Galaxy formation simulations done with ART (I)

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Santa Cruz school, 2010

Lectures

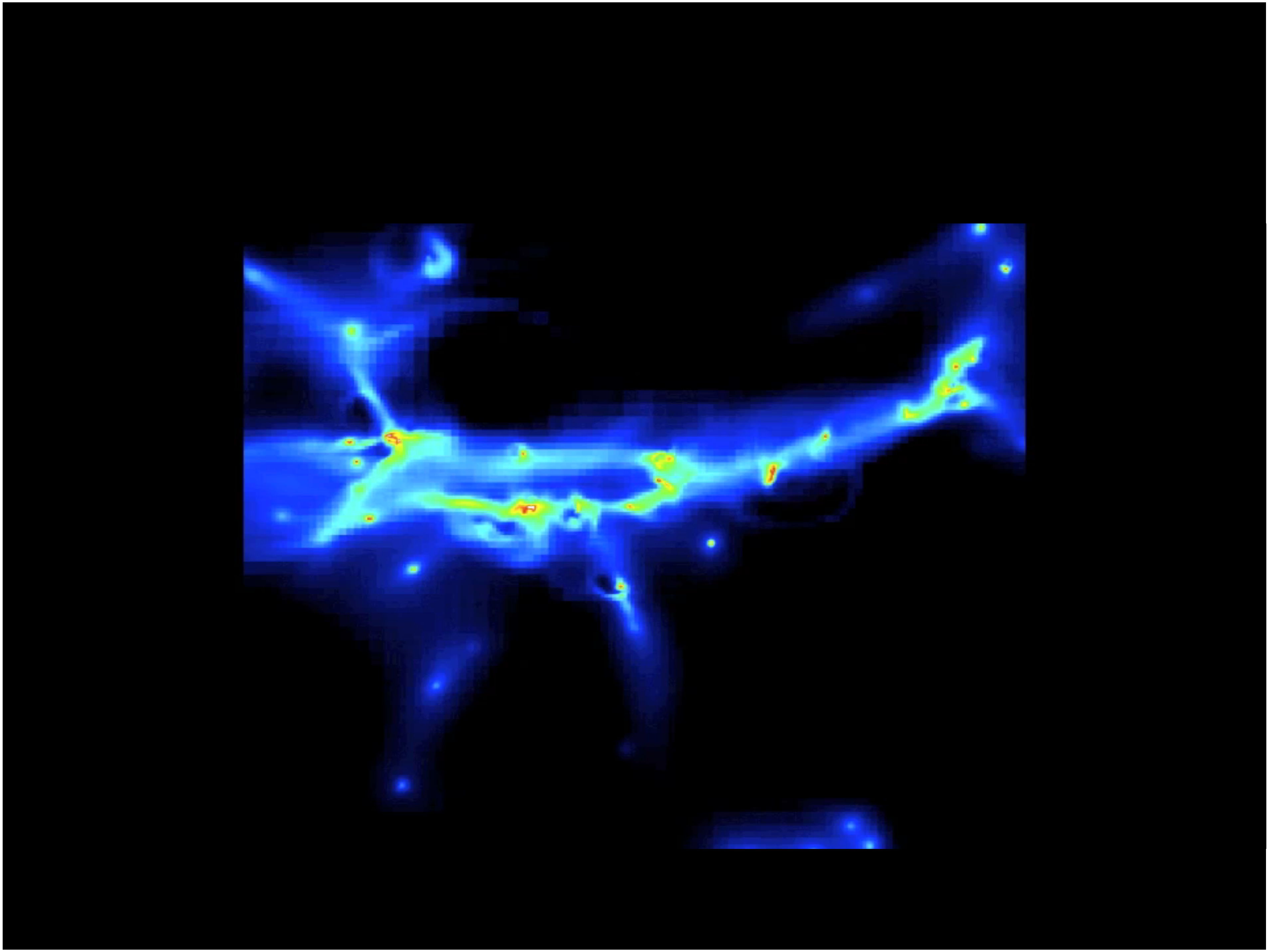
- Tuesday: Description of projects
- Wednesday: Physical models for galaxy formation in ART

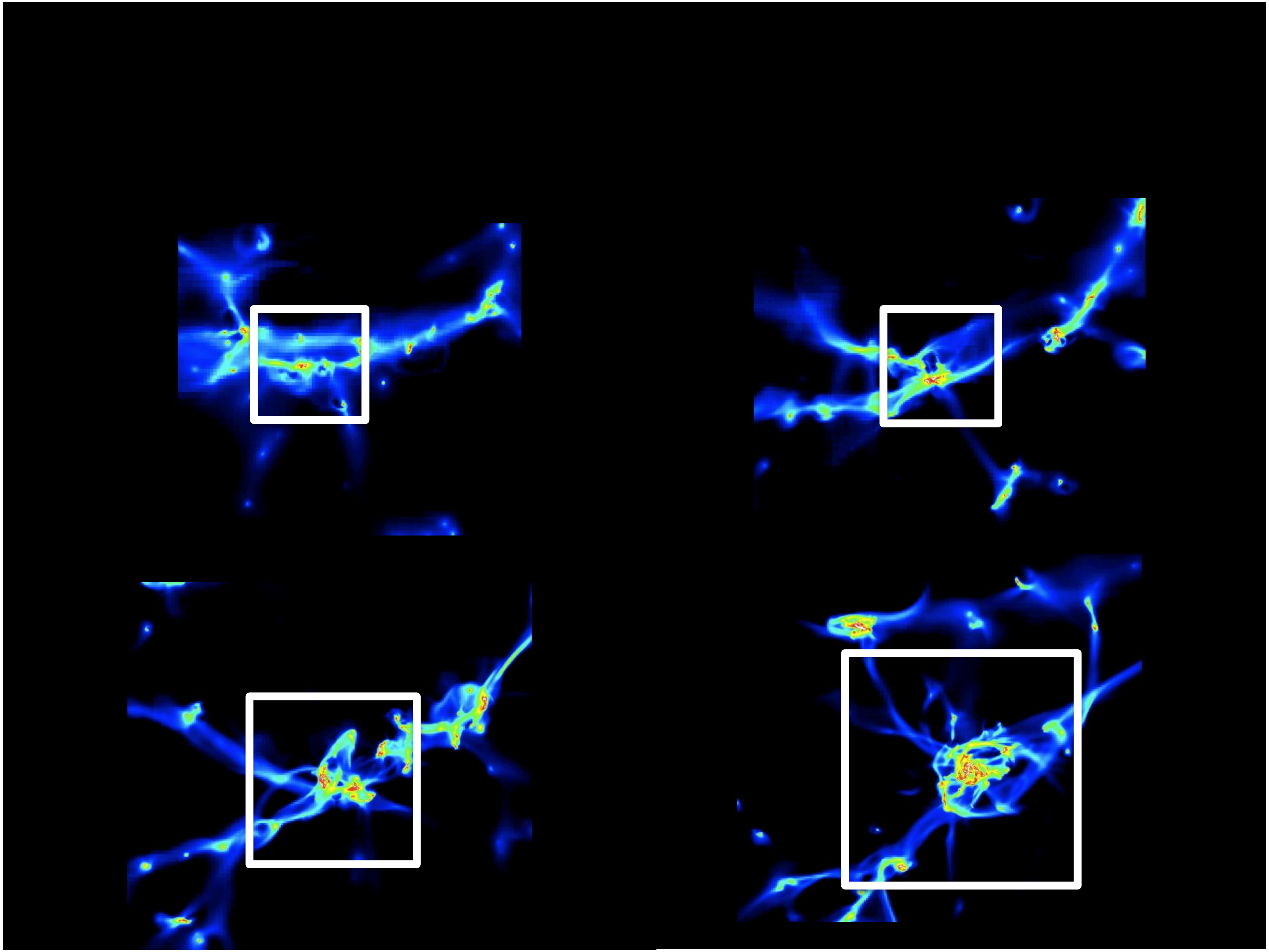
PROJECTS

- Main Goal: Get experience and skills with…
  - running ART
  - dealing with the raw data from simulations
  - doing analysis of ART outputs
- Beyond simple homeworks
- Scientifically relevant (and open) projects.

3 layers of complexity

- Run the test-case + Run the extract-ART code + analysis of the generated outputs
- Run the extract-ART code + analysis
- Analysis of the provided outputs, from the 'galaxy A' run described in Ceverino, Dekel and Bournaud (2010)





List of projects

- 1. Accretion rate onto halos and onto galaxies: DM, gas, stars
- 2. Merger rate
- 3. Interaction of Streams and Disk.
- 4. Angular momentum: in streams vs disk
- 5. Structure of high-z galaxies: Adiabatic contraction? Density profiles of gas, stars, DM. f_b?
- 6. Kinematics of gas: disk rotation curve, dispersion-dominated galaxies,…
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- 9. SFR vs. Accretion rate
- 10. The SSFR plateau (fixed mass) at z>2
- 11. Gas outflows
- 12. Statistics of global galaxy properties: Mv, Mb=Mg+Ms, Mdisk (select n,T, v_tan>f*|v|), Mbulge SFR, Mdot V, sigma R_0.5 Z

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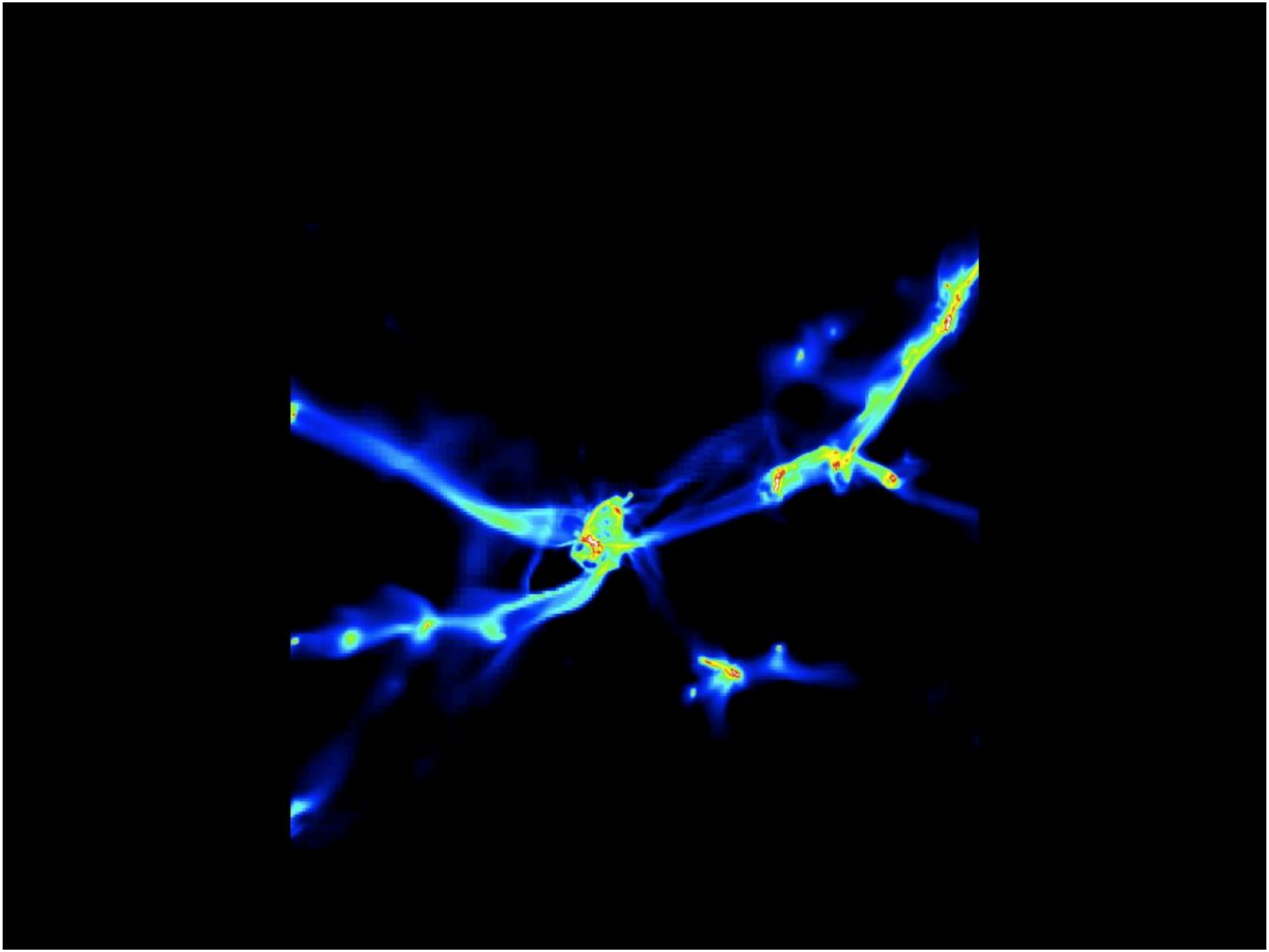

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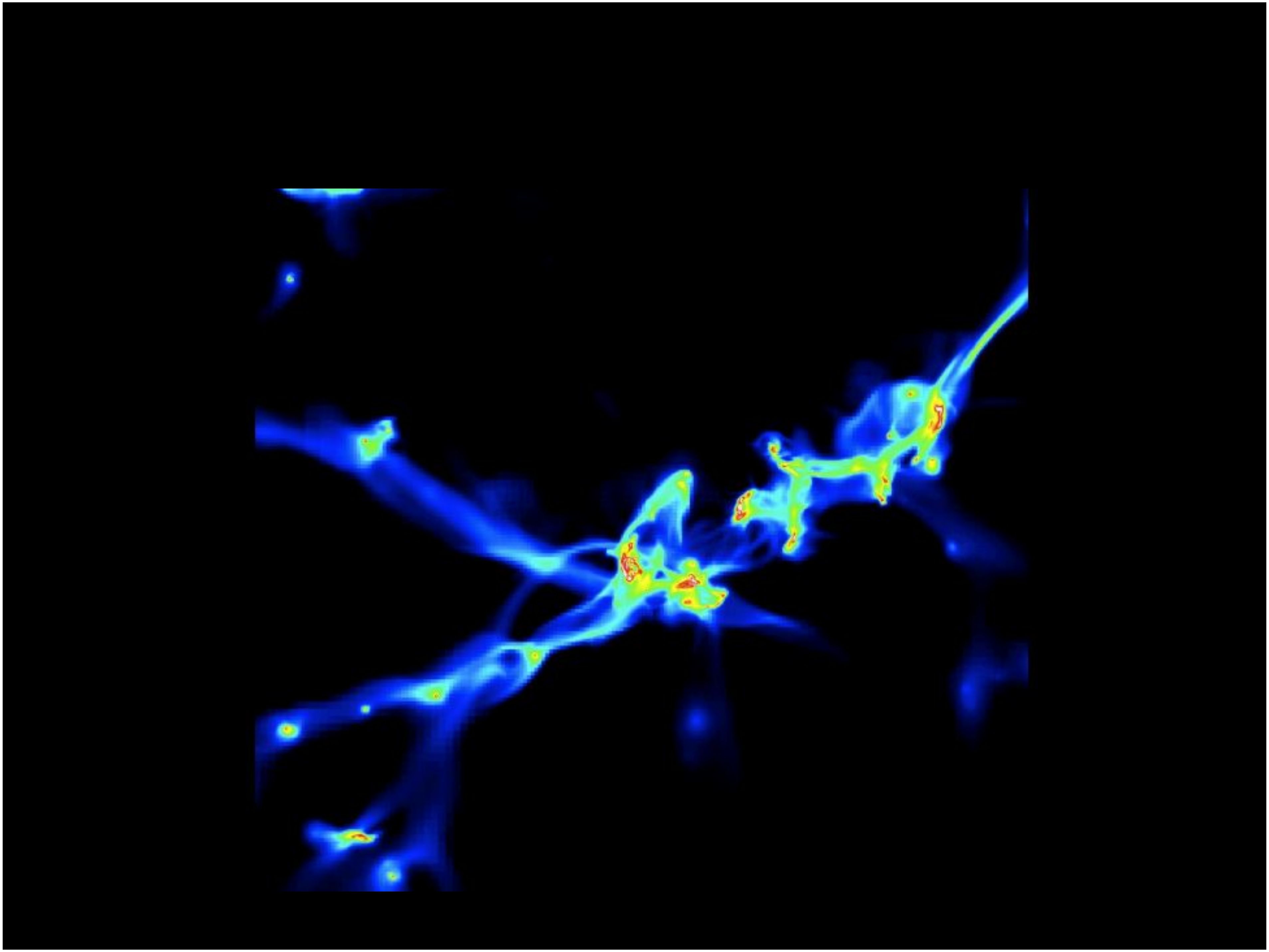

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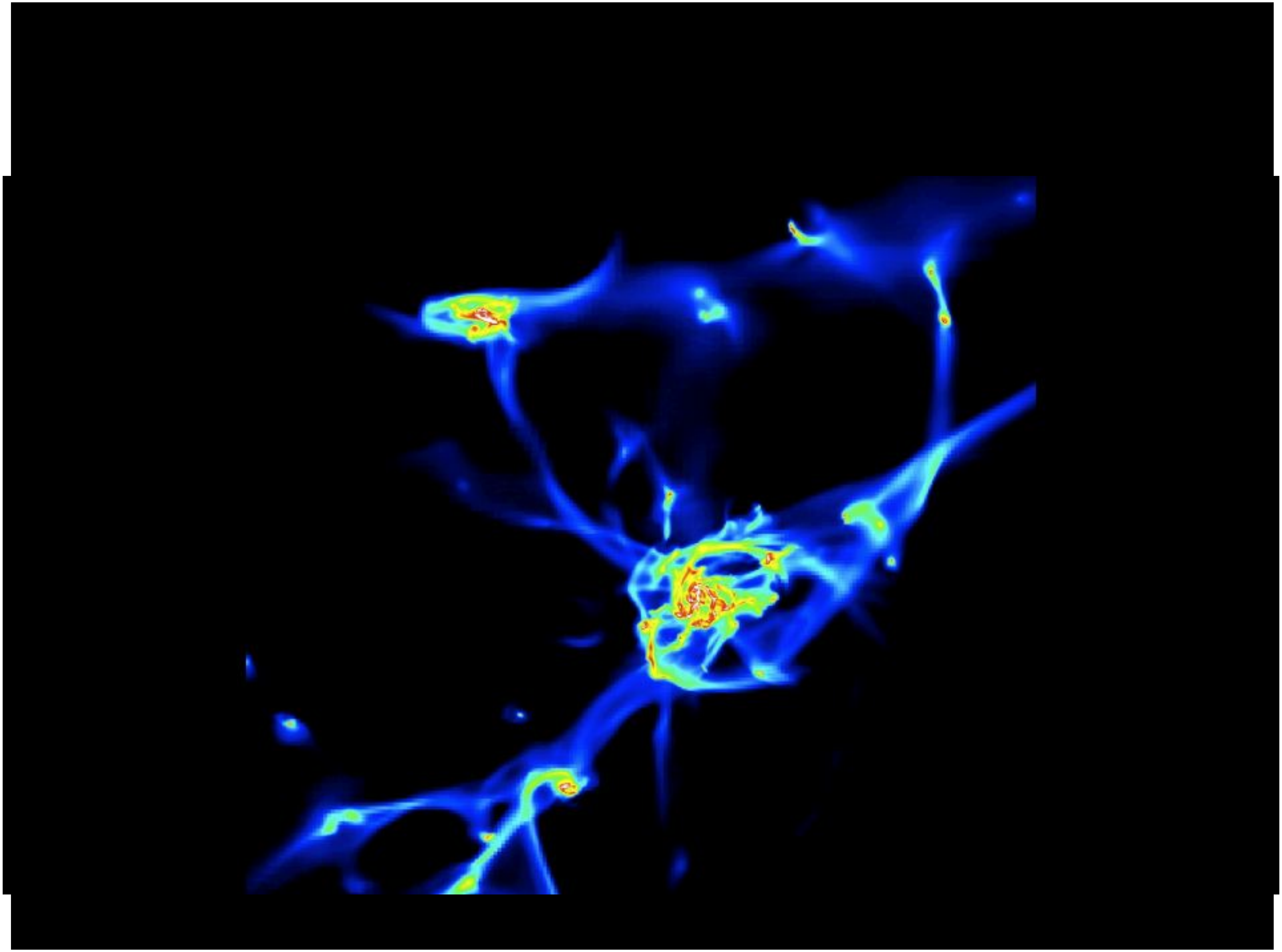

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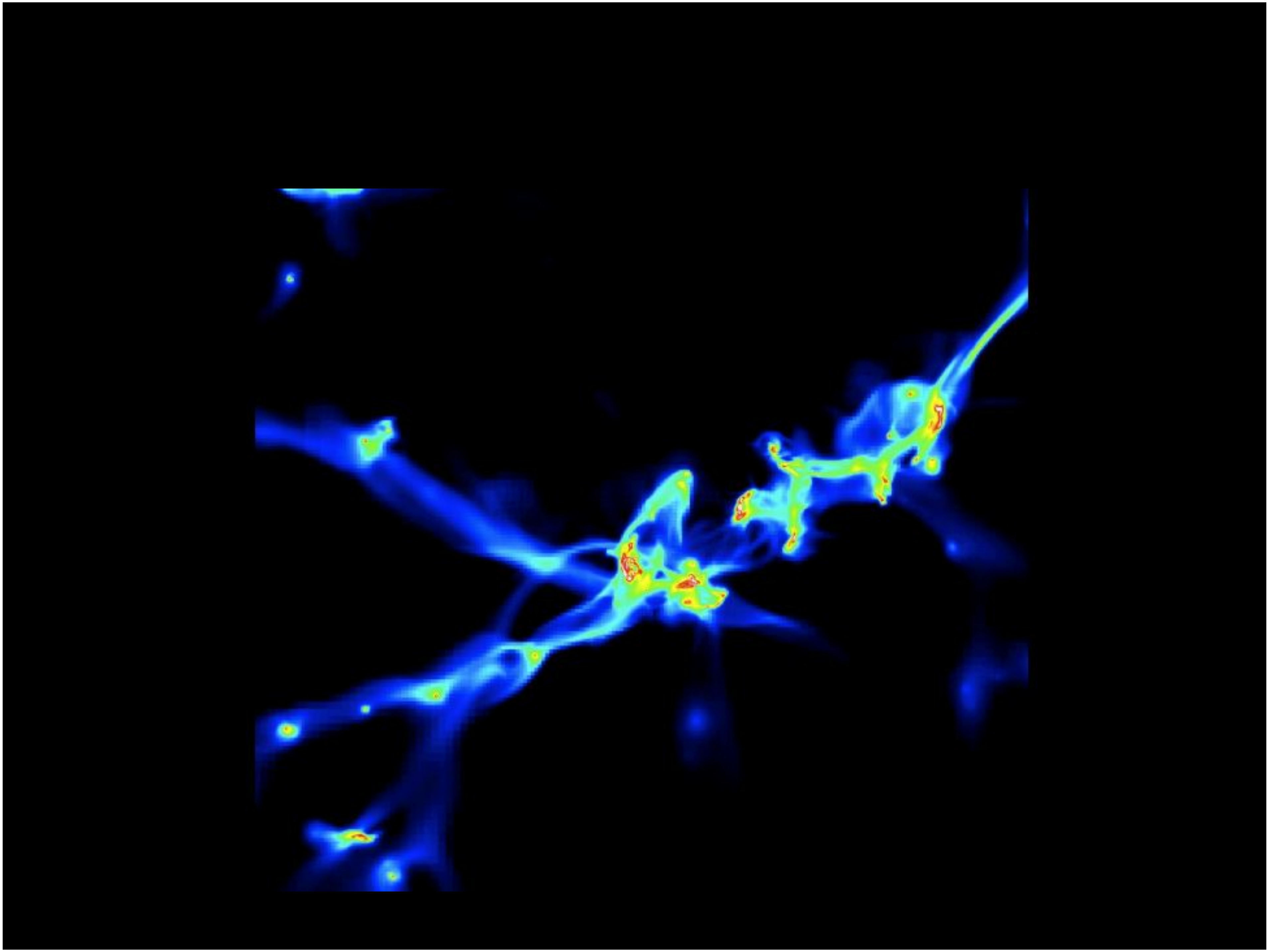

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How to run ART?

How to run ART?

- Untar the code version*.tar in an empty directory at $HOME
- Untar the inicial conditions package (*.tar) in a different directory, where you will actually run the simulation.
- Compile the code: edit the makefile and select the proper fortran and c compiler. Type make
- Place the executable (hartCSF.x) with the files for initial conditions and the input files
- Execute ./hartCSF.x > screen & (check first if the environment variable OMP_NUM_THREADS=#cores)

```
[danielcv@pleiades test2]$ tar -xf IC_Dwarf2.tar.gz
[danielcv@pleiades test2]$ ls
10MpcBox_csf512.d  clcool.dat  control.dat  IC_Dwarf2.tar.gz  PMcrd.DAT  PMcrs0.DAT  pt.dat  sf.dat
[danielcv@pleiades test2]$ 
```

control.dat

```
jobname1  10MpcBox_csf512
path      .
Start       : new run/continuation (T/F) ............................        T
irun        : Input/Output :  irun = 1 (adiabatic), 2 (CSF)..........        2
nfsave      : dump step ..........................................        4
lviewout    : output for view on/off .................................        T
ntc         : time step increase allowed after ntc time steps ........        2
gamma       : gamma of the gas ........................................    1.6666666
cfl         : Courant number..........................................      0.6
timinc      : time step increase factor ..............................      1.2
rhohdr      : Magic density floor  ...................................    1.e-6
wsplit      : split cell if weight > wsplit ..........................      0.2
wjoin       : join  cell if weight < wjoin ...........................      0.1
MinL_Jeans : min level to apply Jeans limit on e (if COOLING defined)        7
Ndiff       : number of weight diffusion iterations .................        4
1          1.         0.1    0      7
2          1.         0.1    3      7
3          0.         0.1    2      9
4          0.         0.1    2      9
5          0.         0.1    2      9
6          0.         0.1    2      9
7          0.         0.1    2      9
8          0.         0.1    2    256
9          0.         0.1    2    256
1. 129.
1. 129.
1. 129.
   107
 0.020
 0.040
 0.060
--More--(66%)
```

sf.dat

```
[danielcv@pleiades test2]$ m sf.dat
alpha_SF   : slope of the Schmidt's law for starformation ...........       1.0
eps_SF     : efficiency of the SF w.r.t to the fiducial value .......      1000.
dtmin_SF   : minimum delta t for SF [yrs] ...........................      2.e7
dm_star_min: minimum stellar particle mass [in Msun] ................      1.e4
rho_SF     : min. n_H for starformation [cm^-3] .....................      1.0e0
T_SF       : max. temperature for starformation .....................      1.0e4
a_IMF      : slope of the IMF (>0 for power law, 0 for user supplied)       0.
aM_stl     : lowest stellar mass in IMF [Msun] ......................       0.1
aM_stu     : upper stellar mass in IMF [Msun] .......................      100.
aM_SNII    : lower mass of stars exploding as SNII [e.g. 8 Msun].....        8.
aM_SNIa1   : lower mass of stars exploding as SNIa [e.g. 3 Msun].....        3.
aM_SNIa2   : upper mass of stars exploding as SNIa [e.g. 3 Msun].....        8.
ejM_SNIa   : ejected mass of metals per SNIa [Msun] .................       1.3
C_SNIa     : fraction of stellar mass in SNIa .......................      5.e-3
t_SNIa     : time of peak in SNIa rate [in Gyrs] ....................       1.0
E_51       : E released per each SN in 1e51 ergs ....................        2.
t_fb       : length of active SNII+winds feedback stage [yrs] .......      4.e7
T0_ml      : T0 const of mass loss function of Jungwiert et al in Myr        5.
c0_ml      : c0 const of mass loss function of Jungwiert et al             0.05
```

Details of the test-Run

- Target halo mass | Max. reso. | dm Mass reso. | Box
- 1.12 10^11 Msun (z=0) | 35-70 pc | 7 10^5 Msun | 10 Mpc/h
- Advance snapshots at z=2, 1, 0.6

How to run extract data from ART snapshots?

How to run extract data from ART snapshots?

- Untarfile: analysisRec.tar
- Compile it: make –f MakeAnaR (select compiler first in MakeAnaR
- Input files: control.dat & schedule_R.dat, plus ana.R.exe and snapshots.

```
[danielcv@pleiades analysis]$ more schedule_R.dat
 Schedule of analysis (flags= 0 Off , 1 On)-------- RECURSIVE
           1     Read N-Body file
           1     Read stellar file
           1     Read HYDRO file
           1     Set units and global variables
           1     Find halo center using particle distribution
           0     Compute angular momentum
           0     ASCII file with last specie of stars or DM  ( see icomponent=2,3)
           1     density, temperature, entropy profiles and Rvir calculation
           0     Binary file with DM particles inside box 4Rvir
           0     Binary file with stellar particles inside box 4Rvir
           0     Binary file with stellar particles inside 4Rvir-box (initial mass)
           0     Binary file with stellar particles inside 4Rvir-box (metallicities)
           0     Binary file with gas cells inside 4Rvir-box
           0      Binary file with gas cells inside 4Rvir-box (metallicities)
     PRE-ANALYSIS
   1.666667      gamma of the gas (check value in control.dat)
   0.13000       rminC (Kpc)
   2.20   0.600000       rmaxC (Kpc)
           1      ioptCenter=1/2/3-->potential/HF/IFRIT

    10.207        xuser

     9.992       yuser

     9.238      zuser
           3      isys for AM calculation 1/2/3 --> dm/stars/cold gas
 3.0000000       Rs (Kpc)
 ----ANALYSIS----------------------------------------
   0.0300        rmin (Kpc )
150              rmax (Kpc )
100         nrbin
test
           2     icomponent=0/1/2/3= all components/gas/stars/DM
  1.000000E+9       T_gas
 1.0000E+10            tAge
 0.5          Zdmax
```

How to run extract data from ART snapshots?

- Untarfile: analysisRec.tar
- Compile it: make –f MakeAnaR (select compiler first in MakeAnaR
- Input files: control.dat & schedule_R.dat
- Output files: fortran unformatted binary files

```
ceverino@carina:~/MW3> more DataSet_README
Brief description of the outputs from cosmological simulations of galaxy formation
-----------------------------------------------------------------------------------
by Daniel Ceverino, Jerusalem, February 2010
-----------------------------------------------------------------------------------

These outputs files are binary fortran files that contains all the information inside a box of 4Rvir centered in th
e major progenitor in cosmological simulations of galaxy formation.

Name of the files:
------------------

The first part is the name of the simulation.
Next, there are one or two letters that determine the type of data in the file:

*_D* --> ID, Position, velocity and mass for DM particles (8 fields)
*_S* --> ID, Position, velocity, mass and age for stellar particles (9 fields)
*_Si*--> ID, Position, velocity, initial mass and age for stellar particles  (9 fields)
*_SZ*--> ID, Position, velocity, mass, age and SNII, SNIa metals mass fraction for stellar particles (11 fields)
*_G* --> Cell size, position, velocity, density and temperature for gas cells (9 fields)
*_GZ*--> Cell size, position, velocity, density, temperature and SNII, SNIa mass metals fraction for gas cells (11
fields)

Next, there is a number that corresponds to the size of the cutout box. It is always equal to 4 times the virial ra
dius (4Rvir).
Finally, the file ends with the expansion parameter, a=1/(1+z), of the snapshot.
For example, the file 'MW2_D120.a0.200.dat' contains the dark matter information of the major progenitor in simulat
ion 'MW2' at a=0.200 (redshift z=4) inside a box of 120 proper kpc centered in that galaxy.

Physical units:
---------------
Units are always in proper (not comoving) units:

Cell size --> pc
Position --> kpc
Velocity --> km/s
mass --> Msun
age --> Gyr
metals mass fraction --> dimensionless
density --> H atoms / cm^3
temperature --> K

Files format:
-------------
These files are written in fortran binary format (big endian). All fields are single precision floating numbers, wi
th the exception of the fields of positions, velocities and masses for stars and dark matter: They have double-prec
ision. The particle ID number is the only integer field.
```

Summary

- Run the test-case + Run the extract-ART code + analysis of the generated outputs (RUN)
- Run the extract-ART code + analysis (snapshots_RUN)
- Analysis of the provided outputs (outputs_CDB)

Bibliography

- Some documentation about the physical model implemented in ART:

http://astronomy.nmsu.edu/danielcv/PhDCeverino.pdf

thanks