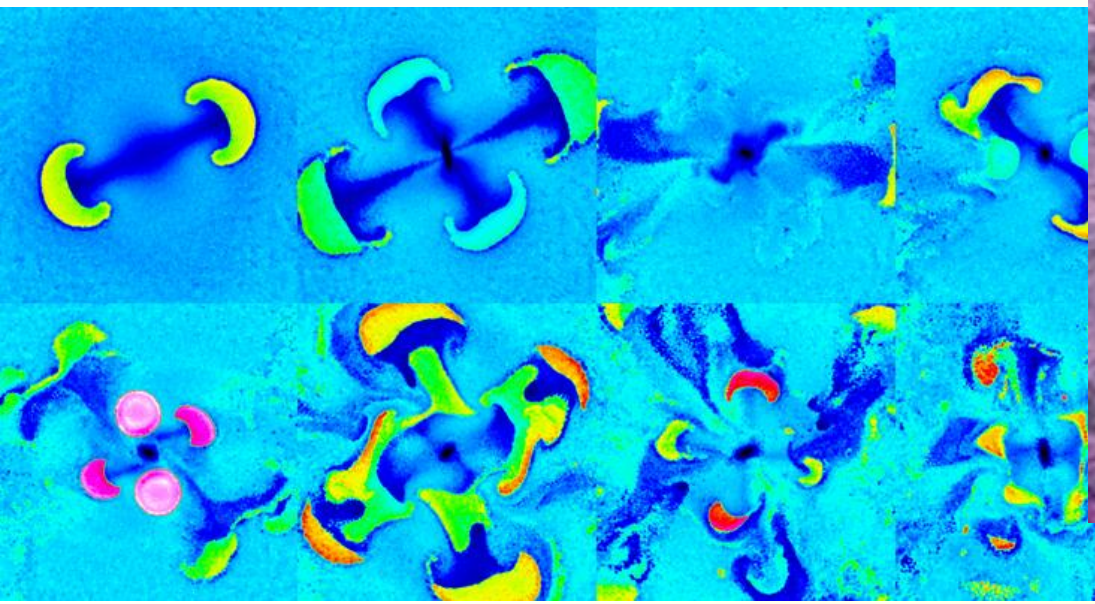
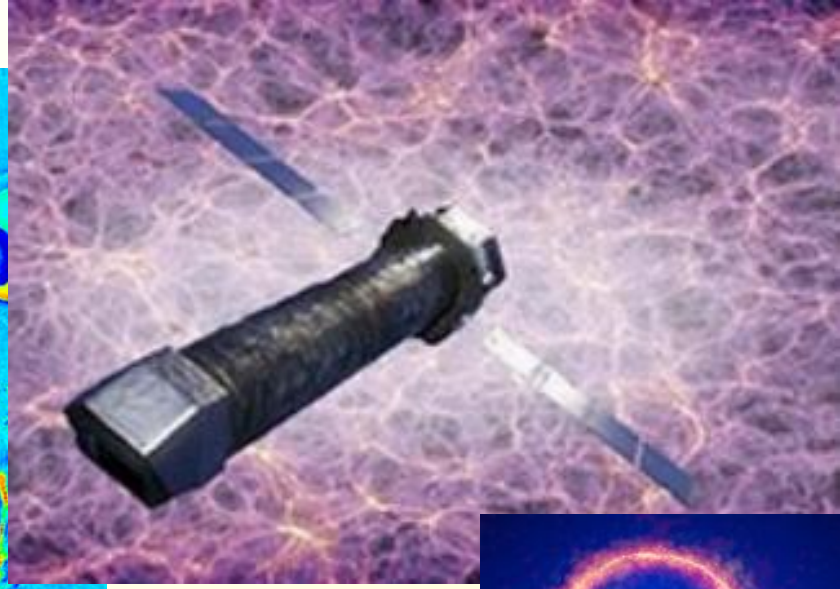


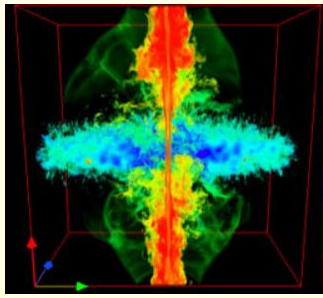


ALMA Synergy with ATHENA

Françoise Combes
Observatoire de Paris

9 September 2015

ALMA & Athena: common issues

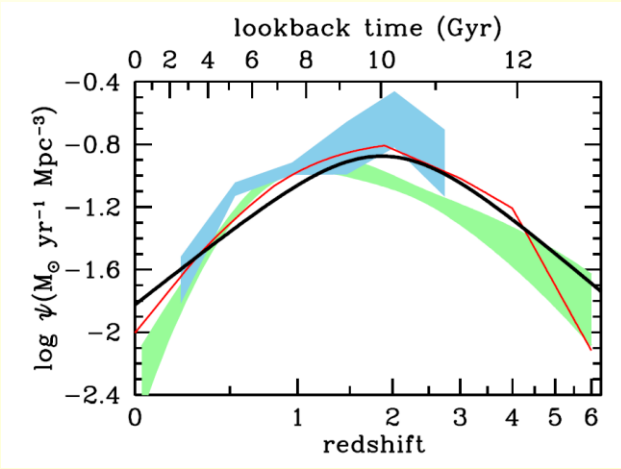


Galaxy formation and evolution, clustering

Surveys of galaxies at high and intermediate redshifts

Mass assembly and star formation, mergers, cold accretion

Co-evolution of galaxies and black holes



AGN, fueling and feedback

Early galaxies and black holes z=10-6

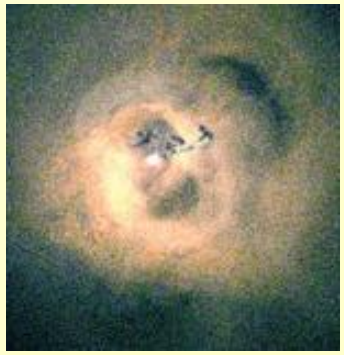
Nearby galaxies, entrained **molecular flows**

Ultra-Fast Outflows (UFO) stirring the ISM

Multi-phase gas in cool core clusters

Bubbles, cavities, cold gas buoyantly up-lifted

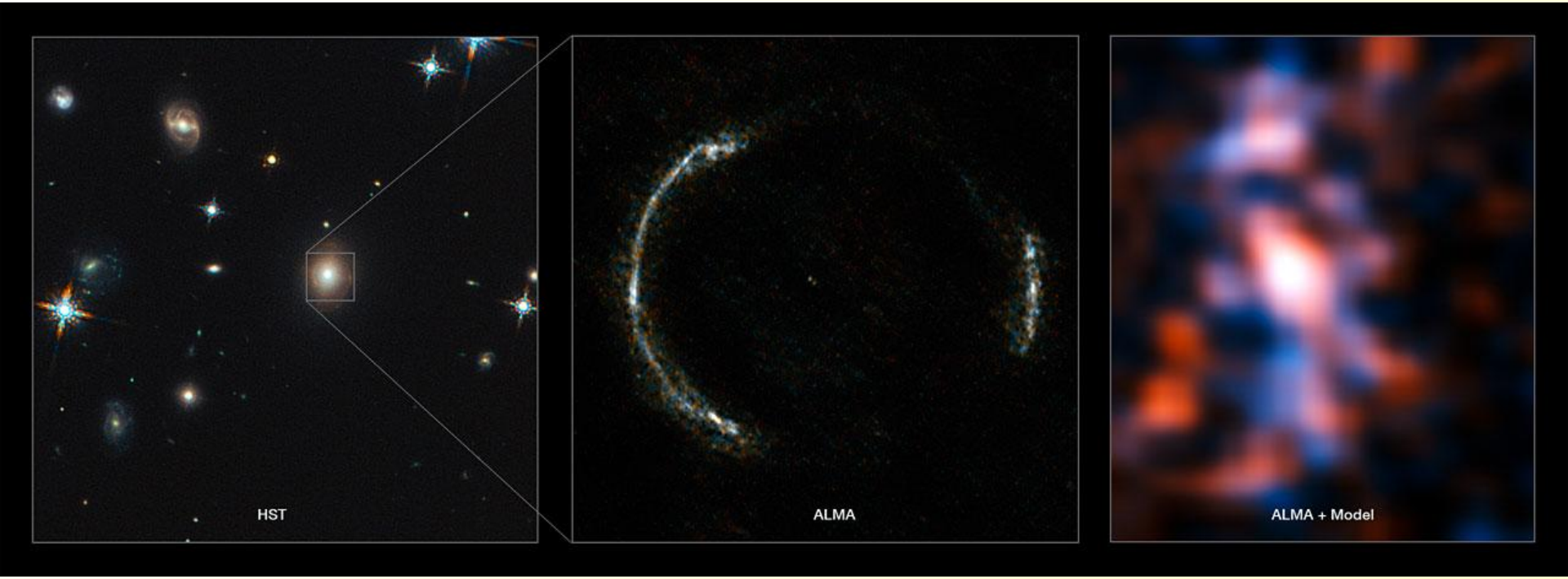
Cold gas filaments, fueling the central AGN



SDP.81, at z=3.042

Large Baselines ➔ **30mas resolution**

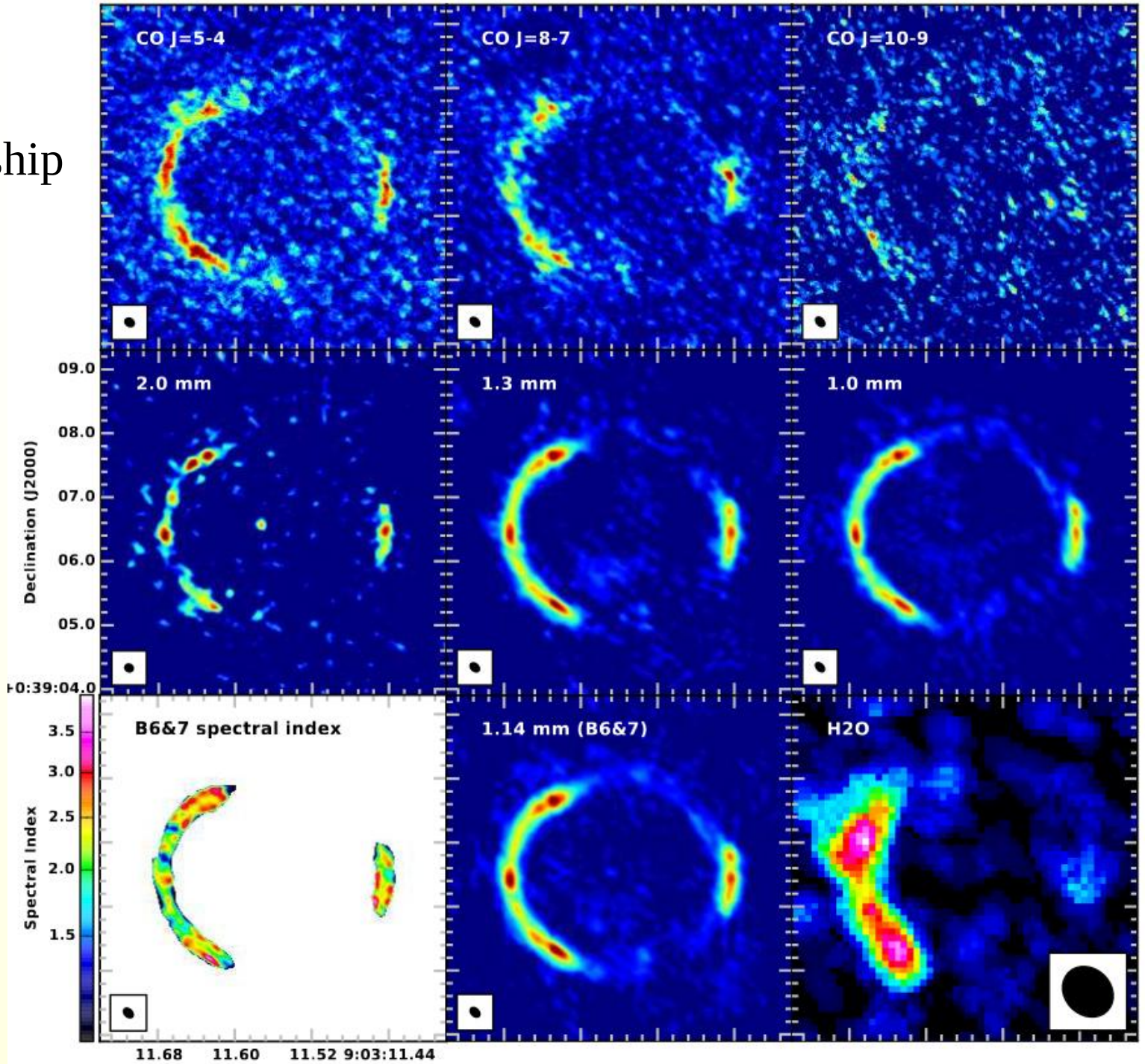
Corresponds to 50-100pc on the z=3 galaxy (gain x 3-4 due to lensing)



Mass within 1.5kpc, 3 10^{10} Mo, almost entirely gas!

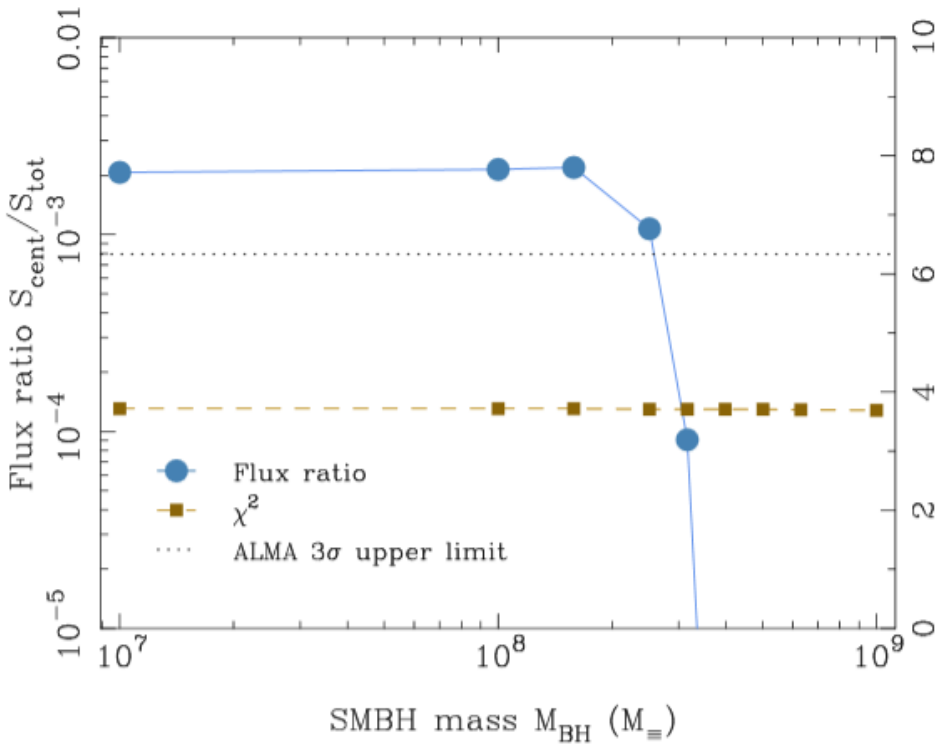
5 different groups have published on this object! 9 papers

ALMA Partnership 2015



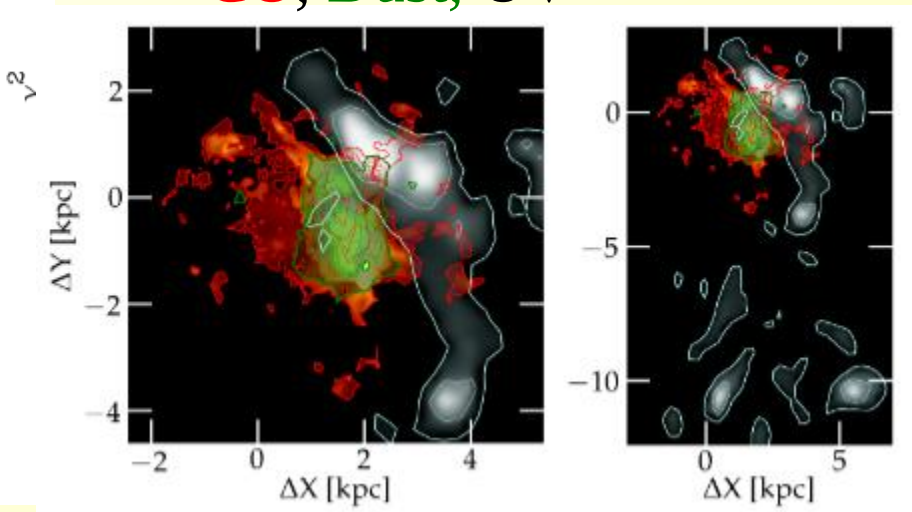
Black hole in the lens (z=0.3)?

The remote galaxy is composed of tens of <100pc SF clumps,
in a 2kpc disk
Ratio between the central image, and the others Scent/Stot



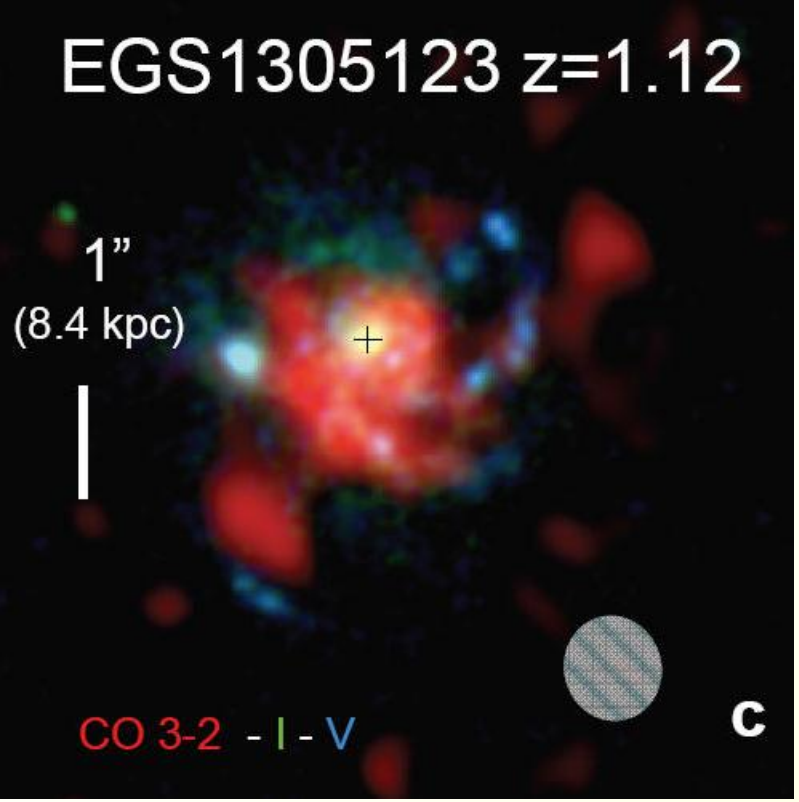
MBH > 3$10^8$Mo to suppress the central image of SDP.81

CO, Dust, UV



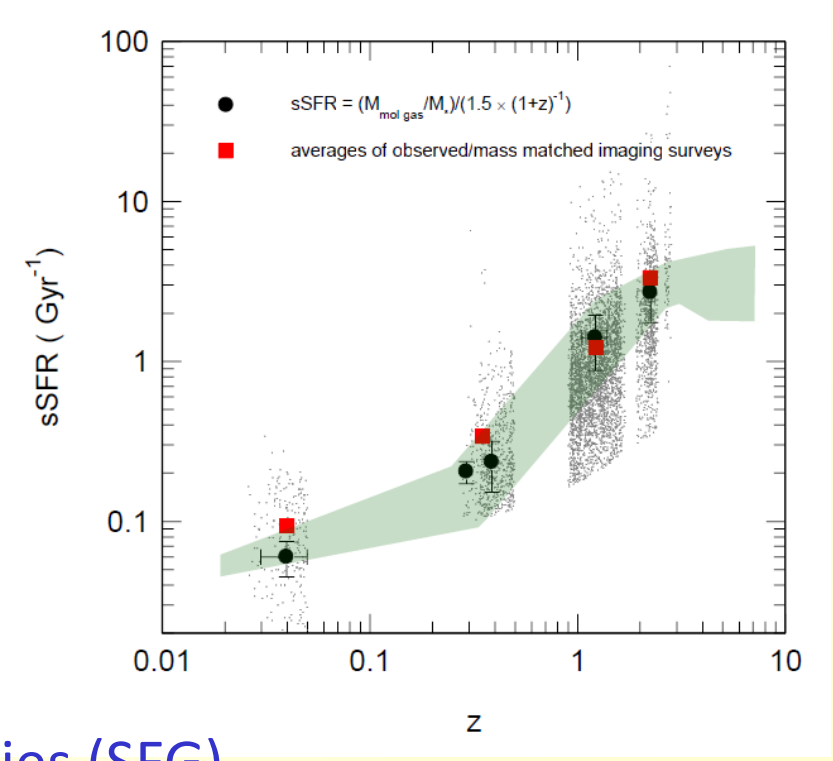
Tamura et al 2015

Rybak et al 2015



PHIBSS: 52 galaxies

Molecular gas at IRAM, z~2.3 & z~1.2



« Normal » massive Star Forming Galaxies (SFG)

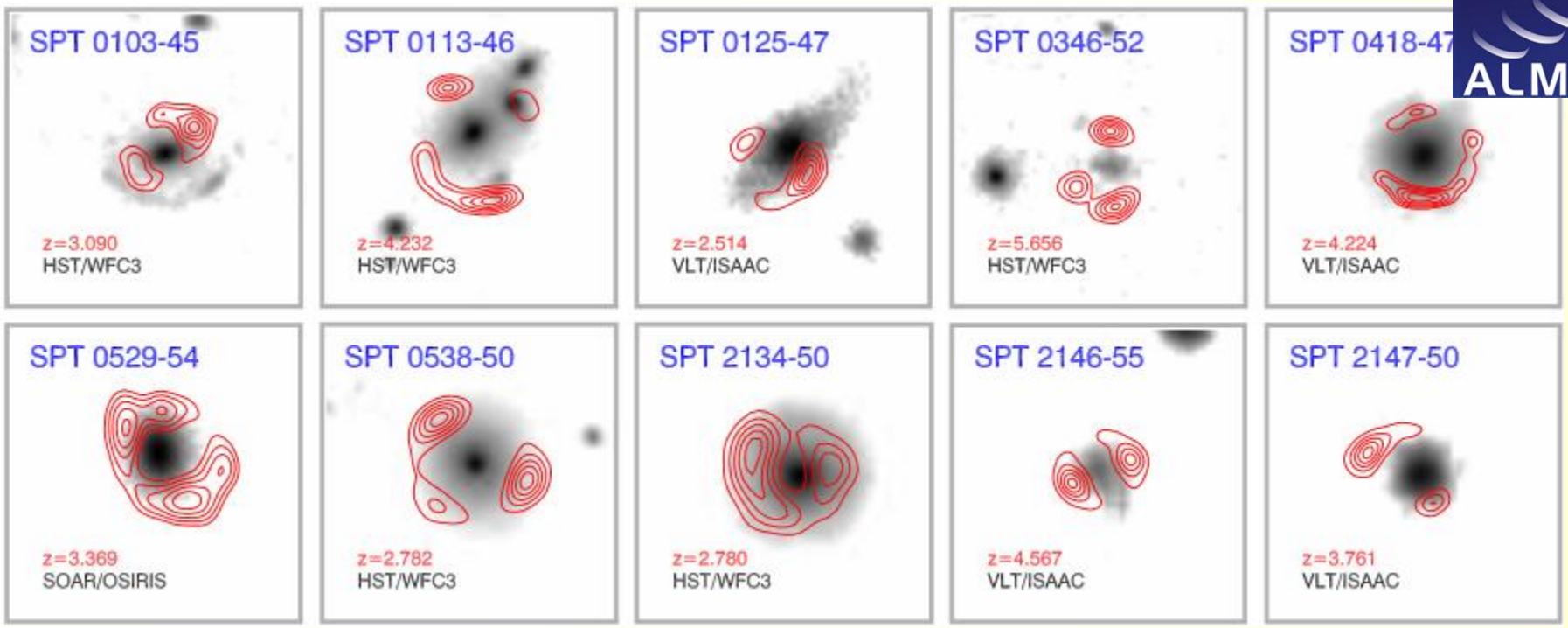
Quiescent SF, in the main sequence

Gas content ~34% and 44% in average at z=1.2 and 2.3 resp.

Star formation efficiency SFE increases in (1+z)

Tacconi et al 2010, 2013

ALMA high-z searches



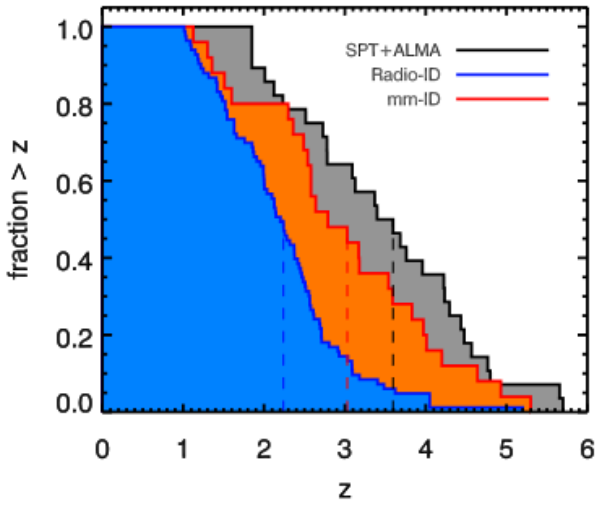
Grey-scale NIR from HST, VLT, SOAR

Vieira et al 2013 (23/26 detected)

10 z > 4

Red=ALMA 870 μm contours, 2min, 0.5”

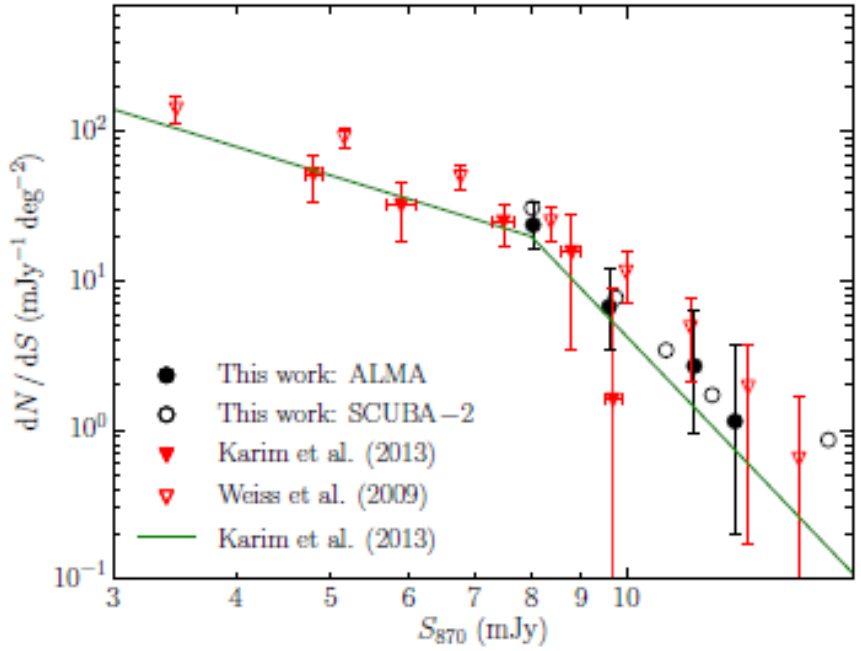
ALMA-obtained spectro redshift

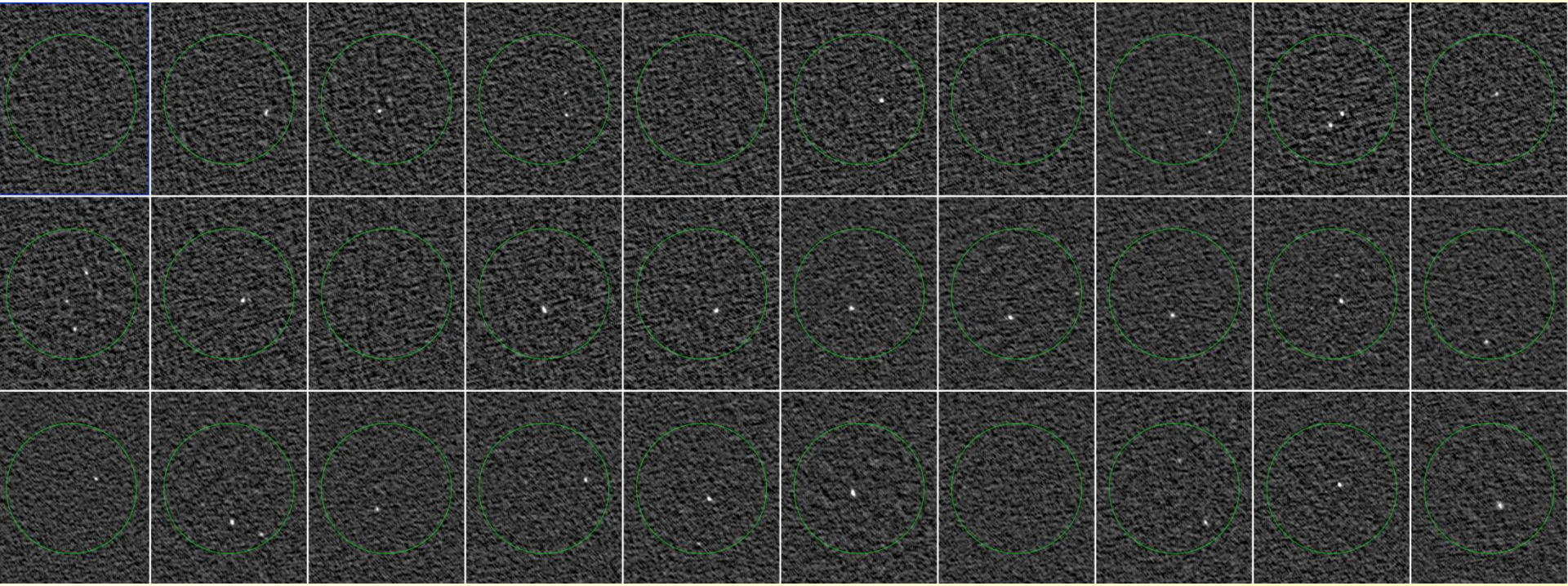


Source counts

Source counts for submm galaxies cut off at S(850μ) ~7 mJy (Simpson et al 2015)

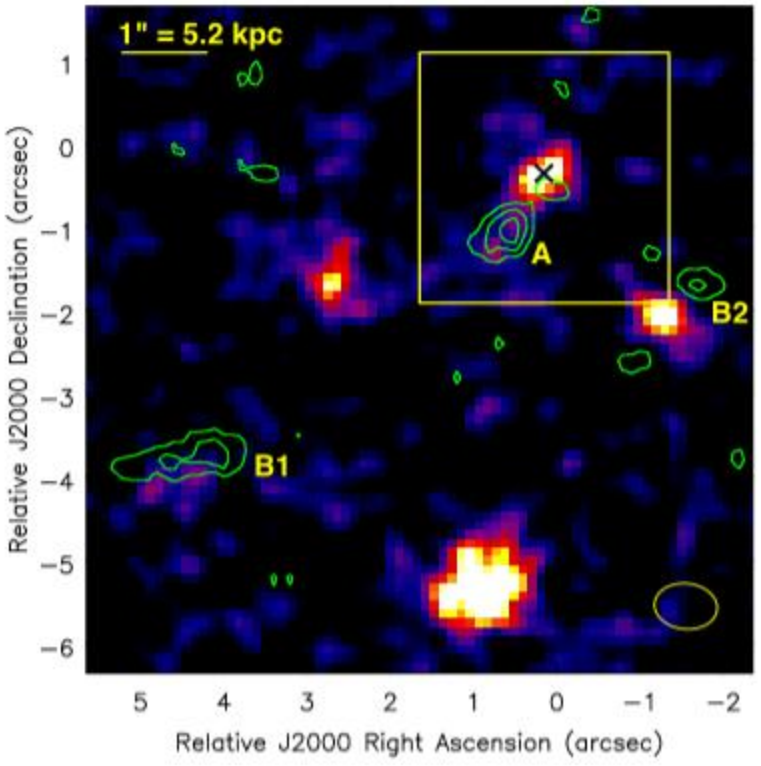
+ Multiplicity (interactions)

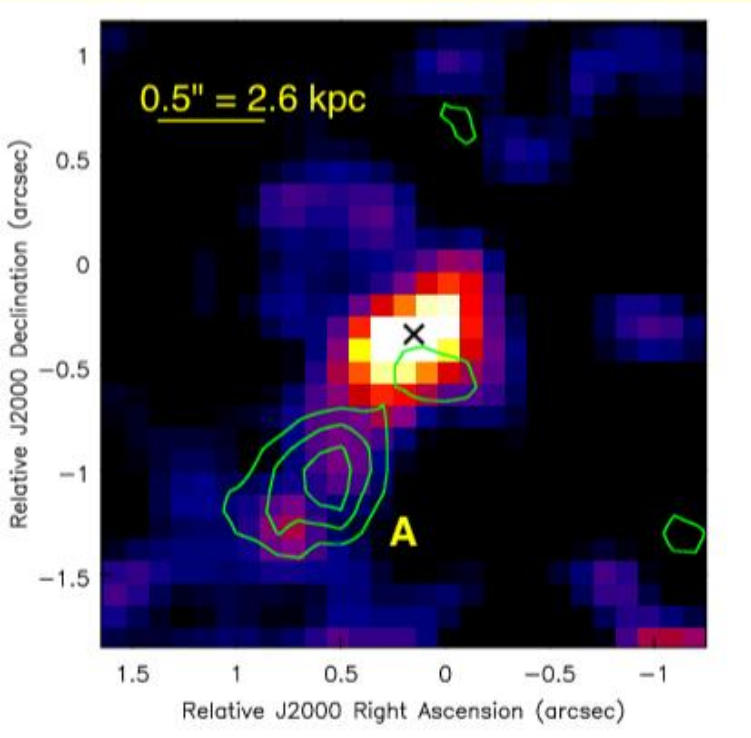




Galaxies during the EoR

CII line in LBG galaxies at z=6.8-7.1, **with ALMA**
SFR = 5-15 Mo/yr





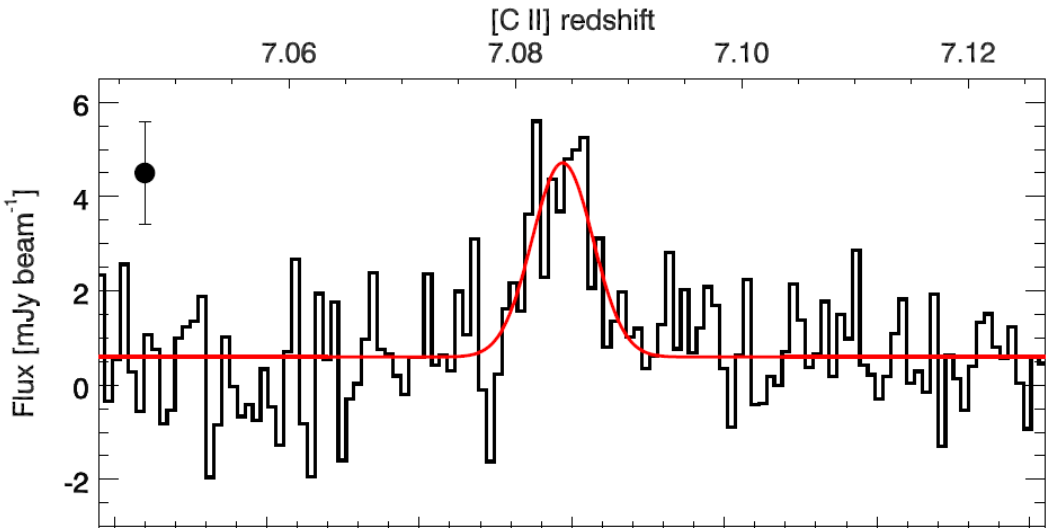
CII Contours Offset from the optical Lyα/UV by 4kpc
Feedback?
No FIR dust
Low Z?

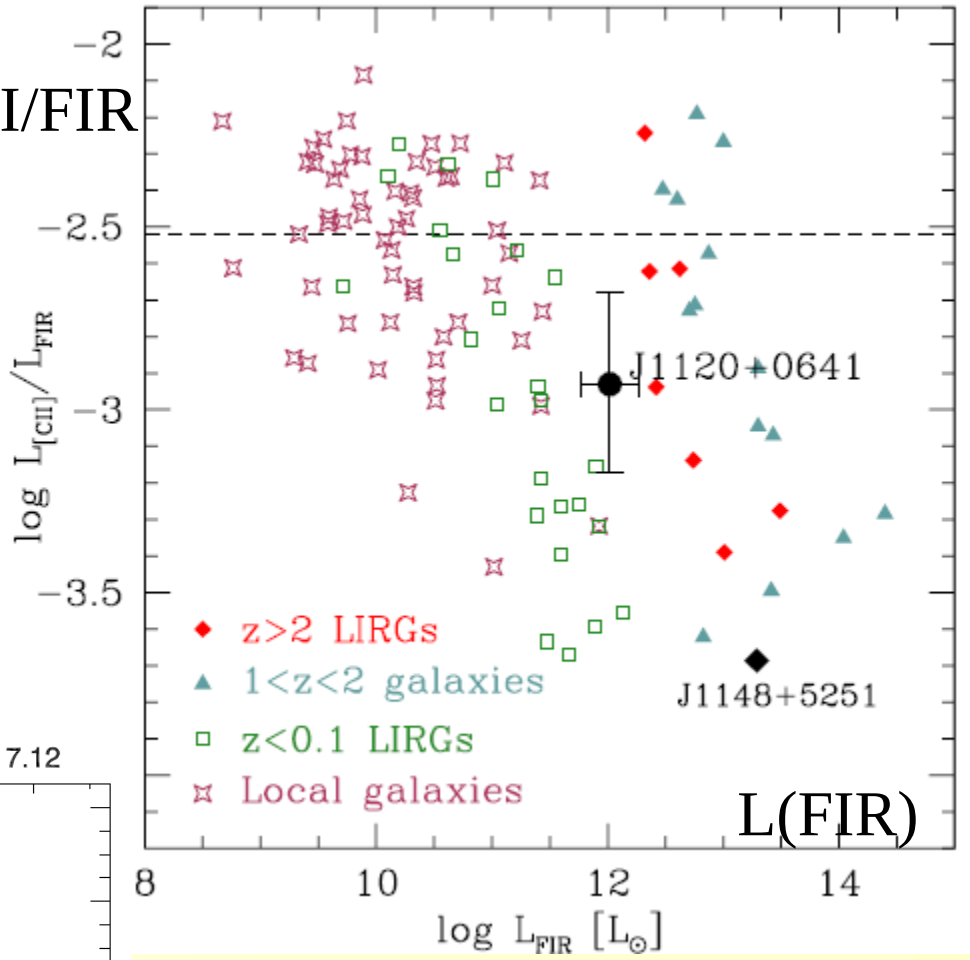
Maiolino et al 2015

QSO at z=7.1: J1120+0641

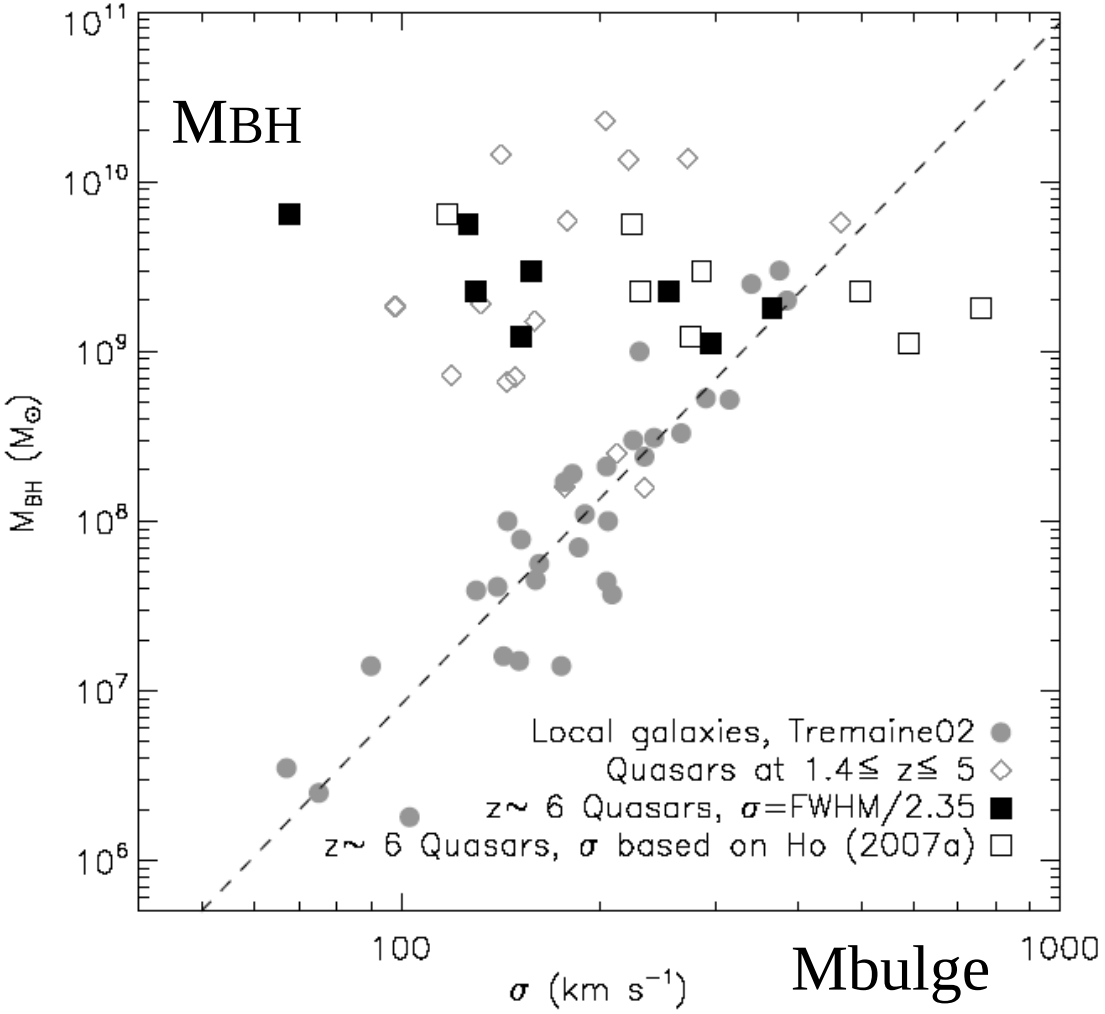
Venemans et al 2012
PdB observations,
Unresolved point source

SFR~160-440 Mo/yr
CII line 4 times lower than in J1148+5251





AGN, SM black holes, MBH/Mbulge



QSO at z=6

➔An order of magnitude higher MBH than expected

Wang et al 2010

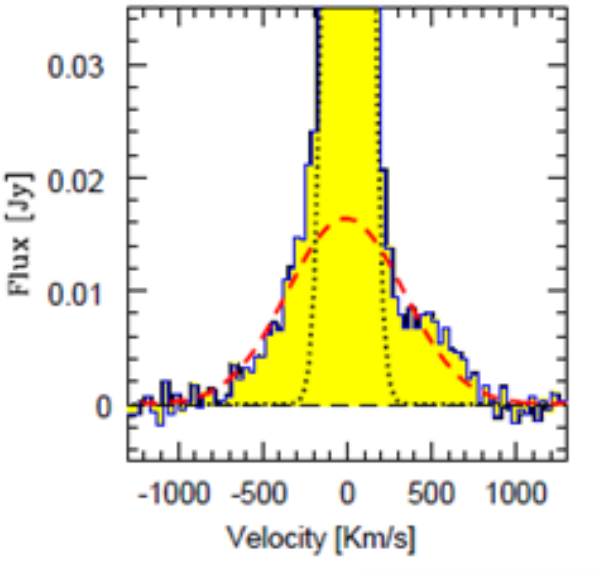
But:
Unknown inclination

Could be a bias in CO width too small due to a detection bias ?

➔ALMA needed to resolve the morphology, and find actual inclinations

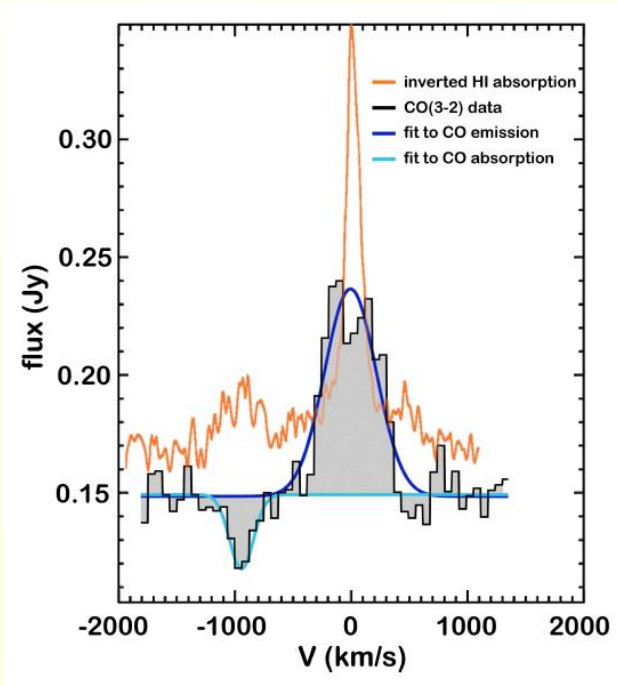
First CII obs with ALMA of 6 QSO-hosts (Wang et al 2013)

AGN feedback



Molecular outflow in Mrk 231

AGN and also nuclear Starburst, 10^7-10^8Mo
Outflow 700Mo/yr

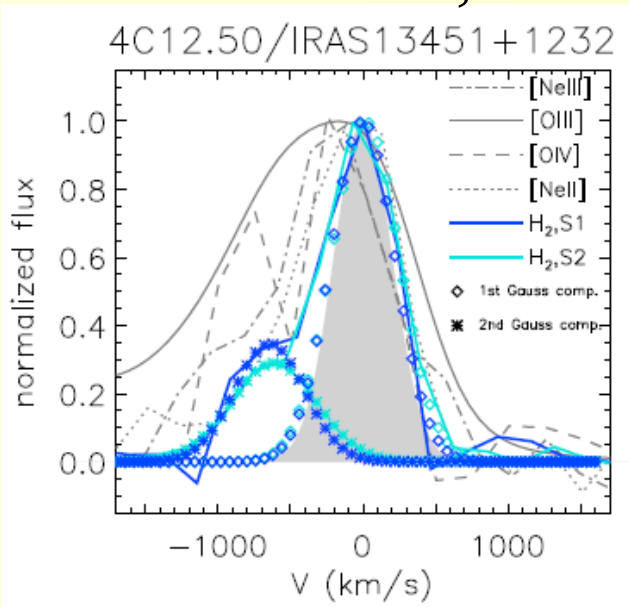


IRAM *Ferruglio et al 2010*

Dasyra & Combes 2011, 2012

4C12.50 Outflow ~130 Mo/yr

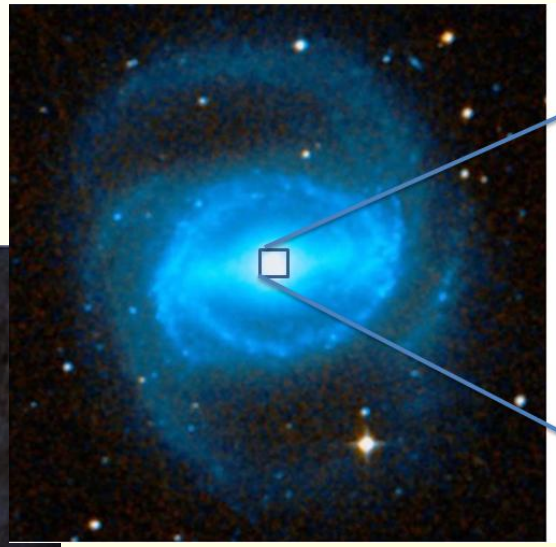
H2 rotational lines
and CO in mm (IRAM-PdB)

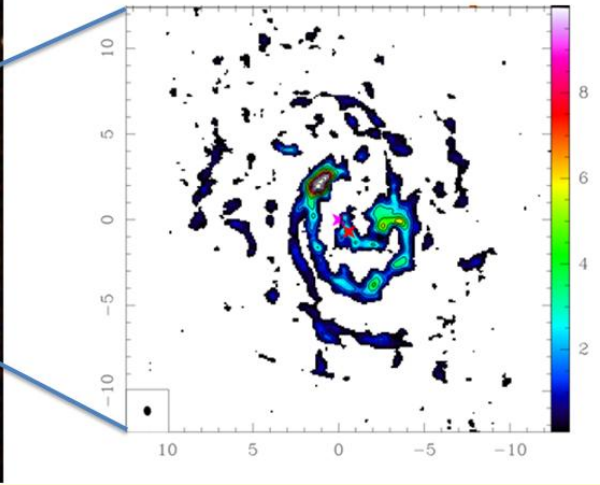


Fueling in low-luminosity AGN

NGC 1433: Sy 2 barred spiral, the « Lord of the Rings »

The smallest molecular AGN-driven outflow



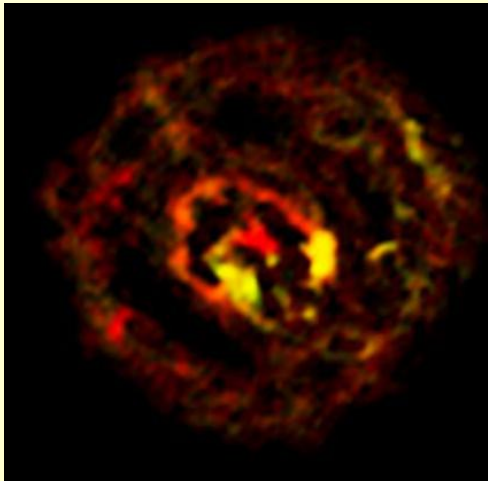


CO(3-2) with ALMA (Cycle 0)

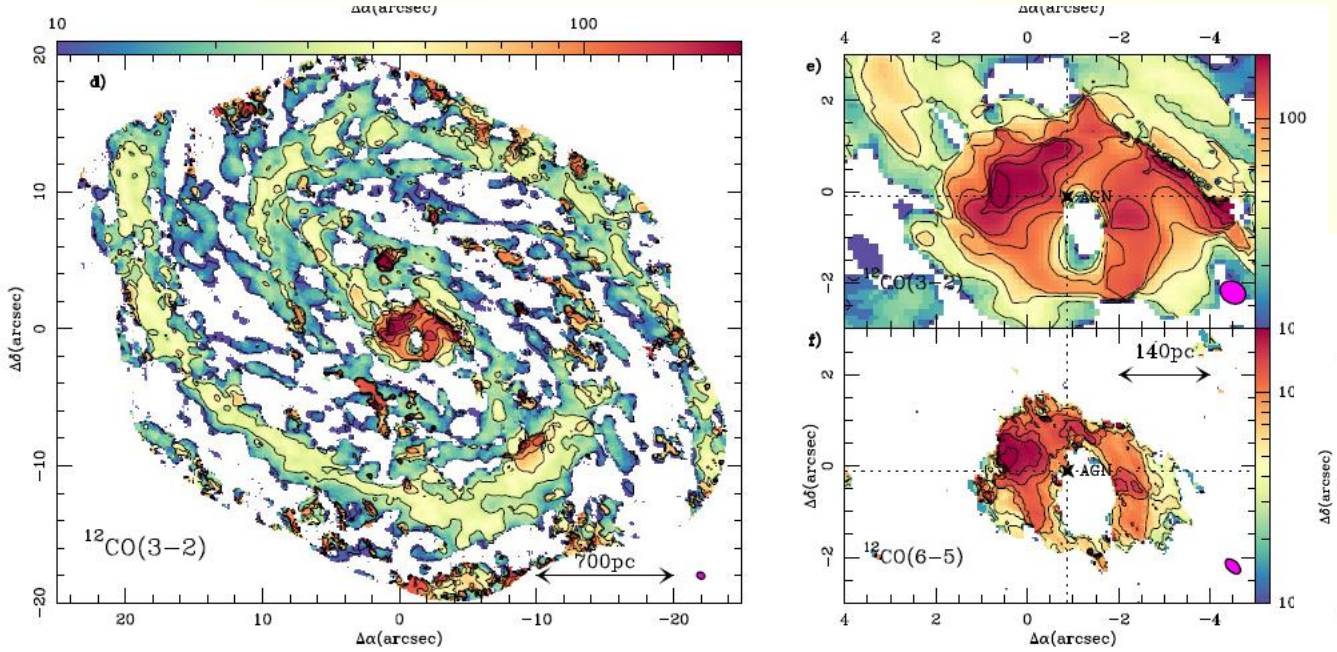
Beam = 0.5” = 24pc

Flow of 60pc size

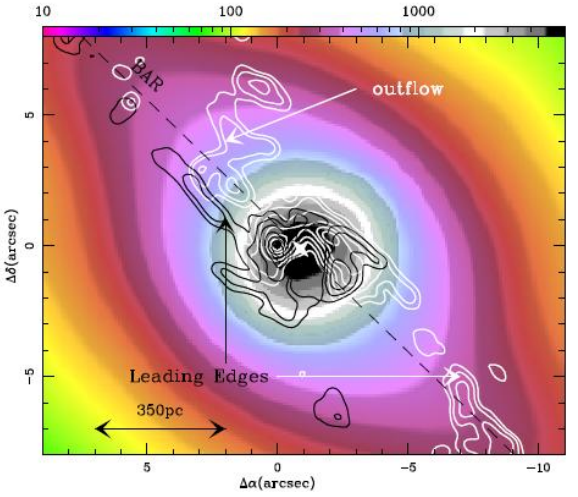
Combes et al 13

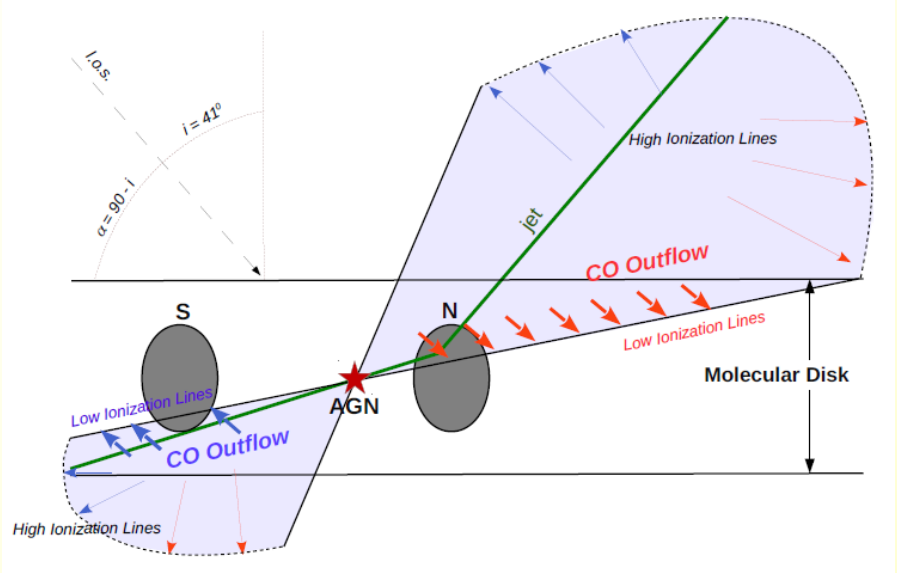


Off-center AGN and outflow in N1068



Black V=-50km/s
White V=50km/s



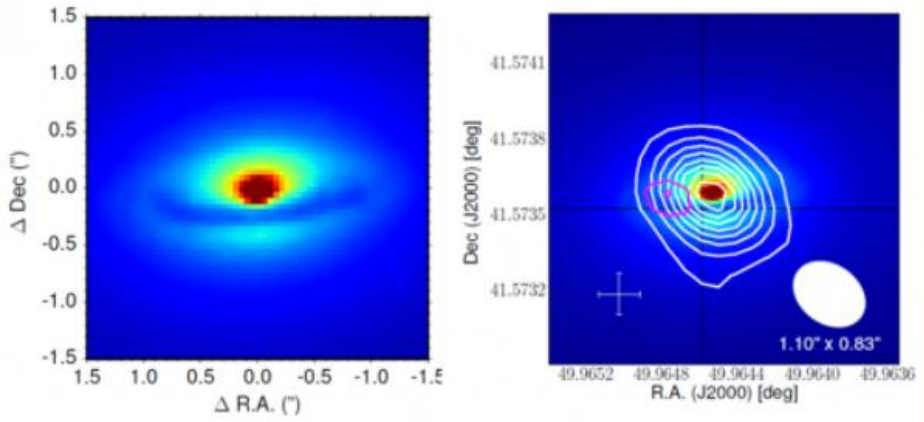


Outflow of 63Mo/yr
About 10 times the SFR in this CMD region

ALMA, *Garcia-Burillo et al 2014*

Are black holes co-evolving with galaxies?

Over massive BH: N1277 (*van den Bosch et al 2012*)

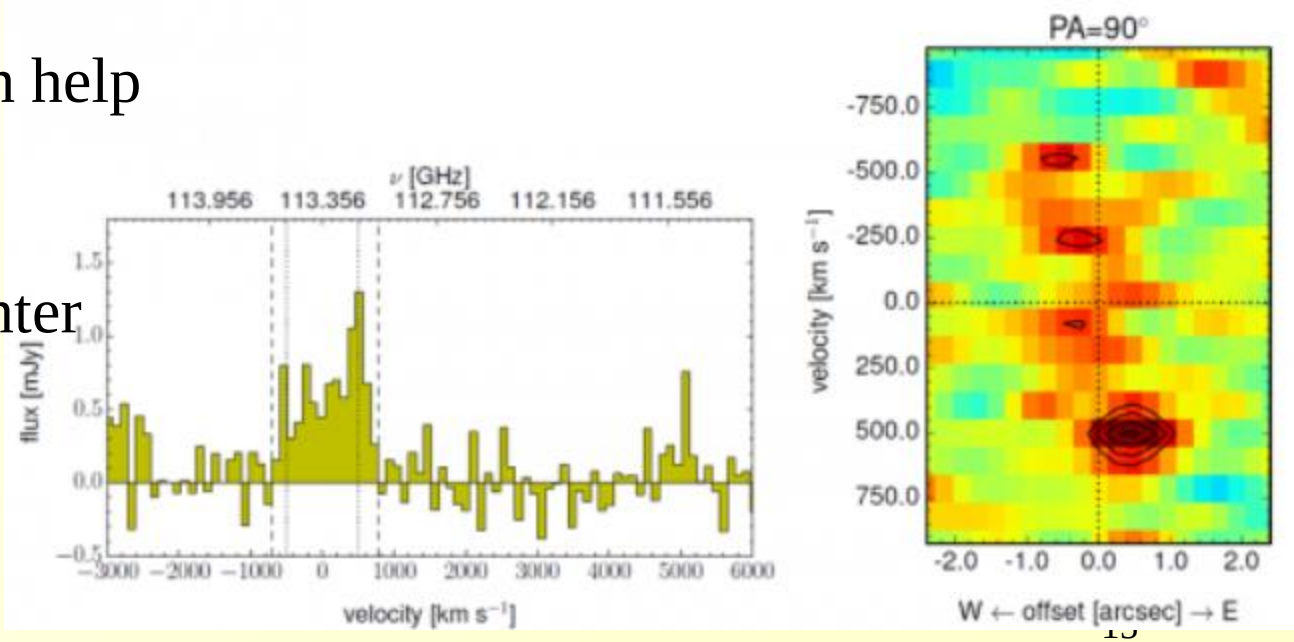


M_{BH}/M_{bulge} ~50%!
M_{BH} = 1.5 10^{10}Mo

Controversial *(Emsellem 2013)*

The molecular gas can help to trace the potential

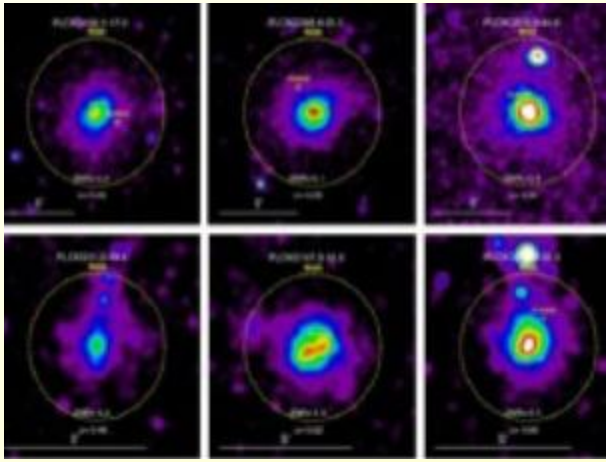
At 320pc from the center Under the sphere of influence of the BH

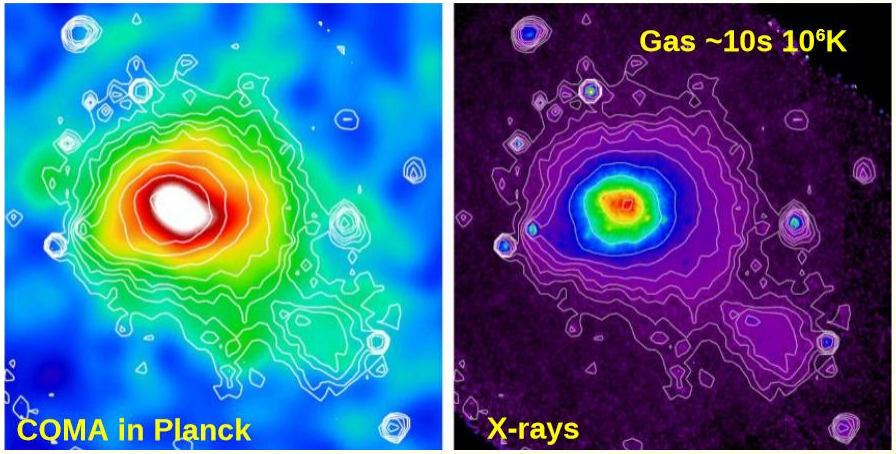


Scharwaechter et al 2015

Clusters in X-rays, Radio

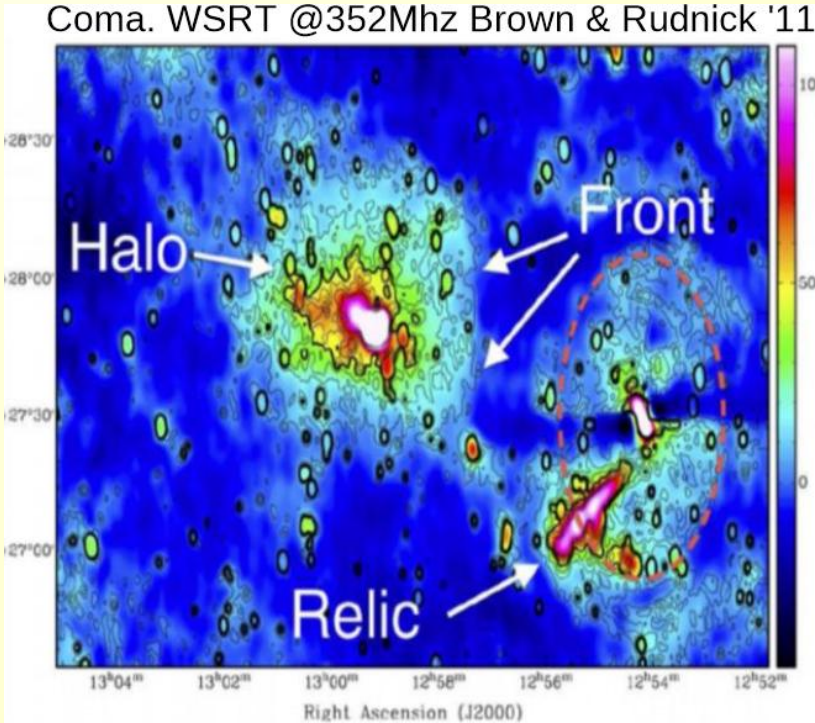
Planck-SZ



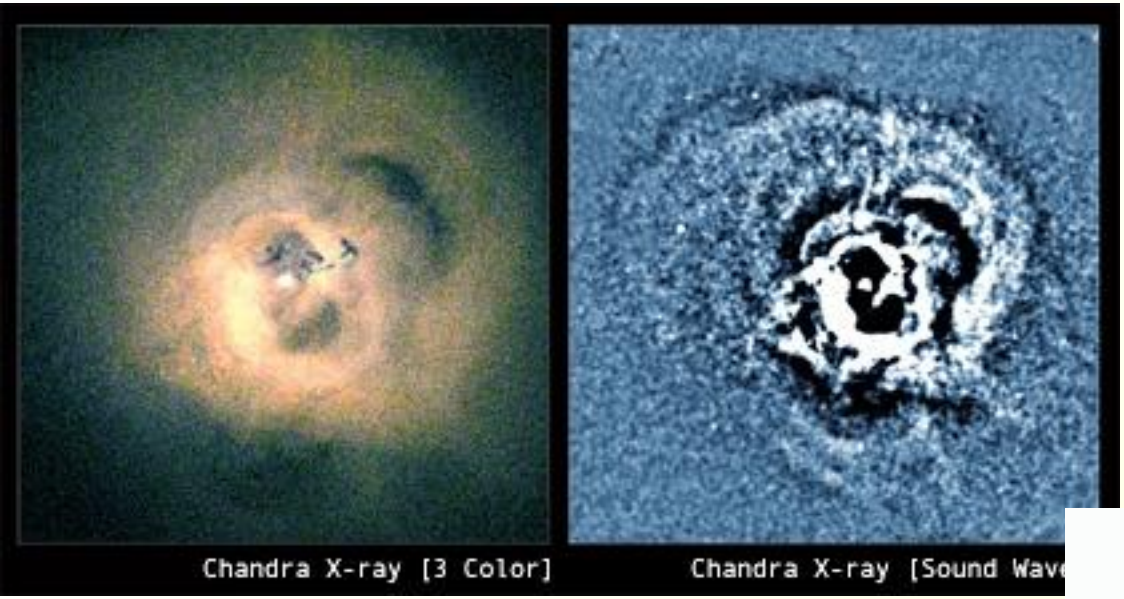


Large number of low-z clusters
Discovered with Planck-SZ

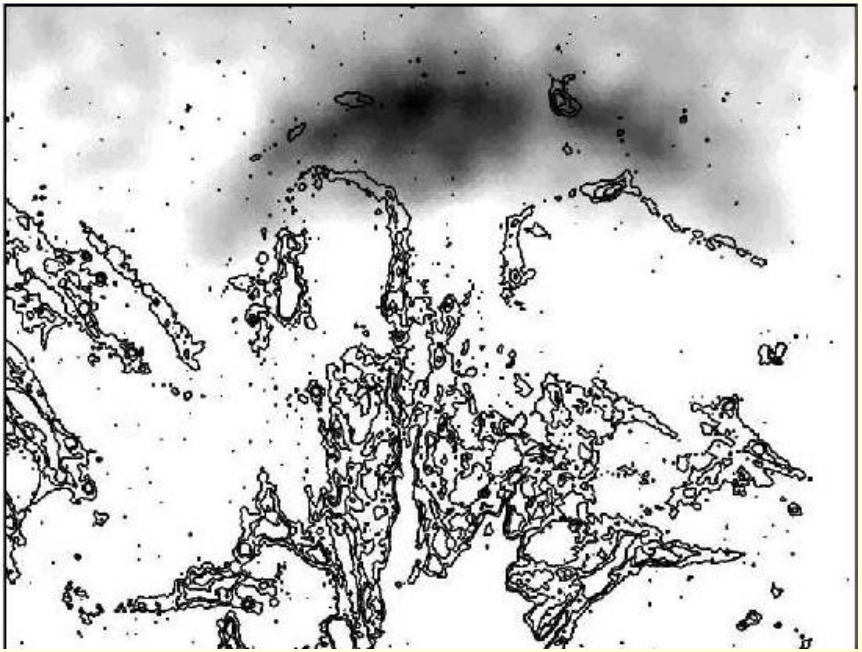
Followed up with XMM
Unrelaxed clusters
With radio halos



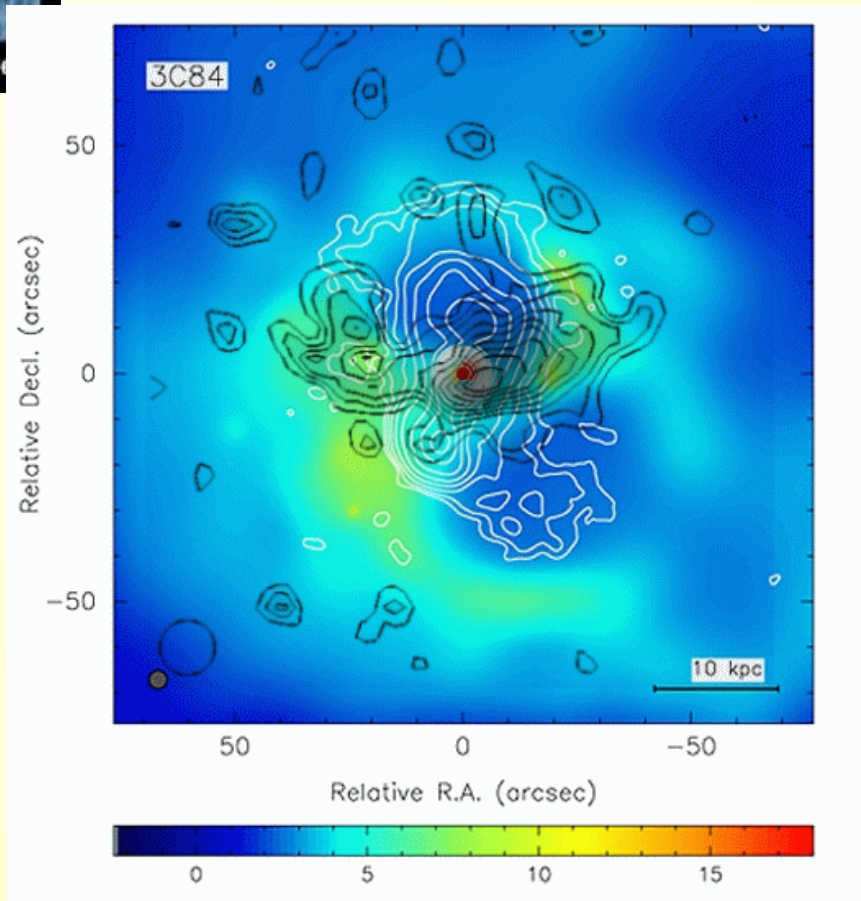
Perseus cool core cluster



Perseus A , *Fabian et al 2003*



Salomé et al 2006



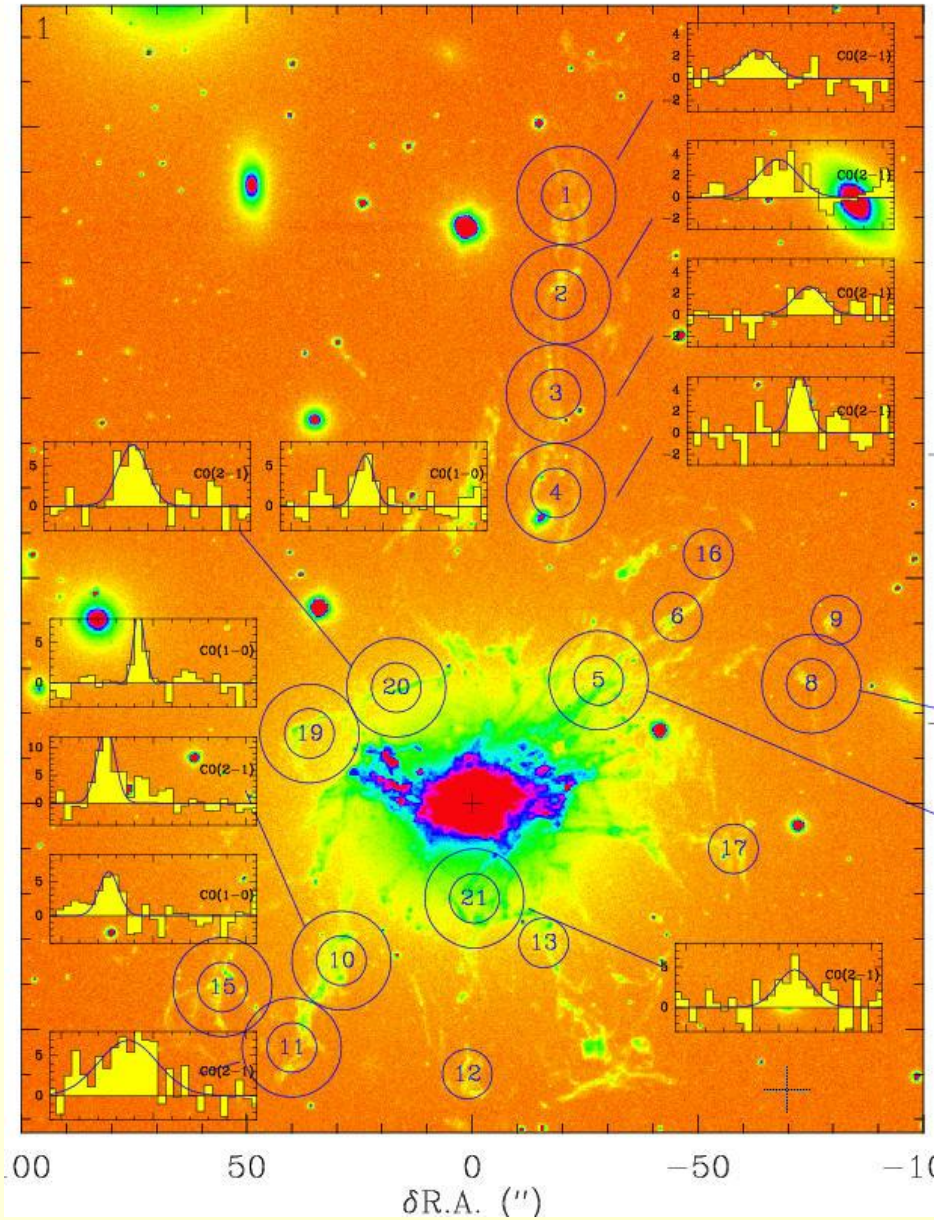
Cold CO in filaments

Inflow and outflow coexist

The molecular gas coming from previous cooling is dragged out by the AGN feedback

The bubbles create inhomogeneities and further cooling

The cooled gas fuels the AGN

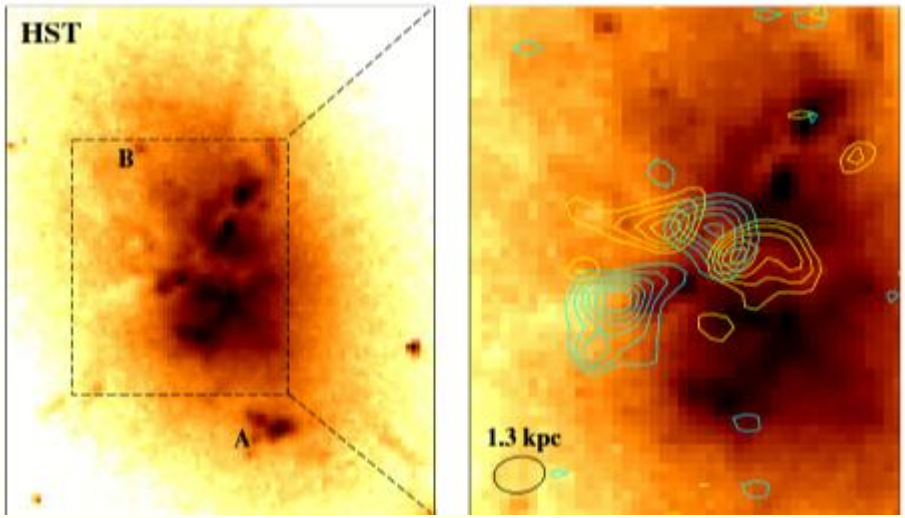


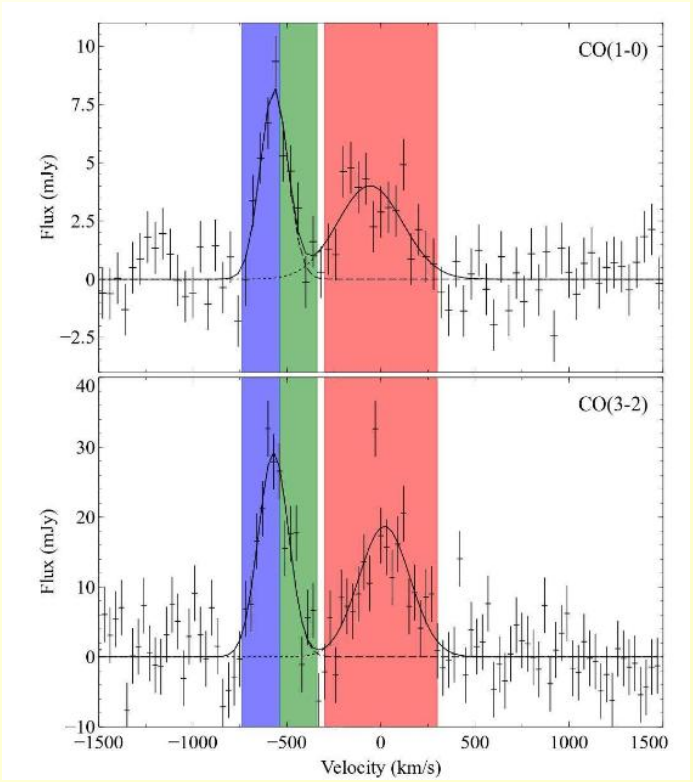
Velocity much lower than free-fall

Salome et al 2008

ALMA: cold gas in cool core clusters

H_2 mass **1.1 10^{10}Mo** in a -250->250km/s component around Vsys and a HVS at -570km/s (an outflow if in front of the BCG?)



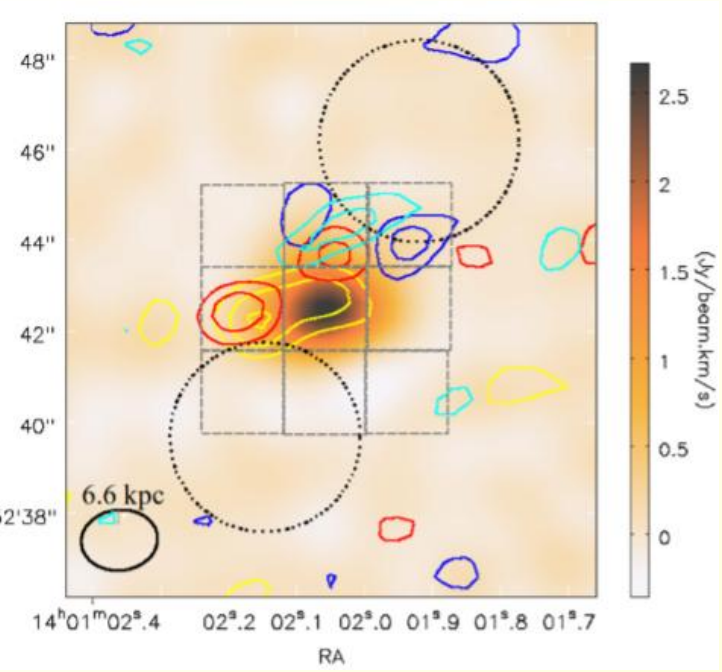


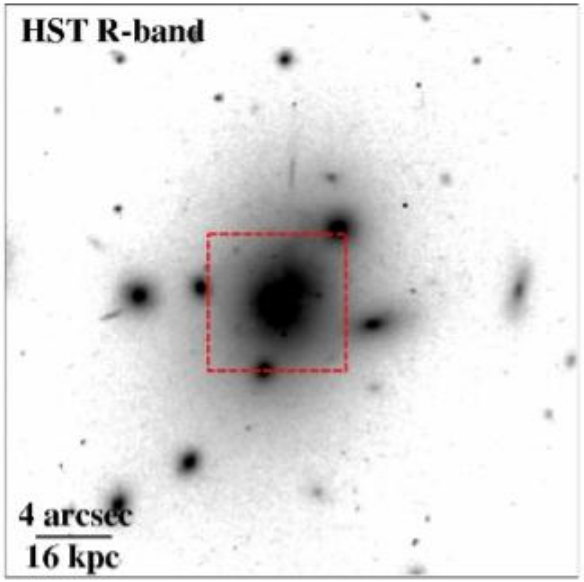
A1664 BCG: CO(3-2) in systemic and HVS

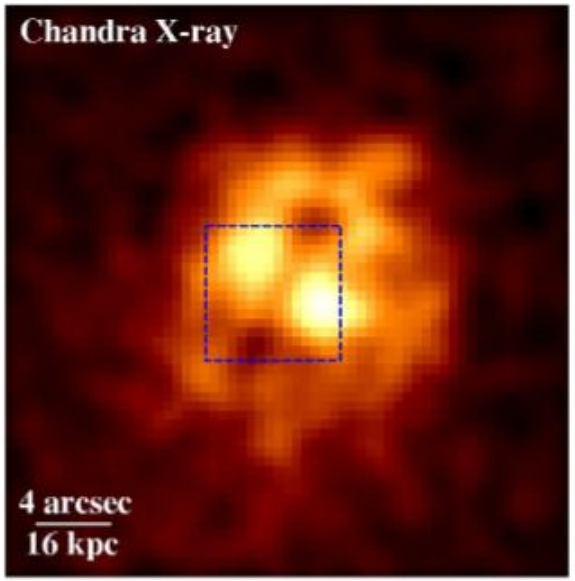
Russell et al 2014

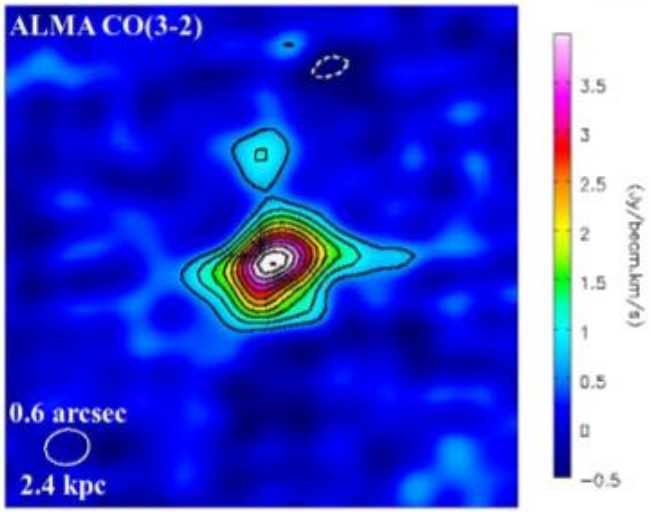
ALMA: molecular gas in A1835

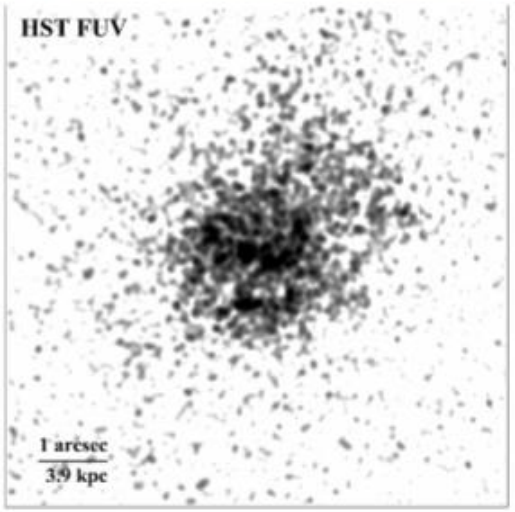
MH_2 = 5 10^{10} Mo within 10kpc of the BCG Abell 1835
Narrow (130km/s) profile: face-on disk?





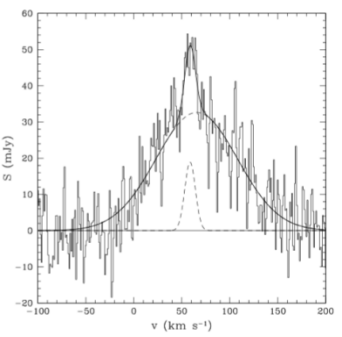






+ High-V components
Outflows?

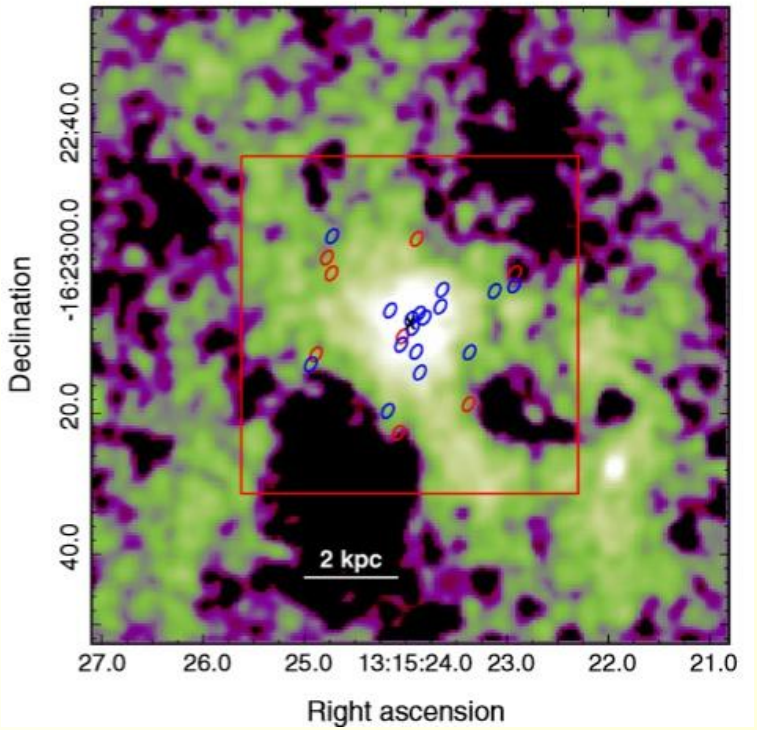
McNamara et al 2014

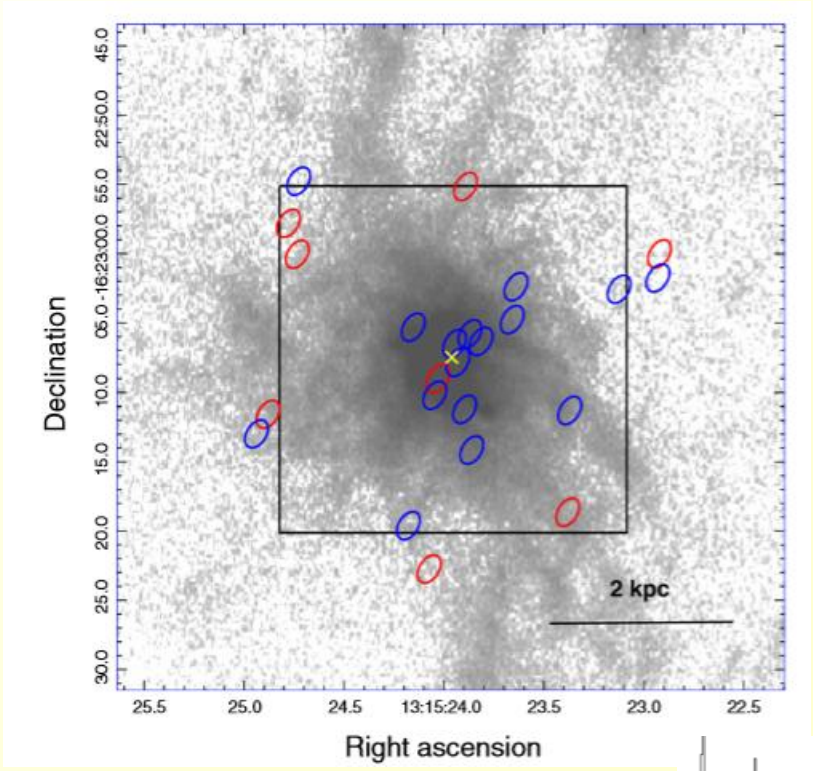


ALMA, cold gas in X-ray groups

CO molecular clouds (blue & red-shifted), on the Chandra image

HST image

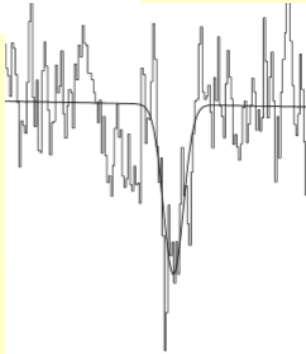




Masses of the clumps, or GMA, 3 10^5 to 10^7 Mo, 10-50km/s

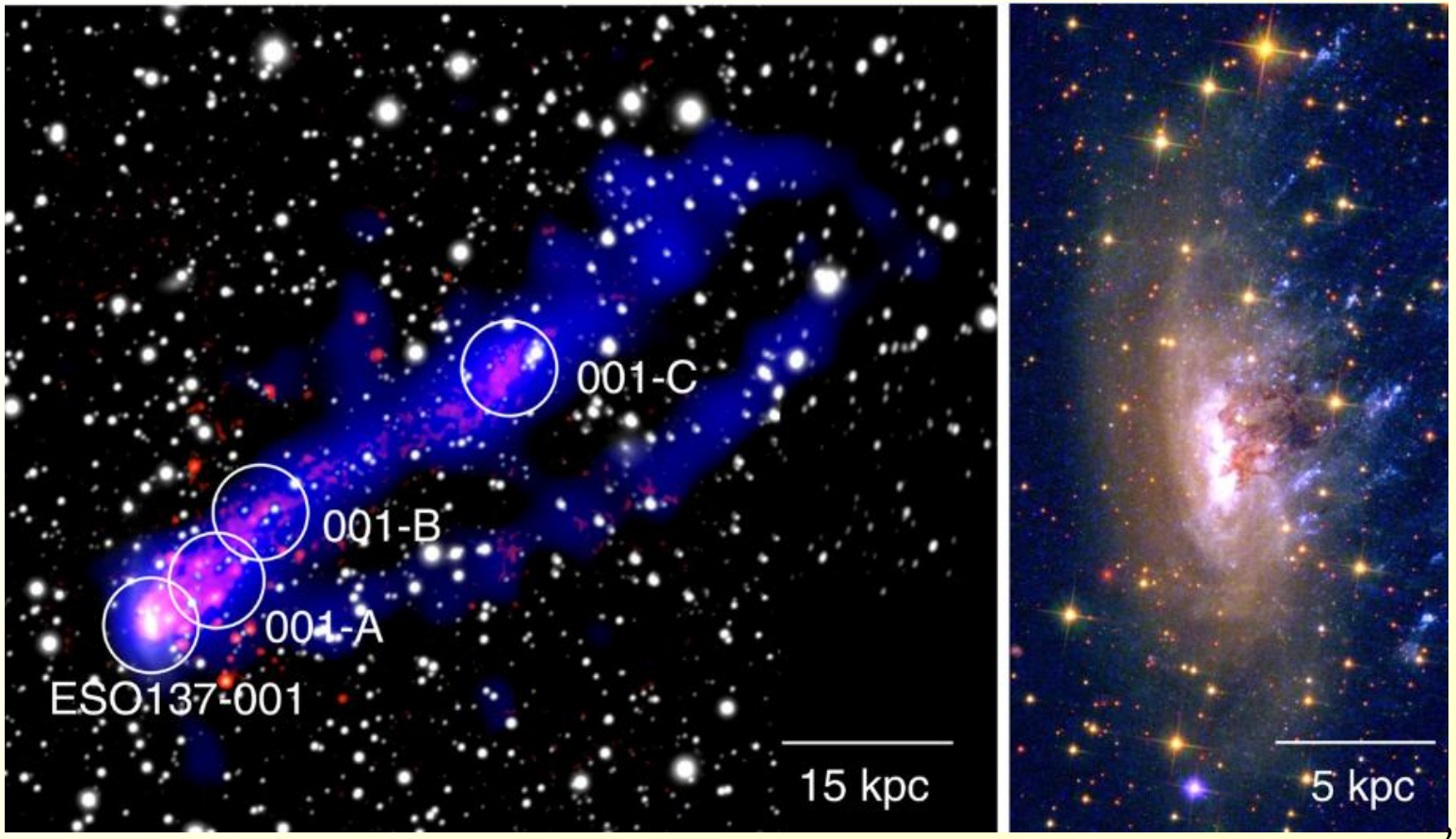
No rotating disk, but clumps also in absorption

David et al 2014



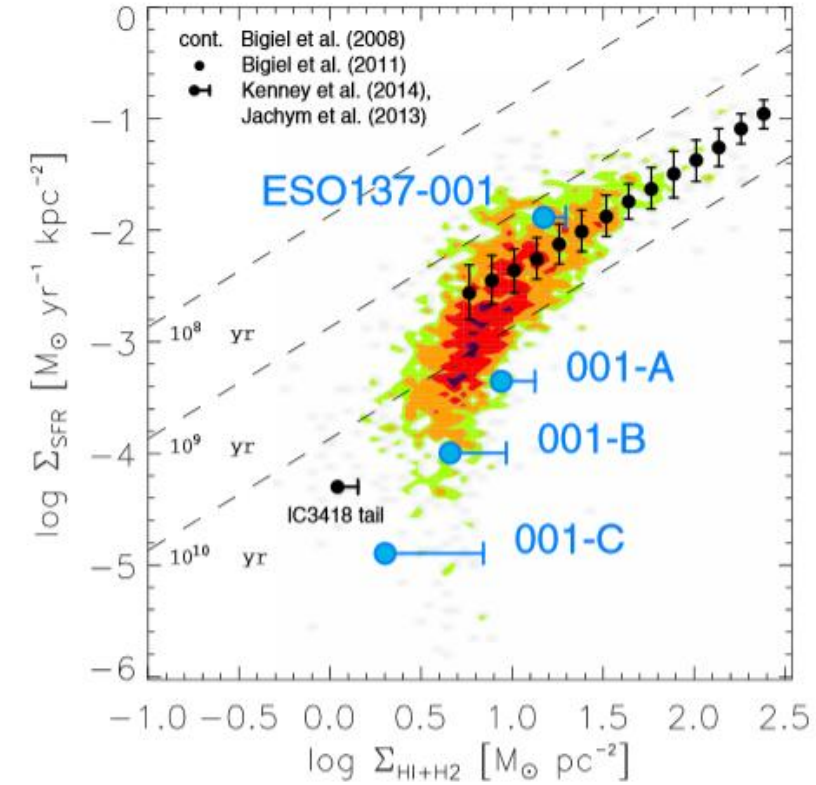
X-ray and molecular tails

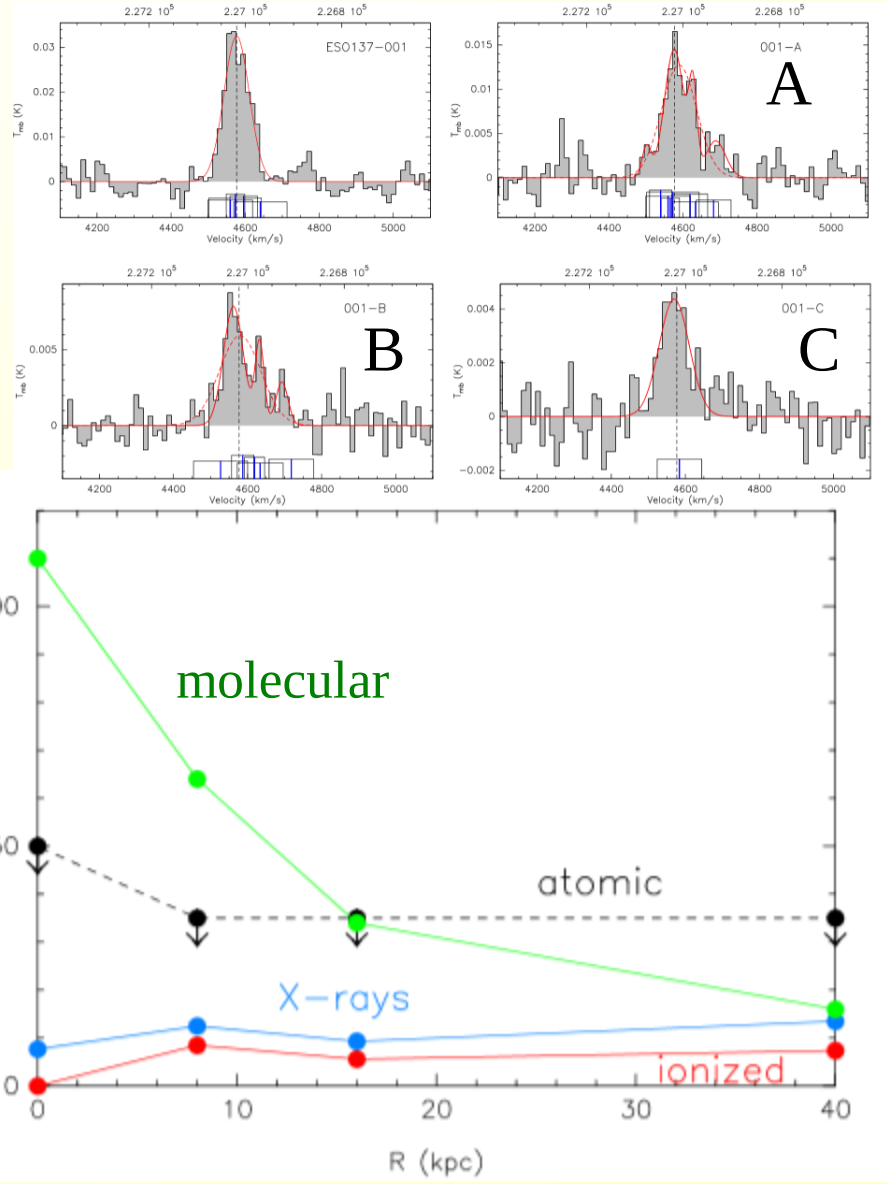
Ram pressure in clusters: **in general slow gas stripping**
but **can be fast** in exceptional cases: ESO137-001



Jachym et al 2014

Ram-pressure quenching SF





Tail of 80kpc in X-ray gas,
40kpc in CO
M(H_2) in C =1.5 10^8Mo

Jachym et al 2014

Synergies Athena and ALMA for galaxies

Galaxy formation, mass assembly
Physics of high redshift galaxies, BH

Co-evolution of SMBH and galaxies
AGN feedback and fueling

Galaxy clusters, Cooling flows
Ram-pressure gas stripping (X-ray and molecular tails)

➔Both will observe AGN and galaxy clusters