

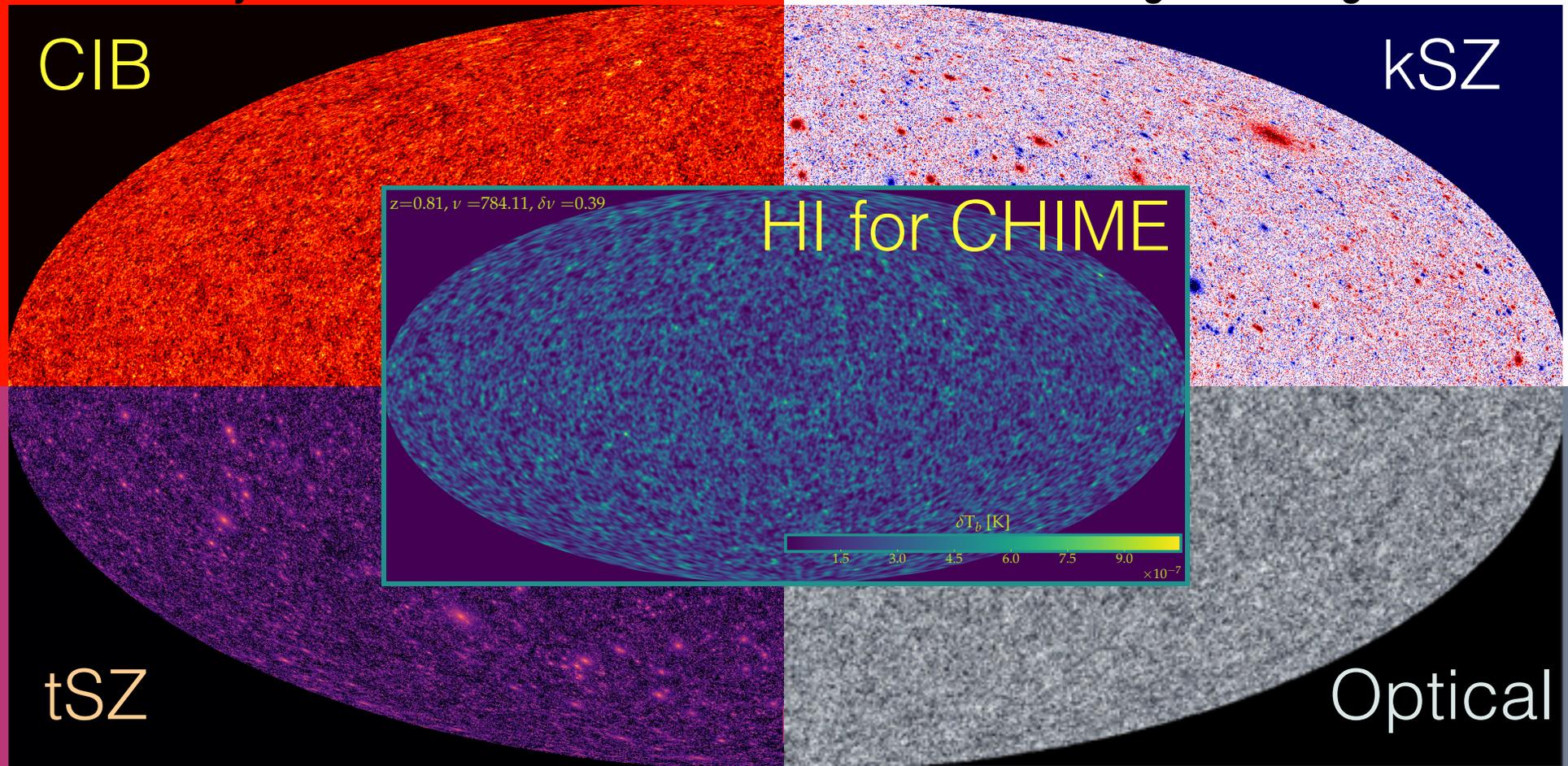
Mocking Heaven @ CIBAR16 **Dick Bond**



Peak Patch Full Sky Models: @CIBAR1991 tSZ, CIB

Peak Patch tSZ, kSZ in Planck 90s Bouchet-Gispert the cosmic sandwich

Planck Sky Model 2015 not-Peak-Patch 00s-10s extragal+ISM fgnd models

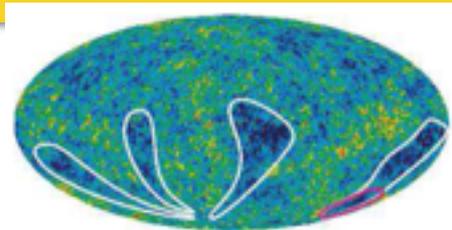


Planck 2015 XII: Full Focal Plane Sims (Nov): FFP8 ensemble of 10K EndtoEnd mission realizations in 1M maps. instrument noise + CMB + PSM + .. (25M NERSC CPU hrs)

BSMc = SMc + primordial anomalies
 $\langle \zeta|T,E \rangle + \delta\zeta \Rightarrow$ study non-Gaussian anomalies

*sigh, Mother Nature puts her
Anomalies @ low L where sample
variance \Rightarrow tantalizing $\sim 2\sigma$'s?*

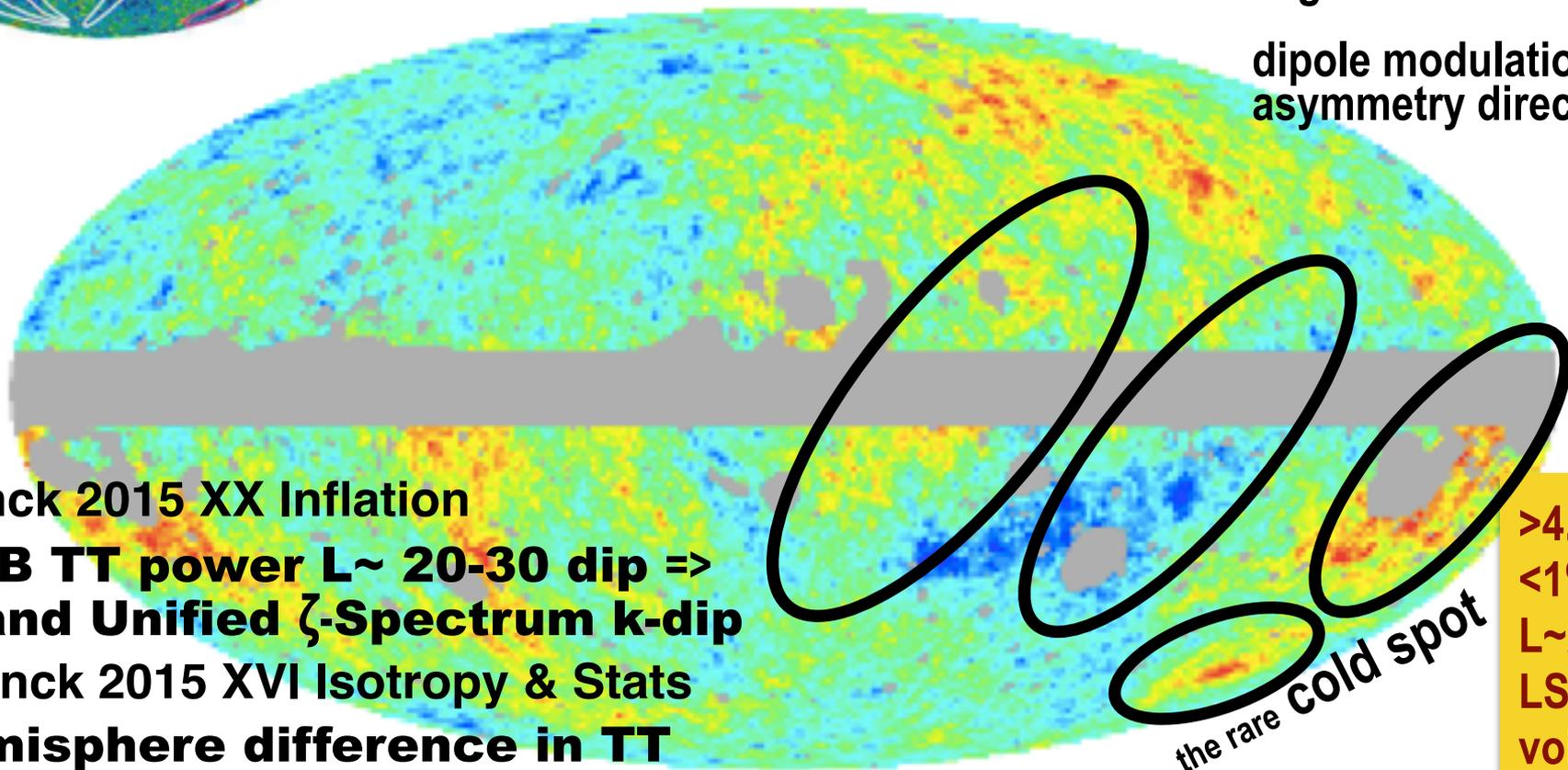
40 arcmin fwhm



$\zeta|T,E$: Planck 2015 XVII nonG

zero-ish $C(\theta) > 60^\circ$
octupole/quadrupole
alignment

dipole modulation/
asymmetry direction



Planck 2015 XX Inflation
CMB TT power $L \sim 20-30$ dip \Rightarrow
Grand Unified ζ -Spectrum k-dip
Planck 2015 XVI Isotropy & Stats
hemisphere difference in TT
power $\sim 7\%$ at low resolution

$>4.5\sigma$
 $<1\%$
 $L \sim 20$
LSS
void?

the rare cold spot

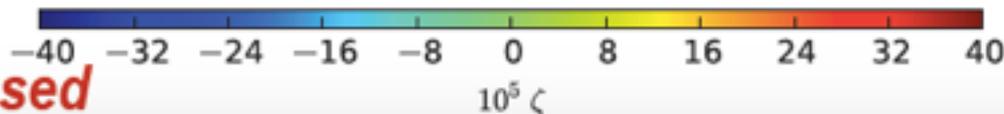
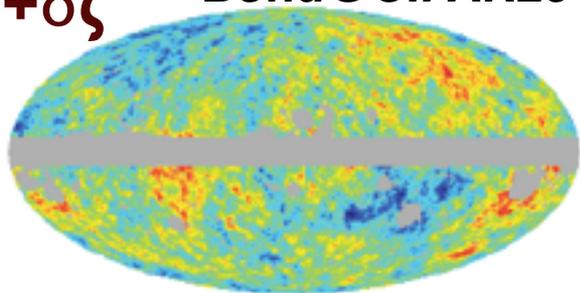
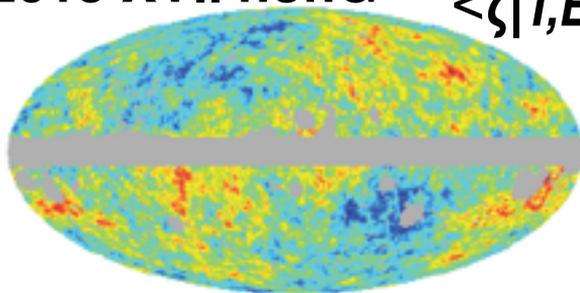
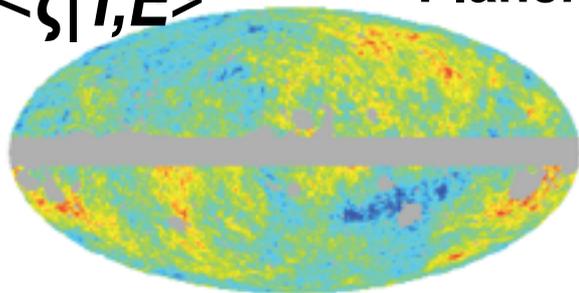
intermittent?

$\langle \zeta | T, E \rangle$

Planck 2015 XVII nonG

$\langle \zeta | T, E \rangle + \delta \zeta$

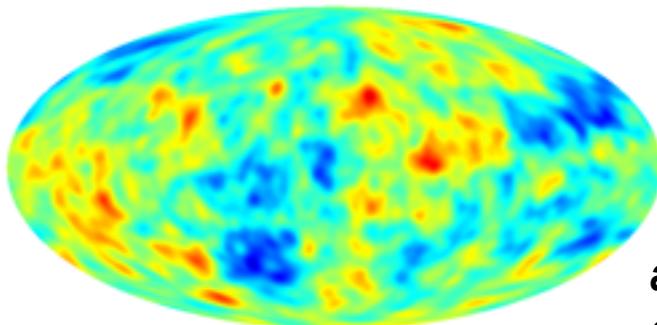
Bond@CIFAR2014



caution: not de-lensed

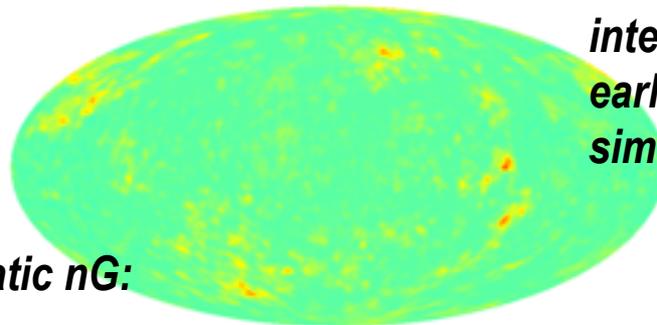
visibility mask

chaotic 10^5 zeta



5deg fwhm

chaotic 10^5 zeta

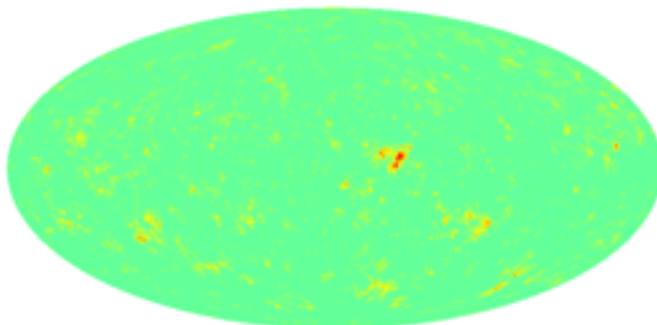


intermittent nG from early U preheating sims - too small



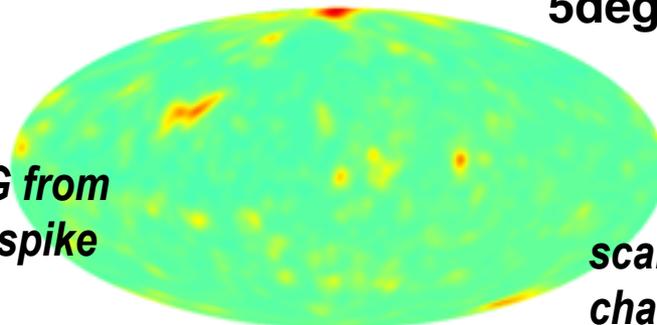
also cf. quadratic nG: correlated fNL uncorrelated large fNL_{eff}

single spike 10^5 zeta



40 arcmin fwhm

single spike 10^5 zeta



5deg fwhm

intermittent nG from early U single spike sims - tunable amplitude, get the "cold spot" etal

scan sims to get chance intermittent alignment to get a "cold spot"



$$u_q(\mathbf{x}) = \sum_c \chi_{qc}(\mathbf{x}-\mathbf{x}_c, R_{Ec}) q_c \delta N_c(\mathbf{x}_c, R_{Ec}) + U_{qf}(X) \Theta_{VE} + U_{qf}(X) (1 - \Theta_{VE})$$

inside = $\Theta_{VE}(X)$, 1 or 0 *outside* = $1 - \Theta_{VE}(X)$ = complement

χ_{qc} **susceptibility** of u_q to the “charge” q_c the art of halo models
 $q = M_{tot}, M_{dm}, M_{gas}, PV, V_E, K_{dm}, S, S_{conf} \dots$ measure: obs, gas sims

CIB

Statistical Cluster Expansion
 aka “Halo Model” Eulerian-space halos
 Lagrangian-space halos = Peak Patches

kSZ

Planck XXX (2014) CIB halo model
 shallow “GNFW” with $c=1.0 \pm 0.2$
 Planck 2015 XXIII tSZxCIB

**BBPS 2011 gas
 sims with feedback**

**BBPS 2011 gas
 sims with feedback**

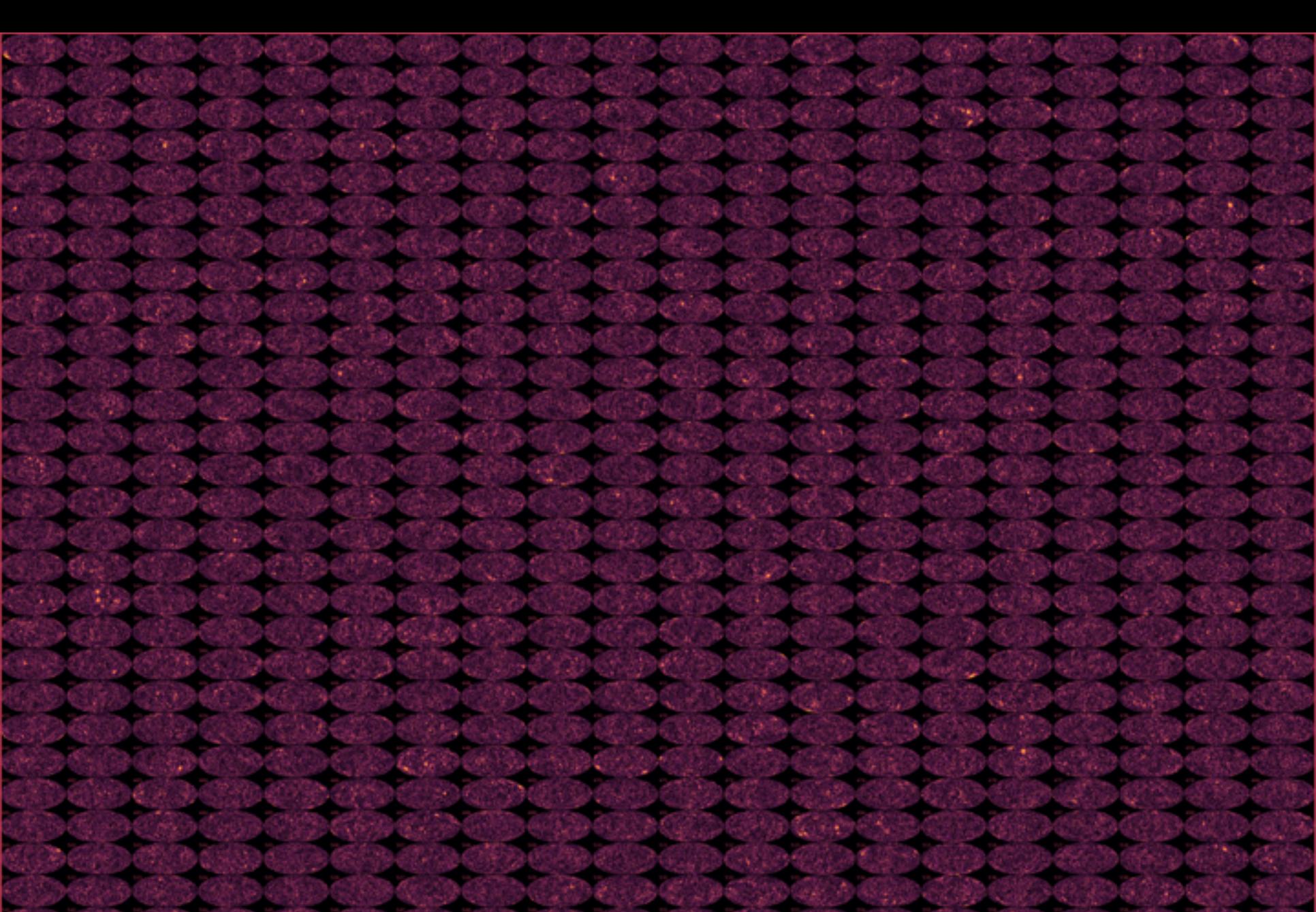
CMASS Manera et al. 2012
 SphereX 2015 in Phase A

tSZ

Intensity Mapping susceptibilities HI, CO, CII

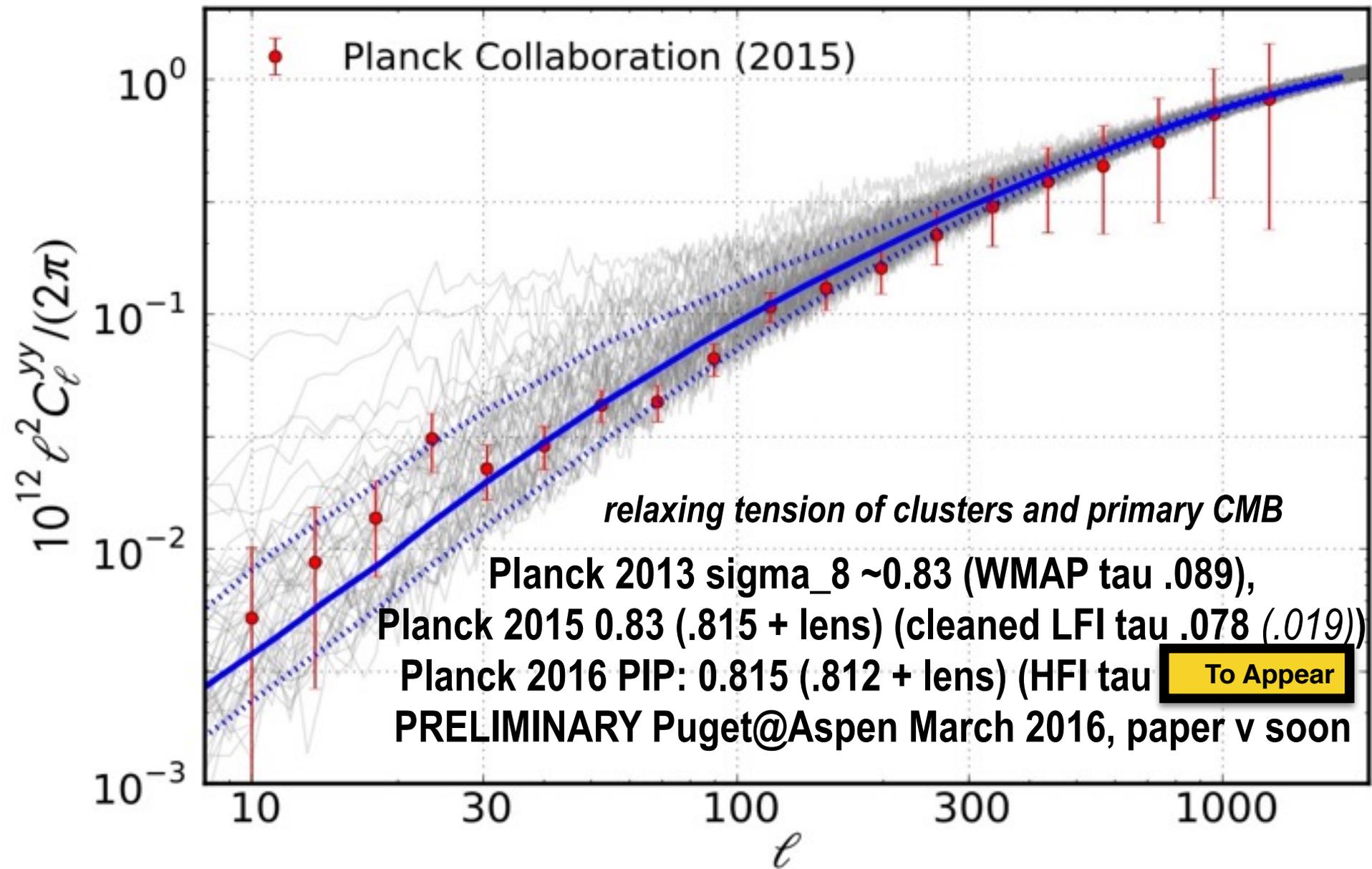
Optical

Eulerian \leq Lagrangian map: 1LPT S_{LC} , 2LPT & beyond the art of SNLC
 $\mathbf{x}_c(t) = \mathbf{x}_c(t_i) + \mathbf{s}_{NLc}(t | \mathbf{x}_c(t_i), t_i)$ $\mathbf{x}_c(t_i) = r_c$ initial Lagrangian position



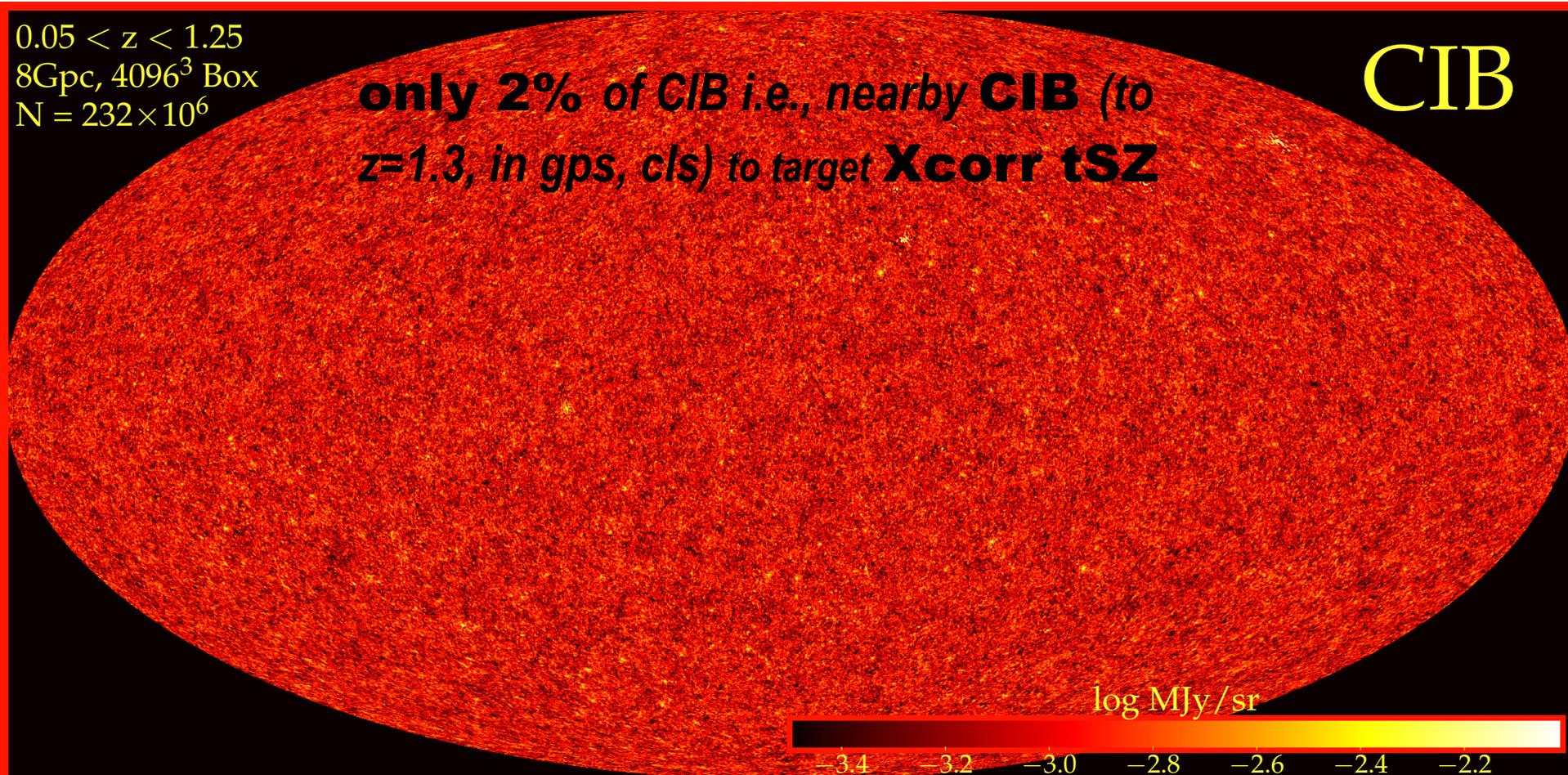
CITA mini-industry

Alvarez, Berger, Bond, Stein, Bahmanyar, Battaglia,..Huang, Frolov 2016



the **Cosmic Web of Clusters**, seen thru the Cosmic Infrared Background via *peak patch sims*

Lightcone Simulation of Clusters $> 1.0 \times 10^{13} M_{\text{sun}}$ to $z=1.3$ in projected emission
~10 minutes all-sky on 1024 cores on SciNet, aLatt=2Mpc, 512 sims ~83hrs



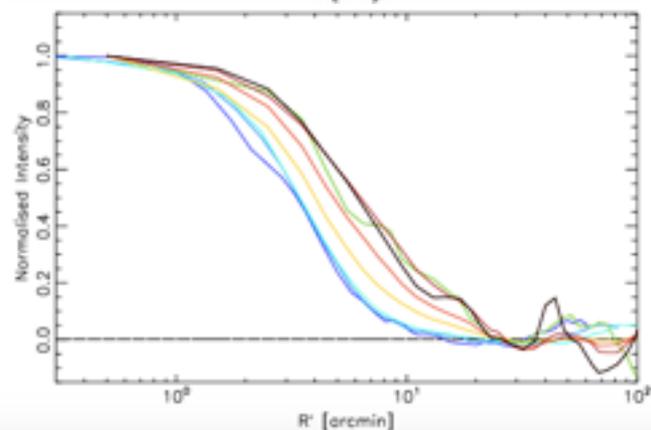
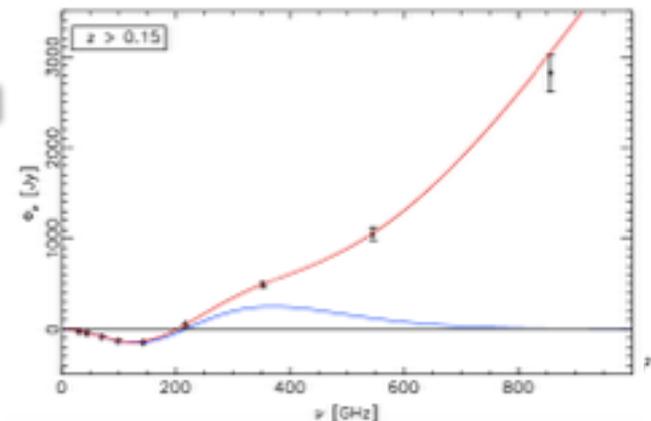
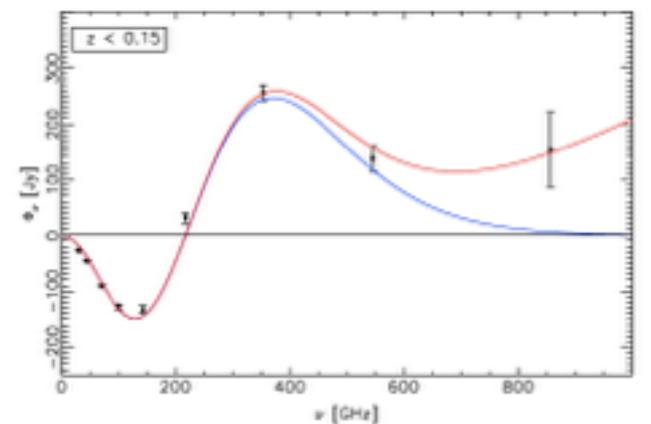
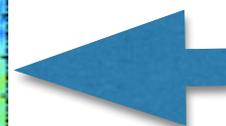
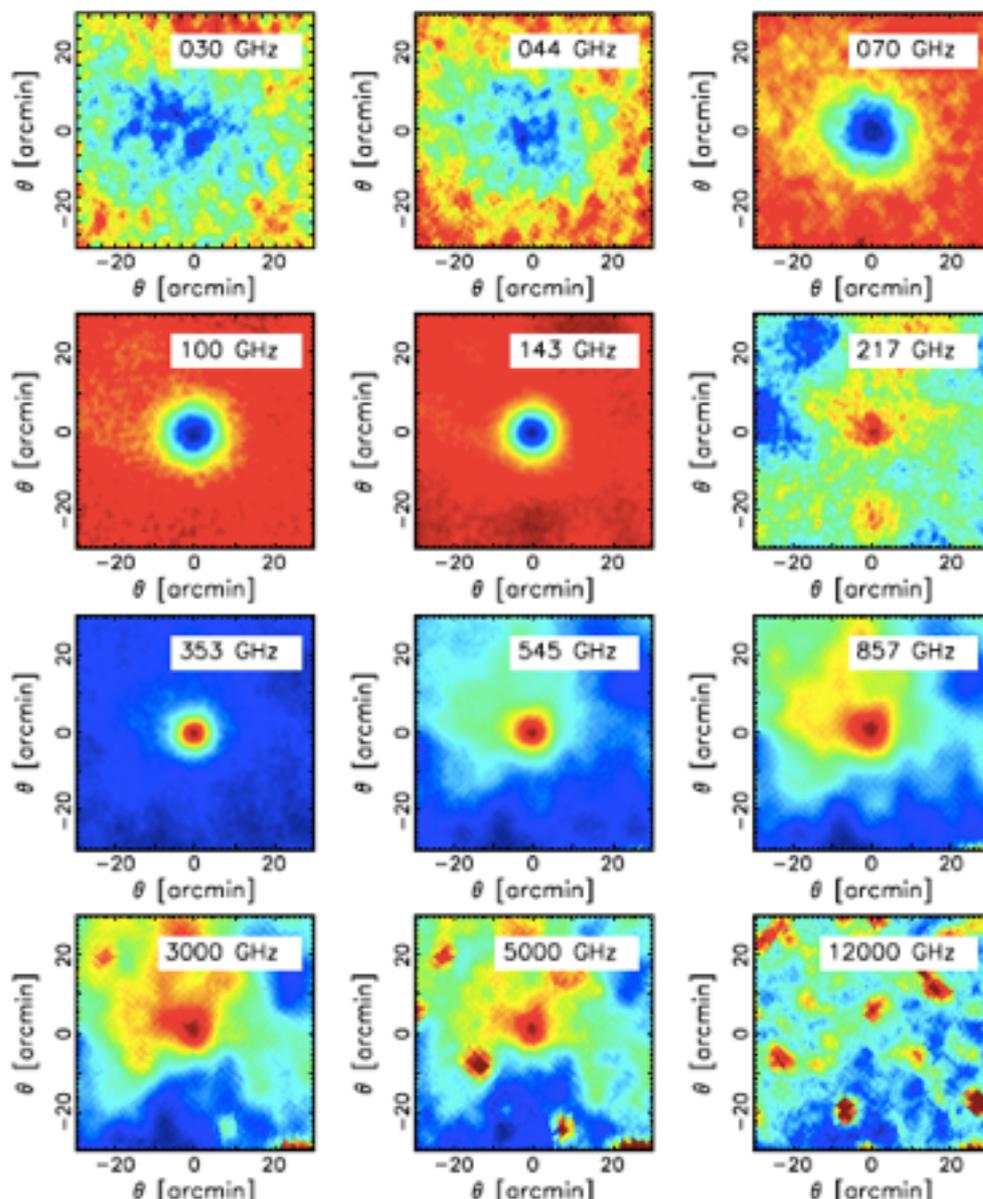
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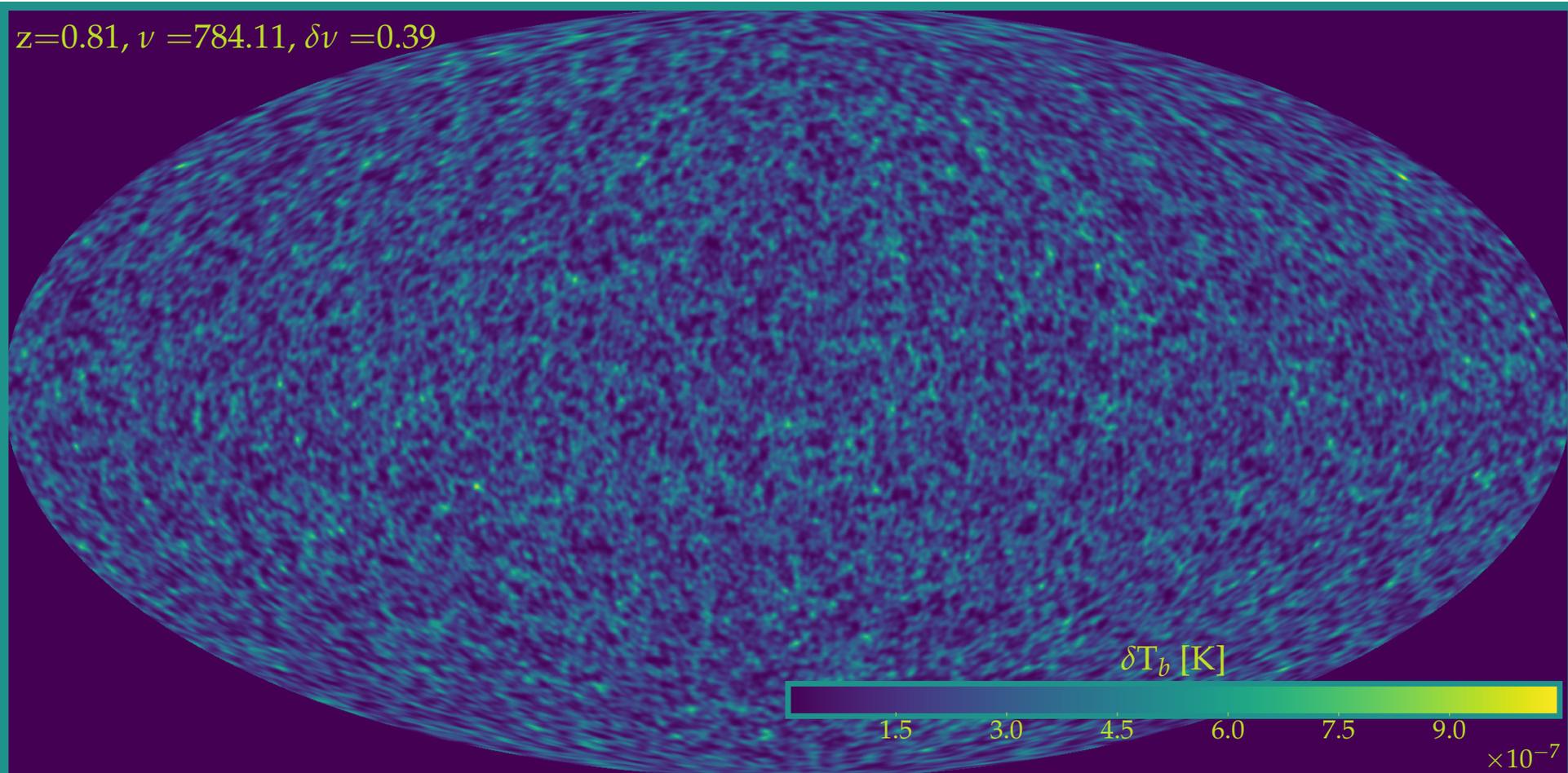
CIB modelling - use Planck 2015 CIB model, Shang+ 2012, Bettermin, but all quite uncertain. e.g., intermittency, cluster suppression, star bursting, etc.

Planck 2015 XXIII tSZxCIB

stack on 1093 Planck 2015
confirmed tSZ clusters $\langle z \rangle = .25$



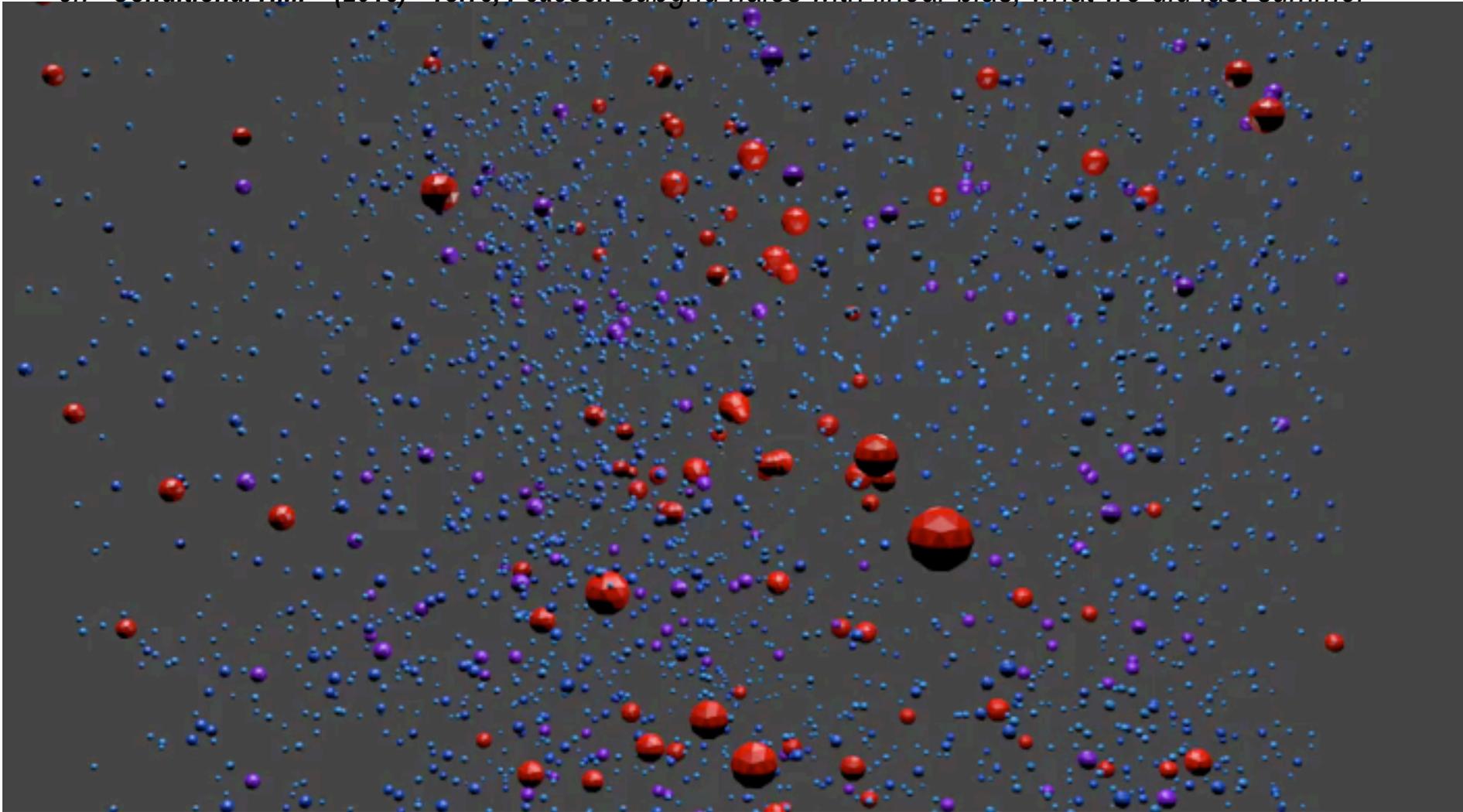
the **Cosmic Web of Galaxies**, seen thru Cosmic HI Intensity Mapping, CHIME $z=.8$ to 2.5, 1024 channels via *peak patch sims*



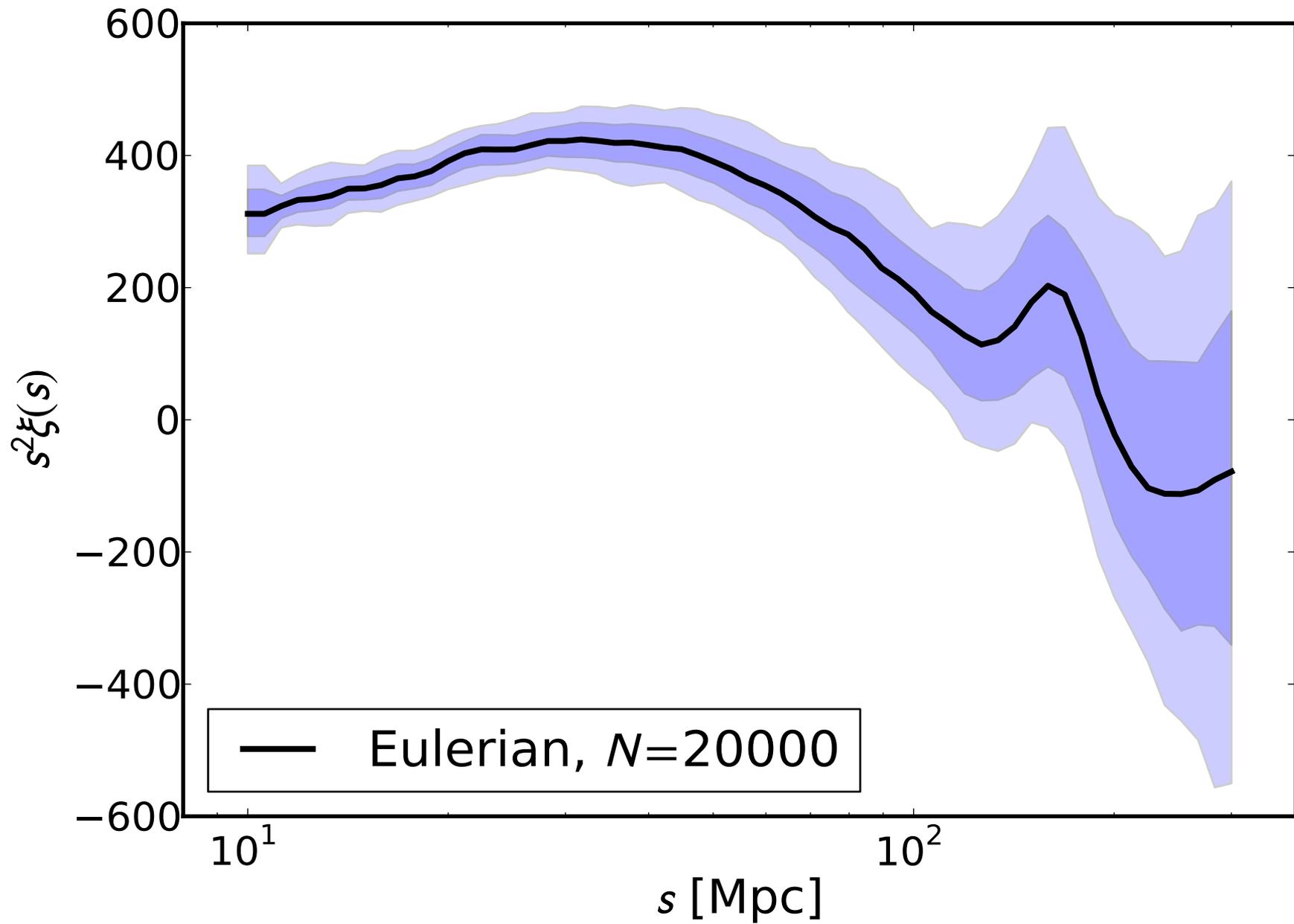
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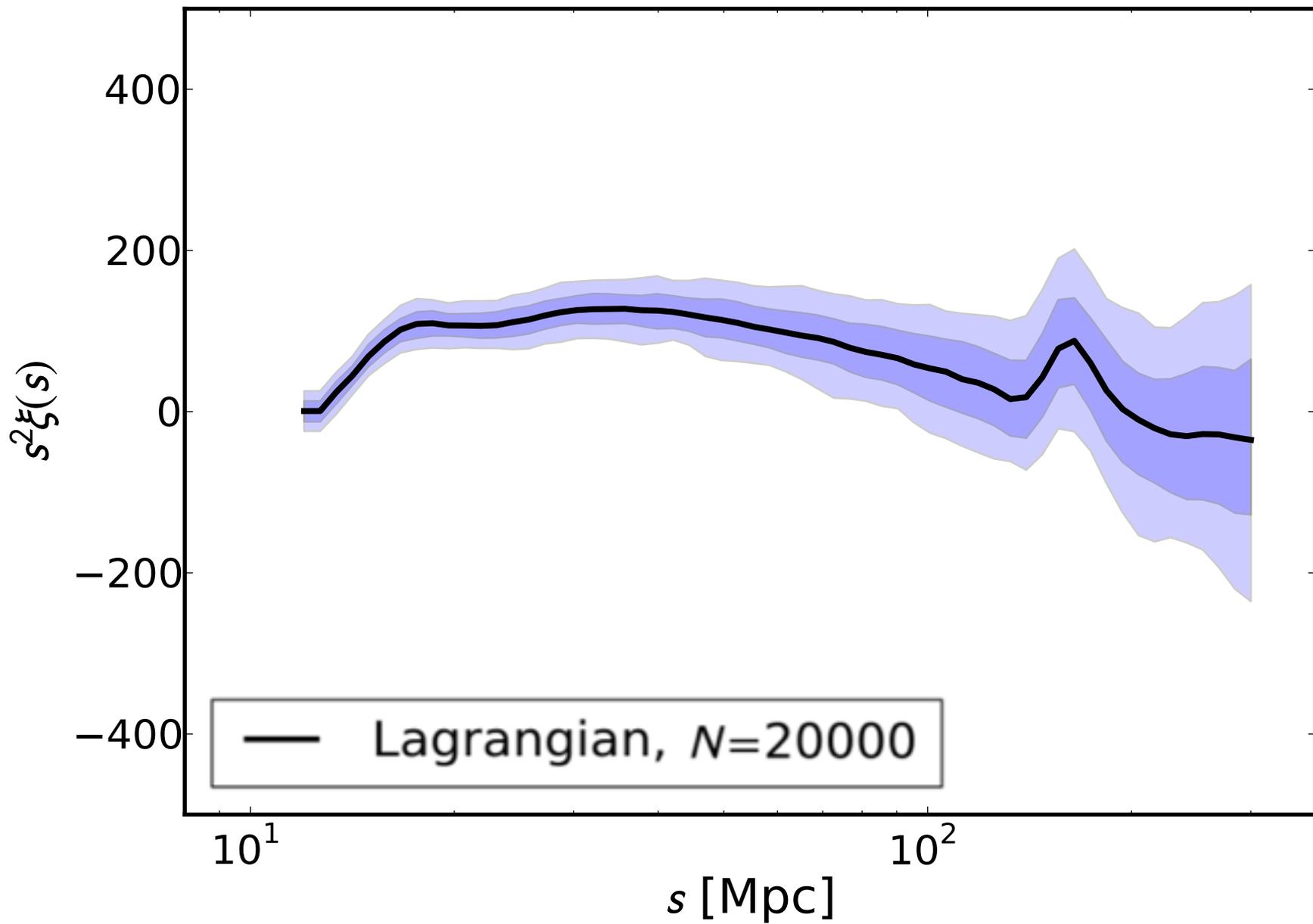
Alvarez, Bond,, Stein, Bahmanyar, Battaglia,..Huang, Frolov2016

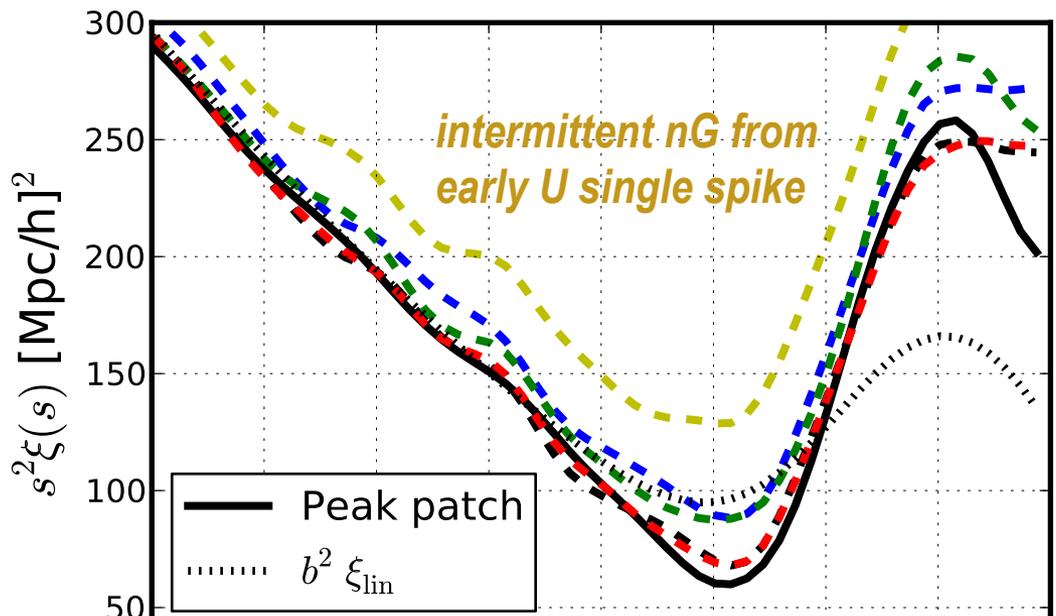
“sub-grid biased halos”, multiparameter nonlinear bias with exclusion, add to Monte Carlo peak patches
cf. “Conditional HMF” (2013) - Torre, Peacock subgrid halos with linear bias, what we did last summer



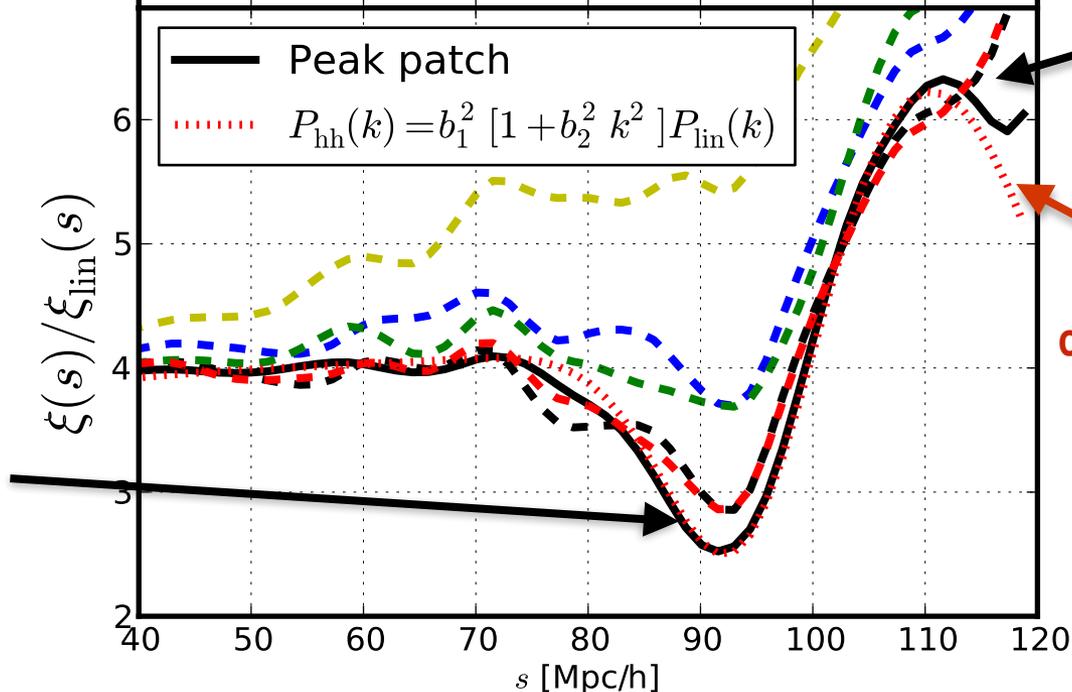
150 Mpc region, with ~ 3000 halos to true min Mass of sim, adds about 6000 more







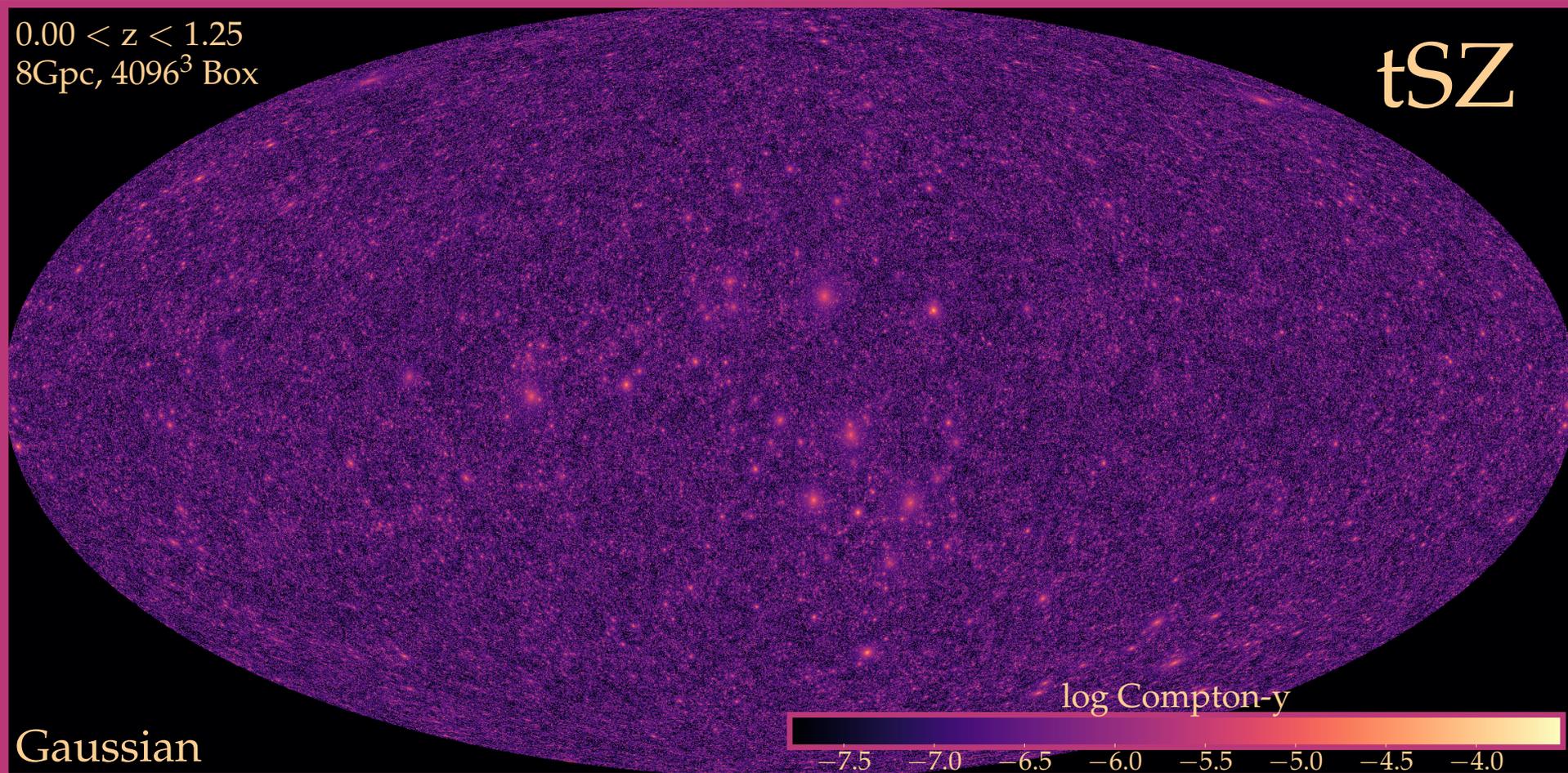
Positive Curvature:
 Overabundance of
 Negative Extrema



cf. fit to N-body results:
 without any tuning it
 comes out from peak
 patches naturally

Positive Curvature:
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 Negative Extrema

the **Cosmic Web of Clusters**, seen thru Compton cooling of high pressure electrons by the CMB via *peak patch sims*
Lightcone Simulation of Clusters $> 1.0 \times 10^{13} M_{\text{sun}}$ to $z=1.3$ in projected BBPS pressure
~10 minutes all-sky on 1024 cores on SciNet, aLatt=2Mpc, 500 sims ~83hrs => stats

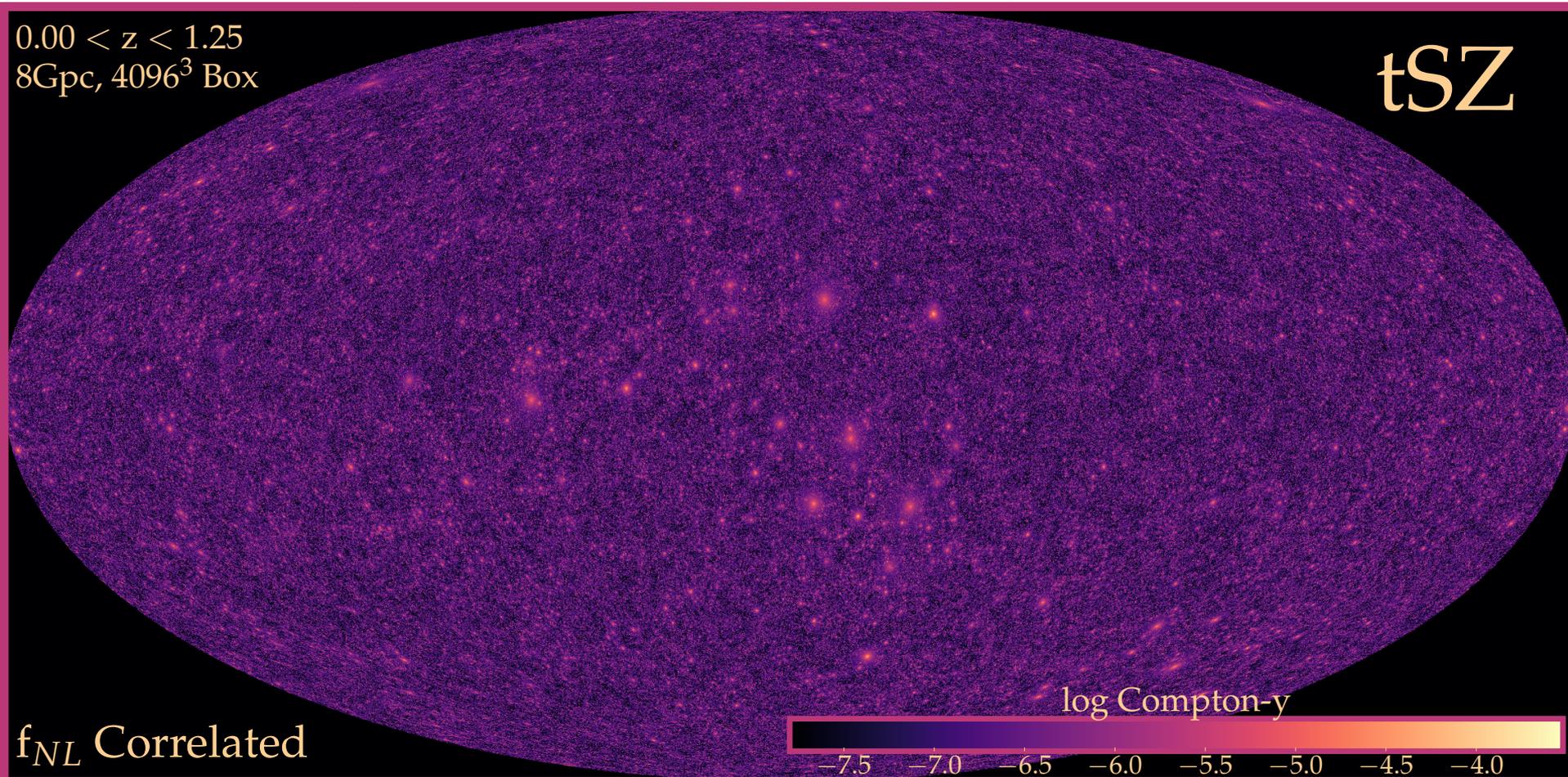


*SIMs to characterize inhomogeneous tSZ map errors (eg in Planck15 y-map)
scaled susceptibility of y to PV dN_cl - used BBPS, but key issue, measure in
high res hydro sims, feedback dependent*

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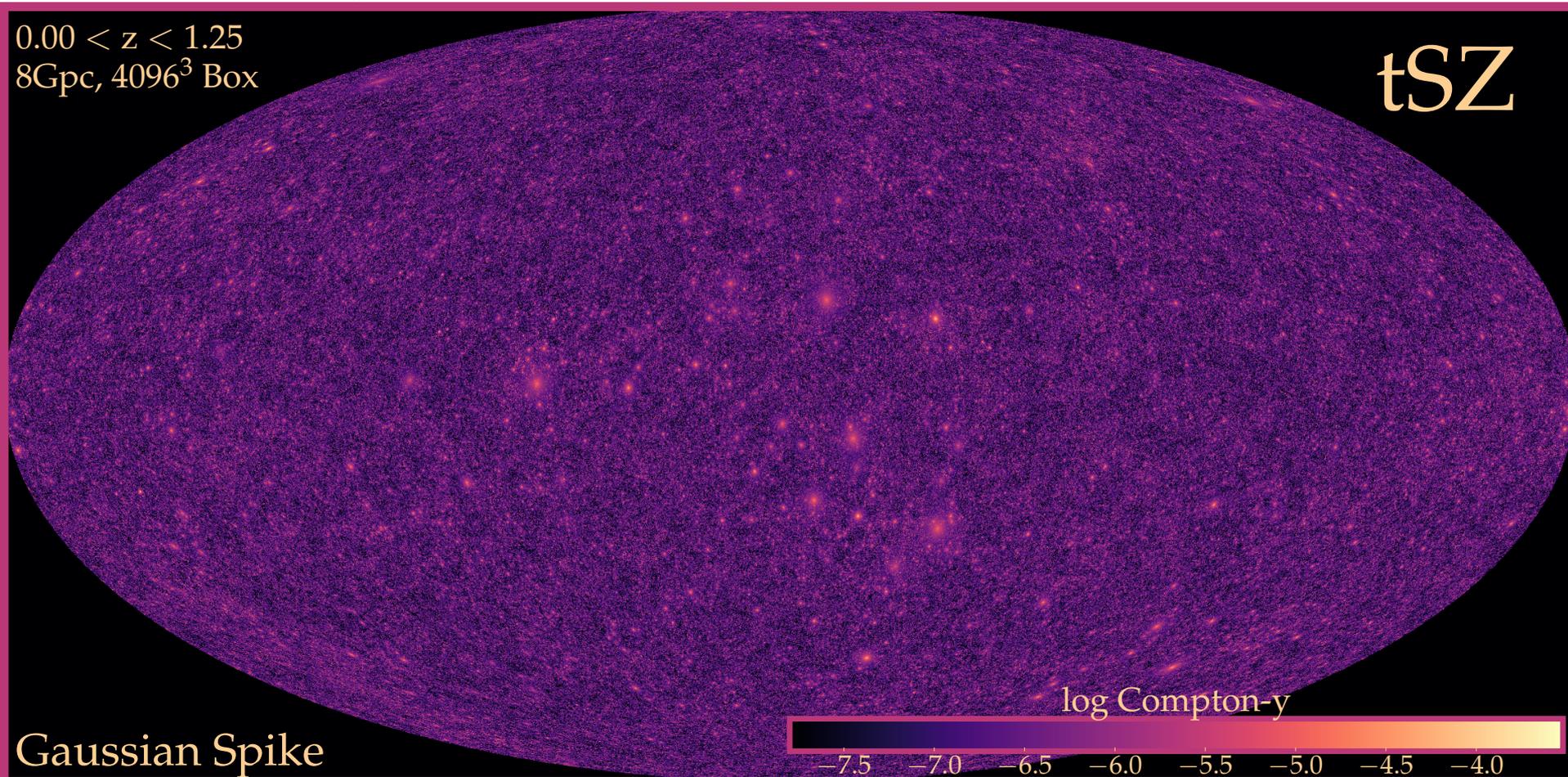


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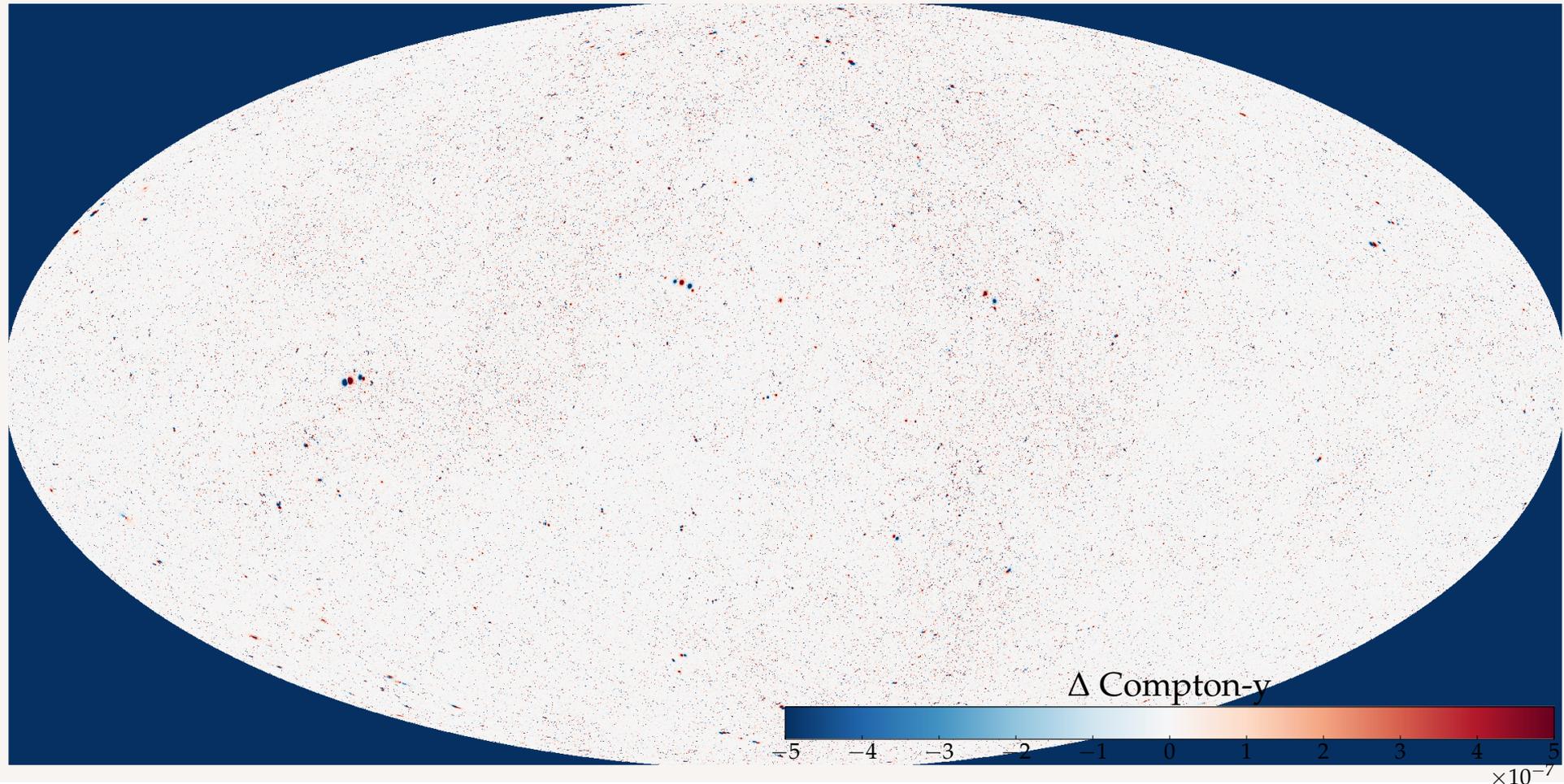


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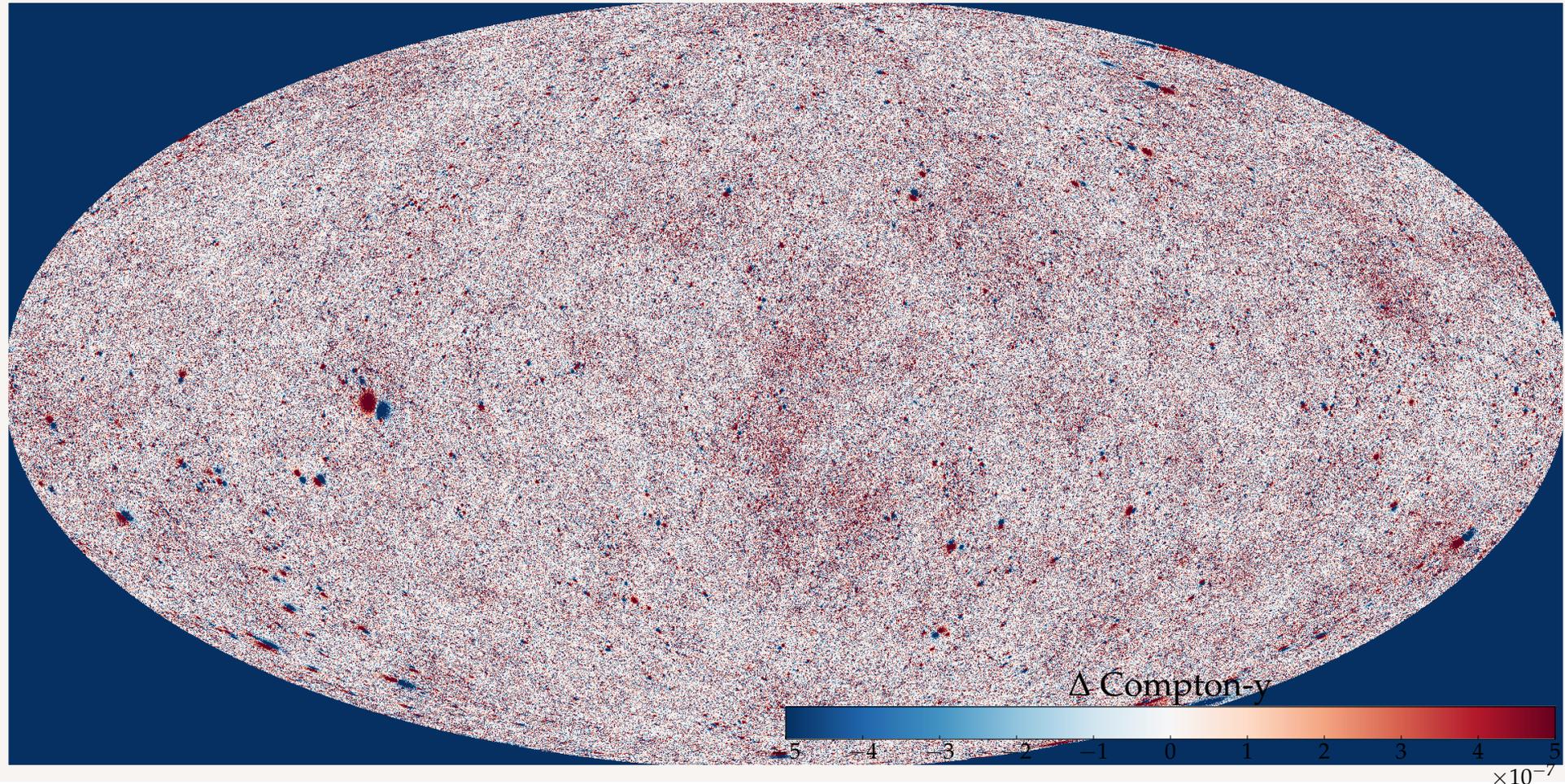


Δ Compton- y
-5 -4 -3 -2 -1 0 1 2 3 4 5
 $\times 10^{-7}$
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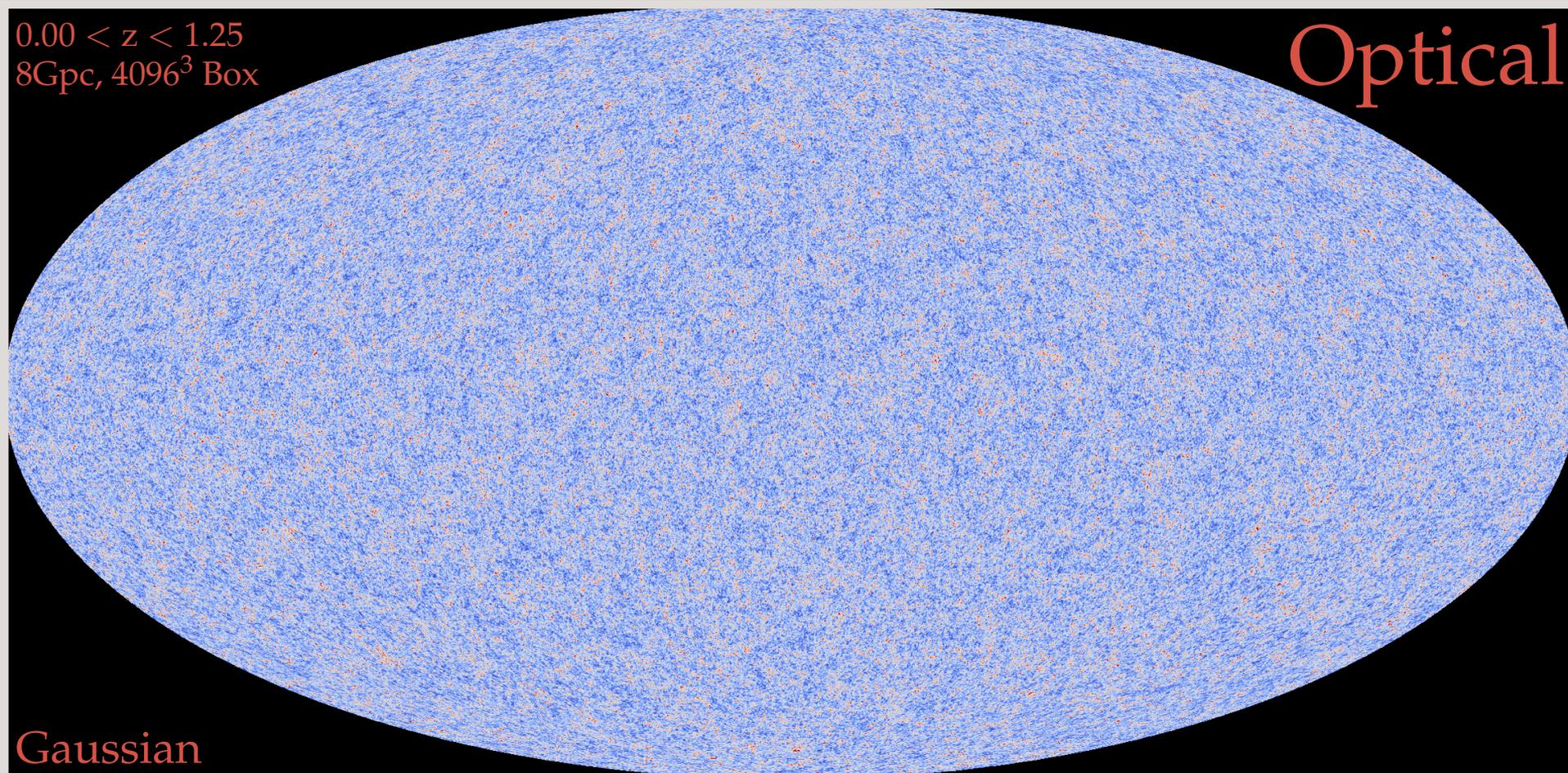


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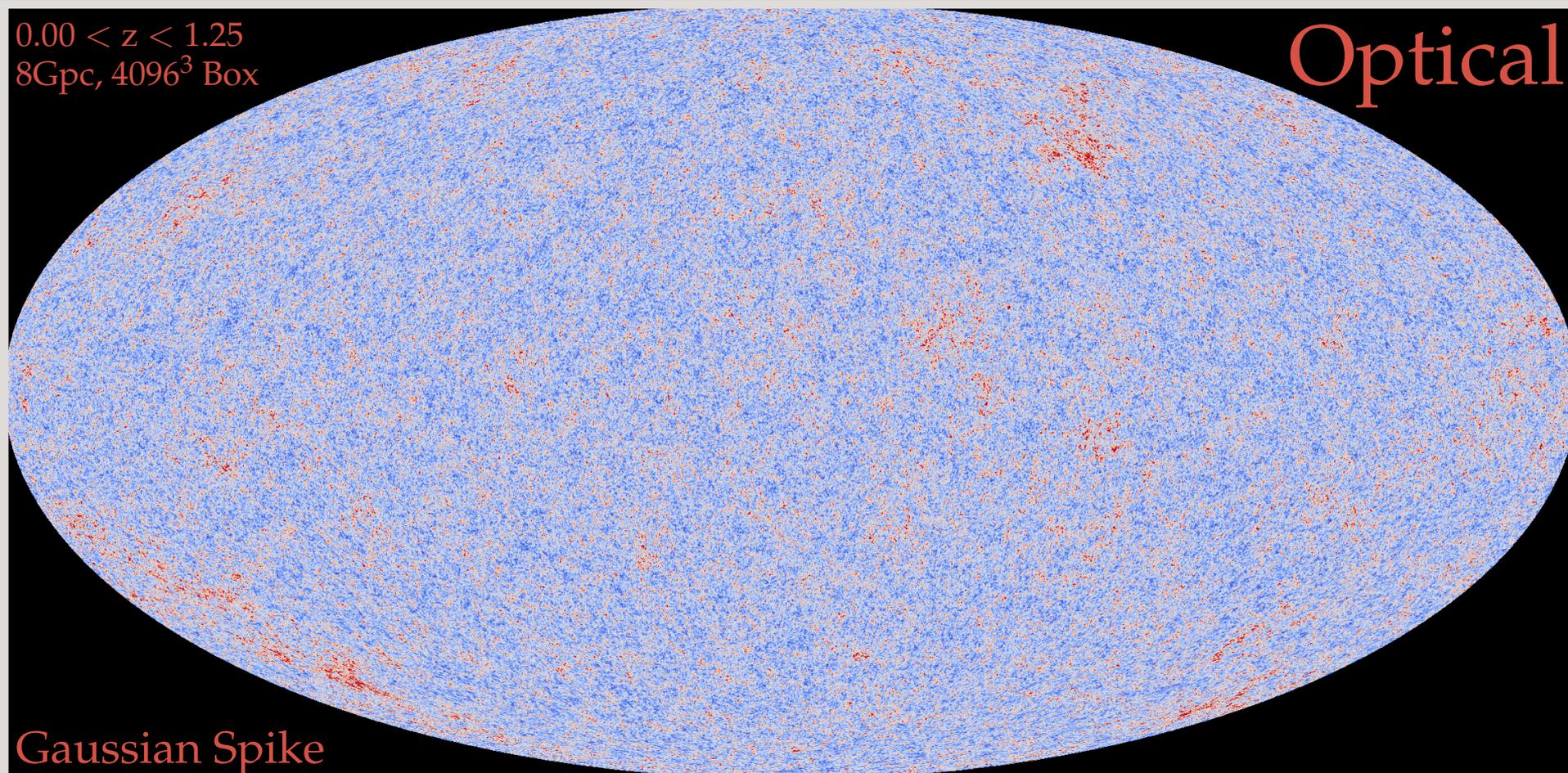


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we are somewhat agnostic about best rapid halo finder: PeakPatches 1993.96 **Bond**, Myers, PThalos 2001 - Scoccimarro, Sheth, PINOCCHIO 2002 - Monaco et, PINpointing Orbit Crossing-Collapsed Hlerarchical Objects, Millenium 2006 N-Body + artful painting **Simon White, Alex**, Volker +, COMoving Lagrangian Acceleration COLA, 2013 Tassev, **Zaldarriaga**, Eisenstein, sCOLA 2015, Augmented LPT APT 2013 - Kitaura, Hess, PATCHY 2013 - Kitaura, Yepes, Prada PerturbAtion Theory Catalog generator of Halo and galaxY distributions, FastPM 2016 - Feng, Chu, **Seljak**, 512 N-body Gadget N-body 2016 **Szalay** +

“mocking heaven” apps: tSZ, CB original motivation => tSZxCIB τ_c , kSZ optical galaxies via HOD for CMASS, DES, HSC, LSST, .. sphereX “intensity mapping” of HI (CHIME, HIREX, ..,SKA) of CO COMAmap well suited: to cross-correlation studies of all sorts well suited: to characterize correlated and non-Gaussian errors Physics: beyond Lambda: dynamical DarkEnergy, modified gravity LSS non-Gaussianity: perturbative, intermittent, scale-dependent bias

good things in PeakPatches: $n(M)$, $n(BE)$, 2-pt, spatial Xcorr with N-Body important 2-halo exclusion; 2-halo nonlinearity assembly bias dependence on 2nd, 3rd, ..., parameters $\xi(x|M1, M2)$, $P(D)$ & other non-Gaussian statistics oriented correlations, filamentary web

ToBeDone for ‘PeakPatches’: => Potential-pit Patches

“subgrid” halos nonlinear bias + exclusion - well underway exterior fluctuations (weak lensing) - we have (good?) ideas interior fluctuations (subclumping, subhalos, $\delta\rho, \delta\rho$)

measurement in hi res sims, some in BBPS,..Illustris, FIRE

3 point function testing **beyond 2LPT**