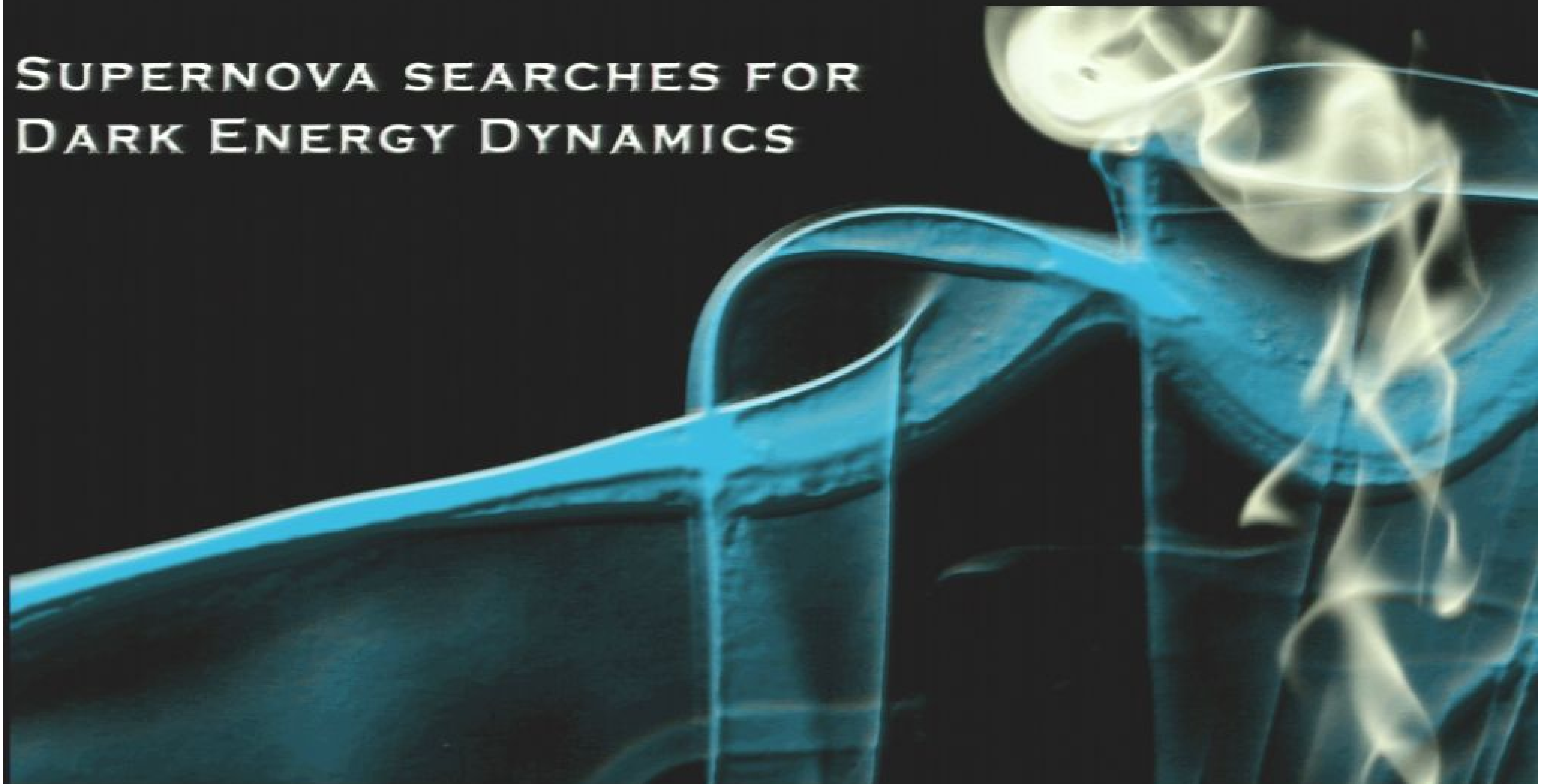
Title: Supernova Searches for Dark Energy Dynamics

Date: Sep 01, 2009 02:00 PM

URL: http://pirsa.org/09090009

Abstract: We present the first year SDSS-II Supernova Survey results and their implications for cosmology and future supernova surveys. We then discuss challenges that face next-generation surveys, such as LSST, which will deliver of order a million supernovae without spectroscopic confirmation. As a way to address these challenges, we introduce BEAMS, a statistical method to do photometric supernova cosmology, and present a preliminary application to SDSS data. Finally we highlight the importance of future surveys such as LSST, given the surprising result that we may not detect dark energy dynamics for the next decade, if the dark energy scales during matter and radiation domination.

Supernova searches for Dark Energy Dynamics



Renée Hlozek
University of Oxford

OUTLINE

- SDSS-II SN results
- Photometric SN cosmology with BEAMS
- Elusive dark energy dynamics

Collaborators

Collaborators

BEAMS applied to the
SDSS-II SN Survey:

COLLABORATORS

BEAMS applied to the SDSS-II SN Survey:

Bruce Bassett, Martin Kunz,
Hubert Lampeitl, Bob Nichol,
Mat Smith, Adam Riess, Bridget Falck
and the SDSS-II SN collaboration

Collaborators

BEAMS applied to the SDSS-II SN Survey:

Bruce Bassett, Martin Kunz,
Hubert Lampeitl, Bob Nichol,
Mat Smith, Adam Riess, Bridget Falck
and the SDSS-II SN collaboration

BBN+scaling constraints:

Collaborators

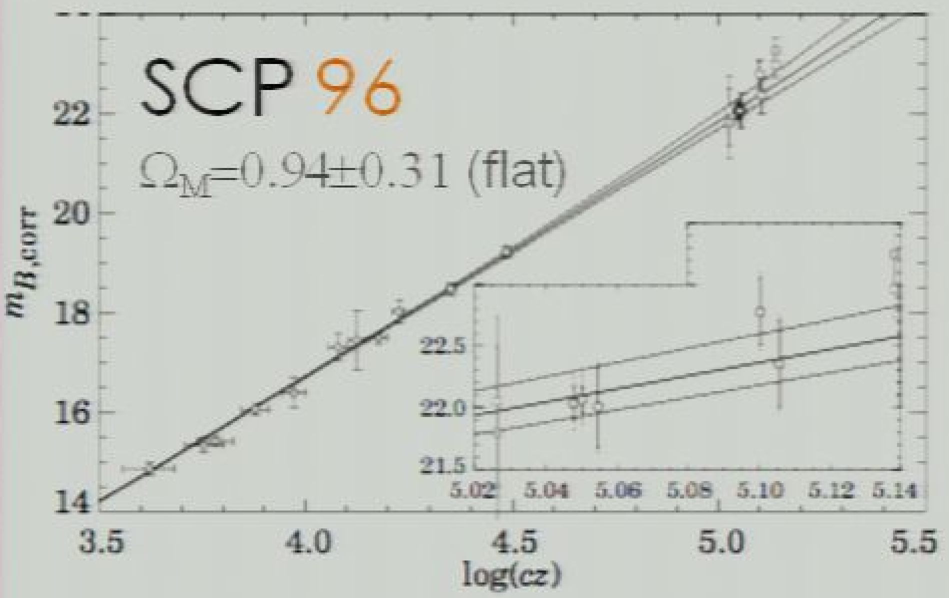
BEAMS applied to the SDSS-II SN Survey:

Bruce Bassett, Martin Kunz,
Hubert Lampeitl, Bob Nichol,
Mat Smith, Adam Riess, Bridget Falck
and the SDSS-II SN collaboration

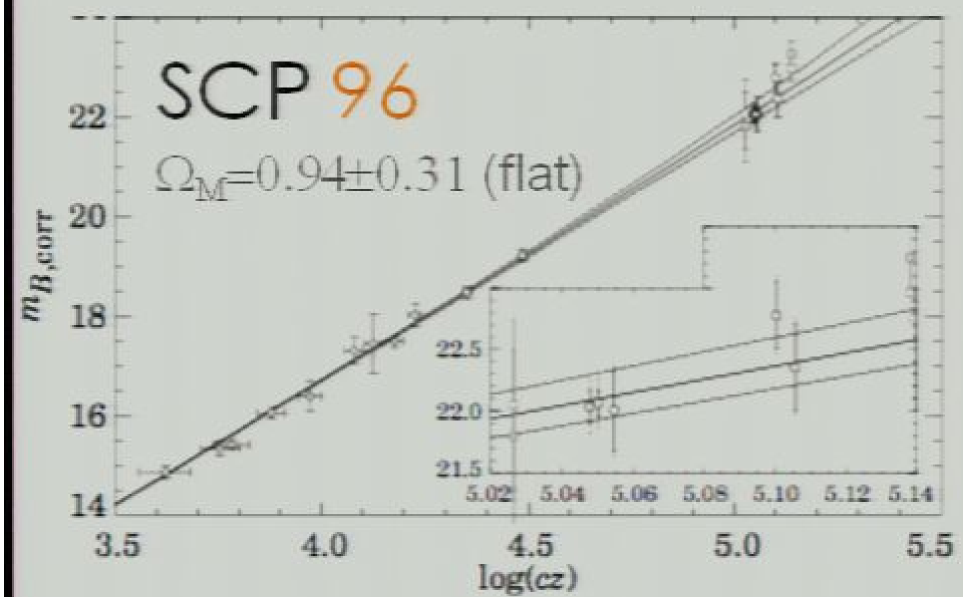
BBN+scaling constraints:

Bruce Bassett, Mike Brownstone,
Antonio Cardoso, Marina Cortes,
Yabebal Fantaye, Jacques Kotze, Patrice
Okouma

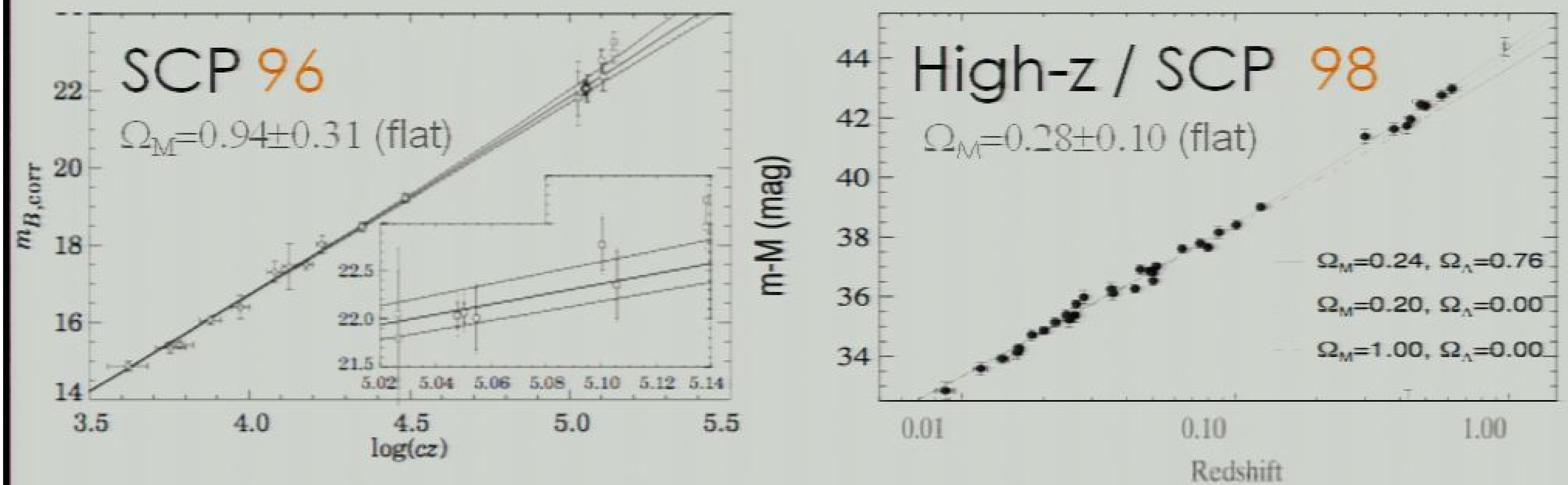
Evolution of the Hubble Diagram 1996-2009



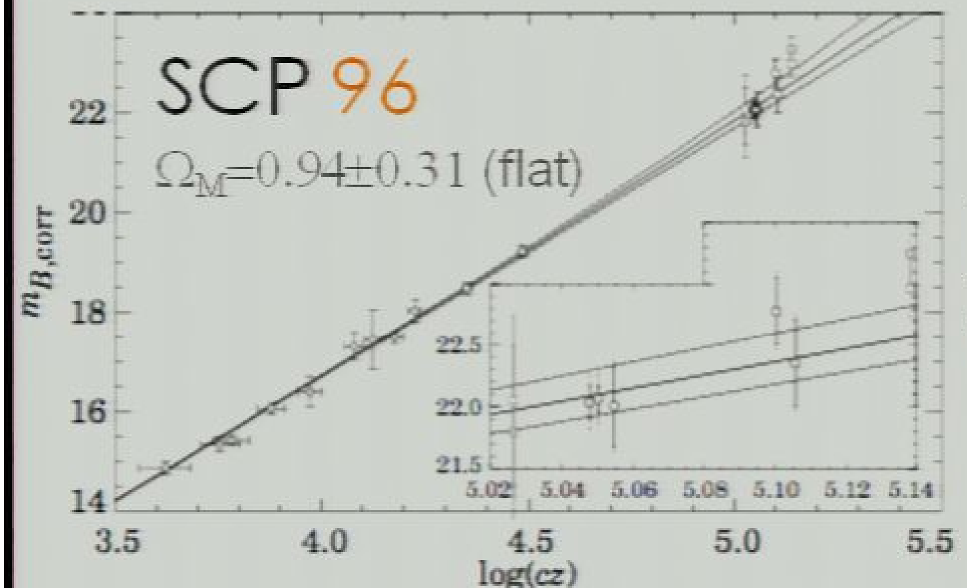
Evolution of the Hubble Diagram 1996-2009

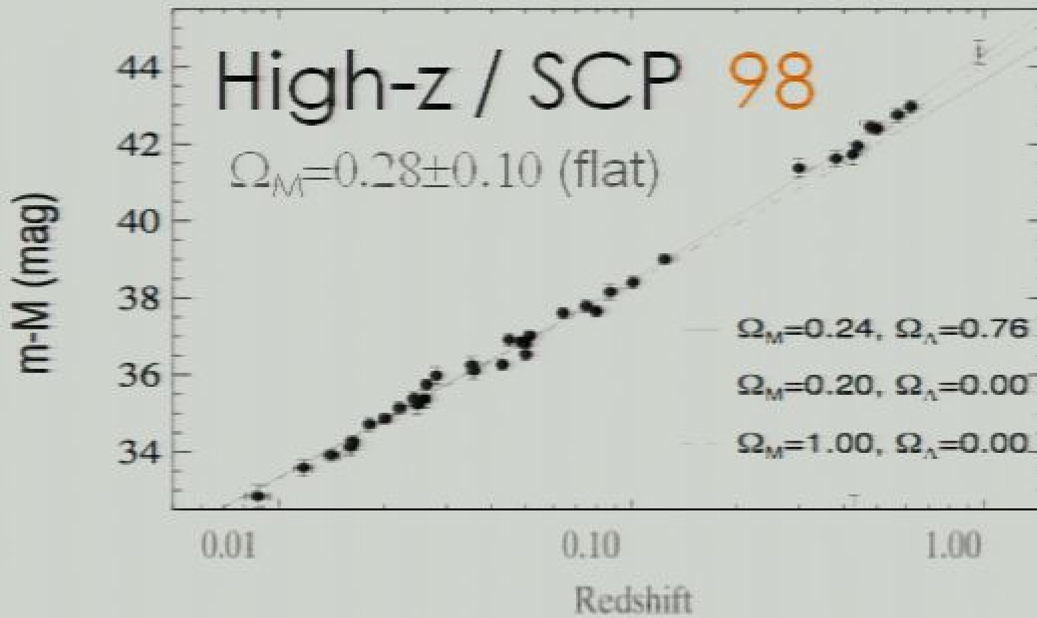


Evolution of the Hubble Diagram 1996-2009

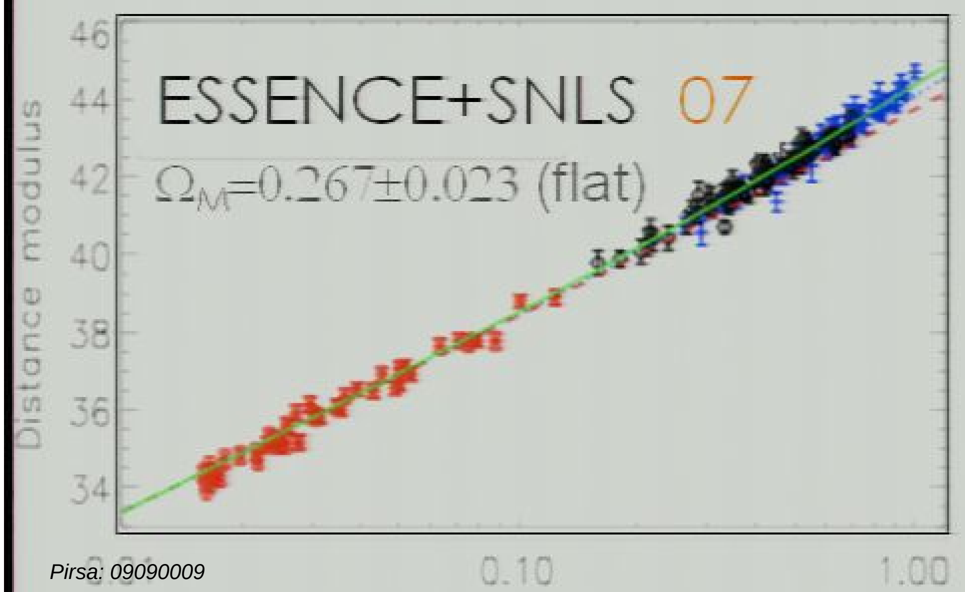


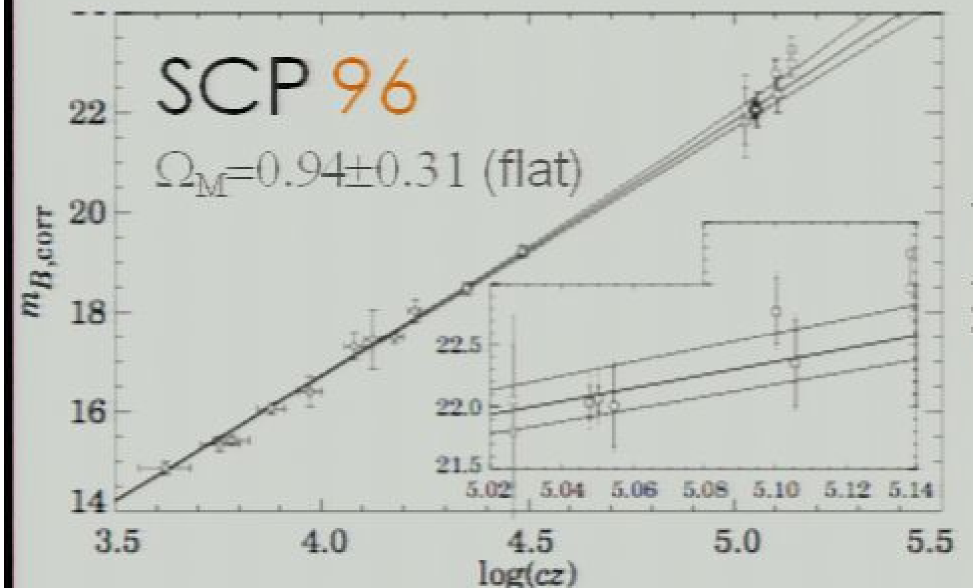
Evolution of the Hubble Diagram 1996-2009

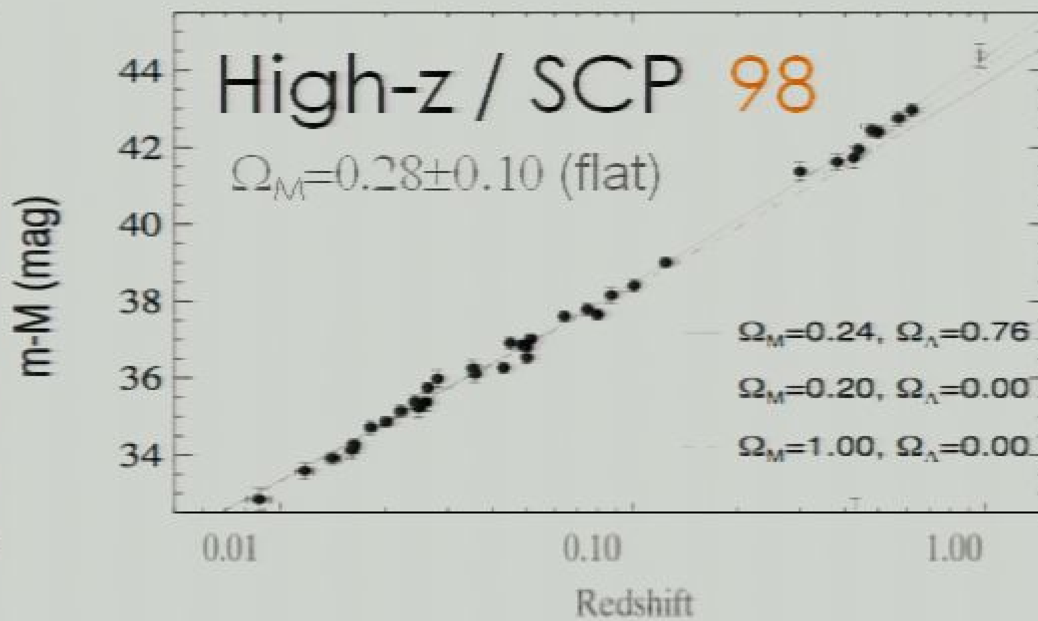




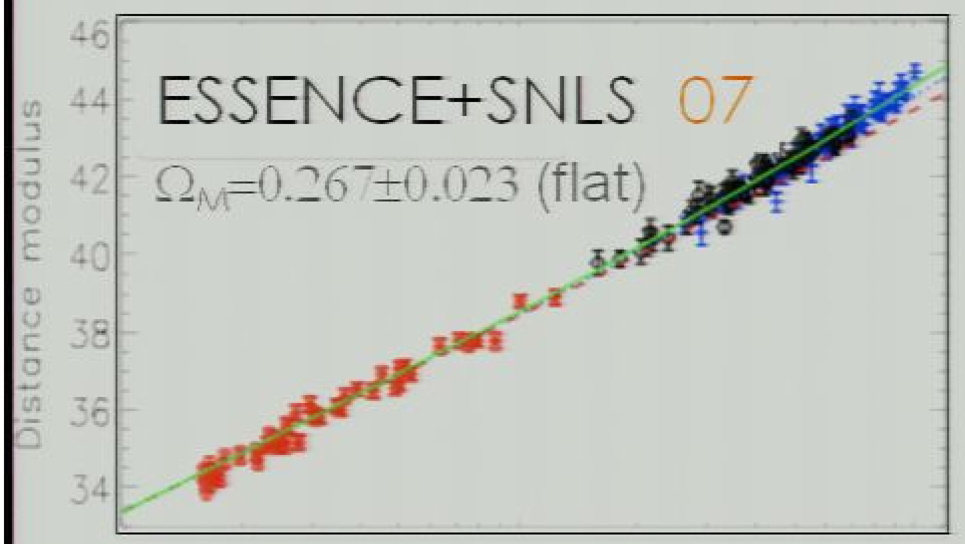
Evolution of the Hubble Diagram 1996-2009

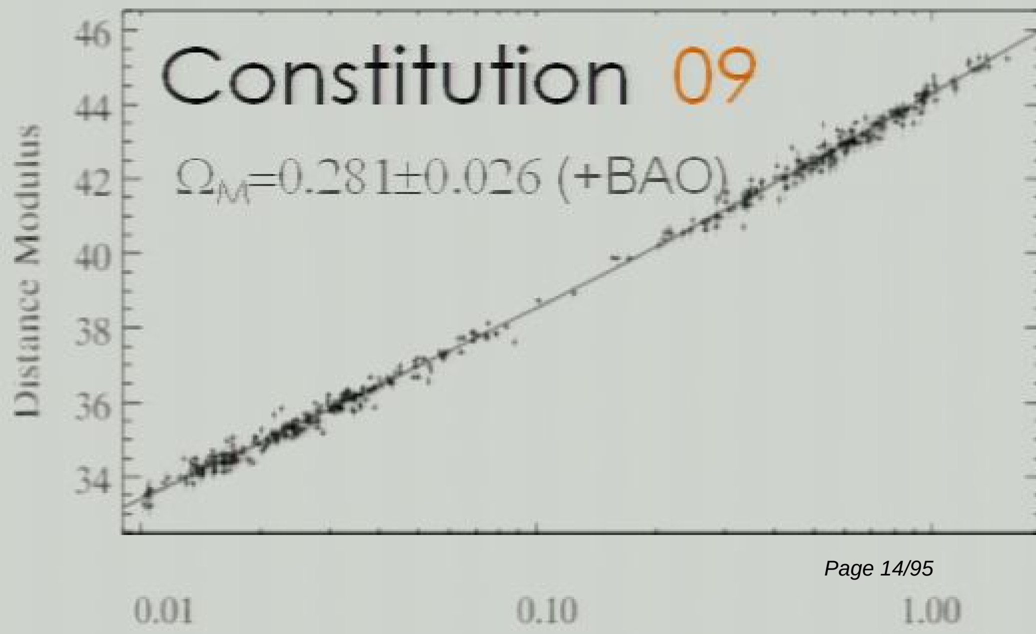


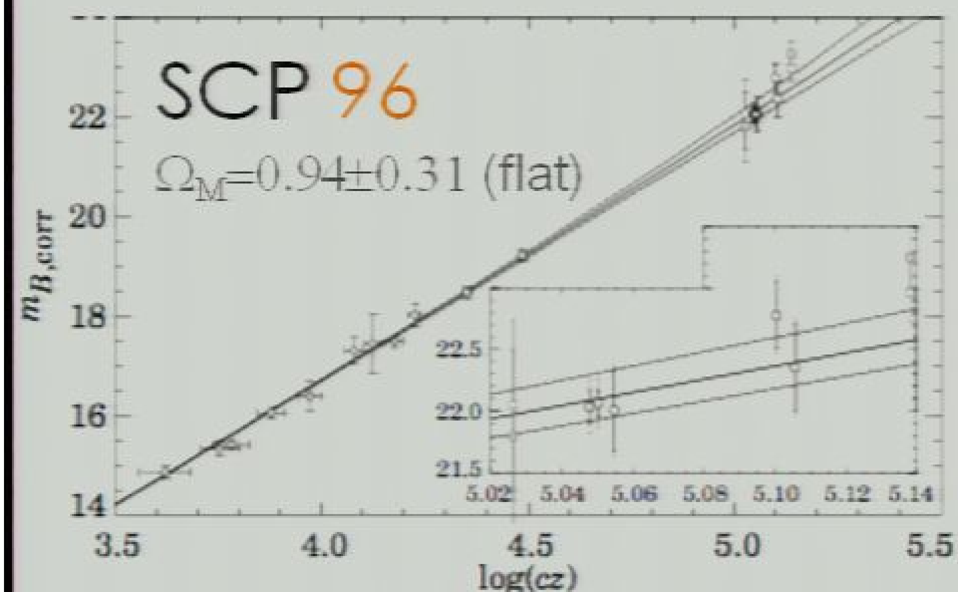


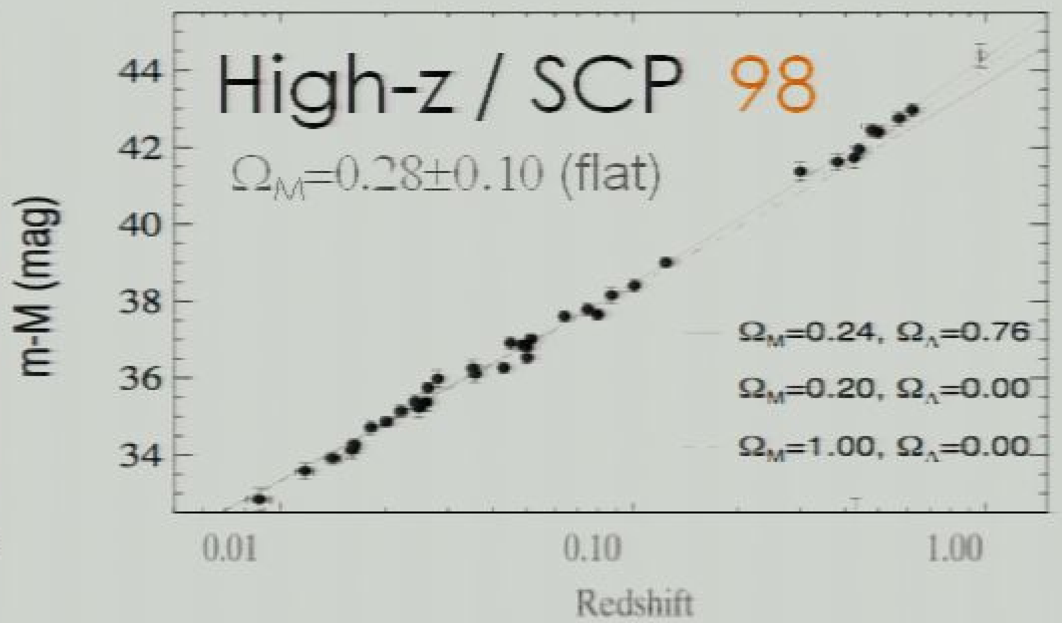


Evolution of the Hubble Diagram 1996-2009

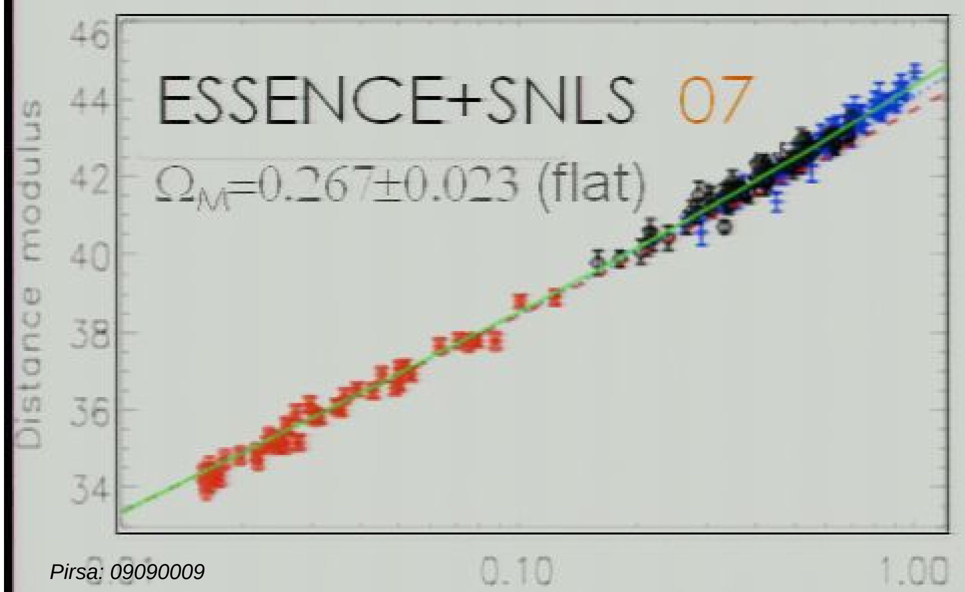


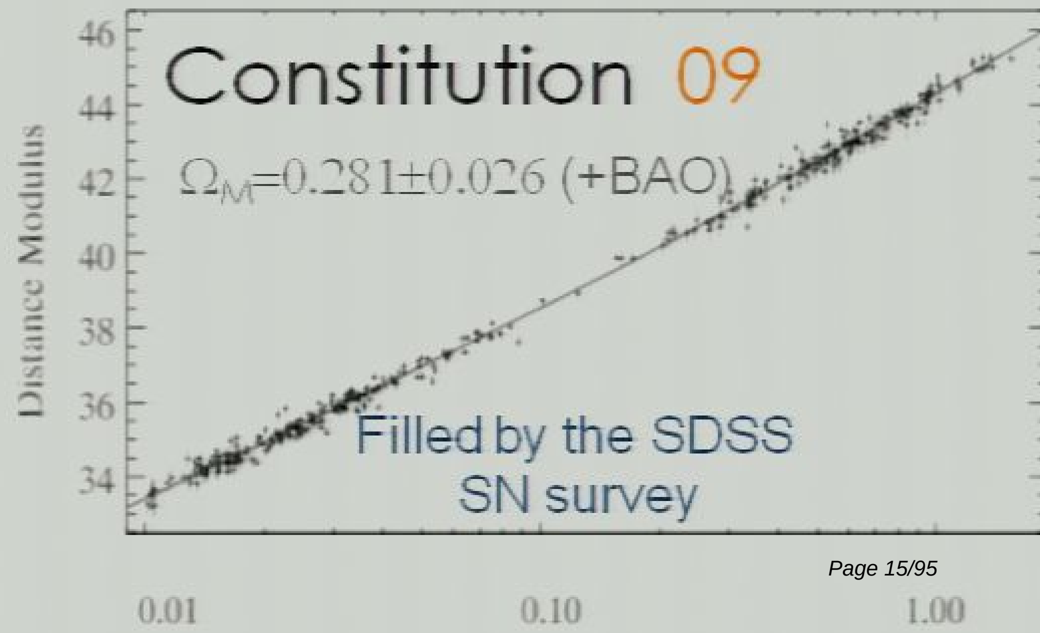






Evolution of the Hubble Diagram 1996-2009





Hot off the press

FIRST-YEAR SLOAN DIGITAL SKY SURVEY-II (SDSS-II) SUPERNOVA RESULTS: HUBBLE DIAGRAM AND COSMOLOGICAL PARAMETERS

Richard Kessler,[1,2] Andrew C. Becker,[3] David Cinabro,[4] Jake Vanderplas,[3] Joshua A. Frieman,[2,1,5]
John Marriner,[5] Tamara M Davis,[6,7] Benjamin Dilday,[8] Jon Holtzman,[9] Saurabh W. Jha,[8] Hubert Lampeitl,[10]
Masao Sako,[11] Mathew Smith,[1012] Chen Zheng,[32] Robert C. Nichol,[10] Bruce Bassett,[12,13] Ralf Bender,[20]
Darren L. Depoy,[14] Mamoru Doi,[15,16] Ed Elson,[12] Alexei V. Filippenko,[17] Ryan J. Foley,[17,18]
Peter M. Garnavich,[19] Ulrich Hopp,[20] Yutaka Ihara,[15,21] William Ketzeback,[22] W. Kollatschny,[24]
Kohki Konishi,[27] Jennifer L. Marshall,[14] Russet J. McMillan,[22] Gajus Miknaitis,[37,5] Tomoki Morokuma,[23]
Edvard Mörtsell,[25] Kaike Pan,[22] Jose Luis Prieto,[26] Michael W. Richmond,[29] Adam G. Riess,[30,31]
Roger Romani,[32] Donald P. Schneider,[33] Jesper Sollerman,[7,28] Naohiro Takanashi,[23] Kouichi Tokita,[15,21]
Kurt van der Heyden,[35] J. C. Wheeler,[34] Naoki Yasuda,[27] and Donald York[1,36]

FIRST-YEAR SLOAN DIGITAL SKY SURVEY-II (SDSS-II) SUPERNOVA RESULTS: CONSTRAINTS ON NON-STANDARD COSMOLOGICAL MODELS

J. Sollerman[1,2], E. Mörtsell[3], T. M. Davis[1,4], M. Blomqvist[2], B. Bassett[5,6], A. C. Becker[7], D. Cinabro[8],
A. V. Filippenko[9], R. J. Foley[9,10,11], J. Frieman[12,13,14], P. Garnavich[15], H. Lampeitl[16], J. Marriner[14],
. Miquel[17,18], R. C. Nichol[16], M. W. Richmond[19], M. Sako[20], D. P. Schneider[21], M. Smith[5,6,16], J. T. Vanderplas[7]
and J. C. Wheeler[22]

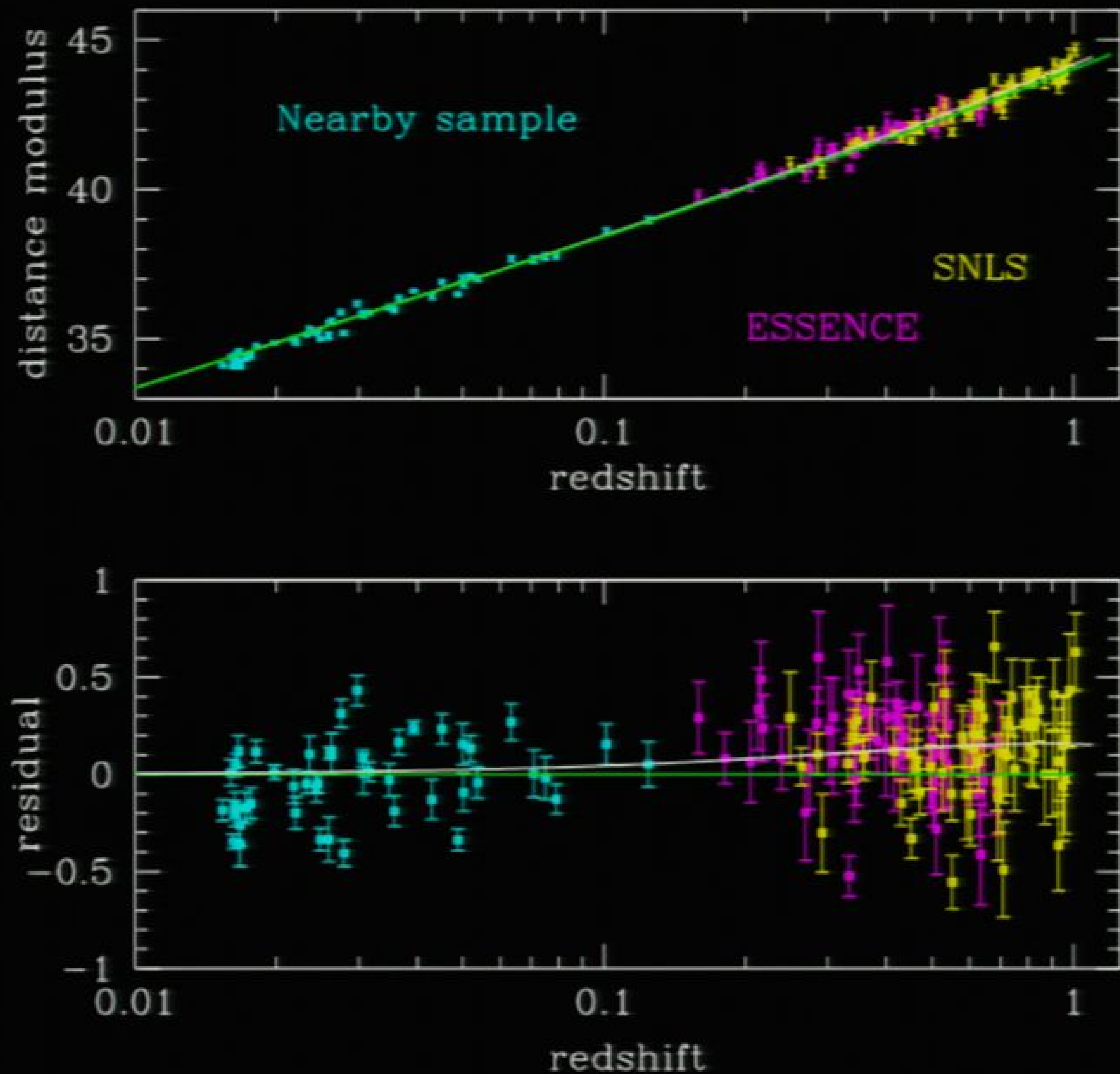
The Sloan Digital Sky Survey-II: Photometry and Supernova Ia Light Curves from the 2005 data

Jon A. Holtzman,[1] John Marriner,[2] Richard Kessler,[3,4] Masao Sako,[5,6] Ben Dilday,[3,7]
Joshua A. Frieman,[2,3,8] Donald P. Schneider,[9] Bruce Bassett,[10,11] Andrew Becker,[12]
David Cinabro,[13] Fritz DeJongh,[3] Darren L. Depoy,[14] Mamoru Doi,[15]
Peter M. Garnavich,[16] Craig J. Hogan,[12] Saurabh Jha,[5,17] Kohki Konishi,[18]
Hubert Lampeitl,[19,20] Jennifer L. Marshall,[14] David McGinnis,[3] Gajus Miknaitis,[3]
Robert C. Nichol,[20] Jose Luis Prieto,[14] Adam G. Reiss,[19,21] Michael W. Richmond,[22]
Roger Romani,[5] Mathew Smith,[20] Naohiro Takanashi,[15] Kouichi Tokita,[15]
Kurt van der Heyden,[11,23] Naoki Yasuda,[18] Chen Zheng[5]

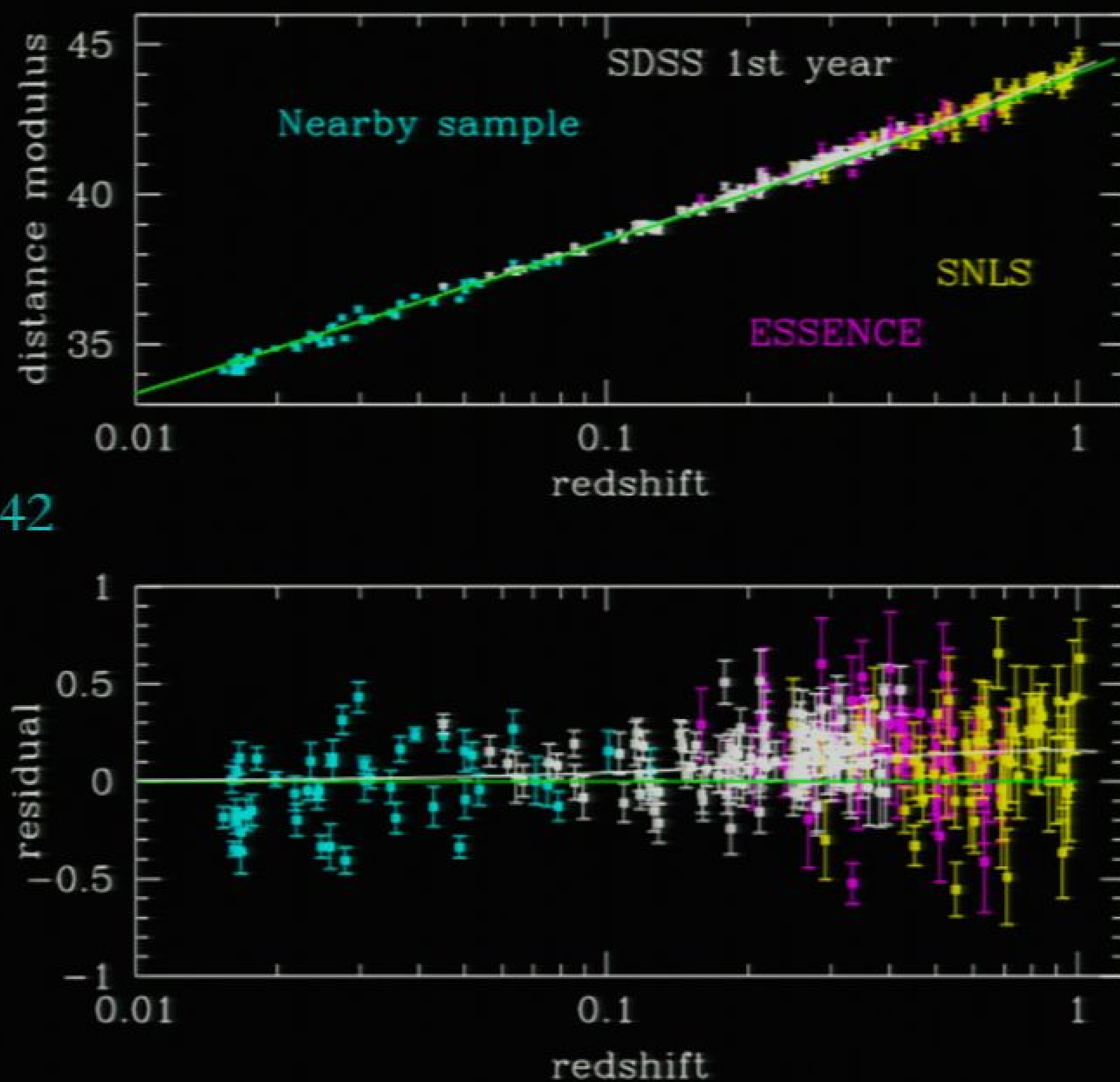
SDSS-II SN Survey

Scan 300 degrees every 2 days

~500 Sne in full 3 years



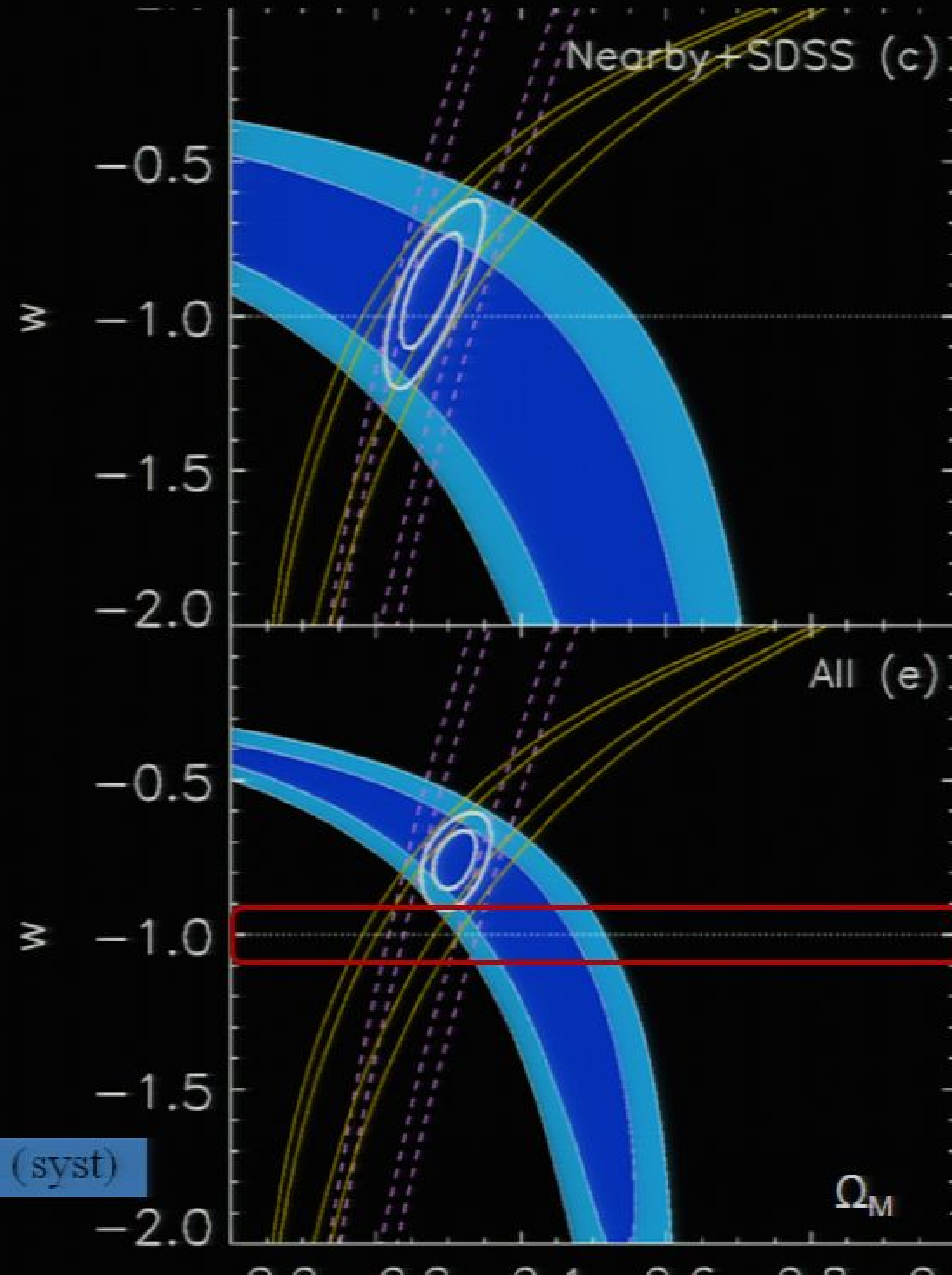
(Josh Frieman)



$0.04 < z < 0.42$

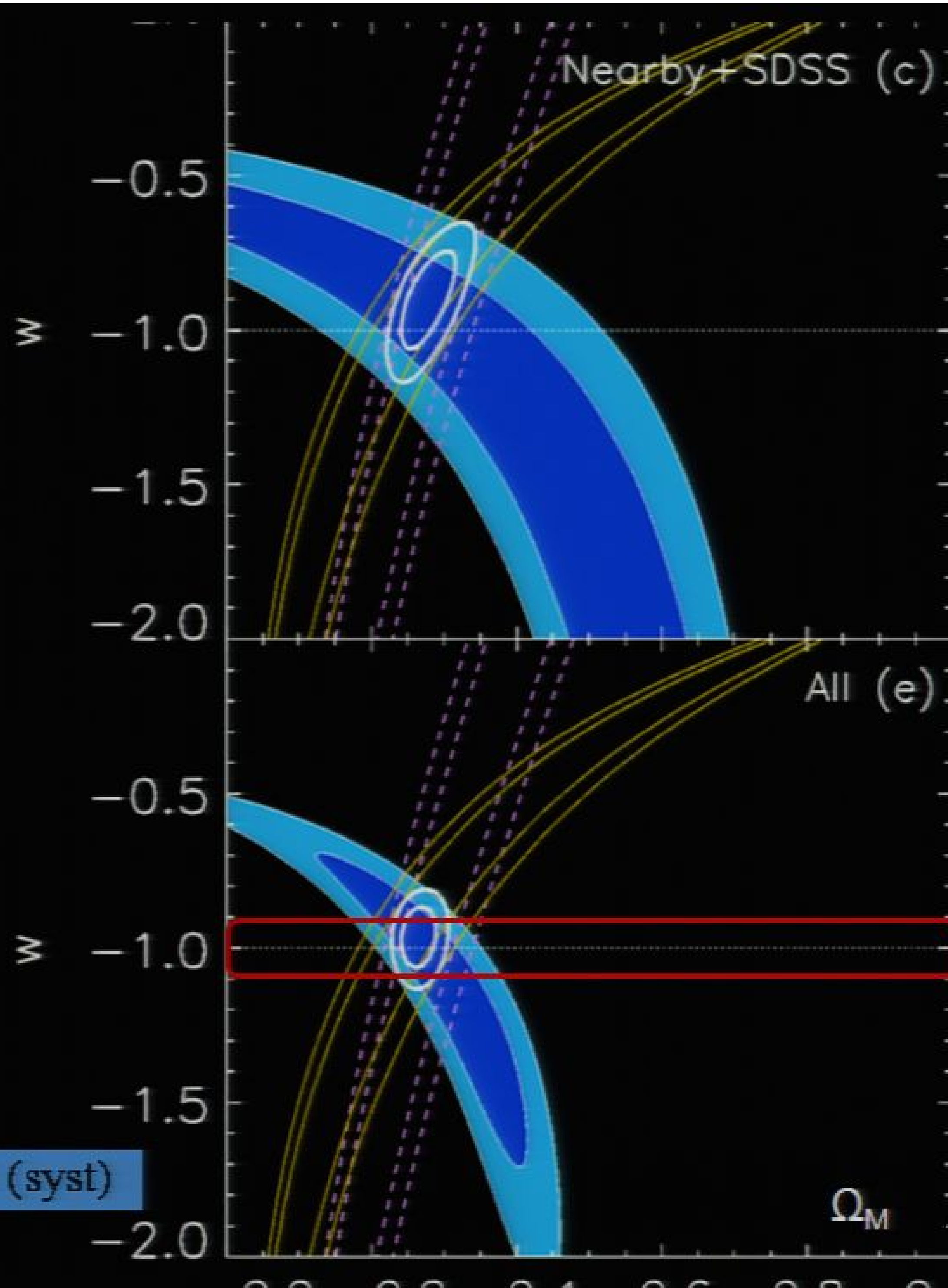
(Josh Frieman)

MLCS2k2 Fitter



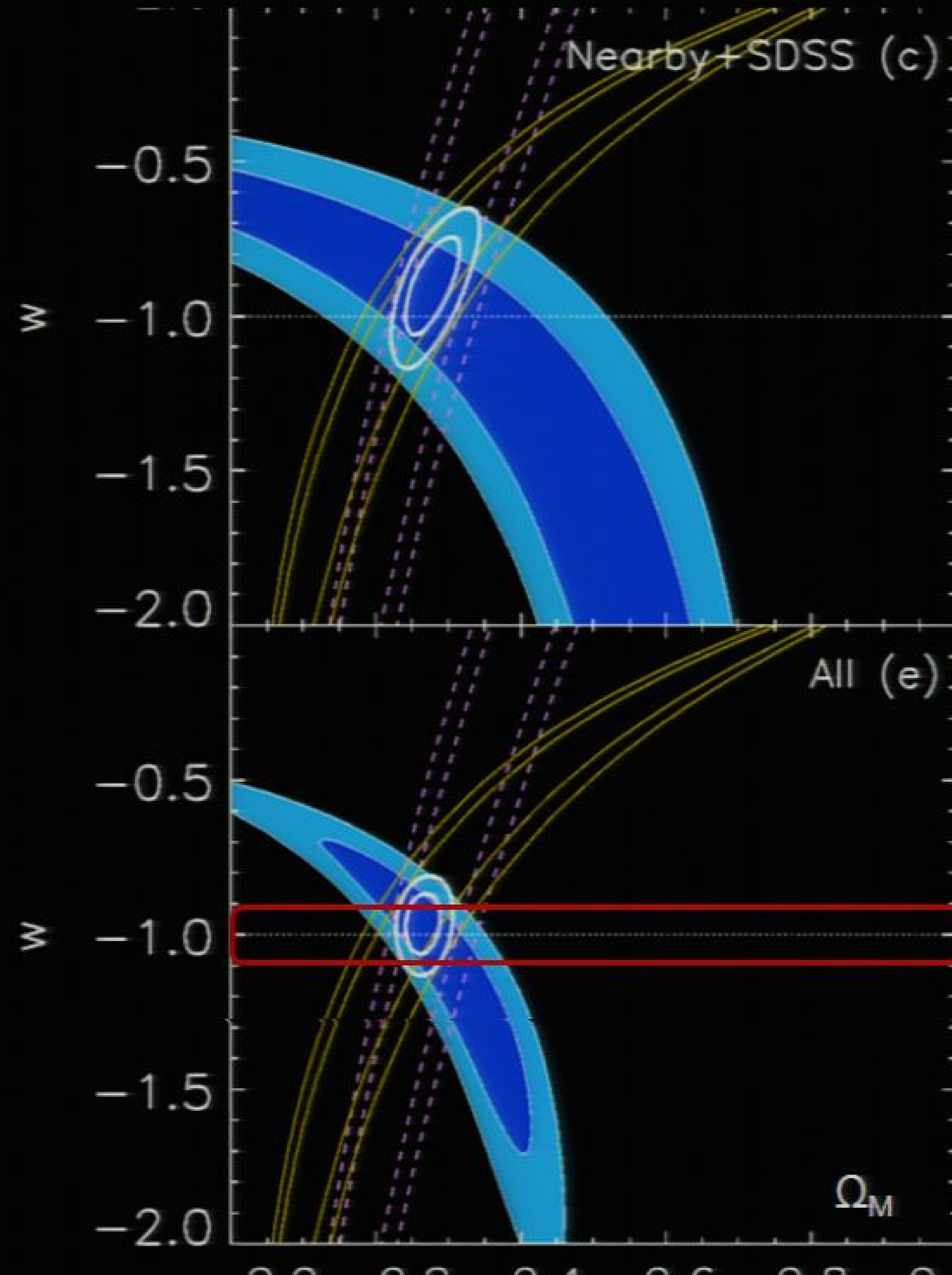
$= -0.76 \pm 0.07\,(\text{stat}) \pm 0.12\,(\text{syst})$

SALT-II Fitter

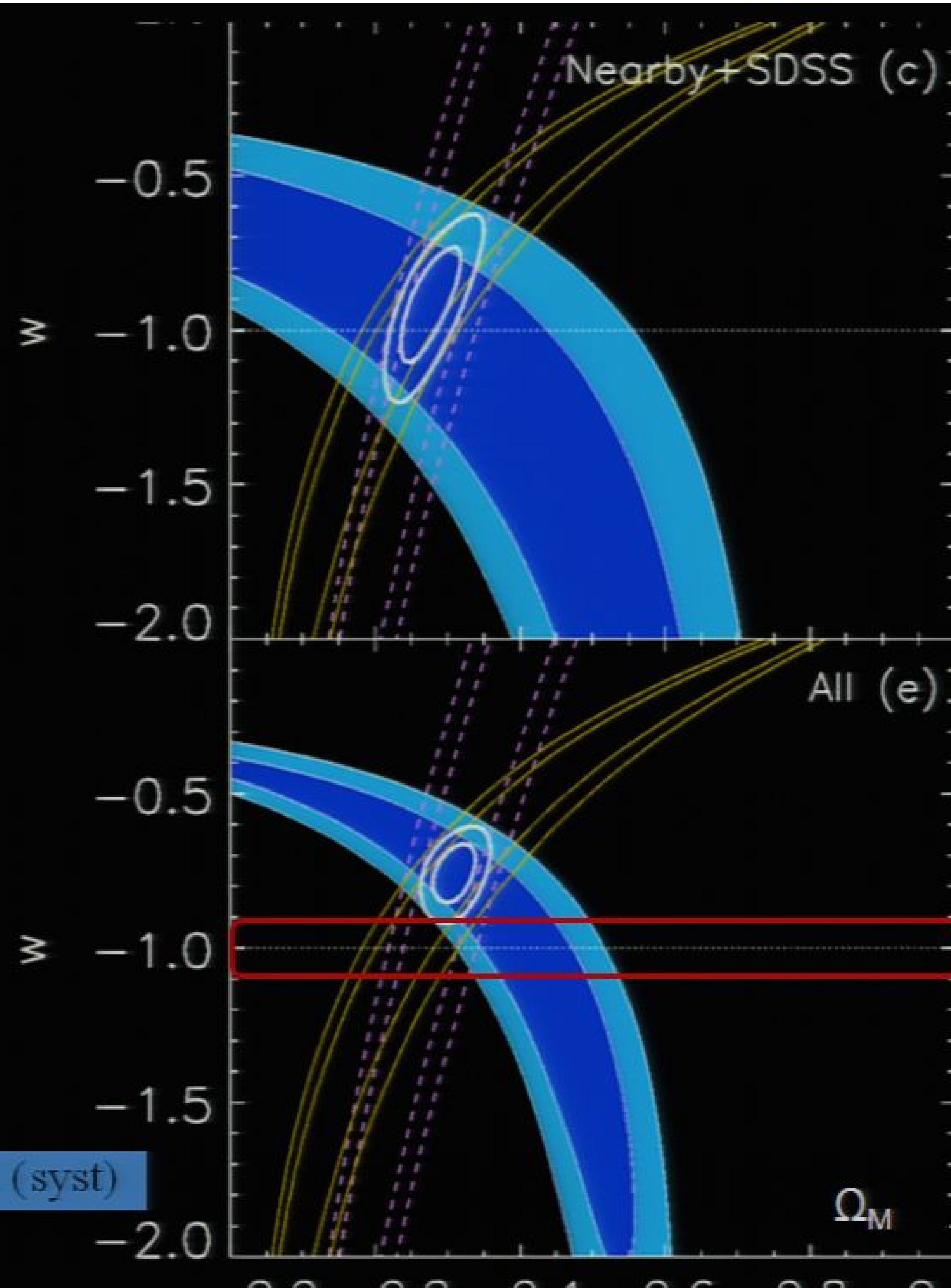


$w = -0.96 \pm 0.06\,(\text{stat}) \pm 0.12\,(\text{syst})$

SALT-II Fitter

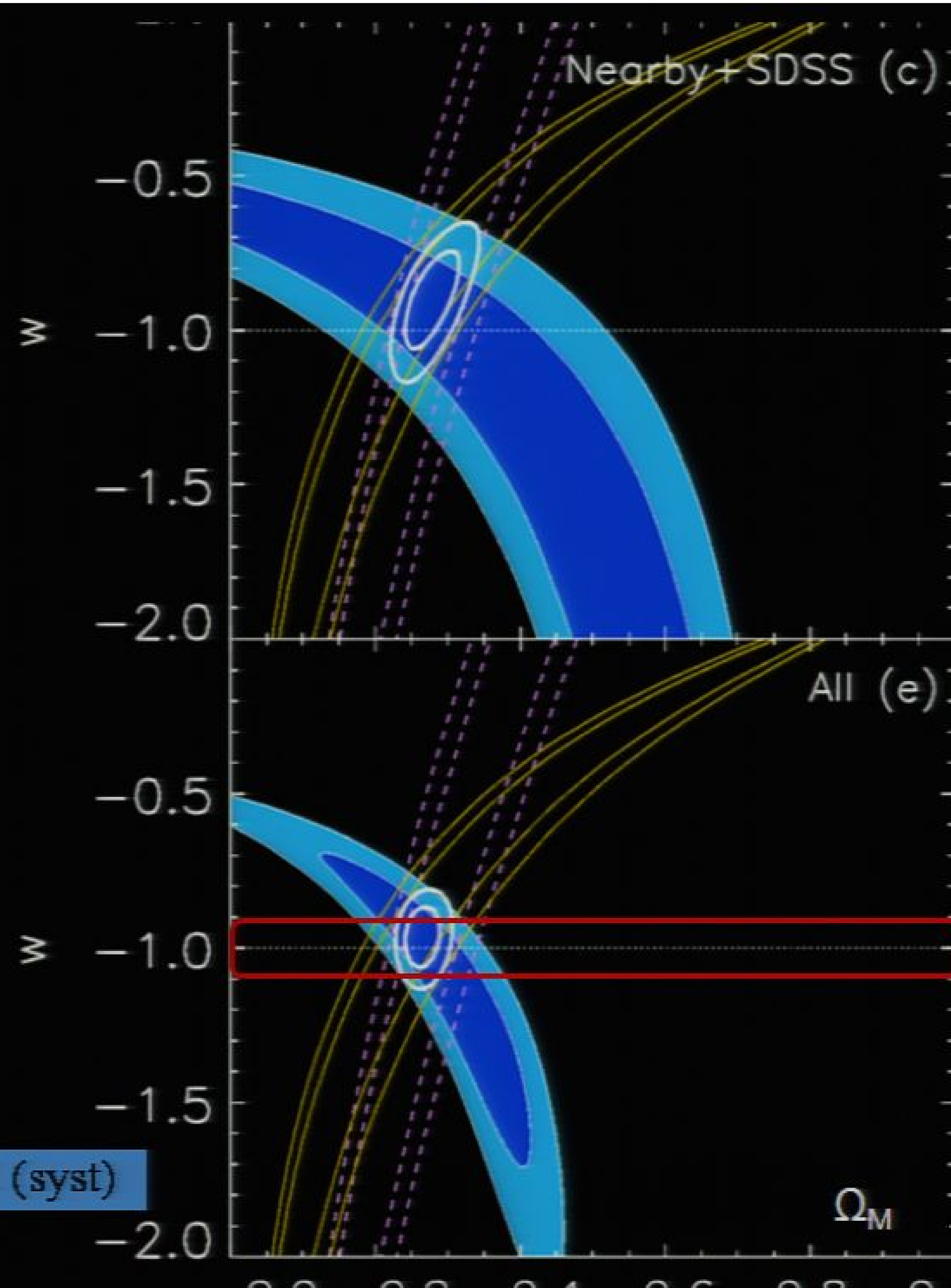


MLCS2k2 Fitter



$= -0.76 \pm 0.07$ (stat) ± 0.12 (syst)

SALT-II Fitter



$= -0.96 \pm 0.06\,(\text{stat}) \pm 0.12\,(\text{syst})$

Systematic Uncertainties

MLCS:

- U-band model trained only on low-redshift (observer-frame) U-band data (calibration, atmospheric variations)
- Assumes *all* excess color due to dust extinction (some of it must be); dust prior dominates at high-redshift

(Josh Frieman)

MLCS:

- U-band model trained only on low-redshift (observer-frame) U-band data (calibration, atmospheric variations)
- Assumes *all* excess color due to dust extinction (some of it must be); dust prior dominates at high-redshift

SALT:

- Global fit for color/dust parameter β: minimizing Hubble-scatter can lead to bias
- Trend toward bluer colors at high-z: if allow $\beta(z)$, see strong trend with redshift

(Josh Frieman)

MLCS:

• U-band model trained only on low-redshift (observer-frame) U-band data (calibration, atmospheric variations)

• Assumes *all* excess color due to dust extinction (some of it must be); dust prior dominates at high-redshift

SALT:

• Global fit for color/dust parameter β: minimizing Hubble-scatter can lead to bias

• Trend toward bluer colors at high-*z*: if allow β(*z*), see strong trend with redshift

Retrain and refine the models with newer data

(Josh Frieman)

MLCS:

- U-band model trained only on low-redshift (observer-frame) U-band data (calibration, atmospheric variations)
- Assumes *all* excess color due to dust extinction (some of it must be); dust prior dominates at high-redshift

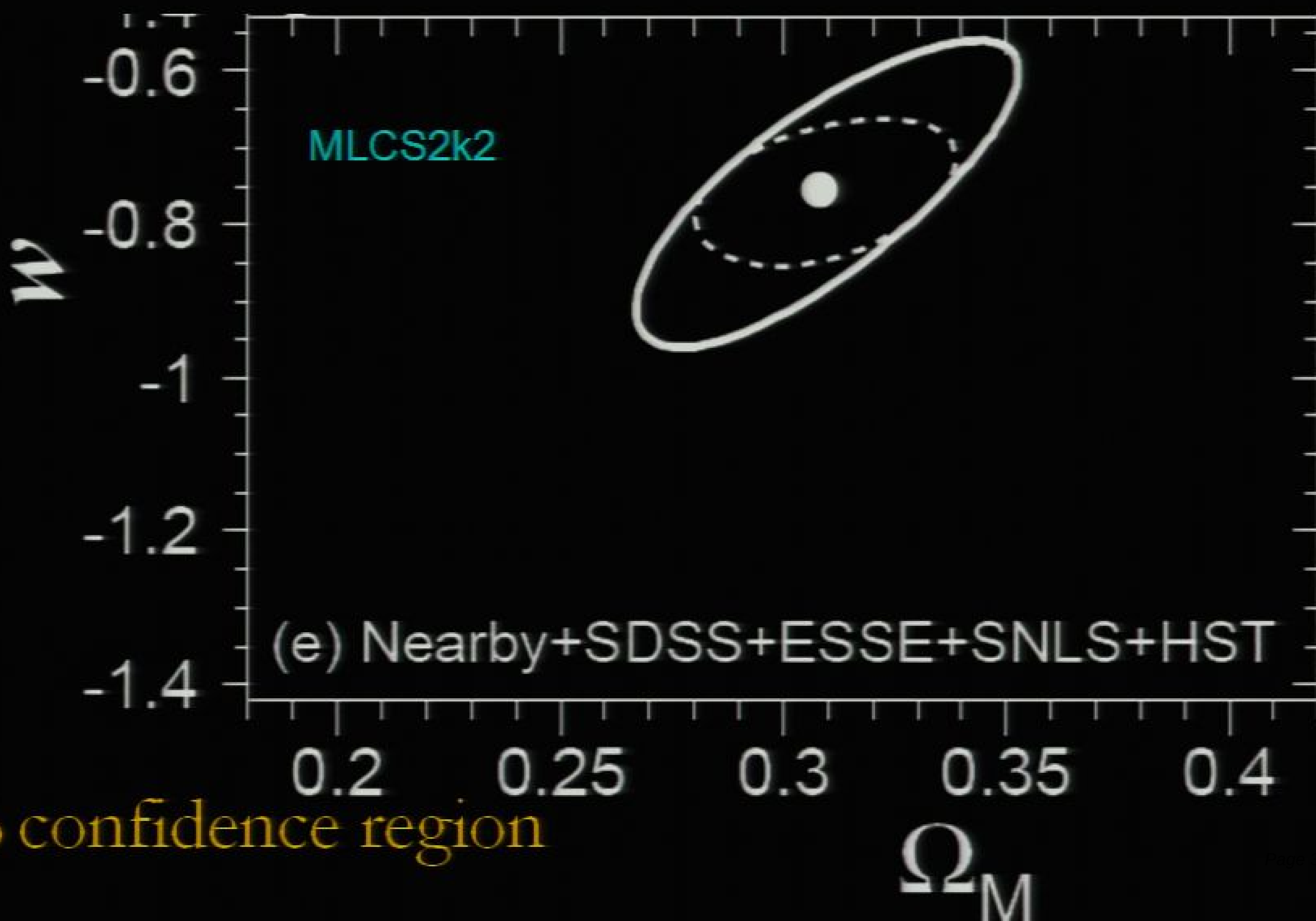
SALT:

- Global fit for color/dust parameter β: minimizing Hubble-scatter can lead to bias
- Trend toward bluer colors at high-z: if allow $\beta(z)$, see strong trend with redshift

Retrain and refine the models with newer data

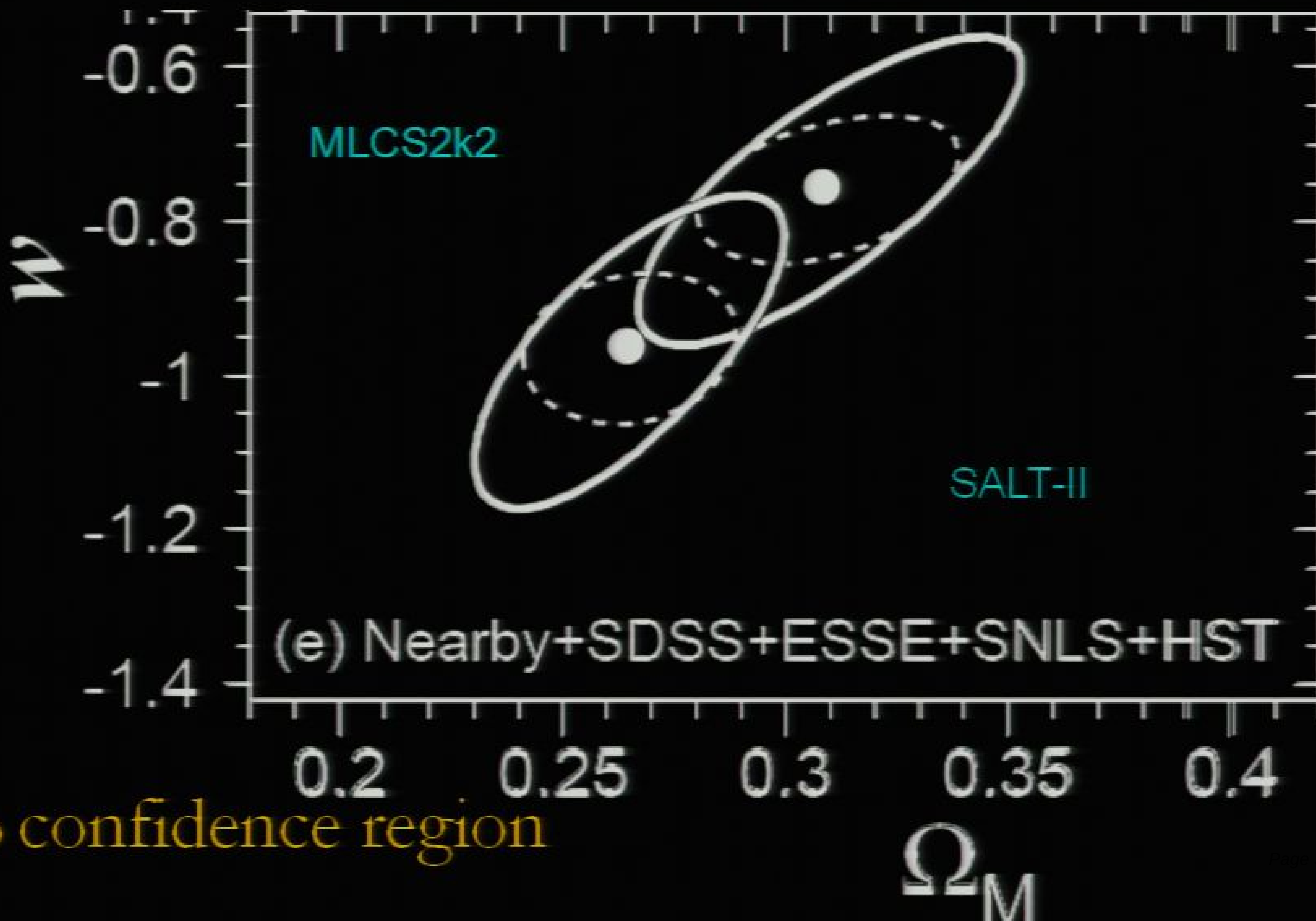
(Josh Frieman)

Systematic Uncertainties

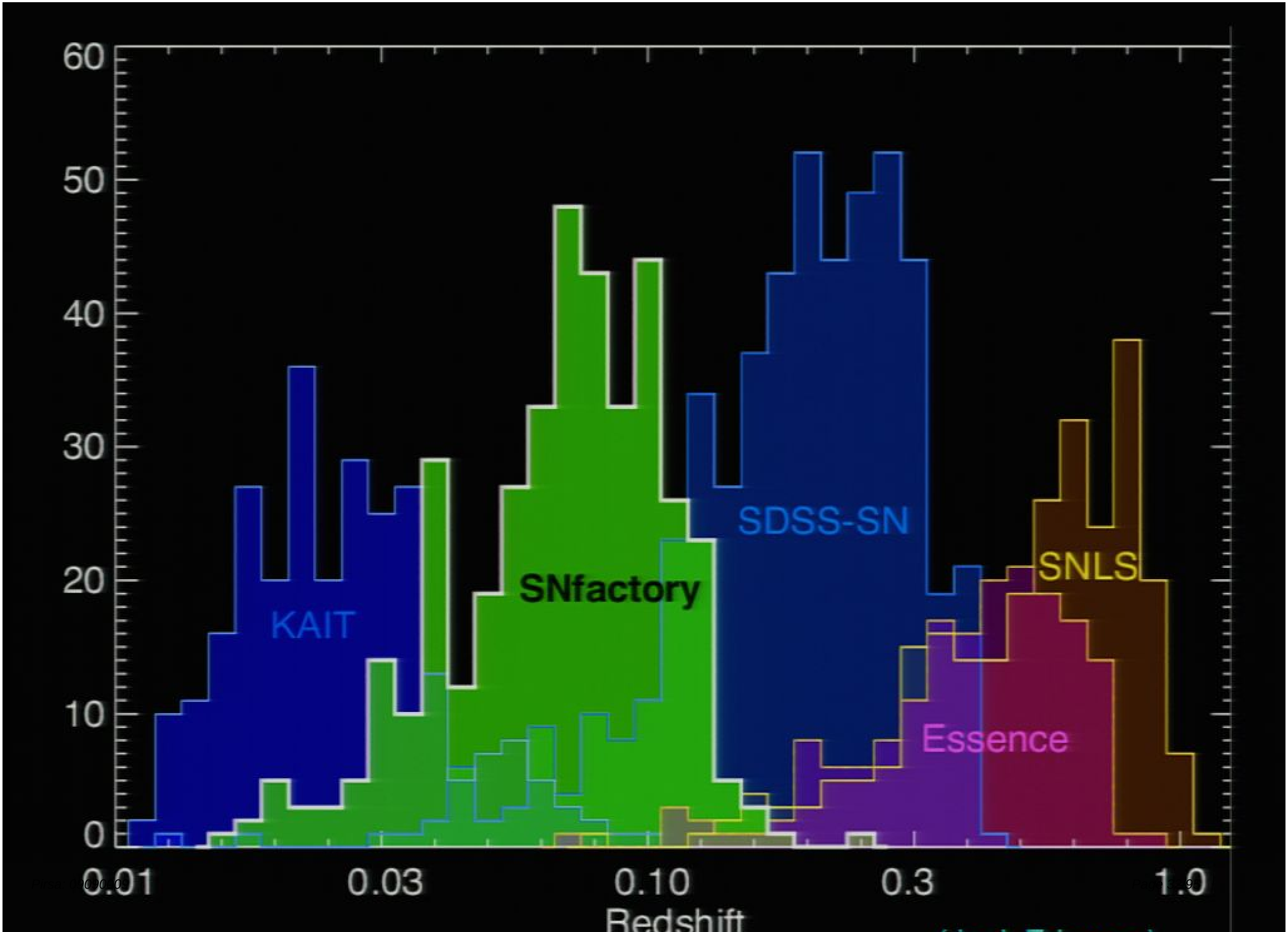


68% confidence region

Systematic Uncertainties



68% confidence region


60
50
40
30
20
10
0
SDSS-SN
SNLS
SNfactory
KAIT
Essence
0.01
0.03
0.10
0.3
1.0
Redshift

What about the next-generation?

[redacted]

Current SN surveys find around 1000 SNIa. *Only* those with spectra are used for cosmology.

Current SN surveys find around 1000 SNIa. *Only* those with spectra are used for cosmology.

LSST will find ~250K SNIa per year for 10 years. Probably only 1% will have spectra.

LSST will find ~250K SNIa per year for 10 years. Probably only 1% will have spectra.

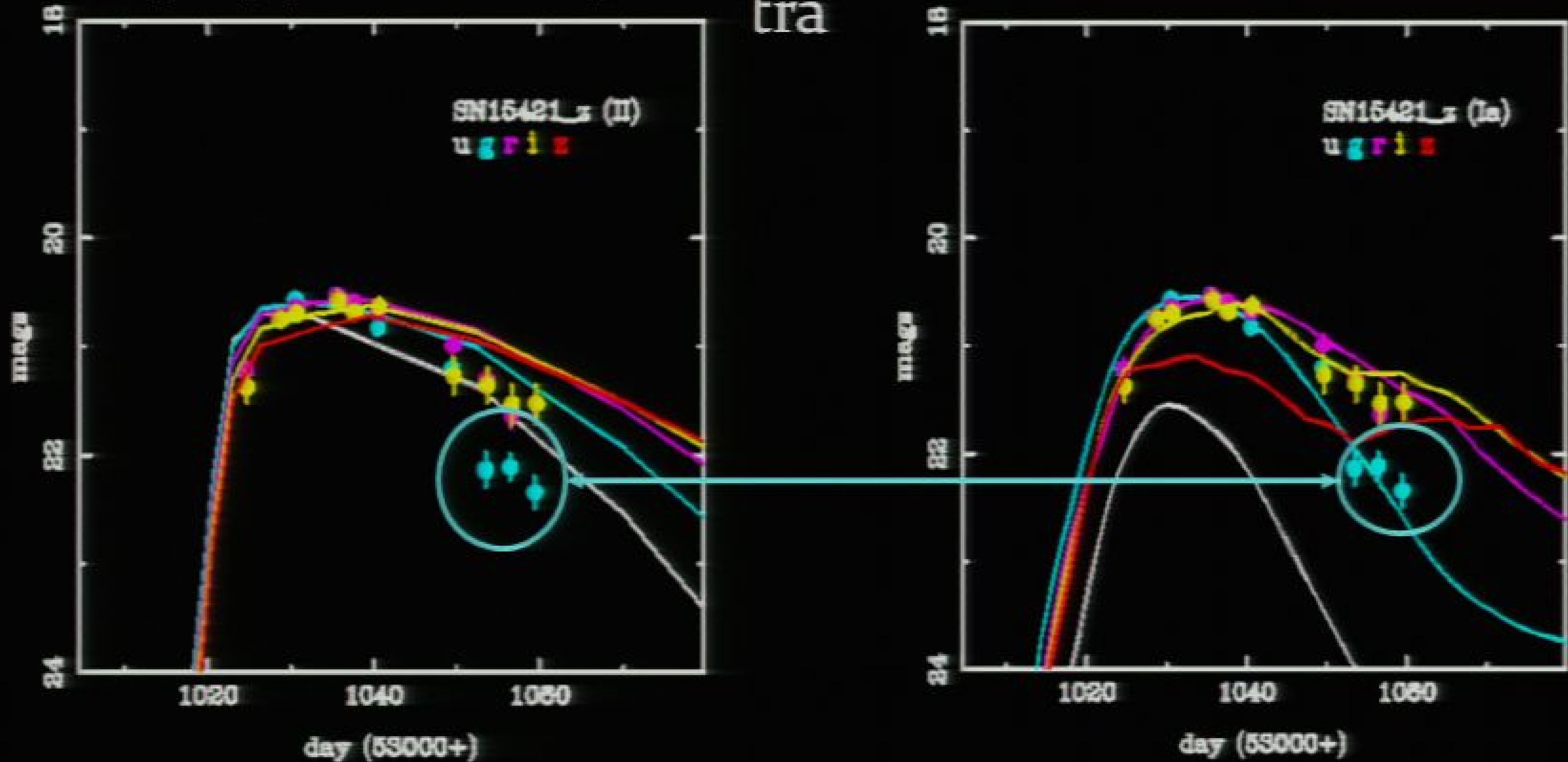
LSST will find ~250K SNIa per year for 10 years. Probably only 1% will have spectra.

VE NEED TO BE ABLE TO DO PHOTOMETRIC SUPERNOVA COSMOLOGY → BEAMS

Current State-of-the-Art

Photometric SN cosmology

tra



SDSS *ugriz* lightcurve template fits (SDSS SN Survey use g,r,i for convenience)

Current State-of-the-Art

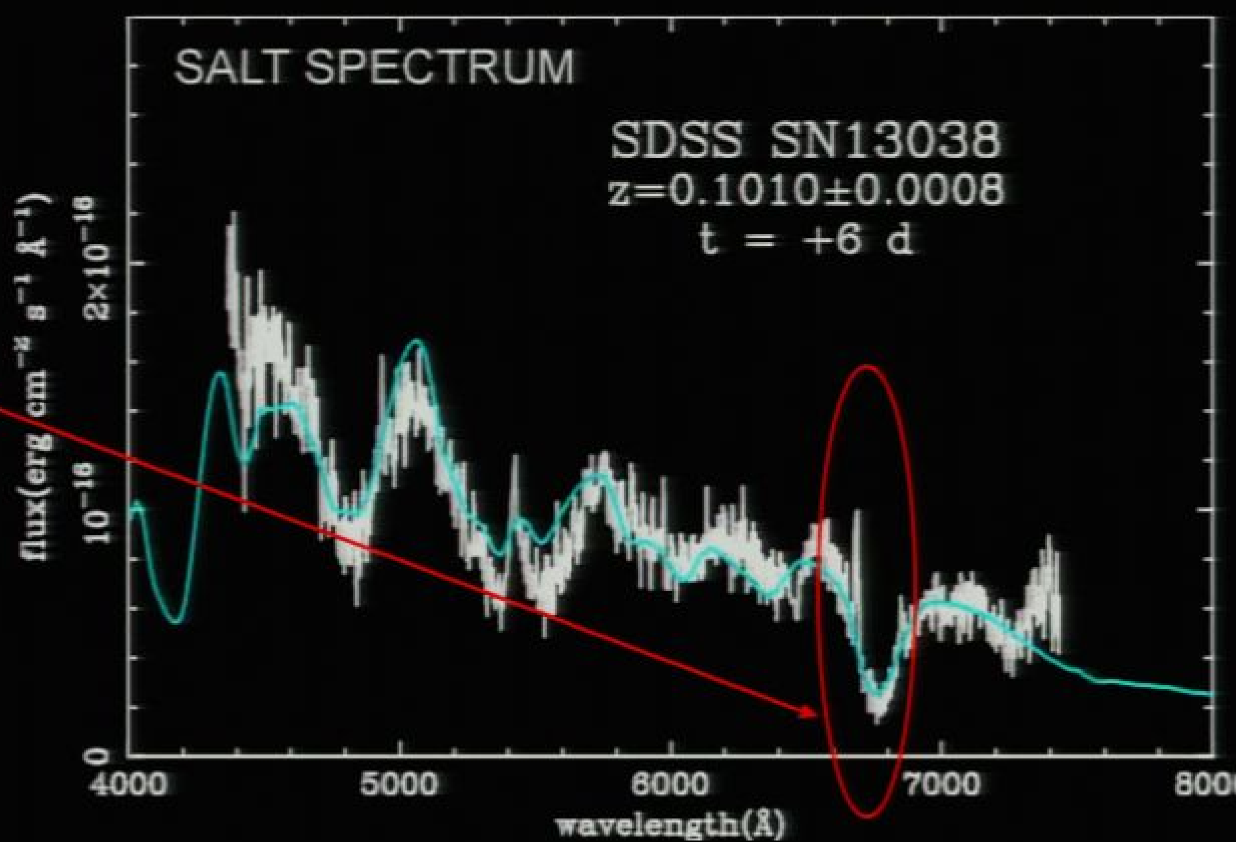
From χ^2 to a probability of being a Type Ia

$$P_i(TypeZ) \propto \exp\left(\frac{-(d_i - t_i(TypeZ)^2)}{2\sigma_i^2}\right)$$

Si II line

6150 Å

rest frame

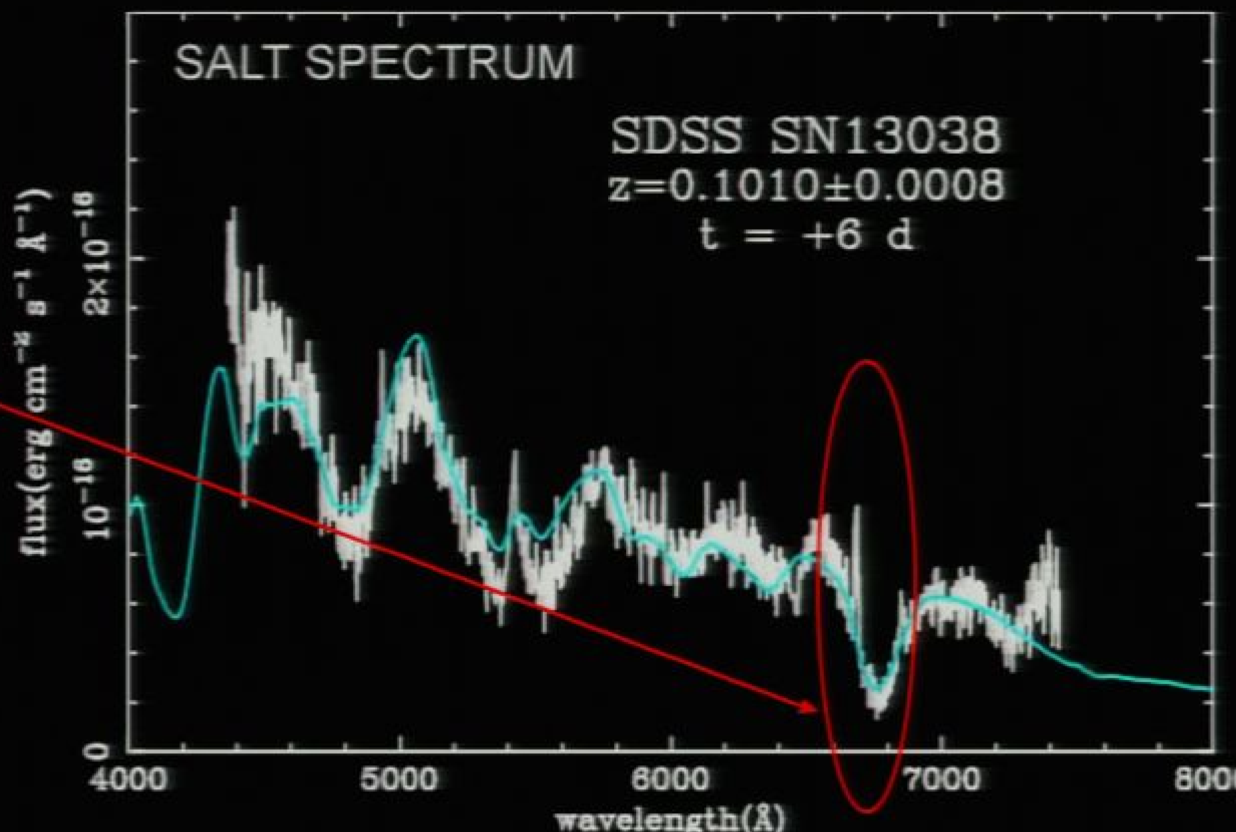


SALT spectrum (Bassett, Chen, van der Heyden, Vaisanen)

Si II line

6150 Å

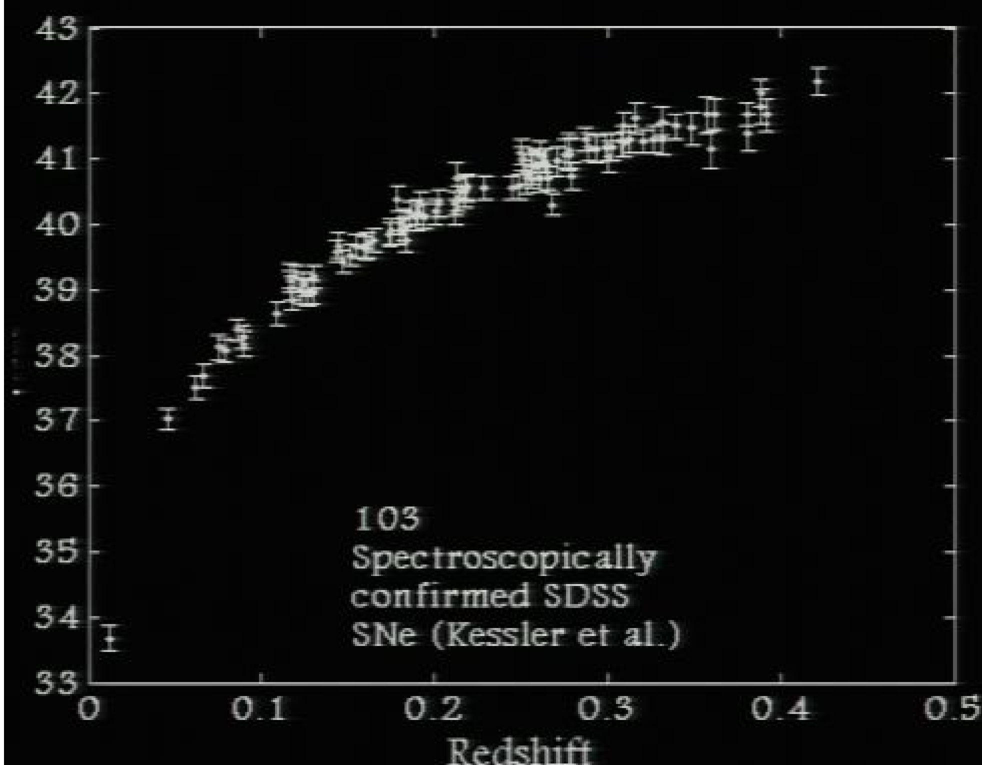
rest frame



SALT spectrum (Bassett, Chen, van der Heyden, Vaisanen)

Only spectroscopically confirmed candidates used in cosmology

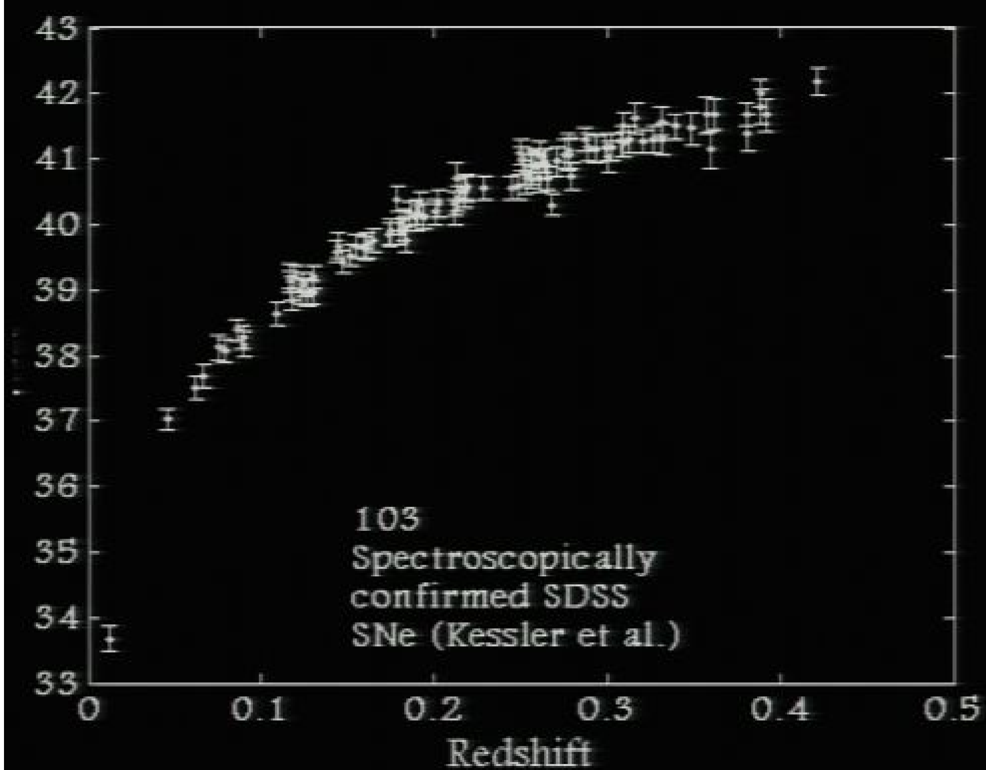
Using Light-curve Candidates...



Probabilities from χ^2 from light-curve

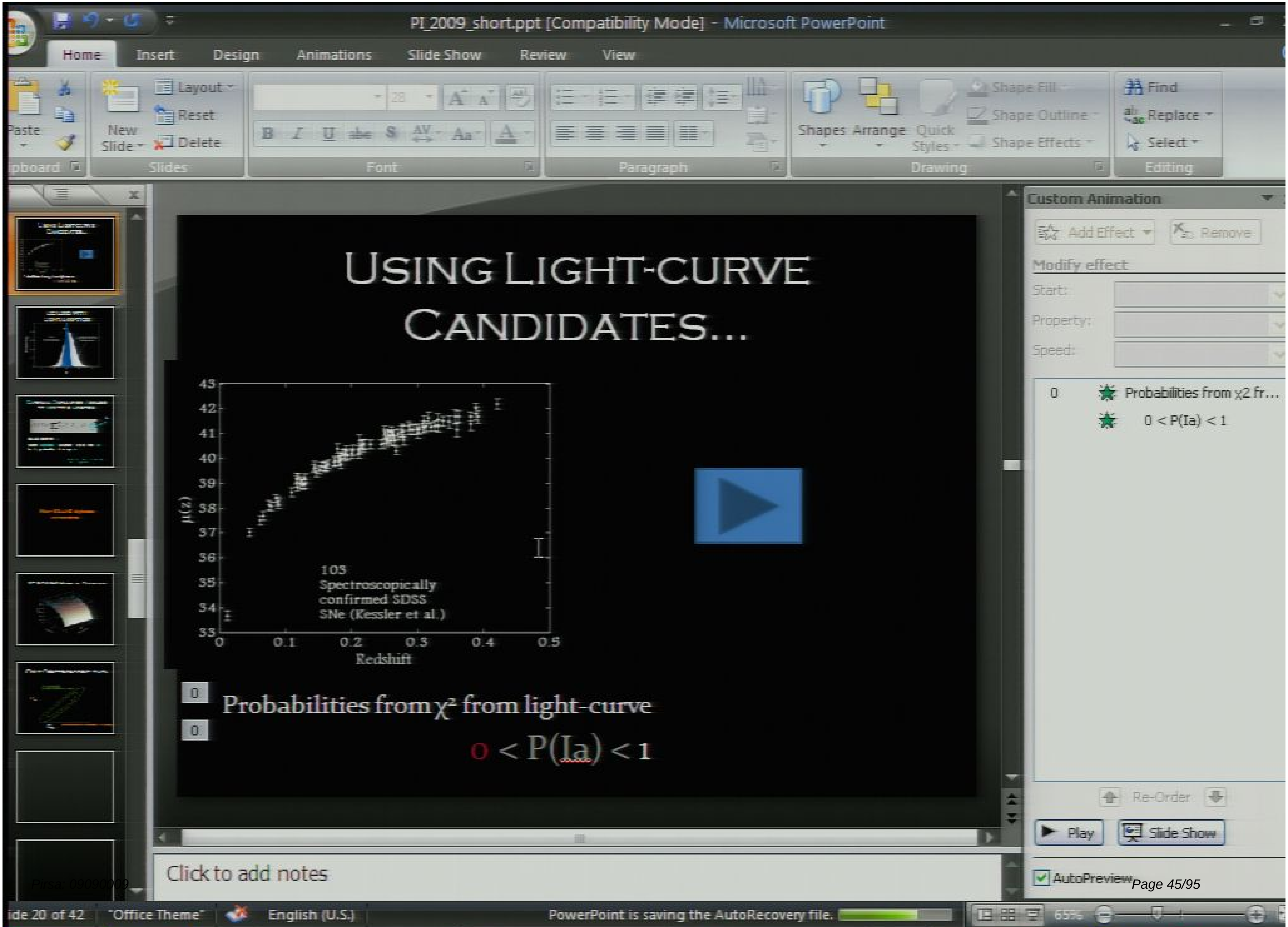
$< P(Ia) < 1$

Using Light-curve Candidates…



Probabilities from χ^2 from light-curve

$0 < P(Ia) < 1$


PI_2009_short.ppt [Compatibility Mode] - Microsoft PowerPoint
Using Light-curve Candidates...
103 Spectroscopically confirmed SDSS SNe (Kessler et al.)
μ(z)
Redshift
Probabilities from χ² from light-curve
0 < P(Ia) < 1
Custom Animation
Click to add notes
Slide 20 of 42
"Office Theme"
English (U.S.)
PowerPoint is saving the AutoRecovery file.

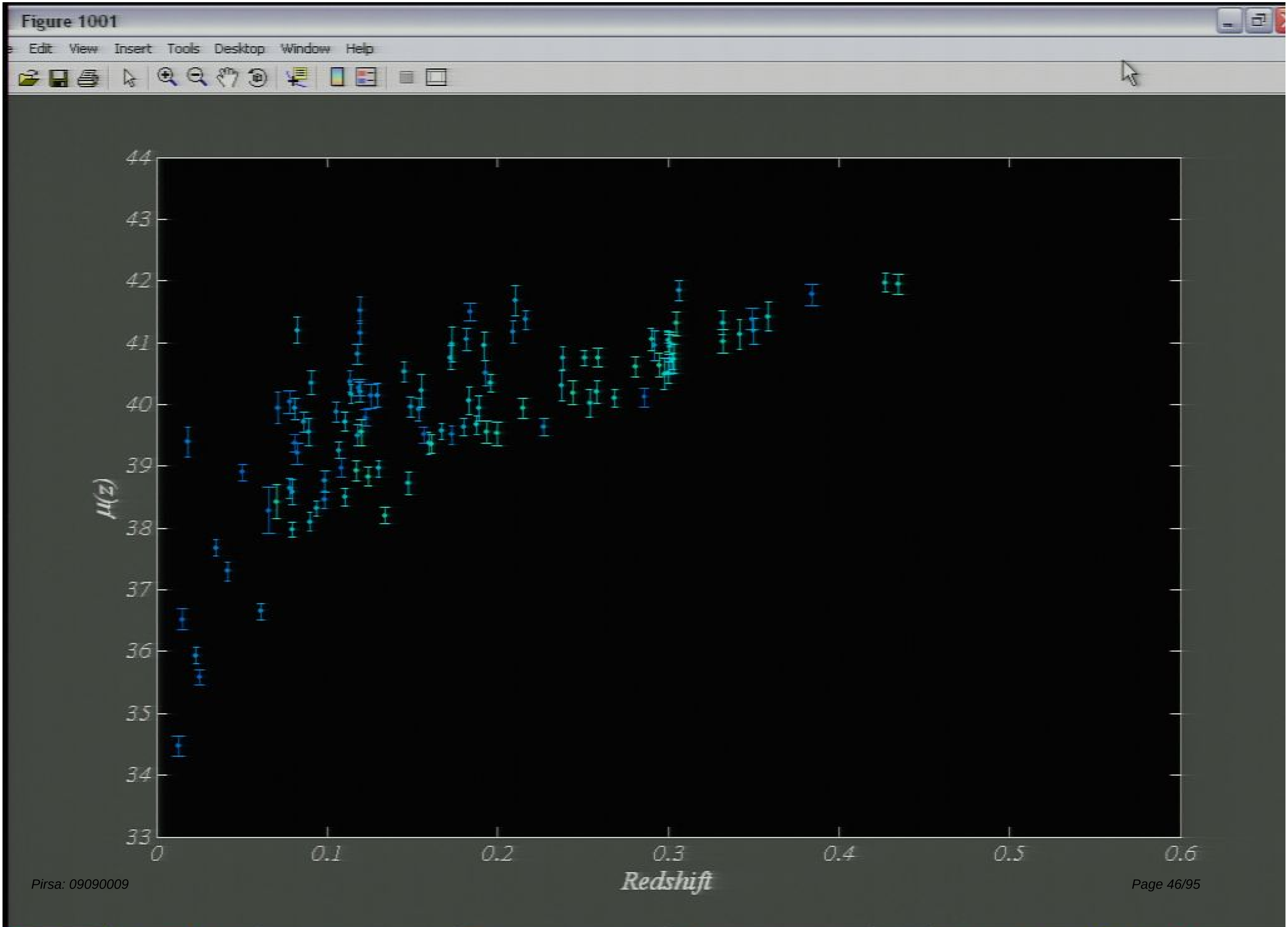


Figure 1001
Edit View Insert Tools Desktop Window Help
44
43
42
41
40
39
38
37
36
35
34
33
μ(z)
0
0.1
0.2
0.3
0.4
0.5
0.6
Redshift

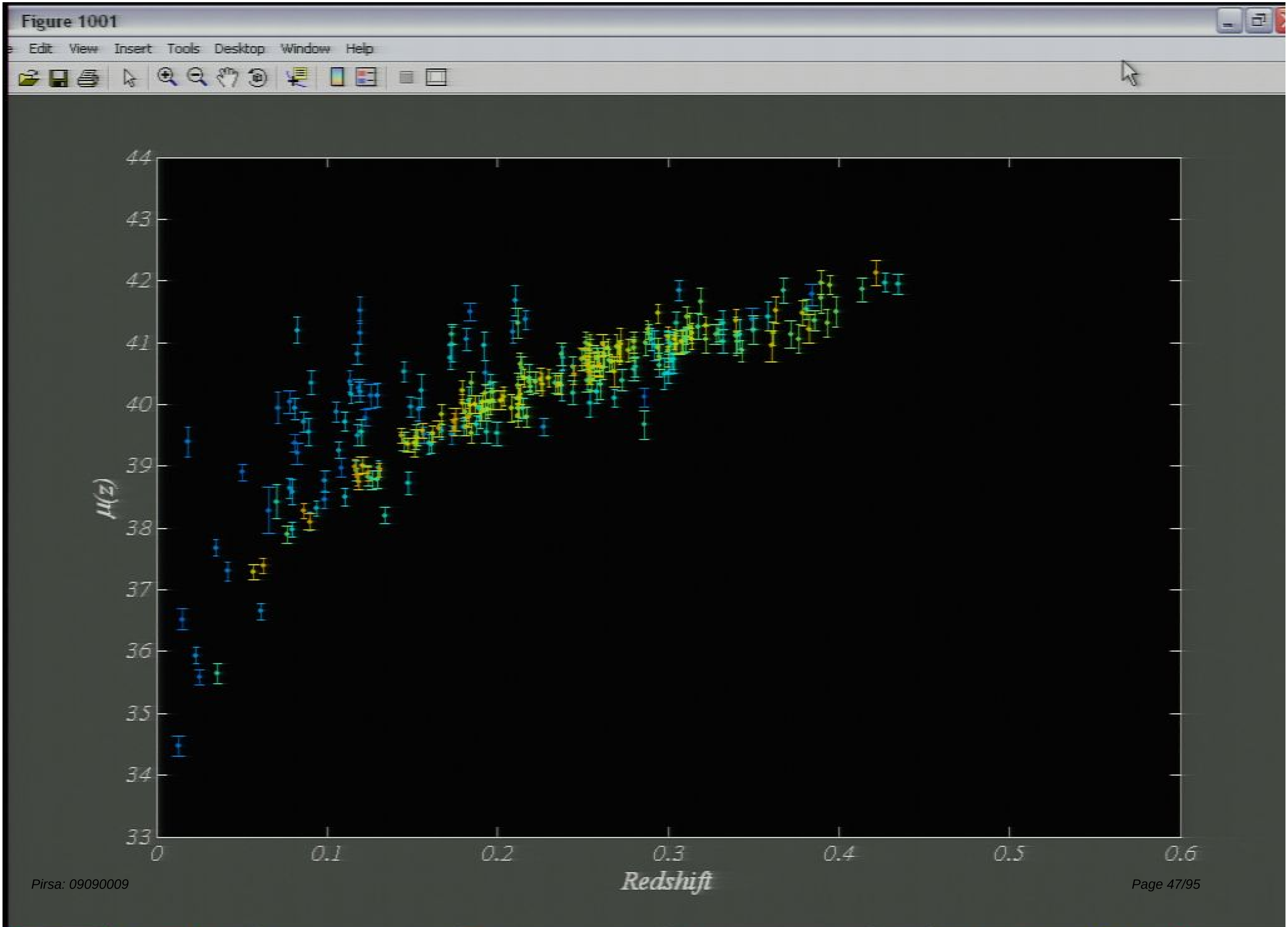
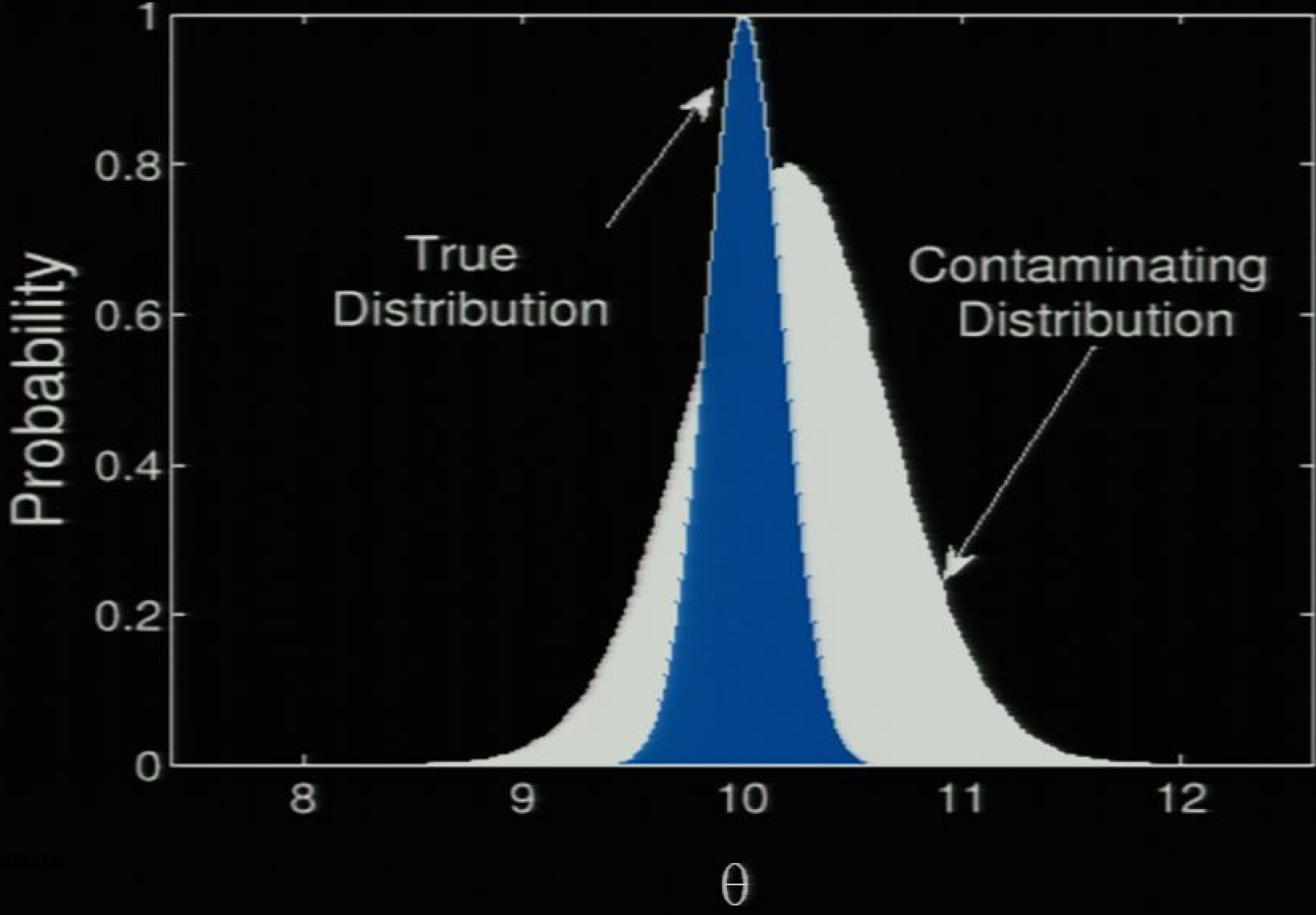
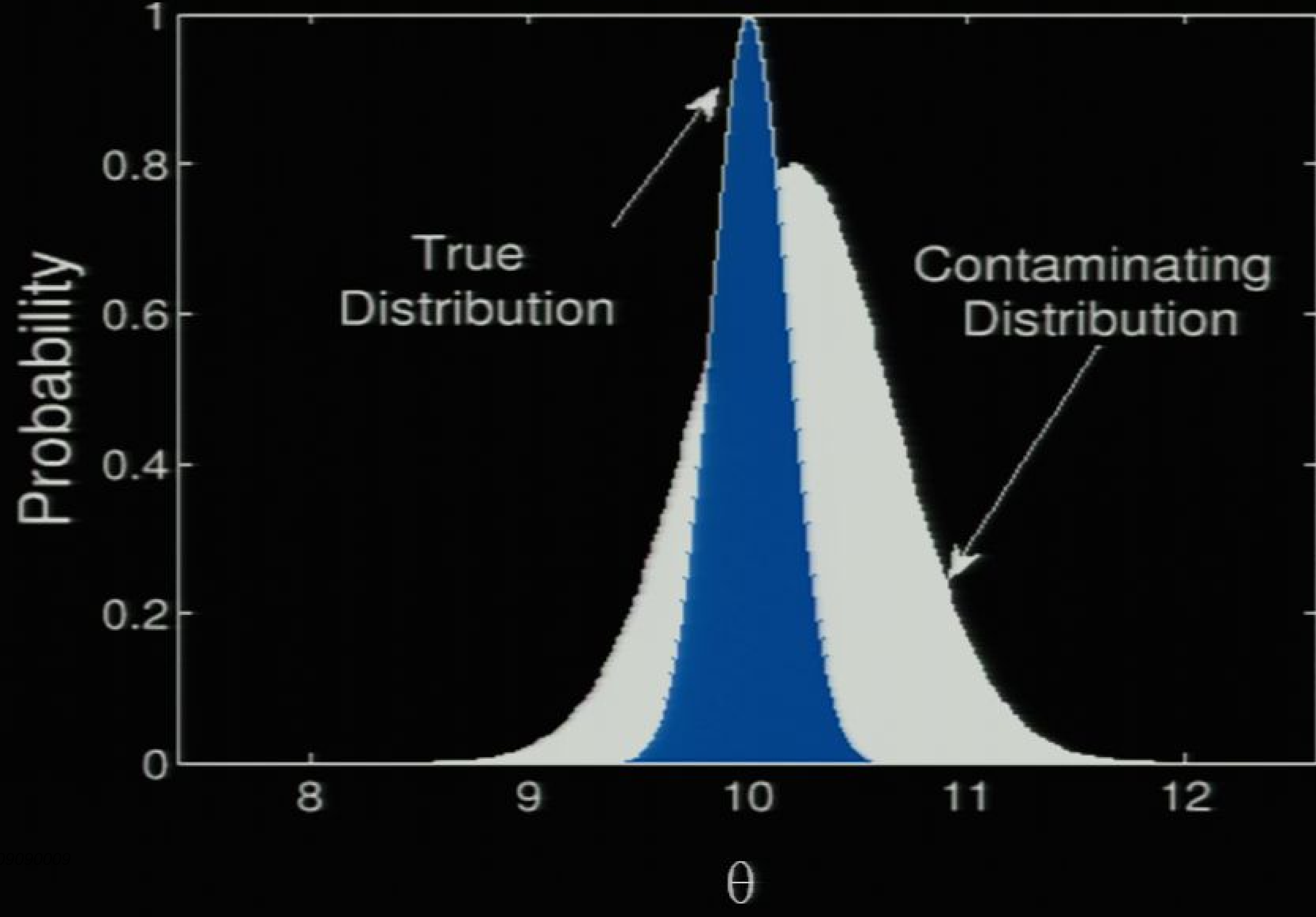


Figure 1001
Edit View Insert Tools Desktop Window Help
44
43
42
41
40
39
38
37
36
35
34
33
μ(z)
0
0.1
0.2
0.3
0.4
0.5
0.6
Redshift

DEALING WITH CONTAMINATION



DEALING WITH CONTAMINATION



Bayesian Estimation Applied to Multiple Species

Martin Kunz, Bruce Bassett , RH

arXiv:astro-ph/0611004

Bayesian Estimation Applied to Multiple Species

$$P(\theta \mid D) \propto \prod_{k=1}^{N} \left[L_{Ia} P_k + L_{NonIa} (1 - P_k) \right]$$

Martin Kunz, Bruce Bassett, RH
arXiv:astro-ph/0611004

Bayesian Estimation Applied to Multiple Species

$$P(\theta \mid D) \propto \prod_{k=1}^{N} \left[L_{Ia} P_k + L_{NonIa} (1 - P_k) \right]$$

P_{IA}

BEAMS Posterior :

weight likelihood assuming it is of type Ia
by P_{Ia}, probability it is type Ia

Martin Kunz, Bruce Bassett , RH
arXiv:astro-ph/0611004

How BEAMS tightens constraints..

Bayesian Estimation Applied to Multiple Species

P_{IA}

$$P(\theta \mid D) \propto \prod_{k=1}^{N} \left[L_{Ia} P_k + L_{NonIa} (1 - P_k) \right]$$

BEAMS Posterior :

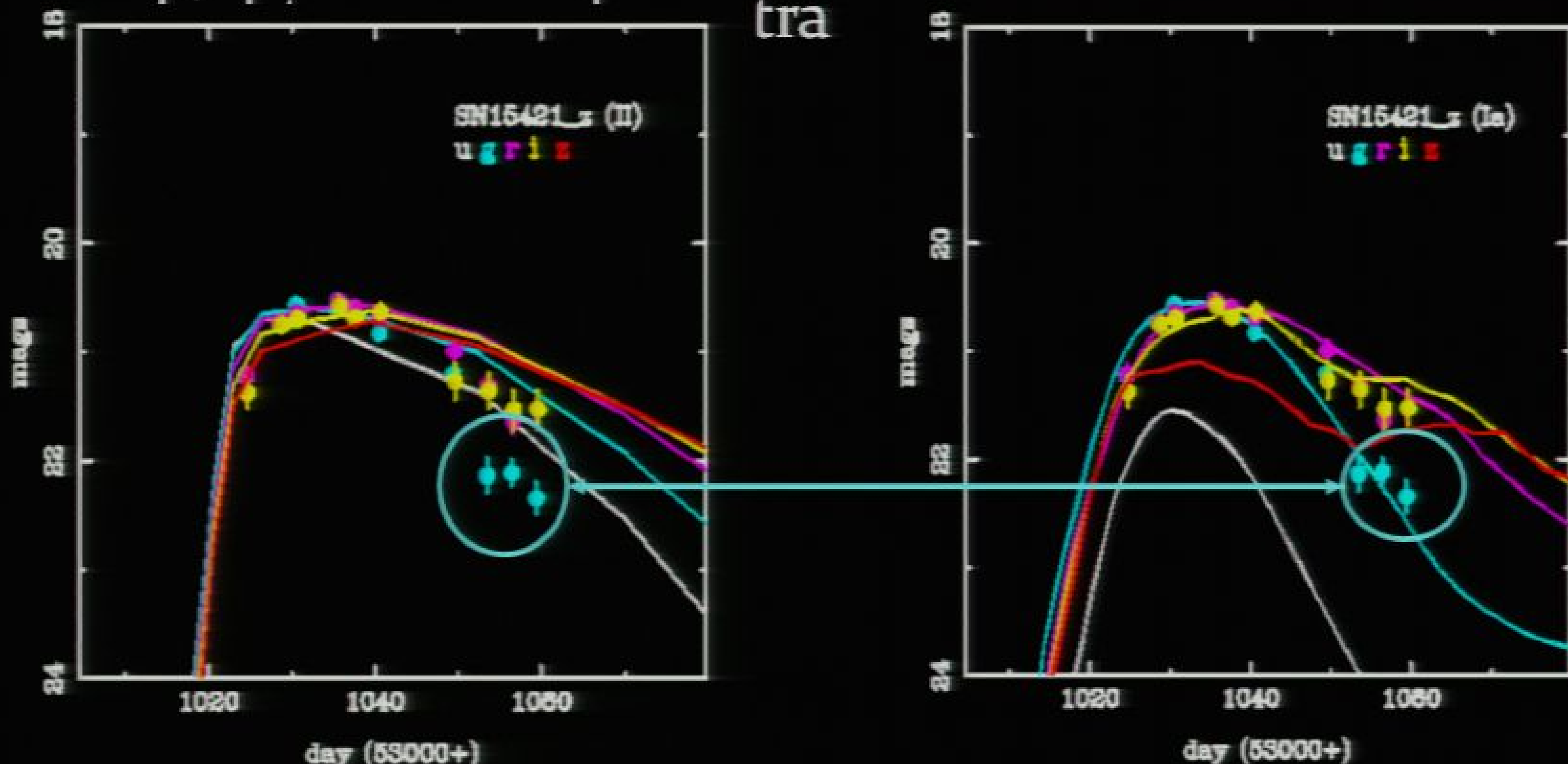
weight likelihood assuming it is of type Ia
by P_{Ia}, probability it is type Ia

Martin Kunz, Bruce Bassett , RH
arXiv:astro-ph/0611004

Current State-of-the-Art

Photometric SN cosmology

tra



SDSS *ugriz* lightcurve template fits (SDSS SN Survey use g,r,i for convenience)

Current State-of-the-Art

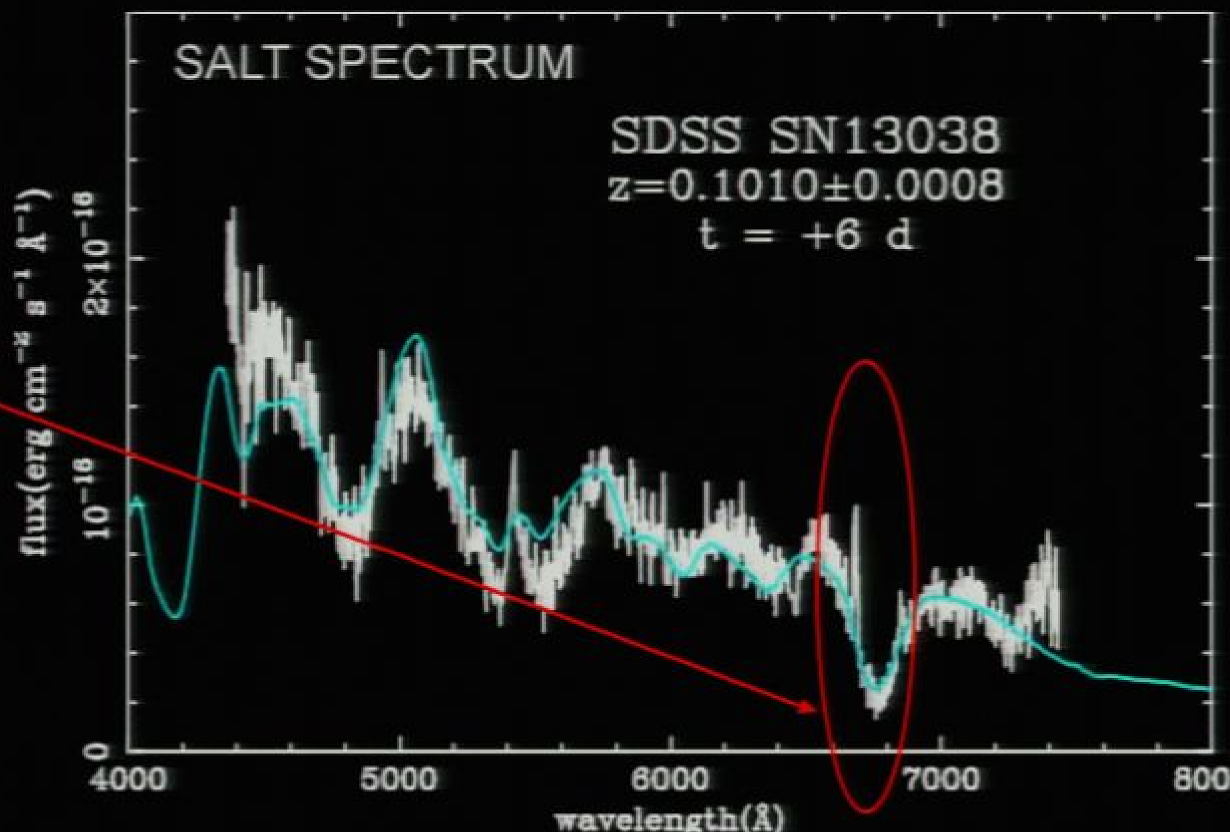
From χ^2 to a probability of being a Type Ia

$$P_i(TypeZ) \propto \exp\left(\frac{-(d_i - t_i(TypeZ)^2)}{2\sigma_i^2}\right)$$

Si II line

6150 Å

rest frame



SALT spectrum (Bassett, Chen, van der Heyden, Vaisanen)

Only spectroscopically confirmed candidates used in cosmology

Bayesian Estimation Applied to Multiple Species

Martin Kunz, Bruce Bassett, RH

arXiv:astro-ph/0611004

How BEAMS tightens constraints..

Bayesian Estimation Applied to Multiple Species

$$P(\theta \mid D) \propto \prod_{k=1}^{N} \left[L_{Ia} P_k + L_{NonIa}(1 - P_k) \right]$$

Martin Kunz, Bruce Bassett, RH
arXiv:astro-ph/0611004

Bayesian Estimation Applied to Multiple Species

$$P(\theta \mid D) \propto \prod_{k=1}^{N} \left[L_{Ia} P_k + L_{NonIa}(1 - P_k) \right]$$

P_{IA}

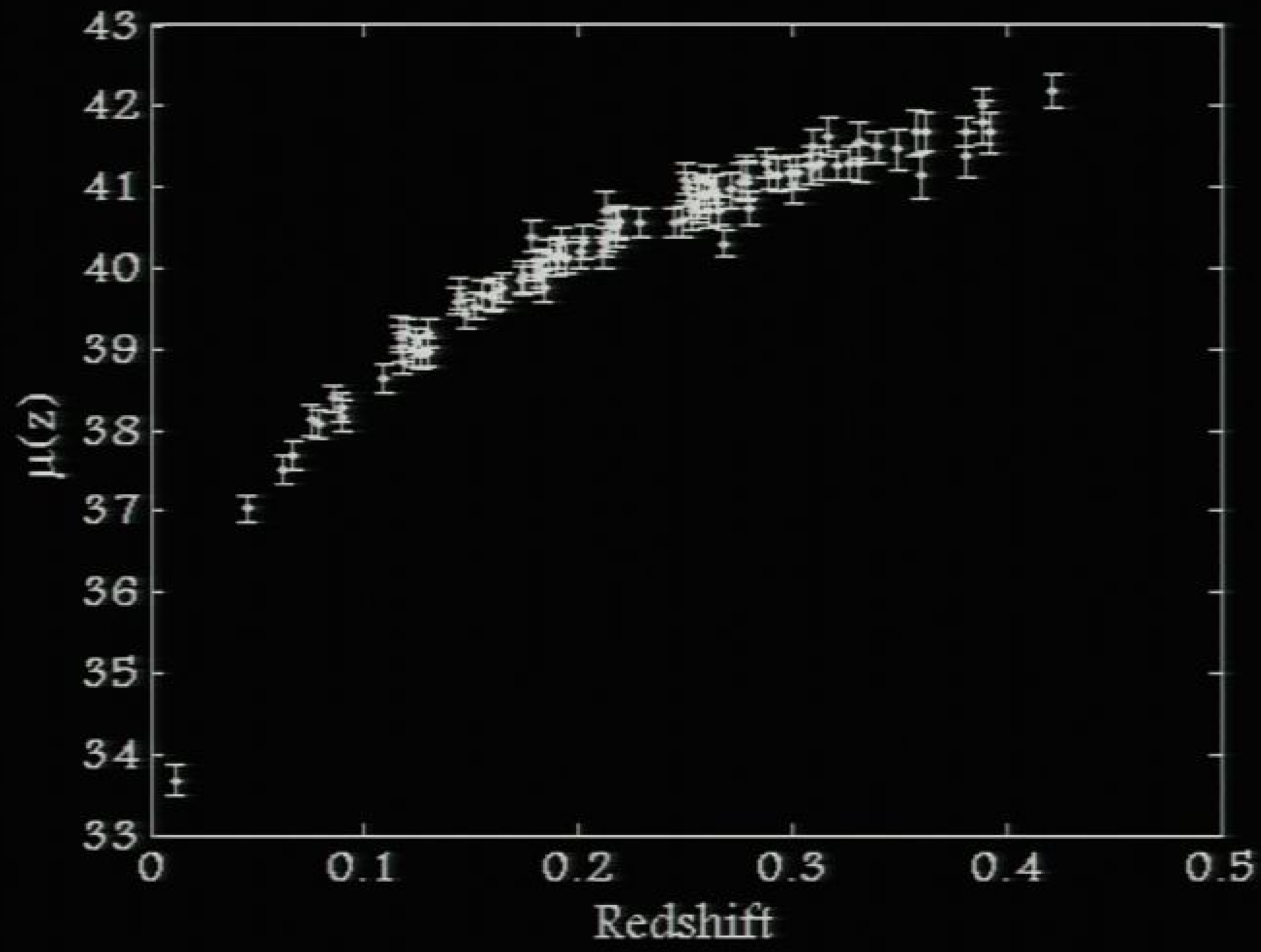
BEAMS Posterior :

weight likelihood assuming it is of type Ia
by P_{Ia}, probability it is type Ia

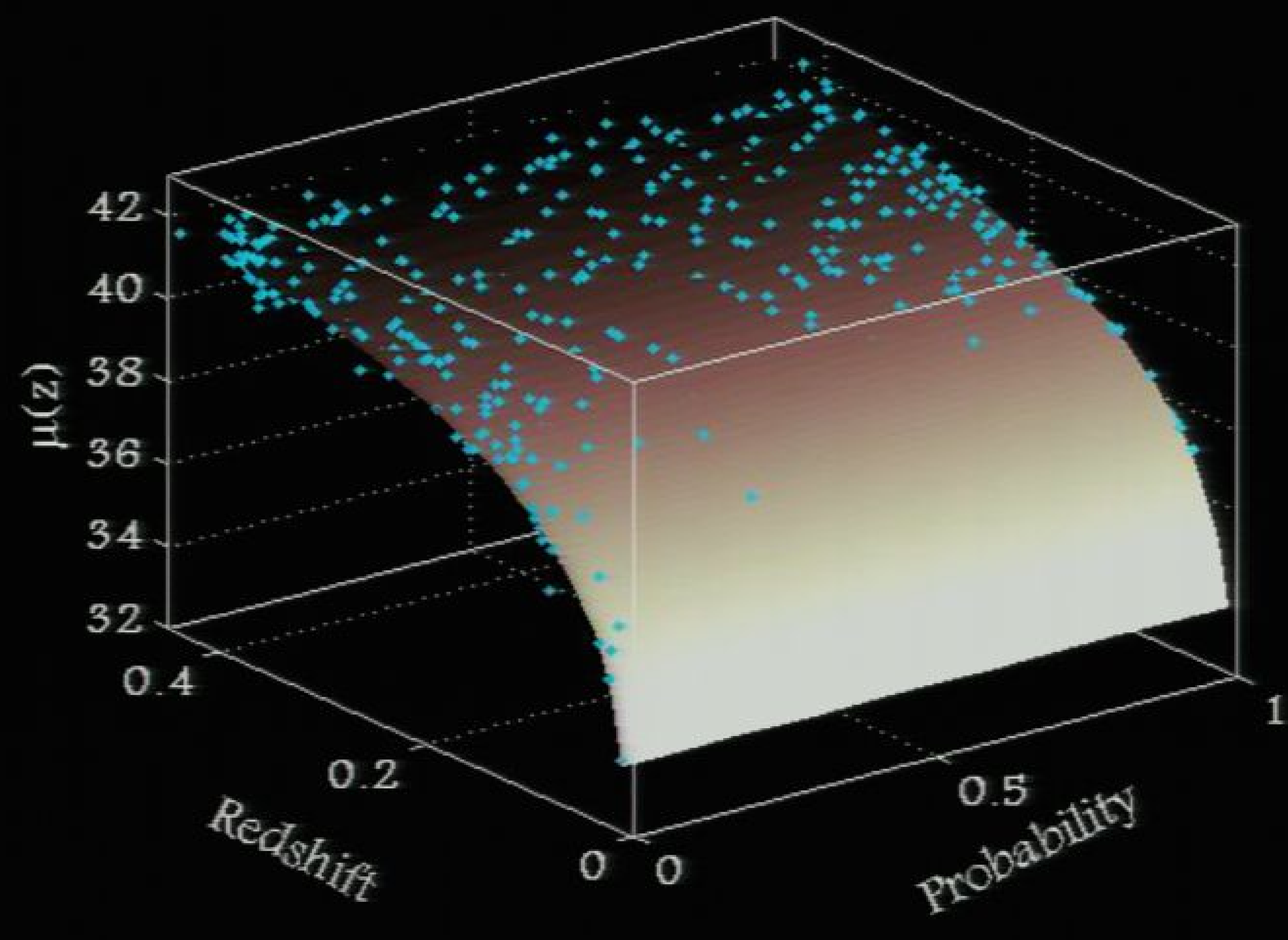
Martin Kunz, Bruce Bassett , RH
arXiv:astro-ph/0611004

How BEAMS tightens constraints..

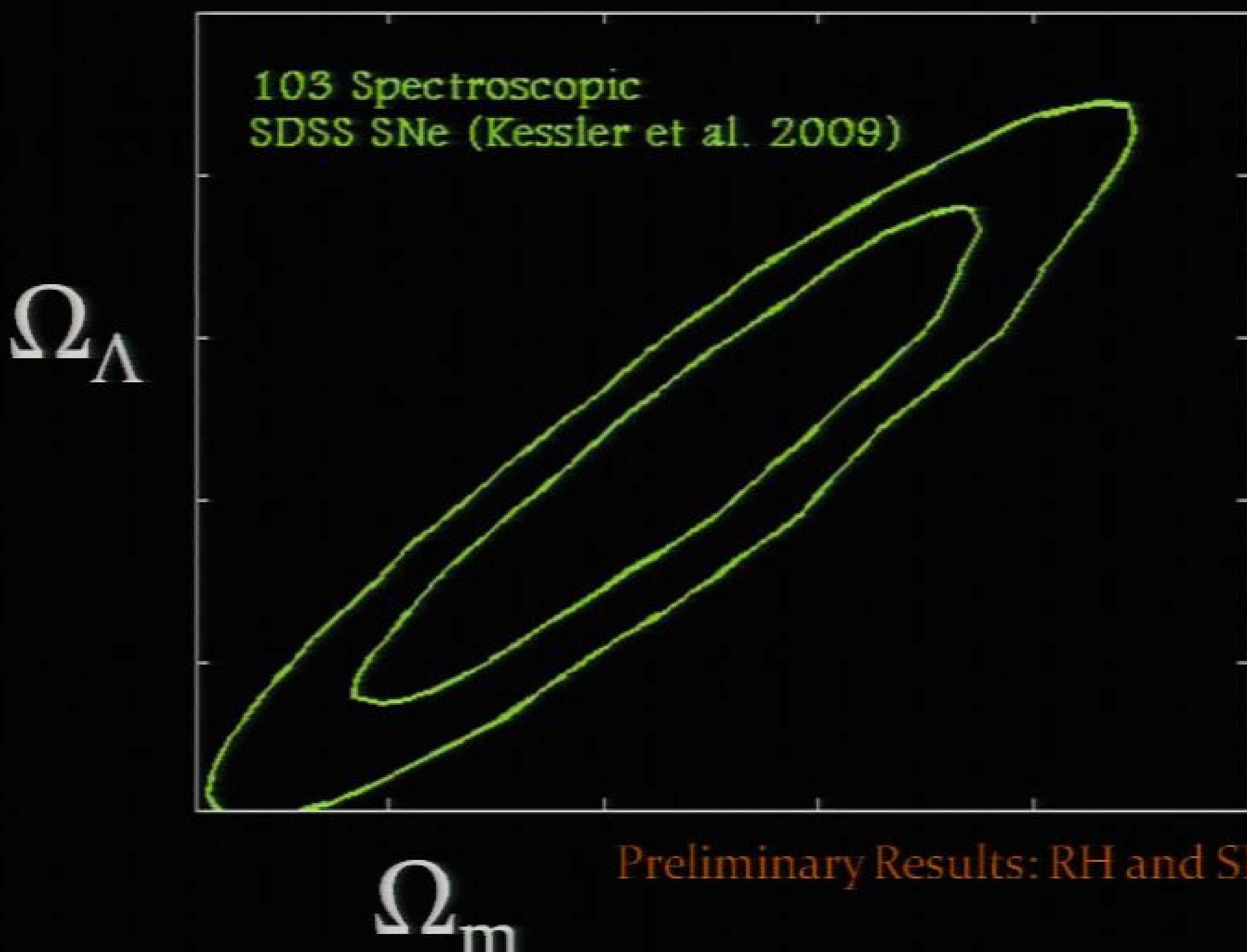
3D SDSS-II Hubble Diagram



3D SDSS-II Hubble Diagram

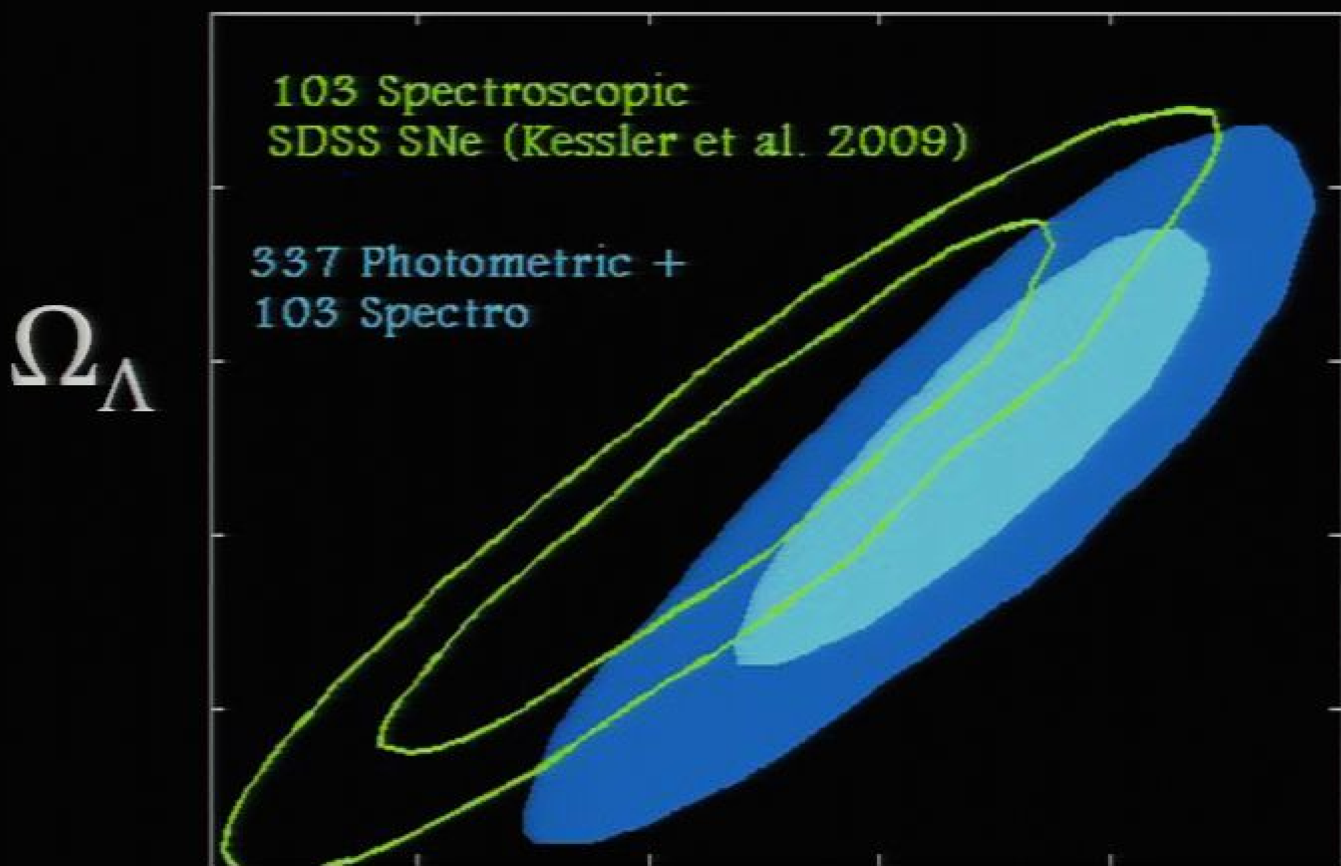


ONLY SPECTROSCOPIC DATA



Preliminary Results: RH and SDSS-II SN survey

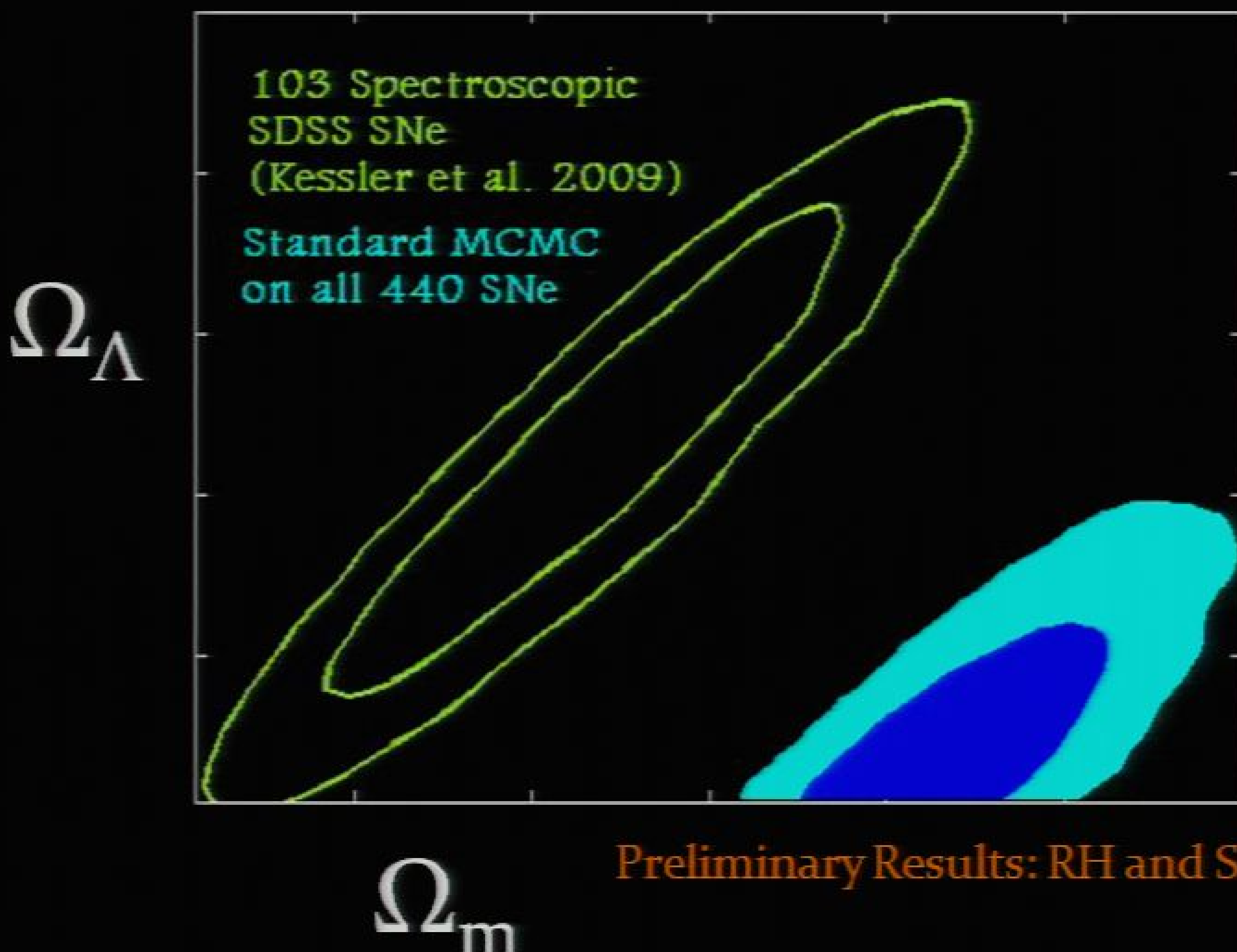
Naïve Application of BEAMS to all the Data



Ω_m

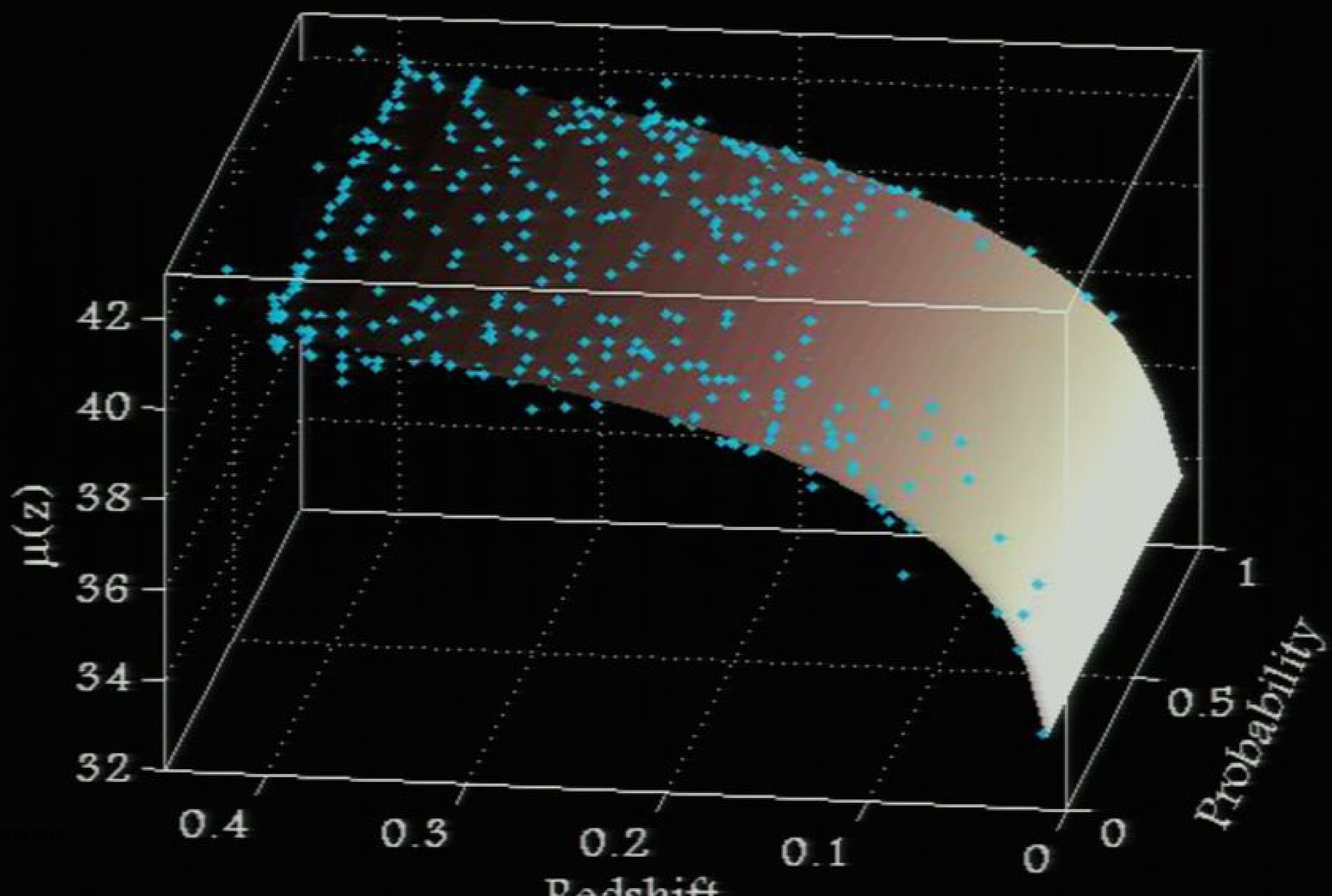
Preliminary Results: RH and SDSS-II SN survey

Just doing the Usual

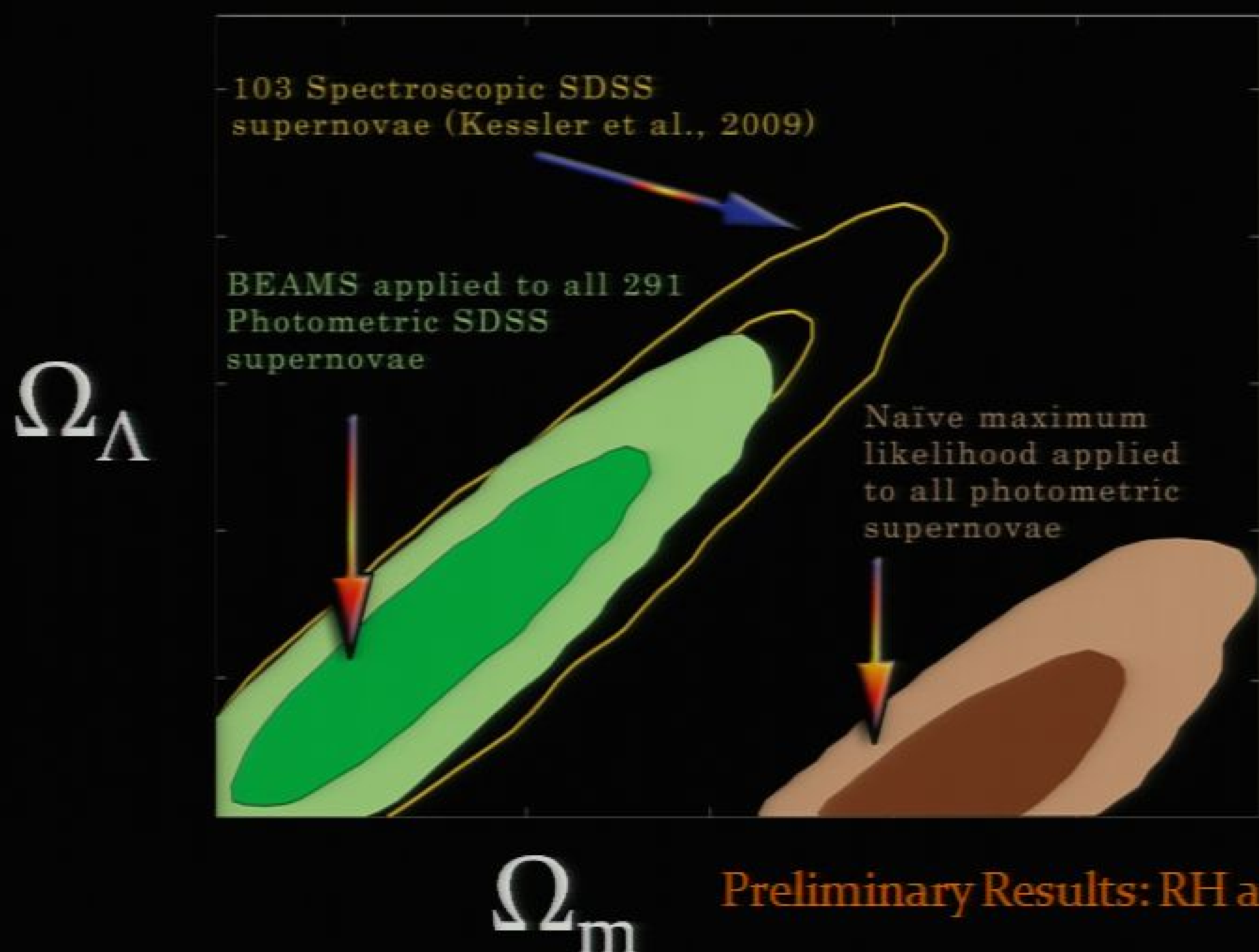


Preliminary Results: RH and SDSS-II SN survey

Dealing with Systematics

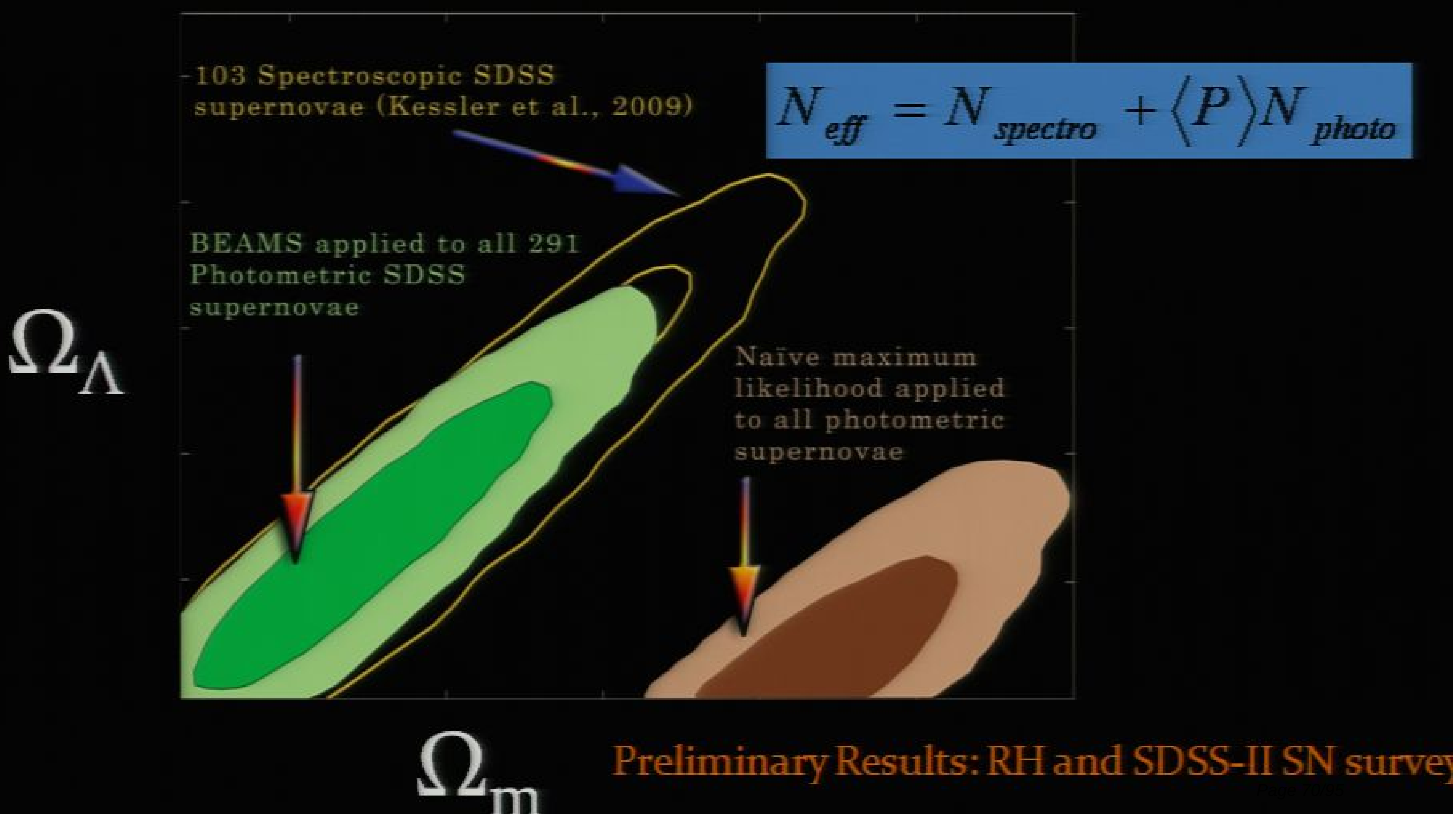


QUALITY CUTS AND NUISANCE PARAMETERS



Preliminary Results: RH and SDSS-II SN survey

Quality Cuts and Nuisance Parameters



Should we be surprised if we don't see dynamics?

Detectability of Dynamics

Early Universe constraints

+

scaling models

=

dynamics invisible for the next decade

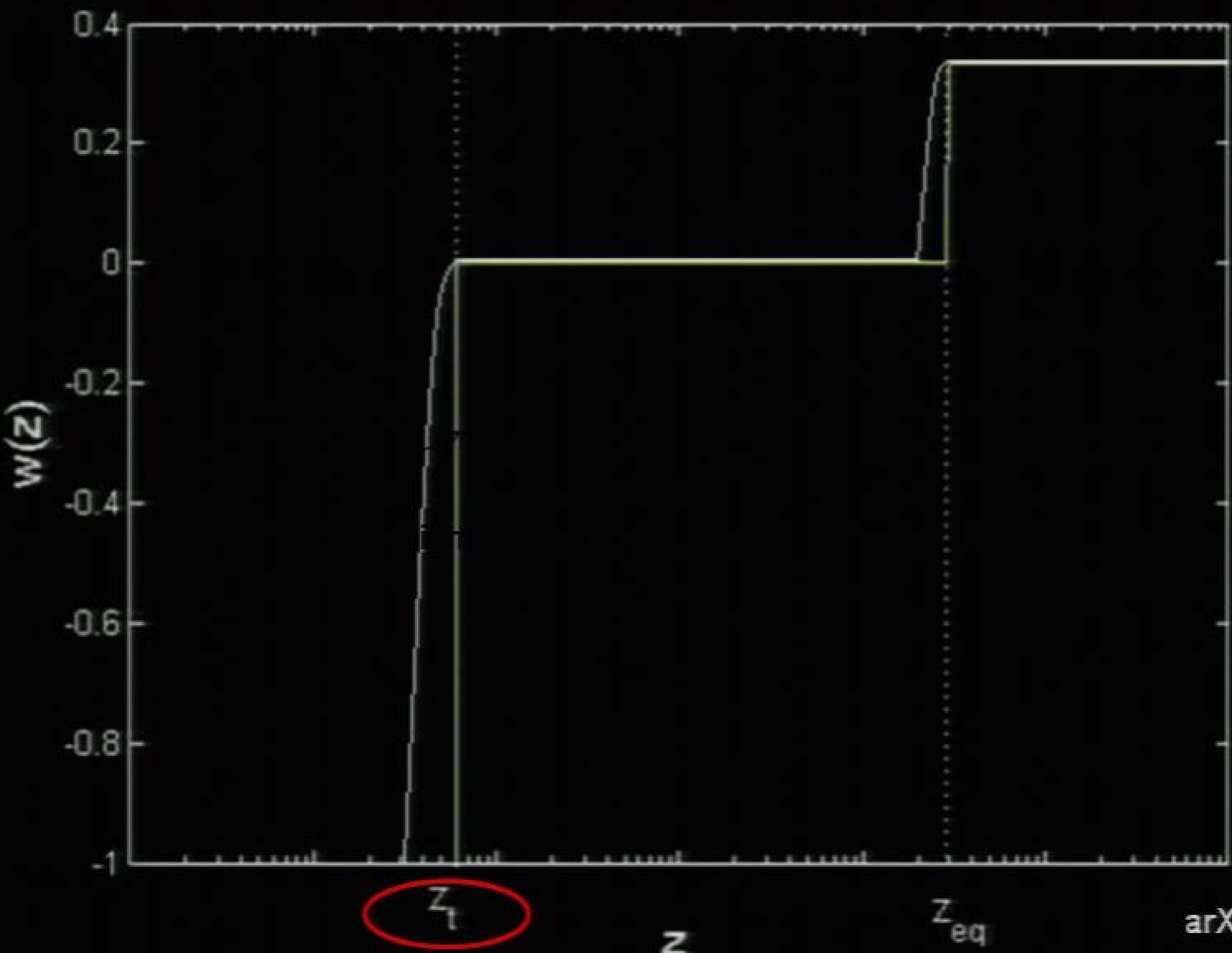
Early Universe Constraints

- Early universe probes (BBN,CMB) strongly limit the amount of dark energy allowed.

$$\Omega_\phi(1MeV) \leq 0.05$$

arXiv:0709.0526

Scaling Models

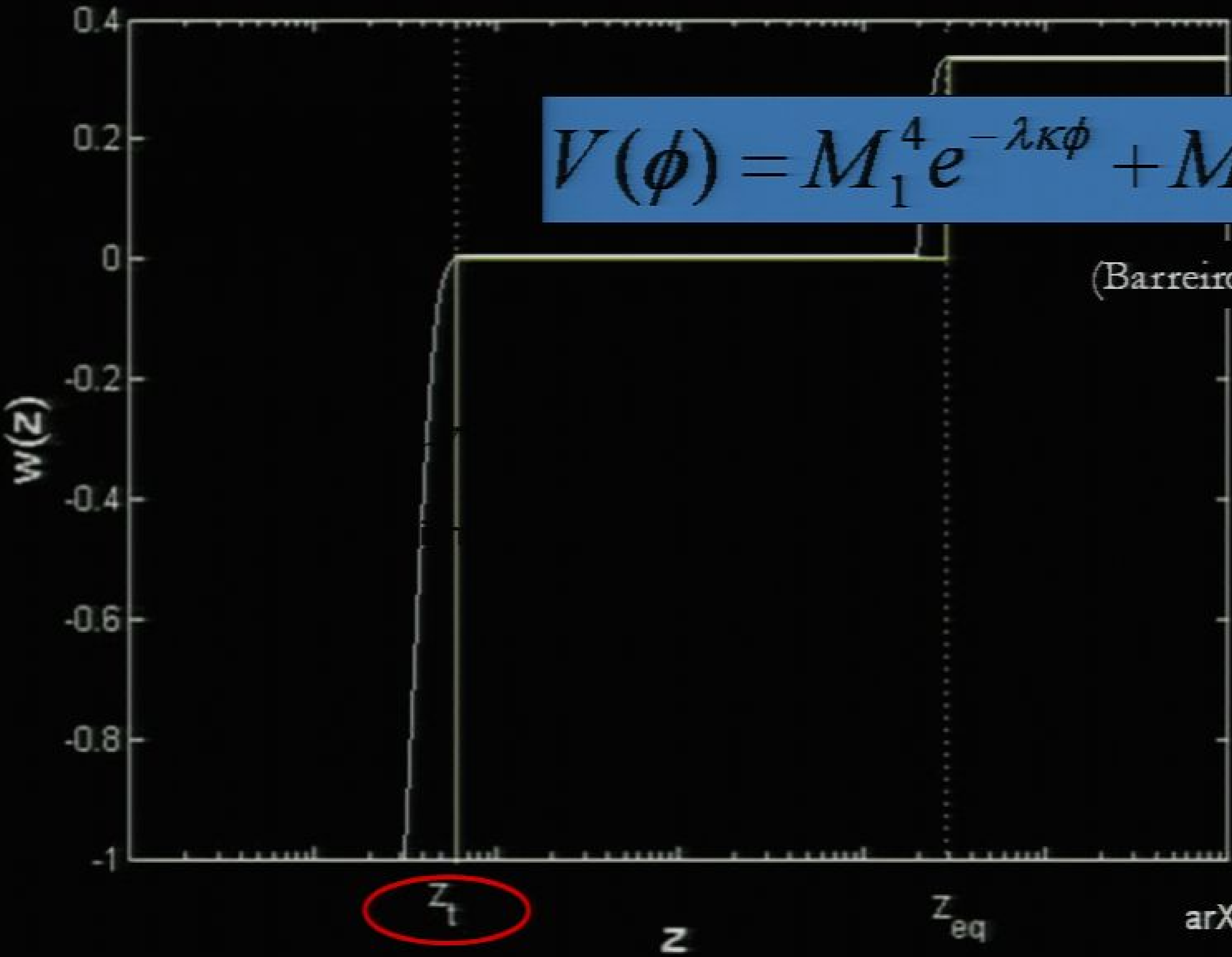


arXiv:0709.0526

Scaling Models

$$V(\phi) = M_1^4 e^{-\lambda\kappa\phi} + M_2^4 e^{-\mu\kappa\phi}$$

(Barreiro et. al 1999)

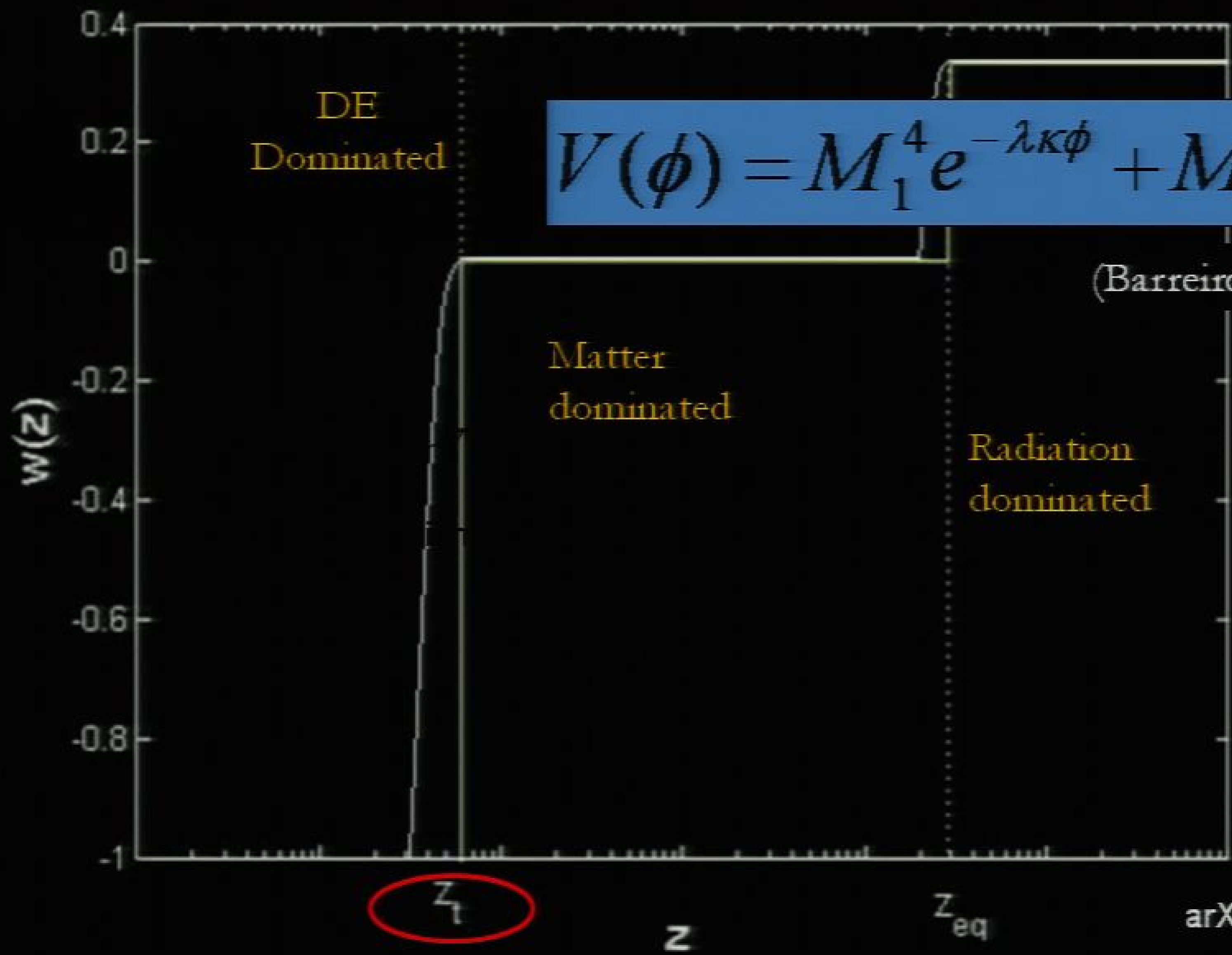


arXiv:0709.0526

Scaling Models

$$V(\phi) = M_1^4 e^{-\lambda\kappa\phi} + M_2^4 e^{-\mu\kappa\phi}$$

(Barreiro et. al 1999)



arXiv:0709.0526

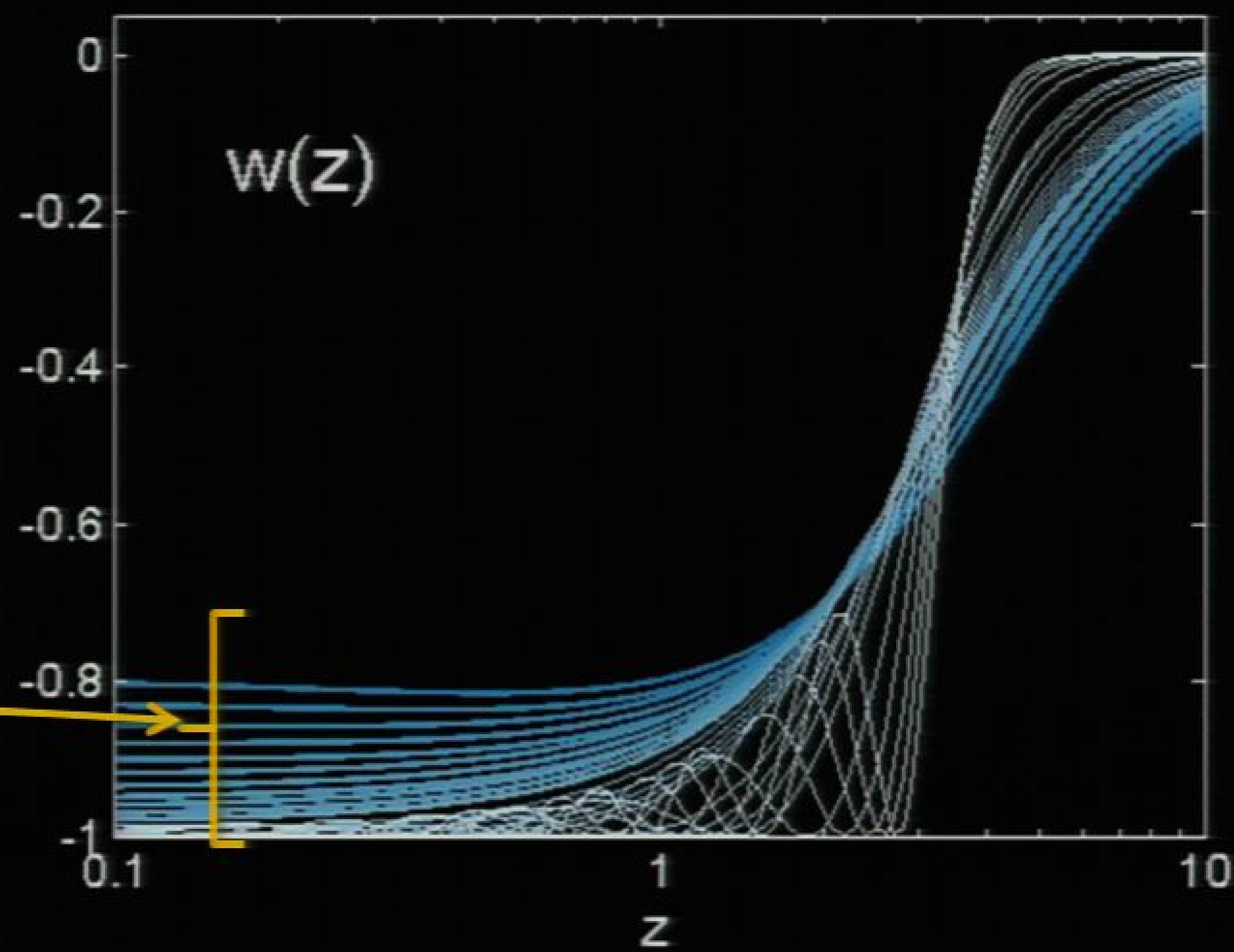
Scaling Models

- Double exponential potential – early universe bounds apply until the field breaks from scaling

arXiv:0709.0526

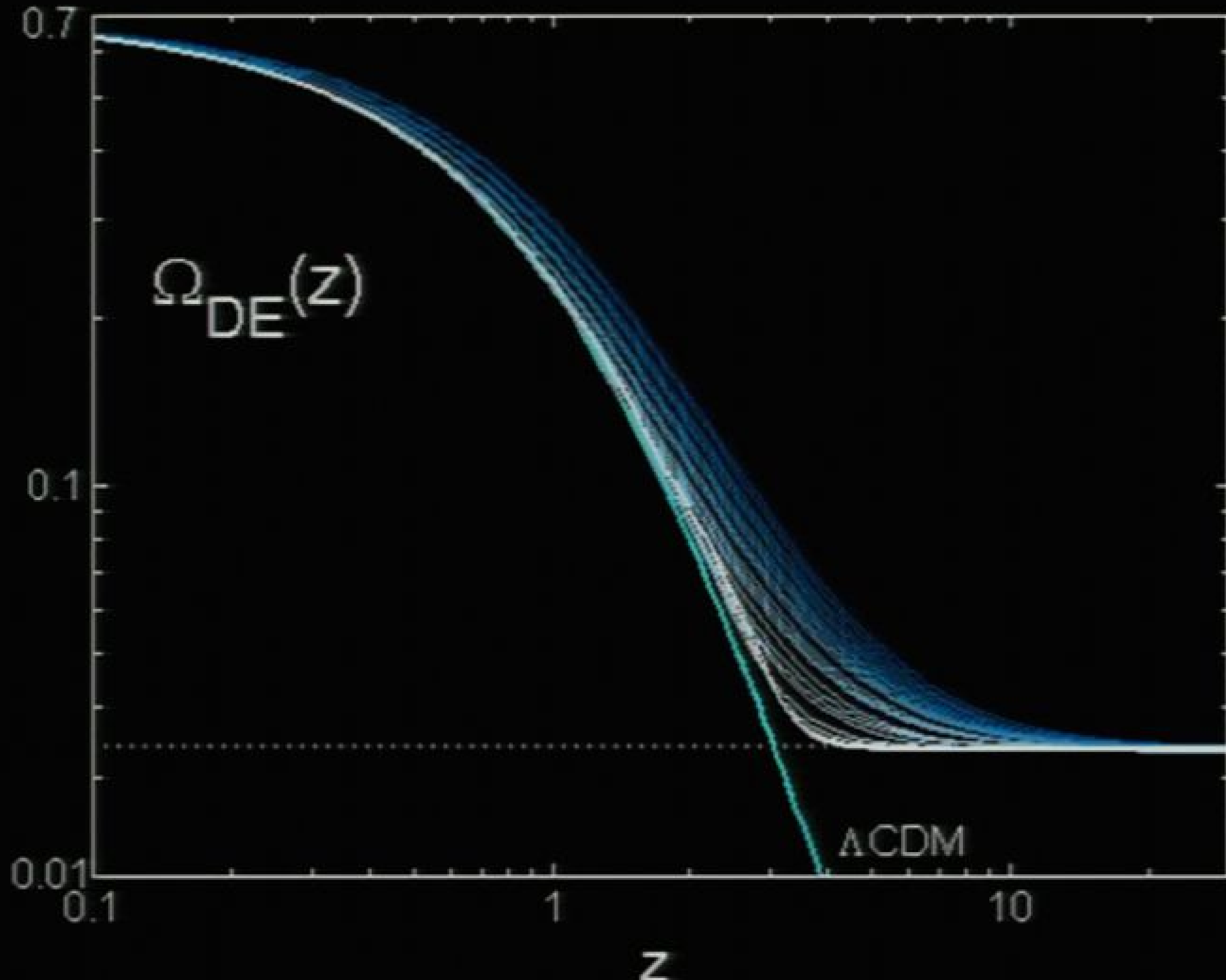
Derived w(z) from Double Exponential V(ϕ)

All models have $w<-0.98$ for $z<0.2$



arXiv:0709.0526

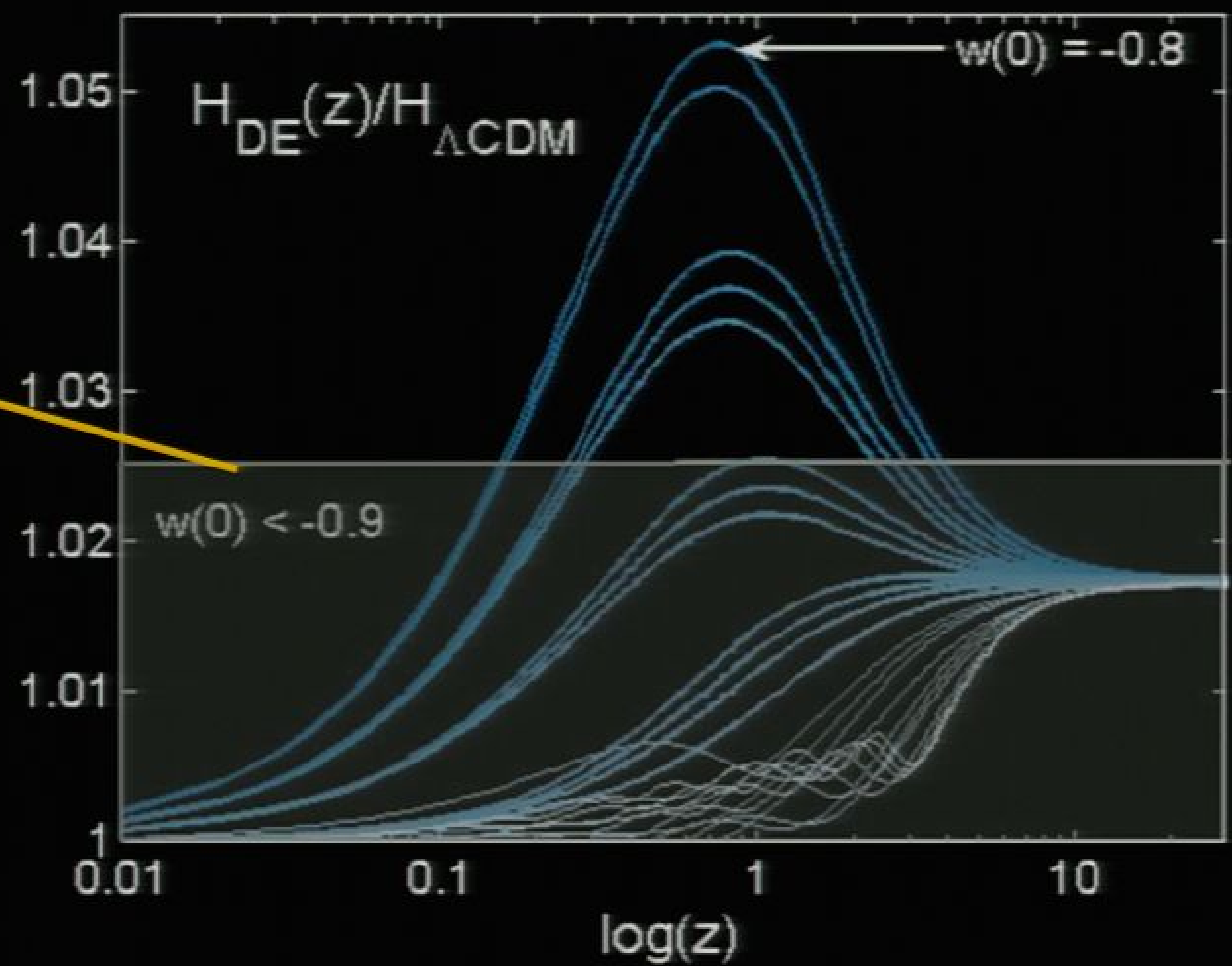
Energy Density - DEP



arXiv:0709.0526

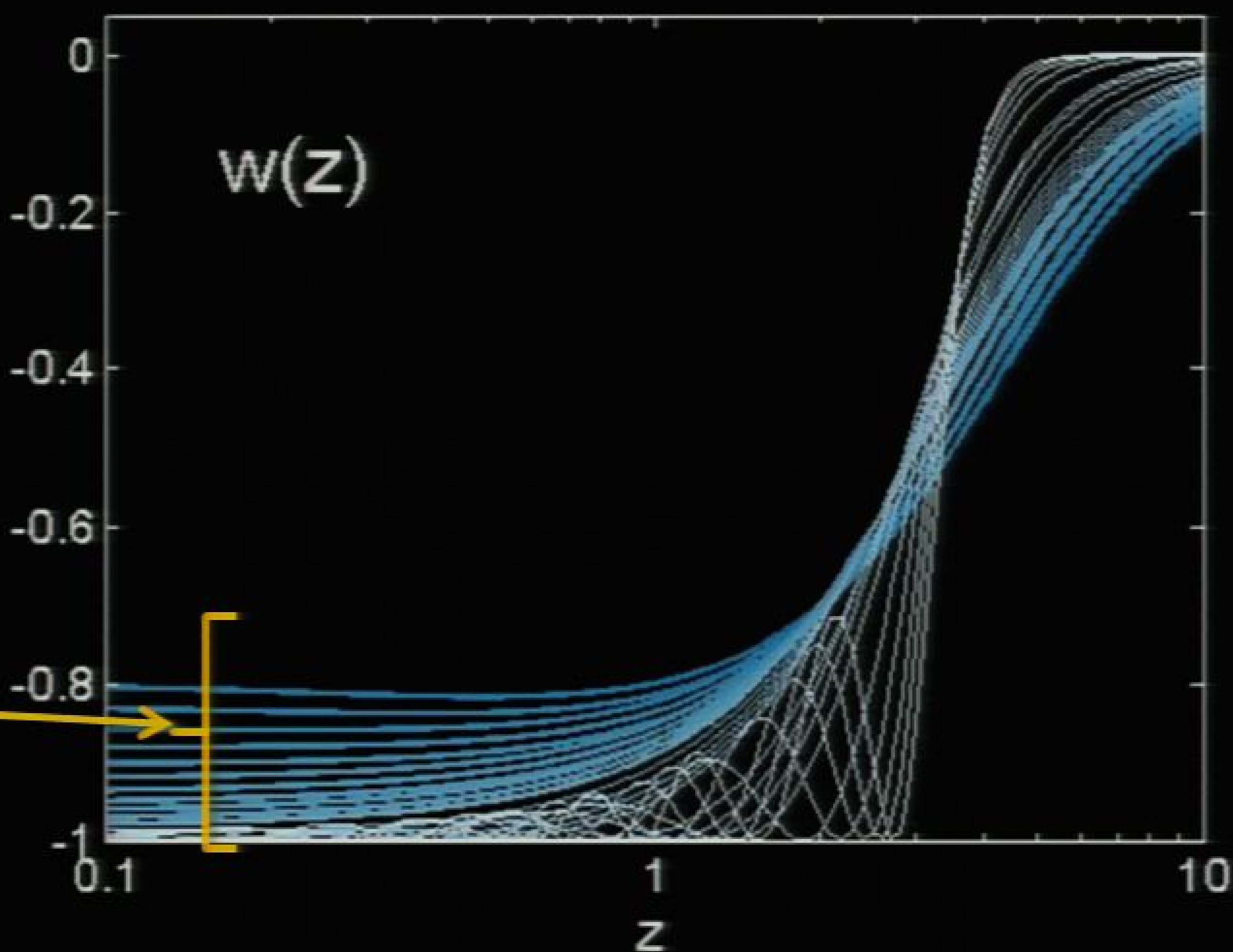
H(z) - DEP

Forcing w(0) < -0.9 means deviation < 2.5%



arXiv:0709.0526

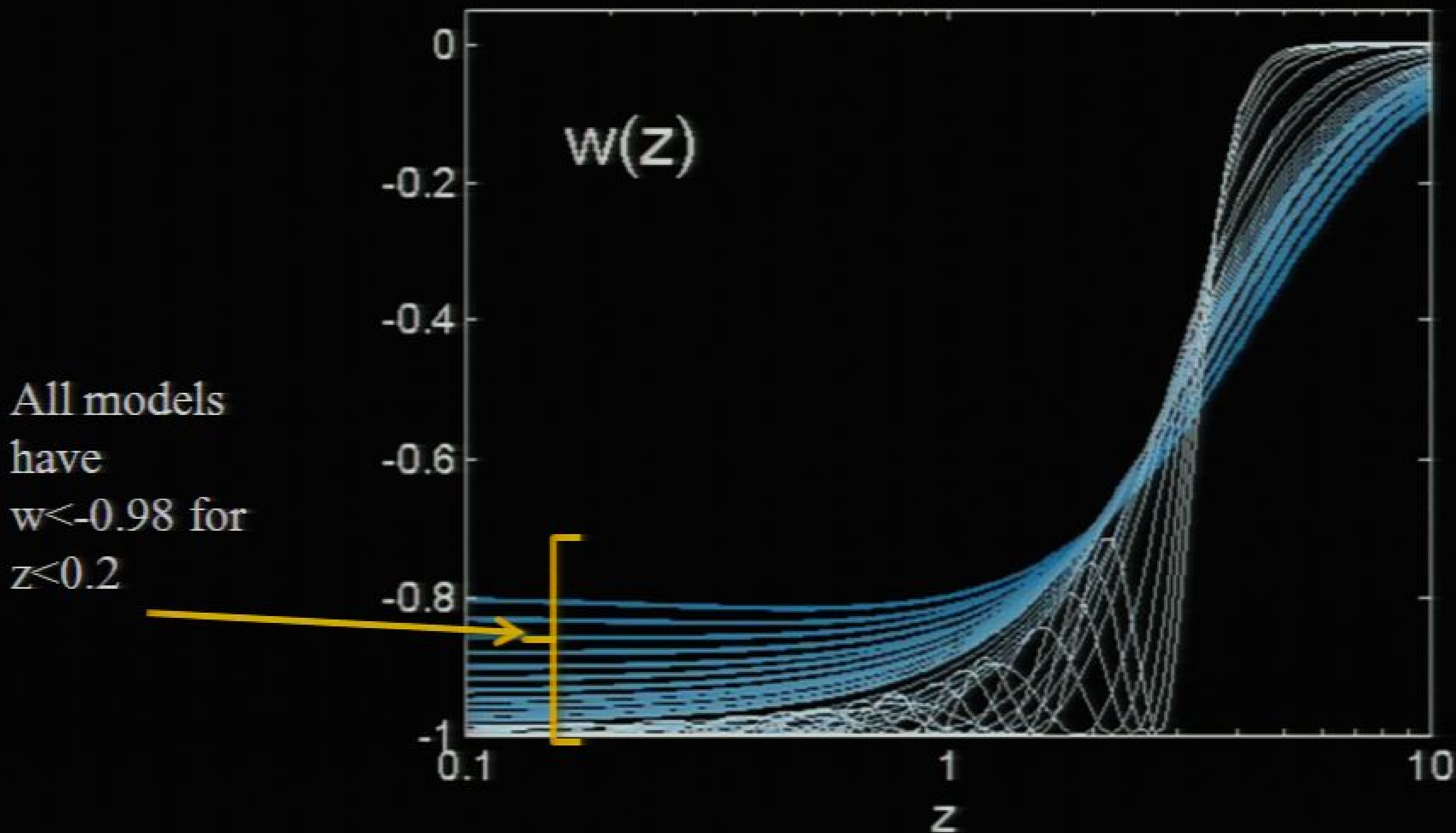
Derived w(z) from Double Exponential V(ϕ)



All models have $w<-0.98$ for $z<0.2$

arXiv:0709.0526

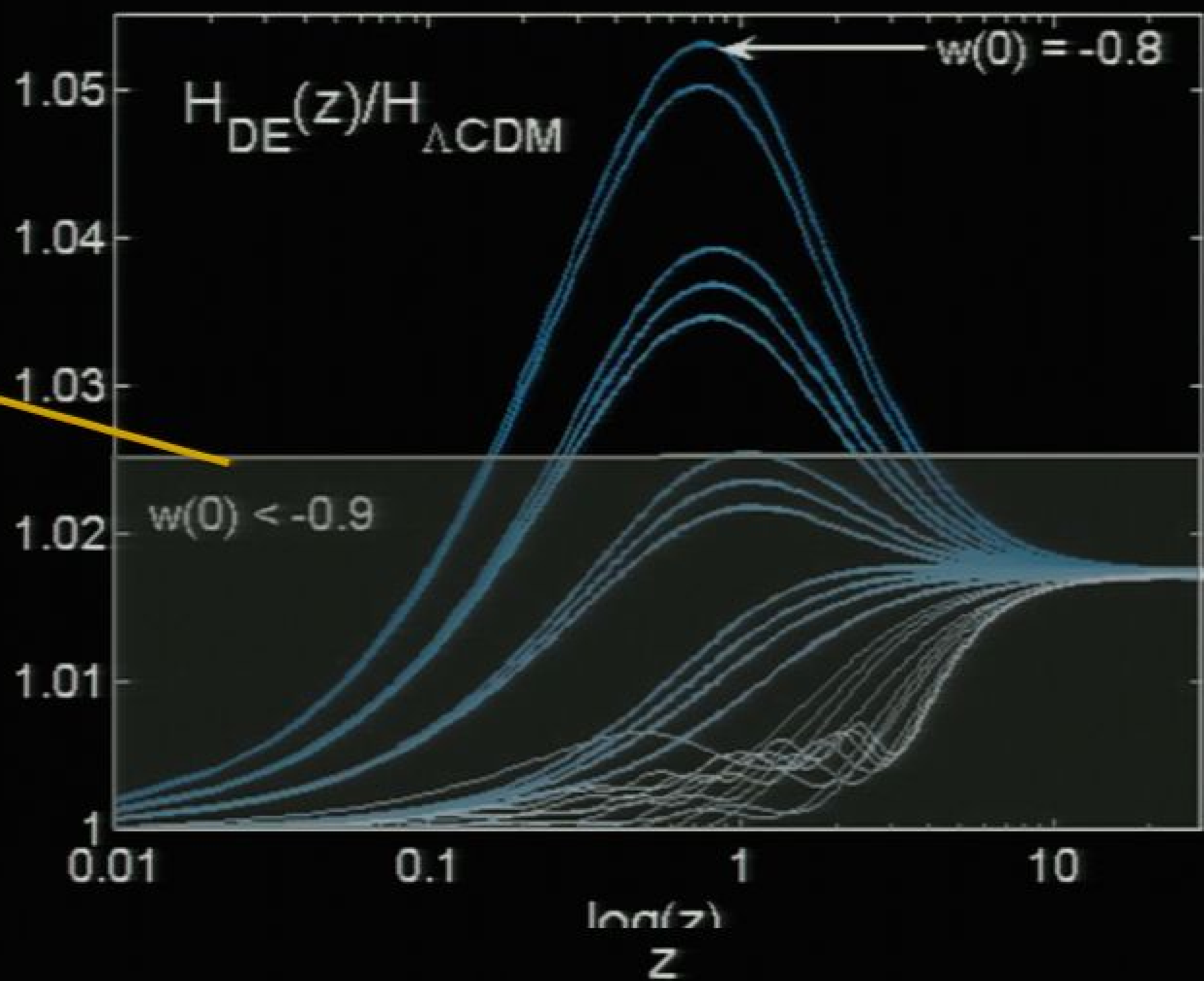
Derived w(z) from Double Exponential V(ϕ)



arXiv:0709.0526

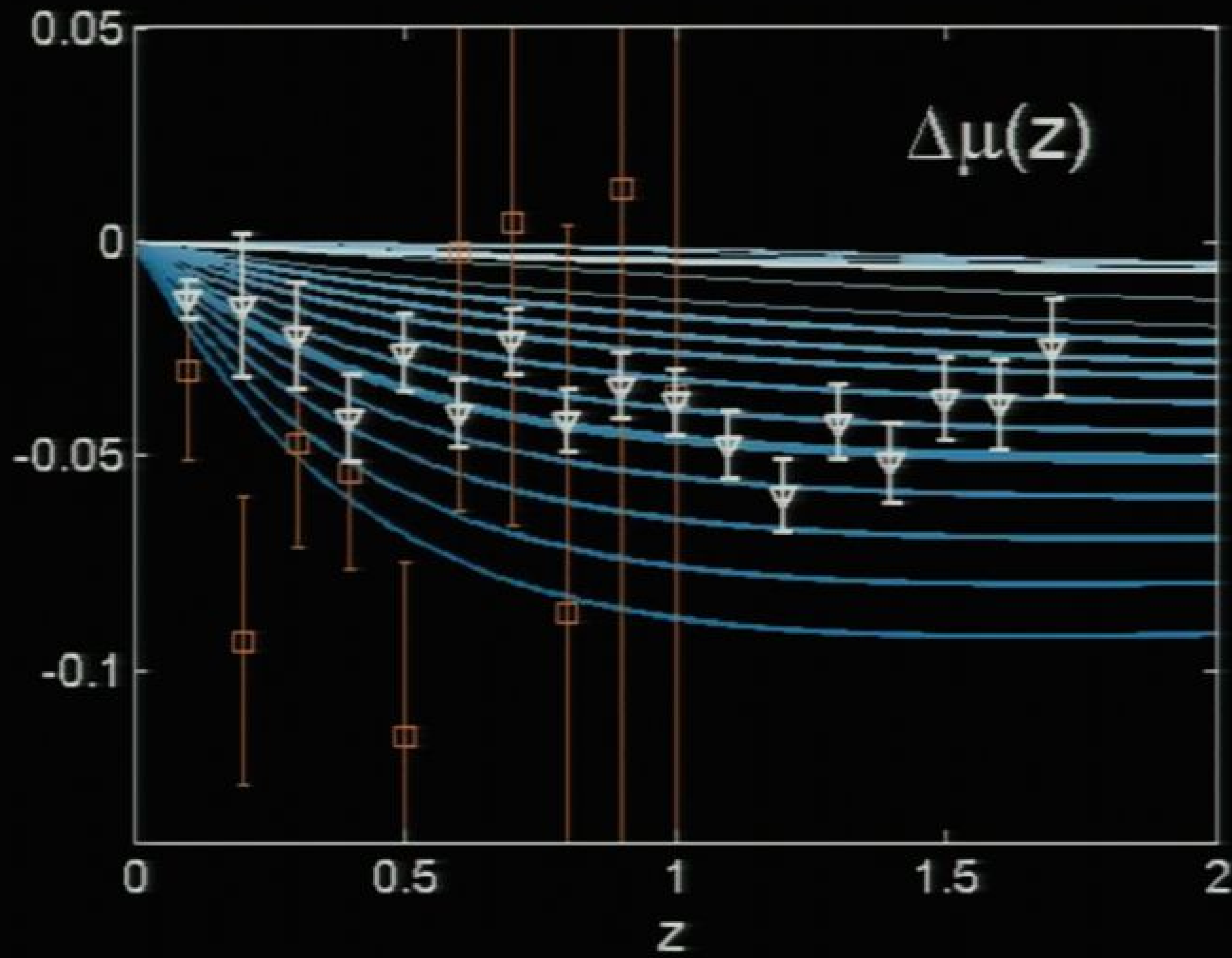
H(z) - DEP

Forcing
w(0) < -0.9
means
deviation <
2.5%



arXiv:0709.0526

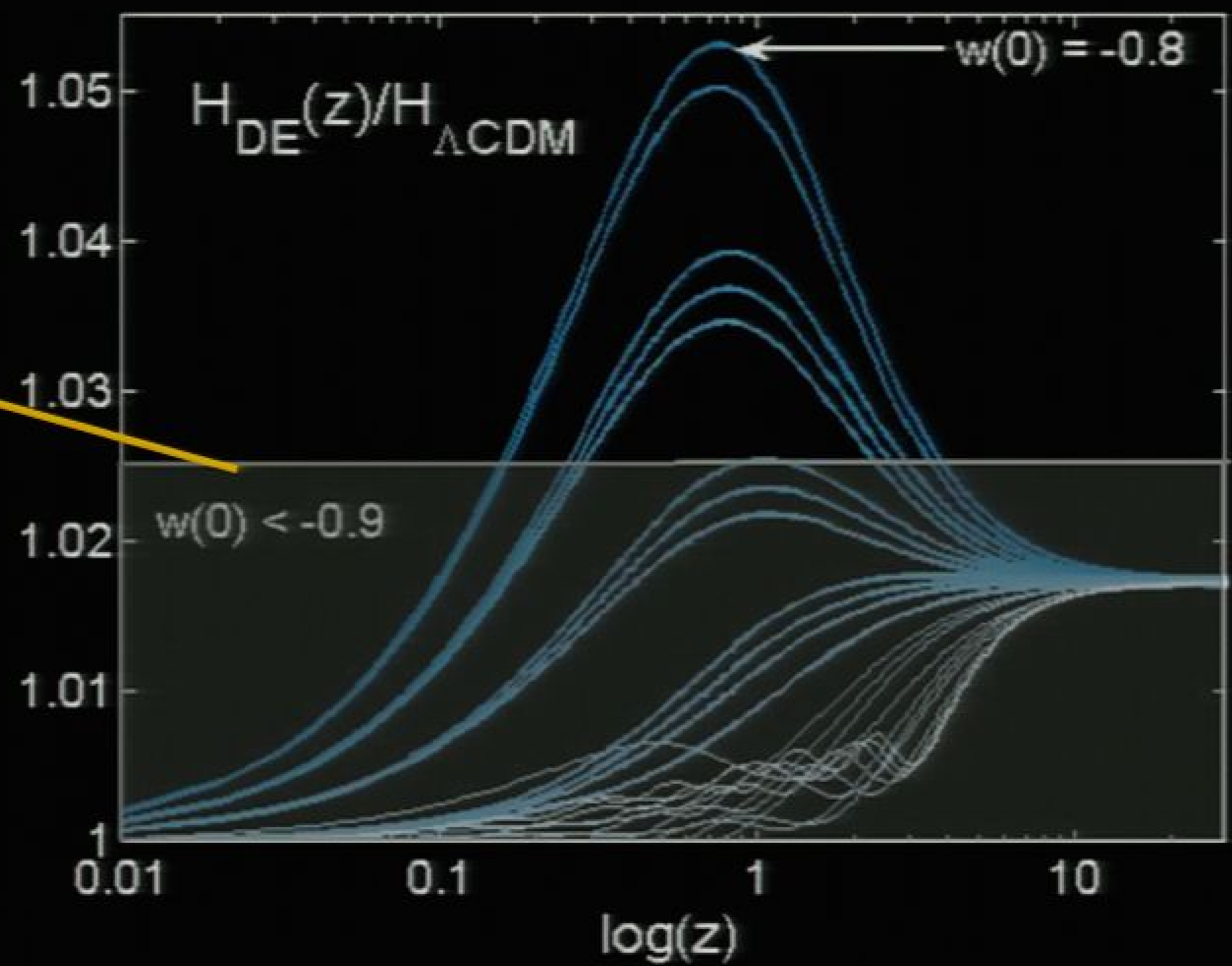
$\Delta\mu(z)$ - DEP



arXiv:0709.0526

H(z) - DEP

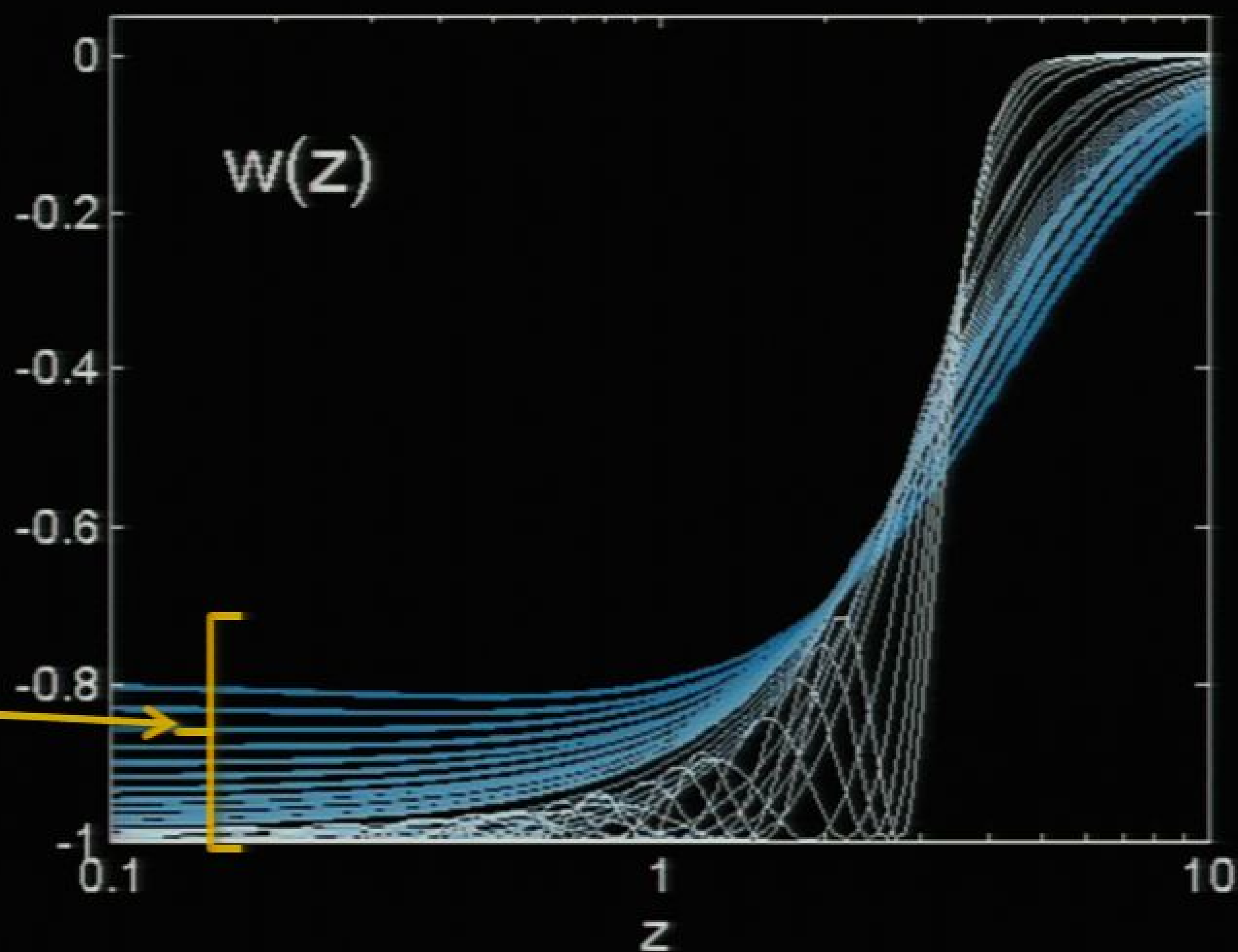
Forcing $w(0) < -0.9$ means deviation < 2.5%



arXiv:0709.0526

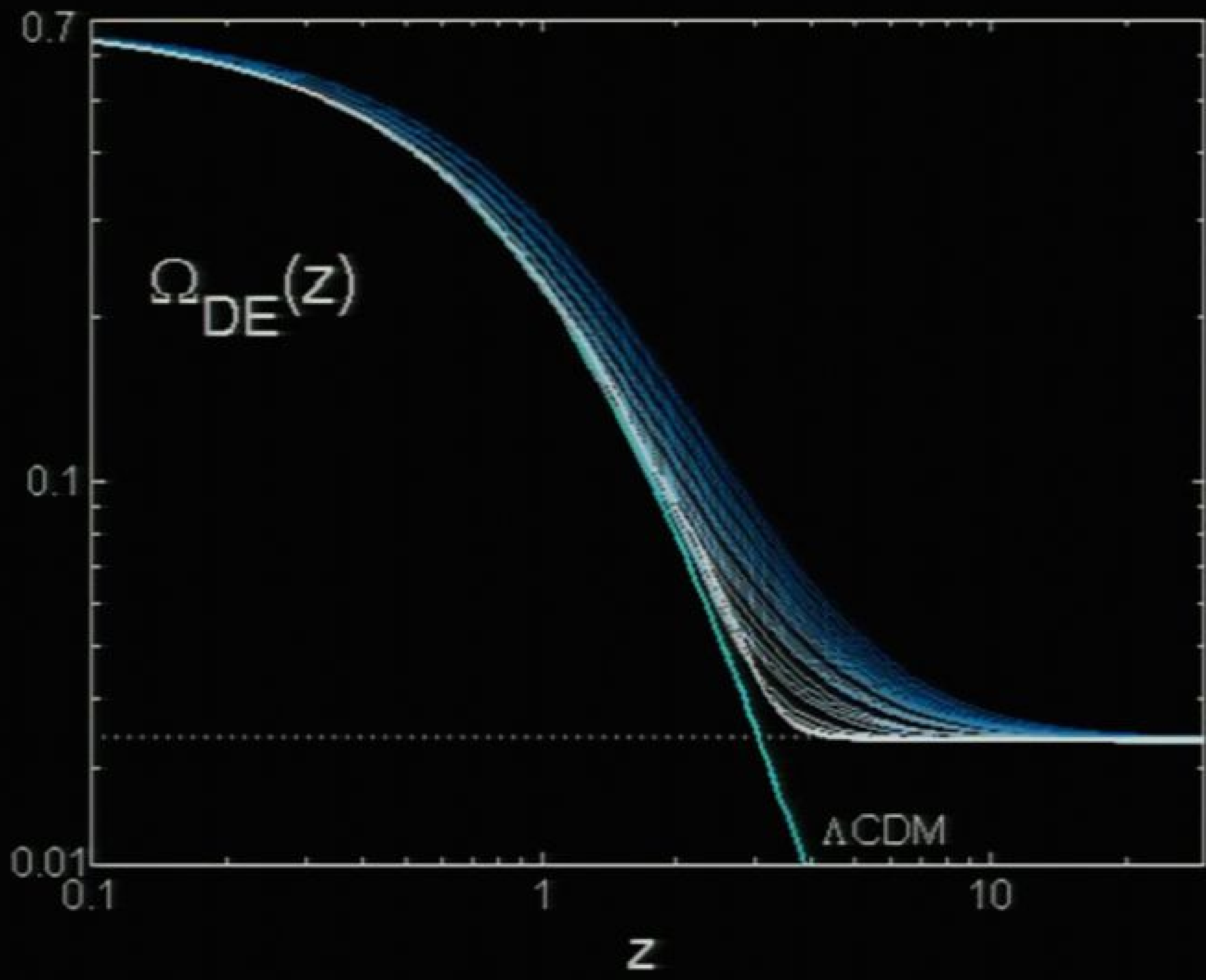
Derived w(z) from Double Exponential V(ϕ)

All models have w<-0.98 for z<0.2



arXiv:0709.0526

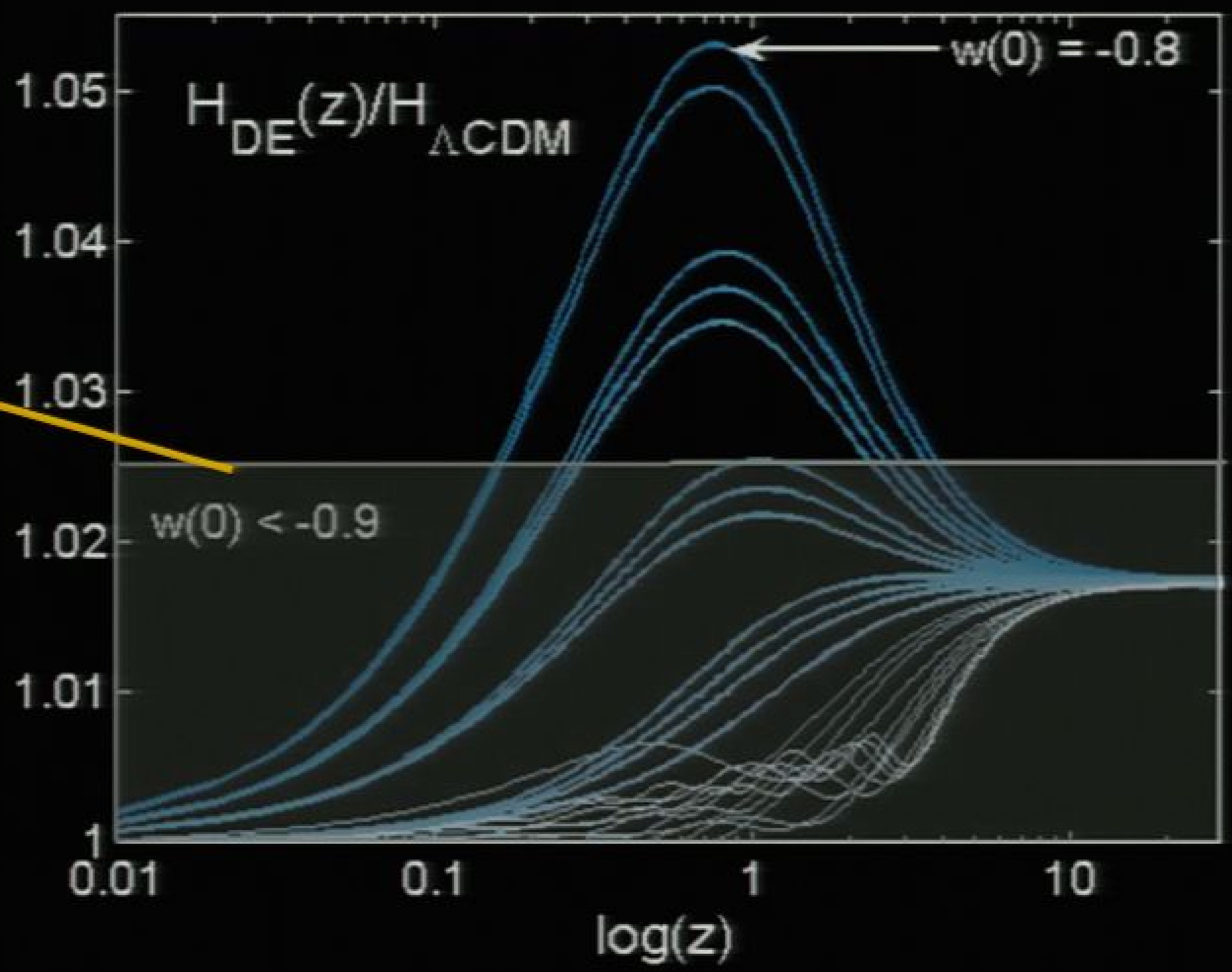
Energy Density - DEP



arXiv:0709.0526

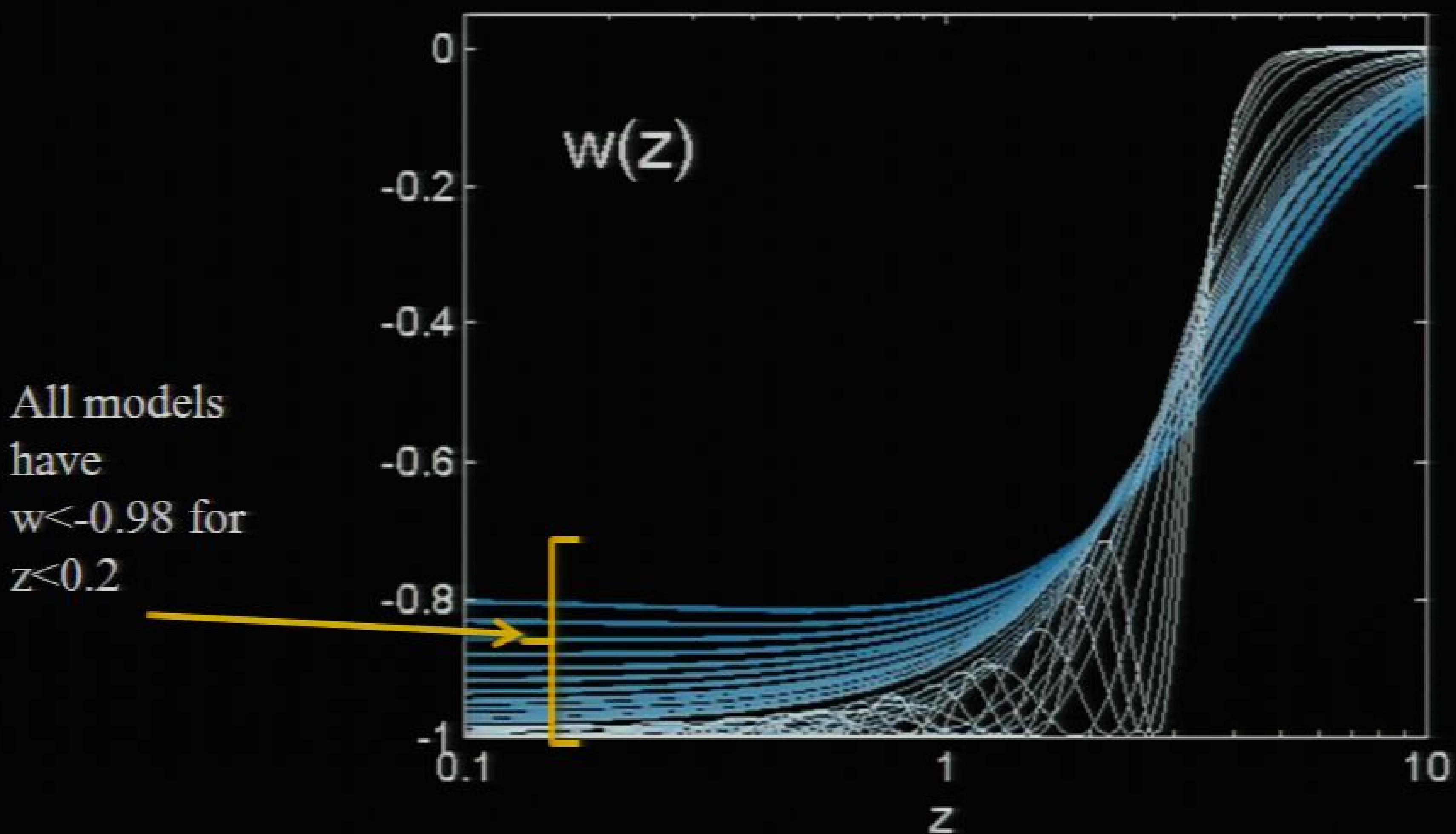
H(z) - DEP

Forcing w(0) < -0.9 means deviation < 2.5%



arXiv:0709.0526

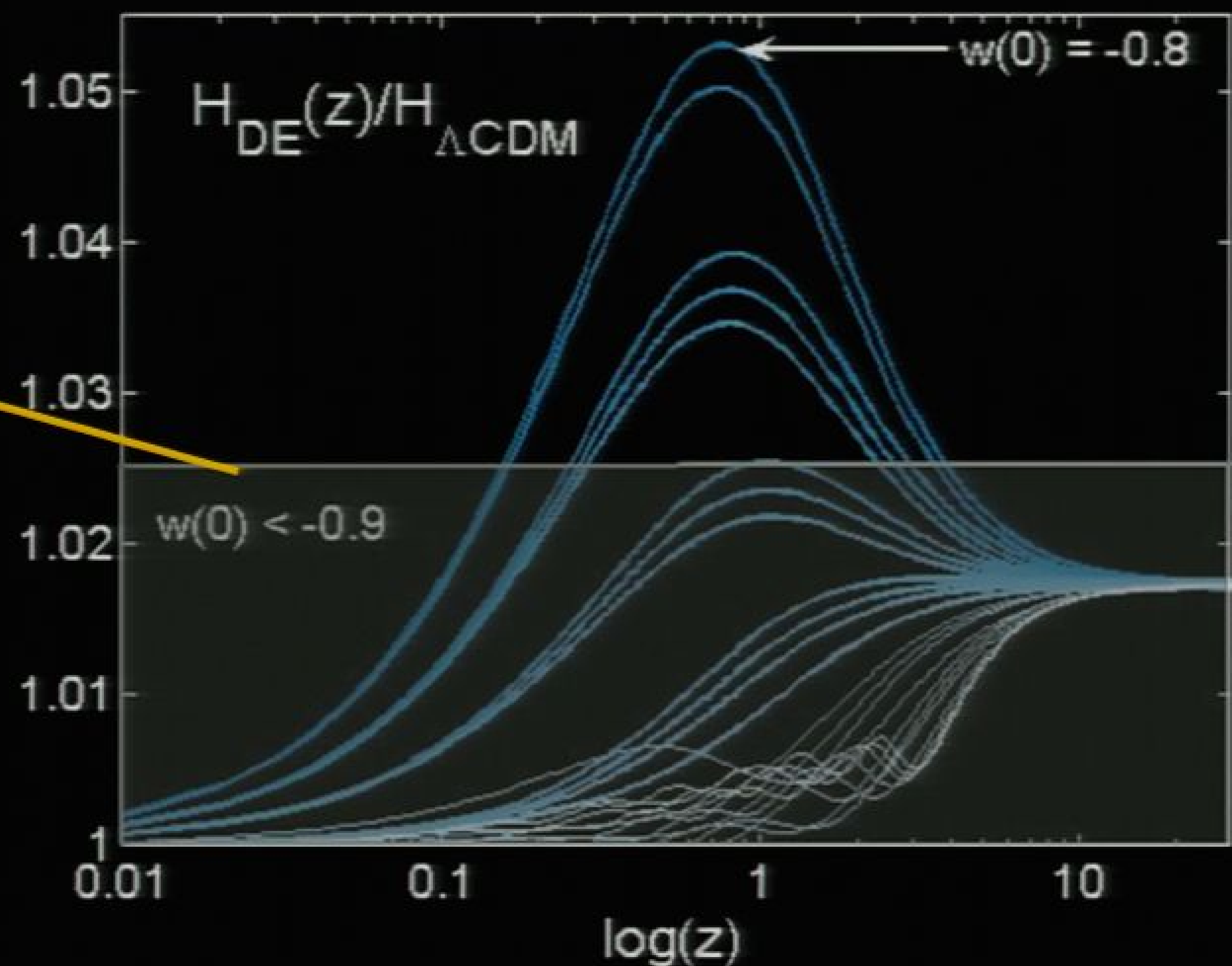
Derived w(z) from Double Exponential V(ϕ)



arXiv:0709.0526

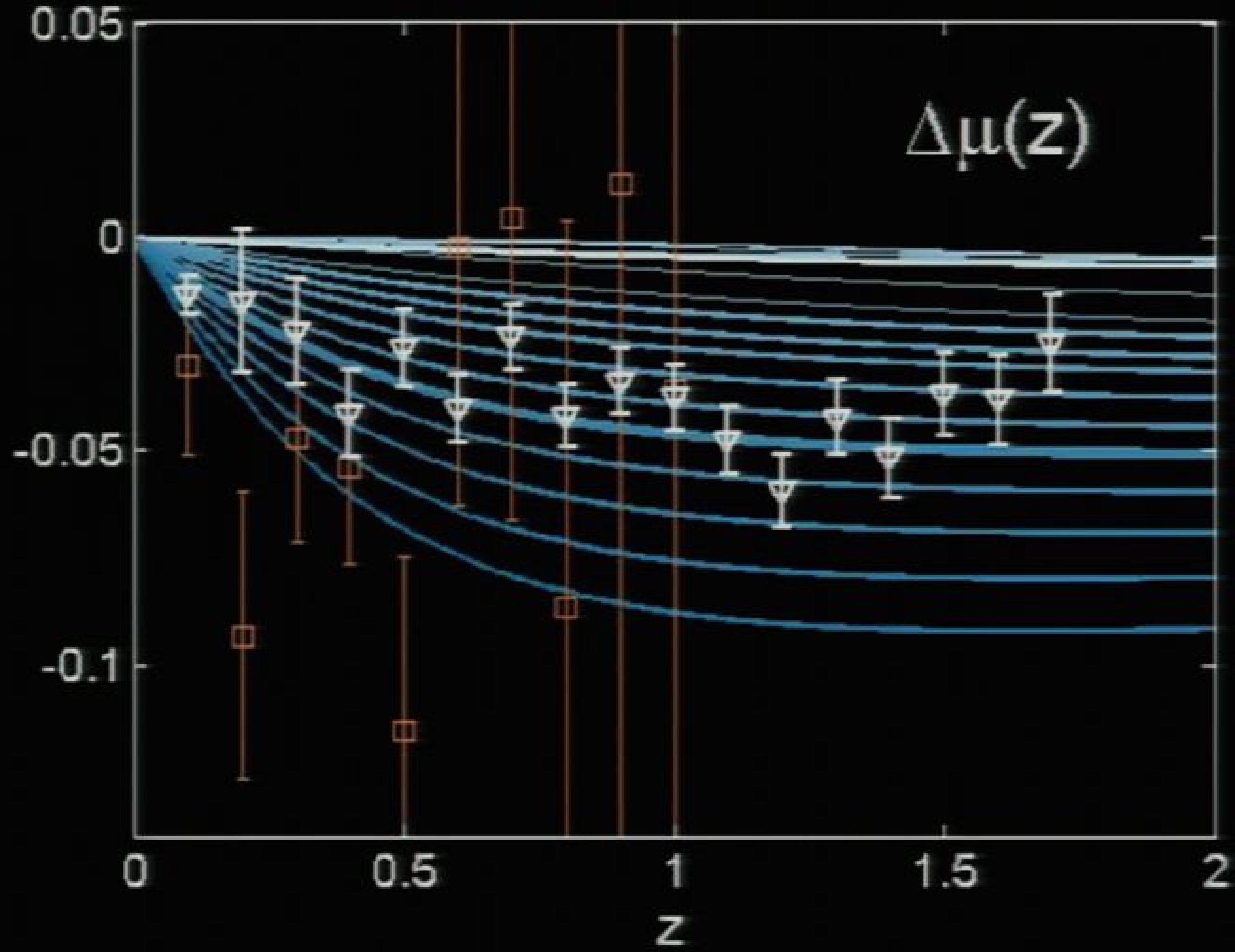
H(z) - DEP

Forcing w(0) < -0.9 means deviation < 2.5%



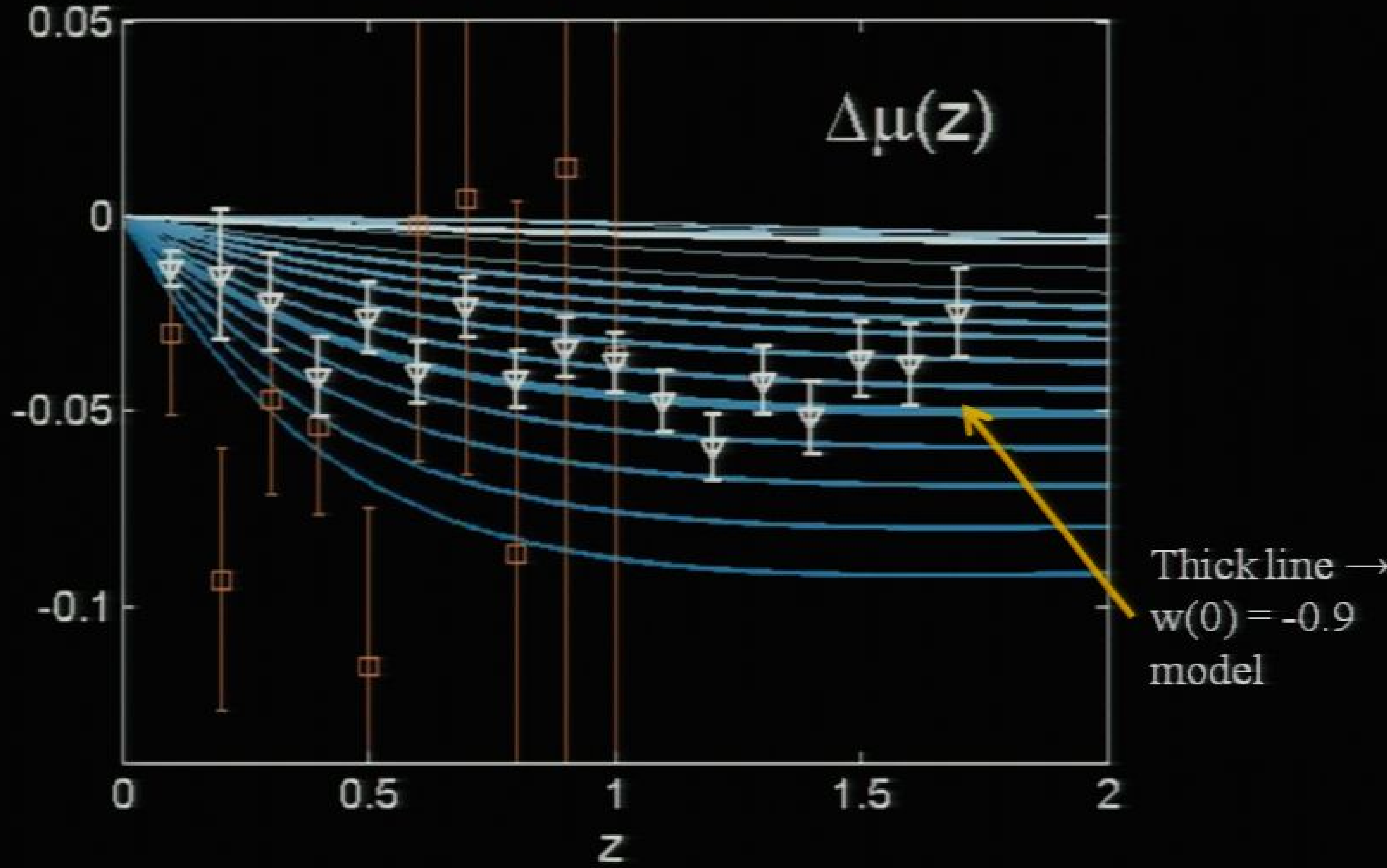
arXiv:0709.0526

Δμ(z) - DEP



arXiv:0709.0526

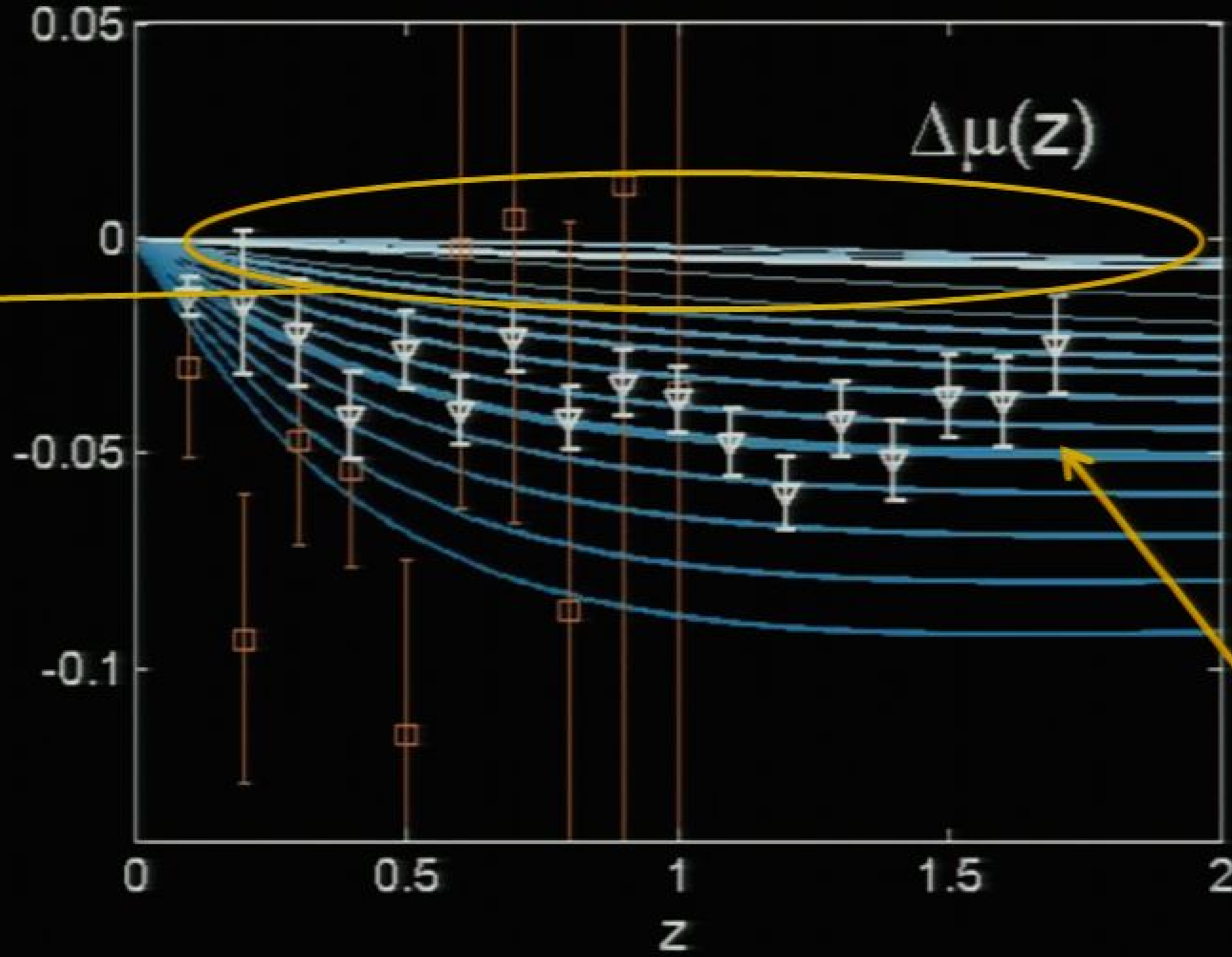
Δμ(z) - DEP



arXiv:0709.0526

$\Delta\mu(z)$ - DEP

All oscillating models have $|\Delta\mu| < 0.032$

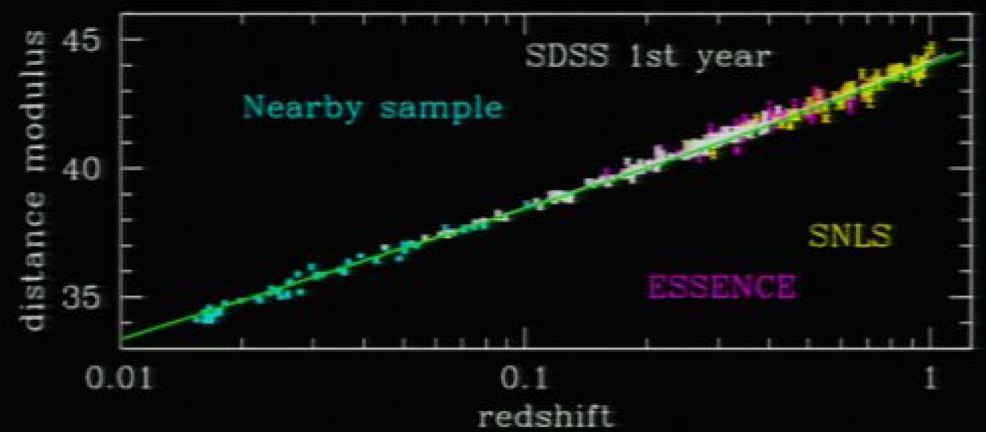


Thick line → $w(0) = -0.9$ model

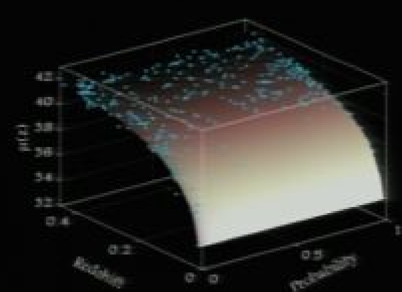
arXiv:0709.0526

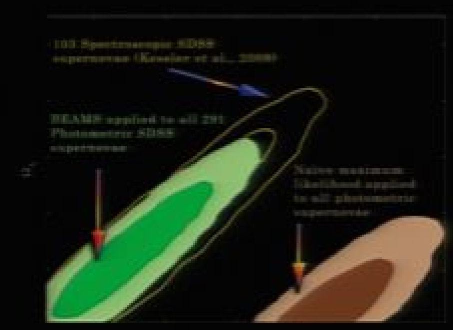
Conclusions and Future

- SDSS

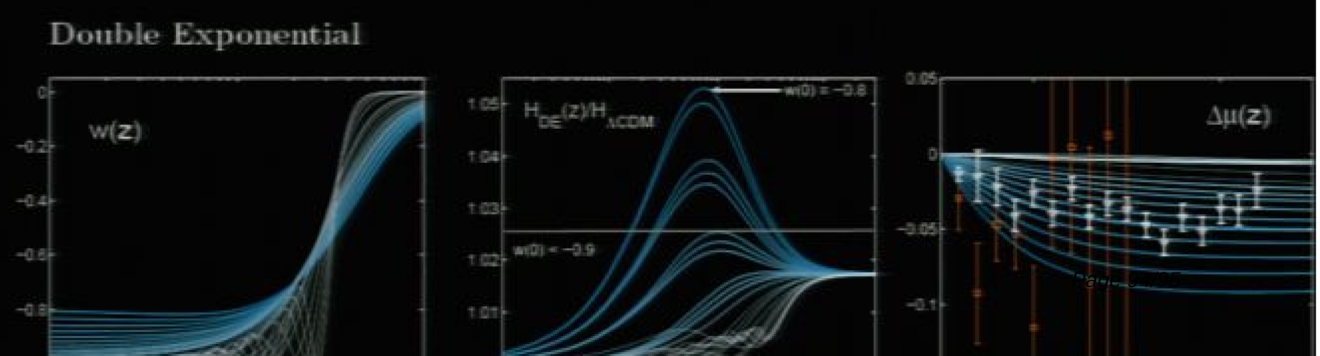


- BEAMS





- DE Dynamics



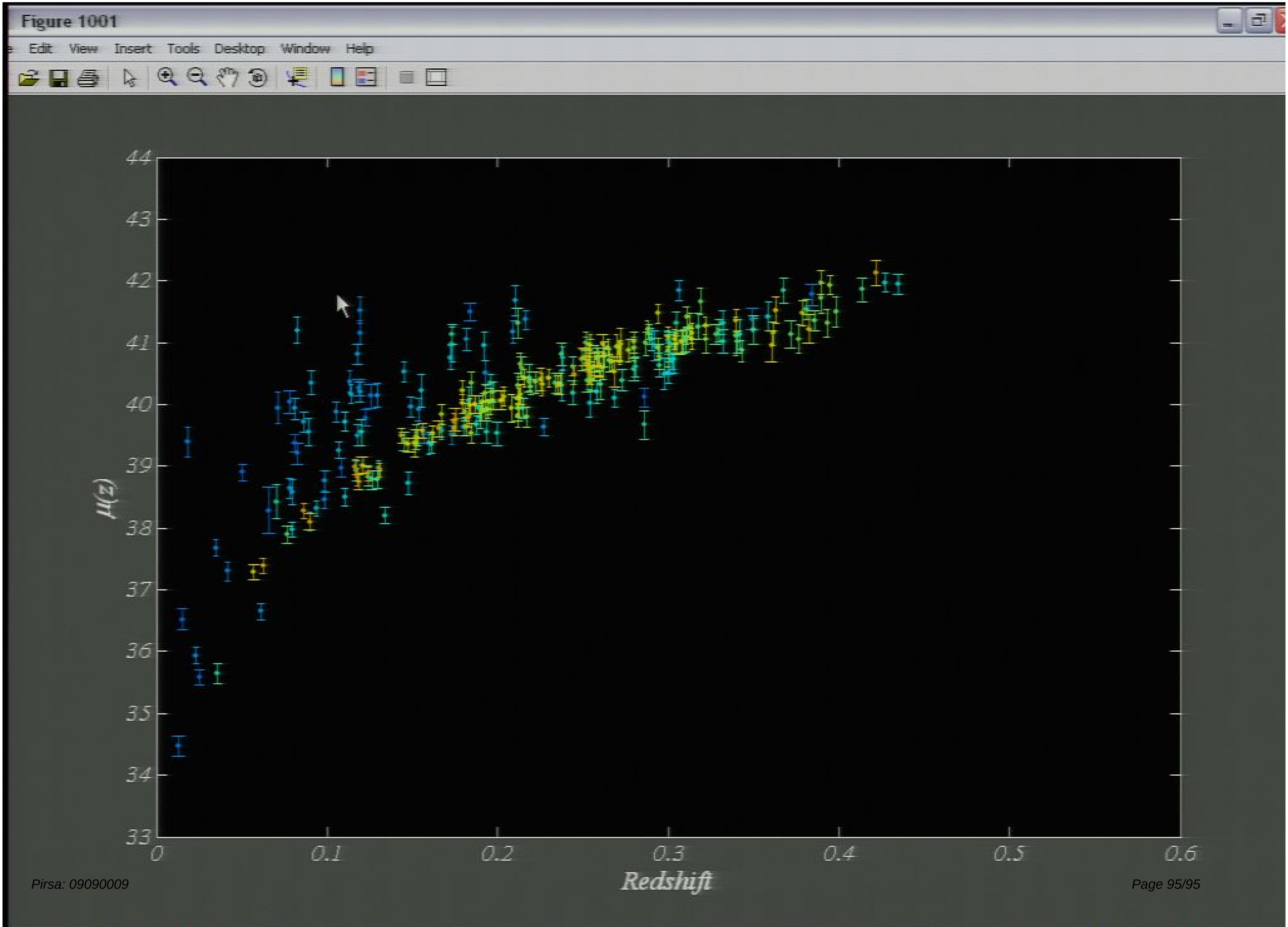


Figure 1001
Edit View Insert Tools Desktop Window Help
44
43
42
41
40
39
38
37
36
35
34
33
μ(z)
0
0.1
0.2
0.3
0.4
0.5
0.6
Redshift