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

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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[2]. 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[3]) 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 Jy < S(430 MHz) < 3.5 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-σ level before summing the records. This procedure

[2]The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under a cooperative agreement with the National Science Foundation.

[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.

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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 $\propto \nu^{-\alpha}$), and Col. 6 is the 1-σ optical depth limit reached.

Source	ID	z	S_{430}(mJy)	α	σ
B0123+257	Q	2.358	1448	0.04	0.0065
J0225+318	Q	2.296	633	1.16	0.0060
J1109+377	RG	2.29	3500	0.89	0.0054
B1123+264	Q	2.341	711	−0.20	0.0116
B1226+105*	Q	2.304	2048	0.84	0.0300
J1411+007	RG	2.27	660	1.10	0.0130
J1710+105	RG	2.349	1100	1.08	0.0048
J1747+183	RG	2.281	3200	0.87	0.0025

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

While it is expected that the final uncertainties on the optical depths will be somewhat lower than the values given here (following corrections for residual standing-wave effects), it is illuminating to consider what an rms optical depth of σ implies in respect to limits on HI column density. This is $N_H \lesssim 1.9 \times 10^{16} T_s \Delta v \, \sigma / f \ cm^{-2}$, where T_s is the HI spin temperature (in K), Δv is the anticipated Gaussian velocity FWHM of the line (in kms^{-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=8×10^3 K and Δv=300 kms^{-1}, giving $N_H \lesssim 4.6 \times 10^{22} \sigma/f \ cm^{-2}$, while b) for HI within a host galaxy, typical values might be T_s=100 K and Δv=30 kms^{-1}, giving $N_H \lesssim 5.7 \times 10^{19} \sigma/f \ cm^{-2}$. It is, of course, vital to examine the best available continuum imaging of the targets in order to estimate appropriate values of f.