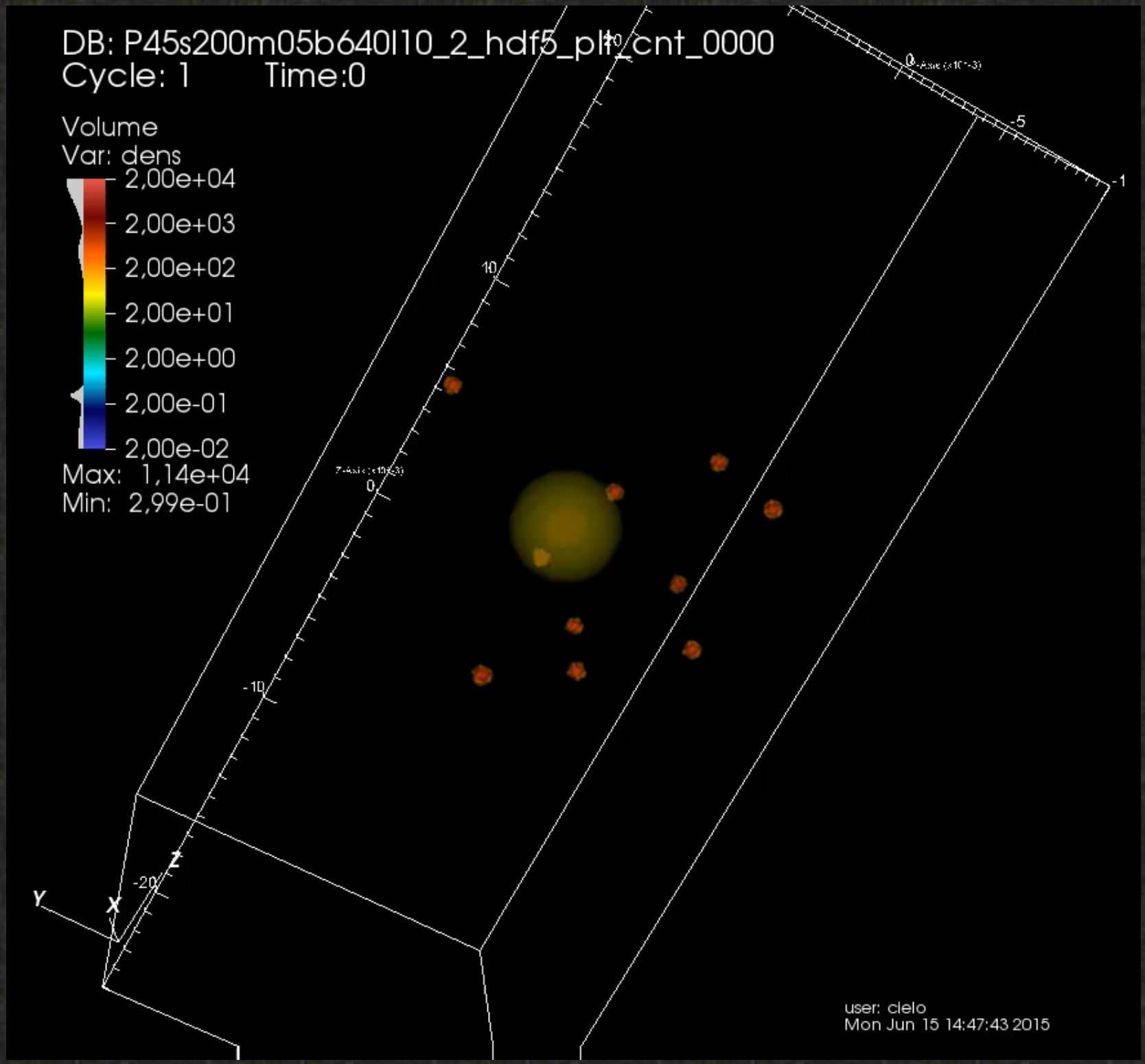
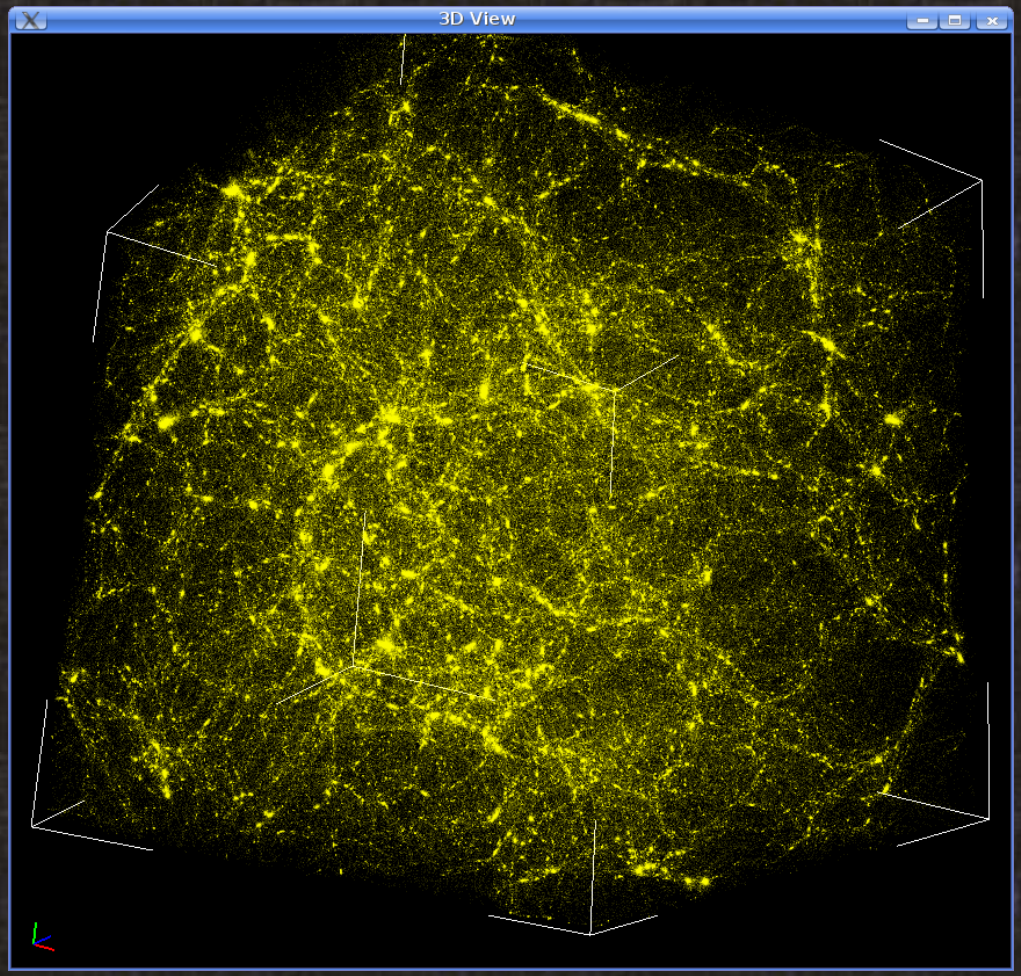
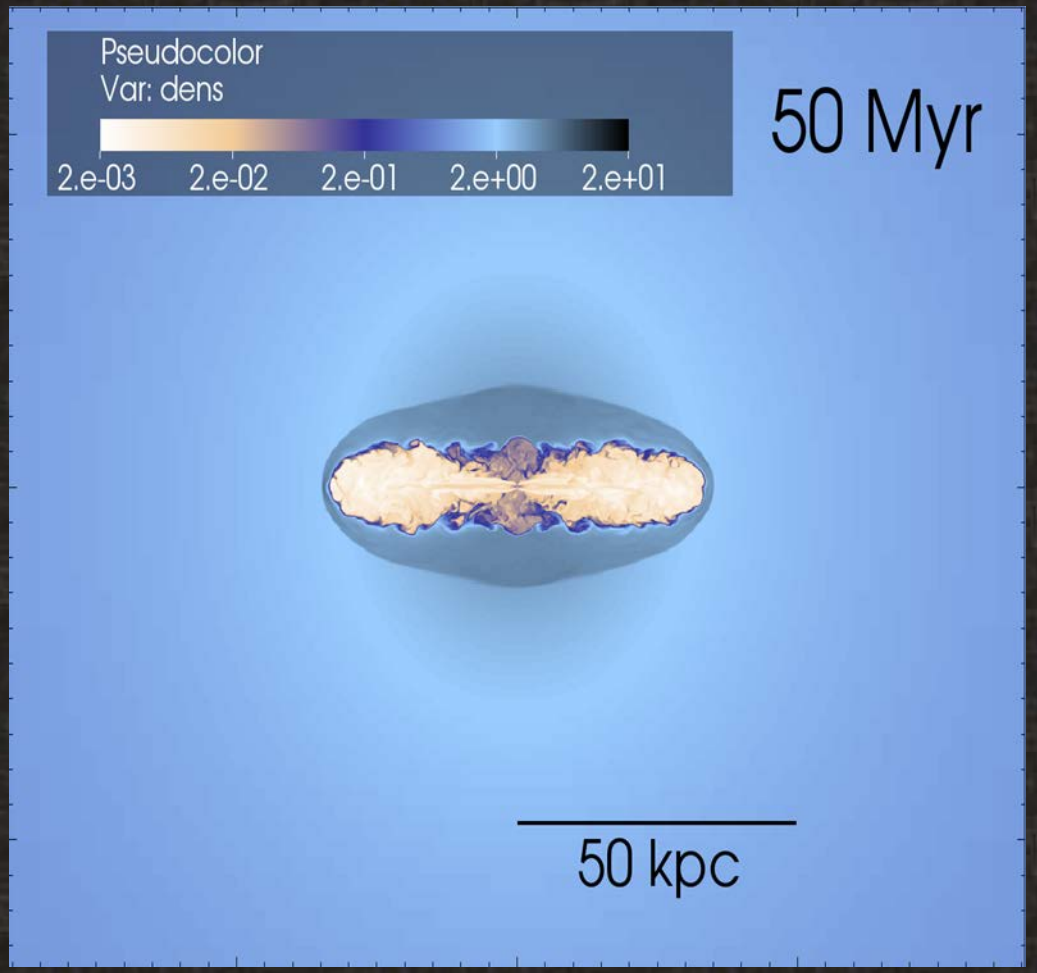
Propagating (almost) relativistic jets within galaxies

V. Antonuccio-delogu (INAF) + S. Cielo (IAP), J. Silk (IAP and Oxford), A. Babul (Victoria), U. Becciani, A. Costa (INAF), A. Dobrotka (Bratislava), A. Romeo (Nanjing)

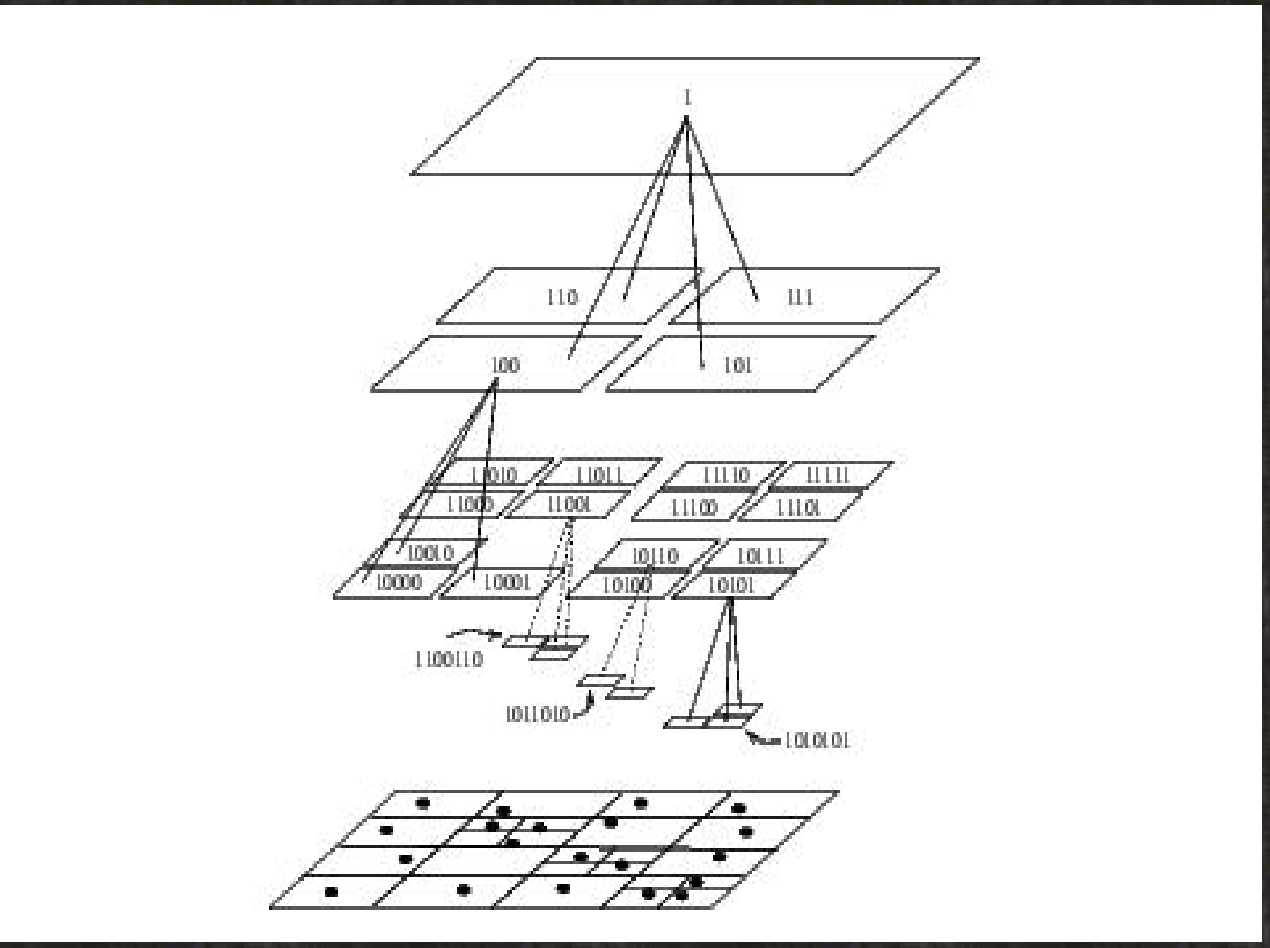

DB: P45s200m05b640l10_2_hdf5_plt_cnt_0000
Cycle: 1 Time:0
Volume
Var: dens
2,00e+04
2,00e+03
2,00e+02
2,00e+01
2,00e+00
2,00e-01
2,00e-02
Max: 1,14e+04
Min: 2,99e-01
10
0
-10
-20
-5
-1
Y
X
Z
user: clelo
Mon Jun 15 14:47:43 2015

Simulating AGNs within cosmological volumes: Tree+AMR / N-body (gravity) + dissipative (gas) : FLY ↔ FLASH





Simulating AGNs within cosmological volumes: Tree+AMR / N-body (gravity) + dissipative (gas) : FLY ↔ FLASH

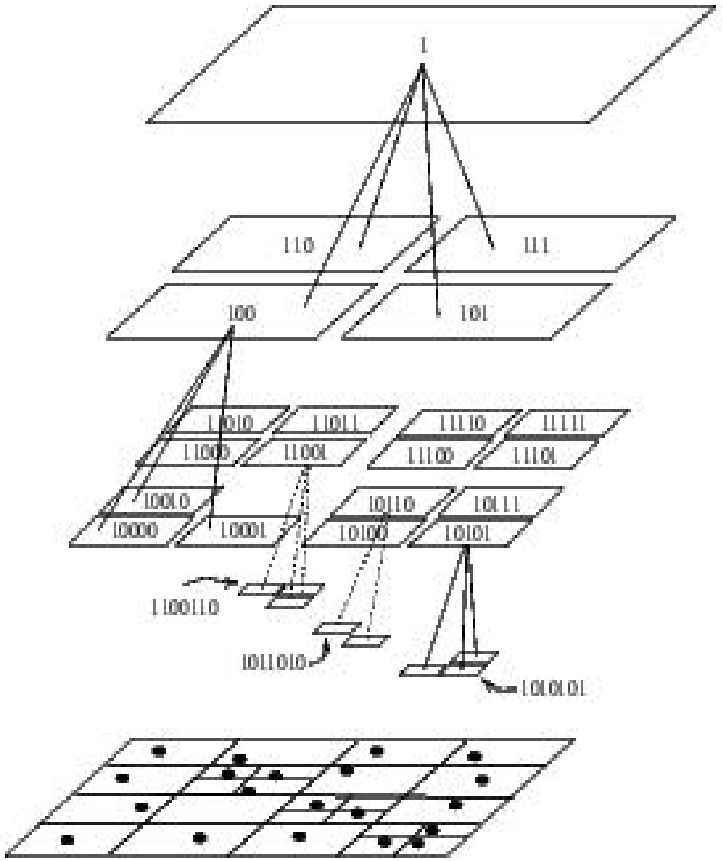


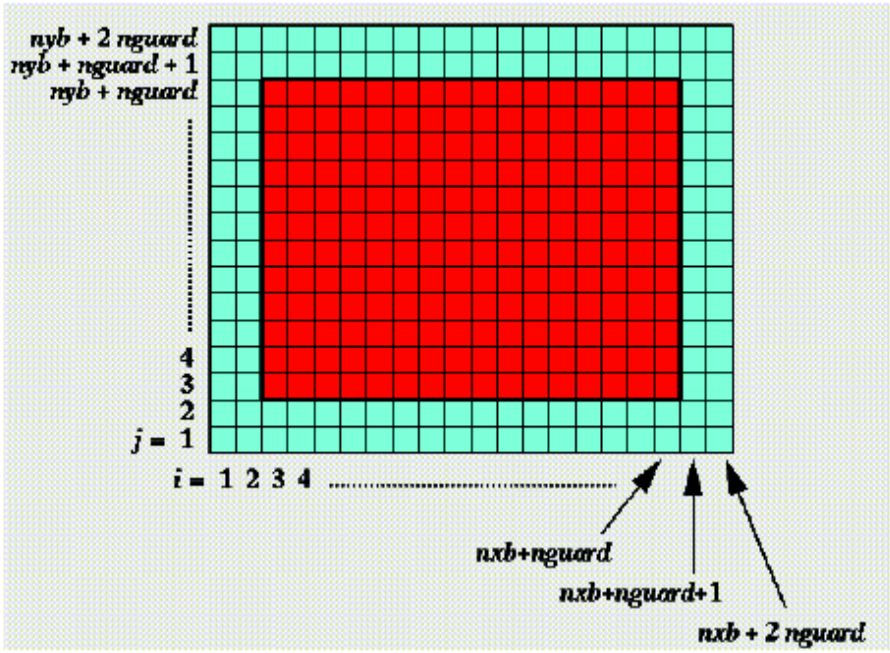
Gravity: Octal tree (Barnes & Hut 1984)

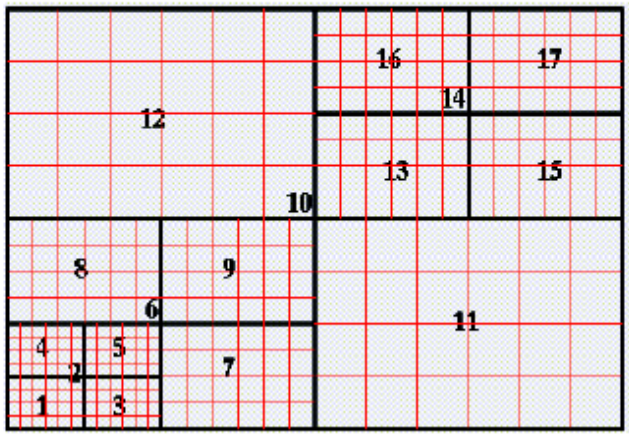
- PARAMESH (AMR) ↔ Block structured Octal tree (FLY)

similar (not identical) data structures → easy mapping in both

Simulating AGNs within cosmological volumes: Tree+AMR / N-body (gravity) + dissipative (gas) : FLY ↔ FLASH



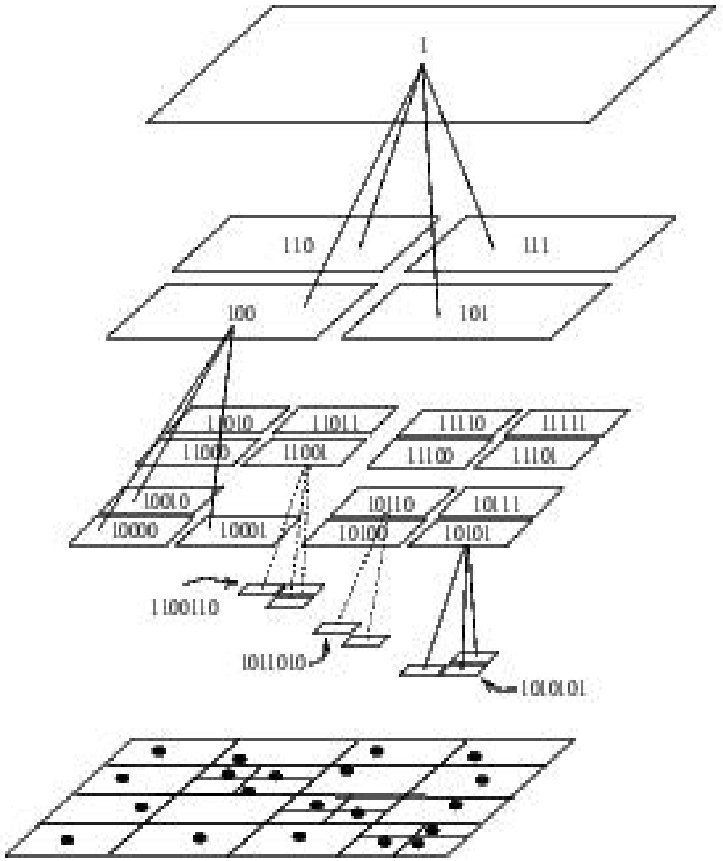


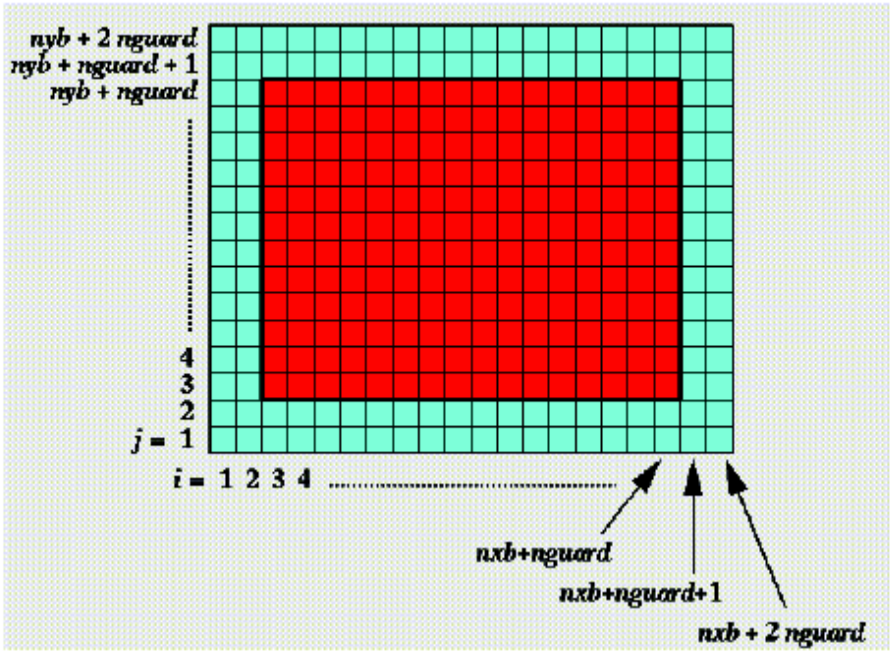


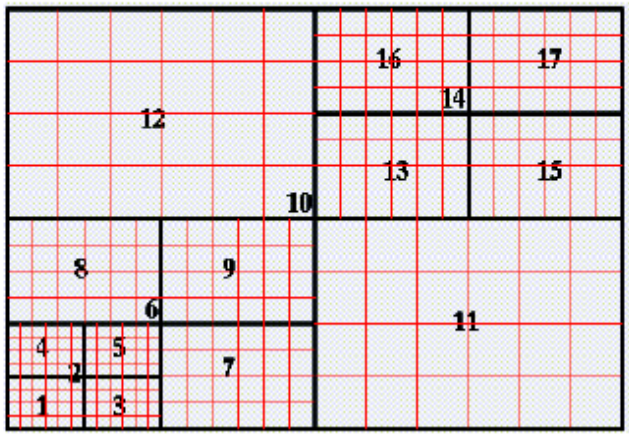
Gravity: Octal tree (Barnes & Hut 1984)

- PARAMESH (AMR) ↔ Block structured Octal tree (FLY)

Simulating AGNs within cosmological volumes: Tree+AMR / N-body (gravity) + dissipative (gas) : FLY ↔ FLASH





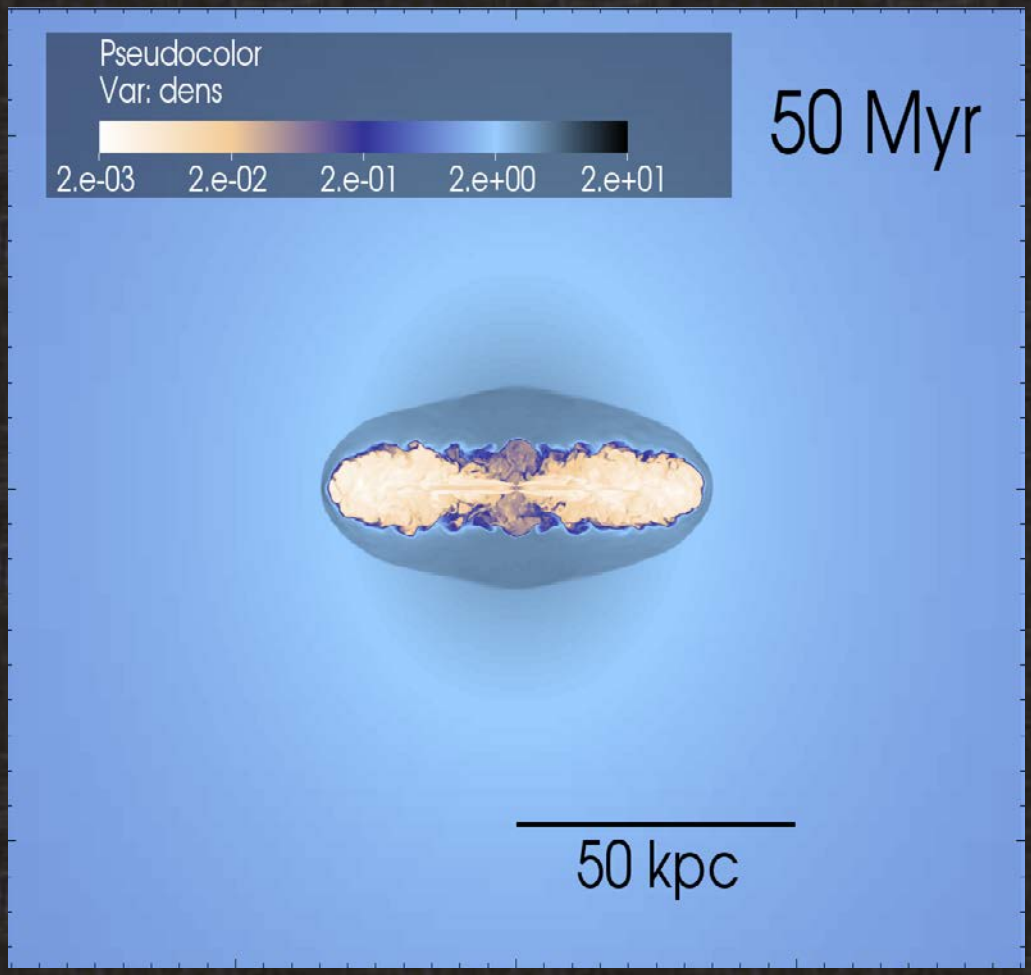


Gravity: Octal tree (Barnes & Hut 1984)

- PARAMESH (AMR) ↔ Block structured Octal tree (FLY)

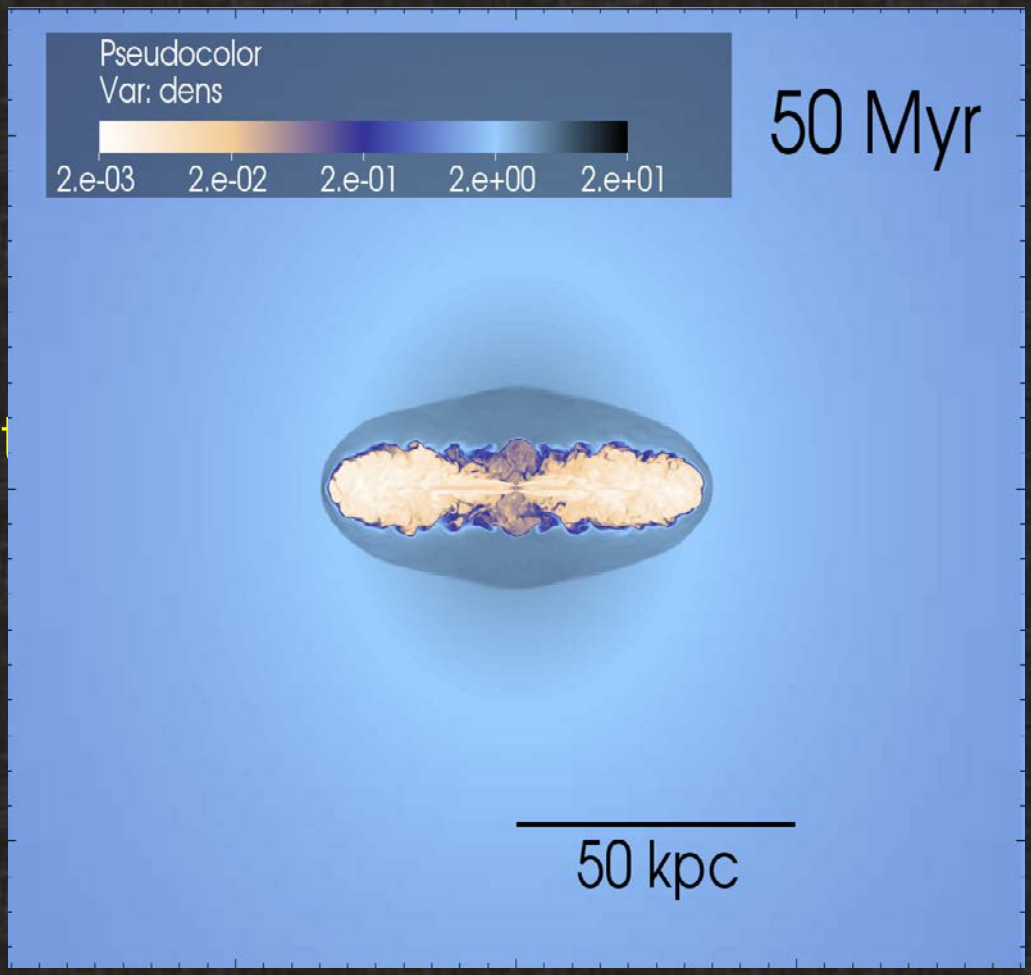
<u>similar</u> (<u>not identical</u>) data structures → easy mapping in both

- Jet propagation into AGN host galaxies: almost spheroidal hot, low density cocoons



- Jet propagation into AGN host galaxies: almost spheroidal hot, low density cocoons

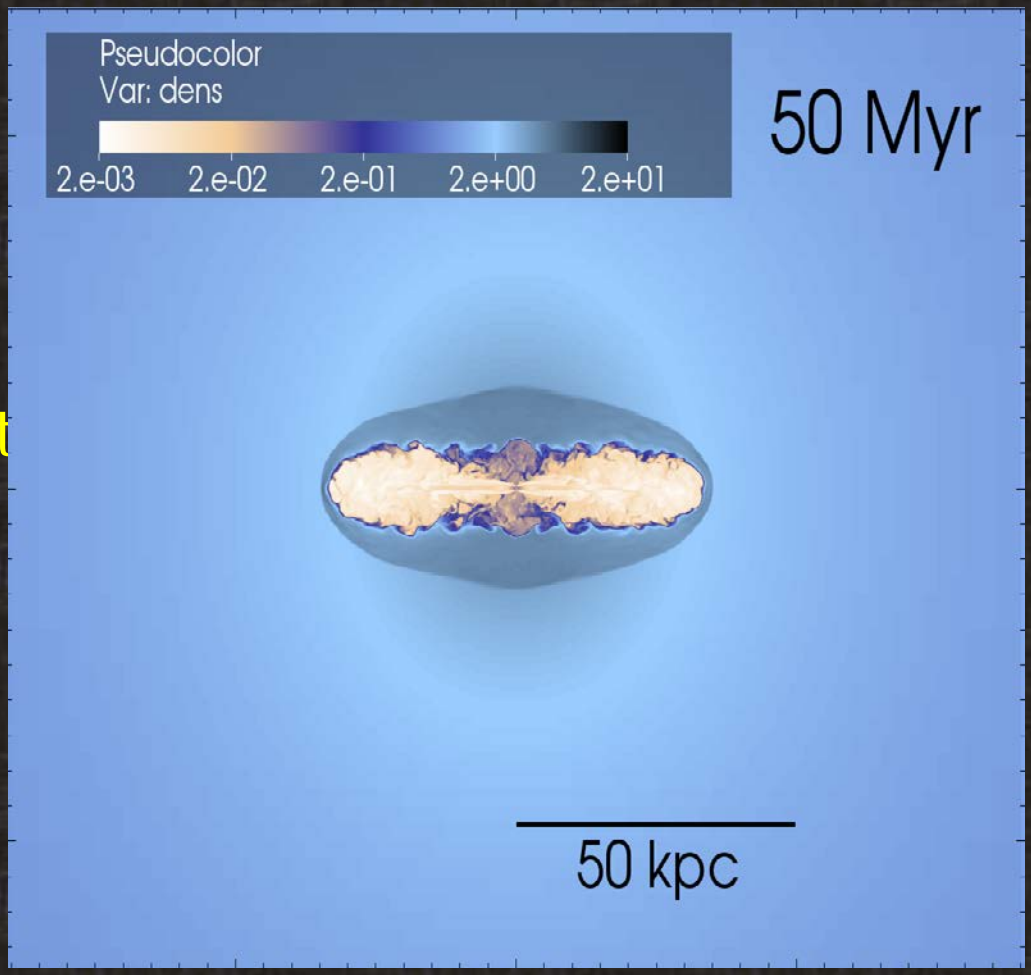
- Semimajor axis: $a(t) \propto t^{5/3}$, aspect ratio $f=1-b/a \approx$ constant



- Jet propagation into AGN host galaxies: almost spheroidal hot, low density cocoons

- Semimajor axis: $a(t) \propto t^{5/3}$, aspect ratio $f=1-b/a \sim$ constant

- AMR (FLASH 4.0): refinement up to maximum level r_{max} (turbulence → unresolved scales)

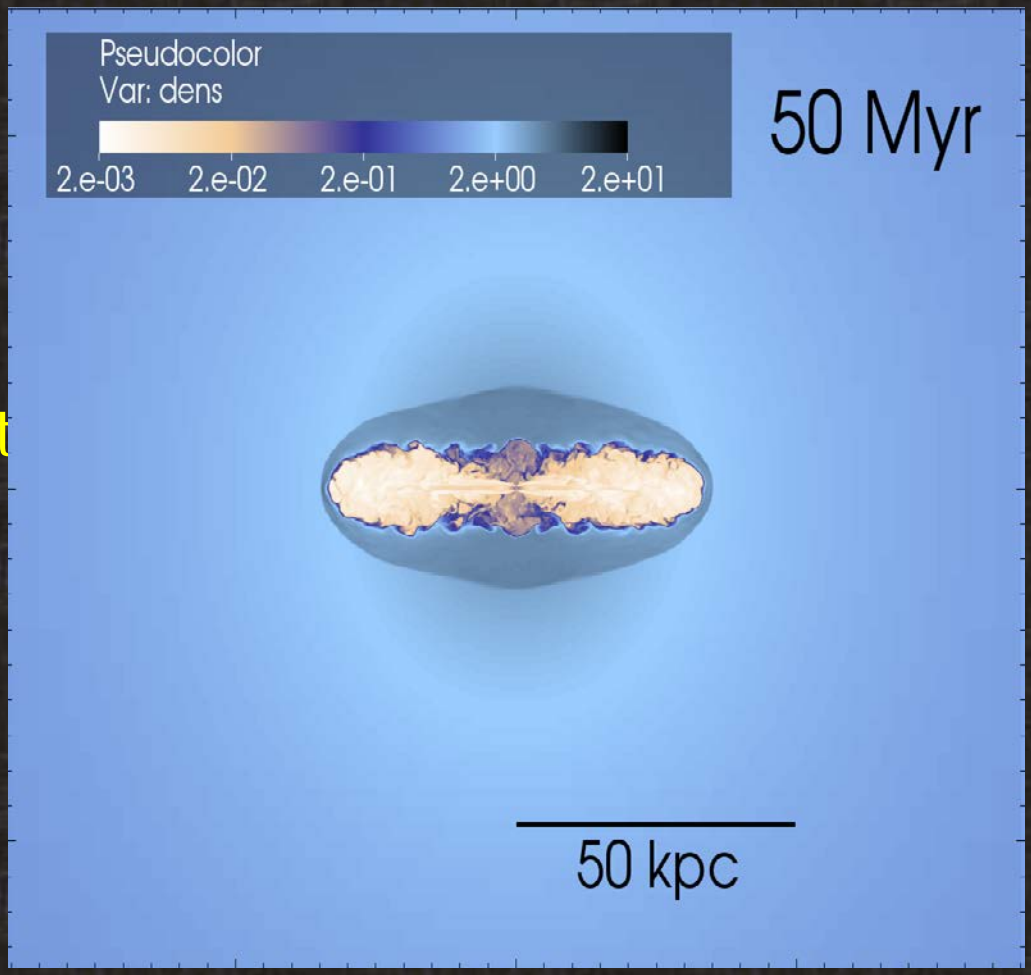


- Jet propagation into AGN host galaxies: almost spheroidal hot, low density cocoons

- Semimajor axis: $a(t) \propto t^{5/3}$, aspect ratio $f=1-b/a \sim$ constant

- AMR (FLASH 4.0): refinement up to maximum level r_{max} (turbulence → unresolved scales)

- $L_{box} \approx 0.1$ - 1 Mpc, $a(t_{max}) \lesssim L_{box}$

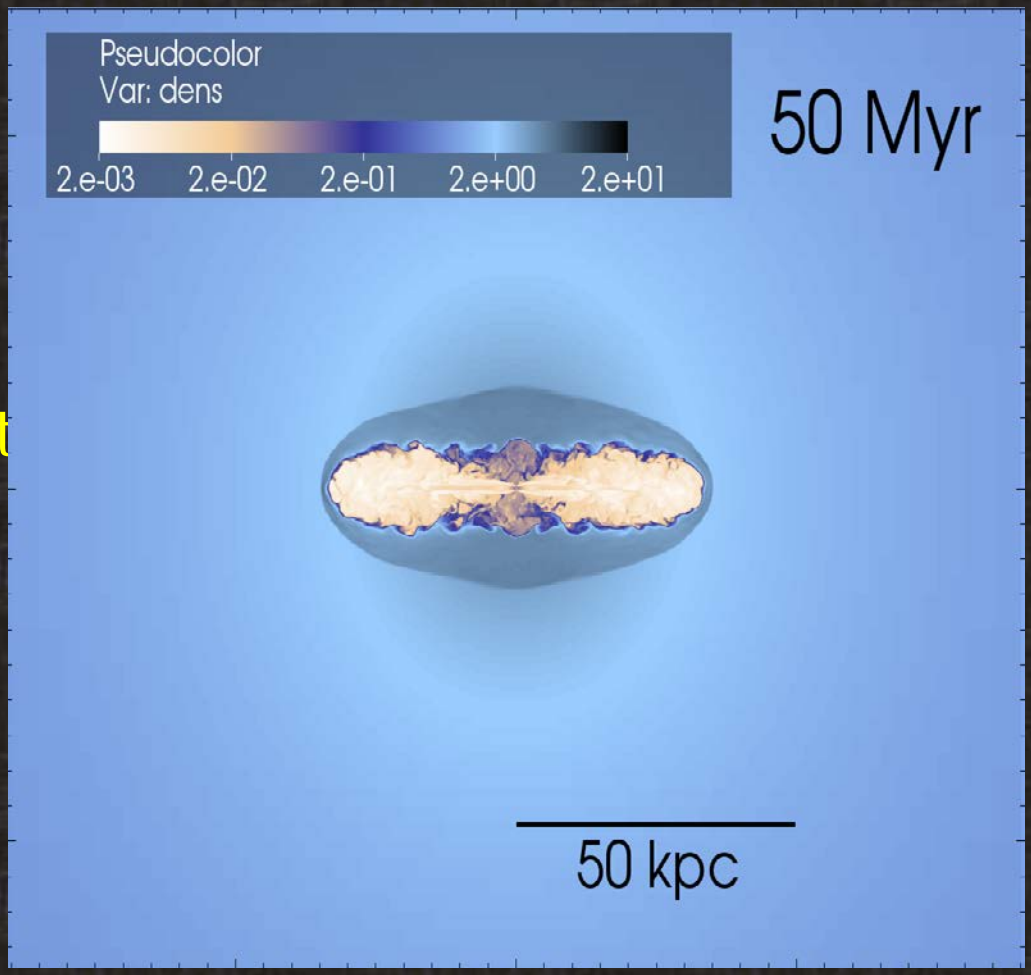


- Jet propagation into AGN host galaxies: almost spheroidal hot, low density cocoons

- Semimajor axis: $a(t) \propto t^{5/3}$, aspect ratio $f=1-b/a \sim$ constant

- AMR (FLASH 4.0): refinement up to maximum level r_{max} (turbulence → unresolved scales)

- $L_{box} \sim 0.1$ - 1 Mpc, $a(t_{max}) \lesssim L_{box}$



✓Going to many AGNs within cosmological volumes....

- Cocoon's volume: $V = \frac{4\pi}{3} a^2 b = \frac{4\pi}{3} a^3 (1 - f) \qquad f = (1 - \frac{b}{a})$

- Cocoon's volume: $V = \frac{4\pi}{3} a^2 b = \frac{4\pi}{3} a^3 (1 - f) \qquad f = (1 - \frac{b}{a})$
- *f:* aspect ratio
- FLASH block's volume $l_b = \frac{L}{n_i 2^r}, \; V_b = l_b^3 = \frac{V_a}{n_i^3 2^{3r}}, \; V_a = L^3$

- Cocoon's volume: $V = \frac{4\pi}{3} a^2 b = \frac{4\pi}{3} a^3 (1 - f) \qquad f = (1 - \frac{b}{a})$
- *f:* aspect ratio
- FLASH block's volume $l_b = \frac{L}{n_i 2^r}, \; V_b = l_b^3 = \frac{V_a}{n_i^3 2^{3r}}, \; V_a = L^3$
- Blocks within a cocoon of sem. axis a(t):

$$n_b(r) = \left[\frac{V_a}{V_b}\right] \simeq \left[\frac{4\pi}{3}(1-f)a^3 \frac{n_s^3 2^{3r}}{V_a}\right] \simeq \left[\frac{4\pi}{3}(1-f)\left(\frac{a}{L}\right)^3 n_s^3 2^{3r}\right]$$

- Cocoon's volume: $V = \frac{4\pi}{3} a^2 b = \frac{4\pi}{3} a^3 (1 - f) \qquad f = (1 - \frac{b}{a})$
- *f:* aspect ratio
- FLASH block's volume $l_b = \frac{L}{n_i 2^r}, \; V_b = l_b^3 = \frac{V_a}{n_i^3 2^{3r}}, \; V_a = L^3$
- Blocks within a cocoon of sem. axis a(t):

$$n_b(r) = \left[\frac{V_a}{V_b}\right] \simeq \left[\frac{4\pi}{3}(1-f)a^3 \frac{n_s^3 2^{3r}}{V_a}\right] \simeq \left[\frac{4\pi}{3}(1-f)\left(\frac{a}{L}\right)^3 n_s^3 2^{3r}\right]$$

- *r:* refinement level

$$N_b(a) = \sum_{r=r_{min}}^{r_{max}} n_b(r) \simeq \left[\frac{\lambda}{7}\left(\frac{a}{L}\right)^3 n_s^3\right] \left(2^{r_{max}} - 2^{r_{min}}\right)$$

$$r_{min} \simeq 3.322 \times \log\left(\frac{L}{n_i a}\right)$$

- Cocoon's volume: $V = \frac{4\pi}{3} a^2 b = \frac{4\pi}{3} a^3 (1 - f) \qquad f = (1 - \frac{b}{a})$
- *f:* aspect ratio
- FLASH block's volume $l_b = \frac{L}{n_i 2^r}, \; V_b = l_b^3 = \frac{V_a}{n_i^3 2^{3r}}, \; V_a = L^3$
- Blocks within a cocoon of sem. axis a(t):

$$n_b(r) = \left[\frac{V_a}{V_b}\right] \simeq \left[\frac{4\pi}{3}(1-f)a^3 \frac{n_s^3 2^{3r}}{V_a}\right] \simeq \left[\frac{4\pi}{3}(1-f)\left(\frac{a}{L}\right)^3 n_s^3 2^{3r}\right]$$

- *r:* refinement level

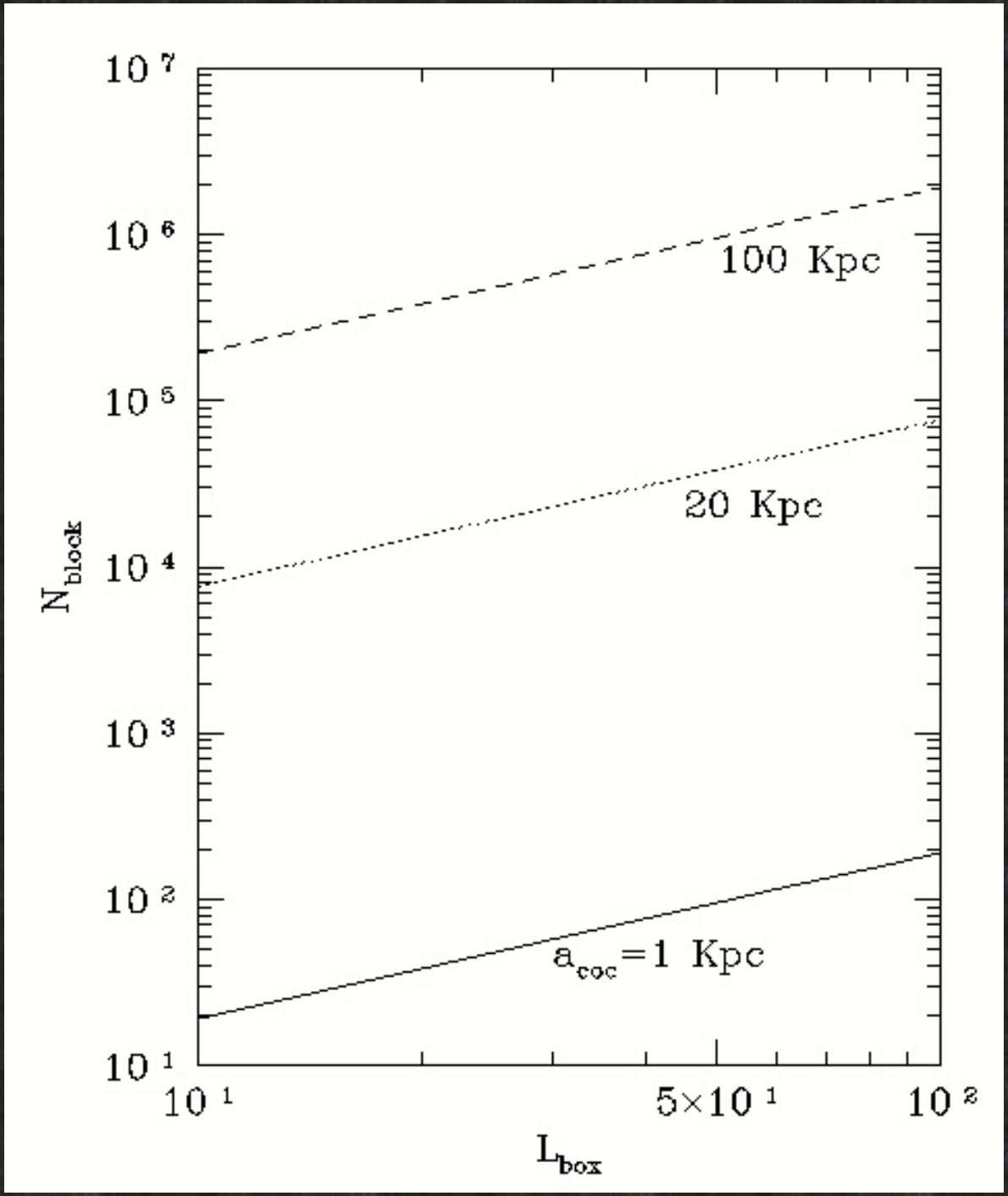
$$N_b(a) = \sum_{r=r_{min}}^{r_{max}} n_b(r) \simeq \left[\frac{\lambda}{7}\left(\frac{a}{L}\right)^3 n_s^3\right](2^{r_{max}} - 2^{r_{min}})$$

$$r_{min} \simeq 3.322 \times \log\left(\frac{L}{n_i a}\right)$$

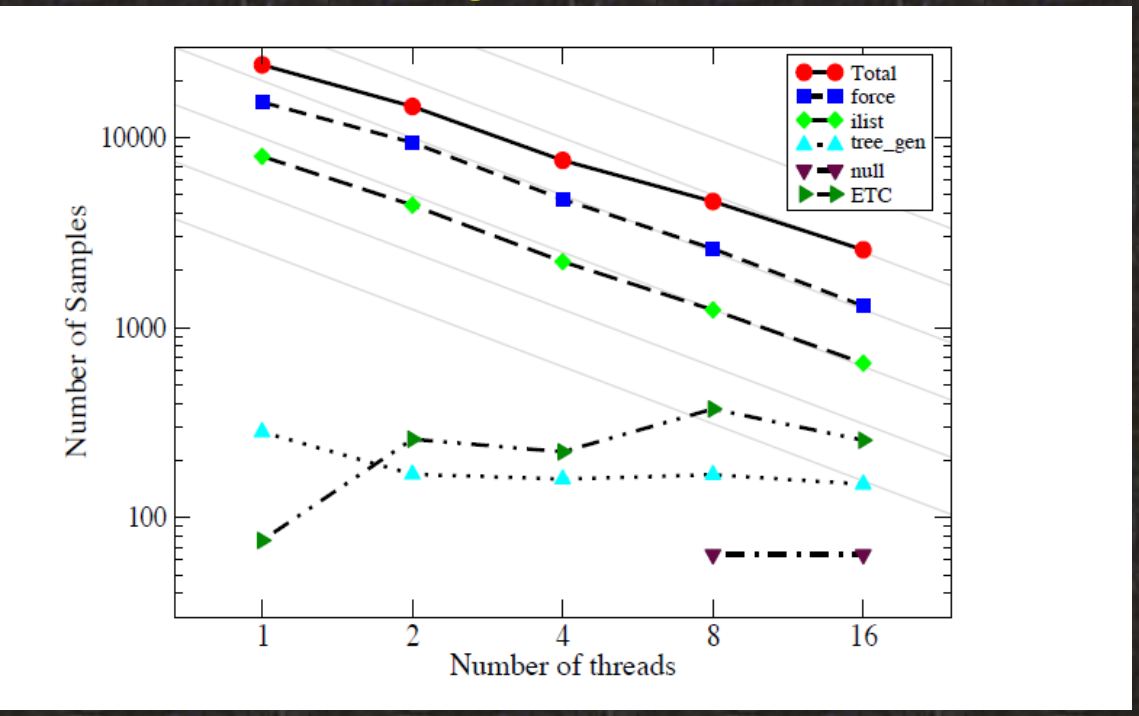
- r_{min}: L/a, r_{max} min resolved scale:

$$\frac{L}{a} = 10^4 \; L = 10\, Mpc, \; a = 1\, kpc \; n_i = 8 \quad r_{min} \simeq 11$$
$$\frac{L}{a} = 10^7 \; L = 10\, Mpc, \; a = 1\, pc \; n_i = 8 \quad r_{max} \simeq 21$$

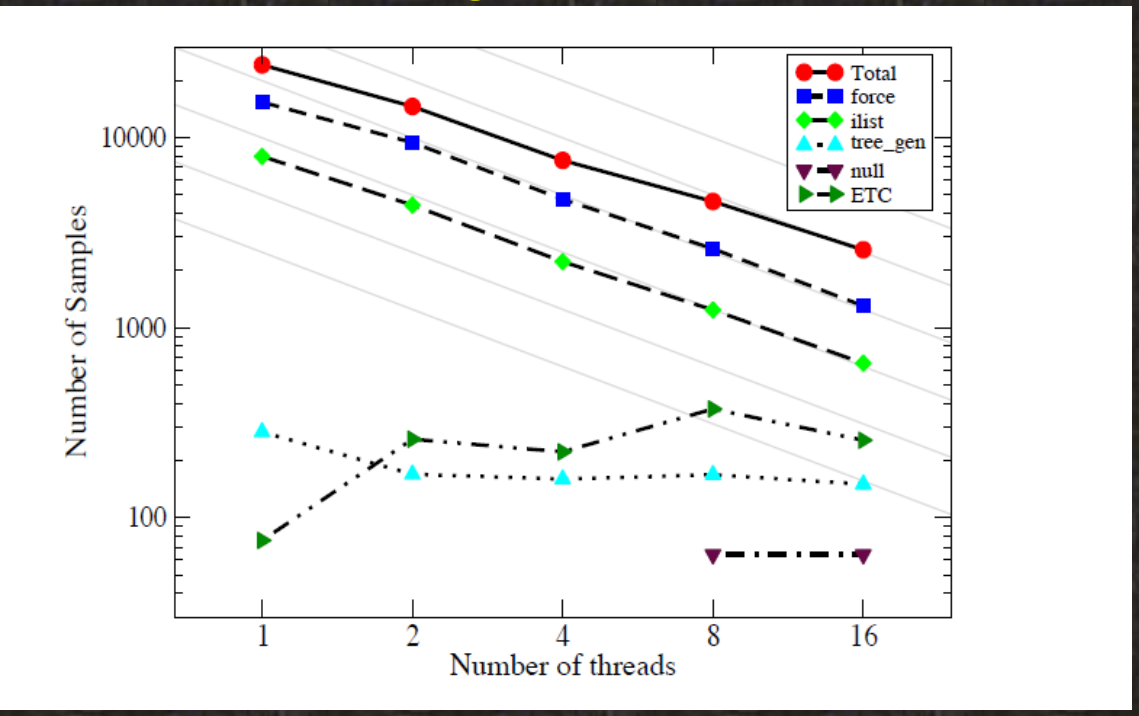
- Scaling memory – halo size



- FLY scaling: OpenMP, Multithreaded

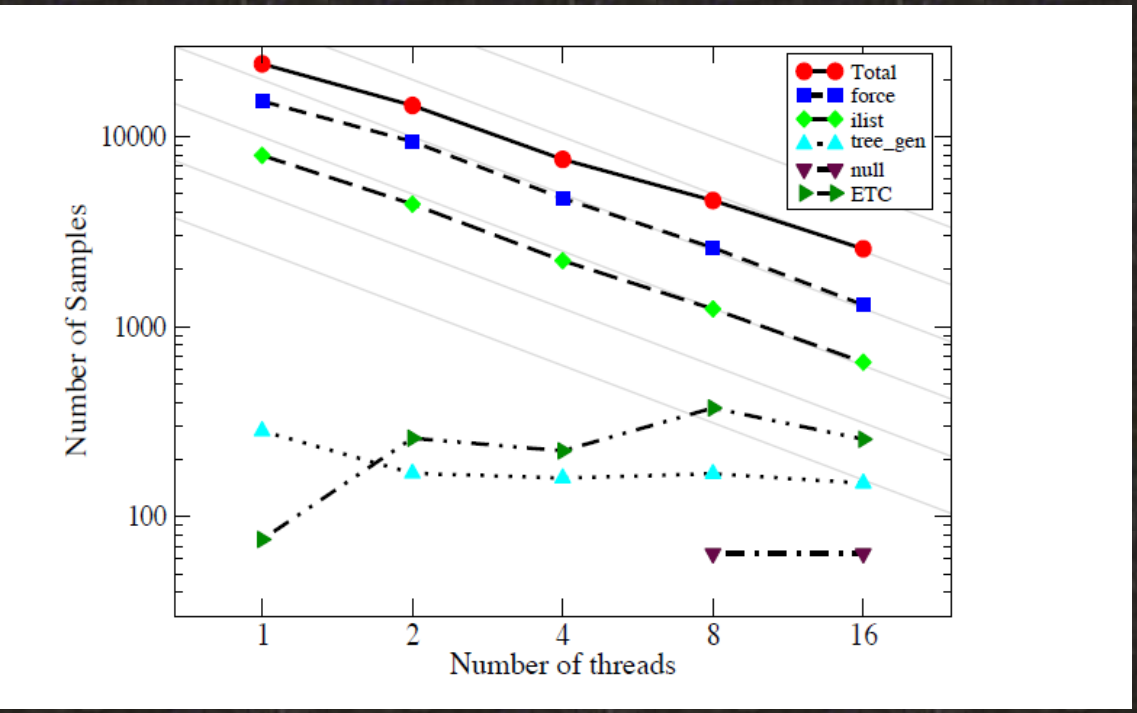


- FLY scaling: OpenMP, Multithreaded



- $t_{step} \approx N_{thread}^{-1.7}$ for large N_{thread}

- FLY scaling: OpenMP, Multithreaded



- $t_{step} \propto N_{thread}^{-1.7}$ for large N_{thread}

- Full details here

Available online at www.prace-ri.eu

Partnership for Advanced Computing in Europe

FLY on Cray: porting, optimization and performance analysis of cosmological simulation code FLY on Cray XE6 architecture

V.Antonuccio-Delogu[a], U.Becciani[a], M.Cytowski*[b], J.Hein[c], J.Hertzer[d]

[a] *INAF - Osservatorio Astrofisico di Catania, Italy*
[b] *Interdisciplinary Centre for Mathematical and Computational Modeling, University of Warsaw, Poland*
[c] *Lunarc Lund University, Sweden*
[d] *HLRS, University of Stuttgart, Germany*