FLASH bootcamp

Kuo-Chuan Pan

Schedule

1. Opening
2. Research Tools
3. FLASH (part 1)
4. (lunch)
5. FLASH (part 2)
6. Visualization with yt
7. FLASH Lab

ASTROPHYSICIST

What my friends think I do

What my mom thinks I do

What society thinks I do

IMPACT OF TYPE Ia SUPERNOVA EJECTA ON BINARY COMPANIONS IN THE SINGLE-DEGENERATE SCENARIO

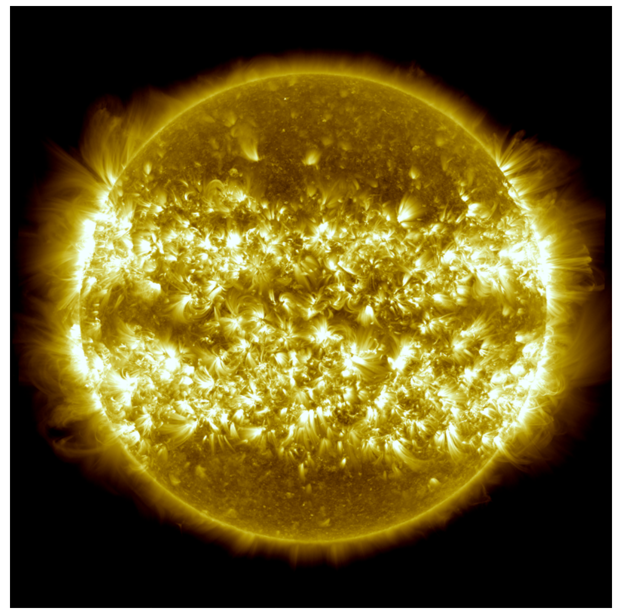
What my professor thinks I do

What I think I do

What I really do

Opening: why we need computation?





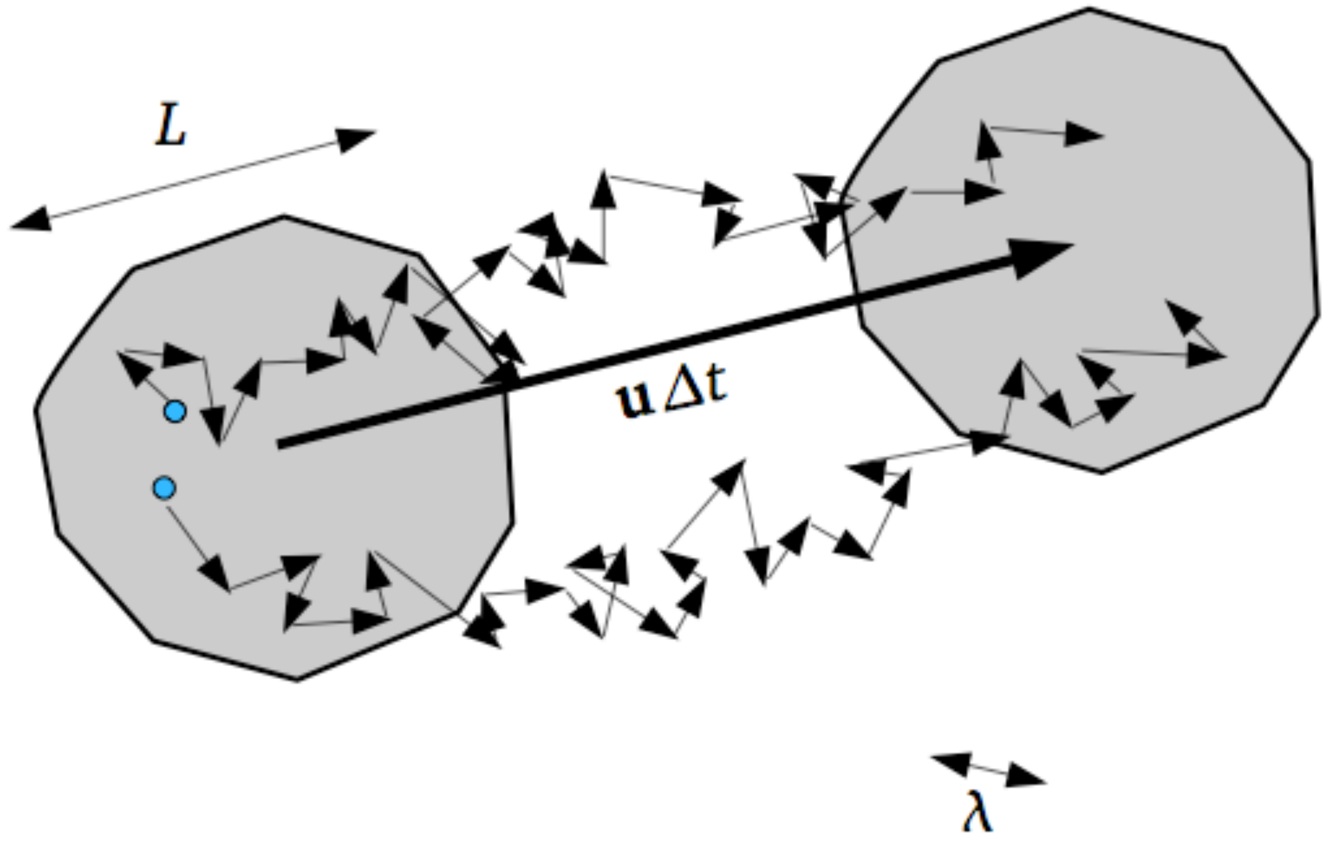
- We receive and record, but we do not experiment or perturb (too distant)
- Astrophysics involves extreme conditions that cannot be replicated in lab (mostly)
- Timescales are >> human lifetime (mostly) >> Ph. D. timescale

Opening: why hydrodynamics?

$$\lambda_{\rm mfp} << l_{\rm ch} \quad \lambda_{\rm mfp} = \frac{1}{n\sigma}$$

- Euler equations:

$$\frac{\partial \rho}{\partial t} + \boldsymbol{\nabla} \cdot (\rho \boldsymbol{v}) = 0,$$
$$\frac{\partial \rho \boldsymbol{v}}{\partial t} + \boldsymbol{\nabla} \cdot (\rho \boldsymbol{v} \boldsymbol{v}) + \boldsymbol{\nabla} P = -\rho \boldsymbol{\nabla} \Phi,$$
$$\frac{\partial \rho E}{\partial t} + \boldsymbol{\nabla} \cdot [(\rho E + P)\boldsymbol{v}] = \rho \boldsymbol{v} \cdot \boldsymbol{\nabla} \Phi$$

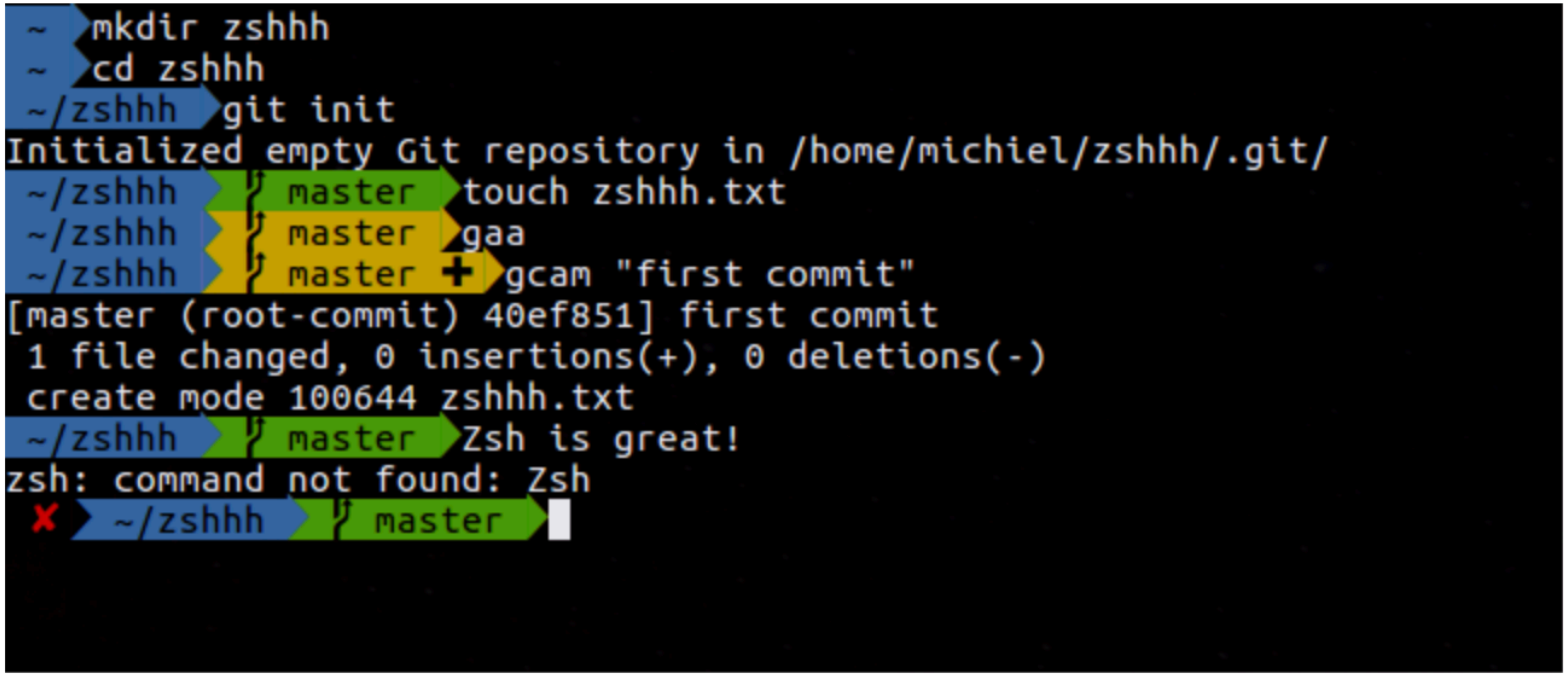


- Poisson equation: $\nabla^2 \Phi = 4\pi G \rho$
- In space, σ (scattering cross section) ~ 10^{-15} cm^2, and n (number density) ~ 1 cm^{-3} (interstellar medium). Therefore, λ ~ $10^{14\text{-}15}$ cm. However, typical sizes of the interstellar clouds are ~ $10^{19\text{-}20}$ cm.

Research Tools

1. Shell: bash/csh/zsh
2. Git & github

Oh-My-Zsh!



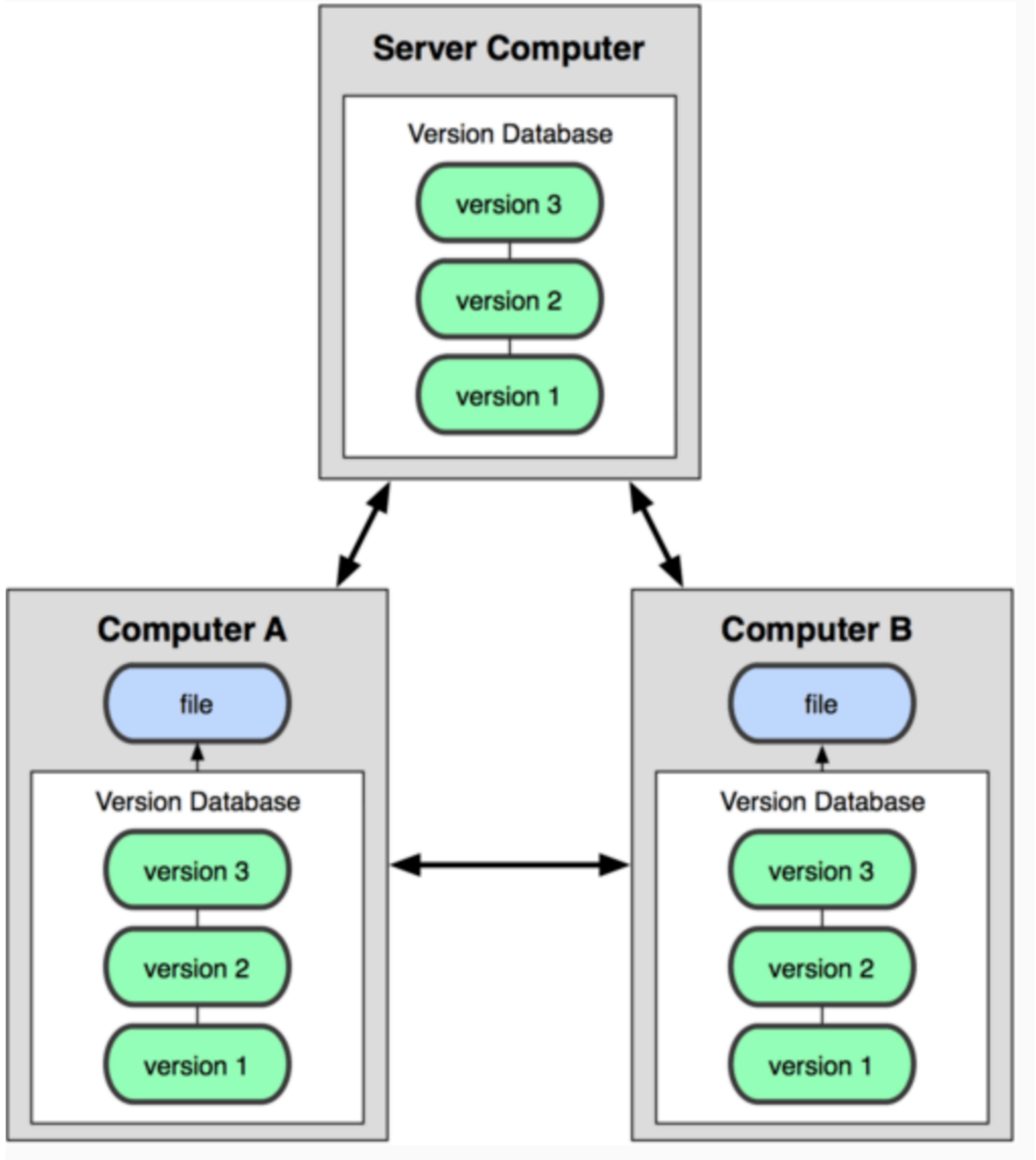
Oh-My-Zsh Agnoster Theme

Version Control

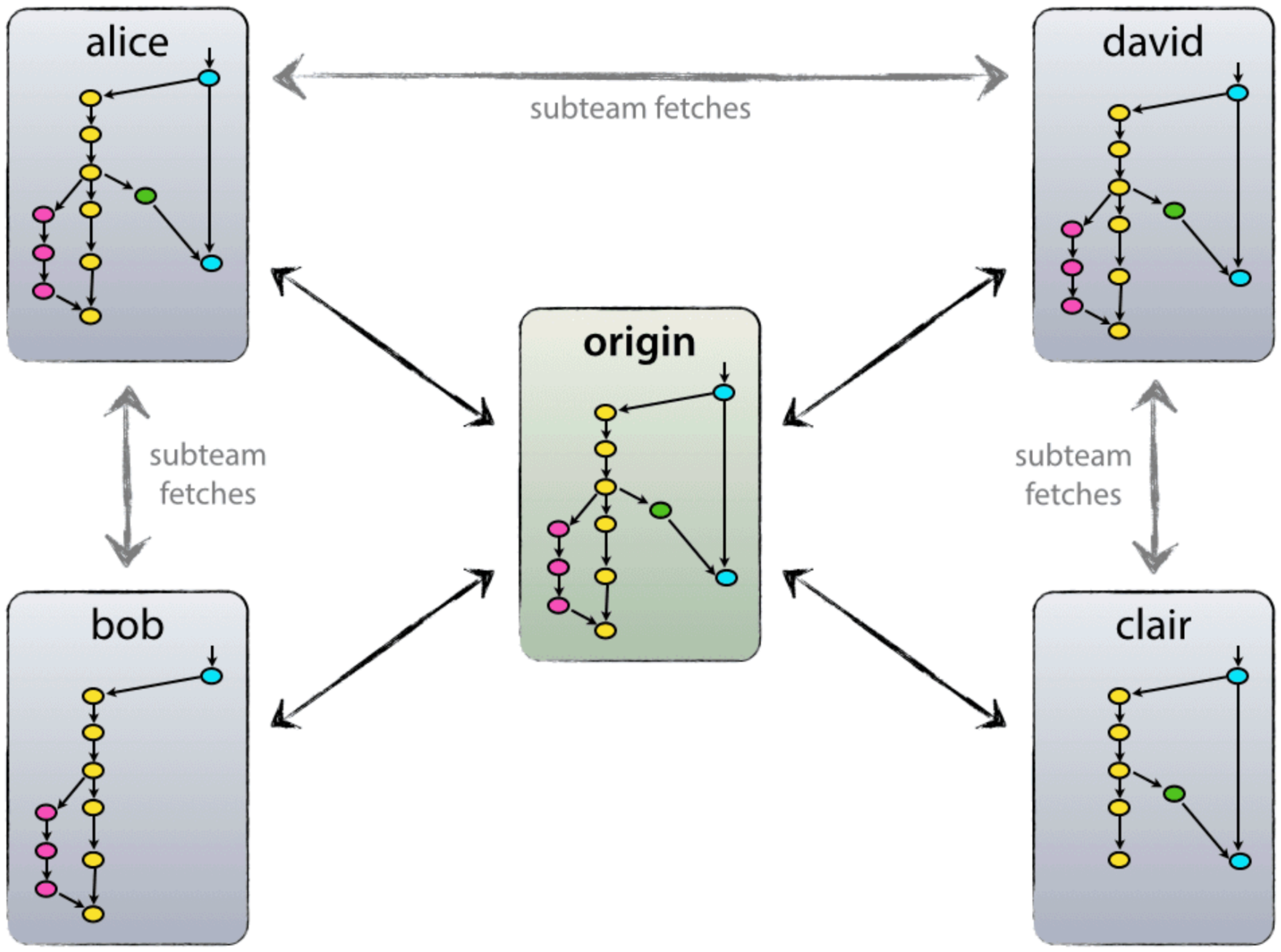
Version Control (git)

https://git-scm.com/book/en/v2

Version Control (git)



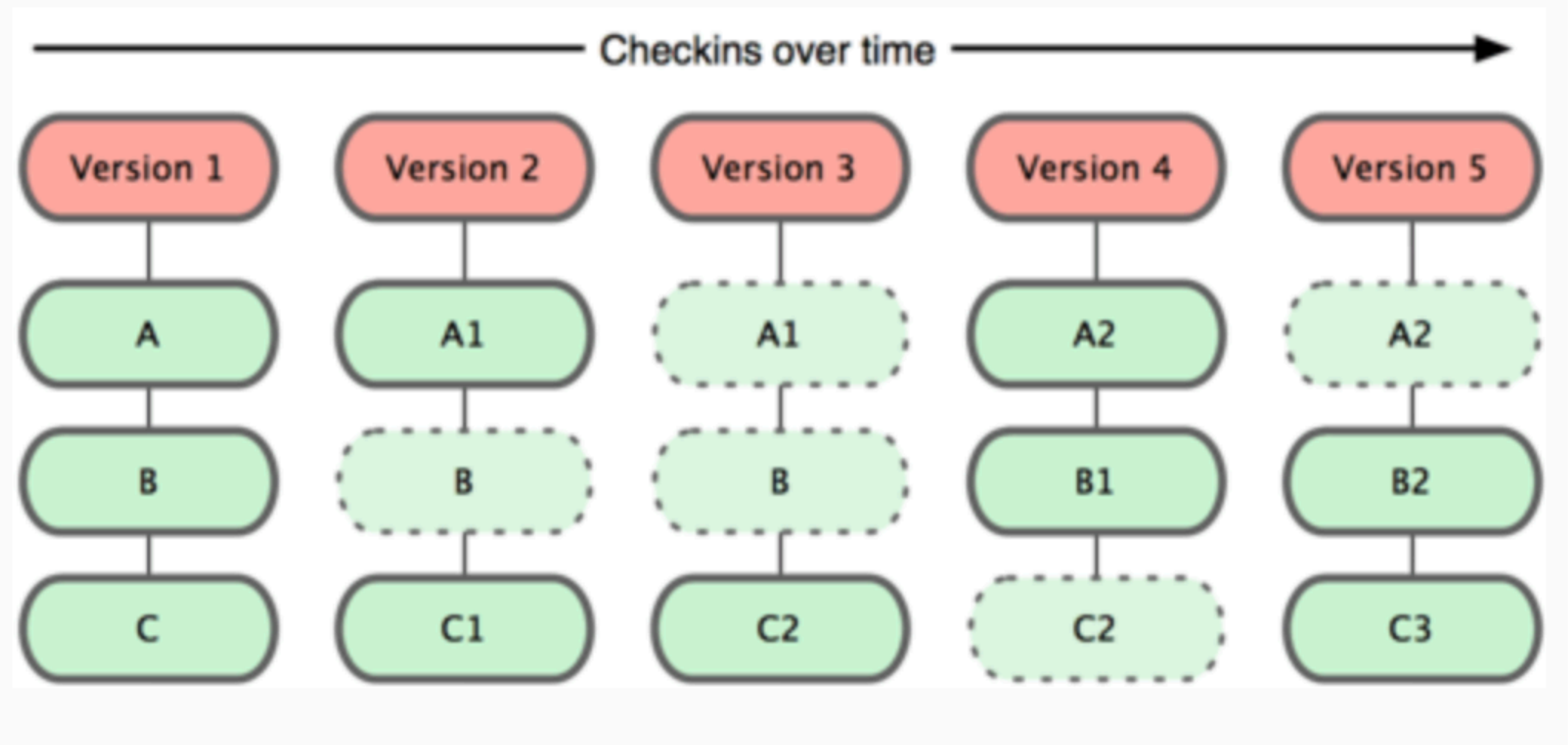
Version Control (git)



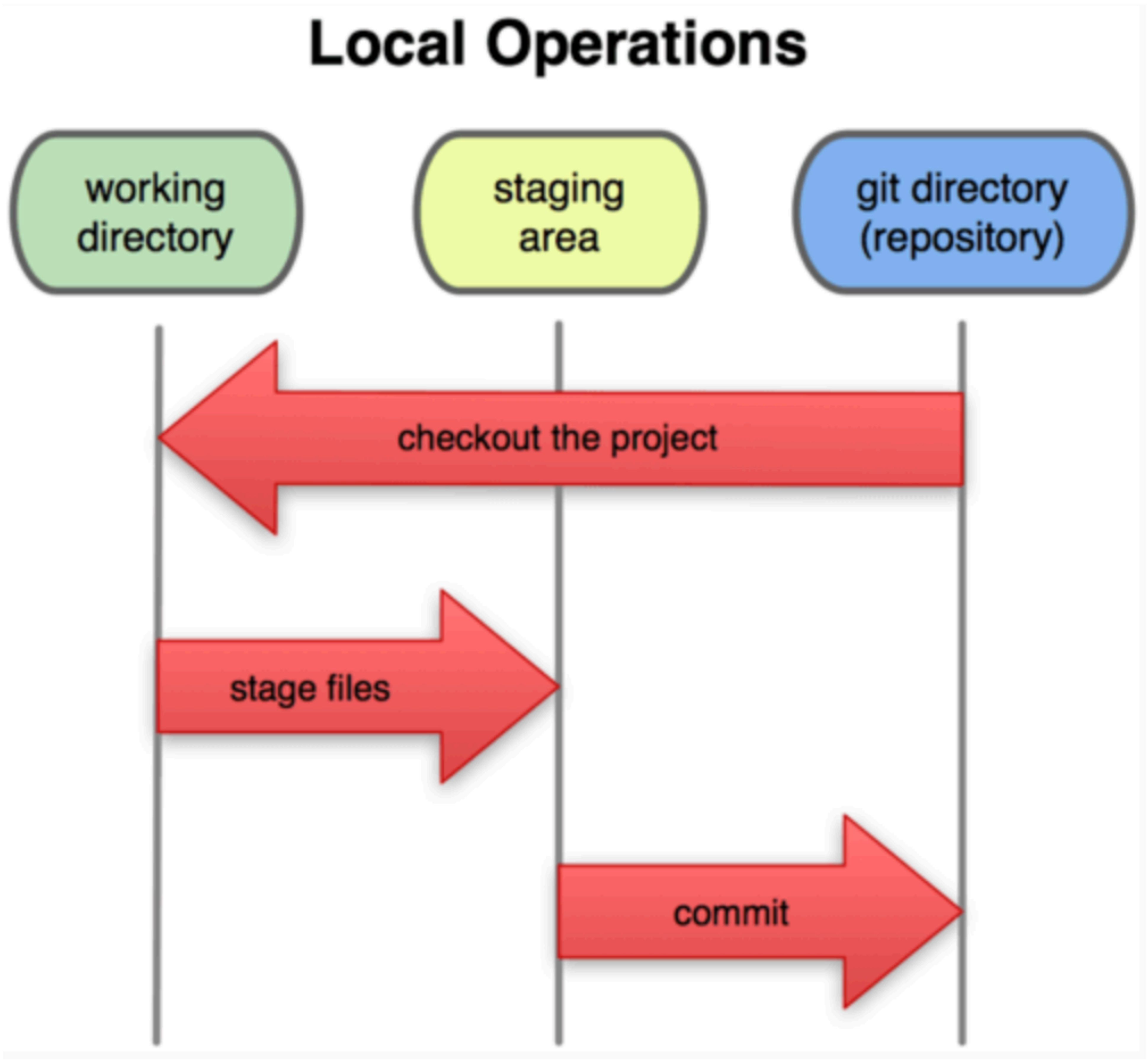
Version Control (git)

xkcd

Version Control (git)



Version Control (git)



Version Control (git)

```
$ git config --global user.name "John Doe"
$ git config --global user.email johndoe@example.com
```

```
$ git config --global core.editor emacs
```

```
$ git config --list
user.name=Scott Chacon
user.email=schacon@gmail.com
color.status=auto
color.branch=auto
color.interactive=auto
color.diff=auto
...
```

.gitconfig

```
[filter "lfs"]
    clean = git-lfs clean %f
    smudge = git-lfs smudge %f
    required = true
[user]
    name = K.-C. Pan
    email = pankuoch@msu.edu
[alias]
    #hist = log --pretty=format:'%h %ad | %s%d [%an]' --graph --date=short
    hist = log --pretty=format:'%Cred%h%Creset %Cgreen%ad%Creset | %s%d %C(bold blue)[%an]%Creset%Cgreen(%cr)%Creset' --graph --date=short
    type = cat-file -t
    dump = cat-file -p
    pure = pull --rebase
[push]
    default = simple
[core]
    excludesfile = /Users/pan/.gitignore_global

```

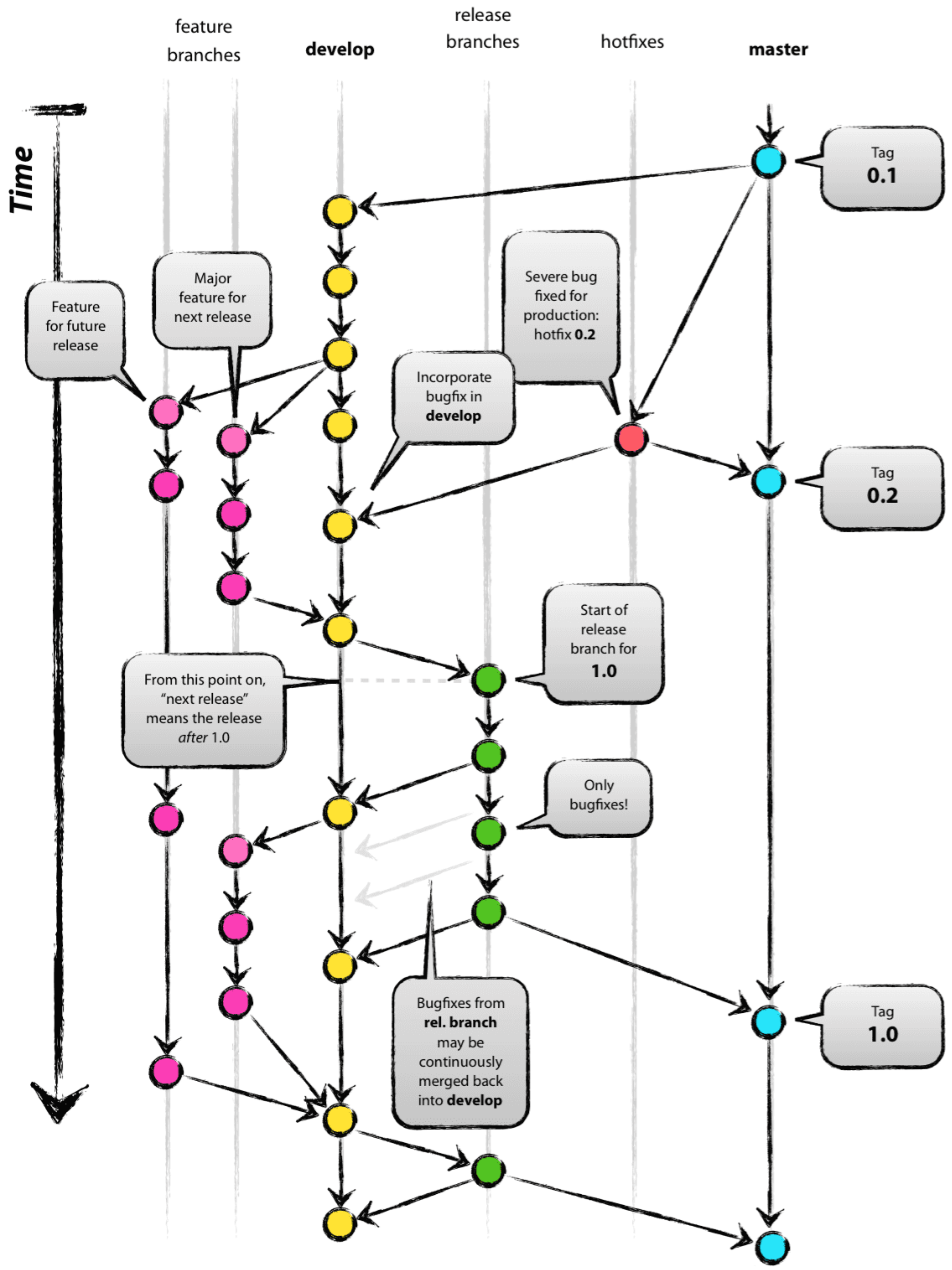
Git tutorial

https://github.com/twtrubiks/Git-Tutorials

Exercise

https://github.com/kuochuanpan/git-tutorial-20180929

A successful git branching

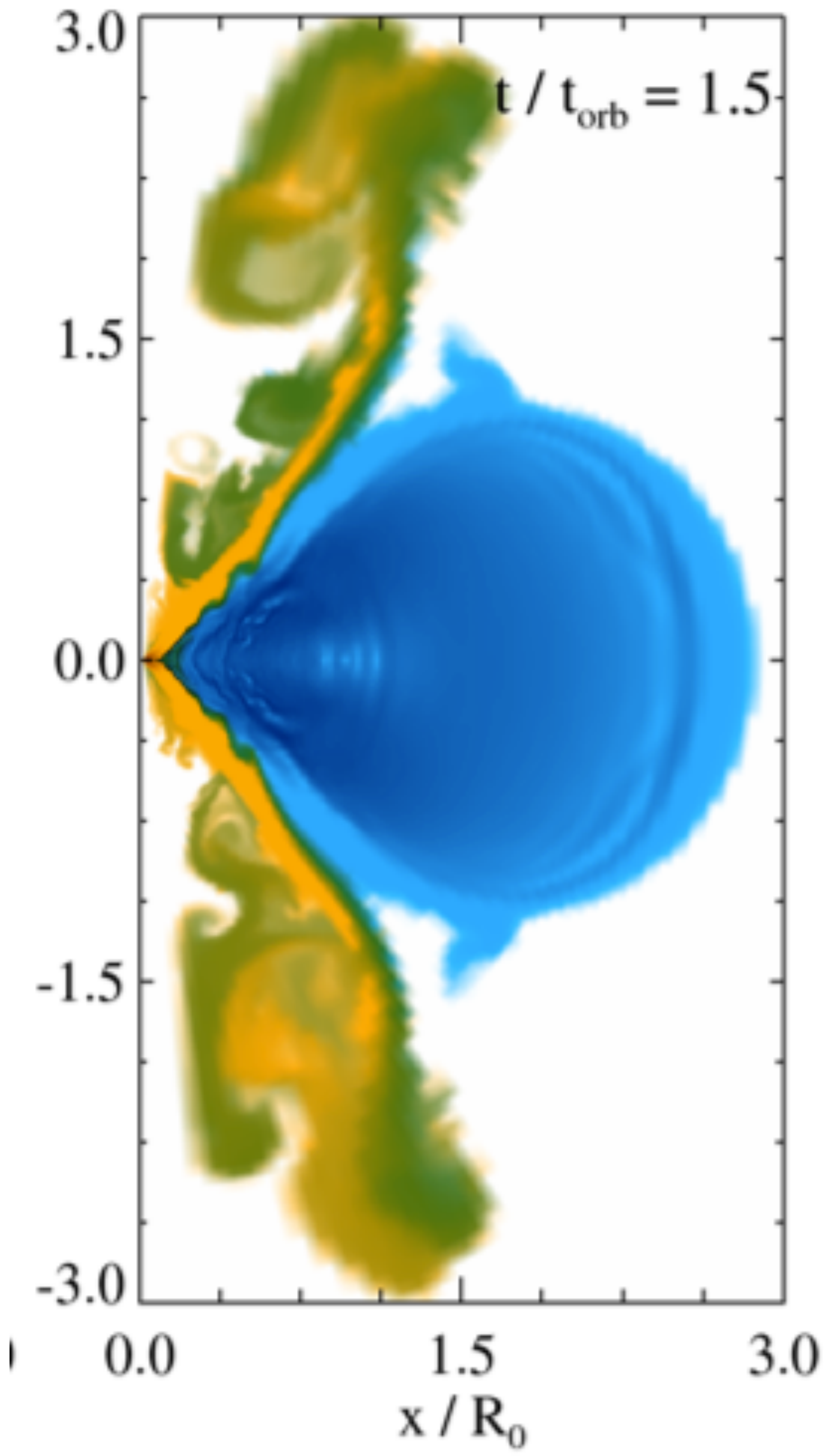


https://nvie.com/posts/a-successful-git-branching-model/?

FLASH 4

http://flash.uchicago.edu/site/

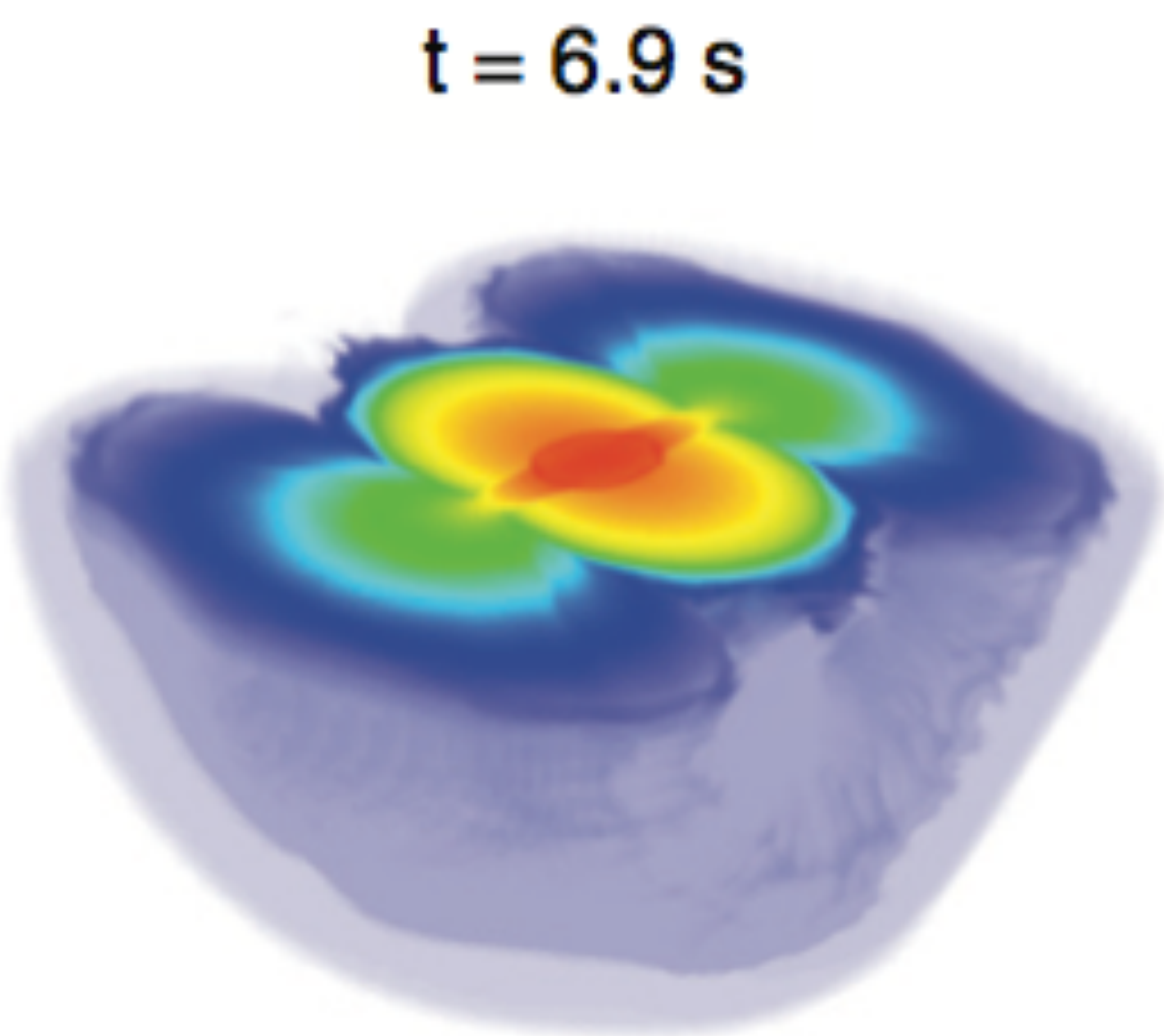
1) Merger of a WD with a NS



2013 ApJ, 763, 108

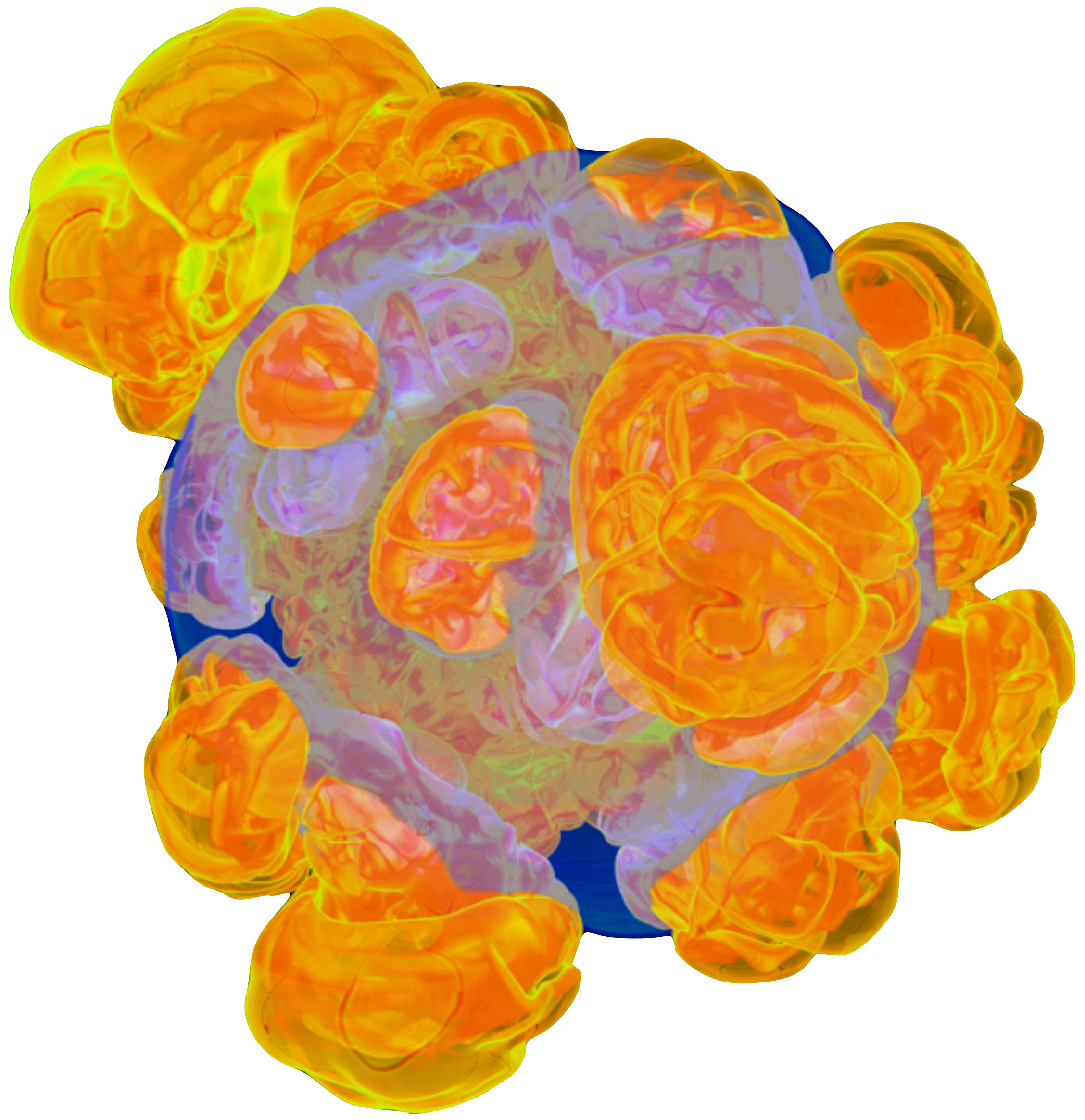
2) Type Ia Supernova

WD WD merger



2012 ApJ, 759, 39

DDT model

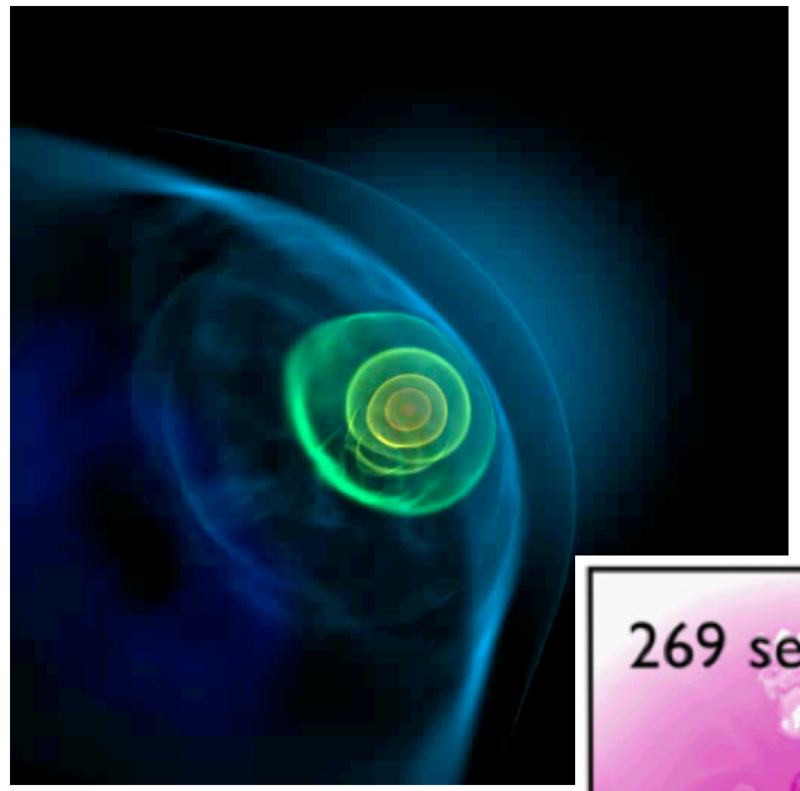


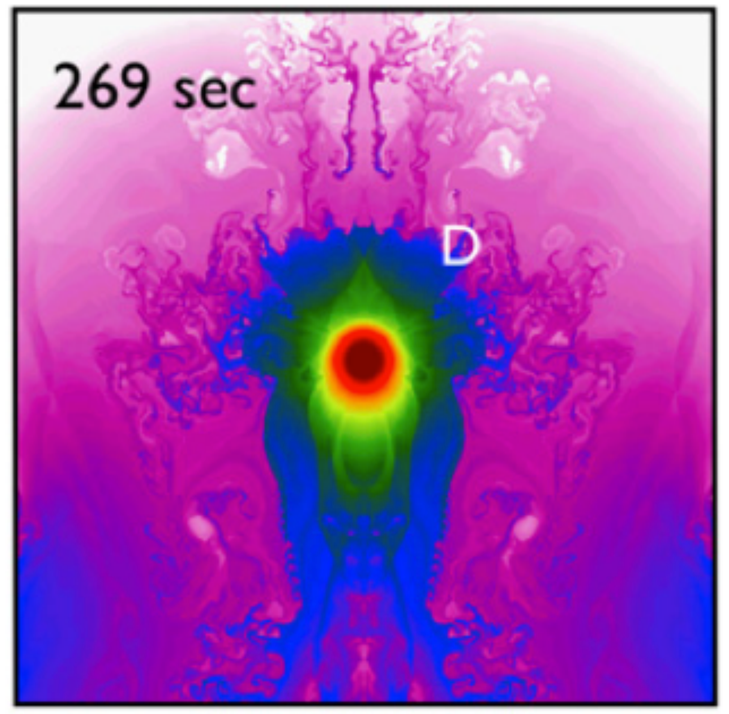
2012 ApJ, 759, 53

FLASH 4

http://flash.uchicago.edu/site/

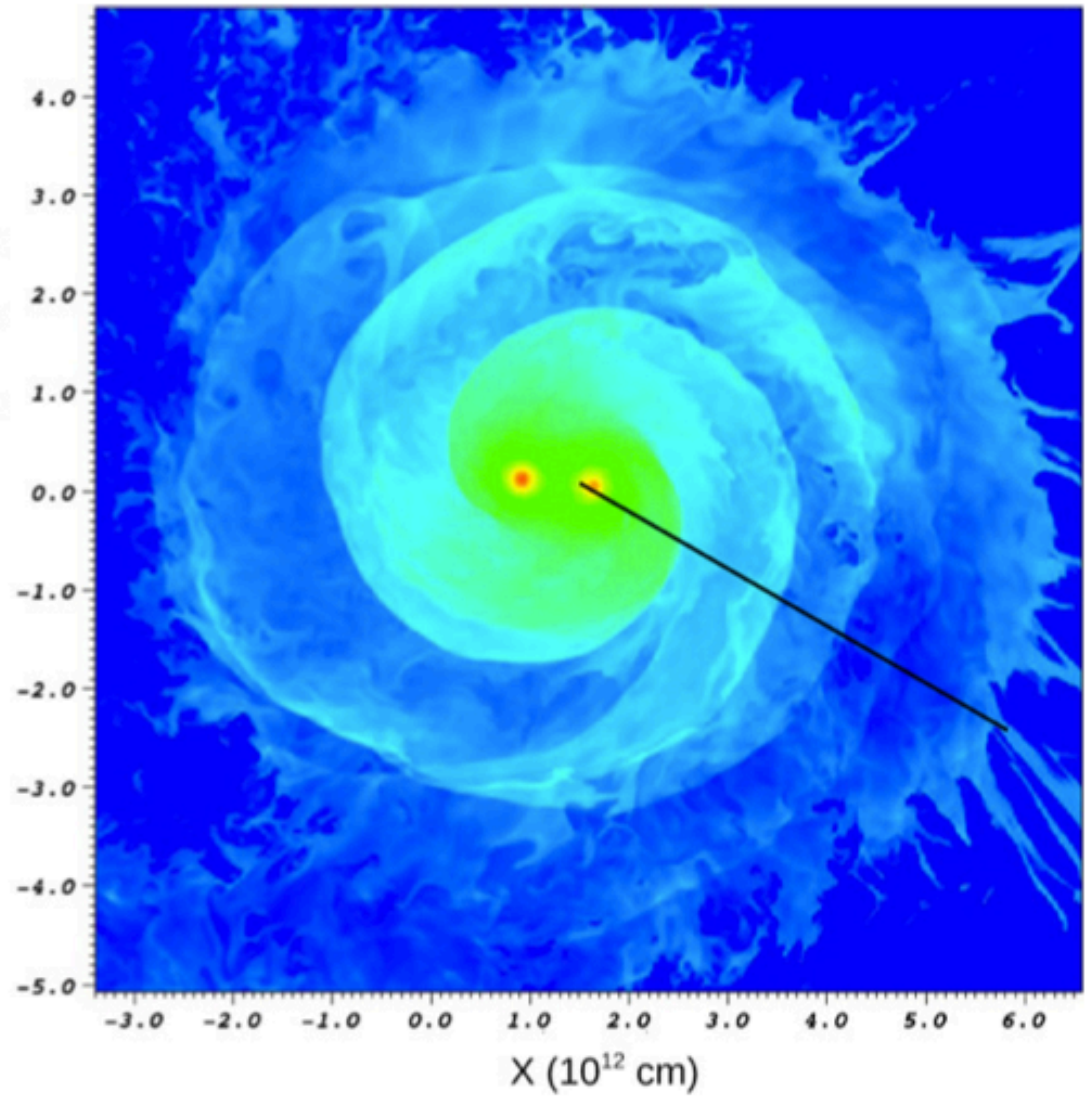
3) Type Ia supernova in binary





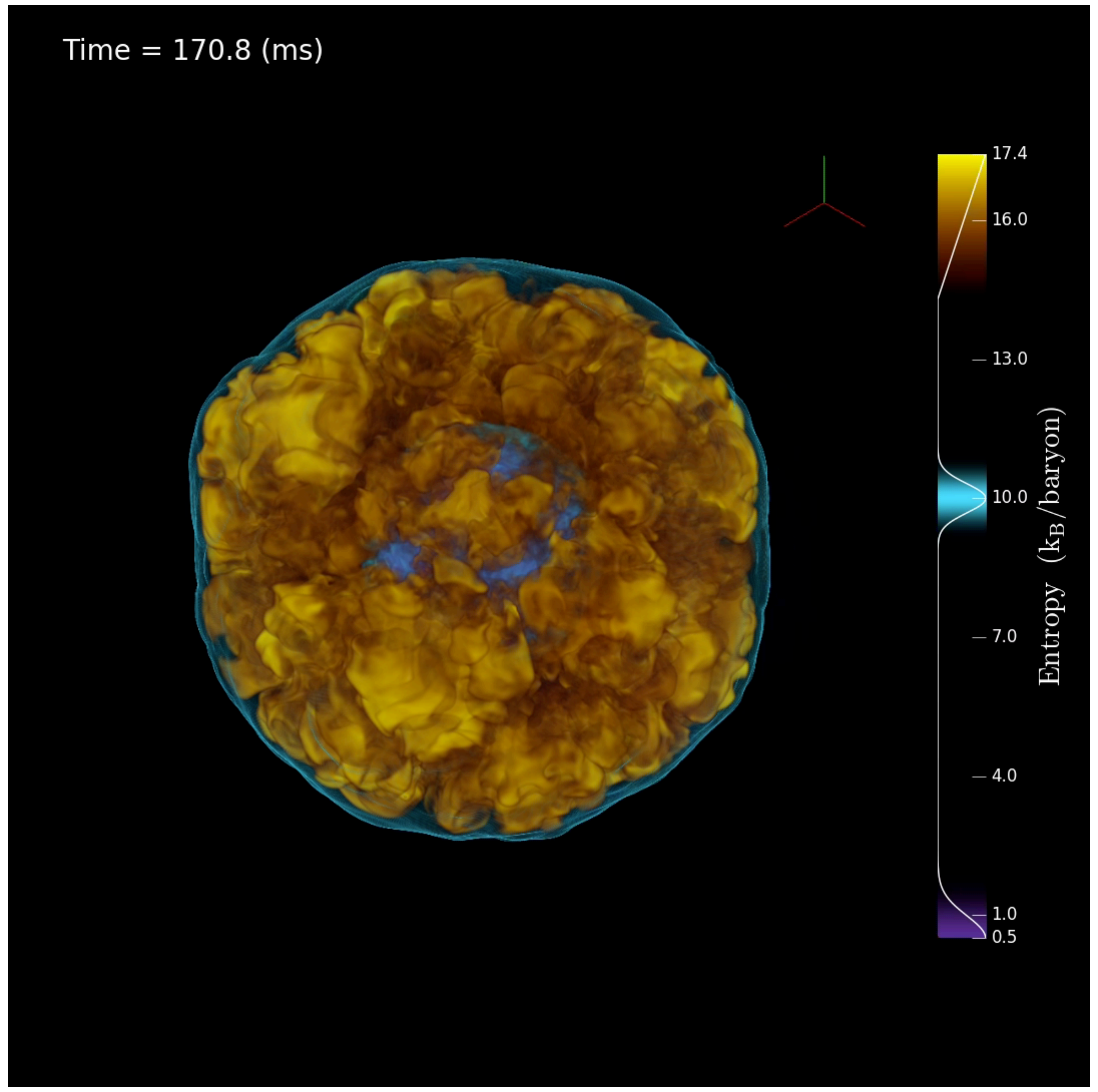
2012 ApJ, 750, 151   2010 ApJ, 715, 78

4) Common envelope



2012 ApJ, 746, 74

5) Core-collapse Supernova



2018 ApJ

FLASH 4

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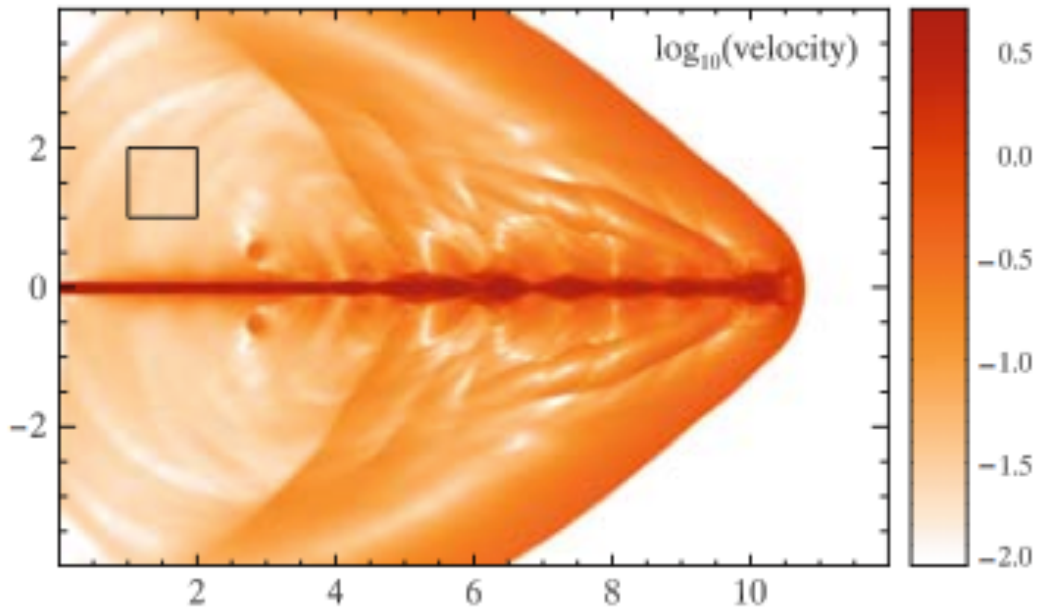
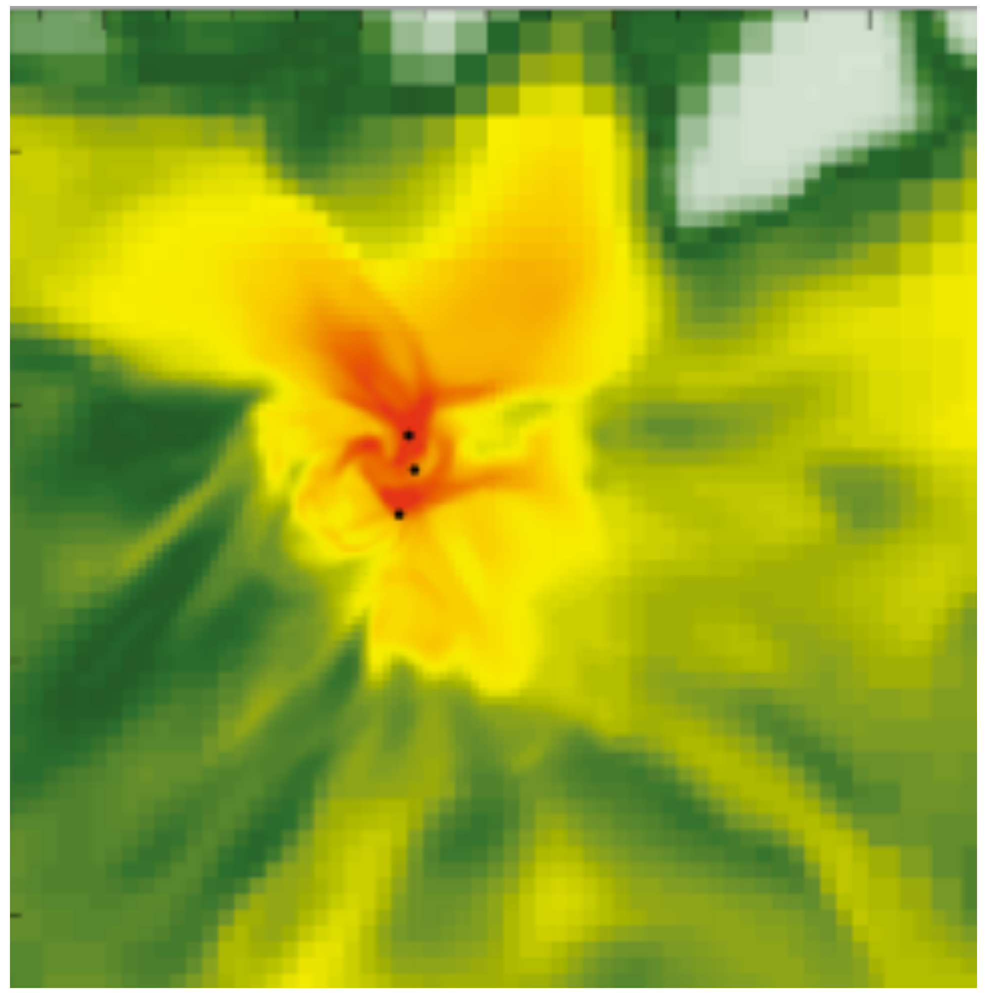
6) Jet driven turbulence



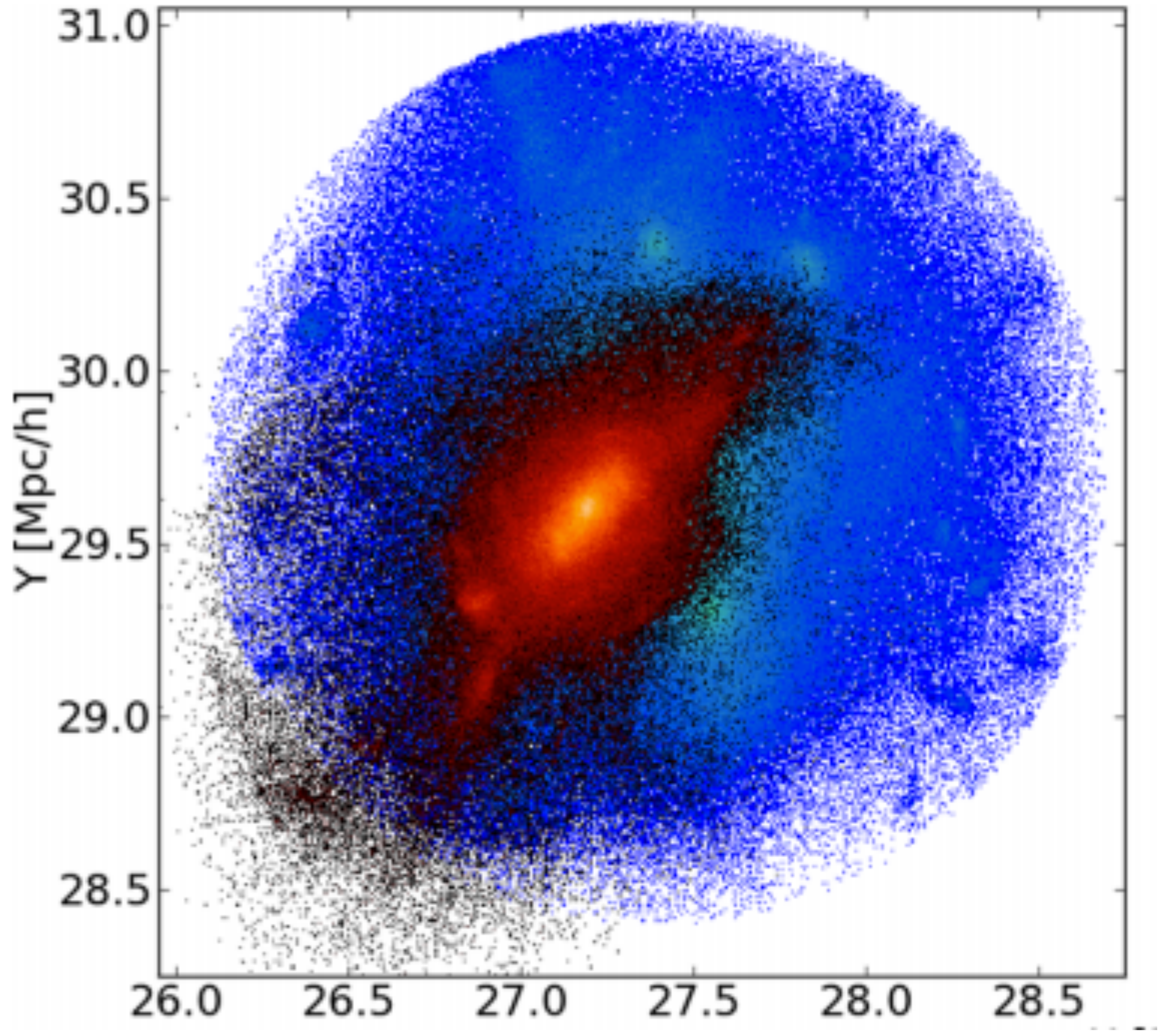
2009PJC, book 421B

7) Star formation in molecular cloud



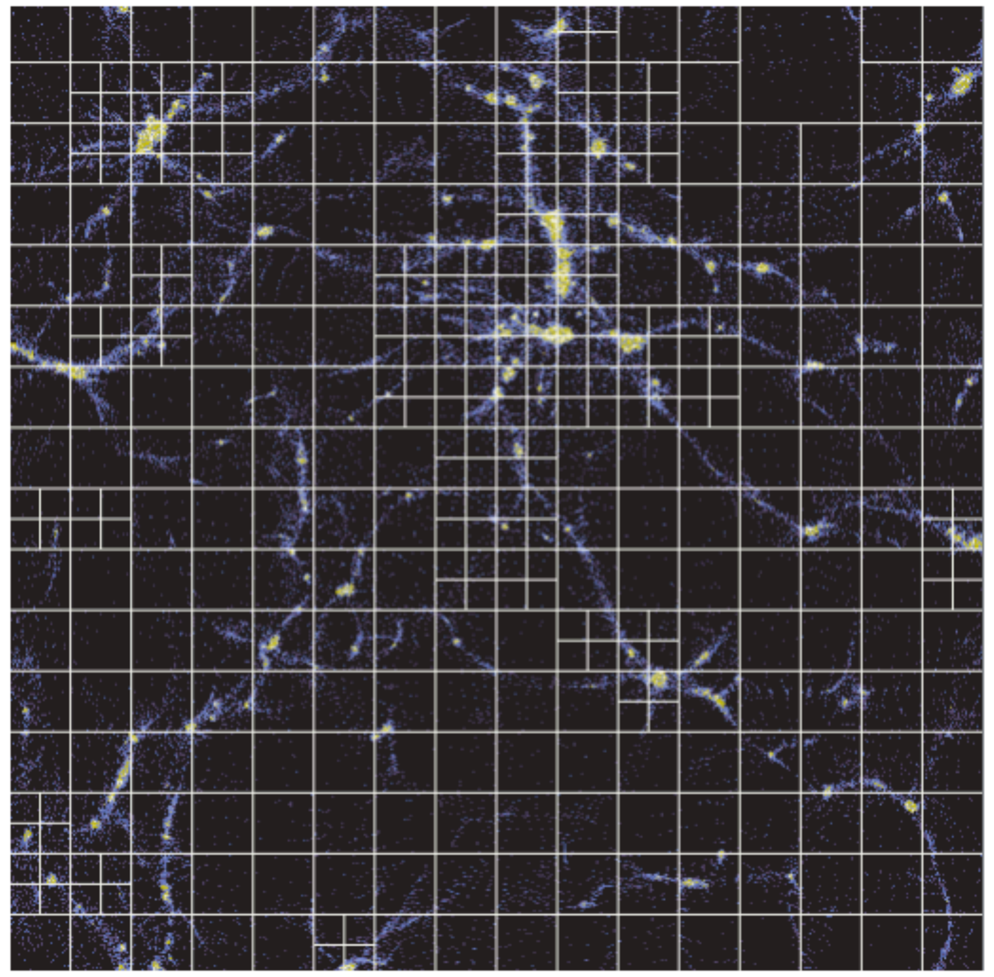
2009 MNRAS 398, 1082

8) group-cluster merger (N-body)



2013MNRAS, tmp.2152V

9) Large scale structure (N-body)



2005 ApJS 160, 28

FLASH 4

http://flash.uchicago.edu/site/

- The FLASH code has been under development since 1997 at the Flash Center for Computational Science at the University of Chicago.
- It is a multi-physics simulation code capable of handling general compressible flow problems in many astrophysical environments.
- Publicly available, modular, portable, massively-parallel scientific application code http://www.flash.uchicago.edu
- 700 scientists from around the world have co-authored roughly 600+ research papers using FLASH.
- FLASH is written principally in Fortran, with some C and Python. (> 1.2 million lines; 25% comments).
- Scalable to tens of thousand processors.

FLASH 4

http://flash.uchicago.edu/site/

Physics solvers

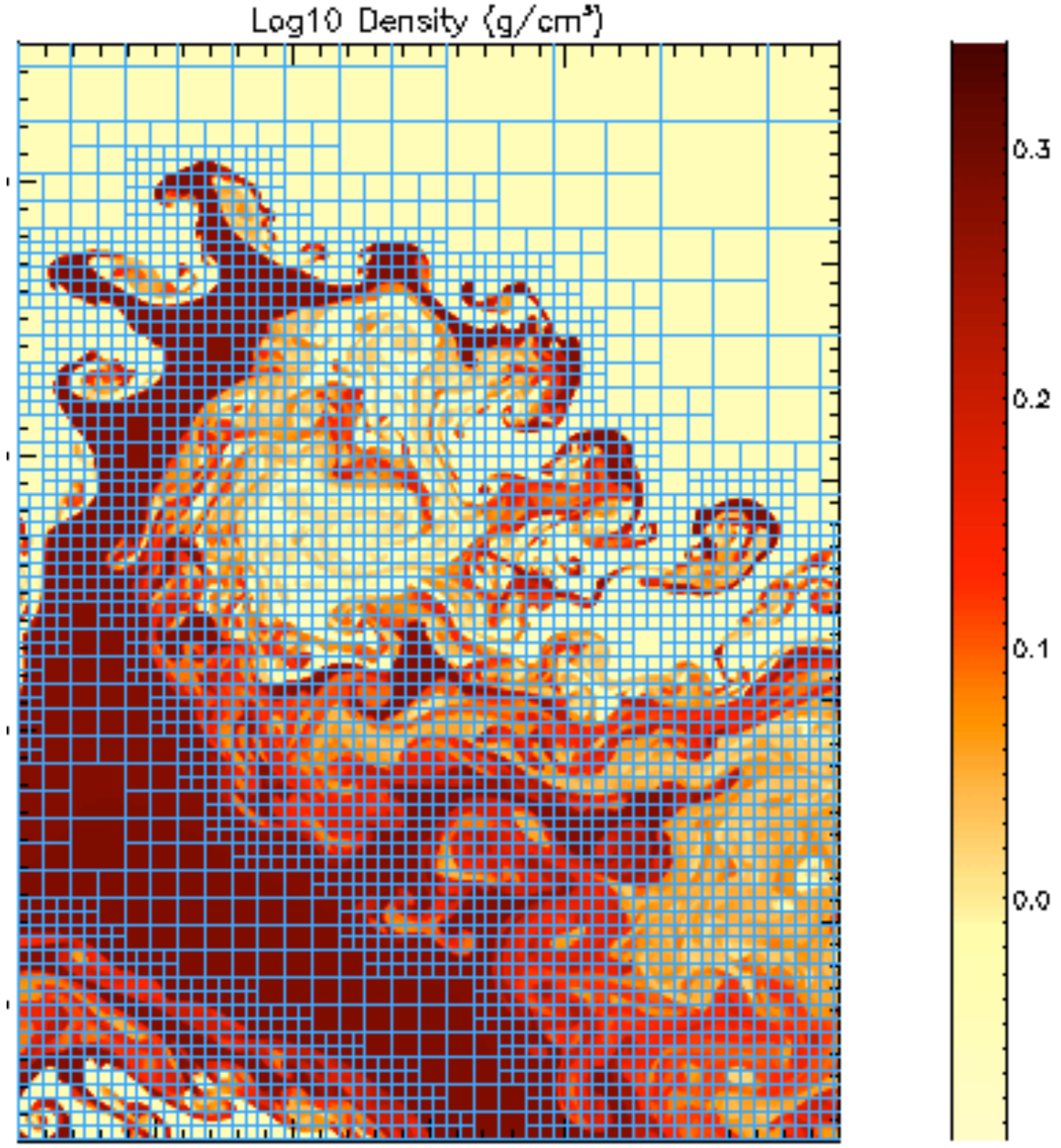
- Hydrodynamics: unsplit PPM and WENO; split PPM; 2T+Radiation
- Magnetohydrodynamics (MHD): unsplit staggered mesh; split 8-wave; …
- Equation of State (EOS): ideal gas; degenerate ionized plasma; multi-material
- Radiation Transfer: multigroup flux-limited diffusion
- Diffusion and Conduction: implicit with AMR
- Laser Energy Deposition: geometric optics with inverse Brensstrahlung
- Opacity: Constant; multi-material tabular
- Particles: tracer; massive; sink; charged
- Nuclear Burning
- Gravity: constant; point mass; planar; self gravity
- Cosmology
- Magnetic Resistivity, Conductivity
- Primordial Chemistry

FLASH 4

http://flash.uchicago.edu/site/

Infrastructure

- Driver: split; unsplit
- Grid: uniform grid; AMR
- GridParticles: Lagrangian framework
- GridSolvers: multigrid; multipole; Barnes-Hut Tree; PFFT; direct solvers for uniform grid
- IO: HDF5; PnetCDF
- Multispecies
- Runtime parameters
- Monitor: MPI Timers; Hooks for TAU



Adaptive Mesh Refinement (AMR)

Hydrodynamics equations

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \boldsymbol{v}) = 0$$

(Mass conservation)

$$\frac{\partial \rho \boldsymbol{v}}{\partial t} + \nabla \cdot (\rho \boldsymbol{v} \boldsymbol{v}) + \nabla P = -\rho \nabla \Phi$$

(Momentum conservation)

$$\frac{\partial \rho E}{\partial t} + \nabla \cdot [(\rho E + P) \boldsymbol{v}] = -\rho \boldsymbol{v} \cdot \nabla \Phi$$

(Energy conservation)

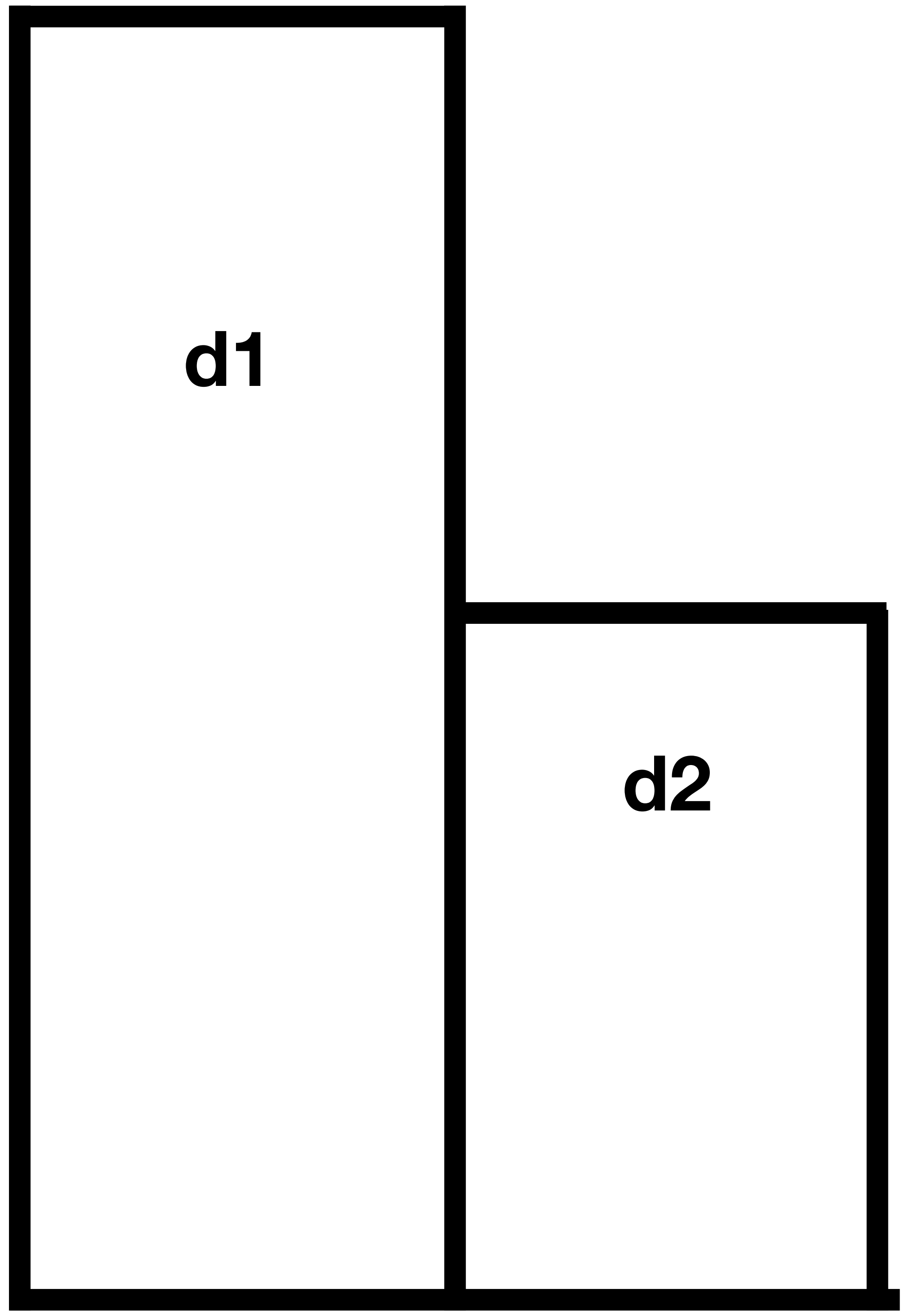
Hydrodynamics equations

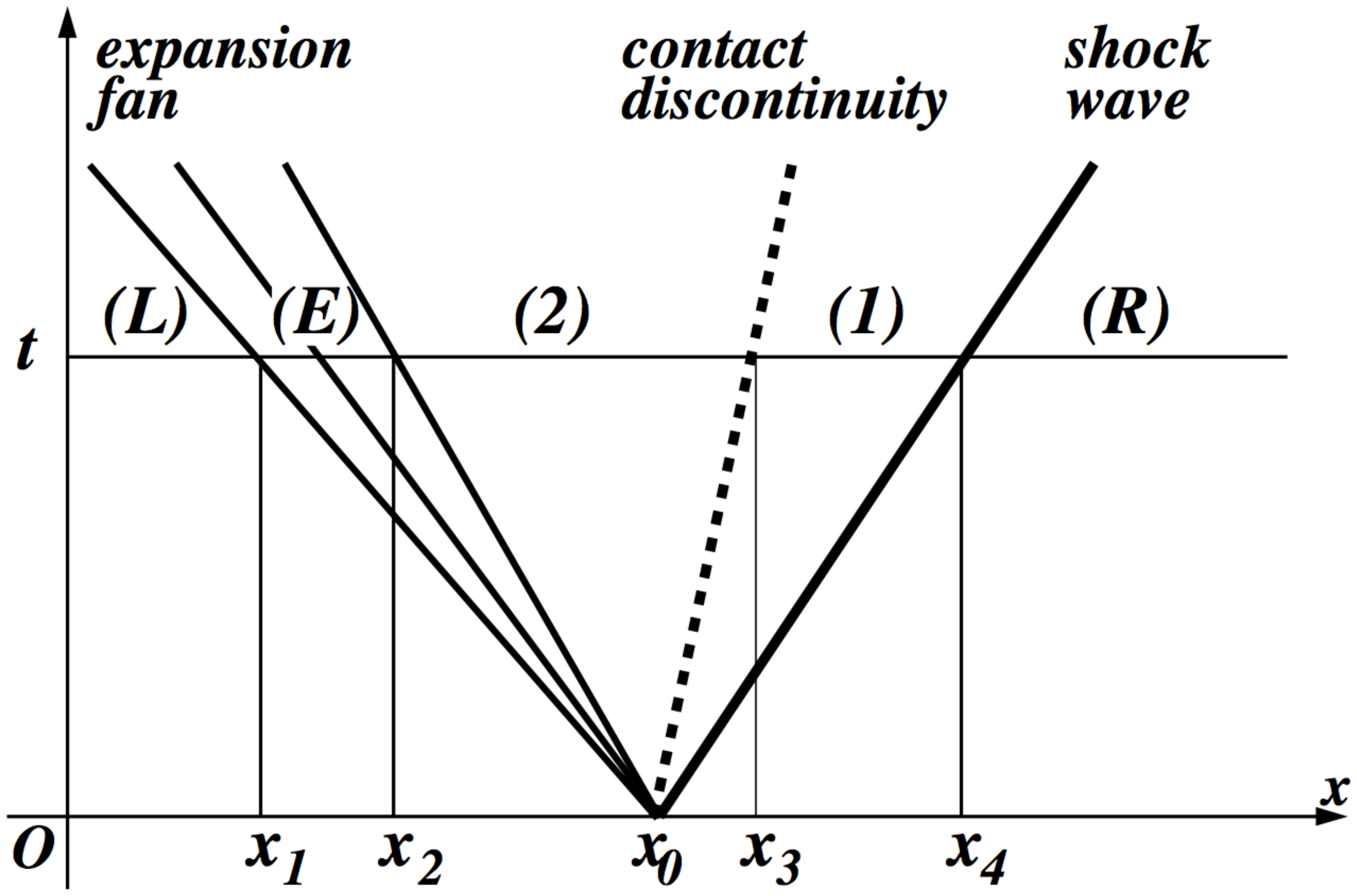
$$\frac{\partial}{\partial t}\underbrace{\begin{pmatrix}\rho\\ \rho U\\ E\end{pmatrix}}_{W(x,t)}+\frac{\partial}{\partial x}\underbrace{\begin{pmatrix}\rho U\\ \rho U^2+p\\ (E+p)U\end{pmatrix}}_{F(W)}=0,$$

S(x,t)

$$E=\frac{p}{\gamma-1}+\frac{\rho}{2}U^2.$$

Riemann Problem





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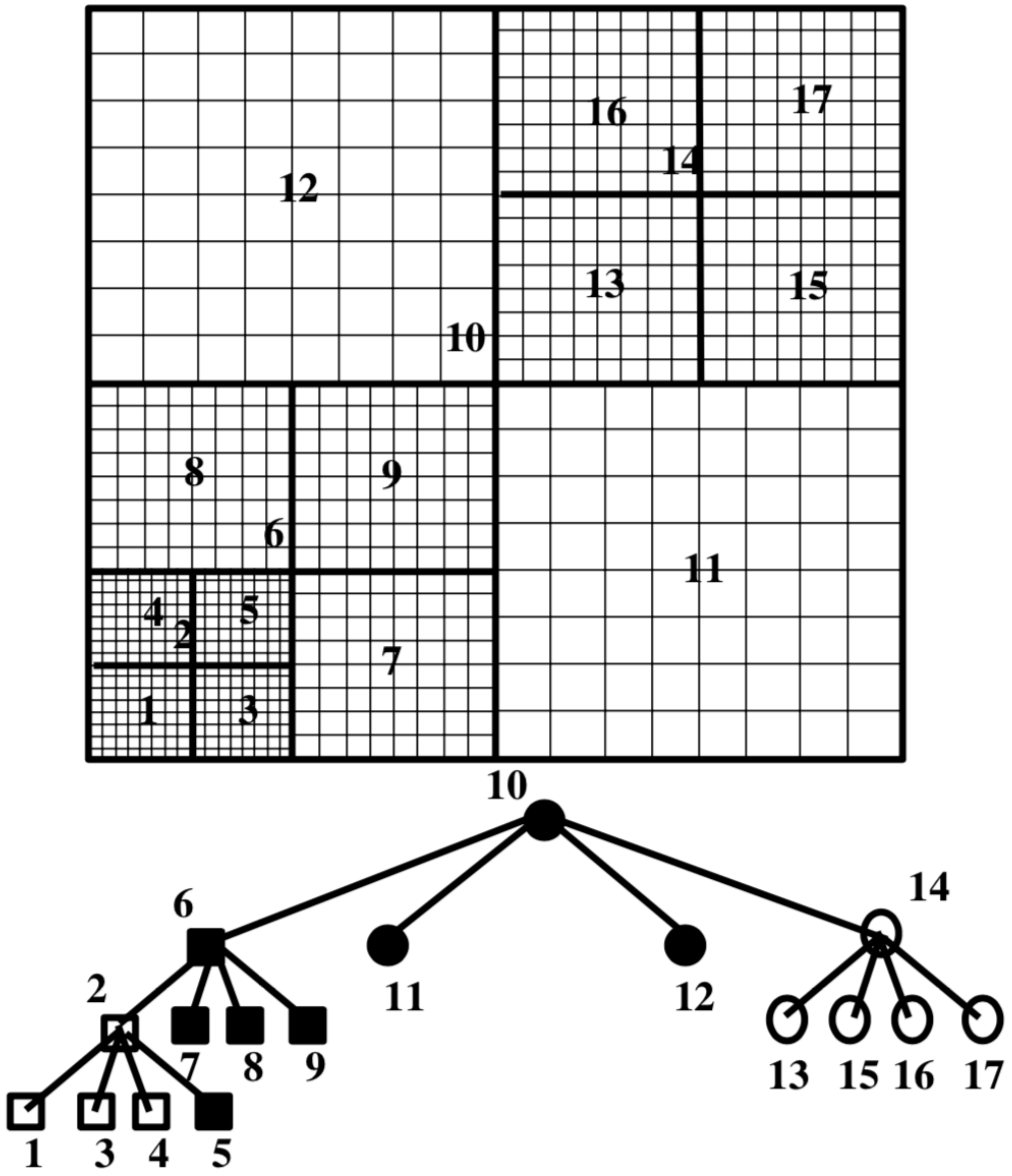

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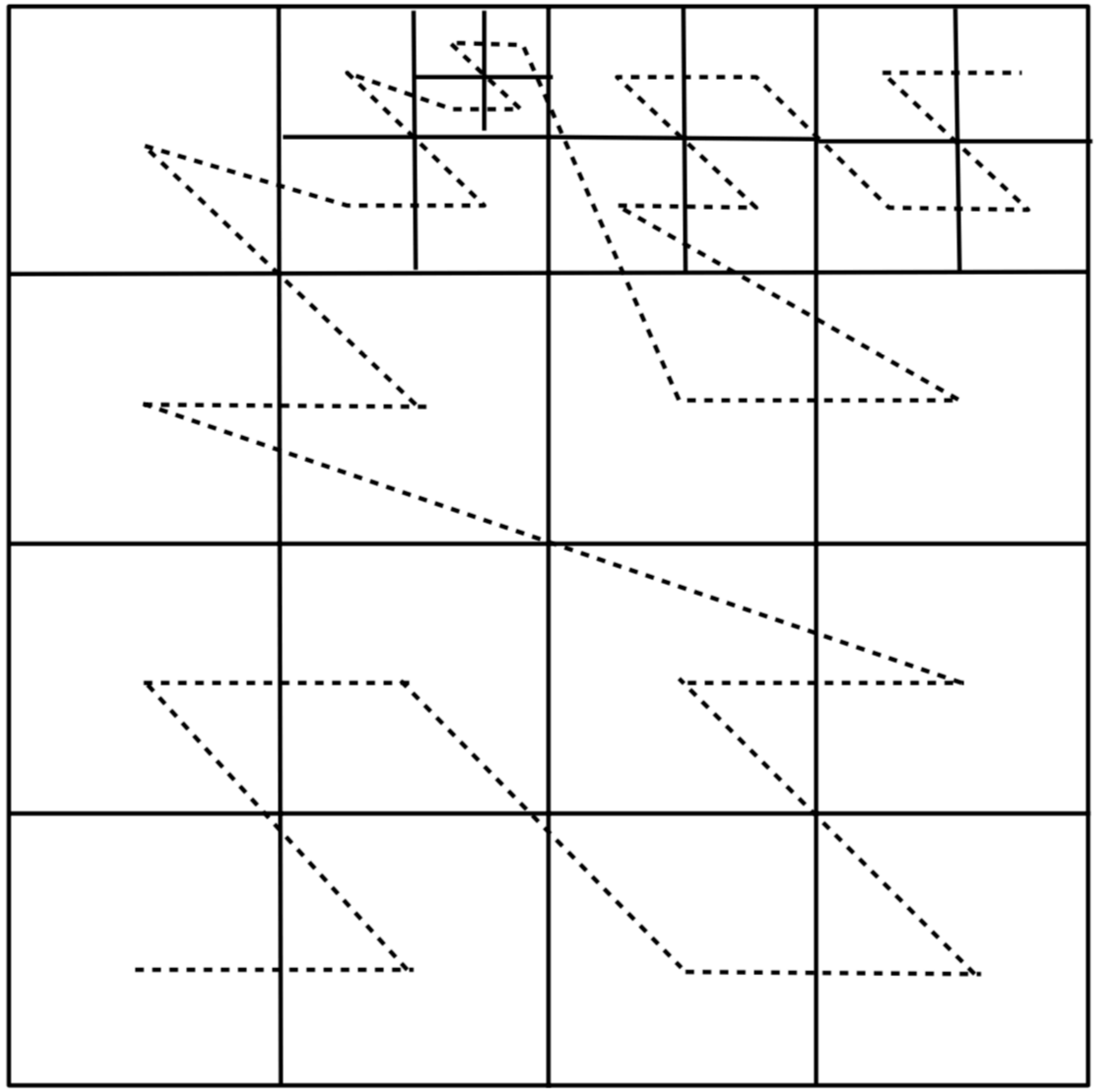

FIG. 3.—Morton space-filling curve for an arbitrary set of blocks of differing spatial resolution

Source codes

cd FLASH4.5/source

d2, v2, t2

d1, v1, t1