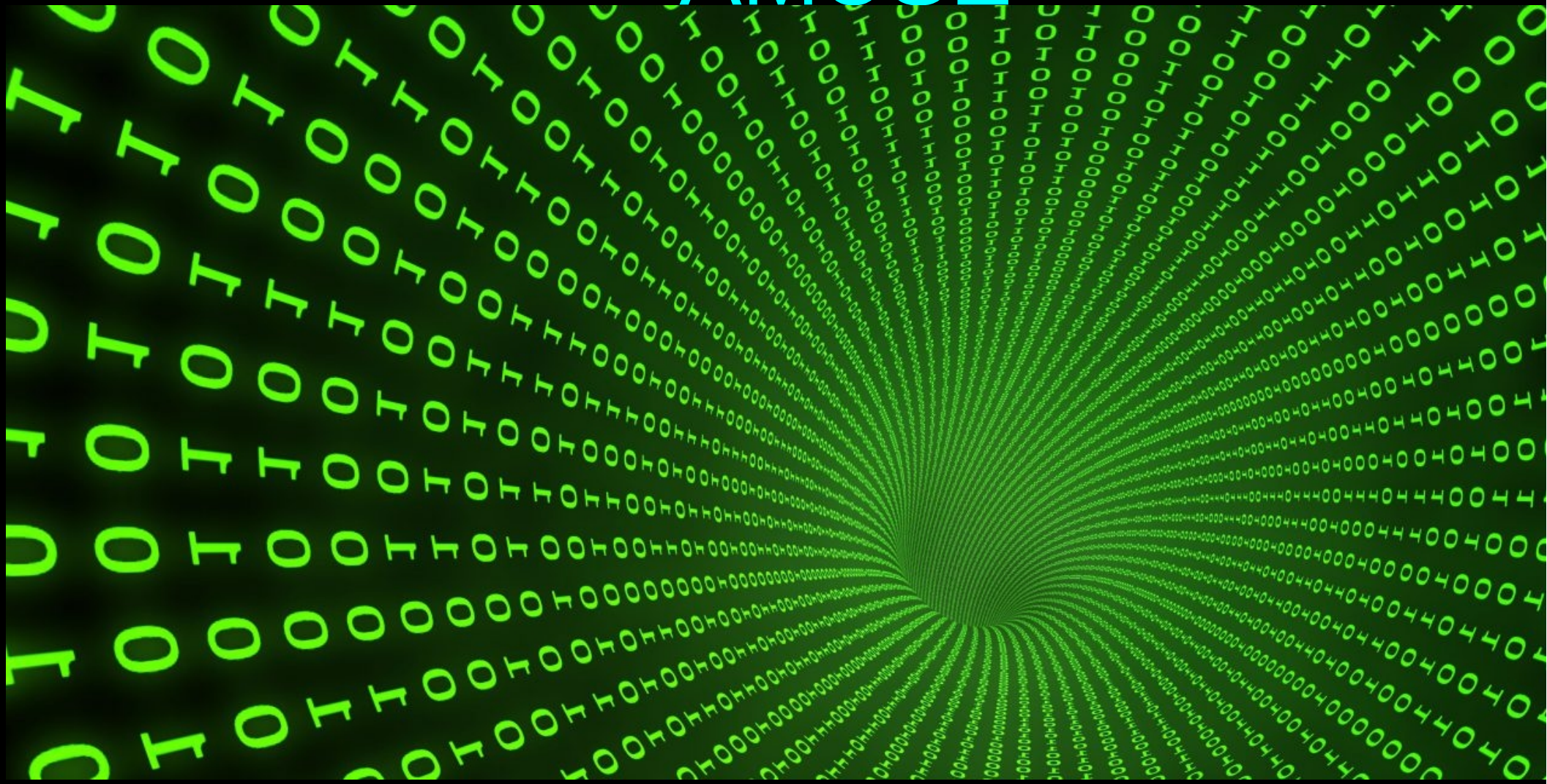
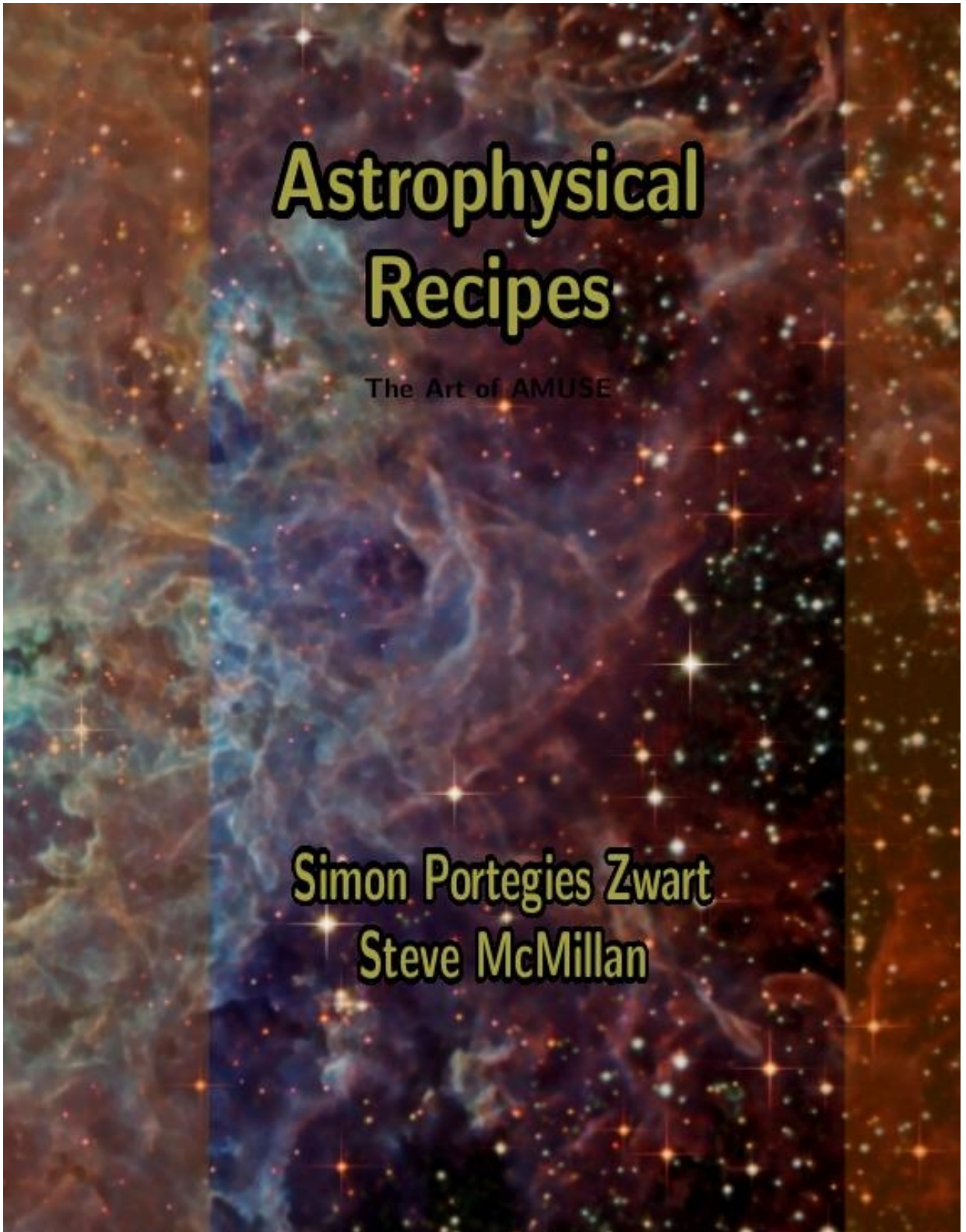
Reproducible Computing with AMUSE

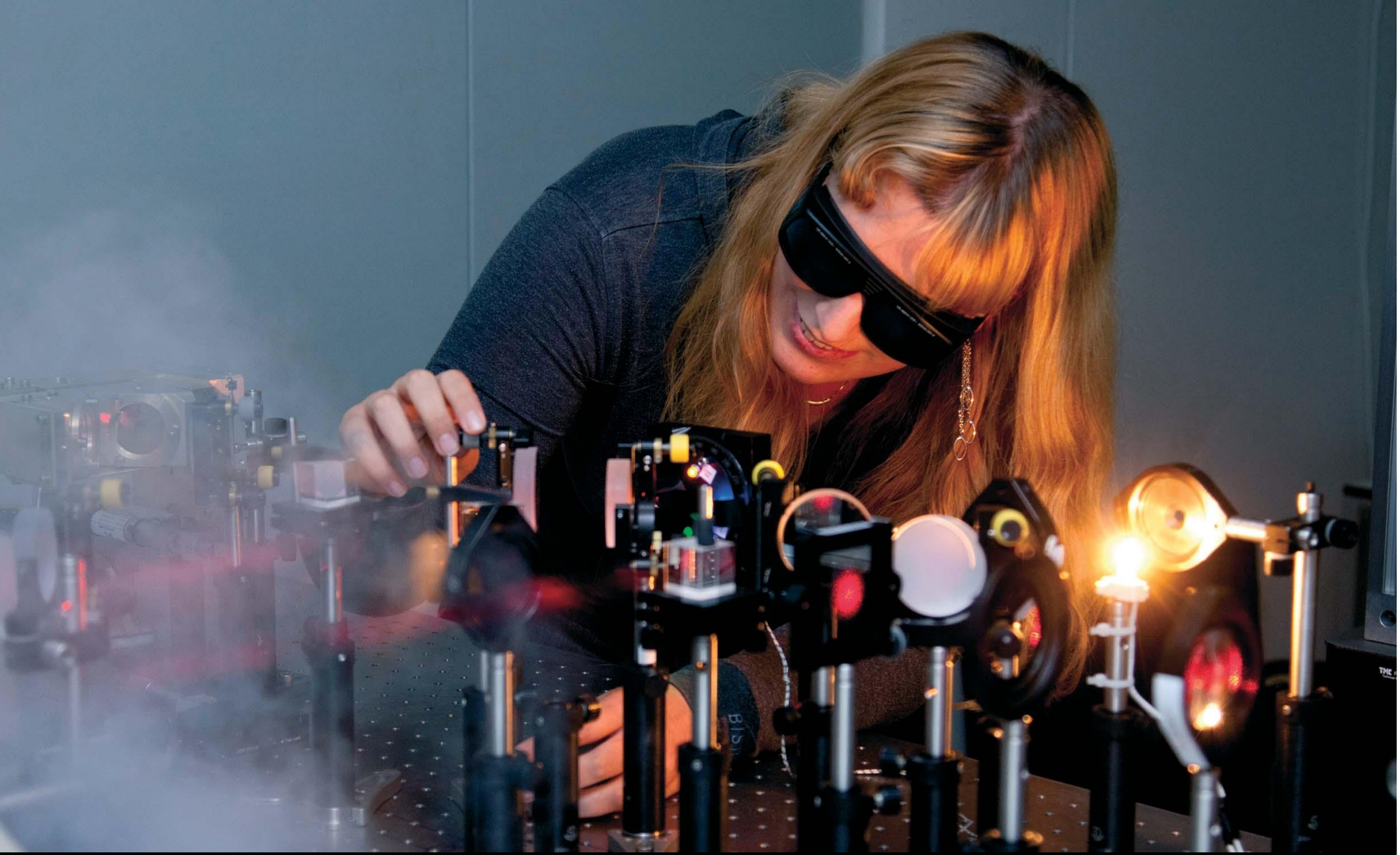


Simon Portegies Zwart
Sterrewacht Leiden

AMUSE

Sterrewacht Leiden


Astrophysical
Recipes
The Art of AMUSE
Simon Portegies Zwart
Steve McMillan



added touch of synthrapol at last minute (b/c I forgot earlier)

- ugh - the surfactant means 's seem to edges (except I then mixed it in - maybe don't bother in future?

1st batch: ~~||||~~ |
4 fat eighths (for solid gradation) 2-4-6-8
1 arashi (6)
1 boushi (4)

2nd batch ||||
1 arashi
1 nui shibori (tried weeks ago)
3 itajime (4-6)

3rd batch (dyed w/ 1st, 1 cycle behind)
2 itajime (one 1×9, one 4×4) ||||
(6, but 5&6 v. quick - just 1 min)

some of the seams - the worst flakes - skimmed before dyeing
temp. maintained ~110-118 °F
shorter dips: ~10 min or so
oxidation 20-30 min (more the latter)
added remainder of stock soln after removing dip 3 of 1st batch

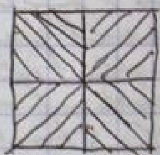
4th batch: 1 itajime |||
(square window pattern)

~5th dip: turned off heat b/c lt rain started
5th batch: 1 FQ, plain ||

bath looking pretty tired by 7th dip on solid 1/8; decided to try + do last dips (4 on 4th batch, 3 on 5th) even if more or less exhausted

5/3: notes

Next goals:
more arashi!
more nui shibori!
itajime
do more 1/2-yd pcs. { - another "window" configuration
- more triangle variations (equilateral + half sq)
- folding on the bias, esp.:

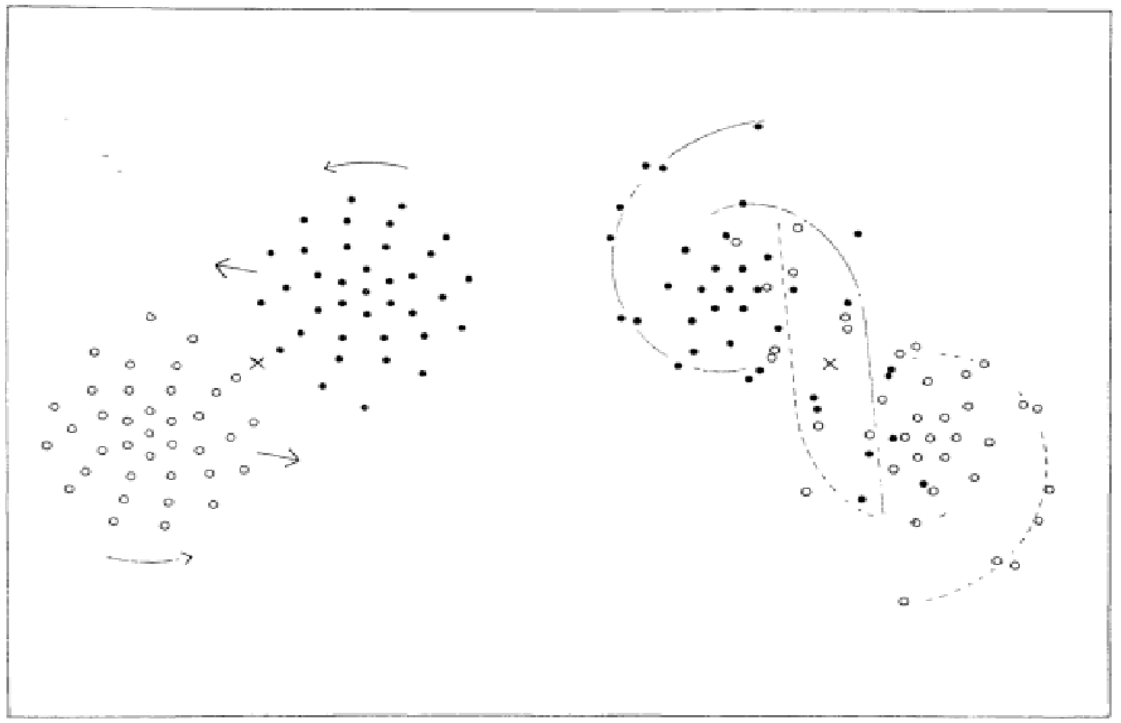


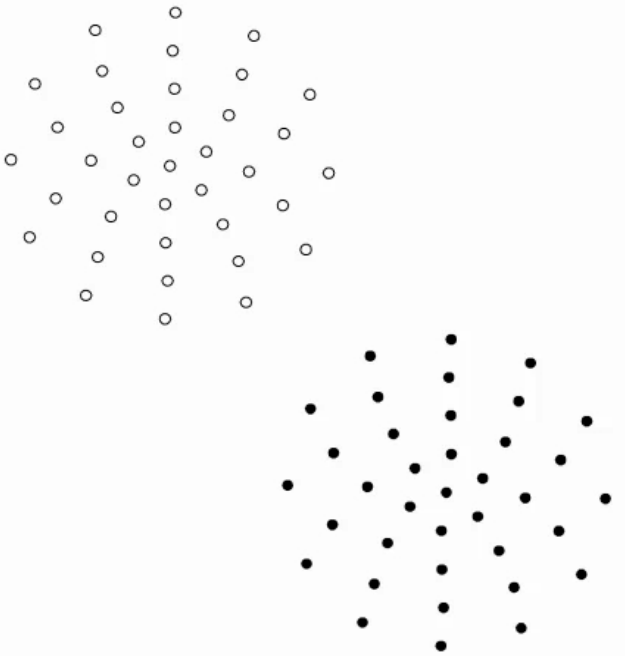
(start w/ sq. + fold in fourths before folding on bias)

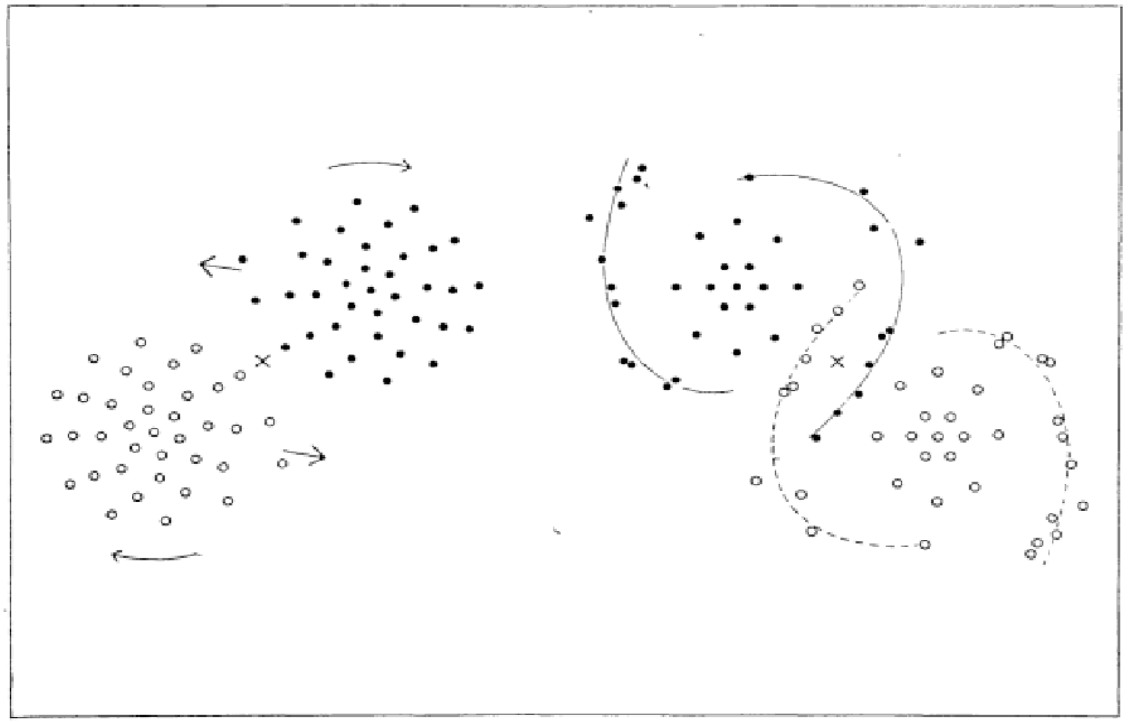
- solid gradation: 1-8
silk shibori

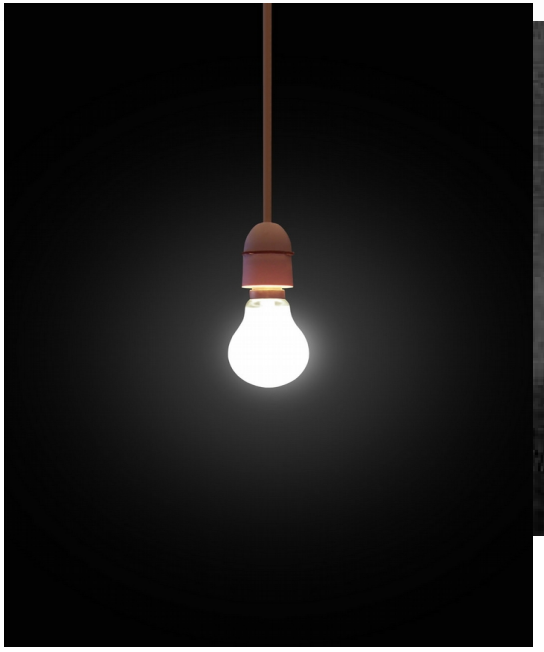
next bath - use less indigo - I think I'm leaving a lot behind in the vat for the sm. amount of fabric that I'm dyeing
|| also Wikipedia "vat dye" entry says better color-fastness w/ less dye + more dippings

5/3
neutralization/rinse began at 5:30pm ~24 hrs after dyeing completed
- vinegar acid bath in warm water, ~1/4 c. per tub
- both baths have a light green cast to them - should I be using longer times for aeration?
- soaked nearly 2 hrs
washed in tub w/ touch of Orvus - signif dye runoff, esp in dark fabrics
- still signif dye runoff despite 3 washings; will rinse + hope

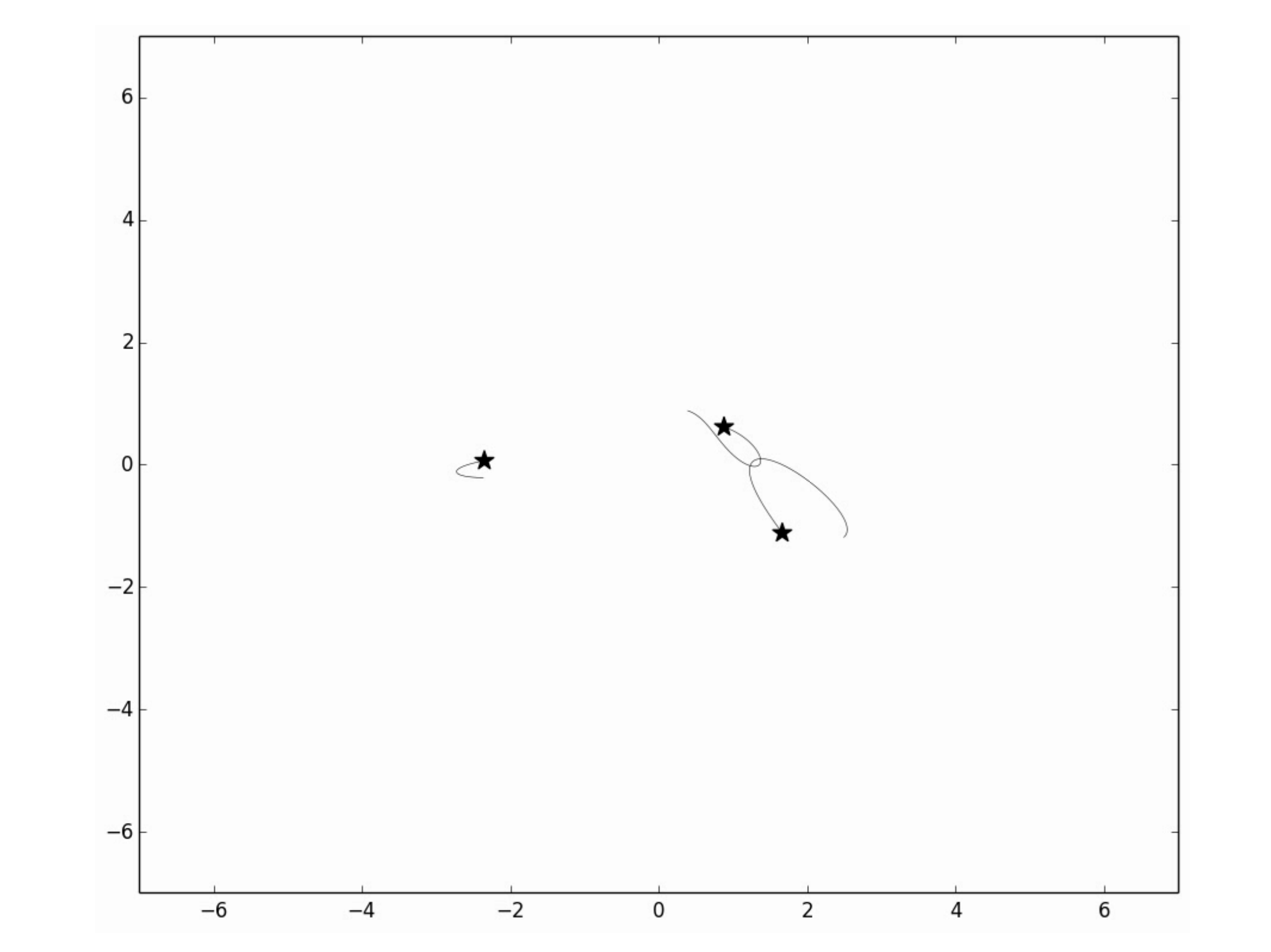








Erik Holmberg
1908-2000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1954

"*Errors in calculations of n-body systems grow exponentially … and may therefore invalidate the results …*" (Miller 1964)

Assahoryu vs Baruto

Radiative transport

Gravity

gas-dynamics

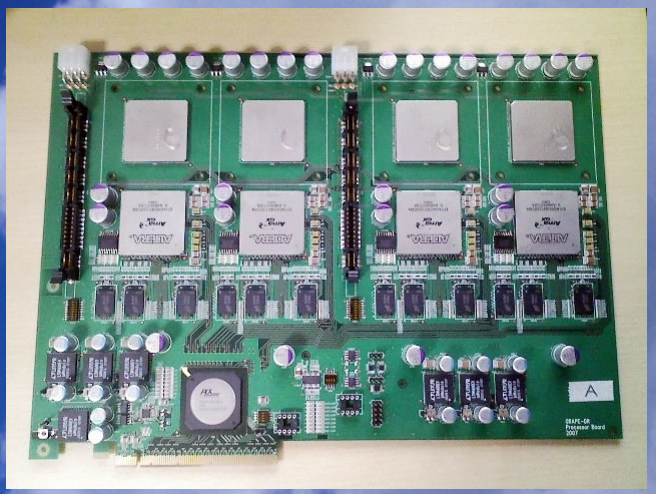
hydro-dynamics

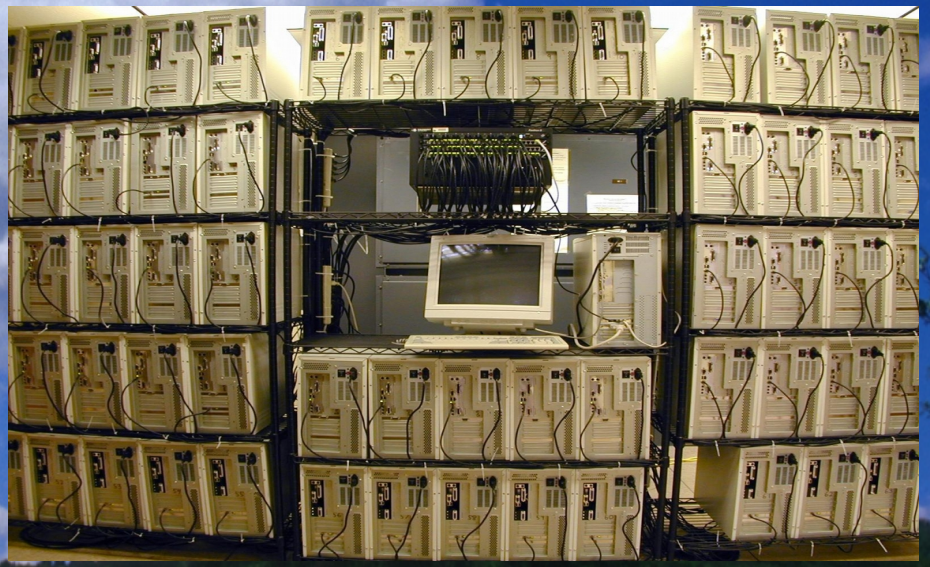
Stellar evolution

Radiative transport

Maxwell equations

Gravity





hydro-dynamics

gas-dynamics

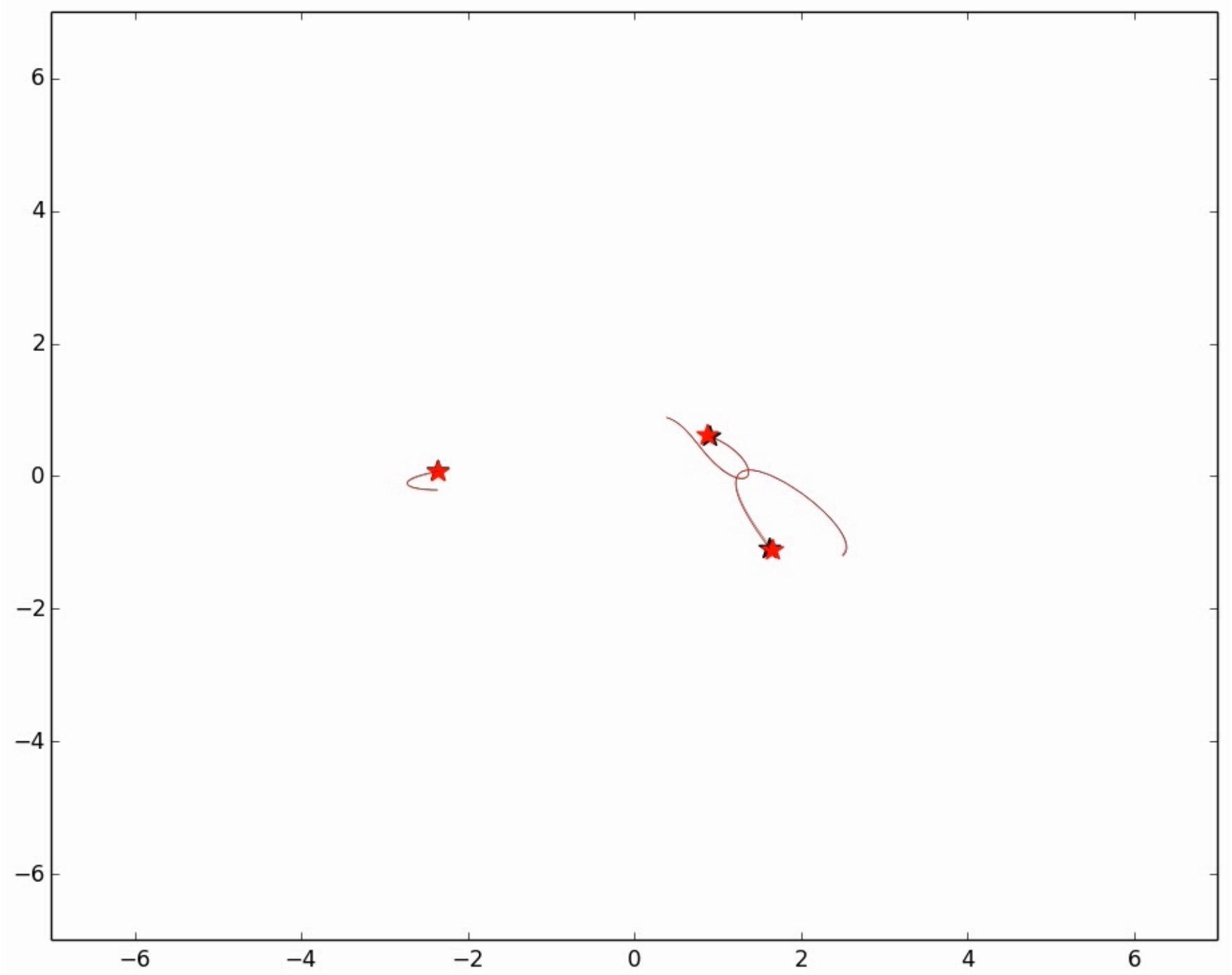
Stellar evolution

BRUTUS

a brute force arbitrary-precision N-body code

- Two ingredients:
  - Gragg-Bulirsch-Stoer method
    - Modified midpoint method
    - Richardson extrapolation
    - Tolerance parameter
  - Arbitrary-Precision arithmetic
    - Number of significant digits

Tjarda Boekholt 2015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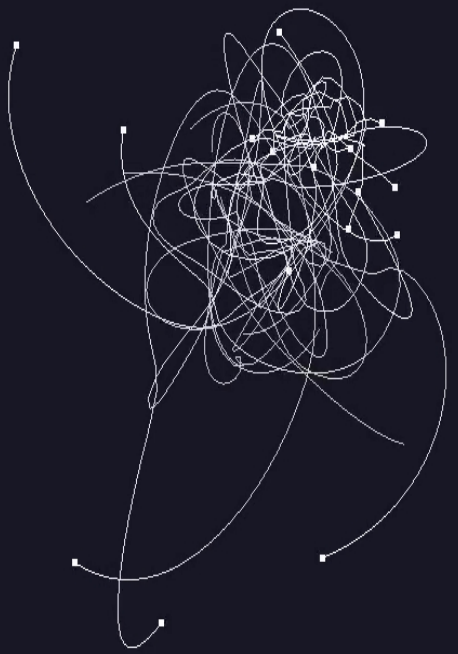

afronding met 6 decimale getallen

AMUSE - philosophy

- Build on community codes
- Standardized interfaces
- Automate as much as possible
- >100 example scripts
- >20M lines of source code

  F*, c/c++, python, java

And a book:
Astronomical Recipes

The AMUSE script

```
%Merge_two_stars
from amuse.lab import *

primary = Particle(mass=0.75|units.MSun)
secondary = Particle(mass=0.55|units.MSun)
stellar = MESA()
stellar.particles.add_particles([primary, secodary])

stellar.evolve_model(10.2|units.Gyr)

stellar.merge_colliding(primary, secondary, MMAMS)

stellar.evolve_model(11.7|units.Gyr)
print stellar.particles
```

The AMUSE script

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%Merge_two_stars
from amuse.lab import *

primary = Particle(mass=0.75|units.MSun)
secondary = Particle(mass=0.55|units.MSun)
stellar = MESA()
stellar.particles.add_particles([primary, secodary])

stellar.evolve_model(10.2|units.Gyr)

stellar.merge_colliding(primary, secondary, Gadget2)

stellar.evolve_model(11.7|units.Gyr)
print stellar.particles
```

The AMUSE script

```
%Merge_two_stars
from amuse.lab import *

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secondary = Particle(mass=0.55|units.MSun)
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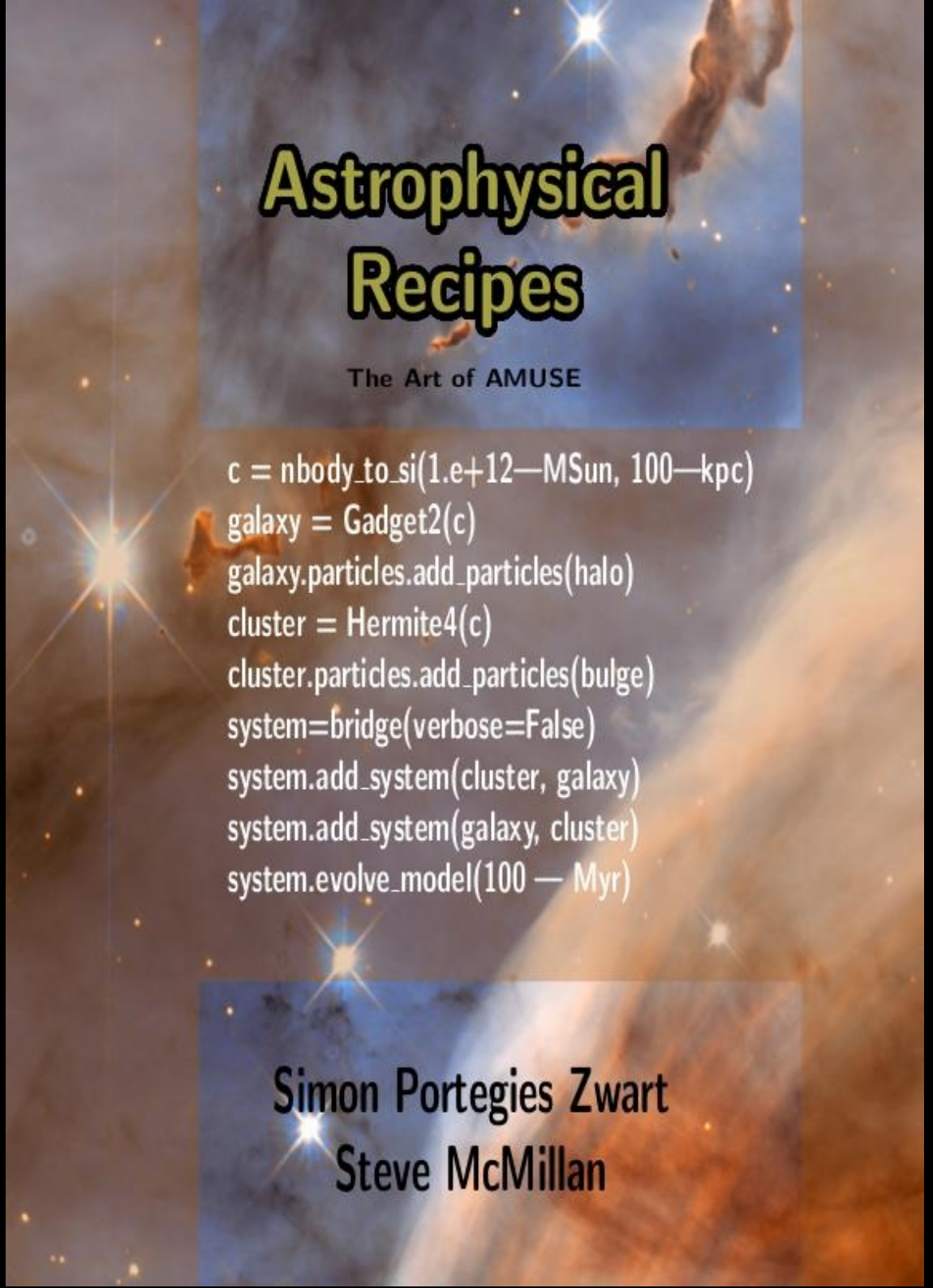
stellar.particles.add_particles([primary, secodary])

stellar.evolve_model(10.2|units.Gyr)

stellar.merge_colliding(primary, secondary, Fi)

stellar.evolve_model(11.7|units.Gyr)
print stellar.particles
```

Summer 2017

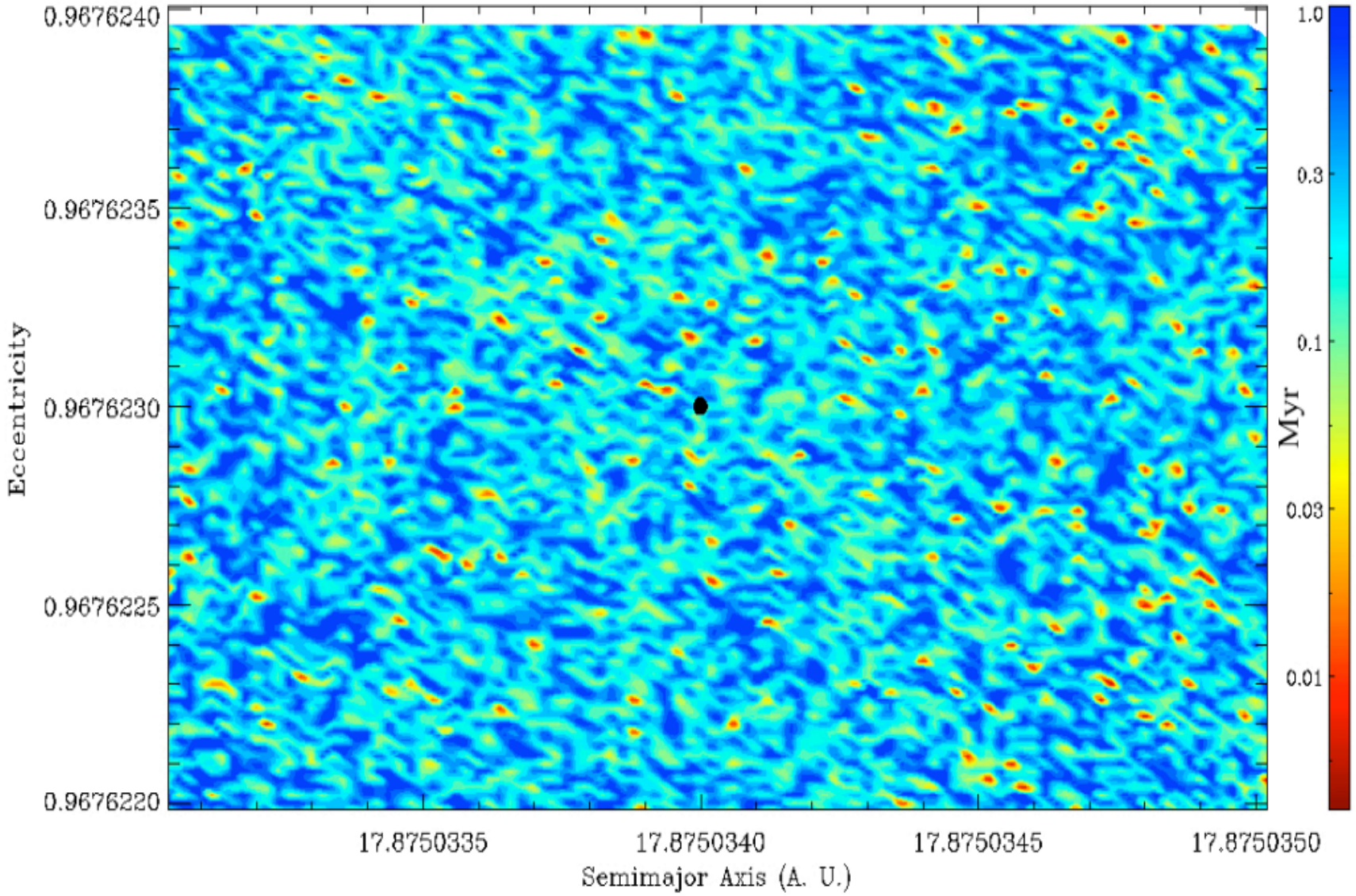


AMUSE

Conclusions

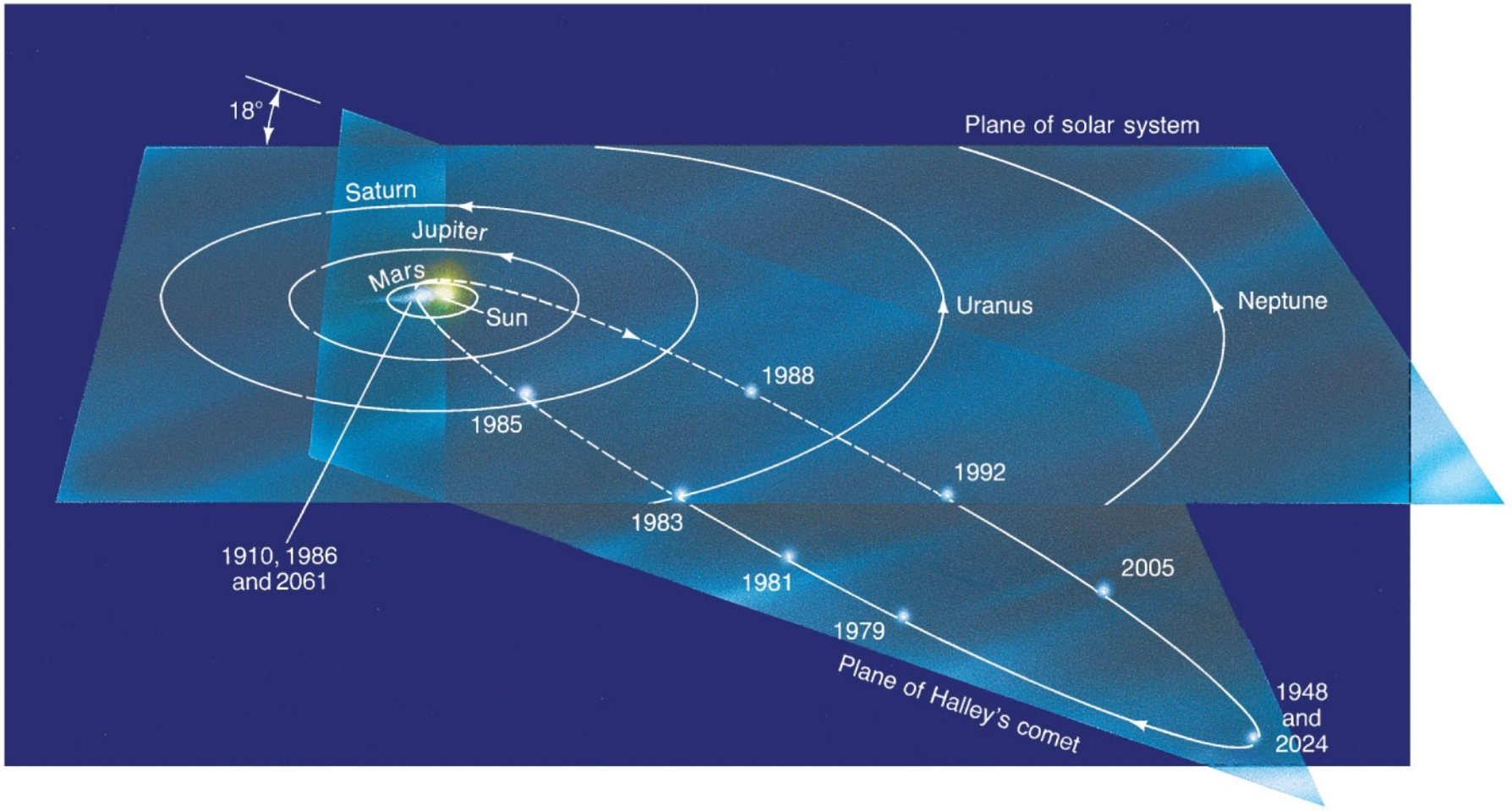
- Reproducibility in Simulation software is an ill studied topic, and it deserves more attention.
- Emphasis should be given to:
  - Software preservation.
  - Guidelines for the proper conduction of simulation experiments
  - Credit for software writing, preservation and validation

Chaos in Halley

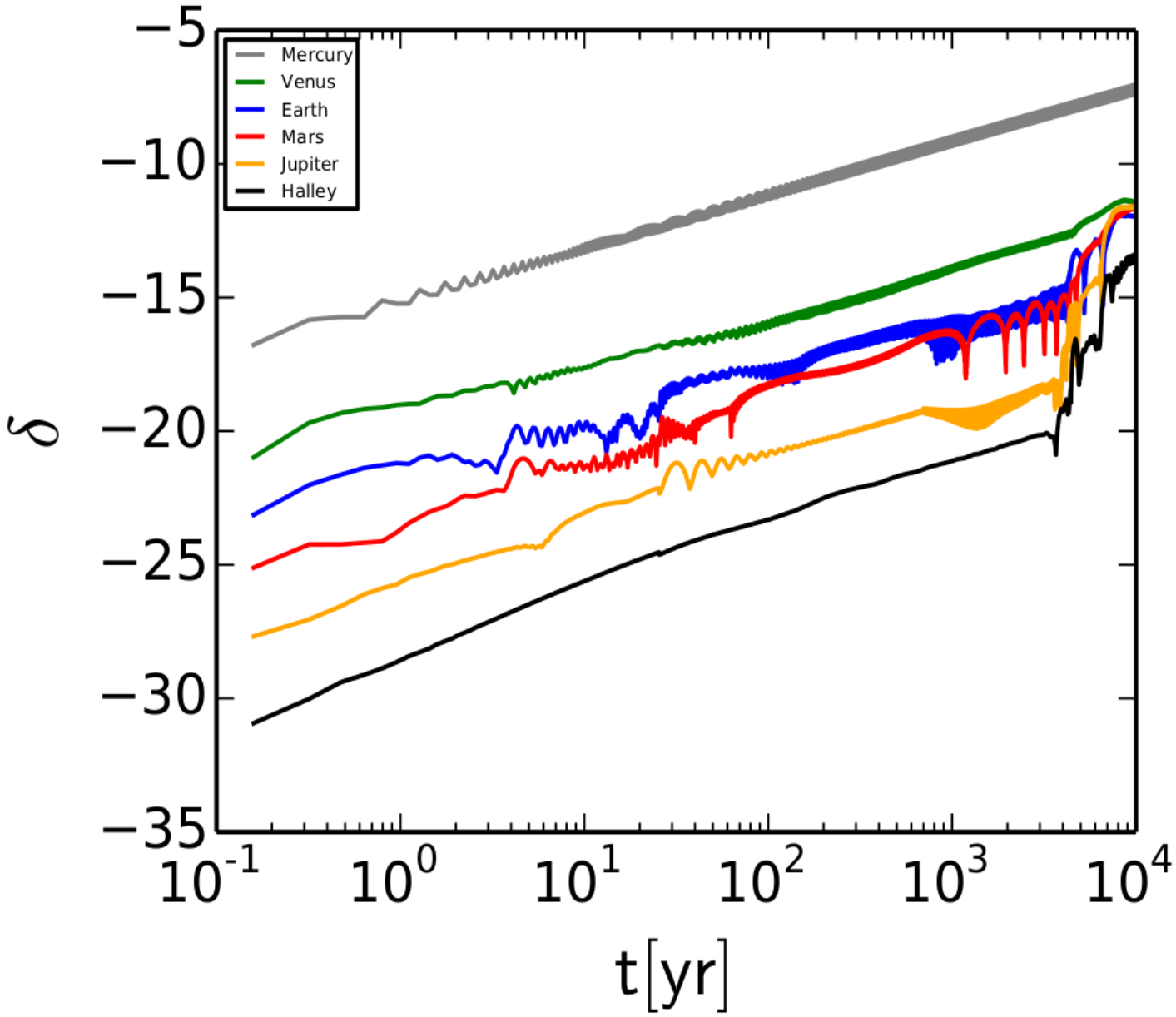


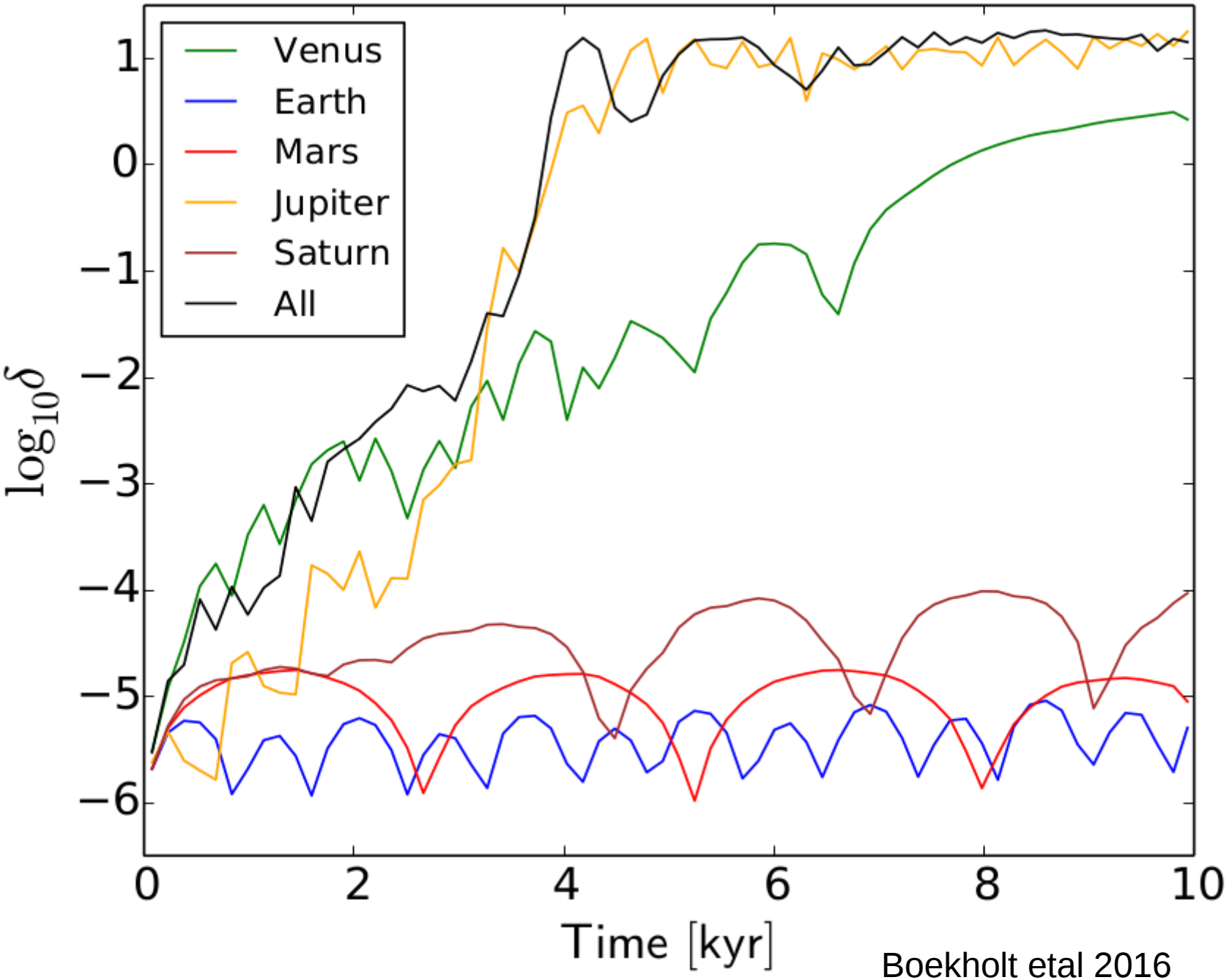
Munoz-Gutierrez etal 2014

Orbit of comet Halley

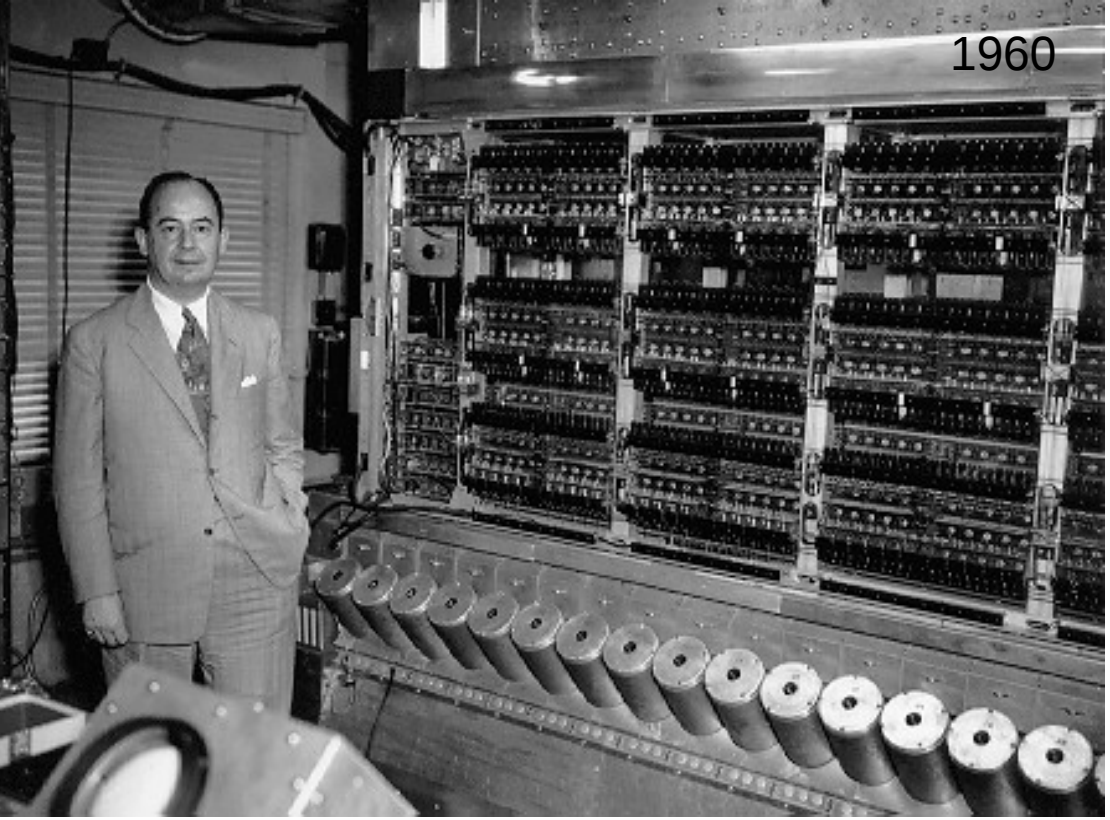


Growth of the error

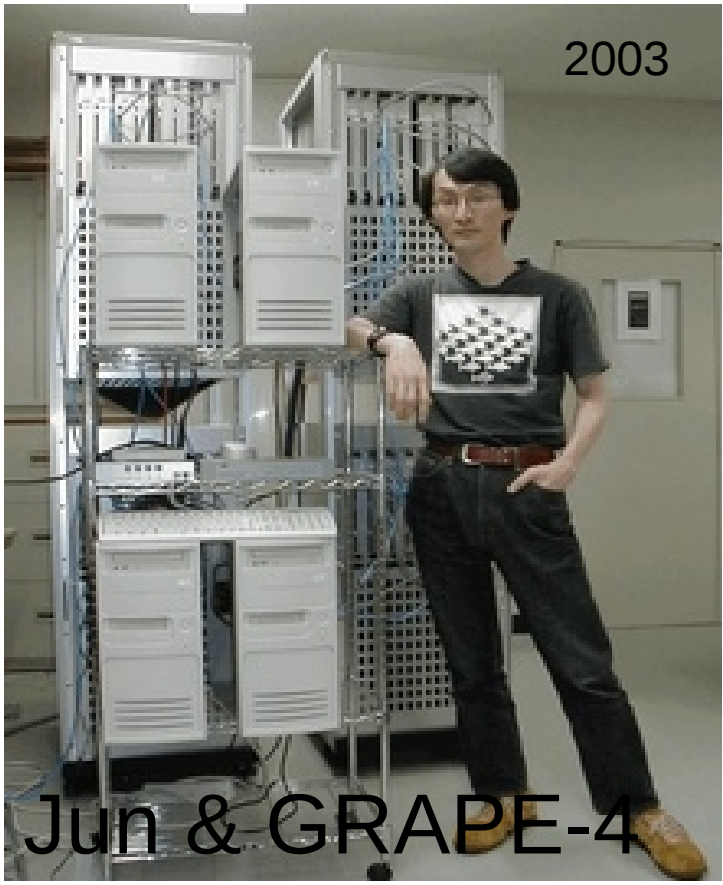




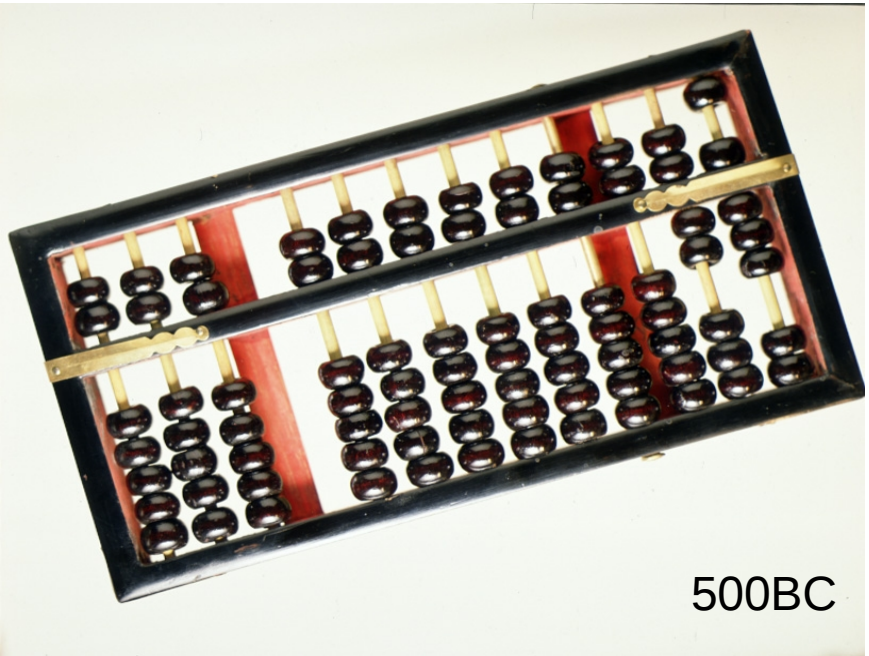
Boekholt etal 2016



von Neuman & IAS



~30 000 000 times faster



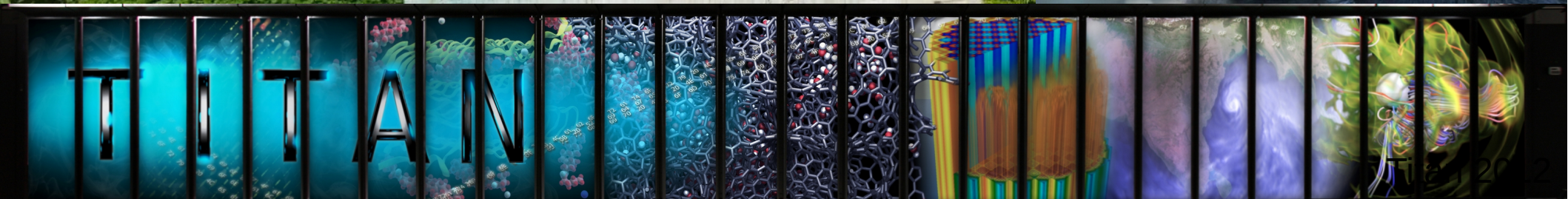
The New supercomputer at Leiden Observatory

Volkskrant 5 April 2017

An ape on the shoulders of a giant,

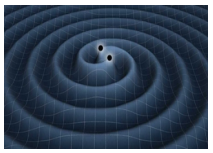
Rodin 1902

Ape 33M B.C.



Gravity's complexities

- Gravity has a negative heat capacity.
- The force calculation is an N*N operation.
- Gravity is global aware: There is no shielding in gravity, such as in molecular dynamics.
- At small distances the force grows limitless.

 $E=3.6\ 10^{56}$ erg/s ~ 1million supernovae

- The equations of motion are intrinsically chaotic (but we do not know why).

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Creating the Virtual Universe

Simon Portegies Zwart and Jeroen Bédorf

In *The Hitchhiker's Guide to the Galaxy*, the guide's editor had a universe in his office. Now you can too. Hopefully, there's no Total Perspective Vortex in this one. —Michiel van Genuchten and Les Hatton

TO UNDERSTAND THE universe, modern science employs a three-pronged strategy: an empirical perspective, by gazing at the stars; a theoretical perspective, by developing conjectures; and simulation. In particular, computer simulations are essential for acquiring this understanding. That's because our view of the heavens is limited to a single perspective in a minuscule volume in space-time, and only a small portion of that universe fits in a lab. Simulation can be separated again into three areas: hardware, algorithms, and software engineering. Here, we focus on software engineering because it's often considered the least important.

The immensity of space and the fact that the smallest scales are intricately coupled to the largest scales make modeling the universe a challenge. We're just starting to understand how to combine and all the physics we don't know, comes together here. This complexity is well posed in the *Hitchiker's Guide to the Galaxy*:

> *All you really need to know for the moment is that the universe is a lot more complicated than you might think, even if you start from a position of thinking it's pretty damn complicated in the first place.*[1]

On the basis of this quote, it seems that astronomers have accepted an impossible task. Nevertheless, to address these challenges and enable scientists to perform this task, we've developed simulation software we call the Astronomical Multipurpose Software Environment (AMUSE).[2]

Addressing the Challenges