Jupiter's Phase Variations From Cassini: a testbed for future direct imaging missions

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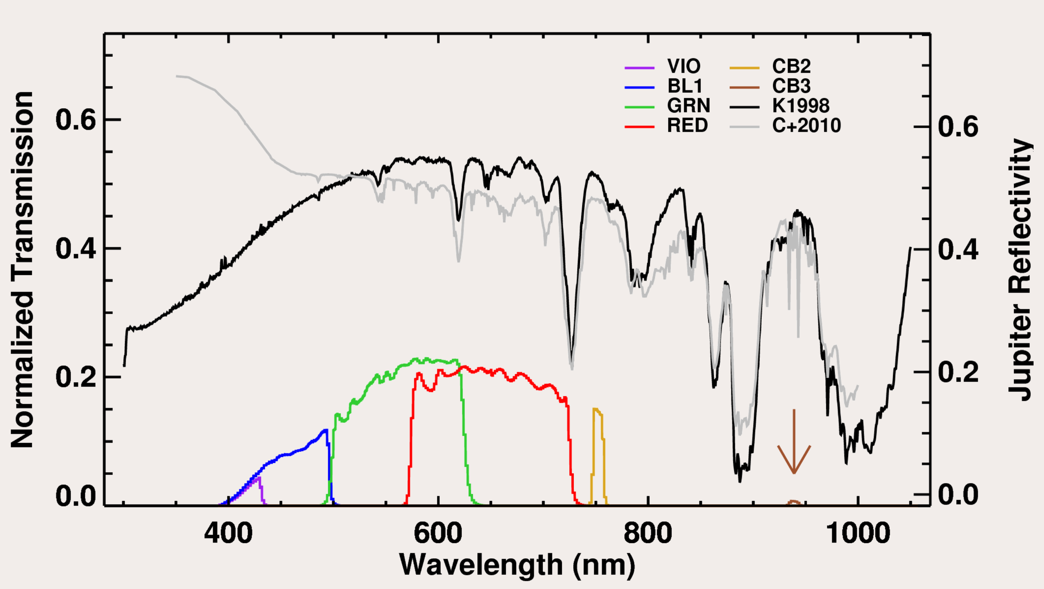
Background

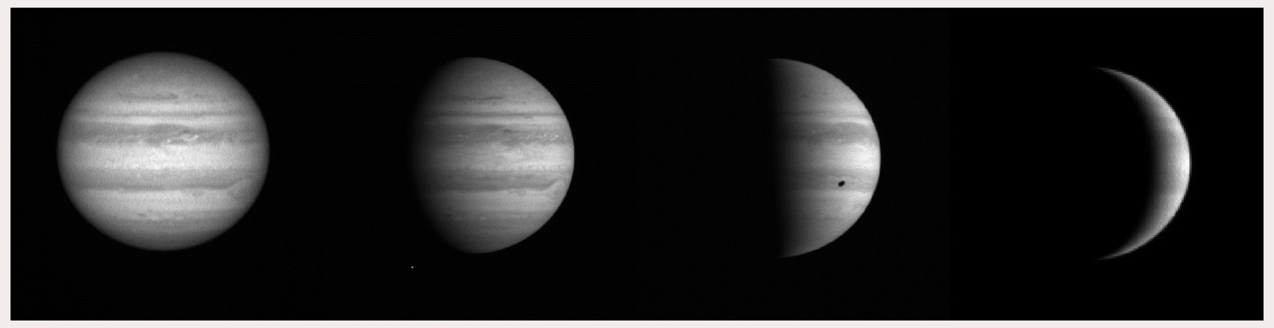
The reflectivity of an exoplanet, or albedo, defines its energy budget and influences its atmospheric temperature, its evolution through time, and defines its detectability. Complete measurements of a planet's albedo requires observations of the planet at all wavelengths and phase angles, α. These observations are called phase curves and are defined generally as follows.

$$\frac{F_p(\lambda,\alpha)}{F_*(\lambda)} = A_g(\lambda)\left(\frac{R_p}{d}\right)^2 \Phi(\lambda,\alpha)$$

The phase function, denoted $\Phi(\lambda,\alpha)$, is often a Lambertian for simplicity. Cassini/ISS is equipped similarly to future direct imaging missions – both are targeting cool giant planets. The Millennium flyby in late 2000 to early 2001 sufficiently imaged Jupiter to generate phase curves in several filters. We fit the phase functions and examine Jupiter's wildly varying color to demonstrate the complex nature of cool giant planets.



The filter transmission curves for the WAC filters used in this study with Jupiter's albedo spectrum from Karkoschka et al. 1998 and the Jupiter-like model from Cahoy et al. 2010.



Example of fully-reduced GRN filter images of Jupiter at about 0°, 50°, 90°, and 125° (left to right).

Acknowledgements

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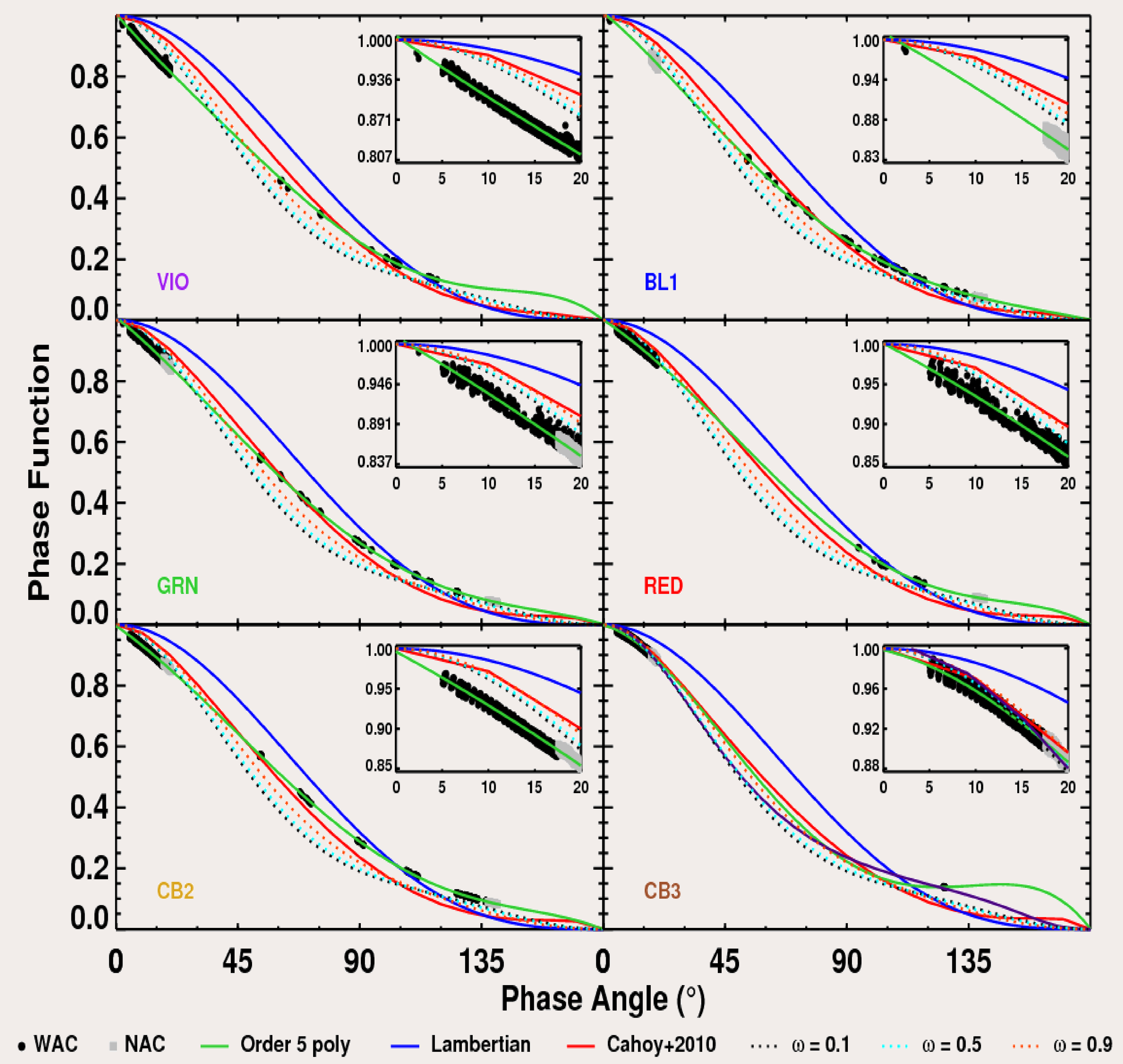
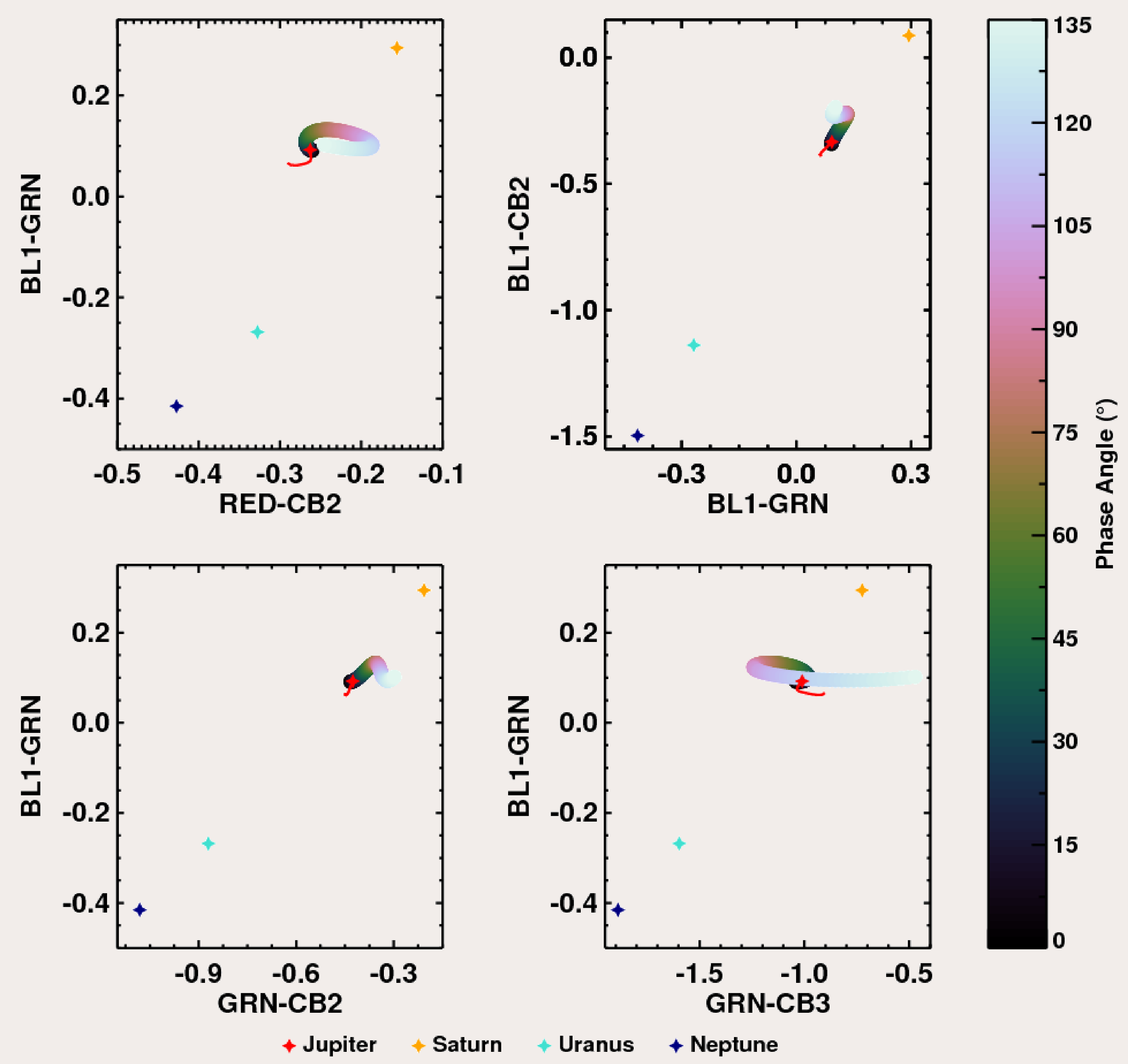
Results



The phase functions for all of the filters in our study and the best fit 5th order polynomial compared to several models. The Dyudina et al. 2015 phase function for CB3 is overplotted in that panel in purple for reference.

Jupiter's brightness falls off more steeply near full phase than previously predicted (inset plots). **Jupiter is also significantly darker than a Lambertian model** in the 60–120 degree regime (~25% near quadrature), where future observations are most likely. The models of Cahoy et al. 2010 and Madhusudhan et al. 2012 represent a uniformly cloudy or clear atmosphere, respectively, and perform as expected.

Jupiter's color exhibits larger variation with phase angle than predicted by Cahoy et al. 2010, ~0.8 mag across all phases and ~0.3 mag between 60–120 degrees. We expect that this color variability is typical of planets, due to their complex structure of clouds and hazes. **Suboptimal filter selection or lack of multi-bandpass observations may hinder classification efforts** and cause Jupiter-twins to appear as different class planets.



Color-color diagrams for Jupiter as a function of phase angle and the Jupiter-like planet of Cahoy et al. 2010 (red curve). The colored stars indicate the Karkoschka et al. 1998 filter-integrated colors of Jupiter at 6.8°, Saturn at 5.7°, and Uranus and Neptune at ~0°