Time-Steps Effects on Planetesimal Dynamics

Robert Arn
University of Washington REU
Millikin University
Advisor: Tom Quinn

IMAGE COURTESY OF NASA

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

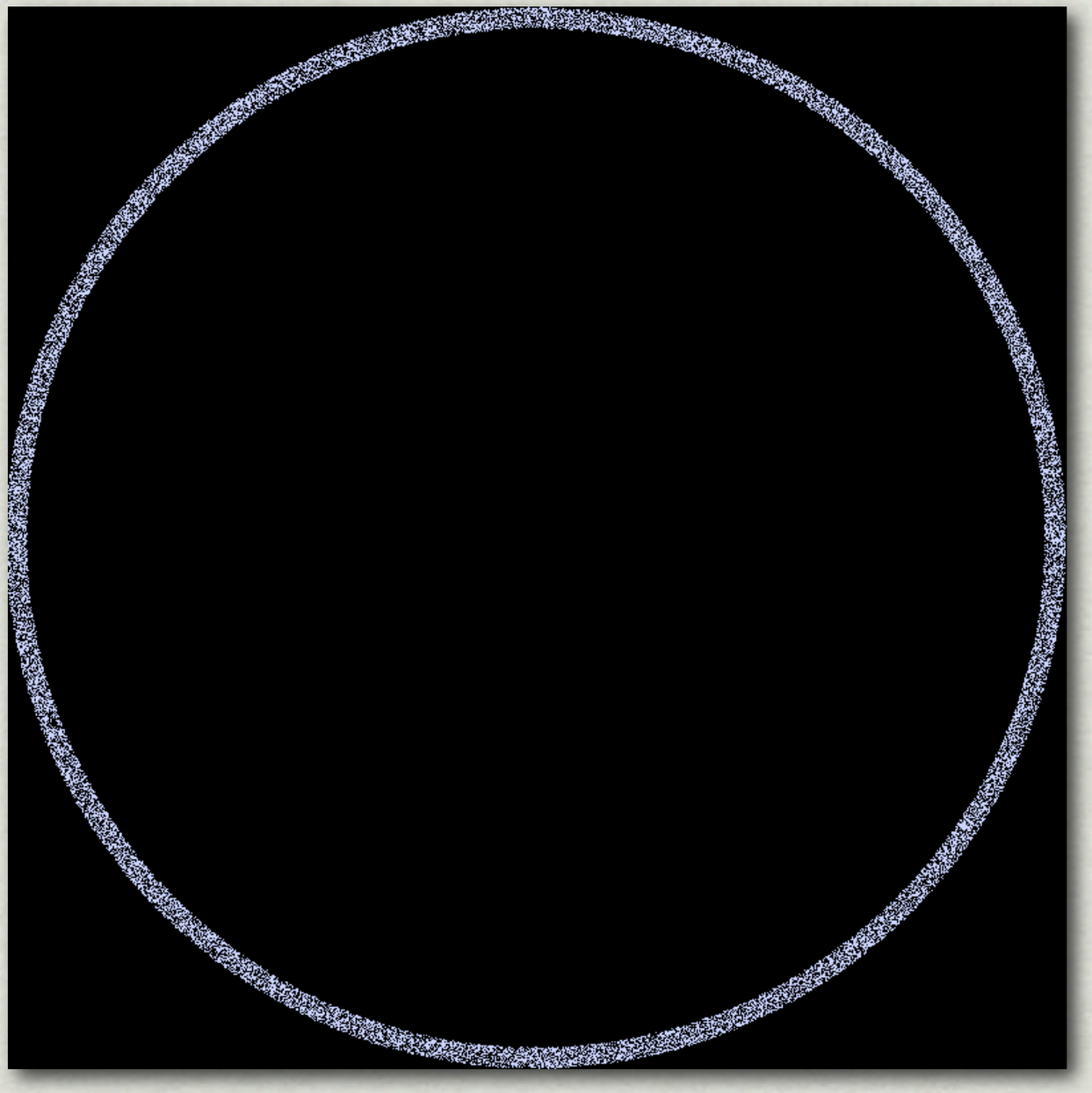


IMAGE CREATED WITH TIPSY (QUINN, KATZ)

Direct Simulations

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

Making Life Easier

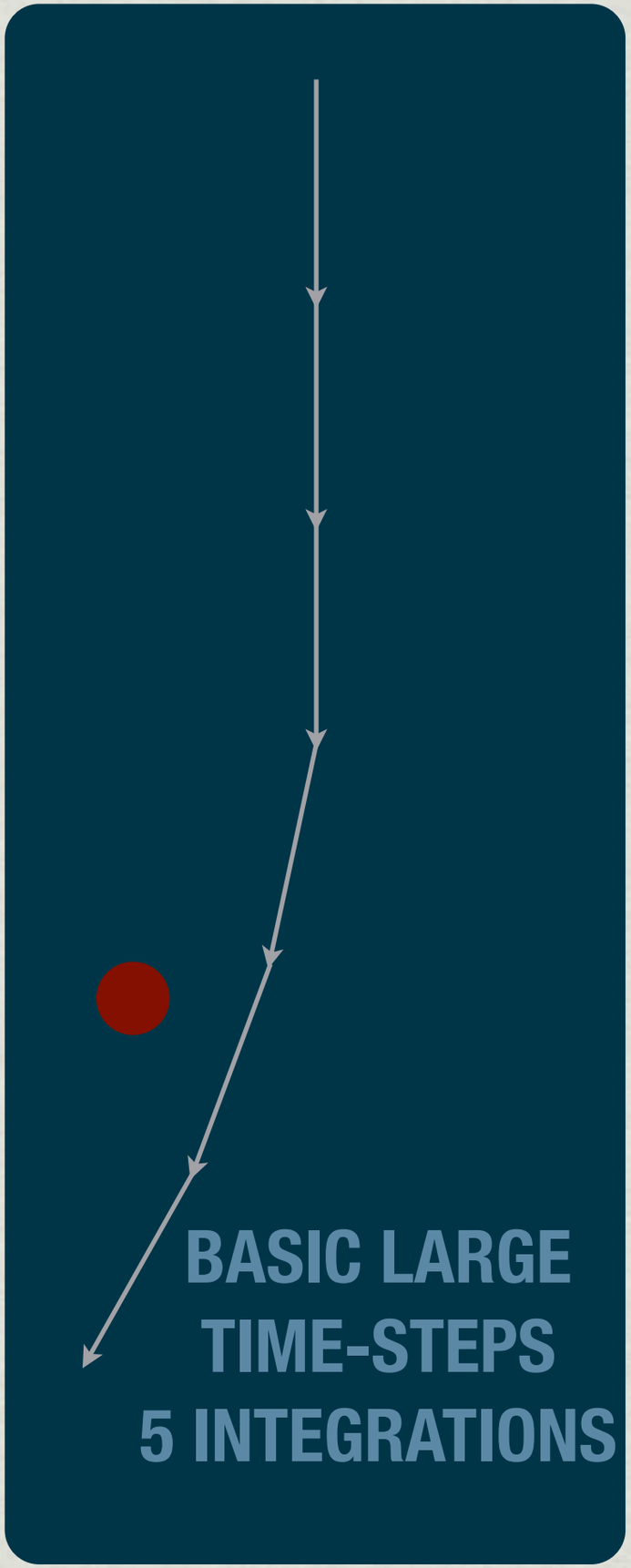
- N-Body Simulations are Highly Complex
- Spherical Objects
- Perfect Accretion
- Artificial Size Scaling

Time-Steps

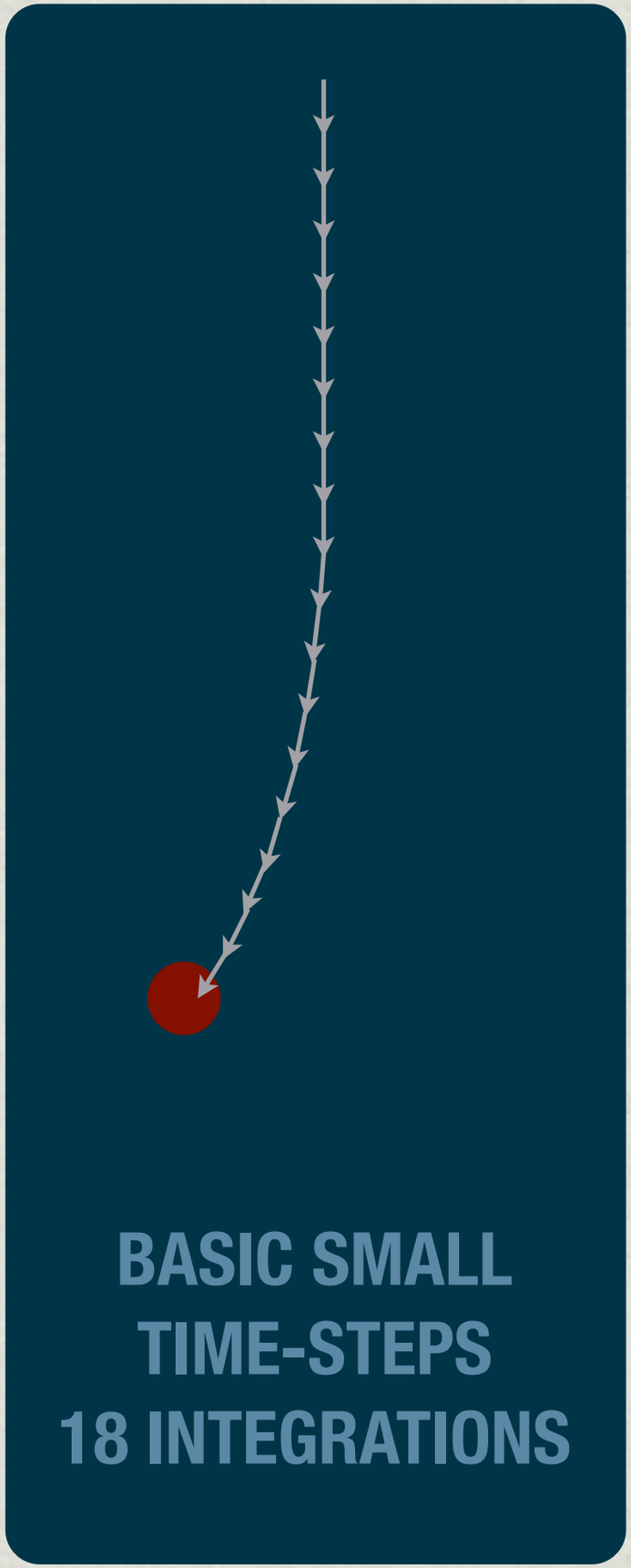
- Basic Time-Step
- Multistepping
  - Saving Computational Time while maintaining accuracy
  - Separating particles into bins

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

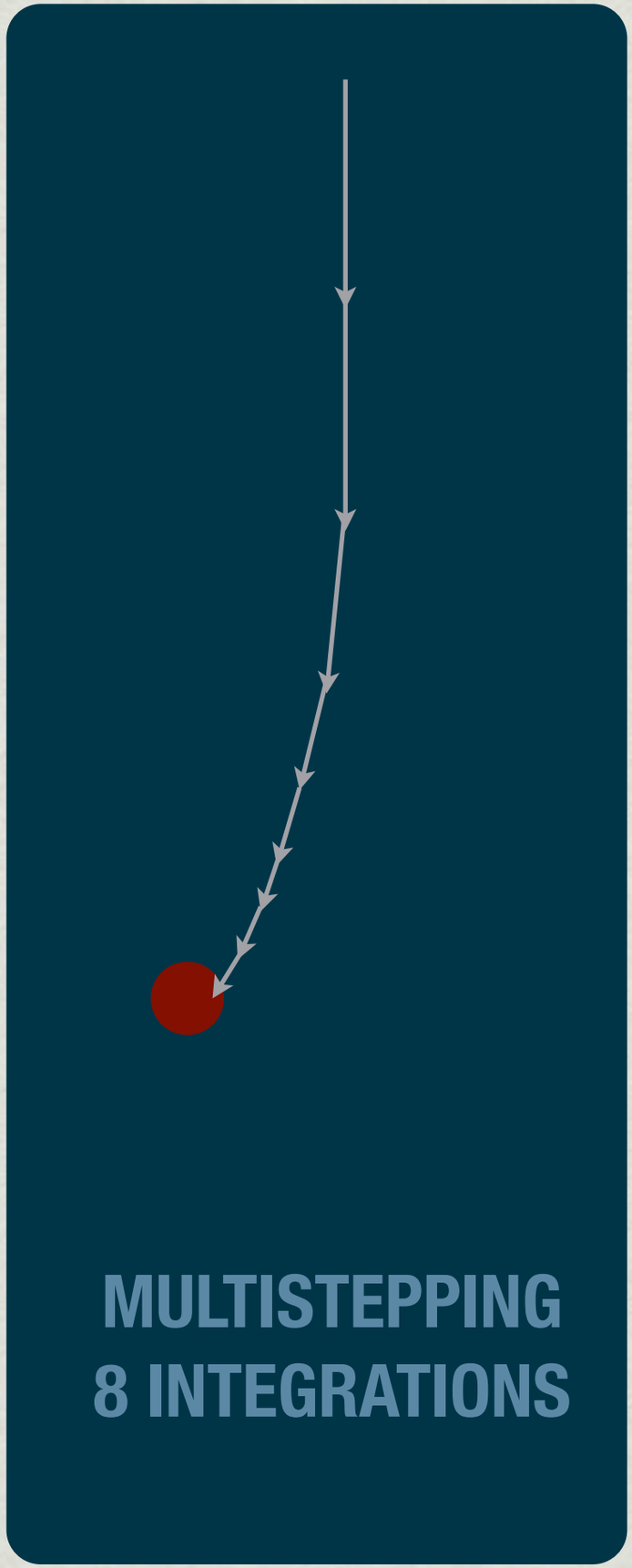
$$\Delta t_{min} = \frac{2\pi/n}{2^{max_{rung}-1}}$$



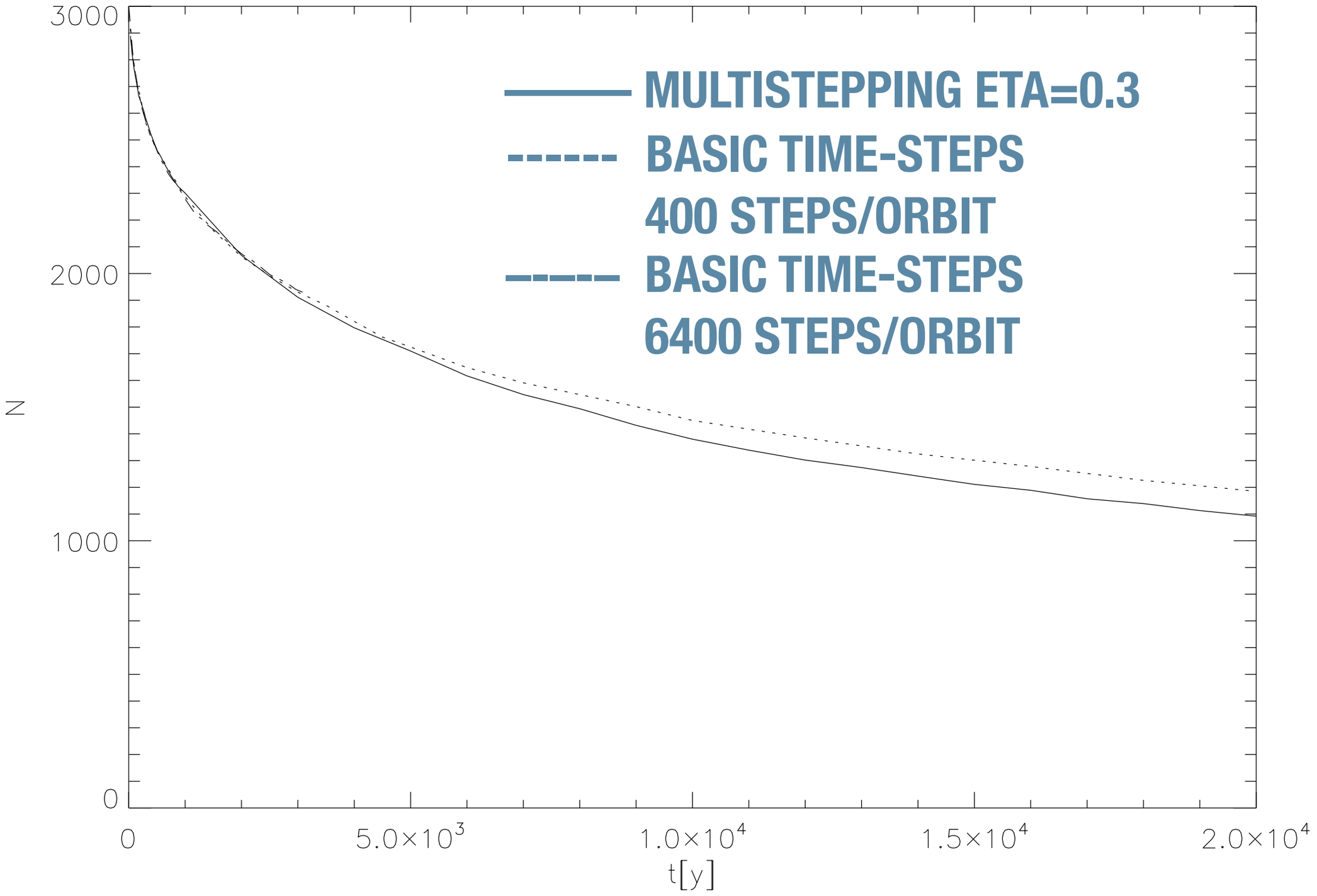
BASIC LARGE
TIME-STEPS
5 INTEGRATIONS

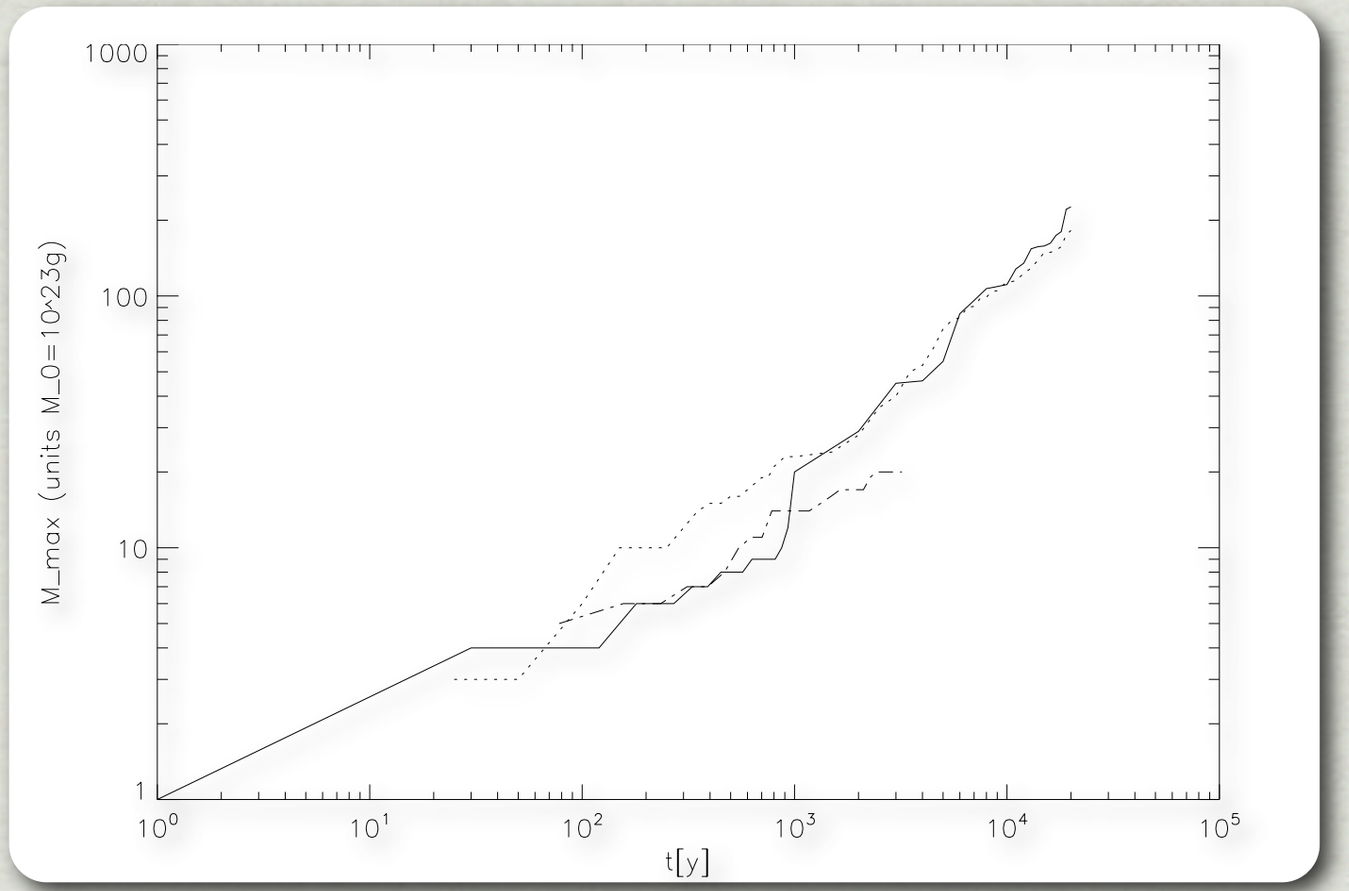


BASIC SMALL
TIME-STEPS
18 INTEGRATIONS



MULTISTEPPING
8 INTEGRATIONS


MULTISTEPPING ETA=0.3
BASIC TIME-STEPS
400 STEPS/ORBIT
BASIC TIME-STEPS
6400 STEPS/ORBIT
N
3000
2000
1000
0
0
5.0×10³
1.0×10⁴
1.5×10⁴
2.0×10⁴
t[y]



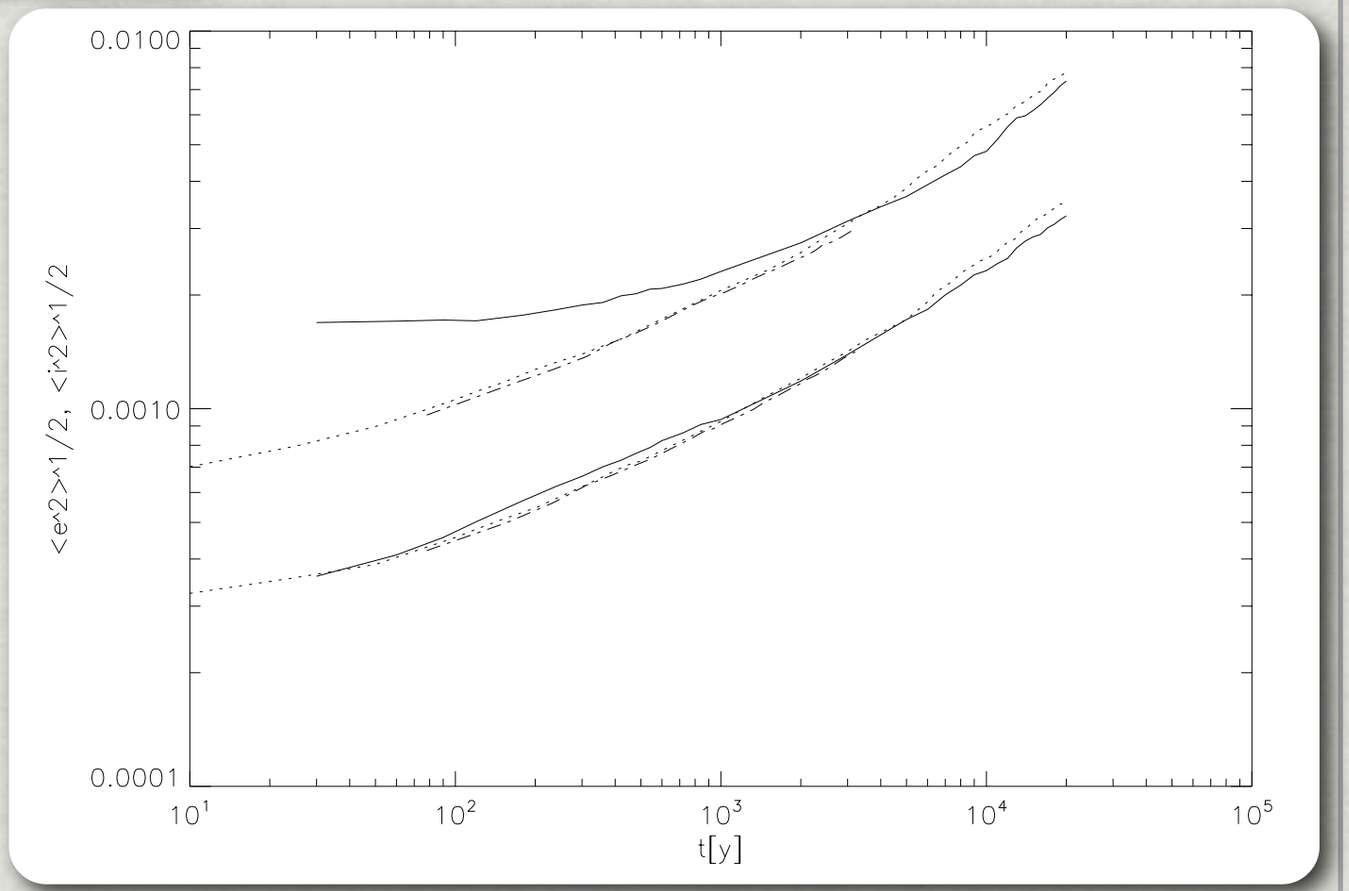
MULTI-STEP

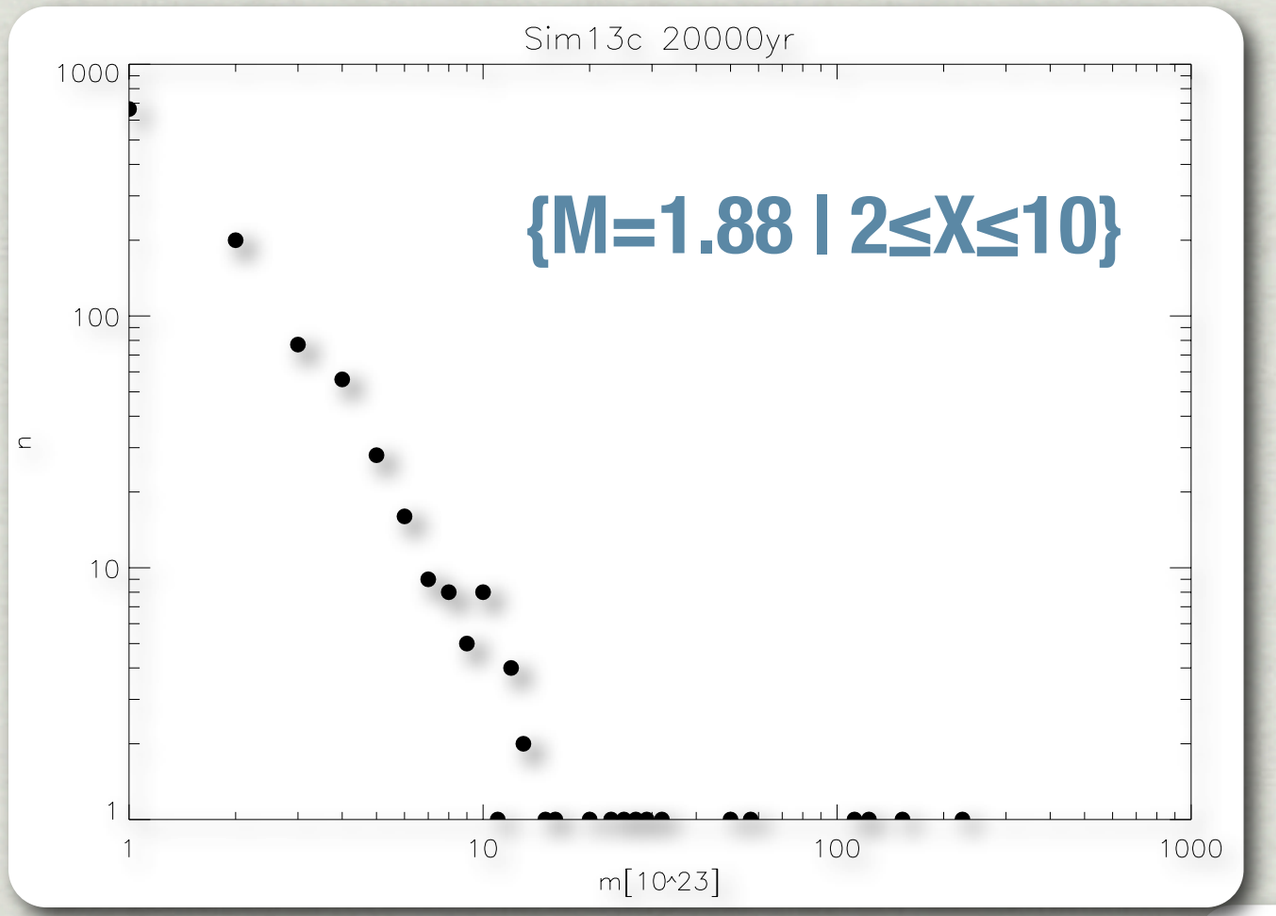
BASIC TIME-STEP LARGE

BASIC TIME-STEP SMALL

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

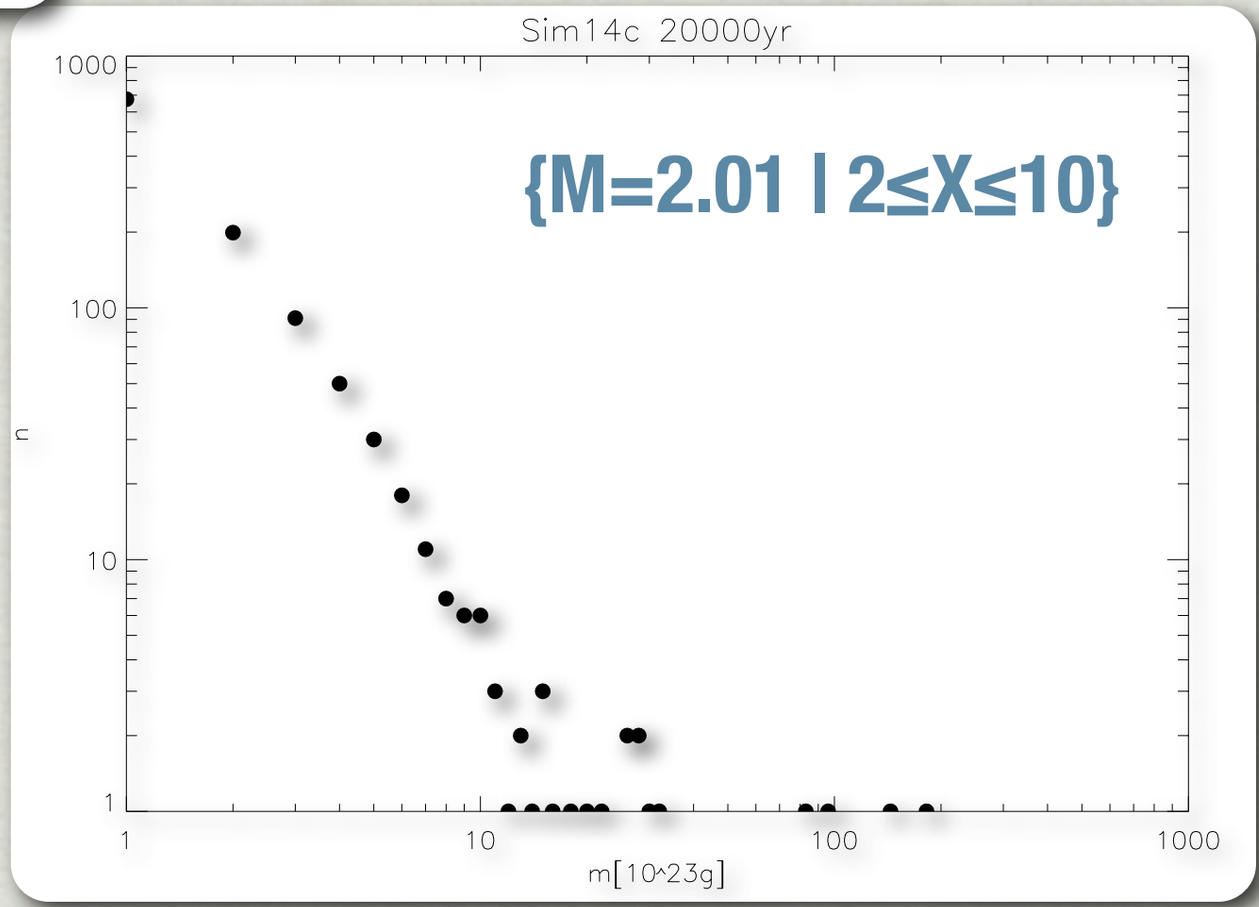
$$h = r_H / a$$





MULTI-STEPPING

BASIC TIME-STEP



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

References

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