Raman mapping of photodissociation regions in Orion

William J. Henney★
Instituto de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Apartado Postal 3-72, 58090 Morelia, Michaoacán, Mexico

Accepted XXX. Received YYY; in original form ZZZ

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 hydrogen columns of about 5×10^{20} cm^{-2}, while the farther wings ($|\Delta\lambda| > 30$ Å) trace columns of about 5×10^{21} cm^{-2}. Absorption features in the pseudo-continuum at 6633 and 6664 Å correspond to neutral oxygen far-ultraviolet absorption lines at 1027.43 Å and 1028.16 Å.

Key words: 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). In Rayleigh scattering, the electron returns to its original state, resulting in the radiation being re-emitted with its original frequency (elastic scattering). In Raman scattering, on the other hand, the electron undergoes a transition to a different excited state, resulting in radiation being re-emitted at a much lower frequency. See Figure 1 for an illustration of the process.

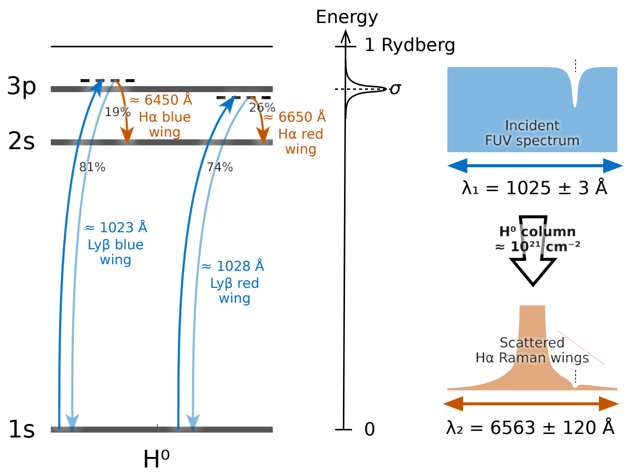

Figure 1. Schematic illustration of Raman scattering of photons from the Lyβ wings to the Hα wings. The relevant energy levels of neutral hydrogen are shown at left. Far ultraviolet photons that are shifted by about $\Delta\lambda_1 = \pm 1$ to 3 Å from the Lyβ rest wavelength can excite transitions from the ground 1s level to a virtual state adjacent to 3p. Most such excitations decay back to 1s (Rayleigh scattering), but in about one-fifth of cases the decay is to 2s instead (Raman scattering). The scattering cross section falls approximately as $\Delta\lambda_1^{-2}$, which gives broad Lorentzian wings to the Hα line, as shown at right. A bandwidth of $\Delta\lambda_1 = \pm 3$ Å around Lyβ is transformed to a bandwidth $\Delta\lambda_2 \approx \pm 120$ Å around Hα. A narrow absorption line in the incident FUV spectrum (vertical thin dashed line) becomes a much broader notch in the scattered wings.

★ w.henney@irya.unam.mx