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How does Saturn's moons influence the velocity dispersion in the A ring

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Abstract

Saturn's moons perturb the rings due to their gravitational interactions with the ring material. Here, we present a model which accounts for the heating of the ring material due to these perturbations. The results emphasize the importance of the moon Prometheus for the velocity dispersion in the outer A ring of Saturn, which is probably 10 times higher than in the innermost A ring. An enhanced velocity dispersion would in turn lead to an enhanced production of smaller debris particles by knocking them off from larger parent bodies. This could lead to an increasing optical depth and brightness and limit the observability of the self-gravity wakes in the outer A ring. Furthermore, the velocity dispersion can be strongly enhanced in the vicinity of the major resonances (e.g. Janus 5:4) explaining the observed halos around them.

1. Model

The kinetic energy in the rings is determined by gain and loss terms

$$\frac{dc^2}{dt} = \left.\frac{dc^2}{dt}\right|_{\text{coll}} + \left.\frac{dc^2}{dt}\right|_{\text{shear}} + \left.\frac{dc^2}{dt}\right|_{\text{torque}} \quad (1)$$

whose balance accounts for the equilibrium. In the following we treat the square of the velocity dispersion $c^2 = 2E_{\text{kin}}/M$ rather then the specific kinetic energy E_{kin}/M. We consider three contributions to the energy balance: (a) Collisions, which lead to a dissipation of energy - cooling, (b) shear, which heats the ring material due to viscous friction and (c) angular momentum transfer, which also leads to an increasing kinetic energy of the ring particle, and thus, a heating.

1.1 Inelastic collisions

The inelastic collisions of the particles lead to a loss of kinetic energy (e.g. [6, 9])

$$\left.\frac{dc^2}{dt}\right|_{\text{coll}} = -k_1 \tau \Omega (1 - \epsilon_{\text{n}}^2) c^2 \quad (2)$$

where τ and Ω are the optical depth of the ring and the Keplerian frequency of the orbit. The inelasticity of the collisions is quantified by the coefficient of restitution ϵ which determines the relative loss of the relative velocity during a collision. The constant k_1 is of the order unity, where we use $k_1 = 1/3$ (see [6]). In case of tangential friction the amount of dissipated energy would be larger.

1.2 Shear friction

The Keplerian shear causes a friction which heats the medium. The amount of energy dissipated by unit time is given by

$$\left.\frac{dc^2}{dt}\right|_{\text{shear}} = k_2 \nu \left(\frac{3\Omega}{2}\right)^2 \quad (3)$$

(e.g. [6, 9]) where the viscosity is denoted by ν and the constant k_2 is set to unity.

1.3 Angular momentum transfer

The moons outside and inside the rings exchange angular momentum with the ring particles due to gravitational interactions. The main contribution is exchanged due to the first order Lindblad resonances. In a dissipating ring the angular momentum transfer leads also to an exchange of energy which can be quantified by

$$\left.\frac{dc^2}{dt}\right|_{\text{torque}} = 2\Omega \sum_m \left(\frac{r}{a_m}\right)^{3/2} \frac{T_m}{M} \quad (4)$$

[3], where we sum over the contributions of all perturbing moons. As a model of the transfered specific angular momentum T_m/M we use a continuous [3] or a discrete model [4]. The semi-major axis of the moons and the radial ring position are denoted by a_m and r.

2 Results

Figure 1 shows the resulting equilibrium velocity dispersion in the A ring. The shear (dashed line) is the leading heating term in the inner A ring where the torque term (dotted line) of the moon Prometheus dominates in the outer A ring. Additionally the torque contributions of the ring moons Pan and Daphnis are included resulting in an enhanced velocity dispersion around the Encke and Keeler Gap. Furthermore, a discrete torque model has been used for the Janus and Mimas resonances leading to an increased velocity dispersion around these resonances.

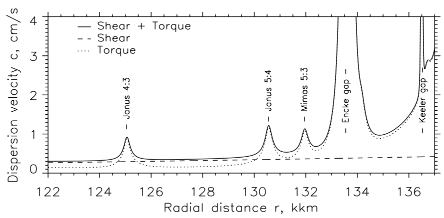

Figure 1: Calculated velocity dispersion in the A ring, where the contributions of shear (dashed line), torque (dotted line) and both (line) are plotted.

3 Conclusions

The velocity dispersion is significantly enhanced in Saturn's outer A ring and in the vicinity of the strong resonances due to interactions between ring material and moons. These higher velocities could (i) suppress the formation of self-gravity wakes and (ii) support the production of smaller ring particles in this regions. Both could explain two phenomena observed in these ring regions: (1) Brightness halos and changes of the spectral properties have been observed around strong resonances (e.g. Janus 5:4 and Mimas 5:3, [5, 7]). (2) The self-gravity wakes cause a brightness asymmetry [8, 2] and a asymmetry in the optical depth profiles between ingress and egress occultation scans (UVIS, VIMS) [1, 5] which are reduced in the outer A ring. Both observations support the model discussed here and motivate its further development.

Acknowledgements

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References

[1] J. E. Colwell, L. W. Esposito, and M. Sremčević. Self-gravity wakes in Saturn's A ring measured by stellar occultations from Cassini. *Geophysical Research Letters* , 33:7201, 2006.

[2] R. G. French, H. Salo, C. A. McGhee, and L. Dones. HST observations of azimuthal asymmetry in Saturn's rings. *Icarus*, 189:493–522, 2007.

[3] P. Goldreich and S. Tremaine. Disk-satellite interactions. *Astrophysical Journal* , 241:425–441, 1980.

[4] R. Greenberg. The role of dissipation in shepherding of ring particles. *Icarus*, 53:207–218, 1983.

[5] M. M. Hedman, P. D. Nicholson, H. Salo, B. D. Wallis, B. J. Buratti, K. H. Baines, R. H. Brown, and R. N. Clark. Self-Gravity Wake Structures in Saturn's A Ring Revealed by Cassini VIMS. *Astronomical Journal* , 133:2624–2629, 2007.

[6] R. Morishima and H. Salo. Simulations of dense planetary rings. IV. Spinning self-gravitating particles with size distribution. *Icarus*, 181:272–291, 2006.

[7] P. D. Nicholson, M. M. Hedman, R. N. Clark, M. R. Showalter, D. P. Cruikshank, J. N. Cuzzi, G. Filacchione, F. Capaccioni, P. Cerroni, G. B. Hansen, B. Sicardy, P. Drossart, R. H. Brown, B. J. Buratti, K. H. Baines, and A. Coradini. A close look at Saturn's rings with Cassini VIMS. *Icarus*, 193:182–212, 2008.

[8] H. Salo, R. Karjalainen, and R. G. French. Photometric modeling of Saturn's rings. II. Azimuthal asymmetry in reflected and transmitted light. *Icarus*, 170:70–90, 2004.

[9] J. Schmidt, K. Ohtsuki, N. Rappaport, H. Salo, and F. Spahn. Dynamics of Saturn's Dense Rings. In Dougherty, M. K., Esposito, L. W., & Krimigis, S. M., editor, *Saturn from Cassini-Huygens*, chapter 14, pages 413–458. Springer Heidelberg, 2009.