The radial structure of galaxy groups in adiabatic hydro simulations

- cosmological zoom-in simulations

- 16 galaxy group size halos

- box size: 150 Mpc (co-moving)

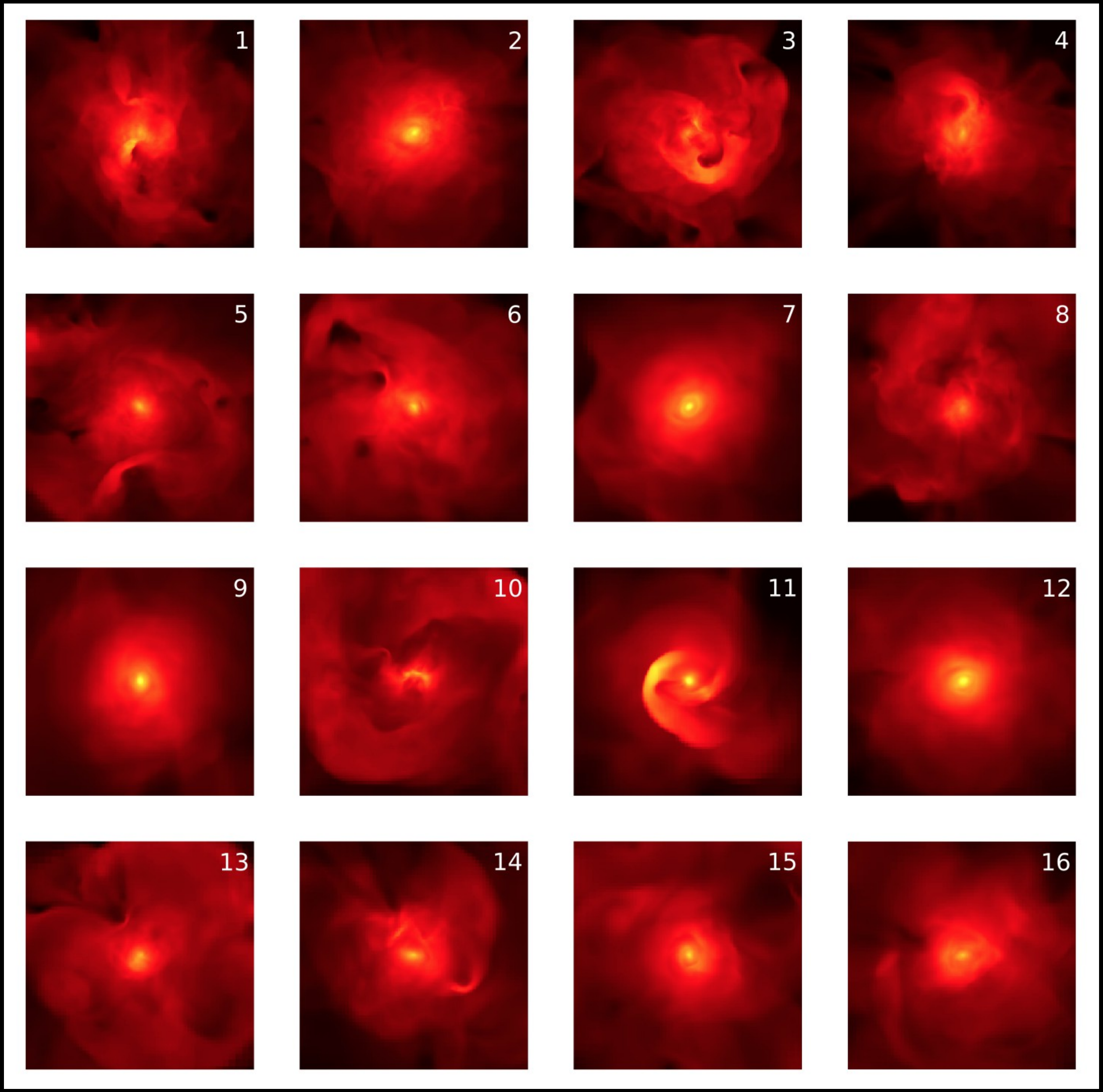
- spatial resolution: 1.25 kpc

- mass resolution:
10 million solar masses

→ more than 1 million particles in one halo

- purely adiabatic hydrodynamics for the baryons

- simulation code: RAMSES



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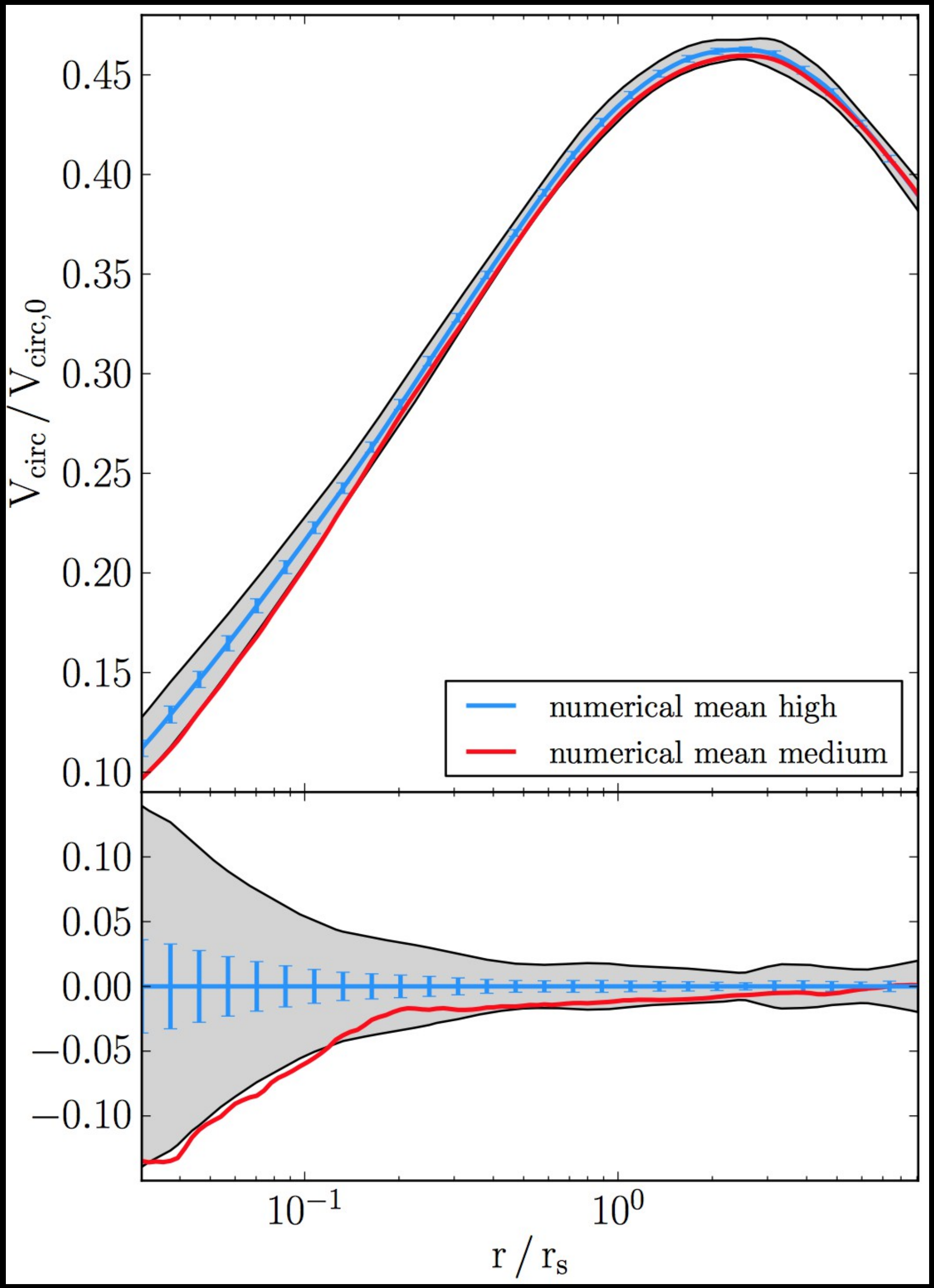
- <u>Context:</u>
- Precision cosmology and large scale structure

- <u>Objective:</u>
- Quantify the radial structure of the halos through their numerical mean profiles
- Profile quantities of interest: density, temperature, entropy, ...

- <u>Key questions:</u>
- How large is the scatter arising from the individuality of the halos ?
- How strong is the effect of changing numerical parameters ?
- How well do our results compare to established analytical models ?



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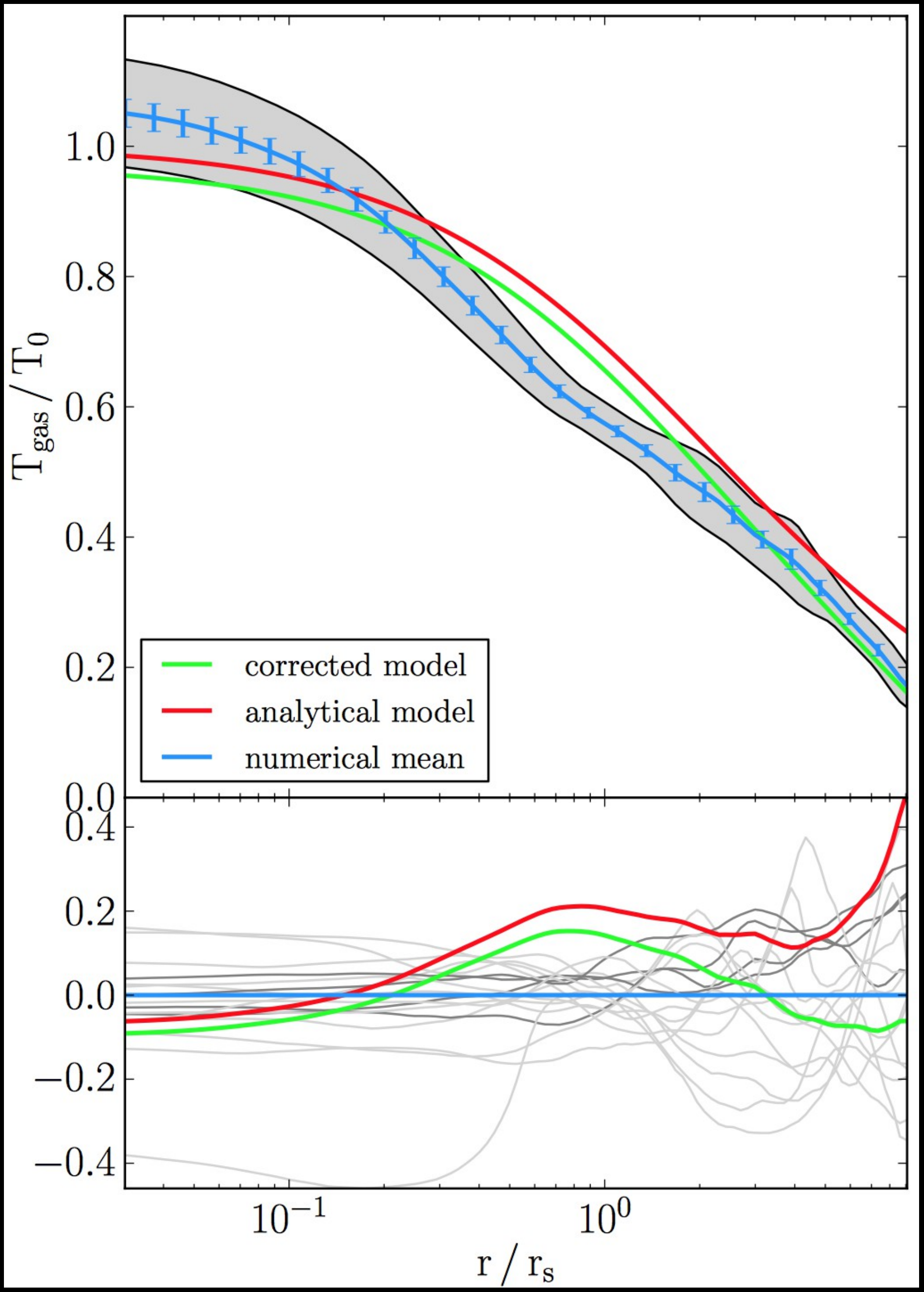
- (Some) Results:
- Numerical effects onto the profiles are smaller than the physical variance arising from the individual halo nature
- Deviations between numerical mean and analytic profiles (NFW + polytrop + turbulent pressure support) are below 20%
- Turbulence needs to be taken into account to properly describe the HSE situation → corrected analytical model
- Correlations found between the amount of turbulence in a halo and its structural parameter c, as well as its time evolution
- In the adiabatic hydro run the halos are slightly more extended and less concentrated than in the pure dark matter only simulation



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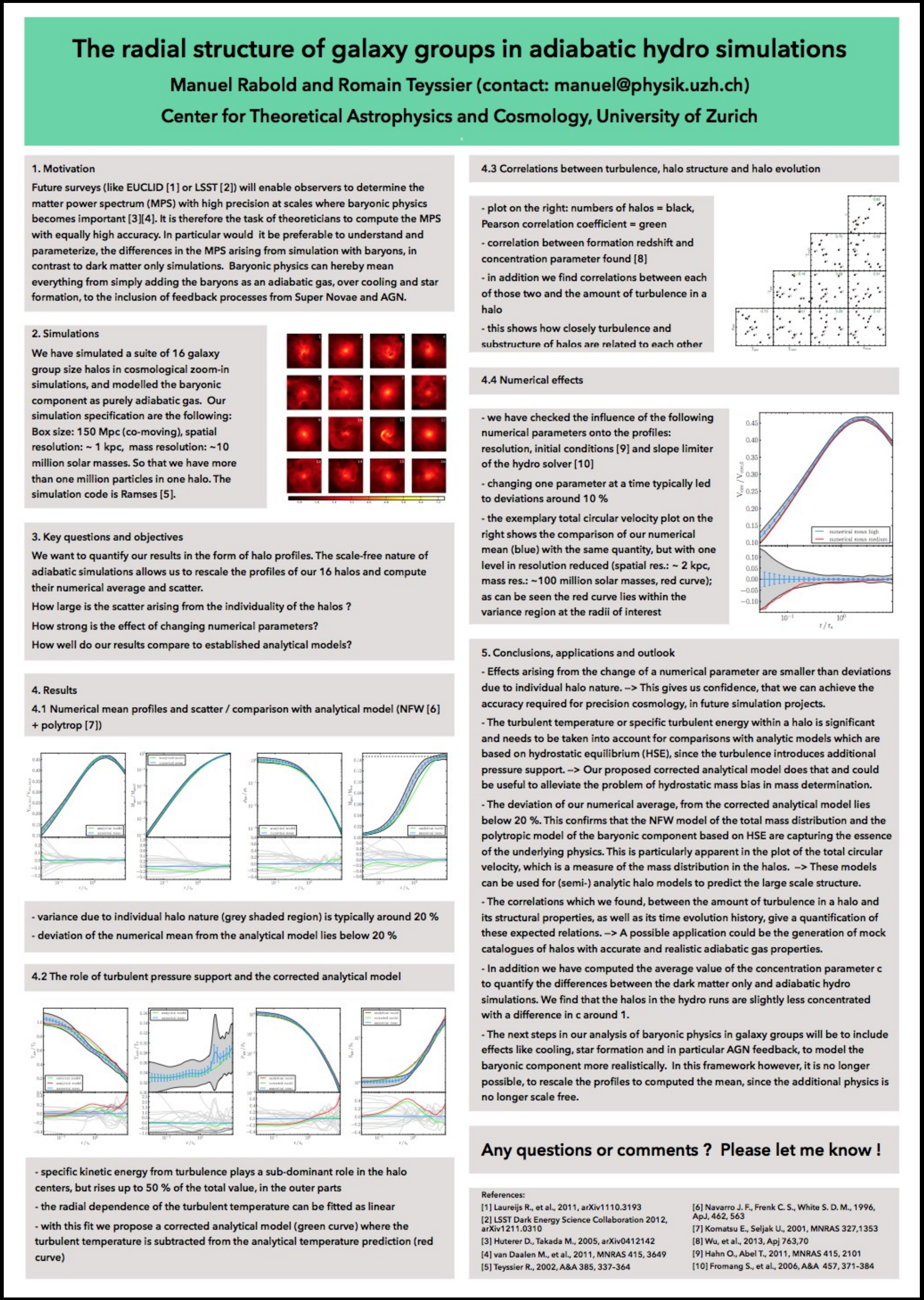
Thanks !



The radial structure of galaxy groups in adiabatic hydro simulations

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1. Motivation

Future surveys (like EUCLID [1] or LSST [2]) will enable observers to determine the matter power spectrum (MPS) with high precision at scales where baryonic physics becomes important [3][4]. It is therefore the task of theoreticians to compute the MPS with equally high accuracy. In particular would it be preferable to understand and parameterize, the differences in the MPS arising from simulation with baryons, in contrast to dark matter only simulations. Baryonic physics can hereby mean everything from simply adding the baryons as an adiabatic gas, over cooling and star formation, to the inclusion of feedback processes from Super Novae and AGN.

2. Simulations

We have simulated a suite of 16 galaxy group size halos in cosmological zoom-in simulations, and modelled the baryonic component as purely adiabatic gas. Our simulation specification are the following: Box size: 150 Mpc (co-moving), spatial resolution: ~ 1 kpc, mass resolution: ~10 million solar masses. So that we have more than one million particles in one halo. The simulation code is Ramses [5].

3. Key questions and objectives

We want to quantify our results in the form of halo profiles. The scale-free nature of adiabatic simulations allows us to rescale the profiles of our 16 halos and compute their numerical average and scatter.

How large is the scatter arising from the individuality of the halos ?

How strong is the effect of changing numerical parameters?

How well do our results compare to established analytical models?

4. Results

4.1 Numerical mean profiles and scatter / comparison with analytical model (NFW [6] + polytrop [7])

- variance due to individual halo nature (grey shaded region) is typically around 20 %
- deviation of the numerical mean from the analytical model lies below 20 %

4.2 The role of turbulent pressure support and the corrected analytical model

- specific kinetic energy from turbulence plays a sub-dominant role in the halo centers, but rises up to 50 % of the total value, in the outer parts
- the radial dependence of the turbulent temperature can be fitted as linear
- with this fit we propose a corrected analytical model (green curve) where the turbulent temperature is subtracted from the analytical temperature prediction (red curve)

4.3 Correlations between turbulence, halo structure and halo evolution

- plot on the right: numbers of halos = black, Pearson correlation coefficient = green
- correlation between formation redshift and concentration parameter found [8]
- in addition we find correlations between each of those two and the amount of turbulence in a halo
- this shows how closely turbulence and substructure of halos are related to each other

4.4 Numerical effects

- we have checked the influence of the following numerical parameters onto the profiles: resolution, initial conditions [9] and slope limiter of the hydro solver [10]
- changing one parameter at a time typically led to deviations around 10 %
- the exemplary total circular velocity plot on the right shows the comparison of our numerical mean (blue) with the same quantity, but with one level in resolution reduced (spatial res.: ~ 2 kpc, mass res.: ~100 million solar masses, red curve); as can be seen the red curve lies within the variance region at the radii of interest

5. Conclusions, applications and outlook

- Effects arising from the change of a numerical parameter are smaller than deviations due to individual halo nature. –> This gives us confidence, that we can achieve the accuracy required for precision cosmology, in future simulation projects.
- The turbulent temperature or specific turbulent energy within a halo is significant and needs to be taken into account for comparisons with analytic models which are based on hydrostatic equilibrium (HSE), since the turbulence introduces additional pressure support. –> Our proposed corrected analytical model does that and could be useful to alleviate the problem of hydrostatic mass bias in mass determination.
- The deviation of our numerical average, from the corrected analytical model lies below 20 %. This confirms that the NFW model of the total mass distribution and the polytropic model of the baryonic component based on HSE are capturing the essence of the underlying physics. This is particularly apparent in the plot of the total circular velocity, which is a measure of the mass distribution in the halos. –> These models can be used for (semi-) analytic halo models to predict the large scale structure.
- The correlations which we found, between the amount of turbulence in a halo and its structural properties, as well as its time evolution history, give a quantification of these expected relations. –> A possible application could be the generation of mock catalogues of halos with accurate and realistic adiabatic gas properties.
- In addition we have computed the average value of the concentration parameter c to quantify the differences between the dark matter only and adiabatic hydro simulations. We find that the halos in the hydro runs are slightly less concentrated with a difference in c around 1.
- The next steps in our analysis of baryonic physics in galaxy groups will be to include effects like cooling, star formation and in particular AGN feedback, to model the baryonic component more realistically. In this framework however, it is no longer possible, to rescale the profiles to computed the mean, since the additional physics is no longer scale free.

Any questions or comments ? Please let me know !

References:

[1] Laureijs R., et al., 2011, arXiv1110.3193

[2] LSST Dark Energy Science Collaboration 2012, arXiv1211.0310

[3] Huterer D., Takada M., 2005, arXiv0412142

[4] van Daalen M., et al., 2011, MNRAS 415, 3649

[5] Teyssier R., 2002, A&A 385, 337-364

[6] Navarro J. F., Frenk C. S., White S. D. M., 1996, ApJ, 462, 563

[7] Komatsu E., Seljak U., 2001, MNRAS 327,1353

[8] Wu, et al., 2013, Apj 763,70

[9] Hahn O., Abel T., 2011, MNRAS 415, 2101

[10] Fromang S., et al., 2006, A&A 457, 371-384