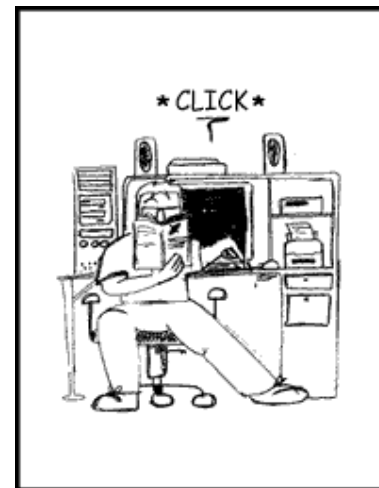
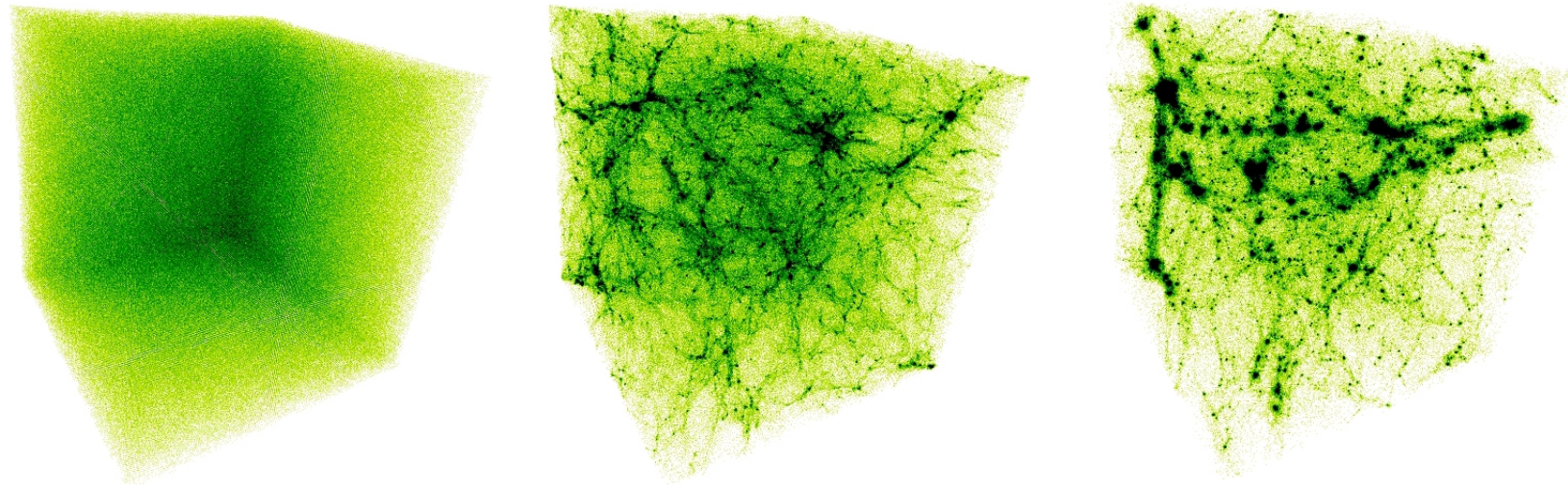


HYBRID CODES

Alexander Knebe, *Universidad Autonoma de Madrid*



HYBRID CODES



┆————— hybrid codes —————>

- Poisson's equation

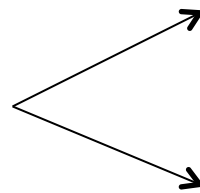
$$\Delta\Phi = 4\pi G\rho$$

$$\vec{F} = -m\nabla\Phi$$

- Poisson's equation

$$\Delta\Phi(\vec{r}) = 4\pi G\rho(\vec{r})$$

$$\vec{F}(\vec{r}) = -m\nabla\Phi(\vec{r})$$



particle approach

$$\vec{F}(\vec{r}_i) = -\sum_{i \neq j} \frac{Gm_i m_j}{(r_i - r_j)^3} (\vec{r}_i - \vec{r}_j)$$

grid approach ($\vec{r}_{i,j,k}$ = position of centre of grid cell (i,j,k))

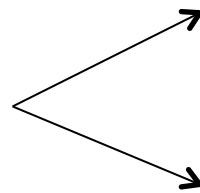
$$\Delta\Phi(\vec{r}_{i,j,k}) = 4\pi G\rho(\vec{r}_{i,j,k})$$

$$\vec{F}(\vec{r}_{i,j,k}) = -m\nabla\Phi(\vec{r}_{i,j,k})$$

- Poisson's equation

$$\Delta\Phi(\vec{r}) = 4\pi G\rho(\vec{r})$$

$$\vec{F}(\vec{r}) = -m\nabla\Phi(\vec{r})$$



mixture

particle approach

$$\vec{F}(\vec{r}_i) = -\sum_{i \neq j} \frac{Gm_i m_j}{(r_i - r_j)^3} (\vec{r}_i - \vec{r}_j)$$

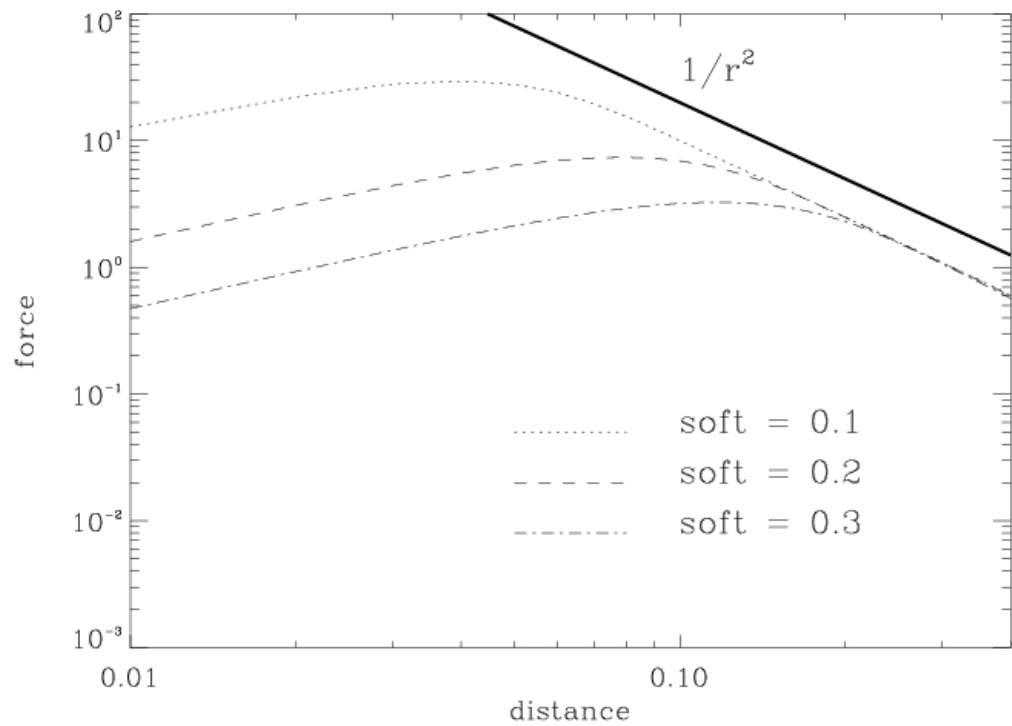
grid approach ($\vec{r}_{i,j,k}$ = position of centre of grid cell (i,j,k))

$$\Delta\Phi(\vec{r}_{i,j,k}) = 4\pi G\rho(\vec{r}_{i,j,k})$$

$$\vec{F}(\vec{r}_{i,j,k}) = -m\nabla\Phi(\vec{r}_{i,j,k})$$

- Poisson's equation
 - the particle approach

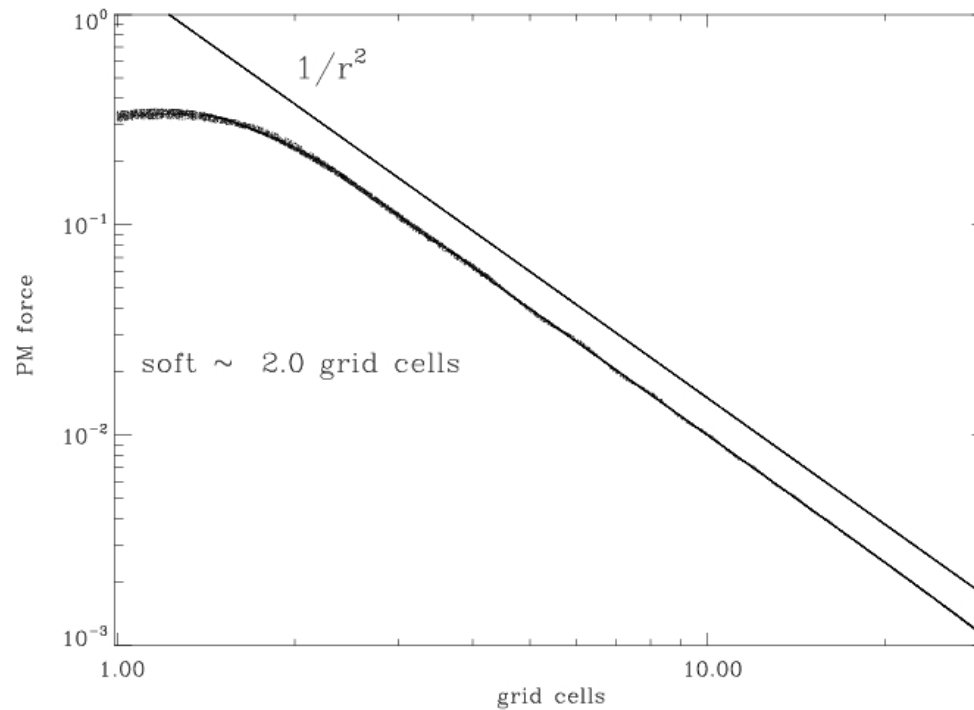
$$\vec{F}(\vec{r}_i) = - \sum_{i \neq j} \frac{Gm_i m_j}{\left(|\vec{r}_i - \vec{x}_j|^2 + \epsilon^2 \right)^{3/2}} (\vec{r}_i - \vec{r}_j)$$



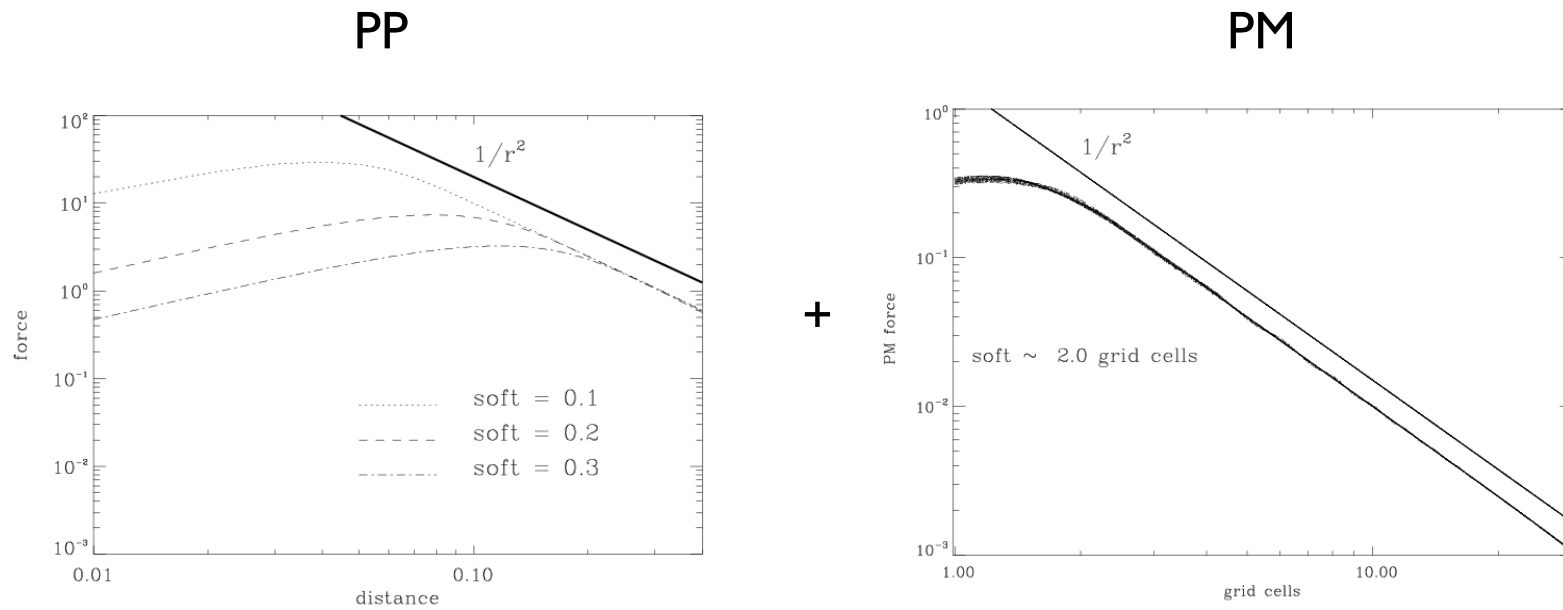
- Poisson's equation
 - the grid approach

$$\Delta\Phi_{i,j,k} = 4\pi G\rho_{i,j,k}$$

$$\vec{F}_{i,j,k} = -m\nabla\Phi_{i,j,k}$$



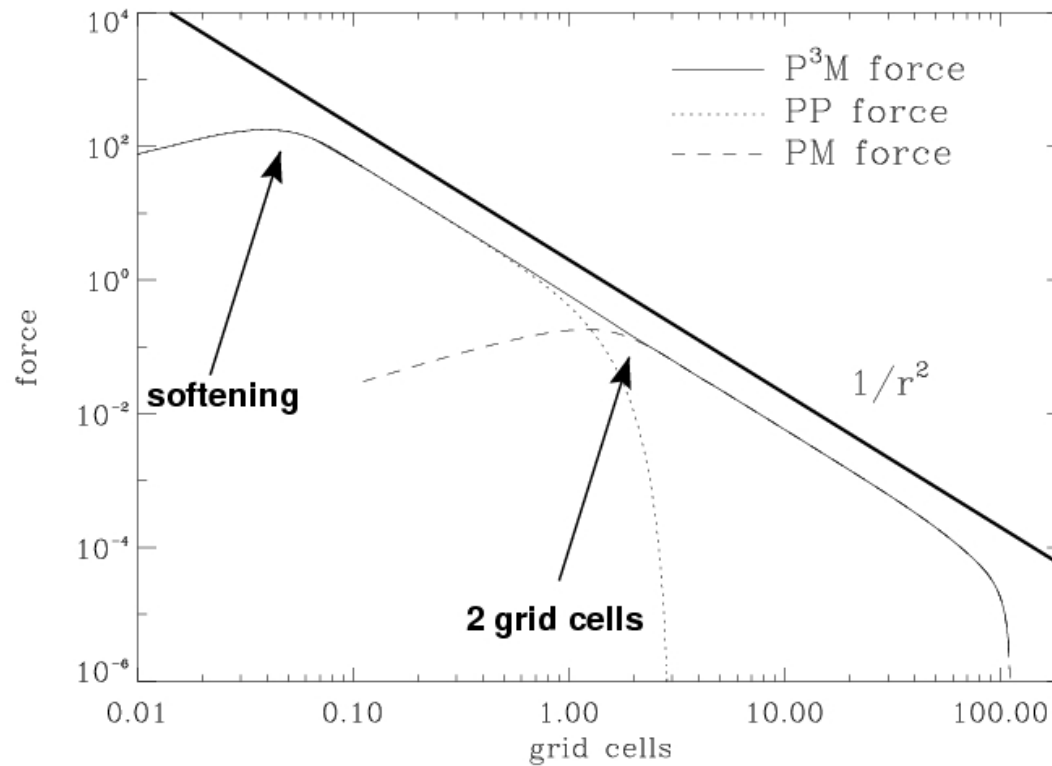
- Poisson's equation
 - the P³M hybrid approach



particle-particle-particle-mesh code...

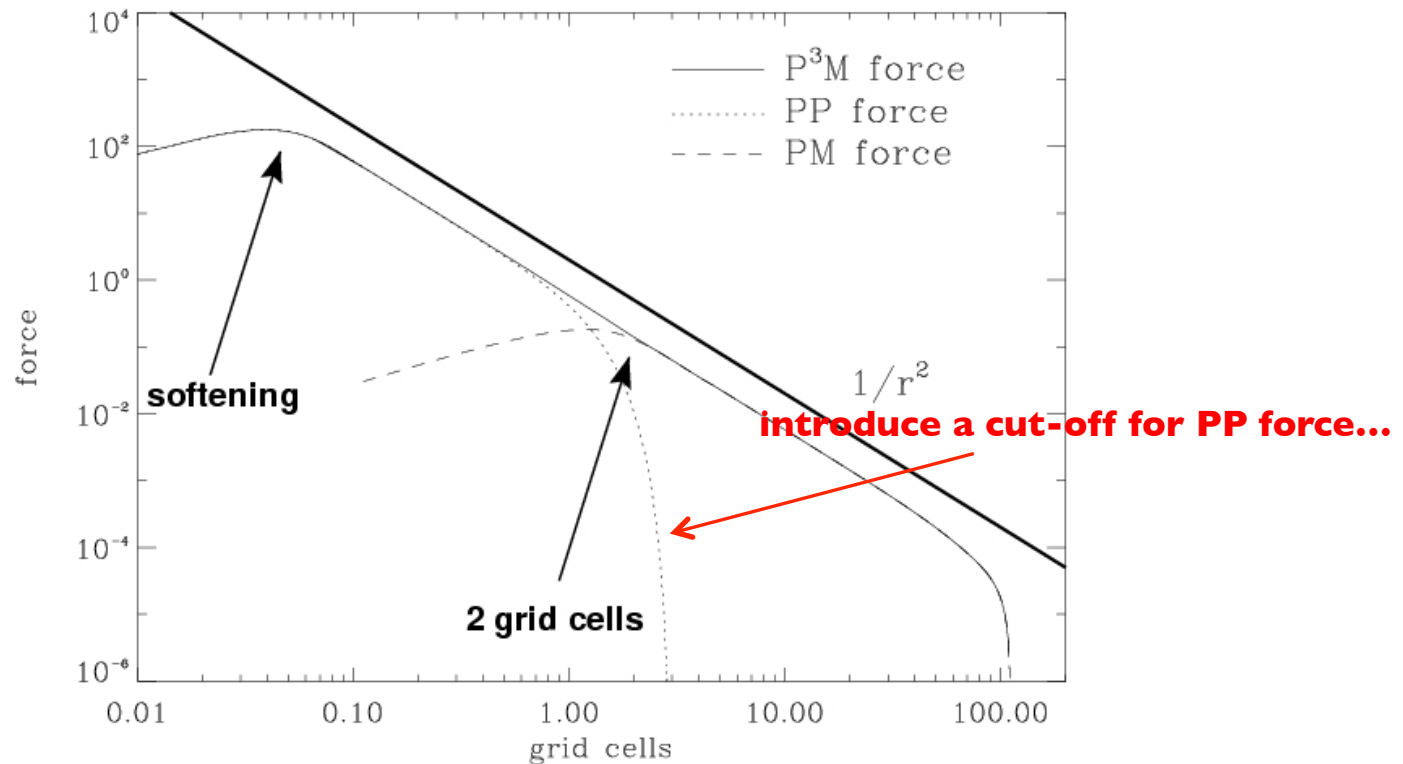
- Poisson's equation - **the P³M hybrid approach**

- short range force: pure PP method
- long range force: pure PM method



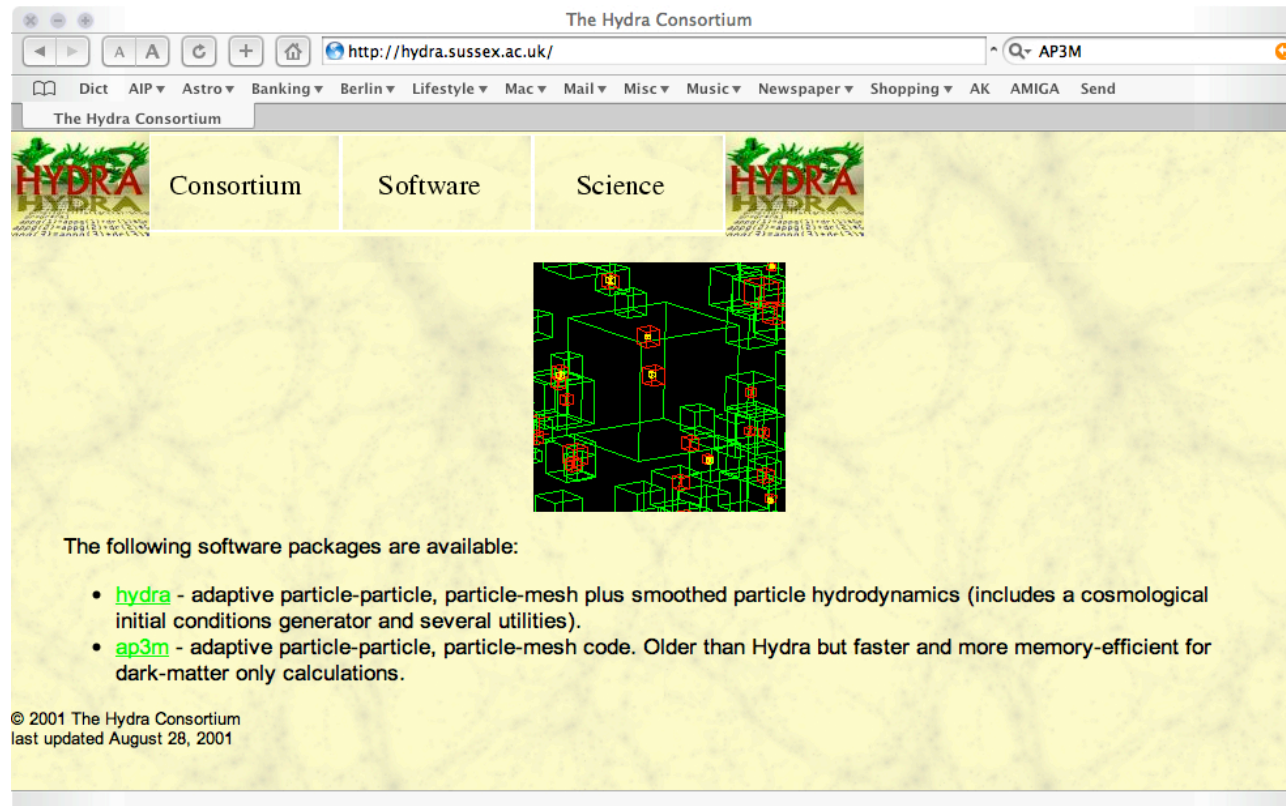
- Poisson's equation - **the P³M hybrid approach**

- short range force: pure PP method
- long range force: pure PM method



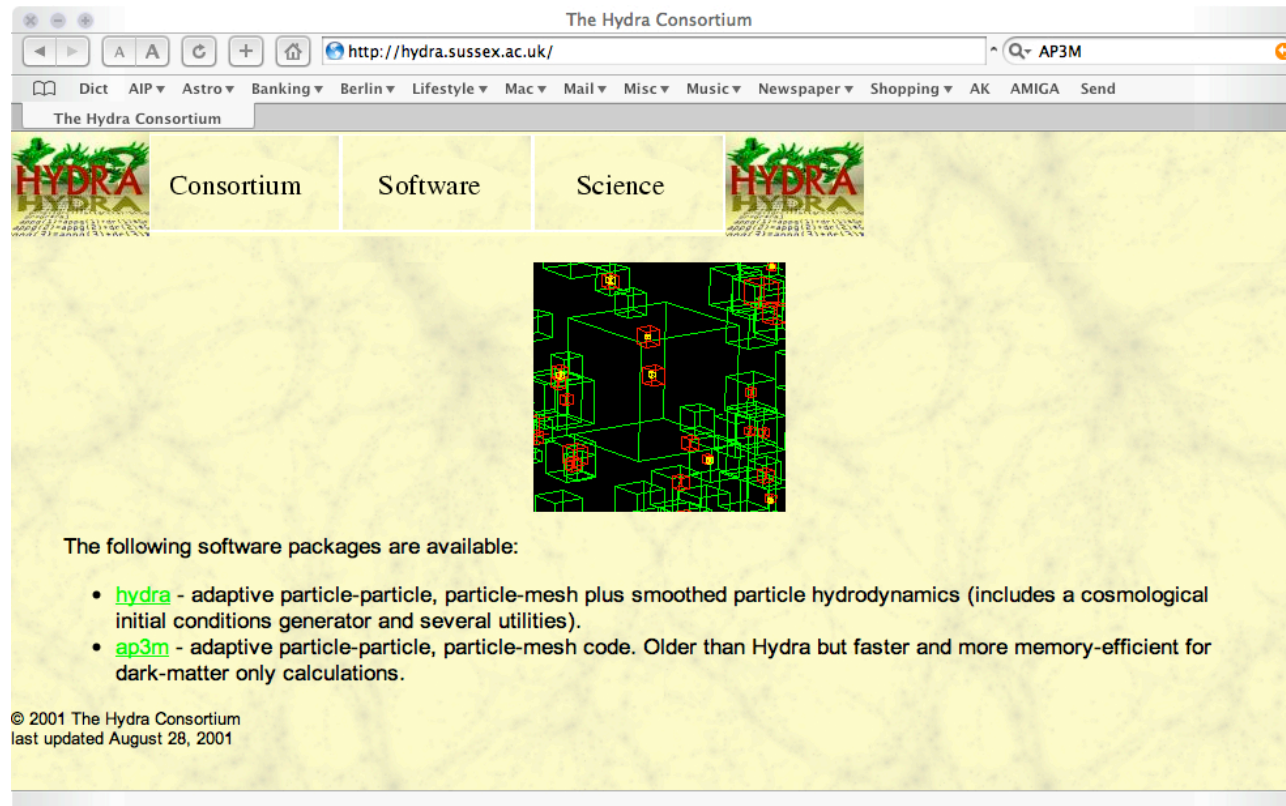
▪ Poisson's equation - **the P³M hybrid approach**

- AP³M code (Couchman 1991)
- HYDRA code (Couchman, Thomas & Pearce 1995)



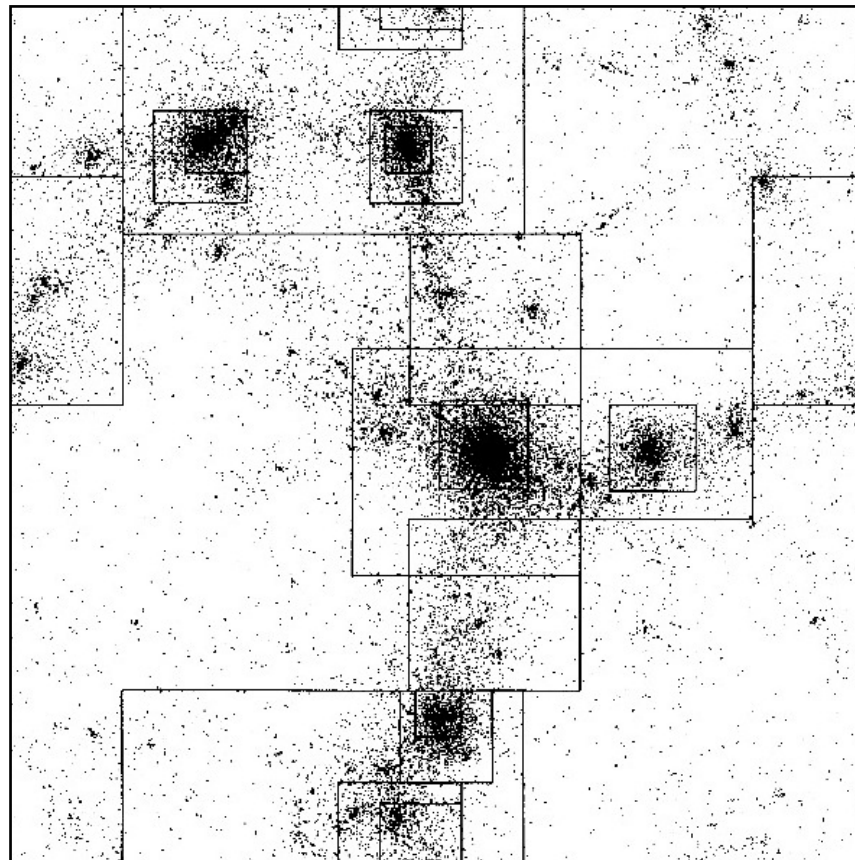
▪ Poisson's equation - **the P³M hybrid approach**

- AP³M code (Couchman 1991)
Adaptive P³M
- HYDRA code (Couchman, Thomas & Pearce 1995)



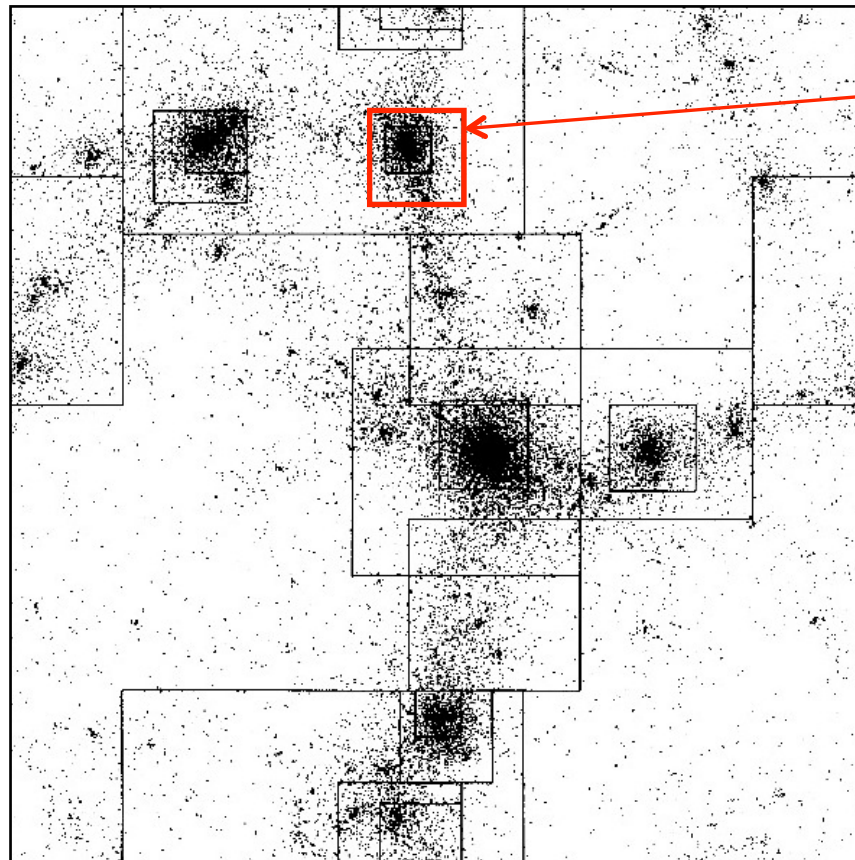
- Poisson's equation - **the P³M hybrid approach**

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▪ Poisson's equation - **the P³M hybrid approach**

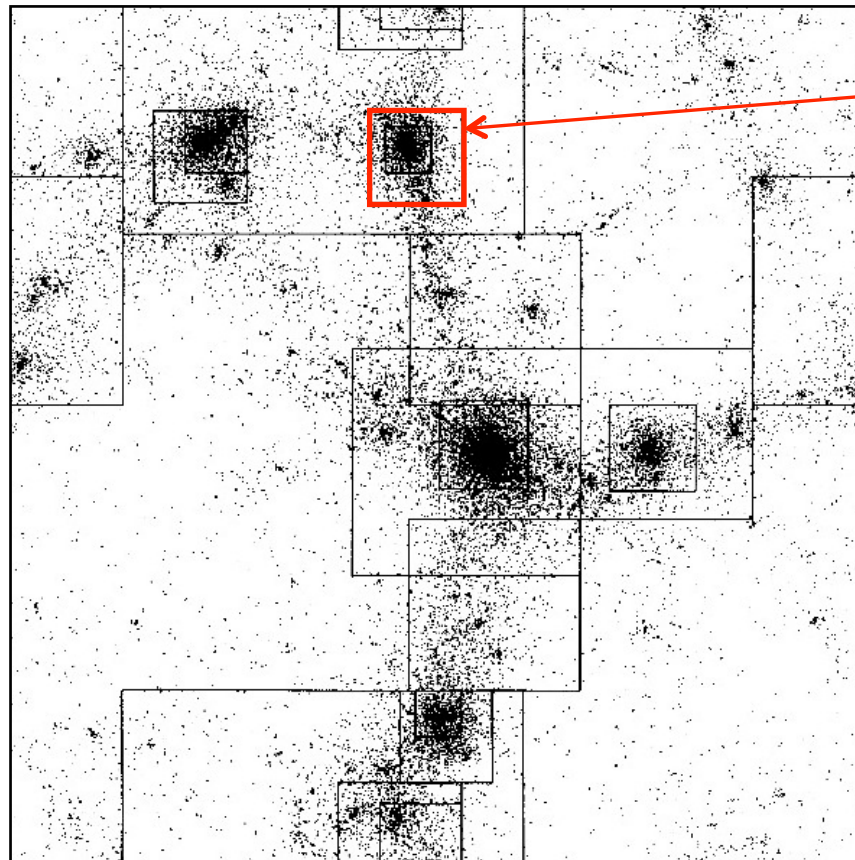
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Adaptive P³M
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**individual P³M calculation
with
isolated boundaries**

▪ Poisson's equation - **the P³M hybrid approach**

- **AP³M code** (Couchman 1991)
Adaptive P³M
- HYDRA code (Couchman, Thomas & Pearce 1995)



**individual P³M calculation
with
isolated boundaries**



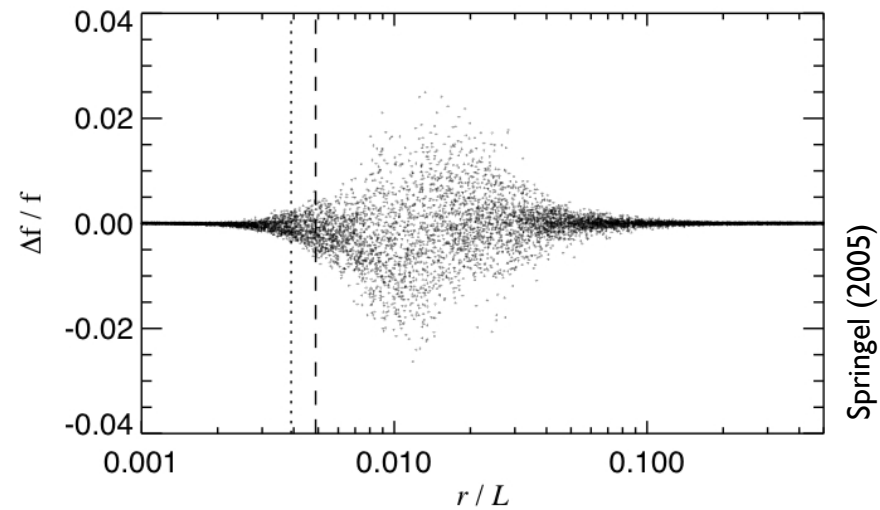
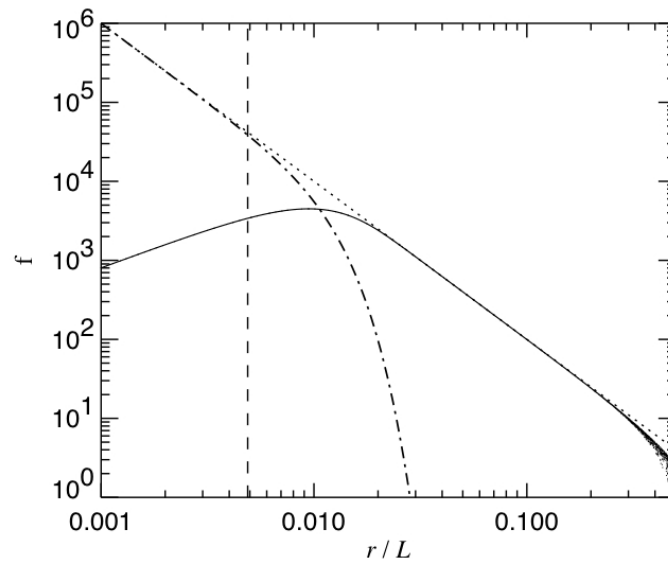
**no gain in accuracy,
“just” speed-up...**

- Poisson's equation - **the hybrid approach**

- (A)P³M (Couchman 1991)
- Tree-PM (Xu 1995; Bode & Ostriker 2003; Dubinski et al. 2004; Springel 2005)
- Moving Mesh Codes (Gnedin 1995; Pen 1995)
- ...

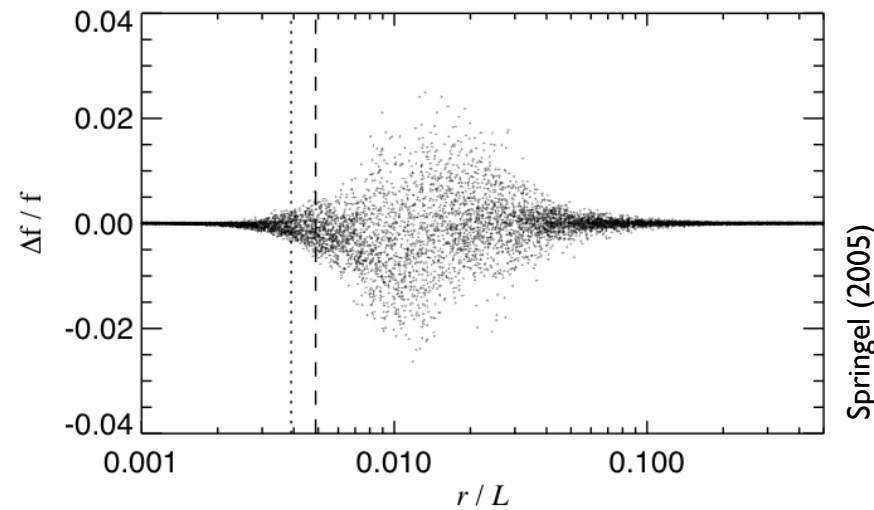
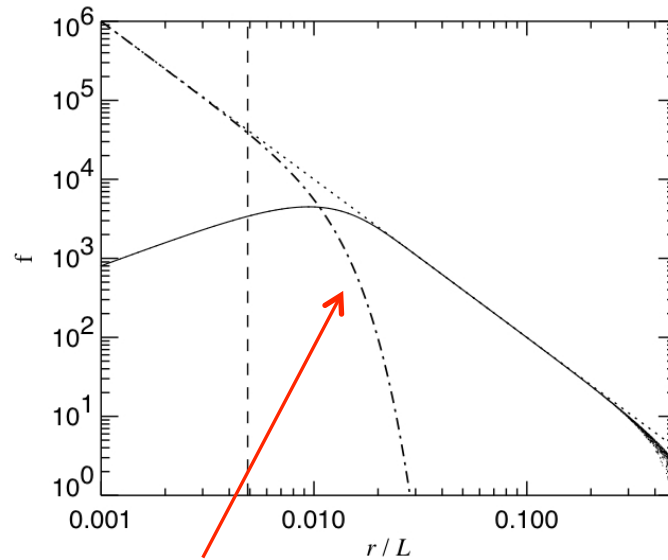
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▪ Poisson's equation - **the hybrid approach**

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- ...



modified via short-range cut-off factor again...

- Poisson's equation - **the hybrid approach**

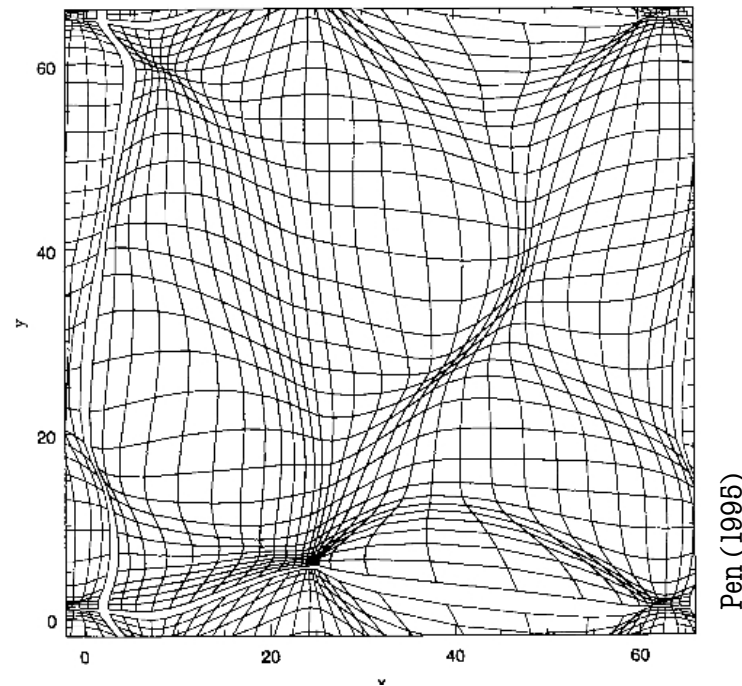
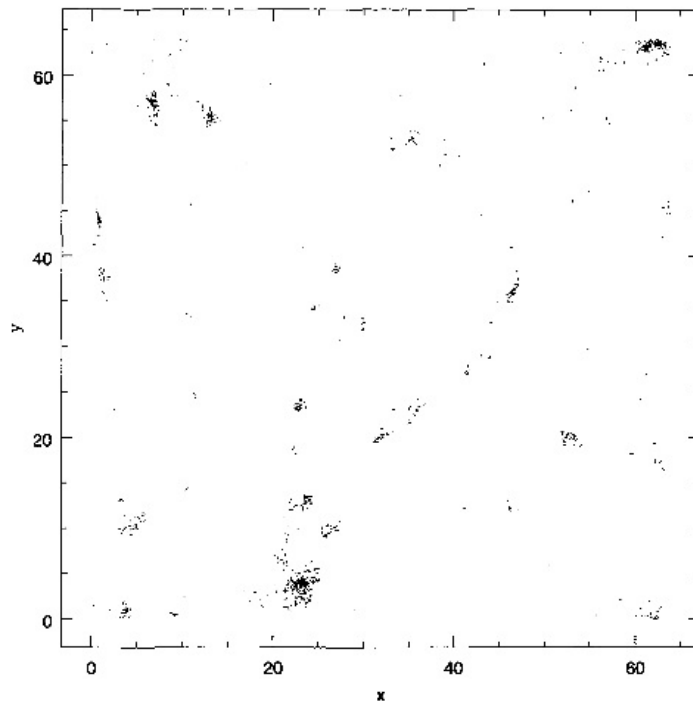
- (A)P³M (Couchman 1991)
- **Tree-PM** (Xu 1995; Bode & Ostriker 2003; Dubinski et al. 2004; Springel 2005)
- Moving Mesh Codes (Gnedin 1995; Pen 1995)
- ...

- tree walk only in spatial vicinity of target particle
- no periodic boundaries

=> substantial performance improvement!

- Poisson's equation - **the hybrid approach**

- (A)P³M (Couchman 1991)
- Tree-PM (Xu 1995; Bode & Ostriker 2003; Dubinski et al. 2004; Springel 2005)
- **Moving Mesh Codes** (Gnedin 1995; Pen 1995)



Pen (1995)