Galaxies in Hydrodynamic Cluster Simulations

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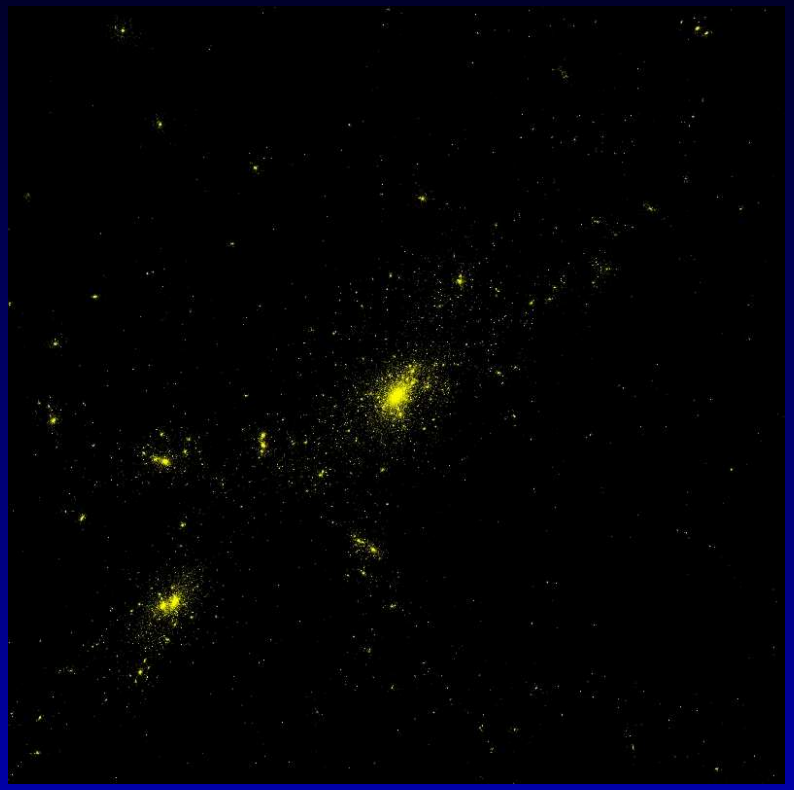
(*) 

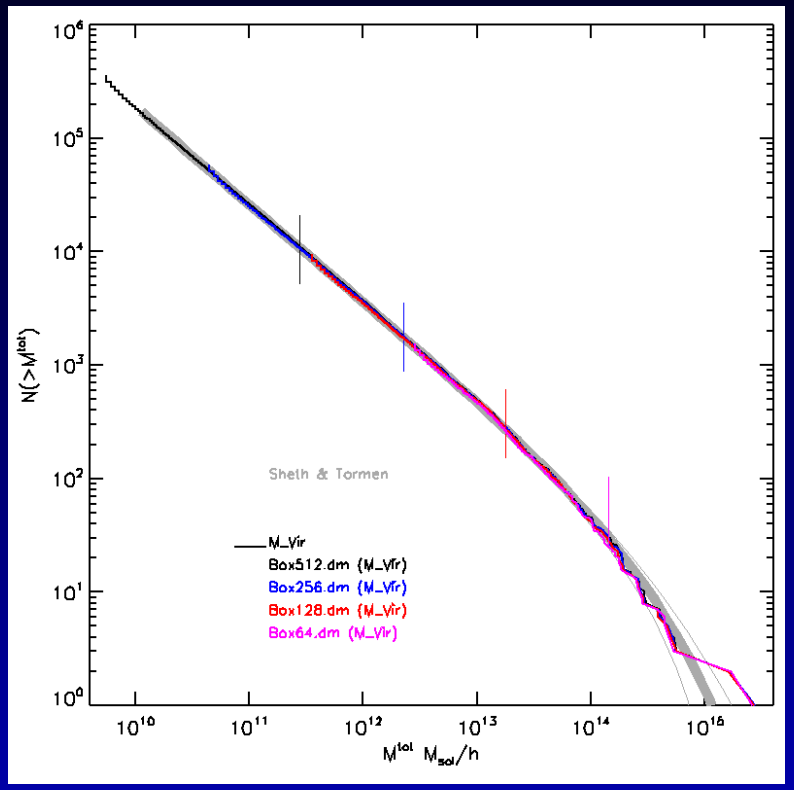
Cluster Simulations

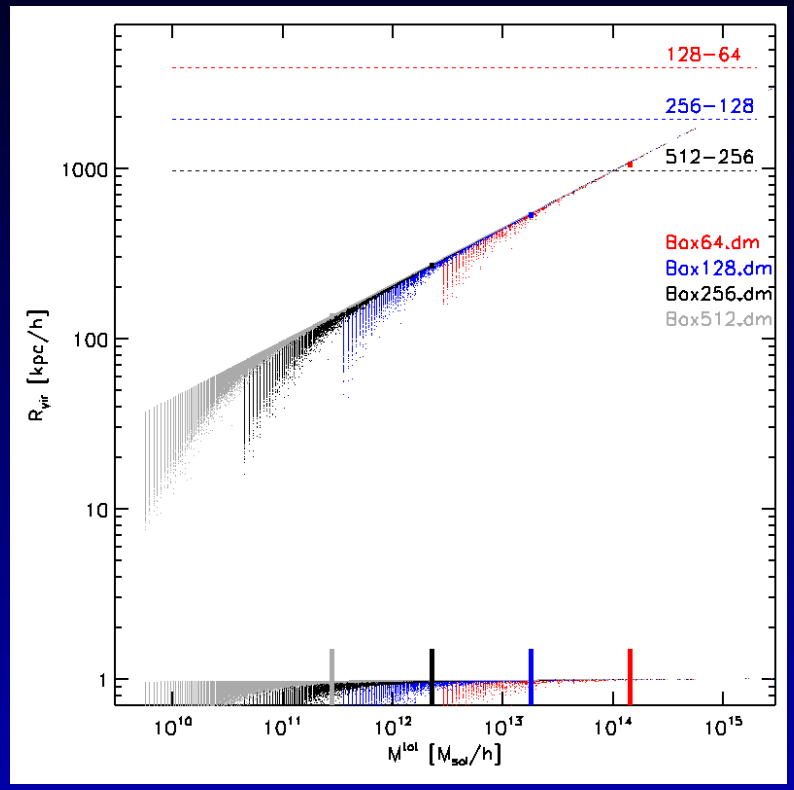


Simple but not jet solved Questions:

- Baryonic fraction ?
- Central overcooling !
- Number/Luminosity of Cluster Galaxies ?

Codes / Resolution





Gadget / Enzo / TVD, 100Mpc box:

- **Effective Resolution (Grid vs. SPH/N-body)**?
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- WHIM / Voids?
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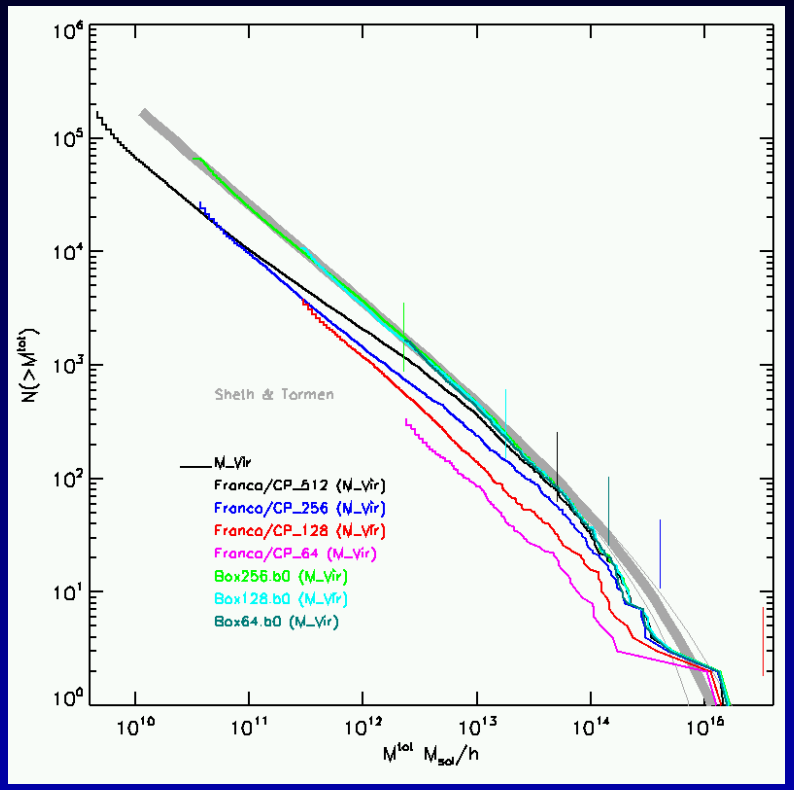

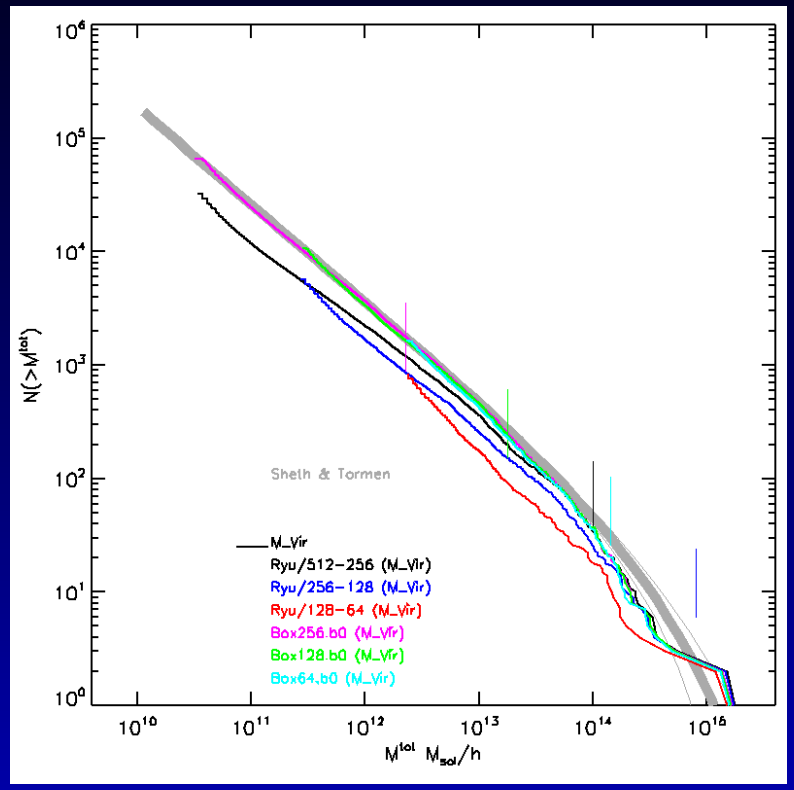

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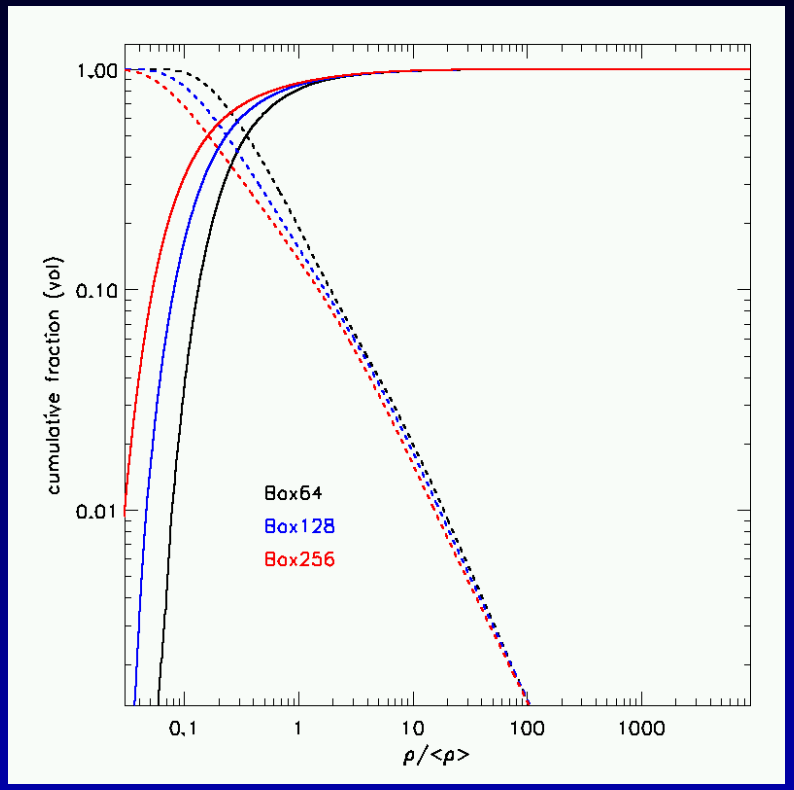

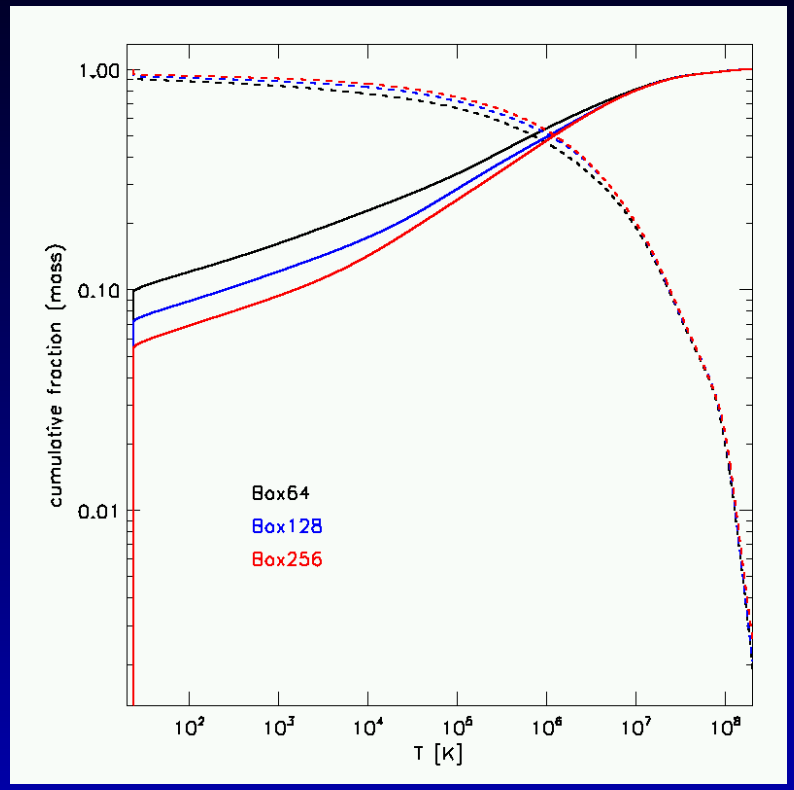

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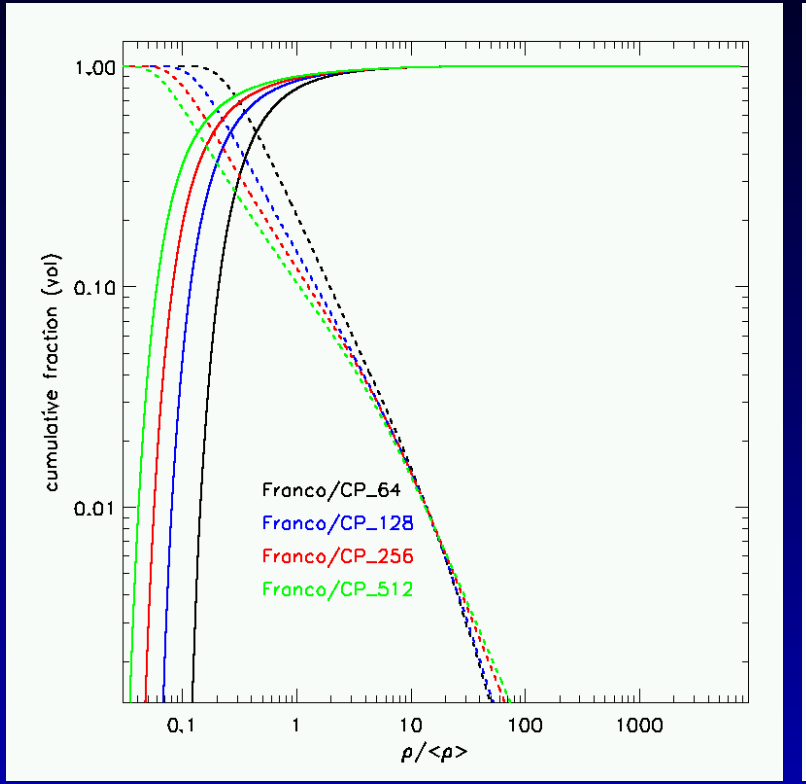

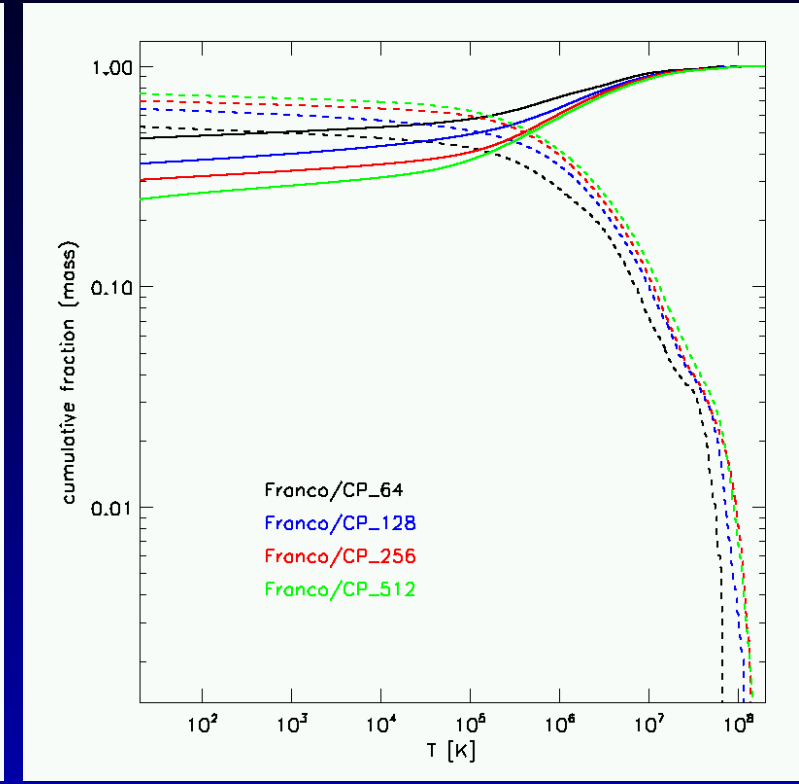

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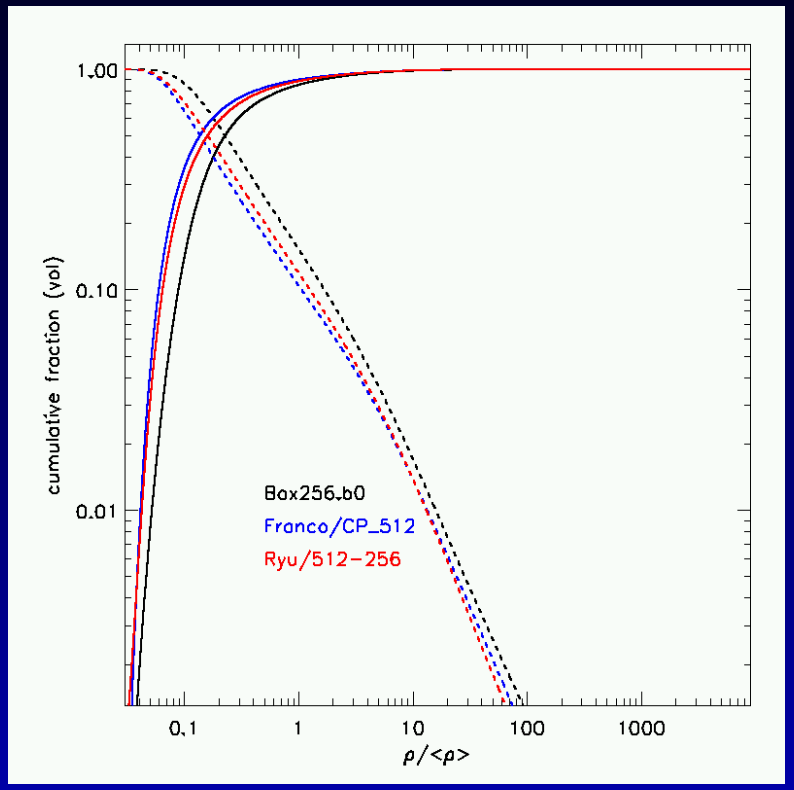

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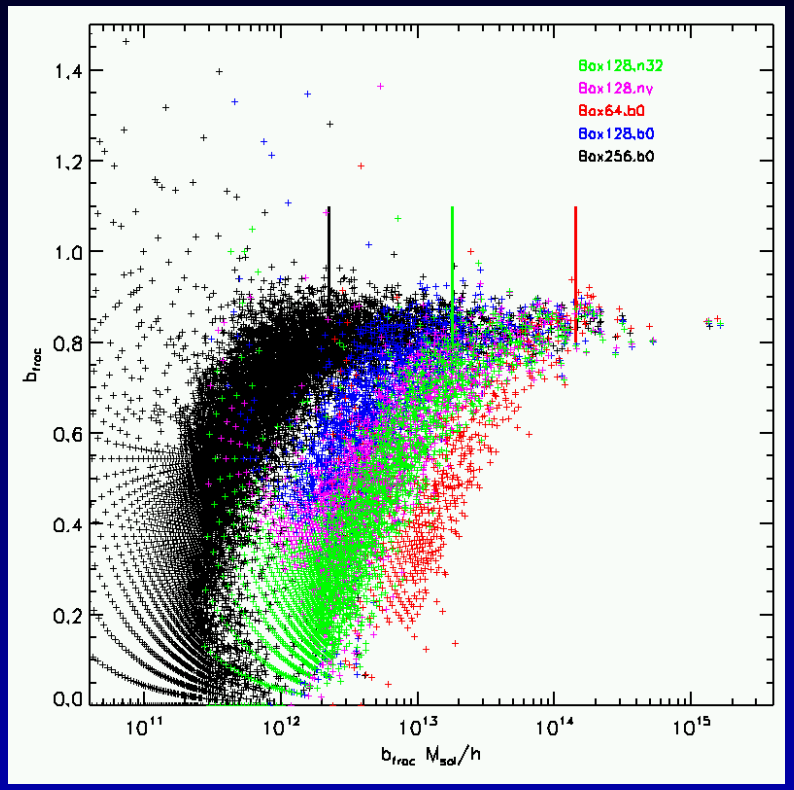

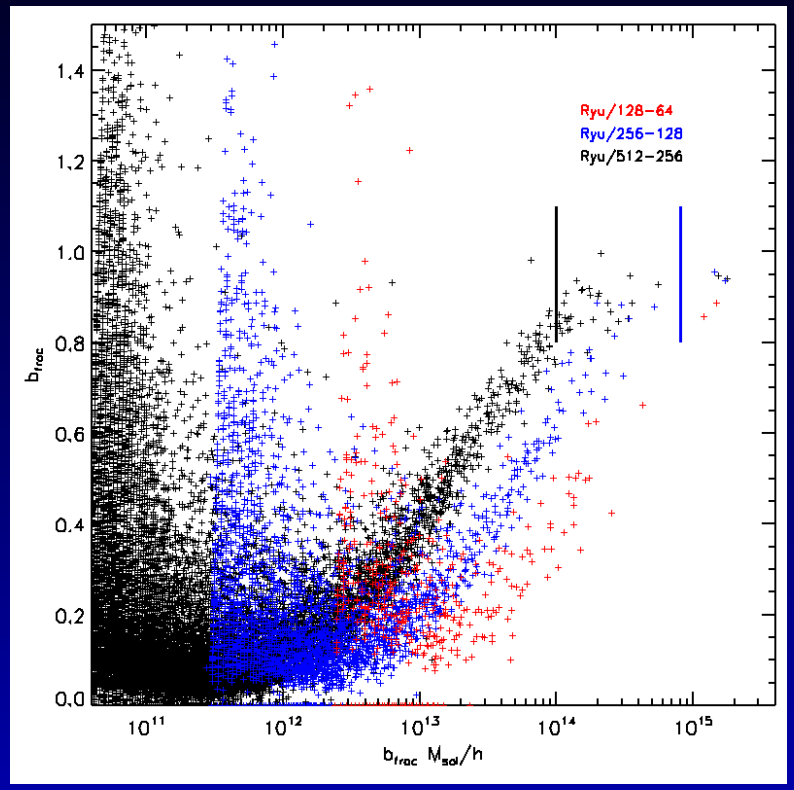

Gadget / Enzo / **TVD**, 100Mpc box:

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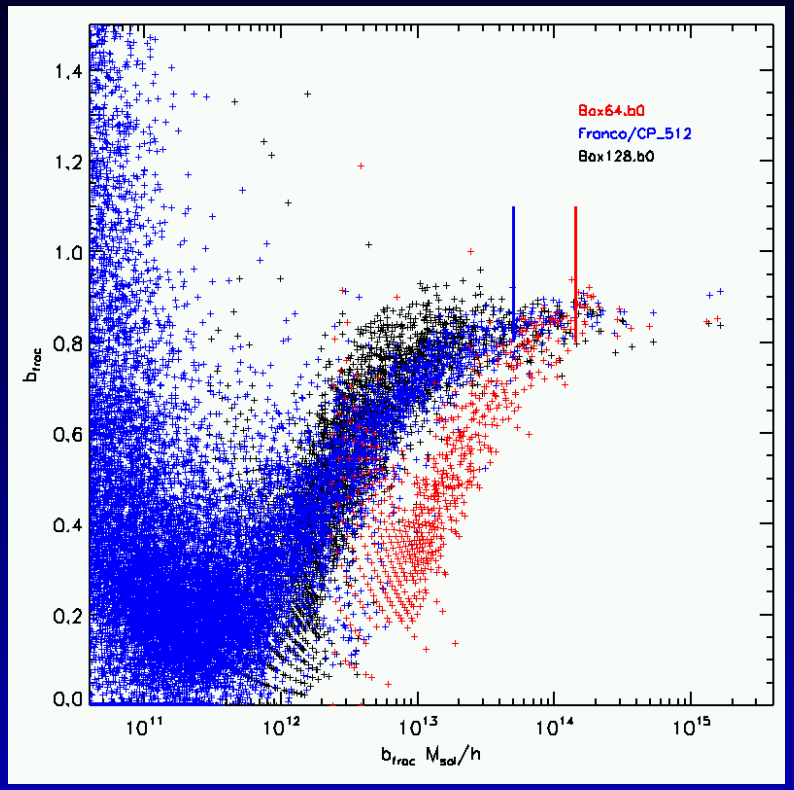

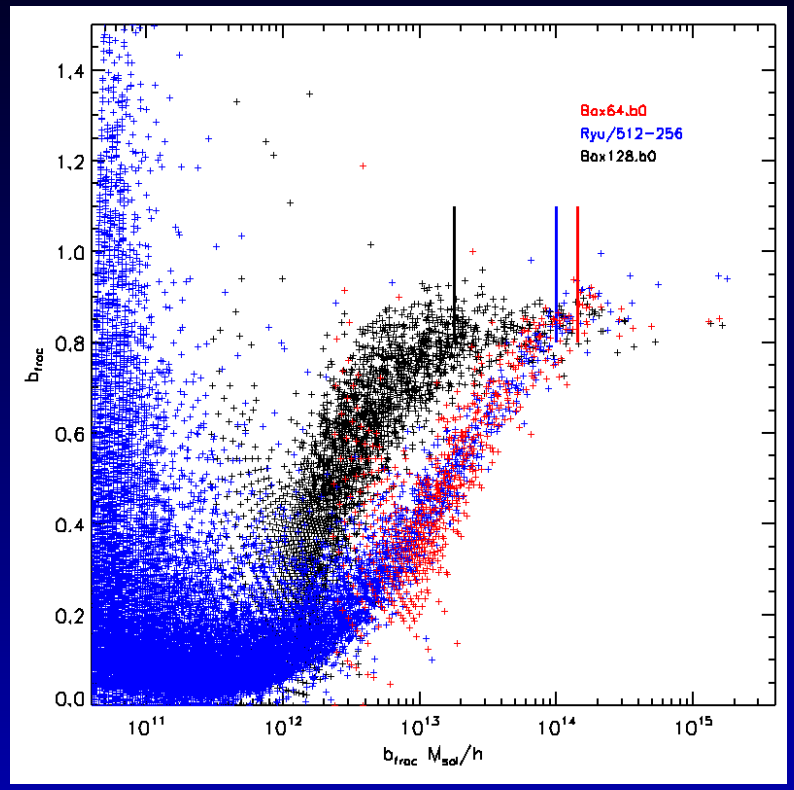

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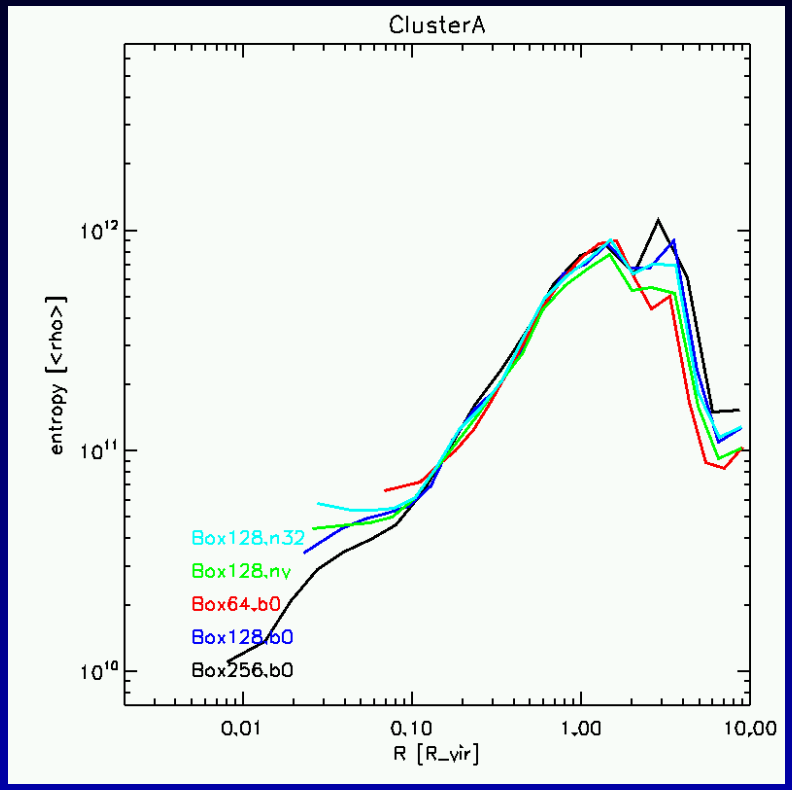

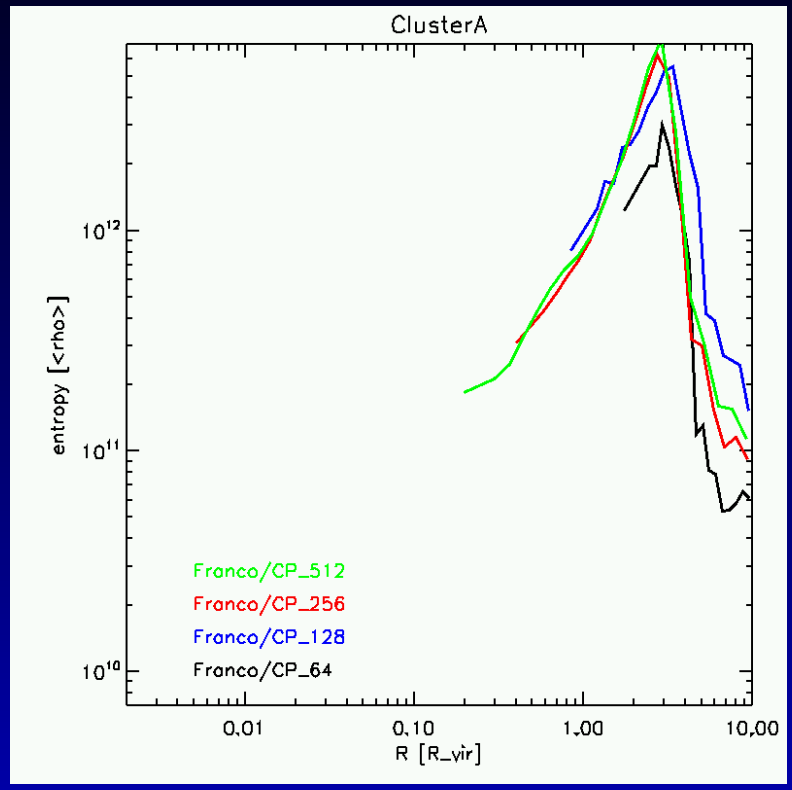

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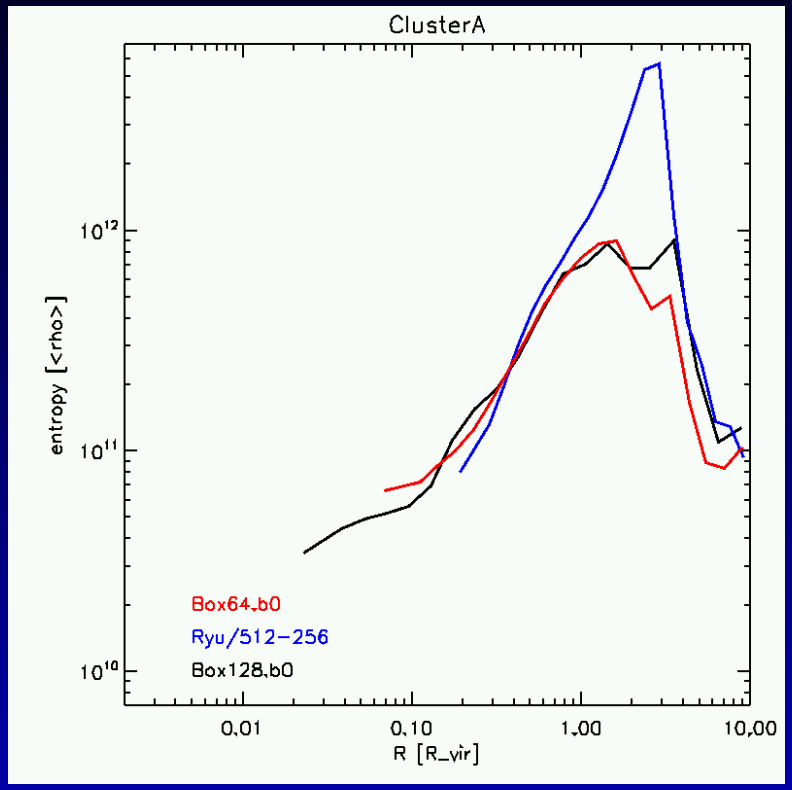

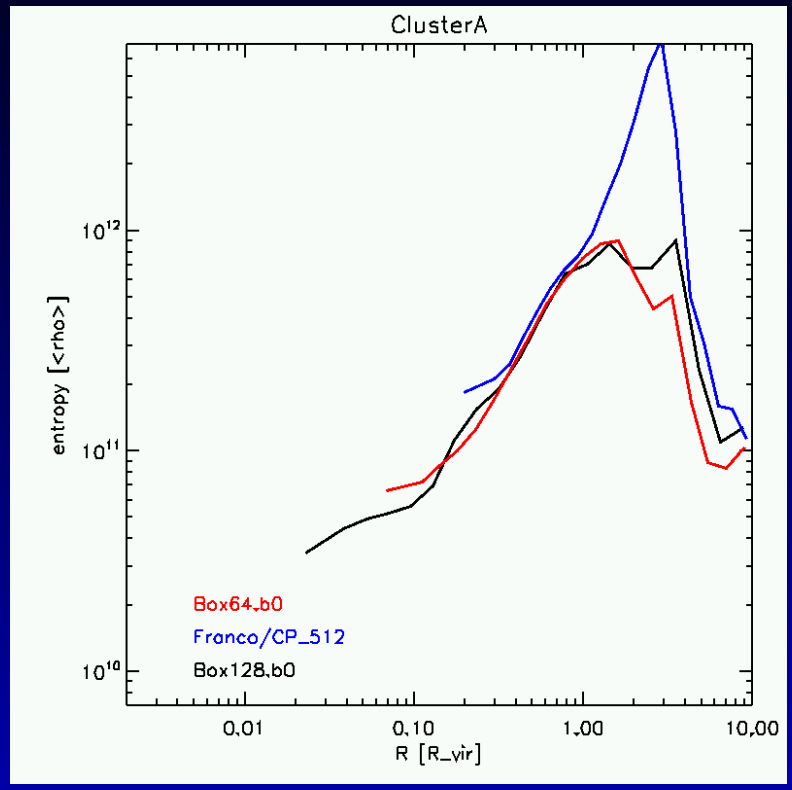

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Conclusions (I)

- In general good agreement between different hydro methods.

but Effective resolution can be small !

- Philosophy of hydro codes reflect convergence !

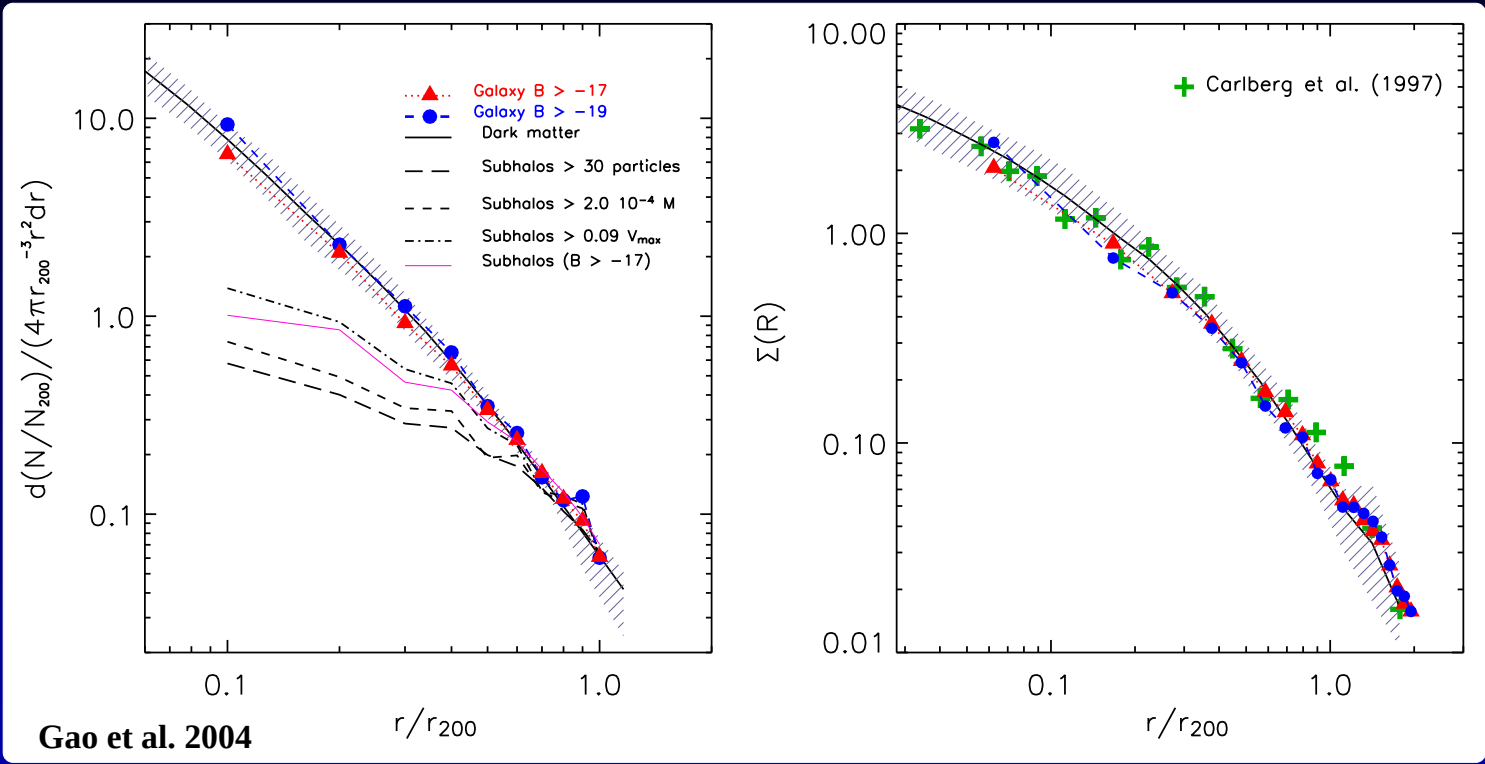
but Baryonic fraction still unclear !

- Predicted Density/Temperature/Entropy profiles very similar !

but Central entropy profile ?

with D. Ryu (TVD), F. Vazza (Enzo), C. Gheller, G. Brunetti

Galaxies in Clusters



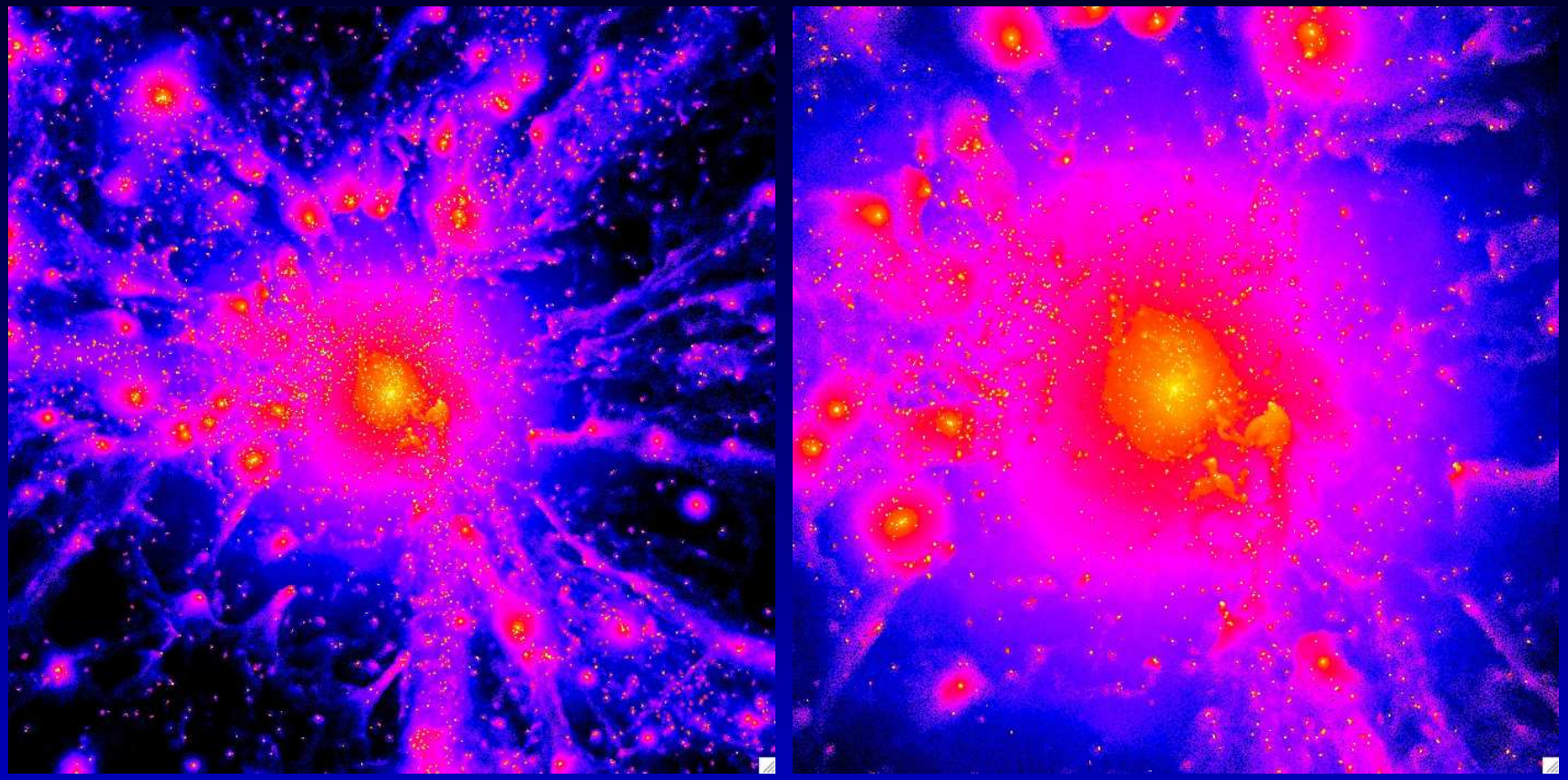
Gao et al. 2004

- DM simulations predict sub-halos distribution to be shallower than DM profile.
- Semi-analytic galaxy formation assume galaxies to survive without DM halo.
- Are hydrodynamic cluster simulations advanced enough to test this hypothesis ?

Methode

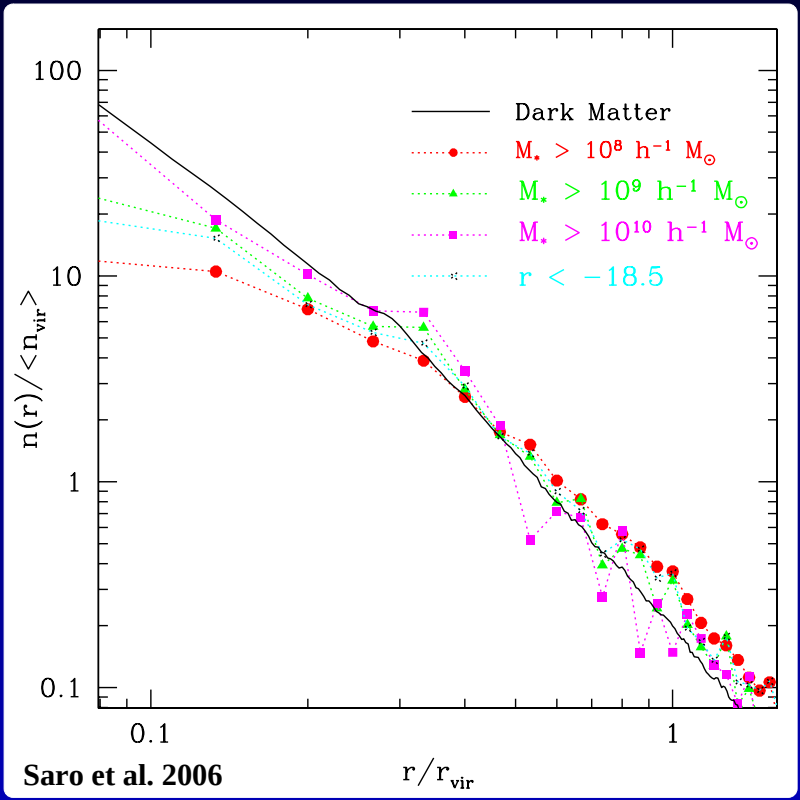
- Zoomed cluster simulations using Gadget2 (Springel et al. 2001, Springel 2005)
  - cooling+starformation+winds Springel & Hernquist 2002/2003
  - Metals and chemical enrichment, SnIa + SnII, No IRA, diff. IMF, ...(Tornatore et al. 2003/2006)
- Identifying galaxies (substructure)
  - Galaxies: SKID (Stadel 2001) applied to star particles
  - Subfind (Springel et al. 2001) applied to all particles
- Assigning luminosities to galaxies
  - GALAXEV (Bruzual & Charlot 2003) to convert stelar population to luminosities L_ν (Saro 2006)

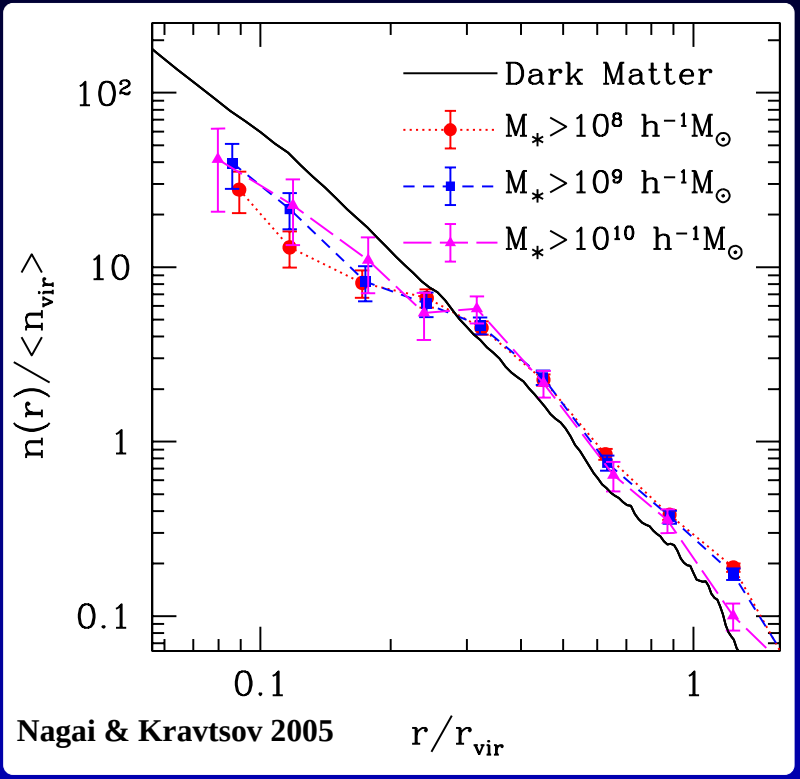
High resolution simulation



- Clusters resolved with several million particles within R_{vir}
- Check for numerics (stars, ICs)
- Check for resolution (26 million particles within R_{vir} !)
- Check for physics (feedback models)

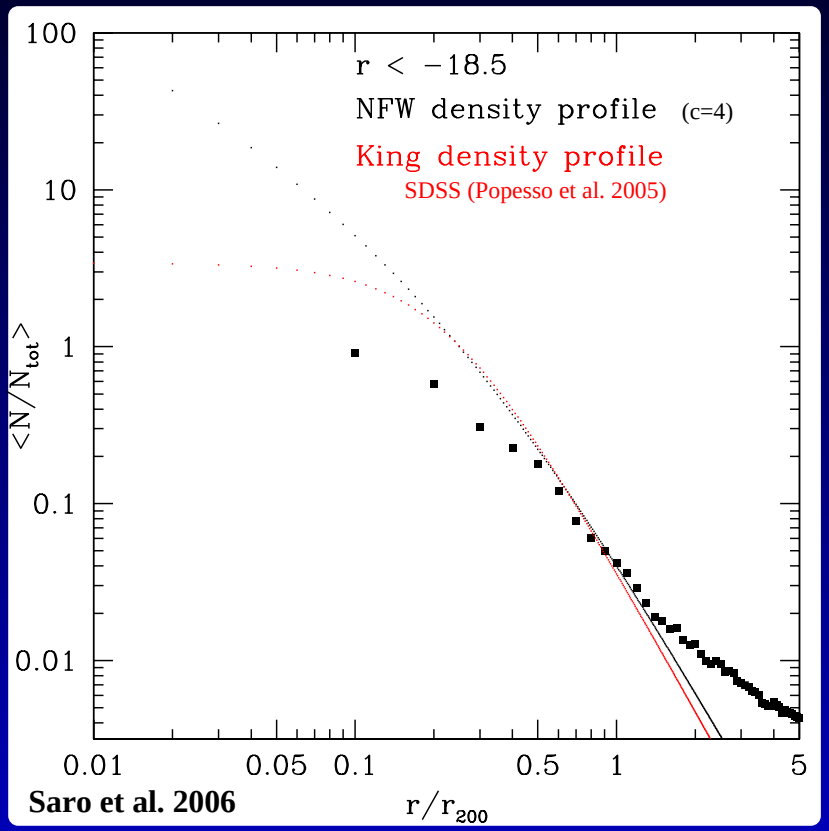
Comparison

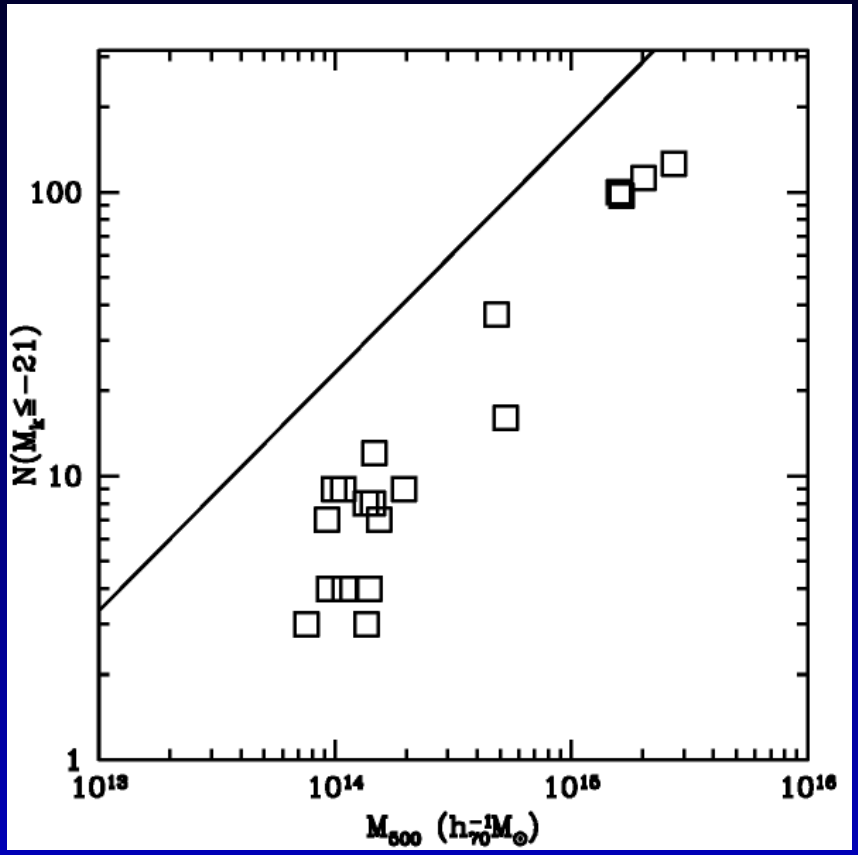




- Including * formation and taking M^* reduces differences, but don't solve the problem once luminosities are used.
- Different numerical schemes predict similar results

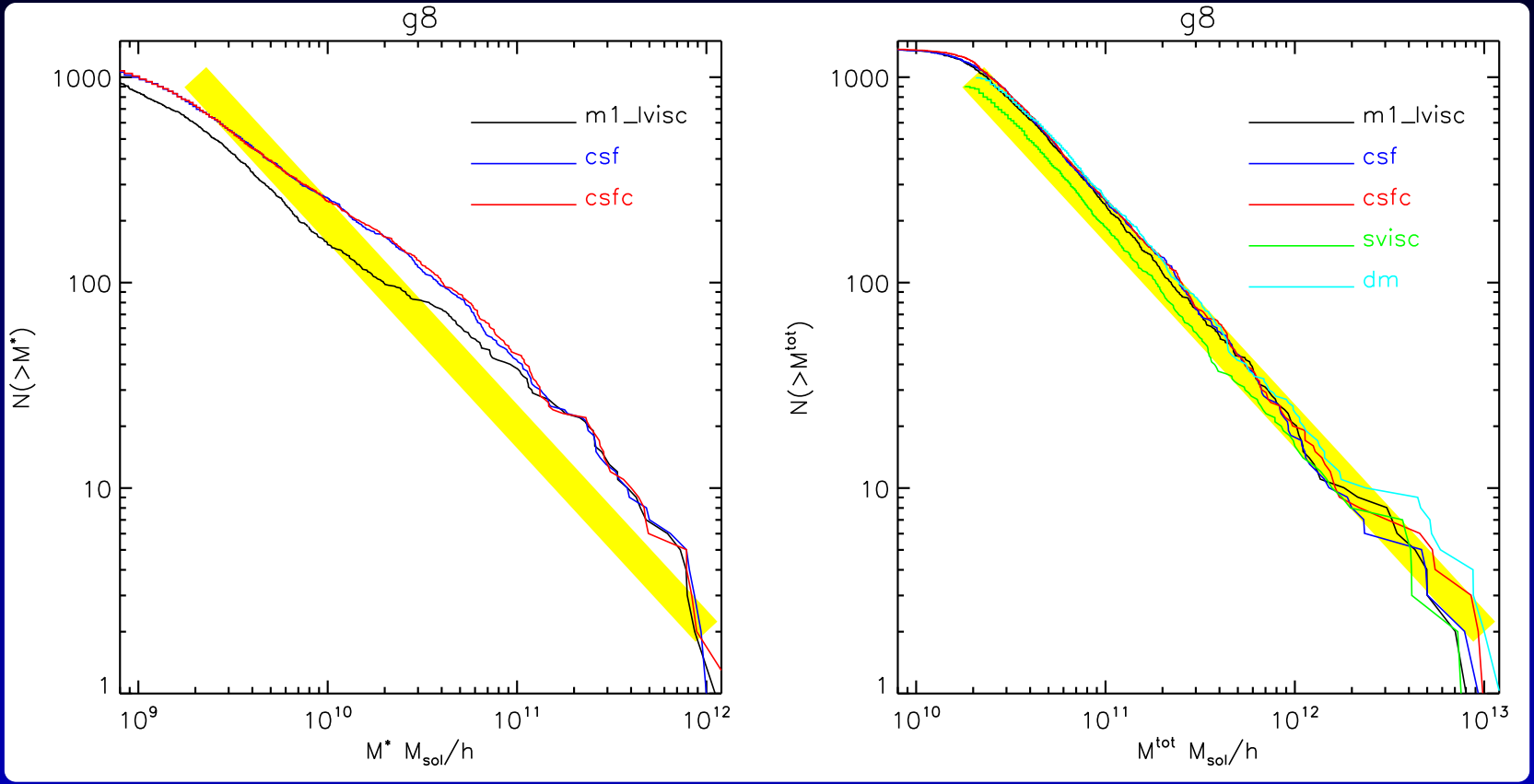
Comparison





- Also total number seems to be too low (ca .3x).

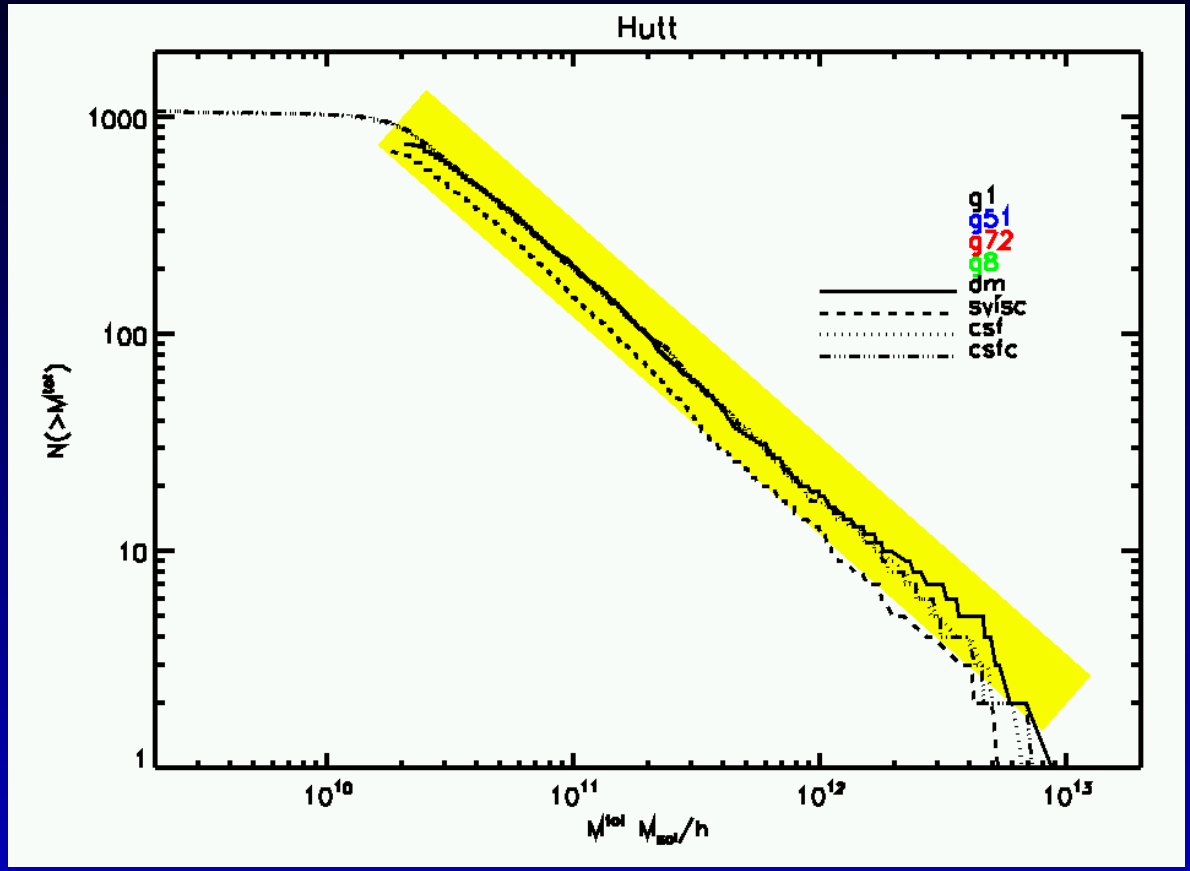
Physics



* (left) and total (right) mass function comparing simulations with different complexity.

- Total mass-function behaves quite as expected.
- * mass function has different shape.
- * mass function (at low mass) depends on feedback details.

Physics



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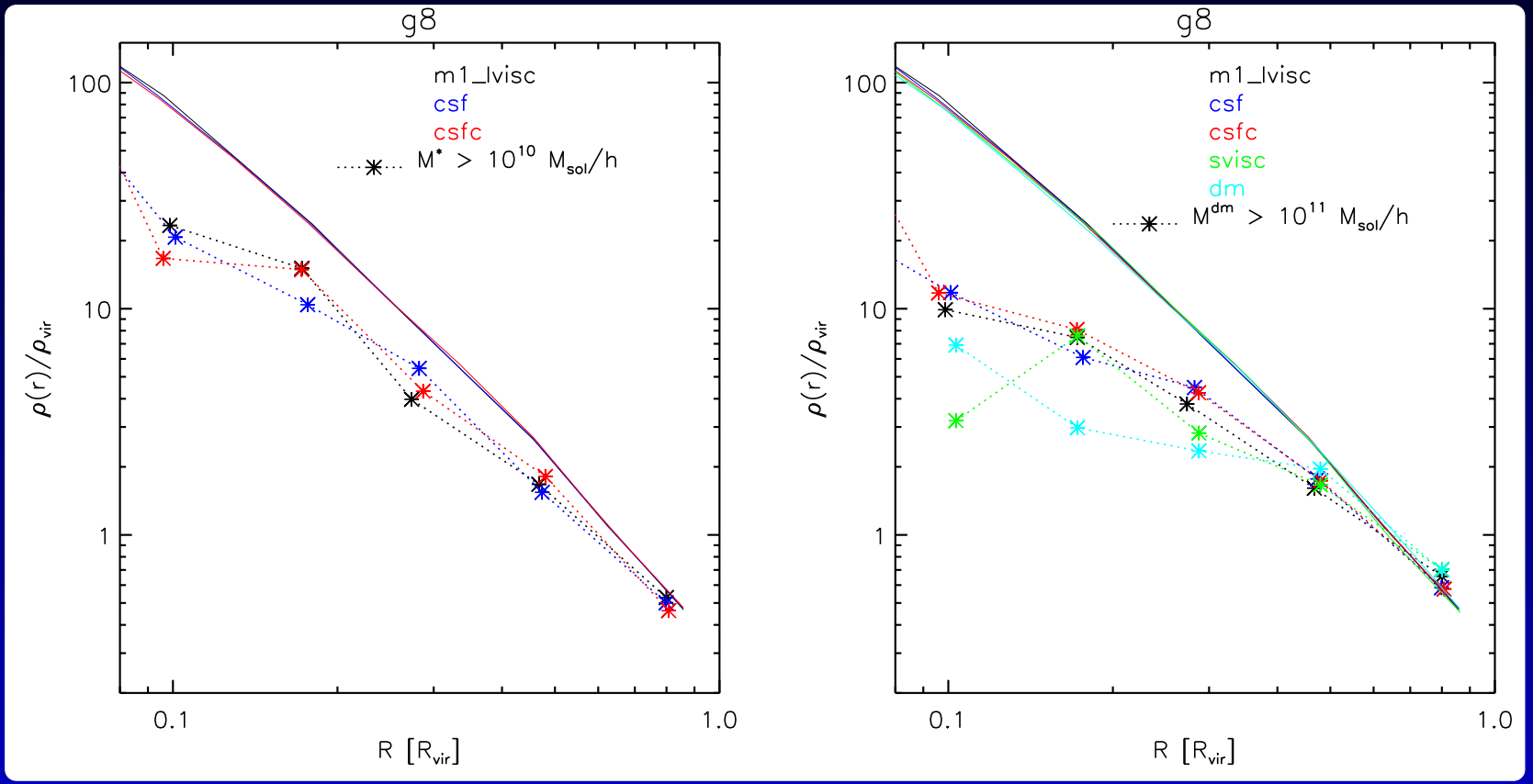
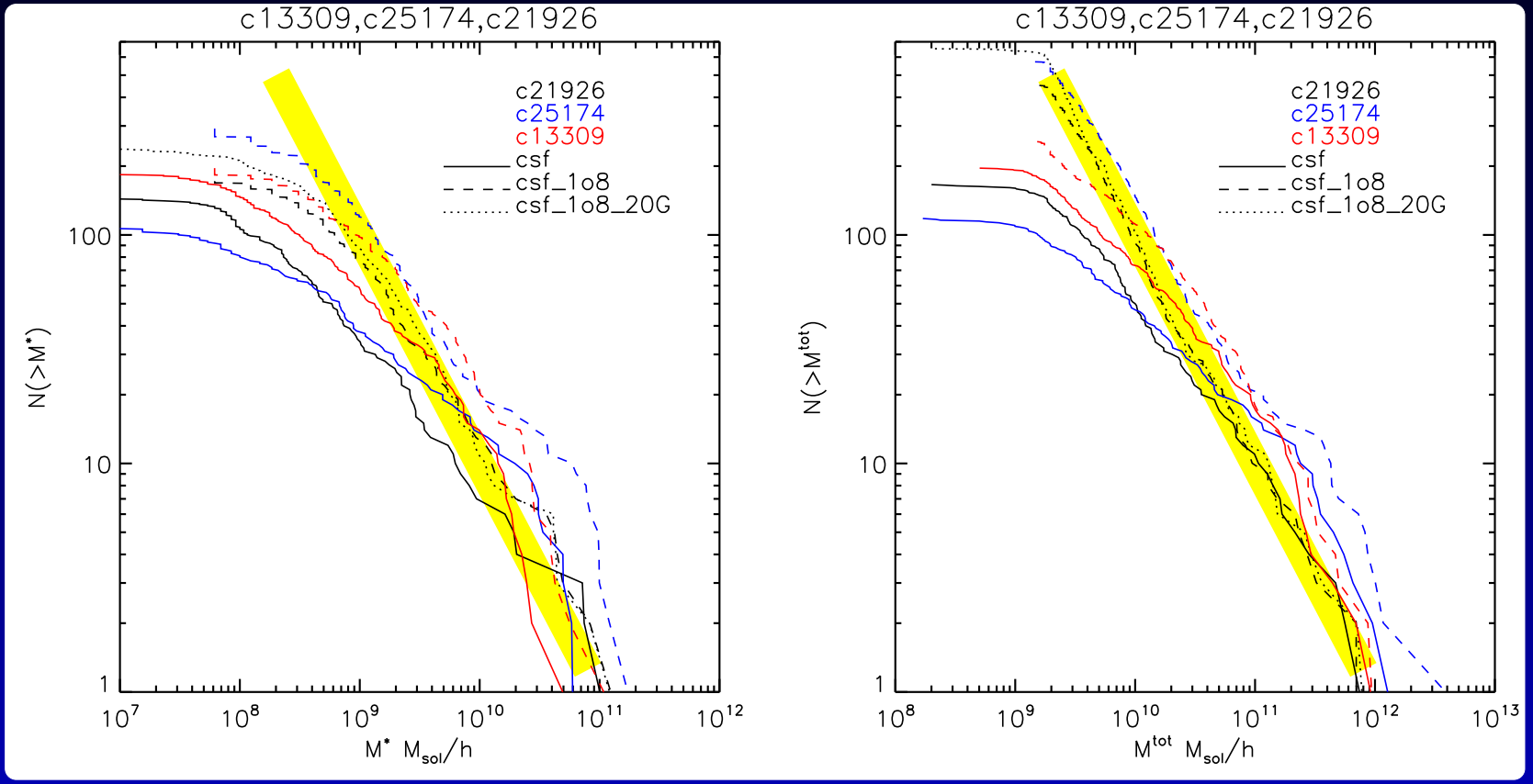


Radial profile for M^* (left) and M^{tot} (right) comparing simulations with different complexity.

- Profiles do not depend strongly on feedback details.

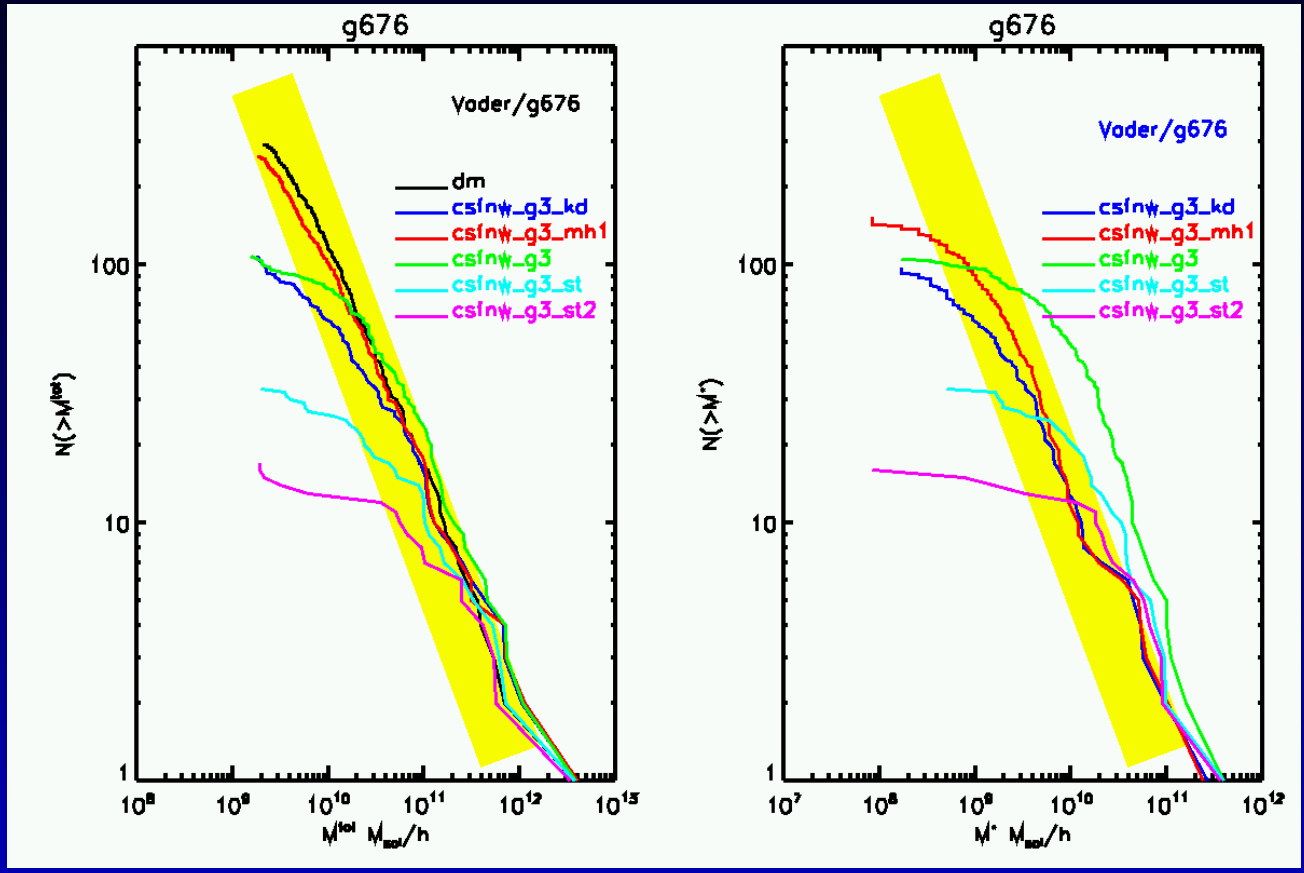
Numerics



Star (left) and total (right) mass function comparing simulations with standard (csf) or equal mass (csf_1o8) treatment of gas particles for three clusters.

- Seems to be crucial for normalization of mass function.
- Equal gas/dm particle mass result in more compact and star-rich galaxies.

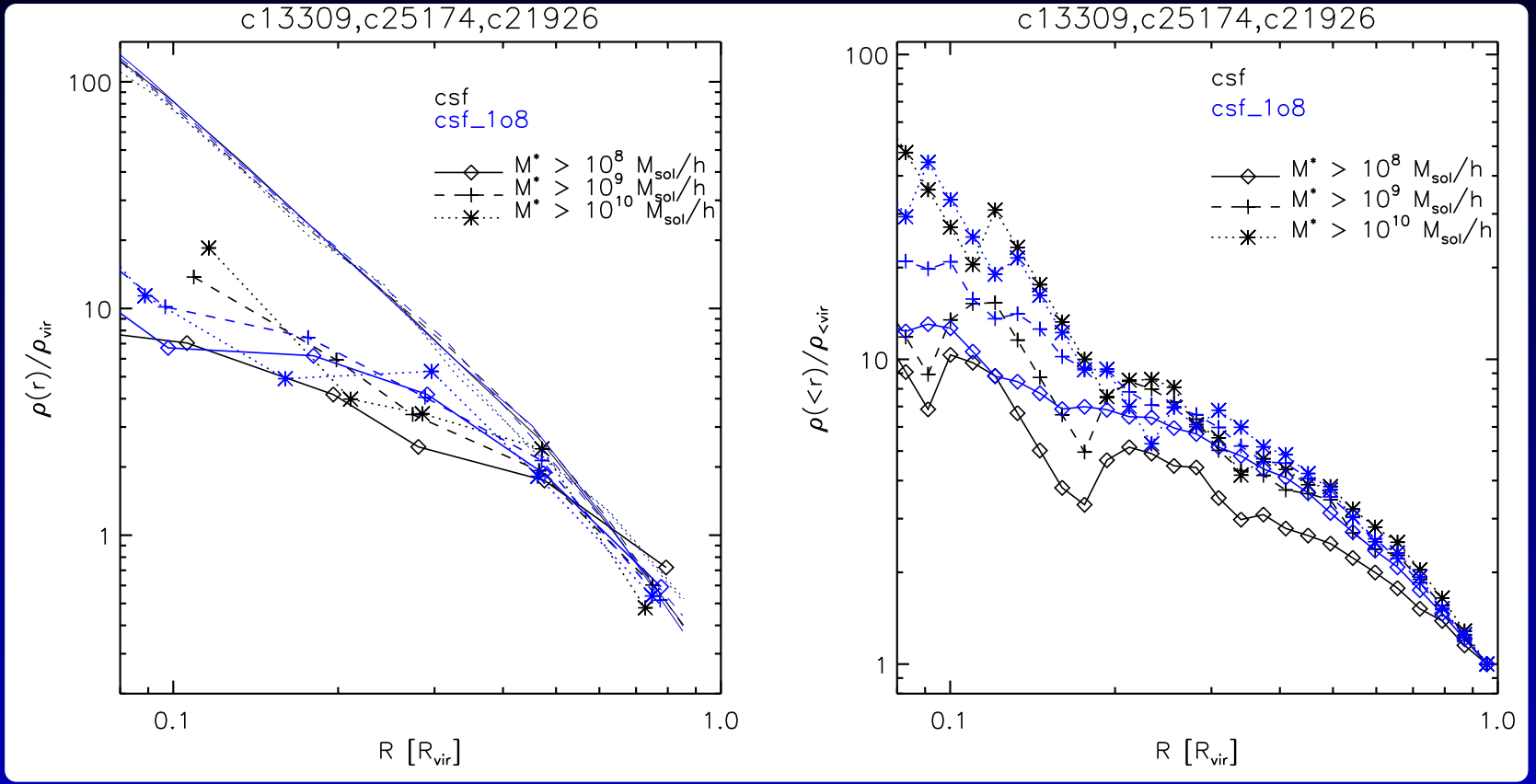
Numerics



Total (left) and star (right) mass function comparing simulations with different numerical parameters.

- Seems to be very sensitive to numerical effects.
- Interaction between particles of different masses clumping on resolution limit.

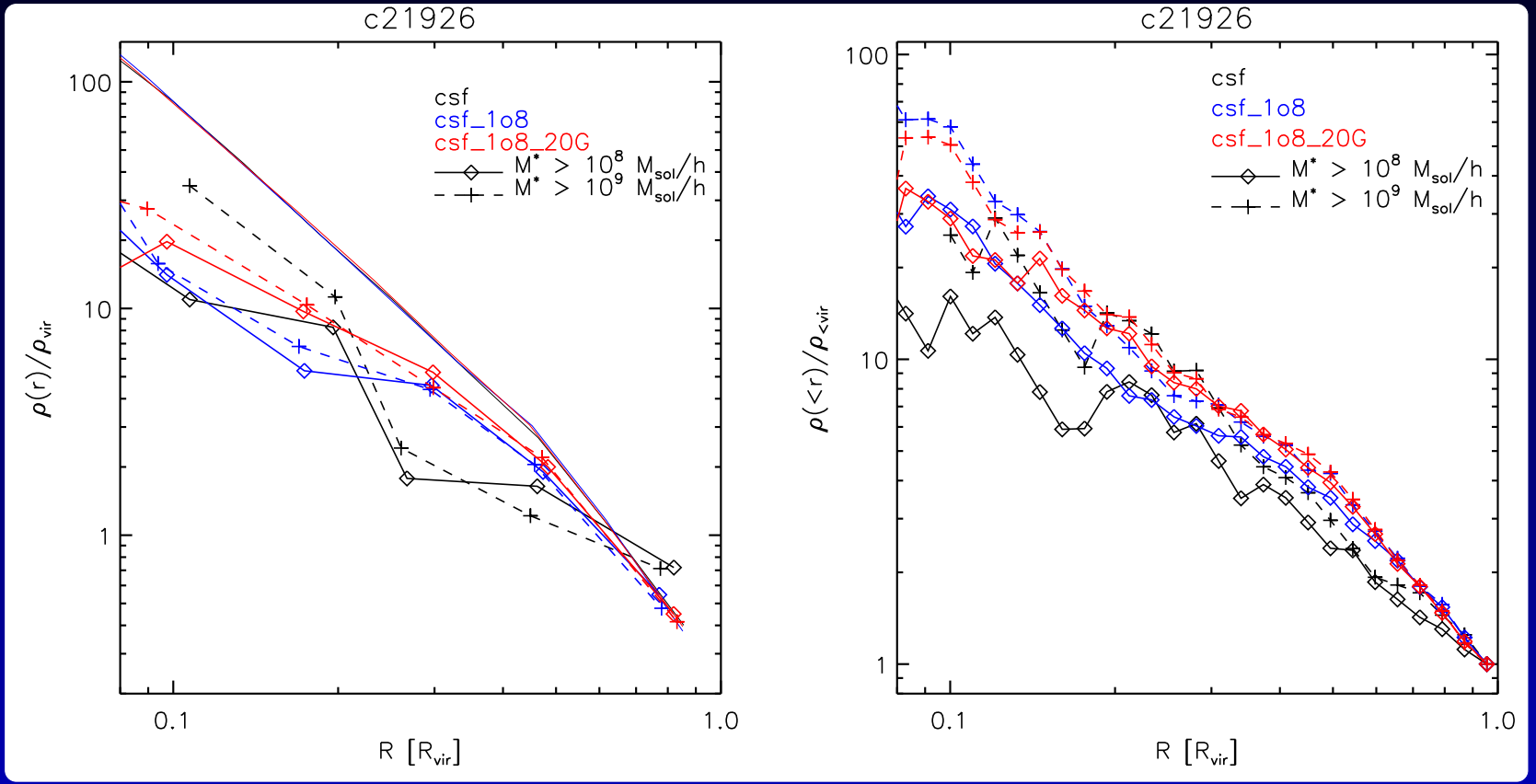
Numerics



Radial profile (left) and cumulative profile (right) comparing simulations with standard (csf) or equal mass (csf_1o8) treatment of gas particles for three clusters.

- Change of the profiles in low mass systems.

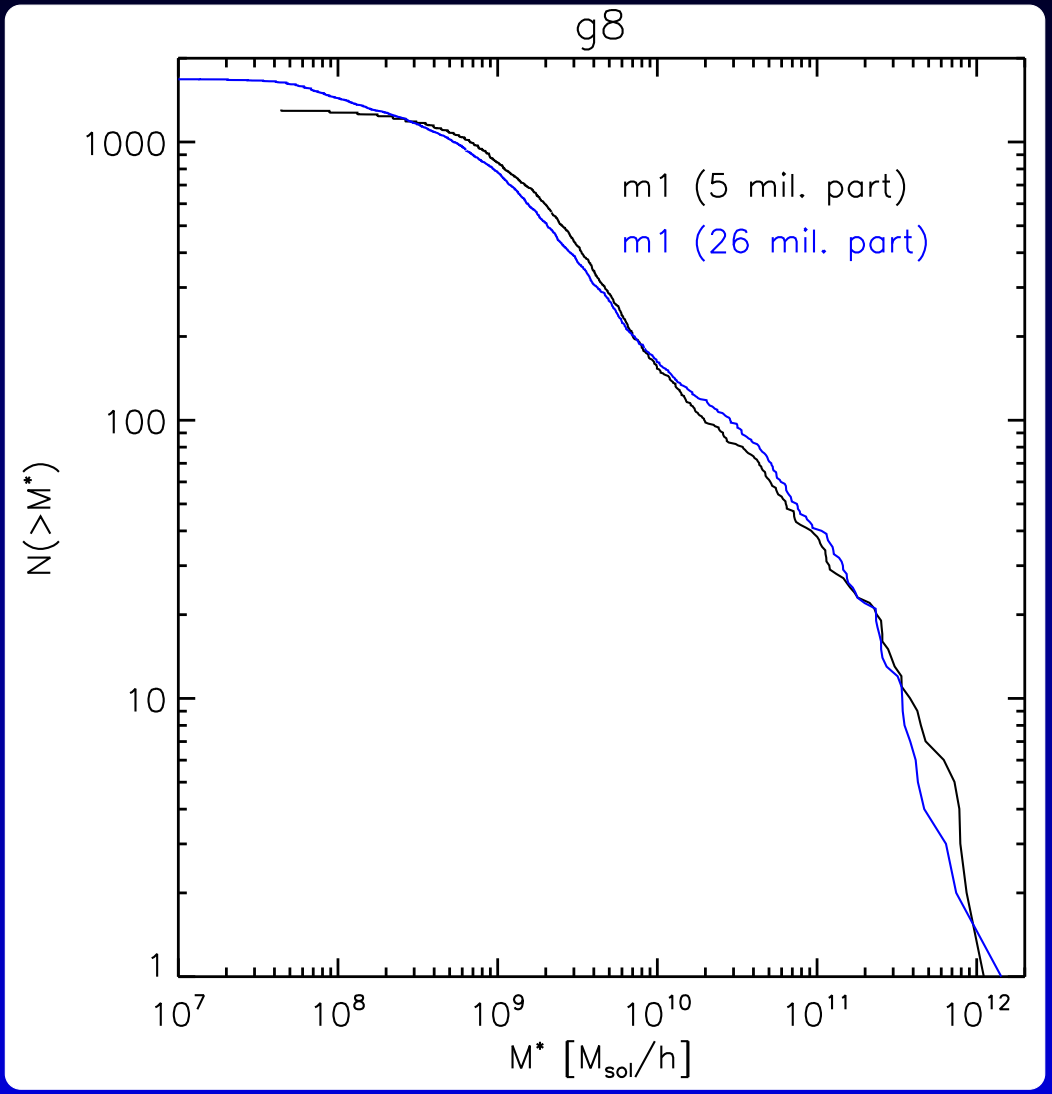
Numerics



Radial profile (left) and cumulative profile (right) comparing simulations with standard 2 generations of stars (csf_1o8) or 20 generations of stars (csf_1o8_20G) for one clusters

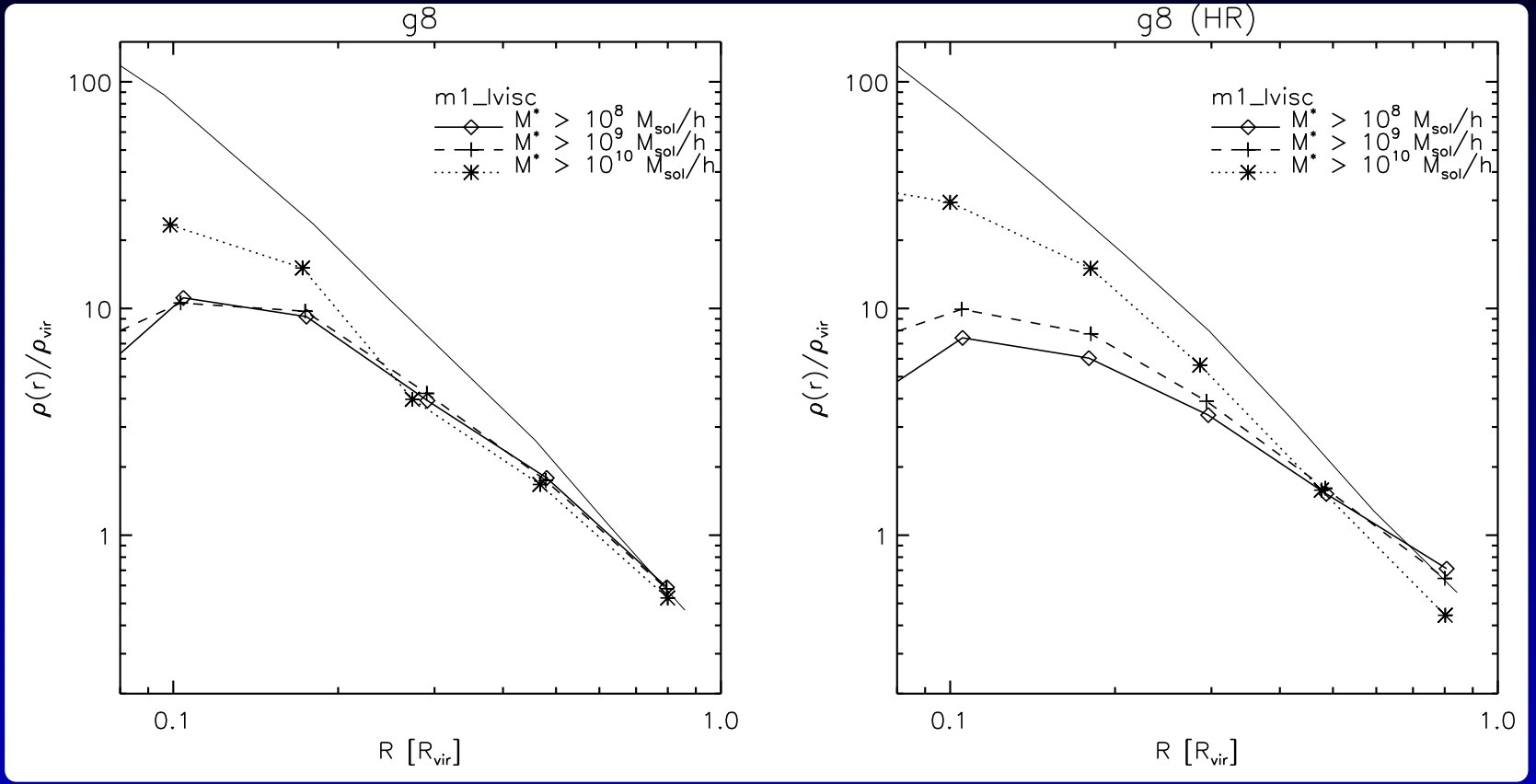
- Improving force resolution in star particle again improves profile for low mass systems.

Resolution



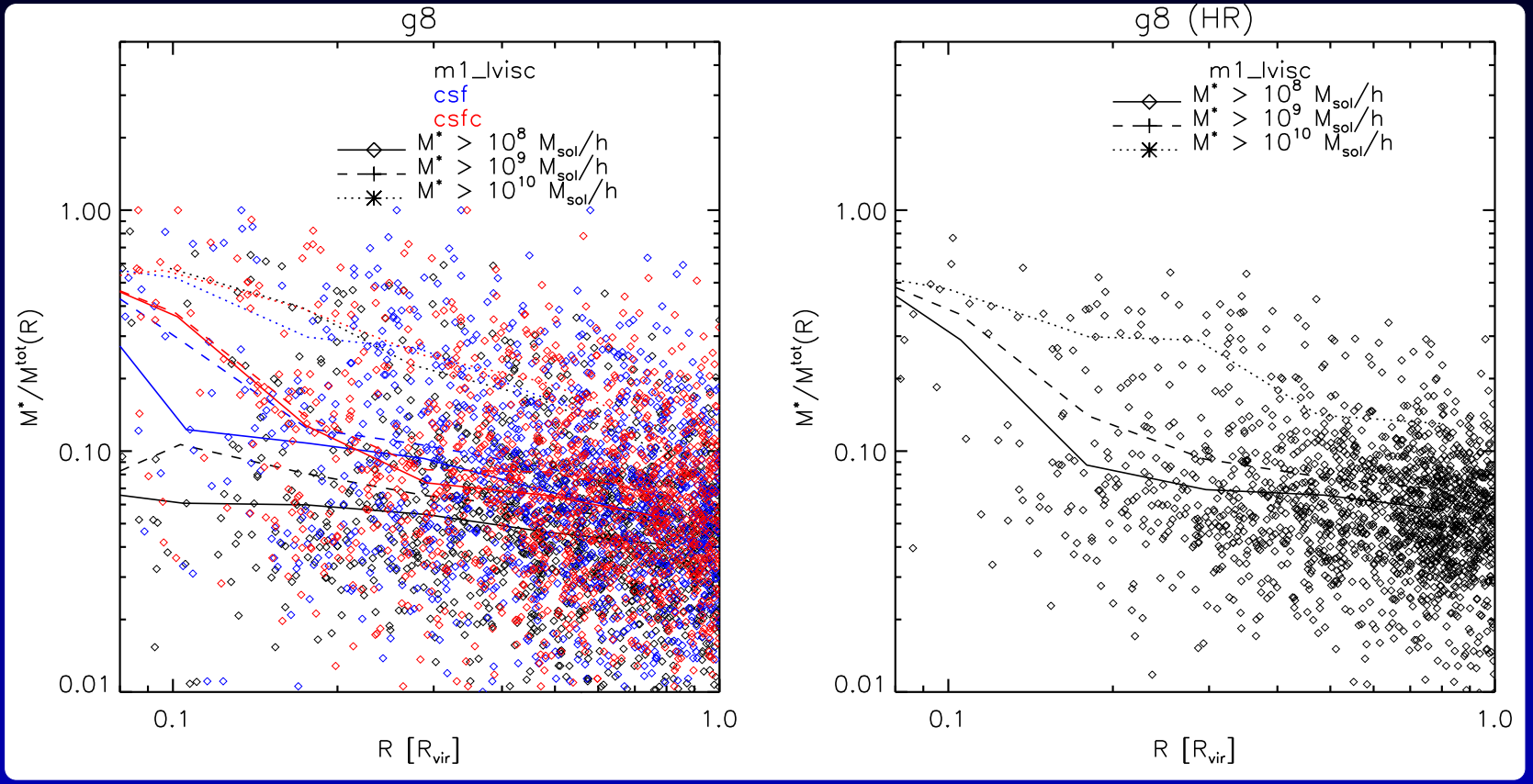
Mass-function seems just to extend to low mass (as expected)

Resolution



- No obvious trend in profile for resolution.

Resolution



- M^*/M^{tot} increases towards center.
- Small number of * dominated galaxies present.
- Resolution / Feedback details crucial for low mass.

Conclusions (II)

- Confirmed previous findings (Nagai & Kravtsov 2005) that selecting galaxies by * mass steepens radial profile.

but depends on mass cut (in M^*)!

but using L_ν instead of * mass flattens profile !

- Including different physics produce reasonable effects on mass function.

but profile not much affected by details of csf !

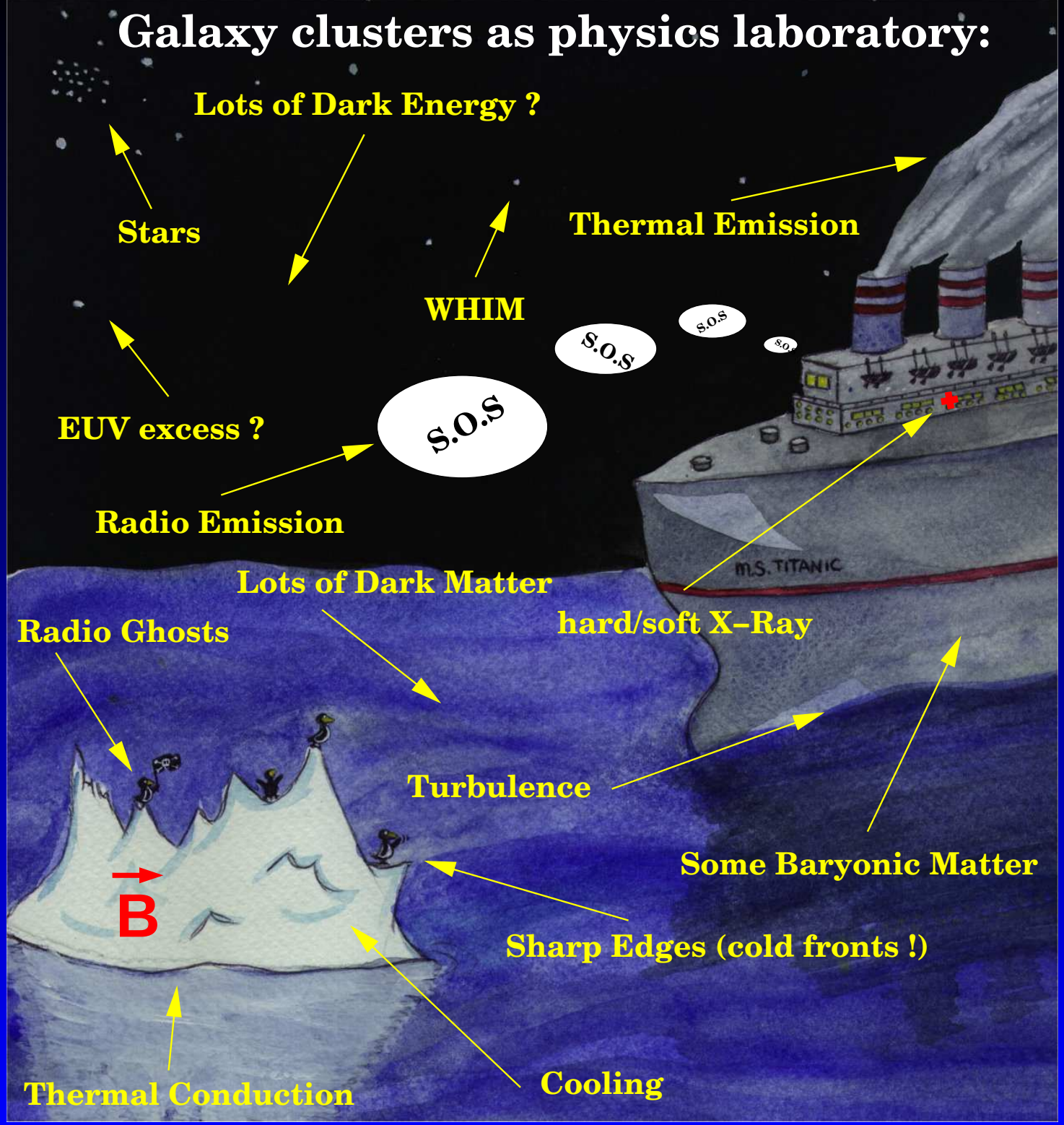
- No obvious trend in profile for different resolution.

but Numerics details seems to be crucial !

- Some pure * galaxies present, specially in the center.

but Still large fraction of haloes get destroyed !

Galaxy clusters as physics laboratory:



Do we understand our "world" !?