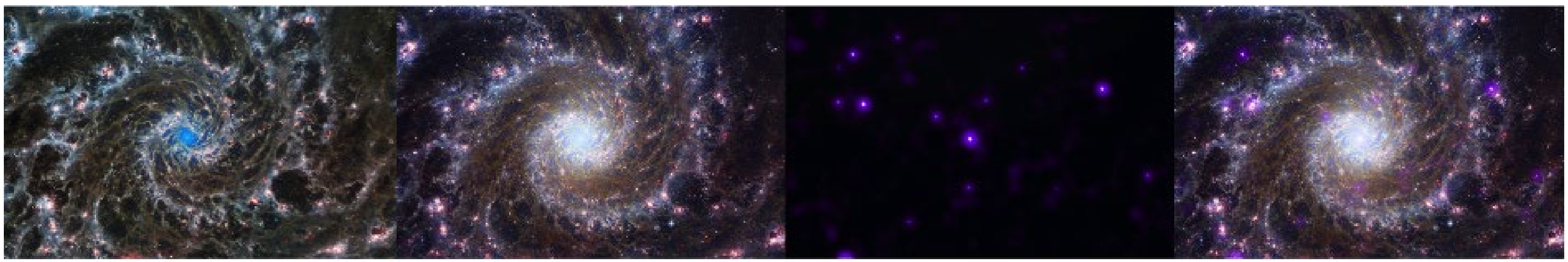
GALAPHYS
Axe 2: galaxies

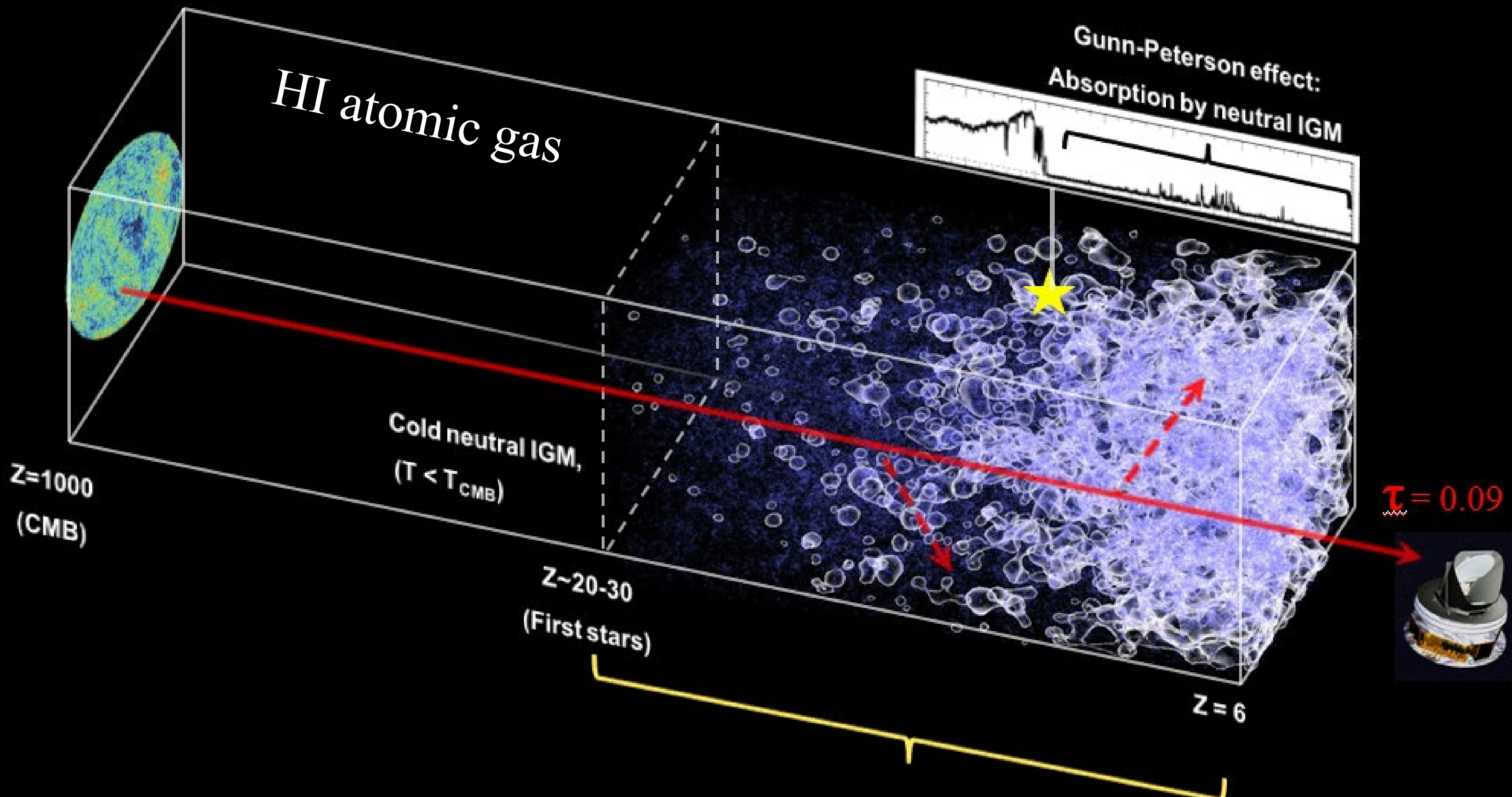


Françoise Combes Observatoire de Paris & Collège de France

Overview

- **Epoch of Re-ionization**
  - Traced by quasars, 21cm HI redshifted to 2m
    - Simulation library, Machine learning
    - Wavelet statistics, 2D compression
- **CMB foreground, dust non-Gaussian statistics**
  - B-mode detection for GW inflation
    - MHD simulation, and wavelet statistics
- **Galaxy evolution and environment**
  - Large-scale surveys, LOTSS (2m), ALMA & NOEMA
    - Jelly-fish galaxies, ram-pressure stripping
    - Redshift evolution, star formation and gas content
- **Active Galaxy Nuclei (AGN) & black holes**
  - AGN fueling and feedback
    - Cooling flows in clusters, BCG
    - Molecular tori, and outflows

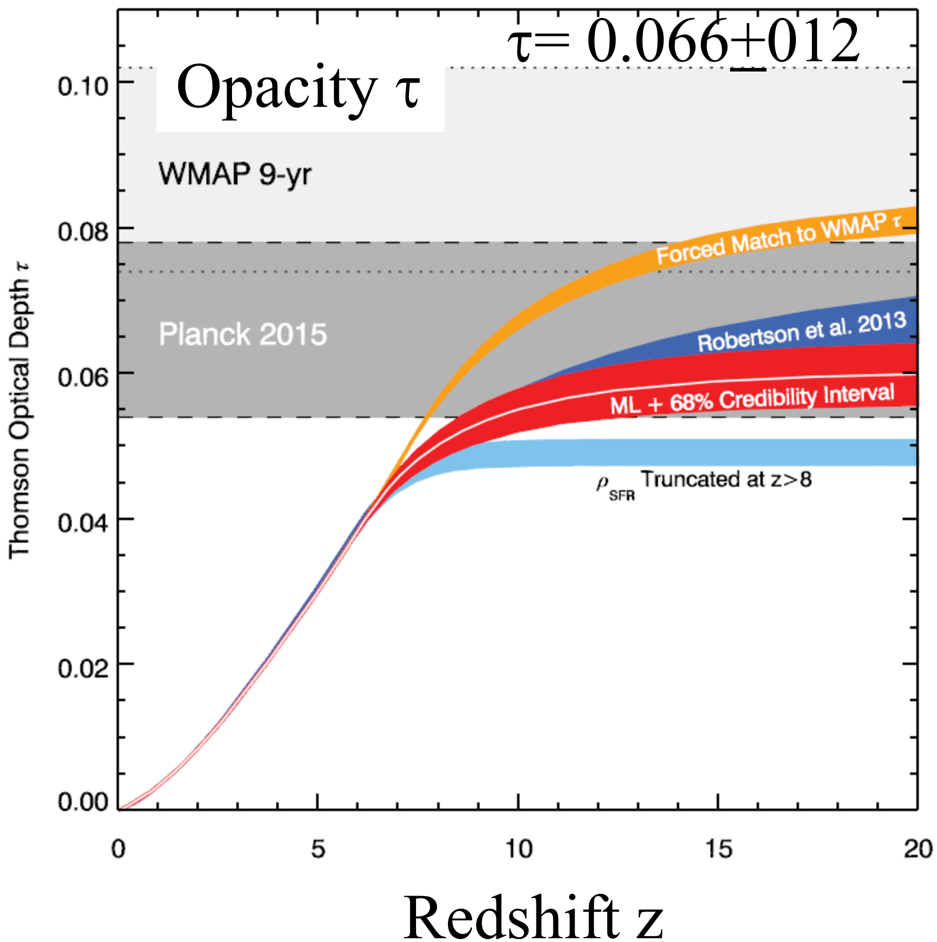
Traces of re-ionisation



21 cm tomography =>
- Source nature
- Luminosity fonction
- Cosmological constraints
- …

LOFAR (2013) SKA (2028)

Determine the epoch of reionisation

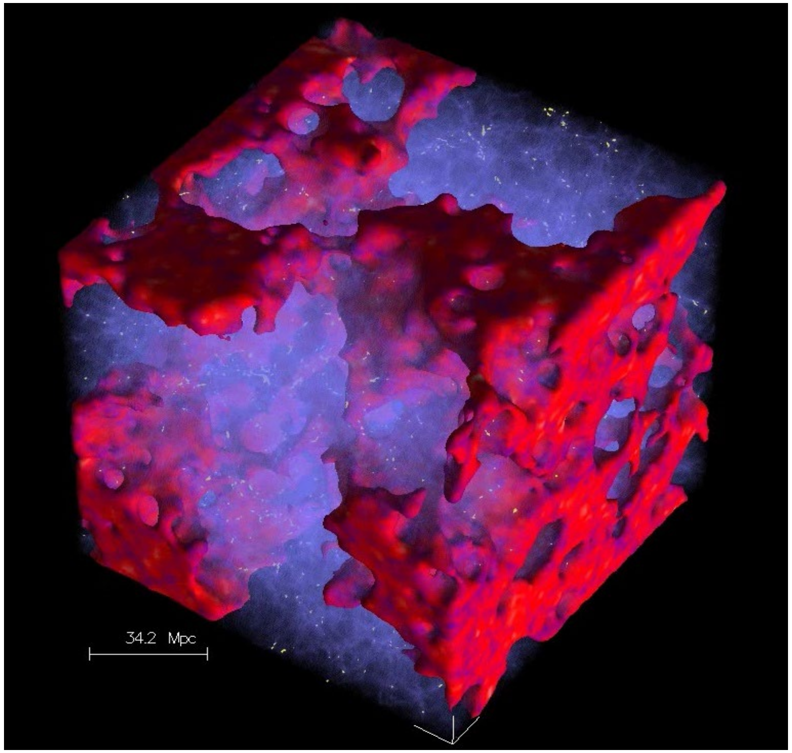


Robertson et al 2015

Constraints from CMB, WMAP, Planck, and Quasars

If $\tau_e = 0.09$ EoR between z=15 & 6

$\tau_e = 0.06 \rightarrow z_{re} = 8.14 + 0.61$



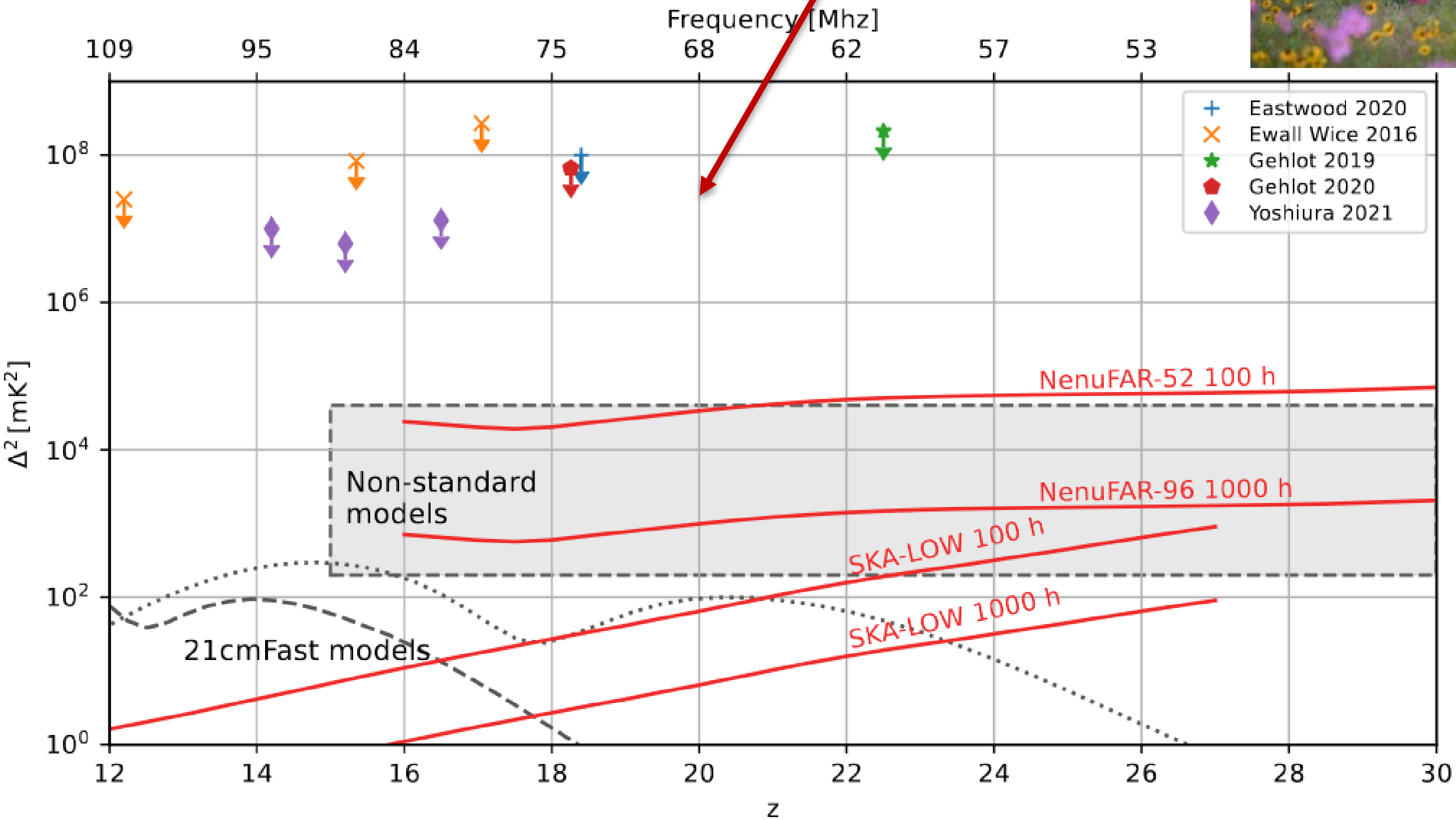
Semelin et al 2007

Upper limits on the reionisation signal

Recent upper limit with NenuFAR at 2σ

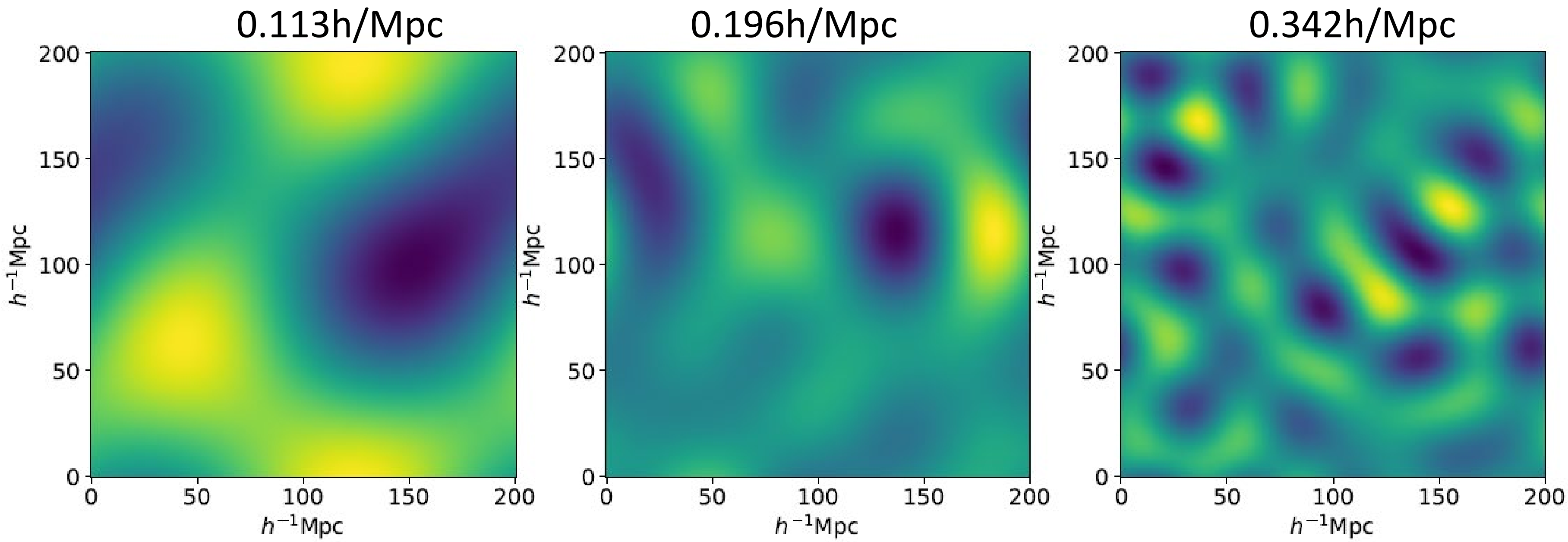
(Munshi et al 2023)

$2.4\ 10^7\ \text{mK}^2$, for z=20 and k = 0.041 h cMpc^{-1}



Mertens et al 2021

Characterization of the 21cm EoR signal

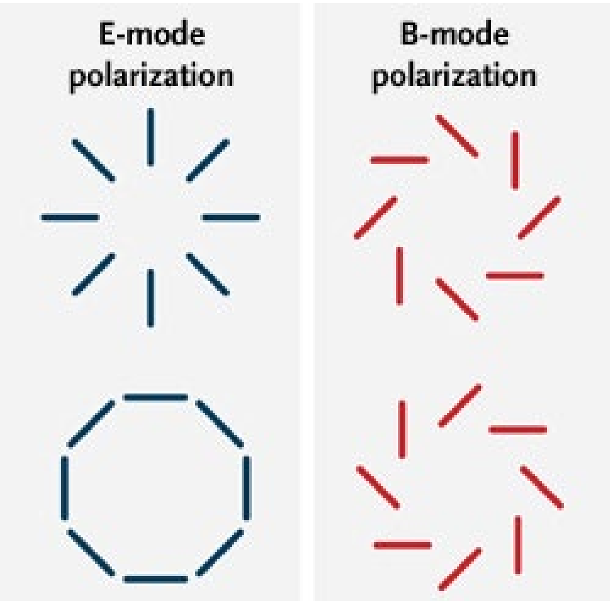


Reduced wavelets transforms, and wavelet moments, evolution-compressed statistics

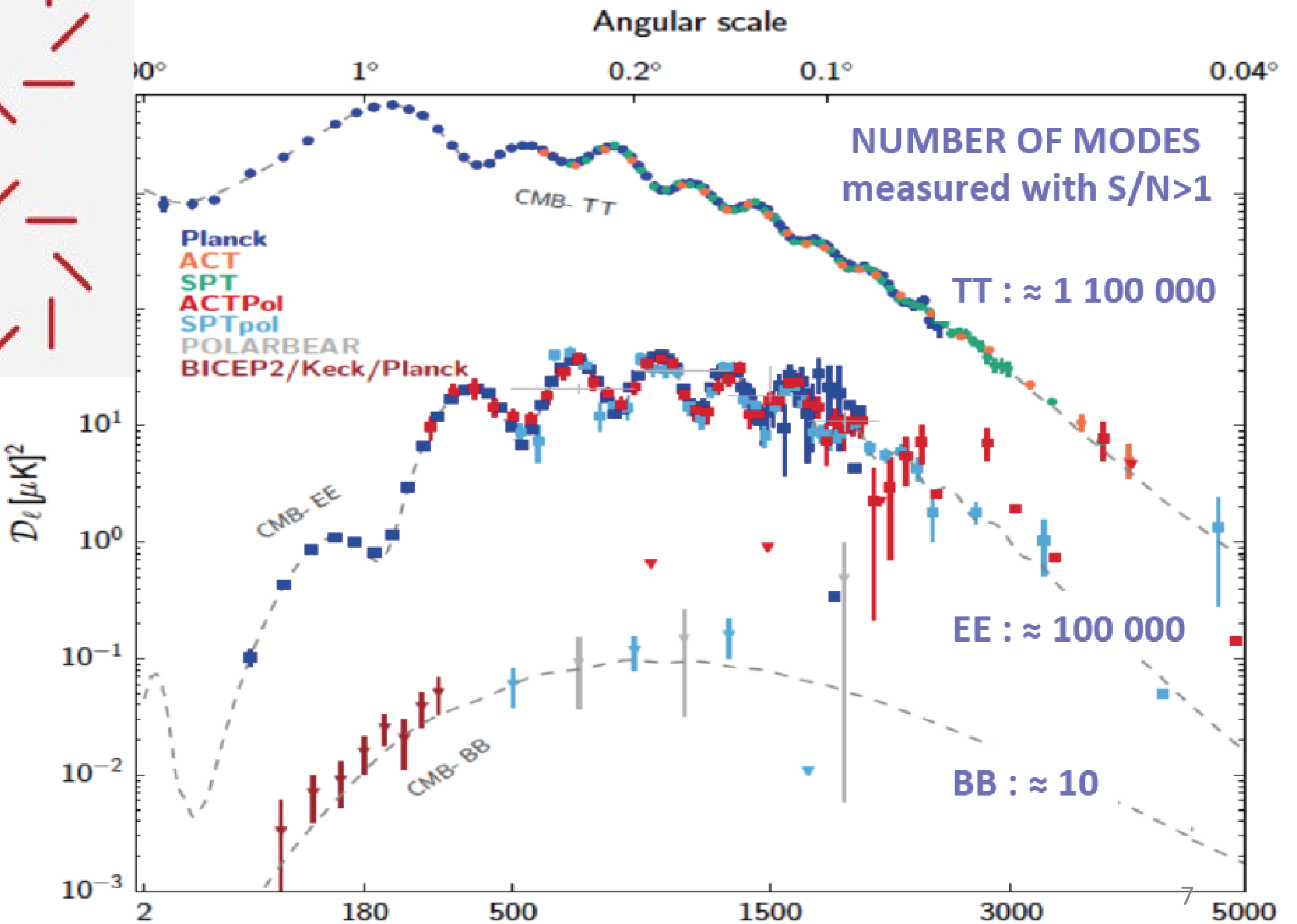
A way to extract more information than 3D isotropic power spectrum

Hothi, Allys, Semelin, Boulanger 2023

Polarisation of CMB: B-mode

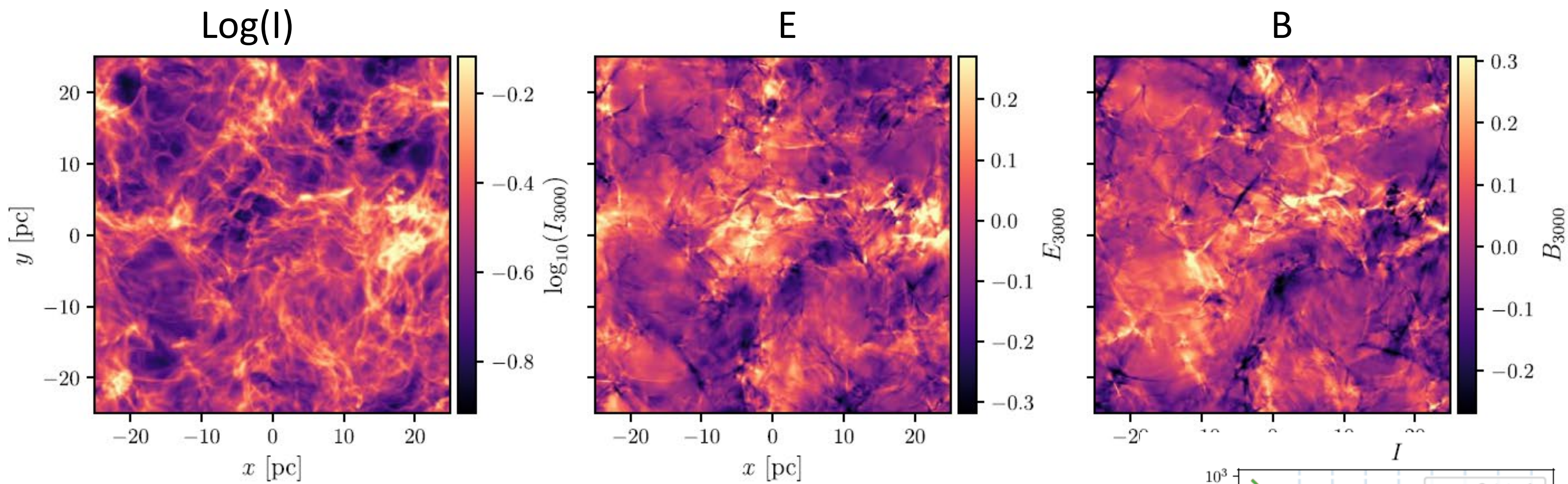


The B modes can only come from GW generated in the inflation (but 300 times < T)



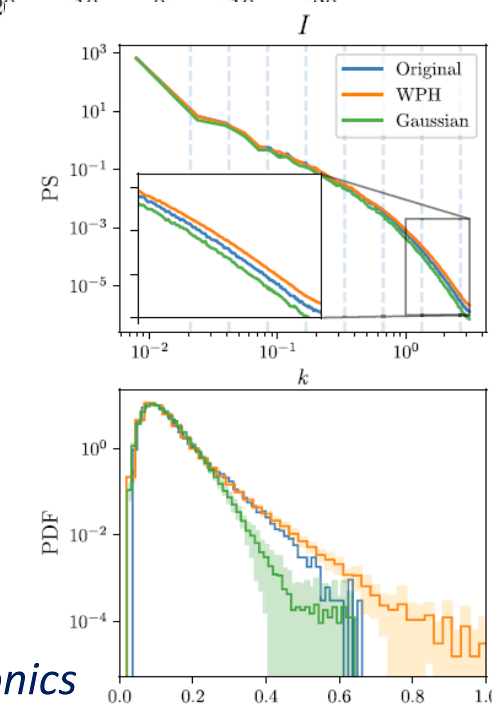
BICEP2 first observed the dust (2014)

Foreground dust emission



Representation through wavelets WPH
from MHD simulations
Statistics of multi-observable (I,E,B)
and multi-frequency of I (SED)
Non-gaussian statistics

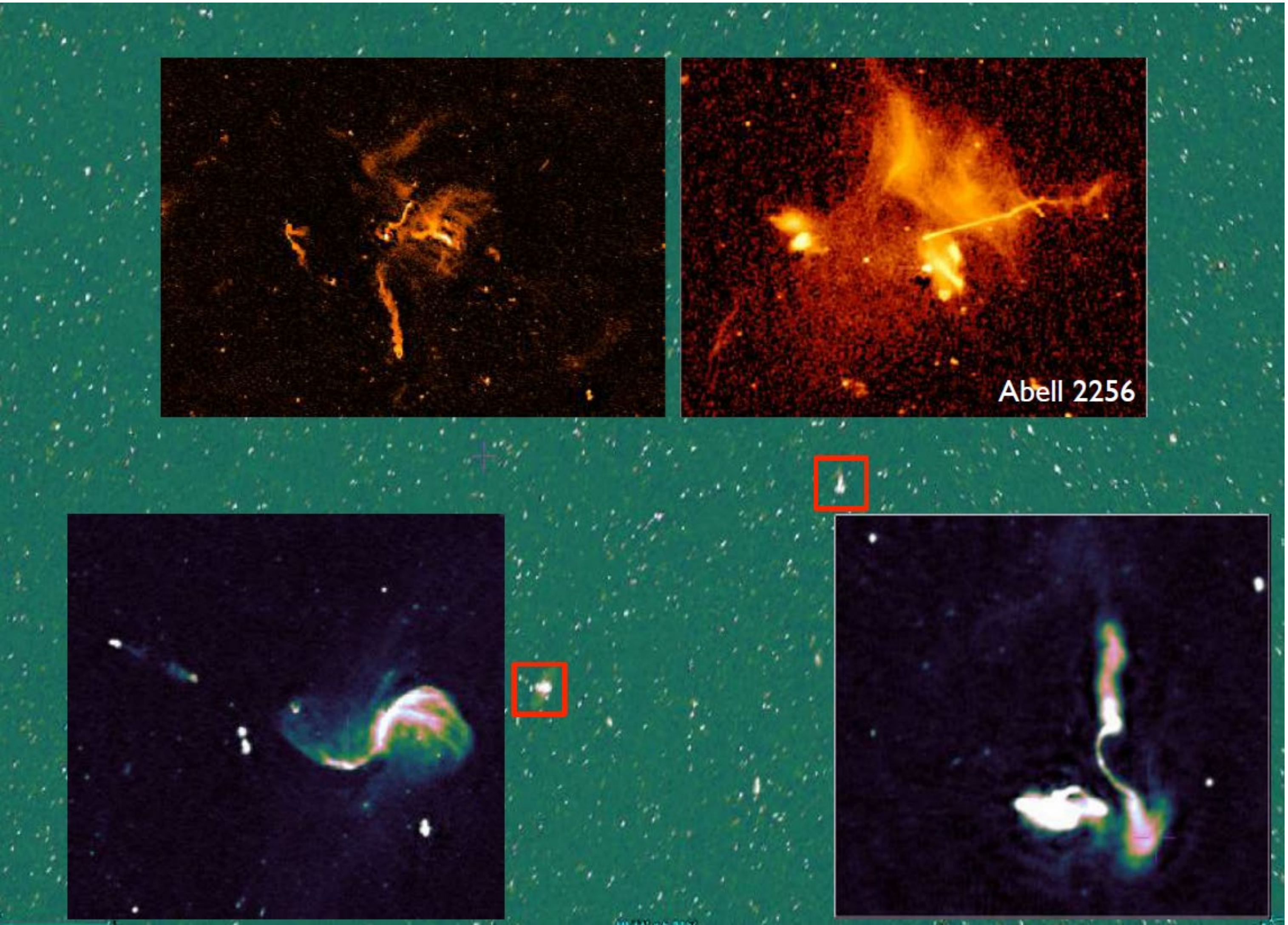
Regaldo-Saint Blancard et al 2023

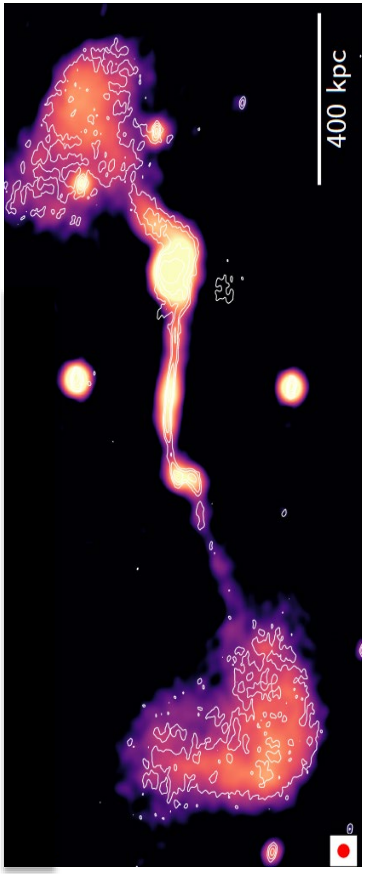


WPH=Wavelet Phase Harmonics

Radio surveys, Giant radio galaxies

Image deconvolution and automatic search of objects *(Tasse et al. 2021)*

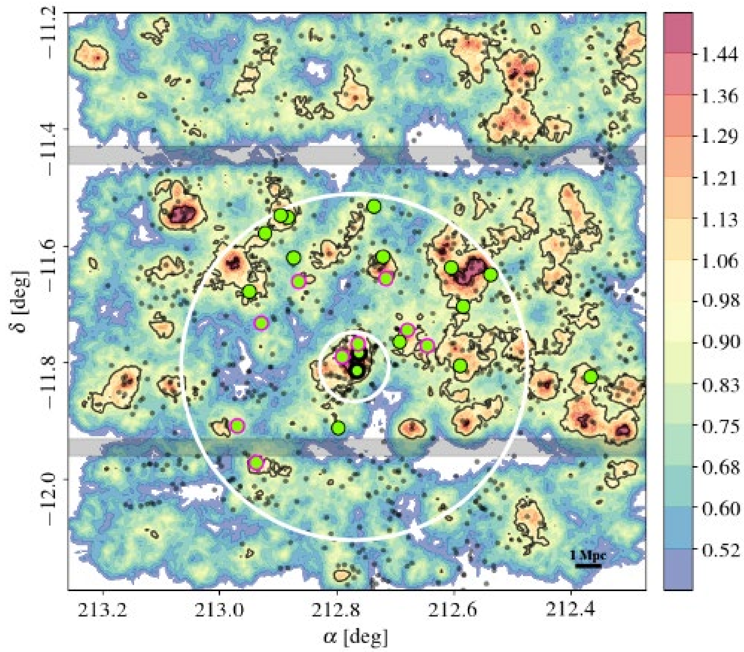




Dabhade etal 2022

Galaxy clusters: quenching mechanisms

SEEDisCS *(Sperone-Longin et al 2021)*

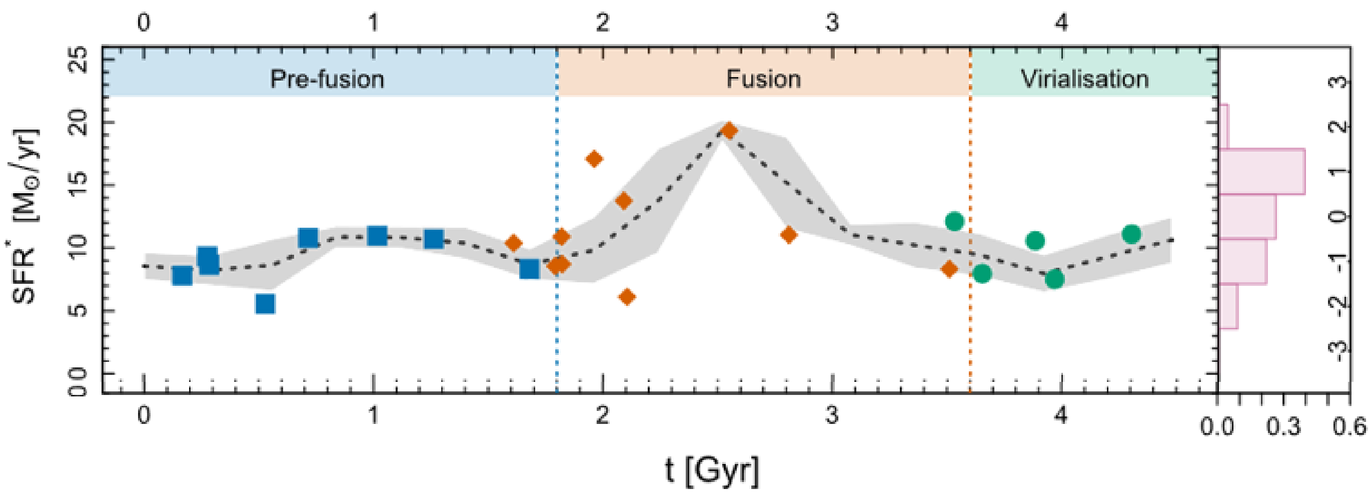


At z < 1, galaxies in clusters are quenched,

A reversal is expected at z> 1.5

The SF increases, to be higher in clusters than in the field

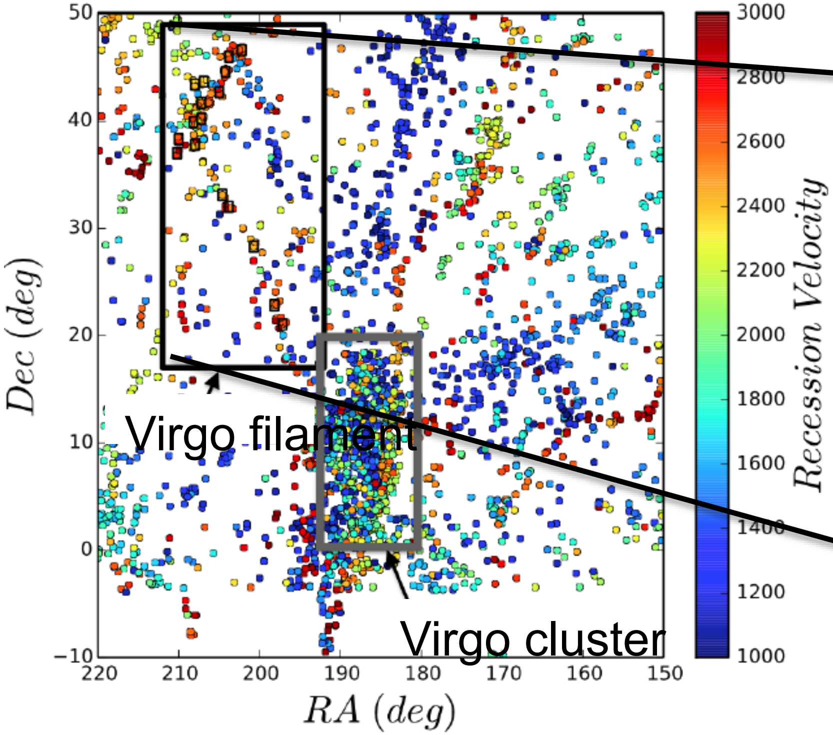
z~0.6 major mergers, scatter scaling relations



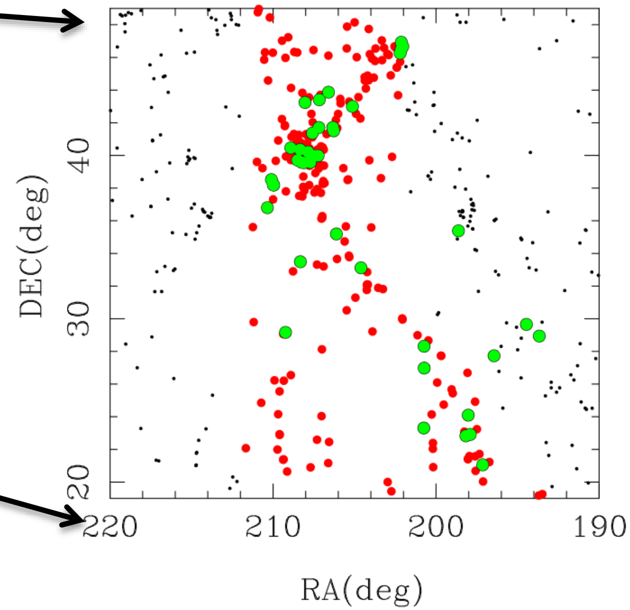
Disks reform later

Puech et al 2019

The cosmic web and galaxy formation



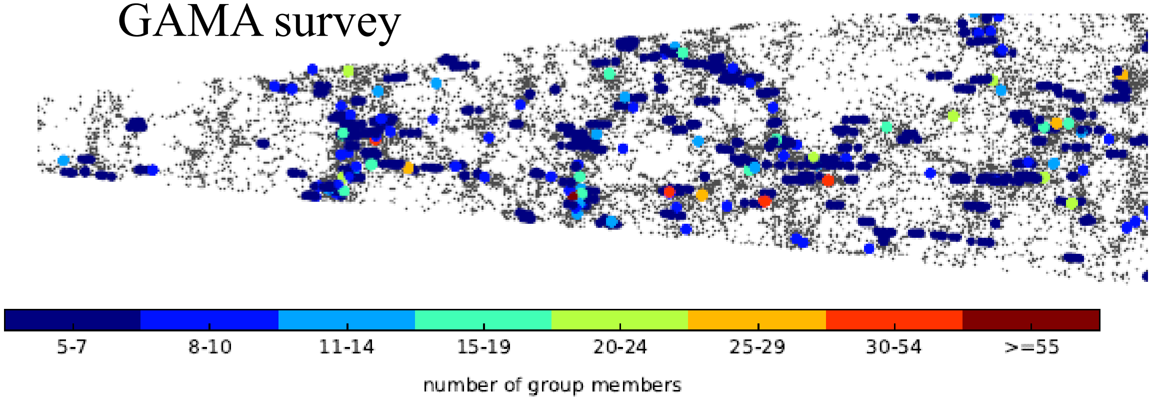
Green: detections
Red: upper limits

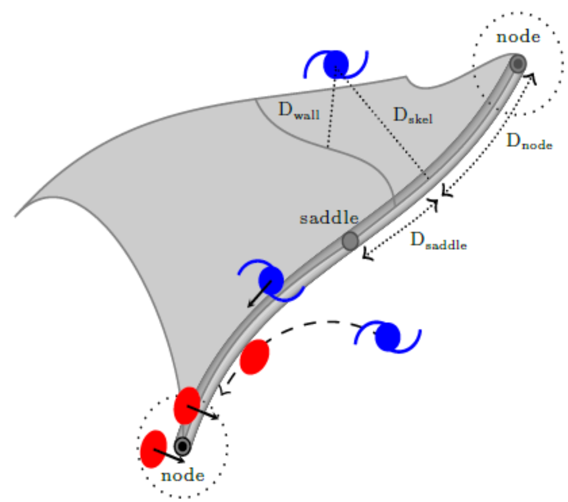


CO and HI survey of Virgo Filaments

Castignani Combes, Salomé et al

GAMA survey

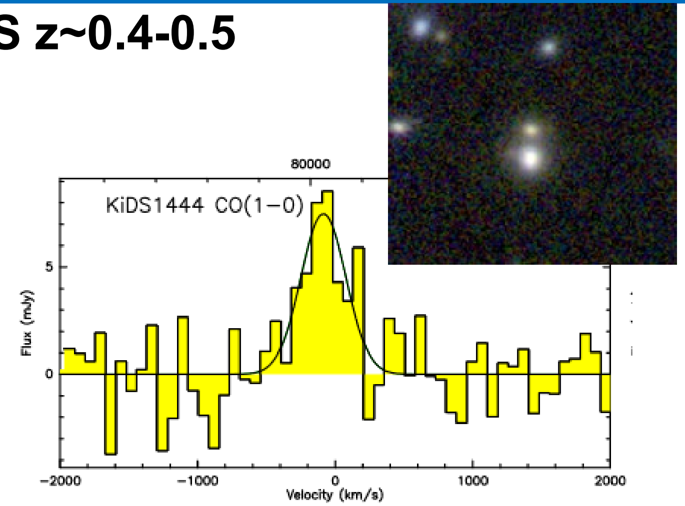




Kraljic et al 2017

BCG, protoclusters, around radio sources

Castignani, Radovich, Combes, Salome et al 2022, **KIDS z~0.4-0.5**

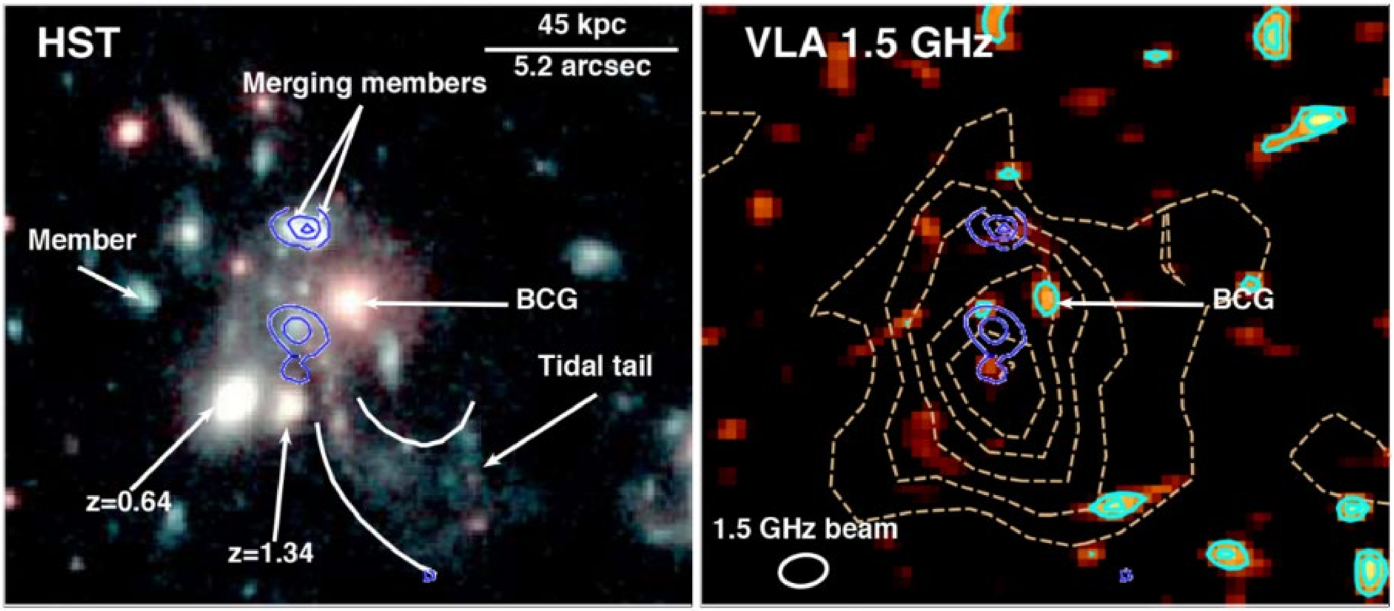


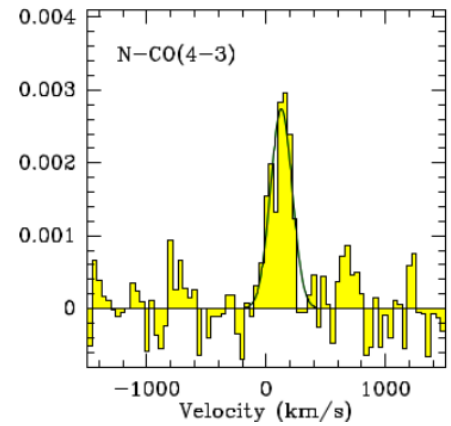
Observations IRAM-30m, NOEMA

CO(4-3) z~1,

Castignani, Combes, Salome 2019, 2020

NOEMA in SpARCS1049 BCG at z = 1.7

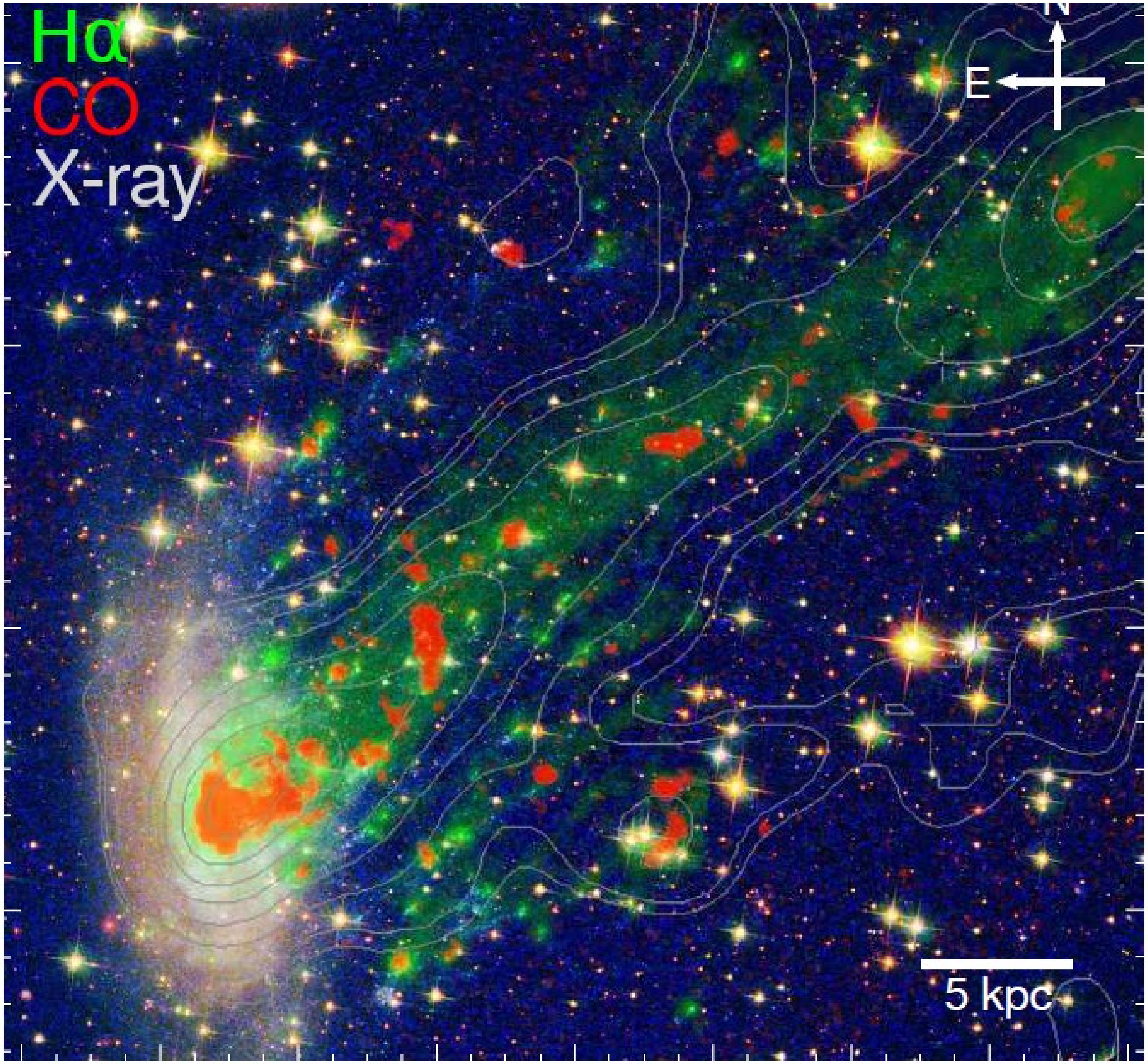




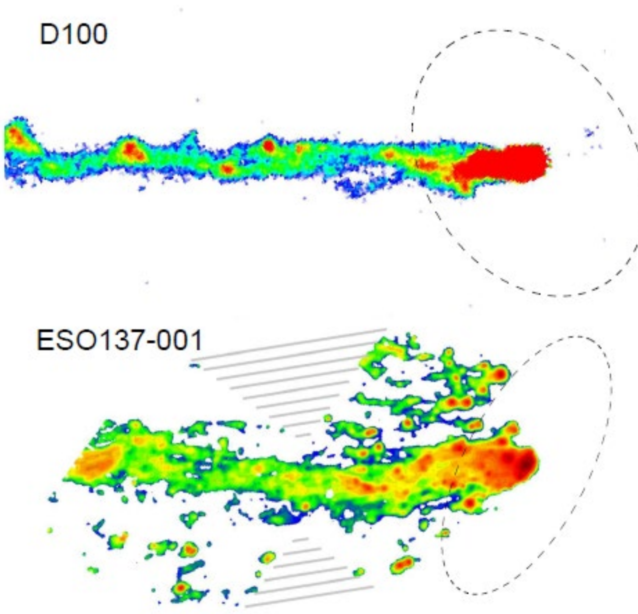
Castignani, Combes, Salome 2020

Galaxy morphology evolution

Jachym et al 2019, 2022



Cluster stripping, harrassment

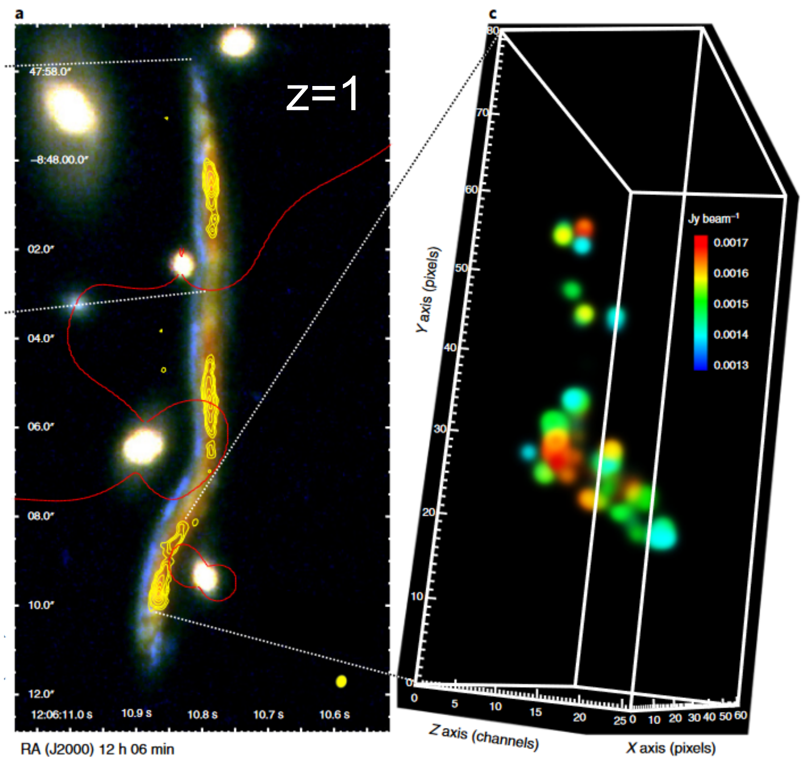


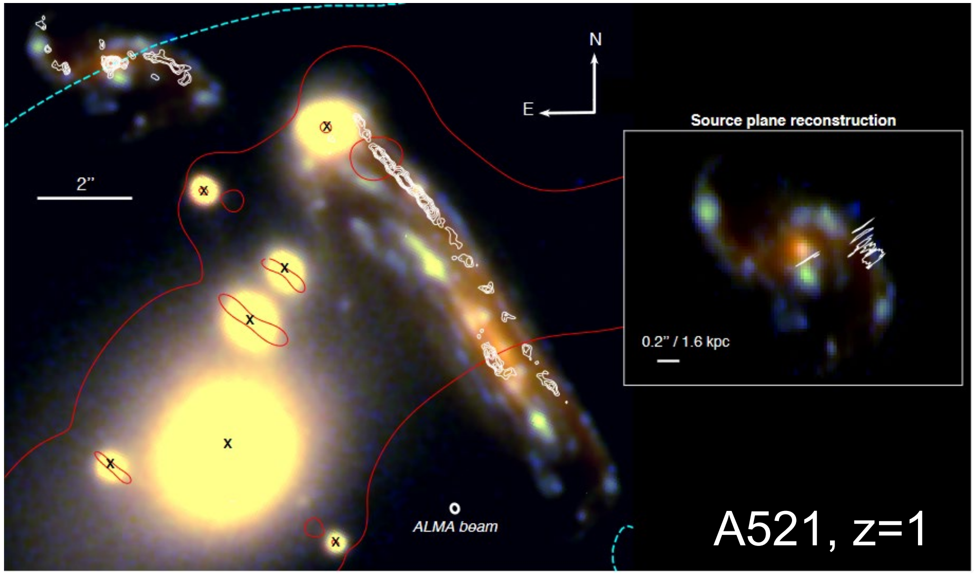
Molecular gas dominant in the ram-pressure tails

Galaxies at high z, with ALMA

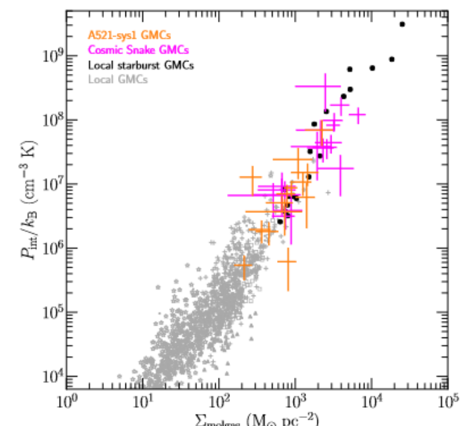
Strong lensing

Gas fraction, depletion time t_{dep}
Star formation efficiency SFE
and evolution with redshift





Bigger and more
Massive GMC



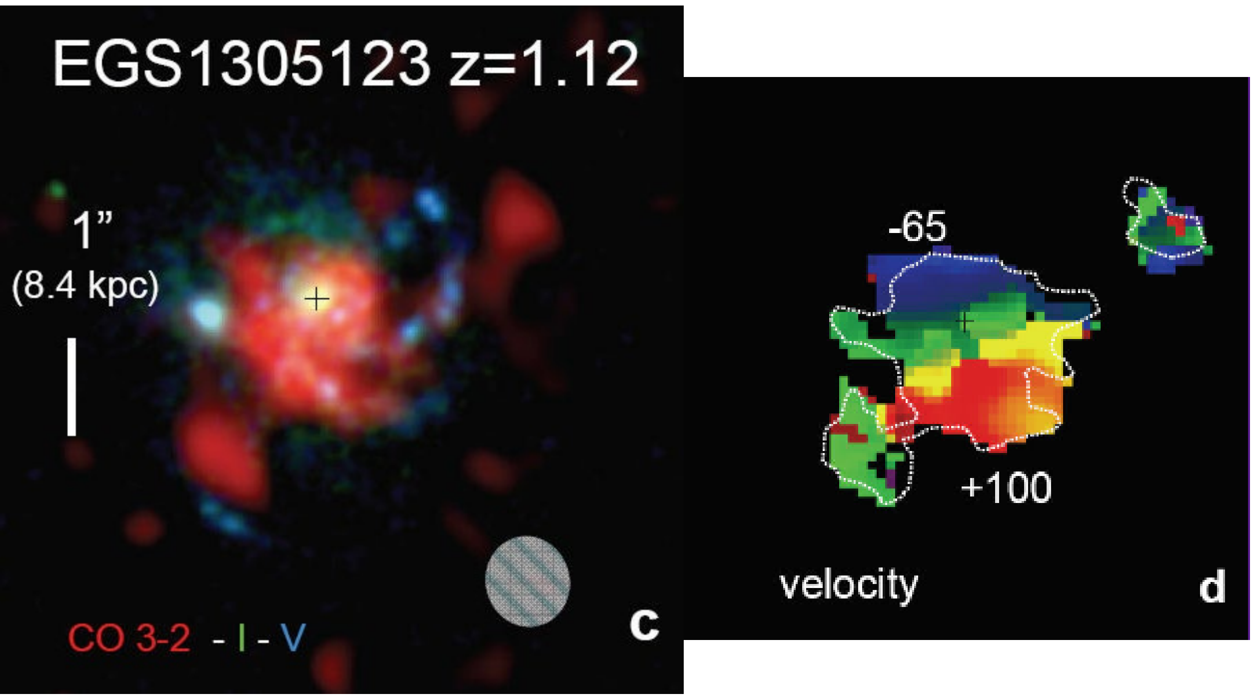
Herschel, VLT, Keck, Euclid

The Snake, *A521, Dessauges-Zavadsky et al 2019, 2023*

PHIBSS: Scaling relations

LP IRAM-NOEMA

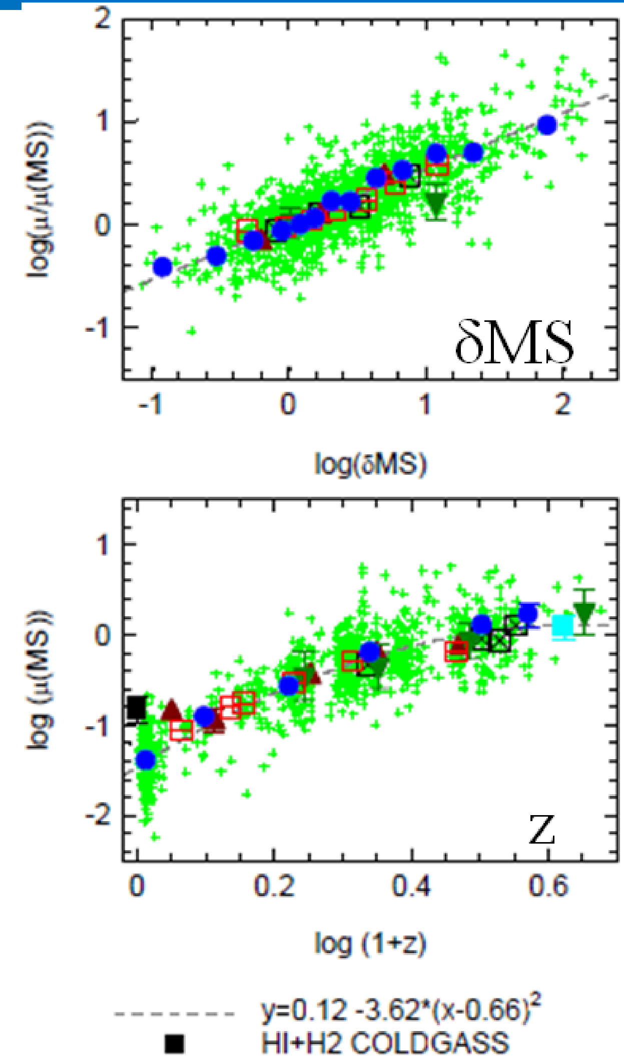
Gas fraction increases regularly with z on the Main Sequence



log(M*/Mo)=9.-11.8, δMS=SFR/SFR(MS)

tdep ~ $(1+z)^{-0.57}$ $(\delta MS)^{-0.44}$

$\mu = M_{mol}/M^* \sim (1+z)^{2.8} (\delta MS)^{0.54} (M^*)^{-0.34}$



Tacconi et al 2018, Freundlich et al 2019 (with Combes, Salome)

Cooling Flows, BCG, AGN

➔Observations

HERSCHEL:

Large Program: sample of cooling flow clusters (*Edge et al*)

SPIRE FTS on PERSEUS

ALMA:

– Feeding the AGN

– Search for cold filaments

Russel et al 2019

ALMA- NOEMA

Perseus: *Salomé et al*

Hamer et al

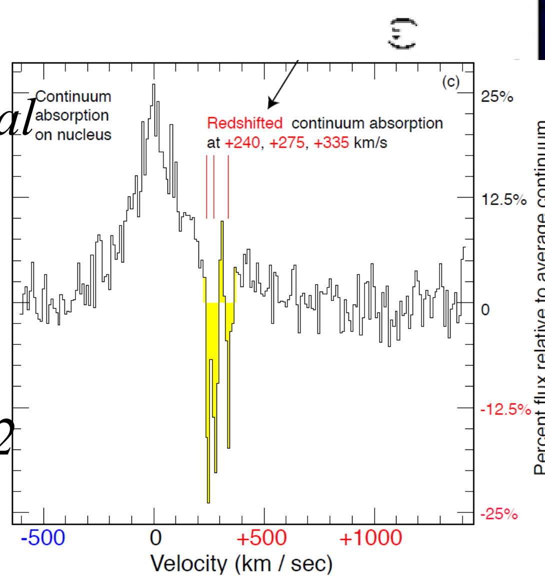
Hydra-A

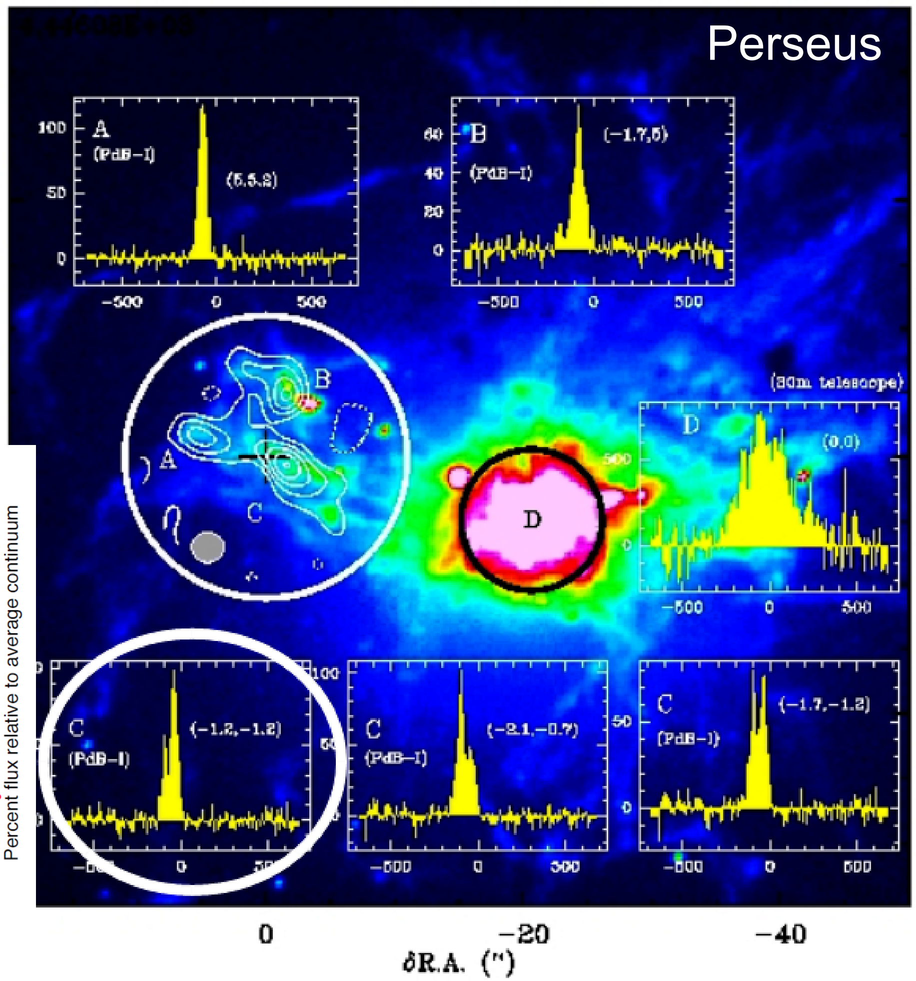
Tremblay etal 2016

+ 73 BCG

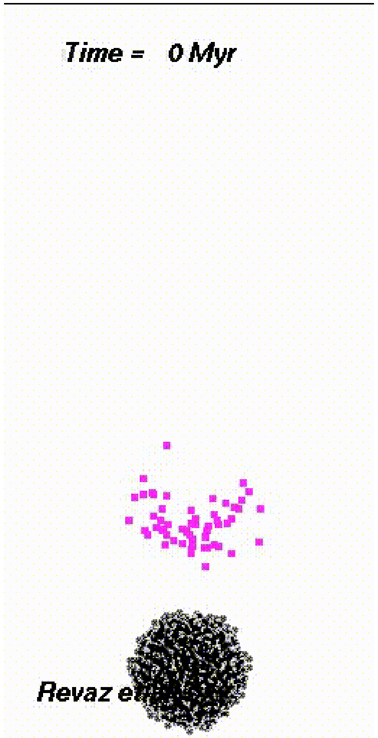
Olivares 2019, 2022

Polles et al 2021



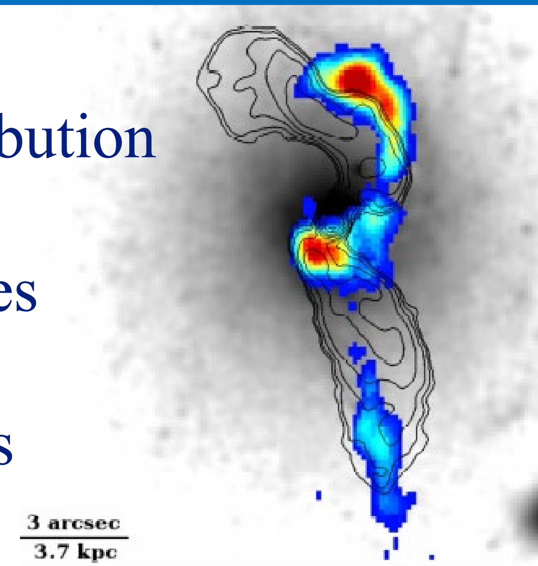


AGN moderation and quenching



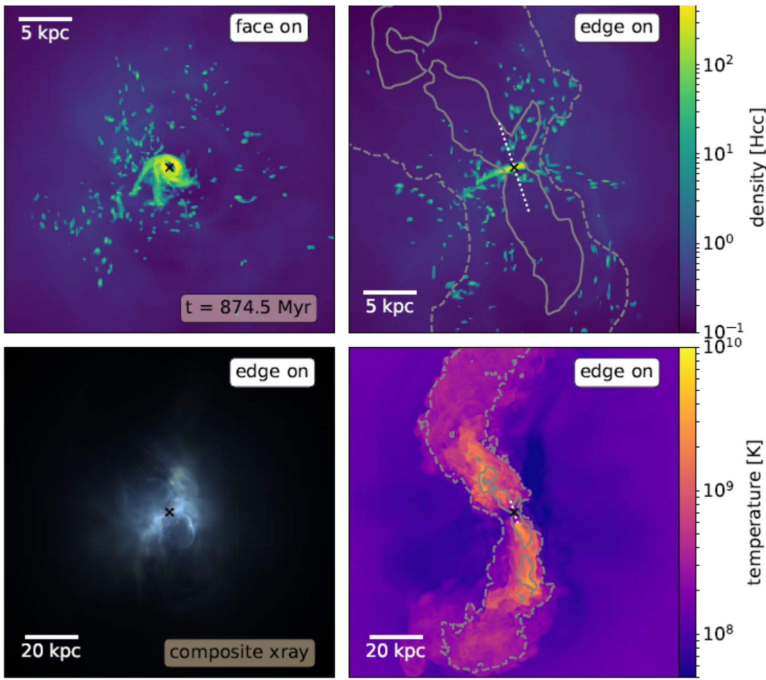
Simulations: Entropy radial distribution

Radio jet diggs bubbles and cavities
in the hot X-ray gas
→ Cooling at the border of cavities

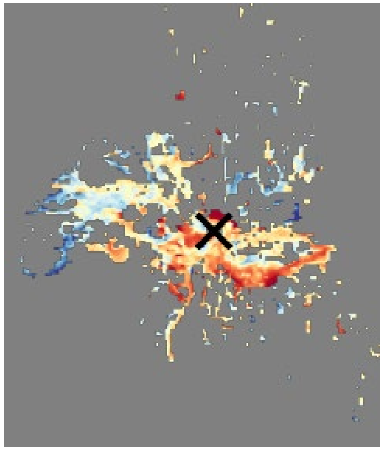


CCA: Cold Chaotic Accretion

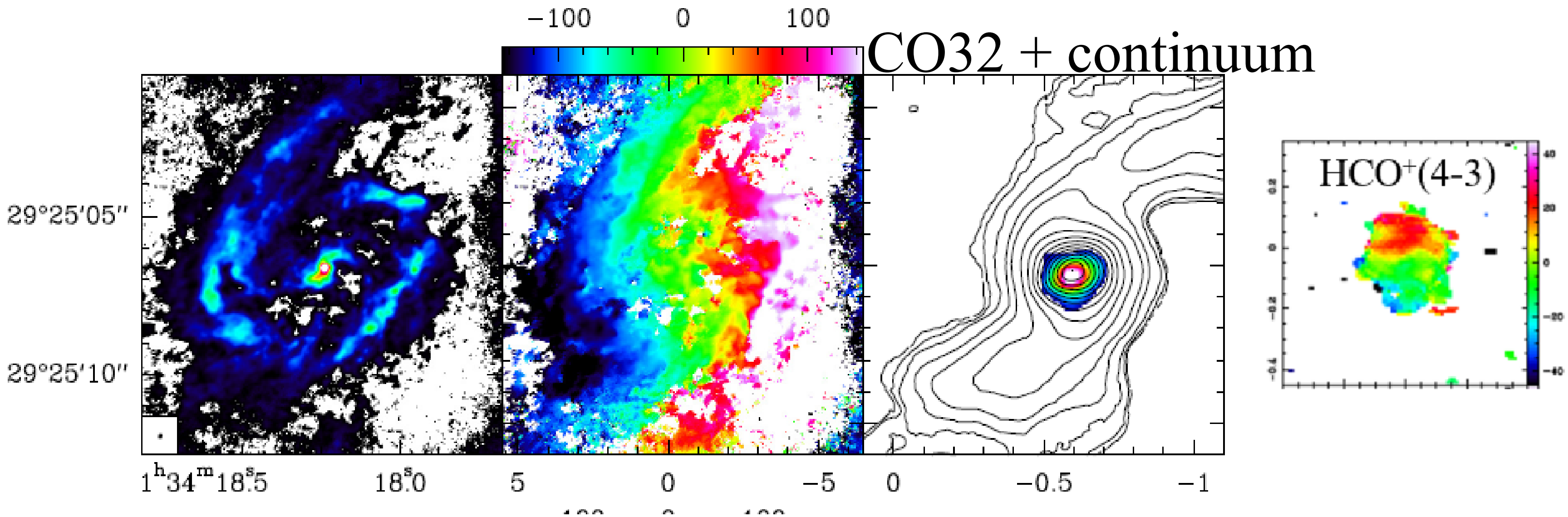
Beckmann et al 2019



Present simulations,
do not represent correctly
the thin filaments, linear,
with coherent velocity
→ more BH spin?

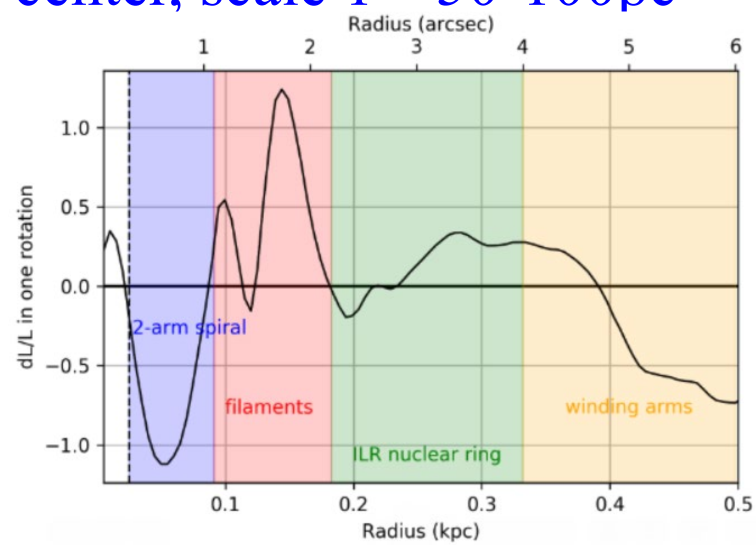


AGN fueling and feedback



➔ **Only ~35%** of negative torques in the center, scale 1"~50-100pc

20 galaxies *(Garcia-Burillo, Combes et al 2012)*



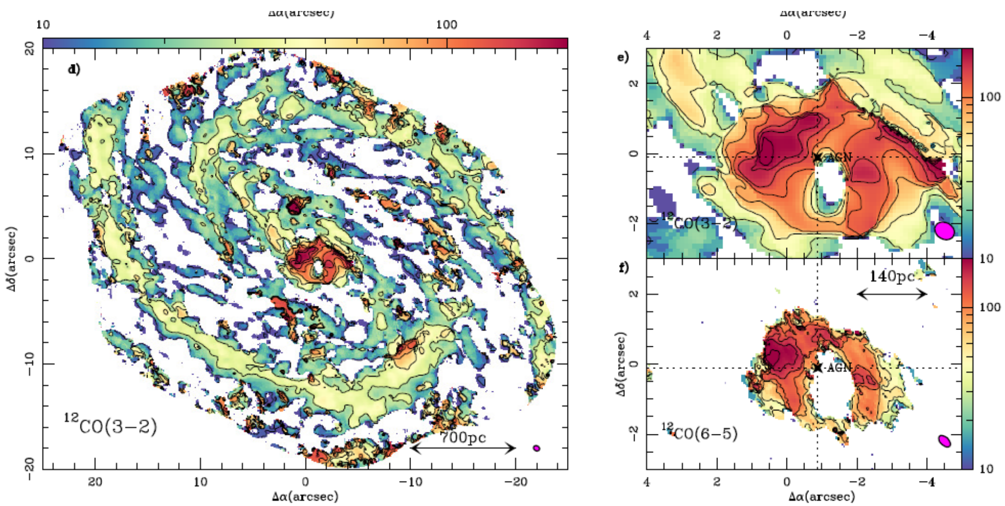
➔ **Discovery of molecular tori**

with ALMA *(Combes et al 2019)*

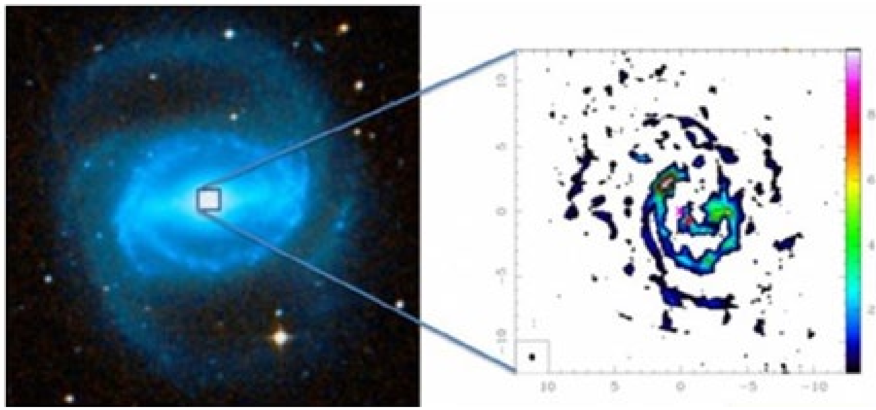
➔ Computation of **gravity torques**

(Audibert et al 2019, 21)

Molecular Outflows + torus (~7pc)



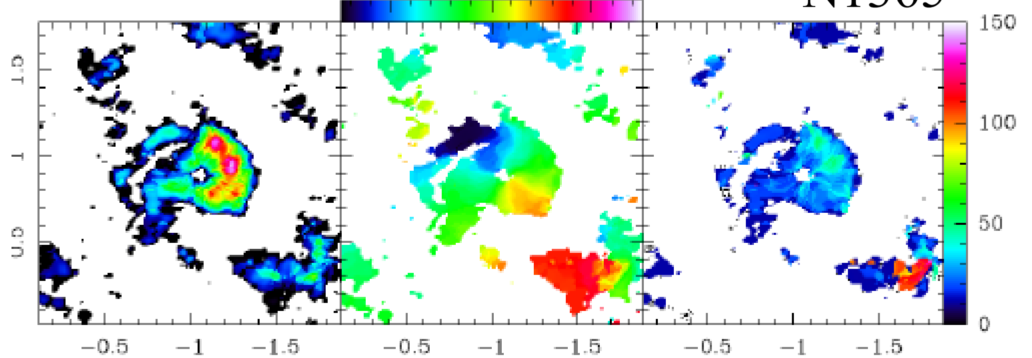
N1433

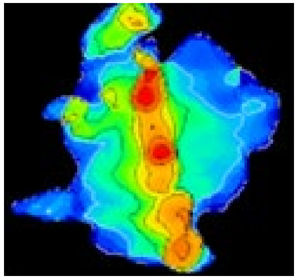


NGC 1068: Outflow of 63Mo/yr
About 10 times the SFR in this CMD

Garcia-Burillo, Combes et al 2018, 2021

N1365

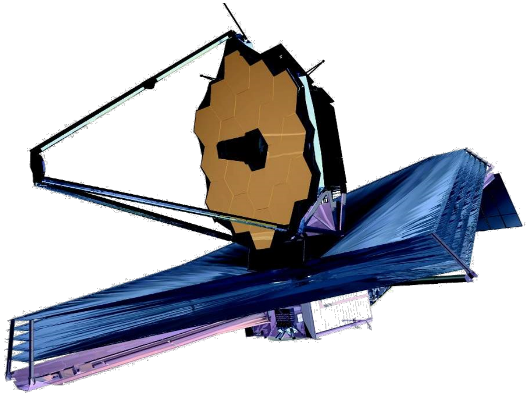




N1377 precessing jet

Aalto et al 2017, 2019

Facilities



SKAO

euclid consortium

James Webb Space Telescope JWST NASA • ESA • CSA

NOEMA

iram

ALMA

Thanks for your attention