CITA ICAT Canadian Institute for Theoretical Astrophysics L'institut canadien d'astrophysique theorique

CIAR

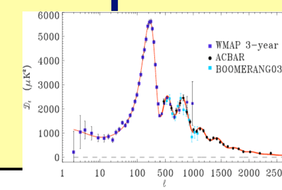
25 years cifar

Dick Bond

the Cosmology of now & then through first light

CMB & tilted ΛCDM status as of May 23, 2008:
ACBAR08 Jan & CBI5year peaks 3+4+5+damping & ACBAR excess cf. CBI excess. QuAD last wk E-pol

WMAP5year March @CIFAR08



What is the Universe made of? Baryons + (cold-ish) dark matter + dark energy + tiny curvature energy (+light neutrinos+photons). ??a bit of strings/textures/PBHs??

July 1982 Nuffield Conference on Very Early Universe UK: how to test inflation – gravitational metric / density fluctuation spectrum

Outgrowth: nearly scale invariant, amplitude TBD

Dec 2007 VEU 25 years after: assess the progress on inflation, both theoretical and observational

THEORIST SIMULATOR OBSERVER EXPERIMENTER
PHENOMENOLOGIST

z-surveys cfa1,2/ ... /2dF/sdss/... jdem/PS1/lsst/des/...
CNOC RCS1,2 virmos-descartes, CFHTLS - lens/sn
CMB cobe, boomerang, cbi/acbar, wmap, planck/act/spt/spider/ebex
Galaxy formation scuba, blast, scuba2, herschel, ...

very early U early to middle to now U **very late U**

string theory/landscape/higher dimensions

inflation cyclic baryogenesis dark matter BBN γdec **dark energy**

ρ_{curv} n_b/n_γ

ρ_{dm}/ρ_b z_{eq}/z_{rec} ρ_{de}/ρ_{dm} $\rho_{de} \sim H^2 M^2_{Planck}$ $\rho_{m\nu}/\rho_{stars}$

$V_{eff}(\phi_{inf})$? $V_{eff}(\phi_{inf})$?

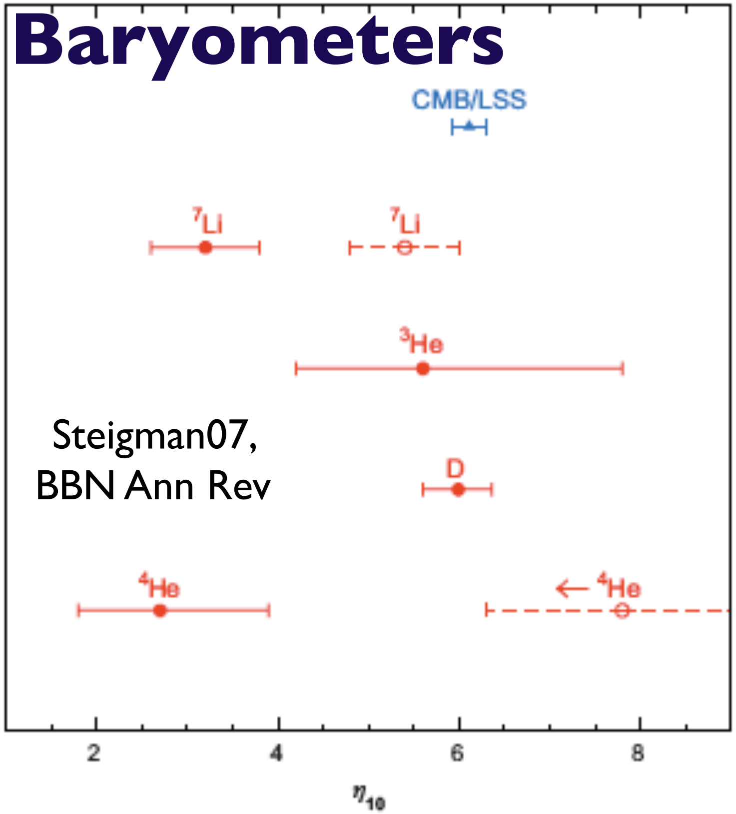
ACT@5170m

why Atacama? driest desert in the world. thus: cbi, toco, apex, asti, act, alma, quiet, clover

CBI2@5040m

COSMIC PARAMETERS THEN & NOW

Baryometers



Steigman07, BBN Ann Rev

Nobel Prize 84 Willy Fowler + Chandra -sekhar

$$\eta_{10} \equiv 10^{10}(n_B/n_\gamma) \equiv 274\ \Omega_B h^2$$

	January 2000	January 2002	June 2002	January 2003	March 2003
$\Omega_b h^2$	$0.0339^{+0.0443}_{-0.0246}$	$0.0222^{+0.0025}_{-0.0021}$	$0.0221^{+0.0024}_{-0.0020}$	$0.0221^{+0.0023}_{-0.0018}$	$0.0233^{+0.0013}_{-0.0013}$

0.0223 ± 0.0007

0.0226 +- 0.0006 wmap3+acbar+cbi+... LSS

0.0233 +- 0.0005 wmap5+acbar+cbi+b03+.+WL+LSS+SN1+Lya

dark matter abundance Ω_m=0.264 +.010 -.009

	January 2000	January 2002	June 2002	January 2003	March 2003
$\Omega_{\rm cdm}h^2$	$0.198^{+0.088}_{-0.080}$	$0.130^{+0.031}_{-0.028}$	$0.124^{+0.026}_{-0.025}$	$0.125^{+0.021}_{-0.022}$	$0.111^{+0.010}_{-0.010}$

CMB only history. LSS drove values closer to current

0.114 +-0.006 CMBall+WL+LSS+SN+Lya

Ω_Λ	$0.34^{+0.28}_{-0.24}$	$0.52^{+0.17}_{-0.20}$	$0.53^{+0.17}_{-0.19}$	$0.57^{+0.14}_{-0.19}$	$0.73^{+0.06}_{-0.10}$

dark energy abundance Ω_Λ=0.736 +.009 -.010

& H_0 = 72 +-1 CMBall+WL+LSS+SN+Lya

Standard Parameters of Cosmic Structure Formation

$\theta \sim \ell_s^{-1}$ $\sim \ln \sigma_8^2$

Ω_k $\Omega_b h^2$ $\Omega_{dm} h^2$ Ω_Λ τ_c $\ln A_s$ n_s $r = A_t / A_s$

1+w0, wa

$dn_s / d\ln k$ n_t

New Parameters of Cosmic Structure Formation

1+w(a)

$\epsilon(k), \quad k \approx Ha$ $\ln H(k_p)$

$\varepsilon_s f(a/a_{\Lambda eq}; a_s/a_{\Lambda eq}; \zeta_s)$

$\ln P_s(k)$ $\ln P_t(k)$

+ subdominant isocurvature/cosmic string/ tSZ

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CIAR 25 years cifar

Constraining Inflationary Histories, now & then

Inflation Now $1+w(a) = \varepsilon_s f(a/a_{\Lambda eq}; a_s/a_{\Lambda eq}; \zeta_s)$

goes to $\varepsilon(a)$ x3/2 = 3(1+q)/2 ~1 good e-fold. only ~2params

ε=-dlnH/dlna ~0 to 2 to 3/2 to ~.4 now, on its way to 0?

cf. w(a): w0,wa, w in z-bins, w in modes, $\varepsilon(a)$: in modes, jerk

Inflation Then $\varepsilon(k)=(1+q)(a)$ = mode expansion in resolution (lnHa ~ lnk)

~r/16 (Tensor/Scalar Power & gravity waves)

Cosmic Probes Now CMB(Apr08), CFHTLS SN(Union 307),WL, LSS/BAO, Lyα

Cosmic Probes Then JDEM-SN + DUNE-WL + Planck1

Zhiqi Huang, Bond & Kofman 08 ε_s=-0.05+-0.24 now, inflaton (potential gradient)^2

to +-0.07 then Planck1+JDEM SN+DUNE WL, weak a_s < 0.3 now <0.21 then

Measuring w (SNe+CMB+WL+LSS+Lya)

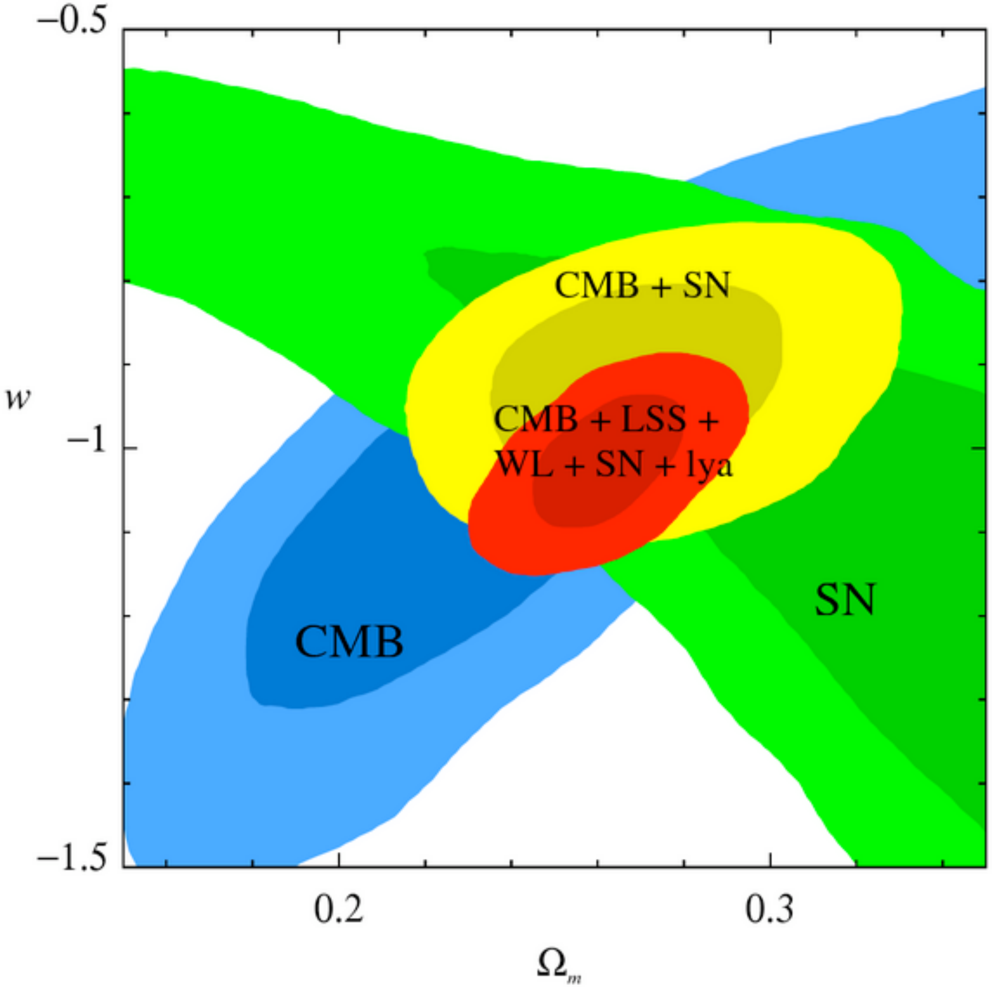
$$w(a) \equiv \frac{p(a)}{\rho(a)}$$

$1+\mathbf{w_0} = -0.01 \pm 0.05$

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

$1+\mathbf{w_0} = 0.05 \pm 0.20$

$\mathbf{w_a} = -0.2 \pm 0.8$



piecewise parameterization

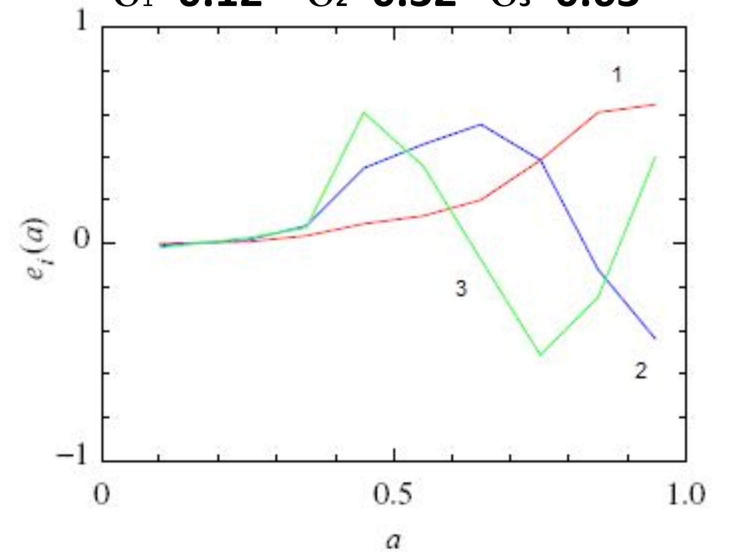
4,9,40 modes in redshift

9 & 40 into Parameter eigenmodes

data cannot determine >2 EOS parameters

DETF Albrecht etal06, Crittenden etal06, hbk07

σ_1=0.12 σ_2=0.32 σ_3=0.63



INFLATION NOW

PROBES NOW

- Cosmological Constant (w=-1)
- Quintessence

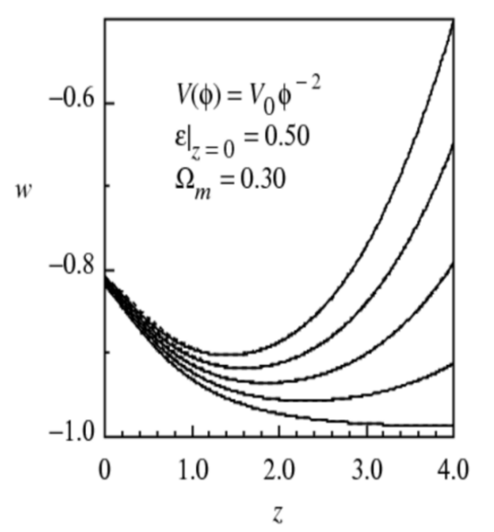
  (-1≤w≤1)
- Phantom field (w≤-1)
- Tachyon fields (-1 ≤ w ≤ 0)
- K-essence

  (no prior on w)

Inflation Now $1+w(a) = \varepsilon_s f(a/a_{\Lambda eq}; a_s/a_{\Lambda eq}; \zeta_s)$

Zhiqi Huang, Bond & Kofman08: 3-param formula accurately fits slow-to-moderate roll & even wild rising baroque late-inflaton trajectories, as well as thawing & freezing trajectories

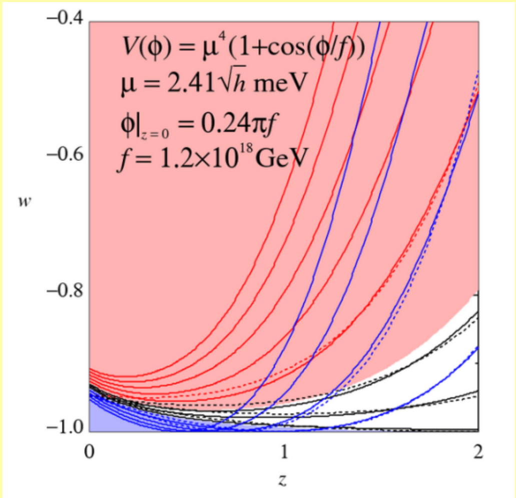
Cosmic Probes Now CFHTLS SN(Union~300),WL,CMB,BAO,LSS,Lyα



$\varepsilon_s = (d\ln V/d\psi)^2/4$ = late-inflaton (potential gradient)^2

=-0.05+-0.24 now;

weak a_s < 0.3 (z_s >2.3) now



ε_s to +-0.07 then Planck1+JDEM SN+DUNE WL, weak a_s <0.21 then, (z_s >3.7)

3rd param ζ_s (~$d\varepsilon_s$ /dlna) ill-determined now & then

cannot reconstruct the quintessence potential, just the slope ε_s & hubble drag info

(late-inflaton mass is < Planck mass, but not by a lot)

3-parameter parameterization $\ddot{\phi} + 3H\dot{\phi} + V'(\phi) = 0$

+ Friedmann Equation + DM+B

$$w(a) = -1 + \frac{2\epsilon_s}{3}\{\frac{(\frac{a_s}{a})^{3-3.6a_s|\epsilon_s|(1-\Omega_{m0})}}{\sqrt{1+\frac{\epsilon_s}{3|\epsilon_s|}(\frac{a_s}{a})^{6-7.2a_s|\epsilon_s|(1-\Omega_{m0})}}}\frac{1}{\sqrt{|\epsilon_s|}}$$

$$+[\sqrt{1+(\frac{a_{eq}}{a})^3} - (\frac{a_{eq}}{a})^3 \ln((\frac{a}{a_{eq}})^{\frac{3}{2}} + \sqrt{1+(\frac{a}{a_{eq}})^3})](1-\zeta_s)$$

$$+0.36\varepsilon_s(1-\Omega_{m0})\frac{(\frac{a}{a_{eq}})^2}{1+(\frac{a}{a_{eq}})^4}[0.9 - 0.7\frac{a}{a_{eq}} - 0.045(\frac{a}{a_{eq}})^2]$$

$$+\frac{2\zeta_s}{3}[\sqrt{1+(\frac{a}{a_{eq}})^3} - 2(\frac{a_{eq}}{a})^3(\sqrt{1+(\frac{a}{a_{eq}})^3} - 1)]\}^2$$

where

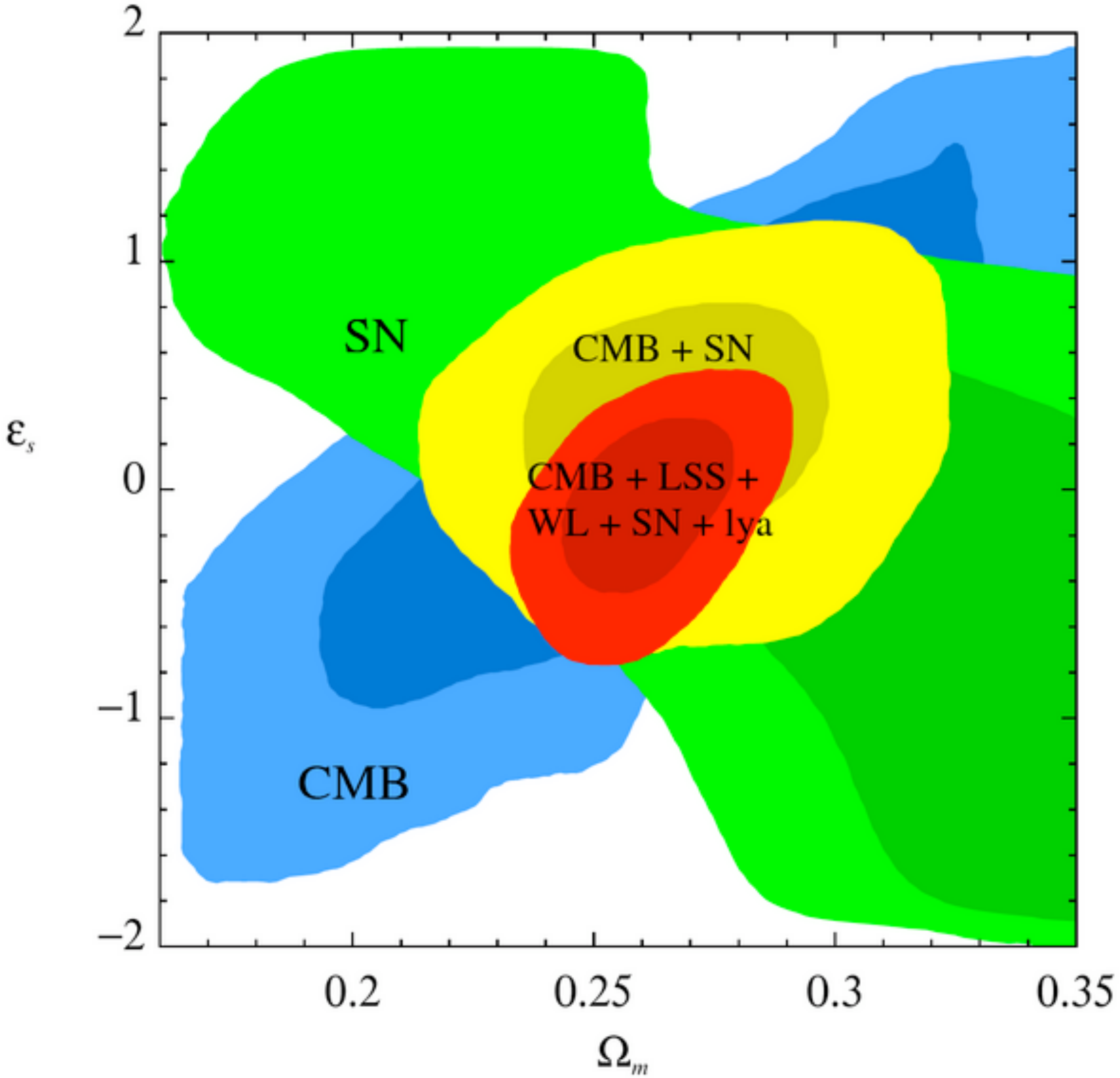
$$a_{eq} \equiv (\frac{\Omega_{m0}}{1-\Omega_{m0}})^{\frac{1}{3[1-0.36\varepsilon_s(1-\Omega_{m0})]}}$$

$$a_s \geq 0$$

$$\sqrt{|\epsilon_V|} = \sqrt{|\epsilon_s|}[1 + \zeta_s((\frac{a}{a_{eq}})^{\frac{3}{2}} - 1)] \qquad -1 < \zeta_s < 1$$

- ~15% thawing, 8% freezing, with flat priors

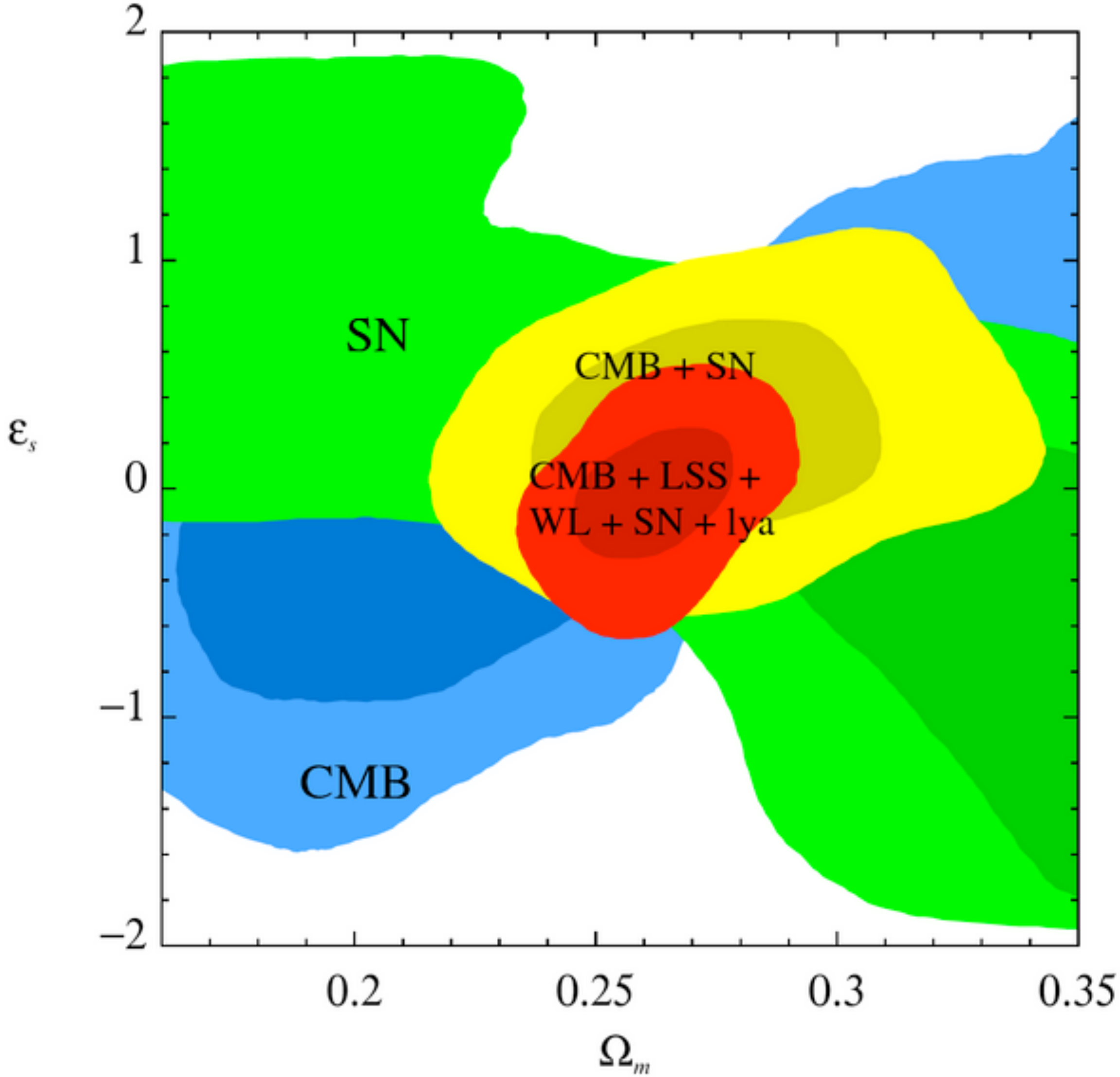
measuring ε_s ζ_s a_s=0 tracking (SNe_{union}+$CMB_{wmap5+acbar+cbi5yr+b03+}$+$WL_{cfhtls+cosmos}$+$LSS_{sdssRG+2dF}$+Lya)



modified CosmoMC with Weak Lensing, SZ, SN,CMB, bias & w(a) slow-to-moderate-roll trajectories with various priors

ε_s	-.03 + .25 -.23	1
	-.00 + .20 -.20	3
	-.05 + .24 -.31	2

measuring ε_s a_s ζ_s scaling+tracking SNe_{union}+CMB $_{wmap5+acbar+cbi5yr+b03+}$+$WL_{cfhtls+cosmos}$+$LSS_{sdssRG+2dF}$+Lya)



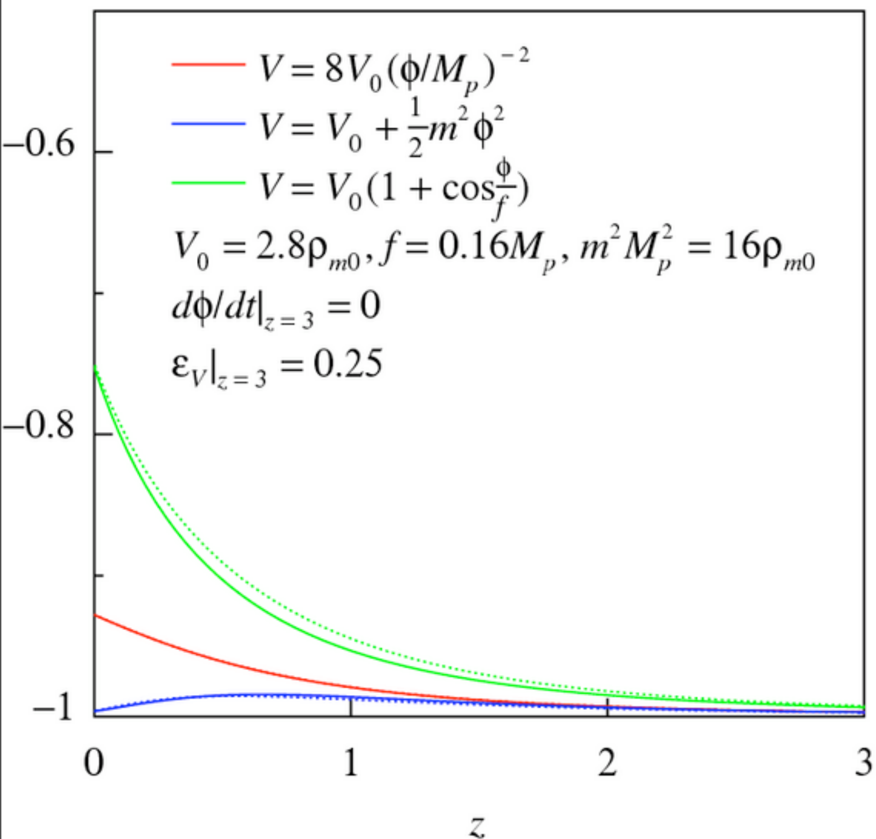
modified CosmoMC with Weak Lensing, SZ, SN,CMB, bias & w(a) slow-to-moderate-roll trajectories with various priors

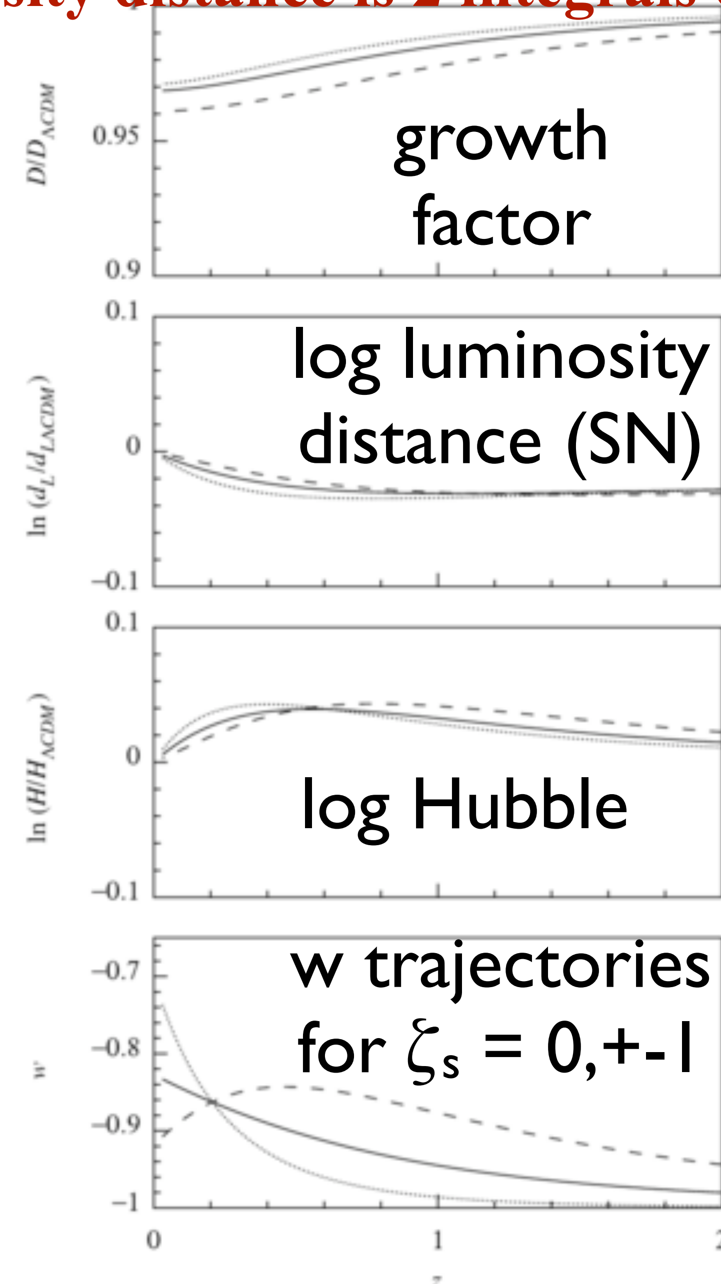
ε_s	-.03 + .25 -.23	1
	-.00 + .20 -.20	3
	-.05 + .24 -.31	2

Why can’t we measure the change of the slope, i.e., the effective mass of the potential? **w changes but the luminosity distance is 2 integrals of it.**

we fit w(z) for tracker potentials very well

$$\sqrt{|\epsilon_V|} = \sqrt{|\epsilon_s|}[1 + \zeta_s((\frac{a}{a_{eq}})^{\frac{3}{2}} - 1)]$$





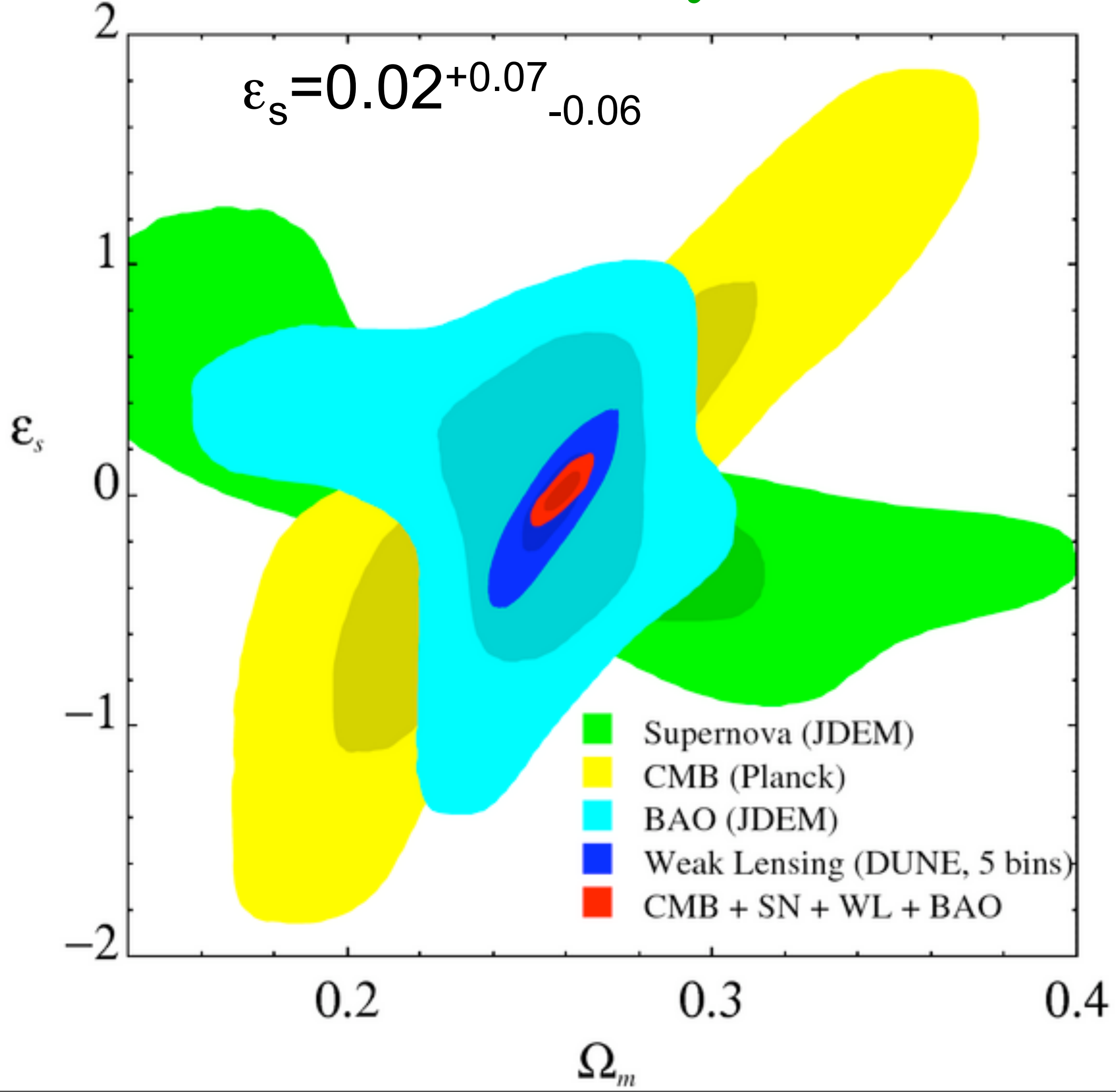
INFLATION NOW

PROBES THEN

Beyond Einstein panel: LISA+JDEM

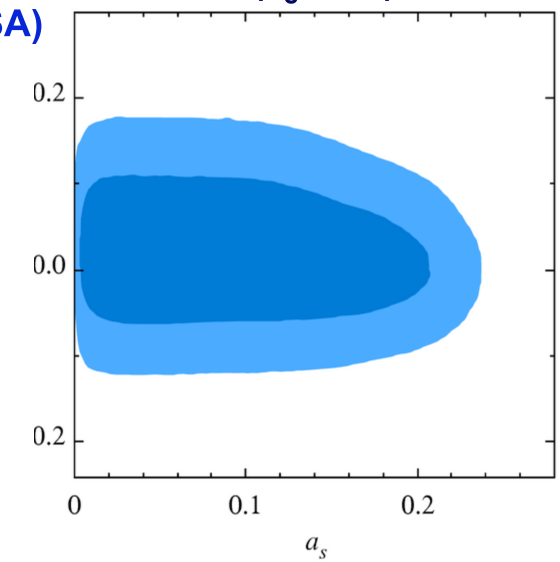
Forecast: JDEM-SN (2500 hi-z + 500 low-z) + DUNE-WL (50% sky, gals @z = 0.1-1.1, 35/min^2) + Planck1yr

ESA (+NASA/CSA)

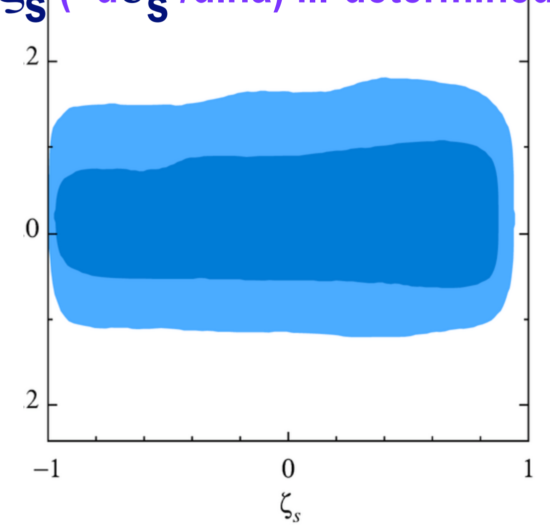


a_s<0.21 (95%CL)

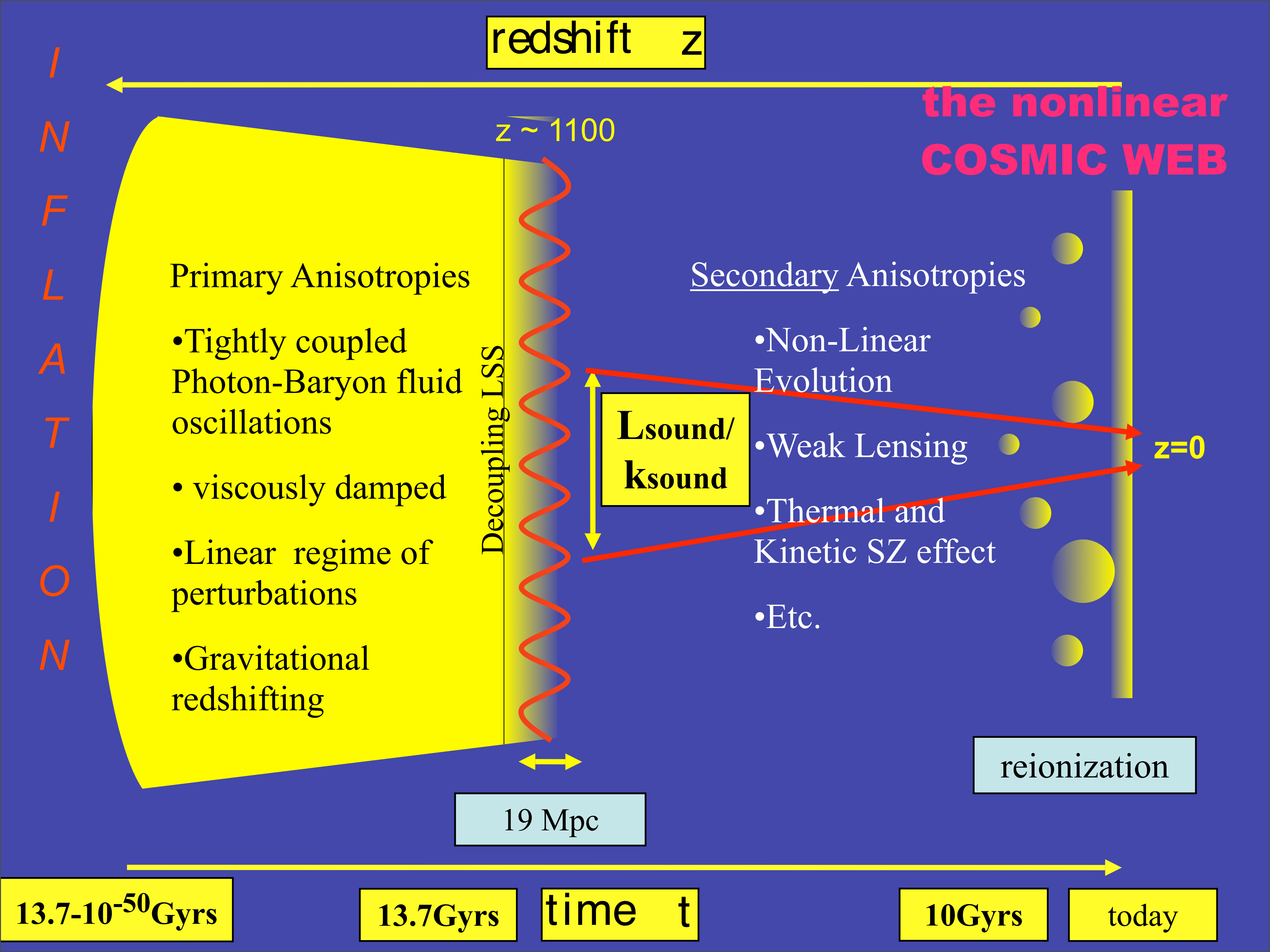
(z_s >3.7)



ζ_s (~$d\varepsilon_s$ /dlna) ill-determined



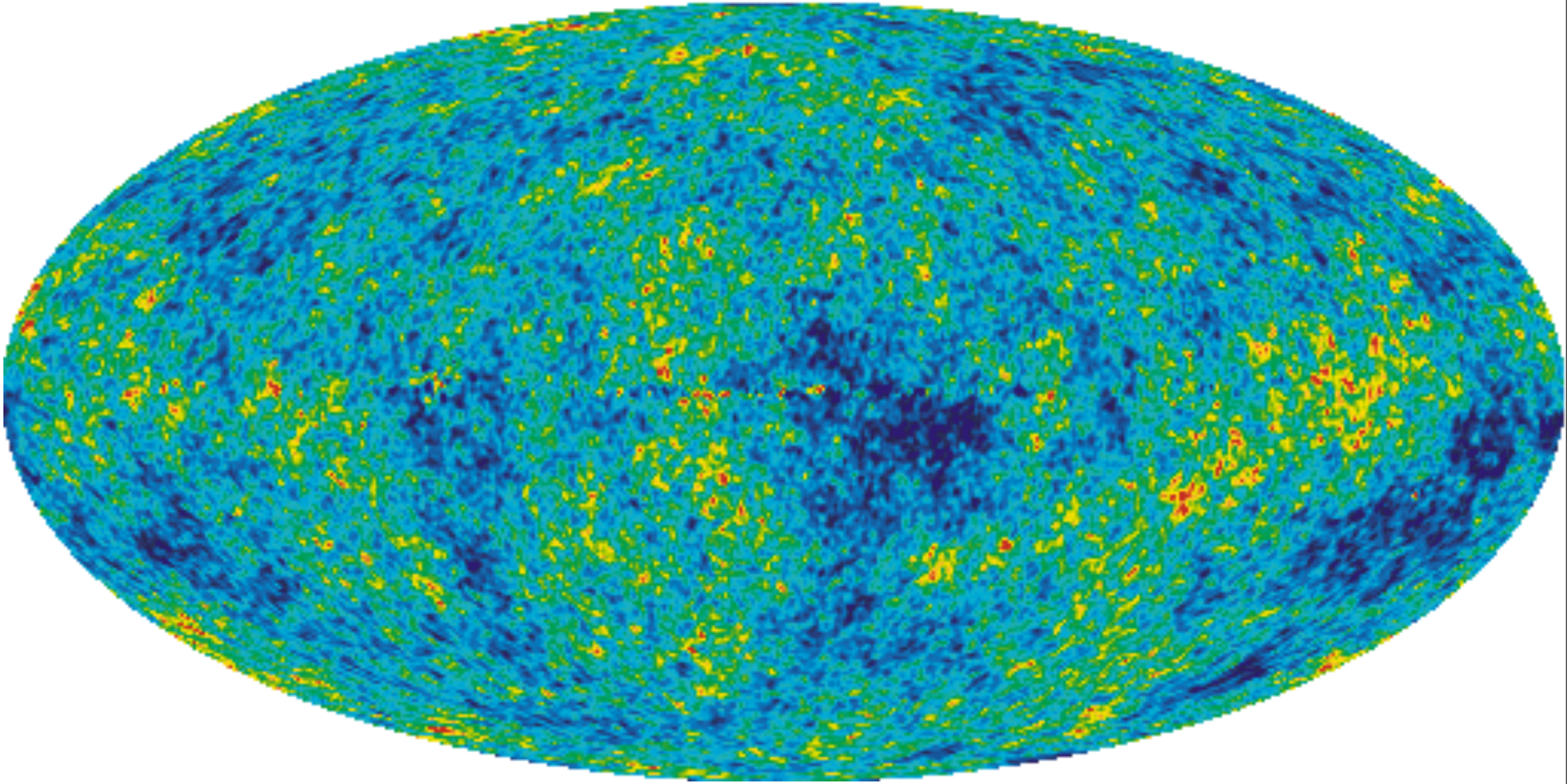
CMB NOW



redshift z
INFLATION
z ~ 1100
the nonlinear COSMIC WEB
Primary Anisotropies
•Tightly coupled Photon-Baryon fluid oscillations
• viscously damped
•Linear regime of perturbations
•Gravitational redshifting
Decoupling LSS
Lsound/ ksound
Secondary Anisotropies
•Non-Linear Evolution
•Weak Lensing
•Thermal and Kinetic SZ effect
•Etc.
z=0
reionization
19 Mpc
13.7-10^-50Gyrs
13.7Gyrs
time t
10Gyrs
today

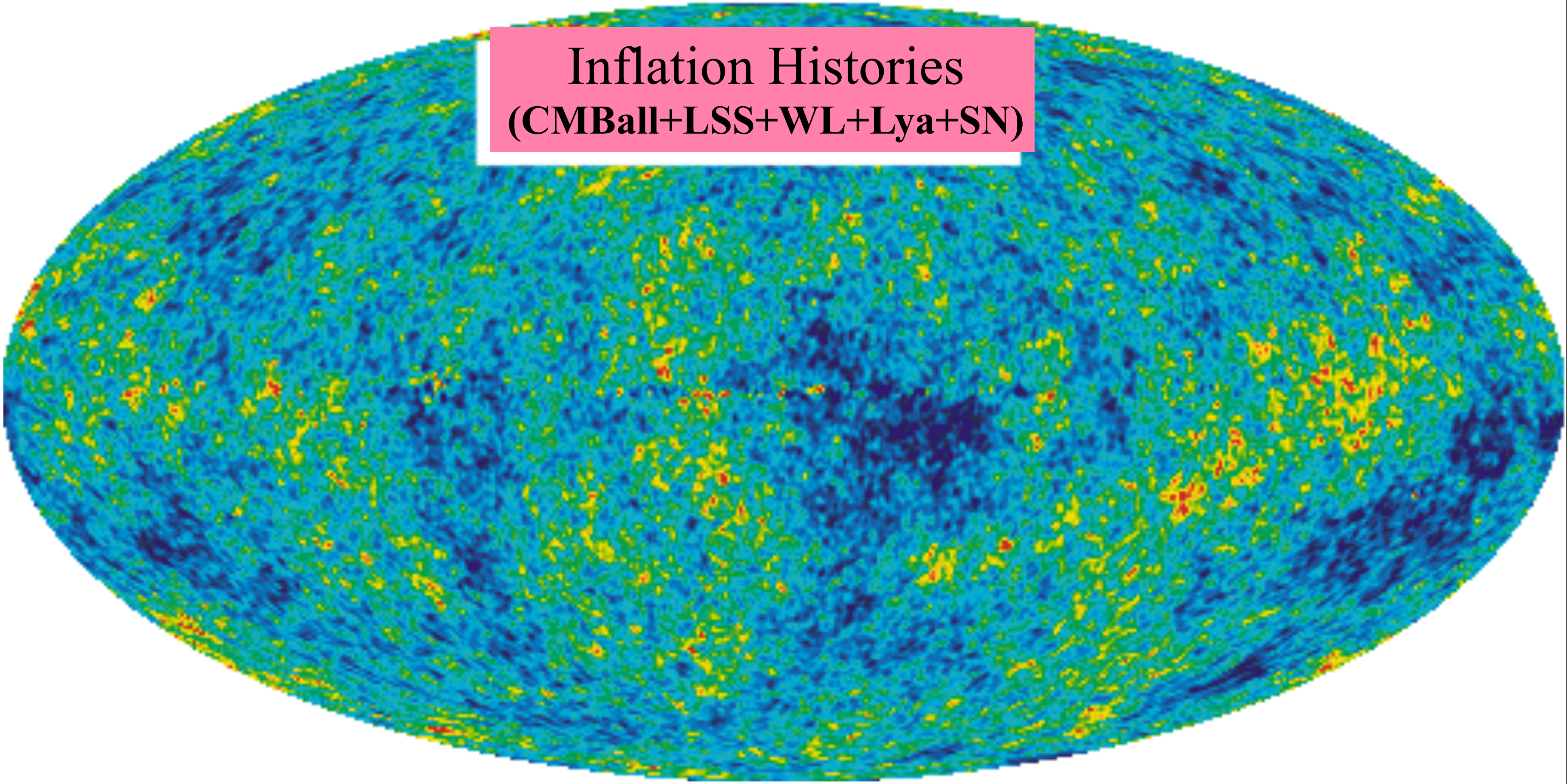
CMBology

Probing the linear & nonlinear cosmic web



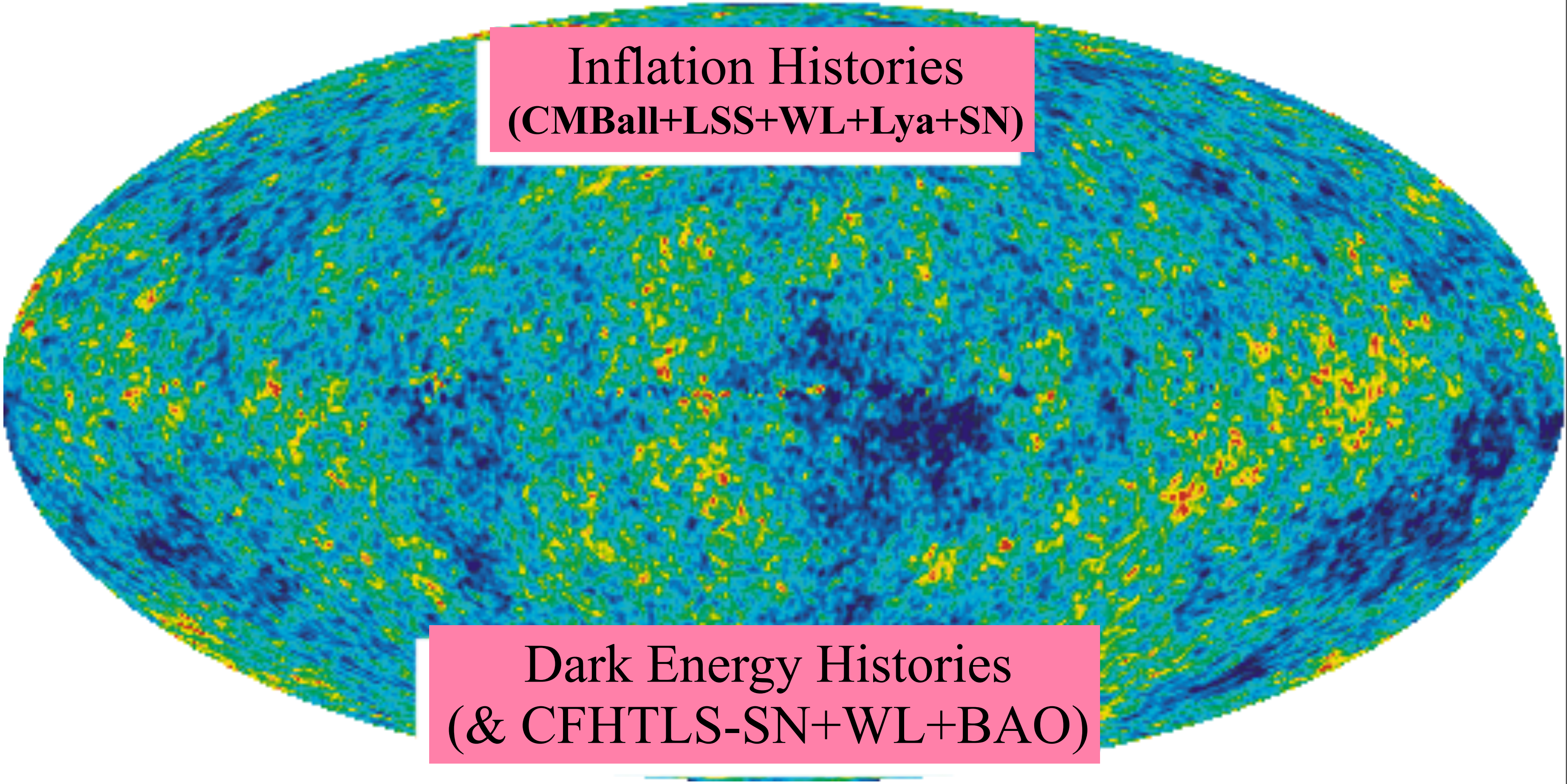
CMBology

Probing the linear & nonlinear cosmic web



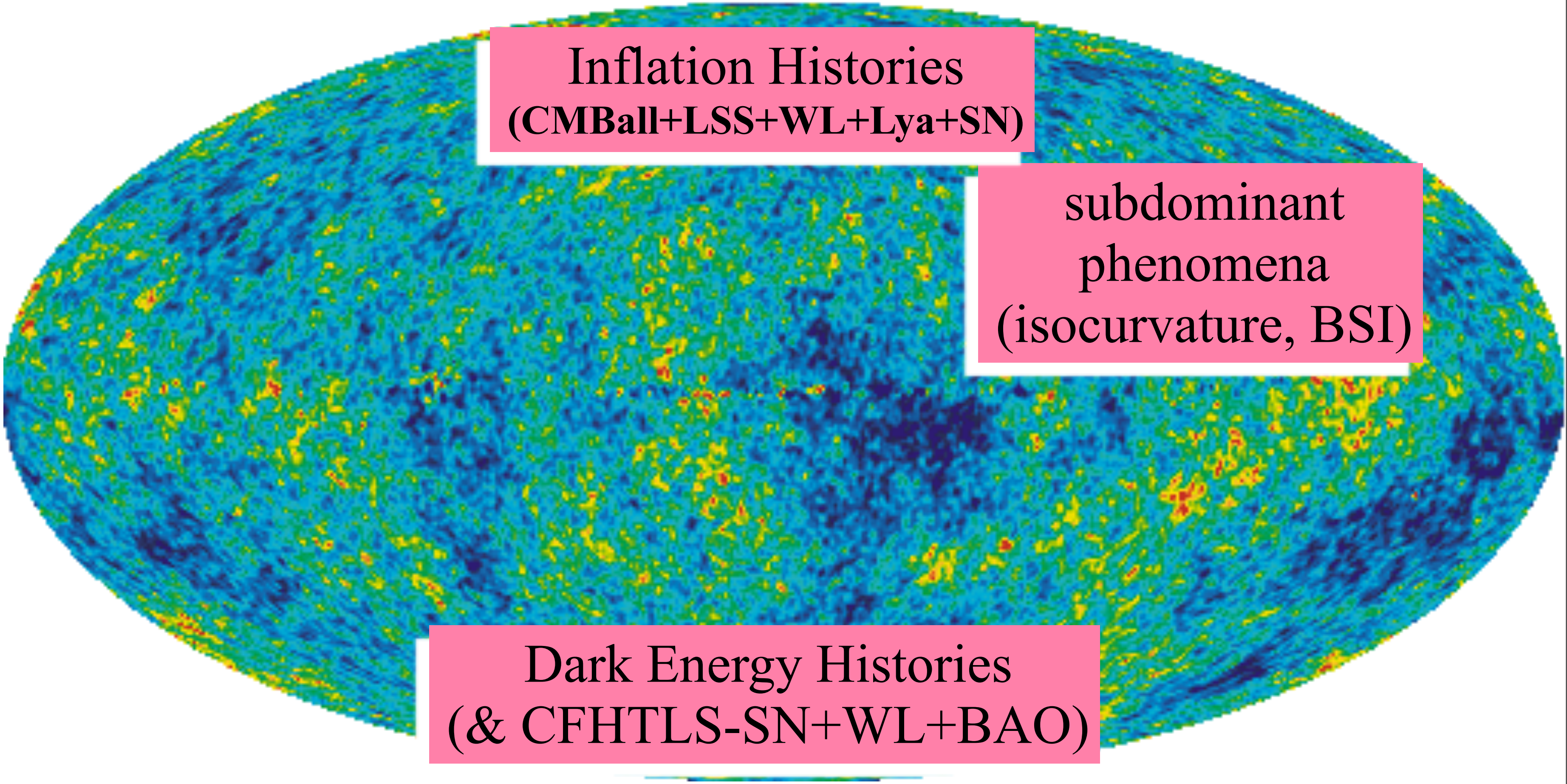
CMBology

Probing the linear & nonlinear cosmic web



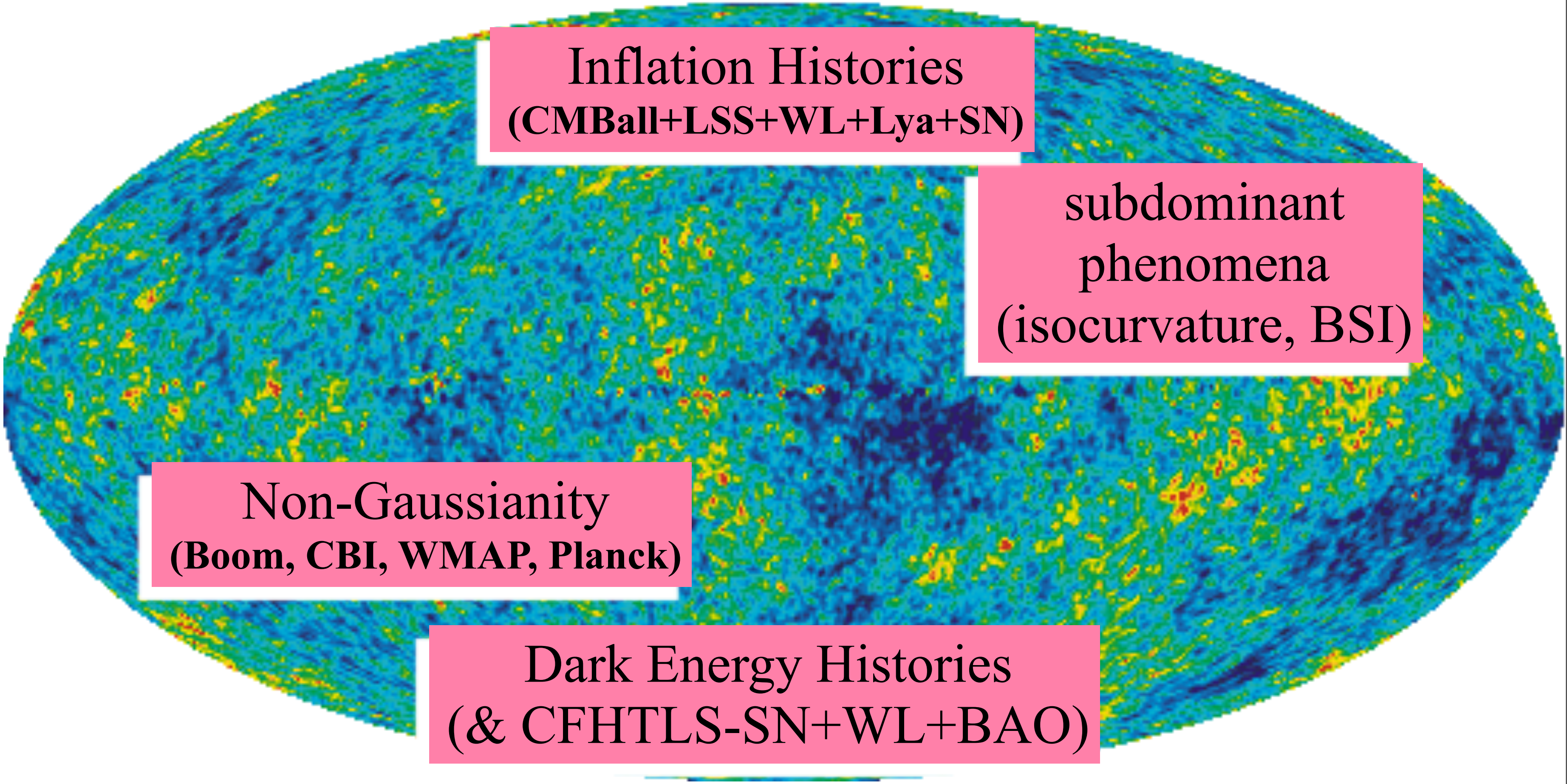
CMBology

Probing the linear & nonlinear cosmic web



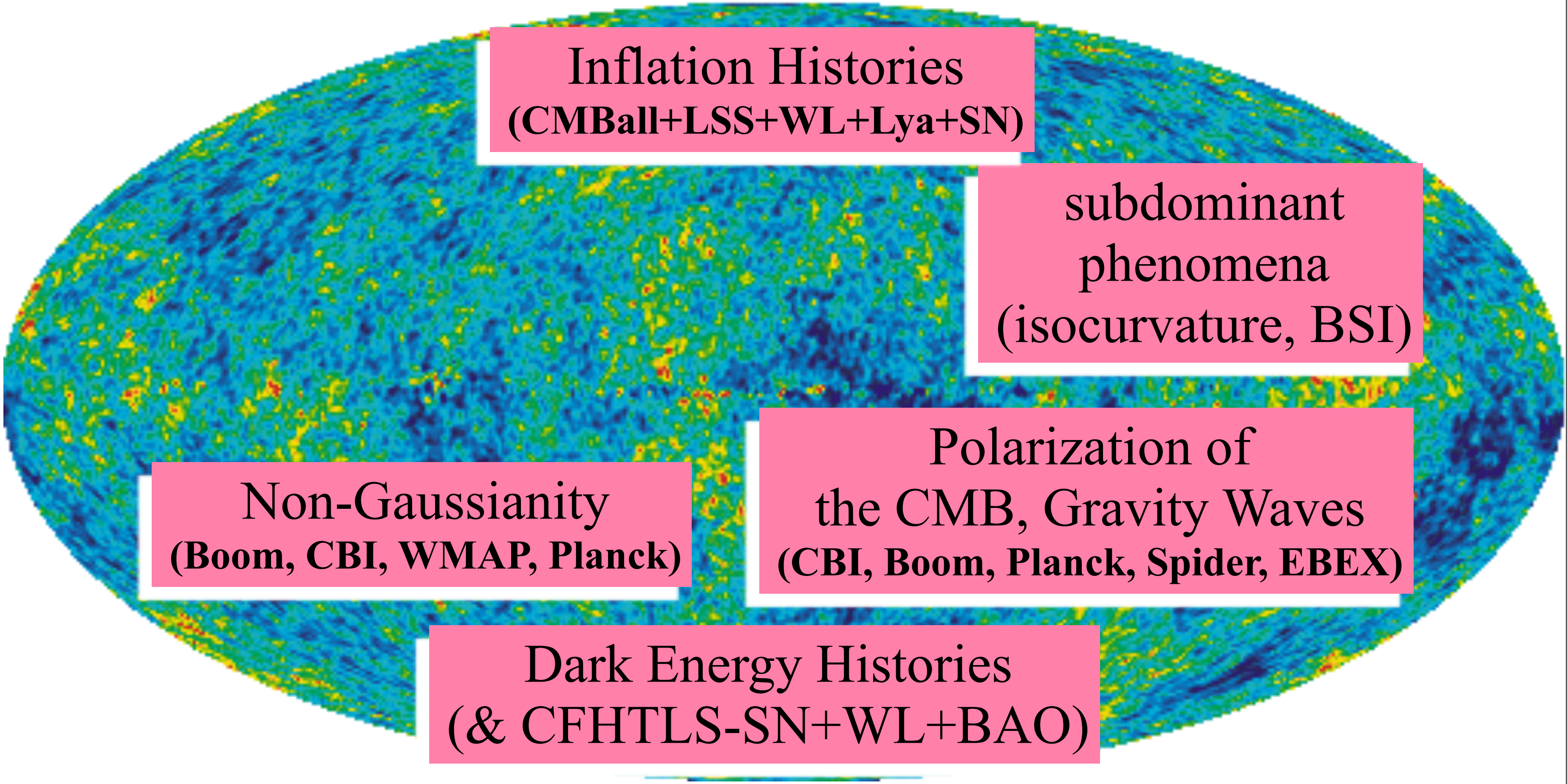
CMBology

Probing the linear & nonlinear cosmic web



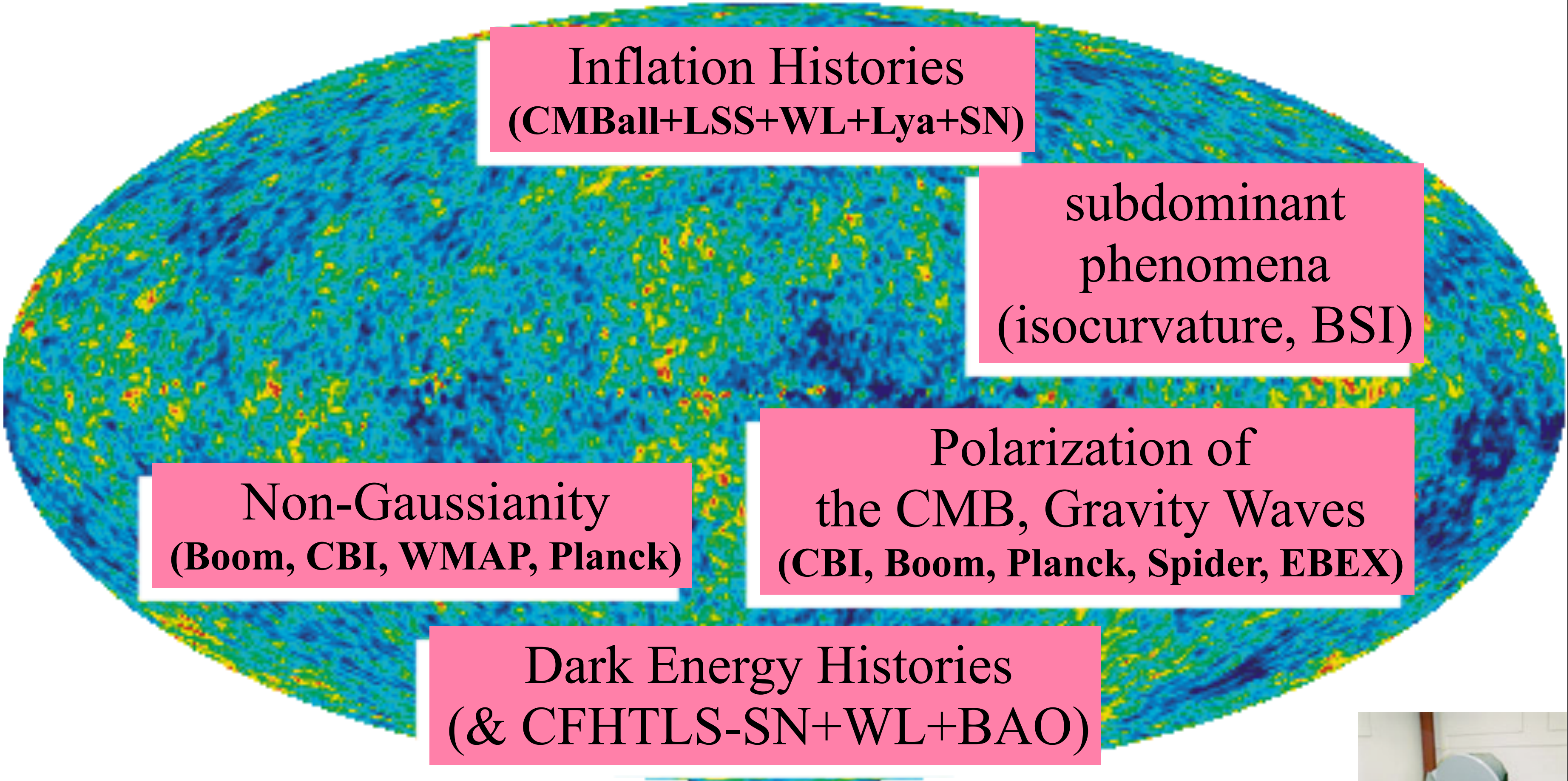
CMBology

Probing the linear & nonlinear cosmic web



CMBology

Probing the linear & nonlinear cosmic web



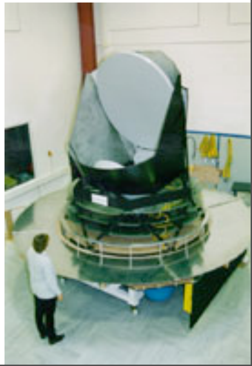
Inflation Histories
(CMBall+LSS+WL+Lya+SN)

subdominant phenomena (isocurvature, BSI)

Non-Gaussianity
(Boom, CBI, WMAP, Planck)

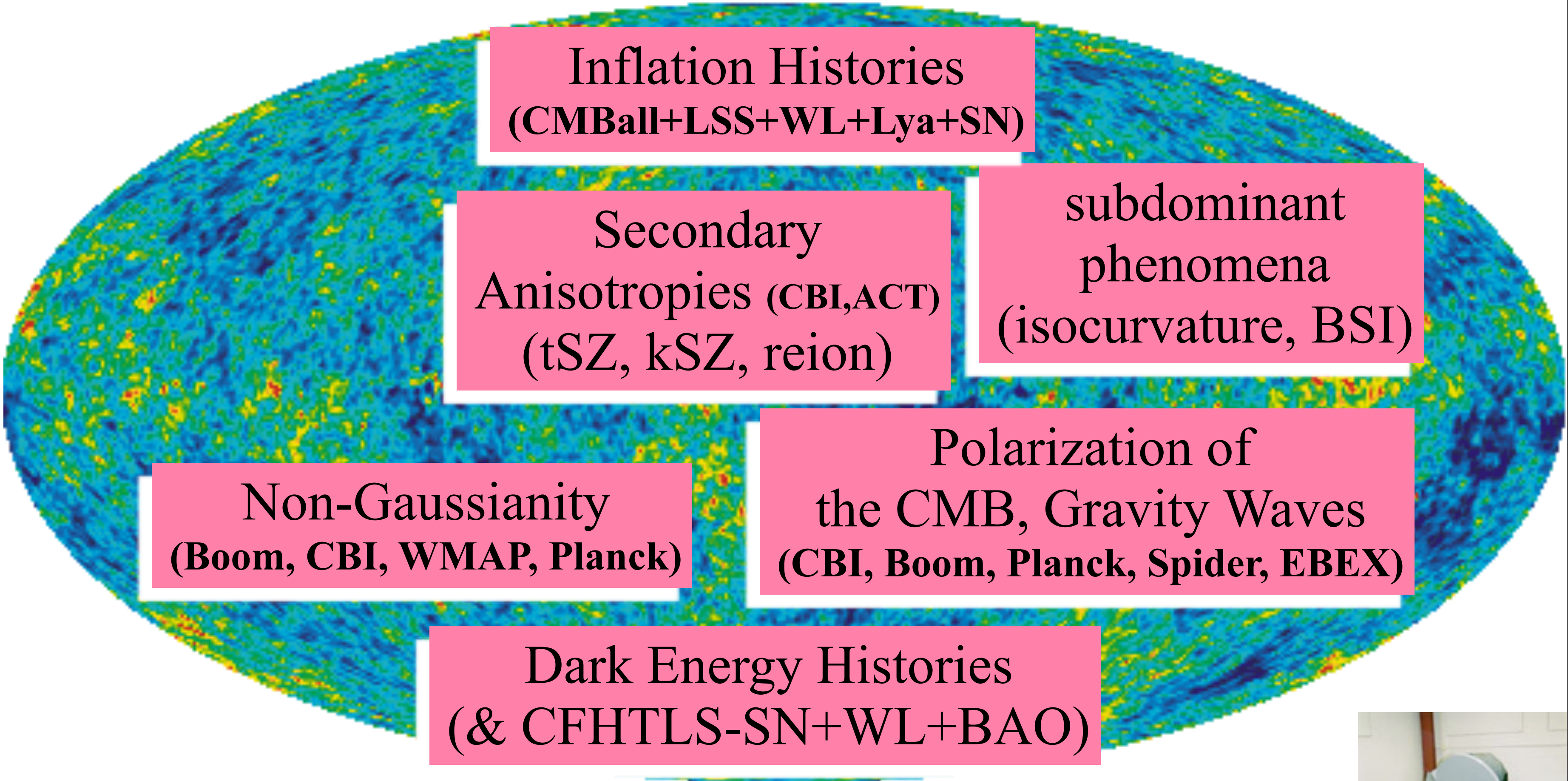
Polarization of the CMB, Gravity Waves
(CBI, Boom, Planck, Spider, EBEX)

Dark Energy Histories
(& CFHTLS-SN+WL+BAO)



CMBology

Probing the linear & nonlinear cosmic web



Inflation Histories
(CMBall+LSS+WL+Lya+SN)

Secondary Anisotropies **(CBI,ACT)**
(tSZ, kSZ, reion)

subdominant phenomena
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Non-Gaussianity
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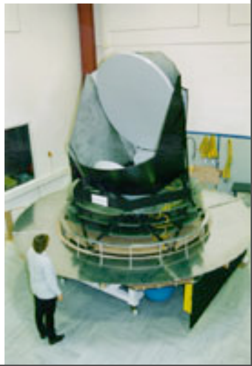
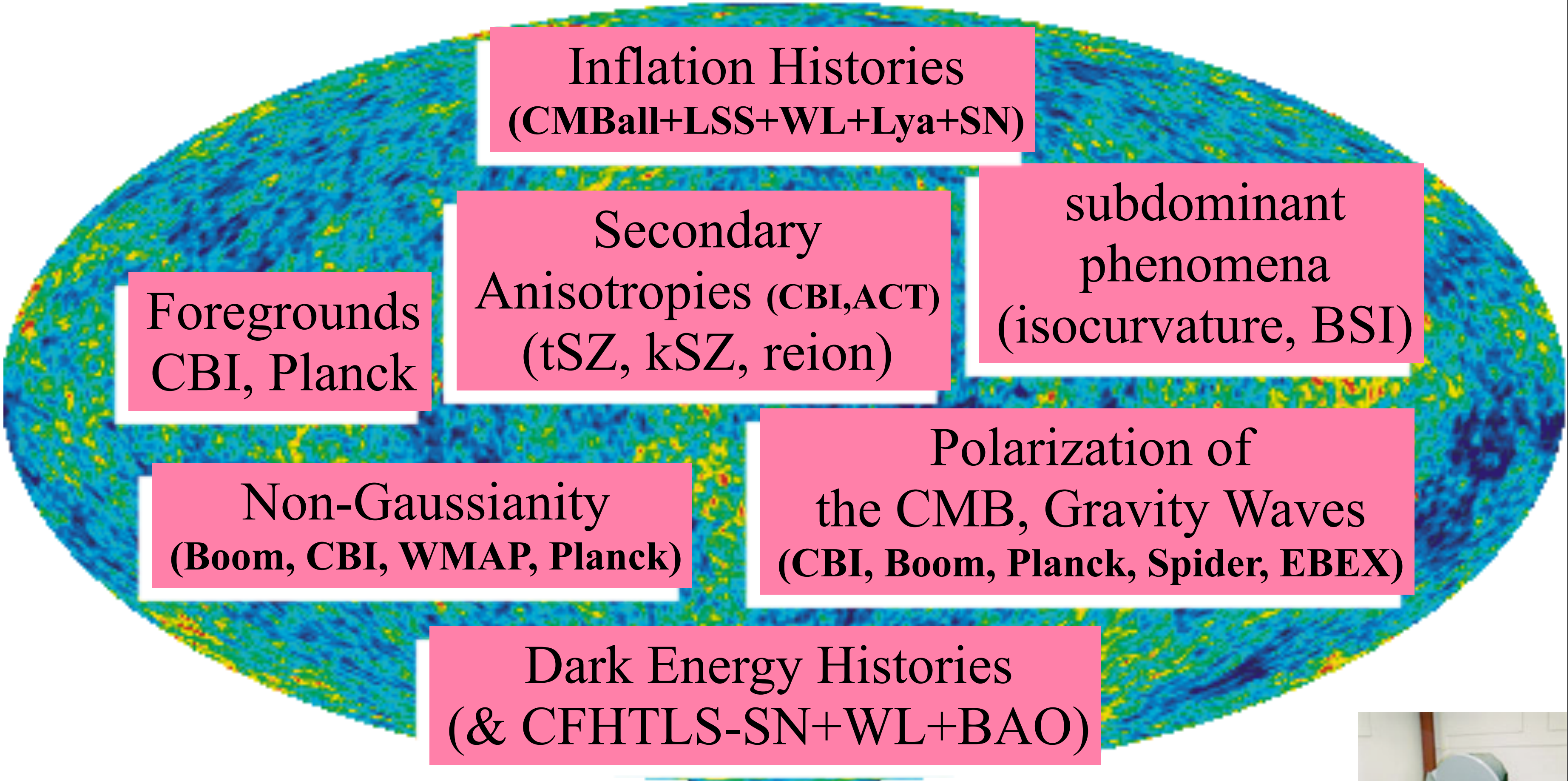
Polarization of the CMB, Gravity Waves
(CBI, Boom, Planck, Spider, EBEX)

Dark Energy Histories
(& CFHTLS-SN+WL+BAO)



CMBology

Probing the linear & nonlinear cosmic web



Inflation Histories
(CMBall+LSS+WL+Lya+SN)

Secondary Anisotropies **(CBI,ACT)**
(tSZ, kSZ, reion)

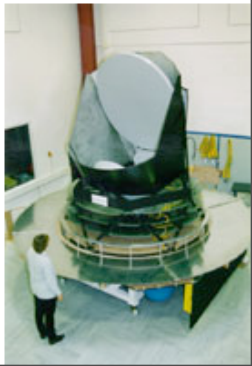
subdominant phenomena
(isocurvature, BSI)

Foregrounds
CBI, Planck

Non-Gaussianity
(Boom, CBI, WMAP, Planck)

Polarization of the CMB, Gravity Waves
(CBI, Boom, Planck, Spider, EBEX)

Dark Energy Histories
(& CFHTLS-SN+WL+BAO)



CBI pol to Apr'05 @Chile

Bicep @SP

Quiet2 (1000 HEMTs) @Chile

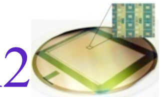
Quiet1

Acbar to Jan'06, 07f @SP

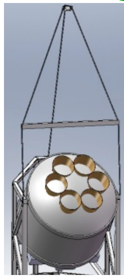
QUaD @SP

CBI2 to early'08

SCUBA2 (12000 bolometers) JCMT @Hawaii



Spider 2312 bolometer @LDB



SZA (Interferometer) @Cal

APEX (~400 bolometers) @Chile

ACT (3000 bolometers) 3 frequencies @Chile

Clover @Chile

Boom03@LDB

EBEX@LDB

2004 2006 2008 LMT@Mexico 2017

2005 2007 SPT LHC 2009 Bpol@L2

WMAP @L2 to 2009-2013?

SPT (1000 bolometers) @South Pole

ALMA (Interferometer) @Chile

DASI @SP

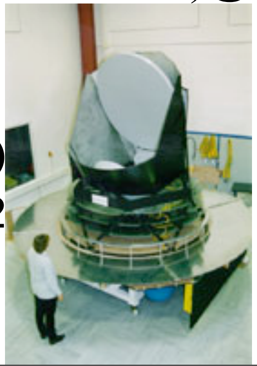
Polarbear (300 bolometers)@Cal

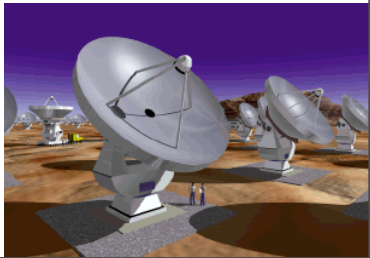
CAPMAP

Planck08.9

AMI

(84 bolometers) + HEMTs @L2 9 frequencies





GBT

CBI pol to Apr'05 @Chile

Bicep @SP

Quiet2 (1000 HEMTs)

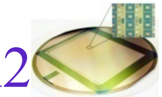
Acbar to Jan'06, 07f @SP

QUaD @SP

CBI2 to early'08

Quiet1 @Chile

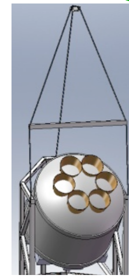
SCUBA2



(12000 bolometers)

JCMT @Hawaii

Spider



2312 bolometer @LDB

SZA (Interferometer) @Cal

APEX (~400 bolometers) @Chile

ACT (3000 bolometers) 3 frequencies @Chile

Clover @Chile

Boom03@LDB

EBEX@LDB

2004 — 2005 — 2006 — 2007 — 2008 — 2009 — 2017

LMT@Mexico

SPT (1000 bolometers) @South Pole

LHC

Bpol@L2

WMAP @L2 to 2009-2013?

ALMA (Interferometer) @Chile

DASI @SP

Polarbear (300 bolometers)@Cal

CAPMAP

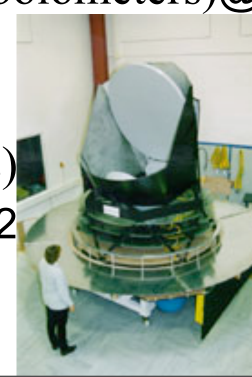
Planck08.9

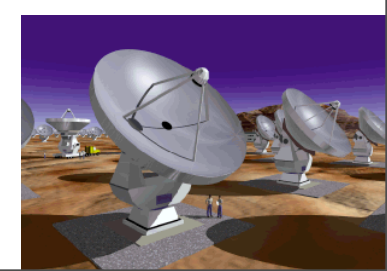
AMI

GBT

(84 bolometers) + HEMTs @L2

9 frequencies





CMB/LSS Phenomenology

CITA/CIfAR here

- Bond
- Contaldi
- Lewis
- Sievers
- Pen
- McDonald
- Majumdar
- Nolta
- Iliev
- Kofman
- Vaudrevange
- Huang

Prokushkin

- Dalal
- Dore
- Kesden
- MacTavish
- Pfrommer
- Shirokov

UofT here

- Netterfield
- Crill
- Carlberg
- Yee

& Exptal/Analysis/Phenomenology Teams here & there

- Boomerang03 (98)
- CBI5yr, CBI2
- Acbar08
- WMAP (Nolta, Dore)
- CFHTLS – WeakLens
- CFHTLS - Supernovae
- RCS2 (RCS1; Virmos-Descart)

CITA/CIfAR there

- Mivelle-Deschenes (IAS)
- Pogosyan (U of Alberta)
- Myers (NRAO)
- Holder (McGill)
- Hoekstra (UVictoria)
- van Waerbeke (UBC)

Parameter data now: CMBall_pol

SDSS P(k), BAO, 2dF P(k)

Weak lens (Virmos/RCS1, CFHTLS, RCS2) ~100sqdeg Benjamin etal. aph/0703570v1

Lya forest (SDSS)

SN1a “gold”(192,15 z>1) CFHTLS

then: ACT (SZ), Spider, Planck, 21(1+z)cm GMRT,SKA

The Parameters of Cosmic Structure Formation

Cosmic Numerology: april08 cmb +LSS/WL/SN includes wmap5

	January 2000	January 2002	June 2002	January 2003	March 2003
n_s	$1.218^{+0.135}_{-0.163}$	$0.949^{+0.083}_{-0.049}$	$0.938^{+0.077}_{-0.042}$	$0.961^{+0.081}_{-0.047}$	$0.978^{+0.025}_{-0.020}$

n_s = .976 +- .011 (+-.005 Planck1)

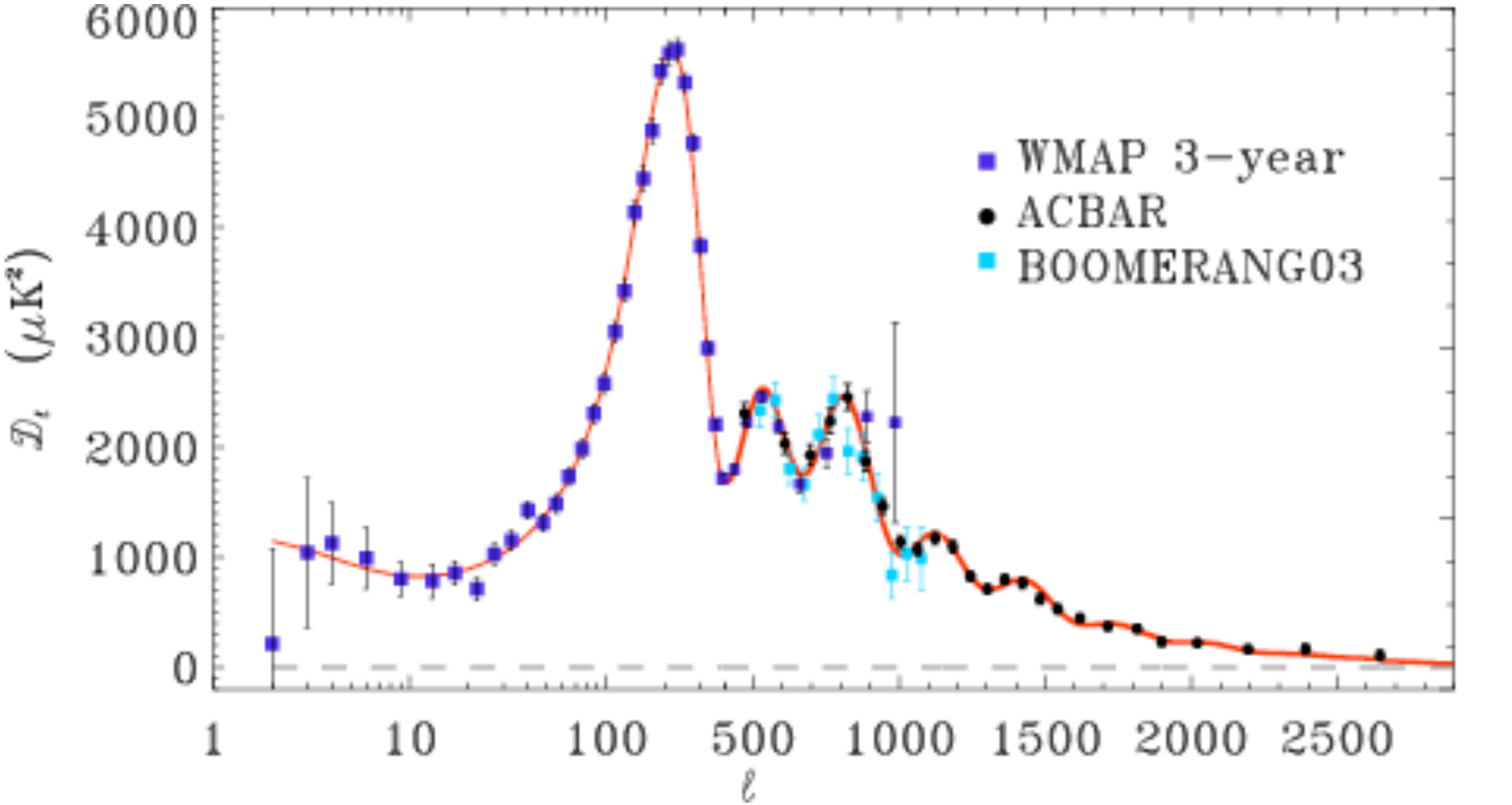
.959 +- .011 CMBall+WL+LSS/BAO+SNunion

$r = A_t / A_s$ < 0.33 cmb 95% CL (+-.03 P1)

dn_s /dln k=-.048 +- .027* (+-.005 P1)

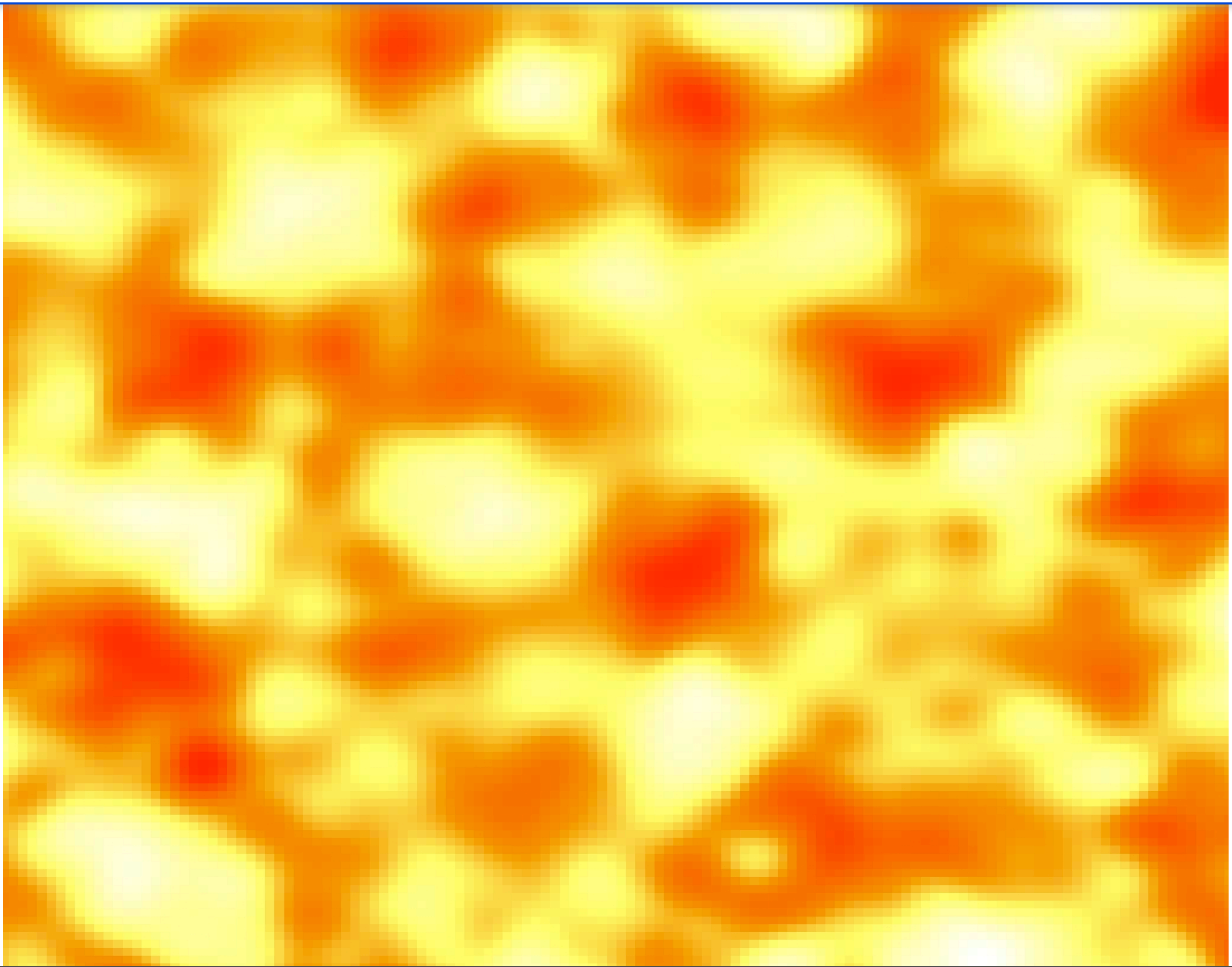
WMAP5+ACBAR08 run&tensor

-9< f_{NL} <111 (+- 5-10 P1)



ACBAR sees 3rd 4th 5th peaks & damping tail out to 2000+

nonlinear Gas & Dark Matter Structure in the Cosmic Web the cluster/gp web “now”, the galaxy/dwarf system “then”



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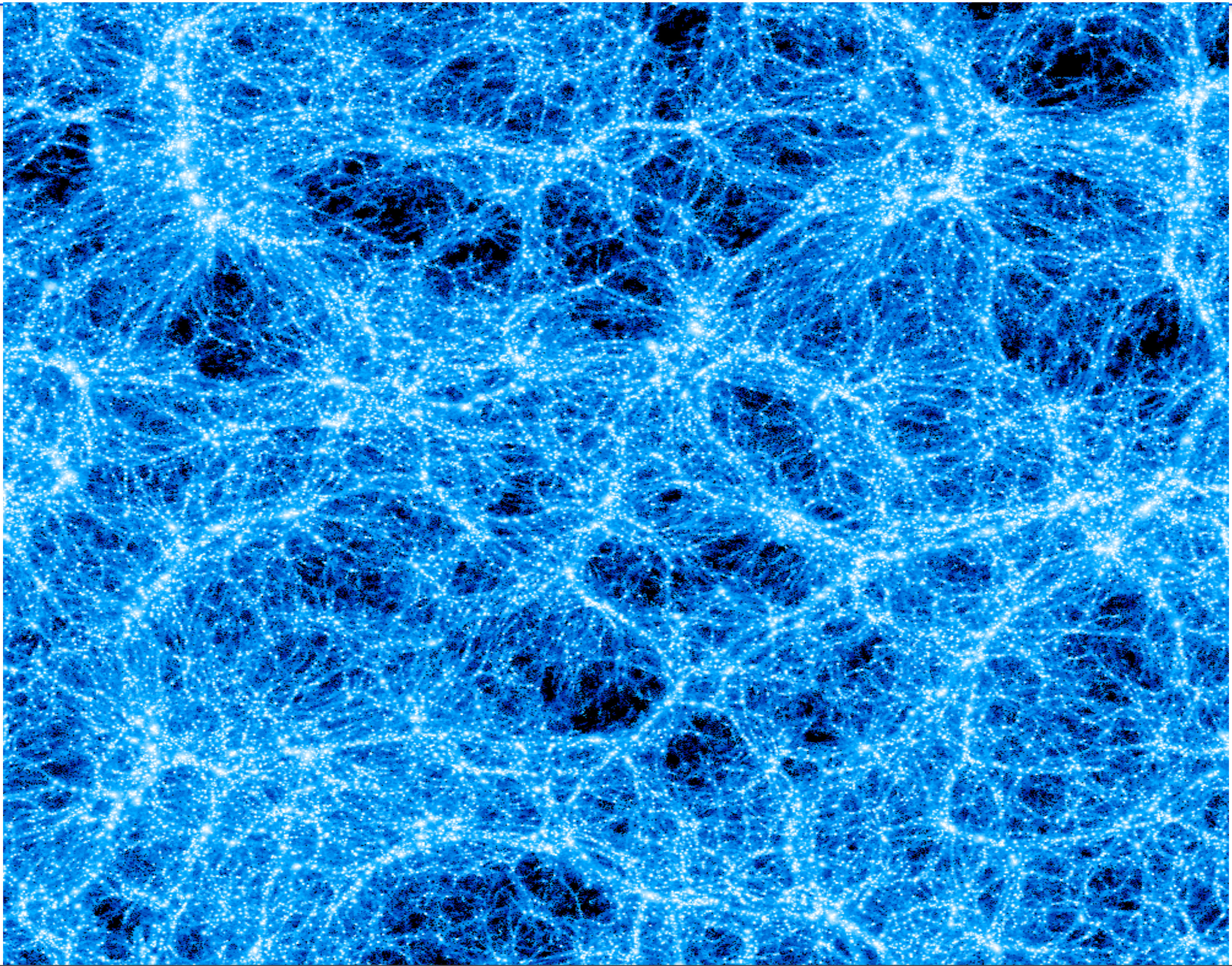

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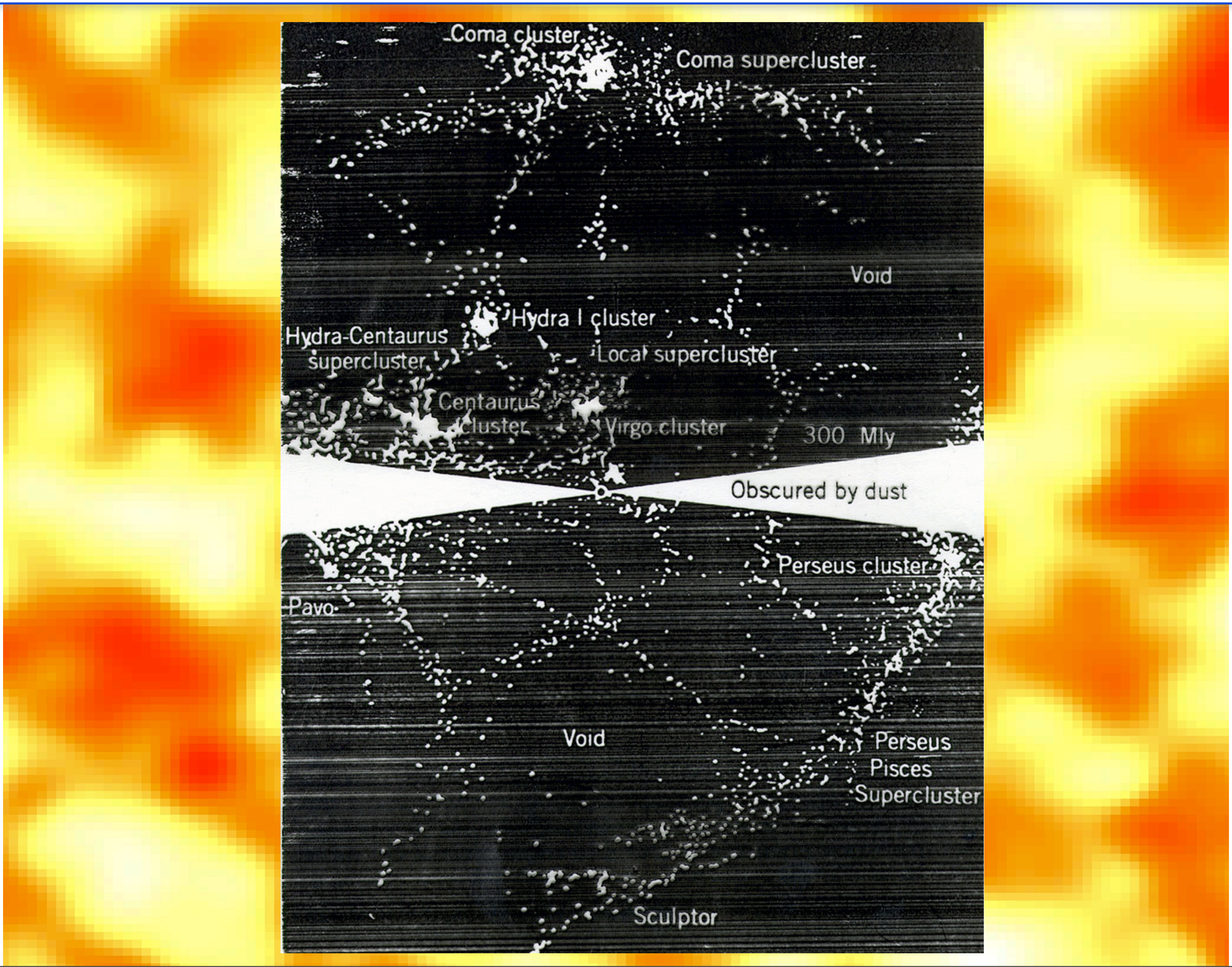

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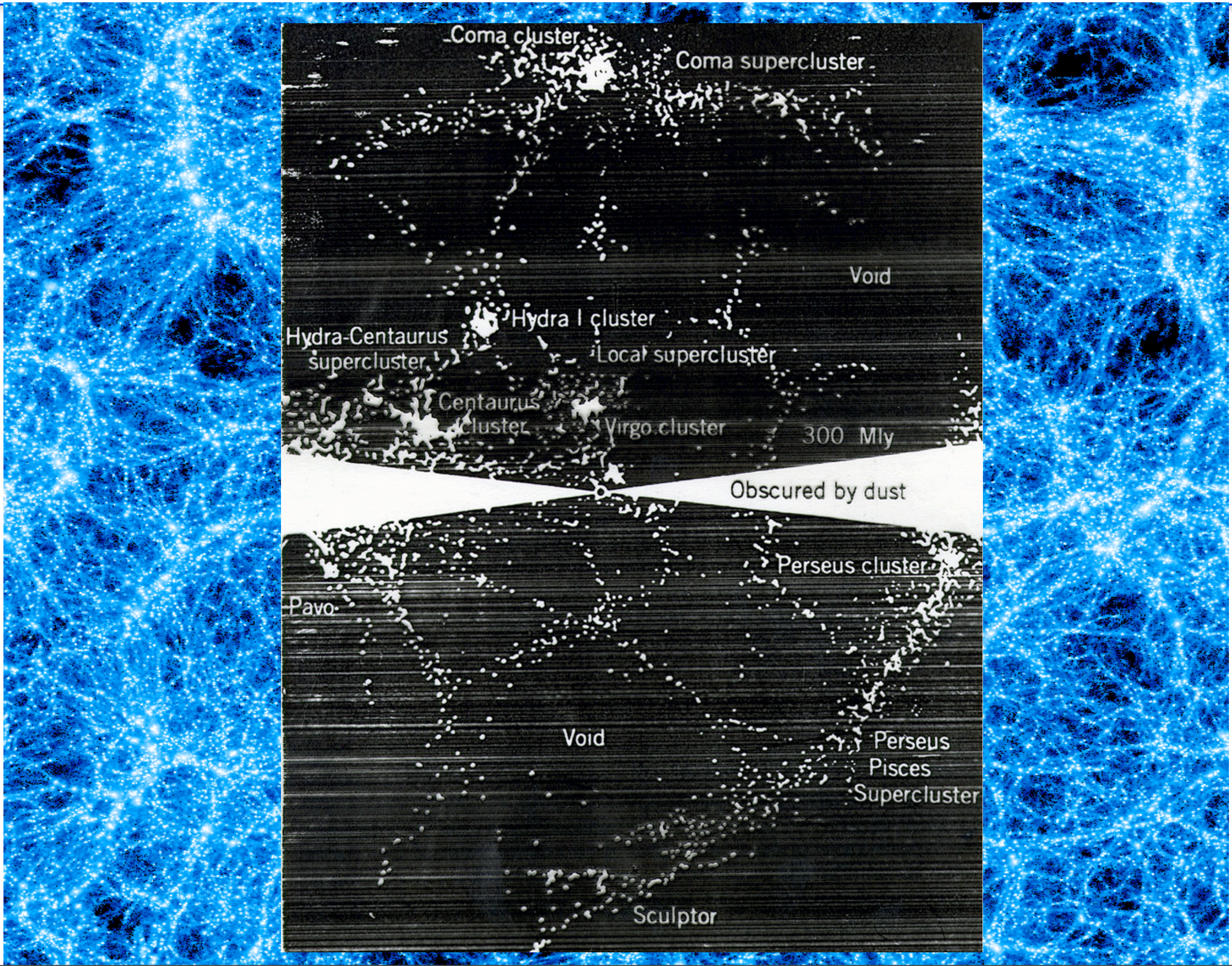
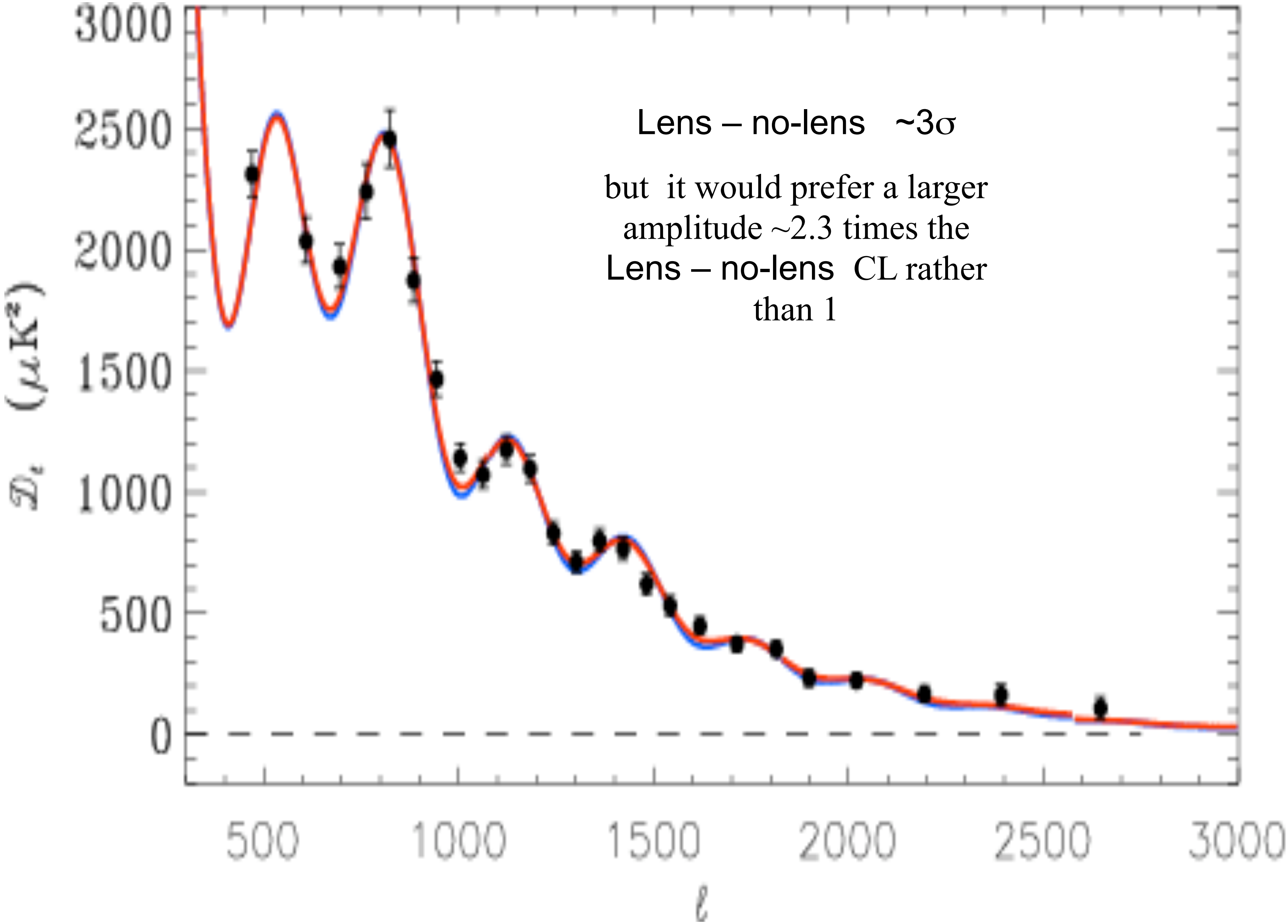
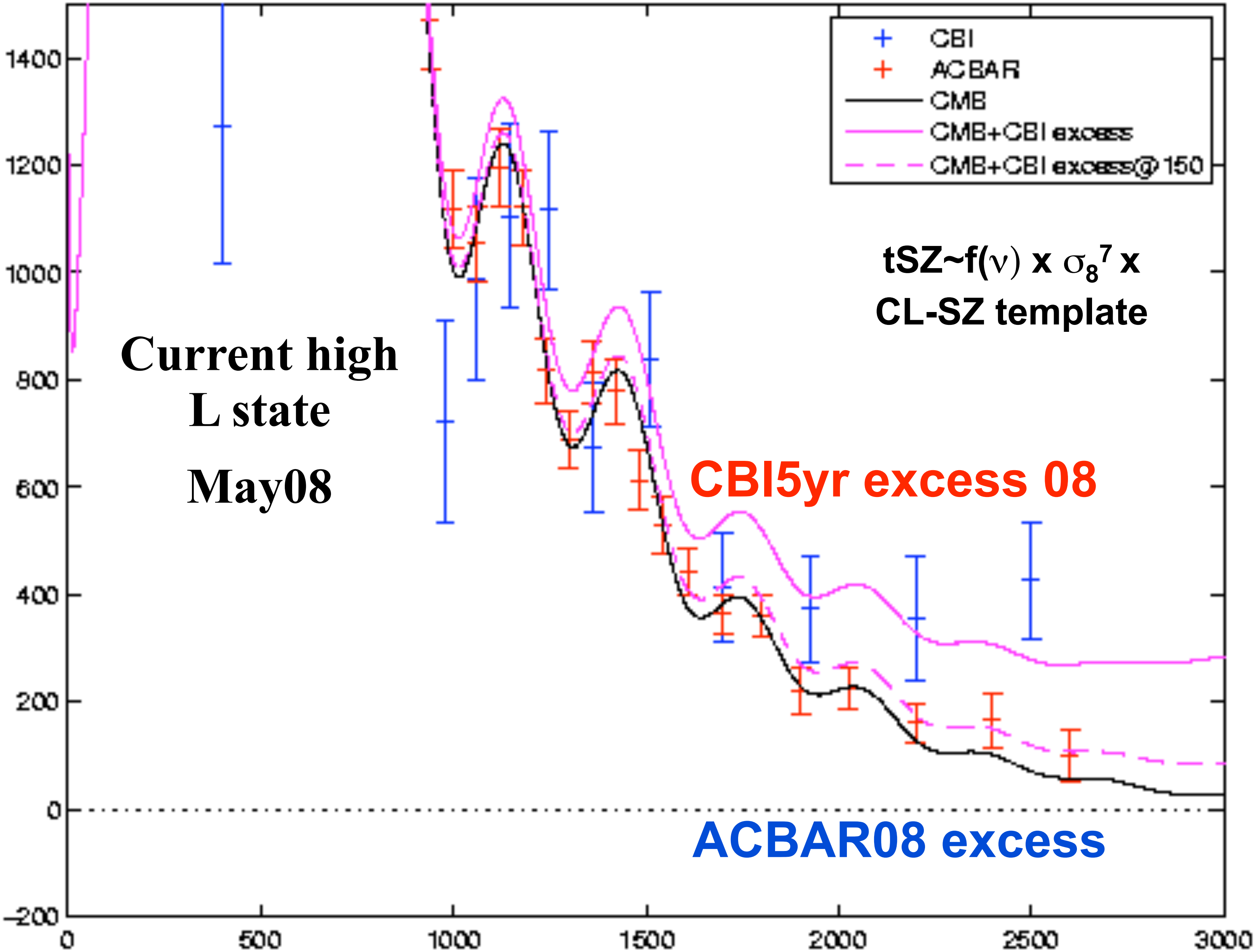


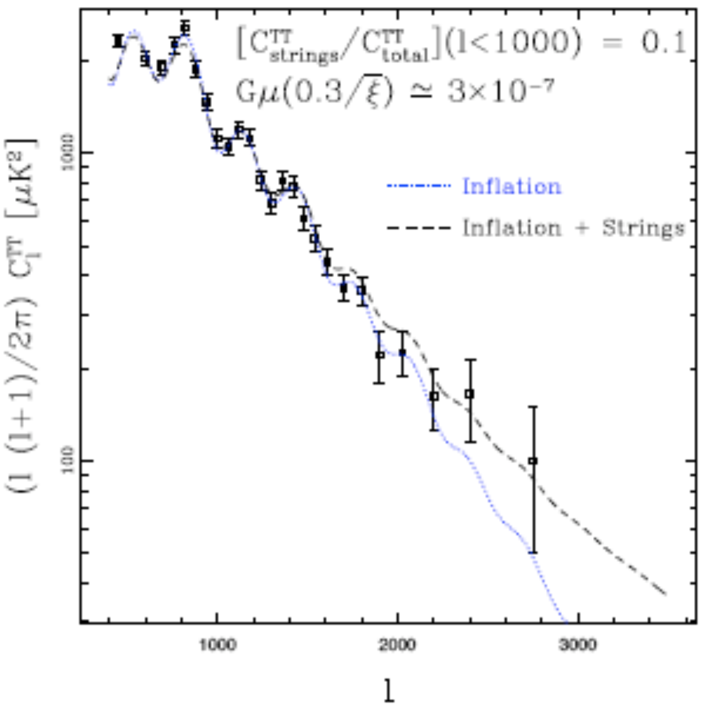

Lens – no-lens ~3σ
but it would prefer a larger amplitude ~2.3 times the Lens – no-lens CL rather than 1
3000
2500
2000
1500
1000
500
0
$\mathcal{D}_\ell$ (μK^2)
500
1000
1500
2000
2500
3000
ℓ

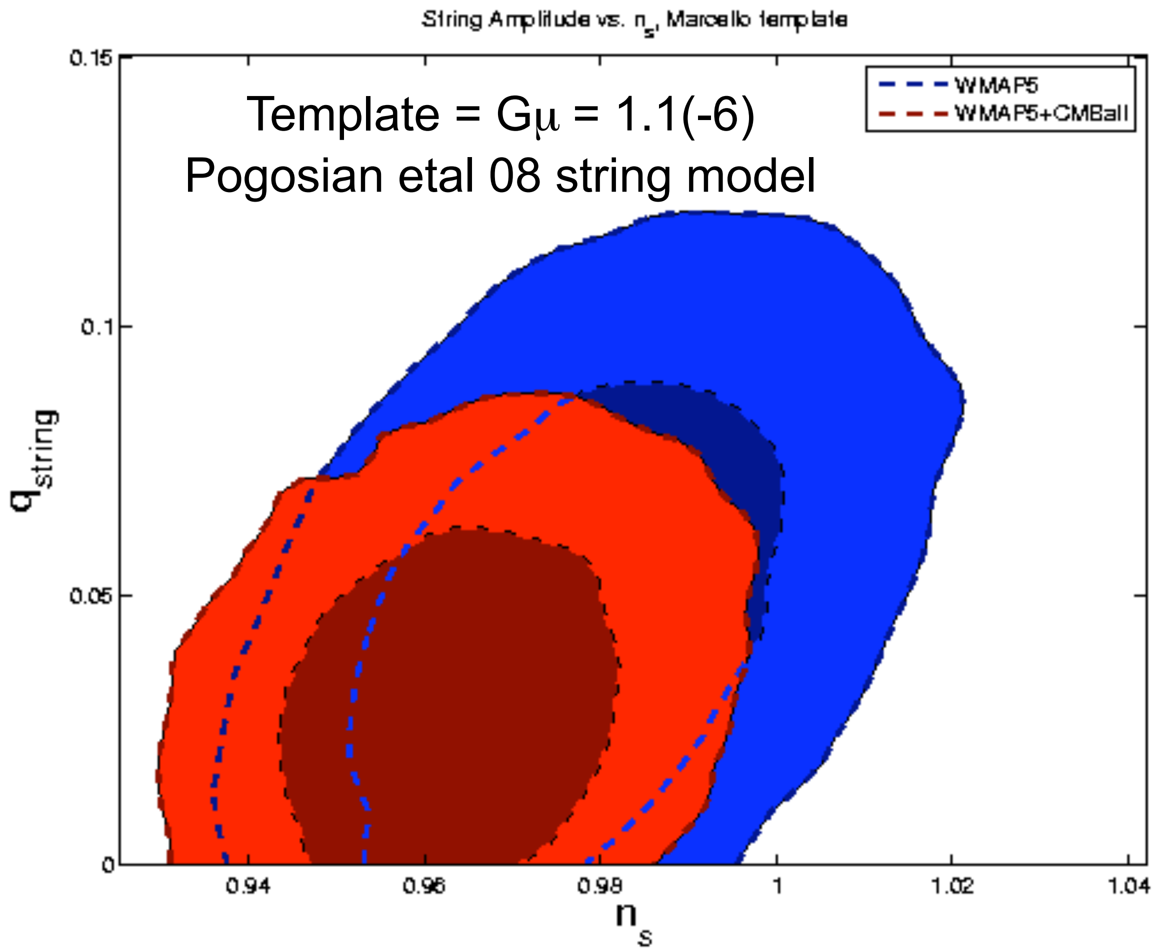


marginalization critical to get n_s & dn_s /dlnk; tSZ, radio, submm sources

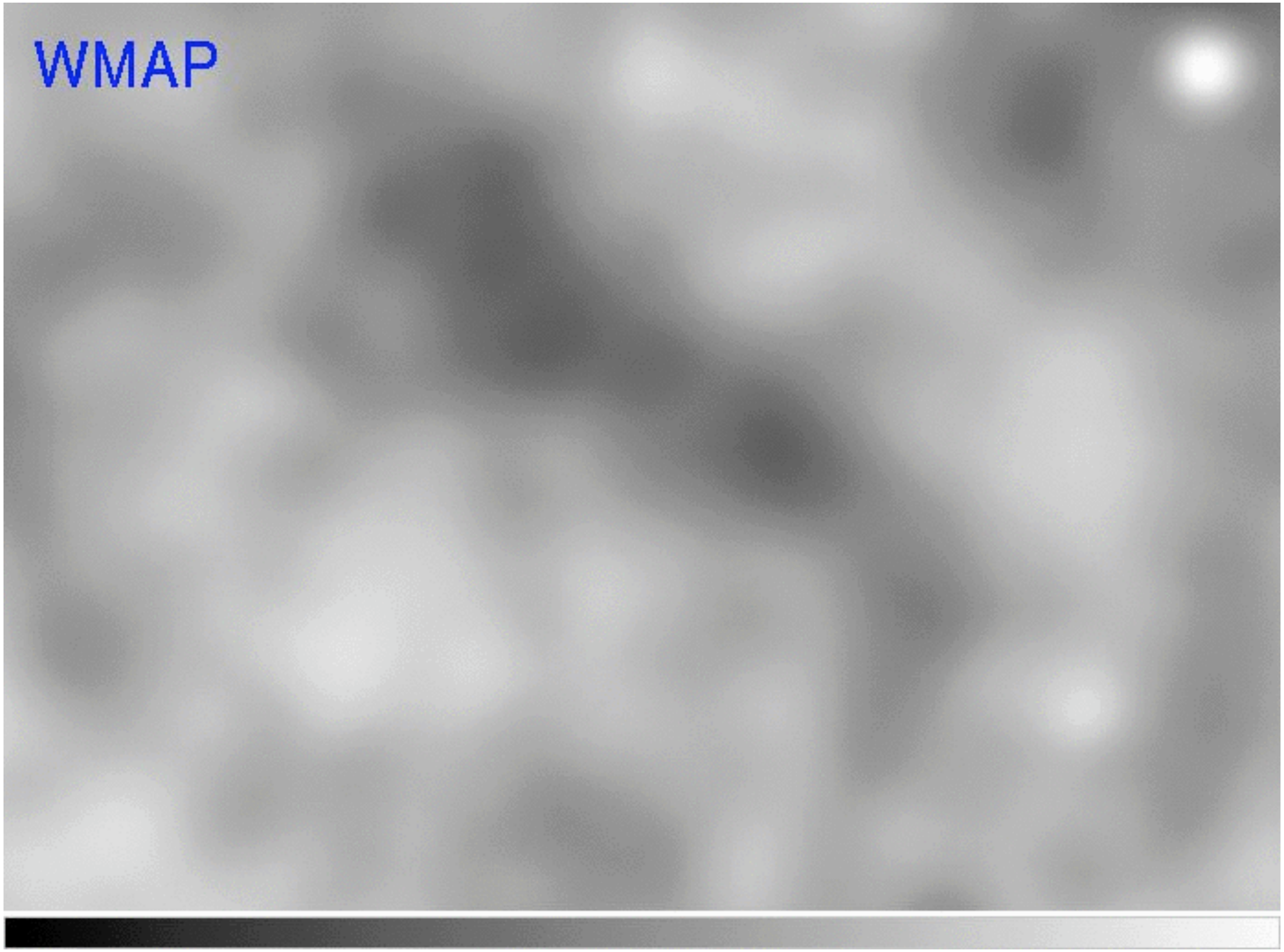
COSMIC STRING CONSTRAINTS using CBI+Acbar+wmap5

SFU Pogosian etal 08 semi-analytic models (cf. numerical string models Bevis 07)





WMAP-BOOM-ACBAR-ACT: the high resolution frontier



Toby marriage 01.08 for the act collaboration

INFLATION THEN

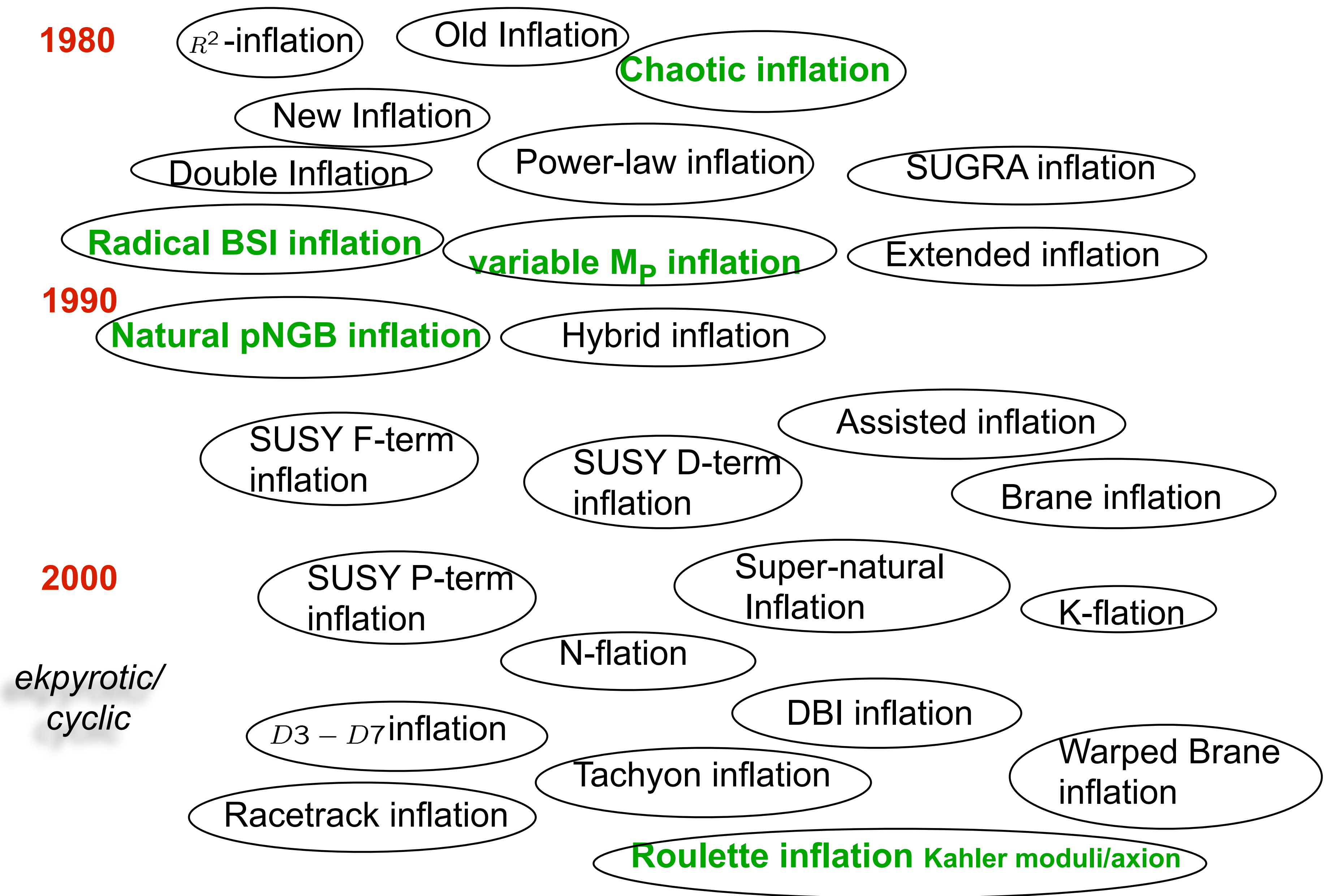
WHAT IS PREDICTED?

Smoothly broken scale invariance by nearly uniform braking (standard of 80s/90s/00s) $r \sim 0.03 - 0.5$

or highly variable braking r tiny

(stringy cosmology) $r < 10^{-10}$

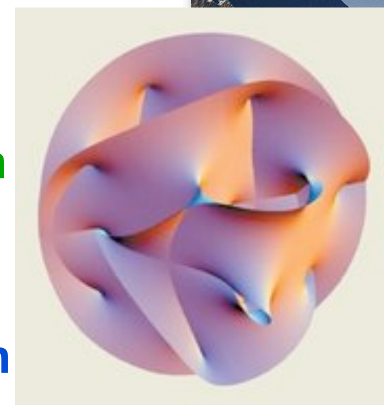
Old view: Theory prior = delta function of THE correct one and only theory



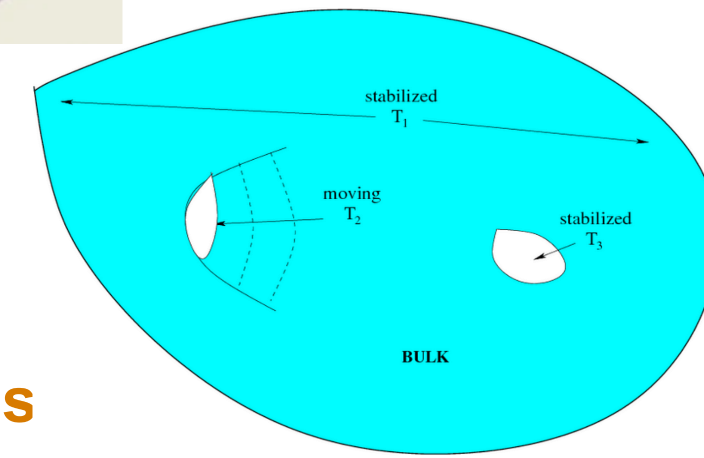
Old view: Theory prior = delta function of THE correct one and only theory

New view: Theory prior = probability distribution on an energy landscape whose features are at best only glimpsed,

huge number of potential minima, inflation the late stage flow in the low energy structure toward these minima. Critical role of collective coordinates in the low energy landscape:



moduli fields, sizes and shapes of geometrical structures such as holes in a dynamical extra-dimensional (6D) manifold approaching stabilization



moving brane & antibrane separations (D3,D7)

Theory prior ~ probability of trajectories parameters of the collective coordinates X probability of the potential parameters X probability of initial conditions

INFLATION THEN

WHAT IS ALLOWED?

radically broken scale invariance by variable braking as acceleration approaches deceleration, preheating & the end of inflation

$\varepsilon(k)=(1+q)(a)=-d\ln H/d\ln a \;=r(k)/16$

Blind power spectrum analysis cf. data, then & now

expand $\varepsilon(k)$ in localized mode functions e.g. Chebyshev/B-spline coefficients ε_b

the measures on ε_b matter choice for "theory prior" = informed priors?

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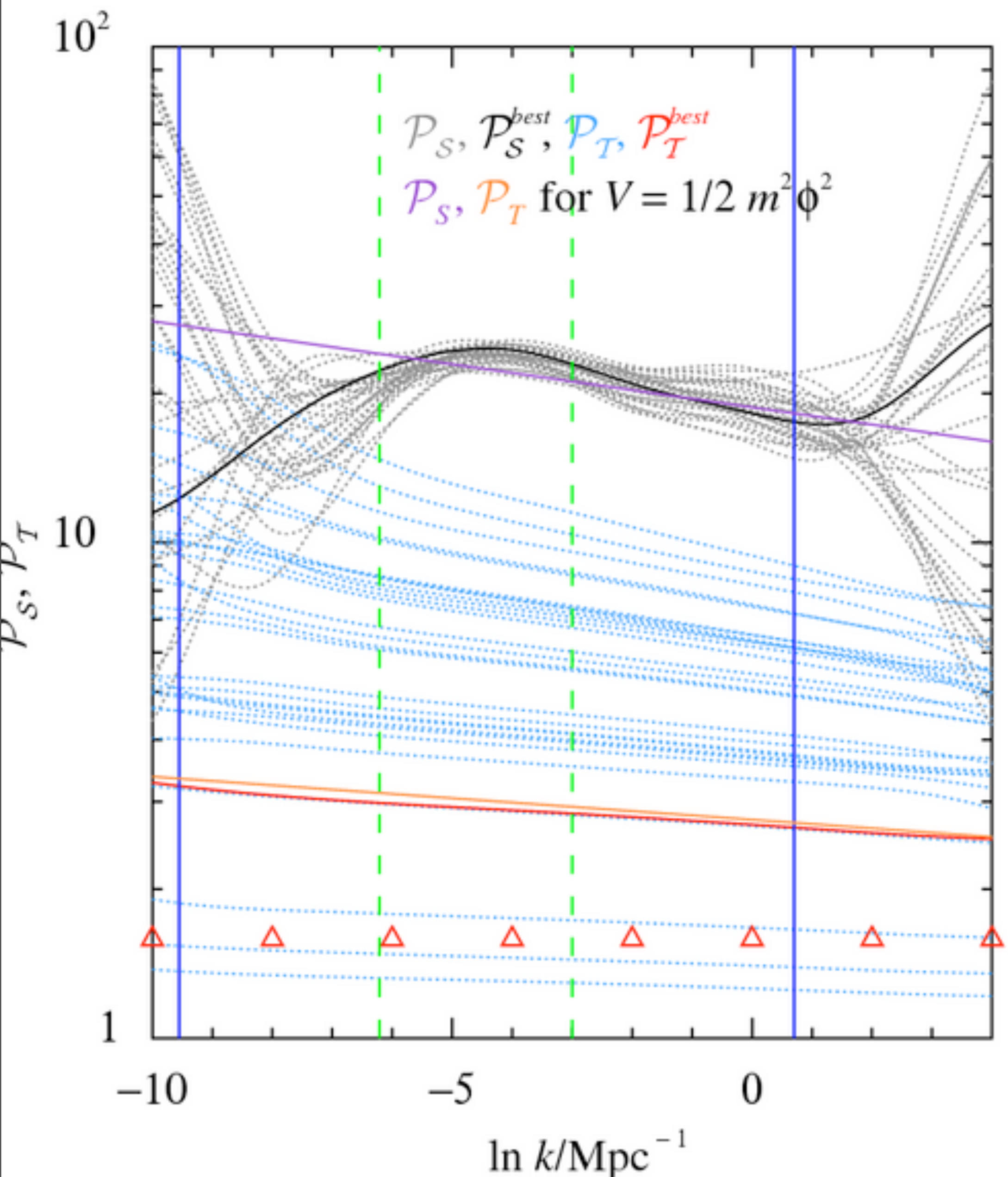
Blind power spectrum analysis cf. data, then & now

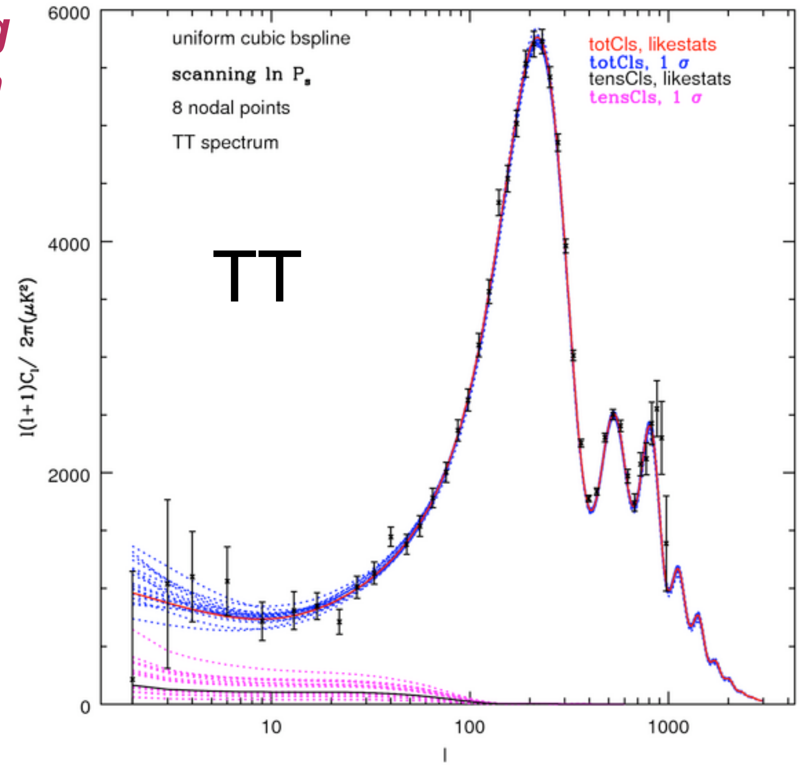
expand $\varepsilon(k)$ in localized mode functions e.g. Chebyshev/B-spline coefficients ε_b

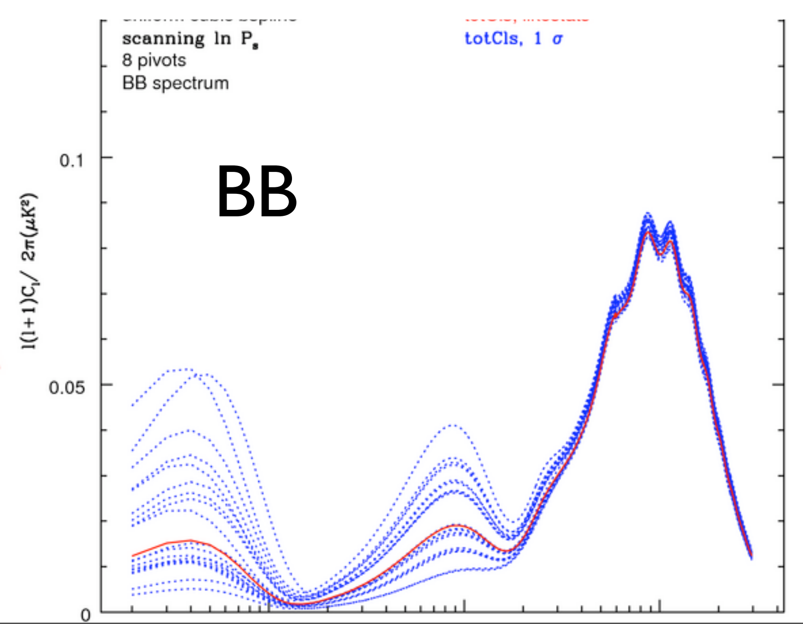
or dual $\ln P_s(k); P_t(k)$

the measures on ε_b matter choice for "theory prior" = informed priors?

partially-blind acceleration trajecteries obeying tensor/scalar consistency relation. May08 data



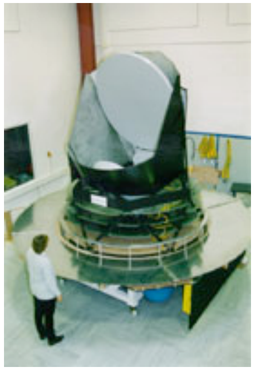




Can we measure GW/scalar curvature: r to +- .02 **PL2.5+Spider; Bpol .001 ?**

BUT foregrounds/systematics? But **r(k), low Energy inflation**

Planck1 simulation: input LCDM (Acbar)+run+uniform tensor



blind order 5 expansions analysis recover input r to r ~0.05

and P_s P_t reconstructed

input of LCDM with scalar running & r=0.01 to 0.5

B-pol simulation: ~10K detectors > 100x Planck

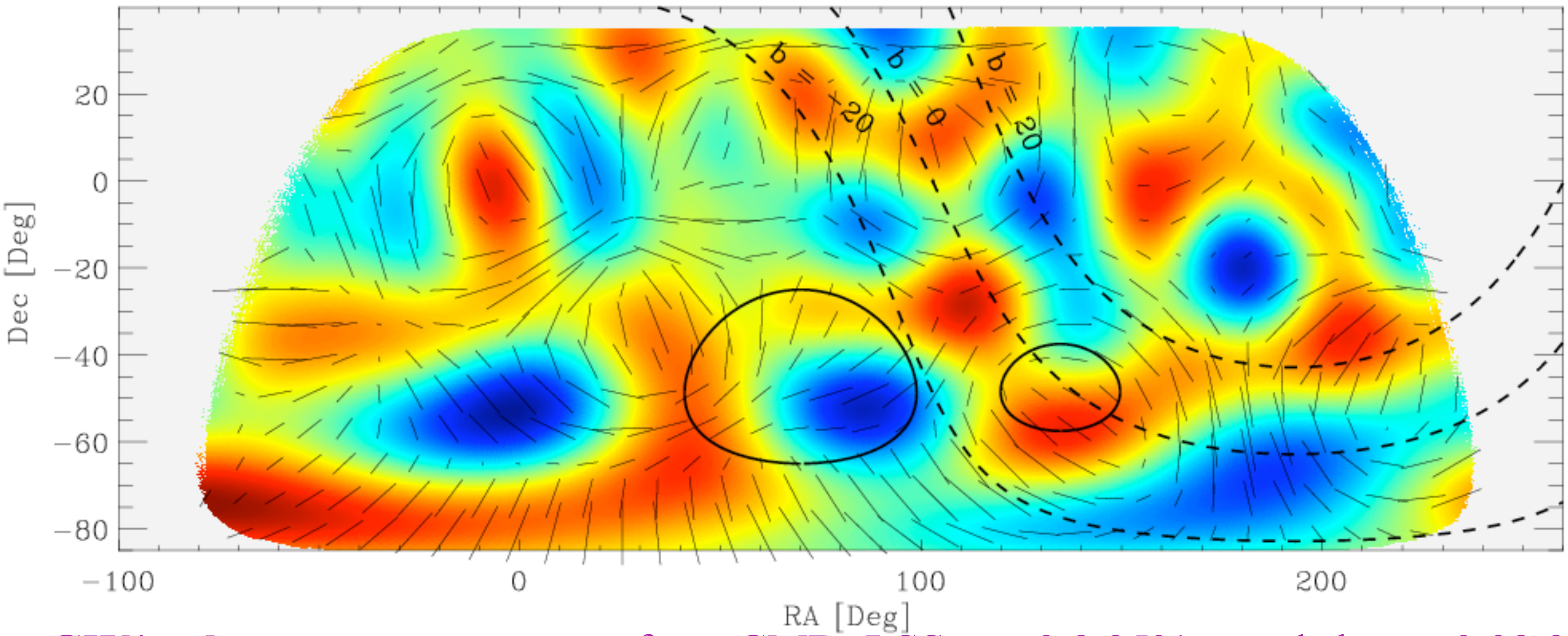
stringent test of the ε-trajectory method: input recovered to r <0.001

SPIDER Tensor Signal

- Simulation of large scale polarization signal

$$\boxed{\frac{A_T}{A_S} = 0.1}$$

No Tensor



GW/scalar curvature: current from CMB+LSS: r < **0.3** 95%; good shot at **0.02** 95% CL with **BB polarization** **(+- .02 PL2.5+Spider), .01 target; Bpol .001** BUT foregrounds/systematics? But **r(k), low Energy inflation**

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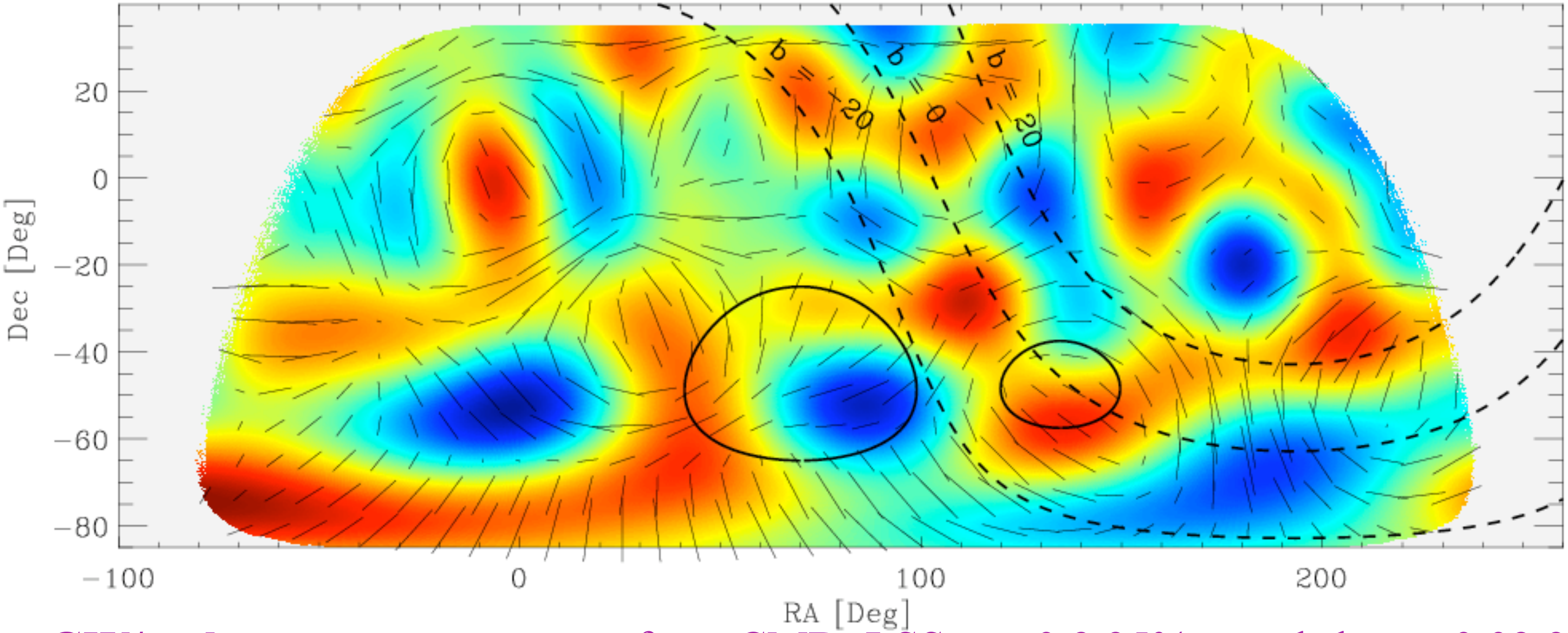

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http://www.astro.caltech.edu/~lgg/spider_front.htm

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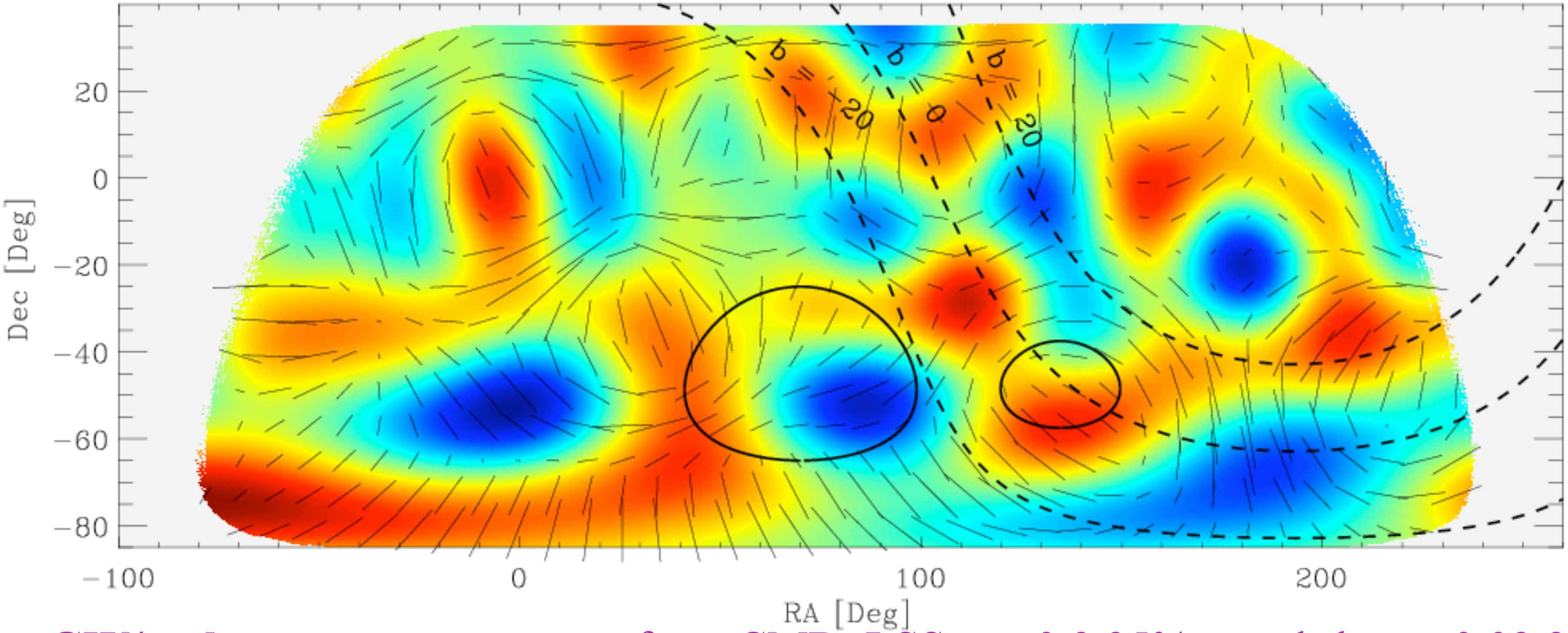

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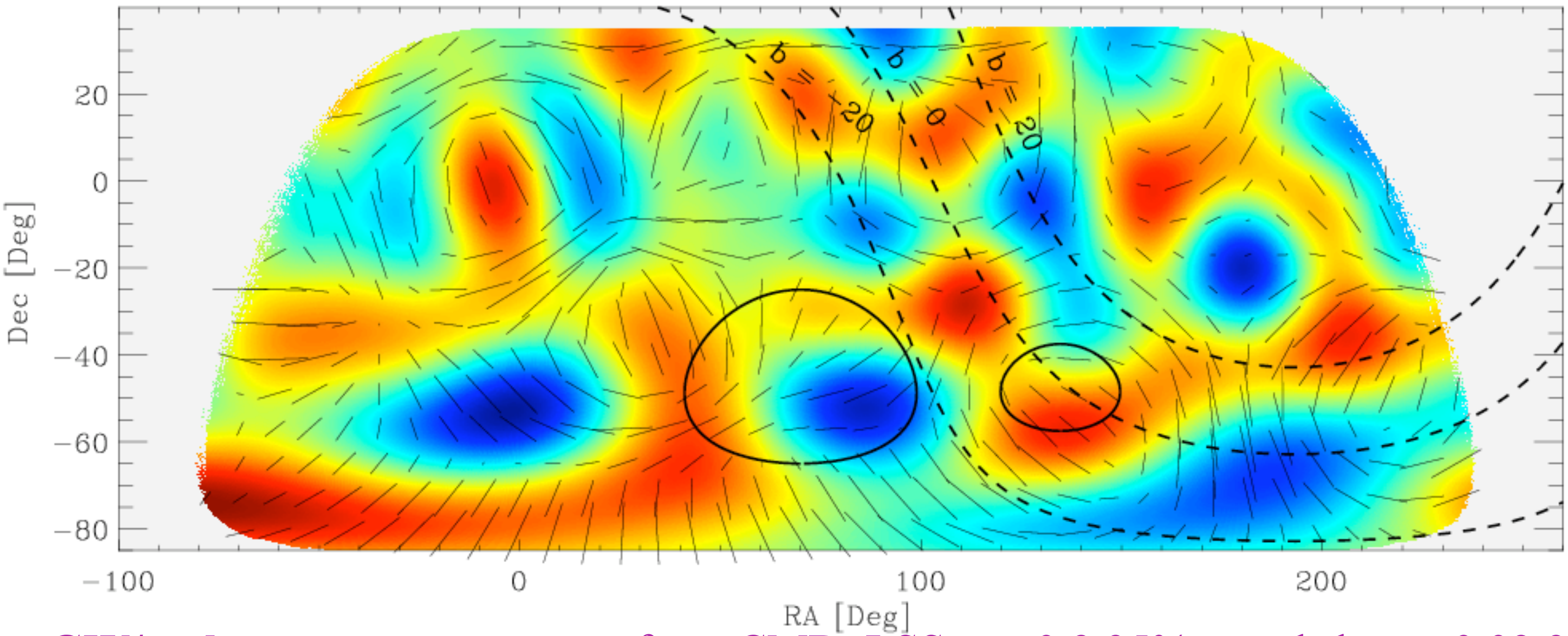
Tensor



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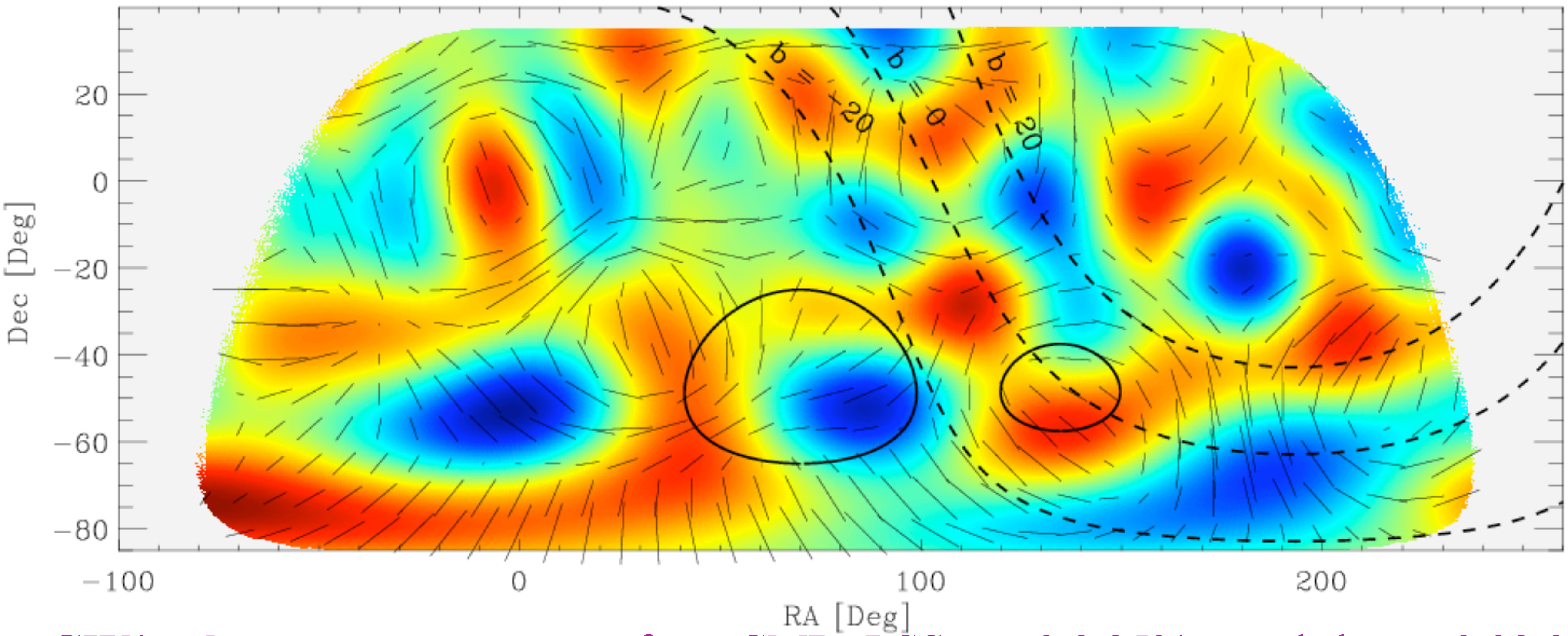

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PRIMARY END @ 2012?

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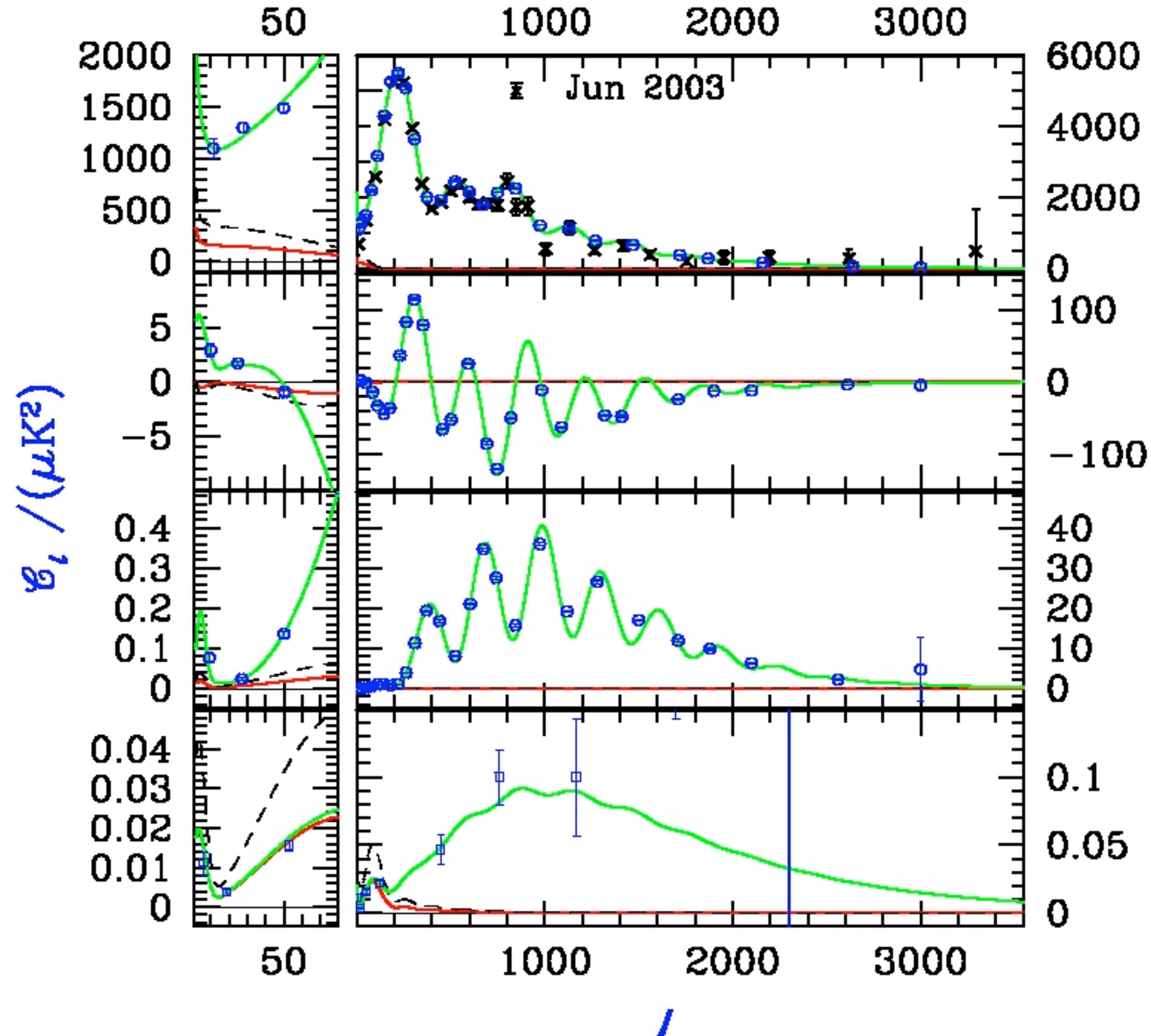
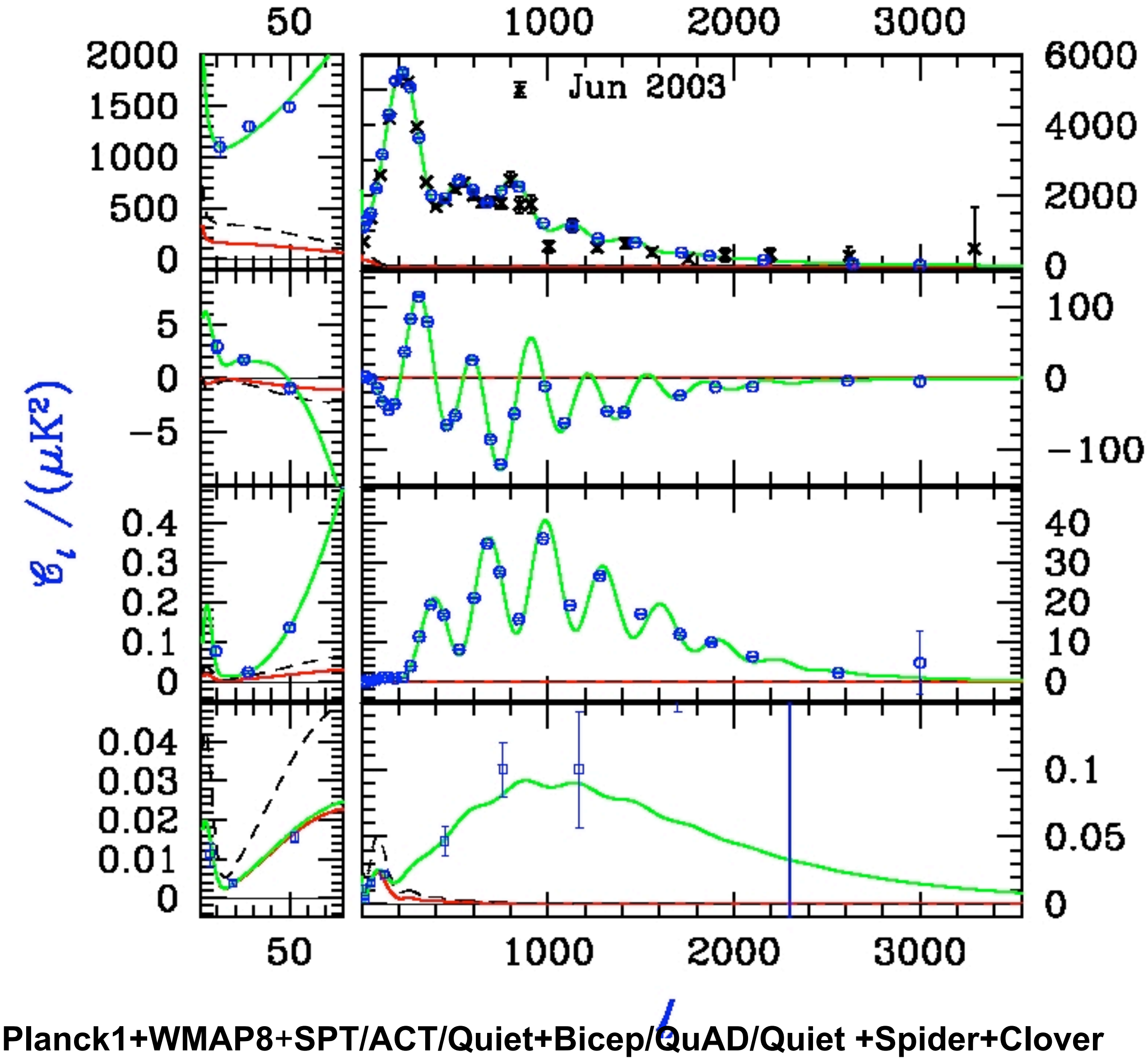


PRIMARY END @ 2012?



CMB ~2009+ Planck1+WMAP8+SPT/ACT/Quiet+Bicep/QuAD/Quiet +Spider+Clover

END

Inflation then summary

the basic 6 parameter model with or without GW fits all of the data OK

Usual GW limits come from adding r with minimal consistency (7 params). r <.3 comes from relating high k region of σ_8 & LSS to low k region of GW C_L

uniform priors in $\varepsilon(k) \sim r(k)/16$: for current data, $\varepsilon(k)$ goes up at low k & the scalar power downturns (if there is freedom in the mode expansion to do this). Enforces GW.
ln $(\varepsilon + \text{TINY})$ prior gives lower r.

a B-pol with r<.001 breaks this prior dependence, even Planck+Spider r~.03

Prior probabilities on the inflation trajectories are crucial and cannot be decided at this time. Philosophy: be as wide open and least prejudiced as possible

An ensemble of trajectories arises in many-moduli string models. Roulette inflation: complex hole sizes in `large 6D volume' TINY $r \sim 10^{-10}$ & data-selected braking to get n_s & $\Delta\psi$ <<1 (general theorem: if the normalized inflaton ψ < 1 over ~50 e-folds then r < .007). By contrast, for nearly uniform acceleration, (e.g. power law & PNGB inflaton potentials), r ~.03-.3 but $\Delta\psi$ ~10. Is this deadly???

Even with low energy inflation, the prospects are good with Spider and even Planck to either detect the GW-induced B-mode of polarization or set a powerful upper limit vs. nearly uniform acceleration, pointing to stringy or other exotic models. Both experiments have strong Cdn roles. Bpol is ~ 20x0

Inflation now summary

- the data cannot determine more than 2 w-parameters (+ csound?). general higher order Chebyshev or spline expansion in 1+w as for "inflation-then" $\varepsilon=(1+q)$ is not that useful. Parameter eigenmodes show what is probed
- Any w(a) leads to a viable DE model. The $w(a)=w_0+w_a(1-a)$ phenomenology requires baroque potentials
- Philosophy of HBK08: backtrack from now (z=0) all w-trajectories arising from quintessence (ε_s >0) and the phantom equivalent (ε_s <0); use a 3-parameter model to well-approximate even rather baroque w-trajectories, as well as thawing & freezing trajectories.
- We ignore constraints on Q-density from photon-decoupling and BBN because further trajectory extrapolation is needed. Can include via a prior on Ω_Q (a) at z_dec and z_bbn
- For general slow-to-moderate rolling one needs 2 "dynamical parameters" (a_s, ε_s) & Ω_Q to describe w to a few % for the not-too-baroque w-trajectories. A 3rd param ζ_s, (~$d\varepsilon_s$ /dlna) is ill-determined now & in a Planck1yr-CMB+JDEM-SN +DUNE-WL future.
- $1+w(a)= \varepsilon_s f(a/a_{\Lambda eq};a_s/a_{\Lambda eq};\zeta_s)$
- ?? extension to ε_s <0 – phantom energy, eg negative kinetic energy
- In the early-exit scenario, the information stored in a_s is erased by Hubble friction over the observable range & w can be described by a single parameter ε_s.
- a_s is < 0.33 current data (z_s >2.0) to <0.21 (z_s >3.7) in Planck1yr-CMB+JDEM-SN+DUNE-WL future
- current observations are well-centered around the cosmological constant ε_s=-0.05+-0.24
- in Planck1yr-CMB+JDEM-SN+DUNE-WL future ε_s to +-0.07
- but one cannot reconstruct the quintessence potential, just the slope ε_s & hubble drag info
- late-inflaton field is < Planck mass, but not by a lot