Near-Infrared Brightness of the Galilean Satellites Eclipsed in Jovian Shadow: A New Technique to Investigate Jovian Upper Atmosphere

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Using the Subaru Telescope and Hubble Space Telescope, we have found that Ganymede and Callisto remain slightly bright at near-infrared (~1.5 μm) even when in the Jovian shadow and not directly illuminated by the Sun (Fig. 1) [1]. Their eclipsed brightness was ~10^{-6} of their uneclipsed brightness, which is low enough that this phenomenon has been undiscovered until now. In addition, Europa in eclipse was not detected except a rare case explained later. Likewise, Ganymede was not detected at 3.6 μm by the Spitzer Space Telescope, suggesting a significant wavelength dependence (Fig. 2).

We considered several possibilities to understand why the satellites remain ever-so-slightly bright even when they are in eclipse. A possibility of illumination from Jupiter by lightning, aurora, and nightside airglow was investigated. However, it is difficult for these illuminators to explain the fact that the brightness of Europa was much darker than the others because Europa was located closer to Jupiter. Next possibility of atmospheric emission from the satellites was also rejected, because the non-detection of Ganymede in eclipse at 3.6 μm is difficult to explain by its atmosphere expected to have OH molecules (Fig. 2) [2]. Only once we detected Europa in eclipse, and it was explained by sunlight reflected from Io out of eclipse located near Europa on that day, but we also confirmed that such reflection from other satellites out of eclipse cannot explain the brightness of Ganymede and Callisto in eclipse we detected.

The most plausible explanation is indirect forward scattering of sunlight by hazes in the upper Jovian atmosphere. Based on this theory, the fact that Europa was darker than the others can be explained because the effect of the scattered sunlight should be less at a satellite closer to Jupiter. In addition, the similarity between spectra of Jupiter and Ganymede in eclipse (Fig. 2) can be also explained because Ganymede was illuminated by the sunlight through Jovian upper atmosphere. If it is the case, this new method of studying the upper atmosphere of Jupiter via transmitted sunlight provides a basis for the study of the exoplanet atmosphere, whose atmosphere is investigated via transmitted starlight during transit observations.

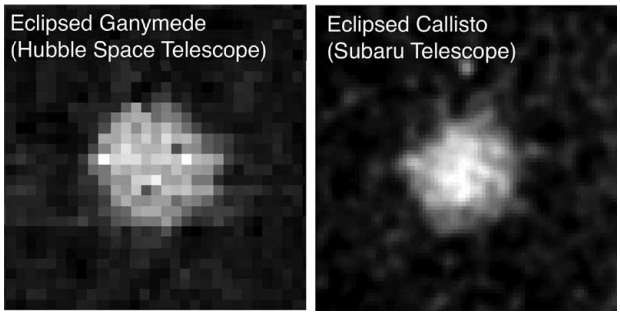

Figure 1: Images of Ganymede (left) and Callisto (right) obtained while they are eclipsed by Jupiter.

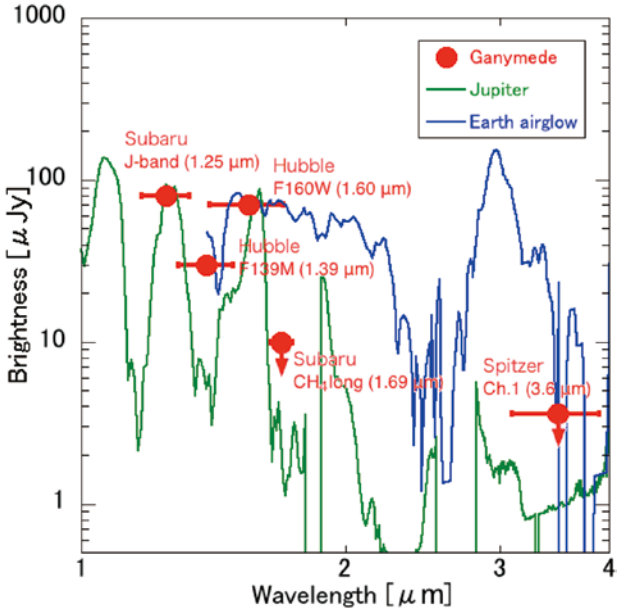

Figure 2: Spectral energy distribution of Ganymede in eclipse. Spectra of Jupiter [3] and the Earths atmosphere [4] are also shown, scaled to the Ganymede brightness.

References

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