HI deficiency in high-mass halos and bias

Catherine Cress, Ron-Ryan Baatjes, Eliab Malefahlo (University of South Africa)

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University of South Africa

Over 400 000 students across globe
Successful distance learning model for over 150 years!
Affordable education

Consider not all Astronomy students want to become professors

Define tomorrow.

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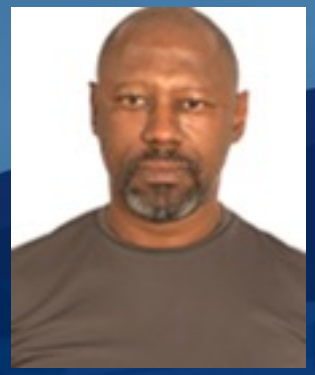
UNISA Astronomy - New Centre for Astrophysics and Space Science (UCASS)

James Chibueze
Radio & mm techniques
Starformation, Clusters

Catherine Cress
Galaxies & Cosmology

Sthabile Kolwa
AGN, radio surveys



Zolile Mguda
ML applications

Amos Kubeka
Theoretical Cosmology

Many Honorary Profs/Associates
8 postdocs, over 20 graduate students, growing fast

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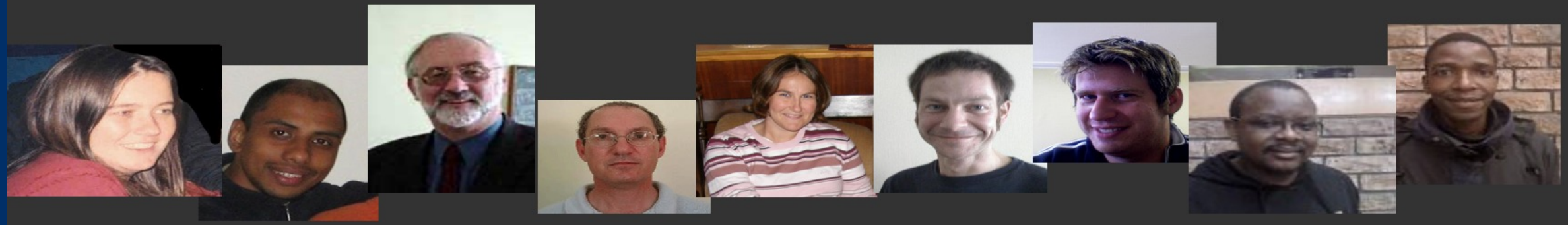
2007 UKZN: Why Join Us?

4. We care about students

   * undergraduates and outreach:
     over 70 outreach talks
     RA funding for >30 undergrads, vacation jobs
     Computational Physics Program

   * postgrads – 13 postgrads, travel opportunities, NASSP

Astro People at UWC 2011



Prof Cress Mhlahlo

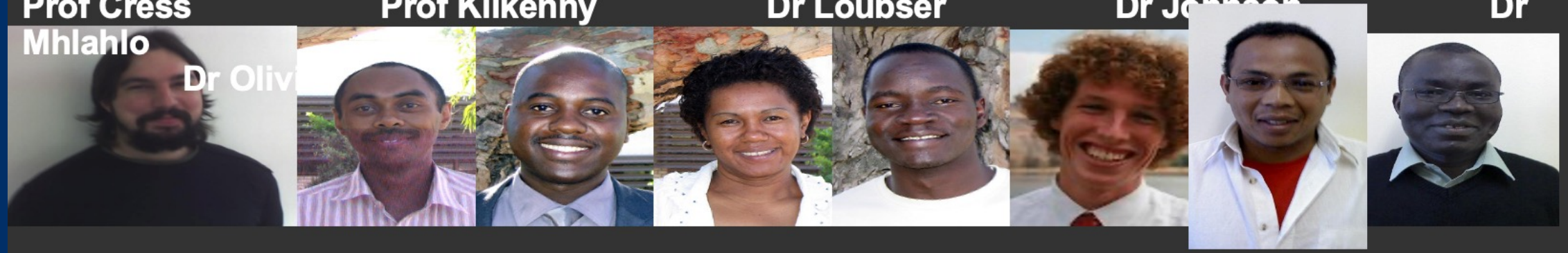
Dr Olivi

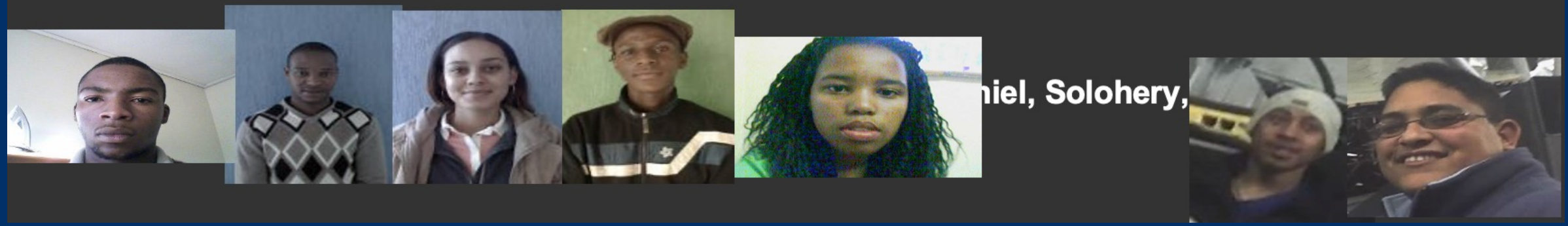
Prof Kilkenny

Dr Loubser

Dr Johnson

Dr

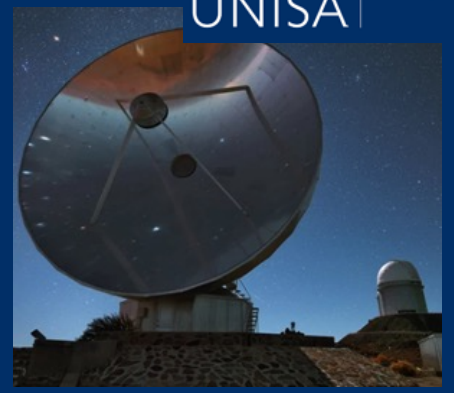




niel, Solohery,

Telescopes in Southern Africa

MeerKAT/SKA Radio Telescope



African mm telescope

HESS (Namibia)
(gamma)

SALT Optical Telescope
10m class

HIRAX
(BAO HI intensity mapping)

HERA
(EOR)

The Square Kilometer Array (~2006)

radio telescope for 2020+
1000's of dishes over 1500km+
1 km^2 collecting area
0.1-22GHz?
US$1 billion+
17 countries

will be built in S. Africa or Australia

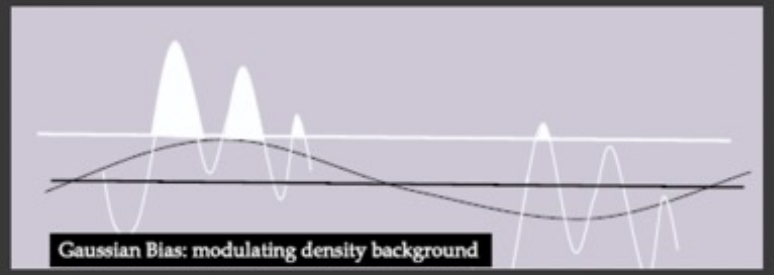
SA demonstrator projects:
KAT, meerKAT, BigKAT
> R800million committed

Other demonstrators:
xNTD, ATA, LOFAR, etc

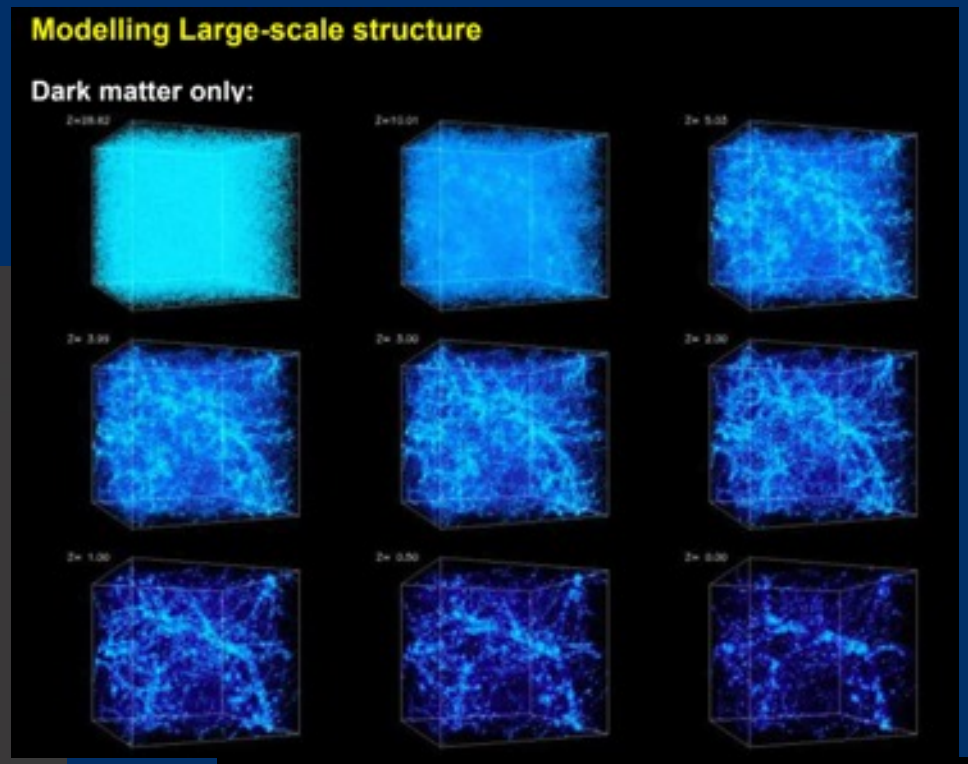
What is bias?

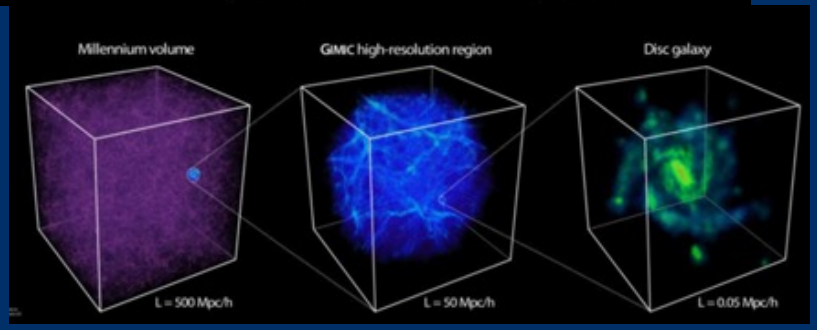
Relationship between dark matter and luminous matter

$$\xi_g(r) = b^2(r)\xi_m(r)$$



Kaiser 1987





Clustering Concepts

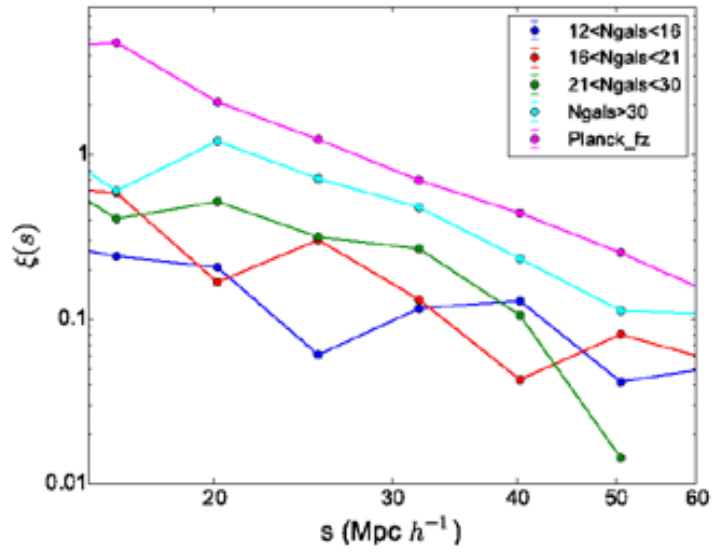
$$\delta = (\rho(x) - \bar{\rho})/\bar{\rho}$$

$$\delta_g \approx b\delta_{DM}$$

$$\delta_g(\mathbf{k}, z) = b(k, z)\delta_m(\mathbf{k}, z)$$

$$\xi(r, z) = b^2(\boxed{\text{K,}} \ z)\xi_{\rm DM}(r, z)$$

Clustering of SDSS clusters in richness bins vs clustering of Planck clusters



Richness Ngals=30 corresponds to M~1.5x10^{14} Msolar (Simet et al. 2016)

Tshililo, Cress & February

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HI bias

SKAbook from Carrucci 2020i

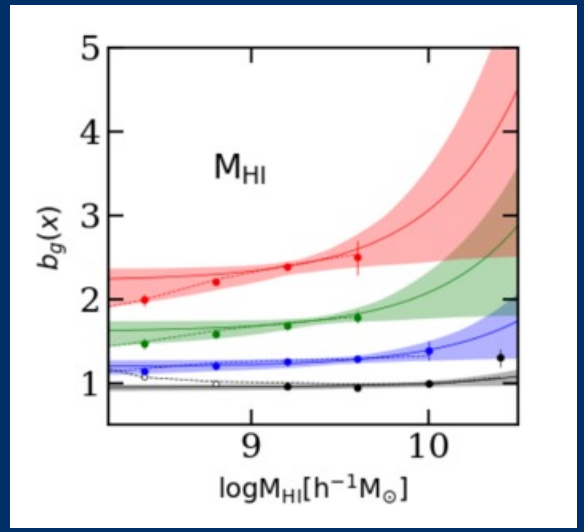
$$\frac{dN}{dz} = 10^{c_1} z^{c_2} \exp(-c_3 z)$$
$$b(z) = c_4 \exp(c_5 z)$$

$$b_{\rm HI}(z) = 0.3(1+z) + 0.5$$
$$\Omega_{\rm HI}(z) = 4.0(1+z)^{0.6} \times 10^{-4},$$

Jolicoeur et al, Cunnington, Villaescusa-Navarro et al

$$b_H(z) = b_{H0}\left(1 + 0.823\, z - 0.0546\, z^2\right) \quad \text{with fiducial value } b_{H0} = 0.842\,.$$

Pan et al 2020



$$b_g(x,z) = a + b(1+z)^e\,(1+\exp[(x-c)d])\,,$$

See also Sarkar et al
Penin et al

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HI depleted in clusters and groups

“One-sixth of the sample within the Virgo 5-degree core have lost more than 90 percent by mass of their original neutral hydrogen, and three quarters of the galaxies found within 2.5 degrees of M87 are H I poor by more than a factor of three.” Haynes & Giovanelli

Clusters and groups hold up to 10% of dark matter – in places where dark matter is densely clumped, very little HI to trace the dark matter

Bias is scale dependent

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HI simulations

(Villaescusa- Navarro 2018)

No turn-over at high-mass end?

Simulation box too small to sample groups/clusters

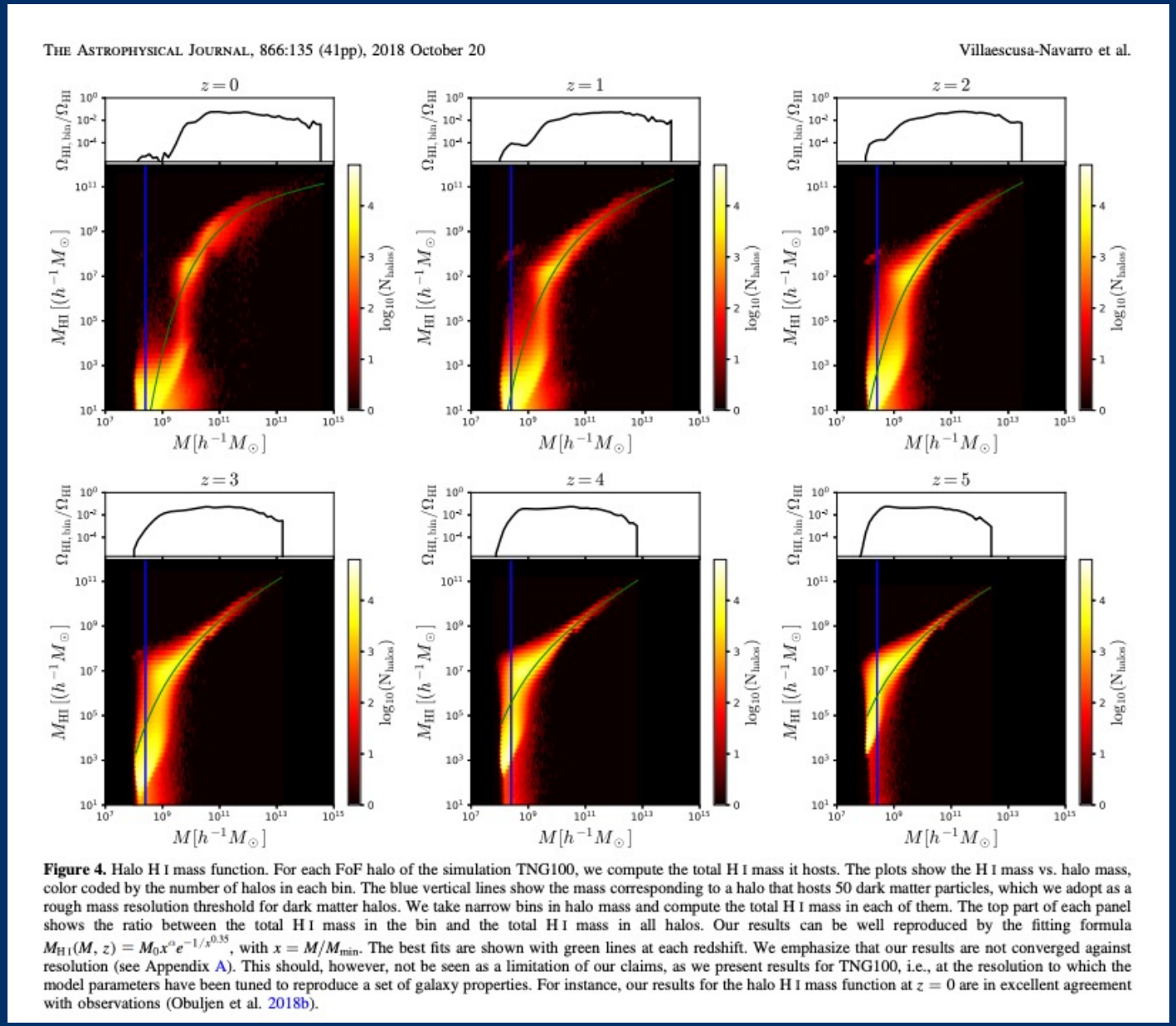

Figure 4. Halo H I mass function. For each FoF halo of the simulation TNG100, we compute the total H I mass it hosts. The plots show the H I mass vs. halo mass, color coded by the number of halos in each bin. The blue vertical lines show the mass corresponding to a halo that hosts 50 dark matter particles, which we adopt as a rough mass resolution threshold for dark matter halos. We take narrow bins in halo mass and compute the total H I mass in each of them. The top part of each panel shows the ratio between the total H I mass in the bin and the total H I mass in all halos. Our results can be well reproduced by the fitting formula $M_{\rm H\,I}(M, z) = M_0 x^{\alpha} e^{-1/x^{0.35}}$, with $x = M/M_{\rm min}$. The best fits are shown with green lines at each redshift. We emphasize that our results are not converged against resolution (see Appendix A). This should, however, not be seen as a limitation of our claims, as we present results for TNG100, i.e., at the resolution to which the model parameters have been tuned to reproduce a set of galaxy properties. For instance, our results for the halo H I mass function at $z = 0$ are in excellent agreement with observations (Obuljen et al. 2018b).

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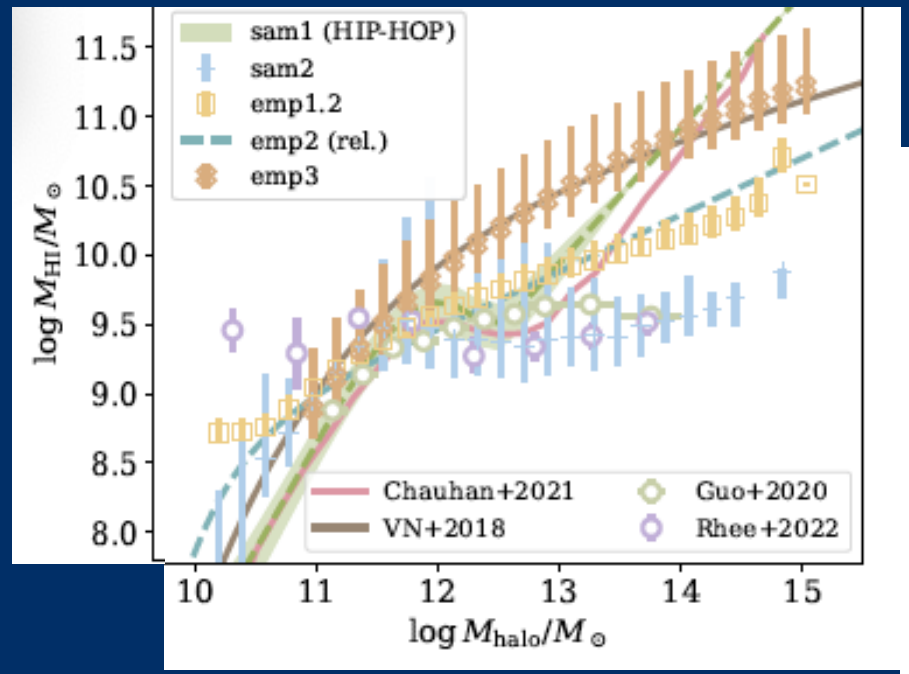
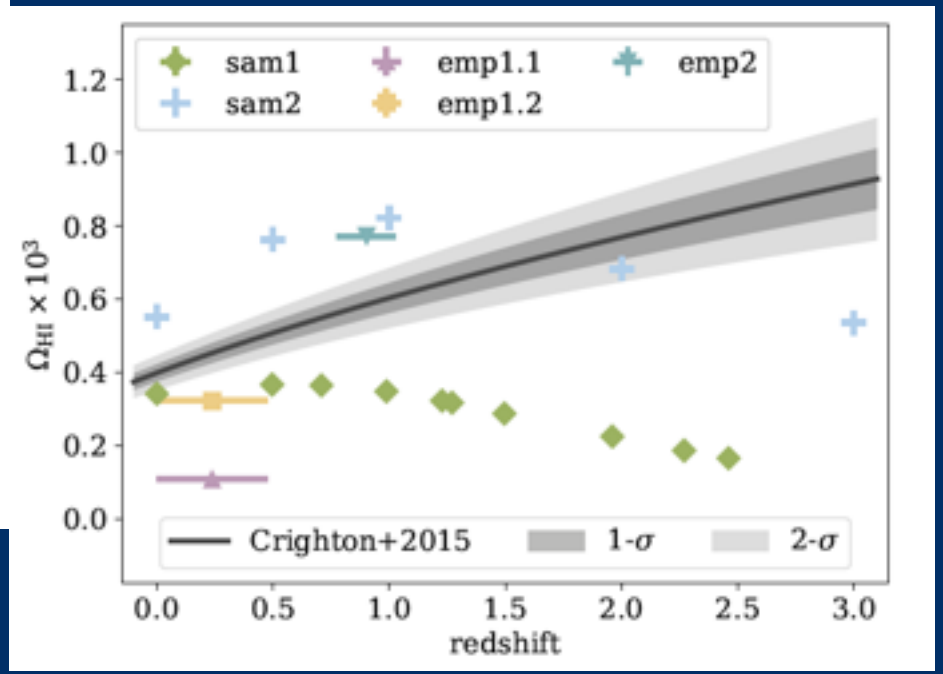
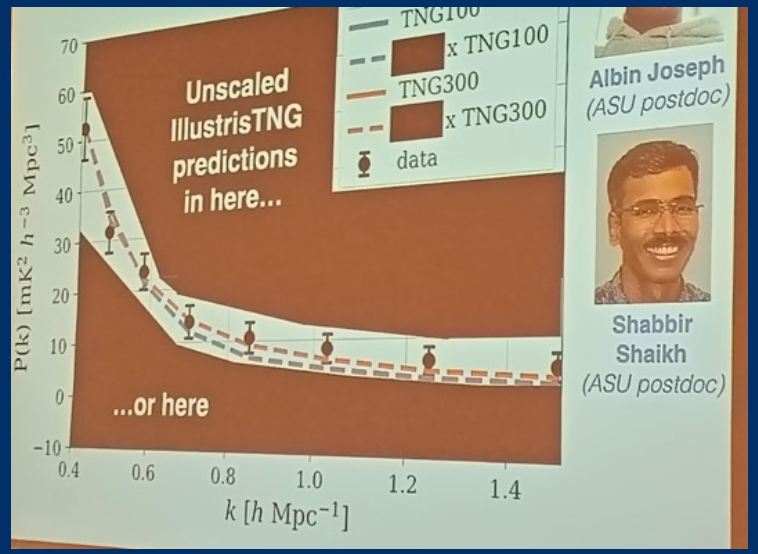
HI simulations

Ronconi et al 2026 SKAbook

Huge variation in predicted HI-H_{halo} relation
And in $\Omega_{HI}(z)$







Albin Joseph
(ASU postdoc)

Shabbir Shaikh
(ASU postdoc)

Foreman talk

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HI depleted in clusters and groups

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Bias is scale dependent

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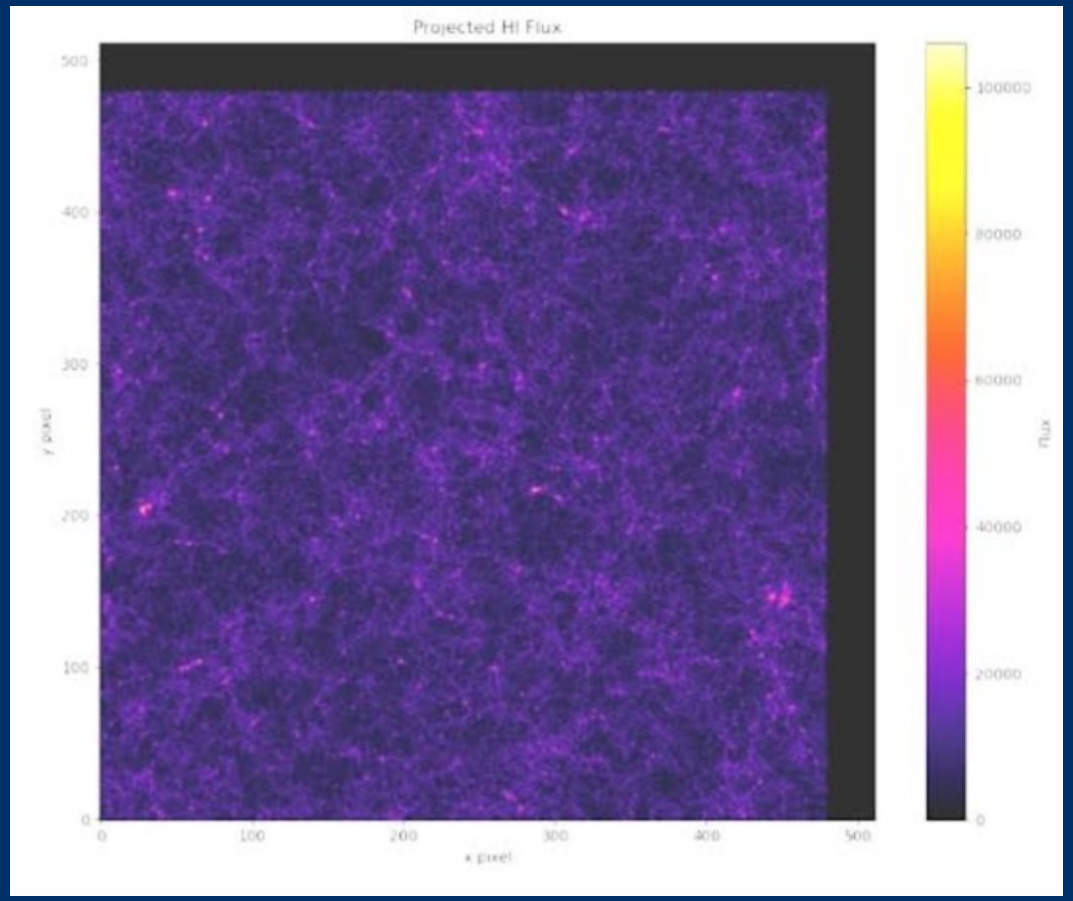
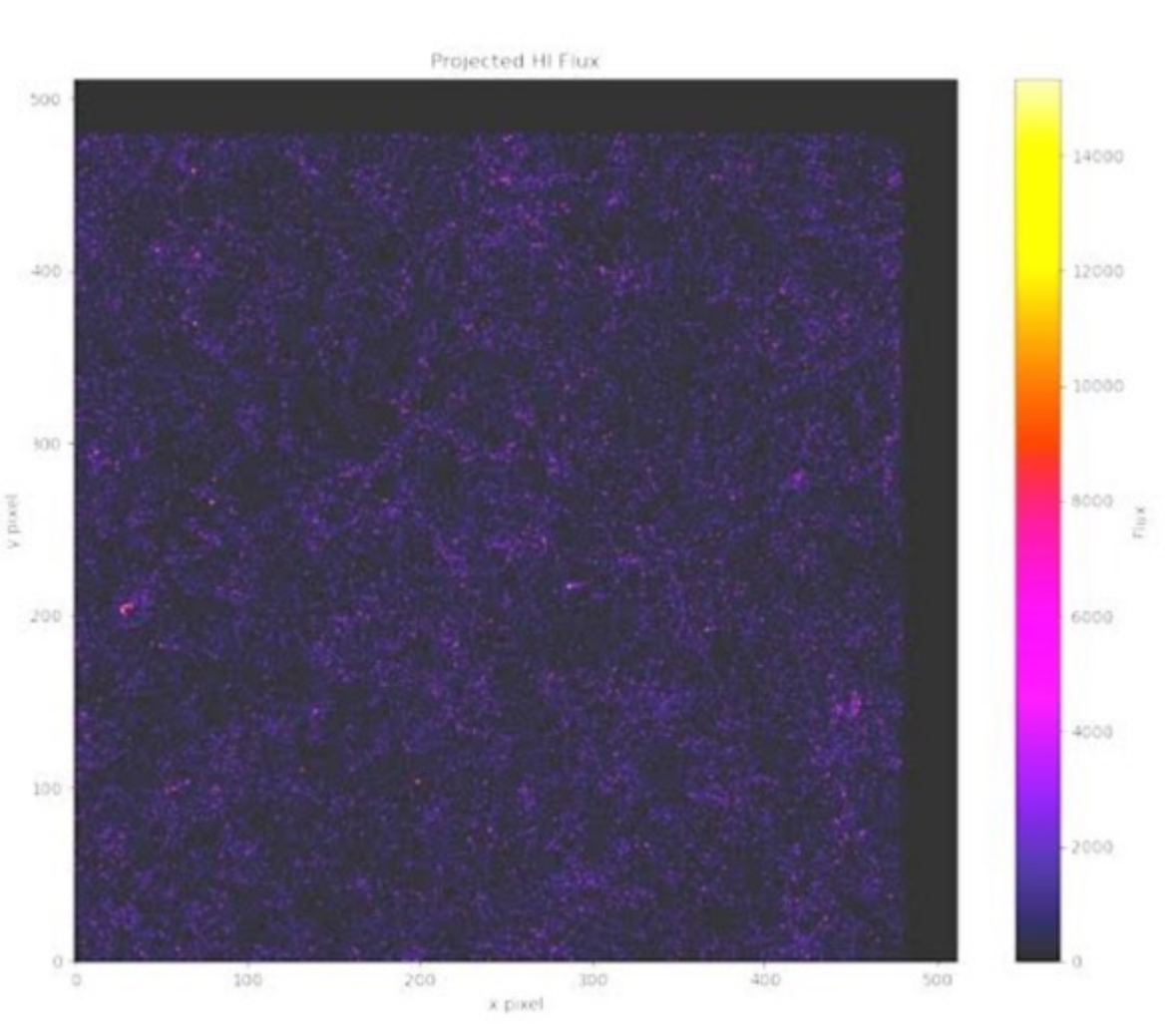
Simulate HI using N-body + M_{HI}-$M_{DM\ Halo}$ relation

HI flux projection – all halos



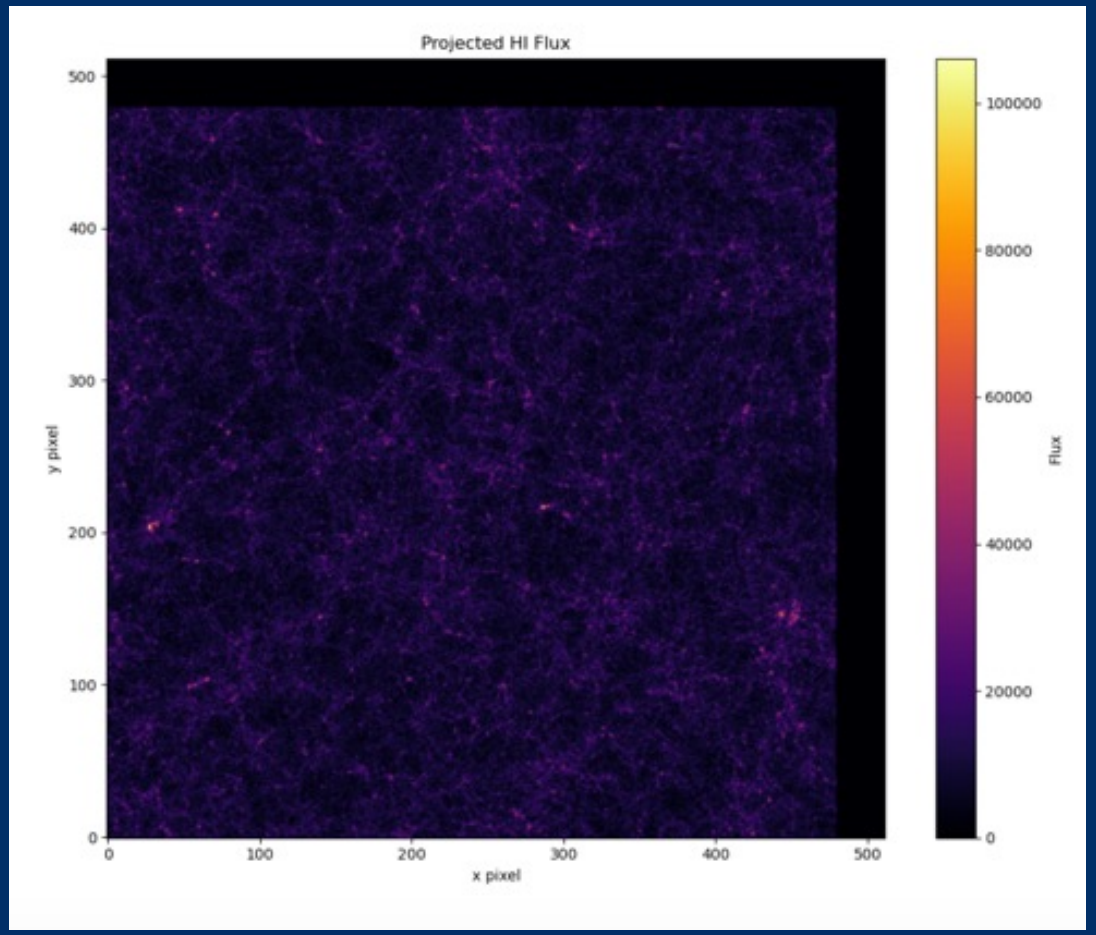
Simulate HI using N-body + M_{HI}-$M_{DM\ Halo}$ relation

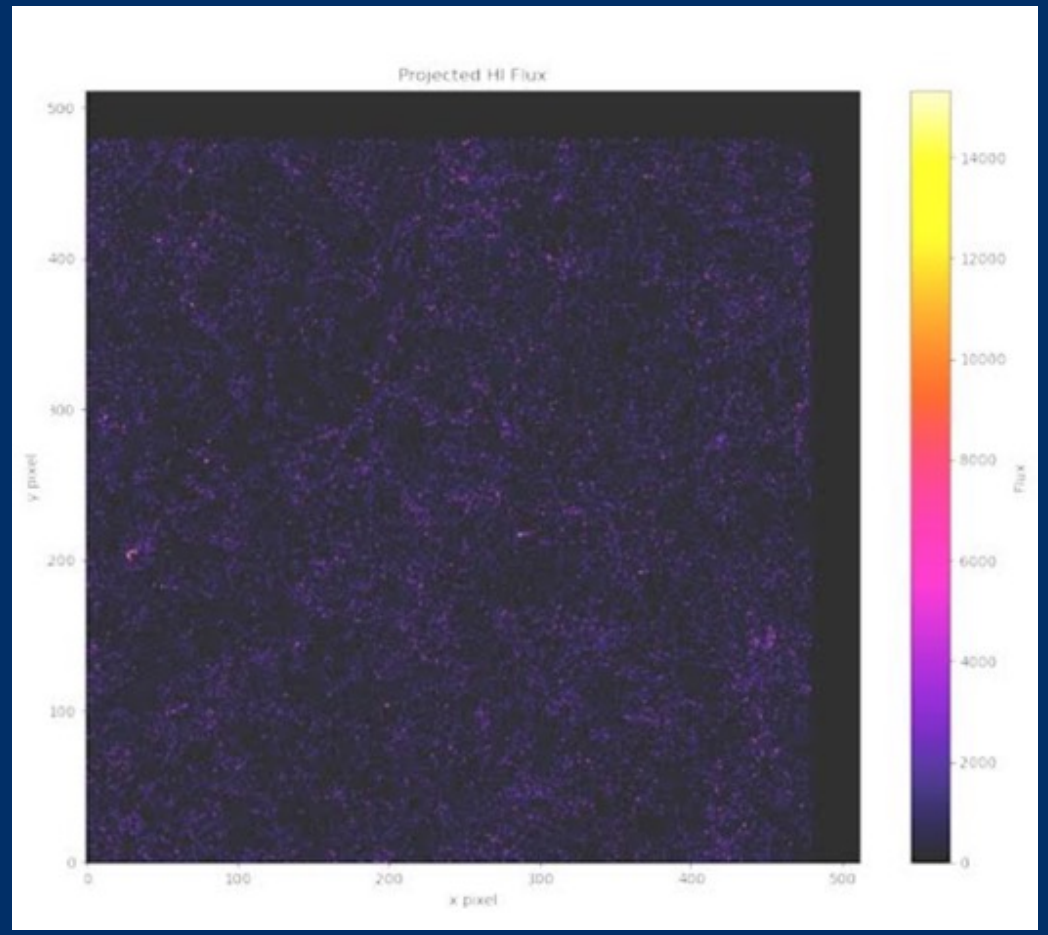
HI flux projection (for cluster and group sized halos)



Simulate HI using N-body + M_{HI}-$M_{DM\ Halo}$ relation

(Can also use HI outputs in semi-analytical models)

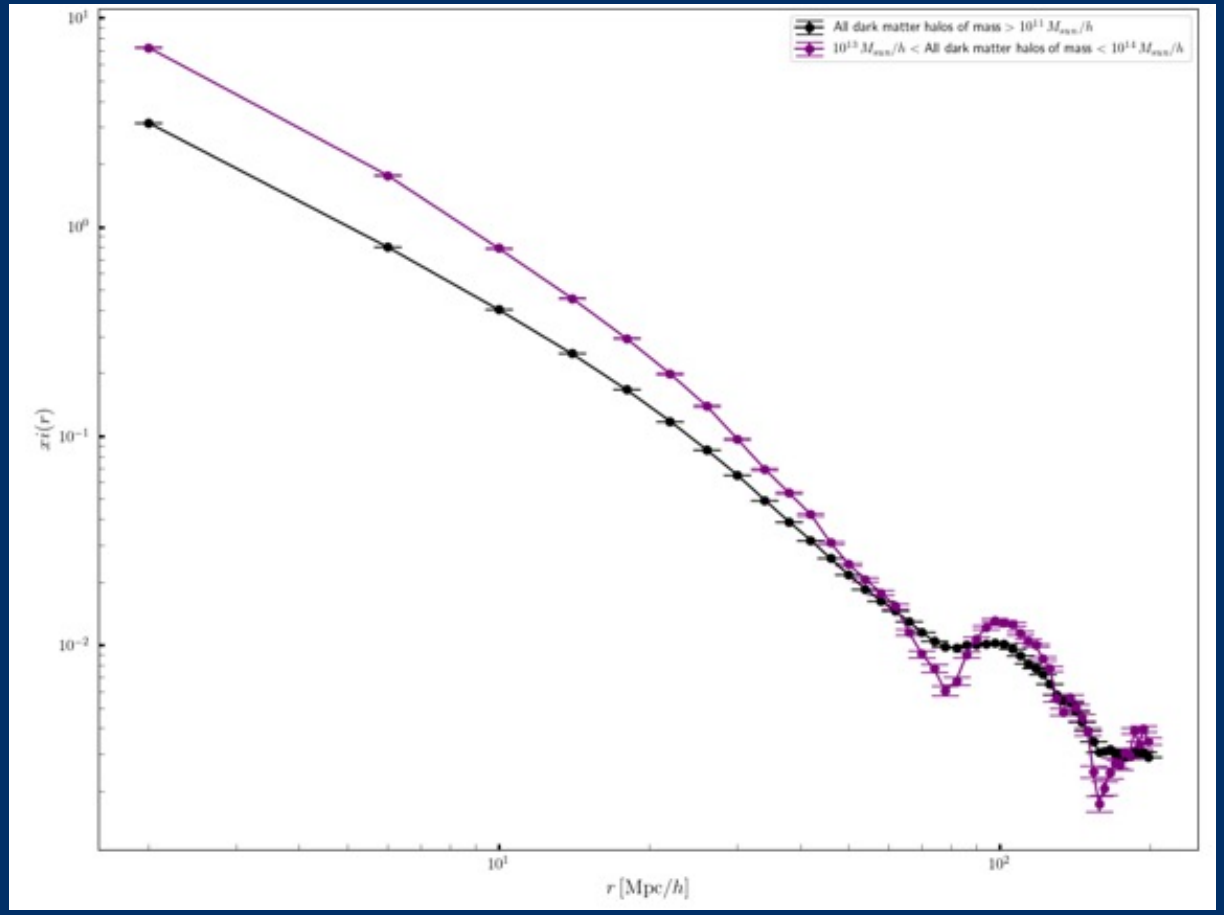




Simulate HI using N-body + M_{HI}-$M_{DM\ Halo}$ relation

BAO experiments:

What happens when you are missing tracers of most massive halos



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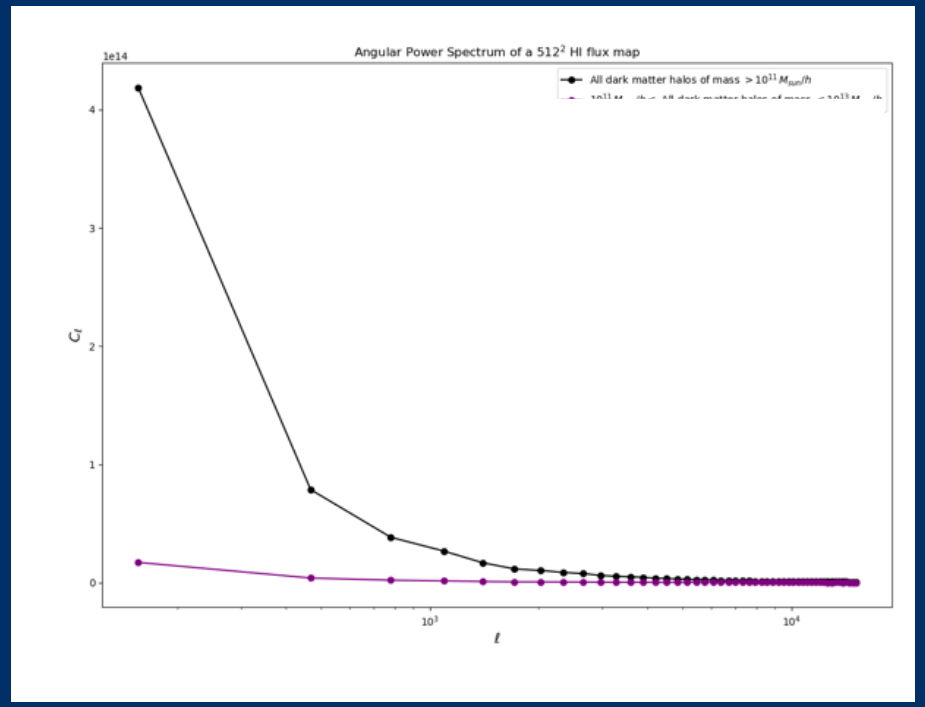
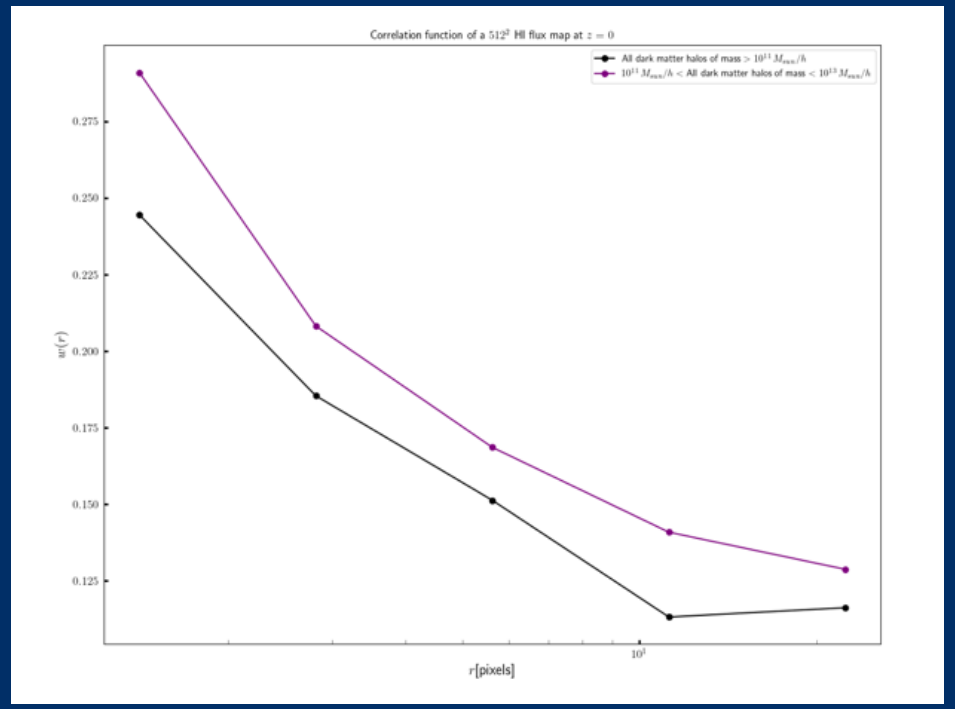
Simulate HI using N-body + M_{HI}-$M_{DM\ Halo}$ relation

Angular correlation





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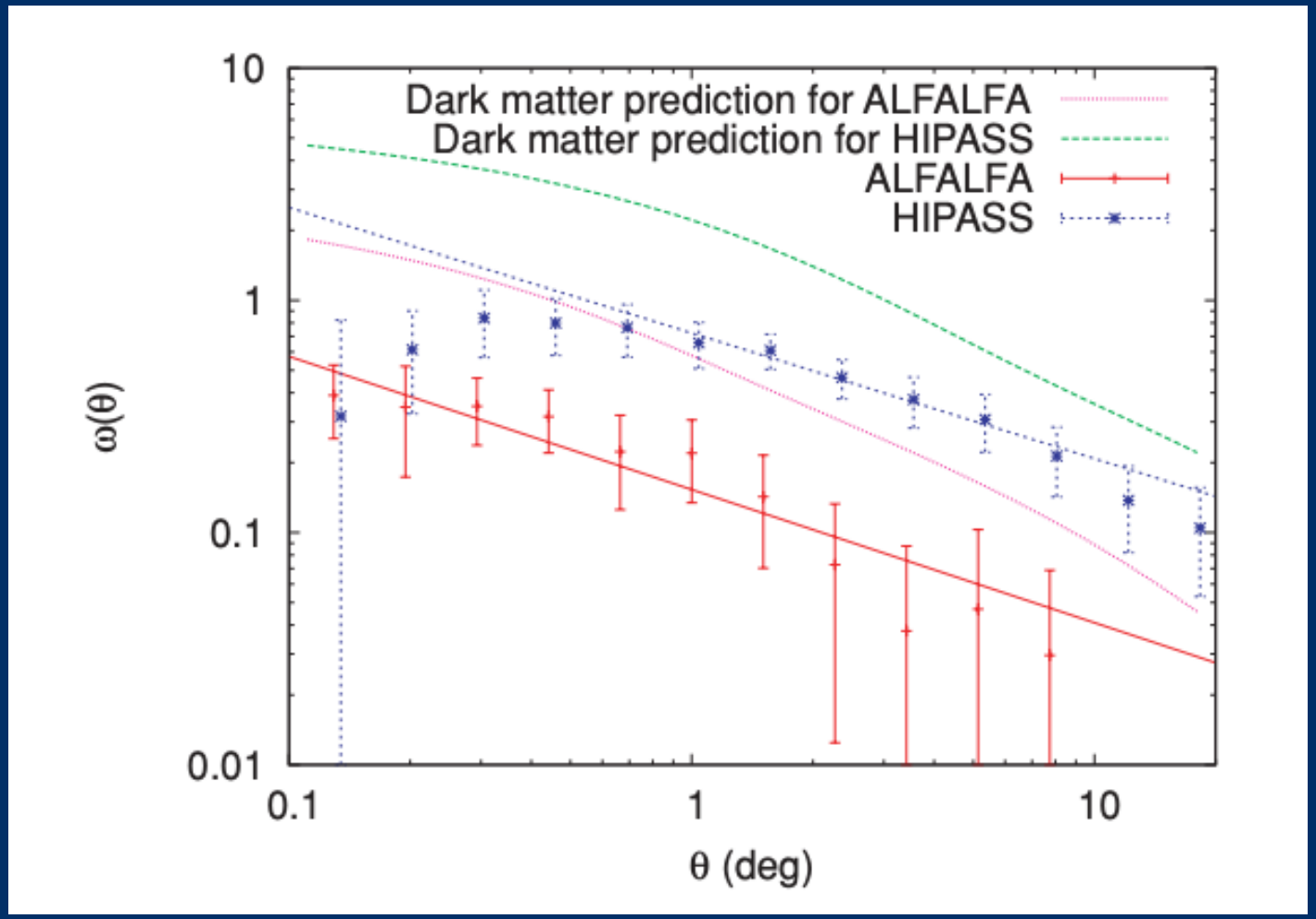
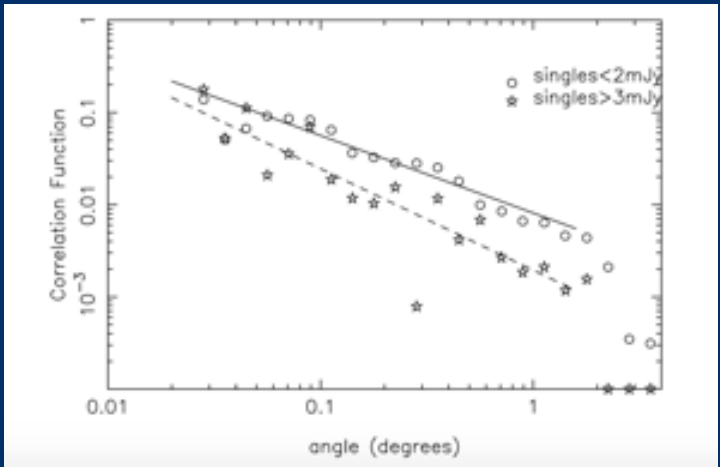
Measurements of HI-clustering

Passmoor, Cress & Faltenbacher 2011



BONUS SLIDE Bias of radio continuum sources

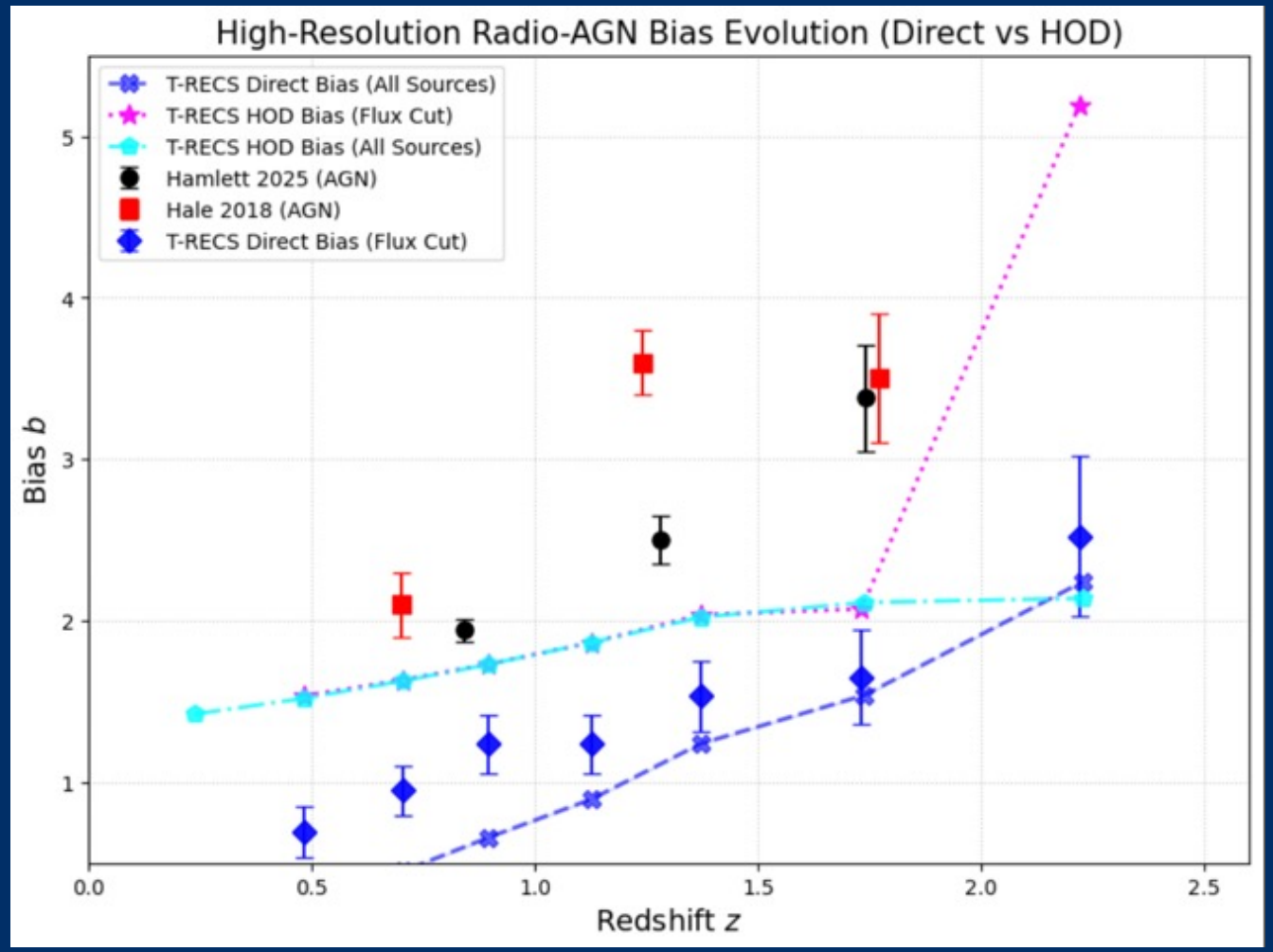


Cress et al 1996

Many papers measuring angular clustering of radio continuum sources (eg Hale et al x10)

Heterogenous population of star-forming galaxies and AGN

Care needed with interpretation of bias in these survey



Malefahlo et al , in prep

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Summary

Forecasting for intensity mapping uses simple assumptions about bias.

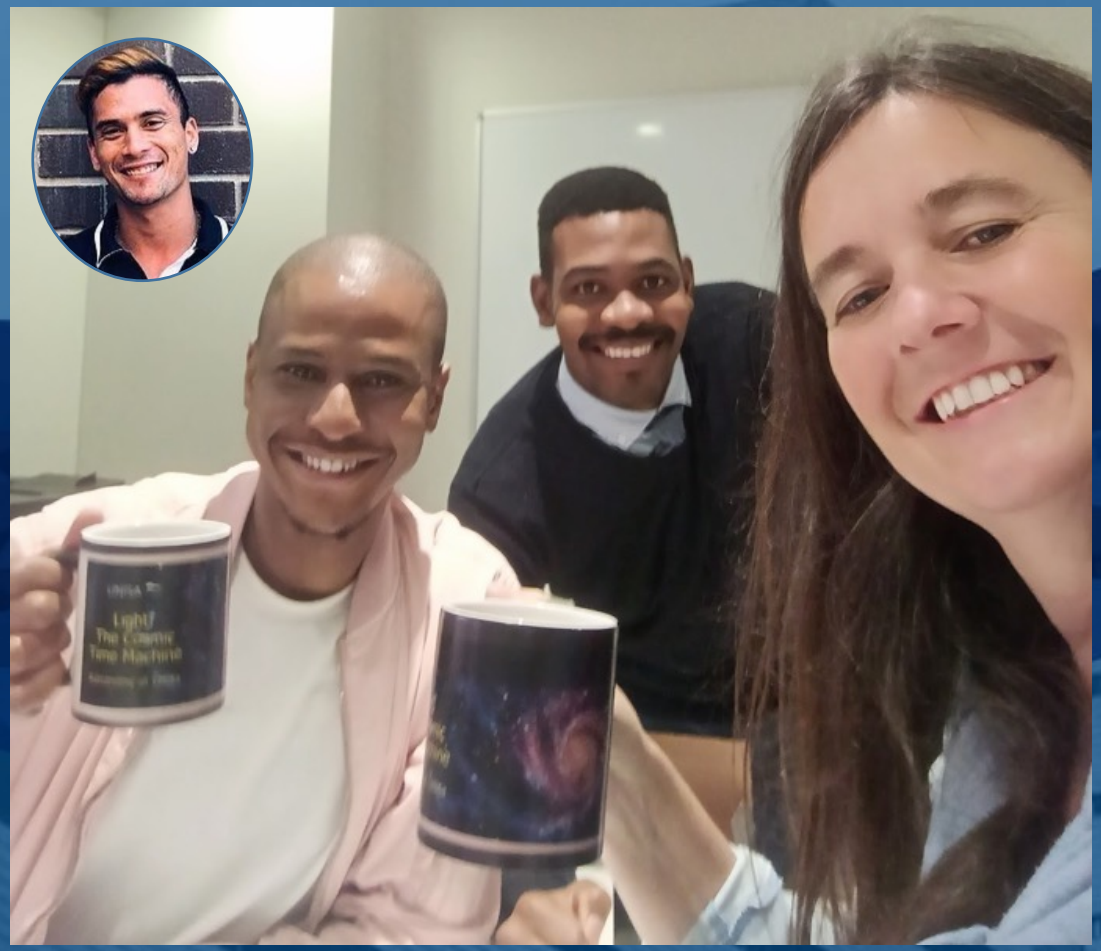
HI depleted in groups and clusters => scale dependence
In relationship between halo mass and HI mass in eg Villaescusa-Navarro, little evidence of HI depletion in high mass halos (box too small?)

Need forecasting/data interpretation to include scale-dependent bias

Bonus:

$\pm$

Radio continuum sources can be used for cosmology but need to be careful of bias



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