Probing Dark Energy: Theoretical Uncertainties

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).

GGI, Firenze, Italy Dark Energy Conference March 02, 2009

Cosmic Acceleration

Modified Gravity

Dark Energy

$$H^2 - \frac{H}{r_c} = \frac{8\pi G}{3}(\rho + \rho_V)$$

Modification of Friedmann equation (5D Gravity)

Phenomen. modification to the GR Lagrangian

Vacuum Energy (Cosmological Constant)

Scalar Fields
Evolving Equation of State

New Physics/Surprises?

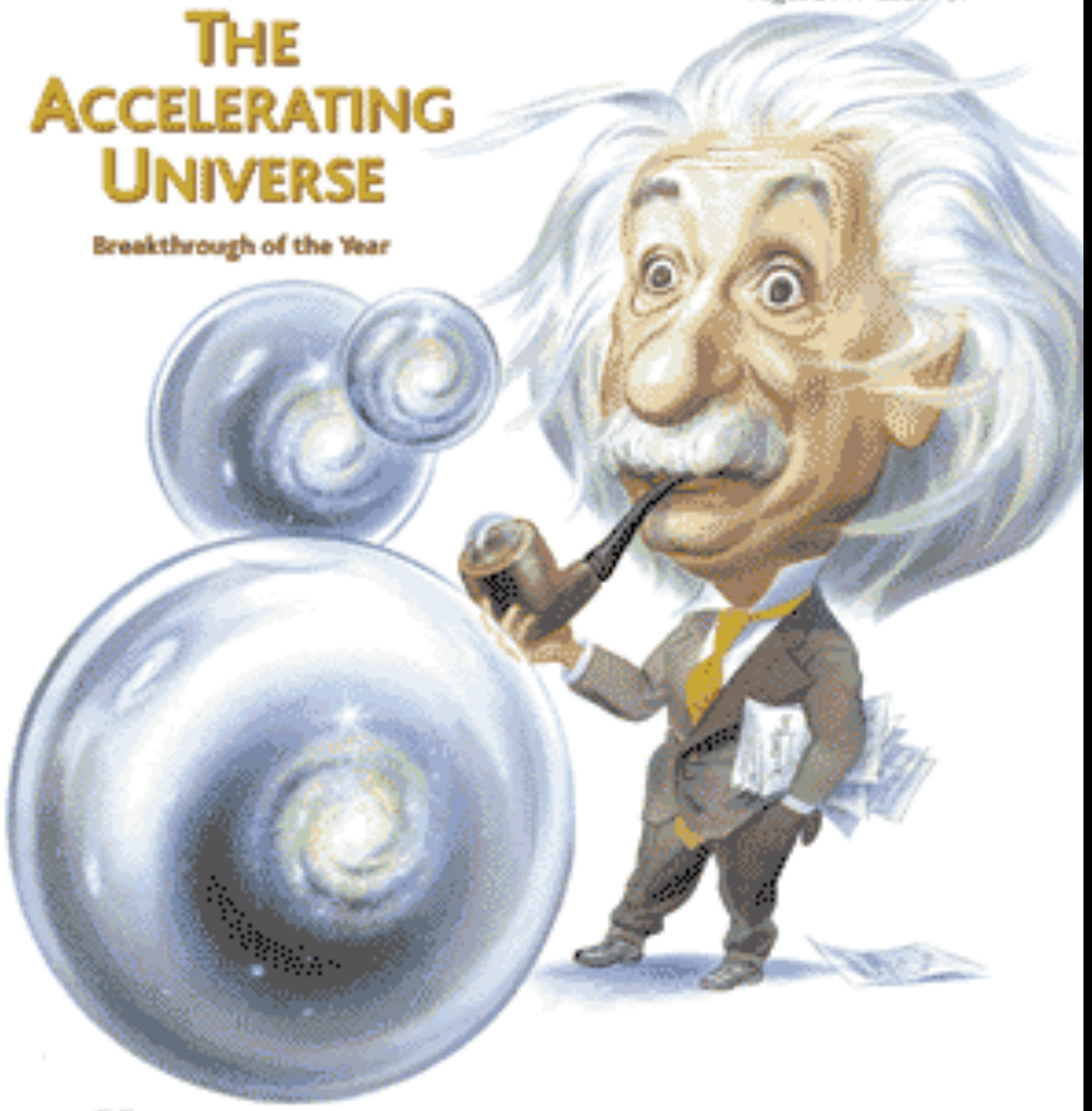
Science

18 December 1998

Vol. 282 No. 5397
Pages 2141–2336 $7

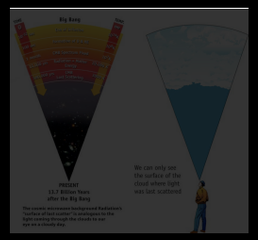
THE ACCELERATING UNIVERSE

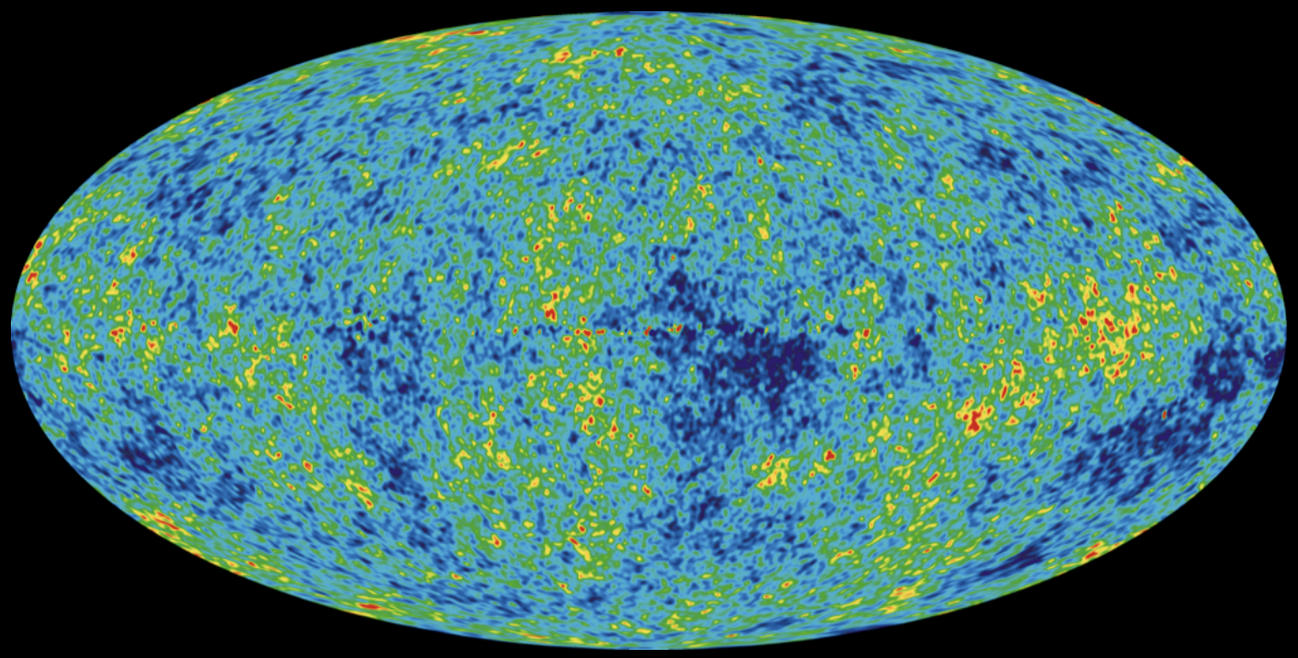
Breakthrough of the Year

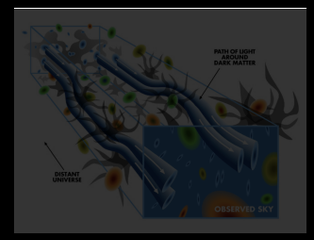


AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Probing Dark Energy







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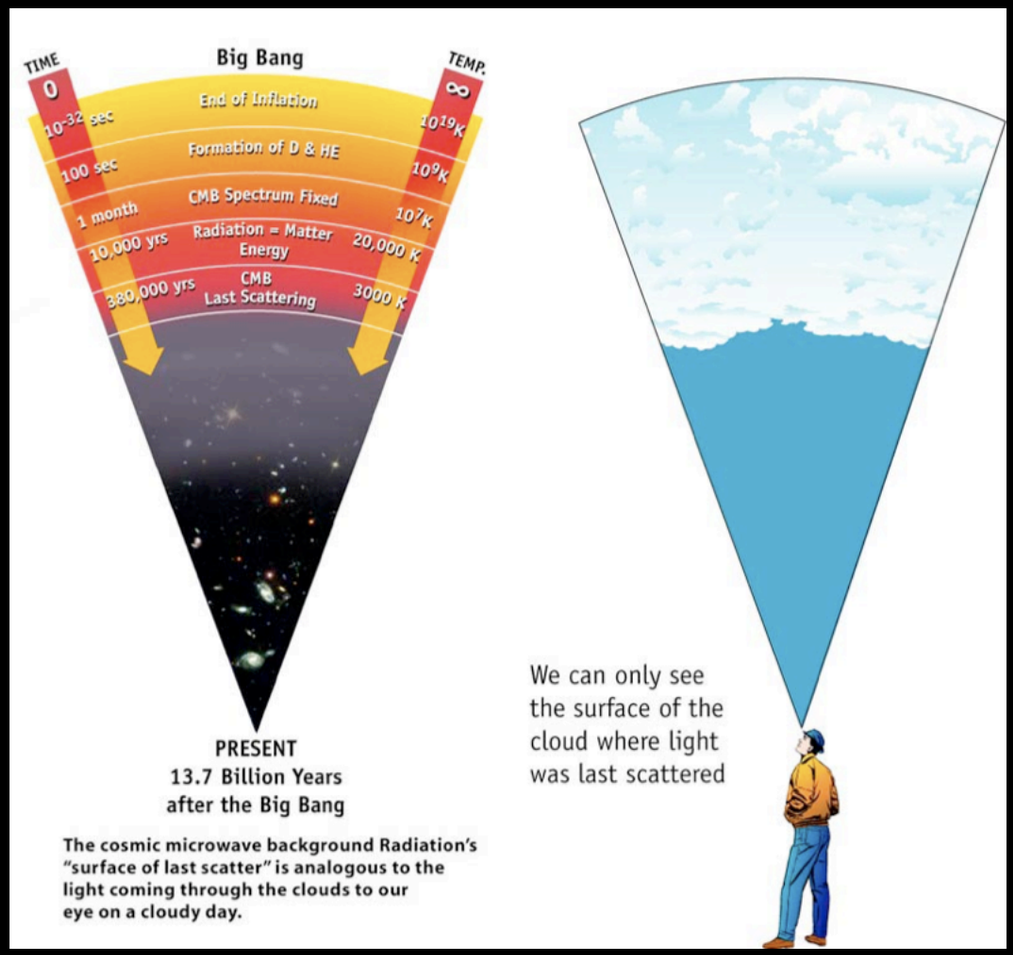

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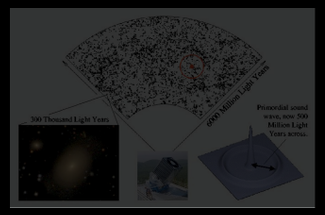

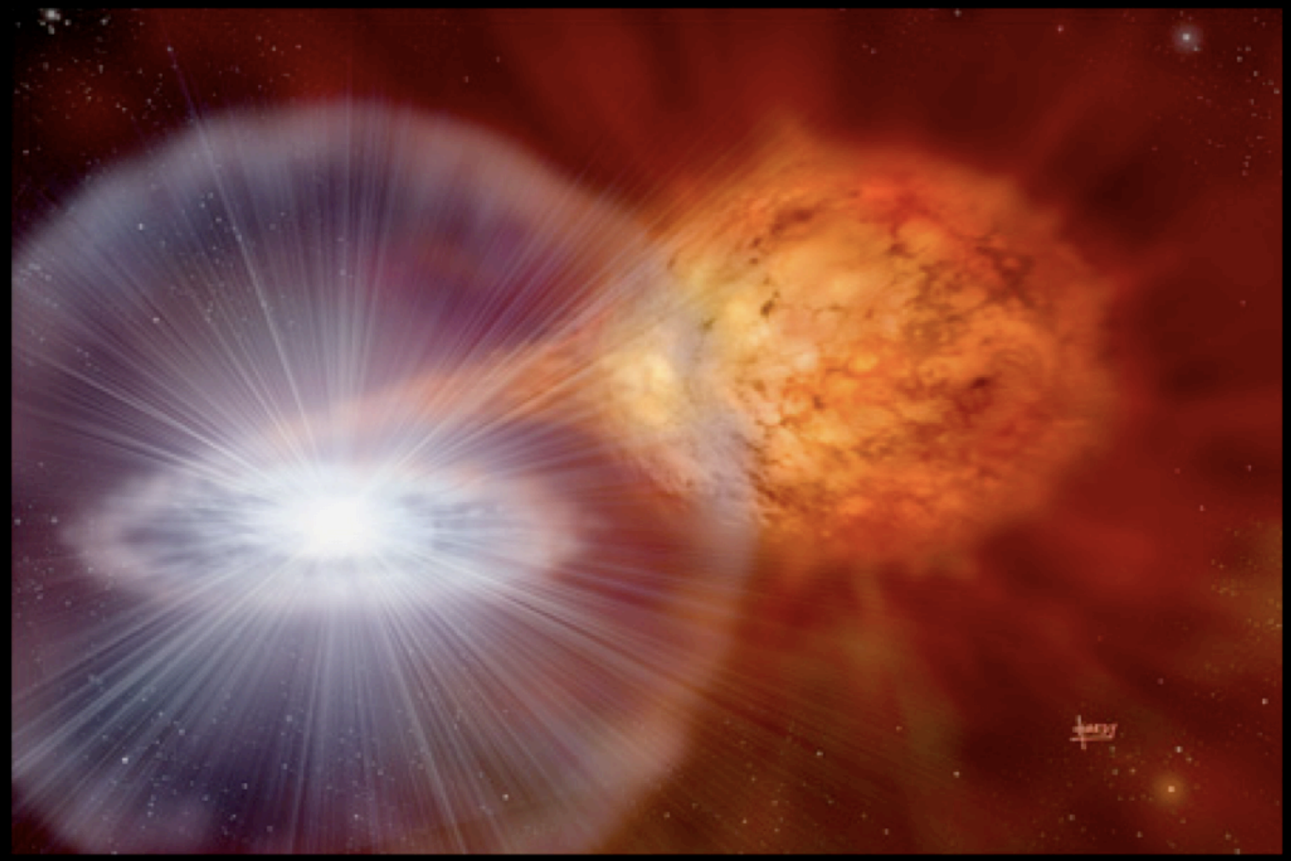

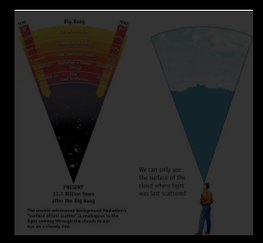

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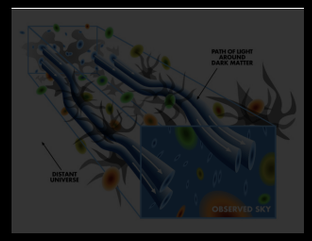

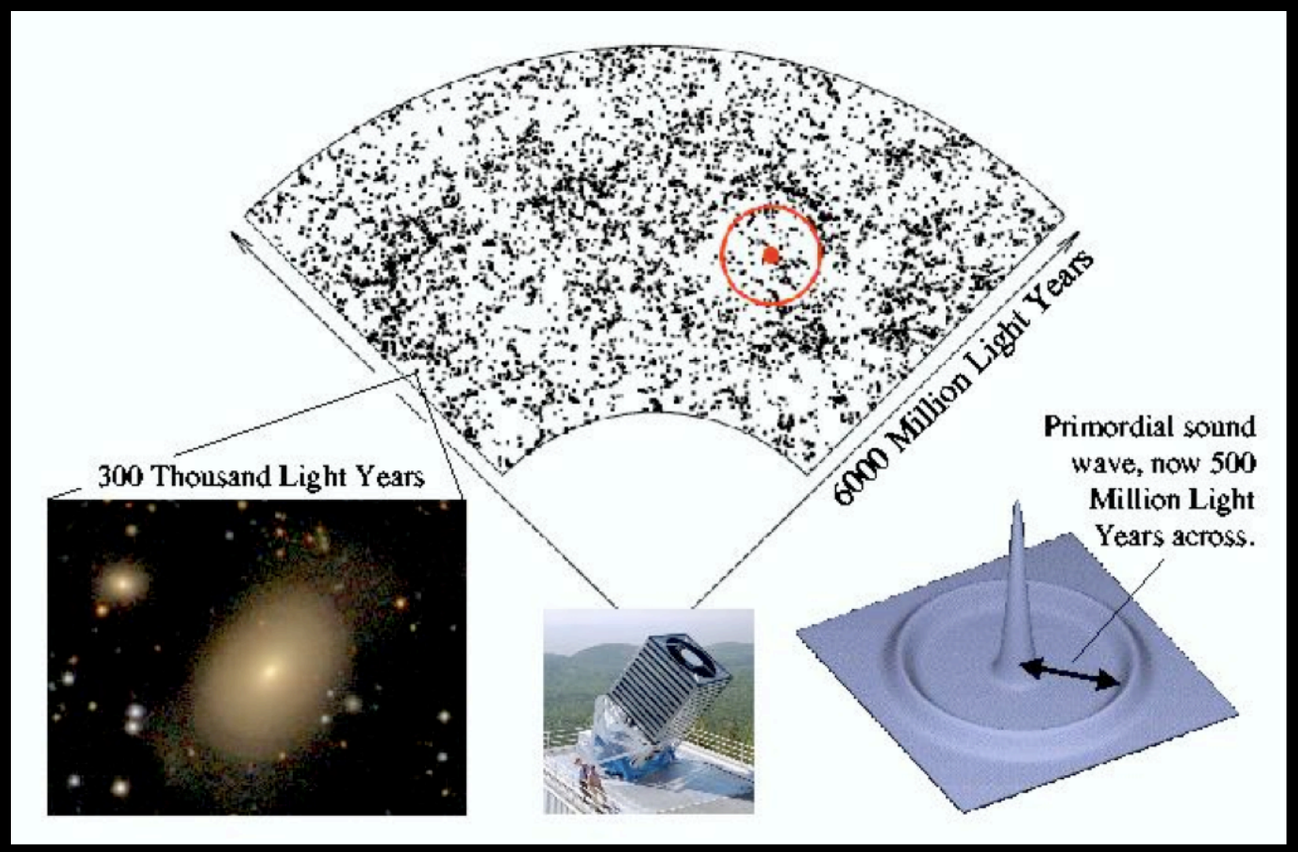

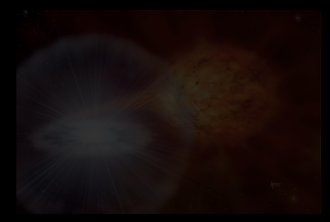

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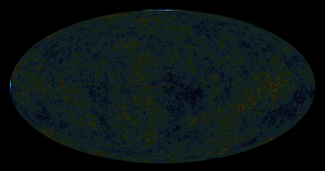
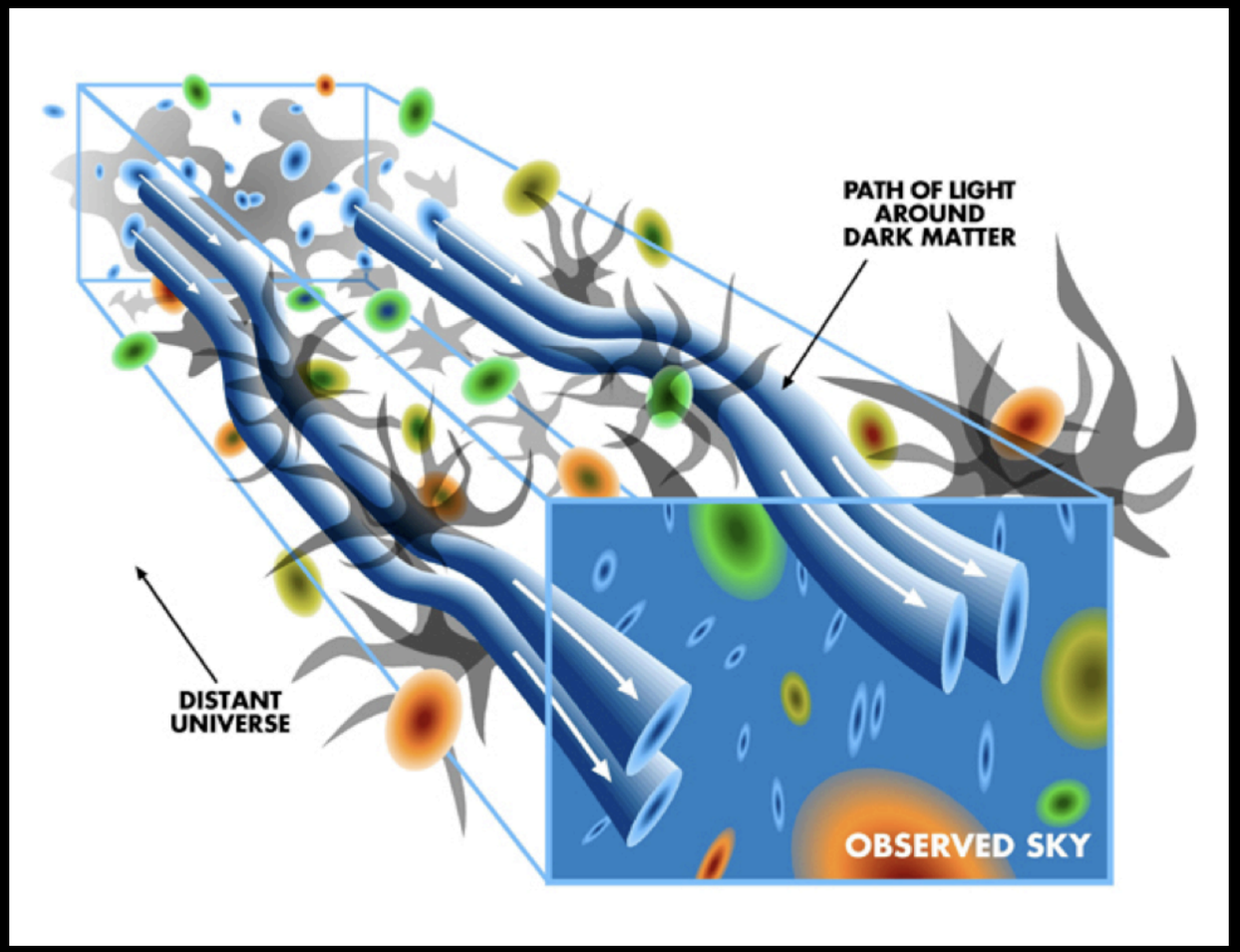
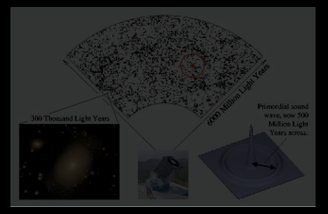
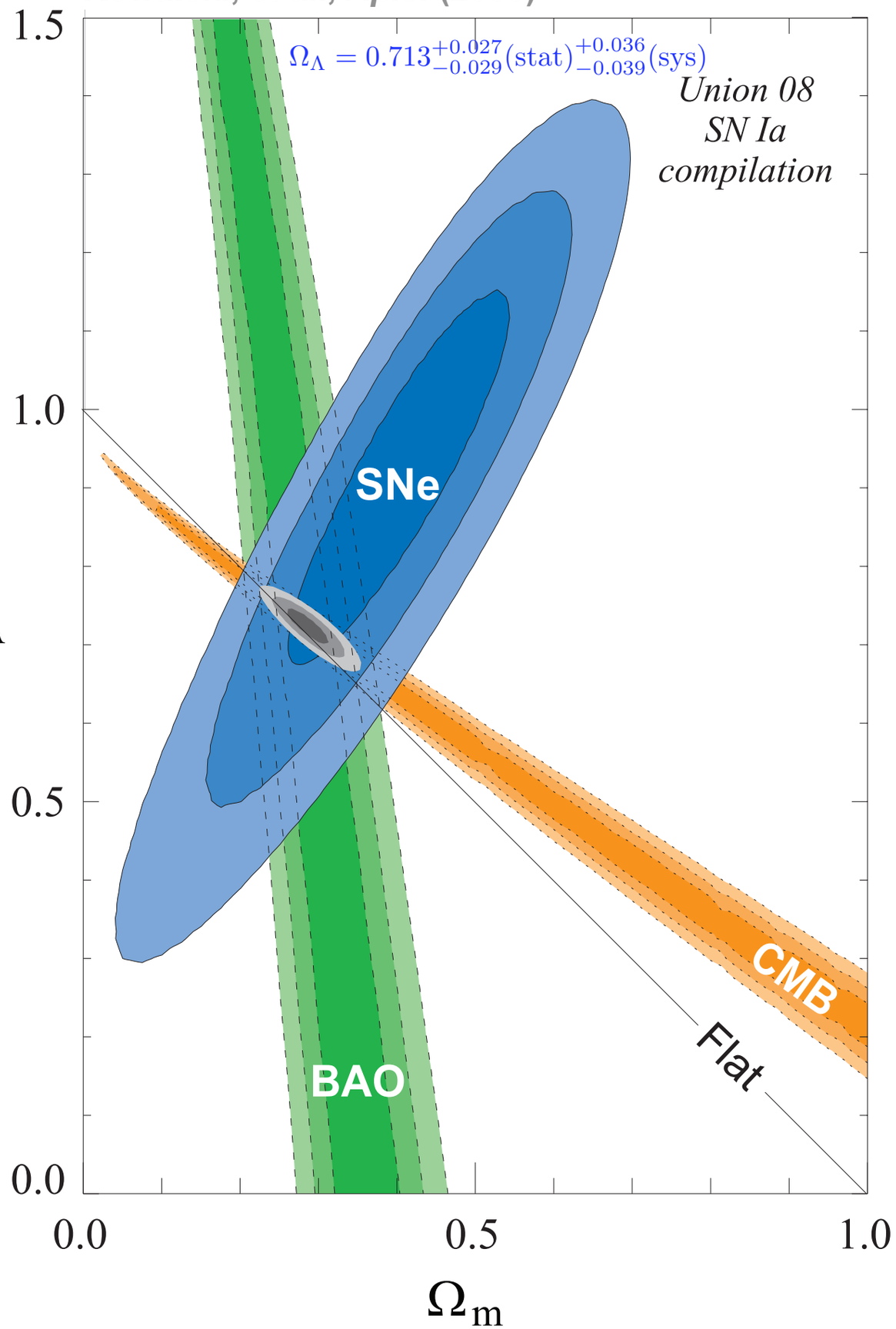
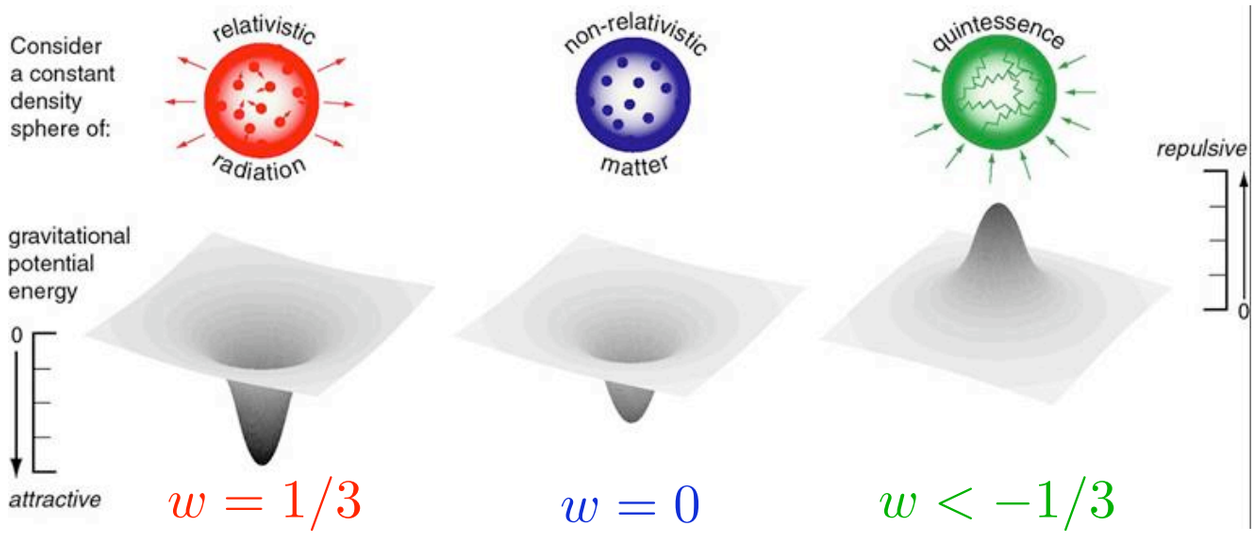




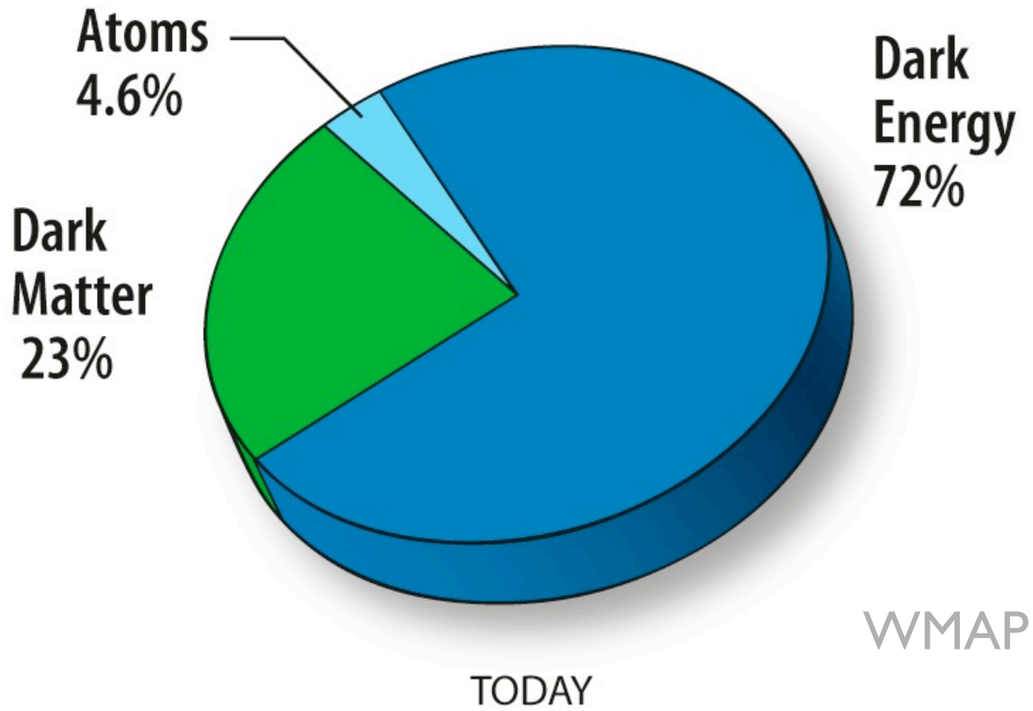


Supernova Cosmology Project
Kowalski, et al., *Ap.J.* (2008)





$$w = p/\rho$$



Running After w(z): The Stumbling Blocks

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Conclusion

Beyond Two w's

I will try to demonstrate that 4 or more independent binned estimates of "w(z)" can be obtained by combining a number of future surveys!

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

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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

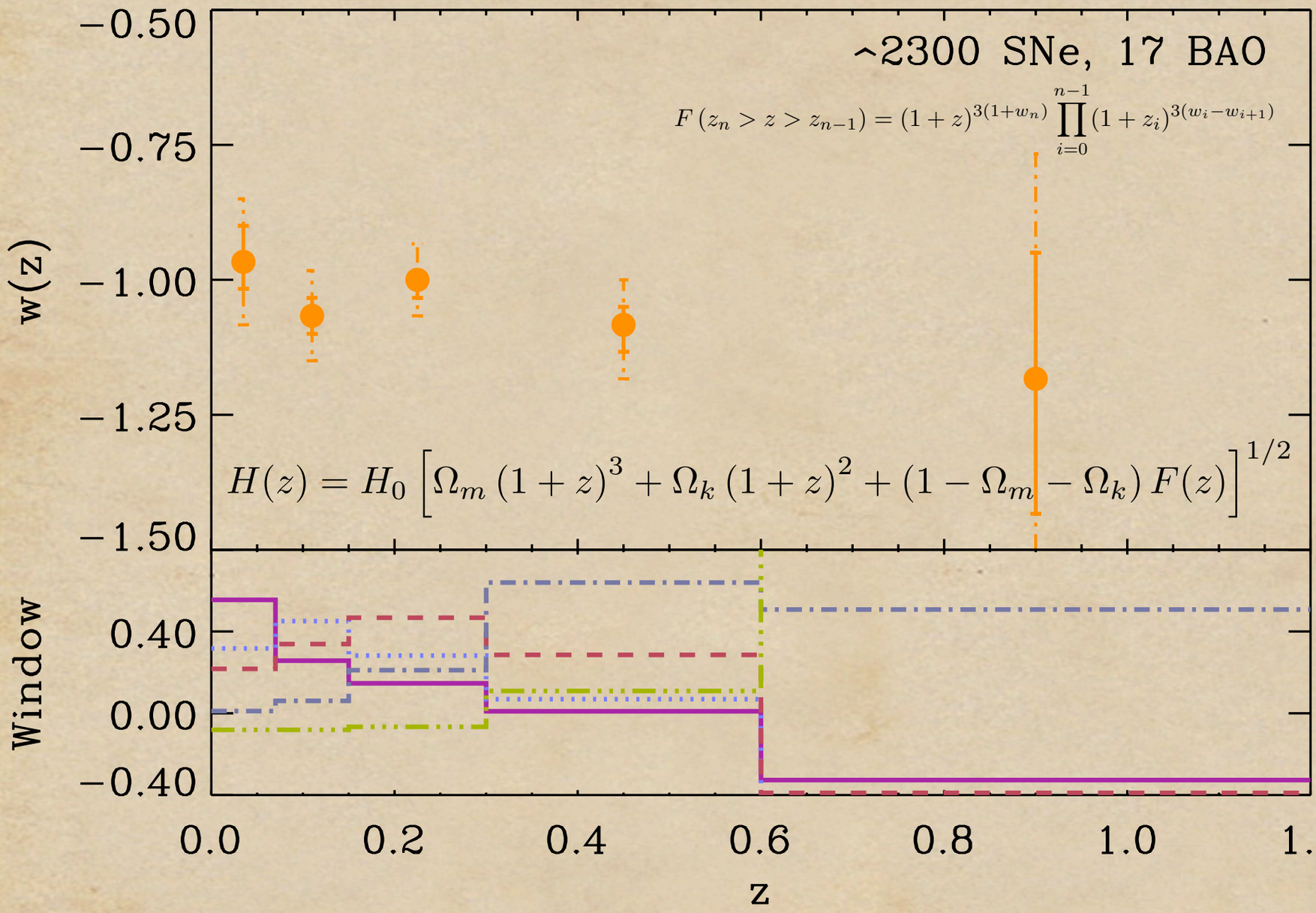
2. Principal Component Analysis

Huterer and Starkman 2003; Dragan's Talk

3. Uncorrelated Estimates of w(z)

Huterer and Cooray 2005; Asantha's Talk

Going Model-Independent: The Future!



w	Zup
w1	0.07
w2	0.15
w3	0.3
w4	0.6
w5	1.2
w6	1.8

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

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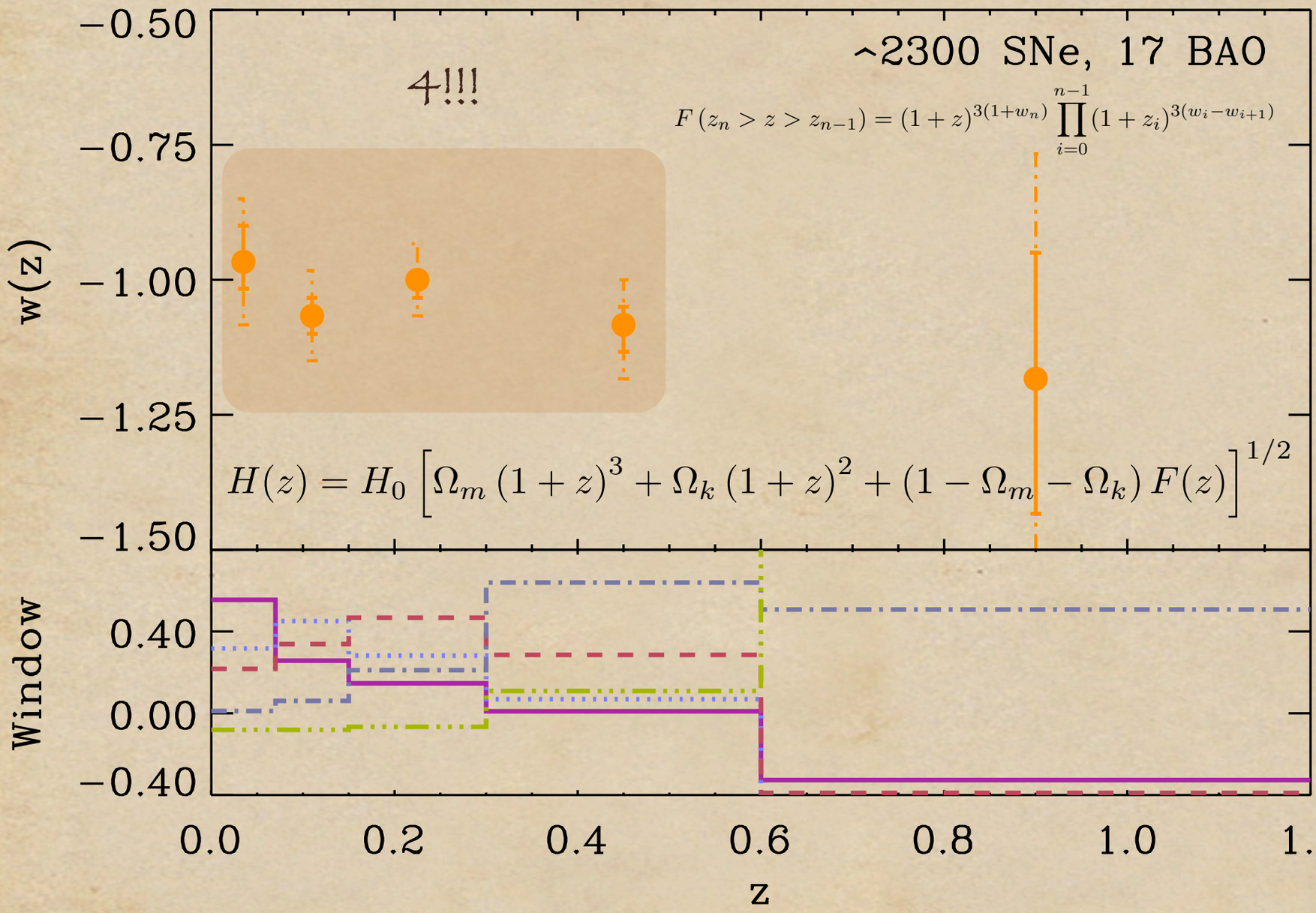

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Influence of Gravitational Lensing?

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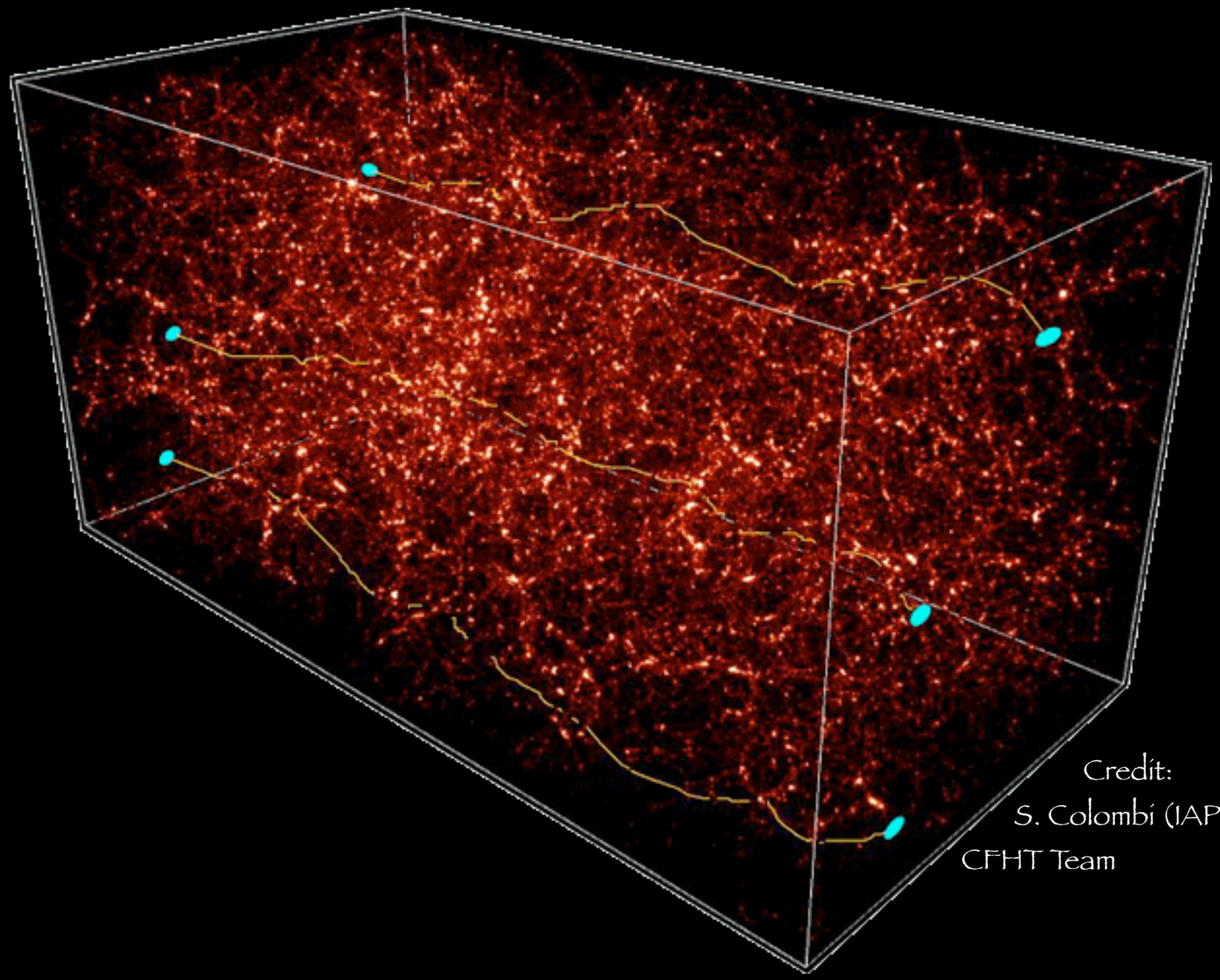

Credit:
S. Colombi (IAP),
CFHT Team

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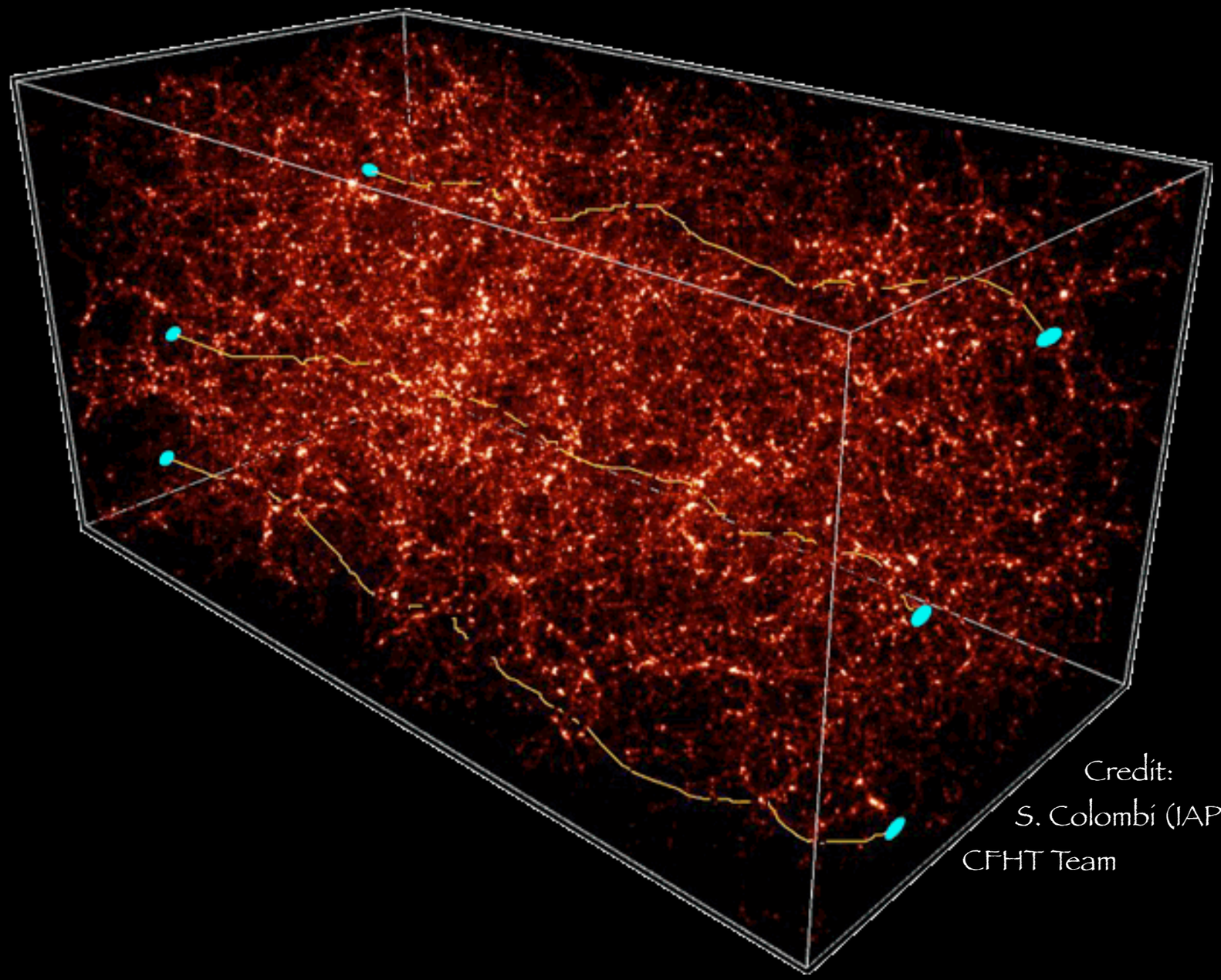

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$$\mathcal{F}^{\mathrm{obs,lensed}}(z,\hat{\mathbf{n}}) = \mu(z,\hat{\mathbf{n}})\mathcal{F}^{\mathrm{obs,true}}(z)$$

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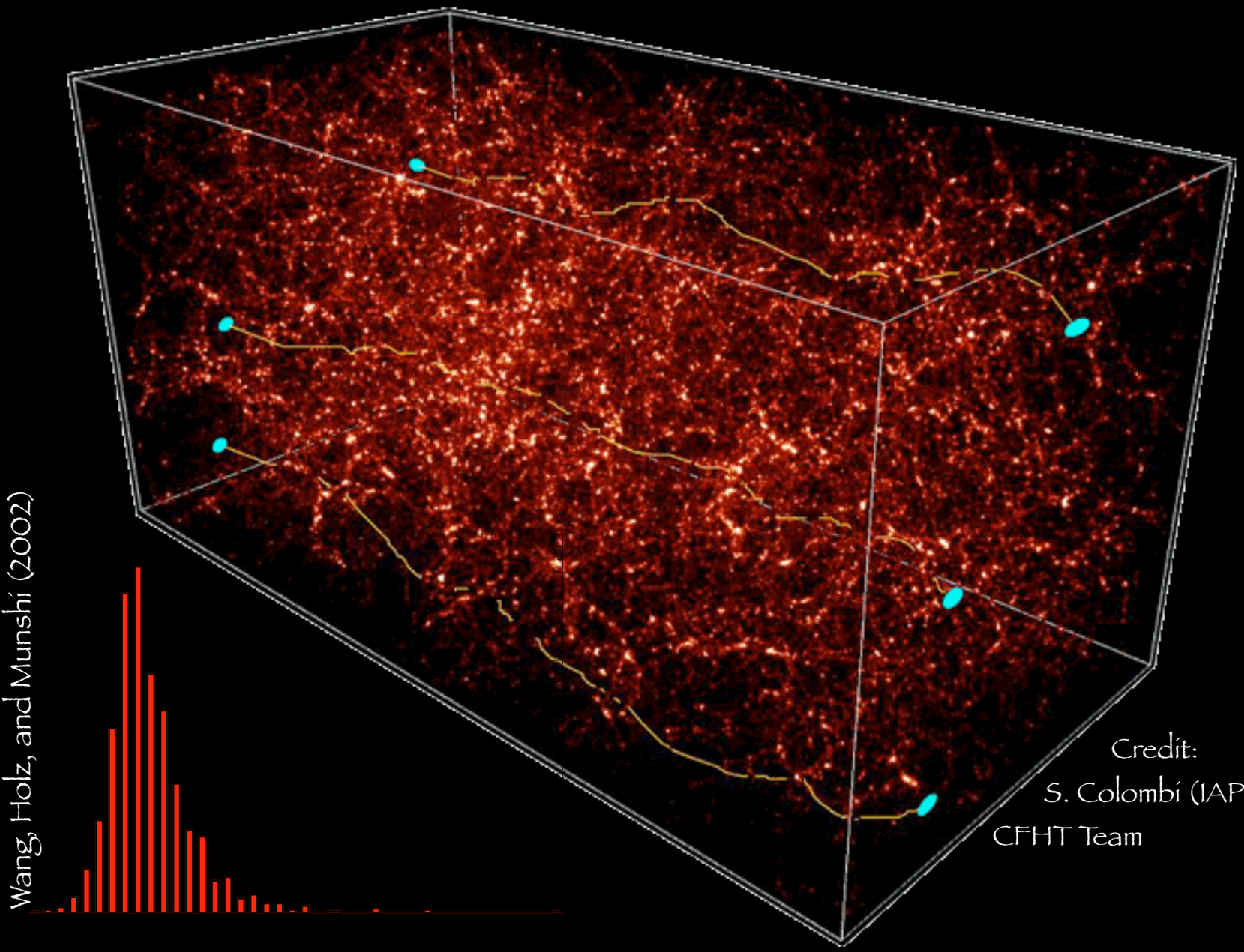

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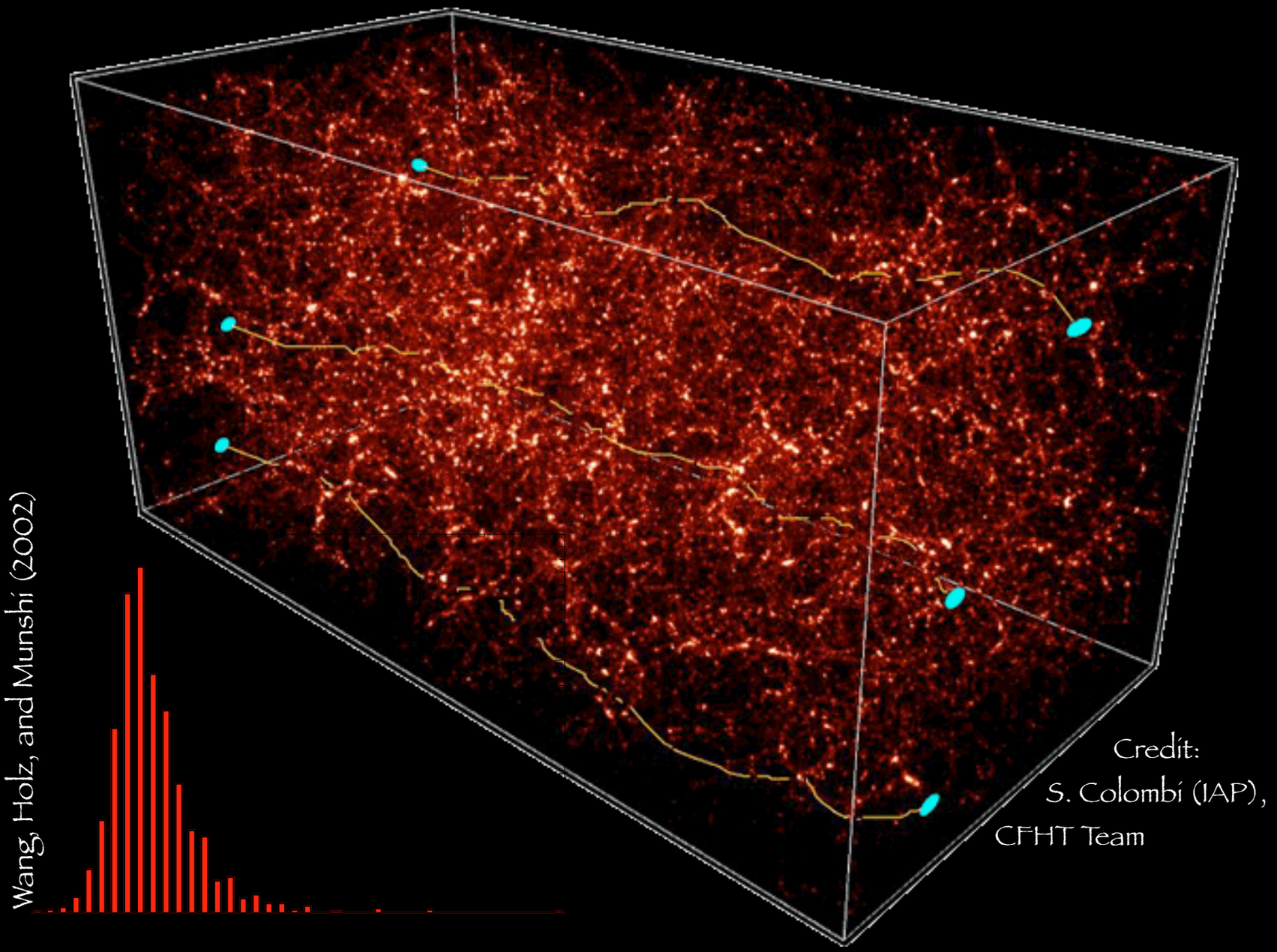

$$\mathcal{F}^{\mathrm{obs,lensed}}(z,\hat{\mathbf{n}}) = \mu(z,\hat{\mathbf{n}})\mathcal{F}^{\mathrm{obs,true}}(z)$$

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

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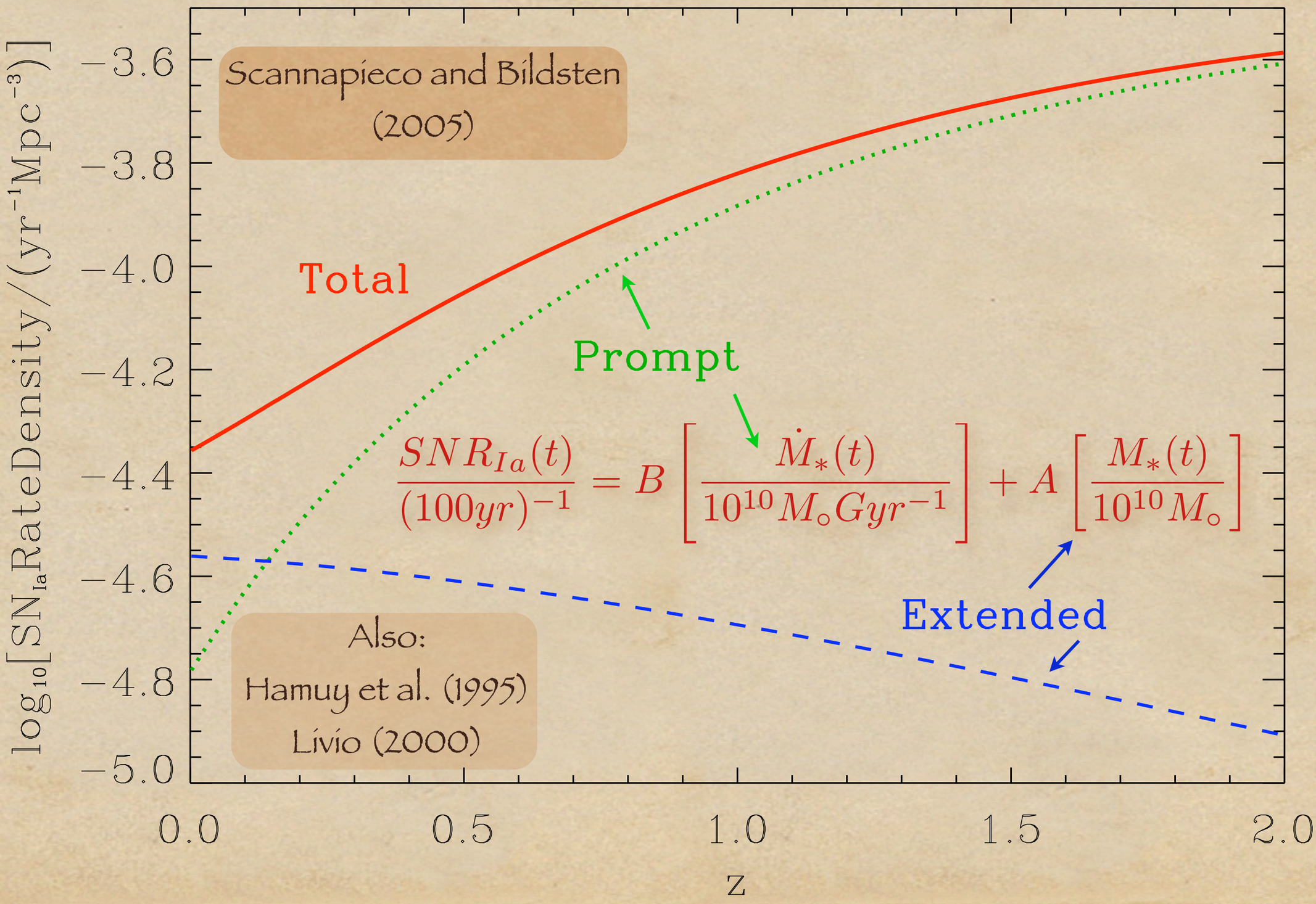
Two Supernova Populations



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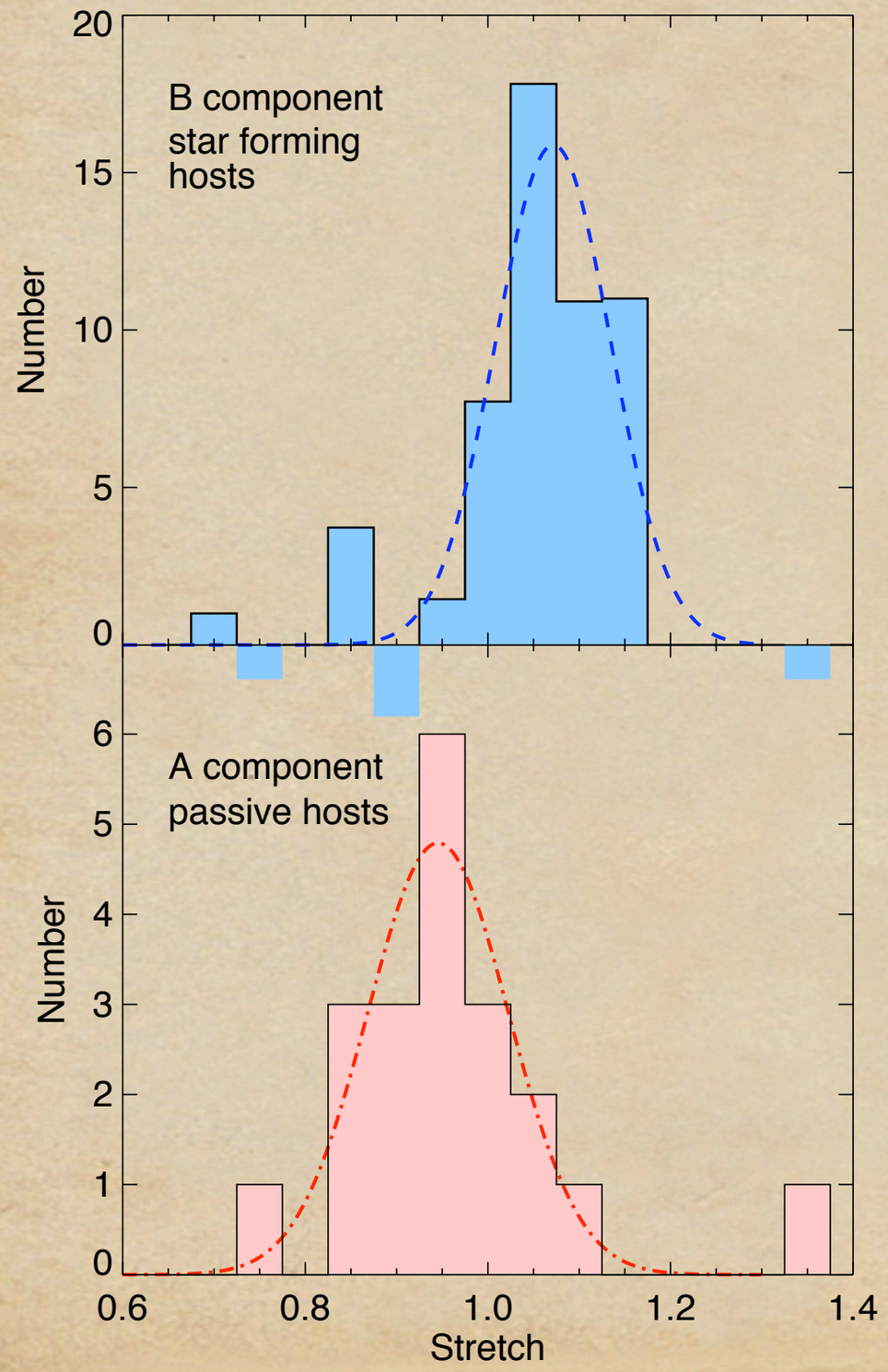

$$\mu_B = m_B^* - M + \alpha(s-1) - \beta c$$

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)

Is There a Signature in the Hubble Diagram?

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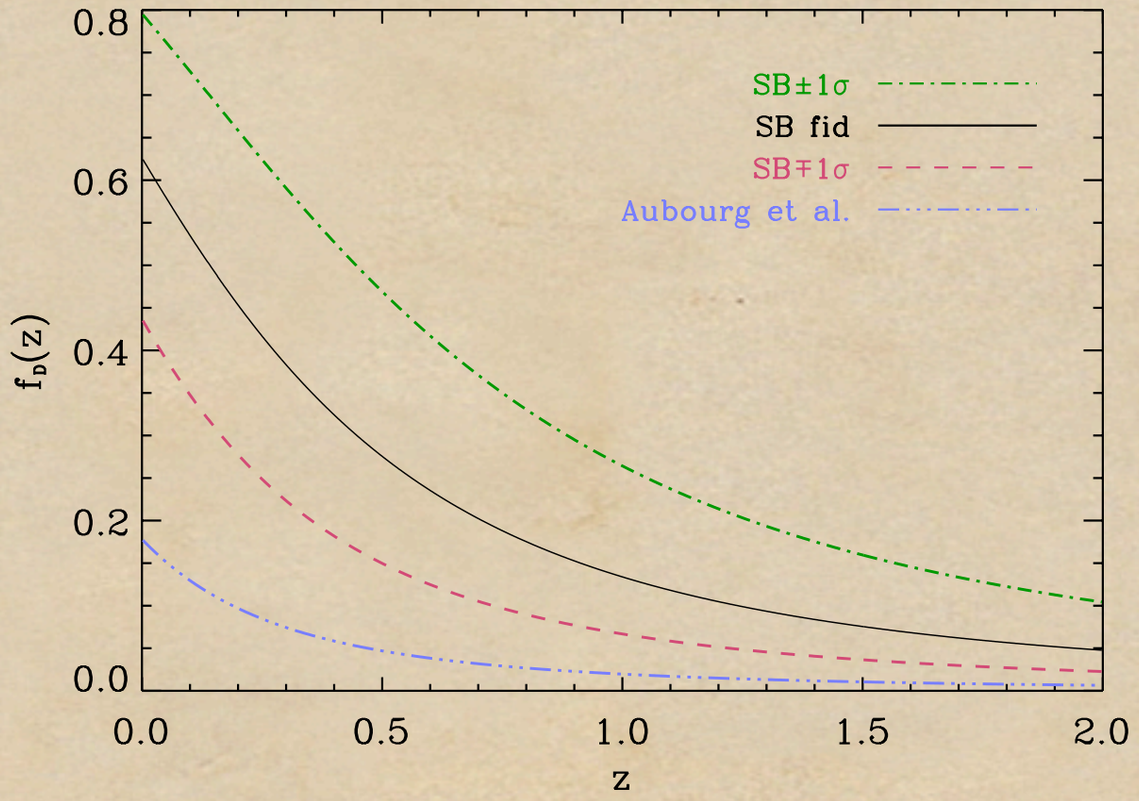
$$m - M = 5 \log \left(\frac{d_L}{\mathrm{Mpc}} \right) + 25 + \mathcal{M}$$

Distance Modulus

Is There a Signature in the Hubble Diagram?

Propose!

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



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

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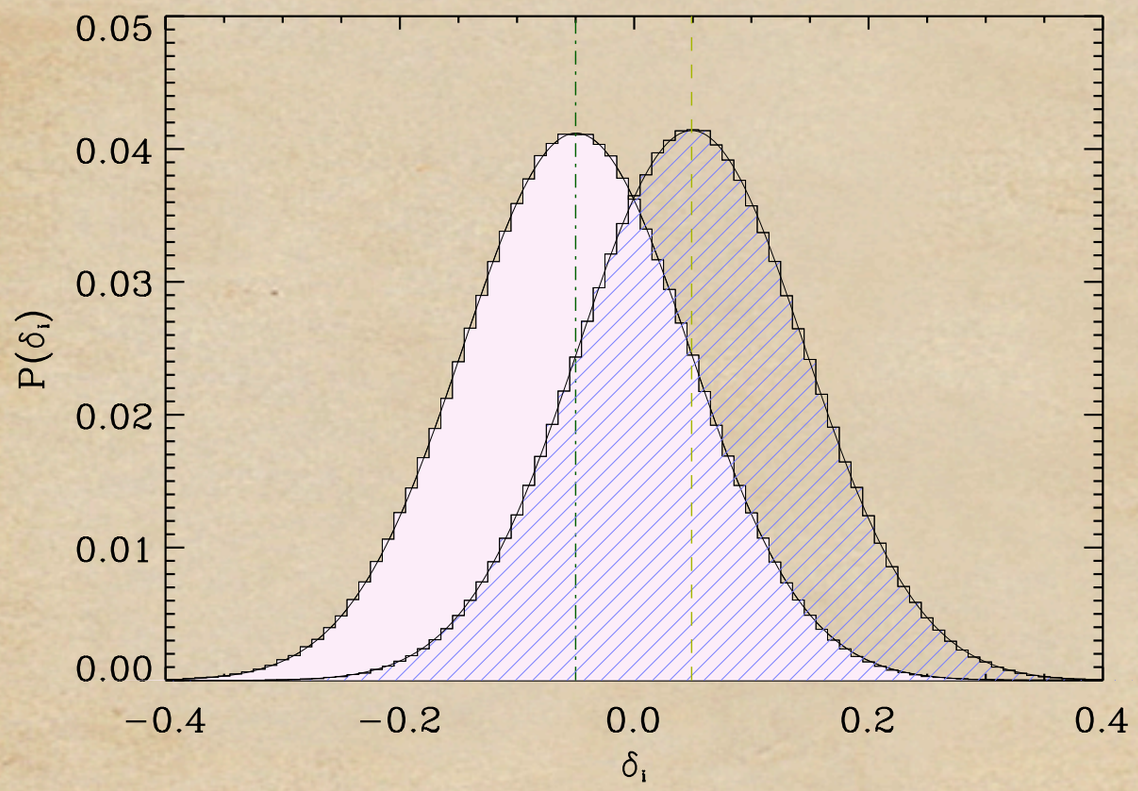

With current data (192 SNe from Davis et al. 2007), the residual is consistent with zero:

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

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

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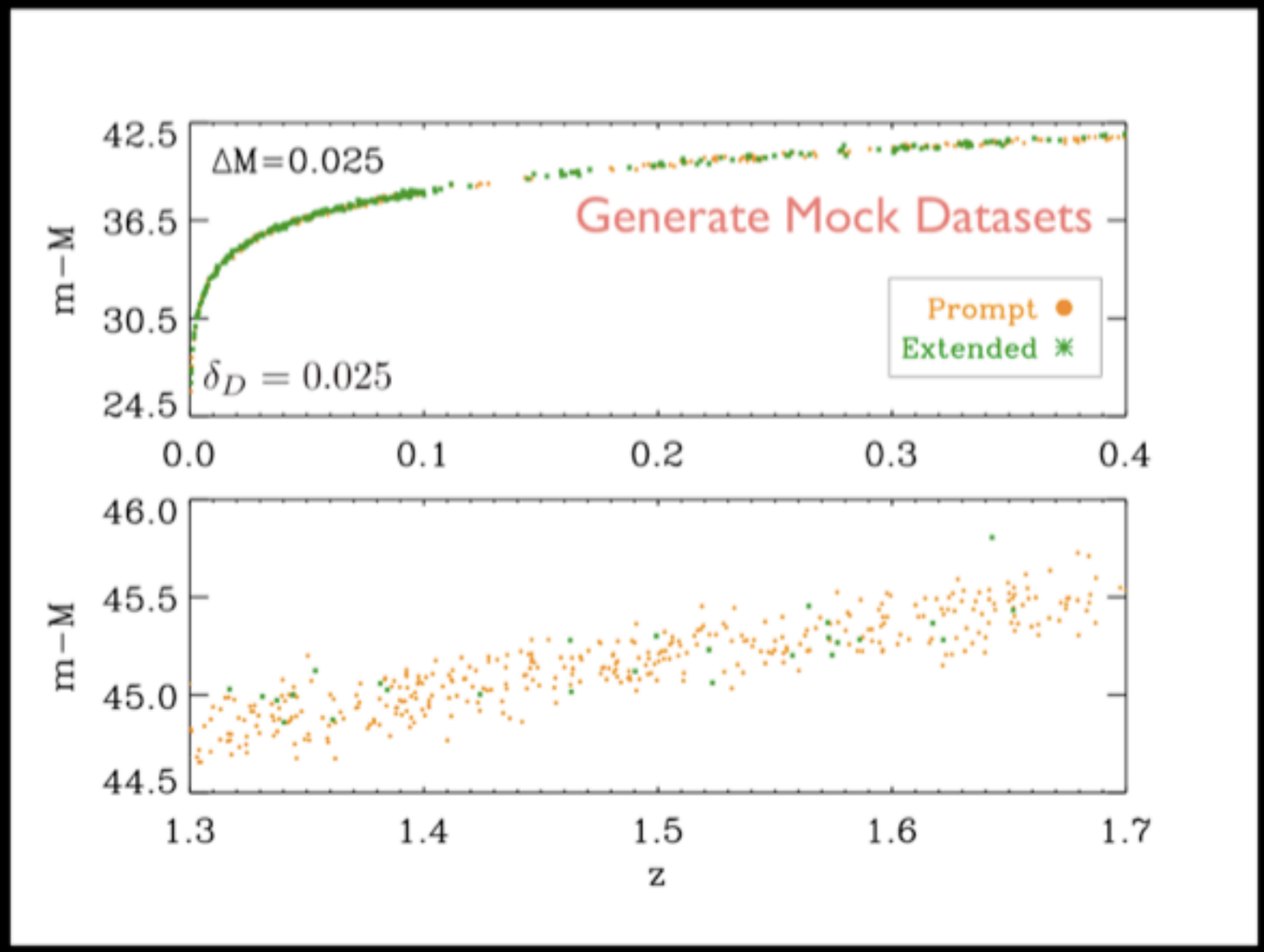
Effect on the EOS: Bias in "w"



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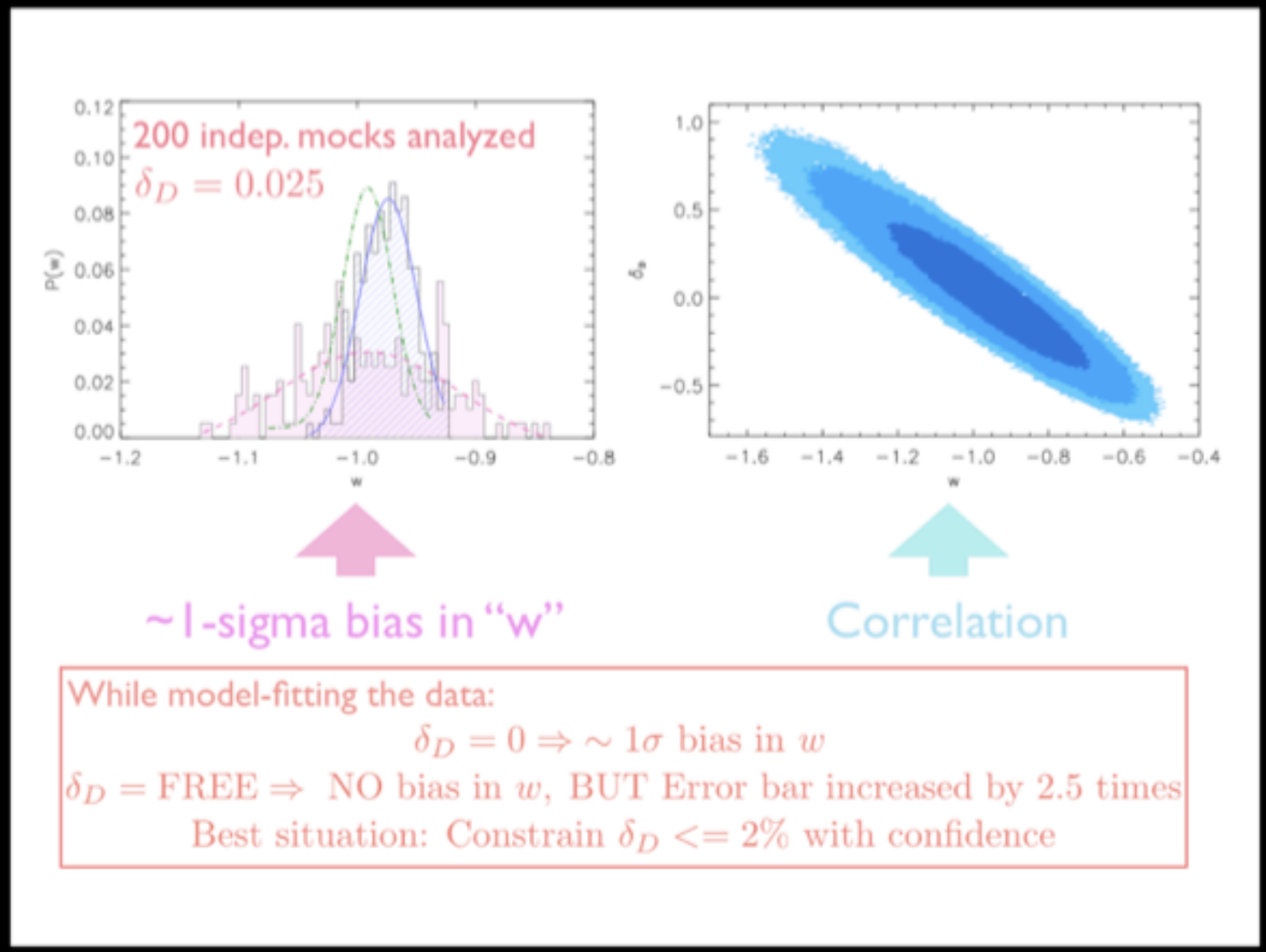

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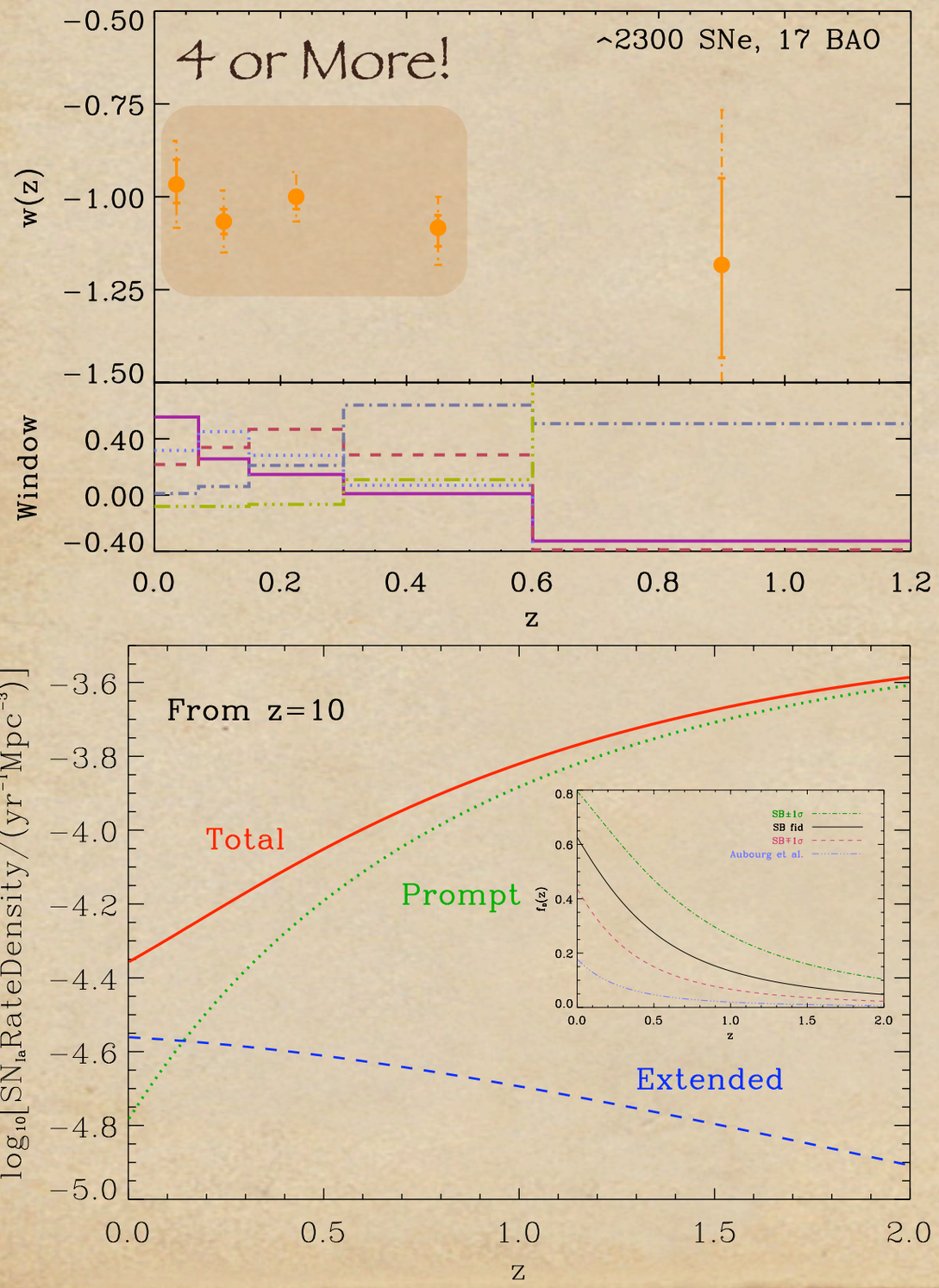
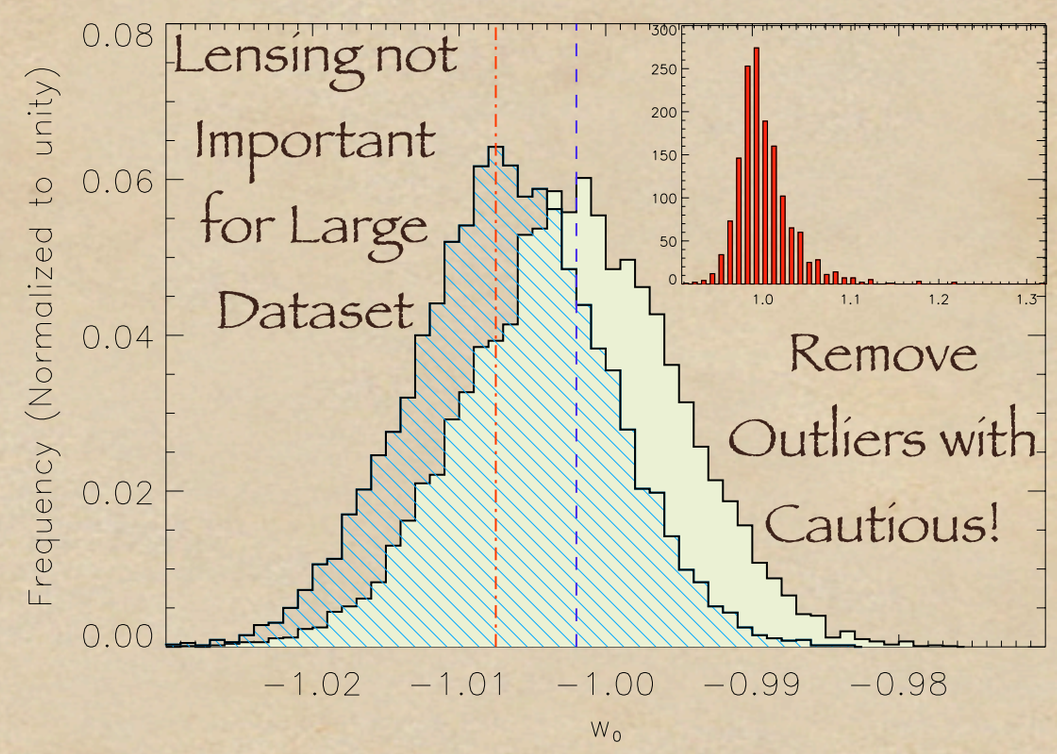
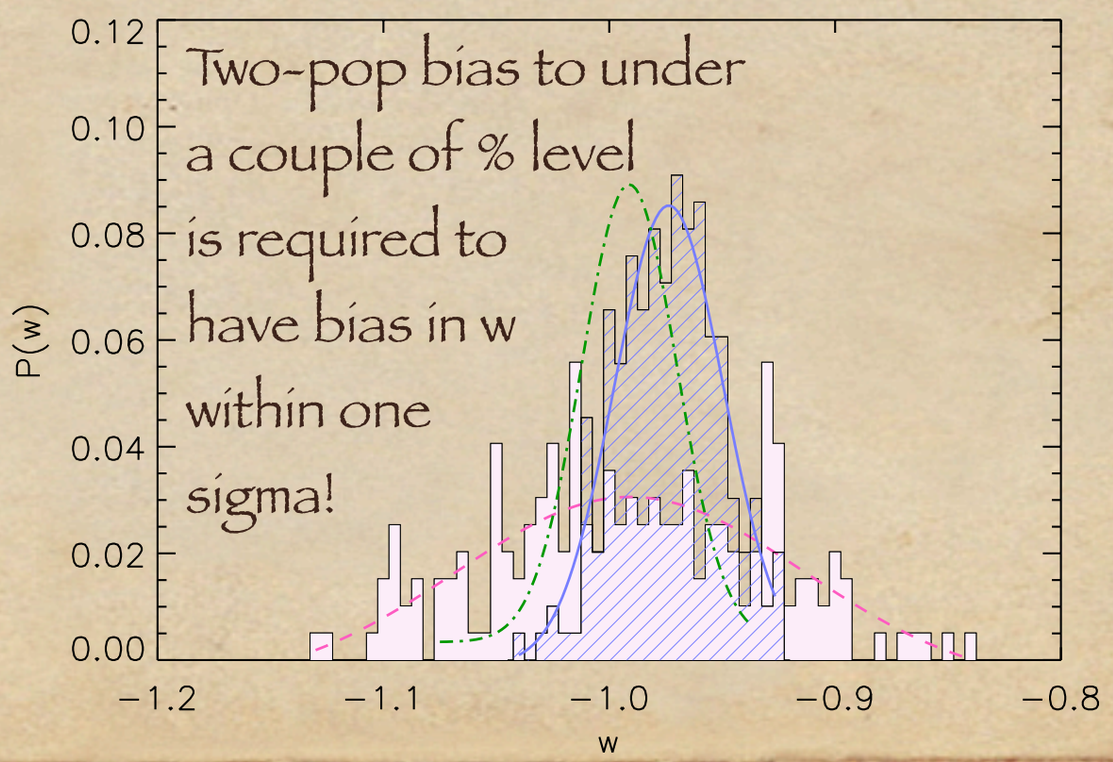
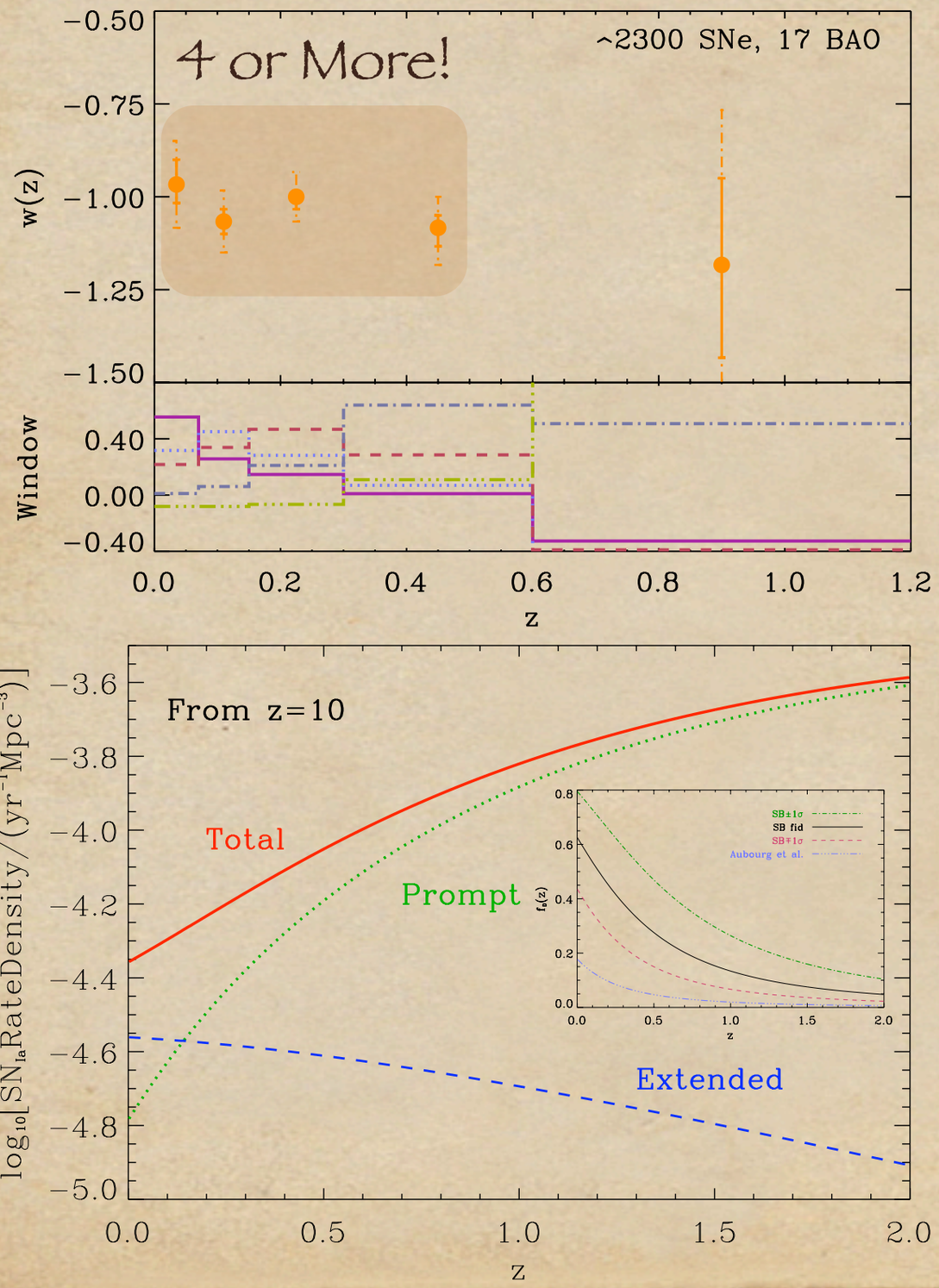
Conclusion


4 or More!
~2300 SNe, 17 BAO
w(z)
Window
z
From z=10
Total
Prompt
Extended
$\log_{10}[SN_{Ia}RateDensity/(yr^{-1}Mpc^{-3})]$
z


Lensing not
Important
for Large
Dataset
Remove
Outliers with
Cautious!
Frequency (Normalized to unity)
w_0


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

Conclusion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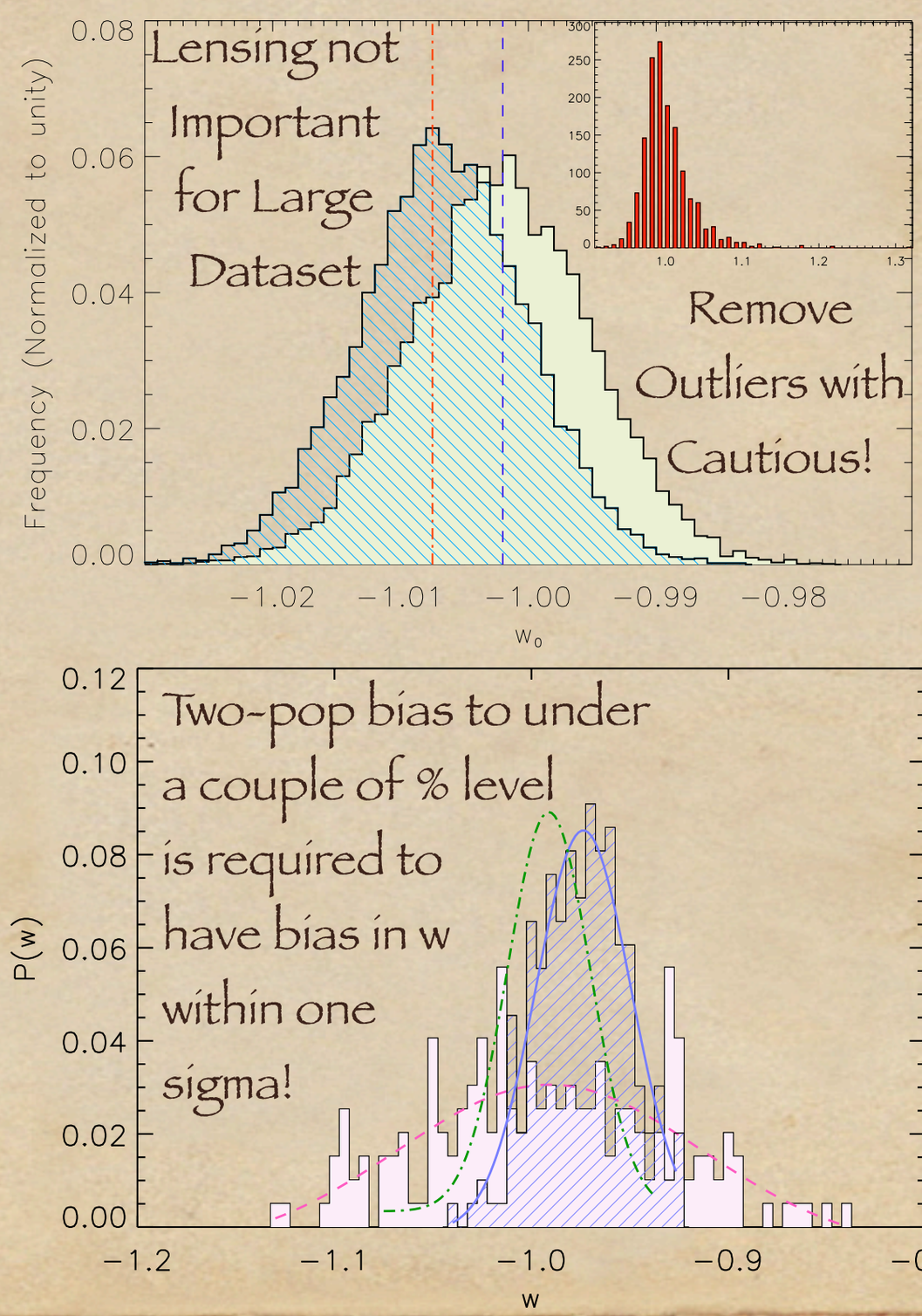
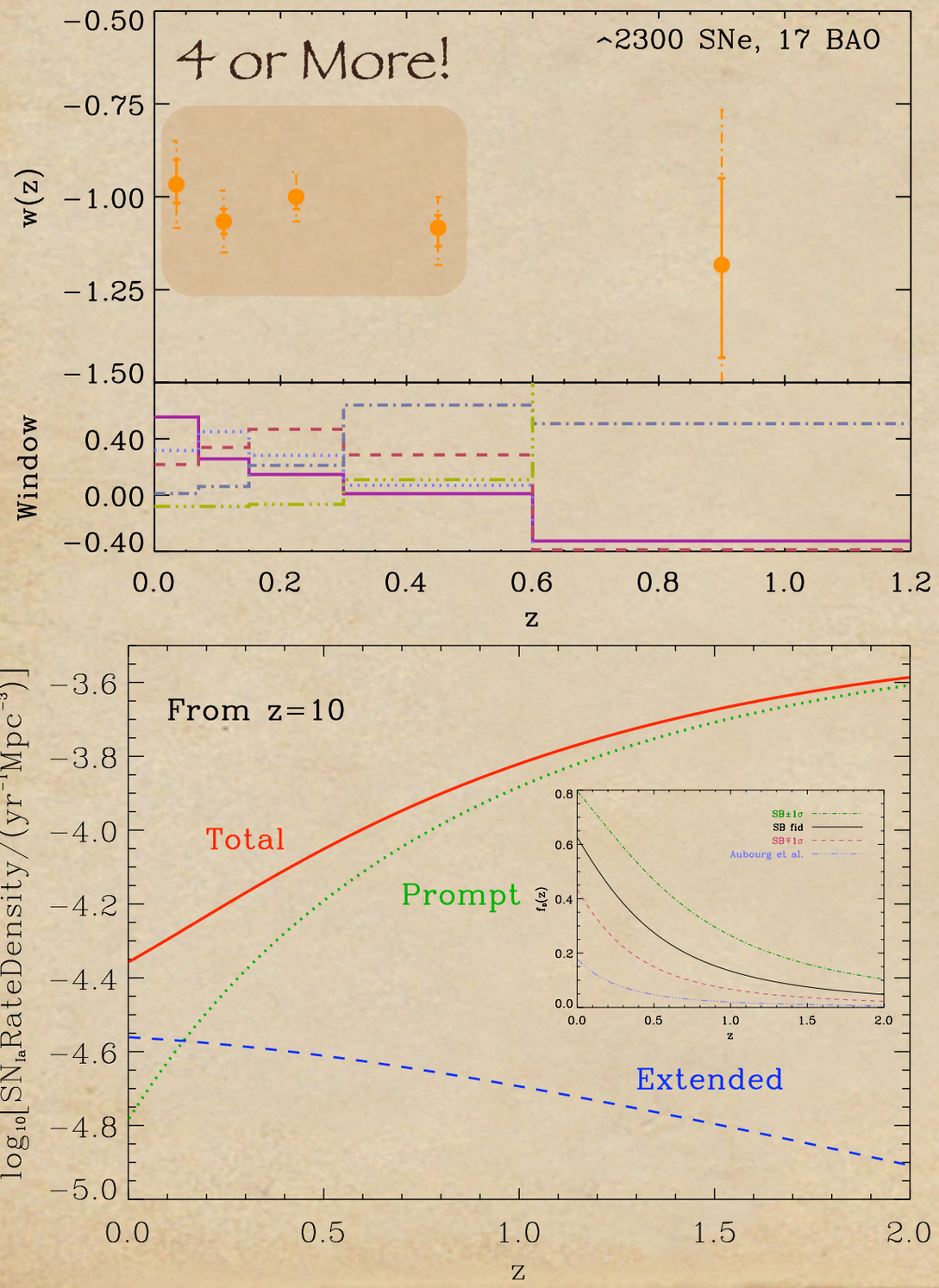
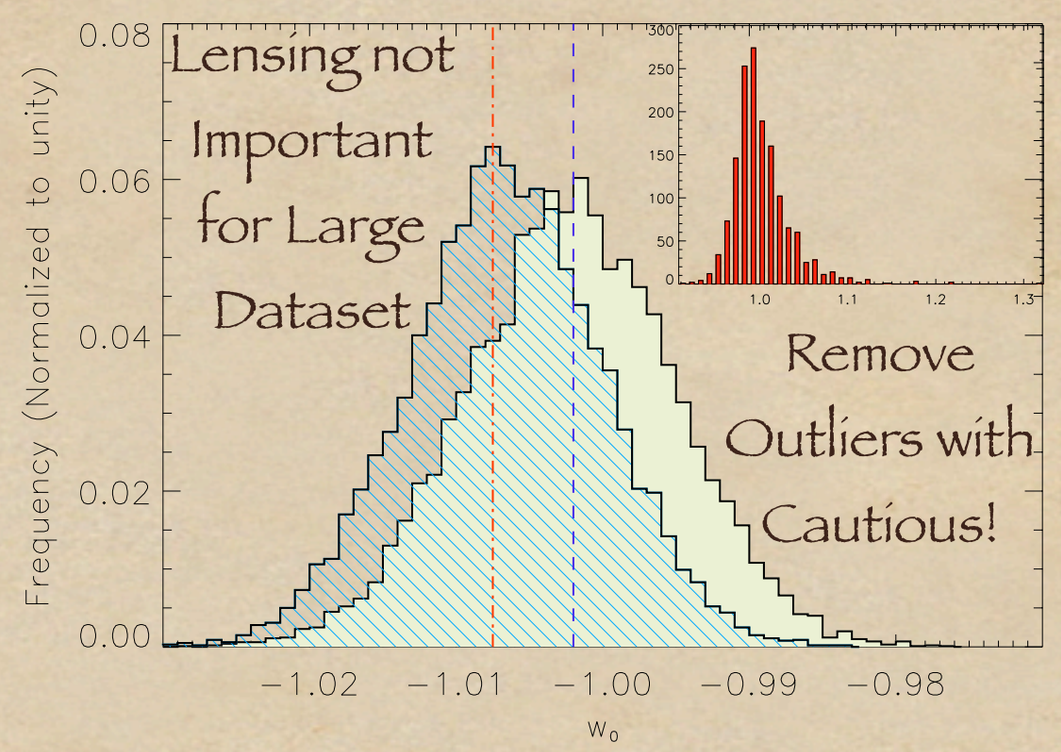
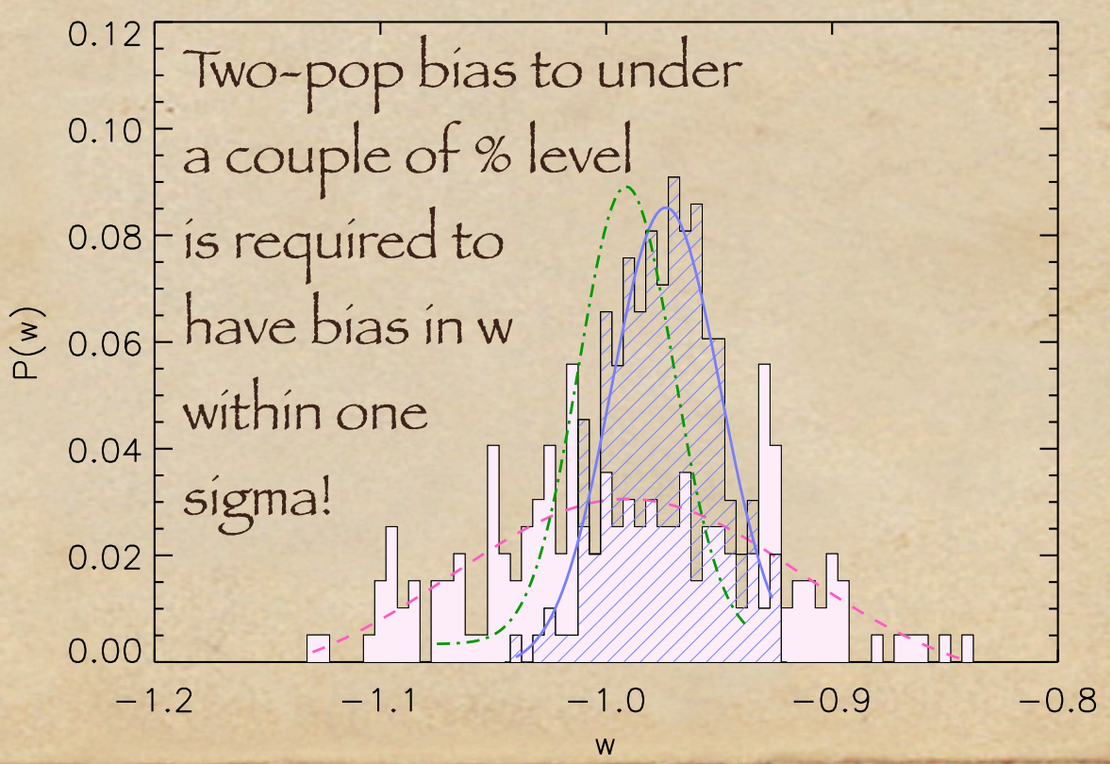
~2300 SNe, 17 BAO
w(z)
Window
z
From z=10
Total
Prompt
Extended
$\log_{10}[SN_{Ia}RateDensity/(yr^{-1}Mpc^{-3})]$
z


Lensing not Important for Large Dataset
Remove Outliers with Cautious!
Frequency (Normalized to unity)
w_0
Two-pop bias to under a couple of % level is required to have bias in w within one sigma!
P(w)
w

Conclusion







THANK YOU!