Mocking the LIM LAM

Dick Bond

Line Intensity Mapping and Line Absorption Mapping *fLIMfLAM*

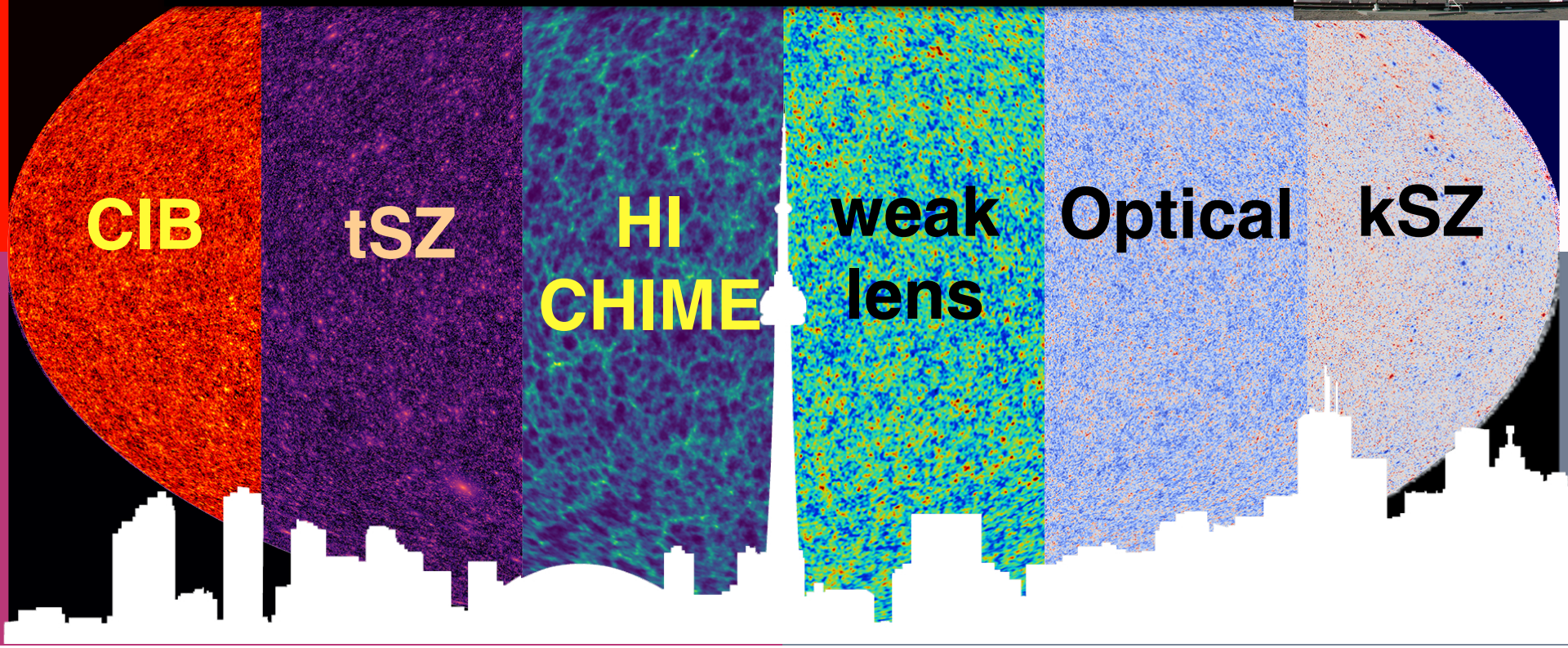
radio: HI CO CII, … + optical Ly a, …

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

Marcelo Alvarez, Dick Bond, George Stein + FIRE: Lakhlani + Murray + Hopkins +

need ***End to End mocks: BSM, nonG, DE/modG, Mnu, …***

need ***all signals to be correlated, 1, 2, 3, .. Npt***



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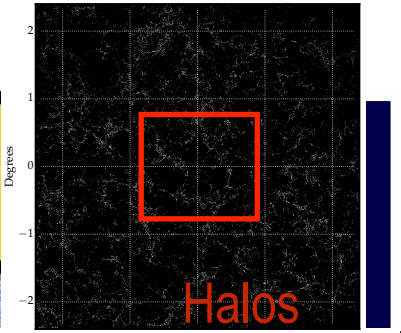
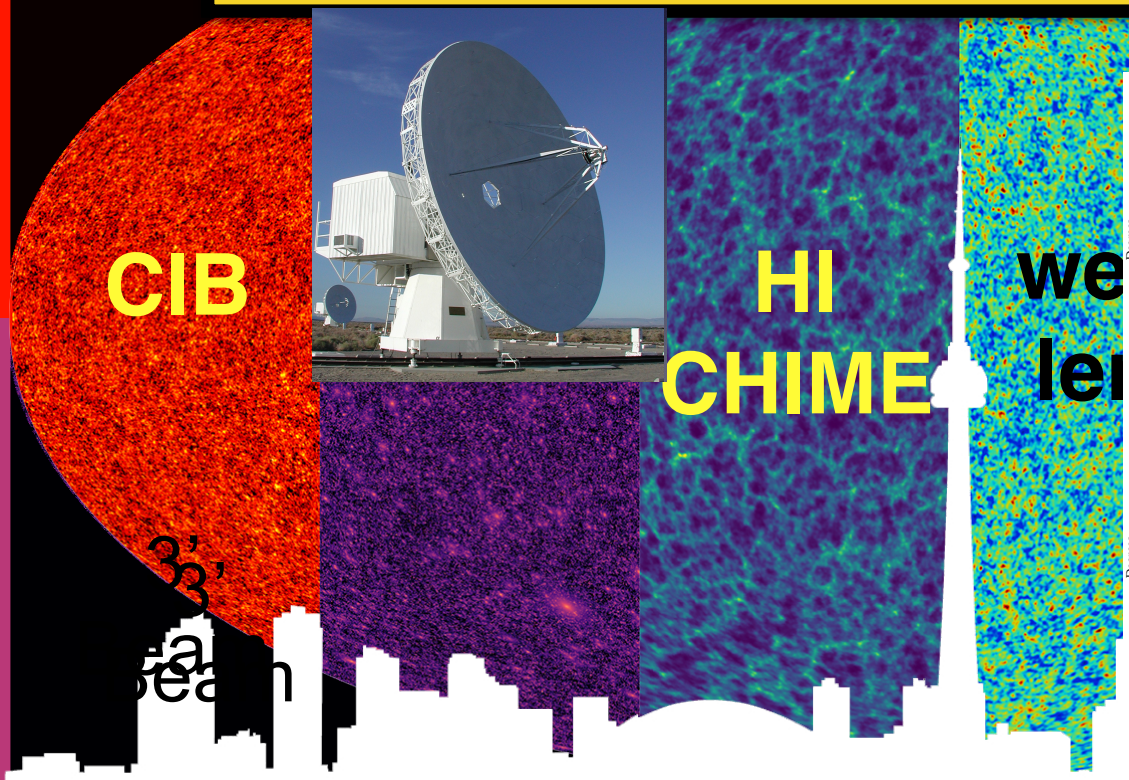
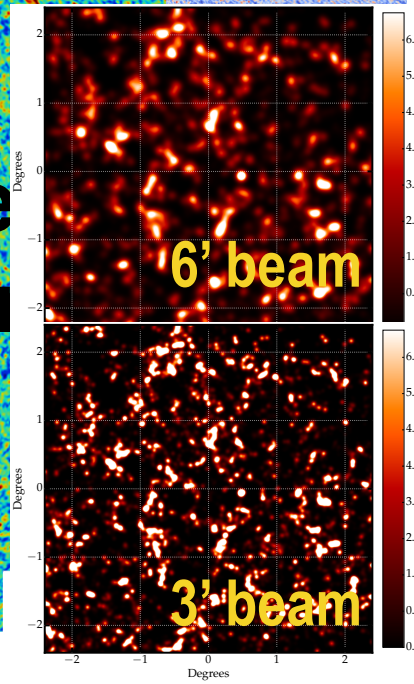
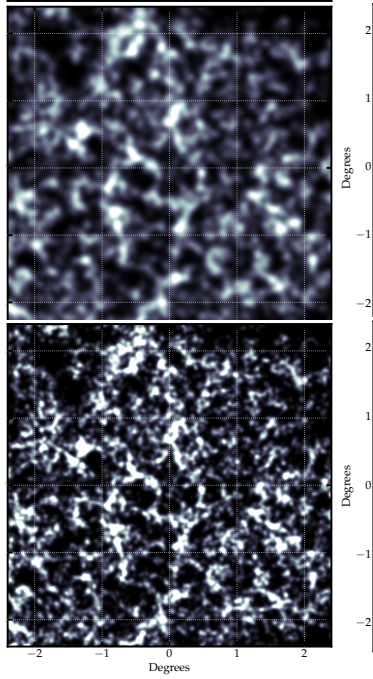
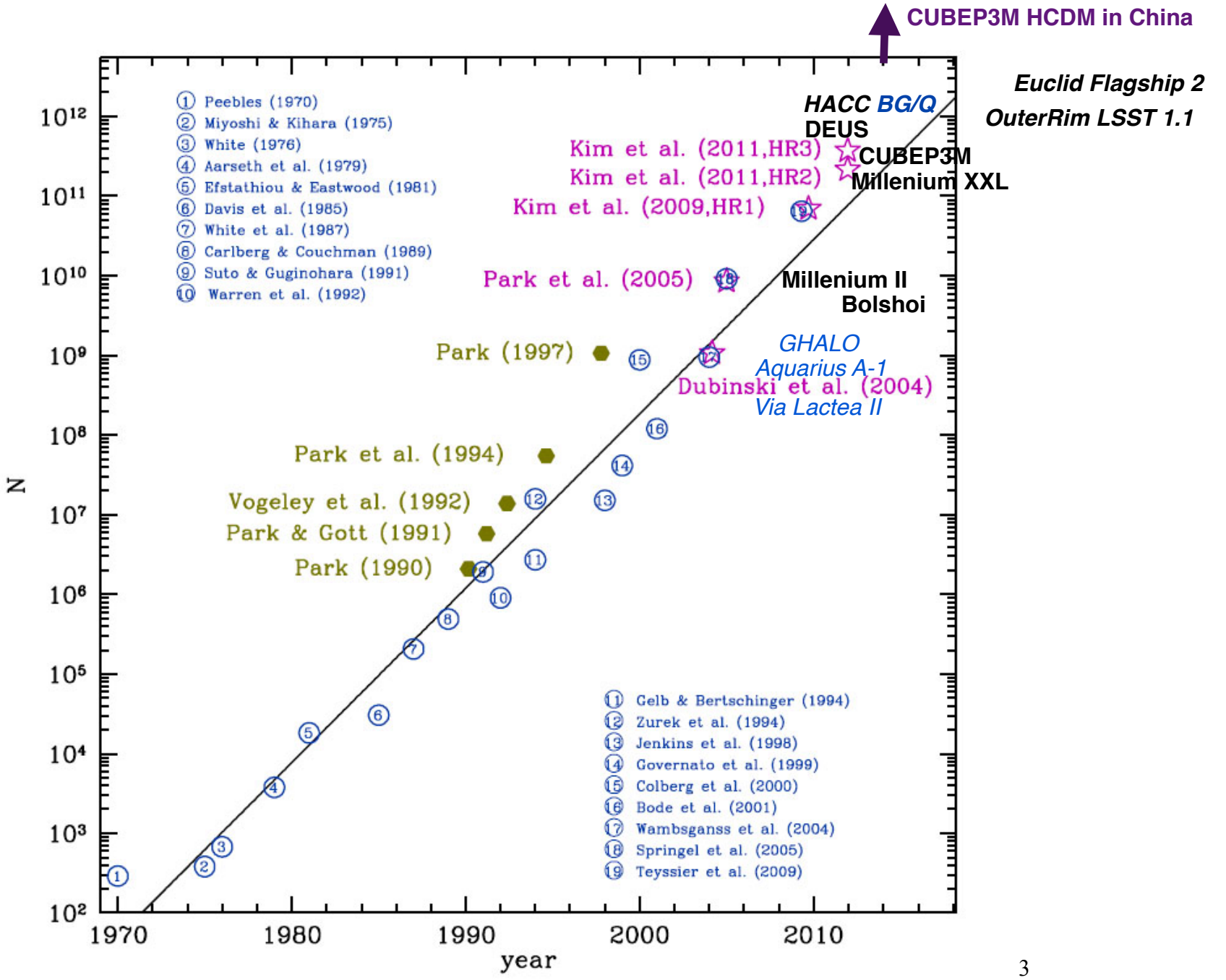
Survey Area











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, 3780 h^{-1}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

- ***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,**
- **PINOCCHIO 2002 - Monaco et, PINpointing Orbit Crossing-Collapsed HIerarchical 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,**
- **cf. Minerva N-body 300 sims 1000^3 1.5 h^{-1}Mpc to cf. ICE-COLA, Pinocchio, PeakPatches**
- **cf. 512 suite of N-body Gadget 2016 Szalay +**

the Peak Patch Picture of Halos

Then & Now = *LSS Effective Field-Cluster-Decomposition*

Dick Bond @ Ovro17.1.11
Marcelo Alvarez, George Stein

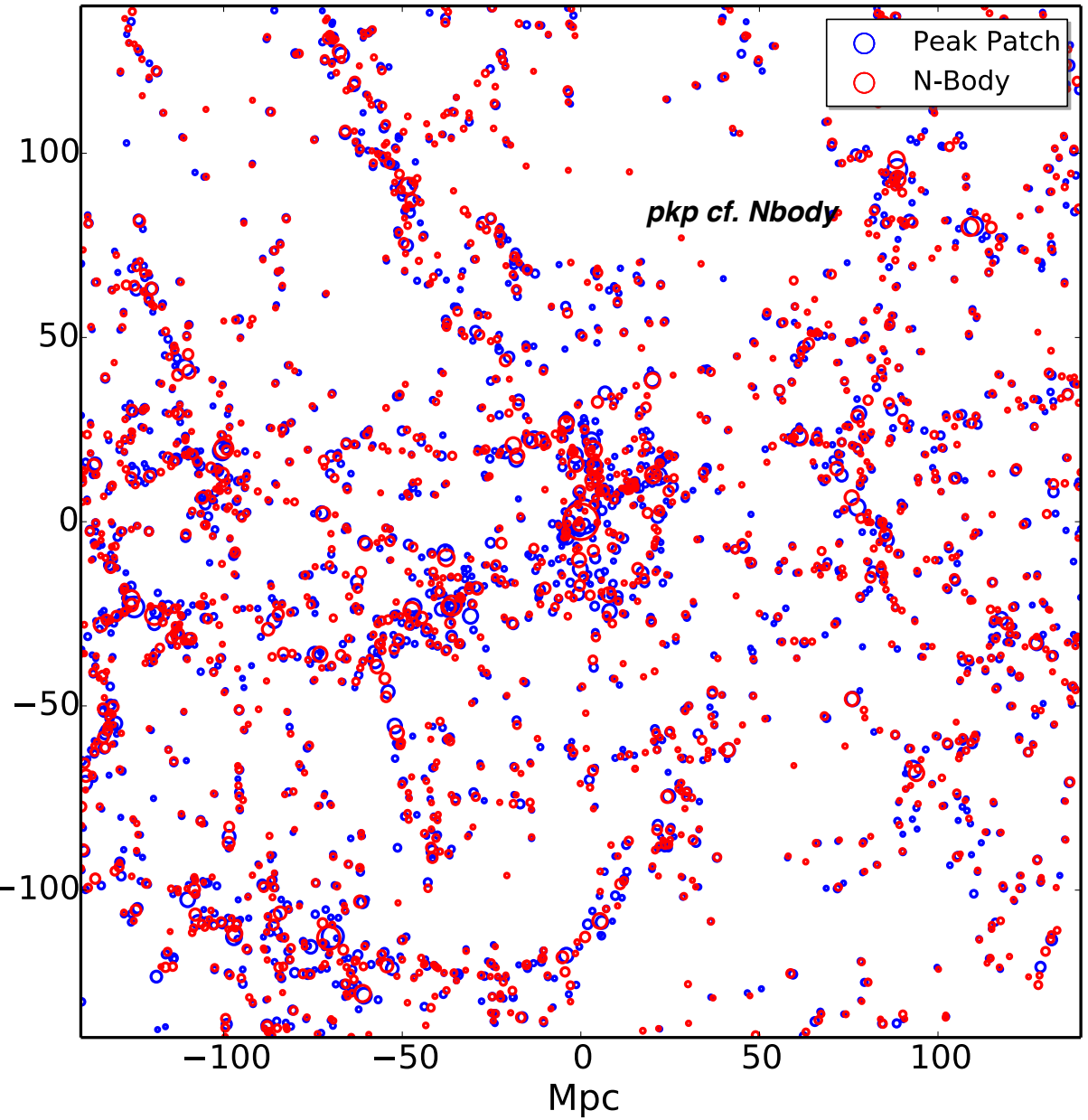
THEN BBKS, BCEK, B+Myers91,93,96, BKP web, BW
NOW: CITA mini-industry Alvarez, Bond, Stein 2017
Battaglia, Berger, Codis, van Engelen, Huang, Bahmanyer, *undergrads*

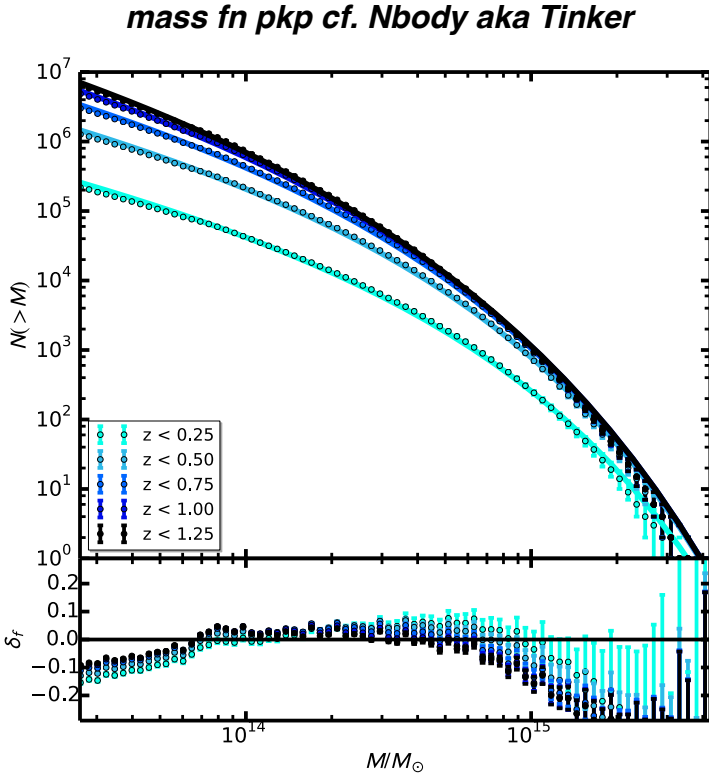
*the **true Effective Field Theory** of Large Scale Structure =*
Hierarchical Peak Patches =Excluding Ellipsoidal Excursions E^3
in **Scale space: resolution = a 5th dimension**
4+1 dimensions => the ADS to our CRFT => scale dreibein => 4+6 dimensions

Hot halos => Warm Cosmic Web Structure => Cool Linear Dynamics of 2LPT

"couplings" are the susceptibilities/ response functions/ form factors of fine grained high entropy phenomena => approach to targeted measures via observations, hi res sims

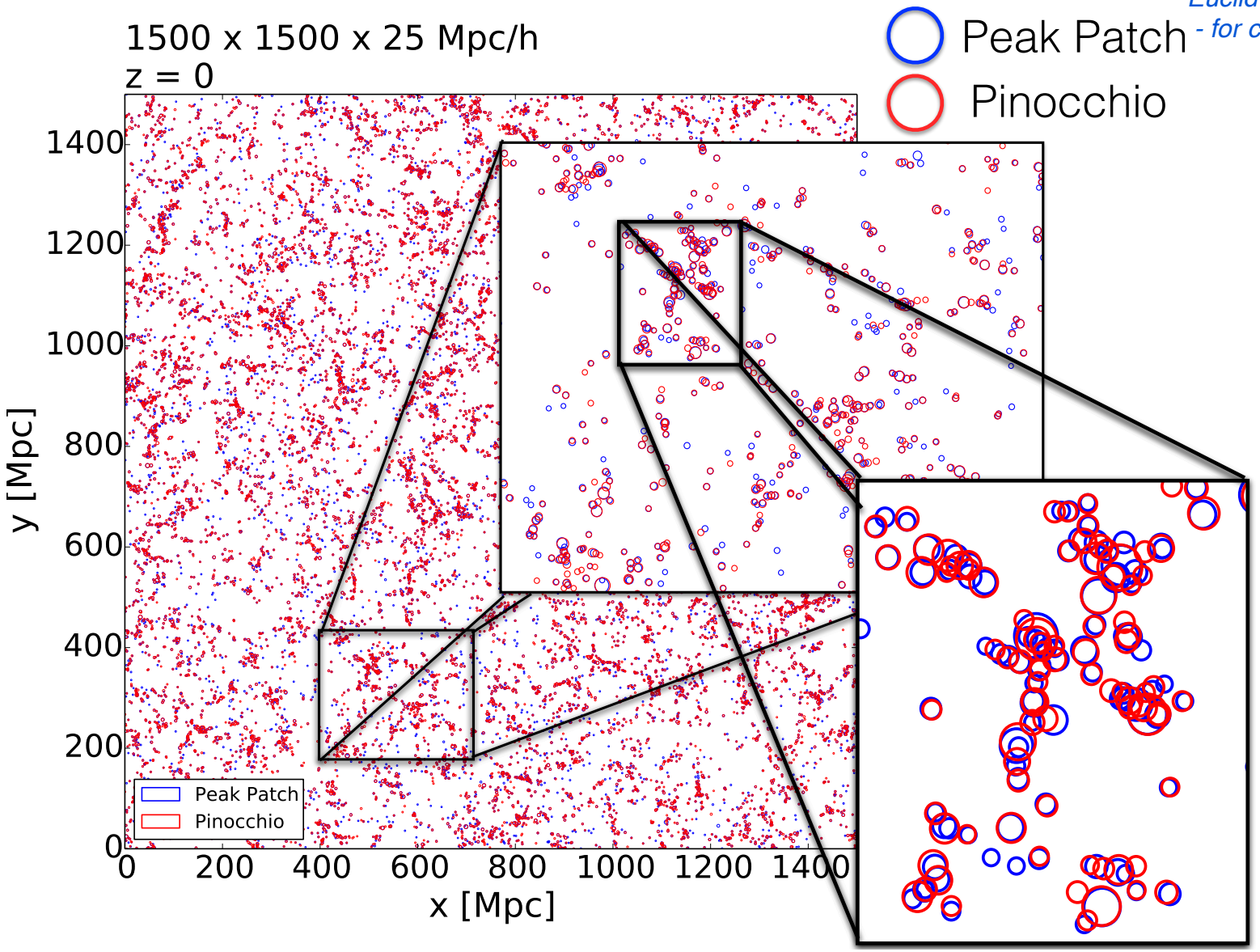
BIAS & 2-point clustering of halos is understood numerically & analytically: move via 2LPT



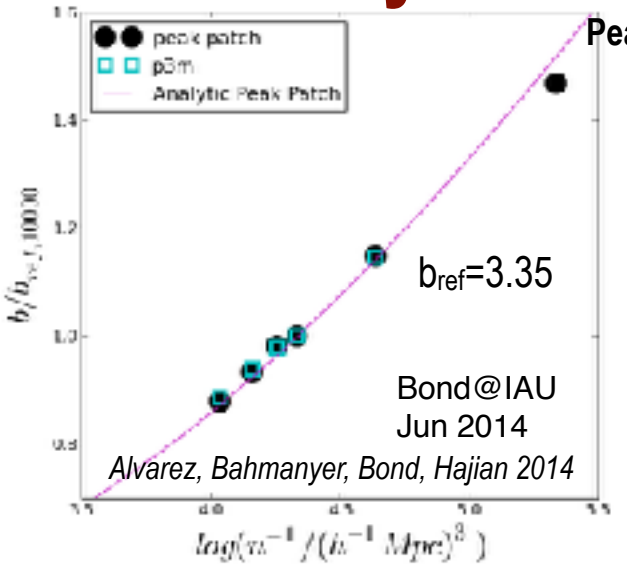


BIAS & 2-point clustering of halos is understood numerically & analytically: move via 2LPT

Euclid Simulation Group Test
- for covariance determination



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

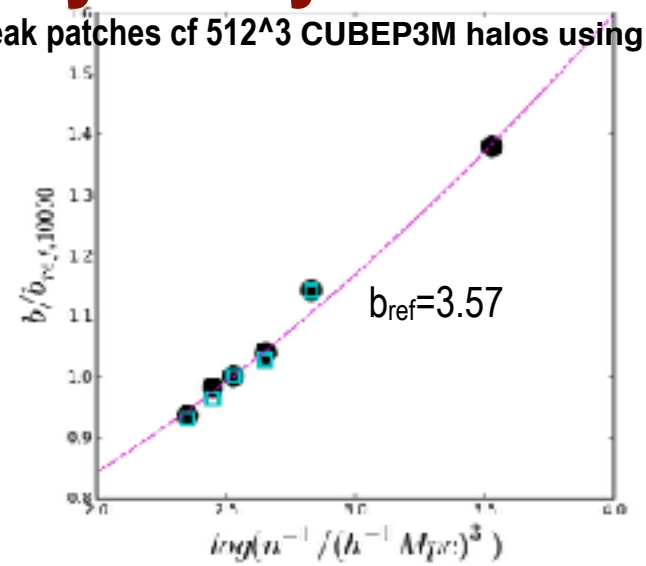


b_{ref}=3.35

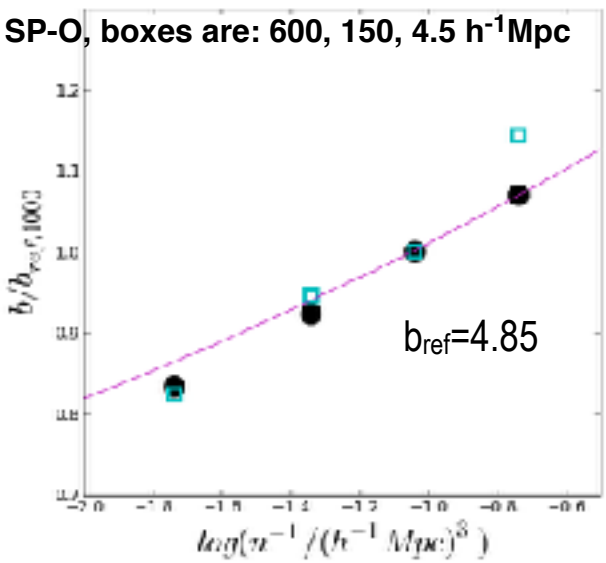
Bond@IAU
Jun 2014

Alvarez, Bahmanyer, Bond, Hajian 2014

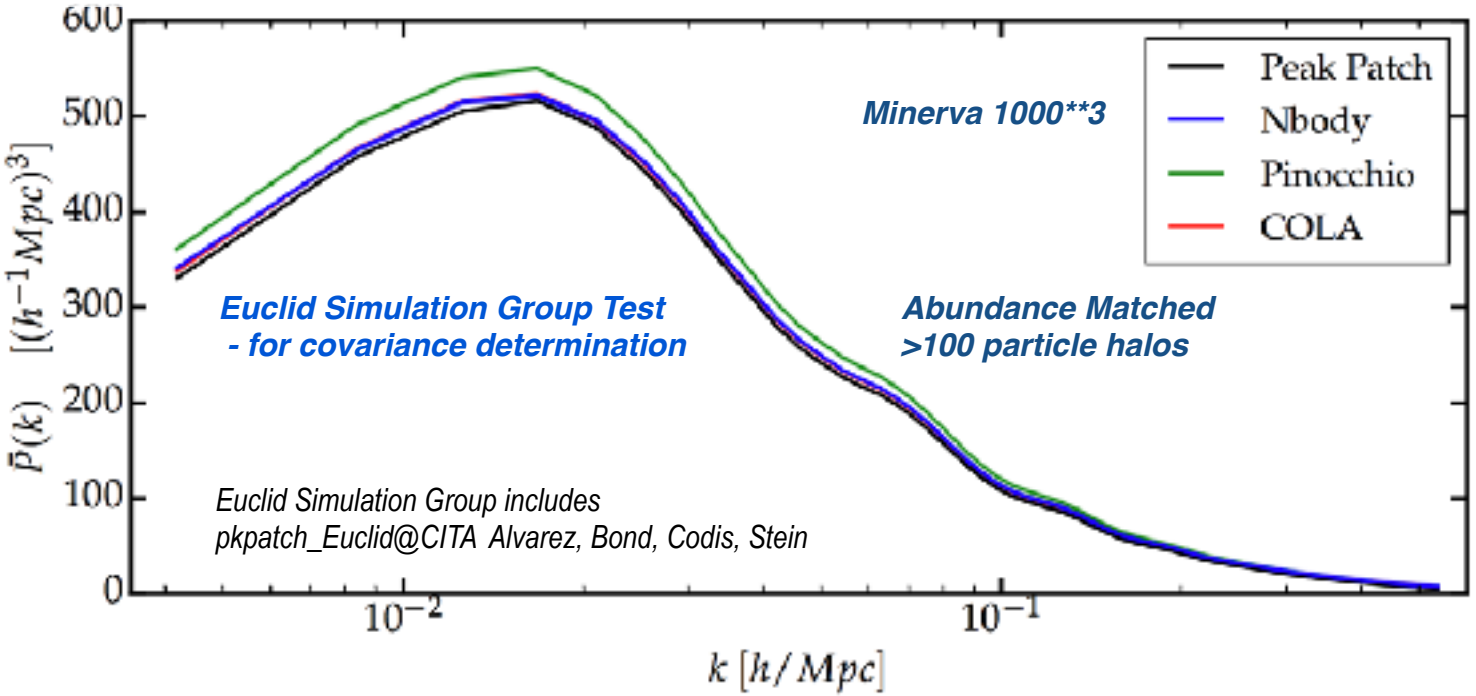
Peak patches cf 512^3 CUBEP3M halos using SP-O, boxes are: 600, 150, 4.5 h^{-1}Mpc



b_{ref}=3.57



b_{ref}=4.85



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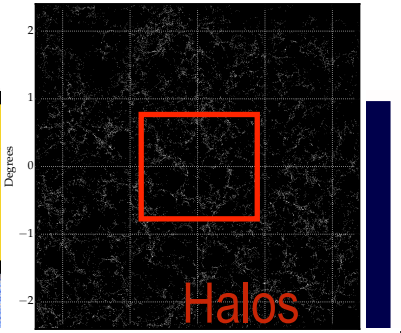
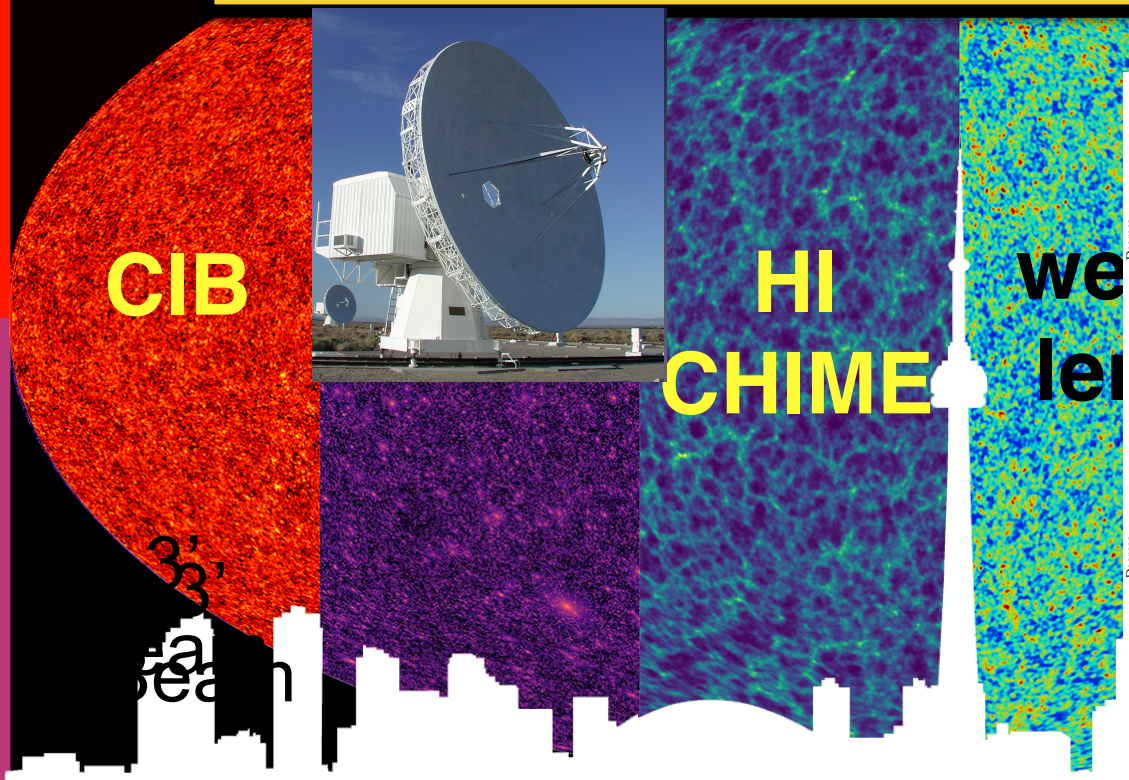
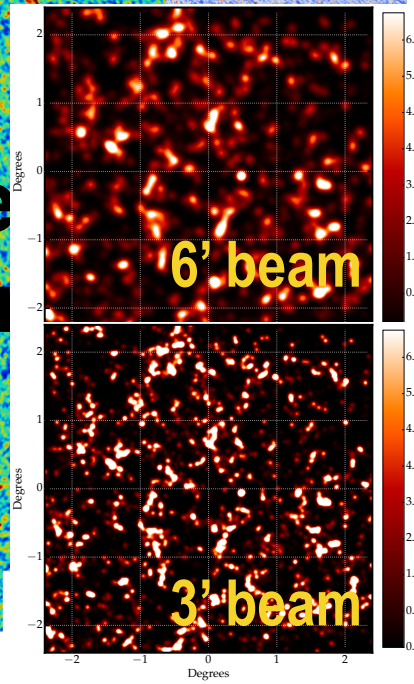
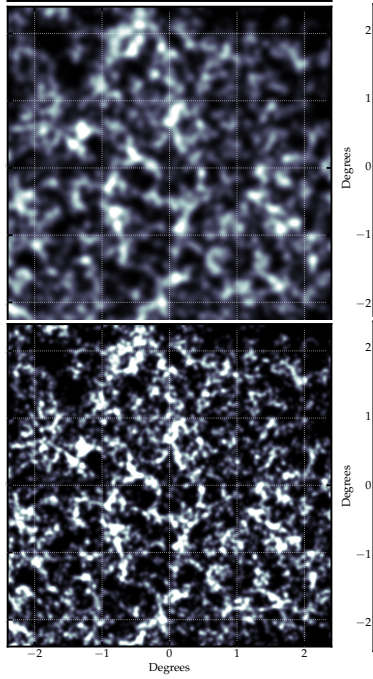








other metal lines, submm, optical

Richard Ellis talk on very deep optical lines HST, ALMA, JWST

Lyman alpha forest with lots of QSOs

TIME bolos redshifted **CII 157.7 mu** line thin strip => expand to larger sky

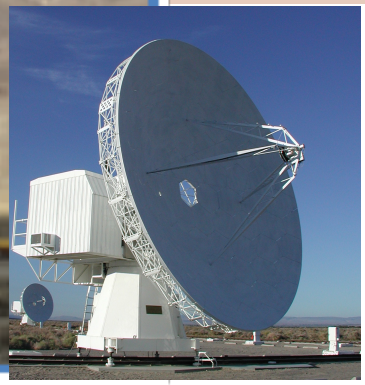
CII 157.7 mu
CCAT-prime consortium: 6m class
Cornell, U. Cologne, U. Bonn, AUI, 10 Canadian Universities incl TO
begin building 2017

press release today 17,04.05

HIRAX: HI at 21cm

COMAP: CO at 115 GHz

@Ovro 10m dishes from CARMA 30GHz : z=2.4-3.4. if 15 GHz EOR



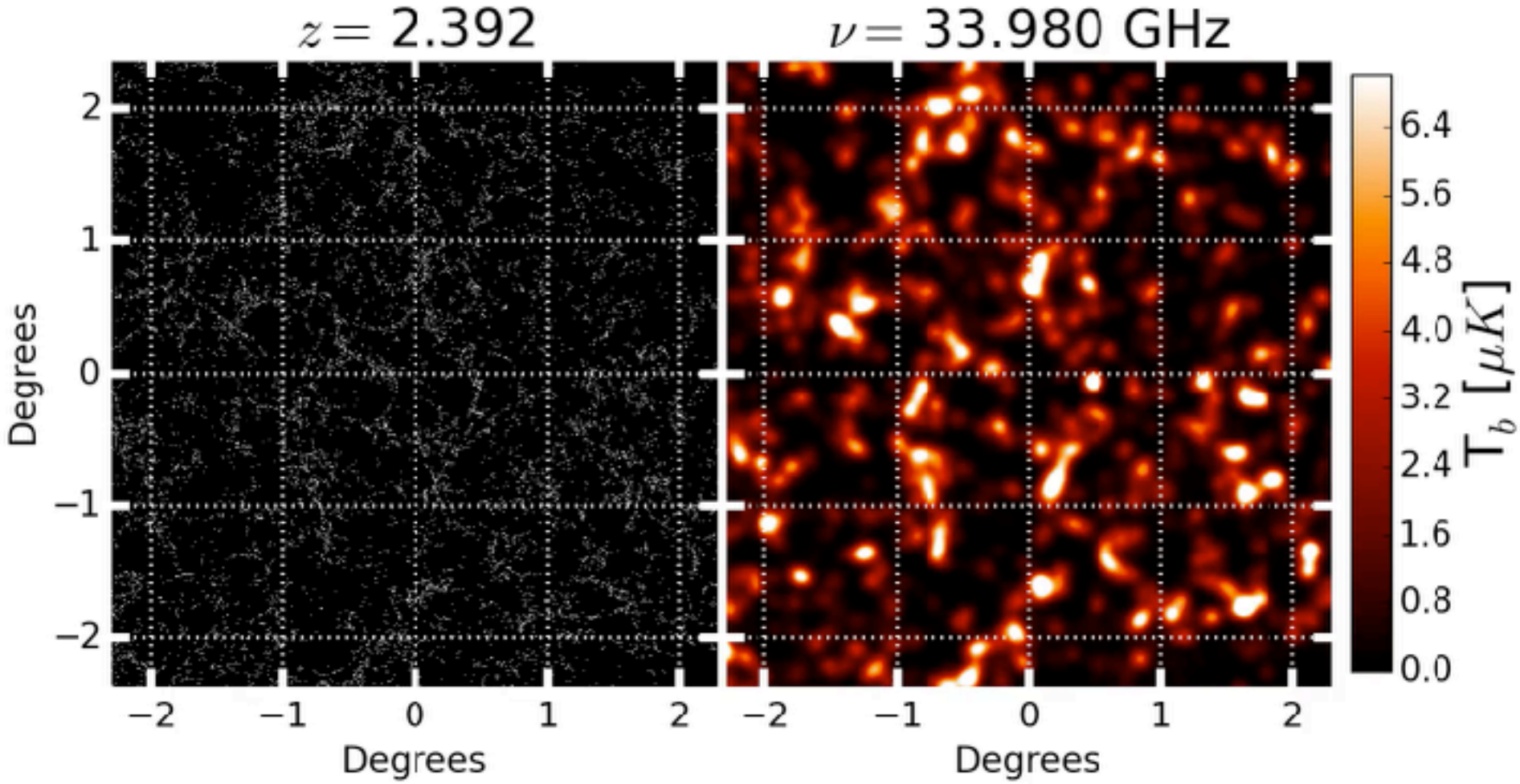
COMAP Jan17
OVRO + Caltech

current **Application to CO (87 sq deg) 1 boxes to tile, 1190 Mpc, 40 MHz moving smoothing window z=2.4-3.4, (4096)^3, M_halo,min =2.5(10) Msun, 52M halos, 2048 CPU cores SciNet, time 20m**

cf. COMAP1 2.5 sq deg

COMAP, split into 1024 frequencies, 6' fwhm, CO intensity mapping

Alvarez, Bond, Stein 2017



gas sims for CO: FIRE feedback in realistic environments: Hopkins++ including CITA

COMAP Jan17
OVRO + Caltech

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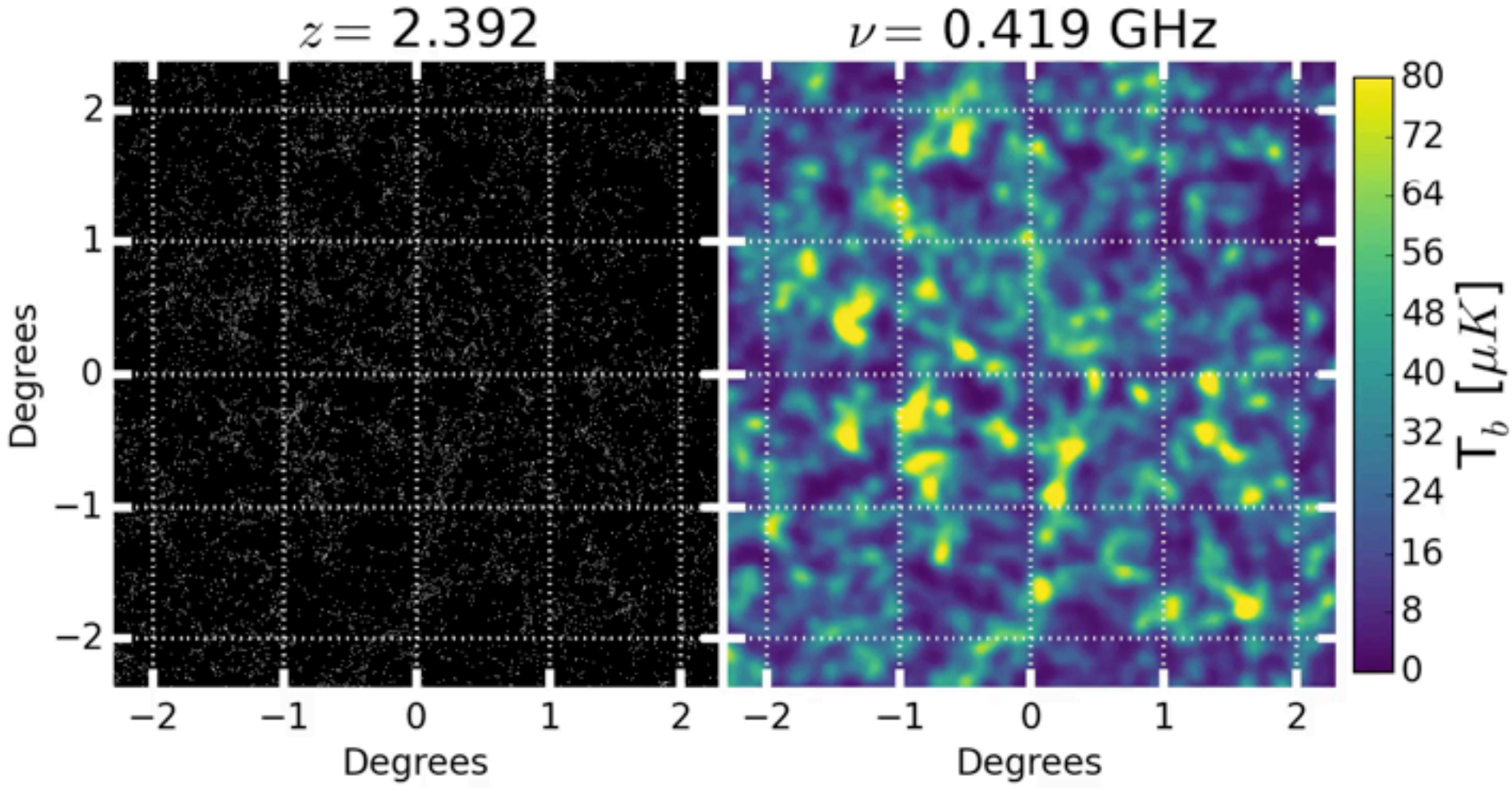
cf. CHIME z=0.8-2.5, ~(8 Gpc)^3

HI map, processed like COMAP 1024 frequencies, 6' fwhm cf. 60' CHIME *Alvarez, Bond, Stein 2017*



$$L_{HI} = \frac{3A_{10}h\nu_0}{4m_p} M_{HI} \qquad M_{HI} = f\frac{M_{Halo}}{1+\frac{M_{Halo}}{M_{Max}}}$$

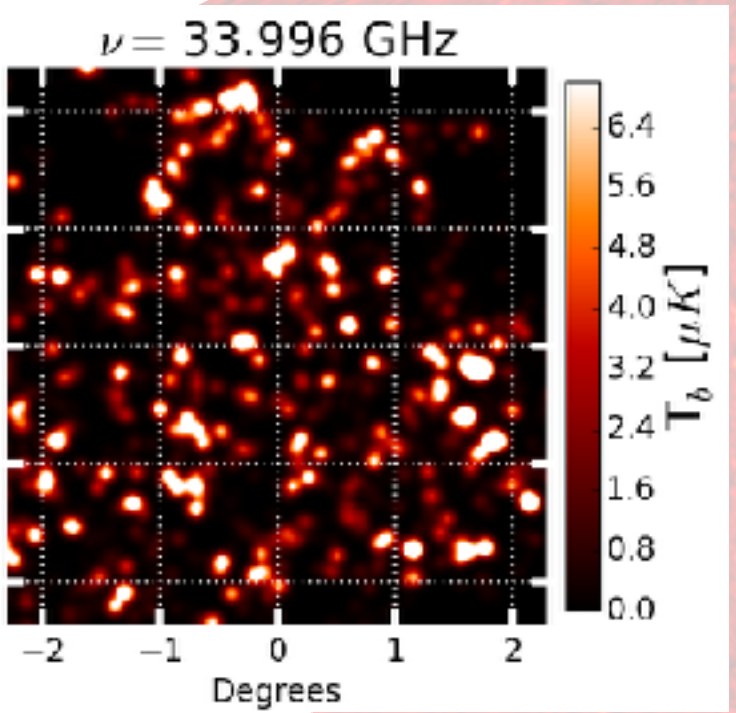
Villaescusa-Navarro et al. 2014

CIB x COMAP

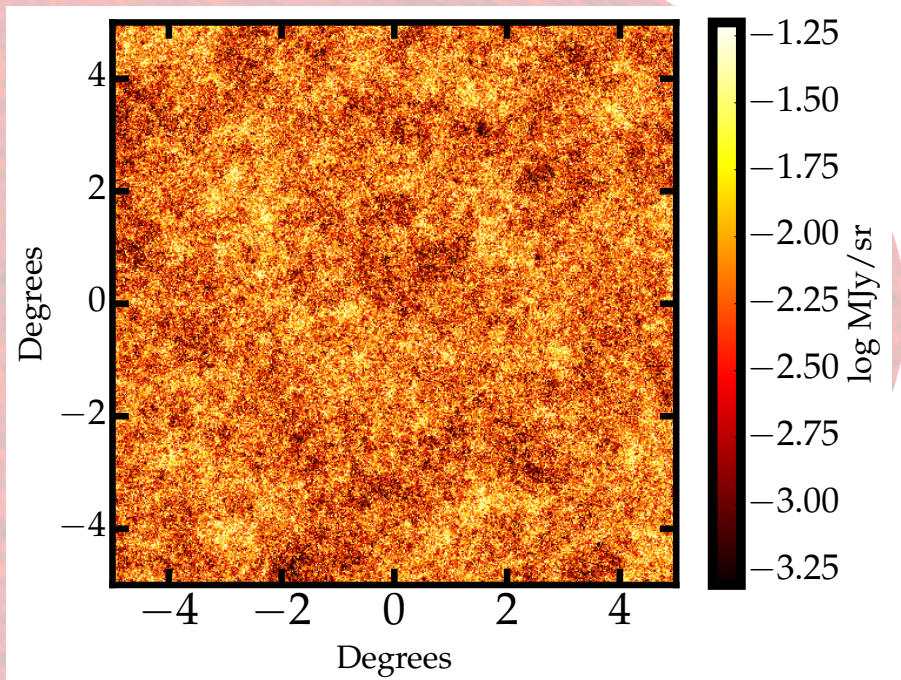
Lya (LAM) X COMAP?? COSMOS z-survey ..

- Planck 2013 CIB model for higher z
- Planck 2015 CIB model targeting tSZ x CIB

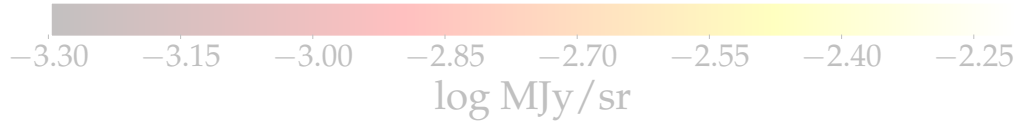
CO



CIB: z = 2.4-2.8

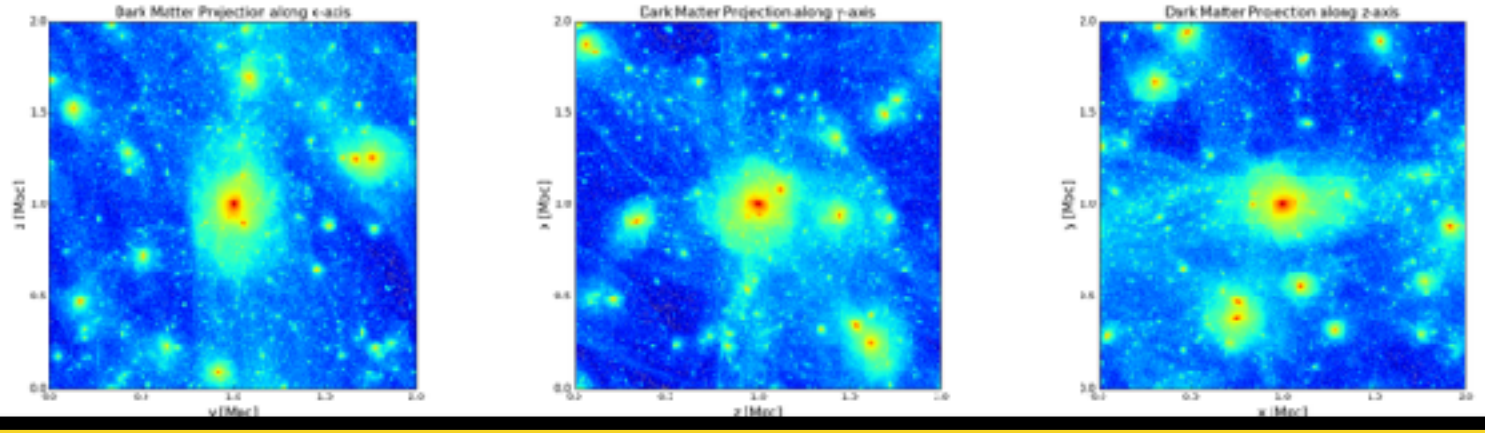


Planck 2013 Model



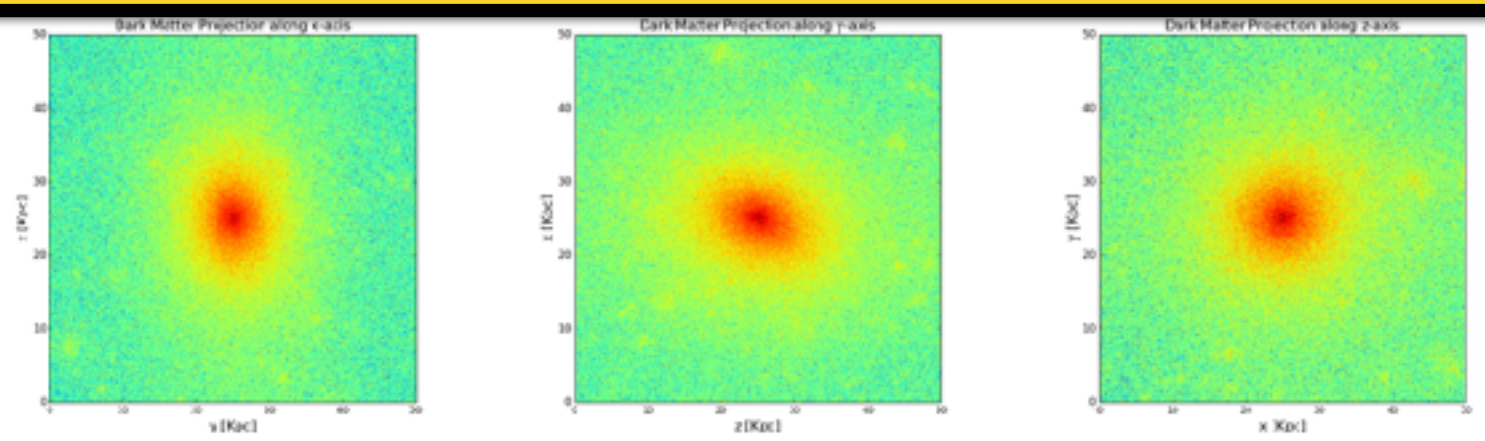
z = 0.0

HI only a little GBT data to anchor susceptibilities on, now trying FIRE sims

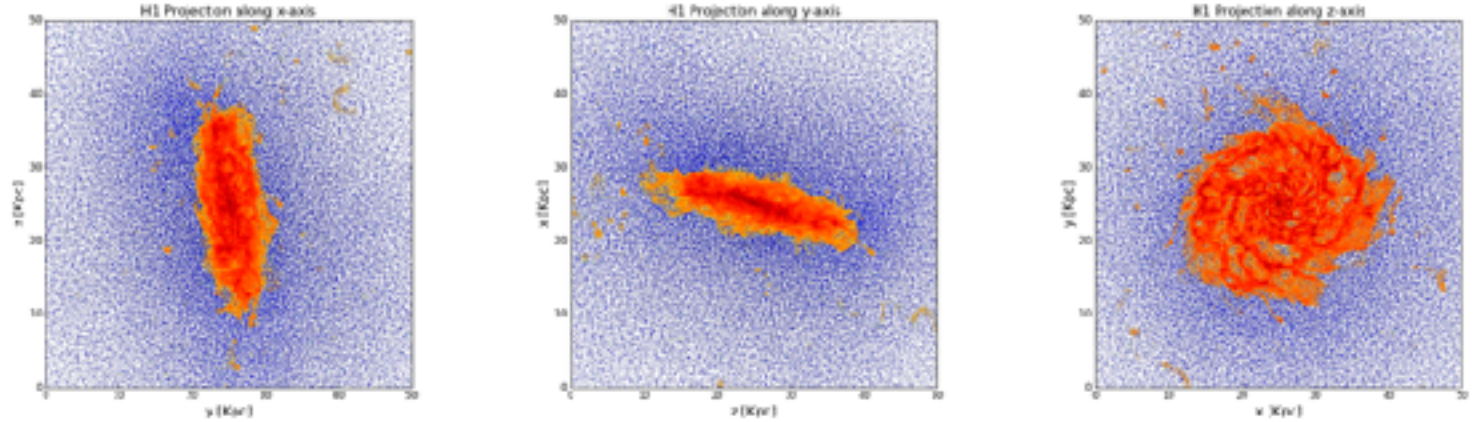


DM

hi res FIRE hydro (Hopkins+) for galaxy formation susceptibilities: Gunjan Lakhlani, Murray +CITA pk patch crew

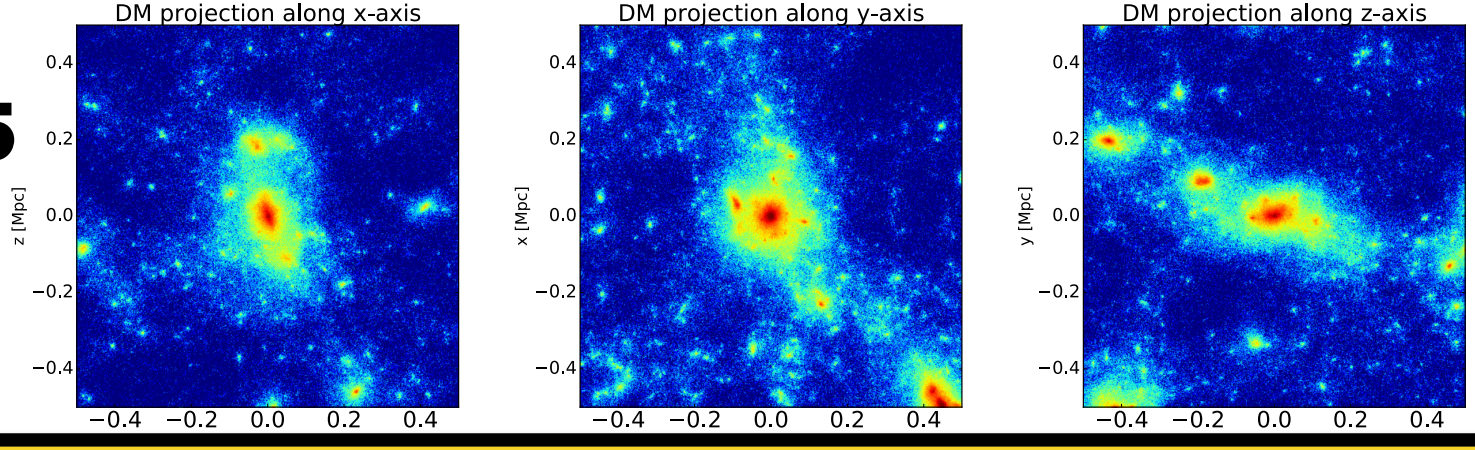


DM



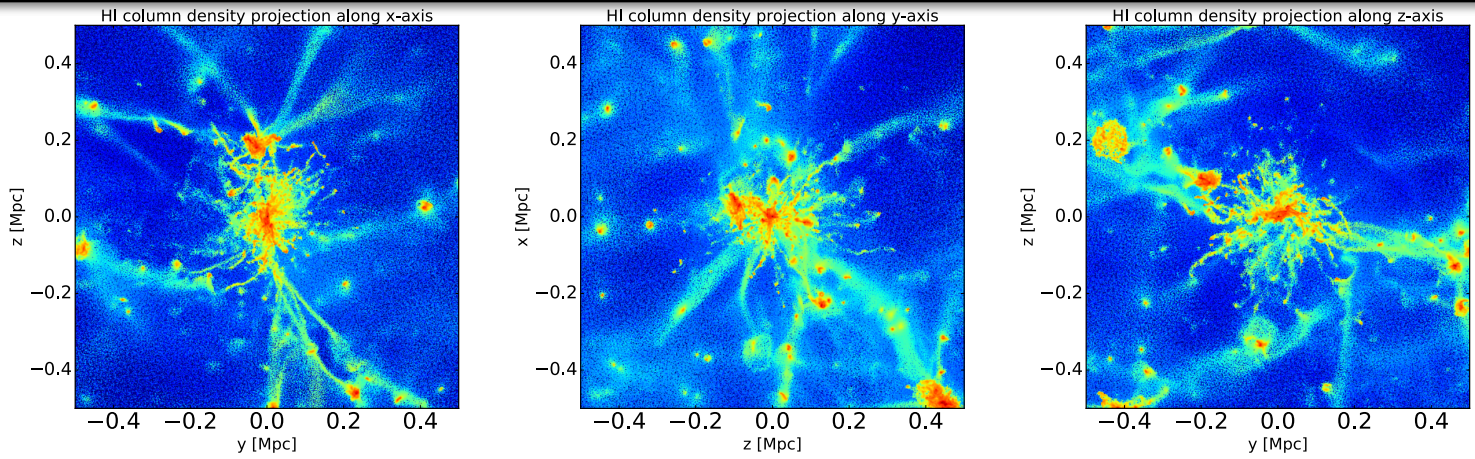
n_HI

z = 2.5



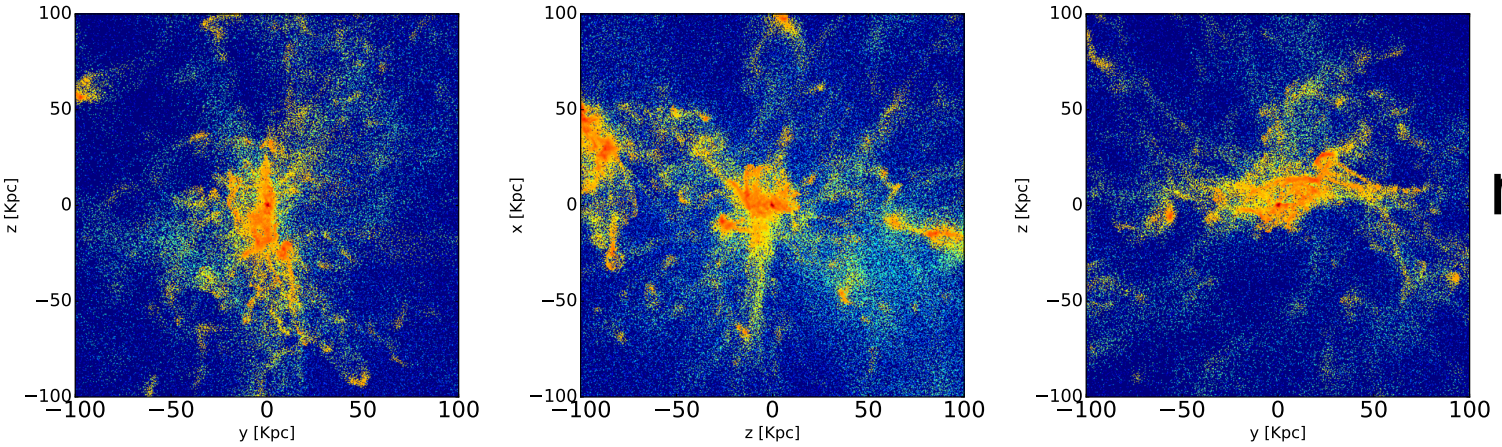
DM

hi res FIRE hydro (Hopkins+) z=2.5 => 10(13) Msun galaxy at z=0 *Gunjan Lakhlani, Murray +ABS*



n_HI

~10^23 /cm^2



n_HI

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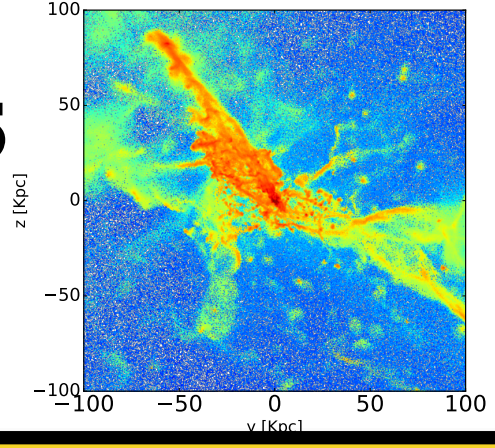
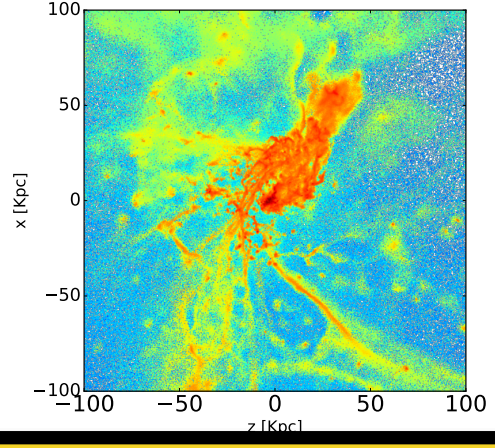
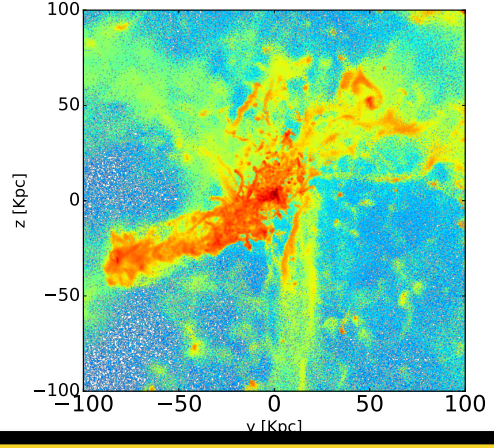
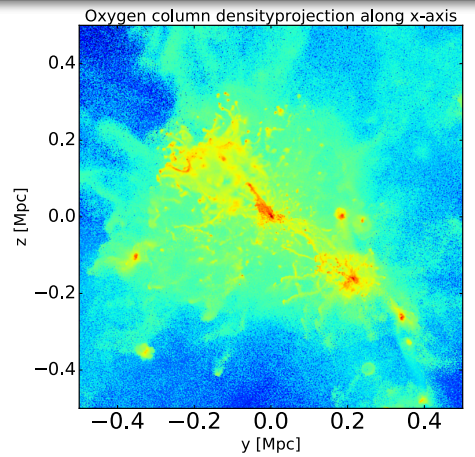


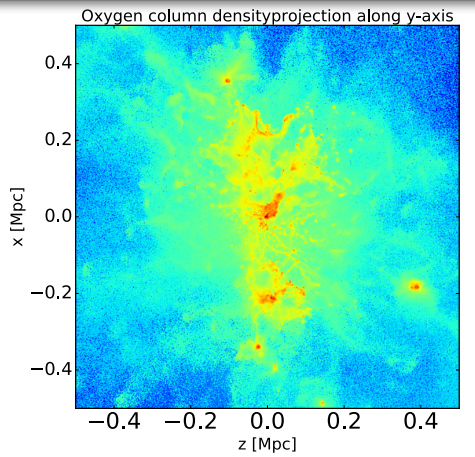


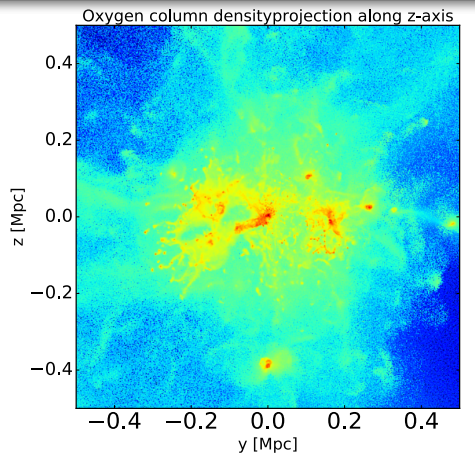


n_HI

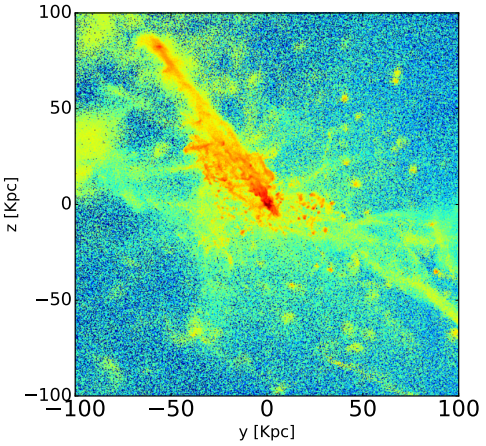
hi res FIRE hydro (Hopkins+) z=2.5 => 10(12) Msun galaxy at z=0 *Gunjan Lakhlani, Murray +ABS*

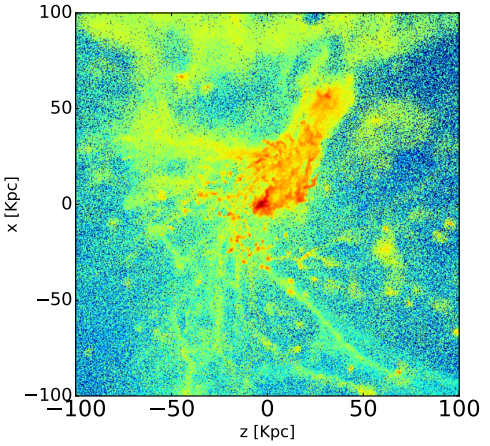


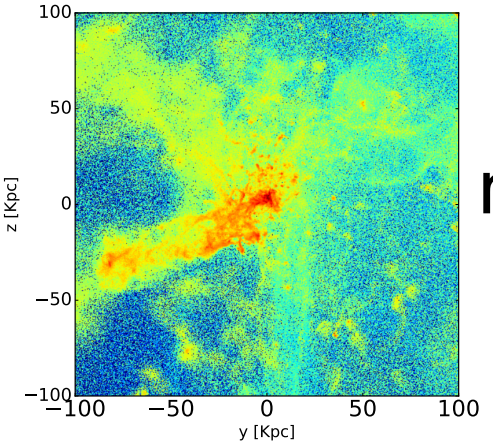




n_O







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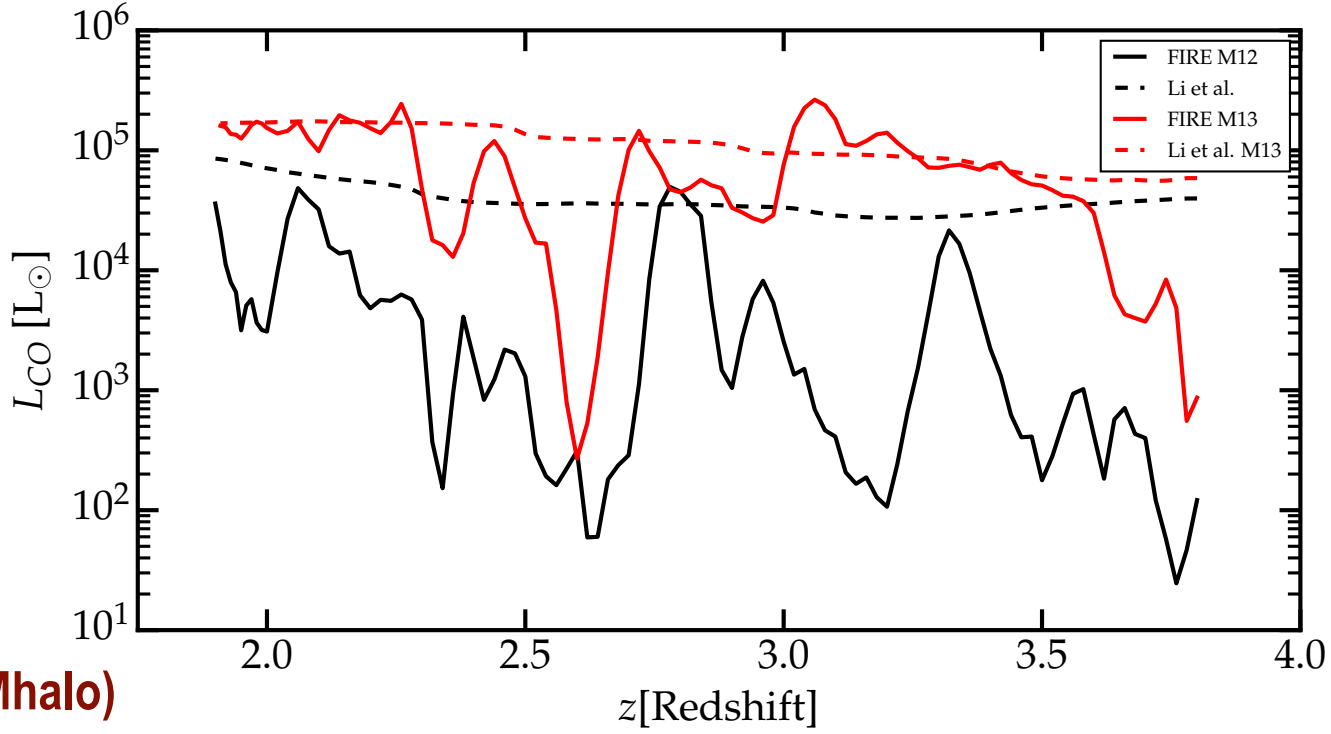
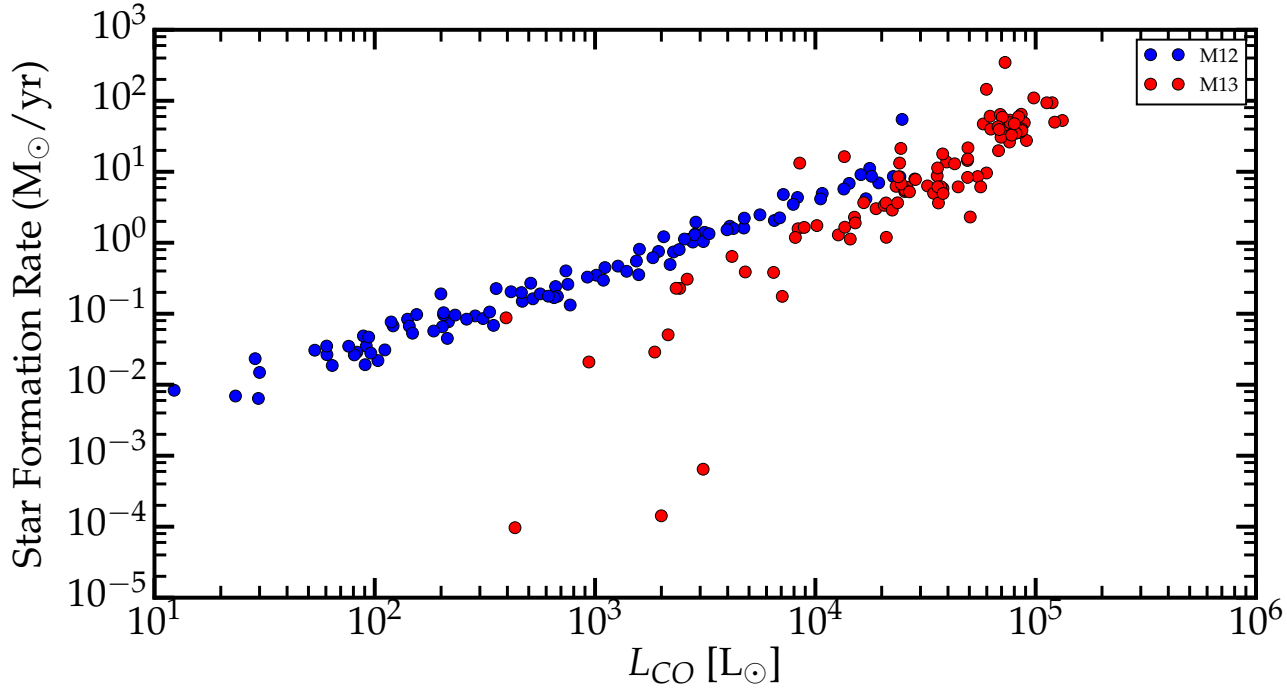
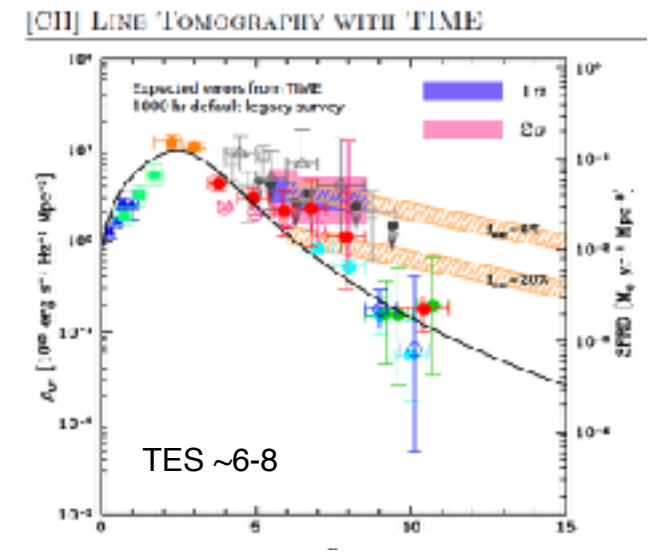


LCO (SFR(z), Mhalo)

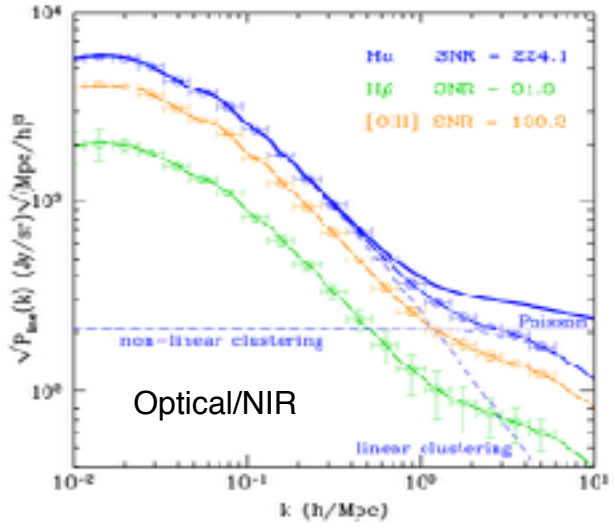
other SFR-correlators??



*Intensity Mapping in the bubbly reionization phase redshfited 21cm HI but also CII, CO, Nitrogen, .. **Xcorr***



SMEX 2014, Step 2 S P I
AO NNH14ZDA013O



tau_Compton from Planck16

HI HERA ++ … SKA

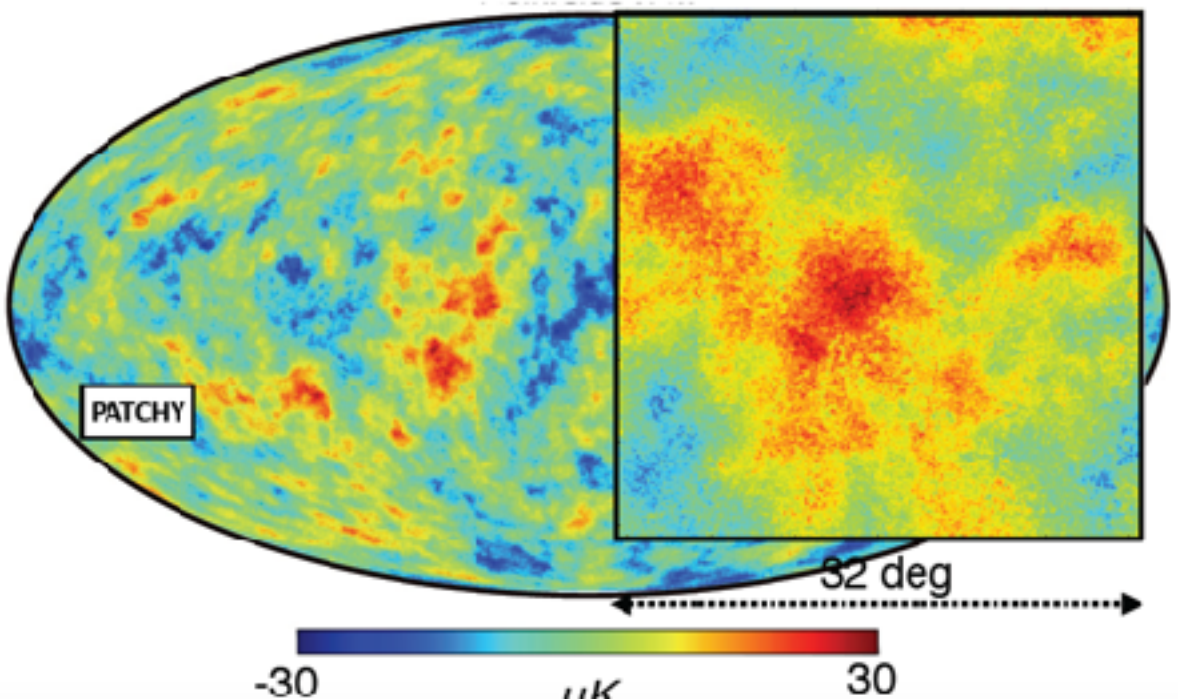
Richard Ellis talk on very deep optical lines
HST, ALMA, JWST
other correlators? especially with SFR

COMAP @ 15 GHZ ~6+

CCATp CII 6m telescope

marcelo alvarez sims: kSZ

Effect of Patchy Reionization on CMB: Mock Observations for AdvACT/Simons Observatory/CMB-S4



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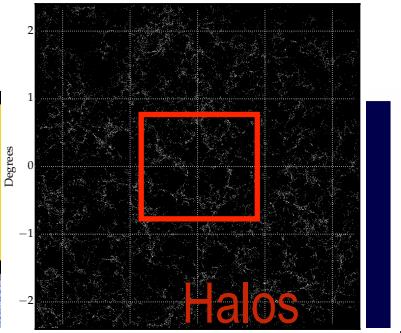
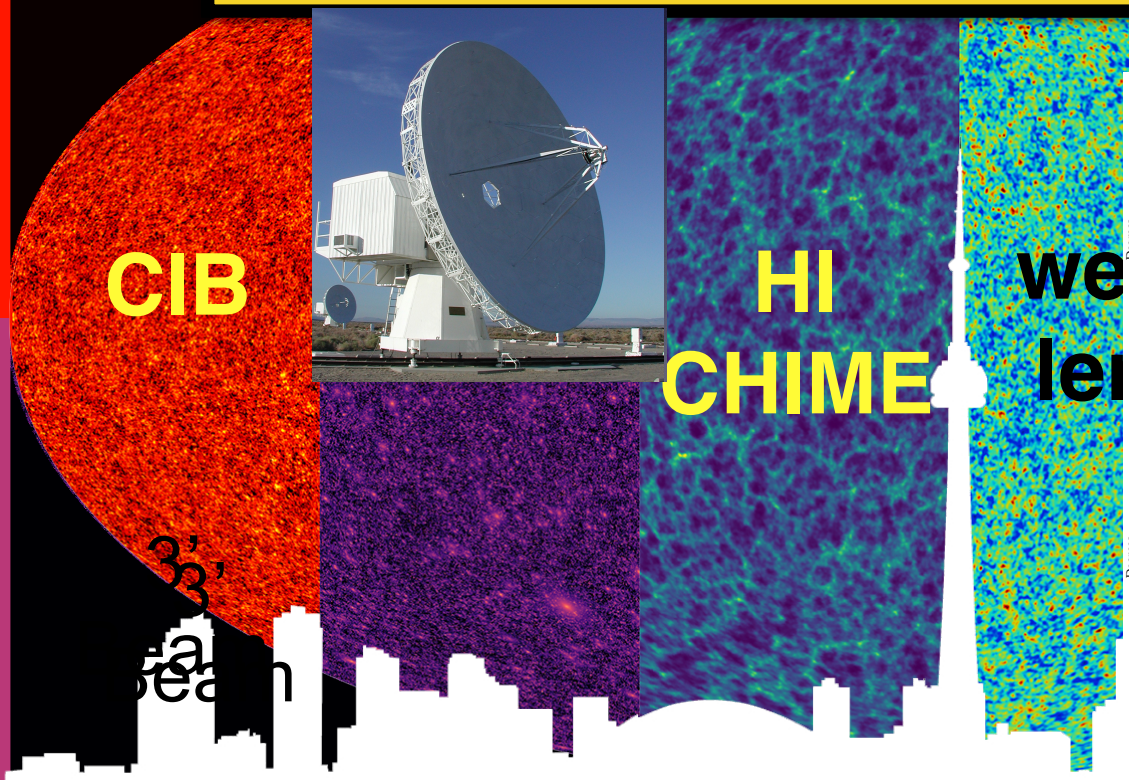
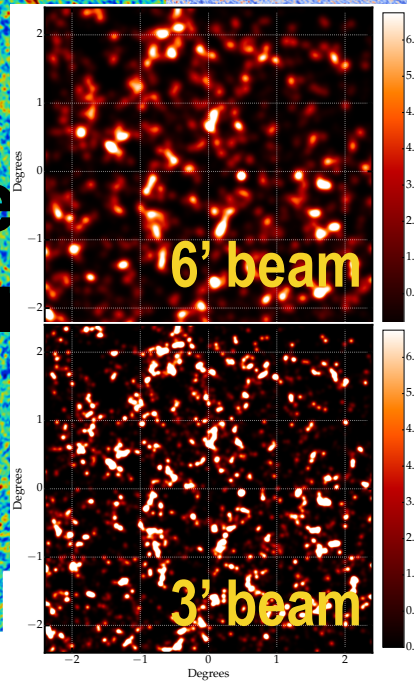
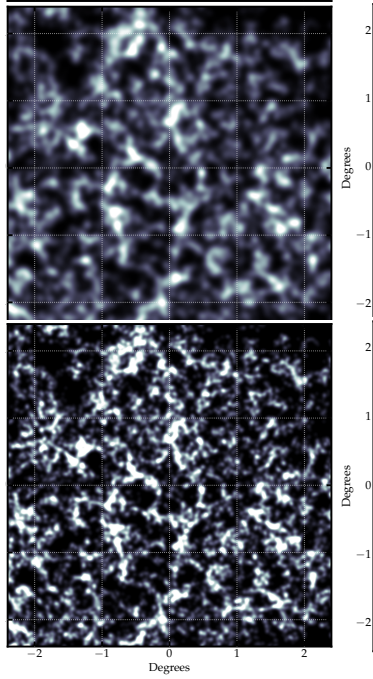
Survey Area





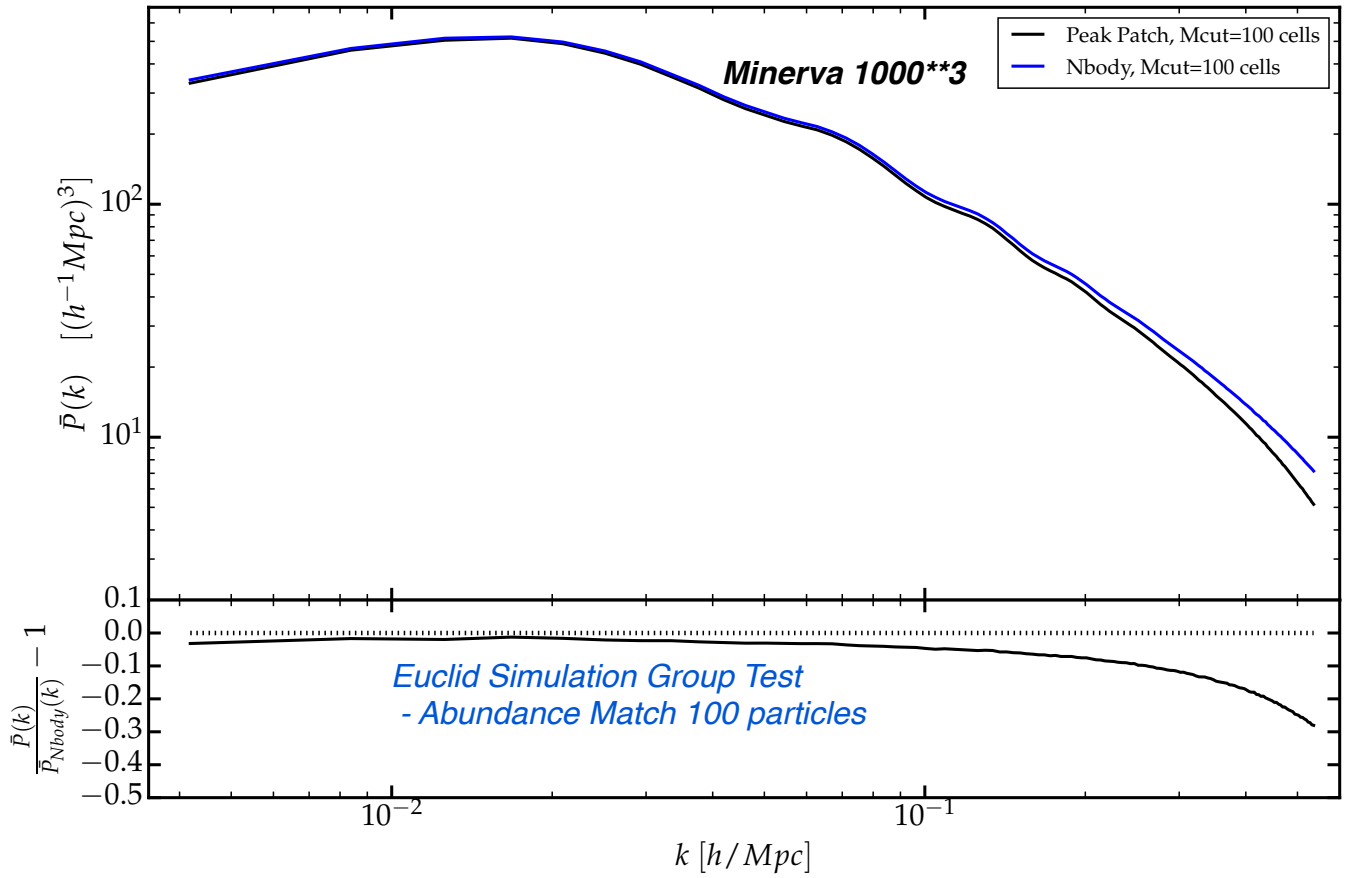


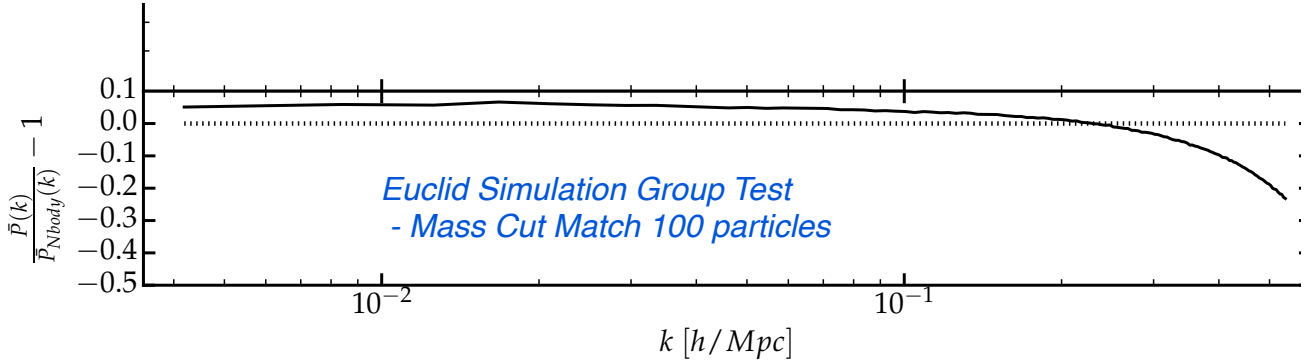


"mocking heaven" apps: tSZ, CIB *original motivation => tSZxCIB*, **kSZ, Lens**
***optical galaxies* via HOD for CMASS, Euclid, LSST, .. DES, HSC, sphereX**
***"intensity mapping"* of HI (CHIME, HIREX, ..,SKA) of CO COmap, CII**
***well suited:* to cross-correlation studies of all sorts**
***well suited:* to characterize correlated/non-Gaussian errors**
***well suited:* light cones** *automatic, no interpolation*
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
ξ(x|M1,M2), P(D) & other non-Gaussian statistics
oriented correlations, filamentary web

ToBeDone for 'PeakPatches': beyond 2LPT embedded ellipsoids >> dynamical accuracy!?
"subgrid" halos nonlinear bias + exclusion - well underway
exterior fluctuations (weak lensing) - done - ish
interior fluctuations (subclumping, subhalos, δp,δρ)
susceptibility measurement in hi res sims, some in BBPS,..Illustris, FIRE
3 point function testing beyond 2LPT


Minerva 1000**3
Peak Patch, Mcut=100 cells
Nbody, Mcut=100 cells
$\bar{P}(k)\quad[(h^{-1}Mpc)^3]$
10^2
10^1
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
$\frac{\bar{P}(k)}{\bar{P}_{Nbody}(k)} - 1$
Euclid Simulation Group Test
- Abundance Match 100 particles
10^{-2}
10^{-1}
$k\ [h/Mpc]$


0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
$\frac{\bar{P}(k)}{\bar{P}_{Nbody}(k)} - 1$
Euclid Simulation Group Test
- Mass Cut Match 100 particles
10^{-2}
10^{-1}
$k\ [h/Mpc]$