Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique

Pole 1: Galaxies and Cosmology

November 2020 (22)

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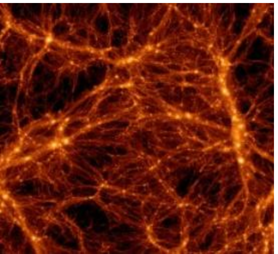
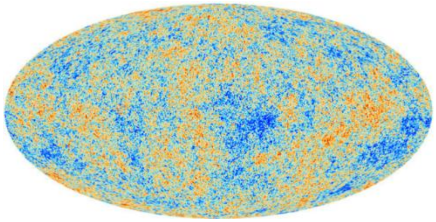
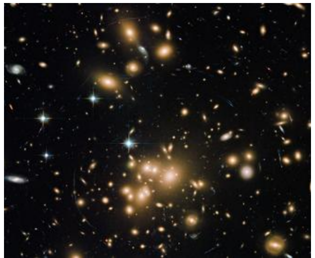
Women ratio 5/11 and 2/11, or 7/22

Pole1: key science issues

➔The Epoch of reionization: what are the main actors of ionization (galaxies, quasars)? Can we predict the HI-signal to be observed by **NenuFAR, SKA,** and then deduce something on these main actors?

➔Galaxy Formation: where are the baryons? how can we explain that 90% of them have left galaxies? or would this constrain the dark matter/energy model? **EUCLID**

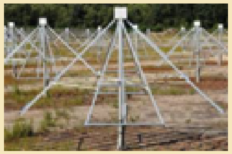
➔The Large-Scale Structures (LSS): what is the role of environment in star formation quenching in galaxies? LSS as cosmology tracers **EUCLID , SKA**

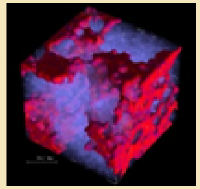
➔AGN fueling and feedback: why are supermassive black holes evolving in symbiosis with galaxies? could AGN be the solution to expel baryons from galaxies?
ALMA/NOEMA, VLT, JWST
SF efficiency, history and stellar populations **CFHT-Sitelle, IRAM**

Four main themes

1- Primordial Universe (7)

- CMB, Sky surveys, Inflation
- EoR, Preparation to SKA + NenuFAR

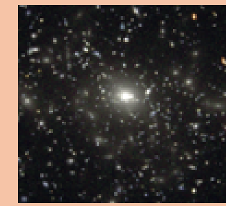




Sémelin, Doussot, Mertens,
Ilic, Coulais, Sanchez, Combes

2- Large-scale structures (6)

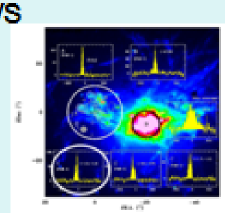
- Galaxy Clusters / Proto-clusters
- Galaxy mass assembly, mass-size relation, morphology
- Euclid Legacy



Mei, Huertas-Company, Cornu,
Afanasiev, Salomé, Combes

3- Formation & evolution of galaxies (6)

- High-redshift galaxies ALMA / NOEMA
- PHIBSS2 Legacy - gas fraction, SF efficiency NOEMA / ALMA
- Cool Core Clusters NOEMA / ALMA / MUSE
- AGN Feedback and molecular outflows NOEMA / ALMA

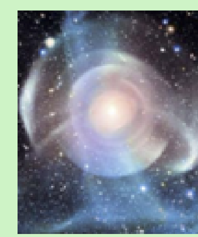


Salomé, Dabhade, Cattaneo,
Koutsouridou, Poitevineau, Combes

4- Nearby Galaxies, resolved in stars (6)

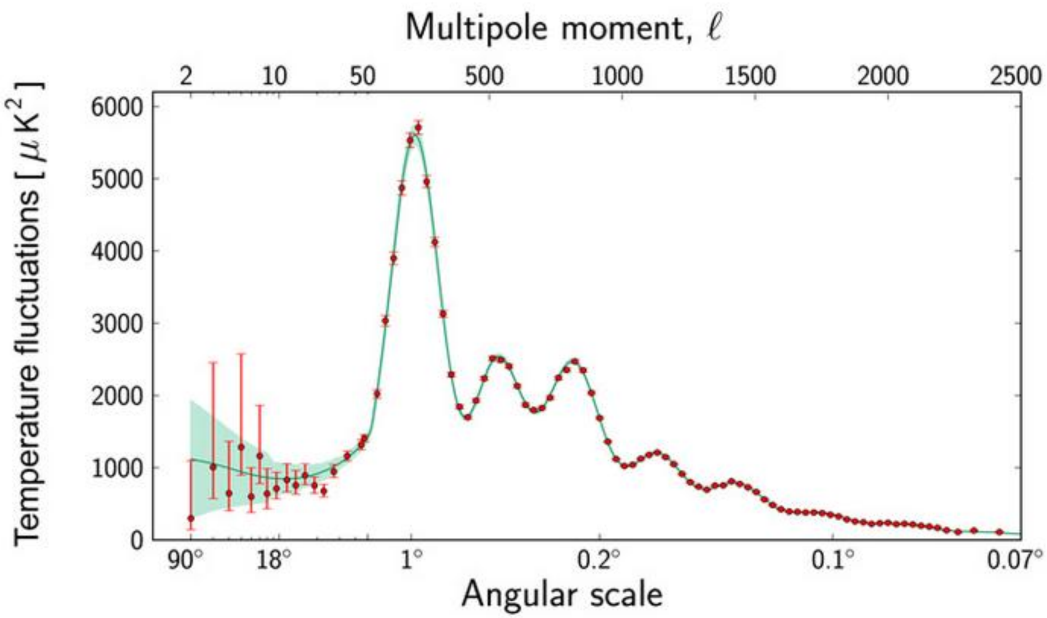
- Star formation laws (KS efficiency, scaling, HI, H2)
- Relation CO-metallicity, CO-dark molecular gas IRAM, CFHT Sitelle
- Low surface Brightness features

Proposition of the MESSIER satellite to the CNES

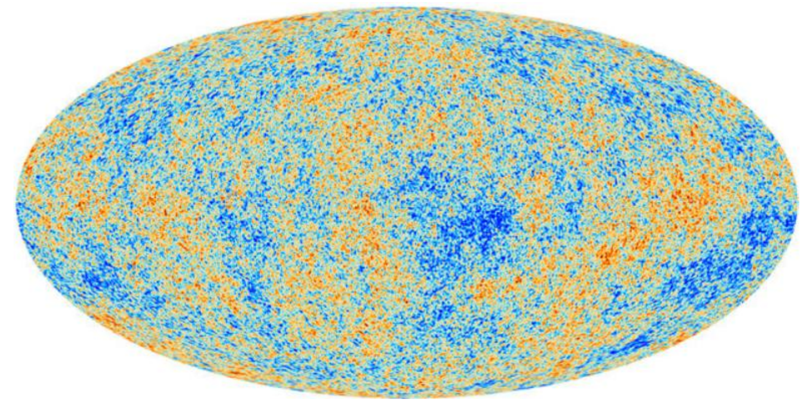


Valls-Gabaud, Melchior, Halle,
Maschmann, Mazzilli, Combes

Planck, Sky Surveys, Inflation



CMB



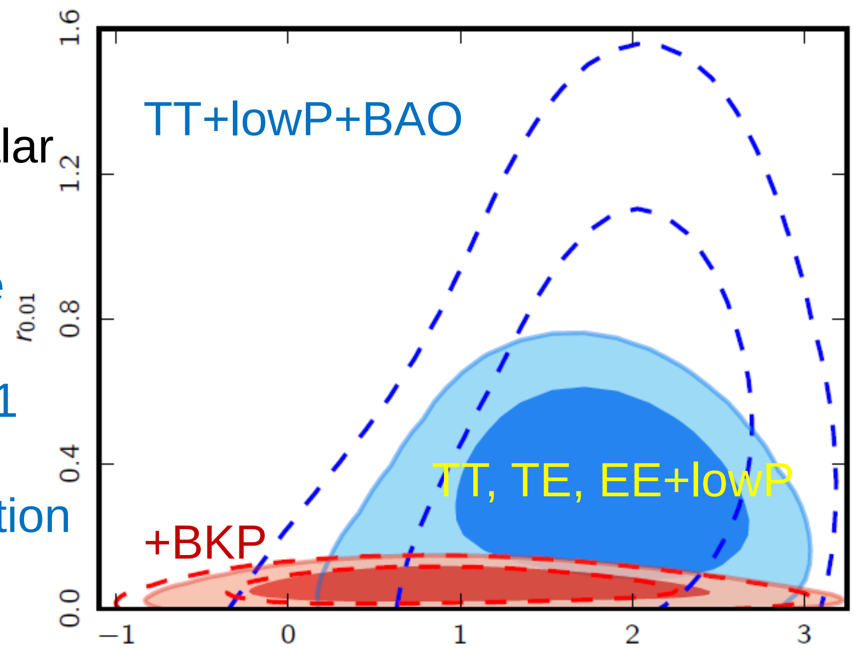
CMB studies will be continued to find the B-mode, and constrain the tensor-to-scalar ratio
ERC project

The Sunyaev-Zeldovich (SZ) effect will be used combined with X-ray, optical, and radio for the evolution of clusters, and cosmic filaments.

Ratio
r=tensor/scalar

No evidence of B-mode
r0.002 < 0.11 (2016)
Natural inflation disfavoured

k=0.002/Mpc



ns Tilt of power spectrum

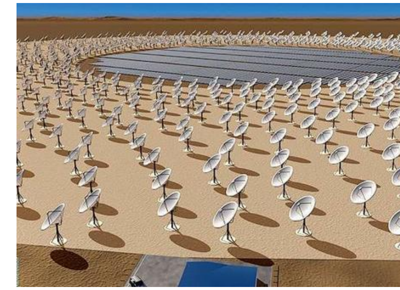
Epoch of Reionization: scientific preparation for the SKA

B. Semelin group

Neutral IGM emits at 21cm for 6<z<30:

➔Tomography with SKA

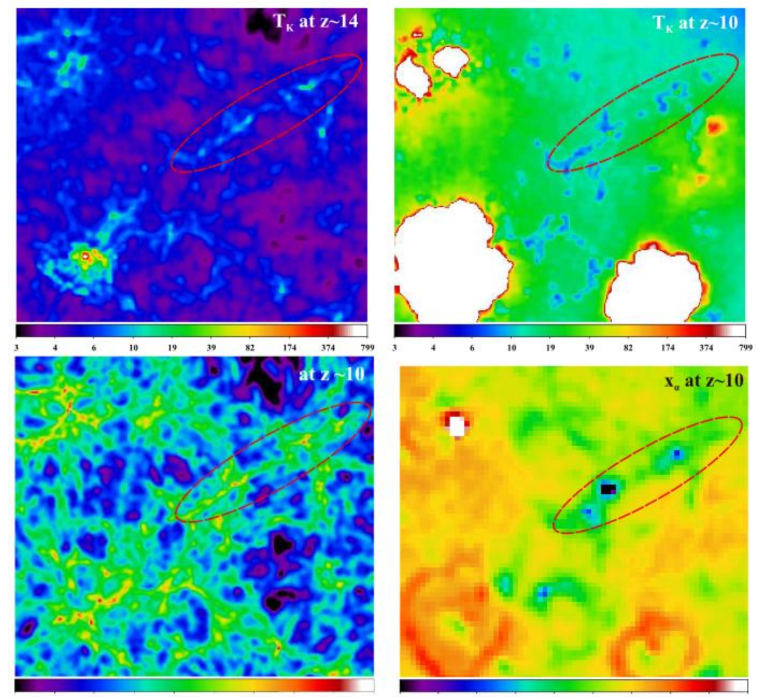
➔Hundreds of planes.



Simulations for design optimization and interpretation of data:

Dynamics + UV + X rays + Lyman lines

512^3 + 1024^3 resolution now….
and 2048^3 soon….
4096^3 needed!
Machine learning (Doussot et al 2019)



Semelin 2016

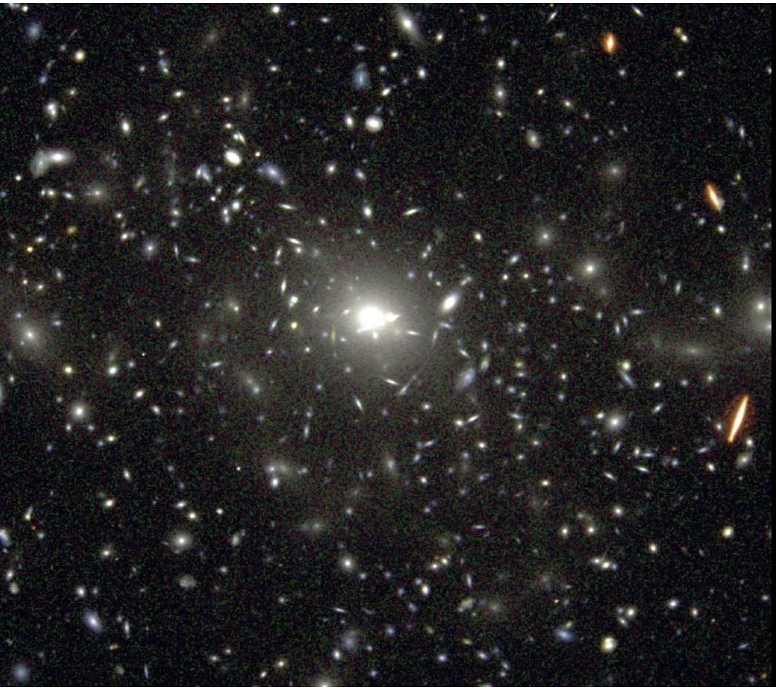
Put contraints on the design of the SKA:

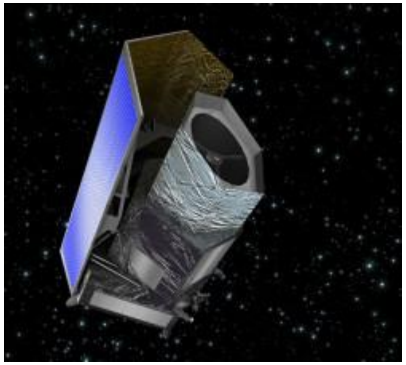
- frequency range
- Resolution/sensitivity tradeoff
- Benefits from large FoV
- Modeling and analazing tomographic data

➔LOFAR and NENUFAR at Nancay

ANR ORAGE (2014-2018)

Euclid legacy - Galaxy clusters





Study of galaxy clusters and their evolution, and the statistical view of galaxy physics in large surveys

Euclid launch in 2022:

not only clues on the dark energy evolution

➔Huge amount of data on billions of galaxies in association to follow-up ground spectroscopy

➔Studies on the influence of environment on galaxy morphology, mass-size relation, mass assembly and star formation efficiency.

Members of the pole are co-coordinator of Science Working Groups in the **Euclid consortium**, on galaxy clusters and proto-clusters, their detection tools, determination of mass and luminosity functions, the classification of galaxies in order to follow their formation and evolution *(Mei, Huertas-Company, Zwolf and their teams)*

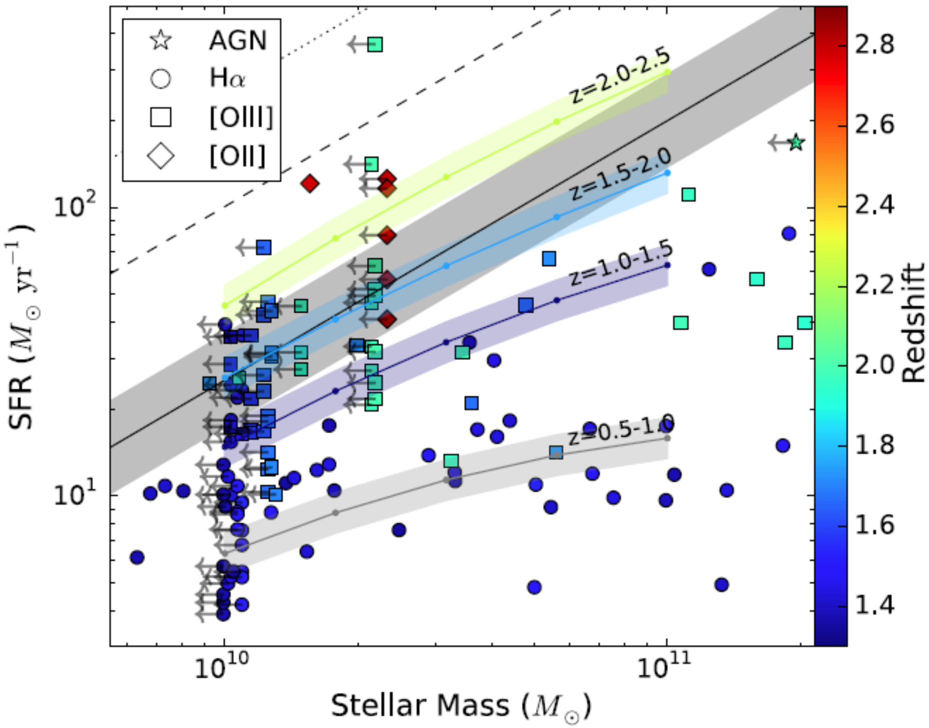
Galaxy Protoclusters: quenching mechanisms

CARLA: Clusters **A**round **R**adio-**L**oud **AGN** (Wylezalek et al 2013)

At z < 1, galaxies in clusters are quenched,

A reversal is expected at z> 1, 1.5,
the AGN fraction increases,
The SF fraction increases,
higher in clusters than in the field

Noirot et al 2017



Selection from IR (Spitzer, WISE)
HST spectroscopy (Noirot + 2017)

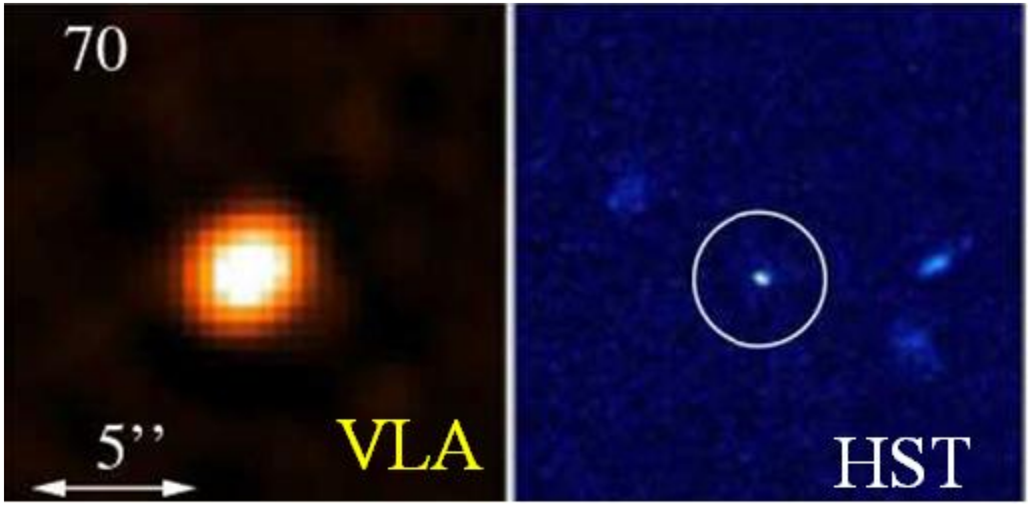
➔Some quenched, some not
Massive galaxies are redder, quicker evolution than in the field

Projects with ALMA & NOEMA (Galametz, Mei et al 2017, 2018)

Protoclusters, around radio sources

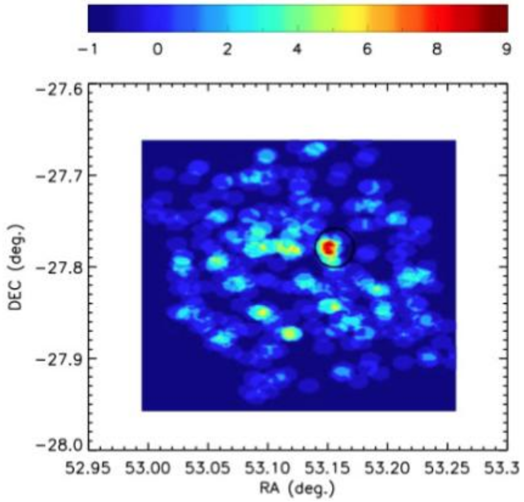
Castignani et al (2014), **FRI in COSMOS field**

Observations IRAM-30m
Negative results on z~1,
CO(4-3)
Castignani, Combes, Salome 2019, 2020

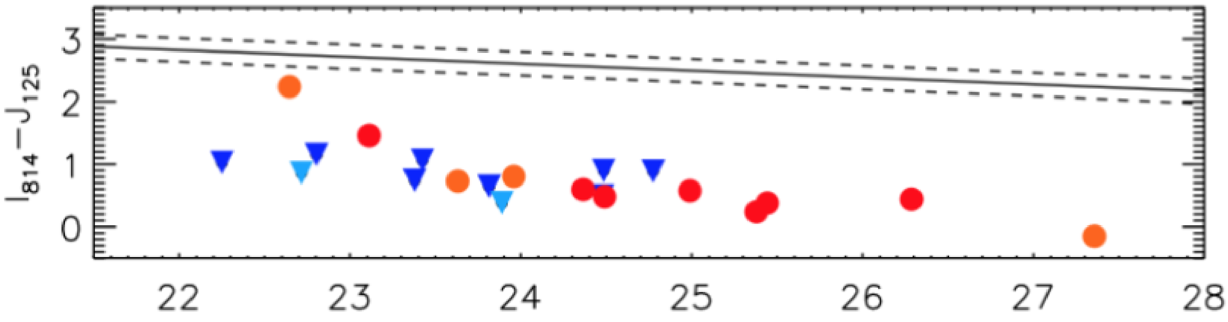


+ CARLA
NOEMA project, Markov et al 2020

Z~2.5, NOEMA project

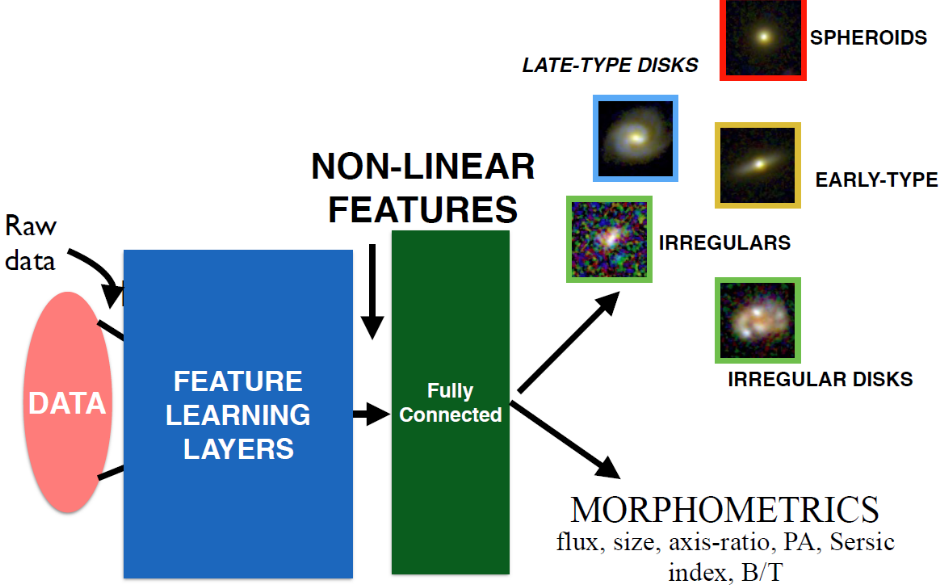


At z~1.9, ETG are not yet red and quenched



Mei et al 2015

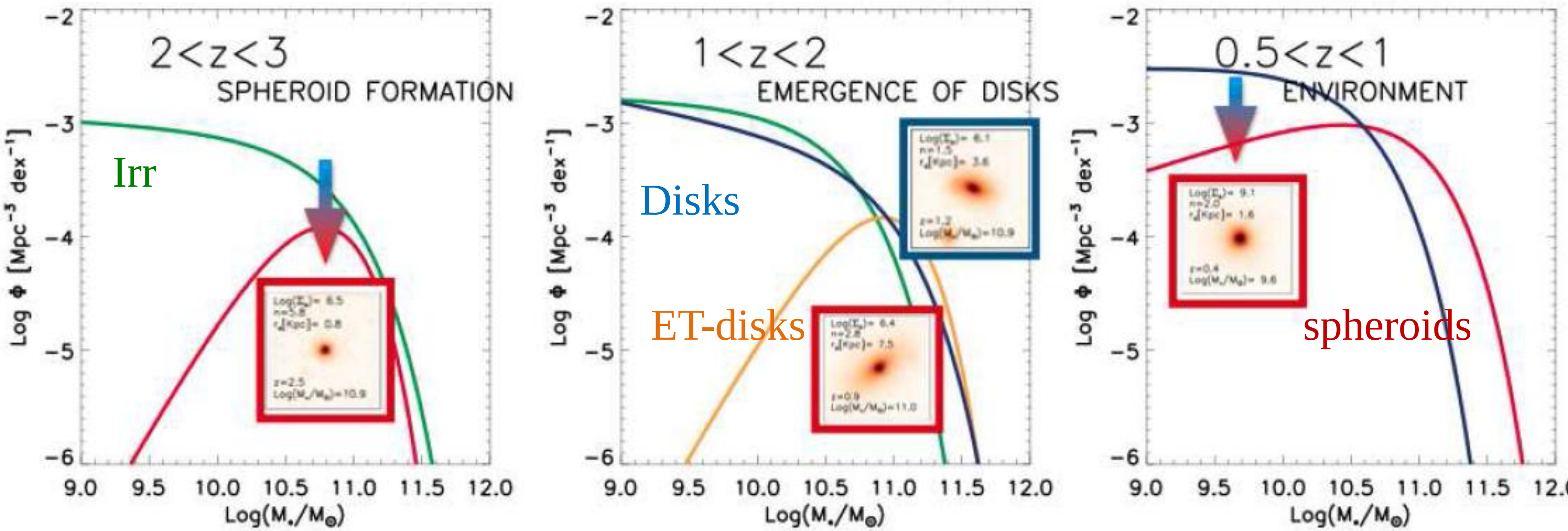
Deep learning-Galaxy classification



Golden age:

➔ Big numbers of galaxies

➔ Artificial intelligence

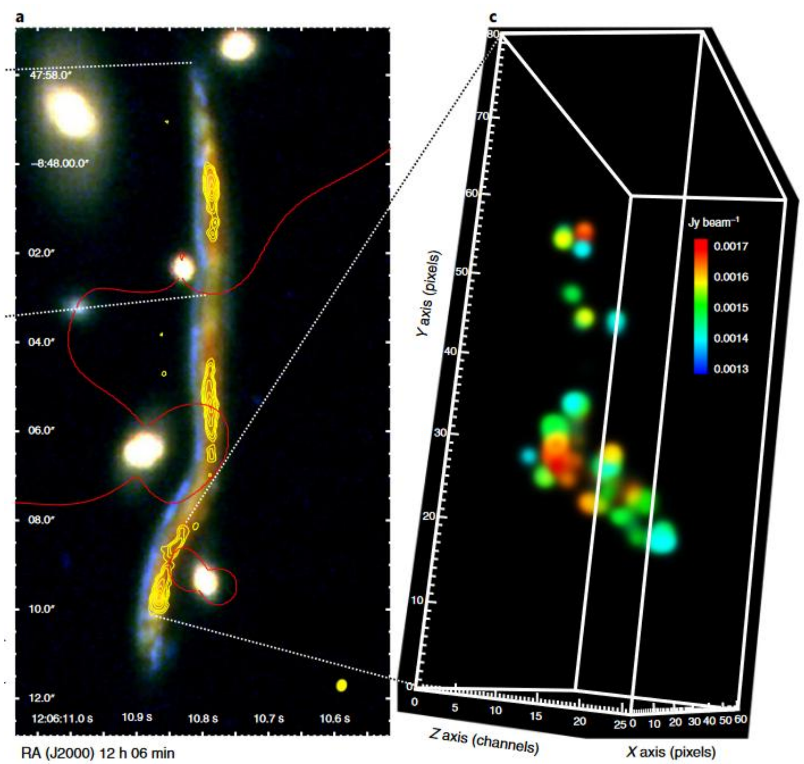


➔ Irregulars dominate at z>2, then become disks, which after bulge formation, acquire mass, and quench to become red

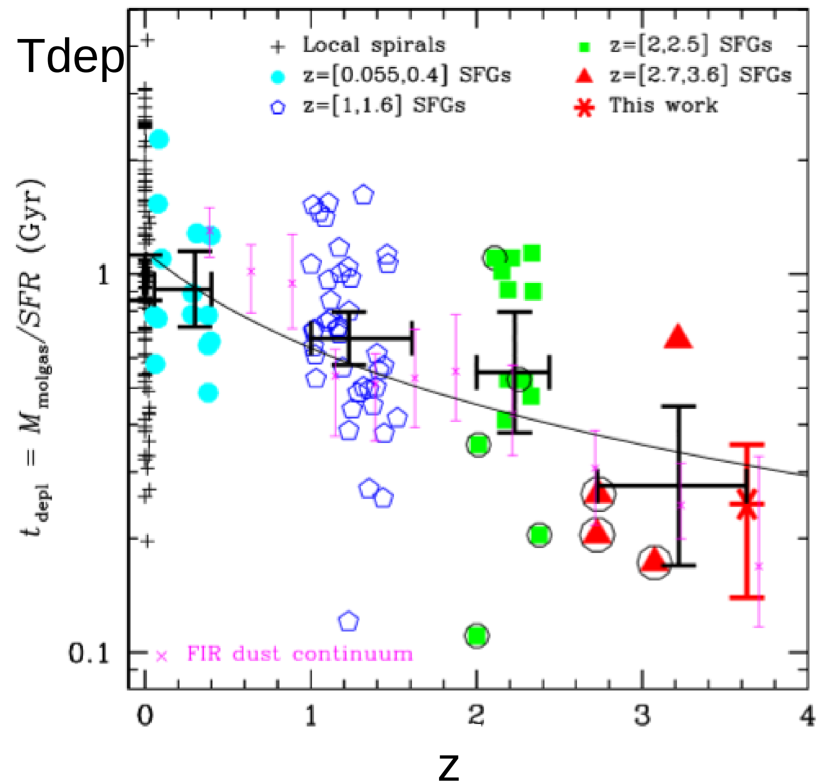
ANR Astrobrain 2017-2019 (Huertas-Company et al 2016, 2018)

ALMA & NOEMA – Galaxies at high z

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

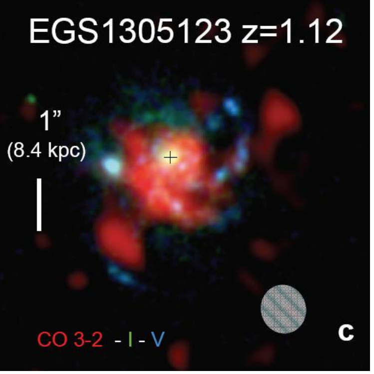


The Snake, *Dessauges-Zavadsky et al 2019*



Dessauges-Zavadsky et al 2017

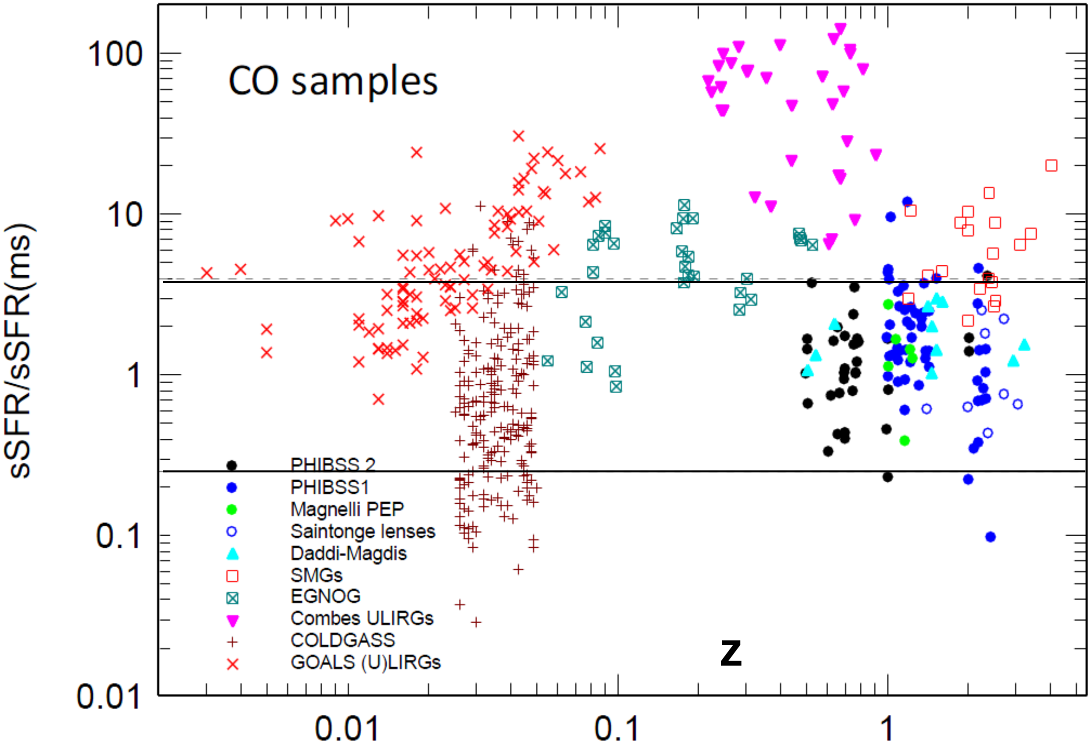
Herschel, VLT, Keck, Euclid

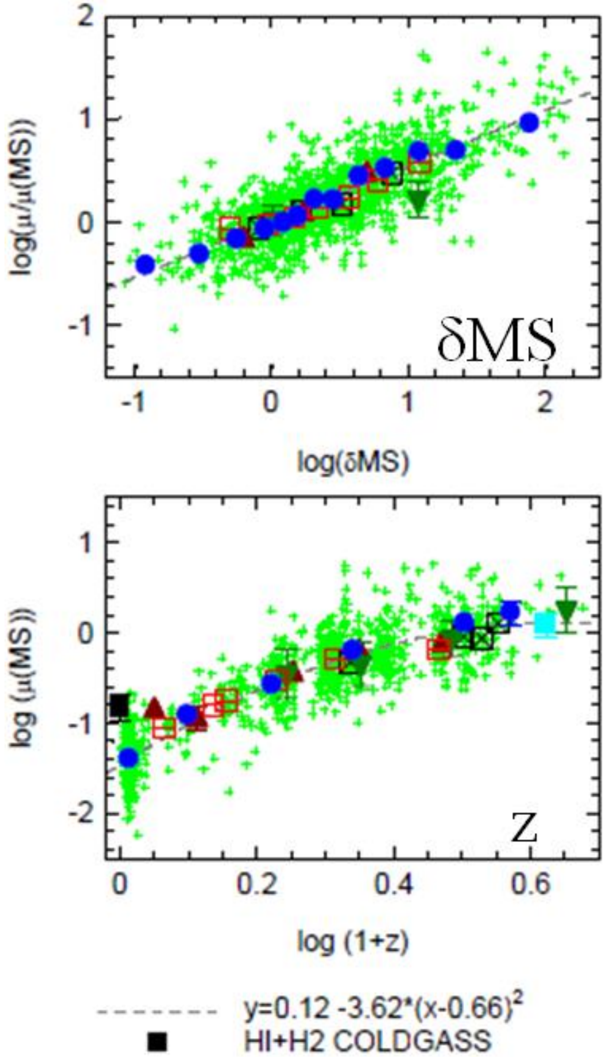


PHIBSS: Scaling relations

LP IRAM-NOEMA

Gas fraction increases regularly with z on the MS





log(M*/Mo)=9.-11.8, δMS=SFR/SFR(MS)

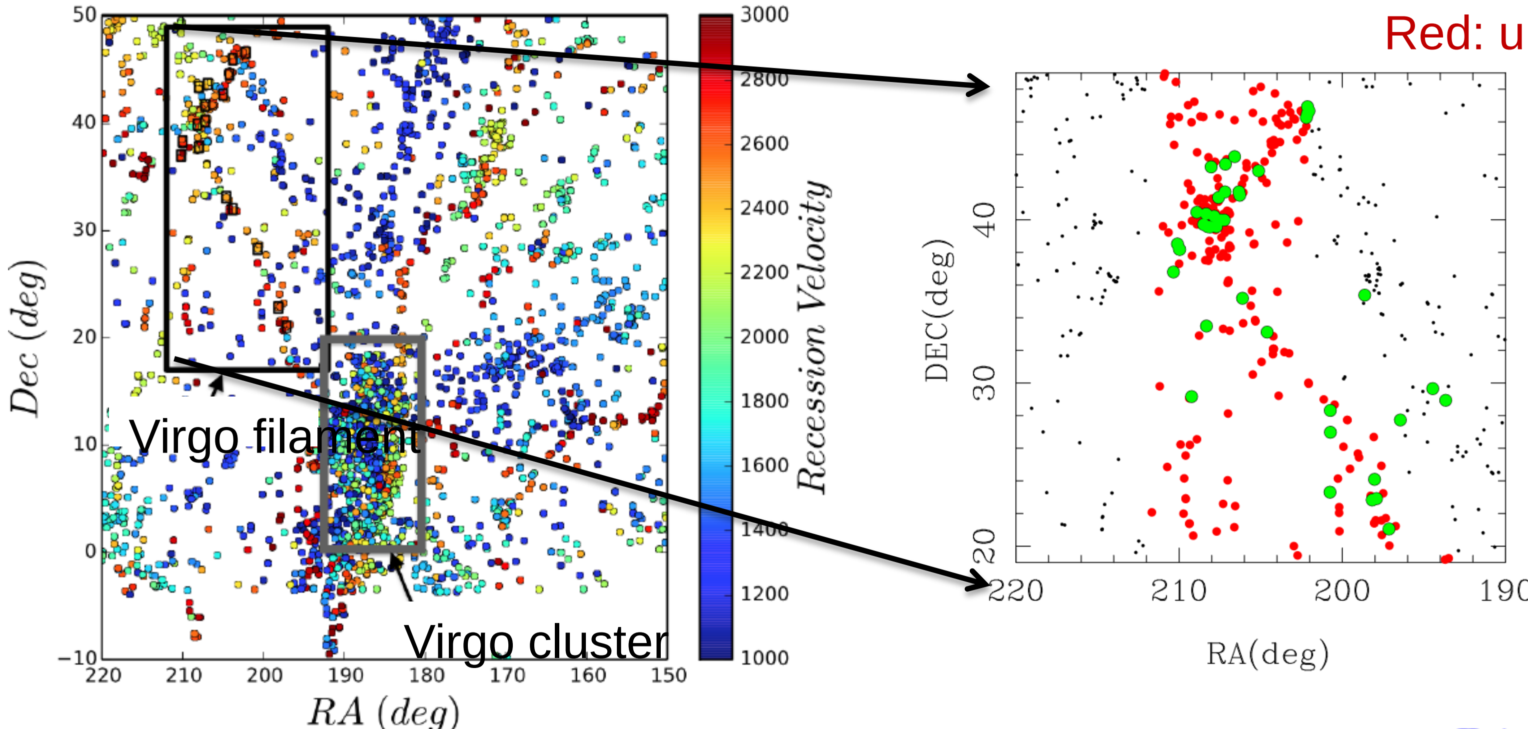
tdep ~ $(1+z)^{-0.57}$ $(\delta MS)^{-0.44}$

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

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

The cosmic web and galaxy formation

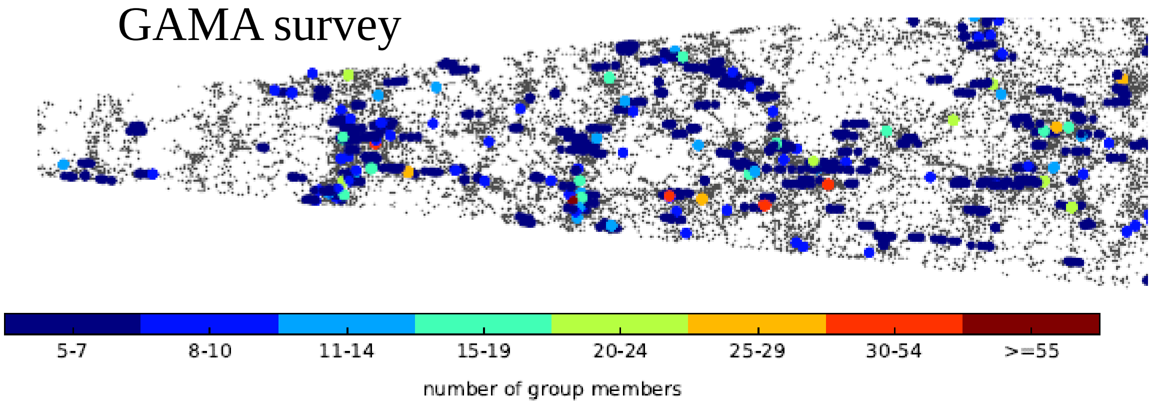
Green: detections
Red: upper limits

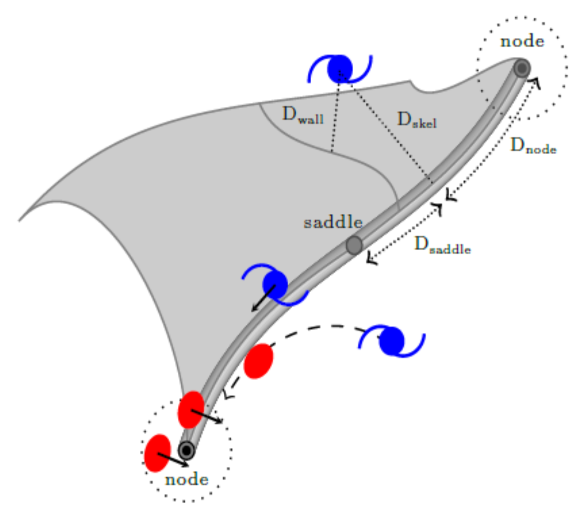


CO and HI survey of Virgo Filaments

Castignani Combes, Salomé et al

GAMA survey



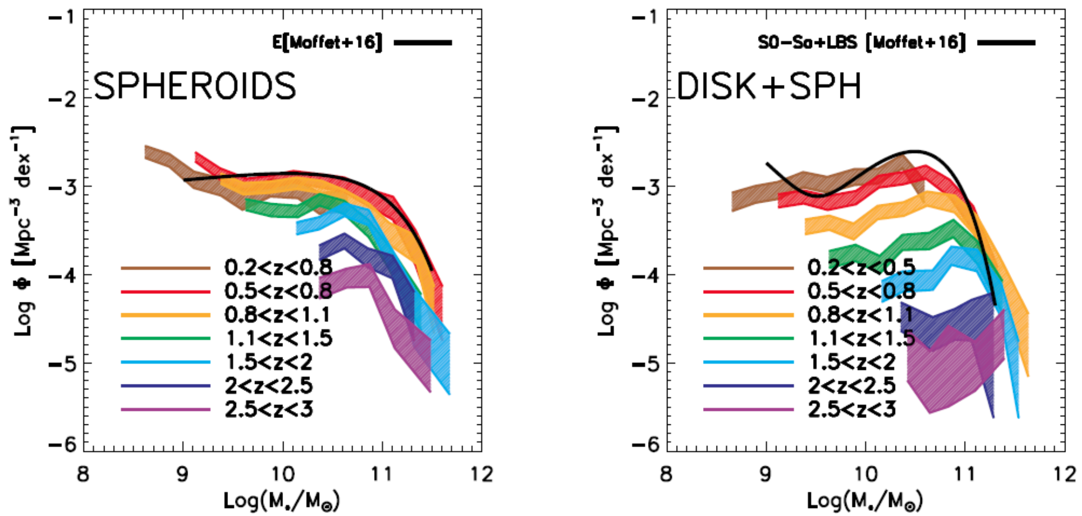


Kraljic et al 2017

Galaxy morphology evolution

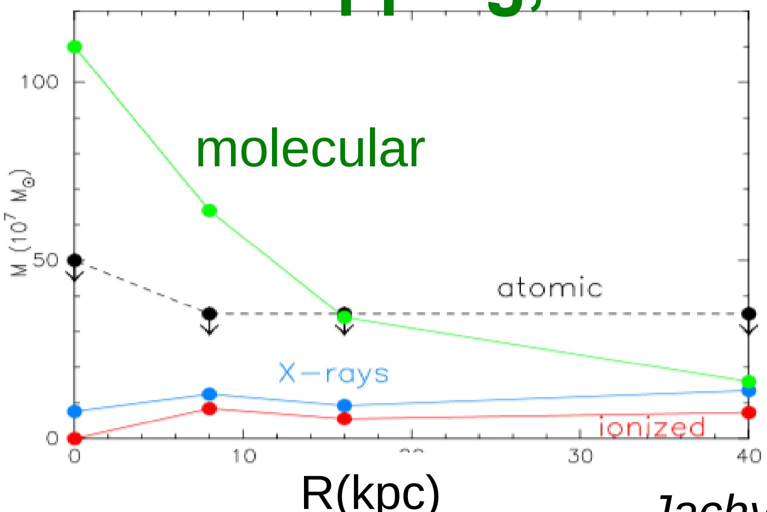
50 000 galaxies in CANDELS

Downsizing in SF galaxies
Quenching as a function
of mass and environment
Inside-out quenching

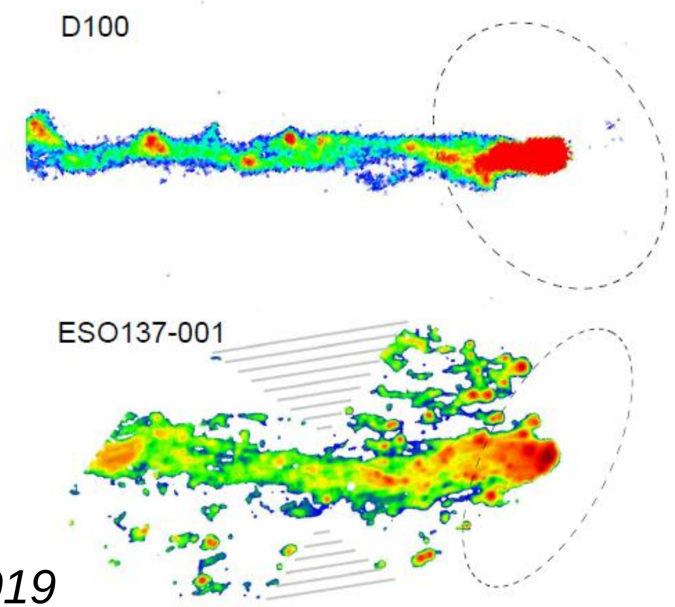


Huertas-Company et al 2016

Cluster stripping, harrassment



Jachym et al 2017, 2019



Cooling Flows, BCG, AGN

➔Observations

HERSCHEL:

Large Program: sample of cooling flow clusters (PI: A. Edge, Durham)

OT1 SPIRE FTS on PERSEUS

(PI: W. Jaffe, Leiden)

ALMA:

with McNamara, Russel

– Feeding the AGN

with J. Lim, David

– Search for cold filaments

IRAM- NOEMA

Perseus PI: P. Salomé (cold gas excitation)

+ S. Hamer

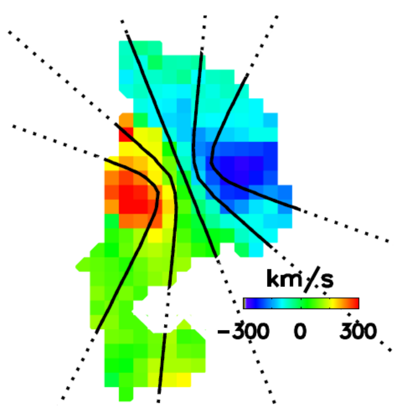
Hydra-A

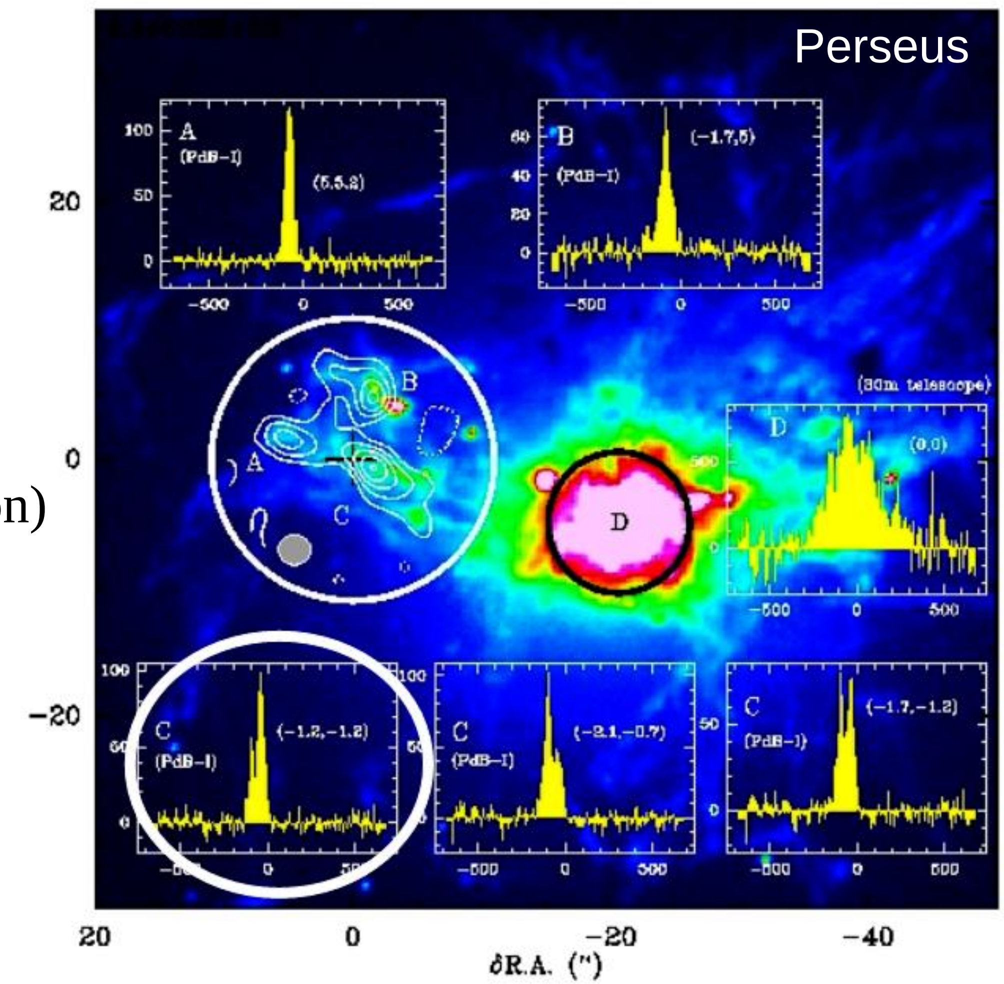
+ 73 BCG

2016

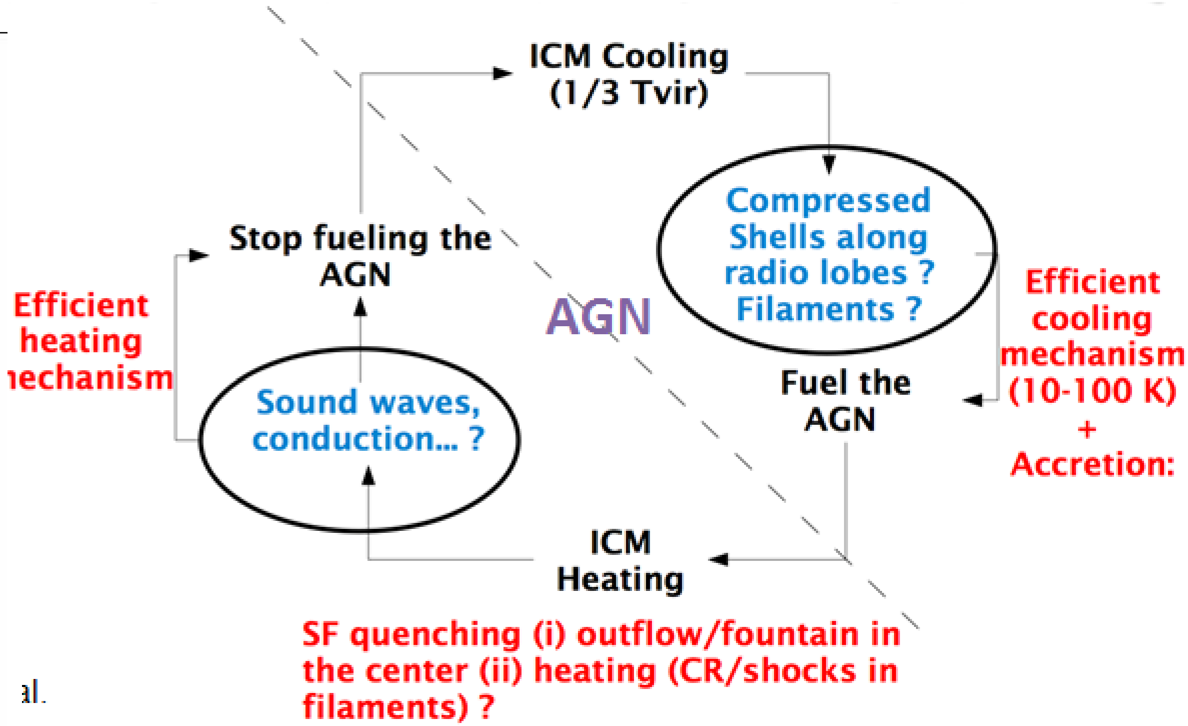
Olivares 2019

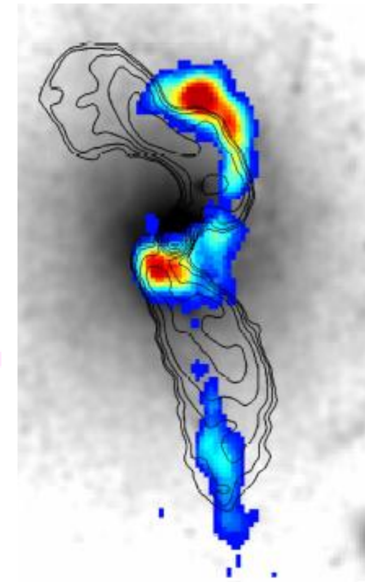
Polles et al 2019





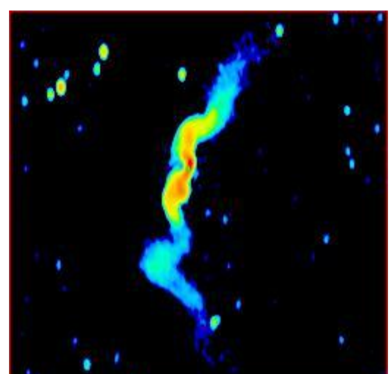
AGN moderation and quenching





Quasar mode: radiative or winds
when L ~$L_{Eddington}$

Radio mode, kinetic, jets
when L < 0.01 L_{Edd}



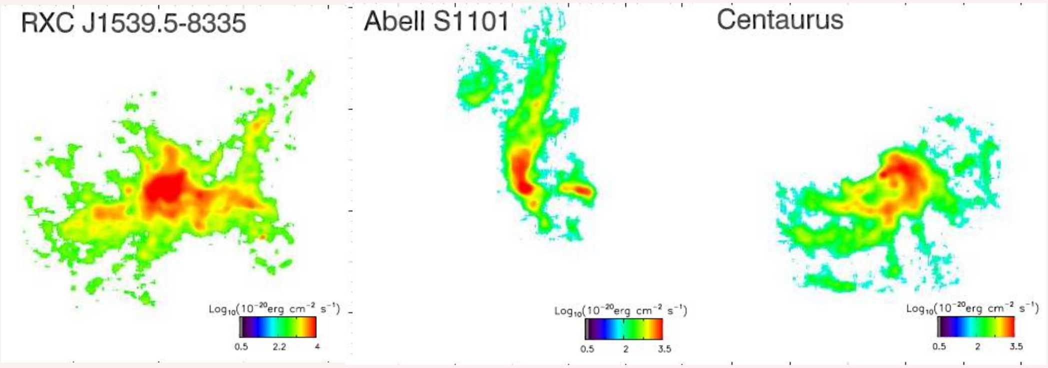
ANR LYRICS 2017-2021, Salome et al

WP1

Data samples in-hand

- MUSE : 22 BCGs + 22 BGGs (25 TB)
- ALMA (3 Observed + 7 archive)
- NOEMA data (Perseus, Abell 1795)

LERMA/IAP Observations and data Reduction (P. Salomé, M. Rodriguez, P. Guillard, M. Lehnert, S. Hamer)



WP2

Gas local excitation modelling

- Photo-ionisation codes (CLOUDY, PDR) and shock models (enough data)

LERMA/IAP (P. Salomé, P. Guillard, B. Godard, G. Pineau des Forêts, F. Boulanger)

WP3

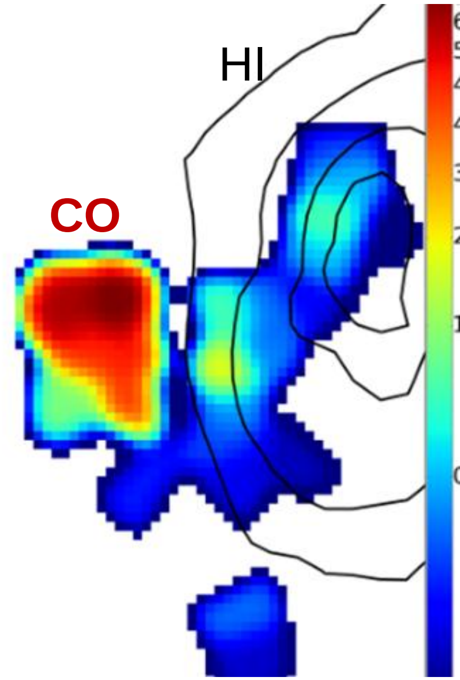
Hydro-dynamics numerical simulation

- Cluster-scale hydrodynamical simulations in the presence of AGN feedback (mapping now possible)

IAP/LERMA (Y. Dubois, S. Peirani, F. Combes, P. Guillard)

AGN positive feedback: Centaurus A
with MUSE and ALMA

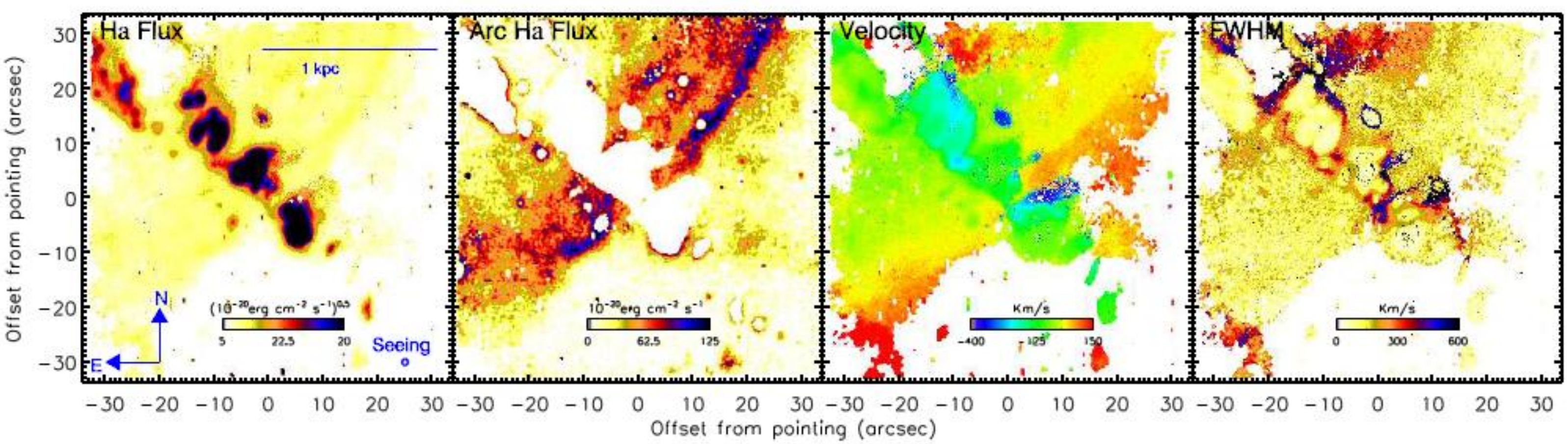
Discovery of arcs perpendicular to the filament
Halpha, [NII], [OIII] and [SII] lines



3 arc streams running perpendicular to the main filament,
Different excitation, kinematics: arcs outside the radiation cone
➔Neutral material swept by a backflow of the AGN jet outburst and ionised through slow shocks

➔H2 gas: **phase transition from HI**, triggered by the jet

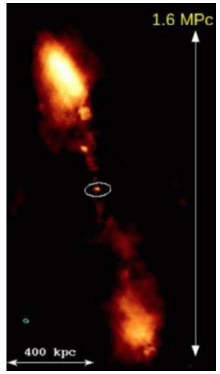
Hamer et al, 2014, Salome et al 2016, 2017, 2018

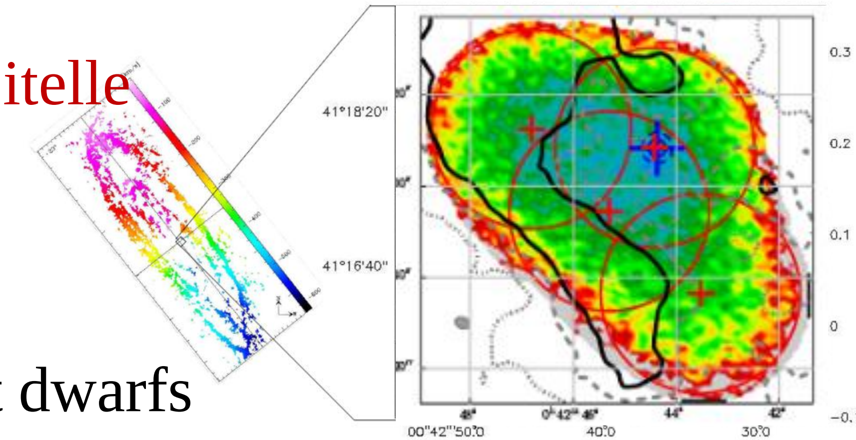


Nearby galaxies, ALMA, NOEMA, MUSE

➔ M31 IRAM + CFHT, Sitelle

➔ Giant Radio Gal

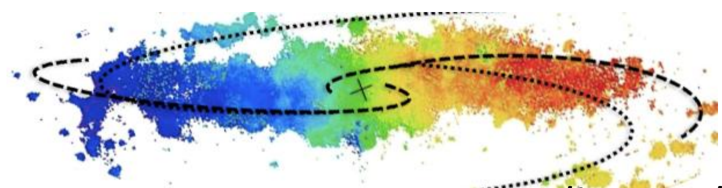




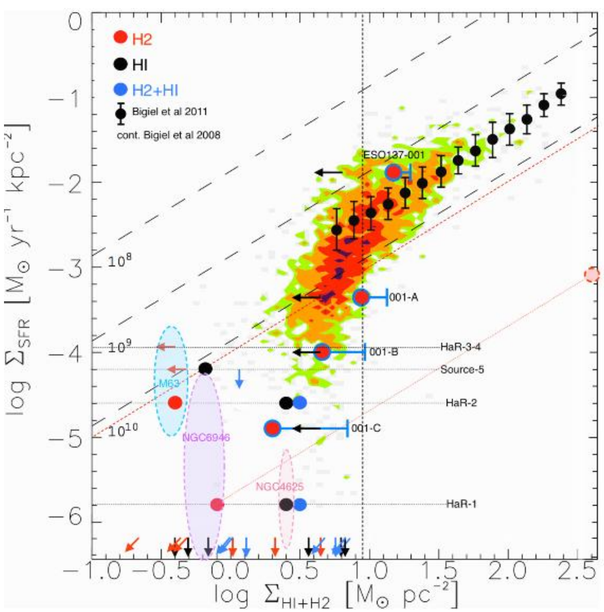
Melchior & Combes 2017 2019

➔ Low-Z dwarf galaxies, Ultra-faint dwarfs

➔ Polar ring galaxies (IRAM survey + ALMA/MUSE)



Iodice et al 2015, 2017



➔ Star formation laws (KS efficiency HI, H_2, scales..)

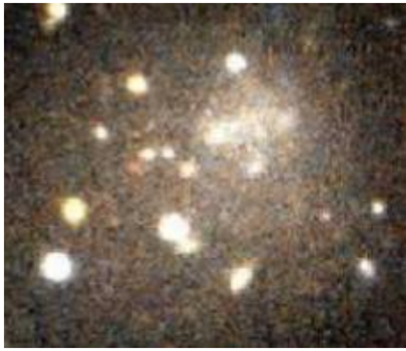
➔ Relation CO-metallicity, CO-dark molecular gas

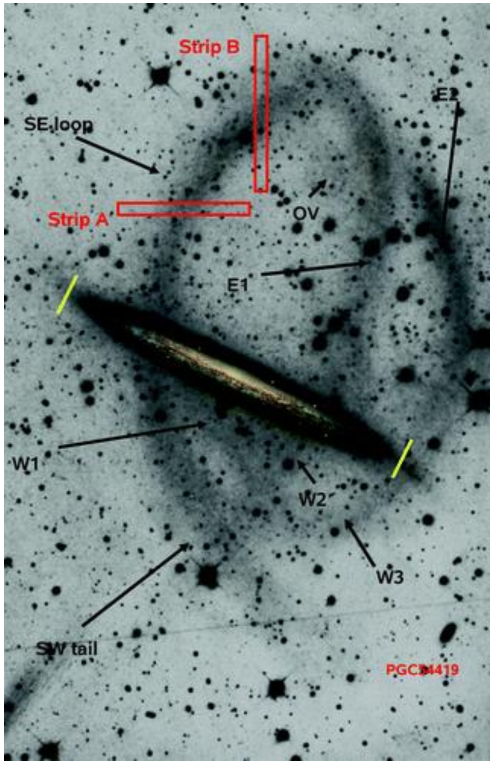
Low Surface Brightness features

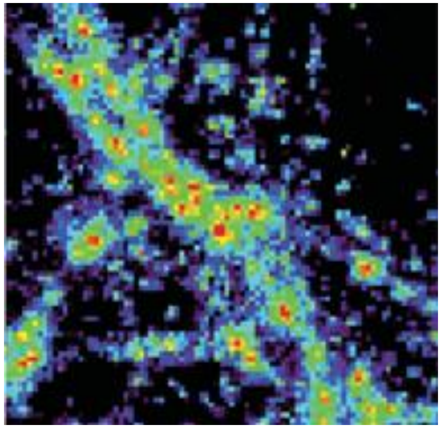
Future plans:
Proposition of the MESSIER satellite to the CNES

LSB galaxies, dwarfs, outer parts tidal tails, loops
Extra-galactic background, Ly-a haloes z=0.65
Cosmic web

DF44, DGSAT 1
Martinez-Delgado et al 2016



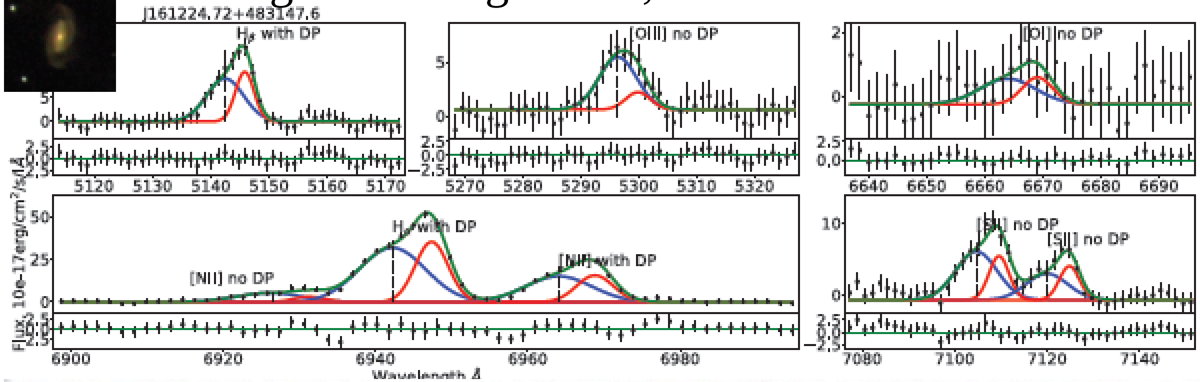




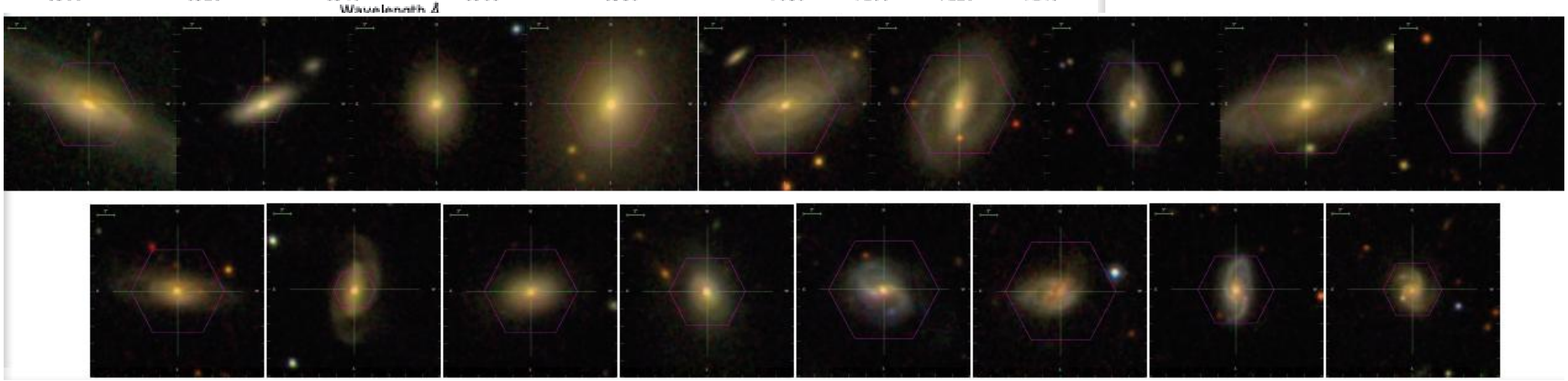
D. Valls-Gabaud et al 2017
Mancillas et al 2018, 2019

SFR Quenching: Double-Peaked MANGA

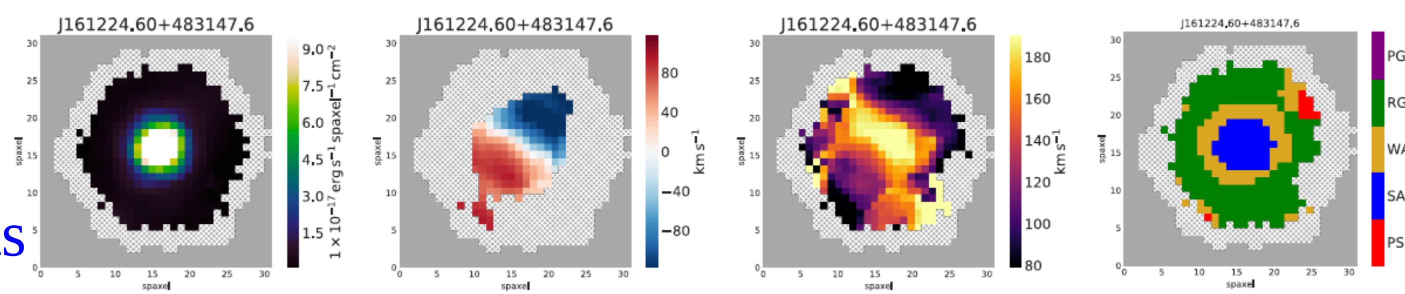
Catalog 5663 DP galaxies, Maschmann et al 2020



Selection of
Close mergers
➔ quenching
by SN or AGN



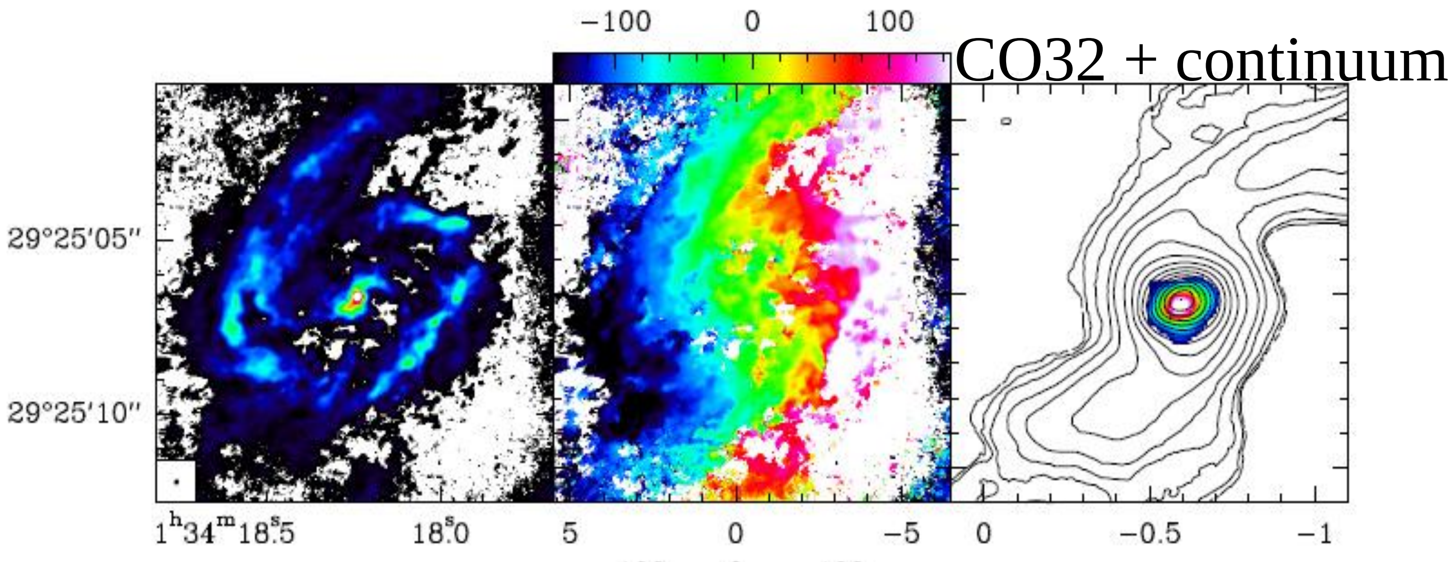
Hα
moments



WHAN
diagram

IRAM obs of double-peaked galaxies, Mazzili-Ciraulo et al 2020

AGN fueling and feedback



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

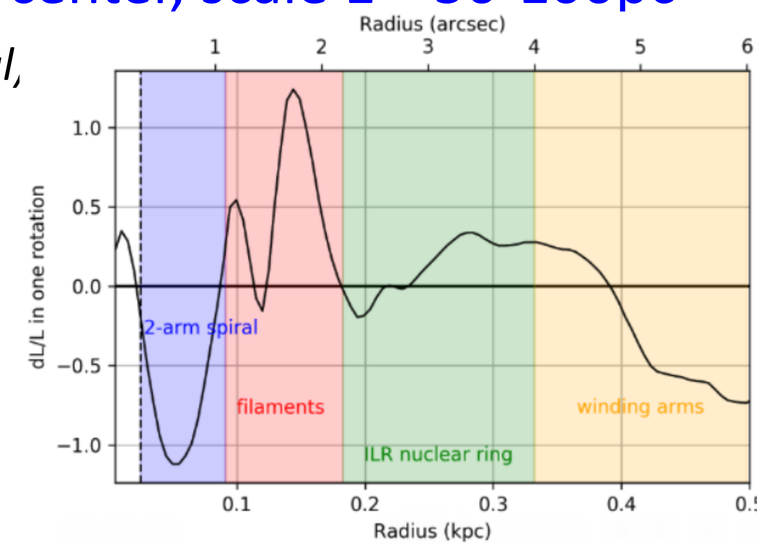
6 out of 16 galaxies *(Garcia-Burillo, Combes et al,*

➔ **Discovery of molecular tori**

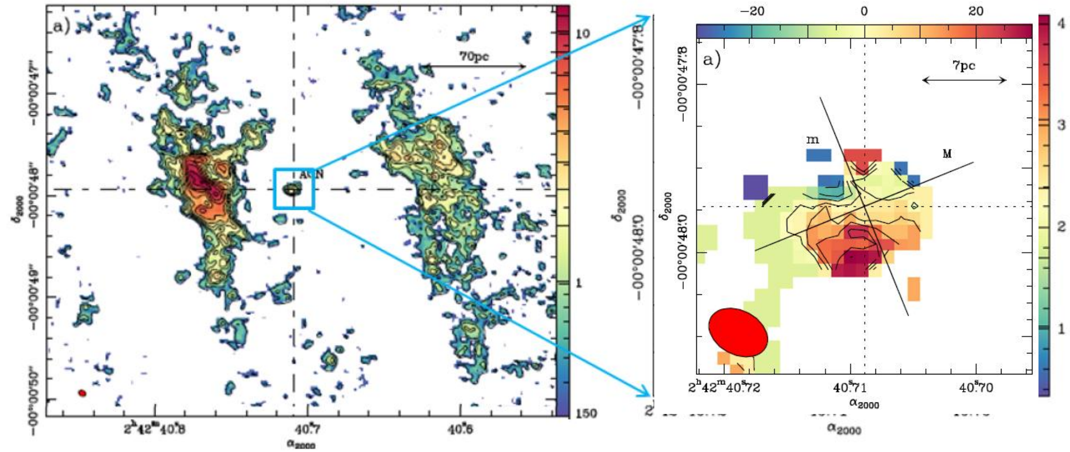
with ALMA (Combes et al 2019)

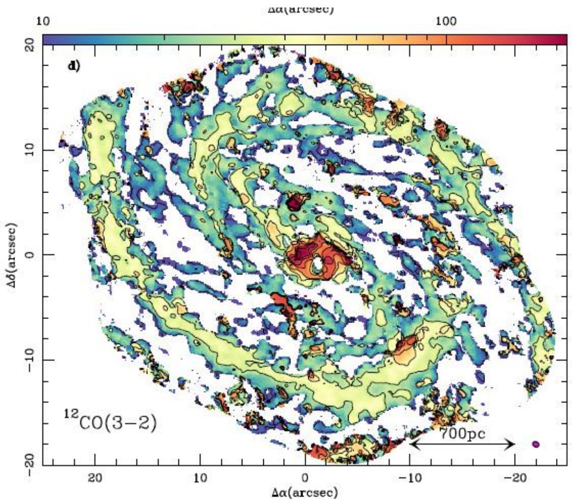
➔ Computation of **gravity torques**

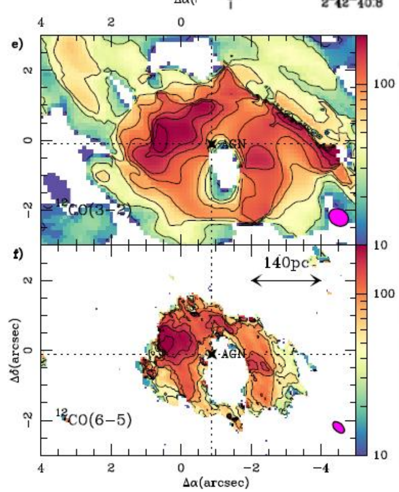
(Audibert et al 2019, 20)

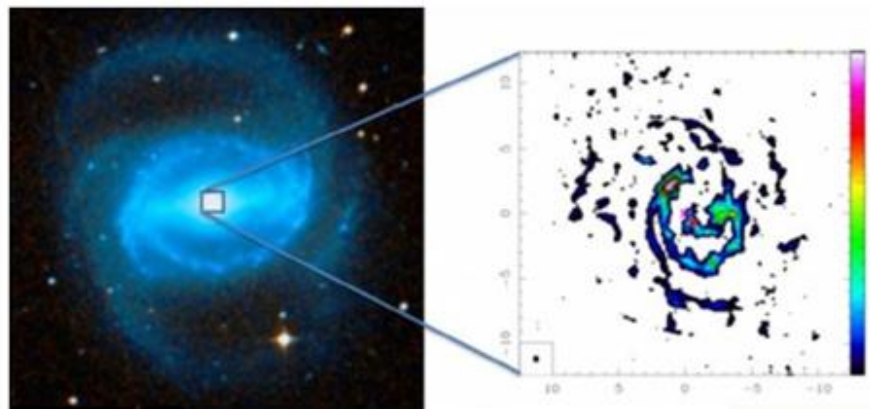


Molecular Outflows + torus (~7pc)



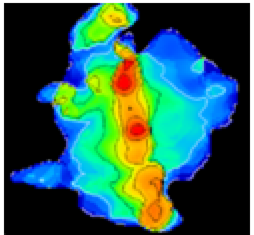






Garcia-Burillo, Combes et al 2016, 2018

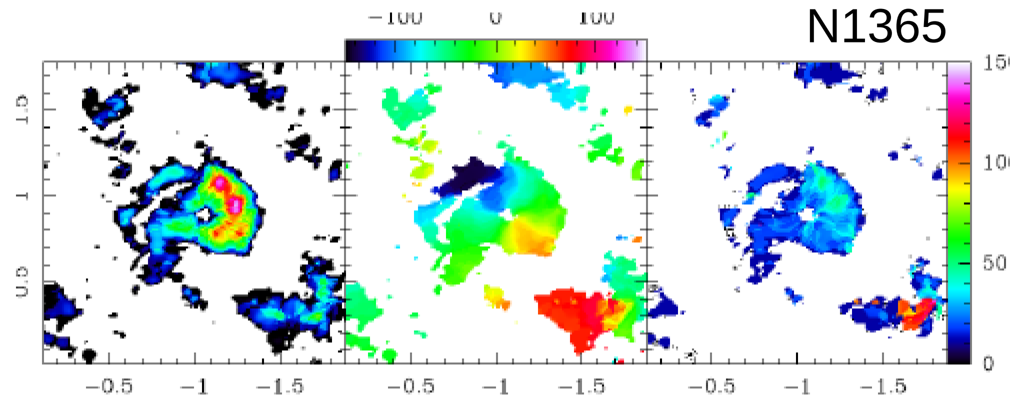
Outflow of 63Mo/yr
About 10 times the SFR in this CMD



N1377 precessing jet

Aalto et al 2017, 2019

N1365

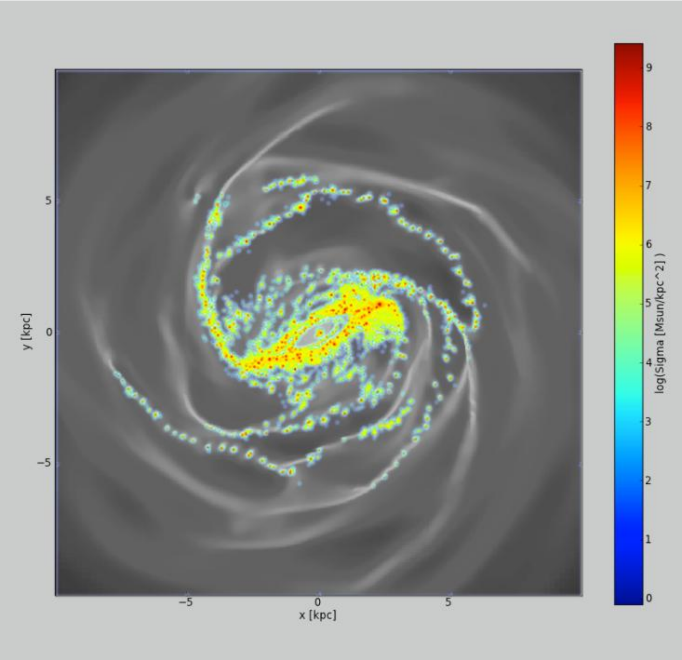


SF history and stellar populations

What are the possible scenarios of *formation* of a galaxy like the Milky Way? (*GAIA perspective*)

➔Simulations of secular evolution, versus mergers (minor and major) to reproduce abundances, gradients, pseudo-bulge, thin and thick disk, radial migration.

Halle et al 2018, Fragkoudi et al 2017, Khoperskov et al 2017



➔ Study of high spatial resolution gas physics *(with F. Bournaud, F. Renaud)*

➔Reproduce the SFH of the universe with baryon fraction, in simple analytical models *(M. Stringer)*

➔Spectrophotometric catalog of galaxies 4 10^5 from UV to NIR *(Melchior, with Chilingarian et al 2017)*

ALMA, NOEMA, MeerKAT

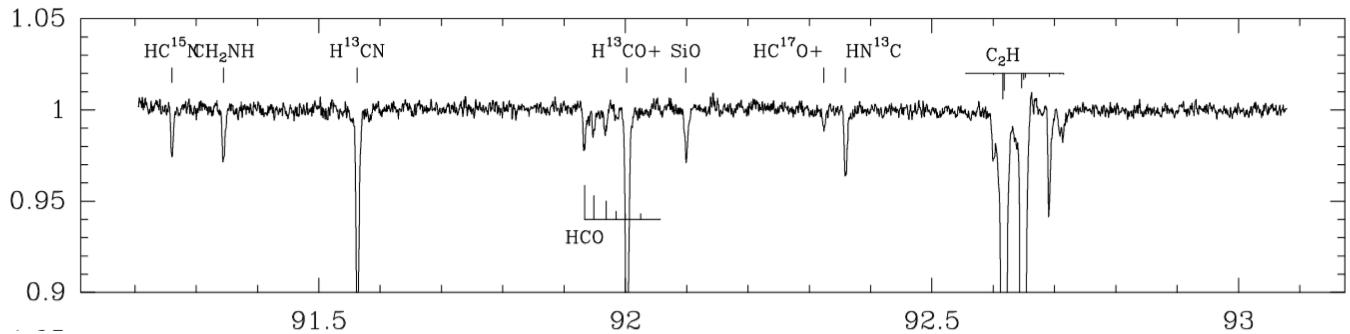
Absorption in PKS1830-211 at z=0.89, *Müller et al 2016-17, Beelen et al 2015*

Constraints on the variation of constants

With CH and H_2O

➔ $\Delta\alpha/\alpha < 5.8 \times 10^{-7}$

or $\Delta\mu/\mu < 1.2 \times 10^{-6}$



Discovery of molecular ions such as CH+, SH+, OH+, H_2O+, H_2Cl+ with their isotopes

Large Program MeerKAT: MALS *(Gupta et al 2017)*

1000 Quasars,
$0 < z < 2$, to search for HI and OH intervening absorbers, blindly

Pole 1: Galaxies & Cosmology

Highlight summary:

➔ **The early universe: inflation, cosmic backgrounds, reionization**

➔ **Dark matter: Cold, warm or modified gravity?**

➔ **Galaxy formation: high-z early galaxies, cosmic star formation, mergers, environment effects in galaxy clusters**

➔ **Black holes and galaxies: AGN, starbursts, symbiotic growth and feedback**

➔ **Star formation efficiency, history and stellar populations**