An HI Search for the Host Galaxies of 27 Radio-loud AGN at $z \sim 2.3$

T. Ghosh, M.M. Davis, C.J. Salter

_Arecibo Observatory, HC3 Box 53995, Arecibo, PR 00612_

M.C. Aller

_Univ. of Michigan, Department of Astronomy, 1013 Dennison Bldg., Ann Arbor, MI 48109-1090_

1. Introduction

This project was inspired by optical and IR imaging suggesting that, while most QSO hosts at high $z$ are too faint to detect, radio-loud quasars are hosted by exceptionally luminous galaxies. Thus, a search was undertaken for HI absorption against the continuum emission of strong radio emitters whose redshifts ($z \sim 2.3$) bring their HI line into the 430-MHz Arecibo passband. The aim was to detect, or set useful limits, on the HI in the hosts, say in dust lanes, introduced by mergers, or situated in obscuring circumnuclear tori. At Arecibo there is a choice of, a) the 430-MHz line-feed system, or b) the new 430-MHz Gregorian-dome feed. In practice, most of the data were taken with the Gregorian system, although some line-feed data were also acquired. This represents the first Arecibo line spectroscopy using the 430-MHz Gregorian receiver.

2. The Observations

The source sample was chosen using the NASA Extragalactic Database (NED) to select all radio-loud AGNs at $z \sim 2.3$ within the Arecibo-accessible "sky". Most had flux densities in the range $0.3 \, \text{Jy} < S(430 \, \text{MHz}) < 3.5 \, \text{Jy}$, 23 being quasars and 4 radio galaxies. All were observed irrespective of their radio structure. We recorded 4 sub-correlators, each of 2048 spectral channels, representing wide (12.5 MHz) and narrow (3.125 MHz) bandwidths for both polarizations. Typical total integrations were for a little over one hour.

During the position-switched observations, radio frequency interference levels were relatively high. To counter this, an analysis procedure was developed which took individual 6-sec records and iteratively clipped all positive-going spikes that exceeded a 4-$\sigma$ level before summing the records. This procedure

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3 This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.
also built up a "clipping map", which logged how much of the original data remained in the final spectrum for each channel. Candidate absorptions could then be checked against the clipping map to find the data quality at the relevant spectral positions. Typically, for the Gregorian data a maximum of 5% of the data were clipped in any record.

3. The Results

The reduction of the data is presently proceeding, and here we present results for the first 8 sources analyzed. For these, no clear absorptions have been detected, although the results do indicate the present performance of the Arecibo Gregorian system at 430 MHz. The results are summarized in Table 1, where Col. 1 gives the source name, Cols. 2 and 3 give the optical identification (with Q for quasar and RG for radio galaxy) and the redshift, Cols. 4 & 5 are the flux density at 430 MHz and the source spectral index (S \propto \nu^{-\alpha})

\[
N_H \approx 1.9 \times 10^{16} T_s \Delta \nu \sigma / f \, \text{cm}^{-2},
\]

where $T_s$ is the HI spin temperature (in K), $\Delta \nu$ is the anticipated Gaussian velocity FWHM of the line (in km$s^{-1}$), and $f$ is the fraction of the total flux density of the source contained in components lying behind the HI. Consider two possible cases: a) for HI in a circumnuclear torus, the expected parameters are about $T_s=8\times10^3$ K and $\Delta \nu=300$ km$s^{-1}$, giving $N_H \approx 4.6 \times 10^{22} \sigma / f \, \text{cm}^{-2}$, while b) for HI within a host galaxy, typical values might be $T_s=100$ K and $\Delta \nu=30$ km$s^{-1}$, giving $N_H \approx 5.7 \times 10^{19} \sigma / f \, \text{cm}^{-2}$. It is, of course, vital to examine the best available continuum imaging of the targets in order to estimate appropriate values of $f$.

\[\begin{array}{cccccc}
\text{Source} & \text{ID} & z & S_{430} (\text{mJy}) & \alpha & \sigma \\
\hline
\text{B0123+257} & Q & 2.358 & 1448 & 0.04 & 0.0065 \\
\text{J0225+318} & Q & 2.296 & 633 & 1.16 & 0.0060 \\
\text{J1109+377} & \text{RG} & 2.29 & 3500 & 0.89 & 0.0054 \\
\text{B1123+264} & Q & 2.341 & 711 & -0.20 & 0.0116 \\
\text{B1226+105} & Q & 2.304 & 2048 & 0.84 & 0.0300 \\
\text{J1411+007} & \text{RG} & 2.27 & 660 & 1.10 & 0.0130 \\
\text{J1710+105} & \text{RG} & 2.349 & 1100 & 1.08 & 0.0048 \\
\text{J1747+183} & \text{RG} & 2.281 & 3200 & 0.87 & 0.0025 \\
\end{array}\]

* The data for B1226+105 were taken with the 430-MHz line feed.