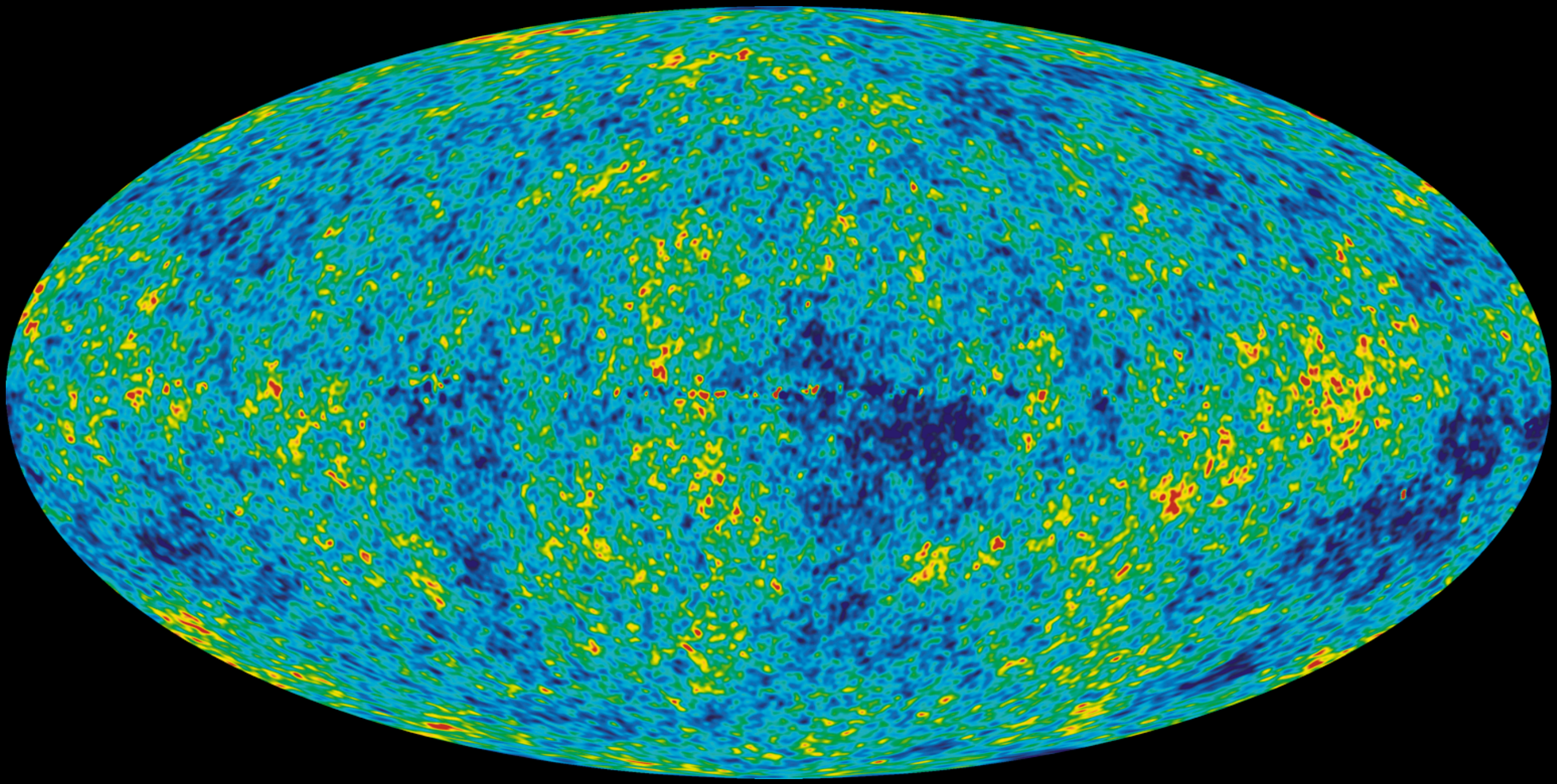
Running After w(z): The Stumbling Blocks

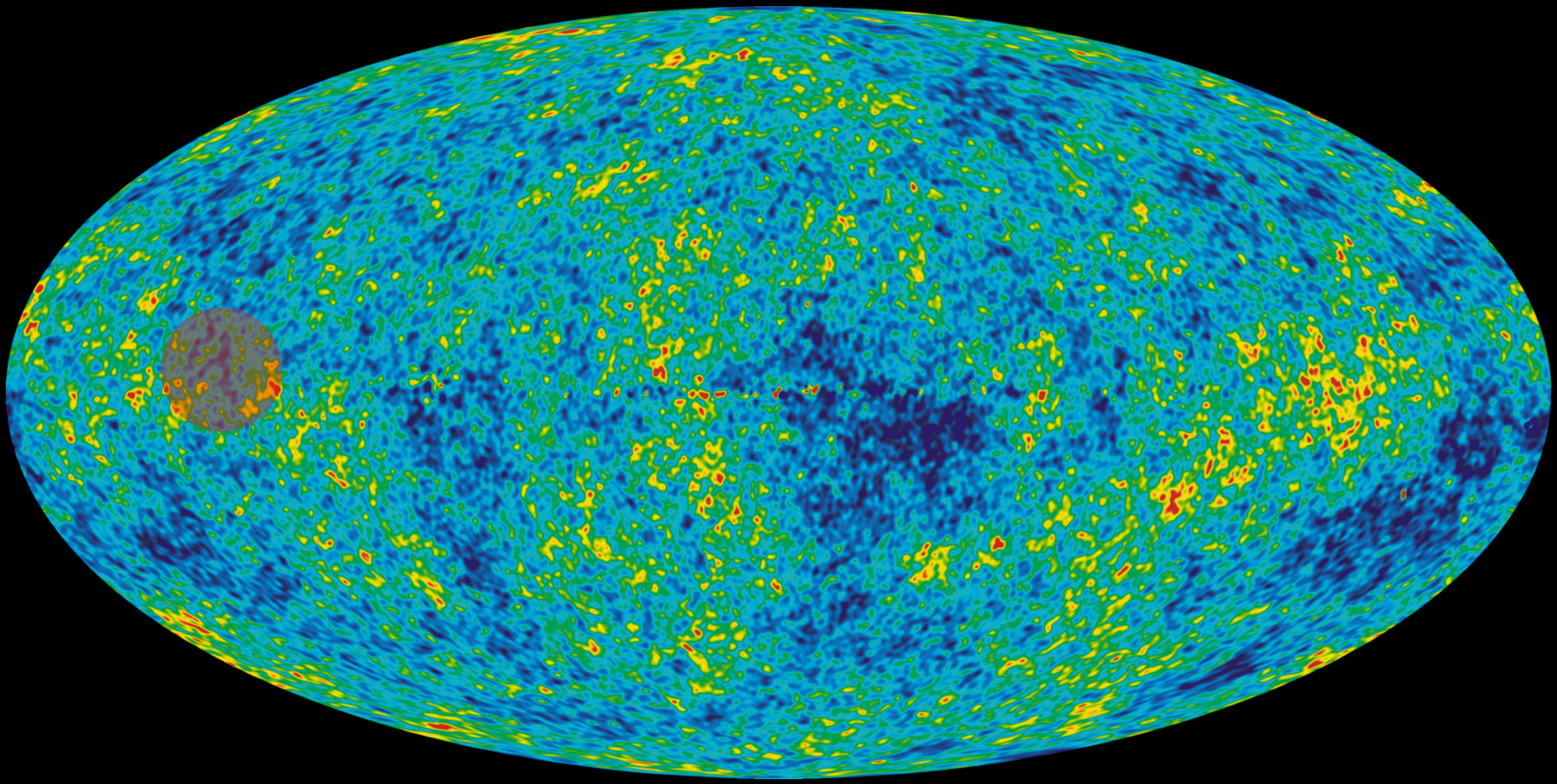
Devdeep Sarkar
Center for Cosmology, UC Irvine

In collaboration with:
Scott Sullivan (UCI/UCLA), Shahab Joudaki (UCI), Alexandre Amblard (UCI),
Daniel Holz (Los Alamos), Asantha Cooray (UCI).

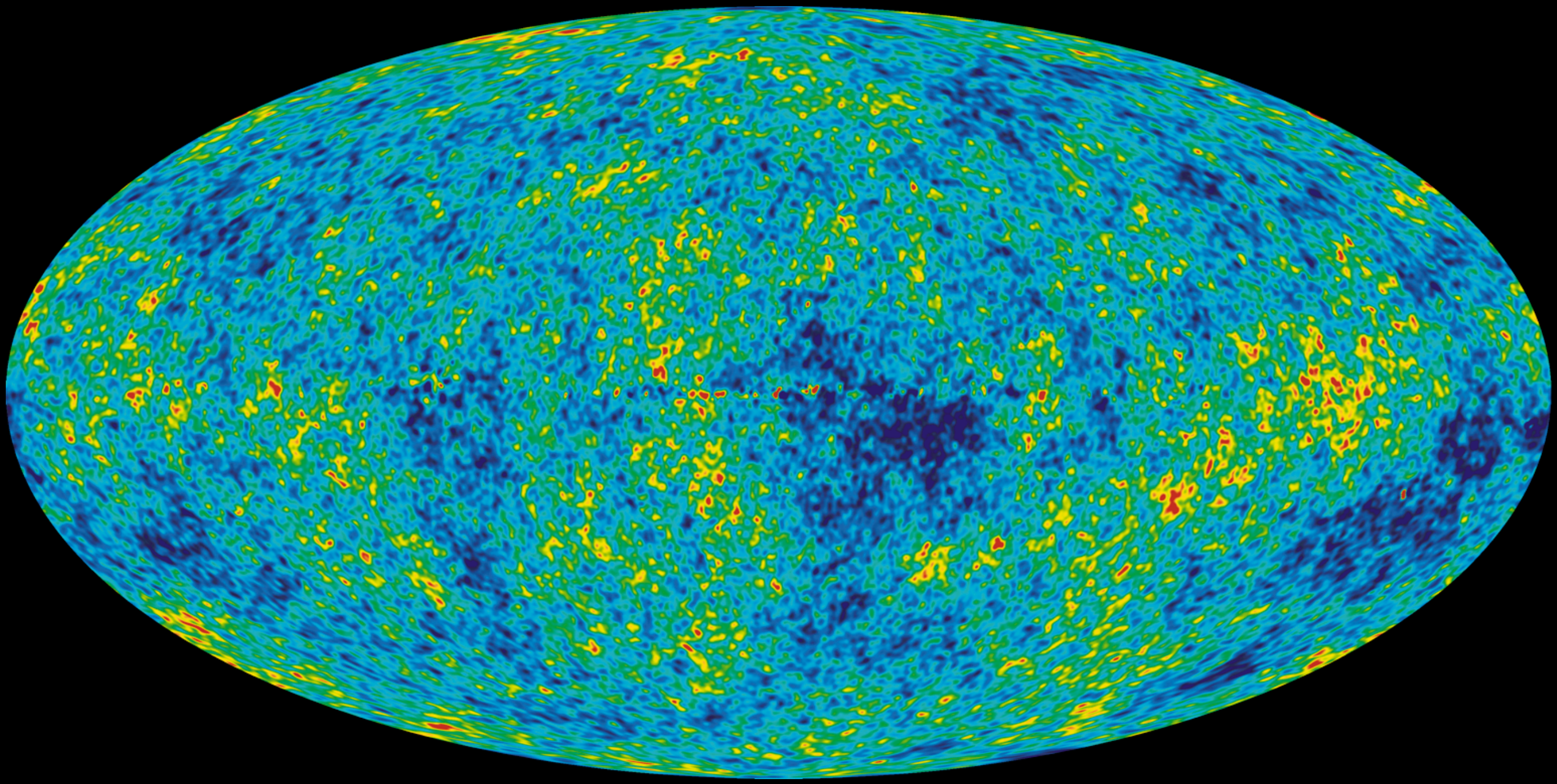
Vancouver TEXAS 2008 Dec 12, '08



Credit: NASA/WMAP Science Team

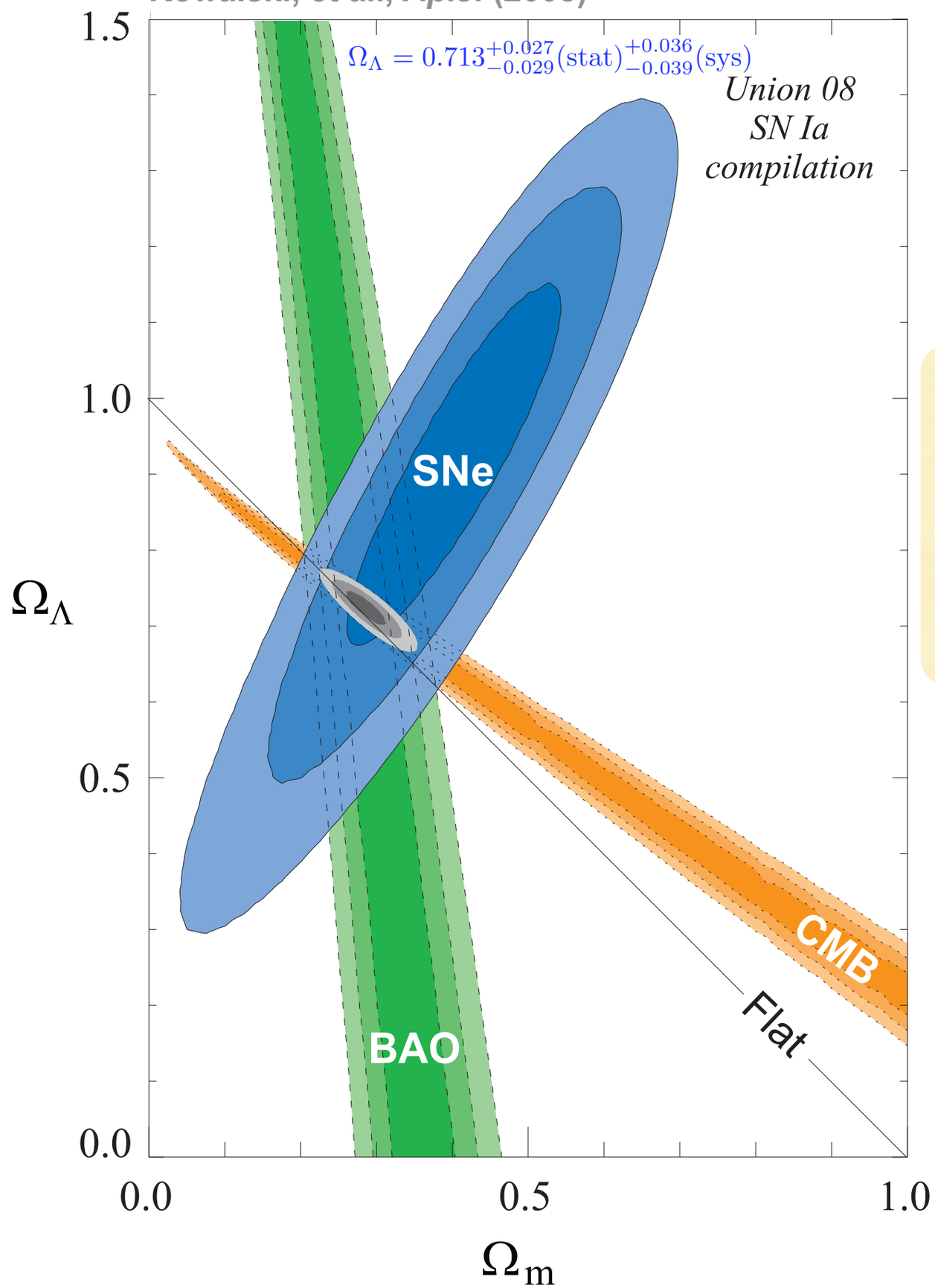


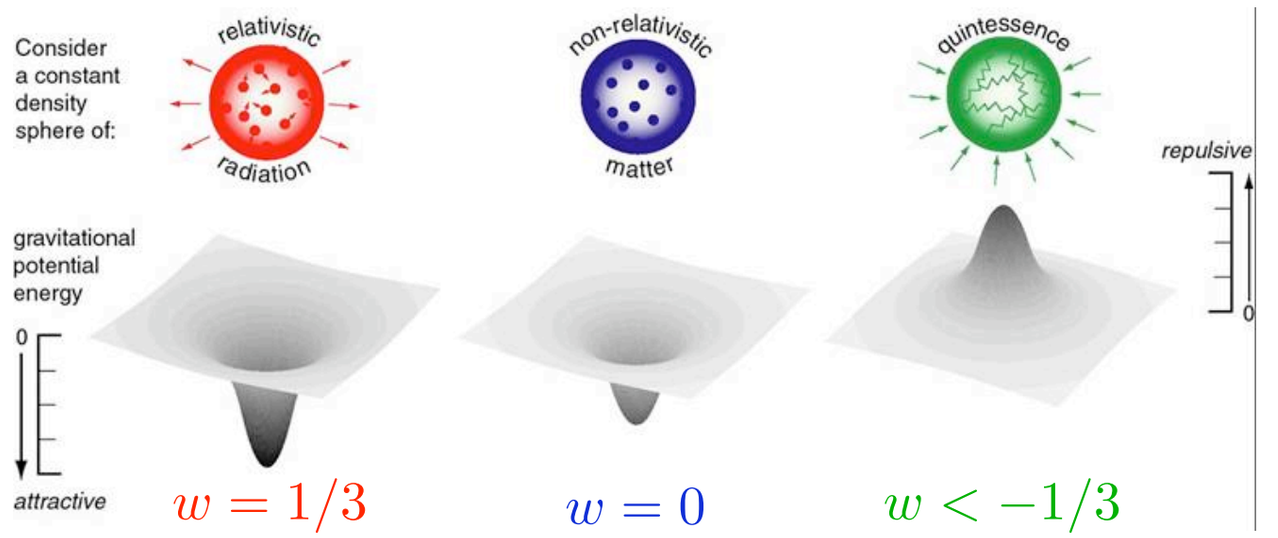
Credit: NASA/WMAP Science Team



Credit: NASA/WMAP Science Team

Supernova Cosmology Project
Kowalski, et al., *Ap.J.* (2008)

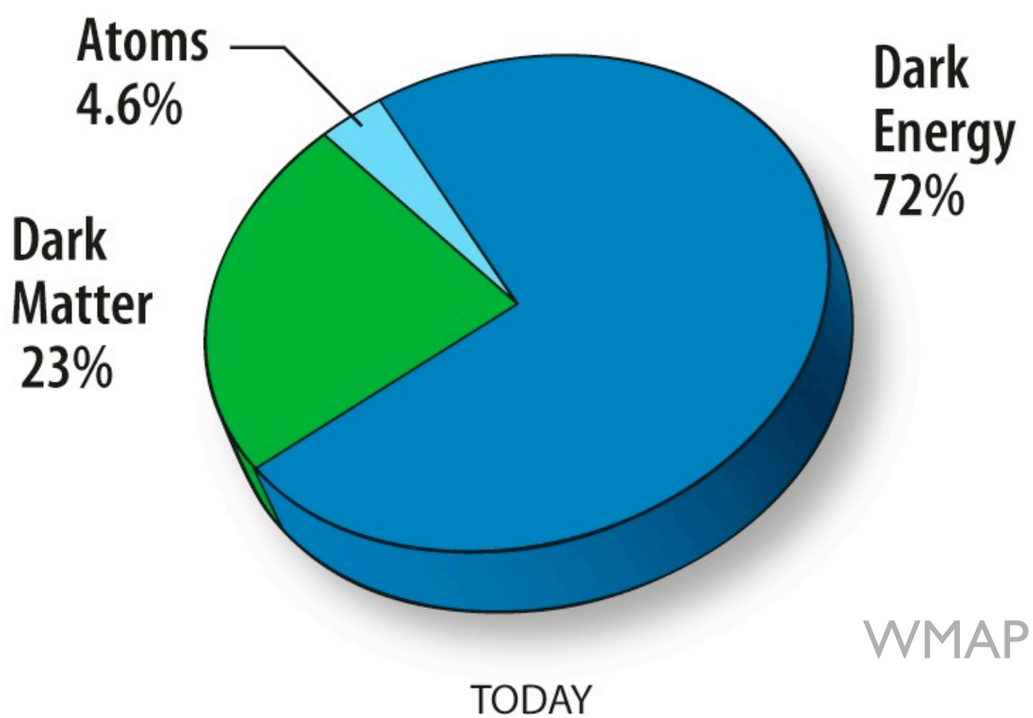




$$w = -0.969^{+0.059}_{-0.063}(\mathrm{stat})^{+0.063}_{-0.066}(\mathrm{sys})\ [\mathrm{Union}]$$

$$w = -\mathrm{x.xxx}^{+0.077}_{-0.077}(\mathrm{stat})^{+0.071}_{-0.071}(\mathrm{sys})\ [\mathrm{SNLS}]$$

(Guy, Conley: Talk at TEXAS 2008 on Dec 09, 2008)



WMAP

Agenda

w(z): To Bin or Not To Bin

Supernovae

Systematics I

- Lensing of SNe
- P(μ)
- Bias on the EOS
- (Not) To Worry About?

Systematics II

- Two Populations of SN
- Leaking into H.D.
- Bias on the EOS
- Increased Error?

Agenda

w(z): To Bin or Not To Bin

Supernovae

Systematics I

- Lensing of SNe
- $P(\mu)$
- Bias on the EOS
- (Not) To Worry About?

Systematics II

- Two Populations of SN
- Leaking into H.D.
- Bias on the EOS
- Increased Error?

Seeking Temporal Evolution of "w"

1. Parametrize w(z) [Adopted by DETF]

$$w(z) = w_0 + w_a z/(1+z)$$

Chevallier and Polarski 2001, Linder 2003

2. Principal Component Analysis

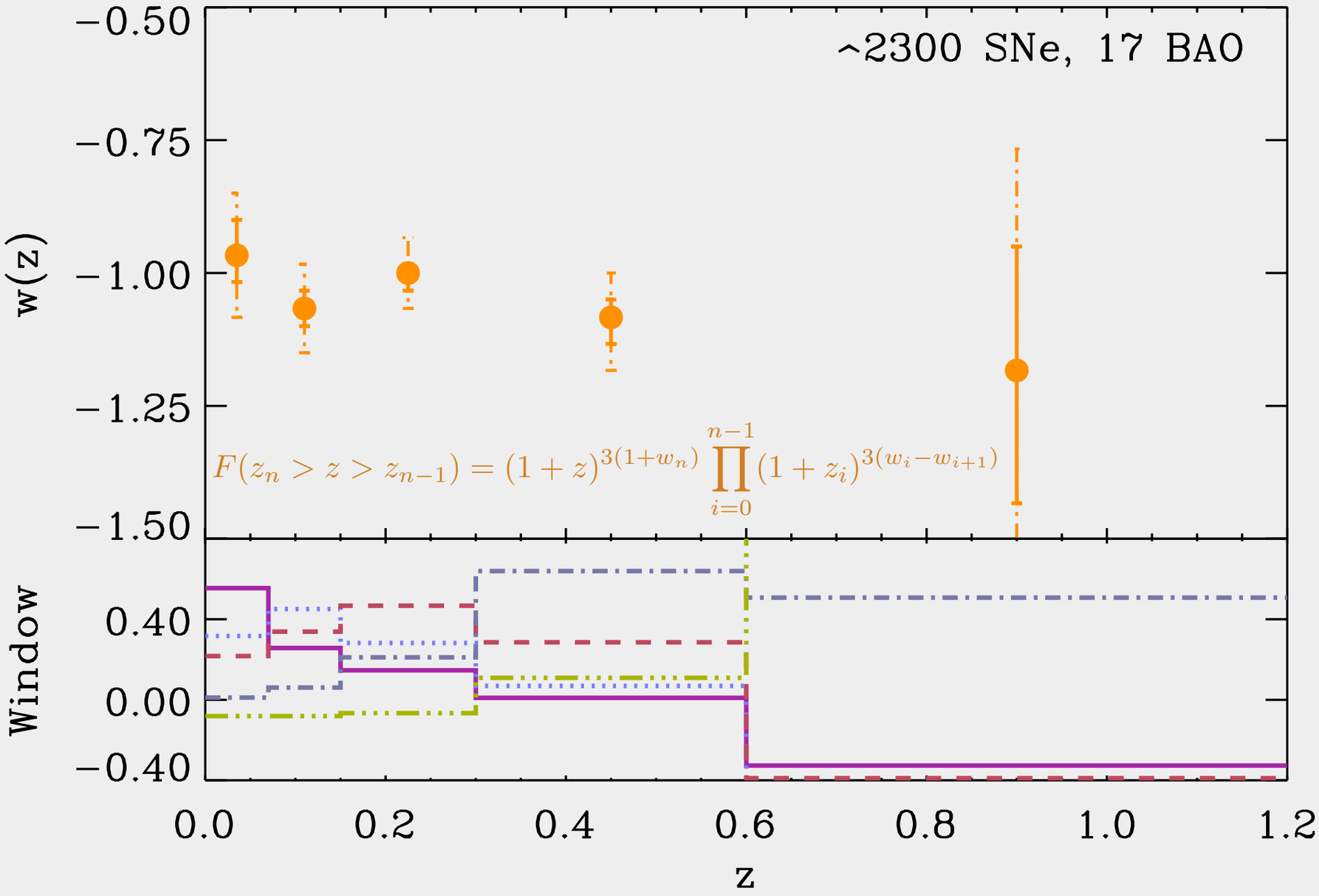
Huterer and Starkman 2003,
Rocky Kolb's Talk

3. Uncorrelated Estimates of w(z)

Huterer and Cooray 2005

Binned Estimates: Future

$$H(z) = H_0 \left[\Omega_m (1+z)^3 + \Omega_k (1+z)^2 + (1-\Omega_m-\Omega_k) F(z)\right]^{1/2}$$

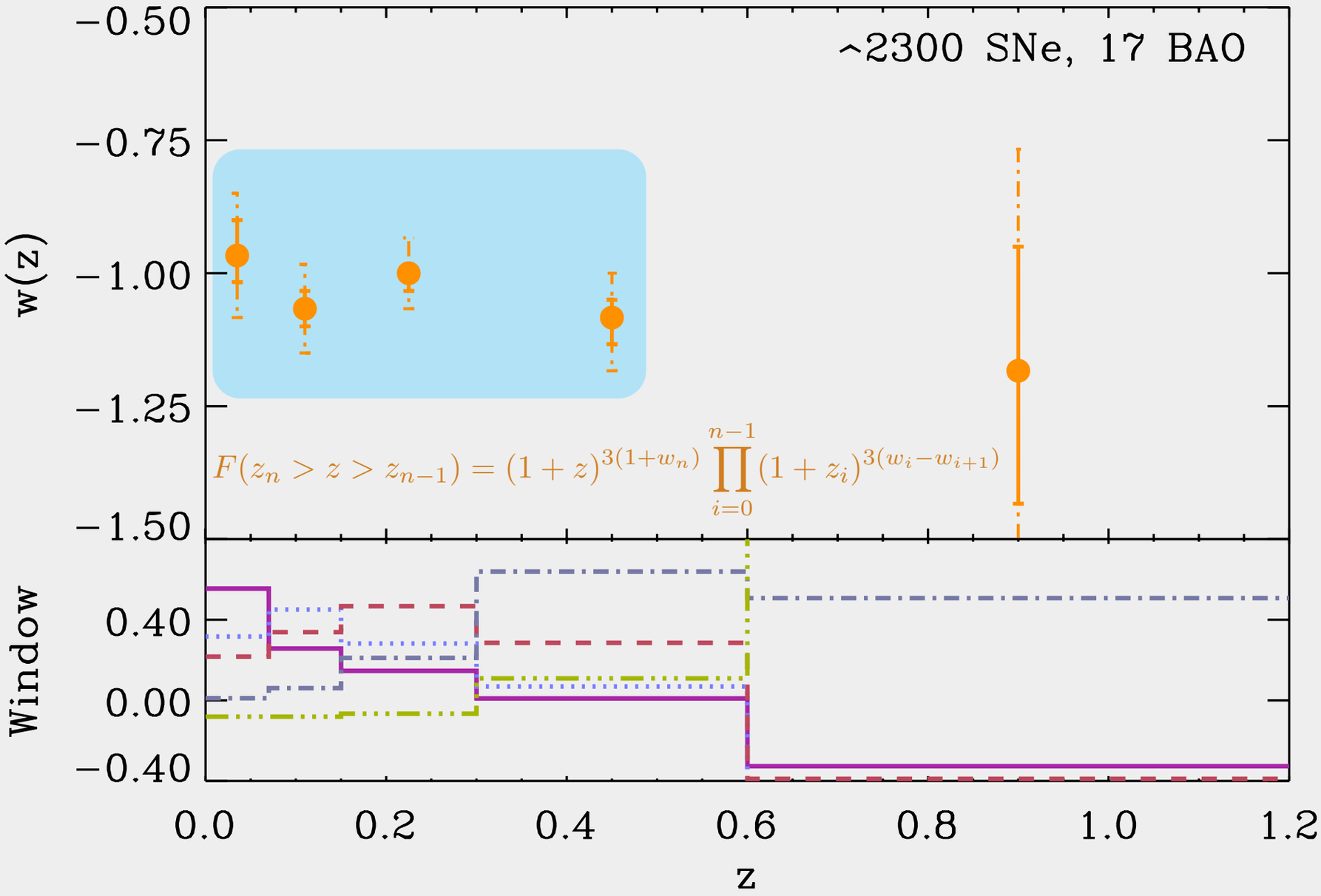


w_1	0-.07
w_2	.07-.15
w_3	0.15-.3
w_4	0.3-0.6
w_5	0.6-1.2
w_6	1.2-2.0

D.S., S. Sullivan, S. Joudaki, A. Amblard, D. Holz, A. Cooray; PRL, 100, 241302 (2008)

Binned Estimates: Future

$$H(z) = H_0 \left[\Omega_m(1+z)^3 + \Omega_k(1+z)^2 + (1-\Omega_m-\Omega_k)F(z)\right]^{1/2}$$



w_1	0-.07
w_2	.07-.15
w_3	0.15-.3
w_4	0.3-0.6
w_5	0.6-1.2
w_6	1.2-2.0

D.S., S. Sullivan, S. Joudaki, A. Amblard, D. Holz, A. Cooray; PRL, 100, 241302 (2008)

Agenda

w(z) : To Bin or Not To Bin

Supernovae

Systematics I

- Lensing of SNe
- P(μ)
- Bias on the EOS
- (Not) To Worry About?

Systematics II

- Two Populations of SN
- Leaking into H.D.
- Bias on the EOS
- Increased Error?

Agenda

w(z) : To Bin or Not To Bin

Supernovae

Systematics I

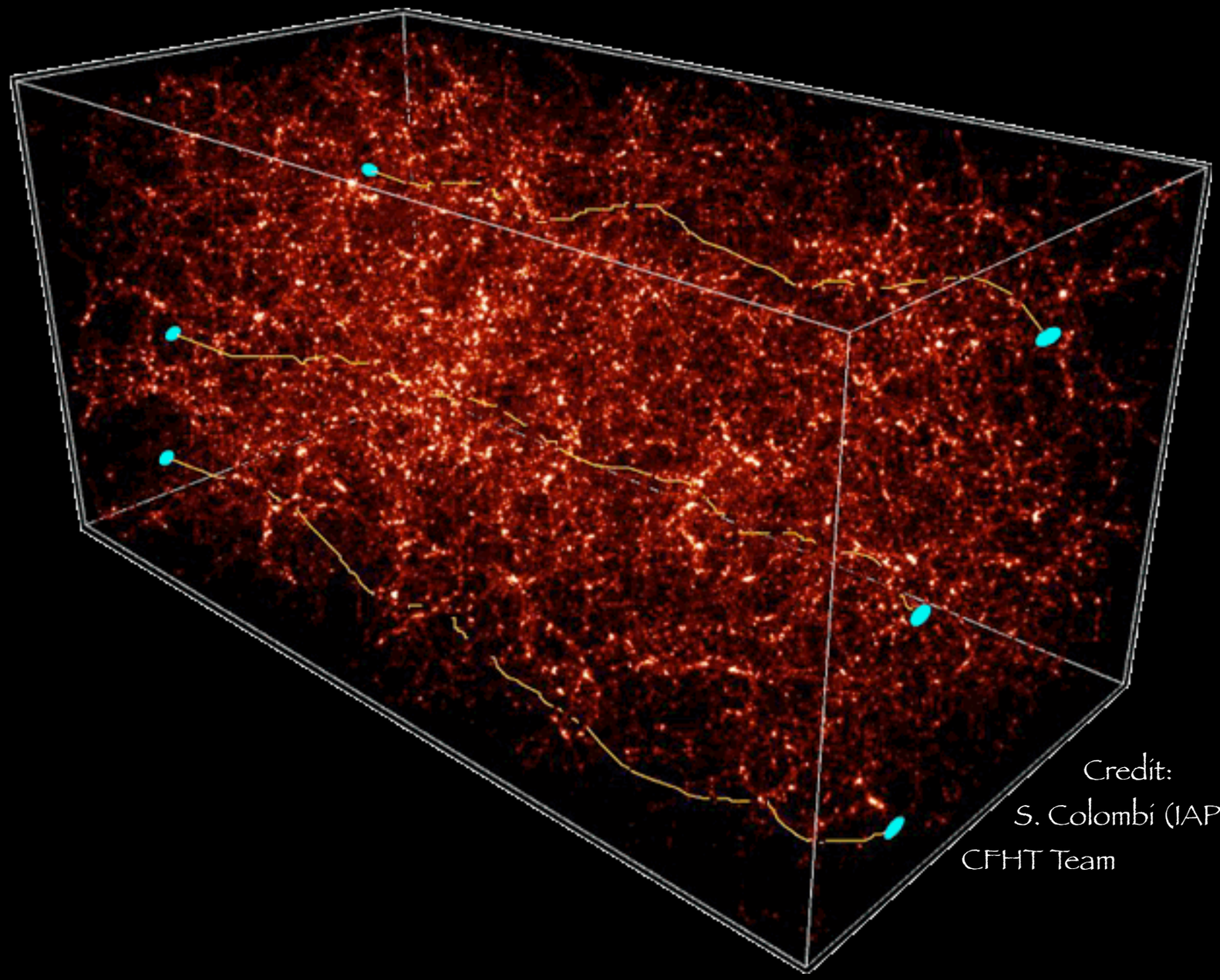
- Lensing of SNe
- P(μ)
- Bias on the EOS
- (Not) To Worry About?

Systematics II

- Two Populations of SN
- Leaking into H.D.
- Bias on the EOS
- Increased Error?

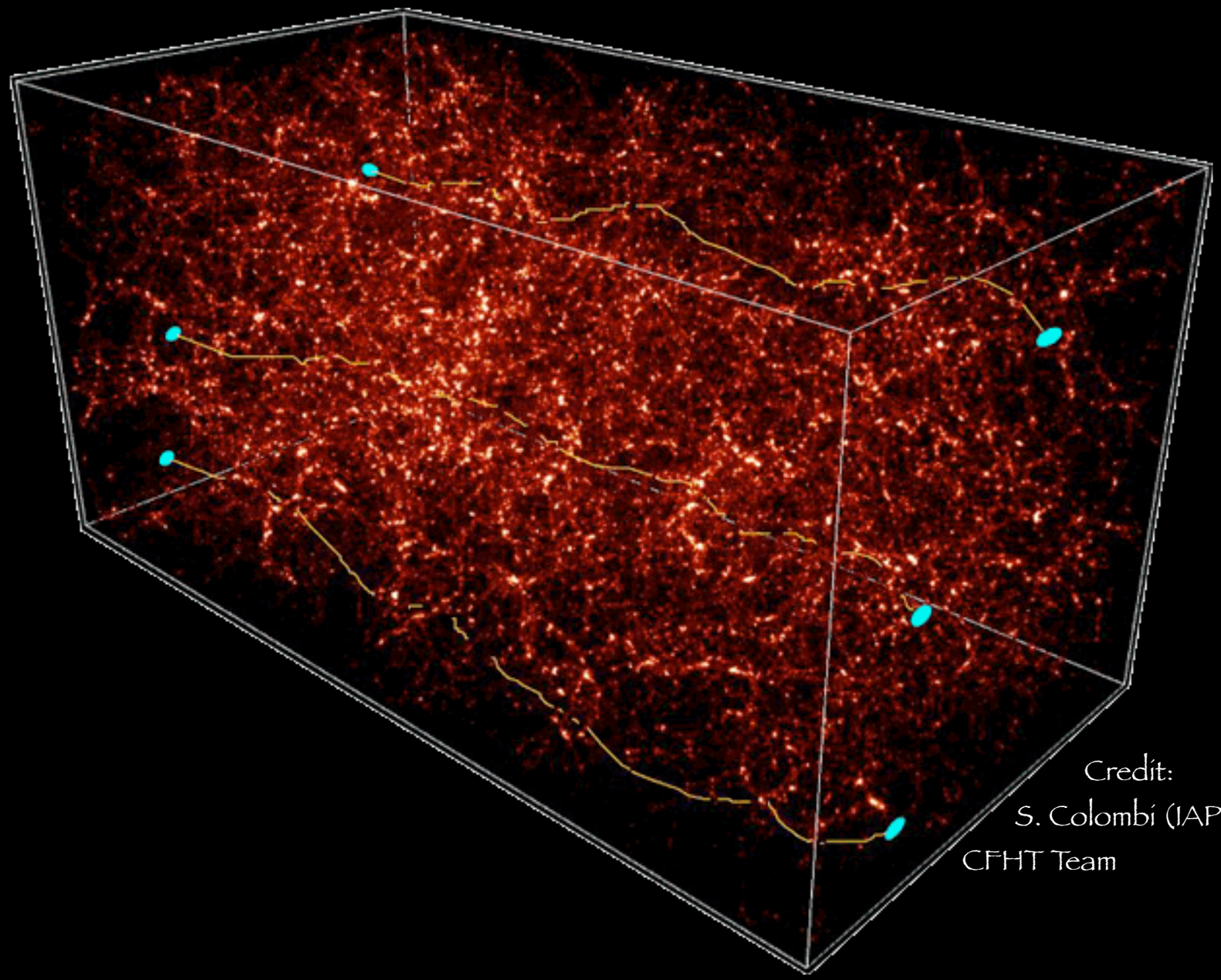
Influence of Gravitational Lensing?

Influence of Gravitational Lensing?



Credit:
S. Colombi (IAP),
CFHT Team

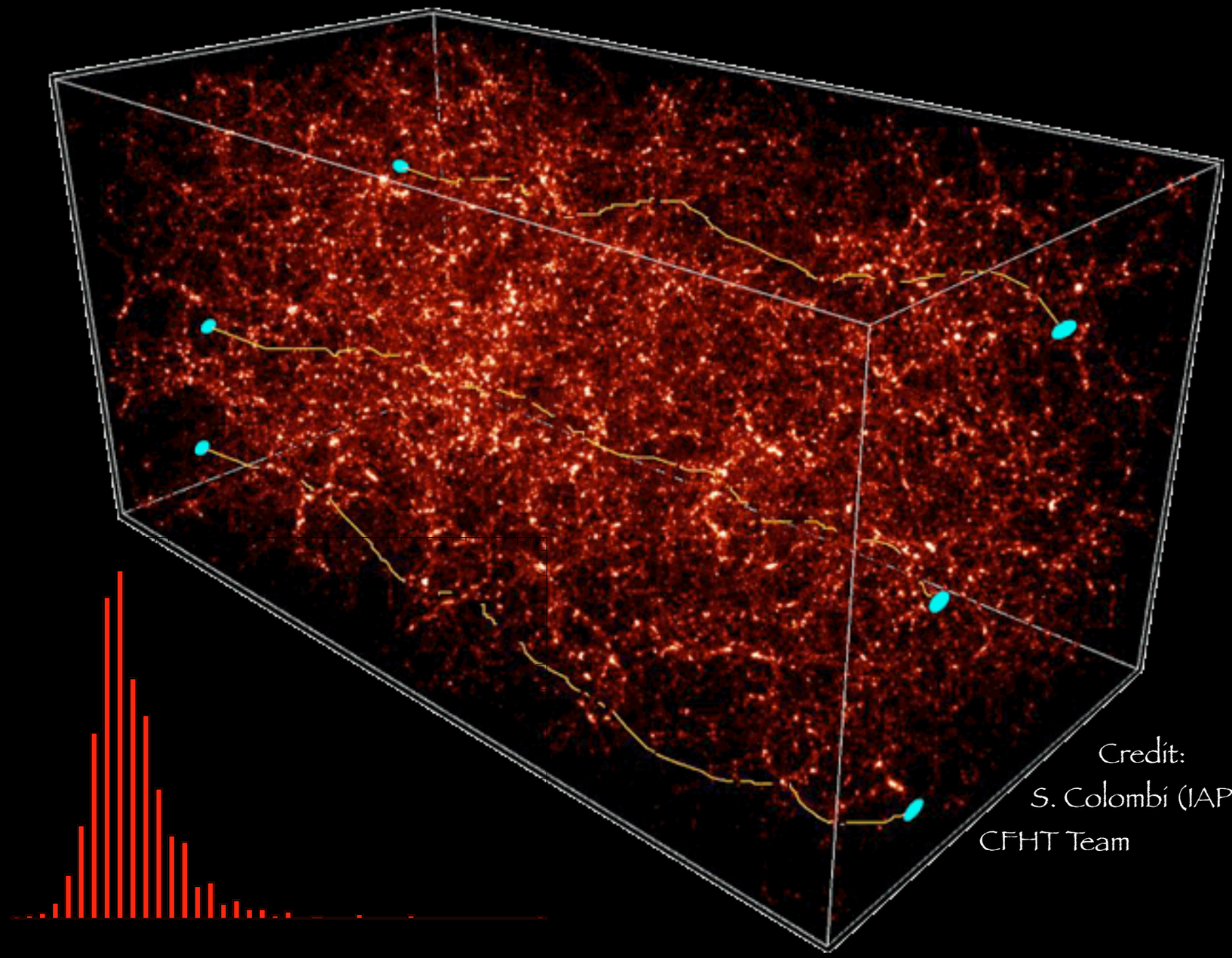
Influence of Gravitational Lensing?



Credit:
S. Colombi (IAP),
CFHT Team

$$\mathcal{F}^{\mathrm{obs,lensed}}(z,\hat{\mathbf{n}}) = \mu(z,\hat{\mathbf{n}})\mathcal{F}^{\mathrm{obs,true}}(z)$$

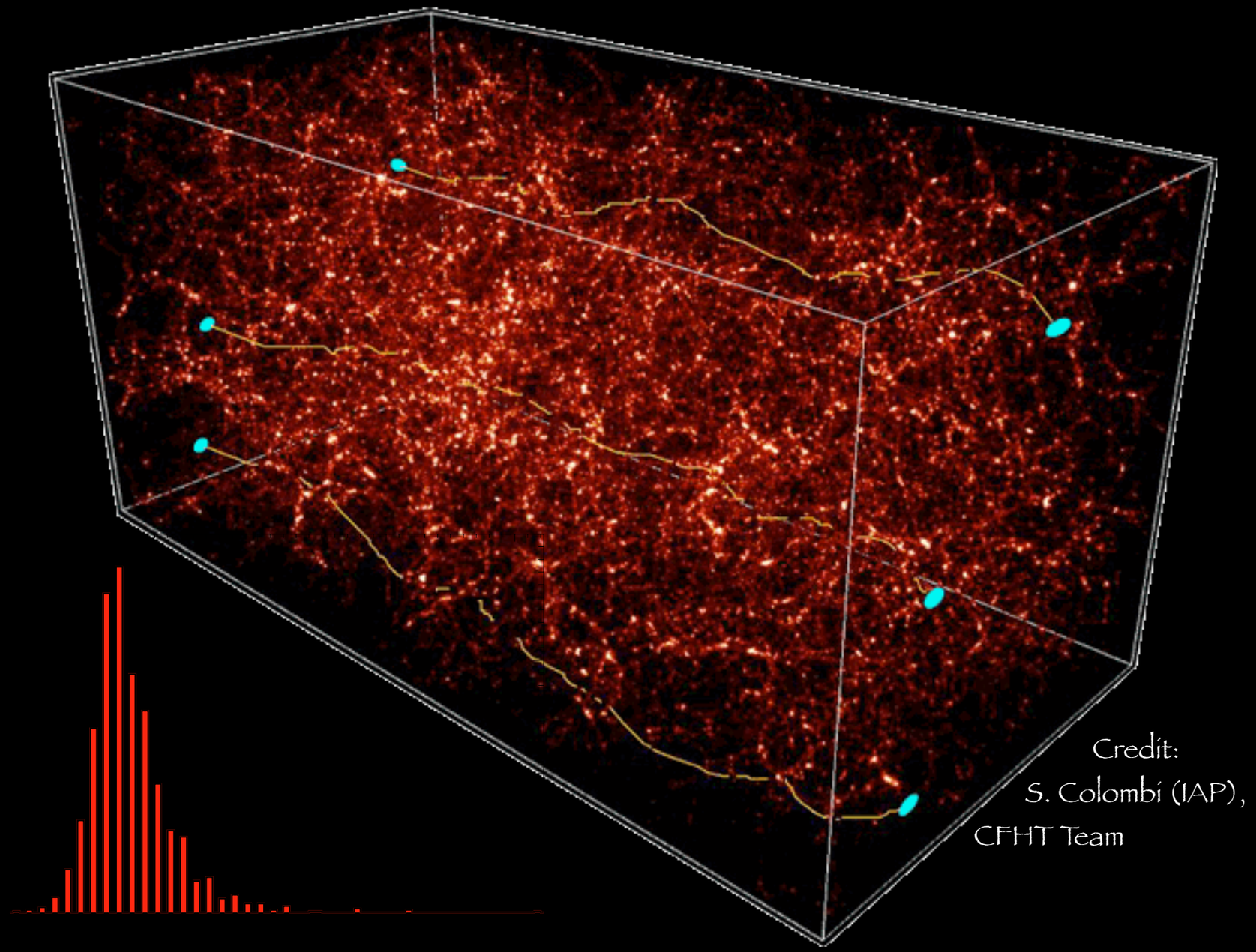
Influence of Gravitational Lensing?



Credit:
S. Colombi (IAP),
CFHT Team

$$\mathcal{F}^{\mathrm{obs,lensed}}(z,\hat{\mathbf{n}}) = \mu(z,\hat{\mathbf{n}})\mathcal{F}^{\mathrm{obs,true}}(z)$$

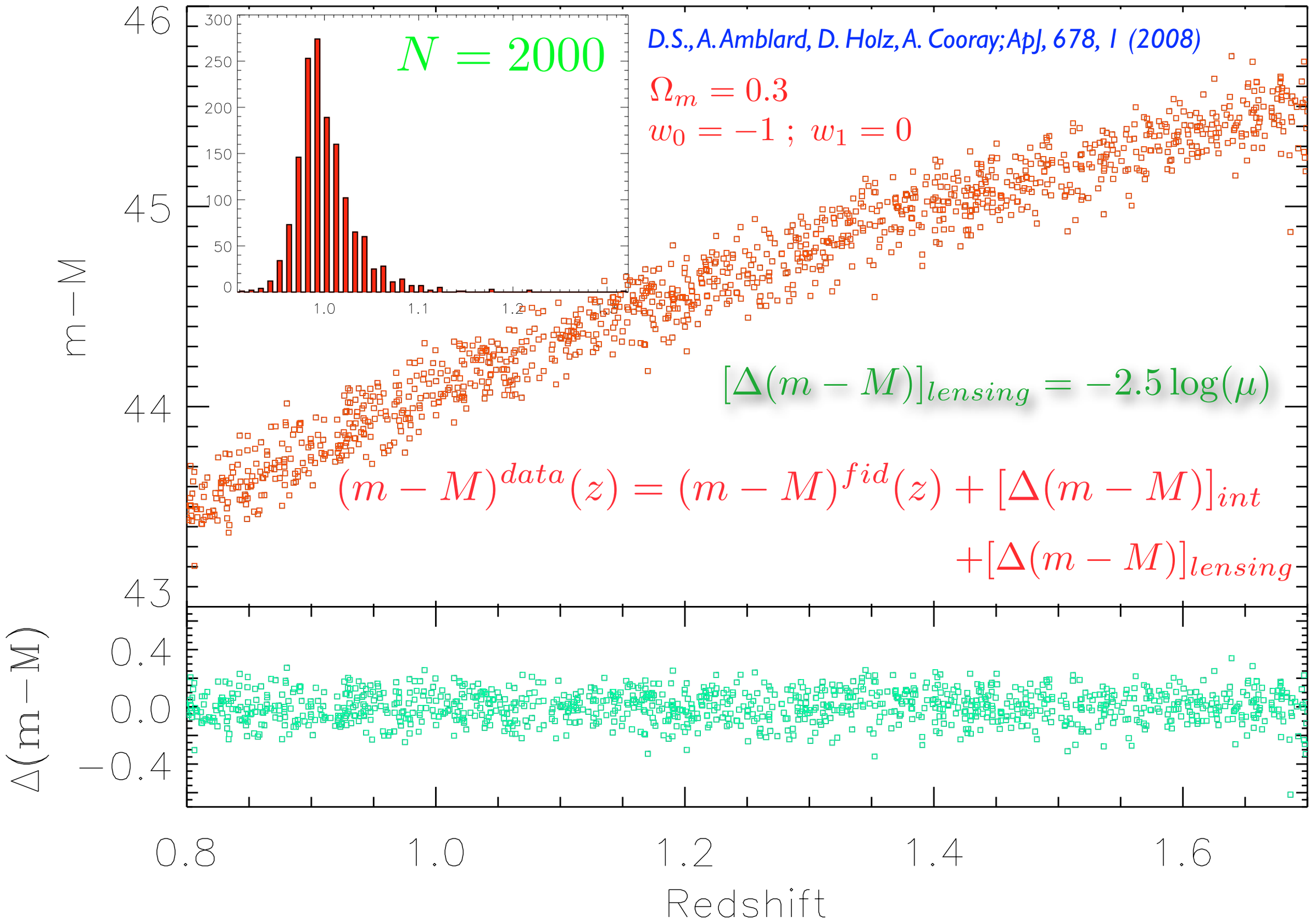
Influence of Gravitational Lensing?



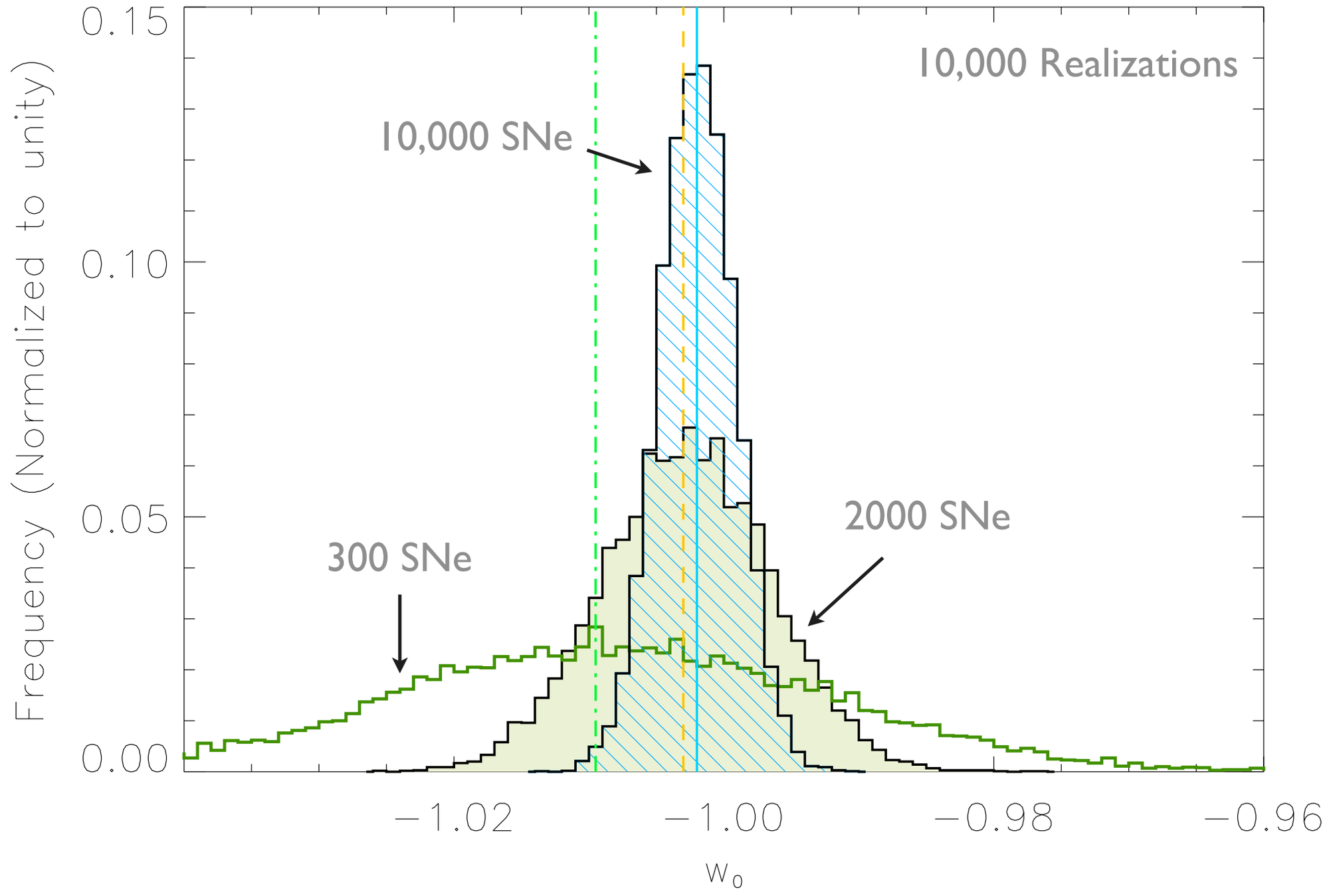
$$\mathcal{F}^{\mathrm{obs,lensed}}(z,\hat{\mathbf{n}}) = \mu(z,\hat{\mathbf{n}})\mathcal{F}^{\mathrm{obs,true}}(z)$$

Weak lensing can modify the SNa flux & bias estimates of w

Our Analysis with Mock Catalogs

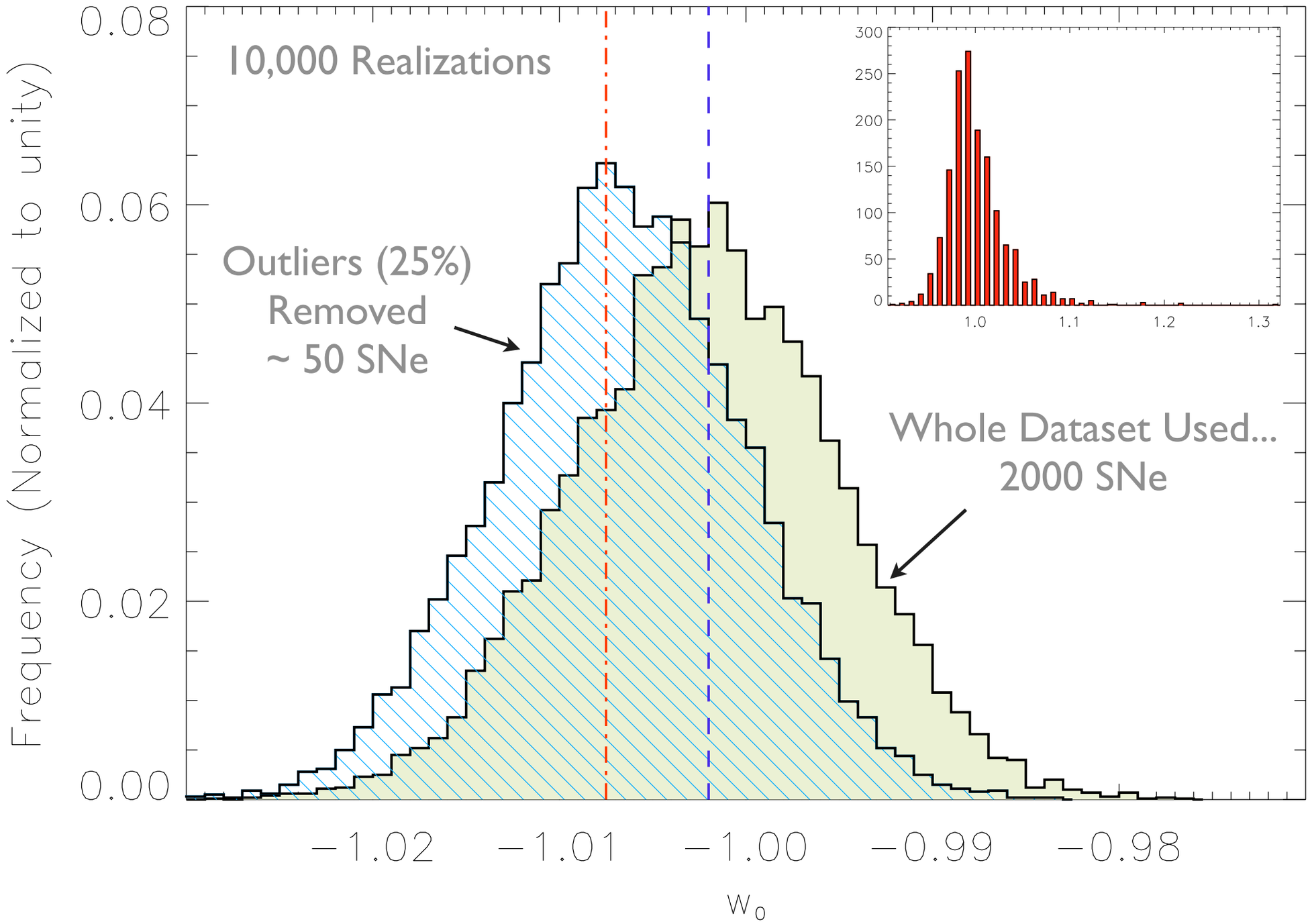


Effect of Weak Lensing on Estimates of "w"



D.S., A. Amblard, D. Holz, A. Cooray; ApJ, 678, 1 (2008)

Effect of Removing the Outliers



D.S., A. Amblard, D. Holz, A. Cooray; ApJ, 678, 1 (2008)

Agenda

w(z) : To Bin or Not To Bin

Supernovae

Systematics I

- Lensing of SNe
- P(μ)
- Bias on the EOS
- (Not) To Worry About?

Systematics II

- Two Populations of SN
- Leaking into H.D.
- Bias on the EOS
- Increased Error?

Agenda

w(z) : To Bin or Not To Bin

Supernovae

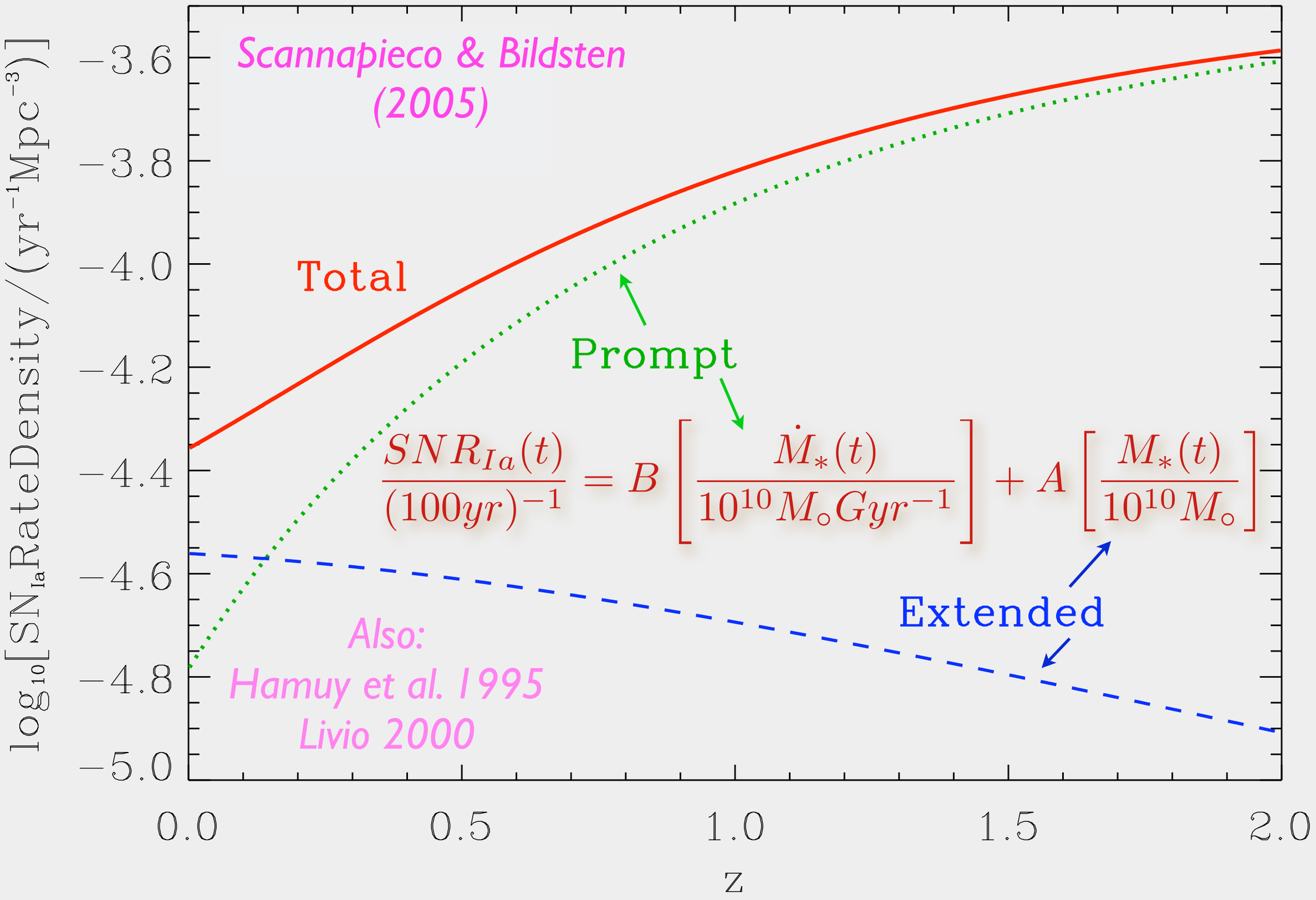
Systematics I

- Lensing of SNe
- P(μ)
- Bias on the EOS
- (Not) To Worry About?

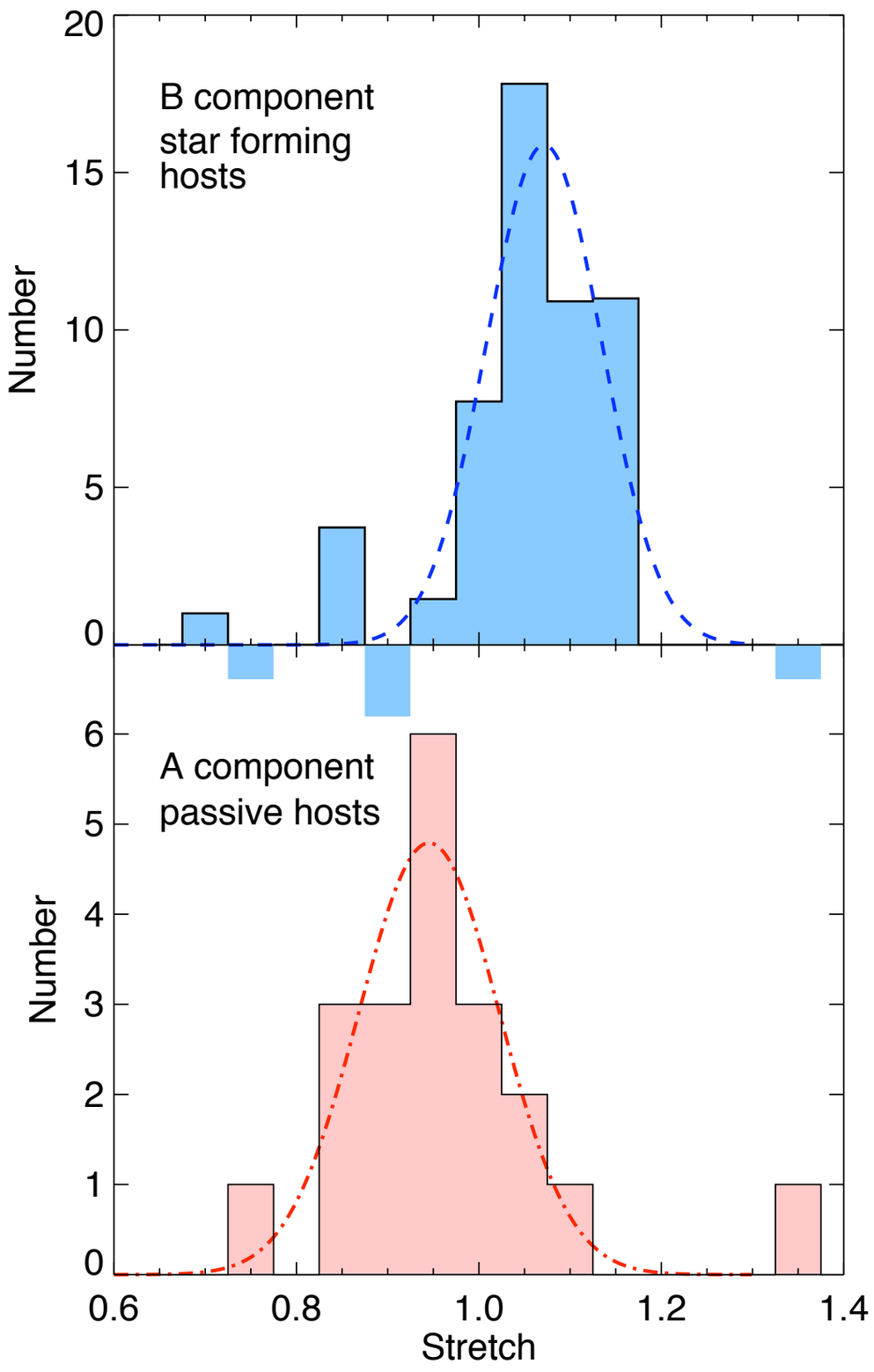
Systematics II

- Two Populations of SN
- Leaking into H.D.
- Bias on the EOS
- Increased Error?

Evolution based on Two SN Populations



Evolution based on Two SN Populations



$$\mu_B = m_B^* - M + \alpha(s-1) - \beta c$$

Tripp (1998), Guy et al. (2005)

PROMPT

12% Dfference
in
Intrinsic Luminosity

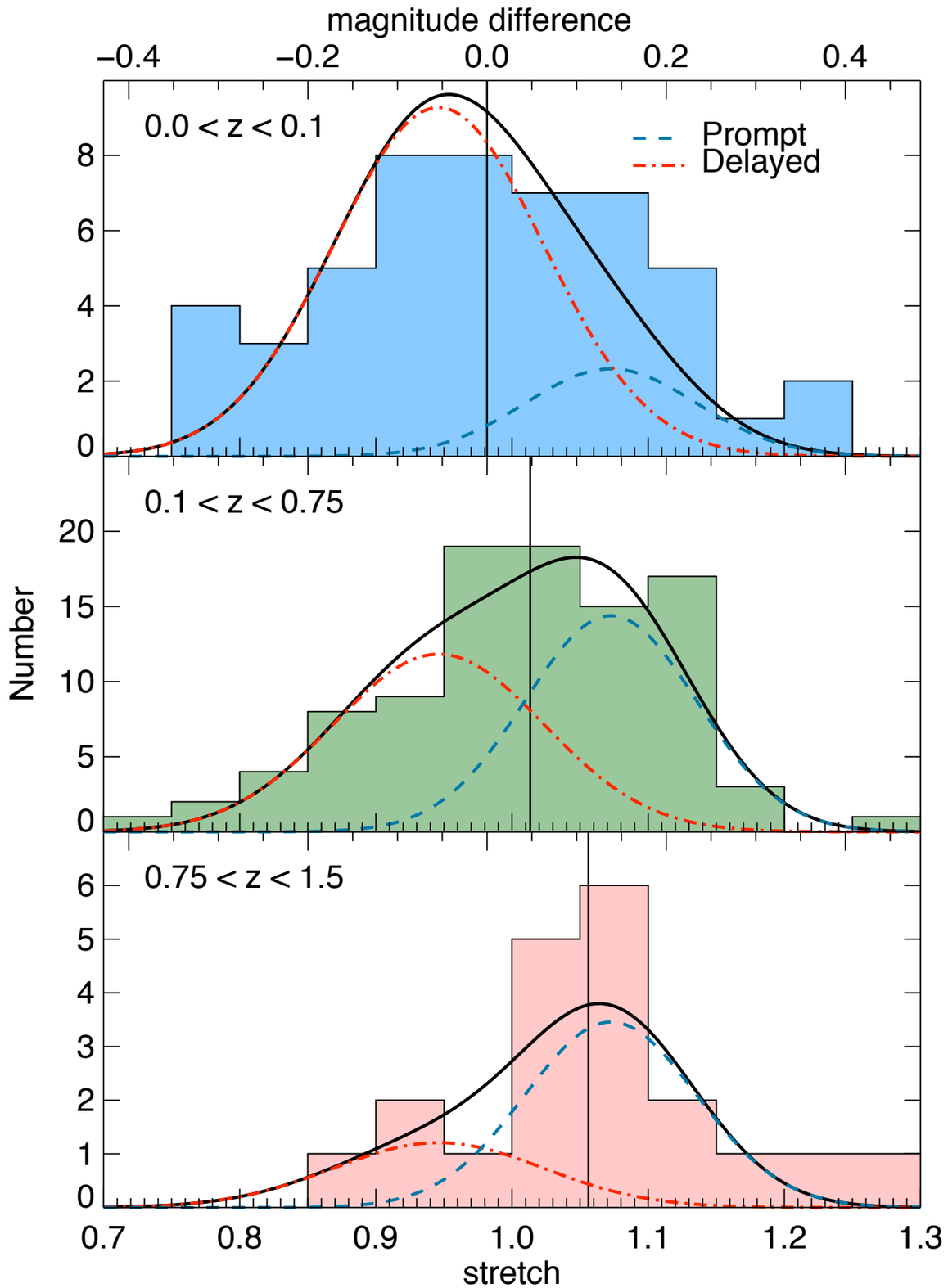
$$\mathcal{L}_P = \mathcal{L}_E + \Delta\mathcal{L}$$

DELAYED

Howell et al. 2007

Data Source: Sullivan et al. 2006 (SNLS)

Evolution based on Two SN Populations



Median Redshift: 0.026
N=50

Median Redshift: 0.55
N=99

Median Redshift: 1.12
N=20

Howell et al. 2007

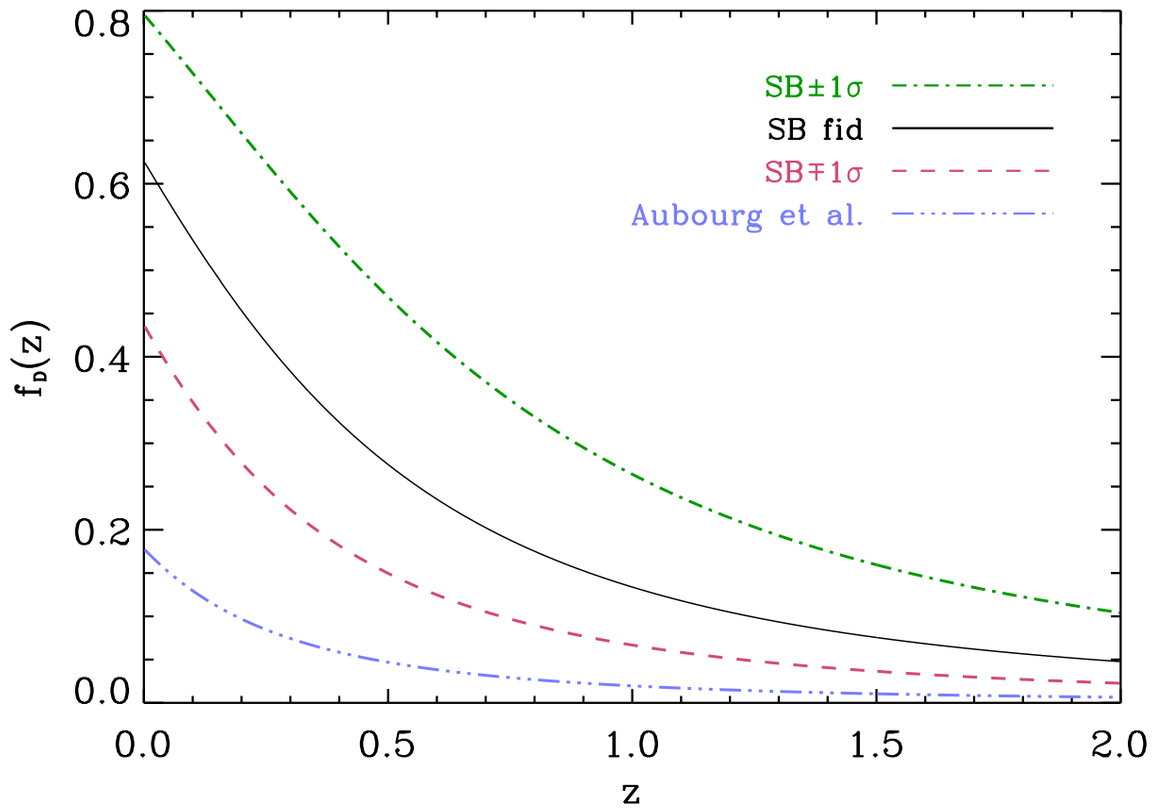
Is there a Signature in the Hubble Diagram?

Is there a Signature in the Hubble Diagram?

$$m - M = 5 \log \left(\frac{d_L}{\mathrm{Mpc}} \right) + 25 + \mathcal{M}$$

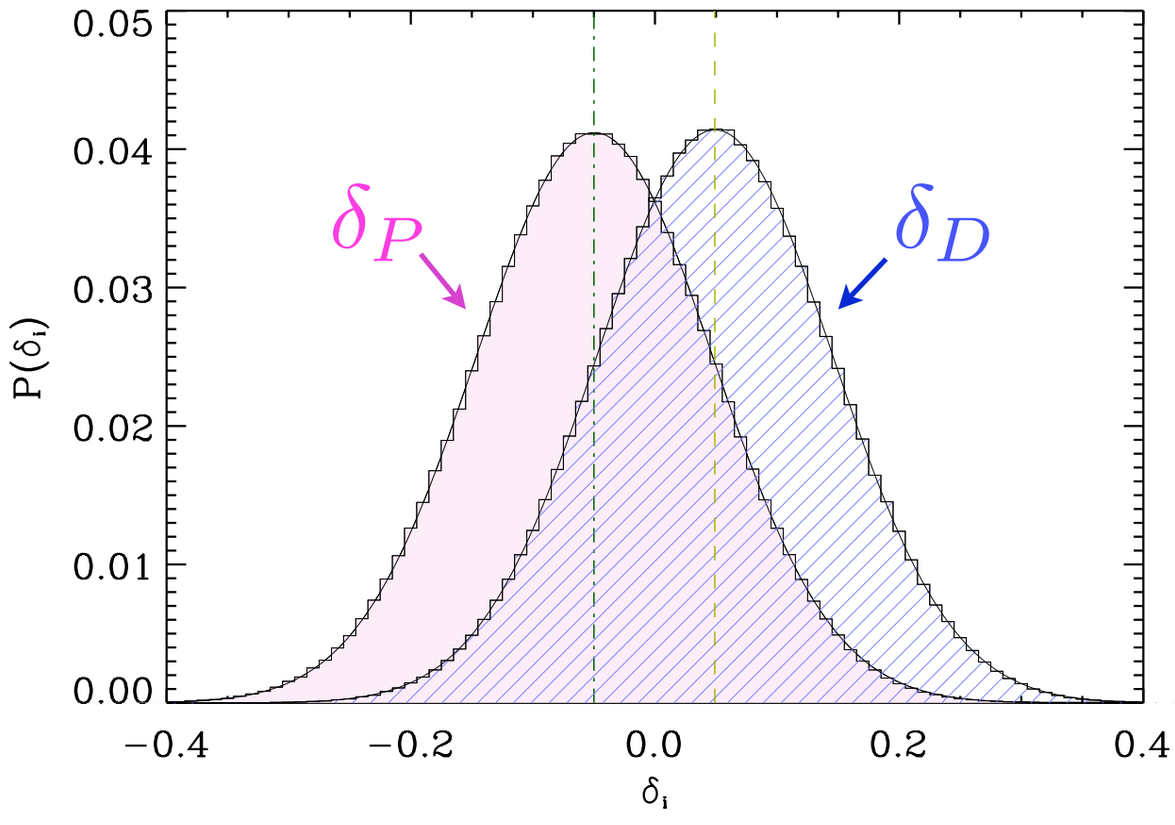
Is there a Signature in the Hubble Diagram?

$$m - M = 5 \log \left(\frac{d_L}{\mathrm{Mpc}} \right) + 25 + \mathcal{M} + \delta_D * f_D(z)$$



Is there a Signature in the Hubble Diagram?

$$m - M = 5 \log \left(\frac{d_L}{\mathrm{Mpc}} \right) + 25 + \mathcal{M} + \delta_D * f_D(z)$$



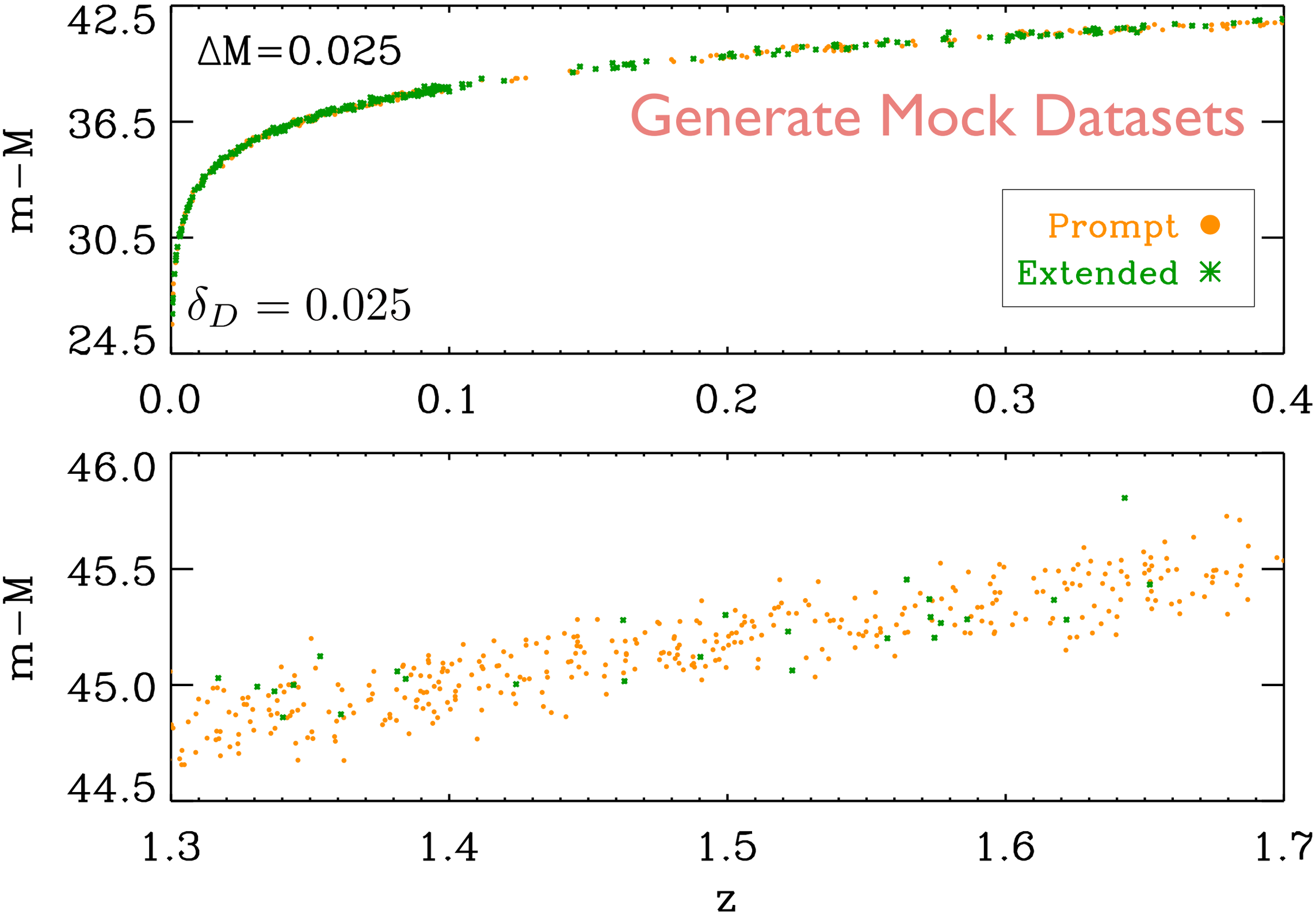
With current data (192 SNe from Davis et al. 2007), the residual is consistent with zero:

$$\delta_D \sim (5 \pm 9)\%$$

With future data, one will be able to constrain the residual much better.

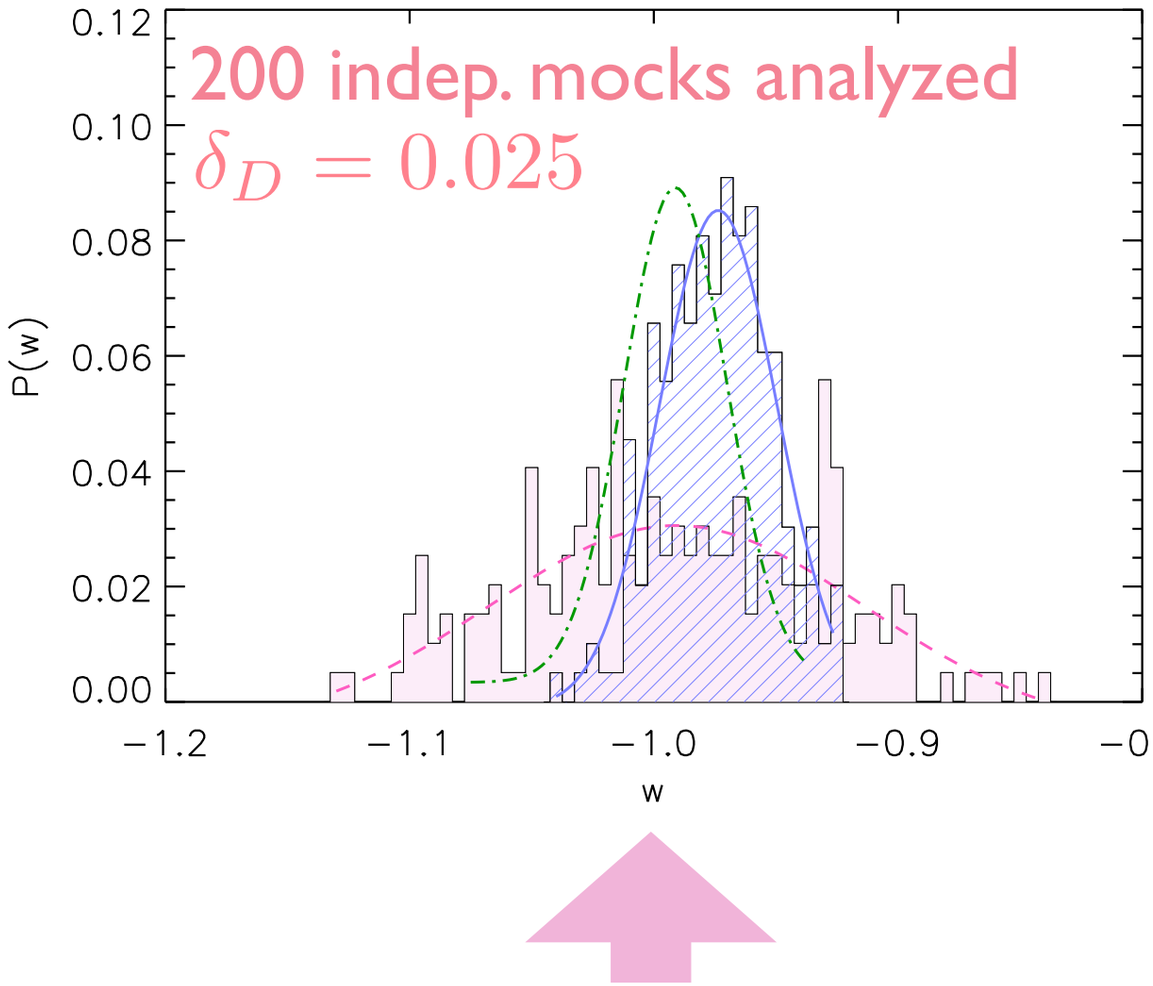
D.S., A. Amblard, A. Cooray, and D. Holz; ApJL, 684, L13 (2008)

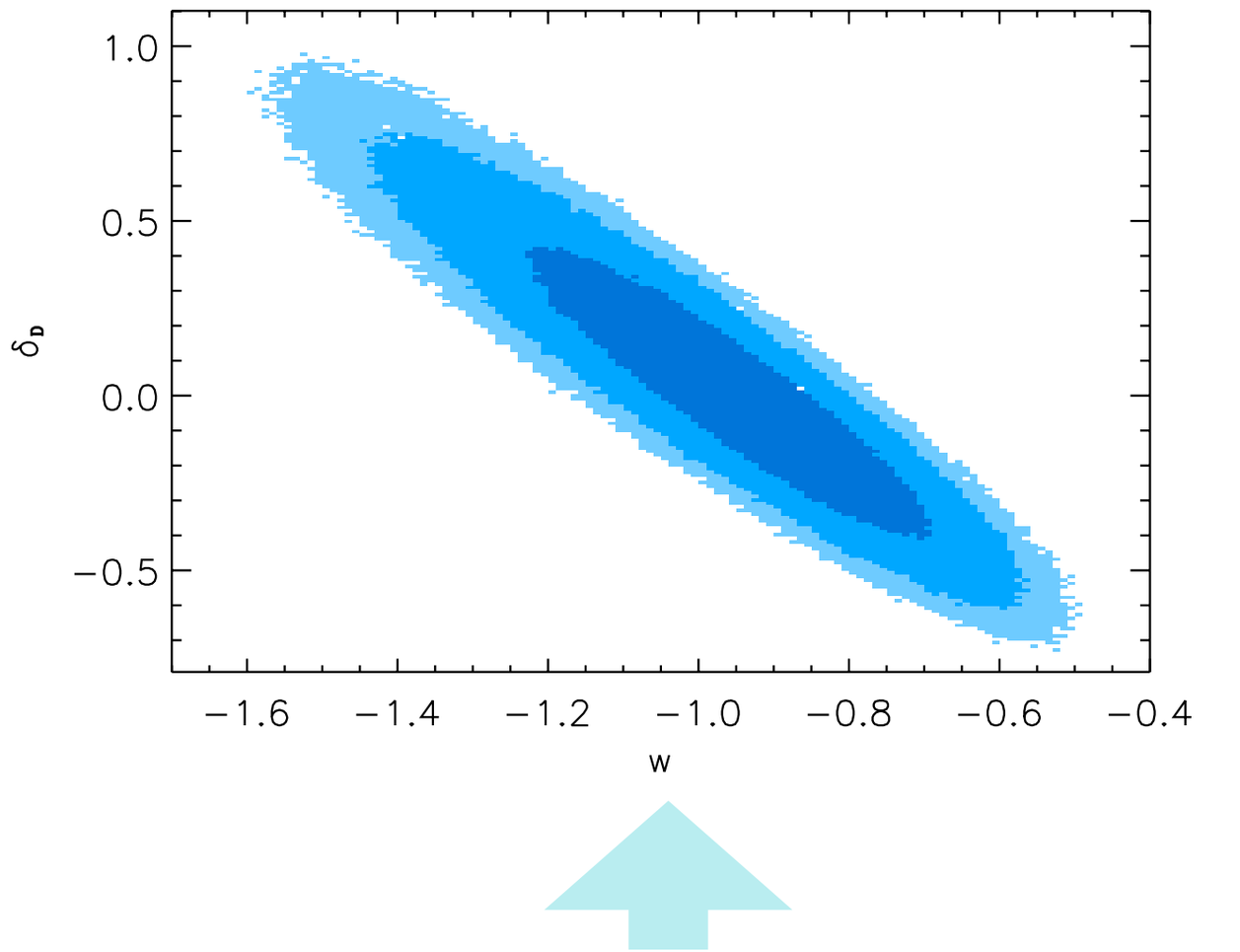
Effect on the EOS Estimates: Bias in "w"



D.S., A. Amblard, A. Cooray, and D. Holz; ApJL, 684, L13 (2008)

Effect on the EOS Estimates: Bias in "w"





~1-sigma bias in "w"

Correlation

While model-fitting the data:

$$\delta_D = 0 \Rightarrow \sim 1\sigma \text{ bias in } w$$

$$\delta_D = \text{FREE} \Rightarrow \text{ NO bias in } w, \text{ BUT Error bar increased by 2.5 times}$$

$$\text{Best situation: Constrain } \delta_D <= 2\% \text{ with confidence}$$

D.S., A. Amblard, A. Cooray, and D. Holz; ApJL, 684, L13 (2008)

Agenda

w(z): To Bin or Not To Bin

Supernovae

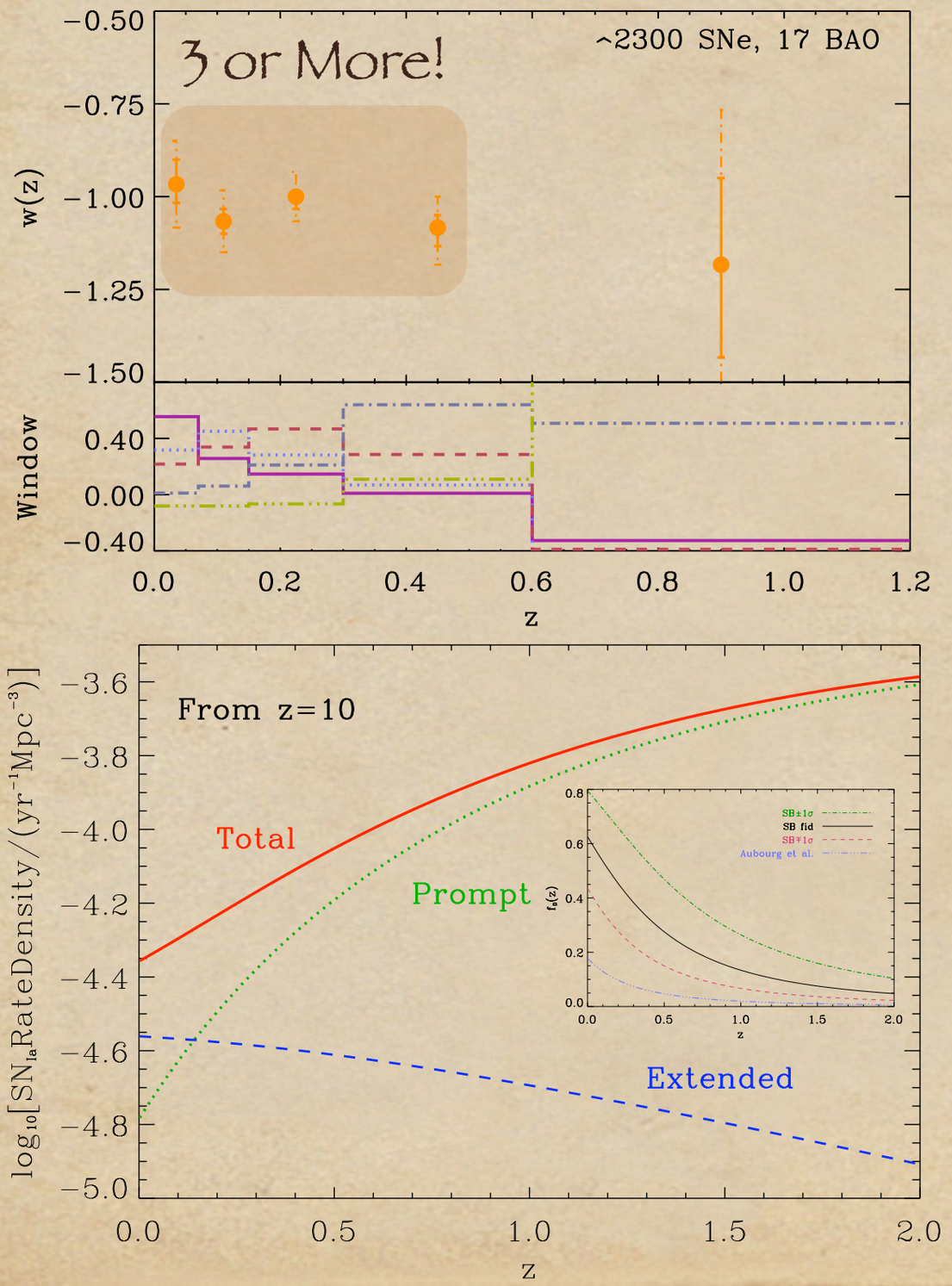
Systematics I

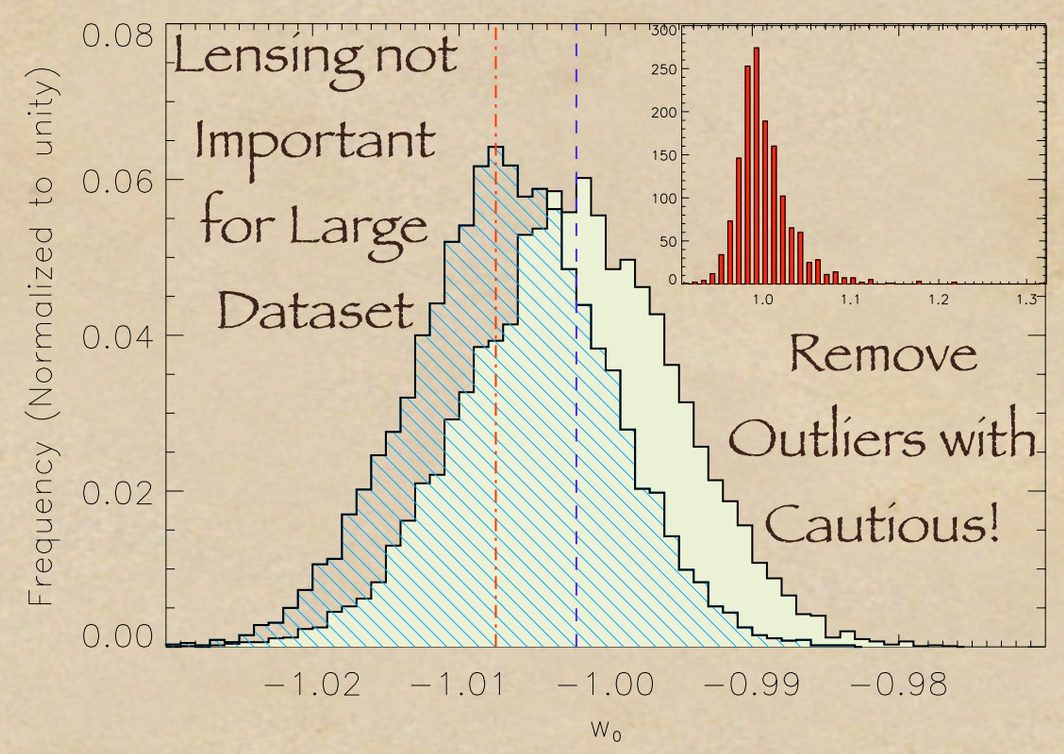
- Lensing of SNe
- P(μ)
- Bias on the EOS
- (Not) To Worry About?

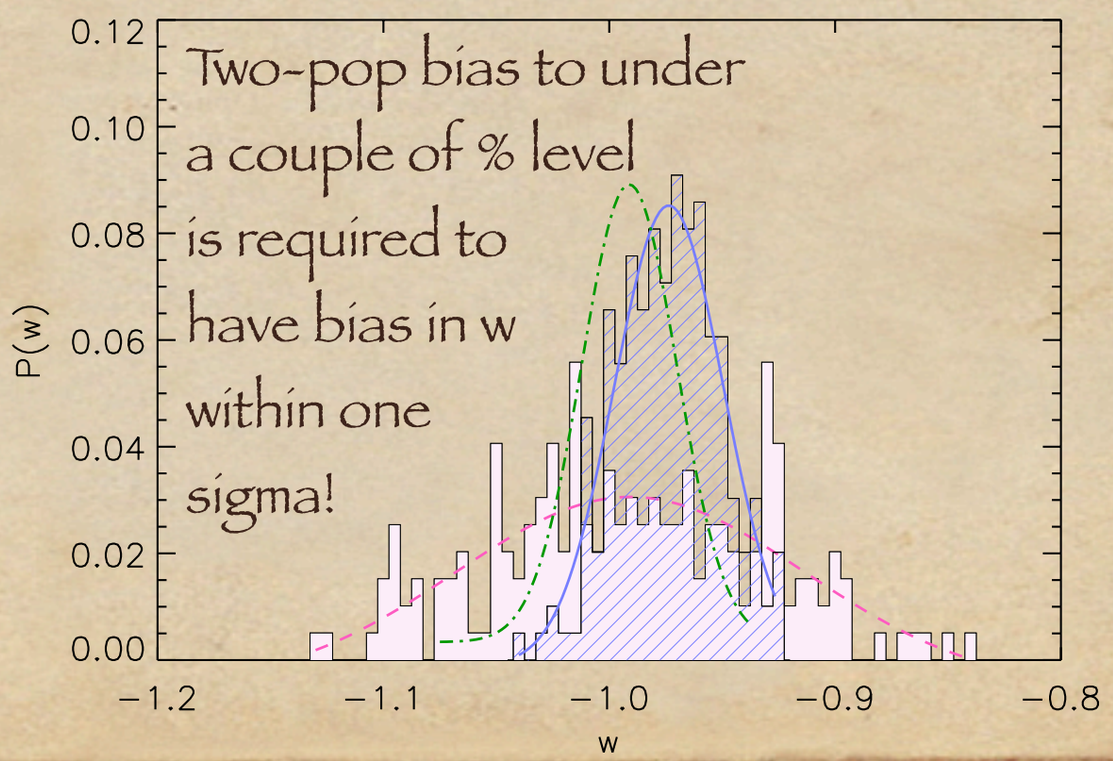
Systematics II

- Two Populations of SN
- Leaking into H.D.
- Bias on the EOS
- Increased Error?

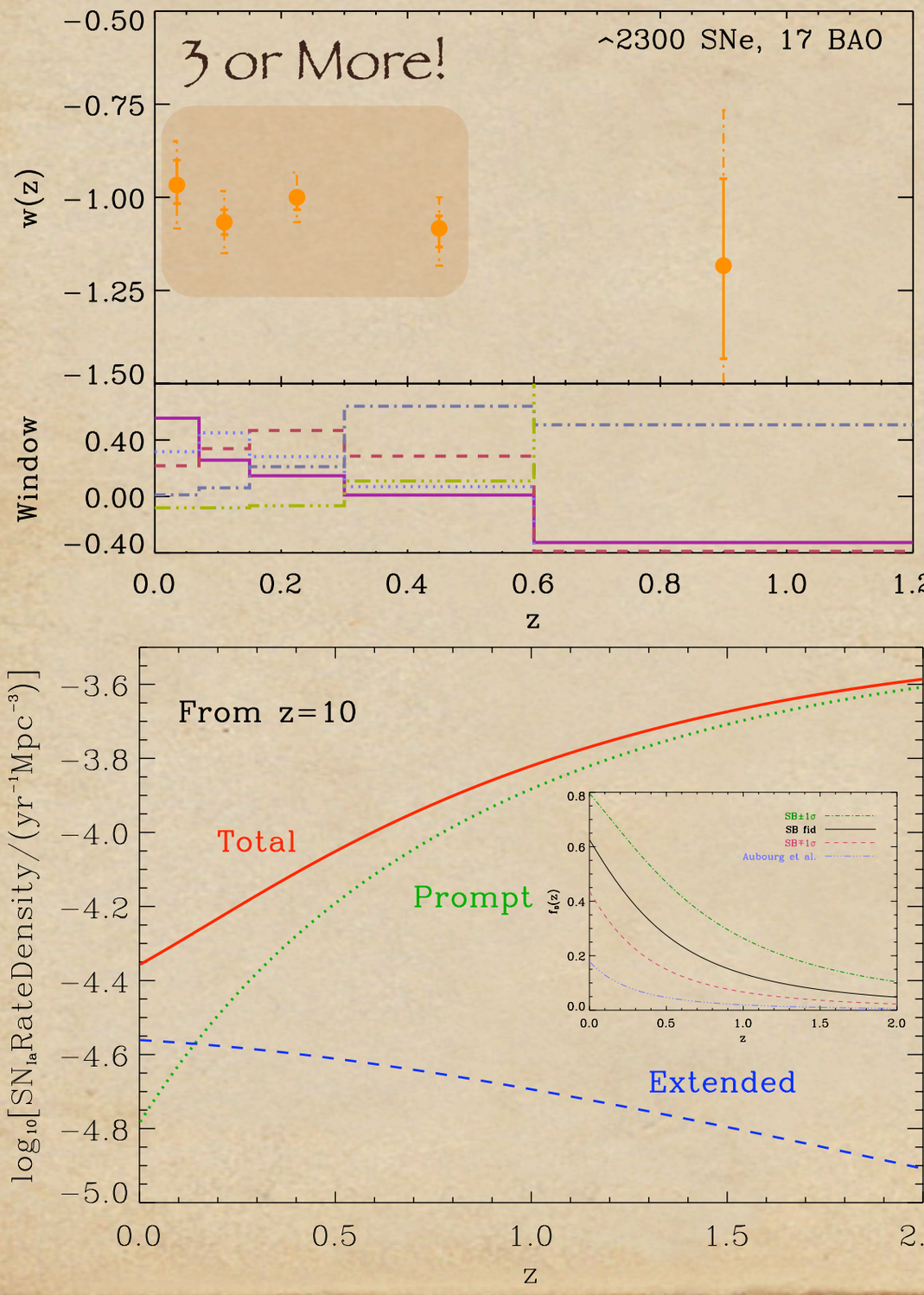
Summary

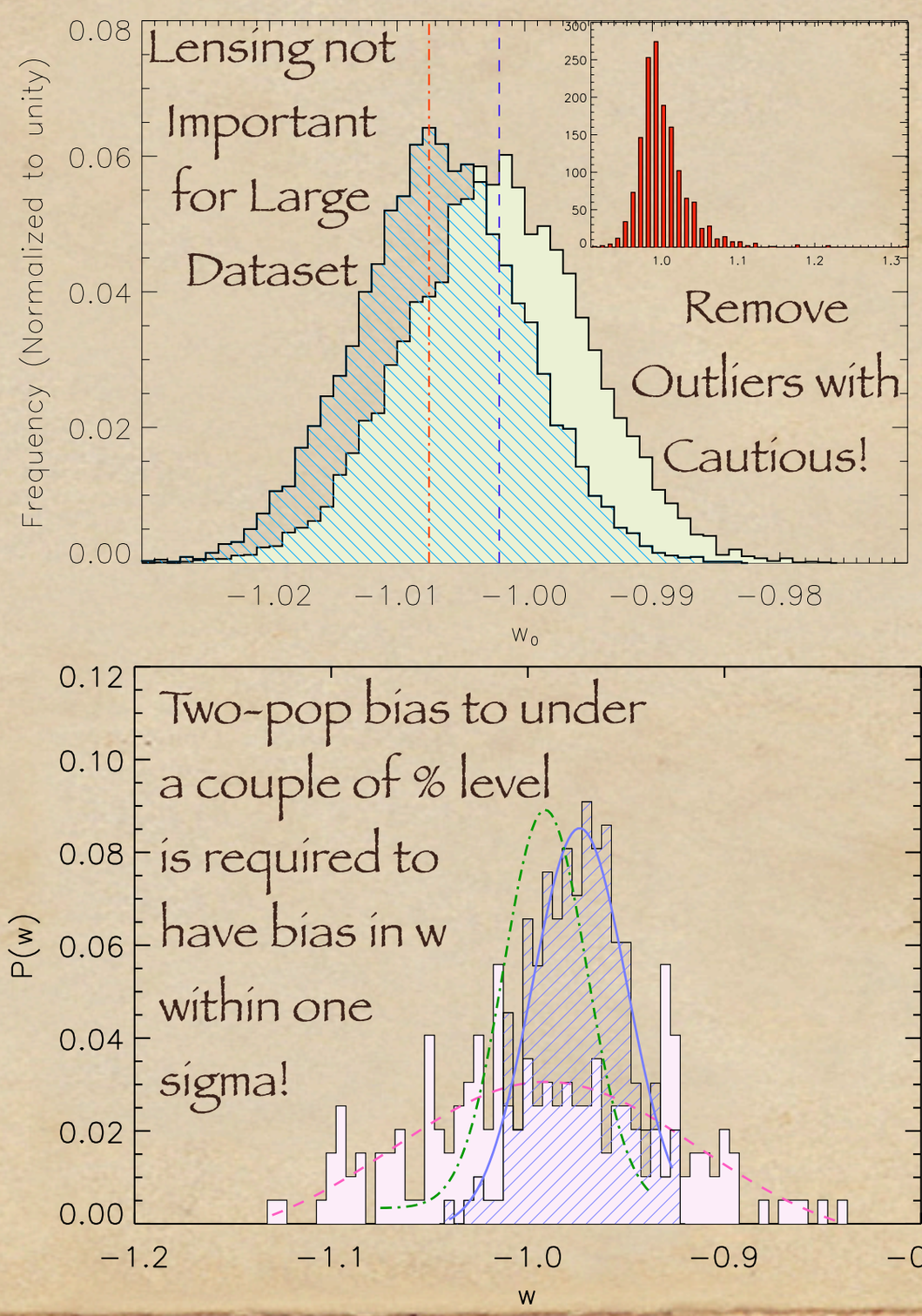

3 or More!
~2300 SNe, 17 BAO
w(z)
Window
z
From z=10
Total
Prompt
Extended
log10[SNIaRateDensity/(yr-1Mpc-3)]
z


Lensing not
Important
for Large
Dataset
Remove
Outliers with
Cautious!
Frequency (Normalized to unity)
w0


Two-pop bias to under
a couple of % level
is required to
have bias in w
within one
sigma!
P(w)
w

Summary





THANK YOU!