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The impact of optically thick HI on the envelopes of molecular clouds and its implication for the HI-to-H_2 transition

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Recent observations of nearby galaxies have shown that the HI surface density sharply saturates at $\sim$10 $M_\odot$ pc^{-2} on kpc scales. This holds even on sub-pc scales, as shown by Lee et al. (2012) for the Perseus molecular cloud. The three-dimensional H_2 formation model by Krumholz et al. (2009) explains this saturation as the minimum HI surface density required for shielding H_2 against photodissociation. While the predicted HI surface density of $\sim$10 $M_\odot$ pc^{-2} for solar metallicity is consistent with the observations, however, the HI saturation could alternatively result from a large amount of the optically thick HI.

We investigate the impact of high optical depth on the observed HI saturation in Perseus by using Arecibo HI emission and absorption measurements obtained toward 26 radio continuum sources (Stanimirović et al. 2014; Lee et al. 2015). We calculate the spin temperatures and optical depths of individual HI components along each line of sight and derive the correction factor for high optical depth HI. The pixel-by-pixel correction to the optically thin HI column density image results in only a $\sim$10% increase in the total HI mass and the HI surface density is still uniform with $\sim$7–9 $M_\odot$ pc^{-2}, suggesting that H_2 formation is mainly responsible for the HI saturation in Perseus. We also compare the optically thick HI with the observed "CO-dark" gas and find that the optically thick HI only accounts for $\sim$20% of the "CO-dark" gas in Perseus.

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