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The Case for Massive and Ancient Rings of Saturn

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Analysis of Voyager and Pioneer 11 results give a mass for Saturn's rings, M = 5 x 10-8 Msat. This is about the mass of Saturn's small moon Mimas. This has been interpreted as a lower limit to the ring mass (Esposito et al 1983), since the thickest parts of the rings were not penetrated by the stellar occultstion, and this calculation assumes an unvarying particle size throughout the rings. Because the rings are constantly bombarded by micrometeroids, their current composition of nearly pure water ice implies such low mass rings must have formed recently. The case is par-ticularly strong for Saturn's A ring, where the data are the best, implying the A ring is less than 10% of the age of the Saturn (Esposito 1986). Cassini results com-pound this problem. UVIS spectra are consistent with either young rings or rings about 10x as massive as the Voyager estimate (Elliott and Esposito (2011). CDA confirms the impacting mass flux is similar to that as-sumed for the pollution calculations (Kempf etal 2015). VIMS analysis of density wave signatures in the B ring gives a value of about 1/3 the Voyager value (Hedmann etal 2016). This VIMS result implies the rings are even younger! The problem is that young rings are very unlikely to be formed recently, meaning that we live in a very special epoch, following some unlikely recent origin… like disruption of a medium sized moon or capture of the fragments of a disrupted comet. This paradox (Charnoz etal 2009) is unre-solved.
Alternative interpretations: To take the VIMS results at face value, Saturn's low mass rings must be very young. The optically thick B ring must be made of small, porous or fractal particles. This is hard to understand, since the particles are continually colliding every few hours and temporary aggregates will stir the collision velocities to higher values. An alternative is that we accept the higher mass interpretation of the Pioneer 11 results (Esposito etal 2008) using the granola bar model of Colwell etal 2007. This would imply that the density wave structure seen by VIMS is not sensing all the mass in the rings, where structure near strong resonances is dominted by temporary aggregates, and where non-linear effects cause the parti-cles to jam (Lewis and Stewart 2009). The density waves may be seeing the mass density in the gaps be-tween self-gravity wakes, whose optical depth is roughly contant and considerably lower than the total B ring opacity (Colwell etal 2007). These massive rings would be consistent with the origin model of Canup (2011) where a Titan-sized difffenrtiated moon was disrupted early in Saturn's formation.