the Peak Patch Picture of Halos

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

Dick Bond @ Ovro17.1.11

Marcelo Alvarez, George Stein

CIFAR CANADIAN INSTITUTE FOR ADVANCED RESEARCH

THEN BBKS, BCEK, B+Myers91,93,96, BKP web, BW

NOW: CITA mini-industry Alvarez, Bond, Stein 2017

Berger, Battaglia, Codis, van Engelen, Huang, Frolov, Bahmanyer

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 1Lpt/2Lpt

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

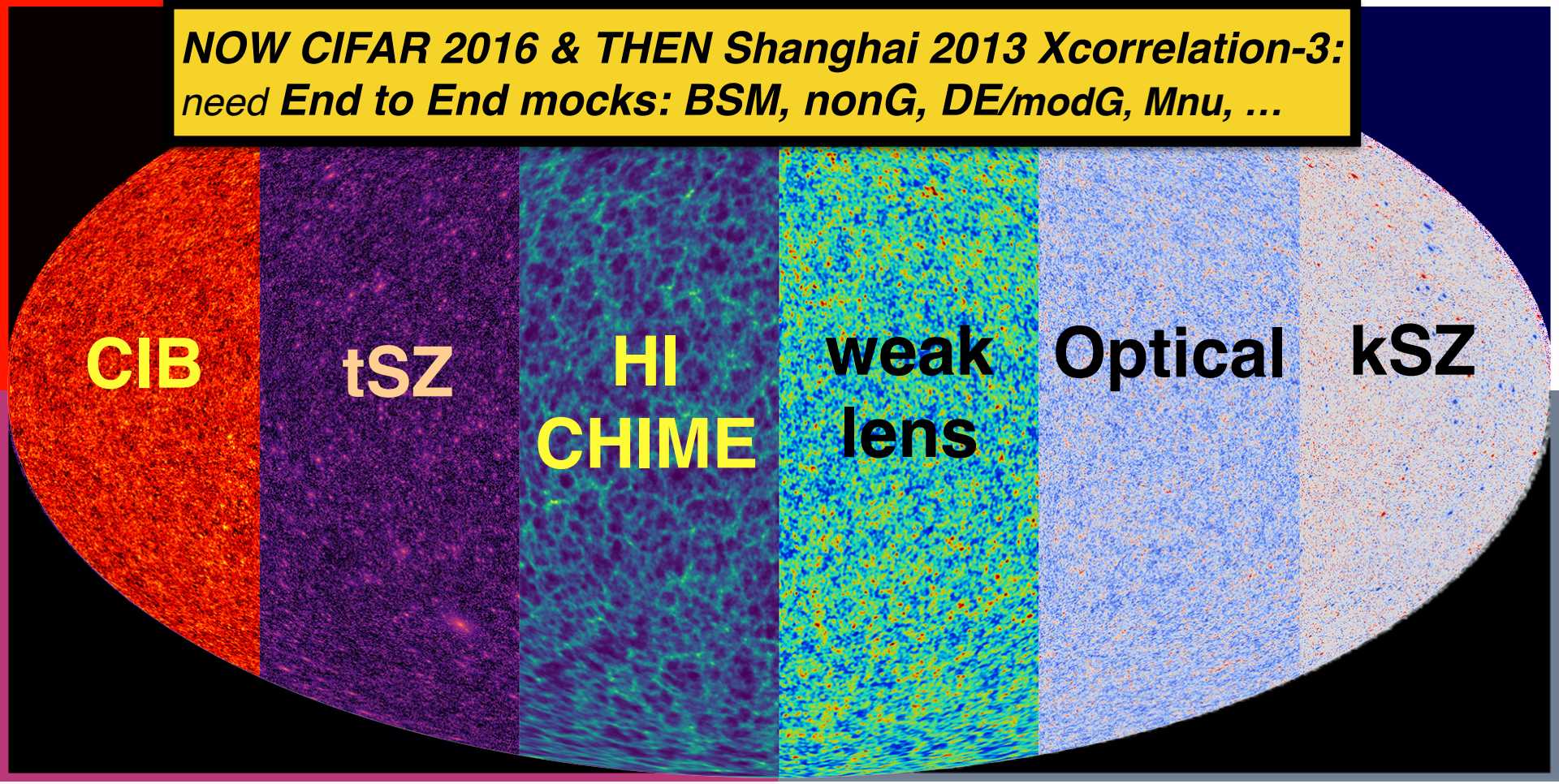
Mocking Heaven @ *CIFAR16* **Dick Bond**

Peak Patch Full Sky Models: @CIFAR1991 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

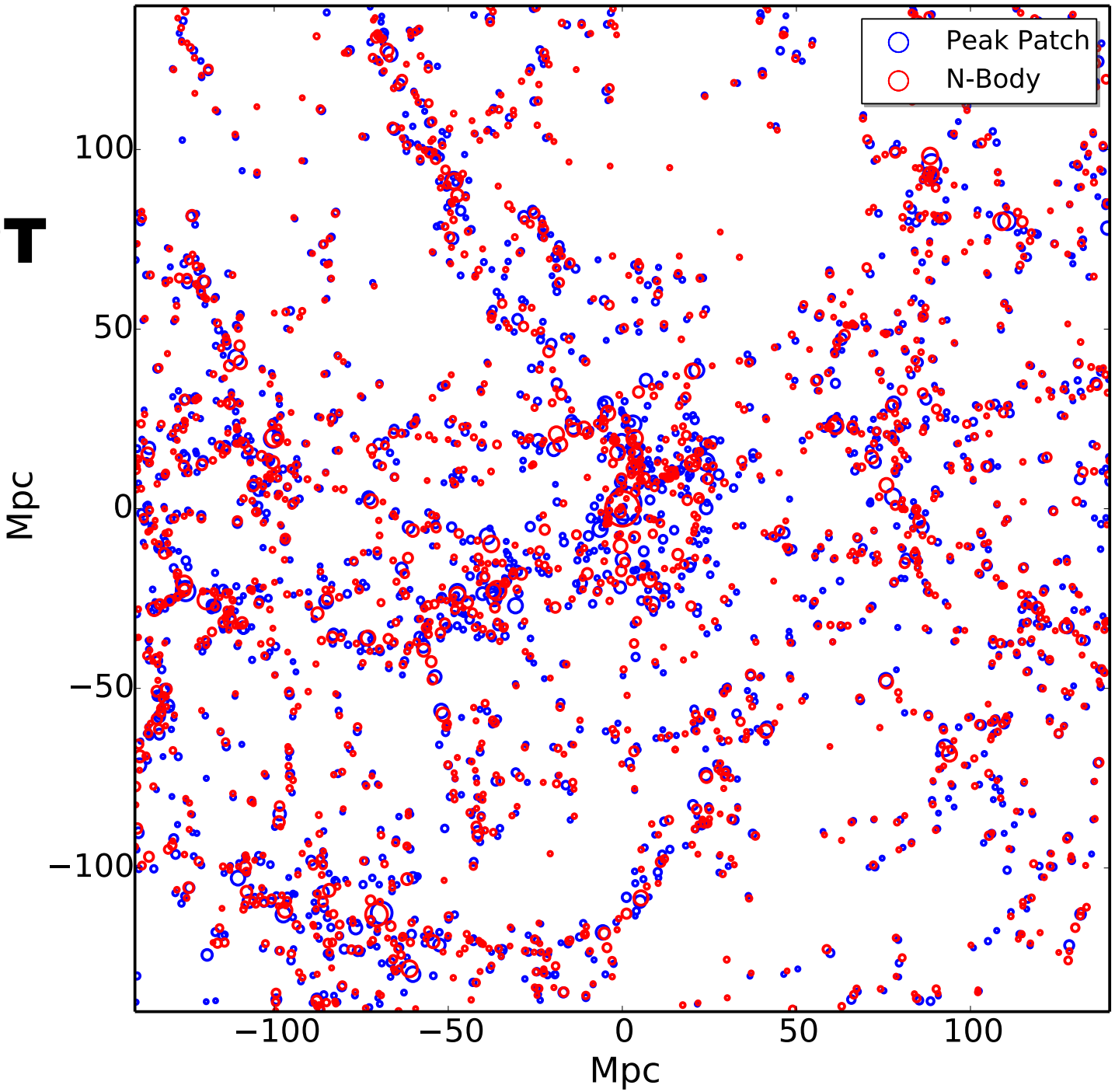
NOW CIFAR 2016 & THEN Shanghai 2013 Xcorrelation-3:
need ***End to End mocks: BSM, nonG, DE/modG, Mnu, …***



Planck 2015 XII: Full Focal Plane Sims (Nov): FFP8 ensemble of10K ***End****to****End*** *mission realizations in 1M maps. instrument noise + CMB + PSM + .. (25M NERSC CPU hrs)*

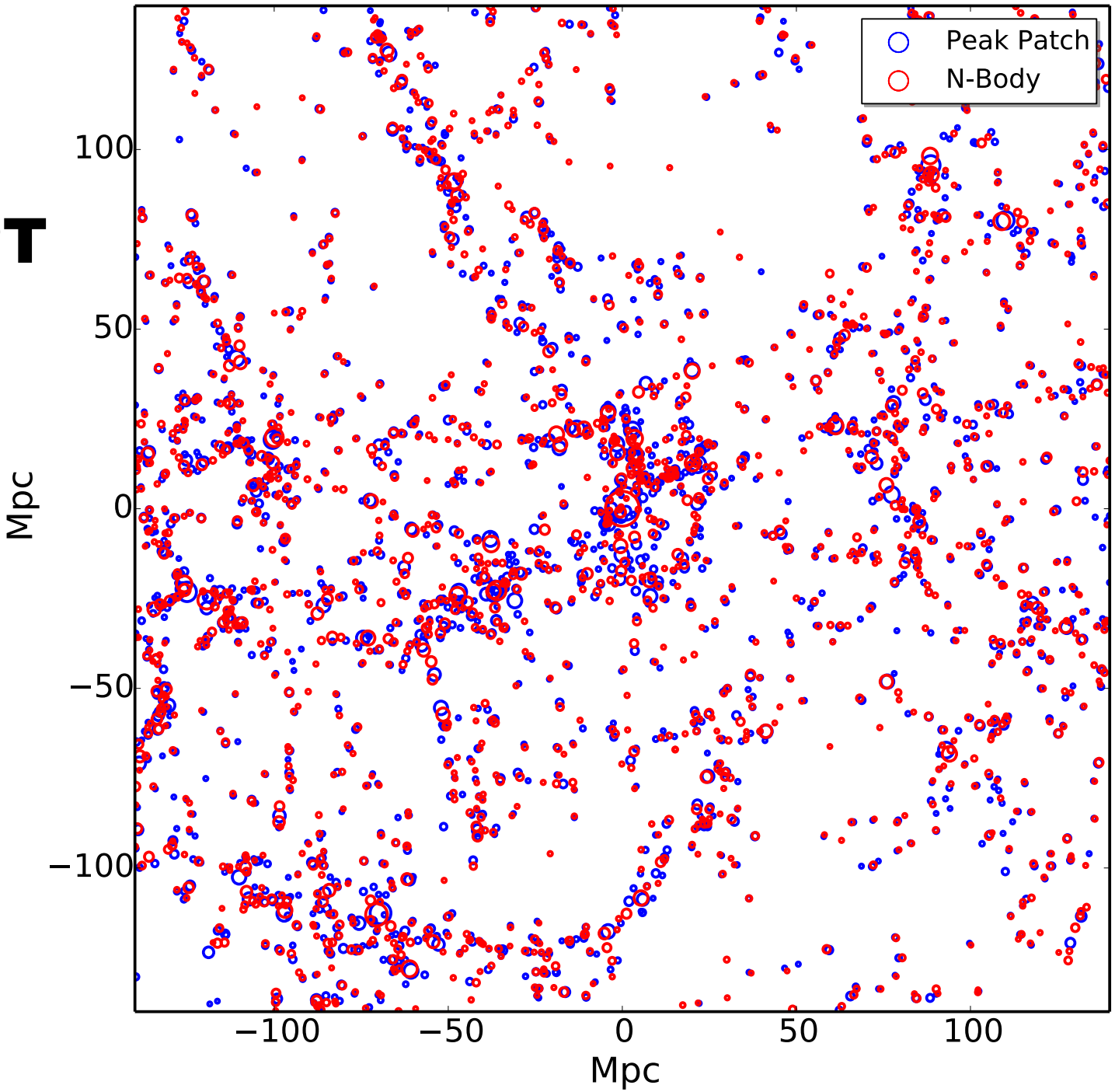
z=0

1LPT



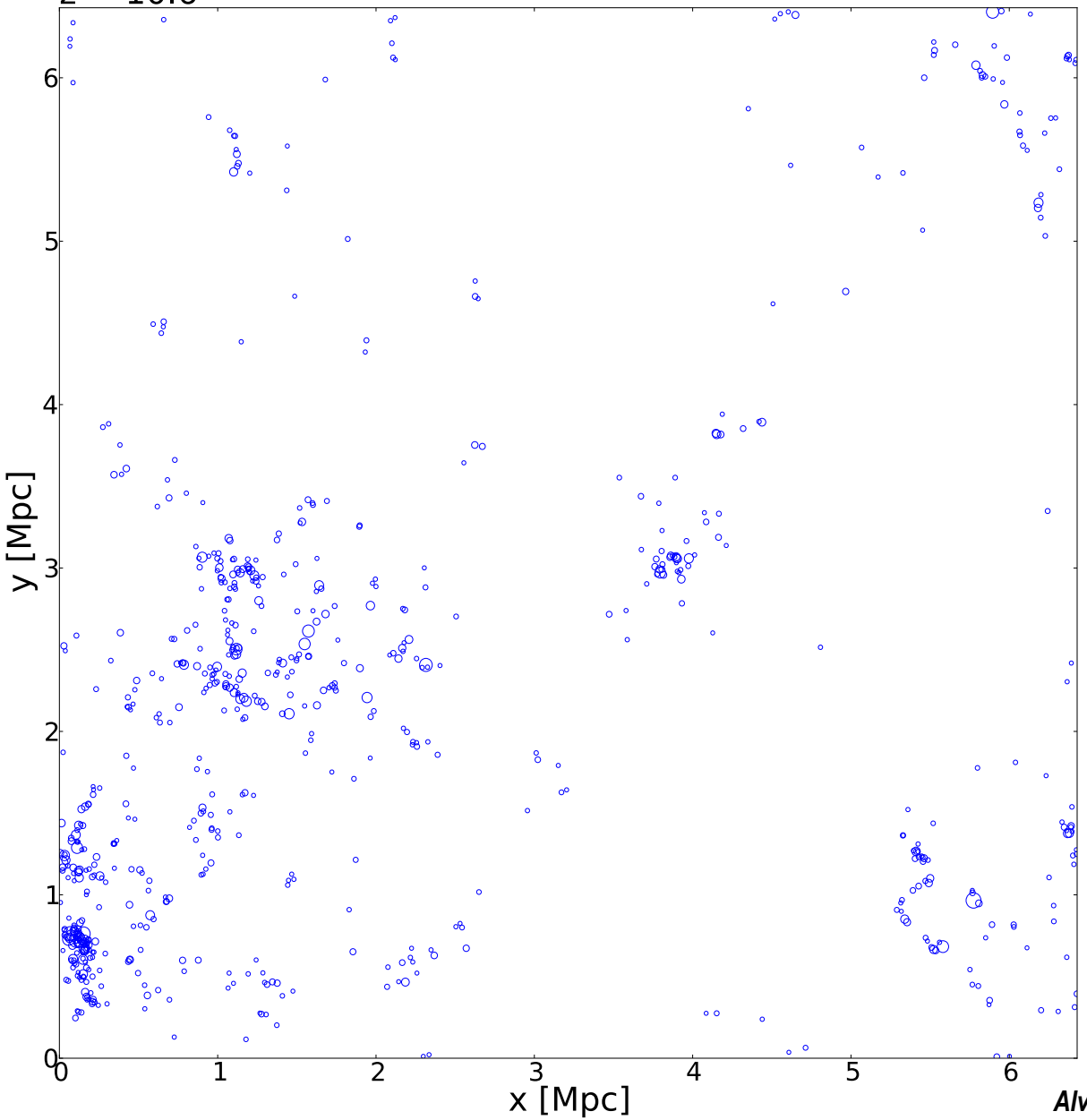
z=0

2LPT



Peak patches cf 512^3 CUBEP3M halos using SP-O, boxes are: 857 Mpc, 214 Mpc, 6.43 Mpc

z~10 CubeP3M Halos
4.5 x 4.5 x 0.9 Mpc/h
z = 10.6



beware: a numerically challenging regime extreme LSS tides

still Peak Patches works!

Application to HI, reionization, first stars & dwarflets

Alvarez, Bond, Hajian, Stein, Emberson 2013

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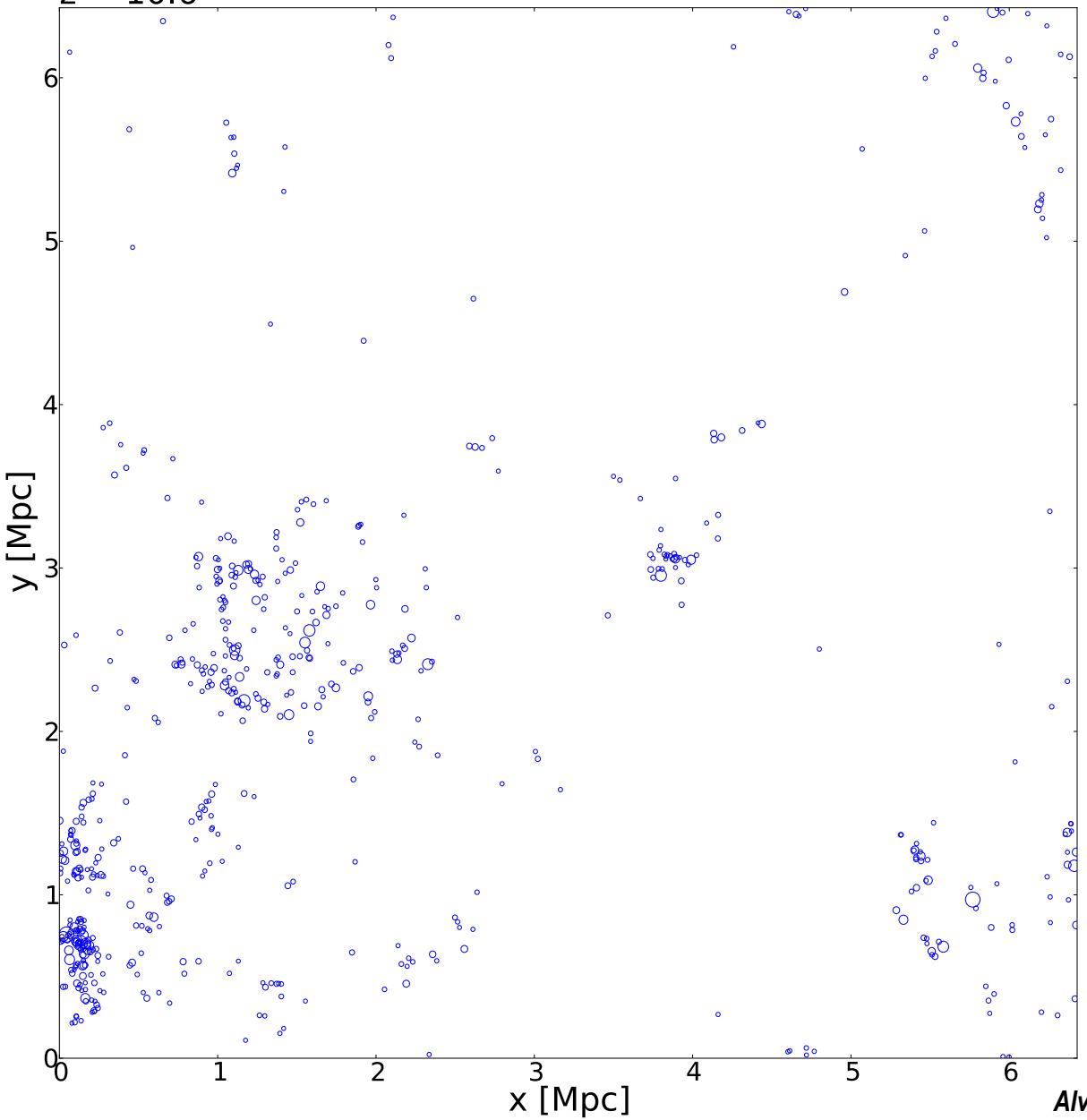

1LPT

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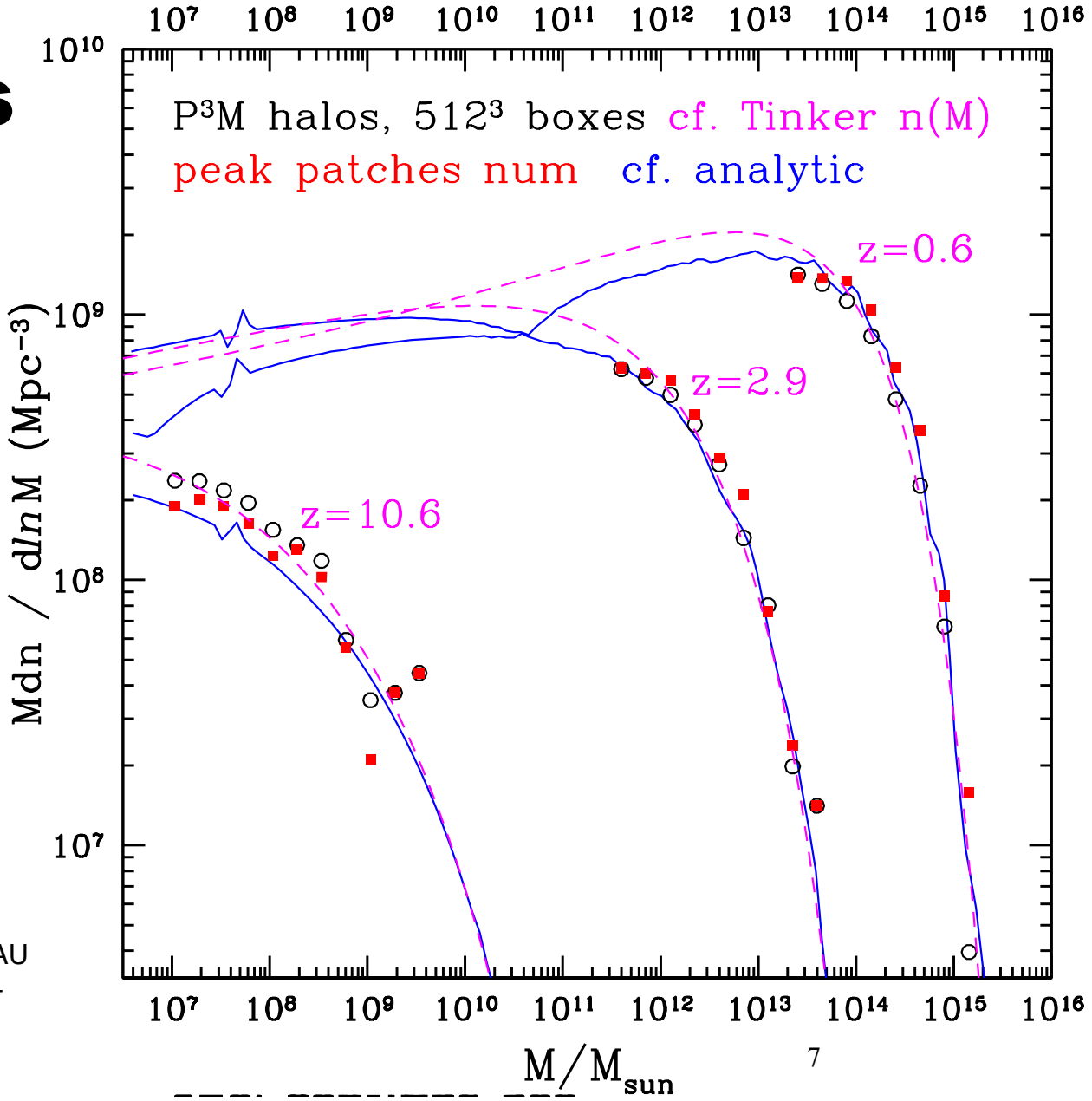
SP-O Halos are exactly **Eulerian-space** Peak Patches

abundances of halos is understood

numerically & analytically

Euler *cf.* Lagrange

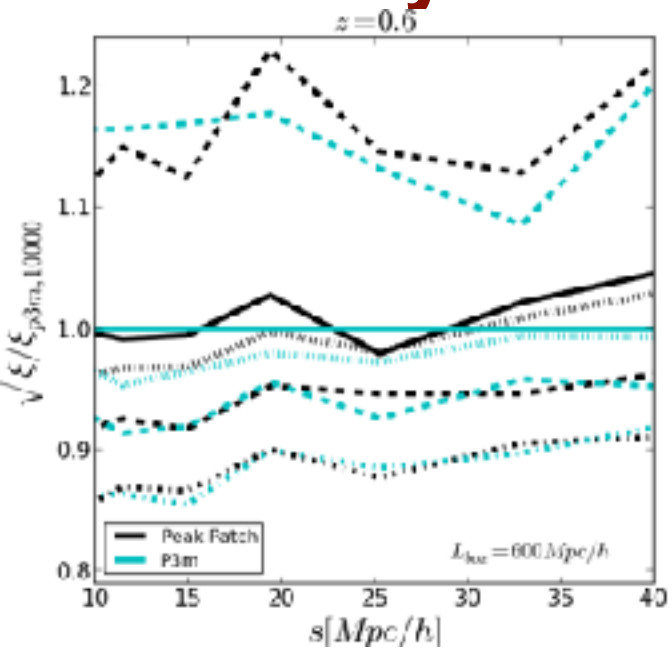
PeakPatches

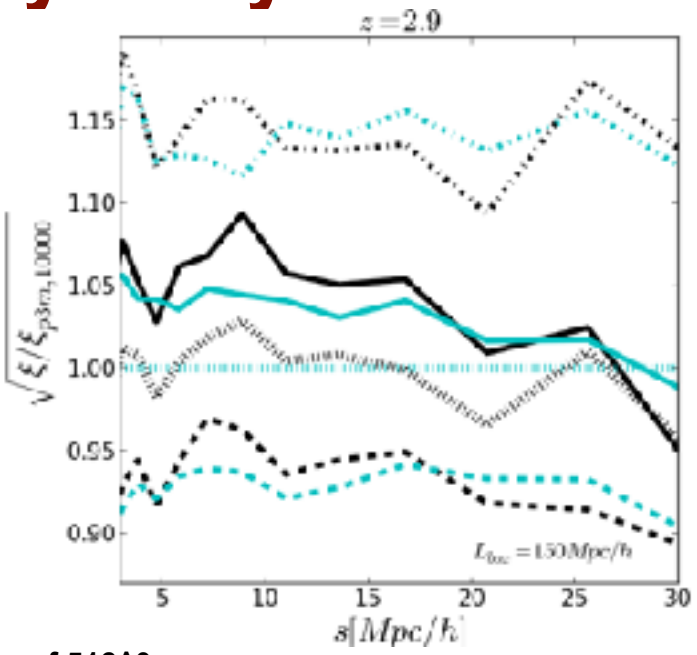


Bond@IAU
Jun 2014

Alvarez, Bond, Hajian, Stein, Emberson 2013

BIAS & 2-point clustering of halos is understood numerically & analytically: move via L1PT + L2PT

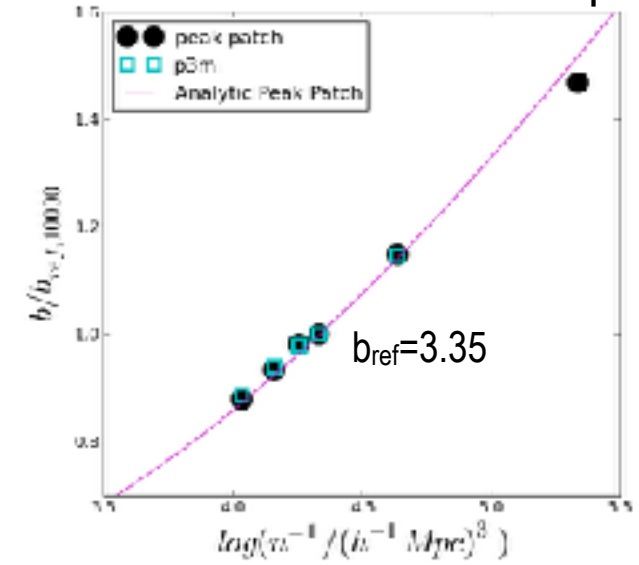


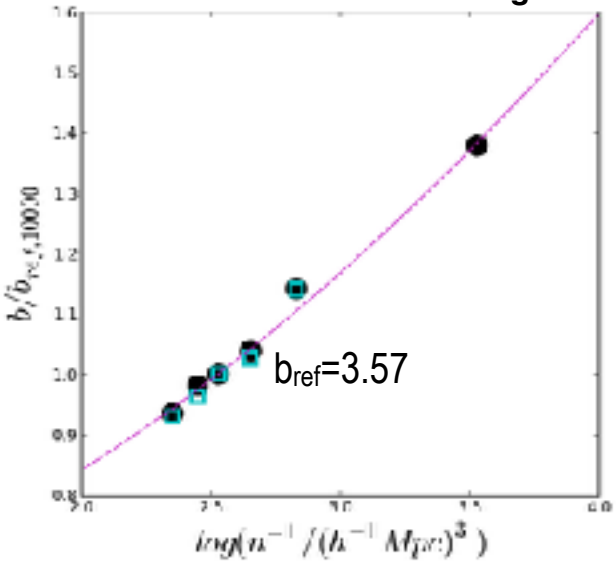


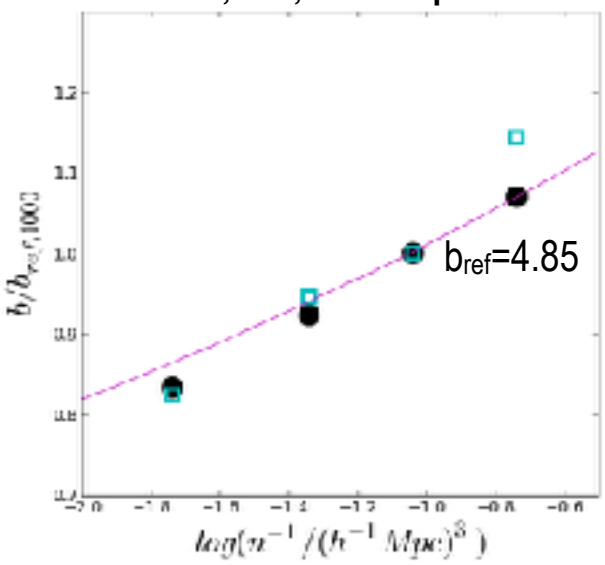
Bond@IAU
Jun 2014

Alvarez, Bahmanyer, Bond, Hajian 2014

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







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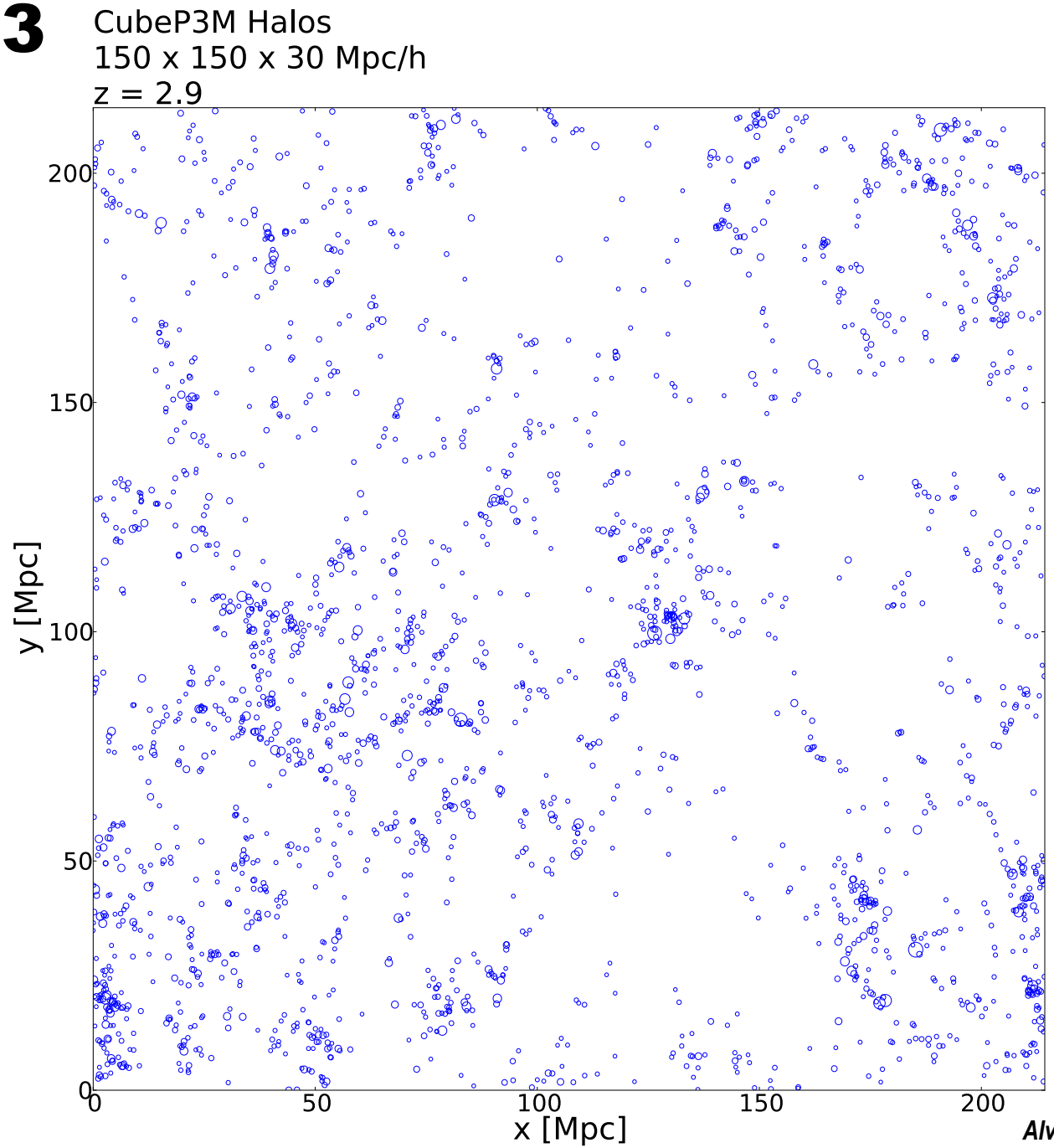
z~3



Application to HI, CO, CIB, …

Bond@Cornell
Gold Lectures
April 2014
George Stein
Summer Student
=> Senior Thesis
=> grad student

Alvarez, Bond, Hajian, Stein, Emberson 2013

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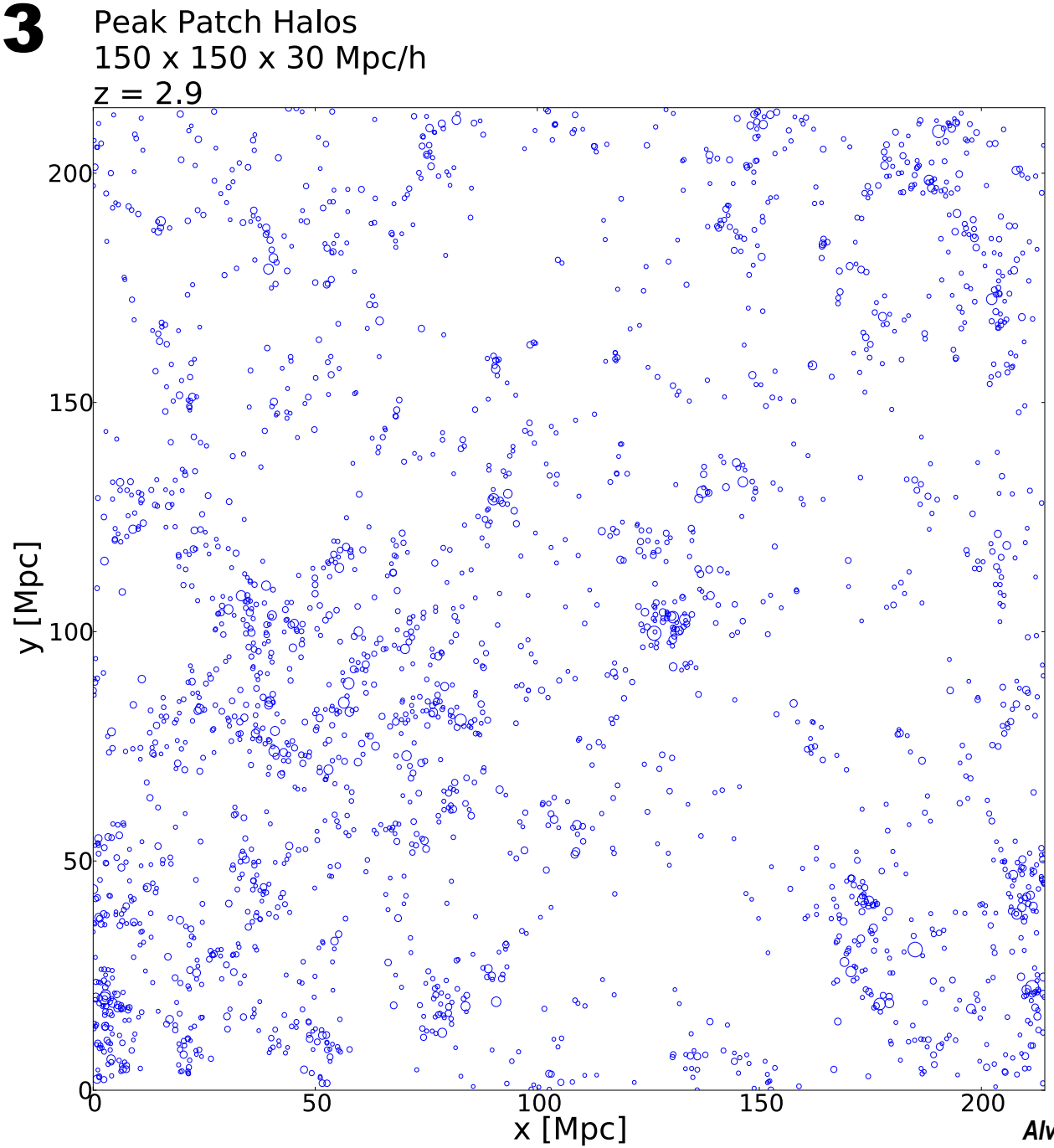

1LPT

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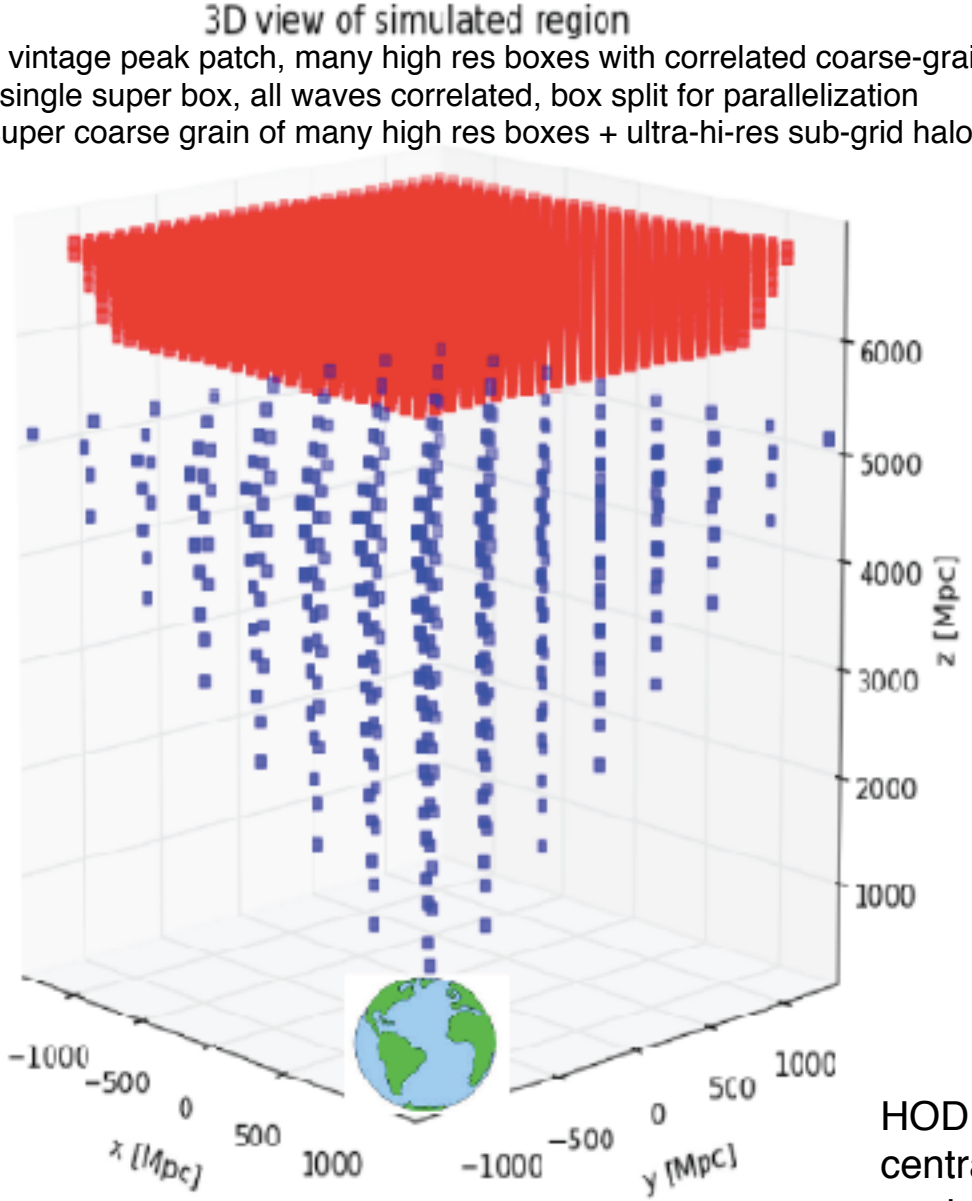
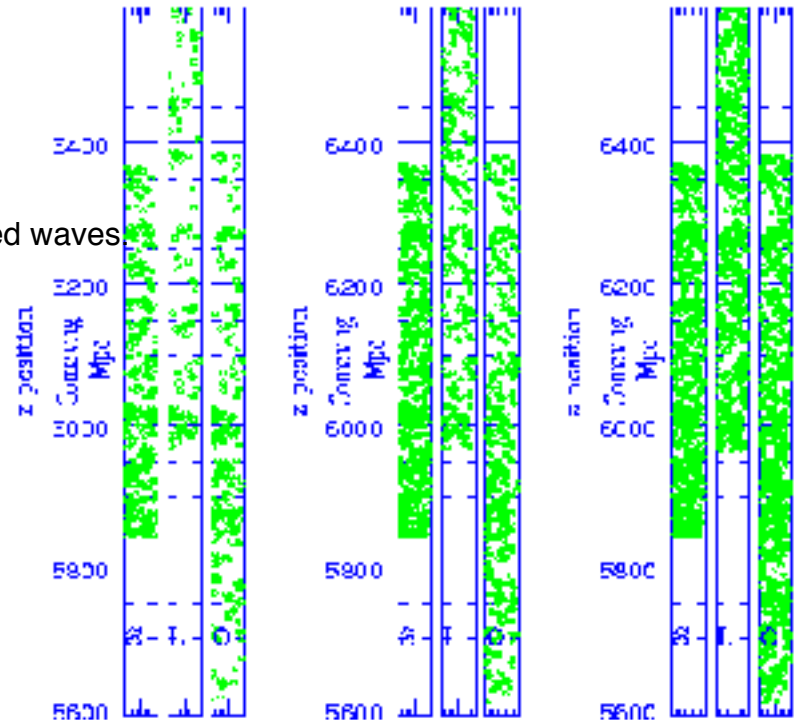
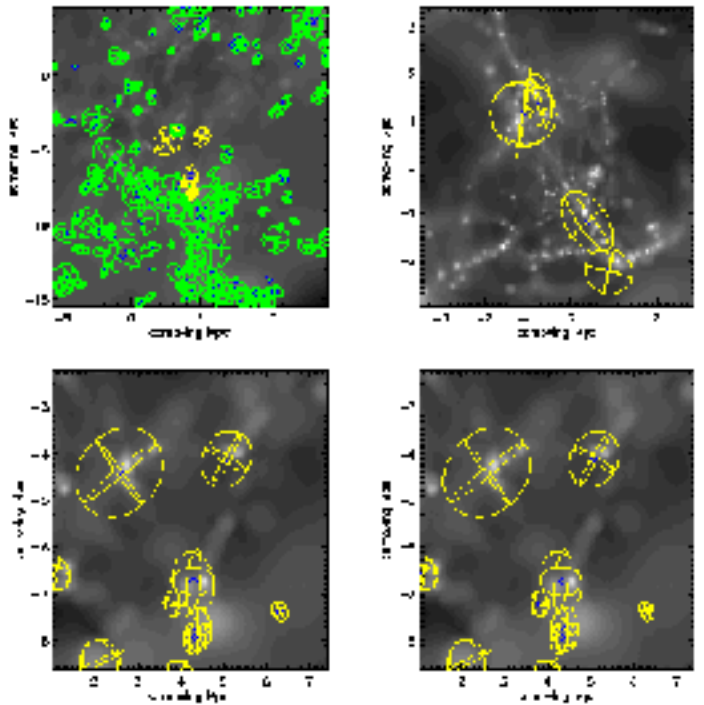
early **Application to CO (400 sqdeg) 6400 boxes to tile, only 10 Mpc thick for illustration, but z=2.5-3.5, 640 CPU cores SciNet, took 4 hrs**



THEN vintage peak patch, many high res boxes with correlated coarse-grained waves
NOW single super box, all waves correlated, box split for parallelization
TBD super coarse grain of many high res boxes + ultra-hi-res sub-grid halos





HOD
central
+satellites

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=> 2014 UBC Senior Thesis
=> 2015 grad student

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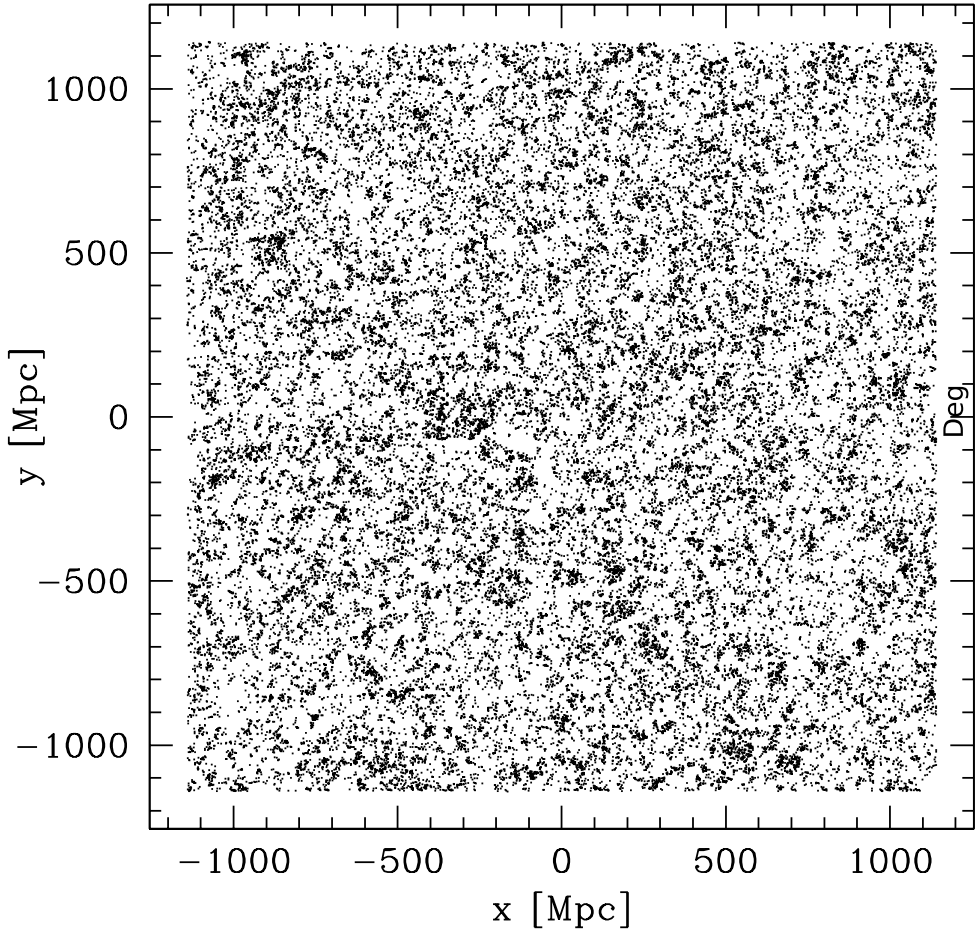
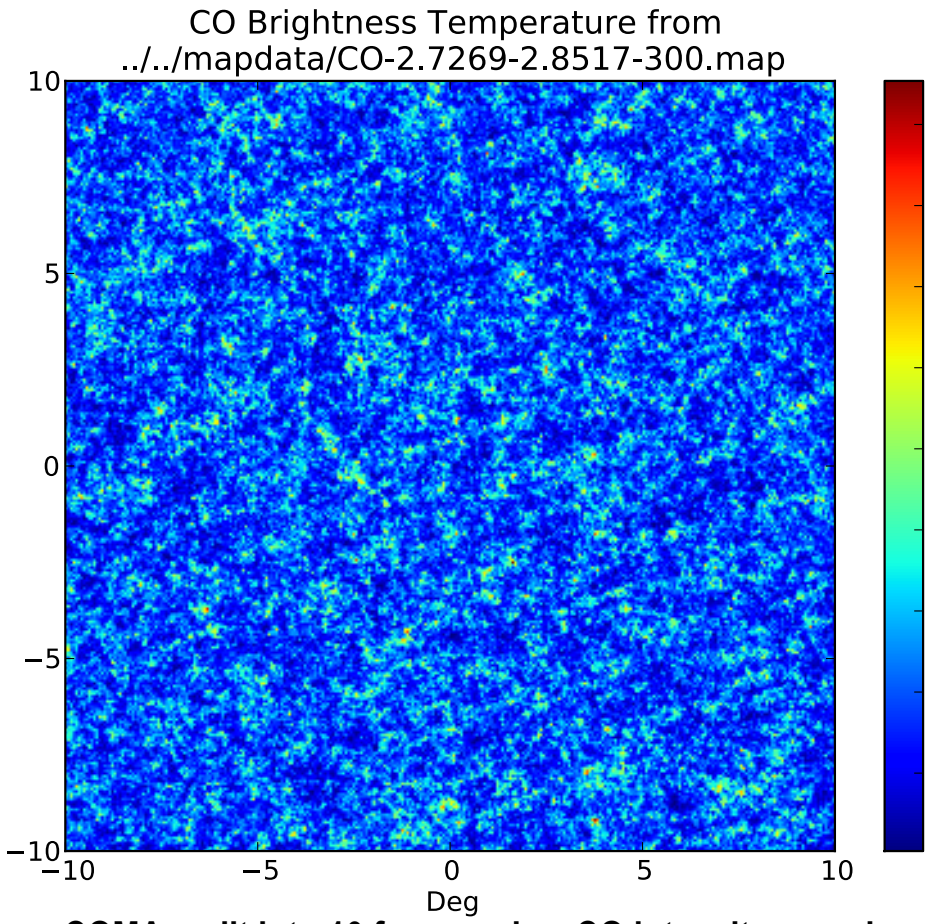


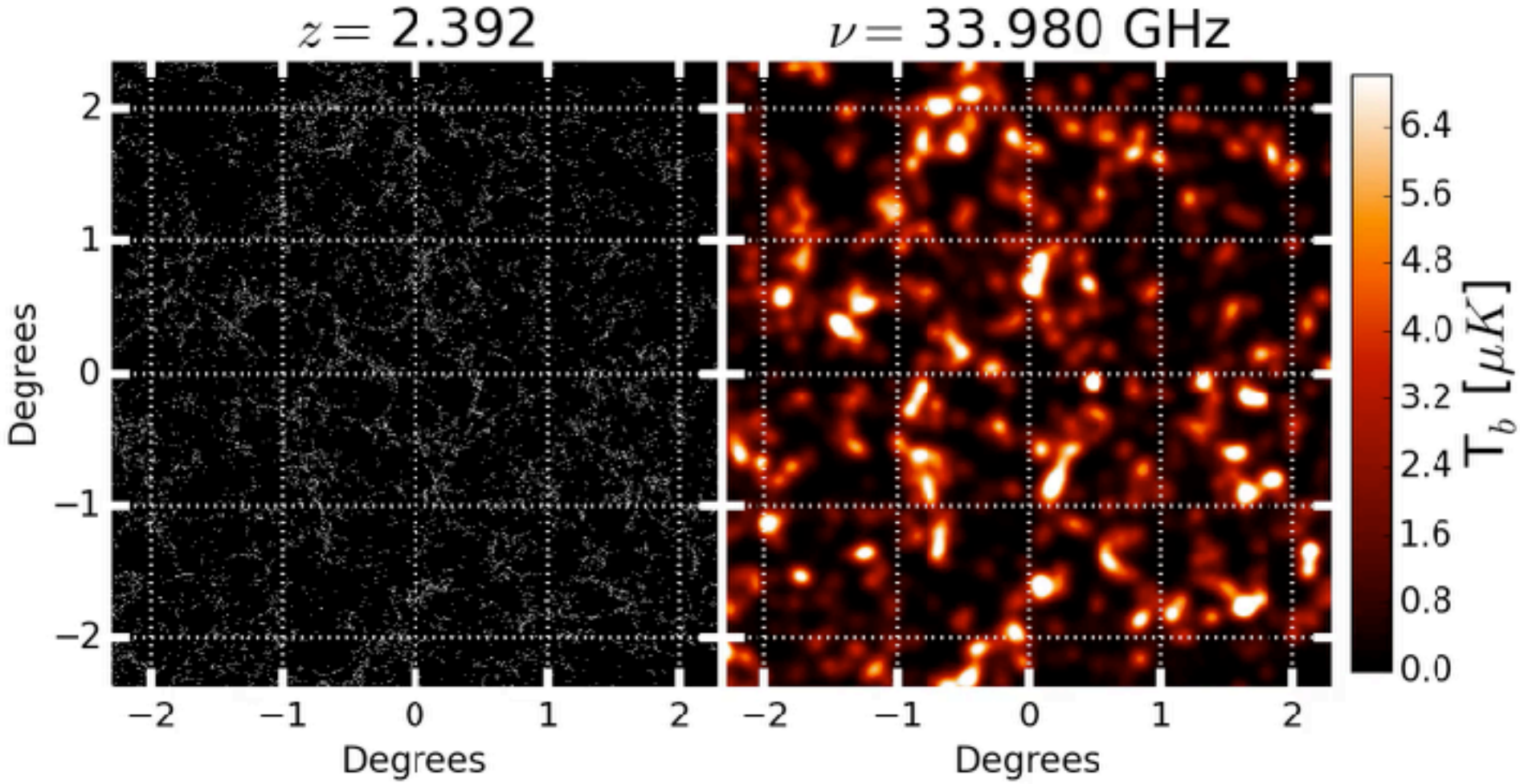


COMA, split into 10 frequencies, CO intensity mapping

Alvarez, Bond, Hajian, Stein, Emberson 2013

current **Application to CO (23 sq deg) 1 boxes to tile, 560 Mpc, 40 MHz moving smoothing window z=2.4-2.8, (2048)^3, M_halo,min =2.5(10) Msun, 512 CPU cores SciNet, time 15m**

cf. COMAP1 2.5 sq deg



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

Alvarez, Bond, Stein 2017

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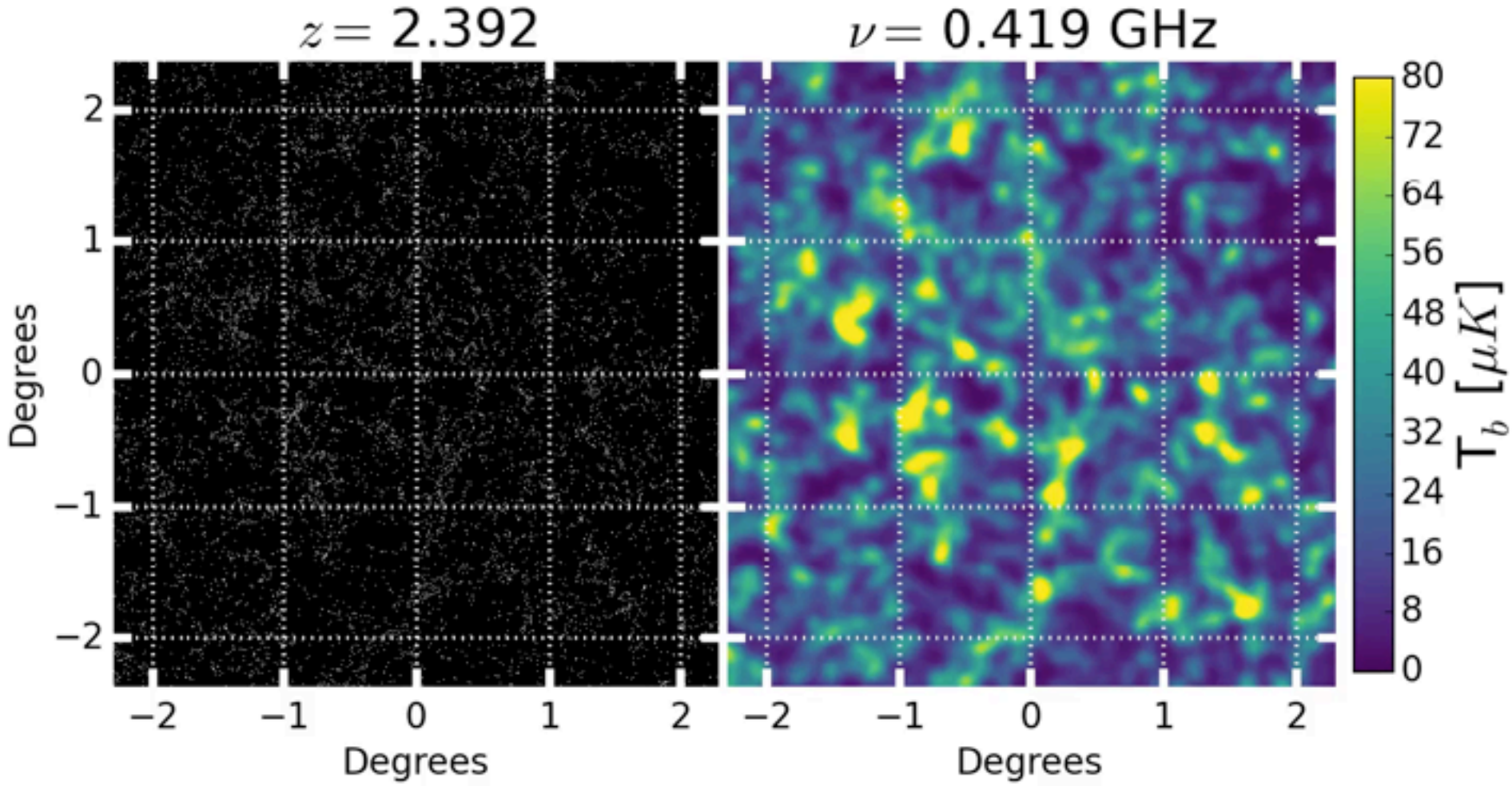
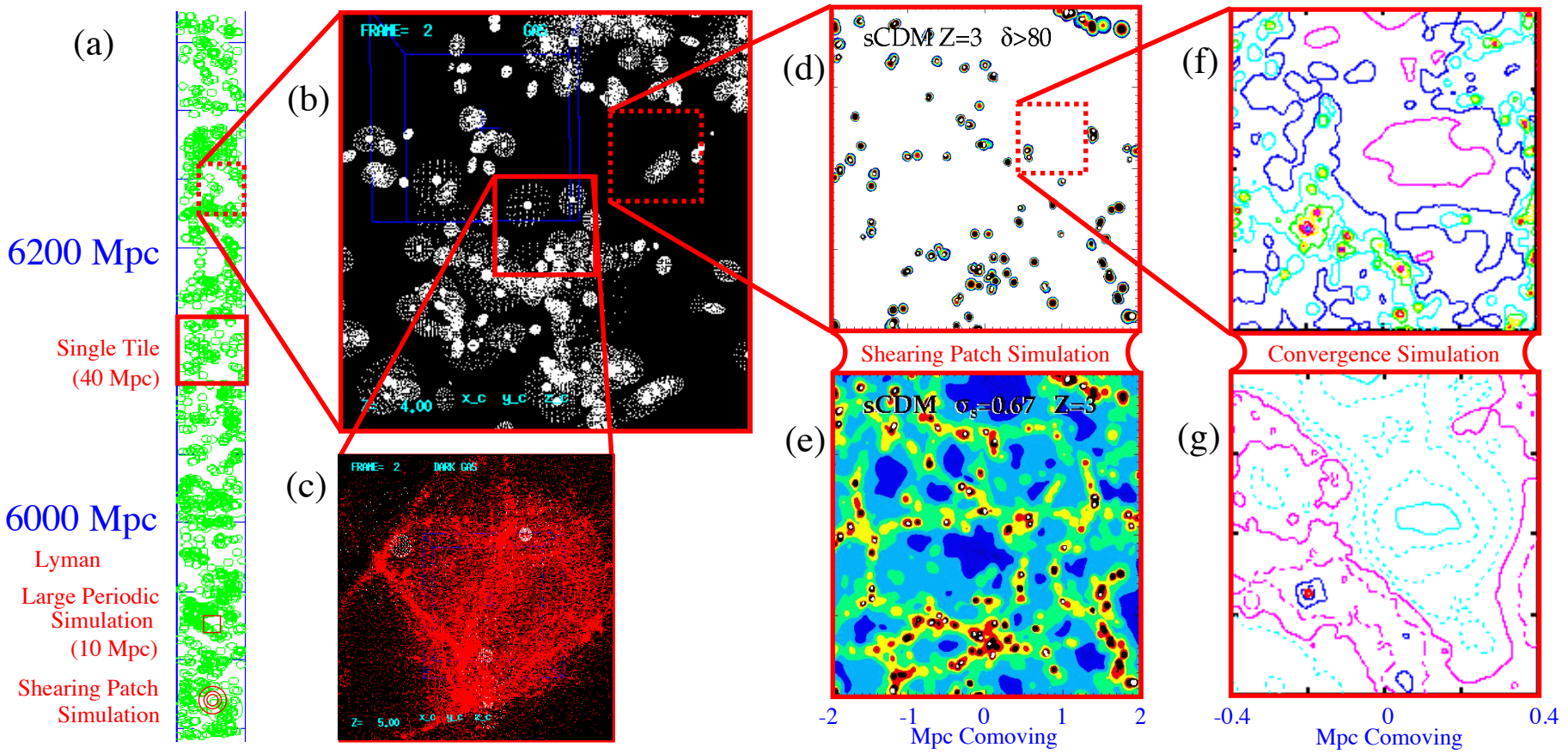
cf. CHIME z=0.8-2.5, ~(8 Gpc)^3



HI map, processed like COMAP 1024 frequencies, 6' fwhm cf. 60' CHIME

Alvarez, Bond, Stein 2017



ultra high res hydro sims e.g., by FIRE

constrain to get galaxy ensemble

need enough res to converge with feedback

measure HI, CO, .. susceptibilties to feed into peak-patches
given a halo of mass Mc what is the mean-field HI, CO response

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

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*

$q=M_{tot},M_{dm},M_{gas},PV,V_E,K_{dm},S,S_{conf}\ N_{HI}\ L_{CO}\ L_{opt}\ L_{IR}\ L_X\ Y_X\ Y_{SZ}$

Intensity Mapping susceptibilities HI, CO, CII via measurement:
in ***high res gas sims*** *e.g., stacked* ***FIRE or*** *stacked* ***observations (Xcorr)***

CIB

Planck XXX (2014) CIB halo model
shallow "GNFW" with c=1.0 *+-.2*
Planck 2015 XXIII tSZxCIB

kSZ

BBPS 2011 gas sims with feedback

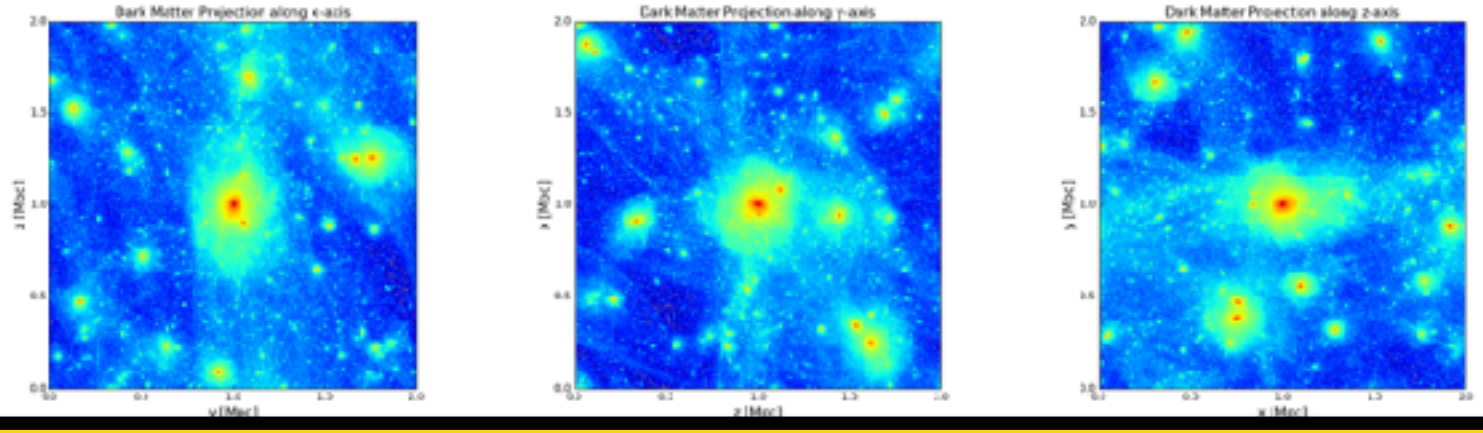
tSZ *stacked*
BBPS 2011
cf. Planck PUPPY
via stacking

CMASS Manera et al. 2012

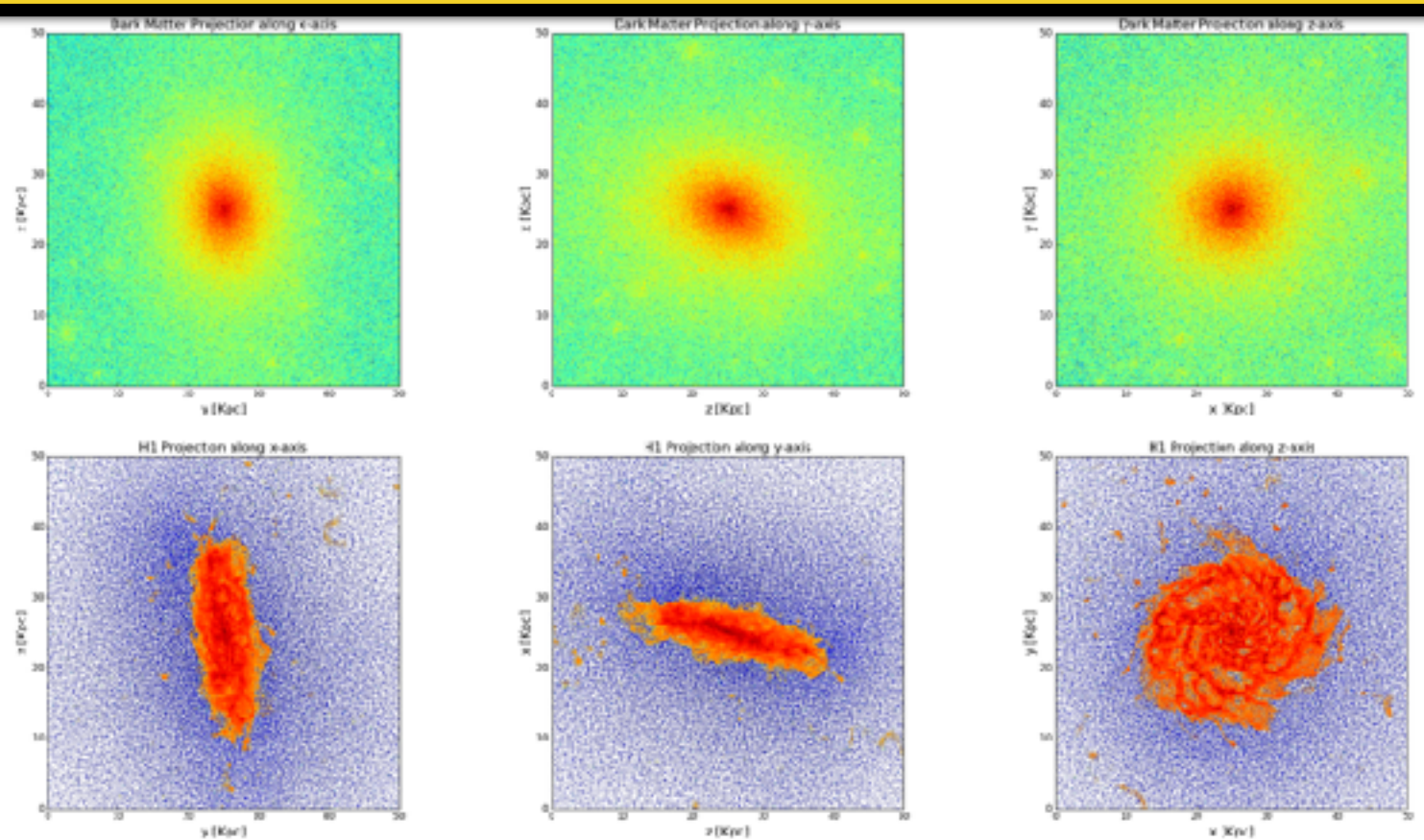
Optical

z = 0.0

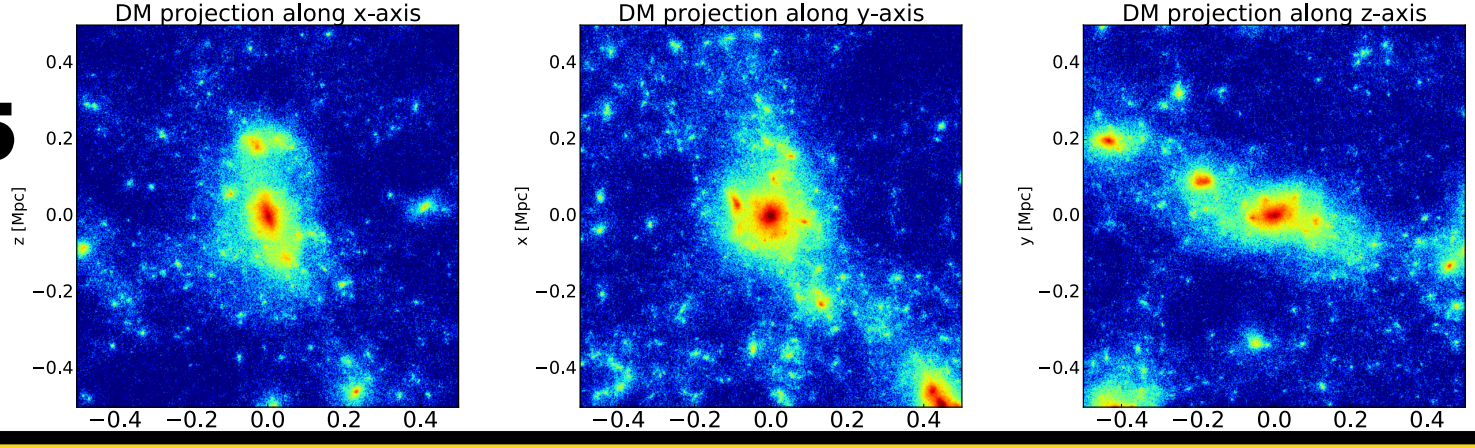
HI only a little GBT data to anchor susceptibilities on, now trying FIRE sims



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

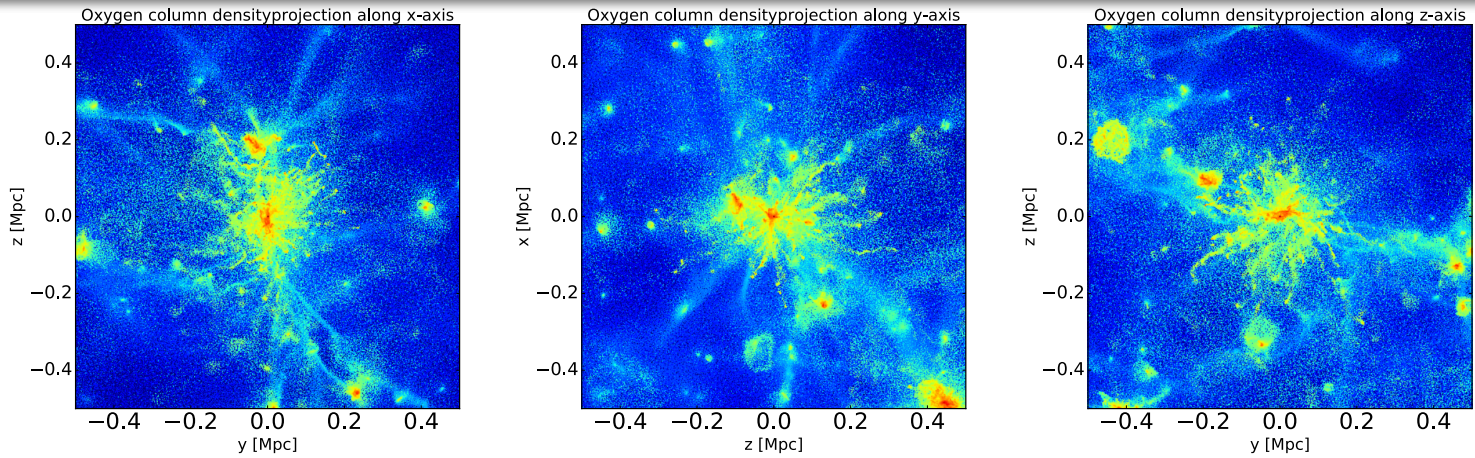


z = 2.5

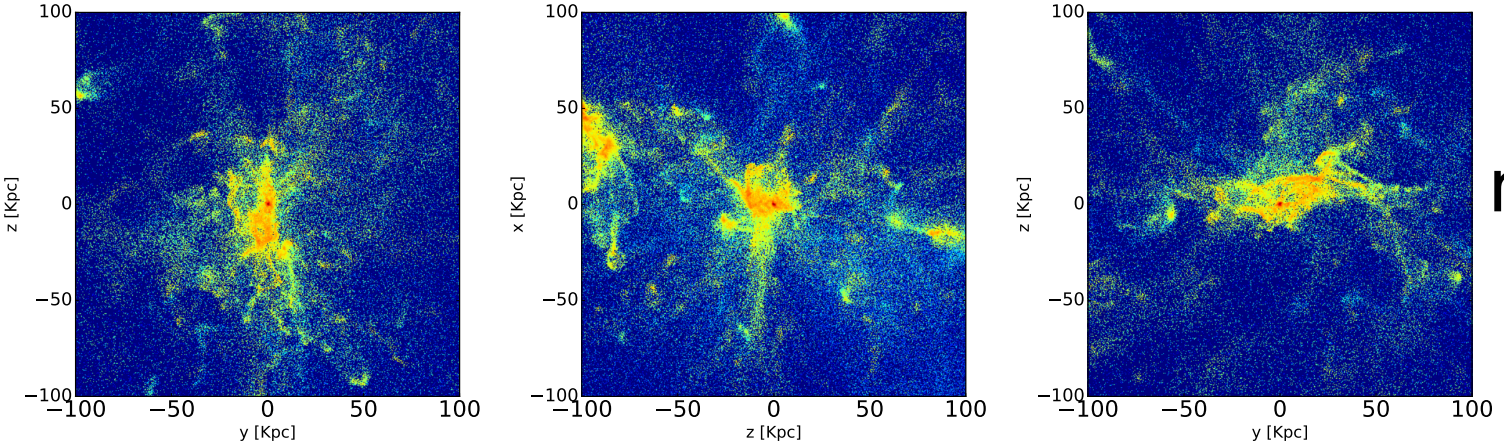


n_HI

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



n_O



n_O

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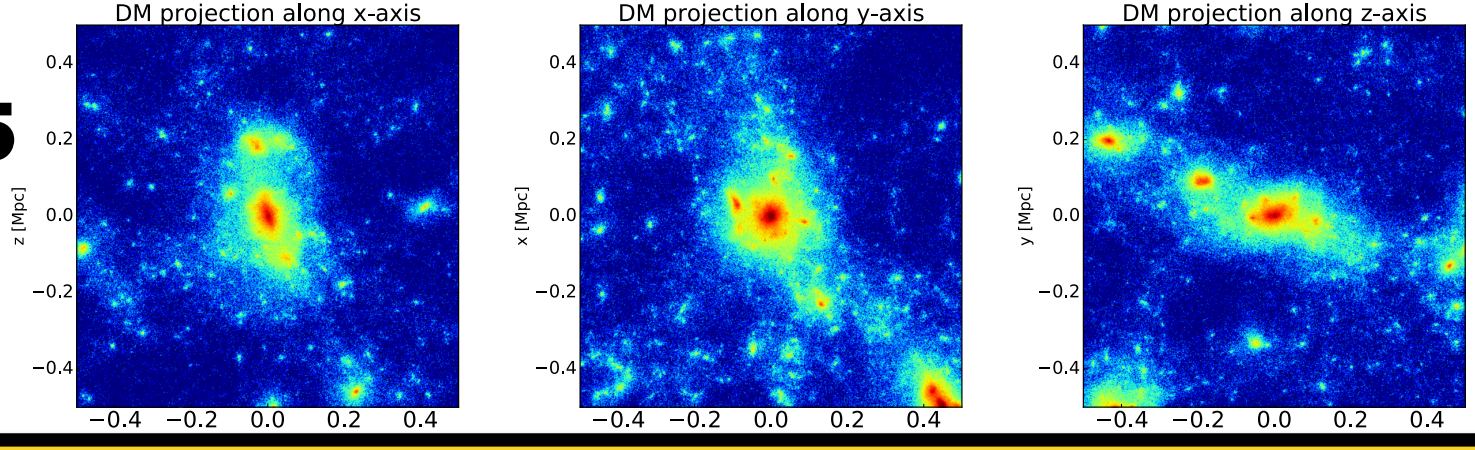

DM

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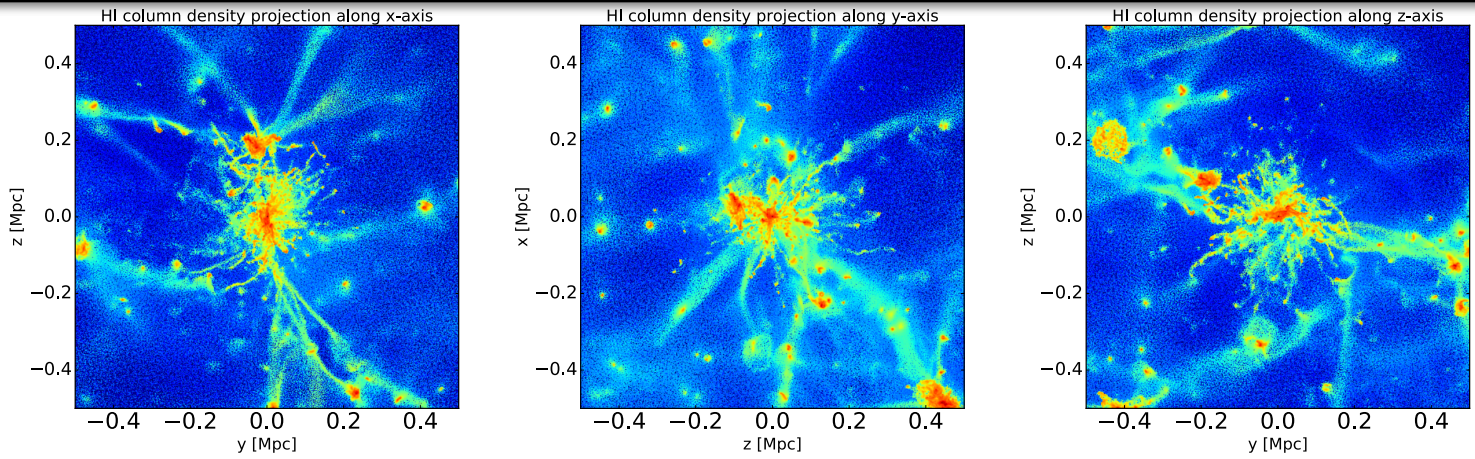
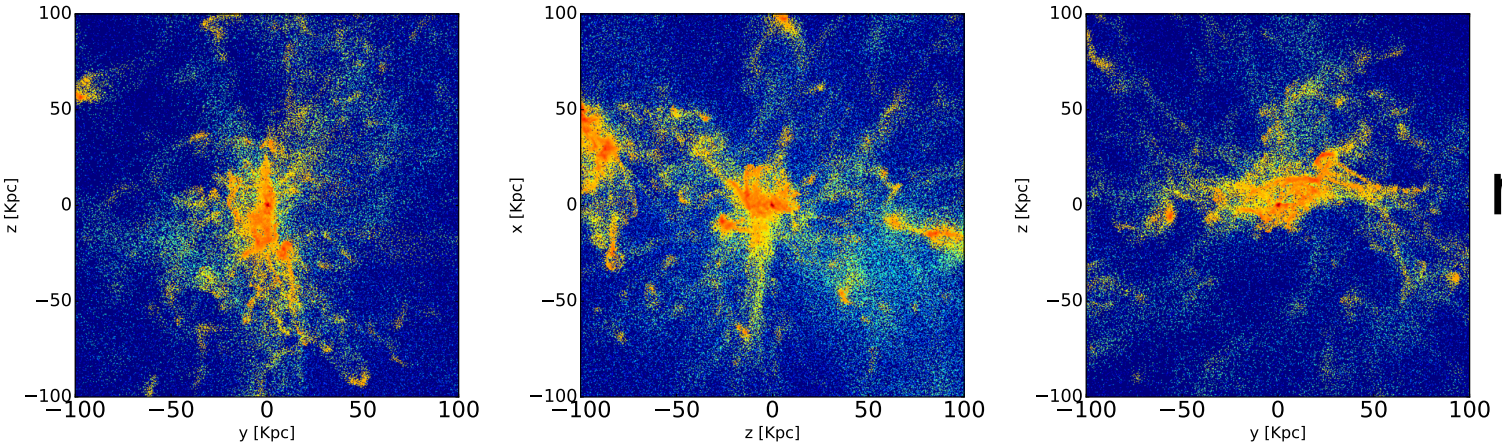


n_HI

~10^23 /cm^2



n_HI

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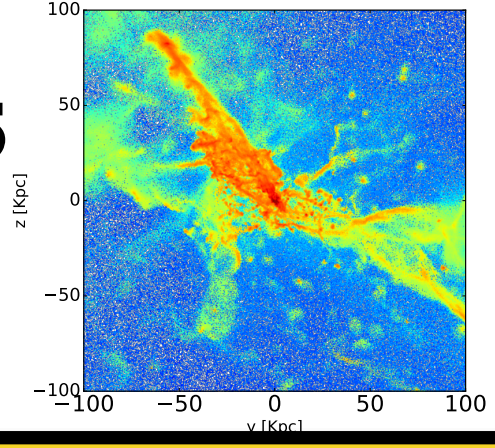

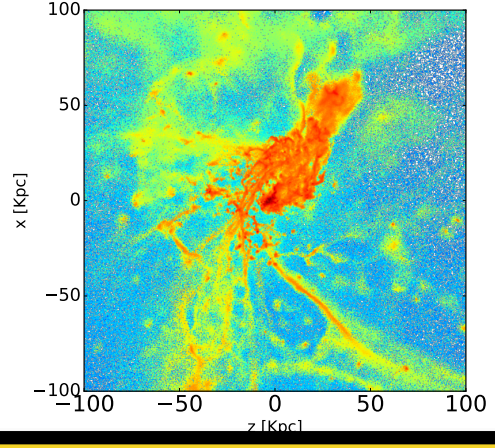

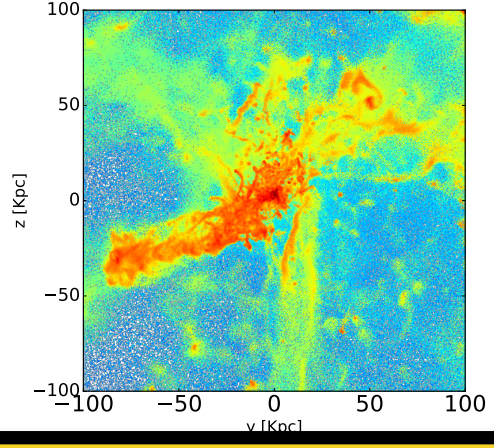

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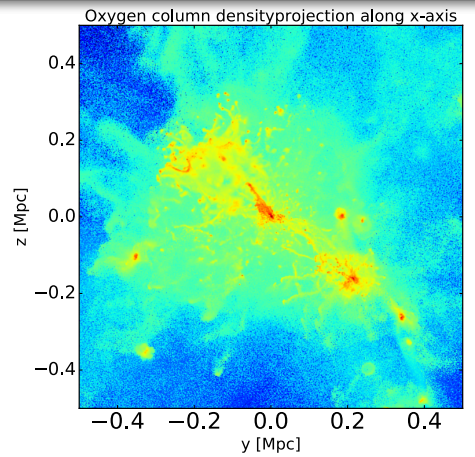
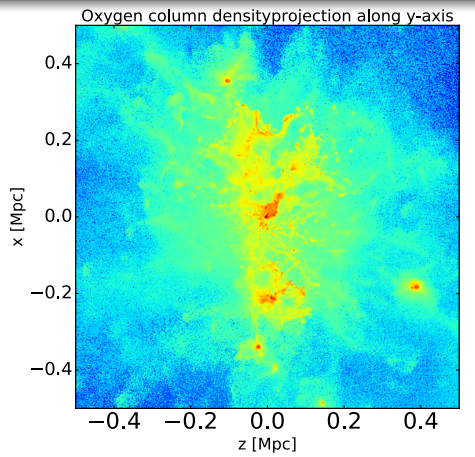
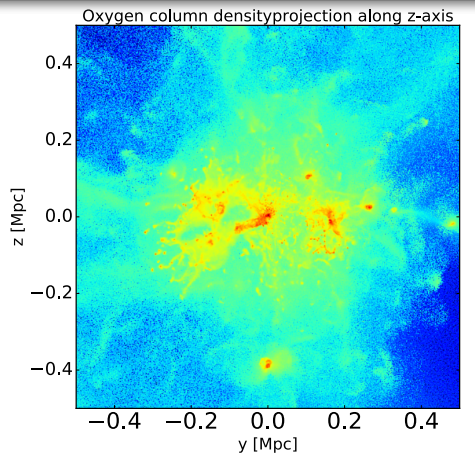
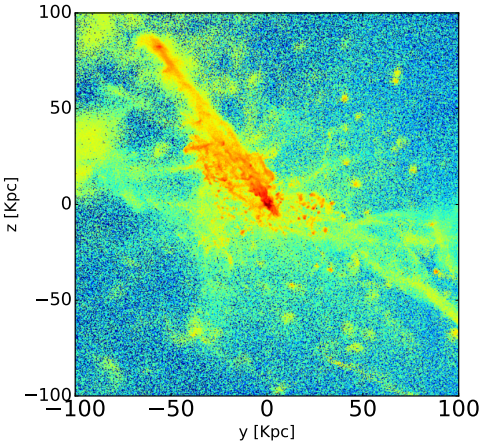
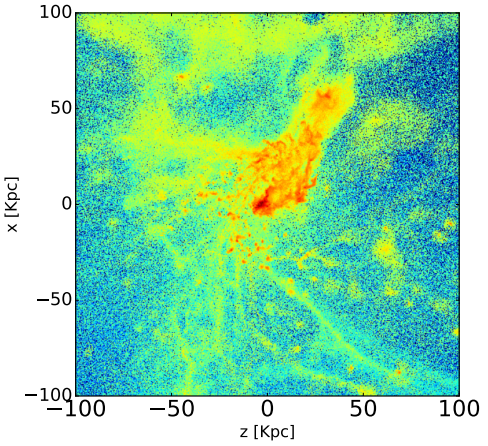


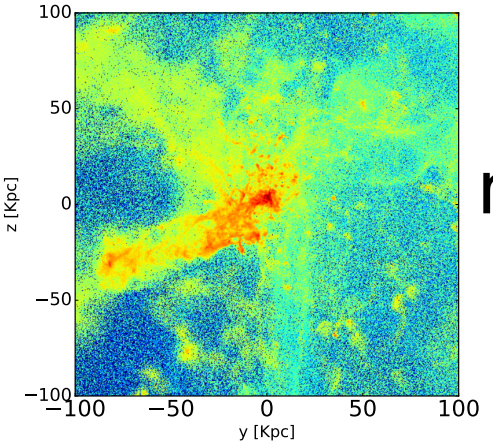




n_O







n_O

END