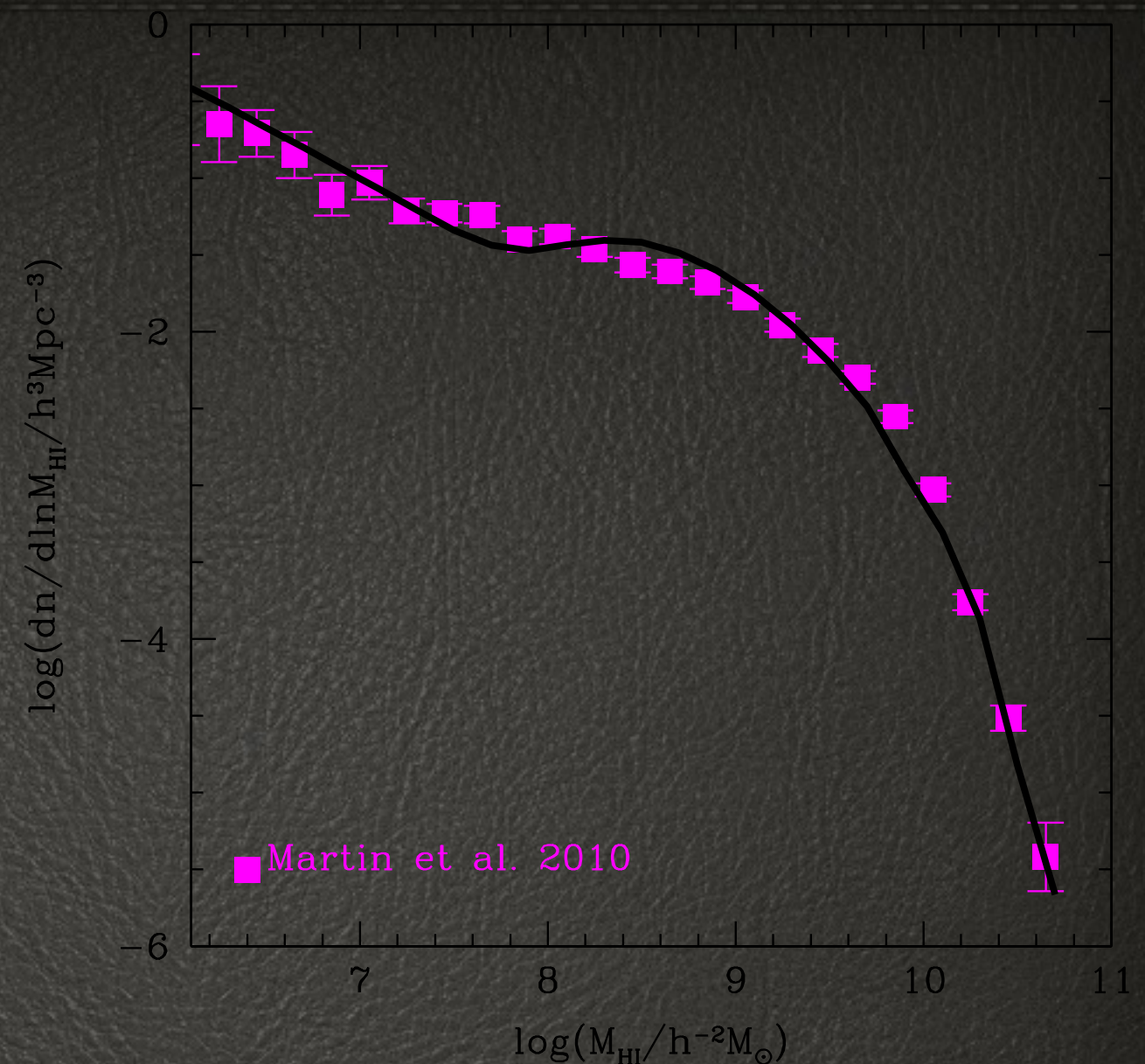
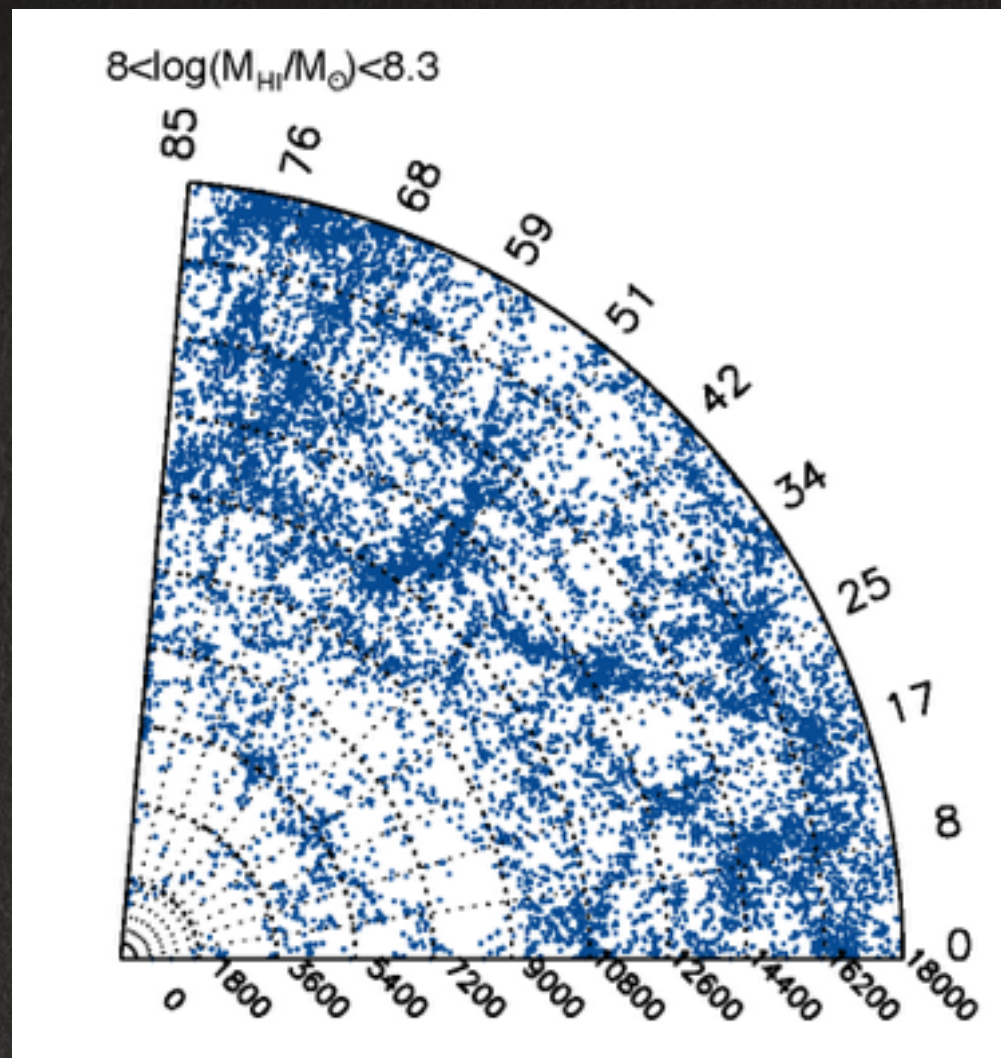
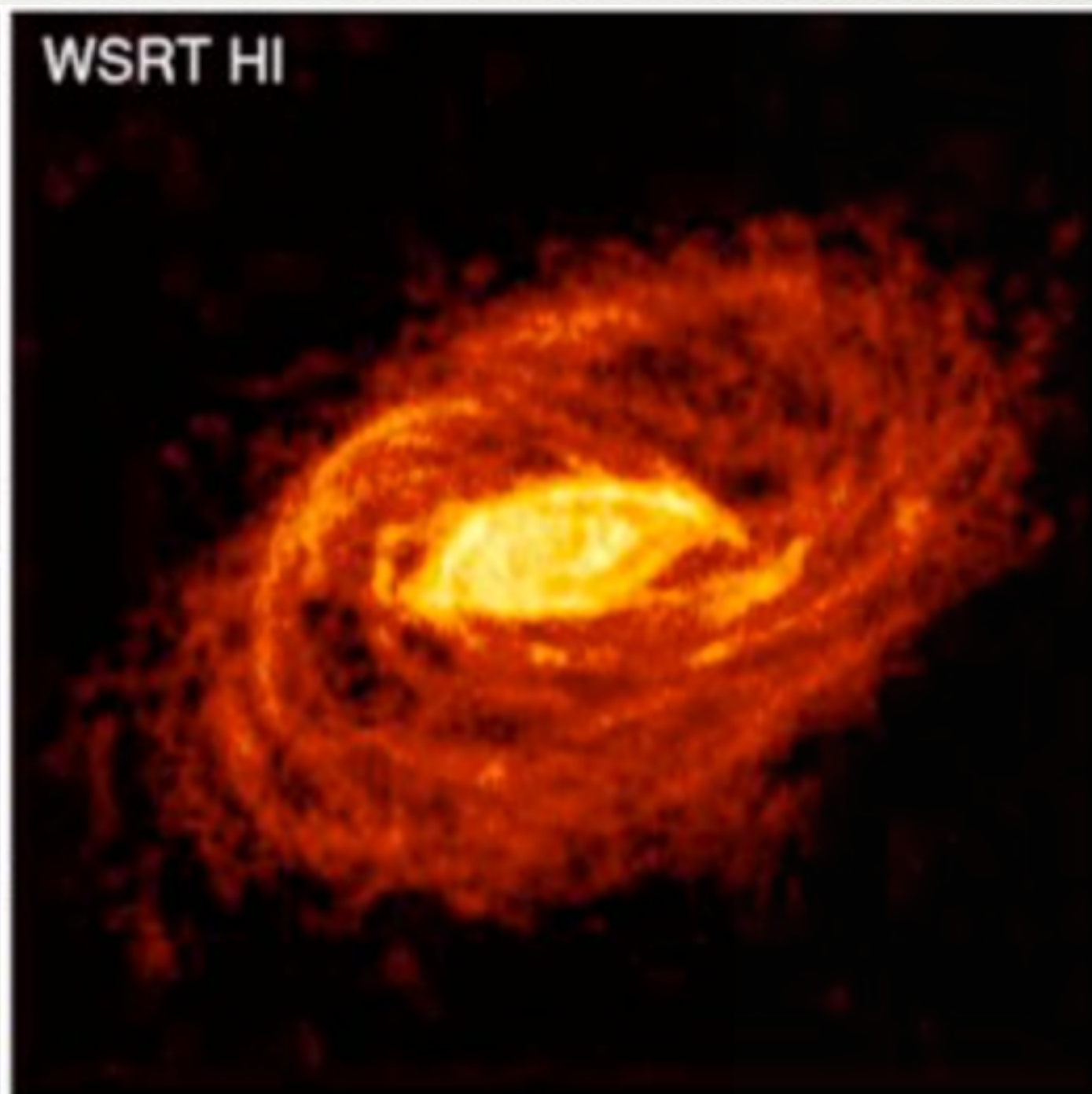
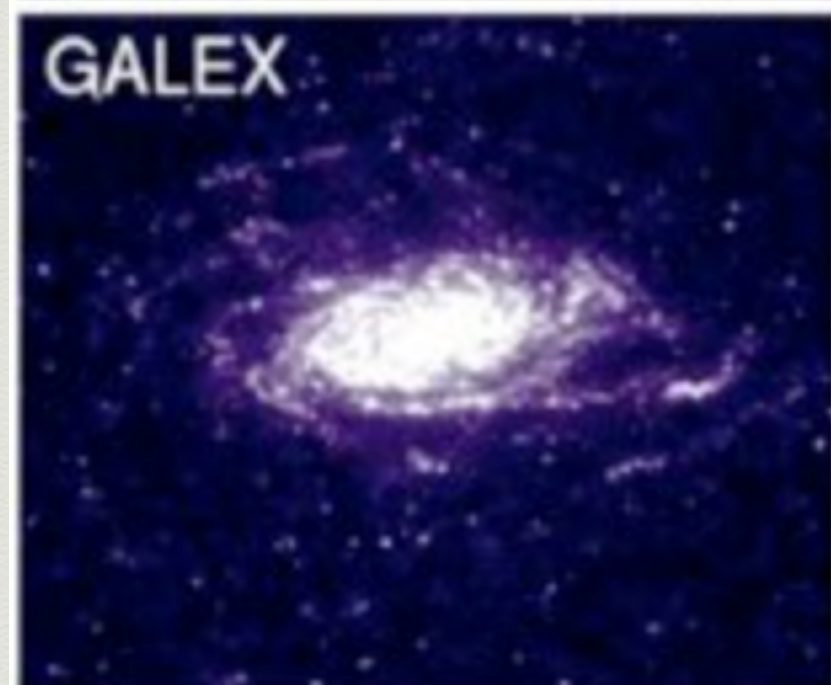
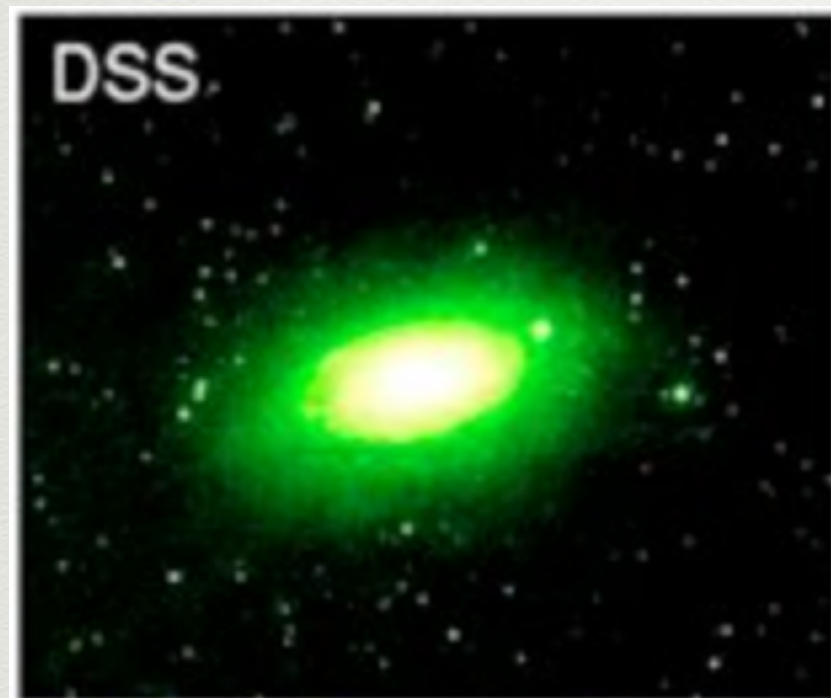


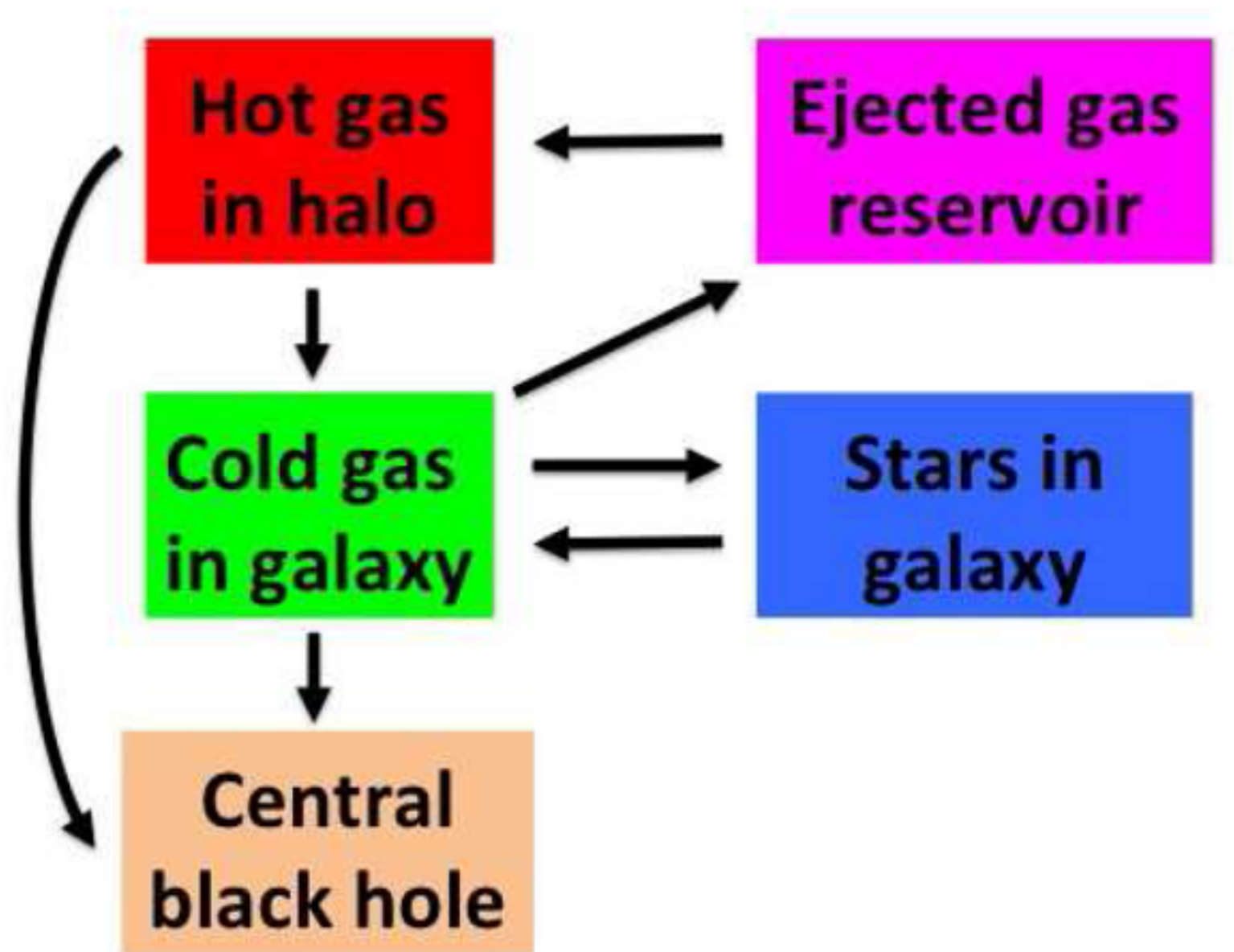


The spatial distribution of neutral hydrogen as
traced by low HI mass galaxies
in hierarchical galaxy formation models

Hansik Kim
University of Melbourne
Stuart, Carlton, Chris, Claudia & Jaehong
7th KIAS workshop on Cosmology and Structure Formation
31/10/2016



Battaglia et al. 2006 & Sancisi et al. 2008



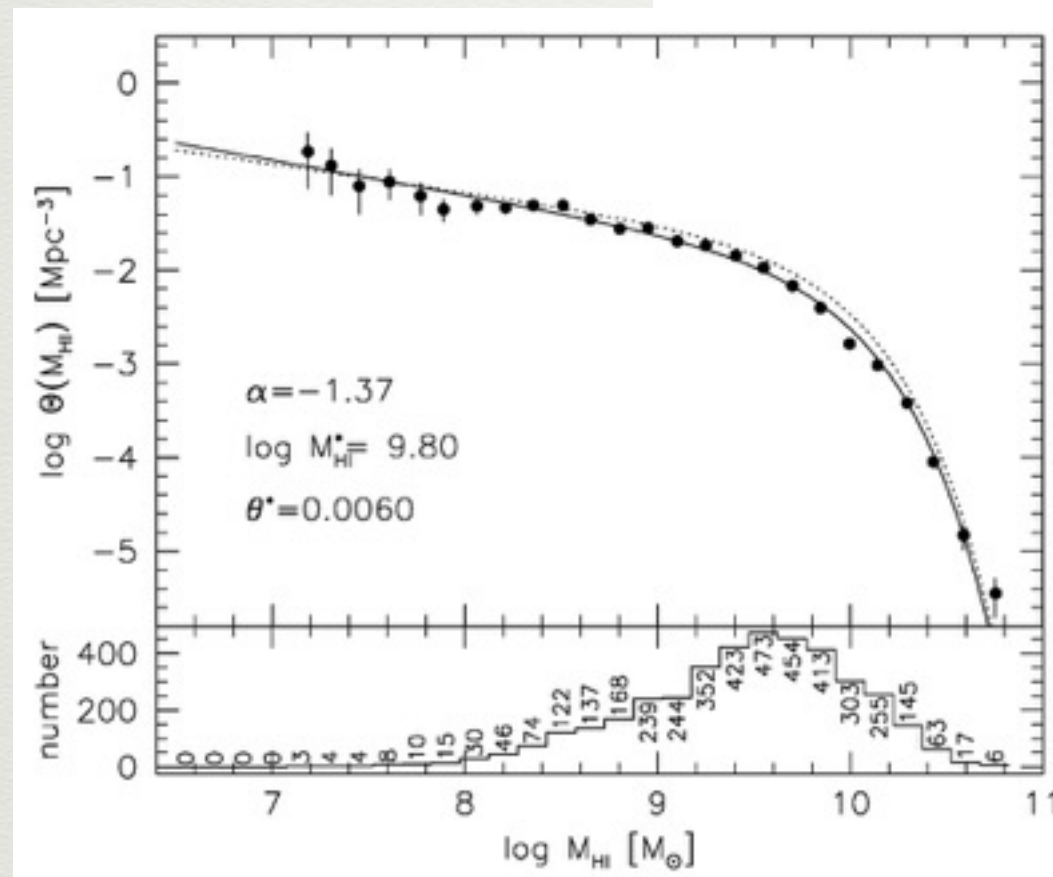
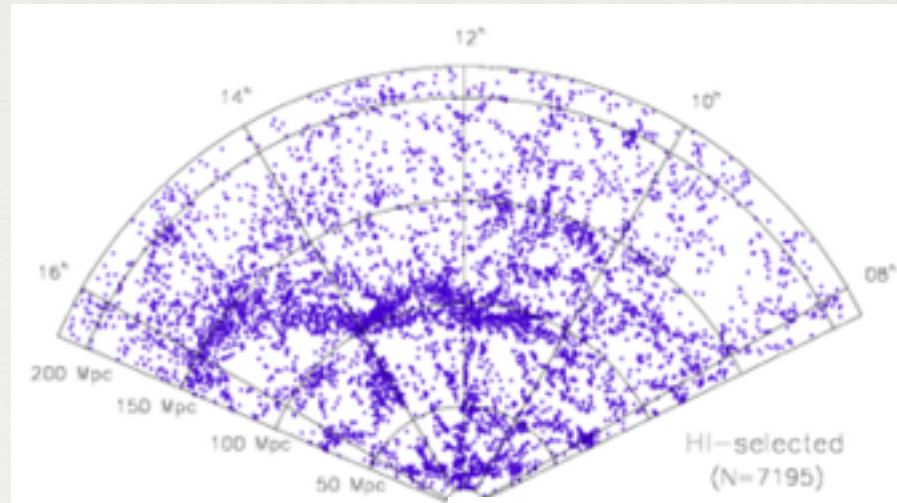
Lacey et al. 2015

Neutral hydrogen is a key ingredient of galaxy formation as it traces the processes of gas accretion, outflow from galaxies and star formation.

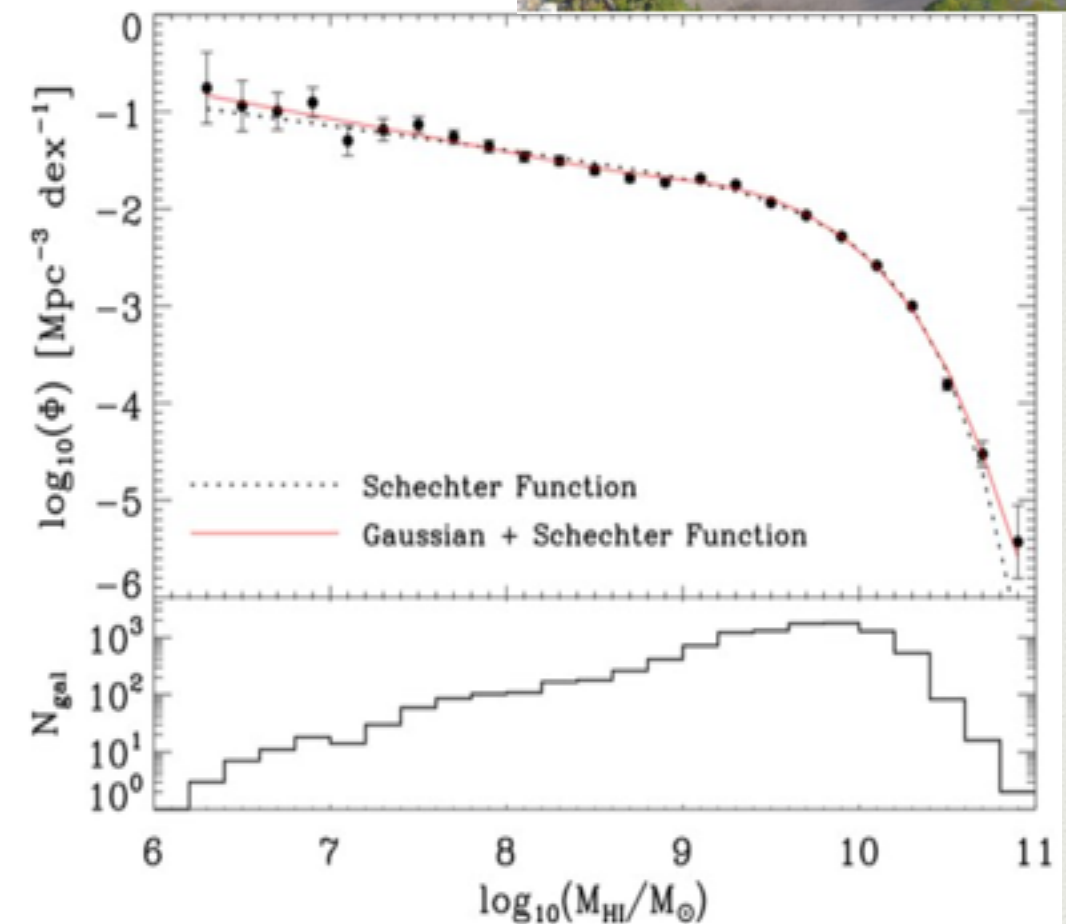
It is therefore important to understand the relation between neutral hydrogen and dark matter haloes.



Caption: CSIRO's Parkes radio telescope. Credit: David McClenaghan, CSIRO

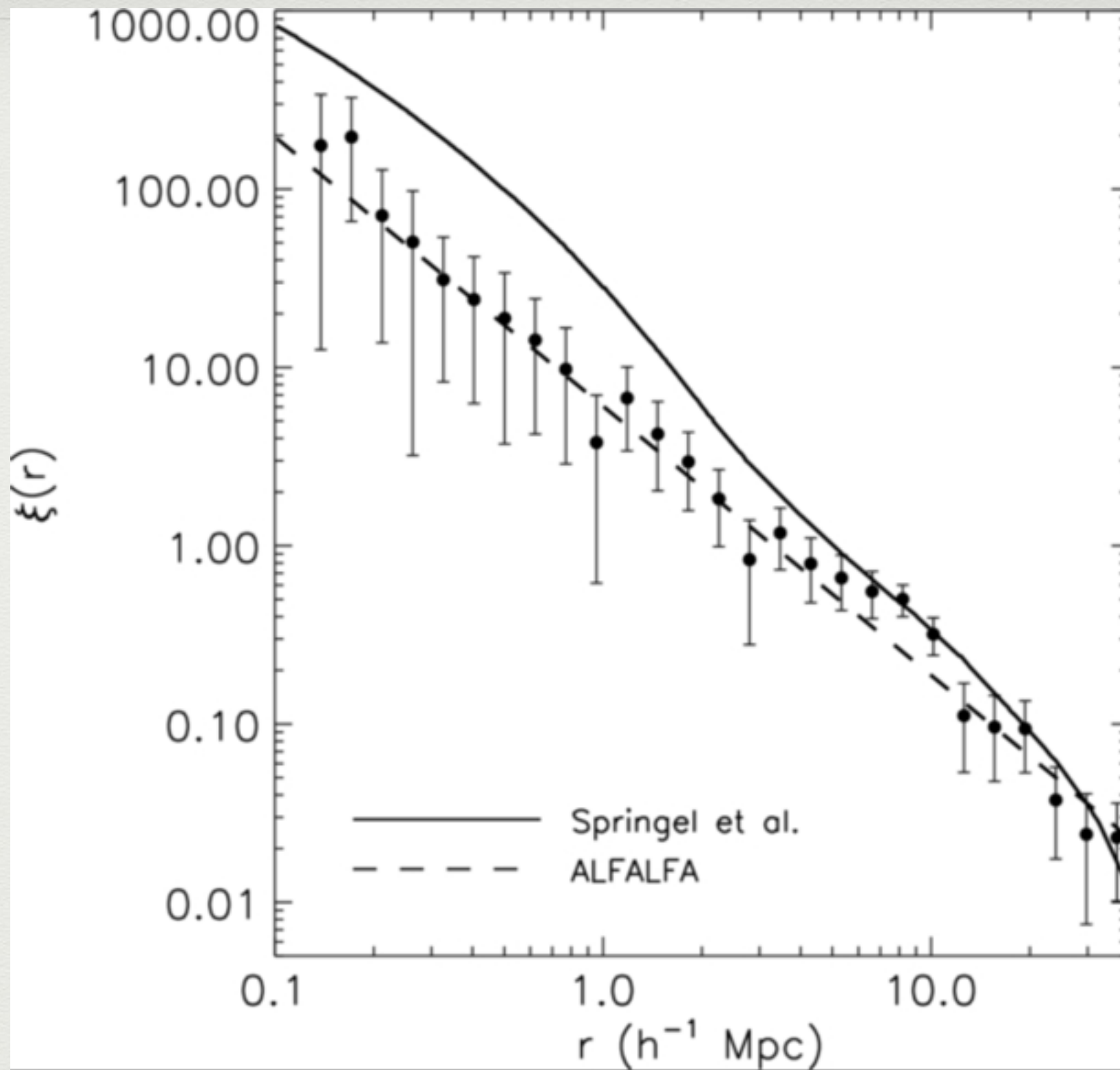


Zwaan et al. 2005



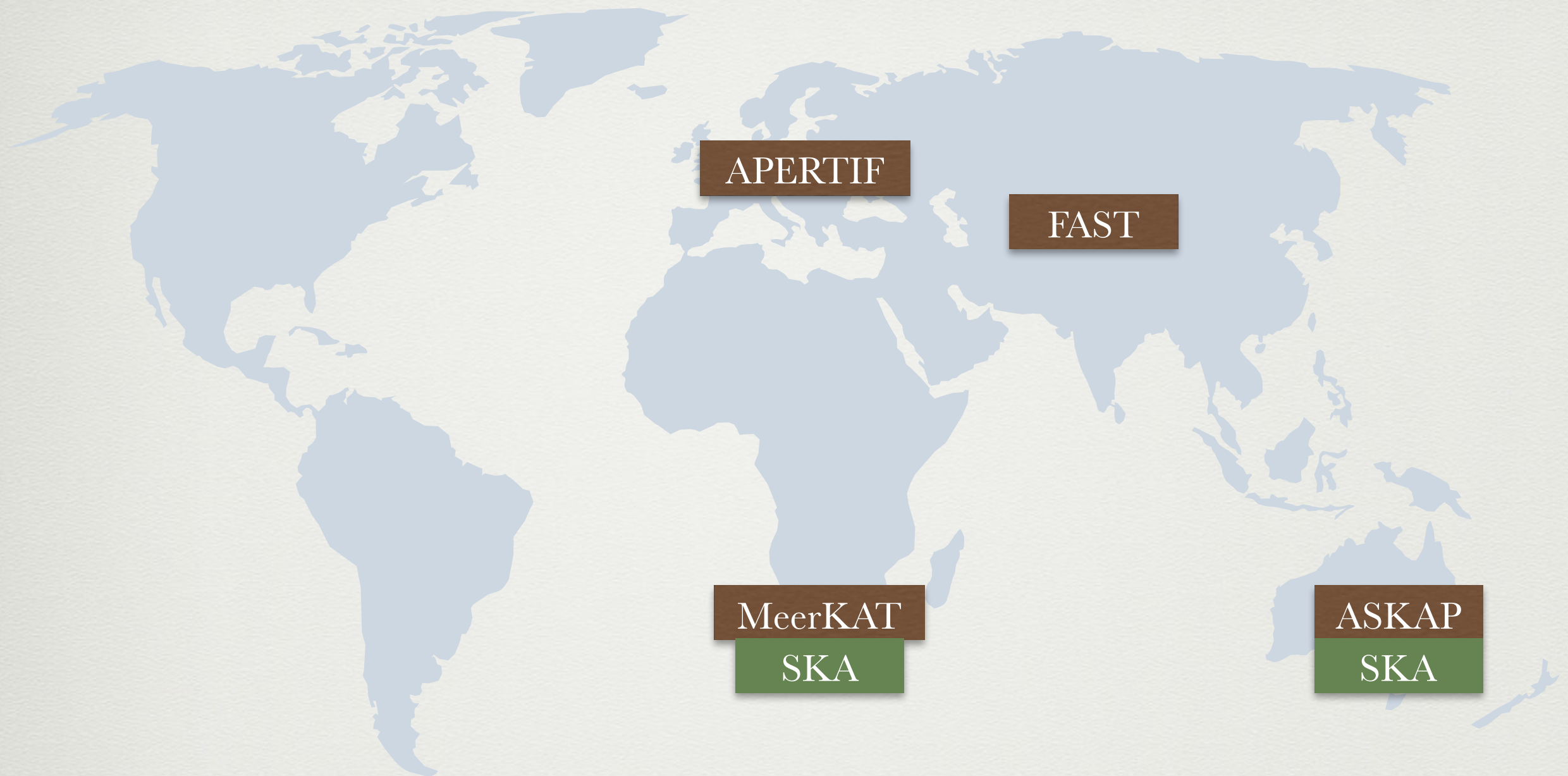
Martin et al. 2010

The last decade has seen improvements in both the volume and flux limit of surveys that probe the HI content of galaxies from the HI Parkes All Sky Survey, the Arecibo Legacy Fast ALFA, and the Arecibo Ultra-DeepSurvey.



Martin et al. 2012

Studies of the distribution of HI-selected galaxies in the local Universe have shown that these galaxies are an unbiased (weakly clustered) galaxy population.



The number of individual galaxies detected in HI will greatly increase through ongoing and upcoming large volume HI-selected galaxy surveys using the SKA and its pathfinders, such as ASKAP and MeerKAT (Meer Karoo Array Telescope in the southern hemisphere, FAST, and APERTIF in the northern hemisphere.



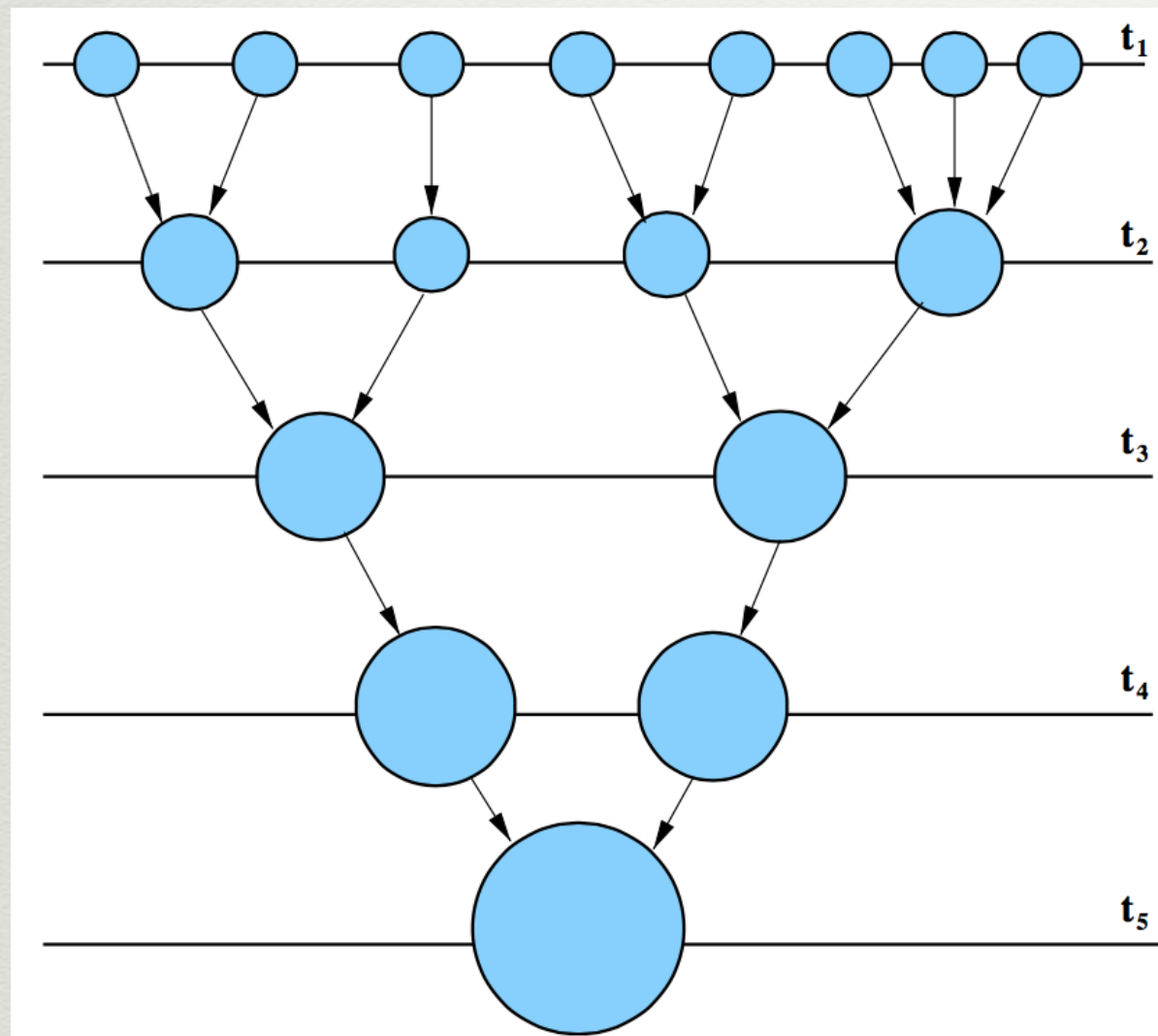
The BINGO, CHIME, and SKA are expected to detect the distribution of neutral hydrogen at $0.5 < z < 3$ in the Universe using the 21cm intensity mapping technique which does not require individual HI-selected galaxies to be resolved.

It is the time to
constrain the galaxy formation models
using the HI galaxy observations
and
predict the upcoming results
from the ongoing or future HI galaxy surveys

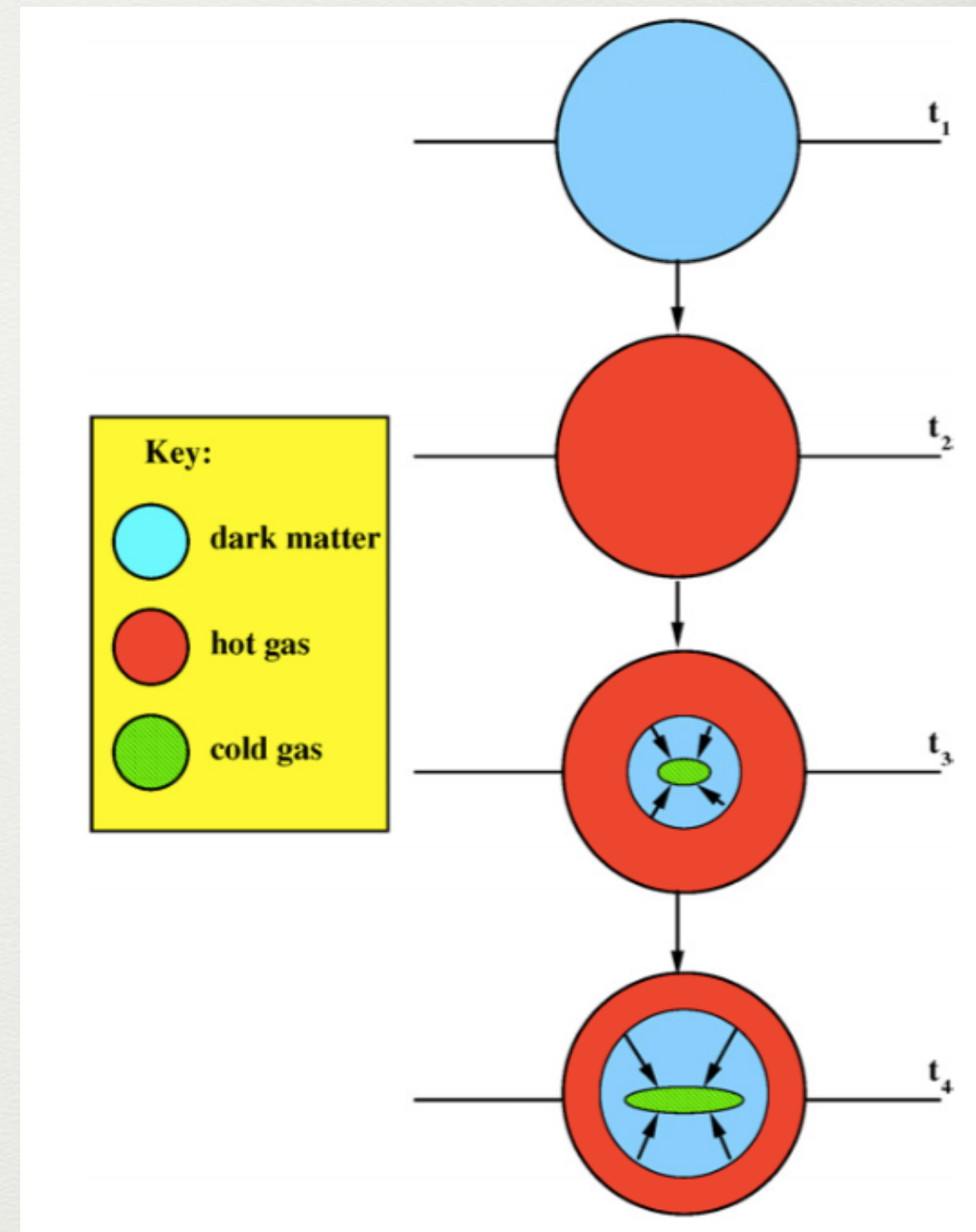
Summary

- Including lower HI mass galaxies increases the clustering amplitude and slope in HI-selected galaxy samples.
- Modelling of low HI mass galaxies is important to understand upcoming 21cm intensity mapping results.

The galaxy formation is
a two-stage process

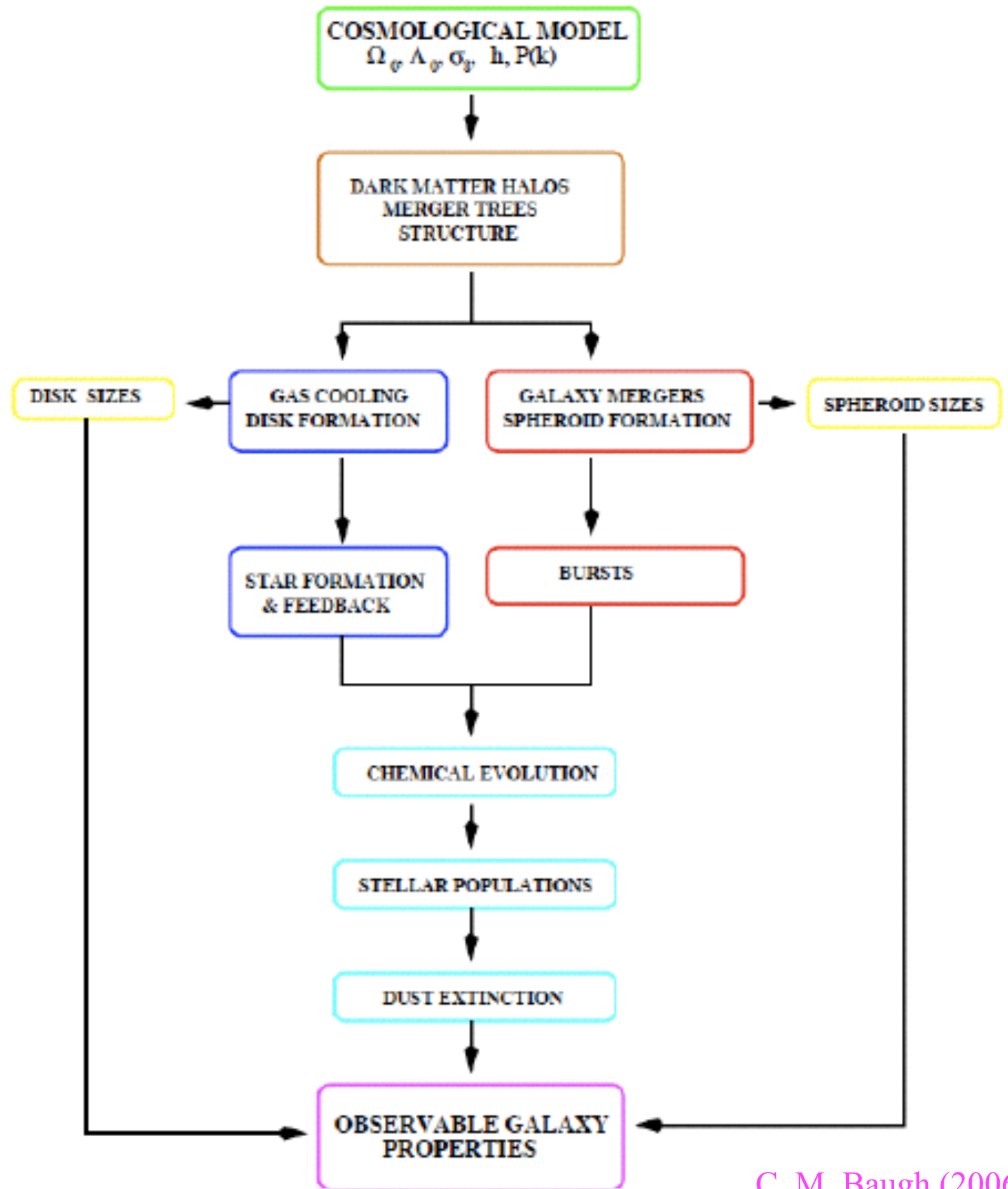
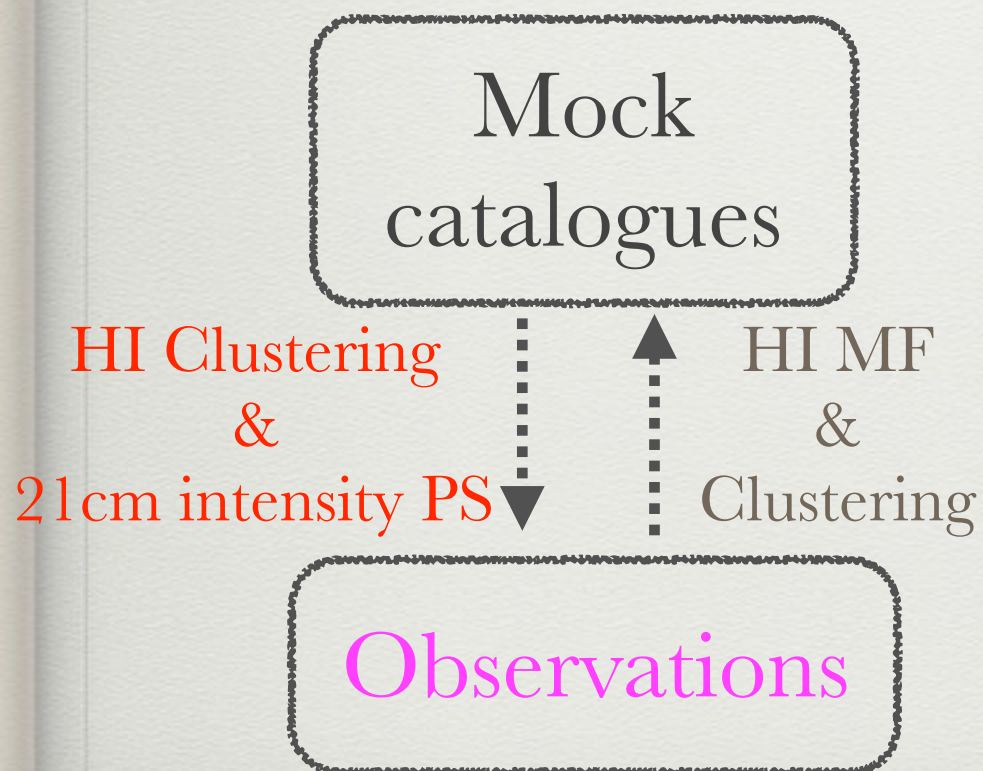


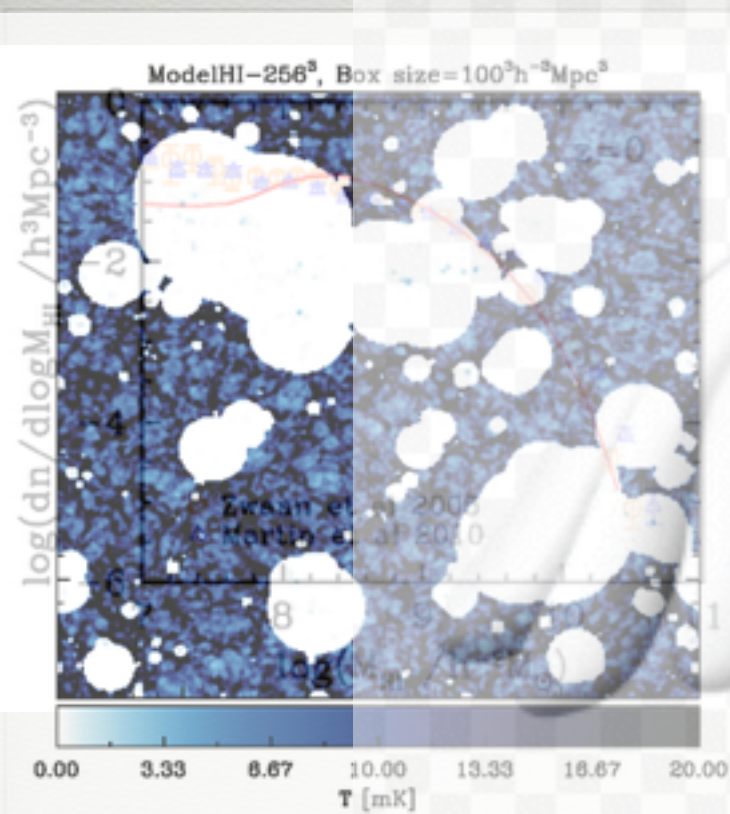
Structure forms in the dark matter
by hierarchical clustering



Galaxies form in dark matter halos

- “Semi-analytic galaxy formation model”.
- Simplified mathematical descriptions. => Evolving dark matter halos.
- **Fast and flexible.**
- Allowing large parameter spaces to be explored.
- Making it easy to generate mock catalogues of galaxies over **large volumes**.

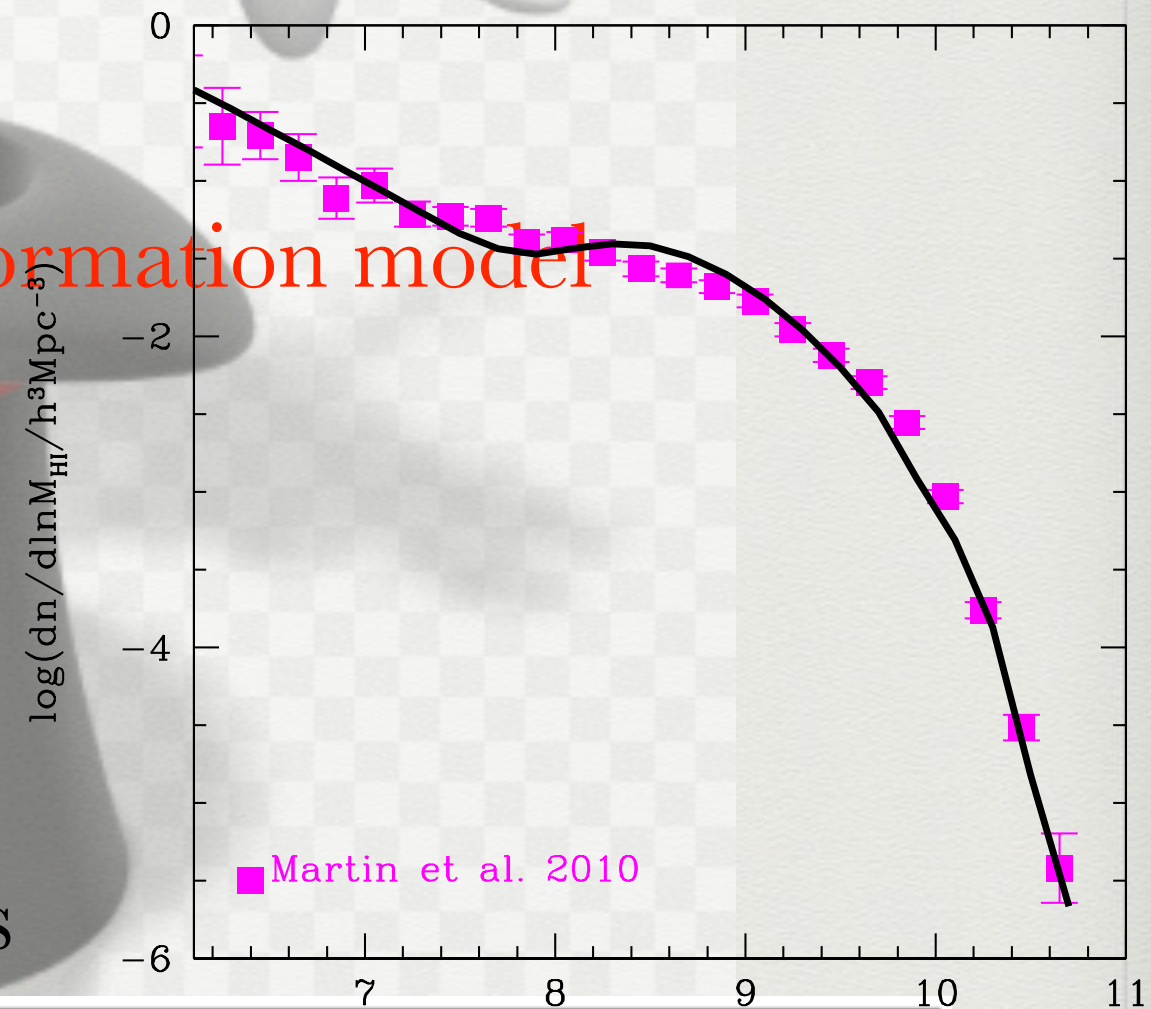




$$V_{\text{cut}}(z)[\text{km/s}] = V_{\text{cut}0}(1+z)^{\alpha_v} \left[1 - \left(\frac{1+z}{1+z_{\text{IN}}} \right)^2 \right]^{2.5/3}$$

Semi-Analytic Galaxy formation model

Assumptions



	$L_{\text{box}} [\text{Mpc}/h]$	N_p	$\epsilon [\text{kpc}/h]$	$m_p [M_{\odot}/h]$	$\log(M_{\text{HI}}/h^{-2}M_{\odot})$	cosmology
Millennium-II	100	10,077,696,000	1.0	6.89×10^6		Millennium
Millennium	500	10,077,696,000	5.0	8.61×10^8		Millennium



The number of individual galaxies detected in HI will greatly increase through ongoing and upcoming large volume HI-selected galaxy surveys using the SKA and its pathfinders, such as ASKAP and MeerKAT (Meer Karoo Array Telescope in the southern hemisphere, FAST, and APERTIF in the northern hemisphere.

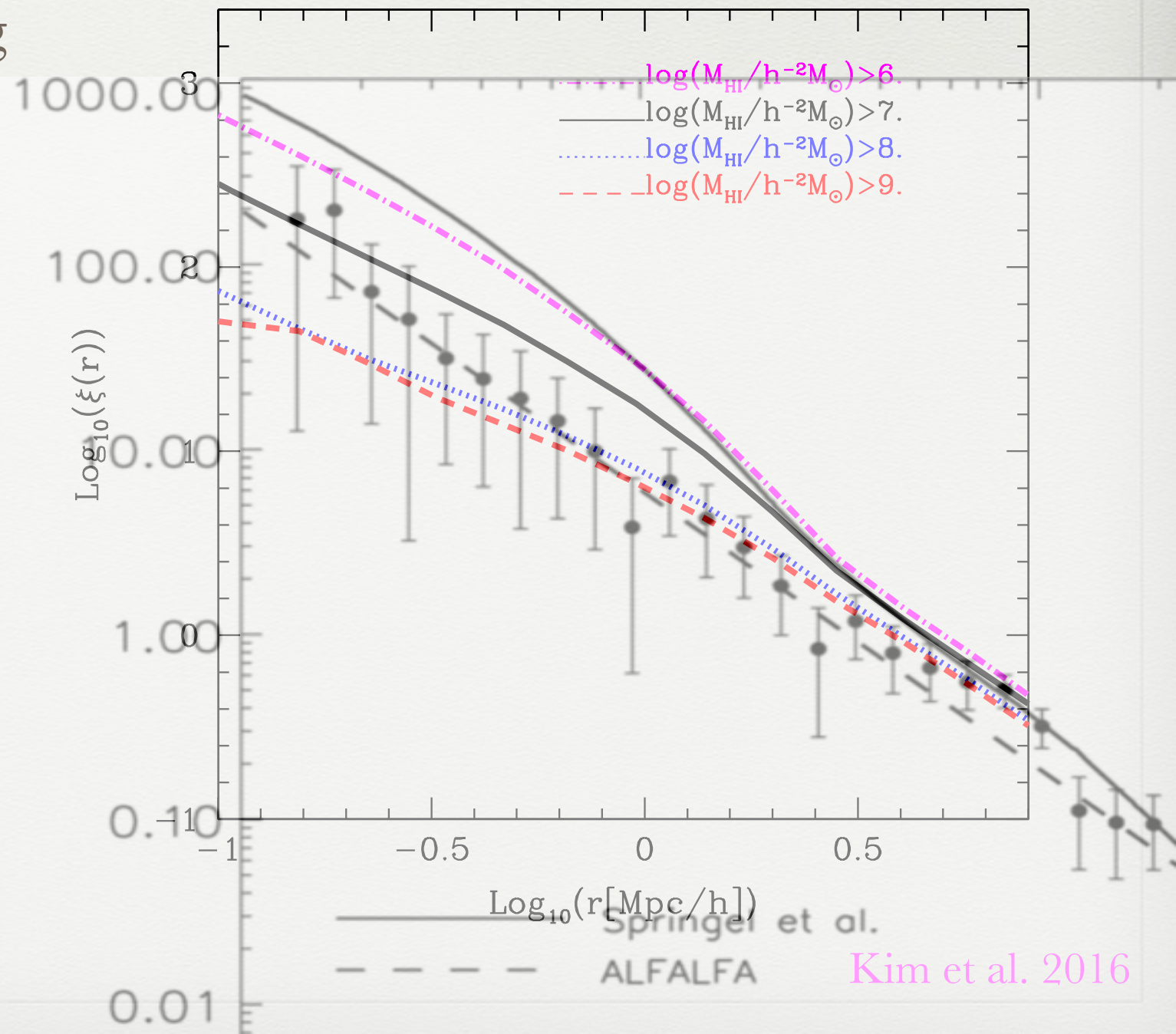
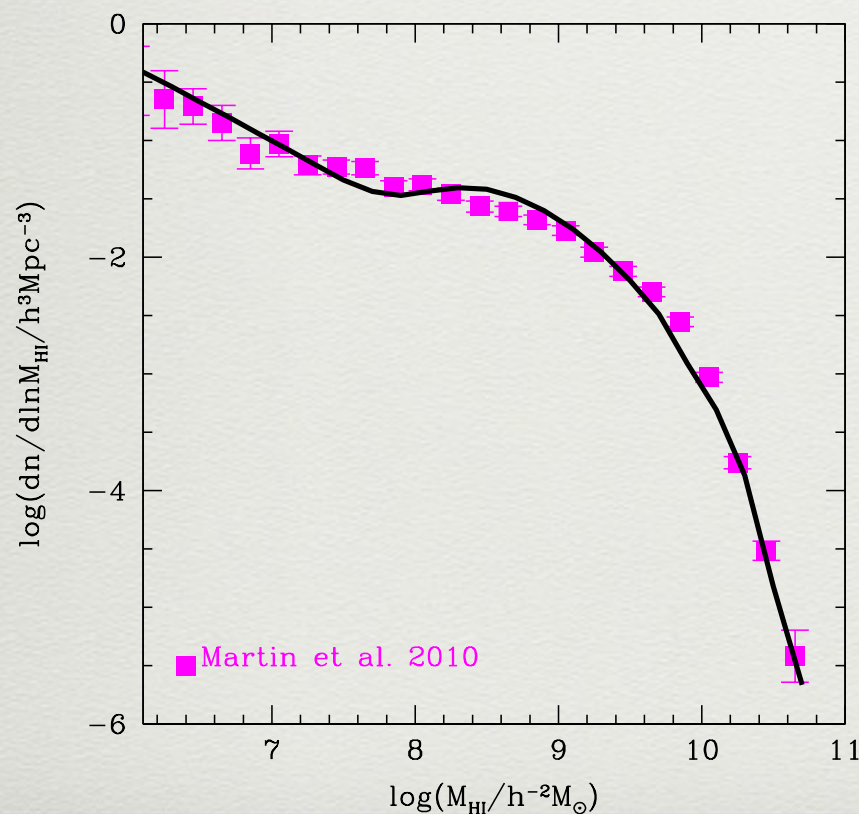
Clustering of HI-selected samples

$$dP = \bar{n}^2 [1 + \xi(r)] \delta V_1 \delta V_2,$$

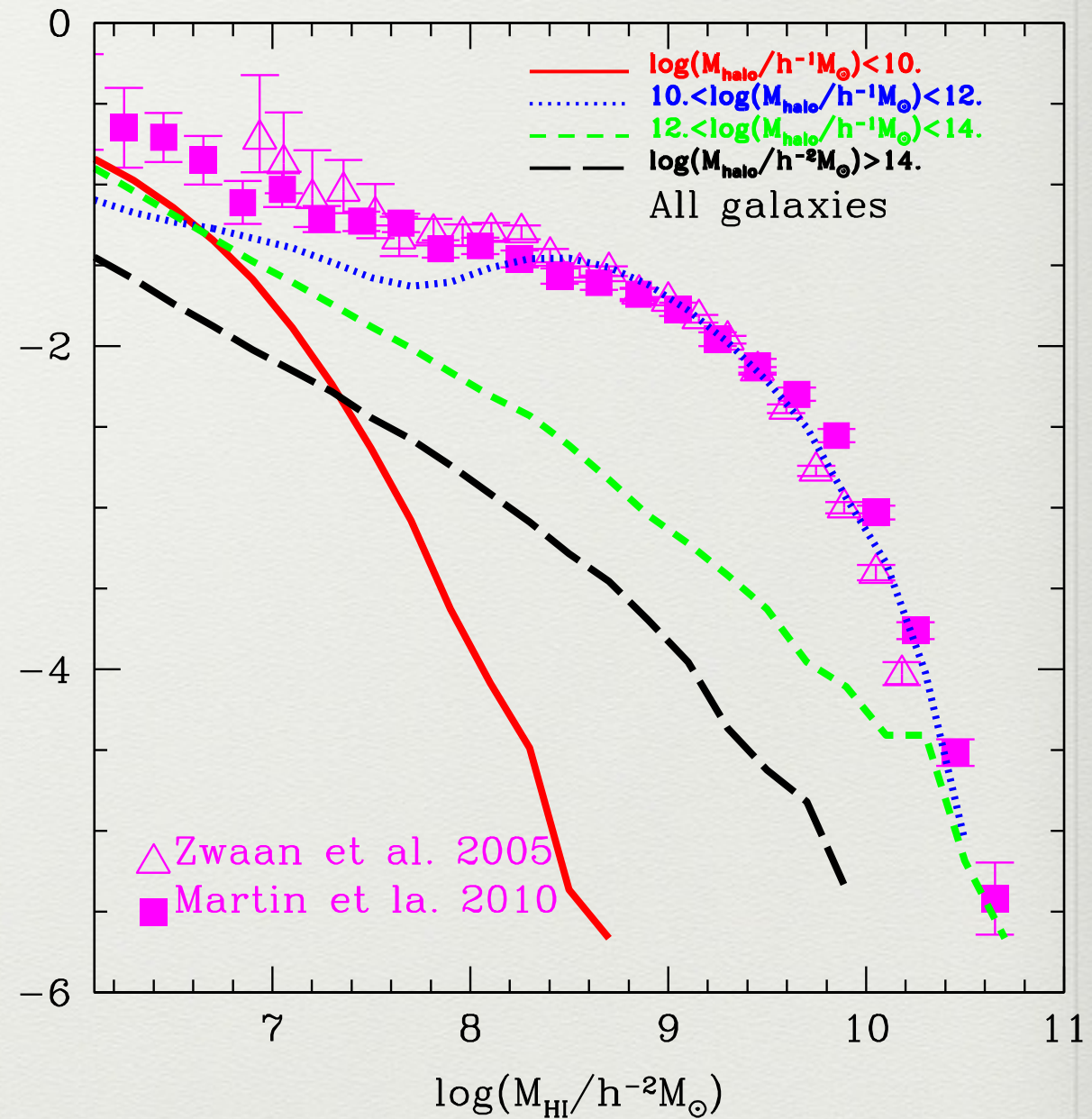
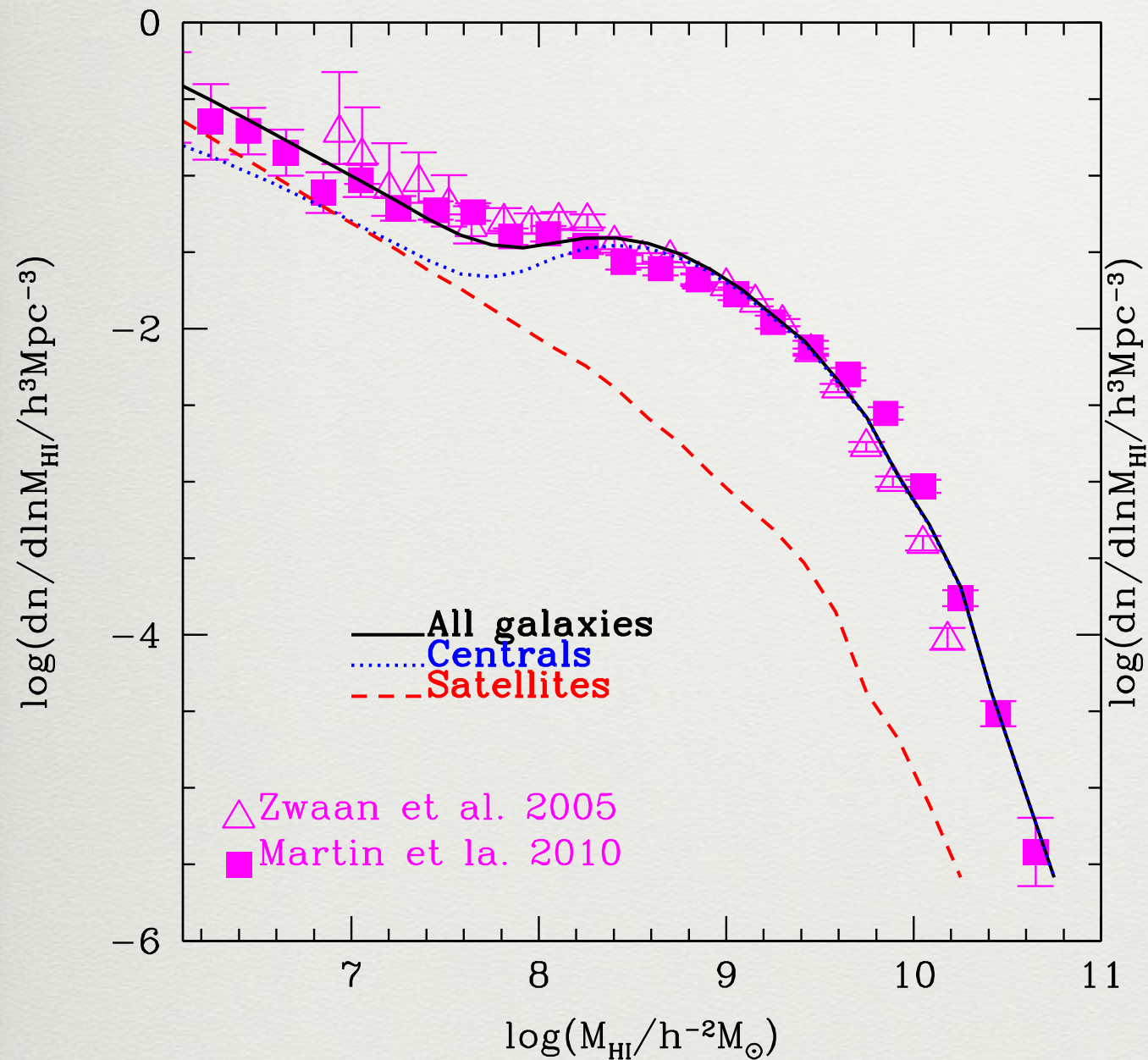
$$\xi(r) = (r/r_0)^{-\gamma}$$

$z=0$

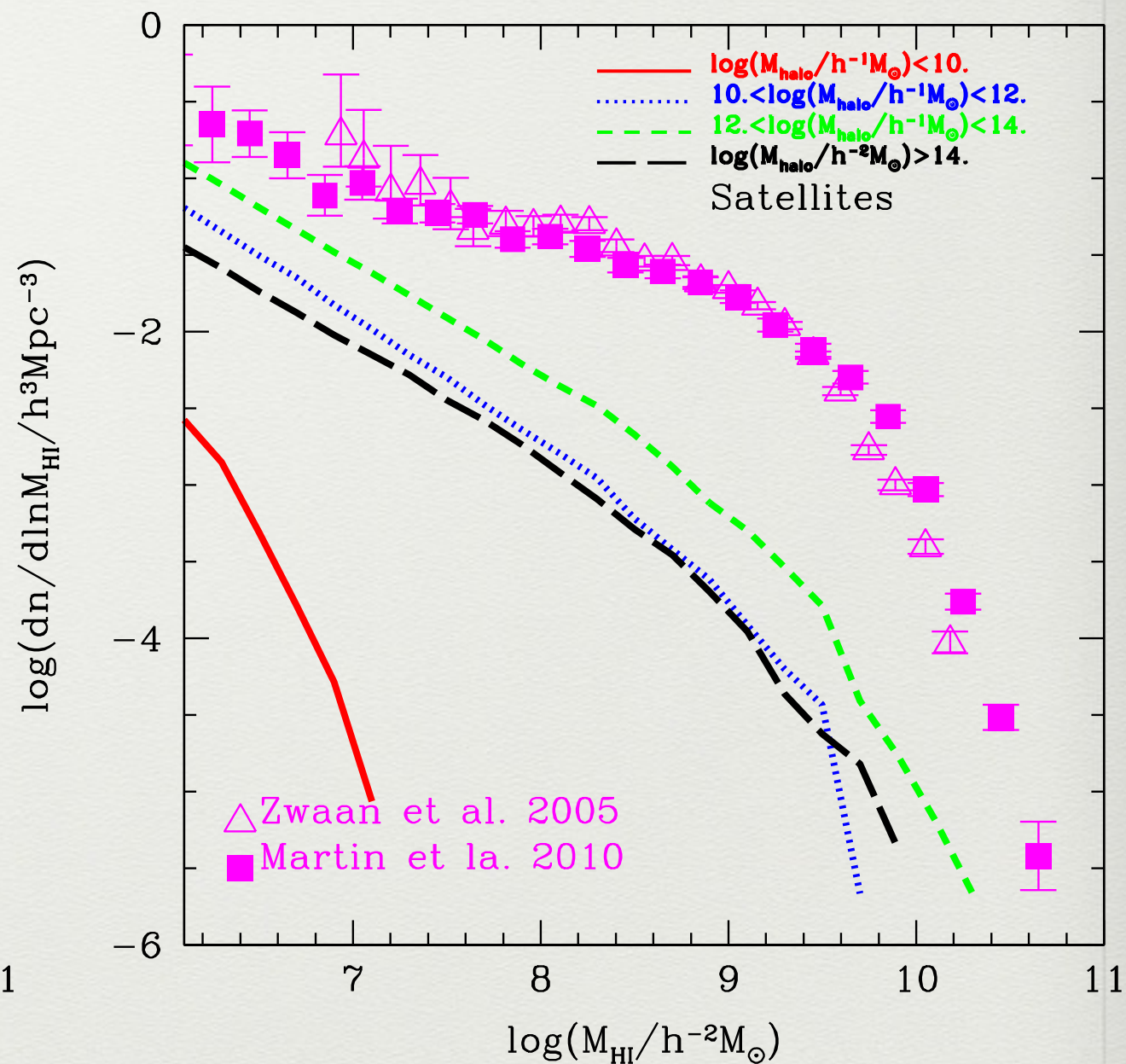
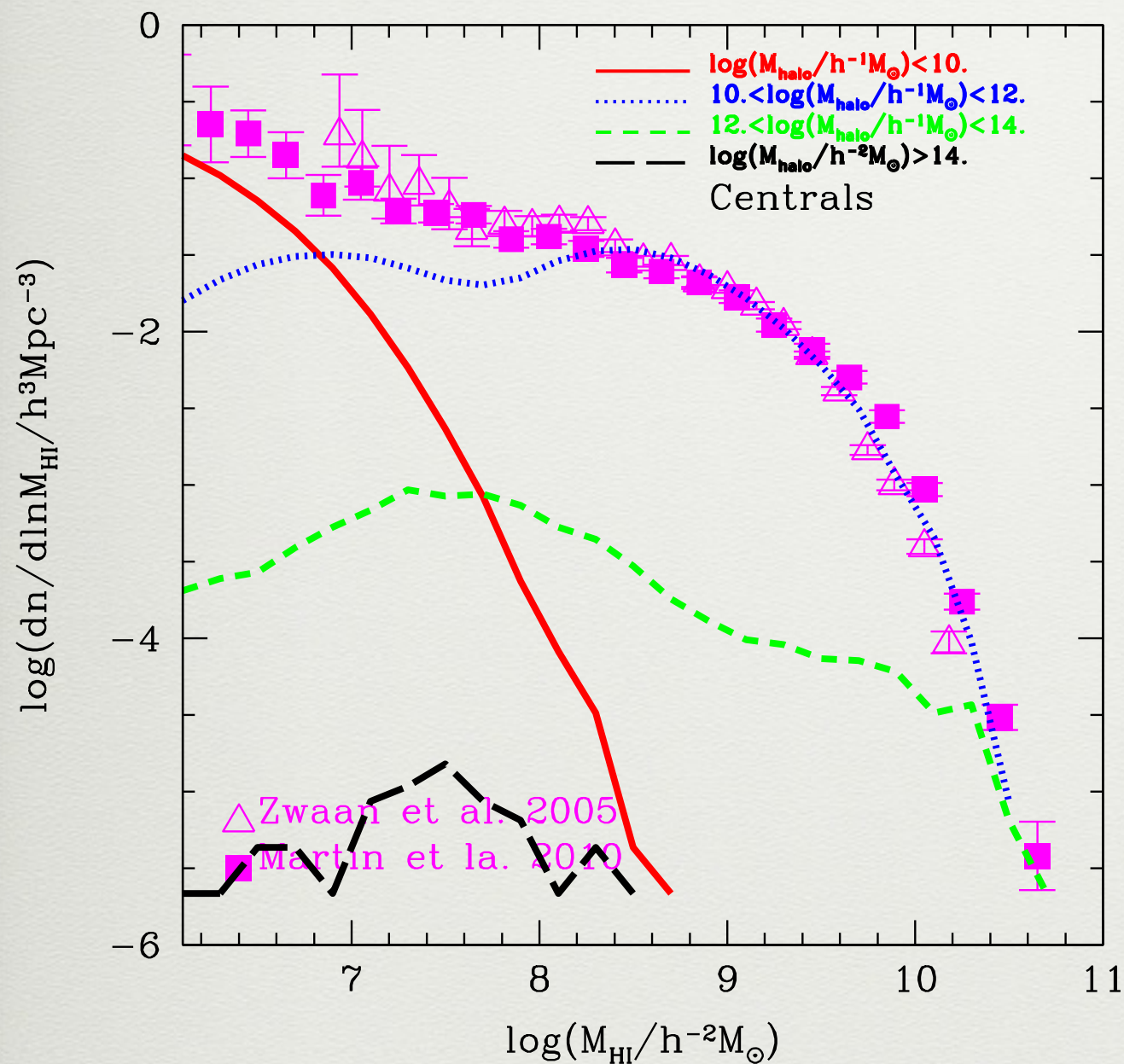
- Overall, the trend of clustering as a function of HI mass threshold shows that galaxies become more clustered as the HI mass threshold decreases.



Understanding the predicted clustering of HI-selected galaxies

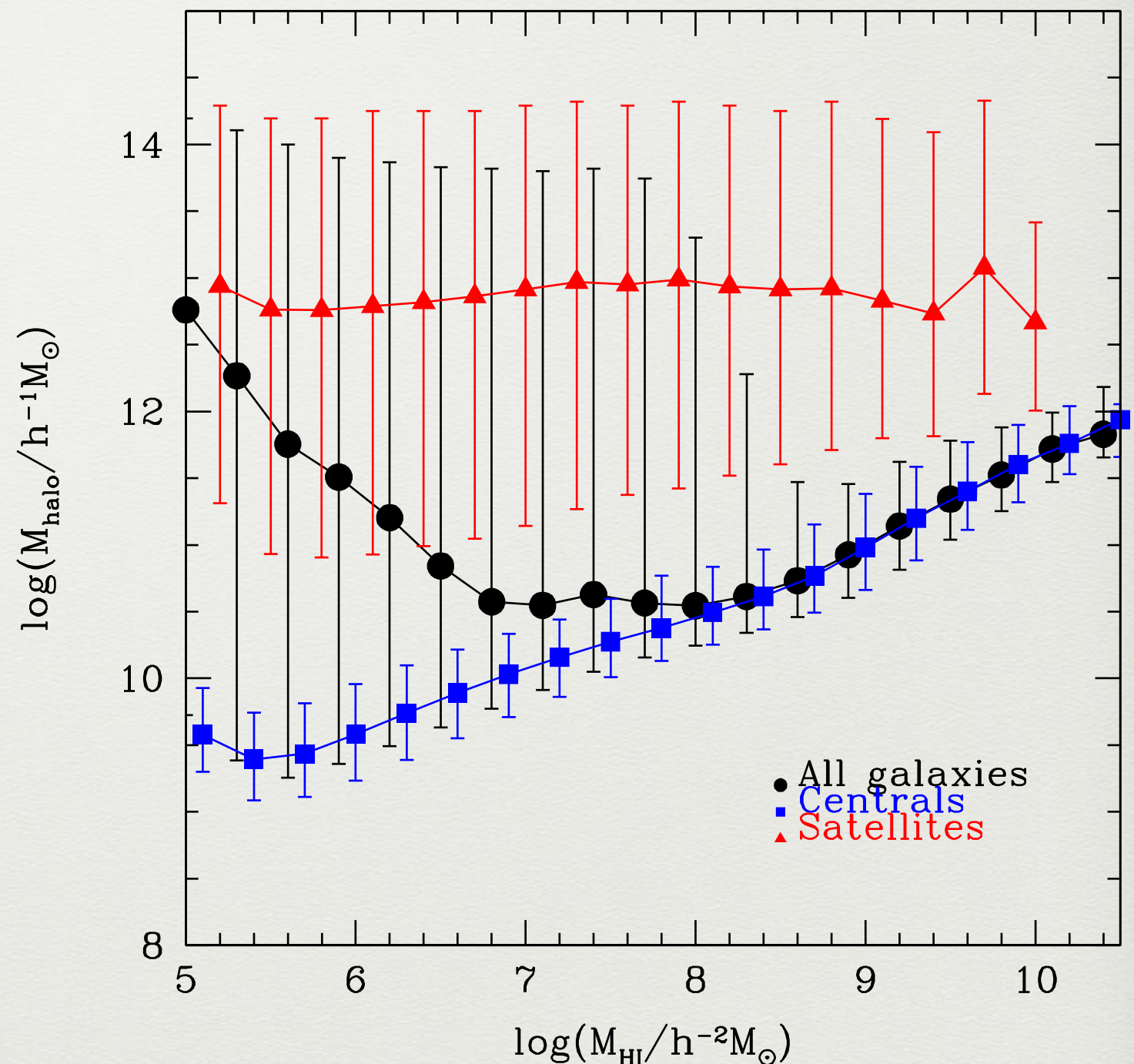


Understanding the predicted clustering of HI-selected galaxies



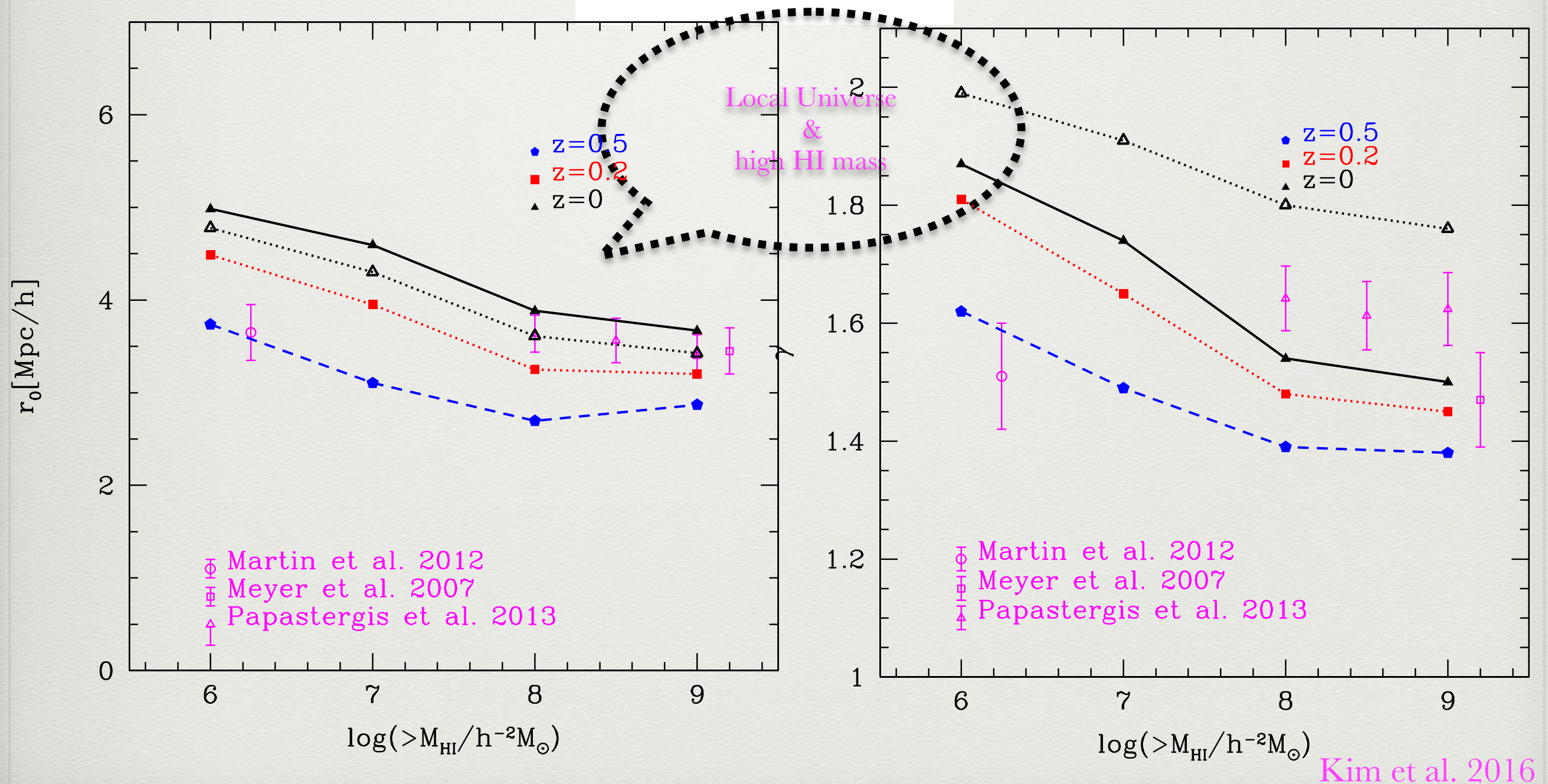
Understanding the predicted clustering of HI-selected galaxies

- The host dark matter halo mass of central HI galaxies increases
- The host dark matter halo mass for satellite HI galaxies is constant over the range of HI masses.



Clustering of HI-selected samples

$$\xi(r) = (r/r_0)^{-\gamma}$$





The BINGO, CHIME, and SKA are expected to detect the distribution of neutral hydrogen at $0.5 < z < 3$ in the Universe using the 21cm intensity mapping technique which does not require individual HI-selected galaxies to be resolved.

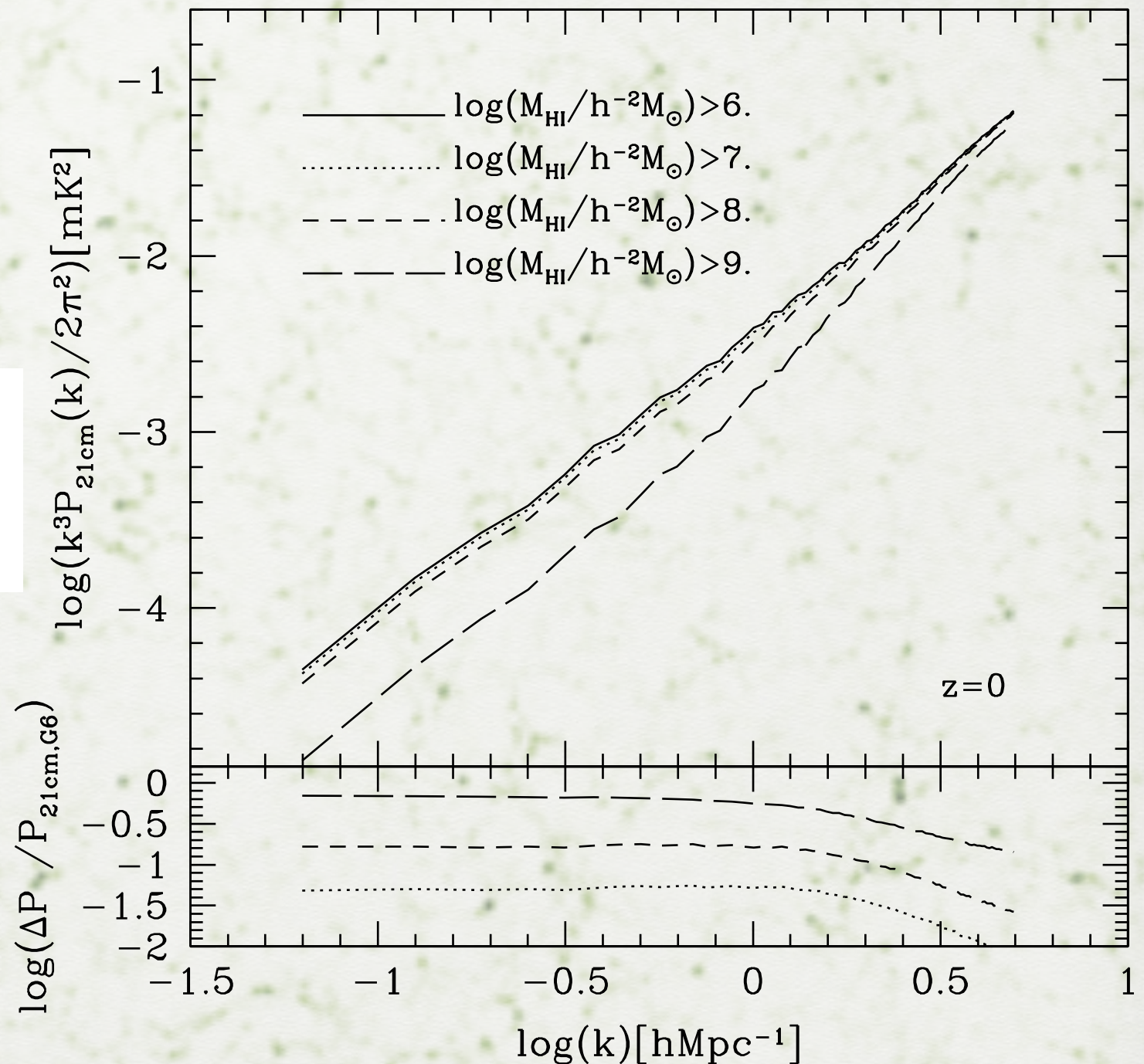
21cm intensity mapping

$$P_{21\text{cm}}(k, z) = T_b^2 \Omega_{\text{HI}}(z) / 0.76 / \Omega_b \times P_{\text{HI}}(k, z).$$

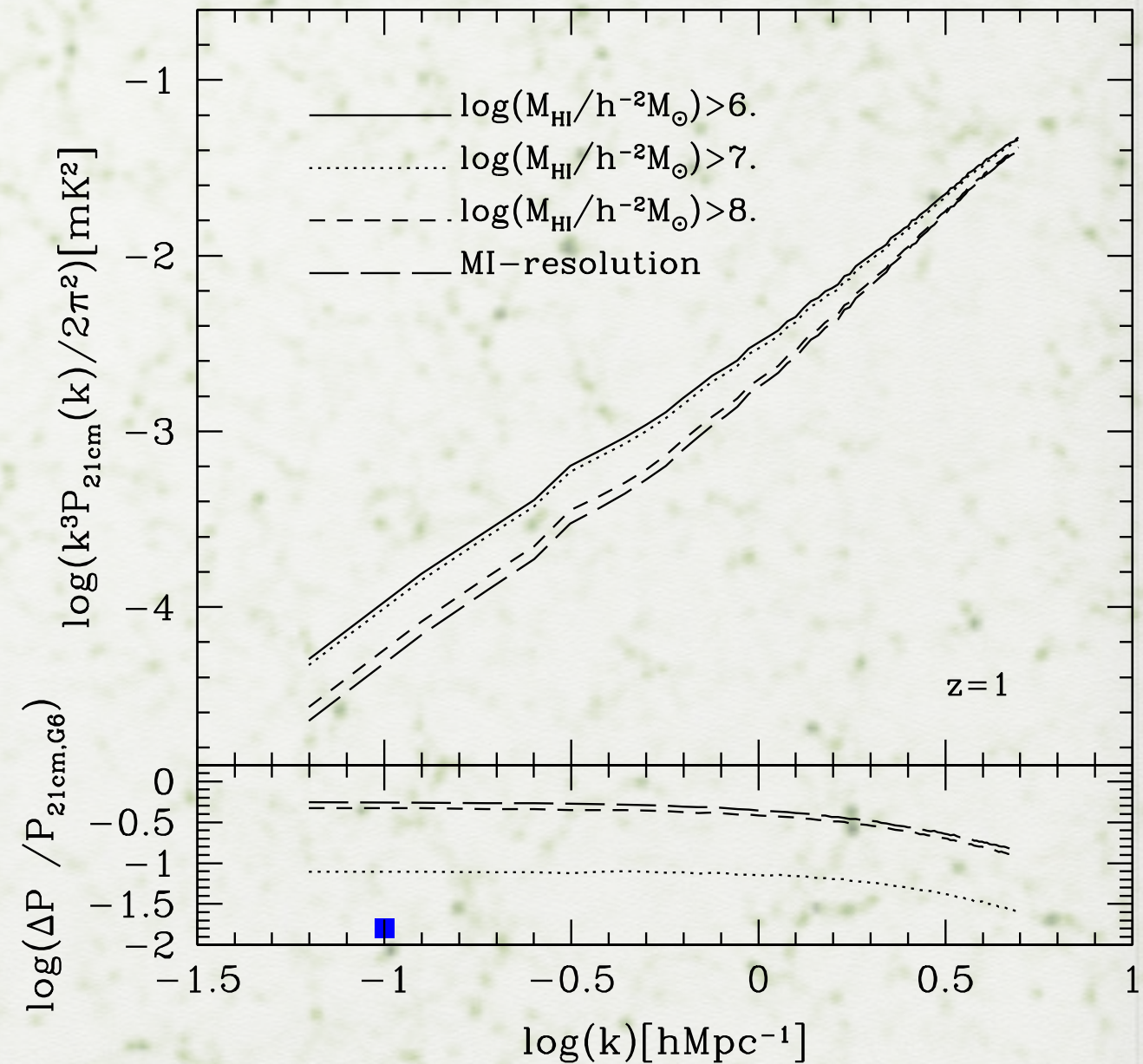
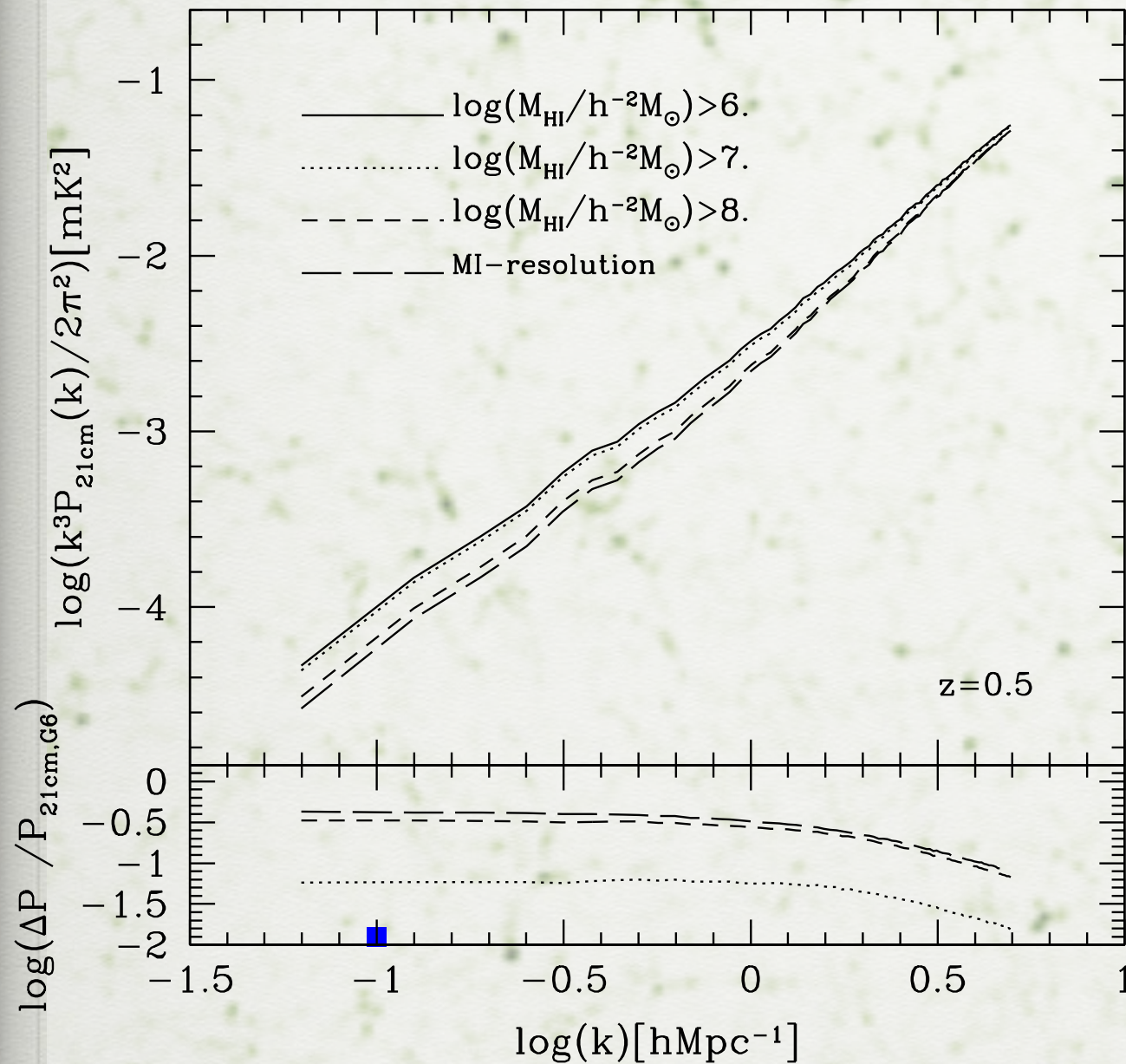
- **The 21cm intensity mapping** uses to detect surface brightness fluctuation of the 21cm emission from a **combined HI galaxies in a low spatial resolution observation**.
- The 21cm intensity mapping can accessible in redshift desert $z=1\sim3$ in optical surveys. $\Rightarrow$ 21cm cosmology.
- GBT (current), BINGO, CHIME, FAST, SKA

Impact of HI mass threshold cut on the 21cm PS

- Varying HI mass threshold for sample galaxies to predict the 21cm power spectrum.

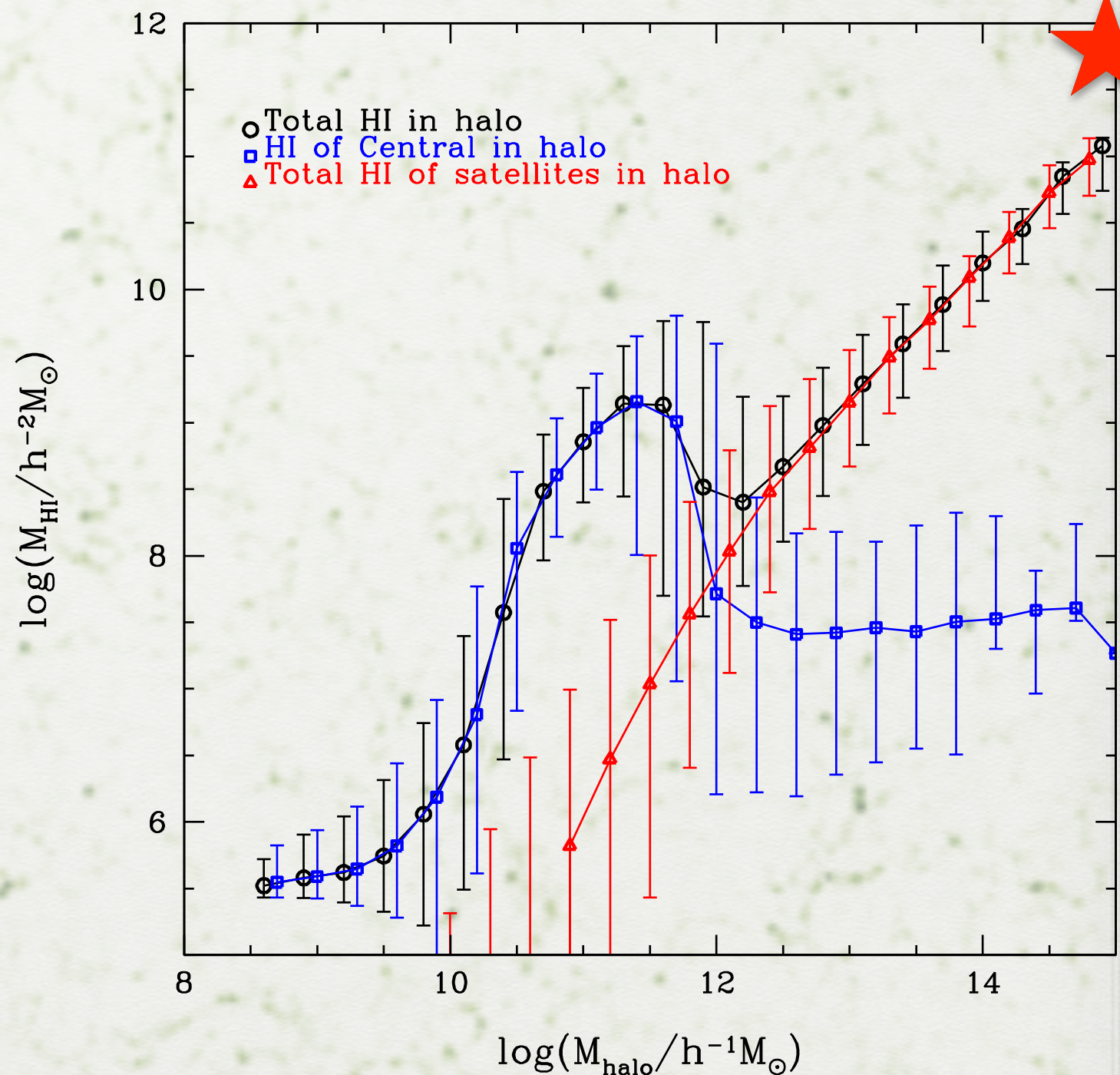


Impact of resolution of dark matter halo on the 21cm PS



Total HI mass contained in a halo

- The total HI mass in a halo contributed mainly by the central galaxy for dark matter haloes less massive than 10^{12} solar mass and satellite galaxies for dark matter haloes more massive than 10^{12} solar mass.



Summary

- Including lower HI mass galaxies increases the clustering amplitude and slope in HI-selected galaxy samples.
- Modelling of low HI mass galaxies is important to understand upcoming 21cm intensity mapping results.

Gam sa hap ni da

감사합니다
Thank you~!