Searching for Obscured AGN in $z \sim 2$ SMGs

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Submillimetre-selected galaxies (SMGs) at high redshift ($z \sim 2$) are potential host galaxies of active galactic nuclei (AGN). If the local universe is a good guide, $\sim$ 50% of the dust-obscured AGN amongst the SMG population could be missed even in the deepest X-ray surveys. Radio observations are insensitive to dust so VLBI can be used as a tool to distinguish between AGN activity and star-formation in extragalactic objects. We present 1.6 GHz EVN observations of four SMGs (with measured redshifts) to search for evidence of compact radio components associated with AGN cores. Out of the four SMGs observed, we detect one source, J123555.14+620901.7, with an integrated EVN flux density of 201 $\pm$ 15.2 μJy, we therefore identify the radio emission from J123555.14+620901.7 as associated with an AGN. We do not detect compact radio emission from the other three sources with the VLBI observations, which may suggest that their radio emission is mostly powered by star formation processes. We present e-MERLIN images of two of the four sources which also support this conclusion.

Source Images

The VLBI, e-MERLIN and *Hubble* images for the target sources are shown here:

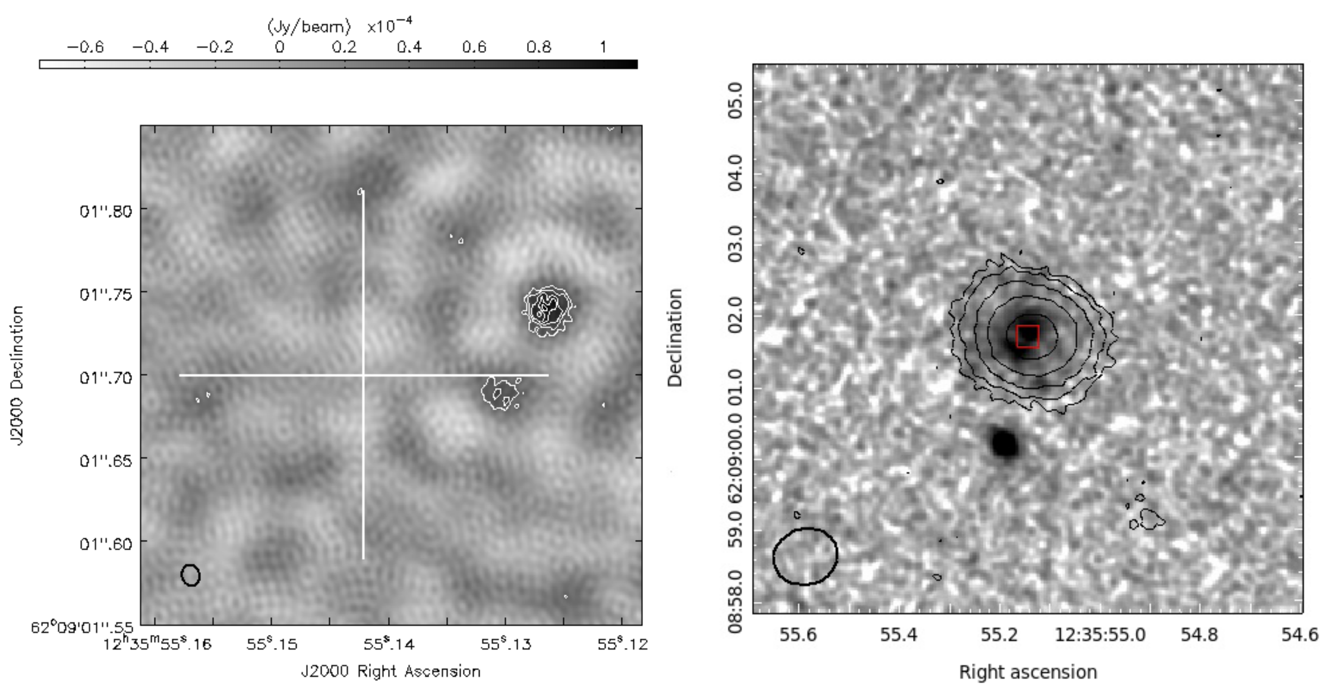

Figure: Contoured maps for the VLBI-detected source J123555.14+620901.7. The left sub-figure is the EVN 1.6 GHz image plotted with contour levels (3, 4, 5, 6, 7) $\times$ the r.m.s noise level. The right sub-figure is the *Hubble* CANDELS F814W ACS image overlaid with contours of the eMERGE-JVLA 1.5 GHz maximum sensitivity image (note the very different scale) plotted at (3, 6, 12, 24, 48) $\times$ the r.m.s noise level. The red square shows the FoV of the left sub-figure.

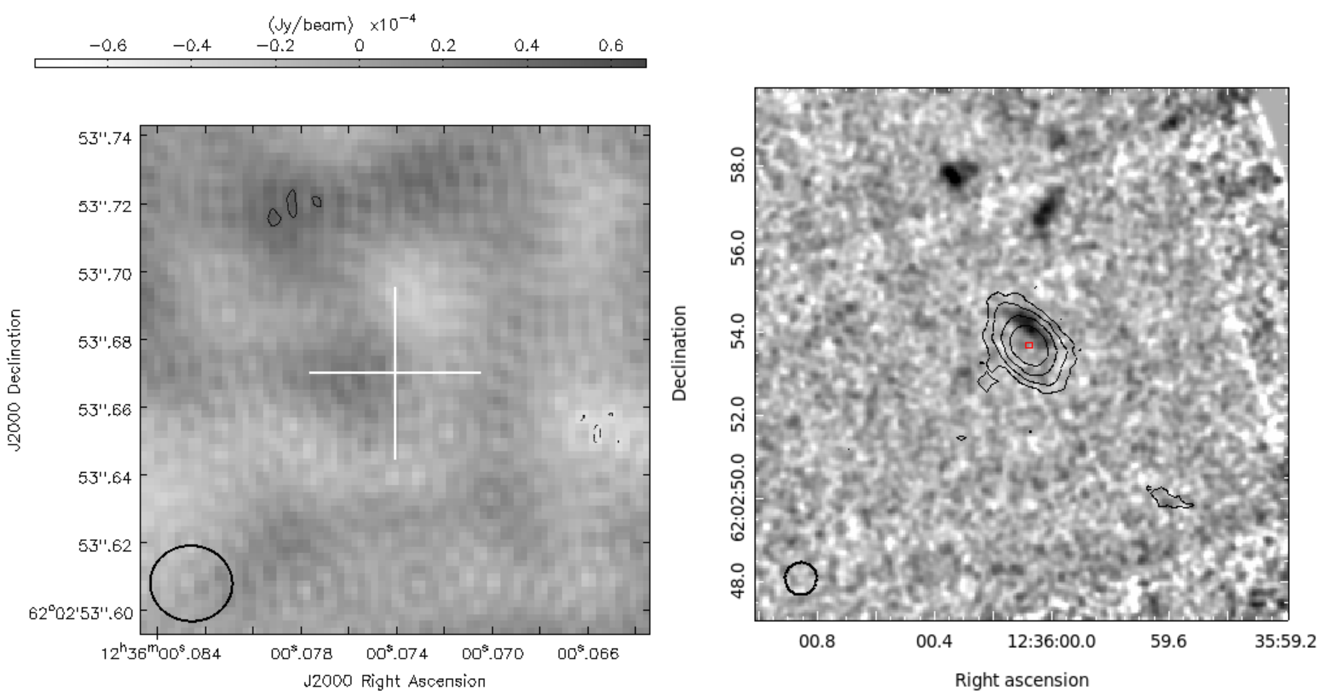

Figure: Left: the EVN 1.6 GHz VLBI image of the field associated with J123600.10 (undetected). This image plotted with contour levels -3, 3 $\times$ the r.m.s noise level. Right: The *Hubble* NICMOS NIC2 F160W image retrieved from the ESA *Hubble* Legacy archive. The overlaid contour was plotted at 3, 6, 12, 24, 48 $\times$ the r.m.s noise level of the eMERGE-JVLA moderate resolution image at 1.5 GHz. The red square shows the FoV of the left sub-figure.

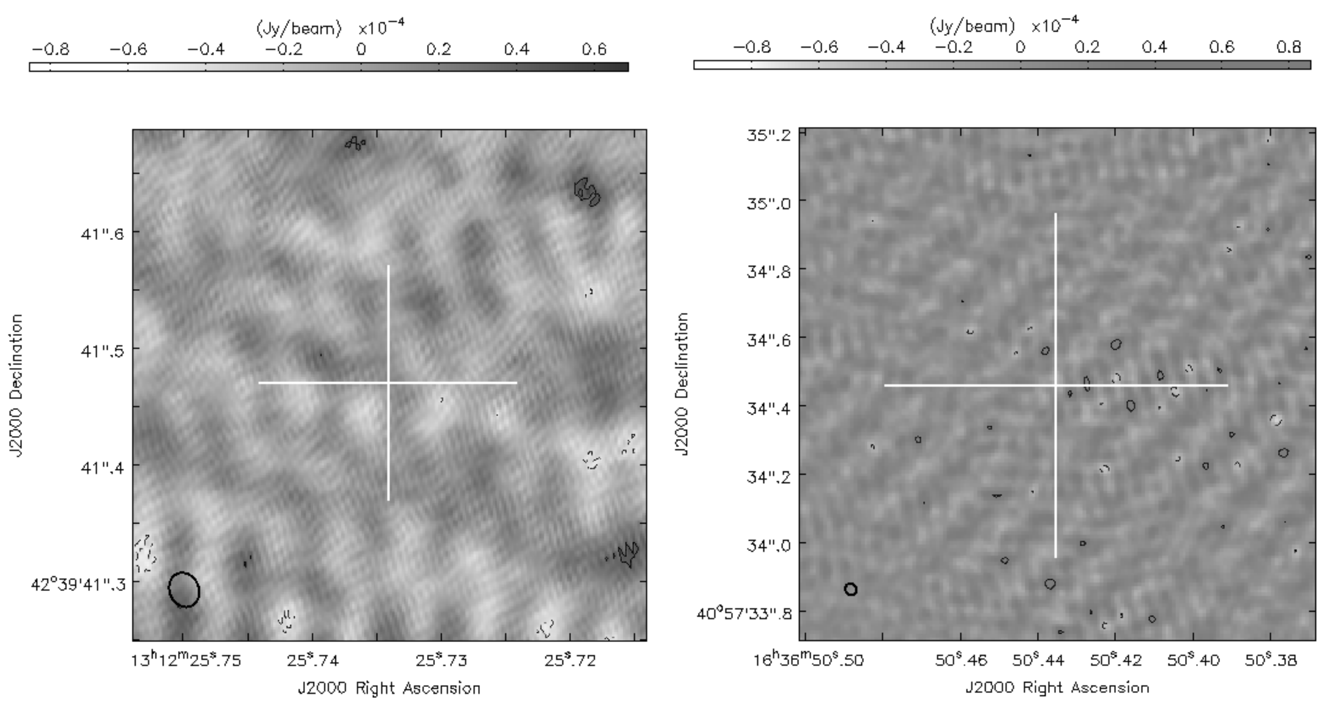

Figure: The EVN 1.6 GHz images of J131225.73 (left; undetected) and J163650.43 (right; also undetected). The maps are presented with contour levels -3, 3 $\times$ the r.m.s noise.

Brightness Temperature

Local observations of starburst galaxies illustrated that the upper limit to the brightness temperature of $z > 0.1$ star-forming galaxies is expected not to exceed $T_b \sim 10^5$K[1], distant SMGs ($z \sim 2$) with T_b above this value are most likely powered by AGN.

$$T_b = 1.22 \times 10^{12}(1+z)\left(\frac{S_\nu}{1\mathrm{Jy}}\right)\left(\frac{\nu}{1\mathrm{GHz}}\right)^{-2}\left(\frac{\theta_{maj}\theta_{min}}{1\mathrm{mas}^2}\right)^{-1}\mathrm{K}, \quad (1)$$

where S_ν is the peak brightness and ν is the observing frequency; θ_{maj} and θ_{min} denote the deconvolved major and minor axes of the source[2]. The detected source J123555.14 has a brightness temperature of $5.2 \pm 0.7 \times 10^5$ K, which is $\sim$ 5 times higher than the star-forming envelope. This supports the interpretation that J123555.14 contains an AGN core.

FIR-radio Correlation

A fairly tight far-infrared-radio correlation applies to a wide-range of galaxy holding at cosmological distances[3]. Radio-loud AGNs are ob- served to have much lower values of q on average, compared to radio quiet or star-forming systems[4].

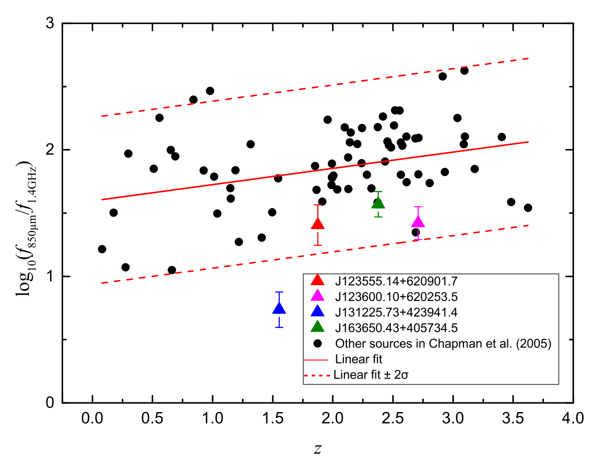

Figure: The non-k-corrected Far-Infrared-radio correlation ($q^{850\mu m}_{1.4\mathrm{GHz}}$) of 76 sources in the chapman2005 sample, including the four VLBI observed sources presented in this paper. J131225.73 (blue triangle) is clearly an outlier in the plot.

The value of q can therefore help to distinguish between AGN activity and star-forming processes in extragalactic systems. We define $q^{850\mu m}_{1.4\mathrm{GHz}}$ as:

$$q^{850\mu m}_{1.4\mathrm{GHz}} = \log_{10}\left(\frac{L_{850\mu m}}{L_{1.4\mathrm{GHz}}}\right) \quad (2)$$

where $L_{850\mu m}$ and $L_{1.4\mathrm{GHz}}$ are the luminosities at 850 μm and 1.4 GHz. The chapman2005 sample[5] has a mean $q^{850\mu m}_{1.4\mathrm{GHz}}$ of $\sim$ 1.85 with a standard deviation from the linear fit of 0.35. One of the sources, J131225.73, has a value of $q^{850\mu m}_{1.4\mathrm{GHz}} \sim 0.74$, which departs from the mean linear fit by $\sim 3\sigma$. It is somewhat surprising that J131225.73 is not detected in our observations considering the strong radio-excess. It would be interesting to observe the structure of this radio source with intermediate resolution e.g. e-MERLIN at 5 GHz in order to better understand the nature of the source.

Conclusion

- We had one detection of J123555.14 in the GOODS-N field. The high brightness temperature may suggest an AGN.
- The non-detections suggest that most of their radio emission is not generated by starburst or extended emissions from jets.
- The undetection of J131225.73, which is relatively bright in the radio (752.5 μ Jy at 1.4GHz) and has very low values of q may indicate that VLBI observations can miss some AGN in the radio.
- It would be interesting to observe the structure of J131225.73 with intermediate resolution e.g. e-MERLIN at 5 GHz in order to better understand the nature of the source.

References

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