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N-body simulations of the Self–Confinement of Viscous Self–Gravitating Narrow Eccentric Planetary Ringlets

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ABSTRACT

The following shows how narrow eccentric planetary ringlets can evolve into a self–confining state.

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1. INTRODUCTION

Narrow eccentric planetary ringlets have properties both interesting and not well understood: sharp edges, sizable eccentricity gradients, and a confinement mechanism that inhibits radial spreading due to ring viscosity. Prevailing ringlet confinement mechanisms include: unseen shepherd satellites (reference), periapse pinch (ref), self gravity (ref), and self-confinement (ref). This study uses N-body simulations to show how narow self–gravitating ringlets can evolve into a self-confining state.

2. RINGLET CONFINEMENT MECHANISMS

This section explains the pros and cons of the various ringlet confinement mechanisms, and then motivates the possibility that ringlets are self confining. That possibility is explored further via numerical simulations using 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 that is sculpted by satellite perturbations (Hahn & Spitale 2013). The new code is very similar to its parent but differs in three significant ways: (*i.*) epi_int_lite is written in python and recoded for more efficient execution, (*ii.*) epi_int_lite uses a more accurate drift step for unperturbed motion around an oblate planet (detailed in Appendix A), and (*iii.*) epi_int_lite uses the $C = 1$ approximation that is justified below (Appendix B).

Otherwise epi_int_lite's treatment of ring self–gravity and viscosity are identical to that used by the parent code; see Hahn & Spitale (2013) for additional details. The epi_int_lite source code is available

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at https://github.com/joehahn/epi_int_lite, and the code's numerical quality is assessed in Appendix C where the output of several numerical experiments are compared against theoretical predictions.

Calculations performed by epi_int_lite use natural units with gravitation constant $G = 1$, central primary mass $M = 1$, and the ringlet's inner edge has initial radius $r_0 = 1$, and so the ringlet masses m_r and radii r quoted below are in units of M and r_0. Converting code output from natural units to physical units requires choosing physical values for M and r_0 and multiplying accordingly, and when this text does so it assumes the primary's mass is Saturn's, $M = 5.68 \times 10^{29}$ gm, and a typical ring radius of $r_0 = 1.0 \times 10^{10}$ cm.

4. N-BODY SIMULATIONS OF VISCOUS GRAVITATING RINGLETS

This Section describes a suite of N-body simulations of narrow viscous gravitating planetary ringlets, to highlight the range of initial ringlet conditions the do evolve into a self-confining state, and those that do not.

4.1. *nominal model*

This nominal model evolves into the self-confining state...

acknowledgments...

APPENDIX

A. APPENDIX A

Derive the more accurate drift step used by epi_int_lite...

B. APPENDIX B

Detail the $C = 1$ approximation used by epi_int_lite, and show that the errors associated with this approximation are negligable...

C. APPENDIX C

Compare epi_int_lite to theoretical predictions

C.1. *radial spreading of viscous viscous*

Show that ringlet viscosity causes circular non-gravitating ringlet to spread at the expected rate...

REFERENCES

Hahn, J. M., & Spitale, J. N. 2013, ApJ, 772, 122