"For if each Star is little more a mathematical Point,
located upon the Hemisphere of Heaven by Right Ascension and Declination,
then all the Stars, taken together, tho' innumerable,
must like any other set of points,
in turn represent some single gigantic Equation,
to the mind of God as straightforward as, say, the Equation of a Sphere,---
to us unreadable, incalculable.
A lonely, uncompensated, perhaps even impossible Task,---
yet some of us must ever be seeking, I suppose."

- Thomas Pynchon, Mason & Dixon

UC Irvine

CENTER FOR COSMOLOGY

Devdeep's
Ph.D. Dissertation

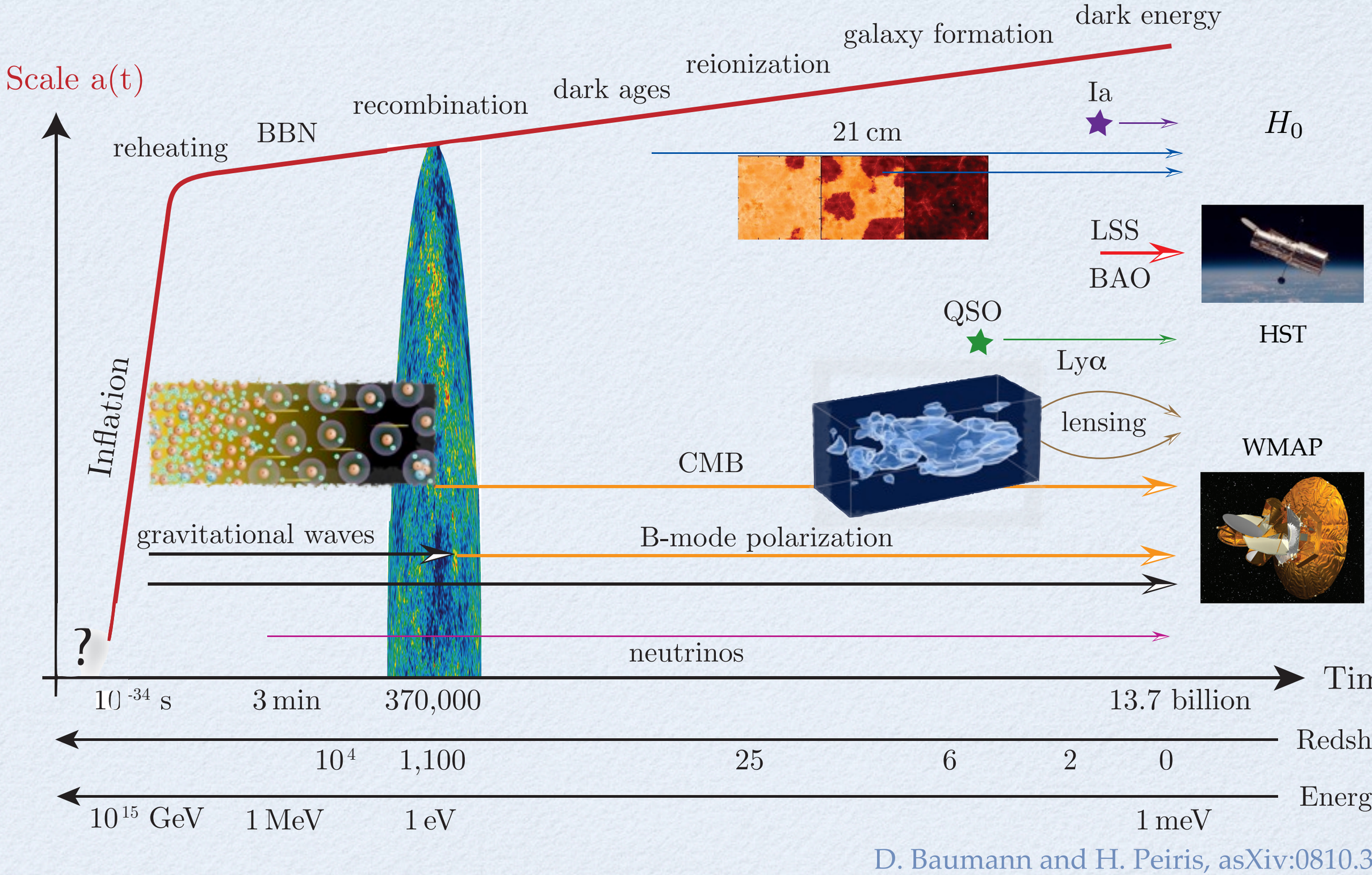
COSMOLOGICAL EXPLORATIONS: FROM PRIMORDIAL NON-GAUSSIANITY TO DYNAMICAL DARK ENERGY

Think Tank: Asantha Cooray (UCI), Daniel Holz (LANL)

Ultimate Help Desk: Alexandre Amblard (UCI), Paolo Serra (UCI)

Collaborators: M. Kaplinghat (UCI), R. Caldwell (Dartmouth), S. Joudaki (UCI), S. Sullivan (UCLA), D. Baumann (Harvard), K. Ichiki (Nayoga), H. Feldman (Kansas), R. Watkins (Willamette)

THE UNIVERSE IN A NUTSHELL



D. Baumann and H. Peiris, asXiv:0810.3022

GW via Weak Lensing

Scale a(t)

Inflation

reheating

BBN

recombination

dark ages

reionization

galaxy formation

dark energy

?

21 cm

Ia

H_0

LSS

BAO

QSO

Lyα

HST

lensing

CMB

WMAP

gravitational waves

B-mode polarization

neutrinos

Time

10^{-34} s

3 min

370,000

13.7 billion

Redshift

10^4

1,100

25

6

2

0

Energy

10^{15} GeV

1 MeV

1 eV

1 meV

D. Baumann and H. Peiris, asXiv:0810.3022

GW via Weak Lensing

CMB Bispectrum Lensing

Scale a(t)

Inflation

reheating

BBN

recombination

dark ages

reionization

galaxy formation

dark energy

21 cm

Ia

H_0

LSS

BAO

QSO

Lyα

HST

lensing

WMAP

CMB

gravitational waves

B-mode polarization

neutrinos

?

Time

10^{-34} s

3 min

370,000

13.7 billion

Redshift

10^4

1,100

25

6

2

0

Energy

10^{15} GeV

1 MeV

1 eV

1 meV

D. Baumann and H. Peiris, asXiv:0810.3022

GW via Weak Lensing

CMB Bispectrum Lensing

Dark Energy Beyond 2 param

Scale a(t)

dark energy

galaxy formation

reionization

dark ages

recombination

BBN

reheating

Inflation

?

Ia

H_0

21 cm

LSS

BAO

QSO

Lyα

HST

lensing

CMB

WMAP

gravitational waves

B-mode polarization

neutrinos

Time

10^{-34} s

3 min

370,000

13.7 billion

Redshift

10^4

1,100

25

6

2

0

Energy

10^{15} GeV

1 MeV

1 eV

1 meV

D. Baumann and H. Peiris, asXiv:0810.3022

GW via Weak Lensing

CMB Bispectrum Lensing

Dark Energy Beyond 2 param

SHoES & Dark Energy

Scale a(t)

dark energy

galaxy formation

reionization

dark ages

recombination

BBN

reheating

Inflation

?

Ia

H_0

21 cm

LSS

BAO

QSO

Lyα

HST

lensing

WMAP

CMB

gravitational waves

B-mode polarization

neutrinos

Time

10^{-34} s

3 min

370,000

13.7 billion

Redshift

10^4

1,100

25

6

2

0

Energy

10^{15} GeV

1 MeV

1 eV

1 meV

D. Baumann and H. Peiris, asXiv:0810.3022

GW via Weak Lensing

CMB Bispectrum Lensing

Dark Energy Beyond 2 param

SHoES & Dark Energy

Are they Skewed?

Scale a(t)

dark energy

galaxy formation

reionization

dark ages

recombination

BBN

reheating

Ia

H_0

21 cm

LSS

BAO

QSO

HST

Lyα

lensing

WMAP

CMB

gravitational waves

B-mode polarization

neutrinos

Inflation

?

Time

10^{-34} s

3 min

370,000

13.7 billion

Redshift

10^4

1,100

25

6

2

0

Energy

10^{15} GeV

1 MeV

1 eV

1 meV

D. Baumann and H. Peiris, asXiv:0810.3022

GW via Weak Lensing

CMB Bispectrum Lensing

Dark Energy Beyond 2 param

SHoES & Dark Energy

Are they Skewed?

Supernova Lensing in Play

Scale a(t)

dark energy

galaxy formation

reionization

dark ages

recombination

BBN

reheating

Inflation

?

Ia

H_0

21 cm

LSS

BAO

QSO

Lyα

HST

lensing

WMAP

CMB

gravitational waves

B-mode polarization

neutrinos

Time

10^{-34} s

3 min

370,000

13.7 billion

Redshift

10^4

1,100

25

6

2

0

Energy

10^{15} GeV

1 MeV

1 eV

1 meV

D. Baumann and H. Peiris, asXiv:0810.3022

GW via Weak Lensing

CMB Bispectrum Lensing

Dark Energy Beyond 2 param

SHoES & Dark Energy

Are they Skewed?

Supernova Lensing in Play

Lack of Bipartisan-ship

Scale a(t)

dark energy

galaxy formation

reionization

dark ages

recombination

BBN

reheating

Inflation

?

Ia

H_0

21 cm

LSS

BAO

QSO

Lyα

HST

lensing

WMAP

CMB

gravitational waves

B-mode polarization

neutrinos

Time

10^{-34} s

3 min

370,000

13.7 billion

Redshift

10^4

1,100

25

6

2

0

Energy

10^{15} GeV

1 MeV

1 eV

1 meV

D. Baumann and H. Peiris, asXiv:0810.3022

GW via Weak Lensing

2007-08

CMB Bispectrum Lensing

2007-08

Dark Energy Beyond 2 param

2007-08

SHoES & Dark Energy

2008-09

Are they Skewed?

2008-09

Supernova Lensing in Play

2006-07

Lack of Bipartisan-ship

2008

Scale a(t)

dark energy

galaxy formation

reionization

dark ages

recombination

BBN

reheating

Inflation

?

Ia

H_0

21 cm

LSS

BAO

QSO

Lyα

HST

lensing

WMAP

CMB

gravitational waves

B-mode polarization

neutrinos

Time

10^{-34} s

3 min

370,000

13.7 billion

Redshift

10^4

1,100

25

6

2

0

Energy

10^{15} GeV

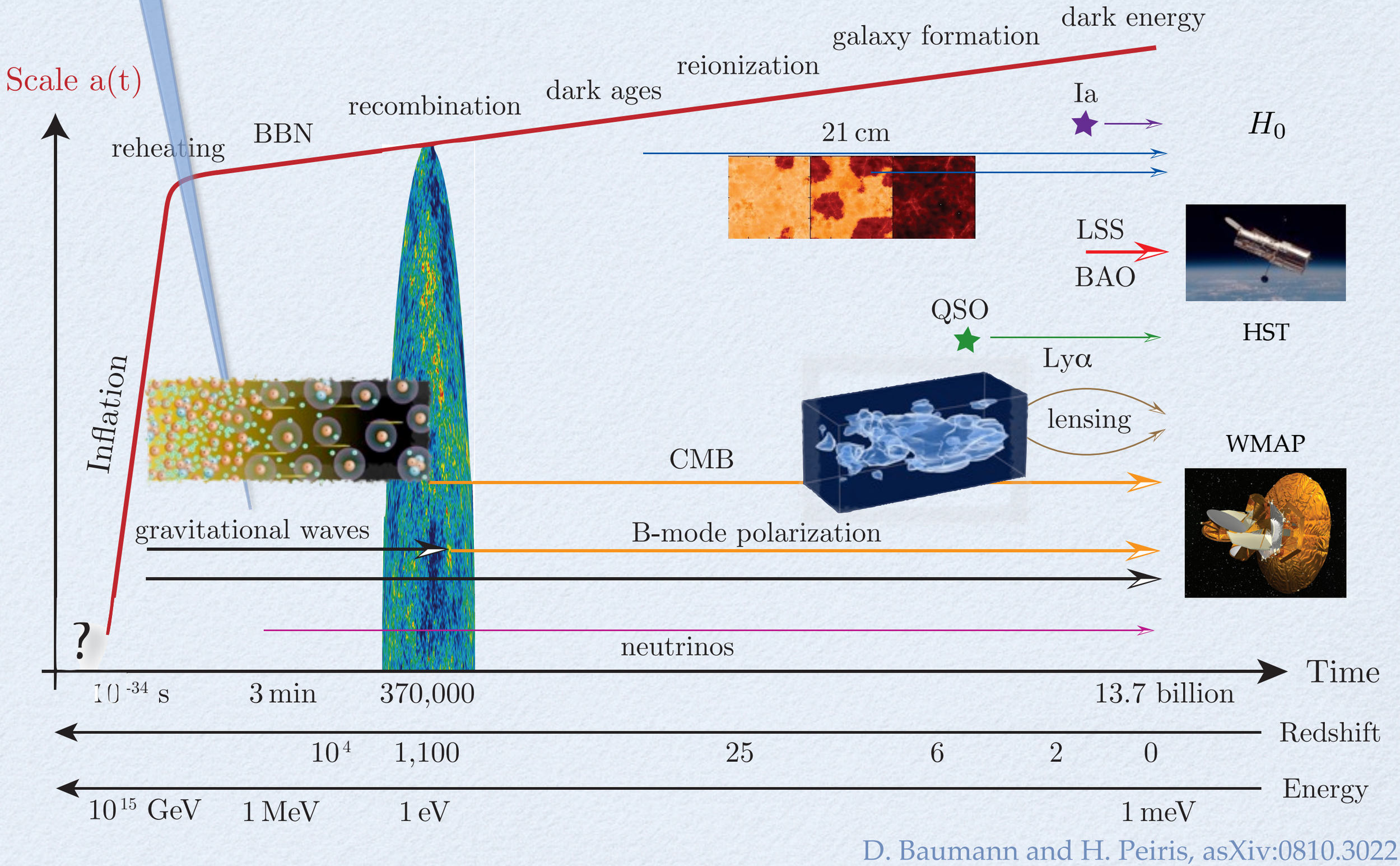
1 MeV

1 eV

1 meV

D. Baumann and H. Peiris, asXiv:0810.3022

PRD 2008



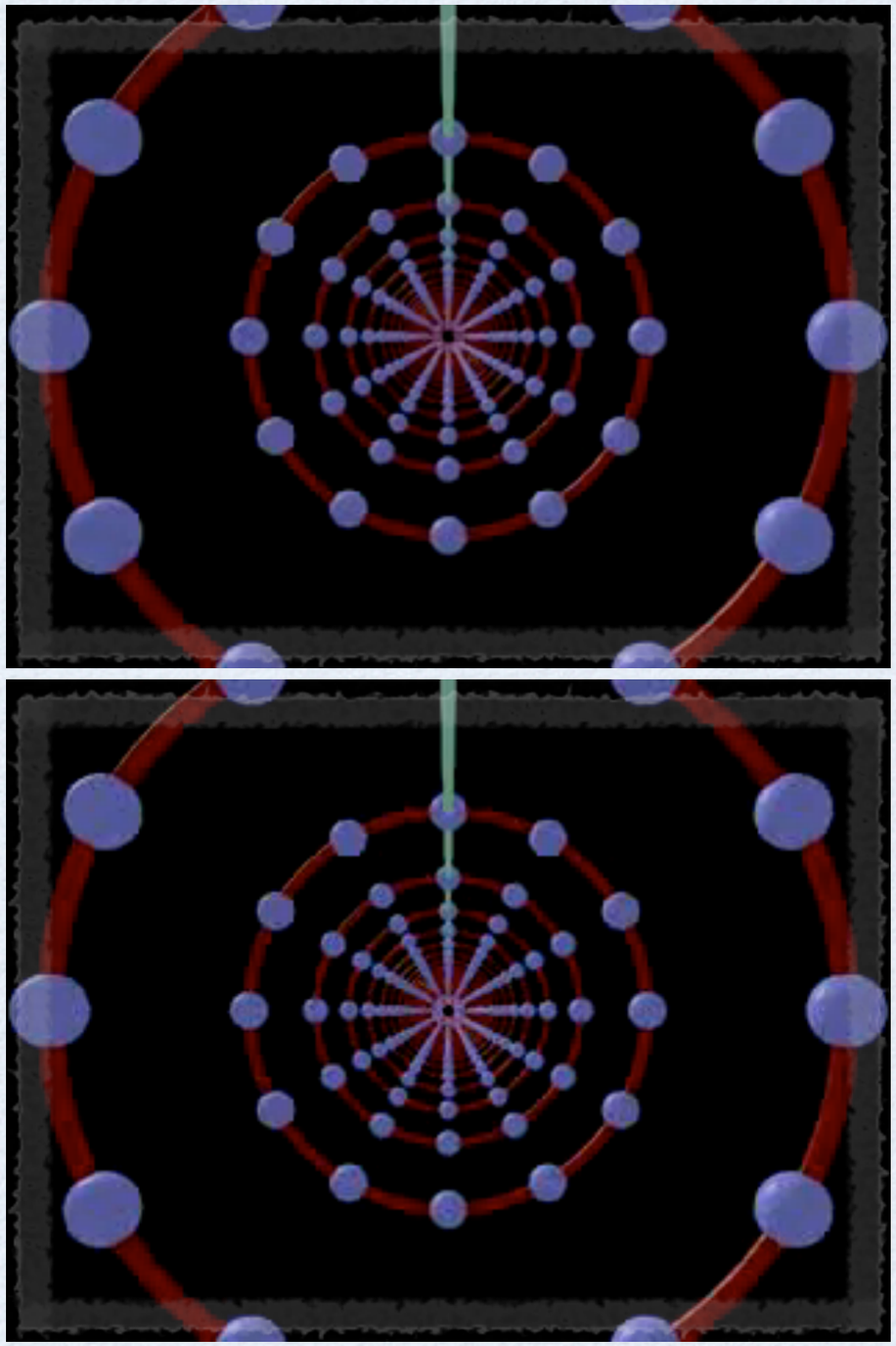
D. Baumann and H. Peiris, asXiv:0810.3022

Gravity Waves

Credit: Michael Penn State Schuylkill

Credit: Michael Penn State Schuylkill

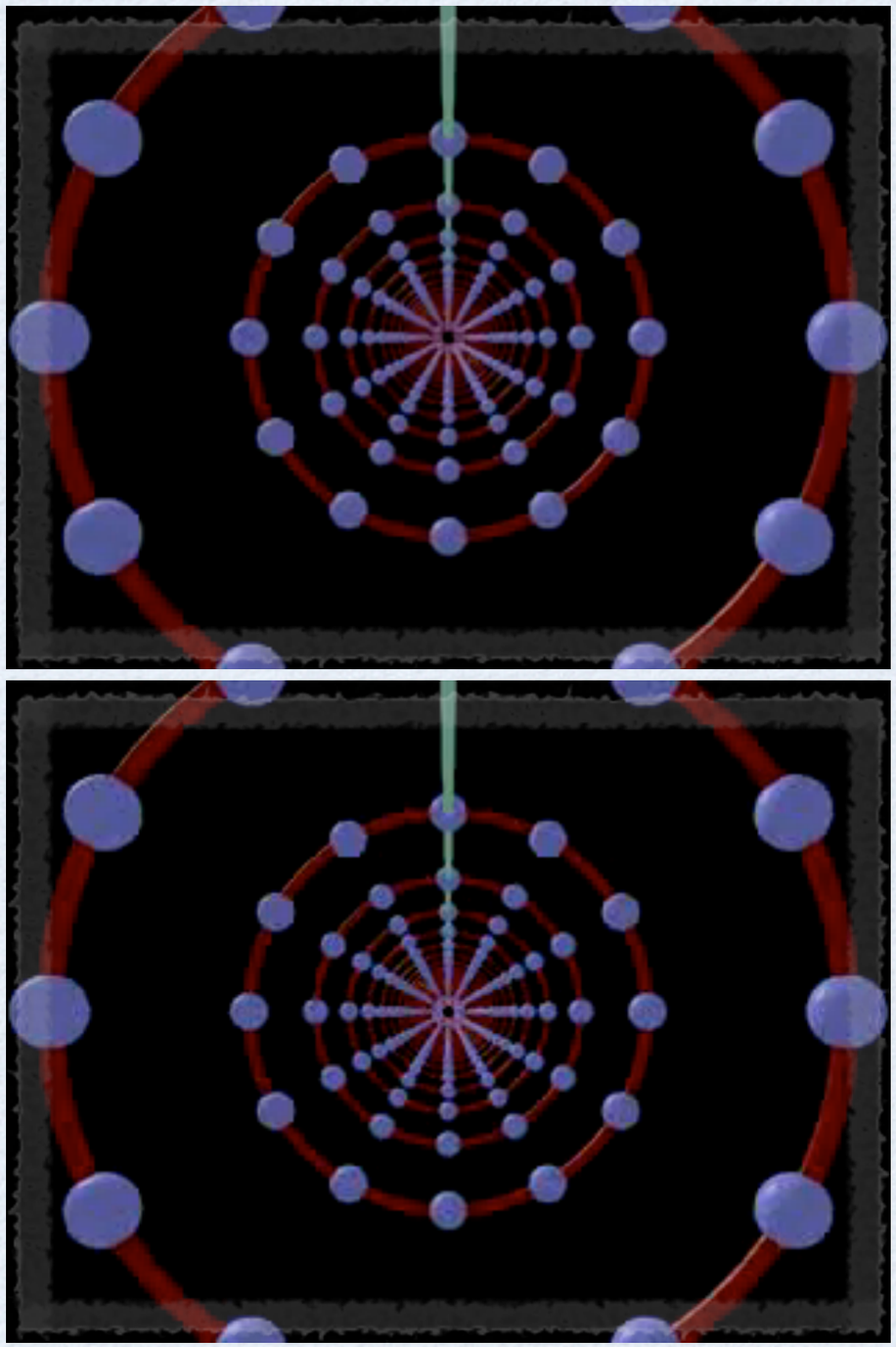
Gravity Waves



Credit: Michael Penn State Schuylkill

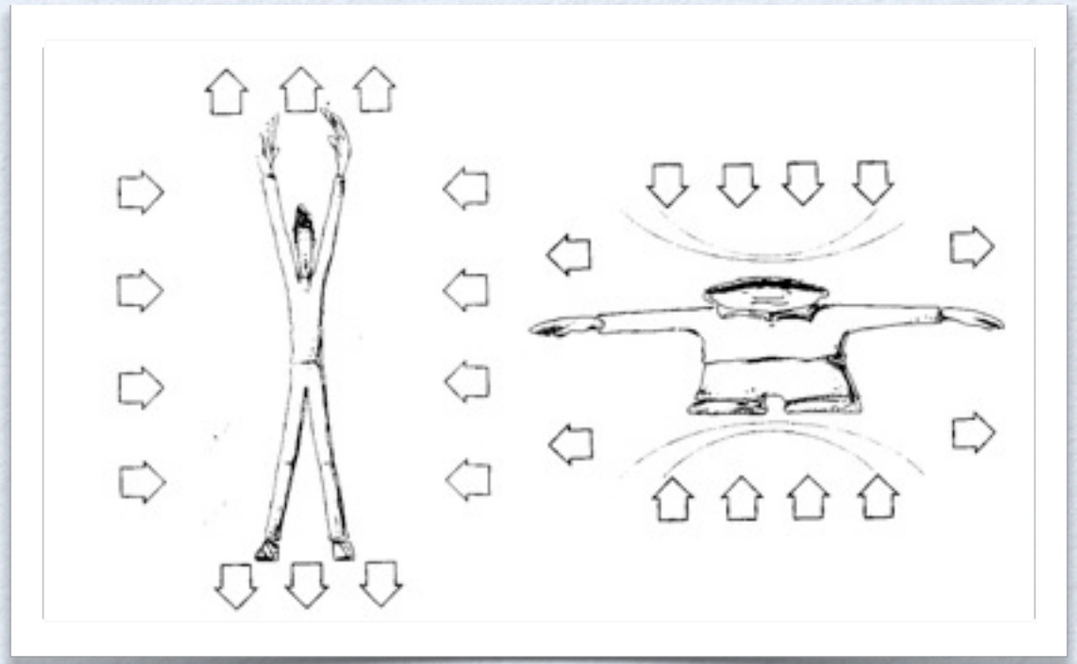
Credit: Michael Penn State Schuylkill

Gravity Waves



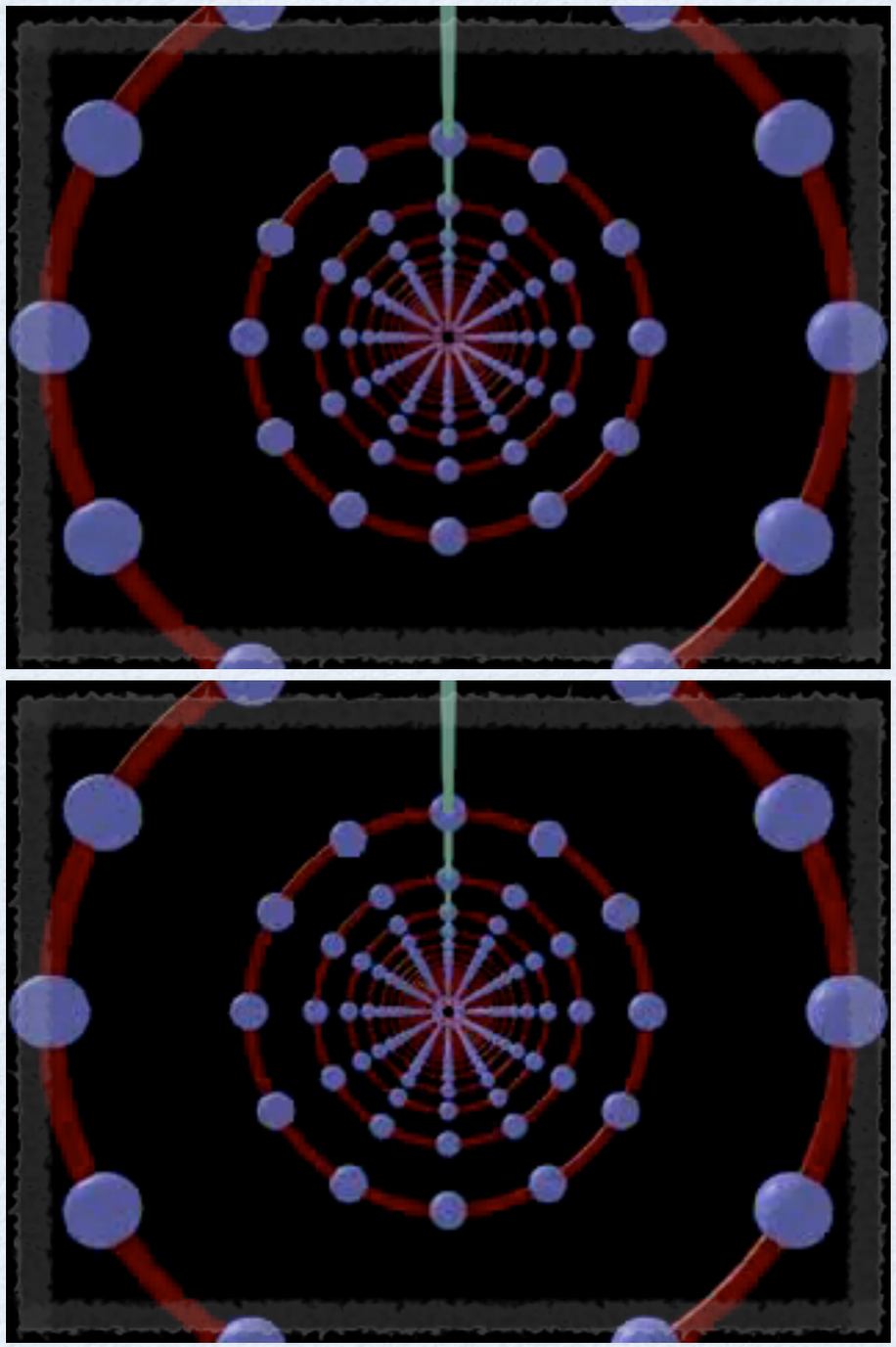
Credit: Michael Penn State Schuylkill

Credit: Michael Penn State Schuylkill



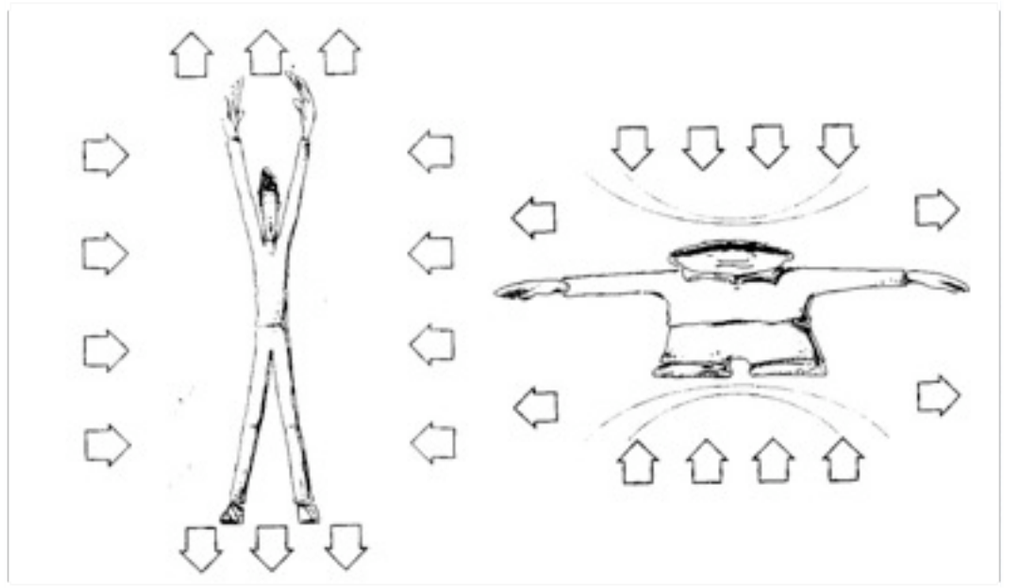
credit: http://www.lnl.infn.it/~auriga/

Gravity Waves



Credit: Michael Penn State Schuylkill

Credit: Michael Penn State Schuylkill



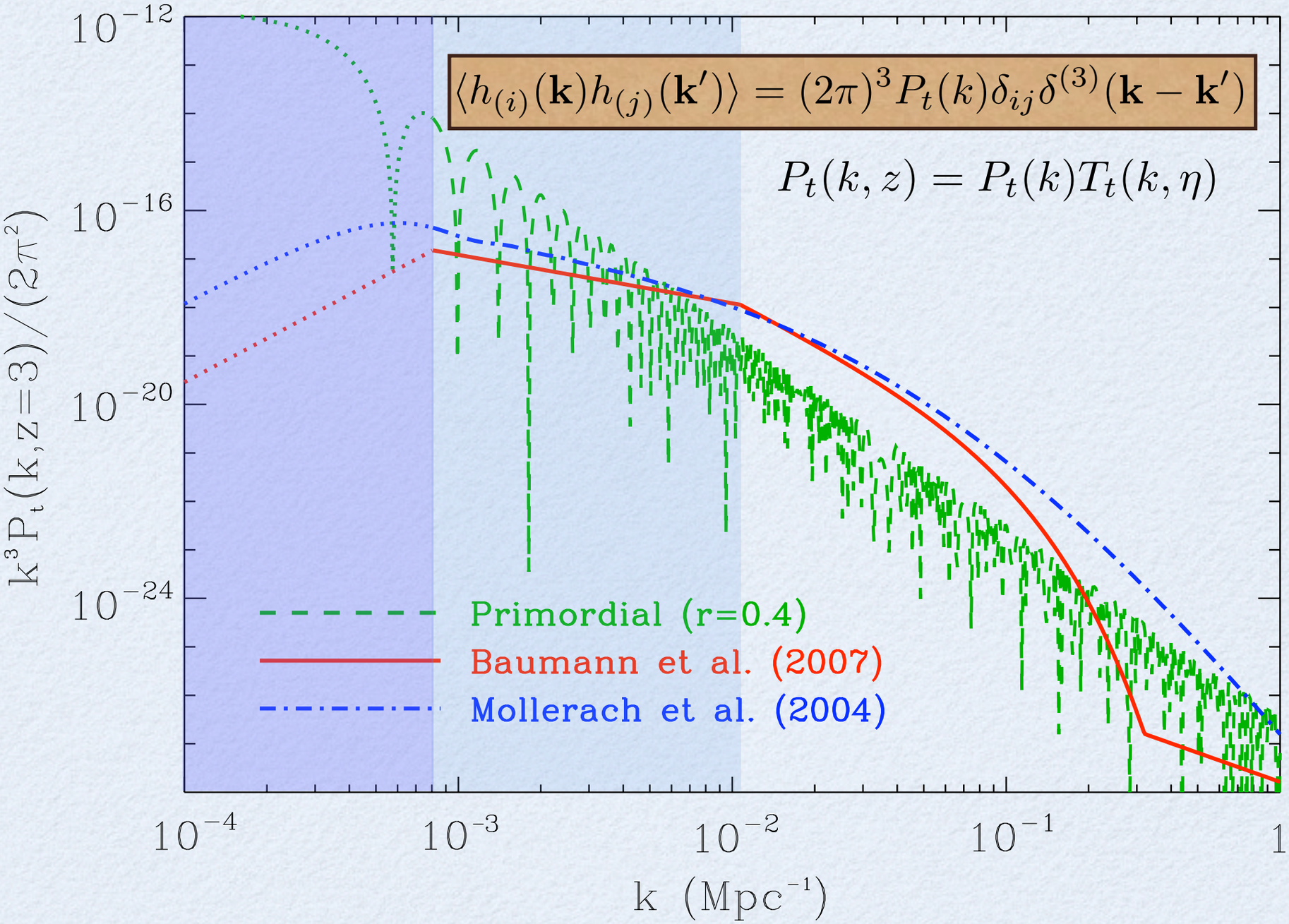
credit: http://www.lnl.infn.it/~auriga/

Can we detect gravity waves via its effect on weak lensing (cosmic shear)?

The Power Spectrum of Gravity Waves

$$\langle h_{(i)}(\mathbf{k}) h_{(j)}(\mathbf{k}') \rangle = (2\pi)^3 P_t(k) \delta_{ij} \delta^{(3)}(\mathbf{k} - \mathbf{k}')$$

$$P_t(k, z) = P_t(k) T_t(k, \eta)$$

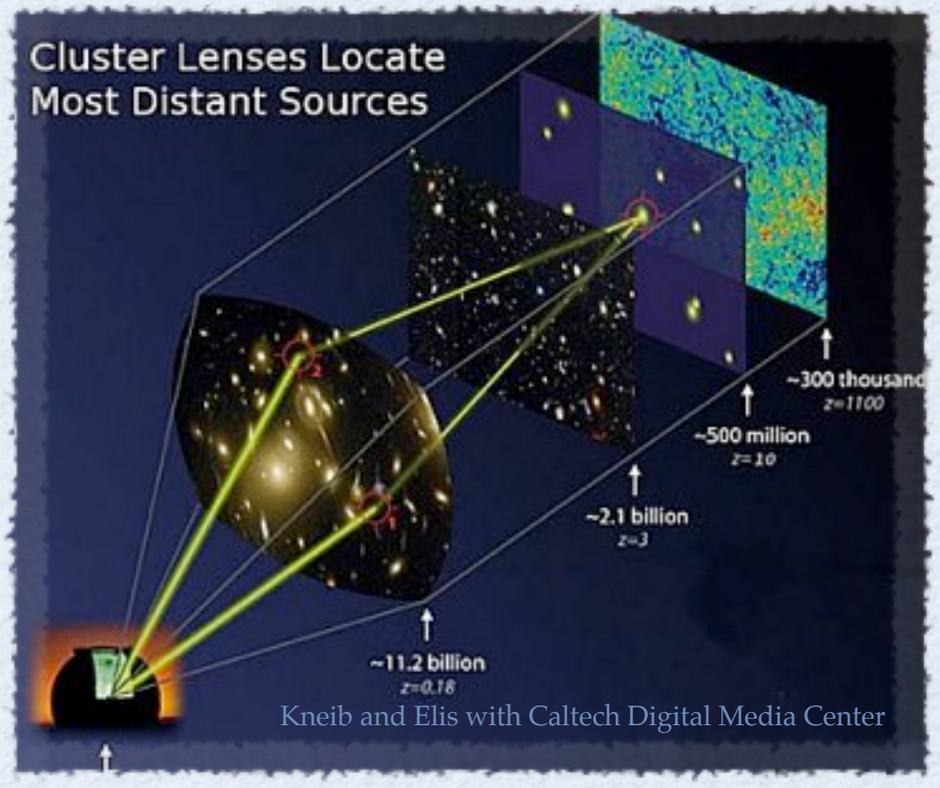


D. Sarkar, P. Serra, A. Cooray, K. Ichiki, D. Baumann, Phys. Rev. D, 77, 103515 (2008)

Bending of Light: Gravitational Lensing 101

Bending of Light: Gravitational Lensing 101

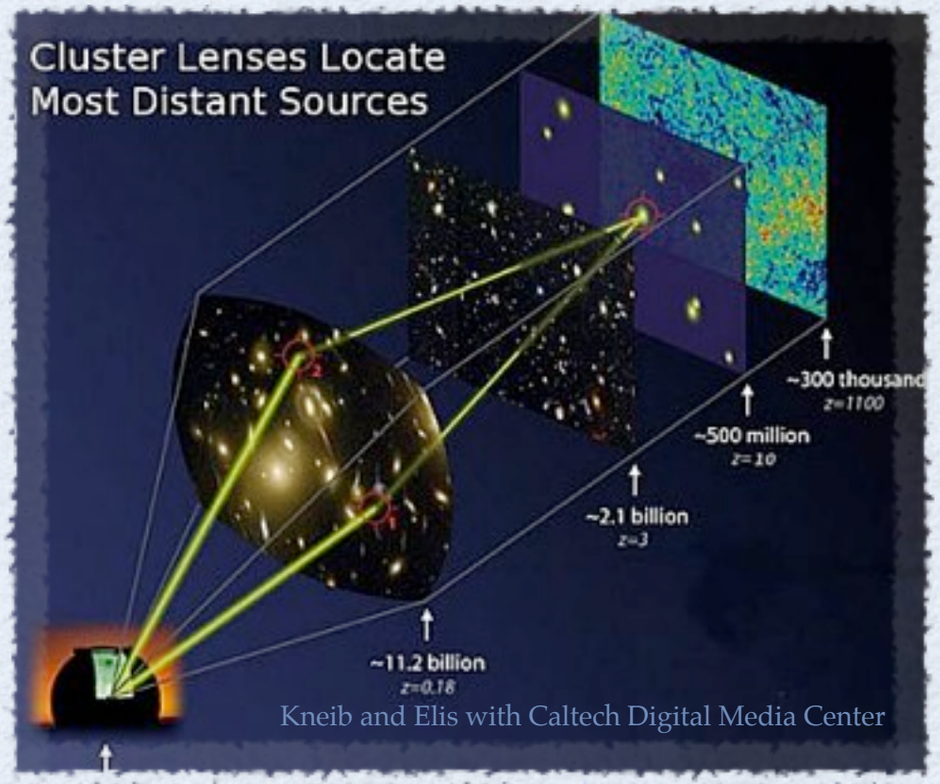
http://www.atnf.csiro.au/people/jlovell/simlens/



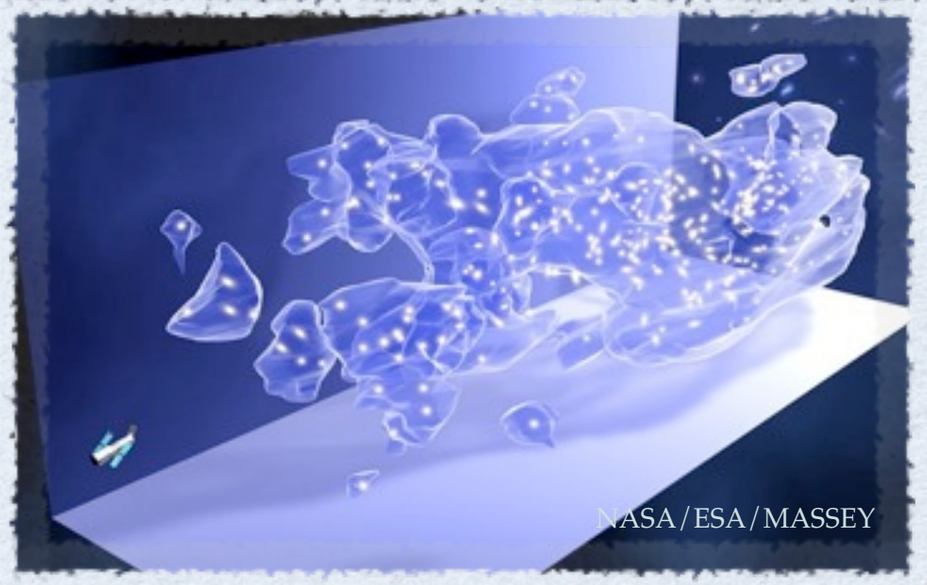
Kneib and Elis with Caltech Digital Media Center

Bending of Light: Gravitational Lensing 101

http://www.atnf.csiro.au/people/jlovell/simlens/



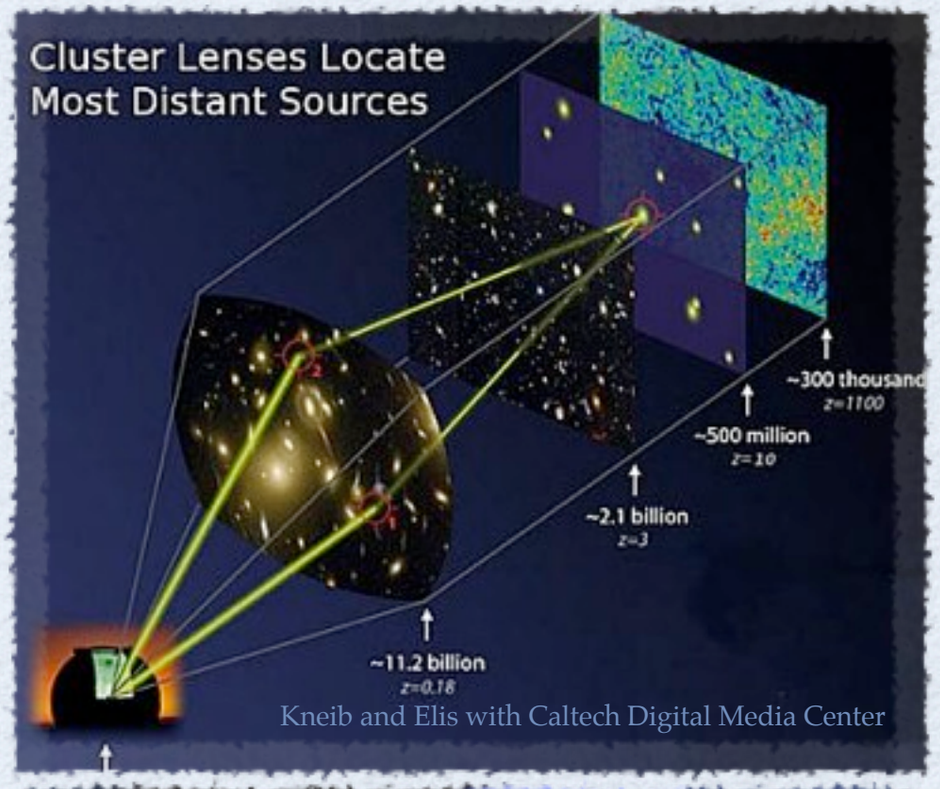
Kneib and Elis with Caltech Digital Media Center



NASA/ESA/MASSEY

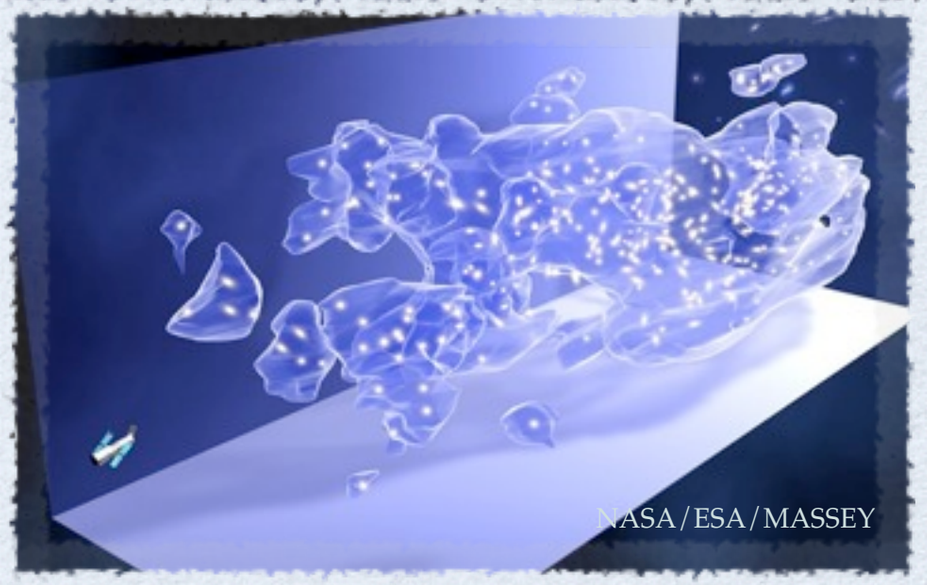
Bending of Light: Gravitational Lensing 101

http://www.atnf.csiro.au/people/jlovell/simlens/



Kneib and Elis with Caltech Digital Media Center

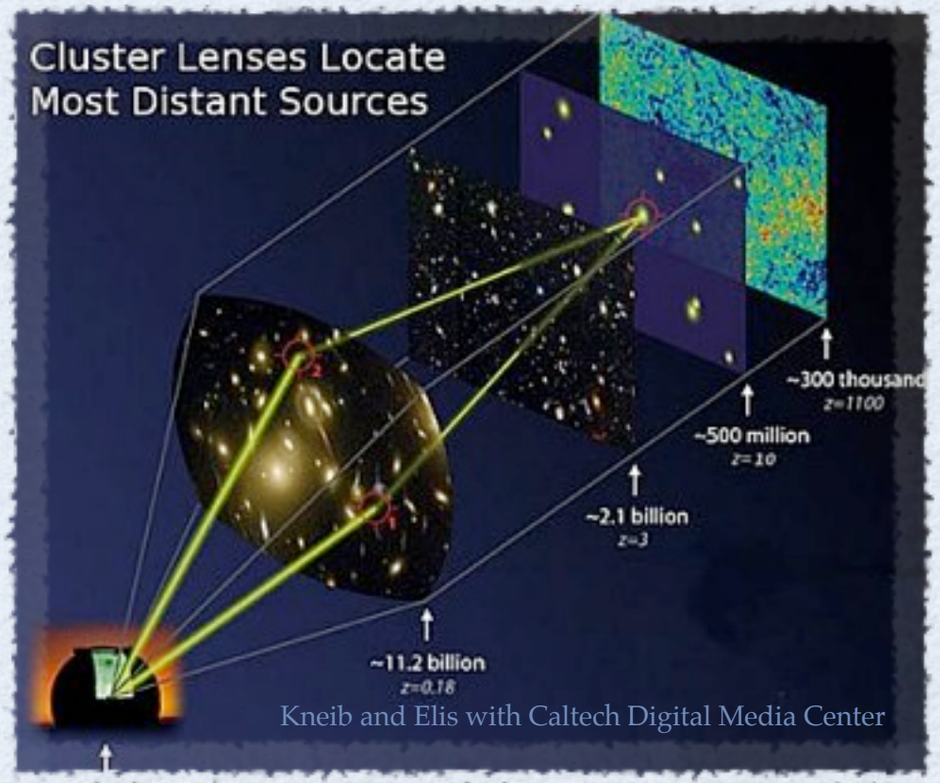
$$\phi(\hat{\mathbf{n}}) \propto \int_0^{r_s} dr' W(r_s, r') \Phi(\mathbf{r}(\hat{\mathbf{n}}), r')$$



NASA/ESA/MASSEY

Bending of Light: Gravitational Lensing 101

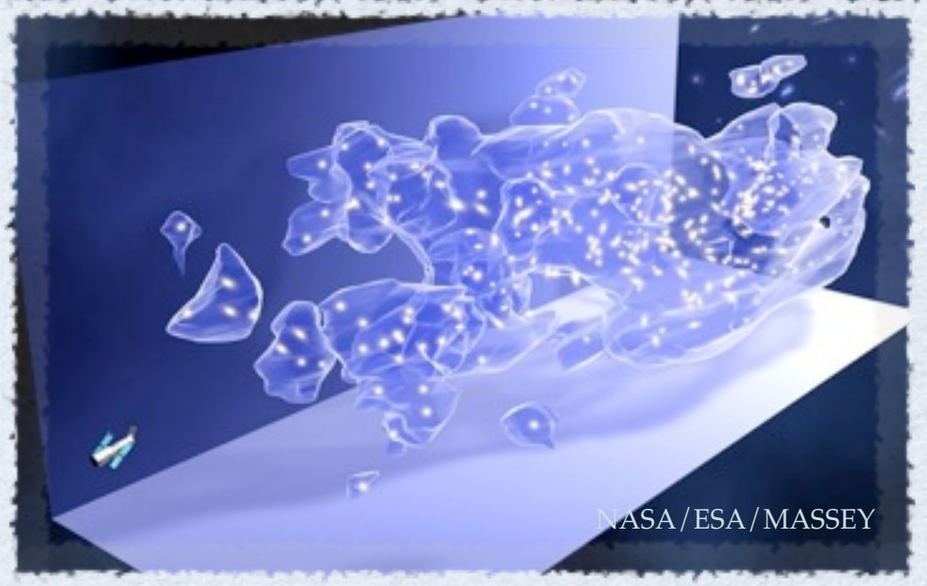
http://www.atnf.csiro.au/people/jlovell/simlens/



Kneib and Elis with Caltech Digital Media Center

$$\phi(\hat{\mathbf{n}}) \propto \int_0^{r_s} dr' W(r_s, r') \Phi(\mathbf{r}(\hat{\mathbf{n}}), r')$$

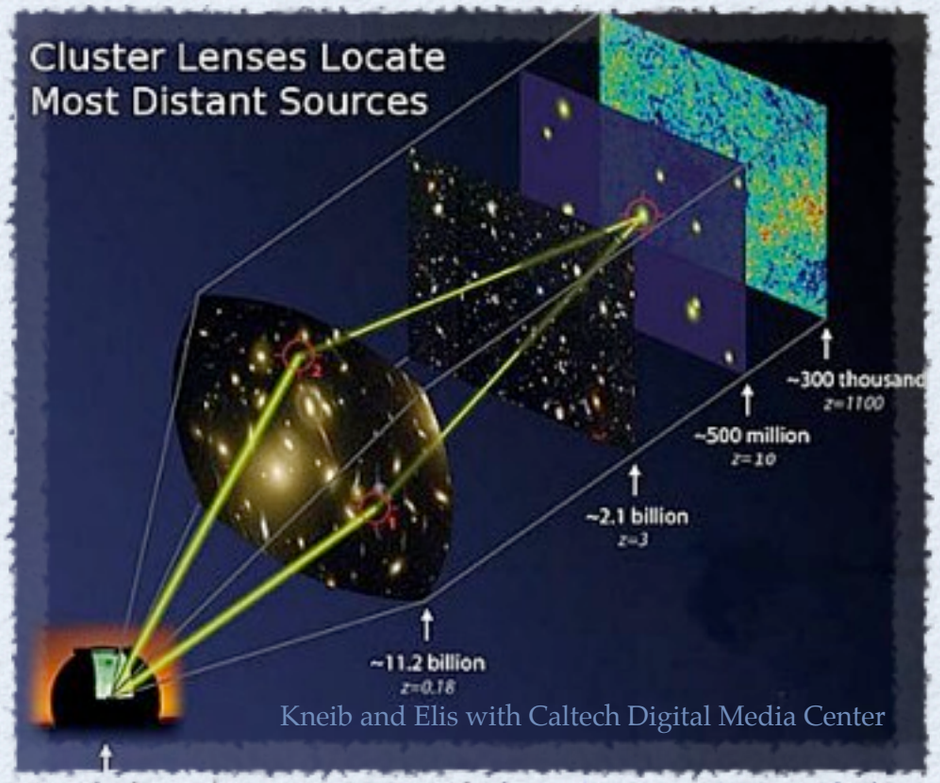
2D Proj. Potential



NASA/ESA/MASSEY

Bending of Light: Gravitational Lensing 101

http://www.atnf.csiro.au/people/jlovell/simlens/

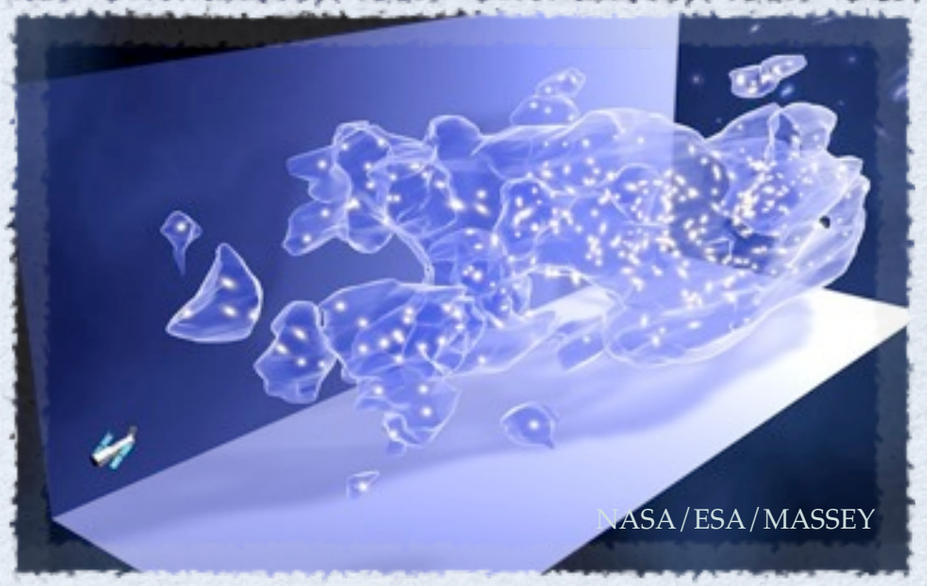


Kneib and Elis with Caltech Digital Media Center

$$\phi(\hat{\mathbf{n}}) \propto \int_0^{r_s} dr' W(r_s, r') \Phi(\mathbf{r}(\hat{\mathbf{n}}), r')$$

2D Proj. Potential

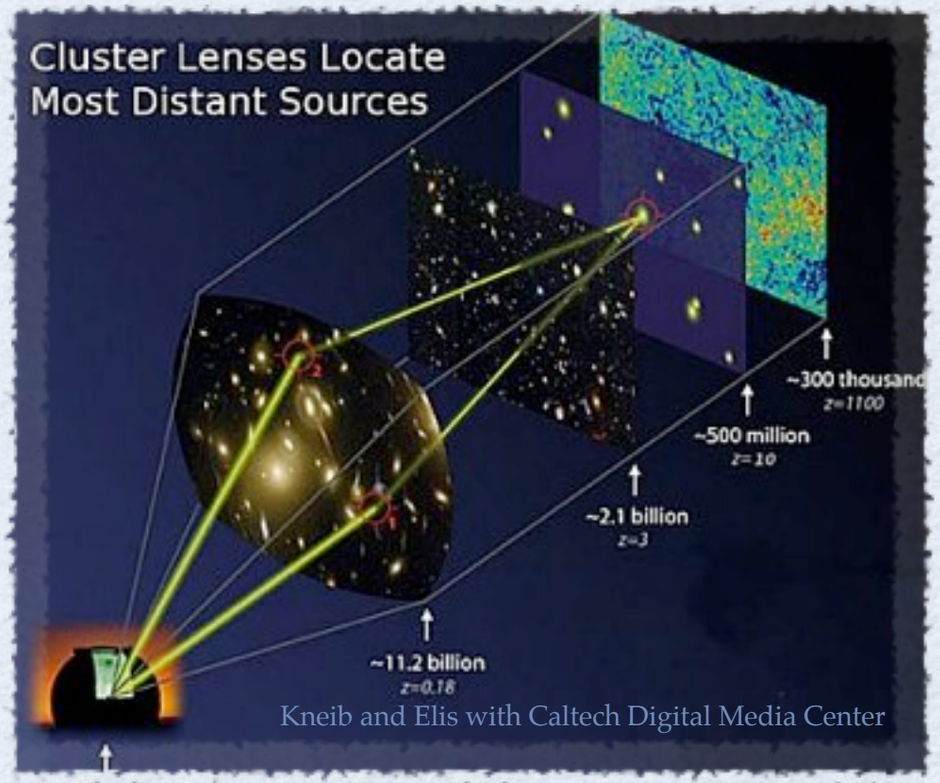
3D Grav. Potential



NASA/ESA/MASSEY

Bending of Light: Gravitational Lensing 101

http://www.atnf.csiro.au/people/jlovell/simlens/



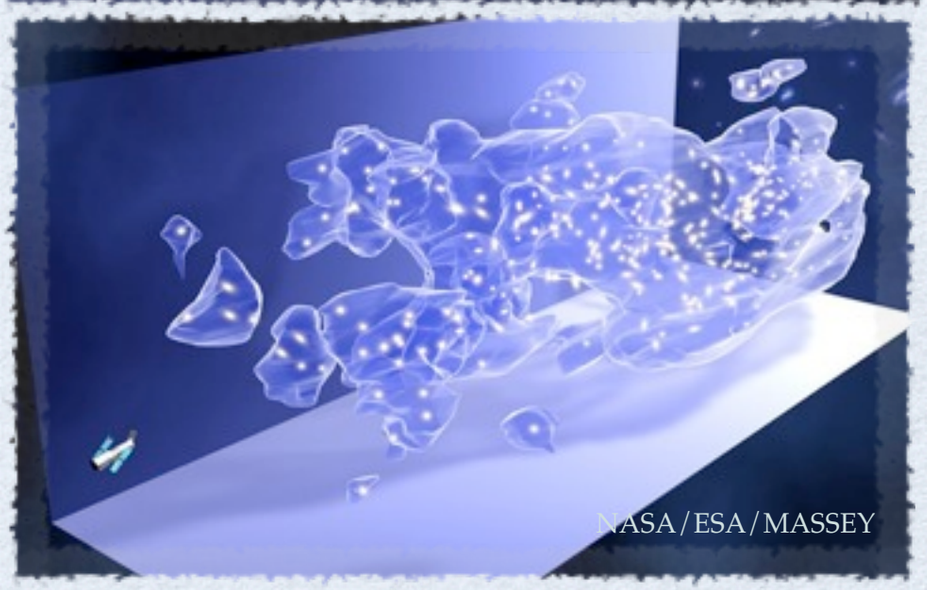
Kneib and Elis with Caltech Digital Media Center

$$\phi(\hat{\mathbf{n}}) \propto \int_0^{r_s} dr' W(r_s, r') \Phi(\mathbf{r}(\hat{\mathbf{n}}), r')$$

2D Proj. Potential

Radial Distance

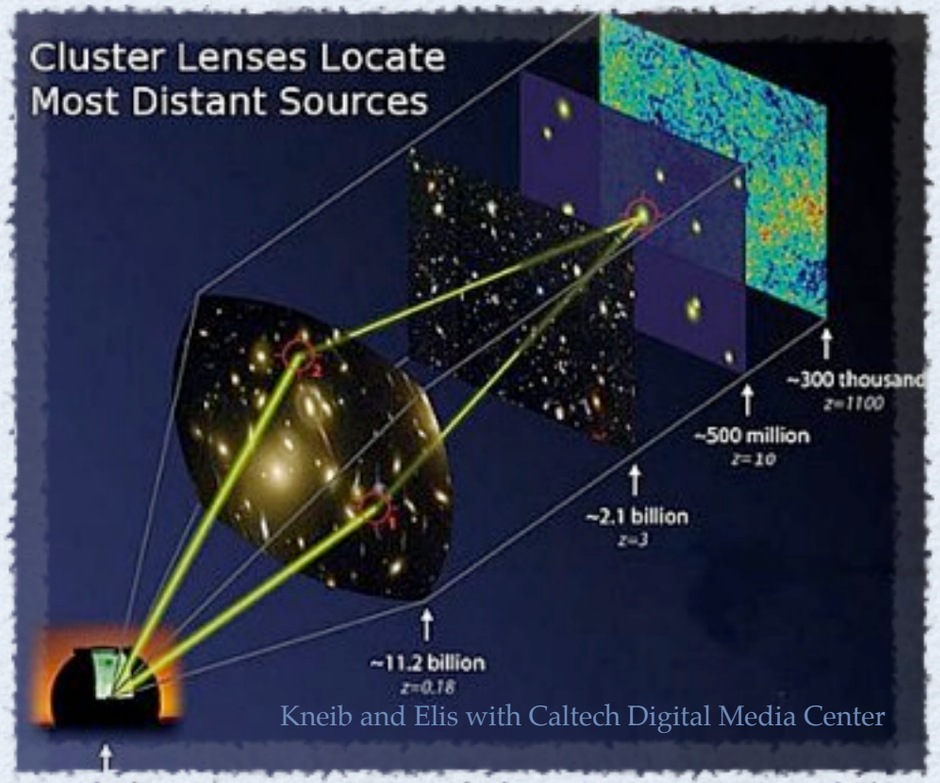
3D Grav. Potential



NASA/ESA/MASSEY

Bending of Light: Gravitational Lensing 101

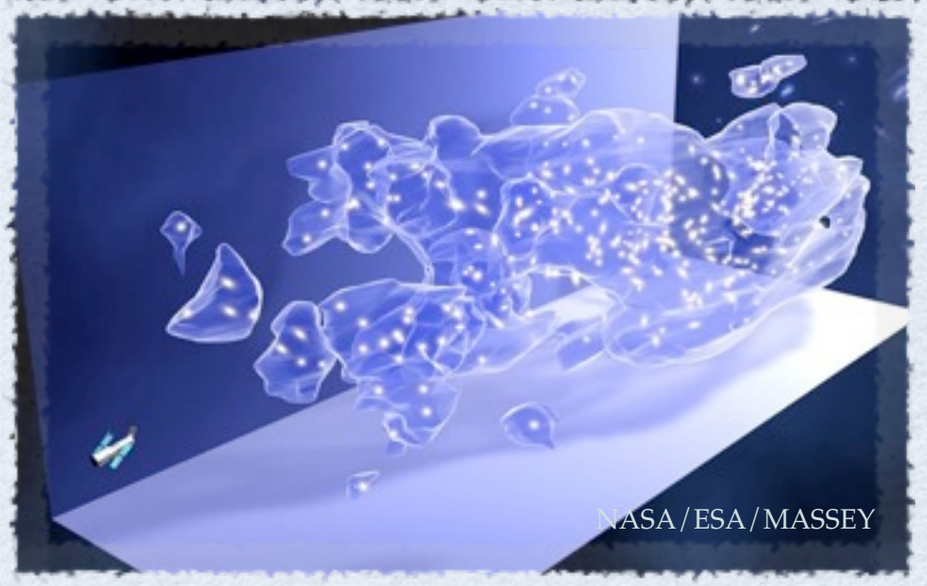
http://www.atnf.csiro.au/people/jlovell/simlens/



Kneib and Elis with Caltech Digital Media Center

$$\phi(\hat{\mathbf{n}}) \propto \int_0^{r_s} dr' W(r_s, r') \Phi(\mathbf{r}(\hat{\mathbf{n}}), r')$$

2D Proj. Potential | Radial Distance | Geom. Factor | 3D Grav. Potential



NASA/ESA/MASSEY

Effect of Gravitational Waves on Cosmic Shear

$$\vec{\beta} = \vec{\theta} - \vec{\alpha}(\vec{\theta})$$

$$\alpha(\vec{\theta}) = \nabla\phi$$

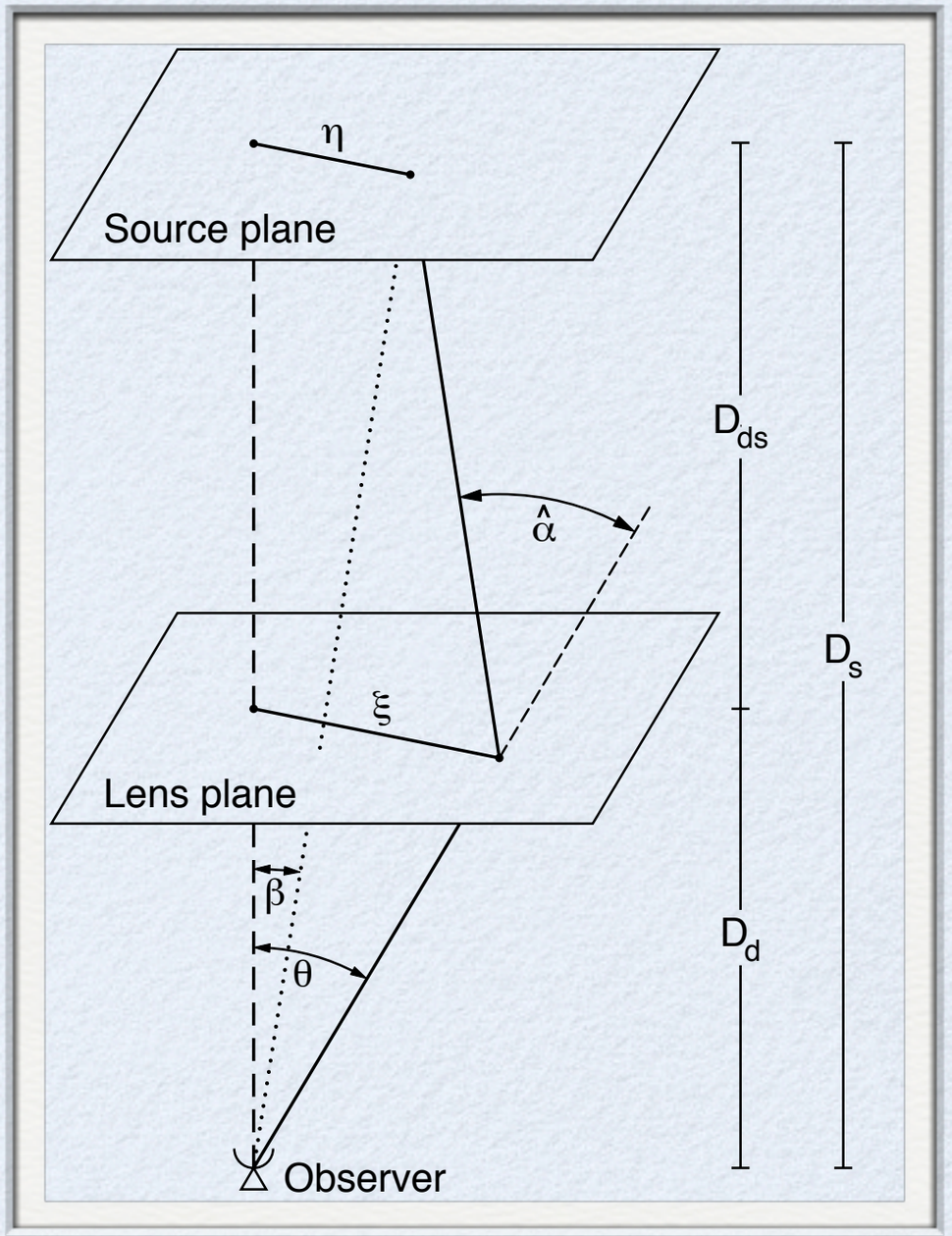
$$\mathcal{A}_{ij} = \frac{\partial x_i^S}{\partial x_j^I} \qquad \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}$$

$$= (1-\kappa)\delta_{ij} - \gamma_{ij} + \omega\epsilon_{ij}$$

trace (convergence)

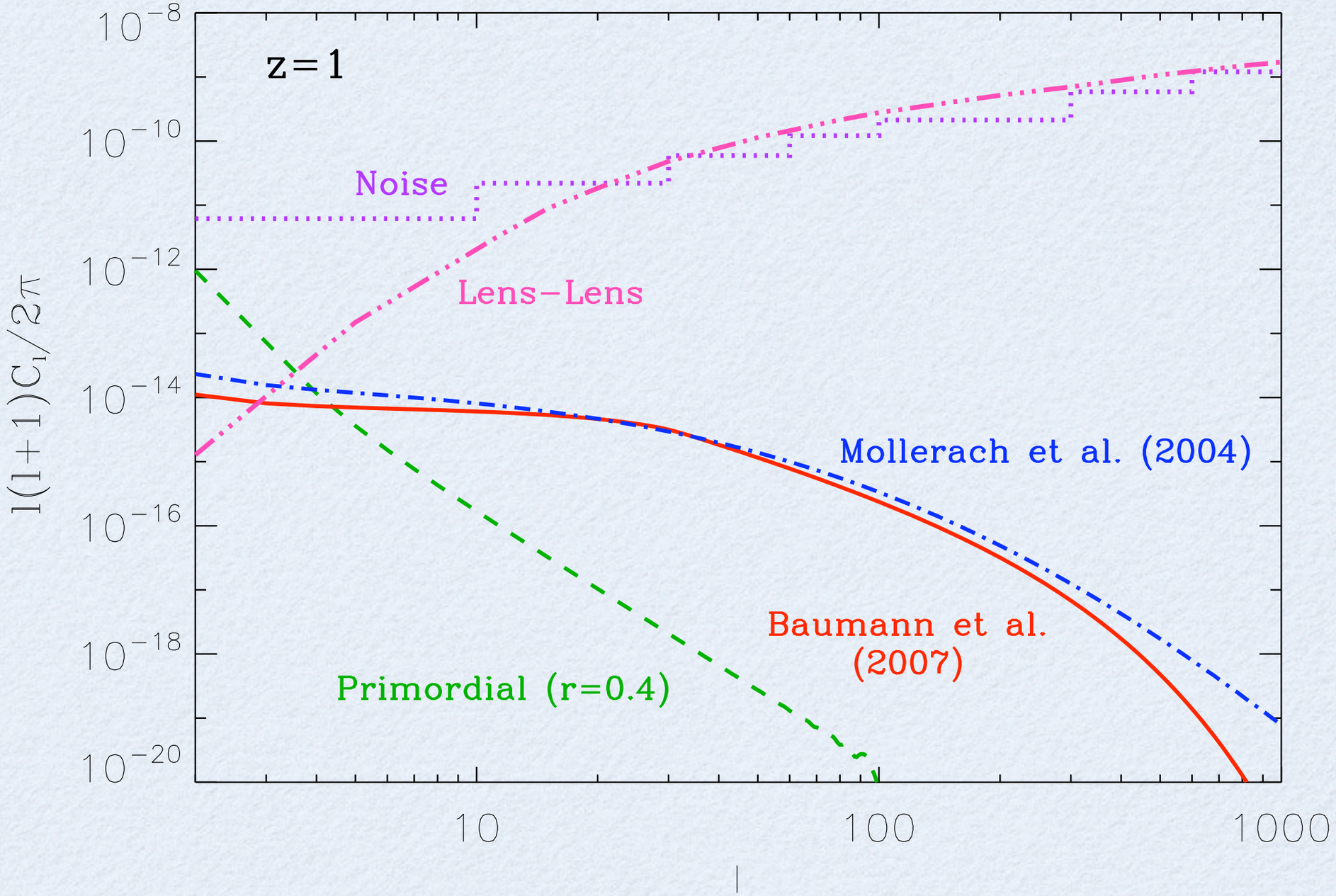
symmetric traceless (shear / distortion)

asymmetric rotation



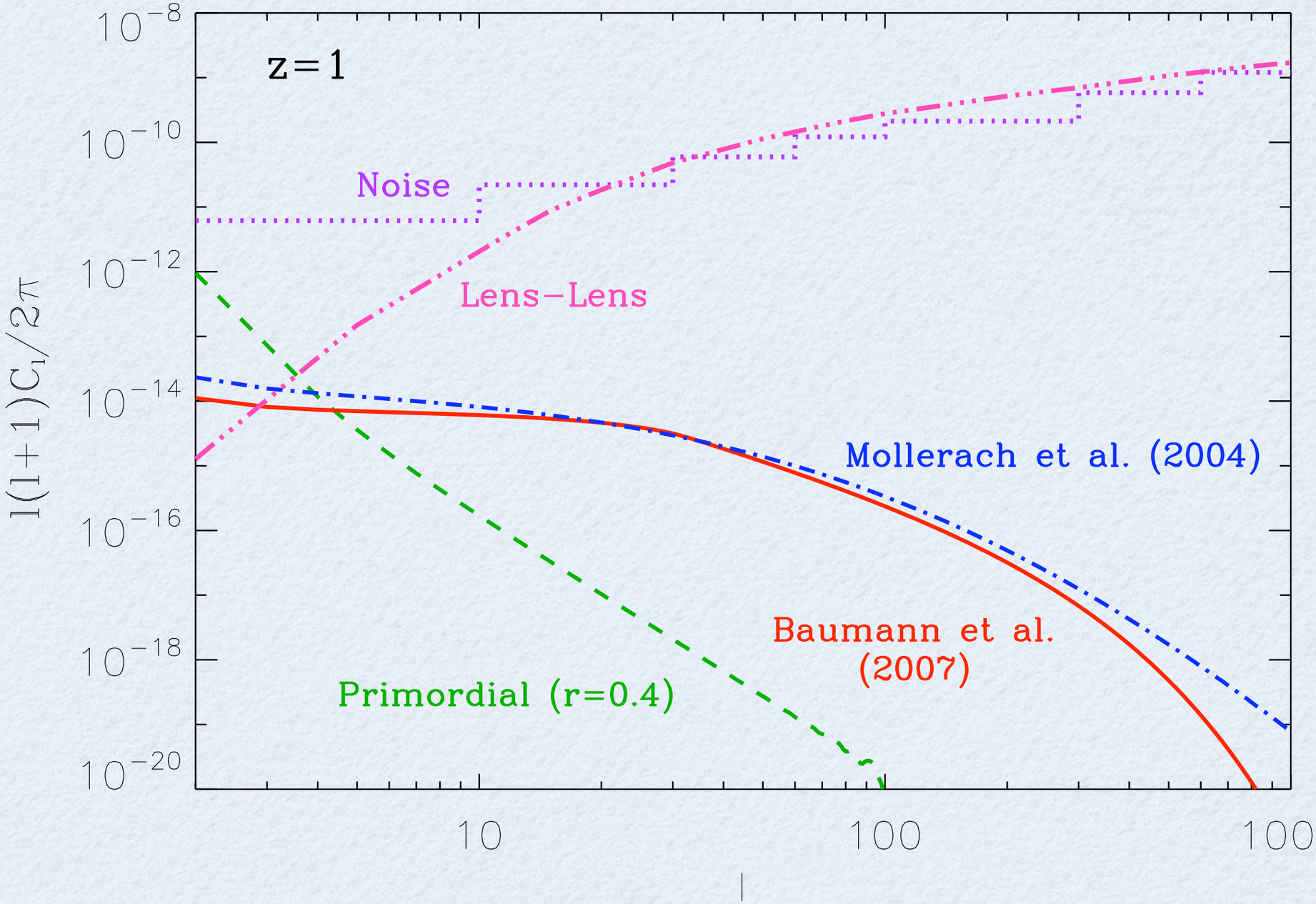
Credit: Bartelmann and Schneider 2001

Curl Mode Angular Power Spectrum: Is it Detectable?



D. Sarkar, P. Serra, A. Cooray, K. Ichiki, D. Baumann, Phys. Rev. D, 77, 103515 (2008)

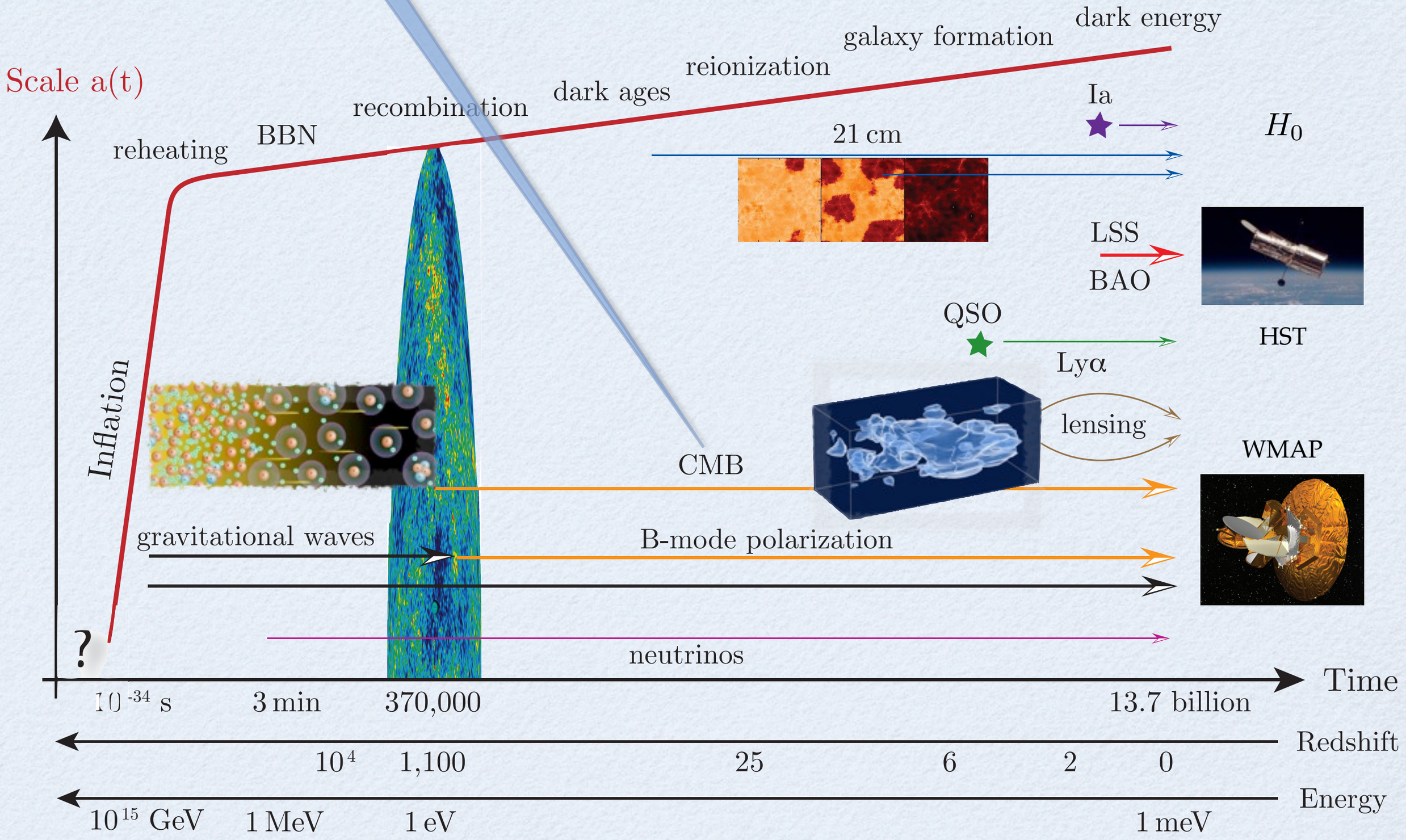
Curl Mode Angular Power Spectrum: Is it Detectable?



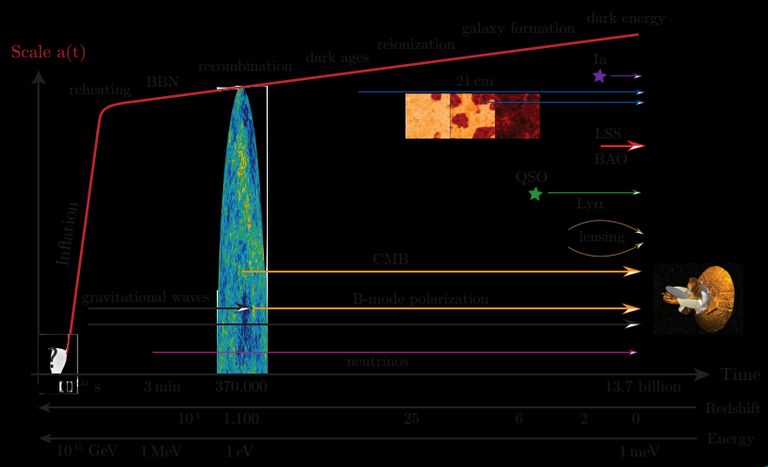
The signal is lower than the Noise level!

D. Sarkar, P. Serra, A. Cooray, K. Ichiki, D. Baumann, Phys. Rev. D, 77, 103515 (2008)

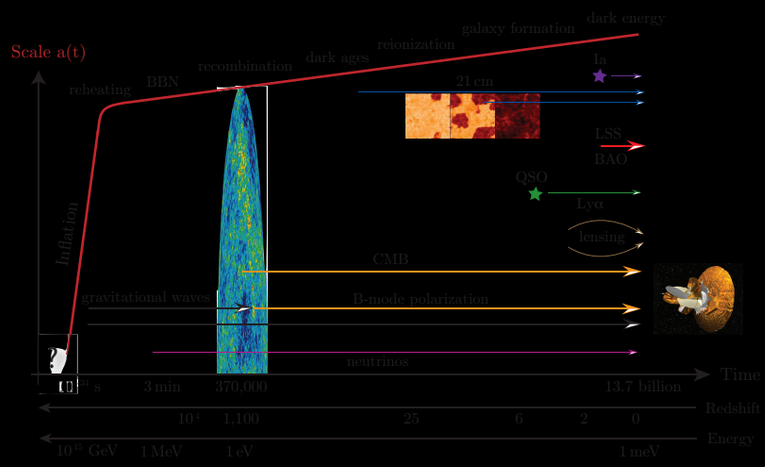
PRD 2008



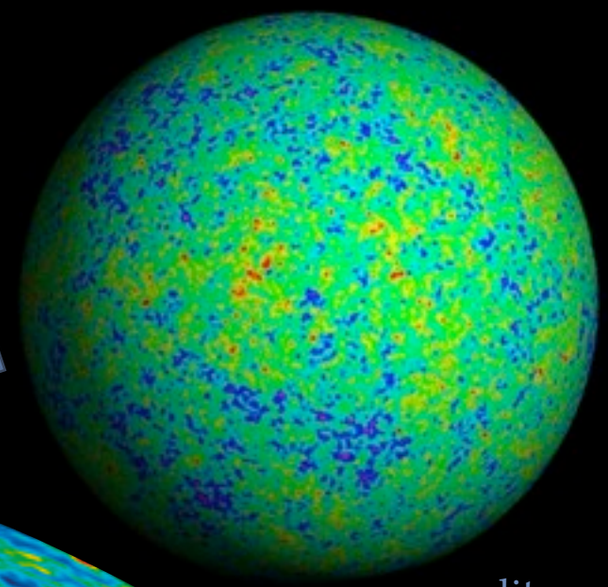
D. Baumann and H. Peiris, asXiv:0810.3022



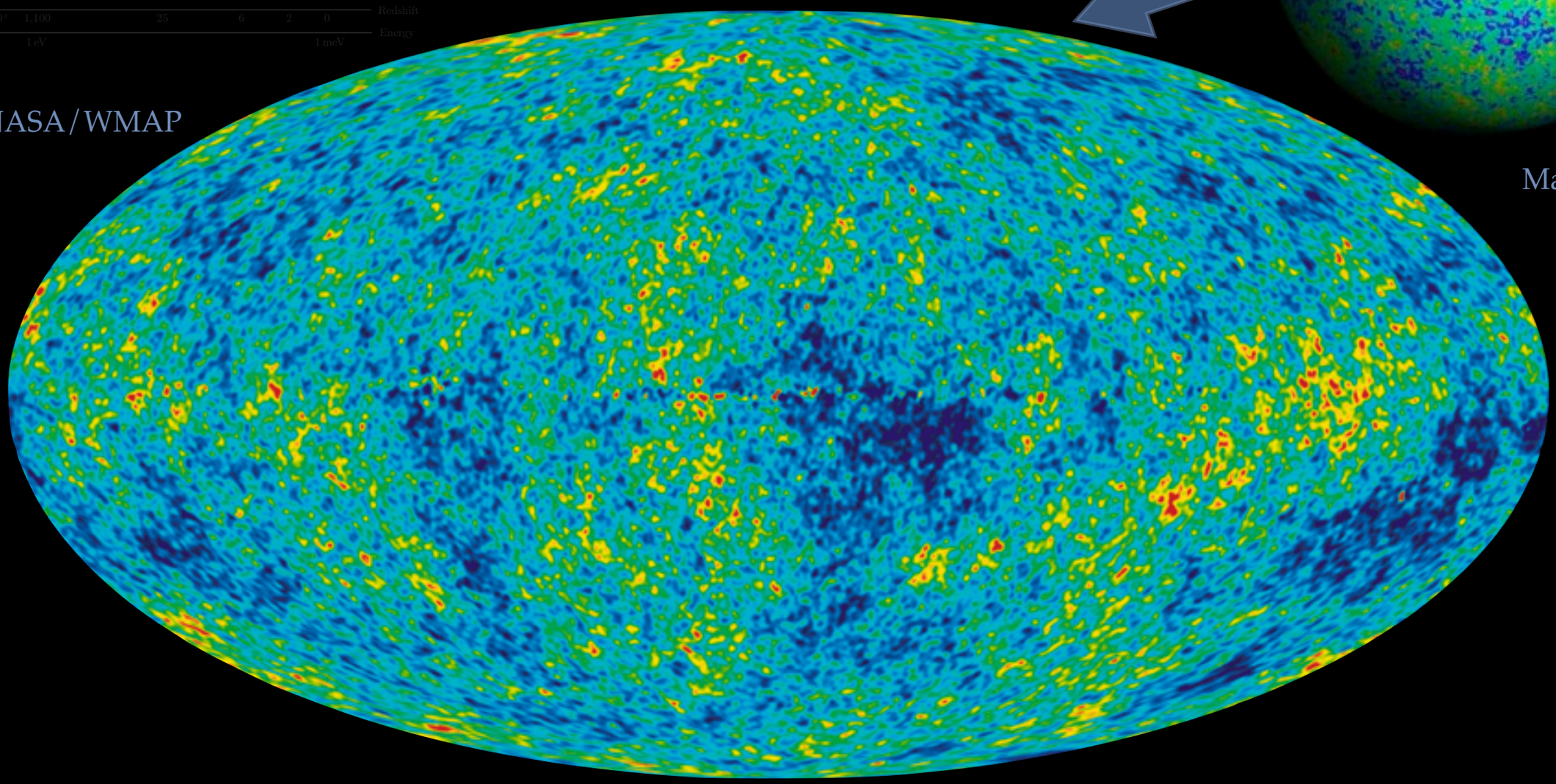
credit: NASA/WMAP

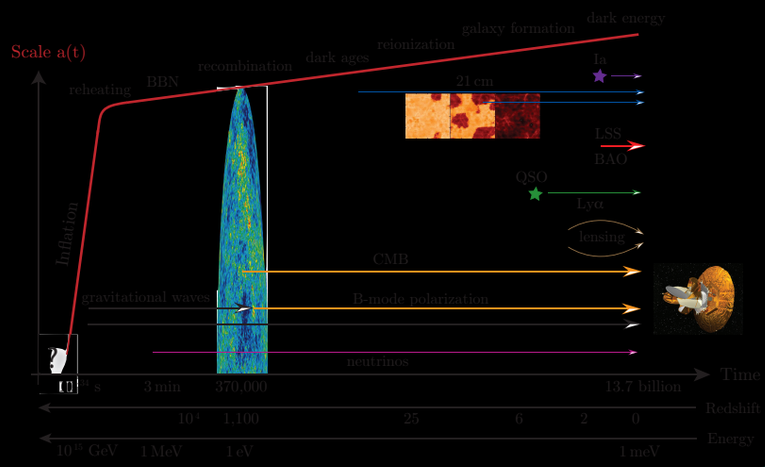


credit: NASA/WMAP

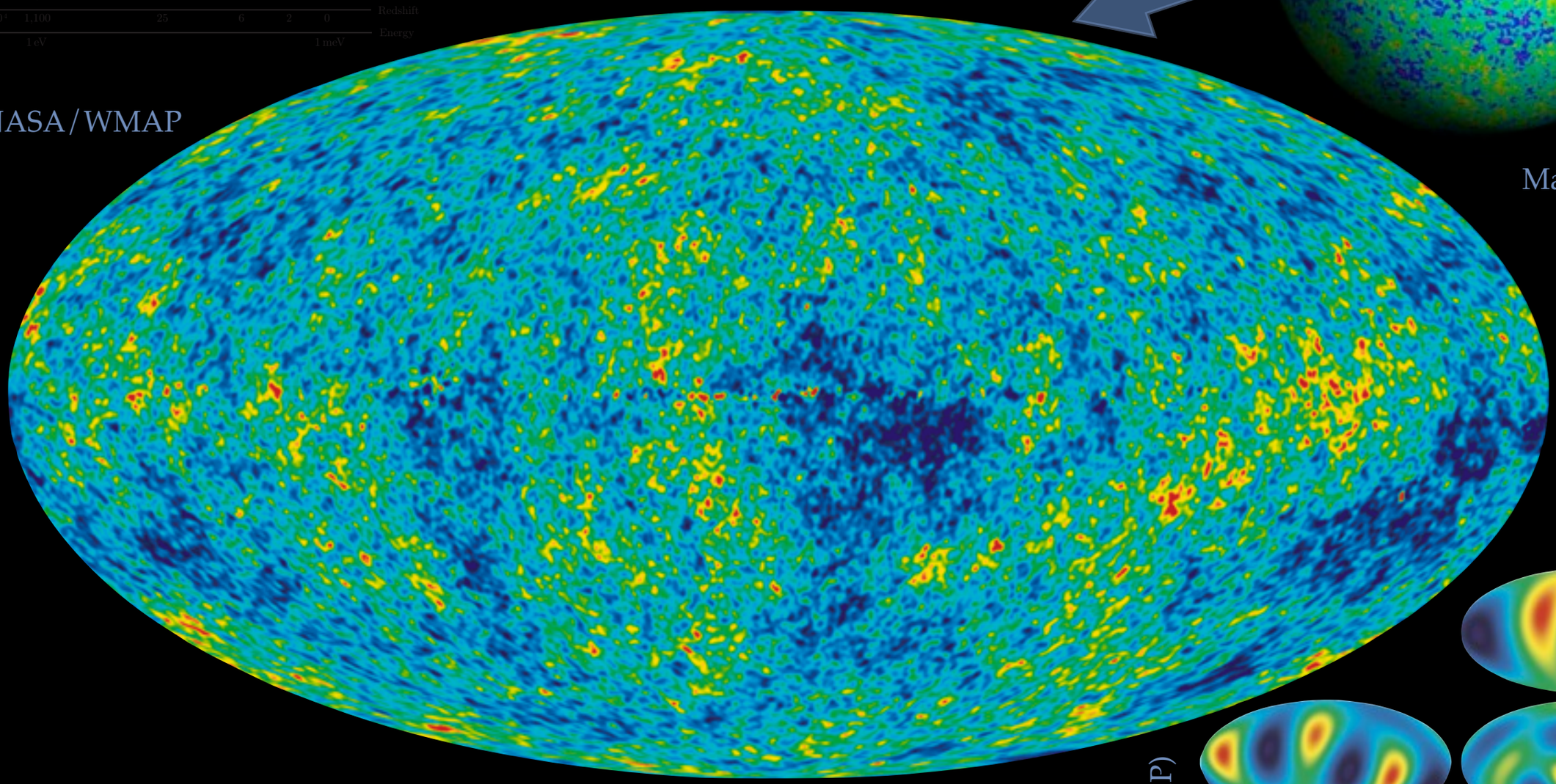


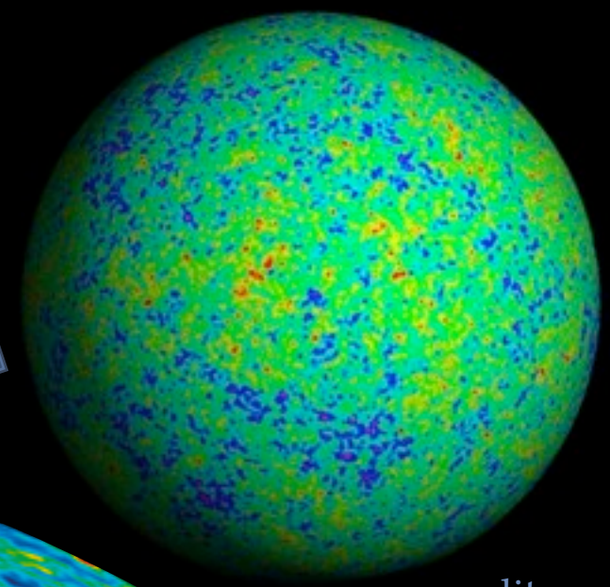
credit:
Max Tegmark



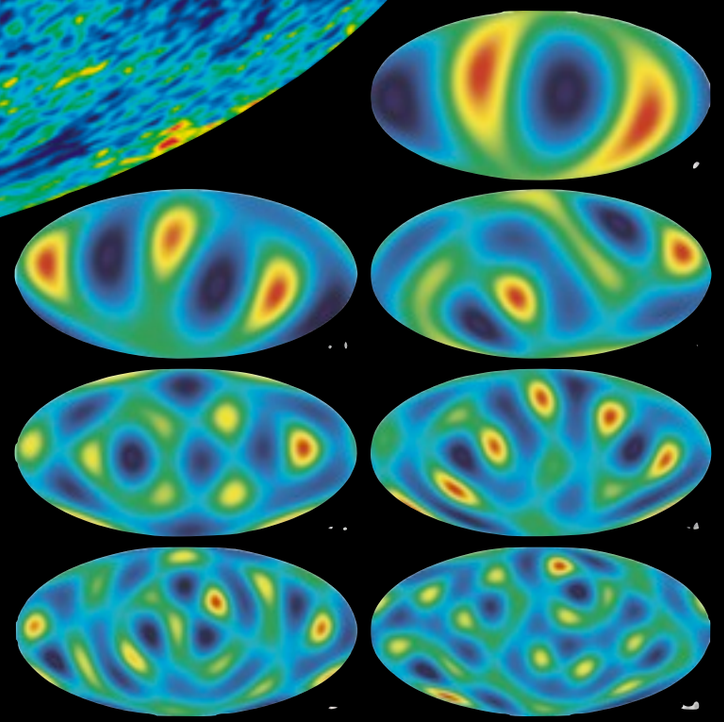


credit: NASA/WMAP

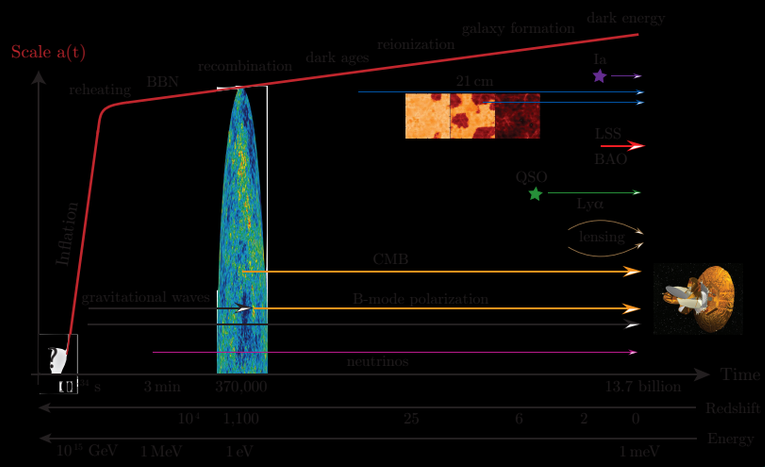




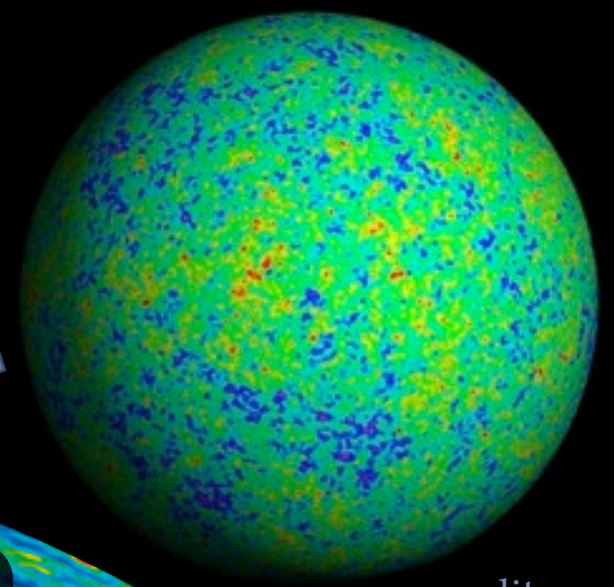
credit:
Max Tegmark



Hinshaw et al. (WMAP)

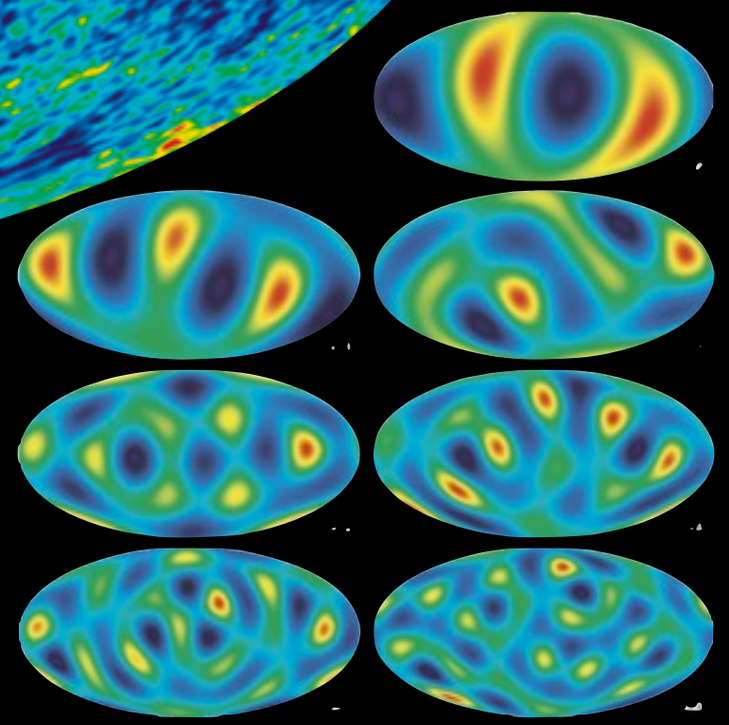


credit: NASA/WMAP

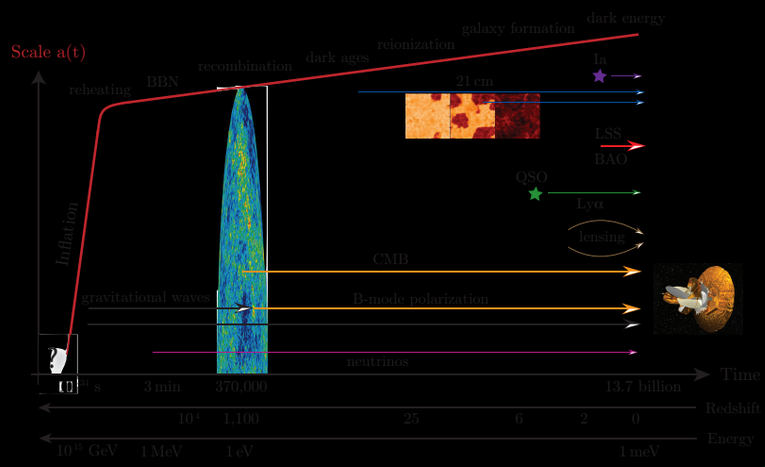


credit:
Max Tegmark

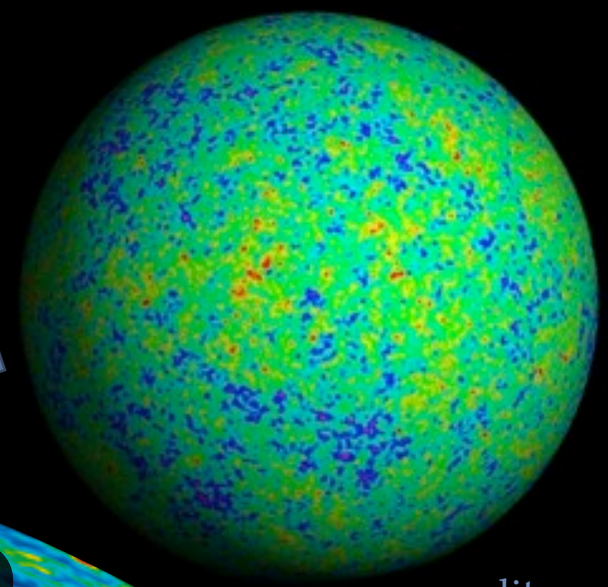
$$\Theta(\hat{\mathbf{n}}) \equiv \frac{\Delta T(\hat{\mathbf{n}})}{T} = \sum_{lm} \Theta_{lm} Y_l^m(\hat{\mathbf{n}})$$



Hinshaw et al. (WMAP)

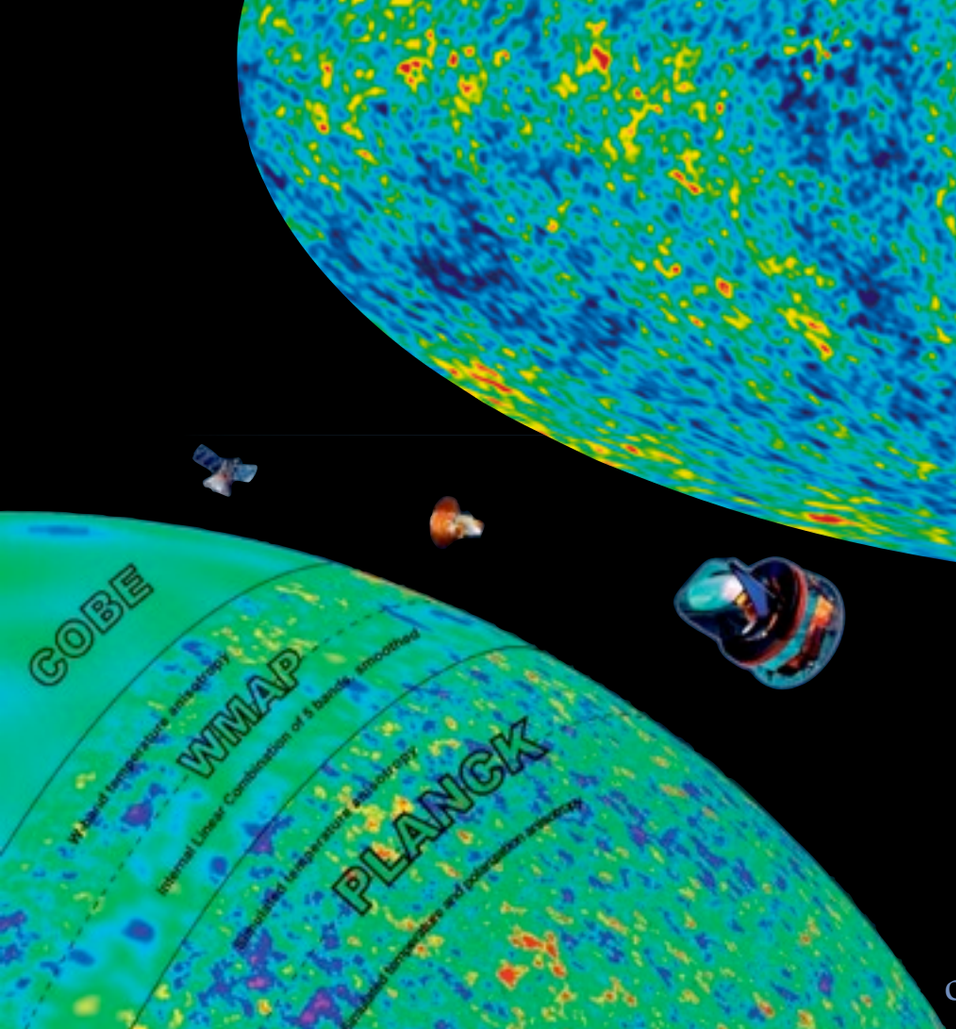


credit: NASA/WMAP

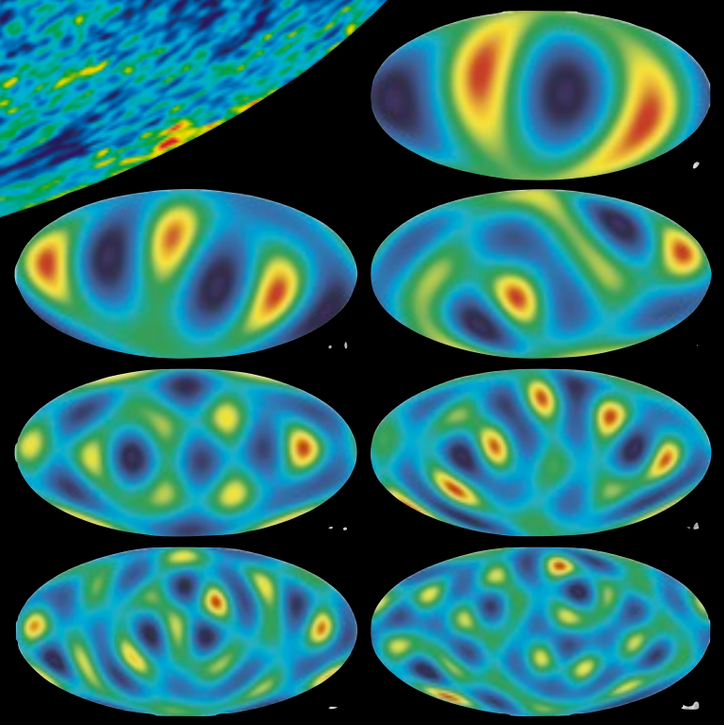


credit:
Max Tegmark

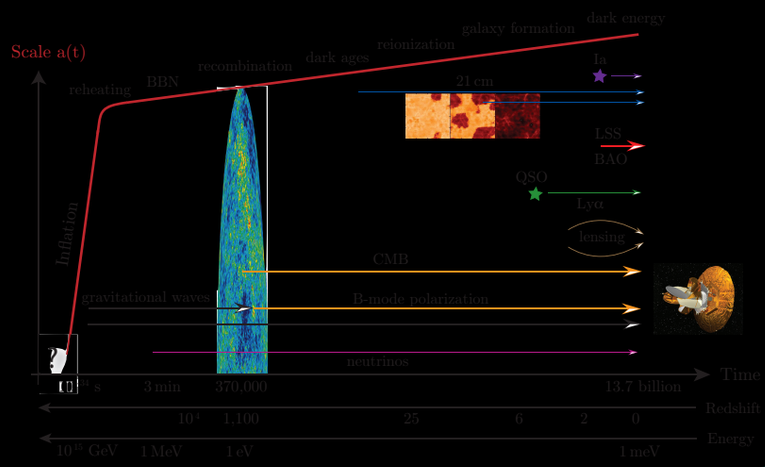
$$\Theta(\hat{\mathbf{n}}) \equiv \frac{\Delta T(\hat{\mathbf{n}})}{T} = \sum_{lm} \Theta_{lm} Y_l^m(\hat{\mathbf{n}})$$



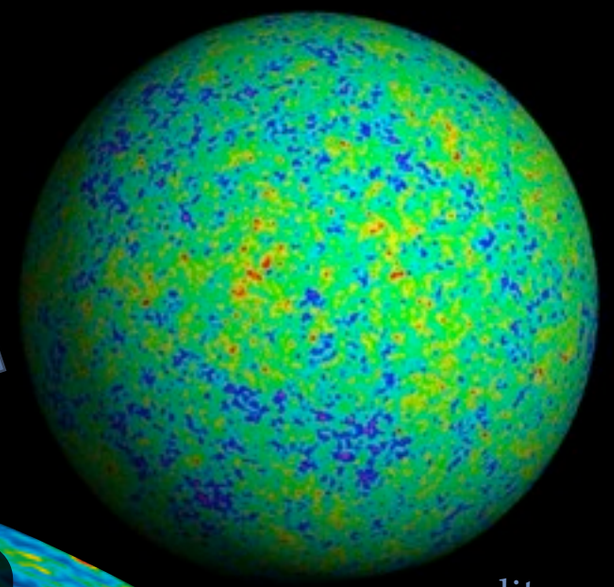
credit: SciDAC Review



Hinshaw et al. (WMAP)



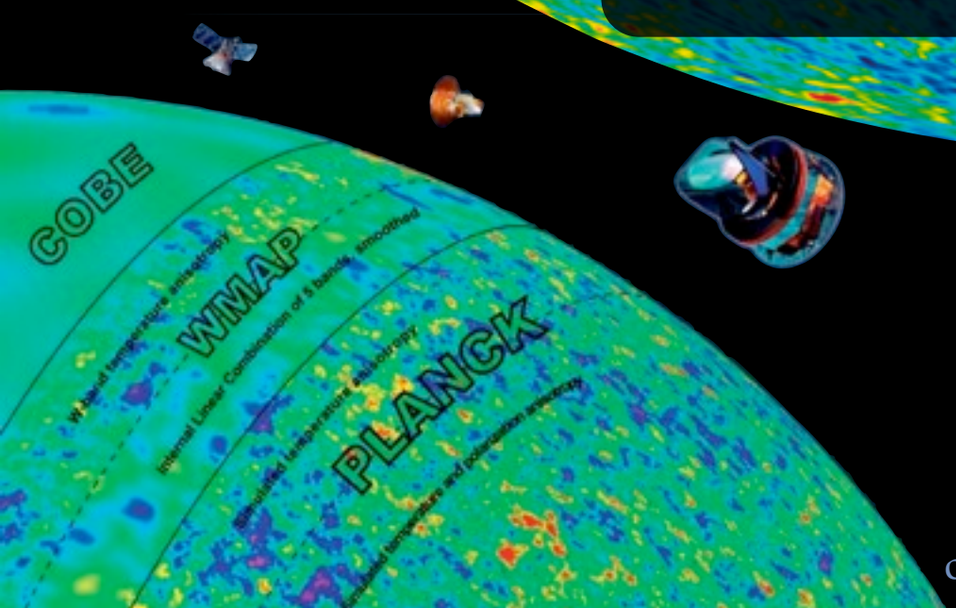
credit: NASA/WMAP



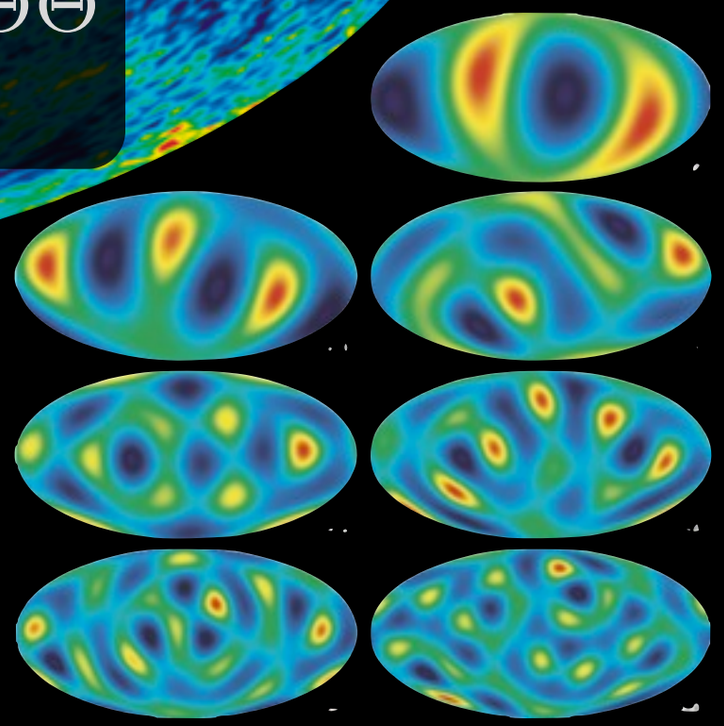
credit:
Max Tegmark

$$\Theta(\hat{\mathbf{n}}) \equiv \frac{\Delta T(\hat{\mathbf{n}})}{T} = \sum_{lm} \Theta_{lm} Y_l^m(\hat{\mathbf{n}})$$

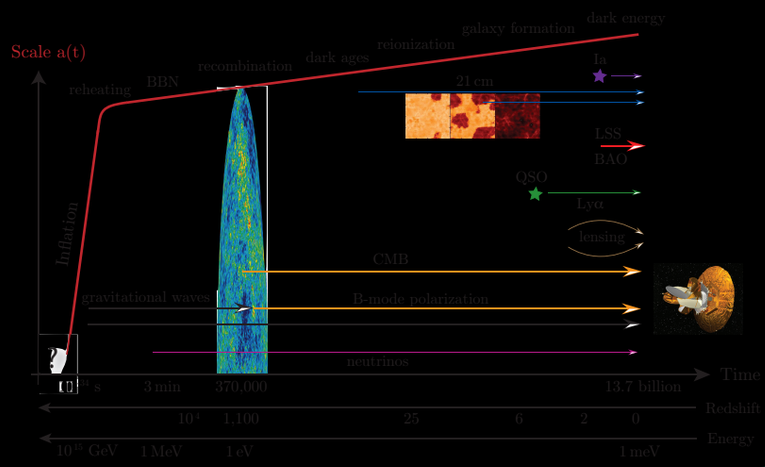
$$\langle \Theta_{lm} \Theta_{l'm'} \rangle = \delta_{l,l'} \delta_{m,m'} C_l^{\Theta\Theta}$$



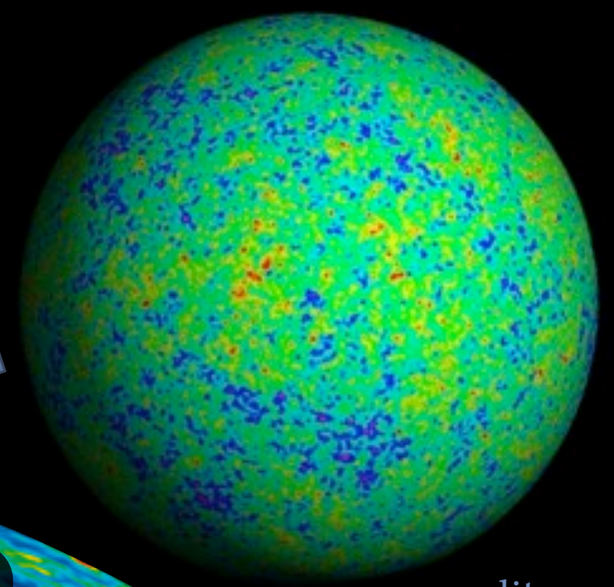
credit: SciDAC Review



Hinshaw et al. (WMAP)



credit: NASA/WMAP

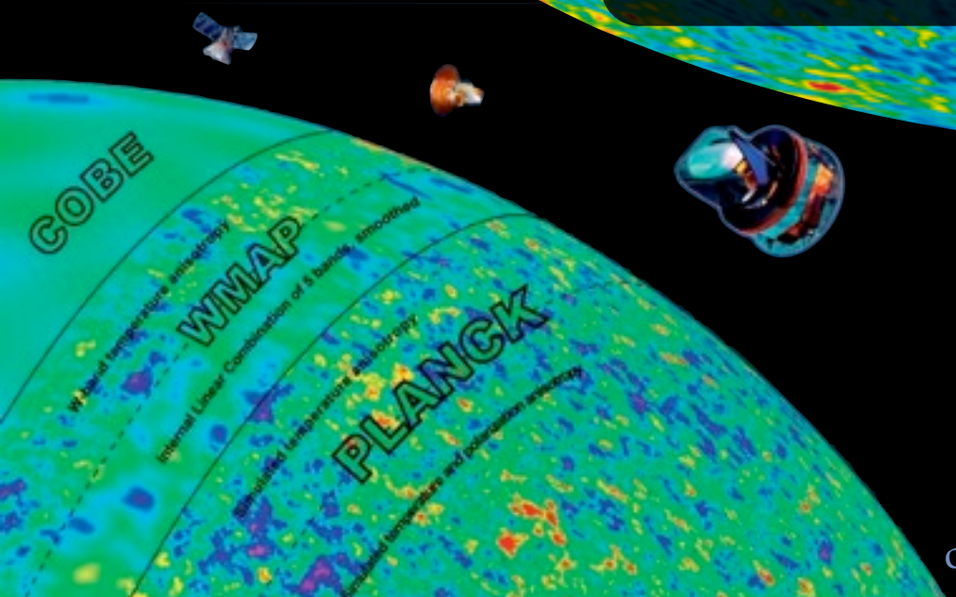


credit:
Max Tegmark

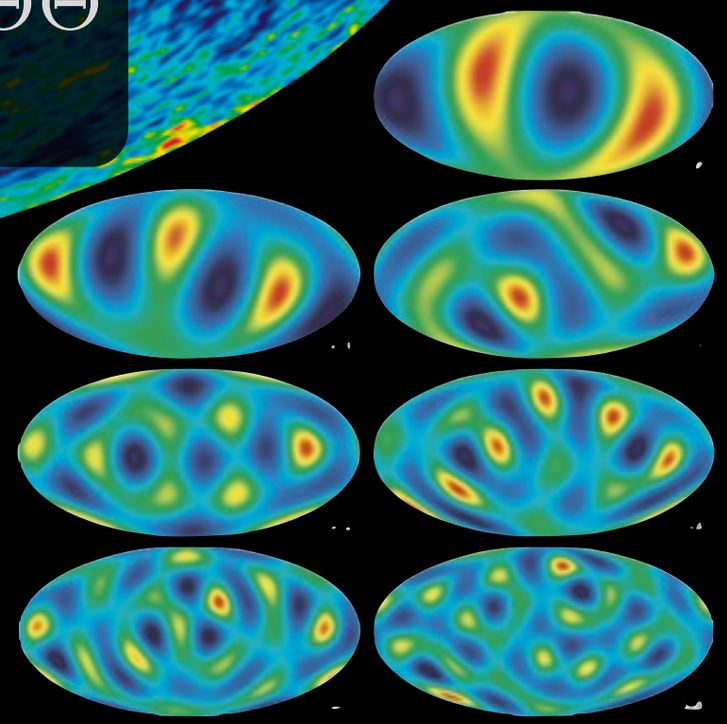
$$\Theta(\hat{\mathbf{n}}) \equiv \frac{\Delta T(\hat{\mathbf{n}})}{T} = \sum_{lm} \Theta_{lm} Y_l^m(\hat{\mathbf{n}})$$

$$\langle \Theta_{l_1 m_1} \Theta_{l_2 m_2} \Theta_{l_3 m_3} \rangle = \begin{pmatrix} l_1 & l_2 & l_3 \\ m_1 & m_2 & m_3 \end{pmatrix} B^{\Theta}_{l_1 l_2 l_3}$$

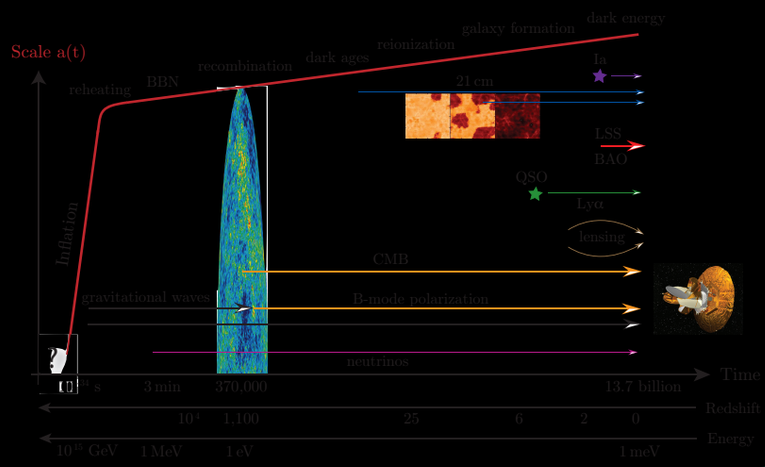
$$\langle \Theta_{lm} \Theta_{l'm'} \rangle = \delta_{l,l'} \delta_{m,m'} C_l^{\Theta\Theta}$$



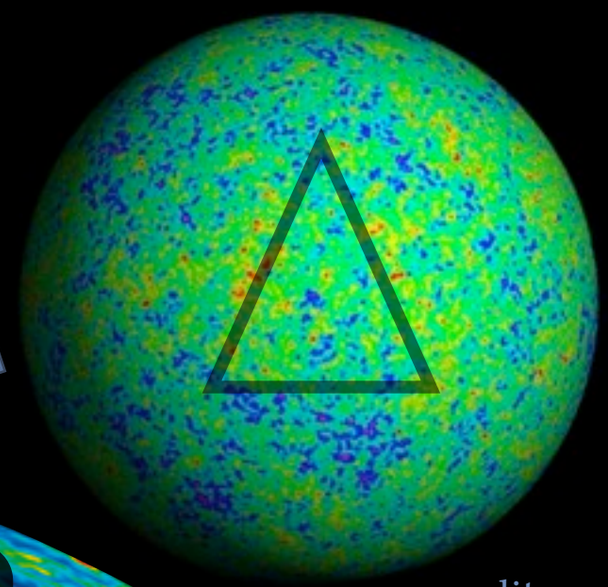
credit: SciDAC Review



Hinshaw et al. (WMAP)



credit: NASA/WMAP

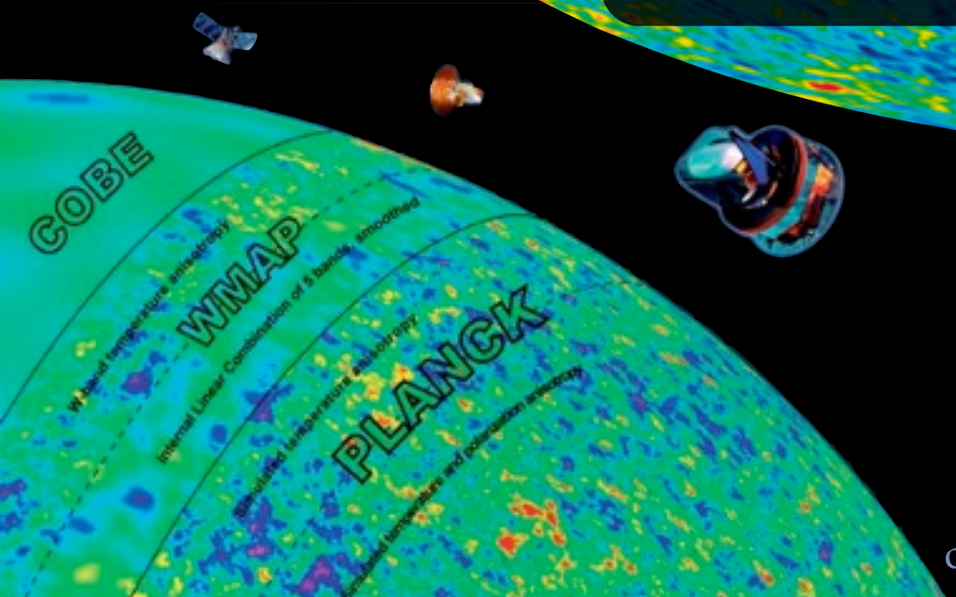


credit:
Max Tegmark

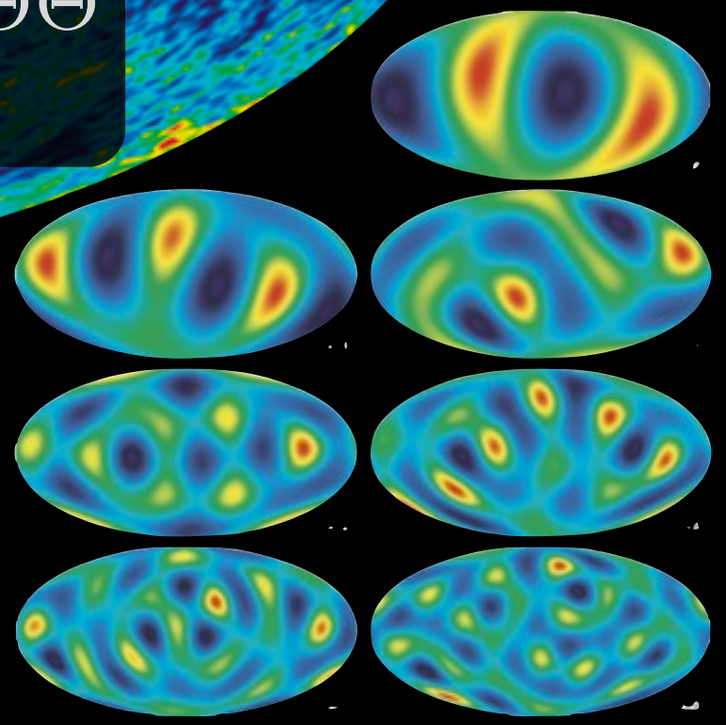
$$\Theta(\hat{\mathbf{n}}) \equiv \frac{\Delta T(\hat{\mathbf{n}})}{T} = \sum_{lm} \Theta_{lm} Y_l^m(\hat{\mathbf{n}})$$

$$\langle \Theta_{l_1 m_1} \Theta_{l_2 m_2} \Theta_{l_3 m_3} \rangle = \begin{pmatrix} l_1 & l_2 & l_3 \\ m_1 & m_2 & m_3 \end{pmatrix} B^{\Theta}_{l_1 l_2 l_3}$$

$$\langle \Theta_{lm} \Theta_{l'm'} \rangle = \delta_{l,l'} \delta_{m,m'} C_l^{\Theta\Theta}$$



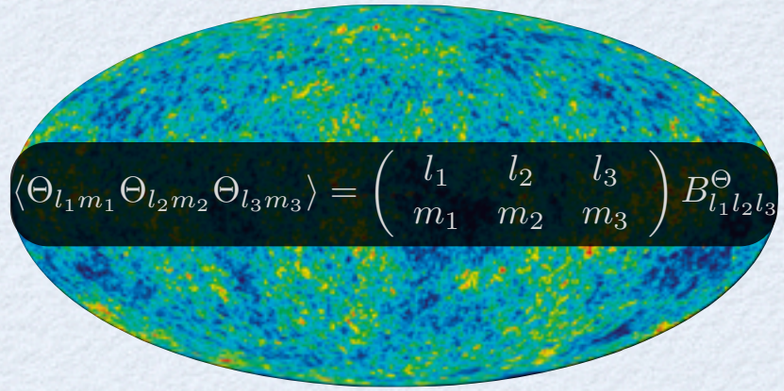
credit: SciDAC Review



Hinshaw et al. (WMAP)

How does it get generated?

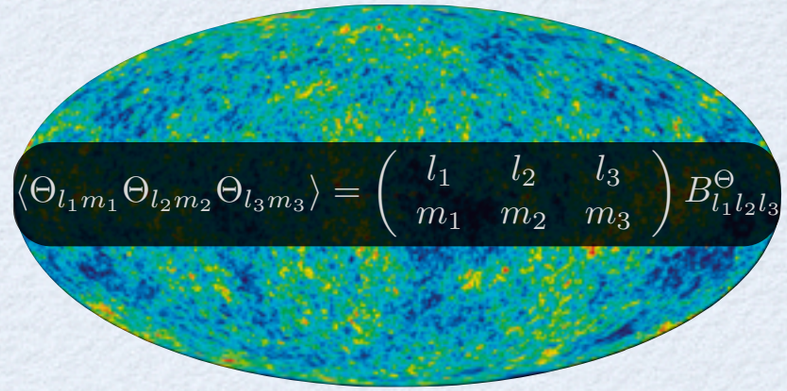
What is Bispectrum Again?



How does it get generated?

$$\frac{\Delta T(\mathbf{x})}{T} \sim \Phi(\mathbf{x})$$

What is Bispectrum Again?

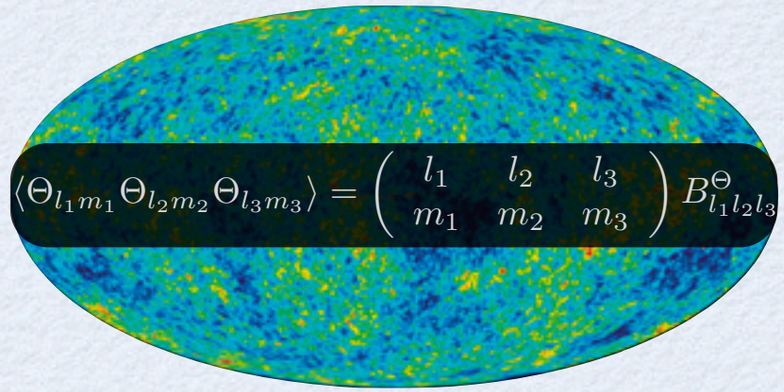


How does it get generated?

$$\frac{\Delta T(\mathbf{x})}{T} \sim \Phi(\mathbf{x})$$

$$\Phi(\mathbf{x}) = \Phi_L(\mathbf{x}) + f_{NL}\left[\Phi_L^2(\mathbf{x}) - \langle\Phi_L^2(\mathbf{x})\rangle\right]$$

What is Bispectrum Again?



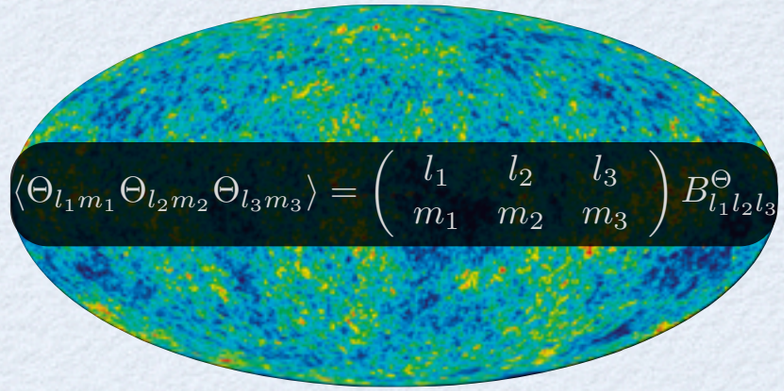
How does it get generated?

$$\frac{\Delta T(\mathbf{x})}{T} \sim \Phi(\mathbf{x})$$

$$\Phi(\mathbf{x}) = \Phi_L(\mathbf{x}) + f_{NL}\left[\Phi_L^2(\mathbf{x}) - \langle\Phi_L^2(\mathbf{x})\rangle\right]$$

Non-Linear Coupling parameter

What is Bispectrum Again?



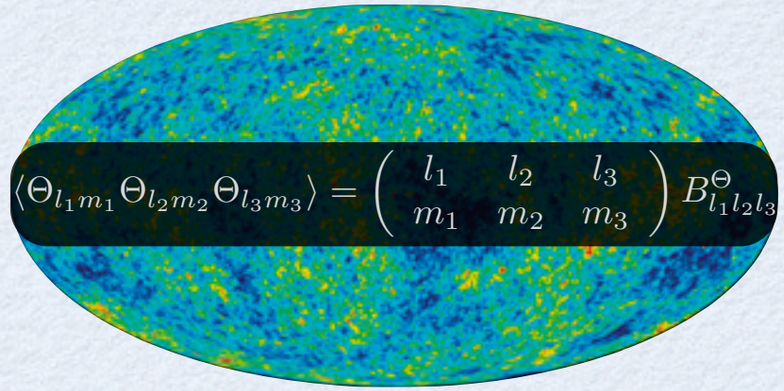
How does it get generated?

$$\frac{\Delta T(\mathbf{x})}{T} \sim \Phi(\mathbf{x})$$

$$\Phi(\mathbf{x}) = \Phi_L(\mathbf{x}) + f_{NL}\left[\Phi_L^2(\mathbf{x}) - \langle\Phi_L^2(\mathbf{x})\rangle\right]$$

Non-Linear Coupling parameter

What is Bispectrum Again?



Measurement of non-Gaussianty of CMB anisotropies can potentially constrain non-Linearity, "slow-rollness" and "adiabaticity" in inflation.

What is the Expected Level of Non-Gaussianity?

The level of Non-Gaussianity predicted by the simplest models of Inflation

$$f_{NL} \sim 0.01 - 1$$

However, much higher values of non-Gaussianity can be predicted by

- Models with multiple scalar fields
- Non-Adiabatic Fluctuations
- Features in the Inflation Potential
- Non-Canonical Kinetic Terms
- ...

Review: N. Bartolo, E. Komatsu, S. Matarrese, and A. Riotto, Phys. Rep. 402, 103 (2004)

Conflicting results in the literature have made this field "Hot"!

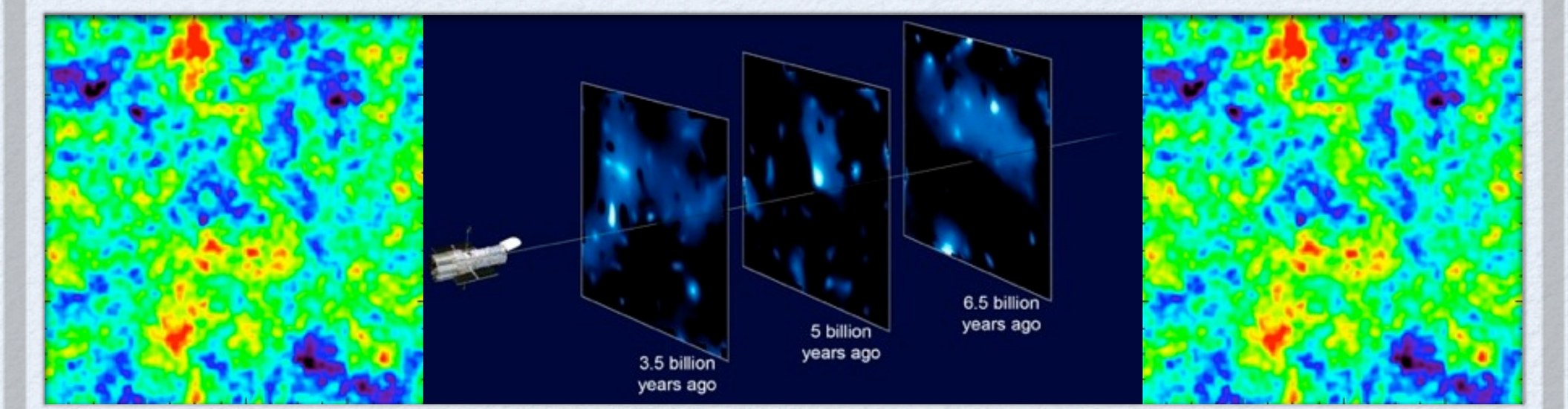
$$27 < f_{NL} < 147 \ (95\% \text{ C.L.})$$

With WMAP 3-Yr. Data
A. Yadav and B. Wandelt, Phys. Rev. Lett. 100, 181301 (2008)

$$-9 < f_{NL} < 111 \ (95\% \text{ C.L.})$$

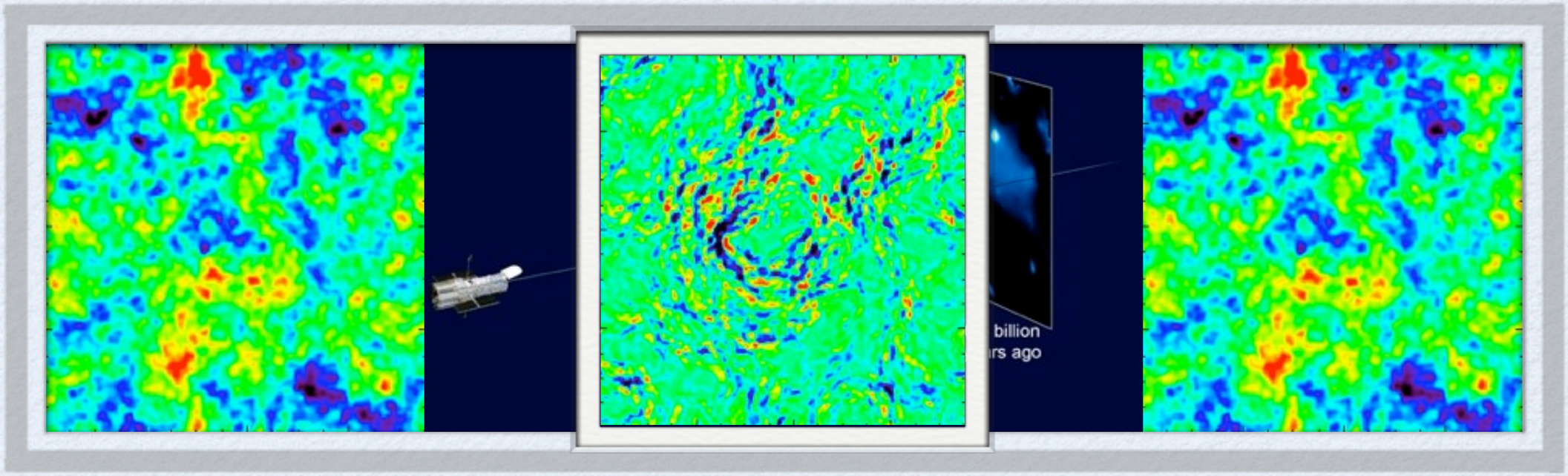
With WMAP 5-Yr. Data
E. Komatsu et al., Astrophys. J. Suppl., 180, 330 (2009)

The Effect of Lensing on the Primary CMB Bispectrum



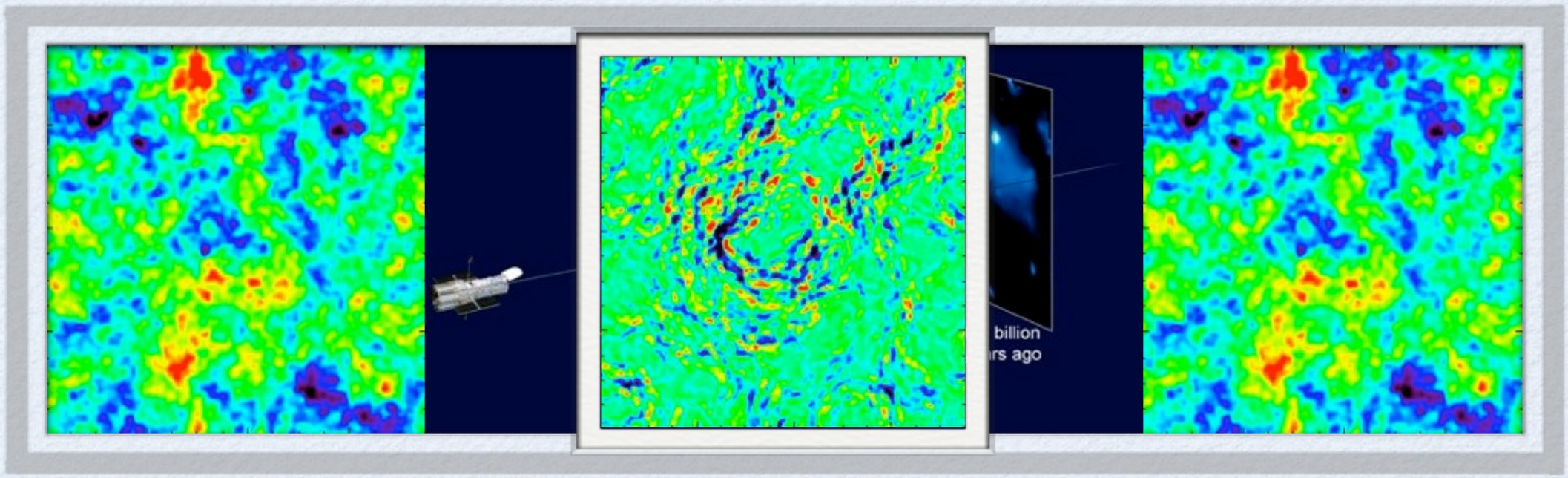
Vale, Amblard, White (2004) NASA, ESA, and R. Massey (CalTech) Vale, Amblard, White (2004)

The Effect of Lensing on the Primary CMB Bispectrum



Vale, Amblard, White (2004) NASA, ESA, and R. Massey (CalTech) Vale, Amblard, White (2004)

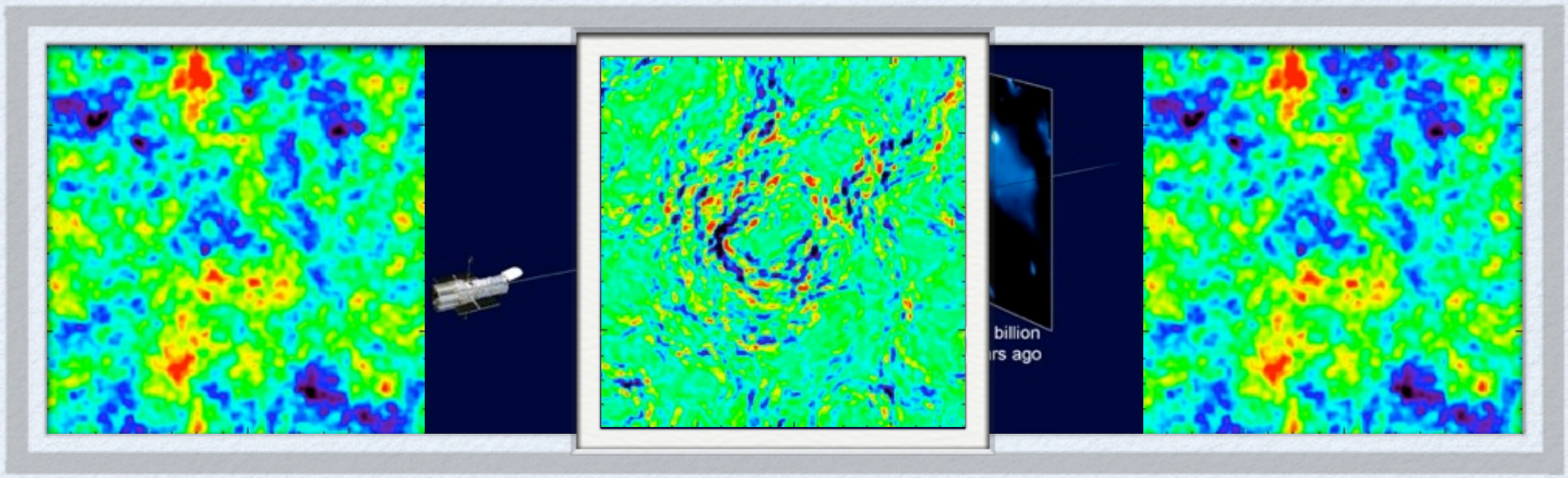
The Effect of Lensing on the Primary CMB Bispectrum



Vale, Amblard, White (2004) NASA, ESA, and R. Massey (CalTech) Vale, Amblard, White (2004)

$$\tilde{\Theta}(\hat{\mathbf{n}}) = \Theta[\hat{\mathbf{n}} + \hat{\alpha}] = \Theta[\hat{\mathbf{n}} + \nabla\phi(\hat{\mathbf{n}})]$$

The Effect of Lensing on the Primary CMB Bispectrum

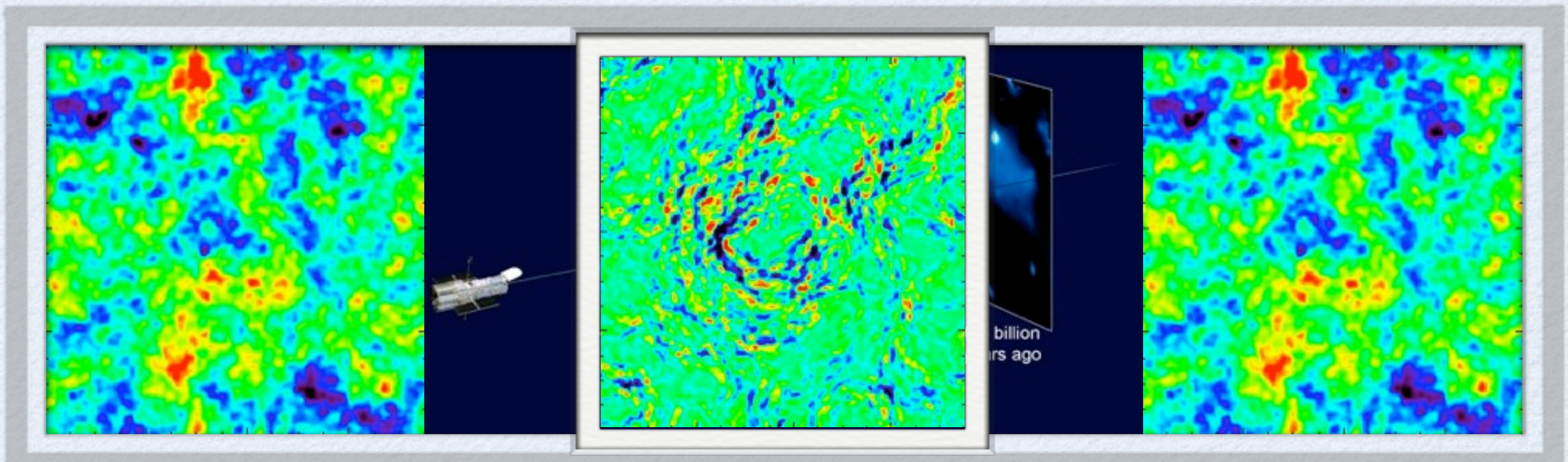


Vale, Amblard, White (2004) NASA, ESA, and R. Massey (CalTech) Vale, Amblard, White (2004)

$$\tilde{\Theta}(\hat{\mathbf{n}}) = \Theta[\hat{\mathbf{n}} + \hat{\alpha}] = \Theta[\hat{\mathbf{n}} + \nabla\phi(\hat{\mathbf{n}})]$$

$$\approx \Theta(\hat{\mathbf{n}}) + \nabla_i\phi(\hat{\mathbf{n}})\nabla^i\Theta(\hat{\mathbf{n}}) + \frac{1}{2}\nabla_i\phi(\hat{\mathbf{n}})\nabla_j\phi(\hat{\mathbf{n}})\nabla^i\nabla^j\Theta(\hat{\mathbf{n}}) + \ldots$$

The Effect of Lensing on the Primary CMB Bispectrum



Vale, Amblard, White (2004) NASA, ESA, and R. Massey (CalTech) Vale, Amblard, White (2004)

$$\tilde{\Theta}(\hat{\mathbf{n}}) = \Theta[\hat{\mathbf{n}} + \hat{\alpha}] = \Theta[\hat{\mathbf{n}} + \nabla\phi(\hat{\mathbf{n}})]$$

$$\approx \Theta(\hat{\mathbf{n}}) + \nabla_i\phi(\hat{\mathbf{n}})\nabla^i\Theta(\hat{\mathbf{n}}) + \frac{1}{2}\nabla_i\phi(\hat{\mathbf{n}})\nabla_j\phi(\hat{\mathbf{n}})\nabla^i\nabla^j\Theta(\hat{\mathbf{n}}) + \dots$$

$$\tilde{B}^{\Theta}_{l_1 l_2 l_3} = \sum_{m_1\, m_2\, m_3} \begin{pmatrix} l_1 & l_2 & l_3 \\ m_1 & m_2 & m_3 \end{pmatrix} \langle \tilde{\Theta}_{l_1\, m_1} \tilde{\Theta}_{l_2\, m_2} \tilde{\Theta}_{l_3\, m_3} \rangle$$

The Effect of Lensing on the Primary CMB Bispectrum

*** Let's dispense with ~ 30 slides full of equations...

The Effect of Lensing on the Primary CMB Bispectrum

*** Let's dispense with ~ 30 slides full of equations...

$$\tilde{B}^{\Theta}_{l_1 l_2 l_3} = \left[1 - \mathcal{R}\left\{l_1(l_1+1) + l_2(l_2+1) + l_3(l_3+1)\right\}\right] B^{\Theta}_{l_1 l_2 l_3}$$

$$+ \sum_{lpq} C_l^{\phi\phi} \Bigg[f_{l_2 l p} f_{l_3 l q} (-1)^n \begin{Bmatrix} l_1 & l_2 & l_3 \\ l & q & p \end{Bmatrix} B^{\Theta}_{l_1 p q}$$

$$+ f_{l_3 l p} f_{l_1 l q} (-1)^n \begin{Bmatrix} l_1 & l_2 & l_3 \\ p & l & q \end{Bmatrix} B^{\Theta}_{p l_2 q}$$

$$+ f_{l_1 l p} f_{l_2 l q} (-1)^n \begin{Bmatrix} l_1 & l_2 & l_3 \\ q & p & l \end{Bmatrix} B^{\Theta}_{p q l_3} \Bigg]$$

A. Cooray, **D. Sarkar**, and P. Serra, Phys. Rev. D, 77, 123006 (2008)

The Effect of Lensing on the Primary CMB Bispectrum

*** Let's dispense with ~ 30 slides full of equations...

$$\tilde{B}^{\Theta}_{l_1 l_2 l_3} = \left[1 - \mathcal{R}\left\{l_1(l_1+1) + l_2(l_2+1) + l_3(l_3+1)\right\}\right] B^{\Theta}_{l_1 l_2 l_3}$$

$$+ \sum_{lpq} C_l^{\phi\phi} \Bigg[f_{l_2 l p} f_{l_3 l q} (-1)^n \begin{Bmatrix} l_1 & l_2 & l_3 \\ l & q & p \end{Bmatrix} B^{\Theta}_{l_1 p q}$$

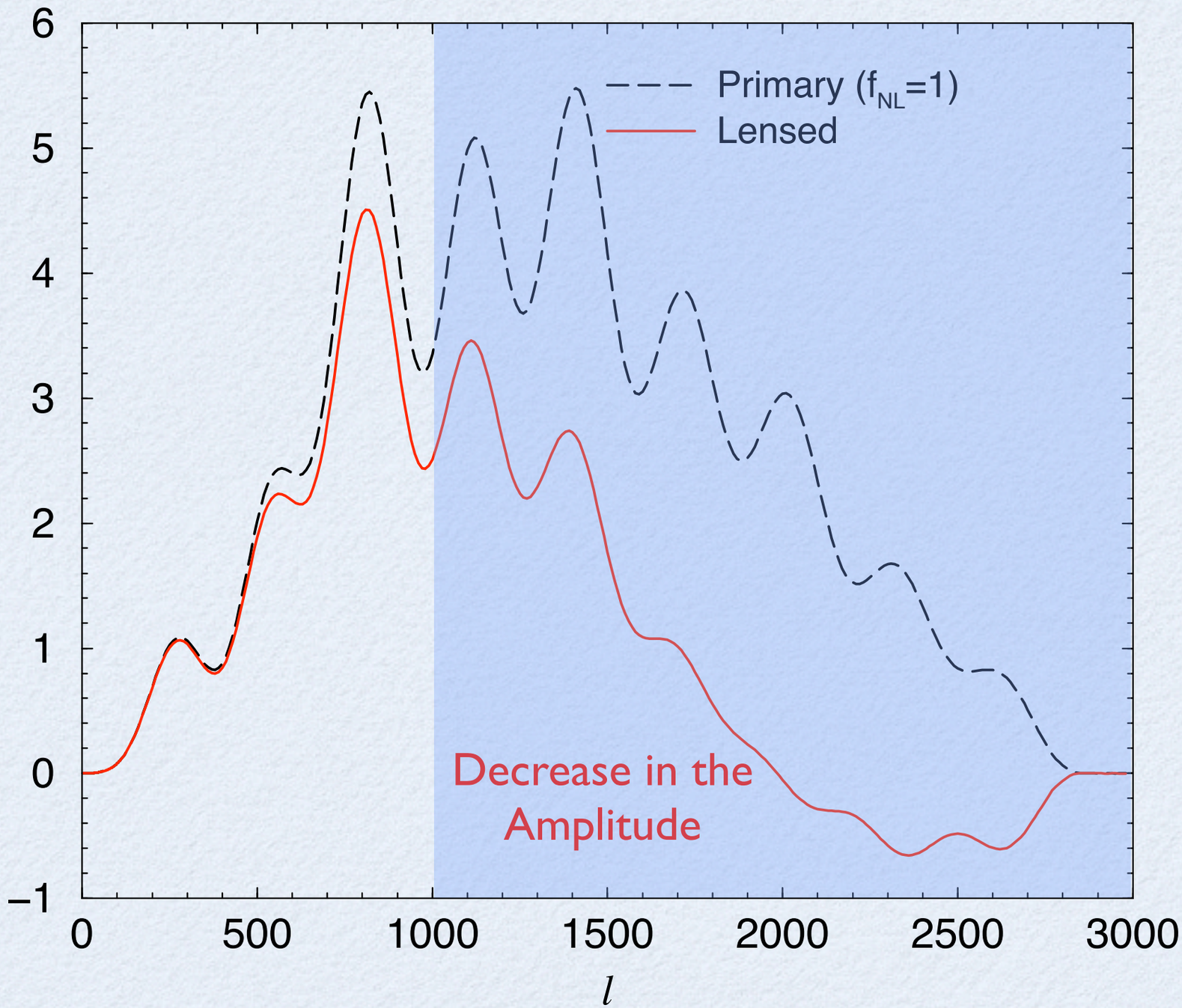
$$+ f_{l_3 l p} f_{l_1 l q} (-1)^n \begin{Bmatrix} l_1 & l_2 & l_3 \\ p & l & q \end{Bmatrix} B^{\Theta}_{p l_2 q}$$

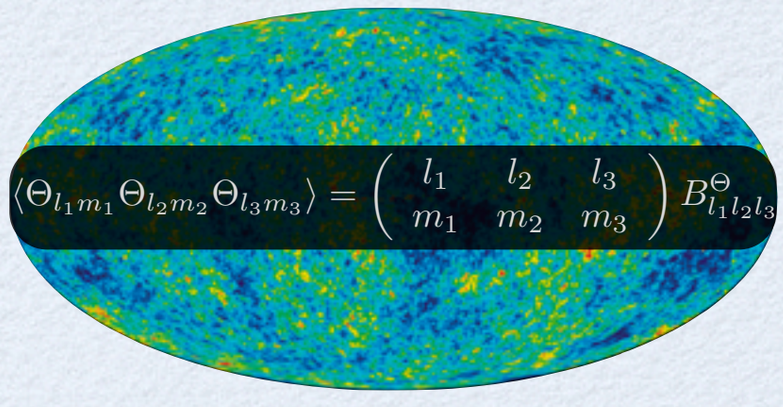
$$+ f_{l_1 l p} f_{l_2 l q} (-1)^n \begin{Bmatrix} l_1 & l_2 & l_3 \\ q & p & l \end{Bmatrix} B^{\Theta}_{p q l_3} \Bigg]$$

$$\mathcal{R} = \frac{1}{4} \sum_l l(l+1) \frac{2l+1}{4\pi} C_l^{\phi\phi}$$

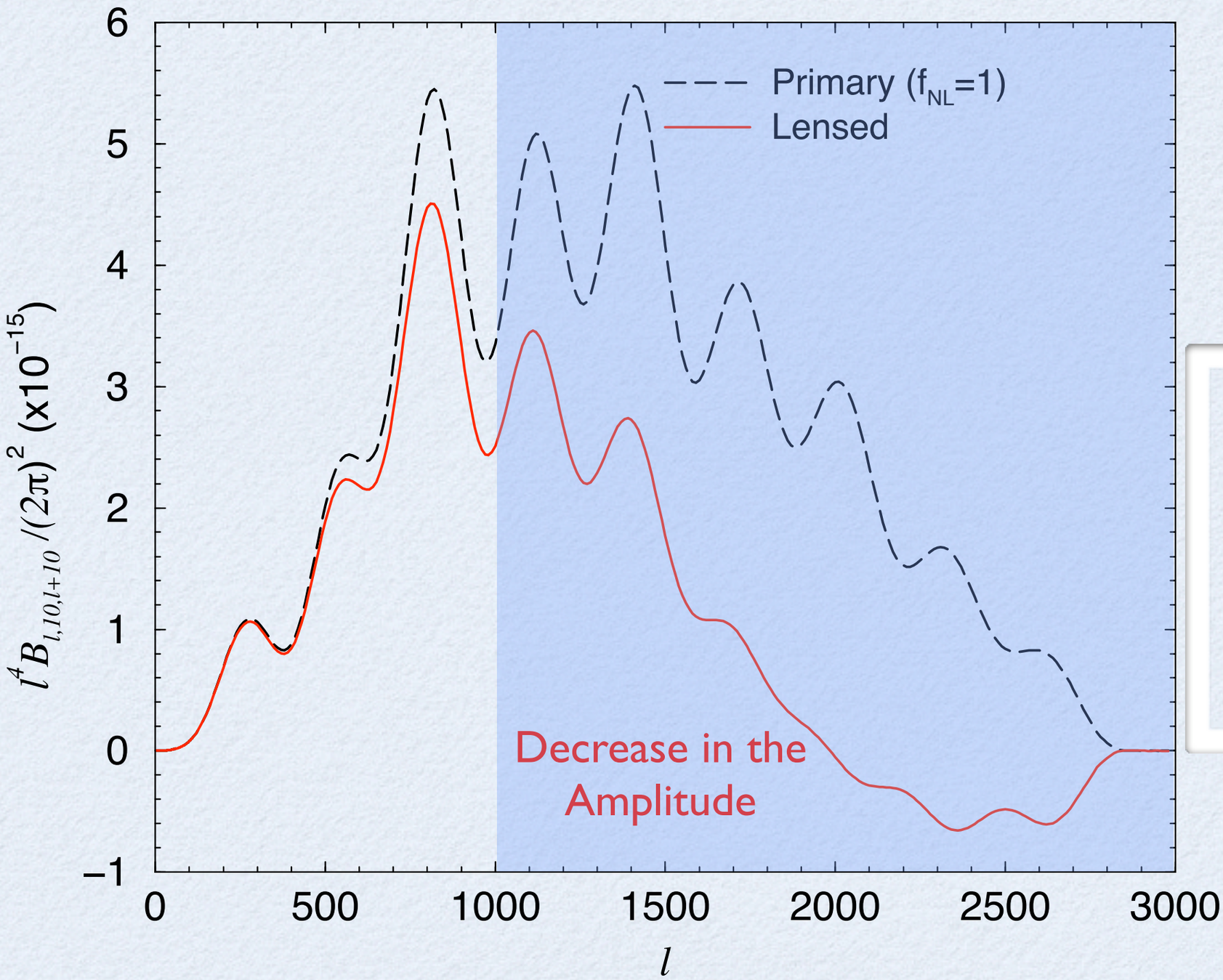
A. Cooray, **D. Sarkar**, and P. Serra, Phys. Rev. D, 77, 123006 (2008)

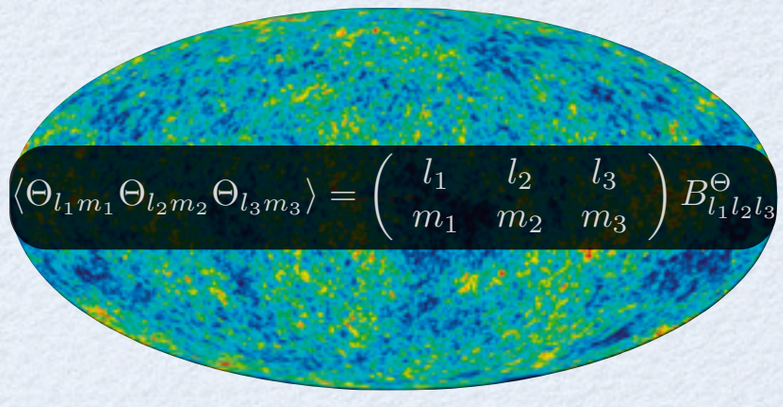
How much is the Magnitude of the Effect?





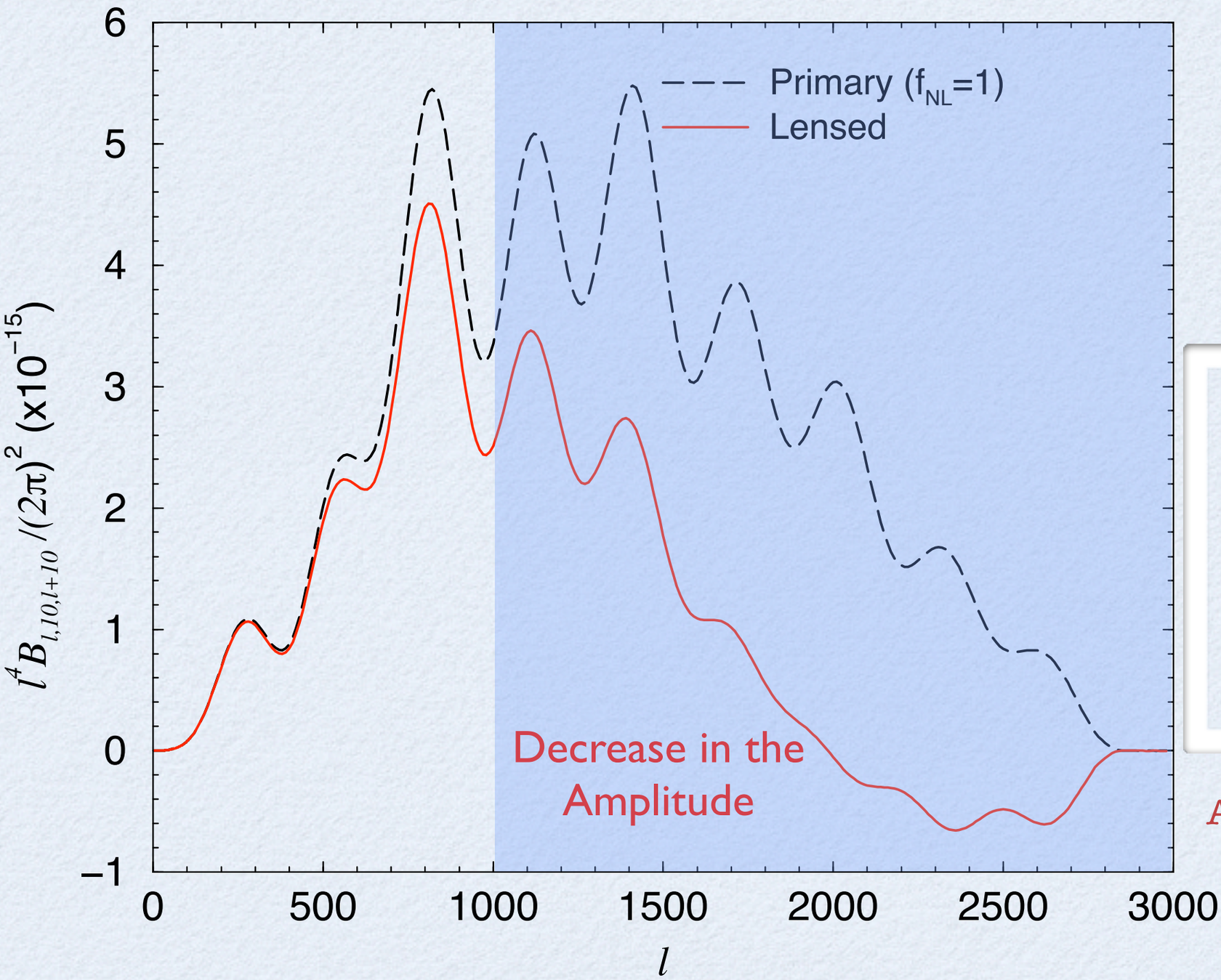
How much is the Magnitude of the Effect?

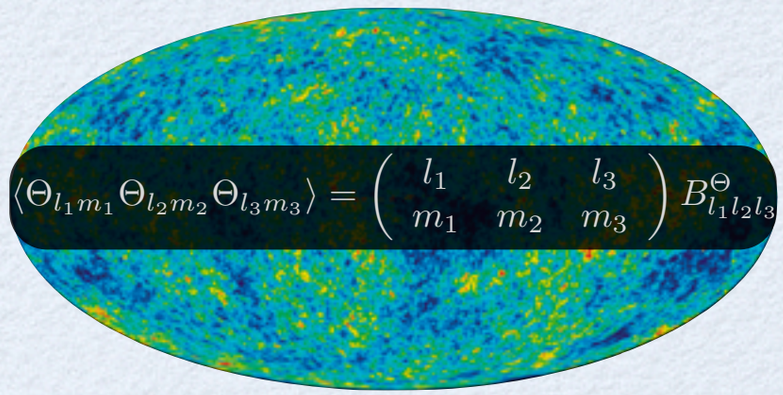




~30% Bias in the estimation of the Non-Linear Param from Planck Data!

How much is the Magnitude of the Effect?

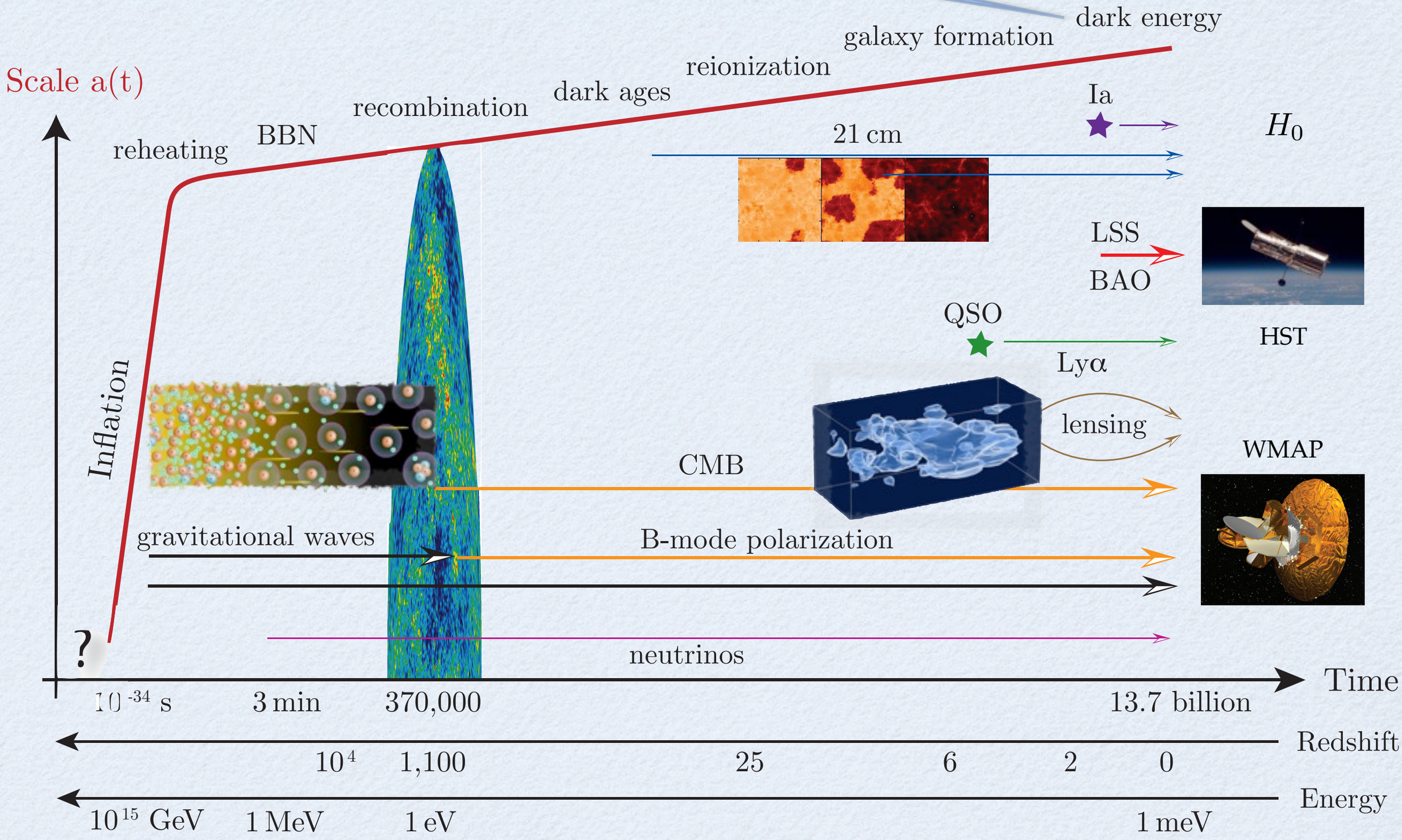




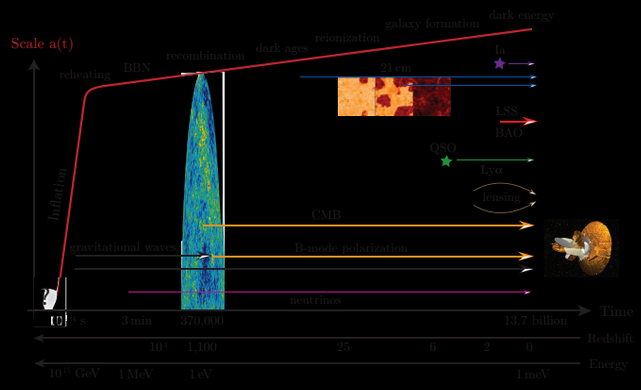
~30% Bias in the estimation of the Non-Linear Param from Planck Data!

A. Cooray, **D. Sarkar**, and P. Serra, Phys. Rev. D, 77, 123006 (2008)

PRL 2008



D. Baumann and H. Peiris, asXiv:0810.3022



Dark Energy
Accelerated Expansion

Afterglow Light
Pattern
380,000 yrs.

Dark Ages

Development of
Galaxies, Planets, etc.

Inflation

WMAP

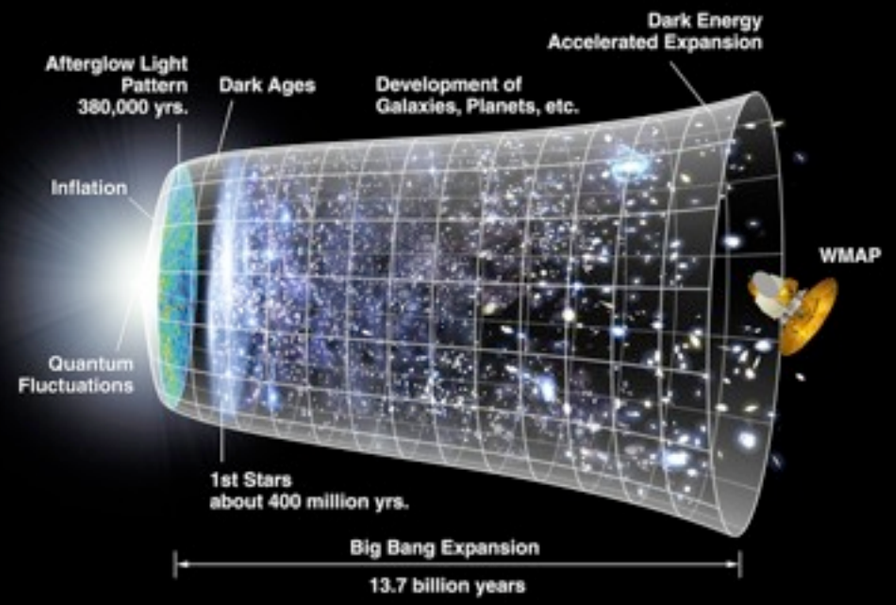
Quantum
Fluctuations

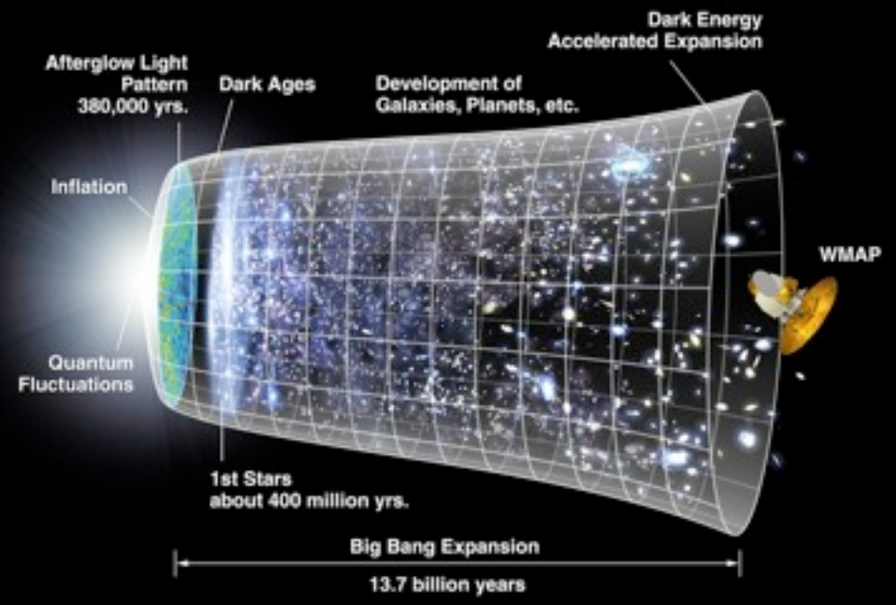
1st Stars
about 400 million yrs.

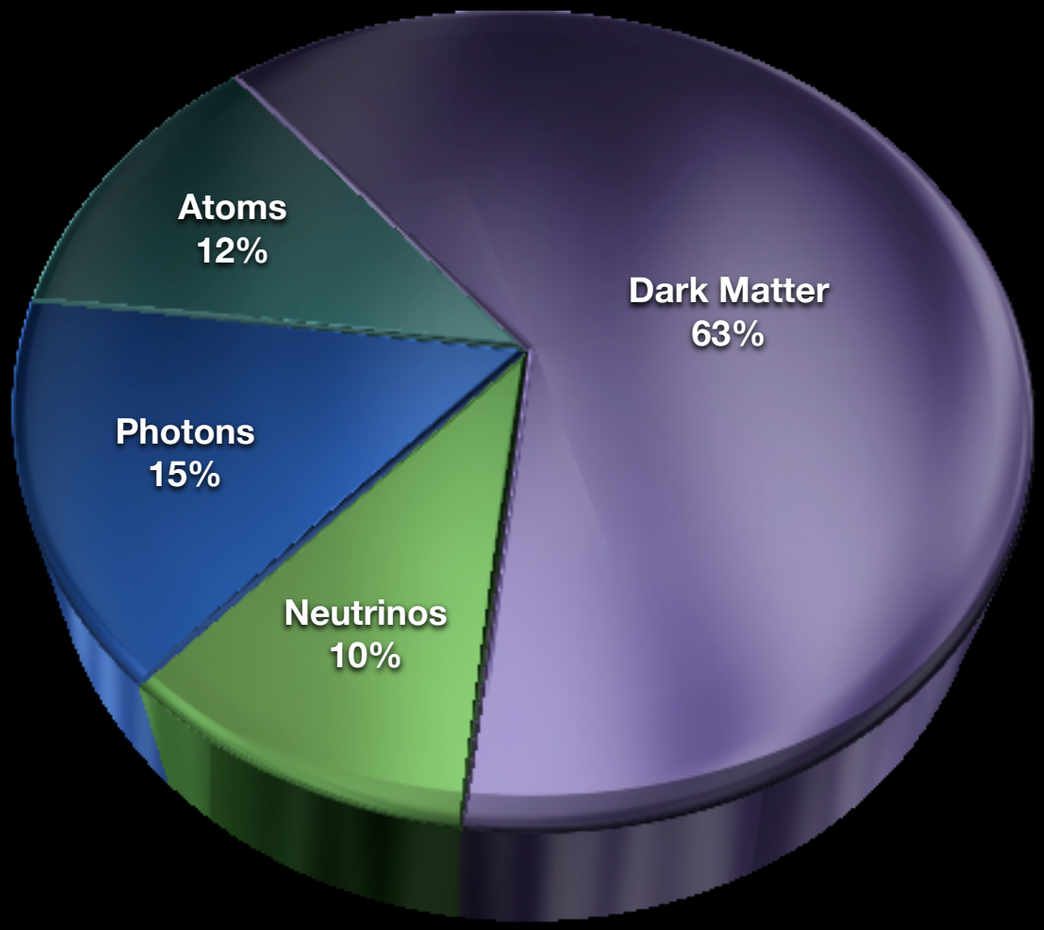
Big Bang Expansion

13.7 billion years

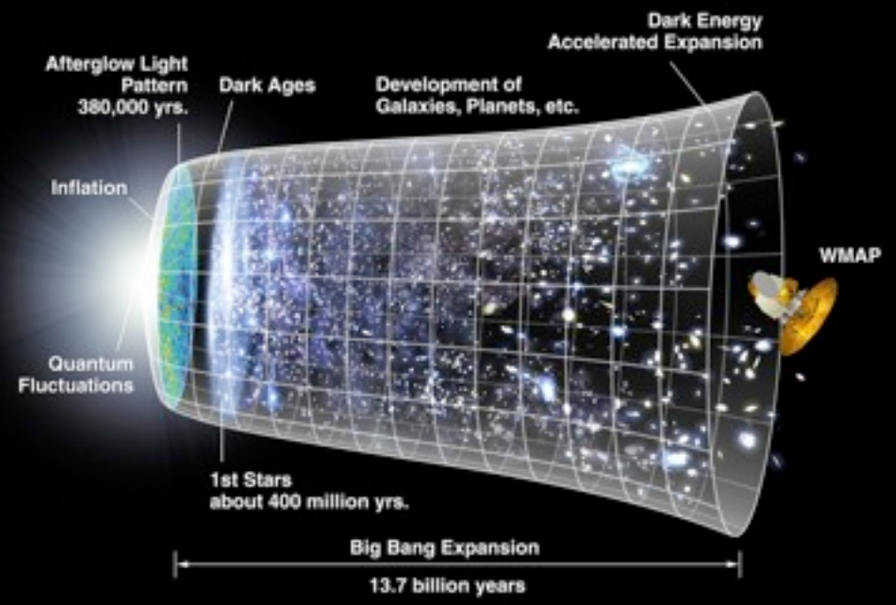
NASA/WMAP Science Team

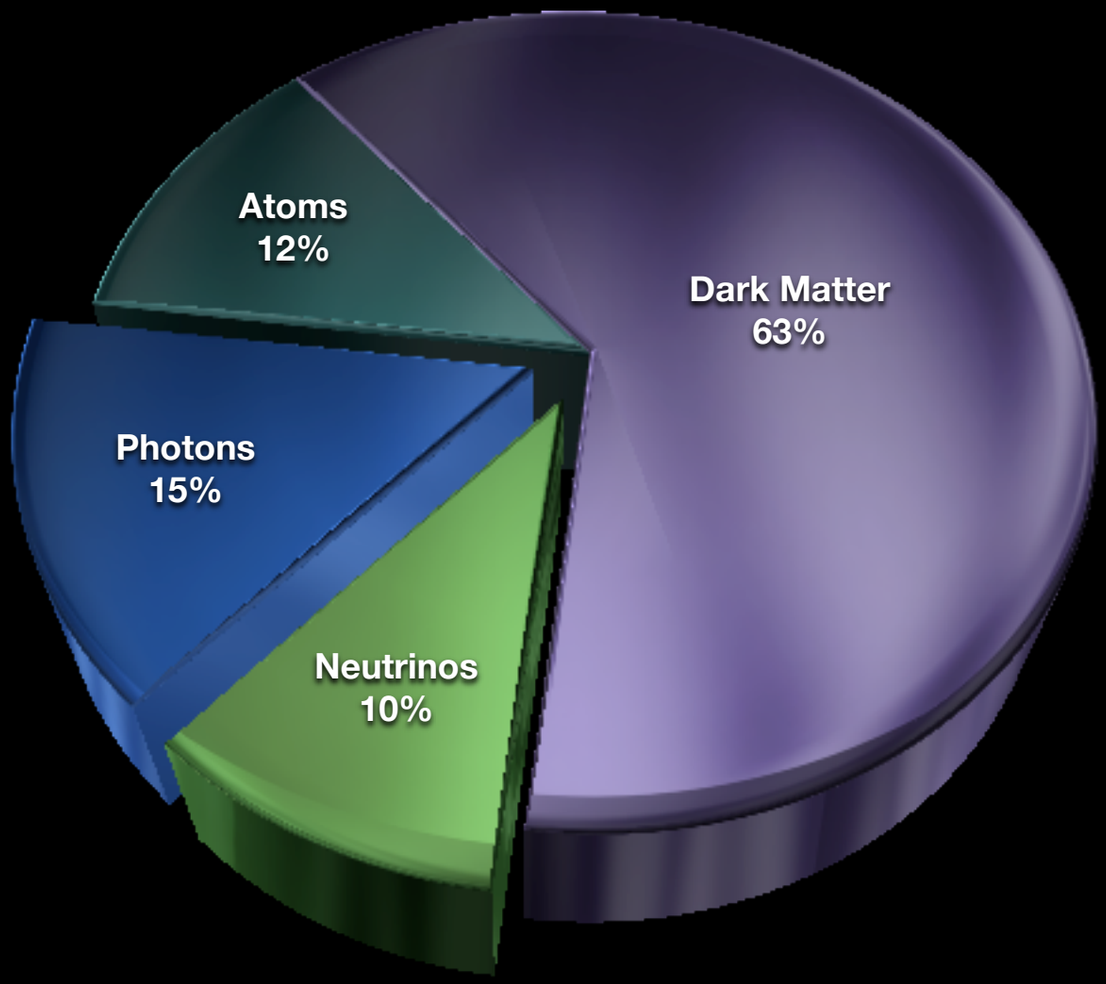

Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years



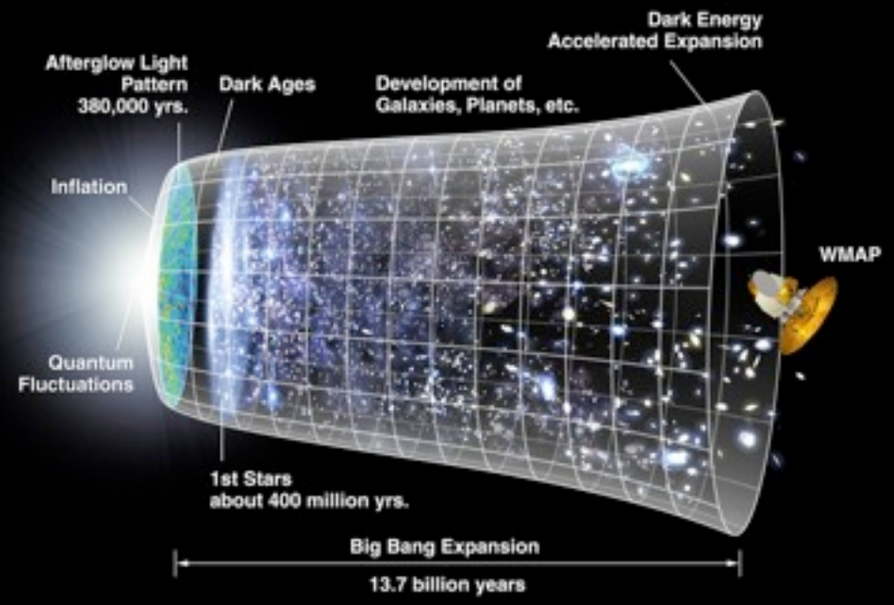


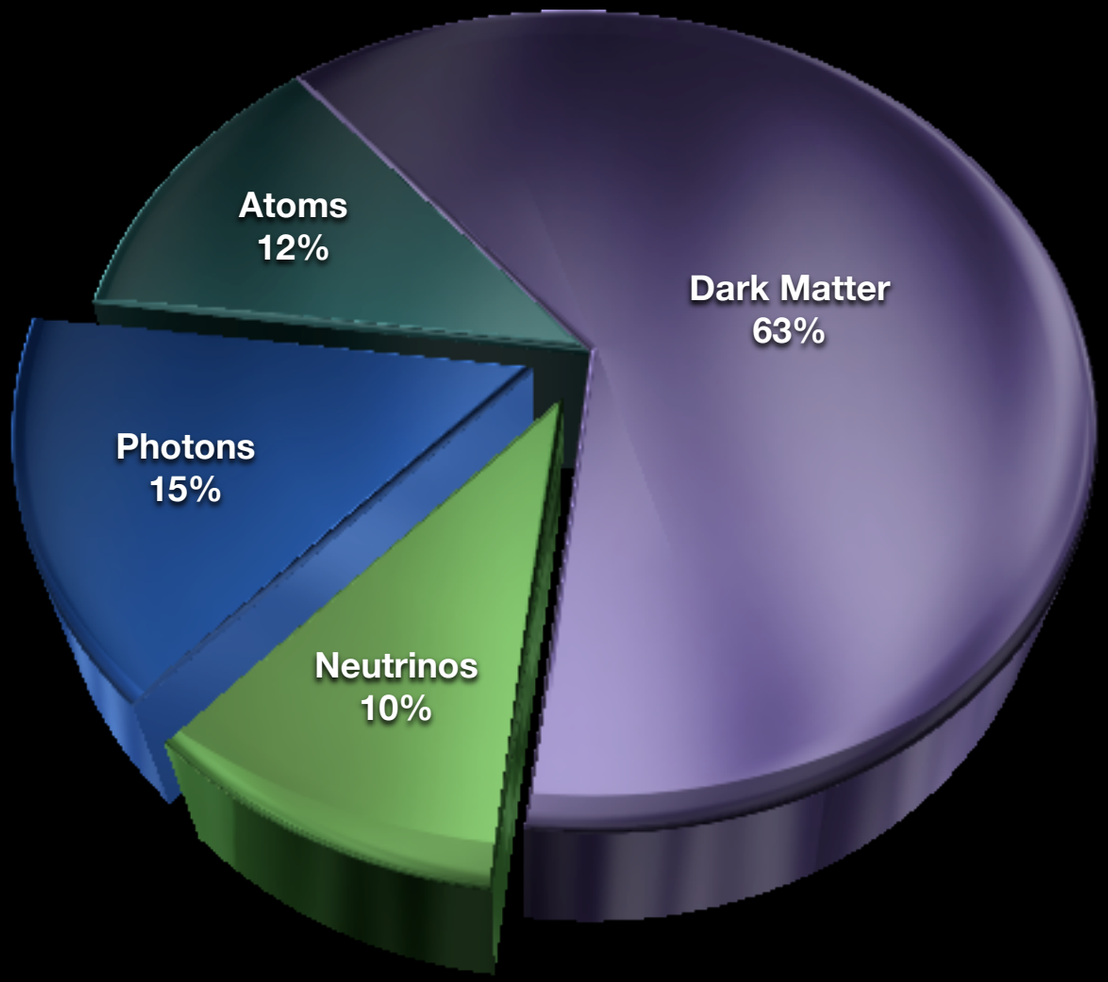
$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

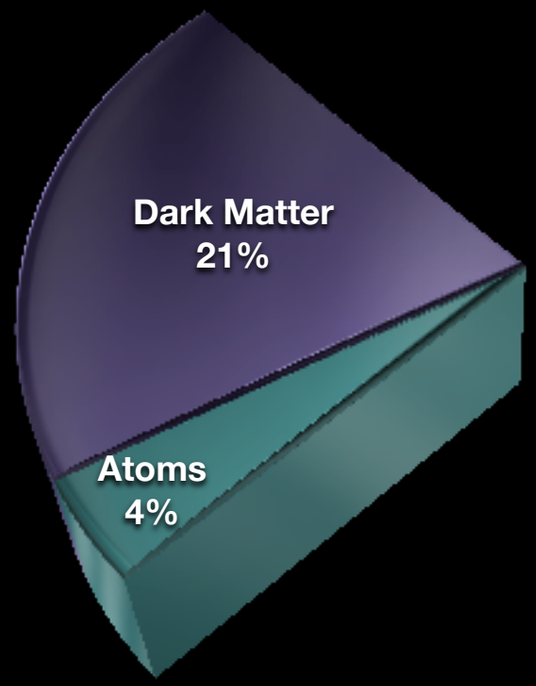




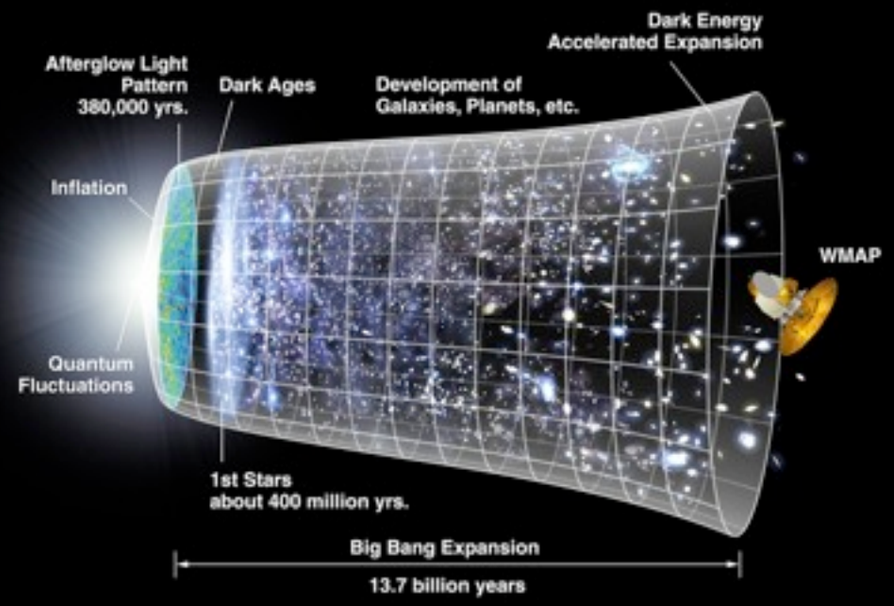
$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

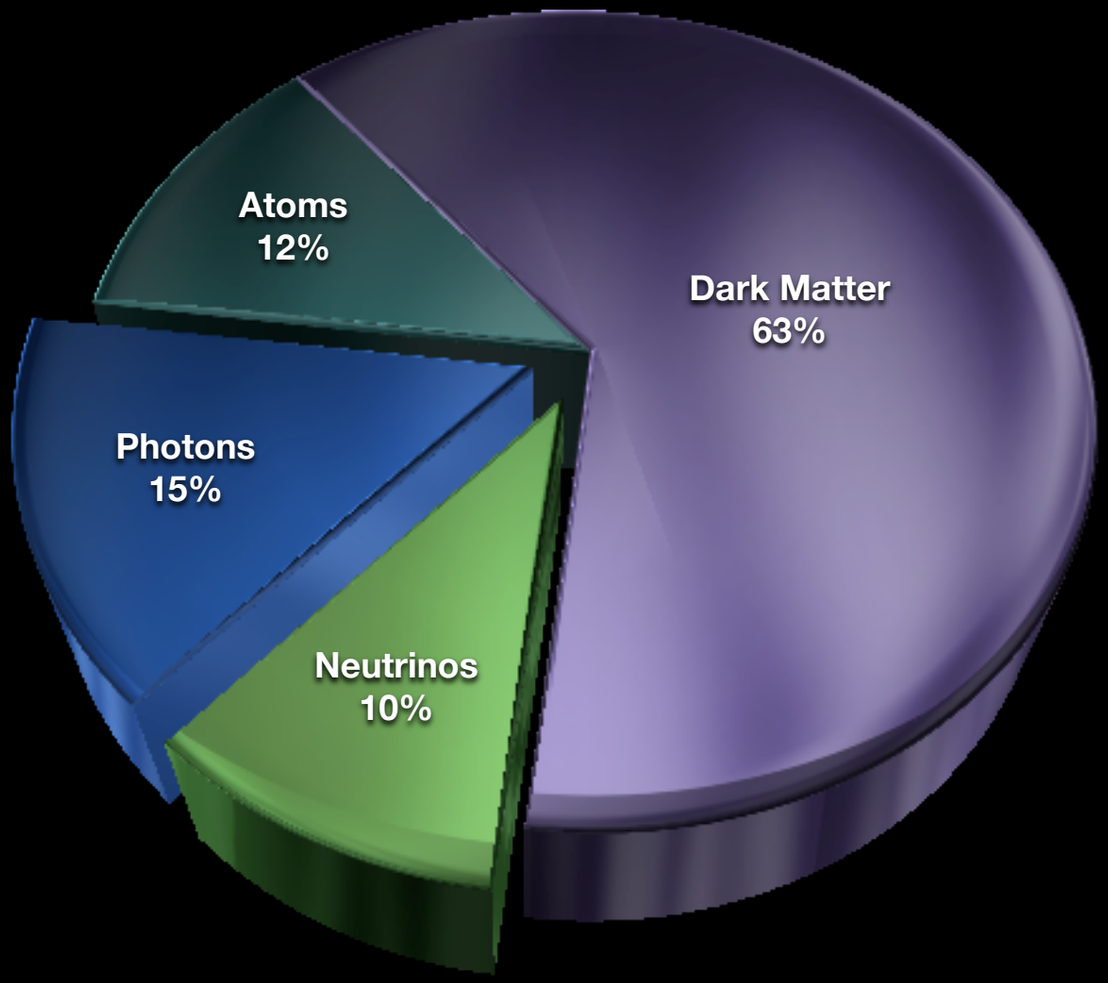


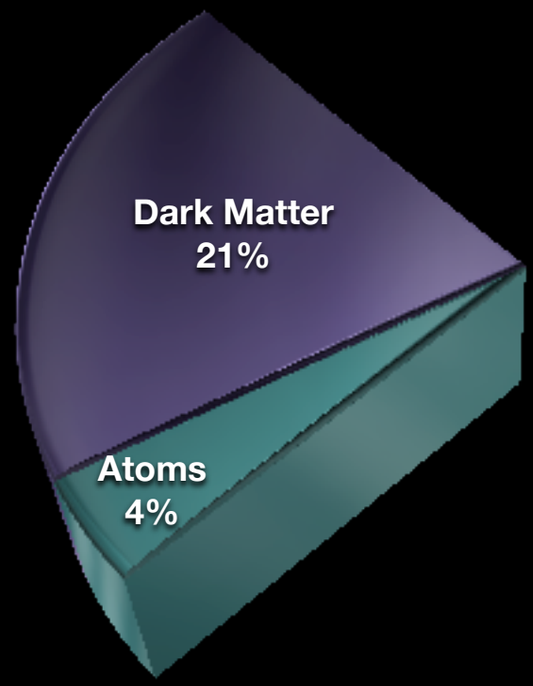




$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

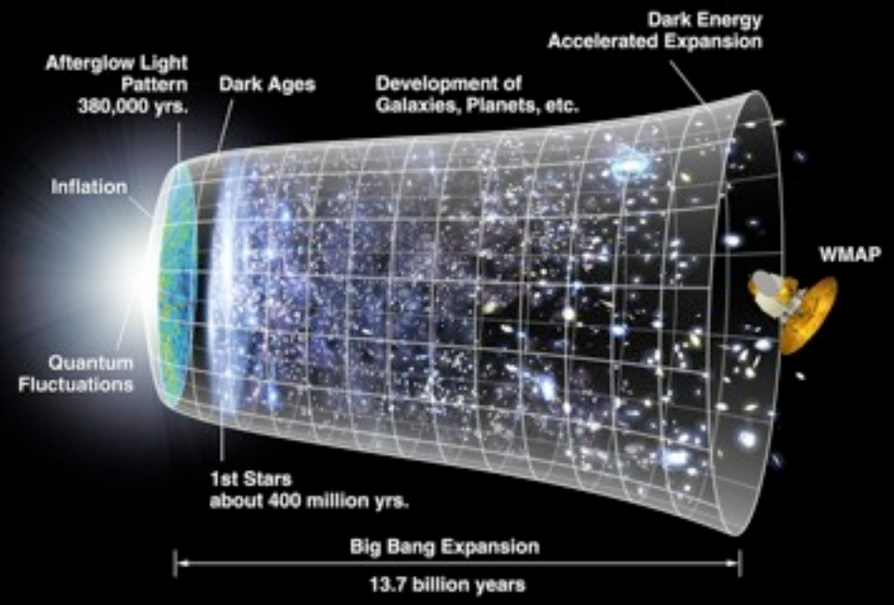


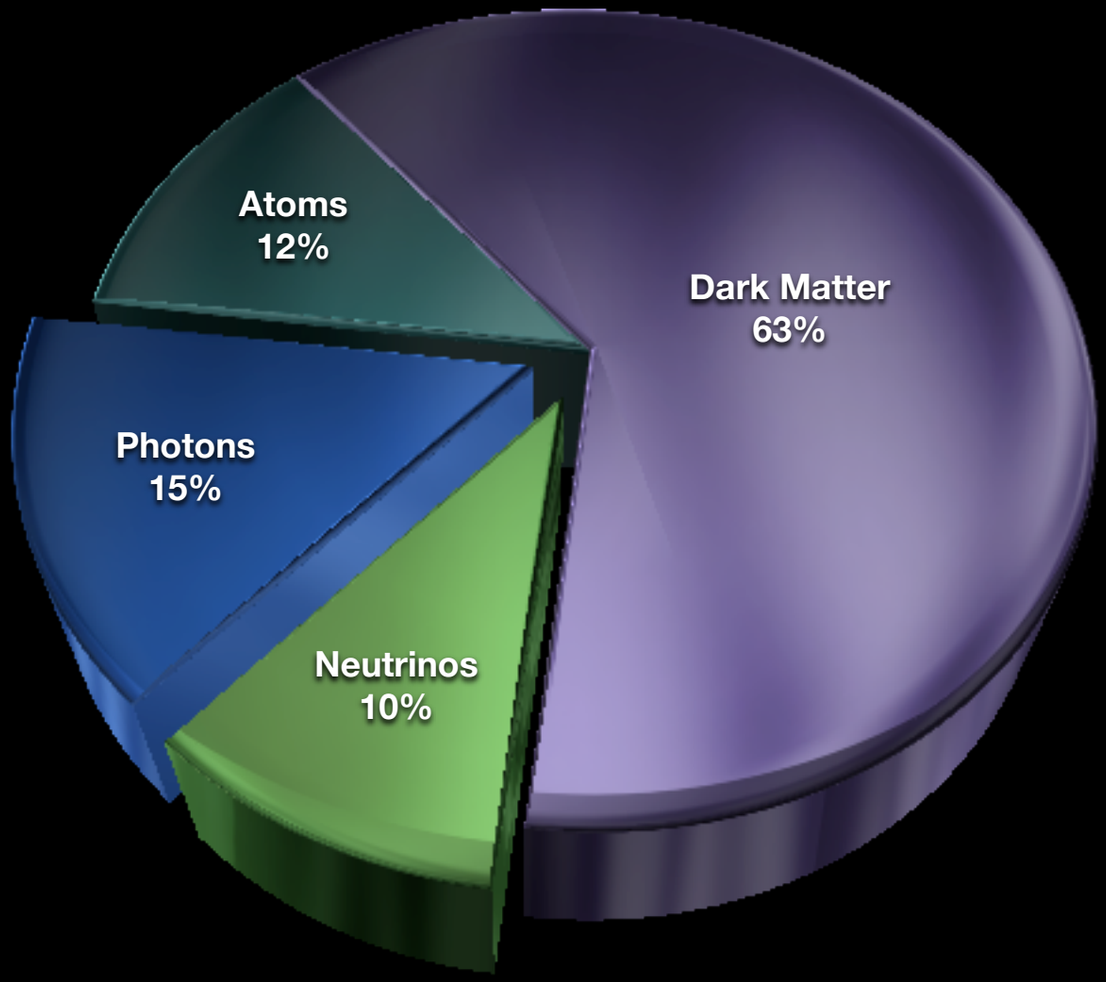




$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

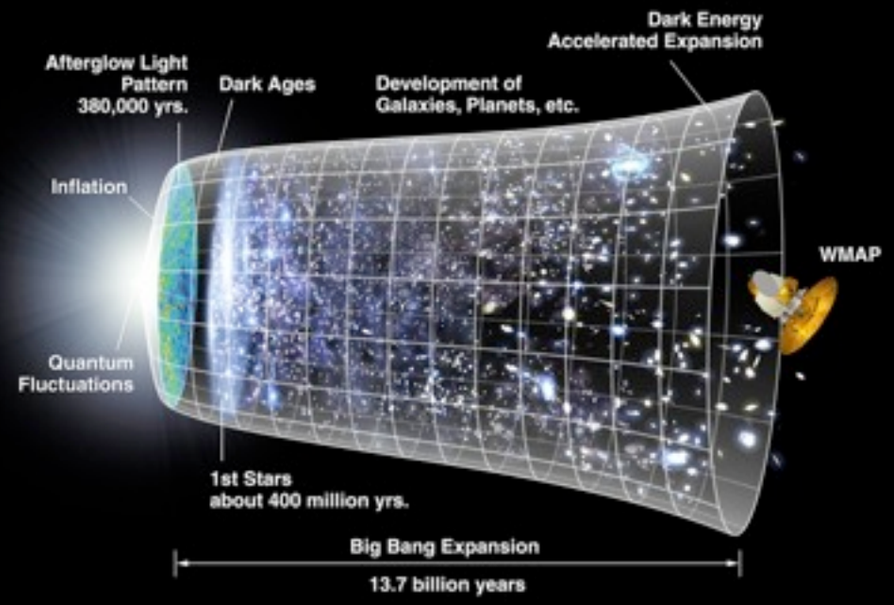
$$\Omega_0 \equiv \frac{\rho_0}{\rho_{cr,0}} \simeq 1$$

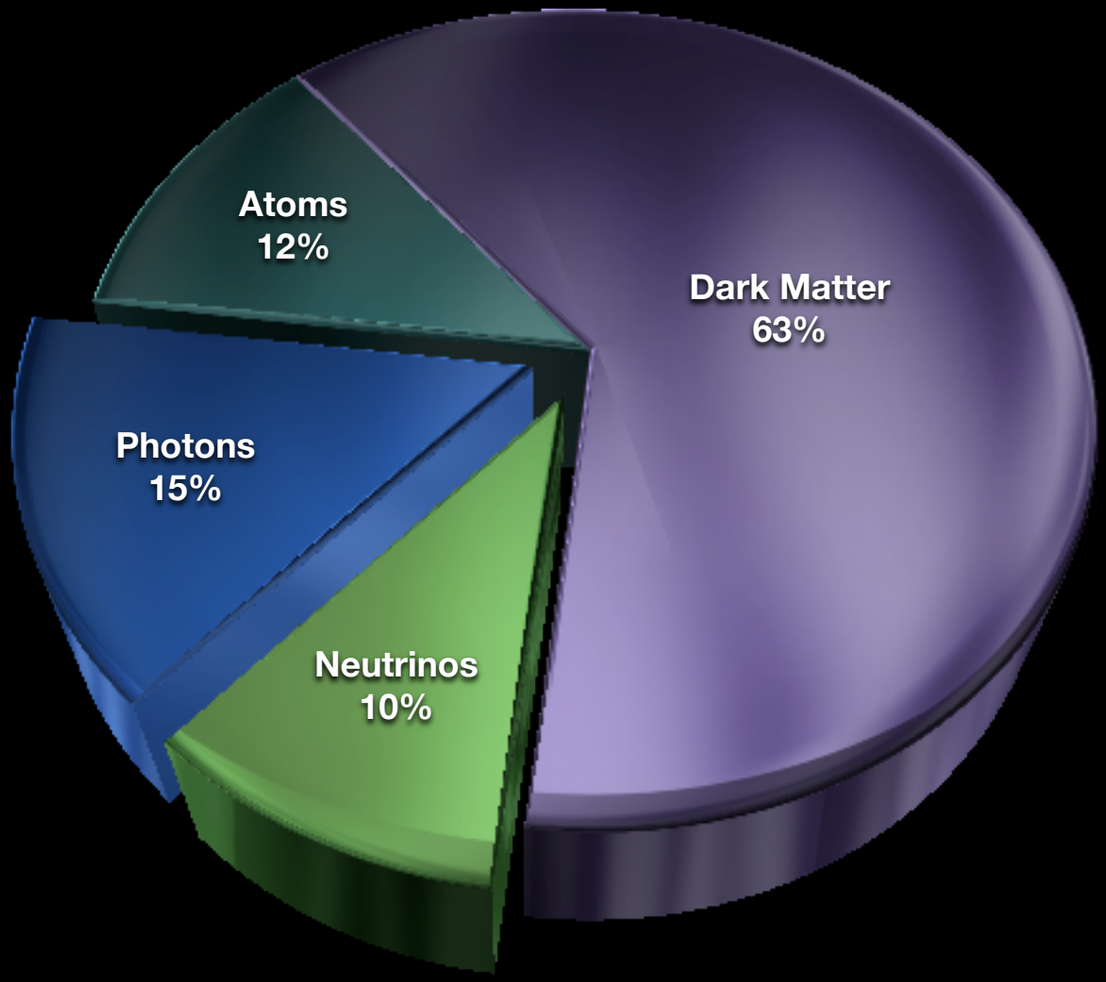




$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

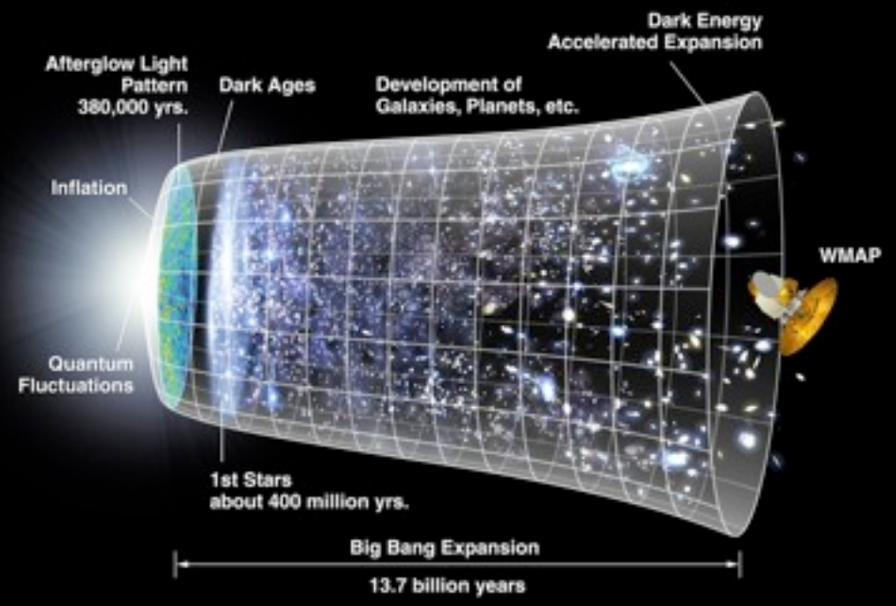
$$\Omega_0 \equiv \frac{\rho_0}{\rho_{cr,0}} \simeq 1$$

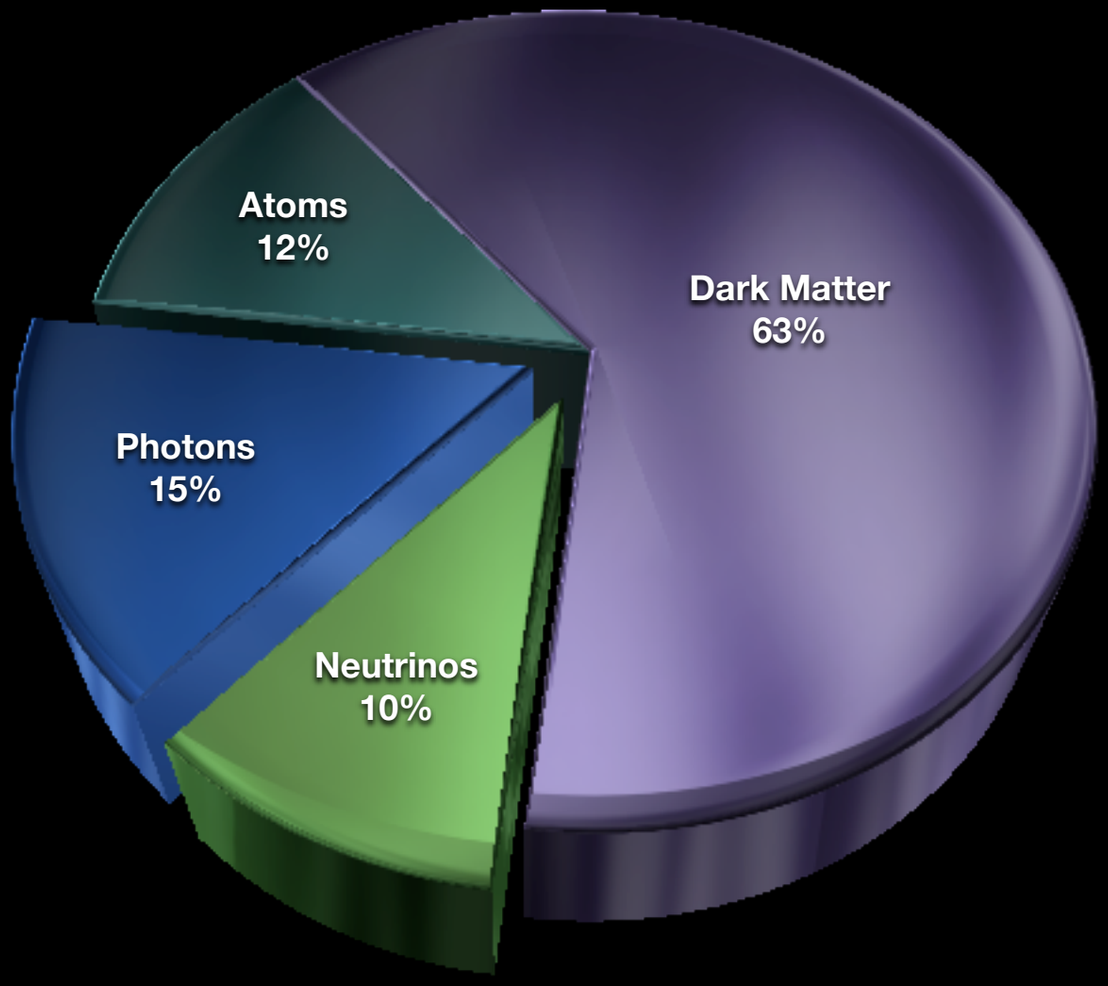


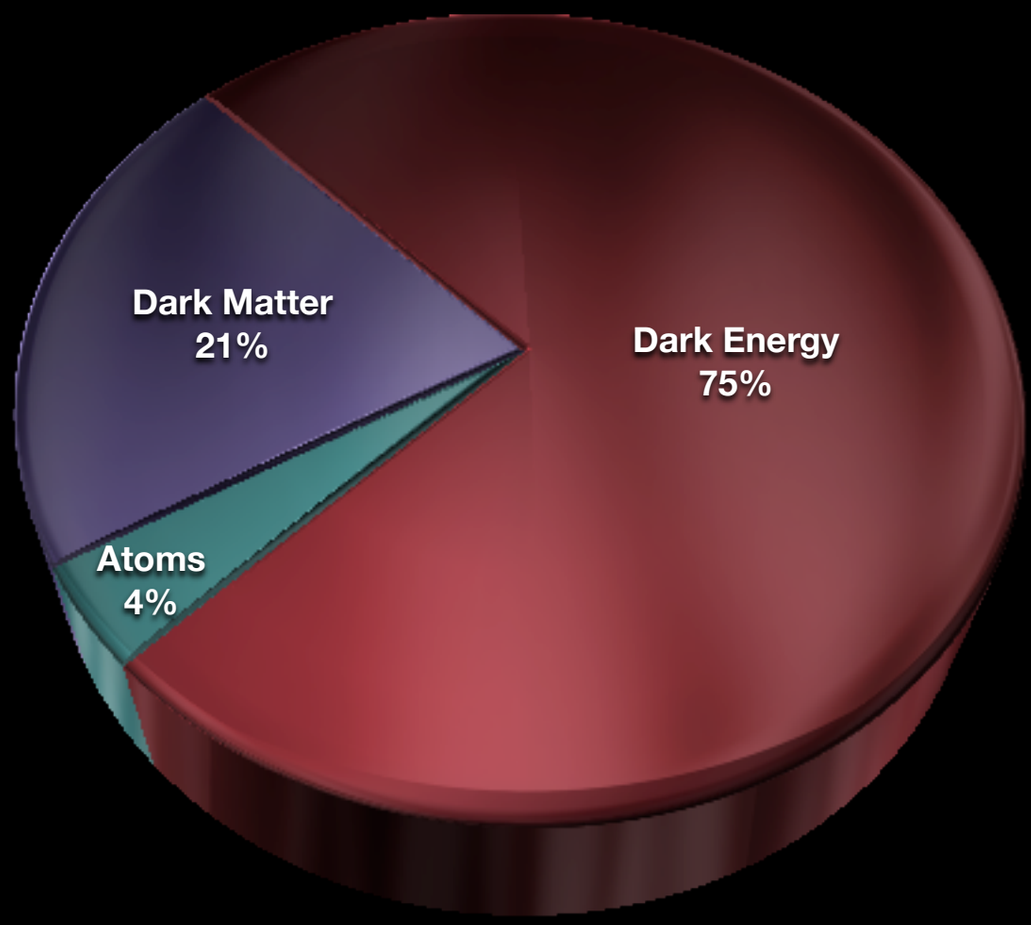


$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

$$\Omega_0 \equiv \frac{\rho_0}{\rho_{cr,0}} \simeq 1$$

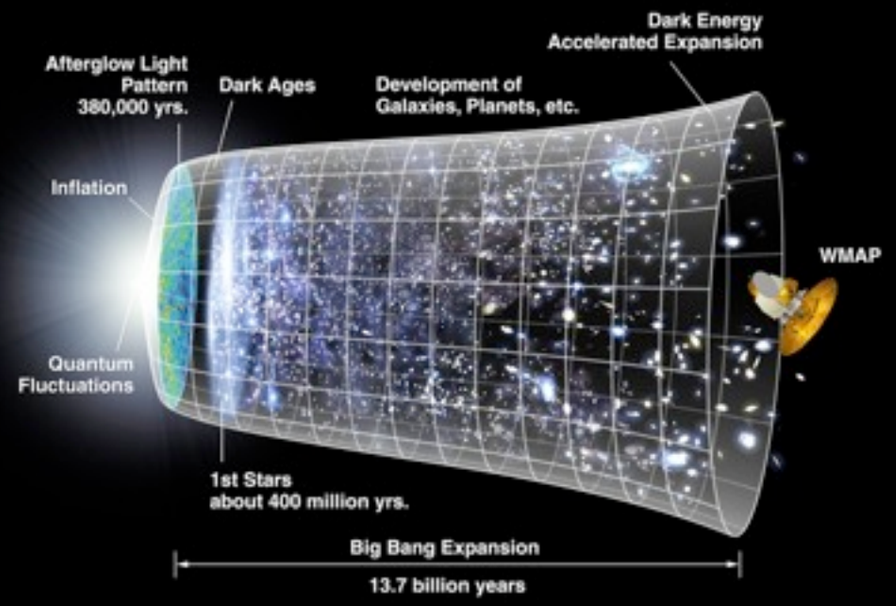


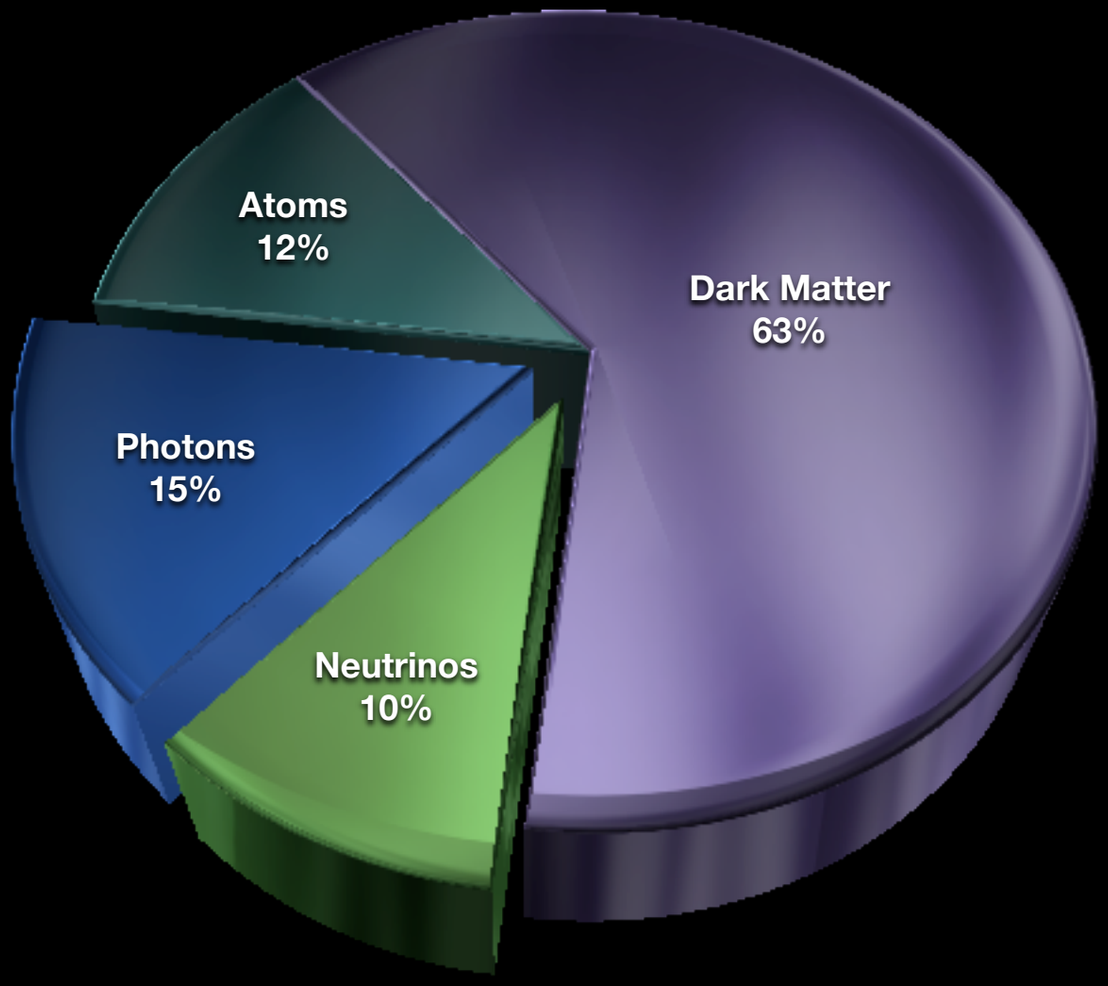




$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

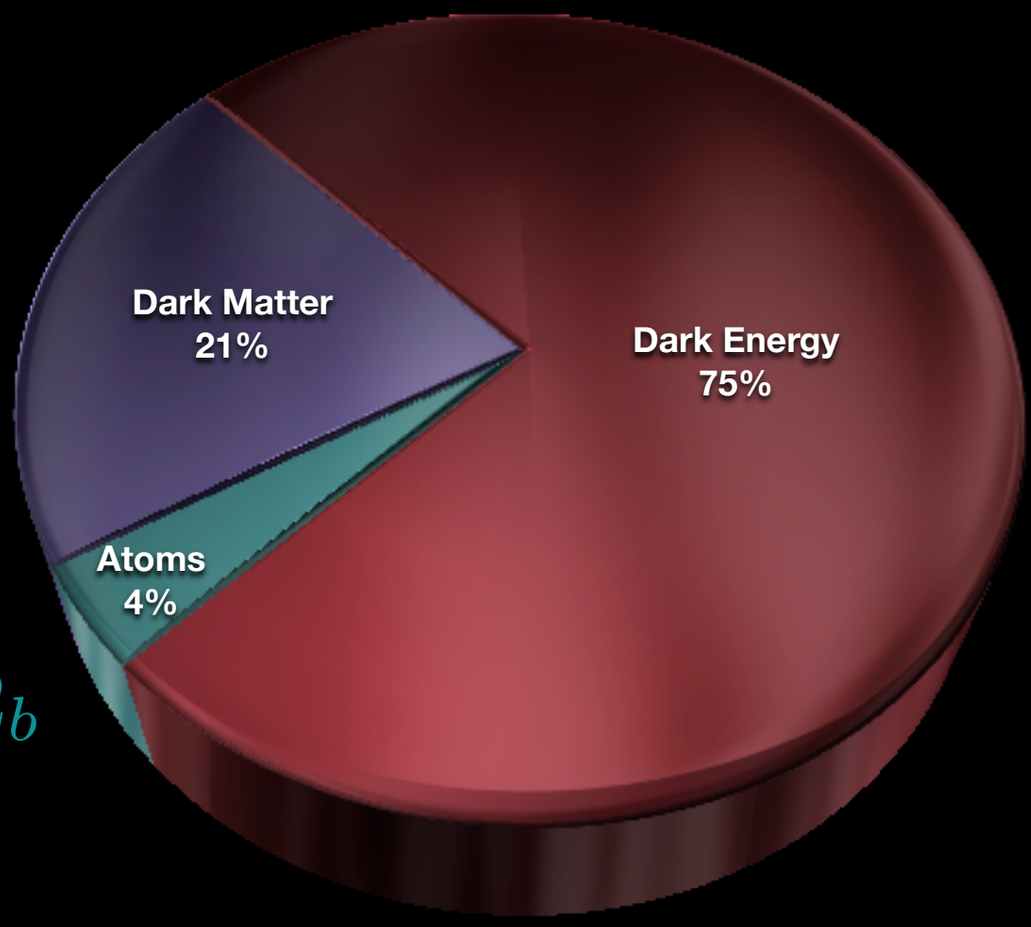
$$\Omega_0 \equiv \frac{\rho_0}{\rho_{cr,0}} \simeq 1$$



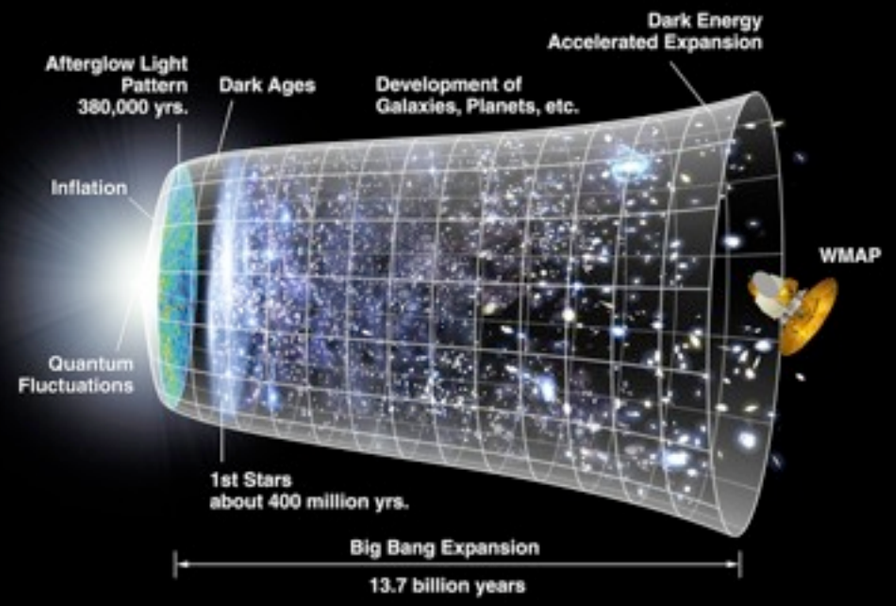


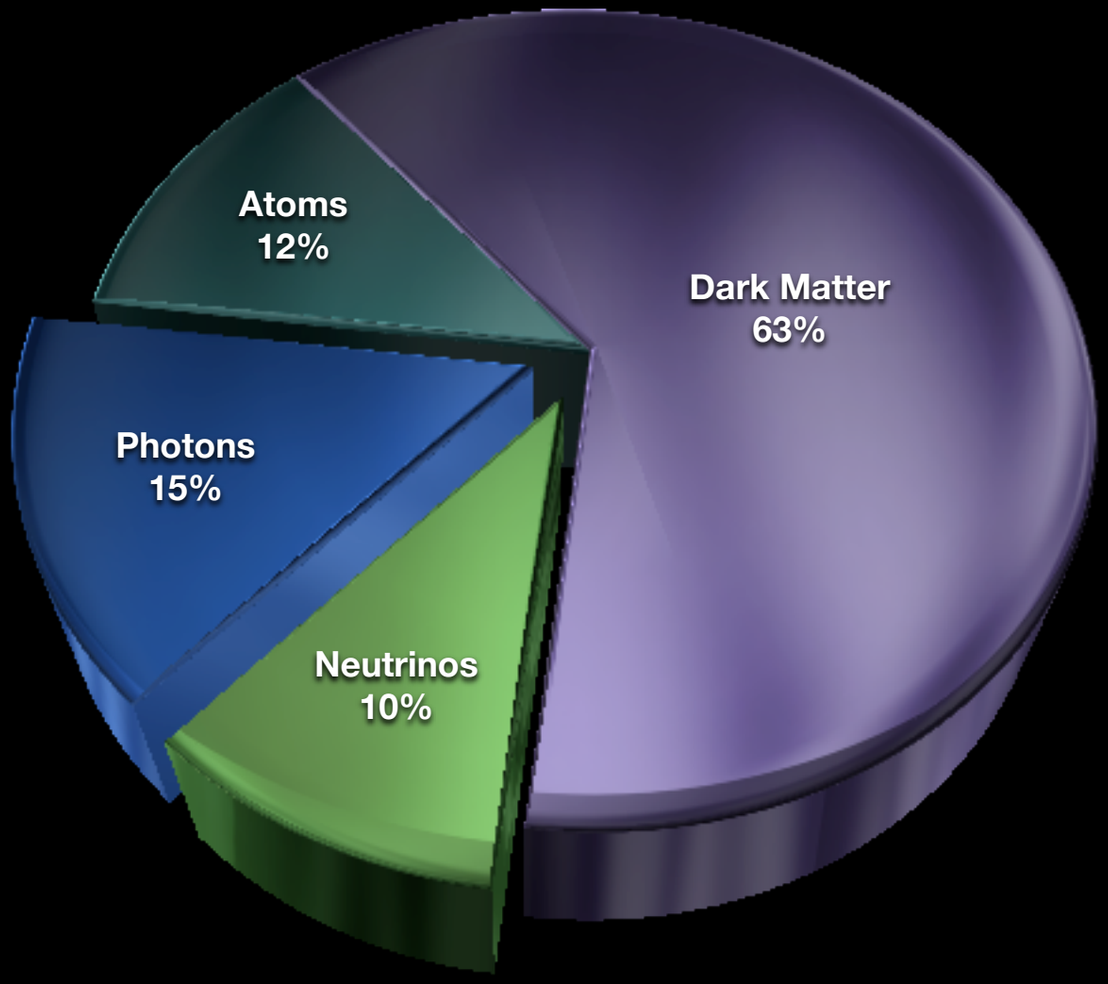
$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

Ω_b

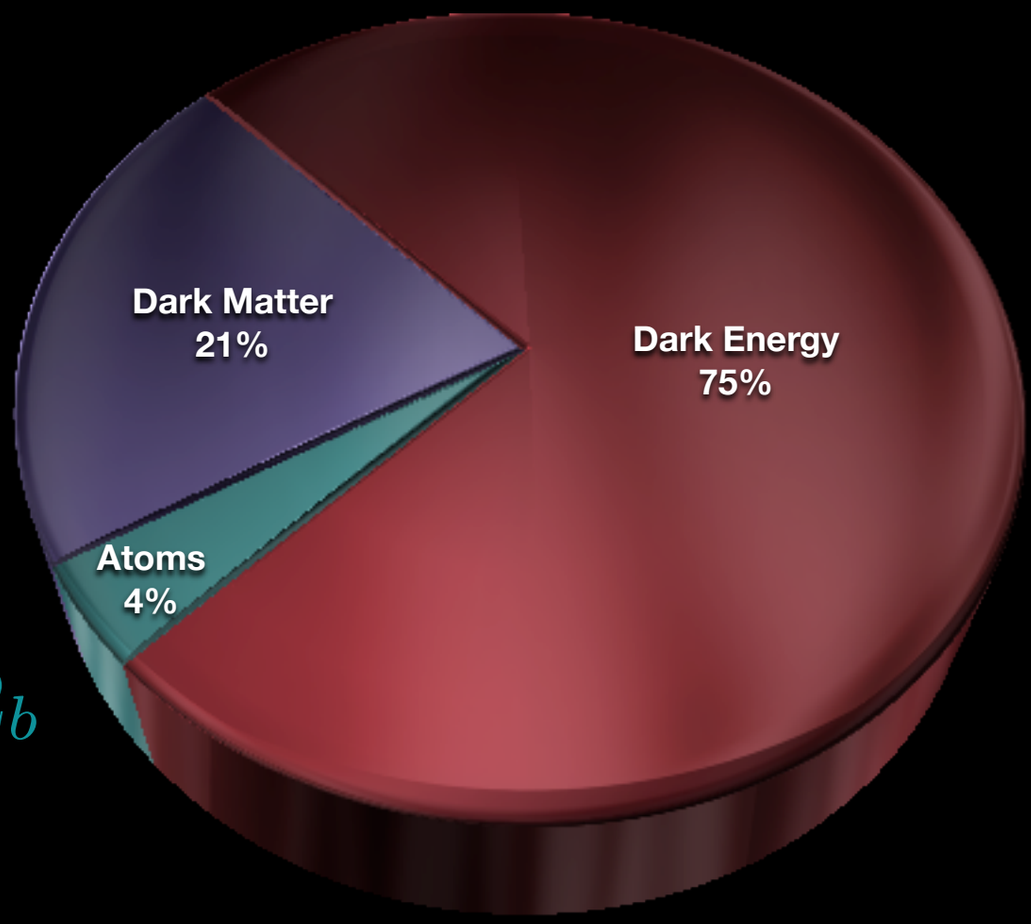


$$\Omega_0 \equiv \frac{\rho_0}{\rho_{cr,0}} \simeq 1$$





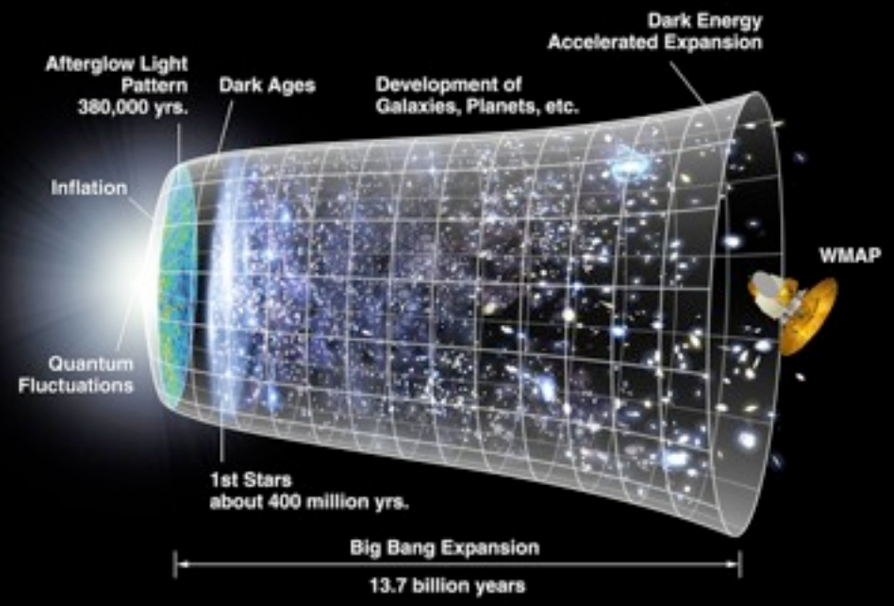
Ω_{cdm}

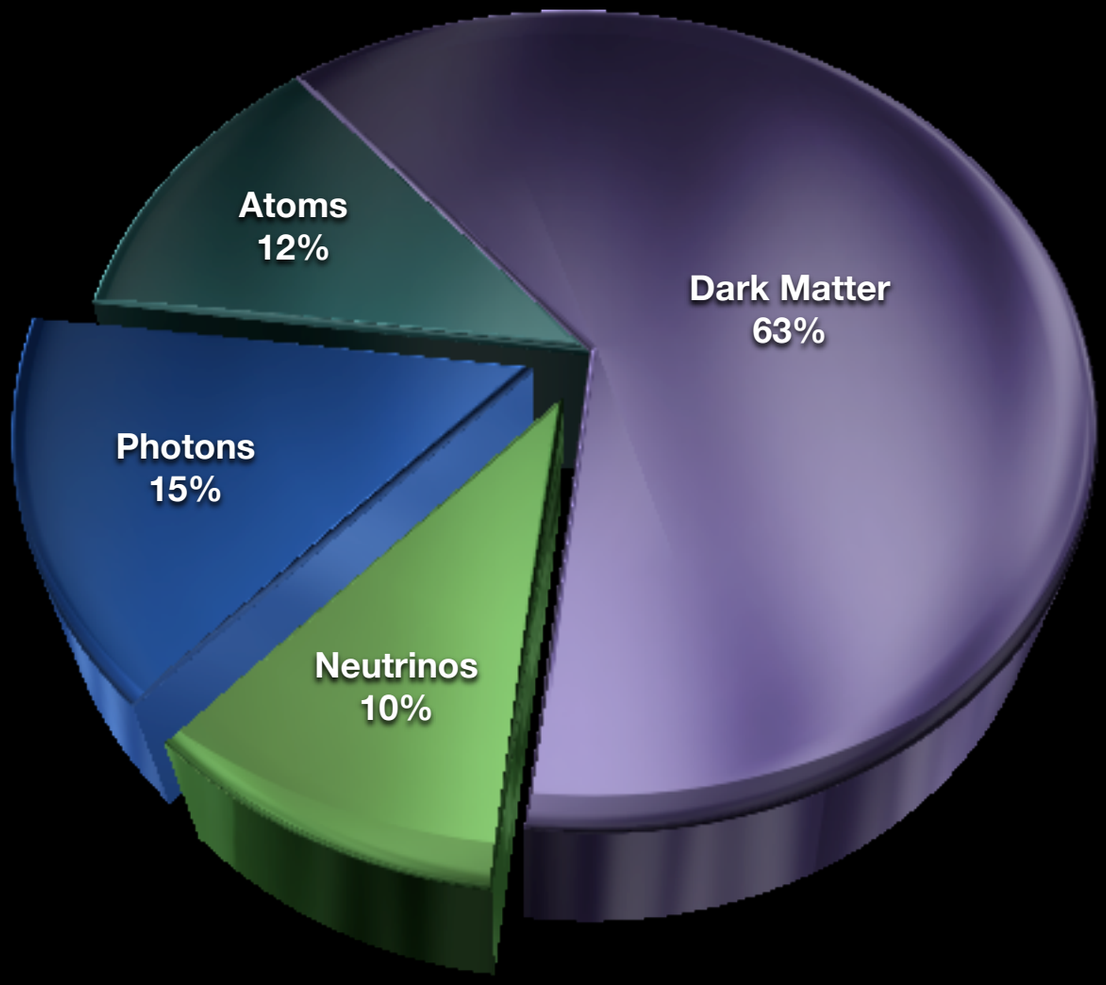


Ω_b

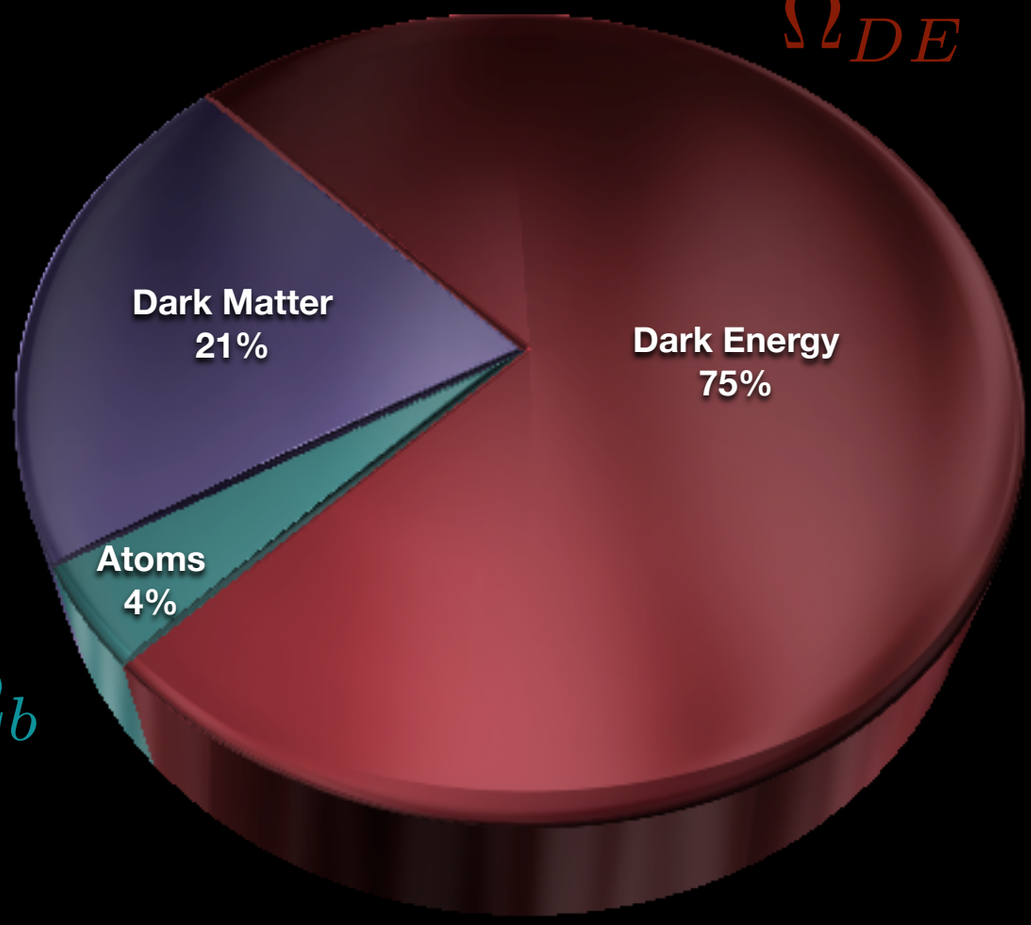
$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

$$\Omega_0 \equiv \frac{\rho_0}{\rho_{cr,0}} \simeq 1$$





Ω_{cdm}

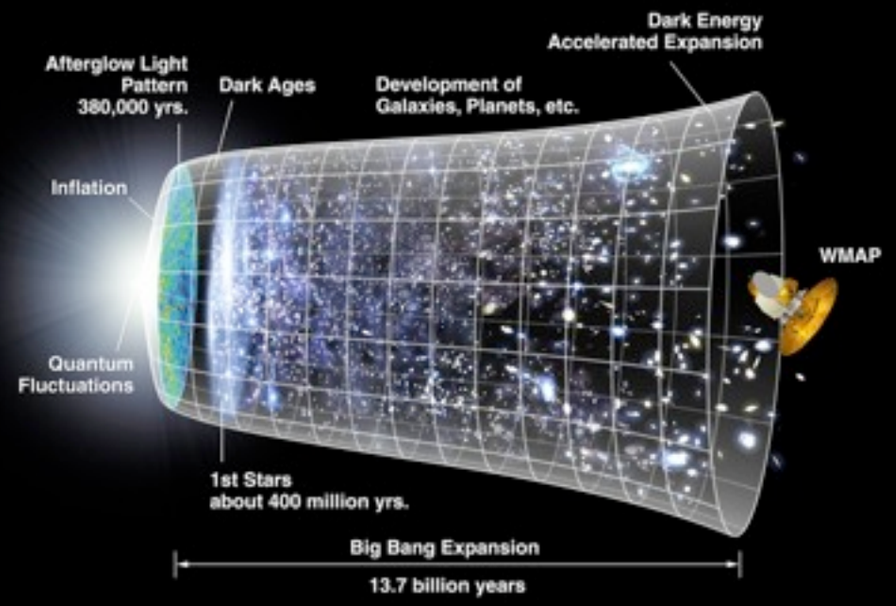


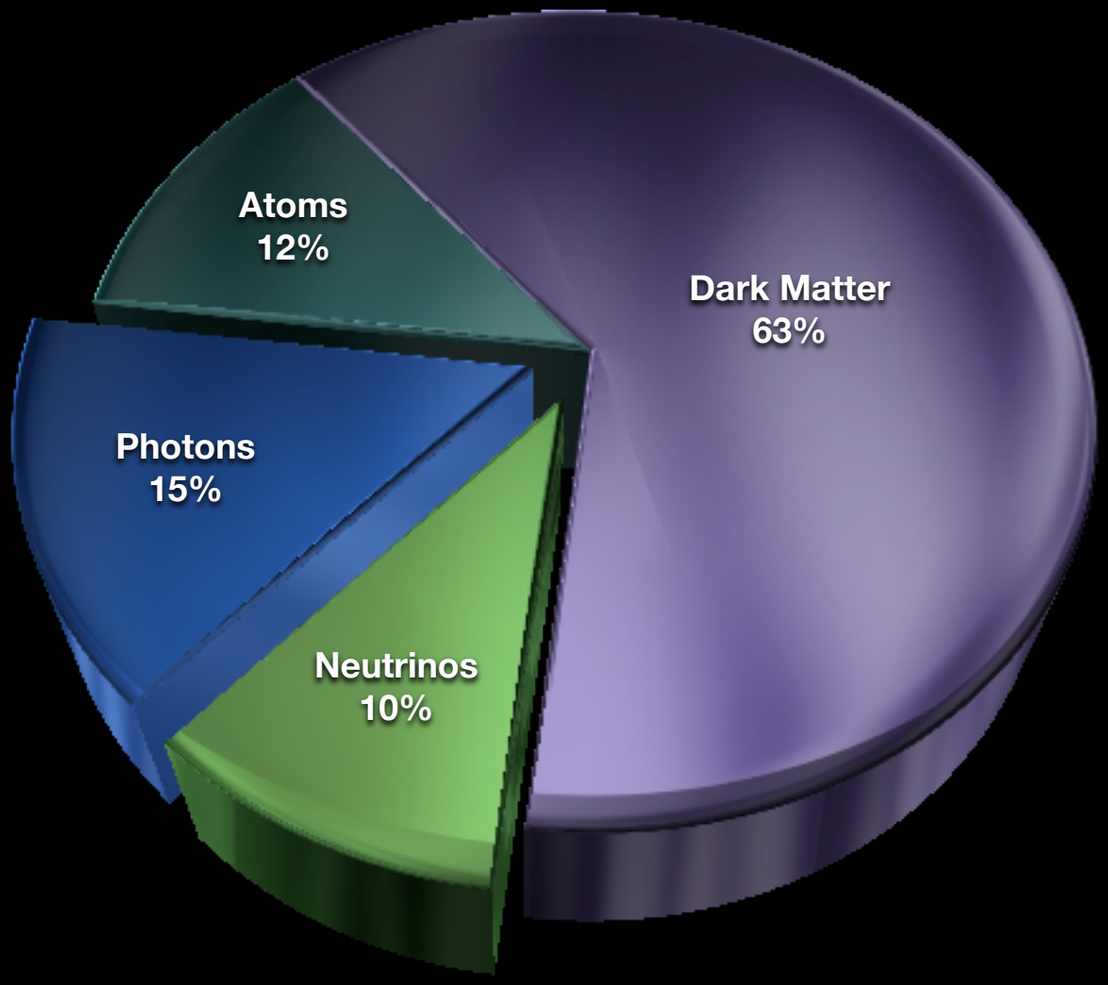
Ω_{DE}

Ω_b

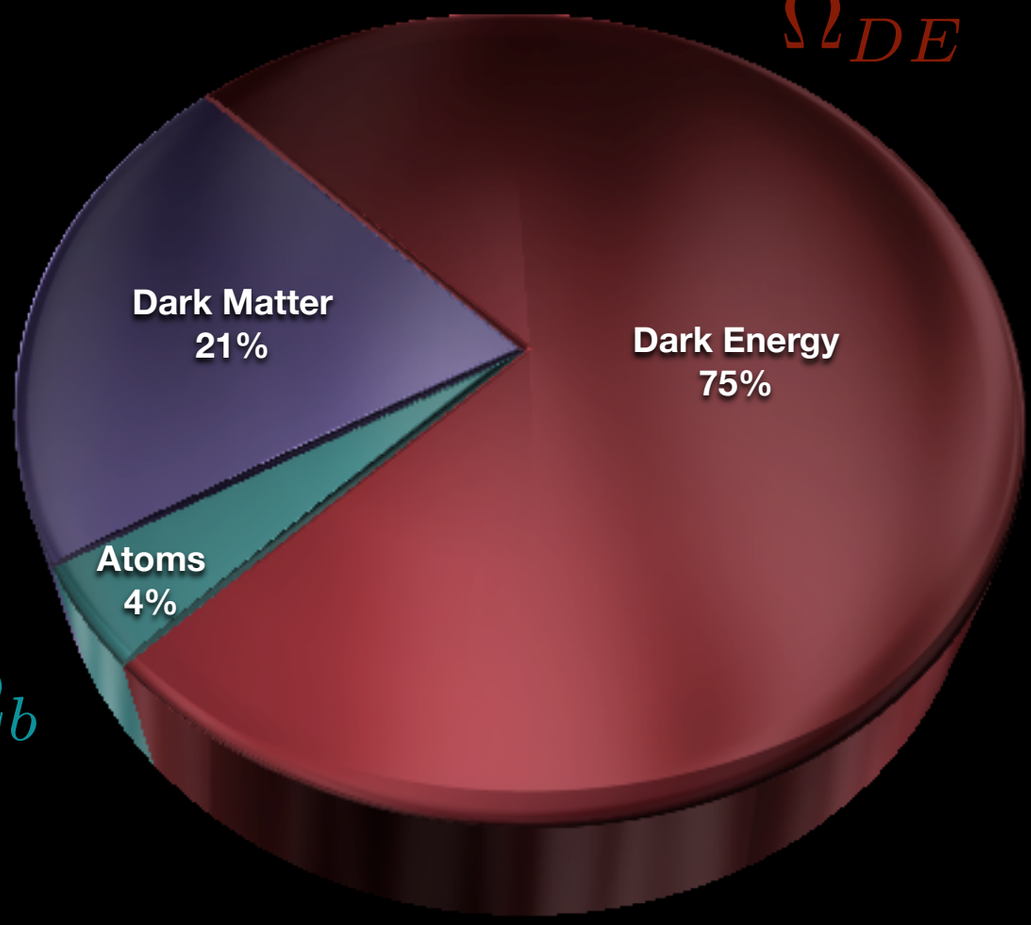
$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

$$\Omega_0 \equiv \frac{\rho_0}{\rho_{cr,0}} \simeq 1$$





Ω_{cdm}



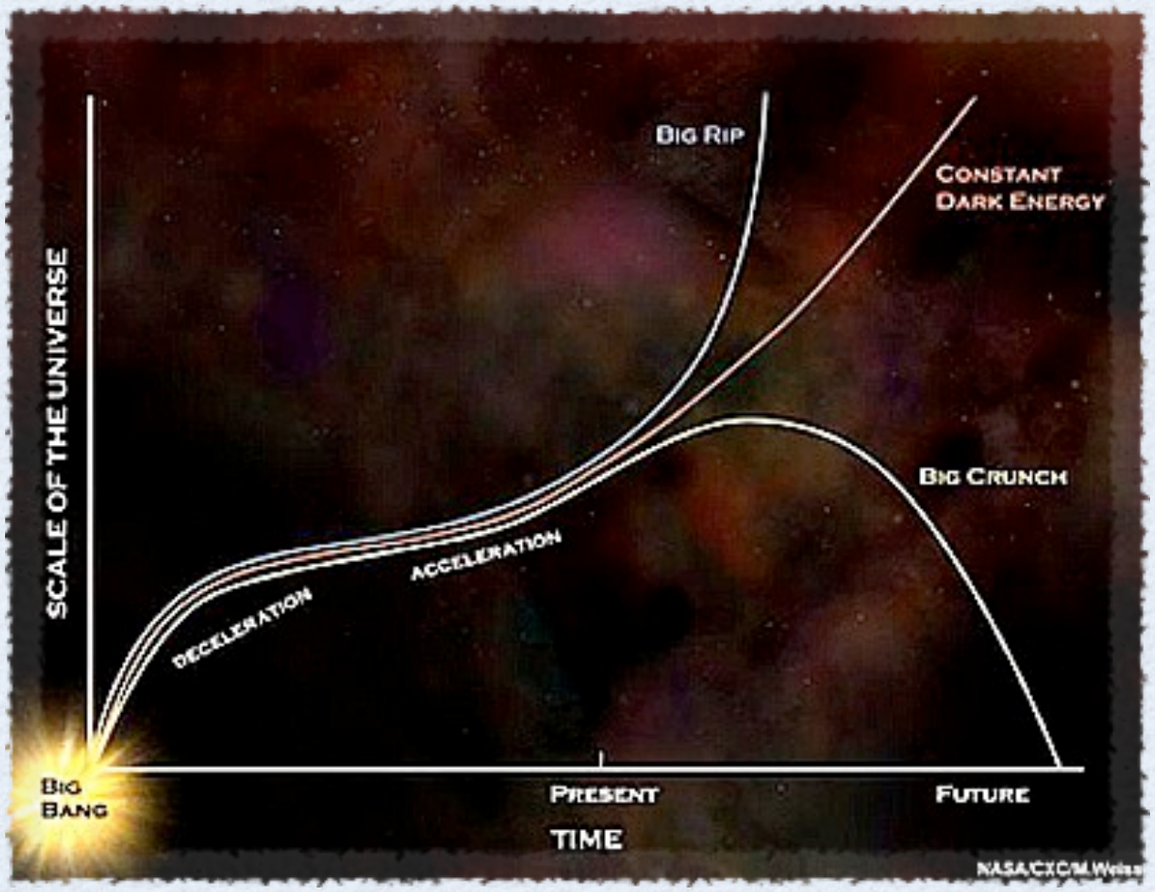
Ω_{DE}

Ω_b

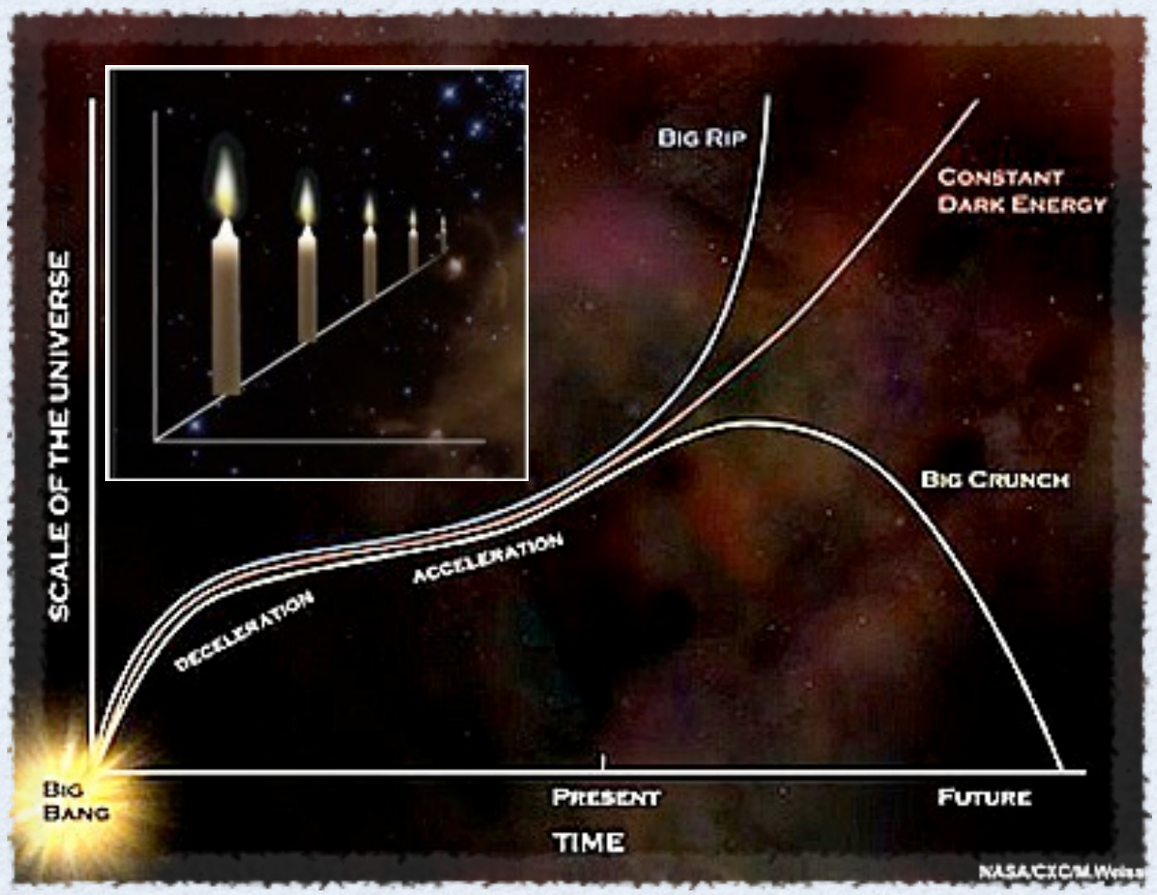
$$\Omega \equiv \frac{\rho}{\rho_{cr}} \simeq 1$$

$$\Omega_0 = (\Omega_b + \Omega_{cdm} + \Omega_{DE}) \simeq 1$$

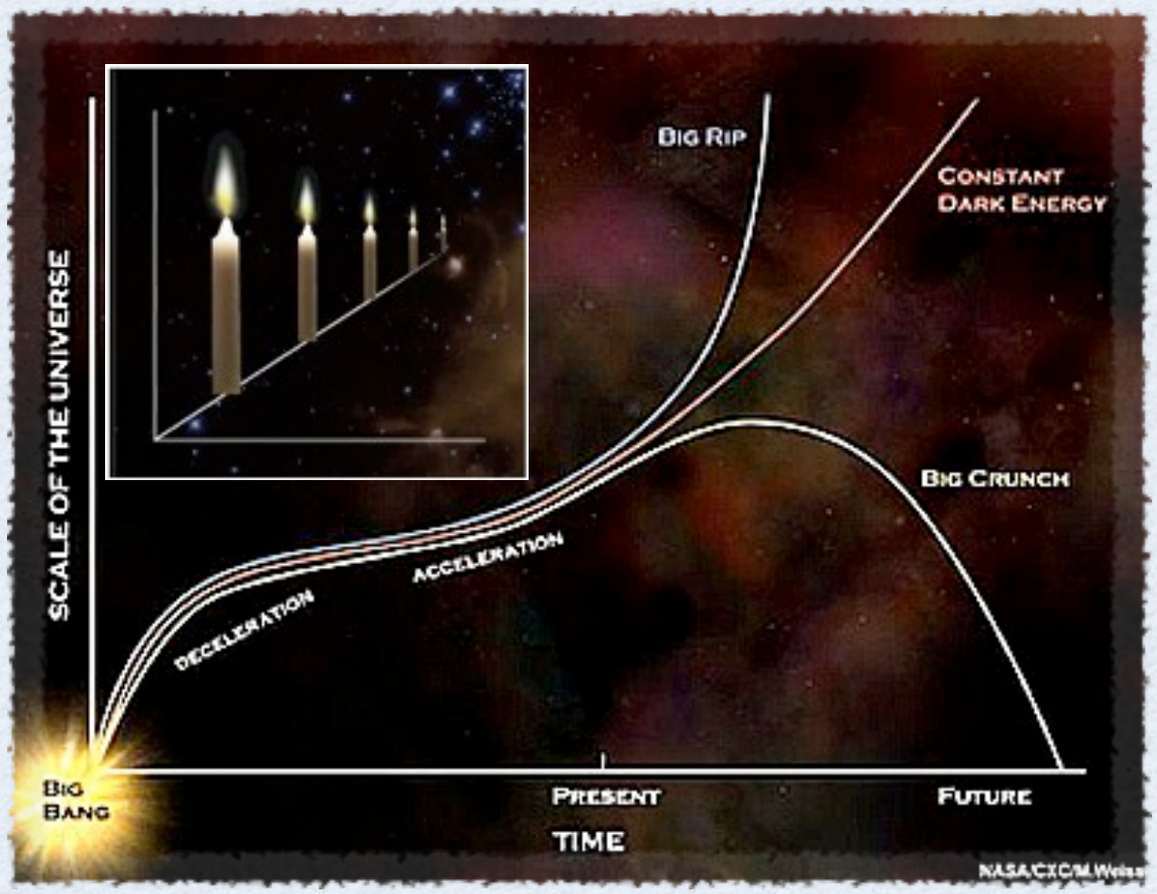
"SEEING" THE DARK ENERGY



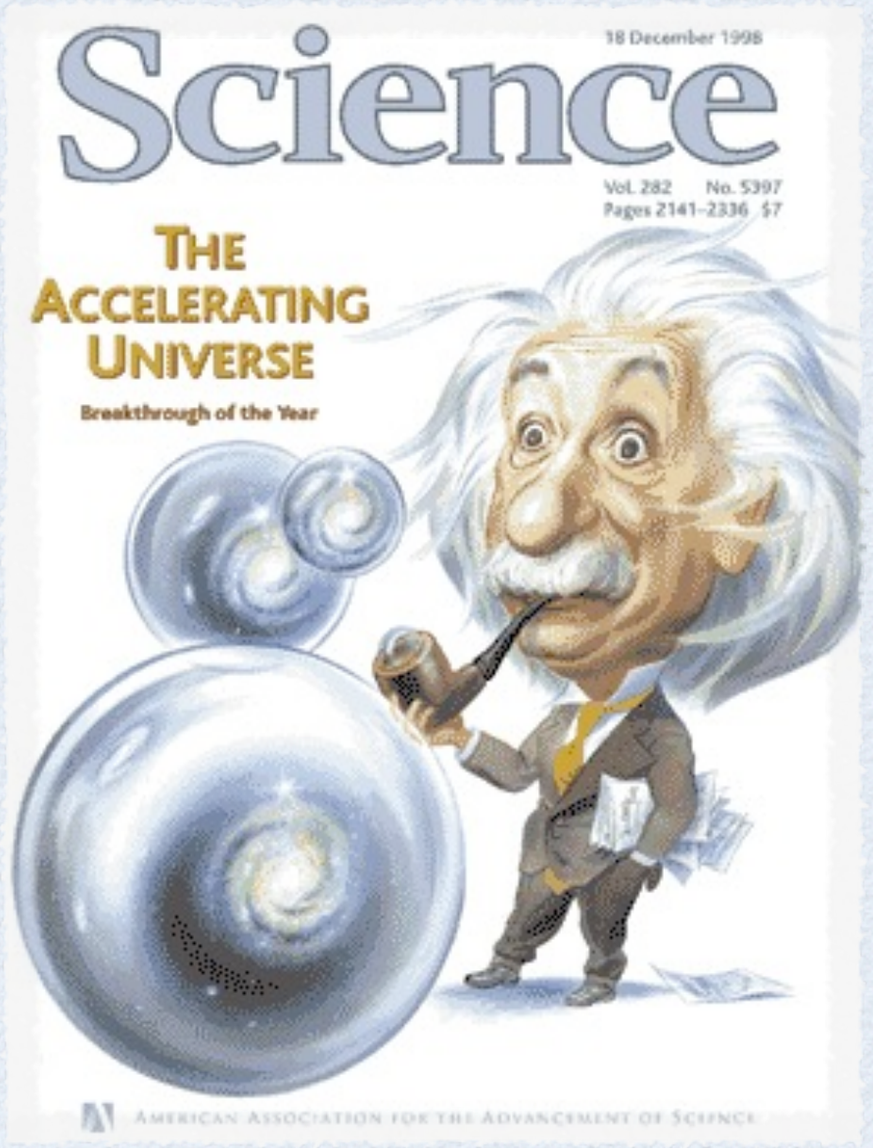
"SEEING" THE DARK ENERGY



"SEEING" THE DARK ENERGY

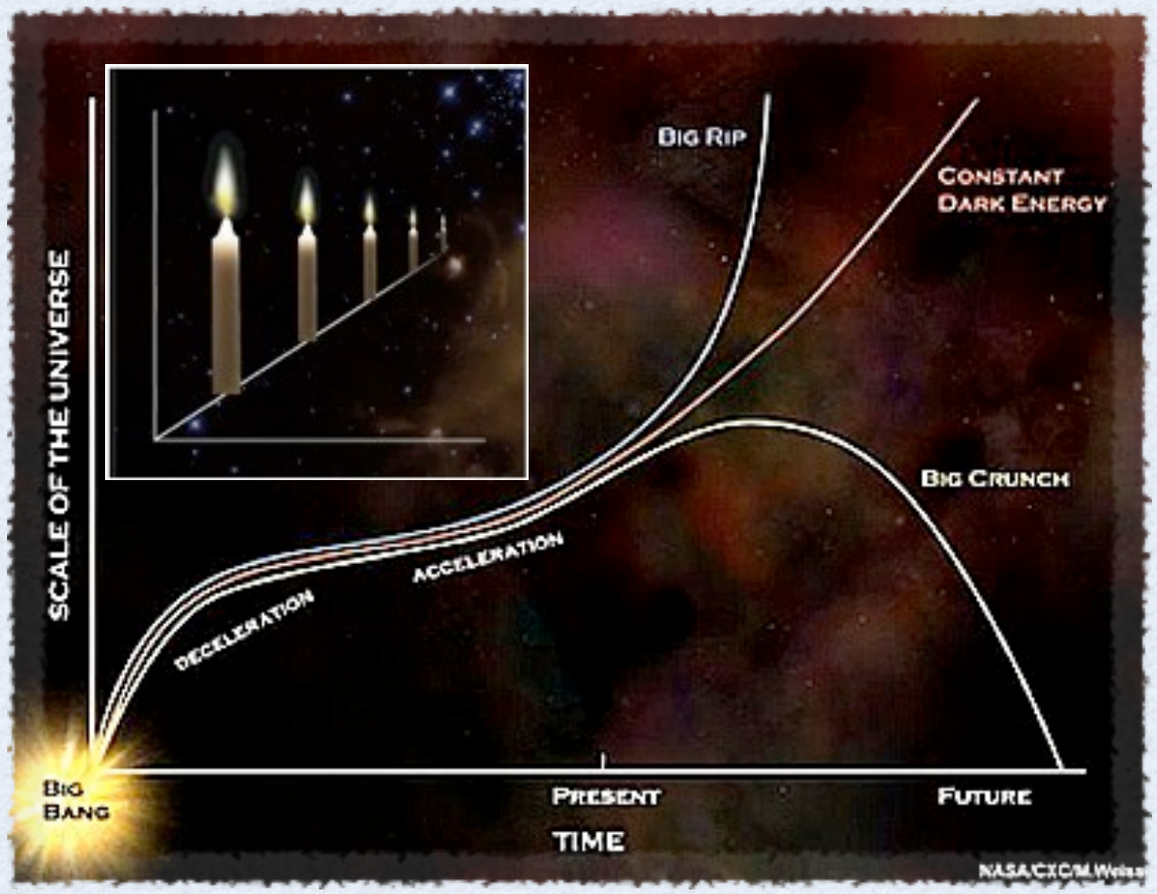


1998

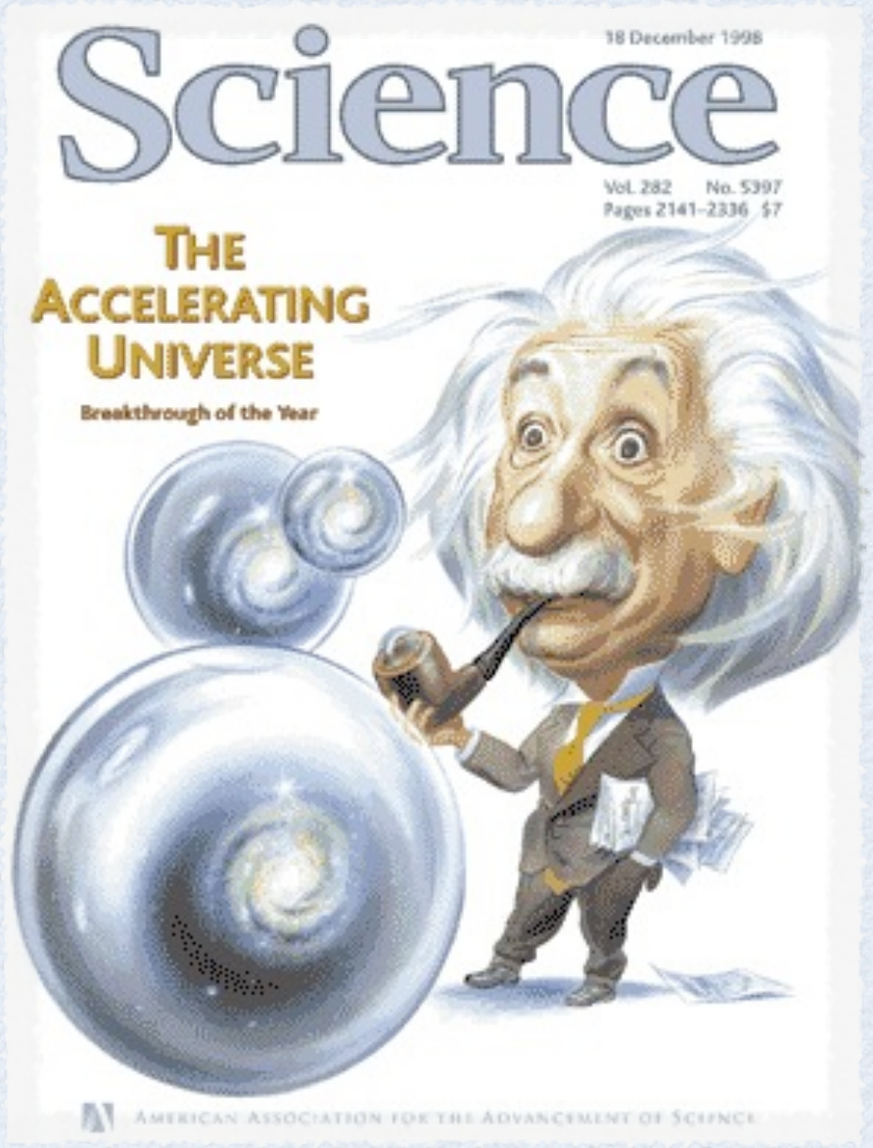


High-z Supernova Search Team

"SEEING" THE DARK ENERGY

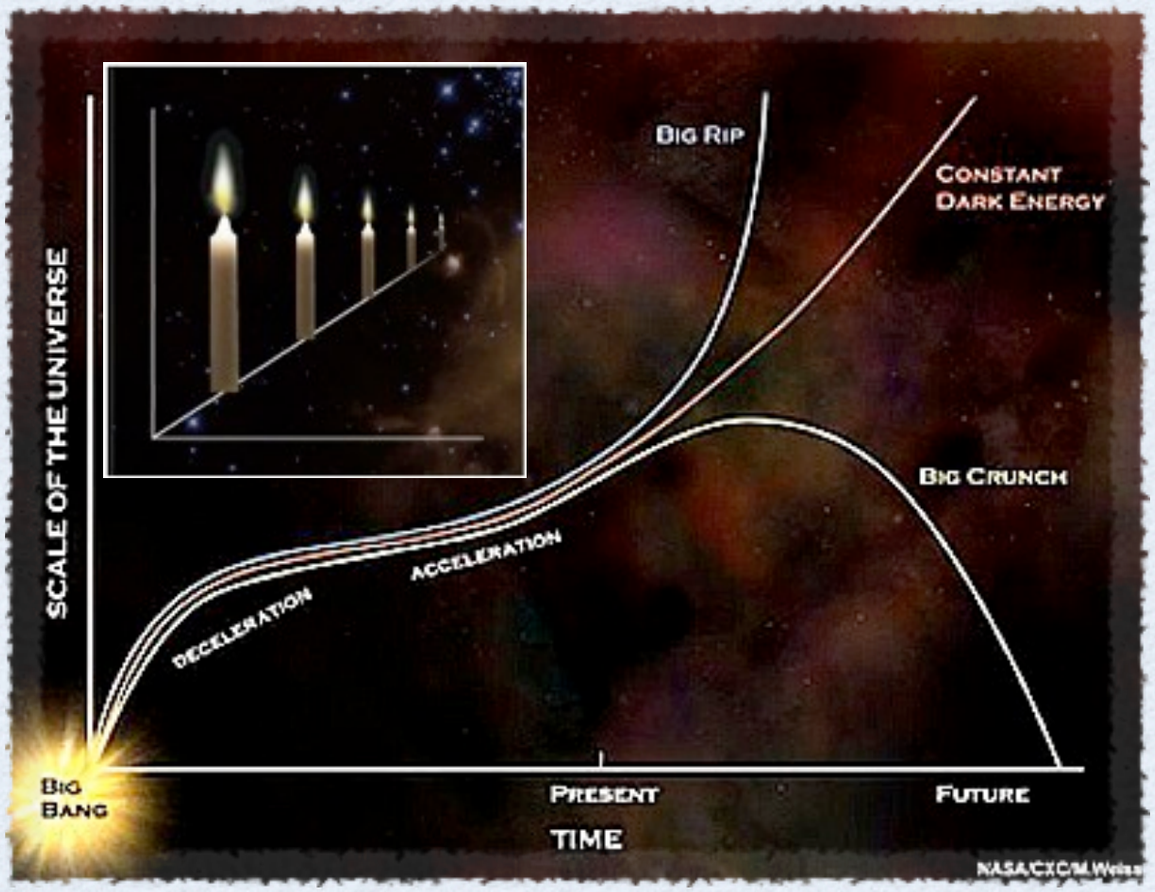


1998



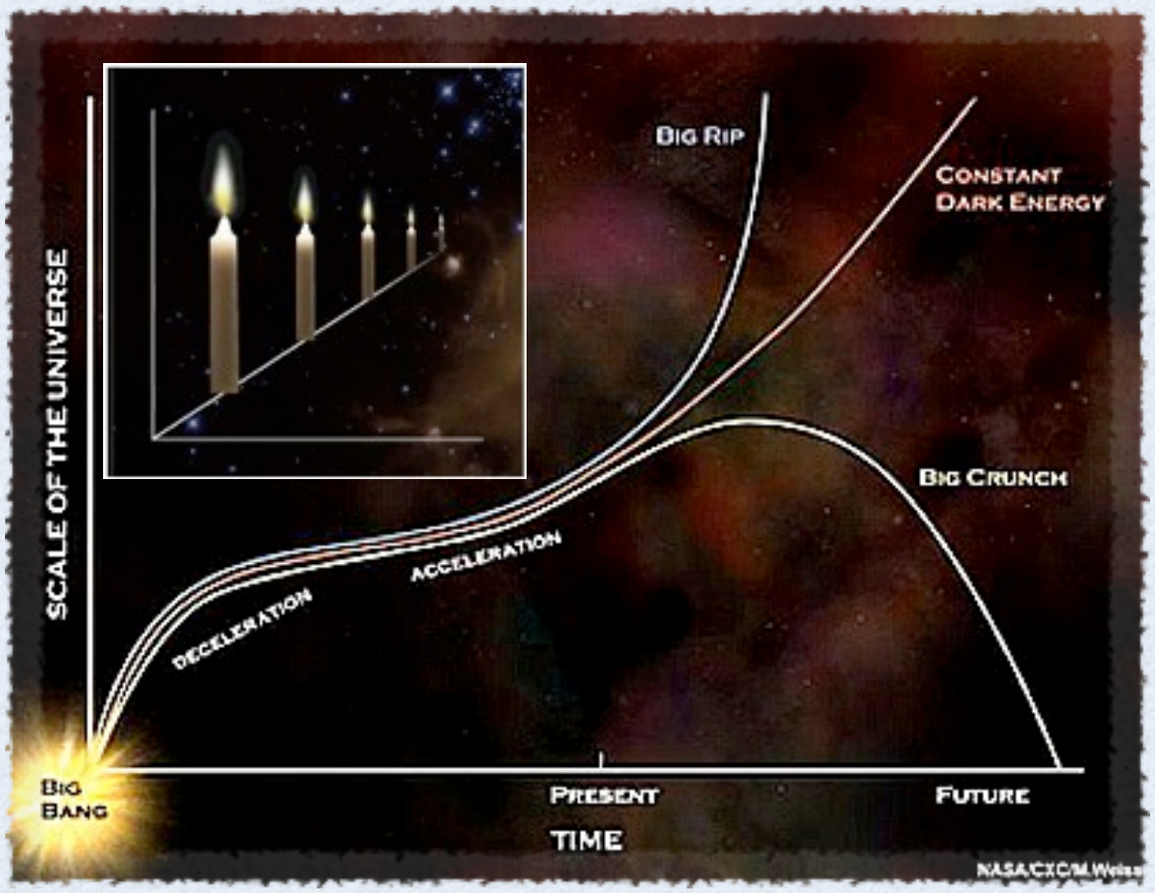
High-z Supernova Search Team
Supernova Cosmology Project Team

"SEEING" THE DARK ENERGY



$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t)$$

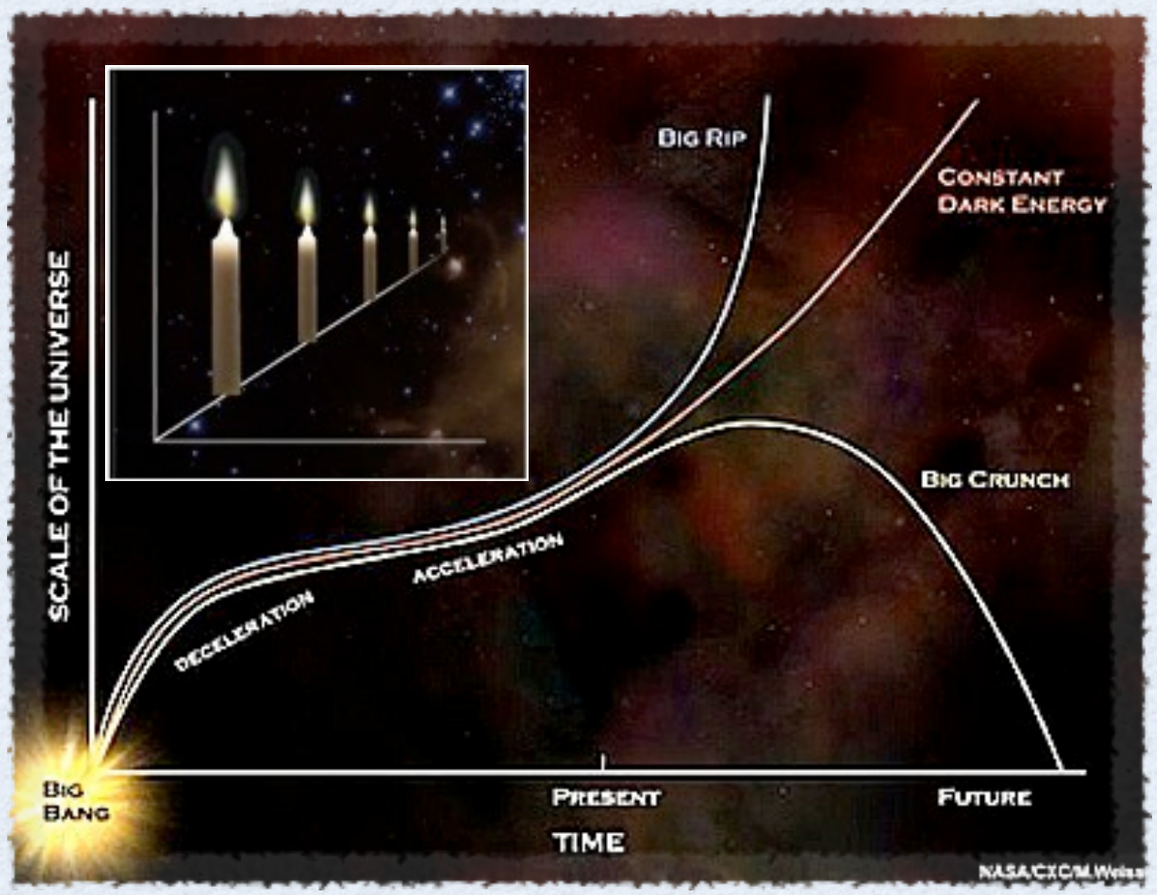
"SEEING" THE DARK ENERGY



$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t)$$

$$H^2(z) = H_0^2\left[\Omega_{m,0}(1+z)^3 + \Omega_{X,0}F(z)\right]$$

"SEEING" THE DARK ENERGY

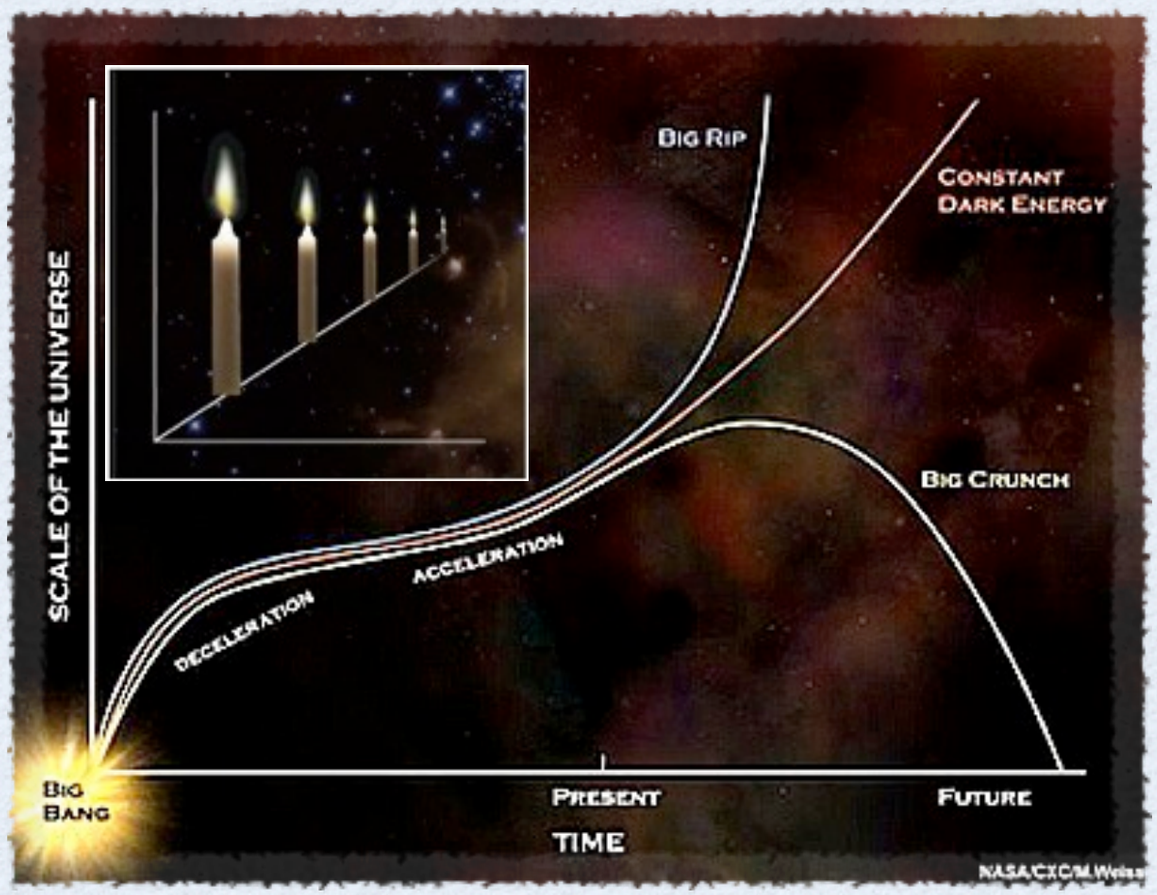


$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t)$$

$$H^2(z) = H_0^2\left[\Omega_{m,0}(1+z)^3 + \Omega_{X,0}F(z)\right]$$

$$d_L(z) = (1+z)\int_0^z \frac{c\,dz'}{H(z')}$$

"SEEING" THE DARK ENERGY



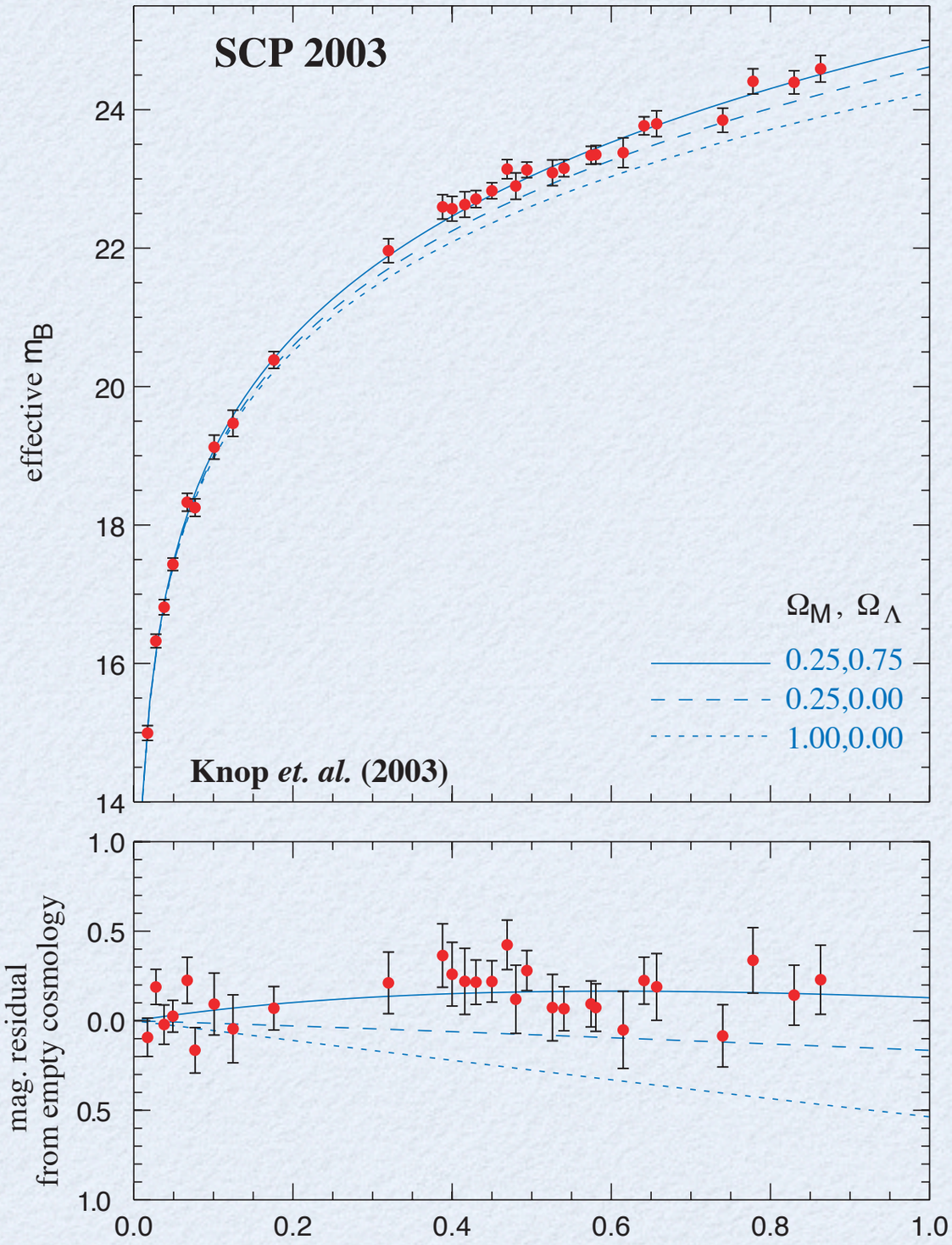
$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t)$$

$$H^2(z) = H_0^2\left[\Omega_{m,0}(1+z)^3 + \Omega_{X,0}F(z)\right]$$

$$d_L(z) = (1+z)\int_0^z \frac{c\,dz'}{H(z')}$$

$$m - M = 5\log_{10}\left(\frac{d_L}{\mathrm{Mpc}}\right) + 25$$

"SEEING" THE DARK ENERGY



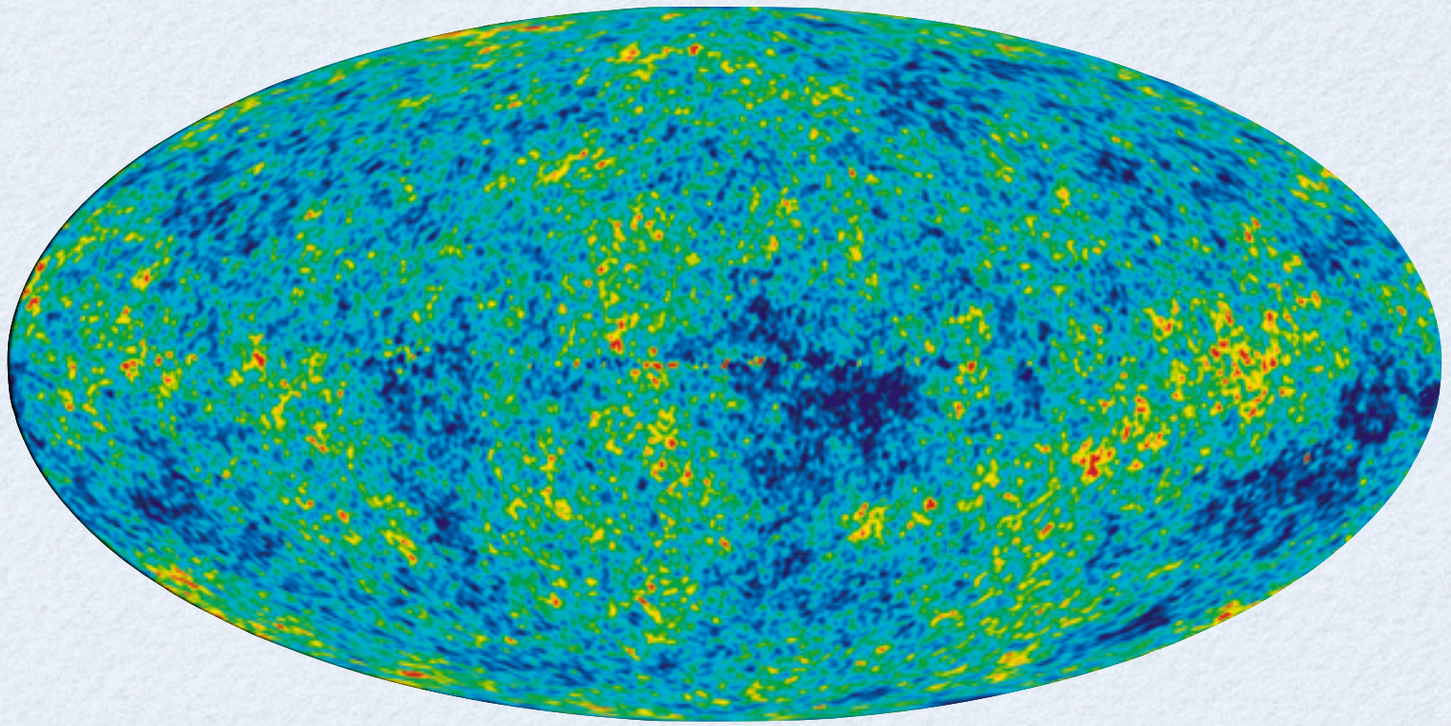
$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t)$$

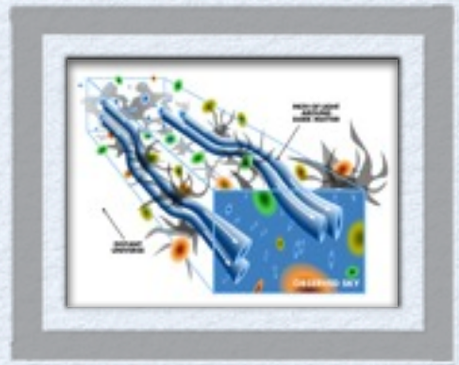
$$H^2(z) = H_0^2\left[\Omega_{m,0}(1+z)^3 + \Omega_{X,0}F(z)\right]$$

$$d_L(z) = (1+z)\int_0^z \frac{c\,dz'}{H(z')}$$

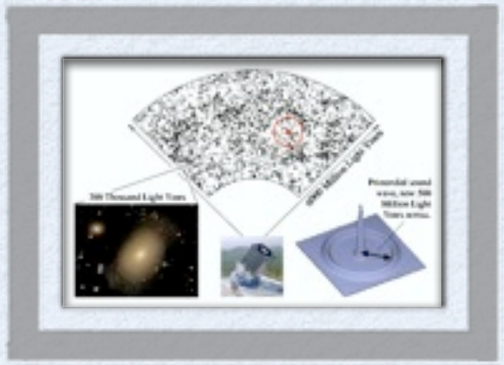
$$m - M = 5\log_{10}\left(\frac{d_L}{\mathrm{Mpc}}\right) + 25$$

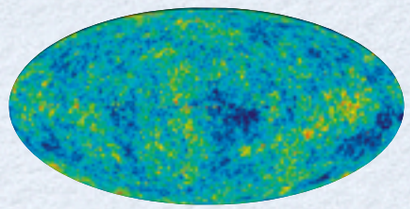
"SEEING" THE DARK ENERGY



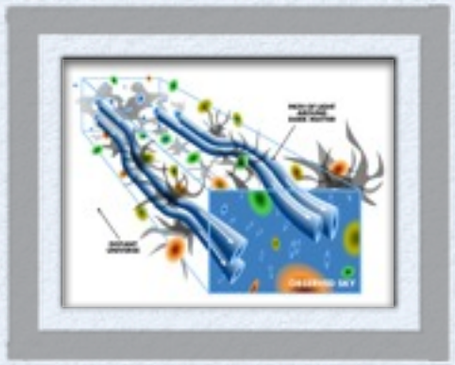


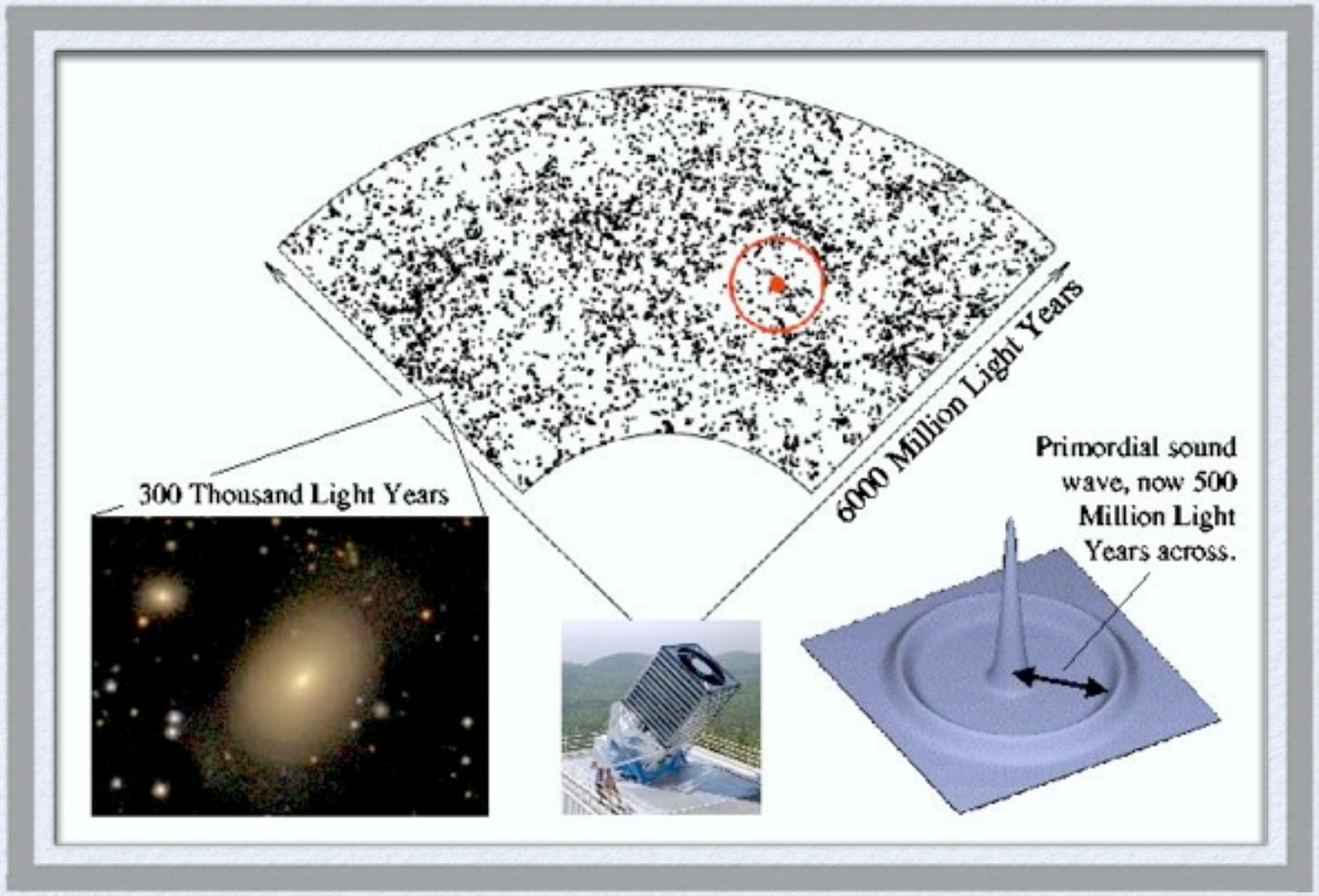
"SEEING" THE DARK ENERGY



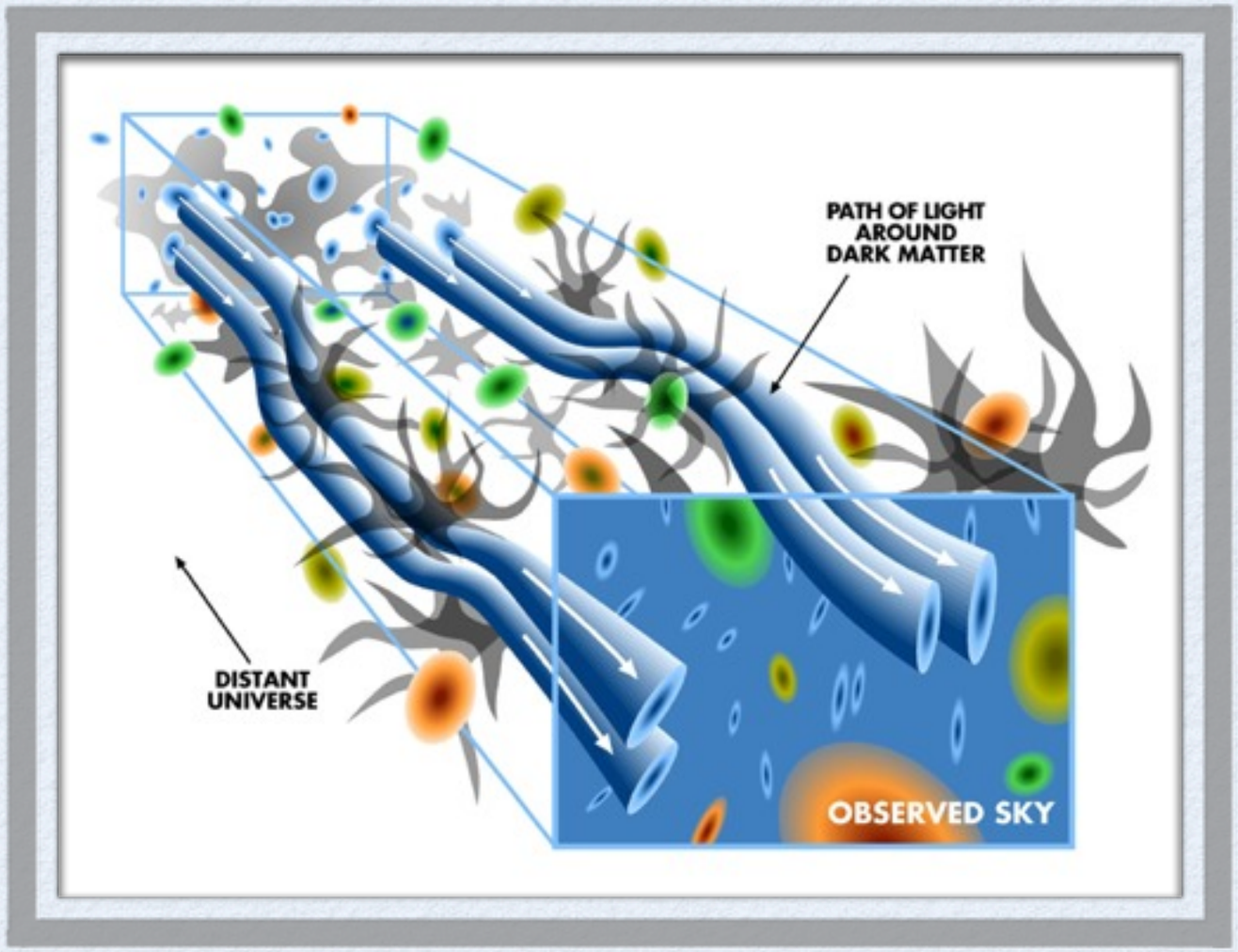


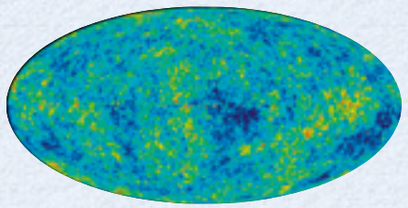
"SEEING" THE DARK ENERGY

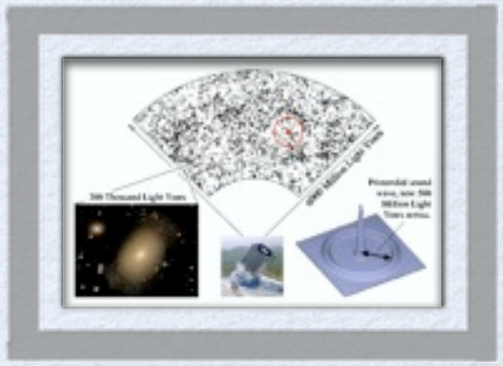




"SEEING" THE DARK ENERGY







DARK ENERGY EQUATION OF STATE

Conservation Equation: $\dfrac{d\rho}{dt} = -\dfrac{3\dot{a}}{a}(\rho + p)$

DARK ENERGY EQUATION OF STATE

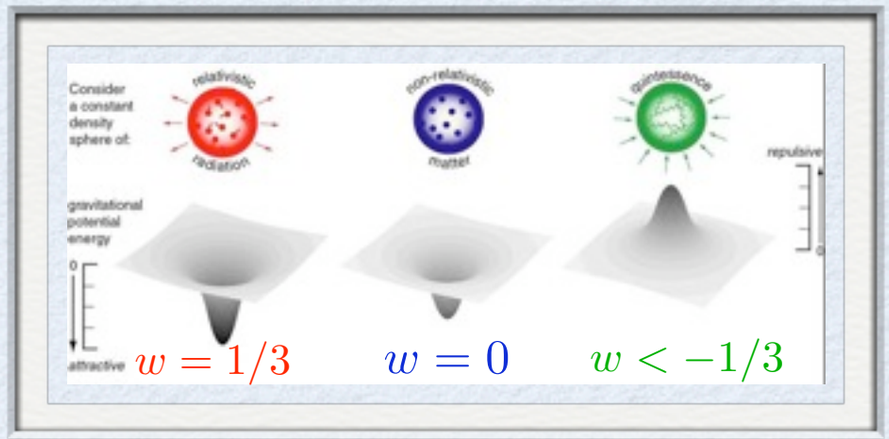
Conservation Equation: $\frac{d\rho}{dt} = -\frac{3\dot{a}}{a}(\rho + p)$

$$p = w\rho$$

DARK ENERGY EQUATION OF STATE

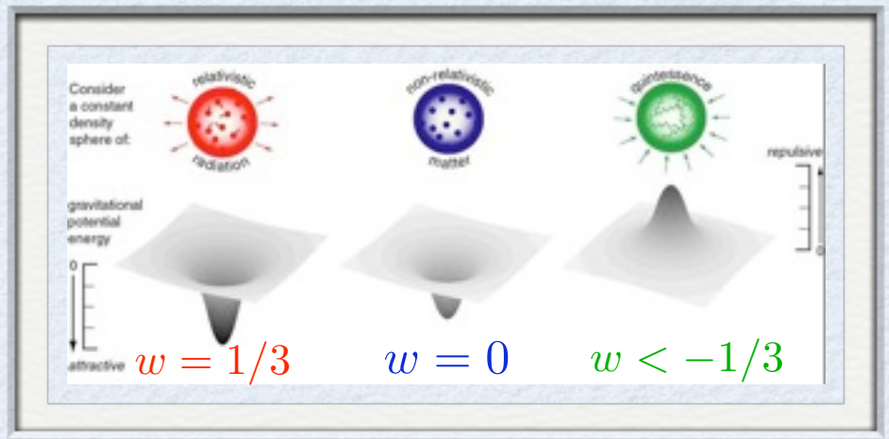
Conservation Equation: $\dfrac{d\rho}{dt} = -\dfrac{3\dot{a}}{a}(\rho + p)$

$$p = w\rho$$



DARK ENERGY EQUATION OF STATE

Conservation Equation: $\dfrac{d\rho}{dt} = -\dfrac{3\dot{a}}{a}(\rho + p)$



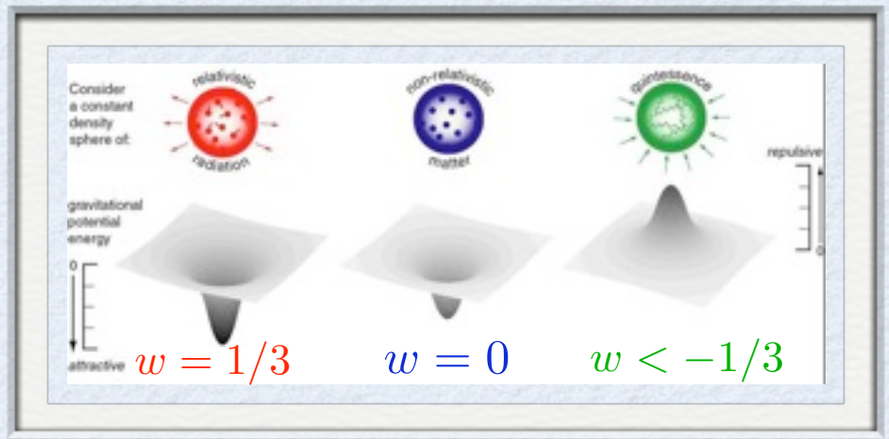
$$p = w\rho$$

If "w" depends of cosmic time

$$\rho(z) = \rho_0 \exp\left(3\int_0^z \frac{1 + w(z')}{1 + z'} dz'\right)$$

DARK ENERGY EQUATION OF STATE

Conservation Equation: $\dfrac{d\rho}{dt} = -\dfrac{3\dot{a}}{a}(\rho + p)$



$$p = w\rho$$

If "w" depends of cosmic time

$$\rho(z) = \rho_0 \exp\left(3\int_0^z \frac{1 + w(z')}{1 + z'} dz'\right)$$

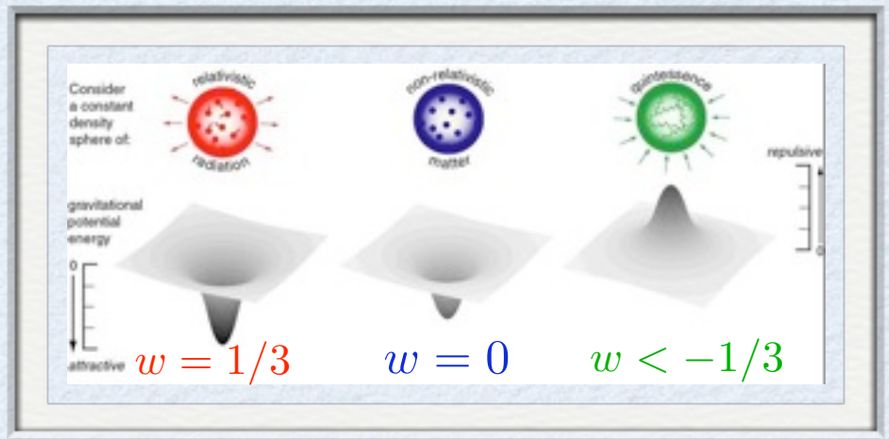
$w = -1$: cosmological constant, Λ

$w =$ constant

evolving w

DARK ENERGY EQUATION OF STATE

Conservation Equation: $\dfrac{d\rho}{dt} = -\dfrac{3\dot{a}}{a}(\rho + p)$



$$p = w\rho$$

If "w" depends of cosmic time

$$\rho(z) = \rho_0 \exp\left(3\int_0^z \frac{1 + w(z')}{1 + z'} dz'\right)$$

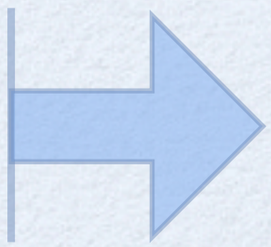
$w = -1$: cosmological constant, Λ

$w =$ constant

evolving w

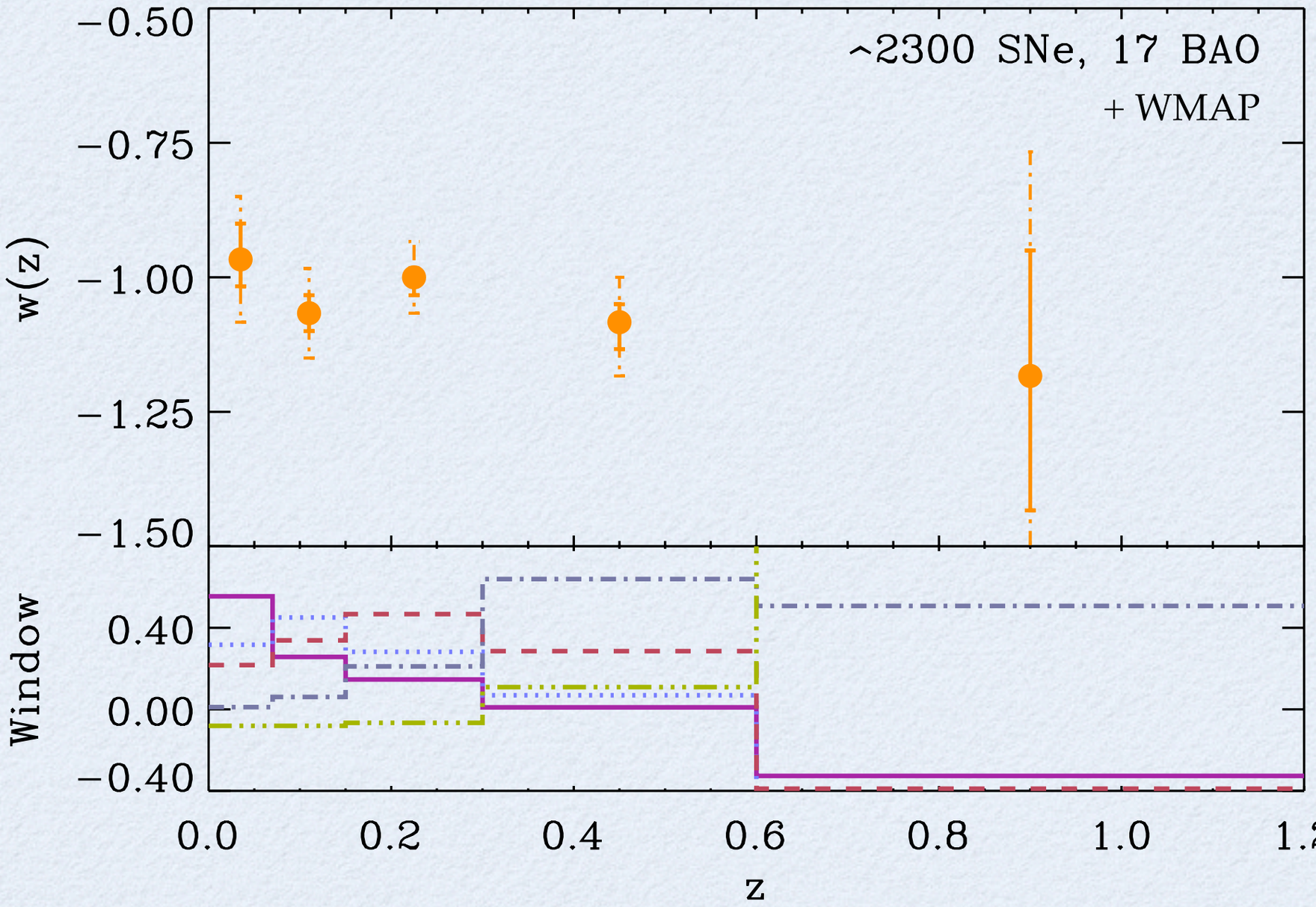
Typically, one (popular) approach is to parameterize the EOS:

$$w(a) = w_0 + (1 - a)w_a$$



2-Parameter description of w(z)

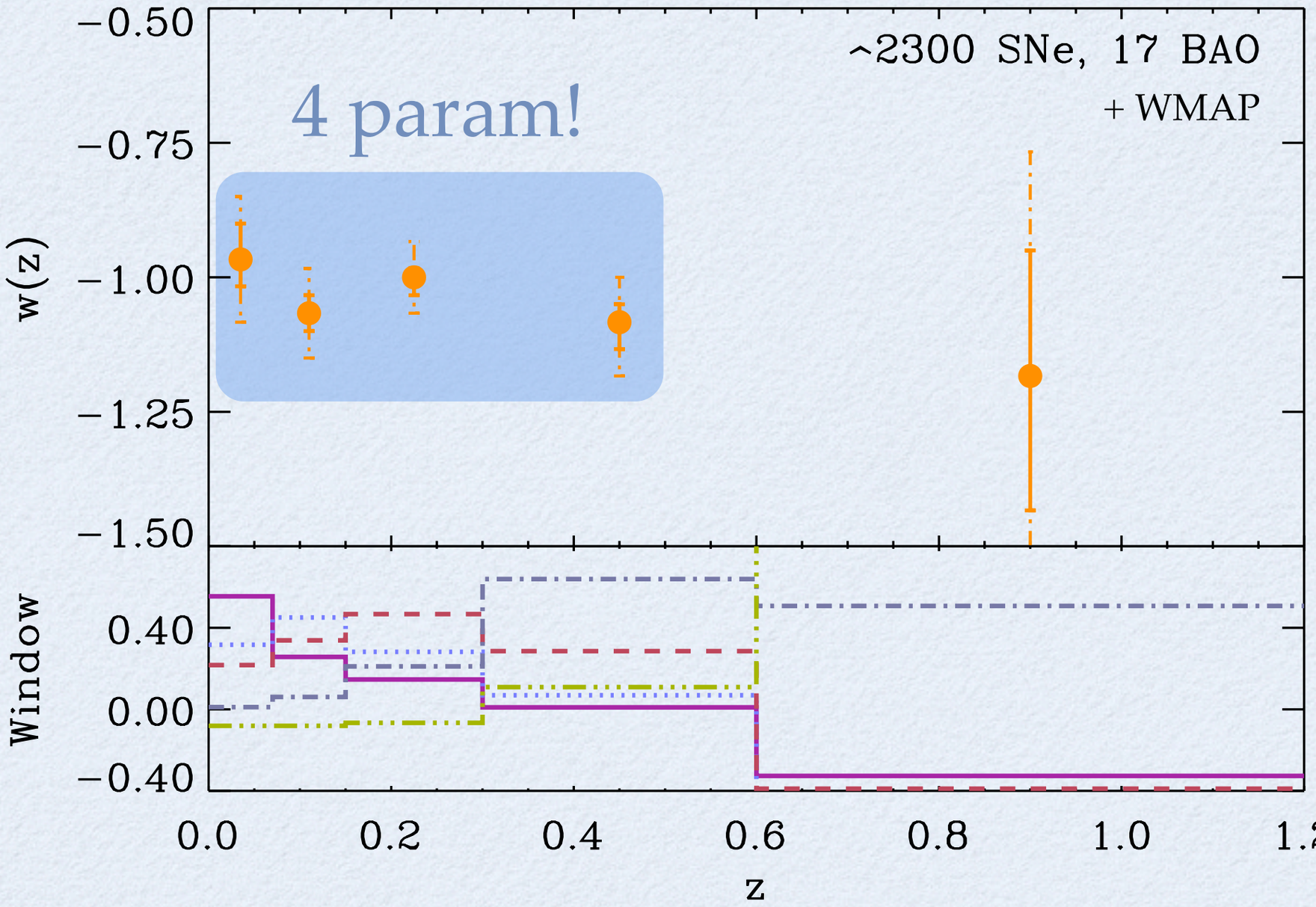
Thinking BEYOND 2-Parameter Description...



W	Zup
w_1	0.07
w_2	0.15
w_3	0.3
w_4	0.6
w_5	1.2
w_6	1.8

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

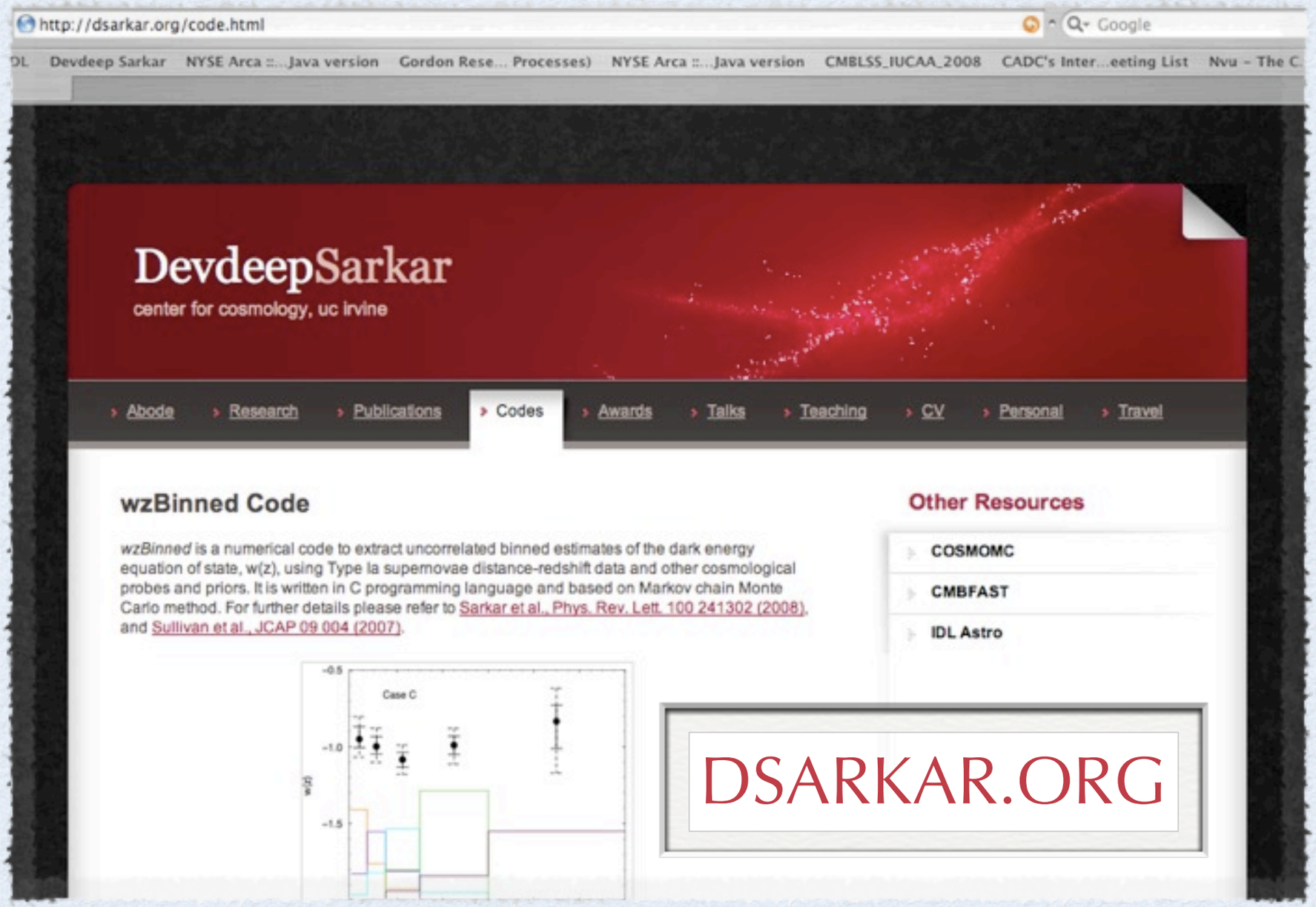
Thinking BEYOND 2-Parameter Description...



W	Zup
w_1	0.07
w_2	0.15
w_3	0.3
w_4	0.6
w_5	1.2
w_6	1.8

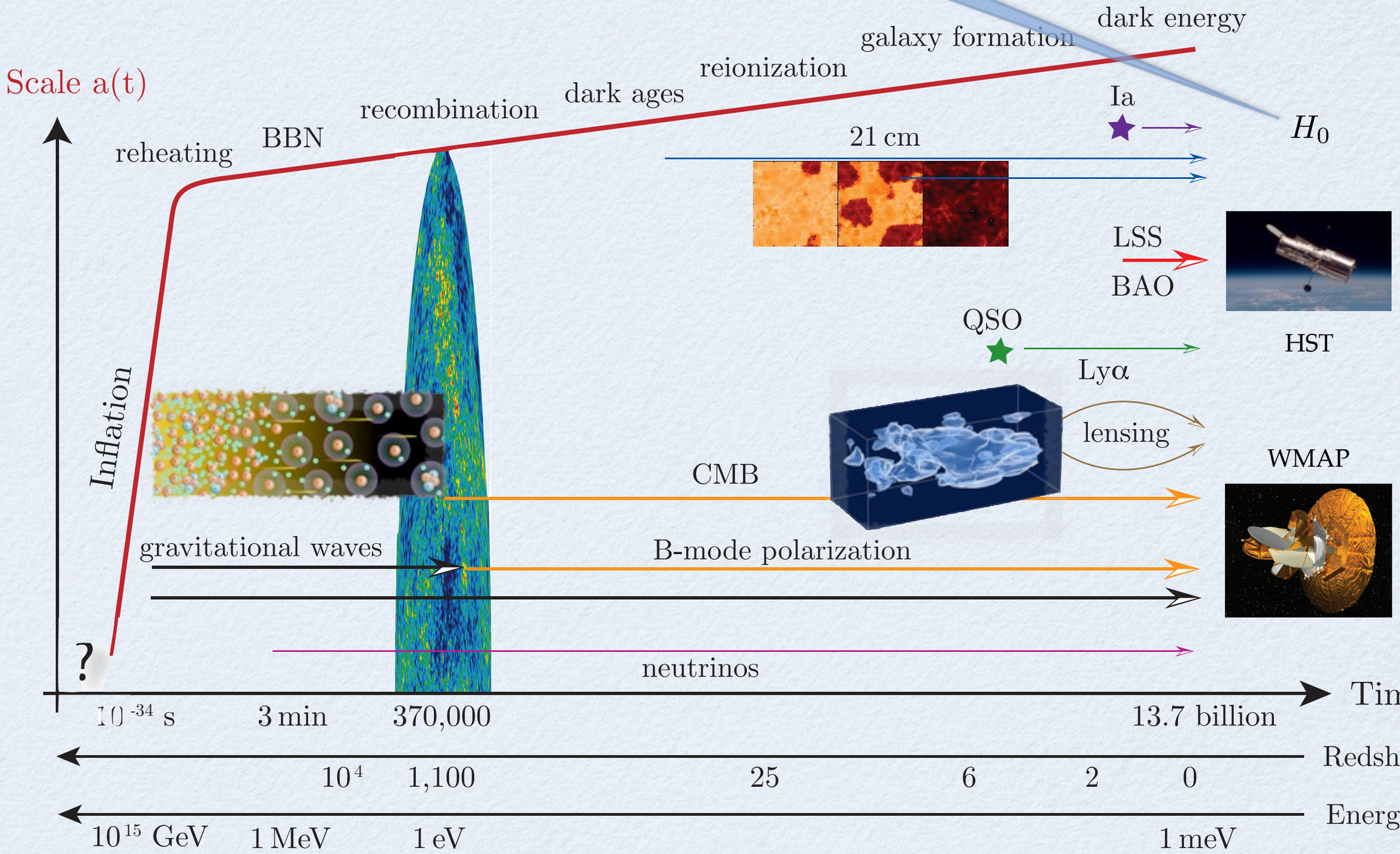
D. Sarkar, S. Sullivan, S. Joudaki, A. Amblard, D. Holz, and A. Cooray, Phys. Rev. Lett., 100, 241302 (2008)

Binned Estimates of w(z) from a combination of datasets



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

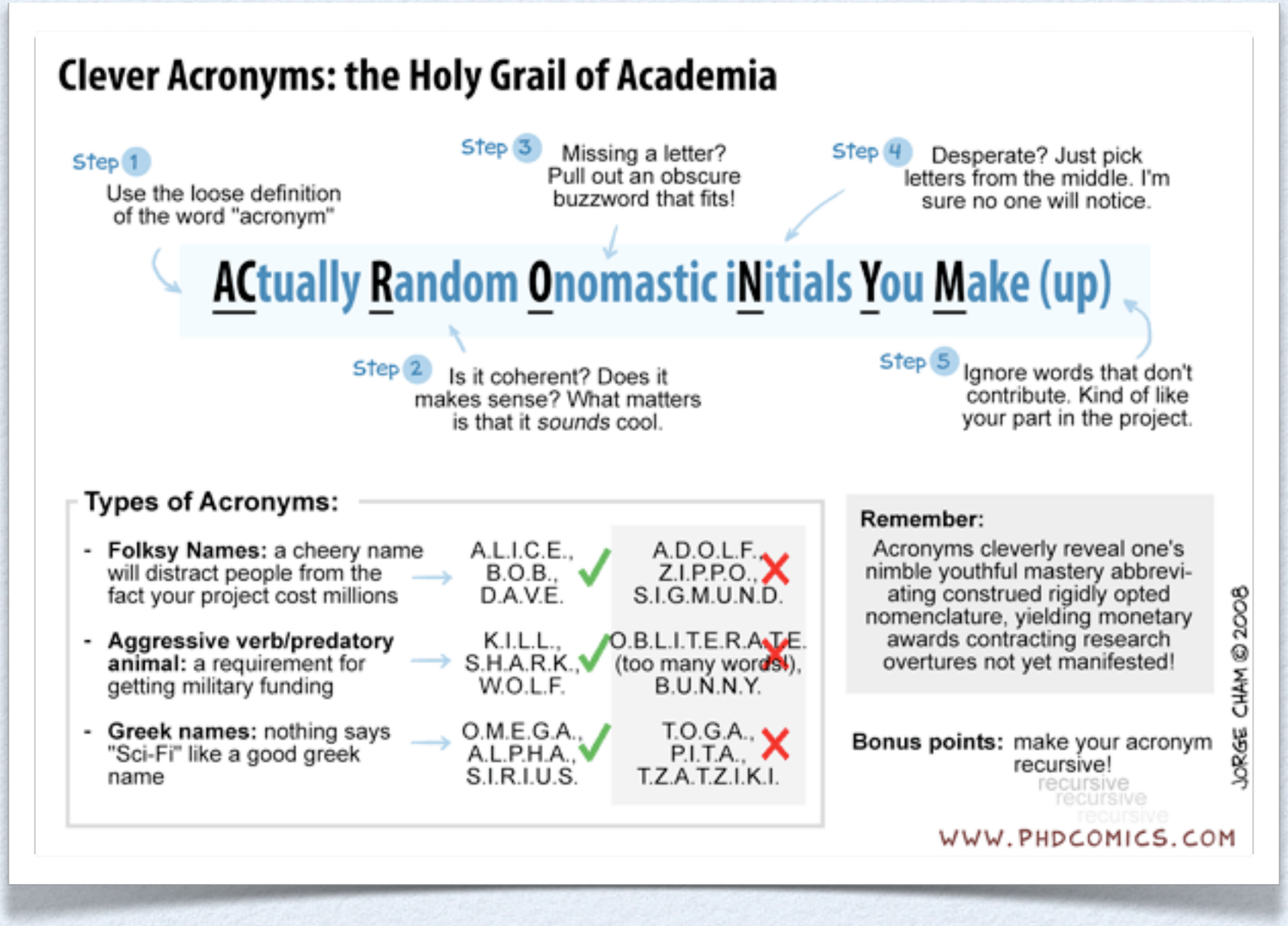
ApJ 2009



D. Baumann and H. Peiris, asXiv:0810.3022

SHoES?

SHoES?


Clever Acronyms: the Holy Grail of Academia
Step 1 Use the loose definition of the word "acronym"
Step 3 Missing a letter? Pull out an obscure buzzword that fits!
Step 4 Desperate? Just pick letters from the middle. I'm sure no one will notice.
ACtually Random Onomastic iNitials You Make (up)
Step 2 Is it coherent? Does it makes sense? What matters is that it sounds cool.
Step 5 Ignore words that don't contribute. Kind of like your part in the project.
Types of Acronyms:
- Folksy Names: a cheery name will distract people from the fact your project cost millions → A.L.I.C.E., B.O.B., D.A.V.E. ✓ A.D.O.L.F., Z.I.P.P.O., S.I.G.M.U.N.D. ✗
- Aggressive verb/predatory animal: a requirement for getting military funding → K.I.L.L., S.H.A.R.K., W.O.L.F. ✓ O.B.L.I.T.E.R.A.T.E. (too many words!), B.U.N.N.Y. ✗
- Greek names: nothing says "Sci-Fi" like a good greek name → O.M.E.G.A., A.L.P.H.A., S.I.R.I.U.S. ✓ T.O.G.A., P.I.T.A., T.Z.A.T.Z.I.K.I. ✗
Remember: Acronyms cleverly reveal one's nimble youthful mastery abbreviating construed rigidly opted nomenclature, yielding monetary awards contracting research overtures not yet manifested!
Bonus points: make your acronym recursive!
recursive recursive recursive
JORGE CHAM © 2008
WWW.PHDCOMICS.COM

SHoES?

Supernova and H_0 for the Equation of State

SHoES Paper Author List:
A.G. Riess (Johns Hopkins/STScI), L. Macri (Texas A&M), S. Casertano (STScI), M. Sosey (STScI), H. Lampeit (Portsmouth), H. C. Ferguson (STScI), A. V. Filippenko (Berkeley), S. W. Jha (Rutgers), W. Li (Berkeley), R. Chornock (Berkeley), **D. Sarkar (UC Irvine)**.

SHoES?

$$H_0 = 72 \pm 8 \text{ km s}^{-1}\text{Mpc}^{-1}$$

(Freedman et al. 2001)

SHoES Paper Author List:
A.G. Riess (Johns Hopkins/STScI), L. Macri (Texas A&M), S. Casertano (STScI), M. Sosey (STScI), H. Lampeit (Portsmouth), H. C. Ferguson (STScI), A. V. Filippenko (Berkeley), S. W. Jha (Rutgers), W. Li (Berkeley), R. Chornock (Berkeley), **D. Sarkar (UC Irvine)**.

SHoES?

$$H_0 = 72 \pm 8 \text{ km s}^{-1}\text{Mpc}^{-1}$$

(Freedman et al. 2001)

$$H_0 = 74.4 \pm 3.6 \text{ km s}^{-1}\text{Mpc}^{-1}$$

SHoES Paper Author List:
A.G. Riess (Johns Hopkins/STScI), L. Macri (Texas A&M), S. Casertano (STScI), M. Sosey (STScI), H. Lampeit (Portsmouth), H. C. Ferguson (STScI), A. V. Filippenko (Berkeley), S. W. Jha (Rutgers), W. Li (Berkeley), R. Chornock (Berkeley), **D. Sarkar (UC Irvine)**.

SHoES?

$$H_0 = 72 \pm 8 \text{ km s}^{-1}\text{Mpc}^{-1}$$

(Freedman et al. 2001)

$$H_0 = 74.4 \pm 3.6 \text{ km s}^{-1}\text{Mpc}^{-1}$$

How Does it Affect DE?

SHoES Paper Author List:
A.G. Riess (Johns Hopkins/STScI), L. Macri (Texas A&M), S. Casertano (STScI), M. Sosey (STScI), H. Lampeit (Portsmouth), H. C. Ferguson (STScI), A. V. Filippenko (Berkeley), S. W. Jha (Rutgers), W. Li (Berkeley), R. Chornock (Berkeley), **D. Sarkar (UC Irvine)**.

SHoES?

$$H_0 = 72 \pm 8 \text{ km s}^{-1}\text{Mpc}^{-1}$$

(Freedman et al. 2001)

$$H_0 = 74.4 \pm 3.6 \text{ km s}^{-1}\text{Mpc}^{-1}$$

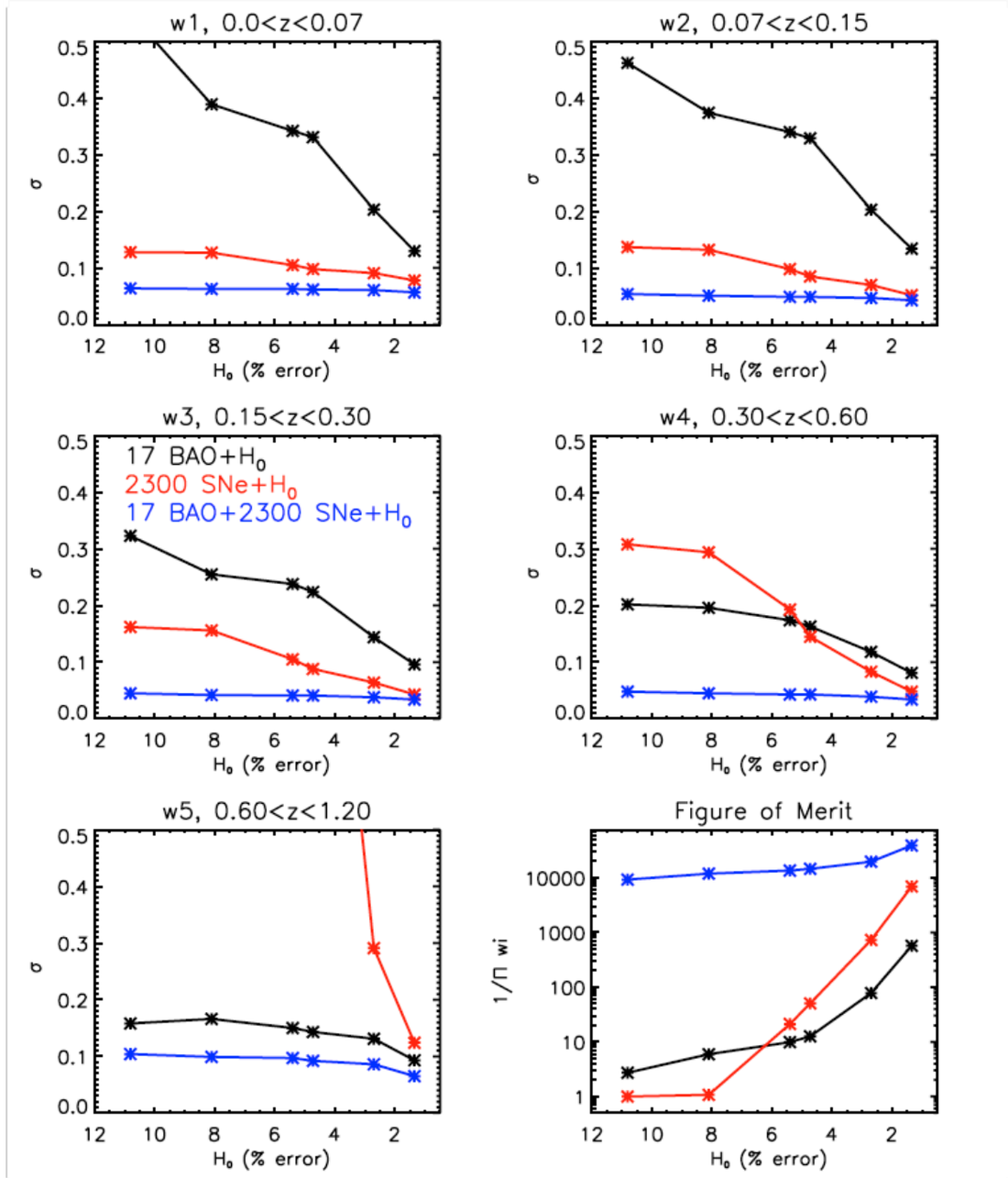
How Does it Affect DE?

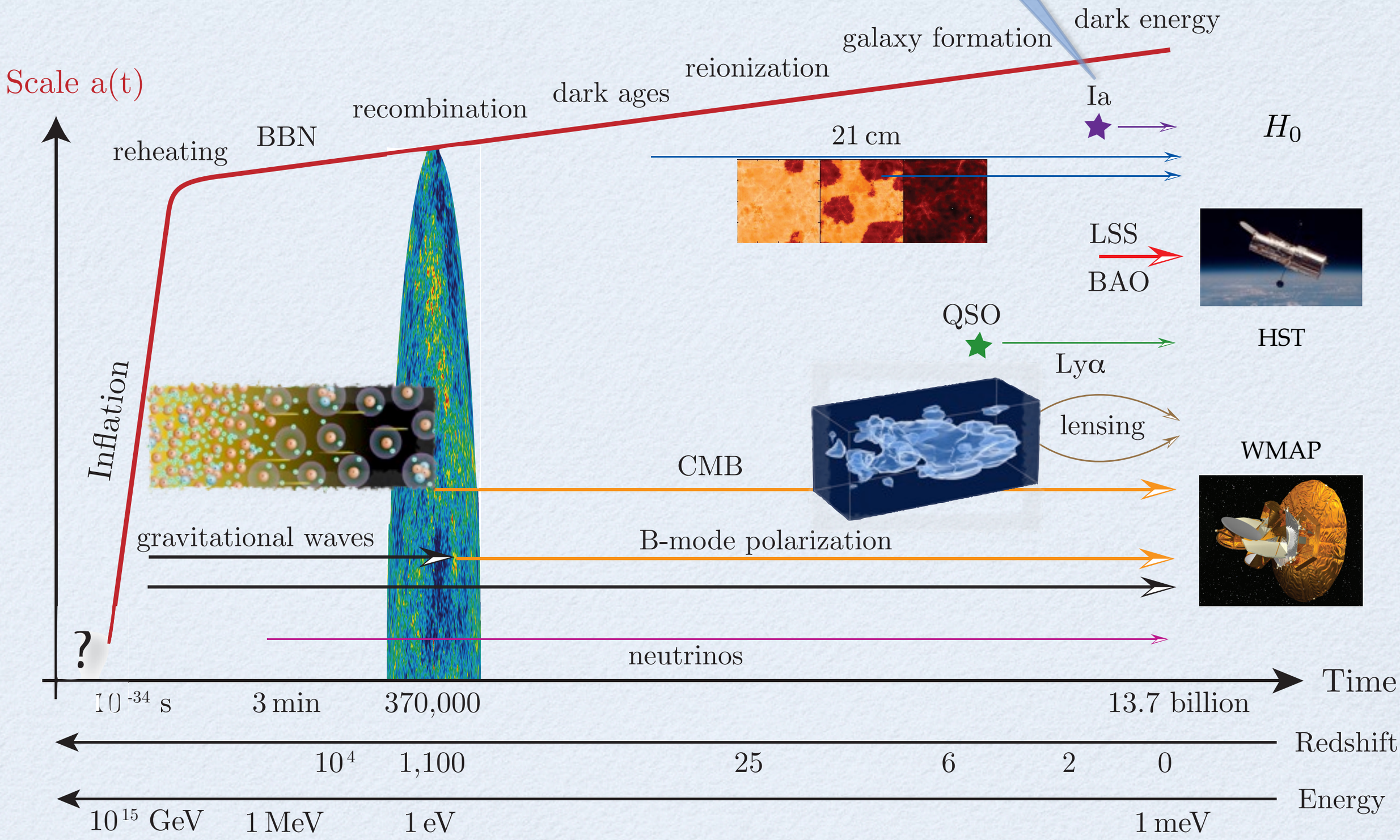
Quite a Bit

SHoES Paper Author List:

A.G. Riess (Johns Hopkins/STScI), L. Macri (Texas A&M), S. Casertano (STScI), M. Sosey (STScI), H. Lampeit (Portsmouth), H. C. Ferguson (STScI), A. V. Filippenko (Berkeley), S. W. Jha (Rutgers), W. Li (Berkeley), R. Chornock (Berkeley), **D. Sarkar (UC Irvine)**.

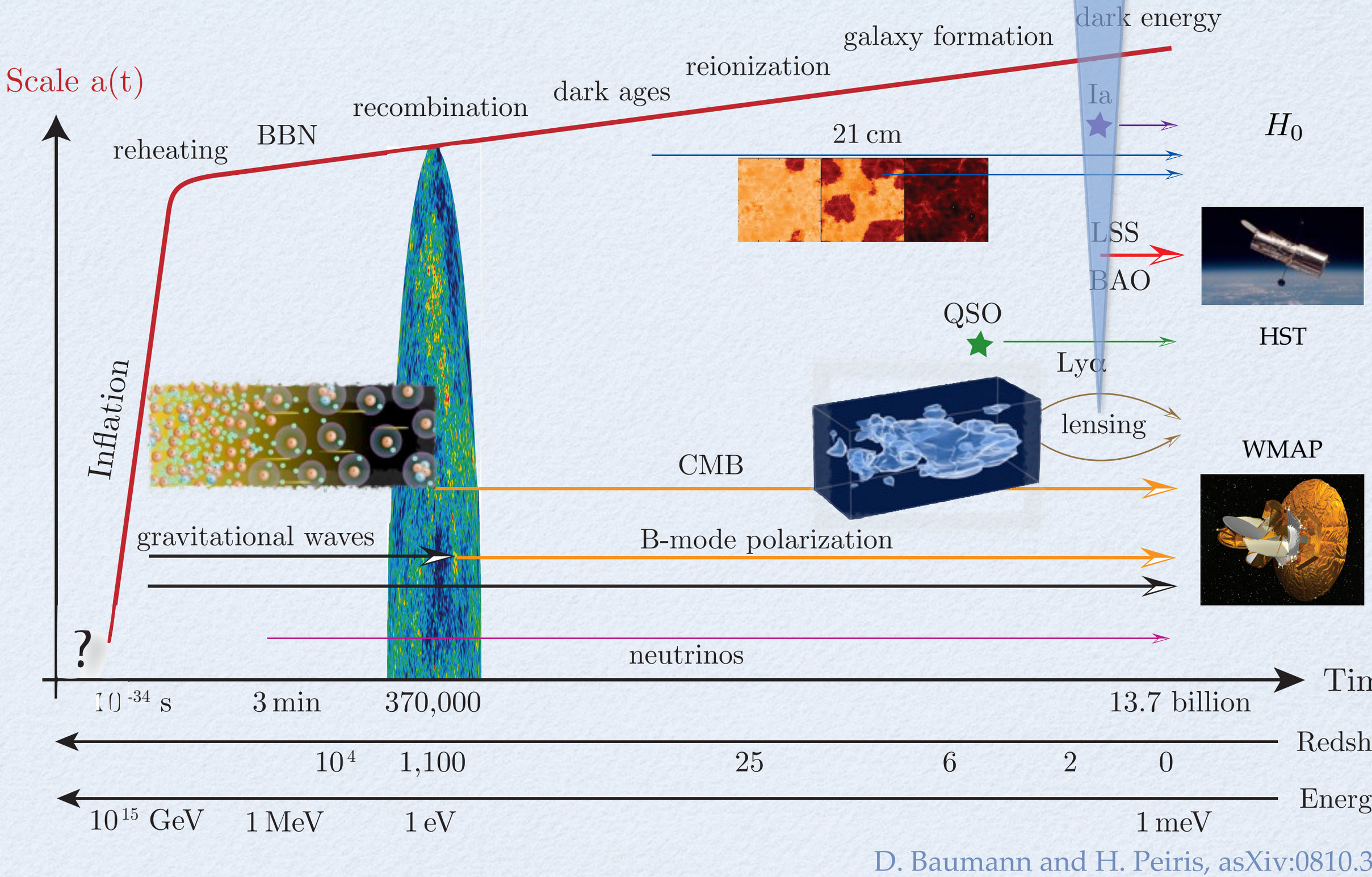
A. Riess et al., Astrophys. J. (2009; in Press)





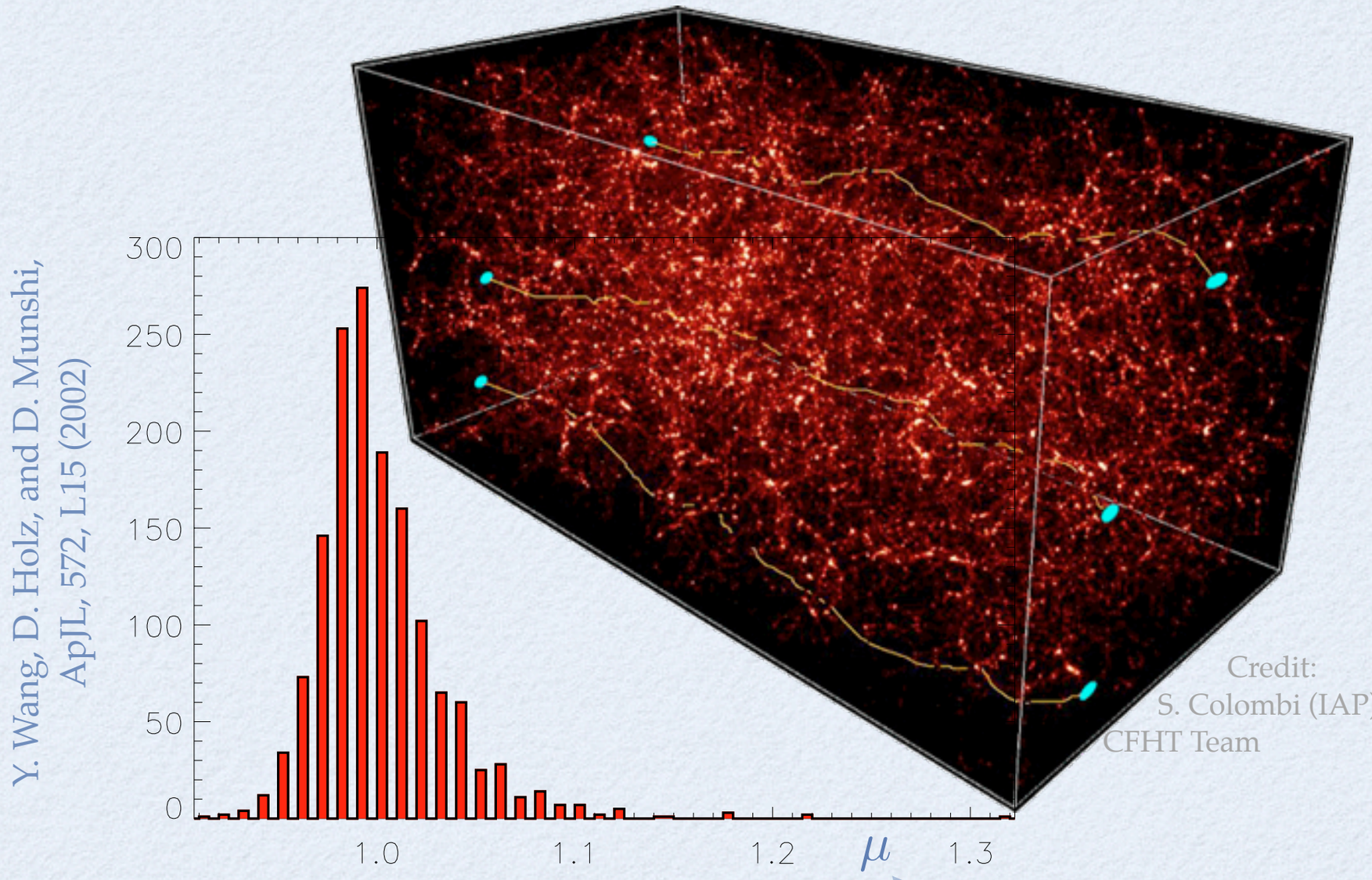
D. Baumann and H. Peiris, asXiv:0810.3022

ApJ 2008



D. Baumann and H. Peiris, asXiv:0810.3022

A Journey through the "clumpy" Universe



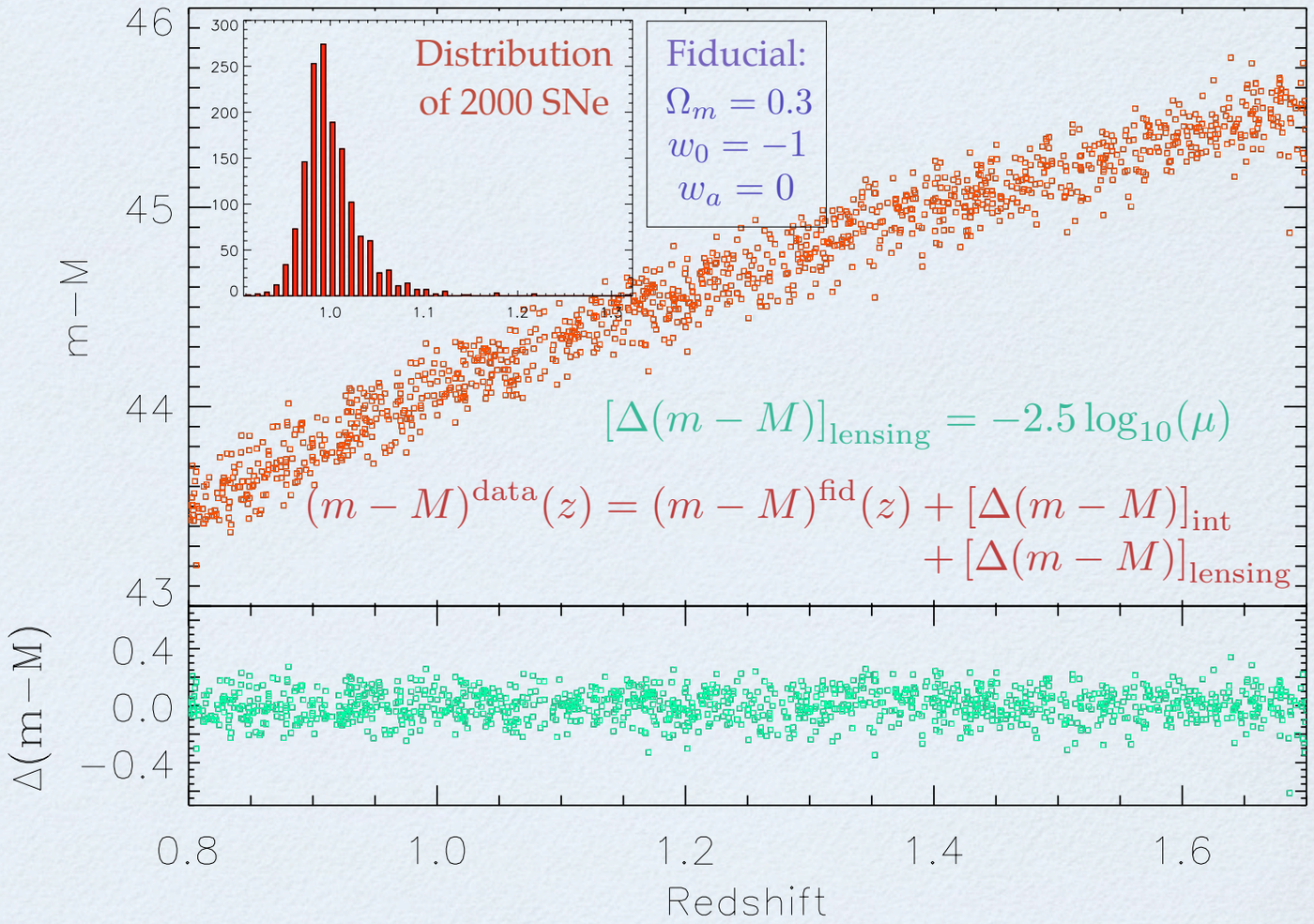
Credit:
S. Colombi (IAP),
CFHT Team

Weak Lensing can modify SN flux and hence can, in principle, bias the measurement of the equation of state (EOS)

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

So how much is the magnitude of this effect?

Aim: Quantify the effect as the "bias on w" for different sample sizes of SN dataset. Find out the significance for the future!

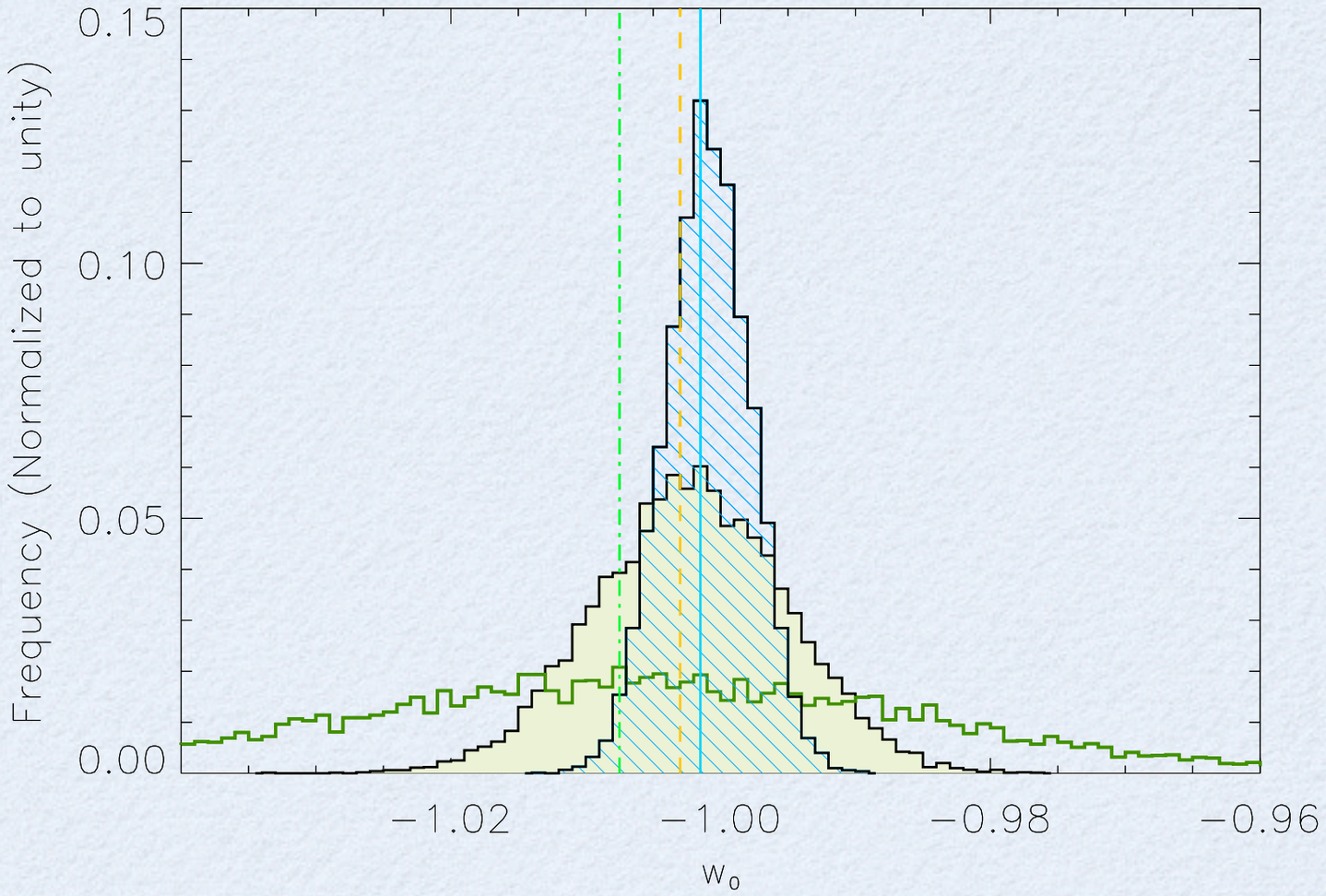


Sample sizes:
A. 300 SNe
B. 2000 SNe
C. 10,000 SNe up to z=1.8!
Analyses performed on 10,000 independent mocks!

D. Sarkar, A. Amblard, D. Holz, and A. Cooray, Astrophys. J., 678, 1 (2008)

So how much is the magnitude of this effect?

Aim: Quantify the effect as the "bias on w" for different sample sizes of SN dataset. Find out the significance for the future!

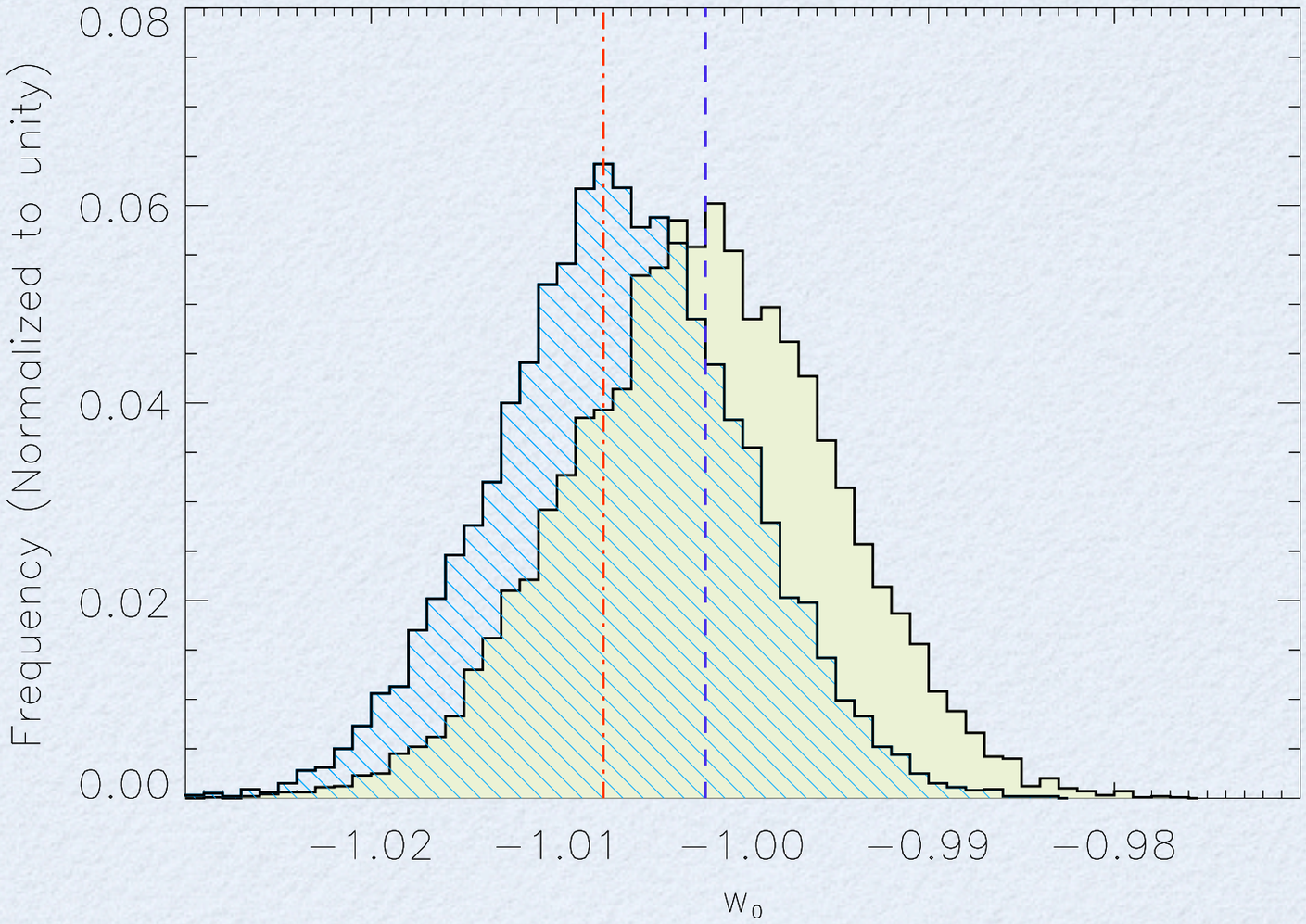


Sample sizes:
A. 300 SNe
B. 2000 SNe
C. 10,000 SNe up to z=1.8!
Analyses performed on 10,000 independent mocks!

D. Sarkar, A. Amblard, D. Holz, and A. Cooray, Astrophys. J., 678, 1 (2008)

So how much is the magnitude of this effect?

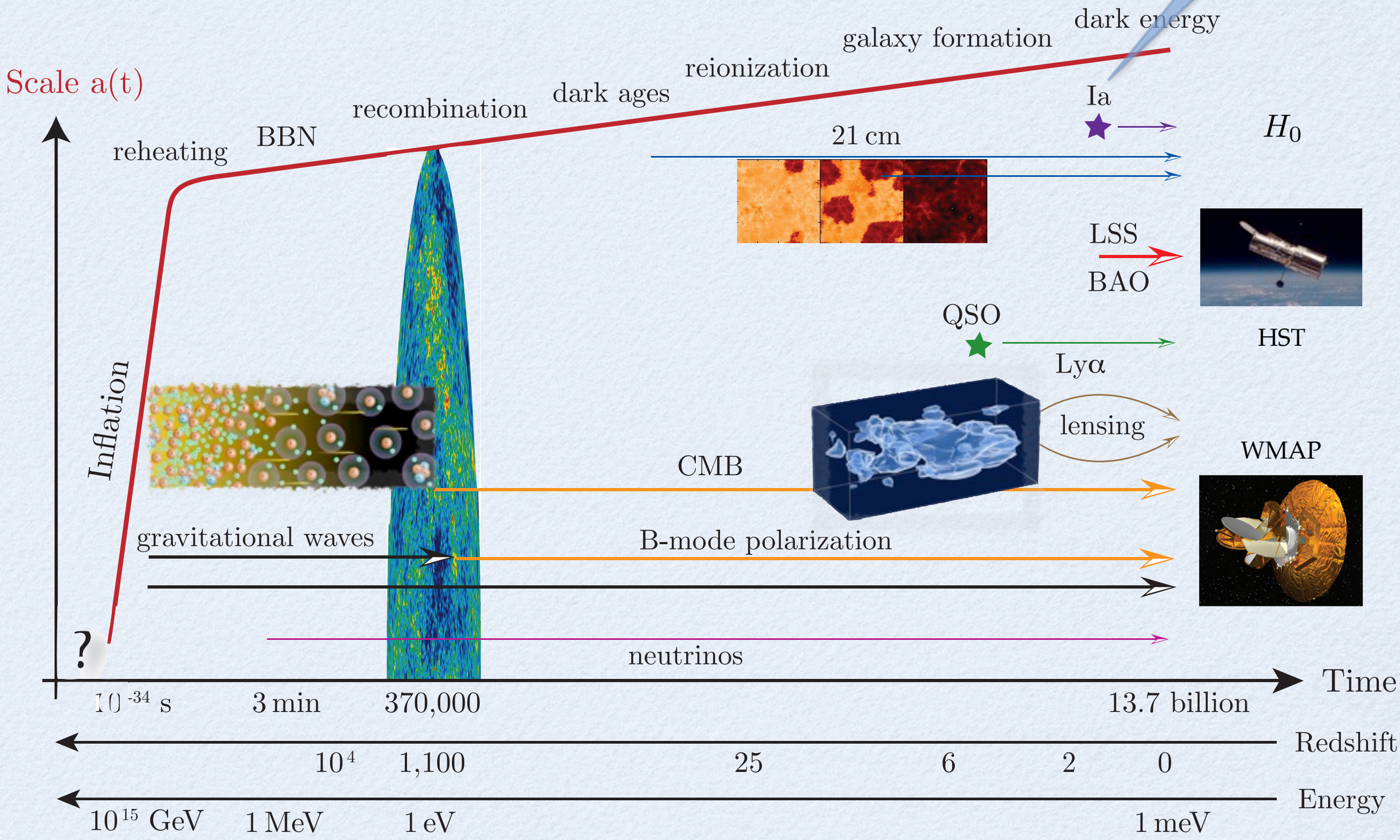
Aim: Quantify the effect as the "bias on w" for different sample sizes of SN dataset. Find out the significance for the future!



Sample sizes:
A. 300 SNe
B. 2000 SNe
C. 10,000 SNe up to z=1.8!
Analyses performed on 10,000 independent mocks!

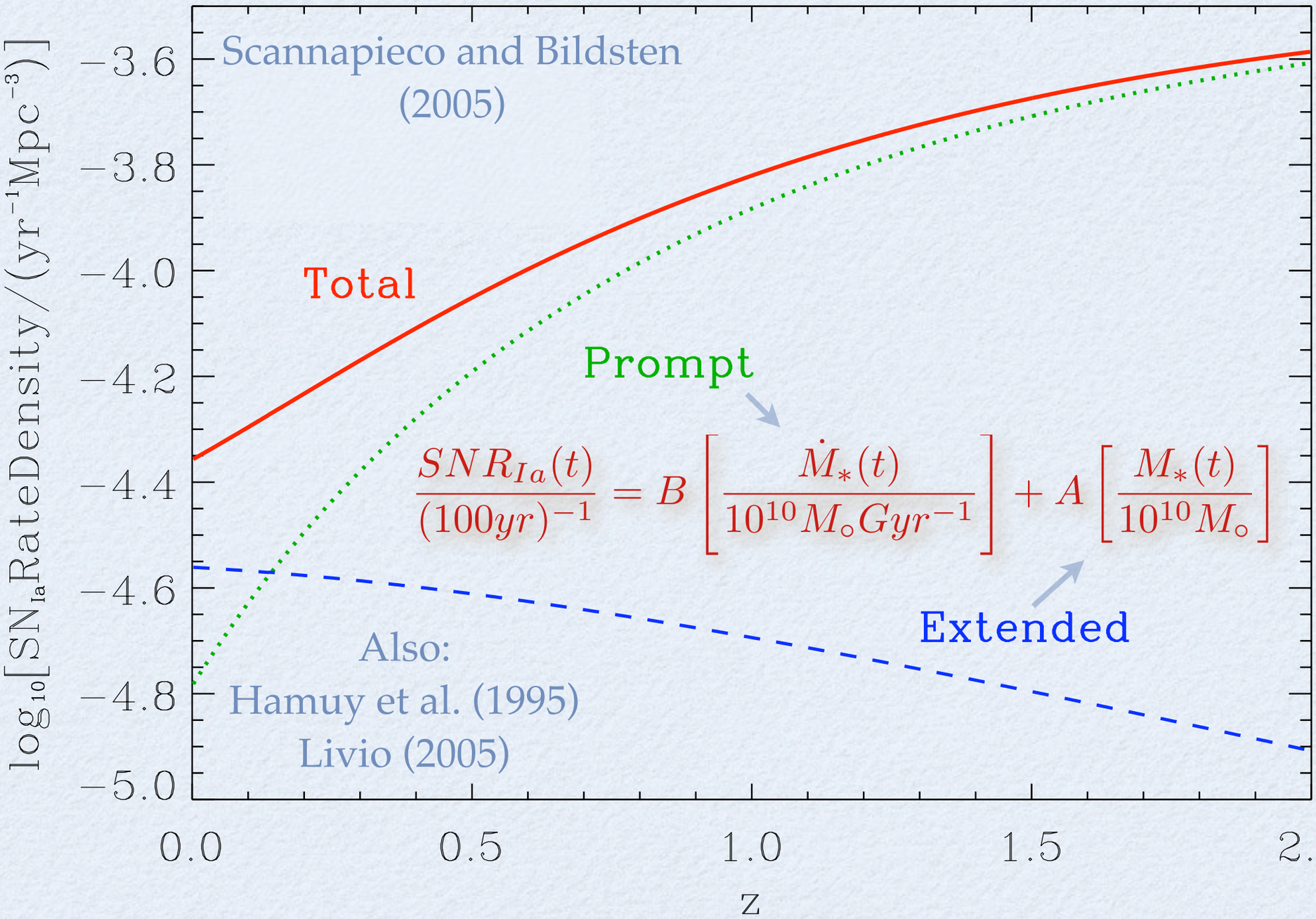
D. Sarkar, A. Amblard, D. Holz, and A. Cooray, Astrophys. J., 678, 1 (2008)

ApJL 2008



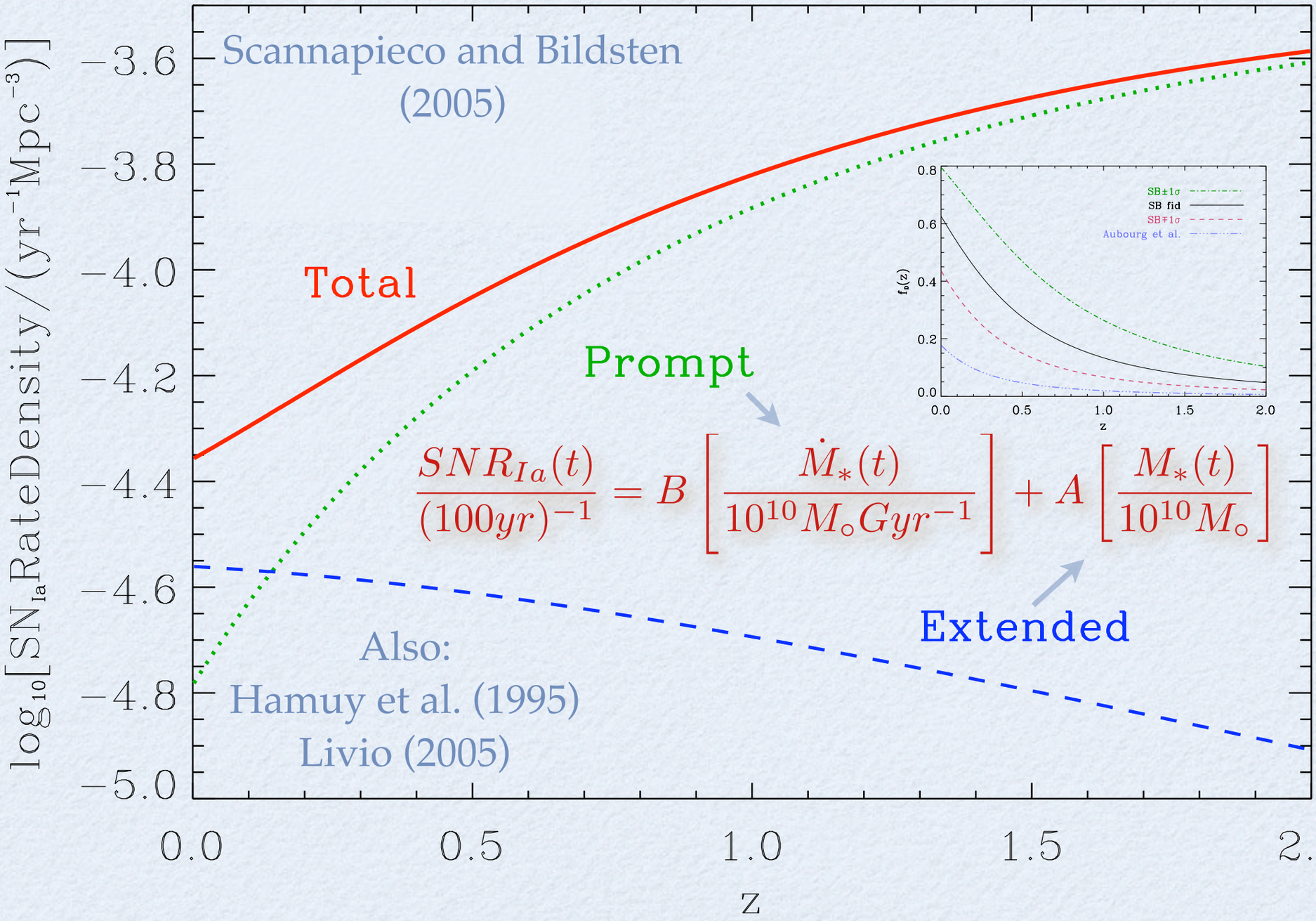
D. Baumann and H. Peiris, asXiv:0810.3022

Introducing the Parties (Populations)...



Prompt	Delayed
SNe Ia in active star forming galaxies!	SNe Ia in galaxies not forming stars!
They are Brighter! and	They are Dimmer! and
dominate @ high redshift	dominate @ low redshift

Introducing the Parties (Populations)...



Prompt	Delayed
SNe Ia in active star forming galaxies!	SNe Ia in galaxies not forming stars!
They are Brighter! and	They are Dimmer! and
dominate @ high redshift	dominate @ low redshift

GW via Weak Lensing | CMB Bispectrum Lensing | Dark Energy Beyond 2 param | SHoES & Dark Energy | Are they Skewed? | Supernova Lensing in Play | Lack of Bipartisan-ship

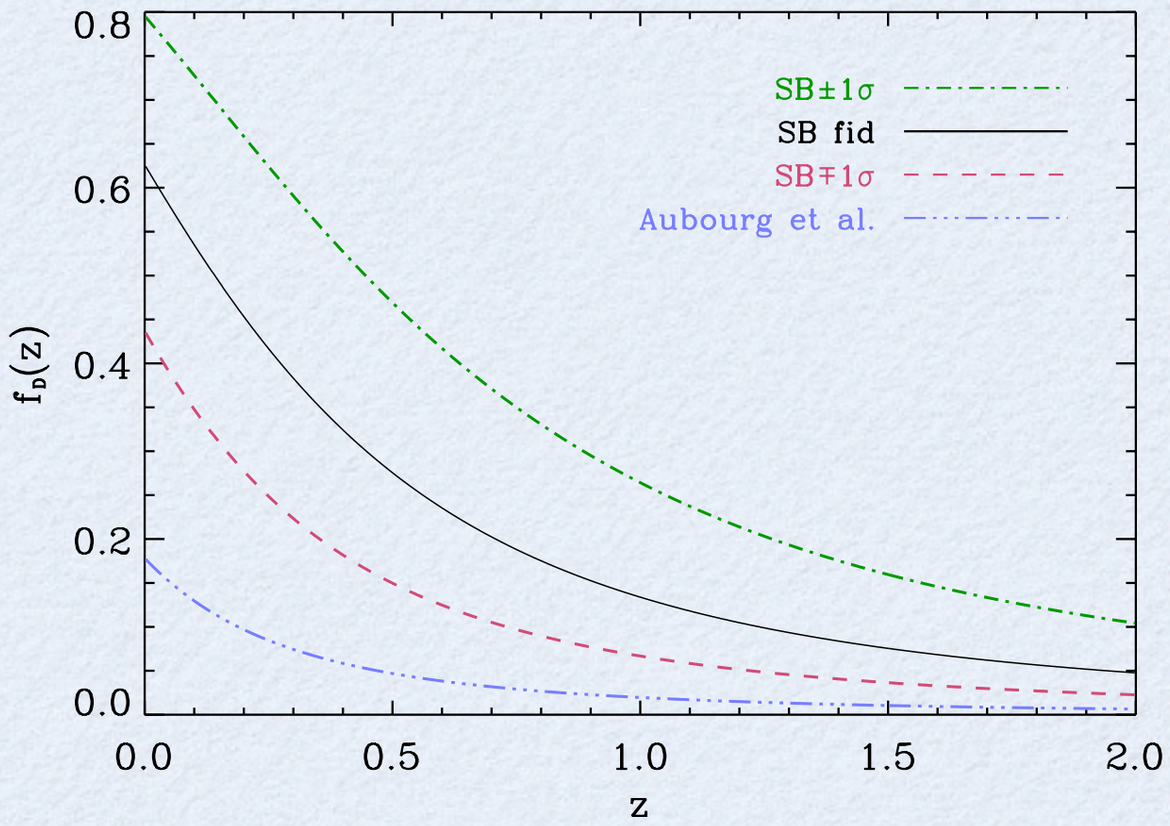
Can the Street Feel it? (Signature in the Hubble Diag.)

Can the Street Feel it? (Signature in the Hubble Diag.)

$$m - M = 5 \log_{10} \left(\frac{d_L}{\mathrm{Mpc}} \right) + 25 + \mathcal{M}$$

Can the Street Feel it? (Signature in the Hubble Diag.)

$$m - M = 5 \log_{10} \left(\frac{d_L}{\mathrm{Mpc}} \right) + 25 + \mathcal{M} + \delta_D * f_D(z)$$



D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Can the Street Feel it? (Signature in the Hubble Diag.)

$$m - M = 5 \log_{10} \left(\frac{d_L}{\mathrm{Mpc}} \right) + 25 + \mathcal{M} + \delta_D * f_D(z)$$

Using 192 SNe (Davis et al. 2007), the residual is consistent with zero!

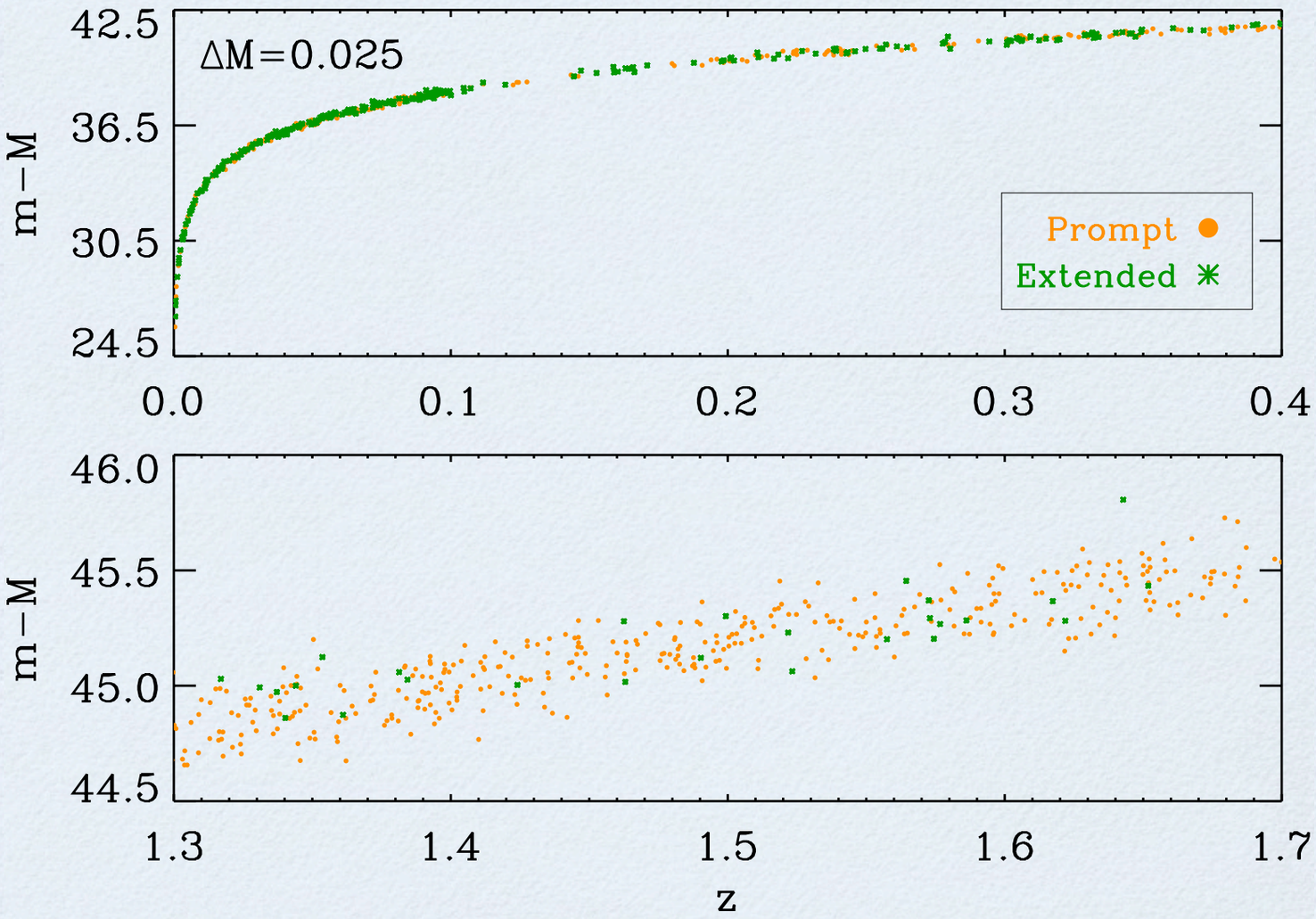
$$\delta_D \sim (5 \pm 9)\%$$

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

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...

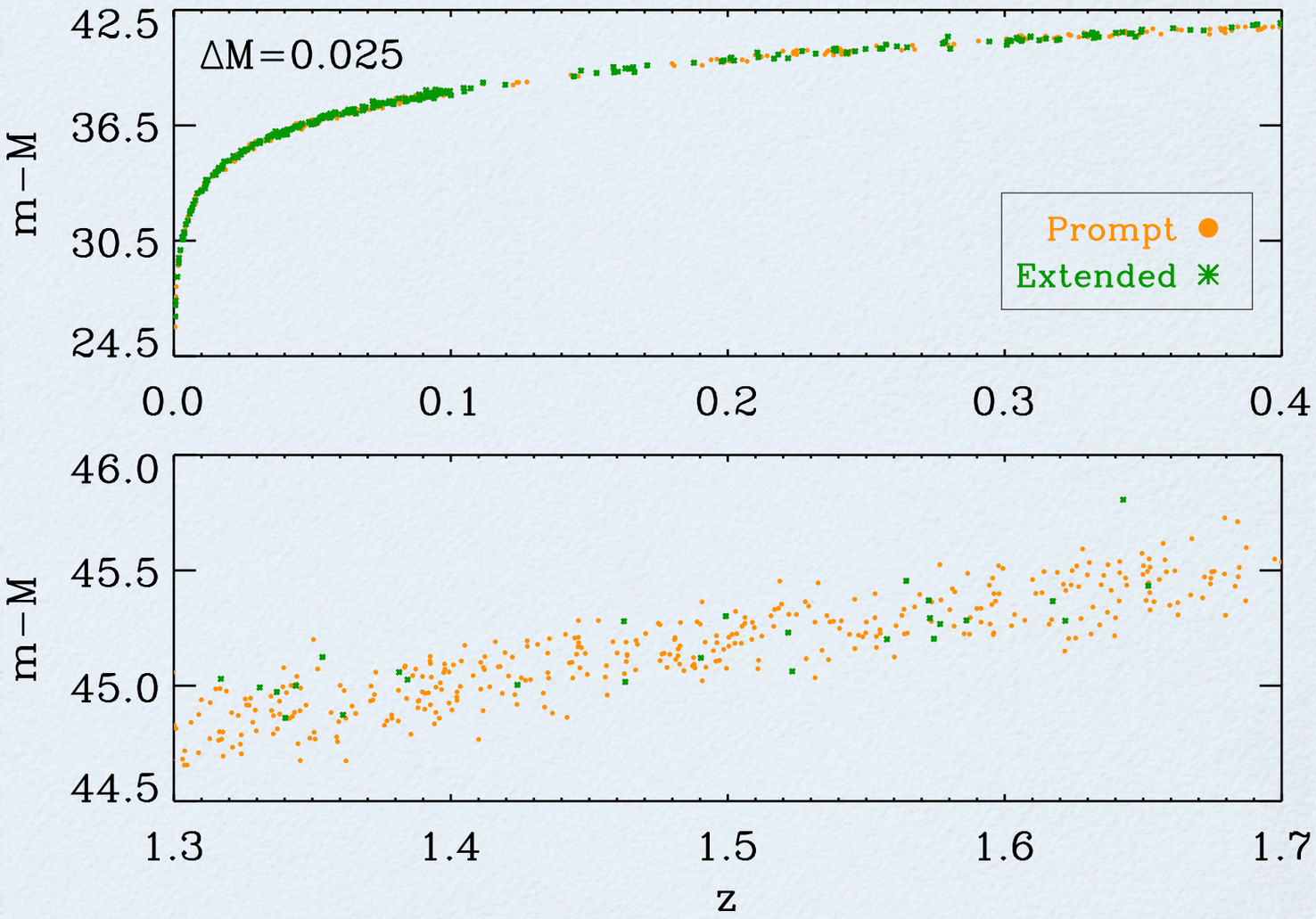


Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...

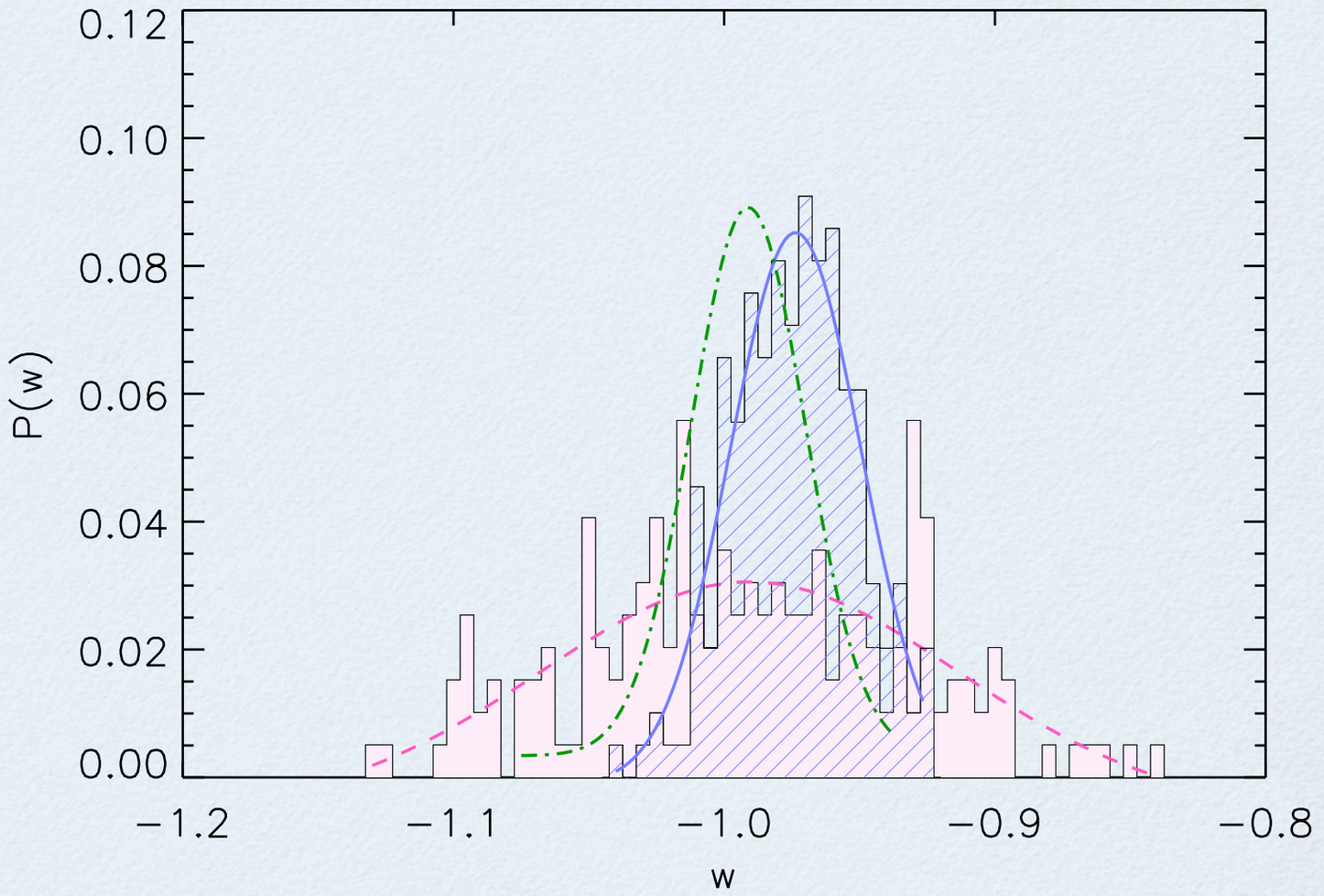


Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...

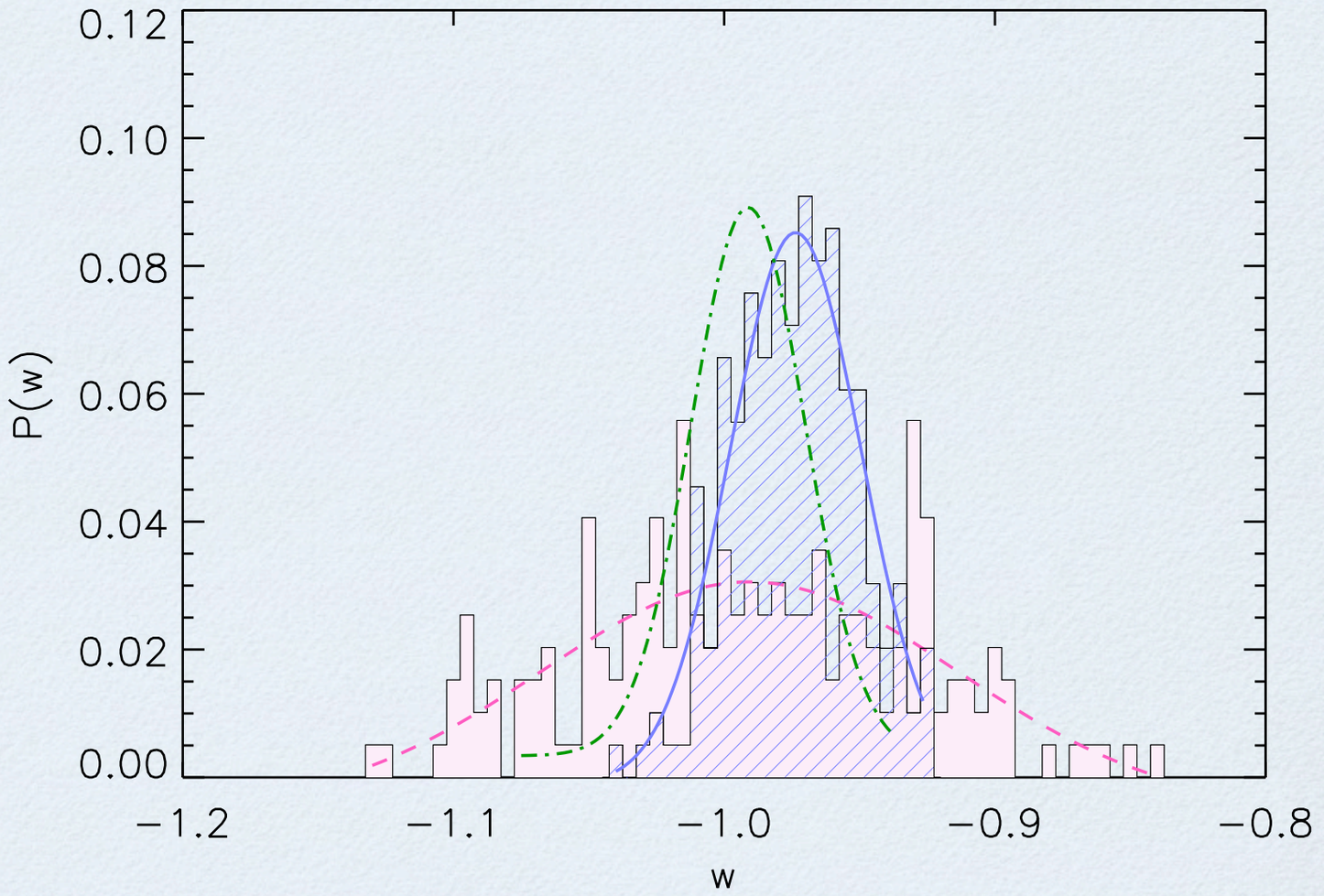


Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...

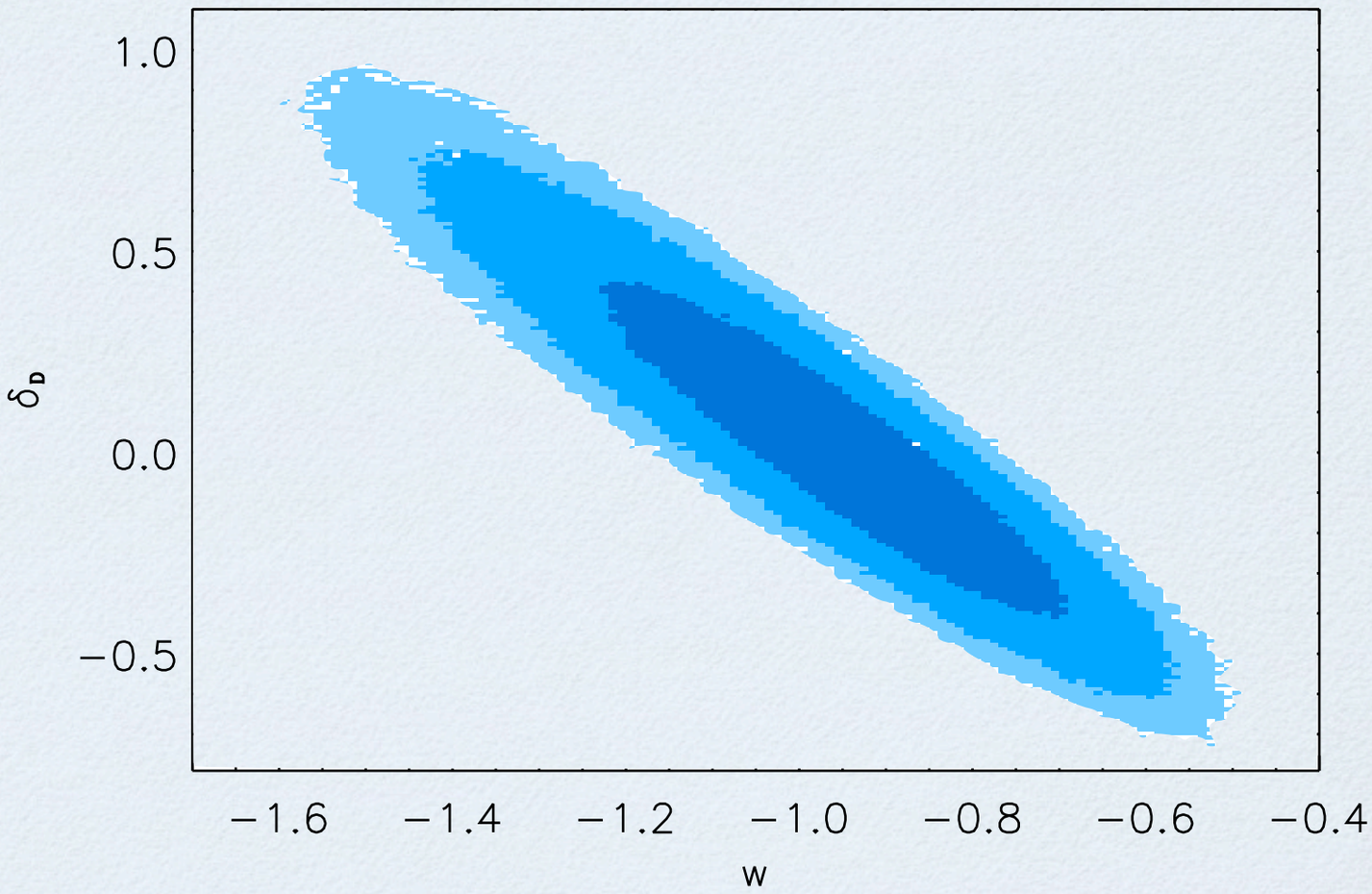


Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...

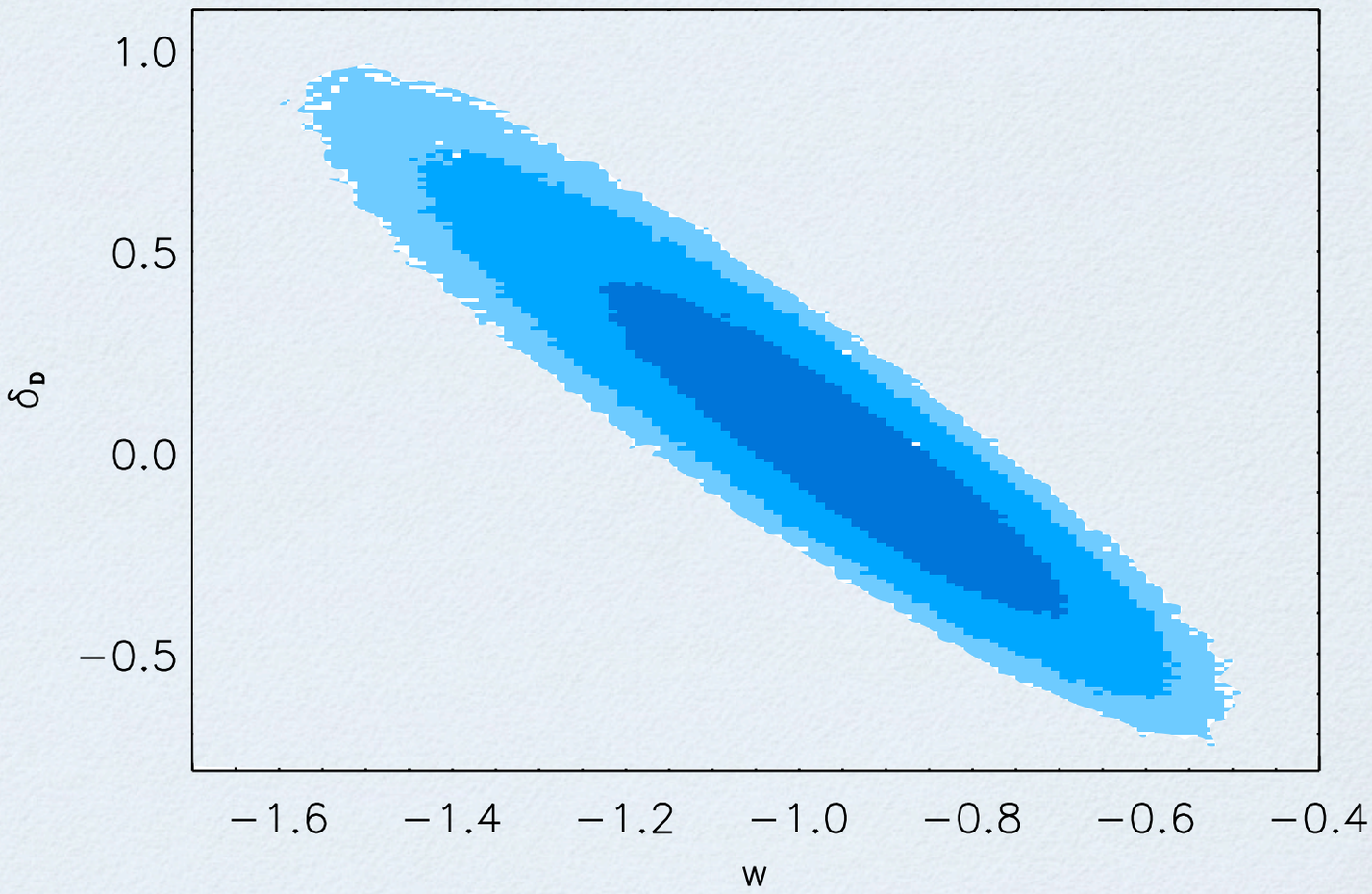


Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...

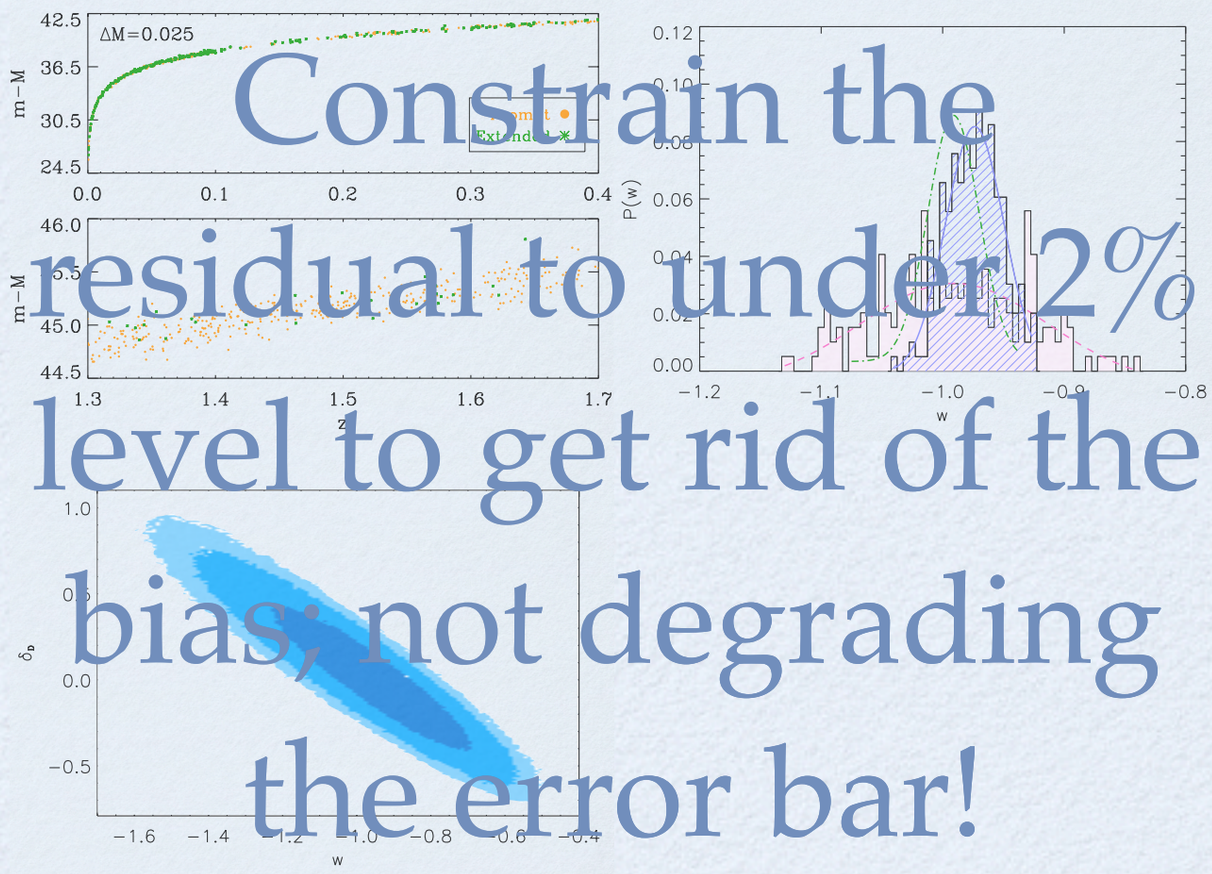


Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...



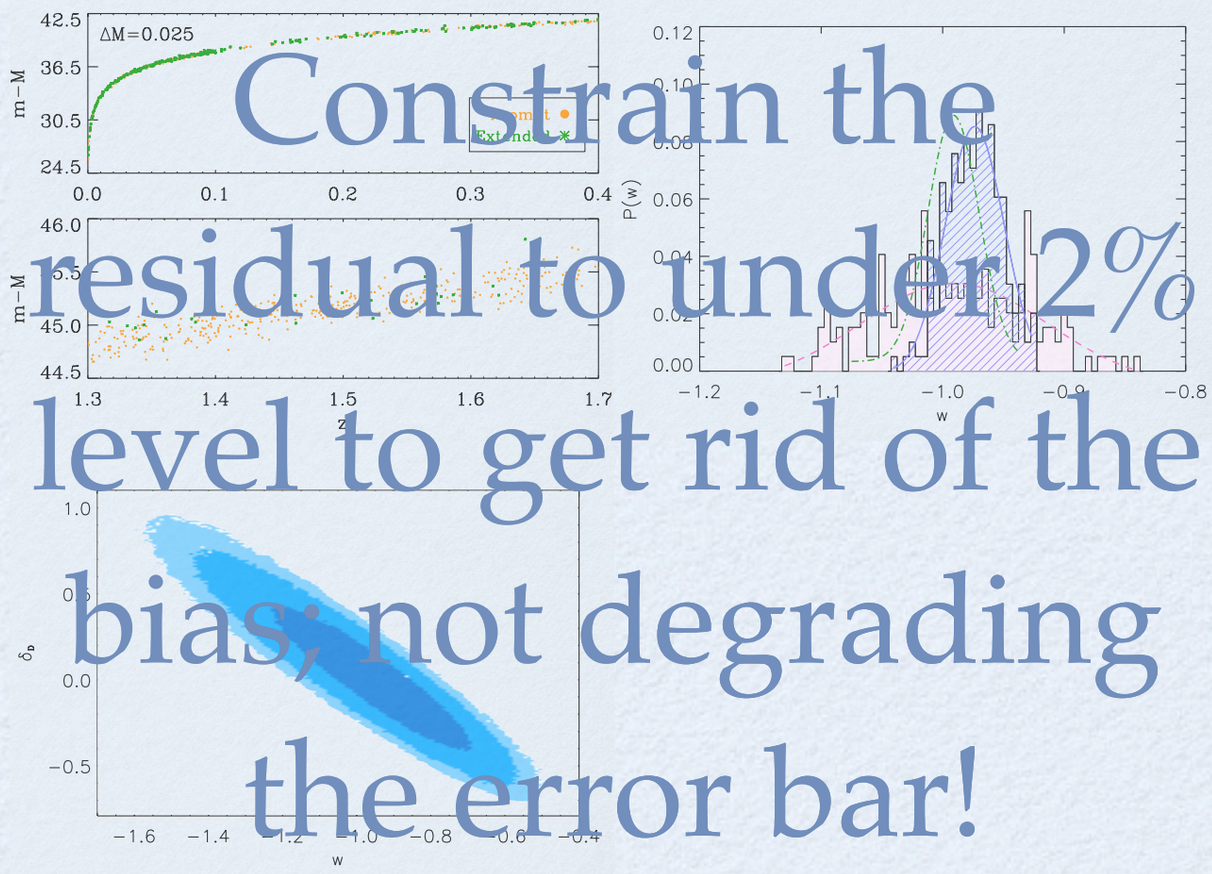
Constrain the residual to under 2% level to get rid of the bias; not degrading the error bar!

Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...



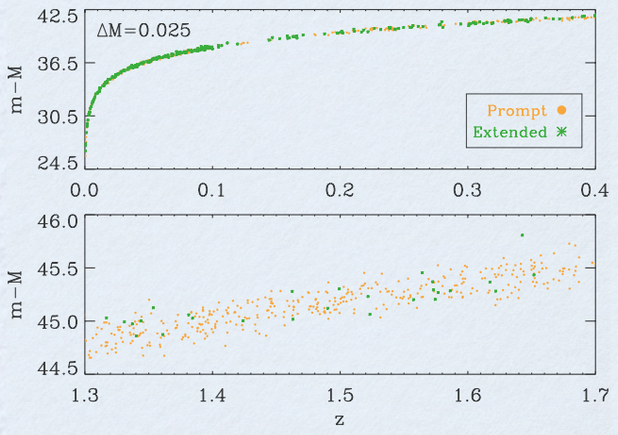
Constrain the residual to under 2% level to get rid of the bias; not degrading the error bar!

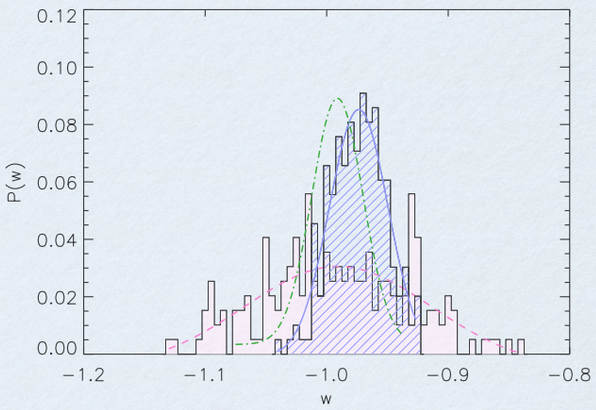
Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

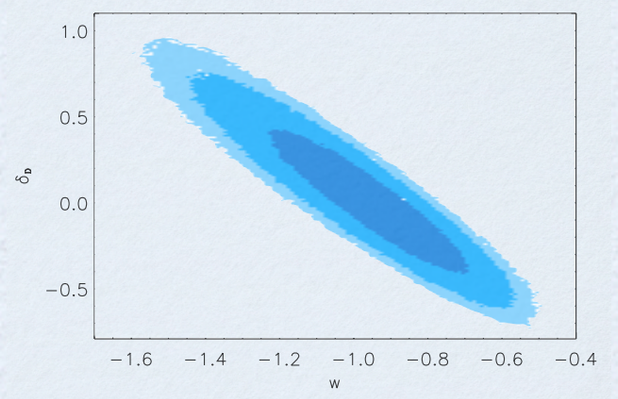
D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

Looking @ w's Future...

Aim: Assuming that the residual is present @ a couple of % level... quantify its effect on the measurements of "w"...





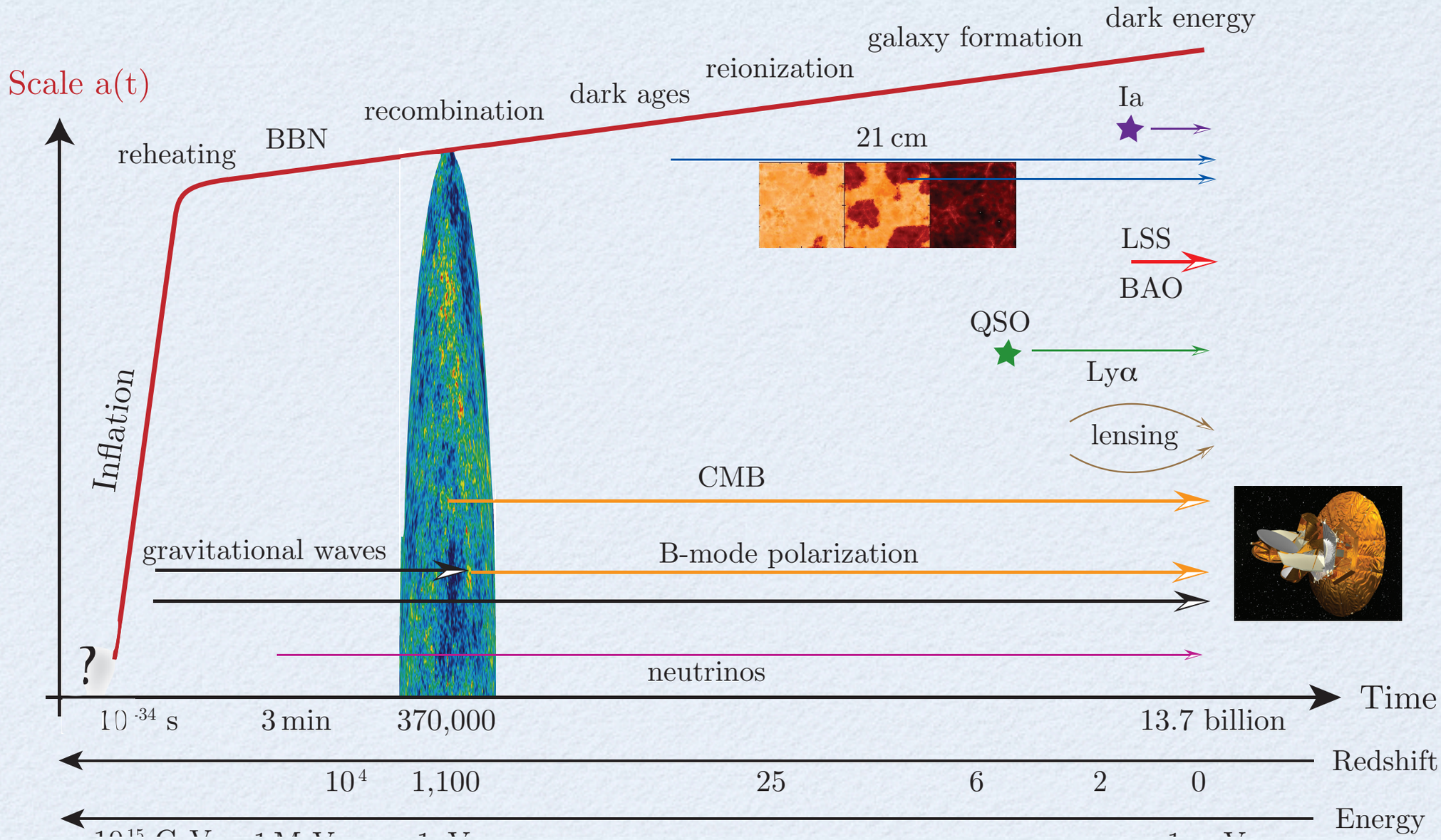


Constrain the residual to under 2% level to get rid of the bias; not degrading the error bar!

Future JDEM type survey with ~ 2300 SNe up to z=1.8. Analysis performed on 200 independent mocks!

D. Sarkar, A. Amblard, A. Cooray, and D. Holz, Astrophys. J. Lett., 684, L13 (2008)

GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	**PRD**	**PRL**	**ApJ**	**(in prep.)**	**ApJ**	**ApJL**



GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	PRD	PRL	ApJ	(in prep.)	ApJ	ApJL

Beautiful idea! But signal too low to be detectable in practice!

GW via Weak Lensing

PRD

CMB Bispectrum Lensing

PRD

Dark Energy Beyond 2 param

PRL

SHoES & Dark Energy

ApJ

Are they Skewed?

(in prep.)

Supernova Lensing in Play

ApJ

Lack of Bipartisan-ship

ApJL

Beautiful idea! But signal too low to be detectable in practice!

Lensing modifies the primary CMB Bispectrum leading to 30% bias in f_{NL} for Planck!

GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	**PRD**	**PRL**	**ApJ**	**(in prep.)**	**ApJ**	**ApJL**

Beautiful idea! But signal too low to be detectable in practice!

Lensing modifies the primary CMB Bispectrum leading to 30% bias in f_{NL} for Planck!

Bin it! A combination of future-generation surveys can constrain 4–5 indep. EOS parameters

GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	**PRD**	**PRL**	**ApJ**	**(in prep.)**	**ApJ**	**ApJL**
Beautiful idea! But signal too low to be detectable in practice!	Lensing modifies the primary CMB Bispectrum leading to 30% bias in f_{NL} for Planck!	Bin it! A combination of future-generation surveys can constrain 4–5 indep. EOS parameters	Improved constrain on H_0 can definitely do good; especially if SN or BAO falters @ high z!			

GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	**PRD**	**PRL**	**ApJ**	**(in prep.)**	**ApJ**	**ApJL**
Beautiful idea! But signal too low to be detectable in practice!	Lensing modifies the primary CMB Bispectrum leading to 30% bias in f_{NL} for Planck!	Bin it! A combination of future-generation surveys can constrain 4–5 indep. EOS parameters	Improved constrain on H_0 can definitely do good; especially if SN or BAO falters @ high z!	Yes they are! One should be aware of the possible effects on the evaluation of the EOS		

GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	**PRD**	**PRL**	**ApJ**	**(in prep.)**	**ApJ**	**ApJL**
Beautiful idea! But signal too low to be detectable in practice!	Lensing modifies the primary CMB Bispectrum leading to 30% bias in f_{NL} for Planck!	Bin it! A combination of future-generation surveys can constrain 4–5 indep. EOS parameters	Improved constrain on H_0 can definitely do good; especially if SN or BAO falters @ high z!	Yes they are! One should be aware of the possible effects on the evaluation of the EOS	Bias in "w" because of lensing of SNe 'under control' if 2000+ SNe are available! Careful w/ outliers!	

GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	**PRD**	**PRL**	**ApJ**	**(in prep.)**	**ApJ**	**ApJL**
Beautiful idea! But signal too low to be detectable in practice!	Lensing modifies the primary CMB Bispectrum leading to 30% bias in f_{NL} for Planck!	Bin it! A combination of future-generation surveys can constrain 4–5 indep. EOS parameters	Improved constrain on H_0 can definitely do good; especially if SN or BAO falters @ high z!	Yes they are! One should be aware of the possible effects on the evaluation of the EOS	Bias in "w" because of lensing of SNe 'under control' if 2000+ SNe are available! Careful w/ outliers!	Bias if "w" could be kept under 1 sigma level if inter-party conflicts can be minimized!

GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	**PRD**	**PRL**	**ApJ**	**(in prep.)**	**ApJ**	**ApJL**
Beautiful idea! But signal too low to be detectable in practice!	Lensing modifies the primary CMB Bispectrum leading to 30% bias in f_{NL} for Planck!	Bin it! A combination of future-generation surveys can constrain 4–5 indep. EOS parameters	Improved constrain on H_0 can definitely do good; especially if SN or BAO falters @ high z!	Yes they are! One should be aware of the possible effects on the evaluation of the EOS	Bias in "w" because of lensing of SNe 'under control' if 2000+ SNe are available! Careful w/ outliers!	Bias if "w" could be kept under 1 sigma level if inter-party conflicts can be minimized!

"Success is a journey, not a destination."

– Arthur Robert Ashe, Jr.

GW via Weak Lensing	CMB Bispectrum Lensing	Dark Energy Beyond 2 param	SHoES & Dark Energy	Are they Skewed?	Supernova Lensing in Play	Lack of Bipartisan-ship
PRD	**PRD**	**PRL**	**ApJ**	**(in prep.)**	**ApJ**	**ApJL**
Beautiful idea! But signal too low to be detectable in practice!	Lensing modifies the primary CMB Bispectrum leading to 30% bias in f_{NL} for Planck!	Bin it! A combination of future-generation surveys can constrain 4-5 indep. EOS parameters	Improved constrain on H_0 can definitely do good; especially if SN or BAO falters @ high z!	Yes they are! One should be aware of the possible effects on the evaluation of the EOS	Bias in "w" because of lensing of SNe 'under control' if 2000+ SNe are available! Careful w/ outliers!	Bias if "w" could be kept under 1 sigma level if inter-party conflicts can be minimized!

"At the last dim horizon, we search among ghostly errors of observations for landmarks that are scarcely more substantial. The search will continue. The urge is older than history. It is not satisfied and it will not be oppressed." -Edwin P. Hubble