

pFoF

A highly scalable halo-finder for large cosmological data sets

Fabrice Roy, Vincent Bouillot, Yann Rasera

Brief history

Situation in 2008:

- Serial fof developed several years earlier by Edouard Audit
- 9 large RAMSES n-body simulations planned (1024^3 particles)
- Discussion with Patrick Hennebelle who suggested the idea behind pFoF (parallel Friends-of-Friends halo finder)
- Development of the first version of pFoF (Roy, Bouillot, Rasera, 2014)
- New version in 2015

What is this idea behind pFoF?

- Divide the simulation box
- Perform a serial halo detection in each subdivision
- Merge the halos that extend across several subdivisions

Merge = give each halo particle the same halo ID

From this idea, 2 versions of pFoF

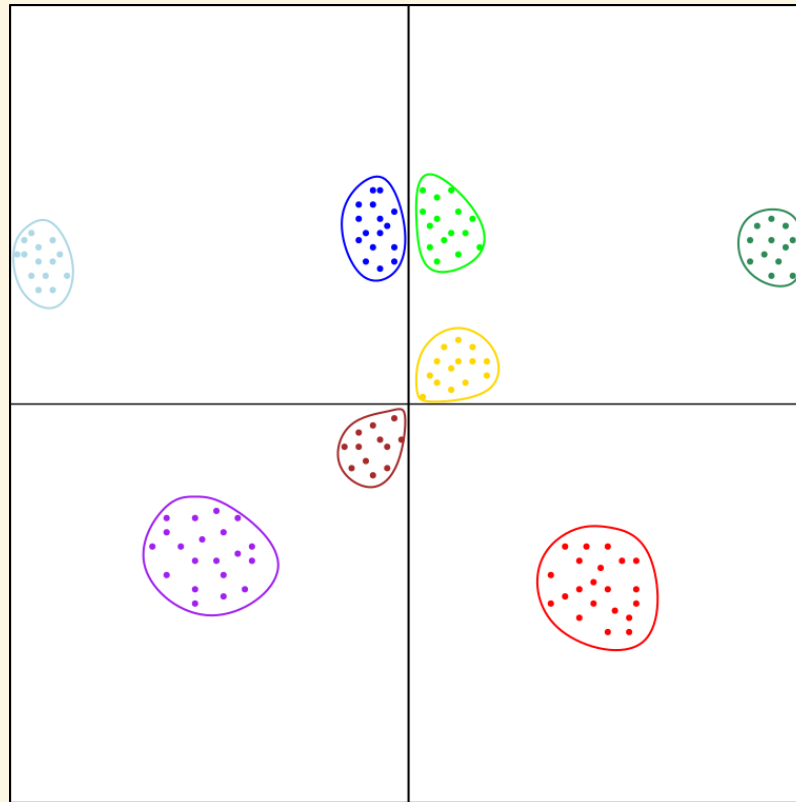
pfof_snap for RAMSES snapshots

- Analyses a RAMSES particles snapshot
- Assumes the boundary conditions are periodic
- Can write the particles distributed in cubic subdivisions ("cube files")
- Can read RAMSES binary files or previously written cube files
- Writes 2 kinds of files: halo properties and list of particles per halo

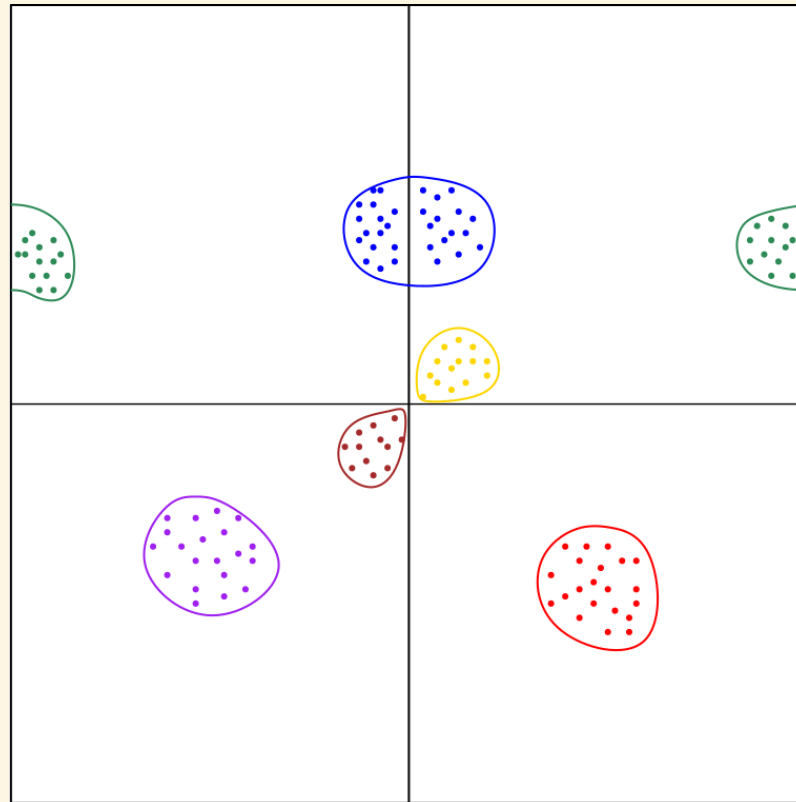
pfof_cone for RAMSES lightcones

- Analyzes a RAMSES particles lightcone
- First version by Vincent Bouillot for DEUS-FUR lightcones (>100 billions particles) in 2012
- New optimized version in 2015
- pfof_cone processes are "mapping" the cone
- No boundary conditions
- Only reads hdf5 shells produced by a tool (conepartcreator)
- Writes 2 kinds of files: halo properties and list of particles per halo

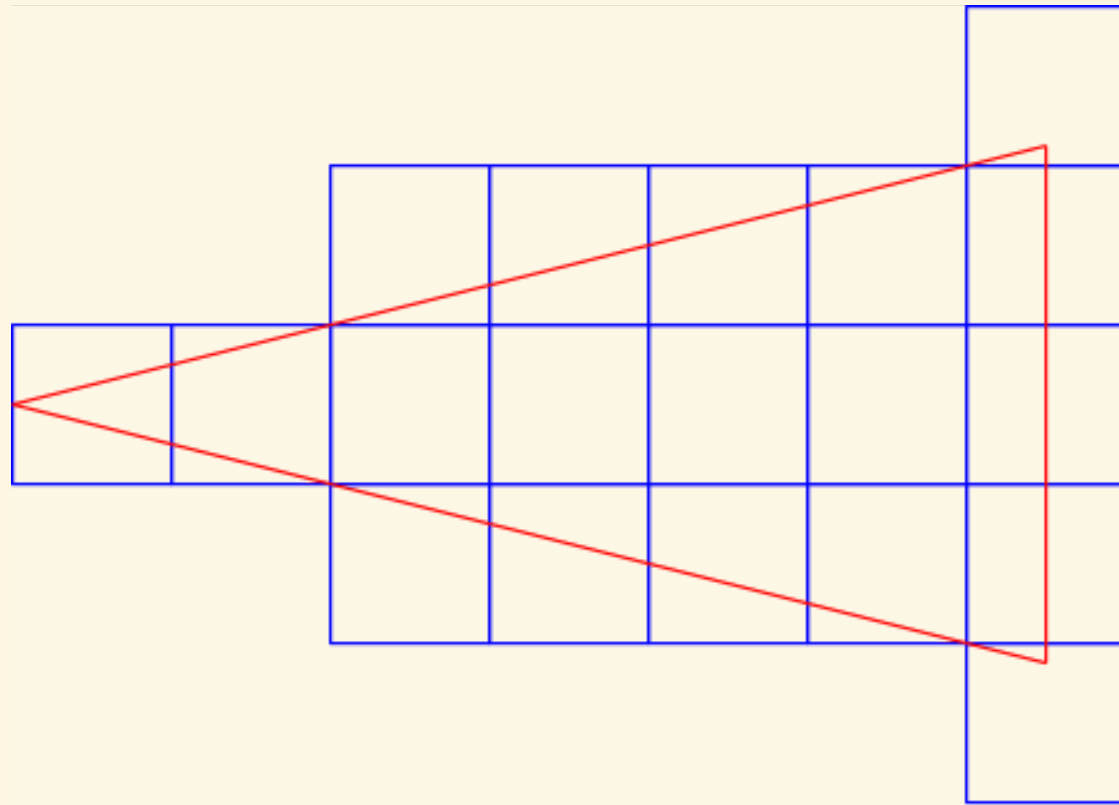
What does it look like?



What does it look like?



How is the lightcone mapped?



Halo properties file

HDF5 file, with some metadata (RAMSES parameters, pfof parameters, etc...)

- Only 1 file, parallel write
- Contains a list of halos with:
 - their number of particles
 - the position and velocity of their center of mass
 - the "radius" of the halo

Halo particles files

HDF5 files, with some metadata (RAMSES parameters, pfof parameters, etc...)

- Several files, 1 per process or 1 per group of processes (parallel write in this case)
- One group per halo
- In each group, the properties of each particle

Pros/Cons of these files

Pros:

- Output files allow easy further analysis (with pFoF, other halo finder, other codes)
- You can perform a FoF with a lower b from halo particles files
- Cubes are easier to handle than the RAMSES binary files
- Parallel writes reduce the number of files

Cons:

- Very costly: lots of communications to gather the particles
- See performance for an example

HDF5 structure of the files

HDFView 2.11 (sur advil.obspm.fr)

Recent Files: /data/home/roy/Cosmo/Test/pfoc_cube_snap_part_data_test_8_process_00000.h5

Tree View:

- pfoc_cube_snap_part_data_test_8_process_00000.h5
 - data
 - gravitational_field_part
 - identity_part
 - position_part
 - potential_part
 - velocity_part
 - metadata
 - npart_file
 - npart_simulation
 - pfoc_snap_parameters
 - foc_parameters
 - input_parameters
 - output_parameters
 - ramses_info

Table (0-based):

	0	1	2
0	-0.021904...	0.02861379...	-0.018065...
1	-0.035323...	0.0386222...	-0.014724...
2	-0.040148...	0.039045...	-0.037558...
3	-0.109298...	0.008484...	-0.052094...
4	4.248629...	0.0036331...	0.01598162...
5	+0.00840...	-0.014600...	0.015441...
6	-0.428243...	-0.0859442...	-0.006541...
7	0.002694...	-0.013502...	0.0215414...
8	-0.00478...	-0.005326...	0.005963...
9	0.0150326...	0.01372841...	0.0119453...
10	0.015091...	0.014001...	1.5100017...
11	0.017014...	0.014473...	-0.002916...
12	0.034854...	0.007599...	0.003461...
13	0.012659...	0.009645...	-0.004421...
14	0.007539...	0.019406...	0.016026...
15	-0.001604...	0.0132022...	0.009491...
16	-0.003222...	0.013186...	0.010008...
17	0.002968...	0.0136228...	0.015868...
18	0.009000...	0.018834...	0.016117...
19	0.001278...	0.010030...	0.0120855...
20	-0.010969...	-0.037087...	0.037265...
21	0.009722...	-0.010329...	0.027964...
22	-0.014604...	-0.011033...	0.0117273...
23	+0.029846...	0.008802...	0.018908...
24	-0.023548...	-0.028889...	0.026482...
25	-0.021668...	-0.025029...	0.0011258...
26	0.0025333...	0.0025138...	0.020104...
27	-0.008758...	-0.014858...	-0.038265...
28	-3.917545...	-0.025371...	-0.037857...
29	5.432545E...	-0.027505...	-0.040247...

ramses_info (11008, 2)

```
Group size = 0
Number of attributes = 17
aexp = 0.903640895892252
boxlen = 1.0
h0 = 72.0
levelmax = 14
levelmin = 7
ncpu = 64
ndim = 3
ngridmax = 1000000
nstep_coarse = 288
omega_b = 0.0
omega_k = 2.98023223876953E-8
omega_l = 0.742699980735779
omega_m = 0.257299989461899
time = -0.109902518148153
unit_d = 3.39840378010395E-30
unit_l = 3.17682715523738E26
unit_t = 3.4995334104160499E17
```

Log Info Metadata

HDF5 structure of the files

HDFView 2.11 (sur advil.obspm.fr)

File Window Tools Help

Recent Files /data/home/roy/Cosmo/Test/pfof_halo_cone_part_data_testpfofcone_00022.h5

position_part at /data/halo_000000000002437015/ [pfof_halo_cone_part_data_testpfofcone_000...]

	0	1	2
0	2.415609	0.17703858	0.1461583
1	2.4157982	0.177107...	0.14569198
2	2.4155777	0.176920...	0.14672625
3	2.4141815	0.17628144	0.1492555
4	2.4141428	0.17750153	0.1488633
5	2.4119587	0.1753814	0.14858234
6	2.4134777	0.17378871	0.14975703
7	2.4123297	0.174789...	0.14908592
8	2.413053	0.174464...	0.15024953
9	2.4141562	0.17635168	0.14960127
10	2.4134417	0.1757132	0.1505737
11	2.4130752	0.177386...	0.15050185
12	2.4137099	0.177480...	0.15054768
13	2.4126918	0.176899...	0.14971244
14	2.413476	0.17578135	0.15036537
15	2.4136665	0.17280279	0.15085556
16	2.4144945	0.17541283	0.15142211
17	2.4154572	0.17673366	0.15156227
18	2.4143512	0.17631175	0.15023269
19	2.4110076	0.17236434	0.1534943
20	2.4107027	0.17367361	0.15353481
21	2.4111907	0.17370024	0.15341838
22	2.4109657	0.17630851	0.15061079
23	2.412379	0.17527982	0.15175138
24	2.4129689	0.17455089	0.15155137
25	2.412457	0.17549985	0.15217726
26	2.410942	0.17728321	0.15174374
27	2.4121807	0.176578...	0.15220812

cone_info_last (1416, 4)
Group Size = 1
Number of attributes = 38
aendcone = 1.00420517916334
aendconem1 = 0.999272703901466
aendconem2 = 0.994309326219456
aexp = 0.999312711551732
aexpold = 0.994420243940124
amax = 0.999272703901466
amin = 1.00420517916334
cone_id = 1
cone_zlim = 0.1
dendcone = -0.152812437664105
dendconem1 = 0.0264851524175867
dendconem2 = 0.208986986786869
dex = 0.0251038829739131
dexold = 0.204720032529258
dmax = 0.0264851524175867
dmin = -0.152812437664105
dtol = 0.0
future = 1
isfullsky = 0
ncpu = 8192
nglobalfile = 1
nstep_coarse = 309
nstride = 0
observer_rds = 0.0
observer_x = 0.5

Log Info Metadata

HDF5 structure of the files

HDFView 2.11 (sur advil.obspm.fr)

File Window Tools Help

Recent Files /data/home/roy/Cosmo/Test/pfof_halo_snap_part_hfprop_test_27_process.h5

pfof_halo_snap_part_hfprop_test_27_pr

- data
 - identity_halo
 - npart_halo
 - position_halo
 - rmax_halo
 - velocity_halo
- metadata
 - npart_simulation
 - pfof_snap_parameters
 - ramses_info

position_halo at /data/ [pfof_halo_snap_part_hfprop_test_27_process.h5 in /data/home/roy/Cosmo...

Table

	0	1	2
0	0.154938...	0.1199261...	0.156814...
1	0.047624...	0.197628...	0.045298...
2	0.1333605...	0.065342...	0.107742...
3	0.065366...	0.187302...	0.0220102...
4	0.1130943...	0.1172145...	0.086996...
5	0.2291536...	0.109614...	0.197404...
6	0.086880...	0.1611225...	0.049176...
7	0.2350572...	0.1788332...	0.117882...
8	0.0215762...	0.248406...	0.065117...
9	0.2453413...	0.1414505...	0.195805...
10	0.029381...	0.385492...	0.116719...
11	0.0208335...	0.313529...	0.093496...
12	0.959599...	0.401088...	0.217709...
13	0.2149333...	0.397695...	0.1678331...
14	0.168656...	0.404102...	0.1550905...
15	0.1823245...	0.476672...	0.2299261...
16	0.208236...	0.488459...	0.204720...
17	0.993707...	0.4112862...	0.201801...
18	0.985448...	0.399360...	0.1917853...
19	0.428454...	0.304566...	0.094336...
20	0.418254...	0.4652422...	0.048356...
21	0.294335...	0.3050051...	0.1171650...
22	0.467808...	0.461095...	0.099333...
23	0.461682...	0.3281456...	0.1425287...
24	0.487366...	0.2825882...	0.1556572...
25	0.439802...	0.481816...	0.1220338...
26	0.416611...	0.286991...	0.115009...
27	0.368098...	0.265671...	0.105410...
28	0.3494115...	0.483445...	0.1623011...
29	0.435486...	0.273097...	0.1920262...
30	0.349816...	0.080799...	0.224601...
31	0.2834337...	0.2176517...	0.109029...
32	0.460084...	0.017867...	0.2474323...
33	0.464676...	0.017603...	0.228460...

ramses_info (11008, 6)

Group size = 0

Number of attributes = 17

aexp = 0.903640895892252

boxlen = 1.0

h0 = 72.0

levelmax = 14

levelmin = 7

ncpu = 64

ndim = 3

ngridmax = 1000000

nstep_coarse = 288

omega_b = 0.0

omega_k = 2.98023223876953E-8

omega_l = 0.742699980735779

omega_m = 0.257299999461899

time = -0.109902518148153

unit_d = 3.39840378010395E-30

unit_l = 3.17682715523738E26

unit_t = 3.4995334104160499E17

Log Info Metadata

Performances (1) - Weak scaling

Λ CDM, $a=0.3$, $b=0.2$, 1024^3 , 64 proc., on Curie (TGCC): 483 s.

- input: 57 s.
- local fof + merging: 43 s.
- halo properties + output: 232 s.

Λ CDM, $a=0.3$, $b=0.2$, 4096^3 , 4096 proc., on Curie: 1923 s.

- input: 605 s. (bad)
- local fof + merging: 47 s. (good)
- halo properties + output: 1015 s. (bad)

Bad comm. scheme + poor I/O scaling on Curie with
>512 processes (Alimi et al. 2012)

Performance (2)

Some examples of pfof_cone execution on Curie

- Narrow cone, Λ CDM, 648 Mpc/h, 2048^3 , $\sim 7.9 \times 10^9$ part., $b=0.2$, 1332 proc.: 190s.
- A large part of the costly I/O is done by coneptcreator: 1h30 on 16 proc.
- Fullsky, Λ CDM, 2592 Mpc/h, 2048^3 , $\sim 9.2 \times 10^9$ part., $b=0.2$, 1472 proc.: 206s.
- coneptcreator: 3h. on 16 proc.

Performance (3)

Largest snapshot analyzed with pFoF (previous version, 2012):

- Λ CDM, 21Gpc/h, $a=1$, $b=0.2$
- 8192^3 particles, 32k proc., on Curie
- Walltime = approx. 2h

Future developments: some ideas

- improve the input and halo properties/output phases
- develop an hybrid MPI-OpenMP version
- add subhalo detection
- add unbinding
- adapt pFoF for zoom and hydro simulations
- ...

If you want to use pFoF

- No public git or subversion yet, it will come soon!
- You can send me an email: fabrice.roy@obspm.fr
- I would be glad to help you install/use/adapt pFoF
- People have already used it at Strasbourg Observatory and KASI in Daejeon (Korea)

Thank you!