The Effect of Stellar and AGN Feedback on Dwarf Galaxy Rotation Curves

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Background/What is Dark Matter?

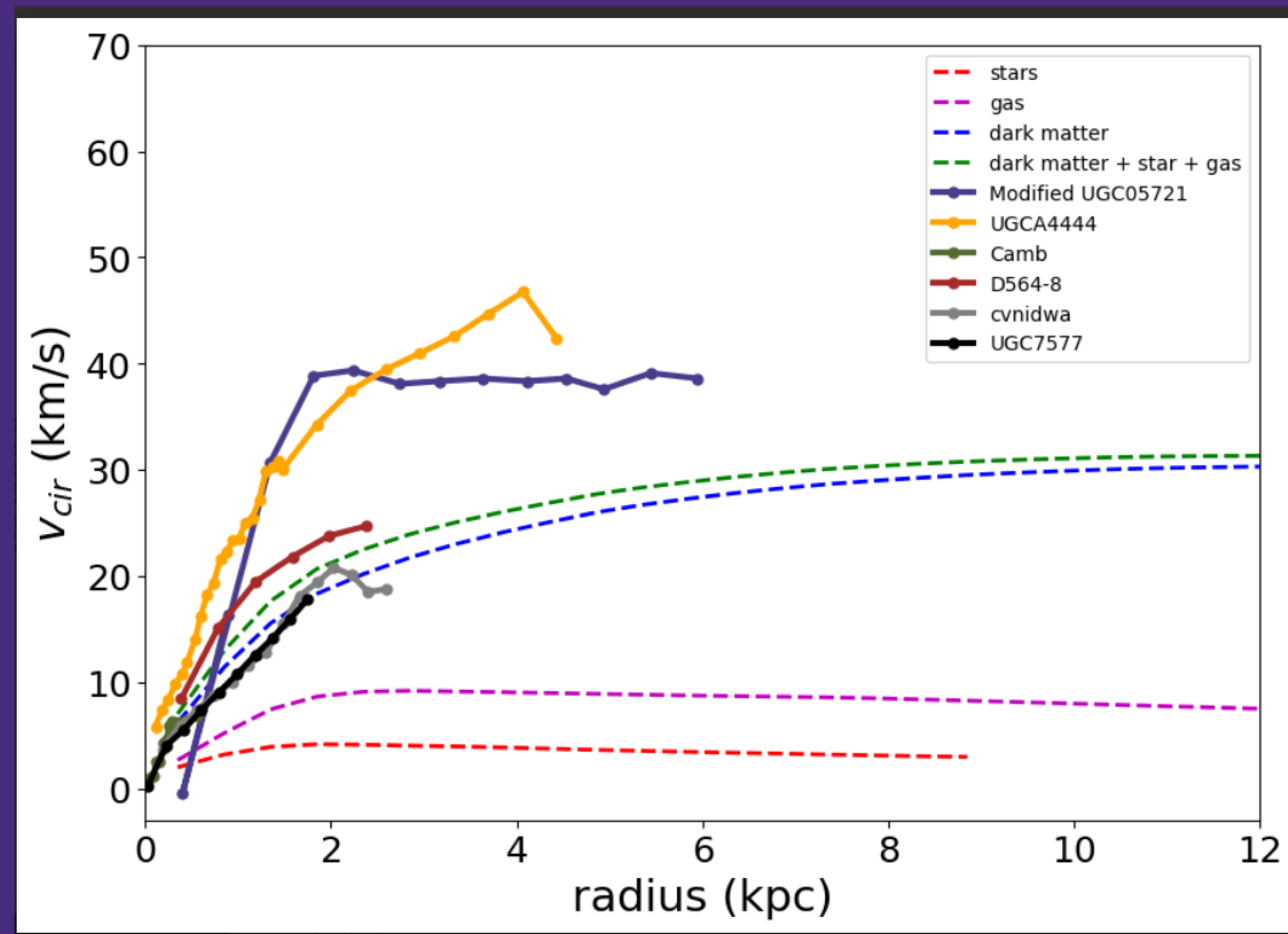
- Makes up 27% of universe
- Does not emit, reflect, or absorb light
- LCDM is dark matter is made up of slow dark moving particles and it is the main leading candidate – WIMPS (Weakly Interacting Massive Particles)
- With LCDM small halos form first then merge into later ones
- Cannot see dark matter, but we can indirectly detect it through methods like gravitational lensing that – its gravity bends light
- Warm Dark Matter suppresses formation of low mass halos which translates into fewer dwarf galaxies. Main problem is too much warm matter can erase structure. Thay interact with gravity
- Self Interacting Dark Matter: Dark matter particles scatter elastically (inner density drops, outer increases)

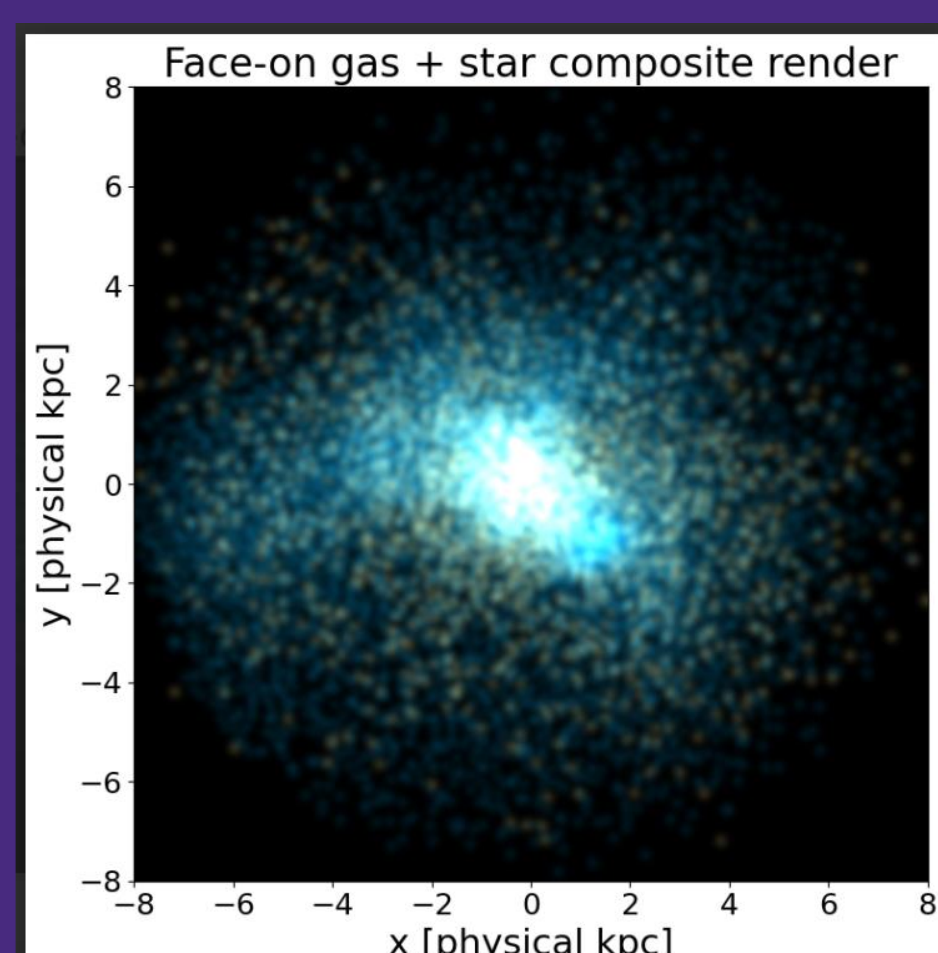
Methodology

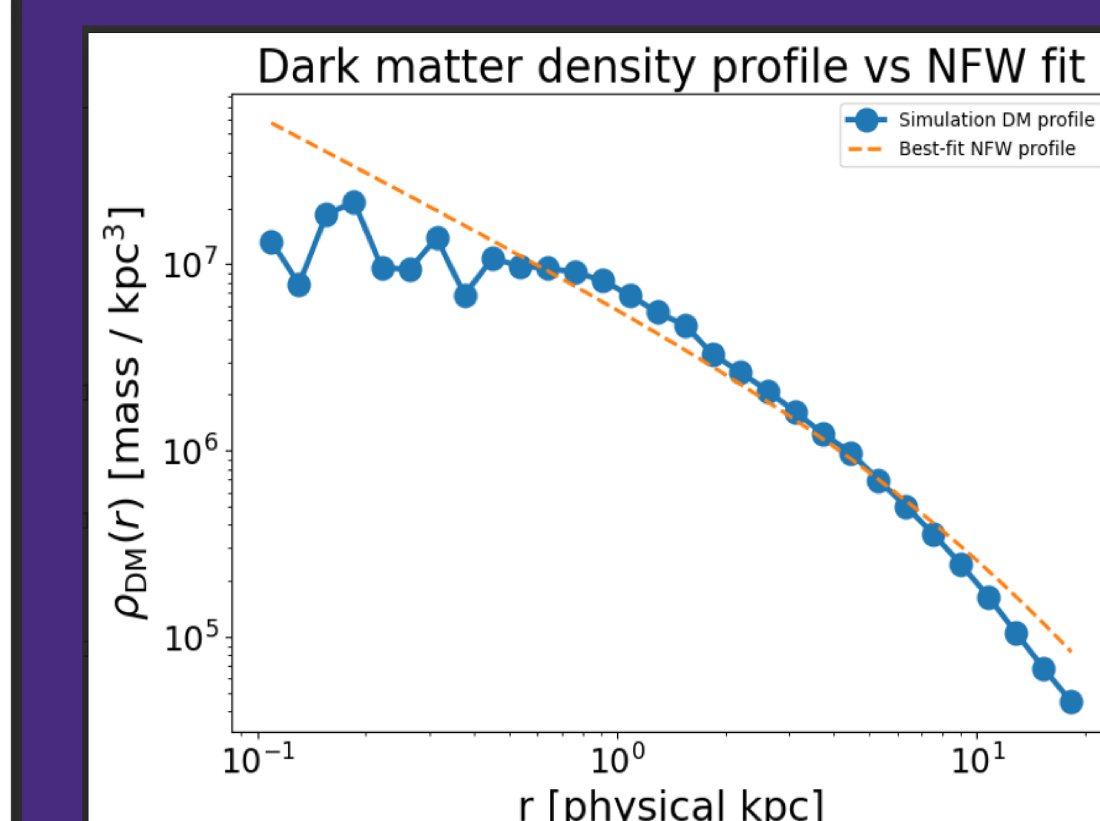
- We use a zoom-in cosmological hydrodynamical simulations through FIRE 2 and Illustrus
- FIRE 2 specifically uses radioactive cooling and healing, star formation, and stellar feedback using a specific code GIZMO analysis

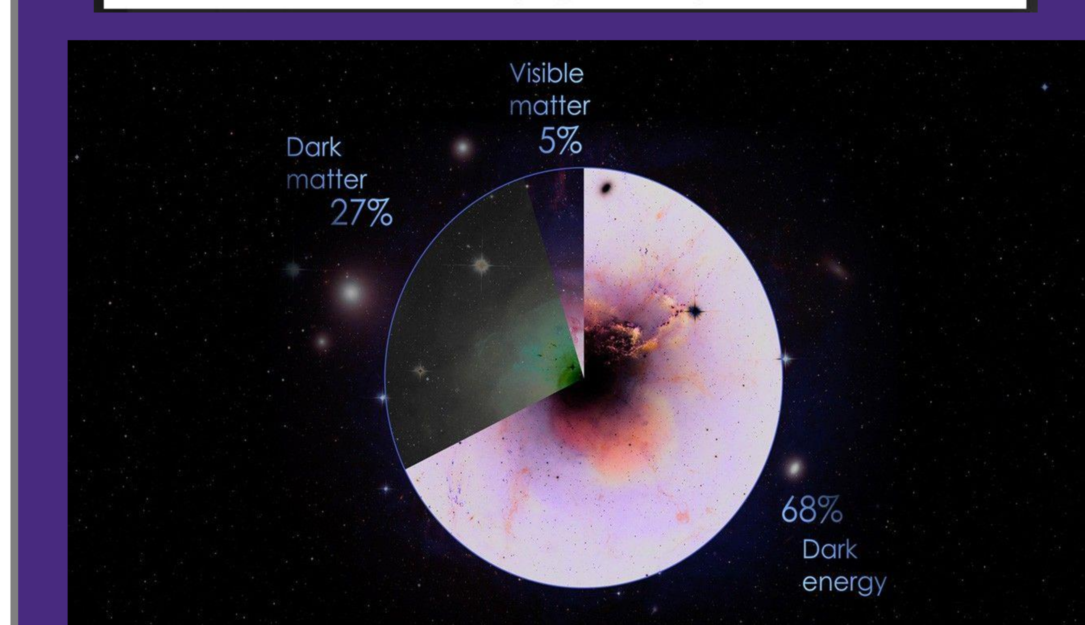
$$V_{\rm circ}(r) = \sqrt{\frac{GM(<r)}{r}}$$

- Utilize Gizmo code to calculate circular velocities as part of rotation curve by first selecting the mass profiles as a function of radius
- We get the radii from mass profiles which we filter using a mask from the halo catalog
- Calculate radius by getting radius positions of stars and using Pythagorean theorem
- We use present day (Z=0) for dwarf galaxies in our analysis
- Initiate the rotation curve for dwarf galaxies in the FIRE simulation for stars, gas, and dark matter

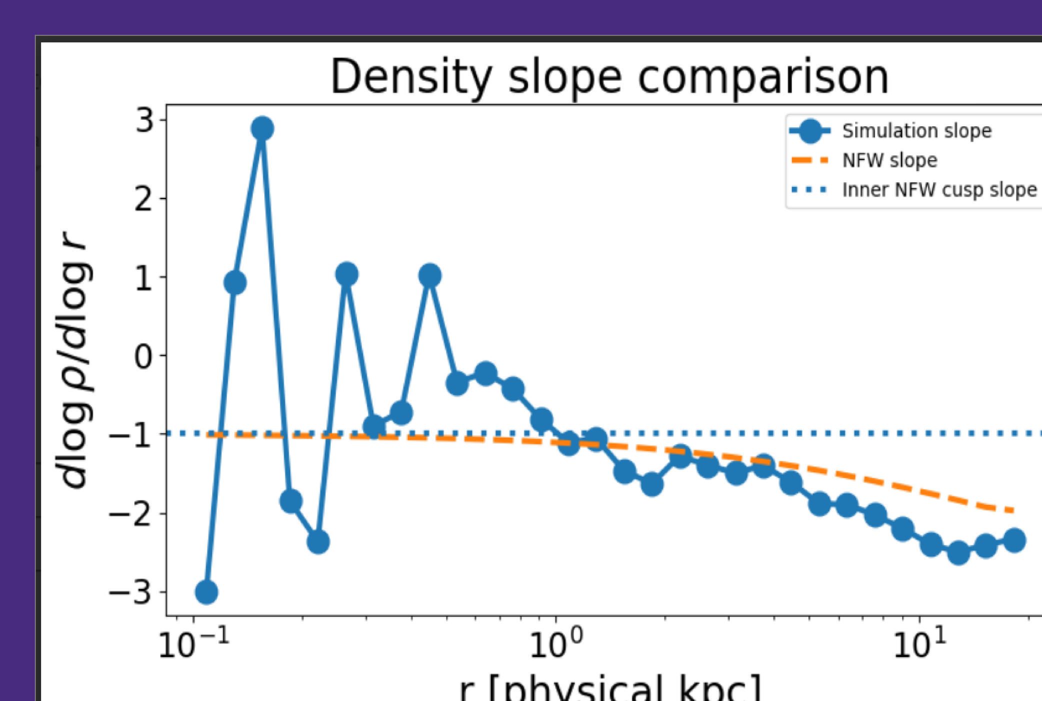






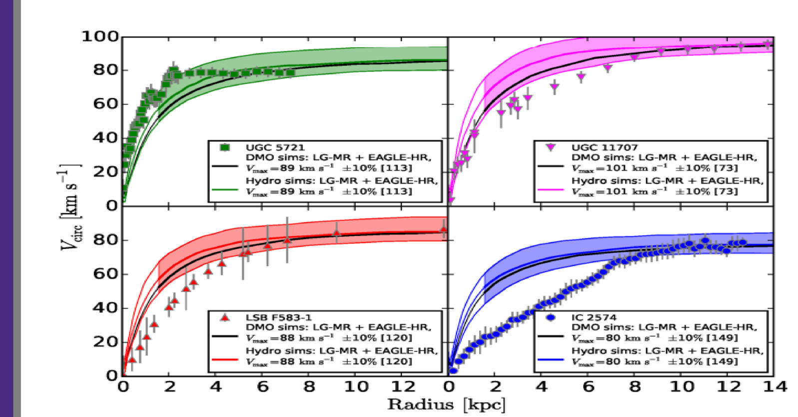


jbjSource: NASA, Dark Matter, *NASA Science*

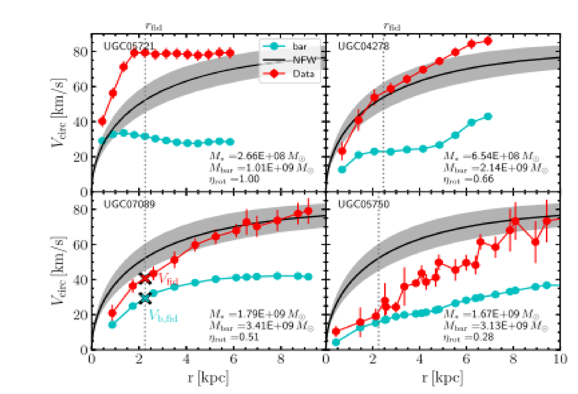


Problems with LCDM

- One main problems is that there is a diversity in the rotation curves of dwarf galaxies with the same mass
- Another problem is the core cusp problem
- The core cusp problem mainly has to deal with the fact that the simulations based on the NFW (Navarro-Frank-White) profiles do not match the observations. In fact, at smaller radii, the rotational velocity does not rise as steeply as the simulations predict – The inner slope of observed dwarfs are less steep than the predictions
- $$\rho(r) \propto \frac{1}{r(1+r/r_s)^2}$$
- The diversity problem deals with galaxies of the similar mass have a wide range of rotation curves at inner radii. According to NFW, at a given halo mass or maximum circular velocity, their inner slopes should be similar, but observations show they are noy – inner mass deficit



Diversity of Rotation Curves of Four Dwarf Galaxies with same Vmax (Oman et al. (2015)):



Cores Cusp Problem of Four Galaxies (Santos-Santos. et al. (2020)) :

Conclusion and Future Suggestions

- We still identify the same problems with the LCDM model; however, we are on track and getting closer to plotting rotation curves more closely aligned with NFW profile
- We plan on fully implementing our techniques for Illustrus as we have mostly done with FIRE-2 by honing of satellite/dwarf galaxies of the host
- In addition, we plan on expanding the number of galaxies we use for our simulations to increase the sample size

References:

- de Blok (2010) - ***"The Core–Cusp Problem."***
- Oman et al. (2015) - "The unexpected diversity of dwarf galaxy rotation curves."
- Wetzel et al. (2023) - *"The FIRE-2 Public Data Release."*
- Hopkins, P. F. (2015). *"A new class of accurate, mesh-free hydrodynamic simulation methods."*
- Santos-Santos, I. M. E. et al. (2020) -. *Baryonic clues to the puzzling diversity of dwarf galaxy rotation curves*