Dick Bond

Cosmic Observables for Fundamental Physics: ***mock WebSkys*** *vs. the* ***real Webskys***

Cosmic TOPOGRAPHY & CARTOGRAPHY

Entanglement & Entropy

IT from BIT
from BITs in IT

the coherent and the entropic,
from ultra-early-U to ultra-late-U

U=R∪S ruled by (information) entropy in bits, entangled. ***the fine grains in the coarse grains***

Universe =*System(s)*+*Reservoir* =Signal(s)+Residual *noise* =Effective Theory+*Hidden variables,*
=*Data*+*Theory,* observer(s)+observed

Early Universe generates a coarse-grained $\zeta(x,t) = \int_{\text{field-path}} (dE+pdV)/3(E+pV) = \ln a(x,\ln H)$

the real $\langle\zeta(x,t)|TE\rangle$ *Websky + fluctuations*

cf. mock $\zeta(x,t)$ *Webskys with subdominant non-Gaussianity*

Primary CMB Webskys are gravitationally lensed; all Secondary CMB Webskys are lensed

weakly and strongly nonlinear Webskys: Secondaries & galaxies /halos &LIM/LAMS

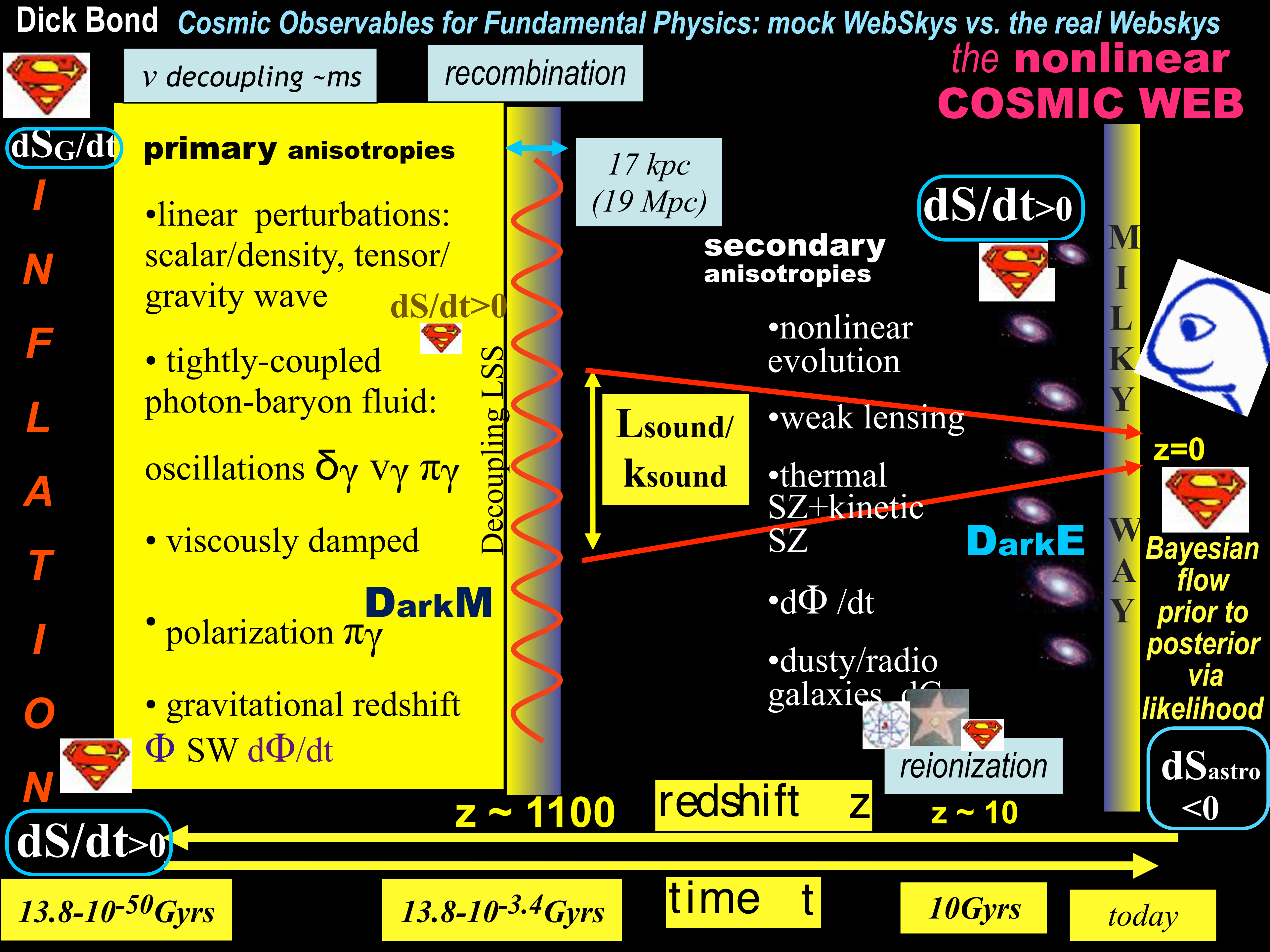
all Webskys are entangled through $\zeta(x,t)$*: WebSkys all large fsky CMB experiments*

& WebSkys of all large sky LSS experiments optical CIB tSZ kSZ lens HI CO Halpha Lyalpha CII

Bayesian flows from theory priors through likelihood sequences to posteriors - now all entangled

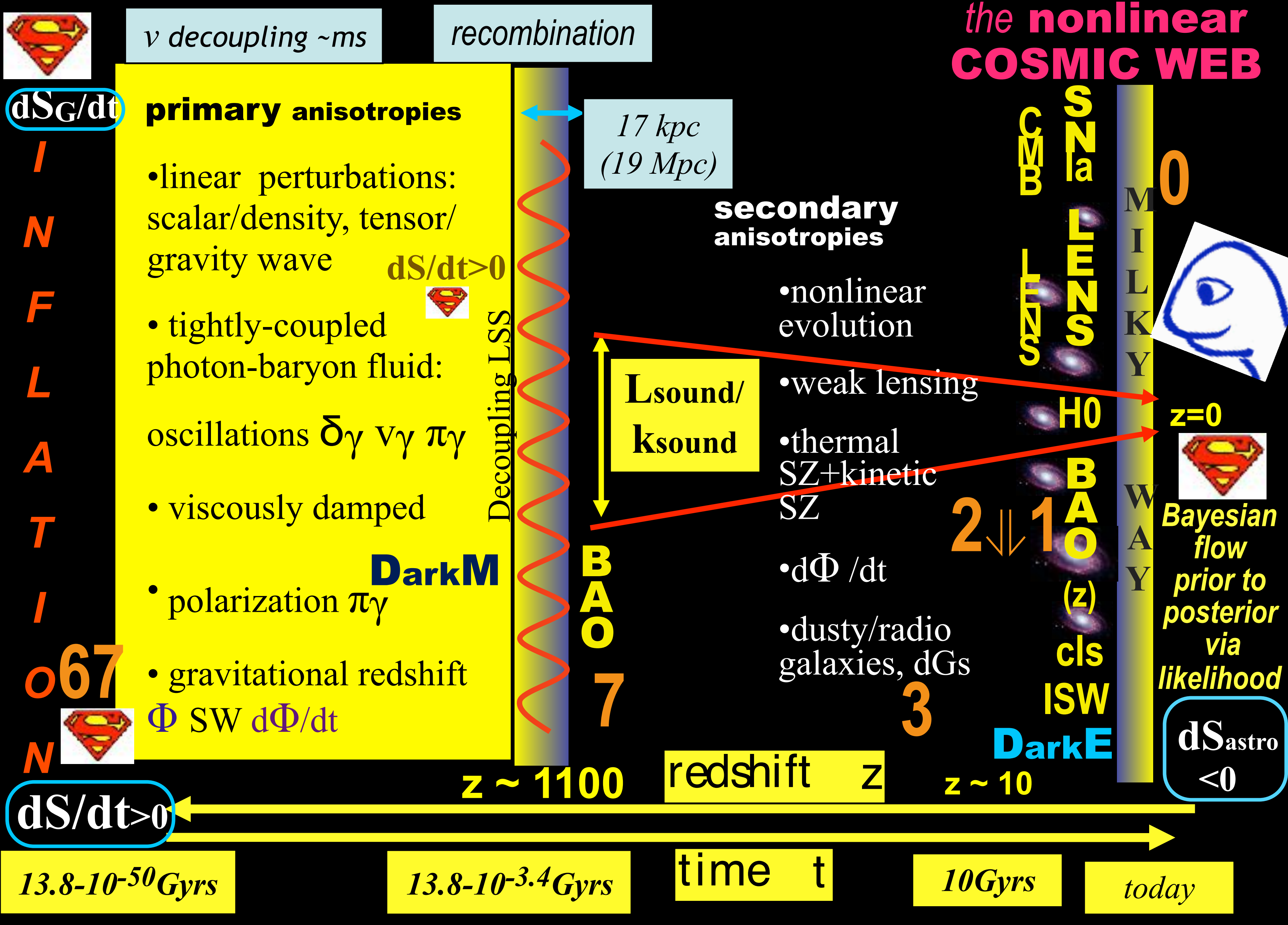
all cosmic parameters are entangled: basic 6++ near degeneracies: marginalize

Theory & Data are entangled: theory & observation



Dick Bond
Cosmic Observables for Fundamental Physics: mock WebSkys vs. the real Webskys
the nonlinear COSMIC WEB
ν decoupling ~ms
recombination
dS_G/dt
INFLATION
primary anisotropies
•linear perturbations: scalar/density, tensor/ gravity wave
dS/dt>0
• tightly-coupled photon-baryon fluid:
oscillations δγ vγ πγ
• viscously damped
DarkM
• polarization πγ
• gravitational redshift
Φ SW dΦ/dt
Decoupling LSS
17 kpc (19 Mpc)
dS/dt>0
secondary anisotropies
•nonlinear evolution
Lsound/ ksound
•weak lensing
•thermal SZ+kinetic SZ
DarkE
•dΦ /dt
•dusty/radio galaxies
reionization
MILKY WAY
z=0
Bayesian flow prior to posterior via likelihood
dSastro <0
z ~ 1100
redshift z
z ~ 10
dS/dt>0
13.8-10^-50 Gyrs
13.8-10^-3.4 Gyrs
time t
10Gyrs
today

Dick Bond *Cosmic Observables for Fundamental Physics: mock WebSkys vs. the real Webskys*



early & late Universe

theory issues

theory of tension reduction?

new physics lurking in anomalies?

what are the degrees of freedom / parameters of the ultra early Universe? TBD

Quantum Inflation - if quantum energy then quantum gravity (entangled) then gravitons
Phonons ***density fluctuations = Trace strain = spatial 3-volume fluctuations***
=> combined entropy-like measure **ζ =inflaton**

$$\zeta(x,t) = \int_{\text{field-path}} (dE+pdV)/3(E+pV)$$

Gravitons ***tensor perturbations transverse traceless strain $P_{GW} = r\, P_\zeta$ grail $r < .07$ now, to $< .001$***
Isocons ***when multiple particle-species - orthogonal scalar degrees of freedom to inflaton/phonon***
Dilatons ***4-volume fluctuations - Higgs inflation $L_G(R)$ gravity - conformally-flatten potentials***
moduli, axions ***connection to particle physics models "fundamental scalars" .. string theory***
fermions, vector gauge fields, ***Standard model of particle physics*** **.. vector perturbations**

begin-inflate => inflate => end-inflate => preheat => non-equlibrium heat+entropy
=> ***Standard Model particle physics*** **QG plasma radiation dominated**
=> dark matter dominated ***structure via gravitational instability*** **=> dark energy now**

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

relic1: ζ from ***inflaton*** *- observable = all cosmic structure CMB&LSS & stars/humans etal*
amplitude & slope <-> acceleration history & Veff simple over observable range

relic2: ***entropy*** *cooled remnant of particle/field plasma post-inflation* $S_{tot} = S_{CMB} + S_{CnuB}$

$10^{88.6}$ cf. $S_G \sim 10^{121.9}$
asymptotic DE

relic3: ***baryon asymmetry*** *of matter over antimatter* N_{baryon}/S_{tot}

$10^{-10.06}$

relic4: ***dark matter*** *from quark/gluon plasma - only seen gravitationally WIMPS, axions,..*

26.8 ± 0.9%

relic5: big bang nucleosynthesis products ***H, He, D, Li*** *(influenced by CnuB)*

relic 6: ***CMB*** *with all its fluctuations & polarization*

relic 7: galaxies & large scale clustering, flows, gravitational lensing

relic 8: ***dark energy*** ***does it have kinetic energy density? is it coupled?***

68.8 ± 0.9%

what are the ***degrees of freedom / parameters*** *of the* ***ultra early Universe? TBD***

relics not yet seen: in quest of what lies Beyond *the Standard Model of cosmology* SMc

from inflation

local nonG for $\Phi_N = G + f_{nl} G^2$ $f_{nl} = 0.8 \pm 5.0$

non-Gaussian features in ζ from weak nonlinearities *(very nearly)* **Gaussian random field**

P15+BKP r<0.09 uniform n_s

gravity waves (not so far - obscured by dust)

cf. 0<r<.11 95% CL P15+BKP 12 knots

isocon relic (not so far) - Planck on CDM isocurvature, neutrino, correlated

< 2% isocurvature role

bubble remnants of tunneling during inflation

from heating

isocon memories (not so far)

strong subdominant but intermittent nonlinearities in ζ (spikes via chaotic billiards)

curvatons oscillons strings domain walls - short lived

rare WIMPzillas as dark matter

from later quark gluon plasma

late phase transitions

anomalies in ***CMB & LSS***

could be ***primordial. large-scale, intermittent? statistics of just a few (modes, spatial rare events)?***

tensions in ***CMB & LSS***

could be systematic error underestimates ***BSMc matter, coupled DE? statistical homogeneity. fuzzy dark matter.***

<ζ|*Temp, E pol>-WebSky* reveals ***early universe phonons***

ζ- TOPOGRAPHY & CARTOGRAPHY

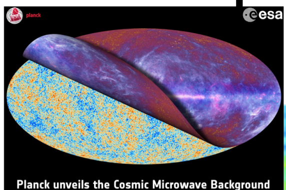
=> @a ~$1/10^{55}$ only 2 numbers
more: r? $n_s(k)$? nonGaussian; isocons

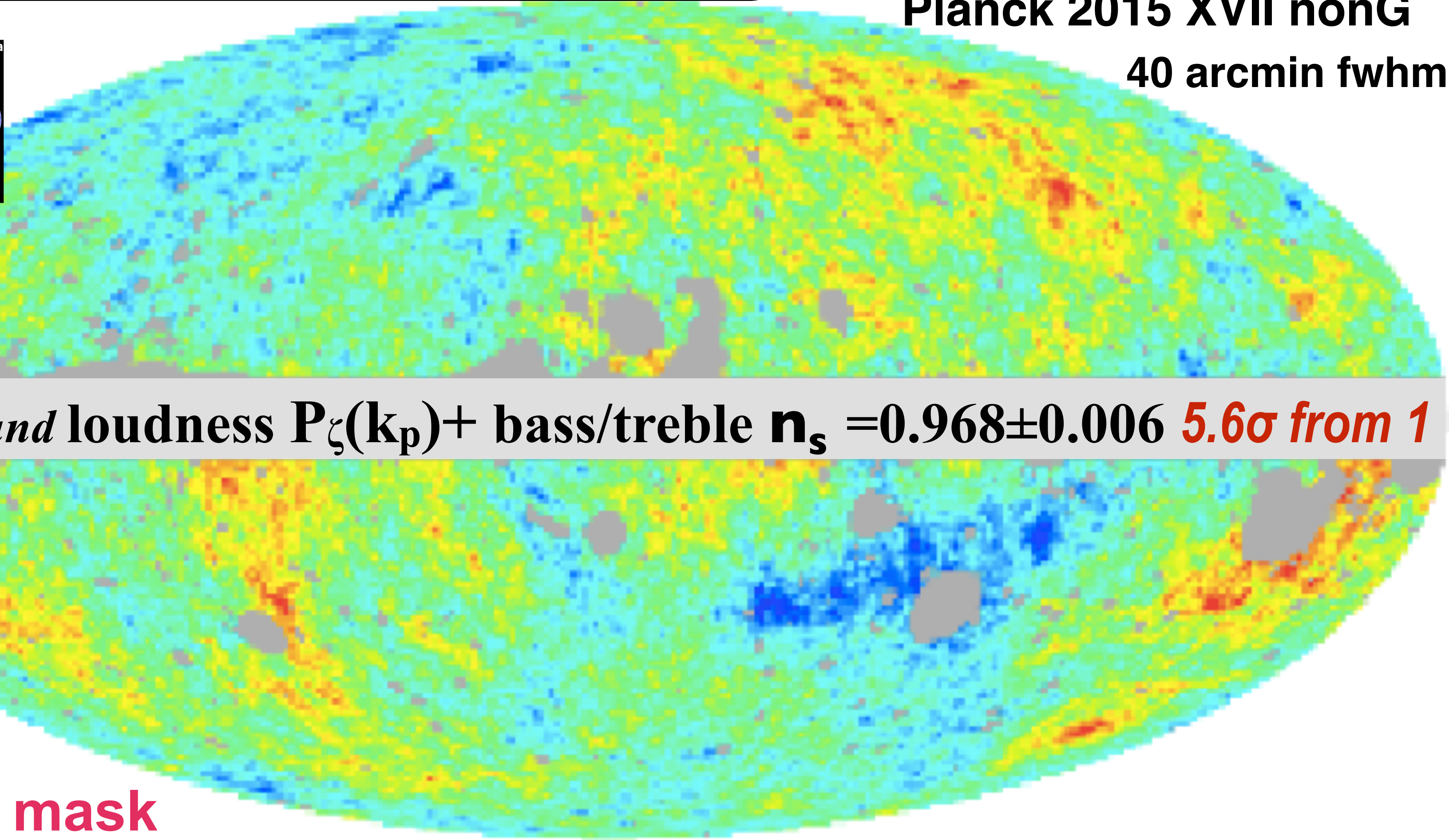
caution: not de-lensed, but the Wiener filter does partially de-lens

Planck 2015 XVII nonG

40 arcmin fwhm

linear map





random sound **loudness $P_\zeta(k_p)$+ bass/treble n_s =0.968±0.006** *5.6σ from 1*

visibility mask

∫d ***visibility****(distance)* <ζ|*Temp, E pol*> *(angles, distance)*

Beyond the Standard Model of cosmology? SMc = *tilted*ΛCDM +r aka (ζ, h_{+x})

BSMc = SMc + primordial anomalies in the true ζ -WebSky

$f_{NL^*} = -0.52 \pm 3.0$ for ζ

std **nonG** $\zeta = \zeta_G + f_{NL^*} (\zeta_G^2 - \langle\zeta_G^2\rangle)$ local & equilateral pattern & orthogonal

non-std nonG $\zeta = \zeta_{inflaton}$ + ***uncorrelated*** $\zeta_{[GRF\}}$ modulated heating intermittent?

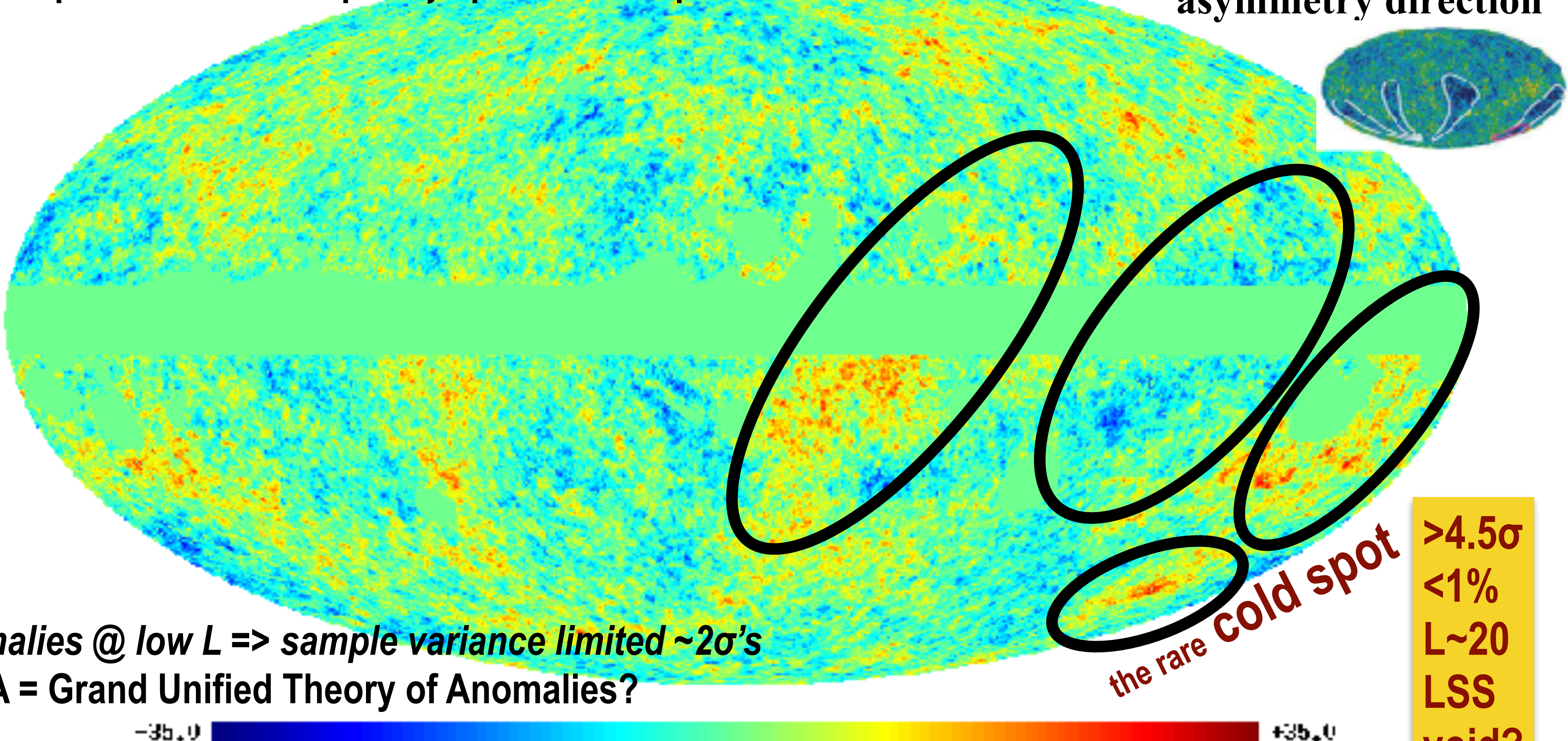
CMB TT correlation C(θ) ~0 @ >60°
hemisphere difference ~7% at low resolution

<ζ |T,E-pol>

octupole/quadrupole alignment

dipole modulation/ asymmetry direction

CMB TT power L~ 20-30 dip => ζ-Spectrum k-dip



>4.5σ
<1%
L~20
LSS
void?

anomalies @ low L => sample variance limited ~2σ's

GUTA = Grand Unified Theory of Anomalies?

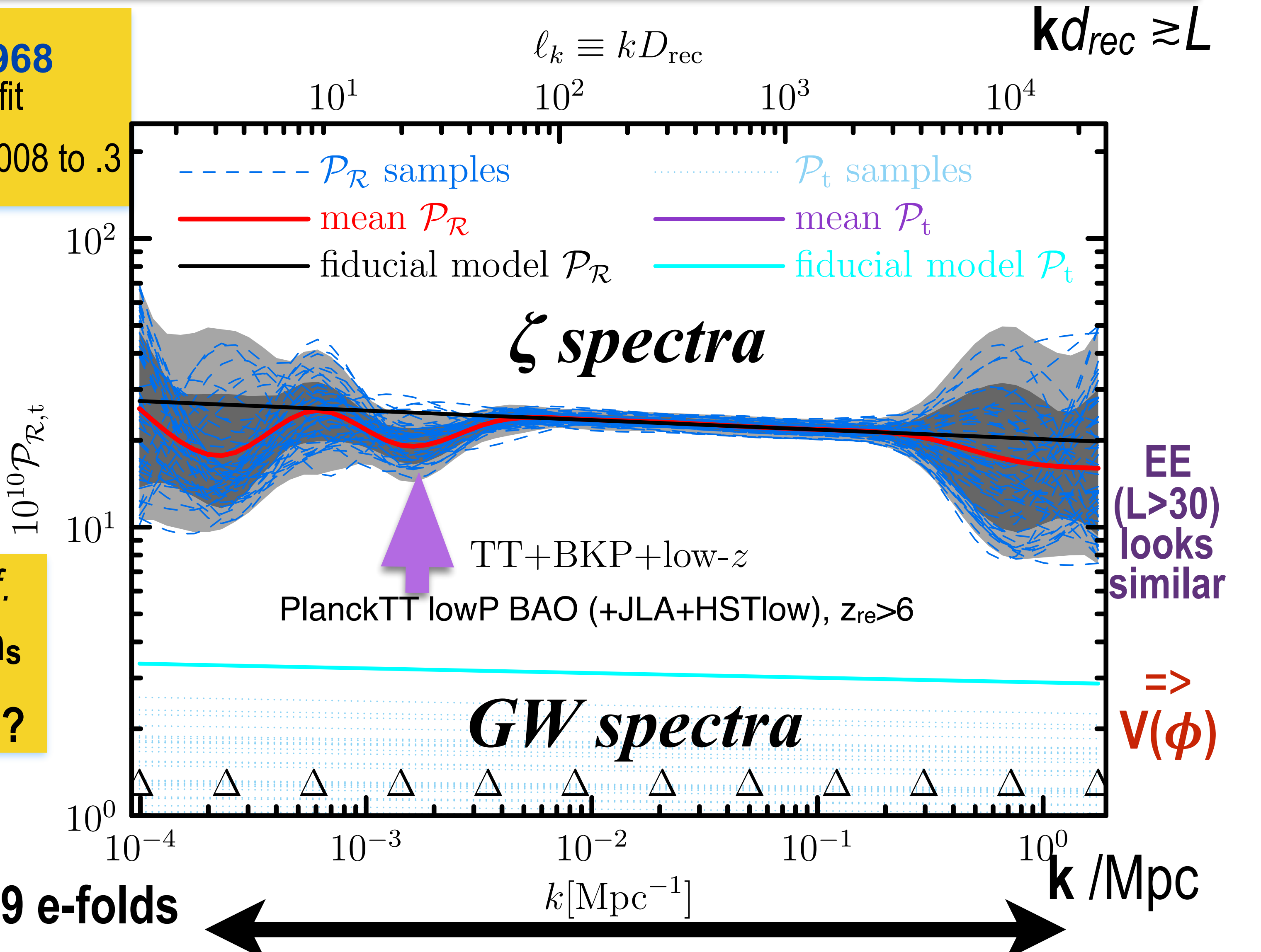
the true quadratic ζ-Websky of the ζ-scape

Planck 2015 XX inflation

CMB TT power L~ 20-30 dip => ζ-Spectrum k-dip; *includes CMB lensing, parameter marginalization*

uniform **n_s=0.968**
P15+LSS best fit
superb 12-knot fit k~ .008 to .3

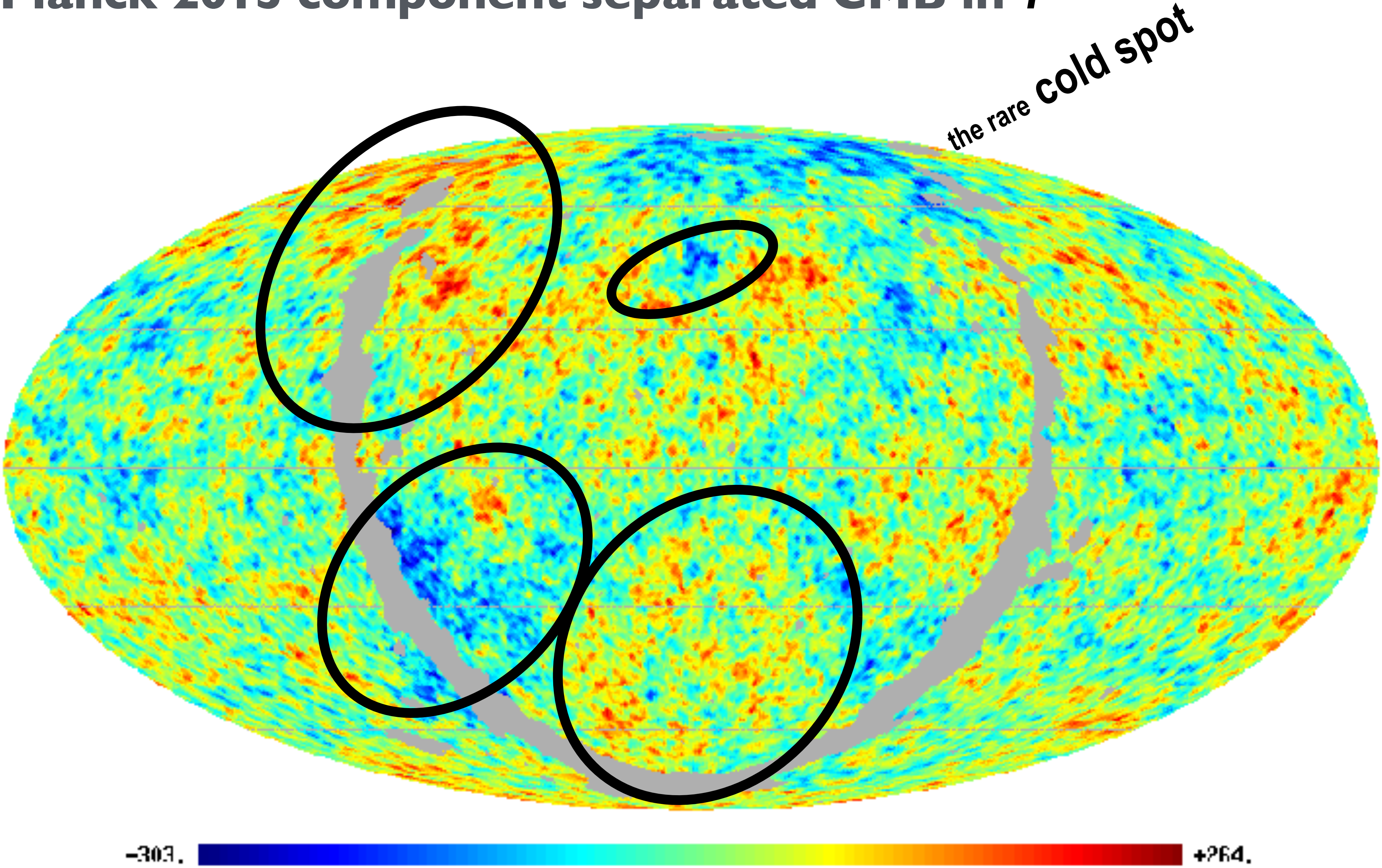
r<.11 95%CL *cf.*
r<0.09 uniform n_s
r<0.07 BK, <0.06?



rotated true T-WebSky

BFH, b+frolov+huang

Planck 2015 component separated CMB in *T*

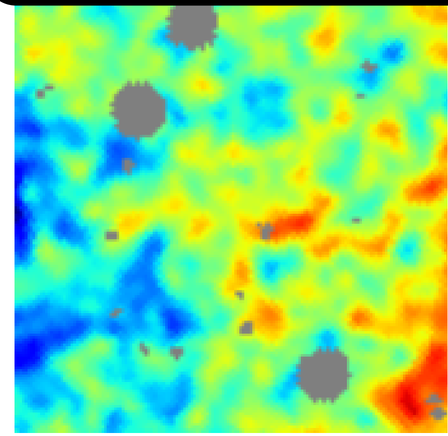


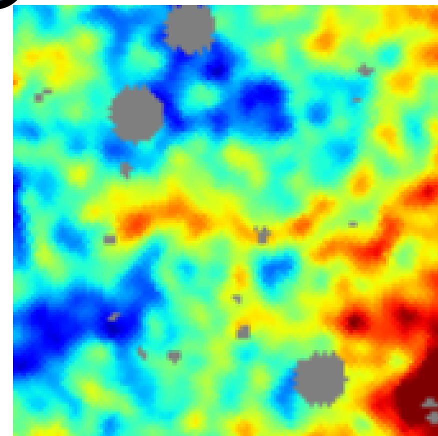
CMB *~10,000,000 T/E modes of SMc aka tΛCDM*

≲500 modes of anomaly ….. ≲100 modes reionization history

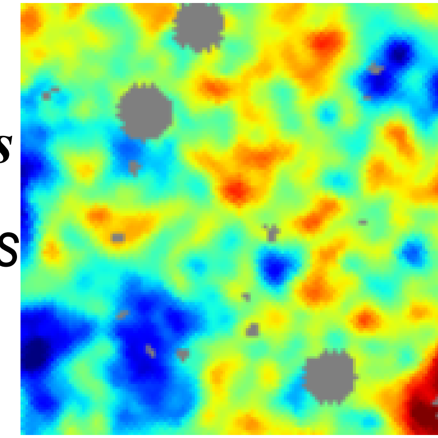
real ζ -WebSky mean field

visibility mask





real ζ-WebSkys with fluctuations

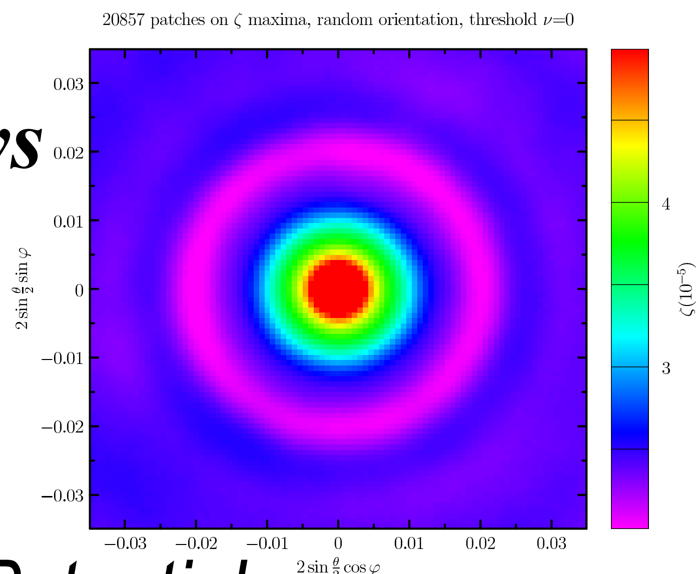


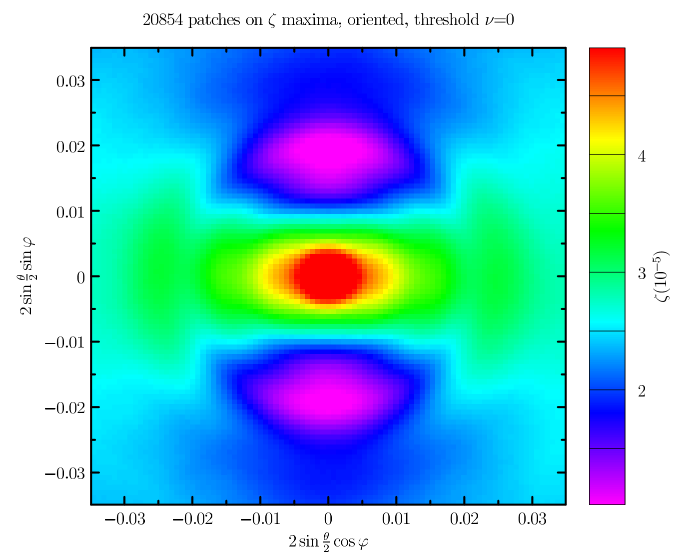
20x20 sq deg

zoom in, higher res: 20 arcmin fwhm

real ζ-WebSkys stacked to damp fluctuations

$<\zeta|\zeta_{pk}>|_{dv}$

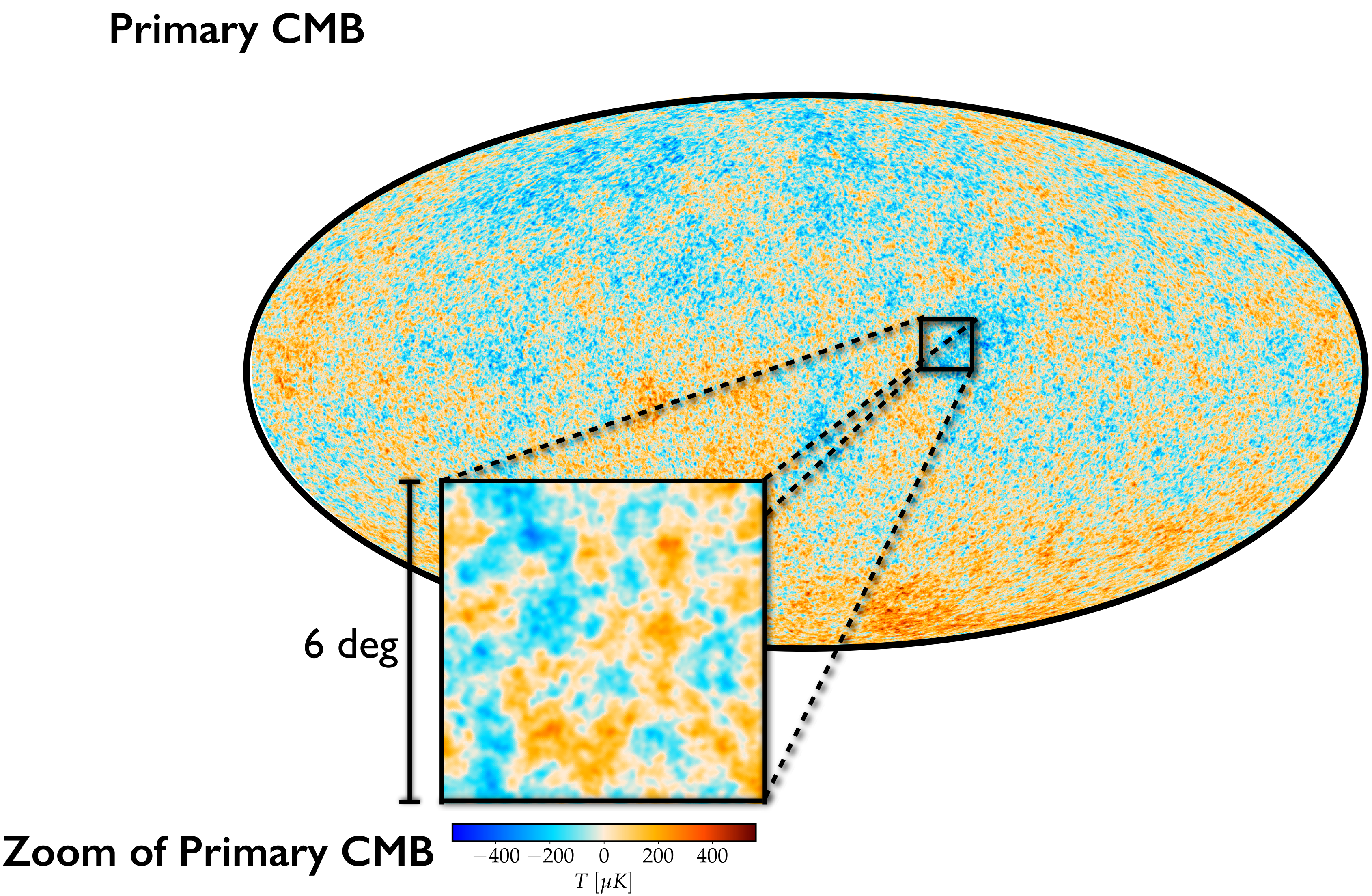




similar to -Gravitational Potential WebSkys

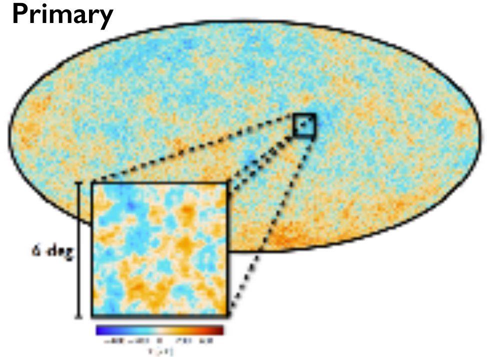
oriented stacks, etc.

Mock WebSky of the Primary CMB



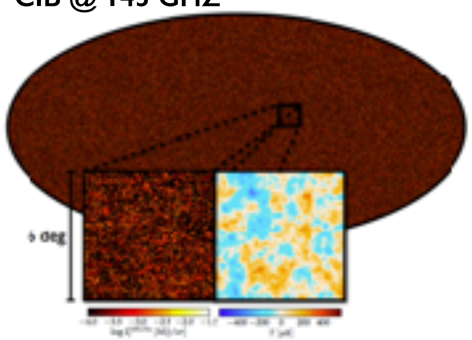
WebSky **Multi-Component WebSkys aka Maps**

Primary



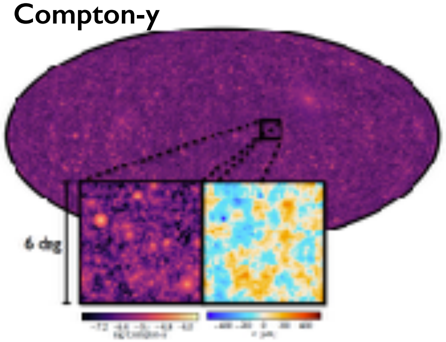
+

CIB @ 143 GHZ



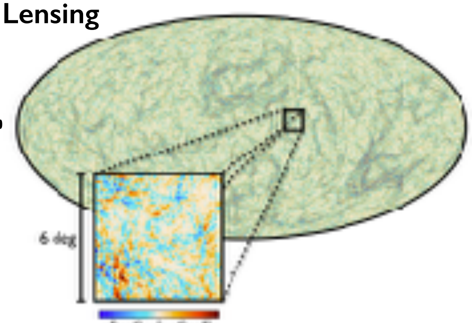
+

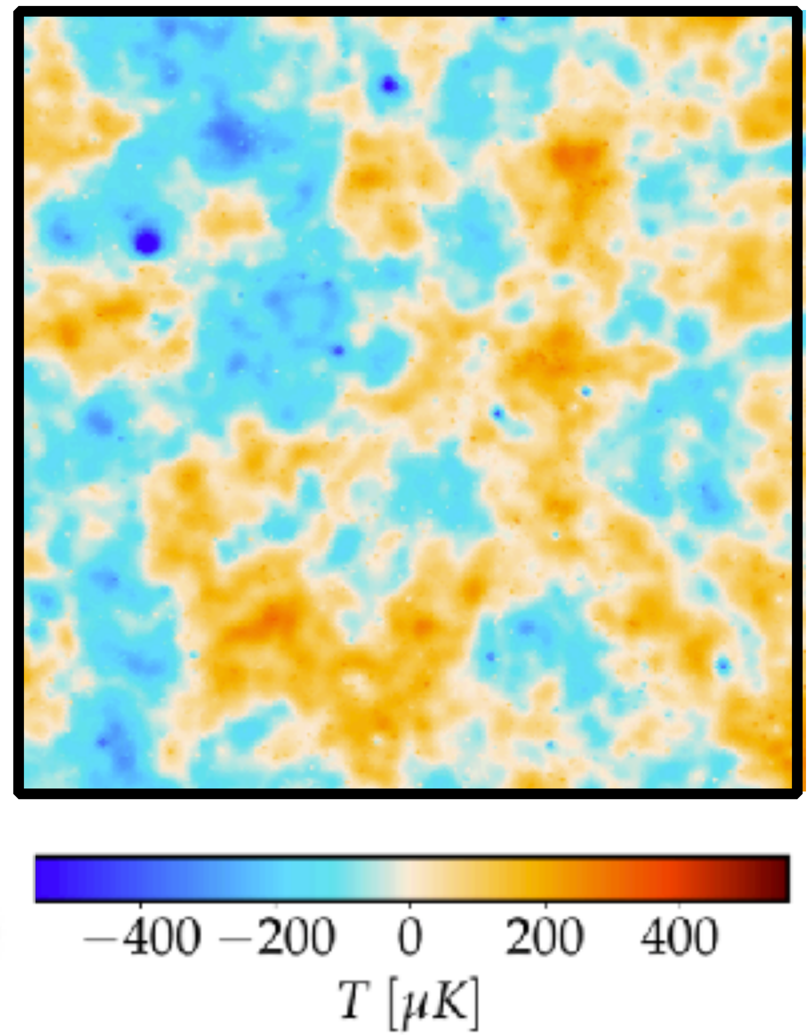
Compton-y



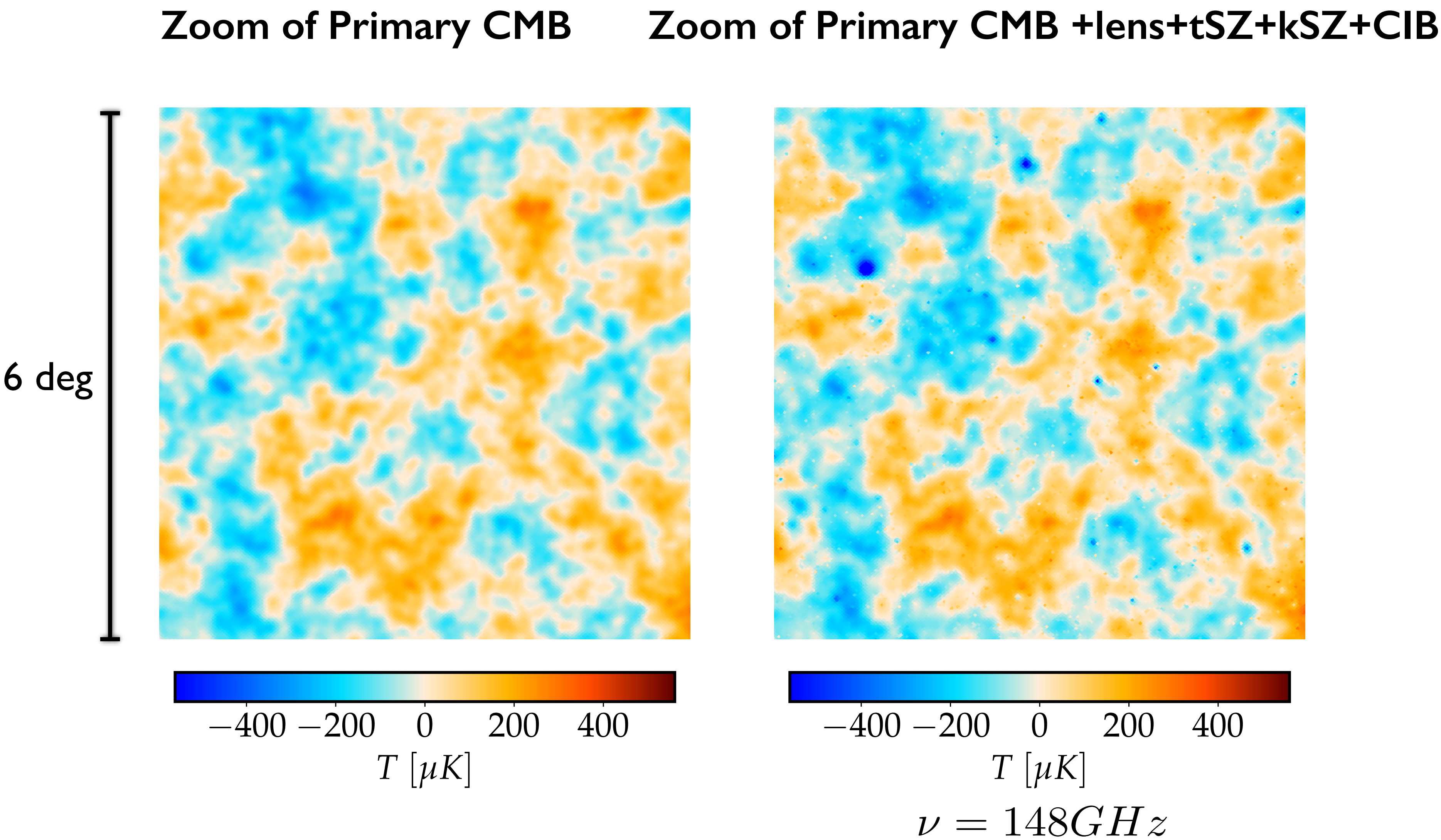
+

Lensing





Mock WebSky of all Primary CMB + secondary CMB extragalactic signals

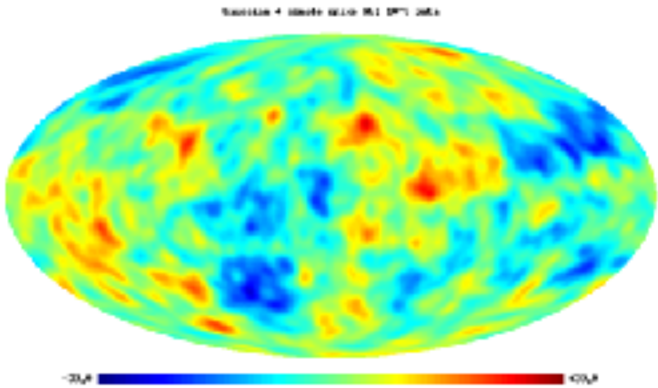


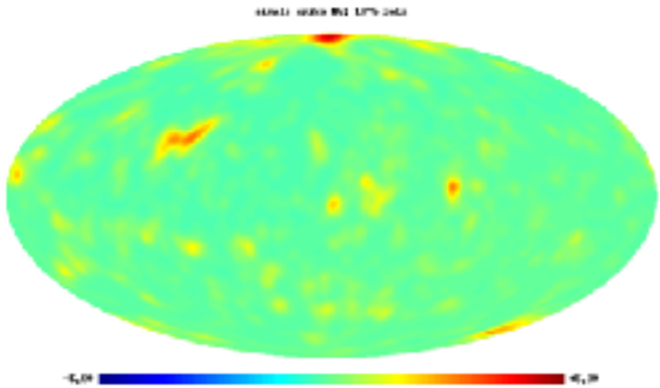
Mock WebSky of Primary CMB with subdominant non-Gaussianity giving coldspot

uncorrelated nonG 'wide open' cf. usual correlated highly constrained nonG f_{nl}

CMB+LSS mocks to test: standard Gaussian inflaton ζ_{inf} + subdominant uncorrelated ζ_{isoc}

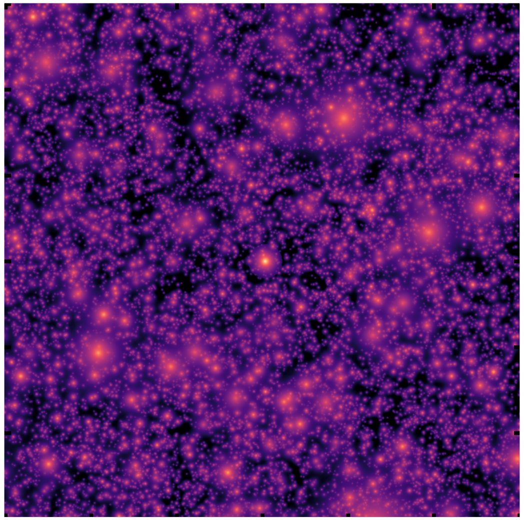
e.g., ***from modulated preheating by isocons***





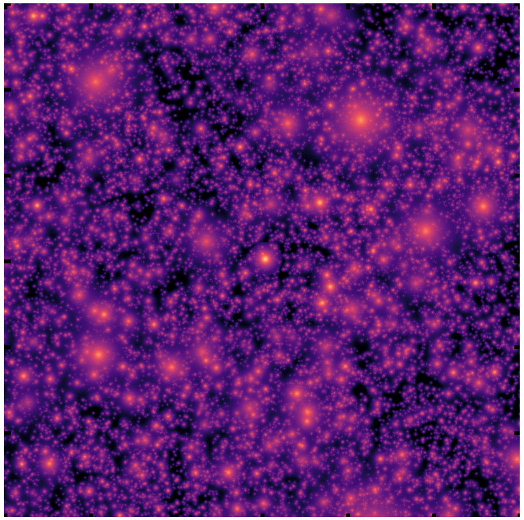
Mock WebSky of tSZ Secondary CMB with subdominant non-Gaussianity

LSS tSZ: Gaussian std **Gaussian ζ_{inf}**



B2FH, b+braden+frolov+huang

LSS tSZ: Gaussian std +
subdominant uncorrelated ζ



ABSB+FH, alvarez+b+stein+frolov+huang

Gaussian ζ_{inf} +
uncorrelated
intermittent nonG ζ_{isoc}

nonlinear LSS WebSkys & Secondary CMB WebSkys

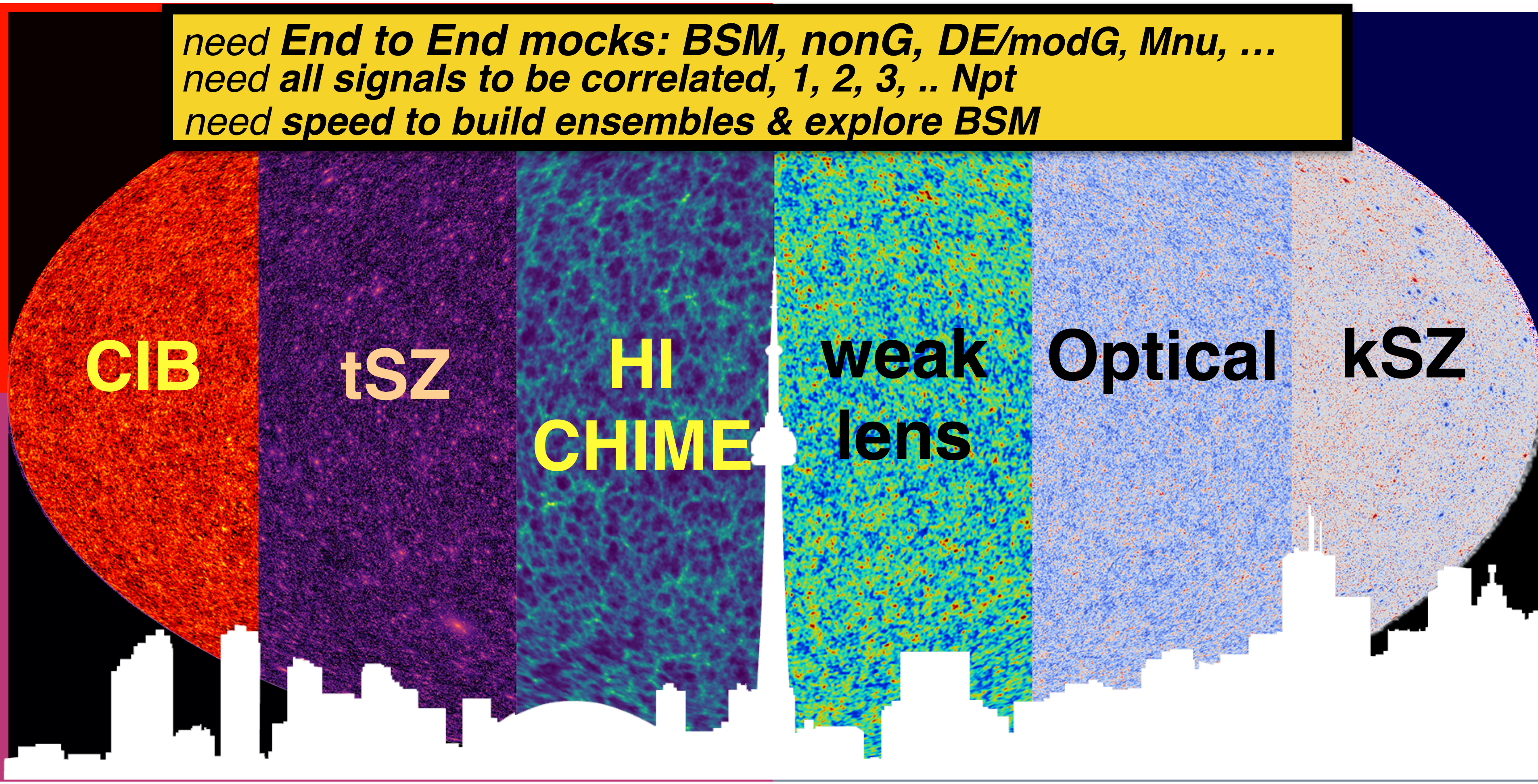
WebSkys: Joint Simulation and Analysis of Very Large hence Highly Correlated CMB and LSS SkyProbes

CITA mini-industry Alvarez, Bond, Stein, Codis + Huang + van Engelen + Connor Bevington, Bruno Régaldo-Saint Blancard + Louis Pham & to HI & LIM Phil Berger, Ronan Kerr + FIRE: Lakhlani + Murray + Hopkins +

z=.8-2.5 z=2.4-3.4 z=6-8

radio: HI CO CII, … + optical Ha, Ly a, …

need ***End to End mocks: BSM, nonG, DE/modG, Mnu, …***
need ***all signals to be correlated, 1, 2, 3, .. Npt***
need ***speed to build ensembles & explore BSM***



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

Surveys of the Web(z)

the LSS data bases for

fundamental physics &/or **cosmic weather**

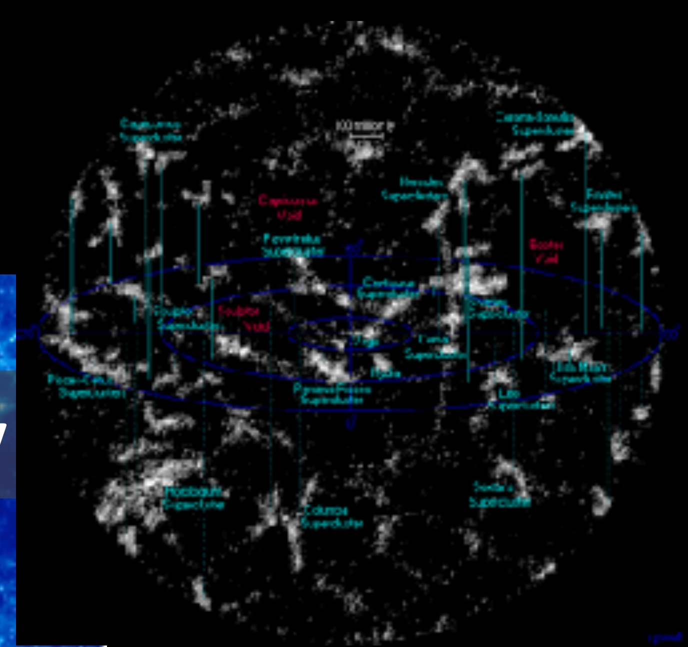
optical z-surveys / weak lensing surveys (CFHT,SDSSx,KIDS,HSC,DES, DESI,LSST,Euclid,WFIRST), hi-z galaxy surveys (LyBreak SphereX...), sub-mm/Cosmic Infrared Background surveys (SCUBA, Blast, Herschel, Planck, ACT, SPT .. CCATp), radio (NVSS, FIRST, CHIME,HIRAX,MeerKAT.., SKA, Paper..), thermal/kinetic Sunyaev-Zeldovich surveys (Planck, ACT, SPT CCATp), HI intensity mapping (CHIME, .. SKA), CO intensity mapping (COMAP),..

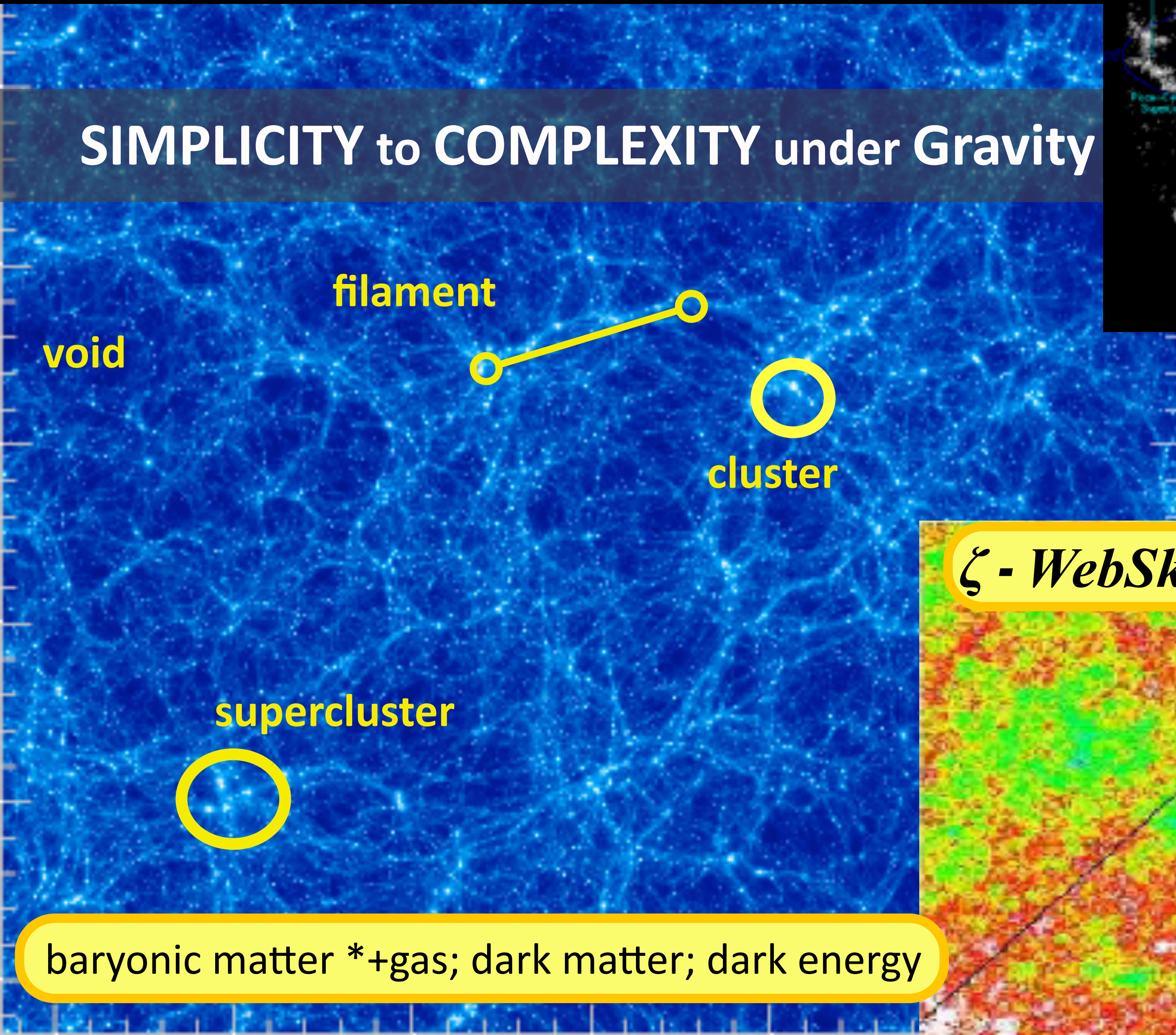
+ Primary CMB surveys Pol r & hi res

Simulation of the **7⁺ numbers**

begets the **Cosmic Web** of clusters

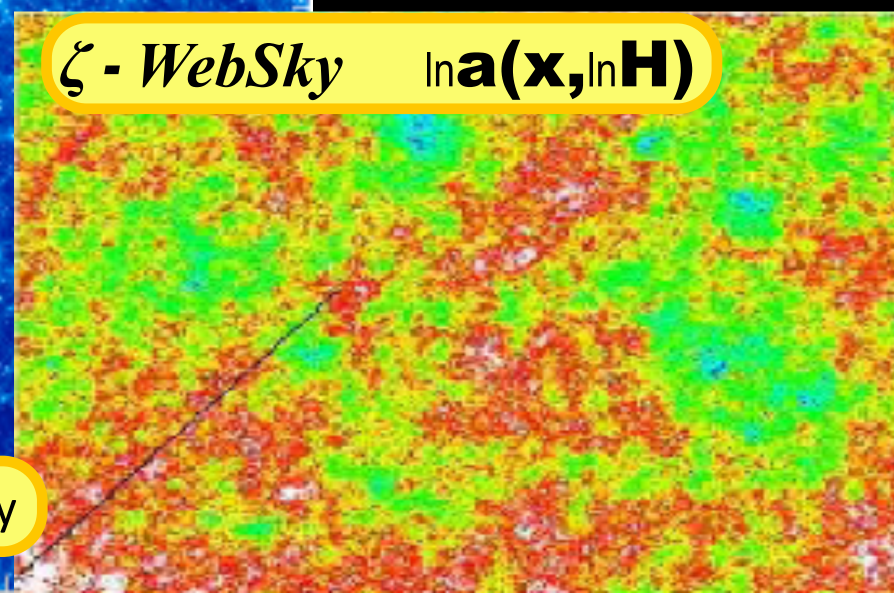
now a~1 & galaxies then a~1/4





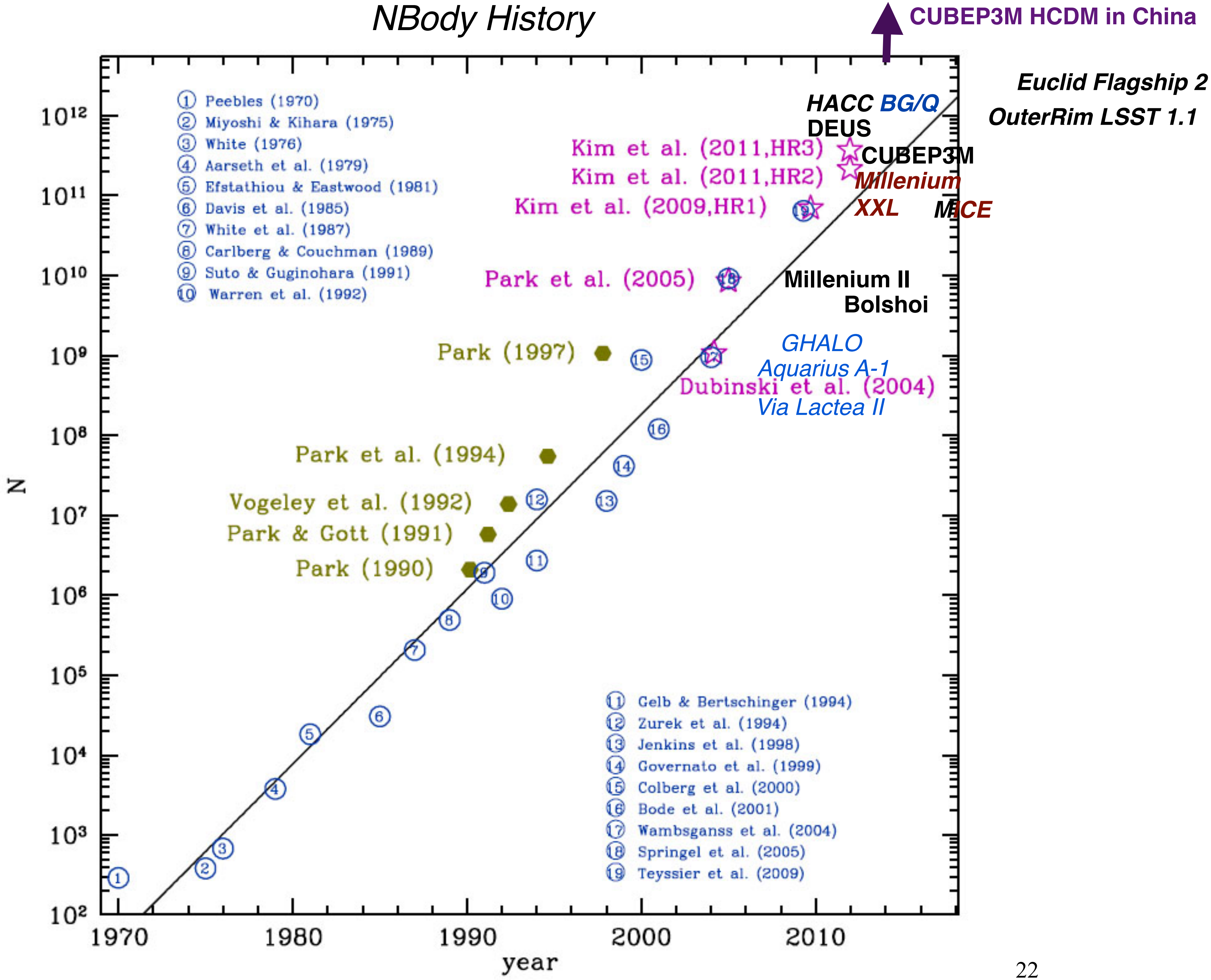
~ billion light years

state of the art simulations
a~1 to 1/1.1



N-body then & now

NBody History



Juhan Kim etal 2011 +

Euclid Flagship simulation, *Stadel, Tessyier, .. all official Euclid estimates will be done with this sim:*
$(12600)^3$ lightcone to z=2.3, 5558 Mpc PKDgrav… *need deeper to cf. Spitzer*
10 trillion particles, 50 billion halos, 125 Mpc tiling, Planck13 parameters
LSST: Argonne Outer Rim simulation $(10300)^3$ aka 1.1 trillion 4200 Mpc, 7 kpc force res,
Ntile=64Mpc, 64^3 cores, *Heitmann, Habib,*
MICE Grand Challenge: Marenostrum $(4096)^3$ 4388 Mpc 71 kpc force res, Fosalba+13 Gadget2
Minerva: 300 $(1000)^3$ sims 2143 Mpc

- ***cf. Approximate Rapid Halo Finders/Movers***

approximate
halo finders/movers

Euclid Flagship simulation, *Stadel, Tessyier, .. all official Euclid estimates will be done with this sim:*
$(12600)^3$ lightcone to z=2.3, 5558 Mpc PKDgrav… *need deeper to cf. Spitzer*
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Minerva: 300 $(1000)^3$ sims 2143 Mpc

- ***Approximate Rapid Halo Finders/Movers***
- **speed for fast Monte Carlo mocks, statistics and BSMc physics cf. accuracy**
- ***we are agnostic about best rapid halo finder:***
- **PeakPatches 1993.96 *Bond, Myers, lightcone naturally comes out, halo by halo***
- **PThalos 2001 - *Scoccimarro, Sheth,***

Alvarez Bond Stein+ 18
speed~1000 X Nbody

- **PINOCCHIO 2002 - *Monaco et,* PINpointing Orbit Crossing-Collapsed HIerarchical Objects,**
- **Millenium 2006 N-Body + artful painting *Volker +, Simon White, Alex Szalay,***
- **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,***
- **cf. Minerva N-body 300 sims 1000^3 1.5 h^{-1}Gpc to cf. ICE-COLA, Pinocchio, PeakPatches**
- **cf. 512 suite of N-body Gadget 2016 *Szalay +***

Peak Patch Picture of Cosmic Catalogues & the Cosmic Web theory

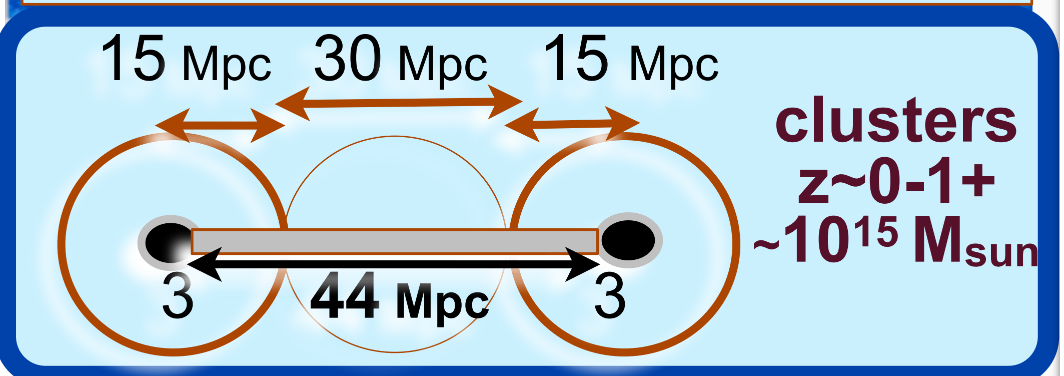
& constrained mean fields + fluctuations "zooms" & importance sampling & superclustering

Peak-patches = "hot" halos
B+Myers 91-96; BBKS 83-86

The ***Cosmic Web***
B+Kofman+Pogosyan 96-99

"Molecular" Picture of LSS
Filaments & Membranes

HALOS are dynamically HOT, the hierarchical standard model, ΛCDM, => scale space (3+1D => 4+1D)
adaptive coarse-grain Zeldovich (->2LPT+) flows of Lagrangian peak-patches agree with N-body Eulerian halo simulations => fast mock surveys

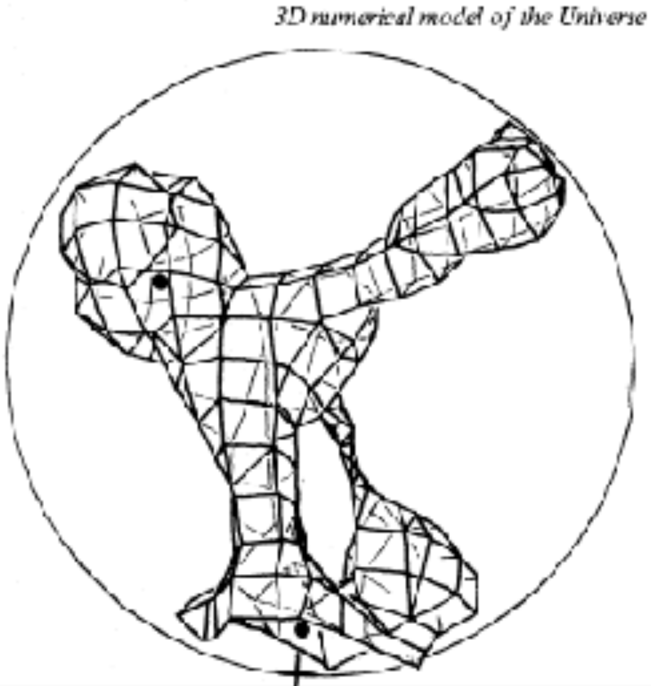


clusters
z~0-1+
$\sim 10^{15}$ M_{sun}

1 Mpc | 2 Mpc **3 Mpc** | 1 Mpc

galaxies
z~2-5
$\sim 10^{11.5}$ M_{sun}

Klypin's vintage 1982
$160h^{-1}$Mpc box 32^3 hDM



deformation tensor
$e_J{}^j = l_J{}^j + eps_J{}^j$
strain/*shear*

~ *linear* **tidal tensor**

The *WebSky* Suite of Sky Simulations

Fast Halo Catalogs for WebSky Simulations with the Peak Patch Approach

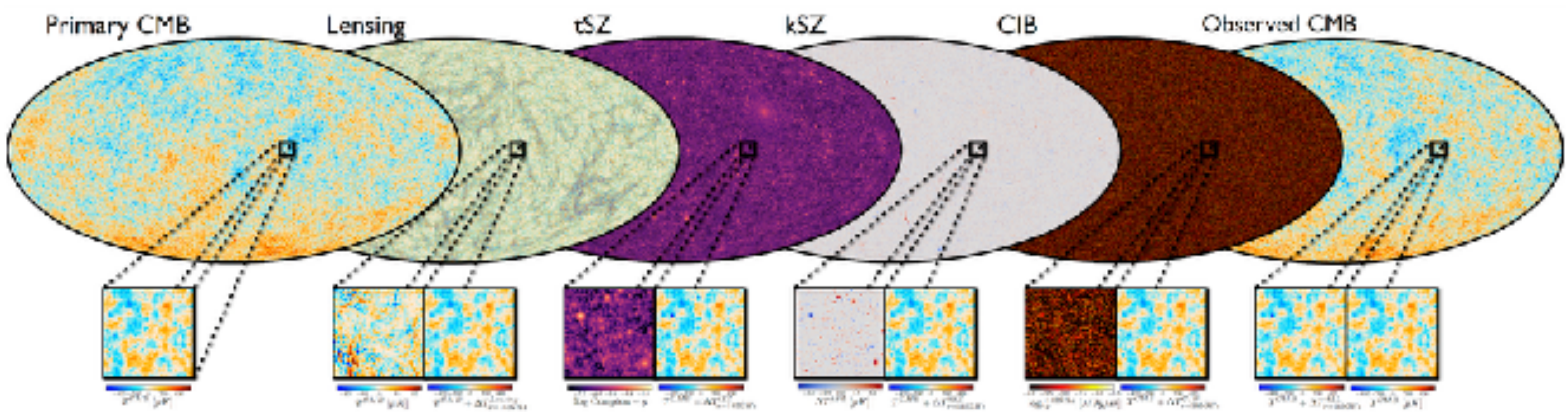
16^3 Gpc^3 Volume @8192^3 Resolution

Halo Mass Resolution ~ 1e13 M_{sun}/h

Memory Footprint: 2 TB

Fully Sky for 0 < z < 4.5

~5000 CPU Hours



recent peak-patch tests:

mass function cf. N-body

tSZ power cf. BBPS1234

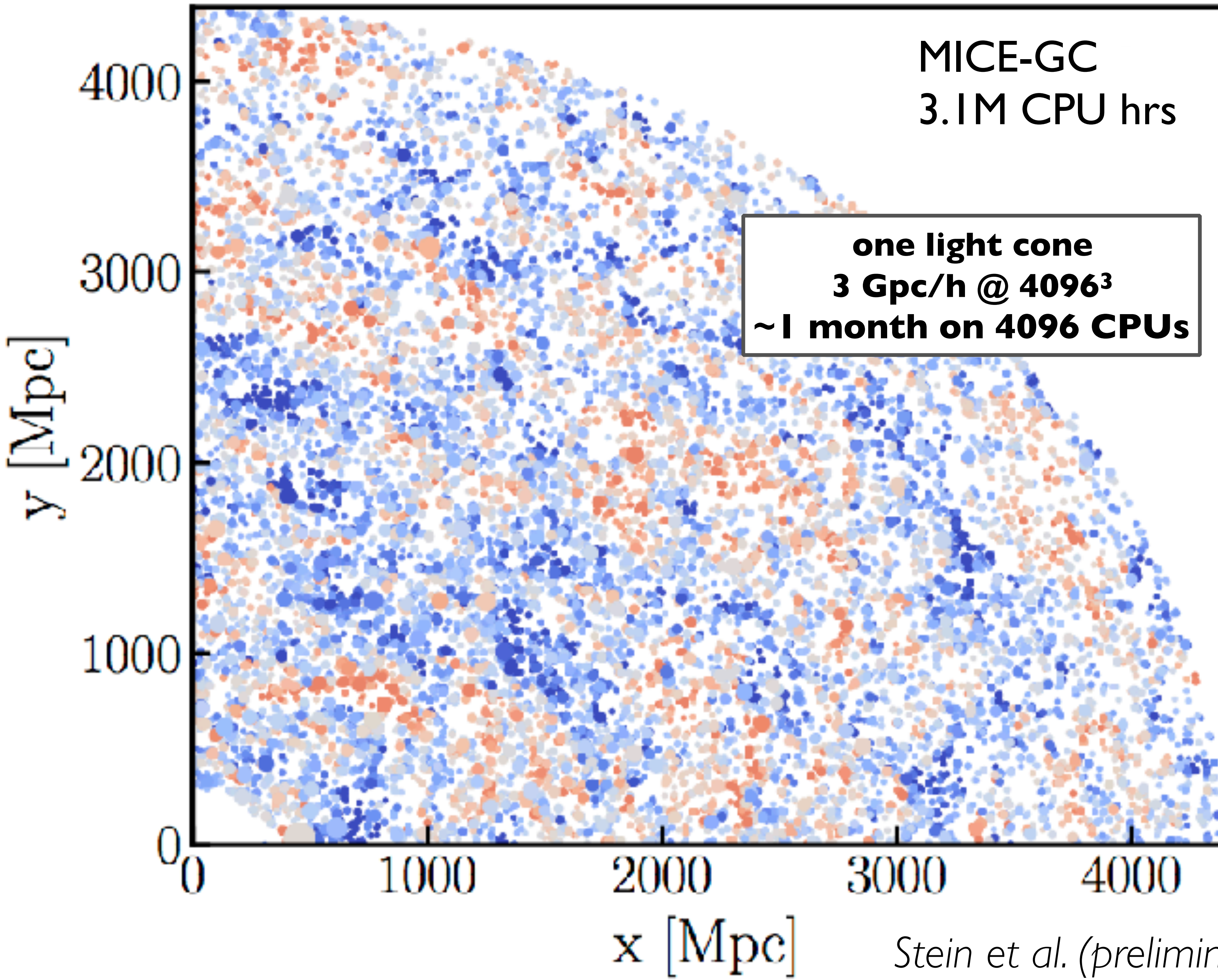
Euclid clustering vs. MICE-GC

Euclid power spectrum/bias vs. Minerva

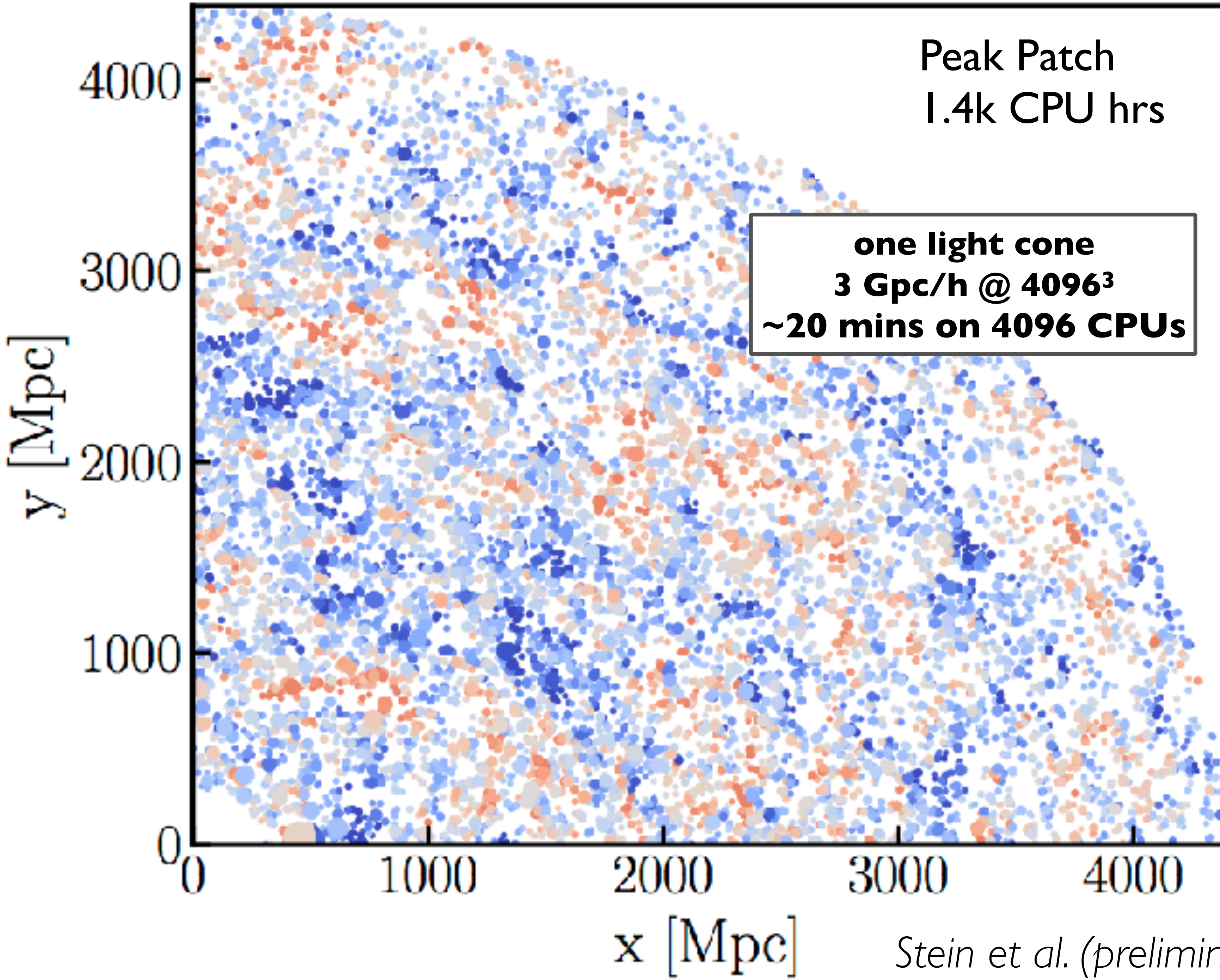
WebSky tSZ x CIB cf. Planck 2015

WebSky CMB Lensing cf. Lewis' Lenspix

++



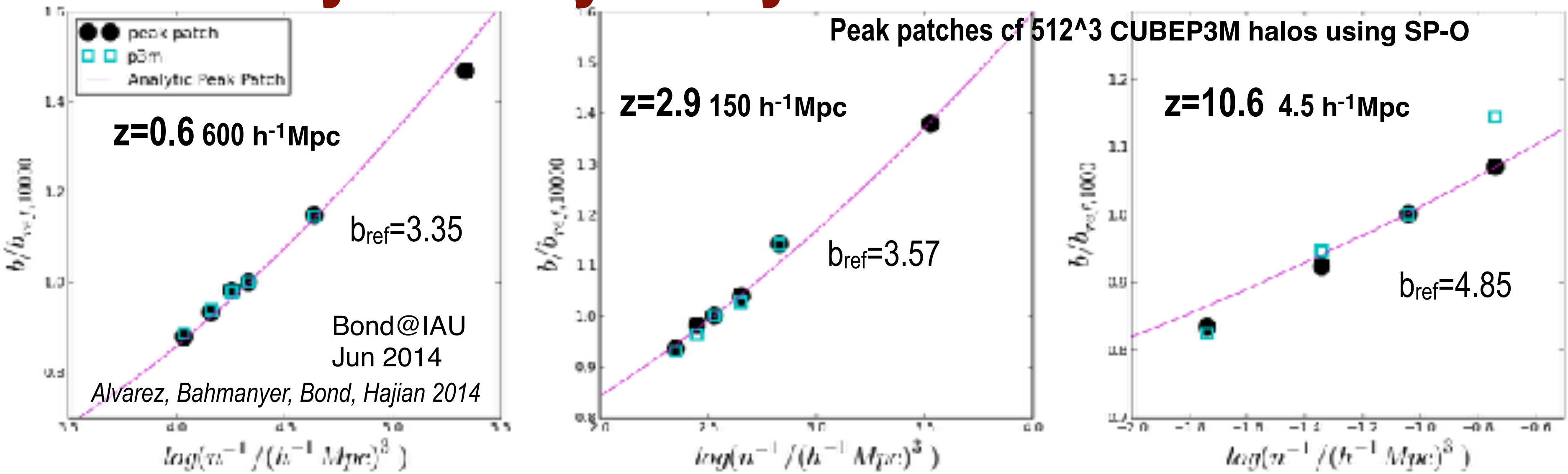
Stein et al. (preliminary)

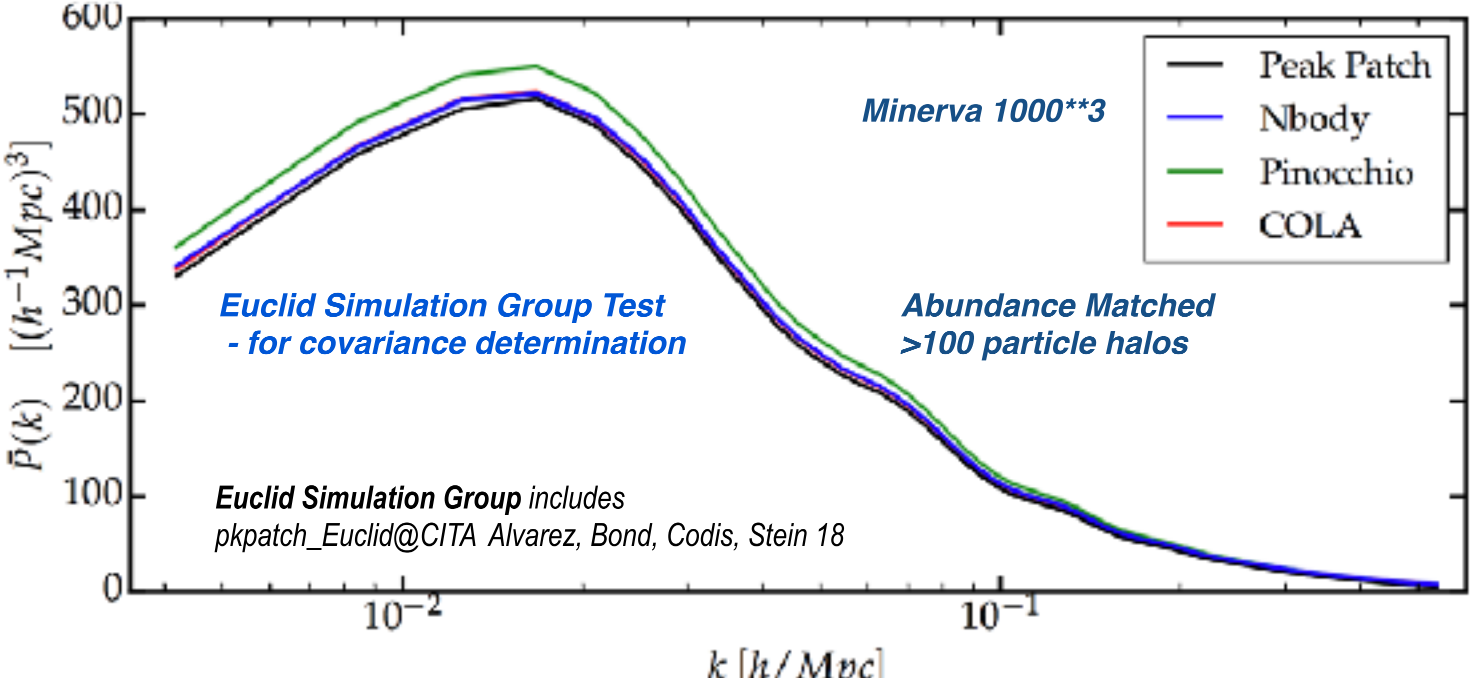


Stein et al. (preliminary)

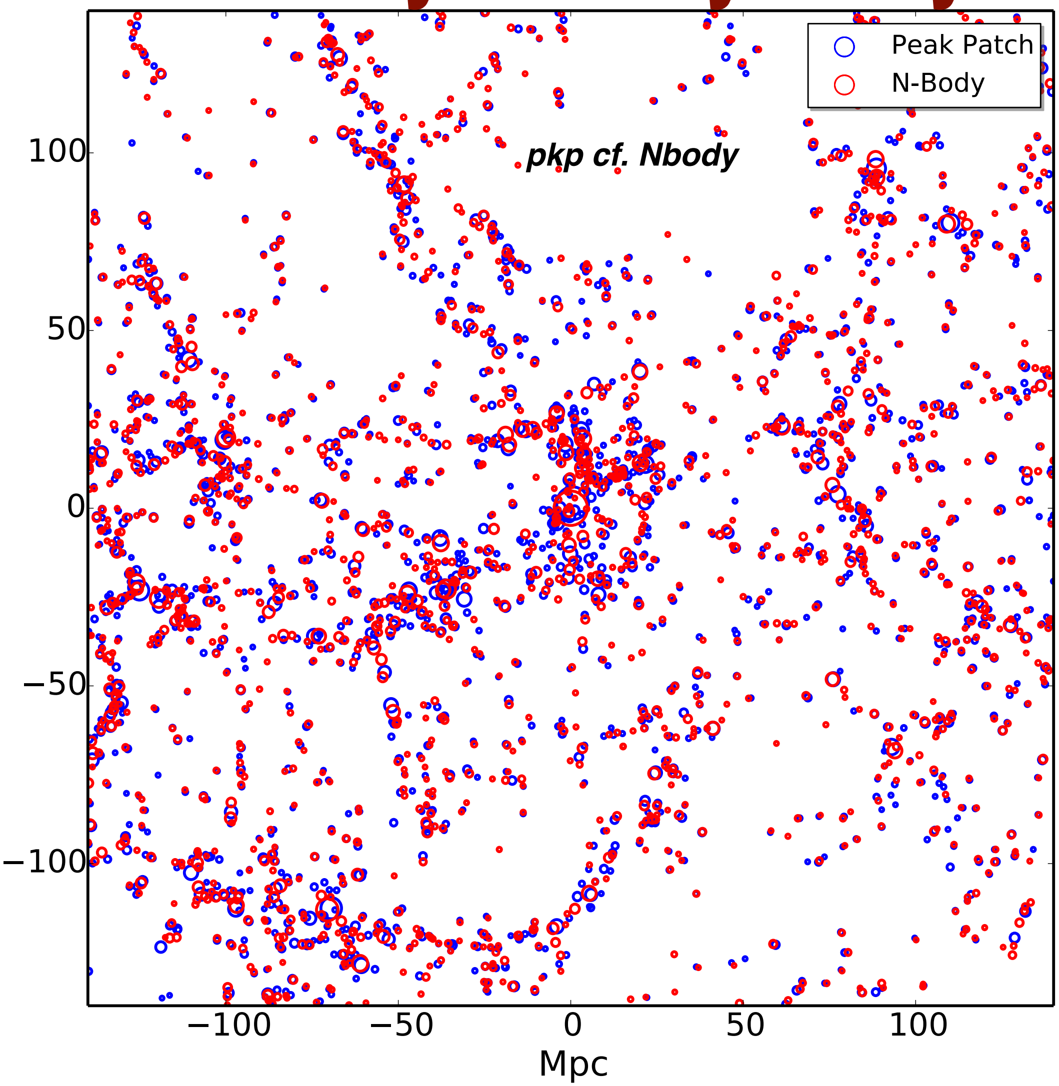
BIAS & 2-point clustering of halos is understood numerically & analytically: move via 1LPT or 2LPT

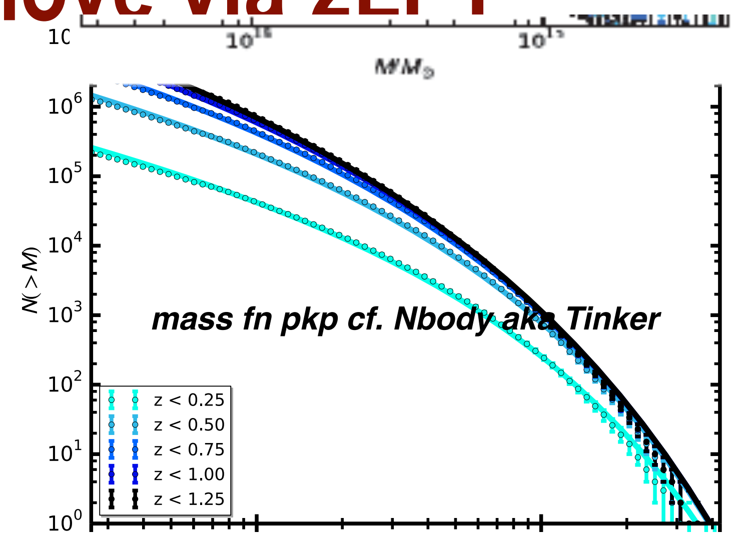
Peak patches cf 512^3 CUBEP3M halos using SP-O



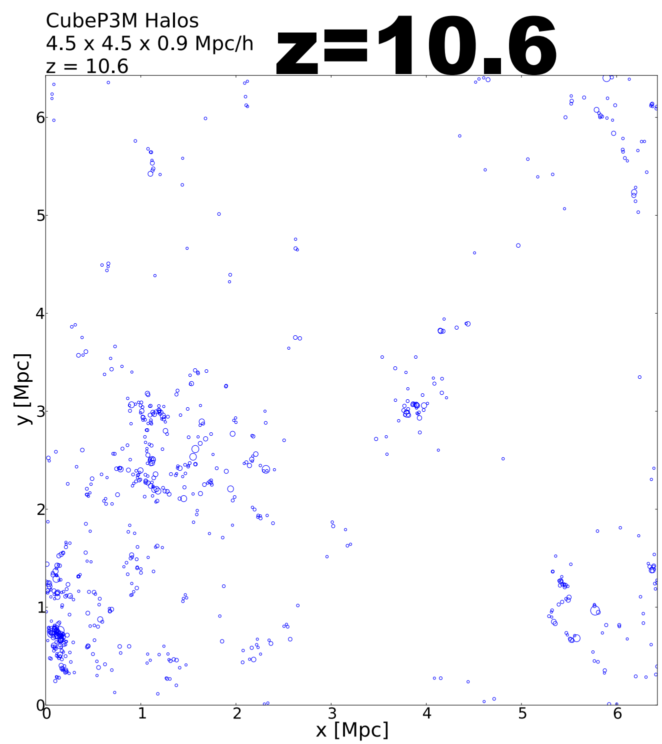


BIAS & 2-point clustering of halos is understood numerically & analytically: move via 2LPT

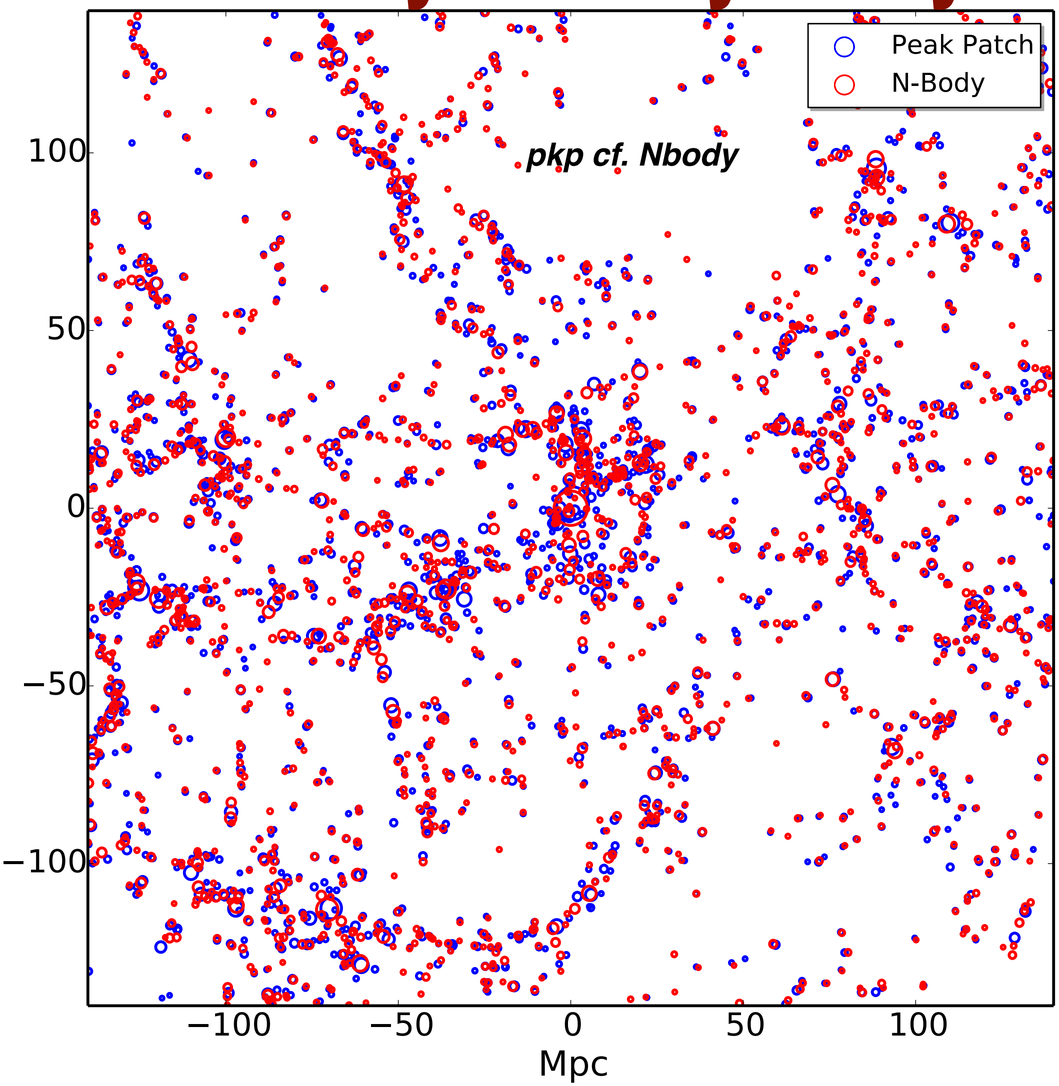


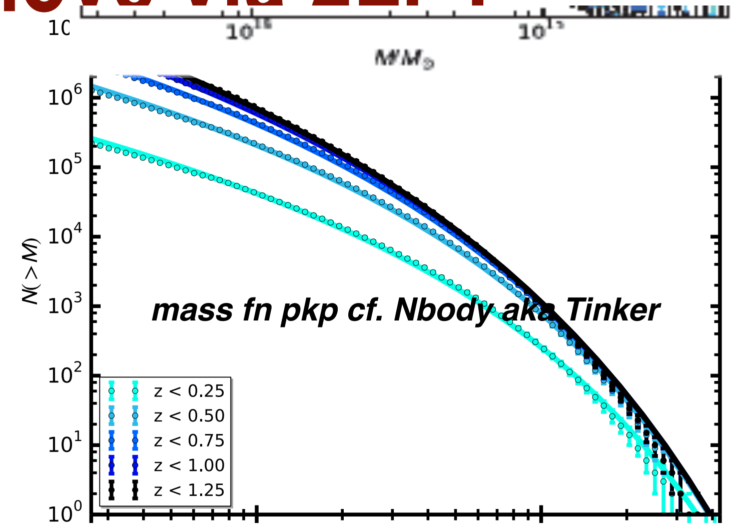


z=10.6

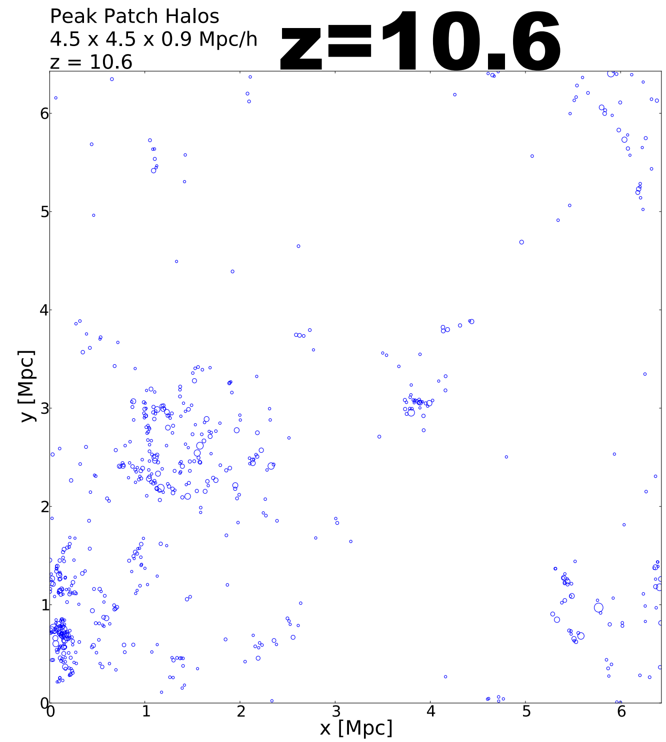


BIAS & 2-point clustering of halos is understood numerically & analytically: move via 2LPT



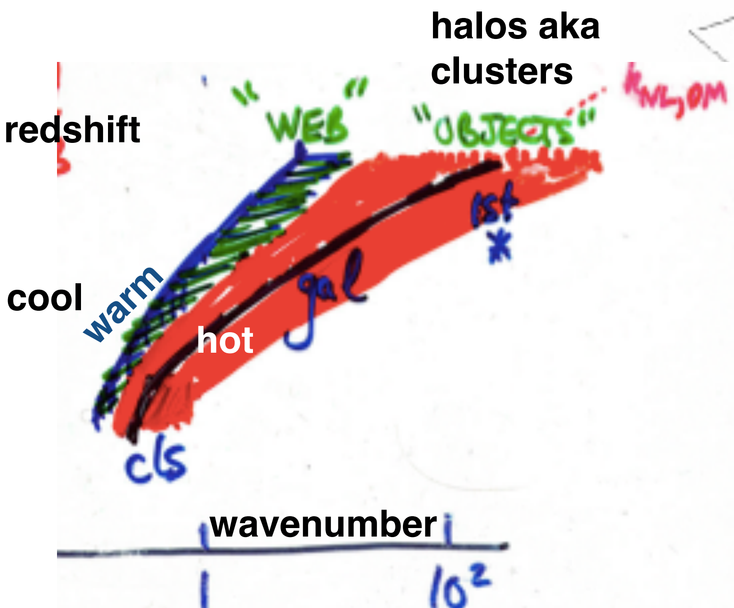


z=10.6



Cosmic Web varies with initial density spectrum tilt

$d\sigma_{\rho L}^2/d\ln k \sim k^{(n_{eff}+3)}$



neff (k) *varies for 'standard' tilted* ***Λ****CDM*

-1.3 cluster scale,

-2.3 galaxy scale,

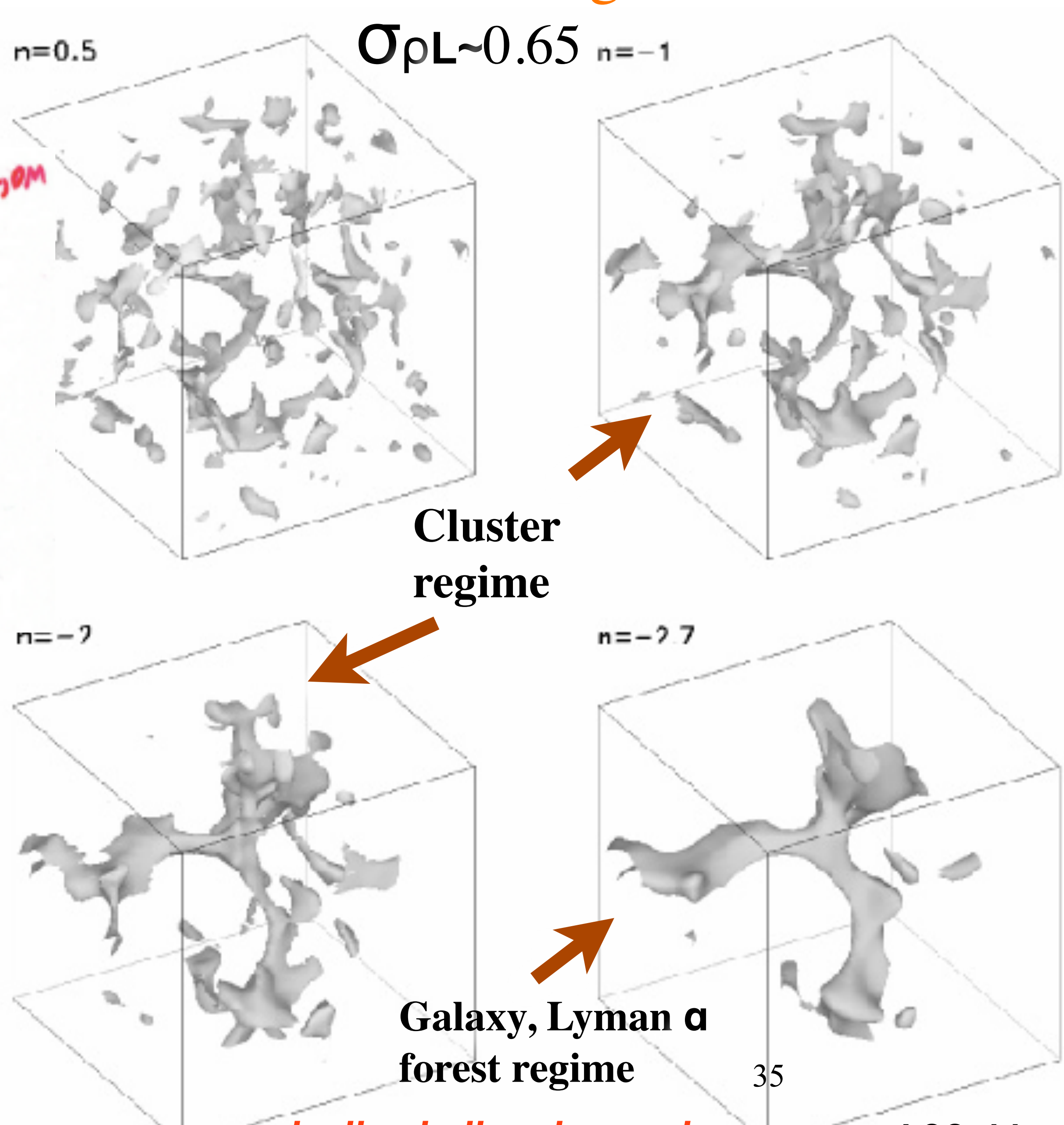
-2.8 Lyman α scale

-3.04 large k, 1st star

percolation threshold contour

smoothing

$\sigma_{\rho L}$~0.65

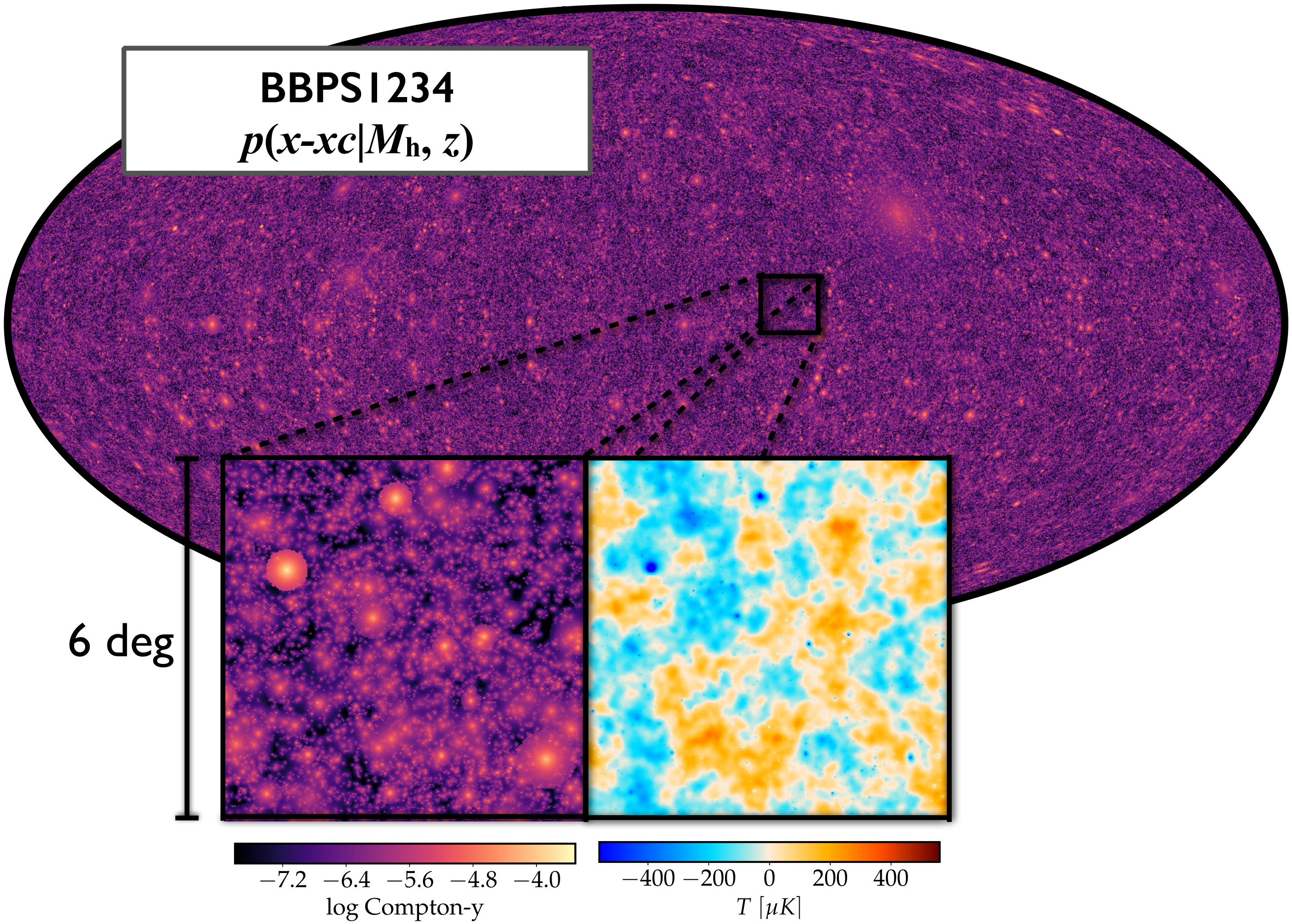


Cluster regime

Galaxy, Lyman α forest regime

beware: a numerically challenging regime **extreme LSS tides**

Compton-y / tSZ WebSkys



BBPS gasdynamical WebSky Simulations ***with AGN/stellar Energy feedback: for tSZ/kSZ,…***

400 Mpc

ΛCDM

WMAP5

gas density

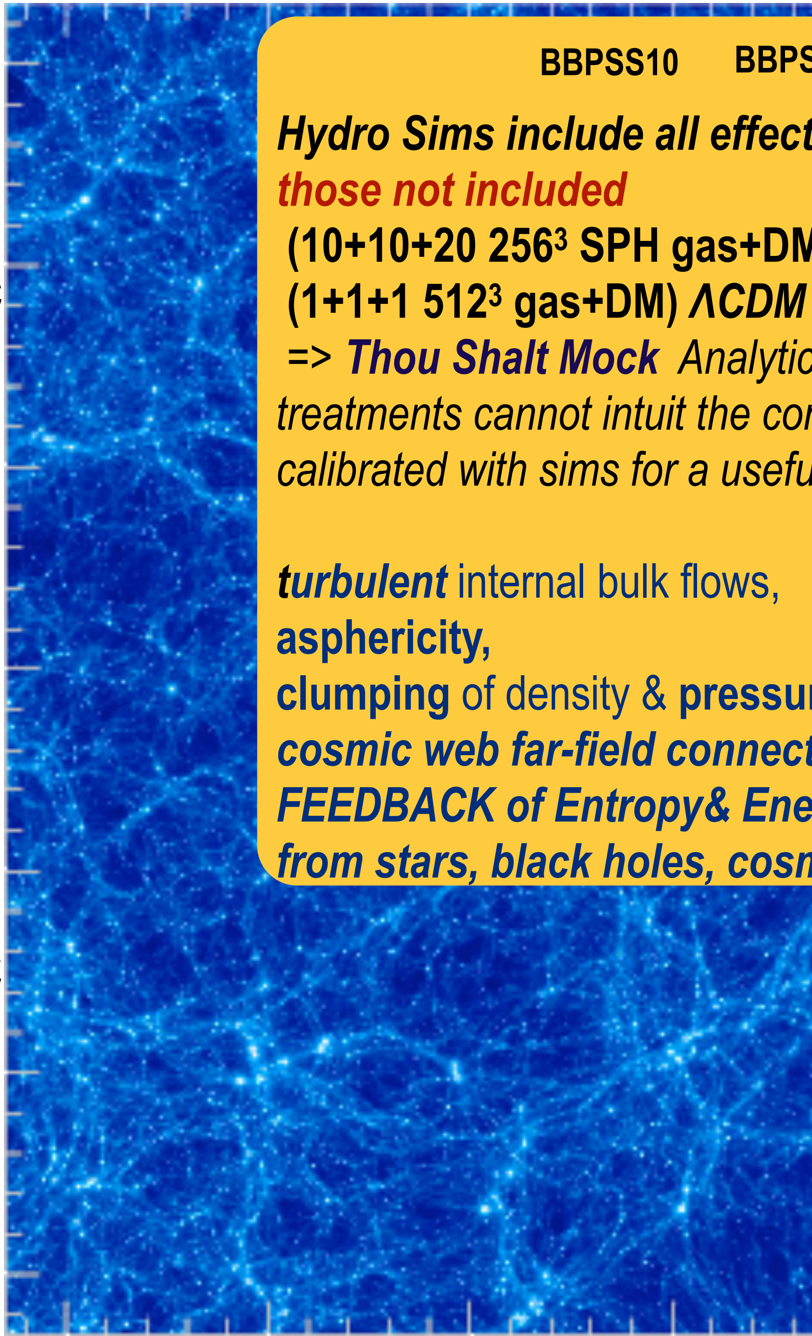
Gadget-3

SF+ SN E+ winds+CRs

512^3

BBPSS10

BBPS1,2,3,4,5



BBPSS10 BBPS1,2,3,4,5

Hydro Sims include all effects -except of course those not included

(10+10+20 256^3 SPH gas+DM)

(1+1+1 512^3 gas+DM) *ΛCDM* + ...

=> *Thou Shalt Mock* *Analytic and semi-analytic treatments cannot intuit the complexity & must be fully calibrated with sims for a useful phenomenology*

turbulent internal bulk flows,

asphericity,

clumping of density & **pressure,**

cosmic web far-field connection thru filaments,

FEEDBACK of Entropy& Energy & Momentum from stars, black holes, cosmic rays, ...

ρ_g(x,t

a~1

very hi res galaxy formation sims better feedback converging?

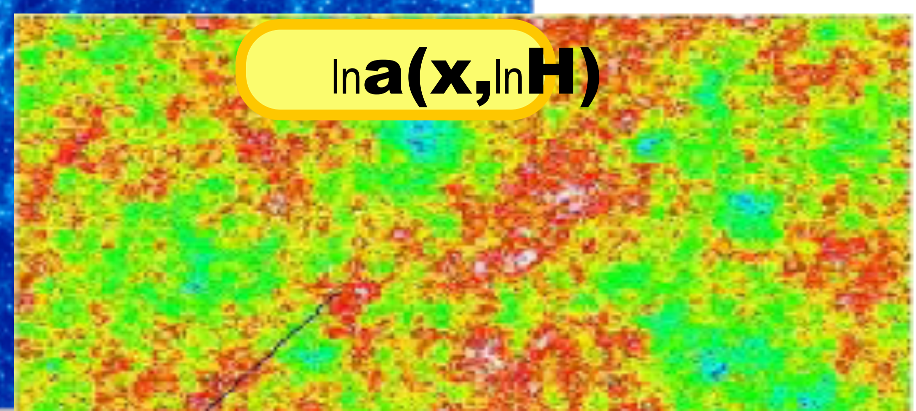
Gadget 3

Gasoline

Illustris TNG

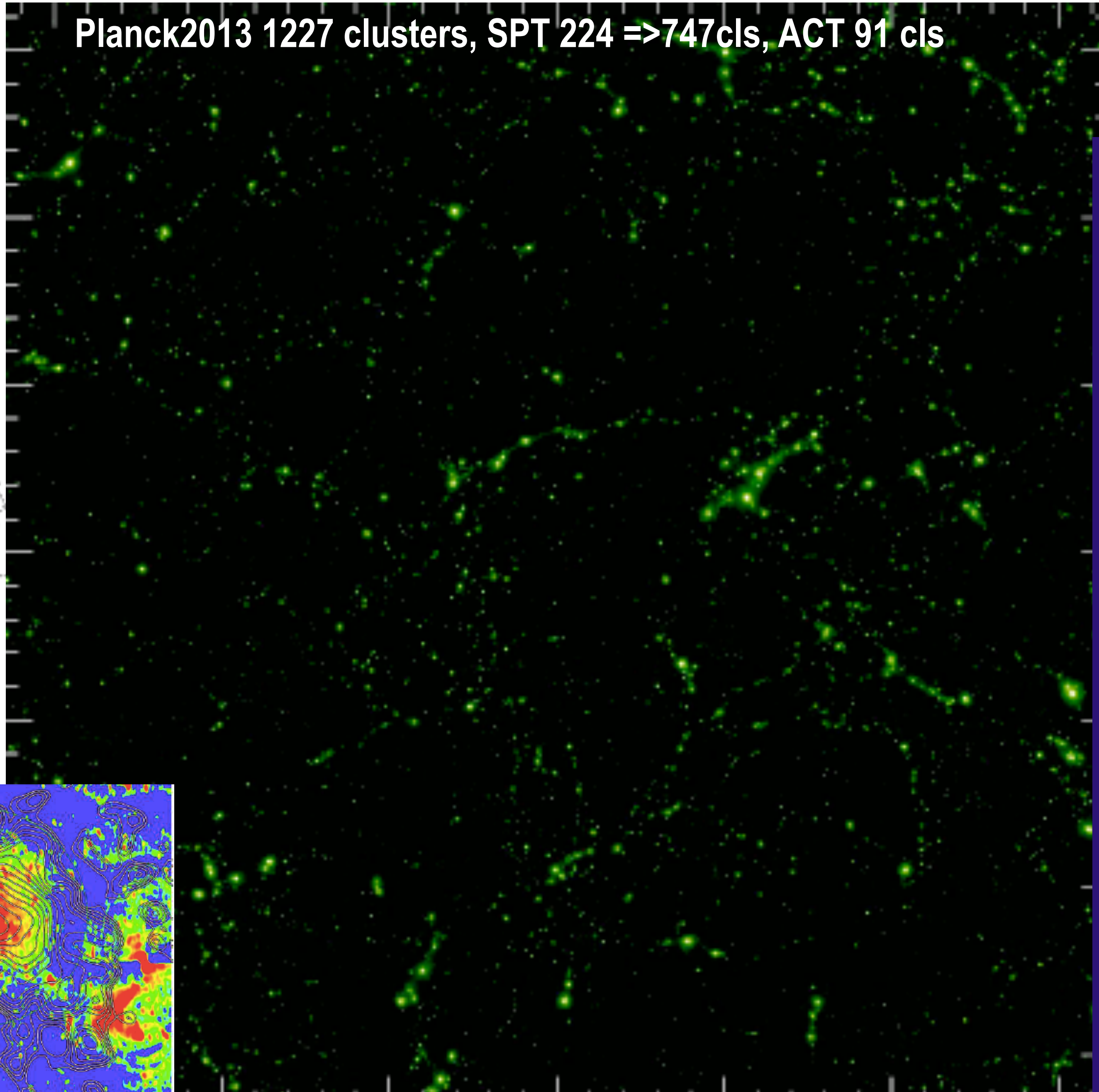
FIRE

a~e^{-67+}



pressure intermittency *in the cosmic web, in cluster-group concentrations probed by* **tSZ**

Secondary Anisotropies
(tSZ, kSZ, WL, reion, CIB; hydro)



$p_e(x,t)$

the thermal Sunyaev Zeldovich Probe

$\gamma + e \rightarrow \gamma + e$

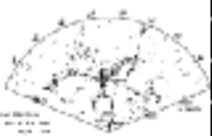
Compton cooling of hot cosmic web gas

$\langle \Delta E_\gamma / E_\gamma \rangle = 4 T_e / m_e c^2$

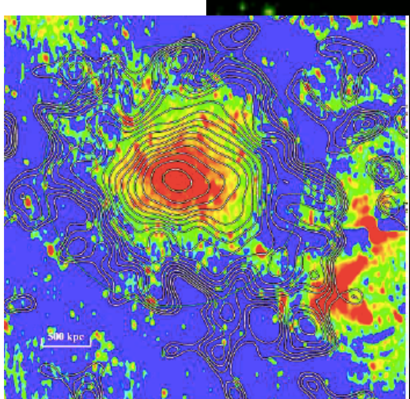
$y = \sigma_T \int p_e \, d\text{line-of-sight}$

$\Delta T/T = y * (x(e^x+1)/(e^x-1)-4)$, $x = h\nu/T_\gamma$

$Y_\Delta \sim E_{th} / D_A^2$



Planck's
Coma

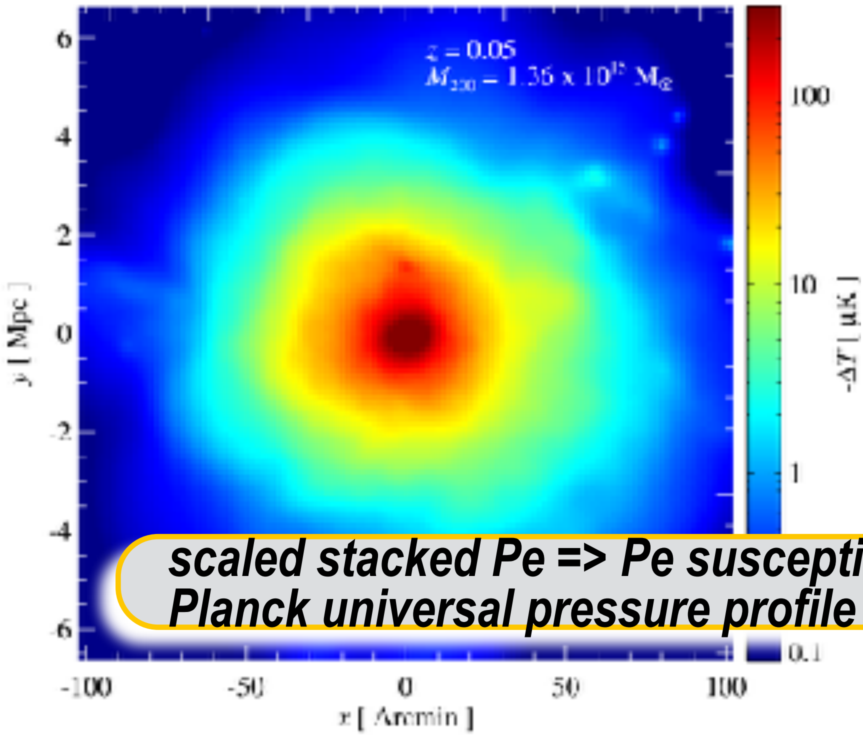


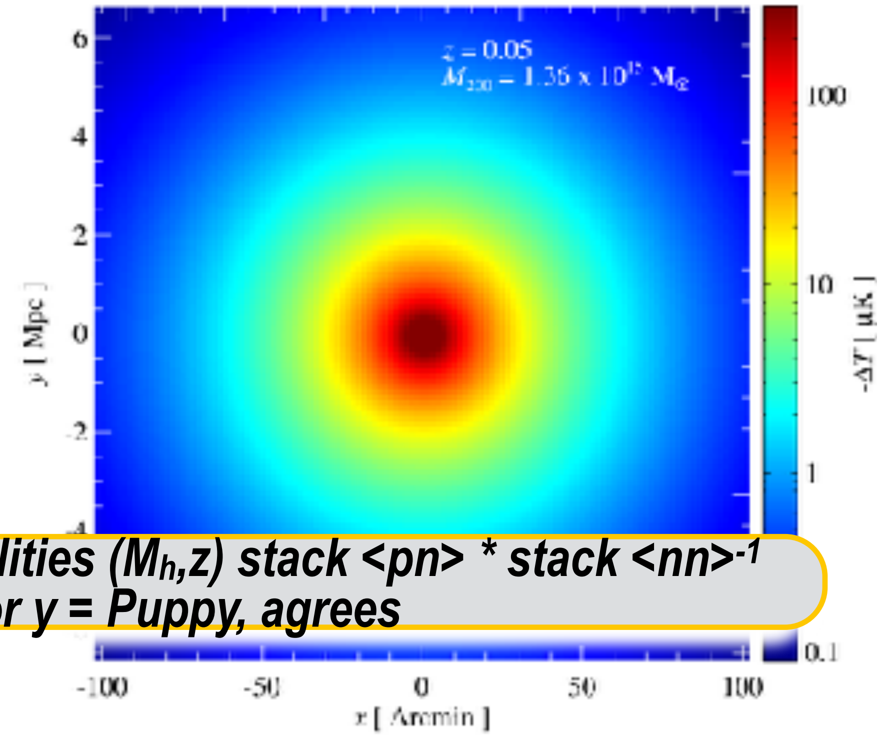
2D pressure exact vs. fit ⇨ pressure sub-structure

Constrained X-Correlation Fns = scaled stacked pressure profiles

aka $p = \langle p \,|\{q \in \mathcal{C}\}\rangle + p_f$ (residual "noise") $\langle p \,|\{q \in \mathcal{C}\}\rangle = \langle p q^\dagger\rangle \langle q q^\dagger\rangle^{-1} q$,

p or $\ln p/\langle p\rangle$. $\langle\, [p(X_c + U x/x_\Delta)/p_{\Delta c}]\; n_{\mathcal{C}}(X_c)\,\rangle / \langle n_{\mathcal{C}}(X_c)\rangle$ = Stack FormFactor(x/x_Δ)





*scaled stacked Pe => Pe susceptibilities (M_h,z) stack <pn> * stack $\langle nn\rangle^{-1}$*
Planck universal pressure profile for y = Puppy, agrees

BBPS gas sims with feedback for tSZ, kSZ aka pe ne

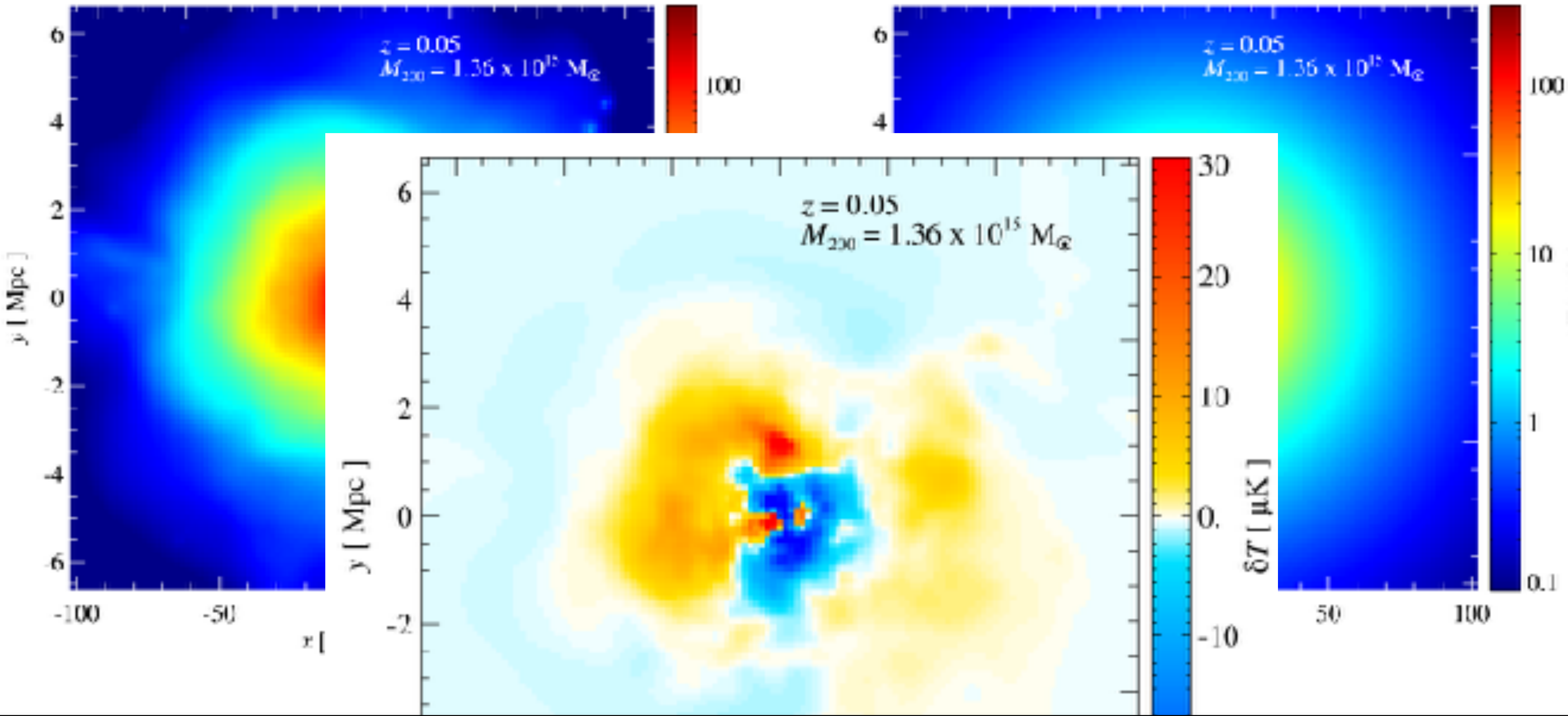
Same cluster (pasted on GNFW according to mass)

@ 30 GHz, z = 0.05 Mass ~10^{15} M_{sun}

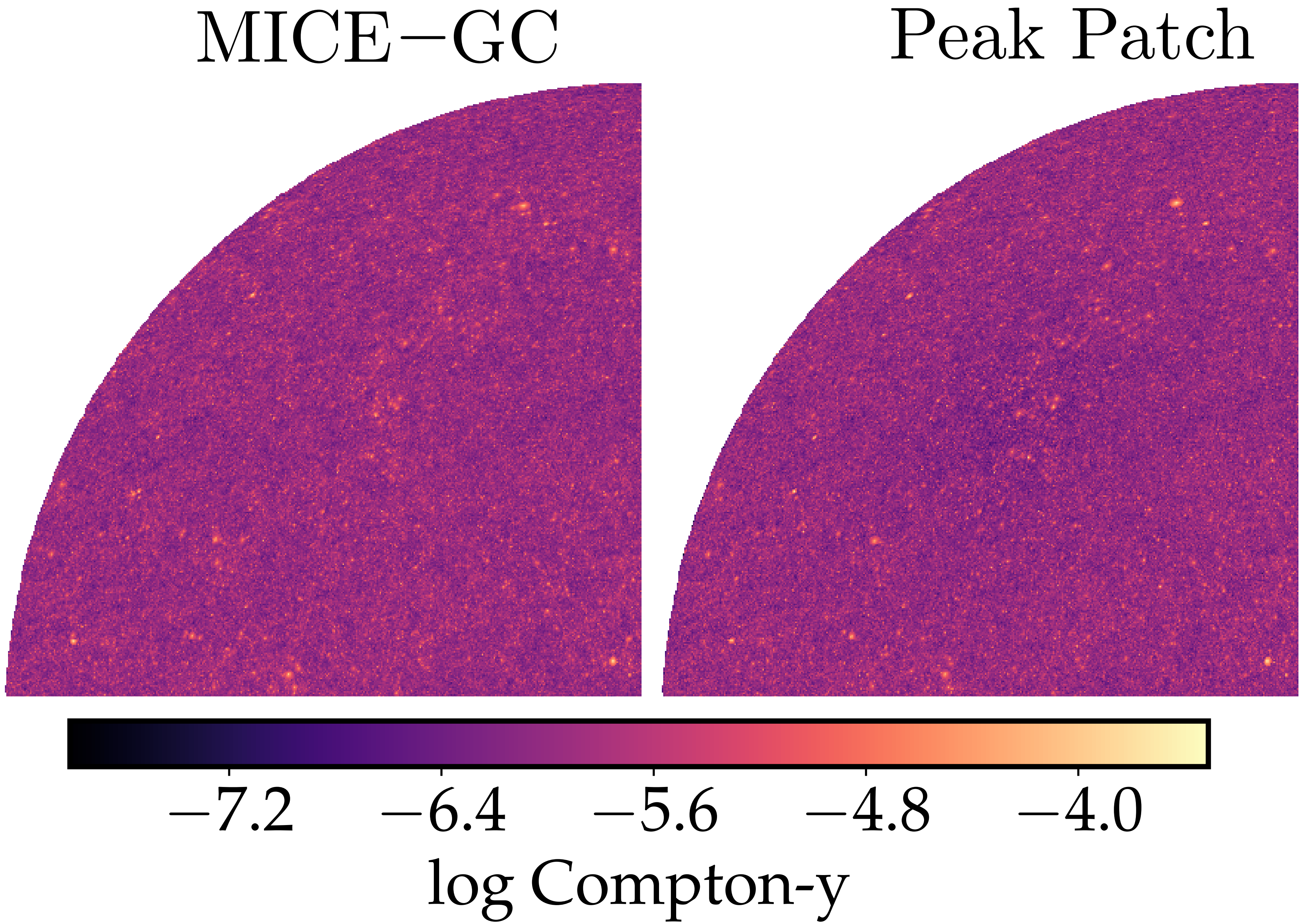
2D pressure exact vs. fit ⇨ pressure sub-structure

BBPS 2011 gas sims with feedback for tSZ, kSZ

p_f (residual "noise")



modelling the fluctuations about mean pressure fields from BBPS gasdynamical sims => complex but not overwhelming



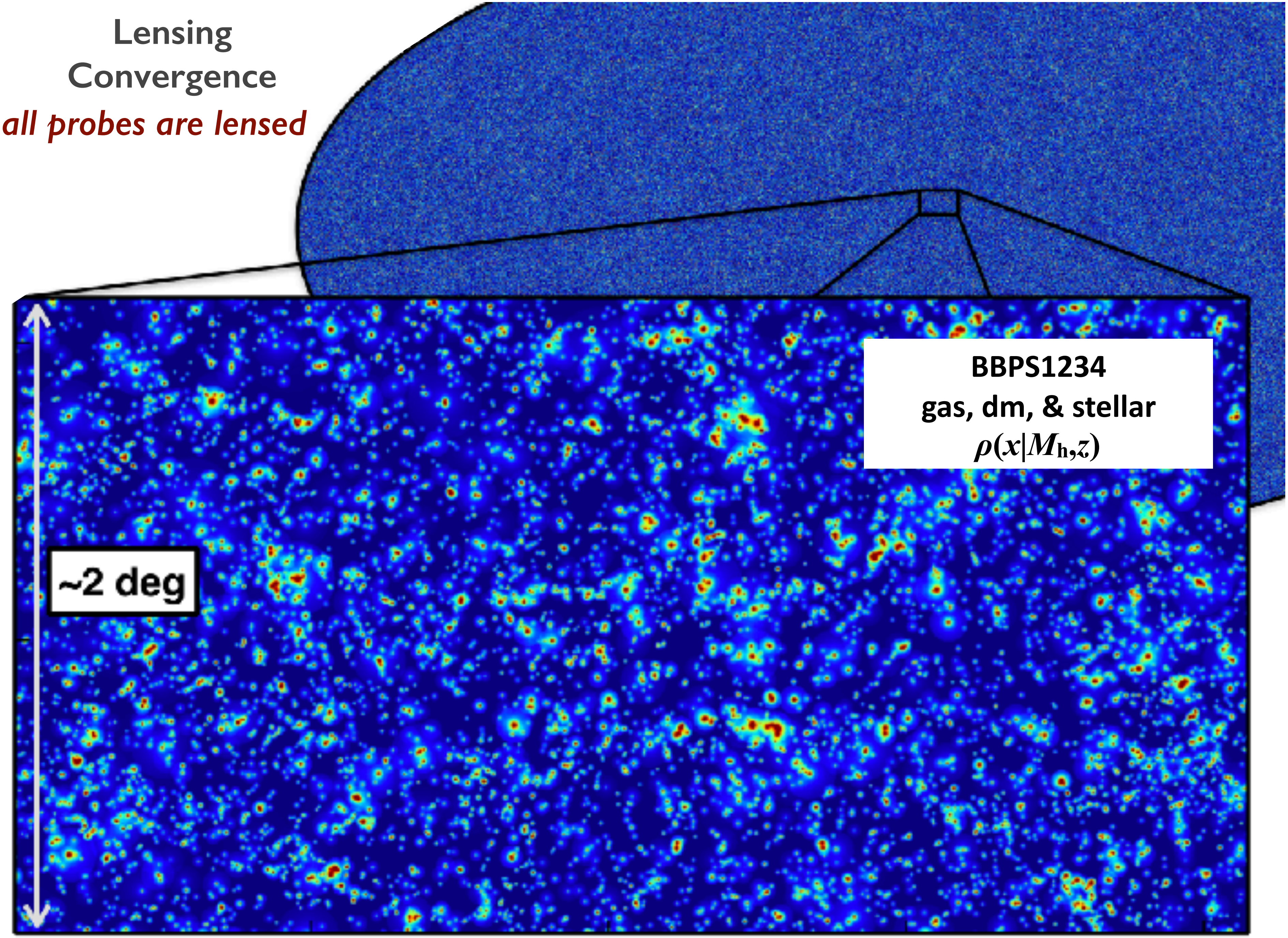
MICE−GC
Peak Patch
−7.2
−6.4
−5.6
−4.8
−4.0
log Compton-y

CMB Lensing

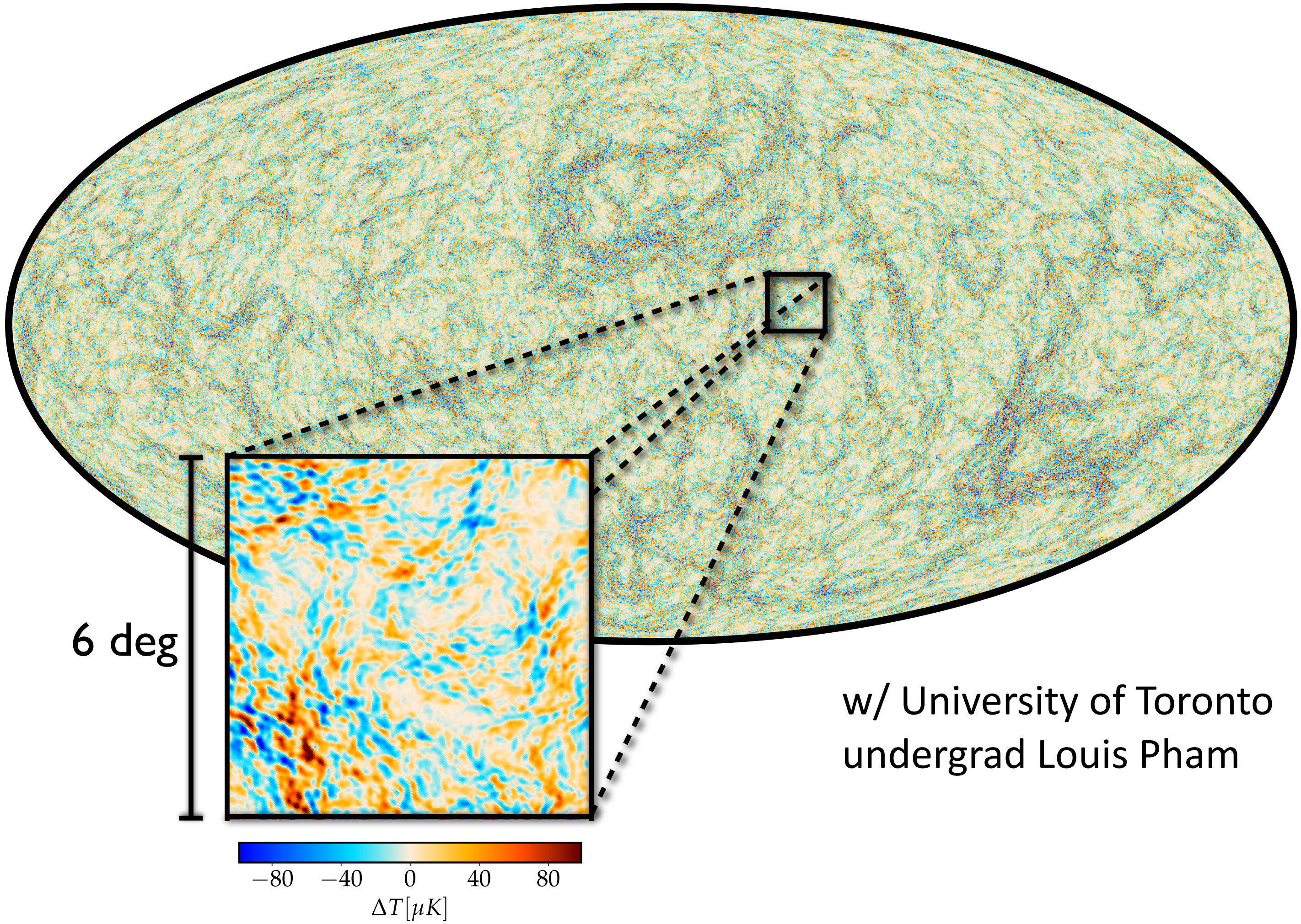
CIB, LIM, galaxy lensing

Lensing Convergence

all probes are lensed



CMB Lensing Difference (convergence map > lensing potential > modified lenspix)

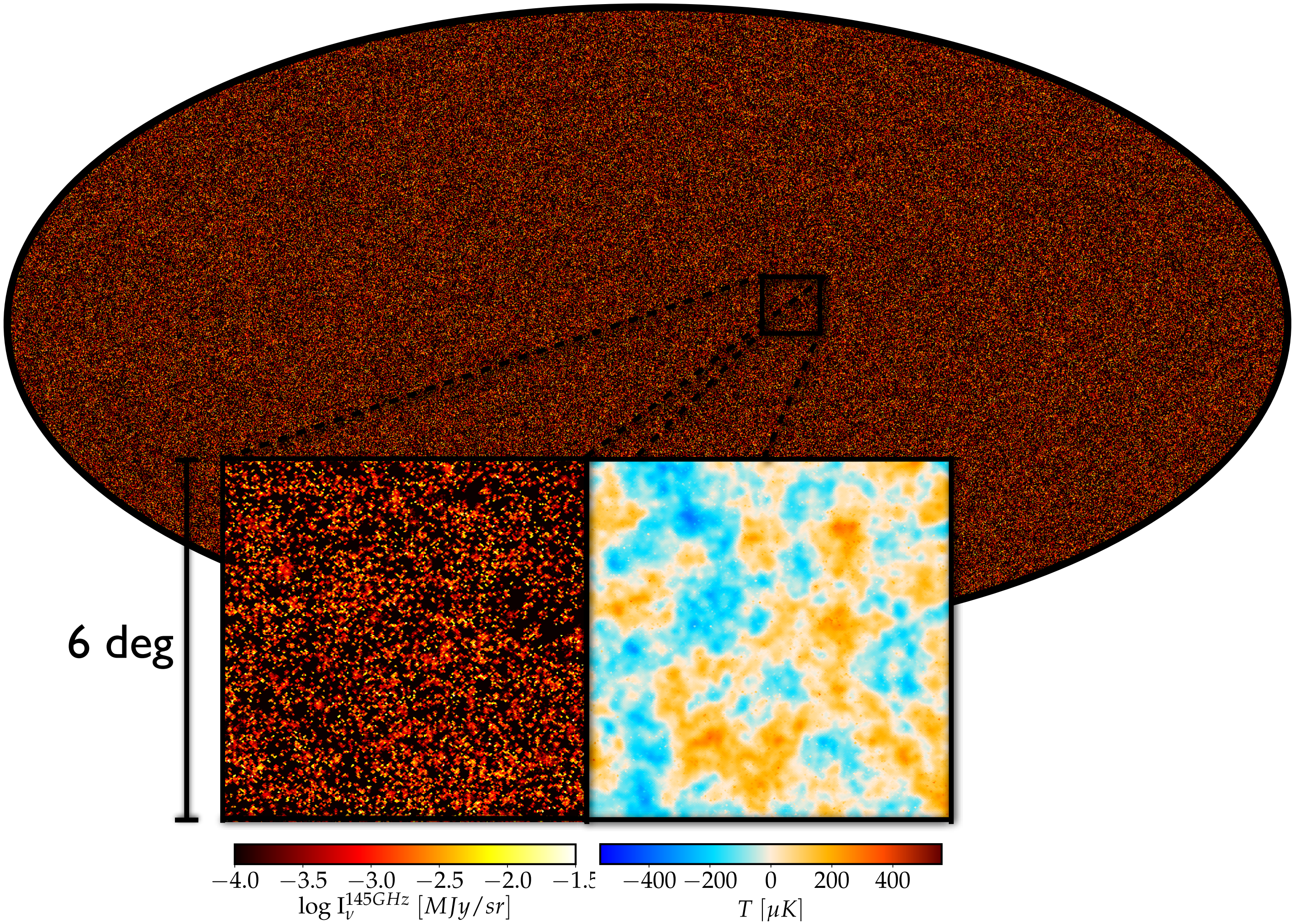


w/ University of Toronto undergrad Louis Pham

CIB near and far

Planck (2015) CIB Model
HOD + subgrid LPT

CIB @ 143 GHz



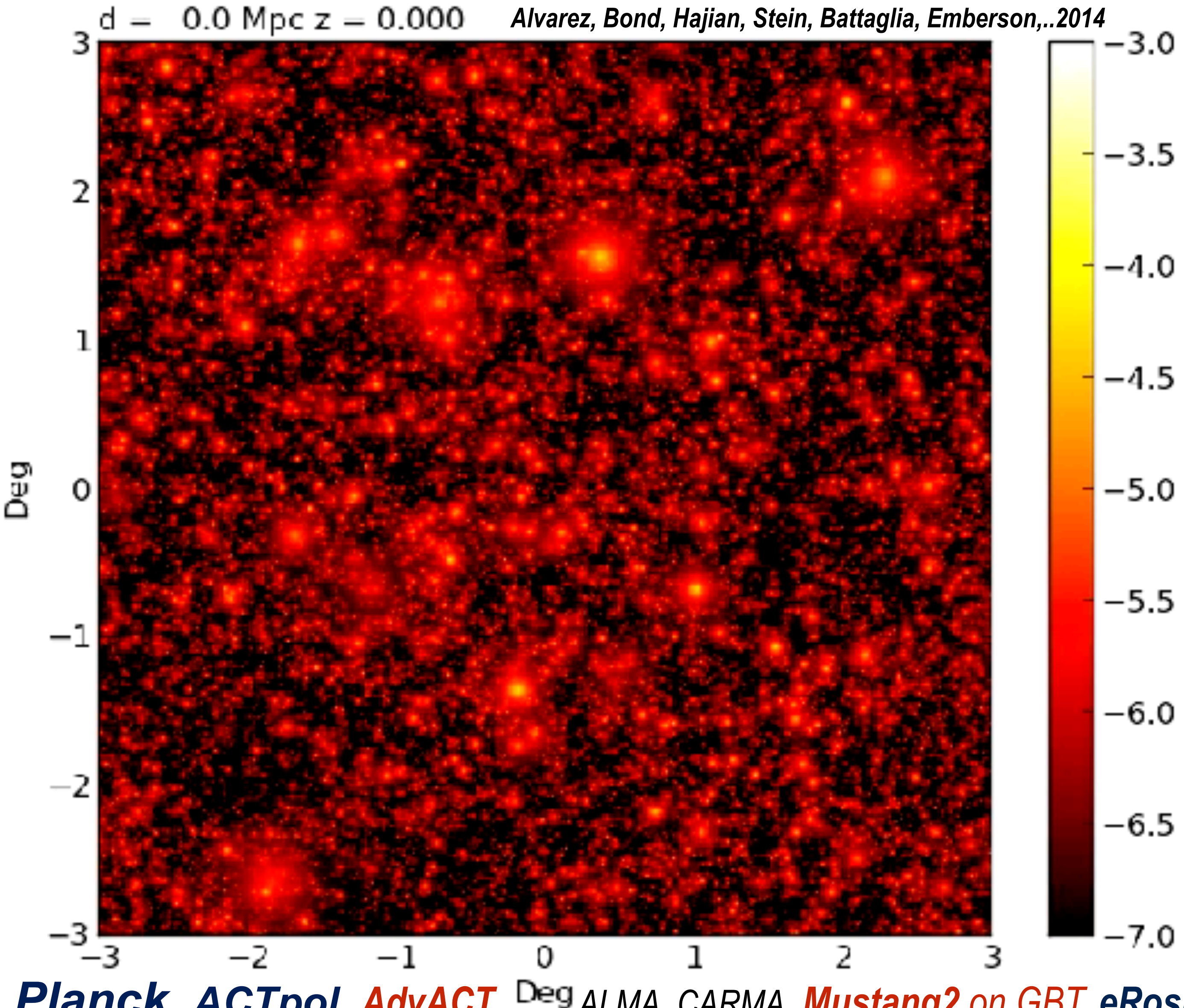
WebSky

to higher res: e.g., include BAO + small galaxies for HI CHIME redshifted 21cm z=.8-2.5

tSZ WebSky **Mocking Heaven:** lightcone sim for tLCDM. 36 sq deg to z=2

Planck all-sky tSZ mock 1.5 hours on 256 cores on SciNet, 30000 core IBM GPC

Alvarez, Bond, Hajian, Stein, Battaglia, Emberson,..2014



for higher map accuracy tSZ PkPatch map needs: 1. **intracluster residual pressure fluctuations** & 2. **cluster orientation via map of Lagrangian strain to Eulerian pressure inertia-tensor**

kSZ Peak-Patch maps use cluster/group dominance =moving cluster effect of Sunyaev + *Zeldovich*

see Calabrese+14 for AdvACT forecast on Reionization Epoch kSZ *Alvarez, Battaglia, Iliev etc. mocking reion kSZ*

mock large z-surveys, HOD
CO, HI intensity mapping
CIB, CIB-tSZ correlation, …

Planck*, *ACTpol*, *AdvACT*,** *ALMA, CARMA, **Mustang2** on GBT,* ***eRosita**.. **COMA**, **CCAT**.. **CHIME

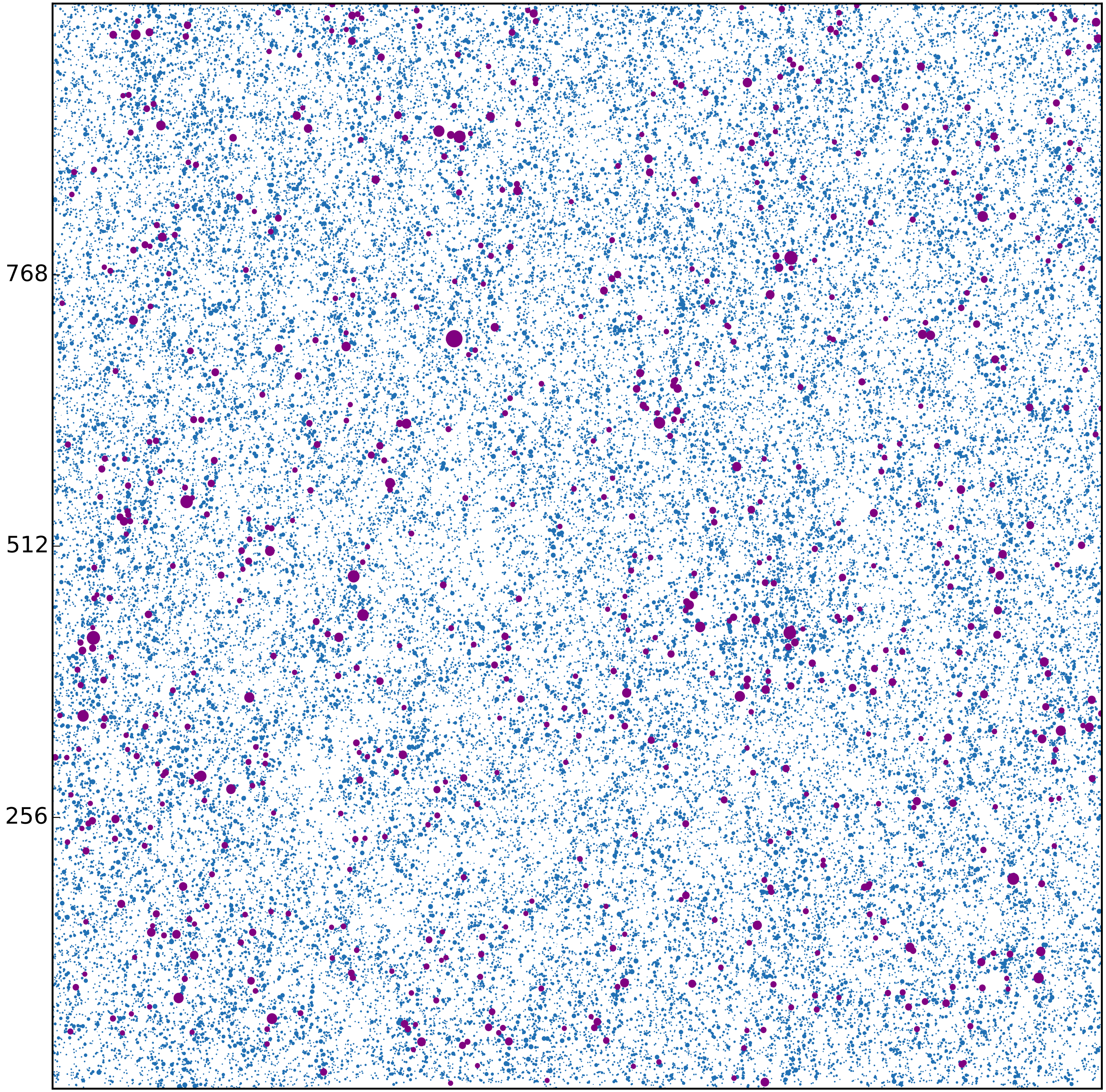
WebSky

increase dynamic range
hierarchical multigrid for
hi res peak patches
in original BM93-96
but now fully correlated
box to box

dynamics: 2LPT for halo motion & field
- new method hierarchical ellipsoidal
dynamics to stop "shell" crossing

Berger+ABS
1 Mpc slice of $(1024\ Mpc)^3$ "zoom in" simulation at redshift 2.5 in a hierarchical box model simulated on a 4096^3 grid with 0.25 Mpc res
halos $>10^{12}\ M_{sun}$ in red as in a single box run cf.
all halos to $2.5x10^{10}\ M_{sun}$.

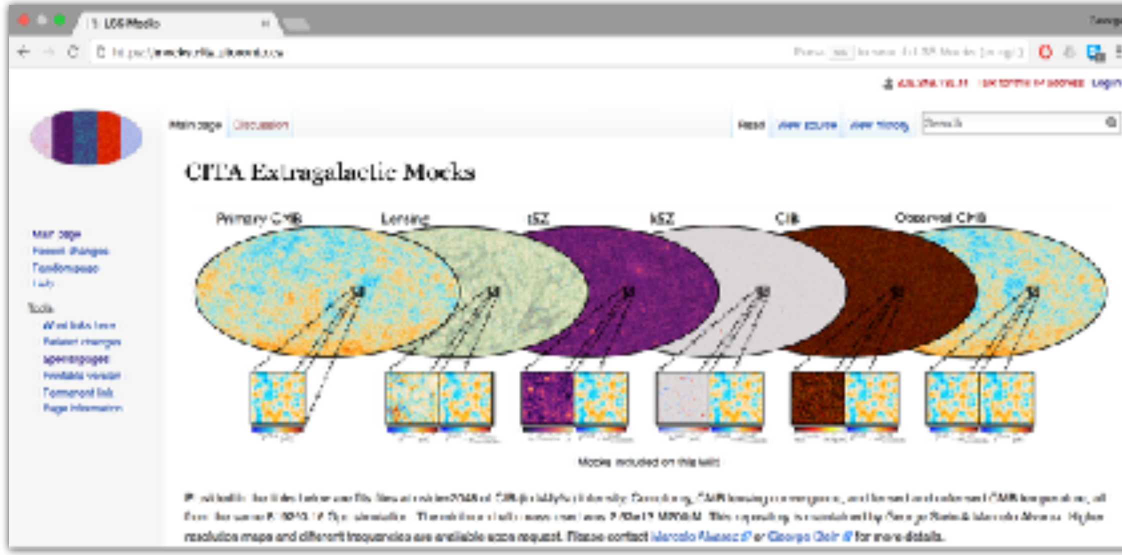
see Phil Berger poster



WebSky Mocks

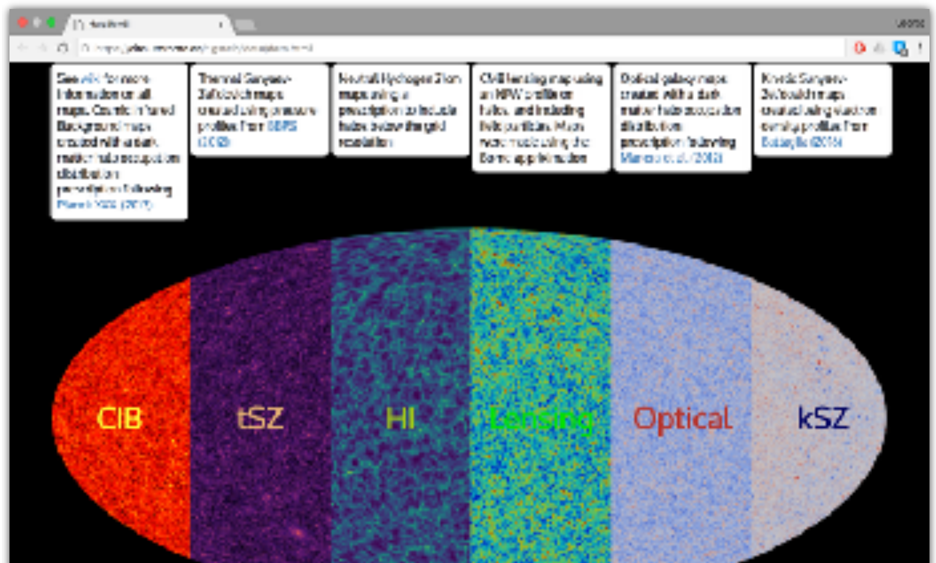
see George Stein poster

Available at
mocks.cita.utoronto.ca



Sims being used for EUCLID, ACT, SO, CMB-S4, COMAP, CHIME, CCAT-p, …

Or through website
cita.utoronto.ca/~gstein



Other useful links:
"Simulations of the Microwave Sky" - Sehgal et al 2009, https://lambda.gsfc.nasa.gov/toolbox/tb_sim_ov.cfm
Euclid halo + galaxy mocks - cosmohub, https://cosmohub.pic.es/, MICE-GC - http://maia.ice.cat/mice/grand_challenge.html

BSMc varieties of nonGaussianity:

conventional correlated perturbative *Planck2015-constrained* f_{NL} *SphereX target, SKA X surveys*

caustics from preheating (1cm scale horizon)
modulated by light non-inflaton fields
fluctuating **on large scales** & super-horizon scales
ζ **uncorrelated** with conventional inflaton-ζ

=> **3D intermittency** cf. 2D WMAP cold spot
unconventional but generic?

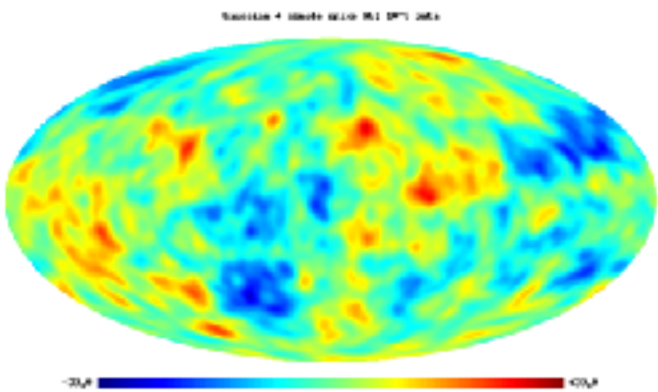
a nonlinear (large scale) bias response to the nearly scale invariant light field
cf. LSS bias of clusters/galaxies via a threshold function on the linear density field

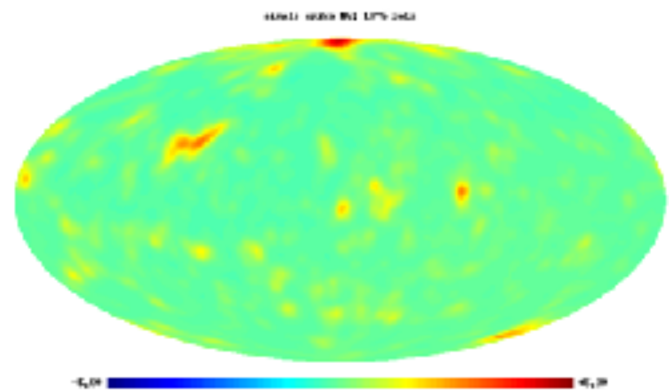
or remnants of bubbles during inflation
or …
apparent breakdown of LSS homogeneity

2D intermittency WMAP cold spot

CMB+LSS mocks to test: standard Gaussian inflaton ζ_{inf}+ subdominant uncorrelated ζ_{isoc}

*e.g., **from modulated preheating***

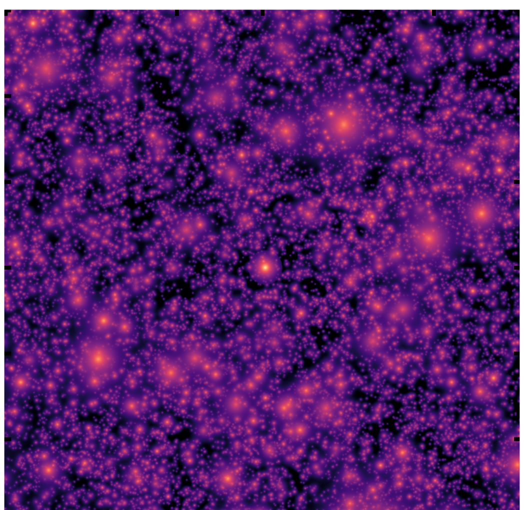




3D intermittency

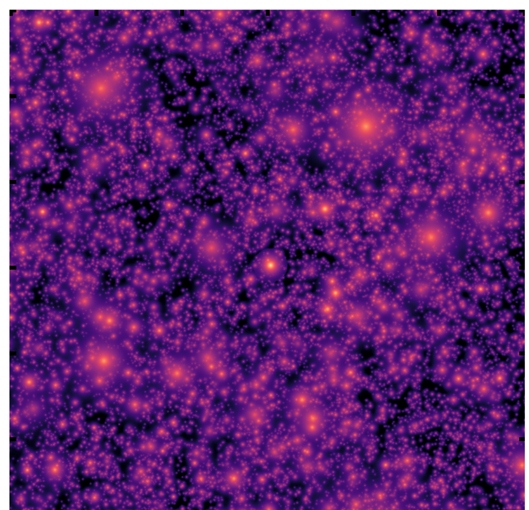
uncorrelated nonG 'wide open' cf. usual correlated highly constrained nonG

LSS tSZ: Gaussian std



B2FH, b+braden+frolov+huang

LSS tSZ: Gaussian std +
subdominant uncorrelated ζ



ABSB+FH, alvarez+b+stein+frolov+huang

BSMc from LSS & LIMLAM?

reconstructing ζ ~ ***early Universe ln a(x,t)***

modes CMB modes ~ $f_{sky} L_{max}^2$ *LSS tomography X k_{max} d_{max}*

std nonG $\zeta = \zeta_G + \mathbf{f_{NL}} * (\zeta_G^2 - \langle \zeta_G^2 \rangle)$ local & equilateral pattern & orthogonal

non-std nonG $\zeta = \zeta_{inflaton}$ + ***uncorrelated*** $\zeta_{[GRF]}$ modulated heating intermittent?

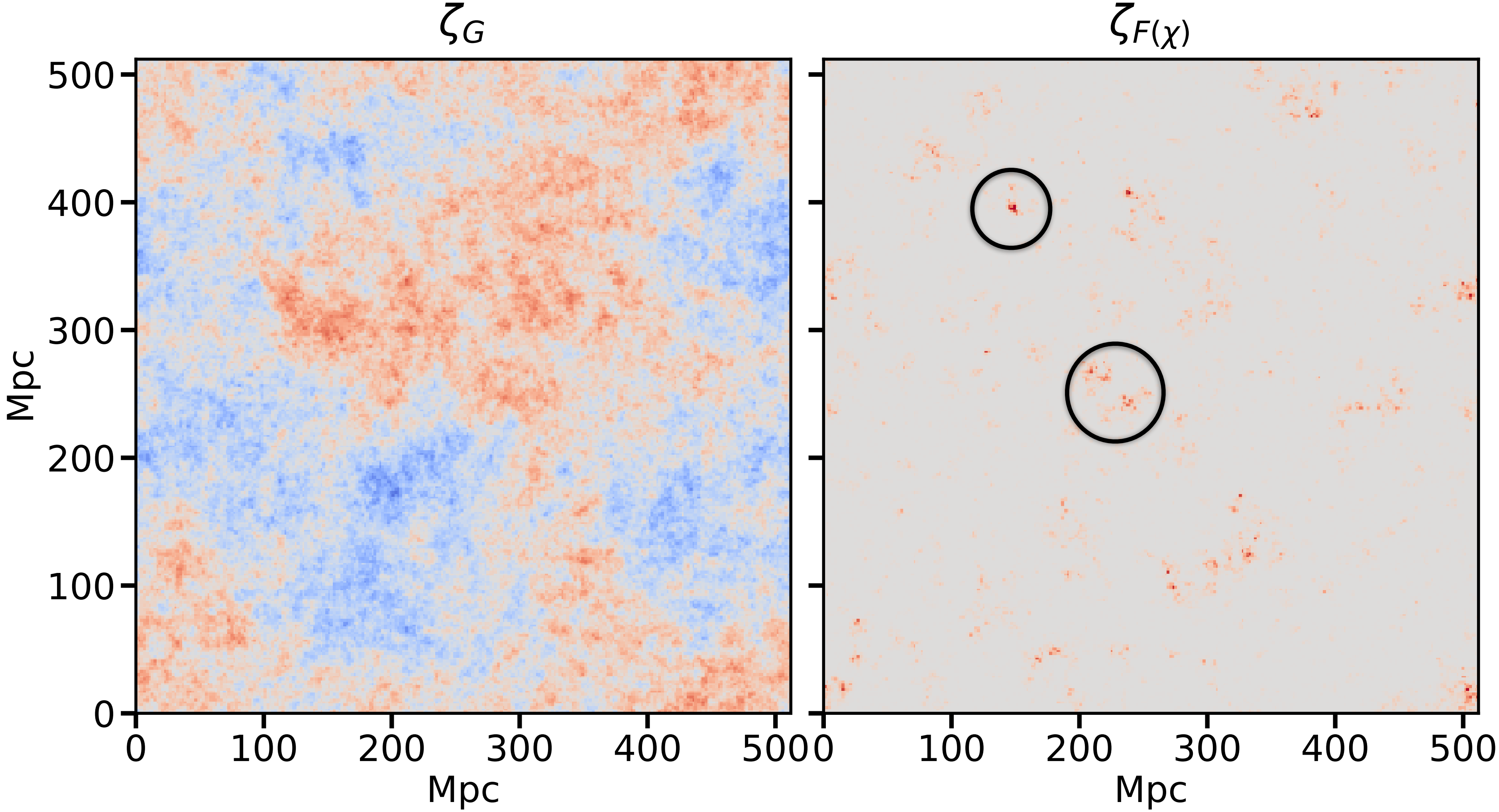
uncorrelated nonG 'wide open' cf. usual correlated highly constrained nonG

=> ***quest for*** unconventional primordial nonGaussian

Primordial Non-Gaussianity in the Peak Patch method:

Intermittent Non-Gaussian case

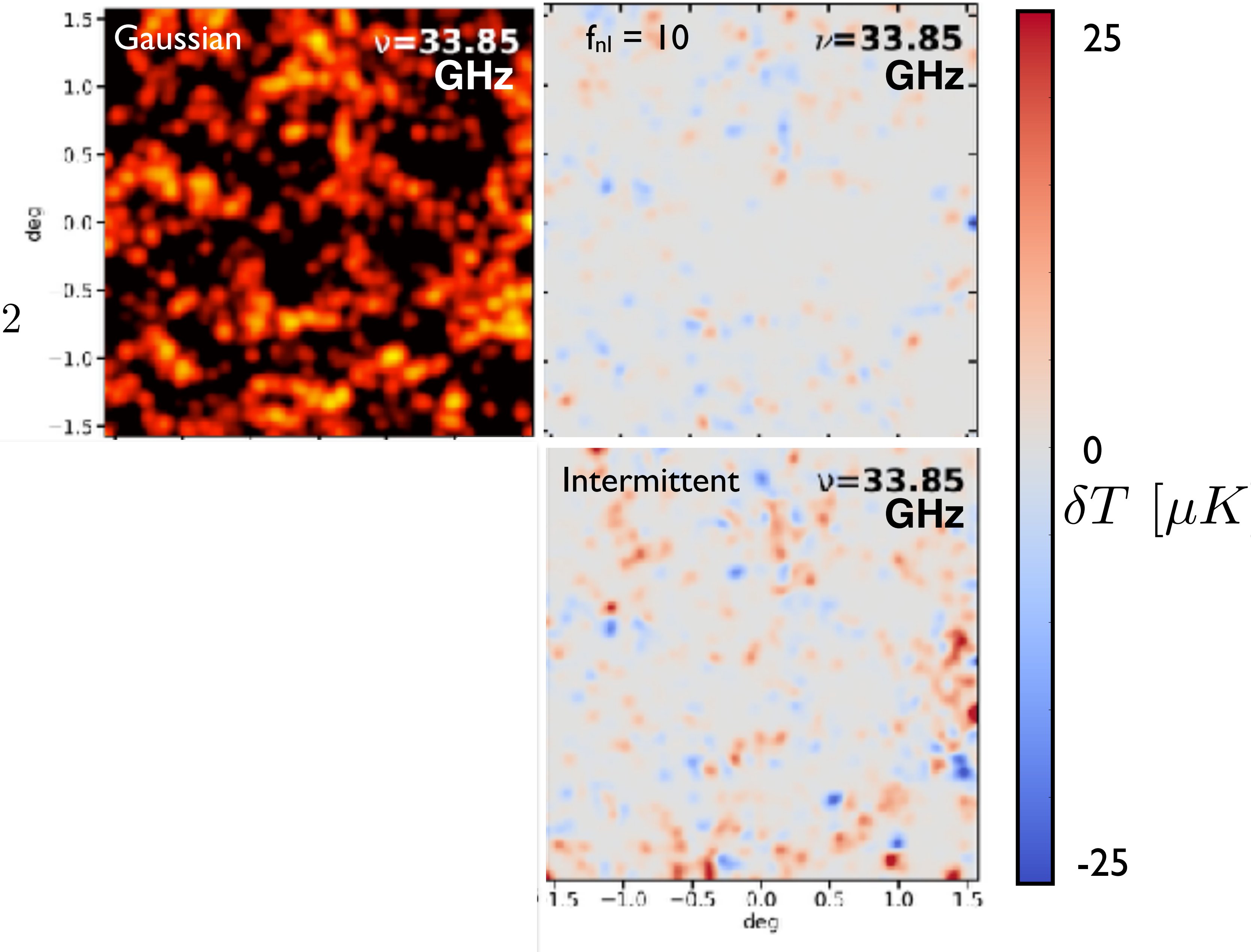
uncorrelated **ζ[GRF]**



Primordial Non-Gaussianity in CO

$\sigma_8 = 0.82$

In all cases

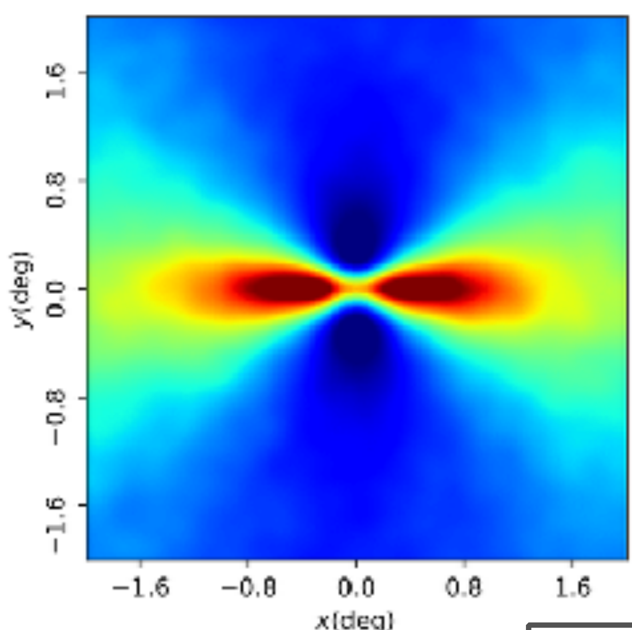


exploring mean asymmetric superclustering structure by stacking

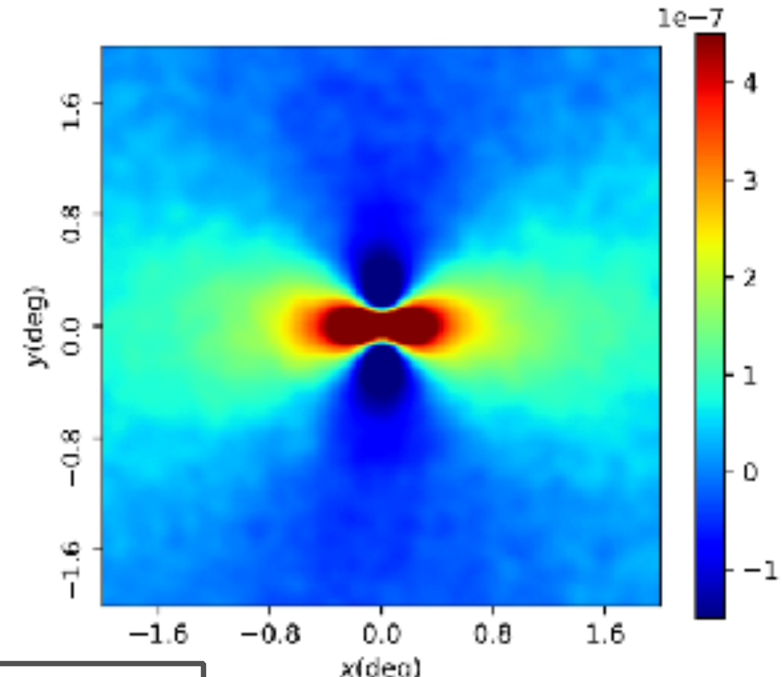
< $y_C|n_{cl}$ > tidal tensor oriented results: *WebSky* vs *SDSS x Planck*

tidal tensor of cluster distribution measured on 10’

WebSky
Halo lightcone x y-map



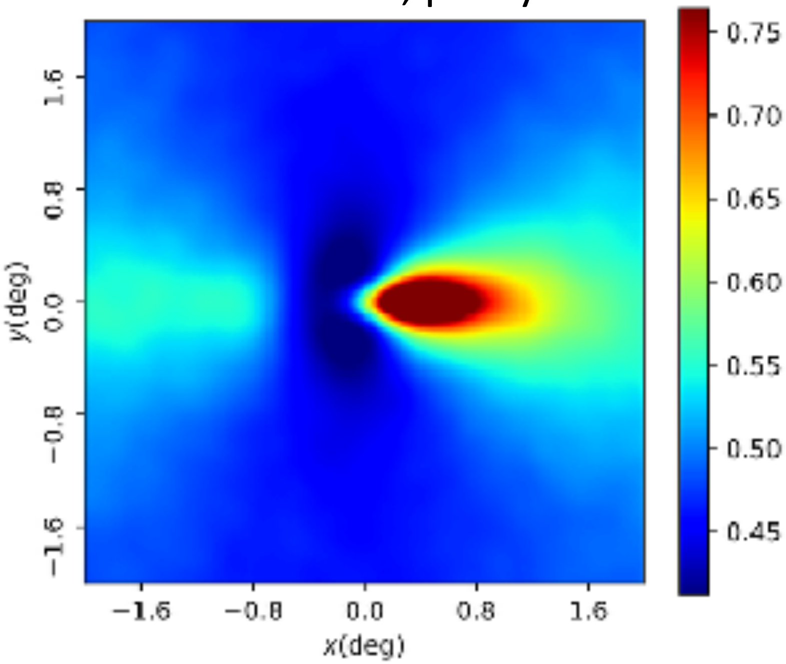
Wen et al. (2013) SDSS cluster sample ; QU orientation on 10’



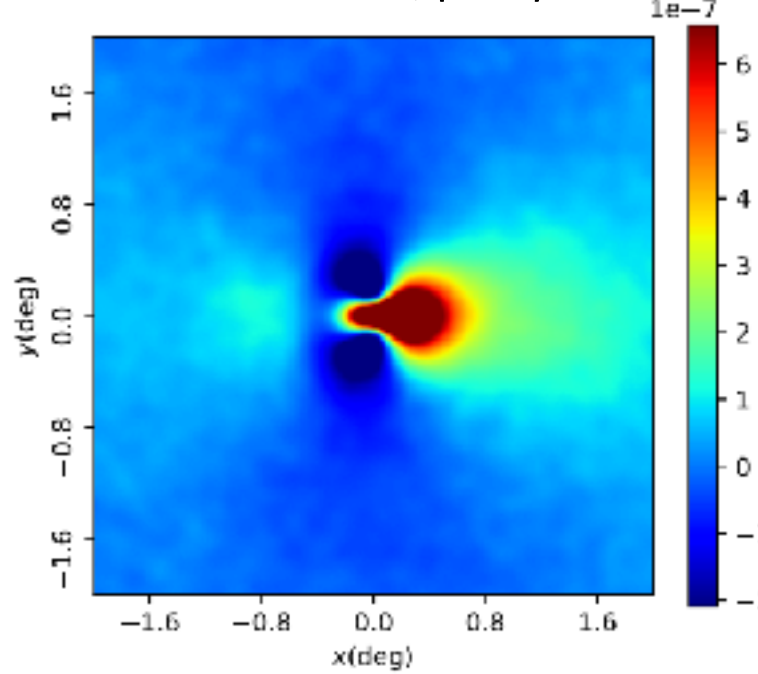
w/ CITA summer student
Connor Bevington

Beyond oriented: Symmetry breaking on <tSZ|n>

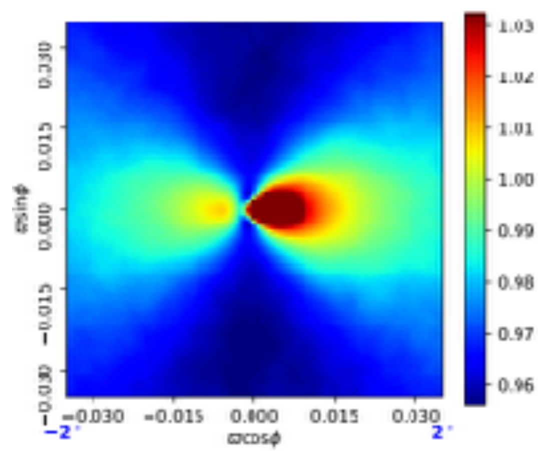
~68000 nearby haloes; QU orientation on 10'; parity on 30'



~75000 WHL clusters; QU orientation on 10'; parity on 30'



dipolar symmetry breaking => positive axes choice cf. beyond the headless 2-basis of pure orientation



parity on 10'

pp *summary:* fast halo finding for ensembles & BSMc works well cf. NBody
"mocking heaven" apps: tSZ, CIB *original motivation => tSZxCIB*, kSZ, Lens

optical galaxies **via HOD for CMASS, Euclid, LSST, .. DES, HSC, sphereX**
"intensity mapping" **of HI (CHIME, HIREX, ..,SKA) of CO COmap, CII**
well suited: **to cross-correlation studies of all sorts**
well suited: **to characterize correlated/non-Gaussian errors**
well suited: **light cones** *automatic, no interpolation*
peak-patch +++: multigrid for hi res; 2LPT -> hierarchical ellipse dynamics
BSMc Physics: *beyond Lambda:* dynamical DarkEnergy, modified gravity
LSS *non-Gaussianity:* perturbative, intermittent, scale-dependent bias

response functions to stimuli= mean susceptibilities ***- internal halo structures***
fluctuations inside controlled? outside 2LPT and subgrid halos adequate?
tSZ in pp control; CO out of pp control?
all WebSkys must be Lensed: CMB, CIB all LIMs
why do LIMLAM? just understand galactic weather / storms
a theorist's hope: component-separate gastrophysics to reveal
fundamental BSMc physics
e.g., using LSS/LIM to further develop the ζ map of the early universe -
stacked ζ primordial nonG of all sorts in 3D. intermittent modulated heating with caustics

END