Measuring the Size of Saturn's Shadow onto its Rings

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Observers of Saturn are very familiar with its shadow onto its rings, typically visible as a one arc-second wide gap between Saturn and its ring system. It is known as sharp, round, featureless, and without color. On March 7, 2003, the Hubble Space Telescope took images of Saturn in 30 filters, from the ultraviolet to the near-infrared. They revealed that the outermost part of the shadow is orange. This is similar to the color of the moon during a deep total lunar eclipse.

The color and size of the umbra during a lunar eclipse has yielded insights into the state of Earth's stratosphere. The size varies slightly with the absorption present in the stratosphere. The color of the umbra changes from eclipse to eclipse and also with location within a single eclipse. The outermost part of the umbra is bluish if the light rays go through areas of large ozone abundance. The umbra can become almost black when stratospheric aerosols are present, such as after major volcanic eruptions. This is a very sensitive probe of the optical depth of aerosols in the stratosphere because of the long path length of light rays through the atmosphere during a lunar eclipse.

We measured the size, shape and color of Saturn's shadow onto its rings to see if we can get insights about Saturn's atmosphere. For each of 36 images in 28 filters, spanning wavelengths 0.26 - 2.2 micrometers, and for each of about 100 ringlets of Saturn's rings, we measured the location at the edge of Saturn's shadow, defined here as the location where the intensity drops to half of the intensity outside the shadow. We compared our measurements with theoretical calculations, taking into account refraction and extinction in Saturn's stratosphere. For each image, we get consistent values for all probed latitudes of Saturn to about 0.1 pixel, indicating that there are no major latitudinal variation in the extinction. We detect a significant variation of the size of the shadow with wavelength.

In the ultraviolet and visible, the size of Saturn as measured by its shadow drops from 300 km above the 1-bar level at the shortest wavelength to about 100 km above the 1-bar level in the red part of the spectrum. This is entirely due to Rayleigh scattering and produces an orange color near the edge of the shadow. Thus, aerosols in Saturn's stratosphere are not significantly contributing to the extinction. In the near-infrared, methane absorption strongly varies with wavelength and thus the measured size of Saturn varies strongly too. Our measurements constrain methane absorption coefficients at about 1 mb pressure, 140 K temperature, and 5000 km pathlength, which are very far from any laboratory conditions. Our data at the strong methane band at 890 nm wavelength indicate slightly lower methane absorption compared to extrapolations from laboratory measurements. These and further measurements will help the analysis of methane band images of the Jovian planets.

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