The Inner Dark Matter Distribution in Hydrodynamic Simulations

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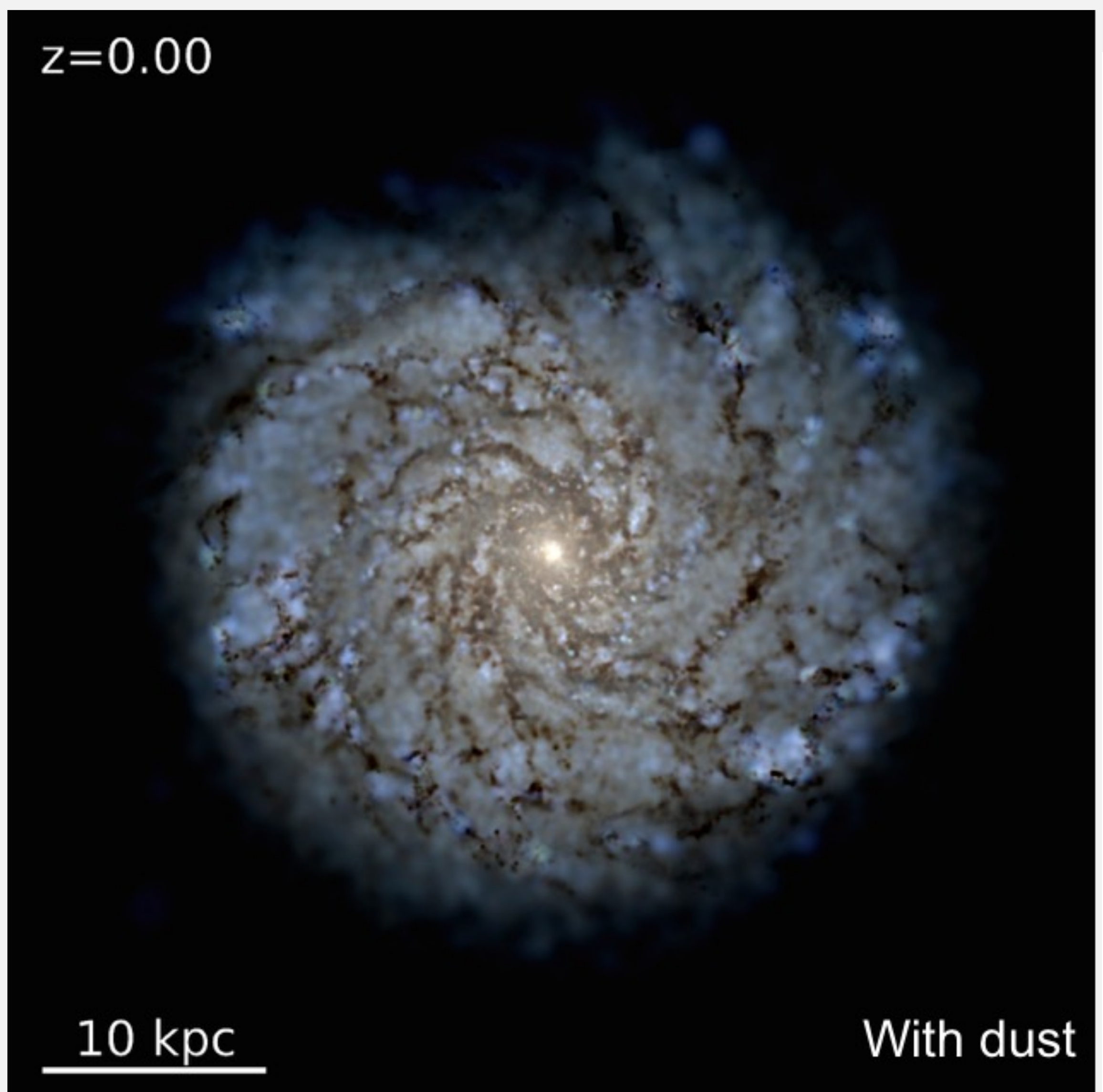
Introduction

- The structure of dark matter haloes on kiloparsec scales is essential for testing the nature of dark matter.
- We can characterize galactic evolution using a simple effective model consisting of two basic types of baryonic
  - Adiabatic contraction
  - Feedback
- Adiabatic contraction (AC) concentrates the dark matter halos from its initial distribution while feedback may have the opposite effect.
- Differences in the numerical methods used to solve the hydrodynamic equations, as well as differences in the implementation of the sub-resolution physics yields drastically different astrophysical predictions.
- We characterize the different sub-resolution models using adiabatic contraction.
- We find that there exists two solutions: a group of simulation suites (namely Vintergatan, TNG-50, Auriga L3) can be described, with some scatter, using AC, while FIRE predicts a lower central DM density due to the feedback prescription.

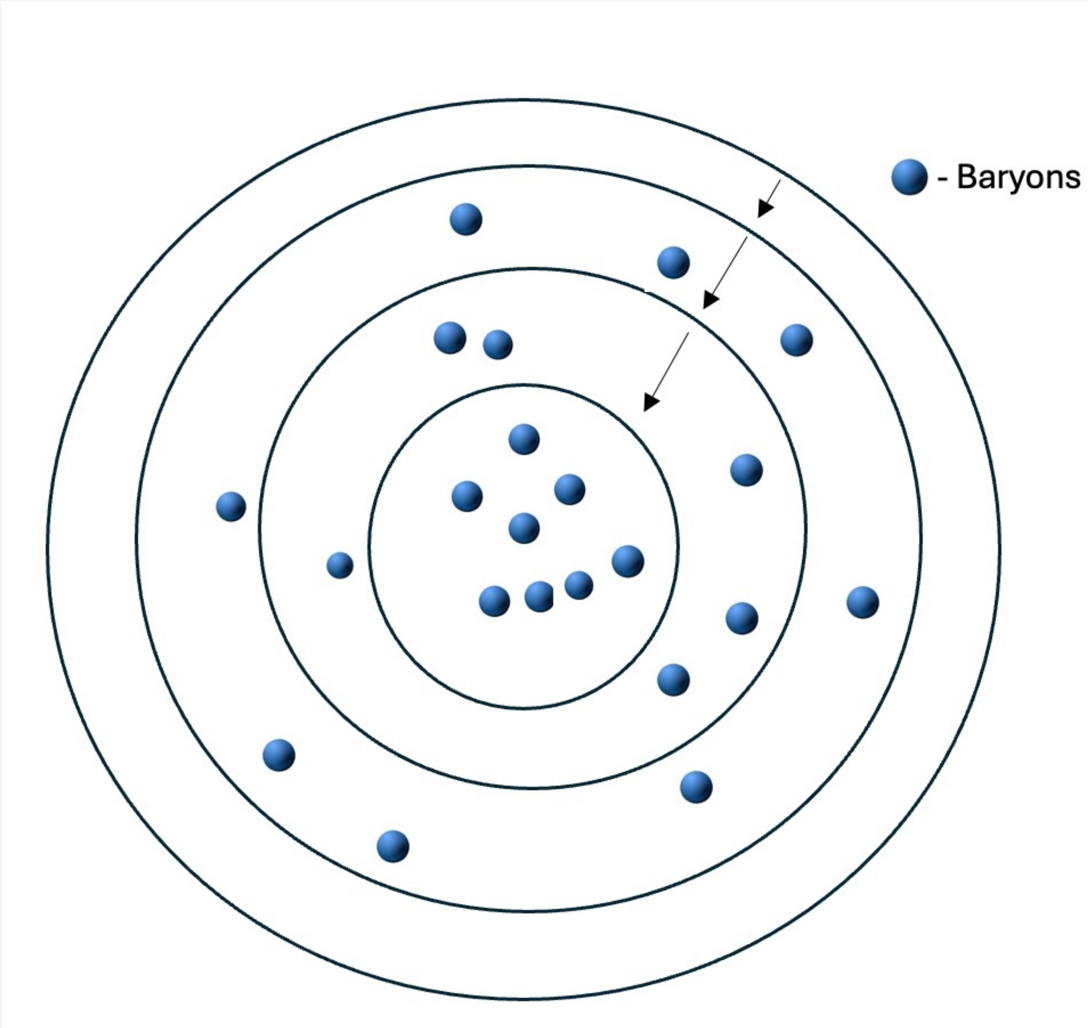
Simulations

- It is essential to test if AC can be used to model the dark matter distribution for a variety of hydrodynamic simulations, we chose the following simulation suites:
  - FIRE -2
  - Auriga
  - TNG-50
  - Vintergatan
- Figure 1 shows face on view of a sample FIRE galaxy at z =0.
- A summary of the DM density distribution in each of the simulations is shown in figure 2.

Figure 1

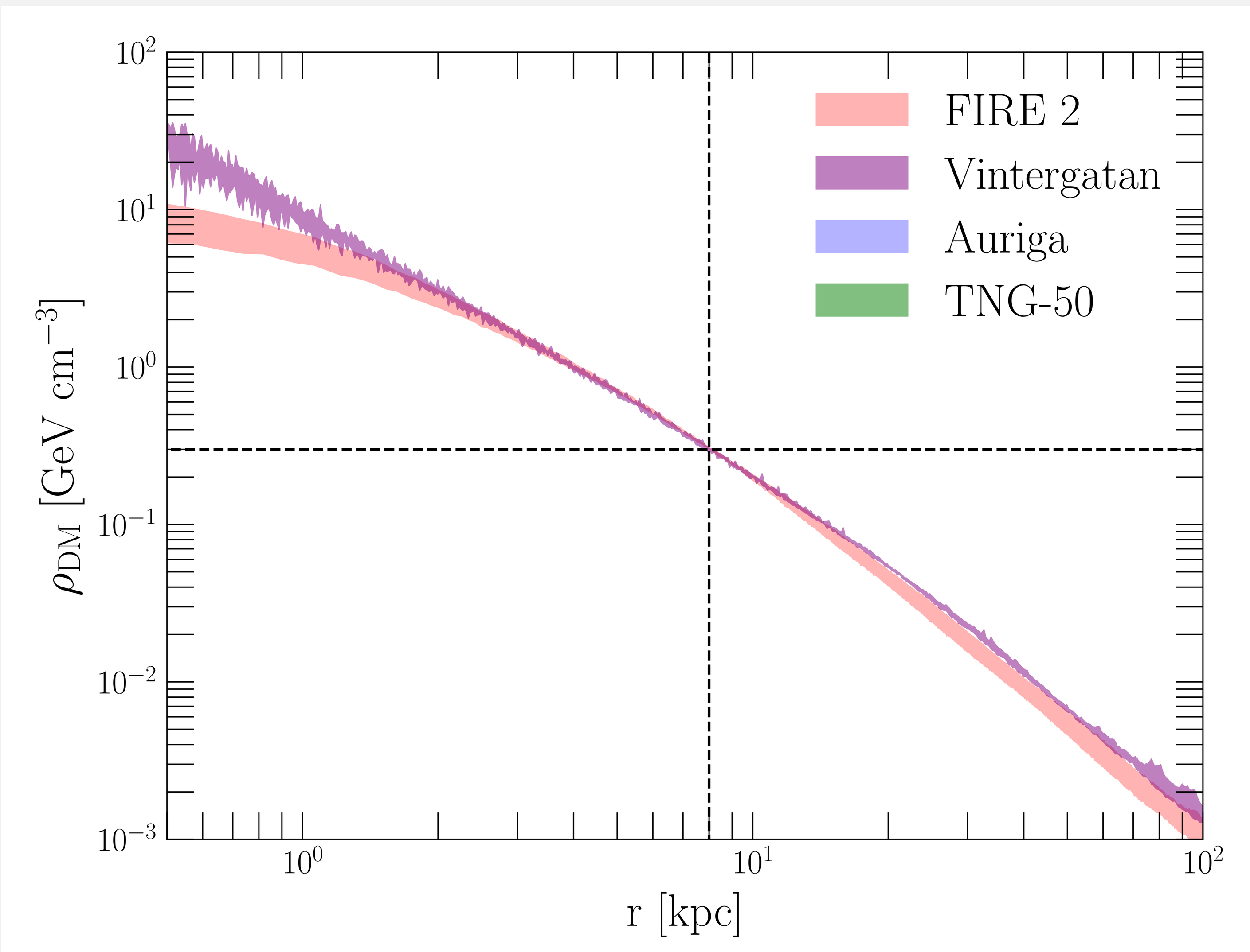


Adiabatic Contraction



- Dark matter particles are on highly eccentric orbits (see (Ghigna et al. 1998)),
- The conserved quantities of eccentric orbits are angular momentum J and the radial action $I_r = \frac{1}{\pi}\int v_r\, dr$:
  - (Gnedin et al. 2004) argued that using the value of the mass within the average radius of a given orbit is a better proxy for the radial action $r * M(\bar{r})$
- We implement Gnedin's adiabatic contraction algorithm to model the DM distribution as follows:
  - $f_b = \frac{M_{stars}^{hydro}(r_{200c})}{M_{DM}^{hydro}(r_{200c})}$
  - $f_{norm} = \frac{M_{DM}^{hydro}(r_{200c}) + M_{stars}^{hydro}}{M_{DM}^{DMO}(r_{200c})}$
  - $M_{DM}^{initial}(r) = \left(M_{DM}^{DMO}(r) . f_{norm}\right) . (1 - f_b)$
  - $M_{stars}^{initial}(r) = \left(M_{DM}^{DMO}(r) .\ f_{norm}\right) . f_b$
  - $r_{initial}\left(M_{DM}^{initial}(\overline{r_{initial}}) + M_{star}^{initial}(\overline{r_{initial}})\right) = r_{final}\left(M_{DM}^{final}(\overline{r_{initial}}) + M_{star}^{final}(\overline{r_{initial}})\right)$

Figure 2



Results

- To compare the AC prediction M_{Dm}^{AC} to M_{DM}^{hydro} we take the ratio of the two $\frac{M_{Dm}^{AC}}{M_{DM}^{hydro}}$ as shown in figure 2.
- We observe two classes of solutions:
  - Vintergatan, Auriga and TNG-50 spread between $0.1 < \frac{M_{Dm}^{AC}}{M_{DM}^{hydro}} < 1.7$ with an average of 1.4
  - FIRE-2 Suite ranges from $0.1 < \frac{M_{Dm}^{AC}}{M_{DM}^{hydro}} < 3$ with an average of 2.5.
- It is quite subtle to correlate the differences in the ratios to variables that describe the stellar feedback in these simulation suites

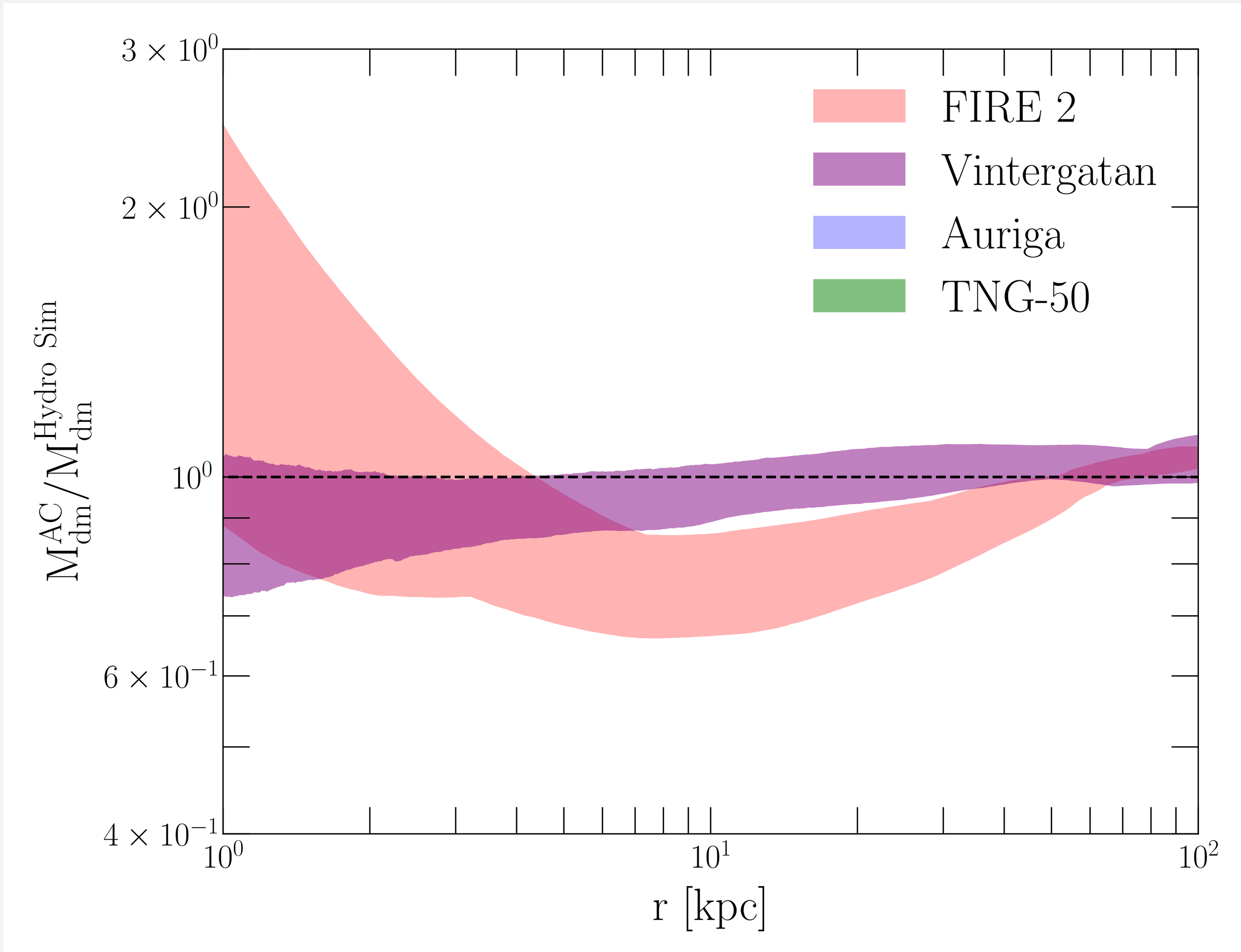


Figure 3

Conclusion

- We find that there exists two solutions: a group of simulation suites (namely Vintergatan, TNG-50, Auriga L3) can be described, with some scatter, using AC, while FIRE predicts a lower central DM density due to the feedback prescription.
- We will use the observed stellar density profile of the milky way to:
  - Predict DM density profile
  - Predict DM annihilation flux

References

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