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# Self–Confinement of Narrow Eccentric Ringlets

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## ABSTRACT

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## 1. INTRODUCTION

Narrow eccentric ringlets have properties that are both interesting and not well understood: they have very sharp edges, they have sizable eccentricity gradients, and the mechanism that prevents their radial spreading due to ring viscosity is of debate. Prevailing ringlet confinement mechanisms include: unseen shepherd satellites (reference), periapse pinch (ref), self gravity (ref), and self-confinement (ref). The following uses N-body simulations to investigate whether narrow eccentric ringlets might be self-confining.

## 2. RINGLET CONFINEMENT MECHANISMS

This section will explain the pros and cons of the various ringlet confinement mechanisms, and then motivate the possibility that ringlets are self confining. That possibility is then investigated via numerical simulations that use the epi_int_lite N-body integrator.

## 3. EPI_INT_LITE

epi_int_lite is a child of the epi_int N-body integrator that was used to simulate the outer edge of Saturn's B ring as it is sculpted by perturbations from satellite Mimas Hahn & Spitale (2013). Although the epi_int integrator is well-suited to evolve the B ring edge over the $10^4$ orbits needed to monitor the B ring's response to Mimas perturbations, that code was unable evolve with sufficient accuracy over the $10^6$ orbits needed to investigate a viscous ringlet's slow radial spreading, and that inability was traced to epi_int's drift step.

Epi_int is a drift-kick integrator, and such integrators alternate between drifting (ie advancing) a particle along its unperturbed trajectory, with each drift followed by a velocity kick that accounts for all other perturbing forces such as ring self gravity and ring viscosity. Drifting a particle efficiently

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along its unperturbed trajectory around an oblate planet requires an analytic expression for that trajectory, and epi_int utilized the Borderies-Rappaport & Longaretti (1994) solution that requires, at every timestep, the conversion of the particle's spatial coordinates and velocities into geometric orbit elements, with the drifted particle's orbit elements then converted back to spatial coordinates every timestep. That conversion is accurate to order $\mathcal{O}(e^2)$ where $e$ is the particle's geometric eccentricity, but the conversion from spatial coordinates to orbit elements and back is not reversible, which means that the drifted particle's trajectory acquires an $\mathcal{O}(e^3)$ error every timestep. Although the accumulation of this error was too slow to significantly impact epi_int's B ring simulations spanning $10^4$ orbit periods, this error does preclude using that code to simulate the much slower viscous evolution of ringlets over $10^6$ orbit periods.

To avoid this accumulation of drift errors, Section 3.2 derives an alternate set of geometric orbit elements that describe the particle's unperturbed motion around an oblate planet. Note though the conversion of spatial coordinates to the new geometric orbit elements is exact and reversible, and so epi_int_lite's drift step is not a significant source of error.

### 3.1. *code design philosophy*

The chief principal guiding the developement of epi_int_lite is that the code be accurate to solve the problem at hand while also being as simple as possible so that the code can be developed, tested, and executed as swiftly as possble. With this in mind, several simplifying approximations are made and are detailed below in Section 3.3 and they simplify code development and shorten run times significantly. Section 4 then assesses the impact of those approximations, and shows that they are truly negligable and do not affect outcomes or conclusions.

### 3.2. *drift-kick*

### 3.3. *approximations*

## 4. TESTING THE APPROXIMATIONS

acknowledgments...

## APPENDIX

## A. APPENDIX

appendix...

## REFERENCES

Borderies-Rappaport, N., & Longaretti, P.-Y. 1994, Icarus, 107, 129

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