

Looking for the Dark through the Light

Xiuyuan Zhang,

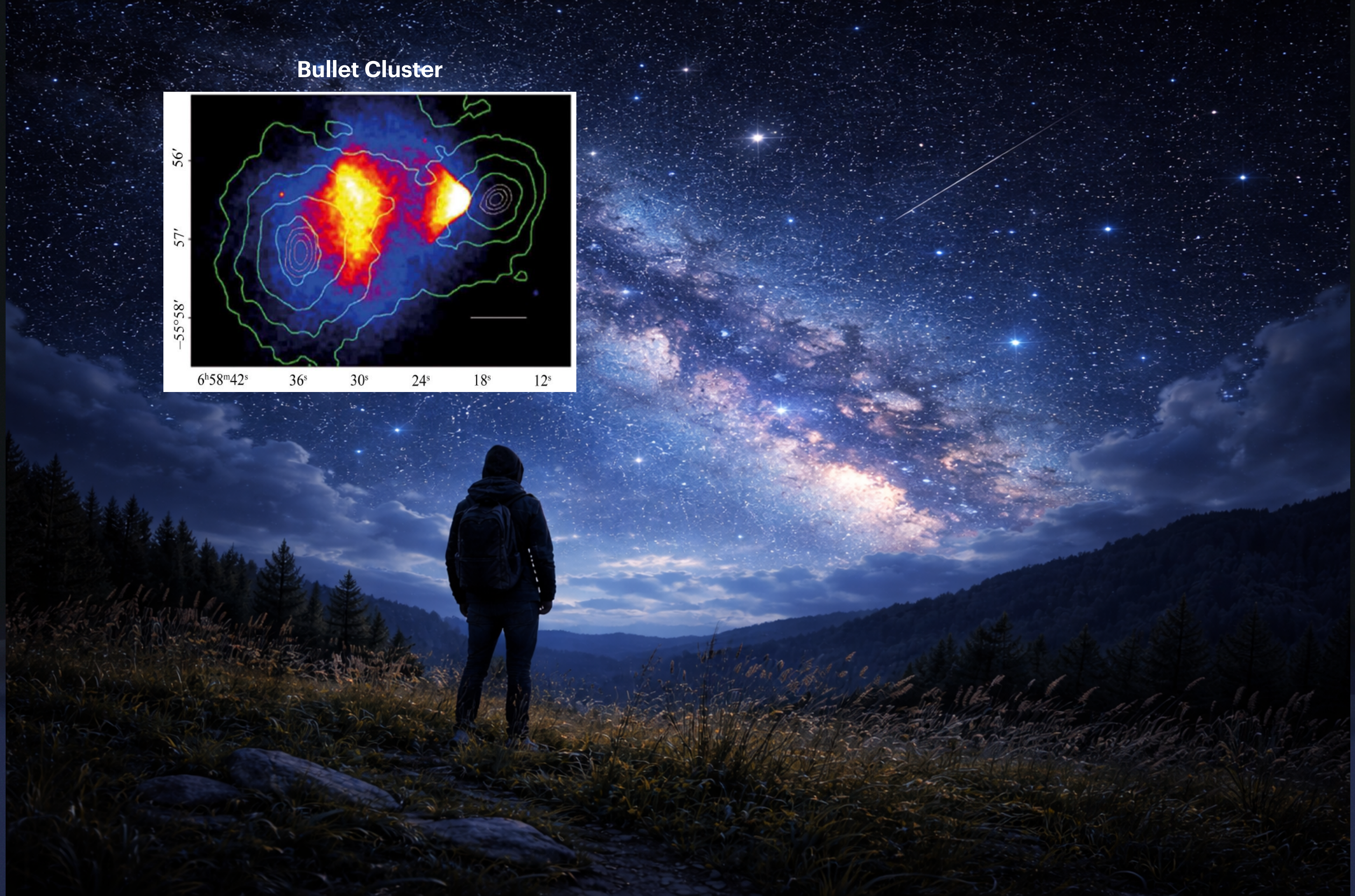
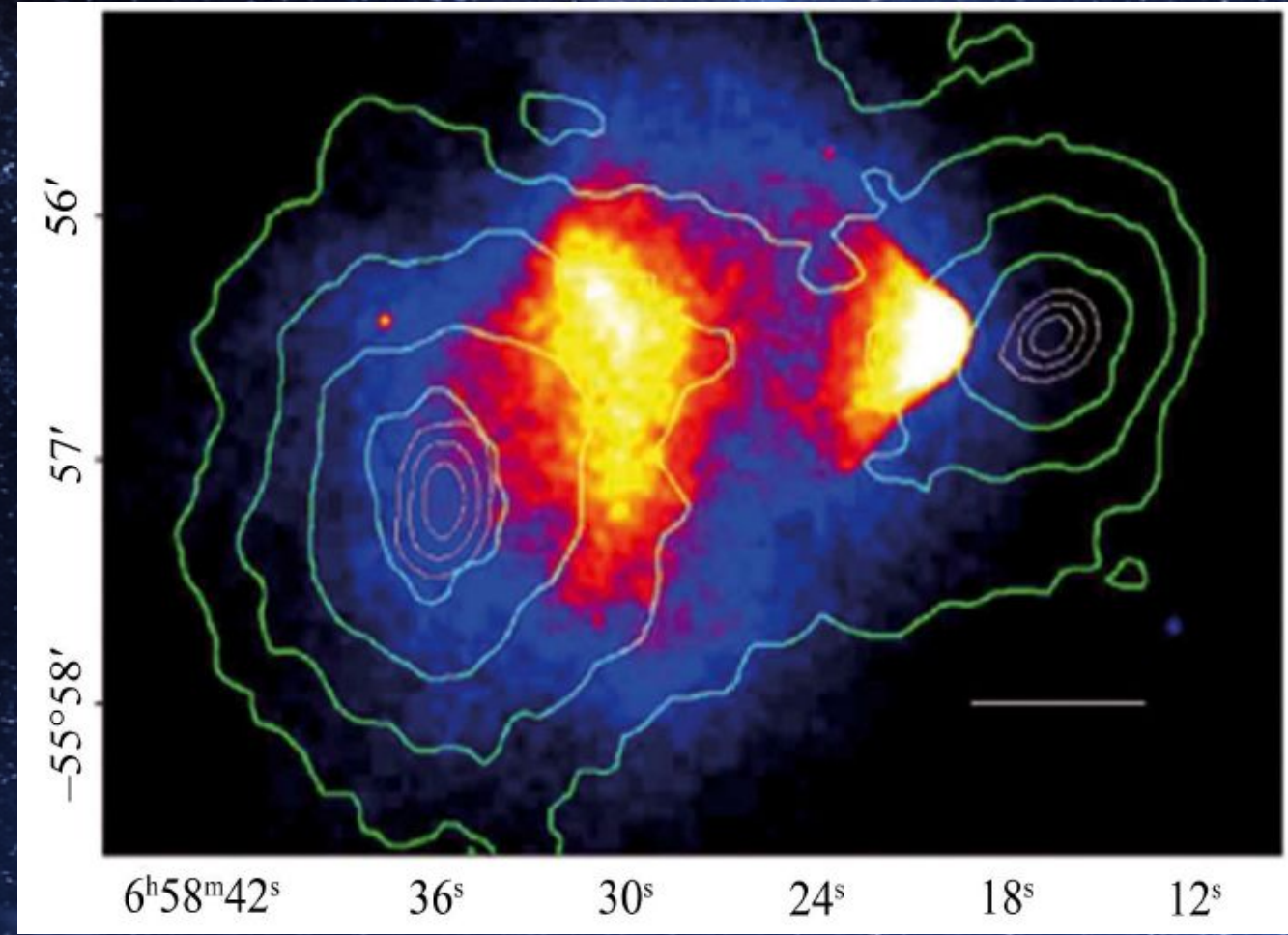
Based on work with Andreas Thoyas, Lina Necib, Andrew Wetzel and
Arpit Arora: 2603.25783

MIT / FIRE Collaboration

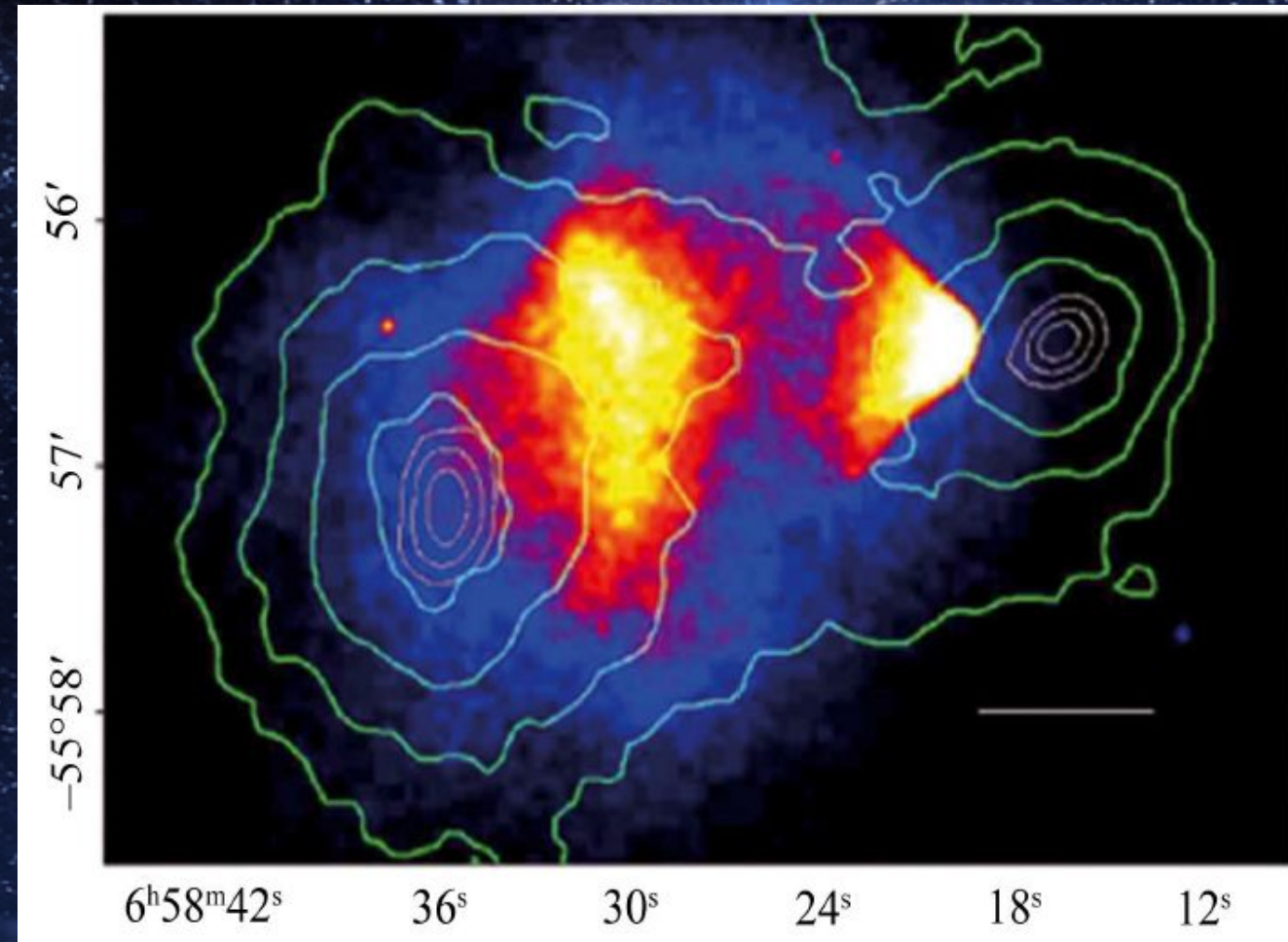




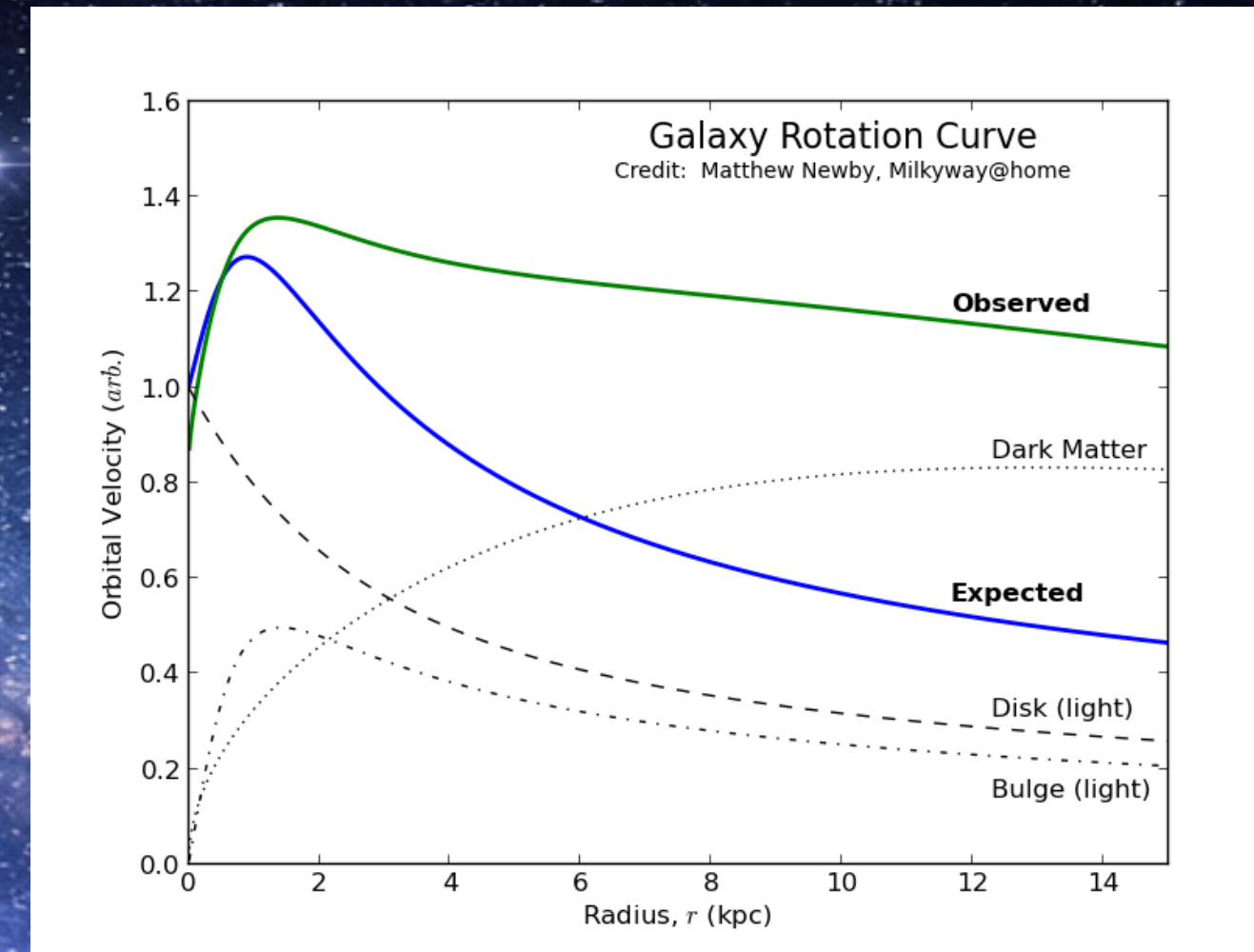
Bullet Cluster



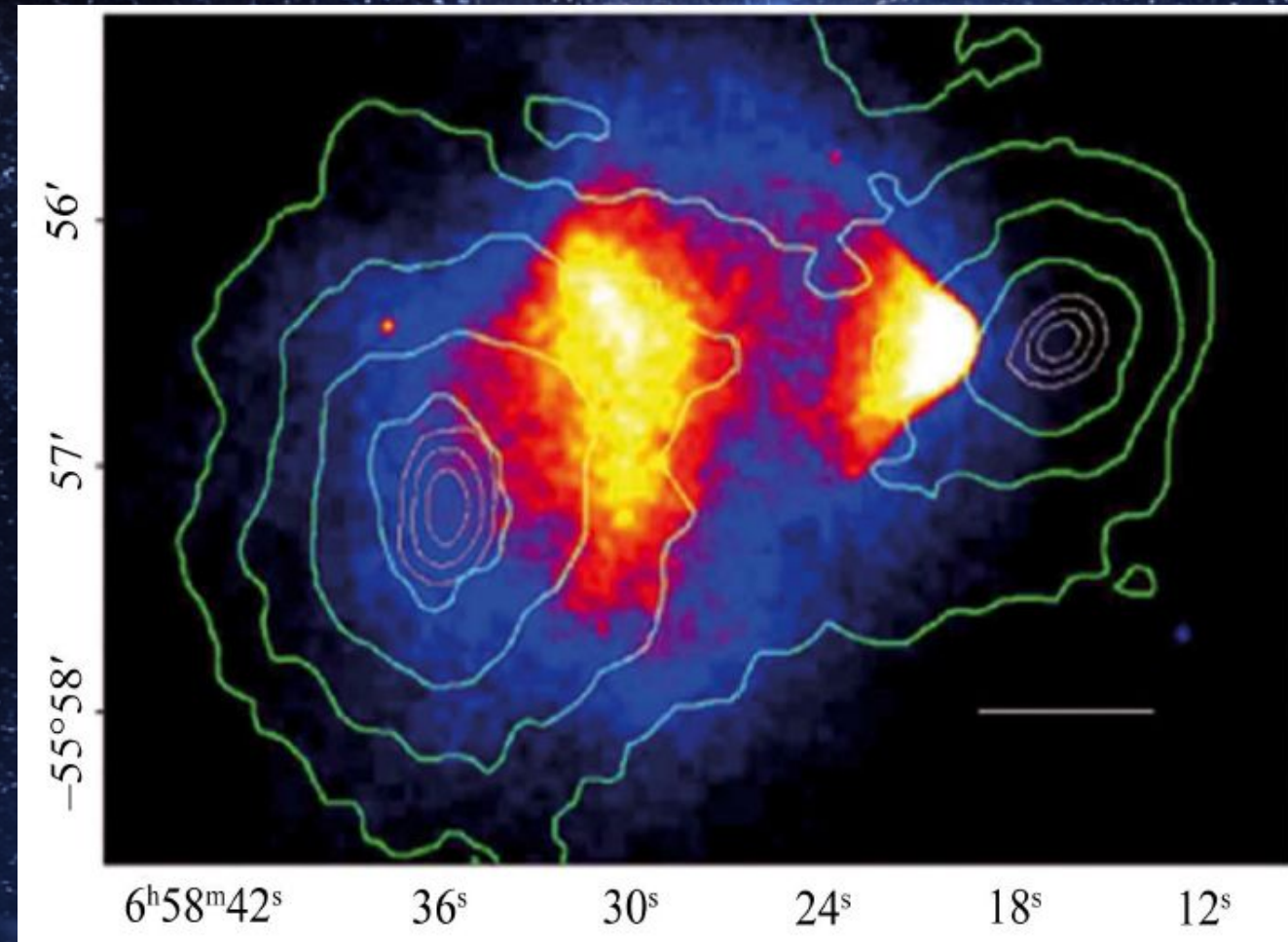
Bullet Cluster



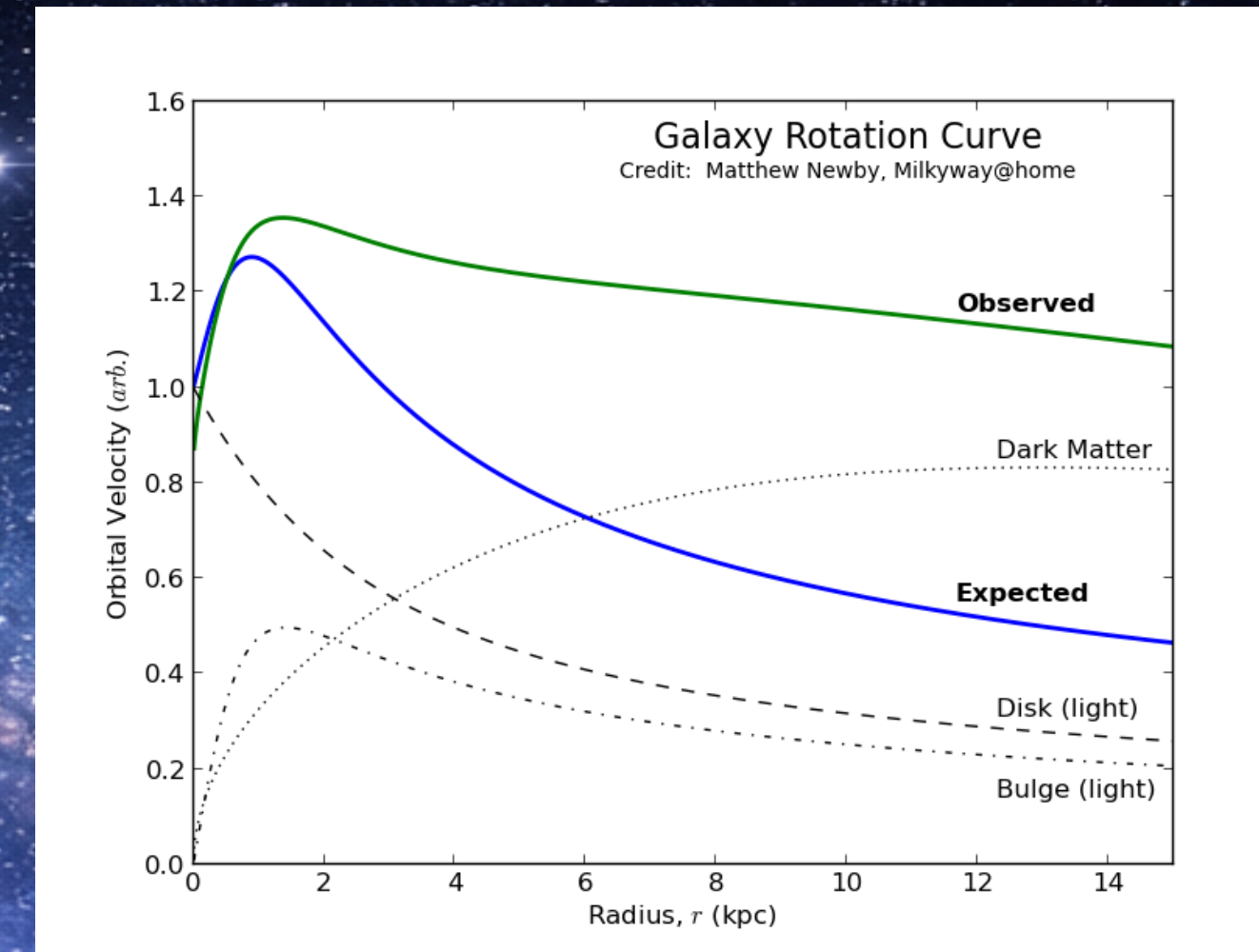
Rotation Curve



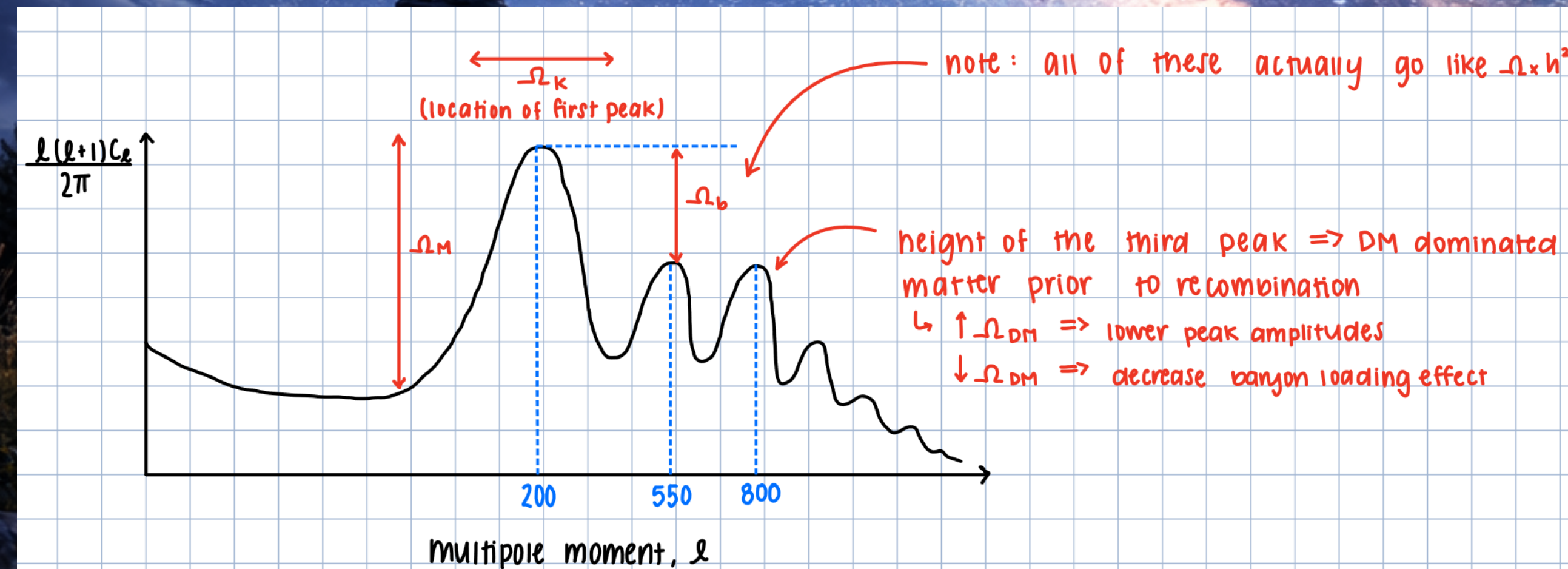
Bullet Cluster



Rotation Curve

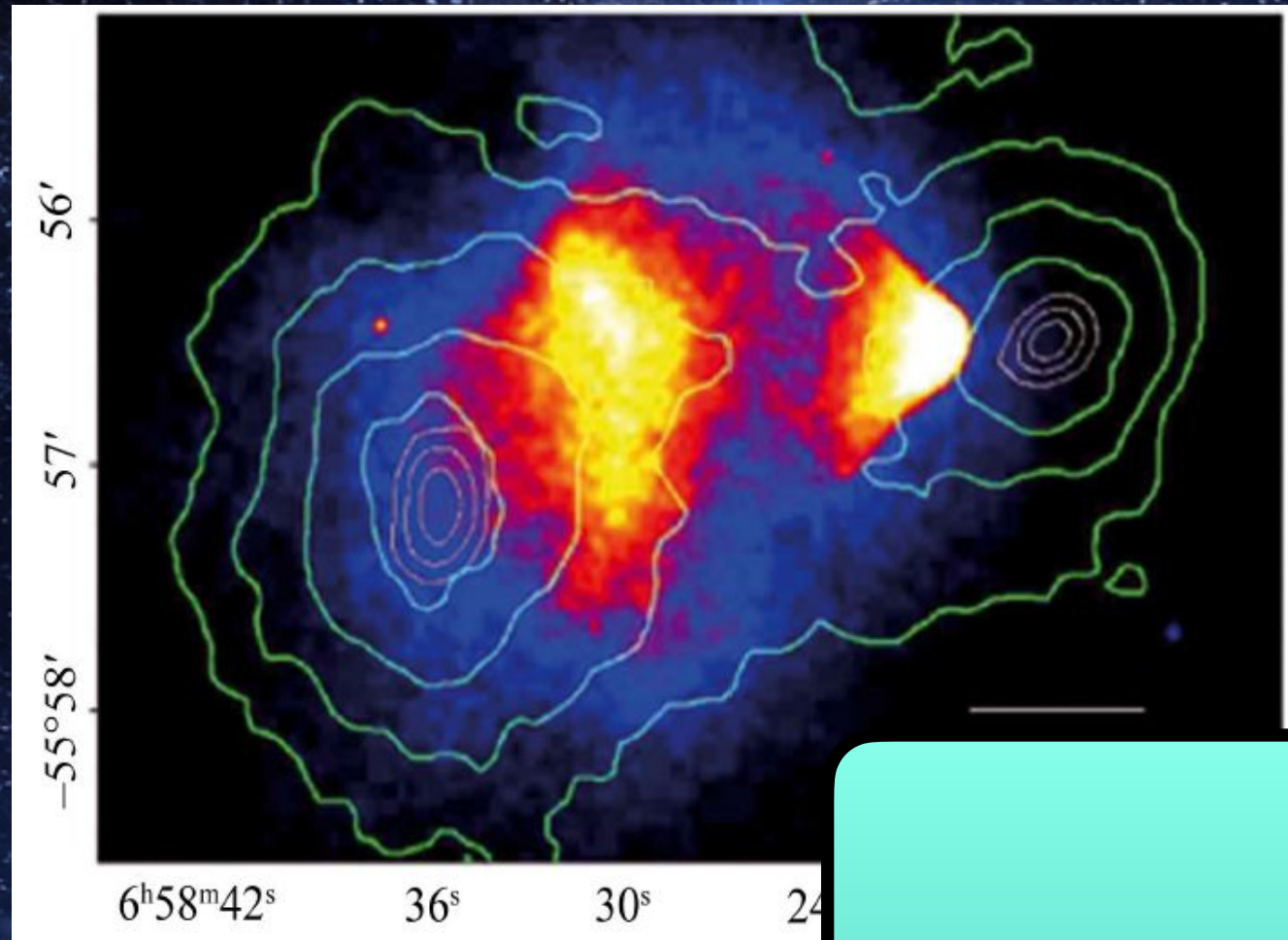


CMB

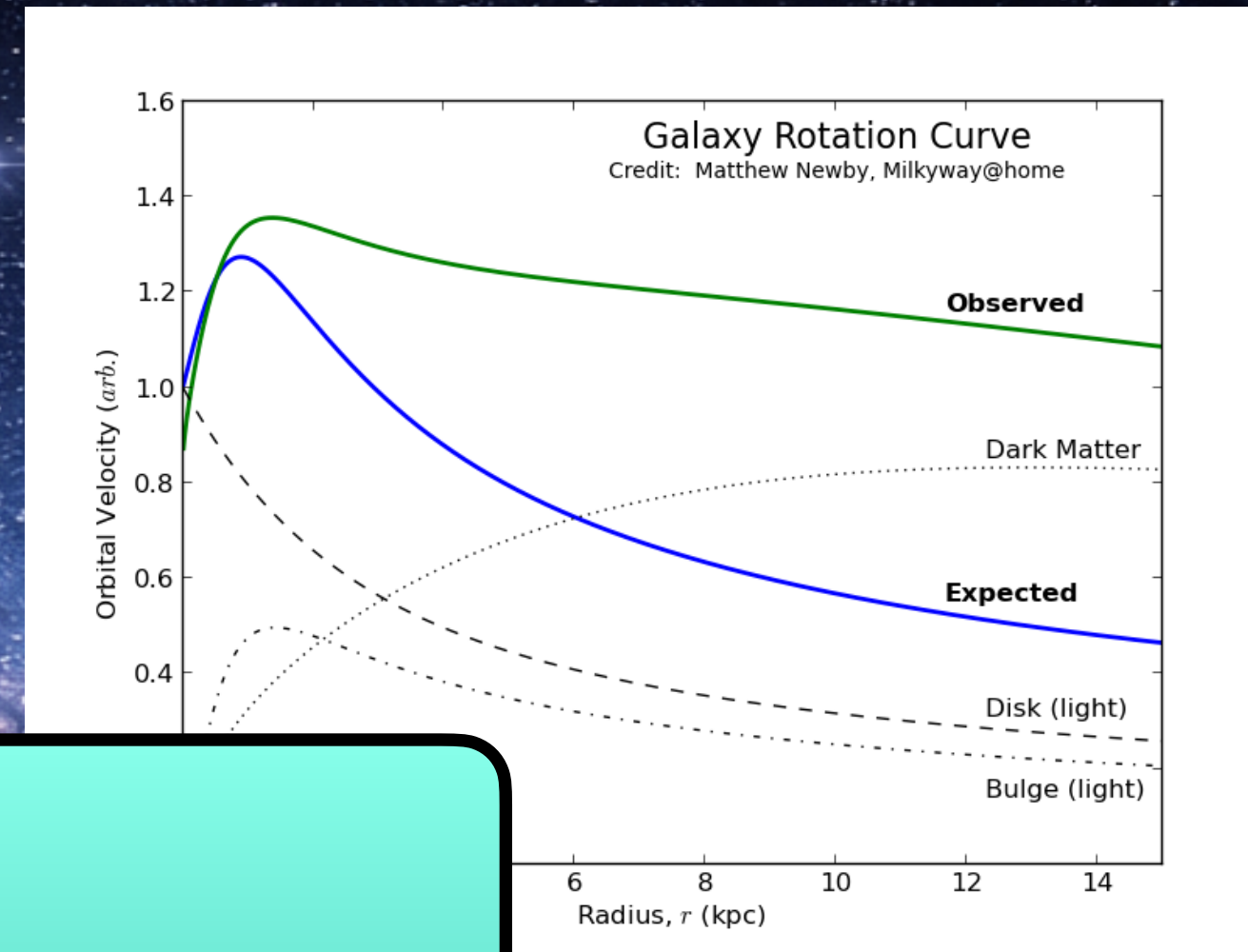


Megan Materson: astrowiki

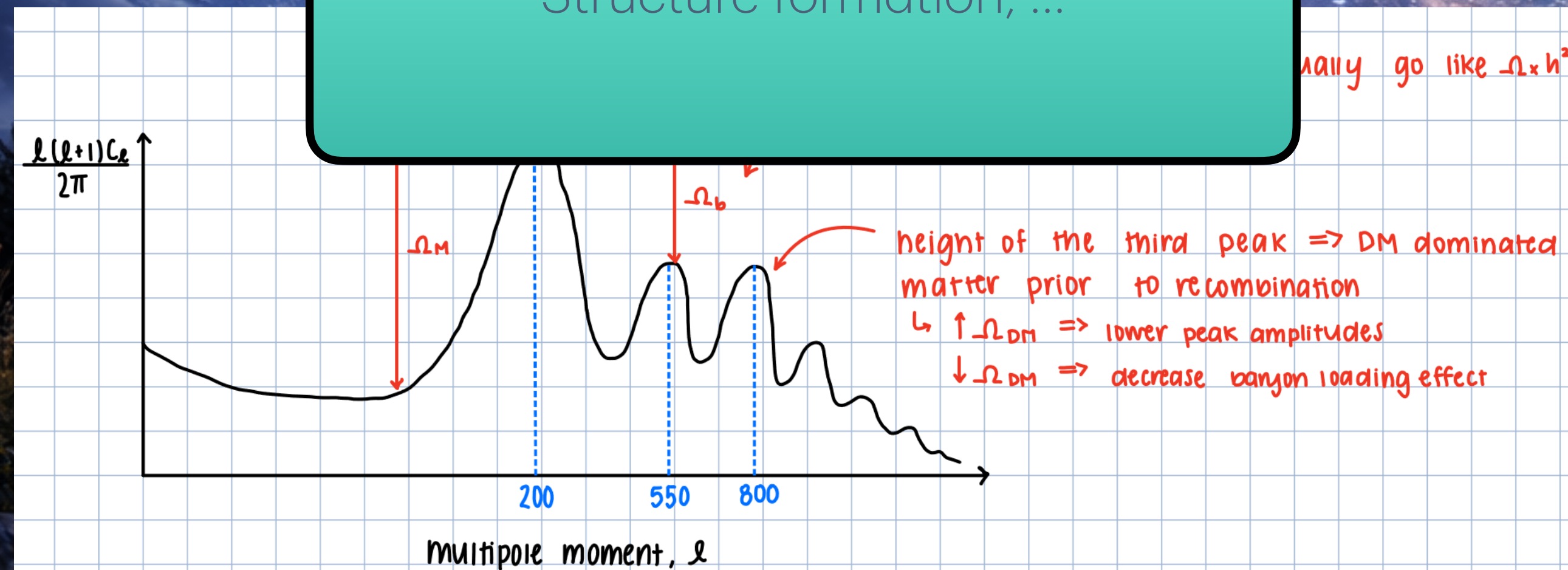
Bullet Cluster



Rotation Curve

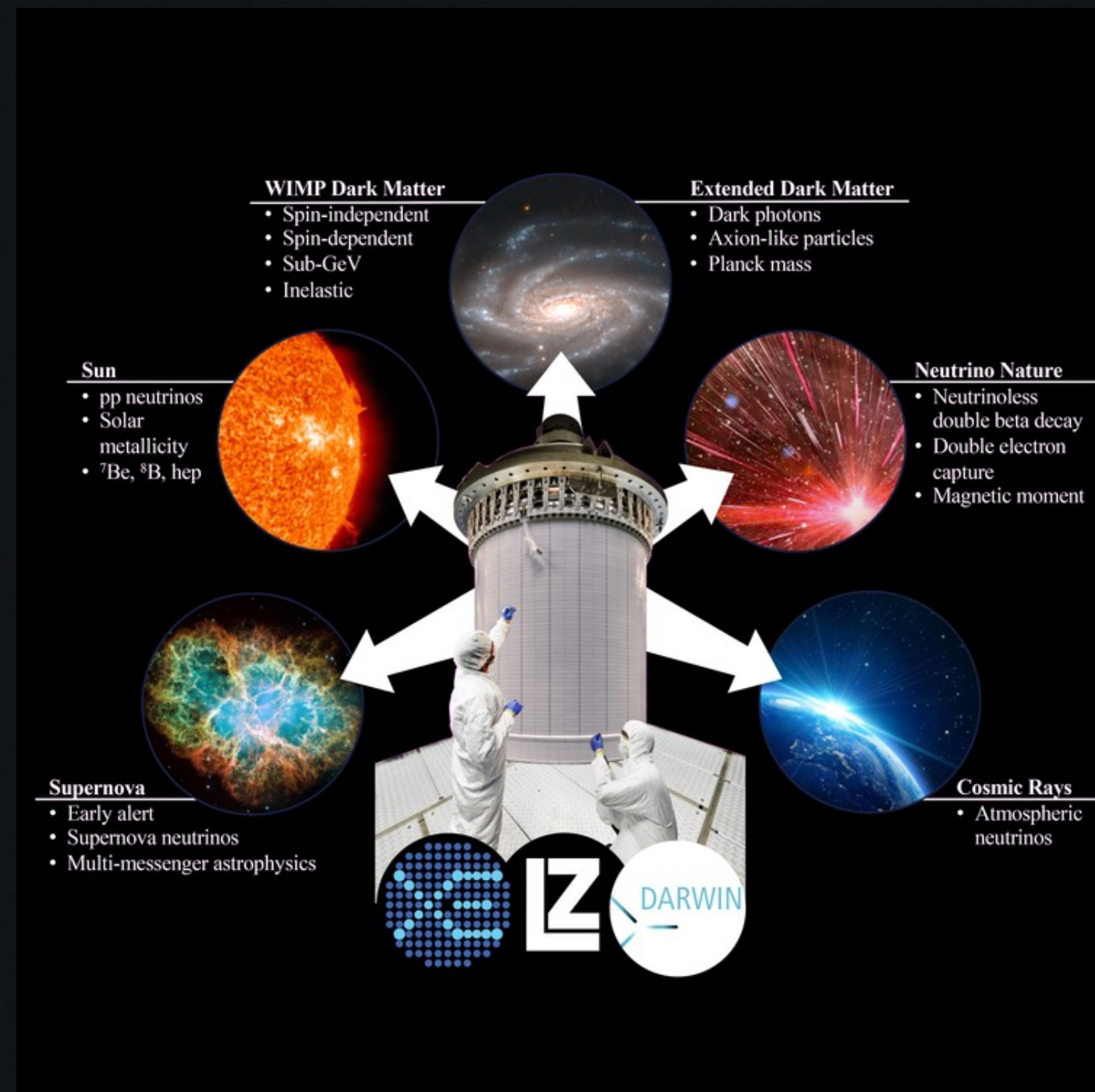


And so much more!
Velocity dispersion, Lyman Alpha,
Structure formation, ...



Megan Materson: astrowiki

Direct Detection



Credit: XLZD

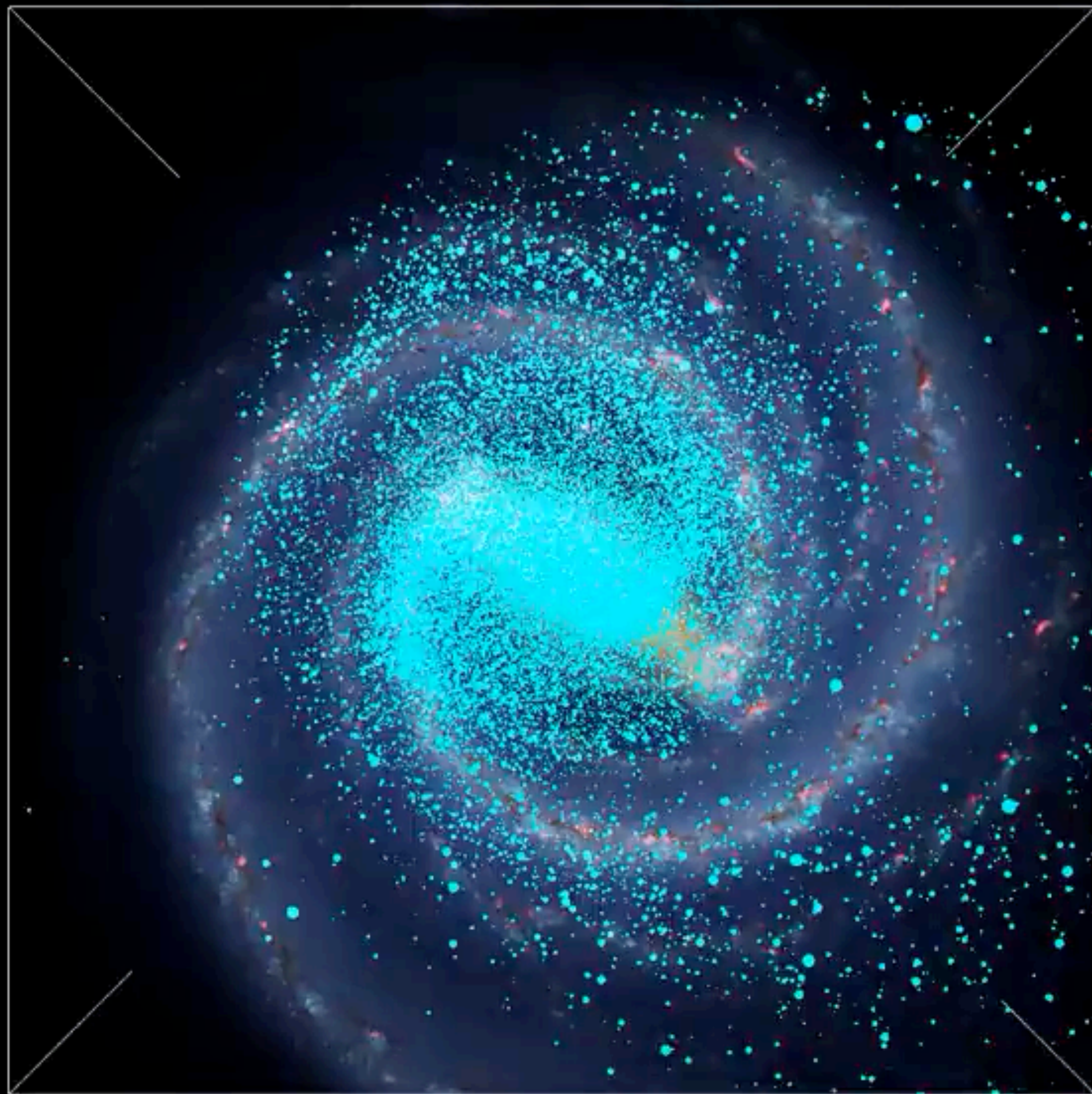
Axion Detection



Credit: ABRACADABRA

$$\frac{dR_{dd}}{dQ} = \frac{\sigma\rho}{2m_\chi m_r^2} F(Q)^2 \int \frac{f(v)}{v} dv$$

$$a(t) = \frac{\sqrt{\rho}}{m_a} \int \sqrt{f(v)} \cos\left[m_a\left(1 + \frac{v^2}{2}\right)t + \phi t\right] dv$$

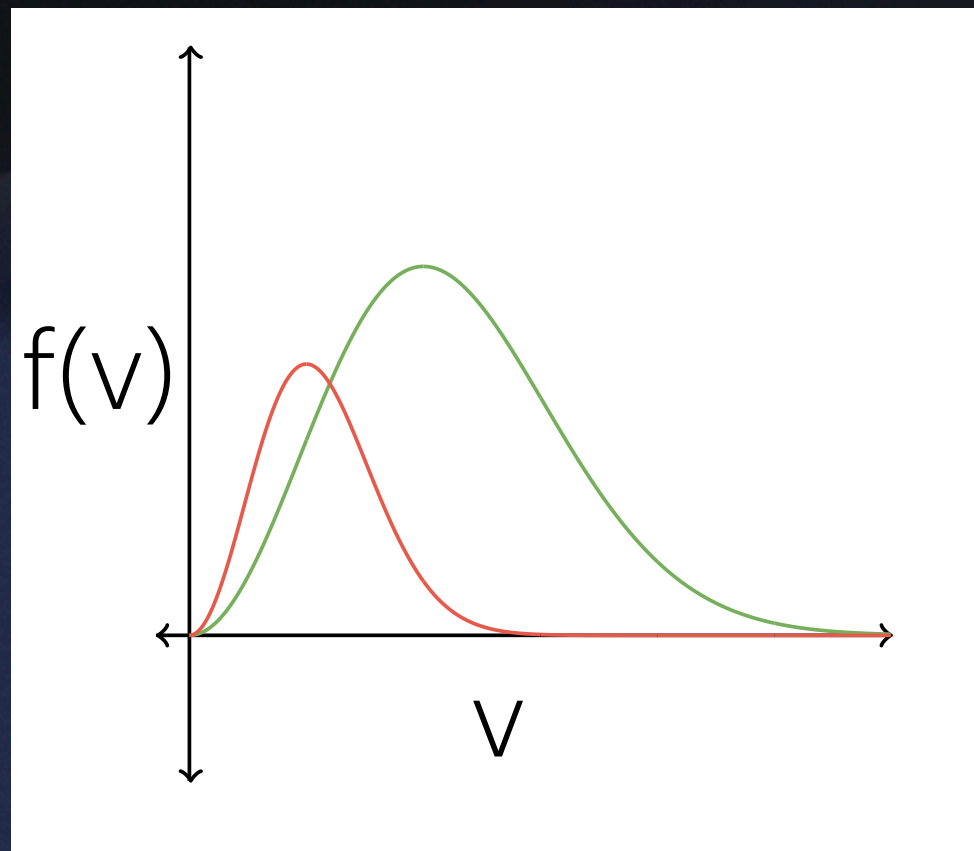
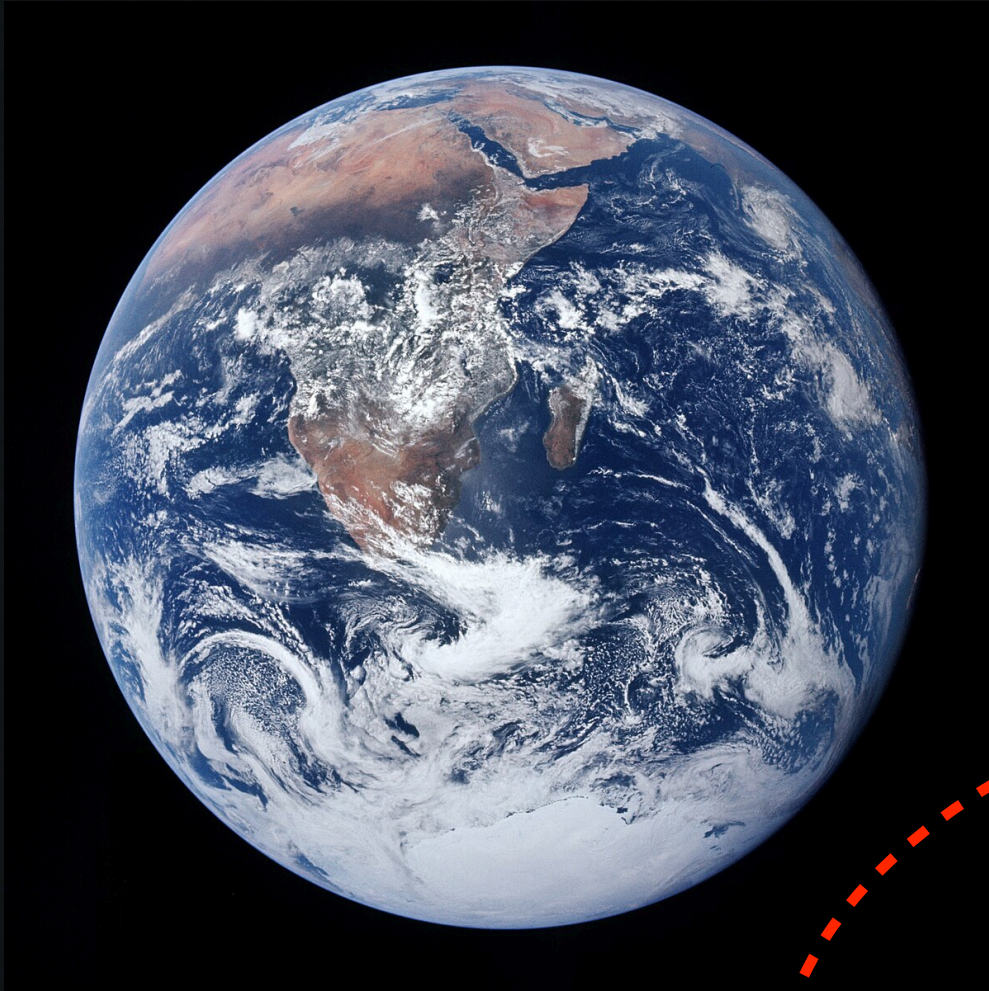


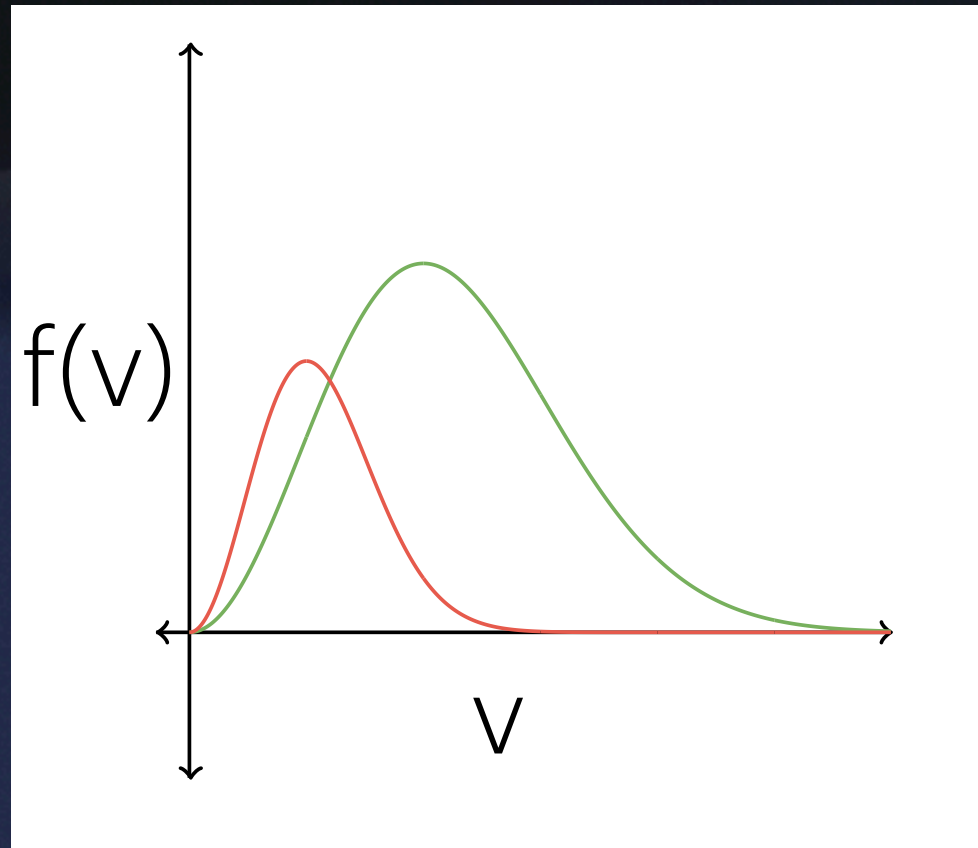
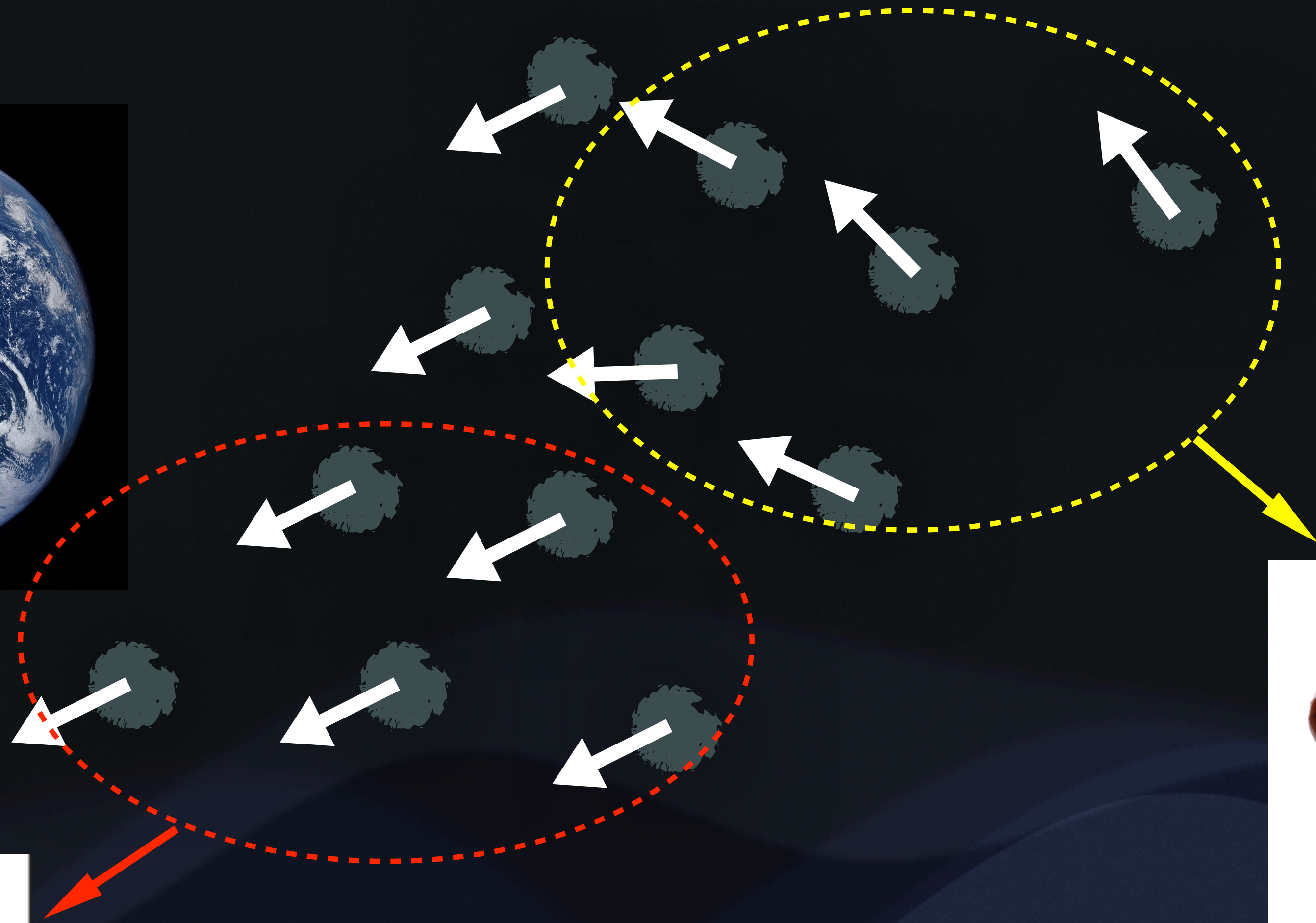
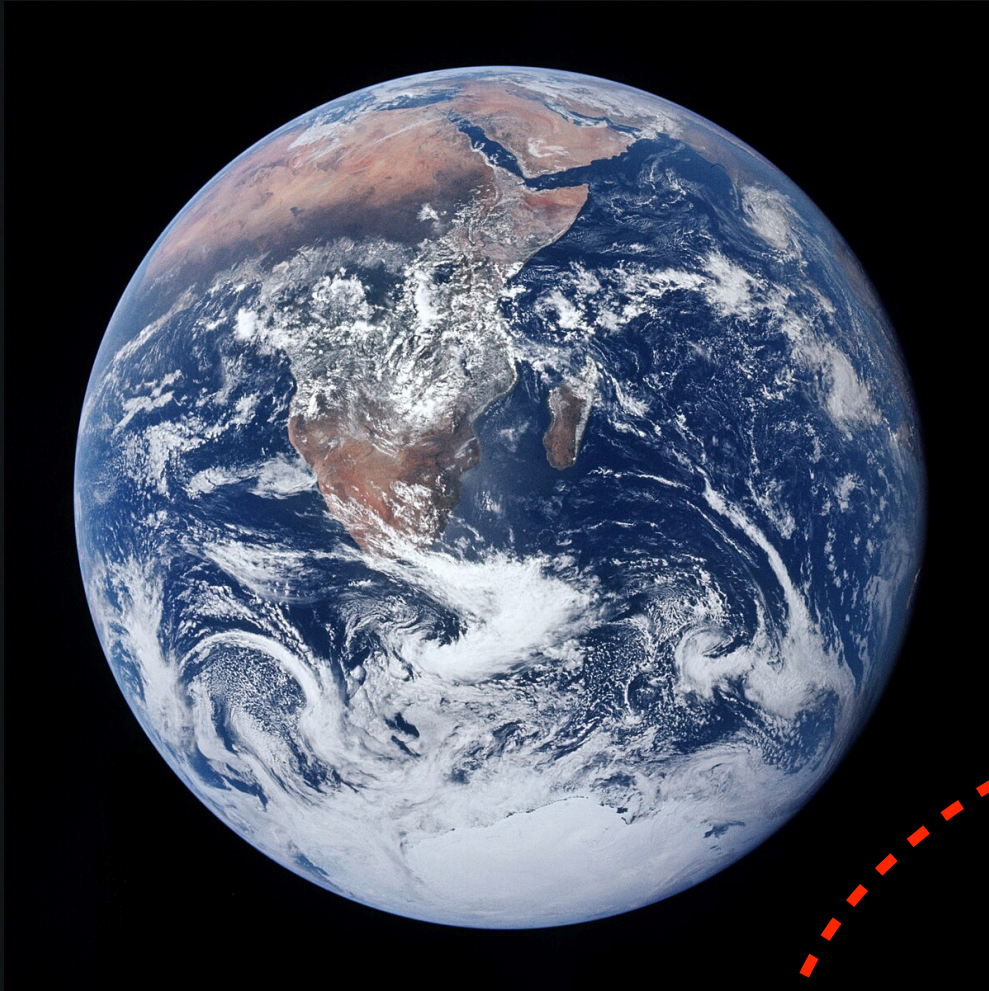
<https://www.youtube.com/watch?v=hVPZhATLDKY>



$f(v)$

v





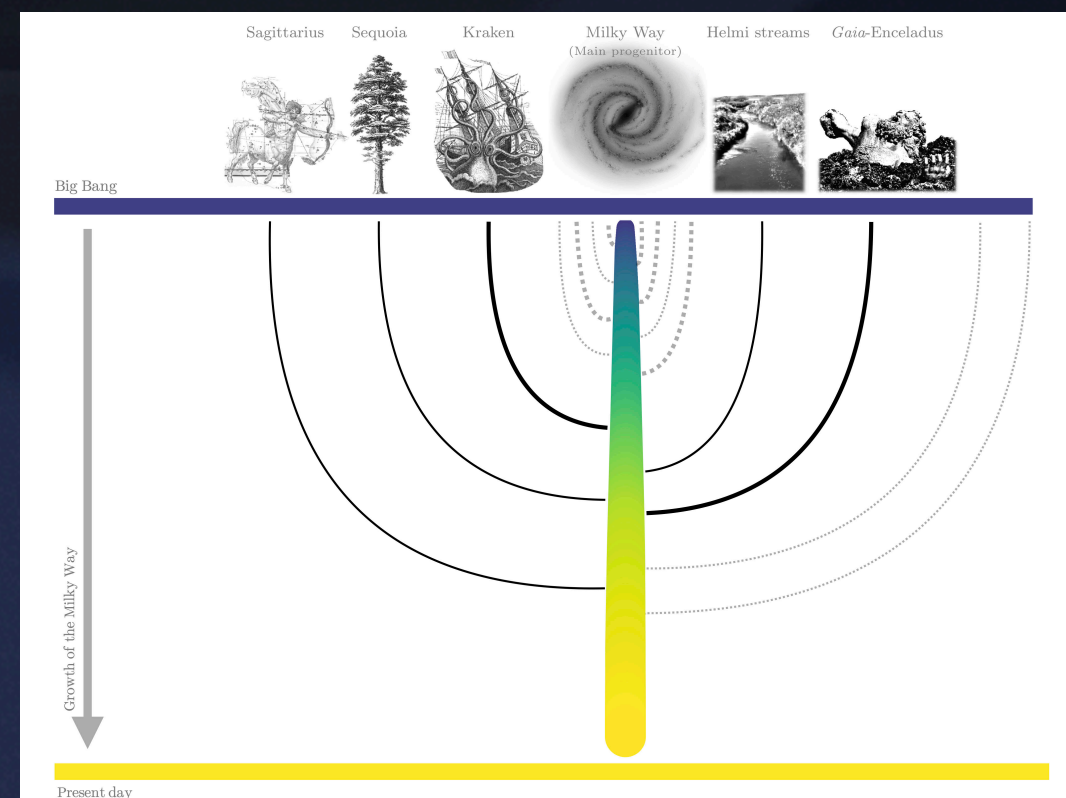


Stellar Tracers of the Local Dark Matter Velocity Distribution

1. FIRE Milky Way Simulations

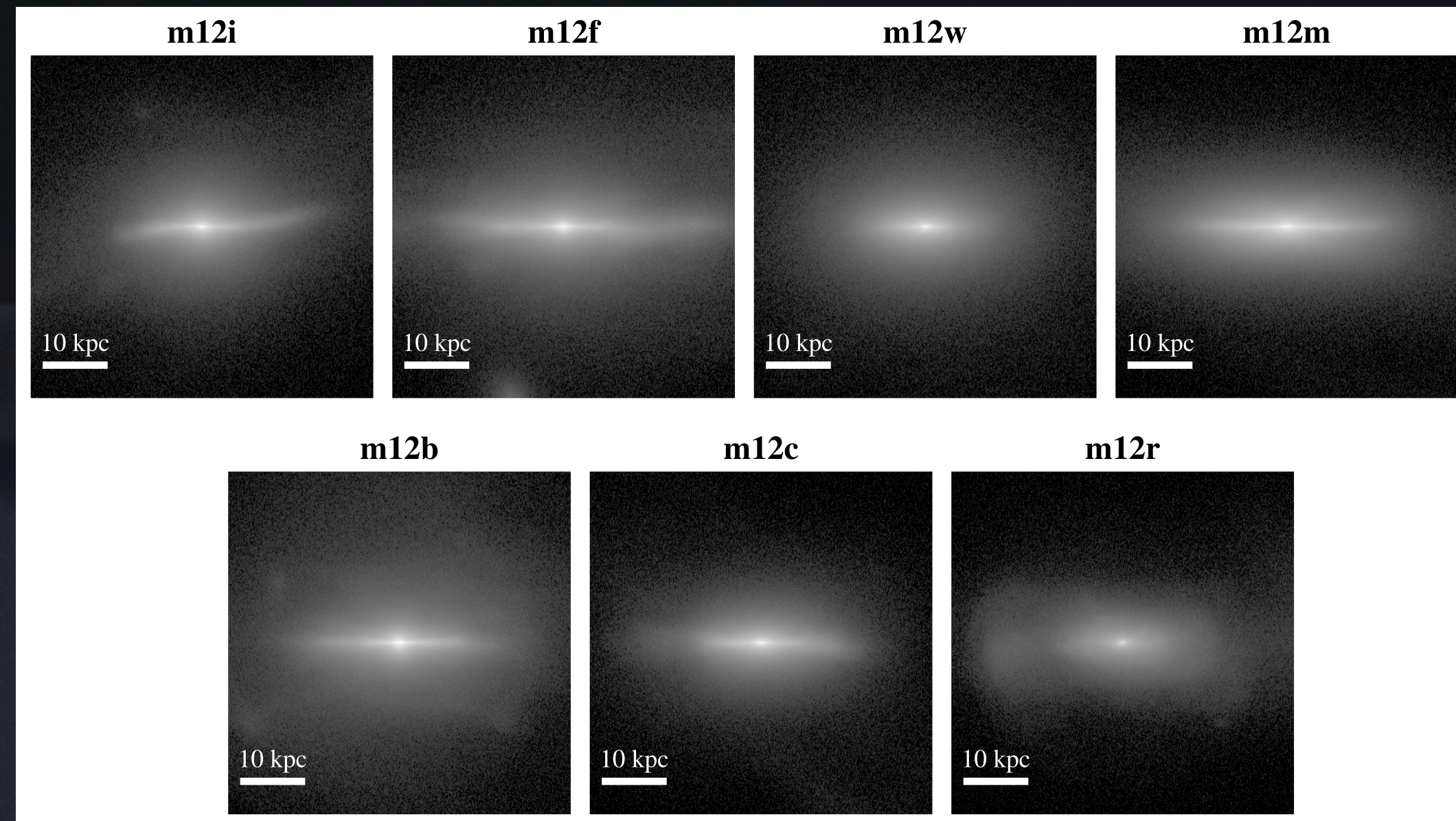
2. Building Merger History of Milky Way-like Galaxies

3. Velocity correlation



FIRE Milky Way Simulations

- FIRE-2 Latte Simulations (Wetzel et al. 2016): High-resolution, cosmological zoom-in simulation of Milky Way-mass galaxies using FIRE-2 physics model (Phil et al. 2018)
- In this study, we study six of the m12 simulations, namely m12i, m12f, m12m, m12w, m12b, m12c



m12i

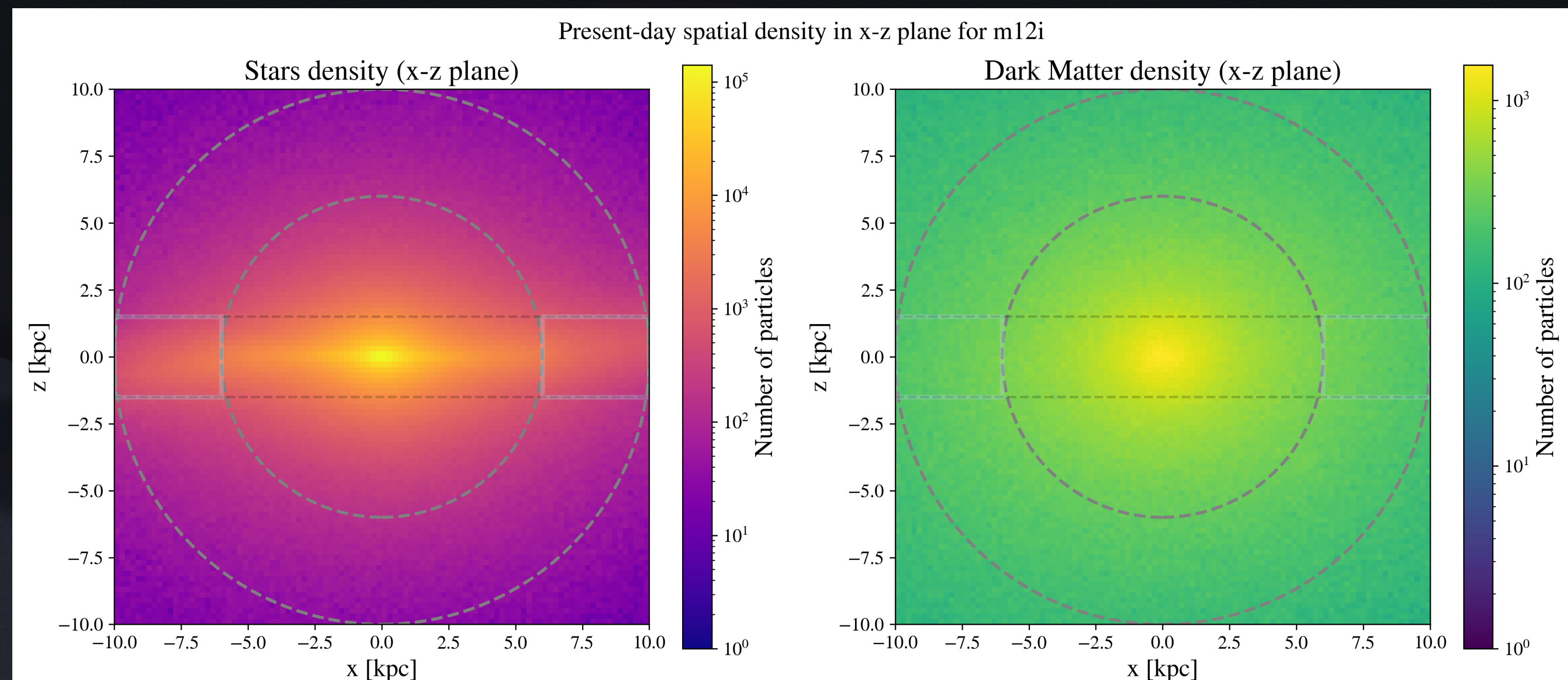
$z=19.0$

10 kpc

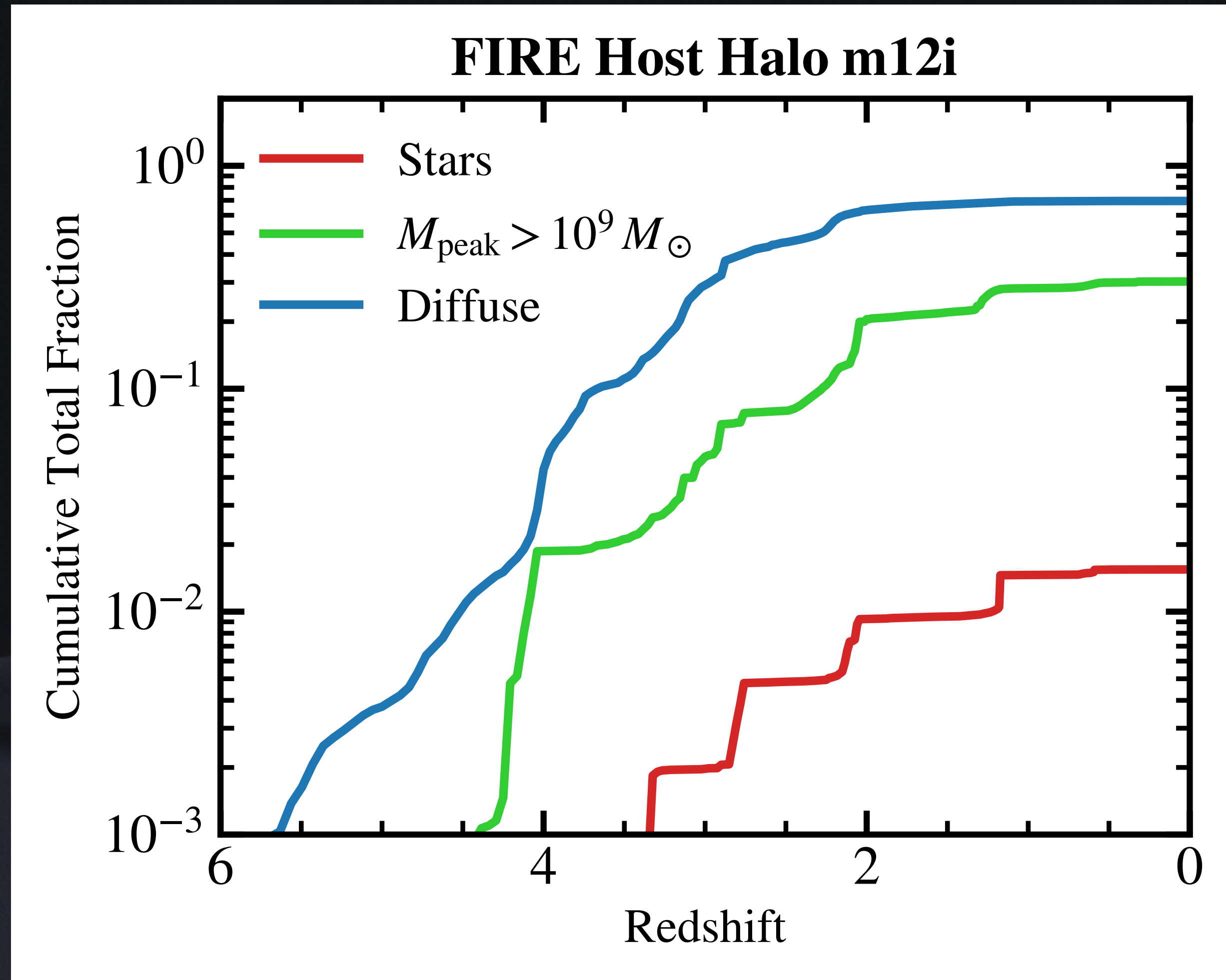
<http://www.tapir.caltech.edu/~phopkins/Site/animations/a-gallery-of-milky-way/>

Building Merger History

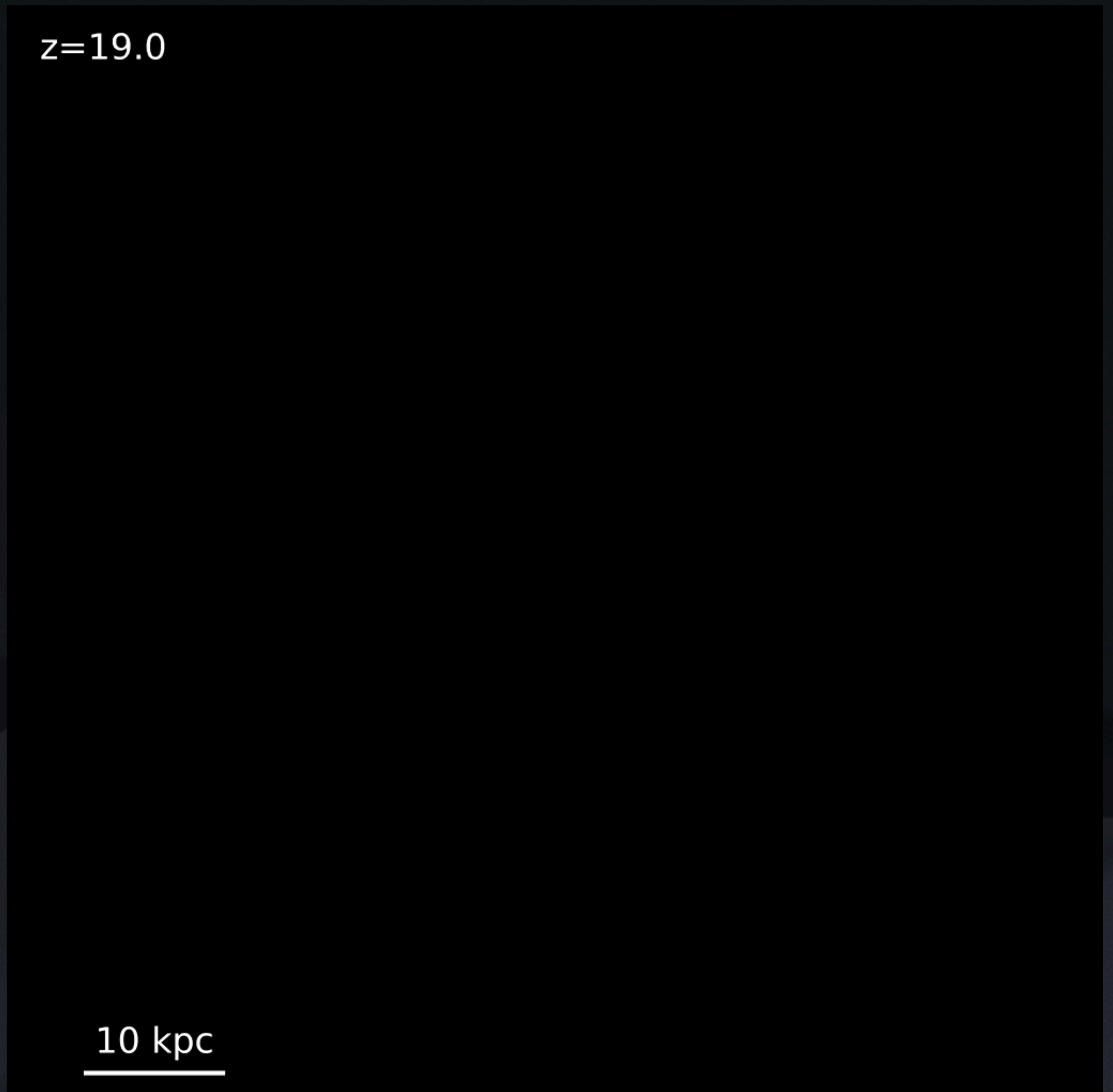
- Particle information is directly read from the simulations
- Subhalo information is generated using Rockstar
- Stars and DM near the solar cycle at $z = 0$: $|r - r_{\odot}| < 2\text{kpc}$ and $|z| \leq 1.5\text{kpc}$



Building Merger History



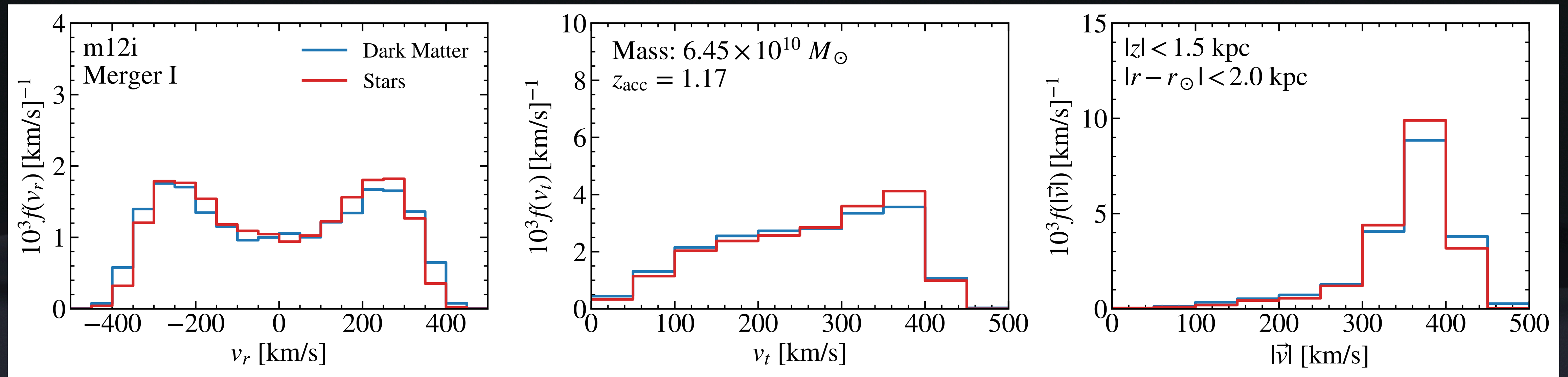
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Analysis and Results

Resolved Component

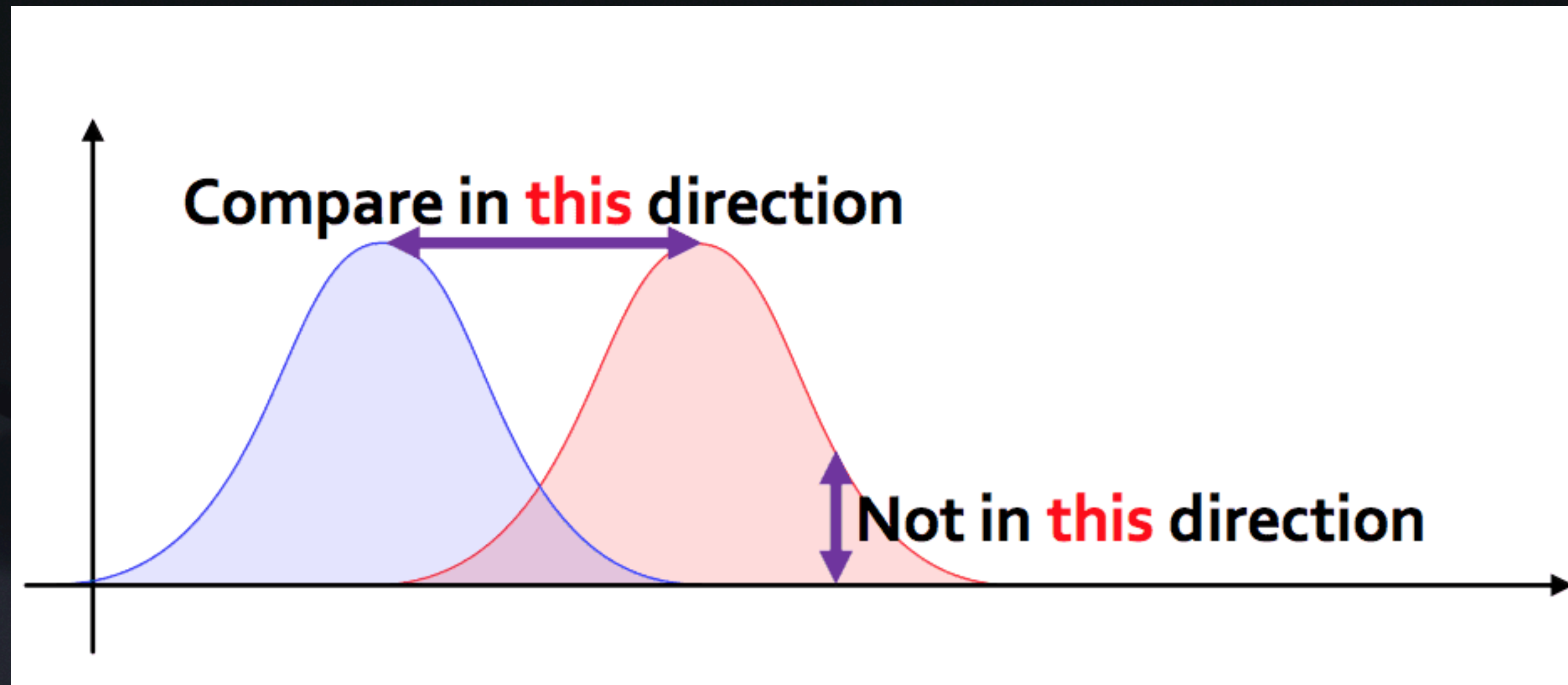
- We pick top four mergers that contribute the greatest fraction of accreted stellar population in each simulation.
- We compare the dark matter and stellar velocity distribution from the same merger



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Earth Mover's Distance

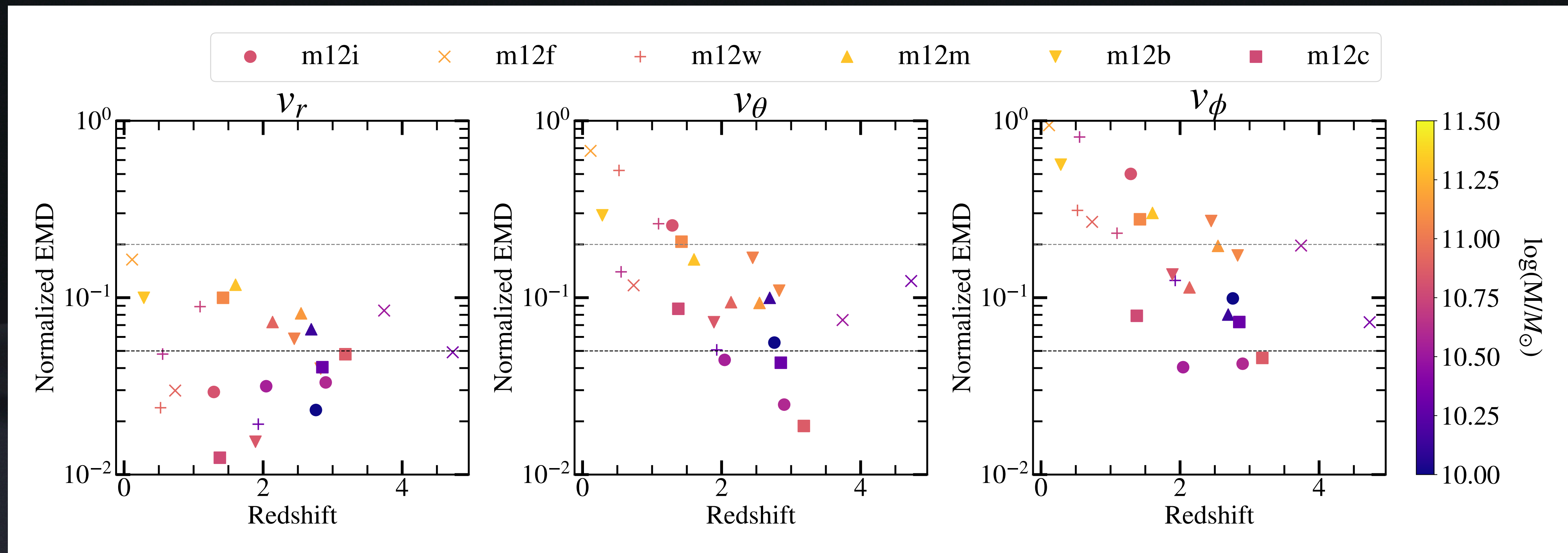
- Earth Mover's Distance (EMD) test measures how many steps it takes to transfer one distribution into another.
- The larger the EMD, the more different the two distributions are



Analysis and Results

Resolved Component

- We compare the EMD for each of the top four mergers in 6 m12 simulations
- Different simulations are marked by different shapes; markers are colored by their mass

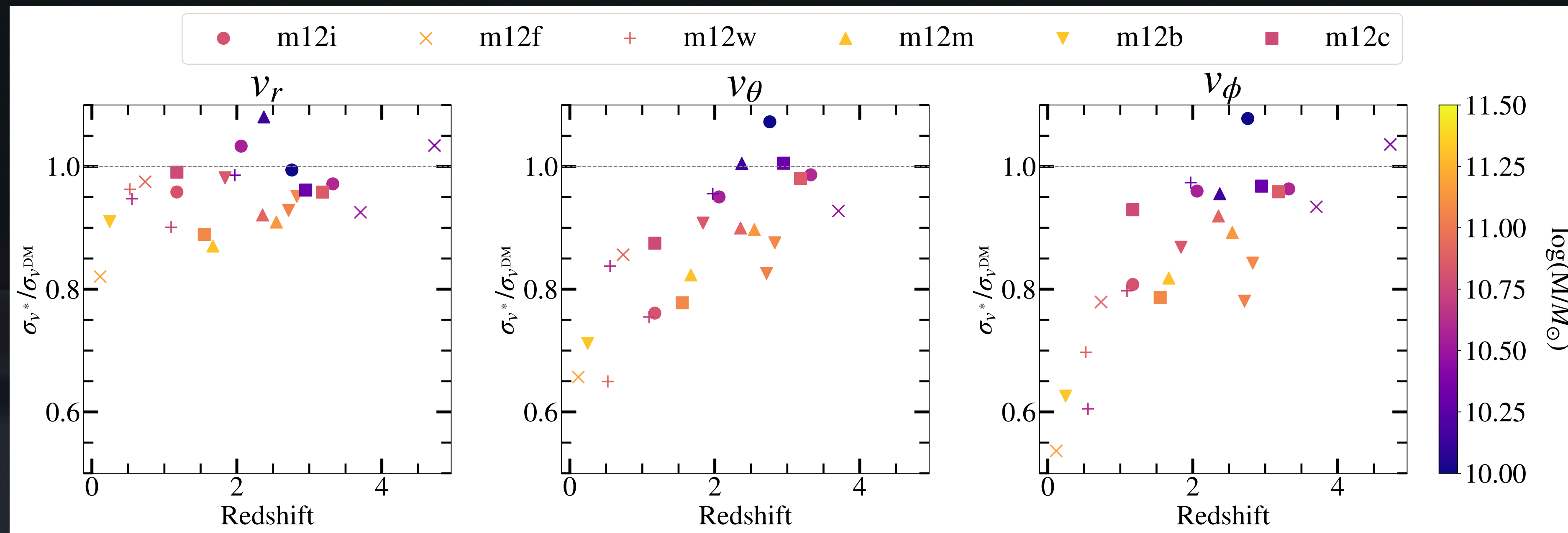


Analysis and Results

Resolved Component

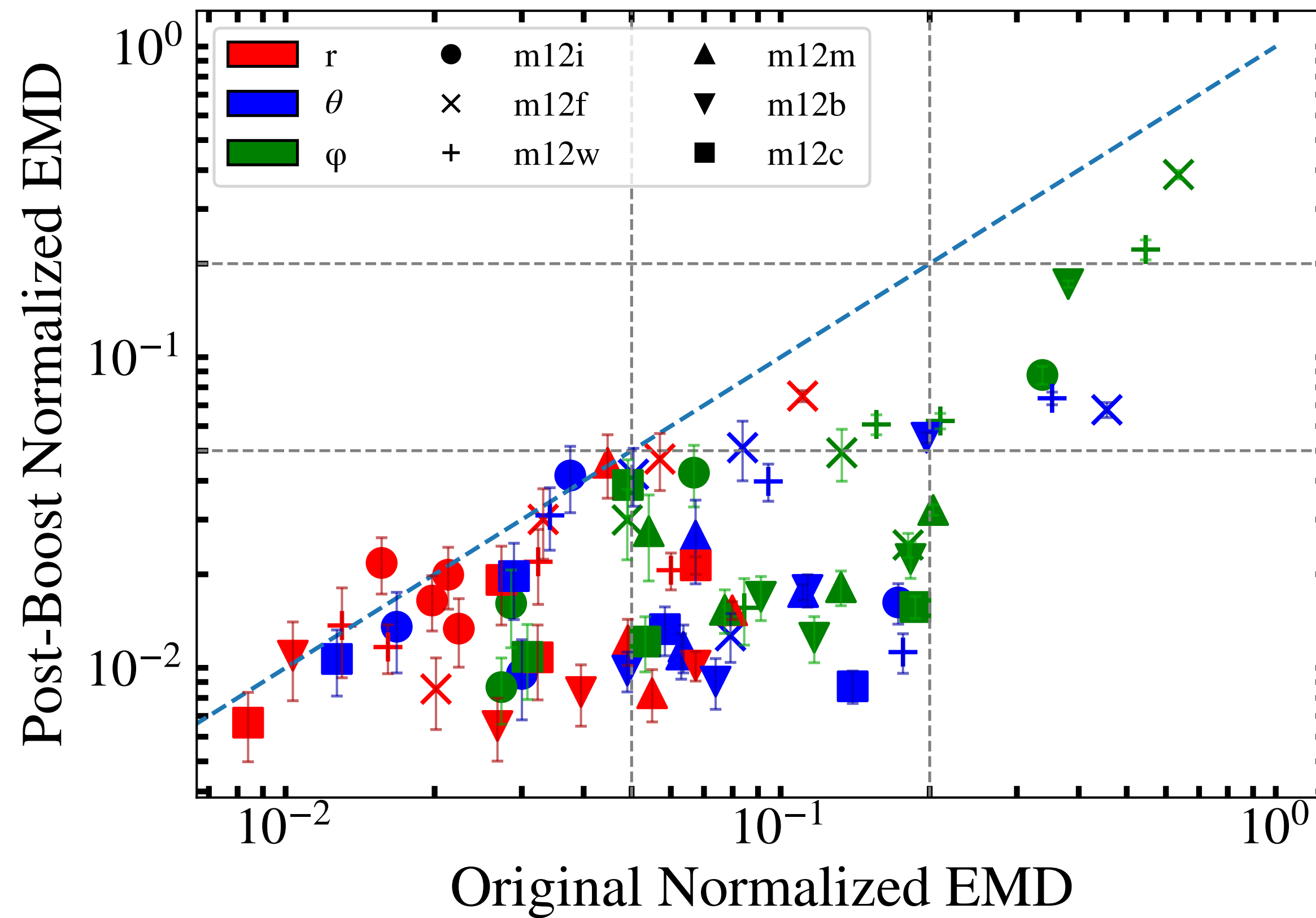
- Stellar velocity dispersion is smaller than DM velocity dispersion in general and scales with redshift

- $f_*(v) = f_{\text{DM}}(v) * \mathcal{N}(0, \sigma(z))$



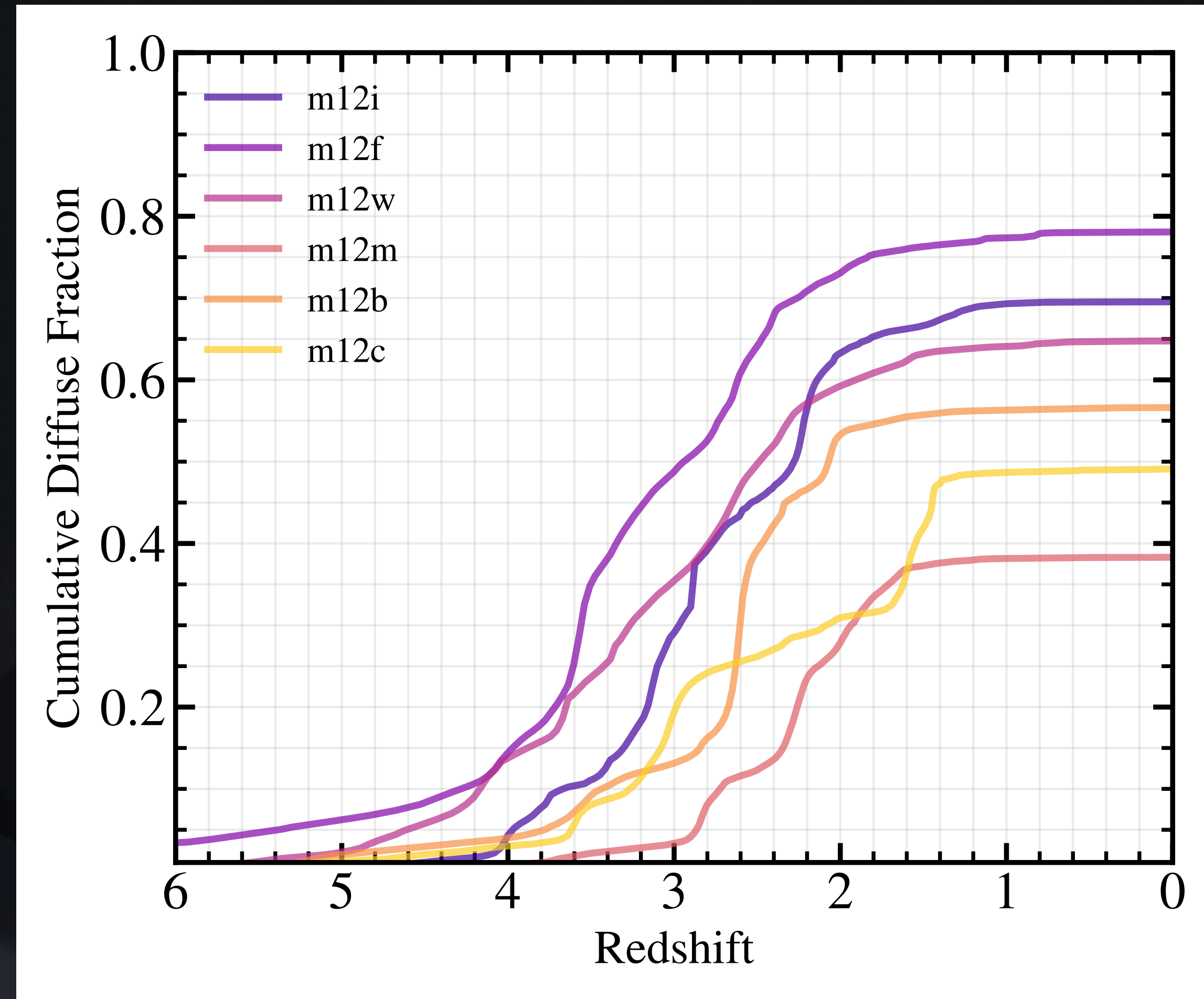
Analysis and Results

Resolved Component



Analysis and Results

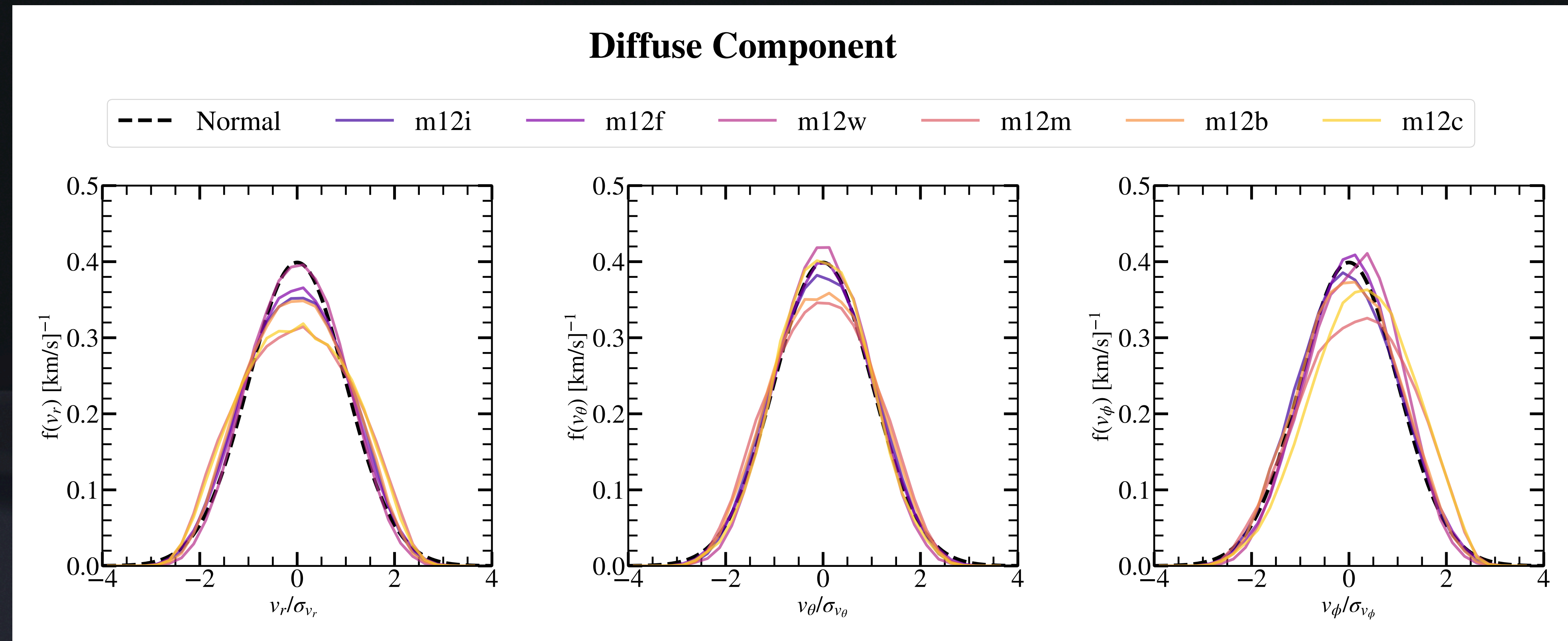
Diffuse Component



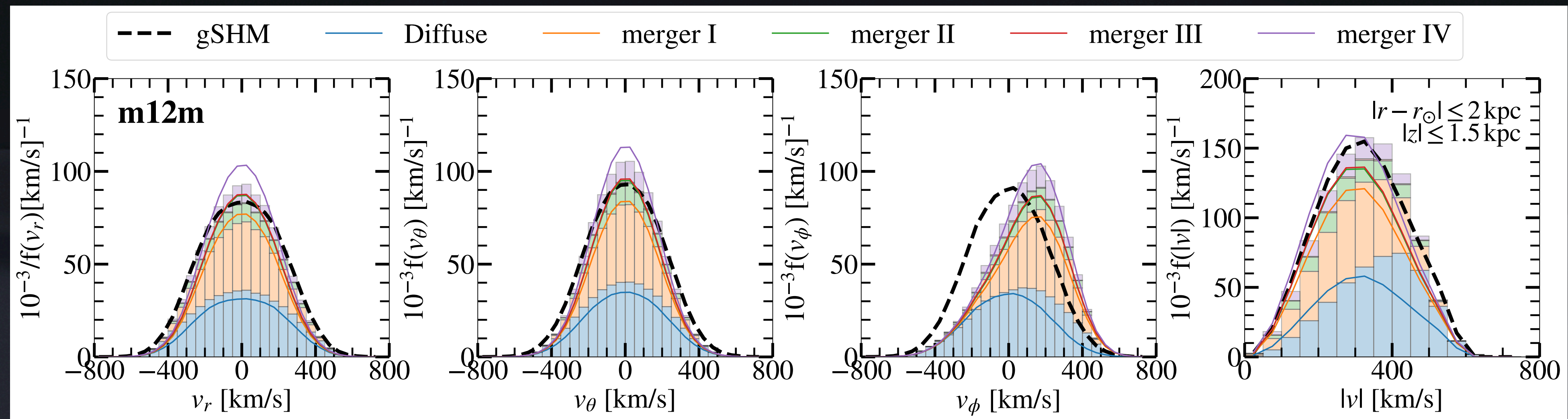
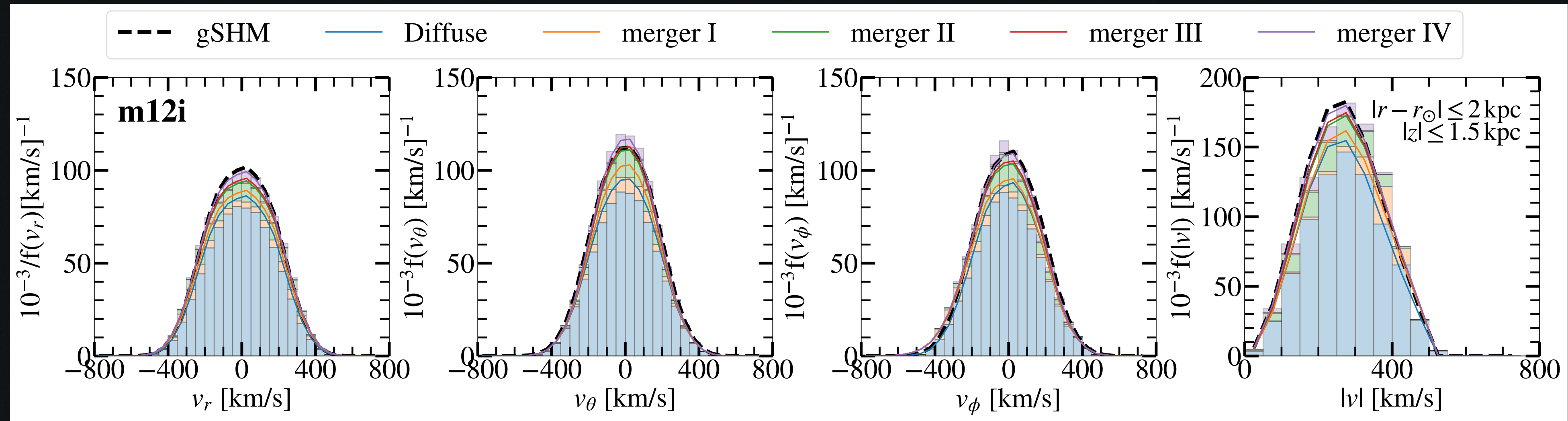
Analysis and Results

Diffuse Component

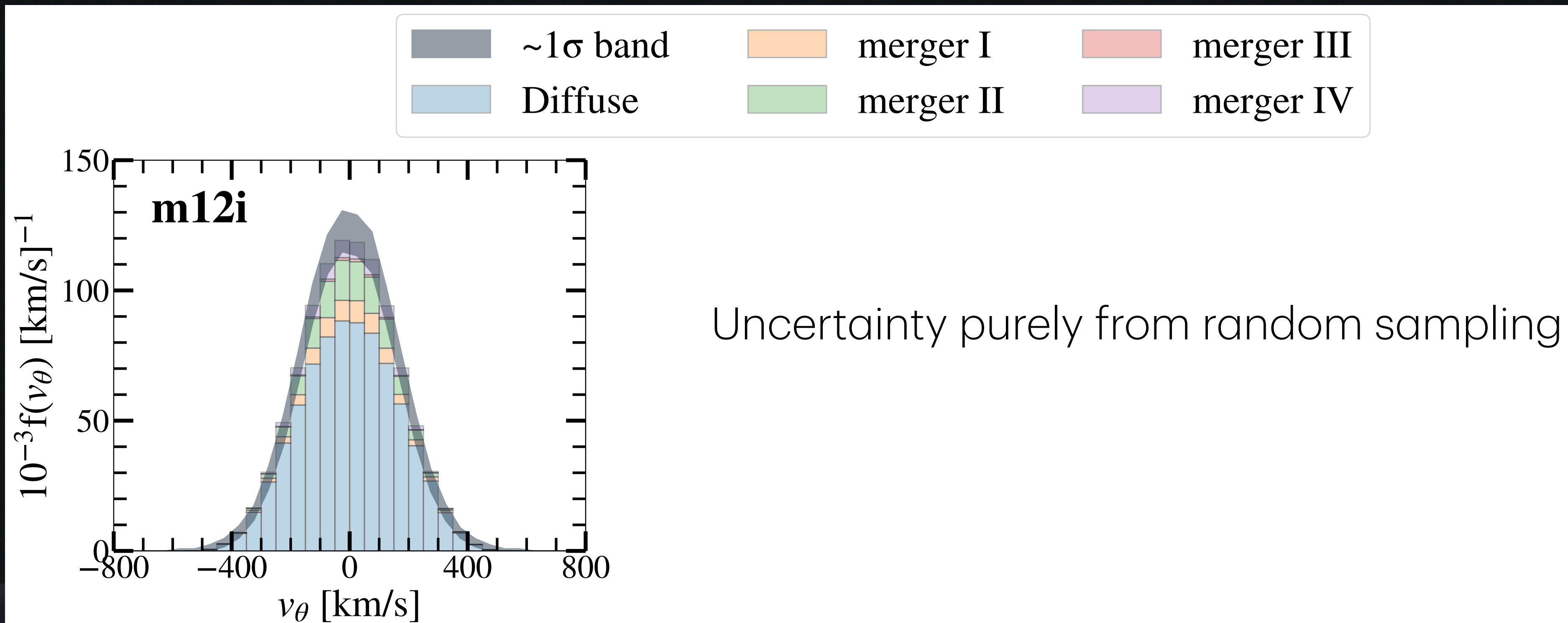
- Diffused component includes smooth accretions and smaller subhalos that are not well resolved



Analysis and Results

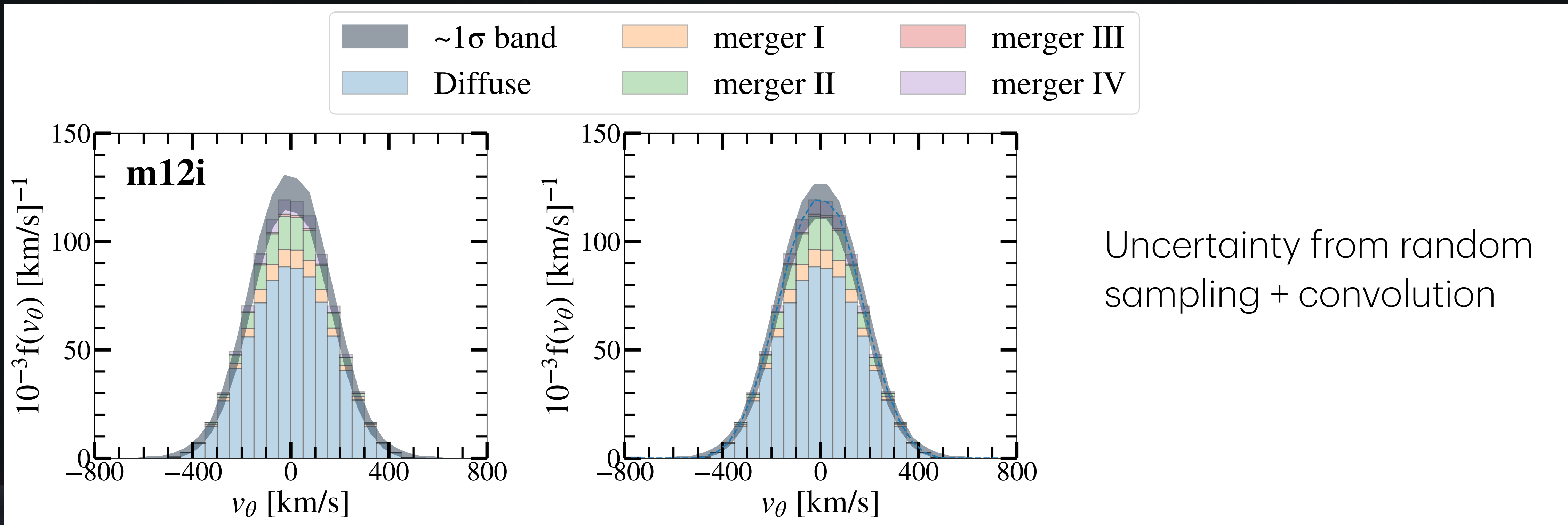


Analysis and Results



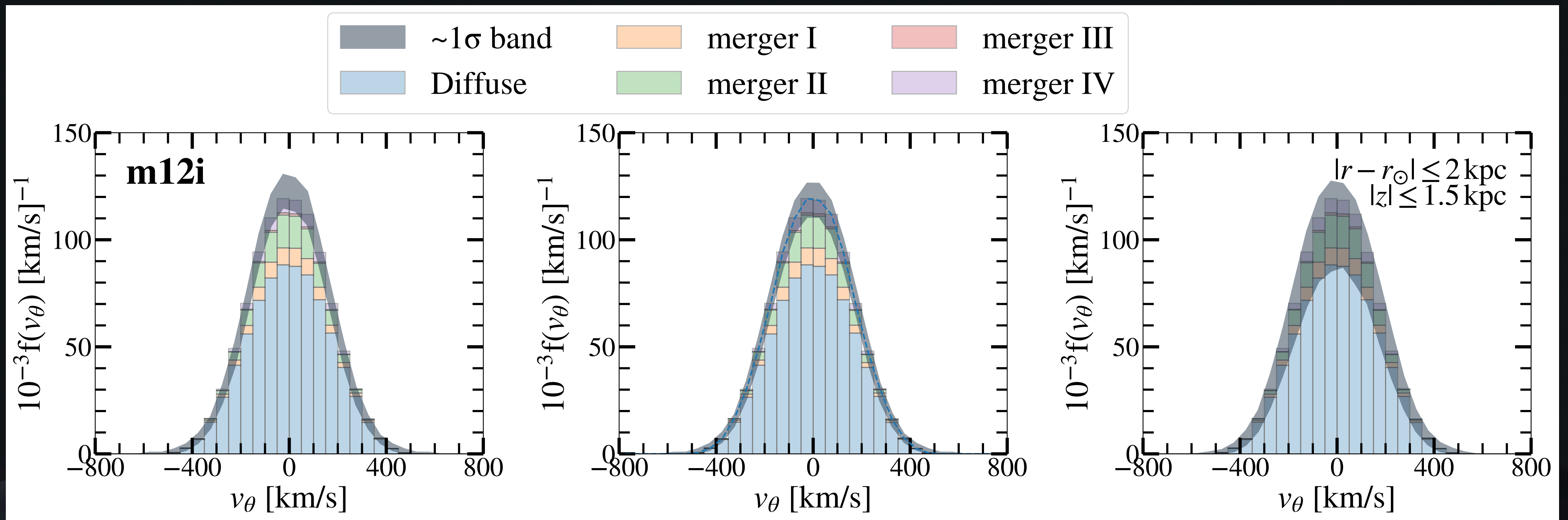
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Analysis and Results



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Analysis and Results



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Conclusion & Outlook

- Local Dark Matter velocity distribution can be improved over the Standard Halo Model
- In upcoming work, we will reconstruct the Dark Matter velocity distribution of Milky Way based on observational data; we will also study the effects of the modification on direct detections and annual modulation
- Thank you all for listening!



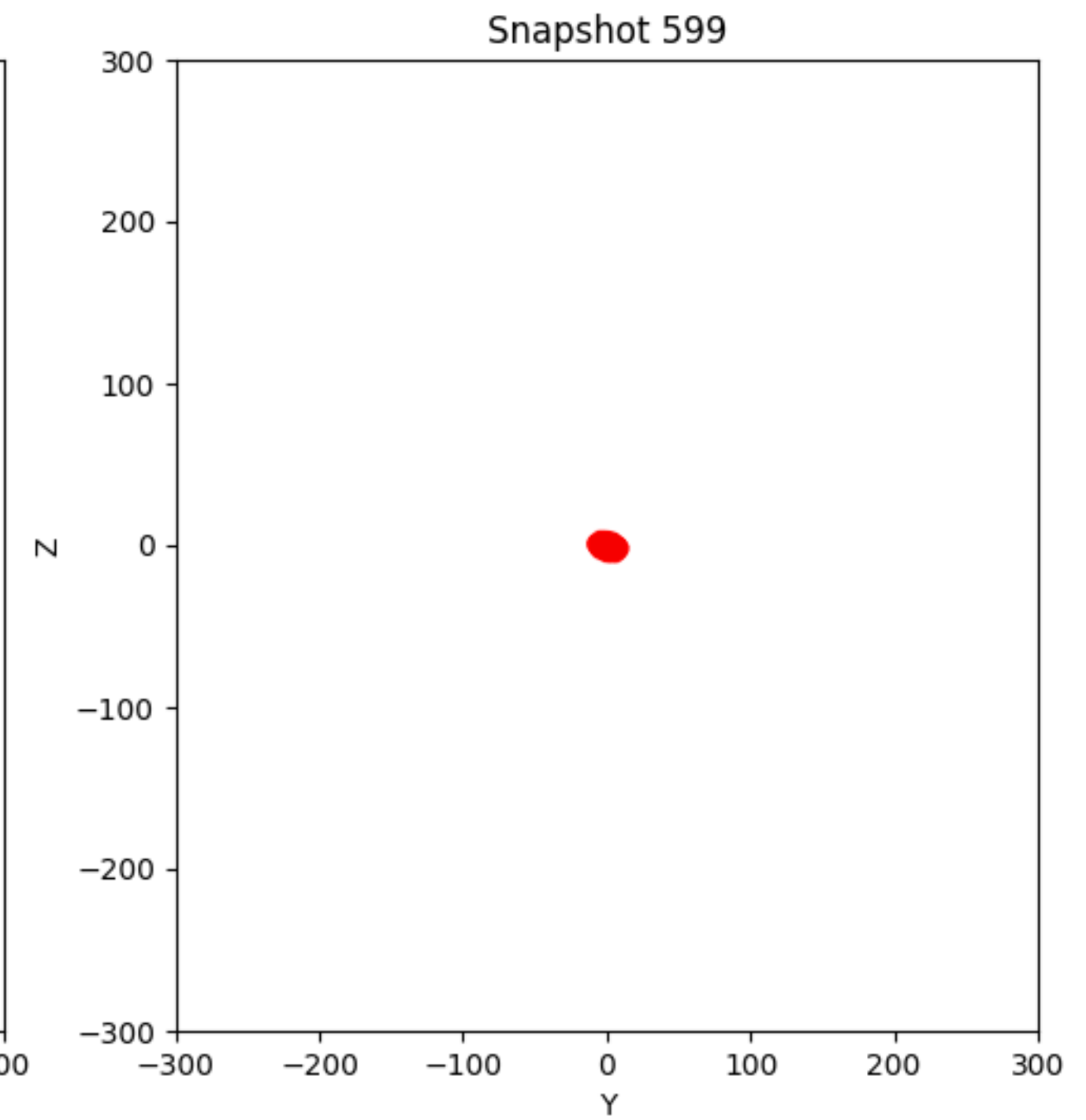
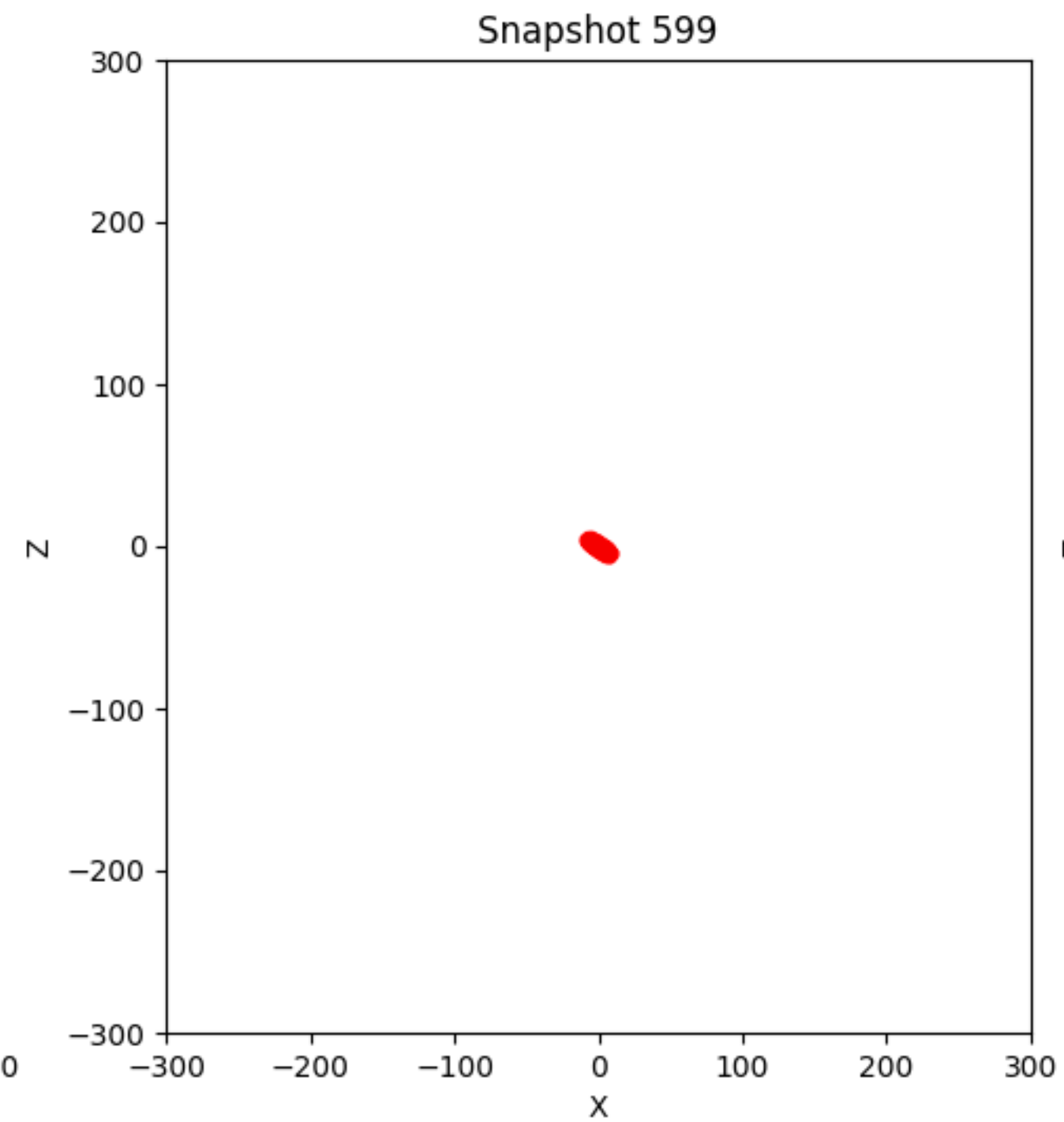
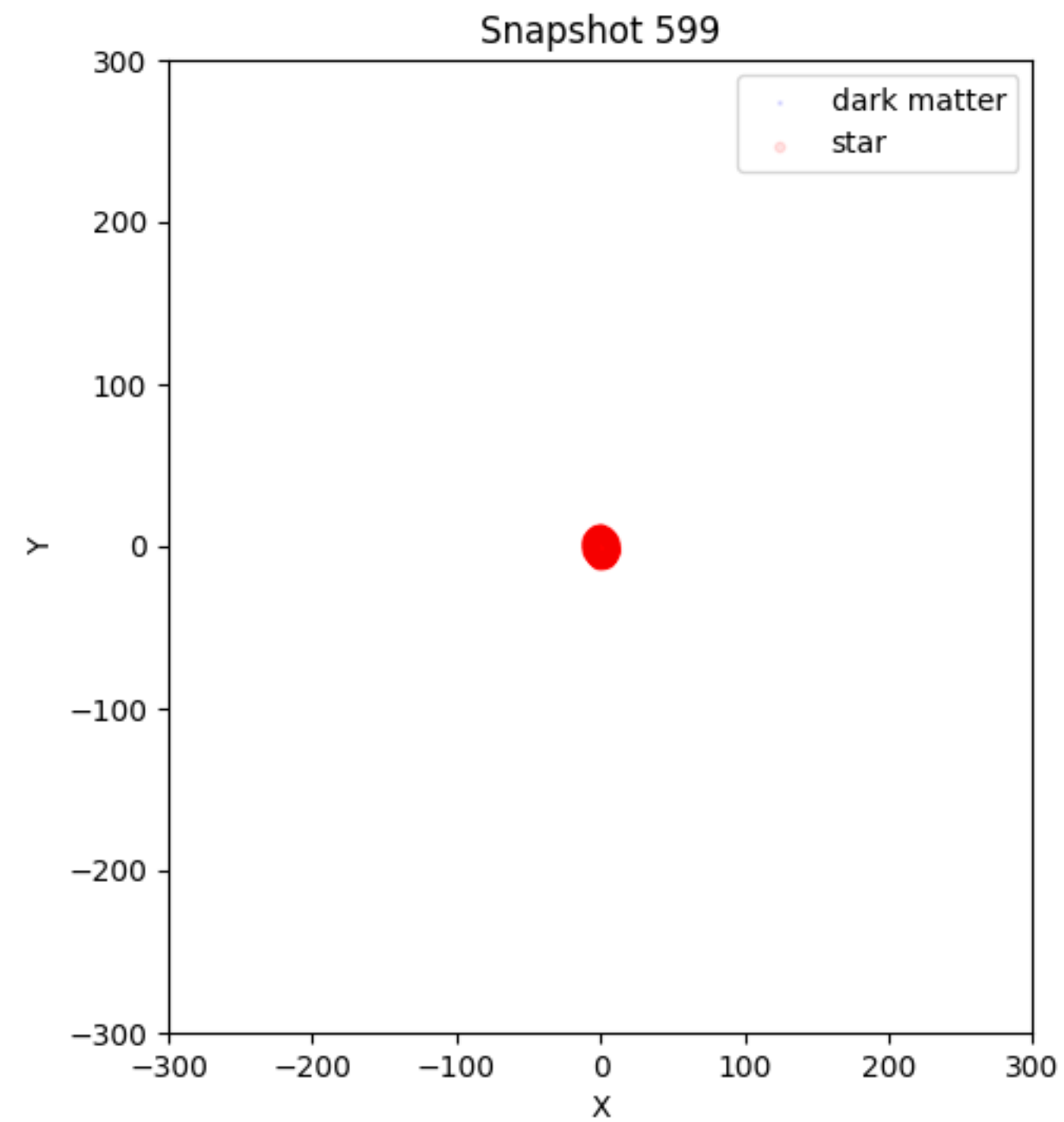
m12r

z=19.0

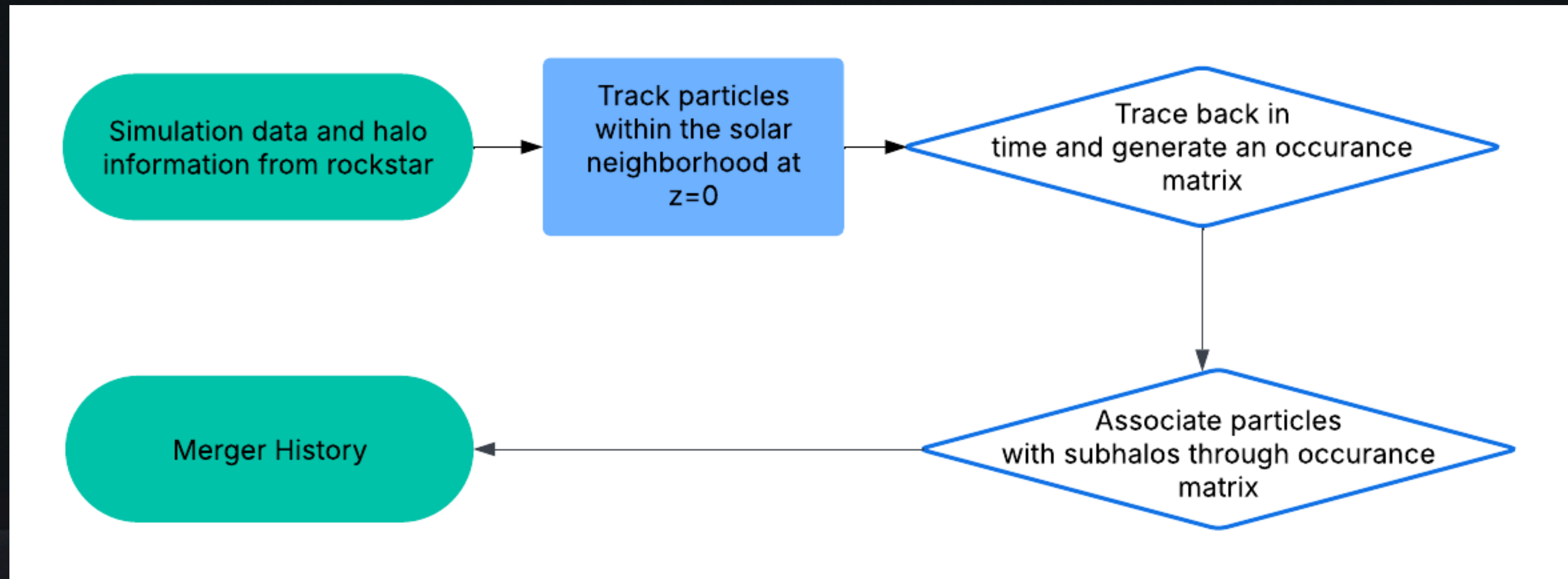
10 kpc

Backup Slides

Building Merger History



Building Merger History



Building Merger History

- We go backwards in time snapshot by snapshot
- At each snapshot, for each particle, we find the halo closest to it and check if its position is within the viral radius of the halo and if its velocity is within 2.5 standard deviations of the halo velocity

Particle ID	...	Snapshot 478	Snapshot 479	Snapshot 480	Snapshot 481	...	Snapshot 599	Snapshot 600
		1	0	1	1		0	0
		0	1	1	1		0	0
		0	0	0	1		0	0
		1	1	1	0		0	0
...	

m12f

z=19.0

10 kpc

