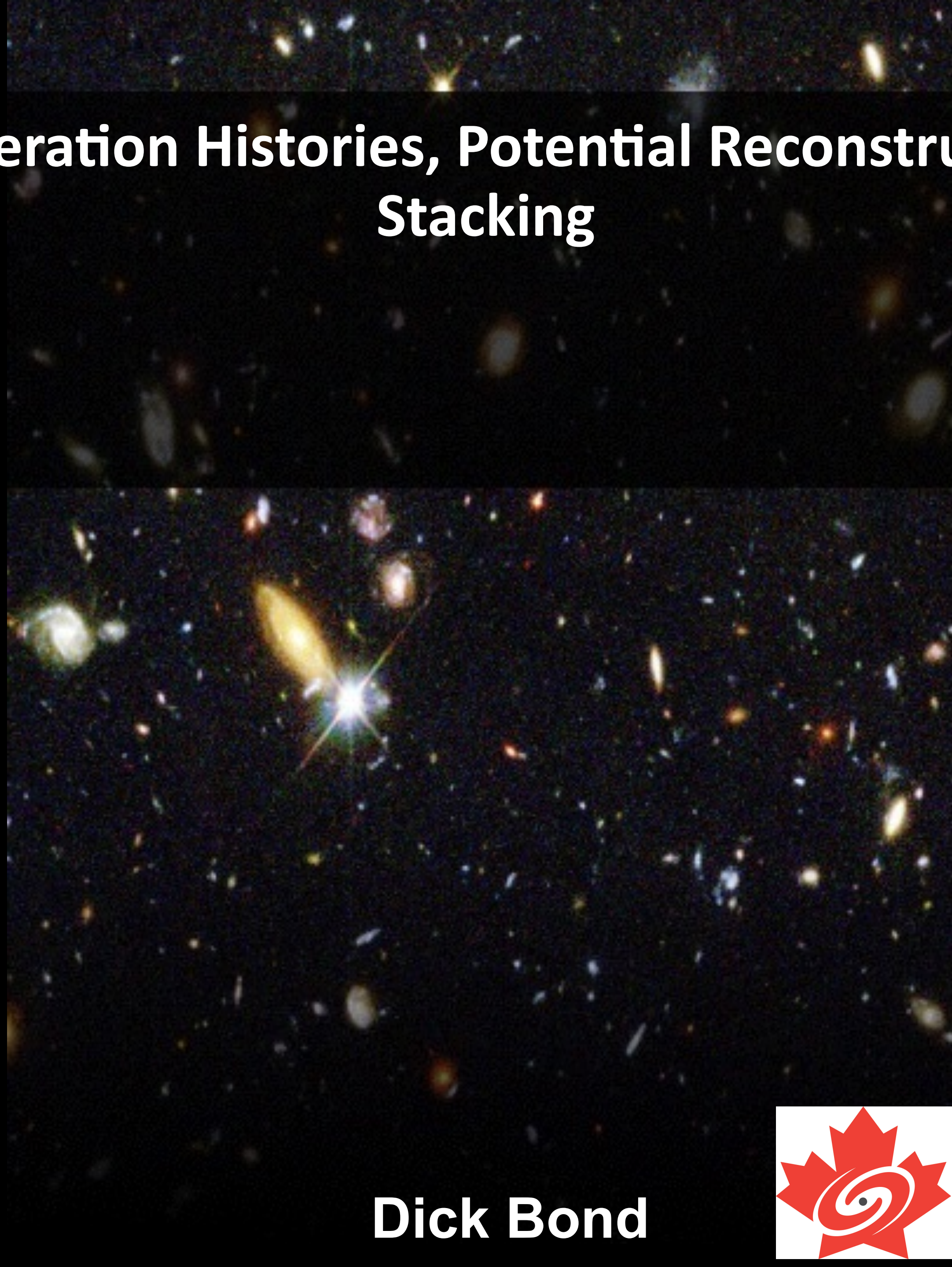
Acceleration Histories, Potential Reconstruction, Stacking



Dick Bond

CIFAR CANADIAN INSTITUTE FOR ADVANCED RESEARCH

CITA ICAT Canadian Institute for Theoretical Astrophysics L'institut Canadien d'astrophysique théorique

Bond since 1993, Canada since 2001, 1st CSA pre-launch contract 2002-09, post-launch 2010-11, 2011-15

Planck+Herschel Launch
May14 09 French Guiana

1.5m telescope,

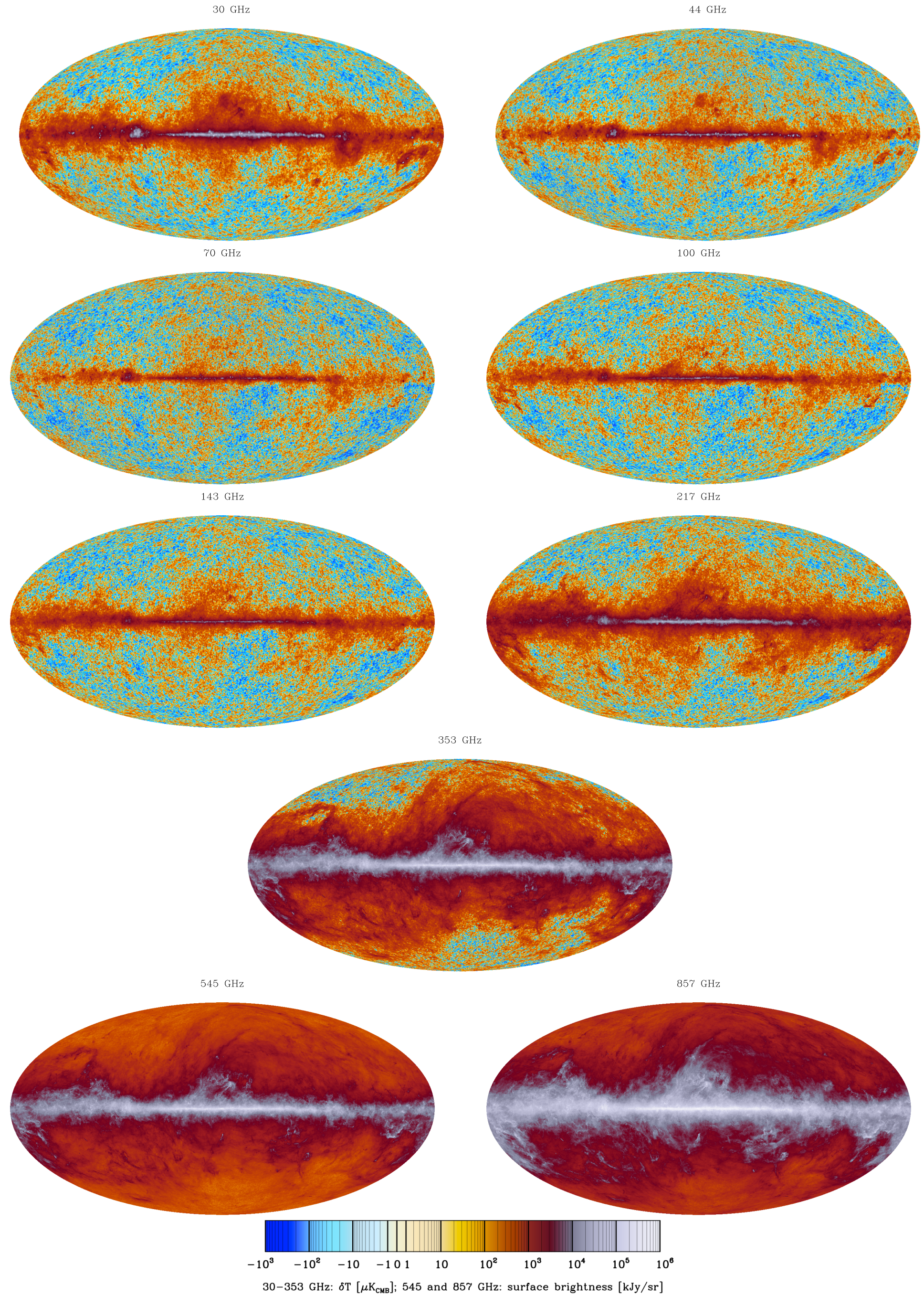
HFI bolometers @6freq
<100mK,

LFI HEMTs@3freq,

some bolometers & all HEMTS are polarization sensitive

- Left earth at ~10 km/s, 1.5 million km in 45 days, cooling on the way (20K, 4K, 1.6K, 0.1K 4 stage). @L2 on July 2 09; Survey started on Aug 13 09
- spin@1 rpm, 40-50 minutes on the same circle, covers all-sky in ~6 month, ~5 HFI surveys, ~8 LFI surveys
- kicked out of L2 Oct 2013

Planck 1.3yr Frequency Maps

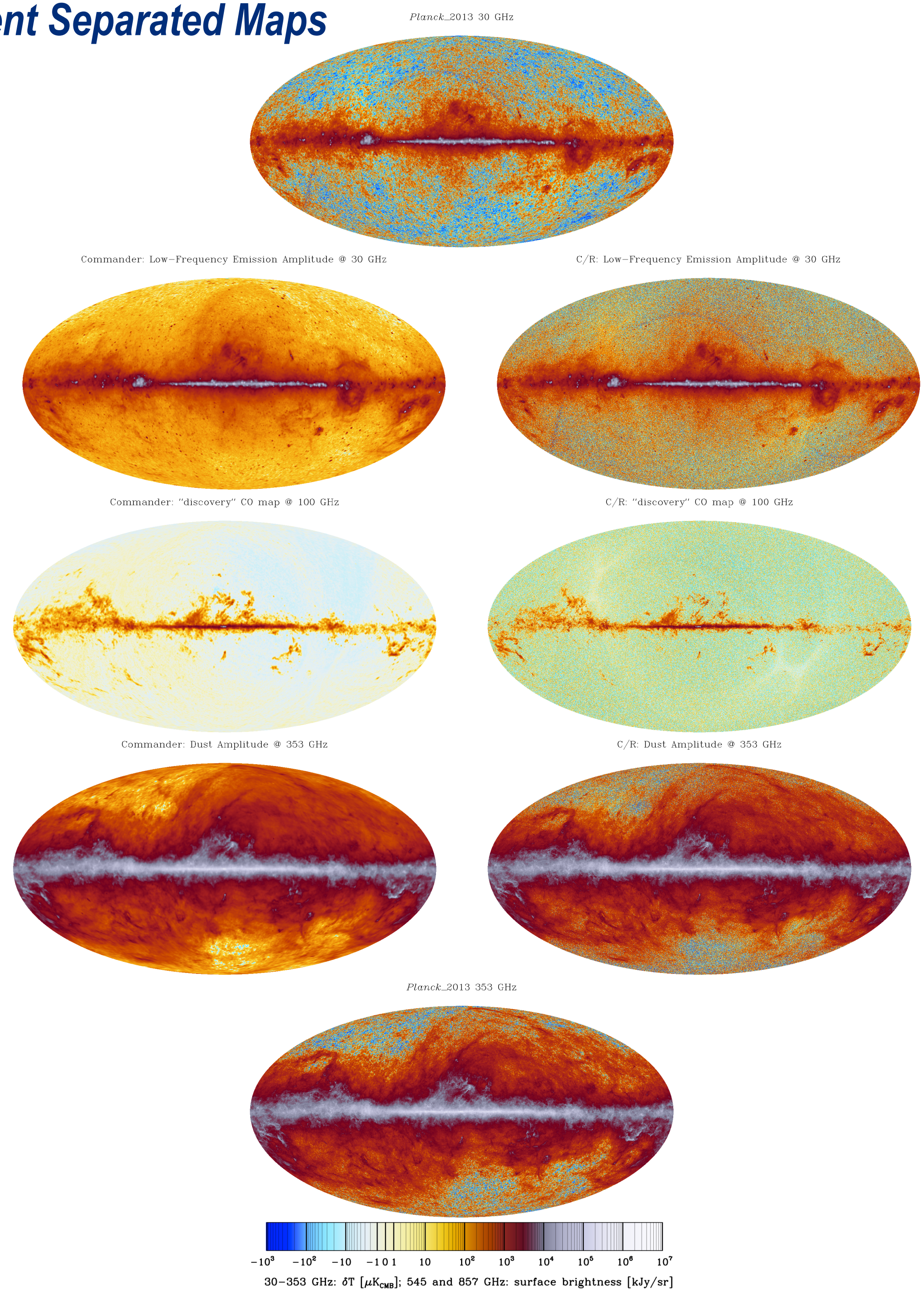


Some Planck Component Separated Maps

LF Synchrotron + bremsstrahlung

Galactic Carbon Monoxide

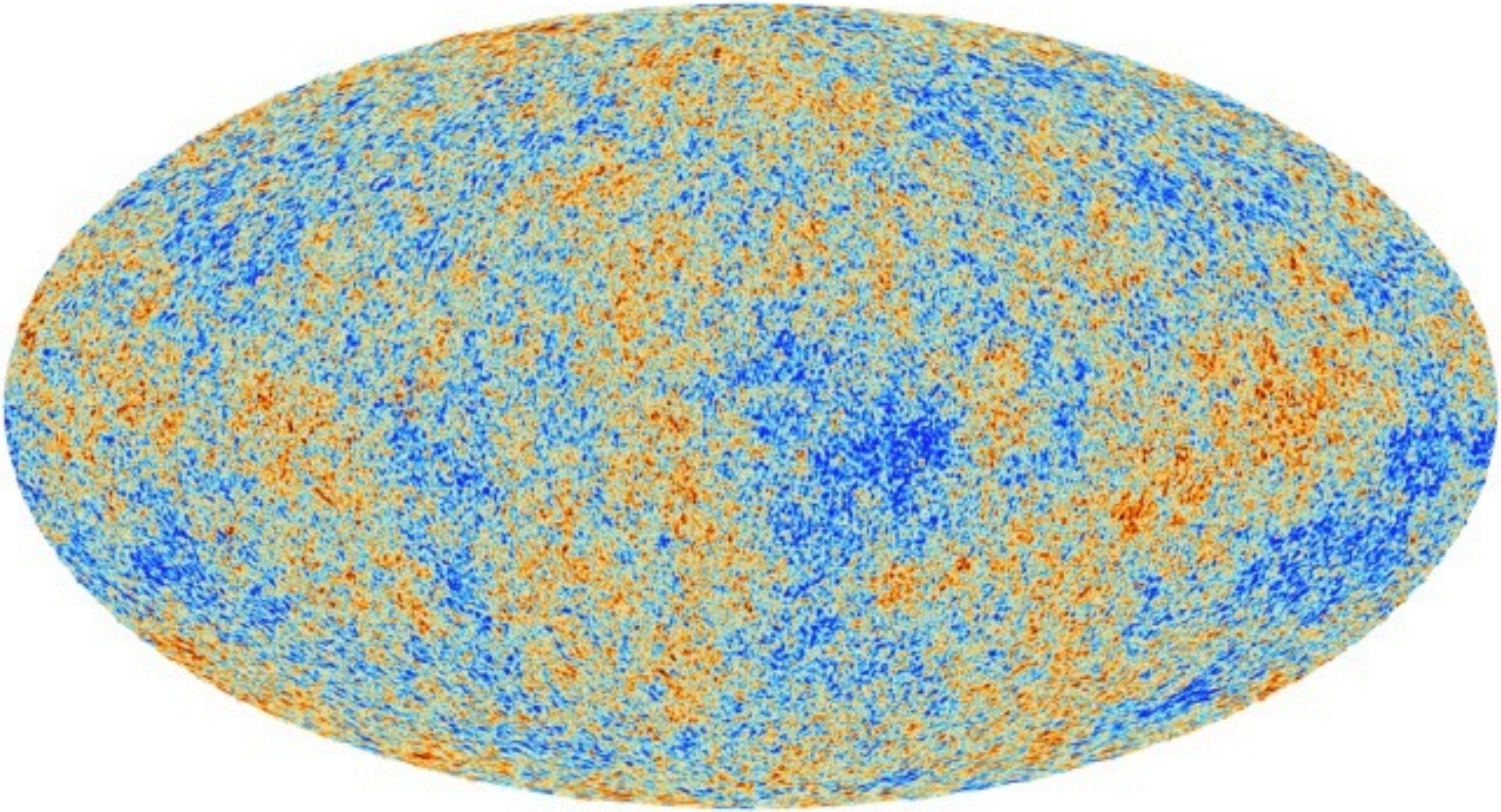
HF Thermal Dust Emission



Planck's primordial light unveiled, March 21, 2013

reveals the SIMPLICITY of primordial cosmic structure

7^+ numbers, 3 densities, 2+1 early-Universe inflation



Temperature changes in micro-degrees

SIMPLICITY

at $a \sim e^{-7} \sim 1/1100$ =>

at $a \sim e^{-67+60} \sim 1/10^{30+25}$

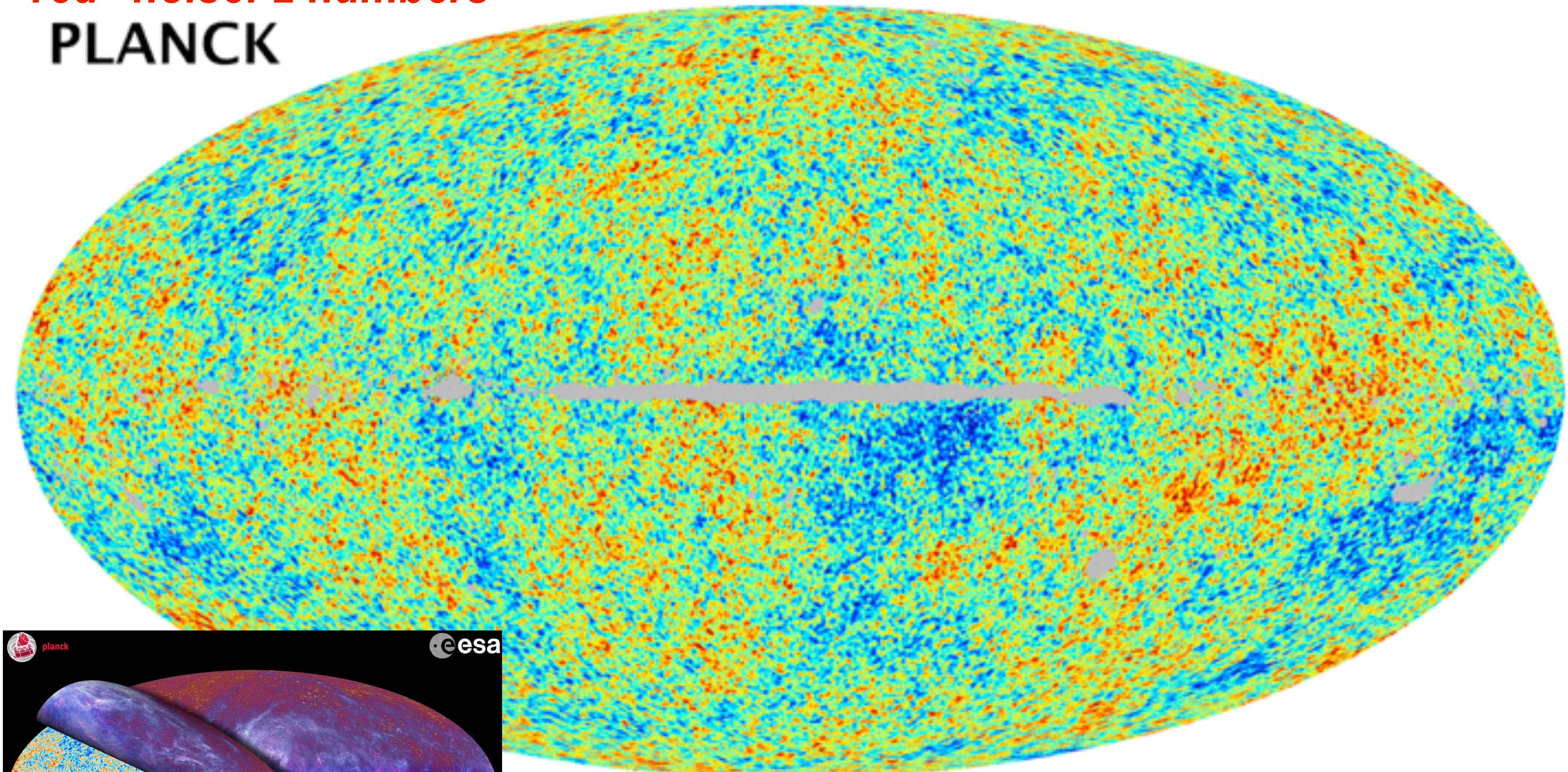
"red" noise: 2 numbers

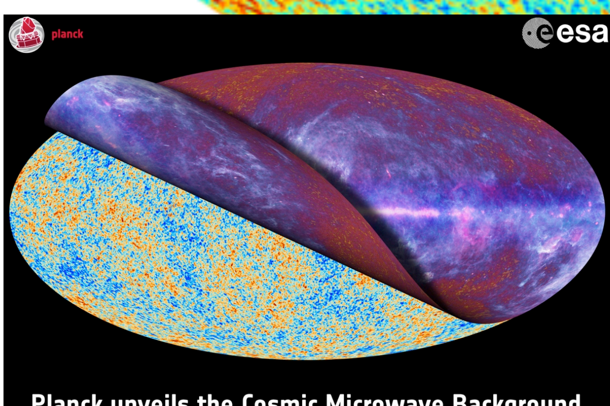
PLANCK

Planck 09 launch

Planck SMICA Map

CMB-data Concordance





Planck CMB / SMICA map, ~5′ resolution
+ NILC, SEVEM, C-R 3 independent component separated CMB maps show the same features

SIMPLICITY

WMAP 01 launch

WMAP W-band, Template Cleaned

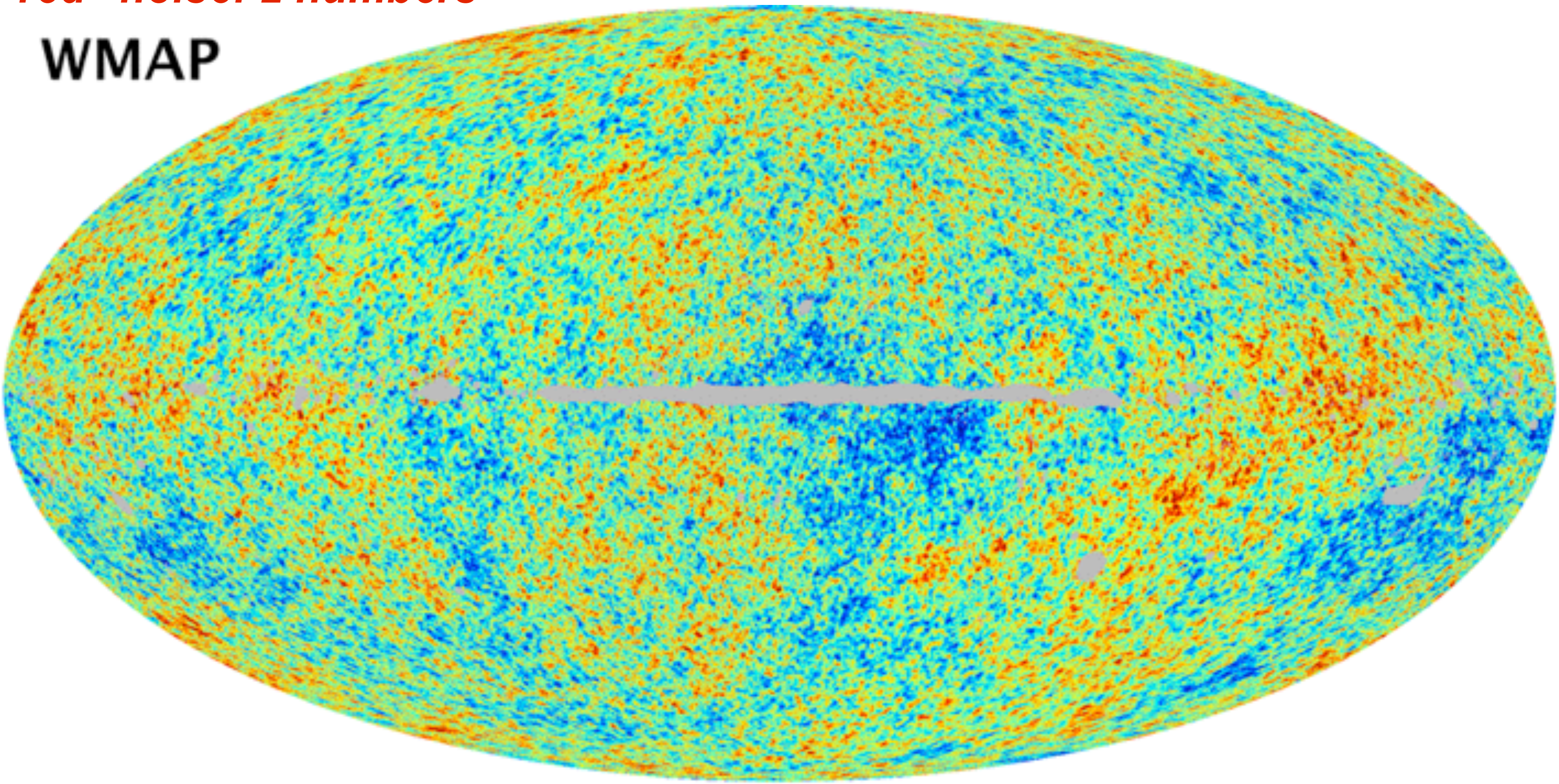
CMB-data Concordance

at $a \sim e^{-7} \sim 1/1100$ =>

at $a \sim e^{-67+60} \sim 1/10^{30+25}$

"red" noise: 2 numbers

WMAP



Cleaned with Planck 353 GHz dust map and low-frequency templates. 12′ resolution.

similar tremendous agreement with the much higher (5X) resolution ACT & SPT maps

total focus on the 1.2% difference in "calibration" between P13 (HFI &LFI) & WMAP9

Planck's information > 4X WMAP9 in multipoles

SIMPLICITY

at $a \sim e^{-7} \sim 1/1100$ =>

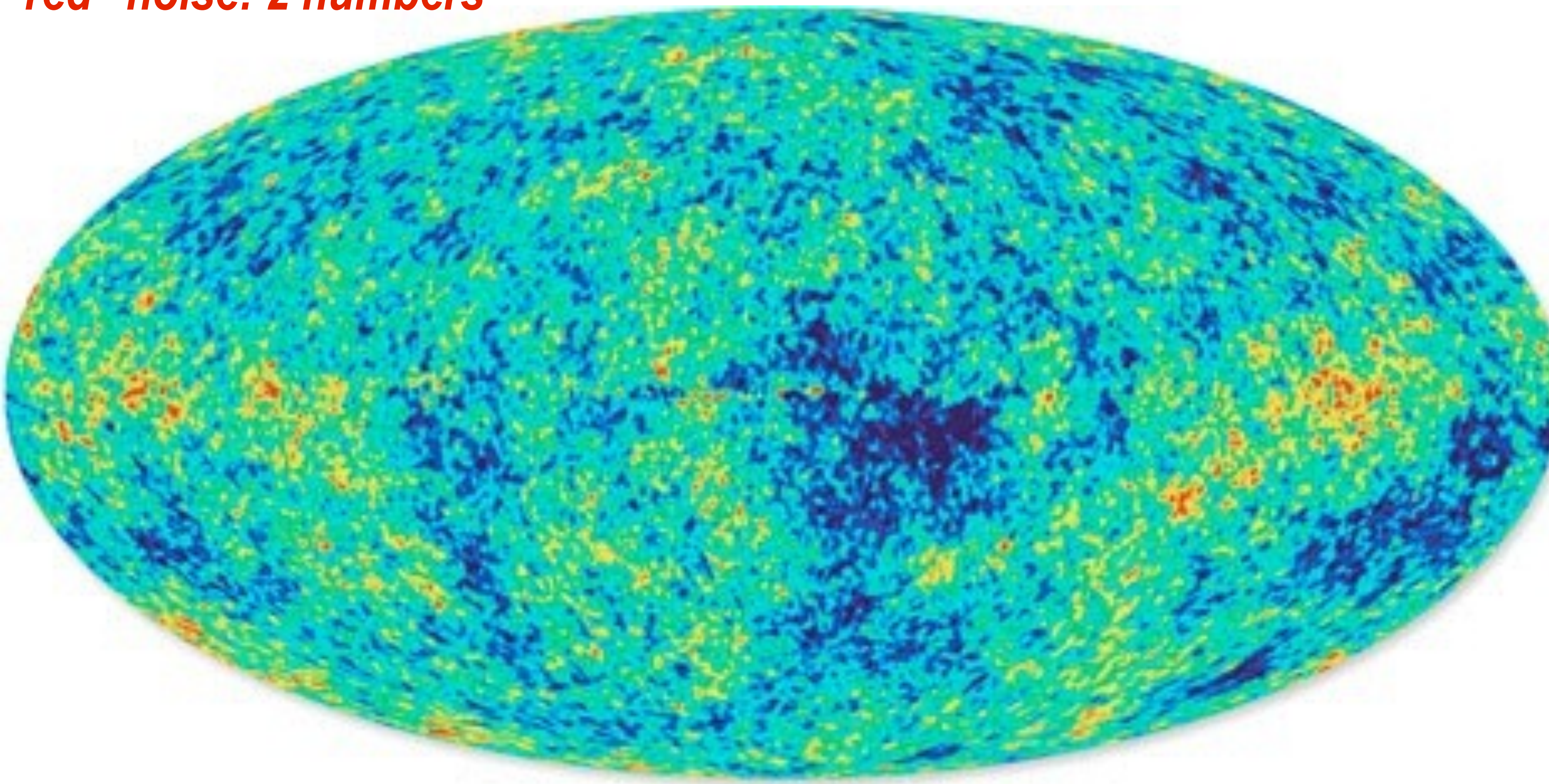
at $a \sim e^{-67+60} \sim 1/10^{30+25}$

"red" noise: 2 numbers

WMAP 01 launch

WMAP W-band, Template Cleaned

CMB-data Concordance



Cleaned with low-frequency templates only.

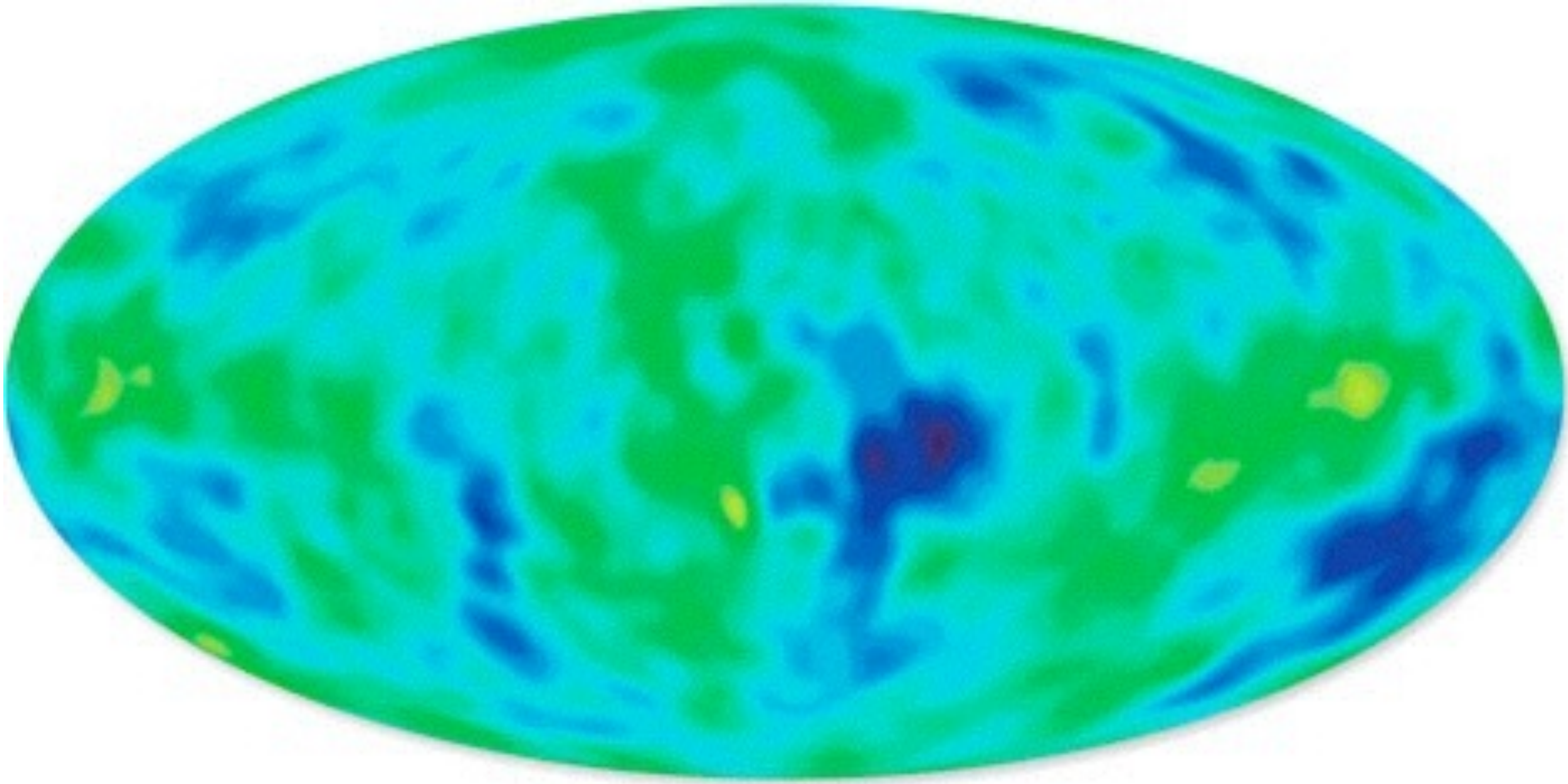
similar tremendous agreement with the much higher (5X) resolution ACT & SPT maps

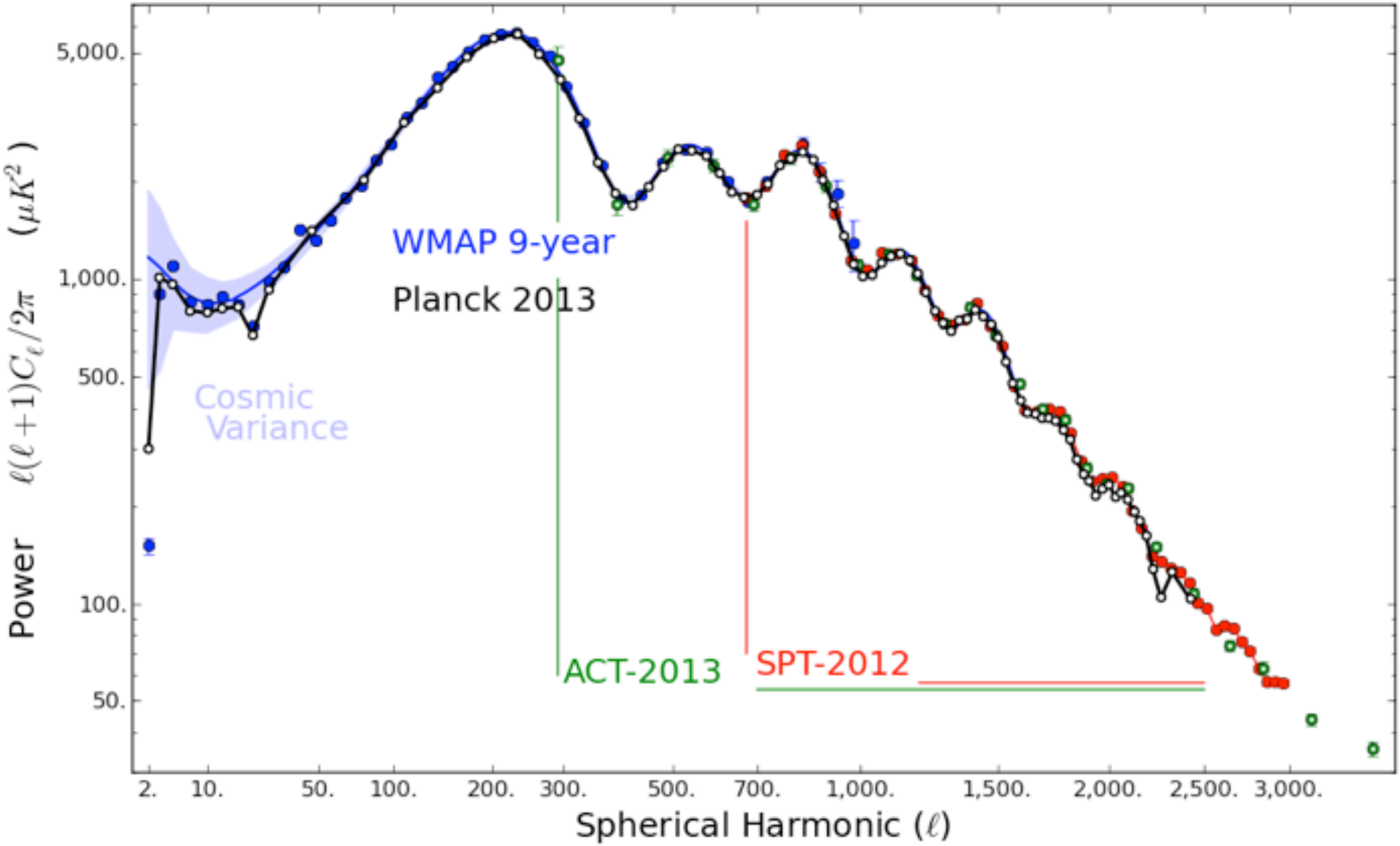
total focus on the 1.2% difference in "calibration" between P13 (HFI &LFI) & WMAP9

COBE 89 launch

COBE

CMB-data Concordance

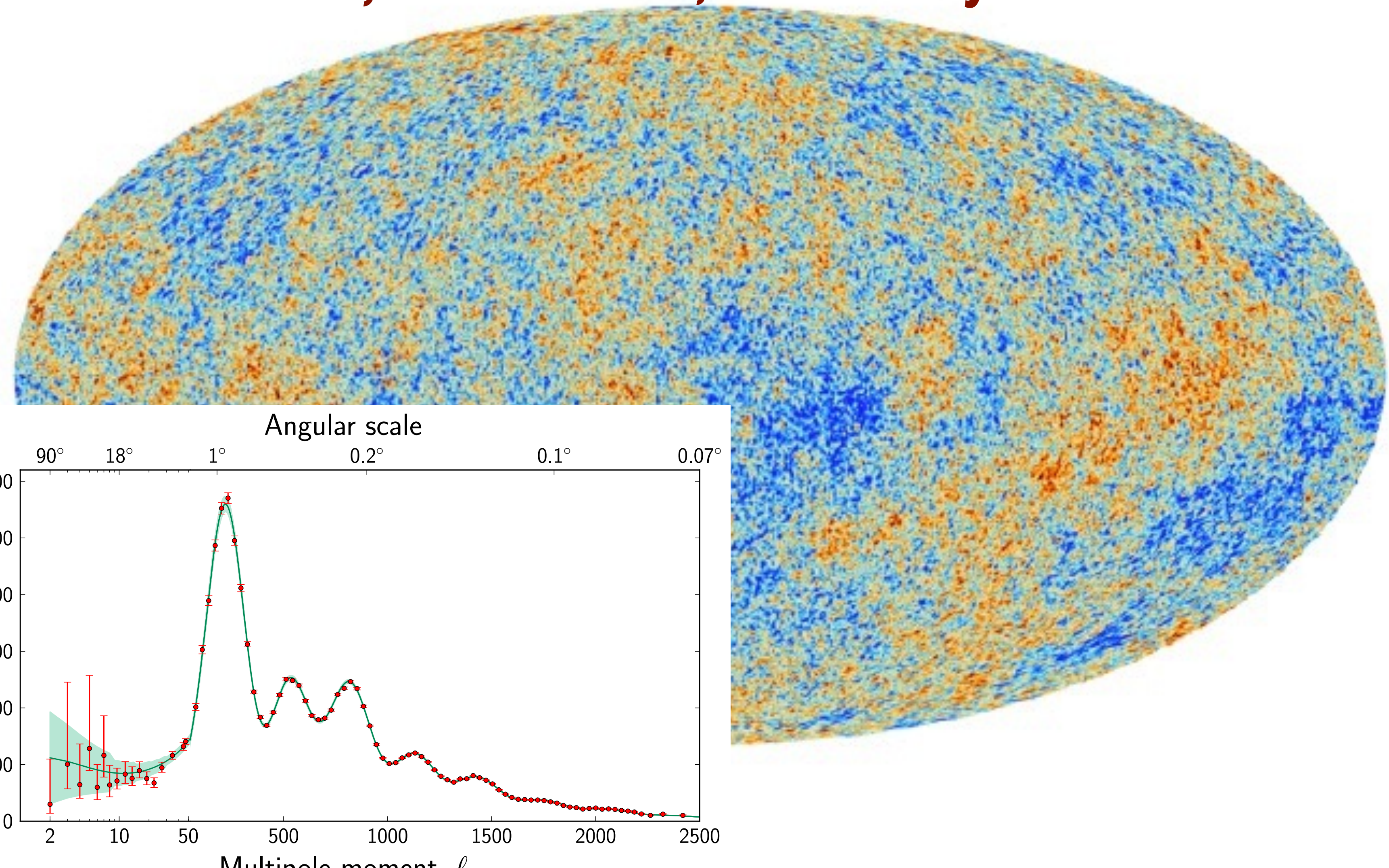




Halpern13 gif: WMAP9 cf. Planck2013 aka Planck1.3yr reveals **primordial sound waves**

=> the inharmonious *'music of the spheres'*

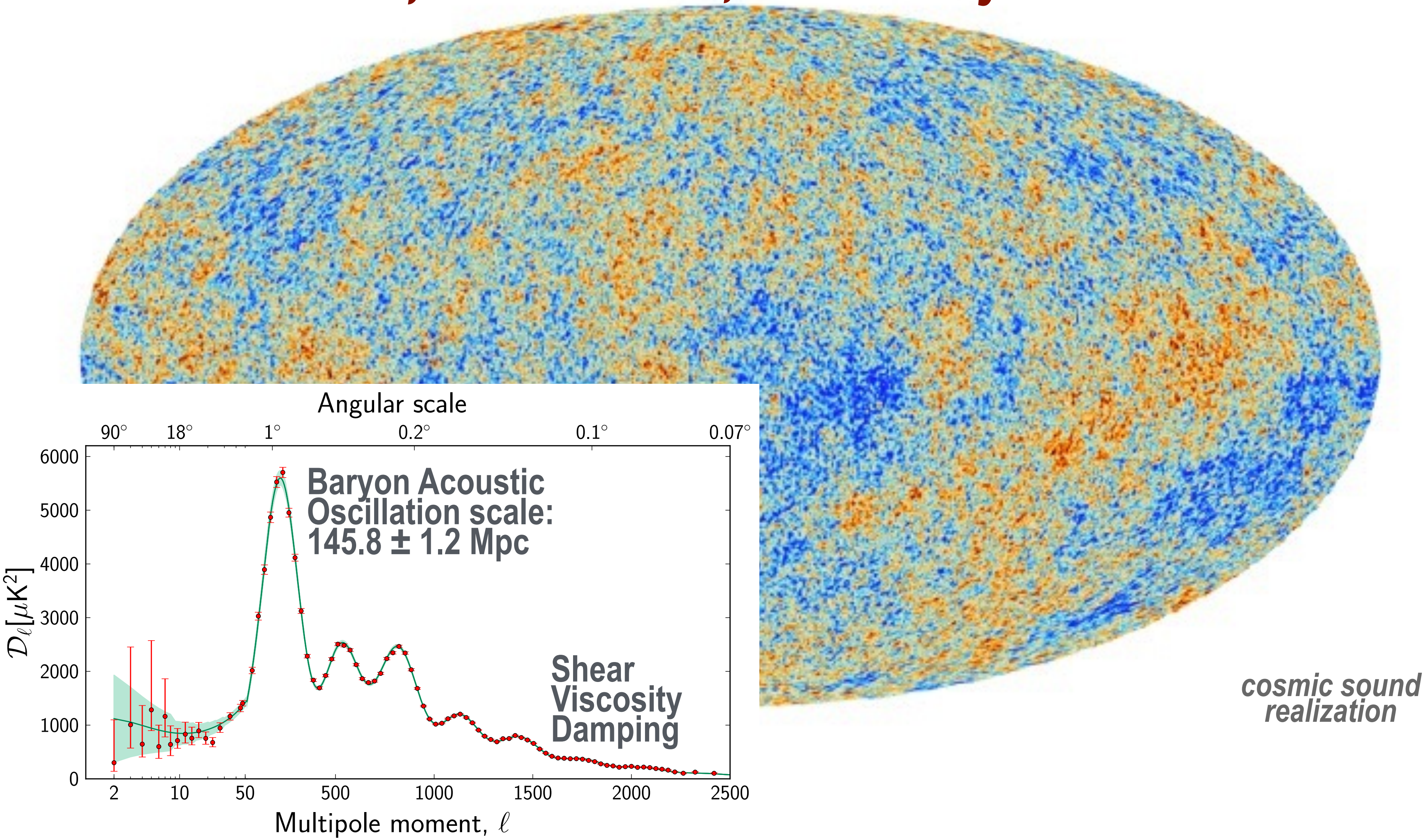
7+ numbers, 3 densities, 2+1 early-Universe inflation



reveals **primordial sound waves**

=> the inharmonious *'music of the spheres'*

7^+ numbers, 3 densities, 2+1 early-Universe inflation



SIMPLICITY

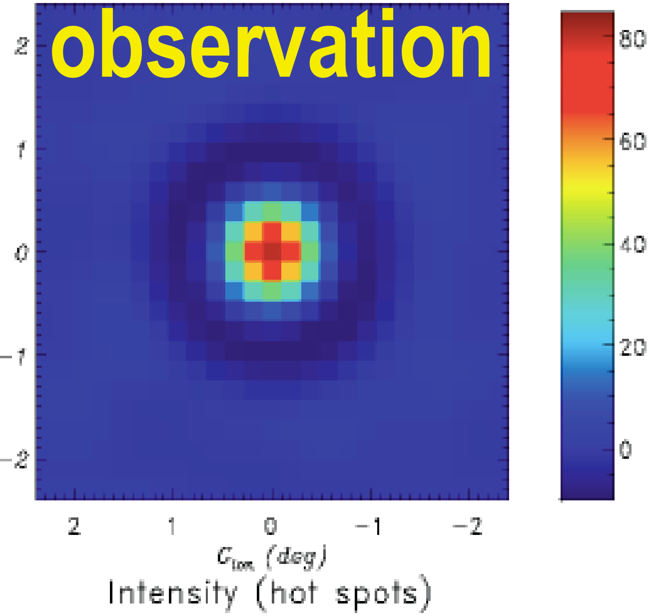
at $a \sim e^{-7} \sim 1/1100$ =>

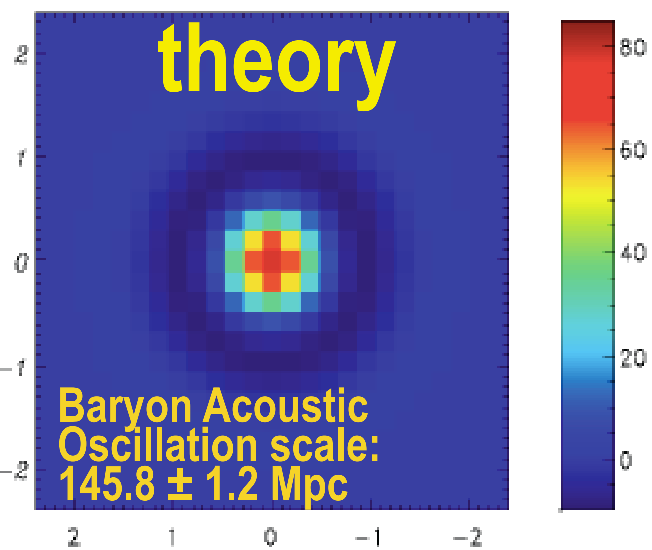
at $a \sim e^{-67+60} \sim 1/10^{30+25}$

reveals ***primordial sound waves in matter***

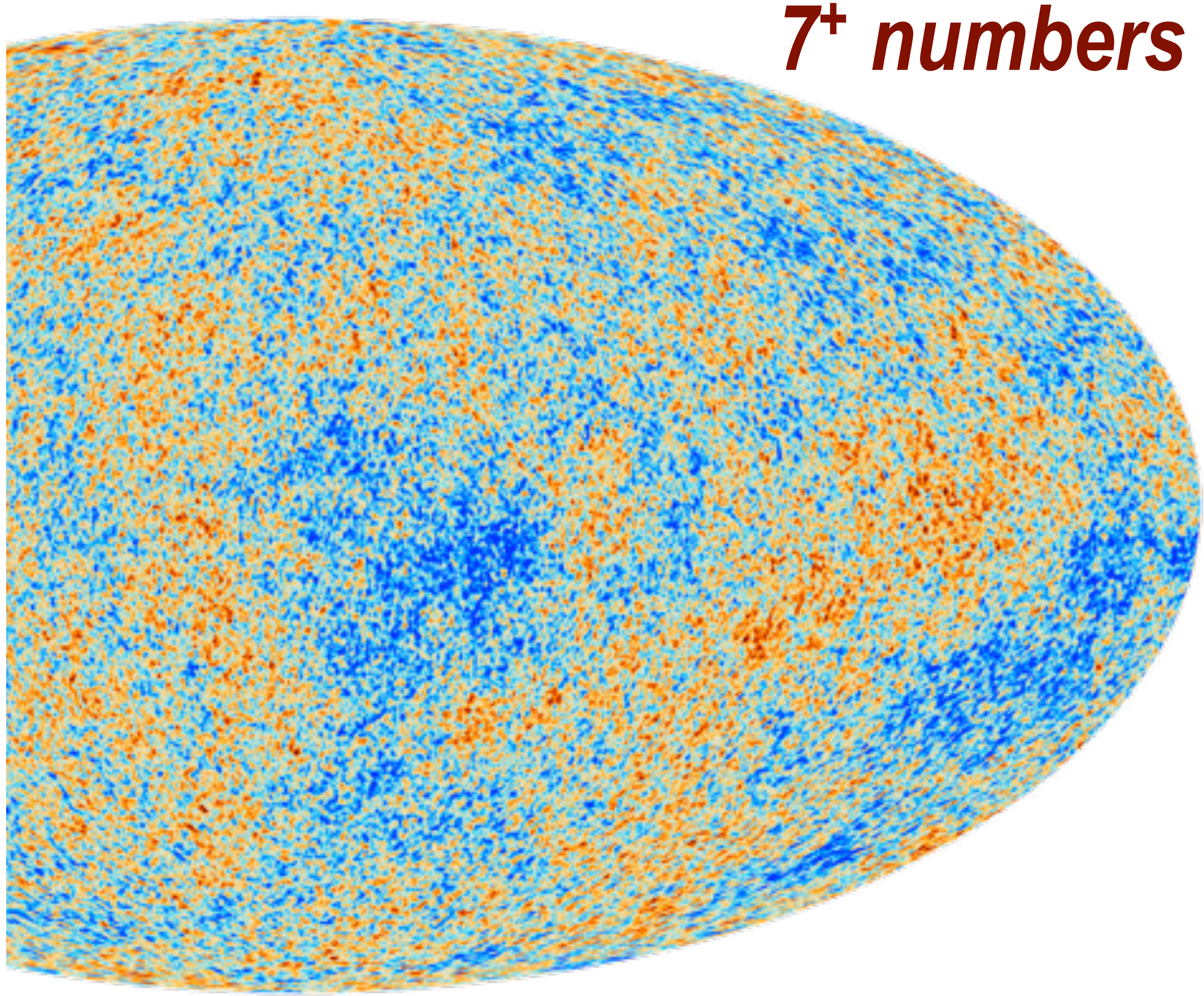
=> *learn* ***contents*** & ***structure*** *at 380000 yr,* $a \sim e^{-7}$

=> *infer the structure far far earlier* $a \sim e^{-67+60}$





7^+ numbers



Dick Bond

Cosmic Observables for Fundamental Physics, revealing Simplicity & Complexity

the **nonlinear COSMIC WEB**

recombination

dS$_G$/dt

I N F L A T I O N

primary anisotropies

- linear perturbations: scalar/density, tensor/gravity wave
- tightly-coupled photon-baryon fluid: oscillations $\delta\gamma$ $v\gamma$ $\pi\gamma$
- viscously damped
- polarization $\pi\gamma$
- gravitational redshift Φ SW $d\Phi/dt$

Type to enter text

dS/dt>0

DarkM

Decoupling LSS

17 kpc (19 Mpc)

Lsound/ ksound

dS/dt>0

secondary anisotropies

- nonlinear evolution
- weak lensing
- thermal SZ +kinetic SZ
- $d\Phi$ /dt
- dusty/radio galaxies, dGs

DarkE

reionization

z=0

Bayesian flow prior to posterior via likelihood

dS$_{astro}$ <0

z ~ 1100

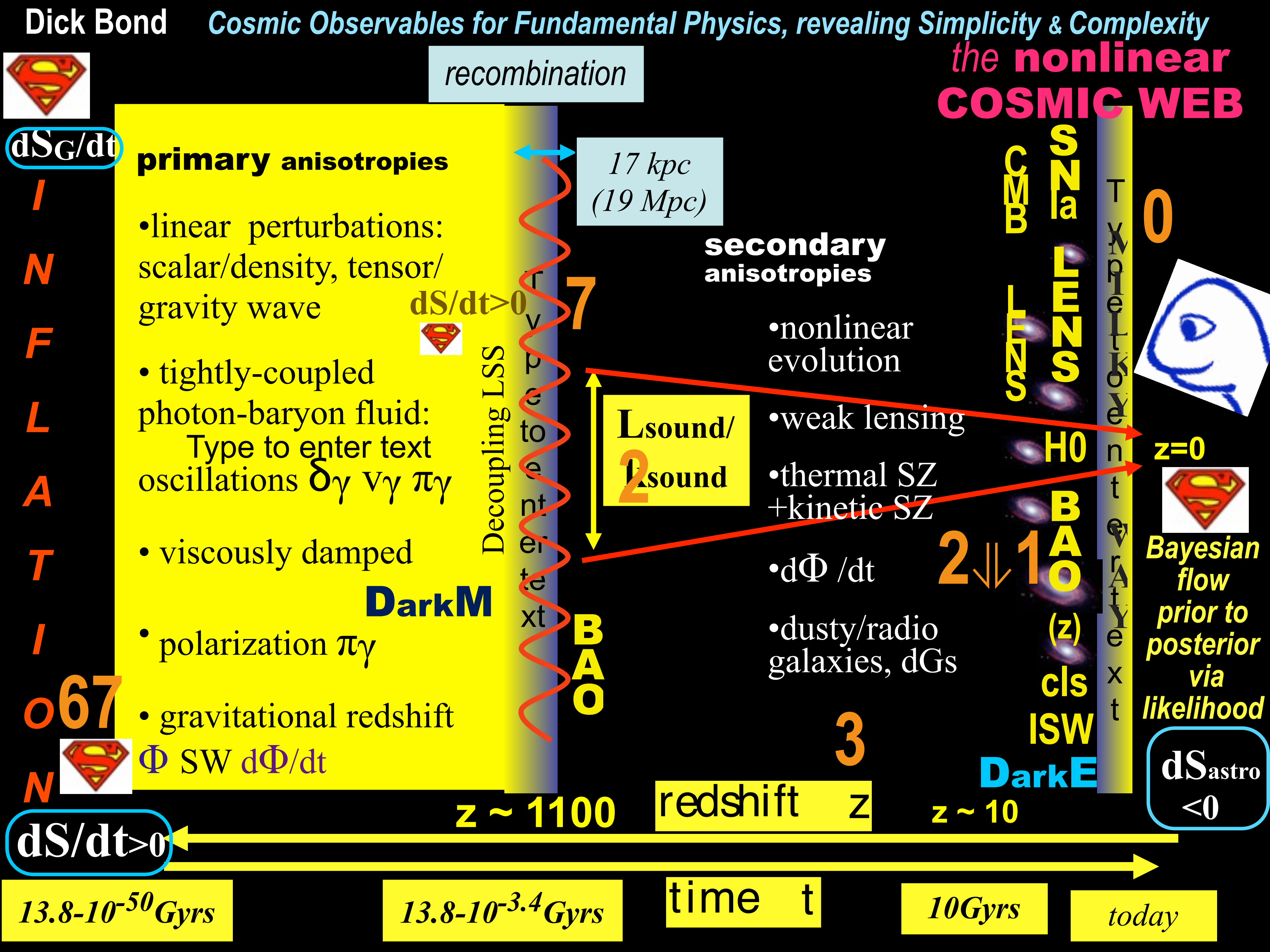
redshift z

z ~ 10

dS/dt>0

time t

13.8-10^{-50}Gyrs | *13.8-10$^{-3.4}$Gyrs* | *10Gyrs* | *today*



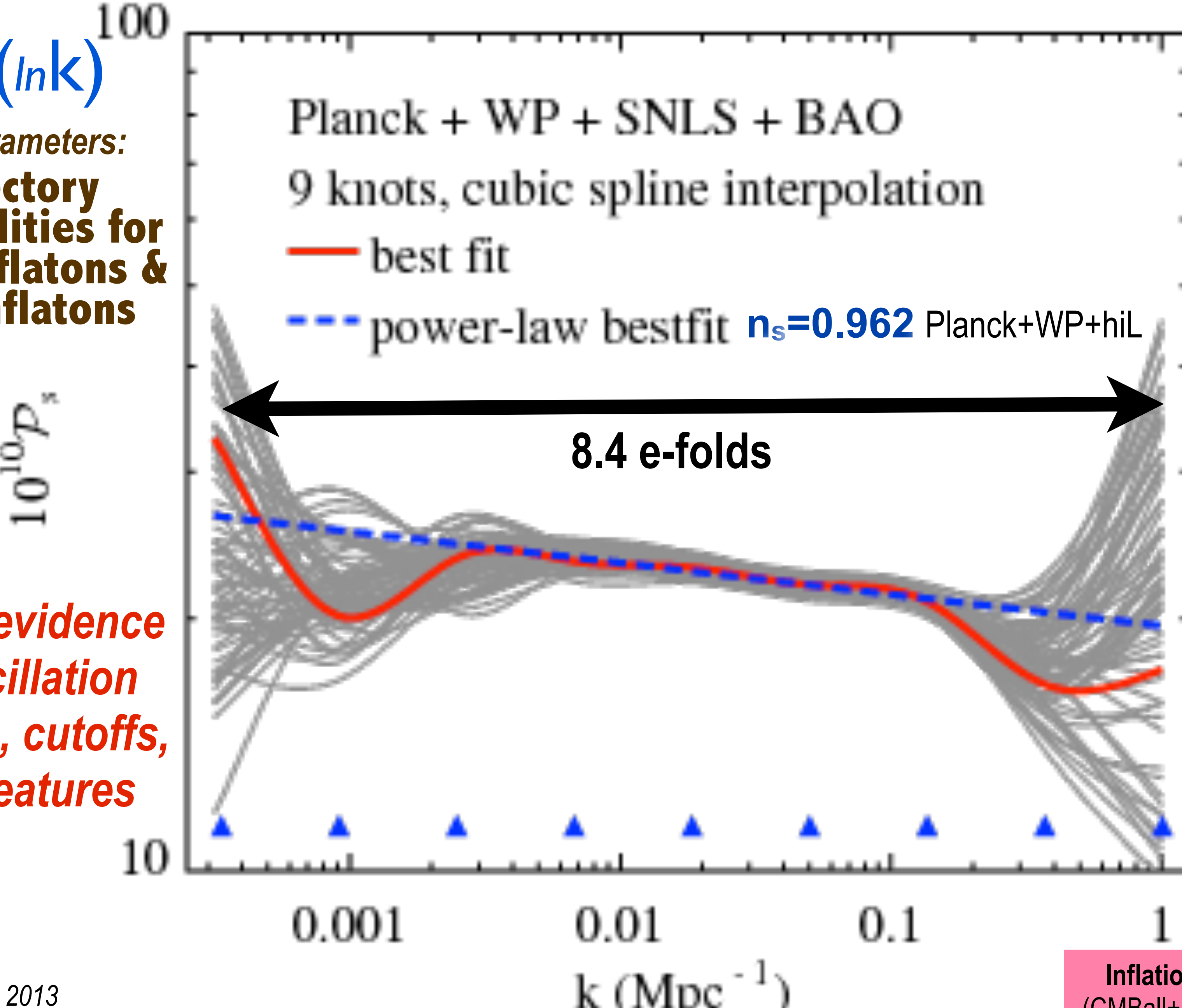
Dick Bond
Cosmic Observables for Fundamental Physics, revealing Simplicity & Complexity
the nonlinear COSMIC WEB
recombination
dSG/dt
INFLATION
o67
primary anisotropies
•linear perturbations: scalar/density, tensor/ gravity wave
dS/dt>0
• tightly-coupled photon-baryon fluid: Type to enter text oscillations δγ vγ πγ
• viscously damped
DarkM
• polarization πγ
• gravitational redshift
Φ SW dΦ/dt
Decoupling LSS
Type to enter text
7
17 kpc (19 Mpc)
Lsound/ Lsound
2
BAO
secondary anisotropies
•nonlinear evolution
•weak lensing
•thermal SZ +kinetic SZ
•dΦ /dt
•dusty/radio galaxies, dGs
3
CMB
LENS
SN Ia
LENS
H0
BAO
(z)
cls
ISW
2↓1
DarkE
Type to enter text
0
z=0
Bayesian flow prior to posterior via likelihood
dSastro <0
z ~ 1100
redshift z
z ~ 10
dS/dt>0
time t
13.8-10^-50 Gyrs
13.8-10^-3.4 Gyrs
10Gyrs
today

scan $\ln \mathbf{P_s}(\ln k)/A_s$, $\ln \mathbf{A_s} = \ln P_s(k_{pivot,s})$, $\mathbf{r}(k_{pivot,t})$; *consistency => reconstruct* **$\varepsilon(\ln Ha)$, $V(\psi)$**

$\ln P_s(\ln k)$

new parameters:

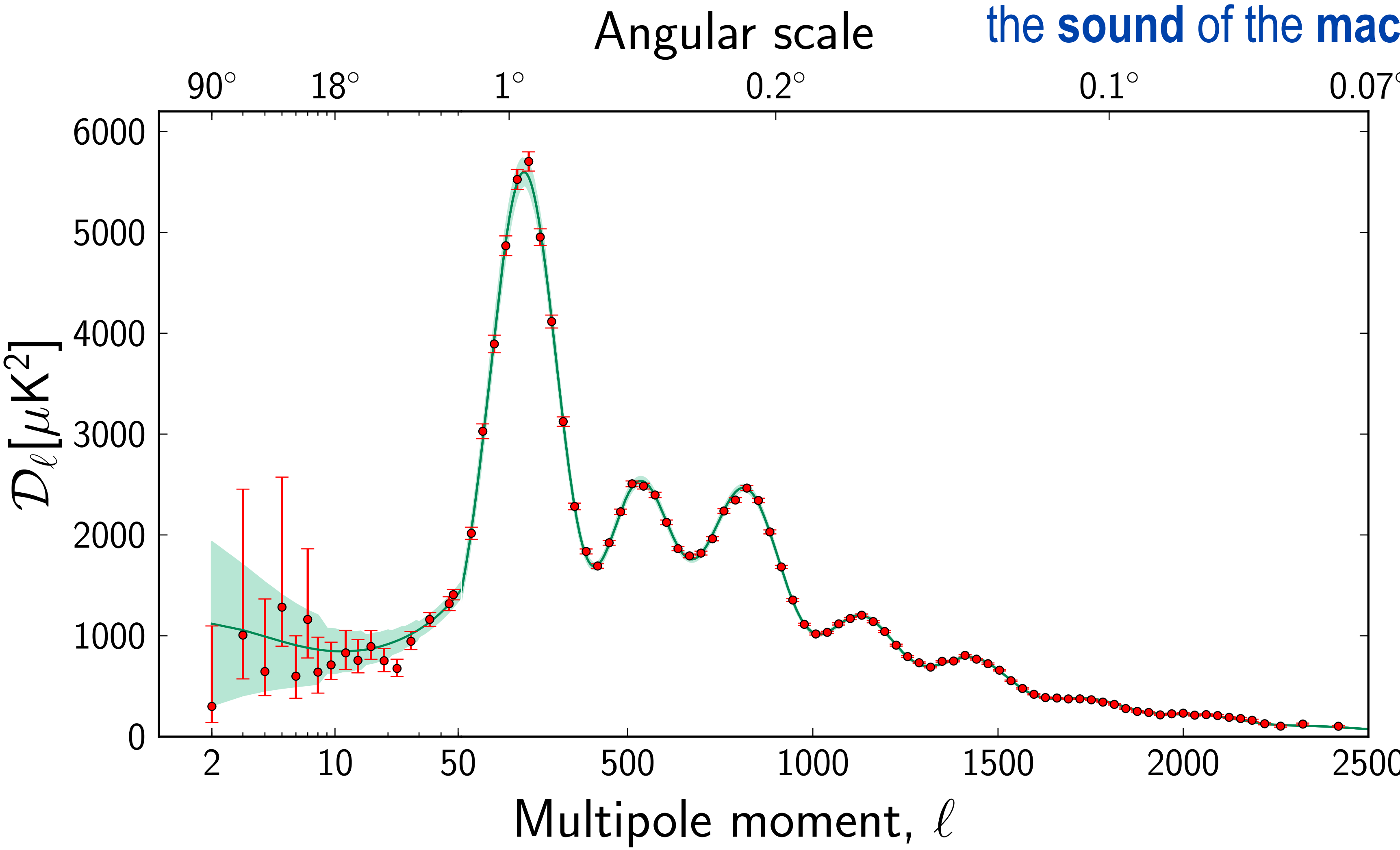
trajectory probabilities for early-inflatons & late-inflatons



no *strong* ***evidence for oscillation patterns, cutoffs, local features***

Bond, Huang 2013

Inflation Histories
(CMBall+LSS+SN+WL)



Excellent agreement between the Planck temperature spectrum at high L and the predictions of the tilted ΛCDM model.
Checks with polarization data provide full support to this conclusion.
extensive grid of cosmic models strongly constrain the x in tilted ΛCDM +x, x = subdominant deviations
Planck basic parameters (Ω_b, H_o ...), agree with BBN, BAO measure of acoustic scale. but H_o lower than HST, small age change
No evidence for additional neutrino-like relativistic particles beyond the three families of neutrinos in the standard model.
The first 30 multipoles are low for the standard ΛCDM, with no obvious explanation. *primordial fluctuation modification?*
Exact scale invariance ruled out, $n_s < 1$, at >4σ Planck alone, >5.4σ Planck + WMAP polarization
No substantial evidence for beyond basic single field slow roll, Bunch-Davis vacuum, standard kinetic term inflation. no f_{NL}

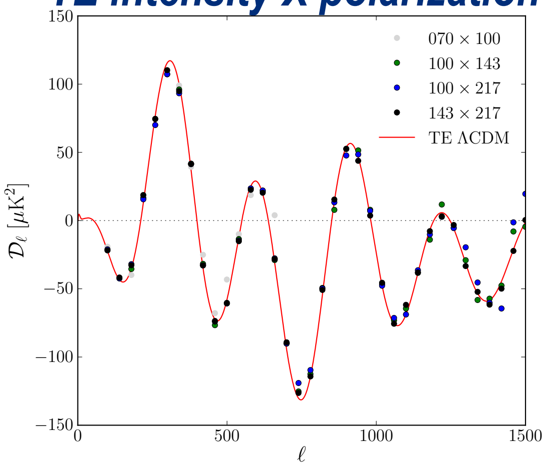
CMB Peak Statistics

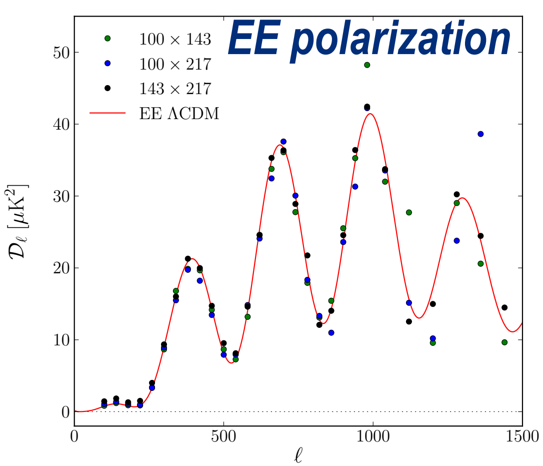
temperature stacked on temperature Peaks

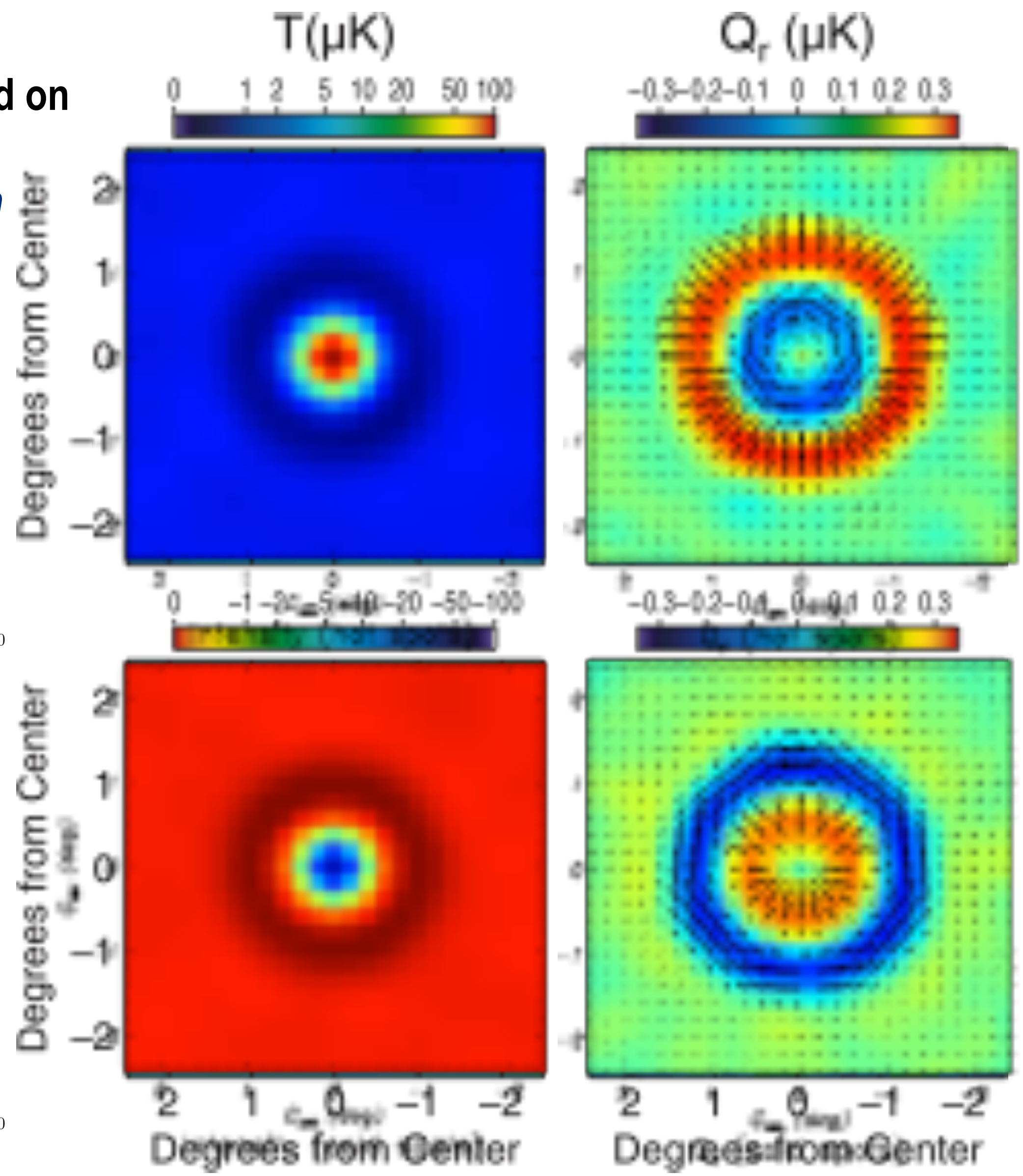
polarization rotated & stacked on temperature Peaks

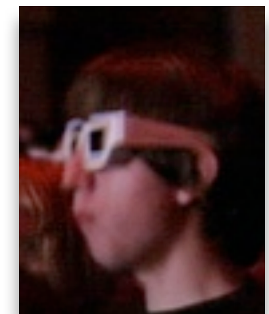
CMB Polarization
BAO in the CMB – Planck2013

TE intensity X polarization









Planck2013 teaser for Planck2014 polarization release

E mode patterns

no B here

Planck2014, 2015 ACTpol, ABS, Spider, AdvACT, GLP, ..

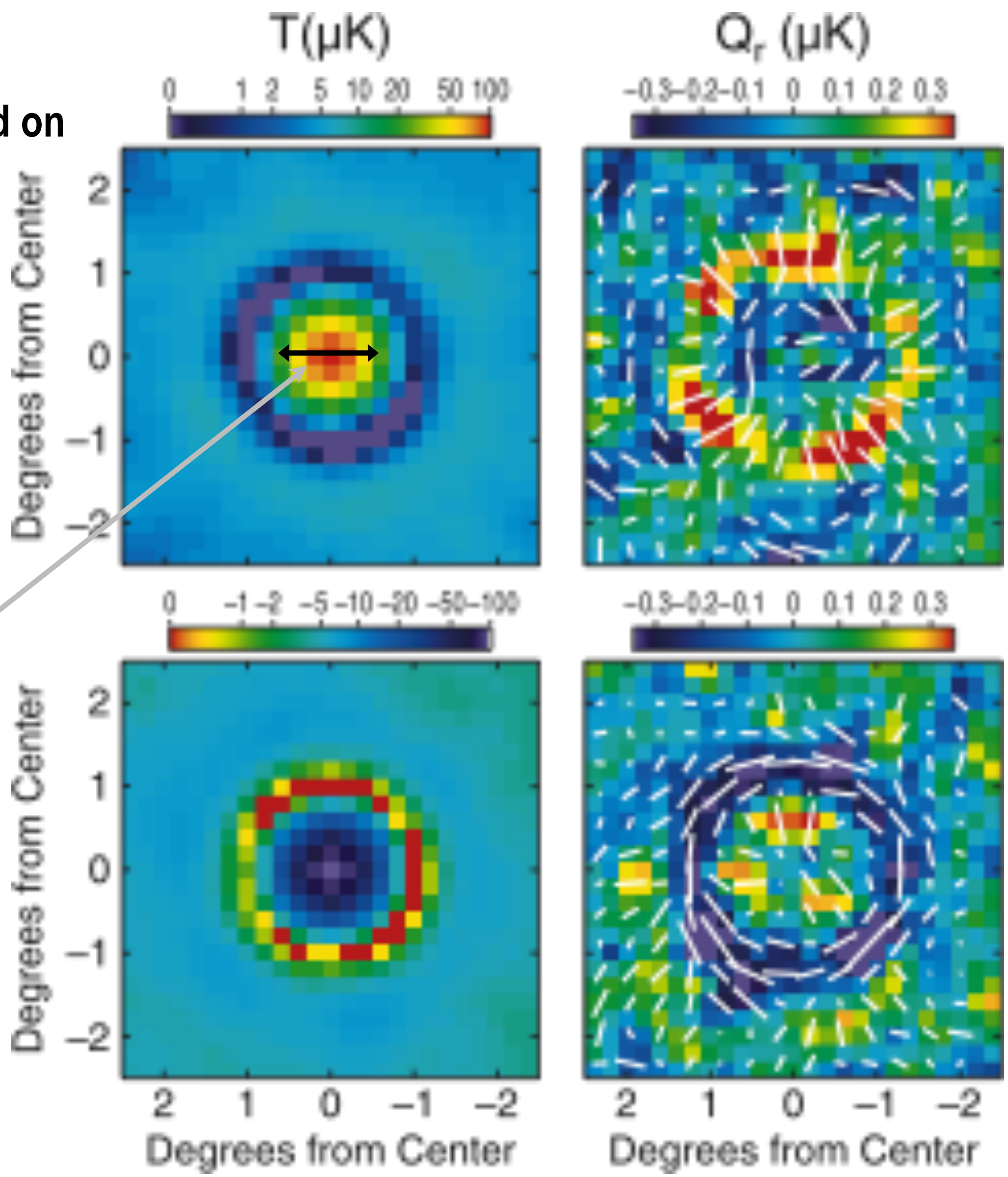
CMB Peak Statistics

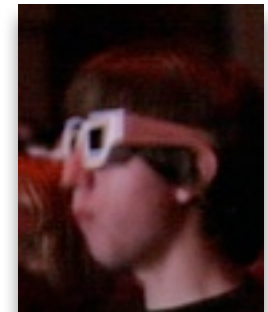
CMB Polarization
BAO in the CMB – WMAP9

temperature stacked on temperature Peaks

polarization rotated & stacked on temperature Peaks

BAO scale:
145.8 ± 1.2 Mpc





B mode of polarization *cf.* E mode

linear scalar fluctuations create only E patterns

strain from CMB lensing tides distorts E pattern into a bit of B *SPT*

anisotropic strain from **gravity waves => E & B**

photons under strain

BICEP2 collaboration 2014

380 sq deg

f_{sky}=0.009

512 antenna coupled TES bolometers
150 GHz for 3 seasons
cross-correlate with BICEP1, 100 GHz,
preliminary cross-correlate with KECK

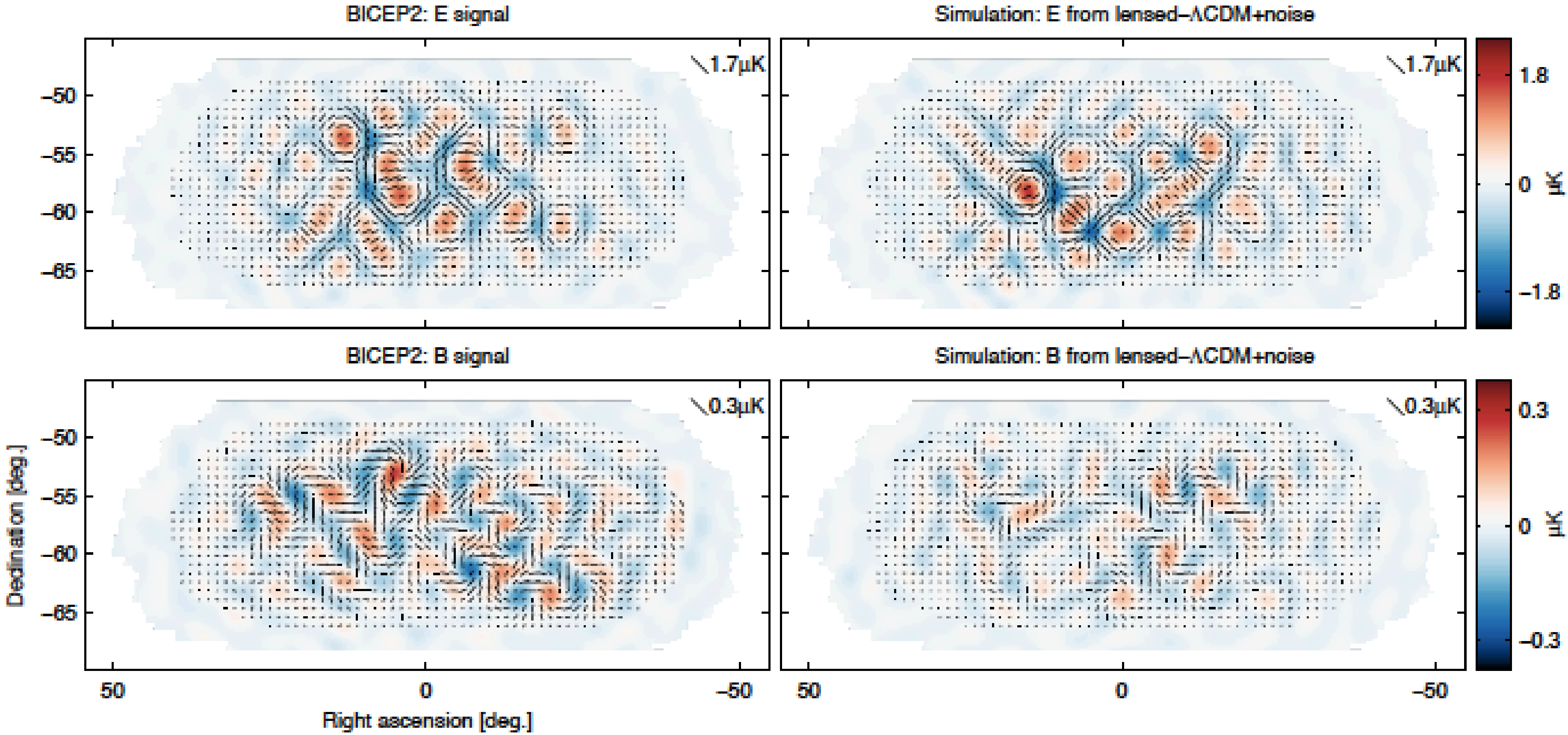
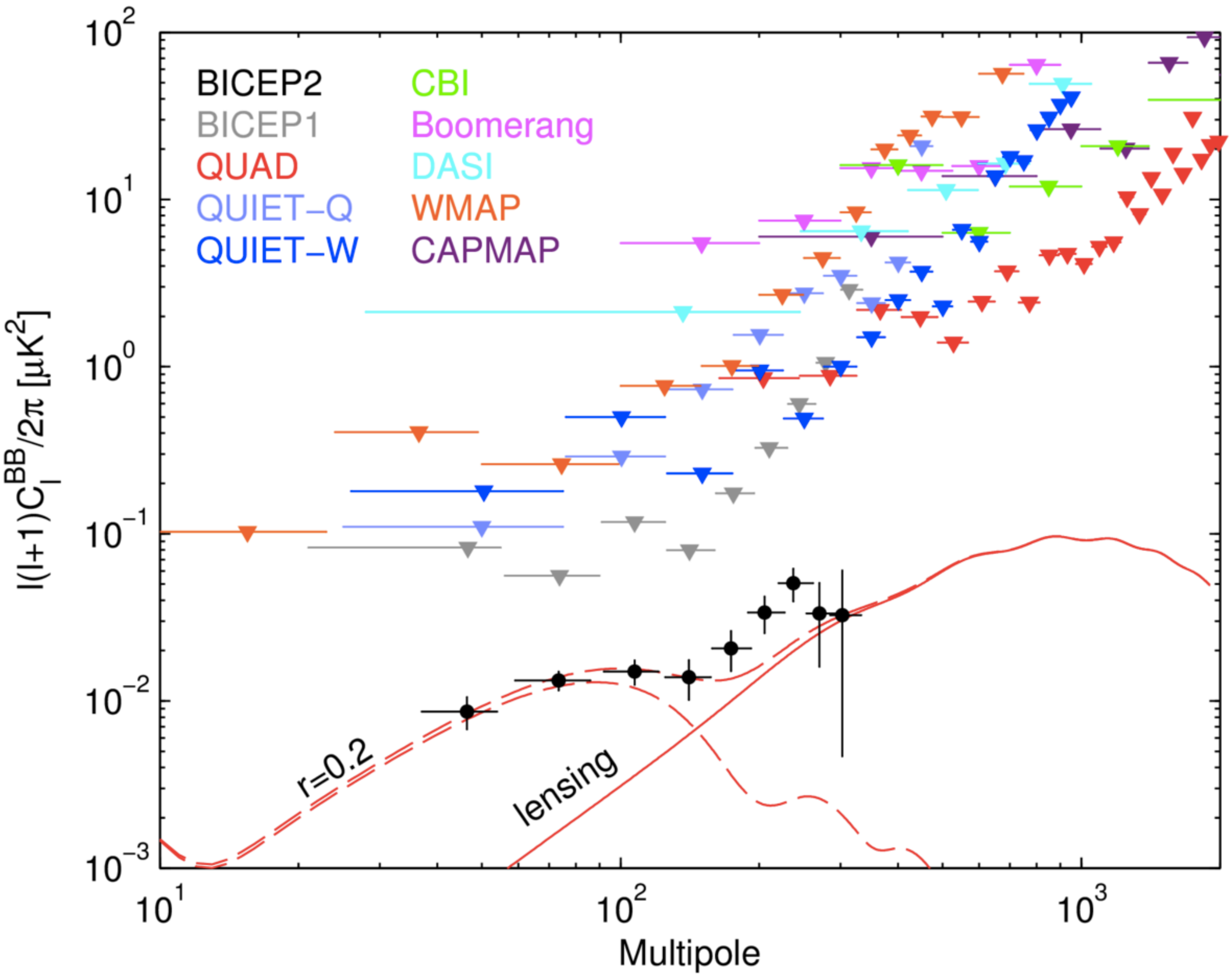


FIG. 3.— *Left:* BICEP2 apodized E-mode and B-mode maps filtered to $50 < \ell < 120$. *Right:* The equivalent maps for the first of the lensed-ΛCDM+noise simulations. The color scale displays the E-mode scalar and B-mode pseudoscalar patterns while the lines display the equivalent magnitude and orientation of linear polarization. Note that excess B-mode is detected over lensing+noise with high signal-to-noise ratio in the map ($s/n > 2$ per map mode at $\ell \approx 70$). (Also note that the E-mode and B-mode maps use different color/length scales.)

BICEP2 collaboration 2014 non-lensing B mode => **r=0.20 +.07-.05**

cf. P13: r from TT

< 0.12 95% CL

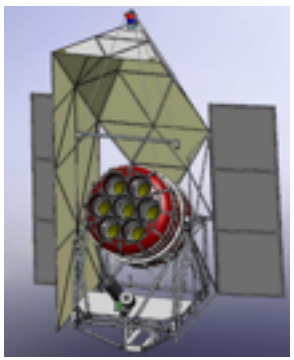


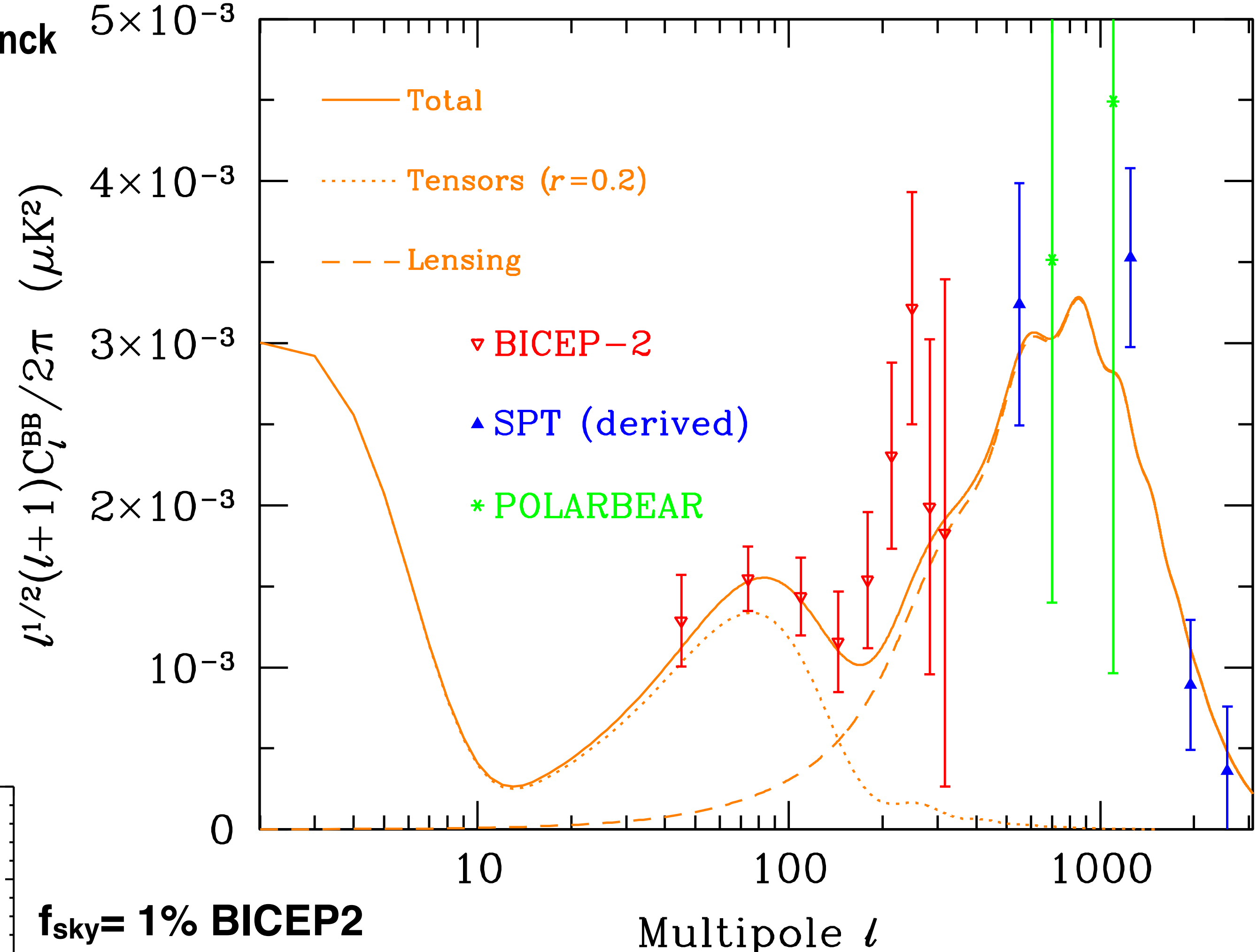
r=GW power/scalar-curvature power $\approx 0.13V/(2\times10^{16}\text{Gev})^4$

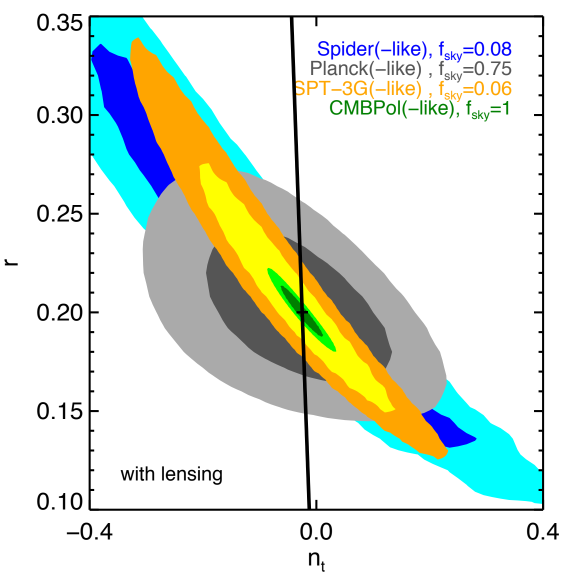
Potential Energy scale is the GUT level!

We are working heavily on Planck polarization, E Nov 2014, B ?

Spider collaboration, LDB flight Fall 2014 +-.02
supposed to fly Fall 13, but US sequester stopped it







f_{sky}= 1% BICEP2
= 6% SPT3G
= 8% SPIDER
= 70% PLANCK

= 50% AdvACT

Spider24days+Planck2.5yr:
r-n_t *matrix*-forecast
for r=0.2 input
($2\sigma_r$ ~0.04 including fgnds)

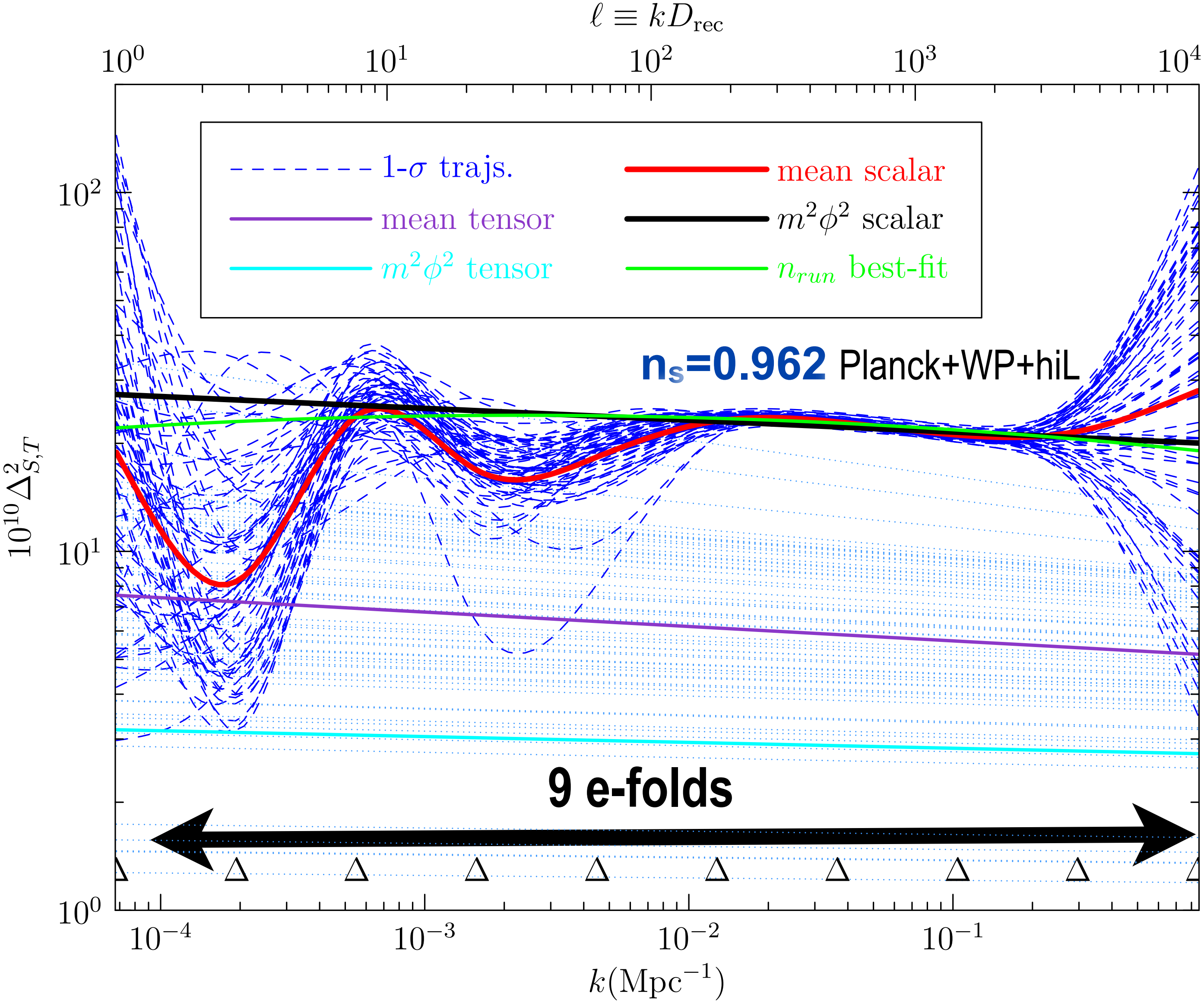
*similar r-forecasts for **ABS+, Keck, AdvACT,..***

*scan ln***P**$_s$(*ln*k)/A$_s$, *ln***A**$_s$=*ln*P$_s$($k_{pivot,s}$), ***r***($k_{pivot,t}$); *consistency => reconstruct* **ε(*ln*Ha), V(ψ)**

lnP$_s$(lnk)

new parameters:

trajectory probabilities for early-inflatons



Bond, Braden, Huang, Frolov,2014

PS: running of PS is a bad fit

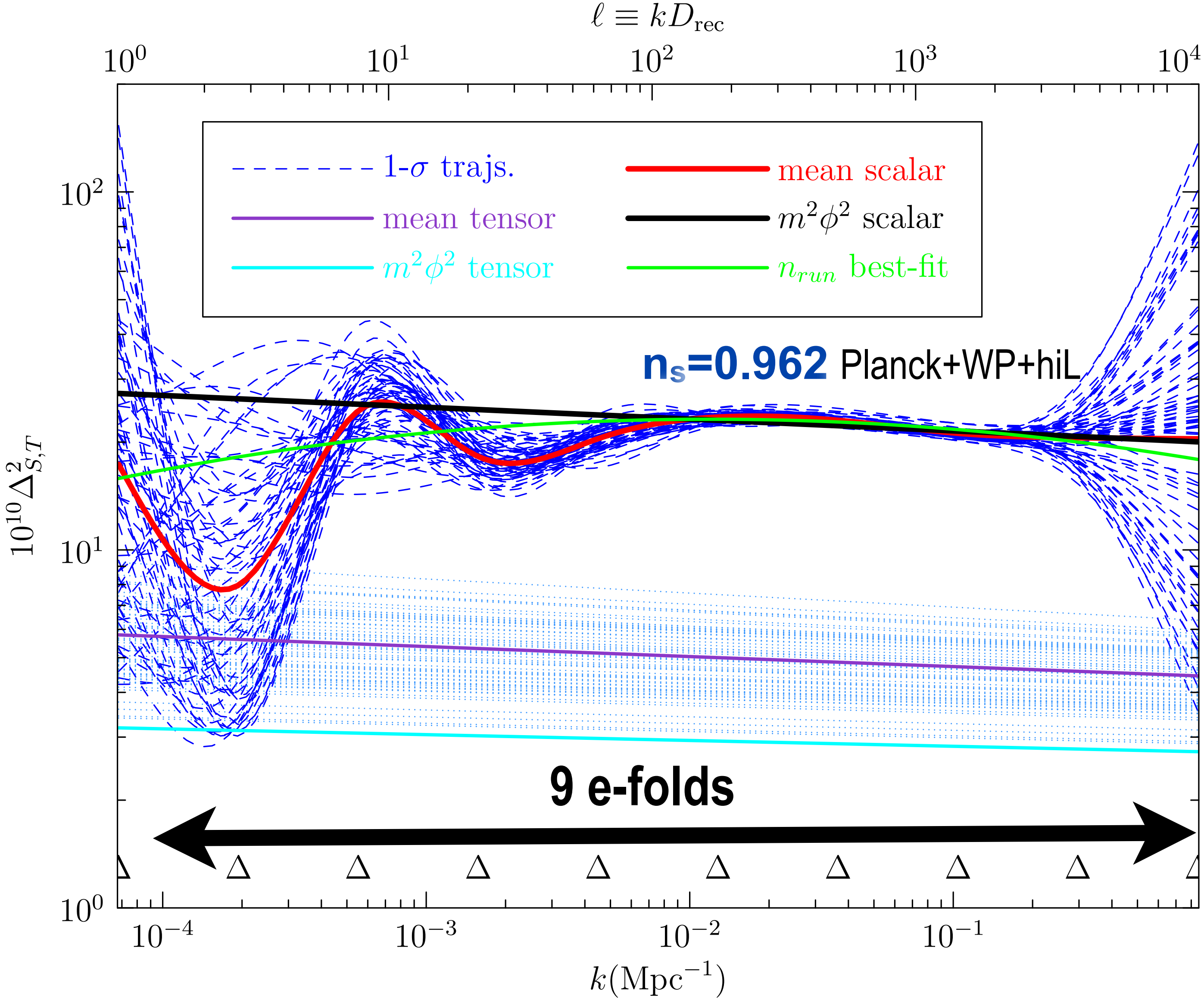
Inflation Histories
(CMBall+LSS+SN+WL)

scan ***ln*** **P_s**(*ln*k)/A_s, ***ln*** **A_s**=*ln*P_s($k_{pivot,s}$), ***r***($k_{pivot,t}$); *consistency => reconstruct* **ε(*ln*Ha), V(ψ)**

lnP_s(*ln*k)

new parameters:

trajectory probabilities for early-inflatons



Bond, Braden, Huang, Frolov,2014

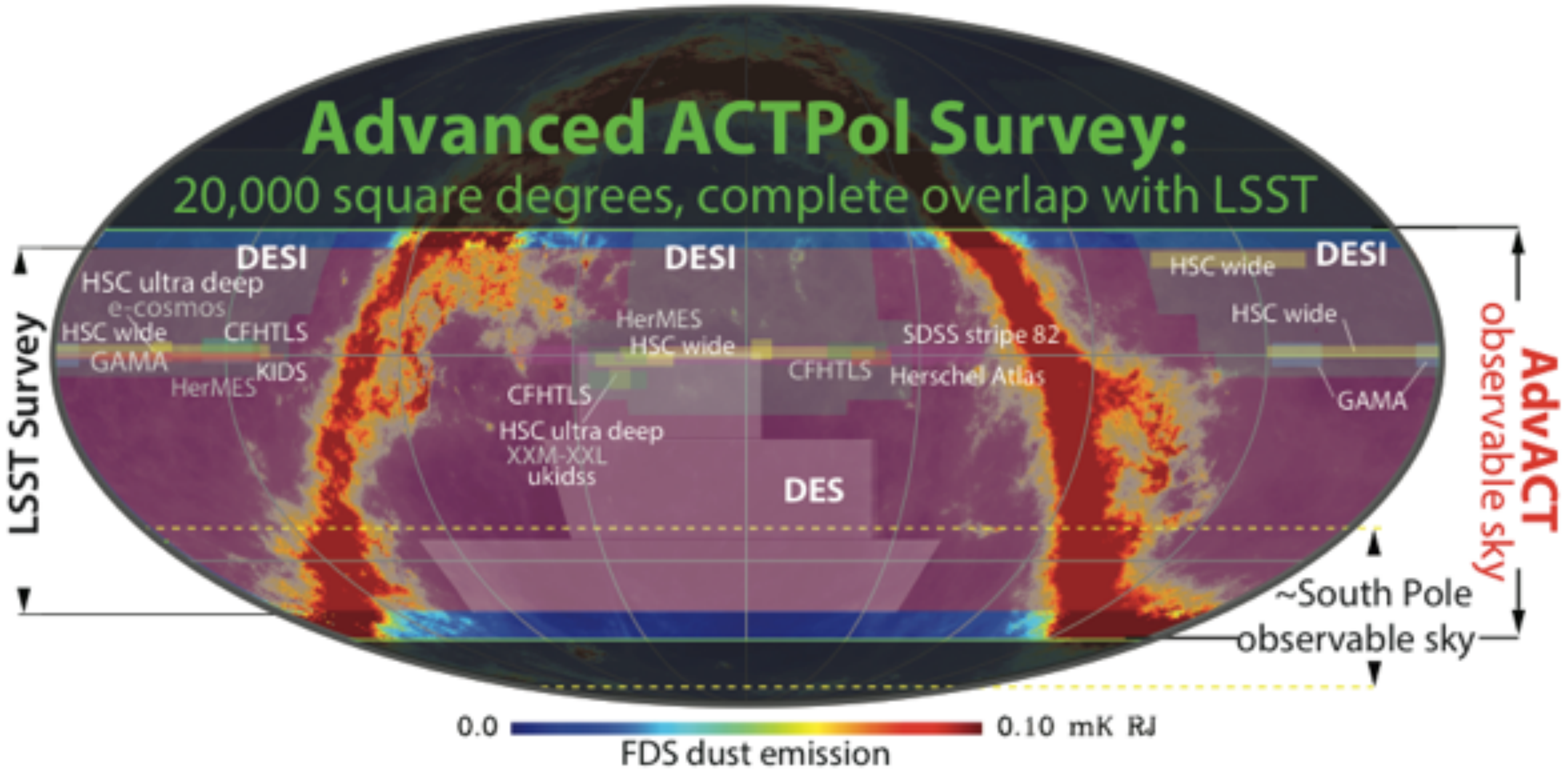
PS: running of PS is a bad fit

Inflation Histories
(CMBall+LSS+SN+WL)

The ACT Collaboration

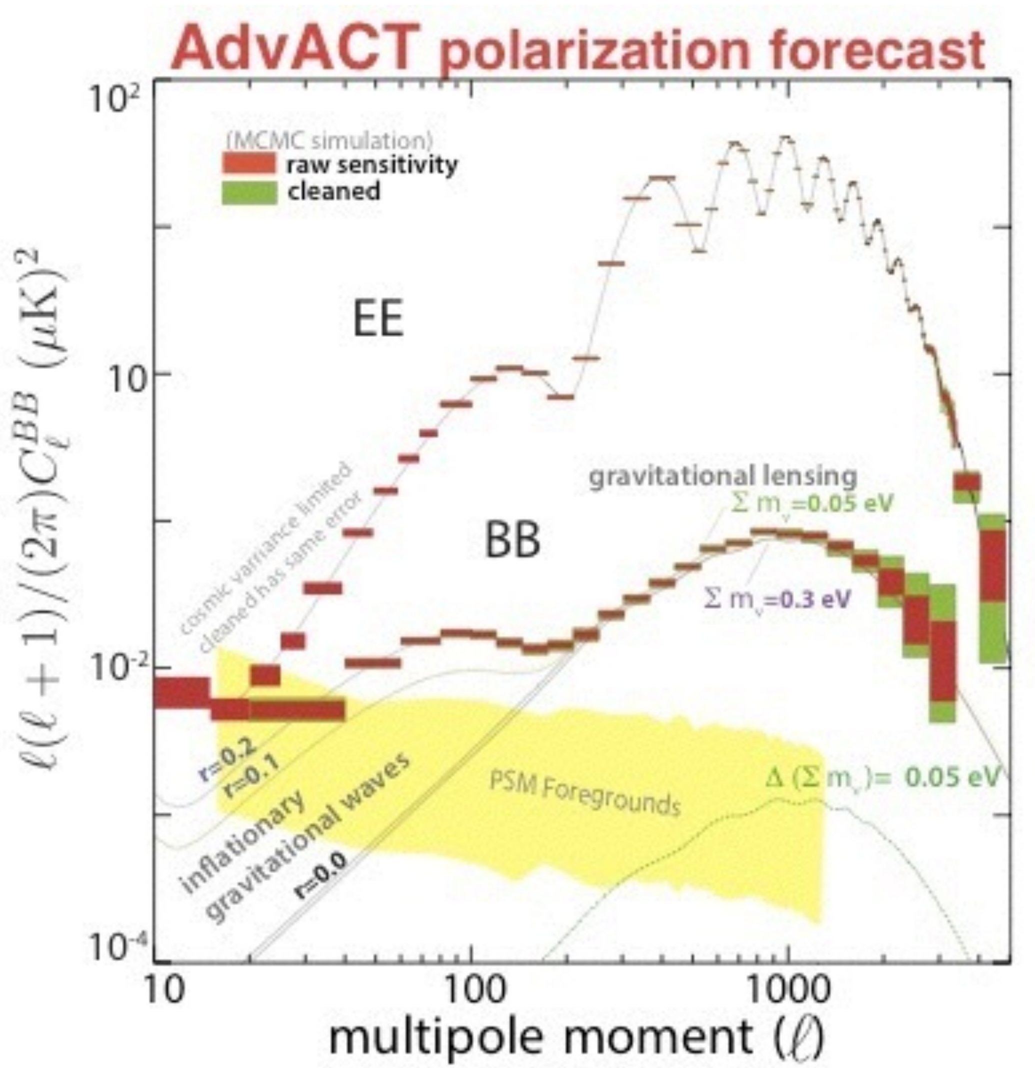
ACT, now ACTpol, => Advanced ACTpol

Advanced ACTPol (AdvACT) Observations



- ~20,000 deg^2 survey (f_{sky}~0.5) with complete LSST overlap as well as DES, ALMA, and other observatories located in Chile
- Substantial overlap with spectroscopic surveys (SDSS, PFS, DESI)

AdvACT: Power Spectra



Error bars above shown for r = 0.2

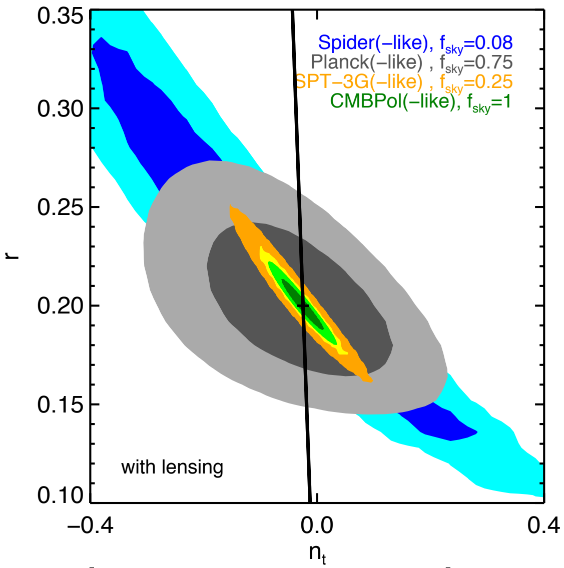
High S/N B-mode detections for r > 0.01 are measured in independent frequency bands (90 & 150 GHz) and on many patches across the sky.

This provides important cross-checks on any detected signal

Also shown:

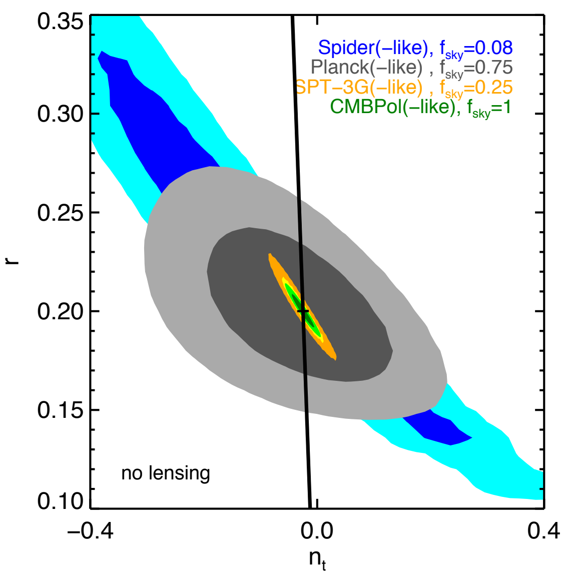
- Error bars before and after foreground cleaning
- Varying amplitudes of the gravitational lensing signal for different values of the sum of the neutrino masses
- Planck forecasts

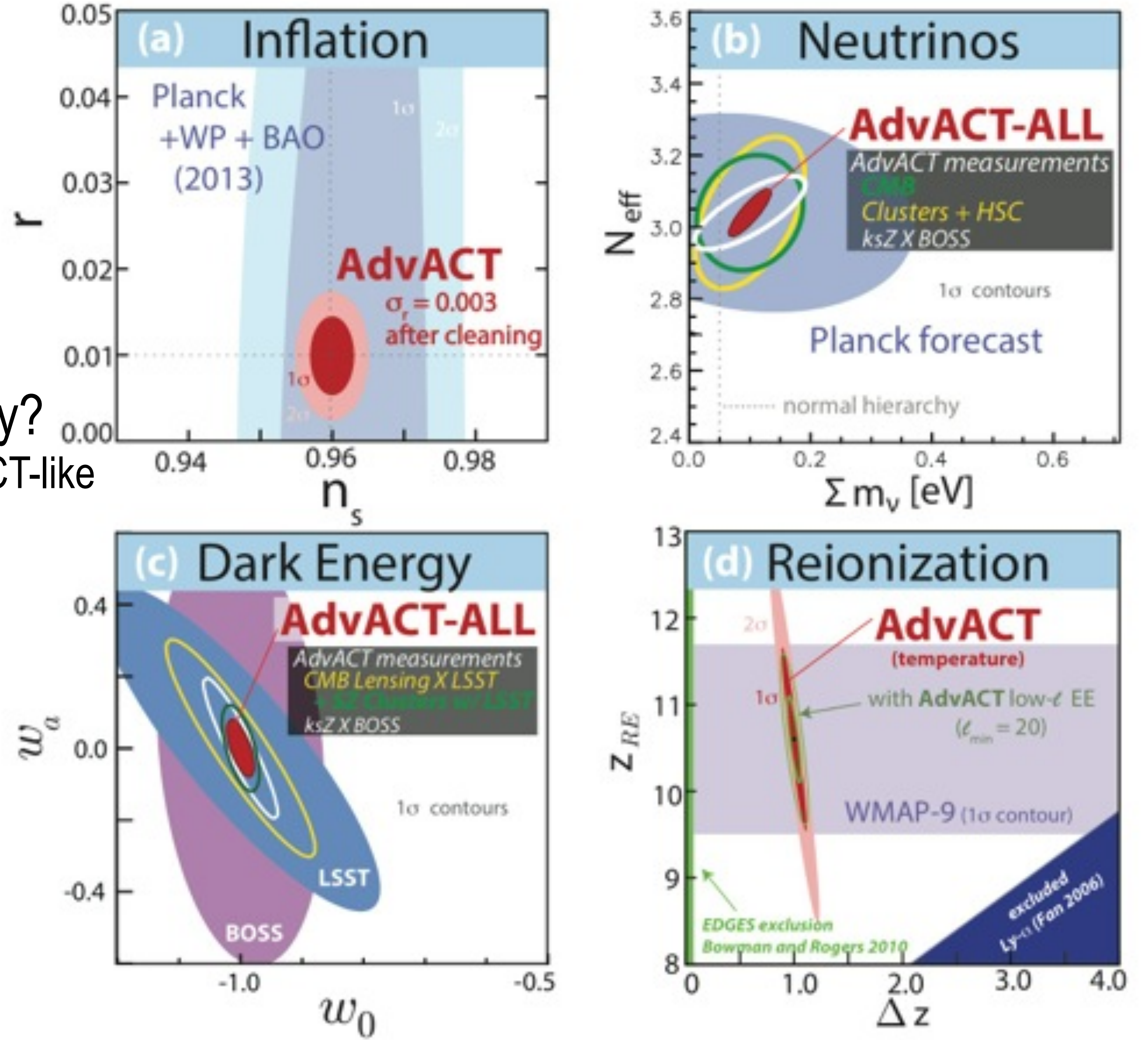
AdvACT: Cosmological Forecasts
& Planck2.5, Spider, future SPT3g, CMBpol



testing tensor consistency?

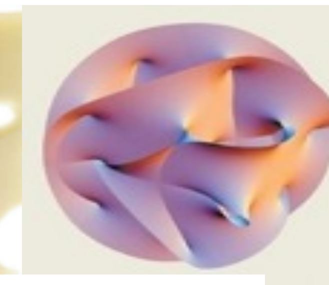
better f_{sky}=25% for spt3g/AdvACT-like than current 6% goal for spt3g

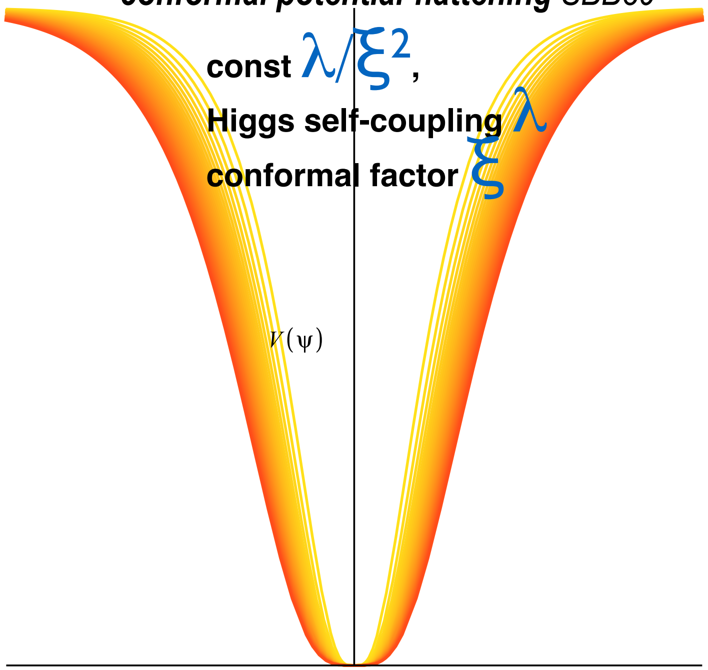


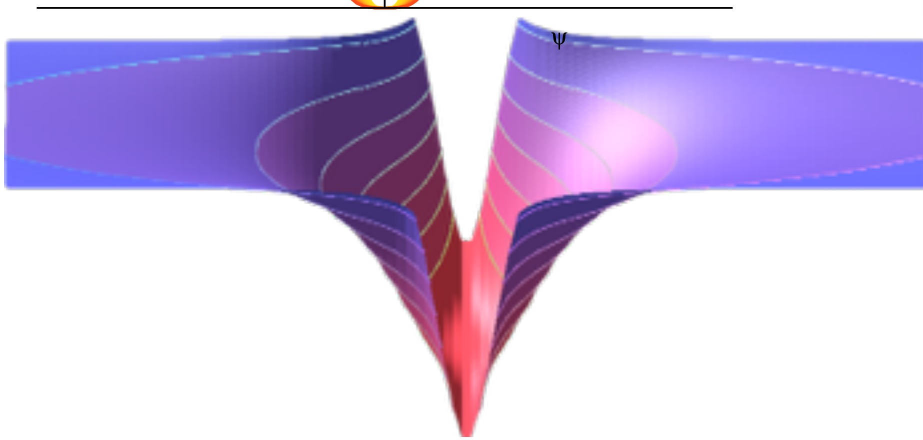


how was *matter & entropy generated at the end of acceleration = inflation*?

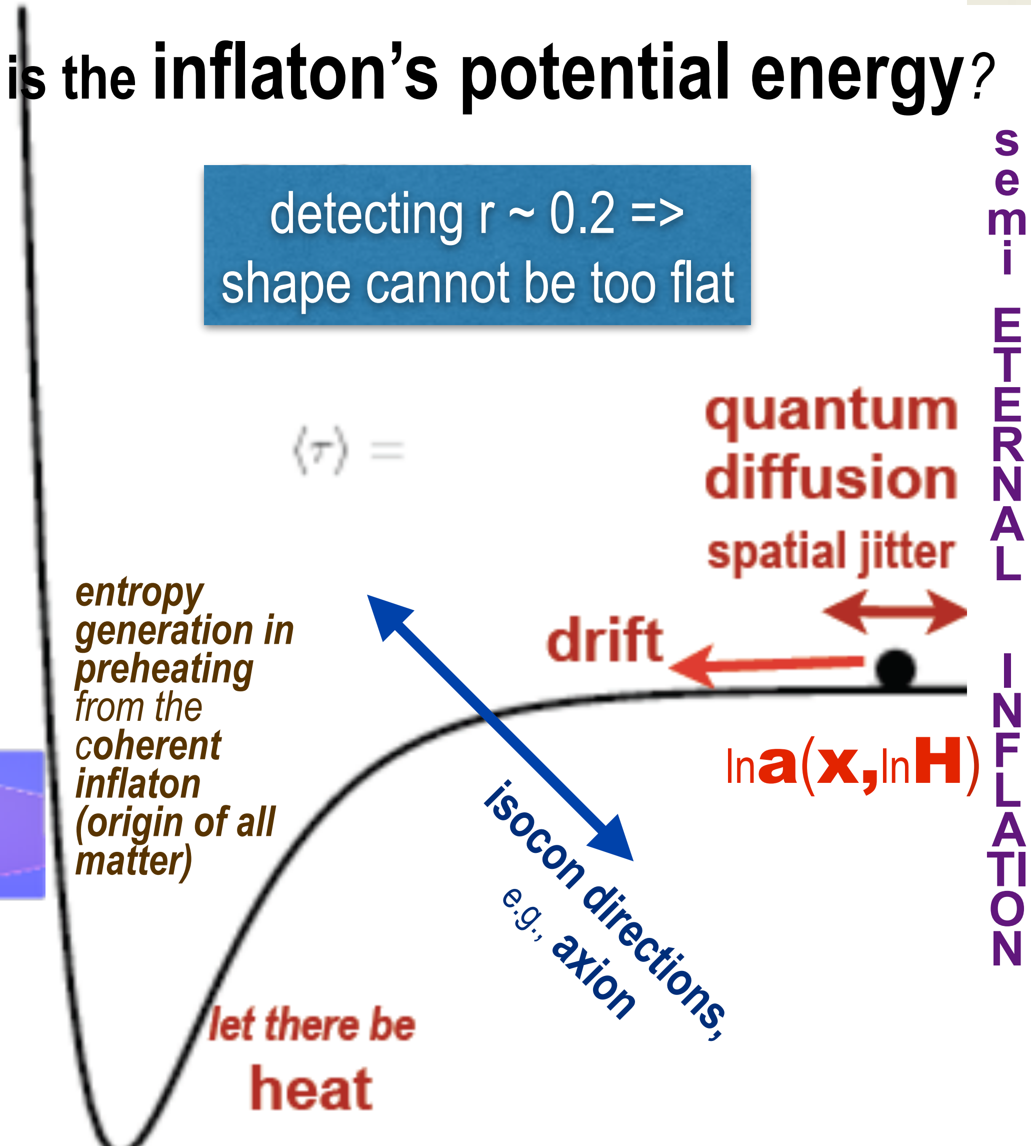
Relate it to the Higgs & standard model?







what is the inflaton's potential energy?

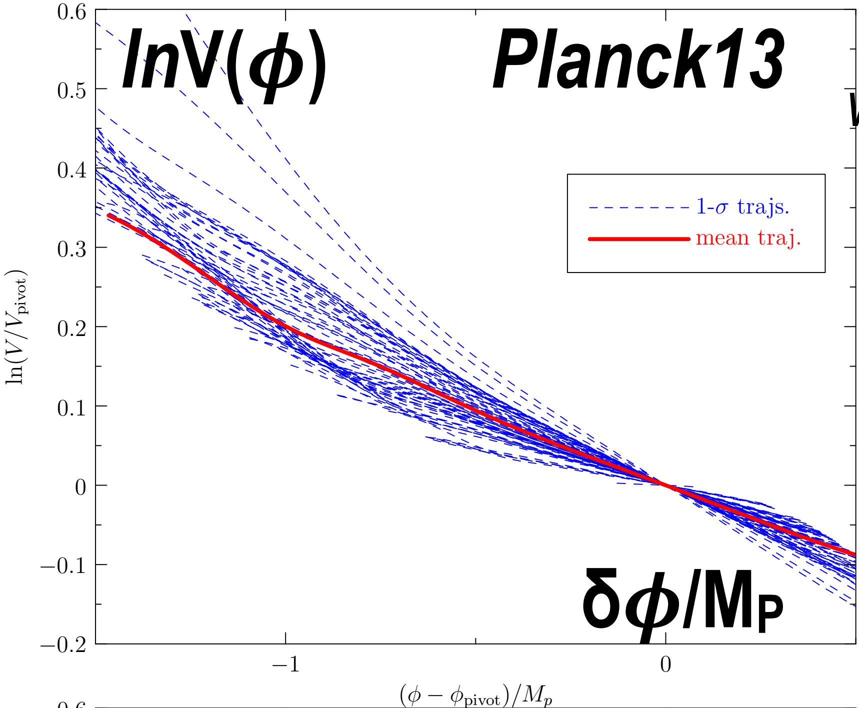


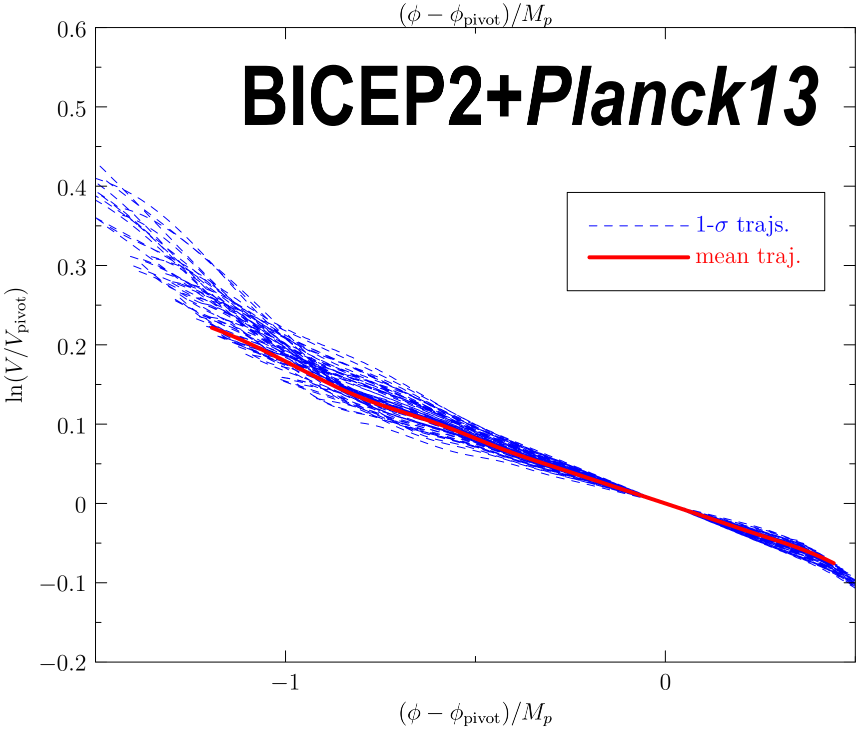
what is the **inflaton's V(ϕ)**?

we **reconstruct** *the* ***scalar curvature powe*** *(isotropic strain) & the early universe* ***acceleration histories*** *as well*

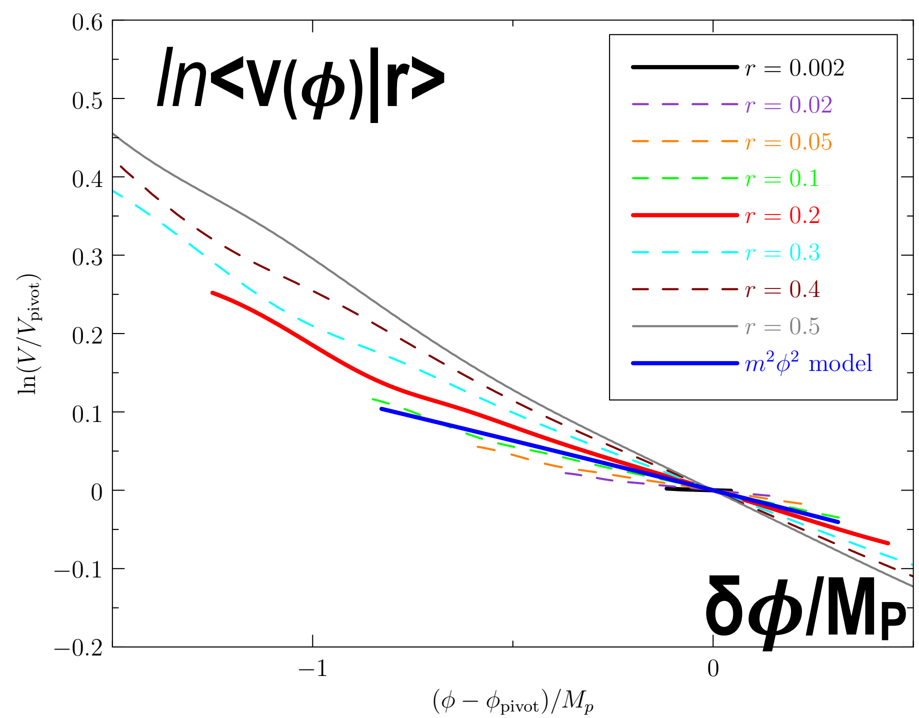
detecting r ~ 0.2 =>

V(ϕ) shape cannot be too flat over the observable range





Reconstructed mean potential (without BICEP constraint)



simplest is V(ϕ) ~ $m^2\phi^2$

END

reconstructing ζ *aka* primordial ***scalar curvature*** ***@uniform density***

Bond, Frolov, Huang, Braden, Nolta

Wiener-filtered ζ maps instead of $\boldsymbol{\zeta}(\mathbf{x})$, $\boldsymbol{\zeta}(\mathbf{k})$, make

$\boldsymbol{\zeta}_{LM}(\chi)$, $\chi=|\mathbf{x}|$ & $\boldsymbol{\zeta}_{LM}(k)$, $k=|\mathbf{k}|$ **maps**

$$T_{LM\, c,s} \sim \int \zeta_{LM\, c,s}(k)\, U^{T}_{L\, c,s}(k)\, dk + res \;\sim \int \zeta_{LM\, c,s}(\chi)\, V^{T}_{L\, c,s}(\chi)\, d\chi + res$$

Gaussian stats => $C^{\zeta\zeta}_{L}(\chi_1,\chi_2)$, $C^{\zeta T}_{L}(\chi)$, C^{TT}_{L}

$< \int \mu_b(\chi)\, \zeta_{LM\, c,s}(\chi)\, d\chi \mid a_{LM\, c,s} >$ + *inhomog* **Gaussian fluctuations**

visibility masks $\mu_b(\chi)$ select bands $\Delta\chi_b$ about χ_b ~ decoupling, reionization (also ISW). ∃ only a single-mode $V^{T}_{L\, c,s}$ direction, fluctuations in orthogonal directions are huge. use the mask for shaped-weighting to control fluctuation-swamping.

full $\boldsymbol{\zeta}_{LM}(k)$ *reconstruction* $<\zeta_{LM}(k) \mid a_{LM}>$ *is fluctuation-swamped*

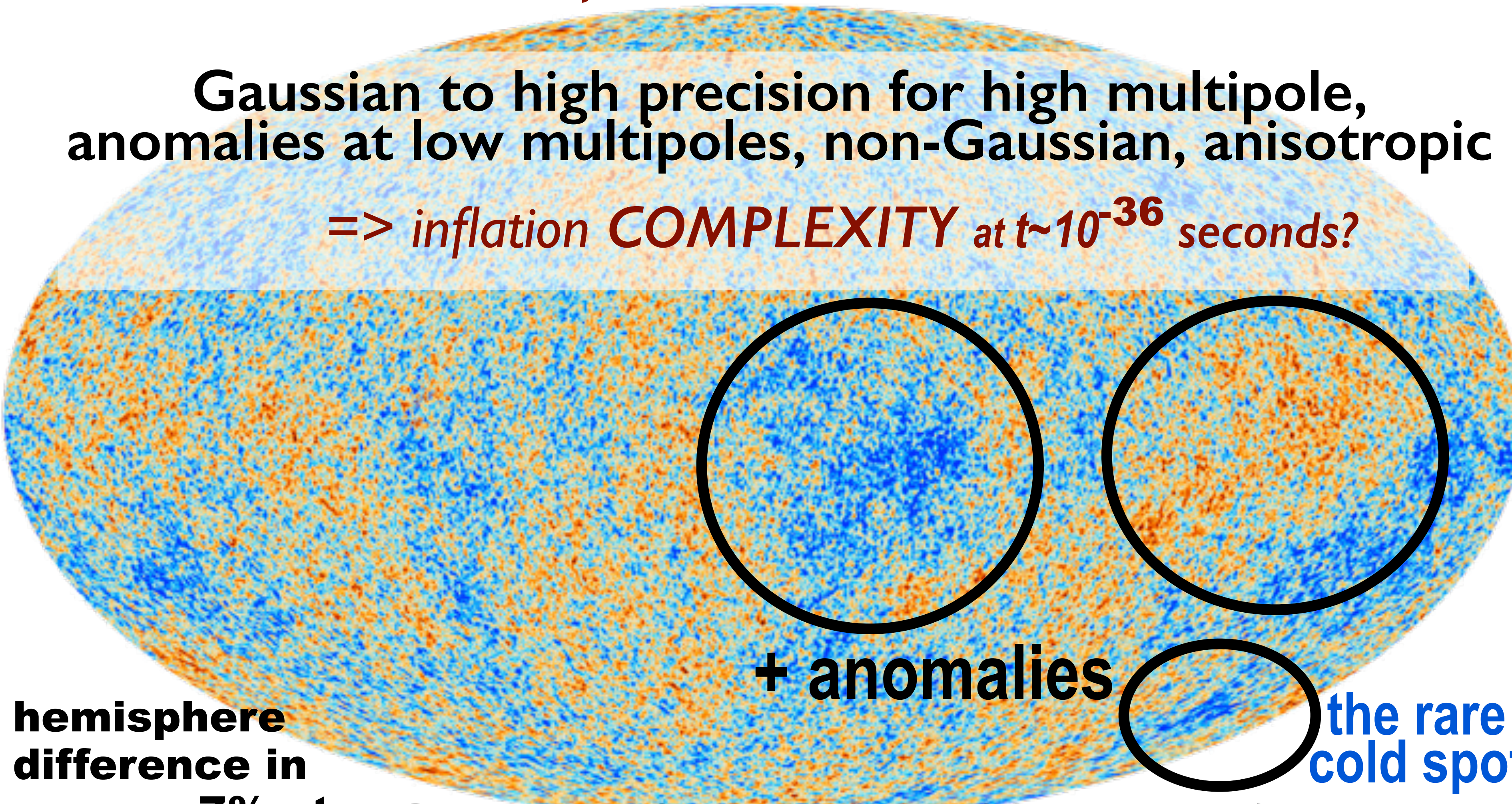
∃ E-pol vector $V^{E}_{L\, c,s}$ overlaps V^{T} but it differs enough so reconstruction improves with E-pol

$C^{\zeta E}_{L}(\chi)$, C^{EE}_{L}, C^{TE}_{L}

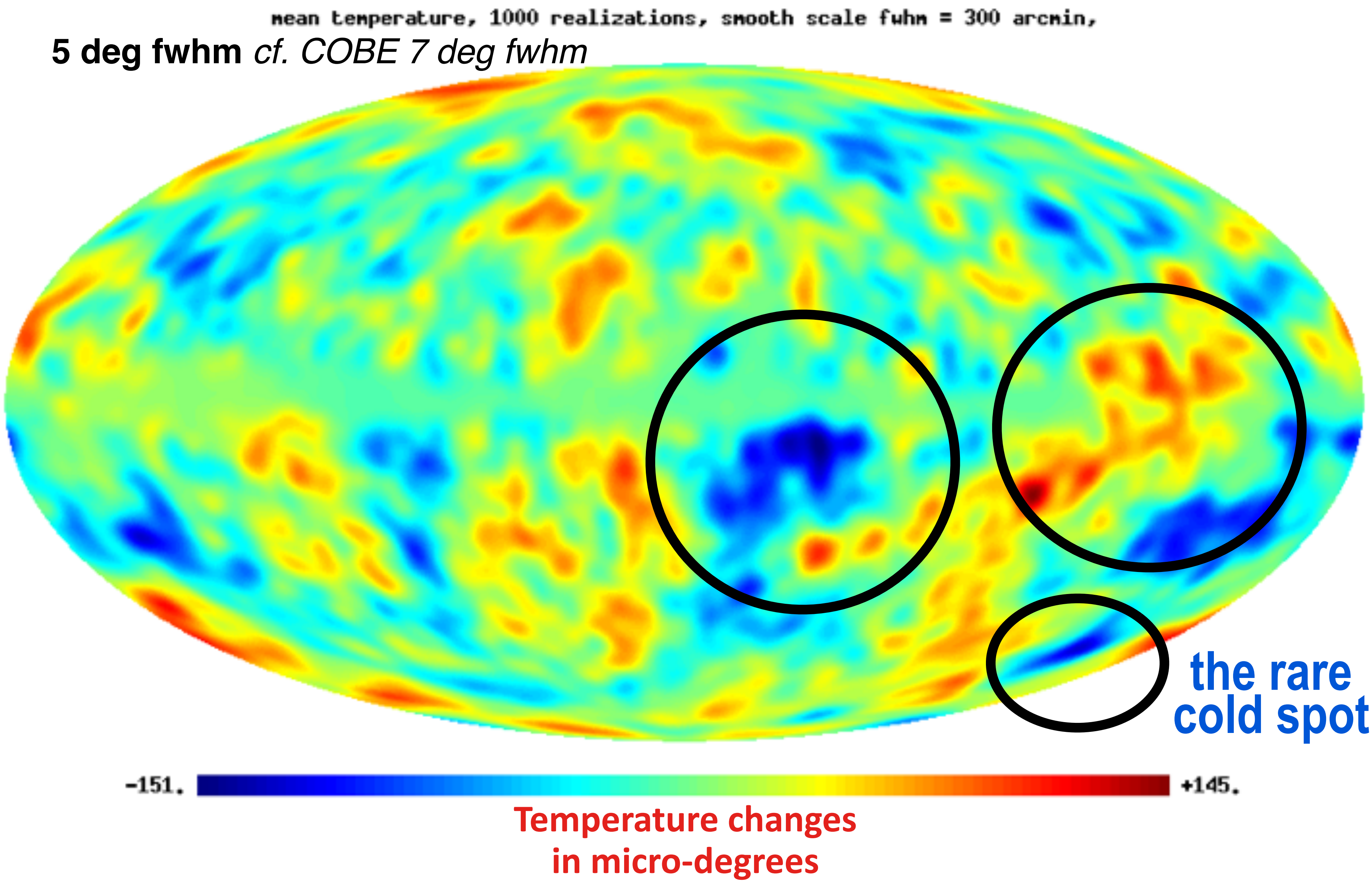
Planck's primordial light unveiled, March 21, 2013

reveals the SIMPLICITY of primordial cosmic structure

7^+ numbers, 2+1 are inflation numbers



temperature map

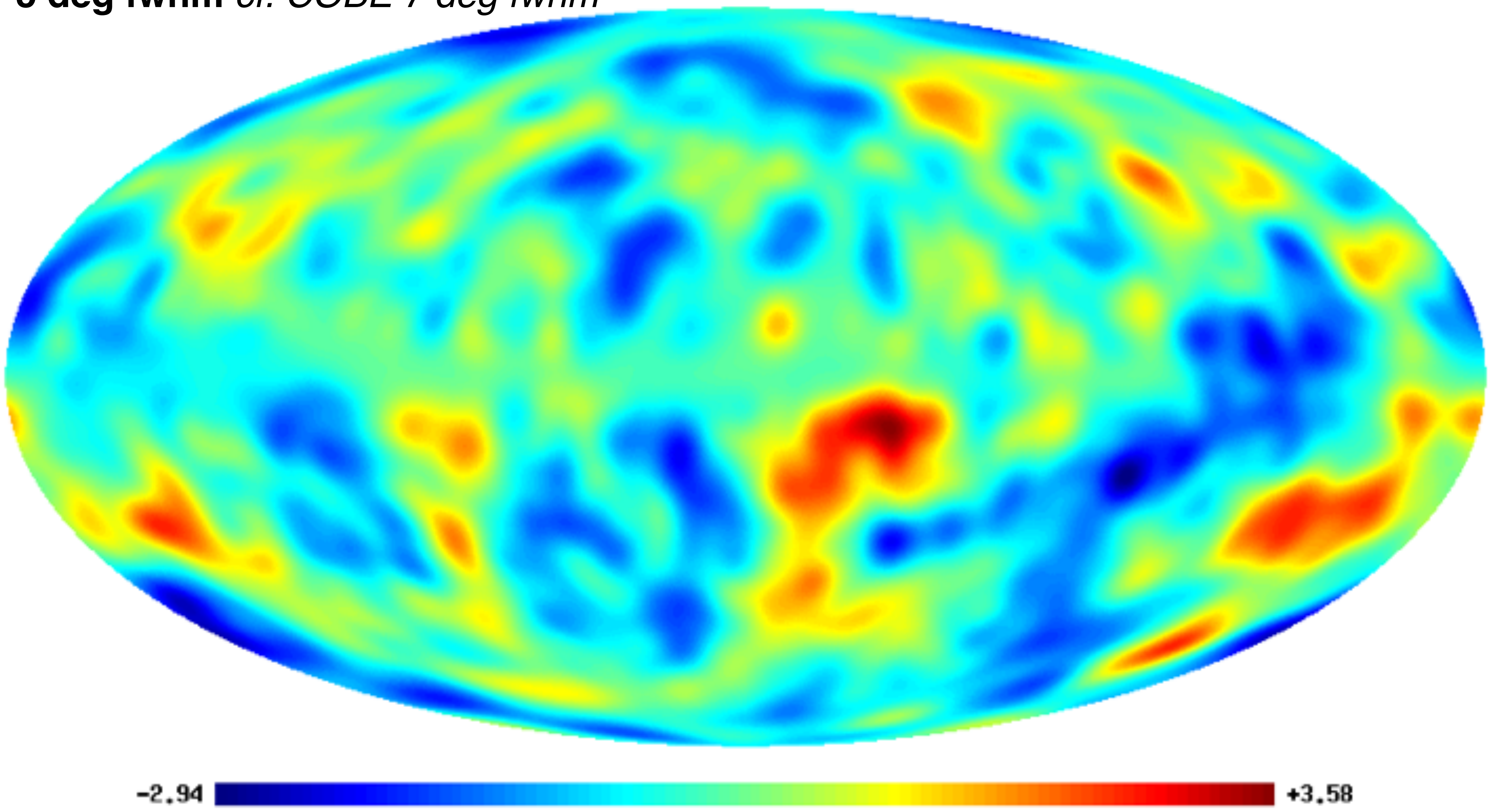


reveals map of **primordial isotropic strain /phonons**

$<Trace(\alpha)|Temp>$

mean zeta, 1000 realizations, smooth scale fwhm = 300 arcmin,

5 deg fwhm *cf. COBE 7 deg fwhm*



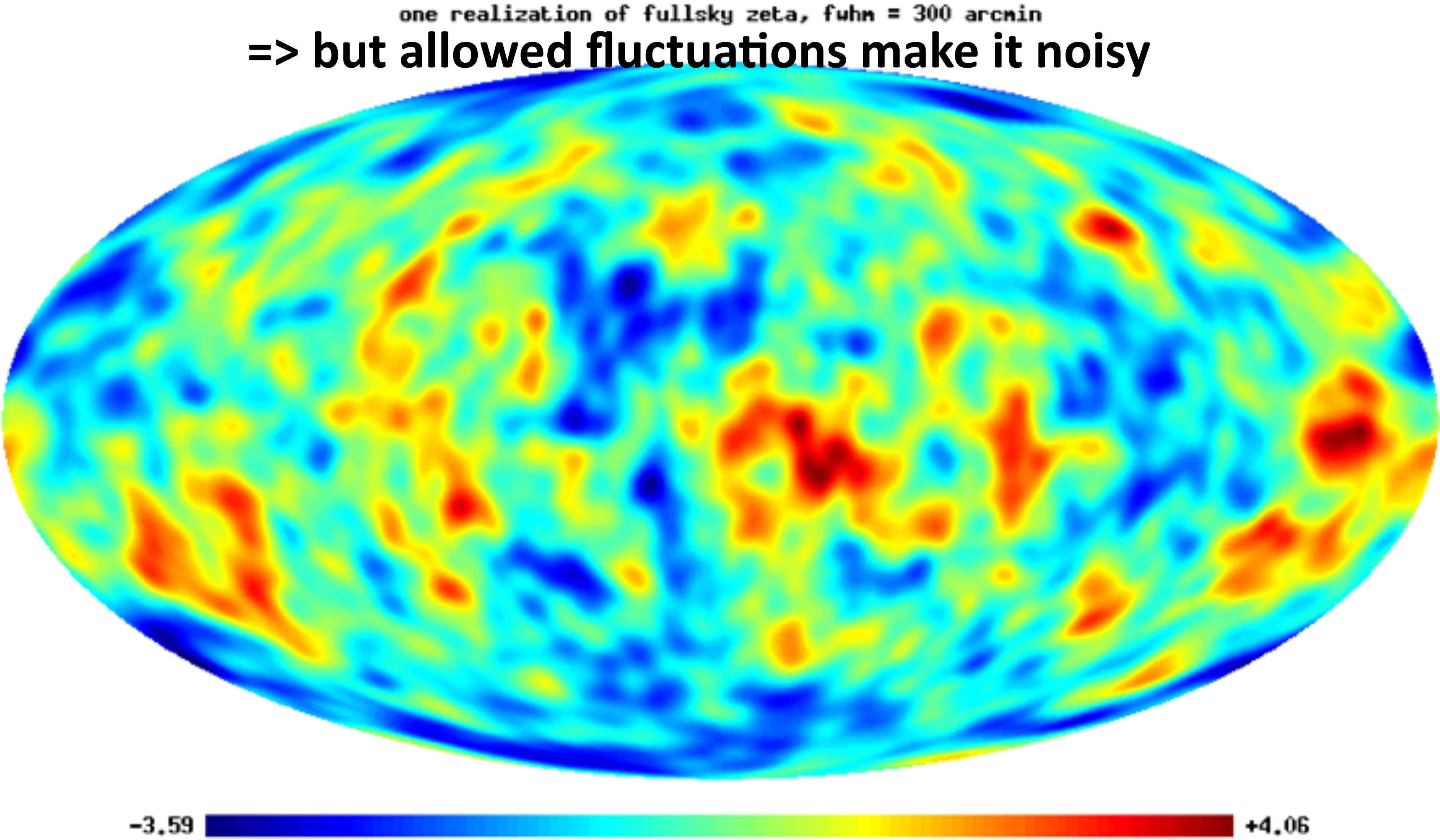
Reconstructing the Early Universe

visibility mask

reveals map of **primordial isotropic strain /phonons**

$$\langle \mathit{\mathbf{Trace}}(\boldsymbol{\alpha}) | \mathit{Temp} \rangle + \delta \mathit{\mathbf{Trace}}(\boldsymbol{\alpha})$$

=> but allowed fluctuations make it noisy

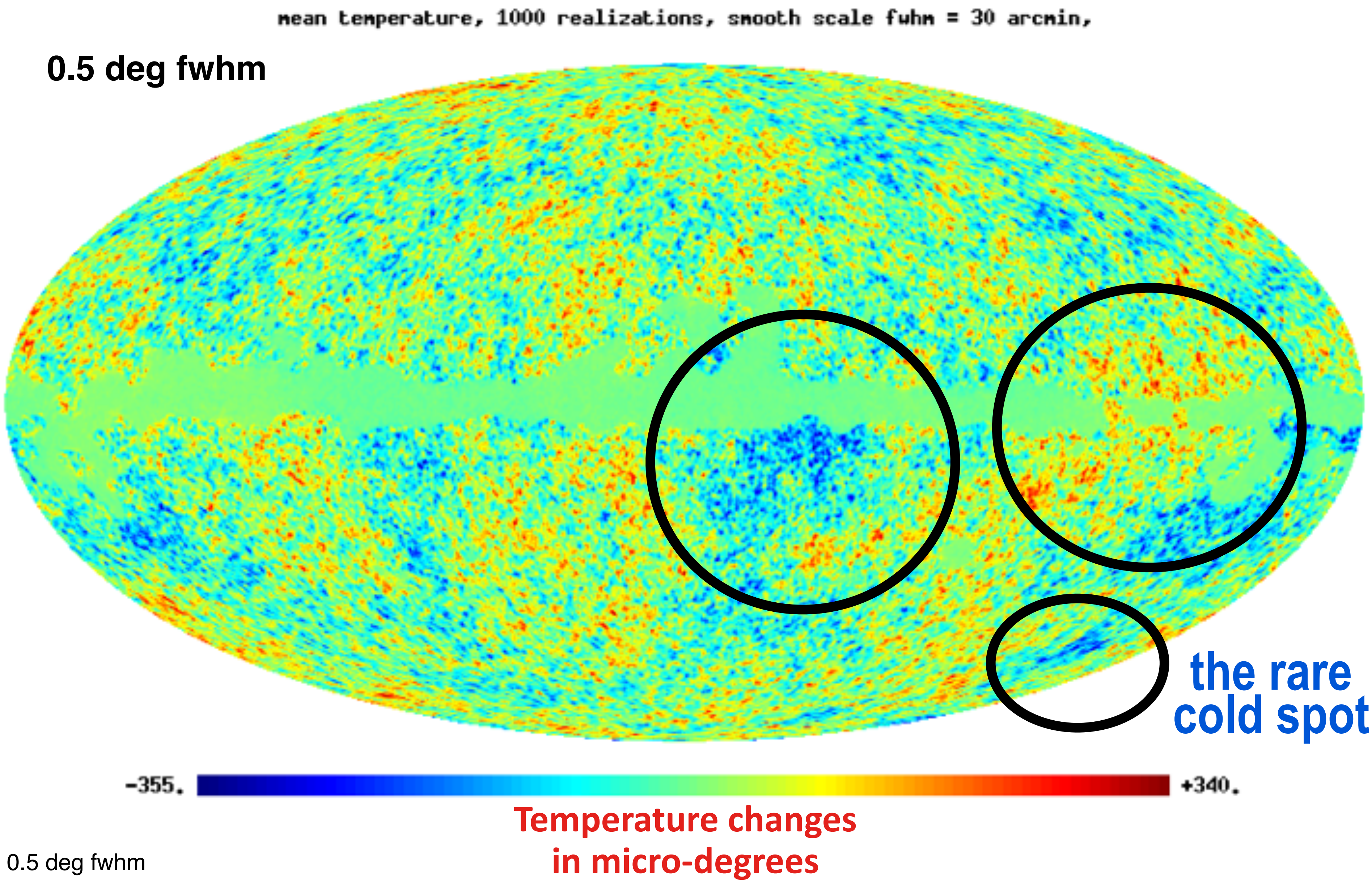


5 deg fwhm cf. COBE 7 deg fwhm

Reconstructing the Early Universe

visibility mask

temperature map



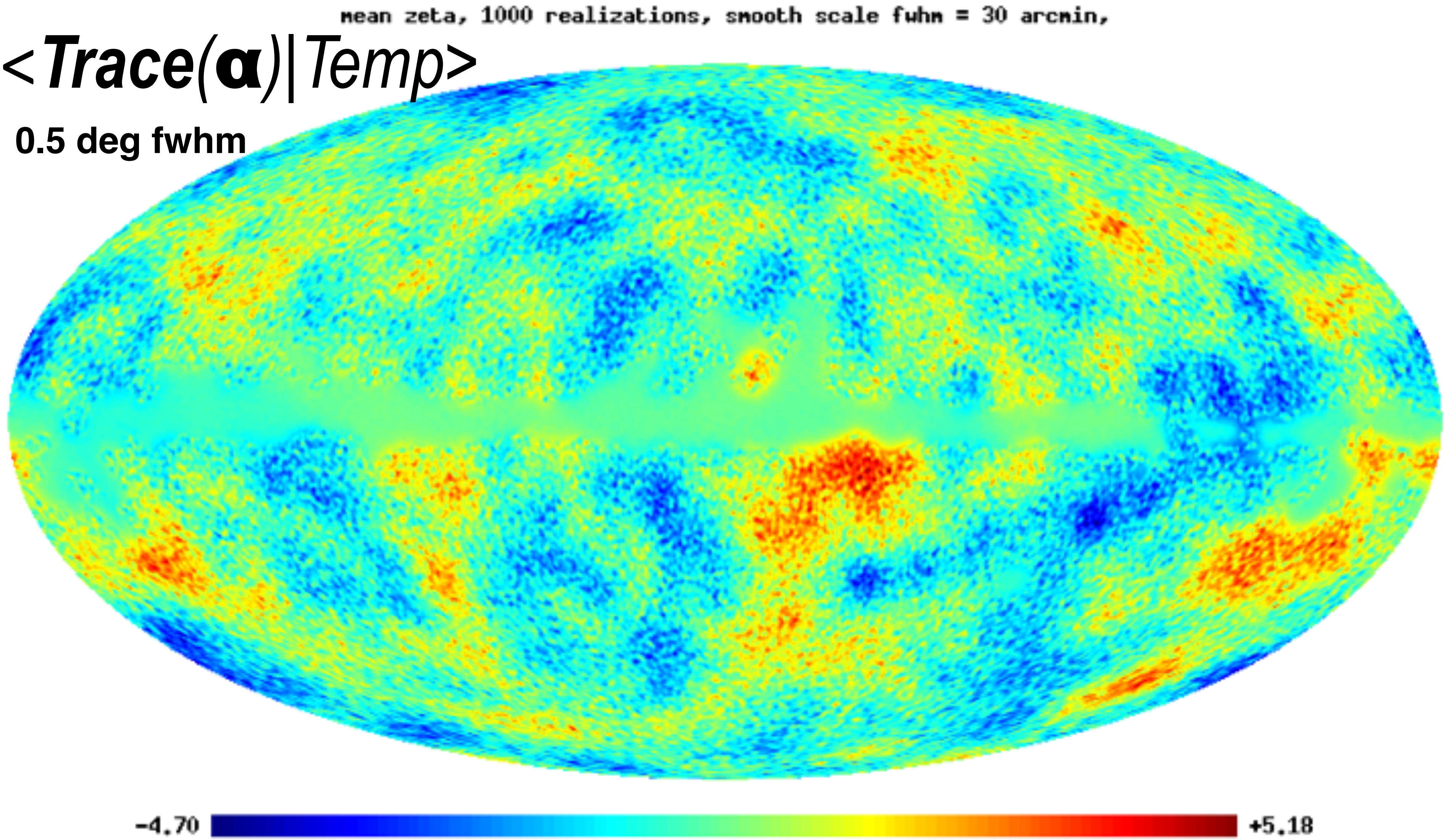
0.5 deg fwhm

reveals map of **primordial isotropic strain /phonons**

=> primordial scalar curvature map of the inflation epoch

$\langle \mathbf{Trace}(\boldsymbol{\alpha})|Temp\rangle$

0.5 deg fwhm



Reconstructing the Early Universe

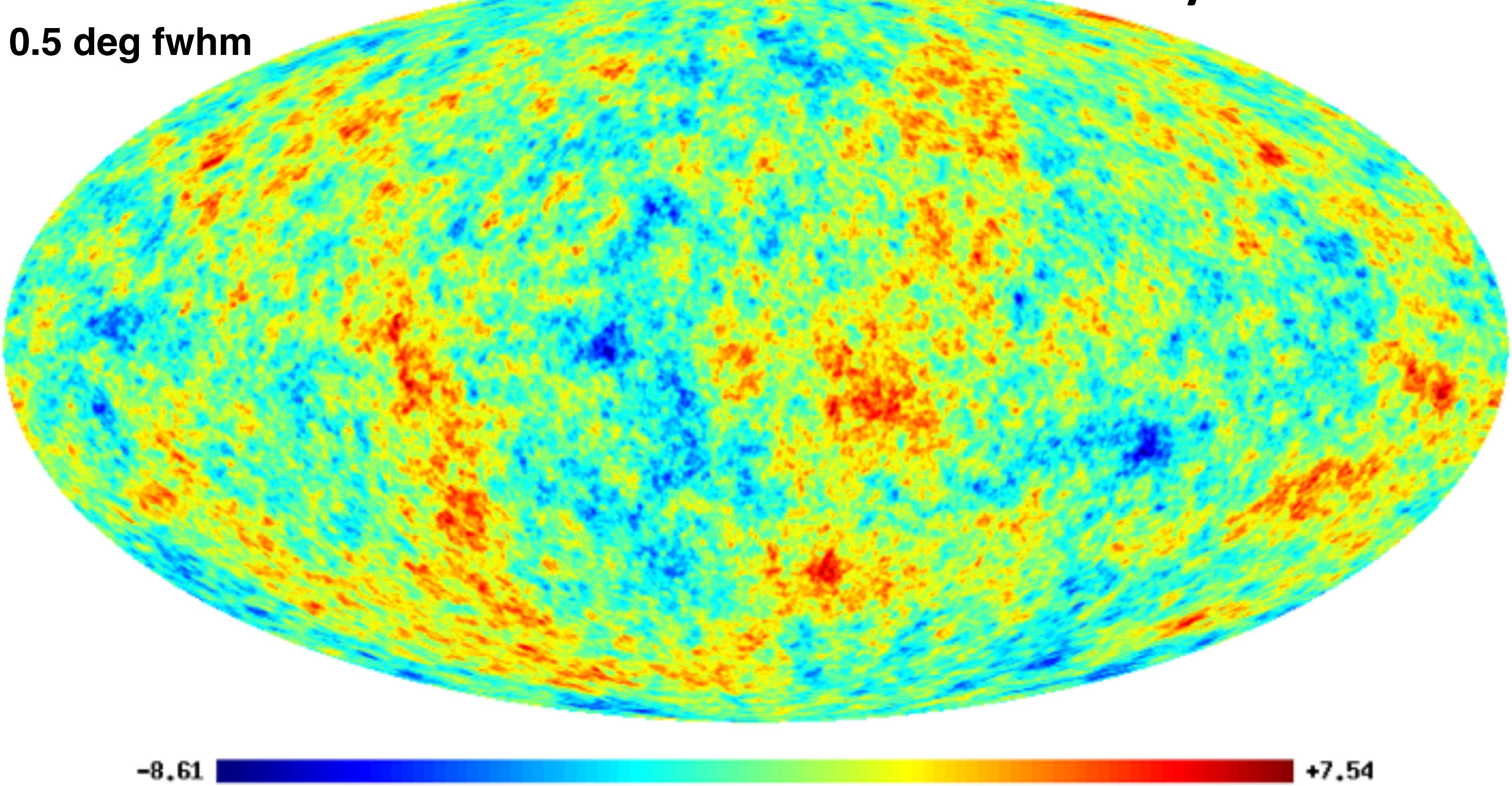
visibility mask

reveals map of **primordial isotropic strain /phonons**

$$\langle \mathit{Trace}(\boldsymbol{\alpha}) | \mathit{Temp} \rangle + \delta \mathit{Trace}(\boldsymbol{\alpha})$$

=> but allowed fluctuations make it noisy

0.5 deg fwhm



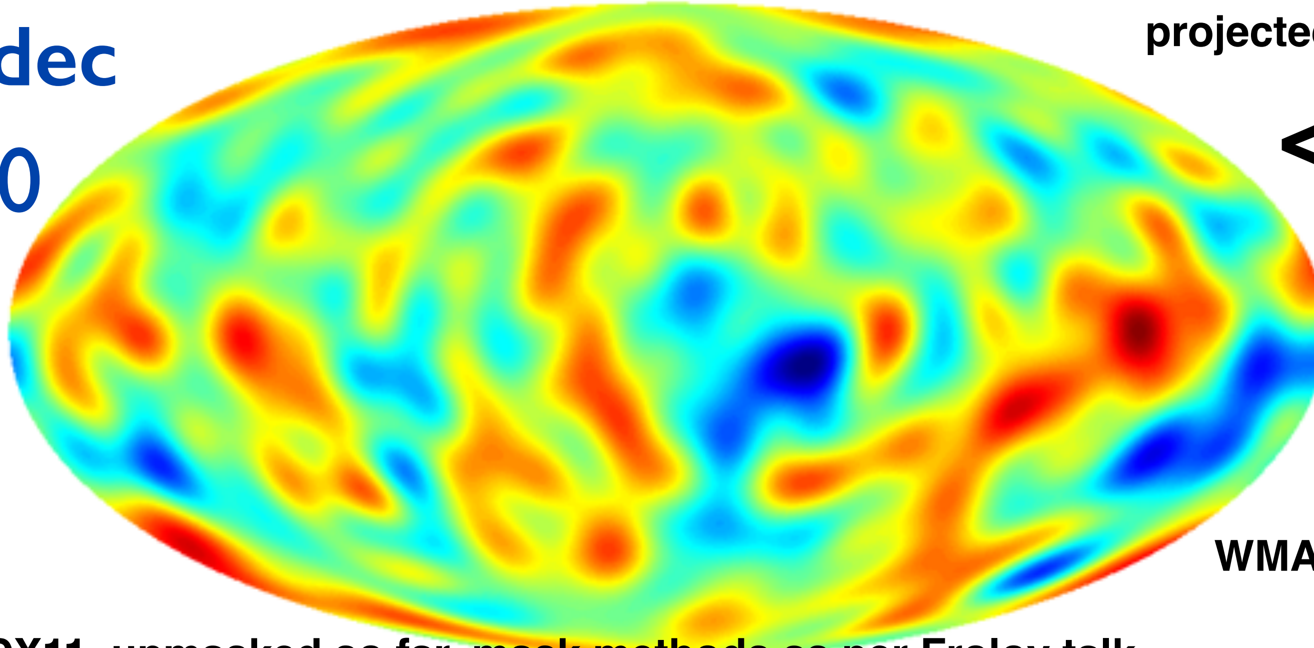
Reconstructing the Early Universe **visibility mask**

$\chi_b = \chi_{dec}$

$L_{cut} = 20$

projected curvature map

$<\zeta_b|T>$



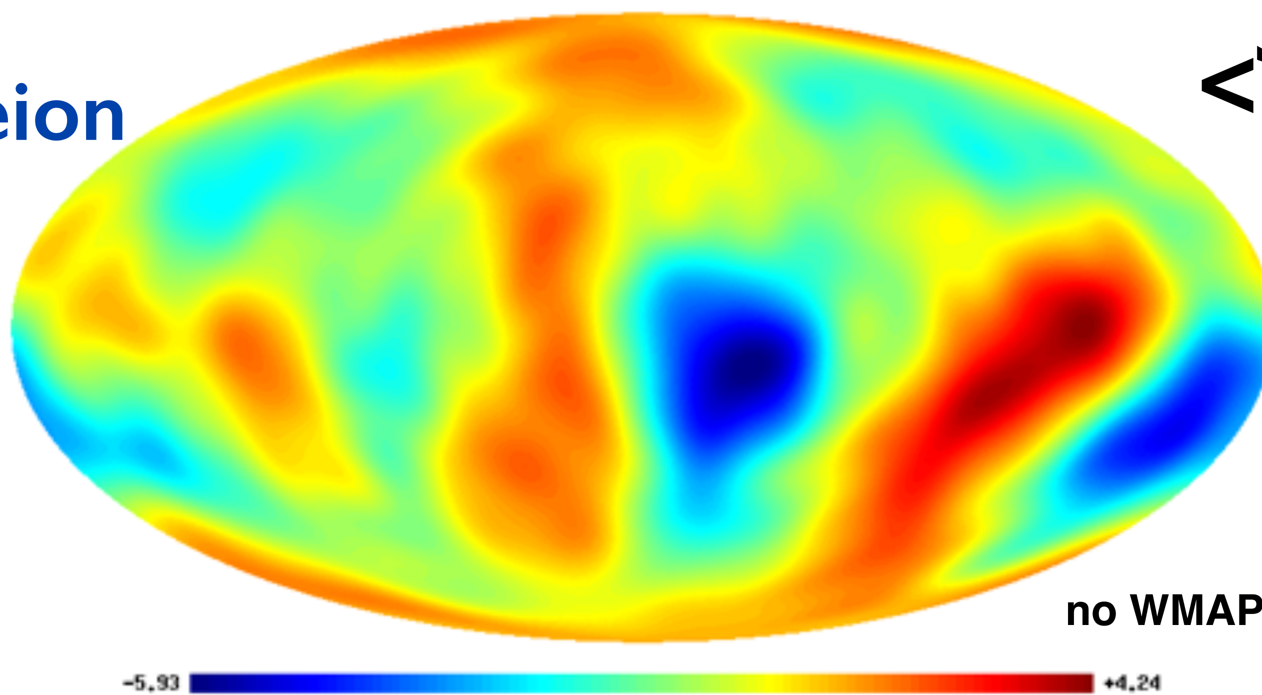
WMAP T COLD SPOT

SMICA preDX11, unmasked so far, mask methods as per Frolov talk

$\chi_b = \chi_{reion}$

$L_{cut} = 20$

$<\zeta_b|T>$



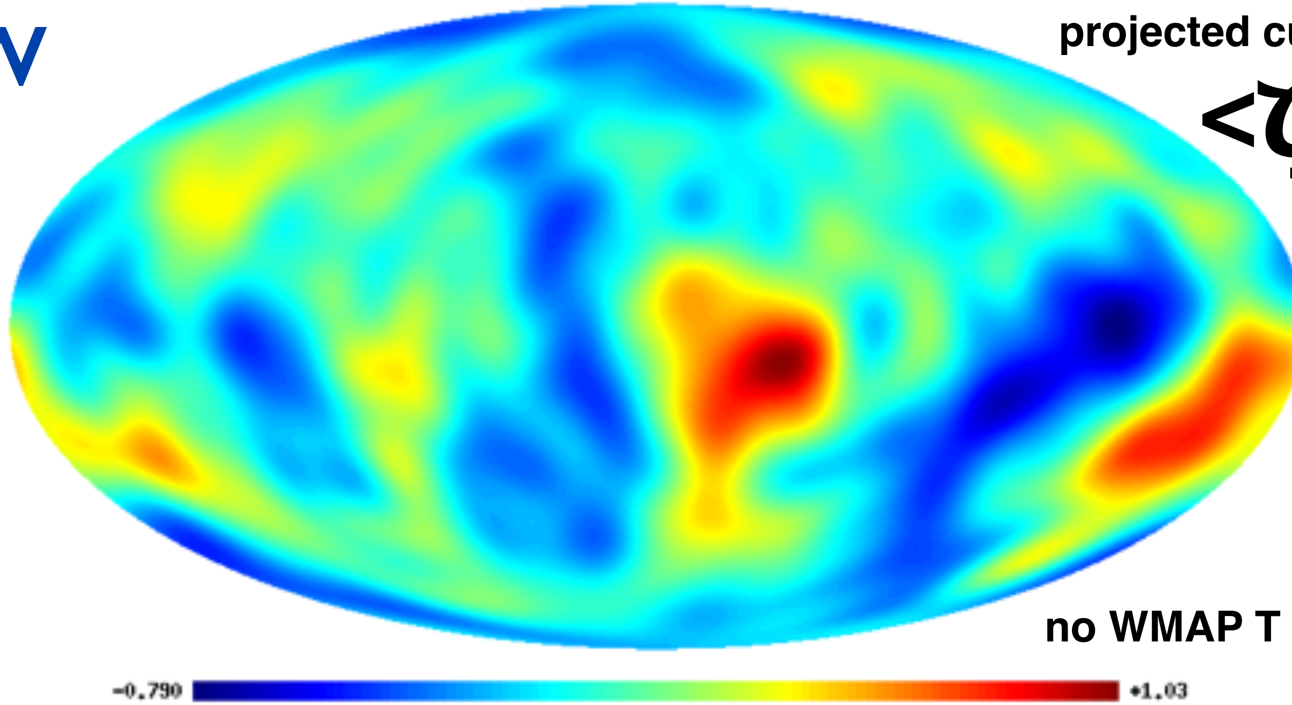
no WMAP T COLD SPOT

$\chi_b = \chi_{ISW}$

$L_{cut} = 20$

projected curvature map

$\langle \zeta_b | T \rangle$

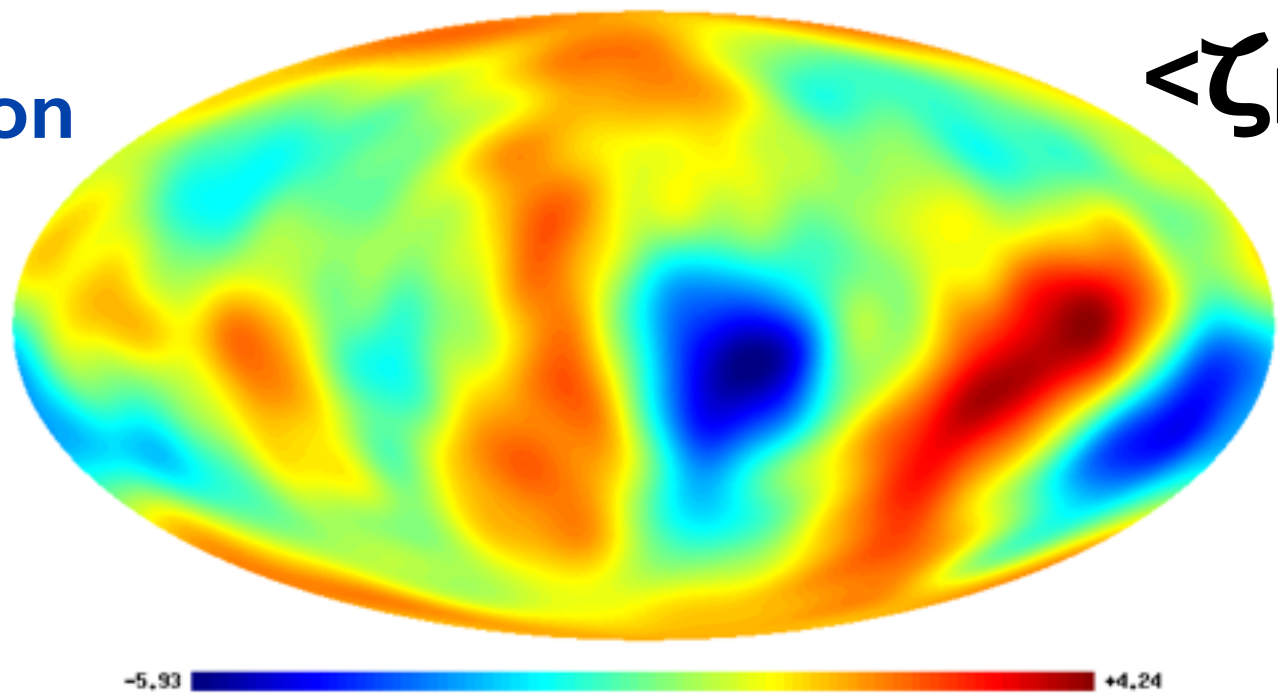


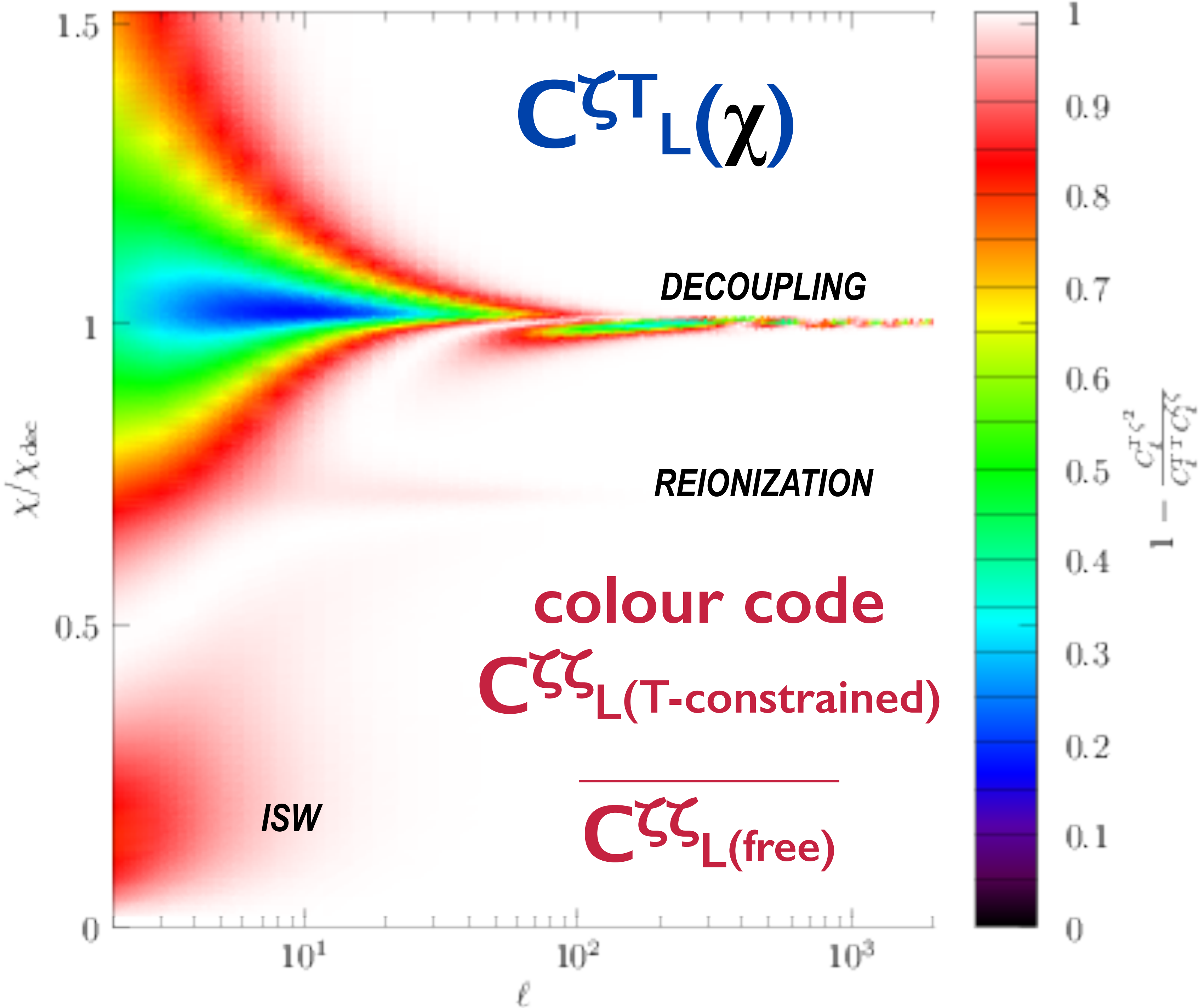
no WMAP T 'COLD' SPOT

$\chi_b = \chi_{reion}$

$L_{cut} = 20$

$\langle \zeta_b | T \rangle$





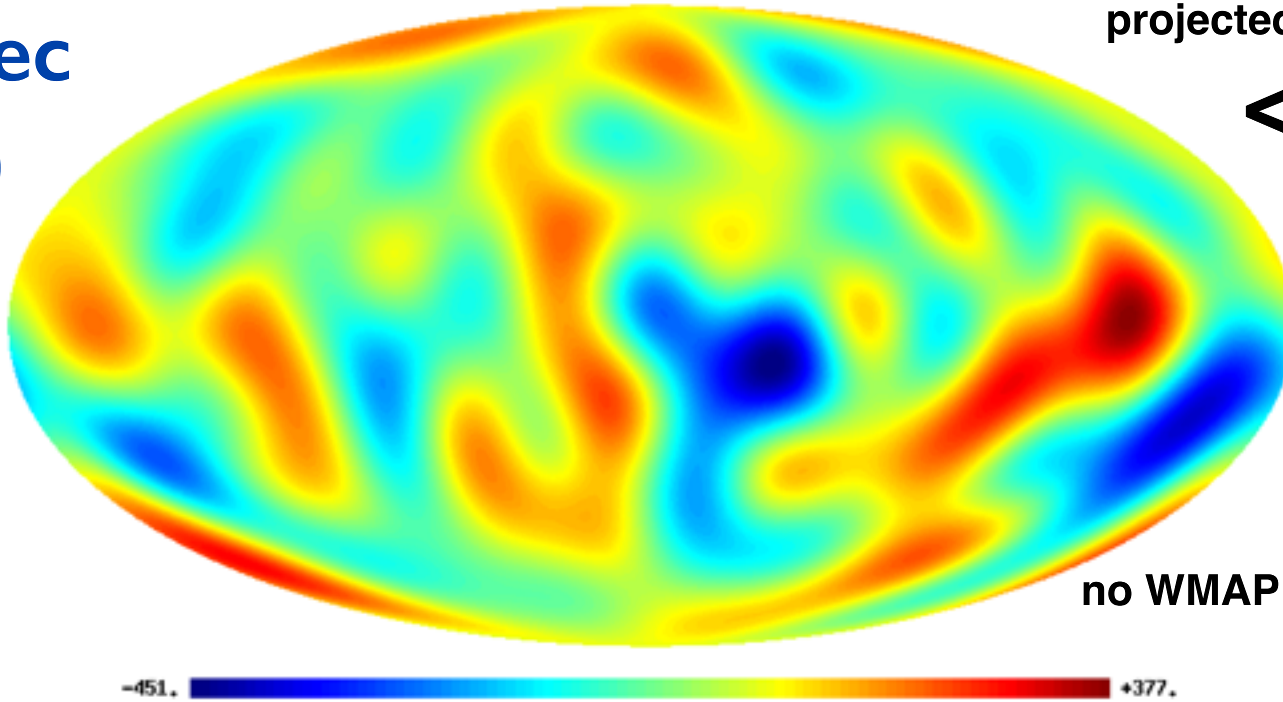
$C^{\zeta T}{}_L(\chi)$
DECOUPLING
REIONIZATION
ISW
colour code
$\frac{C^{\zeta\zeta}{}_{L(\text{T-constrained})}}{C^{\zeta\zeta}{}_{L(\text{free})}}$
$\chi/\chi_{\rm dec}$
ℓ
$1-\frac{C_\ell^{T\zeta^2}}{C_\ell^{TT}C_\ell^{\zeta\zeta}}$

$\chi_b = \chi_{dec}$

$L_{cut} = 10$

projected curvature map

$\langle \zeta_b | T \rangle$

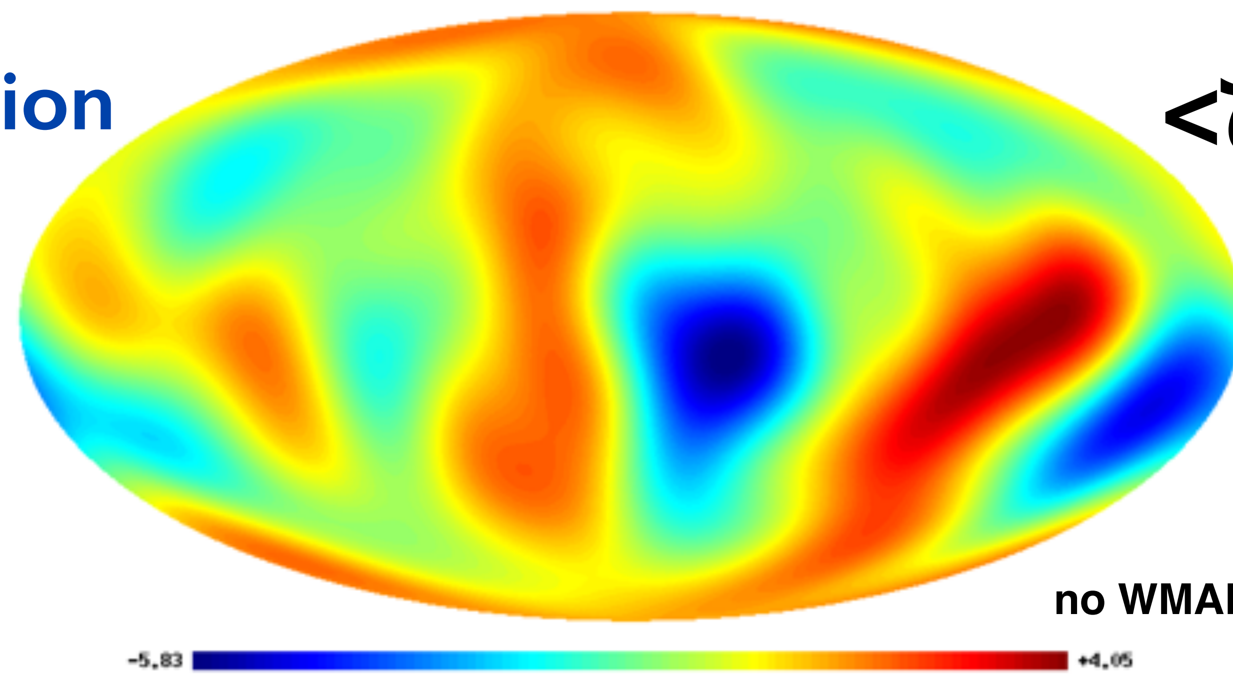


no WMAP T COLD SPOT

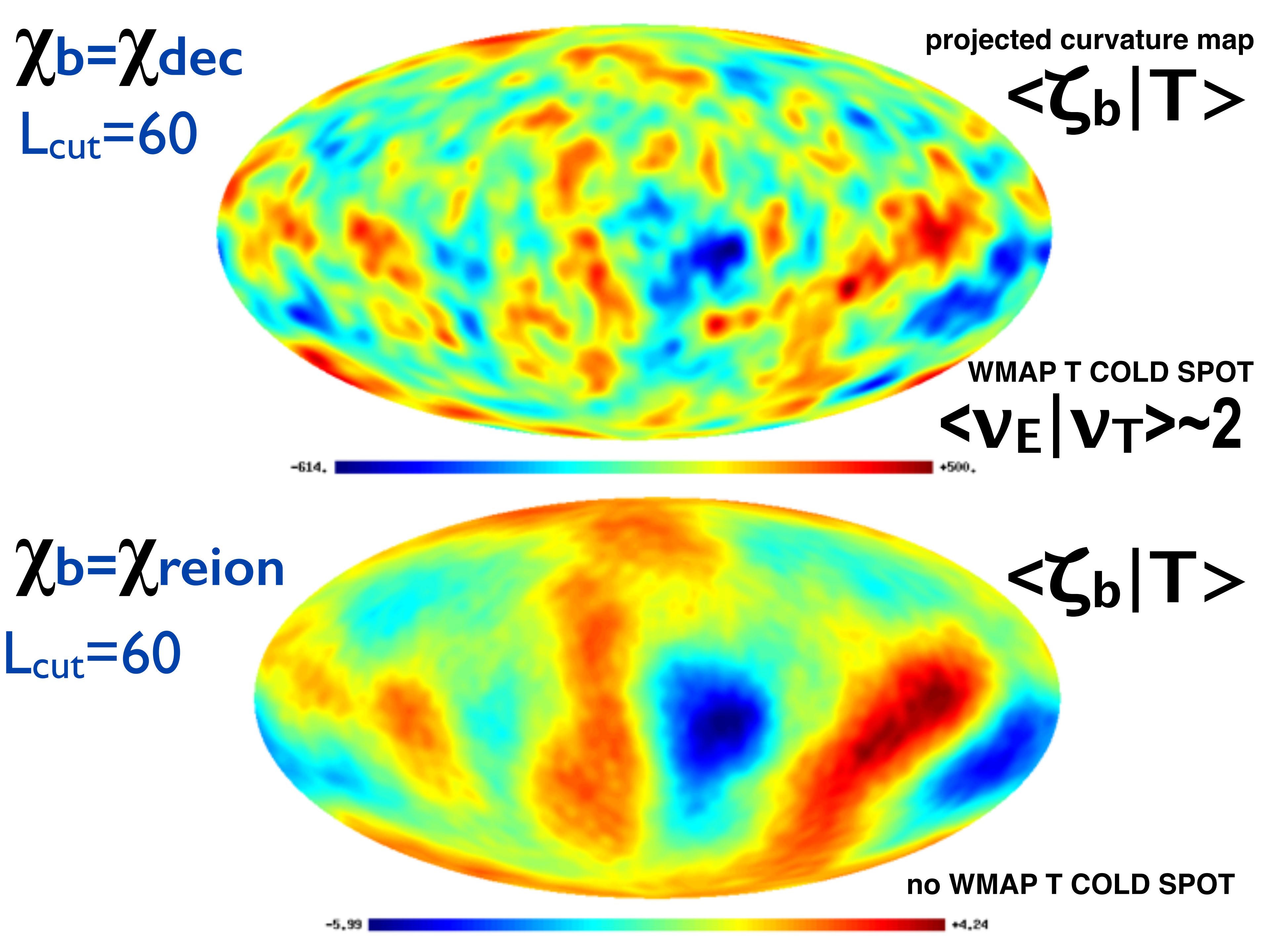
$\chi_b = \chi_{reion}$

$L_{cut} = 10$

$\langle \zeta_b | T \rangle$



no WMAP T COLD SPOT

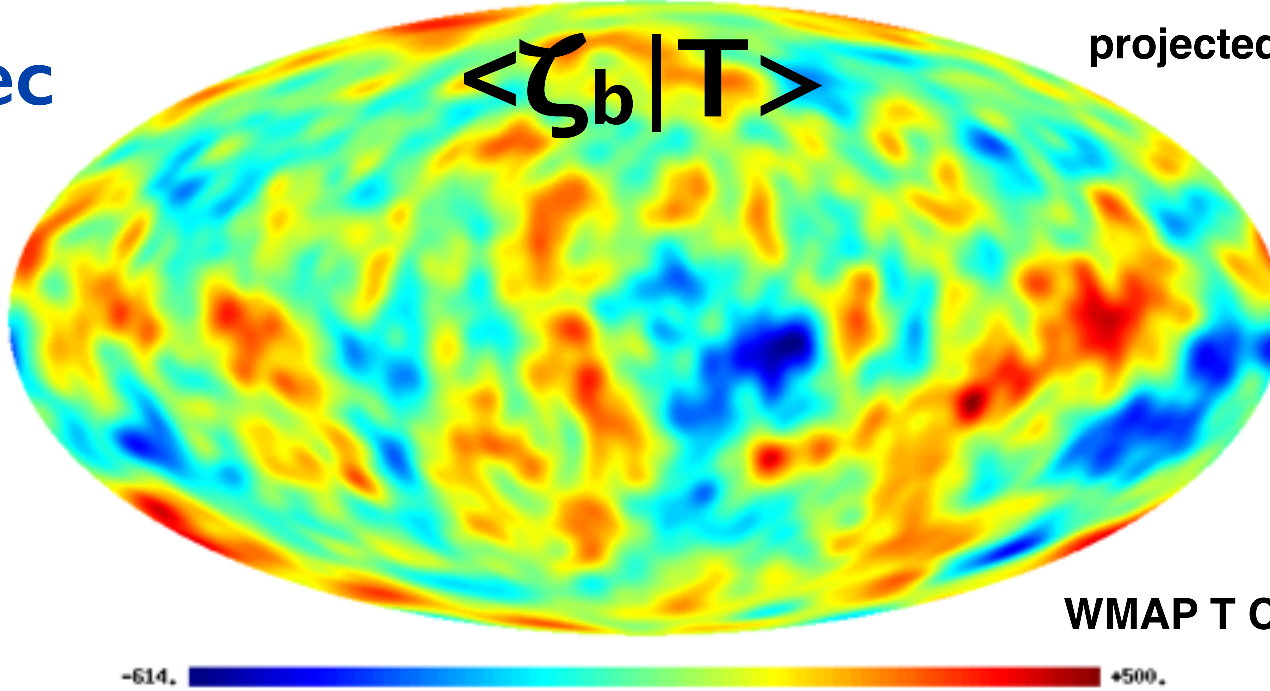

$\chi_b=\chi_{dec}$
$L_{cut}=60$
projected curvature map
$<\zeta_b|T>$
WMAP T COLD SPOT
$<\nu_E|\nu_T>\sim 2$
-614.
+500.
$\chi_b=\chi_{reion}$
$L_{cut}=60$
$<\zeta_b|T>$
no WMAP T COLD SPOT
-5.99
+4.24

$\chi_b=\chi_{dec}$

$L_{cut}=60$

$\langle\zeta_b|T\rangle$

projected curvature map



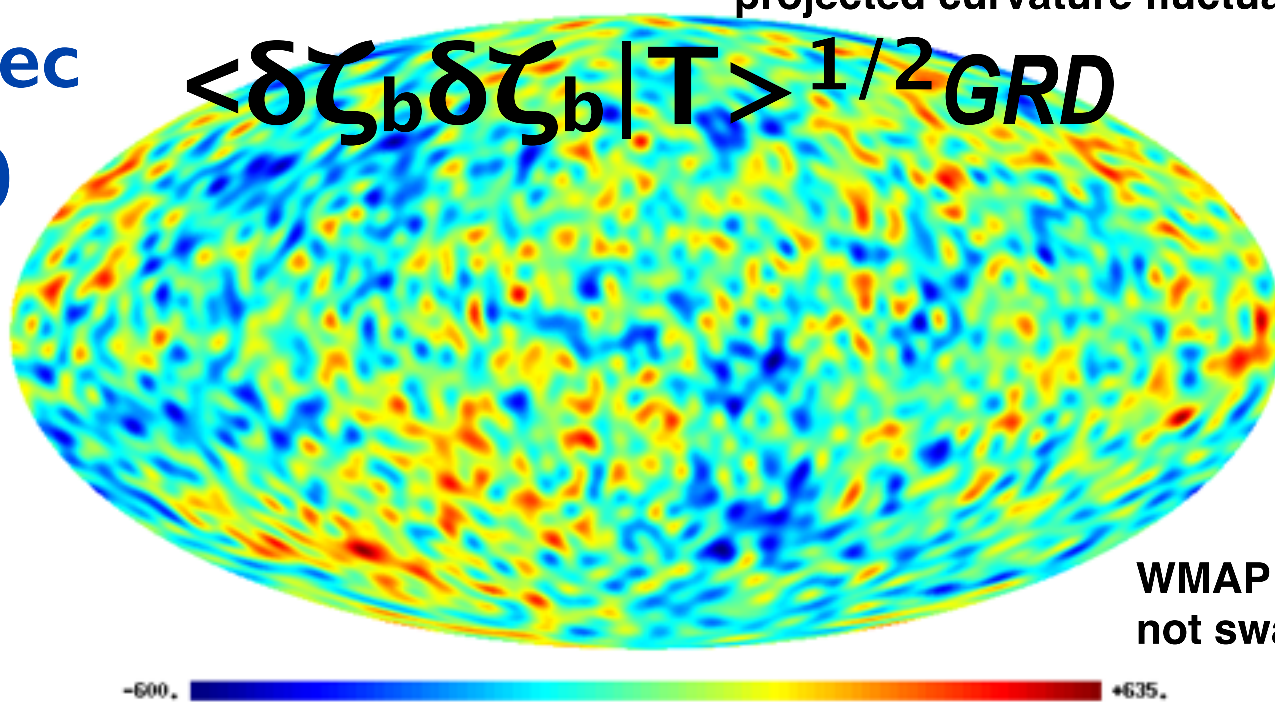
WMAP T COLD SPOT

projected curvature fluctuation realization

$\chi_b=\chi_{dec}$

$L_{cut}=60$

$\langle\delta\zeta_b\delta\zeta_b|T\rangle^{1/2}GRD$

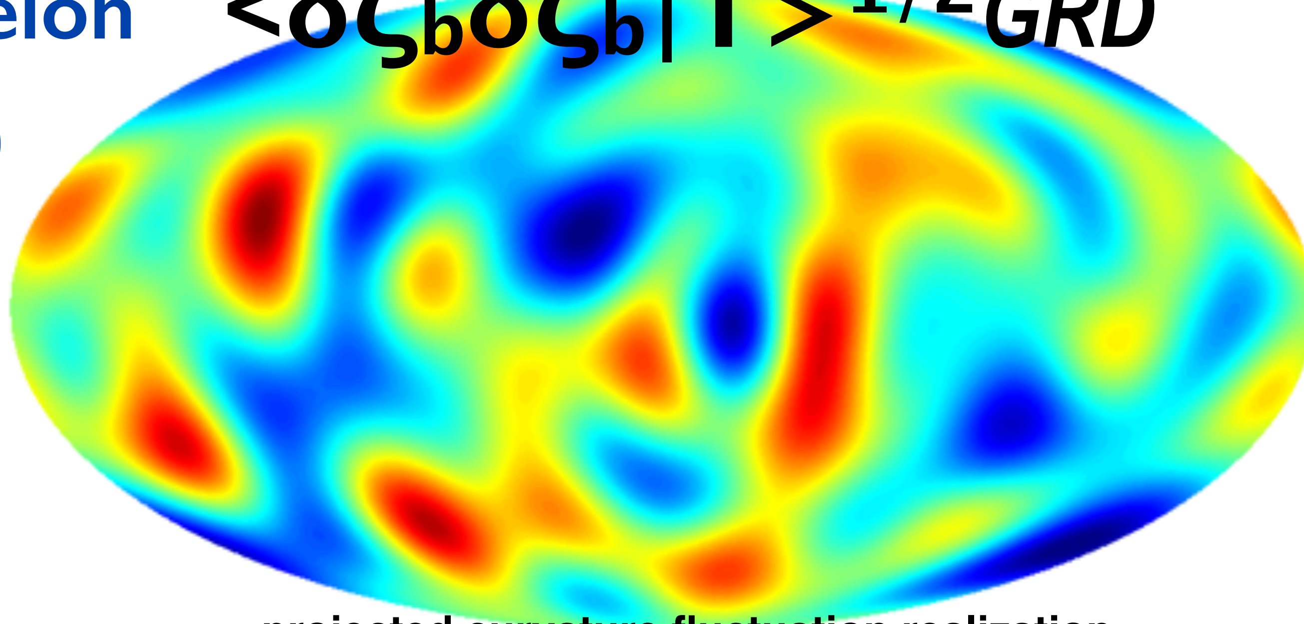


WMAP T COLD SPOT
not swamped by flucs

$\chi_b = \chi_{reion}$

$L_{cut} = 10$

$\langle \delta\zeta_b \delta\zeta_b | T \rangle^{1/2} GRD$



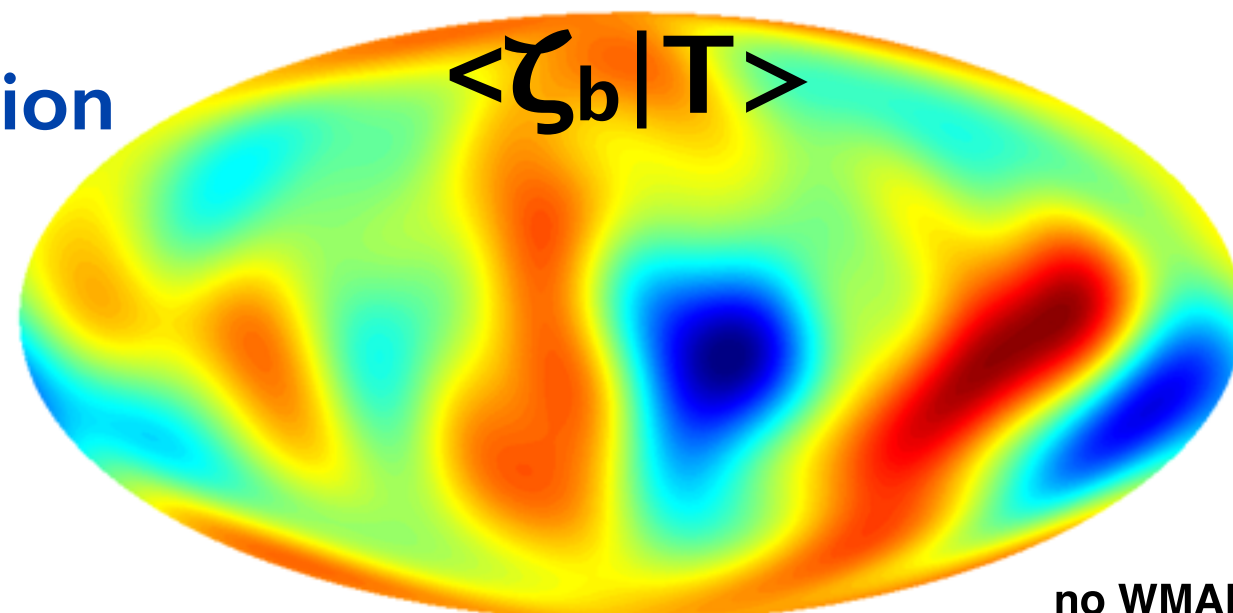
projected curvature fluctuation realization

-20.8 +21.4

$\chi_b = \chi_{reion}$

$L_{cut} = 10$

$\langle \zeta_b | T \rangle$



no WMAP T COLD SPOT

projected curvature map

-5.83 +4.05

Power Deviation from fiducial $<\zeta|T><\zeta|T> + <\delta\zeta\delta\zeta|T> - <\zeta\zeta|\mathrm{free}>$

byproduct, cf. quadratic $P_{\zeta\zeta}$ reconstruction, extra C_s/C_{tot} & regularizer $P^{(i)}_{\zeta\zeta}$

Wiener-filtered anisotropic stress *maps, pks & E-pol*

from < $\zeta_{LM\ c,s}(\chi)$ | $a_{LM\ c,s}$ > reconstruct

(1) *actual* Wiener T_{dec} map at decoupling (not T_{now})

(2) *actual* Wiener *anisotropic photon stress-tensor* (*aka quadrupole*) ***at*** χ_{dec} **to *correlate with E-pol*** (*~sources E*)

=> novel Peaks (eigen-$P_T$eaks), statistics, *mean fields*, stacks

"analytic" results exist or derivable, *a la BE87, BM96, BKP97*

complications: other cosmic parameters fixed at maxL value; inhomogeneous generalized noise enters Wiener filters; is error assessment with FFPn adequate?; de-lensing; …

simple proxy for < $(\nabla^{-2} \nabla_i \nabla_j - \delta_{ij}/2)\, T_{dec}$ | T_{now} > anisotropic stress: *if direct transport from* χ_{dec} **then $(\nabla^{-2} \nabla_i \nabla_j - \delta_{ij}/2)\, T_{now}$**

decompose into Q_T U_T E_T E_T P_T ψ_T akin to Q U E P ψ, with enhanced peak-stacking correlations, oriented stacks

some work on this, reported by Frolov HFI-CT 13.06

primordial sub-dominant **intermittent nonGaussianity**

Bond, Frolov, Huang, Braden

phonon ~ $\zeta_{NL} = \ln(\rho\, a^{3(1+w)})/3(1+w)$ ~ ***scalar curvature @ uniform density***

$\zeta_{NL}(x) = \zeta_G(x) + f_{NL*}\,(\zeta_G^2(x) - \langle\zeta_G^2\rangle)$ => $f_{NL*} = 3/5\, f_{NL} - 1$

$\zeta_{NL}(x) = \zeta_G(x) + F_{NL}(\chi_G)$, inflaton ζ_G & *uncorrelated* isocon χ_G

F_{NL} = *local non-G from modulated preheating caustics*

= a multiple-line spectrum: *spacing = Lyapunov instability coefficient, strength by ?, blending by* $\psi_{G,HF}$ *marginalization*

a weak quadratic non-G regime => translate f_{NL*} constraint

& a strong non-G regime <= super-bias of the ζ-web

F_{NL} generic if isocon ψ_G is light & inflaton-coupled

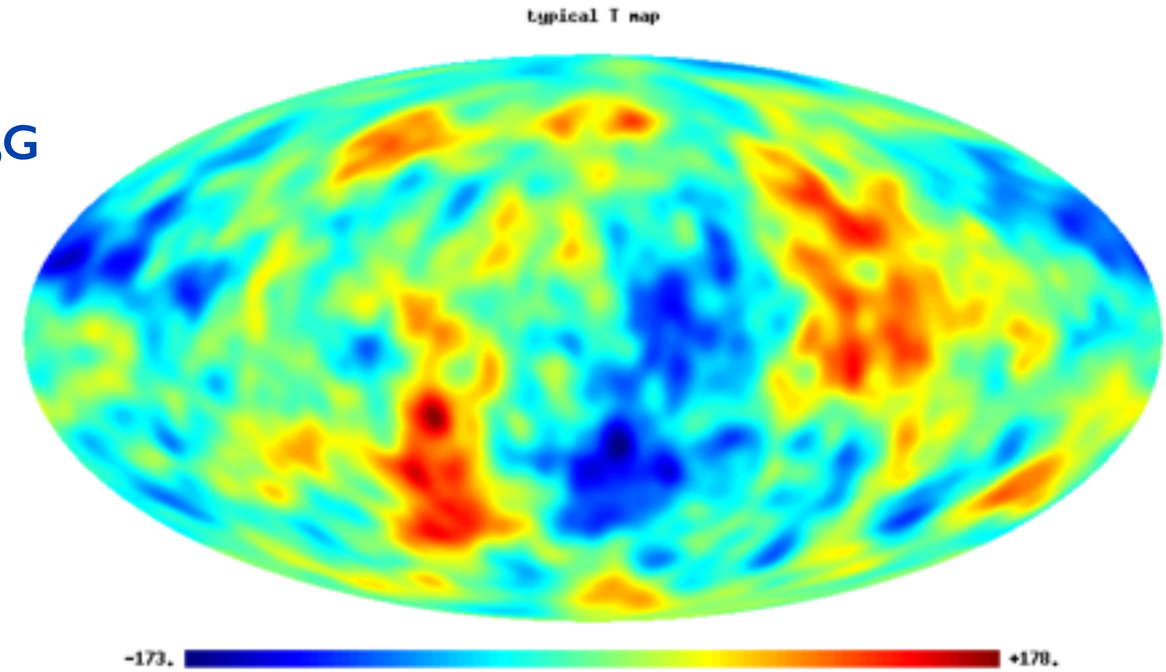
=> search for localized low L extended-sources

=> CONSTRUCTING INTERMITTENT CMB MAPS

"realistic" lattice-computed smoothed F_{NL}

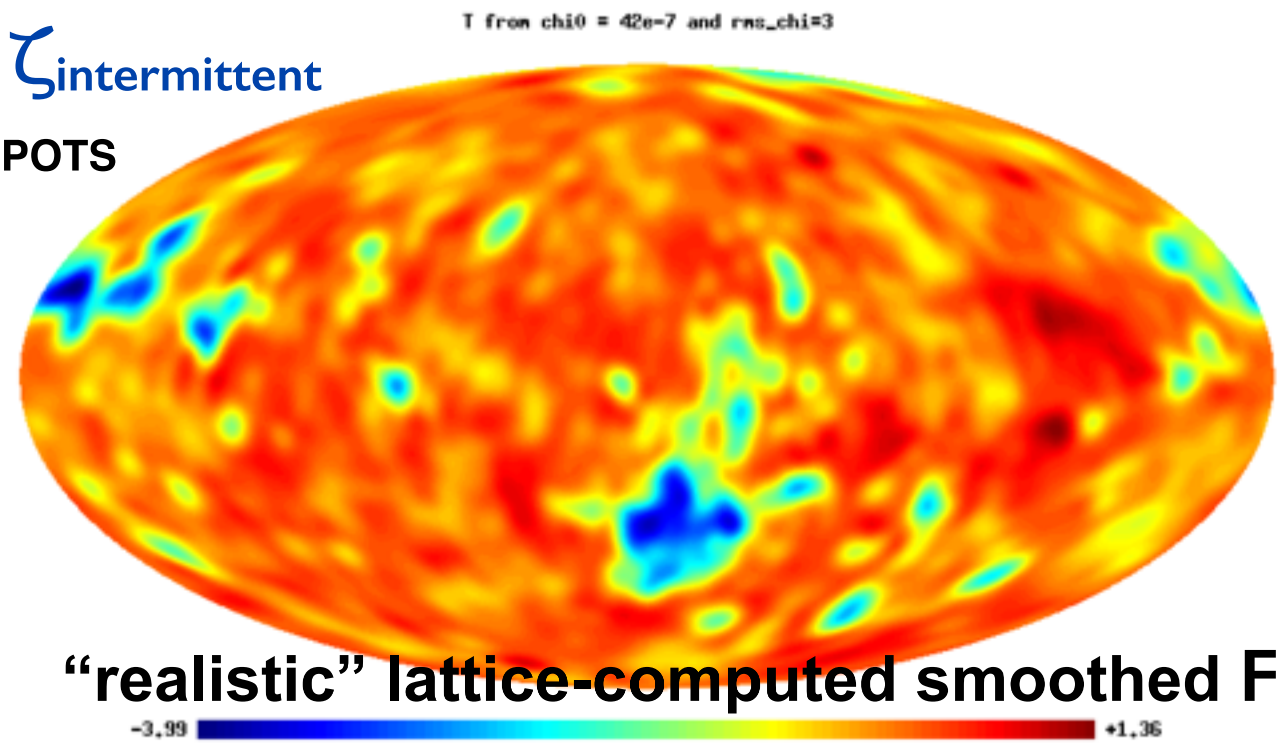
Gaussian lines *(cf. BBKS threshold functions,* **> χ_{crit})**

T from ζ_G



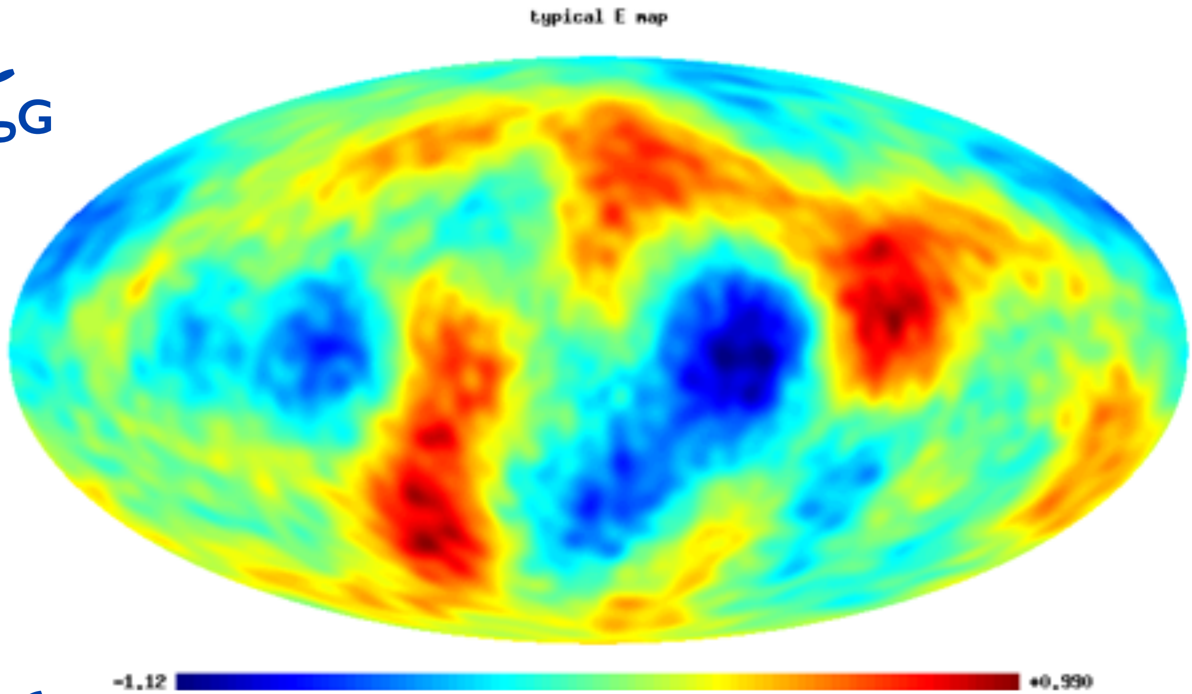
T from $\zeta_{intermittent}$

T COLD SPOTS



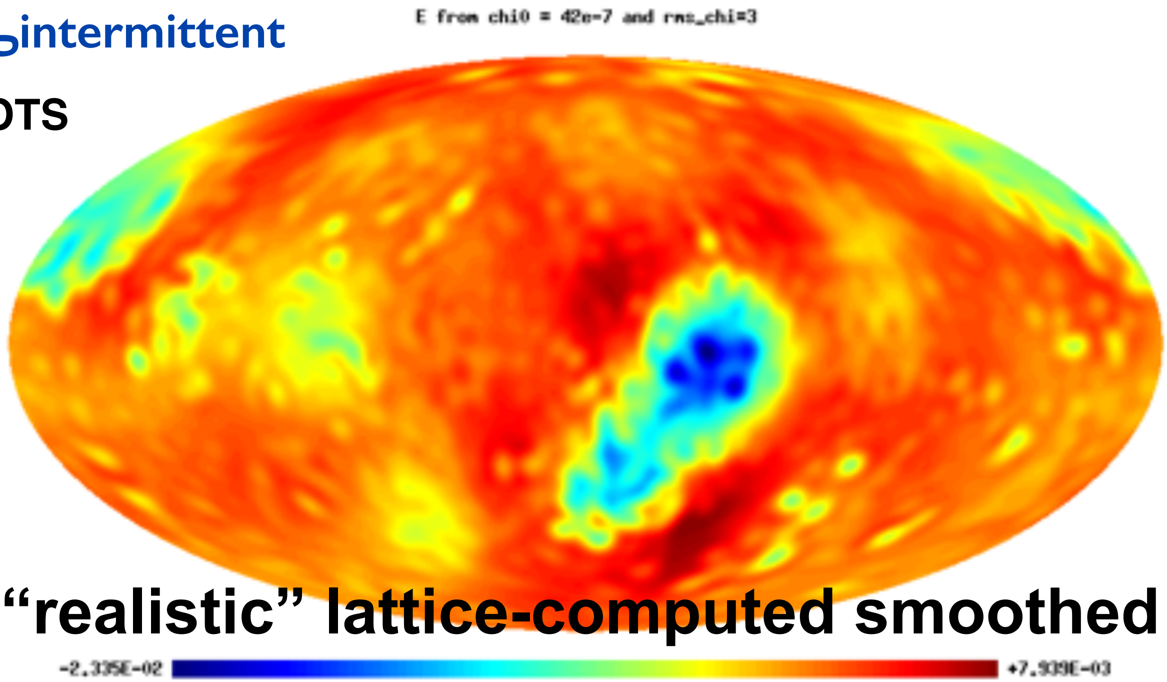
“realistic” lattice-computed smoothed F_{NL}

E from ζ_G



E from $\zeta_{intermittent}$

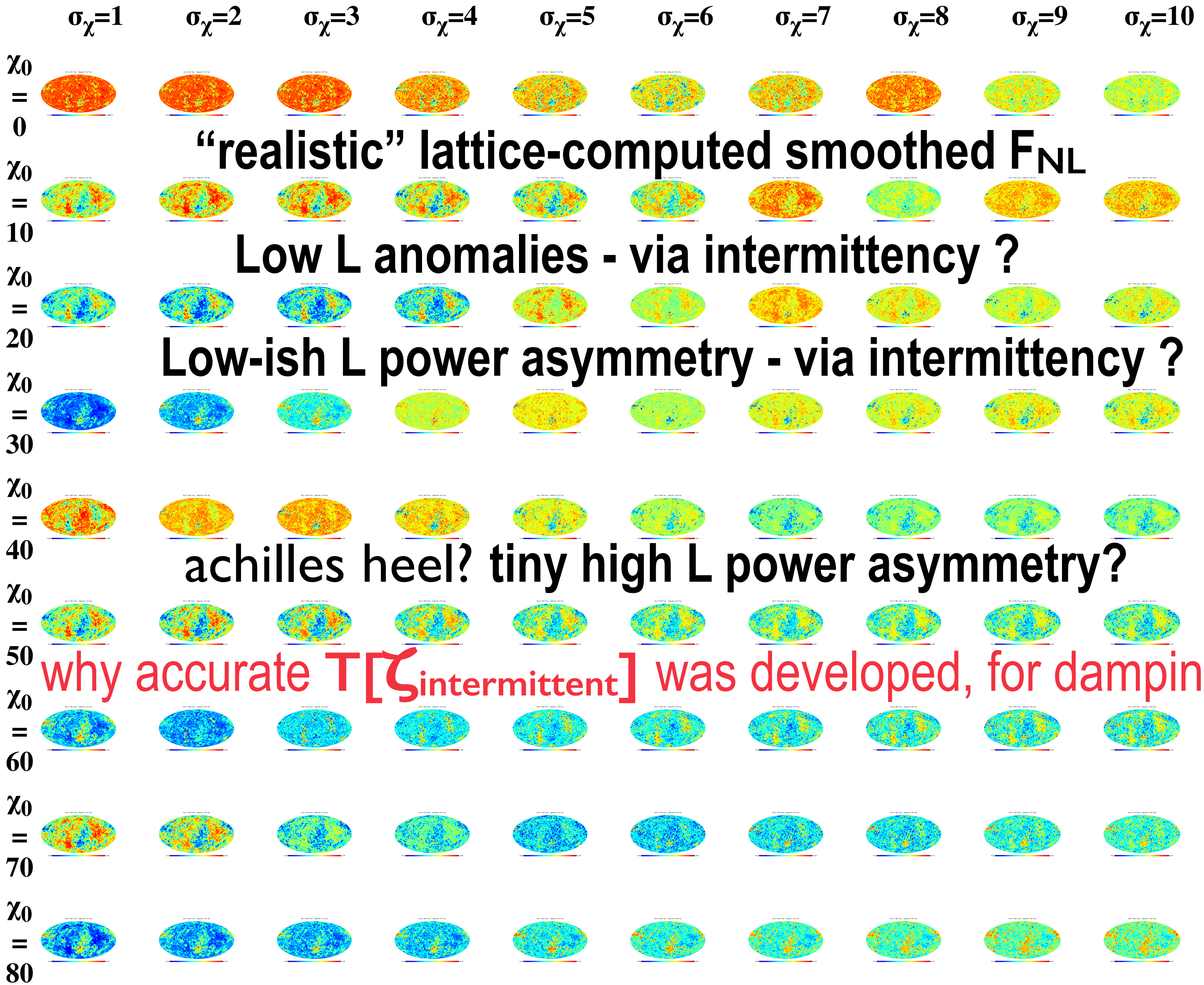
E COLD SPOTS



“realistic” lattice-computed smoothed F_{NL}

scan super-horizon $\chi_{>h}$ & (LSS/CMB smoothing) width); strength fixed by model

Unit 10^{-7} M_p



“realistic” lattice-computed smoothed F_{NL}

Low L anomalies - via intermittency ?

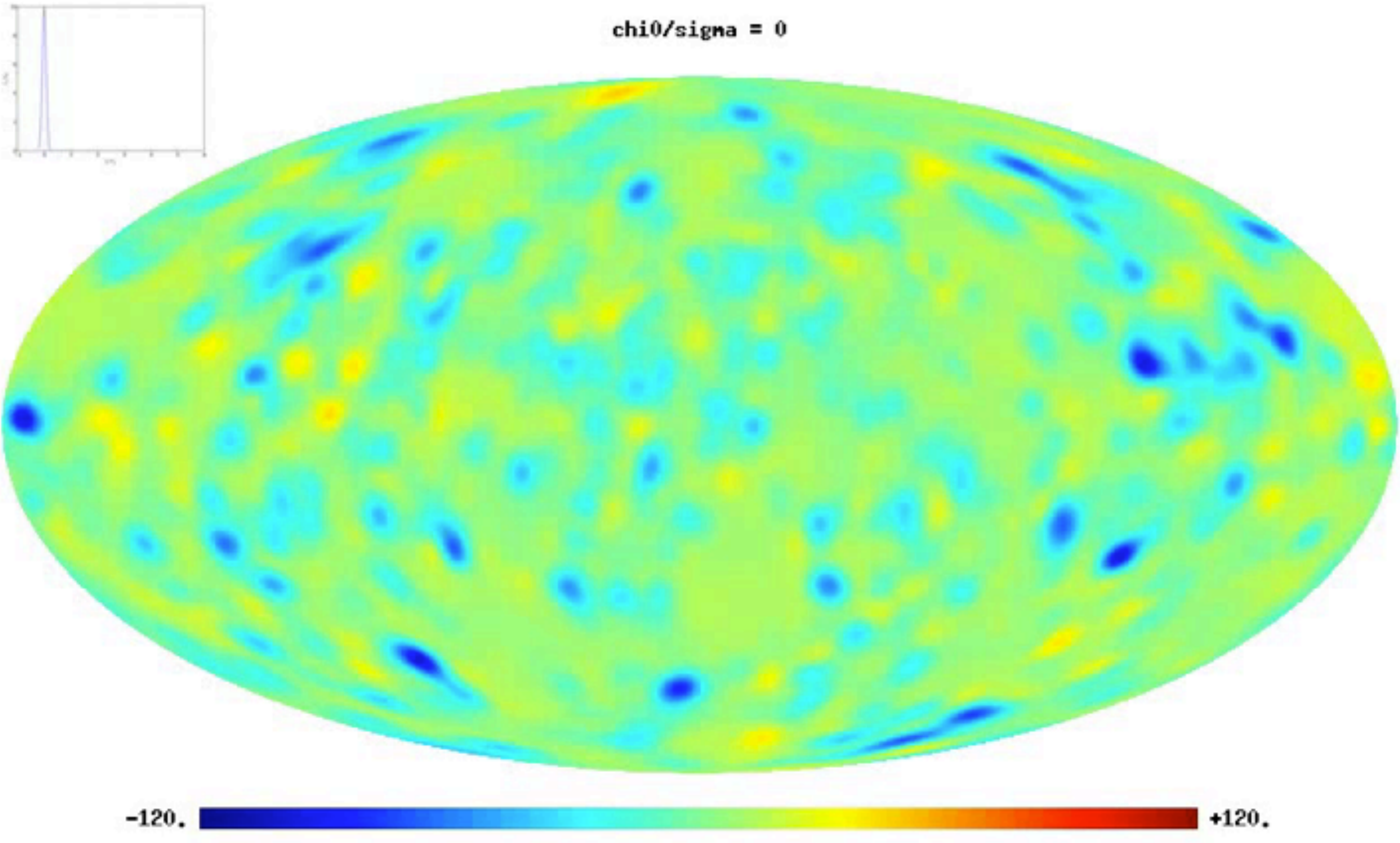
Low-ish L power asymmetry - via intermittency ?

achilles heel? **tiny high L power asymmetry?**

why accurate $T[\zeta_{intermittent}]$ was developed, for damping etc.

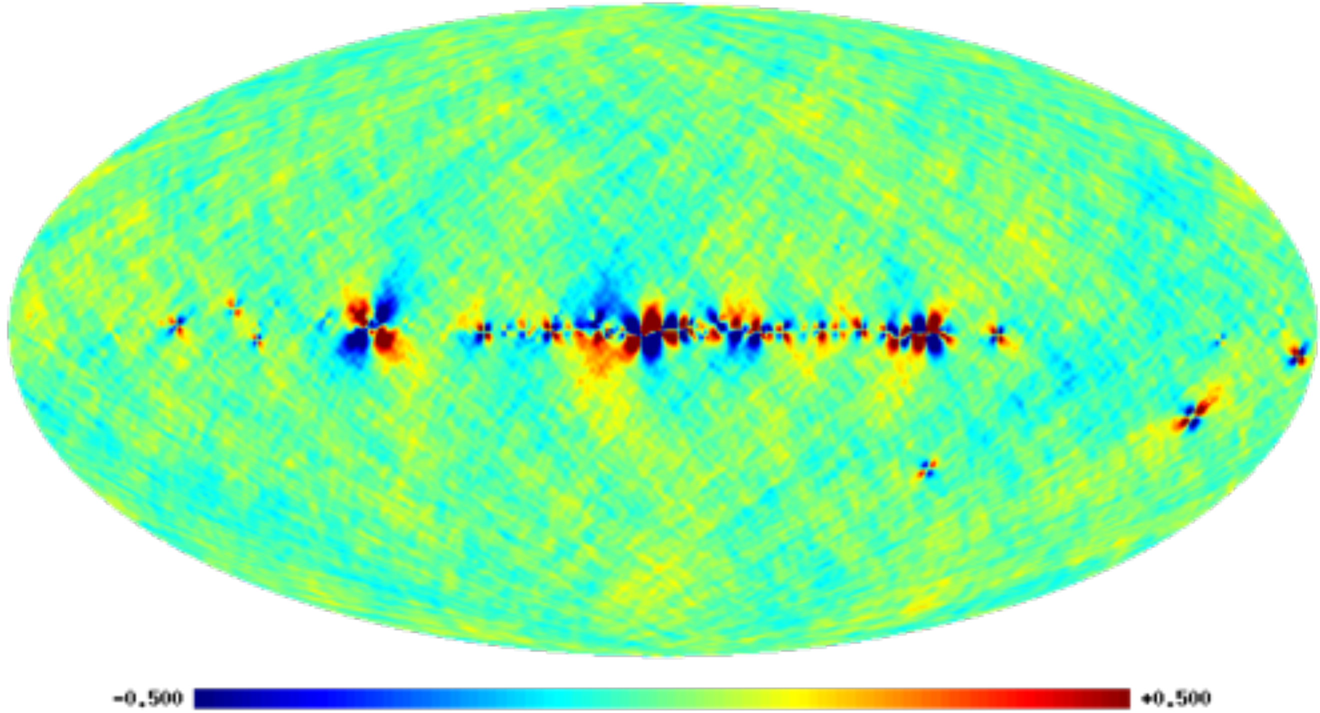
END

phenomenological **Gaussian line:** scan super-horizon $\chi_{>h}$**,** width, strength

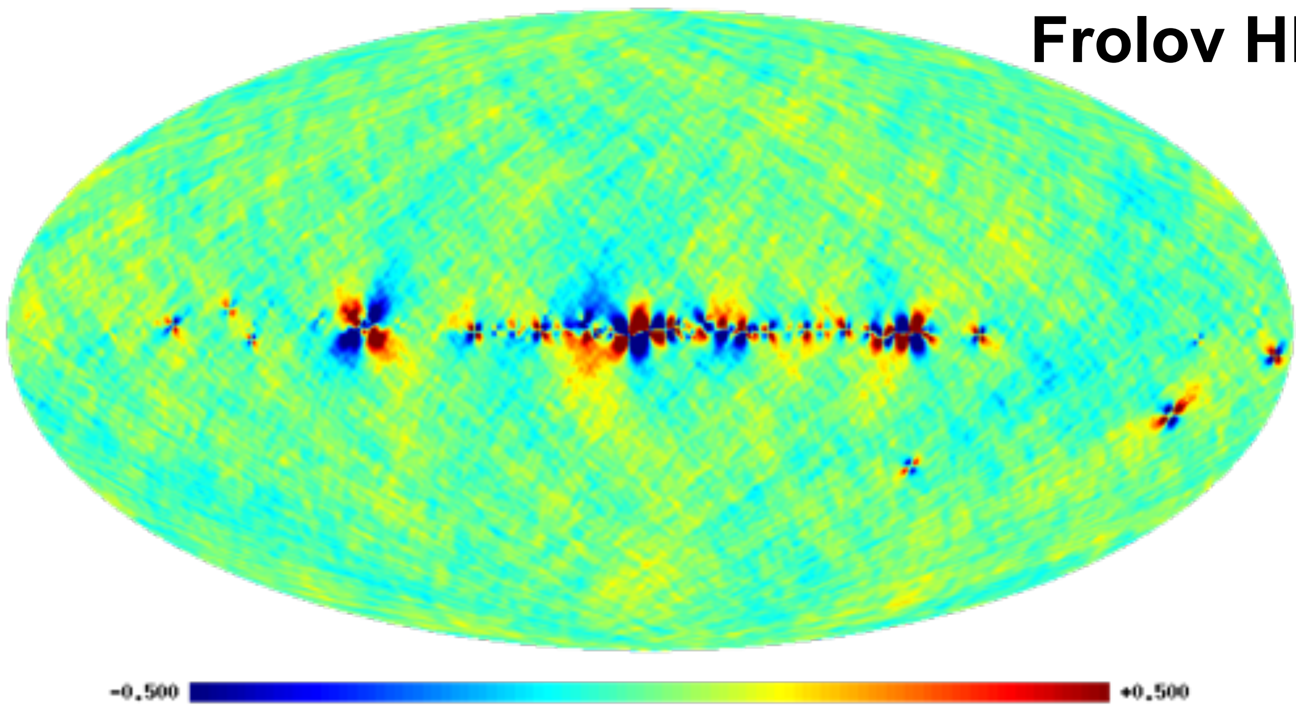


Frolov HFI-CT 13.06

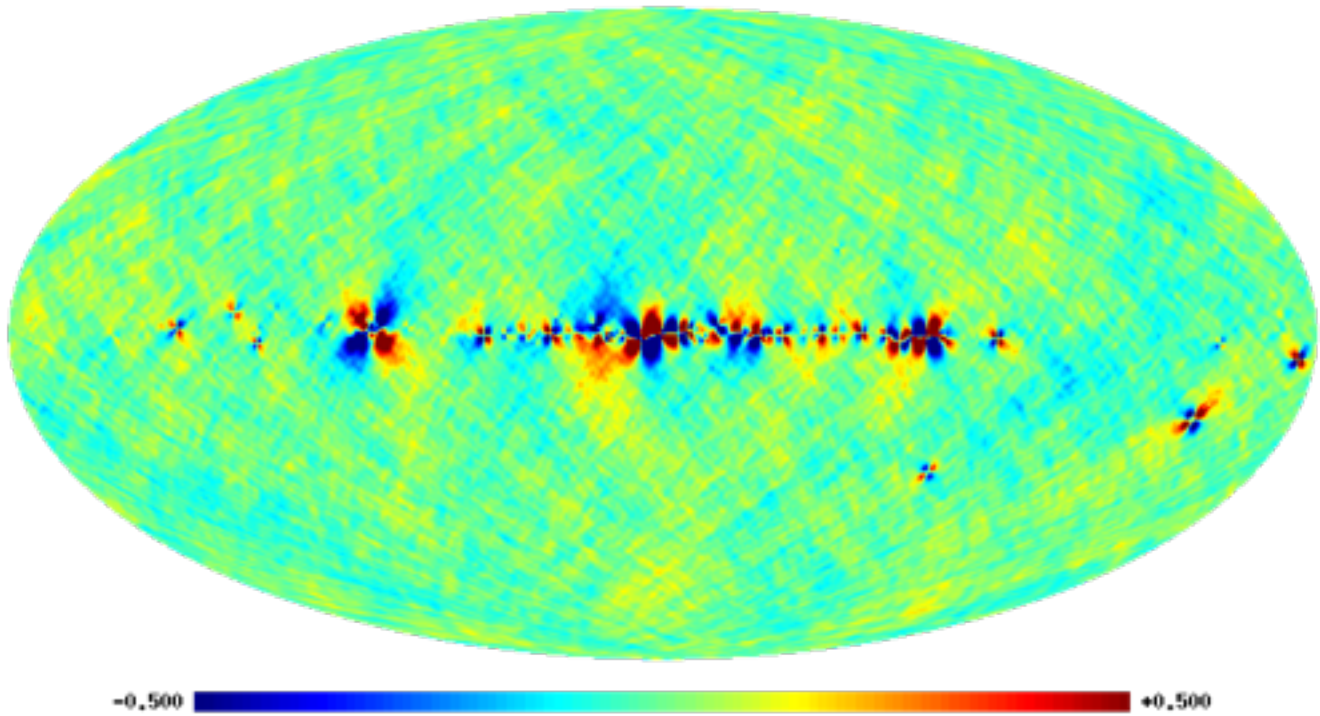
Q_T



U_T

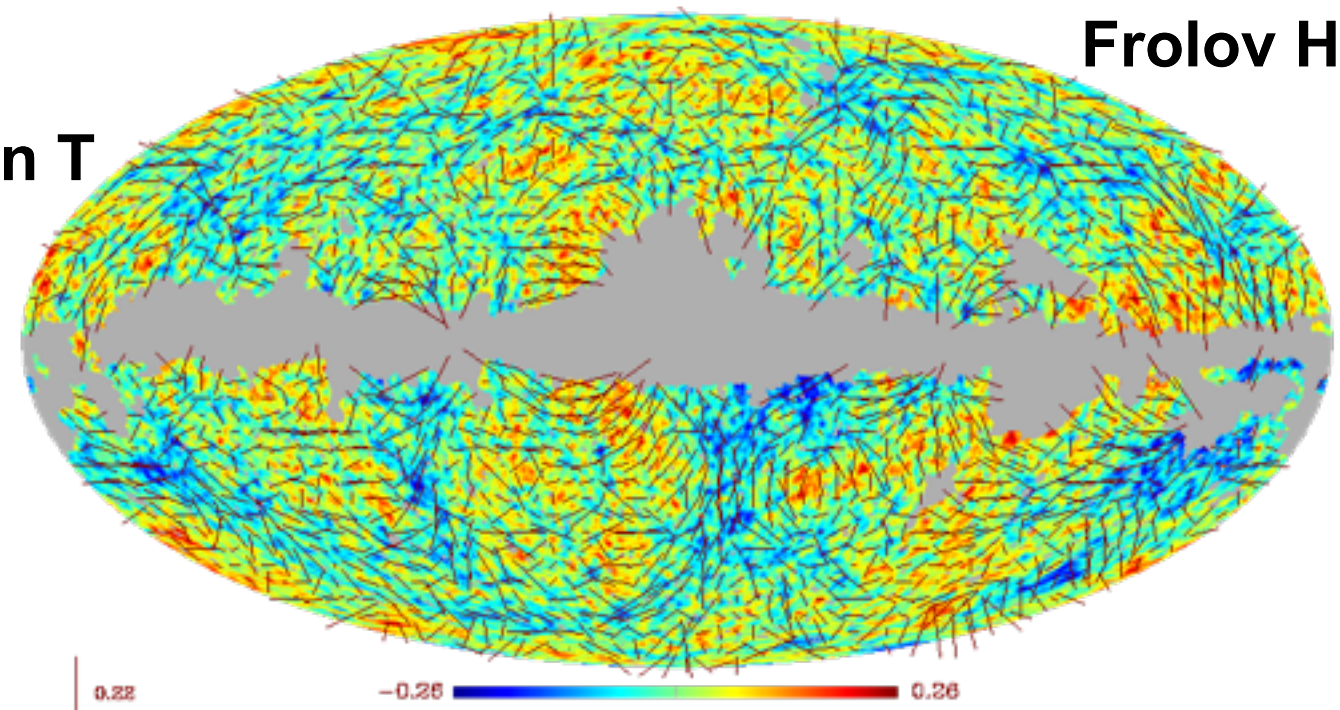


Q_T

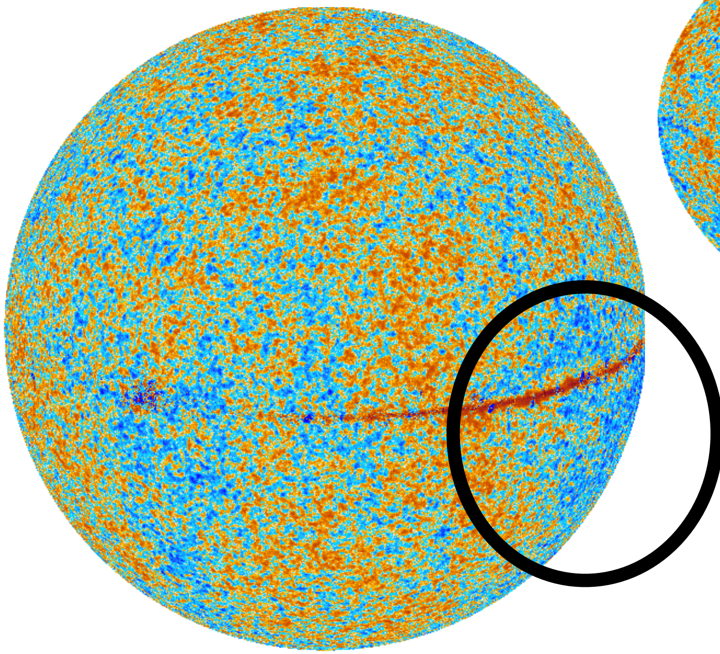


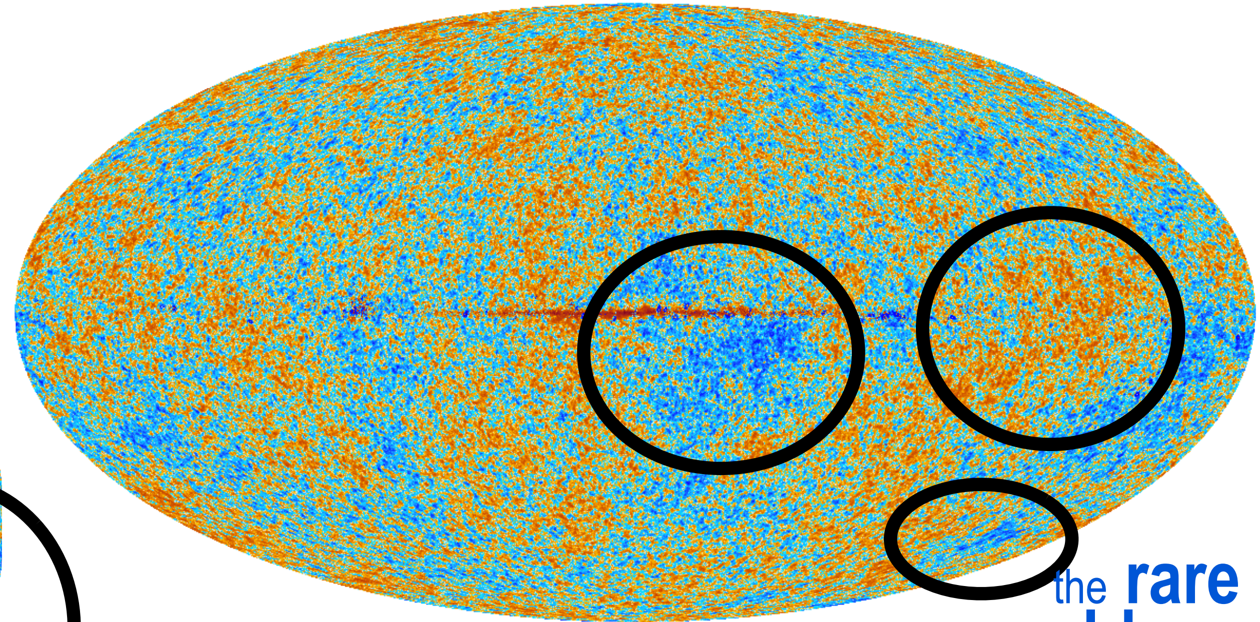
Frolov HFI-CT 13.06

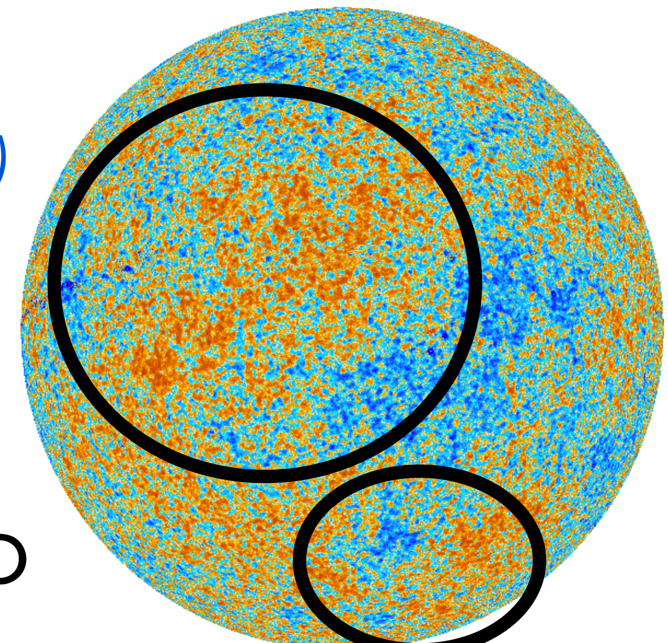
$P_T\ \psi_T$ on T



COMPLEXITY *at* $a \sim e^{-67}$?







WHITEN => MASK => FILTER BANK *(SSG42 filter)*
=> EXTRACT PEAKS ***(hierarchical peak patches)***

filter **= extra dimension: scale space analysis ADS of our CFT**

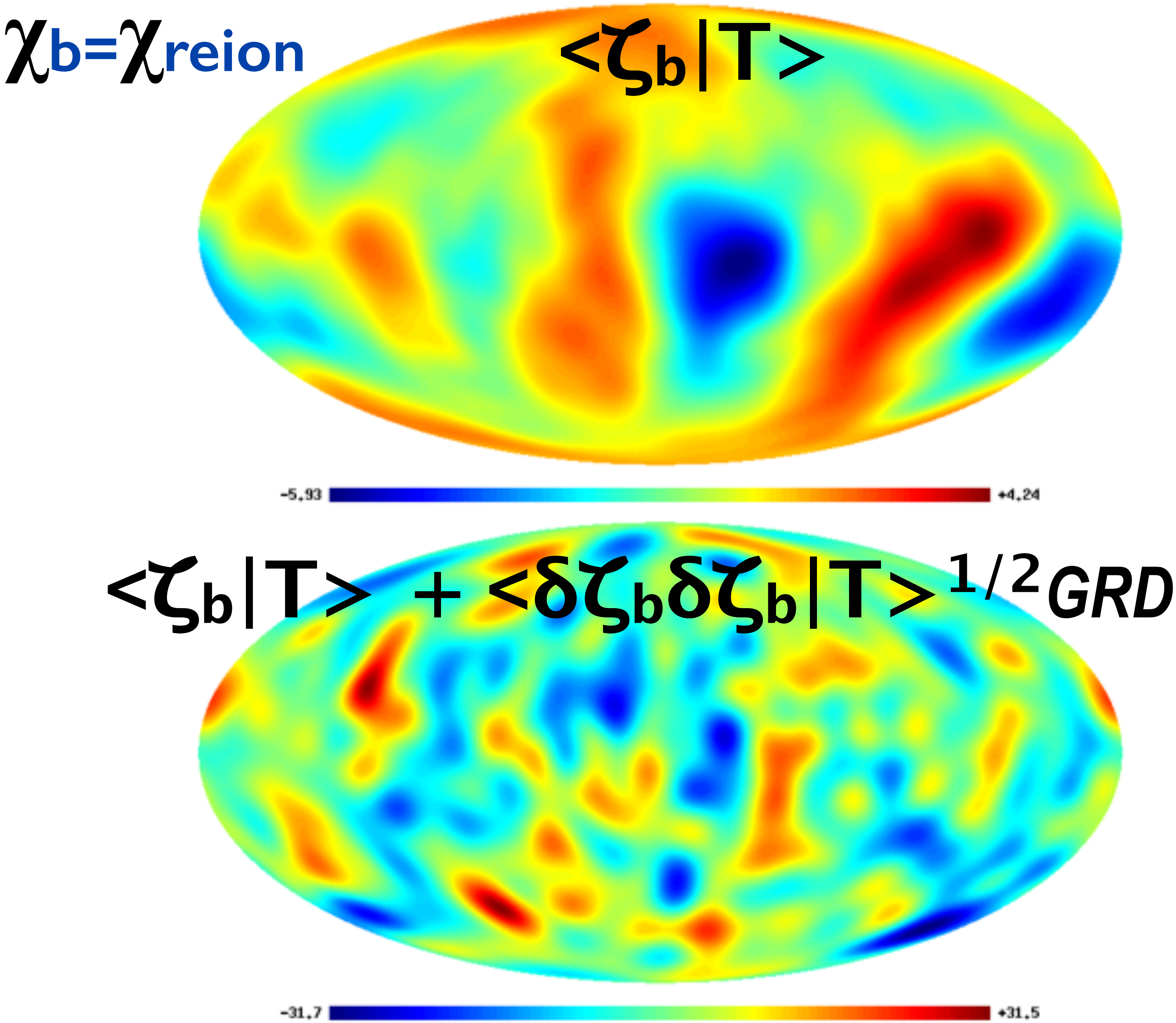
hot & cold peaks** agree with BE87* ***Gaussian stats $n_{pk}(<\nu)$

PLANCK2013: 826', 105 peaks, coldest -4.97σ 1:497

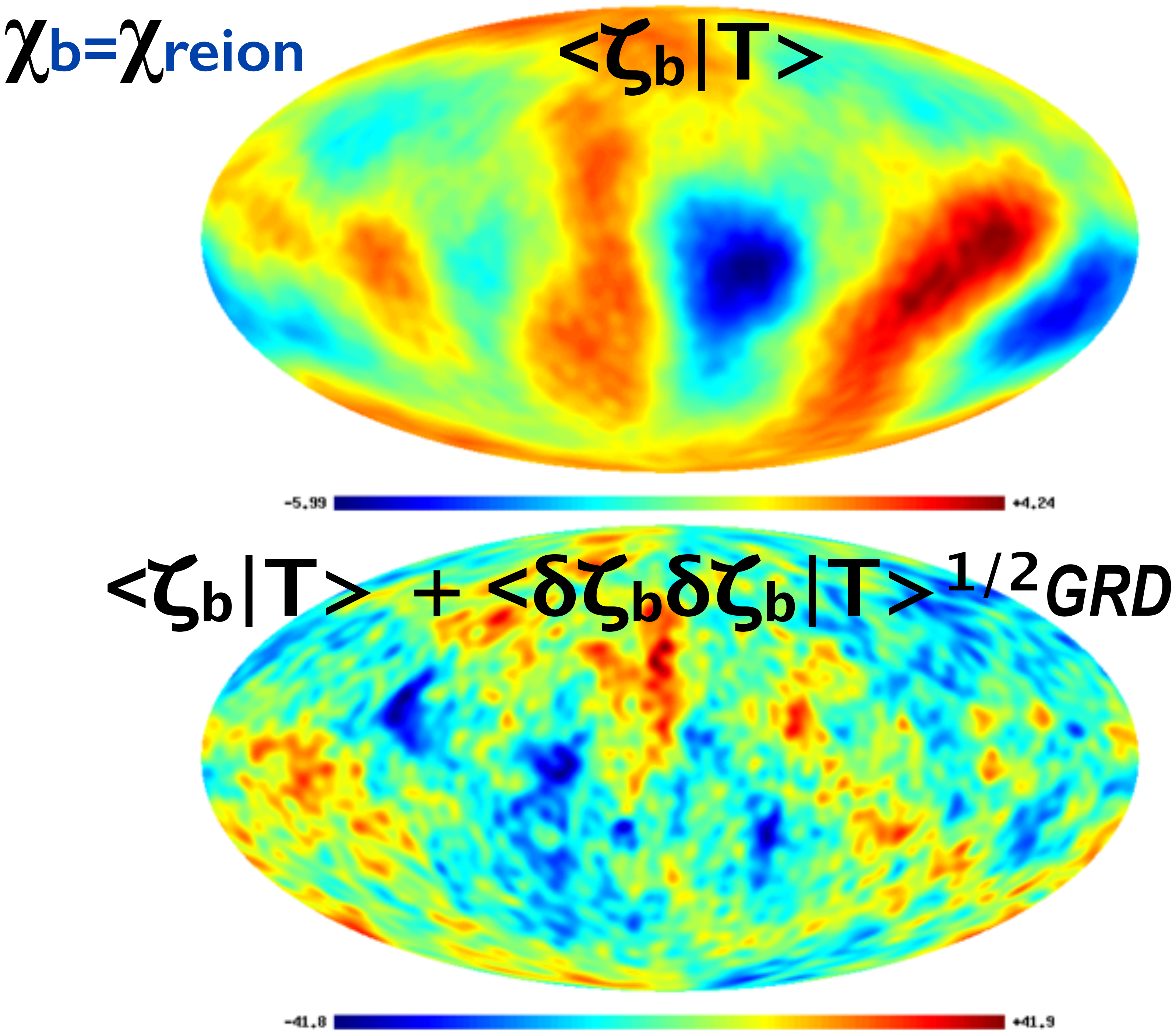
WMAP7: 800', coldest -4.87σ significance 1:300

Grand Unified Theory of Anomalies TBD

Anomalies in Polarization? TBD



$\chi_b=\chi_{reion}$
$<\zeta_b|T>$
-5.93
+4.24
$<\zeta_b|T> + <\delta\zeta_b\delta\zeta_b|T>^{1/2}GRD$
-31.7
+31.5


χb=χreion
<ζb|T>
-5.99
+4.24
<ζb|T> + <δζbδζb|T>1/2GRD
-41.8
+41.9