



Time-Steps Effects on Planetesimal Dynamics

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Planet Formation

- * The “Planetesimal Hypothesis”
- * 4 Major Stages: Initial, Early, Middle, Late
- * Initial and Early Stages dominated by Microphysics, Electrostatics, and Gas Drag
- * Middle to Late Stages dominated by Gravitation Scattering

The Exciting Part

- * Looking at the Middle to Late Stages
- * Starting with 1 km planetesimals and watching their evolution
- * Learning the properties of lunar-sized protoplanets

Modeling Techniques

- ✱ Prior Techniques
 - ✱ Analytical
 - ✱ Statistical
- ✱ Current Techniques
 - ✱ Direct Simulations

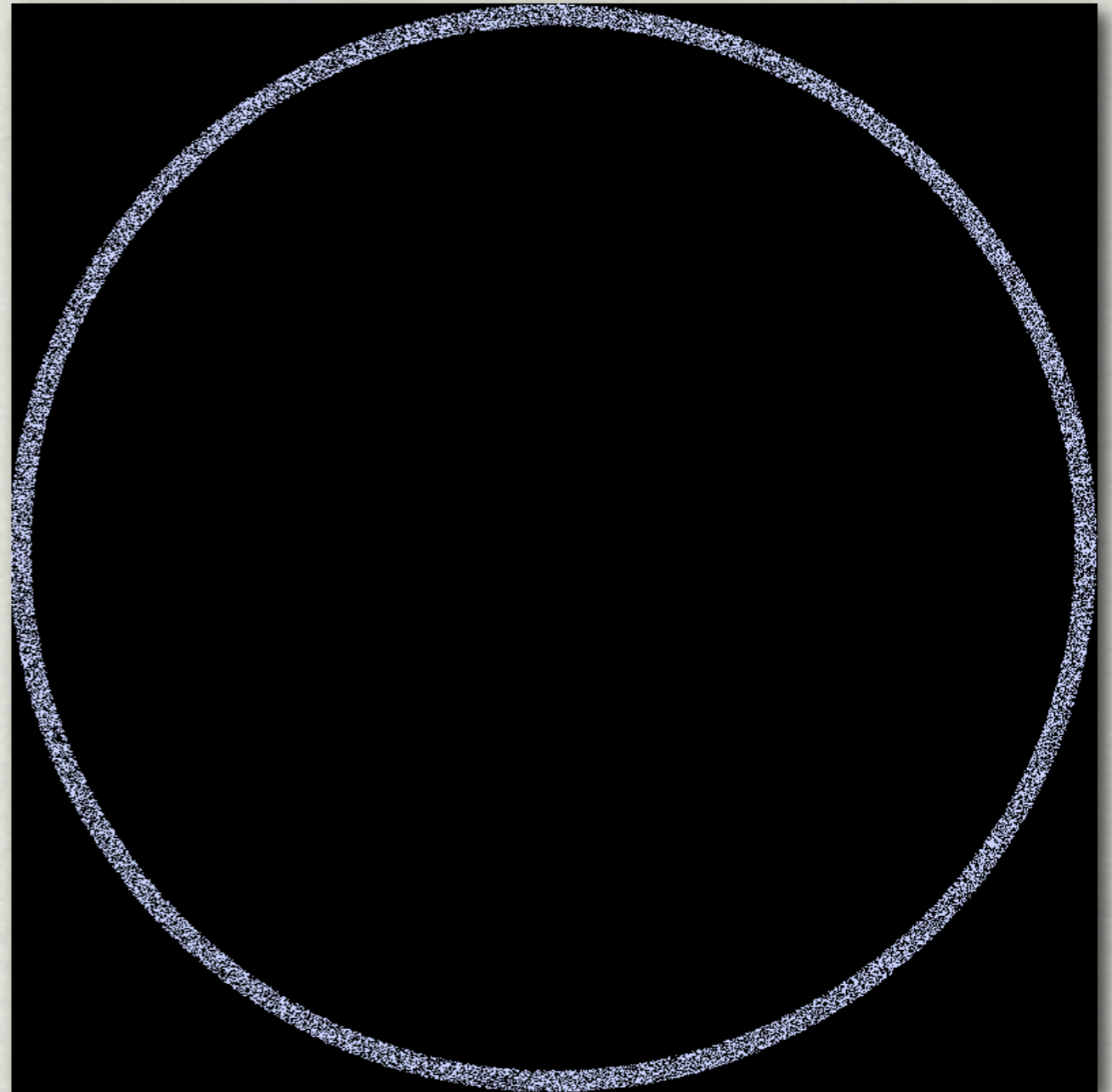


IMAGE CREATED WITH TIPSY (QUINN, KATZ)

Direct Simulations

- * How Numerical Simulations help us understand interactions
 - * Getting Accurate Results
- * Calculations of Gravity
 - * Runaway Growth

Making Life Easier

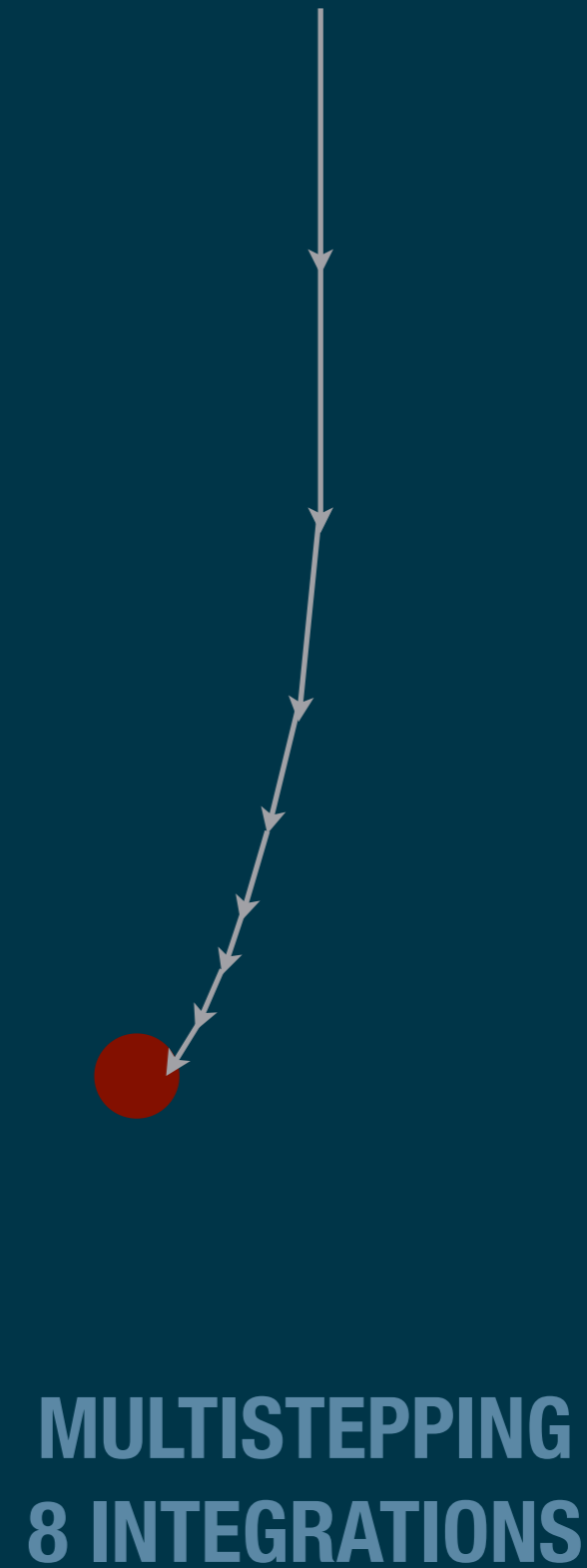
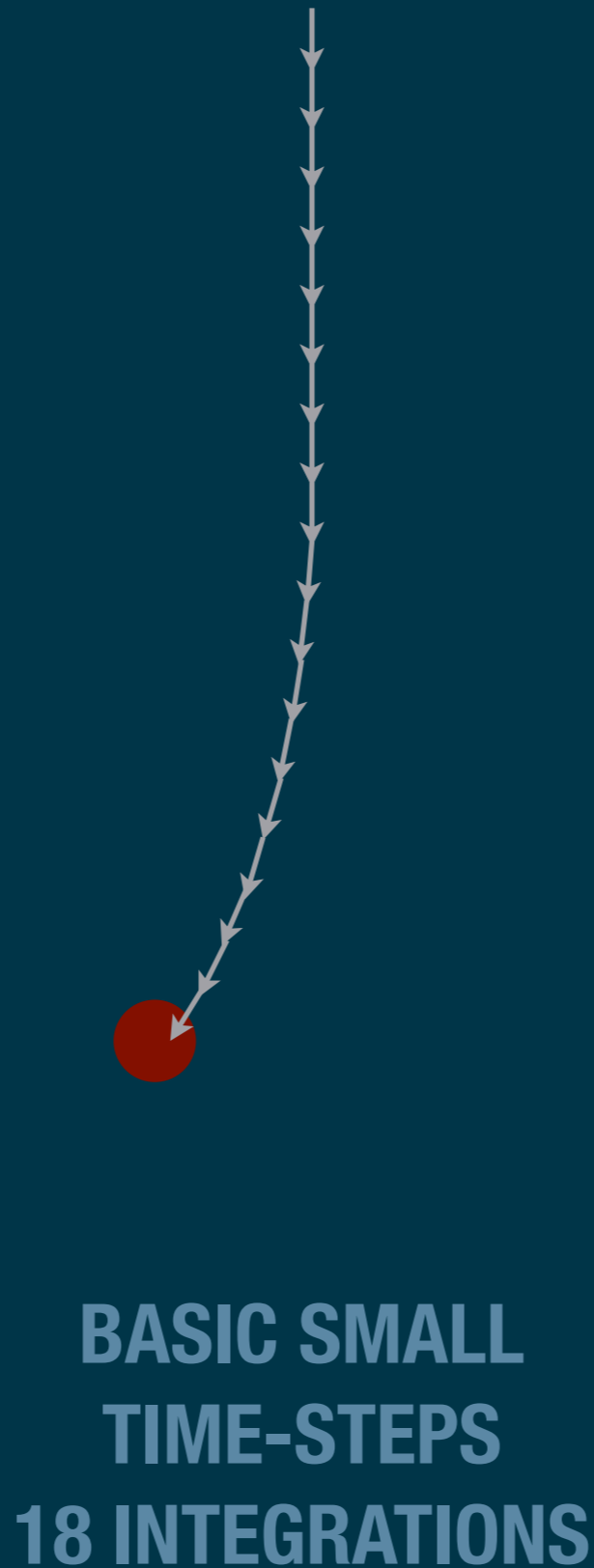
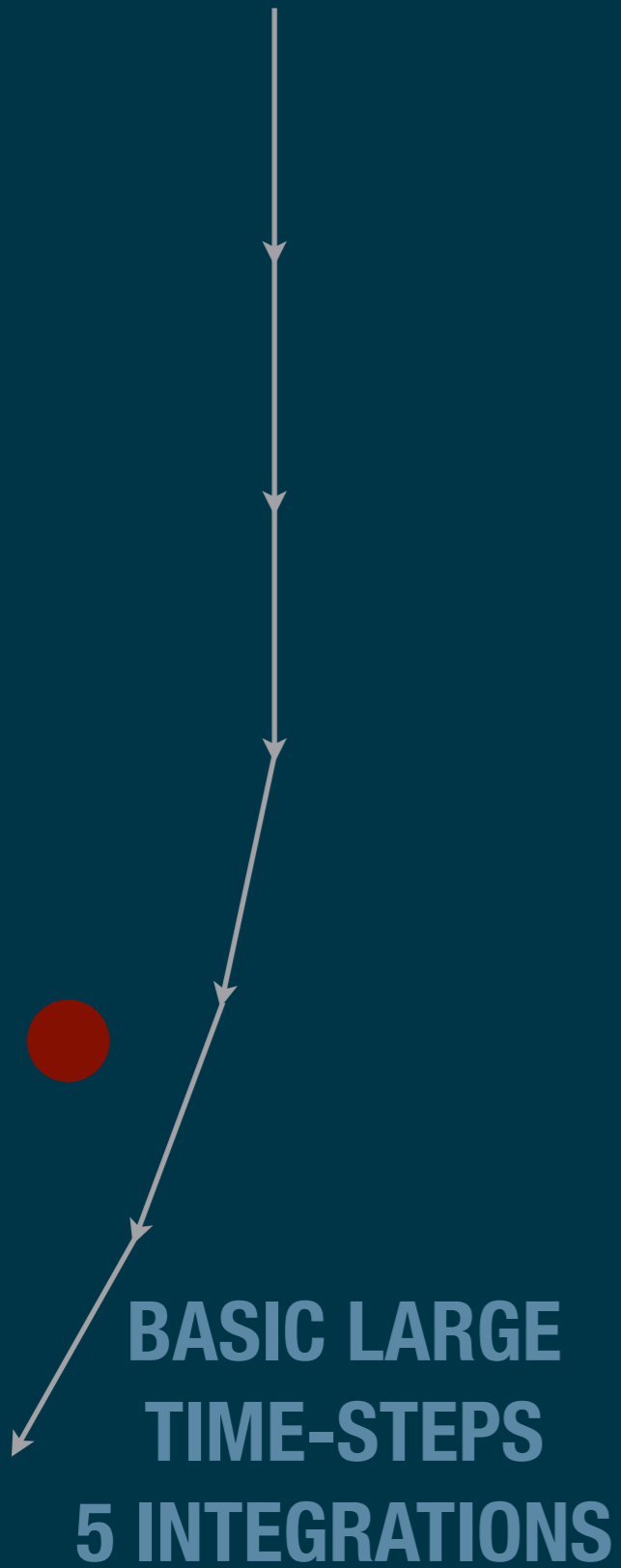
- * N-Body Simulations are Highly Complex
- * Spherical Objects
- * Perfect Accretion
- * Artificial Size Scaling

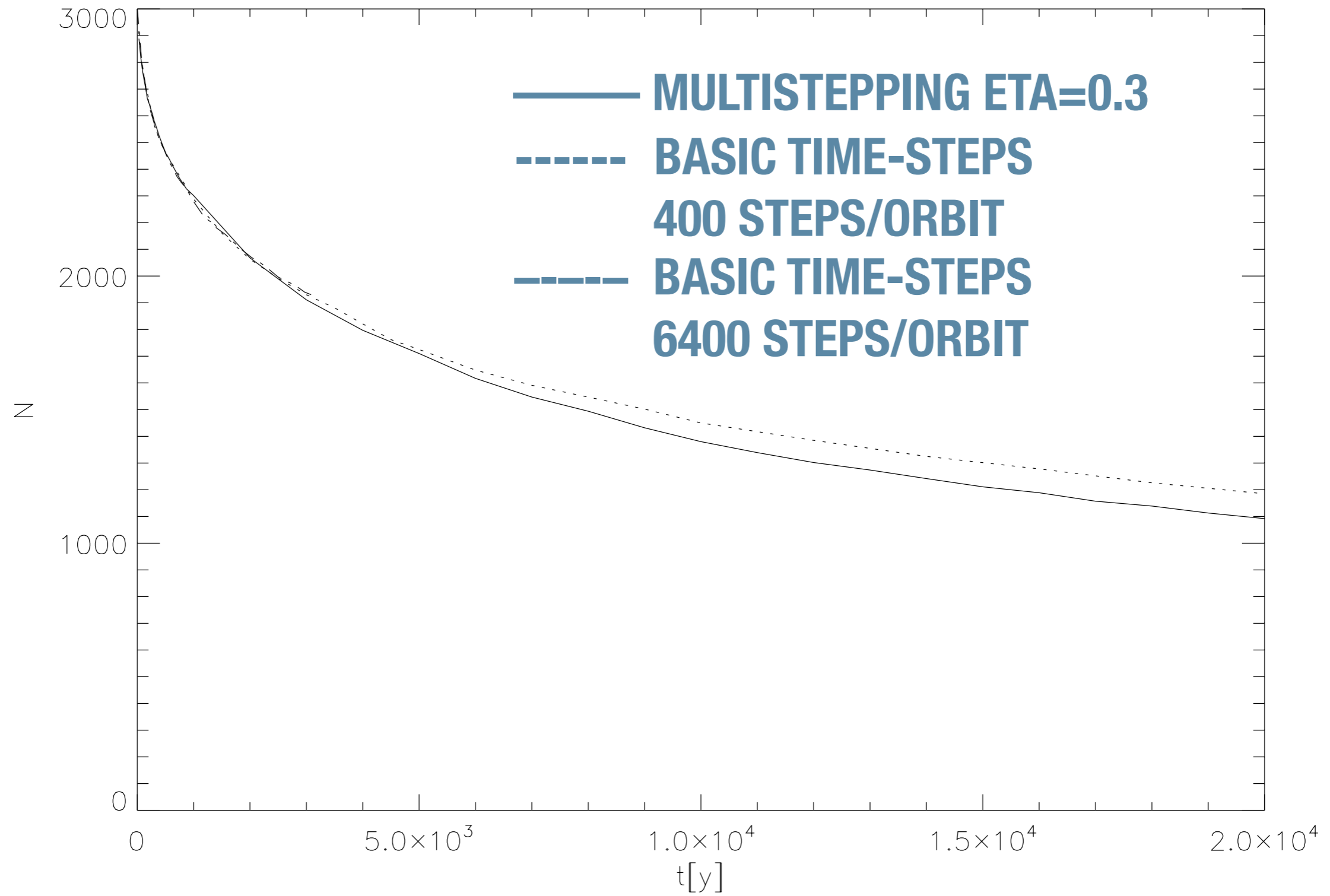
Time-Steps

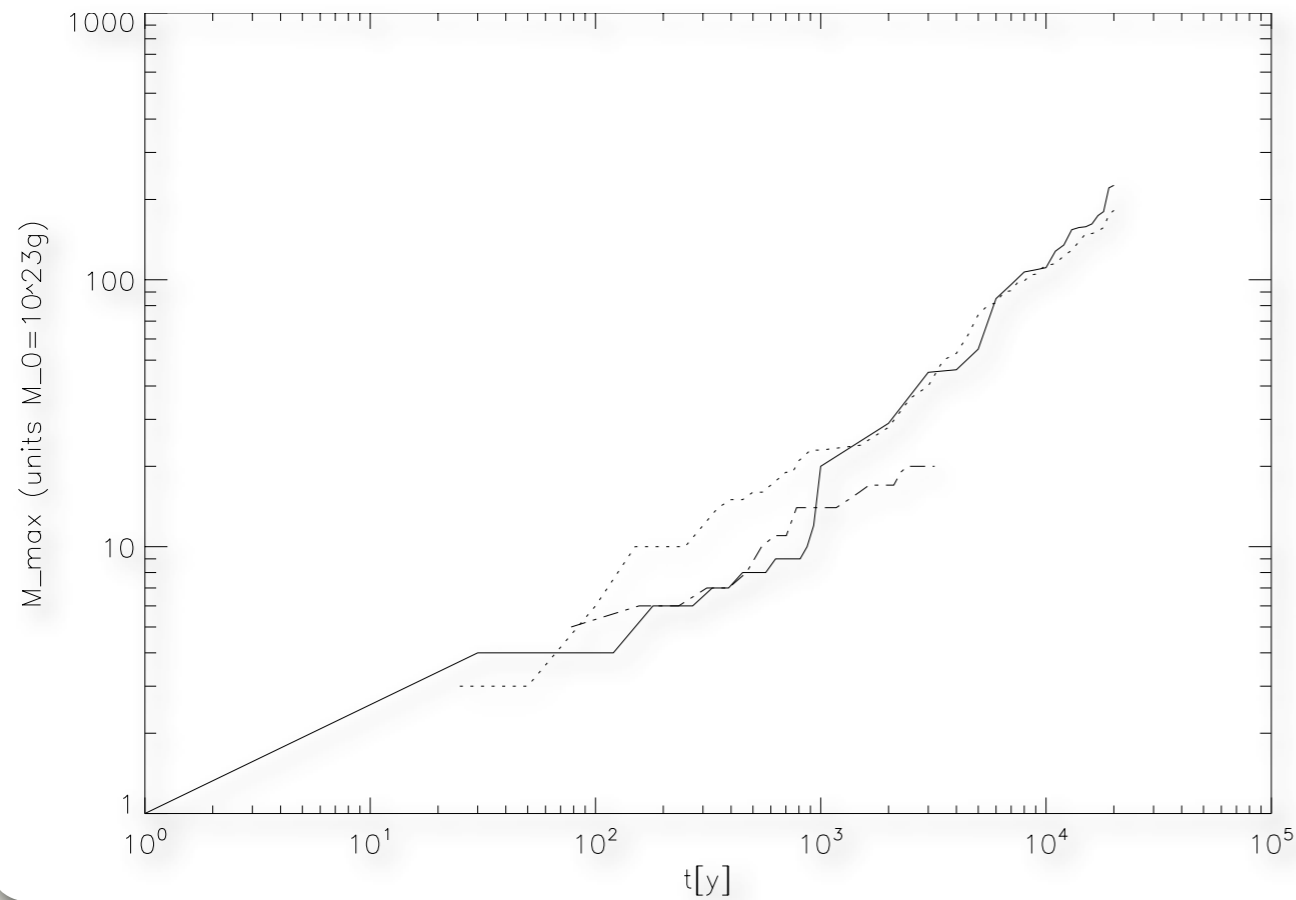
- * Basic Time-Step
- * Multistepping
- * Saving Computational Time while maintaining accuracy
- * Separating particles into bins

$$\Delta t_{new} = \eta(\Delta t_{min}) \sqrt{\frac{r_{1,2}^2}{(M_1 + M_2)G}}$$

$$\Delta t_{min} = \frac{2\pi/n}{2^{max_{run}-1}}$$



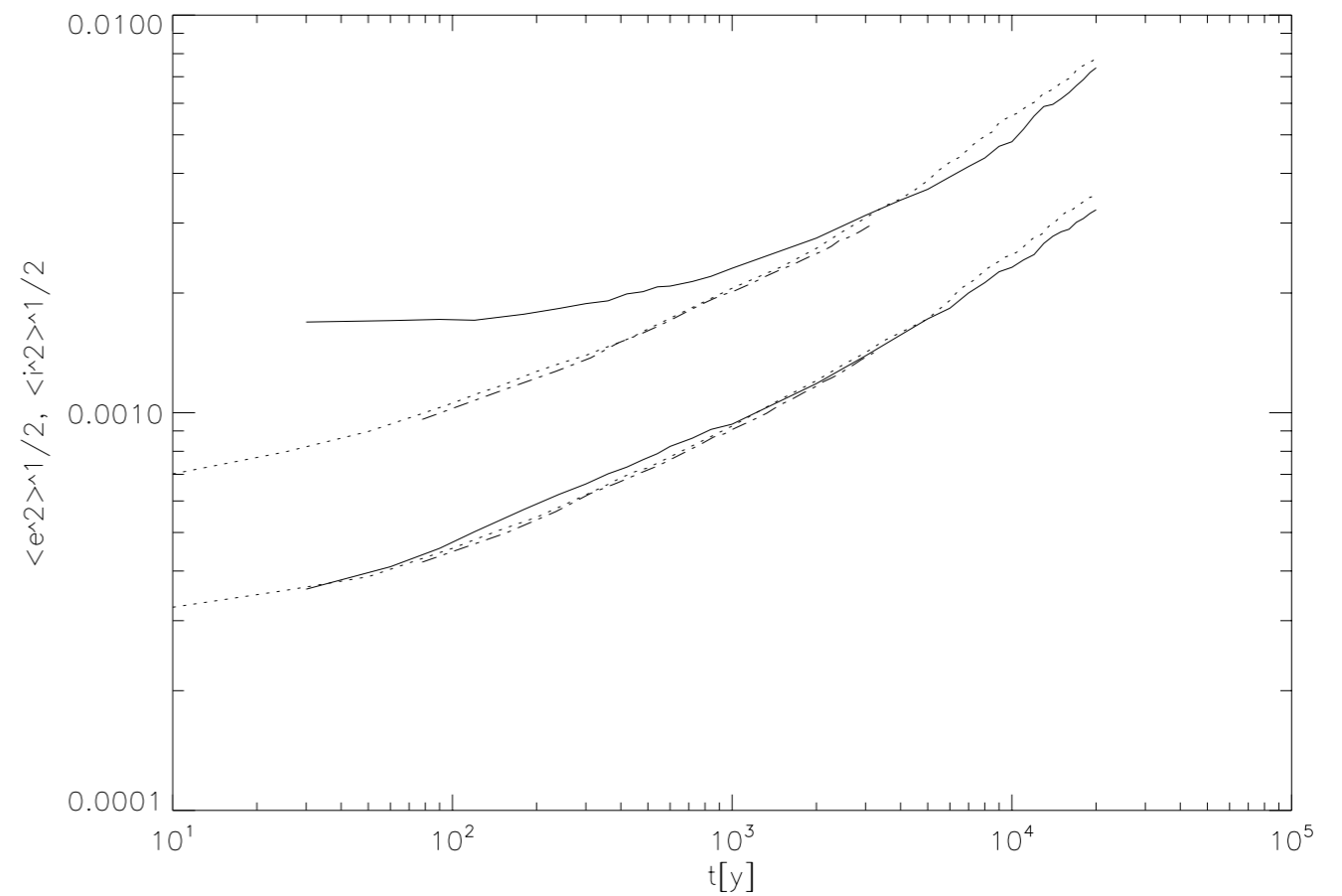




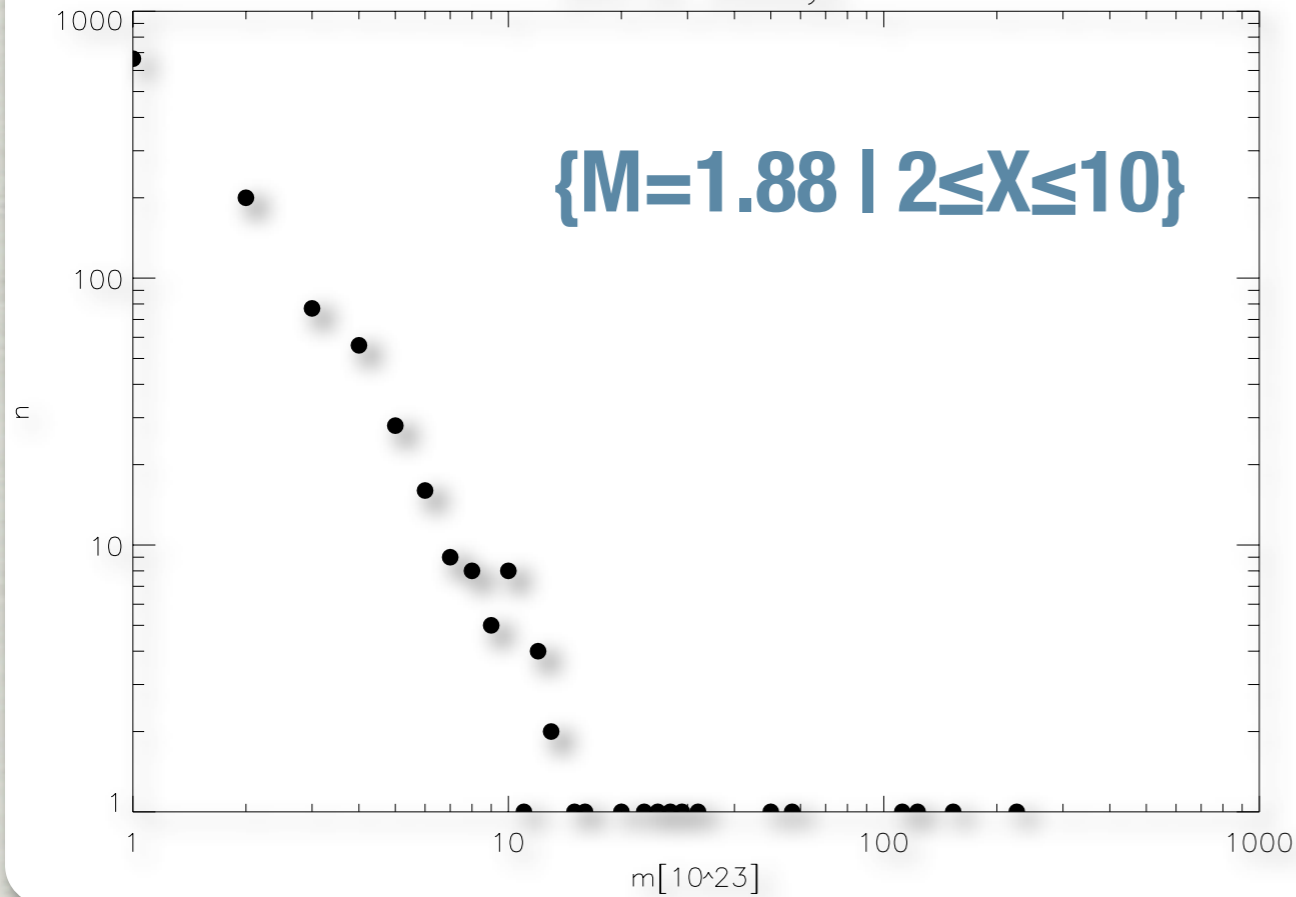
- MULTI-STEP
- - - BASIC TIME-STEP
LARGE
- · - · - BASIC TIME-STEP
SMALL

$$\langle e^2 \rangle^{1/2} = 2 \langle i^2 \rangle^{1/2} = 2h$$

$$h = r_H / a$$



Sim13c 20000yr

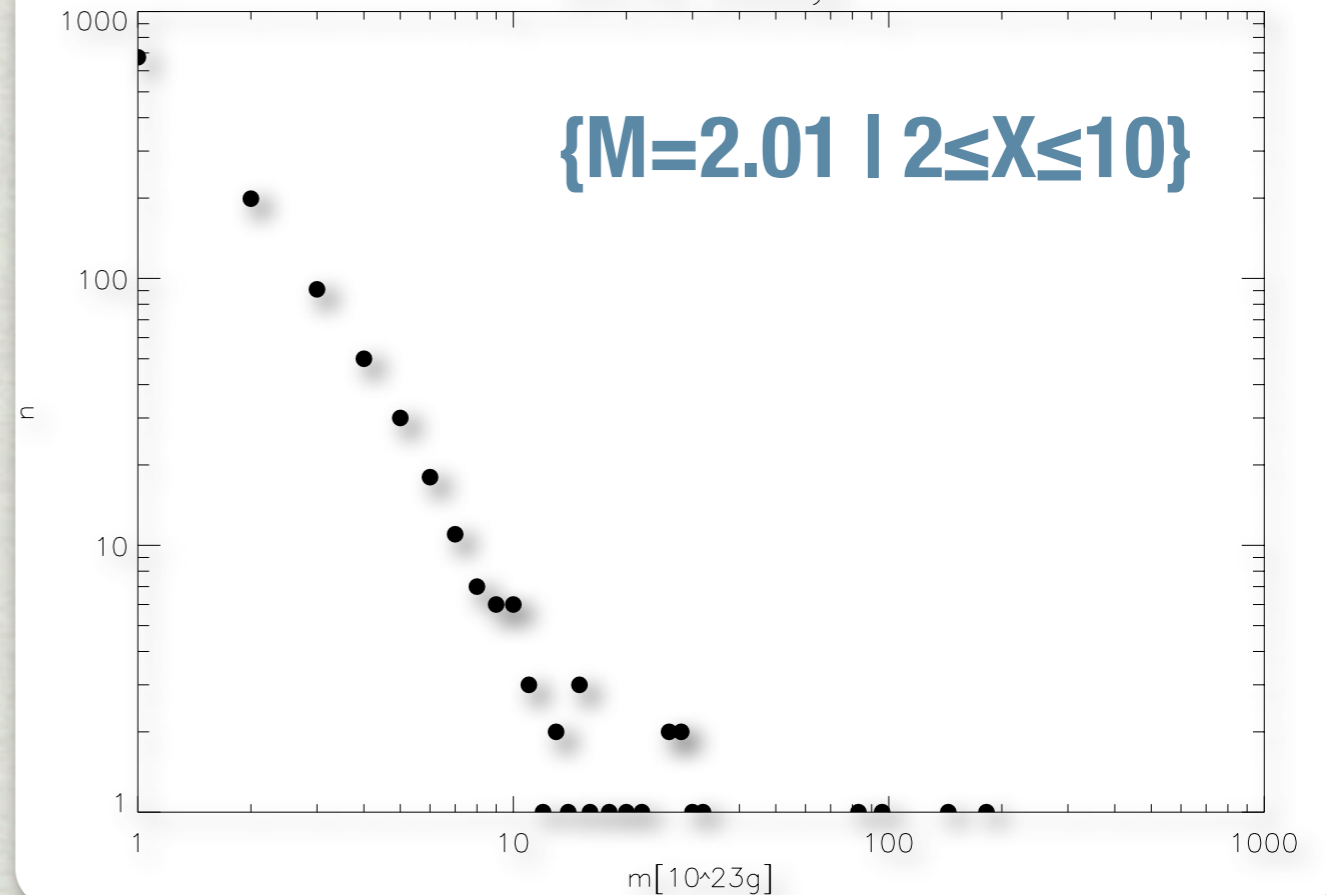


MULTI-STEPPING

BASIC TIME-STEP

COMPUTATIONAL TIME
BASIC TIME-STEP SMALL = 1.8 WCD
BASIC TIME-STEP LARGE \approx 54 WCD
MULTI-STEPPING = 3.1 WCD

Sim14c 20000yr



References

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