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Pluto's Ultraviolet Spectrum, Airglow Emissions, and Surface Reflectance

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Abstract

In the early morning hours of 2015 July 14, while still more than 300,000 km from Pluto, the Alice ultraviolet spectrograph aboard the New Horizons spacecraft made a series of observations of Pluto to search for airglow emissions. We analyzed 3,900s of these data, and detect airglow emissions from H I, N_2, N I, N II, and CO above the disk of Pluto. We find Pluto's brightness at Lyman-α to be 29.3±1.9R, in good agreement with pre-encounter estimates and several times fainter than the background interplanetary medium brightness of 133.4±0.6R. The detection of the N II multiplet at 1085Å marks the first direct detection of ions in Pluto's atmosphere. We do not detect any emission from argon or other noble gasses and place a 3σ upper limit of 0.14R on the Ar I 1048Å line. We compare the observed brightness of airglow emissions to several pre-encounter model predictions and our own model, which is constrained by atmospheric density profiles observed by New Horizons. Pluto's atmosphere is limb-darkened in the far ultraviolet, and we do not detect any airglow emissions off the limb. We observe the solar flux, reflected from the surface of Pluto, at wavelengths greater than 1400Å. By modeling the atmospheric absorption along the Alice line of sight, we derive a surface reflectance factor (I/F) upper limit of 17% between 1400-1850Å. We show that the for wavelengths greater than 1430Å, the optical depth of Pluto's atmosphere is <1, meaning that solar FUV photons reach the surface and can contribute to space weathering. We also detect methylacetylene (propyne), in absorption at a column density of $\sim 5\times10^{15}$ cm^{-2}, corresponding to a column-integrated mixing ratio of 1.6×10^{-6}.

1. Introduction

On approach to Pluto, Alice made numerous observations in search of airglow emissions. We analyzed 3,900s of these observations, chosen for their favorable pointing and proximity to closest approach. After applying standard Alice data reduction techniques and carefully subtracting scattered light from the Lyman-α airglow emission, the EUV airglow spectrum of Pluto is shown in Figure 1.

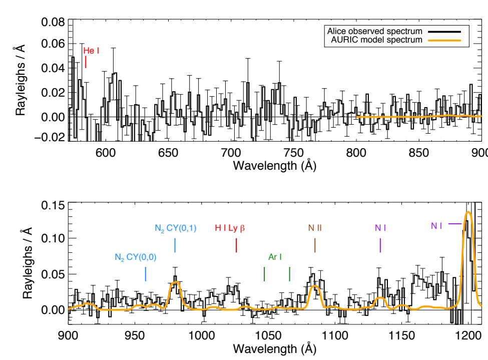

Figure 1: EUV airglow spectrum of Pluto. The orange curve is an airglow model prediction (Lyman-β not included), based on the atmospheric profiles of [1].

The absorption cross section of methane decreases by several orders of magnitude at wavelengths longer than 1400Å. As a result, the vertical optical depth of Pluto's atmosphere is less than unity at these wavelengths, and reflected sunlight dominates Pluto's observed spectrum.

To detect the faint airglow emissions in the FUV, we must subtract the reflected sunlight from Pluto's spectrum. We therefore model absorption by the known species in Pluto's atmosphere [1] and find that absorption by methyl-acetylene is required to match the data. We observe additional absorption by the atmosphere between 1520-1580Å from one or more as yet undetermined species. Between 1400-1850Å, Pluto's surface reflectance appears to be nearly a constant 17%. The far ultraviolet airglow spectrum of Pluto is shown in Figure 2.

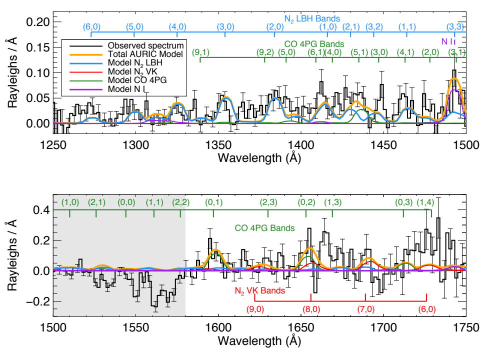

Figure 2: FUV airglow spectrum of Pluto. The region in gray contains absorption not included in our atmospheric model, and thus results in an over-subtraction of the reflected solar spectrum. Predicted airglow spectra are shown with colored lines.

2. Conclusions

The main conclusions of this abstract are as follows:

1. The brightness of IPM Lyman-α at a heliocentric distance of 32.5AU in the direction of Pluto (α=18^h 2^m 38.7^s, δ=-14° 37' 2"), as seen from the New Horizons spacecraft is 133.4±0.6R. Lyman-β has a brightness of 0.24±0.02R, and we place a 3σ upper limit of 0.10R on the brightness of He I 584Å.
2. We have detected airglow emissions from N_2, N I, N II, H I, and CO in Pluto's upper atmosphere. Detected emissions range in brightness from a few tenths of a Rayleigh to 29.3±1.9R for Lyman-α.
3. The discovery of the N II multiplet at 1085Å is the first direct detection of ions in Pluto's atmosphere. However, since this multiplet results from the prompt emission of N II after the dissociative photoionization of N_2, it is not diagnostic of ionospheric density.
4. We detected a new species in Pluto's atmosphere: methylacetylene (propyne): the first detection of a C_3 hydrocarbon in Pluto's atmosphere. In our observations, methylacetylene has a column density of approximately 5×10^{15} cm^{-2}, corresponding to a column-integrated mixing ratio of 1.6×10^{-6}.
5. Solar FUV photons with λ>1430Å reach Pluto's surface, with implications for space weathering. Pluto's surface reflectance between 1400-1850Å is nearly wavelength-independent with an I/F of 0.17.

Acknowledgements

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References

[1] Young, L., Kammer, J., Steffl, A., et al.: Structure and composition of Pluto's atmosphere from the New Horizons solar ultraviolet occultation, Icarus, Vol. 300, pp. 174-199, 2018.