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The ballistic transport instability and structure formation in Saturn's B and C-rings

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Abstract

We take a fresh look at the dynamics of the ballistic transport instability, as first proposed by Durisen (1995), and consider its role in the formation of 100 km radial wavetrains and `flat' zones in the inner B-ring and 100 km plateaus and low-amplitude 1000 km undulations in the C-ring.

The physical problem is reformulated so as to apply to a local patch of disk (the shearing sheet), which, with a few other weak assumptions, considerably simplifies the mathematics. The new streamlined model helps facilitate our physical understanding of the instability, and also makes more tractable the analysis of its nonlinear dynamics.

For realistic throw distributions, a simple stability criterion emerges in terms of background optical depth and the magnitude of the local viscosity. This criterion suggests that the A-ring is always stable while the inner B-ring and the C-ring are probably unstable but near criticality.

We subsequently show, with analytical methods and simulations, that the instability saturates through the generation of slowly moving nonlinear wavetrains of various amplitudes and morphologies. There is also an interval of optical depth near 1, where the system can be in either a stable wave state or a stable homogeneous ('flat') state. Here the rings are 'bistable' and exhibit hysteresis behaviour.

This analysis suggests that indeed low-amplitude waves should characterise the C-ring, while the inner B-ring may split into flat and wavy zones, in accord with observations. However, a more detailed comparison of the morphologies of these structures, requires the inclusion of further physical effects in our model.

References

[1] Durisen, R. H., 1995. Icarus, 115, 66