Molecular gas in Low Luminosity Radio Galaxies in (proto-)clusters at z~0.4-2.6

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Abstract: We investigate the role of the environment in processing molecular gas in radio galaxies (RGs). We observed five RGs at z=0.4-2.6 in dense Mpc-scale environment with the IRAM-30m telescope. We set four upper-limits and report a CO(7-6) detection for COSMOS-FRI~70 at z=2.63, which is the most distant brightest cluster galaxy (BCG) candidate detected in CO. *We speculate that the cluster environment might have played a role in preventing the refueling via environmental mechanisms* such as galaxy harassment, strangulation, ram-pressure, or tidal stripping. The RGs of this work are excellent targets for ALMA as well as next generation telescopes such as the *James Webb Space Telescope*.

Work based on observations carried out under project s 073-16 and 074-17 with the IRAM 30m telescope (PI: Castignani).

Distant Low Luminosity Radio Galaxies (LLRGs)

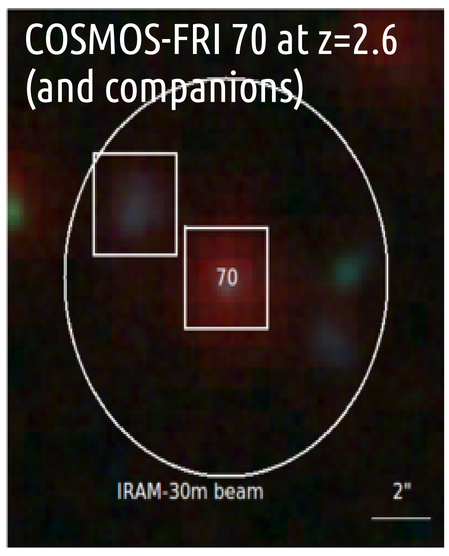
LLRGs are the bulk of the radio galaxy population

- Most massive black holes and host galaxies (cD, Zirbel 1996)
- Radio-mode AGN feedback (SMBH / host galaxy / Mpc scale environment / cooling flows)
- Cosmological evolution (Sadler+07, Smolcic+09, McAlpine+13, Castignani+14a)
- Brightest Cluster Galaxies (BCGs, von Der Linden+07, Yu+18
- What's the fate of molecular gas reservoirs observed in distant proto-clusters ? (Papadopoulos+00, De Breuck+05, Emonts+13)

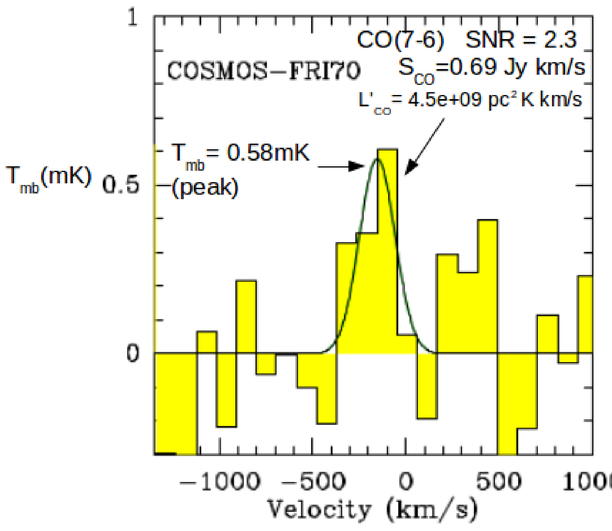
The sample: five star forming LLRGs at z~0.4-2.6

- Two LLRGs at z_{spec} =0.4, 0.6 selected within the DES SN deep fields and with WISE 22μm flux
- Three COSMOS-FRI sources (Chiaberge+09) at z_{spec} = 0.9, 1.0, 2.6 with FIR WISE/Spitzer fluxes
- All found in overdensities using redshifts of galaxies (Knobel+09,12, Castignani+14ab,18)
- $L_{1.4GHz, NVSS}$ ~(1-20)10^{32} erg s^{-1} Hz^{-1} : >~10 times less bright than powerful high-z RGs (Miley & De Breuck 2008)
- $SFR_{24μm}$ ~(20-200) $M_{\odot}$/yr : progenitors of local star forming BCGs (Perseus A, Cygnus A, Fraser-McKelvie+14).

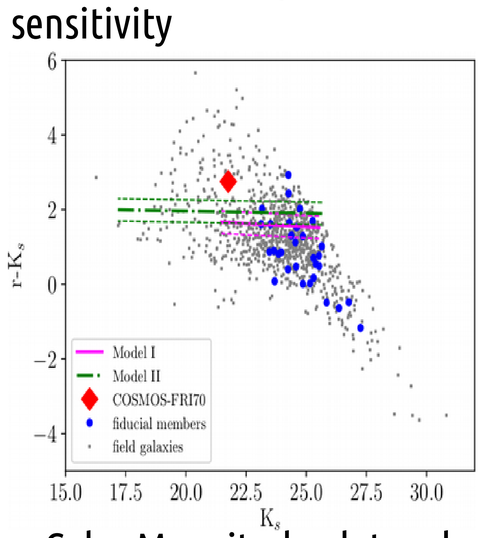
The most distant proto-BCG detected in CO? (Castignani, Combes+18)



RGB image - CO(7-6) induced by stripping, merging, or cooling flow? Need of higher-res. and sensitivity

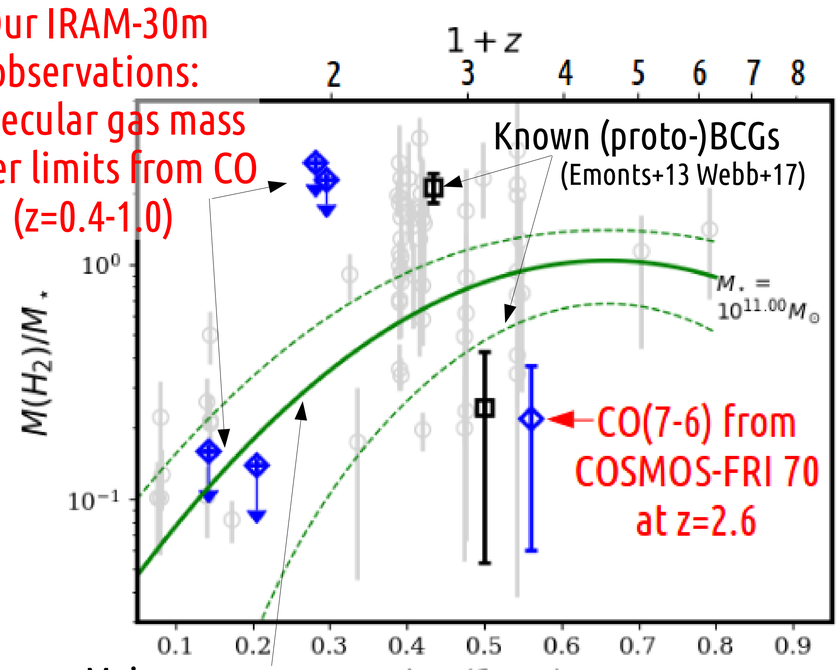


CO(7-6) spectrum (IRAM-30m)



Color Magnitude plot and red sequence model

Our IRAM-30m observations: molecular gas mass upper limits from CO (z=0.4-1.0)



Main sequence predictions (Tacconi+18)

Future Perspectives

- The LLRGs are optimal targets for ALMA/JWST
- With more statistics, we will contribute to probe the cosmic history of molecular gas reservoirs in early-type (proto-)cluster core galaxies.

References: Castignani et al. 2014a, ApJ, 792, 114• Castignani et al. 2014b, ApJ, 792, 113 •Castignani, Combes et al. 2018, submitted to A&A • Chiaberge et al. 2009, ApJ, 696, 1103 • De Breuck et al. 2005, A&A, 430, 1 • Emonts et al. 2013, MNRAS, 430, 3465 • Fraser-McKelvie et al. 2014, MNRAS, 444, 63 • Knobel et al. 2009, ApJ, 697, 1842 • Knobel et al. 2012, ApJ, 753, 121 • McAlpine et al. 2013, MNRAS, 436, 1084 • Miley & De Breuck 2008, AARv, 15, 67 • Papadopoulos et al. 2000, ApJ, 528, 626 • Sadler et al. 2007, MNRAS, 381, 211 • Smolcic et al. 2009, ApJ, 696, 24 • Tacconi et al. 2018,, ApJ, 853, 179 • von der Linden et al. 2007, MNRAS, 379, 867 • Webb et al. 2017, ApJ, 844, 17 • Yu et al. 2018, ApJ, 853, 100 • Zirbel 1996, ApJ, 473, 713