An Introduction to N-body Codes

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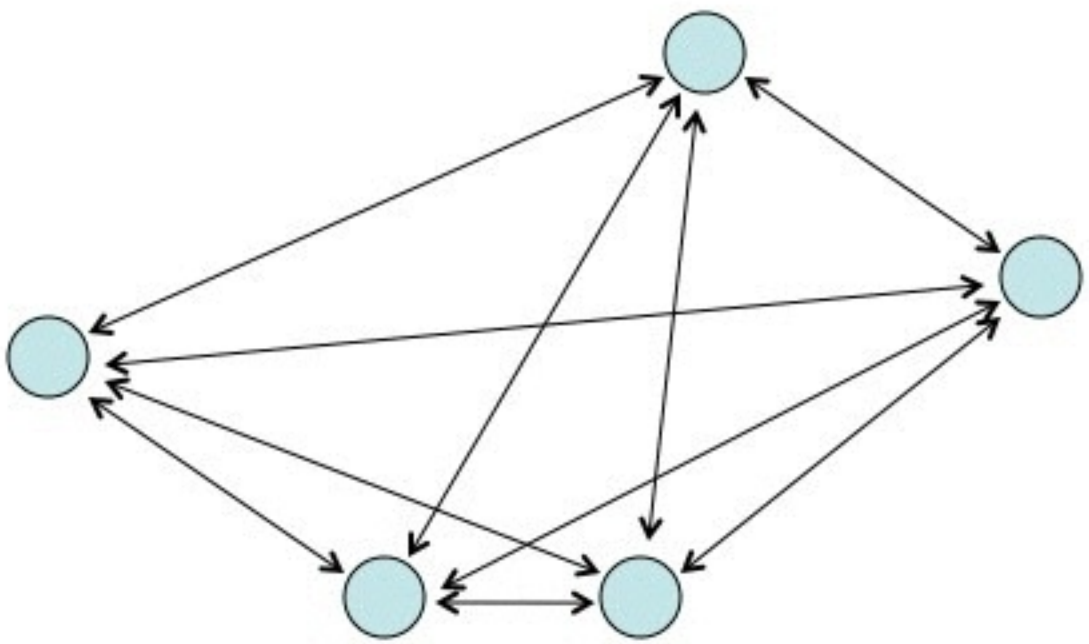
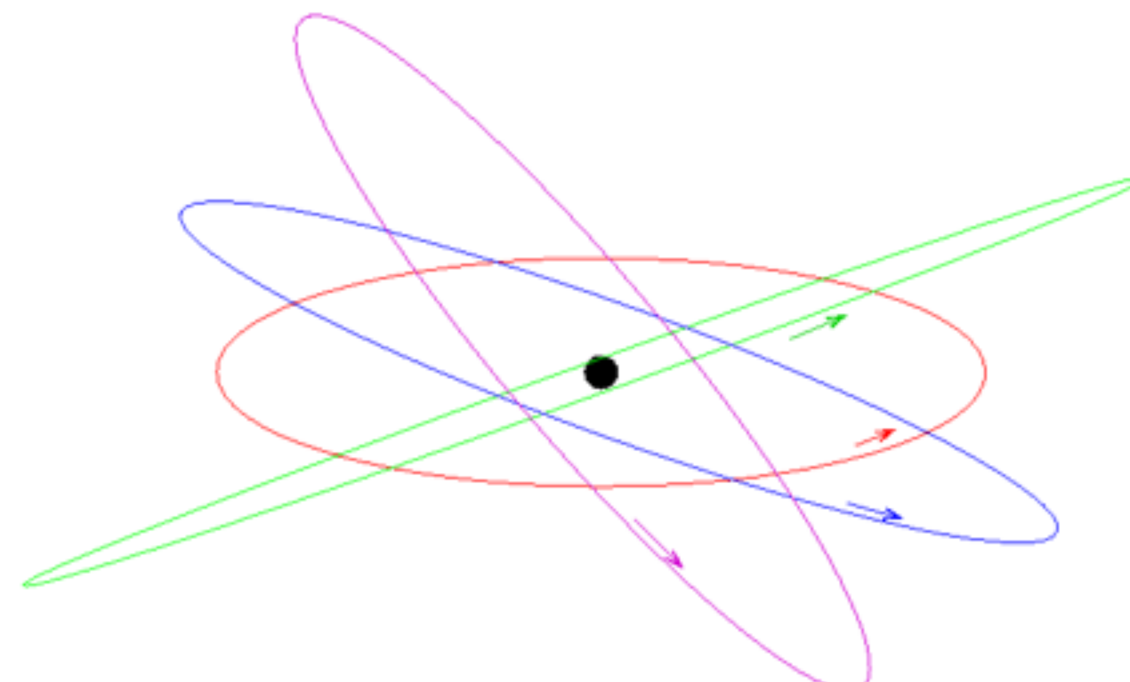
The General N-Body Problem





We're Interested in this Version:
A Central Body Dominates

Standard Versions:
Mercury
Swift
Symba
HNBody

Mercury is the reigning champion
HNBody is my personal choice

If you haven't done so, download Mercury now:
http://star.arm.ac.uk/~jec/home.html

Mercury

- You can treat it like a black box, but it's important to understand it
- Orbital dynamics is an old subject with arcane language, subtle points, and crotchety old men. Beware!
- Don't try anything crazy, and you should be OK
- …Or find yourself a dynamicist Jedi and have her/him teach you the subtleties and plan on studying dynamics for decades!

Mercury is fast, but limited applicability:

"MERCURY is a general-purpose software package for doing N-body integrations. It is designed to calculate the orbital evolution of objects moving in the gravitational field of a large central body. For example MERCURY can be used to simulate the motion of the planets, asteroids and comets orbiting the Sun; or a system of moons orbiting a planet; or a planetary system orbiting another star."

Not exomoons in a planetary system. Sorry, René!

MERCURY assumes input coordinates are in "bodycentric" coordinates
Orbital elements are of standard definition
Output can be in other coordinate systems (e.g. barycentric, Jacobi)
N.B. General relativity doesn't actually work!

How to do an integration

Read the manual: mercury6.man!
You will need to modify big.in, param.in and small.in
Other .in files just have to live in the directory

<u>Integration Method</u>
MVS: Streamlined for a central potential, very fast
Bulirsh-Stoer: Very accurate, 2-10x slower than MVS
Hybrid: Usually MVS, switch to B-S for encounters
- Good for collisions

Body Types

“Big” bodies feel each other
“Small” bodies don’t feel all others
- if no mass, only feel big bodies
- if with mass, don’t feel each other, but bigs do

Massless (“test”) particles sample the gravity
- Faster than all bigs: O(N)
- Embarrassingly parallel runs

Massive smalls good for sims like the Nice Model

Enough Talk!

http://www.astro.washington.edu/users/rory/MercuryTutorial/

<u>Galilean Satellites</u>

100 big particles orbiting Jupiter
Semi-major axes between Io and Callisto
Total mass = Total Galilean satellites
$e < 0.05$, $i < 3^{o}$ (dynamically “hot”)
Download the .in files and run!
Look in “info.out” to see how the simulation progresses

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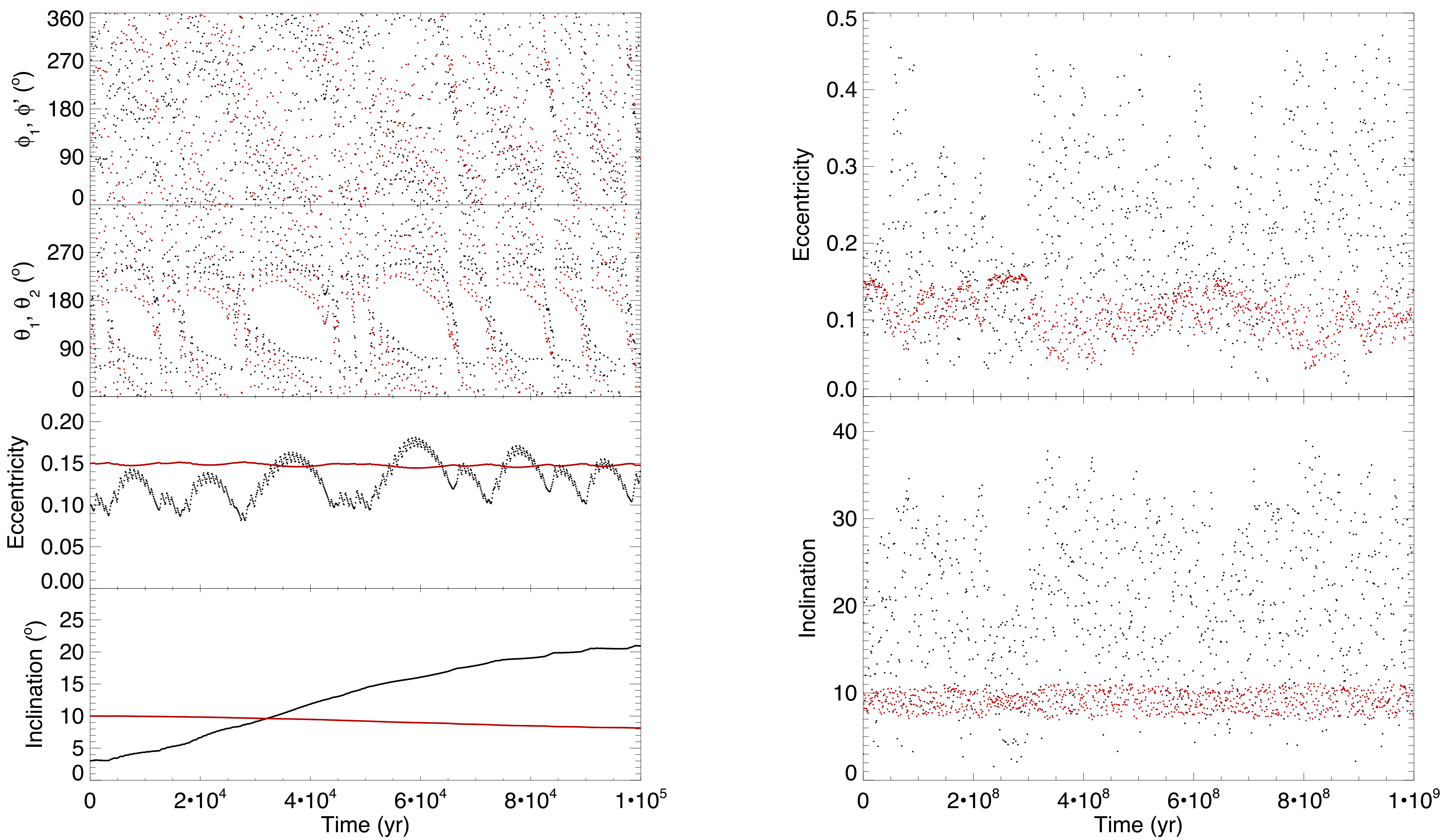
<u>ChaoticResonance</u>

Two planets in the 2:1 resonance with inclinations



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ChaoticResonance

Two planets in the 2:1 resonance with inclinations

What happens to an outer disk?

small.in contains 100 particles
    between 3 and 5 AU

Run for 1000 years

The disk is tilting ->