Dick Bond CITA on behalf of the Planck collaboration

planck

Beyond Planck 2014 +LSS: Inflation futures from CMB & LSS

esa

phonon ~ $\zeta = ln\rho|_a /3(1+\langle w \rangle)$ = *energy-density quanta*

isotropic (volume) strain ~ $\zeta = ln a|_\rho$ $\zeta_{NL} = ln(\rho\, a^{3(1+w)})/3(1+w) \Leftarrow dE+pdV$

Cosmic_Probes[$\zeta(\mathbf{x})$, q_{cosmic}, isoc, ..] or $\zeta(\mathbf{k})$,

or looking out: $\zeta_{LM}(\chi)$, $\chi = |\mathbf{x}|$ & $\zeta_{LM}(k)$, $k = |\mathbf{k}|$ maps

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Beyond Planck 2014 +LSS: Inflation futures from CMB & LSS

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CMB_Probe no tomography:

projected-χ *few modes per LM* $\langle\zeta_{LM}(\chi)|T_{LM}\rangle$ $\langle\zeta_{LM}(\chi)|E_{LM}\rangle$

available modes: $f_{sky} L_{max}^2$ $-f_{sky} L_{min}^2$ $L_{max} \sim L_{damp}$

Planck near limit of nonG exploration with CMB (ACT/SPT) $f_{NL} \pm 5$

gravity waves ~Transverse_Traceless_Strain: *no tomography, limited L range* n_t

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CMB_Probe no tomography:

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LSS_Probe tomography:

Large Scale Structure Galaxy Surveys

available modes ~ $f_{sky} L_{max}^2\ k_{max} d_{max}$

~ $f_{sky}(k_{max}^3 d_{max}^3)$, $\quad k_{min} \sim 2\pi/d_{max}$ $\quad V_{com} \sim d_{max}^{\ 3}$

How many high precision extra modes can we realize?

Mapping *the Planck 2014 Early Universe*
Phonon Spectrum $\zeta = \ln a|_\rho = \ln \rho|_a / 3(1+\langle w \rangle)$

Inflation = phenomenology of gravitons = Transverse_Traceless_Strain quanta

$$\text{phonon} \sim \zeta_{NL} = \ln(\rho\, a^{3(1+w)})/3(1+w)$$

Inflation = phenomenology of phonons = energy-density quanta

inflaton = "condensate" of phonon fluctuations, $\langle\rho|_{k<Ha}\rangle + \delta\rho$ oscillations

relativistic negative-pressure Equation of State (1+w)

phonon = **collective mode** **composed of** fundamental **scalar fields (many ϕ_b?)**

in linear perturbation theory, the phonon = linear combination of fundamental scalars

all that CMB+LSS can deliver is this phonon/strain wave Inflation Phenomenology
how does it fit into a UV-complete theory (ultra-high energy to the Planck scale) strings, landscape, ..
& IR-complete theory (post-inflation heating -> quark/gluon plasma)??? TBD

Mapping *the Planck 2014 Early Universe* **Phonon Spectrum** $\zeta = \ln a|_\rho = \ln\rho|_a / 3(1+\langle w\rangle)$

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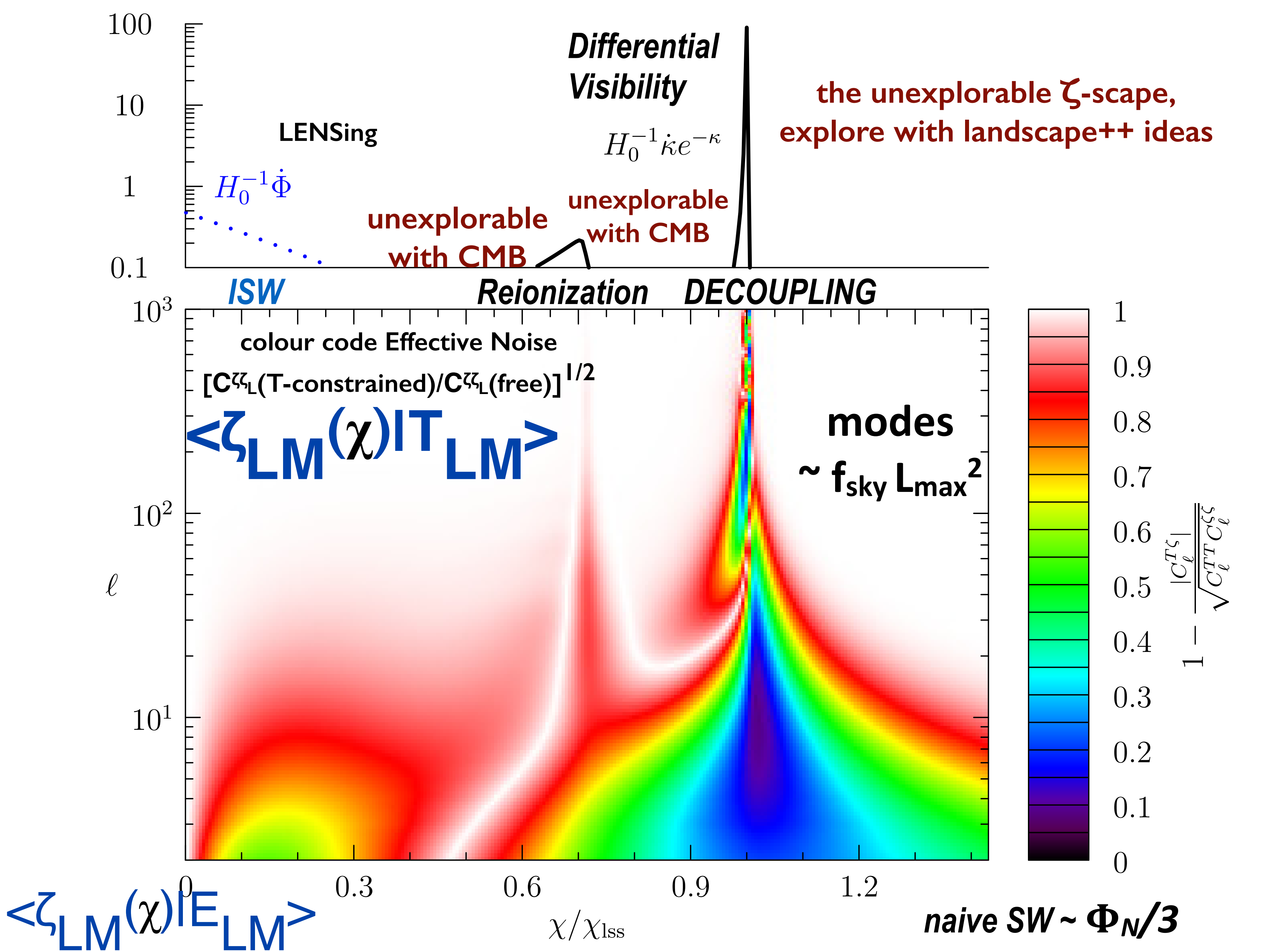
& IR-complete theory (post-inflation heating -> quark/gluon plasma)??? TBD

the ***ζ-scape***

$\rho(\phi_b, \pi_b, \ln a)$ =>*coarse-grained k<Ha* ***Hamiltonian-density*** **attractor** $\rho(\phi_b) = 3M_P^2H^2$

$d\phi_b/d\ln a = -M_P^2 \nabla_{\phi b} \ln\rho$, **a gradient / Morse flow =>** ***Hamilton-Jacobi eq^n,***

"adiabatic" fluctuations along the Morse flow (phonons) isocurvature directions ⊥ the flow



Differential Visibility
$H_0^{-1}\dot\kappa e^{-\kappa}$
the unexplorable ζ-scape, explore with landscape++ ideas
LENSing
$H_0^{-1}\dot\Phi$
unexplorable with CMB
unexplorable with CMB
ISW
Reionization
DECOUPLING
colour code Effective Noise
$[C^{\zeta\zeta}_L(\text{T-constrained})/C^{\zeta\zeta}_L(\text{free})]^{1/2}$
<$\zeta_{LM}(\chi)$|T_{LM}>
modes
~ $f_{sky} L_{max}^2$
ℓ
$1-\frac{|C_\ell^{T\zeta}|}{\sqrt{C_\ell^{TT}C_\ell^{\zeta\zeta}}}$
χ/χ_{lss}
<$\zeta_{LM}(\chi)$|E_{LM}>
naive SW ~ $\Phi_N/3$

*we don't need all LM+k modes to reconstruct L-independent $\mathcal{P}_\zeta$(**k**) in quadratic space*

$k^2 \sim L^2 d_{rec}^{-2} + k_{||}^2$

bonus: top-down ***de-lens***

cf. **Planck13+LSS**

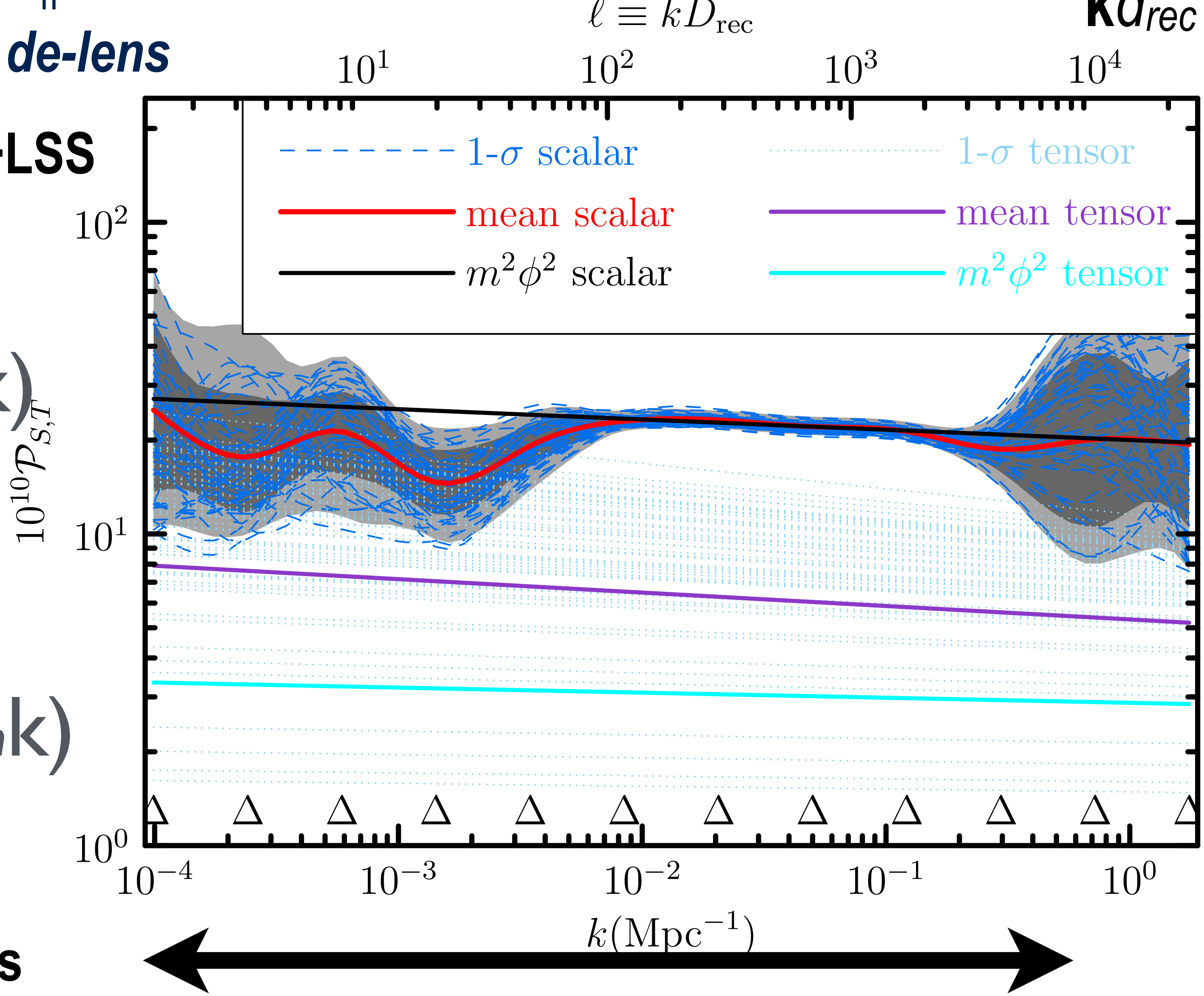
12 knots, cubic spline

k$d_{rec} \gtrsim L$

$\ln \mathcal{P}_\zeta(\ln k)$

Planck13 & WMAP => stable features

$\ln \mathcal{P}_{GW}(\ln k)$



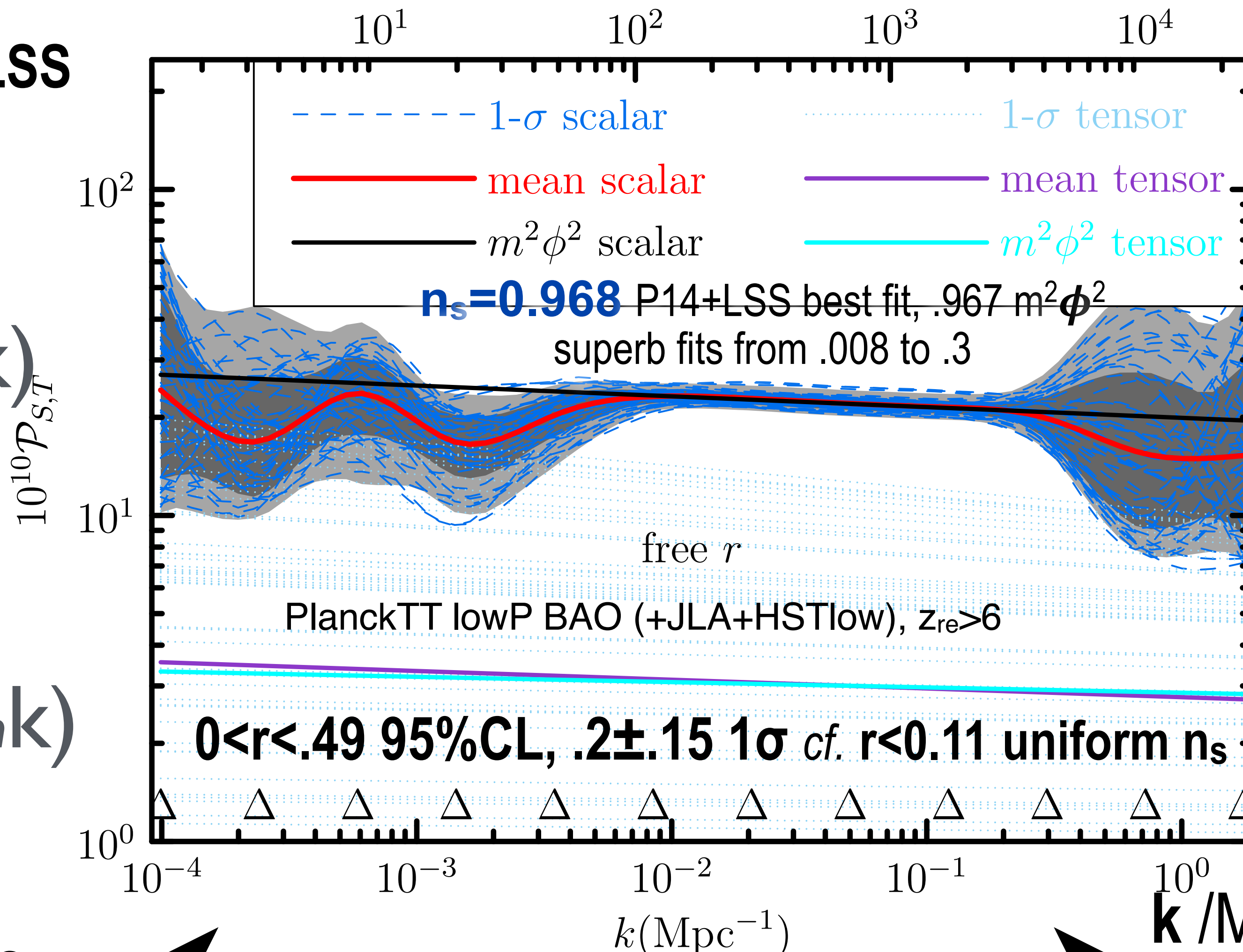
9 e-folds

Quadratic $ln\mathcal{P}_\zeta(ln k)$ Maps *aka* Radical Compressions
=> ultra-early Universe sound/phonon spectrum

Preliminary 12 knots, cubic spline

kd_{rec} ≳ L

Planck14+LSS



$ln\mathcal{P}_\zeta(ln k)$

r - $\mathcal{P}_\zeta$ partial degeneracy if r floats

$ln\mathcal{P}_{GW}(ln k)$

k /Mpc

9 e-folds

Quadratic $ln\mathcal{P}_\zeta(ln k)$ Maps *aka* Radical Compressions
=> ultra-early Universe sound/phonon spectrum

Preliminary 12 knots, cubic spline

constrain r ≡ 0.01

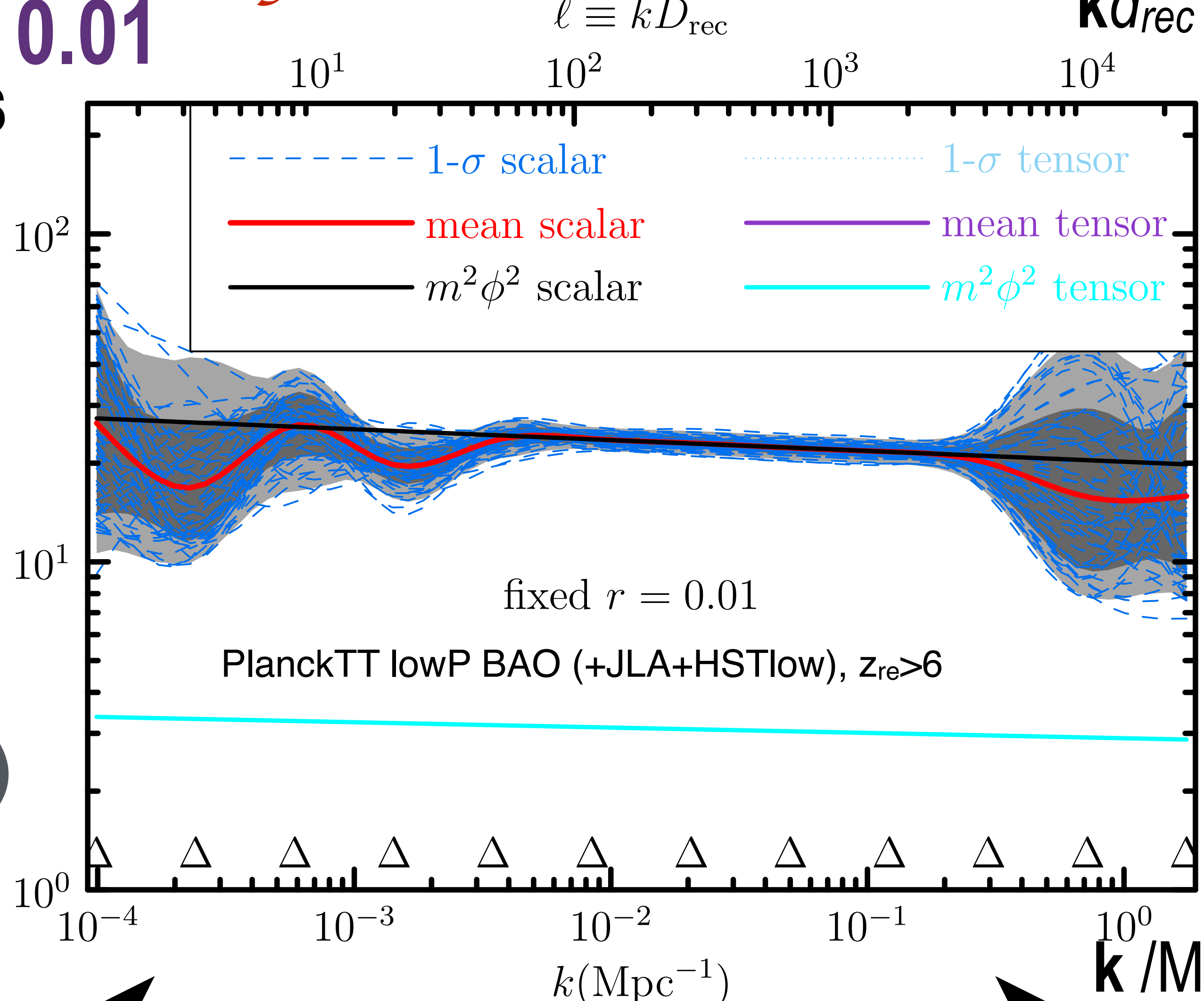
Planck14+LSS

$ln\mathcal{P}_\zeta(ln k)$

future r=0.01 constraint break degeneracy => stable features

$ln\mathcal{P}_{GW}(ln k)$

$kd_{rec} \gtrsim L$



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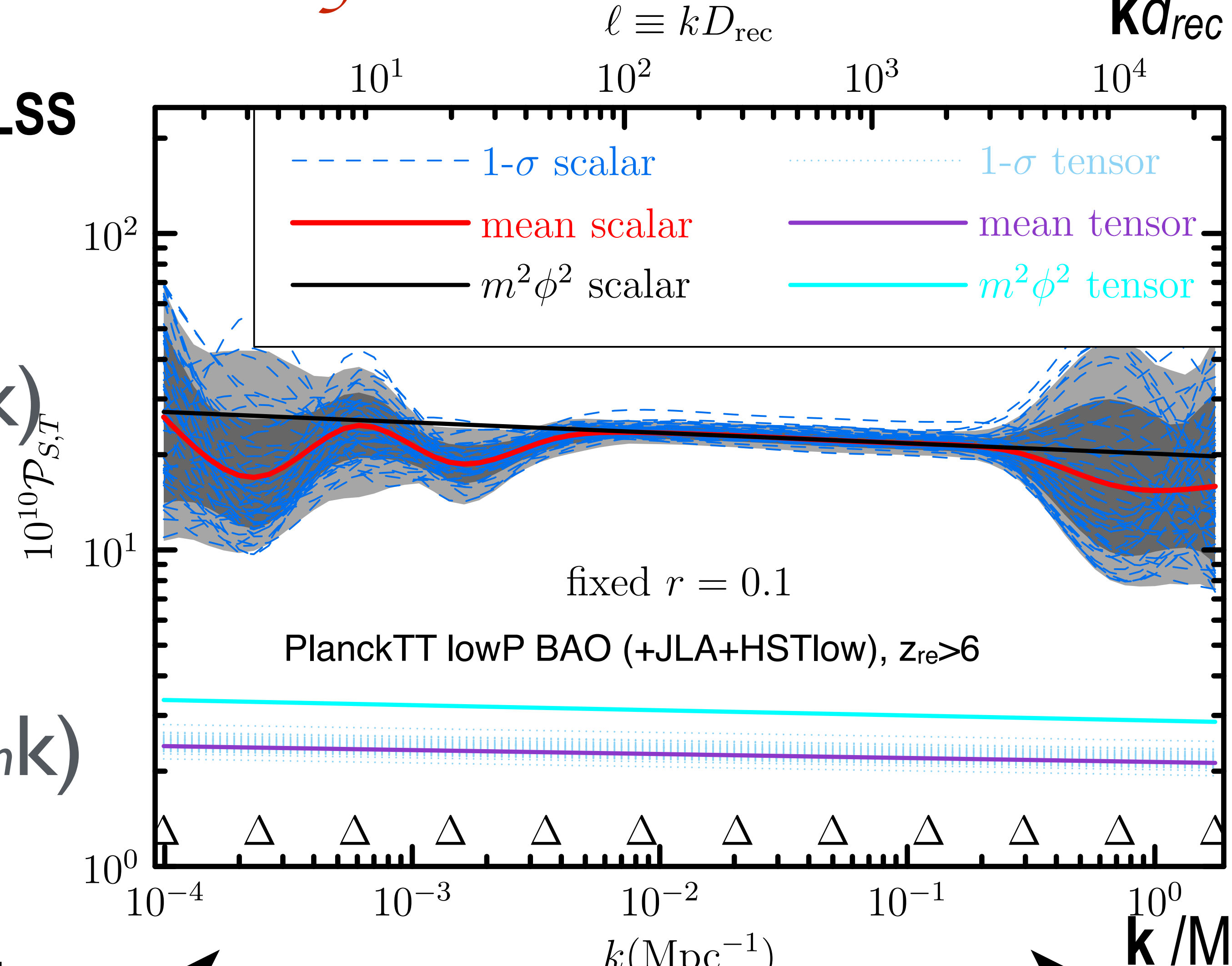

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adding high L polarization => stable features

$ln\mathcal{P}_{GW}(lnk)$

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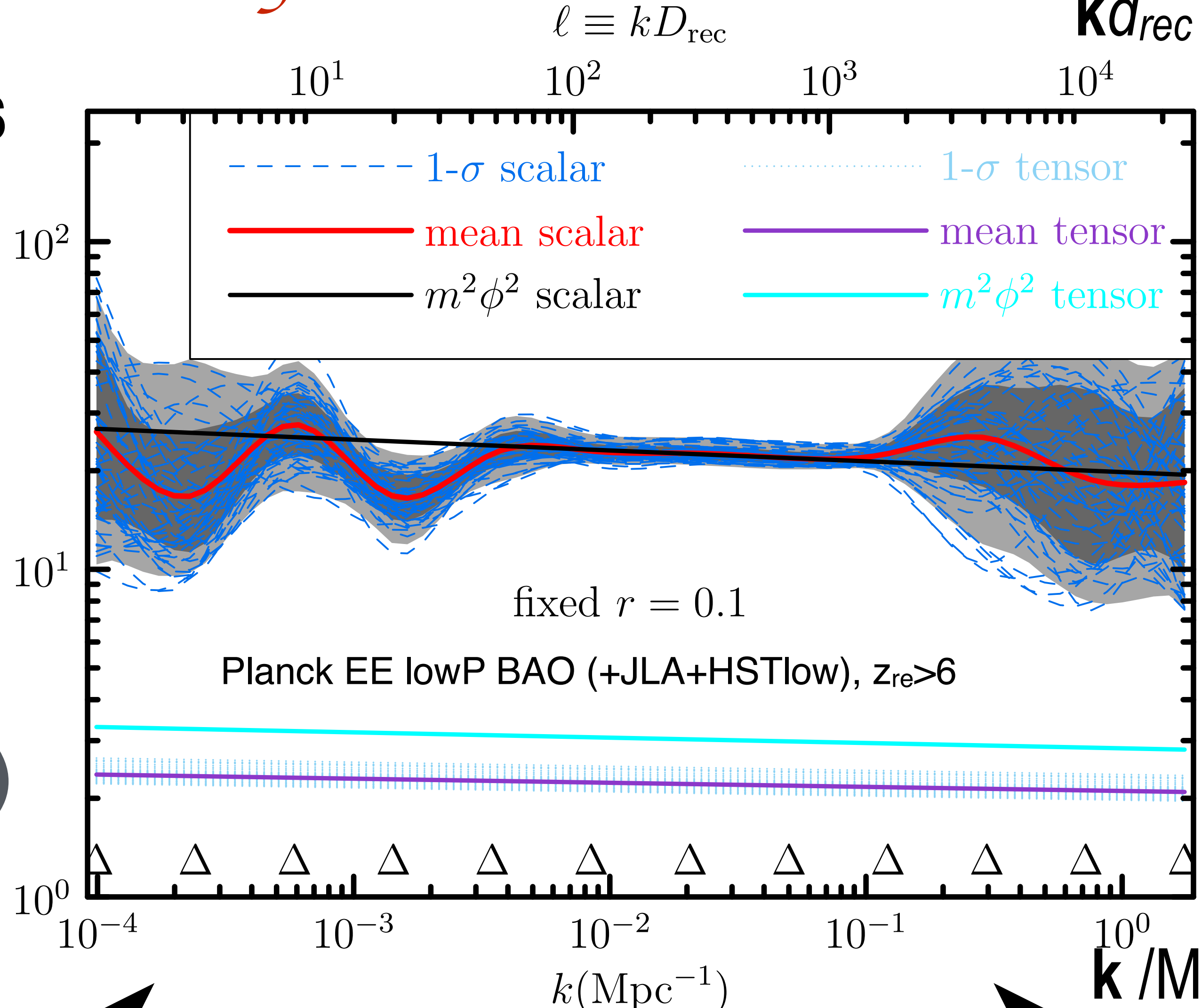

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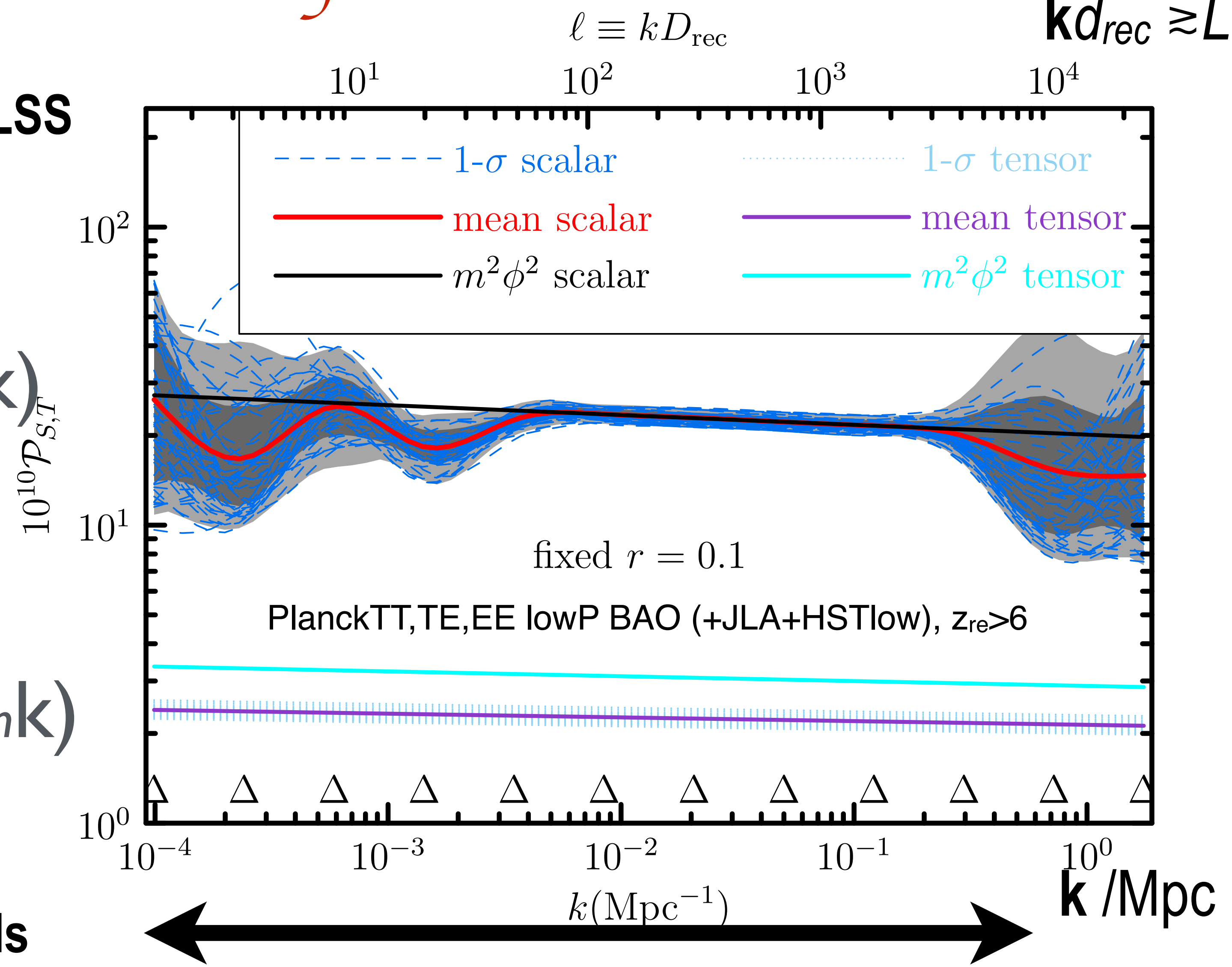
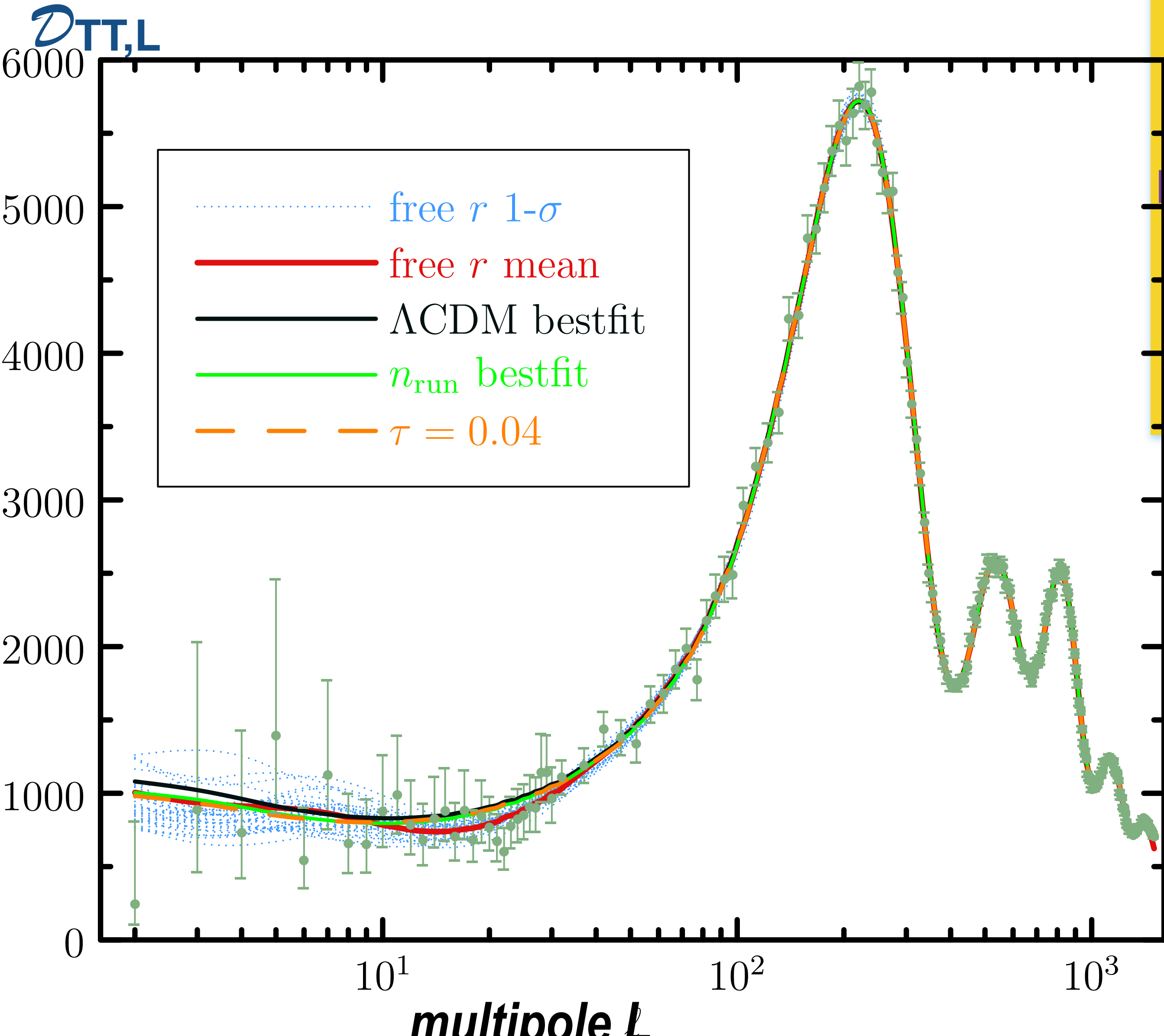


9 e-folds

trajectories of $\mathcal{D}_{TT,L}$

cf. Planck 2014 Commander Low L spectrum + Likelihood high L $\mathcal{D}_{TT,L}$

Preliminary 12 knots, cubic spline



running of $\mathcal{P}_\zeta$
≡ 3 Chebyshev modes
=> very stiff
=> not what the data wants

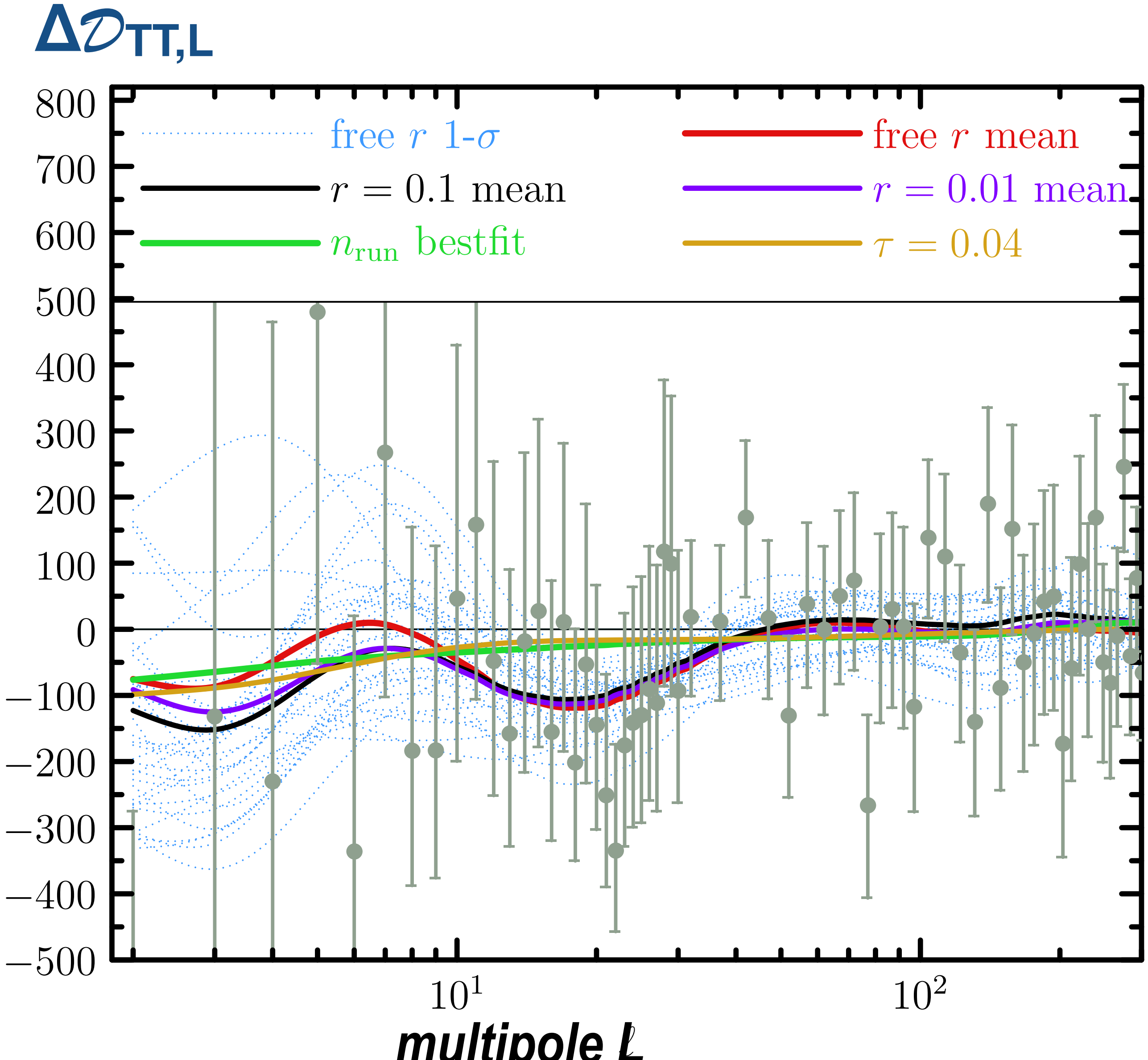
Lower τ => shape similar to running at low L

similar response on $\mathcal{D}_{TT,L}$ for constrained & free r
modified by τ freedom

trajectories of $\mathcal{D}_{TT,L}$

cf. Planck 2014 Commander Low L spectrum with Blackwell-Rao errors

Preliminary 12 knots, cubic spline



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≡ 3 Chebyshev modes
=> very stiff
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Lower τ => shape similar to running at low L

similar response on $\mathcal{D}_{TT,L}$ for constrained & free r

modified by τ freedom

running of $\mathcal{P}_\zeta$

NOT wanted

the down-up-down tendency

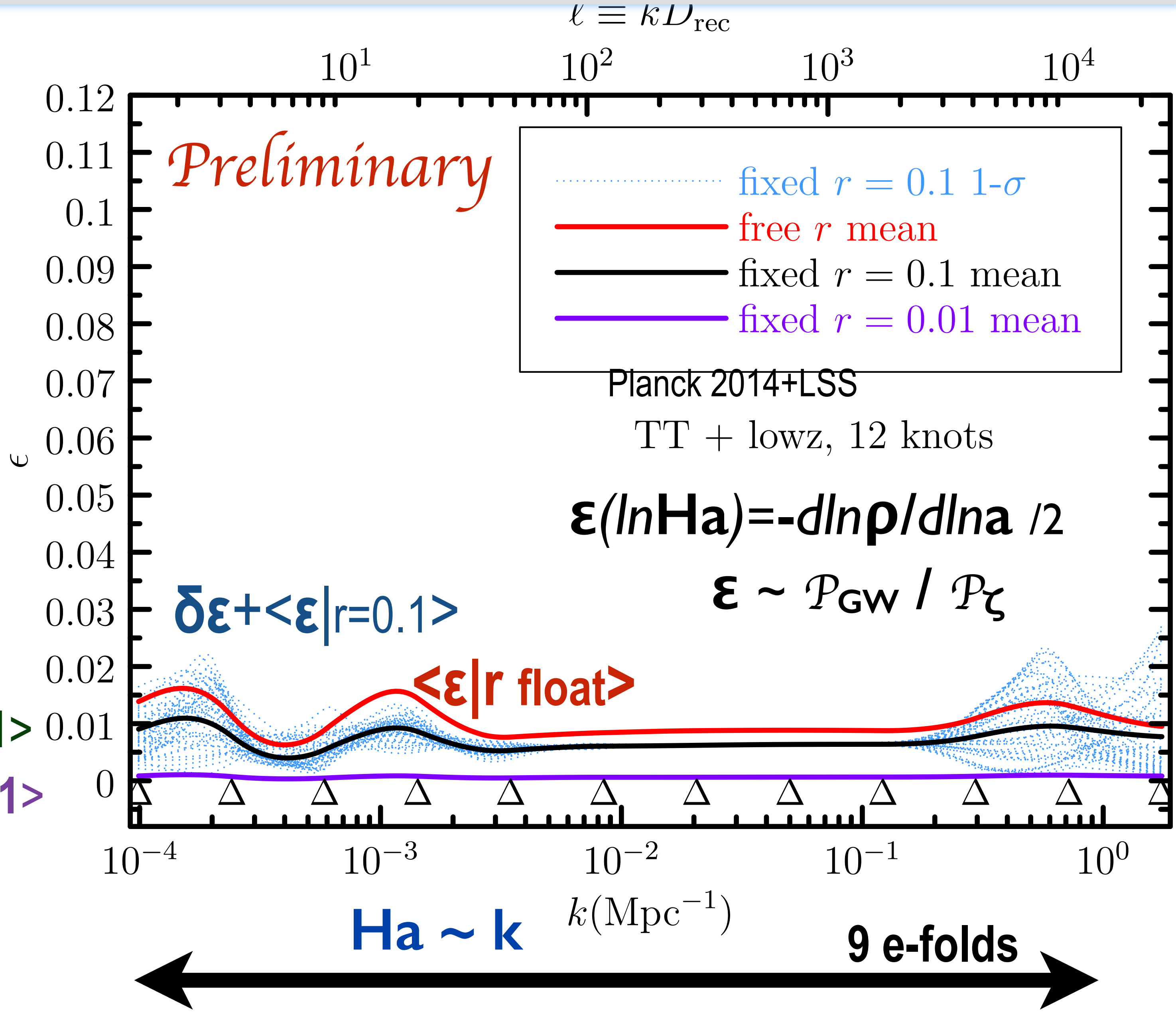
is here to stay,

2014-2022-…

early universe **acceleration histories = EOS histories** *3(1+w)/2*

ε=3(1+**w**)/2

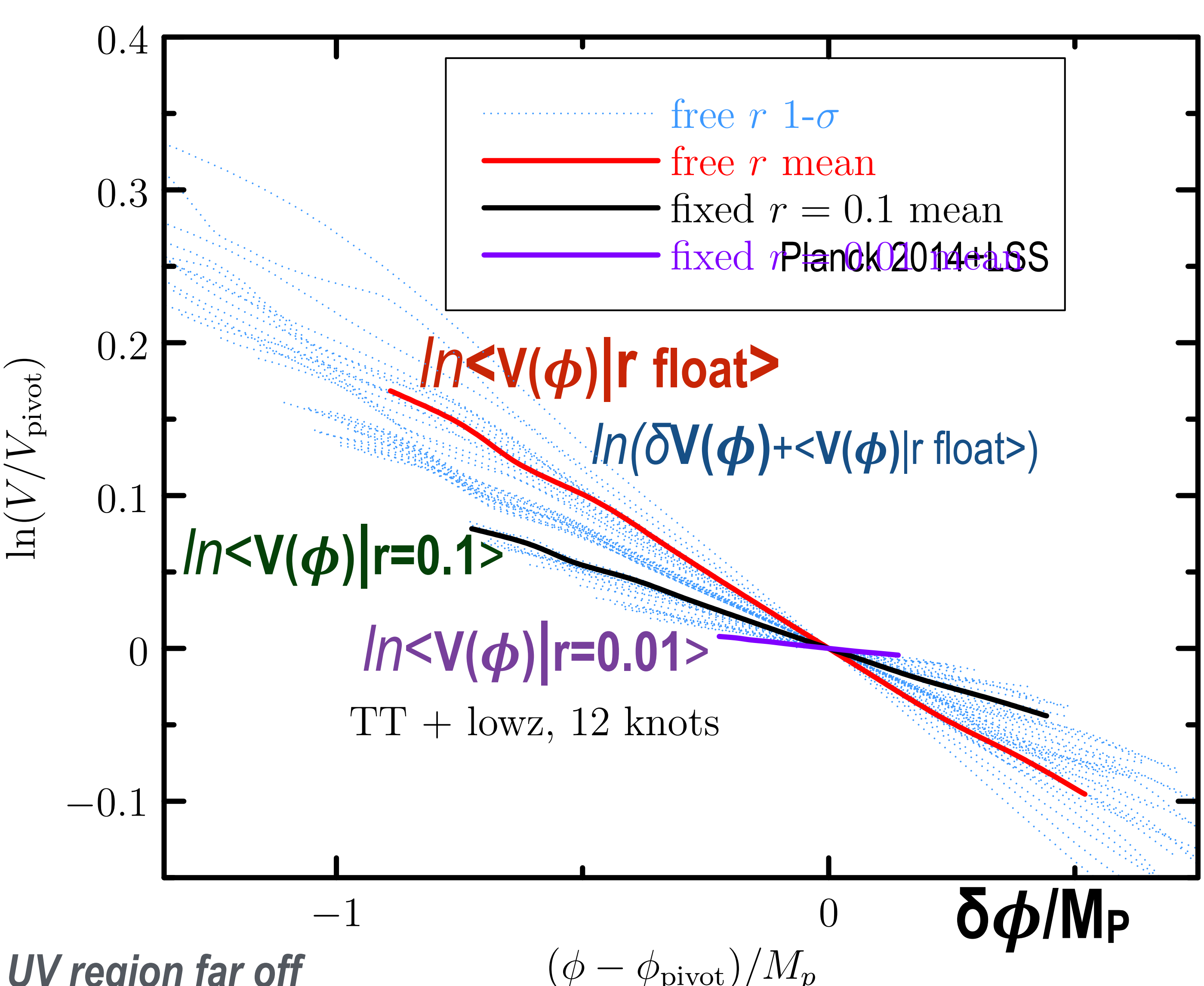
≈ **r**(k)/16



inflaton $V(\phi)$-maps $=3M_P^2 H^2 (1-\varepsilon/3)$ *HJ eqn,* $d\phi/M_P / d\ln a = \pm\mathrm{sqrt}(2\varepsilon)$

along the gradient / Morse flow

Preliminary



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

UV region far off => many ways to extrapolate

r to **+-0.02 Spider** forecast

r to **+-0.003 AdvACTpol** forecast w/ fgnds

inflaton V(ϕ)-maps $=3M_P^2 H^2 (1-\varepsilon/3)$ *HJ eqn*, $d\phi/M_P / d\ln a = \pm\mathrm{sqrt}(2\varepsilon)$

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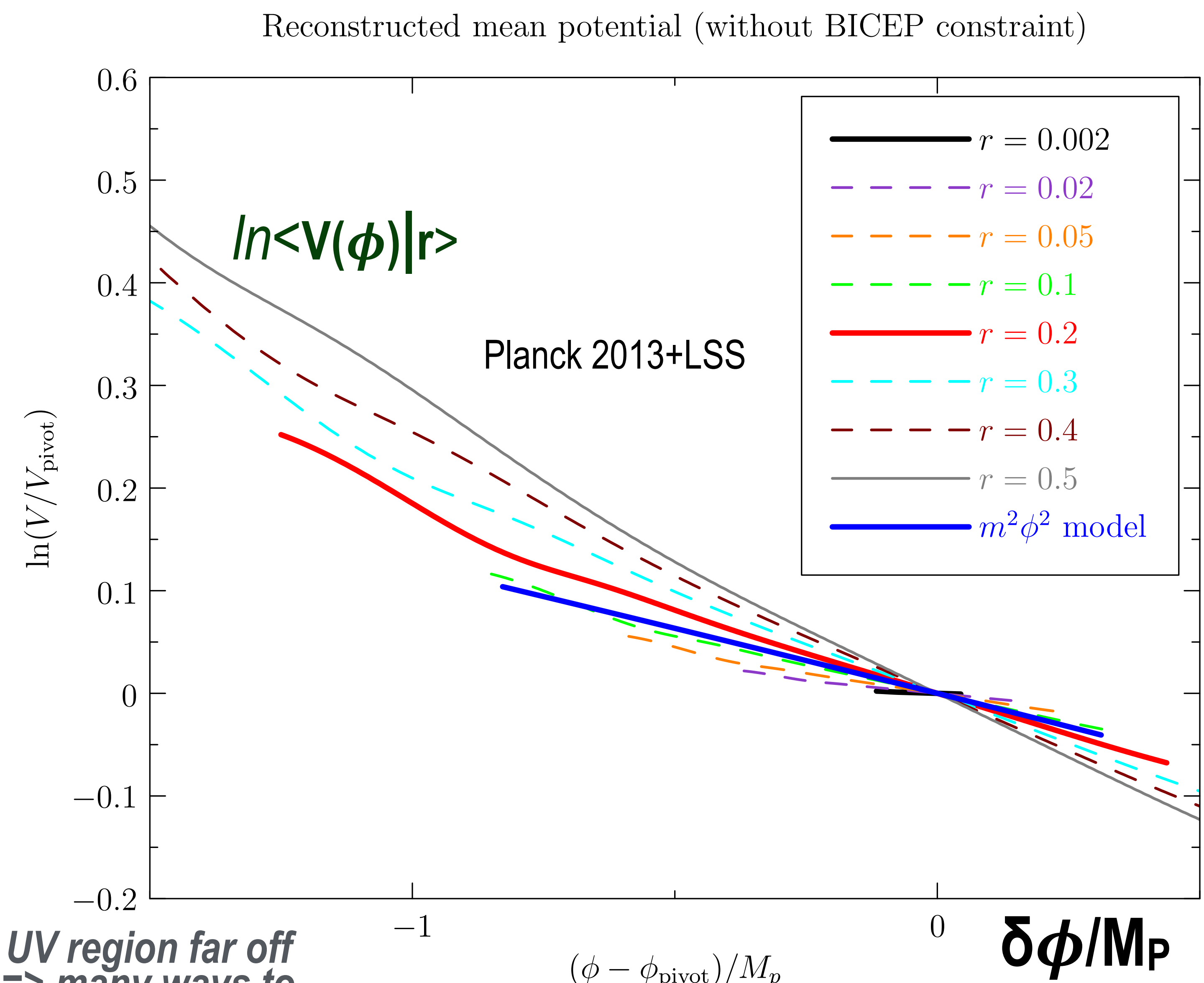

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UV region far off => many ways to extrapolate

δϕ/M_P

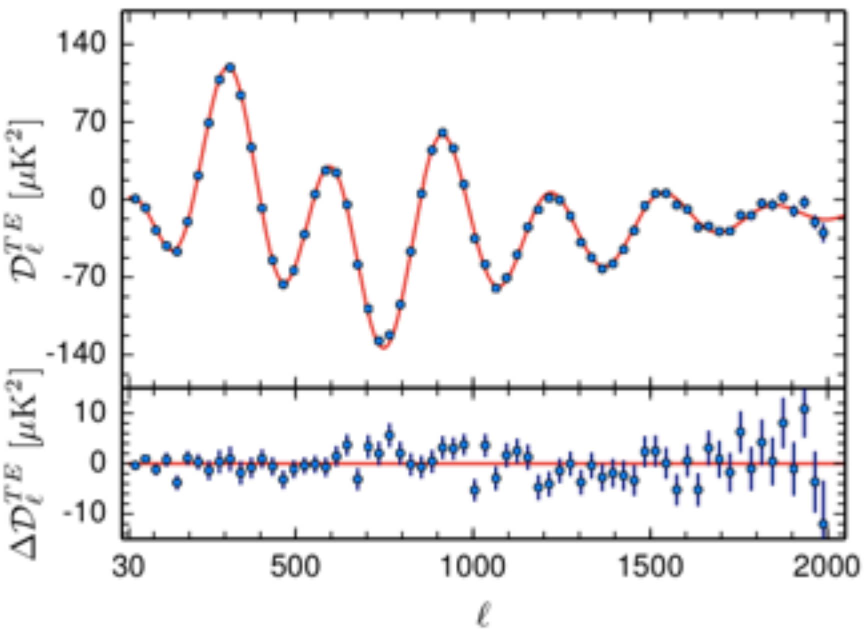
r to **+-0.02 Spider** forecast

r to **+-0.003 AdvACTpol** forecast w/ fgnds

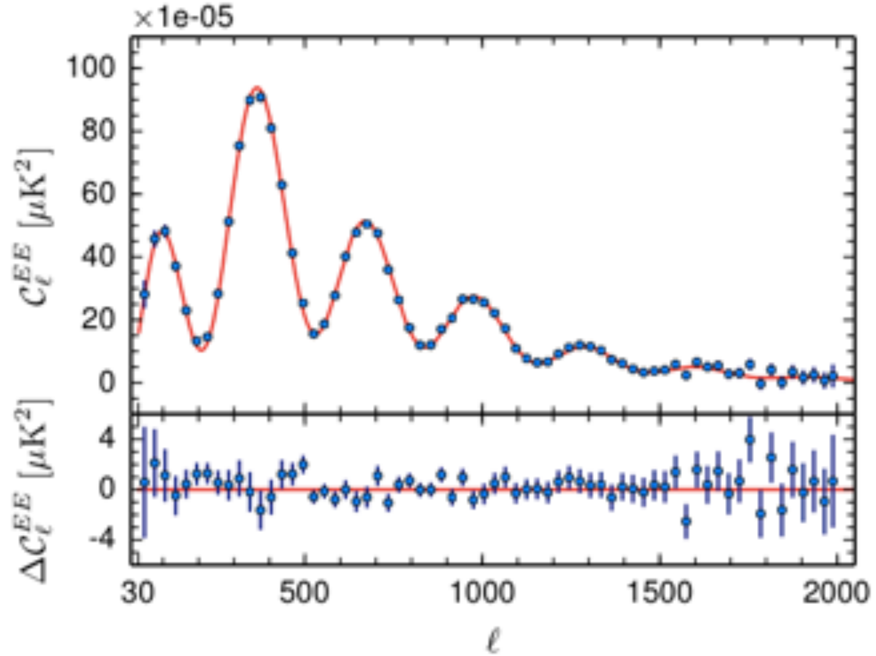
Beyond Planck 2014 +LSS: Inflation futures from CMB & LSS

Planck 2014 TE/EE cf. TT => constrains subdominant primordial power contributions not phase-locked with the acoustic-peaks *of the* pure adiabatic case. see Planck 2014 inflation paper

TE



EE



Preliminary

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada.

Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

CMB stage II, III, IV

lyman page, ferrara 2014

Ground Based

Chile

		Have data	Current or planned freqs
*	ABS		145 GHz
	ACTPol/AdvACt		30, 40, 90, 150, 230 GHz
	POLARBEAR		90, 150 GHz
*	CLASS		40, 90, 150 GHz

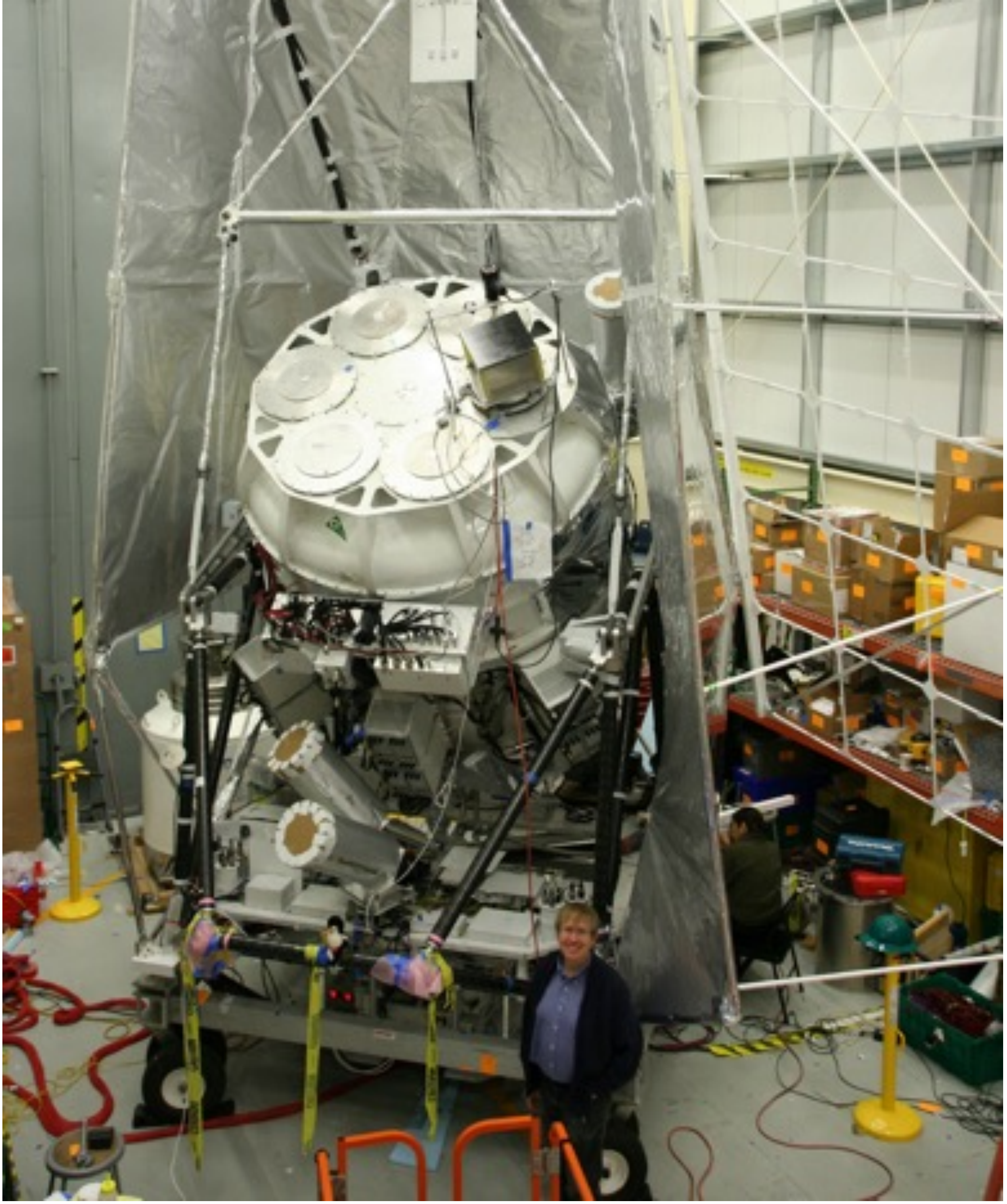
Antarctica

*	BICEP/KECK		90, 150, 220 GHz
	SPTPol		90, 150 GHz
	QUBIC-Bolo int.	2016	90, 150, 220 GHz

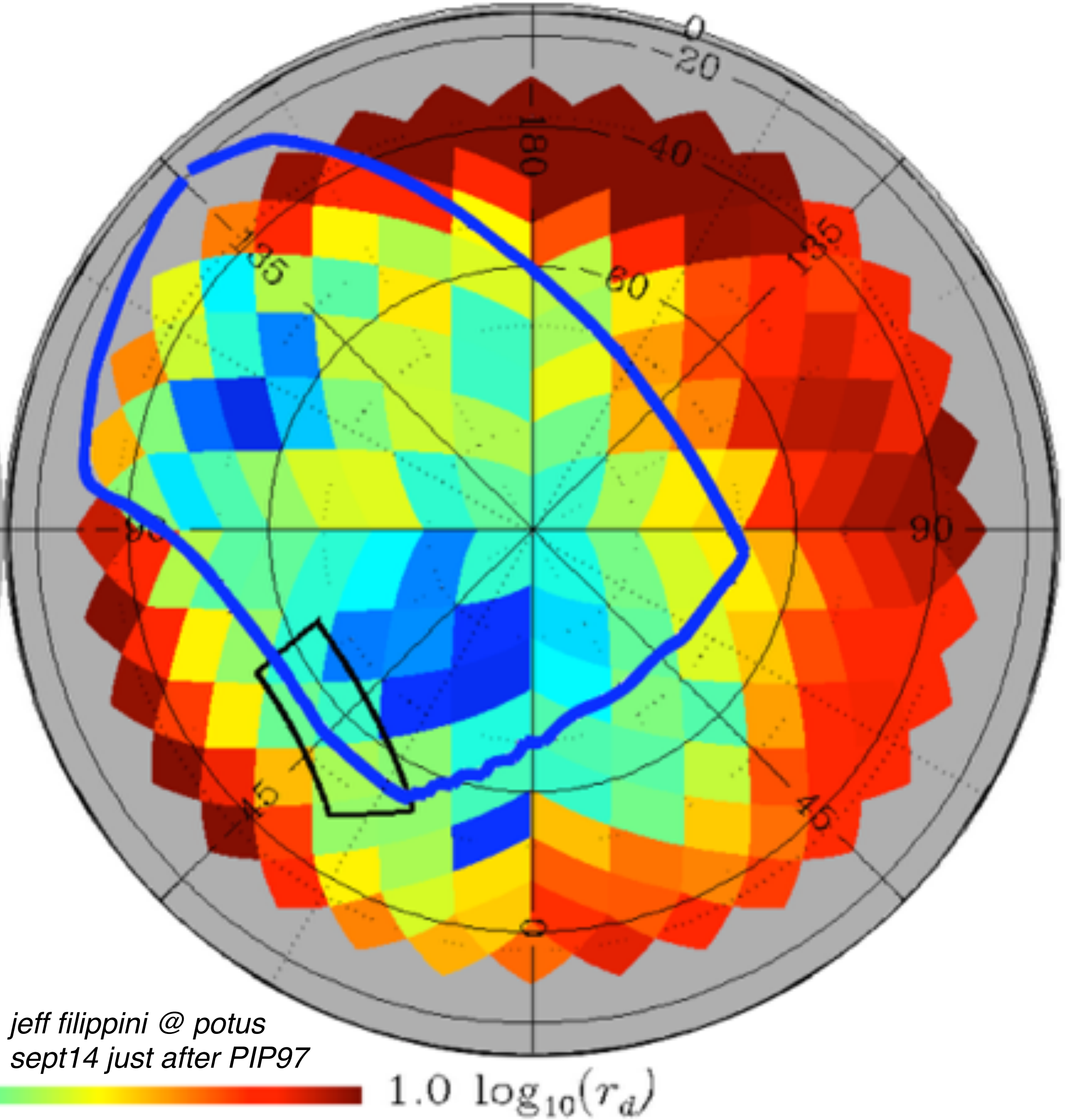
Elsewhere (for now)

	B-Machine –WMRS		40 GHz
*	GroundBIRD, LiteBIRD	2016	150 GHz
*	GLP – Greenland	TBD	150, 210, 270 GHz
*	MuSE-Multimoded	TBD	44, 95, 145, 225, 275 GHz
	QUIJOTE –Canaries, HEMPTS		11-20, 30 GHz

SPIDER



SPIDER



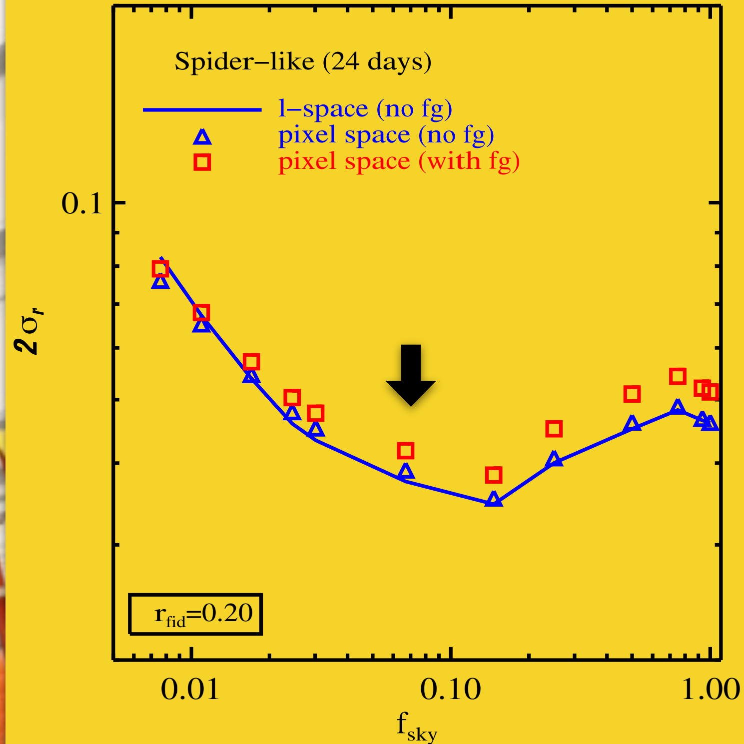
jeff filippini @ potus
sept14 just after PIP97

PRINCETON UNIVERSITY
SLAC NATIONAL ACCELERATOR LABORATORY
Imperial College London
UNIVERSITY OF TORONTO
CITA ICAT Canadian Institute for Theoretical Astrophysics L'institut canadien d'astrophysique théorique
STANFORD UNIVERSITY
CASE WESTERN RESERVE UNIVERSITY EST. 1826
NASA NSF NIST CSA ASC NSERC CRSNG JPL
the David & Lucile Packard FOUNDATION
UNIVERSITY OF KWAZULU-NATAL
UBC
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

SPIDER

cooled to subK, ready to go at McMurdo Dec 2014

Dec 2014 flight ~ 20d ?
fsky=0.8
3/3 @ 90/150 GHz
~2K detectors incl yield
L ~ 10-300
2015 flight
2/2/2 @ 90/150/280 GHz



forecasts
0.03 2 sigma 1st flight no fgnd
0.02 2 sigma 2nd flight
0.03 2 sigma 2nd flight fgnd cleaned

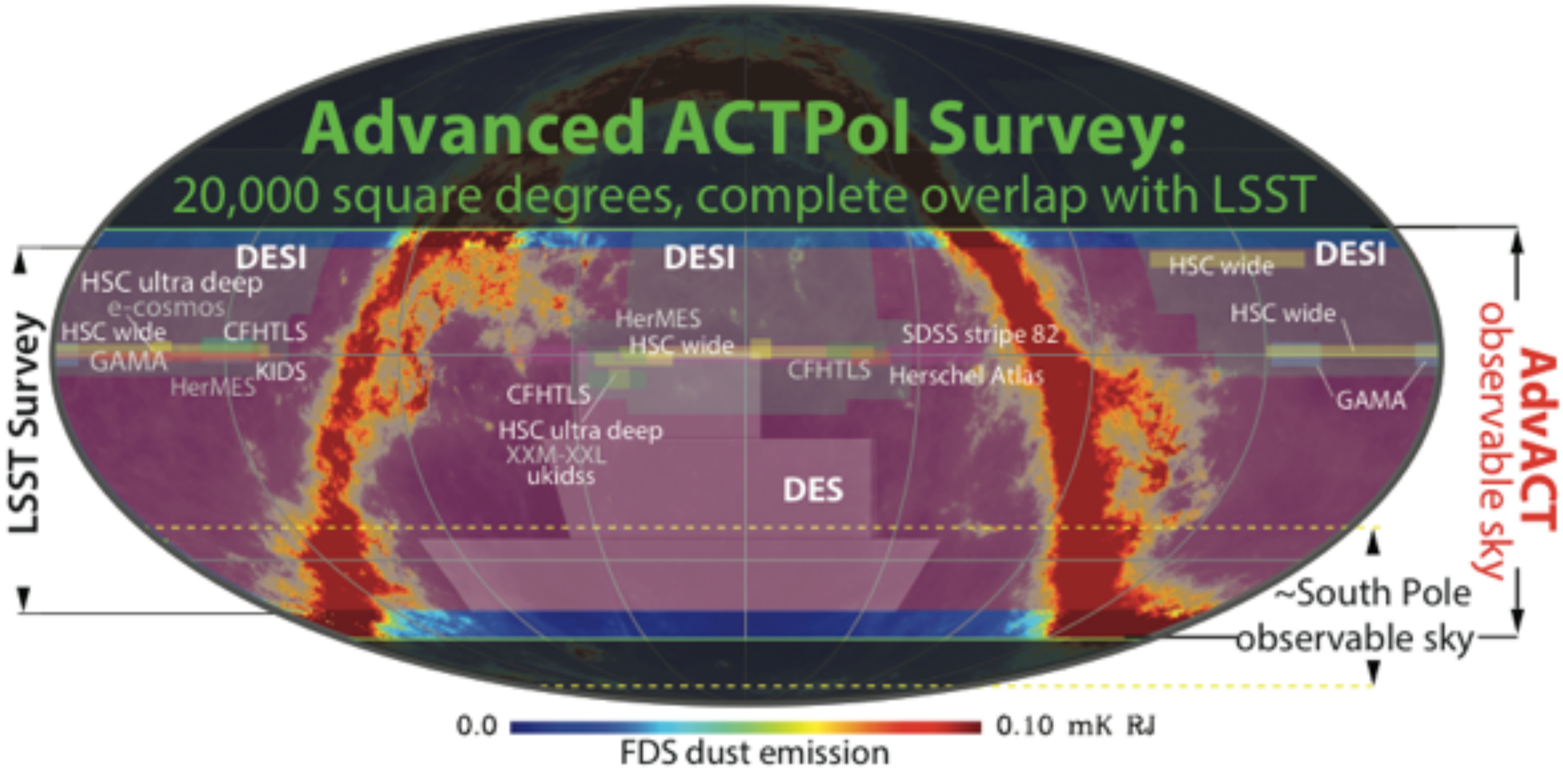
The ACT Collaboration

ACT, now ACTpol, => Advanced ACTpol

NSF

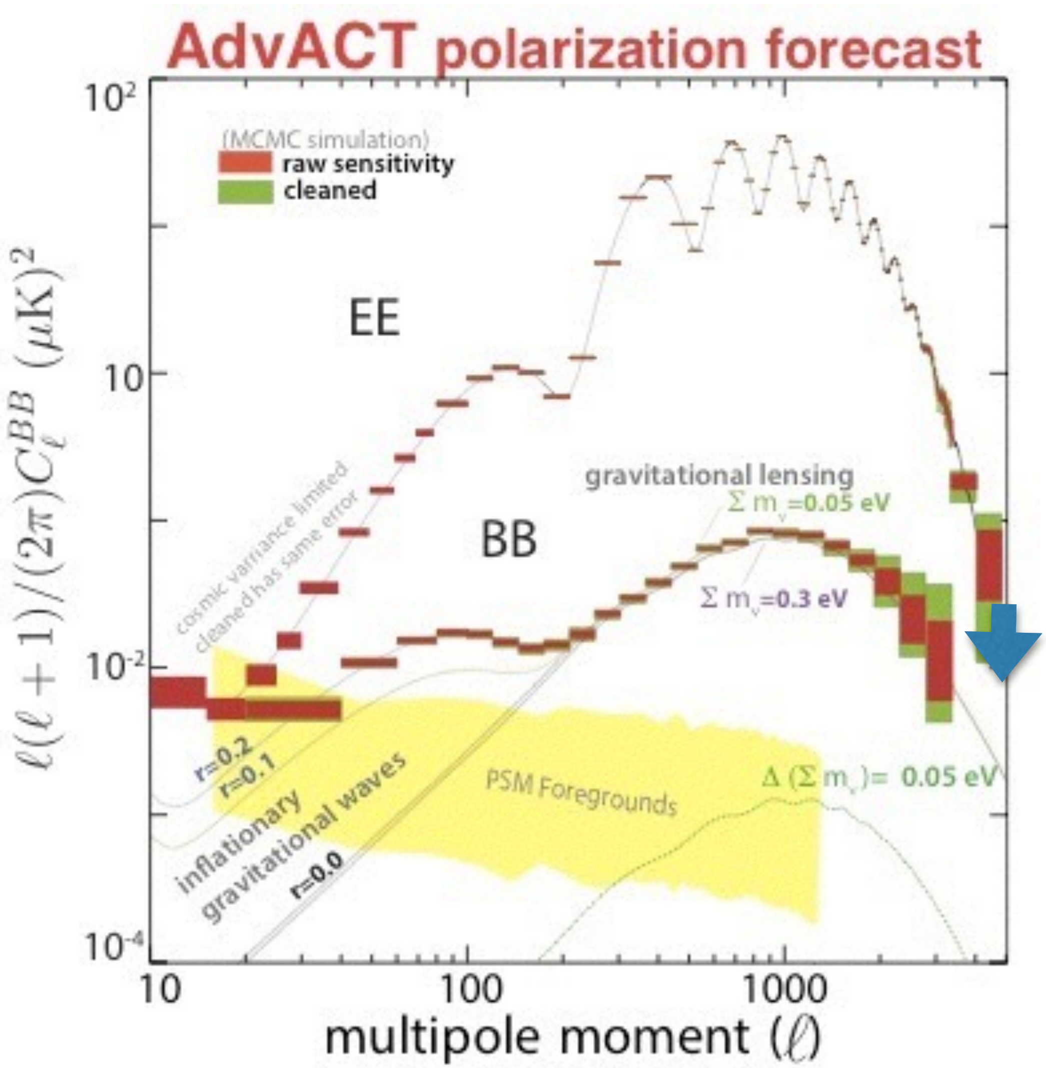
CITA ICAT | CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD | Carnegie Mellon University | HAVERFORD | IAS Institute for Advanced Study | INAOE | NASA | NIST | Stony Brook University | UBC | Berkeley | MIAMI | MICHIGAN | Penn University of Pennsylvania

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

CMB stage IV
DOE funding, *grand unification of ground efforts*
200-500K detectors @ SP, Atacama, Greenland (GLP)?

Inflation Physics from the Cosmic Microwave Background and Large Scale Structure

Topical Conveners: J.E. Carlstrom, A.T. Lee

K.N. Abazajian, K. Arnold, J. Austermann, B.A. Benson, C. Bischoff, J. Bock, J.R. Bond, J. Borrill, I. Buder, D.L. Burke, E. Calabrese, J.E. Carlstrom, C.S. Carvalho, C.L. Chang, H.C. Chiang, S. Church, A. Cooray, T.M. Crawford*, B.P. Crill, K.S. Dawson, S. Das, M.J. Devlin, M. Dobbs, S. Dodelson, O. Doré, J. Dunkley, J.L. Feng, A. Fraisse, J. Gallicchio, S.B. Giddings, D. Green, N.W. Halverson, S. Hanany, D. Hanson, S.R. Hildebrandt, A. Hincks, R. Hlozek, G. Holder, W.L. Holzapfel, K. Honscheid, G. Horowitz, W. Hu, J. Hubmayr, K. Irwin, M. Jackson, W.C. Jones, R. Kallosh, M. Kamionkowski, B. Keating, R. Keisler, W. Kinney, L. Knox, E. Komatsu, J. Kovac, C.-L. Kuo, A. Kusaka, C. Lawrence, A.T. Lee, E. Leitch, A. Linde, E. Linder, P. Lubin, J. Maldacena, E. Martinec, J. McMahon, A. Miller, V. Mukhanov, L. Newburgh, M.D. Niemack, H. Nguyen, H.T. Nguyen, L. Page, C. Pryke, C.L. Reichardt, J.E. Ruhl, N. Sehgal, U. Seljak, L. Senatore, J. Sievers, E. Silverstein, A. Slosar, K.M. Smith, D. Spergel, S.T. Staggs, A. Stark, R. Stompor, A.G. Vieregg, G. Wang, S. Watson, E.J. Wollack, W.L.K. Wu, K.W. Yoon, O. Zahn, and M. Zaldarriaga

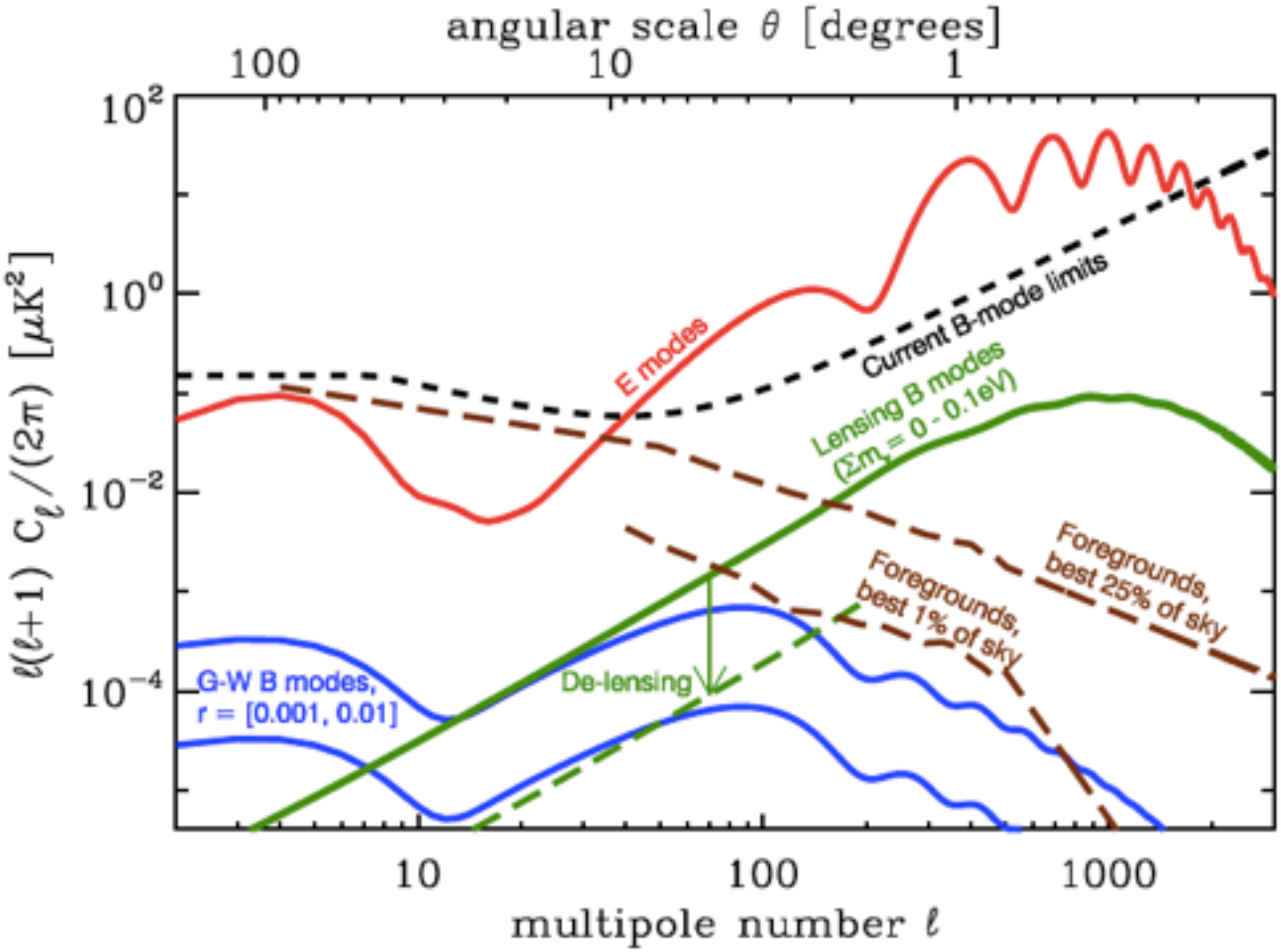
Cdns on the case; CMBpol satellites too?

SATELLITE MISSION OPPORTUNITIES FOR CMB POLARIZATION: WHITE PAPER FOR THE CANADIAN LRP MIDTERM REVIEW

Dick Bond[2,3], Scott Chapman[6], Matt Dobbs[1,*], Mark Halpern[4], Gary Hinshaw[4,*], Gil Holder[1], Peter Martin[2,3,5], Barth Netterfield[2], Douglas Scott[4], Kendrick Smith[7], Keith Vanderlinde[2,5]

Draft version November 29, 2014

CMB stage IV

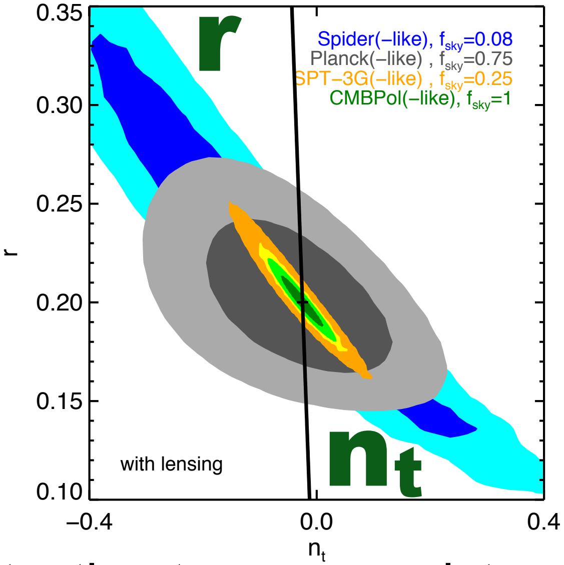


angular scale θ [degrees]
100
10
1
10^2
10^0
10^{-2}
10^{-4}
$\ell(\ell+1)\ C_\ell/(2\pi)\ [\mu K^2]$
E modes
Current B-mode limits
Lensing B modes
(Σm_ν = 0 - 0.1eV)
Foregrounds, best 25% of sky
Foregrounds, best 1% of sky
G-W B modes,
r = [0.001, 0.01]
De-lensing
10
100
1000
multipole number ℓ

future

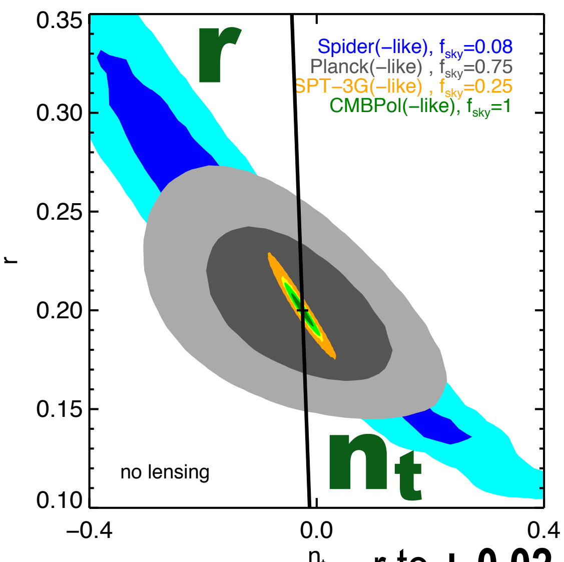
AdvACTpol (f_{sky}~50%): ***Cosmological Forecasts***

Planck_f, Spider, SPT3g, .. CMBpol (CoRE,Pixie,..)



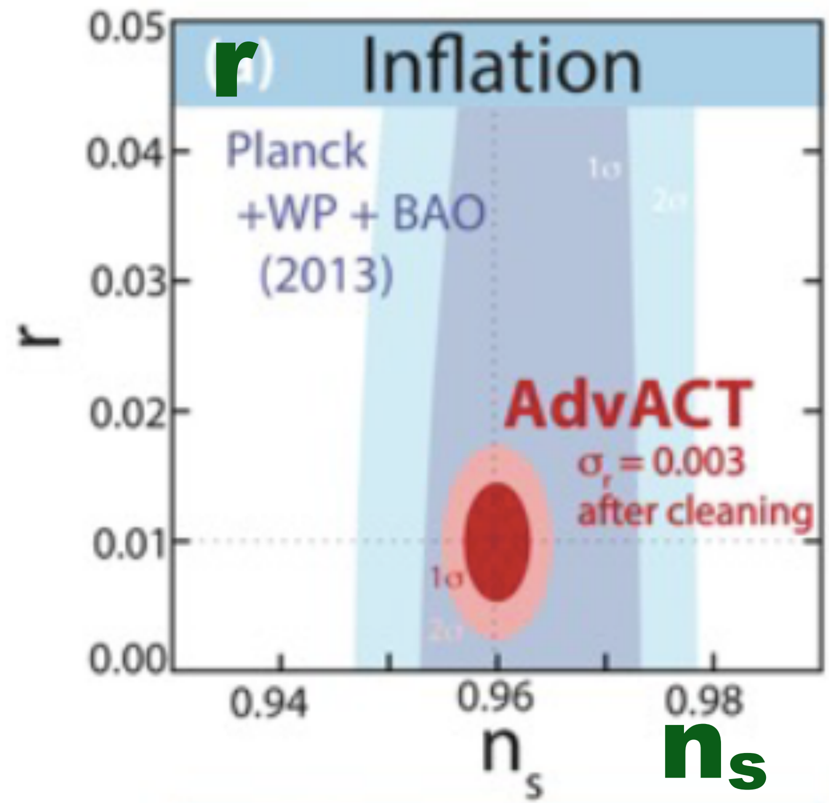
testing tensor consistency?

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



$n_t \approx -r/8$

nice BB spectra, hence a slope, but tensor consistency is a steep relation. how well we can do will depend upon the ability to de-lens to get to the high L tail

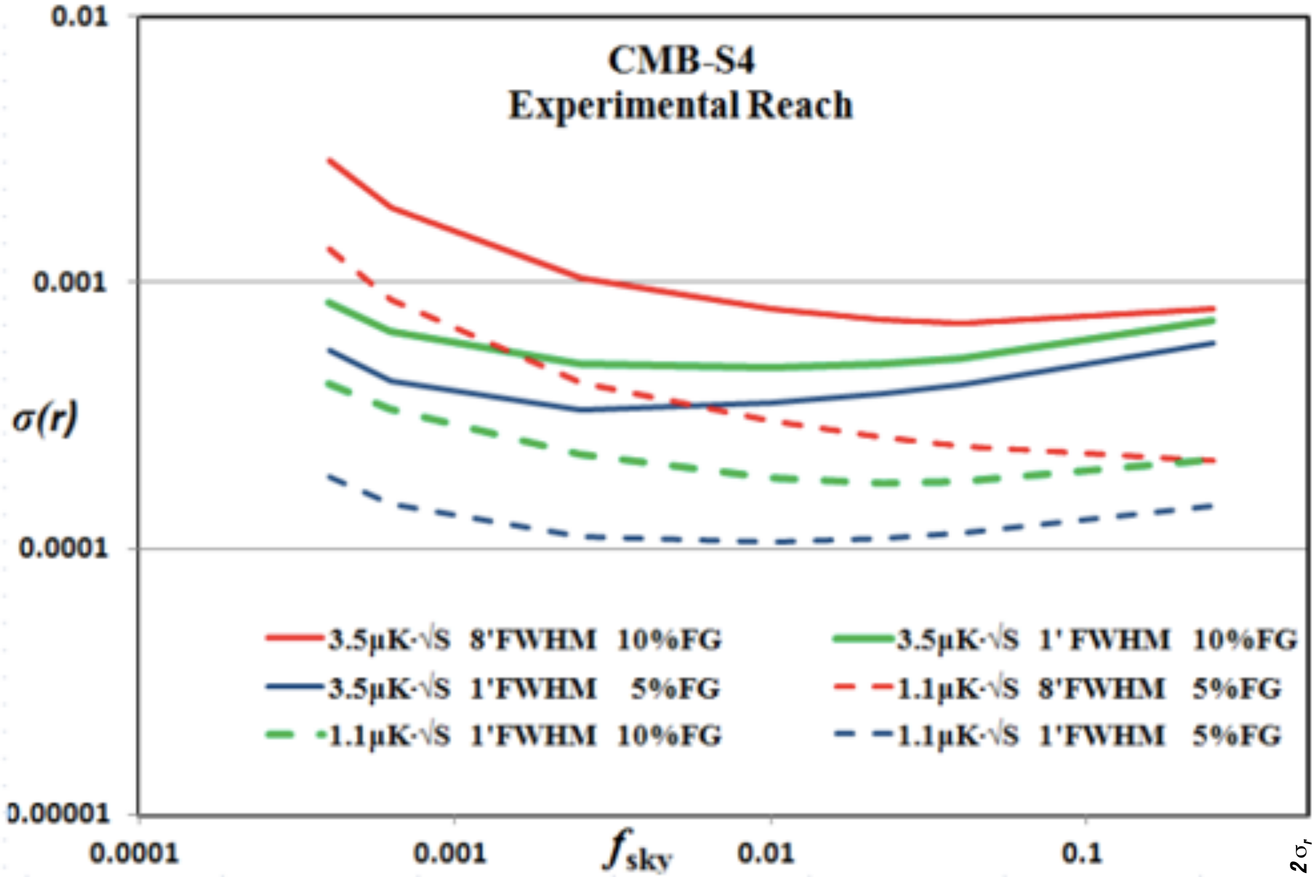


Planck_f uses pre-launch blue book forecast sensitivities

r to **+-0.02 Spider** forecast

r to **+-0.003 AdvACTpol** forecast w/ fgnds

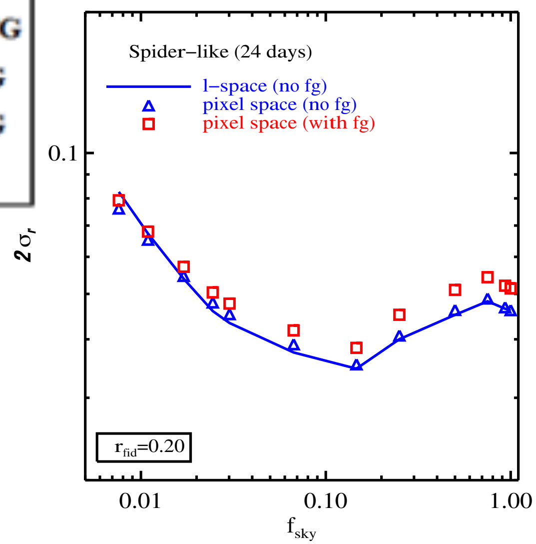
CMB stage IV
200-500K detectors @ SP, Atacama, Greenland (GLP)?



can we get such precision from the ground?
optimism informed by great technology
but to be shown

balloon future, higher frequency
ULDB?

satellites?



Beyond Planck 2014 +LSS:
Inflation futures from CMB & LSS: LSS & nonG

$\gtrsim$10,000,000 T/E modes of tΛCDM
$\lesssim$1000 modes of (slight) anomaly
$\lesssim$200 modes T/E reionization history
the vast CMB-un-illuminated $\zeta_{LM}(d)$
LSS tomography f_{sky} L_{max}^2 k_{max} d_{max}
LSS ~ CMB x 1000?

New bispectrum constraints using full mission data including polarization

Shape and method	f_{NL}(KSW) Independent	ISW-lensing subtracted
SMICA (T)		
Local	9.5 ± 5.6	**1.8 ± 5.6**
Equilateral	−10 ± 69	**−9.2 ± 69**
Orthogonal	−43 ± 33	**−20 ± 33**
SMICA (T+E)		
Local	6.5 ± 5.1	**0.71 ± 5.1**
Equilateral	−8.9 ± 44	**−9.5 ± 44**
Orthogonal	−35 ± 22	**−25 ± 22**

ben wandelt, ferrara 2014
on behalf of Planck

2.3.1 Non-Gaussianity from the CMB

Preliminary

The current best limits on primordial non-Gaussianity are obtained using data from the *Planck* satellite [67]: $f_{NL}^{local} = 2.7 \pm 5.8$, $f_{NL}^{equilateral} = -42 \pm 75$ and $f_{NL}^{orthogonal} = -25 \pm 39$. At the angular scales that contribute most of the weight to the f_{NL} constraints, *Planck* has measured the CMB temperature fluctuations as well as they can be measured (i.e., the constraints on f_{NL} is now limited by cosmic variance, not noise). Adding CMB polarization information will improve this constraint, but at most by $\sqrt{3}$.

LSS & nonG

1412.4671

white paper on nonG+LSS on arXiv this week

outcome of CITA October 23-24 2014 meeting

DESI, LSST, Euclid .. CHIME .. SphereX proposal

the varieties of nonG f_{NL} ... feature nG … preheating F_{NL} [χ,g]

scale-dependent bias & power spectrum on very large scales

bispectrum - more promising than scale-dependent bias it seems

nonG intermittent F_{NL}

=> *search for large scale rare events, e.g., superduper superclusters*

TESTING INFLATION WITH LARGE SCALE STRUCTURE: CONNECTING HOPES WITH REALITY

Conveners: Olivier Doré and Daniel Green

Marcelo Alvarez[1], Tobias Baldauf[2], J. Richard Bond[1,3], Neal Dalal[4], Roland de Putter[5,6], Olivier Doré[5,6], Daniel Green[1,3], Chris Hirata[7], Zhiqi Huang[1], Dragan Huterer[8], Donghui Jeong[9], Matthew C. Johnson[10,11], Elisabeth Krause[12], Marilena Loverde[13], Joel Meyers[1], P. Daniel Meerburg[1], Leonardo Senatore[12], Sarah Shandera[9], Eva Silverstein[12], Anže Slosar[14], Kendrick Smith[11], Matias Zaldarriaga[1], Valentin Assassi[15], Jonathan Braden[1], Amir Hajian[1], Takeshi Kobayashi[1,11], George Stein[1], Alexander van Engelen[1]

[1] *Canadian Institute for Theoretical Astrophysics, University of Toronto, ON*

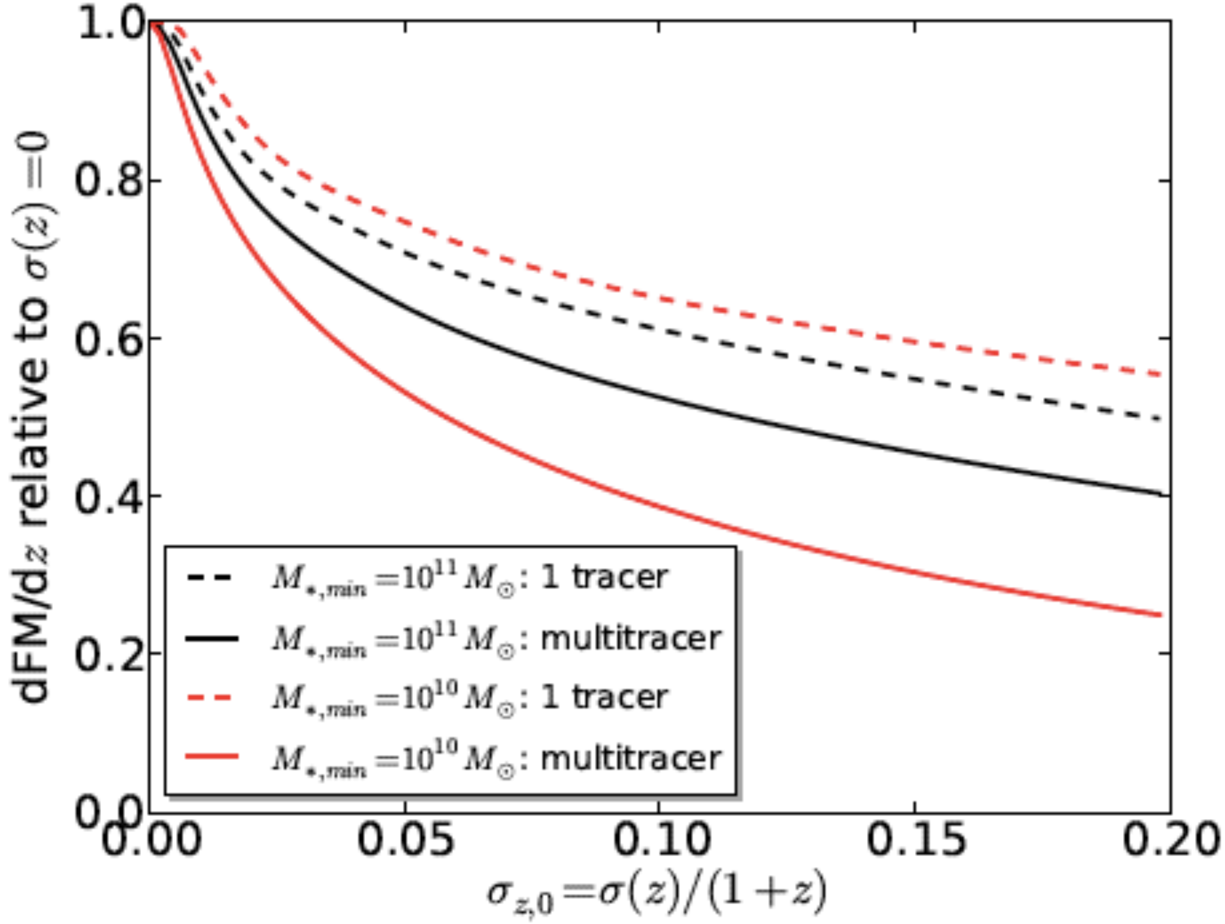
LSS & nonG

	LSST	DESI	Euclid	SPHEREx	CHIME
Survey type	photo	spectro	photo+spectro	low-res spectro	21-cm
Ground or space	ground	ground	space	space	ground
Previous surveys	CFHTLS, DES, HSC	BOSS, eBOSS, PFS	no direct precursor	PRIMUS, COMBO-17, COSMOS	GBT HIM
Survey start	2020	2020	2018	2020	2016
Redshift-range	$z < 3$ (1% sources above 3)	$z < 1.4$, $2 < z < 3.5$ (Lya)	$z < 3$	$z < 1.5$	$0.75 < z < 2.5$
Survey area [deg^2]	20k	14k	15k	40k	20k
Approximate number of objects	2×10^9 (WL sources)	22×10^6 gal., $\sim 2.4 \times 10^5$ QSOs	40×10^6 redshifts, 1.5×10^9 photo-zs	15×10^9 pixels	10^7 pixels
Galaxy clustering	✓✓°	✓	✓	✓	✓
Weak lensing	✓		✓		✓
RSD		✓	✓	✓✓	✓✓
Multi-tracer	✓✓	✓✓	✓✓	✓	

Table 2. A selection of currently funded or planned surveys. Other important surveys not included in the table are PFS, JPAS, PAU, EMU. Relevant survey links [LSST],[DESI],[Euclid], [UBC],[PFS], [JPAS],[PAU], [EMU]. °Galaxy clustering is possible, but very strong radial degradation.

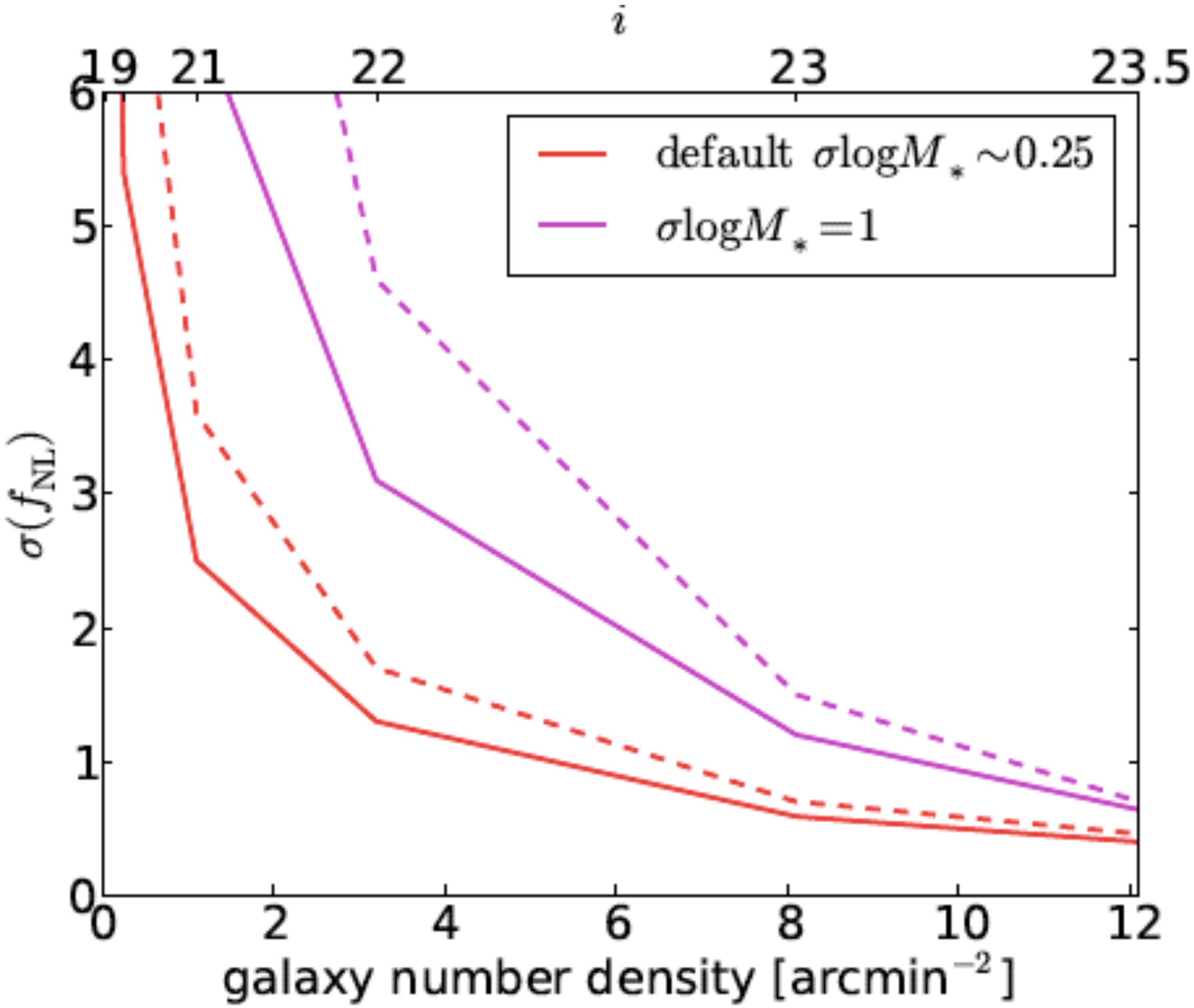
LSS & nonG

1412.4671



LSS & nonG

1412.4671



LSS & nonG

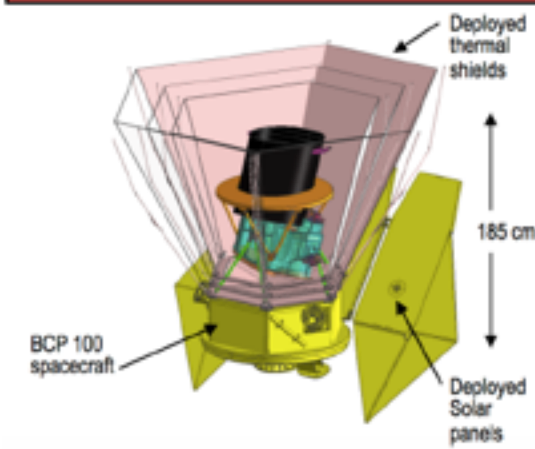
SPHEREx: An All-Sky Spectral Survey

A high throughput, low-resolution near-infrared spectrometer

Optical-IR imaging spectrometer
λ= 0.75-4.1 μm R=41.5
λ= 4.1-4.8 μm R=150
20cm telescope
Passively cooled
6.2”x6.2” pixels
2x(3.5x7) sq. deg. FOV

- ➡**Inflation Science**
  - ➡ Cosmology derived from 3-D galaxy large-scale structure.
  - ➡ Survey the $z < 1.5$ universe to fundamental limits to measure signatures of inflation, non-Gaussianity, the primordial power spectrum, and dark energy.
  - ➡ Complement Euclid and WFIRST which survey smaller areas at $z > 1$.
- ➡**Determine how interstellar ices bring water and organics into proto-planetary systems through absorption in ice spectra**
- ➡**Measure Extra-galactic Background Light to probe EOR**

SPHEREx data-set:
R=40 spectra spanning (0.75μm< λ <4.81μm) for every 6.2” pixel over the entire sky



SPHEREx Creates a High Legacy All-Sky Survey

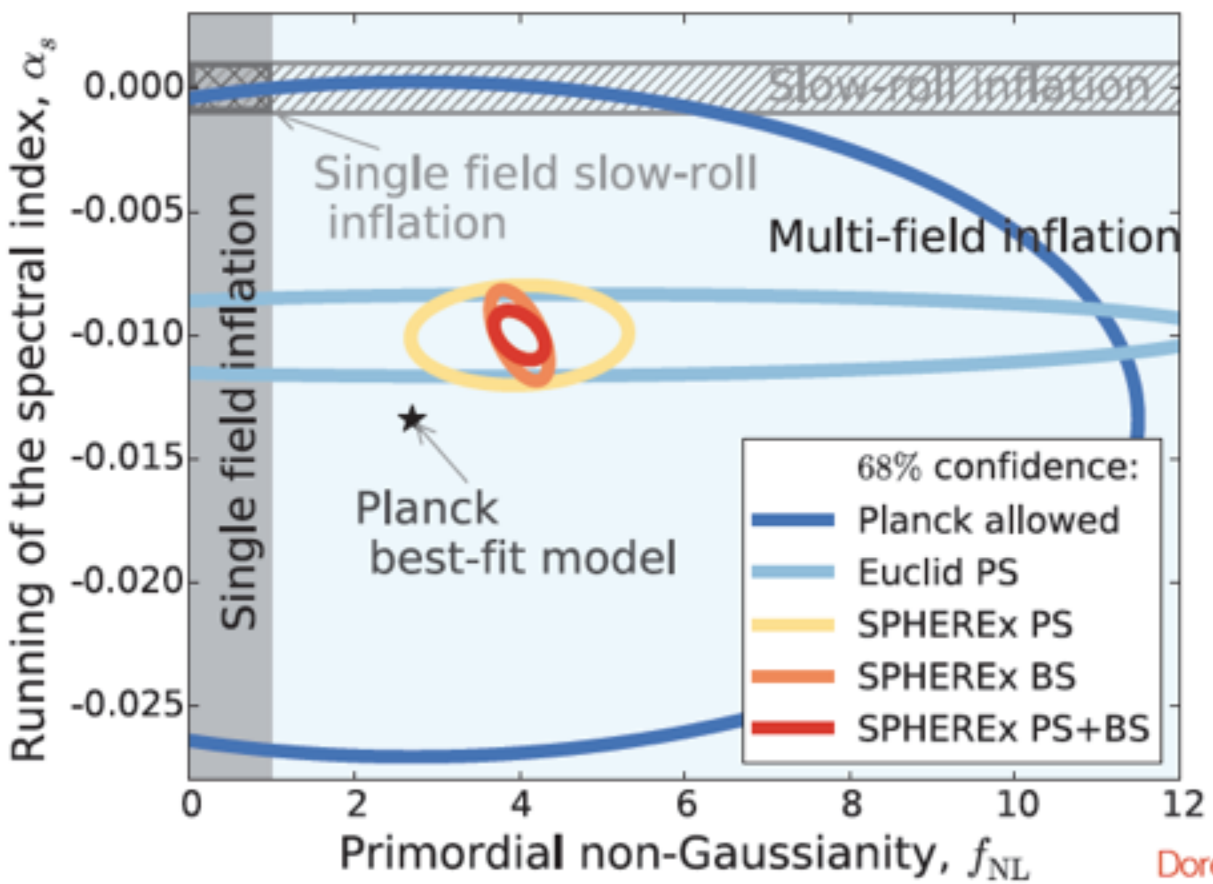
Extra-galatic sources	1.4 billion
	120M
	9.8M
	>1.5M QSOs with redshift
	0-300 QSOs with redshift > 7
	25,000 galaxy clusters with redshift
Galactic sources	>100M
	>10^4
	>400 brown dwarf spectra

SMEX Concept; PI: J. Bock, PS: O. Doré

LSS & nonG

SPHEREx as a Probe of non-Gaussianity

$\sigma(f_{NL}^{loc}) \sim 0.8$ (3-D Powerspectrum)
$\sigma(f_{NL}^{loc}) \sim 0.2$ (3-D Bispectrum)



Doré, Bock et al. 2014
Alvarez et al. 2014 1412.4671

CHIME Collaboration

THE UNIVERSITY OF BRITISH COLUMBIA

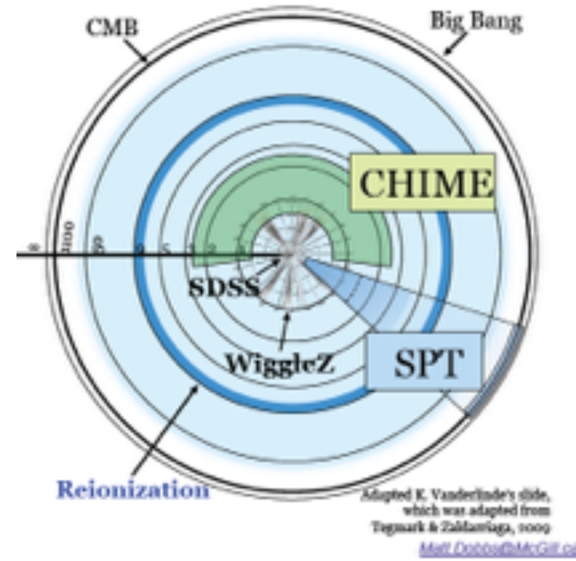
- Graeme Addison
- Mandana Amiri
- Meiling Deng
- Mateus Fandino
- Kenneth Gibbs
- Carolin Hofer
- Mark Halpern
- Adam Hincks
- Gary Hinshaw
- Kiyo Masui
- Kris Sigurdson
- Mike Sitwell
- Rick Smegal
- Don Wiebe

McGill

- Kevin Bandura
- J-F Cliché
- Matt Dobbs
- Adam Gilbert
- David Hanna
- Juan Mena Parra
- Graeme Smecher
- Amy Tang

UNIVERSITY OF TORONTO

- Dick Bond
- Liam Connor
- Nolan Denman
- Peter Klages
- Laura Newburgh
- Ue-Li Pen
- Andre Recnik
- Richard Shaw
- Keith Vanderlinde

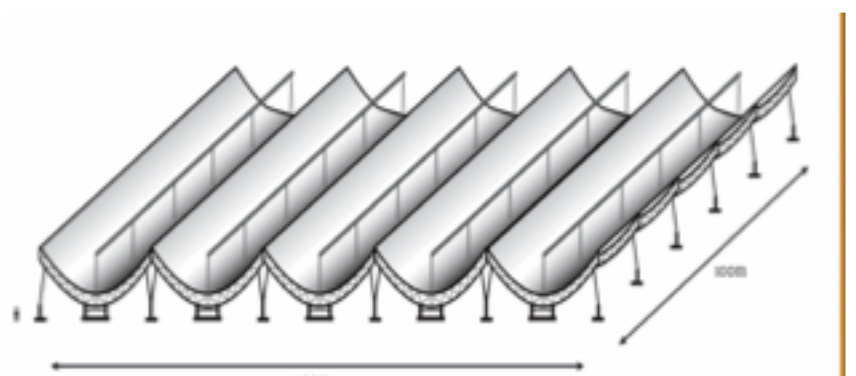


NRC · CNRC

- Tom Landecker

will generate more data per second than the annual internet use of every smartphone in the world combined

the new radio astronomy, GPU-enabled



CHIME Collaboration

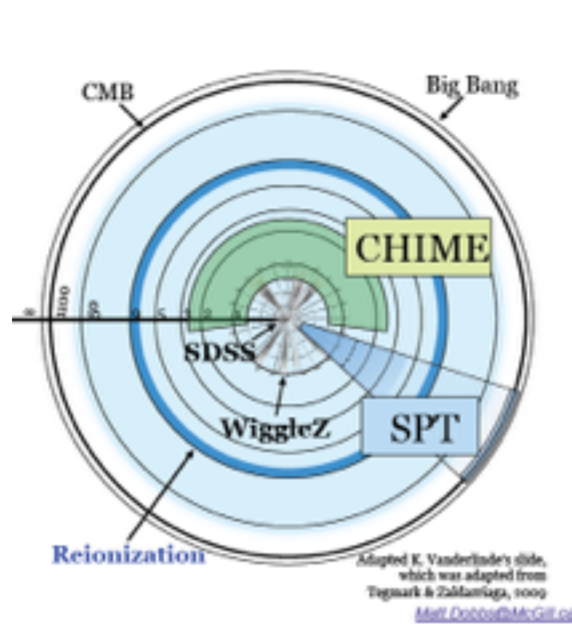
THE UNIVERSITY OF BRITISH COLUMBIA

McGill

UNIVERSITY OF TORONTO

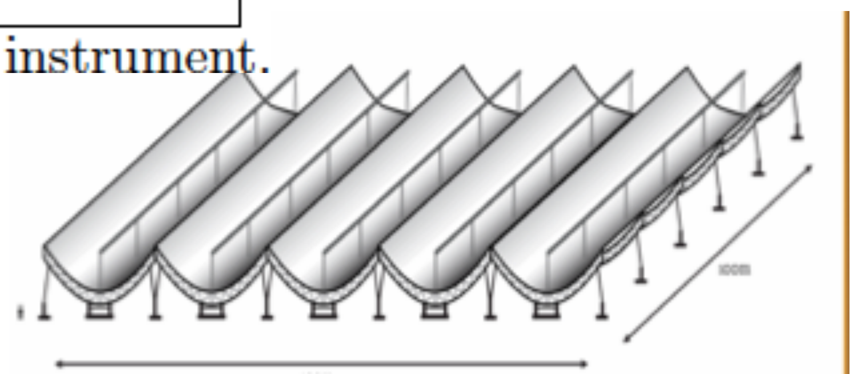
Location	DRAO (49°19′N, 119°37′W)
Number of inputs	2560
Frequency range	400 – 800 MHz
Frequency resolution	0.39 MHz
Wavelength range	75 – 37 cm
Redshift range	z = 2.5 – 0.8
Epoch	11 – 8 Gyr
E-W FOV	2.5° – 1.3°
N-S FOV	∼90° about zenith
Angular resolution	0.52° – 0.26°
Spatial resolution	10 – 50 Mpc

Table 1: The salient features of the CHIME instrument.



bandura+14, newburgh+14
spie proceedings, arXiv

the new radio astronomy, GPU-enabled



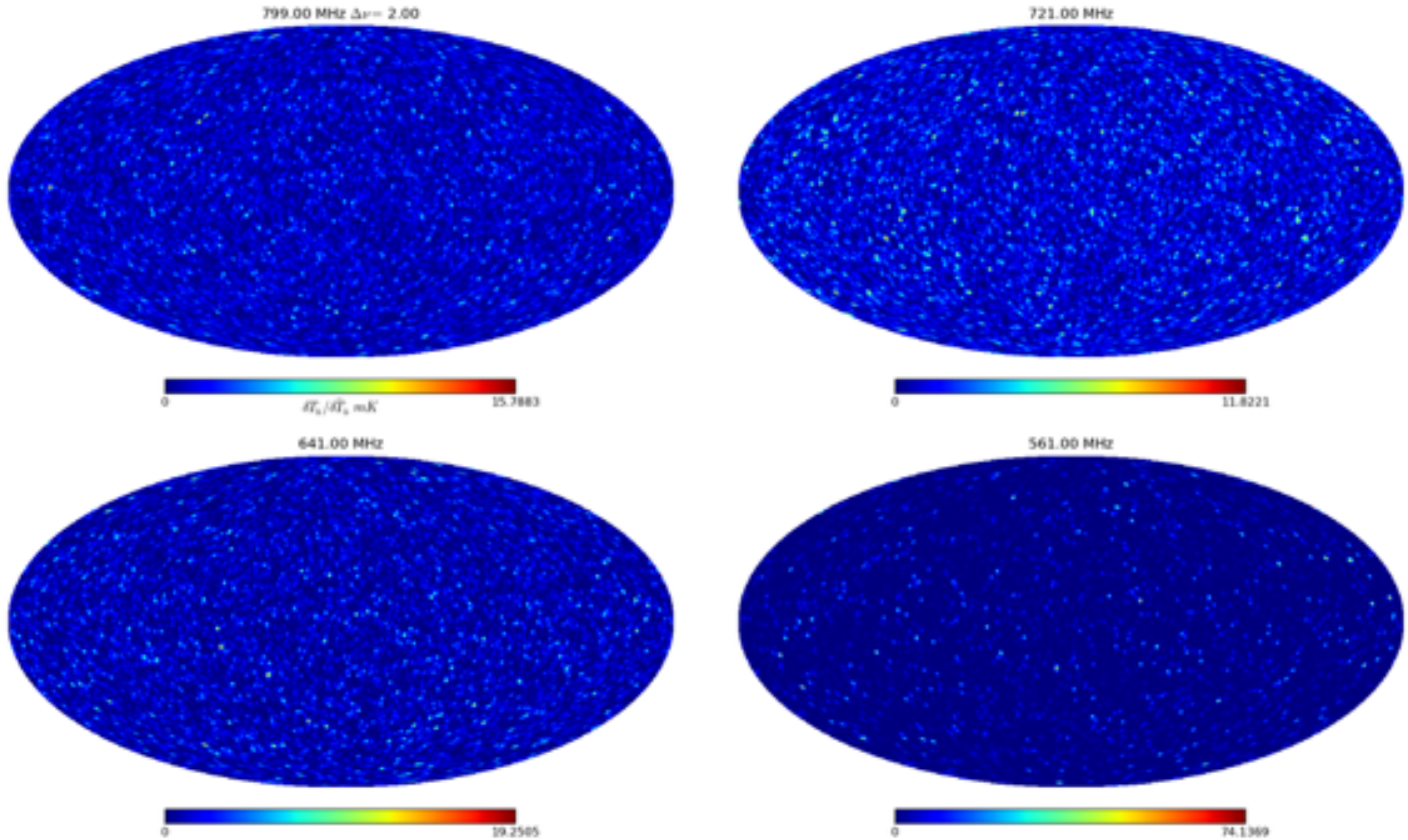
CHIME

a few sample all sky $\Delta\nu$ =0.2 MHz frequency maps from full sky sim to 16 Gpc reduce to cover z=0.8 to 2.5, 40% of sky

$$\frac{L_{HI}}{M_H} = \frac{L_{HI}}{M_{HI}}\frac{M_{HI}}{M_H} = \frac{3hA_{10}\nu_0}{4m_{HI}}\left(\frac{\Omega_{HI}}{\Omega_m f_{col}}\right)$$

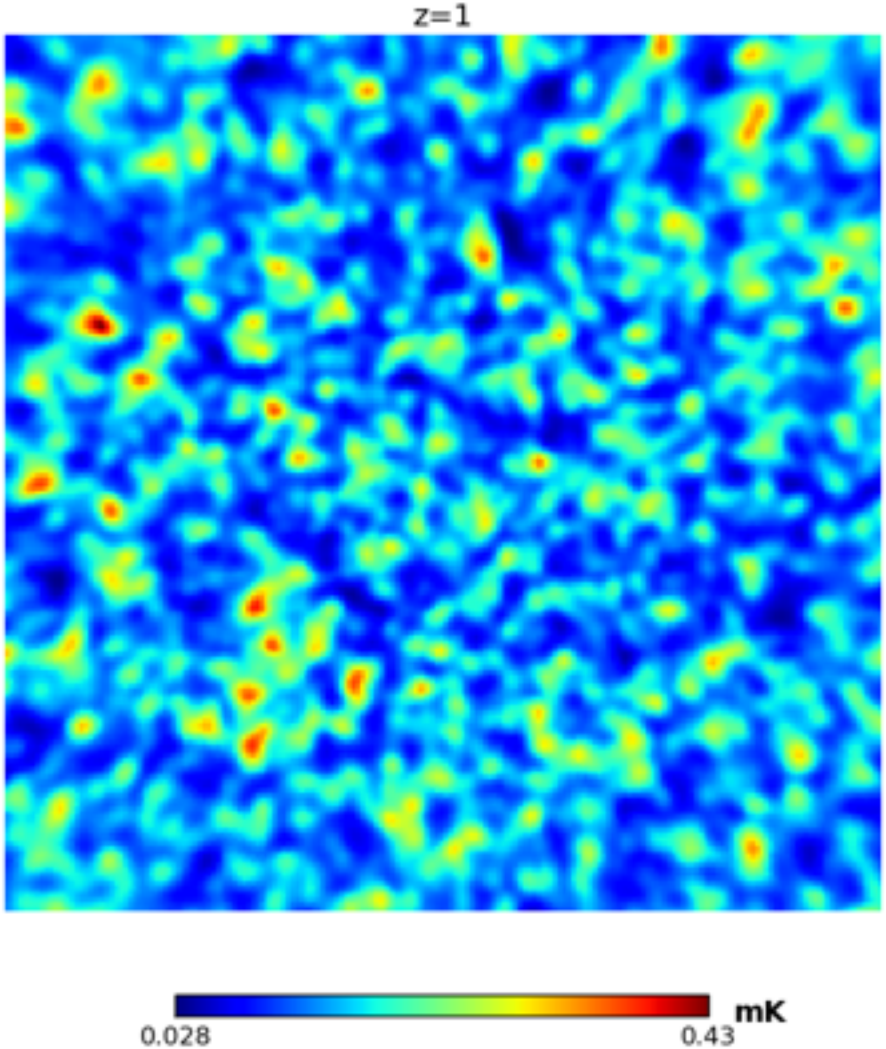
halo mass to total flux: Ω_{HI} = 0.5 x10^{-3} from GBT X corr observations and f_{coll} = 0.2

normalized to the mean of the map



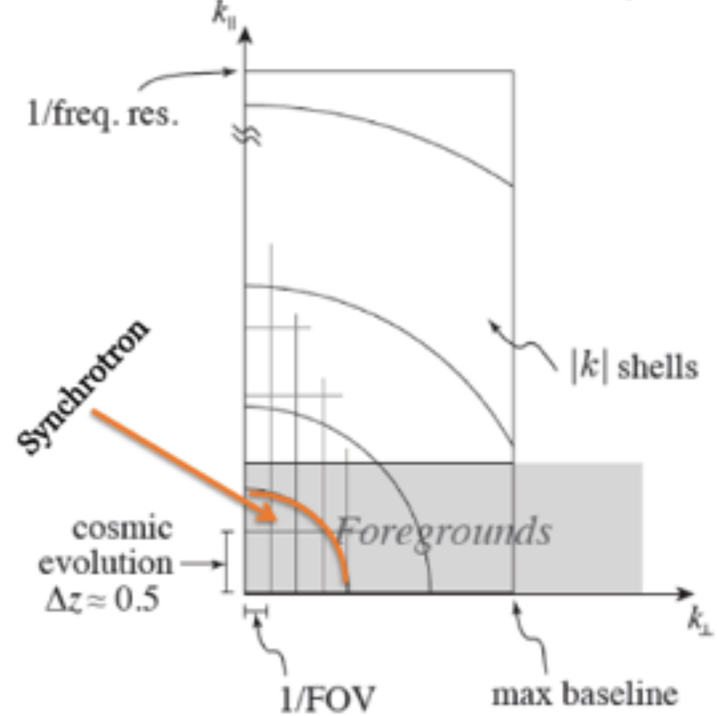
CHIME

z=1 zoom in brightness temperature zoom (with a stacked 20 MHz bandwidth)



Galactic foregrounds (synchrotron) are smooth, but many many orders of magnitude cleaning is needed,
signal-to-noise eigenmode method Shaw+14
nontrivial processing is needed

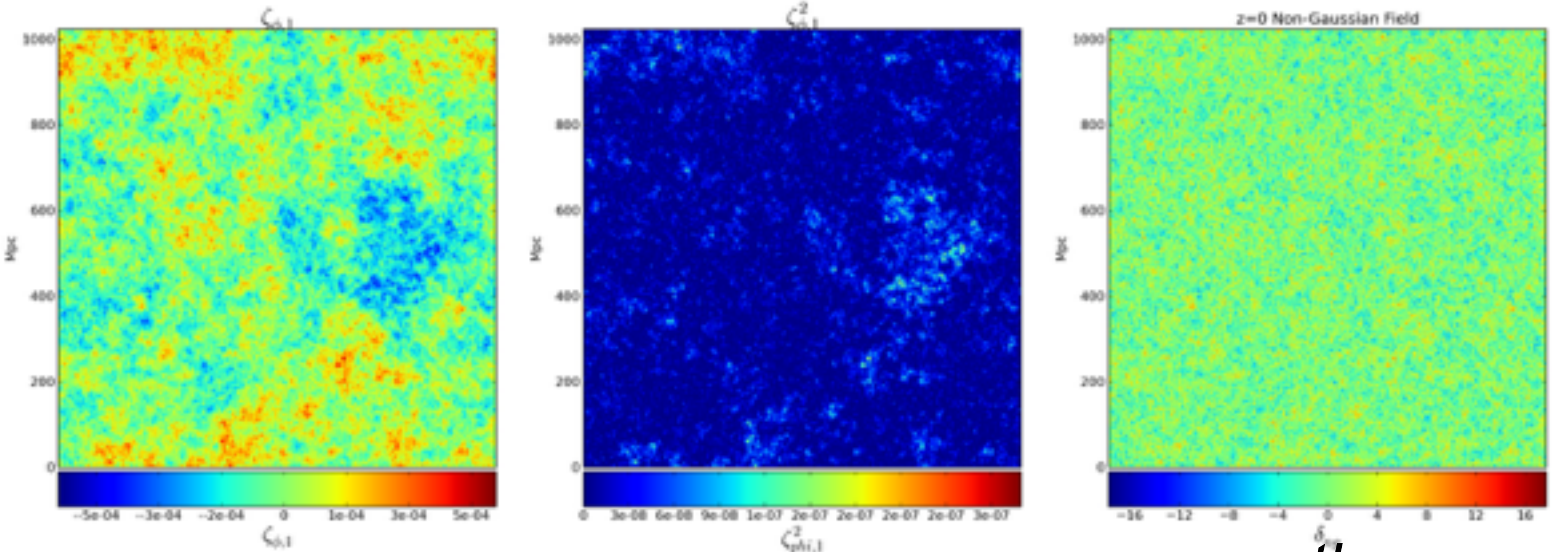
From Morales & Whythe 2009



alatt=1Mpc, N=1024

Alvarez,Bond,Huang,Stein,Braden,Frolov14

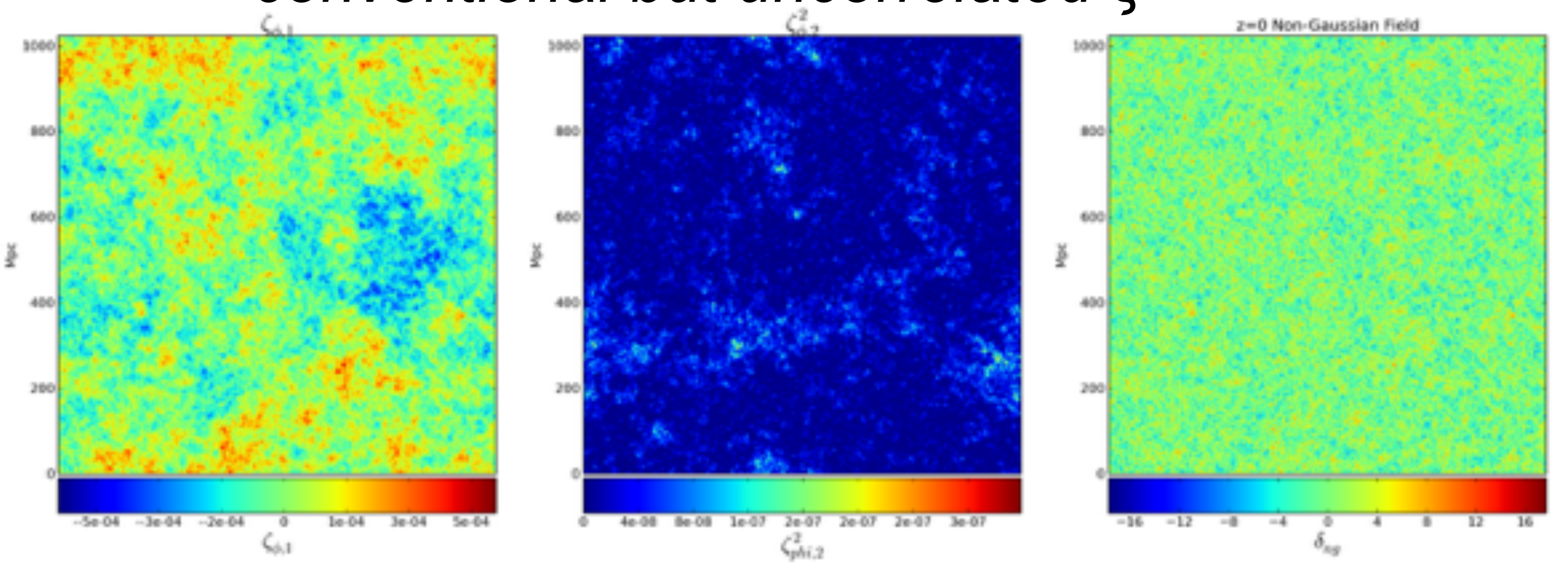
LSS & nonG mocks



conventional inflaton-induced correlated ζ^2

conventional but uncorrelated ζ^2

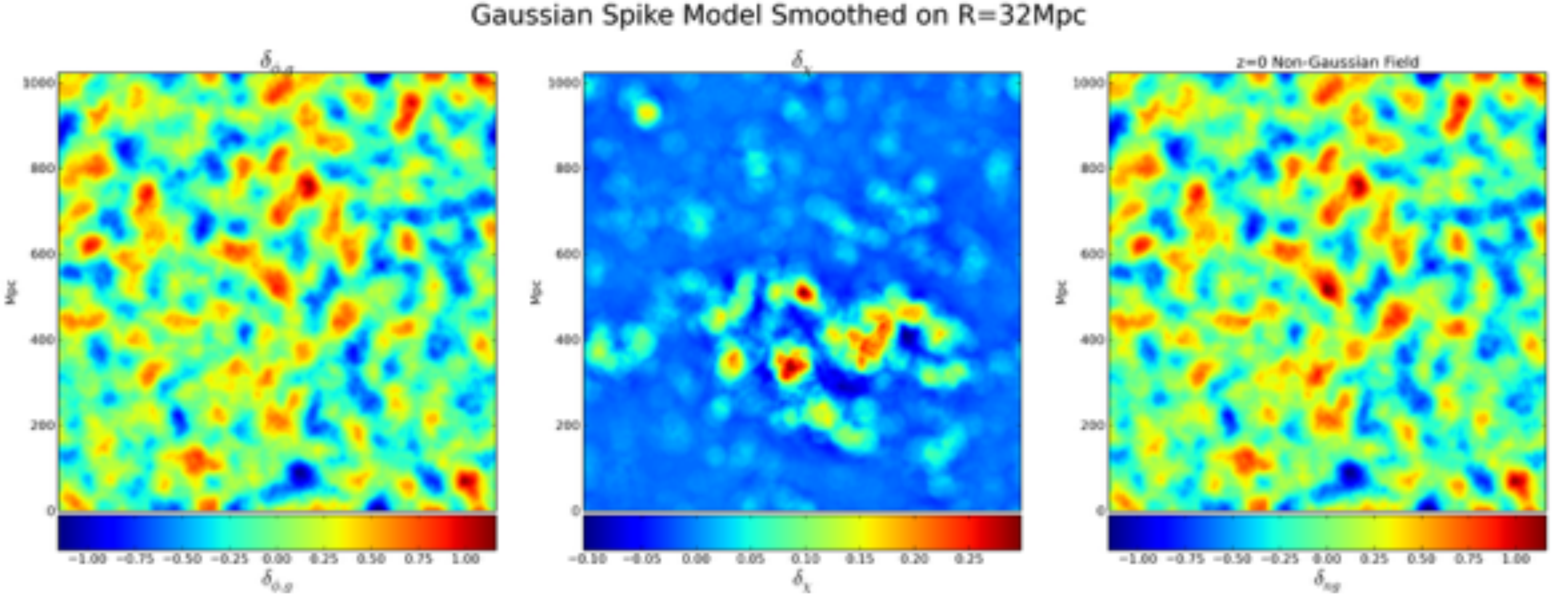
the non-Gaussian initial density field



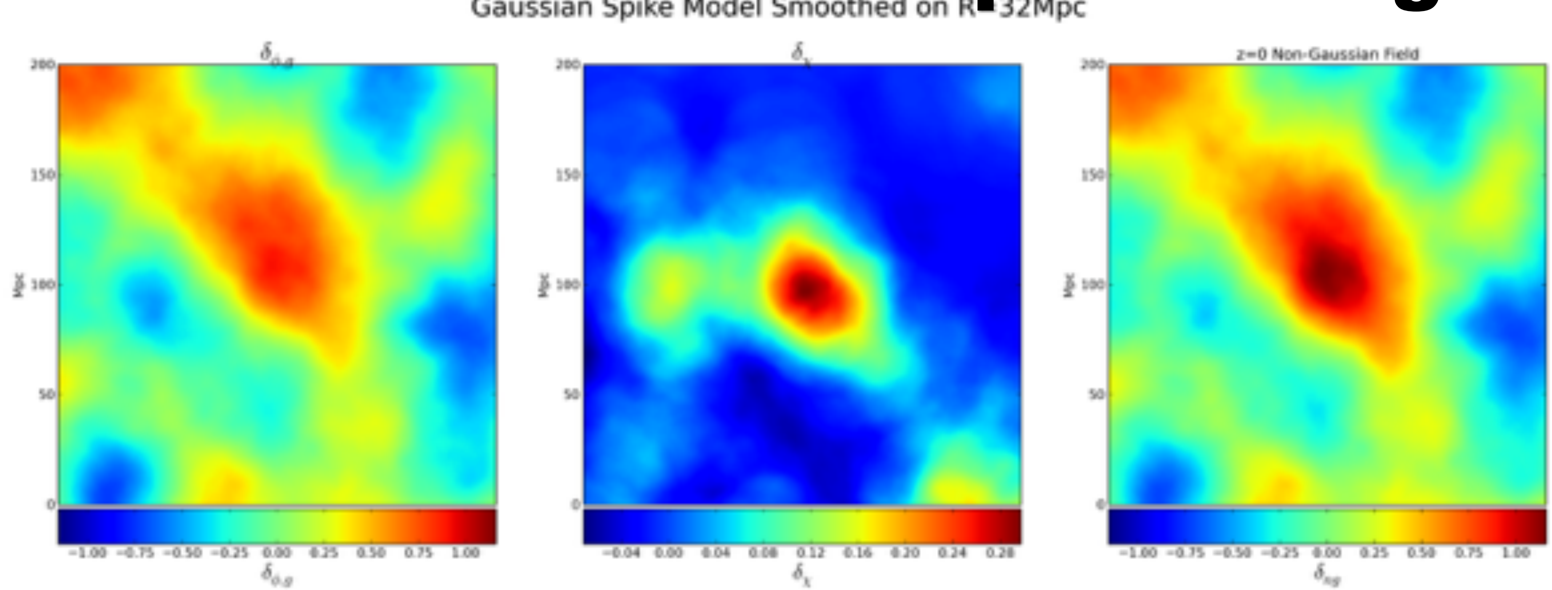
search with bispectrum & scale-dependent bias in power spectrum alatt=1Mpc, N=1024

LSS & nonG mocks

Alvarez,Bond,Huang,Stein,Braden,Frolov14



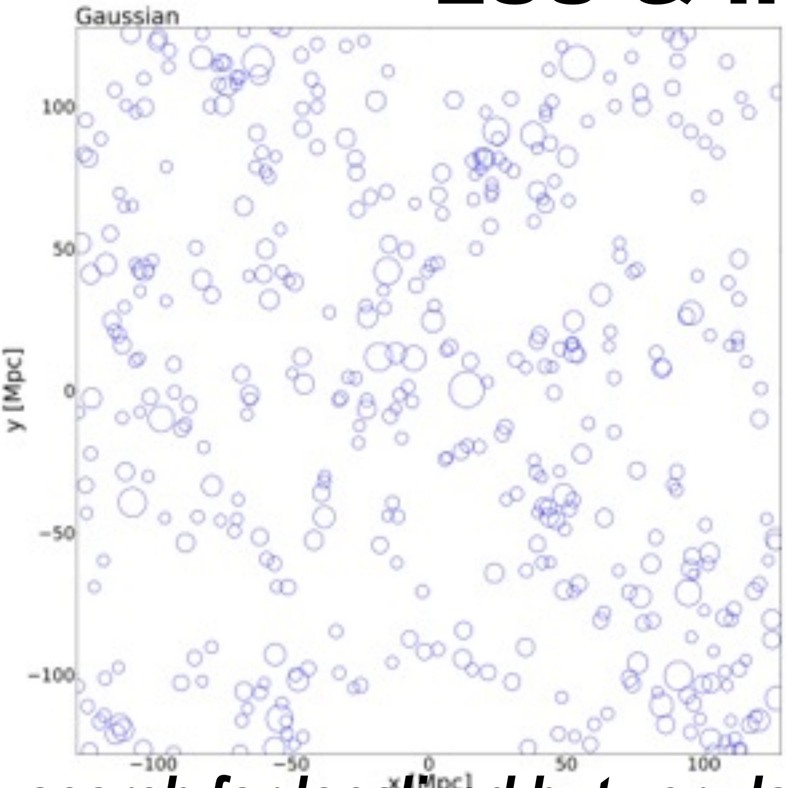
modulated intermittent preheating nonG



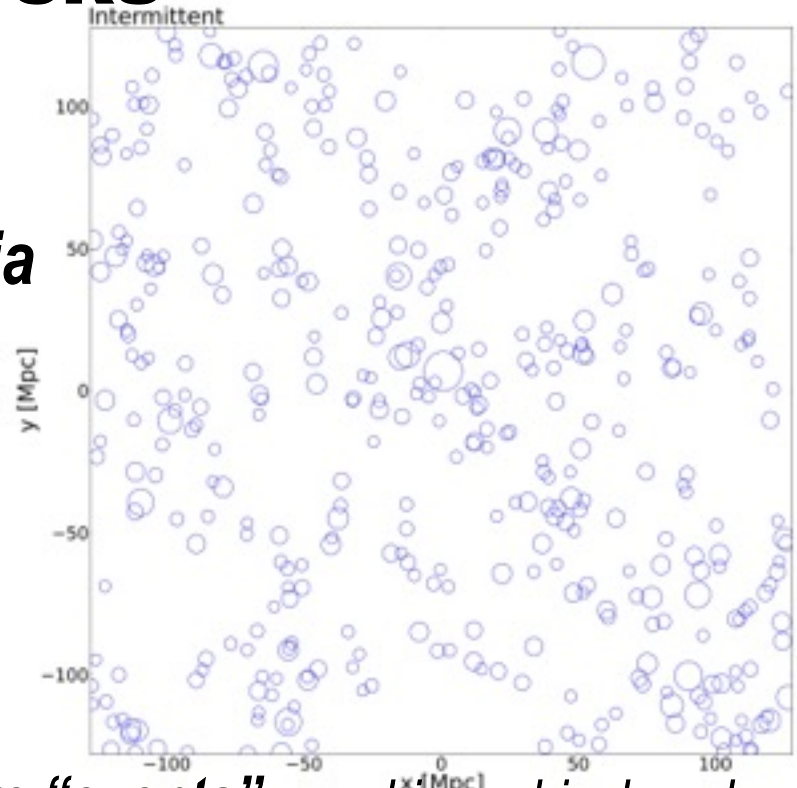
search for localized but very large scale rare "events" *e.g., hierarchical peaks*

LSS & nonG mocks

Alvarez,Bond,Huang,Stein,Braden,Frolov14



halo nonG patterns galaxies via HoD



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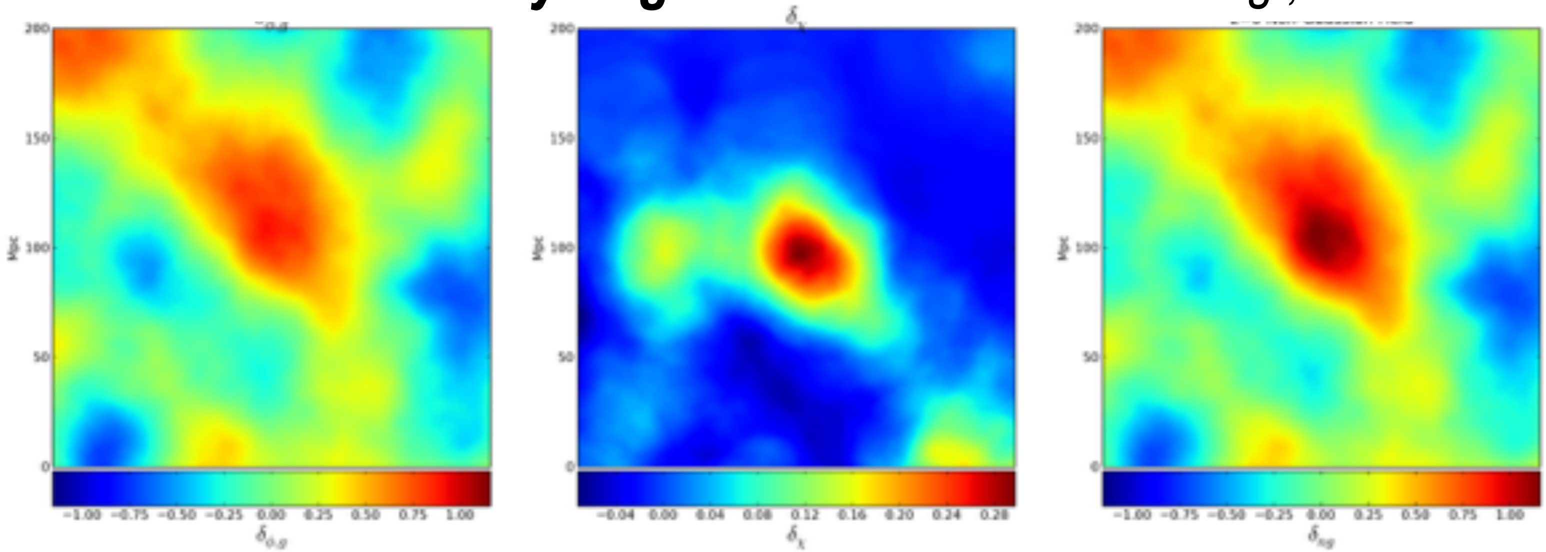
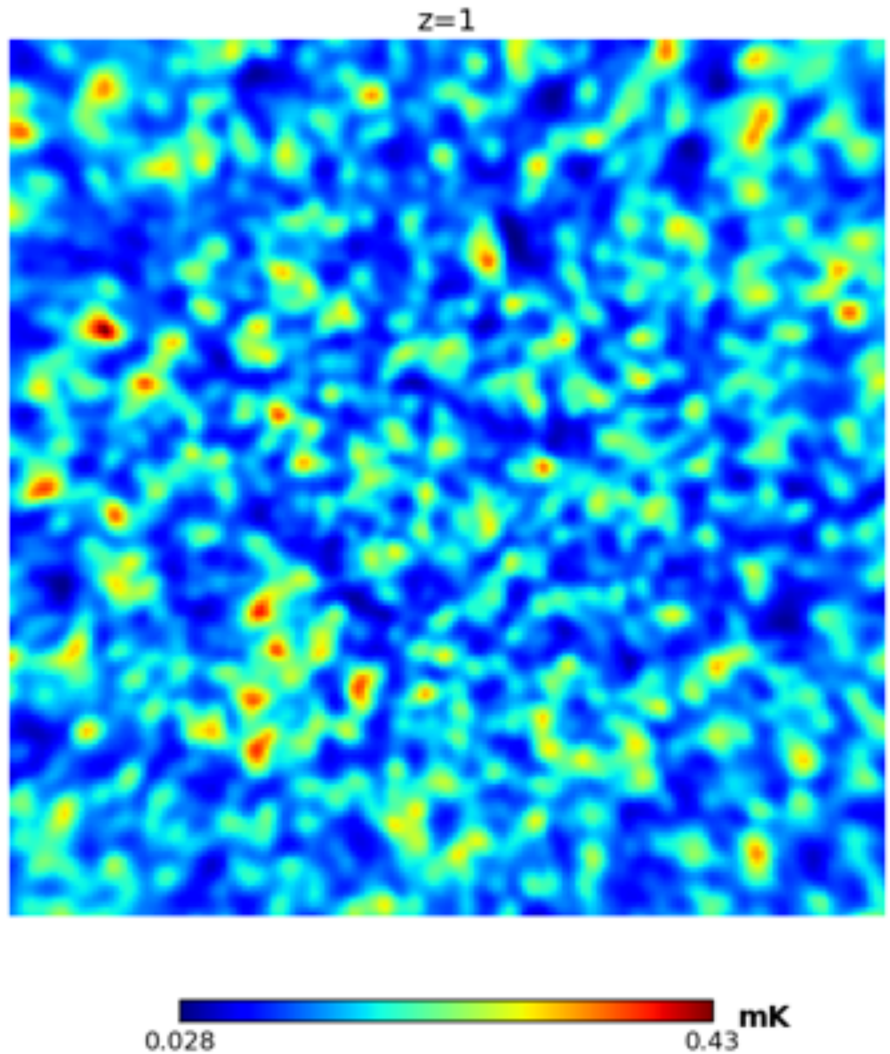


CHIME

SphereX *is also low-ish res, photo-z*

z=1 zoom in brightness temperature zoom (with a stacked 20 MHz bandwidth)



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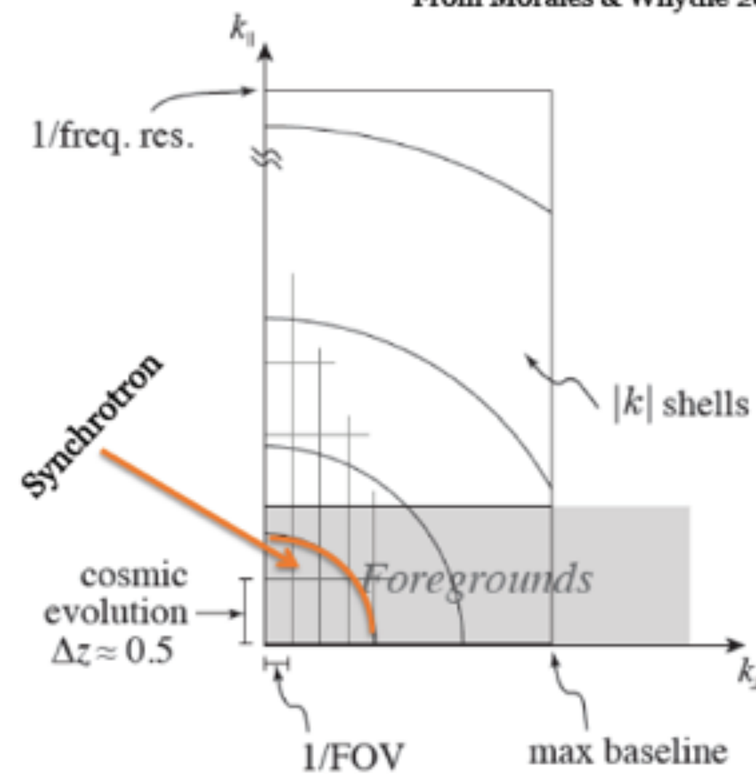

CMB restricts us to a projected 2D ζ-scape
we will reconstruct **phonon/isotropic strain** power,
but the future may look much the same as now (perhaps) => **V** => **ε**

r futures look bright modulo the dirty MW
we will reconstruct **graviton** power
de-lens for **consistency check r-n_t TBD**

thou shalt mock the LSS future *end-to-end*
to probe the 3D ζ-scape, modes abound
success modulo large scale mode control of systematics

the END