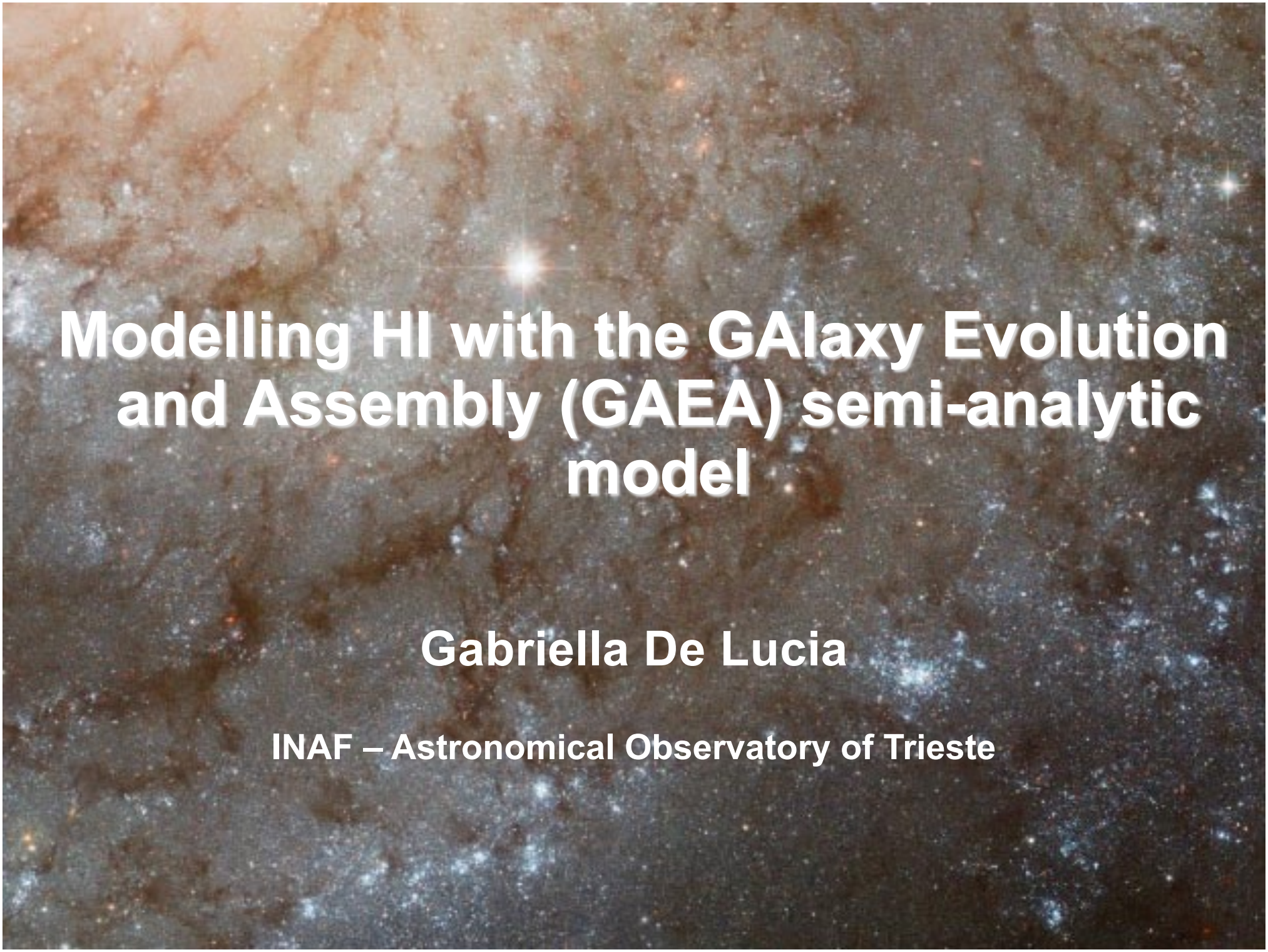


Modelling HI with the GAlaxy Evolution and Assembly (GAEA) semi-analytic model

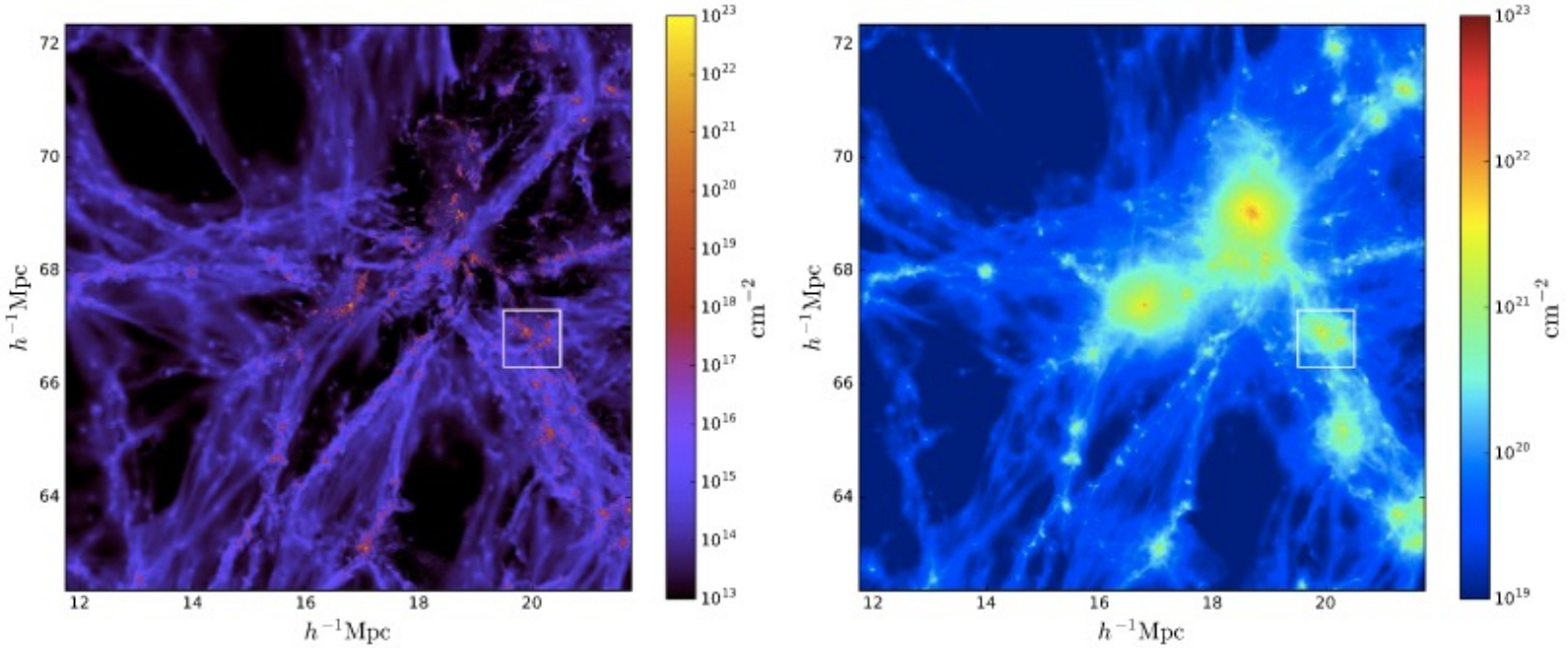
Gabriella De Lucia

INAF – Astronomical Observatory of Trieste

A complex physical problem

HI/H_2 transition governed by the balance between H_2 formation (that occurs predominantly on the surface of dust grains) and H_2 photo-dissociation by UV radiation in the LW band. The latter is shielded by dust, HI and H_2. The process depends on cosmic epoch and environment.

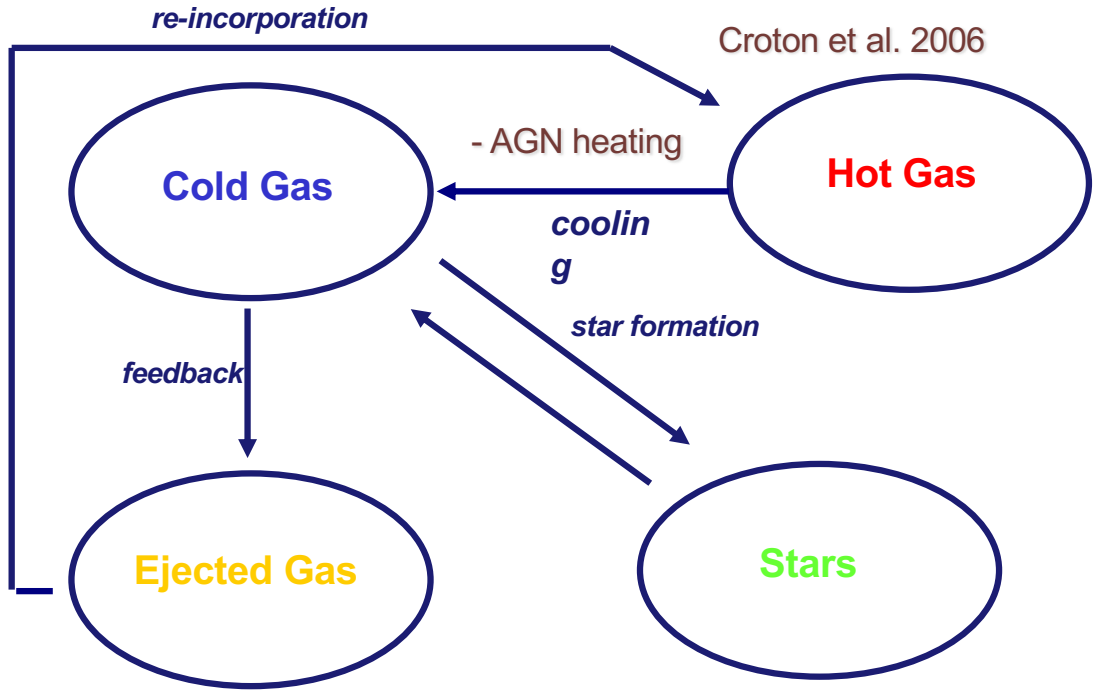
Given the range of scales and complexity of physical processes involved, the approach typically used for cosmological simulations is to estimate amount of HI in post-processing.



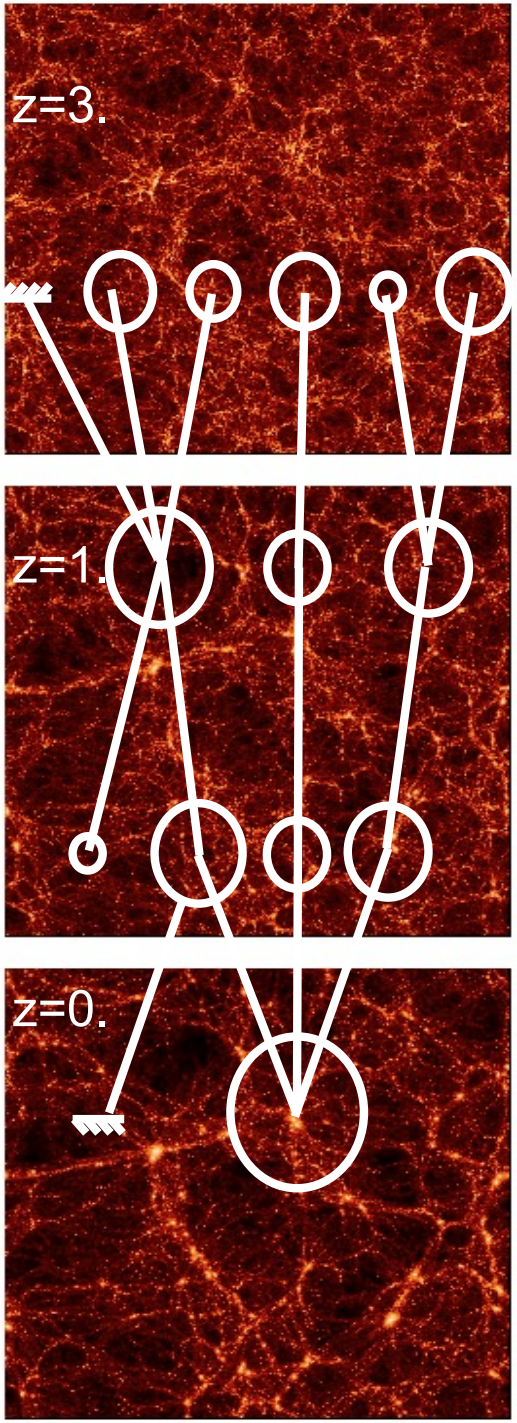
Villaescusa-Navarro et al. 2018

Semi-analytic models

Rely on simple, yet physically and/or theoretically motivated prescriptions to model the evolution of the baryons. Coupled to dark matter simulations that are used to specify the location and evolution of dark matter haloes. Limited computational times. But no explicit description of the gas dynamics.

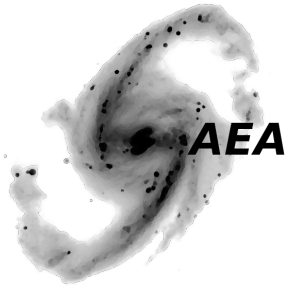


De Lucia, Kauffmann & White, 2004



Kauffmann et al., 1999

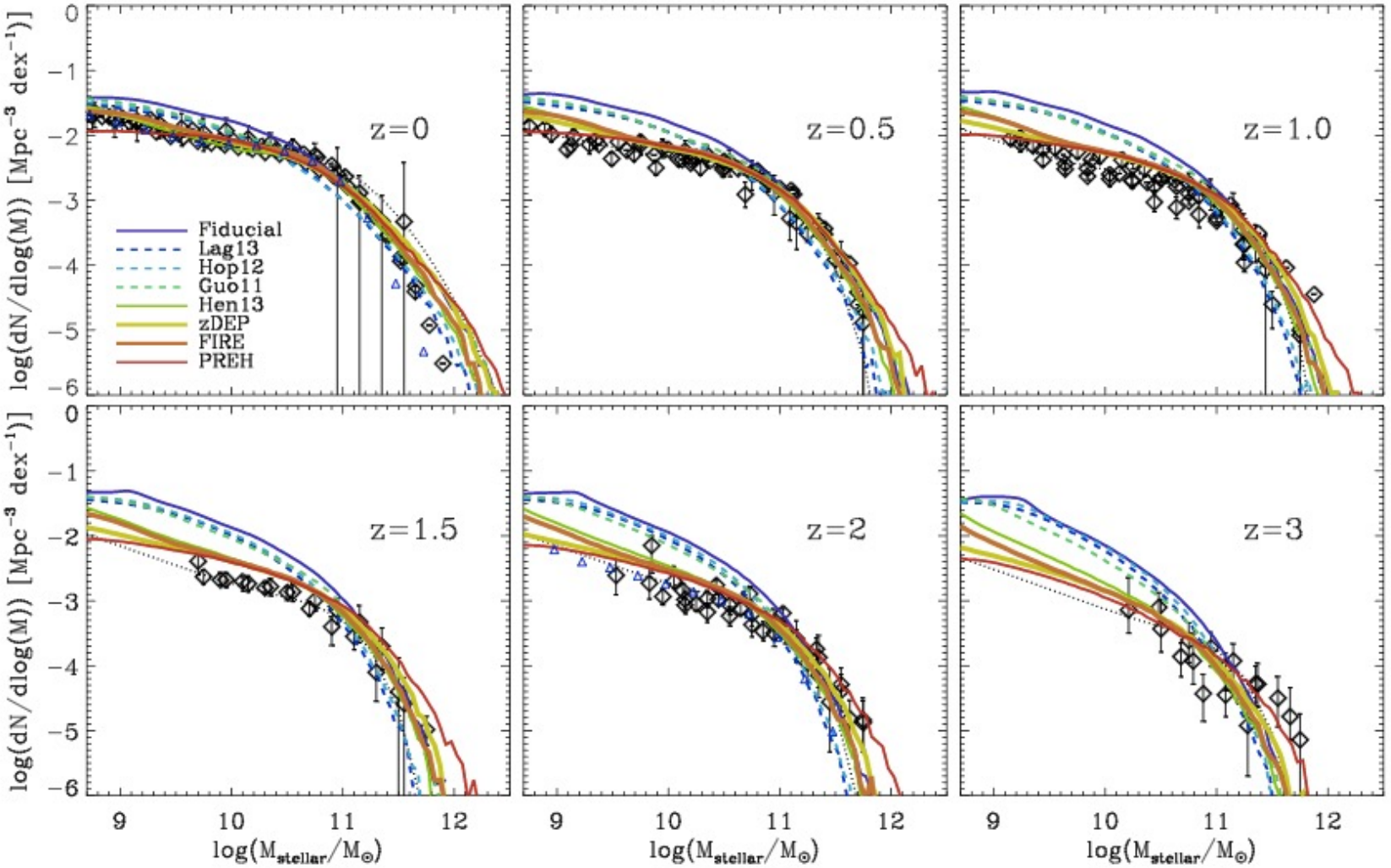
GAlaxy Evolution and Assembly



- A chemical enrichment scheme that accounts for non-instantaneous recycling of gas, energy and metals (**De Lucia et al. 2014**) plus a new stellar feedback scheme (**Hirschmann et al. 2016**)
- An explicit partition of the cold gas in its atomic and molecular component and a star formation law based on the density of molecular hydrogen (**Xie et al. 2017**)
- Updated treatment of AGN feedback (**Fontanot et al. 2020)** and environment (ram pressure of cold and hot gas plus tracing of angular momentum – **Xie et al. 2020**)
- A treatment for a varying stellar Initial Mass Function (**Fontanot et al. 2017; 2018**)
- access to Millennium I and Millennium II (including rescaled merger trees); high-res zoom-in simulations of galaxy clusters; P-Millennium merger trees under construction; dedicated software for construction of light-cones (**Zoldan et al. 2017**)

Reference model calibration

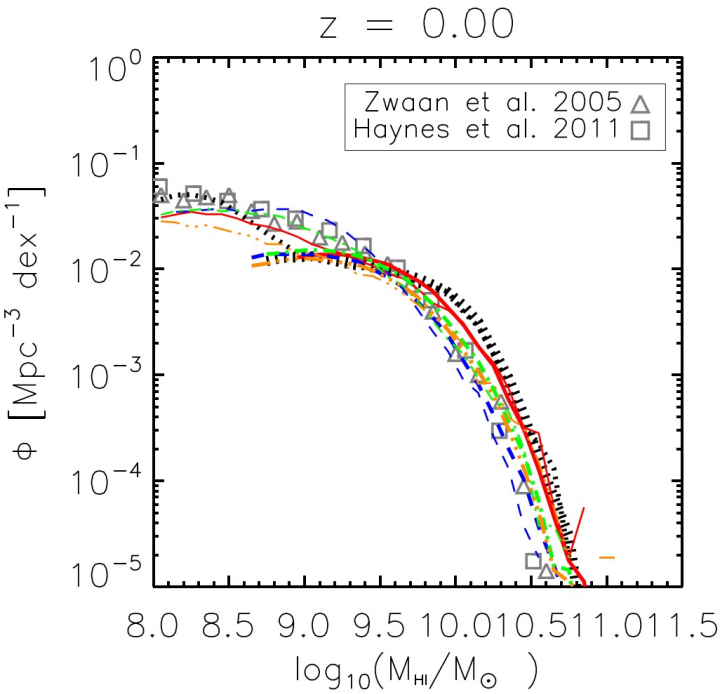
*Hirschmann, De Lucia & Fontanot 2016



* Available at : https://apps.sciserver.org

More info and data at https://sites.google.com/inaf.it/gaea

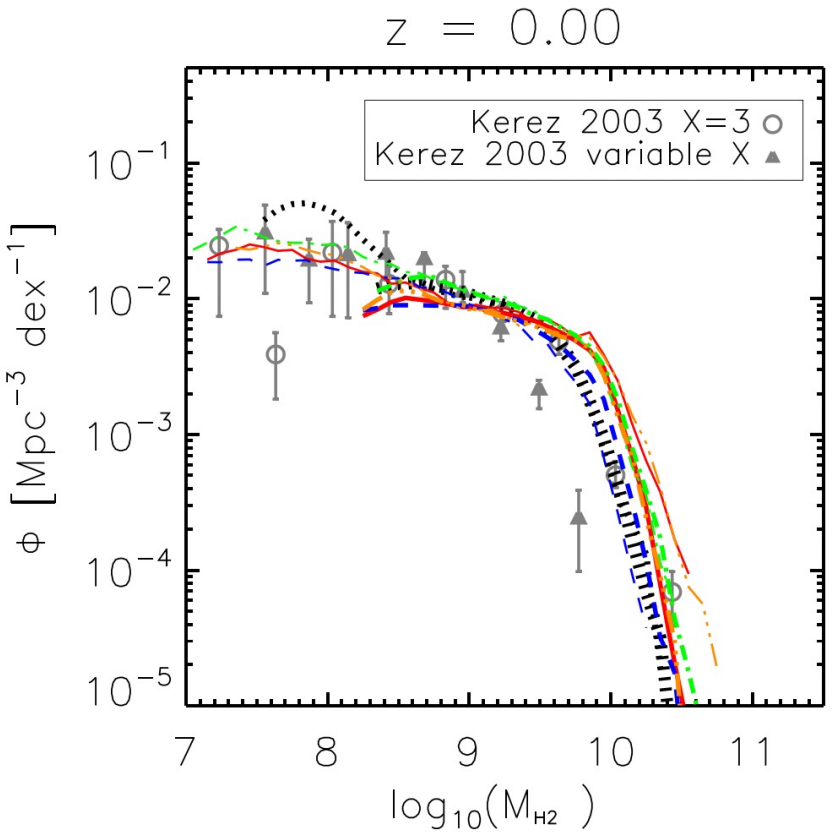
Molecular and atomic hydrogen



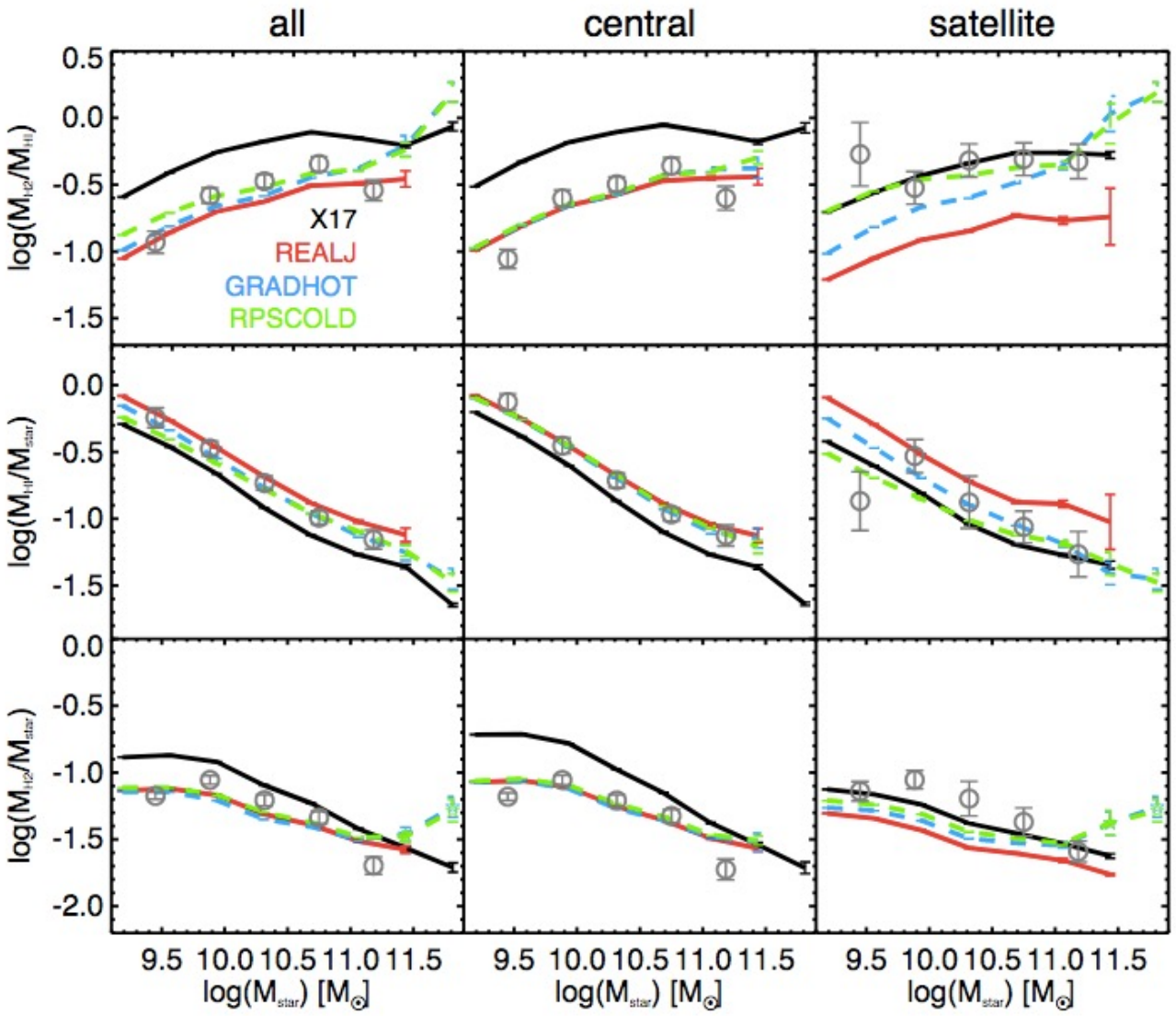
Different prescriptions to model the partition of the cold gas in its molecular and atomic components (empirical, analytic, based on controlled simulations of the ISM).

Our reference model (tracing the angular momentum exchange and including a SFR based on molecular hydrogen) is calibrated mainly on the HI and H_2 local mass functions.

Lagos et al. 2011;
Somerville et al. 2015;
Xie et al. 2017



Predicted scaling relations



Our updated model includes now:

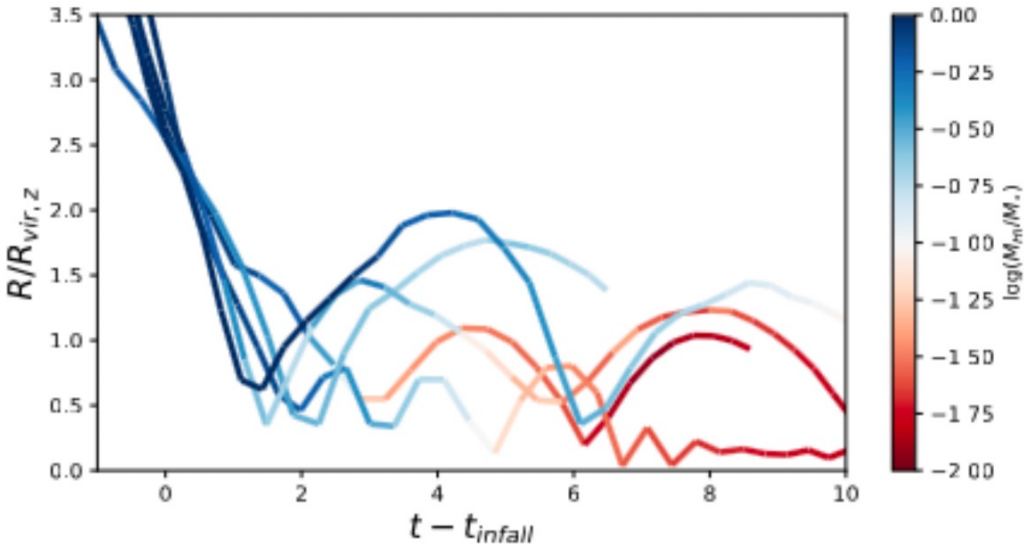
(i) A refined treatment for the angular momentum transfer;

(ii) A treatment for the gradual stripping of hot gas;

(iii) A treatment for ram-pressure stripping of cold gas.

Xie et al. 2020

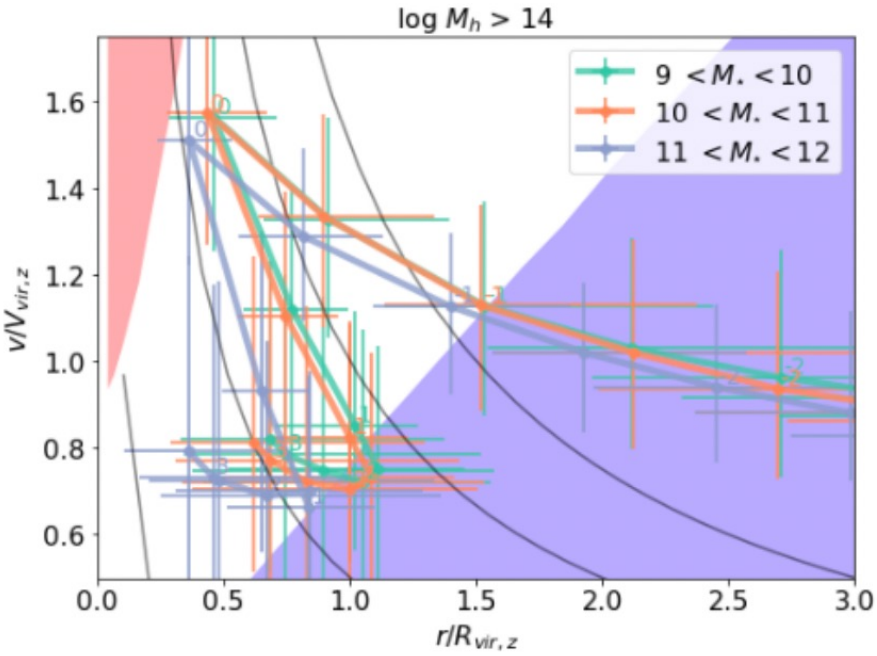
Quenching of satellite galaxies



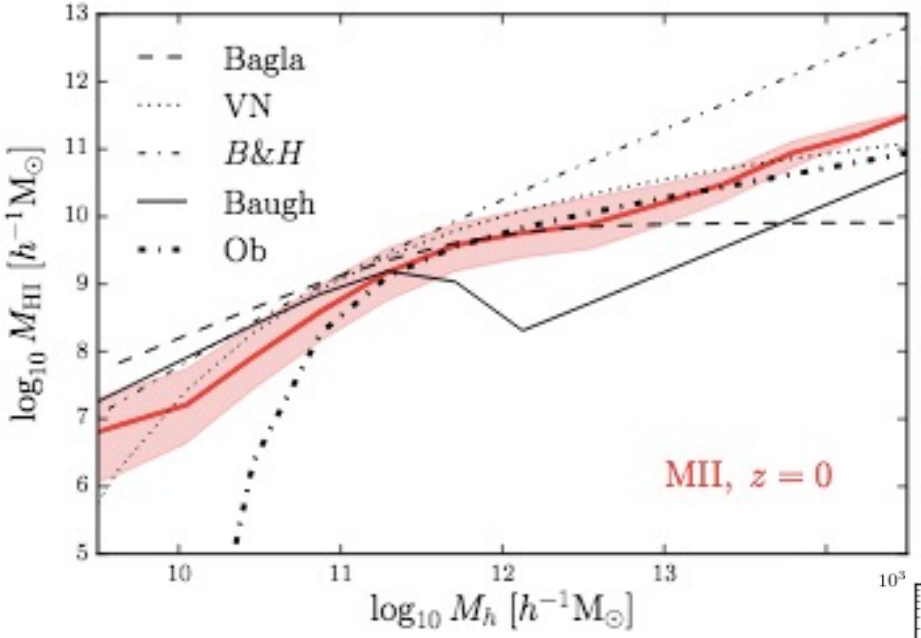
HI deficiency correlated with orbital decay, but most of our satellites retain a non negligible fraction of HI after their first pericentric passage.

Xie et al., in preparation

Very few satellites reach the `strong' ram-pressure region at their first pericentric passage, or ever during their orbital decay. Statistically, ram-pressure stripping is not the dominant process driving satellite quenching.



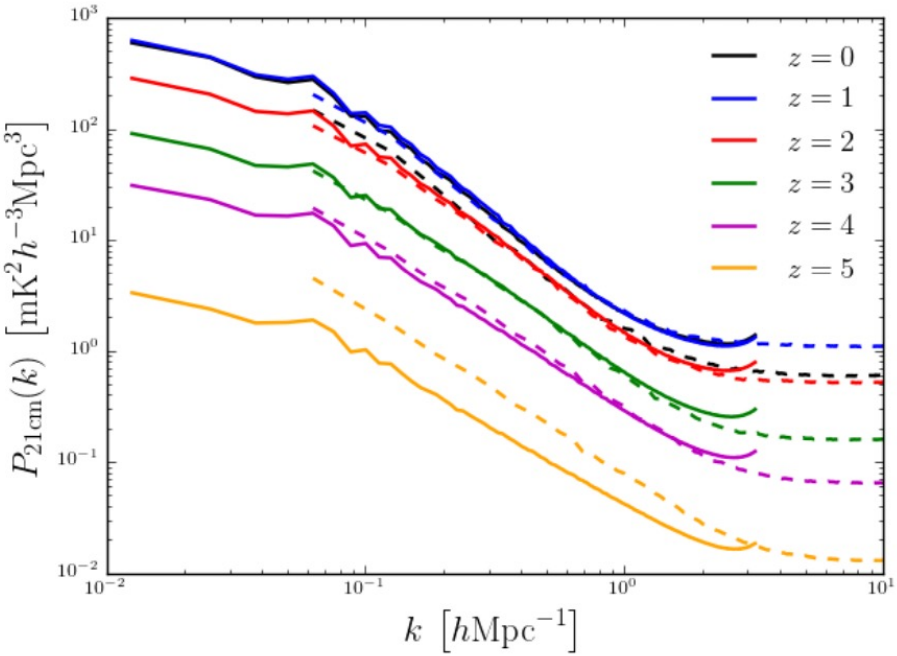
HI content of haloes



Characterization of the relation between M_{HI} and M_{halo}, and of its scatter (we find it is dependent on formation time of the halo).

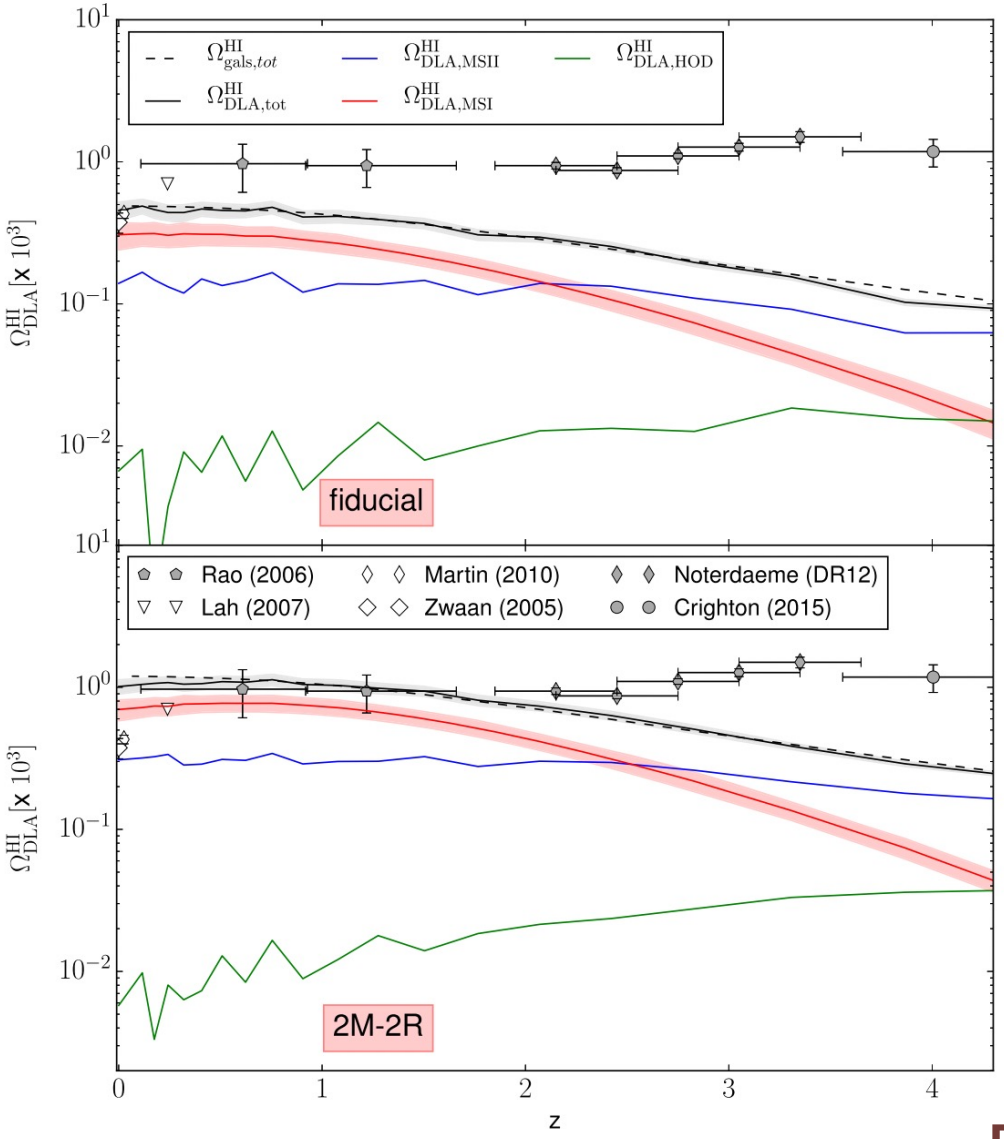
Can be used to populate dark matter only simulations in a more realistic way than using simple HOD.

Approach can be used to make forecast for future experiments, while quantifying how the different ingredients depend on physical processes and galaxy types.



Spinelli et al. 2020

The cosmic evolution of atomic hydrogen



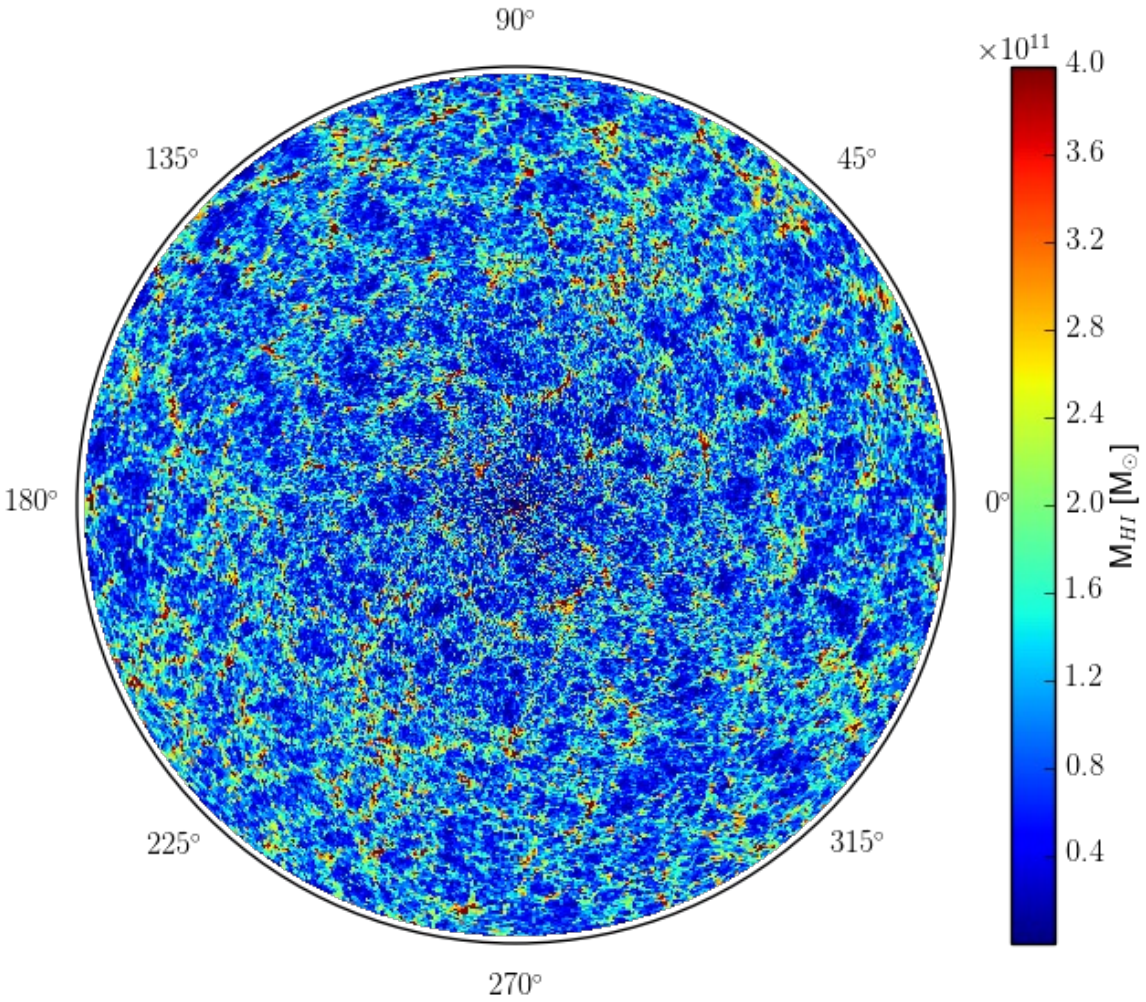
Reference model predicts the correct shape of the column density distribution function of DLAs, but the normalization falls short of the data. The disagreement increases with increasing *z*.

We find that the contribution from unresolved haloes is negligible.

Data are reproduced by doubling the mass and sizes of HI disk. Implications for assumed partitioning of cold gas in atomic and molecular as a function of redshift.

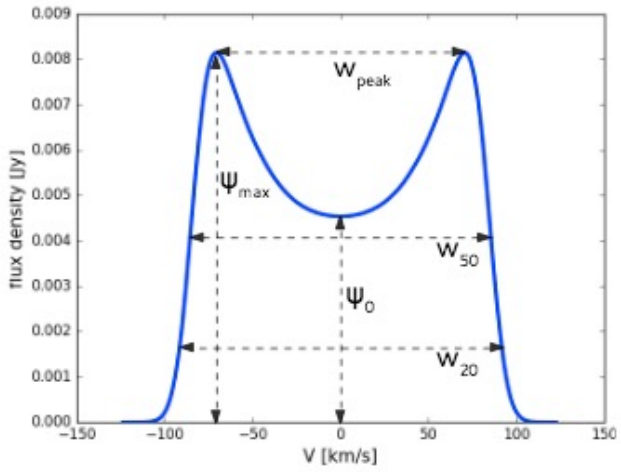
Di Gioia et al. 2020; PhD Thesis

Mock catalogues



Dedicated light-cones including HI and other physical/observable properties.

These can also be used for cross-correlation studies with galaxies samples based on different selections.



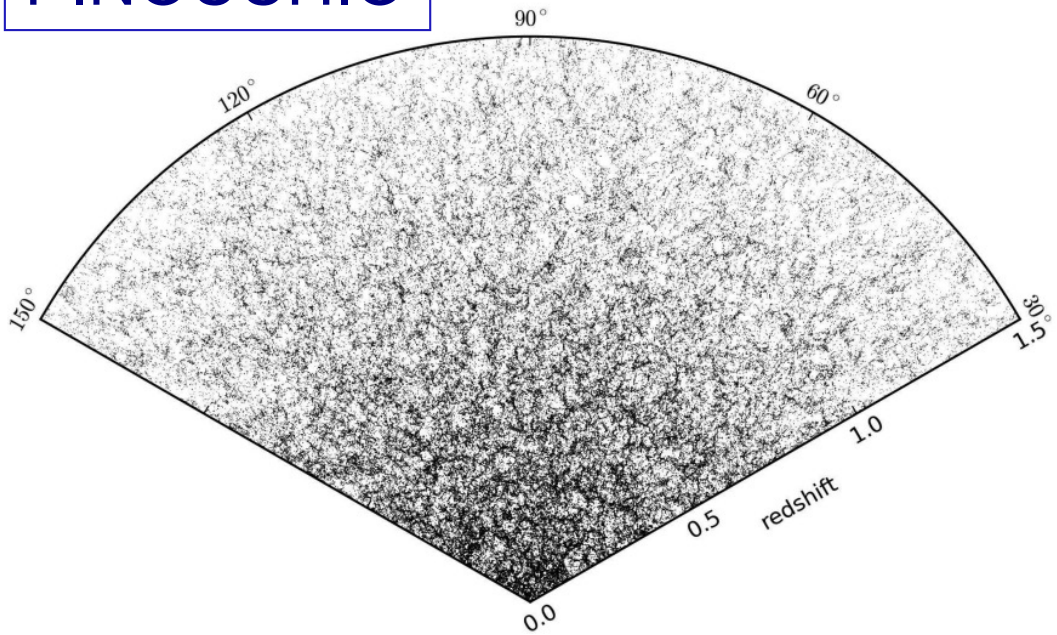
Anna Zoldan, PhD thesis

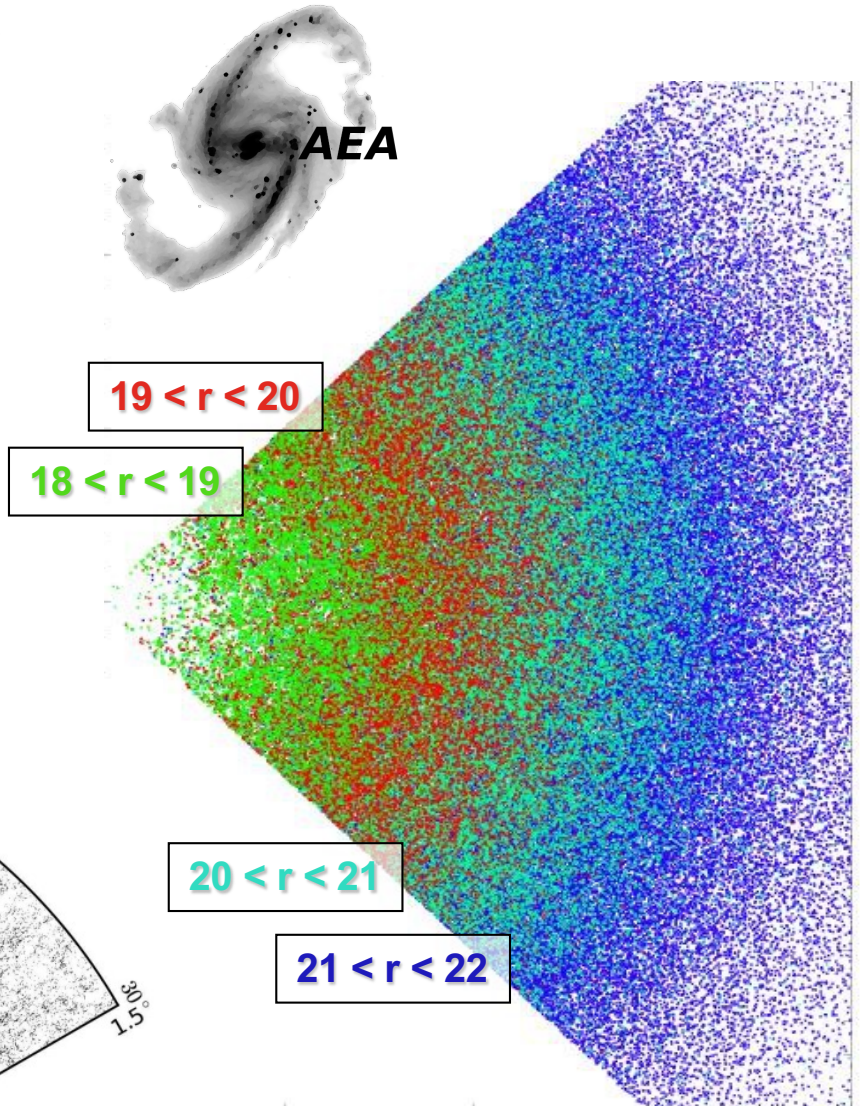
Large, deep, many mocks

Using approximate methods to create (many) large and deep light-cones of dark matter haloes (also based on alternative cosmologies) on the fly (no need to replicate simulated boxes).

Coupling to a semi-analytic model to populate haloes with galaxies.

PINOCCHIO





Vieri Cammelli, in progress

Final remarks

- Semi-analytic models represent a *flexible tool to model galaxy formation in a cosmological context* (limited computational costs, large dynamic range in mass and spatial resolution).
- GAEA includes an explicit partition of cold gas in HI and H_2, and reproduces nicely a large number of observational constraints. *Ideal tool to build dedicated mocks* for interpretation of existing/coming data and forecasts for future experiments.
- Work ongoing to allow construction of *many, larger, deeper mocks*.
- An explicit treatment of *ram-pressure stripping of cold gas* in disks and of the hot reservoir associated with infalling galaxies is *required, but* cold gas stripping is *not the dominant process* driving satellite quenching.
- *Cosmic density of atomic hydrogen under-predicted at high-redshift*. Only partially explained but unresolved haloes and gas in filamentary structures. *Implications on partition of cold gas as a function of redshift*.