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Investigating Pluto's lower atmosphere from a central-flash stellar occultation

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Abstract

A central-flash occultation is visible when the observer is located near the center of the shadow path. In 2007, we observed a stellar occultation from four sites from New Zealand and Australia. One of our sites, Mt. John Observatory, was 70 km from the shadow center and observed a central flash. Due to the large aperture and predicted near central location for this site, we chose to carry out a dual-wavelength observation from Mt. John Observatory. The central-flash observations for both the blue and red channels were very similar in structure and amplitude. We have modeled the central flash assuming either a haze layer or a thermal gradient. For the haze-only model, the rays contributing to the central flash come from an altitude of 1130 km. This altitude is much less than the current best estimate for Pluto's radius. For this reason, the purely refractive solution (thermal gradient) is preferred to the extinction only solution (haze layer). A thermal gradient of 5 K/km fits the flux level and an ellipticity of 0.085 and a nearly prolate orientation match the separation and relative strength of the two peaks. Intermediate solutions with some haze and some thermal gradient are possible.

1. Occultation observations

The July 31, 2007 occultation was observed from Mt. John Observatory, Auckland Observatory, Mt. Canopus Observatory and our PHOT system (consisting of a 14-in portable telescope and high-speed camera) from Mussleroe Bay Tasmania in Australia. The center of the occultation shadow path passed 70 km from Mt. John. The central-flash part of the stellar occultation light curve is shown in Figure 1.

The red- and blue-channel light curves both show a distinctive double-peak central flash and despite the difference in wavelength both light curves have similar amplitudes.

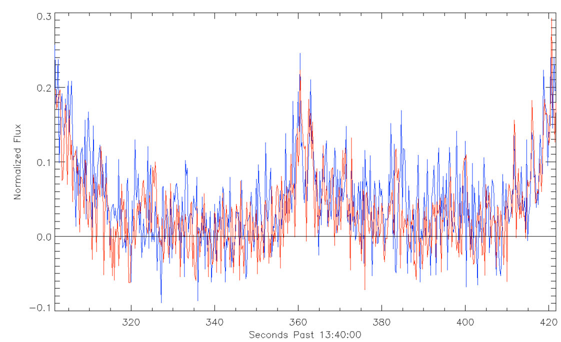

Figure 1: Expanded view of the central-flash as observed from Mt. John Observatory. The red line is the red channel (effective wavelength 0.76 μm) and the blue line is the blue channel (effective wavelength 0.51 μm)

2. Modeling the central-flash data

We modified the central-flash model of French et al. 1998 [1] to include a term for the partial focusing of the starlight due to the curvature of the planetary limb (see Elliot and Young, 1992 [2]). This modification was required because of the small size of Pluto. We modeled the upper atmosphere using results from the main drop and recovery of the light curves observed for this event with a temperature of 103K, pressure of 2.1 μbar and thermal gradient of -0.09K/km at a radius of 1275 km. The lower atmosphere was modeled in two different ways: either an extinction-only model or a thermal-gradient model.

The separation and location of the two peaks of the central flash are sensitive to the ellipticity and orientation of the elliptical profile of the atmosphere. The flux level is sensitive to the haze or thermal

Both models (haze and thermal gradient) fit the data well with an ellipticity of 0.085 and a position angle for ellipse of 85°. The prolate solution is preferred because the initial peak in the central flash is higher than the second peak.

Figure 2 shows the extinction-only model fit. For this model fit, the optical depth for the blue channel is 2.6 ± 1.5 and the ratio of the extinction (blue to red) is 0.99 ± 0.17. The starlight contributing to the central flash is coming from a radius of 1130 km. This radius is implausibly small. Mutual event (Tholen et al. 1997 [3]) and other arguments (Lellouch et al. 2009 [4]) place Pluto's radius at more than 1151 km. The small radius required rules out the extinction-only solution.

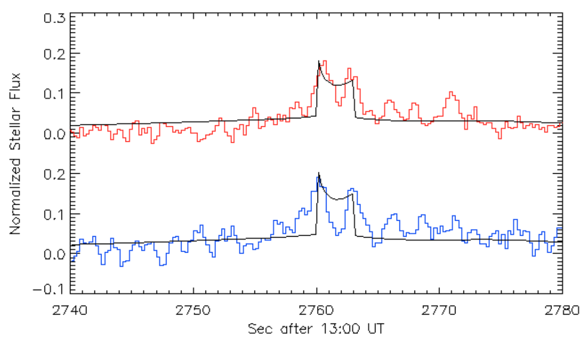

Figure 2: The central flash data (red and blue; binned by 2) and the light curve model based on an elliptical atmosphere.

Next we address the thermal-gradient model. The stellar flux level at the lowest part of the light curve can be modeled with a thermal gradient of 5 K/km. These rays would pass within 1196 km of Pluto's center above the expected radius of Pluto.

It is possible that the lower atmosphere of Pluto is a combination of extinction and thermal gradient.

6. Summary and Conclusions

We fit for the shape of the atmosphere using the central-flash occultation and find the ellipticity of the profile of Pluto's atmosphere on July 2007 is 0.085 with a nearly prolate orientation. We can exclude an extinction-only solution for the lower atmosphere of Pluto. The lower atmosphere is either composed of a thermal gradient or a combination of thermal gradient and extinction. Future work will be to address the depth of the trough between the two peaks of the central flash.

Acknowledgements

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