

NBODY6++ IN AMUSE & HDF5 OUTPUT

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PLANETARY SYSTEMS IN STAR CLUSTERS



N: $10^2 \sim 10^5$
R: 10^1 ly
M: $10^2 \sim 10^5 M_{\odot}$
T: \sim Myr
dE/E: $\sim 10^{-5}$

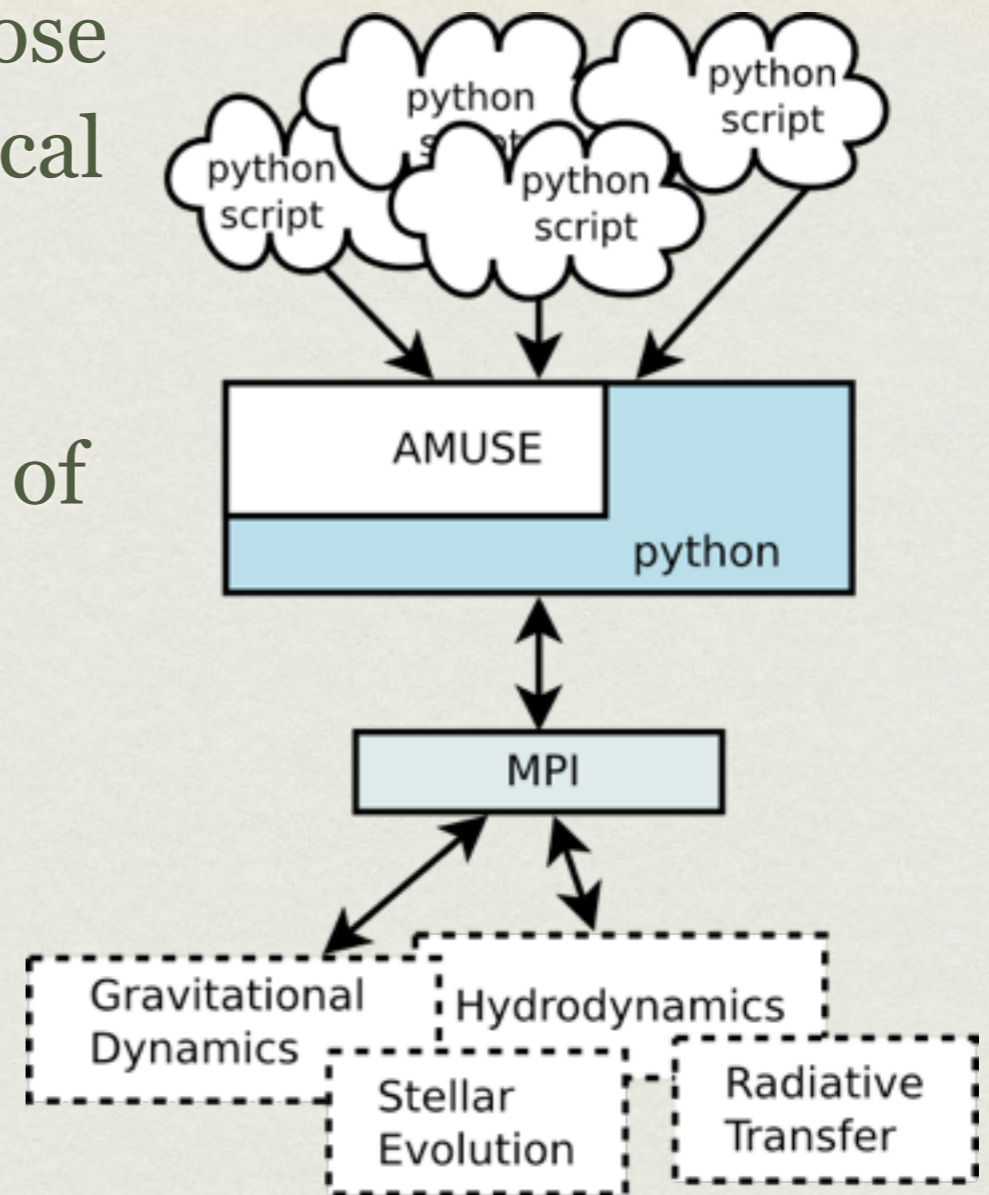


N: $10^0 \sim 10^1$ (planets)
R: $10^{-1} \sim 10^2$ AU
M: $10^{-1} \sim 10^2 M_{\oplus}$
T: yr
dE/E: $\sim 10^{-10}$

Different
treatments
needed!

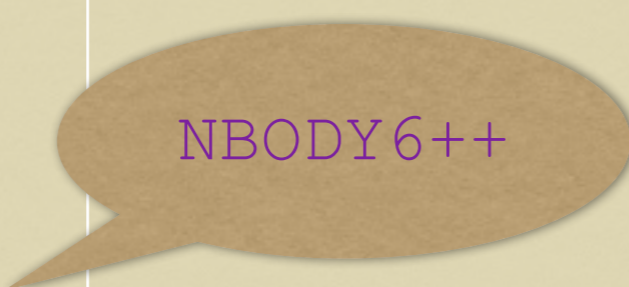
AMUSE?

- AMUSE - Astrophysical Multipurpose Software Environment (Astrophysical **Multi-Scale** Environment)
- Modularity architecture revolution of astronomical simulation codes
- Physically motivated interface for **existing** astronomical simulation codes (community codes)
- Implemented with Python + MPI + ...

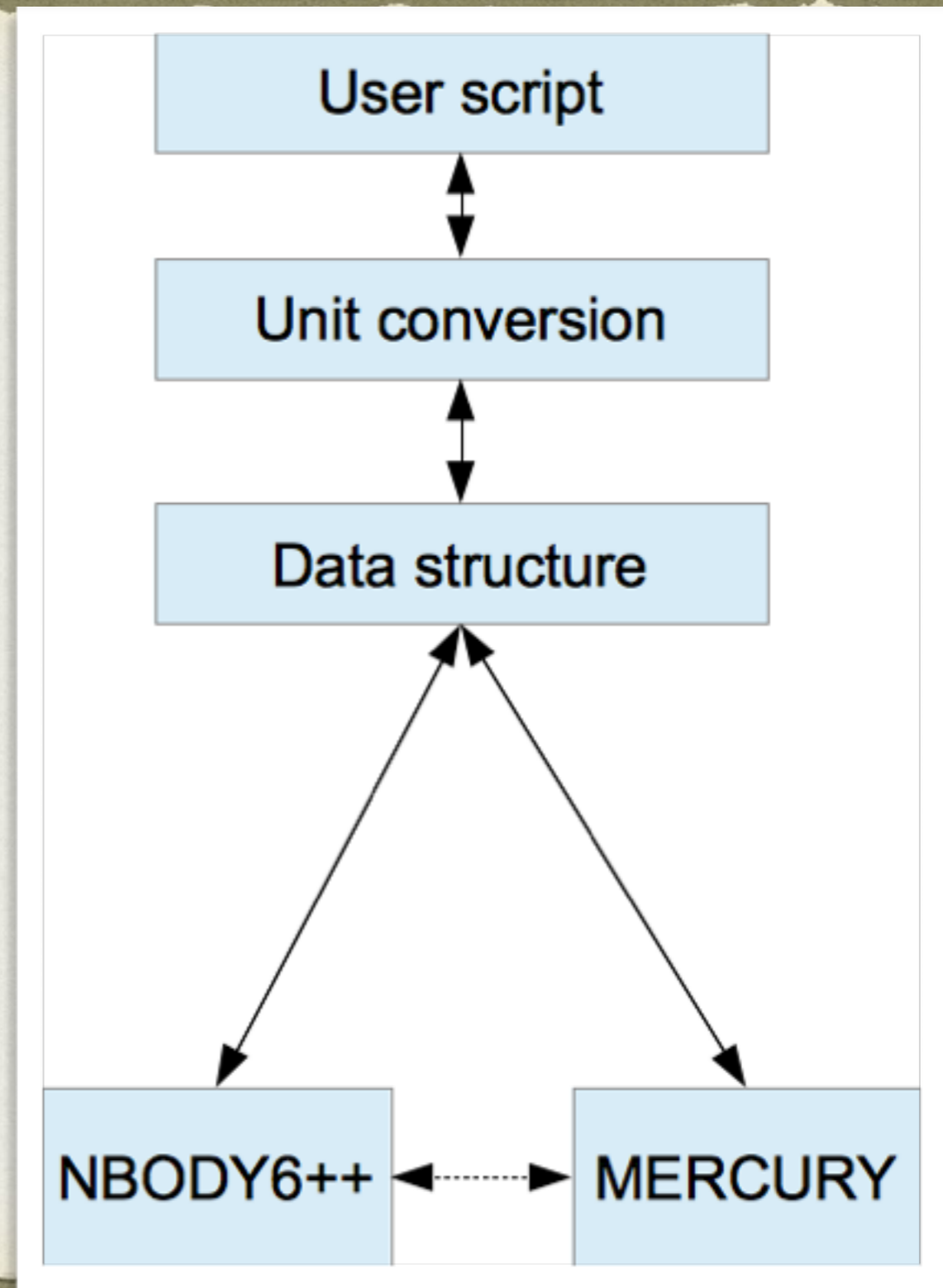
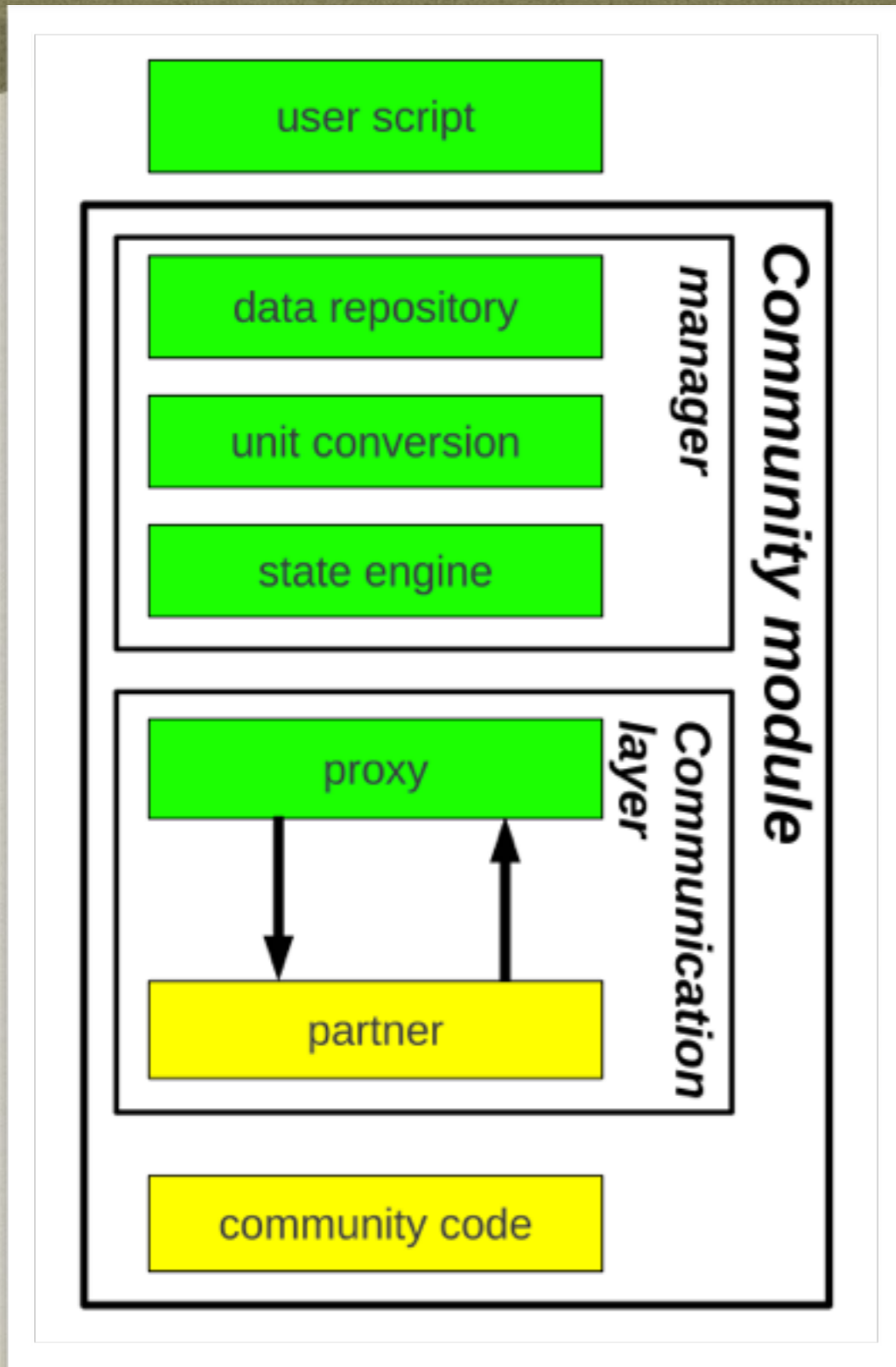


Portegies Zwart, et al, 2012

SUPPORTED PHYSICS

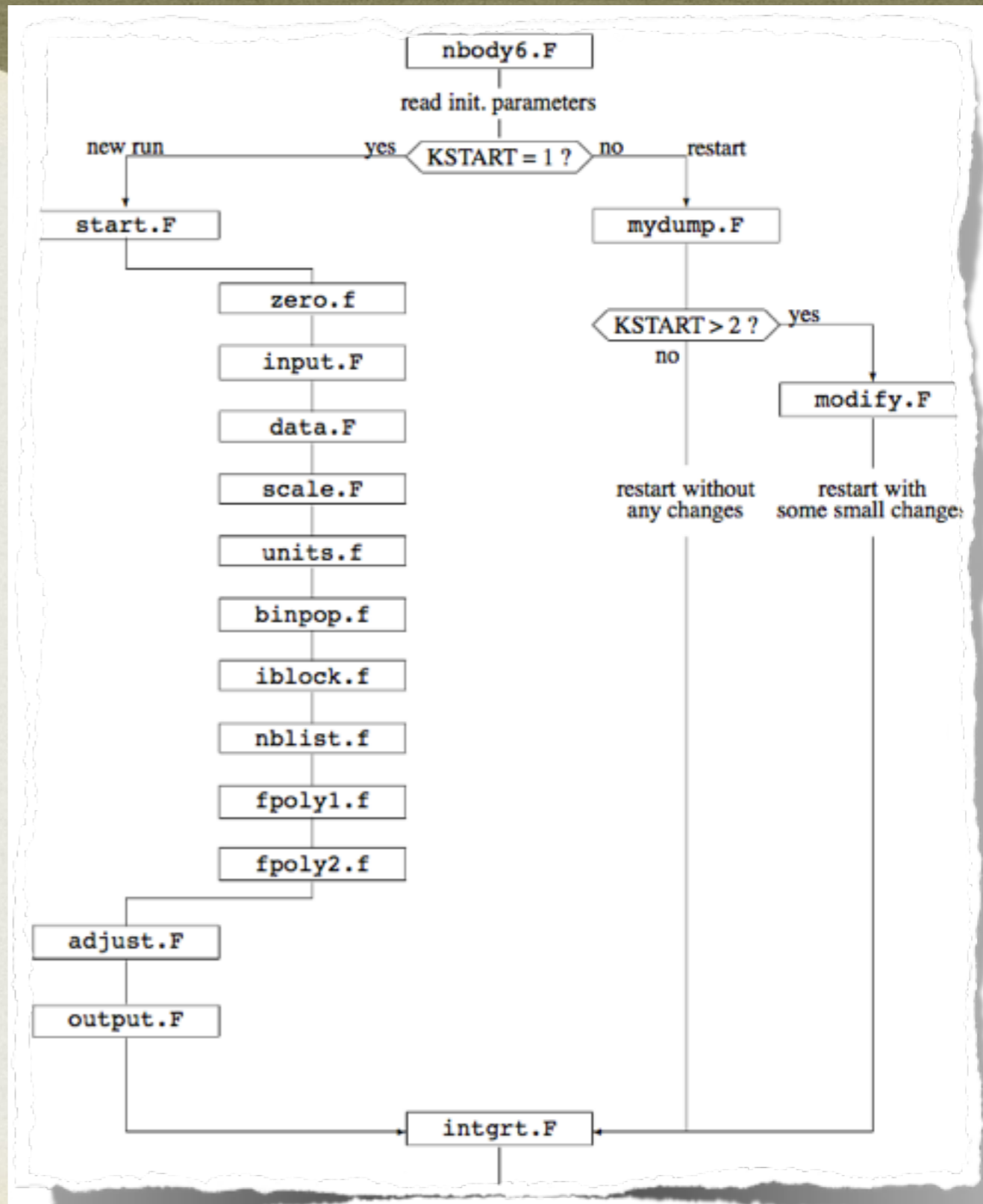
Stellar Dynamics	Stellar Evolution	Hydrodynamics	Radiative Transfer
<ul style="list-style-type: none">• BHtree• hermite0• phiGRAPE• twobody• smallN• octgrav• mercury• huayno• mmc• HiGPUs	<ul style="list-style-type: none">• sse• bse• evtwin• mesa  <p>NBODY6++</p>	<ul style="list-style-type: none">• athena• capreole• fi• gadget2	<ul style="list-style-type: none">• SimpleX

ARCHITECTURE



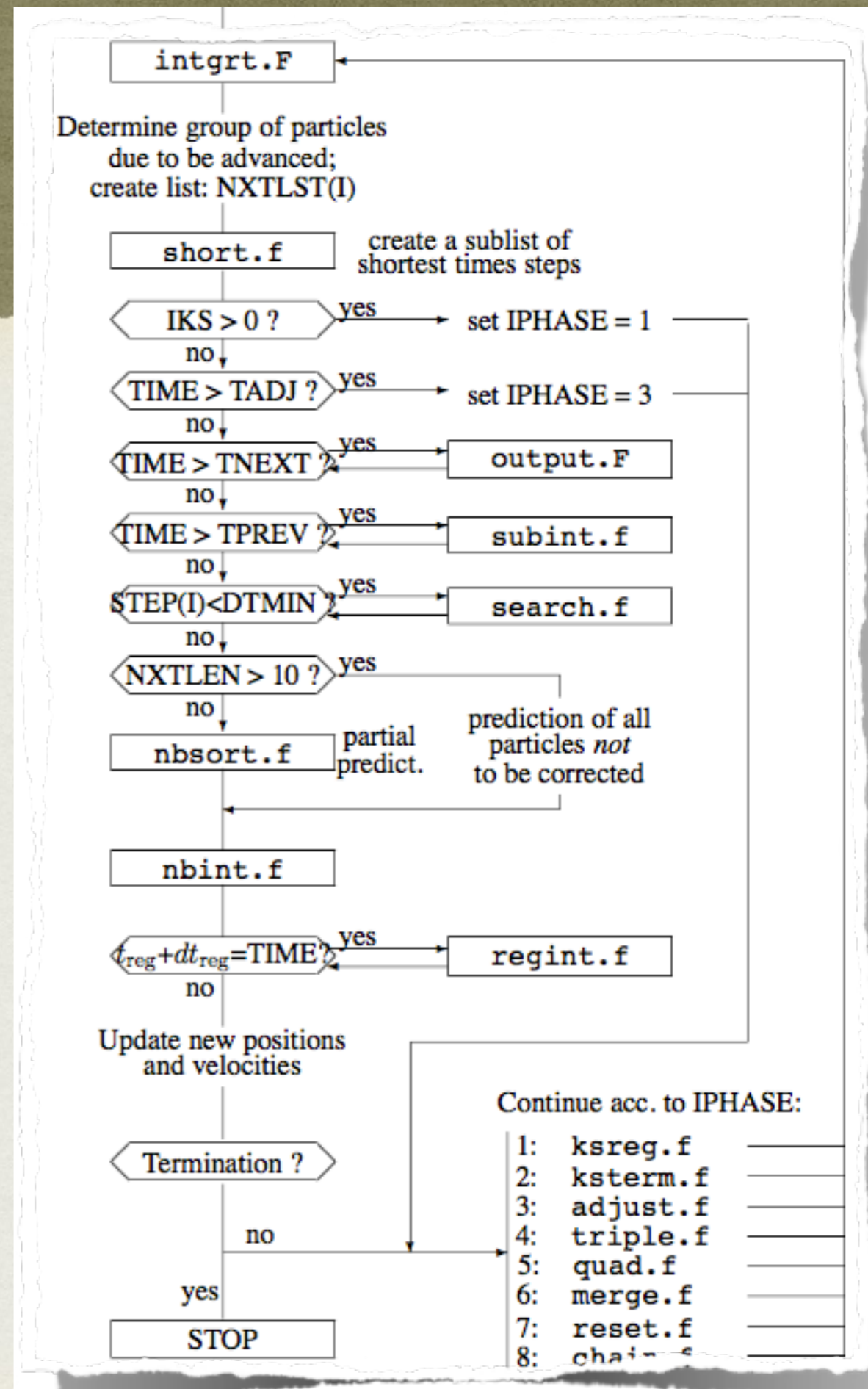
INTERFACE NBODY6++

- Set up initial conditions [Py]
- Call initialization [Py - NB6]
- WHILE `t < t_end`: [Py]
 - Integrate [NB6]
 - Manipulate data [Py]
- Terminate [Py]



PORTING

- NBODY6++ data structure
⇔ AMUSE data structure
- NBODY6++ integration loop
⇒ Python loop
- NBODY6++ units ⇒ AMUSE units
- NBODY6++ input ⇒ Python **set** functions



RUNNING NBODY6++ WITHIN AMUSE

NBODY6++ & AMUSE

```
from amuse.lab import *
from interface import nbody6xx
from amuse.units import nbody_system

inst = nbody6xx()

ptls = new_plummer_model(1000)
#ptls = new_king_model(1000,3)

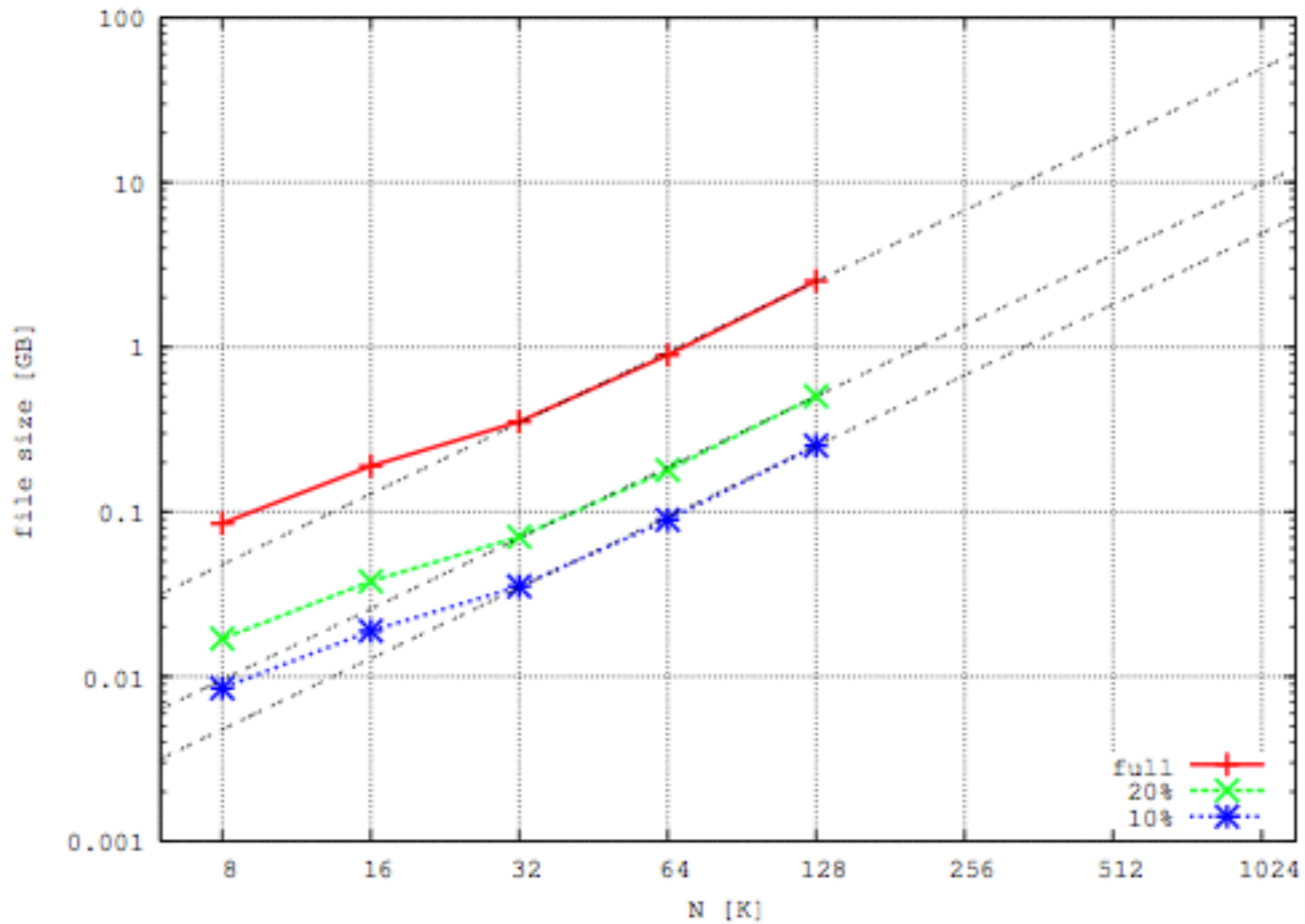
inst.particles.add_particles(ptls)

t_end = 10 |nbody_system.time
while(t<t_end):
    inst.evolve_model(t)
    # do something else...
inst.stop()
```

Traditional

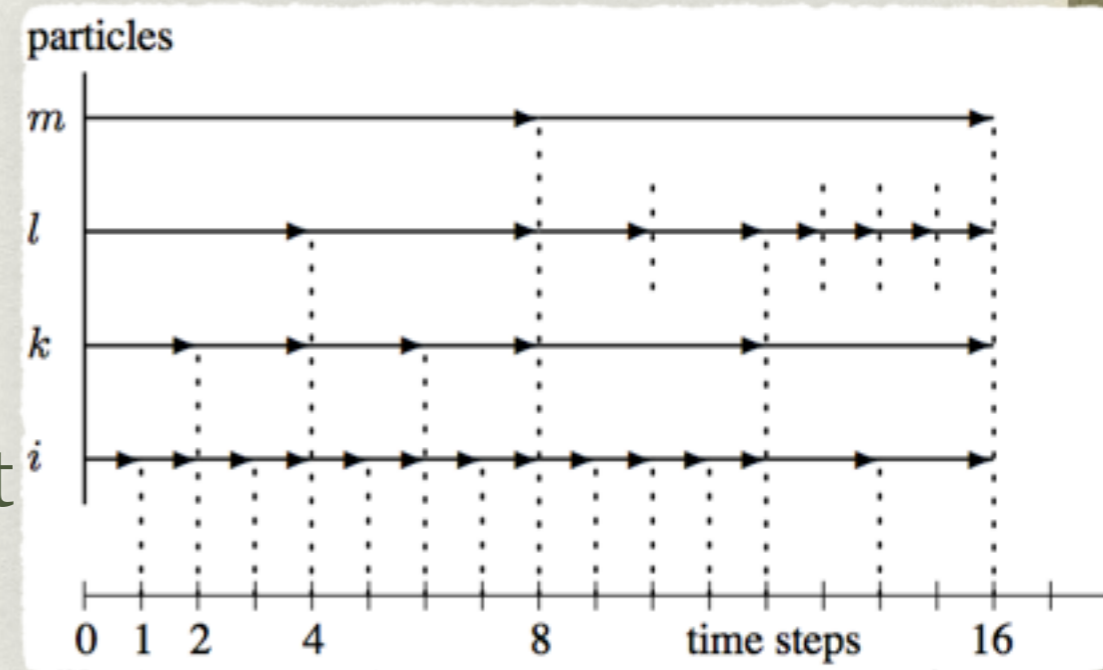
```
1 10000.0 1.E6 40 40
1000 1 10 4353 80 1
0.05 0.05 0.12 1.0 1.0 100
2.0E-05 1.0 0.7
1 2 1 0 1 1 4 0 0 2
1 0 0 0 2 1 0 0 3 2
1 0 2 0 0 2 0 0 0 2
0 0 2 0 1 0 1 1 0 1
0 0 0 0 0 0 0 0 0 0
1.0E-04 0.01 0.1 1.0 1.0E-06
0.01
2.35 20.0 0.1 0 0 0.0 0 0.0
0.5 0.0 0.0 0.0
0.005 -1.0 1.0 5.0 5 0
```


SIMULATION DATA HANDLING



ROOM FOR IMPROVEMENTS

- Fast access to a certain part of the data file:
`/path/to/resource`
- Recording only active particles
- Self-describe, machine-independent
- Large file support, Parallel I/O
- ==> HDF5 (Hierarchical Data Format version 5)



HDF5 STORAGE SCHEMA

- **Step#0: T0=...**

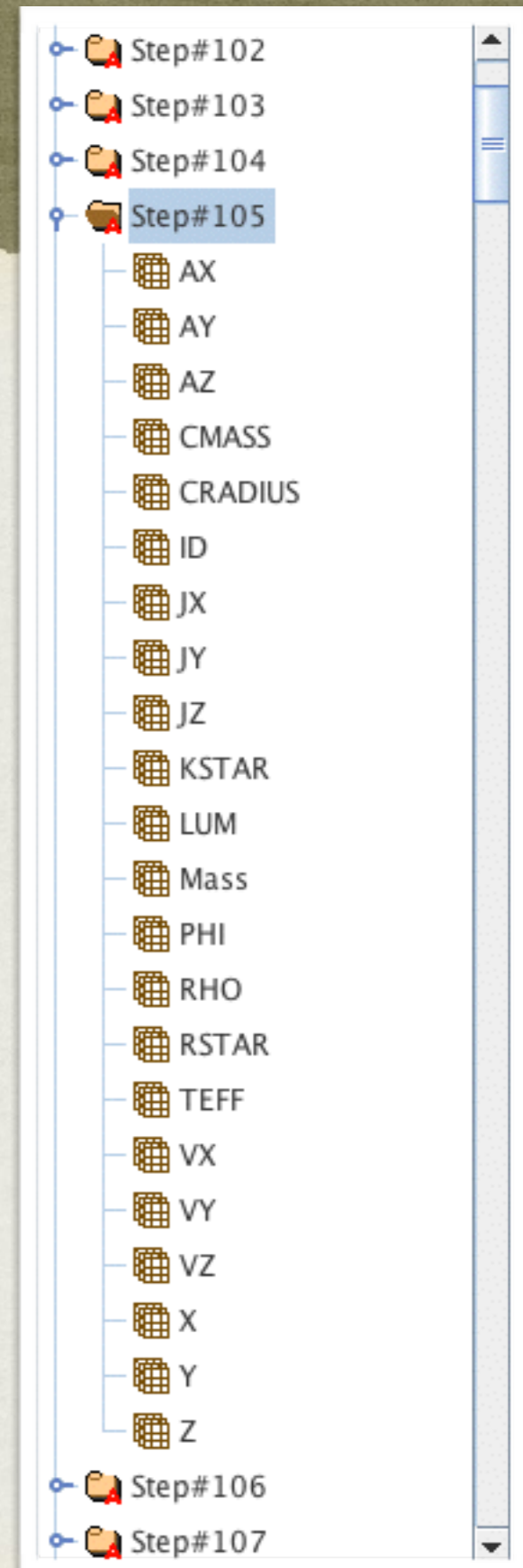
ID, x, y, z, vx, vy, vz, ax, ay, az, jx, jy, jz, mass, kstar, rho, phi, radius, luminosity, coremass, coreradius, teff, zmet...

- **Step#1: T0=...**

ID, x, y, z, vx, vy, vz, ax, ay, az, jx, jy, jz, mass, kstar, rho, phi, radius, luminosity, coremass, coreradius, teff, zmet...

- **Step#2: T0=...**

...



OUTPUT CONTROL

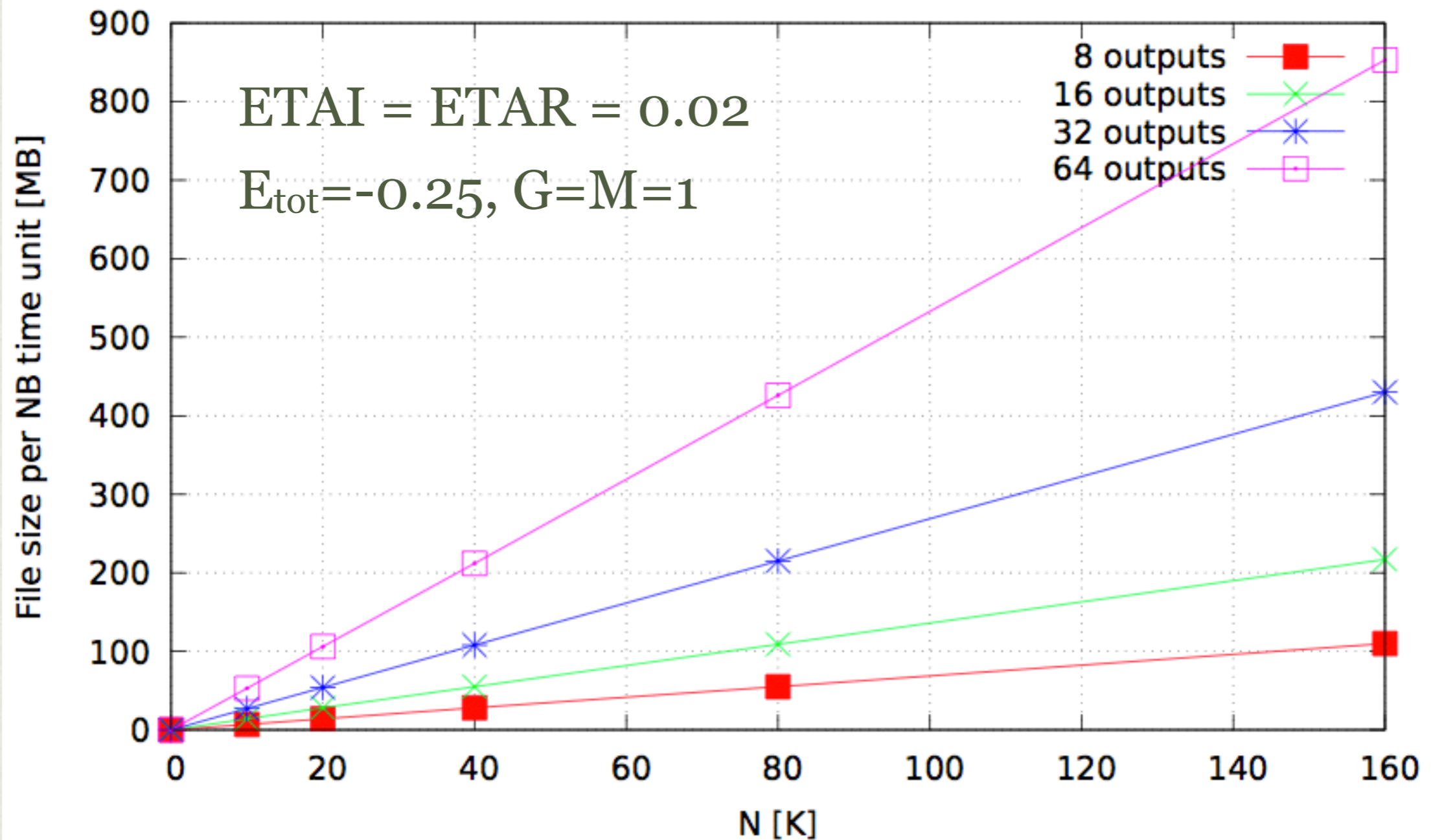
- $KZ(46)=1 \Rightarrow$ CSV
 $KZ(46)=2 \Rightarrow$ HDF5 (H5Part)
- $KZ(47)$: Output frequency
=0: Output all integrations
>0: Output $2^{KZ(47)}$ times per N-Body time unit
- Input file & AMUSE script example

```
1 1000000.0 1.E6 40 40
32000 1 10 4353 100 1
0.02 0.02 0.1 1.0 1.0 10.0 2.0E-05 1.0 0.7
1 2 1 0 1 1 4 0 0 2
1 1 0 0 2 1 0 0 3 2
1 0 2 0 0 2 0 0 0 2
0 0 2 0 1 0 1 1 0 1
0 0 0 0 0 1 8 0 0 0
1.0E-04 0.01 0.1 1.0 1.0E-06 0.01
2.35 20.0 0.1 0 0 0.0 0.0 0.0
0.5 0.0 0.0 0.0
0.005 -1.0 1.0 5.0 5 0
```

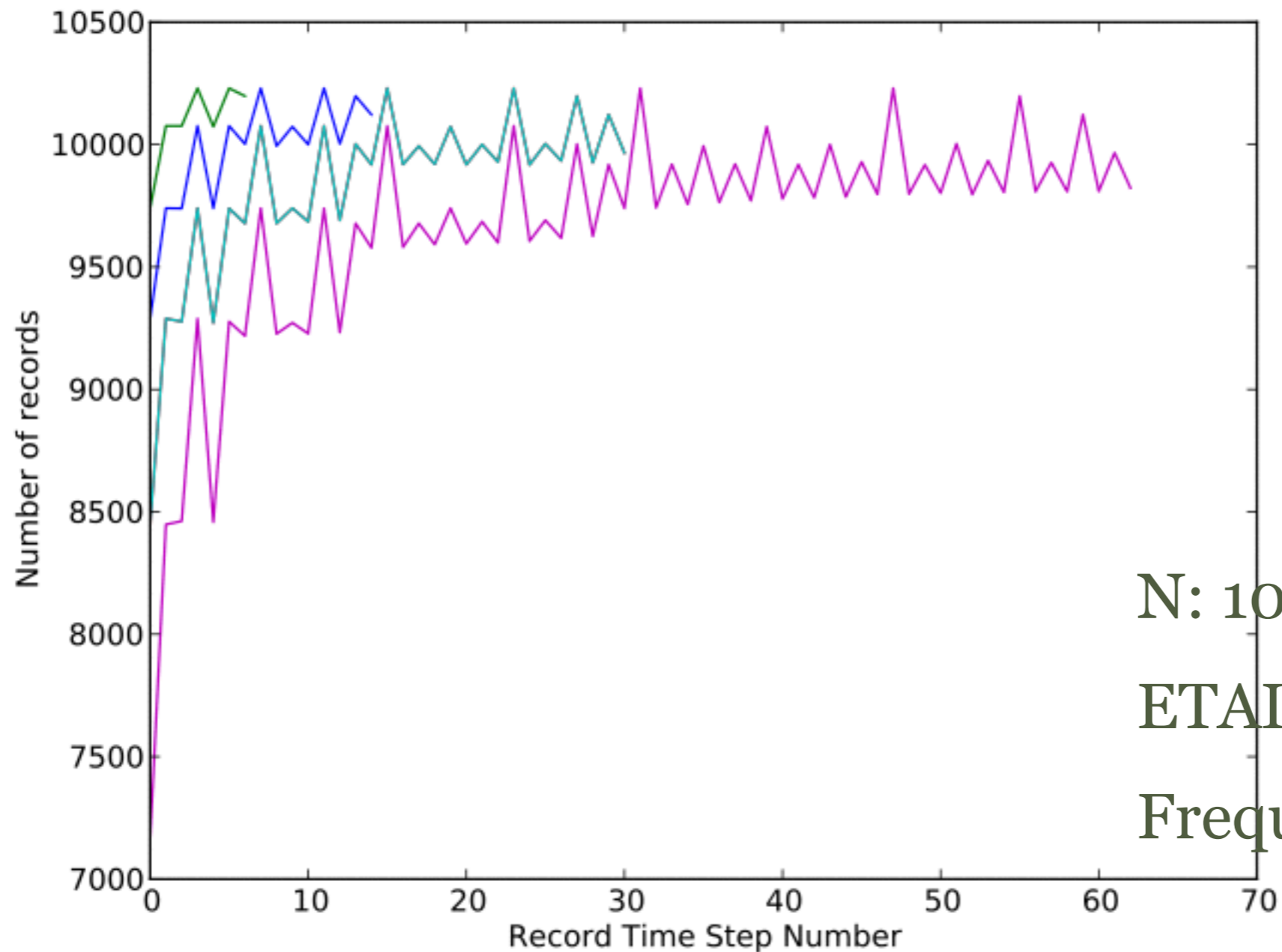
AMUSE script:

```
instance.set_kz(46,1)
instance.set_kz(47,8)
```

FILE SIZE BENCHMARKS



FLUCTUATION OF RECORD NUMBERS

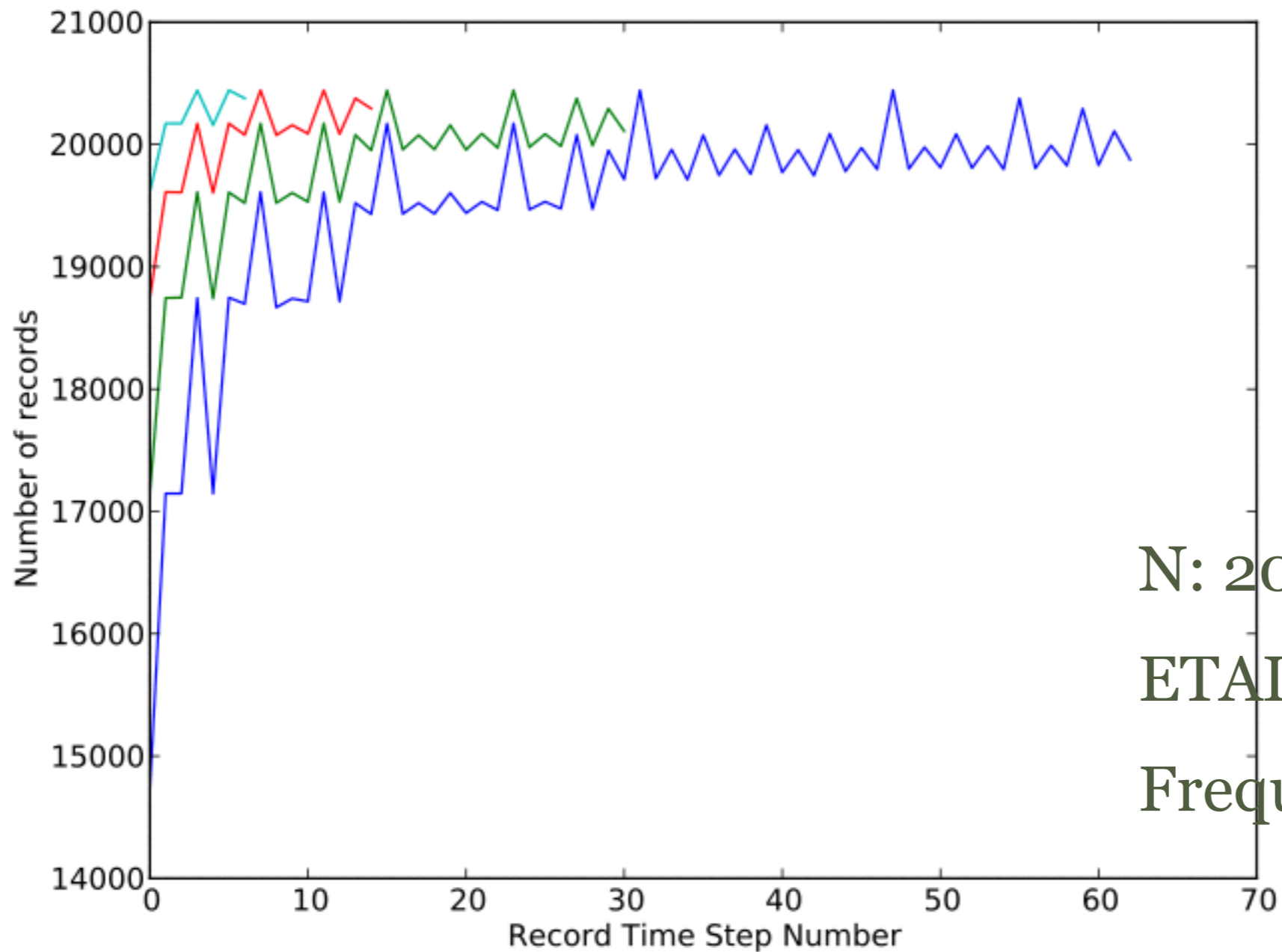


N: 10240 (10k)

ETA_I = ETAR = 0.02

Frequency: 8, 16, 32, 64

FLUCTUATION OF RECORD NUMBERS

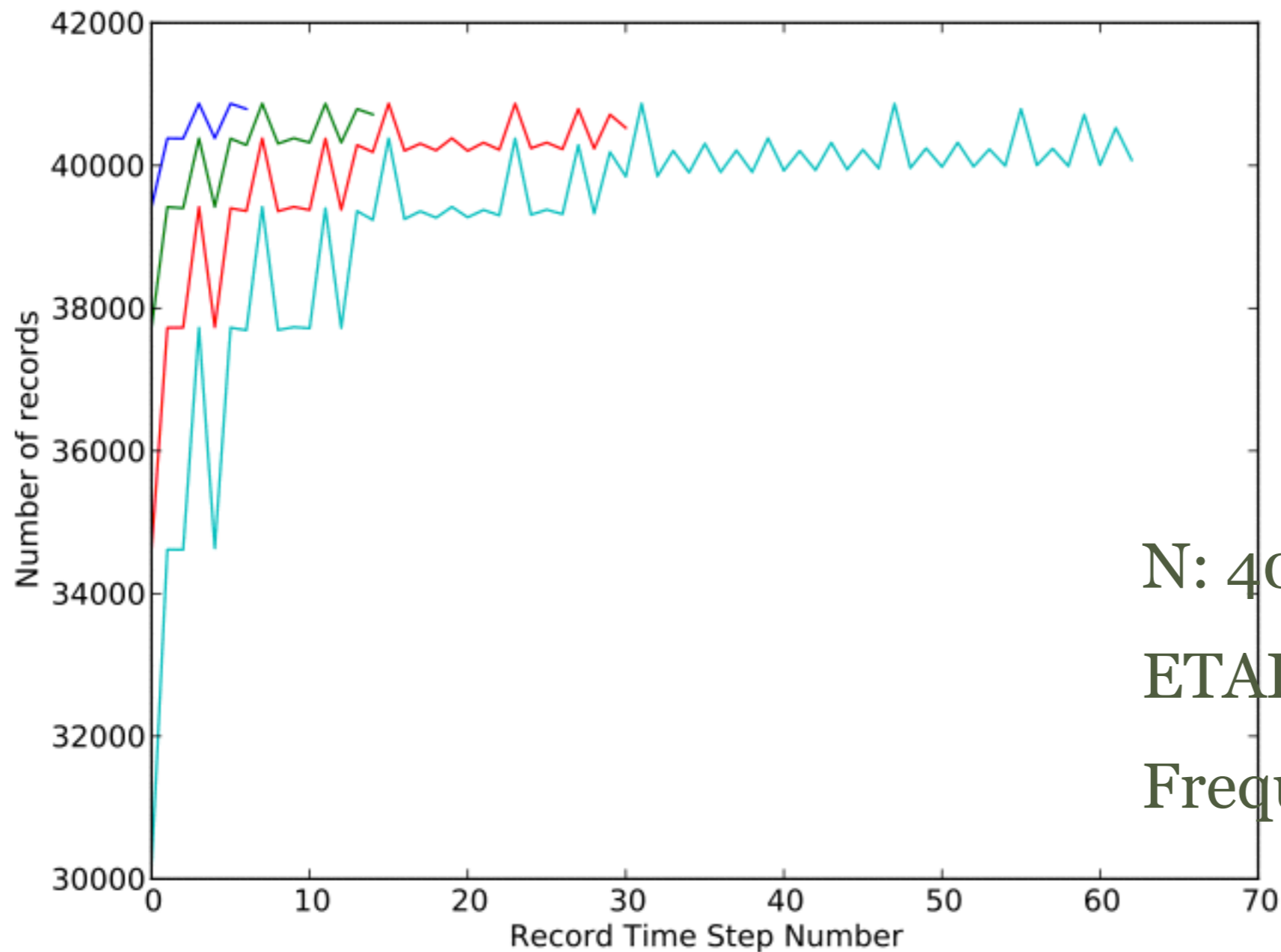


N: 20480 (20k)

ETA_I = ETAR = 0.02

Frequency: 8, 16, 32, 64

FLUCTUATION OF RECORD NUMBERS

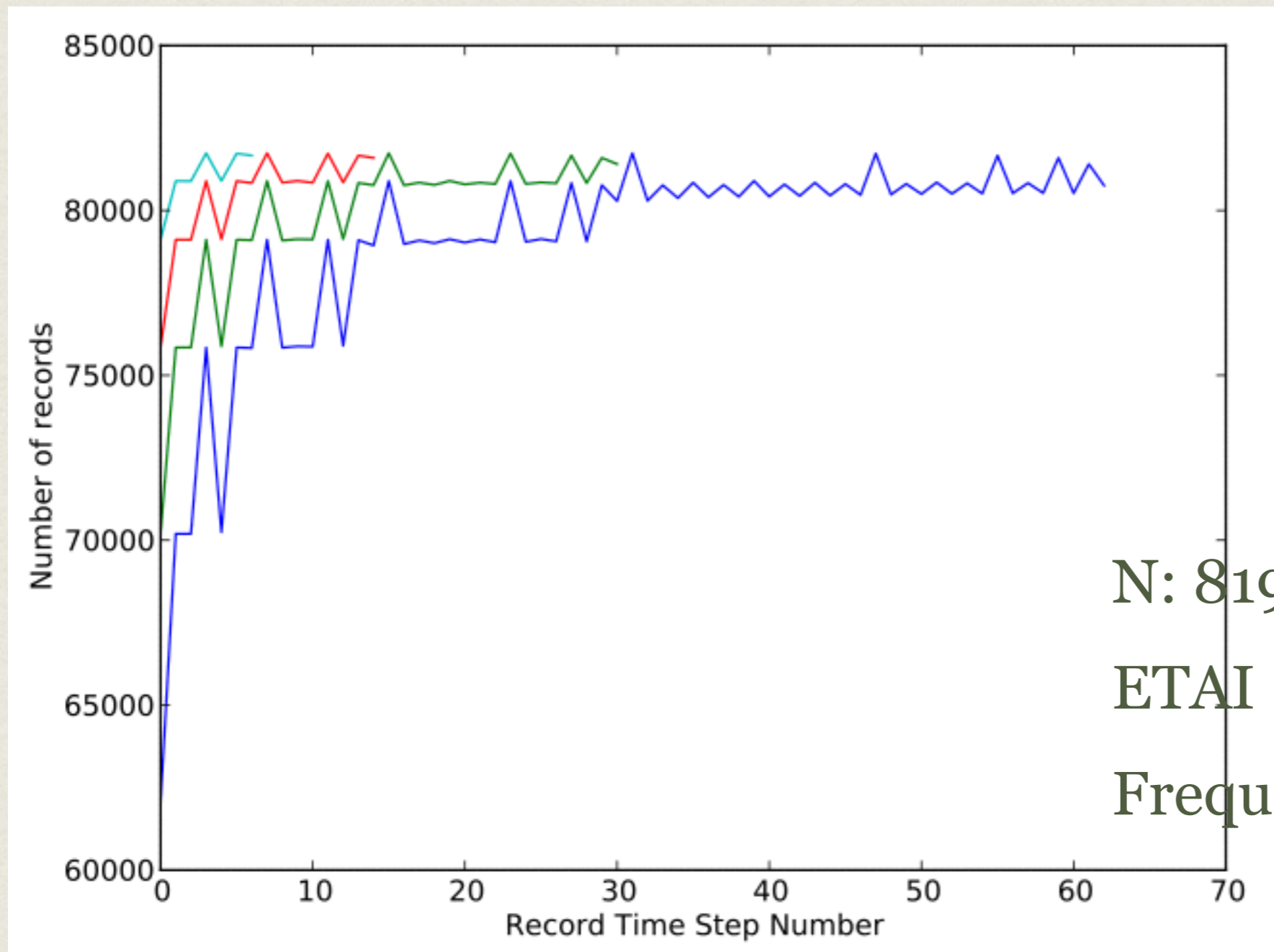


N: 40960 (40k)

ETA_I = ETAR = 0.02

Frequency: 8, 16, 32, 64

FLUCTUATION OF RECORD NUMBERS

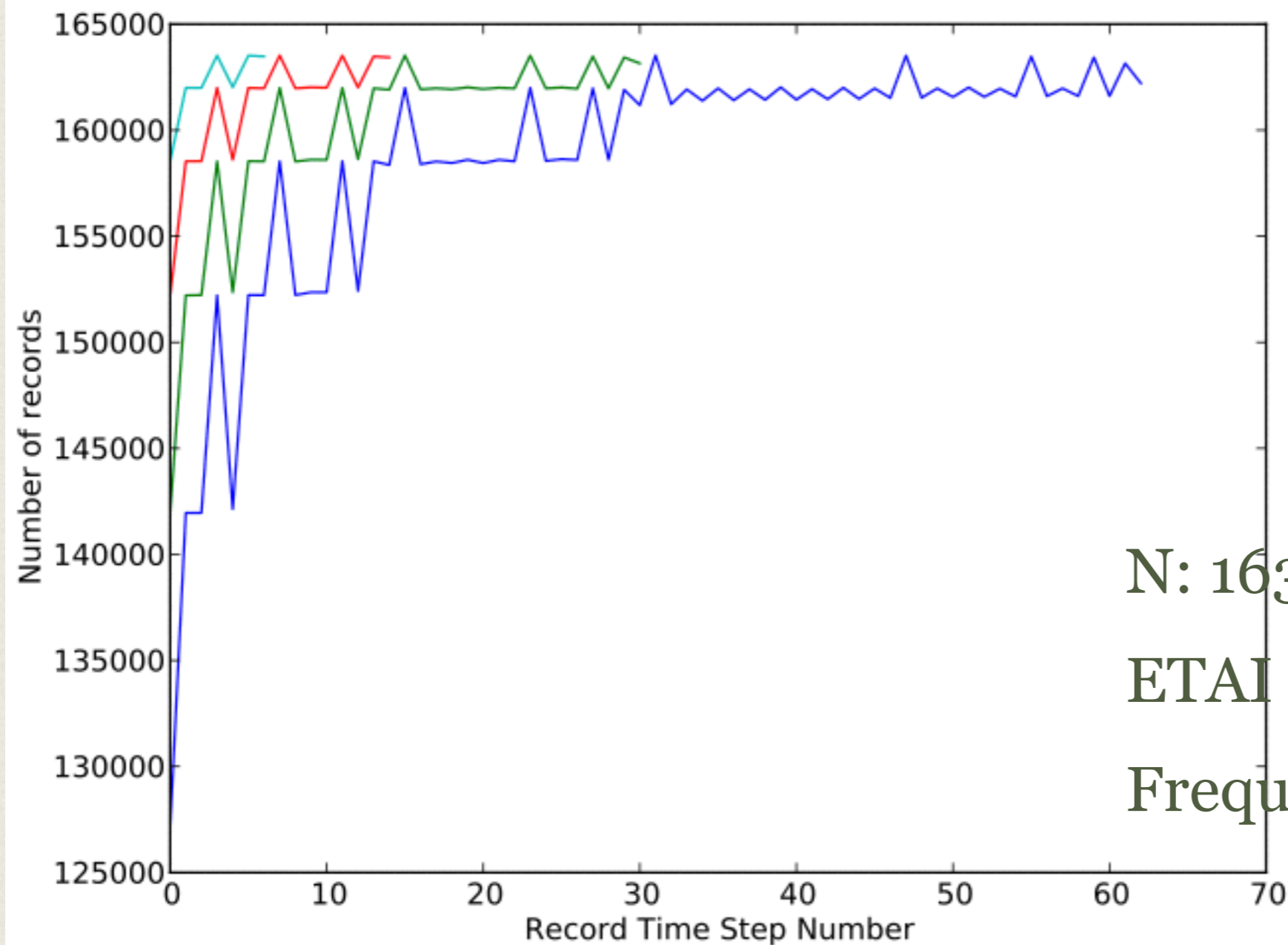


N: 81920 (80k)

ETA_I = ETAR = 0.02

Frequency: 8, 16, 32, 64

FLUCTUATION OF RECORD NUMBERS



N: 163840 (160k)

ETA_I = ETAR = 0.02

Frequency: 8, 16, 32, 64

DEMO

LINKS

- NBODY6++: <http://silkroad.bao.ac.cn/repos/worknb6/>
- VisNB6: <http://silkroad.bao.ac.cn/repos/visnb6/>
- AMUSE: <http://amusecode.org/>
- HDF5: <http://www.hdfgroup.org/>
- ParaView: <http://www.paraview.org/>

== FIN ==

THANK YOU

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