Calibrating Galaxy Mass Modeling Methods with Numerical Simulations

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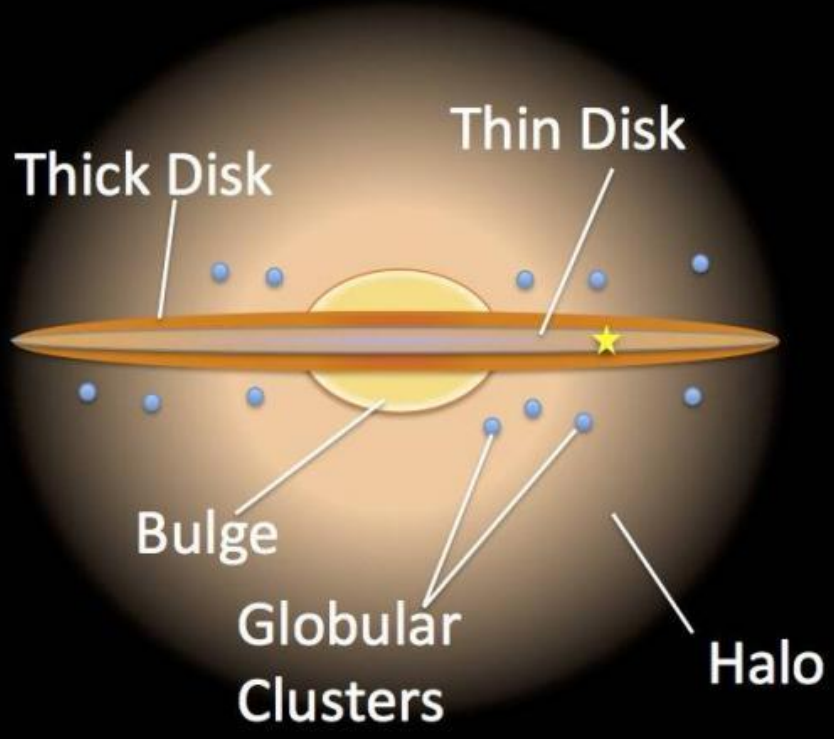
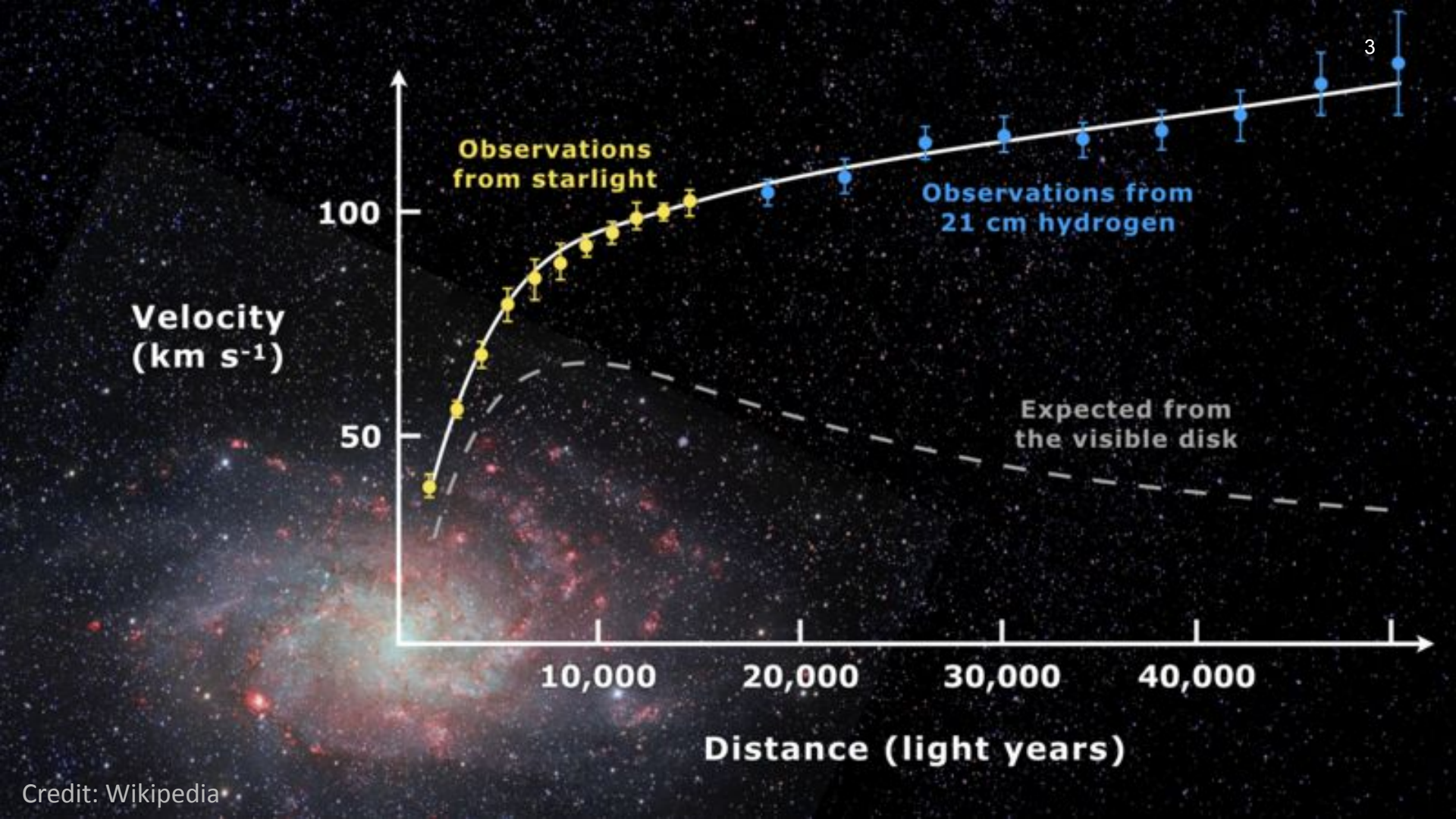


Credit: https://www.sci.news/



Credit: Wikipedia

Problems in Tracking the Missing Matter

$$m_{tot}(R) = m_{stars}(R) + m_{gas}(R) + m_{DM}(R)$$

$$V(R) = \sqrt{\frac{GM(R)}{R}}$$

$$V_{DM} = \sqrt{V_{circ}^2 - V_{stars}^2 - V_{gas}^2}$$

Problems in Tracking the Missing Matter

$$m_{tot}(R) = m_{stars}(R) + m_{gas}(R) + m_{DM}(R)$$

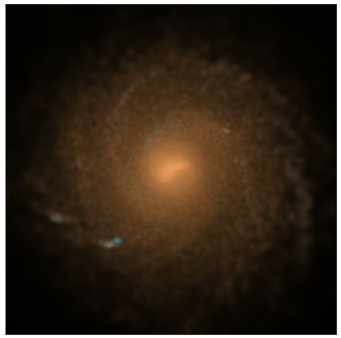
Limited knowledge of the "Ground Truth":

- Mass-to-light ratio
- Dust content
- Projection effects
- Intrinsic component shapes
- Non-circular motions
- Sampling issues
- Model assumptions
- etc.

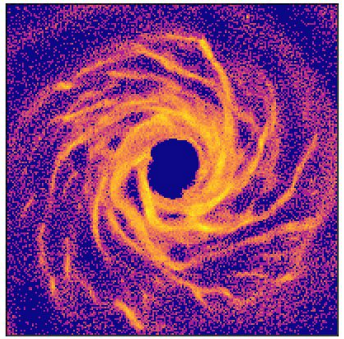
Credit: https://esawebb.org/

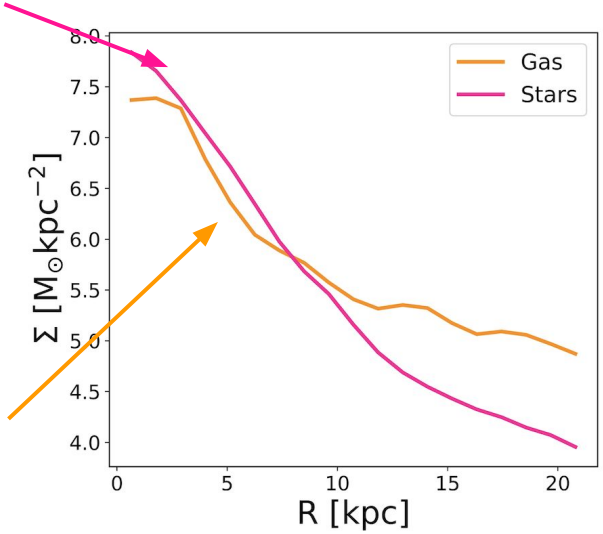
Cosmological Hydrodynamical Simulations

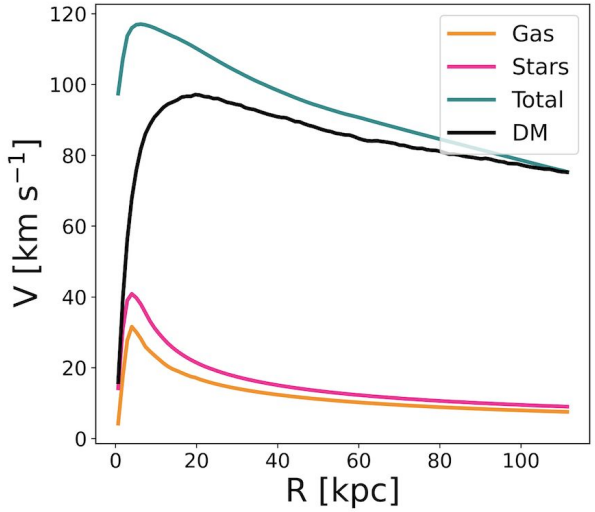
Stars



Gas







Definitions

- Rotational Velocity*: Line-of-sight (LOS) velocity through Doppler shift

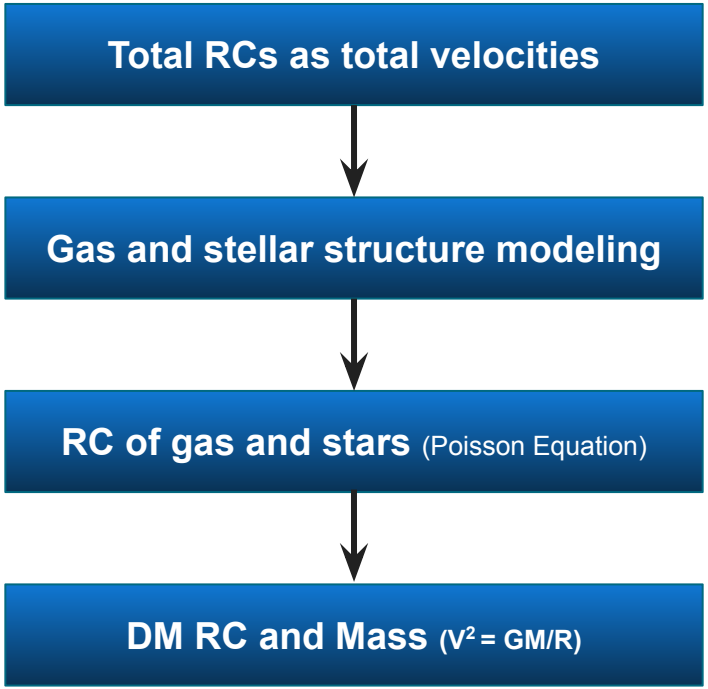
  ($V(R) = \sqrt{\frac{GM(R)}{R}}$)

- Circular velocity: Extracted from the gravitational potential

  ($v^2(R) = R\frac{d\phi}{dR}$)

*Note: All galaxies aligned edge-on

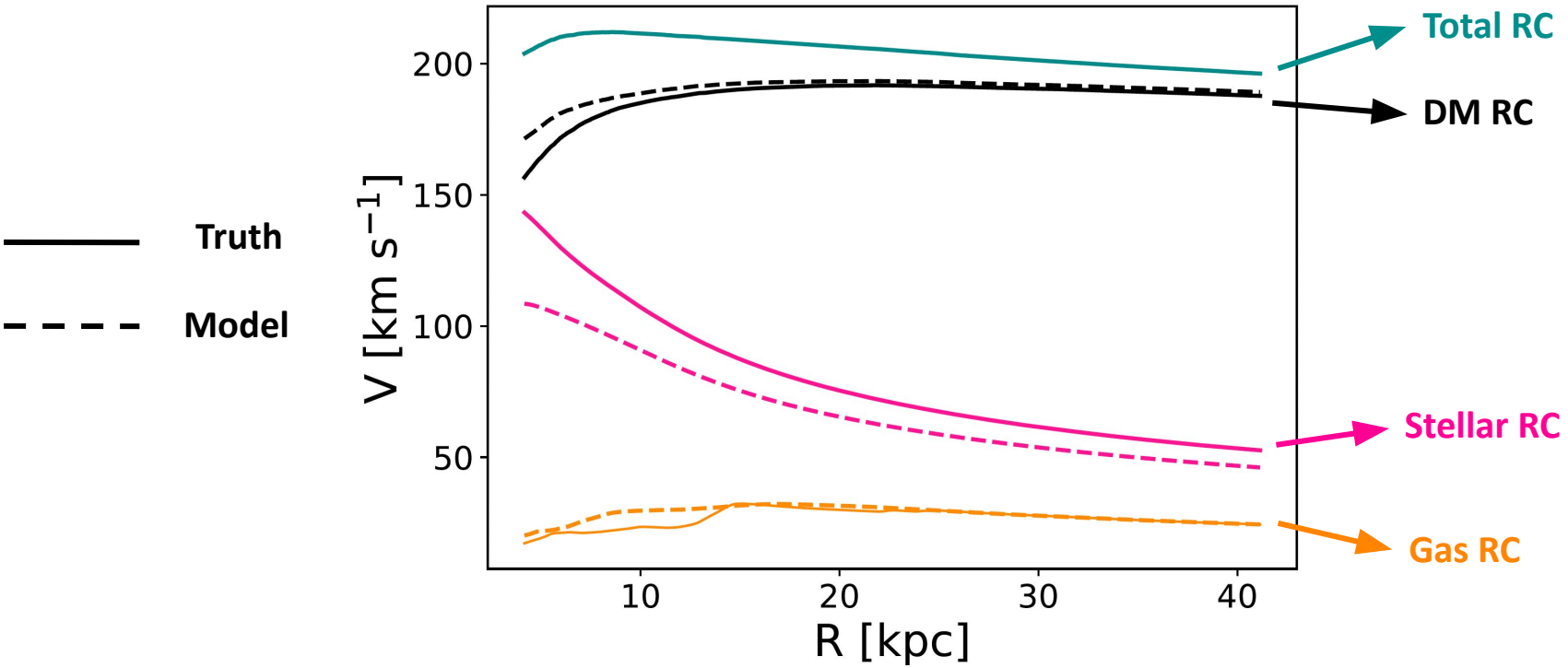
Methods: Velocity space



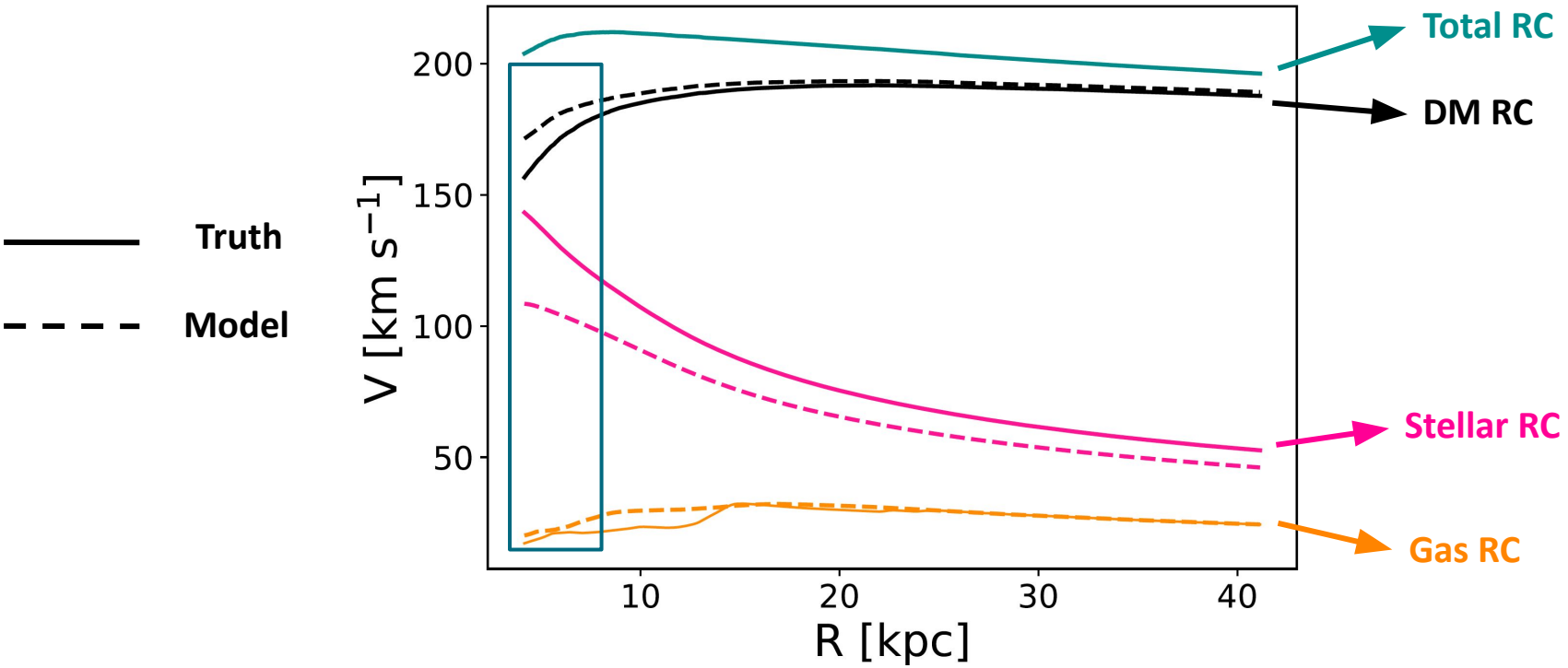
Assumptions:

- Neglect non-circularities (motion only from modeled potential)
- Structural assumptions
- Neglect velocity dispersion
- Virialized DM halo

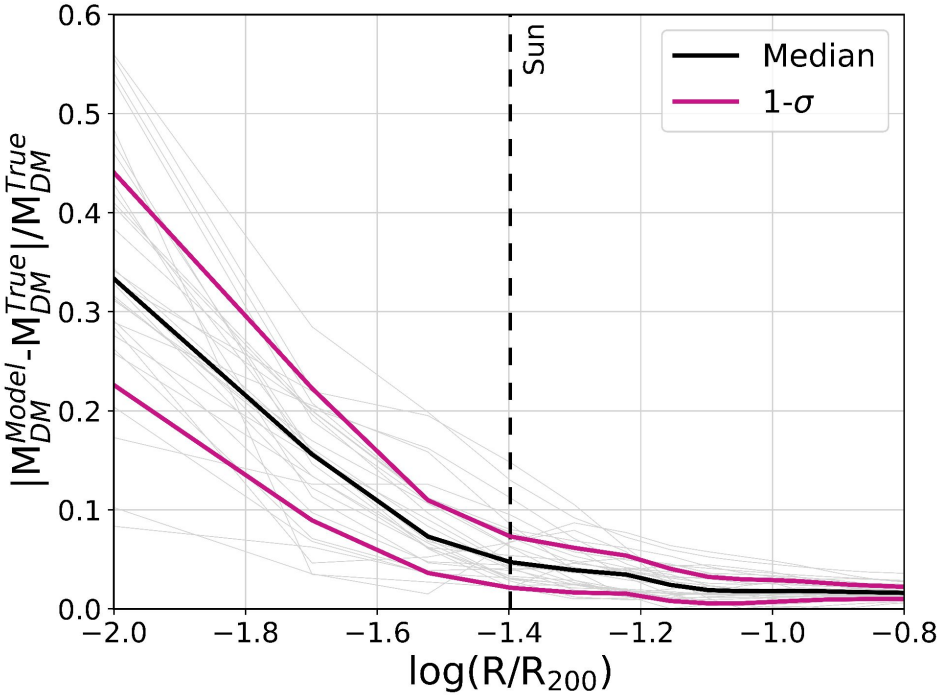
Rotation Curves



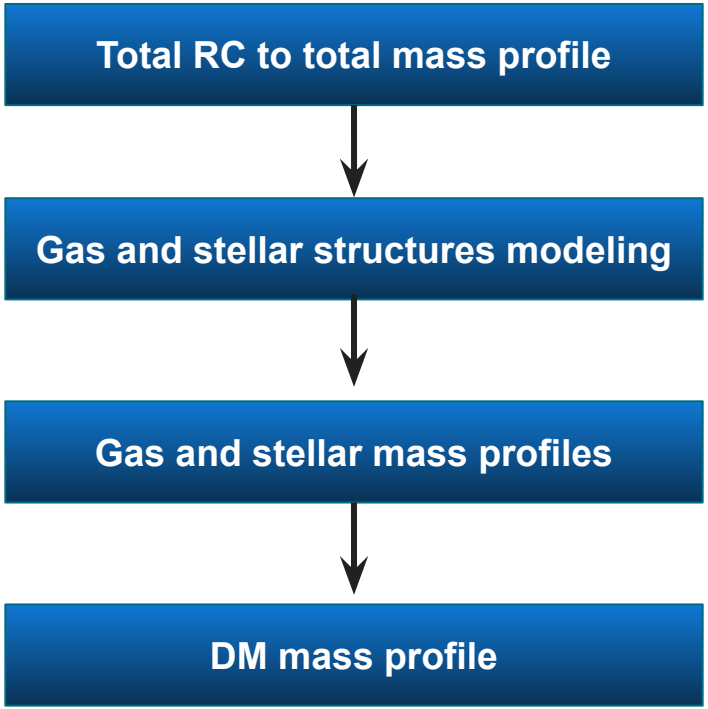
Rotation Curves



Velocity Space: Dark Matter mass Offset



Methods: Mass Space

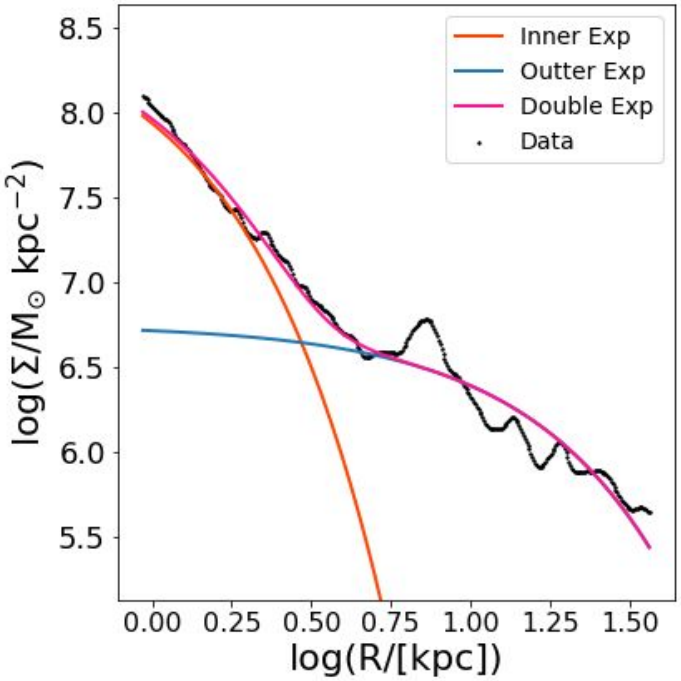


Assumptions:

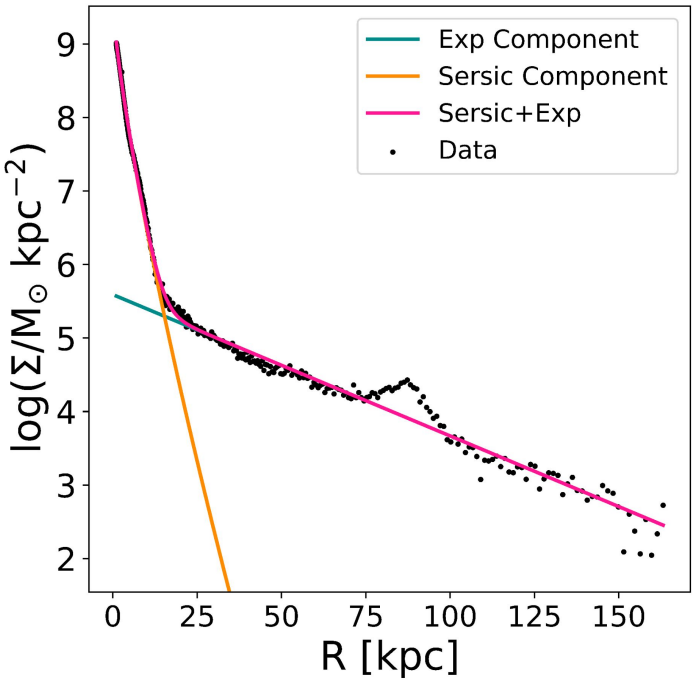
- Spherically symmetric mass distribution
- Neglect non-circularities
- Structural assumptions

Mass space: gas and stars

Gas Profile, Double Exponential Fit

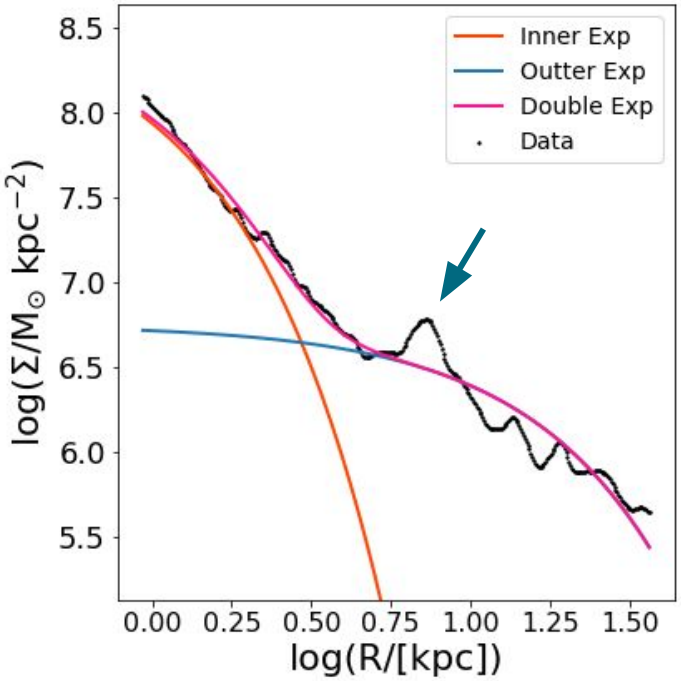


Stellar Profile, Sersic + Exp Fit

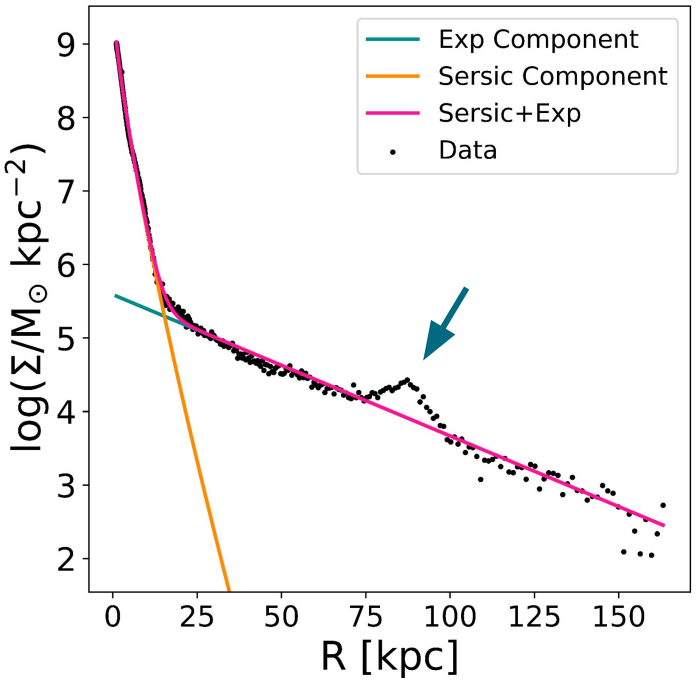


Mass space: gas and stars

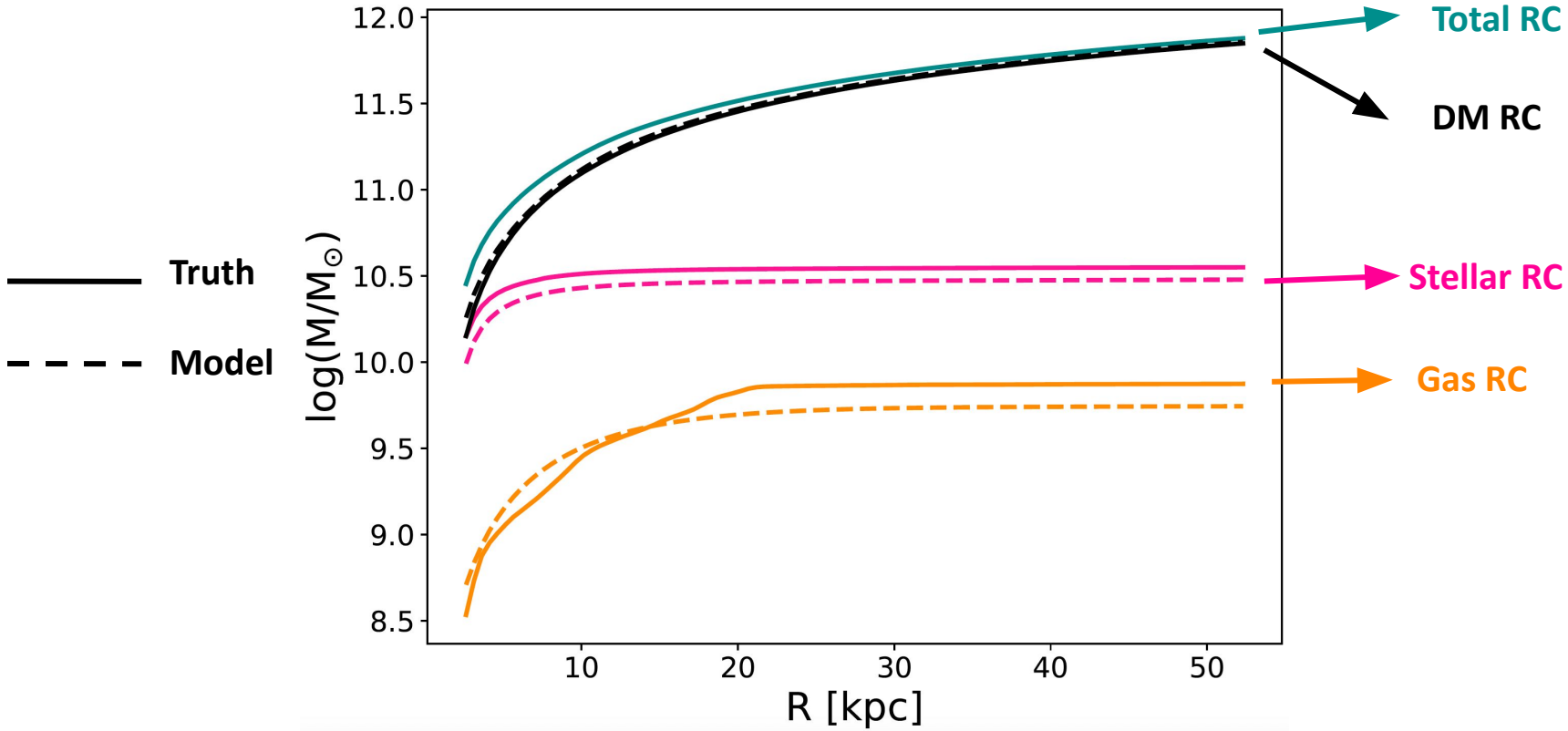
Gas Profile, Double Exponential Fit



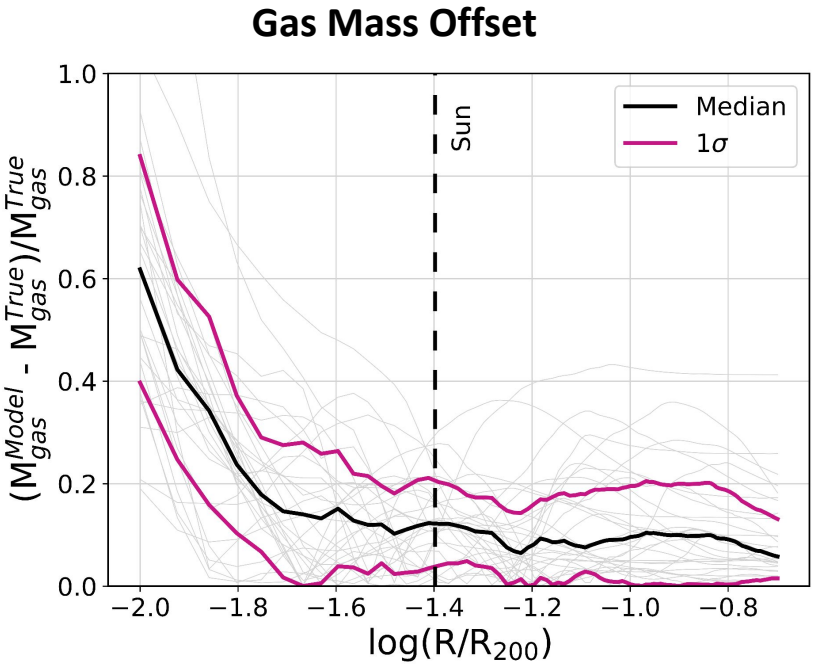
Stellar Profile, Sersic + Exp Fit

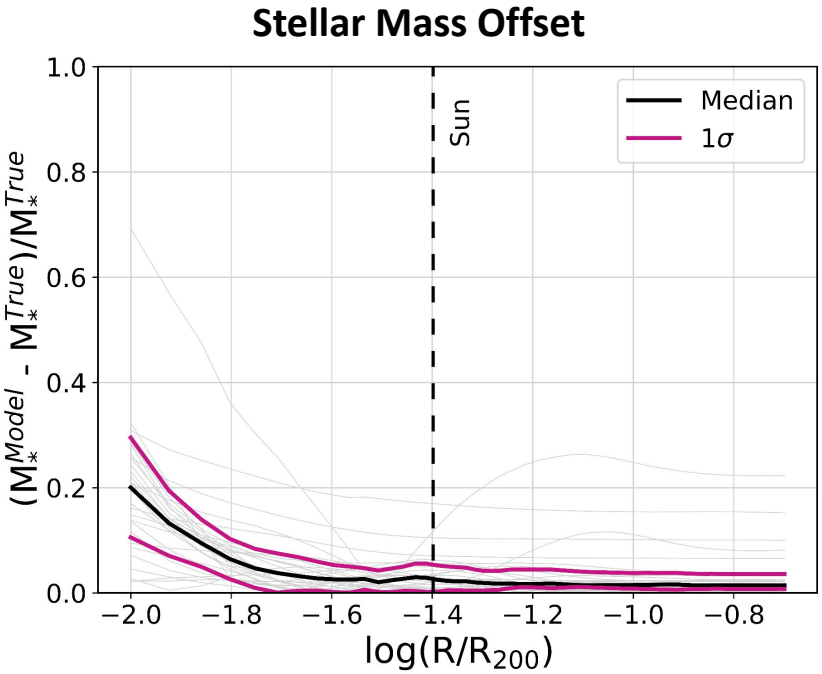


Mass Profiles

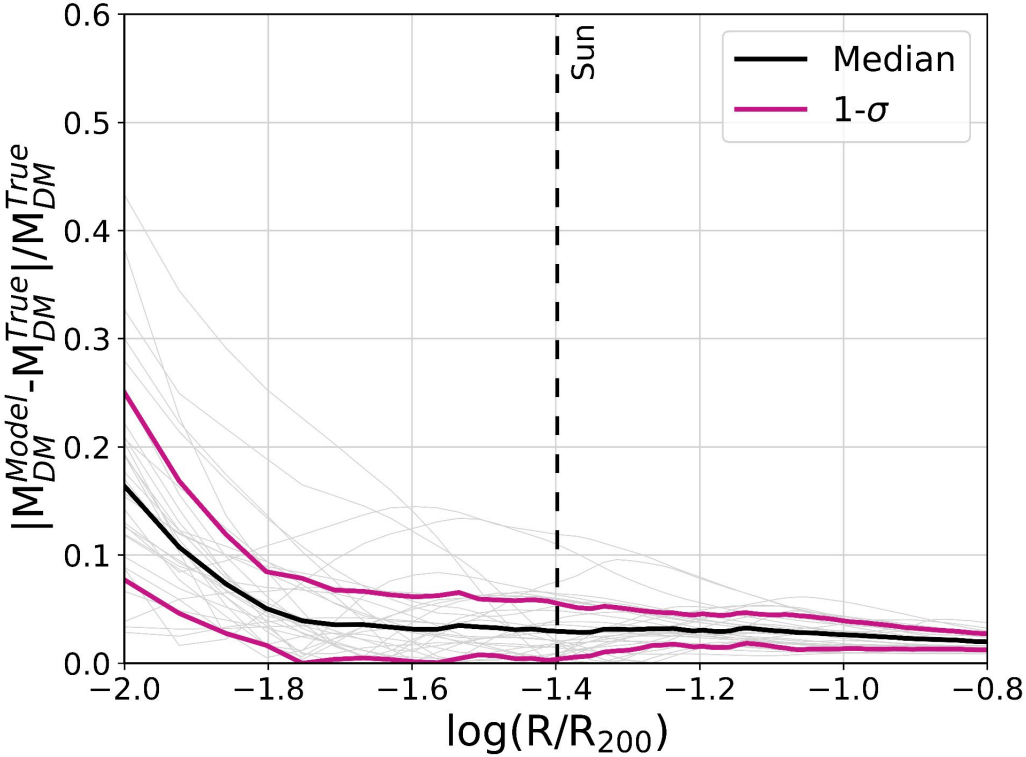


Modeled Gas and Stars Mass Offset





Mass Space: Dark Matter offset



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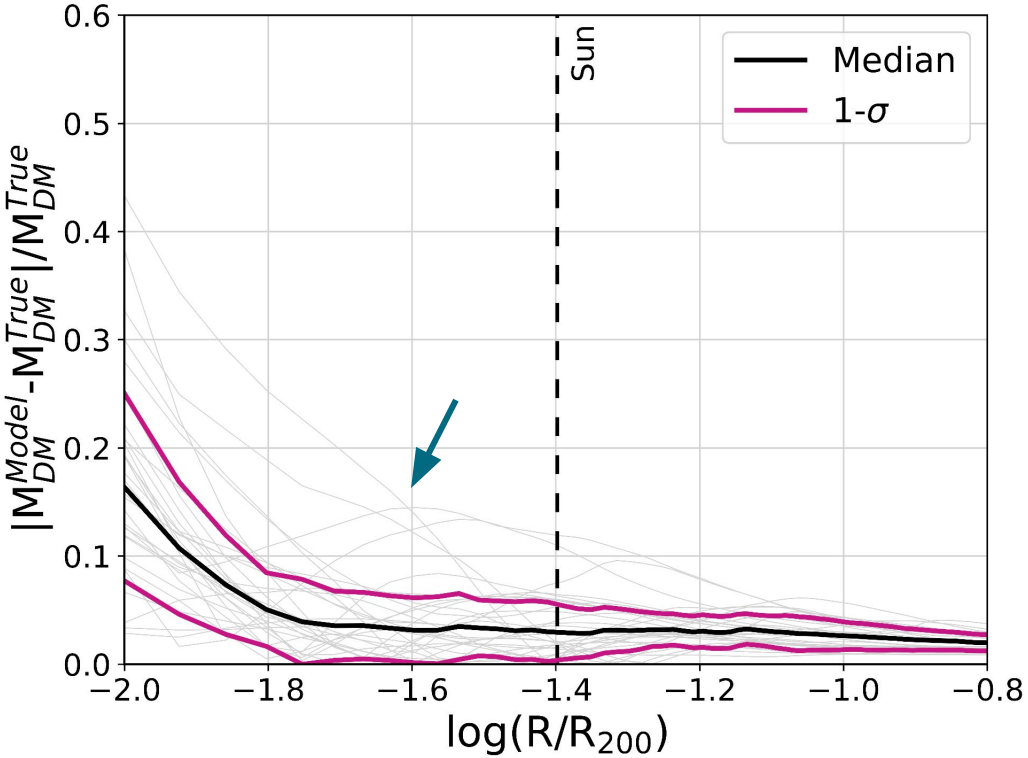
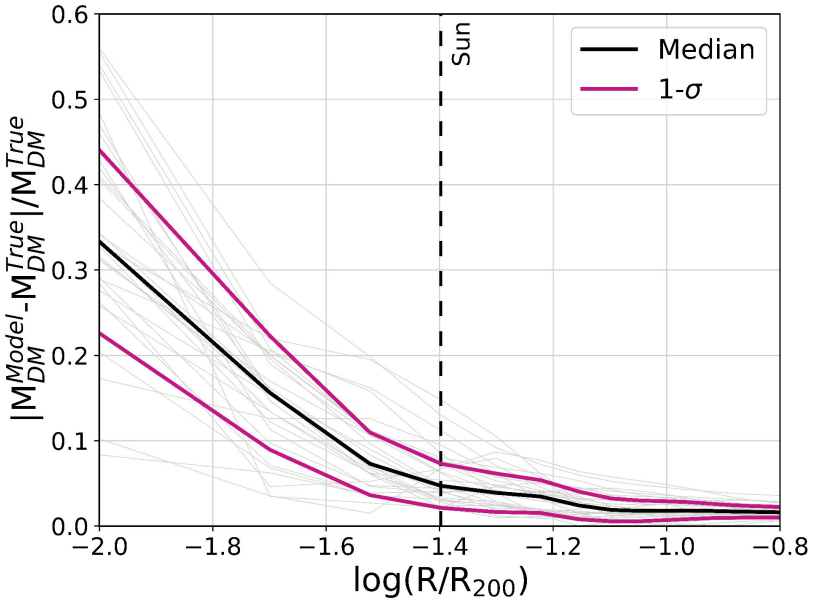
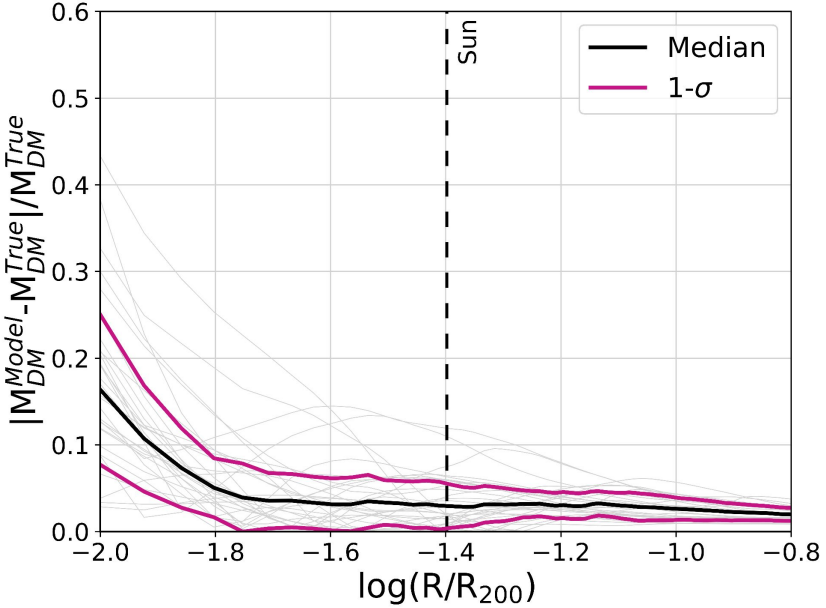


Method Comparison

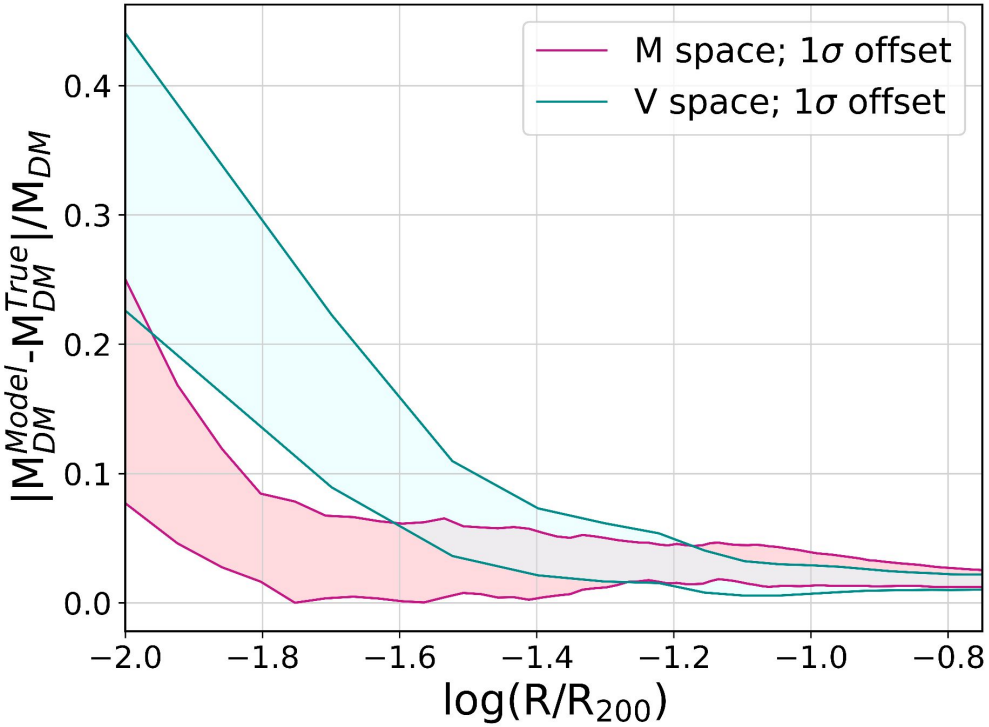
Velocity Space



Mass Space



Method Comparison



Conclusions

Standard mass modeling techniques shown to work well…

- Especially at large R where model discrepancies are dominated by observational errors
- At small R, model discrepancies are dominated by non-circular motions and structural assumptions (e.g., B/D models)
- Our analysis preferred extracting DM mass using mass space method compared to the velocity space method (improperly modeled bulges)

Thank You!

Non-Circular motion