Title: Baryon Fraction in Halos: Observational Constraints from HI, X-ray, and Stellar Components

Speakers: Ajay Dev

Collection/Series: Cosmic Ecosystems

Subject: Cosmology

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Abstract:

Feedback processes, particularly from active galactic nuclei (AGN), play a crucial role in redistributing baryons within halos. These mechanisms can displace gas to halo outskirts or eject it entirely, leading to baryon fractions below the cosmic mean. While simulations such as TNG, SIMBA, and EAGLE predict these effects across a wide halo mass range, observational constraints remain largely limited to high-mass groups and clusters.
In this talk, I will present a systematic analysis of the observed baryon content of halos in the local universe across a mass range of $10^{10} - 10^{15} M_{\odot}$

, using a compilation of empirical measurements from the literature. We quantify the contributions of hot gas, stars, and cold gas to the total baryon budget, constructing baryonic mass-to-halo mass scaling relations. We also use the latest eROSITA and ASKAP data to provide the current constraints on the average hot gas and cold gas content in halos through stacking analysis. The baryonic scaling relations are constructed from group- and cluster-scale halos down to $10^{12} M_{\odot}$

for all three components, while additional individual galaxy measurements allow us to extend HI and stellar mass scaling relations to $10^{10} M_{\odot}$

.
By combining these relations with the halo mass function, we then determine the baryon density distribution as a function of halo mass and calculate the cosmic mass densities of stars, HI, and hot gas within halos in the local universe. Our results provide key observational constraints on the distribution of baryons in the local universe, offering insights into potential mechanisms, such as feedback, that regulate baryon retention and redistribution.

Hot gas, Cold Gas and Stars : Mapping the halo baryon budget in the local Universe

Ajay Dev

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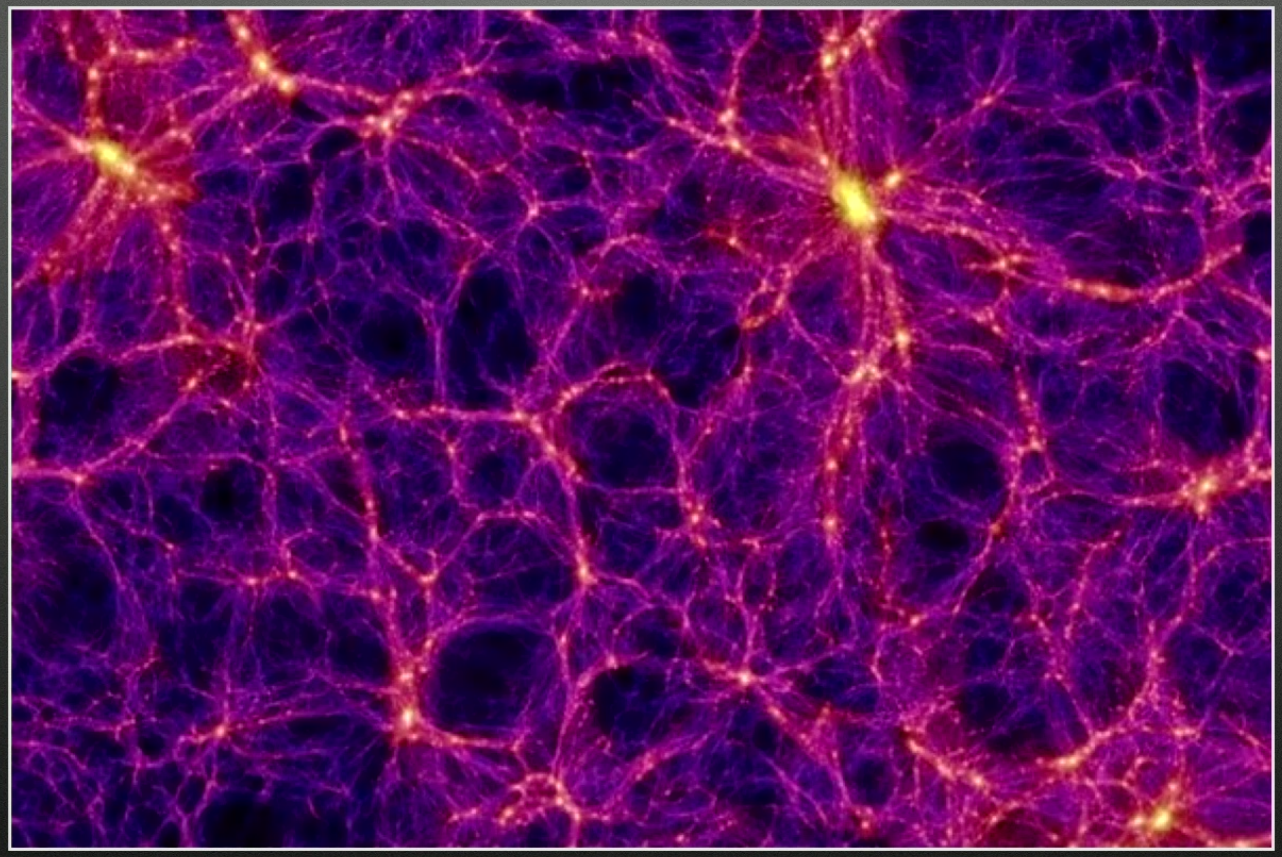
Paola Popesso (ESO)

International Centre for Radio Astronomy Research

THE UNIVERSITY OF WESTERN AUSTRALIA

Cosmic Ecosystems

Perimeter Institute - 31/07/2025



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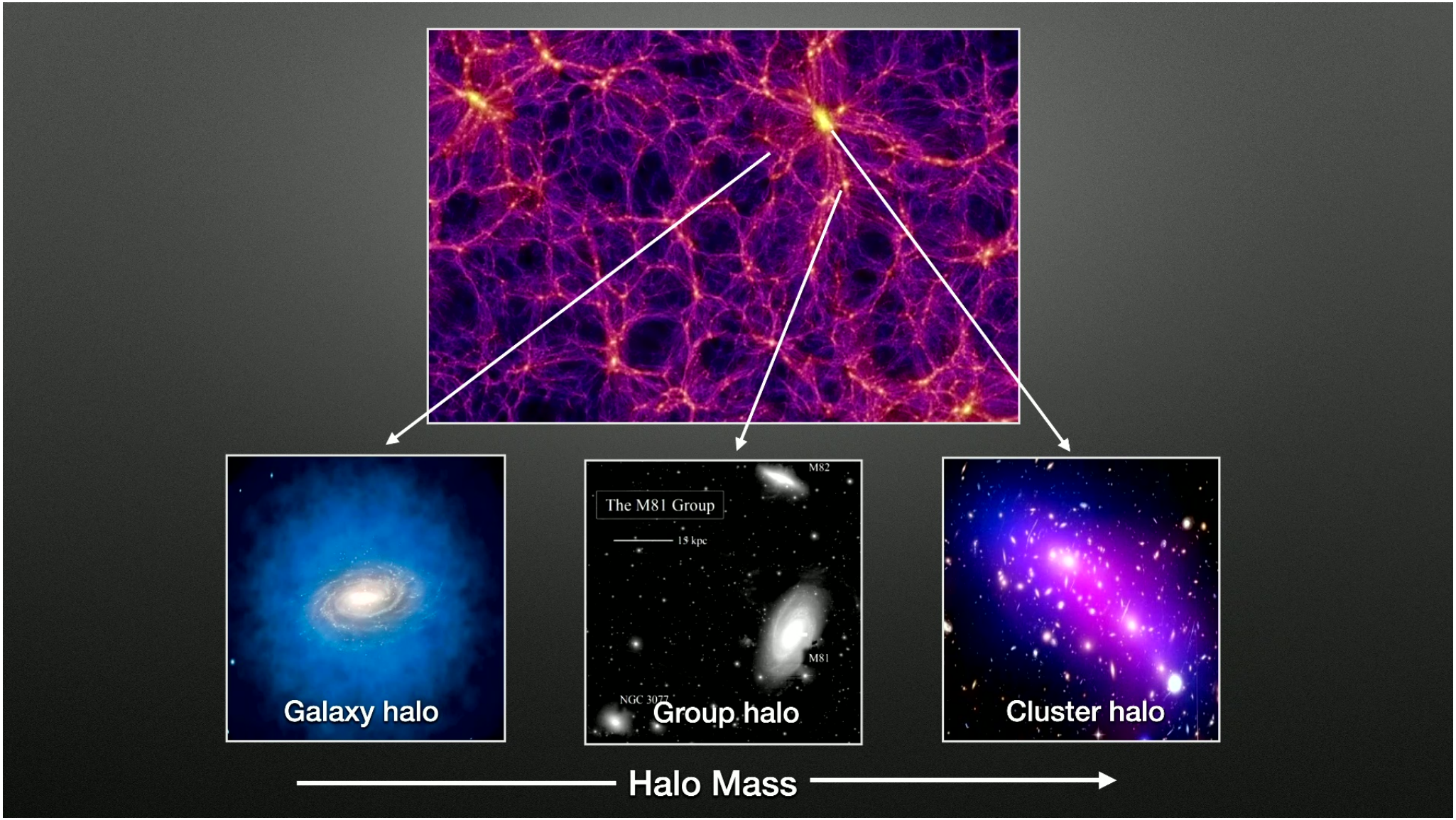
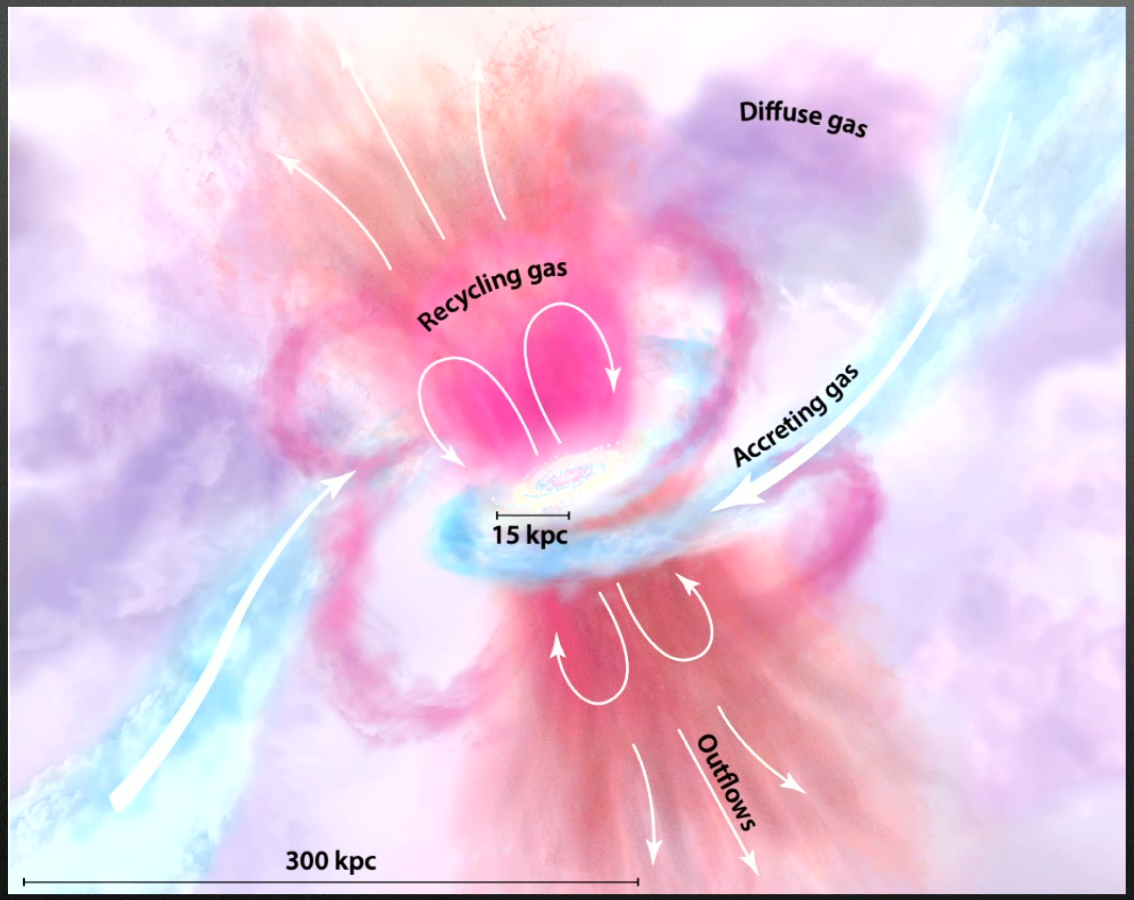

Galaxy halo
The M81 Group
15 kpc
M82
M81
NGC 3077
Group halo
Cluster halo
Halo Mass

Halo Baryon Content

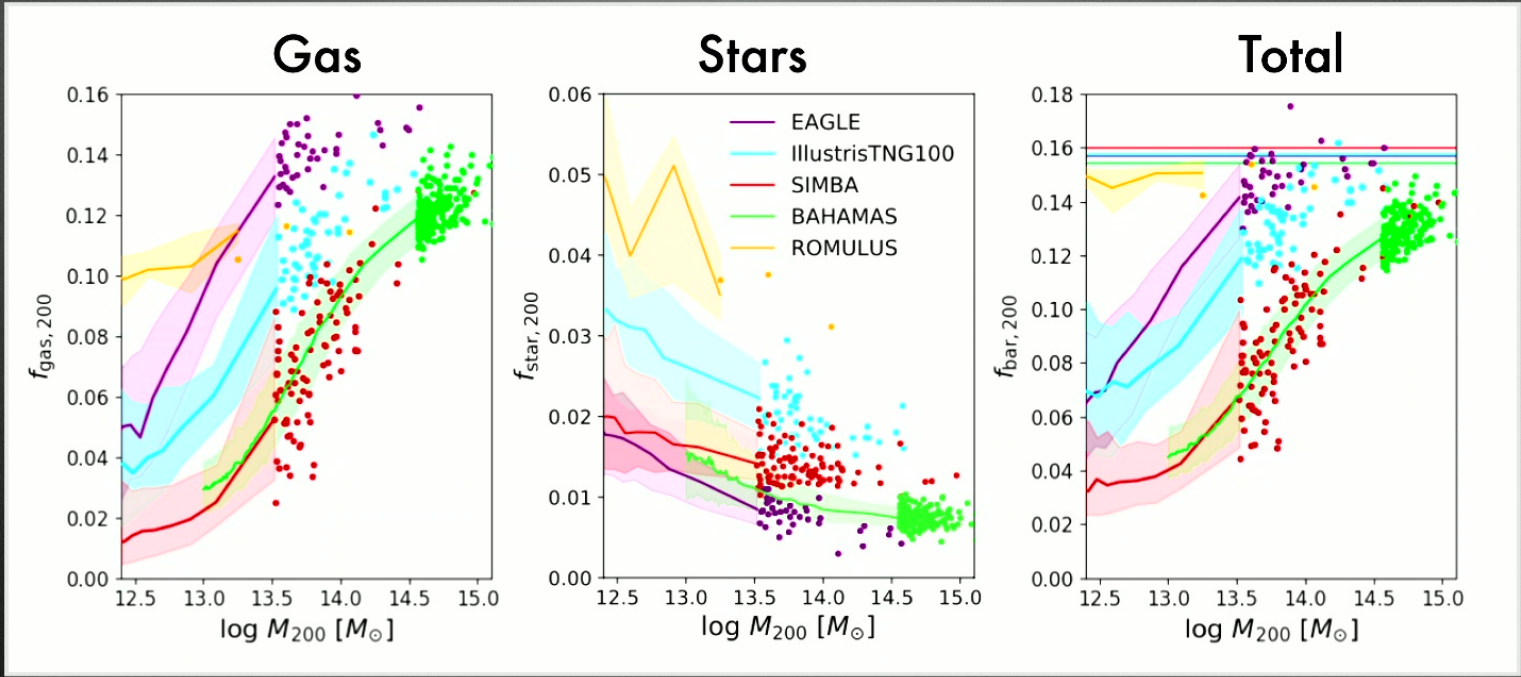


Tumlinson+18

Three main baryonic phases

- Cold gas (Radio)
- Hot gas (X-ray)
- Stars (Optical)

Halo Baryon Content



Oppenheimer+21

Halo Baryon Content

? What are the dominant baryon phases in different environments

? Is the halo baryon fraction universal

? Is there an evolution with redshift

What do we need

✳ Good multi-wavelength data

✳ Good spectroscopic survey

✳ Good group catalogue

SDSS

GAMA

Halo Baryon Content

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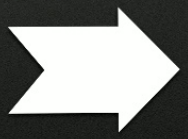

Large area

Deep / sensitive

Complete

Resolution

Halo Baryon Content

? What are the dominant baryon phases in different environments

? Is the halo baryon fraction universal

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This work -
GAMA, SDSS (optical)
DINGO, ALFALFA (HI)
eROSITA (X-ray)

What do we need

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Large area
Deep / sensitive
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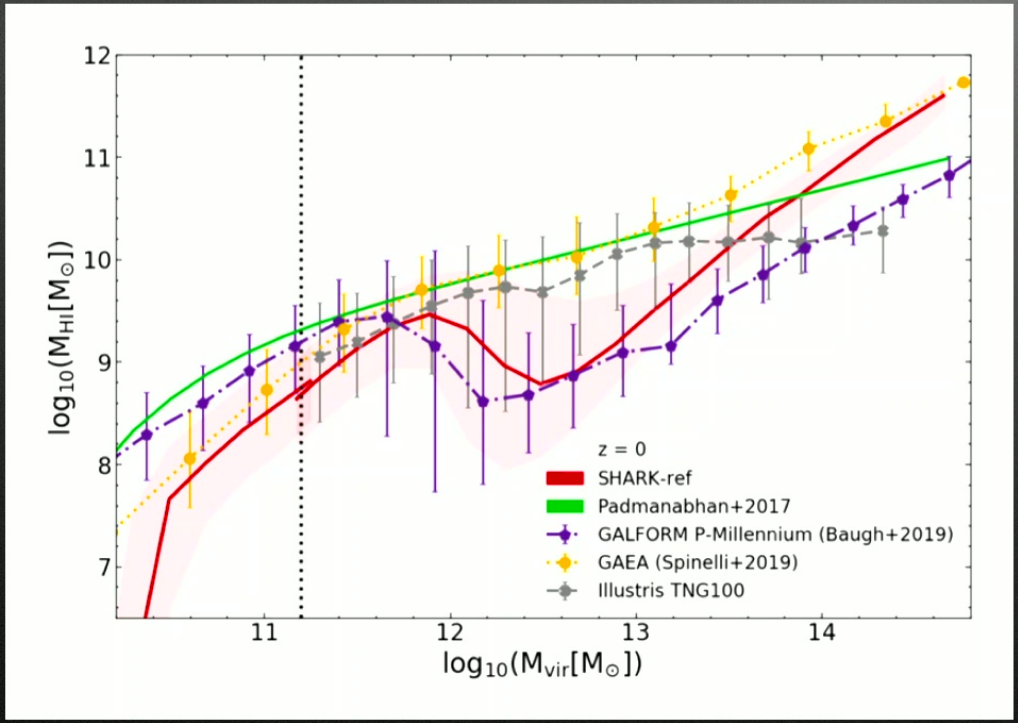
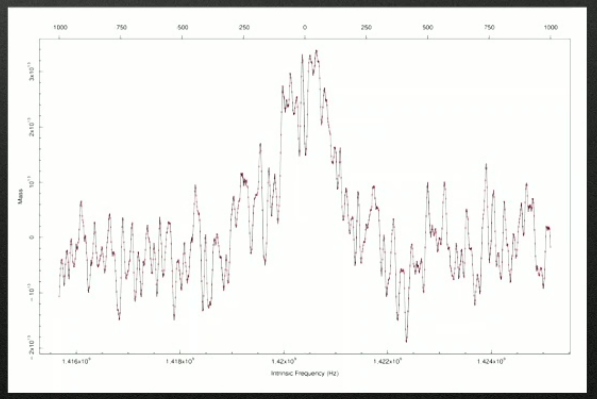
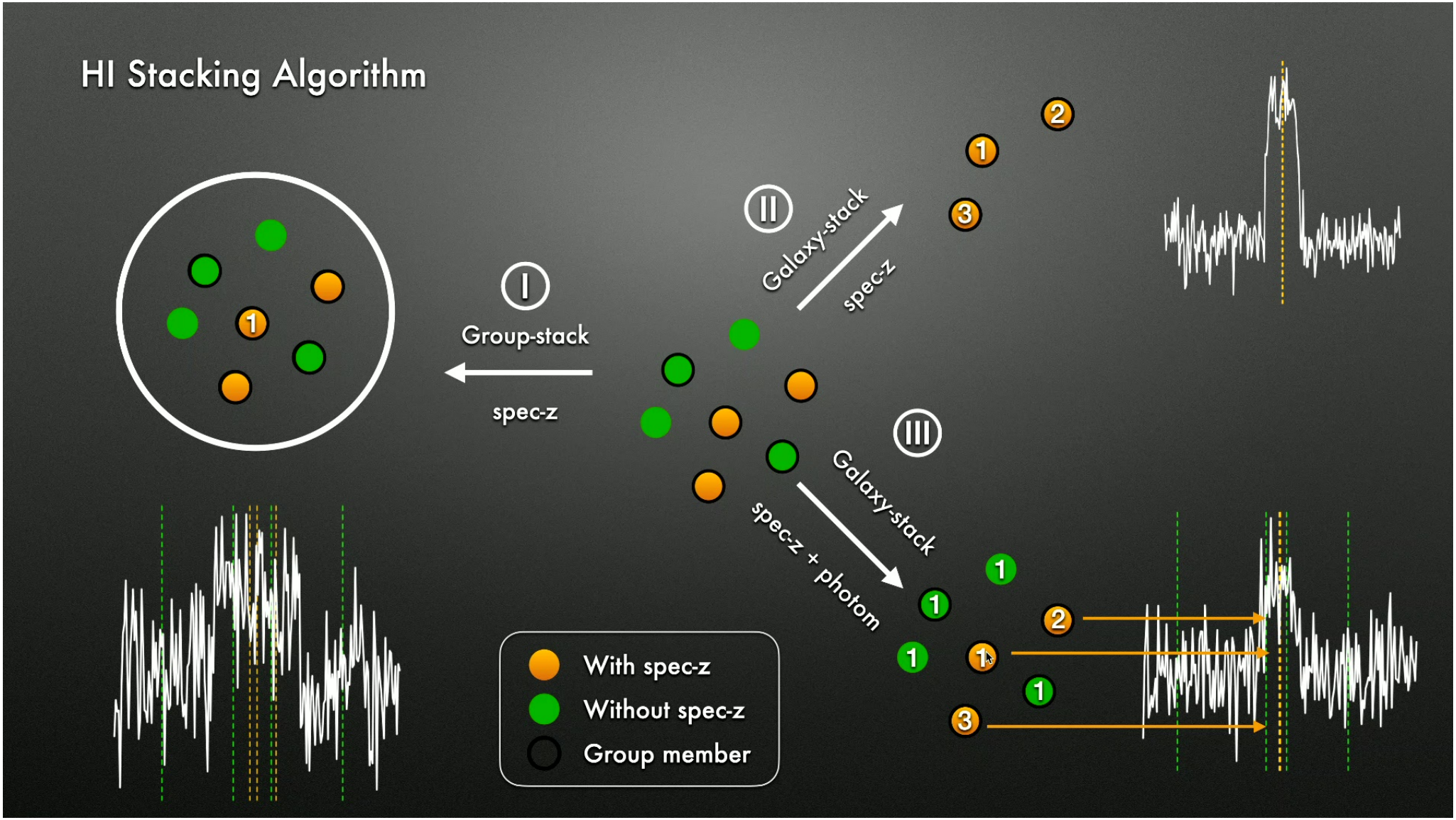
HI - halo mass relation

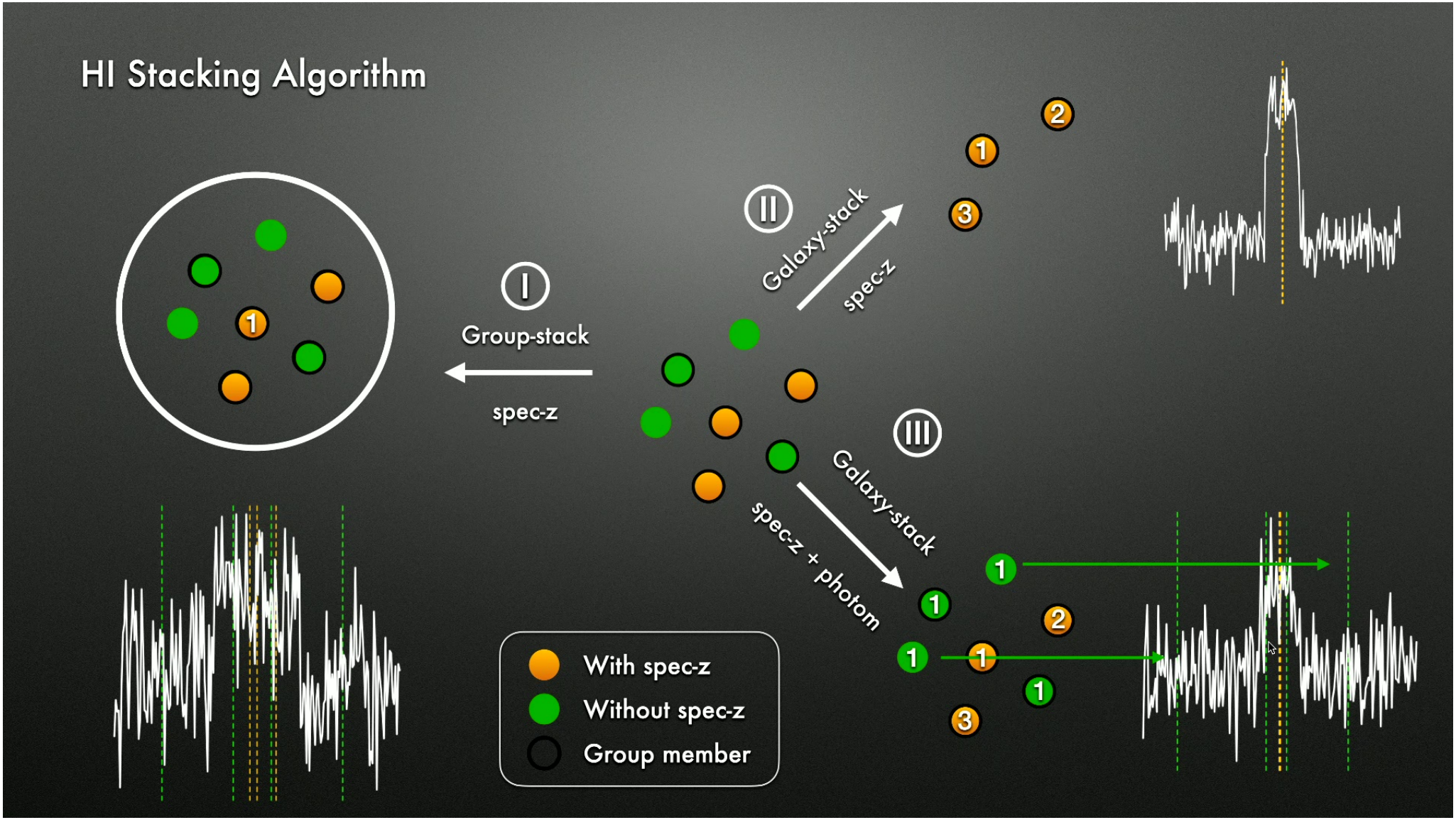


Chauhan+20

- HI which is the fuel for star-formation is at the intermediate stage in the baryon cycle of galaxies.
- Large diversity in model predictions; as well as large scatter in the observed relation.
- Stacking with prior galaxy location info is powerful to estimate the mean trends




HI Stacking Algorithm
I
Group-stack
spec-z
II
Galaxy-stack
spec-z
III
Galaxy-stack
spec-z + photom
With spec-z
Without spec-z
Group member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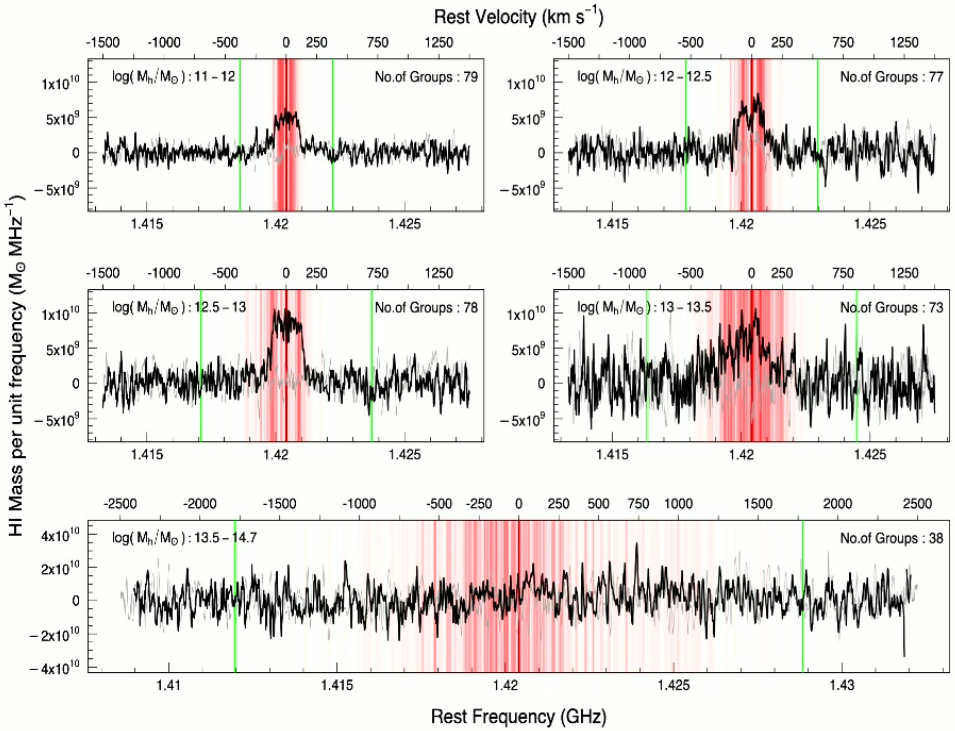
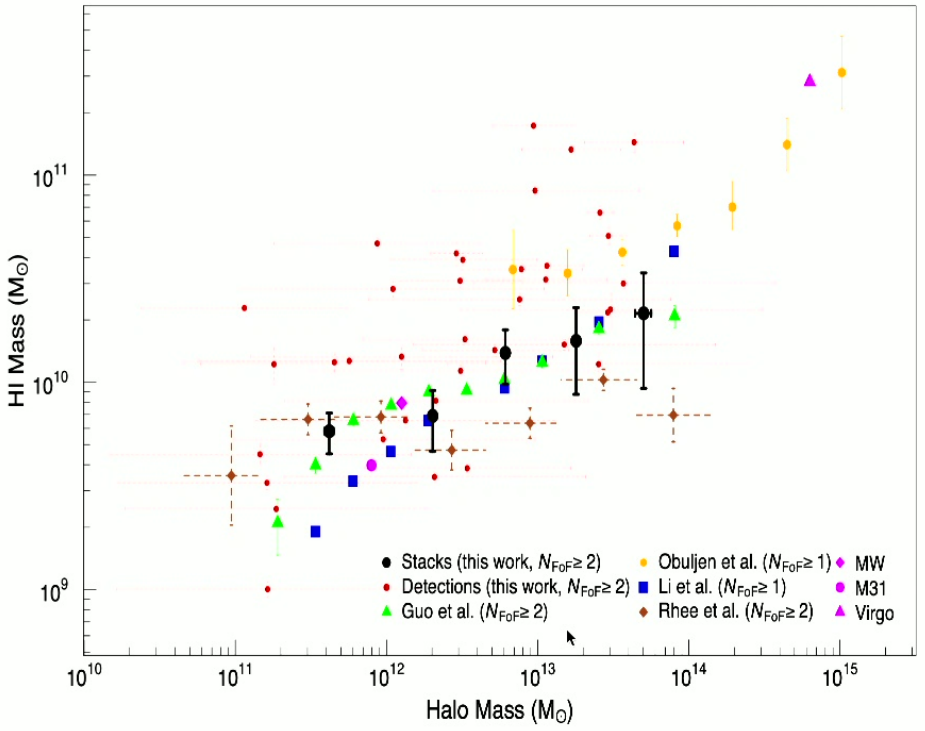
Without spec-z
Group member

Group spectral stacking

Data - GAMA (specz + group cat) + ALFALFA (HI)



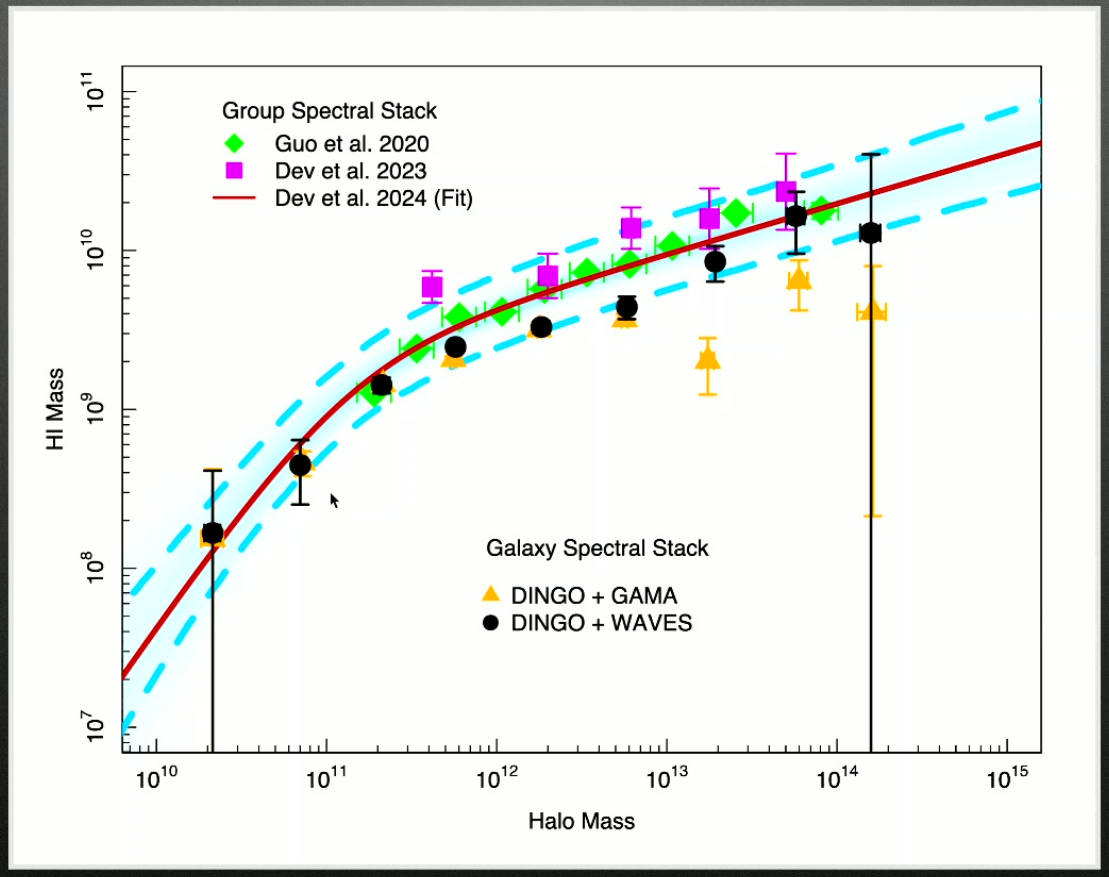


Group spectral stacks in halo mass bins

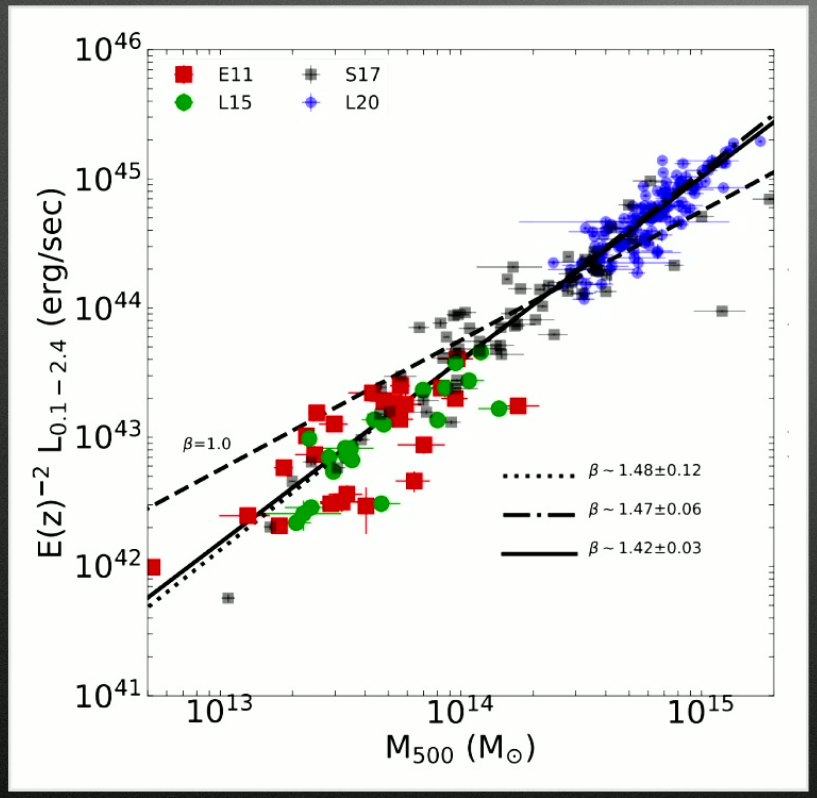
HIHM

Dev+23

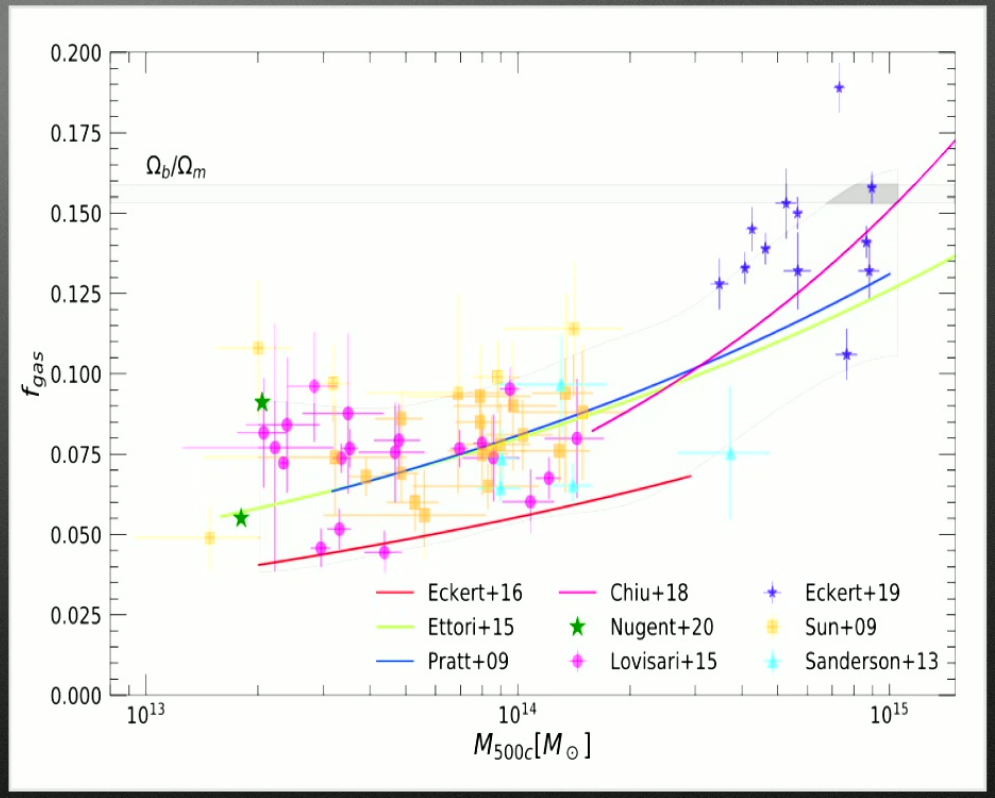
Galaxy spectral stacking



Hot gas scaling relations

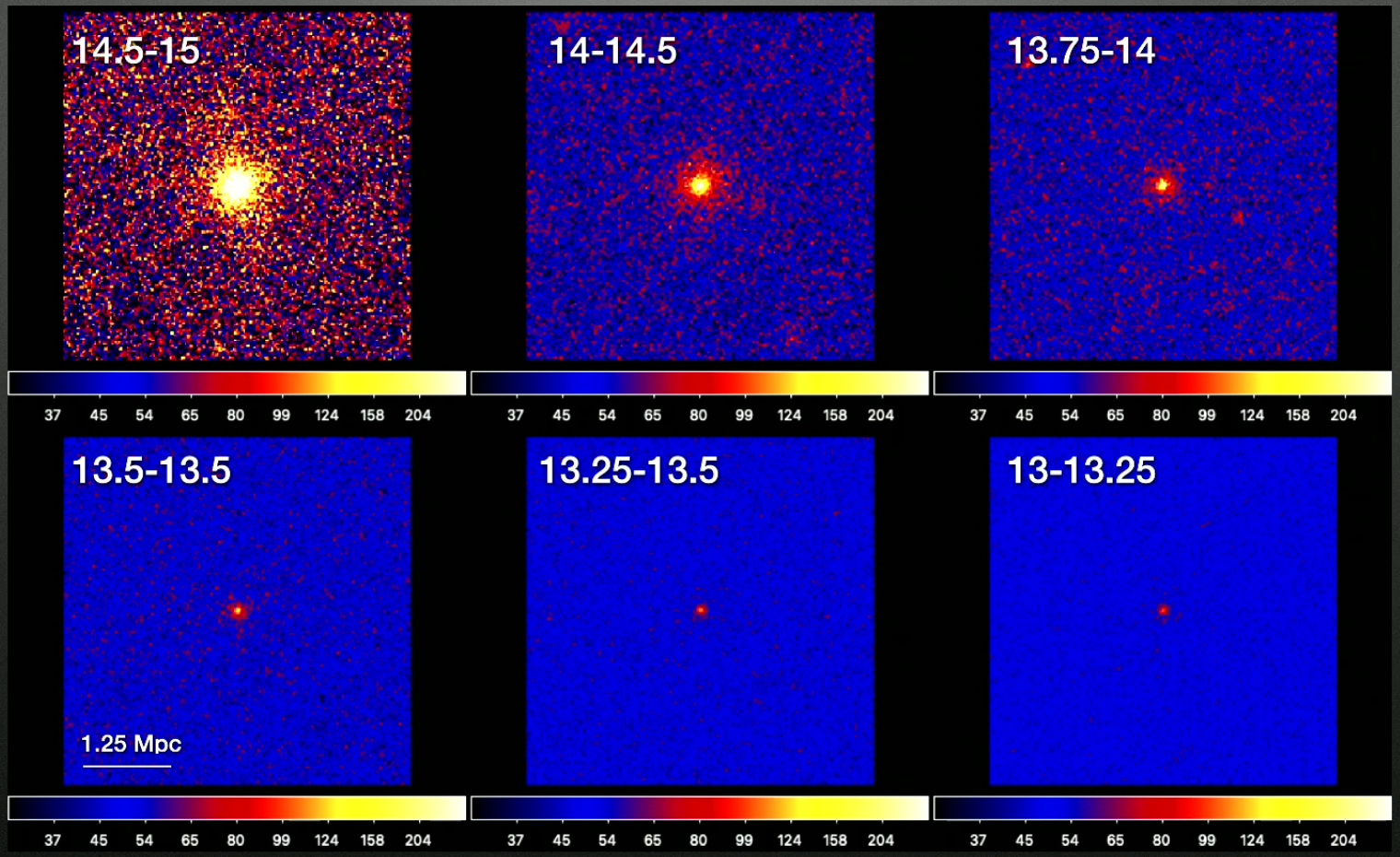


Lovisari+21



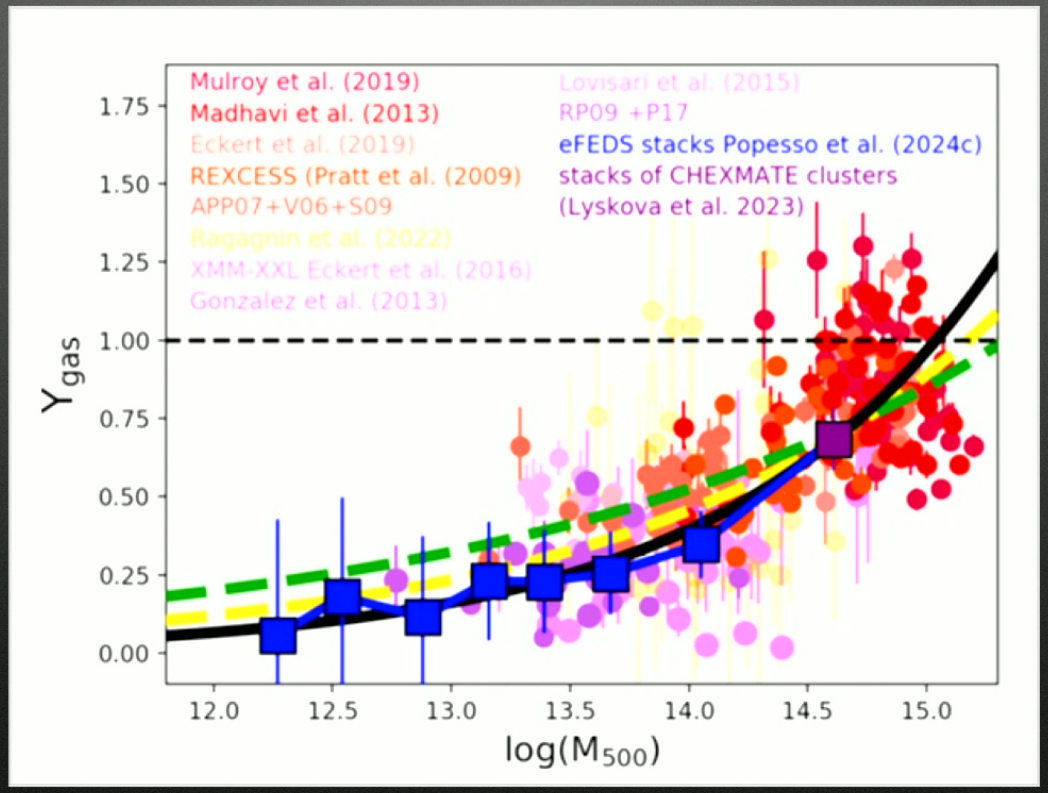
Eckert+21

eROSITA (eRASS1) stacks on SDSS group cat



Hot gas - halo mass relation

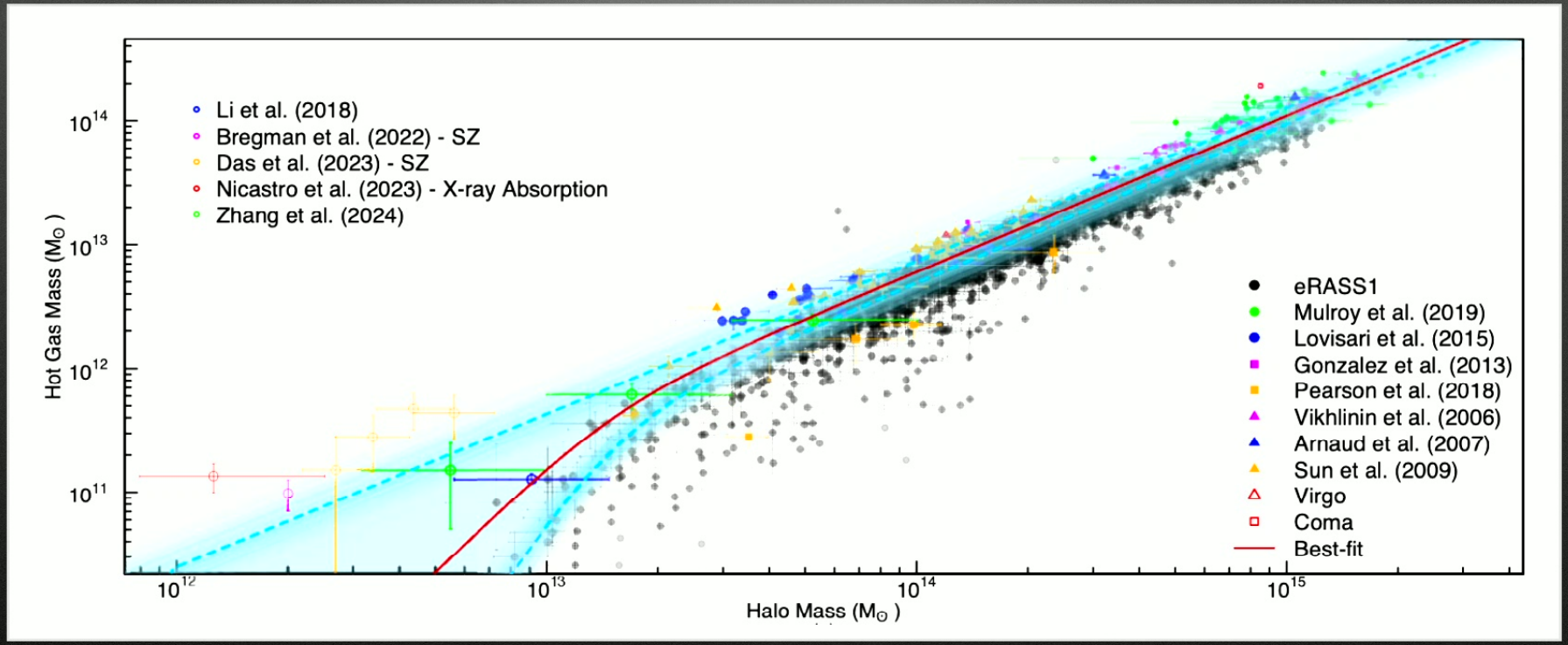
Data : eFEDS (X-ray)
+ GAMA (group cat)



Popesso+25

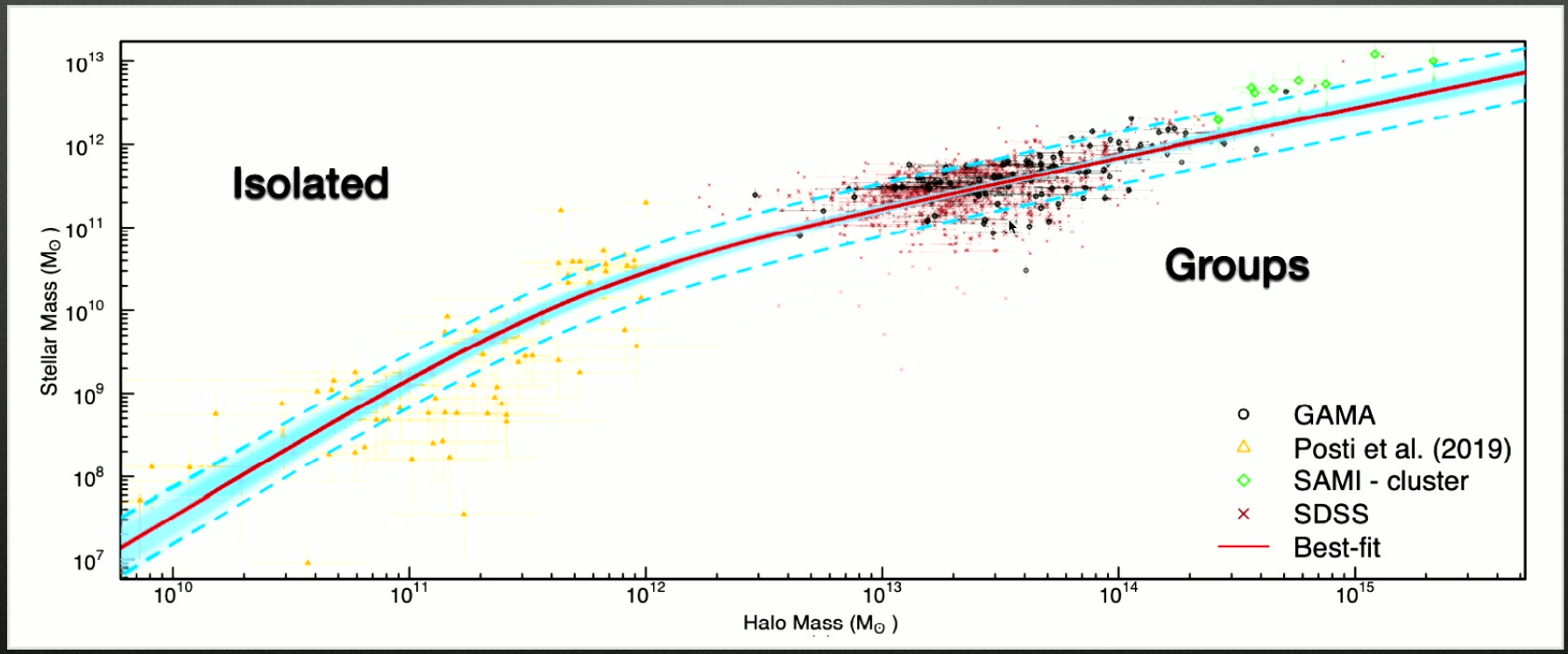
See also -
Popesso+24(a,b,c)
Marini+24,25
Zhang+24(a,b), 25

Hot gas - halo mass relation



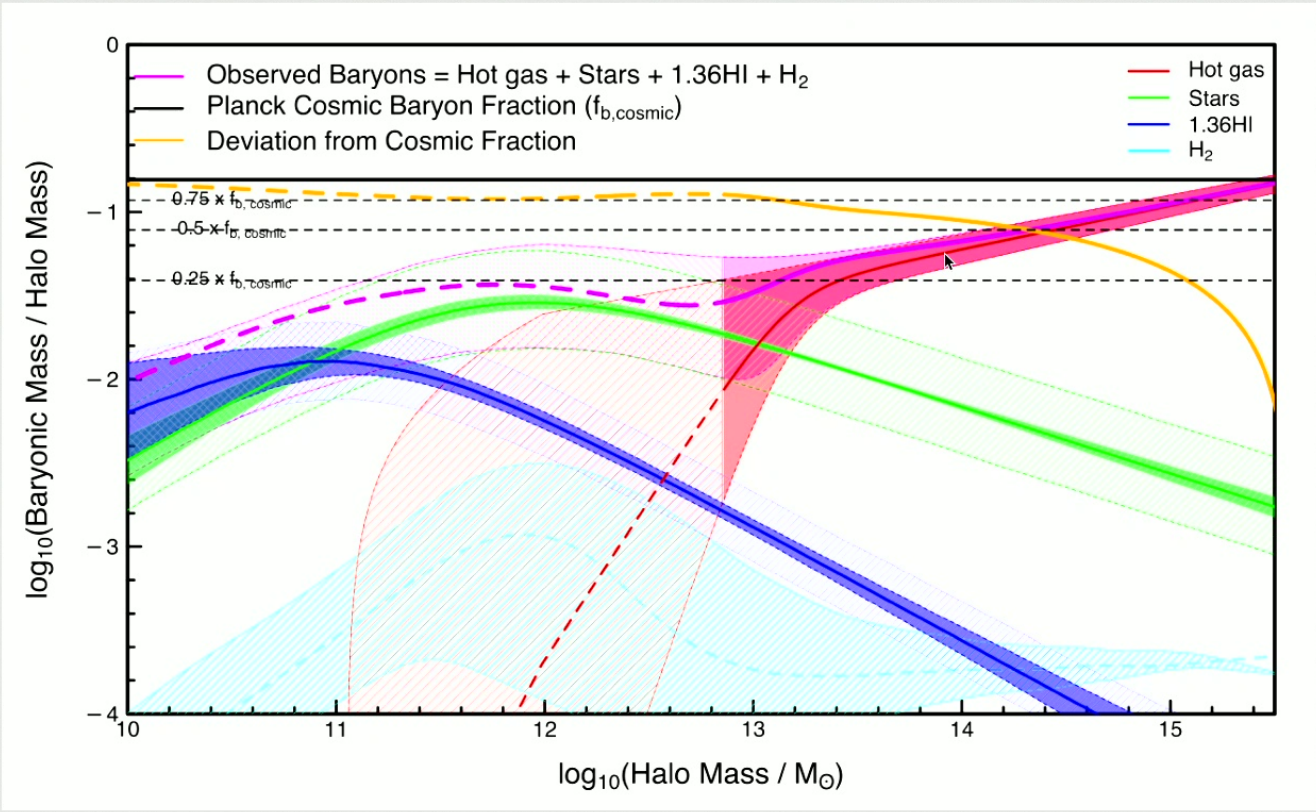
Dev+24

Stellar - halo mass relation



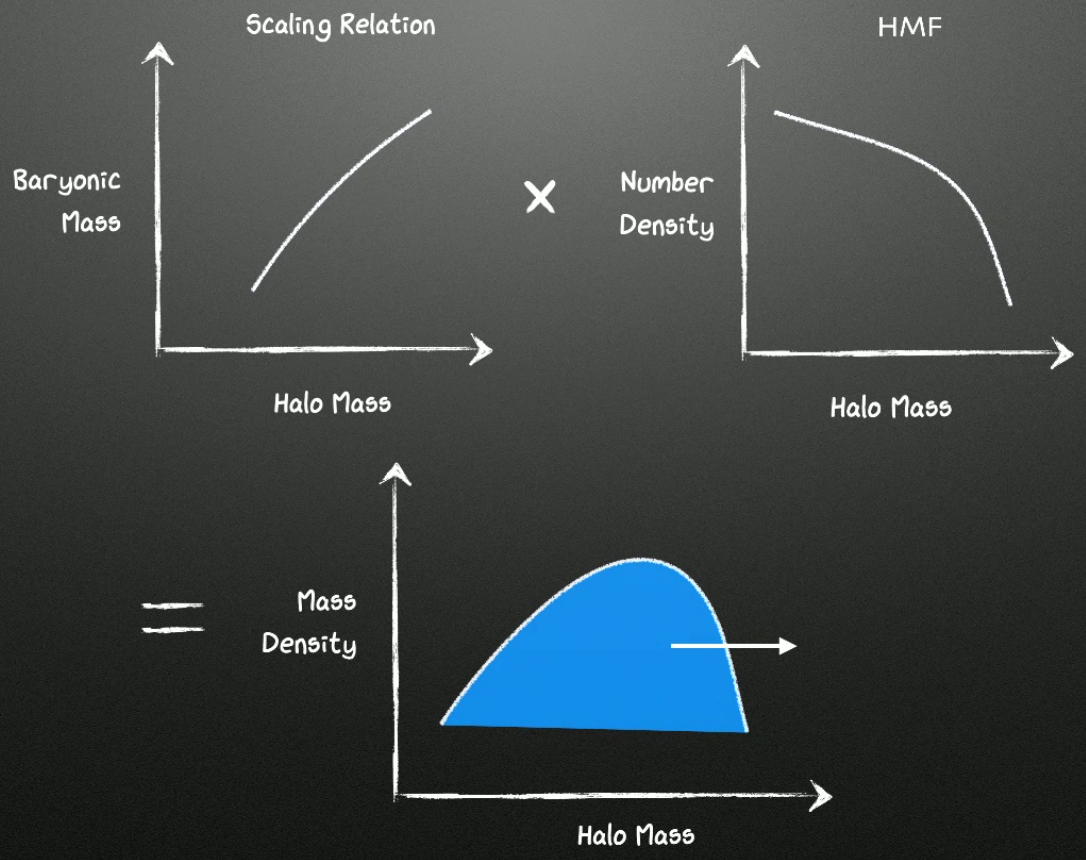
Dev+24

Baryon fraction - halo mass

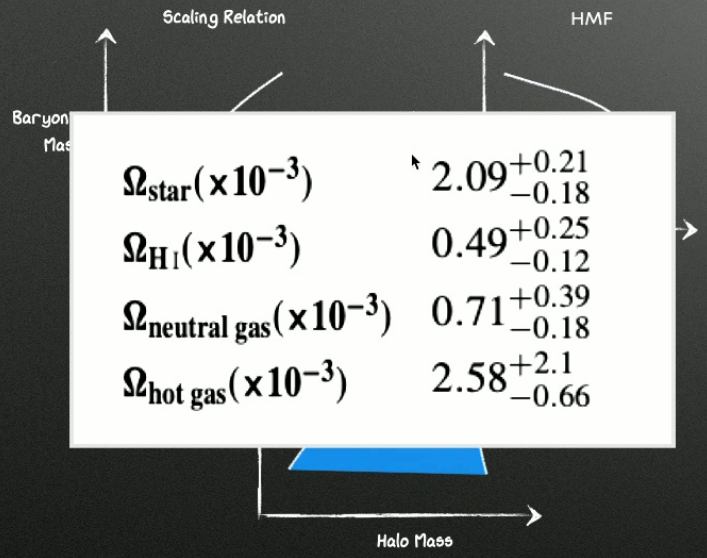


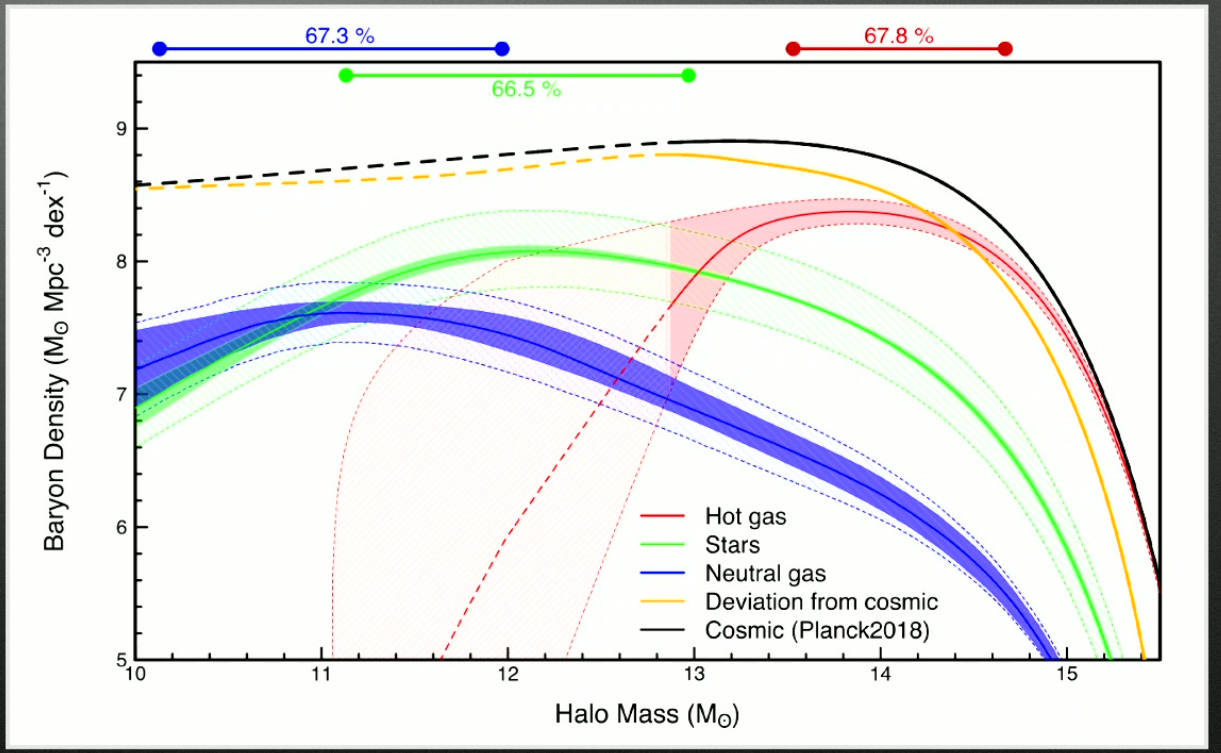
Dev+24

Baryon density - halo mass



Baryon density - halo mass

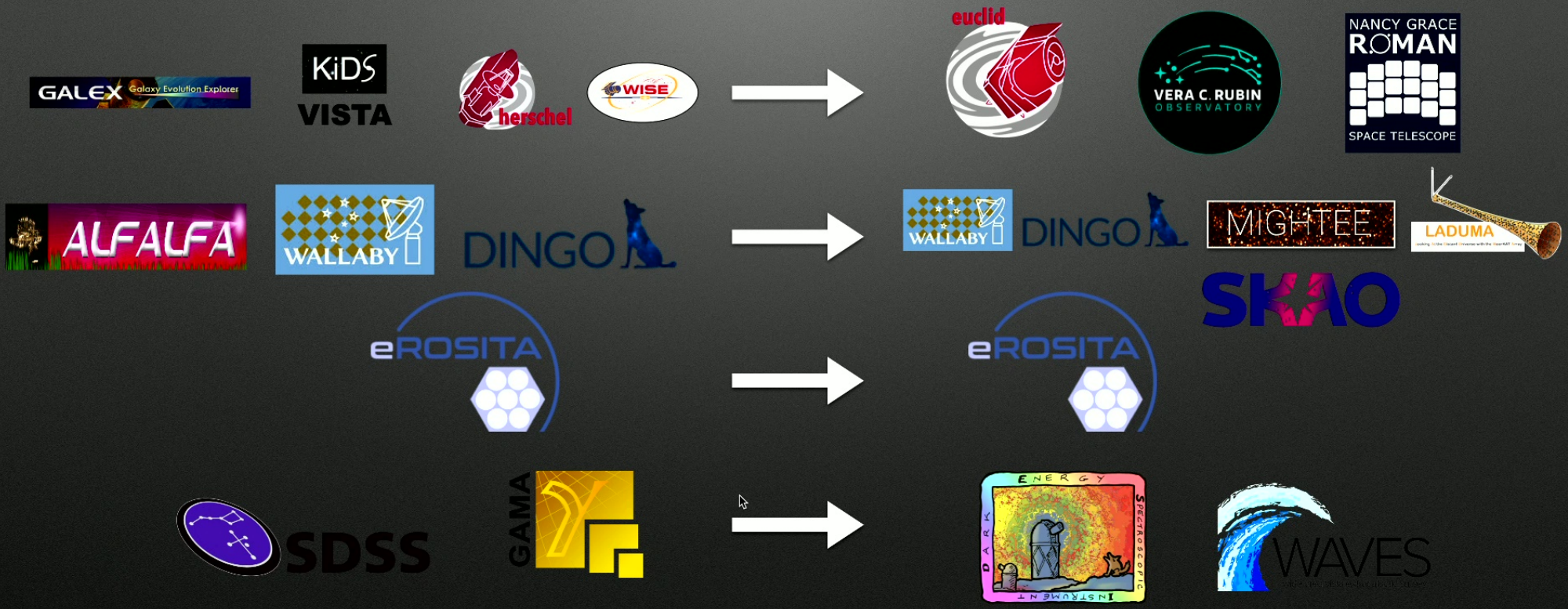




Dev+24

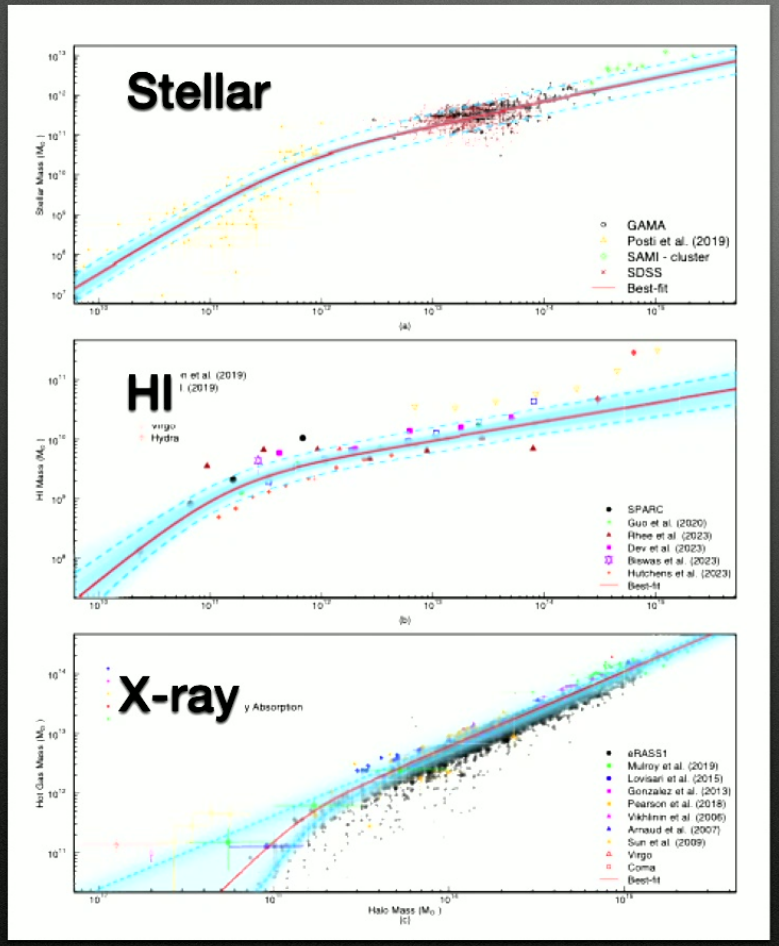
Halo Baryon Content

How can we improve in future



Summary

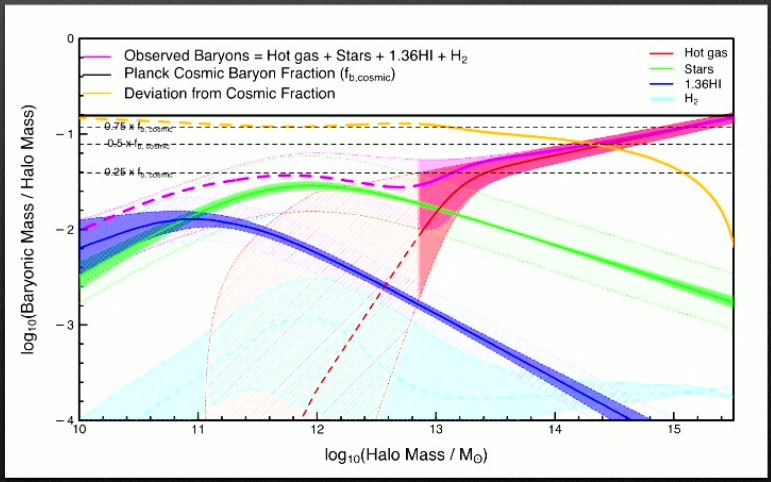
“ How are baryons distributed as a function of halo mass ? ”



Stacking - HI and X-ray

Three baryonic scaling relations

Baryon fractions and densities as a function of halo mass



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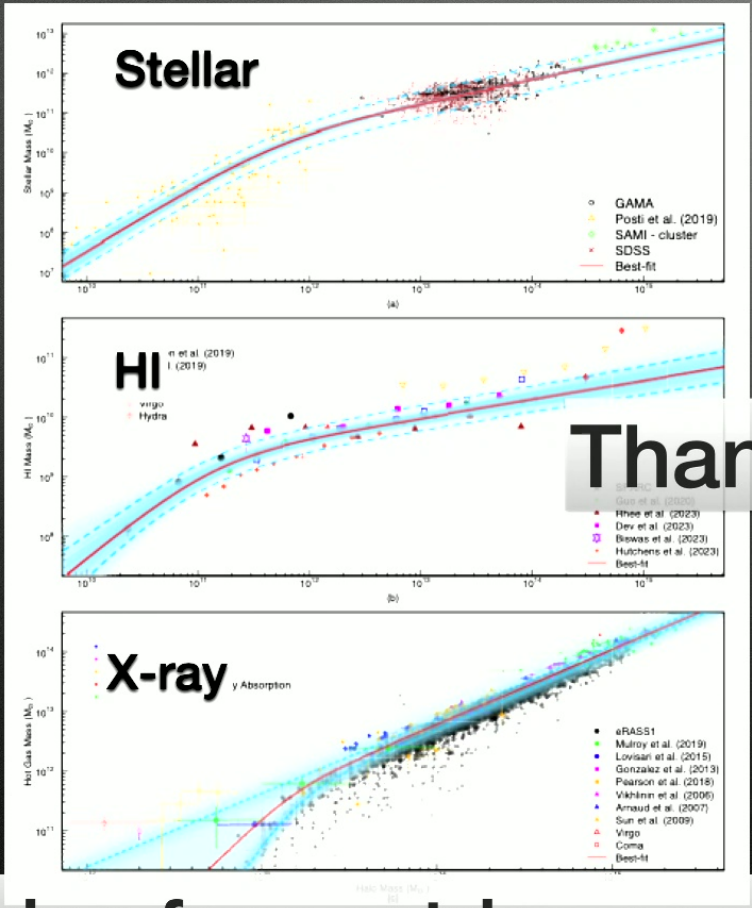
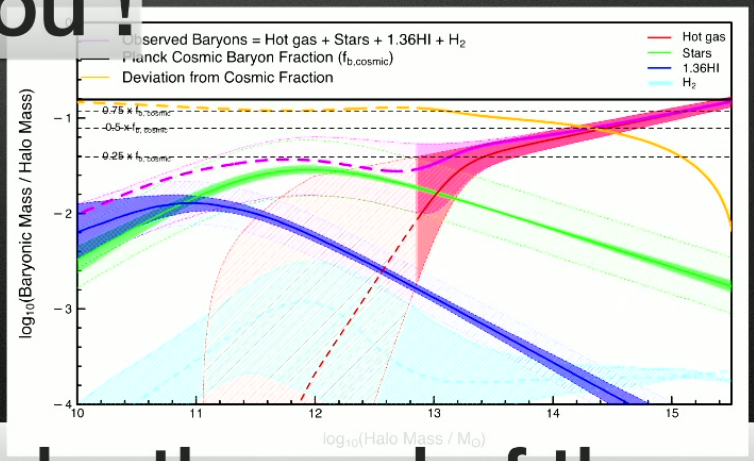


Stacking - HI and X-ray

Three baryonic scaling relations

Baryon fractions and densities as a function of halo mass

Thank you !



Looking for postdoc position by the end of the year!