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Raman mapping of atomic hydrogen in the Orion Bar and Orion South

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Abstract

I show that the broad Raman-scattered wings of Hα can be used to map neutral gas illuminated by high-mass stars in star forming regions. The near wings ($\Delta\lambda \approx \pm 10$ Å) trace neutral columns Absorption features in the pseudo-continuum at 6634 and 6663 Å correspond to neutral oxygen far-ultraviolet absorption lines at 1027.43 Å and 1028.16 Å.

Keywords: Atomic physics; Radiative transfer; Photodissociation regions

1. INTRODUCTION

Raman scattering is the inelastic analog of Rayleigh scattering by atoms or molecules. Both processes begin with a radiation-induced transition of an electron to a virtual bound state (non-eigenstate)

non-resonant scattering Recently, Dopita et al. (2016) identied Raman scattering wings to the Hα line in the Orion Nebula and a number of H II regions in the Magellanic Clouds.

Dopita et al. (2016) propose that the Raman wings form at the transition zone near the ionization fronts in H II regions. However, the total neutral hydrogen column through the ionization front can be no more than about $10/\sigma_0 \approx 2 \times 10^{18}\,\mathrm{cm}^{-2}$, where $\sigma_0 \approx 6.3 \times 10^{-18}\,\mathrm{cm}^2$ is the ground-state hydrogen photoionization cross section at threshold (Osterbrock & Ferland 2006). The Raman scattering cross section at wavelengths responsible for the observed wings is much lower than this: $\sigma_{\mathrm{Raman}} \sim 10^{-22}\,\mathrm{cm}^2$ (Chang et al. 2015), meaning that the Raman scattering optical depth through the ionization front is only of order 0.0001. A vastly larger column density of neutral hydrogen is available in the photodissociation region outside the ionization front, so it is more likely that Raman scattering will occur there instead, so long as there is sufficient far ultraviolet radiative flux in the vicinity of the Lyman β line (1025 Å).

2. OBSERVATIONS

MUSE (Bacon et al. 2010) observations of the Orion Nebula (Weilbacher et al. 2015; Mc Leod et al. 2015).

Keck HIRES spectra described in Henney & O'Dell (1999) and Bally et al. (2000). The spectrum I use is of HH 529 base region in Orion South. Published results from these data have concentrated on strong nebular lines, but here I use a small section of the spectrum in the range 6660 Å to 6670 Å for reasons which will become apparent.

3. DISCUSSION

The effective resolving power of the optical spectrograph is multiplied by 6.4 for the FUV domain.

The O I lines should be in absorption in the spectrum seen by the Raman scatterers.

Salgado et al. (2016) had found low dust cross-section in Orion Bar PDR, but there are loopholes. First, they assume plane-parallel geometry with exactly edge-on viewing angle, while in reality it is a roughly cylindrical filament. Second, they ignore scattering, see Watson et al. (1998).

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