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The Deuterium Balmer Series

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Abstract. The first detection and identification of deuterium Balmer lines were recently reported in H *ii* regions, using high spectral resolution data secured at CFHT and VLT. The D *i* lines appear as faint, narrow emission features in the blue wings of the H *i* Balmer lines and can be distinguished from high-velocity H *i* emission. The identification as deuterium and the excitation mechanism as fluorescence are both established beyond doubt. The deuterium Balmer series might lead to a new, optical method of deuterium abundance measurement in the interstellar medium. This may be the only way to observe atomic deuterium in objects like the Magellanic Clouds or low metallicity blue compact galaxies.

1. Introduction

Deuterium is believed to be produced within minutes of the Big Bang and then destroyed through astration. Measuring its abundance brings constraints on Big-Bang nucleosynthesis and on Galactic evolution. Although the evolution of the deuterium abundance seems to be qualitatively understood, the different types of measurements have not yet converged to definite values and still show some dispersion. D/H measurements are mainly performed through Lyman series observations in absorption. We explore here the possibility of using a new method, namely the Balmer emission lines of deuterium, hitherto undetected.

2. Observations

We performed the first detection and identification of the deuterium Balmer lines Dα and Dβ in emission in the Orion Nebula using CFHT + Gecko. The narrowness of these lines (FWHM $\simeq$ 10 km s^{-1}) and their relative fluxes are incompatible with recombination excitation, but could be understood in terms of fluorescence excitation by stellar UV continuum in the Photon Dominated Region (PDR), located behind the ionized region. The velocity shift between the H *i* and D *i* lines agrees with this interpretation (Hébrard et al. 2000a).

By assuming that both the ionization of the H *ii* region and the deuterium fluorescence are due to a 4×10^4 K black body, and that all of the Ly$\beta_{\rm D}$ photons (and only them) produce Dα photons, we predict the flux ratio $I(\mathrm{D}\alpha)/I(\mathrm{H}\alpha) \simeq 3 \times 10^{-4}$, close to the observed value ($\sim 2.2 \times 10^{-4}$). This very coarse estimate shows that deuterium fluorescence is a plausible mechanism.

The discovery of the deuterium Balmer lines was confirmed by new observations of the whole Balmer series in Orion that we secured at the VLT with UVES. The increase of the D *i* lines intensity relative to the H *i* lines with principal quantum number n supports fluorescence rather than recombination as the

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D *i* emission mechanism. The lack of counterparts to D *i* lines other than H *i* (*e.g.,* [N *ii*], [O *ii*], or [O *iii*]) allows any interpretation in terms of emission from high-velocity ionized gas to be excluded (Hébrard et al. 2000b).

Deuterium Balmer lines have been detected in five H *ii* regions with the VLT (M 42, M 8, M 16, M 20, and DEM S 103 in the Small Magellanic Cloud), demonstrating that these lines are of common occurrence. One should note that the detection of Dα in the SMC is the first detection of atomic deuterium in this object by whatever means. Since the metallicity of the SMC is low, the deuterium abundance should be closer to primordial in this extra-galactic region.

Another H *ii* region was observed at the VLT: M 17. Here the emission features detected in the blue wings of the H *i* lines differ from those shown in previous targets: (1) they are broad (FWHM $\simeq 20$ km s^{-1}; (2) their fluxes are proportional to the H *i* lines fluxes; (3) [N *ii*], [O *ii*], and [O *iii*] lines are present counterparts at the same velocity. It is concluded that, in this case, the features should be mainly due to H *i* emission from ionized material.

3. Identification

Here we summarize the different arguments in favor of identifying the observed lines with the deuterium Balmer series, emitted by fluorescence in the PDR.

The lines are produced in the PDR because (1), the narrowness of the lines does imply they originate in a cold, localized region along the line of sight; (2), their radial velocities coincide with those of the neutral and molecular material, not with those of the ionized gas.

They are excited by fluorescence because (1), the narrowness of the lines excludes Raman scattering, stellar light scattering, or recombination; (2), their relative fluxes are incompatible with recombination; (3), their fluxes are roughly in agreement with fluorescence mechanism.

They are identified with deuterium because (1), they are not instrumental artifacts since they have been detected using different instruments (see also O'Dell et al. 2001) and they were not detected in wings from any lines but H *i*, nor in PNe; (2), they are not due to other elements since a whole series is detected; (3) they are not due to high velocity ionized structure, because they are not emitted through recombination and they show no counterparts in other species; and (4), they are not due to H *i* fluorescence in high velocity neutral structures: such structures are unknown whereas these lines are of common occurrence.

References

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