Molecular gas in star-forming galaxies of the intermediate redshift cluster Zw Cl0024+1652

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Introduction

- It is know that the fraction of star-forming (SF) cluster galaxies increases with lower local densities, that generally means larger cluster-centric distances. This relation can provide clues on the stage of infall at which galaxies experience the bulk of their transformations.
- Moreover, these relations evolve with cosmic time (e.g. Webb et al 2013).
- The level of SF activity is primary linked to the amount of cold gas. It is therefore important to determine the relation between the cold gas content (as traced by the CO lines) and the star formation rate (SFR).
- At intermediate redshift, previous works (see Jablonka et al 2013 and references therein) suggest an environmental depletion of the reservoirs of cold gas.
- However, the results are based on a very small number of observations. Therefore, adding data (sampling different environments and cosmic times) is crucial to complete the picture. This work is aimed at providing additional data to tests the current hypotheses.

Results

- The table below summarizes the outcome of our data processing and analysis:

Galaxy	CO(1-0) detection	Line SNR	RMS (mJy)	CO(2-1) detection	Line SNR	RMS (mJy)
247B	Y (see Fig. 1)	2.8	0.94	Y	2.1	0.83
255A	Y	4.5	0.98	Y	2.5	0.97
282B	Marginal	2.0	0.92	Y	3.25	0.93
405A	Y	3.2	1.0	Y (see Fig. 2)	4.1	0.86
625A	N	-	1.4	Marginal	2.1	1.2
919B	Y, weak	2.9	1.4	Marginal	2.1	1.2
966A	N	-	2.7	Y, weak	2.3	1.6

- We have eventually decided to include in our analysis only the CO(2-1) clear detections and to derive as $L'_{CO(1\text{-}0)} = L'_{CO(2\text{-}1)}/0.65$ (Leroy et al. 2022), rather than using CO(1-0) fluxes directly, to minimize confusion/blending effects due to the large beam size of the telescope at 82 GHz (30").
- $L'_{CO(1\text{-}0)}$ can be transformed directly into $M(H_2)$ (e.g. $M(H_2)$ [$M_\odot$]= 0.8 x $L'_{CO(1\text{-}0)}$ (K km/s pc^2] for ULIRGs, Geach et al 2009).

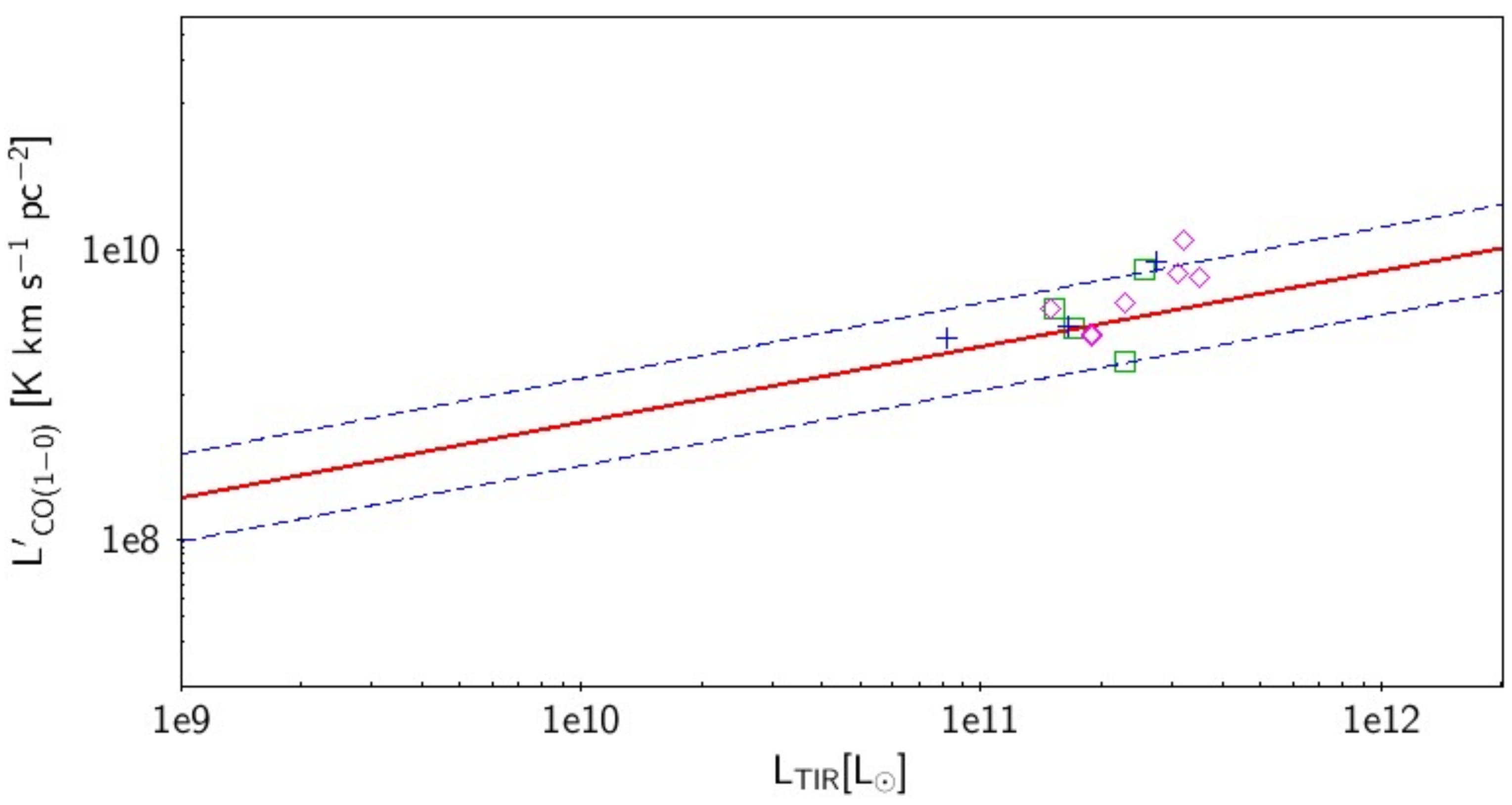


Fig 3: $L'_{CO(1\text{-}0)}$ vs L_{TIR} for our sample (green squares), Jablonka et al. 2013 (blue crosses) and Geach et al, 209, 2011 (magenta diamonds). The red line is the global relation for local field galaxies derived in the full range of L_{TIR} depicted in the plot, from Jablonka et al 2013.

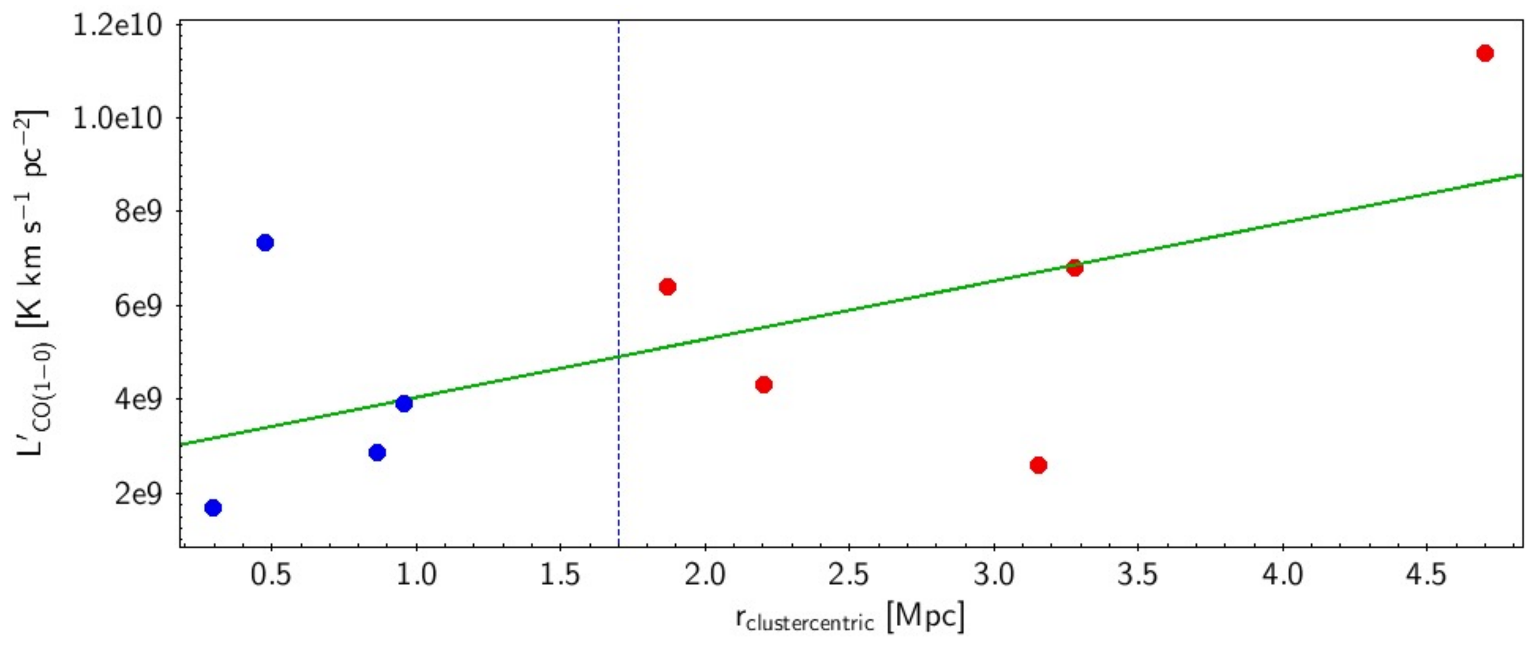
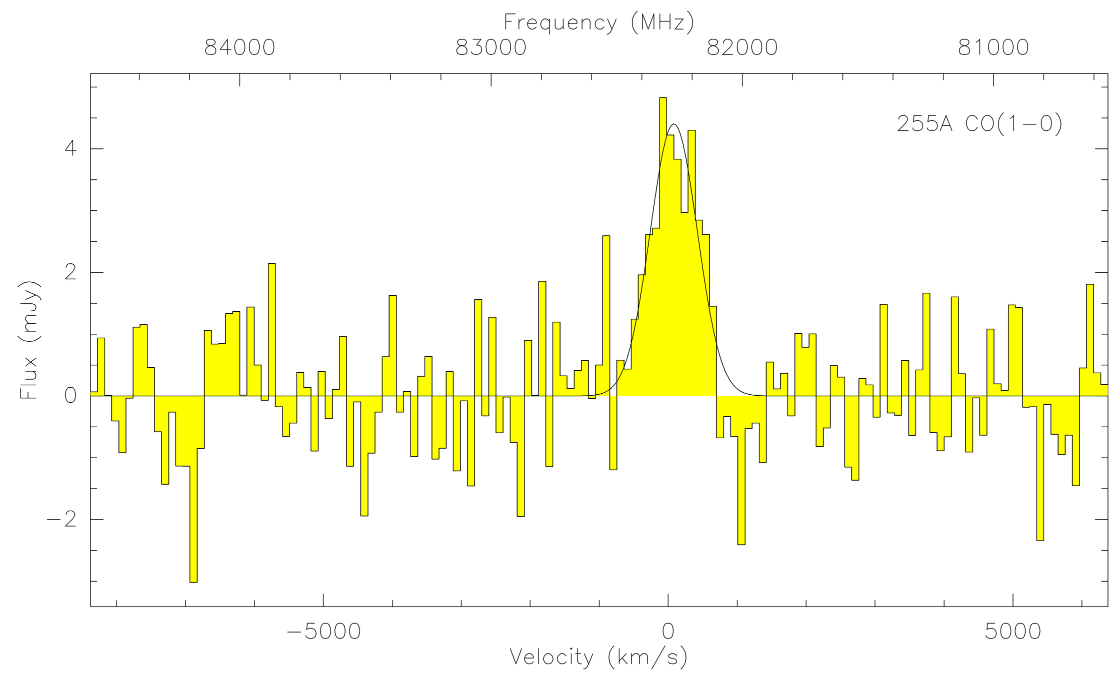


Fig 4: $L'_{CO(1\text{-}0)}$ vs $r_{cluster}$ for our sample (blue dots) and Geach et al, 209, 2011 (red dots). The green solid line is the best fit to the complete sample. The blue dashed line marks the virial radius.

Observations and data reduction

- The observations were performed at the IRAM 30-meter telescope (Pico Veleta, Granada, Spain) with the EMIR heterodyne instrument, in several slots along the Summer 2020 Semester (program ID 073-20, PI. Sánchez-Portal)
- Seven galaxies of the ZwCl0024+1652 cluster at z=0.395 with Hα line tuneable filter (TF) detections (GLACE survey, Sánchez-Portal et al. 2015) and conspicuous FIR emission (Pérez-Martínez 2016) were observed simultaneously in CO(1-0) at ~82 GHz (band E0, ~30" beam size) and CO(2-1) at ~165 GHz (band E1, ~15" beam size). All galaxies but one belong to main cluster structure, and all have been classified as star-forming according to the Ho et al. 1997 criterion (Sánchez-Portal et al. 2015) . Redshifts have been derived from our Hα tuneable filter detections (see Fig. 1 & 2)
- Tracked wobbler switching mode (WSW) was used to optimize the sky subtraction.
- The FTS backend in wide mode (200 kHz spectral resolution), complemented with the WILMA autocorrelator (2 MHz resolution) were connected to the front-end.
- The data were reduced using the GILDAS software suite; we have concentrated in the reduction of FTS data that show better quality than those produced by WILMA. The platforming effects were corrected using available scripts. A great effort was invested in identifying and discarding the spectra with higher noise and worse cosmetics (e.g. strong baseline ripples).



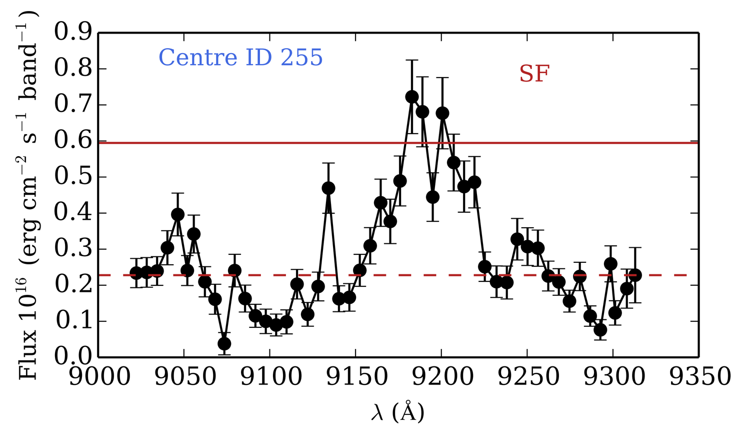
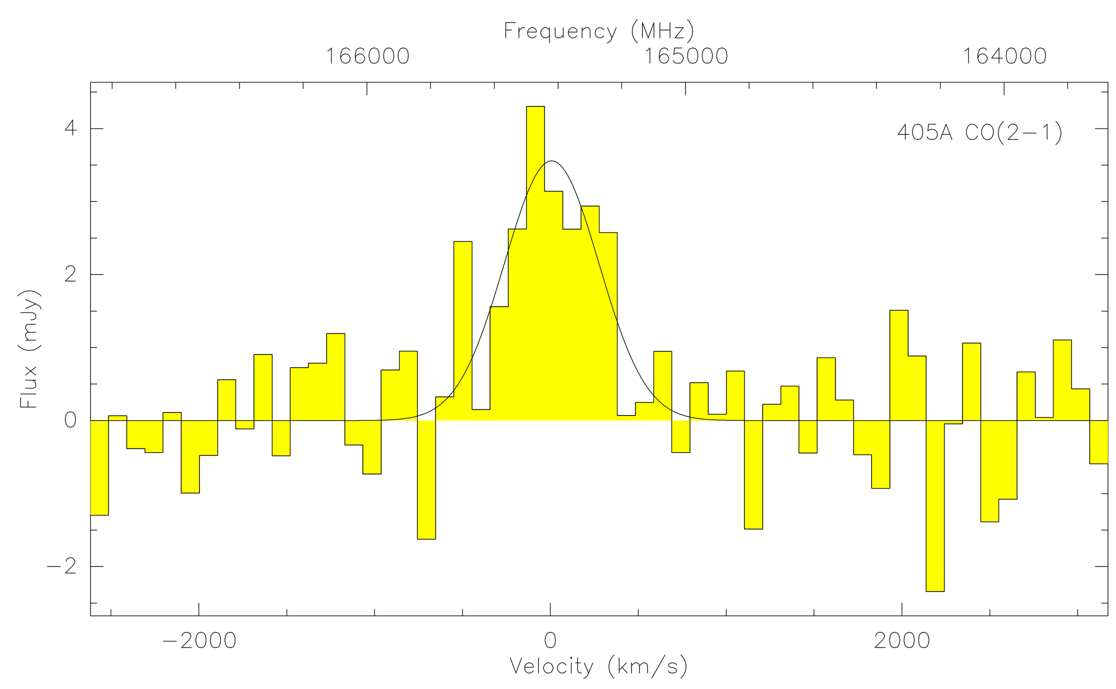


Fig 1. Left: 255A CO(1-0) spectrum. Up: Hα TF spectrum (GLACE).



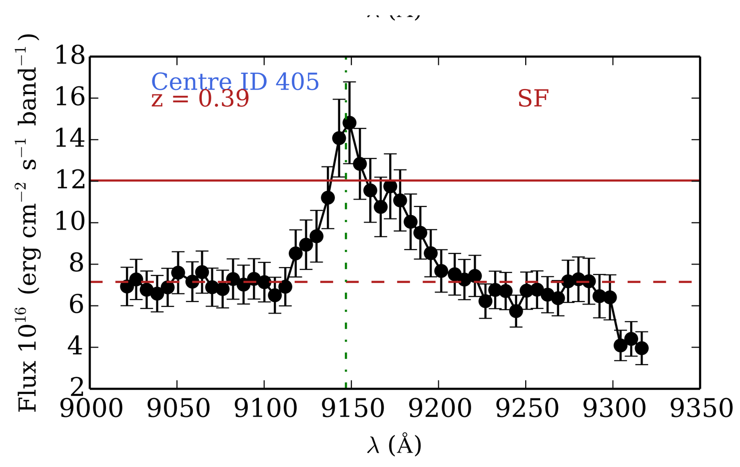


Fig 2 Left: 405A CO(2-1) spectrum. Up: Hα TF spectrum (GLACE).

Discussion and conclusions

- In Fig. 3, we plot $L'_{CO(1\text{-}0)}$ vs L_{TIR} for our sample and intermediate redshift clusters (z = 0.397 and z = 0.489) from Jablonka (2013) and data on Cl0024 galaxies from Geach (2009, 2011). The solid line corresponds to the fit from Jablonka+2013 for local field galaxies in the full L_{TIR} range. Dashed lines correspond to the dispersion of local data. The cluster data are generally encompassed within the dispersion of the local relation. There is a good agreement between our data and the other works, although our points seem to lie in the lower part of the relation.
- The cluster data seem to extend the local relation to higher L_{TIR}. However, when compared with field galaxies with similar L_{TIR}, the cluster galaxies seem to be down-shifted (Jablonka et al. 2013). This is even clearer for our galaxies that are located at smaller cluster-centric distances than the rest of the samples. **This might suggest that, at a given L_{TIR} (or equivalently SFR), the $L'_{CO(1\text{-}0)}$ (or equivalently the reservoir of molecular gas) is smaller, and that this effect is more pronounced at smaller cluster-centric radii.**
- In Fig. 4, we depict $L'_{CO(1\text{-}0)}$ vs r_{clus} for Cl0024, expanding our sample with the galaxies from Geach et al (2009, 2011). As shown in the plot, our galaxies are placed within the virial radius, while those from Geach are located in the outskirts of the cluster. Even though there is a substantial dispersion, **the result of the fit suggest that the amount of available cold gas increases with the cluster-centric distance, hence pointing to an environmental dependency.**

References: Webb,, T.M.A., et al 2013, AJ 146, 84; Sanchez-Portal, M. et al 2015, A&A 578, A30; Pérez-Martínez, R. 2016, PhD Thesis, UCM; Leroy, A.K. et al 2022, ApJ 927, 149; Jablonka, P. et al 2013, A&A 557, A103; Geach, J. et al 2009, MNRAS 395, L62; Geach, J. et al, 2011 ApJ 730, L19