Evidence of clumpy ISM in high redshift, star-forming galaxies

PROBING MORPHOLOGY WITH UNRESOLVED LOW-FREQUENCY RADIO OBSERVATIONS

University of Hertfordshire UH

J. Ramasawmy, J. E. Geach, M. Hardcastle

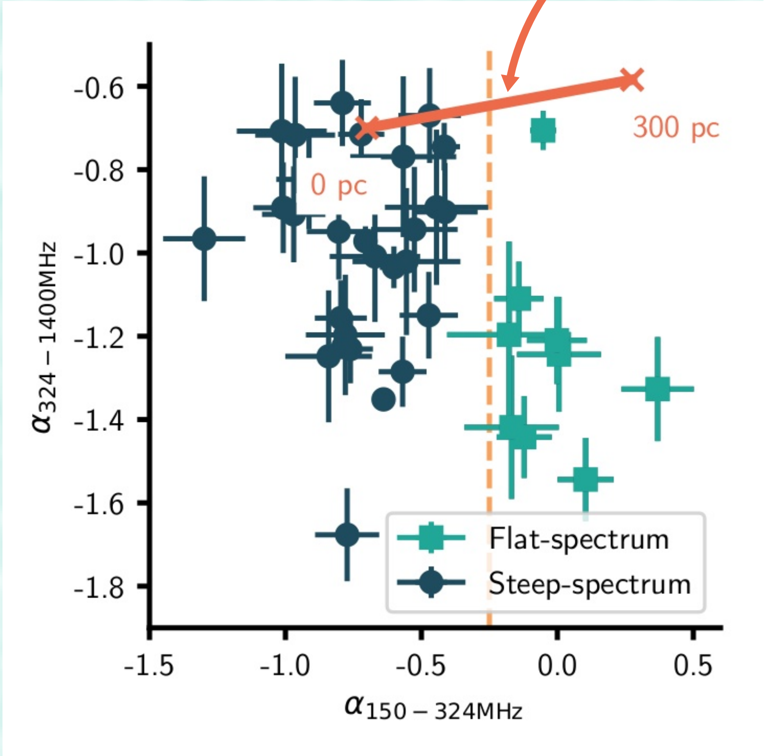
Project Overview

Taking advantage of the overlapping coverage of the Lockman Hole in both the Low Frequency Array (LOFAR) deep fields and the SCUBA-2 Cosmology Legacy survey (S2CLS) – both the deepest surveys in their respective wavelength regimes – we investigate the low-frequency radio properties of bright submillimetre galaxies (SMGs). These sources are dusty, star-forming galaxies with a median redshift of $z = 2.61$. Combining these data with additional observations at 324, 610 and 1400 MHz, we find surprising diversity in the shapes of the radio spectra of this remarkably submillimetre-homogeneous sample.

Method

To quantify the shape of the radio spectrum, we define two “colours” or spectral slopes α: a low-frequency slope between 150 and 324 MHz, and a high-frequency slope between 324 and 1400 MHz. Plotting these into a “colour-colour” type figure (see Fig. 1), we find that while the majority of sources lie in the $\alpha_{low} \approx \alpha_{high} \approx -0.7$ locus, the typically assumed power-law index of a star-forming galaxy's radio spectrum, ~20% of our sources have significantly flatter low-frequency spectra. We define a cut-off at $\alpha_{low} = -0.25$, splitting our sources into two populations. Investigating characteristics of these two populations, such as distribution in luminosity and redshift, and mid-IR colour properties, we find no statistically significant differences between any of their observable properties.

We therefore infer that any difference must be on scales smaller than we can resolve. We attribute this spectral flattening to free-free absorption caused by a dense, clumpy ISM, and model the effect this absorption has on the spectrum (Fig. 2).



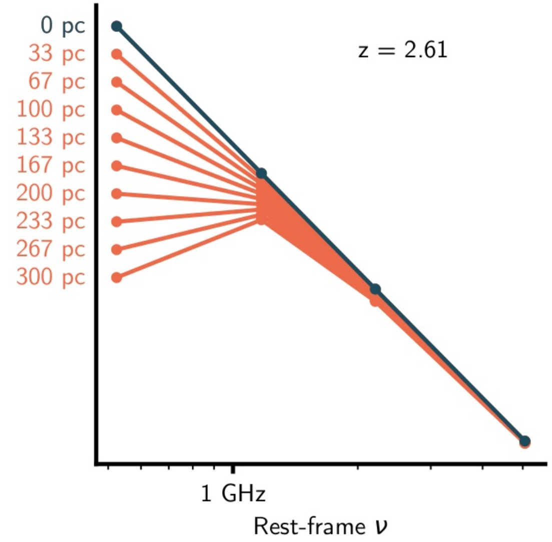


Figure 1 (left): a “colour-colour” plot of the radio spectral indices of our sample. The dashed line marks our cutoff between extremely flat and normal spectral index sources, with the majority of sources located around the expected $\alpha_{low} \approx \alpha_{high} \approx -0.7$ locus but a non-neglible fraction (~20%) with significantly flatter low-frequency spectral indices.

Figure 2 (above): a simple model of the effects of free-free absorption on a typical star-forming galaxy's radio spectrum, taking typical values of electron density and temperature for increasing column densities of gas. The result of this in colour-colour space is shown on Figure 1 with the orange line.

Conclusions

Assuming that the spectral flattening observed is due to free-free absorption and that our sample is representative of the larger poulation of sources, our results are in agreement with a scenario in which ~20% of SMGs have dense due to dense, clumpy gas distributions, with column densities of several hundred parsecs. Very high resolution interferometric studies of large numbers of SMGs would be required to investigate this further. Our results present resolution-independent evidence from radio observations in support of this scenario of some fraction of SMGs having clumpy gas morphologies.

Read more details here -
J. Ramasawmy et al, 2021,
arXiv:2103.09677

Contact me during the coffee sessions, or email joanna.ramasawmy@stfc.ac.uk