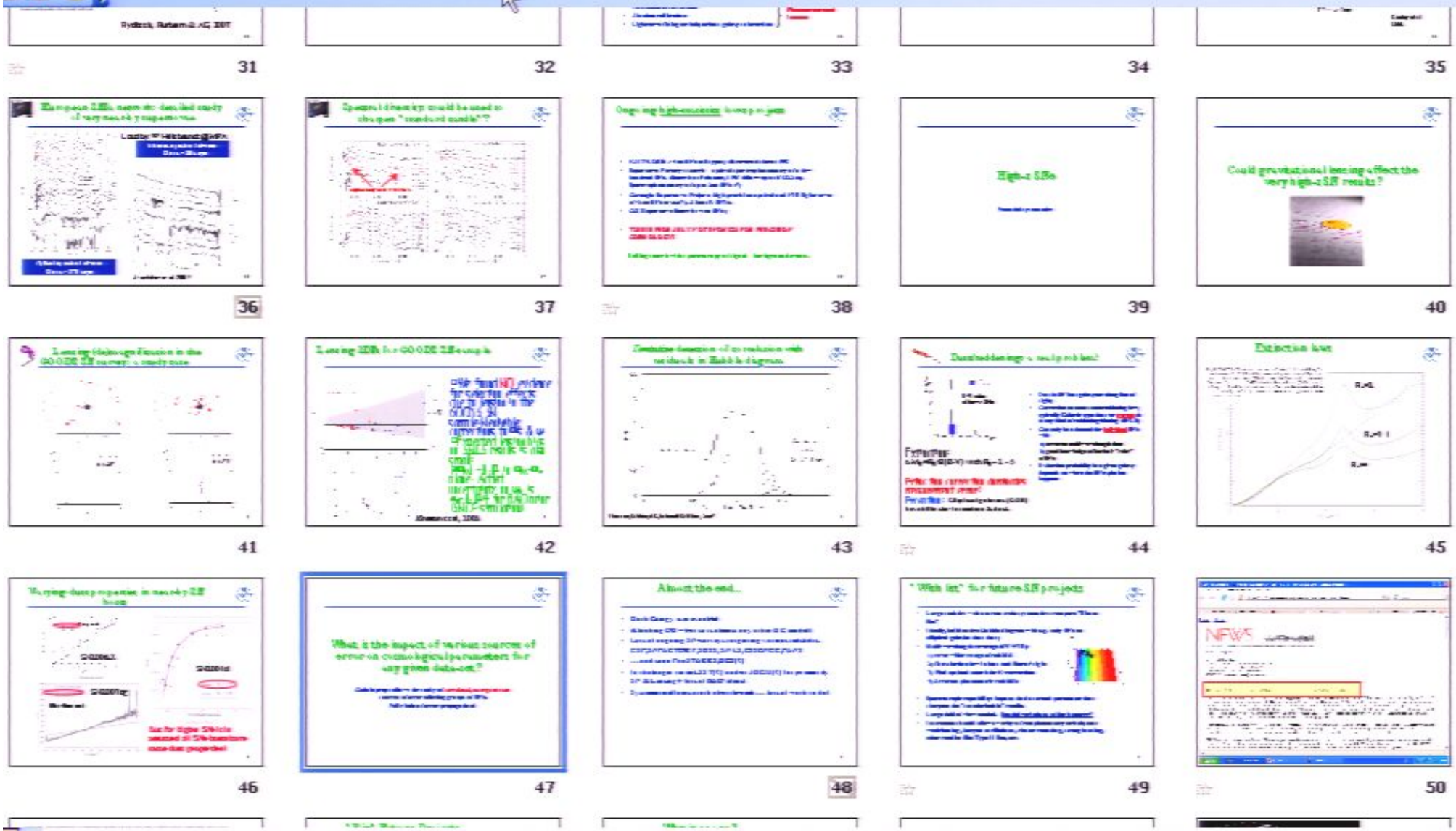

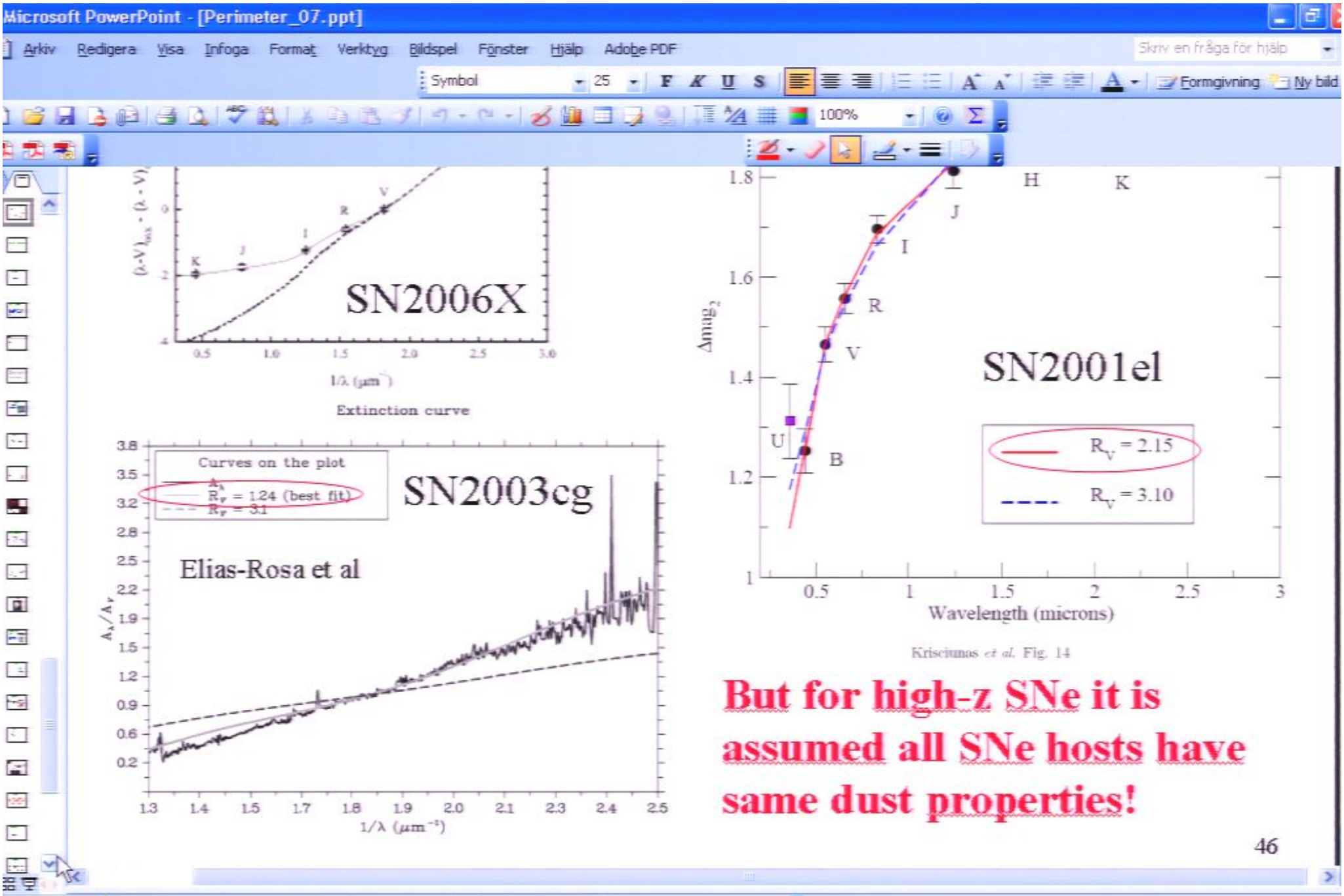
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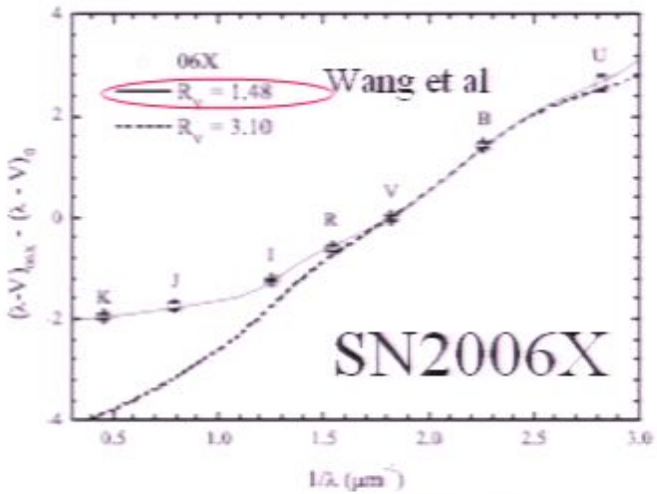
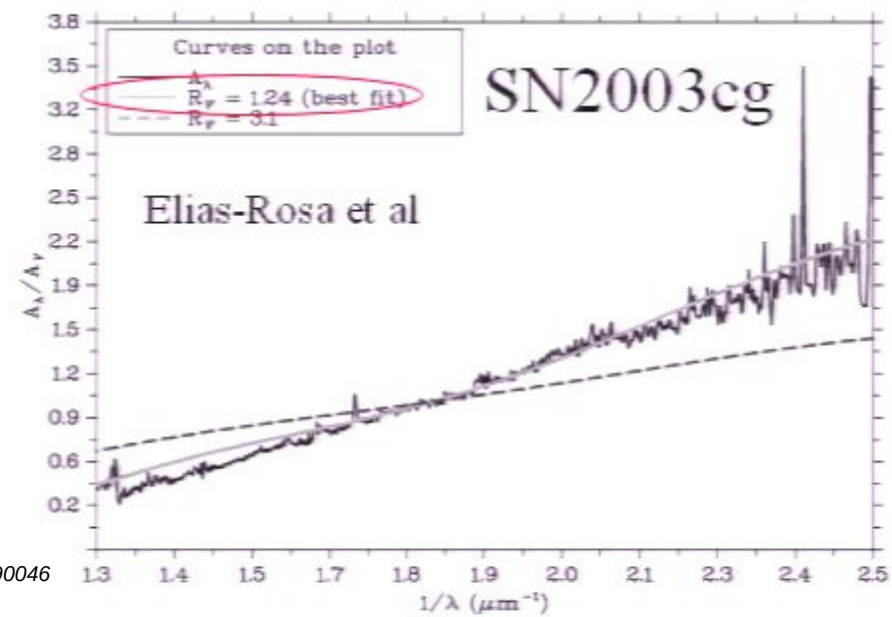
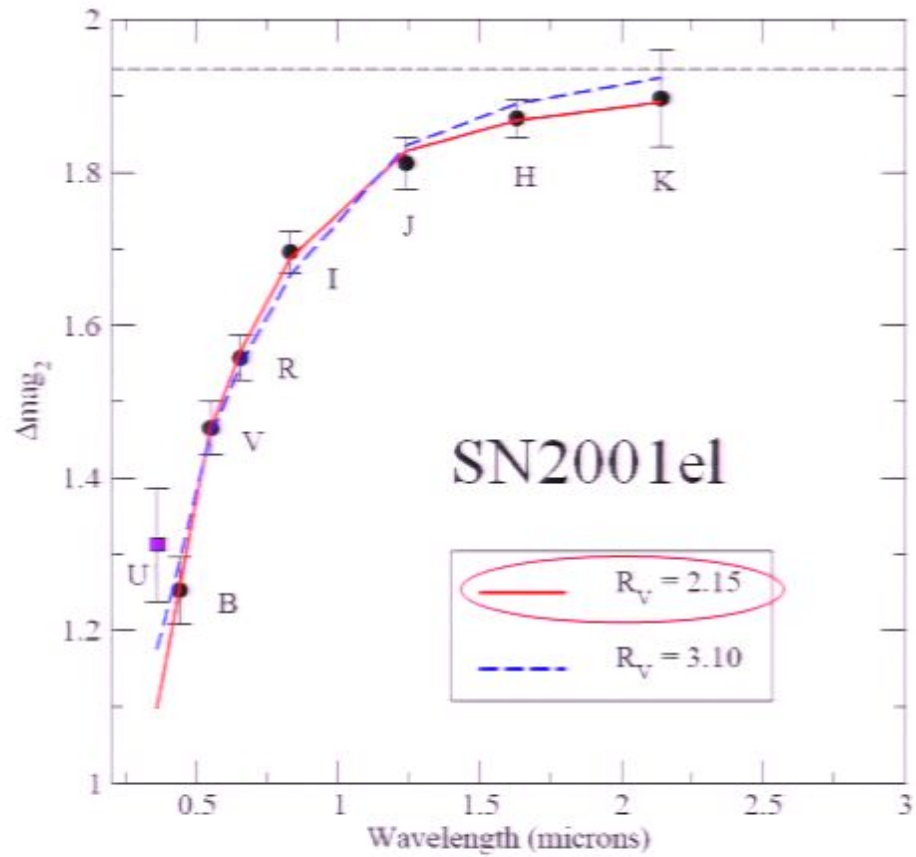
SN2006X
Extinction curve
SN2003cg
Elias-Rosa et al
Curves on the plot
R_V = 1.24 (best fit)
R_V = 3.1
A_λ/A_V
$1/\lambda$ (μm^{-1})
SN2001el
R_V = 2.15
R_V = 3.10
Δmag_λ
Wavelength (microns)
Krisciunas et al. Fig. 14
But for high-z SNe it is assumed all SNe hosts have same dust properties!
46

Varying dust properties in near-by SN hosts



Extinction curve





Krisciunas *et al.* Fig. 14

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Tktest

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Col.spread	0	0	0
Rv_bias	3.1	3.1	1.6
Rv.spread	0	0	0
Spread	0	0	0

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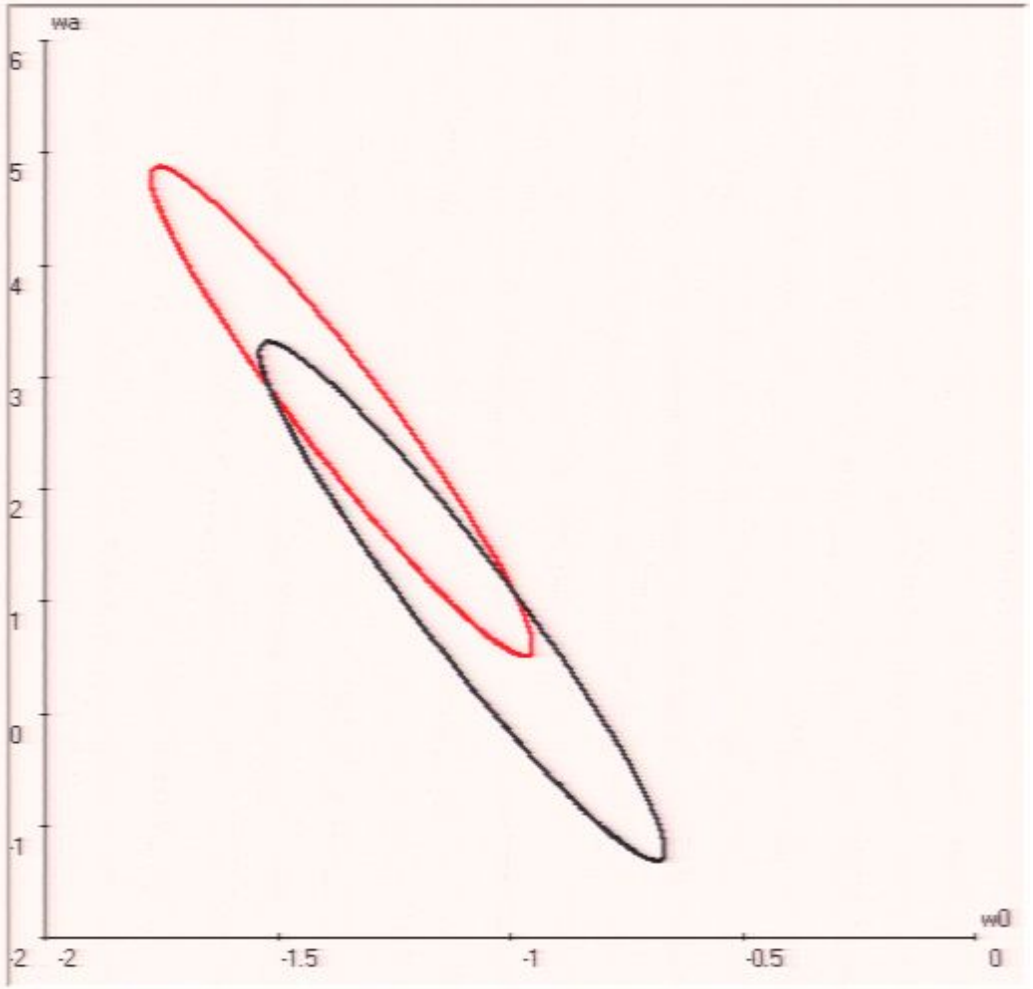

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Tktest

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Bias	0	0	0
Col.spread	0	0	0
Rv_bias	3.1	1.6	1.6
Rv.spread	0	0	0
Spread	0	0	0

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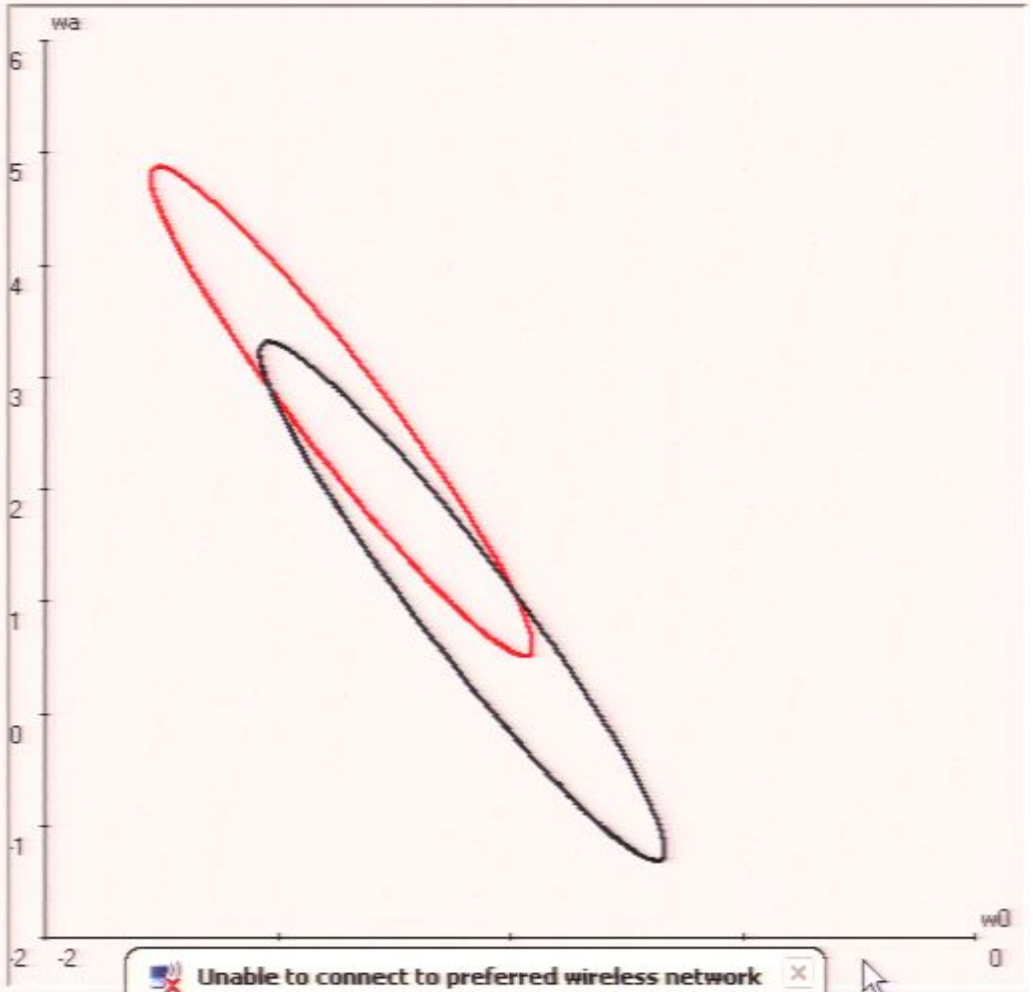
Quit Reset w0min



Unable to connect to preferred wireless network

Windows could not connect to any of your preferred wireless networks. Windows will keep trying to connect. To see a list of all networks, including others you can connect to, click this message.

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Tktest

Error	Low-z	Mid-z	High-z
Z_bias	0	0	0
Z_spread	0	0	0
Col.bias	0	0	0
Bias	0	0	0
Col.spread	0	0	0
Rv_bias	3.1	1.6	1.6
Rv.spread	0	0	0
Spread	0	0	0

Lensing

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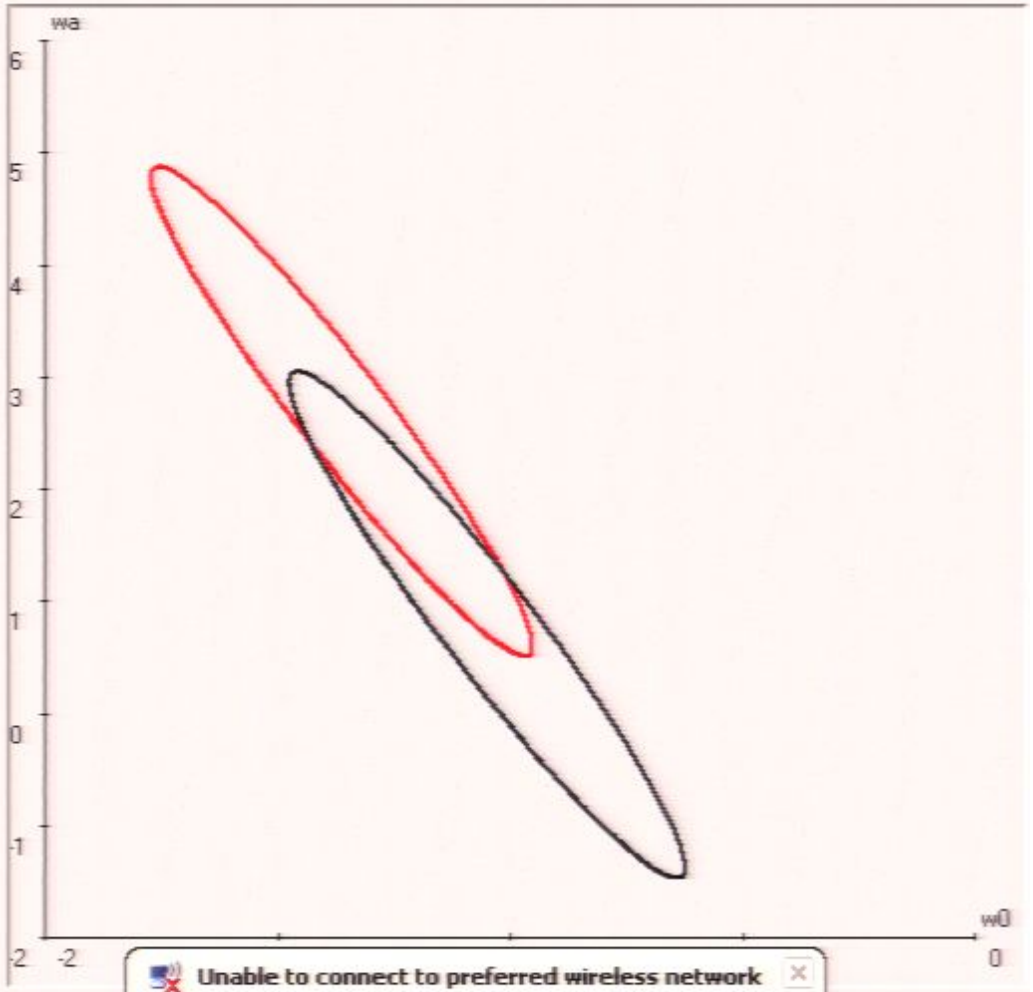
- Steep metal evo.

Quit Reset w0min



Unable to connect to preferred wireless network

Windows could not connect to any of your preferred wireless networks. Windows will keep trying to connect. To see a list of all networks, including others you can connect to, click this message.

Bild 46 av 71 Per_099rv1

Microsoft PowerPoint - [Perimeter_07.ppt]

Arkiv Redigera Visa Infoga Format Verktyg Bildspel Fönster Hjälp Adobe PDF

Tktest

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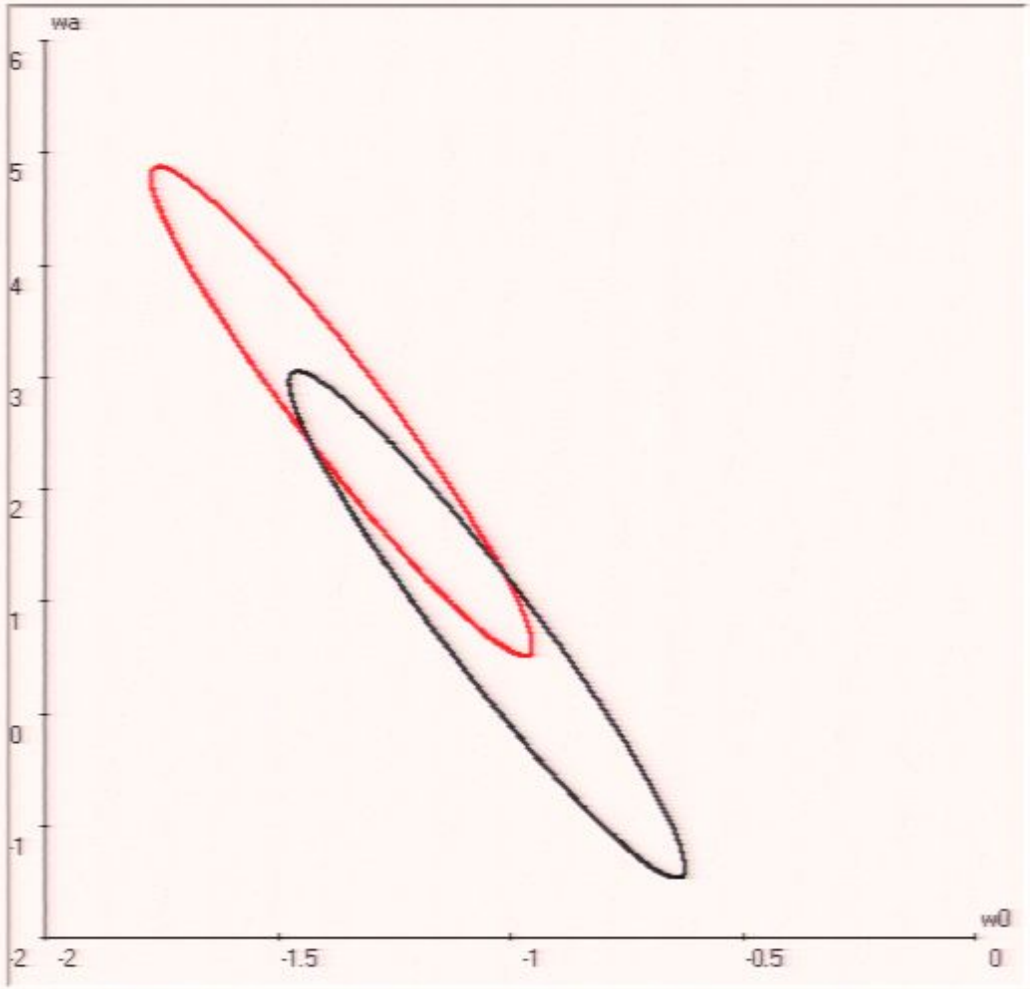

Quit Reset w0min -2 w0max 0 wamin -2 wamax 6 Redraw

Bild 46 av 71 Per_099rv1 Engelska (USA)

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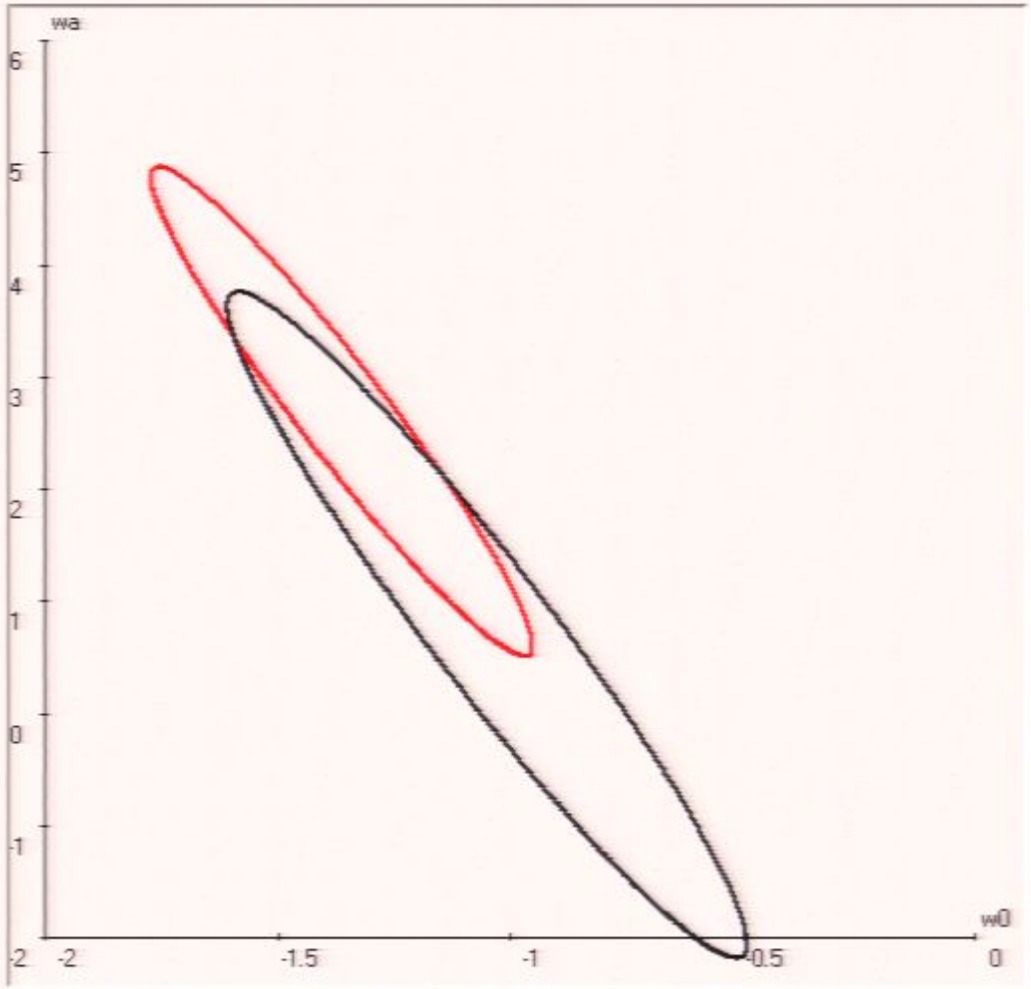

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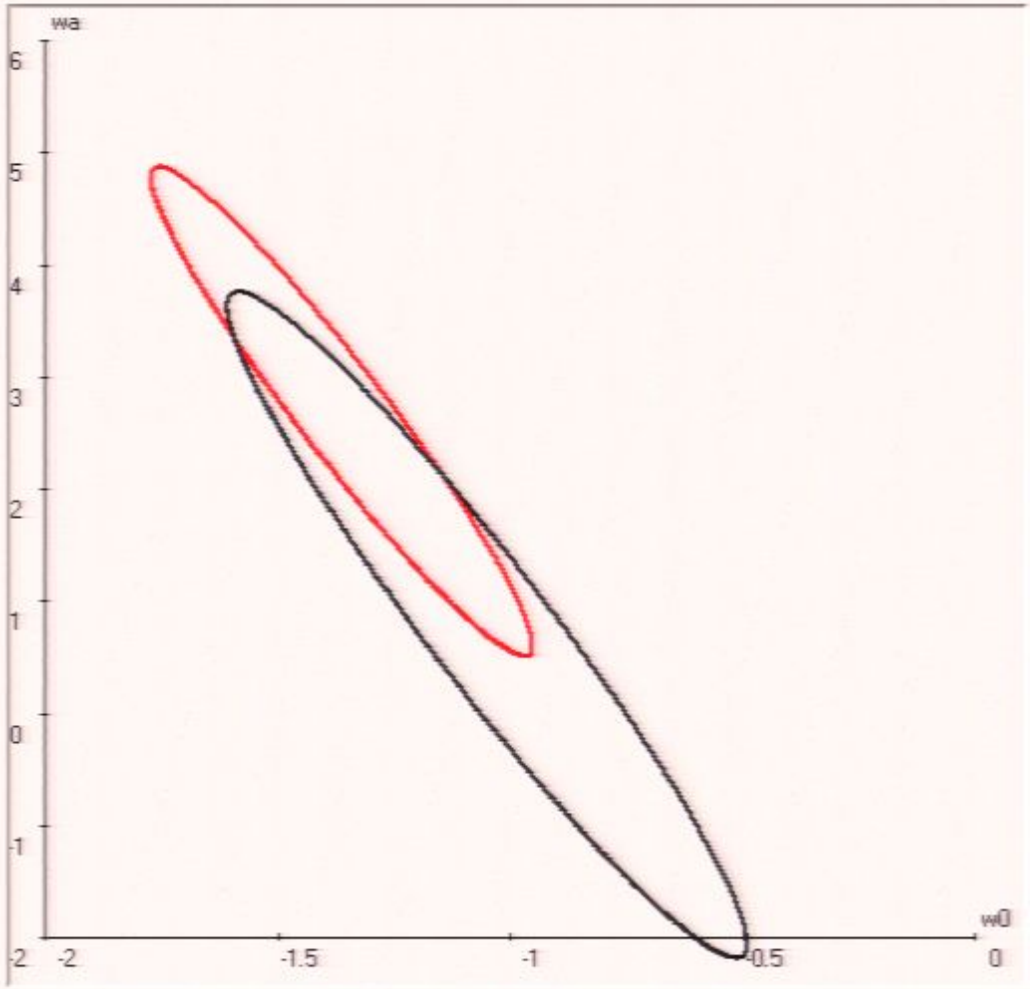

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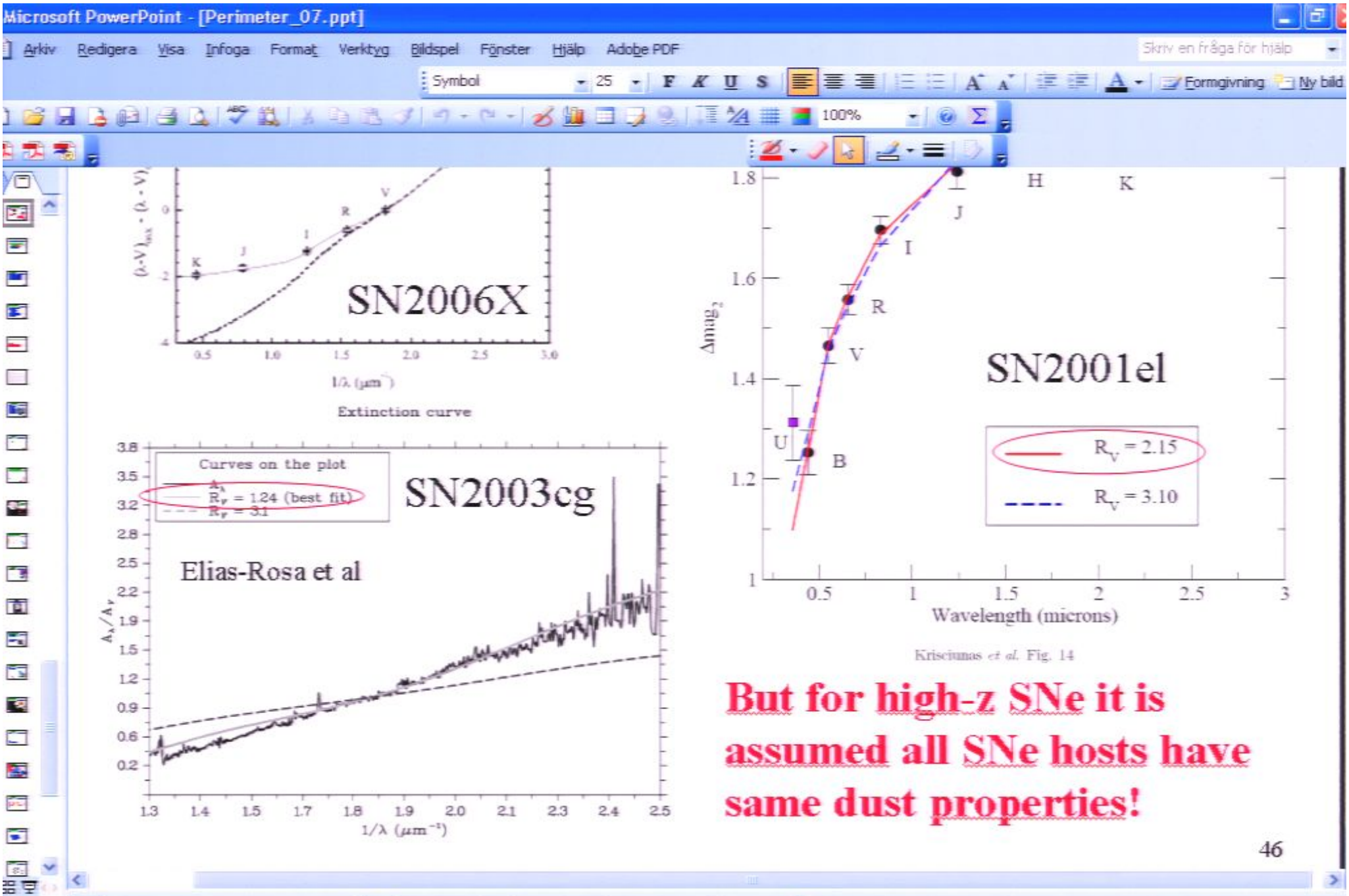

But for high-z SNe it is assumed all SNe hosts have same dust properties!

46

”Wish list” for future SN projects

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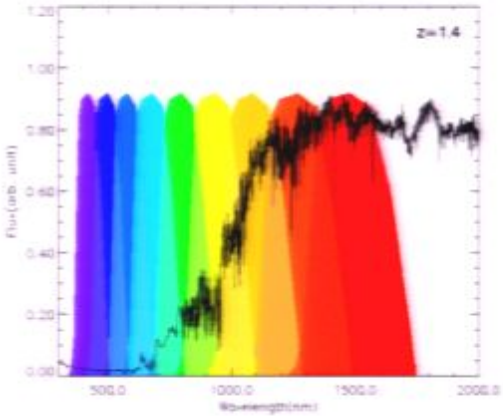

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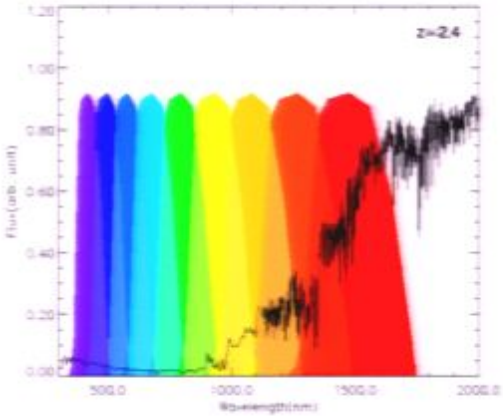

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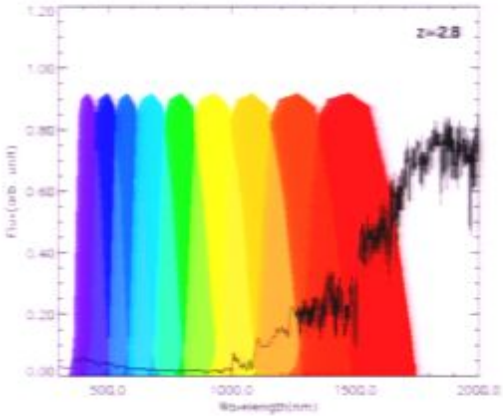

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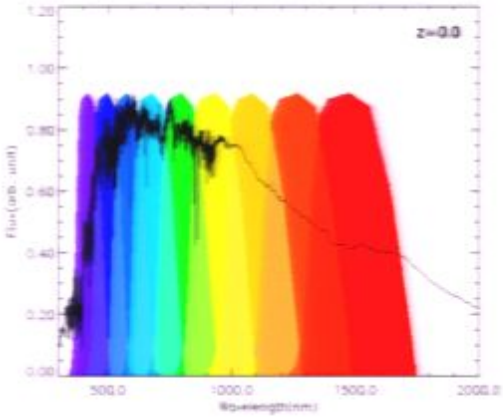

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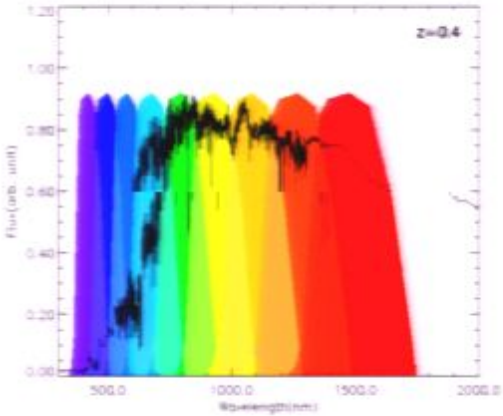

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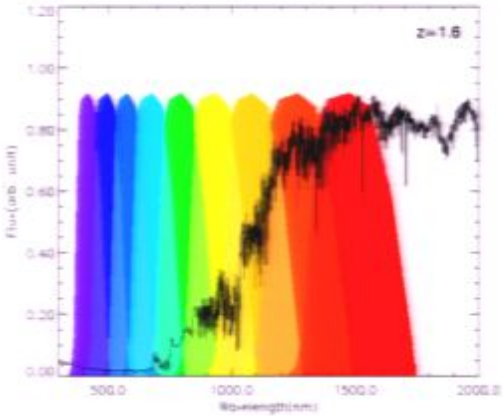

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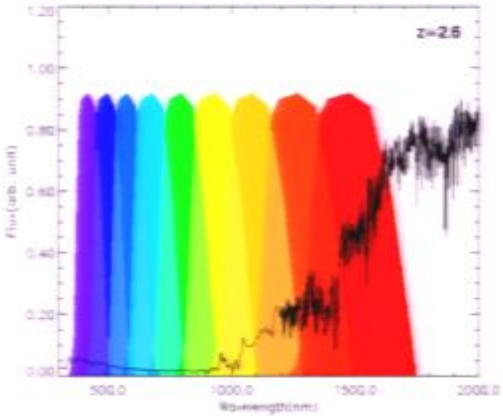

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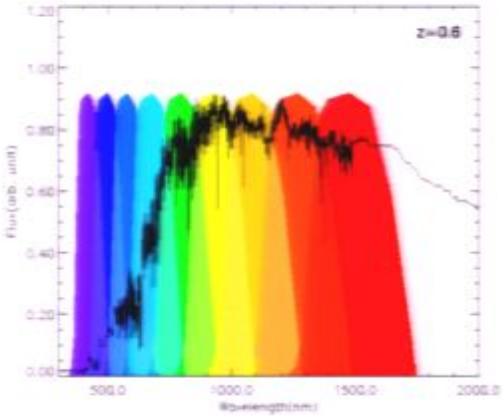

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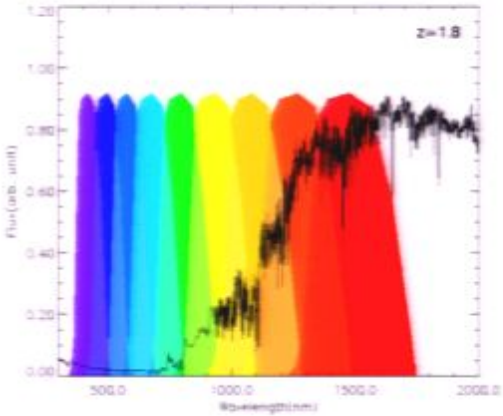

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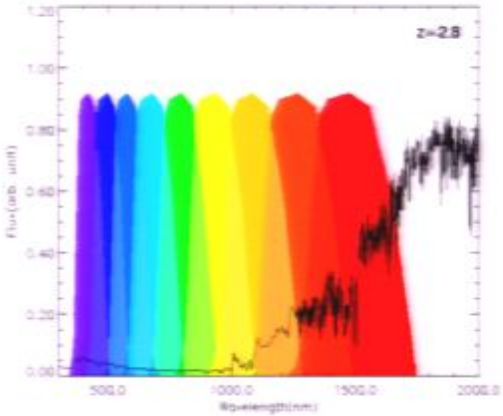

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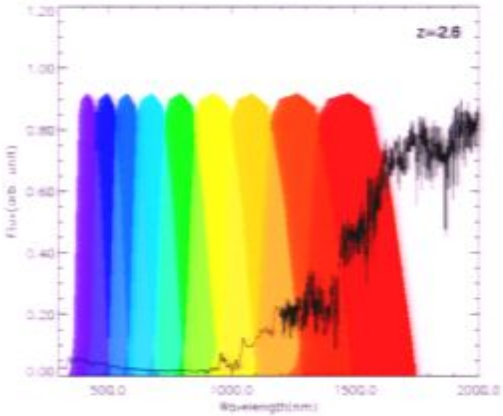
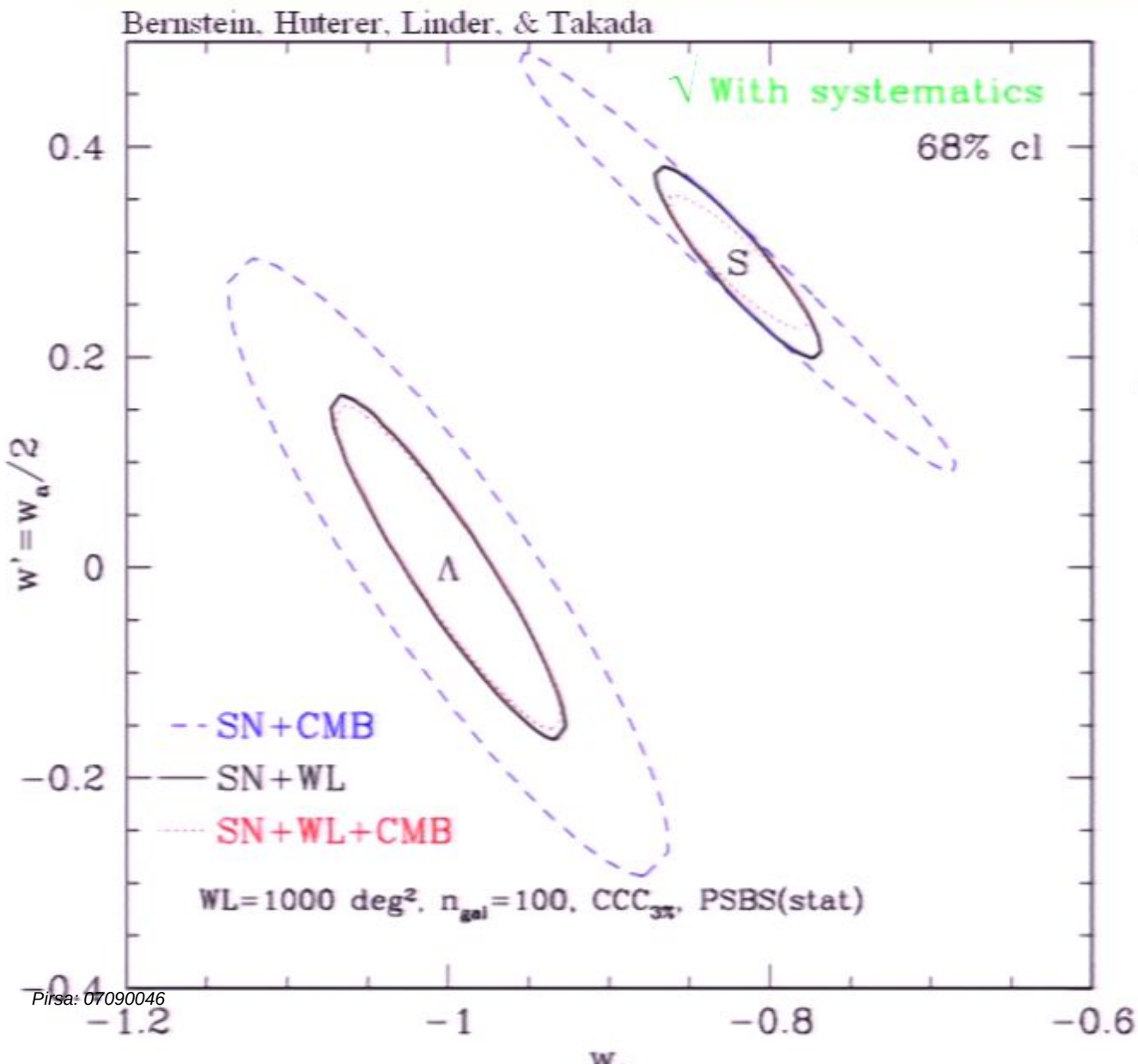


- Spectroscopic capability: hope to find a second parameter that sharpens the ”standarizable” candle.

SNe + Weak Lensing



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- **Independent test of flatness to 1-2%**
- **Complementary:**

w_0 to 5%, w' to 0.11

+baryon oscillations?

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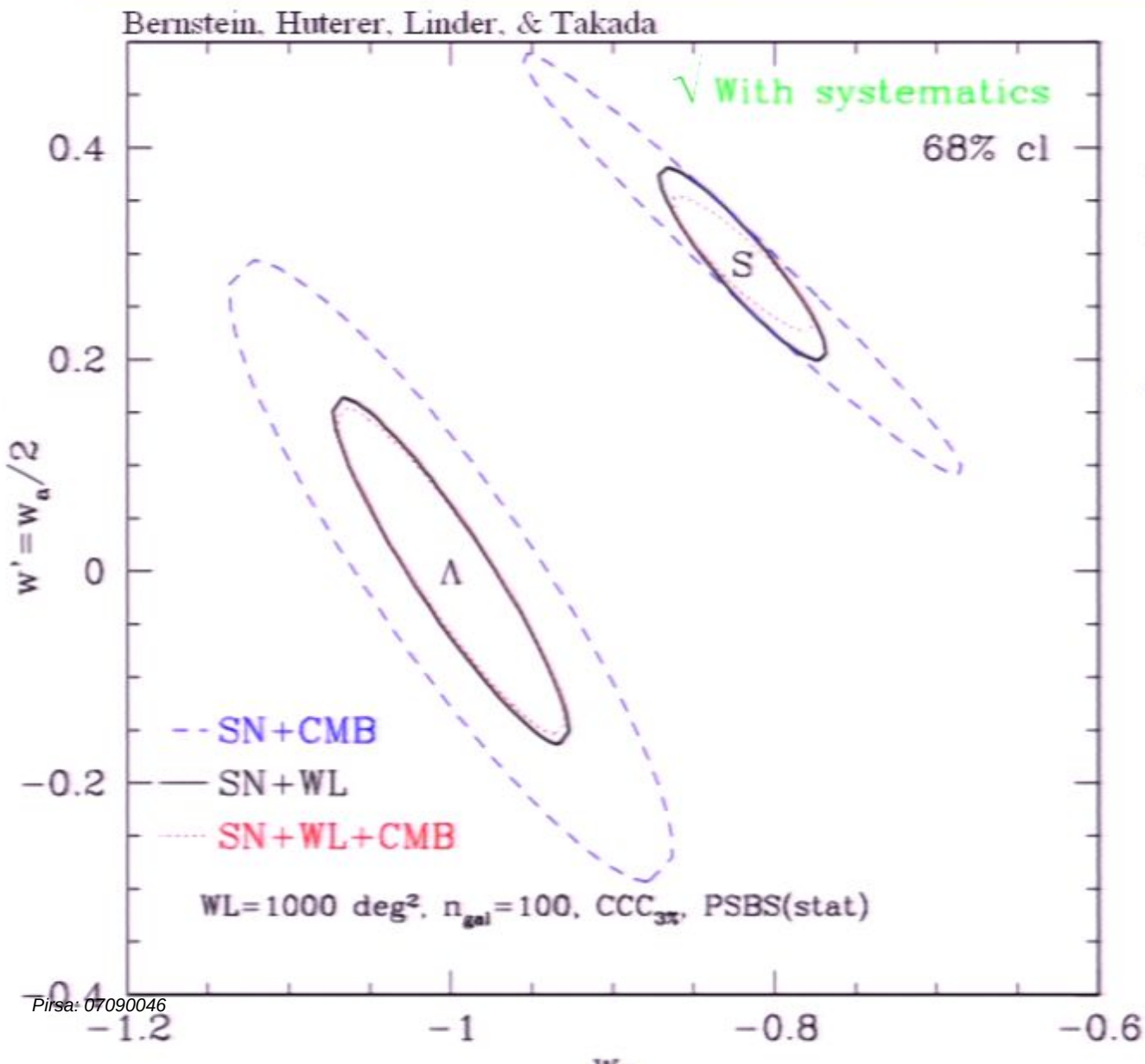

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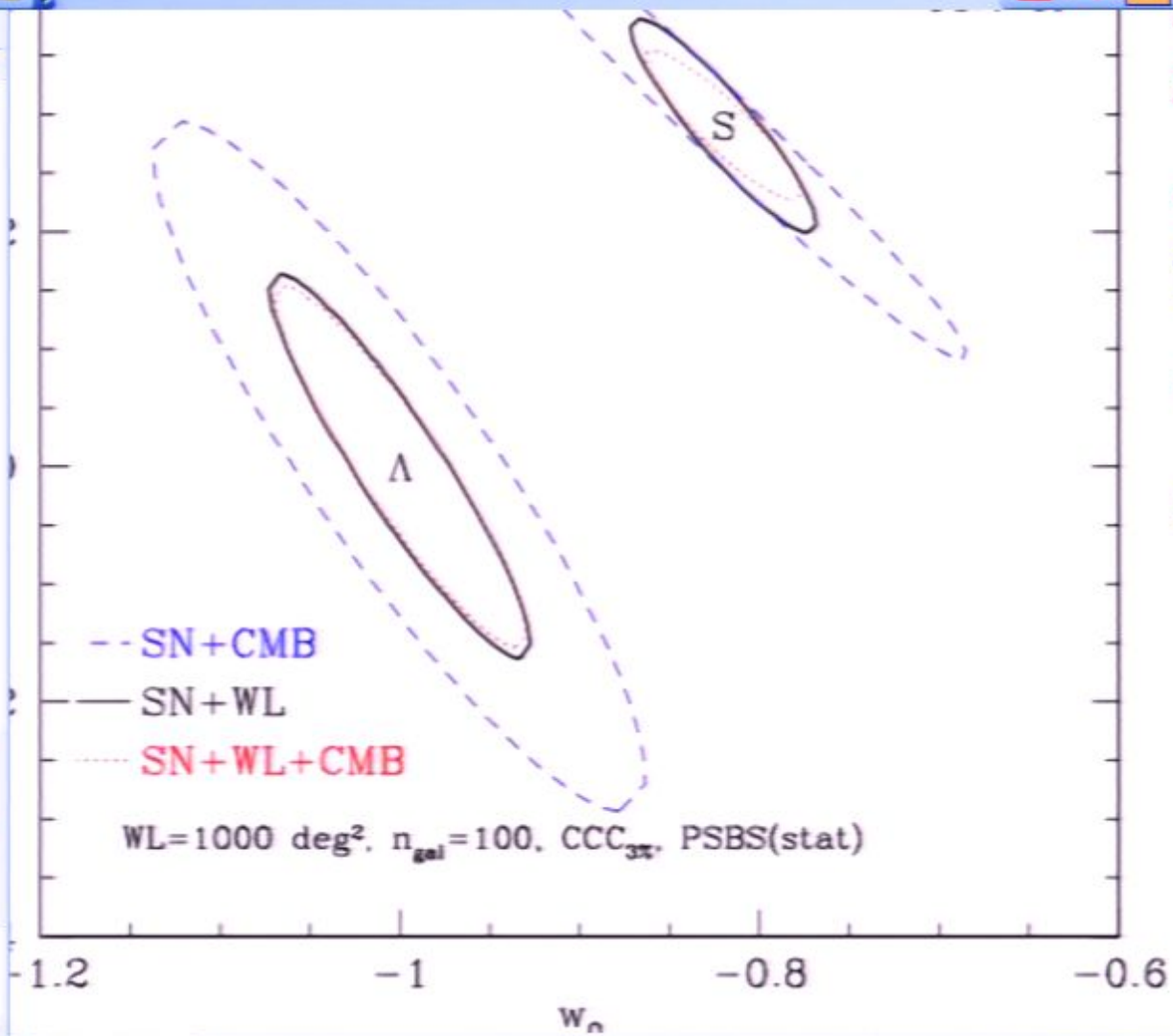

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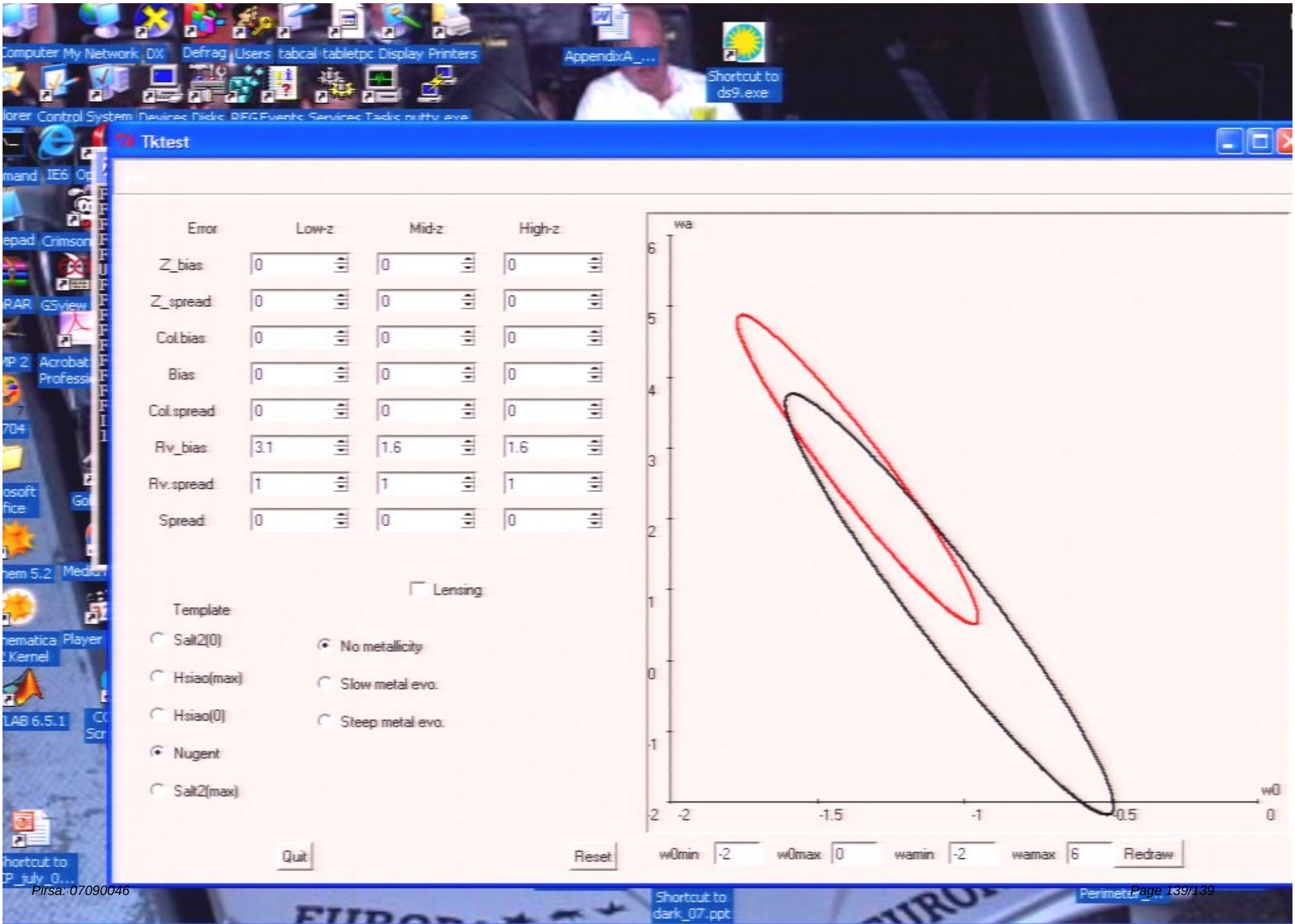
Tktest
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