PHOTOCHEMISTRY IN SATURN'S ATMOSPHERE: RING SHADOW AND RING REFLECTION.

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Abstract: Cassini orbited Saturn for over thirteen years, nearly a half Saturn year. During this period, the ring shadow has moved from covering a relatively large portion of the northern hemisphere (Figure 1a) to covering a large swath of territory south of the equator as solstice approaches. At Saturn Orbit Insertion on July 1, 2004, the sub-solar point was ~24º South. At this time, the projection of the optically thick B-ring onto Saturn reached as far as 40ºN at the central meridian (~52ºN at the terminator). At its maximum extent, the ring shadow can reach as far as 48ºN/S (~58ºN/S at the terminator). The net result is that the intensity of both ultraviolet and visible sunlight penetrating into any particular latitude will vary greatly depending on both Saturn's axis relative to the Sun and the optical thickness of each ring system. In essence, the rings act like semi-transparent Venetian blinds (Figure 2) over the atmosphere of Saturn.

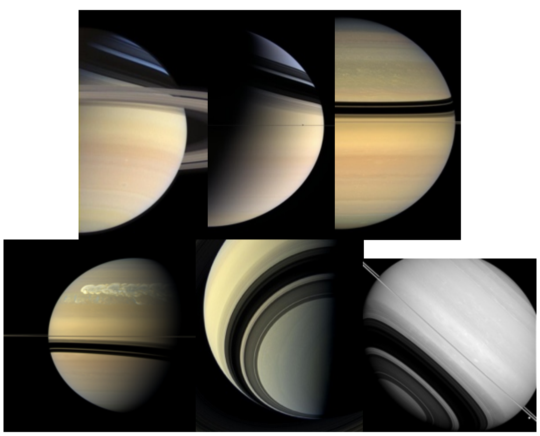

Figure 1. Saturn's atmosphere changes in response to the changing inclination of the ring plane relative to the Sun: (a) December 14, 2004, (b) March 16, 2006, (c) April 23, 2008, (d) July 6, 2011, (e) July 29, 2013, (f) November 24, 2014. Images are courtesy of NASA/JPL/Space Science Institute.

Previous work [1,2] examined the variation of the solar flux as a function of solar inclination, i.e. ~7.25 year season (Figure 3) at Saturn. Beginning with methane, phosphine and ammonia, we investigate the impact on production and loss rates of the long-lived photochemical products leading to haze formation at several latitudes over a Saturn year. Here, we report on how the oscillating ring shadow modifies the photolysis and production rates of hydrocarbons in Saturn's stratosphere and upper troposphere, including acetylene, ethane, and propane. A new element of this work is that the magnitude of reflected UV sunlight from the rings on the atmosphere illuminated by ring-shine is further explored. Detailed calculations of geometric parameters for scattering off of the rings onto an oblate planet have been worked in detail for a fine grid of latitudes and longitudes. Ultraviolet ring reflectancs from previously published UVIS data is incorporated.

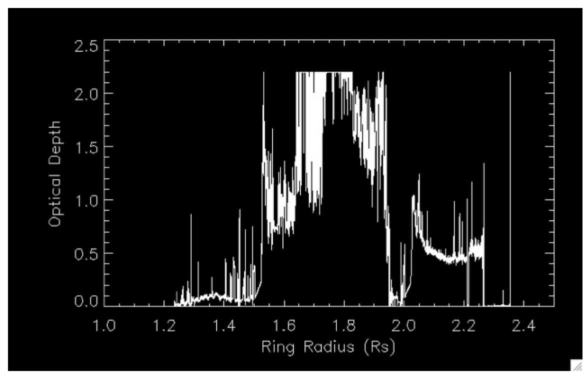

Figure 2. The optical depth of Saturn's rings in the ultraviolet (Josh Colwell, *pers. comm.*) The rings act like a periodic Venetian blind that will shield atmospheric molecules from solar photons.

Similarly, we assess the impact of these effects on phosphine abundance, a disequilibrium species whose presence in the upper troposphere is a tracer of convection processes in the deep atmosphere. Comparison to the corresponding rates for the clear atmosphere and for the case of Jupiter, where the solar insolation is known to be insignificant (~3º inclination), will also be presented. Our ongoing analysis of Cassini's CIRS, UVIS, and VIMS datasets that provide abundances of key molecules and estimates of the evolving haze content of the both hemispheres is updated.

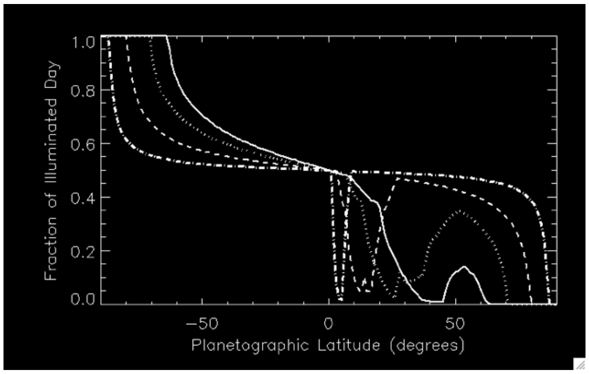

Figure 3. This plot illustrates the fraction of Saturn's day that is illuminated by the Sun as a function of solar declination, i.e. season. The curves correspond to sub-solar points of 26.7ºS (solid), 19.6ºS (dotted), 10.7ºS (dashed), and 3.5ºS (dot-dashed). Ultimately, this will determine the flux of photons allowed to enter the atmosphere relative to those of a clear, unshaded atmosphere.

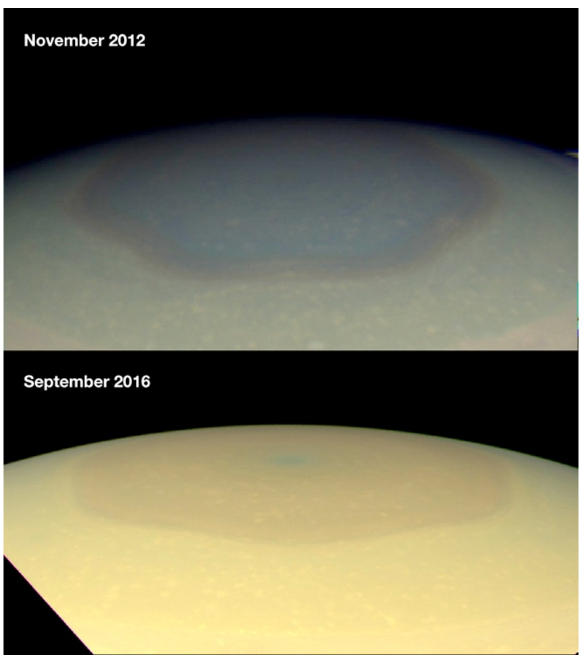

Figure 4. One of the aims of this exercise is to characterize the haze content Saturn's atmosphere. Several Cassini data sets from ISS (above) and VIMS (below) are being used to meet this goal.

The implications for dynamical mixing on the transport of molecules and haze is explored. In particular, we will examine how the now famous hexagonal jet stream (Figure 4) acts like a barrier to transport, isolating Saturn's north polar region from outside transport of photochemically-generated molecules and haze. Future research will explore the role to which increasingly intense sunlight plays in the buildup of hydrocarbon hazes in the polar region and determine exactly how isolated polar region is unaffected by transport from more southerly latitudes.

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References:

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[2] Edgington, S.G., R.A. West, K.H. Baines, S.K. Atreya, E.H. Wilson, G.L. Bjoraker, L.N. Fletcher, and T. Momary, 2012. Photochemistry in Saturn's Ring Shadowed Atmosphere: Modeling, Observations, and Preliminary Analysis. *Bull. American. Astron. Soc.*, **38**, 499 (#11.23)