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An absolute radius scale for Saturn's rings from Cassini RSS, VIMS, and UVIS occultations

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Abstract

The radial structure of Saturn's rings has been revealed in remarkable detail from over 150 stellar and radio occultation observations obtained using the Cassini RSS, VIMS, and UVIS instruments. As part of a comprehensive determination of the orbital properties of hundreds of sharp-edged ring features, we have established an absolute radius scale for the ring system with an estimated absolute accuracy of about 200 m. Using an iterative approach, we identified a set of 70 high-SNR and accurately measureable equatorial and quasi-circular features in the Cassini Division and the C and B rings, solved for low-order corrections to the nominal spacecraft trajectory, and accounted for a number of small systematic effects that affected the fitted ring plane radius of individual ring features at the few hundred meter level. In the end, we fitted over 8300 individual ring measurements, with a post-fit standard deviation per DOF of only 140 m. The number of measurements per ring varied between 68 and 158, with fewer measurements for the inner C ring features that were less-frequently captured during chord occultations. As part of the fit, we took account of both free and forced normal modes for some of the rings. In particular, 11 C ring "circular" features were measurably affected by the m=1 mean motion resonance associated with Titan, and the four nearly circular Cassini Division features used for this study revealed the m=2 mean motion resonance with Mimas. A few additional low-order free normal modes had fitted radial amplitudes greater than 100 m, our criterion for inclusion in the orbit model. The ring-by-ring RMS residuals varied from a remarkably small 86 m to 221 m; we excluded from consideration all quasi-circular features with RMS residuals in excess of 250 m. The formal absolute error in the ring radii is only 20 m, but this ignores significant sources of potential systematic error, such as uncertainties in Saturn's rotational pole direction and precession rate, slight errors in the catalog positions of the occulted stars, and residual errors in the Cassini spacecraft trajectory. From sensitivity studies in which we varied the pole direction and precession rate by plausible amounts from the nominal values, our current estimate of the accuracy of the radius scale is closer to about 200 m, as note above. Our derived radius scale agrees to within about 1 km with the less accurate results given by French et al. 1993 [1], which were based on Voyager 1 and 2 occultation observations and multiple-station observations of the occultation of 28 Sgr in 1989. Our next steps will be to compare our solutions with results of a completely independent orbit-fitting code that does not make use of the reconstructed spacecraft trajectories we have employed in our fits, and to quantify the sensitivity of the derived radius scale to the assumed Saturn pole direction and precession rate. With these results in hand, we will then perform a global solution for Saturn's pole direction, precession rate (and implicitly, Saturn's moment of inertia) by including all historical Voyager 1 and 2, 28 Sgr, and HST occultation observations. These results will be useful for ring studies that require a highly accurate radius scale for each occultation, such as determining the relative phases of unidentified density waves in the C ring, examining the internal structure of features such as the Maxwell Ringlet, and examining structures associated with satellite resonances.

References

[1] French, R. G., and 17 colleagues 1993. Geometry of the Saturn system from the 3 July 1989 occultation of 28 SGR and Voyager observations. Icarus 103, 163-214.