

## N(HI) and Jet Power/Emission in AGNs

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**Abstract.** Neutral hydrogen (HI) 21-cm absorption has been detected against very powerful radio jets. In this paper, based on Gupta’s sample (Gupta *et al.* 2006), we present our preliminary study of the correlations between the HI column density N(HI) and the jet power, N(HI) versus the low frequency luminosity at 408 MHz, and N(HI) versus the radio luminosity at 1400 MHz.

**Key words.** Galaxies: active—galaxies: nuclei—quasars: absorption lines: galaxies.

### 1. Introduction

Relativistic plasma jets represent one of the possible ways in which enormous energy is released by active nuclei and it can also interact with and affect the interstellar medium (Morganti *et al.* 2010). It was suggested that radioactivity might be associated with the presence of cold gas. The rotation axis of the cold gas is usually aligned with the radio axis (Van Gorkom *et al.* 1989). Gupta *et al.* (2006) showed that the HI absorption for compact radio sources could be due to gas clouds accelerated by radio jets, and it might be an evidence of jet–cloud interaction.

It is widely believed that the energy output from AGN is triggered by the supply of gas to the central engine, the dependence of N(HI) on radio luminosity could provide clues towards understanding this phenomenon (Gupta *et al.* 2006). Pihlström *et al.* (2003) found an anti-correlation between N(HI) and linear size of the jet and Gupta & Saikia (2006) also found that N(HI) is related to the core prominence parameter and some other parameters. In this paper, we will study the correlations between the intrinsic low-frequency radio luminosity and jet power with HI column density around the jets ( $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ ,  $\Omega_M = 0.3$  and  $\Omega_\Lambda = 0.7$  were adopted and spectral index  $\alpha$  is defined as  $f_\nu \propto \nu^{-\alpha}$ ).

### 2. Sample selection and data collection

Gupta *et al.* (2006) obtained a sample of 96 radio sources from literature which is a heterogeneous superset of sources with available HI absorption observations. The sample includes 27 gigahertz peaked spectrum (GPS), 35 compact steep spectrum

(CSS), 13 compact flat spectrum (CFS) and 21 large (LRG) sources, spanning a wide range of  $\sim 6$  orders of magnitude in luminosity at 5 GHz and  $z \leq 1.4$ . We have collected the radio data for this sample at 1.4 GHz, 408 MHz, 365 MHz, 333 MHz, 151 MHz and 178 MHz. The radio data at 1.4 GHz were from VLA first survey or NVSS survey, the radio data at 408, 151 MHz and other low frequency data were obtained from NASA/IPAC Extragalactic Database (NED).

Jet power is a fundamental parameter reflecting the energy transport to large spatial scales from the central engine by the radio jet. In this study, we estimated the jet power using the relation in Punsly (2005):

$$Q_{\text{jet}} = 5.7 \times 10^{44} (1+z)^{1+\alpha} Z^2 F_{151} \text{ erg s}^{-1}, \quad (1)$$

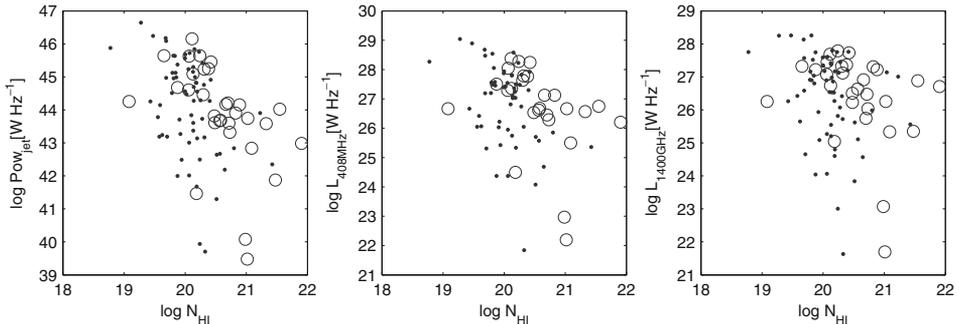
$$Z \approx 3.31 - 3.65 \times [(1+z)^4 - 0.203(1+z)^3 + 0.749(1+z)^2 + 0.444(1+z) + 0.205]^{-0.125}, \quad (2)$$

where  $F_{151}$  is the optically thin flux density from the lobes measured at 151 MHz in units of Jy, and  $\alpha \approx 1$  is assumed (see Punsly 2005 for more details).

### 3. Correlation analysis

We investigated the correlations between  $N(\text{HI})$  and the jet power, and luminosity at 1.4 GHz and 408 MHz. The jet power  $Q_{\text{jet}}$  was calculated either directly from the radio flux at 151 MHz or from the extrapolated 151 MHz flux density from the available flux density at 160, 178, 330, 365 or 408 MHz assuming  $\alpha \approx 1$ . The whole data table will be presented in a forthcoming paper (Wu *et al.* 2011). Due to the fact that the  $N(\text{HI})$  are only given as upper limits in a large fraction of source due to non-detections, we used the Astronomy Survival Analysis (ASURV) package (Isobe & Feigelson 1990) in our correlation analysis when the upper limits were involved.

We find a significant negative correlation between  $Q_{\text{jet}}$  and  $N(\text{HI})$  with Spearman correlation coefficient of  $r = -0.707$  at  $\gg 99.99\%$  level for the sample with  $N(\text{HI})$  detections (31 sources) and  $r = 0.242$  at  $\sim 98.23\%$  level for the whole



**Figure 1.** Left: Jet power *versus*  $N(\text{HI})$ ; middle: low-frequency radio luminosity at 408 MHz *versus*  $N(\text{HI})$ ; right: low frequency radio luminosity at 1400 MHz *versus*  $N(\text{HI})$ . Open circles represent the sources with detected  $N(\text{HI})$  while the black dots are those sources with only the upper limit of  $N(\text{HI})$ .

sample (95 sources) by using ASRUV package (see Fig. 1). For the radio luminosity at 1400 MHz, we find a strong negative correlation (see Fig. 1) for detections (29 sources) with  $r = -0.5$  at  $\sim 99.2\%$  level and no correlation for the whole sample (91 sources). In case of the radio luminosity at 408 MHz, we find a significant negative correlation,  $r = -0.626$  at  $\gg 99.99\%$  level for detections and  $r = -0.199$  at  $\sim 92.4\%$  level for the whole sample (81 sources) (see Fig. 1). The inclusion of non-detections seems to significantly weaken the correlation, which was also found to affect the correlation between N(HI) and jet size in Curran & Whiting (2010).

As the jet power and low frequency radio luminosity are normally believed to indicate the intrinsic jet power or emission, our results may imply that the HI gas around the powerful radio jet might be tightly related to radio jets. However, this needs further investigations due to the small sample size, and only upper limits of N(HI) in many sources.

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