



Radio Observations of the *Chandra* Deep Field South

Exploring the possible link between radio emission and star formation in X-ray selected AGN

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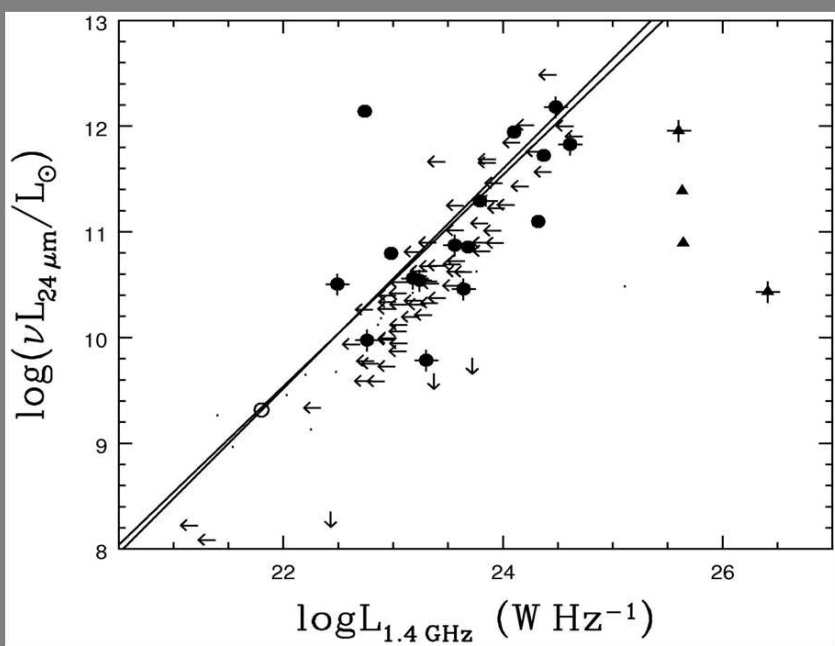
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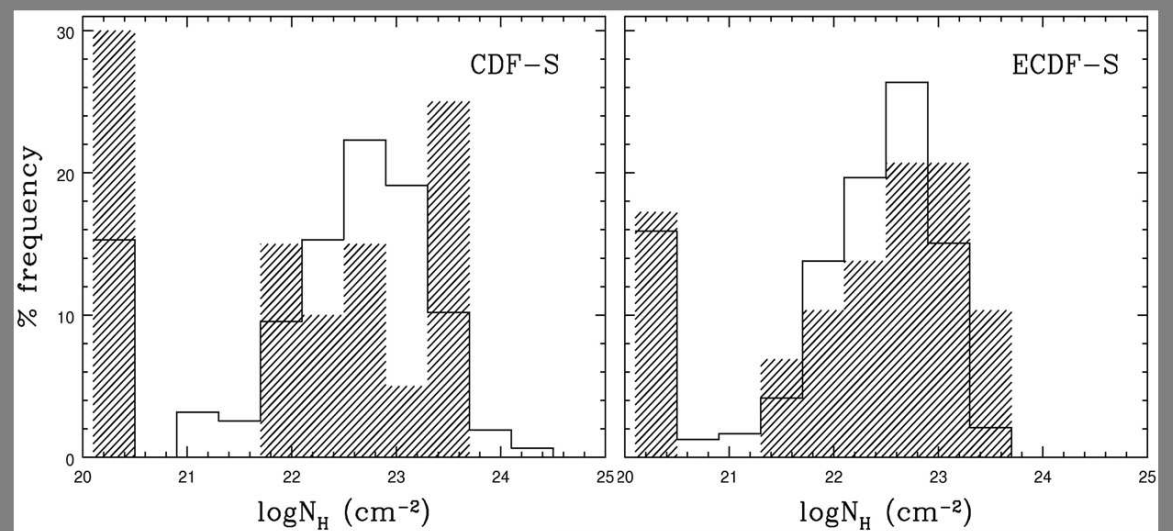
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Abstract: We have cross-correlated radio data from the Australia Telescope Compact Facility (ATCA) with X-ray observations of the southern *Chandra* Deep Fields (CDF-S and ECDF-S). We get radio detection rates of 14% and 9% for the CDF-S and ECDF-S respectively, while a large fraction of the radio emission is starburst connected, as suggested by the *Spitzer* infrared and radio correlation. We find no evidence for the presence of a number non X-ray detected radio-excess AGN. No strong evidence is found of correlation between radio emission and X-ray obscuration and we interpret this result considering non isotropic X-ray obscuration.



Infrared (24 micron) against radio luminosity of AGN in our sample. The (hard-selected) X-ray sources seem to follow the correlation observed for normal galaxies (lines), which means that their radio emission is star-formation connected. However upper limits of infrared luminosity (downward arrows) show that for non infrared detected sources this is not the case, so the AGN has to be the generator of their radio fluxes. X-ray non detected sources (represented with dots) stay close to the line, demonstrating that they are probably normal galaxies and not buried active nuclei, i.e. we do not find evidence for the presence of a number non X-ray detected radio-excess AGN, in contrast with Donley et al. (2005). Finally, radio loud sources (with $\log(L_r > 10^{25} \text{ W Hz}^{-1})$) occupy a different region in the diagram. We omit radio loud objects from any analysis.



Hydrogen column density (N_H) distribution of non radio loud AGN in the southern *Chandra* Deep Fields. Shaded are the distributions of radio detected sources. We detect no statistically important differences of the radio detected and non radio detected distributions, except if we ignore unobscured sources (i.e. the left columns) and sources not detected in the infrared. This gives a hint that the correlation breaks partly because part of the radio emission is not star-formation connected and partly as a result of the anisotropic distribution of the X-ray absorbing material.

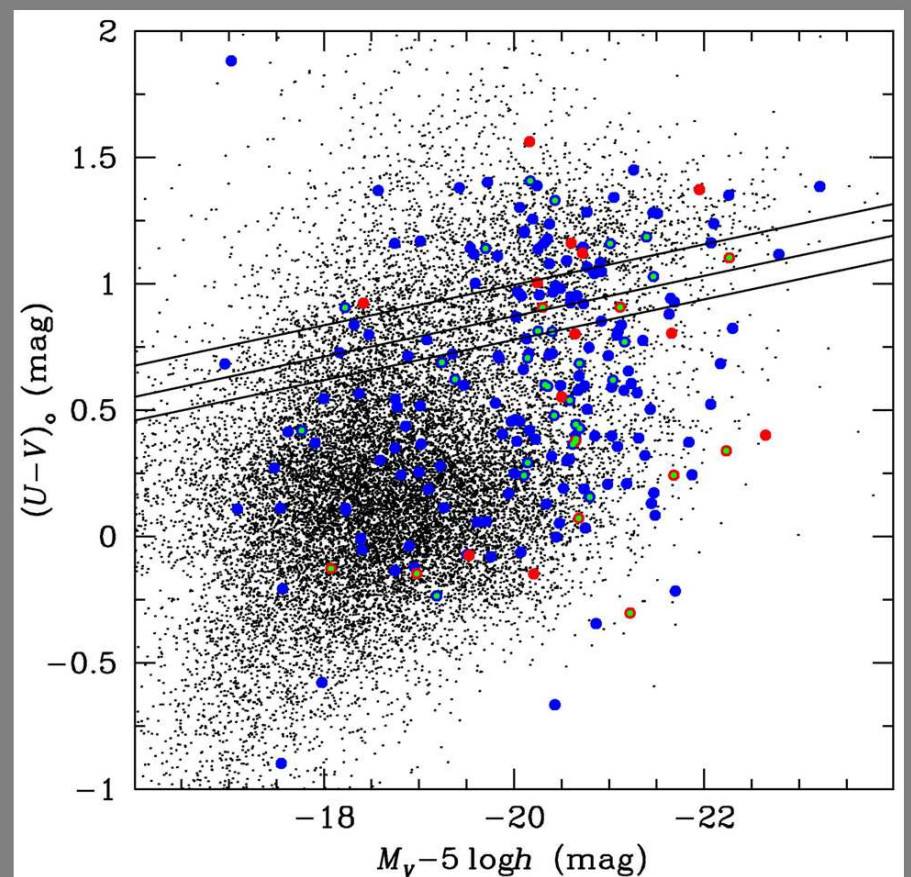
Data and Methodology

We use the public catalogues of the *Chandra* Deep field South (CDF-S, Giacconi et al. 2002; Alexander et al. 2003) and the Extended *Chandra* Deep field South (ECDFS, Lehmer et al. 2005), reaching flux depths of 2.8×10^{-16} and $6.7 \times 10^{-16} \text{ erg cm}^{-2} \text{ s}^{-1}$ respectively. The radio observations are made with ATCA and have a flux limit of $60 \mu\text{J}$ (Afonso et al. 2005). We also use archival *Spitzer* MIPS data with a flux limit of $80 \mu\text{Jy}$.

We find radio detection rates of X-ray to be 14% and 9% for the CDF-S and ECDF-S respectively. We then select only hard detected sources and classify them based on their X-ray luminosities and hardness ratios. We calculate the hydrogen column densities from the hardness ratios and compare the results using different selections based on the existence of a radio counterpart.

Conclusions

- Radio emission is linked with star formation for a large fraction of the AGN, as suggested by a radio-infrared correlation. There is also a number of AGN whose radio emission is attributed to the AGN, especially at high radio luminosities.
- The colour distribution of radio detected X-ray sources as seen in the colour-magnitude diagram could distinguish between starburst and AGN generated radio emission.
- We do not find strong evidence for the presence of numerous radio excess AGN, as derived by the Lir-Lr relation, which are not detected in the 1 Ms CDF-S exposure.
- We found no strong evidence for the correlation between radio emission and X-ray absorption, in contrast with Georgakakis et al. (2004) and Bauer et al. (2002). This is partly a result of the AGN being responsible for the radio emission of some sources and partly a result of the obscuring material being anisotropically distributed.



Color-magnitude diagram for hard X-ray selected AGN. In the background are COMBO-17 sources (mostly normal galaxies) and the lines are the borders between the "blue cloud" and the "red cloud" for three different redshifts (0.5, 0.9 and 1.2). The distribution of AGN (blue and red circles) is different with many sources occupying the "red cloud" and the "valley" between the clouds. In red are marked radio detected AGN and we see no preferential distribution of them. A green circle marks an infrared detection and a closer look reveals that no radio detected AGN in the "red cloud" is detected in the infrared, so their radio emission is not starburst connected.