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Limits on the H I content of the dwarf galaxy Hydra II *(Research Note)*

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ABSTRACT

Sensitive 21 cm H I observations have been made with the Green Bank Telescope toward the newly-discovered Local Group dwarf galaxy Hydra II, which may lie within the leading arm of the Magellanic Stream. No neutral hydrogen was detected. Our 5σ limit of $M_{\rm HI} \leq 210\ M_\odot$ for a 15 km s^{-1} linewidth gives a gas to luminosity ratio $M_{\rm HI}/L_V \leq 2.6 \times 10^{-2}\ M_\odot\ L_\odot^{-1}$. The limits on H I mass and $M_{\rm HI}/L_V$ are typical of dwarf galaxies found within a few hundred kpc of the Milky Way. Whatever the origin of Hydra II, its neutral gas properties are not unusual.

Key words. galaxies: dwarf – Galaxy: halo – Local Group – galaxies: individual: Hydra II

1. Introduction

Hydra II is a dwarf galaxy in the Local Group, newly-discovered during the Survey of the Magellanic Stellar History (SMASH) using the Dark Energy Survey Camera DECam (Nidever & Smash Team 2015; Martin et al. 2015). It lies at a distance of 134 kpc from the Sun with $V_{\rm hel}$ = 303 km s^{-1}, and has physical properties, such as a half light radius of 66 pc, a high dynamical mass-to-luminosity ratio, and a metallicity $\langle$[Fe/H]$\rangle$ = -2.02 ± 0.08, indicating that it is a dwarf galaxy and not a cluster in the Milky Way's halo (Martin et al. 2015; Kirby et al. 2015). It is located in the same region of the sky as the leading arm of the Magellanic Stream and has a similar velocity (Nidever et al. 2008, 2010). The distance to the leading arm is not known and estimates range from 21 kpc to >100 kpc (McClure-Griffiths et al. 2008; Besla et al. 2012; Martin et al. 2015). If Hydra II originated in the Magellanic Clouds it may have a considerably different history and properties than other Milky Way dwarfs (Martin et al. 2015). For this reason, we made very sensitive observations of the 21 cm H I emission in Hydra II using the Green Bank Telescope, which has been used to produce some of the most strict limits on the H I content of other Local Group dwarf galaxies (Spekkens et al. 2014).

2. Observations and analysis

Measurements of 21 cm emission from Hydra II were made with the 100-m diameter Robert C. Byrd Green Bank Telescope (GBT) of the National Radio Astronomy Observatory[1] on 2015, July 7–8 and July 17, centered at the position J2000 = $12^{\rm h}21^{\rm m}42.1^{\rm s}{-}31°59'07''$ given by Martin et al. (2015). The GBT 1.4 GHz receiver had a total system temperature toward Hydra II of about 21 K. The GBT VEGAS spectrometer was used to measure spectra with both in-band frequency switching for 23 min and position-switching to a reference location displaced $\pm 5^{\rm m}30^{\rm s}$ in right ascension from the source for 110 min. The 9$'$.1 FWHM beam of the GBT at 21 cm completely encompasses Hydra II, which is estimated to have an angular size of about 1$'$.7 on the sky (Kirby et al. 2015).

The 21 cm spectra covered ±2000 km s^{-1} centered on zero velocity in the local standard of rest (LSR). In the position-switched observations, emission at Milky Way velocities between −70 and +180 km s^{-1} is partially cancelled, but as the stars in Hydra II have a mean $V_{\rm LSR}$ = +301 km s^{-1}, this does not affect our results. The data were reduced using the standard GBTIDL routines and calibrated correcting for atmospheric attenuation to produce $T_{\rm a}^\star$ as a function of $V_{\rm LSR}$. Frequency-switched data were calibrated and corrected for stray radiation using the method described in Boothroyd et al. (2011). The final spectra, smoothed to a velocity resolution of 0.30 km s^{-1} from the intrinsic resolution of 0.15 km s^{-1}, are shown in Fig. 1. We combine the noise limits from position- and frequency-switched spectra for

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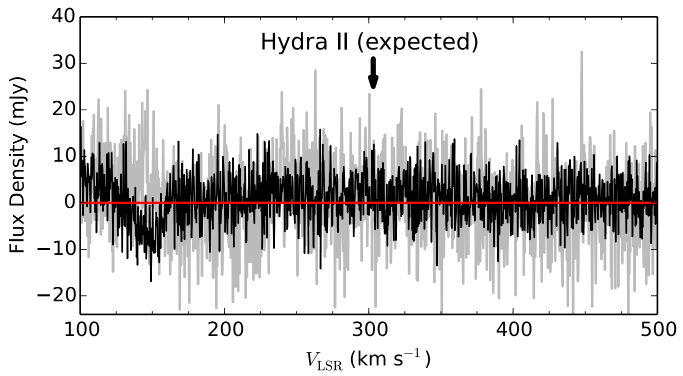

Fig. 1. GBT 21 cm H I spectra toward Hydra II over the velocity range appropriate to that galaxy. The grey and black are the frequency- and position-switched spectra, respectively. Their differing noise level is a consequence of the difference in exposure times: 23 min for frequency switching and 110 min for position switching. The combined rms noise is 9.1 mK in an 0.30 km s^{-1} channel. The dip in the position-switched spectrum near 150 km s^{-1} results from partial cancellation of Milky Way emission.

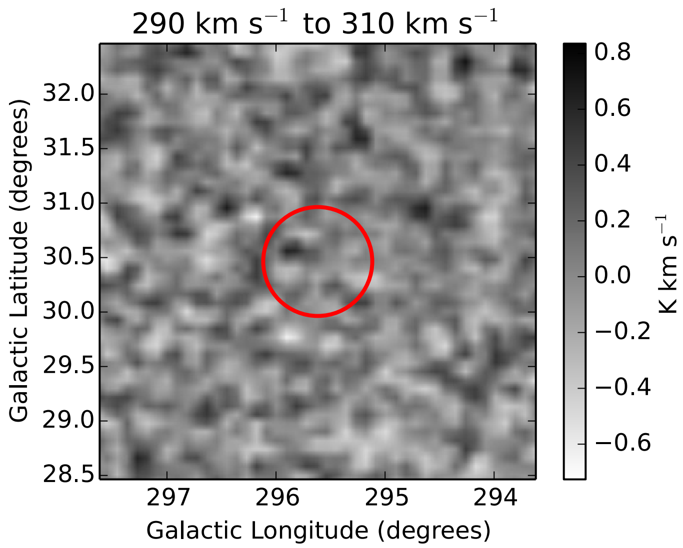

Fig. 2. The integrated 21 cm H I emission in the field of Hydra II from the GASS survey (McClure-Griffiths et al. 2009; Kalberla et al. 2010) over 20 km s^{-1} around the stellar velocity of Hydra II, whose location at $\ell, b = 295\overset{\circ}{.}62 + 30\overset{\circ}{.}46$ is marked with the circle. No significant emission is detected. The brightest H I within a degree of the galaxy is consistent with a 2.3σ noise feature.

a final estimated rms noise in $T_a^\star$ of 9.1 mK (4.55 mJy) in an 0.30 km s^{-1} channel.

No signal from H I associated with Hydra II is detected. The 5σ limit on the velocity-integrated flux density over 15 km s^{-1} is $5 \times 4.55 \times 0.3 \times \sqrt{15/0.30} = 48.3$ mJy km s^{-1}. The H I mass within the beam is given by

$$M_{\rm HI}\ (M_\odot) = 2.36 \times 10^5\ D^2 \int S\,{\rm d}v \qquad (1)$$

(Roberts 1975), where D is the source distance in Mpc, and $\int S\,{\rm d}v$ is the velocity integrated flux in Jy km s^{-1}. We assume an H I linewidth of 15 km s^{-1}, consistent with that used in the analysis of other local dwarfs (Spekkens et al. 2014). At the 0.134 Mpc distance of Hydra II, our measurements give a 5σ limit $M_{\rm HI} \leq 210\ M_\odot$.

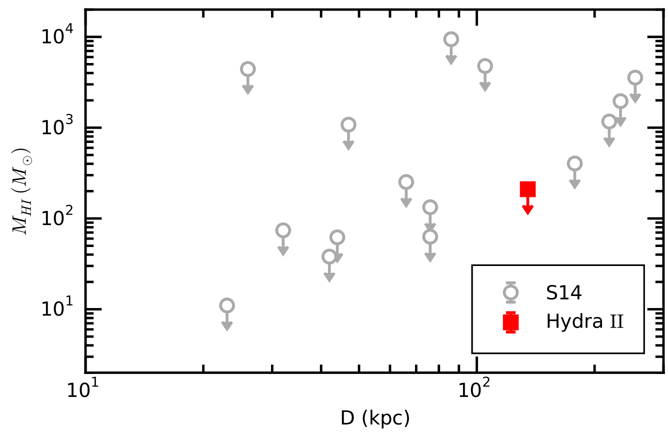

Fig. 3. 5σ H I mass limits of local dwarf galaxies from Spekkens et al. (2014; S14 open symbols) as a function of heliocentric distance, with the Hydra II measurement as the filled symbol. The limit on $M_{\rm HI}$ of Hydra II is consistent with that of other dwarfs near the Milky Way.

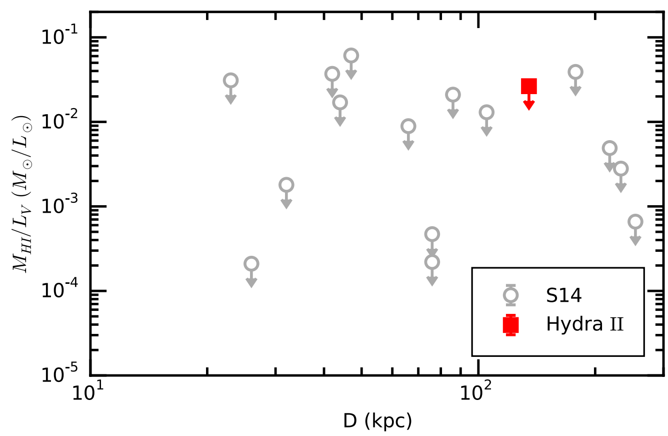

Fig. 4. 5σ H I mass to L_V ratios of local dwarf galaxies from Spekkens et al. (2014; S14) as a function of heliocentric distance with open symbols, and the Hydra II measurement as a filled symbol using L_V from Martin et al. (2015). The limit for Hydra II is consistent with that of other dwarfs near the Milky Way.

To explore whether there might be some H I associated with Hydra II but displaced somewhat in position or velocity from the stars, we integrated the GASS H I survey, made with the Parkes radio telescope at an angular resolution of $14\overset{\prime}{.}4$ (McClure-Griffiths et al. 2009; Kalberla et al. 2010) over 20 km s^{-1} around the velocity of the galaxy. Figure 2 shows the resulting noise map. No H I is detected. The brightest GASS pixel within one degree of Hydra II has an integrated intensity of 0.7 K-km s^{-1}, or 2.3σ of the measured noise. Over the area of the Parkes telescope beam anywhere in this field, the 5σ limit on $M_{\rm HI}$ is 9350 $M_\odot$.

3. Discussion

We do not detect any H I directly toward Hydra II, nor is there any evidence of significant H I nearby that galaxy, in position or velocity. Our 5σ limit $M_{\rm HI} \leq 210\ M_\odot$ shown in Fig. 3, is consistent with values derived for other Local Group dwarf galaxies that lie within the ≈300 kpc virial radius of the Milky Way (Blitz & Robishaw 2000; Grcevich & Putman 2009; Spekkens et al. 2014; Westmeier et al. 2015). Likewise, the derived H I mass-luminosity limit (using L_V from Martin et al. 2015) of $M_{\rm HI}/L_V \leq 2.6 \times 10^{-2}\ M_\odot\ L_\odot^{-1}$ is also similar to that found for dwarfs near the Milky Way, as shown in Fig. 4. Dwarf galaxies at larger distances from the Milky Way typically have $M_{\rm HI}/L_V \approx 1$ (McConnachie 2012).

The lack of detectable H I in nearby dwarf galaxies is usually ascribed to tidal or ram pressure stripping in the Milky Way's hot halo (Blitz & Robishaw 2000; Mayer et al. 2006; Grcevich & Putman 2009; Gatto et al. 2013). Presumably, similar processes have removed the gas from Hydra II. In this regard, Hydra II's location near the leading arm of the Magellanic Stream has apparently not affected its neutral Hydrogen properties as compared with other dwarfs at similar distances.

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