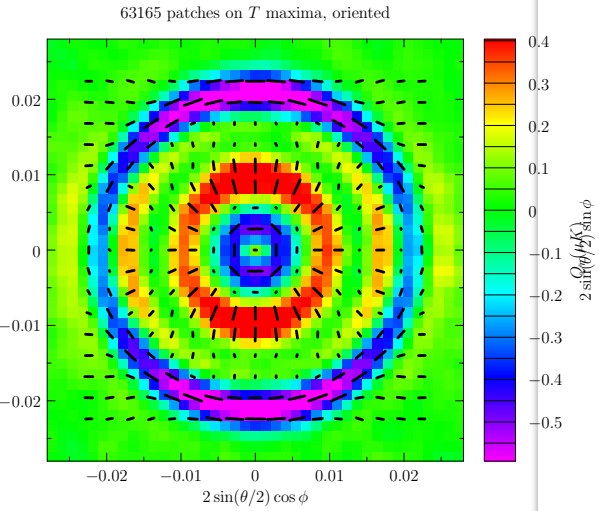
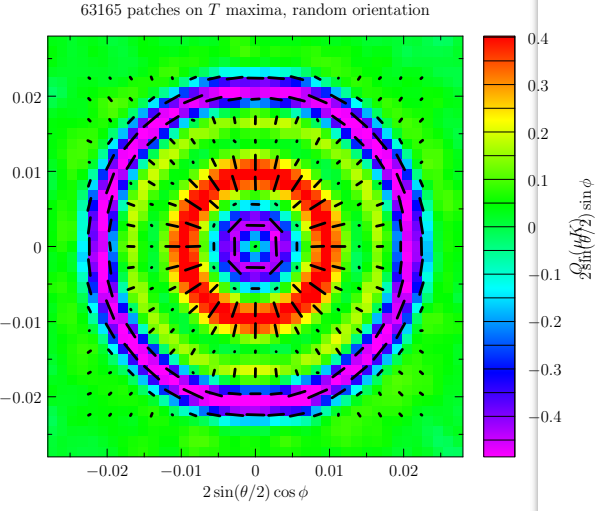
CMB Peak Statistics

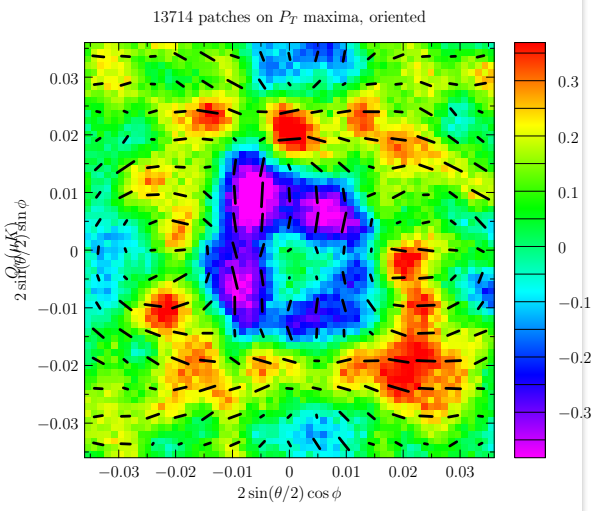
polarization rotated & stacked on temperature Peaks

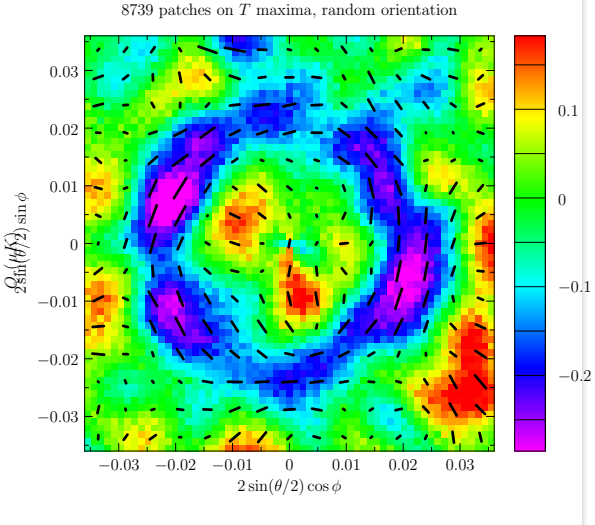
CMB Polarization

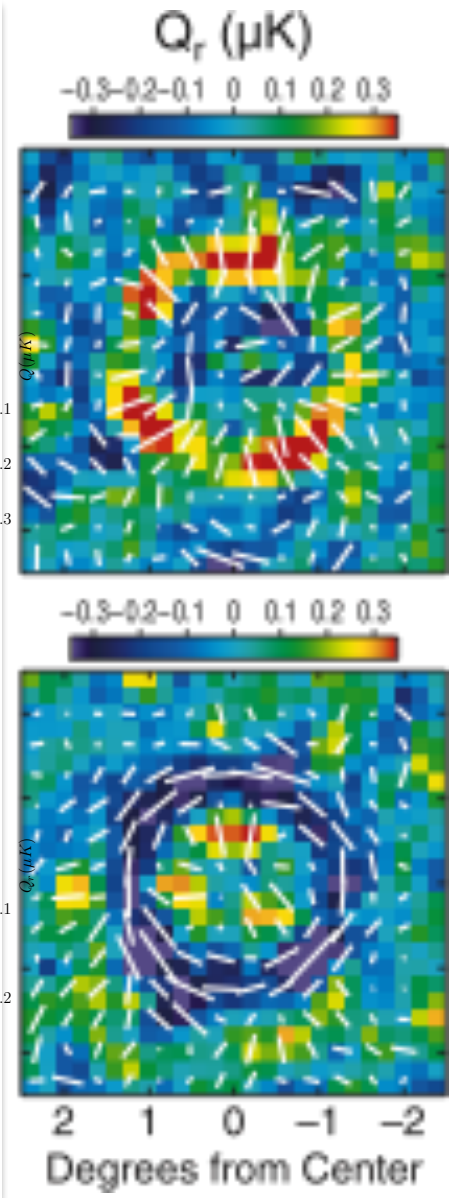
BAO in the CMB – WMAP9











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

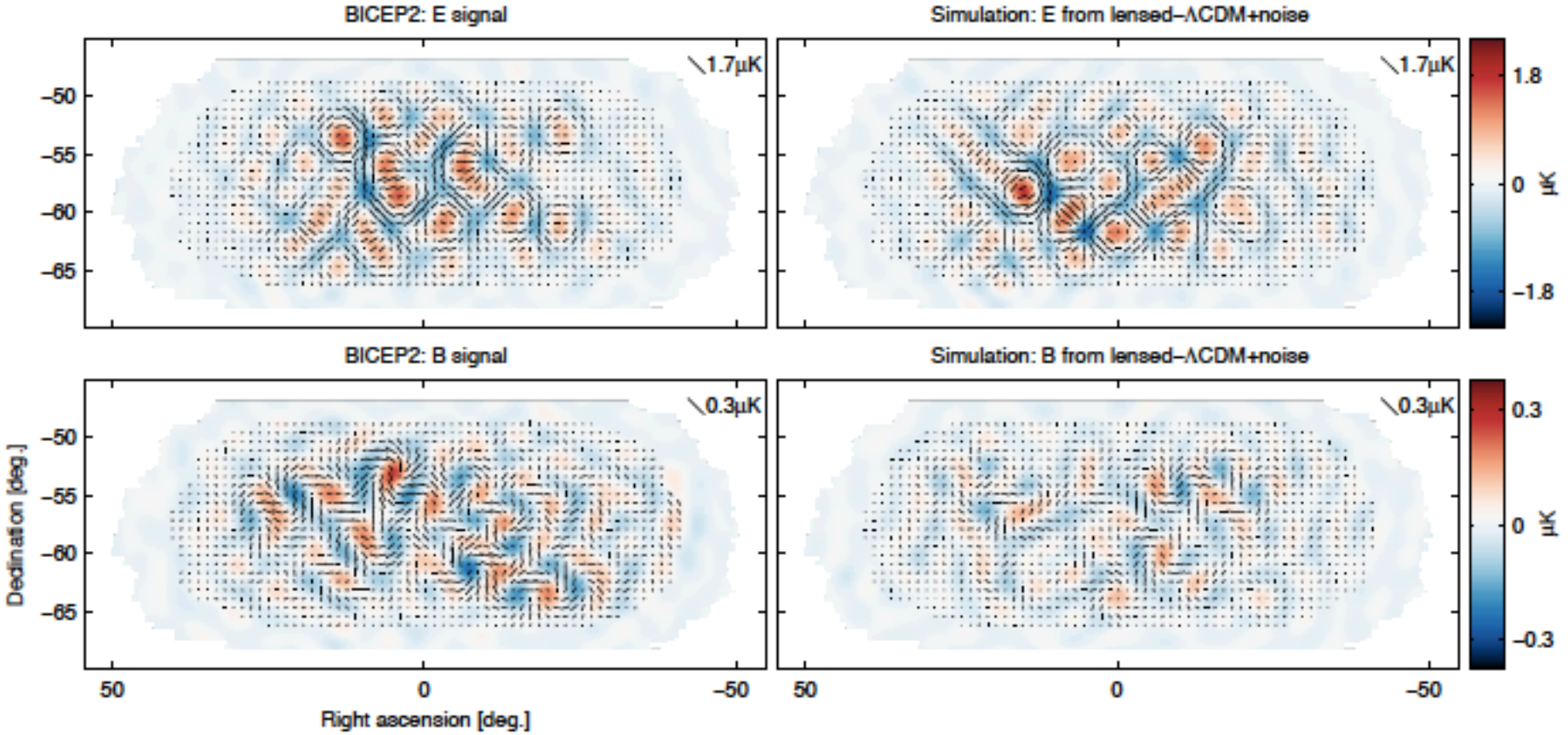
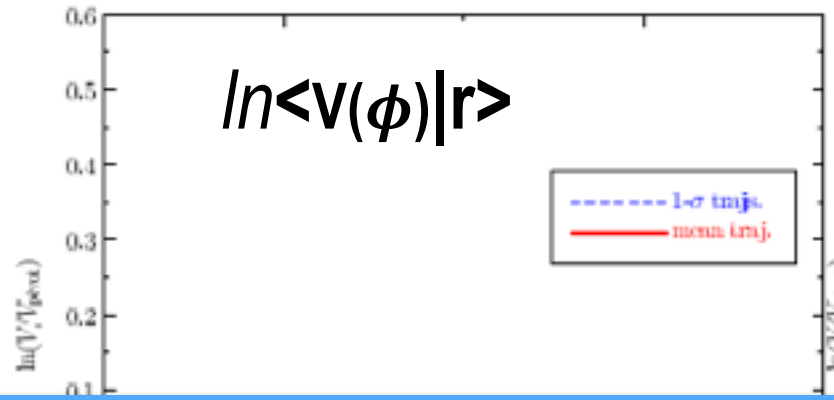
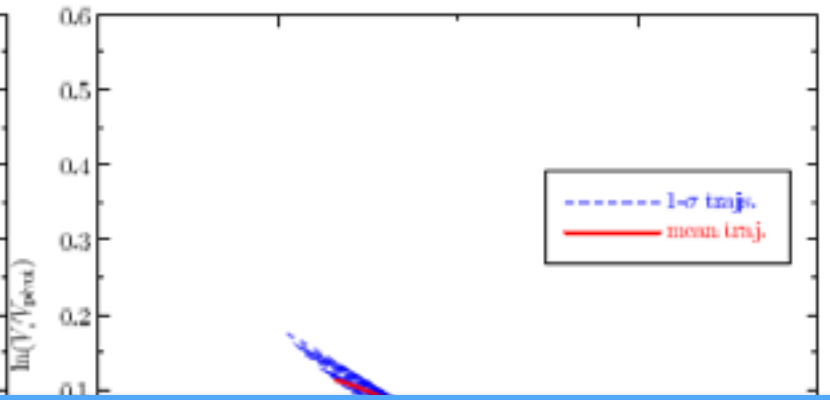


FIG. 3.— *Left:* BICEP2 apodized E-mode and B-mode maps filtered to $50 < \ell < 120$. *Right:* The equivalent maps for the first of the lensed-ΛCDM+noise simulations. The color scale displays the E-mode scalar and B-mode pseudoscalar patterns while the lines display the equivalent magnitude and orientation 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.)



$ln\langle V(\phi)|r\rangle$



heating region is far off => many ways to extrapolate => ???

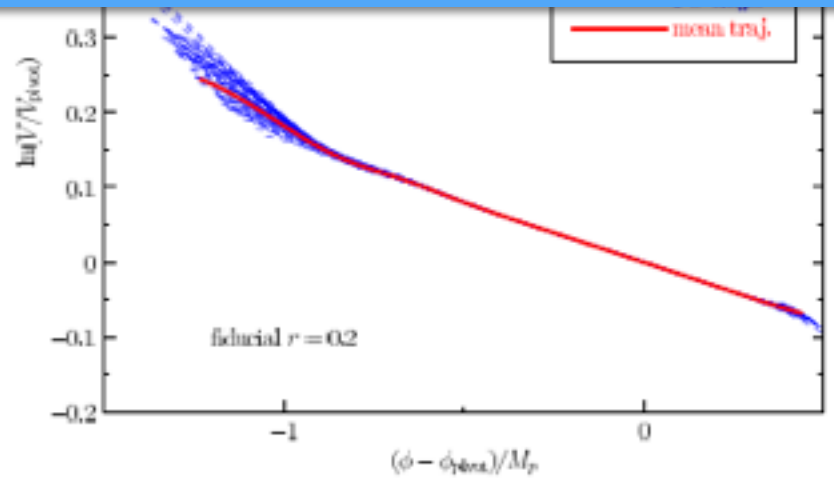
B2FH14: preheat with Einstein + canonical kinetic + $V(\phi)$ +$G(\phi)$Vint(χ,…) sims

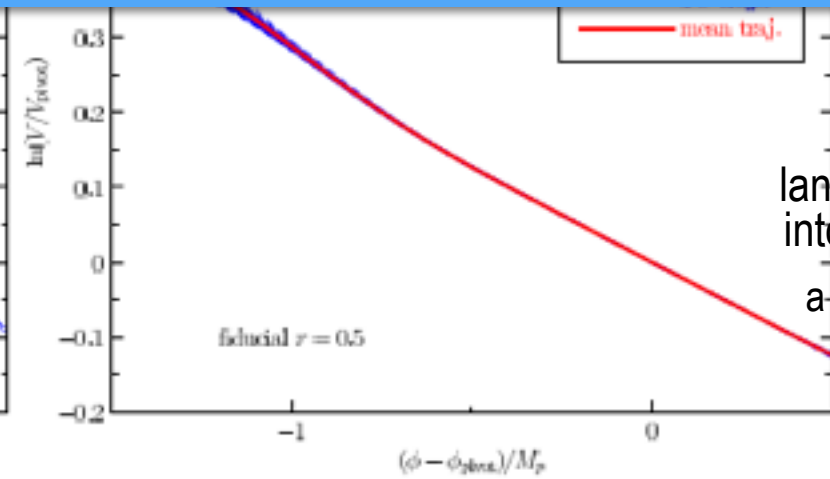
e.g., Higgs inflation with M_P^2 (ϕ) R/2 or $K(\phi)$ $d\phi^2$ /2 difficult with high r, but sims

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

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

= a multiple-line spectrum: *spacing = Lyapunov instability*





landscape tun
into a high V t

a-la Susskind

cf. r=0.2+-0.02 Spider forecast no fgnd, better if r lower

cf. r=0.01+-0.003 AdvACTpol forecast w/ fgnds

ultra-early Universe sound spectrum $\epsilon = -d\ln H/d\ln a$

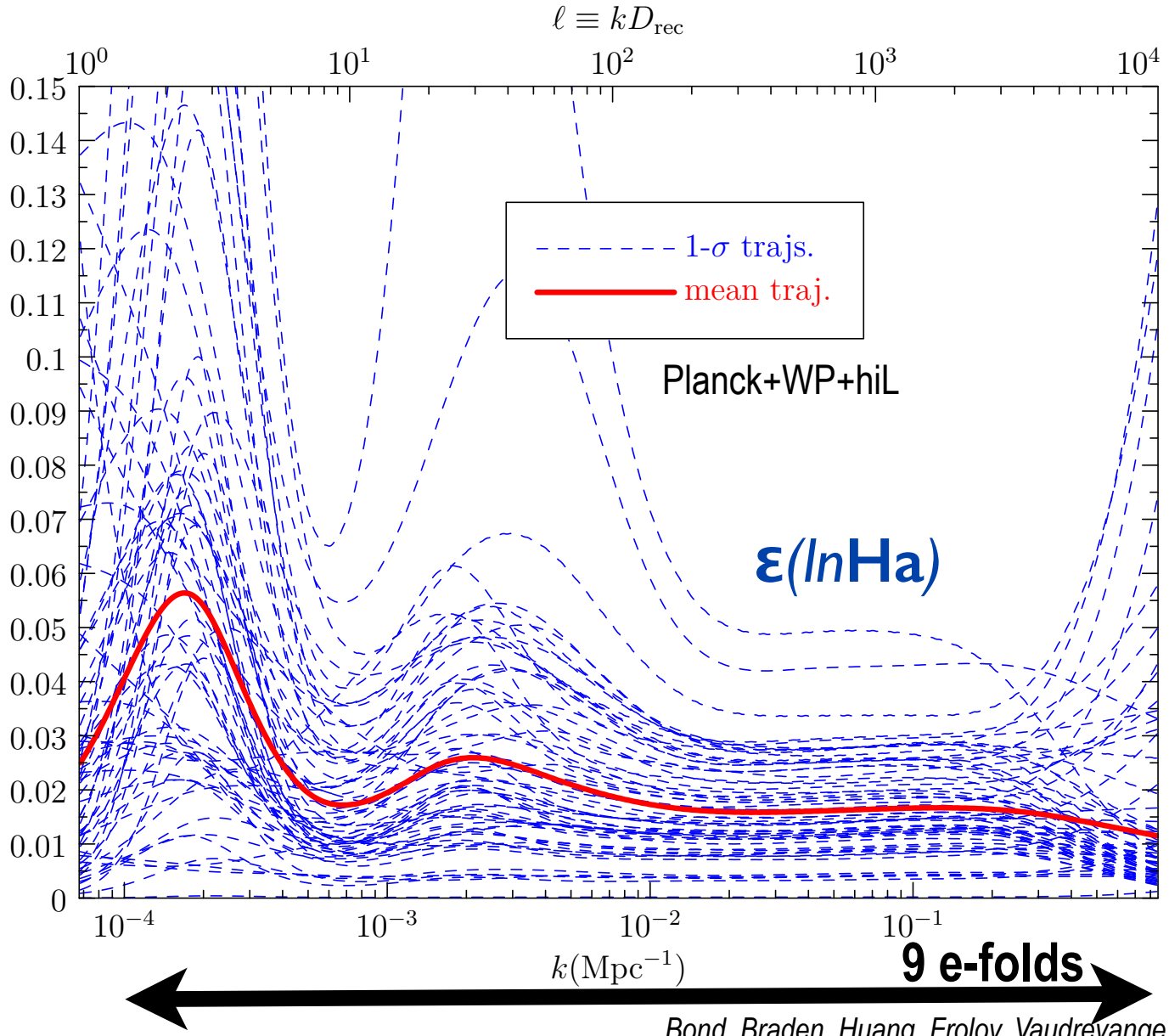
new parameters:

trajectory probabilities for early-inflatons

no strong evidence for oscillation patterns, cutoffs, local features

but hints of change on large L<100 scales

PS: running of P_s is a bad fit



Bond, Braden, Huang, Frolov, Vaudrevange 2014

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

ultra-early Universe sound spectrum $\varepsilon = -d\ln H/d\ln a$

new parameters:

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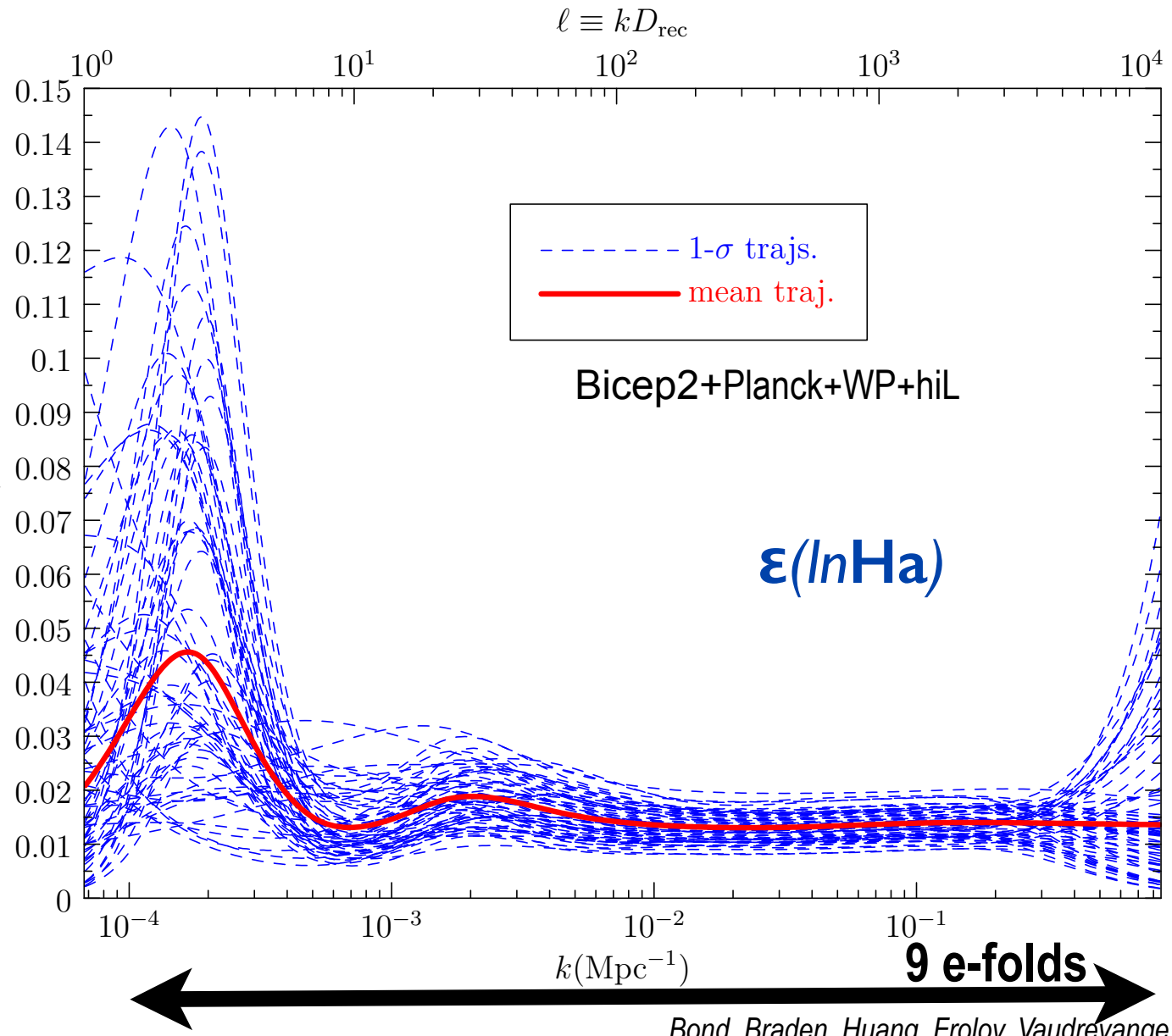

Bond, Braden, Huang, Frolov, Vaudrevange 2014

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

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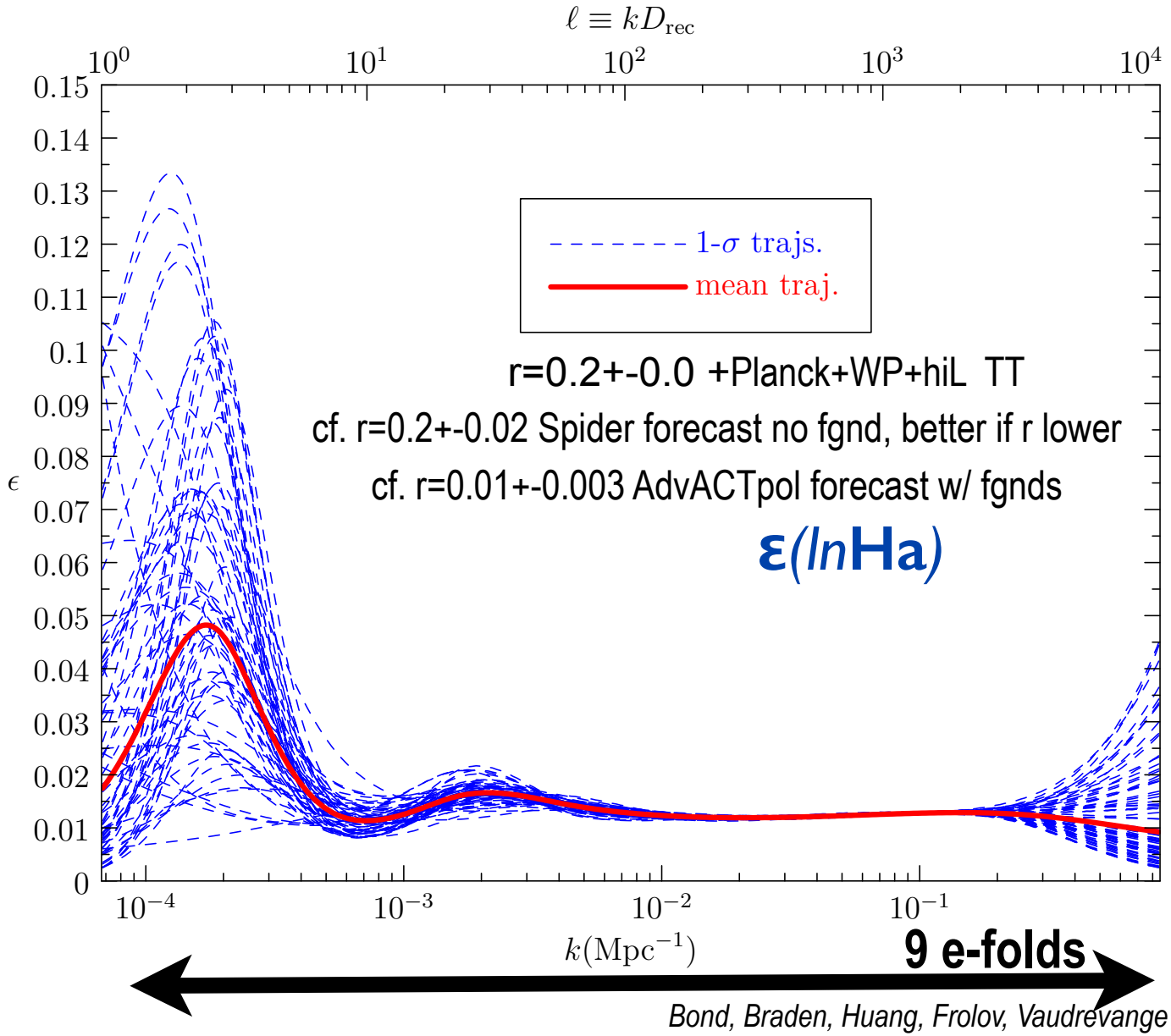

Bond, Braden, Huang, Frolov, Vaudrevange 2014

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

ultra-early Universe sound spectrum $\varepsilon = -d\ln H/d\ln a$

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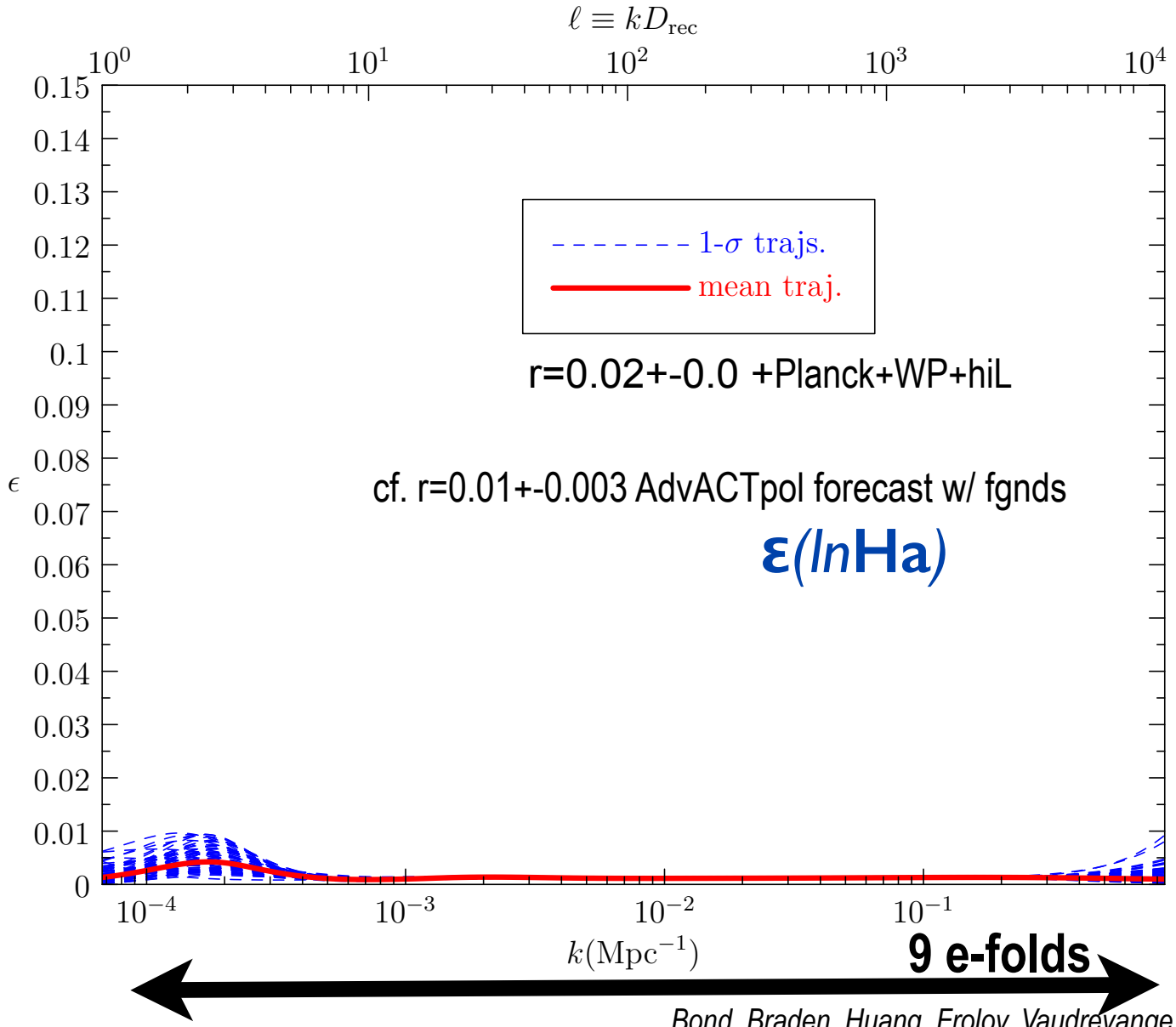
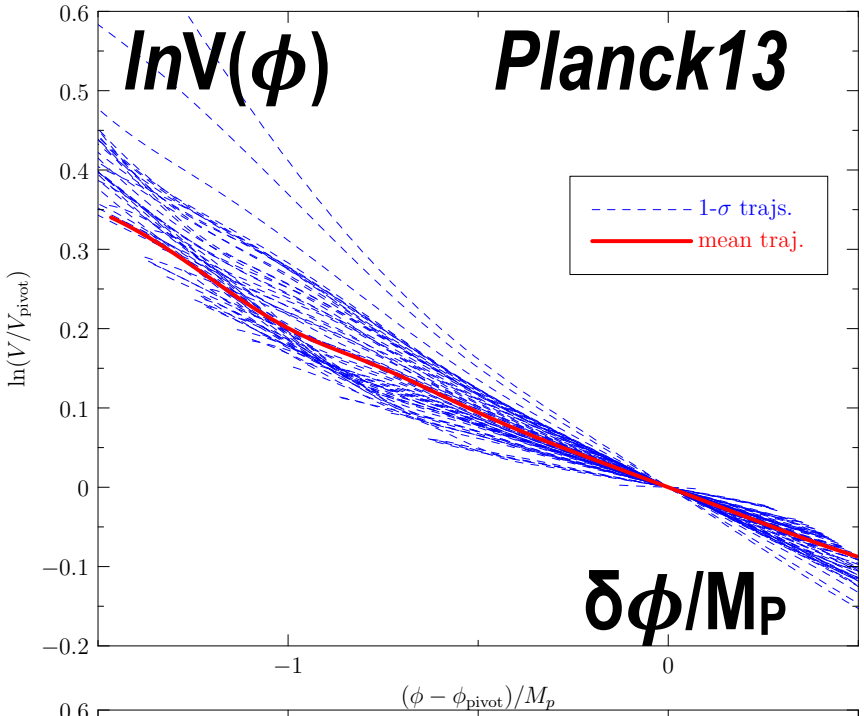
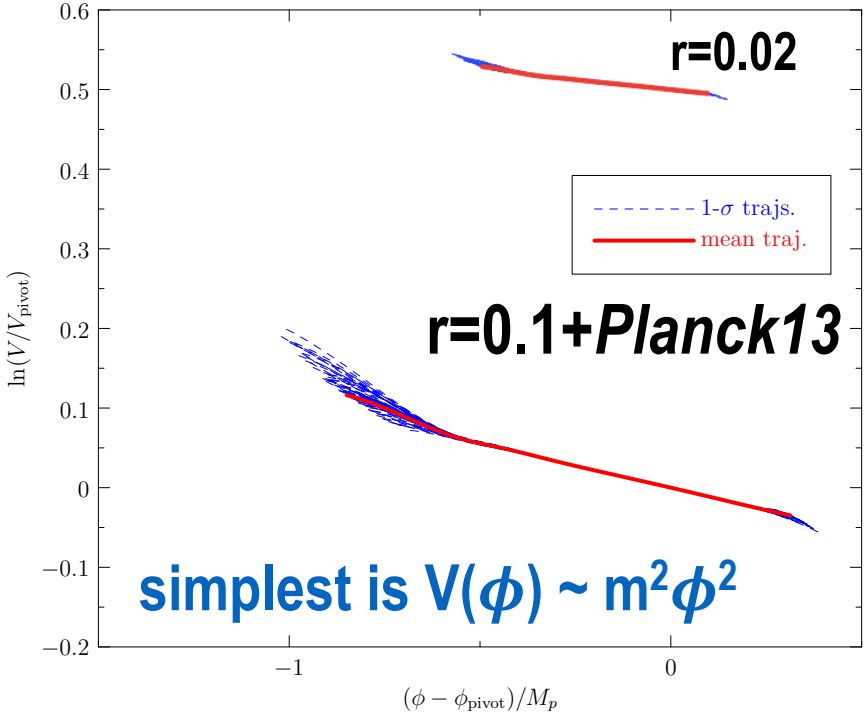
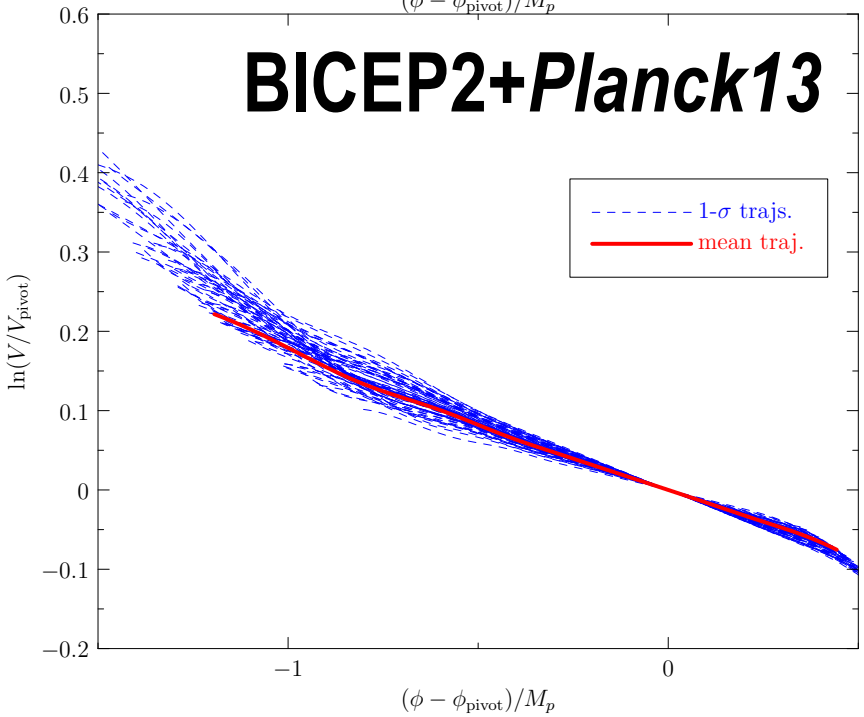


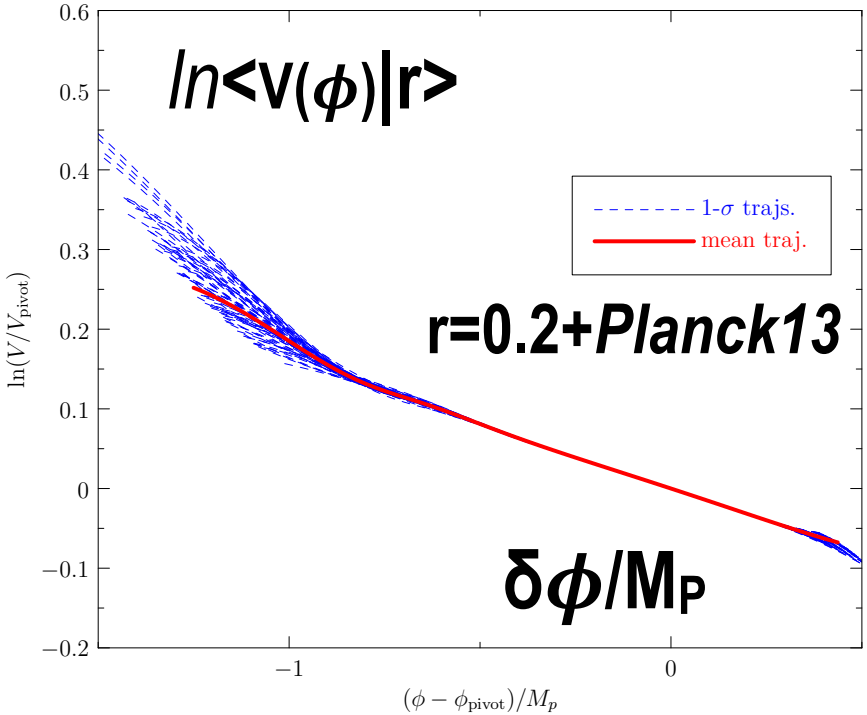
Bond, Braden, Huang, Frolov, Vaudrevange 2014

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


lnV(ϕ)
Planck13
δϕ/MP
1-σ trajs.
mean traj.
ln(V/V_pivot)
(ϕ − ϕ_pivot)/M_p


r=0.02
r=0.1+Planck13
simplest is V(ϕ) ~ m²ϕ²
1-σ trajs.
mean traj.
ln(V/V_pivot)
(ϕ − ϕ_pivot)/M_p


BICEP2+Planck13
1-σ trajs.
mean traj.
ln(V/V_pivot)
(ϕ − ϕ_pivot)/M_p


ln<V(ϕ)|r>
r=0.2+Planck13
δϕ/MP
1-σ trajs.
mean traj.
ln(V/V_pivot)
(ϕ − ϕ_pivot)/M_p

Power Deviation from fiducial $\langle\zeta|T\rangle\langle\zeta|T\rangle + \langle\delta\zeta\delta\zeta|T\rangle - \langle\zeta\zeta|\text{free}\rangle$

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 $\langle \zeta_{LM\ c,s}(\chi) \mid a_{LM\ c,s} \rangle$ 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 $\langle (\nabla^{-2}\,\nabla_i\,\nabla_j - \delta_{ij}/2)\,T_{dec} \mid T_{now} \rangle$ anisotropic stress: *if direct transport from* χ_{dec} **then $(\nabla^{-2}\,\nabla_i\,\nabla_j - \delta_{ij}/2)\,T_{now}$ decompose into $Q_T\ U_T\ E_T\ E_T\ P_T\ \psi_T$ akin to Q U E P ψ, with enhanced peak-stacking correlations, oriented stacks**

B2FH14

primordial sub-dominant **intermittent nonGaussianity**

Bond, Frolov, Huang, Braden

phonon ~ ζ_{NL} =ln(ρ $a^{3(1+w)}$)/3(1+w) ~ scalar curvature @ uniform density

$\zeta_{NL}(x)= \zeta_G(x)+ f_{NL*} (\zeta_G^2(x)-<\zeta_G^2>)$ => 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})**

B mode of polarization *cf.* E mode

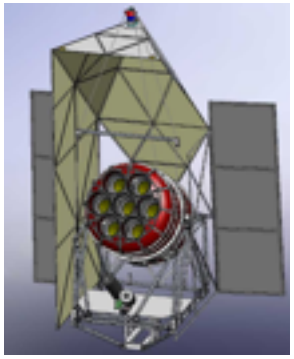
linear scalar fluctuations create only E patterns

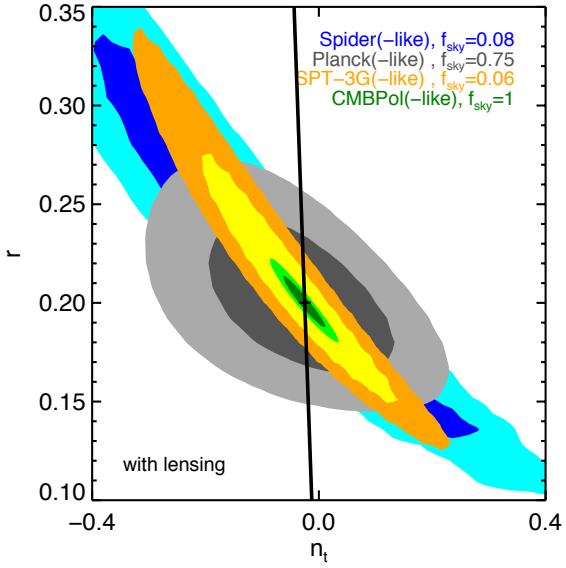
strain from CMB lensing tides distorts E pattern into a bit of B *SPT*

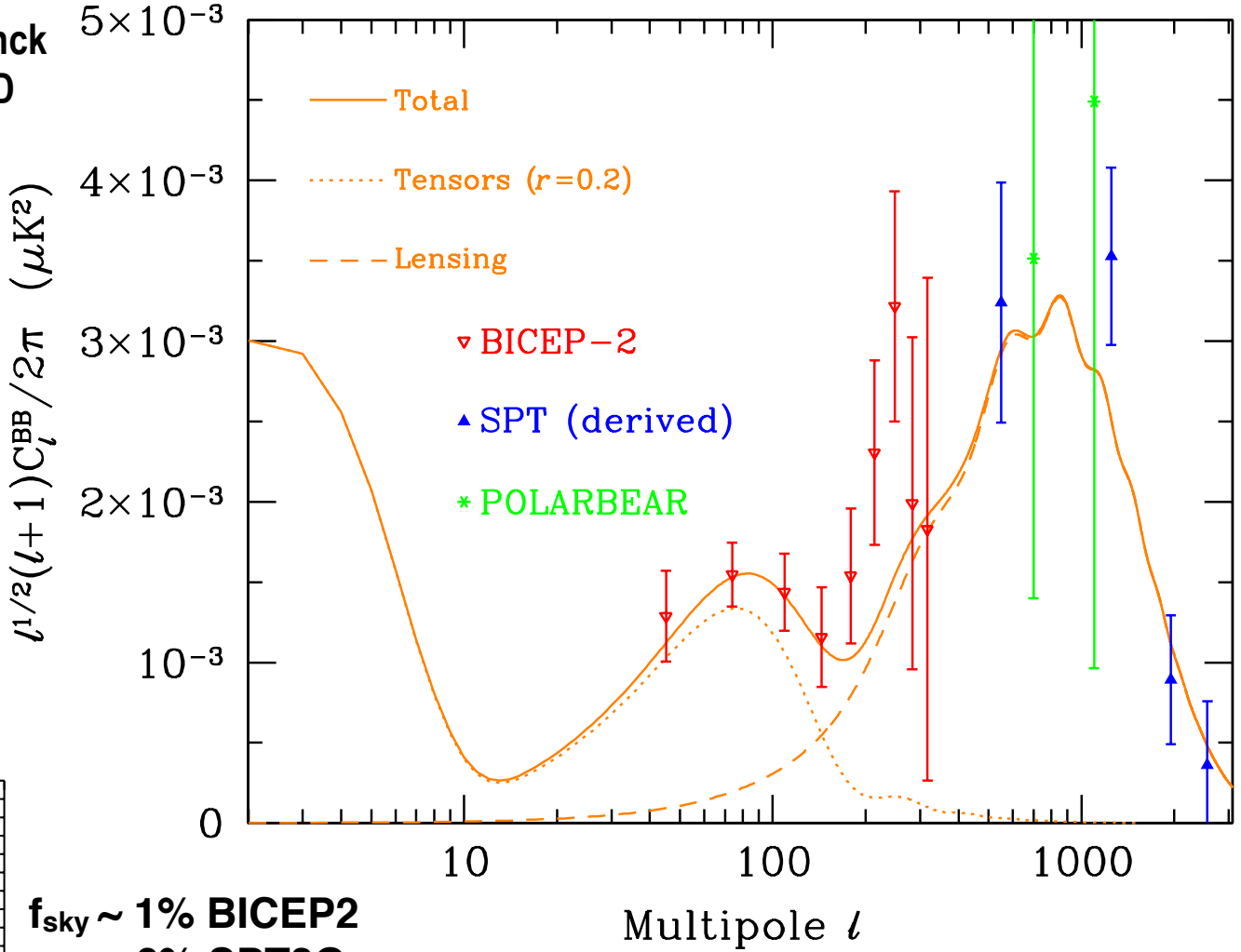
anisotropic strain from **gravity waves => E & B**

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

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,..***

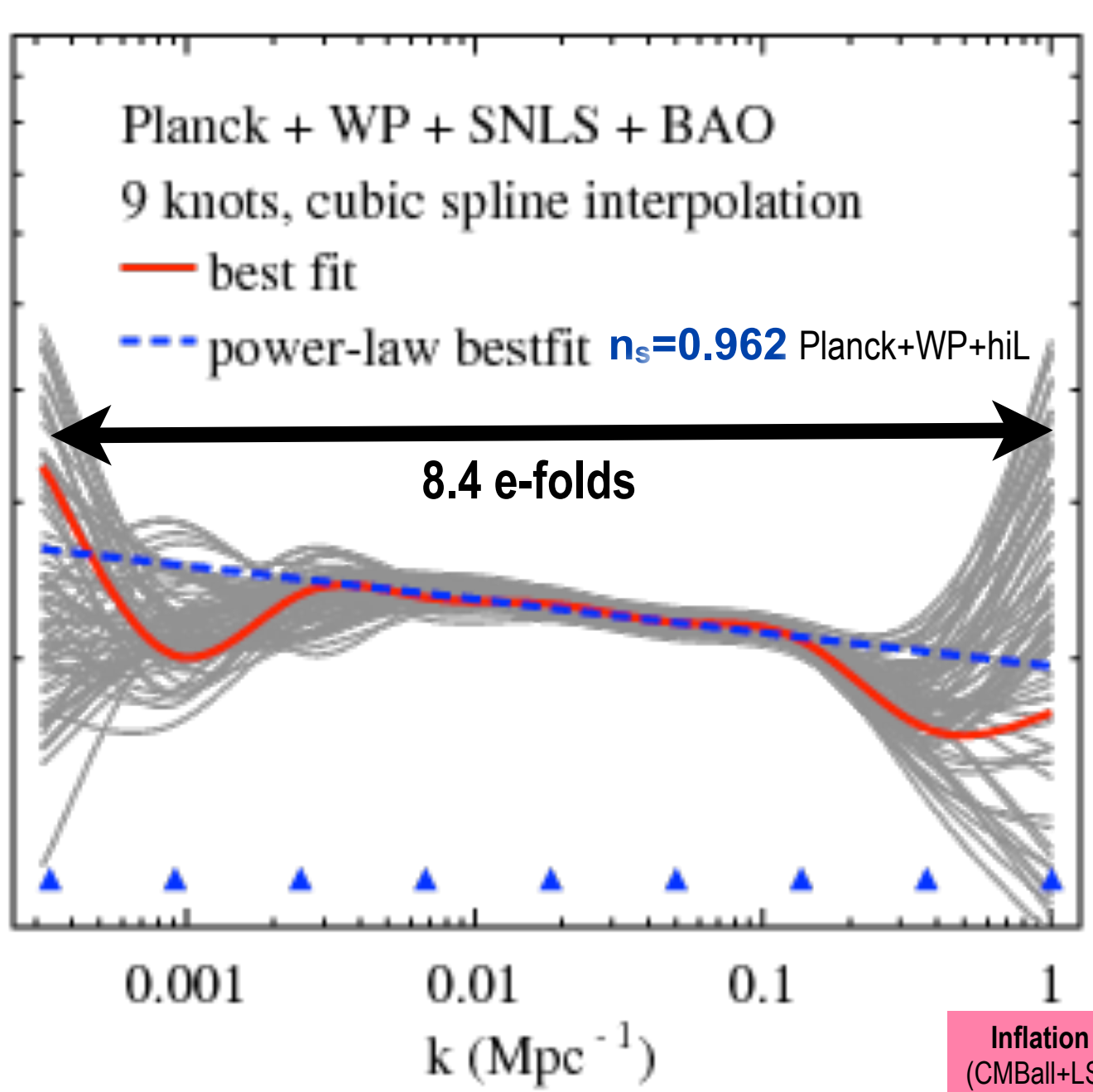
scan $ln\mathbf{P_s}(ln k)/A_s$, $ln\mathbf{A_s}=ln P_s(k_{pivot,s})$, $\mathbf{r}(k_{pivot,t})$; *consistency => reconstruct* $\boldsymbol{\varepsilon}(ln\mathbf{Ha})$, $\mathbf{V(\psi)}$

$ln P_s(ln k)$

new parameters:

trajectory probabilities for early-inflatons & late-inflatons

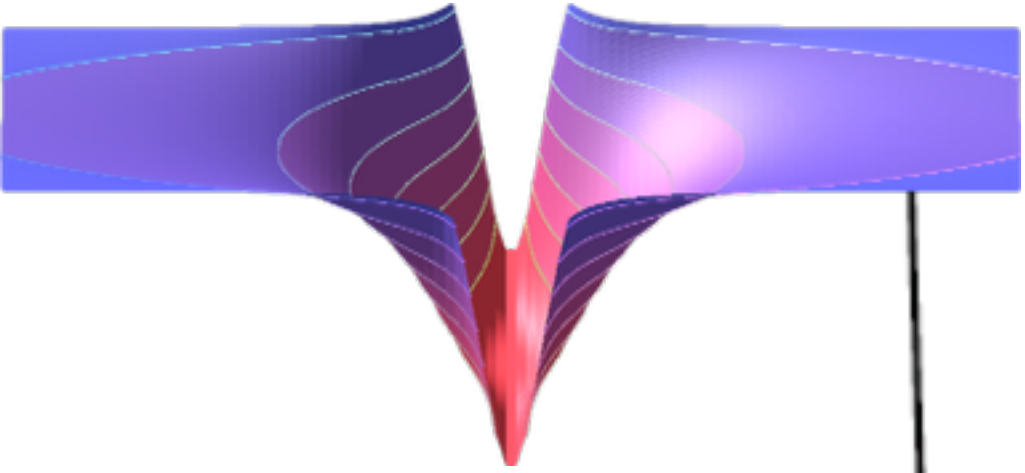
no strong evidence for oscillation patterns, cutoffs, local features

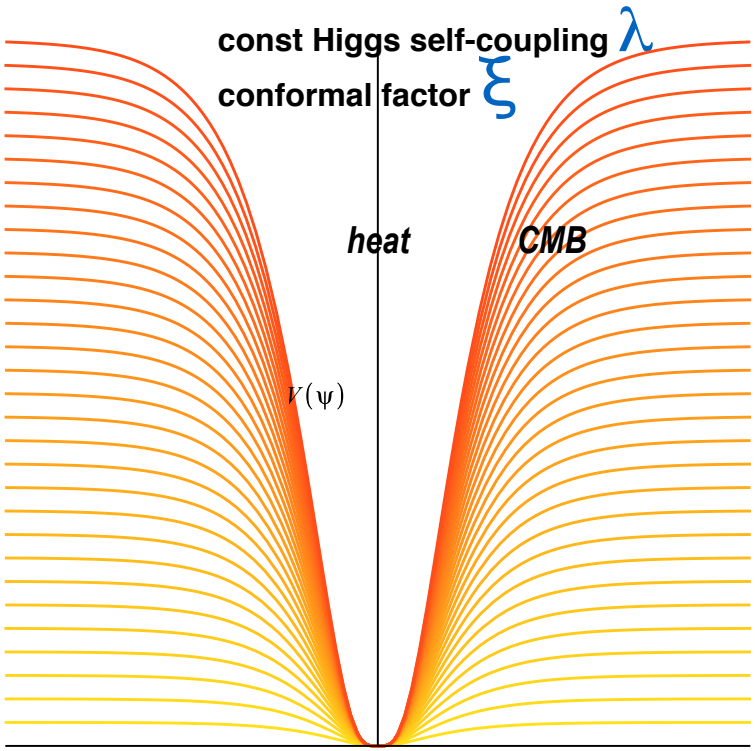


Bond, Huang 2013

Inflation Histories
(CMBall+LSS+SN+WL)

what is the inflaton's potential?



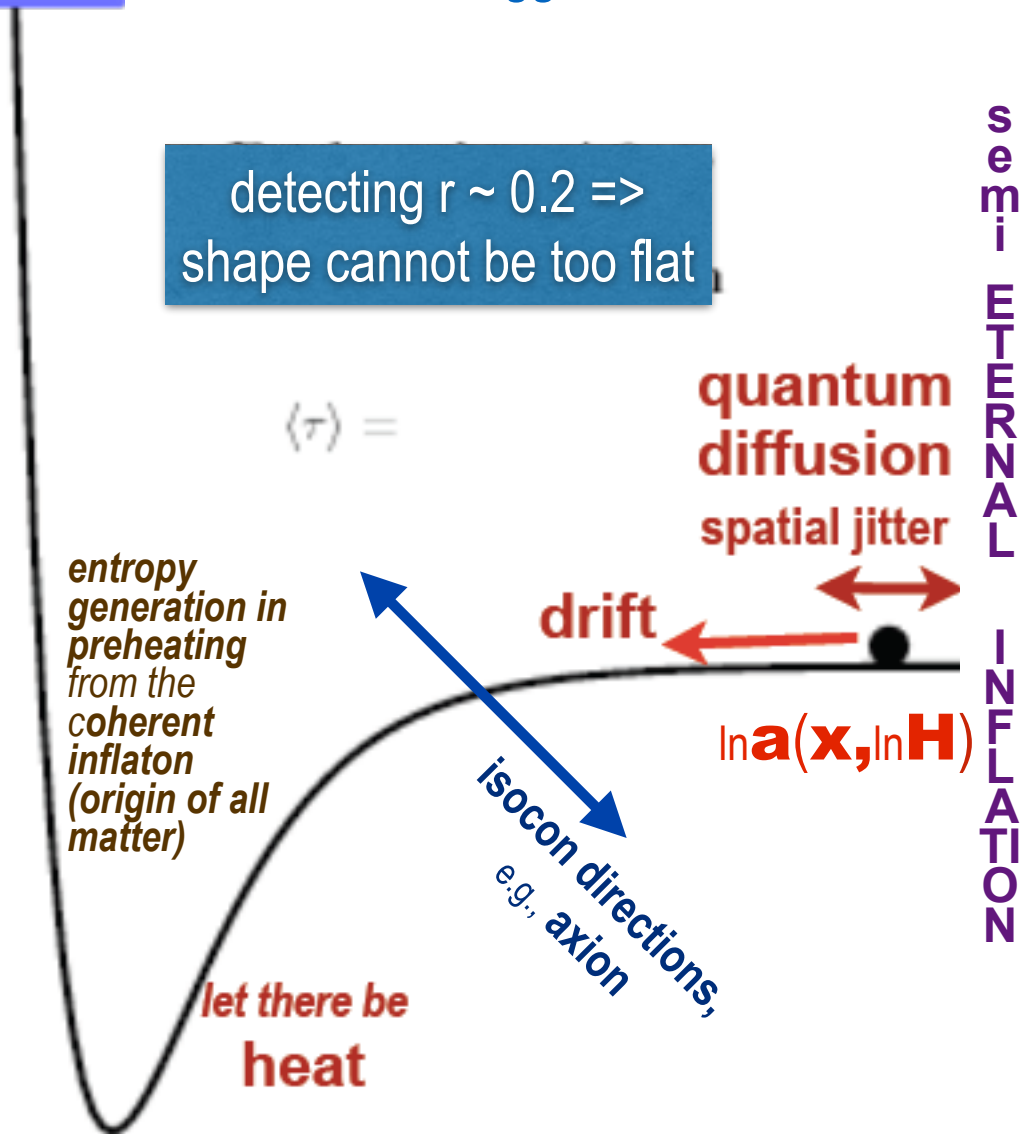


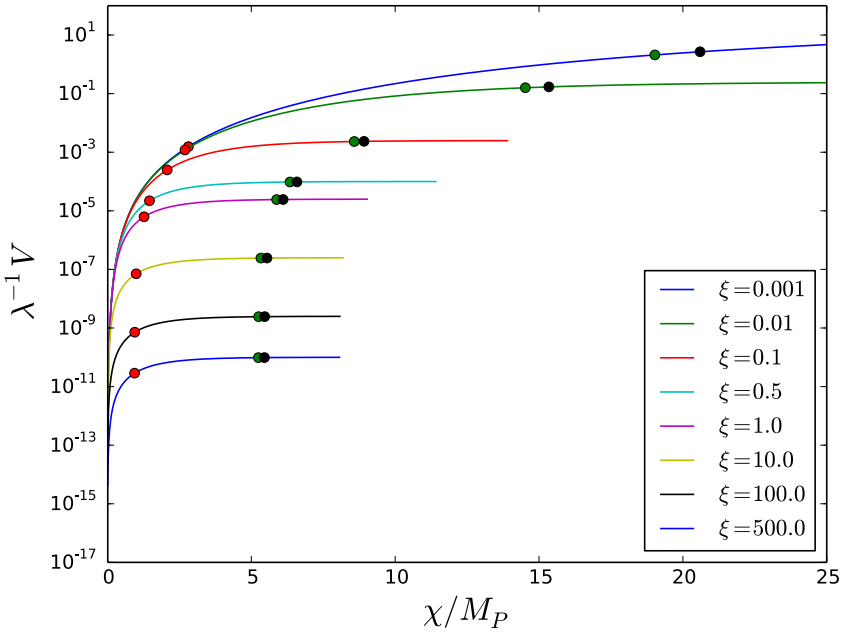
conformal potential-flattening SBB89

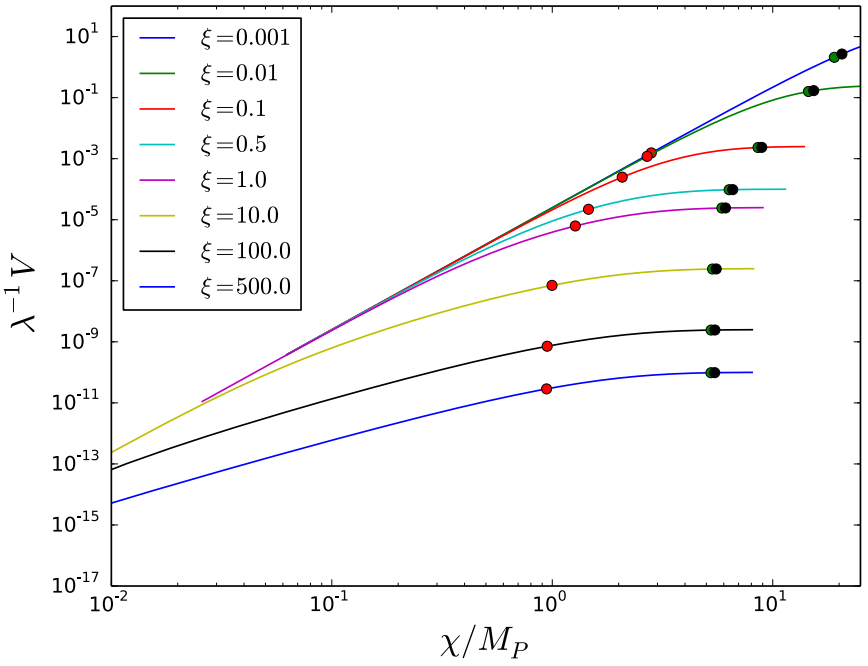
how was *matter & entropy generated at the end of acceleration = inflation*?

Relate it to the Higgs & standard model?

detecting r ~ 0.2 =>
shape cannot be too flat




$\lambda^{-1}V$
χ/M_P
$\xi=0.001$
$\xi=0.01$
$\xi=0.1$
$\xi=0.5$
$\xi=1.0$
$\xi=10.0$
$\xi=100.0$
$\xi=500.0$


$\lambda^{-1}V$
χ/M_P
$\xi=0.001$
$\xi=0.01$
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$\xi=0.5$
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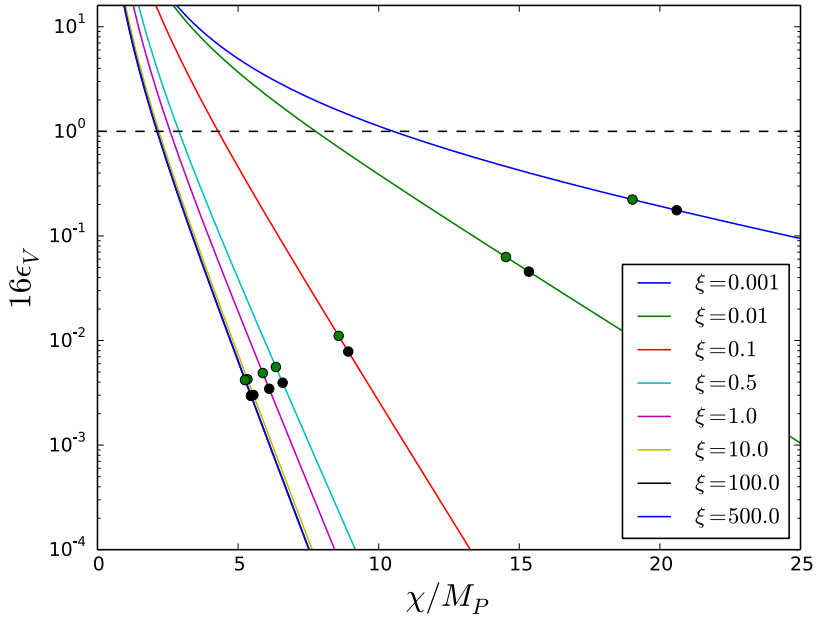
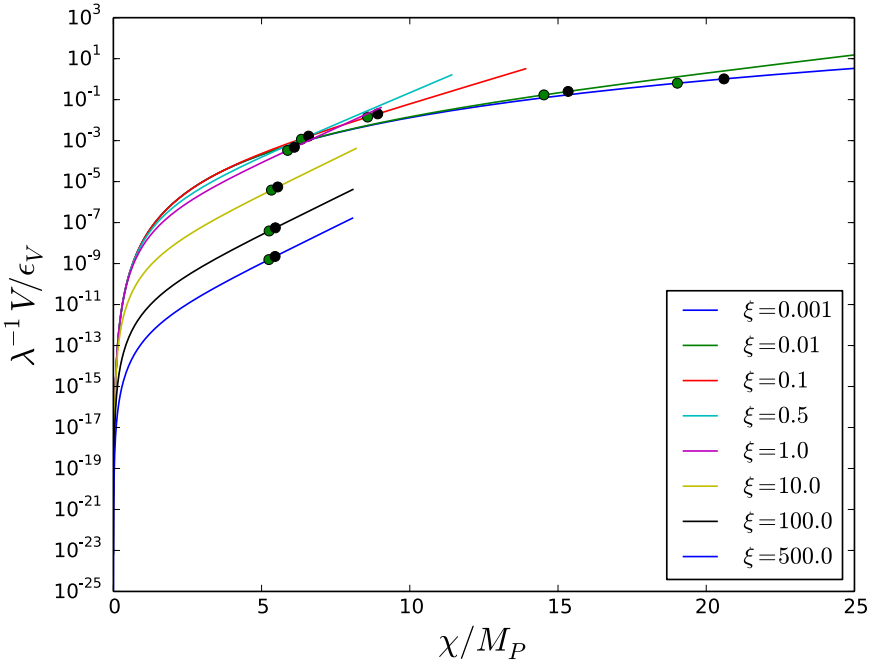
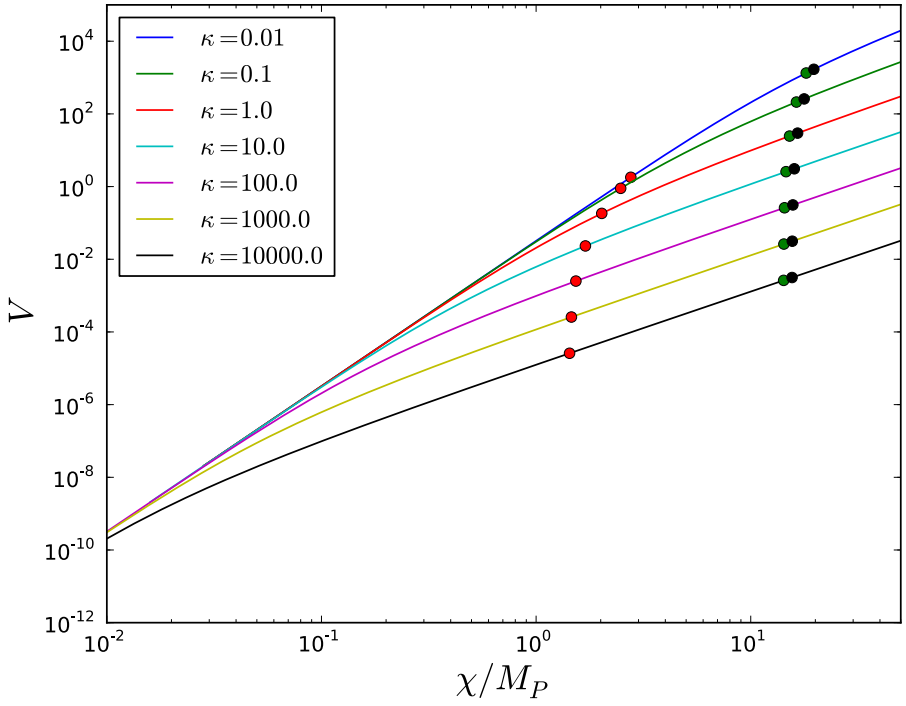
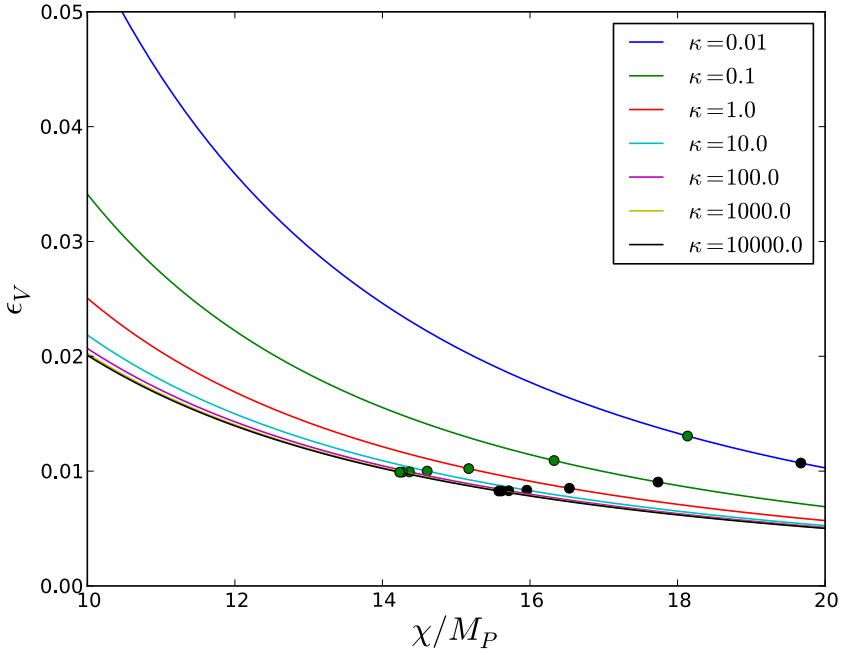
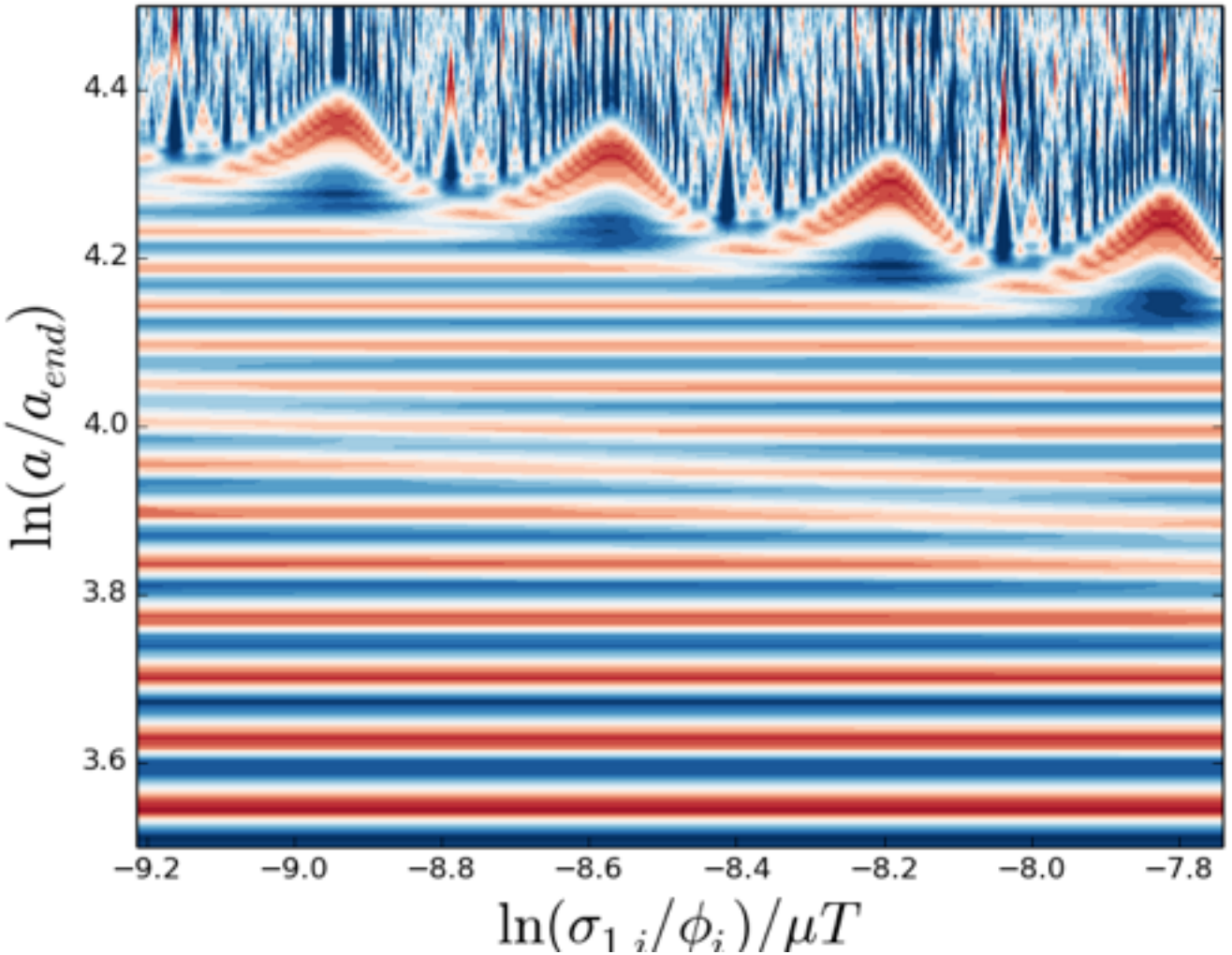

$16\epsilon_V$
χ/M_P
$\xi=0.001$
$\xi=0.01$
$\xi=0.1$
$\xi=0.5$
$\xi=1.0$
$\xi=10.0$
$\xi=100.0$
$\xi=500.0$


$\lambda^{-1}V/\epsilon_V$
χ/M_P
$\xi=0.001$
$\xi=0.01$
$\xi=0.1$
$\xi=0.5$
$\xi=1.0$
$\xi=10.0$
$\xi=100.0$
$\xi=500.0$


$\kappa = 0.01$
$\kappa = 0.1$
$\kappa = 1.0$
$\kappa = 10.0$
$\kappa = 100.0$
$\kappa = 1000.0$
$\kappa = 10000.0$
V
χ/M_P


$\kappa = 0.01$
$\kappa = 0.1$
$\kappa = 1.0$
$\kappa = 10.0$
$\kappa = 100.0$
$\kappa = 1000.0$
$\kappa = 10000.0$
ϵ_V
χ/M_P

Caustics with many fields => spikes in curvature, as with 2



The ACT Collaboration

ACT, now ACTpol, => Advanced ACTpol

Power Deviation from fiducial $\langle\zeta|T\rangle\langle\zeta|T\rangle+\langle\delta\zeta\delta\zeta|T\rangle-\langle\zeta\zeta|\text{free}\rangle$

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

Quadratic expansions in mode functions: which function to expand (ln $P_{\zeta\zeta}$), which modes (cubic B-spline), number?, priors on amplitudes, etc.

from $\langle\, \zeta_{LM\ c,s}(\chi) \mid a_{LM\ c,s}\,\rangle$ 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)*

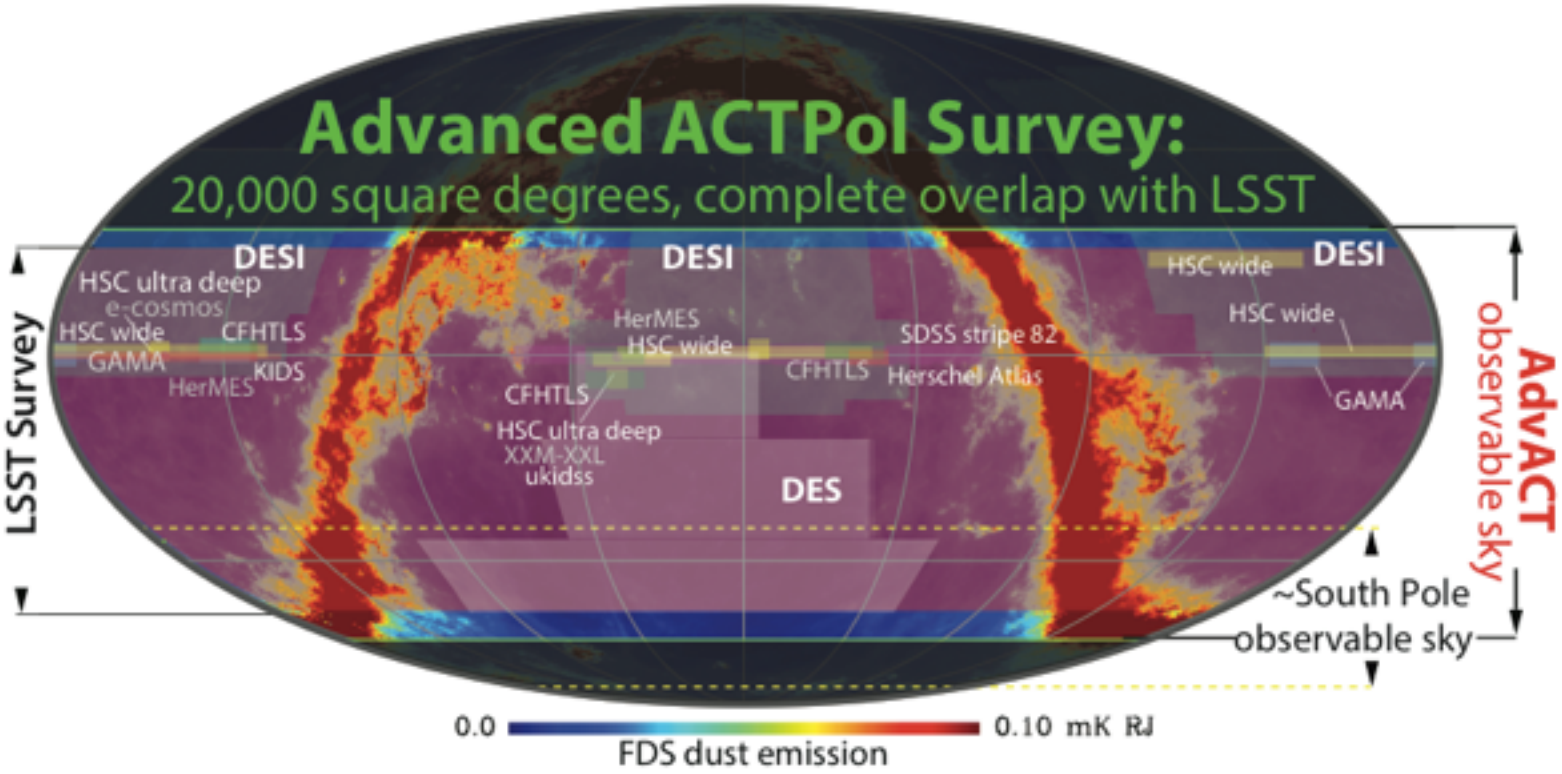
=> novel Peaks (eigen-$P_T$eaks), statistics, *mean fields*, stacks

"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; …

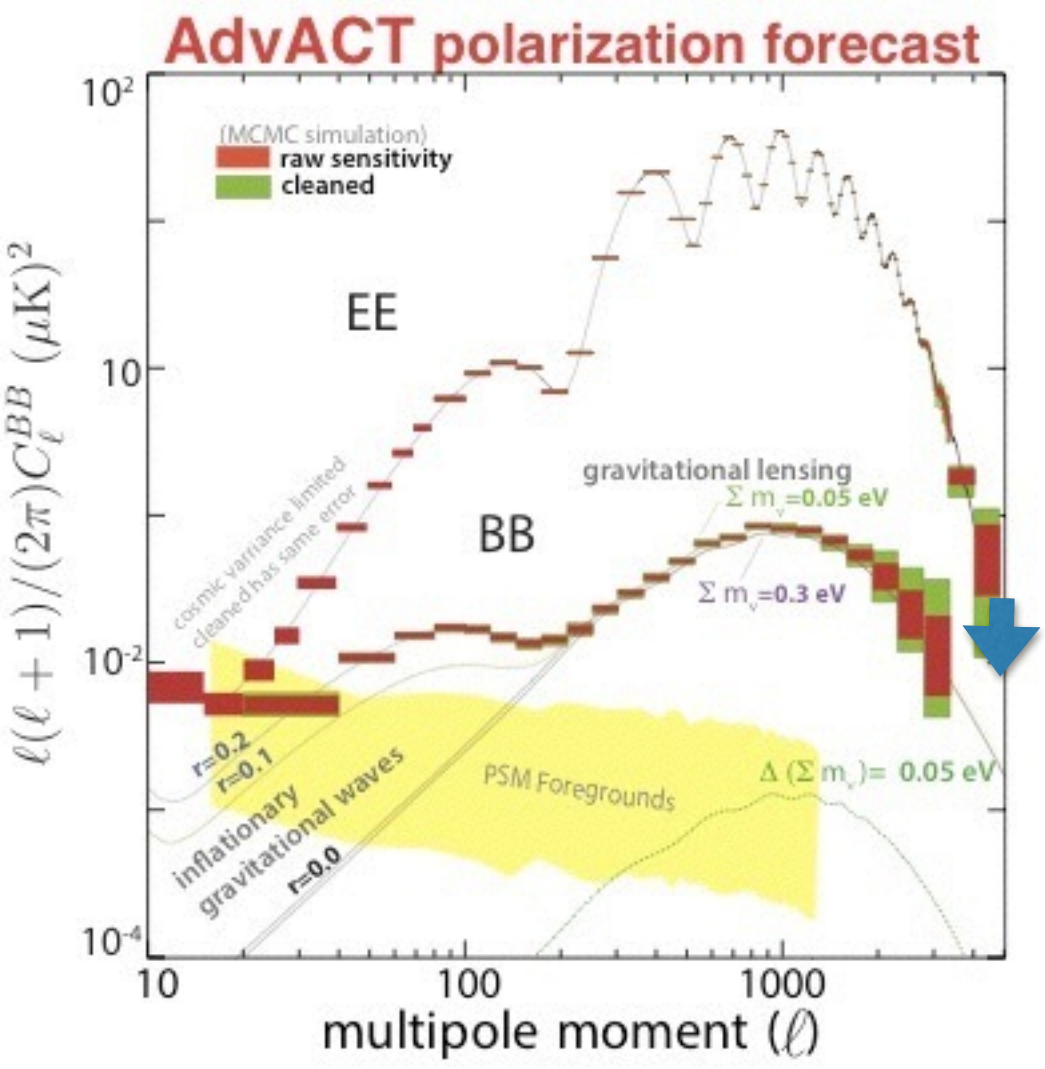
simple proxy for $\langle\, (\nabla^{-2}\,\nabla_i\,\nabla_j - \delta_{ij}/2)\,T_{dec} \mid T_{now}\,\rangle$ anisotropic stress: *if direct transport from* χ_{dec} **then $(\nabla^{-2}\,\nabla_i\,\nabla_j - \delta_{ij}/2)\,T_{now}$ decompose into $Q_T\ U_T\ E_T\ E_T\ P_T\ \psi_T$ akin to Q U E P ψ, with enhanced peak-stacking correlations, oriented stacks**

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

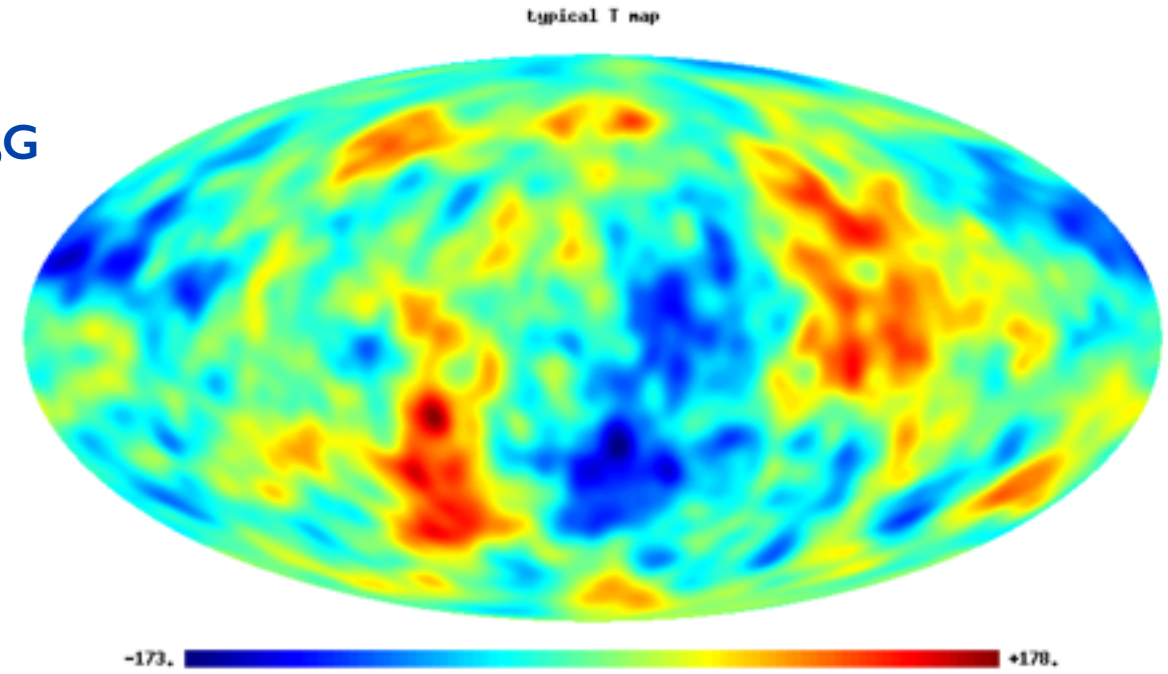
High S/N B-mode detections for r > 0.01 are measured in independent frequency bands (90 & 150 GHz) and on many patches across the sky.

This provides important cross-checks on any detected signal

Also shown:

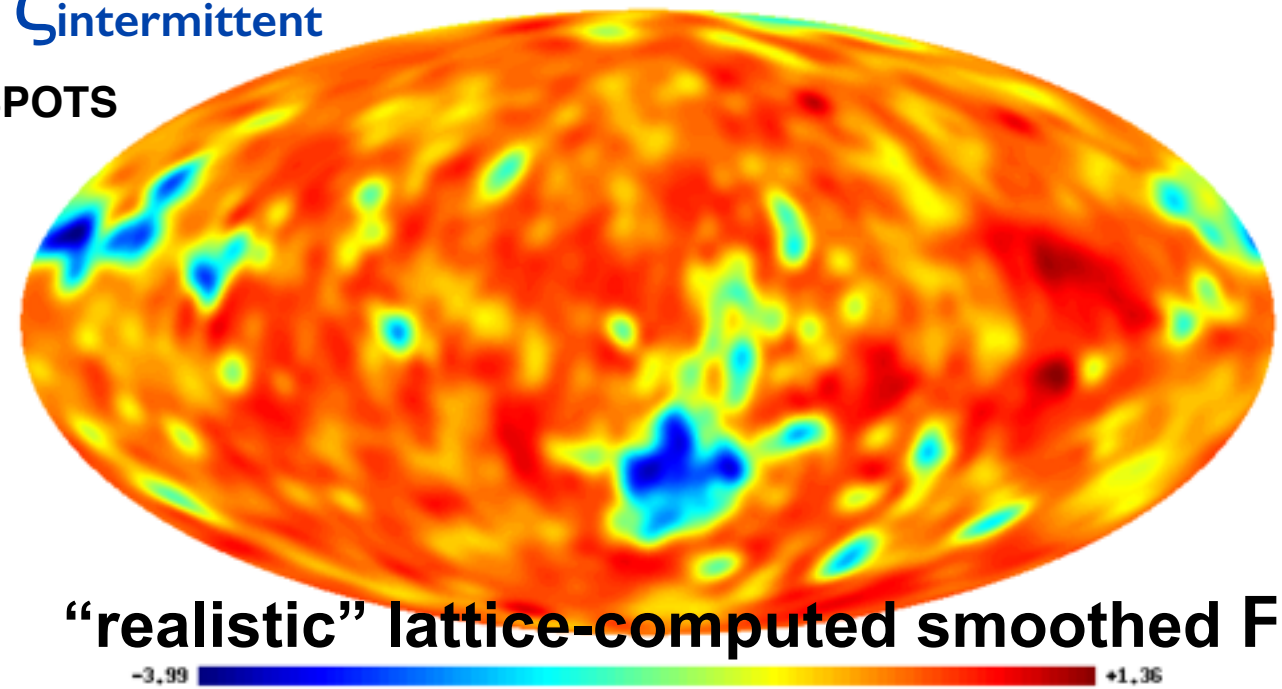
- Error bars before and after foreground cleaning
- Varying amplitudes of the gravitational lensing signal for different values of the sum of the neutrino masses
- Planck forecasts

T from ζ_G



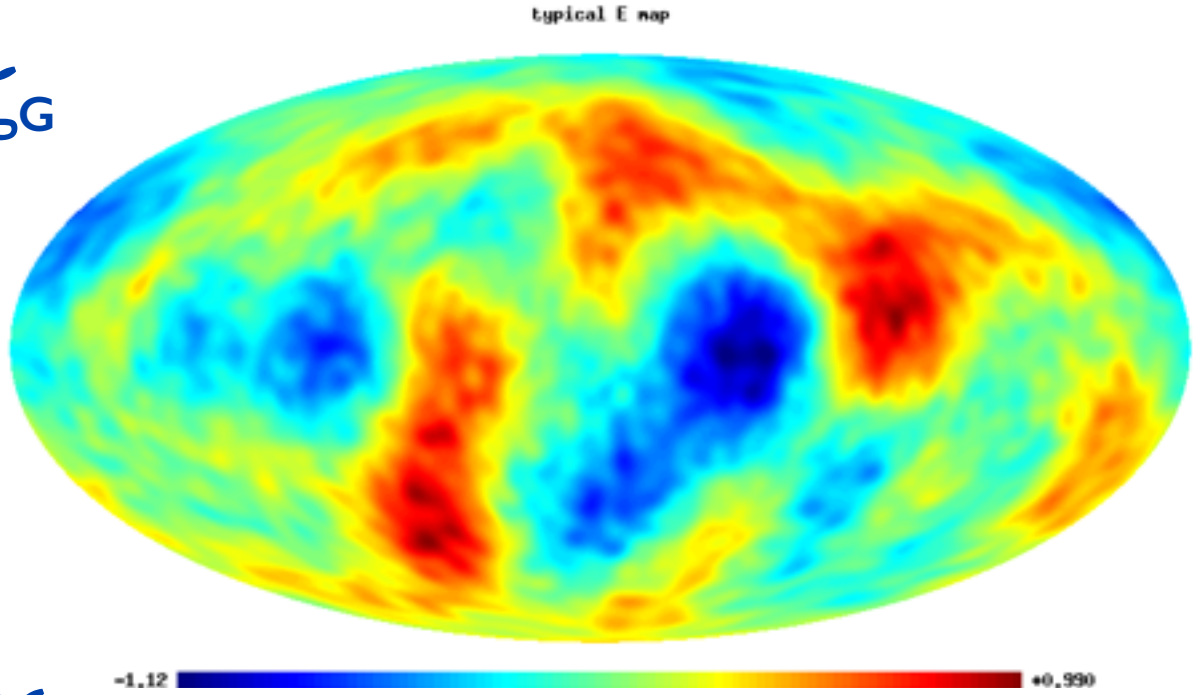
T from $\zeta_{intermittent}$

T COLD SPOTS



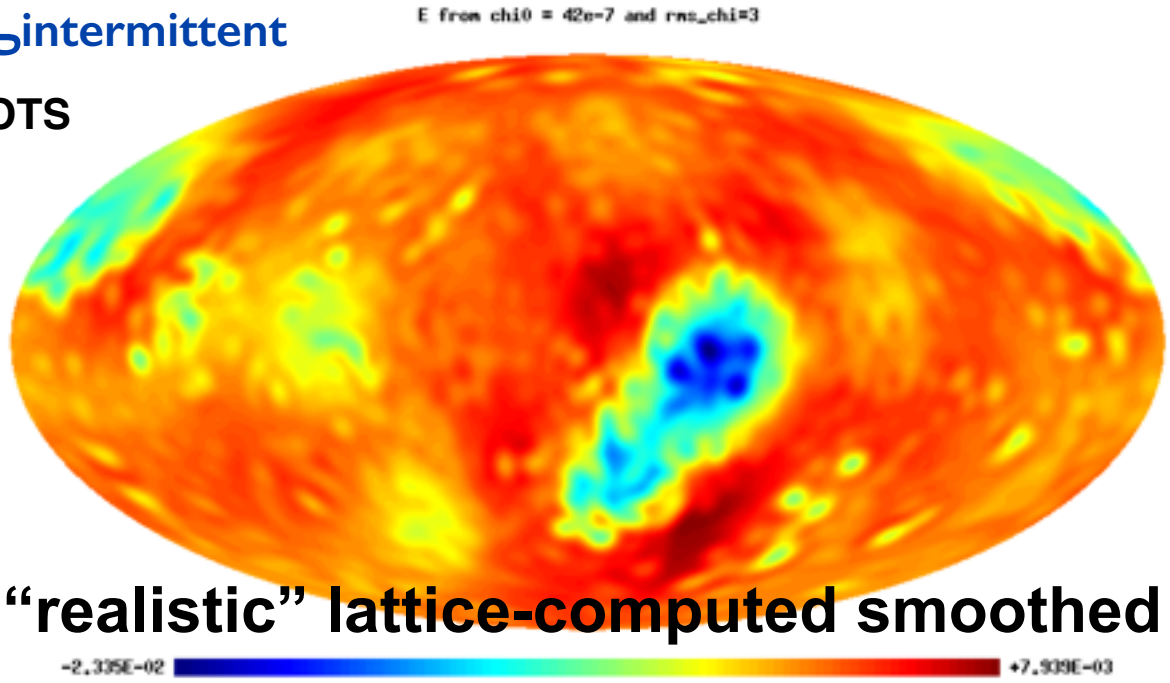
"realistic" lattice-computed smoothed F_{NL}

E from ζ_G



E from $\zeta_{intermittent}$

E COLD SPOTS



"realistic" lattice-computed smoothed F_{NL}

esa

planck

cnes

agenzia spaziale italiana

NASA

cnrs

DTU Space
National Space Institute

Science & Technology Facilities Council

INAF ISTITUTO NAZIONALE DI ASTROFISICA

CSIC
Consejo Superior de Investigaciones Científicas

National Research Council of Italy

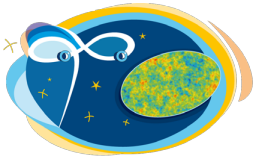
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

CSA ASC

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.

UK SPACE AGENCY

MAX-PLANCK-GESELLSCHAFT



PLANCK LFI

HFI PLANCK
a look back to the birth of Universe

IAS orsay

IAP

INAF - IASF BO
ISTITUTO NAZIONALE DI ASTROFISICA
ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA DI BOLOGNA

Aalto University

ioa

KICC Kavli Institute for Cosmology Cambridge

Cavendish Astrophysics

University of Cambridge

Cardiff University
Prifysgol Caerdydd

irfu
saclay

CEFCA

CESR

CITA–ICAT

IASF

cnrs INSU
Observer & comprendre

cnrs IN2P3
Les deux infinis

ipac

Helsinki Institute of Physics

Instituto de Astrofísica de Canarias

IFCA
Instituto de Física de Cantabria

Imperial College London

Università degli Studi di Milano

NÉEL institut

IPAG
Institut de Planétologie et d'Astrophysique de Grenoble

ISDC
Data Centre for Astrophysics

JPL

Laboratoire de l'Accélérateur Linéaire

l'Observatoire de Paris — LERMA

LPSC Grenoble
Laboratoire de Physique Subatomique et de Cosmologie

The University of Manchester

MilliLab

Max-Planck-Institut für Astrophysik

NUI Maynooth

INAF Osservatorio Astronomico di Padova

University of Oxford

Dipartimento di Fisica Sapienza Università di Roma

Science & Technology Facilities Council
Rutherford Appleton Laboratory

Università Tor Vergata

Osservatorio Astronomico di Trieste

UBC

UC Universidad de Cantabria

UCSB

SISSA

ALMA

ESO

University of Sussex

Haverford

esa

University of Helsinki

Université de Genève

University of Toronto

Université de Paris-Sud XI

asdc
ASI Science Data Center

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

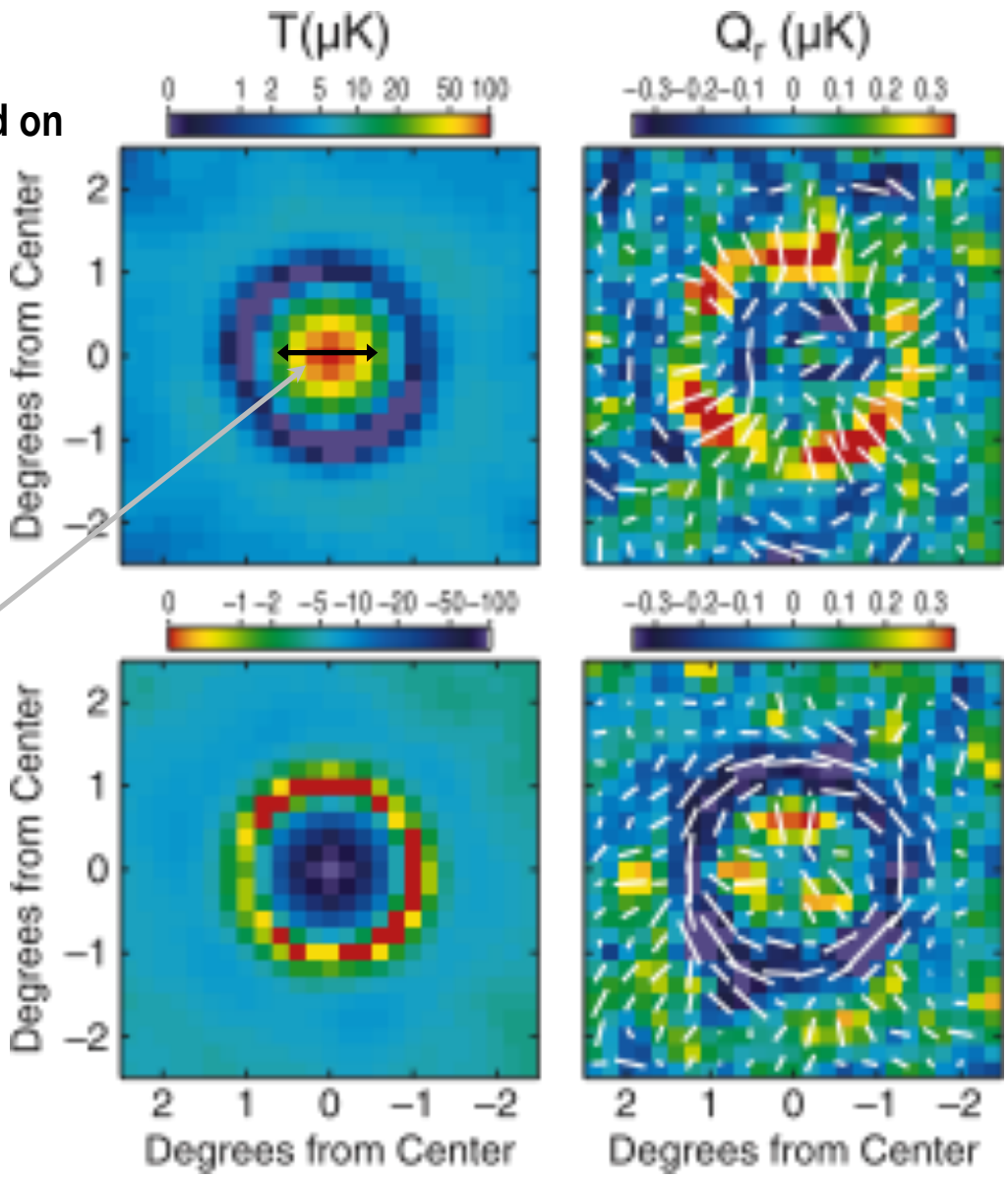
CMB Peak Statistics

temperature stacked on temperature Peaks

polarization rotated & stacked on temperature Peaks

CMB Polarization

BAO in the CMB – WMAP9



BAO scale:
145.8 ± 1.2 Mpc

⟷

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

CMB Peak Statistics

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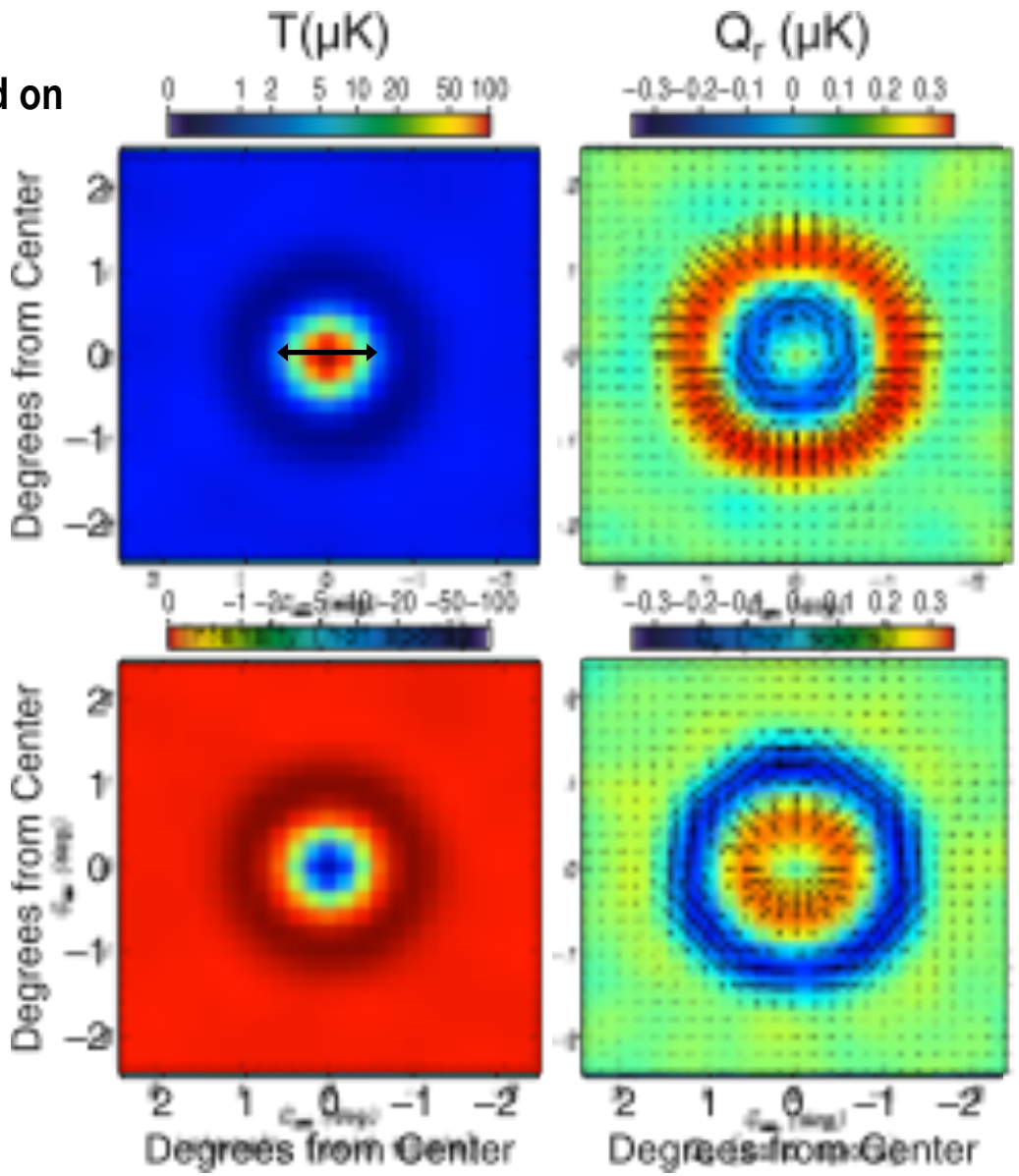
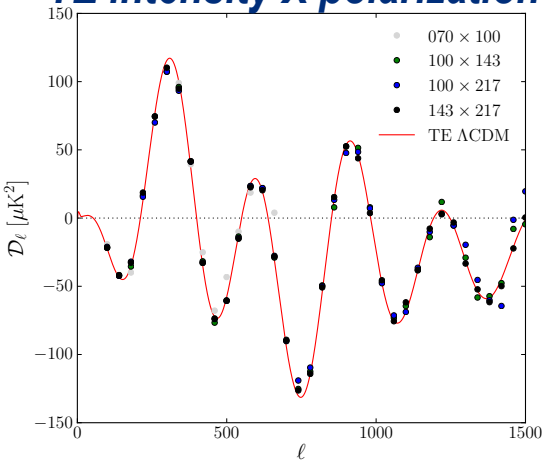
polarization rotated & stacked on temperature Peaks

CMB Polarization

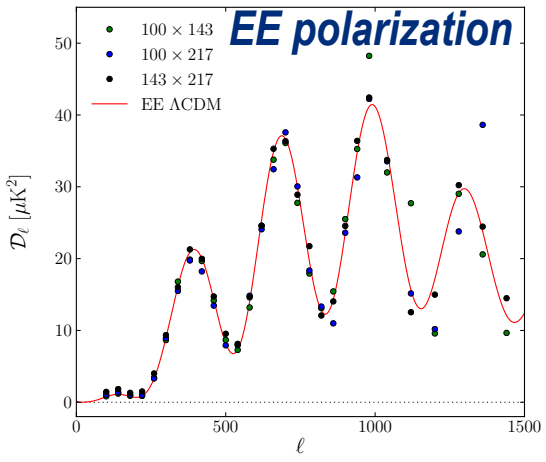
BAO in the CMB – Planck2013



TE intensity X polarization



EE polarization



Planck2013 teaser for Planck2014 polarization release

E mode patterns

no B here

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

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polarization rotated & stacked on temperature Peaks

BAO scale:
145.8 ± 1.2 Mpc

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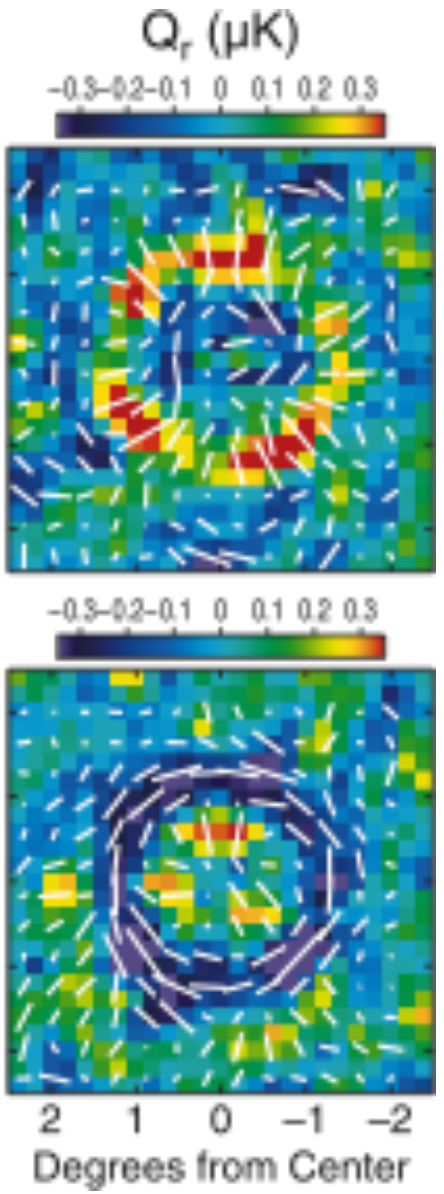
BAO in the CMB – WMAP9



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

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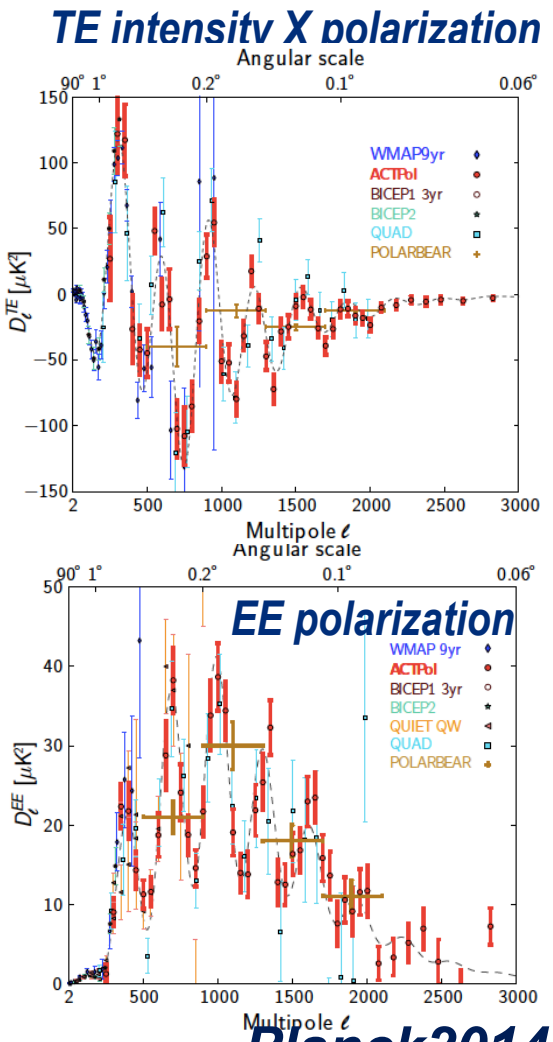
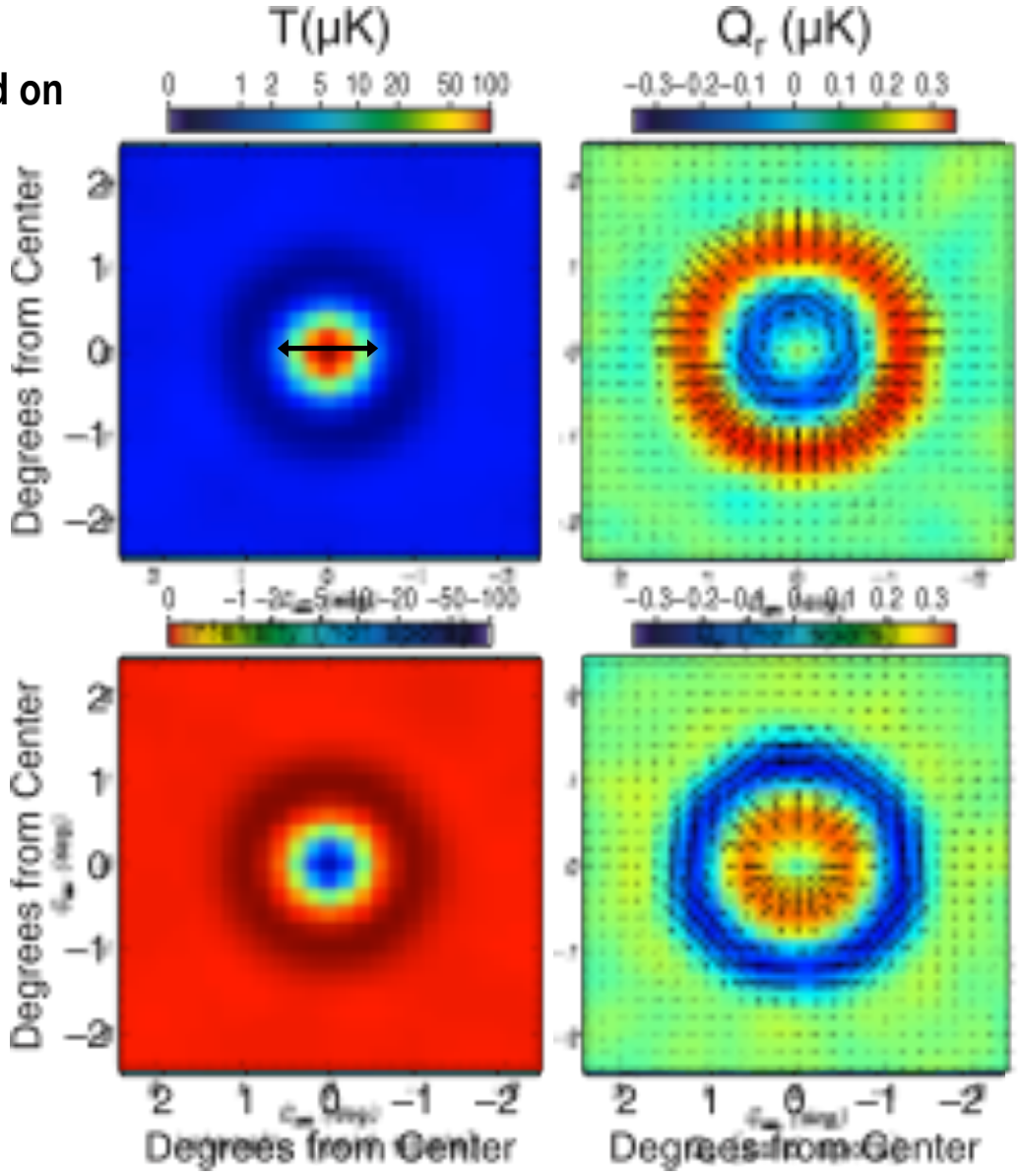


CMB Polarization

BAO in the CMB – Planck2013



Planck2013 teaser for Planck2014 polarization release

E mode patterns

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CMB Peak Statistics

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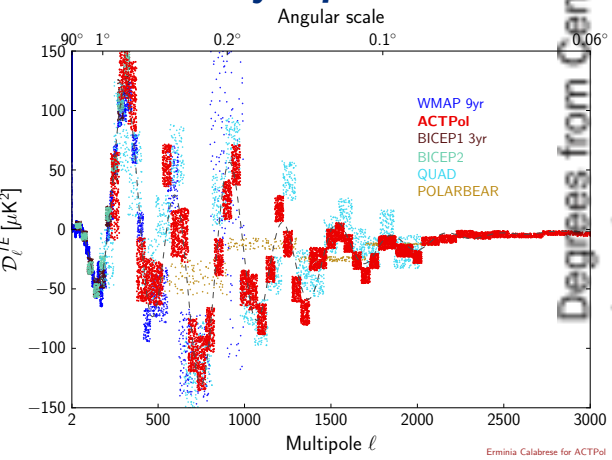
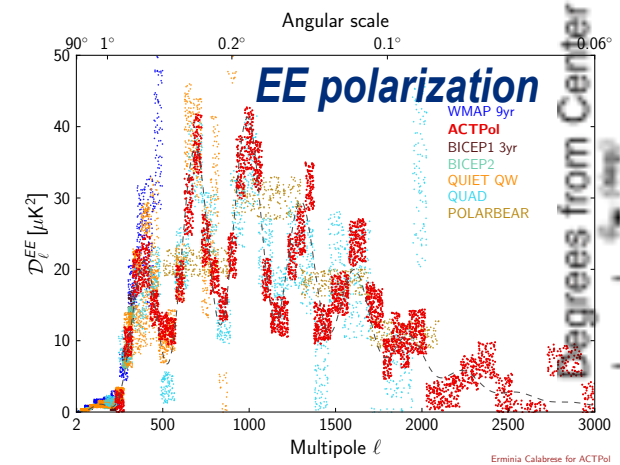
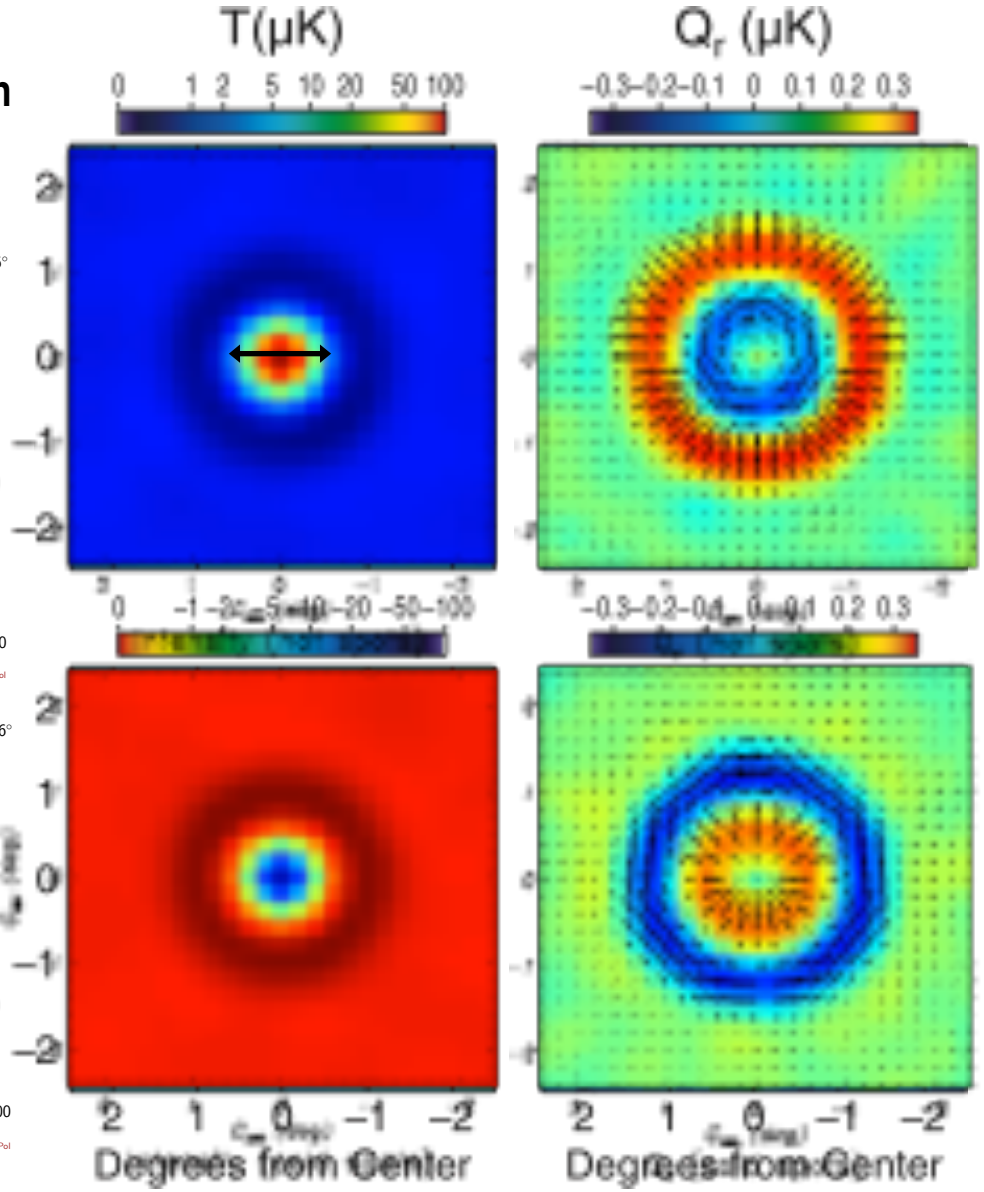
TE intensity X polarization





CMB Polarization

BAO in the CMB – Planck2013



Planck2013 teaser for Planck2014 polarization release

E mode patterns

no B here

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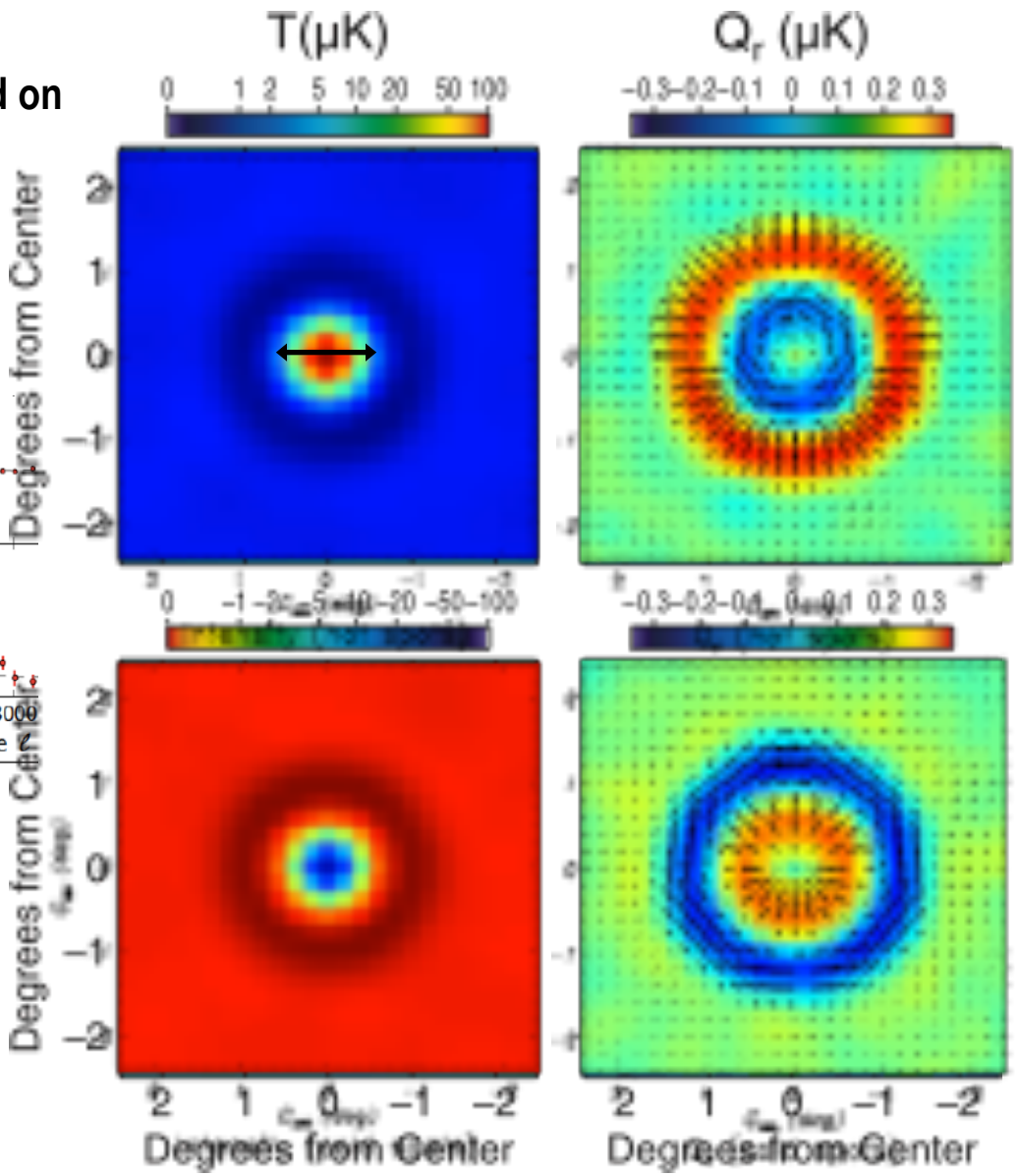
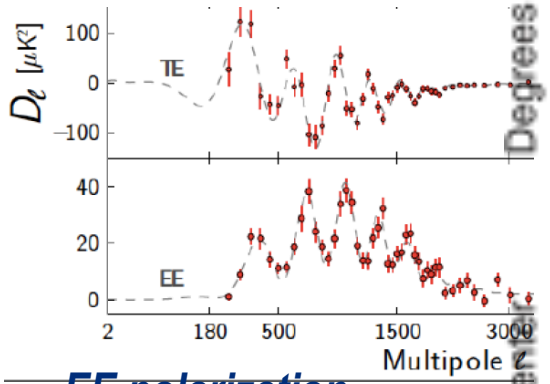
CMB Polarization

BAO in the CMB – Planck2013



TE intensity X polarization



EE polarization

Planck2013 teaser for Planck2014 polarization release

E mode patterns

no B here

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

SIMPLICITY

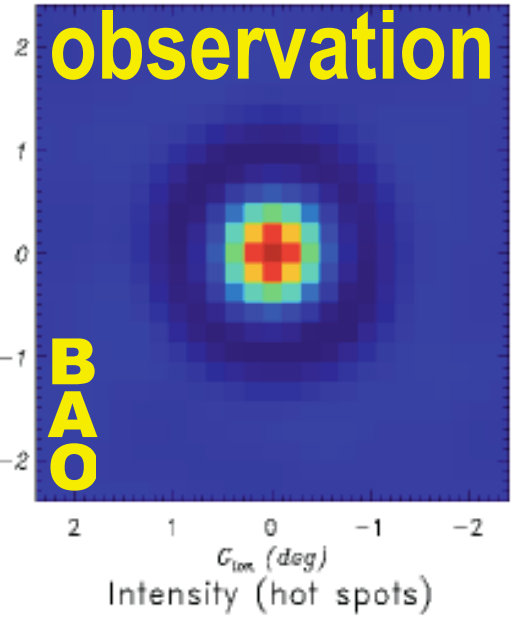
at a~e^{-7}~1/1100 =>

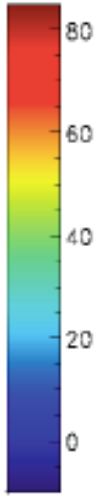
at a~e^{-67+60}~1/10^{30+25}

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

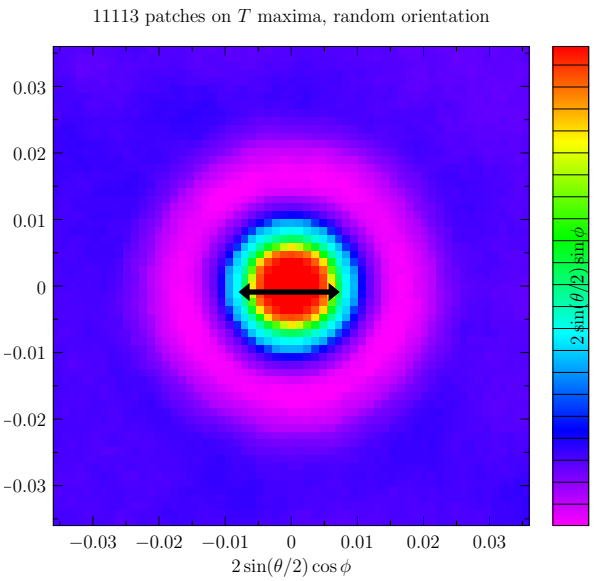
Planck2013

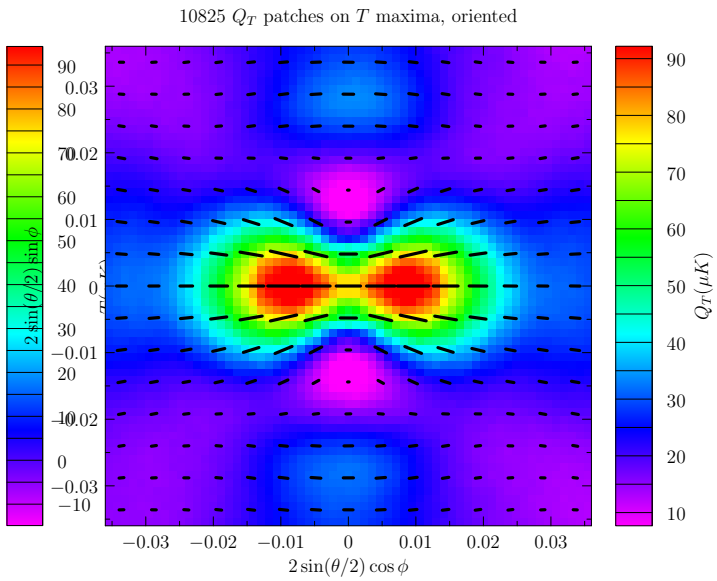
oriented peaks, anisotropic CMB strain

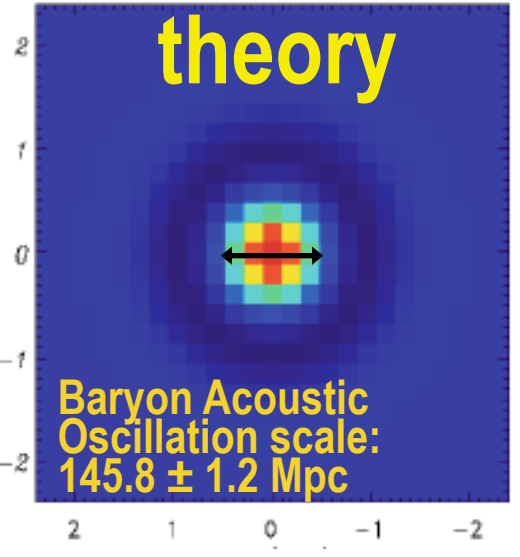


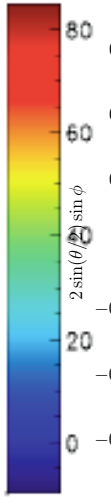


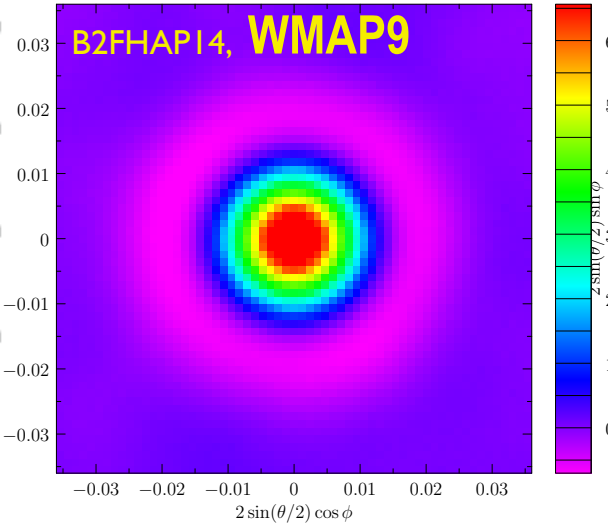
B2FHAP14, Planck2013

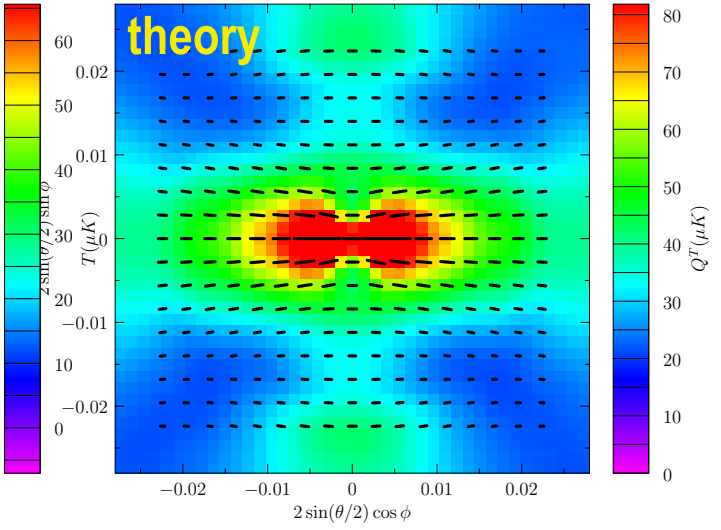








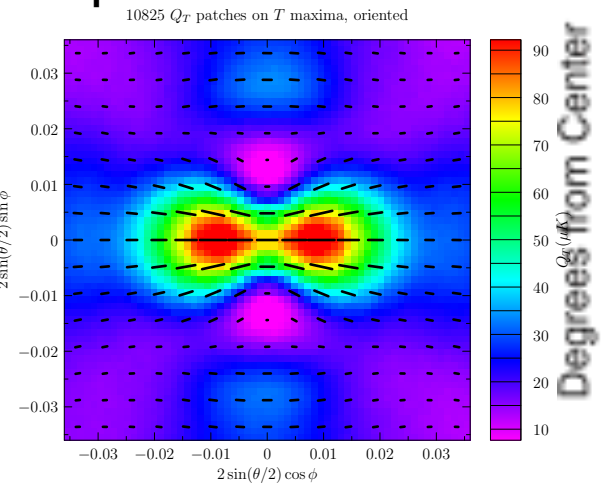


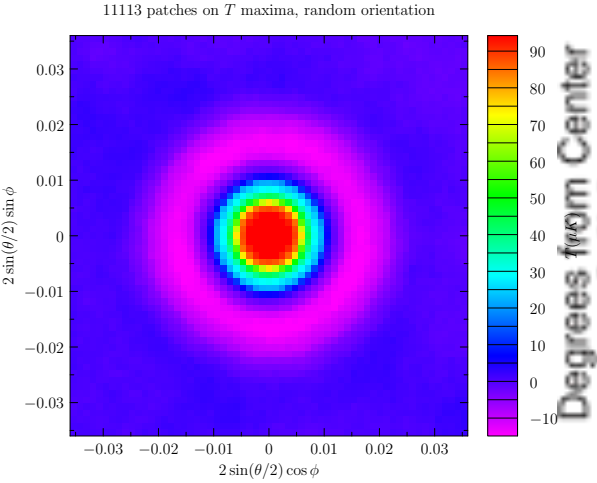


CMB Peak Statistics

temperature stacked on temperature Peaks

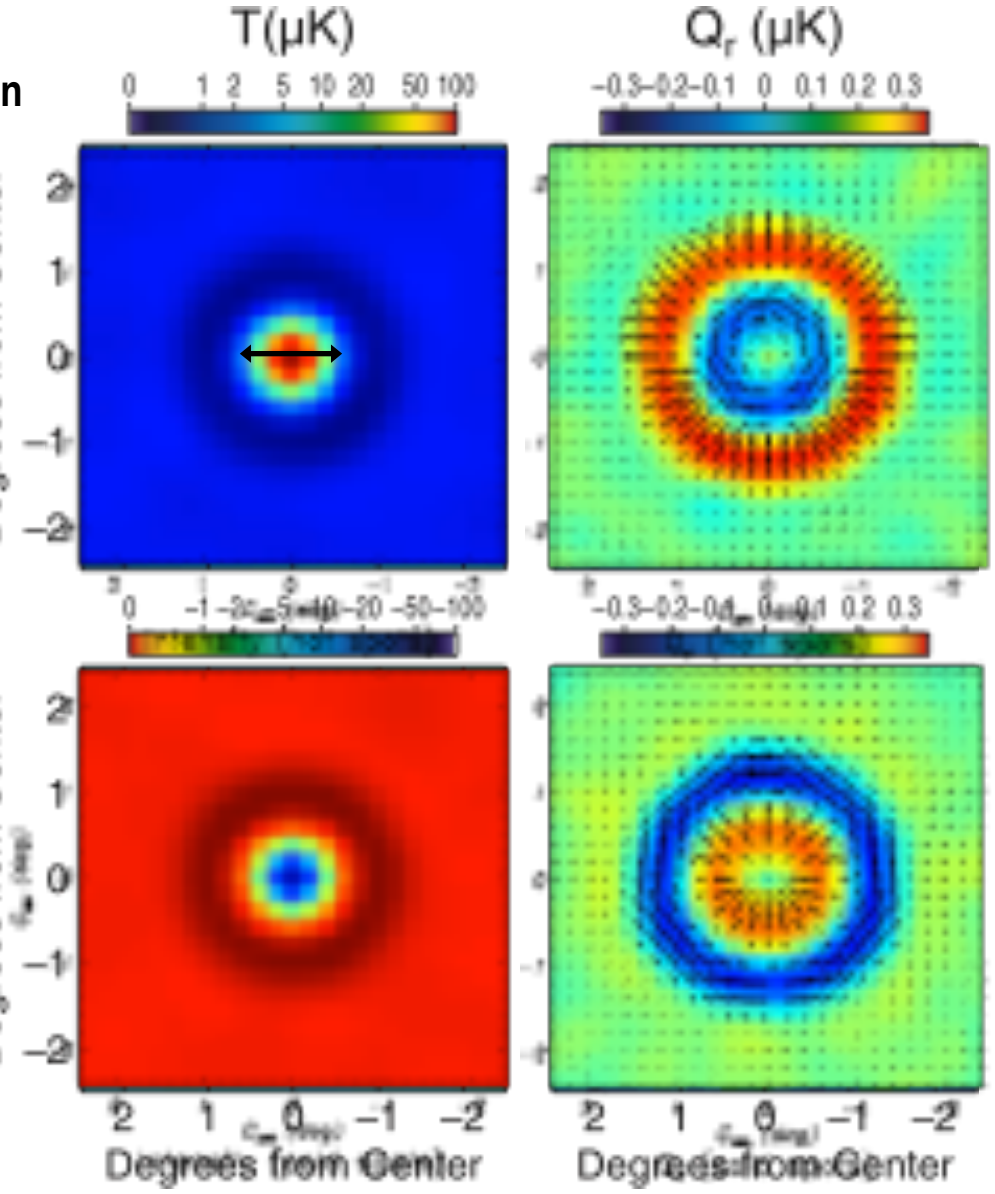
polarization rotated & stacked on temperature Peaks





CMB Polarization

BAO in the CMB – Planck2013



Planck2013 teaser for Planck2014 polarization release

E mode patterns

no B here

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

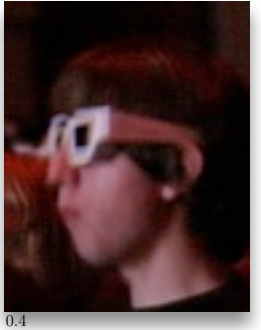
CMB Peak Statistics

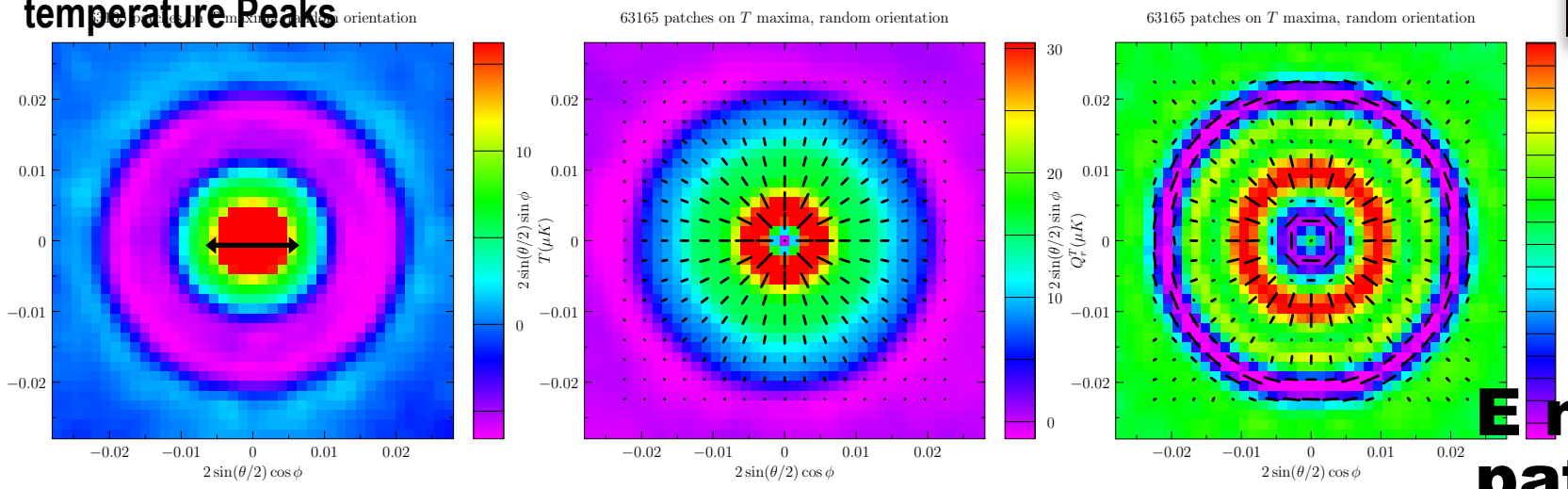
temperature stacked on temperature Peaks
polarization rotated & stacked on temperature Peaks

CMB Polarization

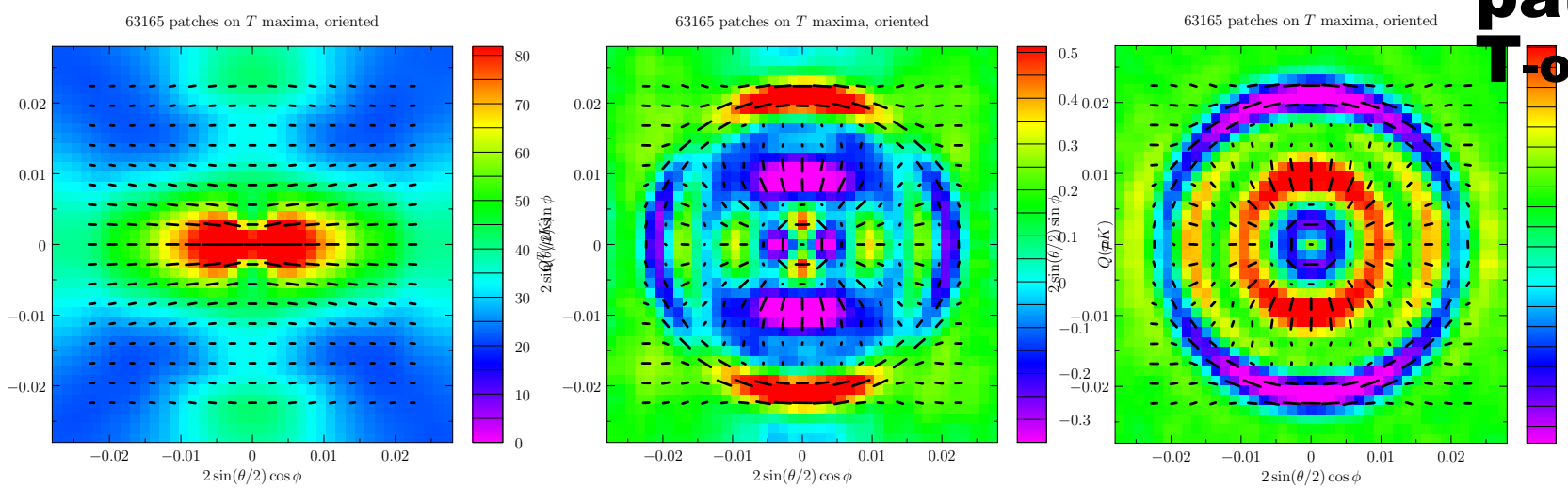
sample temperature and polarization patterns for

Planck2014: oriented peaks





E mode patterns T-oriented



no B here

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

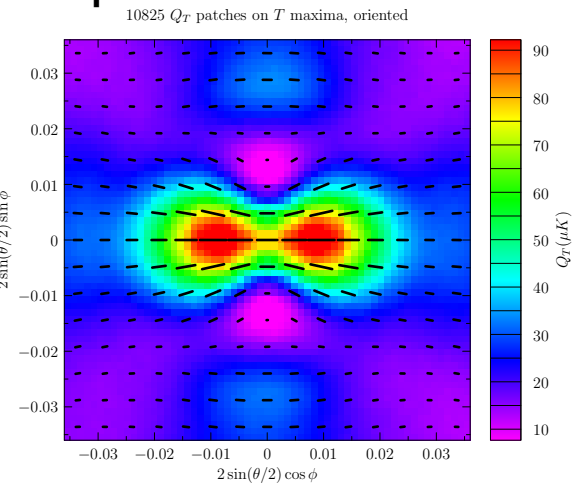
CMB Peak Statistics

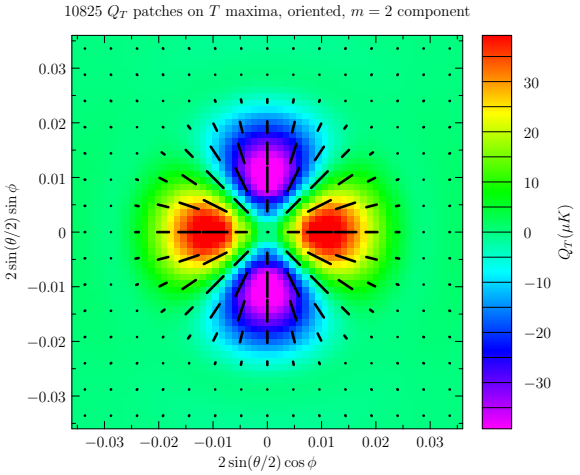
CMB Polarization

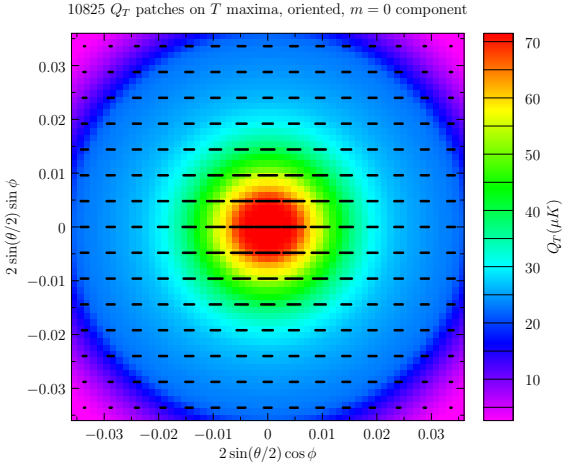
Planck 2013

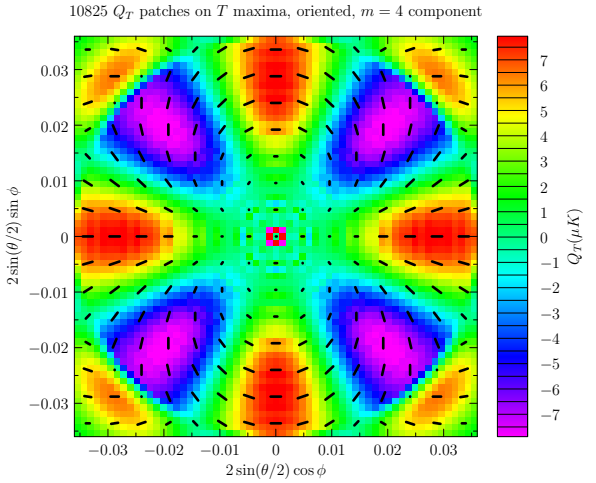
temperature stacked on temperature Peaks

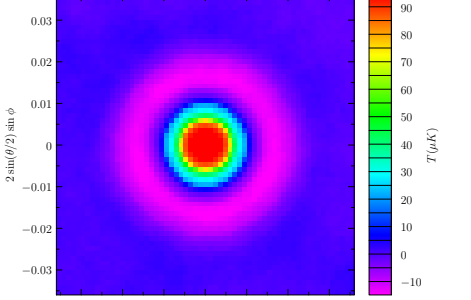
polarization rotated & stacked on temperature Peaks

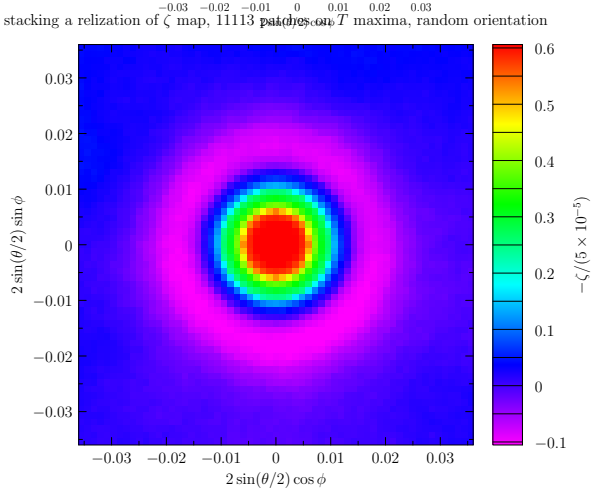


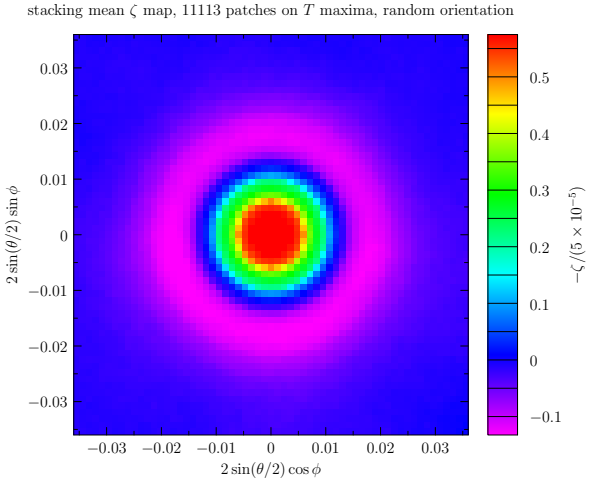












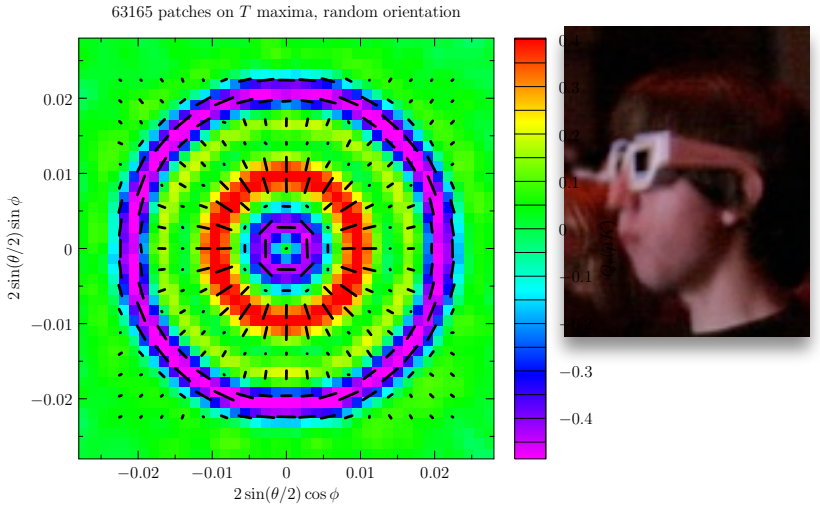
CMB Peak Statistics

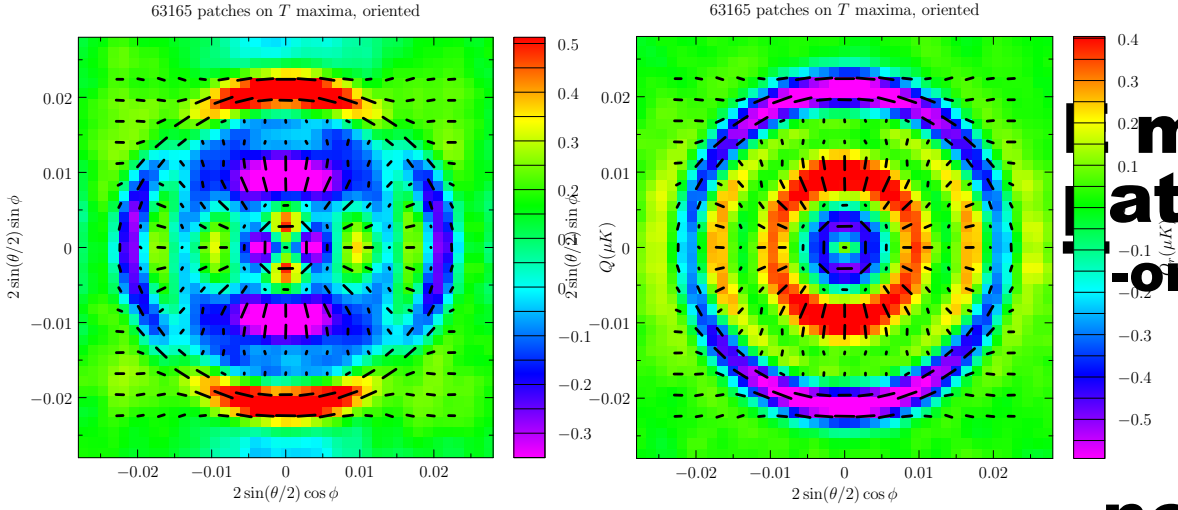
temperature stacked on temperature Peaks
polarization rotated & stacked on temperature Peaks

CMB Polarization

sample temperature and polarization patterns for

Planck2014: oriented peaks





E mode patterns -oriented

no B here

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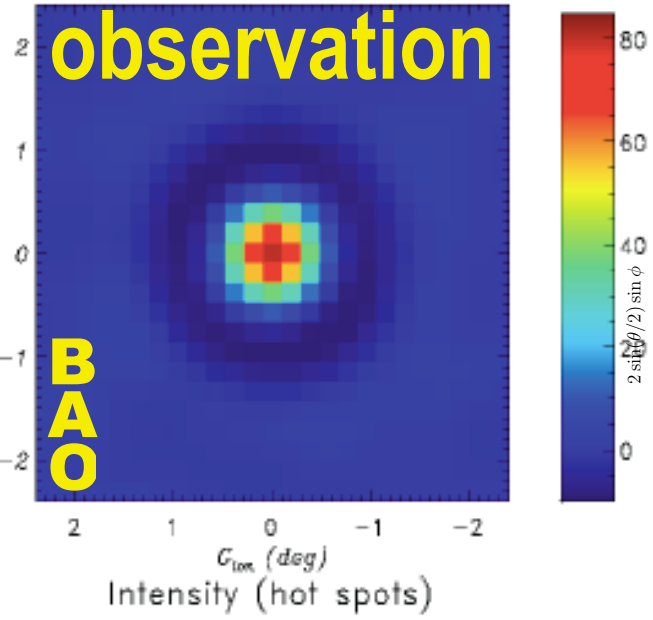
SIMPLICITY

at a~e^{-7}~1/1100 =>

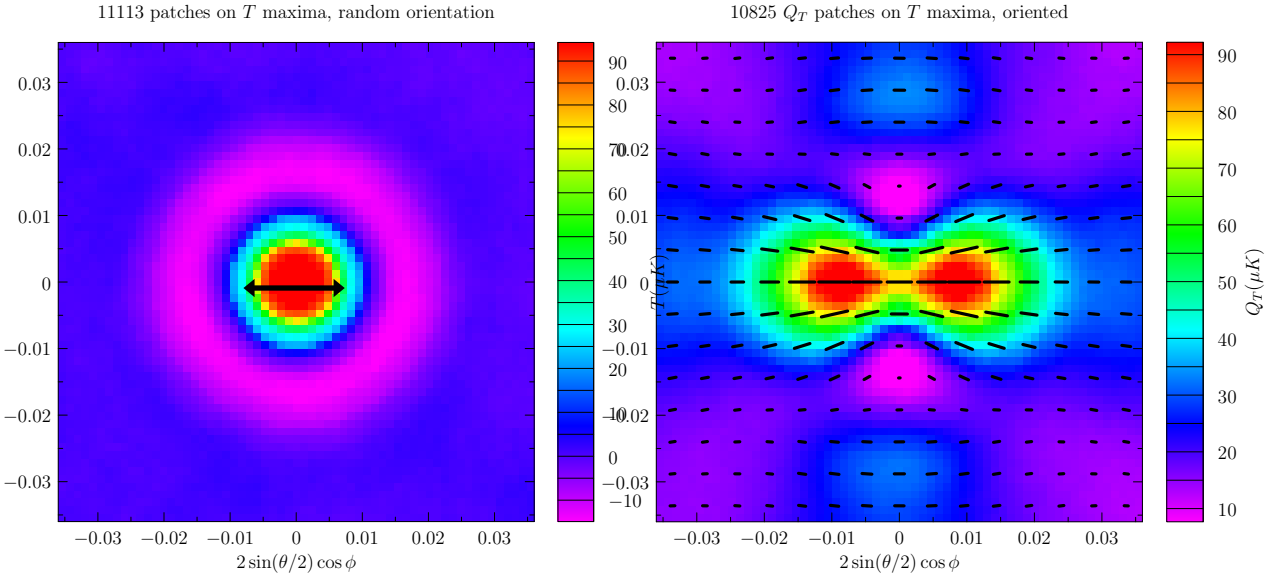
at a~e^{-67+60}~$1/10^{30+25}$

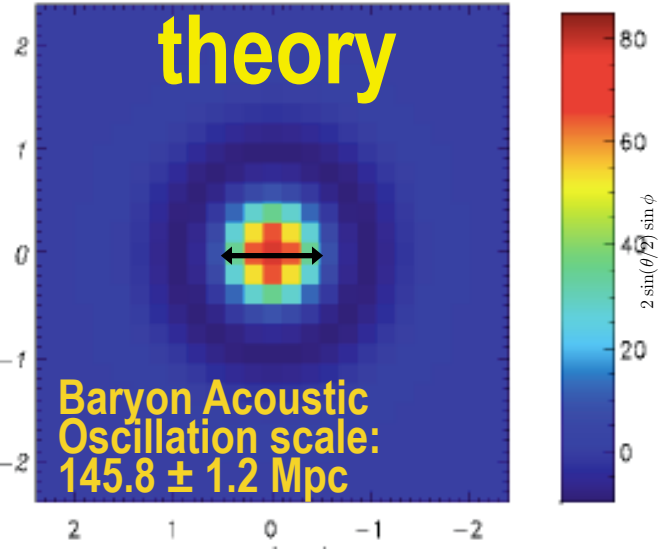
reveals ***primordial sound waves*** *in matter*

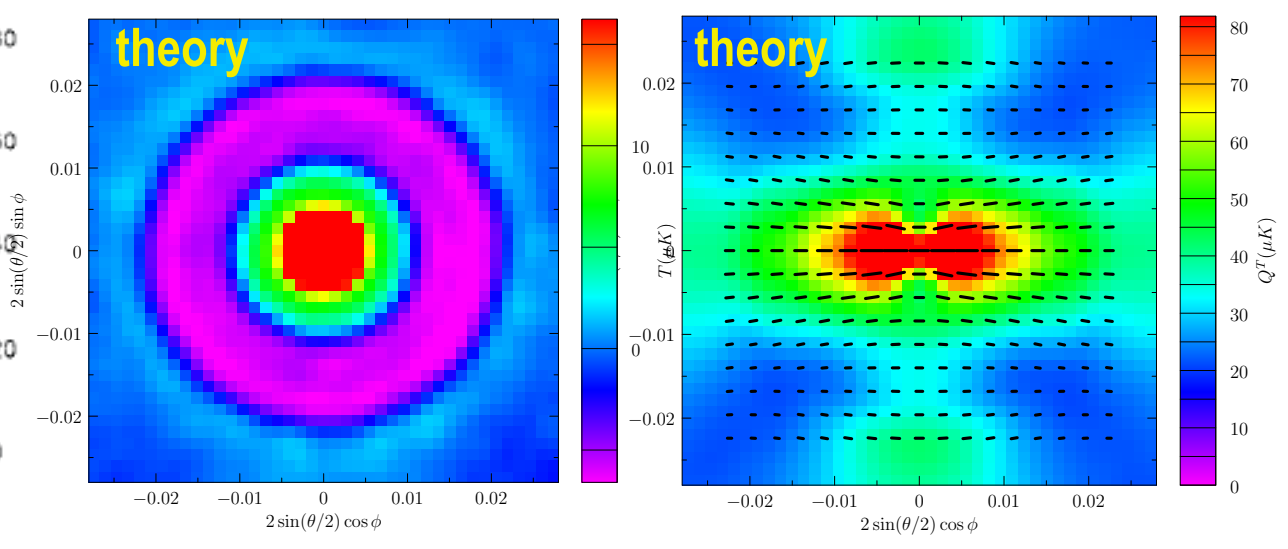


B2FHAP14, Planck2013

oriented peaks, anisotropic CMB strain

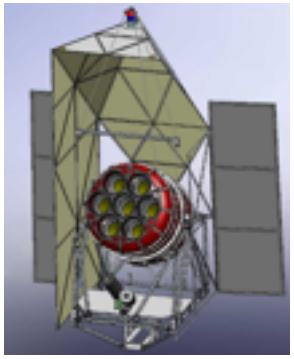


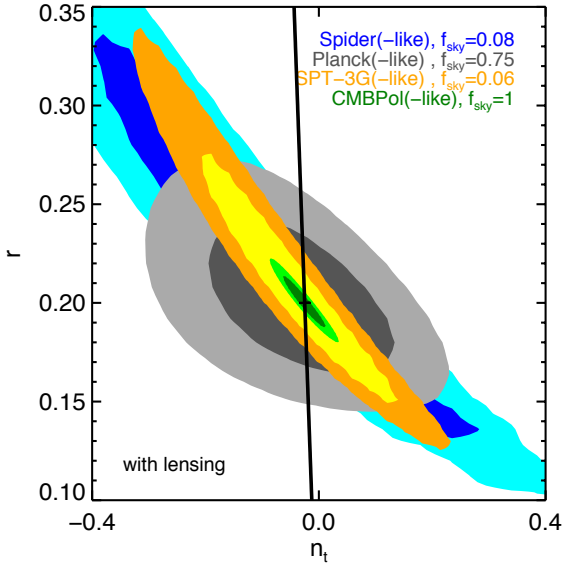


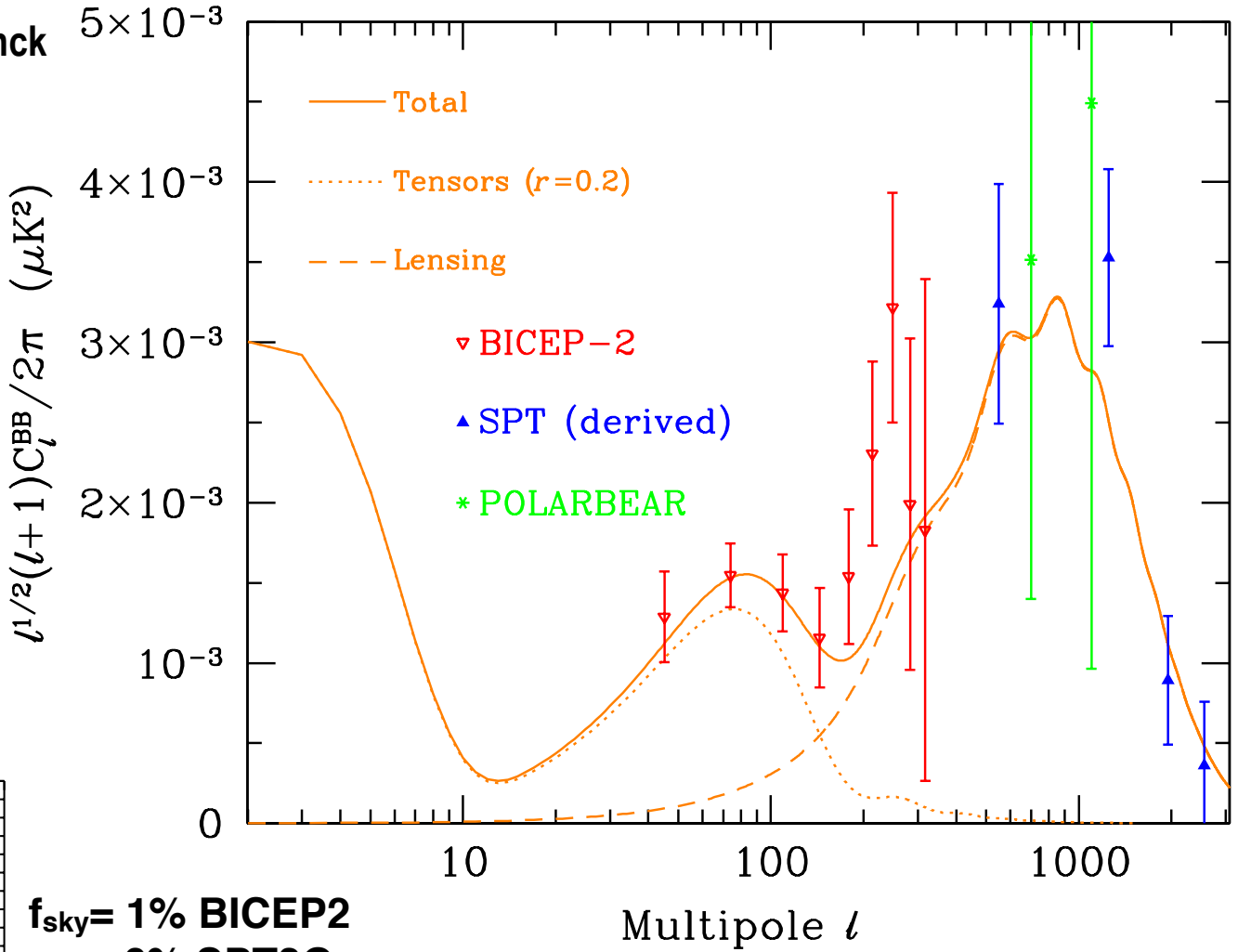


We are working heavily on Planck polarization, E Nov 2014, B ?

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)

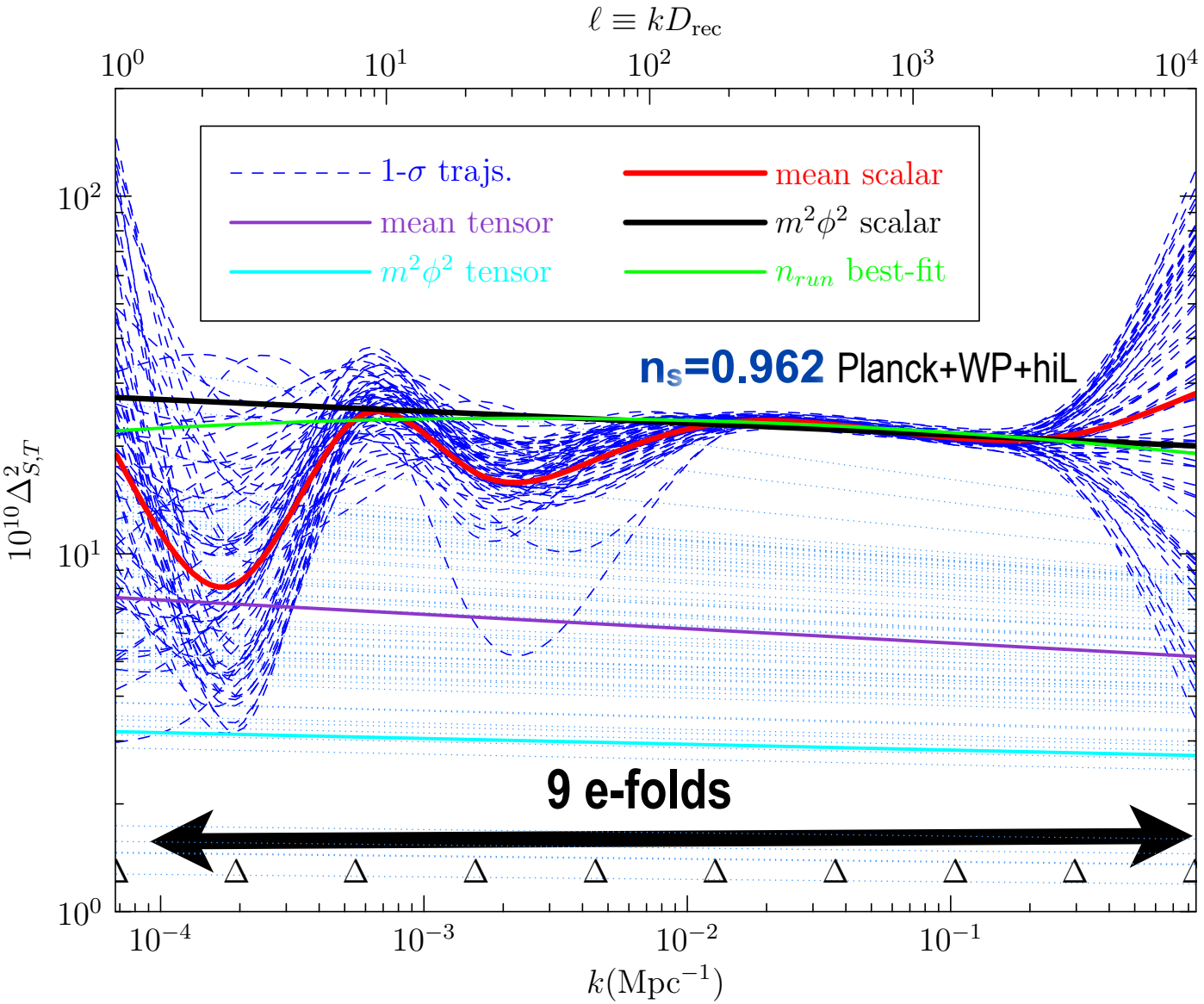
*similar r-forecasts for **ABS+, Keck, AdvACT,..***

*scan ln**P**s(lnk)/As, ln**As**=lnPs(kpivot,s), **r**(kpivot,t); consistency => reconstruct* **ε(ln*Ha*), V(ψ)**

ln*P*s(ln*k*)

new parameters:

trajectory probabilities for early-inflatons



Bond, Braden, Huang, Frolov,2014

PS: running of PS is a bad fit

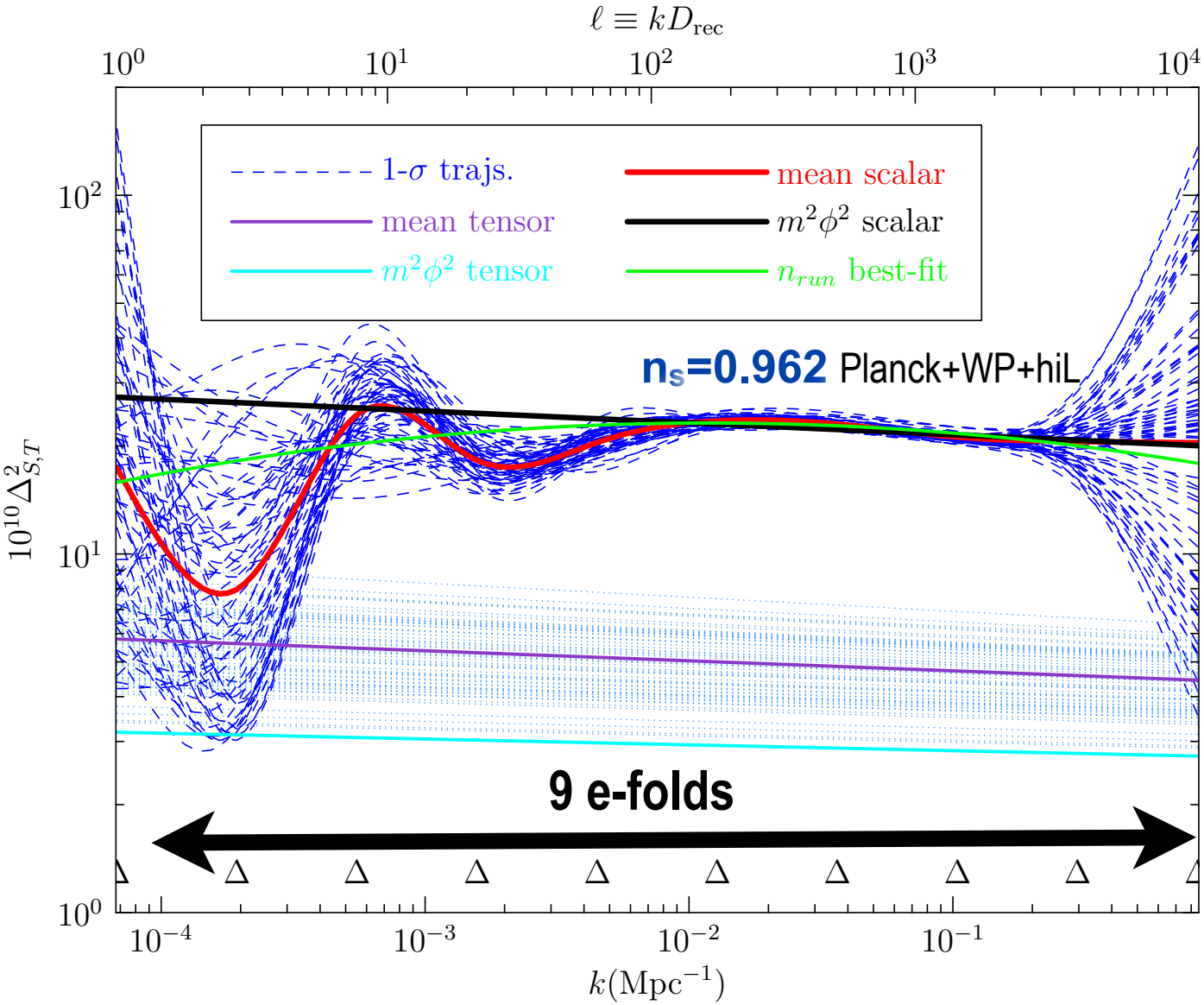
Inflation Histories
(CMBall+LSS+SN+WL)

*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)**

*ln*P$_s$(*ln*k)

new parameters:

trajectory probabilities for early-inflatons



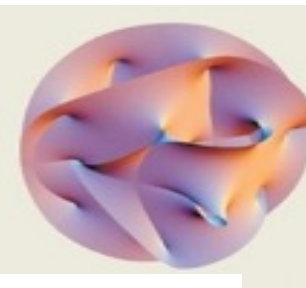
Bond, Braden, Huang, Frolov,2014

PS: running of PS is a bad fit

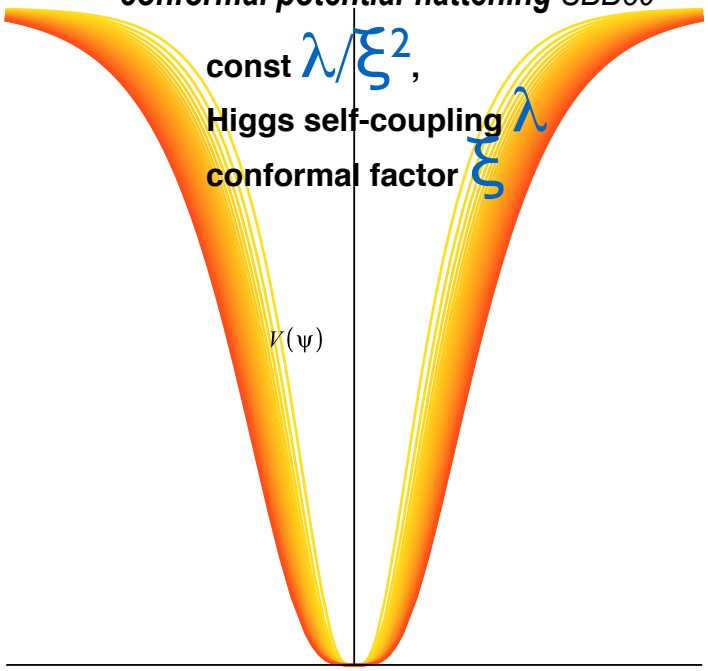
Inflation Histories
(CMBall+LSS+SN+WL)

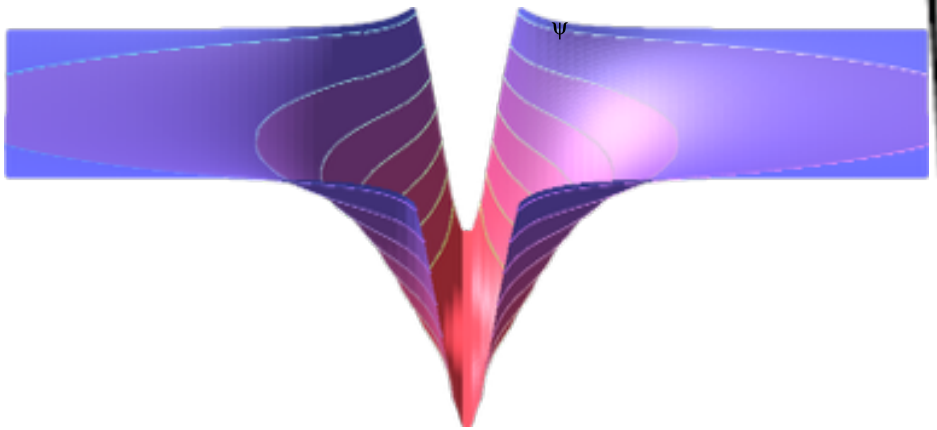
how was *matter & entropy generated at the end of acceleration = inflation*?

Relate it to the Higgs & standard model?



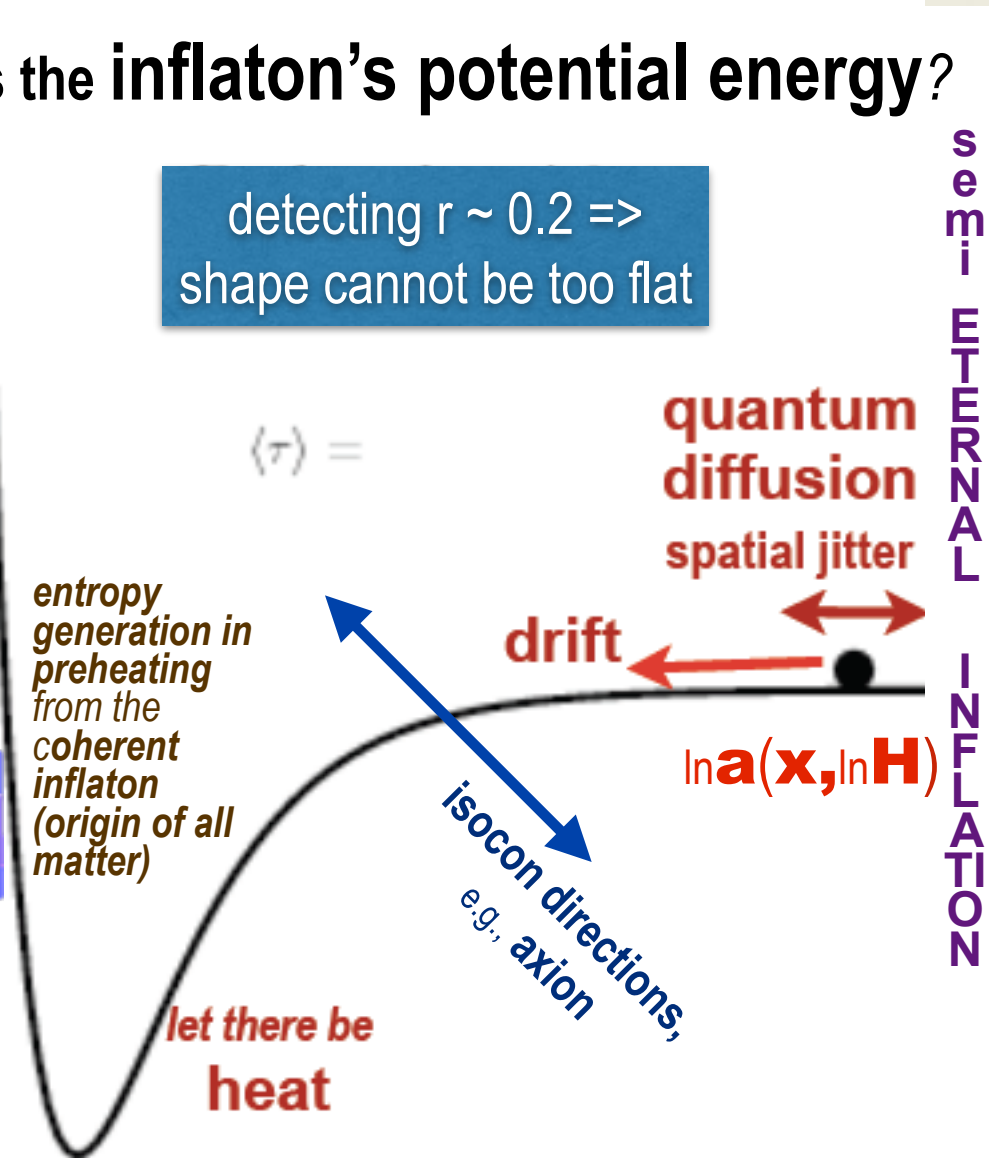
conformal potential-flattening *SBB89*





what is the **inflaton's potential energy**?

detecting r ~ 0.2 =>
shape cannot be too flat



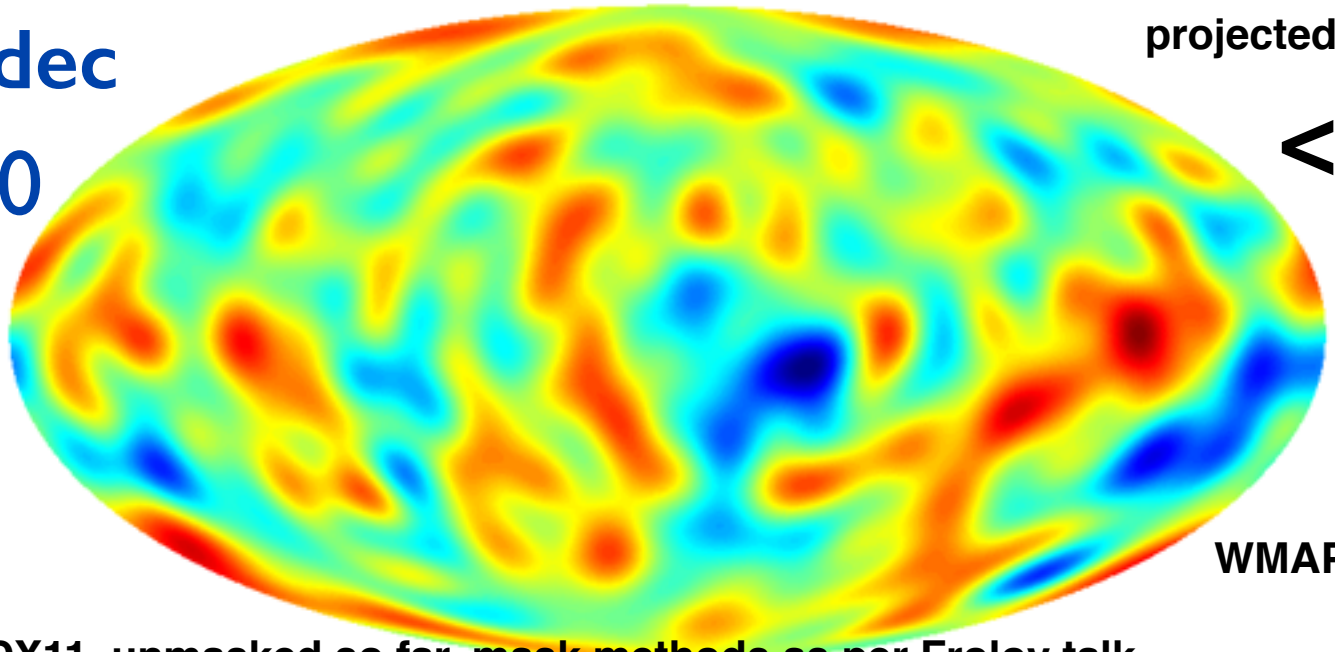
END

$\chi_b=\chi_{dec}$

$L_{cut}=20$

projected curvature map

$\langle\zeta_b|T\rangle$



WMAP T COLD SPOT

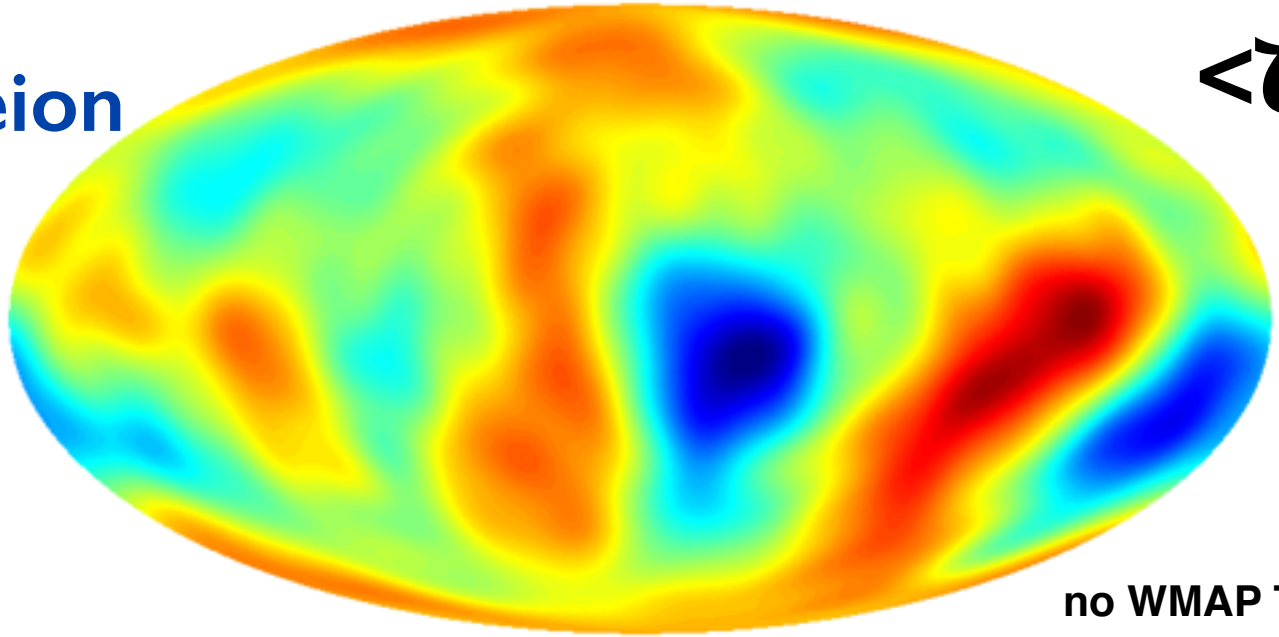
SMICA preDX11, unmasked so far, mask methods as per Frolov talk

-569. +441.

$\chi_b=\chi_{reion}$

$L_{cut}=20$

$\langle\zeta_b|T\rangle$



no WMAP T COLD SPOT

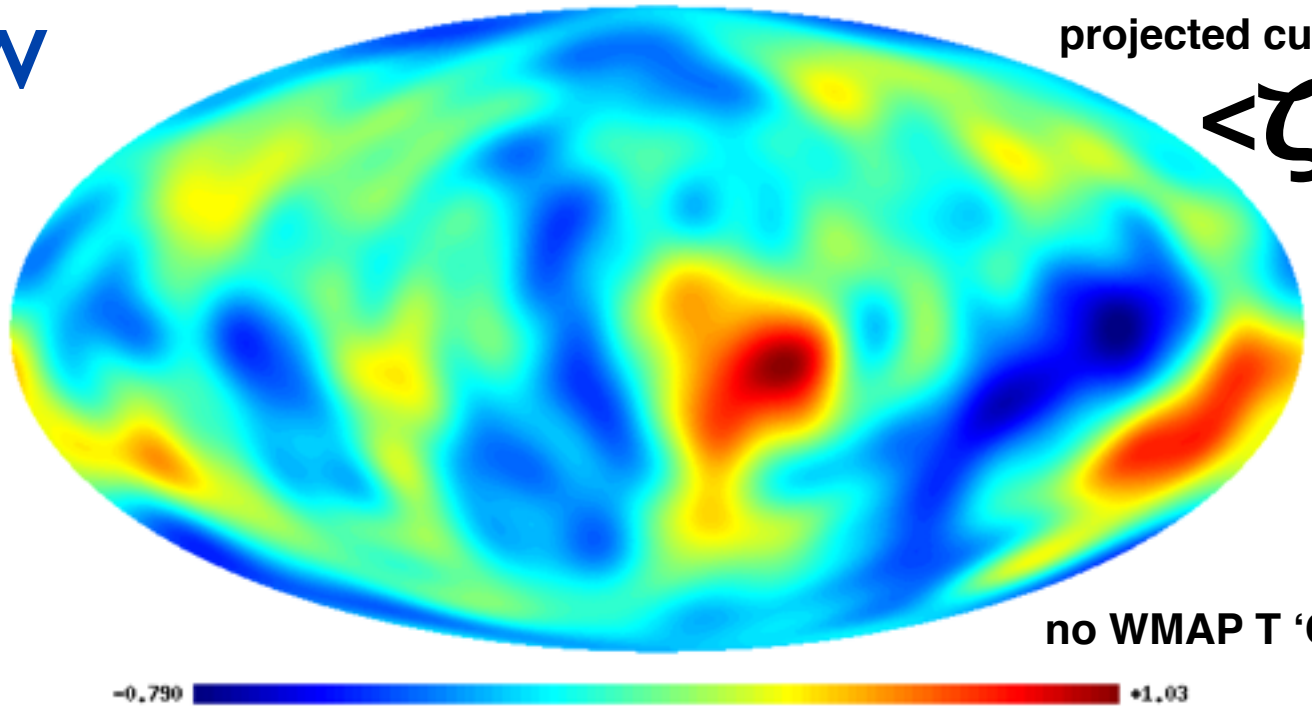
-5.93 +4.24

$\chi_b=\chi_{ISW}$

$L_{cut}=20$

projected curvature map

$\langle\zeta_b|T\rangle$

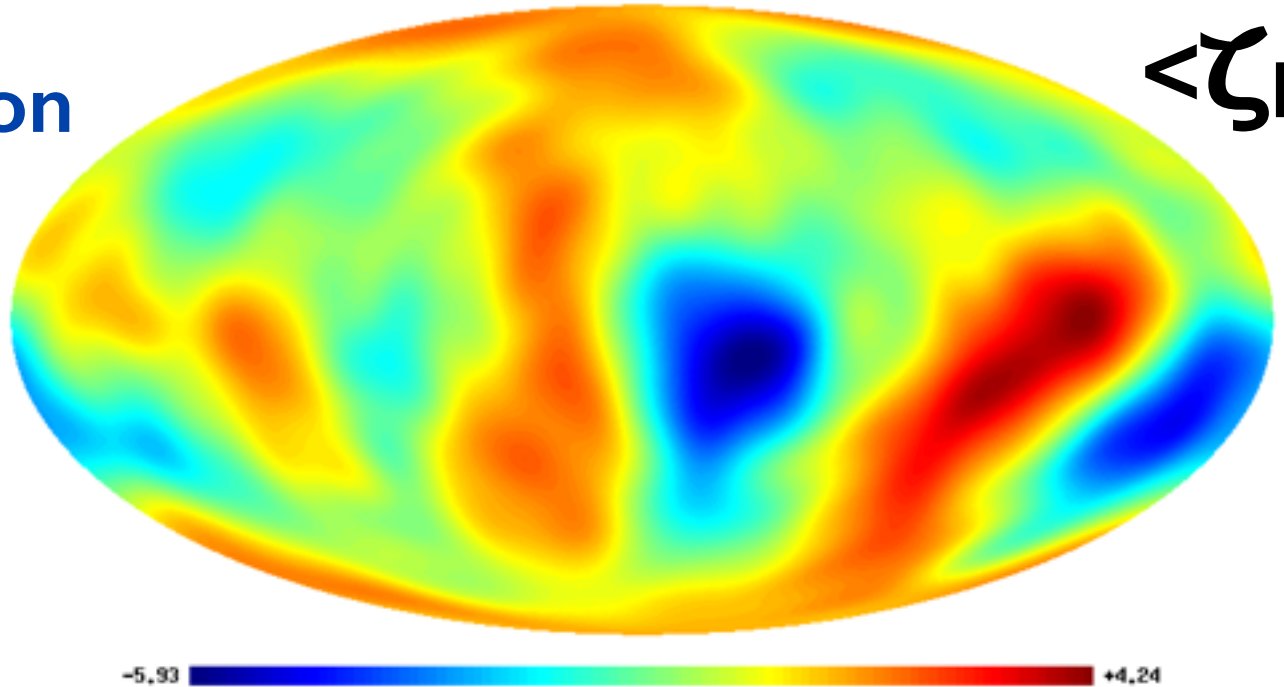


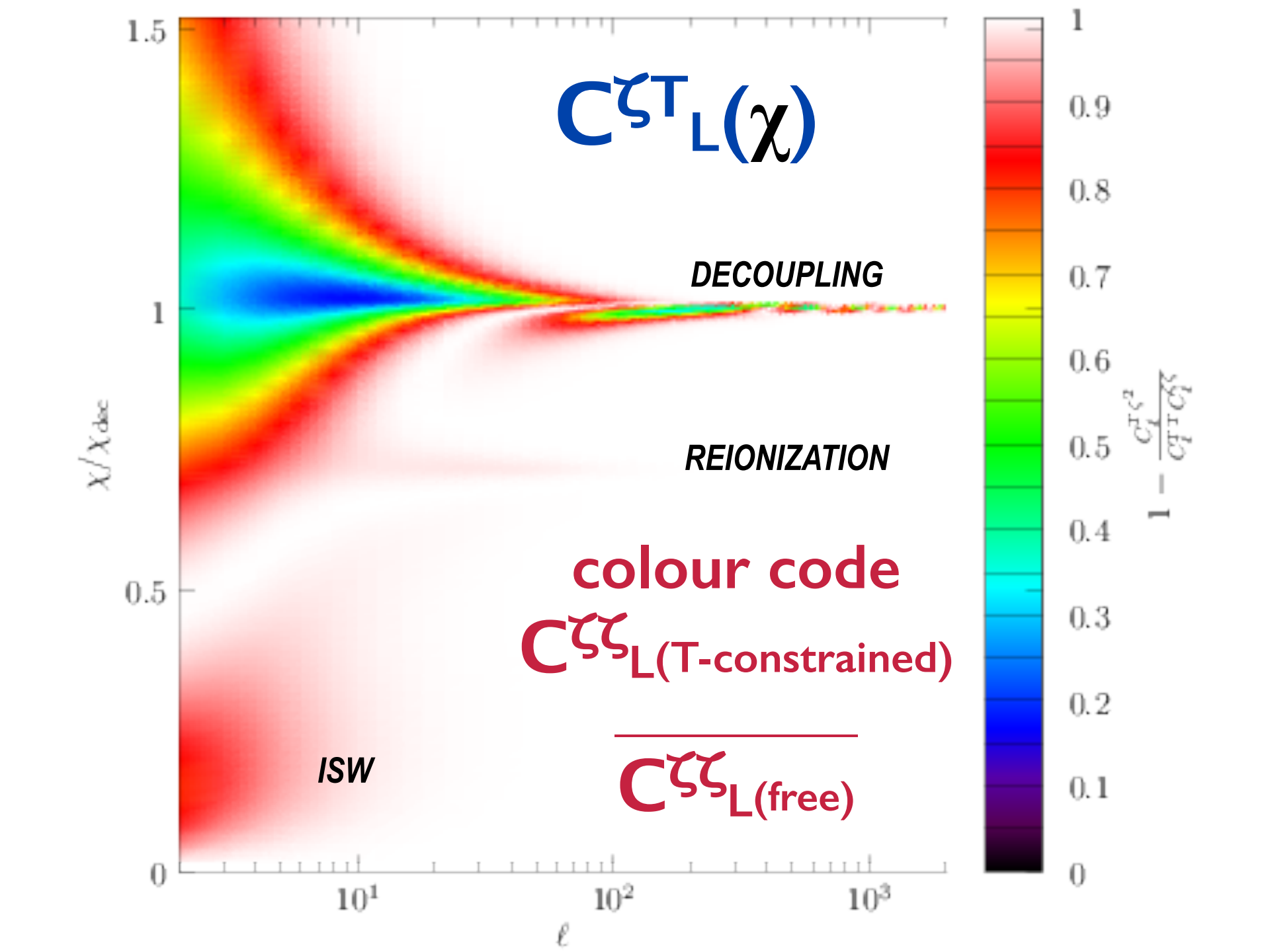
no WMAP T 'COLD' SPOT

$\chi_b=\chi_{reion}$

$L_{cut}=20$

$\langle\zeta_b|T\rangle$



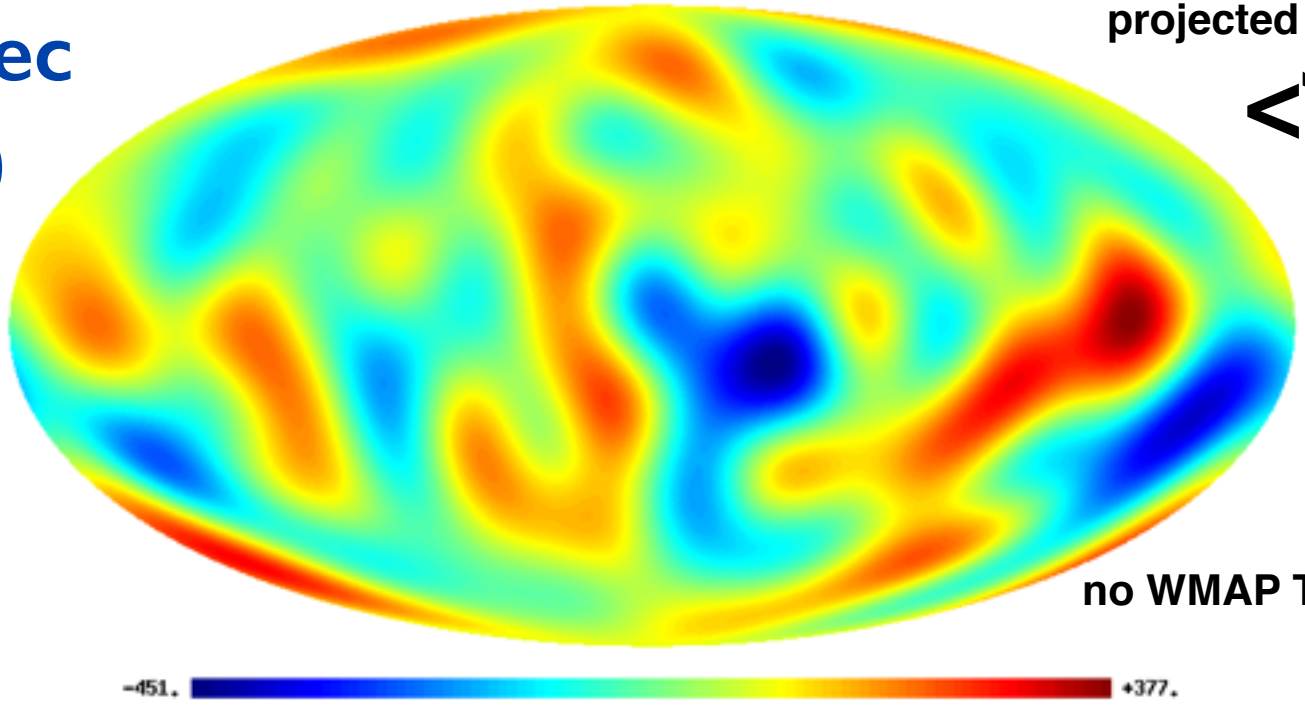

$C^{\zeta T}_L(\chi)$
DECOUPLING
REIONIZATION
ISW
colour code
$C^{\zeta\zeta}_{L\,(\text{T-constrained})}$
$C^{\zeta\zeta}_{L\,(\text{free})}$
$\chi/\chi_{\rm dec}$
ℓ
$\frac{\zeta_{\rm T}\zeta_{\rm T}}{\zeta\zeta}\frac{C^{\zeta^2}_\ell}{C^{\rm T^2}_\ell} - 1$

$\chi_b=\chi_{dec}$

$L_{cut}=10$

projected curvature map

$\langle\zeta_b|T\rangle$

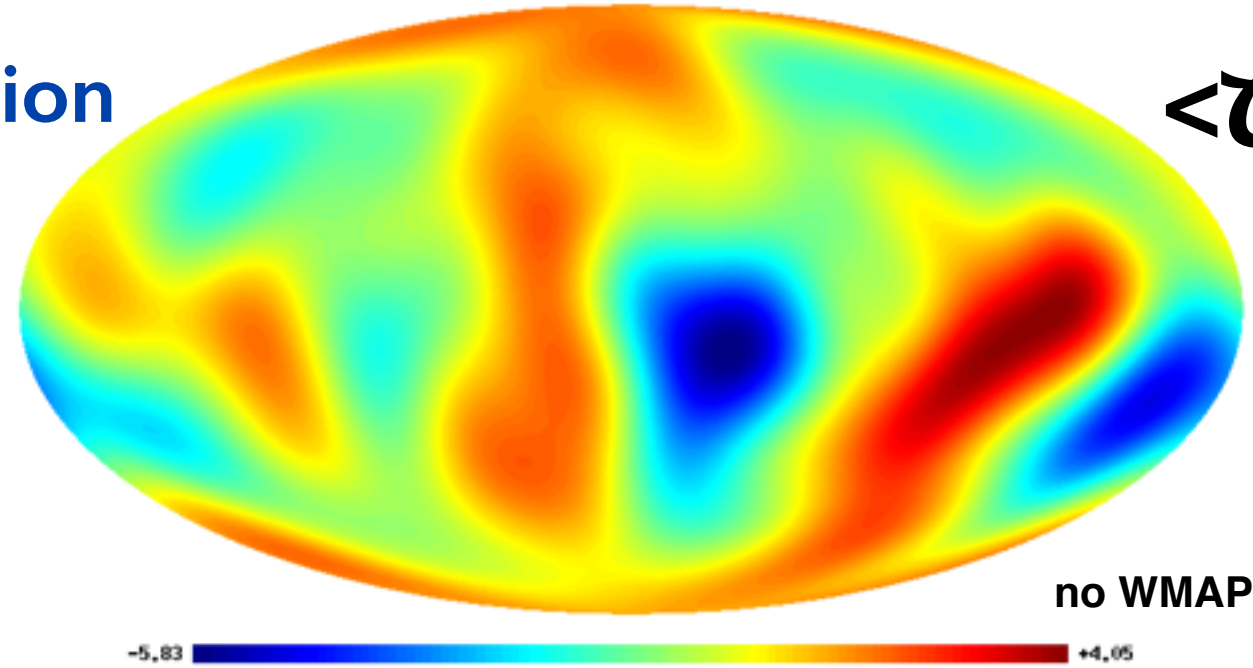


no WMAP T COLD SPOT

$\chi_b=\chi_{reion}$

$L_{cut}=10$

$\langle\zeta_b|T\rangle$



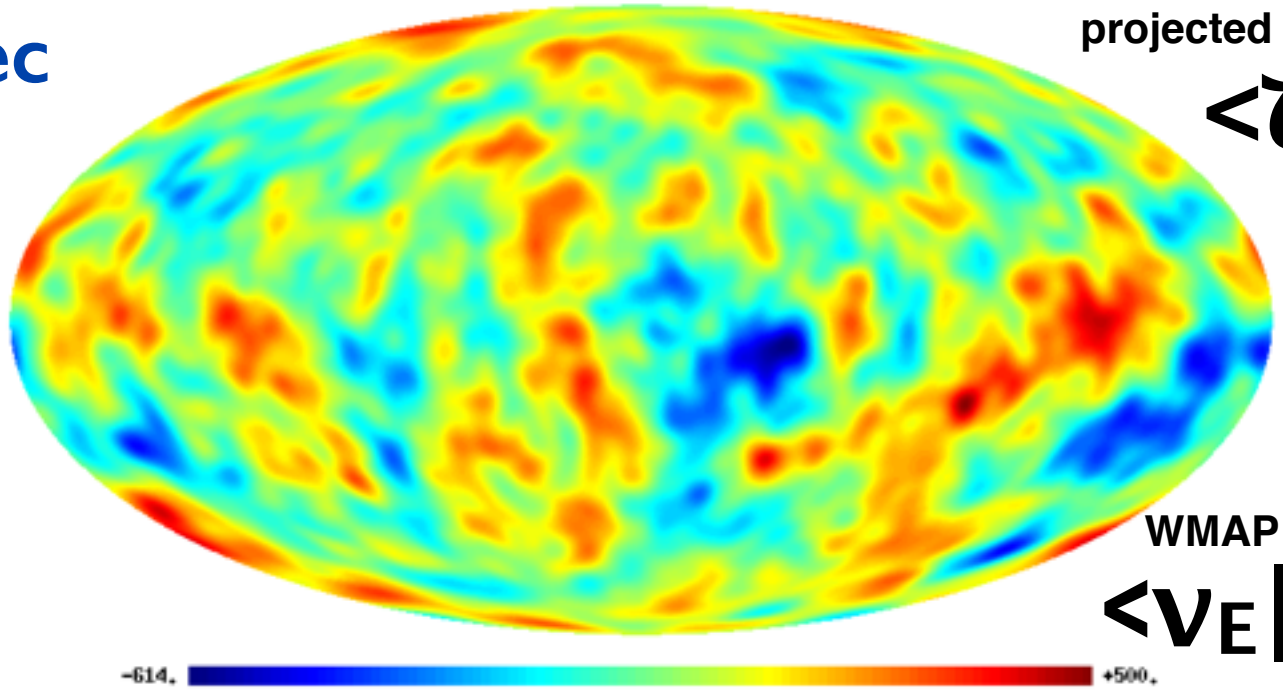
no WMAP T COLD SPOT

$\chi_b=\chi_{dec}$

$L_{cut}=60$

projected curvature map

$\langle\zeta_b|T\rangle$



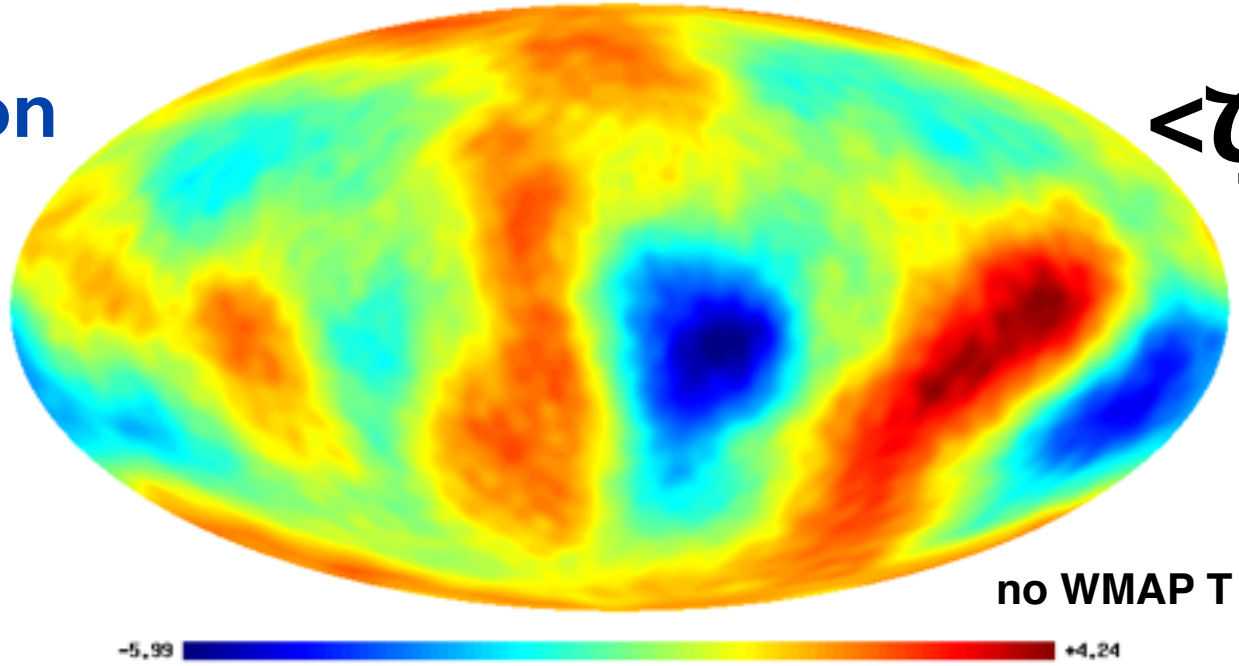
WMAP T COLD SPOT

$\langle\nu_E|\nu_T\rangle\sim2$

$\chi_b=\chi_{reion}$

$L_{cut}=60$

$\langle\zeta_b|T\rangle$



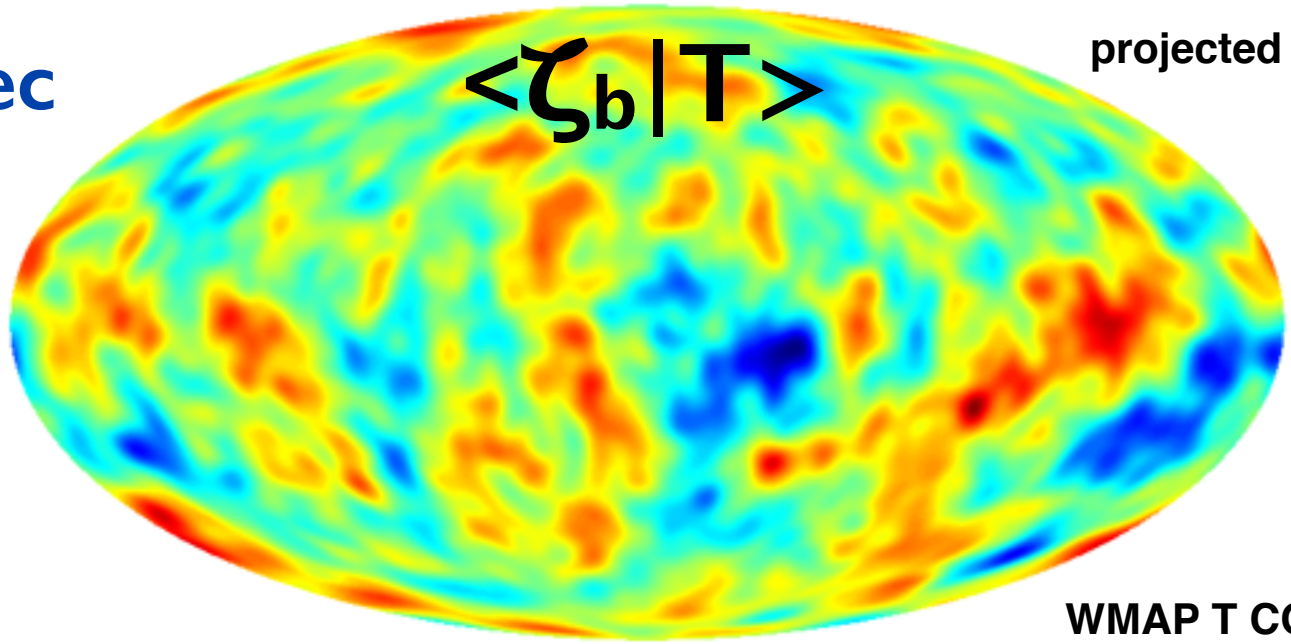
no WMAP T COLD SPOT

$\chi_b = \chi_{dec}$

$L_{cut} = 60$

$\langle \zeta_b | T \rangle$

projected curvature map



WMAP T COLD SPOT

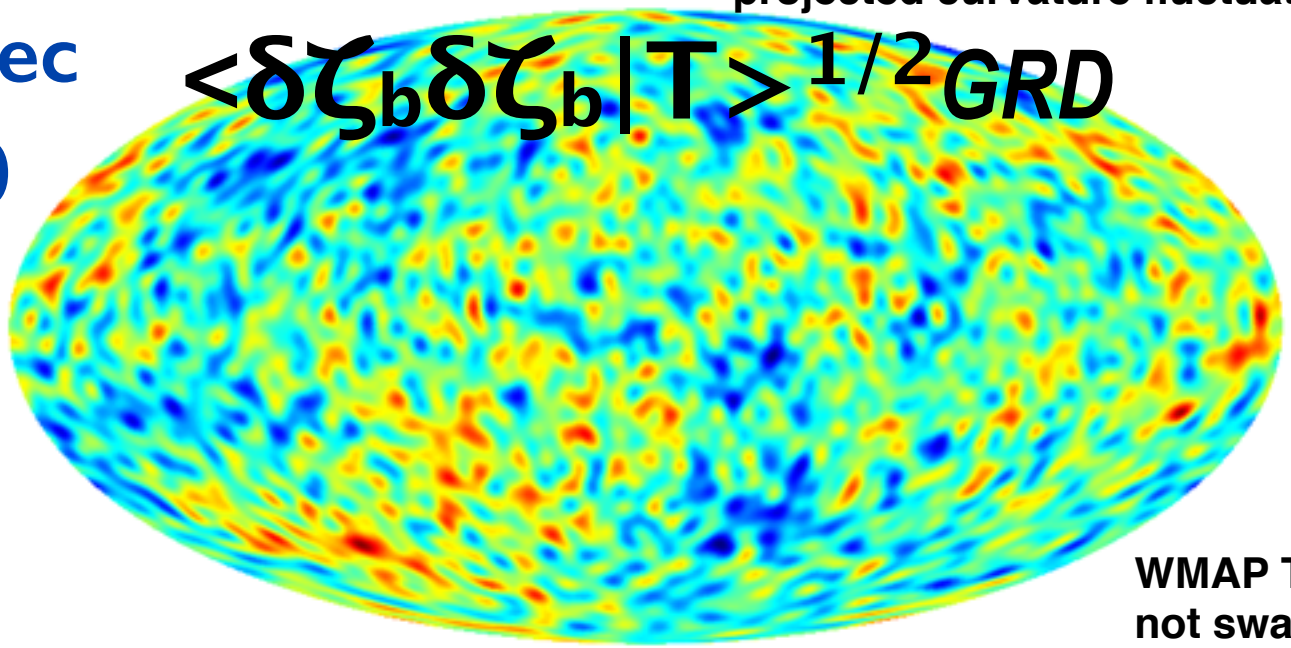
-614. +500.

projected curvature fluctuation realization

$\chi_b = \chi_{dec}$

$L_{cut} = 60$

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



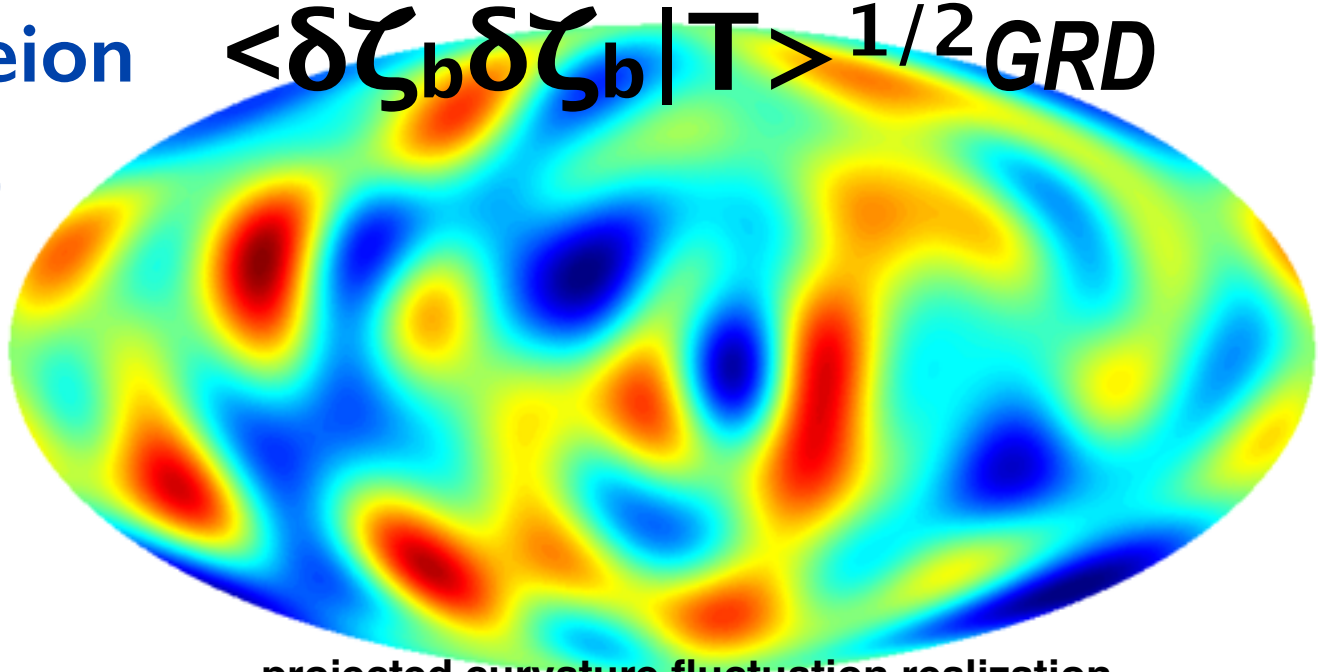
WMAP T COLD SPOT
not swamped by flucs

-600. +635.

$\chi_b=\chi_{reion}$

$L_{cut}=10$

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



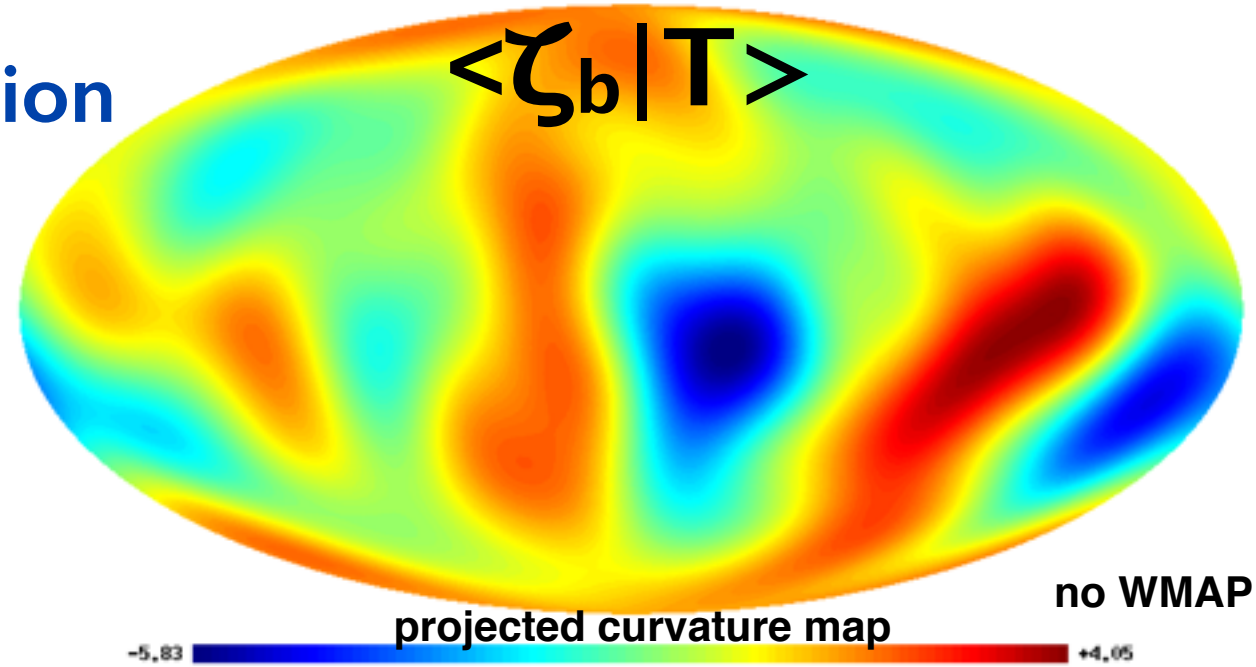
projected curvature fluctuation realization

-20.8 +21.4

$\chi_b=\chi_{reion}$

$L_{cut}=10$

$\langle \zeta_b | T \rangle$

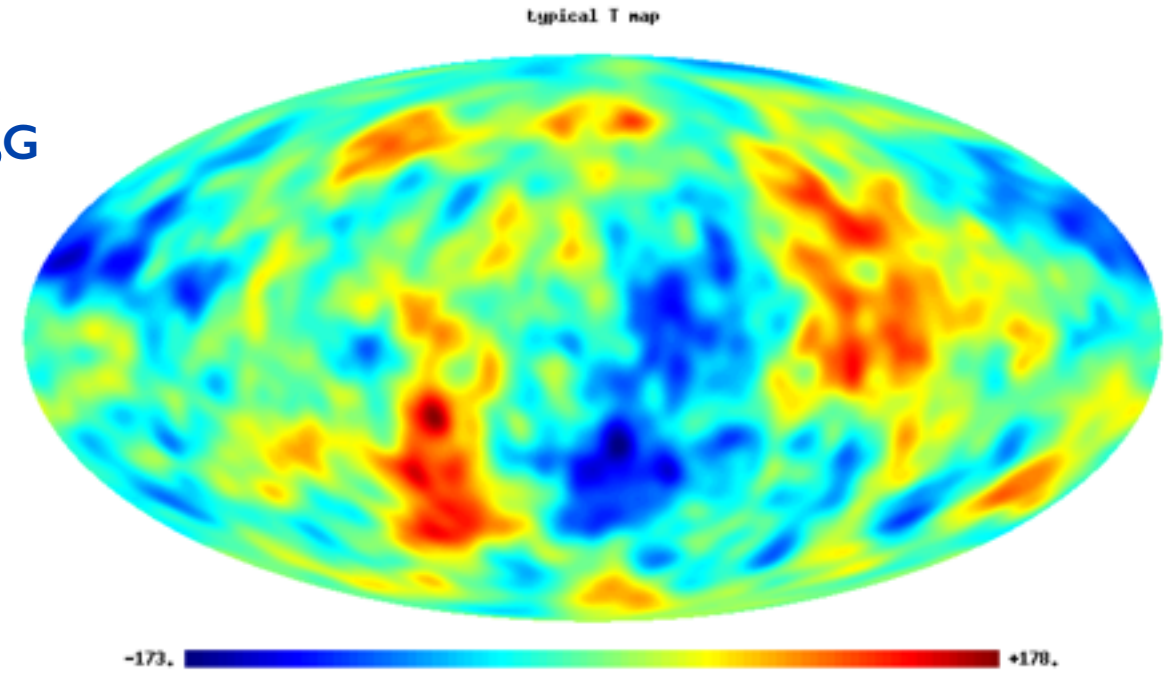


projected curvature map

-5.83 +4.05

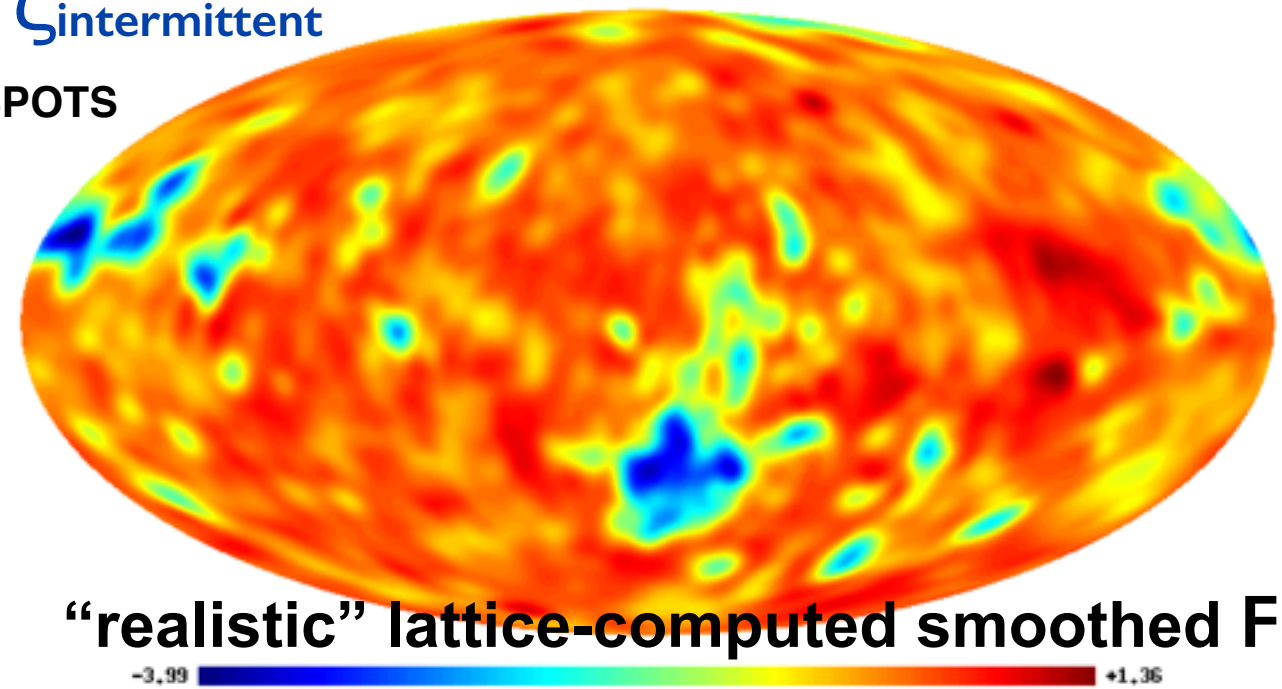
no WMAP T COLD SPOT

T from ζ_G



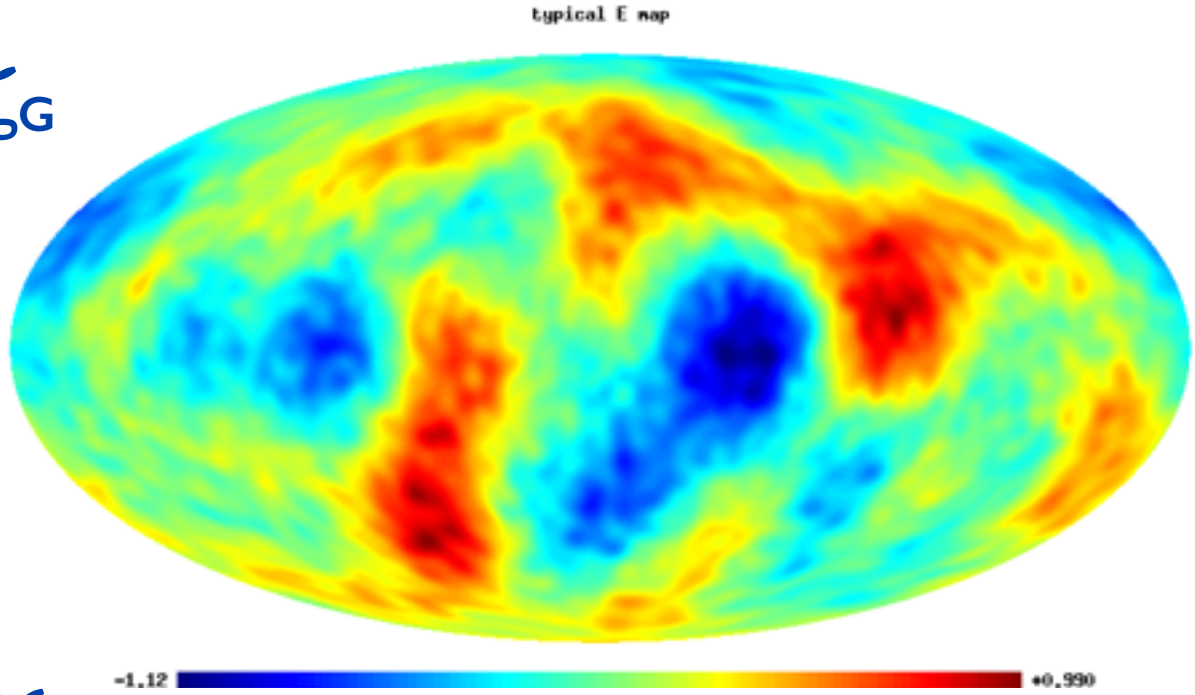
T from $\zeta_{intermittent}$

T COLD SPOTS



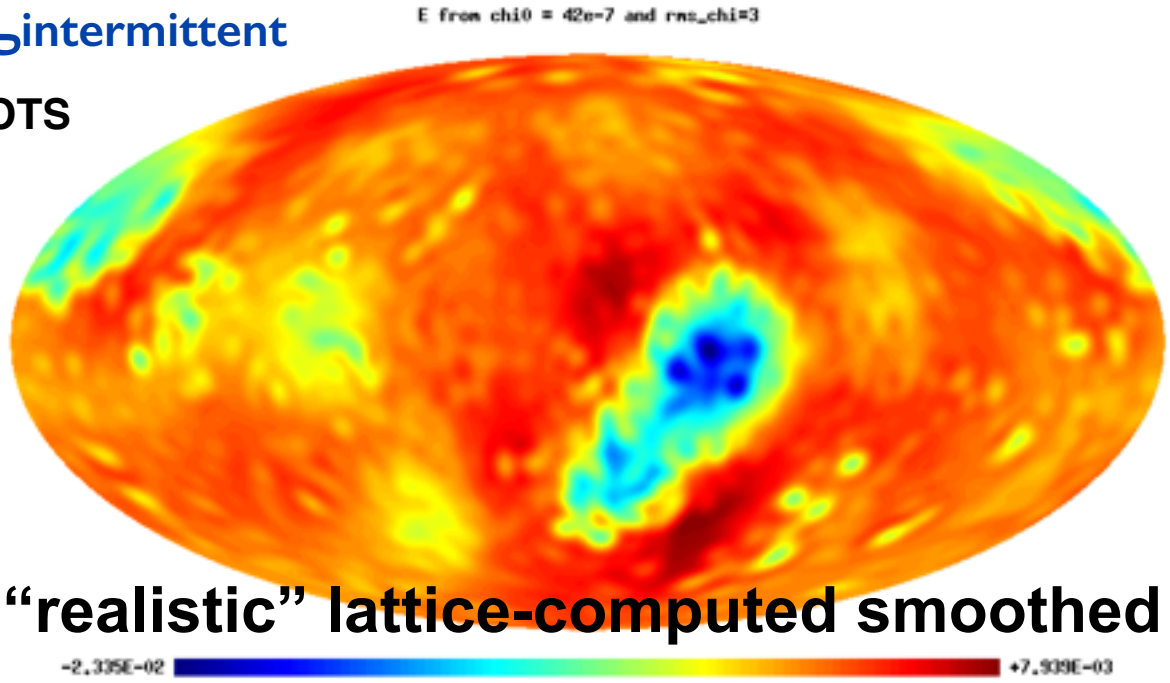
"realistic" lattice-computed smoothed F_{NL}

E from ζ_G



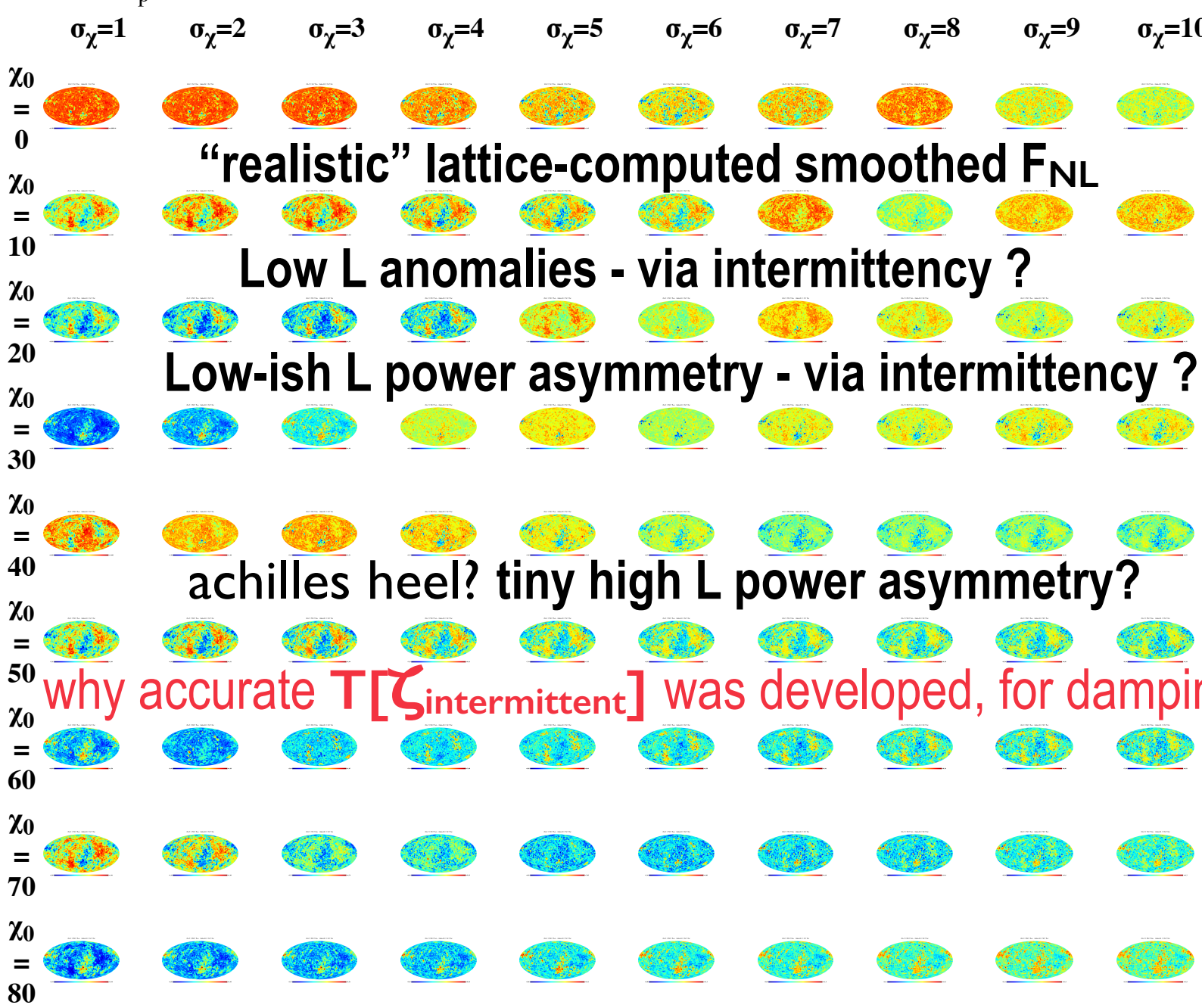
E from $\zeta_{intermittent}$

E COLD SPOTS



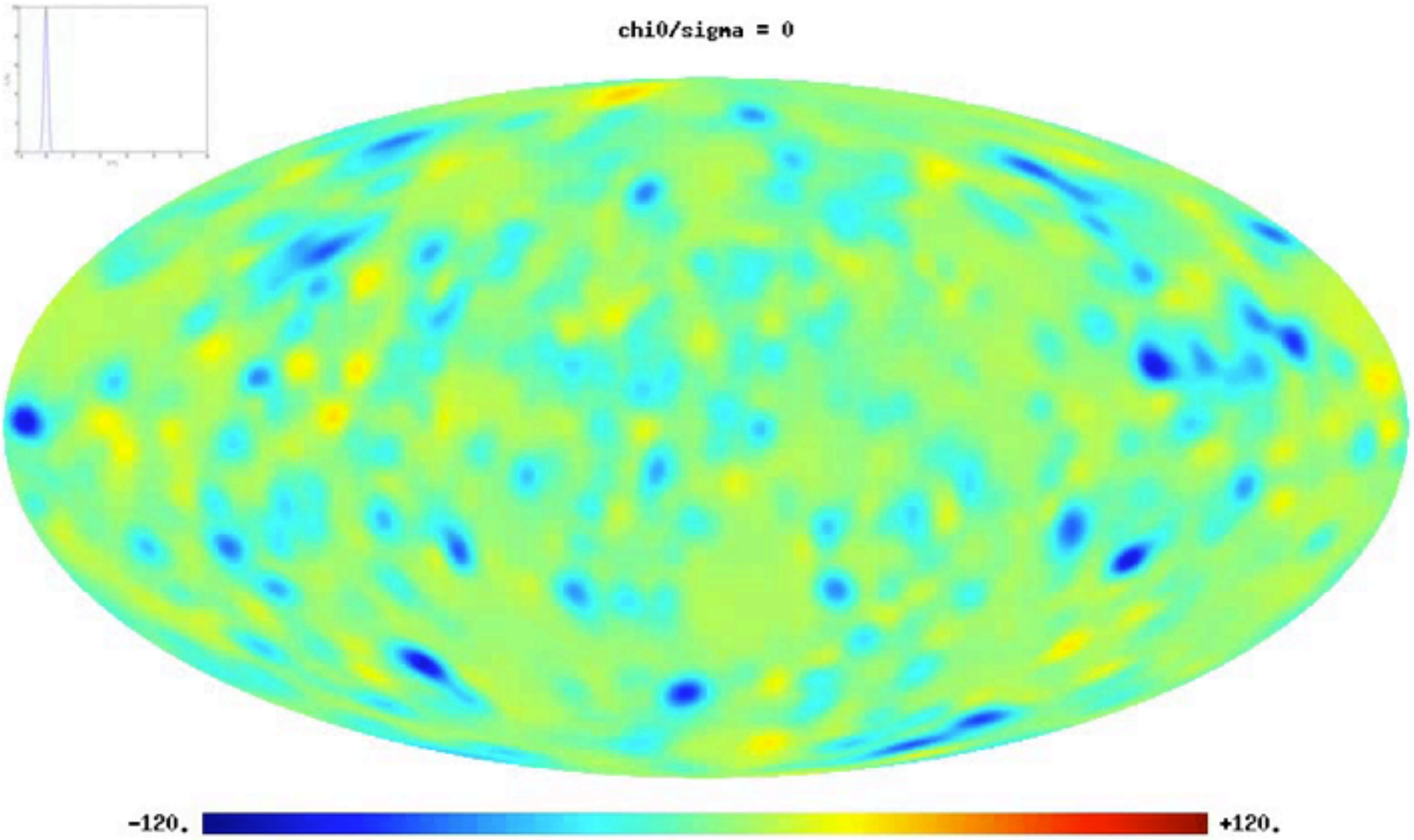
"realistic" lattice-computed smoothed F_{NL}

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

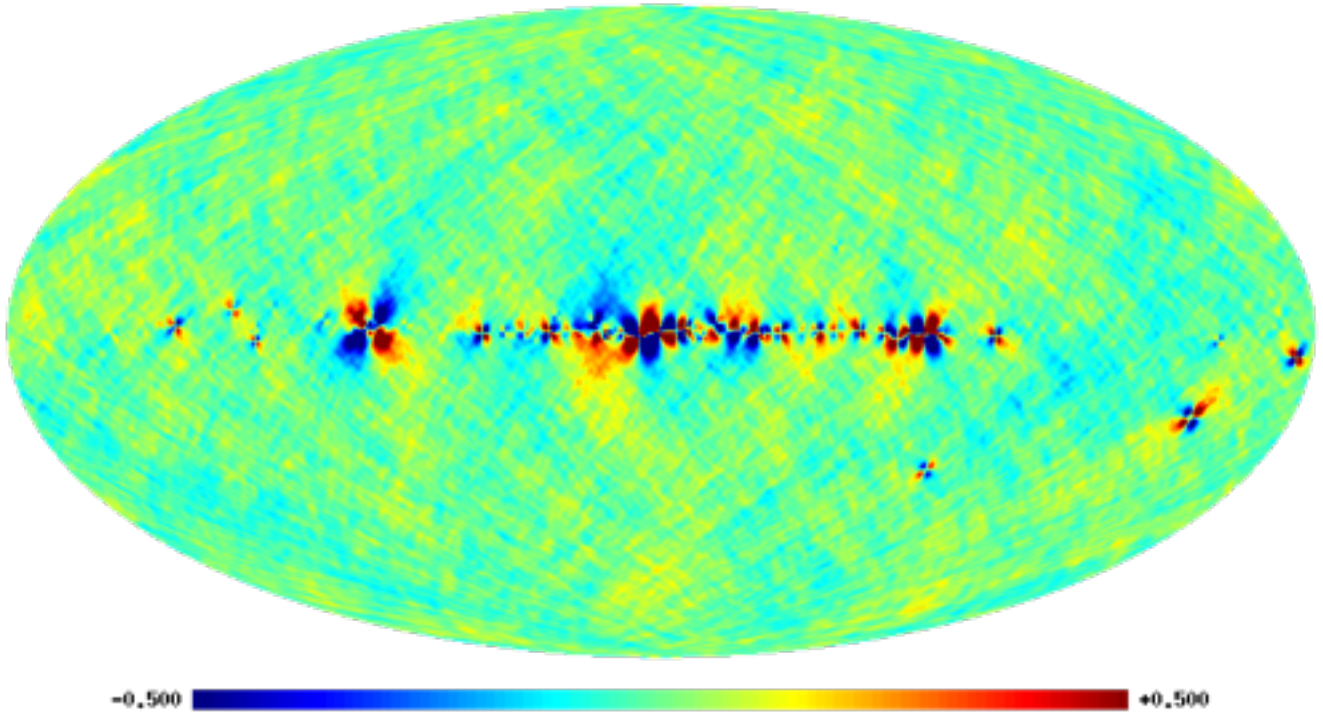


END

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

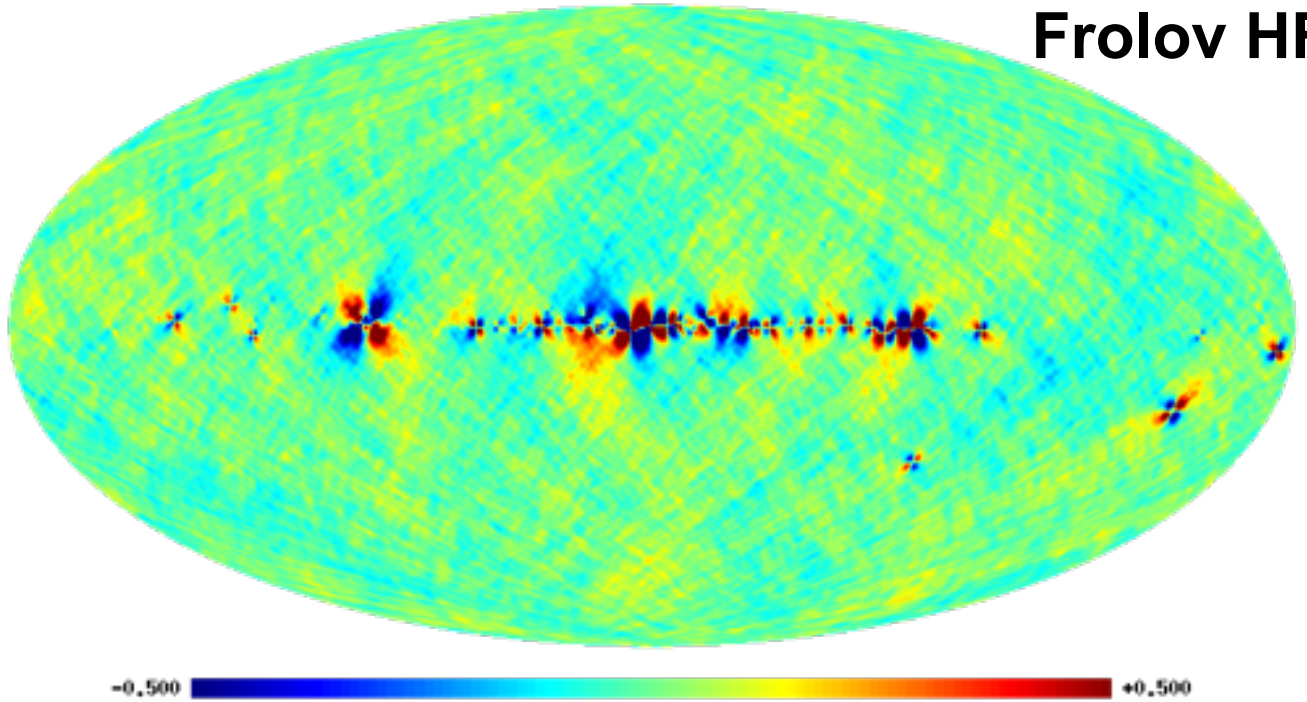


Q_T

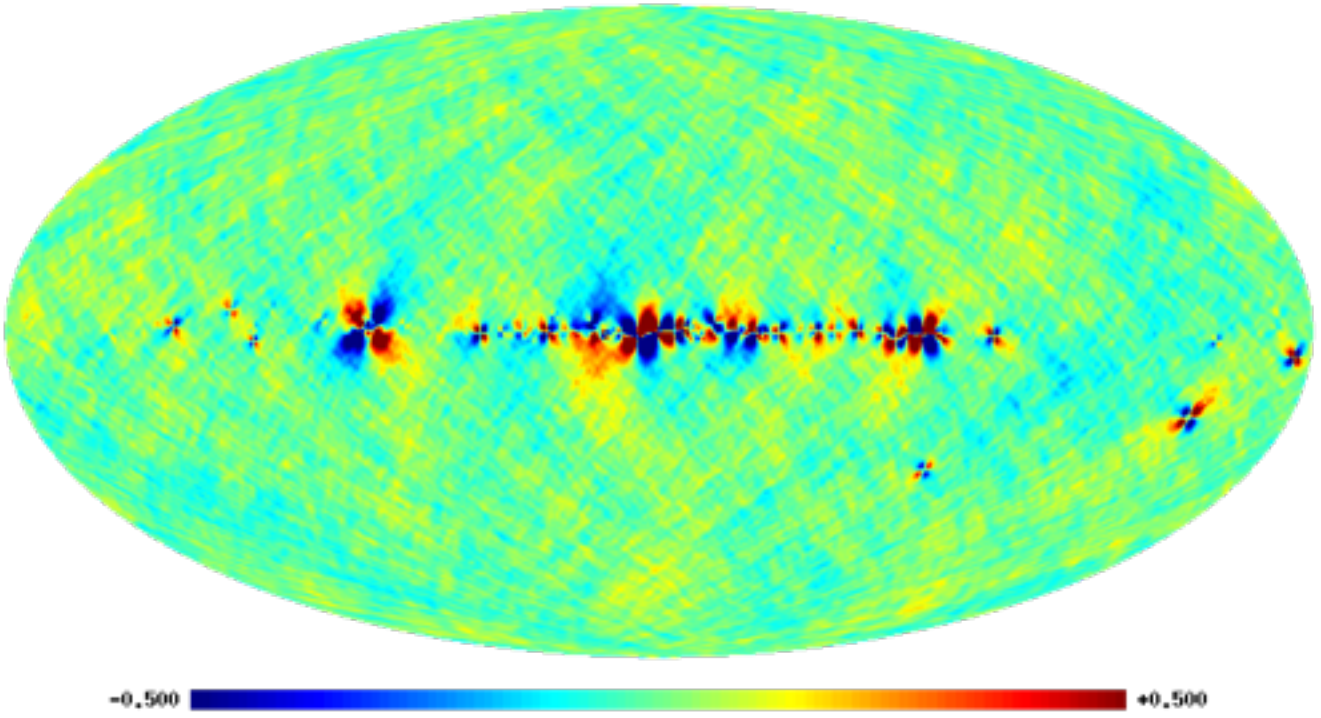


Frolov HFI-CT 13.06

U_T

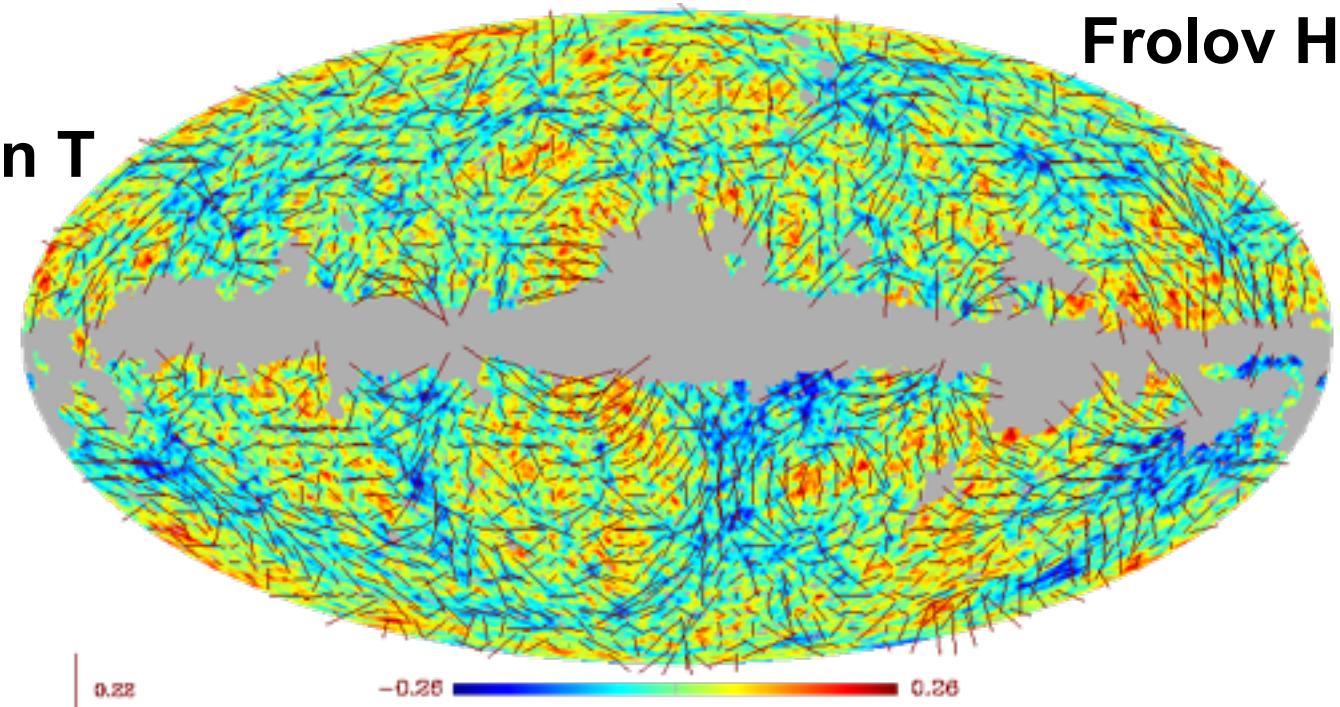


Q_T



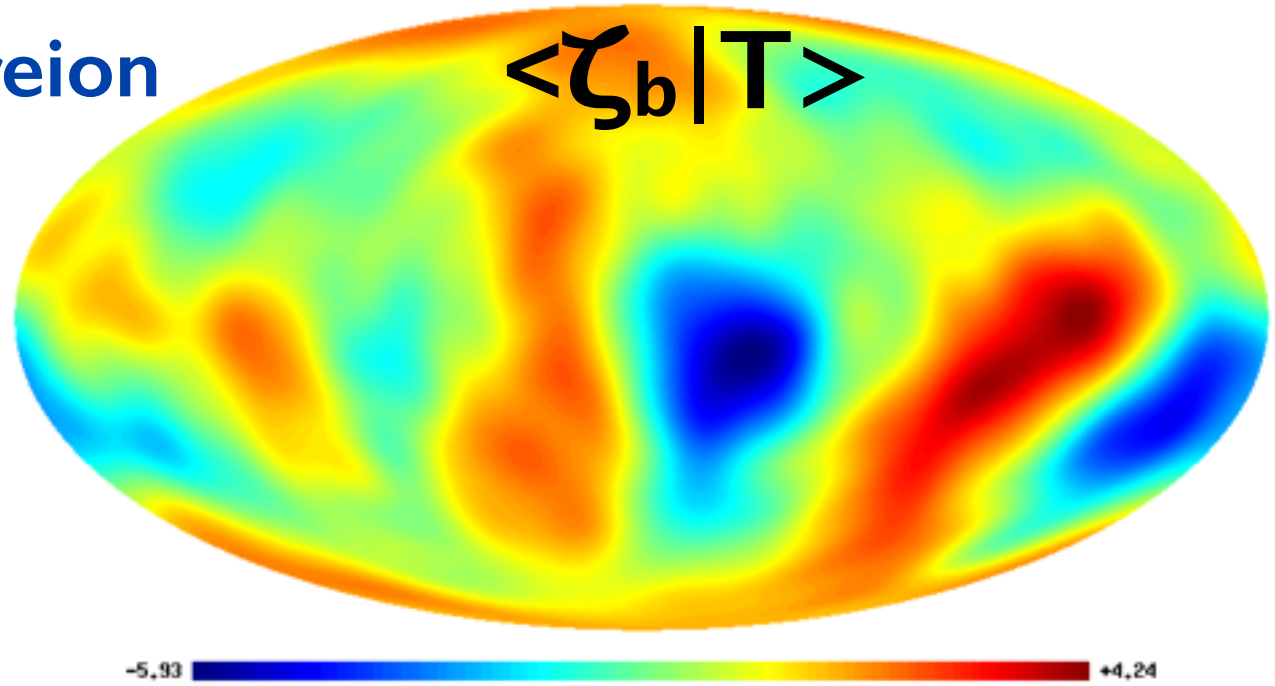
Frolov HFI-CT 13.06

$P_T\ \psi_T$ on T

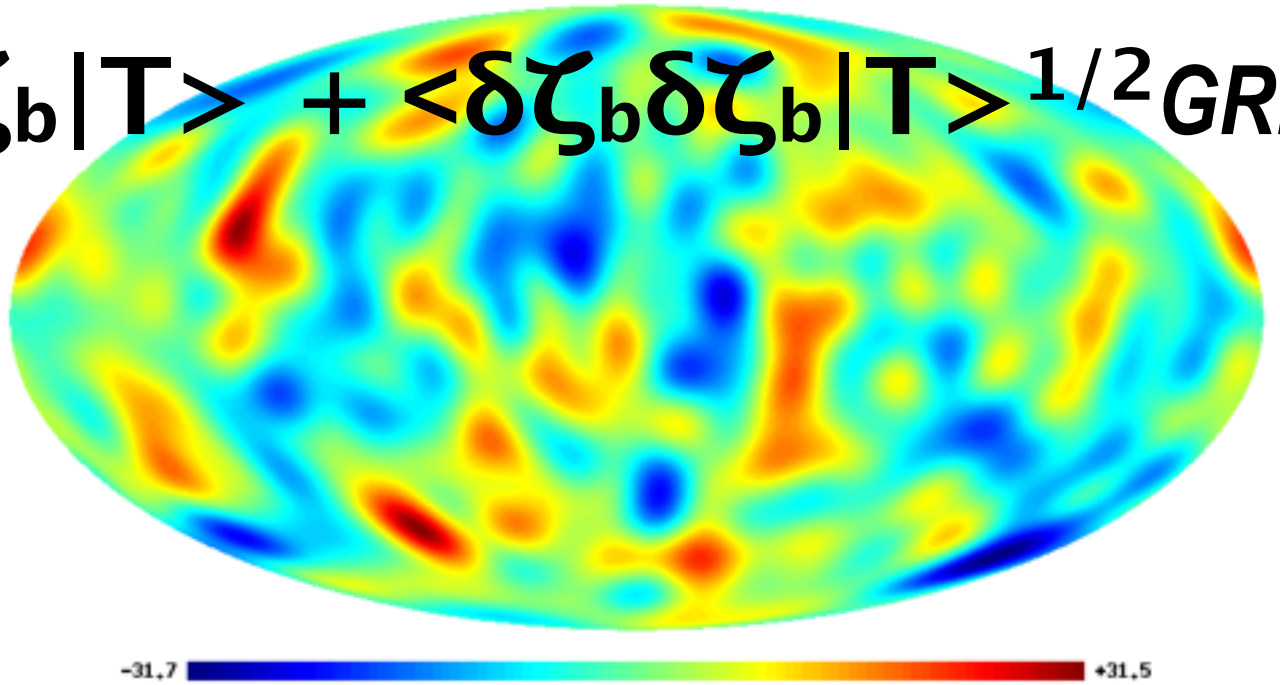


$\chi_b = \chi_{reion}$

$\langle \zeta_b | T \rangle$

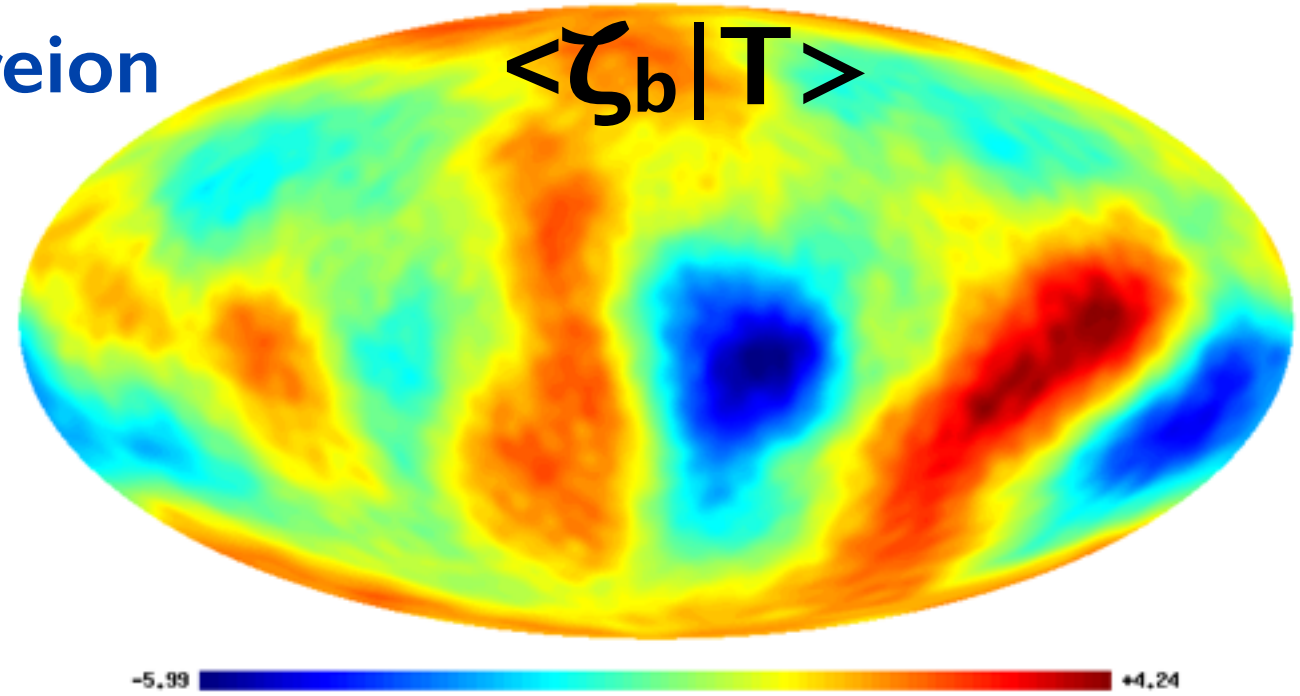


$\langle \zeta_b | T \rangle + \langle \delta\zeta_b \delta\zeta_b | T \rangle^{1/2} GRD$

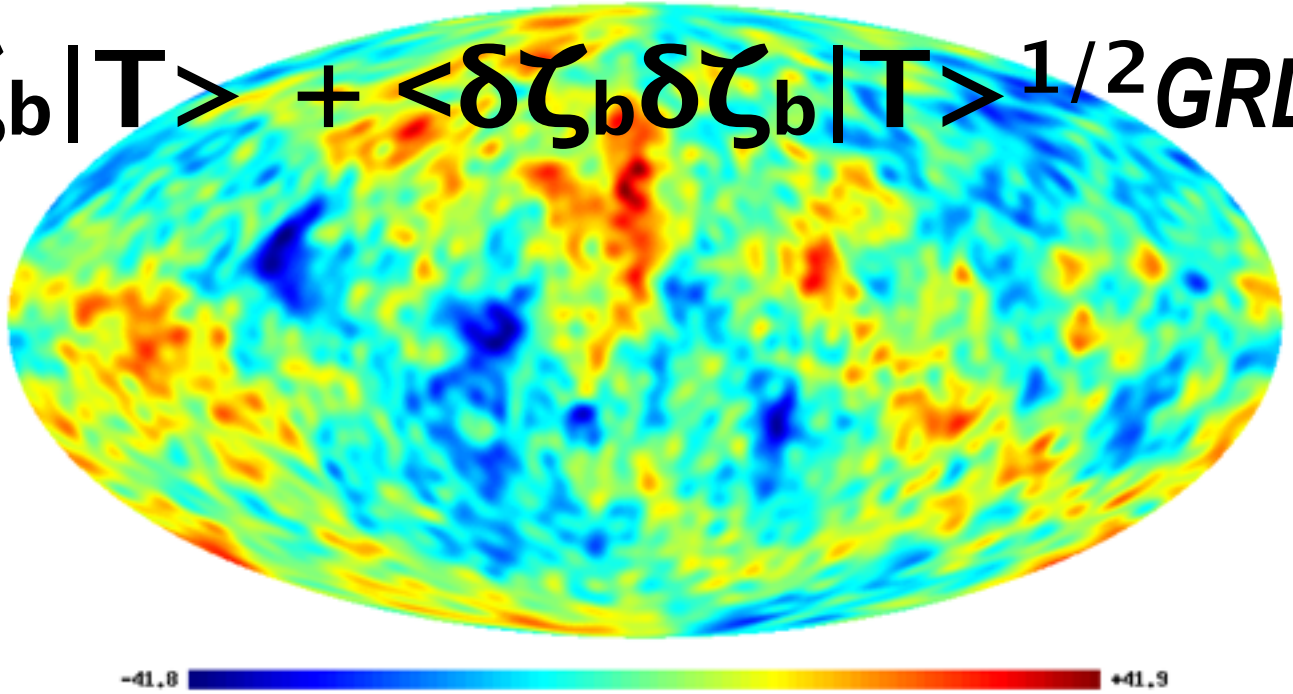


$\chi_b = \chi_{reion}$

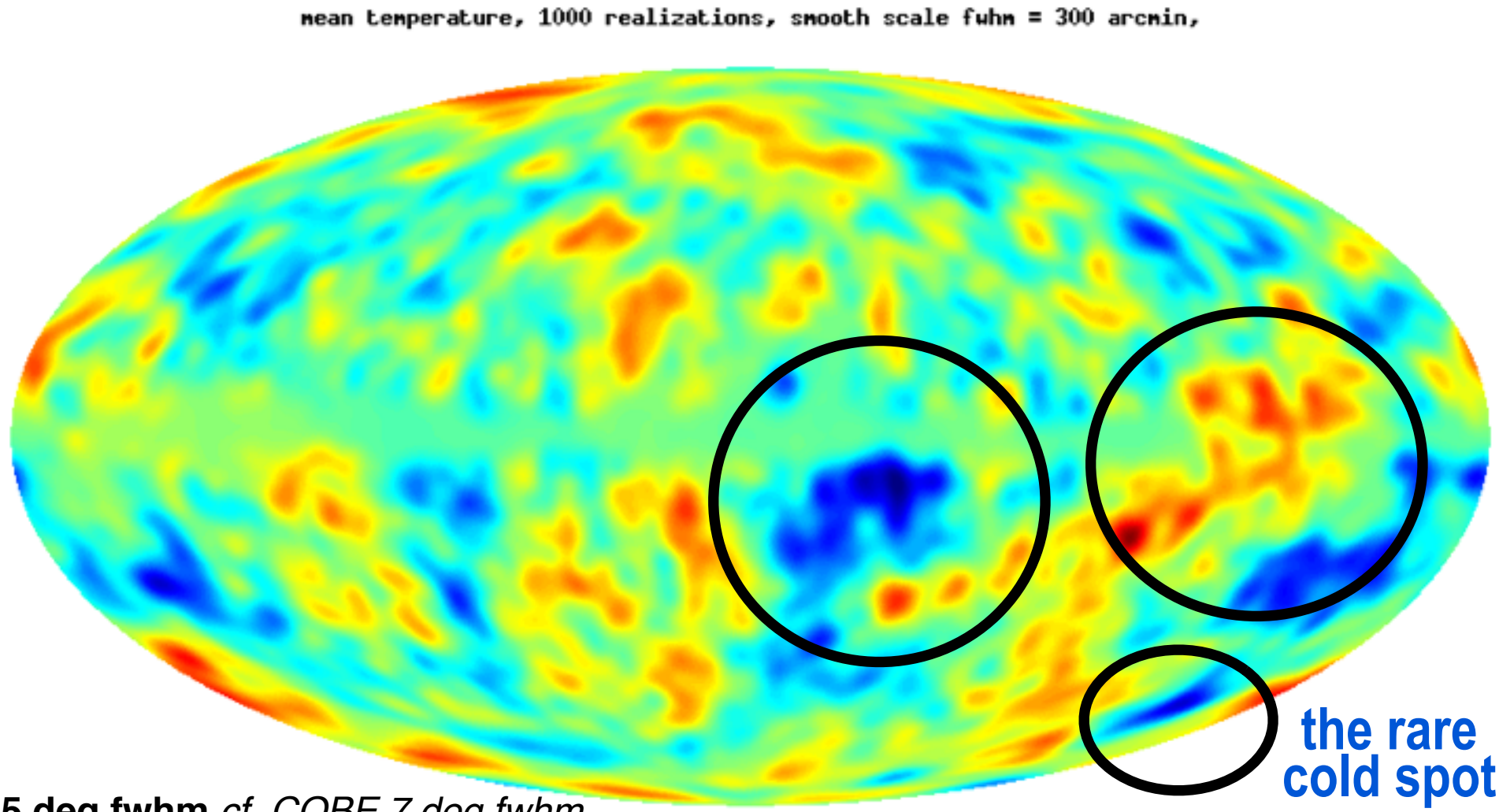
$\langle \zeta_b | T \rangle$



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



temperature map



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

$\zeta_{NL}(x) =$ ln a on isodensity hypersurfaces sb90 / uniform Hubble hs

ultra-early Universe sound spectrum $\ln P_s(\ln k)$

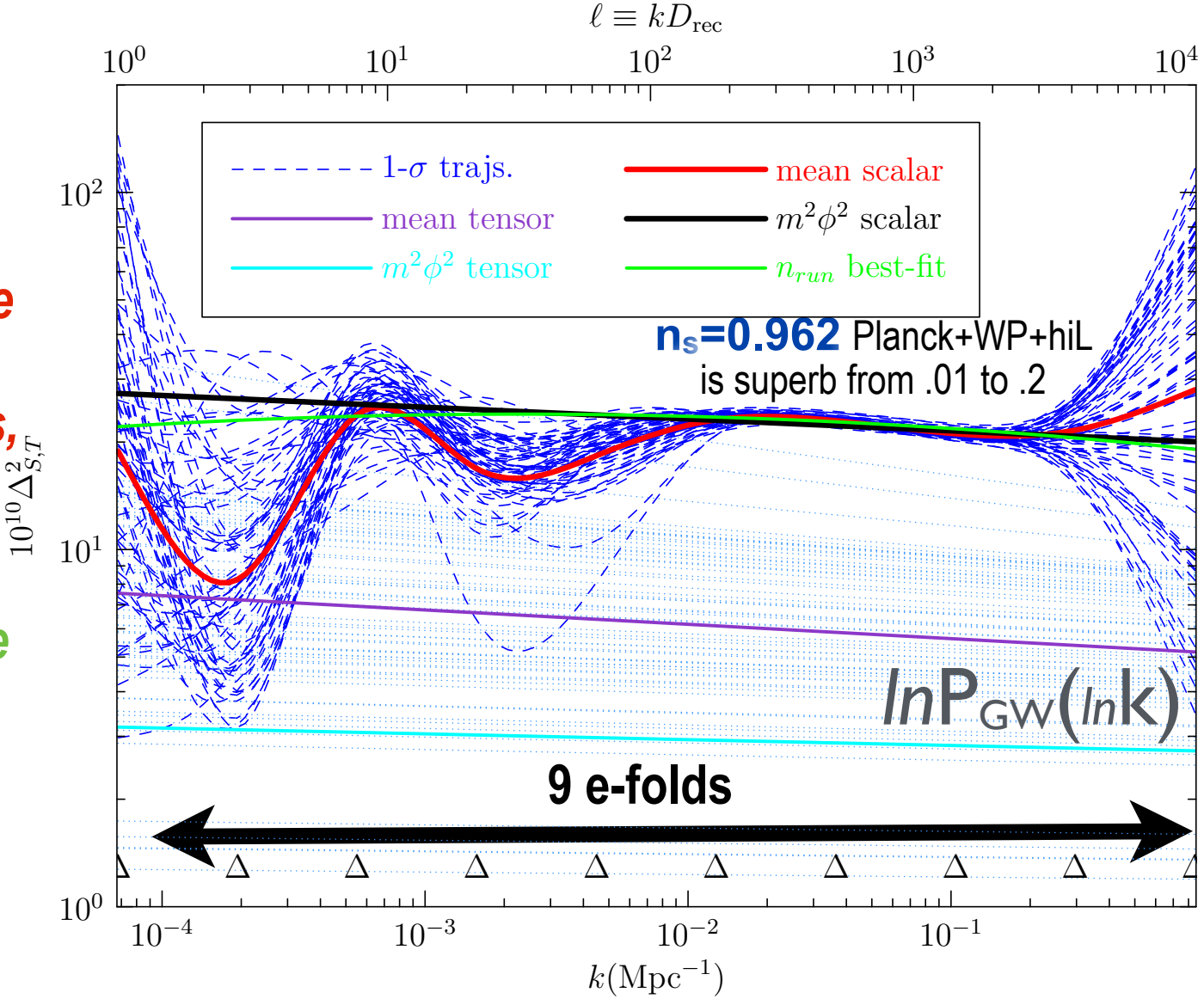
new parameters:

trajectory probabilities for early-inflatons

no strong evidence for oscillation patterns, cutoffs, local features

but hints of change on large L<100 scales

PS: running of P_s is a bad fit



Bond, Braden, Huang, Frolov, Vaudrevange 2014

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

ultra-early Universe **sound** spectrum $\ln P_s(\ln k)$

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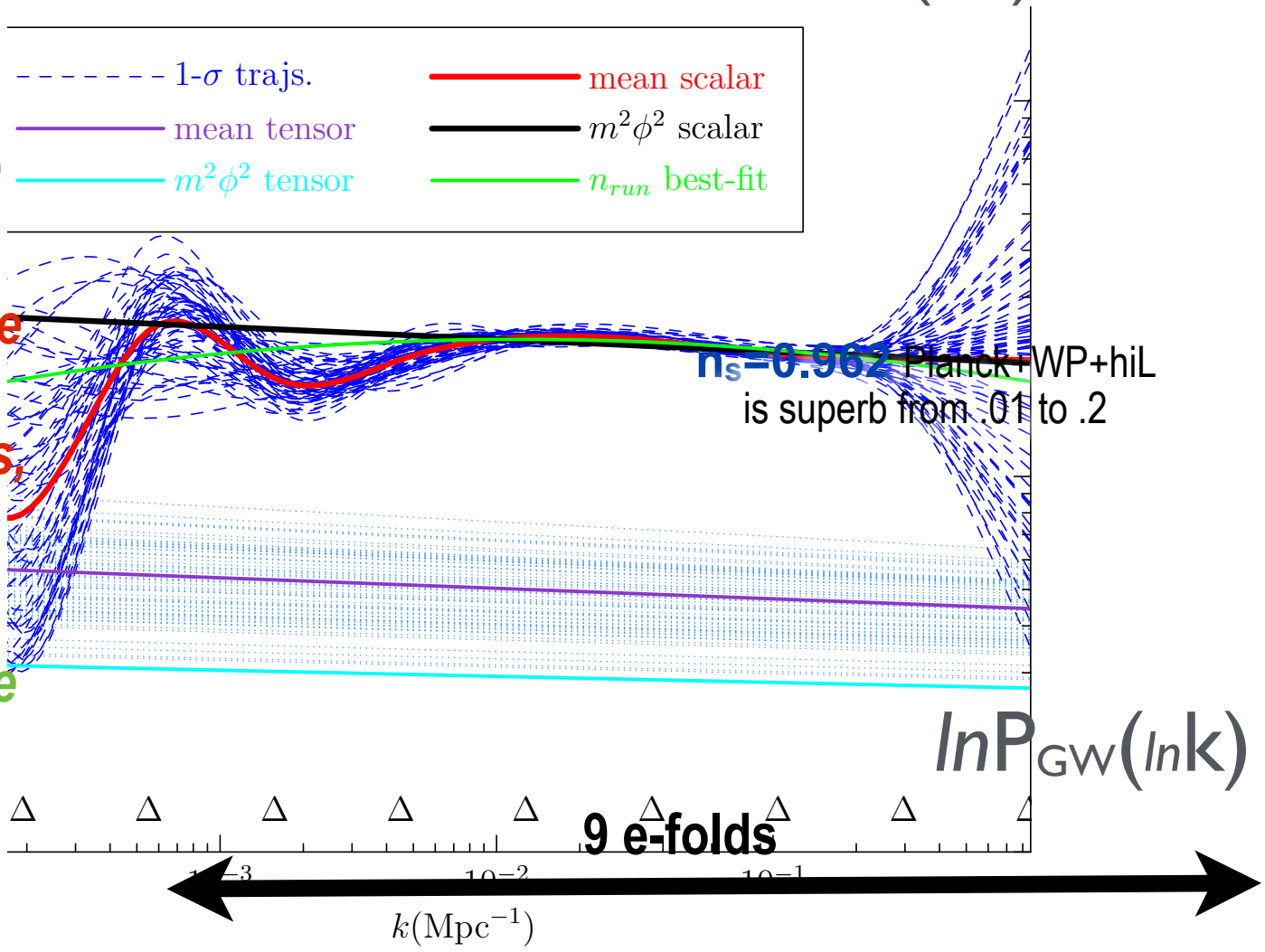
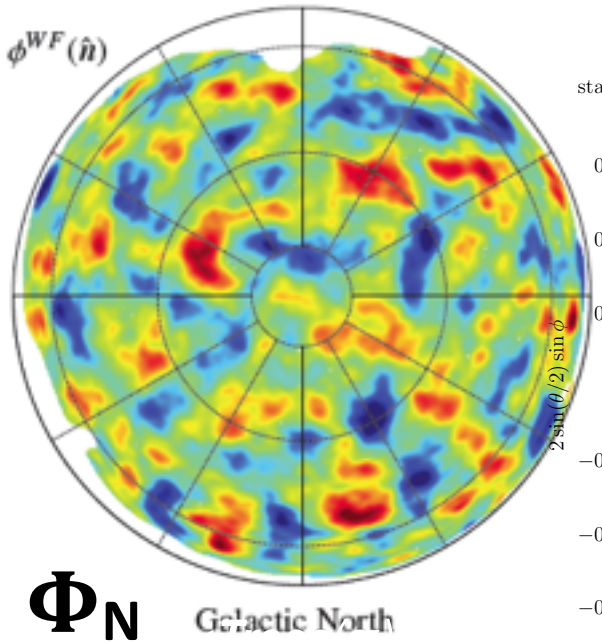


Bond, Braden, Huang, Frolov, Vaudrevange 2014

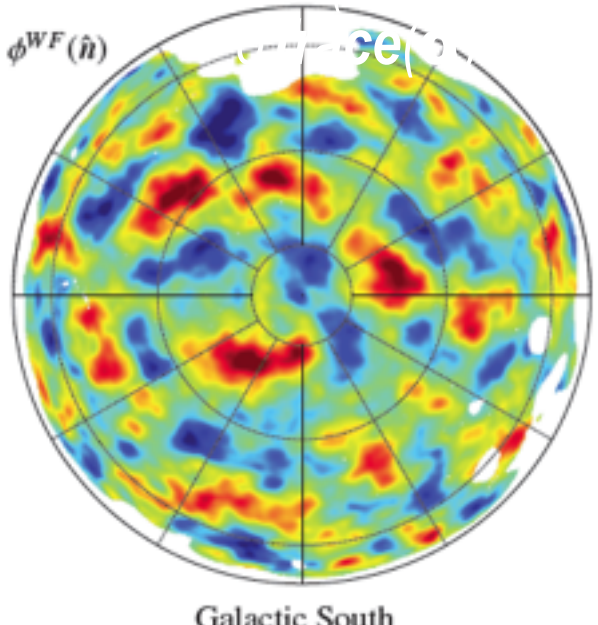
scan $\ln \mathbf{P_s}(\ln k)/A_s$, $\ln \mathbf{A_s}=\ln P_s(k_{pivot,s})$, $\boldsymbol{r}(k_{pivot,t})$; *consistency => reconstruct* $\boldsymbol{\varepsilon}(\ln \mathbf{Ha})$, $\mathbf{V}(\boldsymbol{\psi})$

Planck13 CMB Lensing: reconstructed projected $\Phi_N = -3/5 (D(t)/a(t))\, \mathrm{Tr}\alpha$ grav. potential

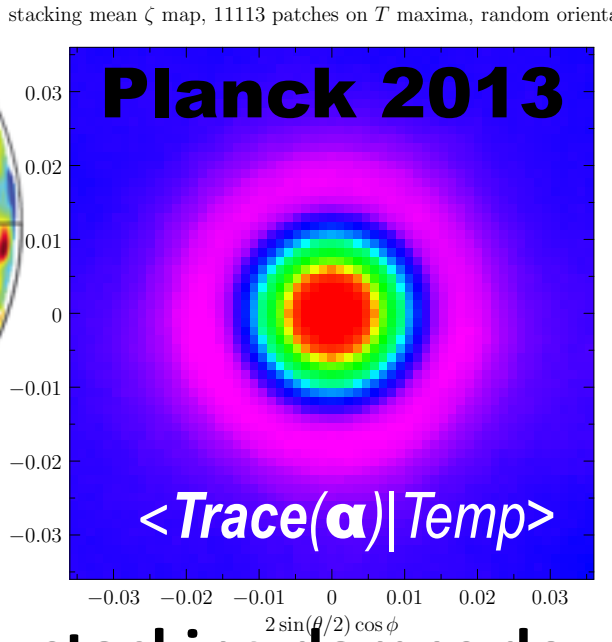
~ dark+baryonic matter map, mean-field map = Wiener filter (beware: fluctuations about mean-field)

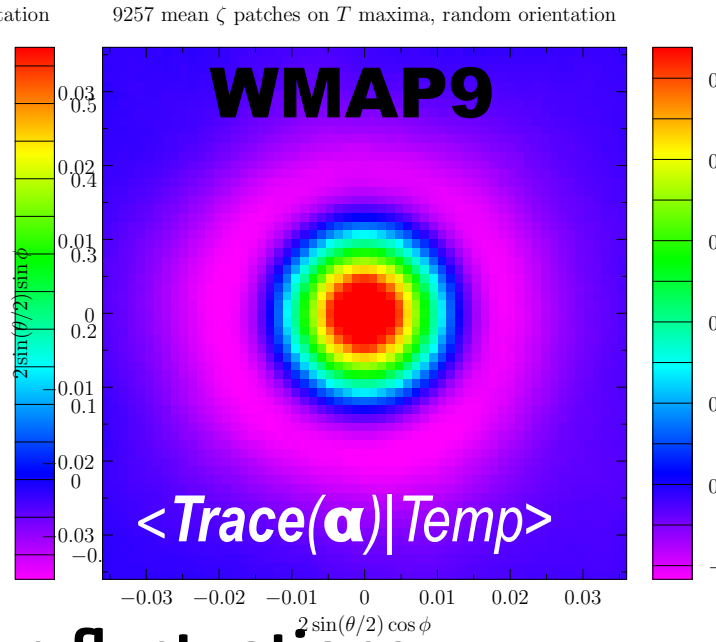


Φ_N

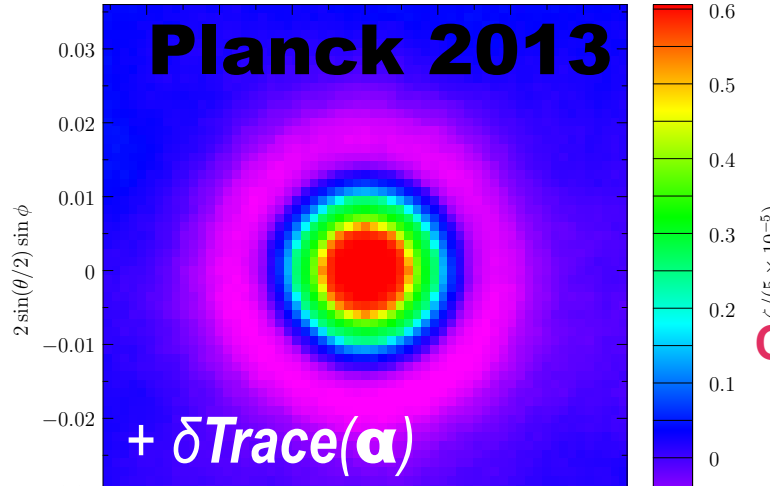


primordial isotropic strain $\mathrm{Tr}\alpha$





stacking damps down fluctuations,



0.5 deg fwhm

reconstruction of the Early Universe

mean-field

constrained-correlation

Compton differentiable-visibility mask on α