

# Near field cosmology with constrained simulations: the CLUES project

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# Collaborators

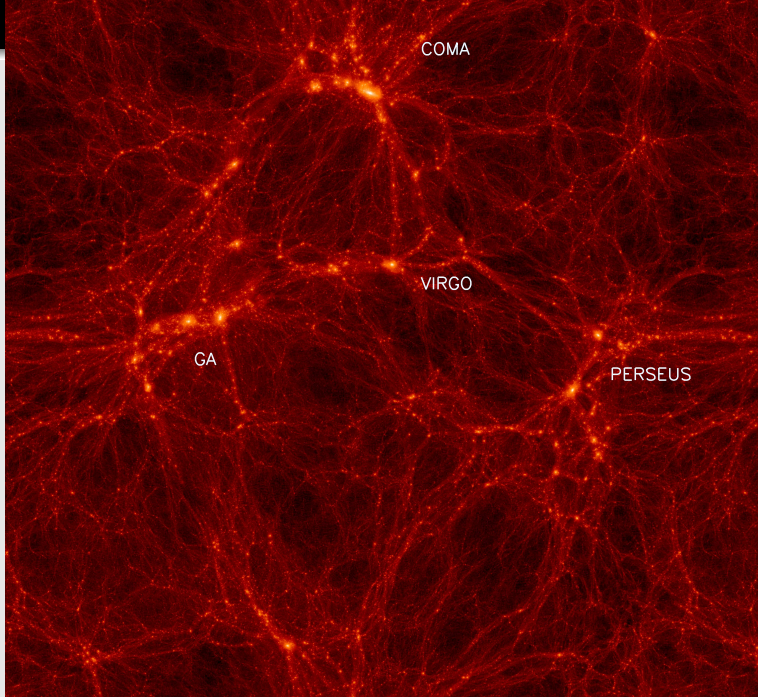
- Yehuda Hoffman (HU, Jerusalem)
- Gustavo Yepes (UAM, Madrid)
- Noam Libeskind (AIP, Potsdam)
- Brent Tully (IfA, Hawaii)
- Helene Courtois (IPNL, Lyon)
- Jenny Sorce (IPNL, Lyon and AIP, Potsdam)
- Alejandro Benitez-Llambay (Cordoba)
- Mario Abadi (Cordoba)
- Julio Navarro (Victoria)
- Matthias Steinmetz (AIP, Potsdam)

# Why are we interested in the Local Universe?

- The local neighborhood of the Milky Way is the most well known piece of the universe.
- Thus it is an ideal place to test on small scales models of structure formation against observations.
- However, the local universe is not a representative part of the universe. It is dominated by the Local Group with two massive galaxies, the the huge Local void and a few clusters which build together the Laniakea Supercluster (Brent's talk on Tuesday, lani = sky, heaven, akea = broad, wide).
- Constrained simulations are an ideal tool to compare theoretical predictions (computer experiments) with local observations
- see also Paco Kitaura's talk yesterday

# Observational data and constraints for CLUES

- Wiener Filter algorithm (Zaroubi et al., 1995)
- Radial velocity field (MARK III, Willick et al., 1997, Tonry 2001, Karachentsev 2004)
- Nearby cluster positions (Reiprich & Böhringer, 2002)
  
- Cosmic Flows 2 (Courtois, Tully 2013)
- Reverse Zeldovich Approximation (Doumler et al. 2012, Sorce et al 2014)
- Grouping of velocity data (Tully 2014)

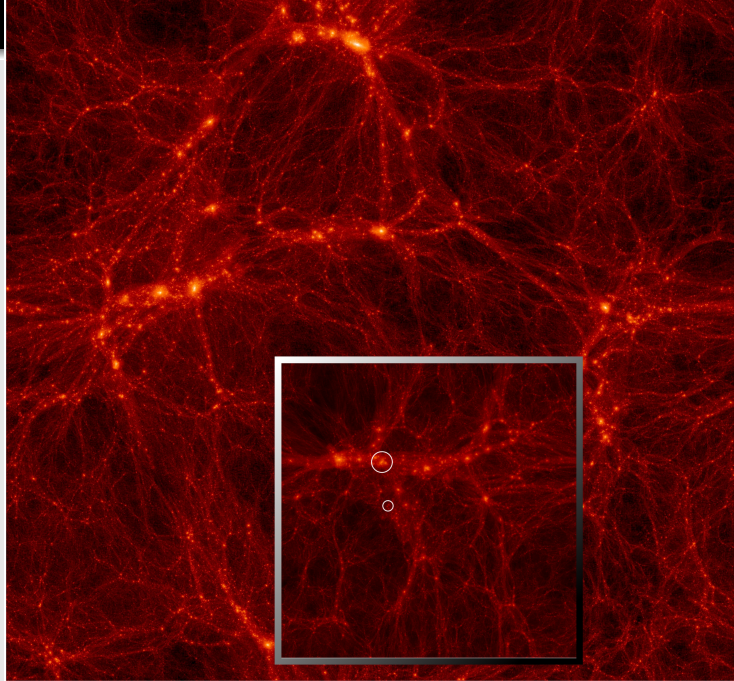


COMA

VIRGO

GA

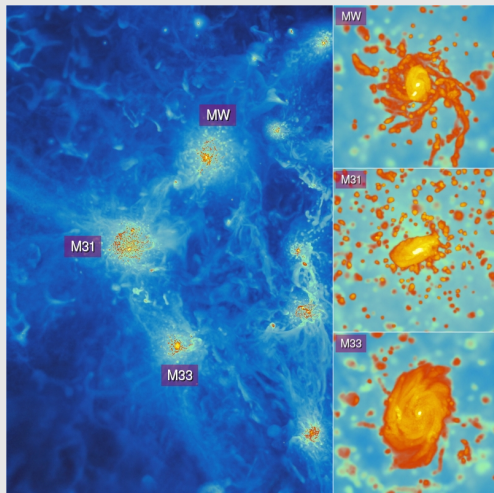
PERSEUS



$160h^{-1}\text{Mpc}$

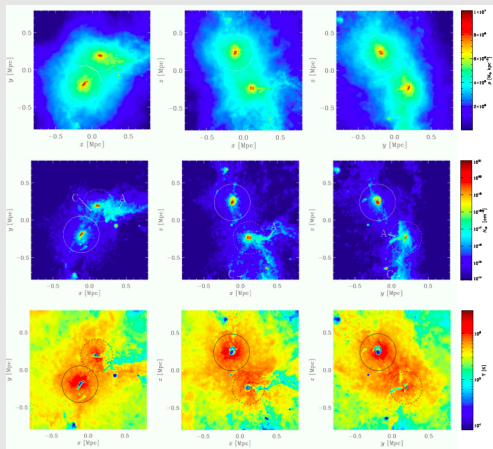
$64h^{-1}\text{Mpc}$

# Gas distribution in the local group



- box  $64h^{-1}\text{Mpc}$
- $4096^3$  particles locally
- DM particles:  
 $2.1 \times 10^5 h^{-1}M_{\odot}$
- gas particles:  
 $4.4 \times 10^4 h^{-1}M_{\odot}$
- force resolution:  
 $150h^{-1}\text{pc}$

# Gas distribution in the local group

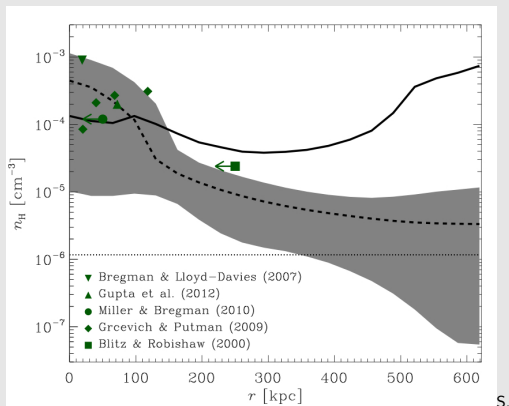


- gas density (upper panel)
- HI column density (middle panel)
- temperature (lower panel)
- virial radius (circles)

S. Nuza et al. (2013)



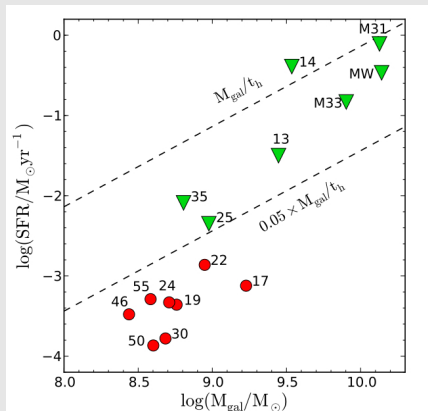
# Gas distribution in the local group



- hydrogen number density profile
- shaded area: standard deviation over random directions
- thick line: direction to Andromeda

Nuza et al. (2013)

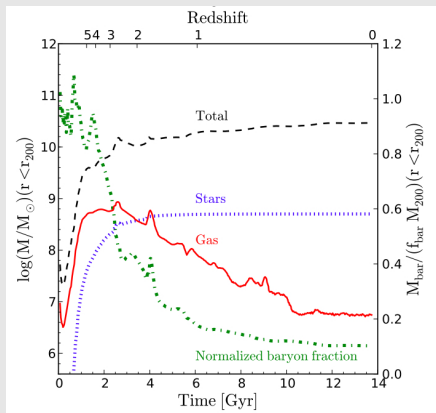
# Dwarfs in the Local Group



- isolated dwarfs without interactions with one of the massive galaxies in the past
- all within a sphere of  $R = 1.5 \text{ Mpc}/h$  of the center of the Local Group
- triangles: galaxies that form stars at rates comparable to their past average
- circles: star formation has largely ceased

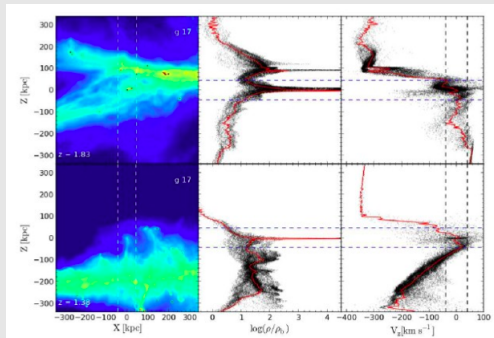
Alejandro Benitez-Llambay et al. (2013)

# Dwarfs in the Local Group



- masses within the virial radius of galaxy 30
- sudden loss of baryons at  $z \approx 2$
- ram pressure arising from crossing a large-scale pancake

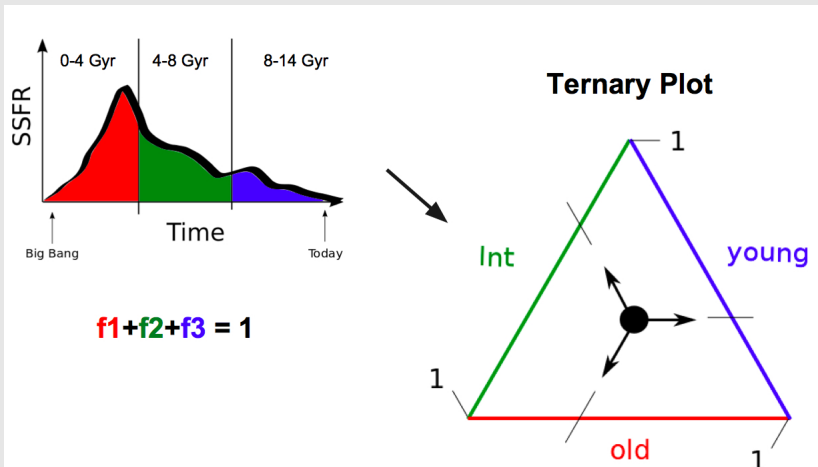
# Cosmic web stripping



Alejandro Benitez-Llambay et al. (2013), movies made by Alejandro

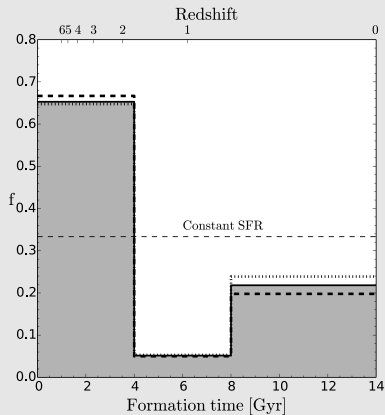
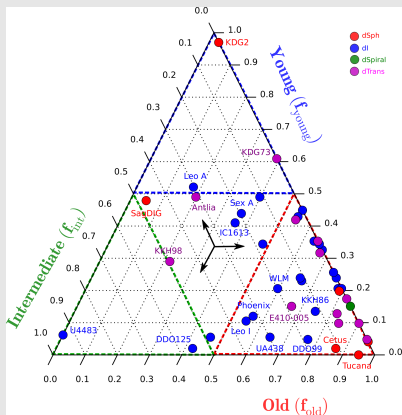
- gas from the halo is removed by the cosmic web environment due to ram pressure
- **Cosmic Web Stripping**

# Classification of star formation histories



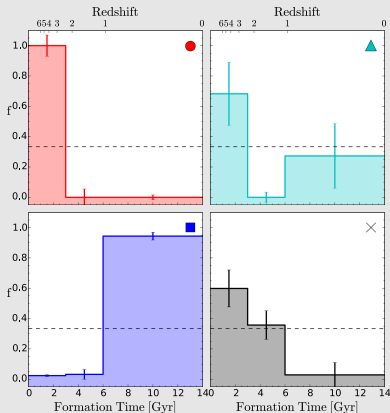
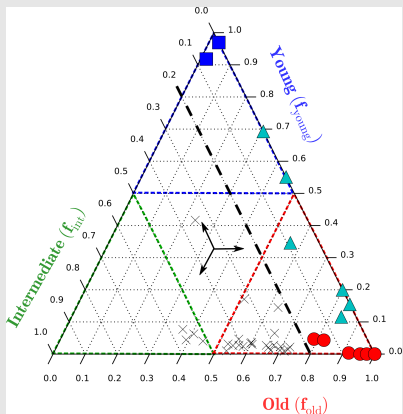
Alejandro Benitez-Llambay et al. (2014)

# Nearby observed dwarfs



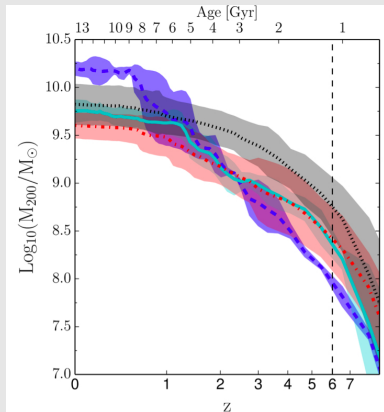
Nearby dwarfs from literature (LCID4 and the ANGST5 projects),  $7 < M_B < 16$  ( $10^5 < M_{gal}/M_{\odot} < 10^9$ ), out to 4.5 Mpc from MW, no satellites ( $> 300$  kpc to MW, M31, M81 and M82)

# Simulated dwarfs next to the LG



Can we see the observed distribution also in the simulation. Yes, we can!

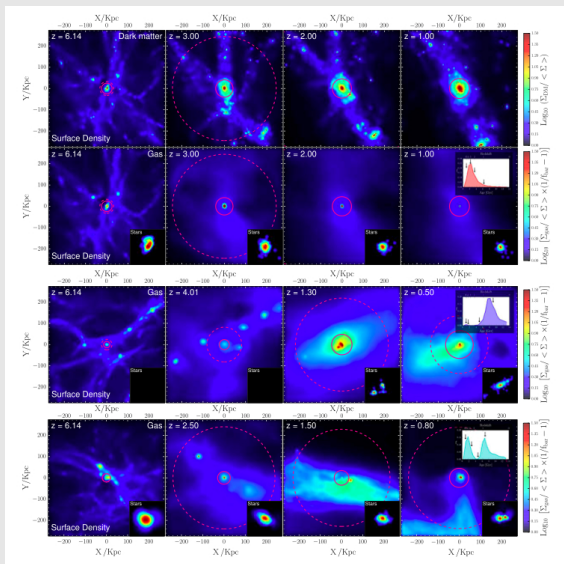
## Dwarfs in the Local Group



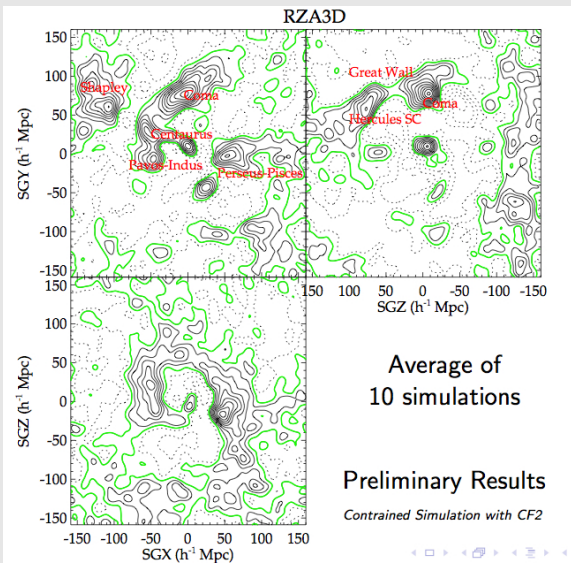
- colors (grey, red, blue, cyan) as in the previous plots
- most massive (grey) keep gas after reionisation
- less massive lose it fast, single old population (red)
- least massive may grow and collect gas for late star formation (blue)



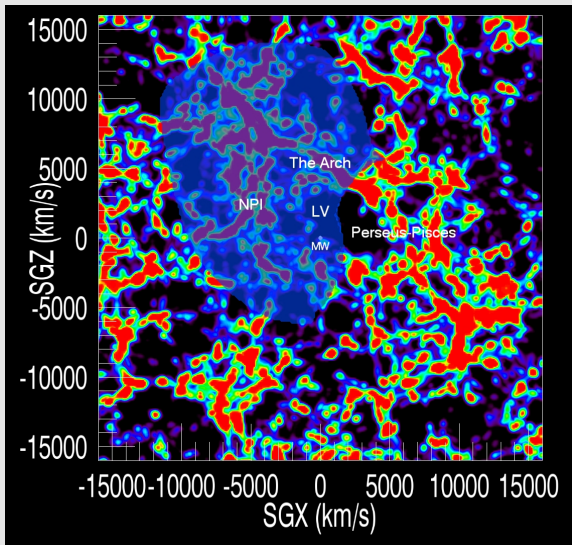
# Evolution of DM, gas and stars



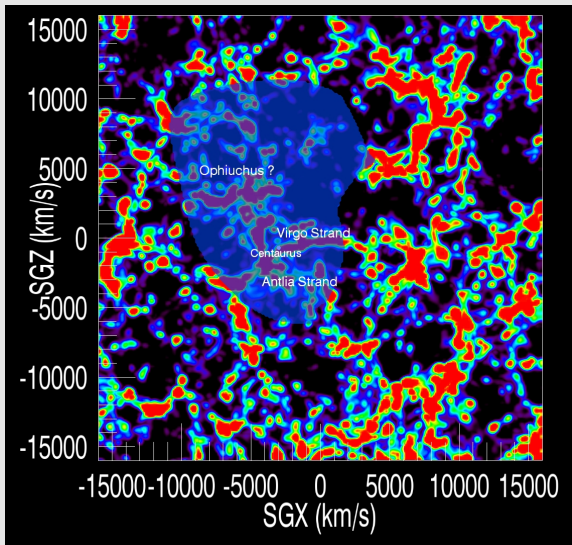
# Constrained simulations from Cosmic Flows 2



# Constrained simulations from Cosmic Flows 2



# Constrained simulations from Cosmic Flows 2



# Summary

- **Constrained numerical simulations are an important tool to study the formation of the observed structures in the local universe.**
- **Web stripping is an important ingredient for understanding the evolution of dwarfs.**
- **Reionisation changes the subsequent star formation history.**
- **The CF2 data together with the improved technique substantially improve the quality of our constrained simulations**

## CosmoSim database

# CosmoSim beta

The CosmoSim database provides results from cosmological simulations performed within different projects: the [MultiDark project](#), the [BolshoiP project](#), and the [CLUES project](#).

**MULTIDARK**  
Multimessenger Approach for Dark Matter Detection

The Spanish MultiDark Consolider project supports efforts to identify and detect matter, including dark matter simulations of the universe.

MDR1  
MDPL  
Bolshoi

**BolshoiP**  
Cosmological Simulations

The BolshoiP project contains a simulation like Bolshoi, with the same box size and resolution, but with Planck cosmology.

BolshoiP

**CLUES**  
Constrained Local Universe Simulations

The CLUES project deals with constrained simulations of the local universe, partially with gas and star formation.

[coming soon]

Please visit the linked sites for more information about the projects and about the appreciated form of acknowledgment, if the data is used in a scientific publication or proposal. The MultiDark simulations MDR1 and MDPL as well as the Bolshoi simulation are also available via the [MultiDark database](#).

[Register to CosmoSim](#)



**AIP**

CosmoSim.org is hosted and maintained by the Leibniz-Institute for Astrophysics Potsdam (AIP).



**GAVO**  
German Astrophysical Virtual Observatory

It is a contribution to the German Astrophysical Virtual Observatory.

The MultiDark and Bolshoi simulations are part of the MDC02.

<http://www.cosmosim.org/>

Kristin Riebe, Adrian Partl, Harry Enke

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