

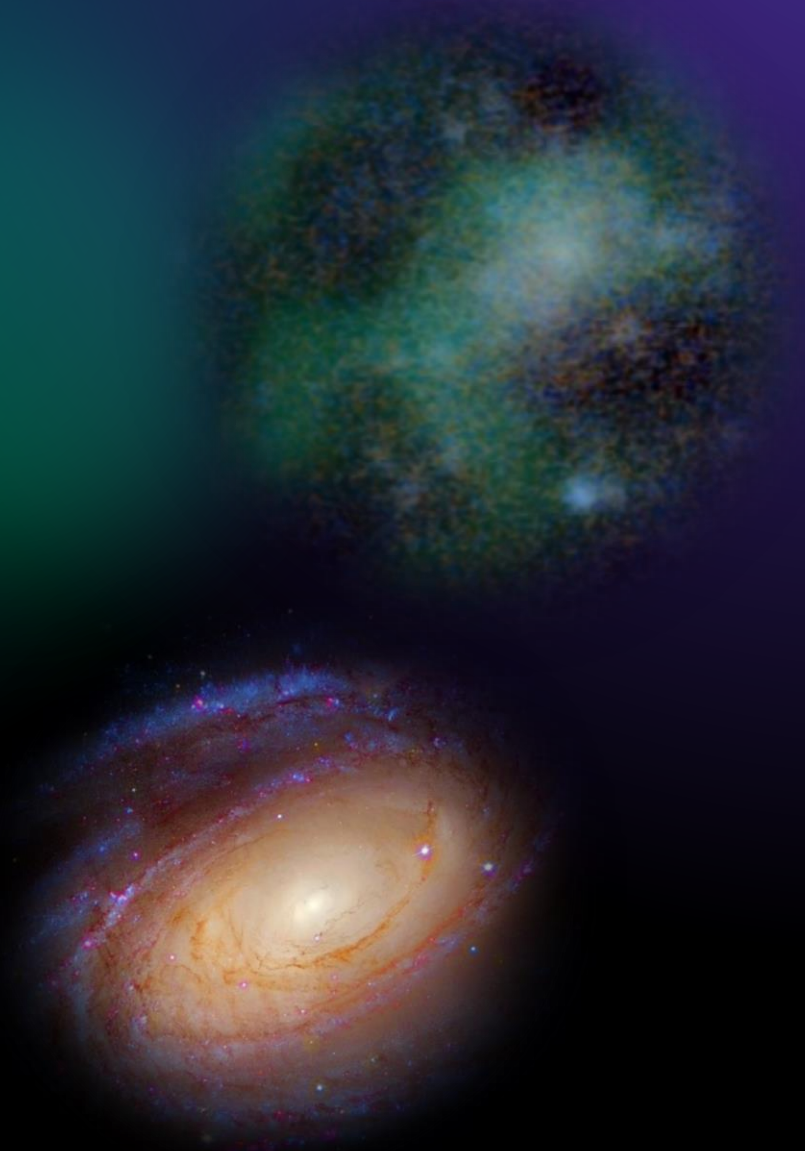
Modelling the Kinematics of an Ultra Diffuse Galaxy to Determine its Dark Matter Content

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FOR: CANADIAN ASTRO-PARTICLE
PHYSICS SUMMER STUDENT TALK
COMPETITION 2022

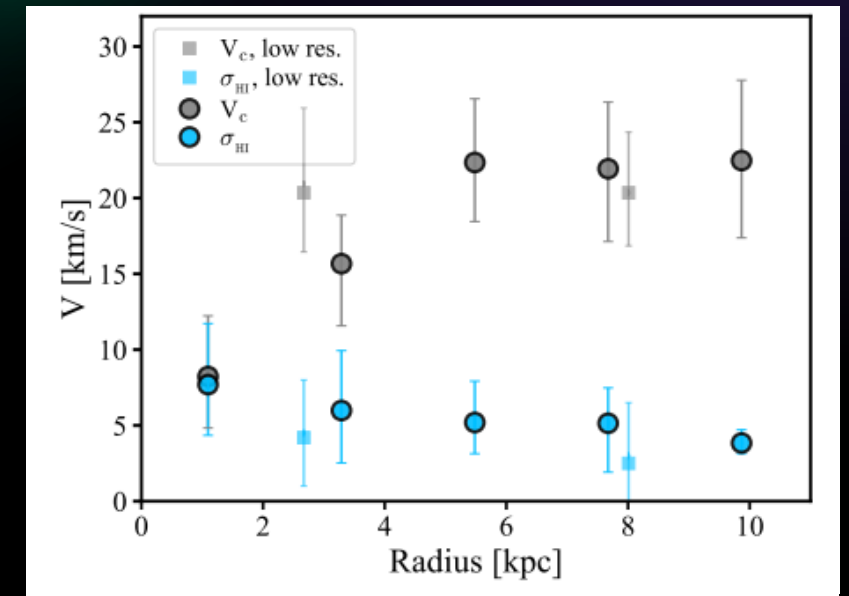
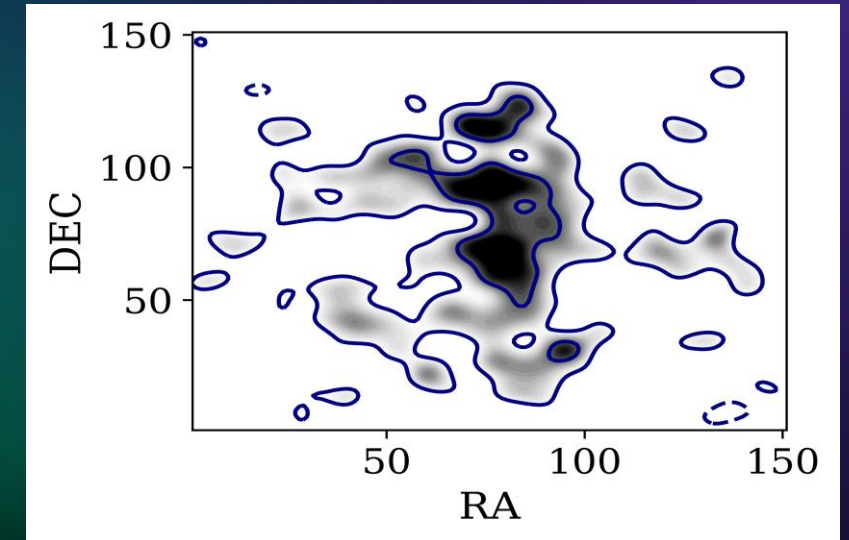
Background Information

- An **Ultra Diffuse Galaxy (UDG)** is a low surface brightness galaxy whose matter content is spread out over a large volume [1].
- Imagine a galaxy with a mass thousands of times smaller than the Milky way that occupies a similar amount of space.



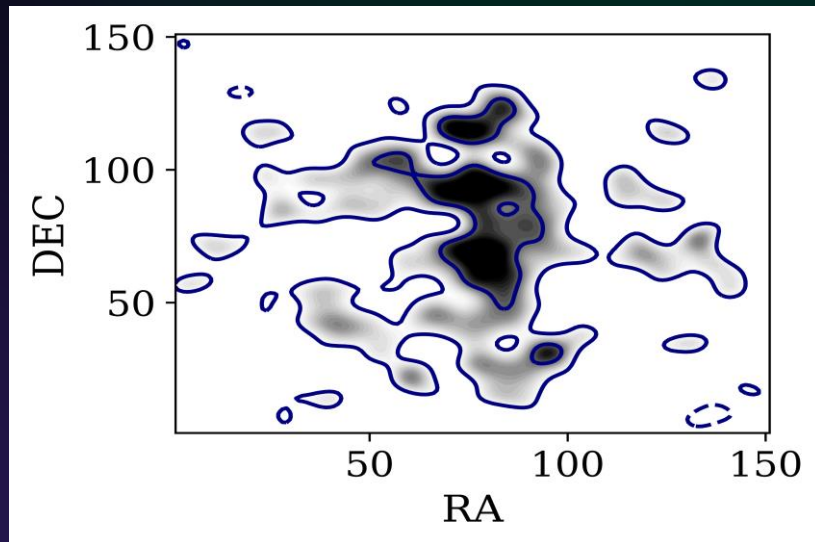
Ultra Diffuse Galaxy: AGC 114905

- From analysis of the neutral hydrogen maps of AGC 114905, it has been suggested that **AGC 114905 contains little to no dark matter** [2] (henceforth MP22).
- This claim stems from the rotation curve and velocity dispersion profile of the galaxy which appears to be completely explained by baryonic matter.

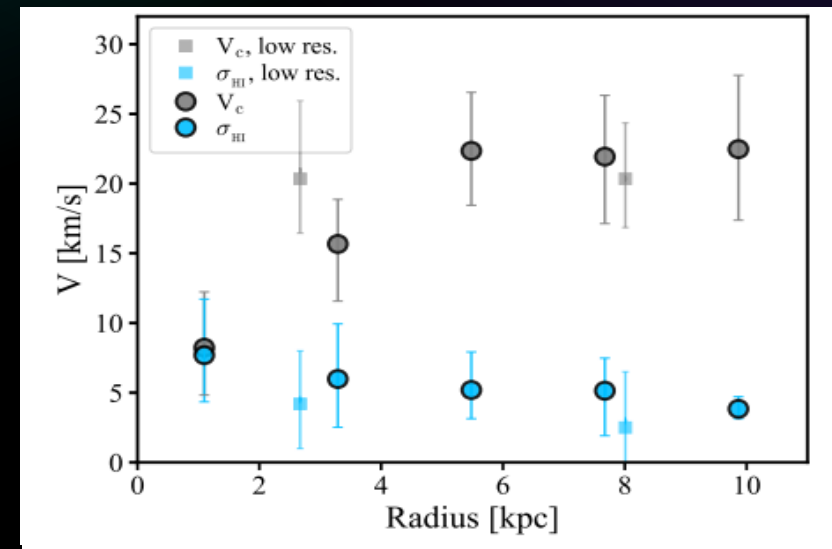


Scientific Goal

- To investigate whether AGC 114905 needs dark matter to explain its kinematics.
- I've done this by analyzing the reliability of 3D-Barolo, the software used to derive these claims, in the ultra diffuse galaxy regime [3].



3D-Barolo



Procedure

Create

Create mock observations of galaxies with properties similar to AGC 114905

Model

Model the kinematics of these mock galaxies with 3D-BAROLO software

Compare

Compare results with the known properties of the mock galaxy AND published results in MP22

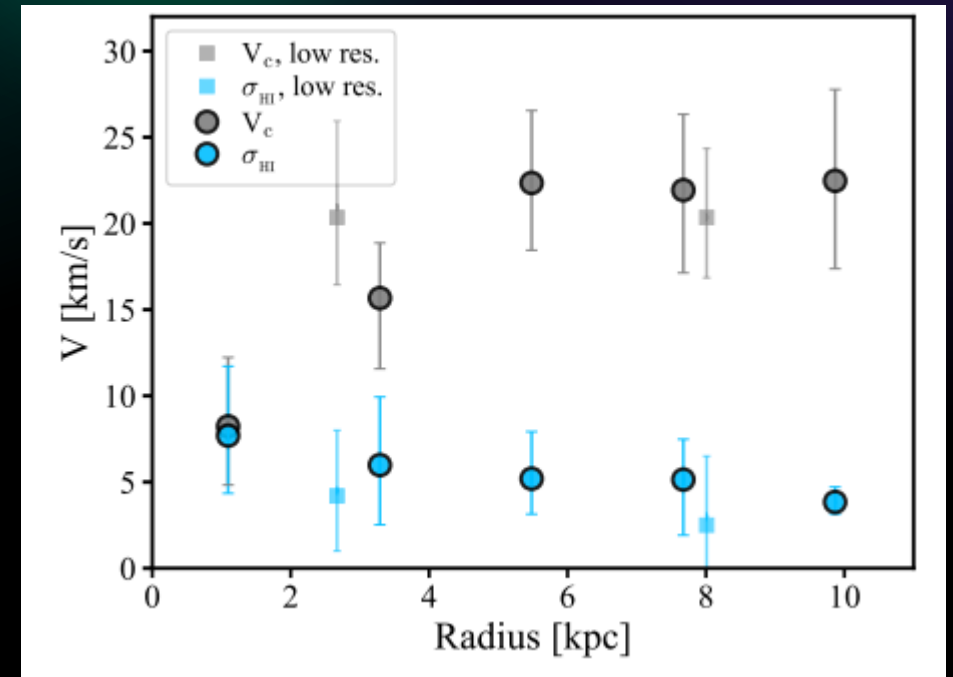
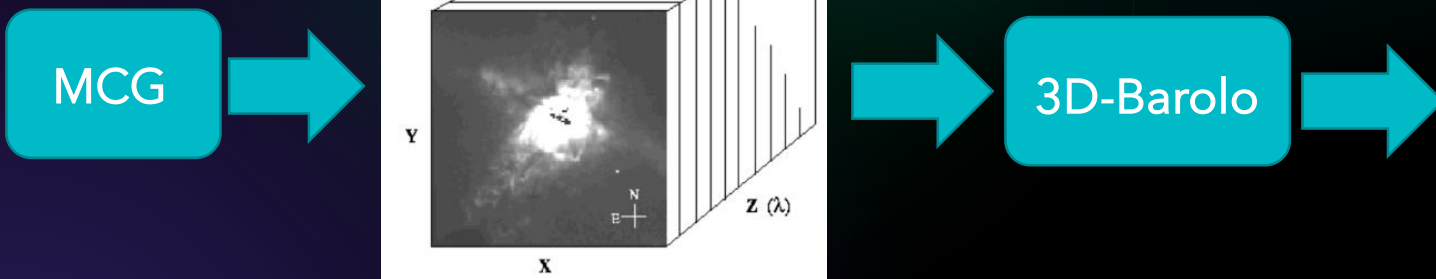
Software Information

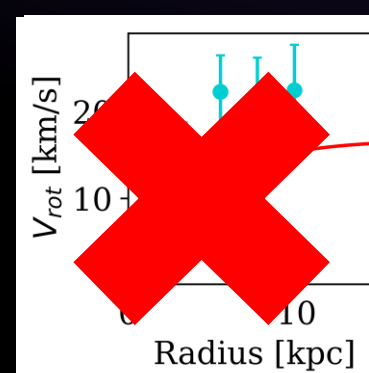
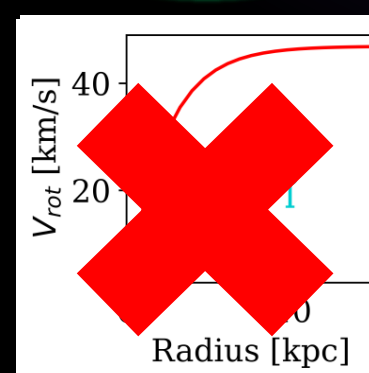
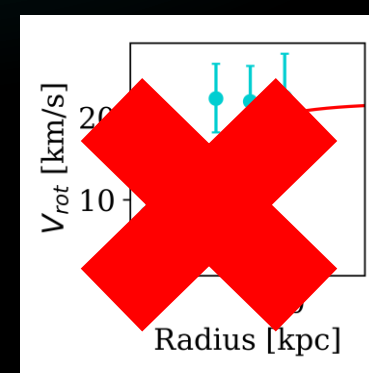
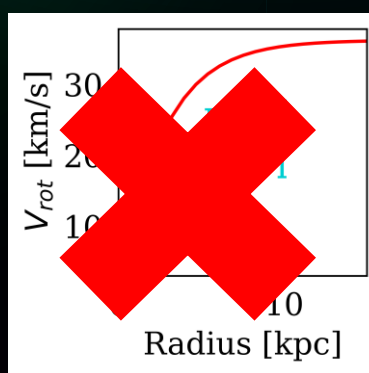
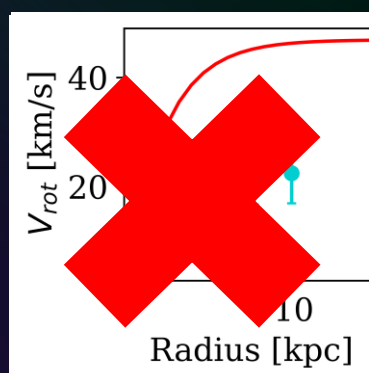
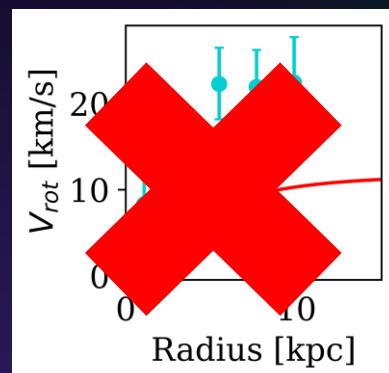
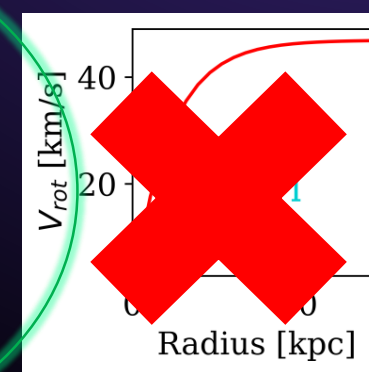
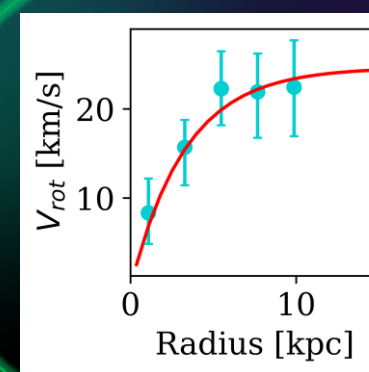
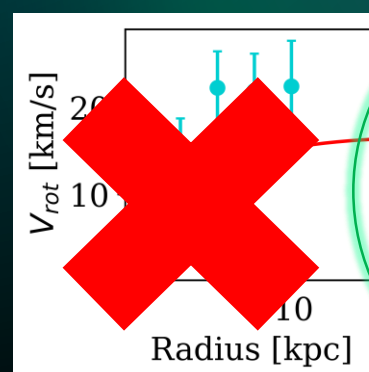
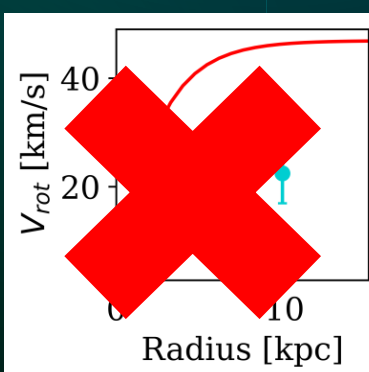
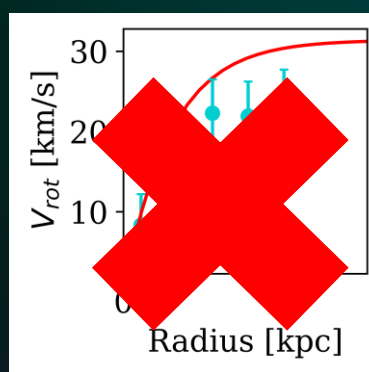
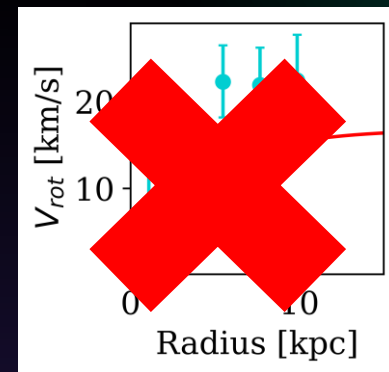
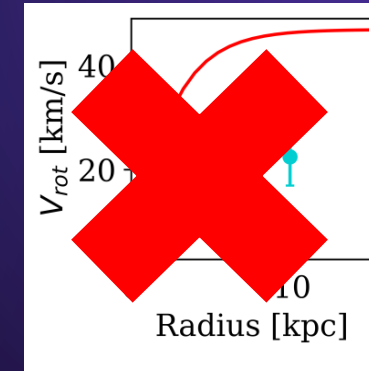
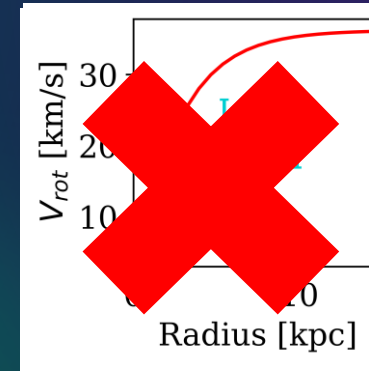
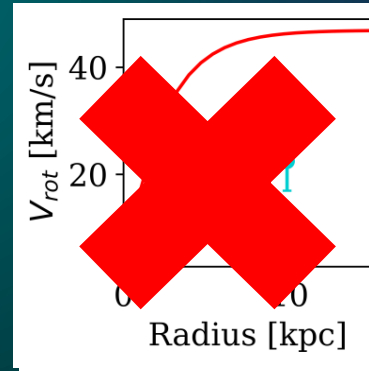
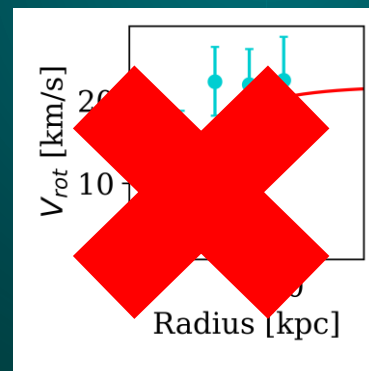
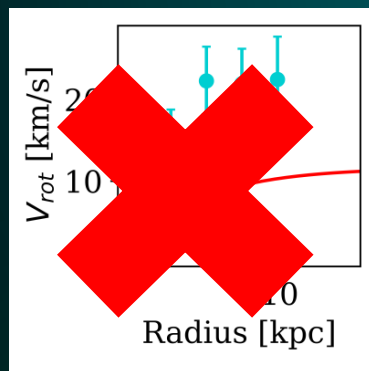
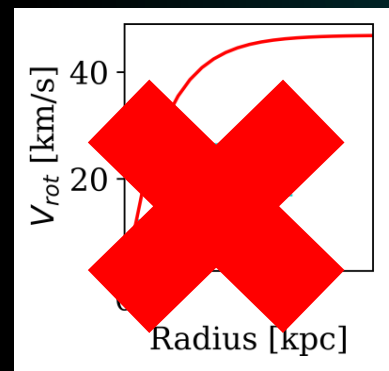
Mock Cube Generator (MCG)

- Creates observations of mock galaxies with user specified properties

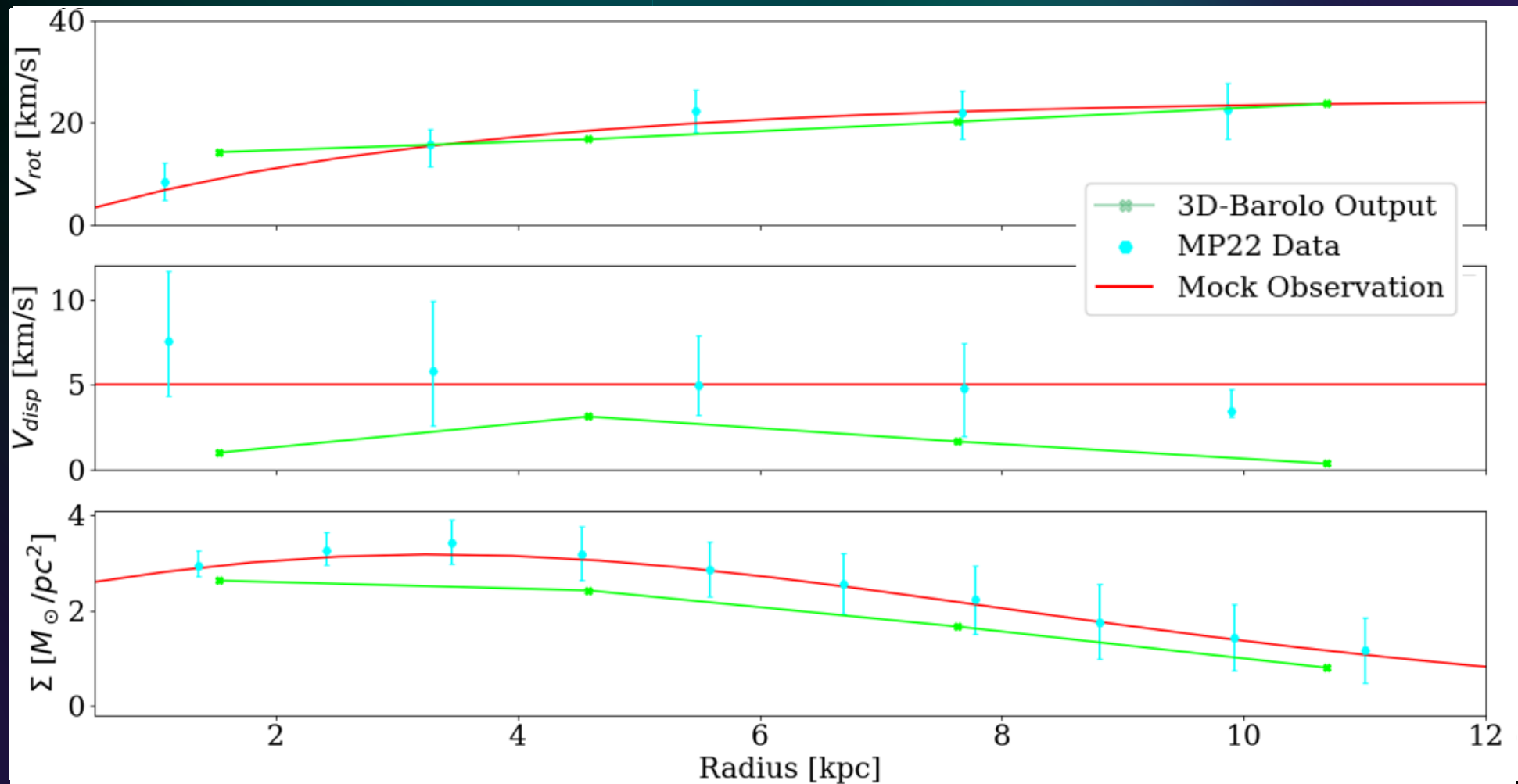
3D-Barolo

- Extracts the kinematic properties of a galaxy from observations

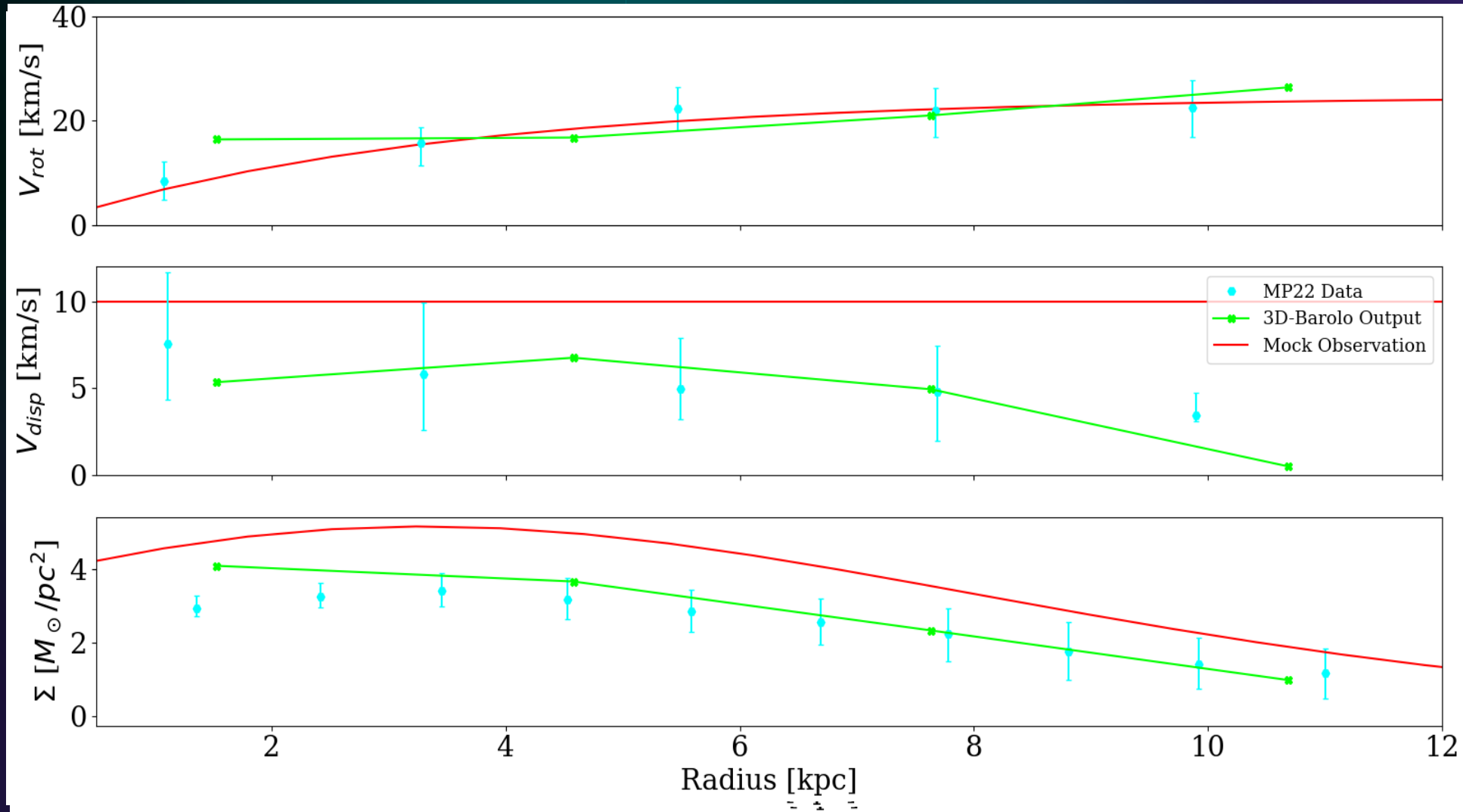




What happens when you put in a MP22-like mock model into 3D-Barolo?

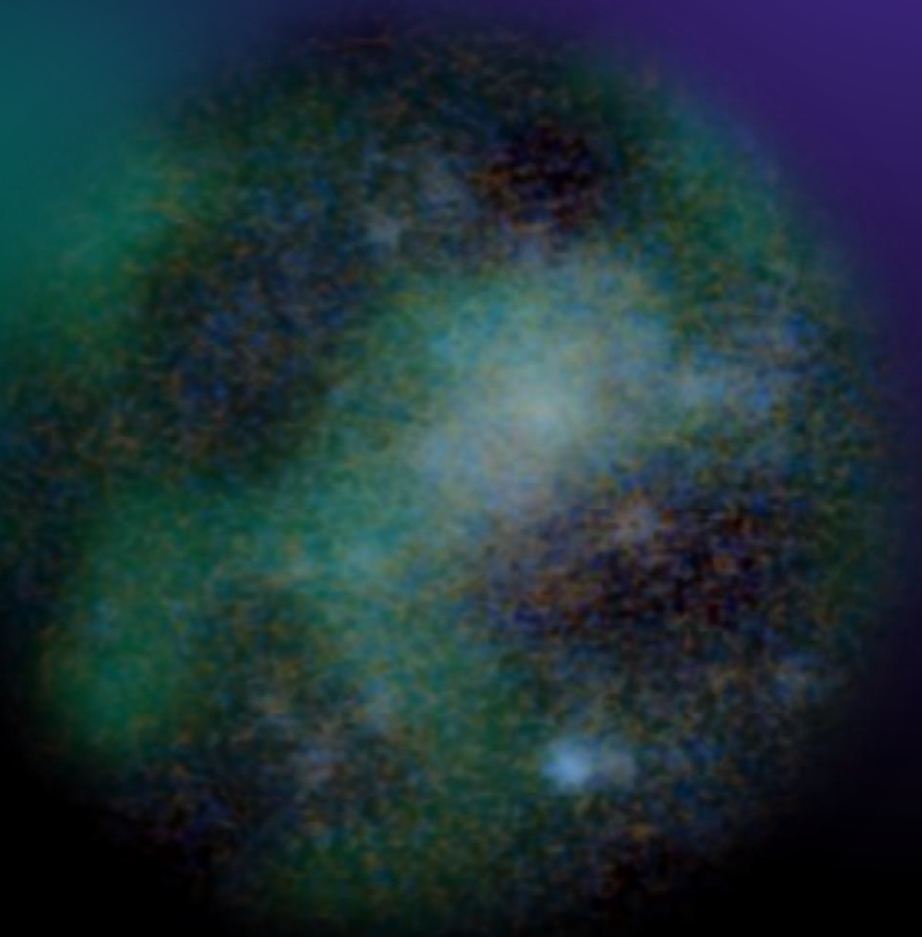


Finding AGC 114905's Properties



Results and Conclusions

- By producing mock observations of ultra diffuse galaxies, the accuracy of the kinematics produced by 3D-BAROLO were quantified
- The velocity dispersion of AGC 114905 is likely $4.8 \pm 0.5 \text{ km/s}$ higher than what is reported in MP22
- Galaxies with **higher velocity dispersion** tend to have **more massive DM halos** [4].



References

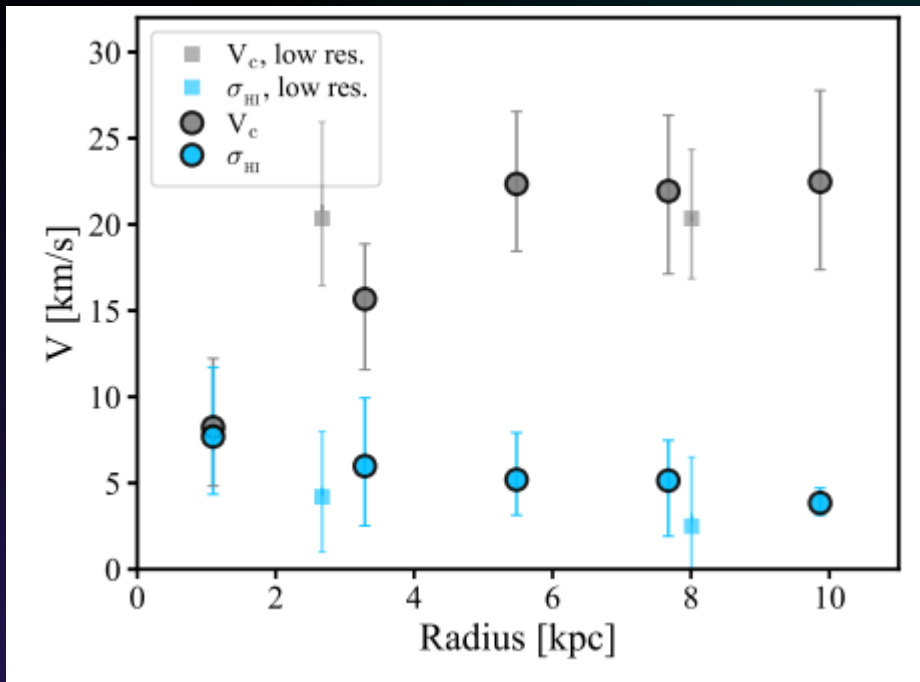
- [1] P. G. van Dokkum, R. Abraham, A. Merritt, J. Zhang, M. Geha, and C. Conroy, "FORTY-SEVEN MILKY WAY-SIZED, EXTREMELY DIFFUSE GALAXIES IN THE COMA CLUSTER," *The Astrophysical Journal*, vol. 798, no. 2, p. L45, jan 2015. [Online]. Available: <https://arxiv.org/abs/1410.8141>
- [2] P. E. M. Pí n a, F. Fraternali, T. Oosterloo, E. A. K. Adams, K. A. Oman, and L. Leisman, "No need for dark matter: resolved kinematics of the ultra-diffuse galaxy AGC 114905," *Monthly Notices of the Royal Astronomical Society*, vol. 512, no. 3, pp. 3230–3242, dec 2021. [Online]. Available: <https://doi.org/10.1093%2Fmnras%2Fstab3491>
- [3] E. Di Teodoro and F. Fraternali, "3d-barolo: a new 3d algorithm to derive rotation curves of galaxies," 2015. [Online]. Available: <https://arxiv.org/abs/1505.07834>
- [4] P. J. Elahi, C. Power, C. d. P. Lagos, R. Poulton, and A. S. G. Robotham, "Using velocity dispersion to estimate halo mass: Is the Local Group in tension with CDM?" *Monthly Notices of the Royal Astronomical Society*, vol. 477, no. 1, pp. 616–623, 03 2018. [Online]. Available: <https://doi.org/10.1093/mnras/sty590>

Image Credits

1. AGC 114905: <https://earthsky.org/space/dark-matter-missing-from-galaxy-agc-114905/>
2. Milky Way: <https://www.amnh.org/explore/ology/astronomy/the-milky-way-galaxy2>
3. Both figures in slide 3 are from ref. [2].
4. Significance of Results Galaxy: <https://astronomy.com/magazine/ask-astro/2017/12/galaxy-rotation>
5. Significance of Results Frisbee: https://commons.wikimedia.org/wiki/File:Frisbee_freestyle_claudio_cigna_2009.jpg
6. Gravitational Potential Well: https://en.wikipedia.org/wiki/Gravitational_potential
7. Balloon: <https://www.turbosquid.com/3d-models/3d-inflated-balloon/1036754>

Key Questions

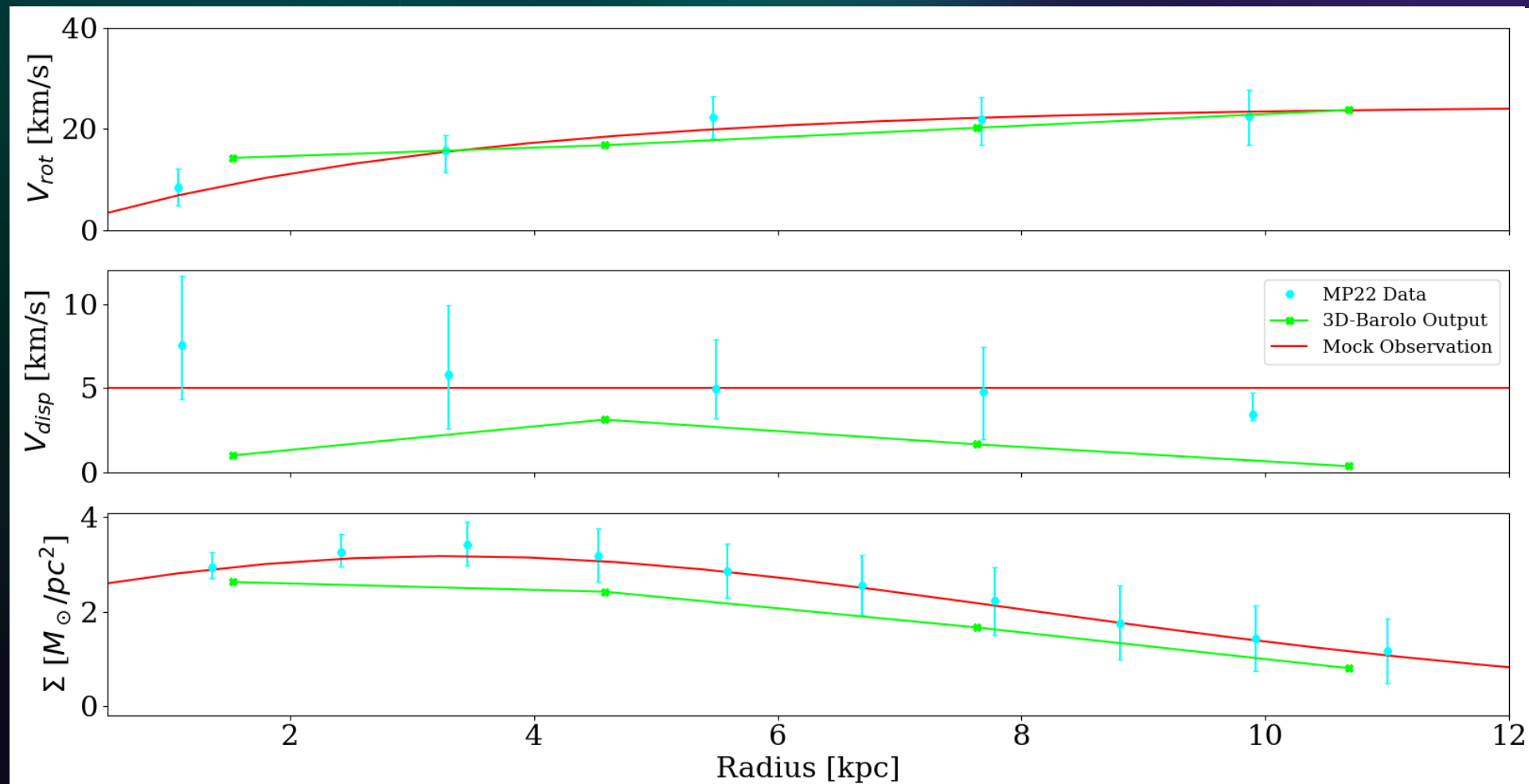
For a mock galaxy with properties like AGC 114905 in MP22, what do the profiles output by 3D-Barolo look like?



What kind of mock galaxy is needed for 3D-Barolo to output profiles similar to what is seen in MP22?

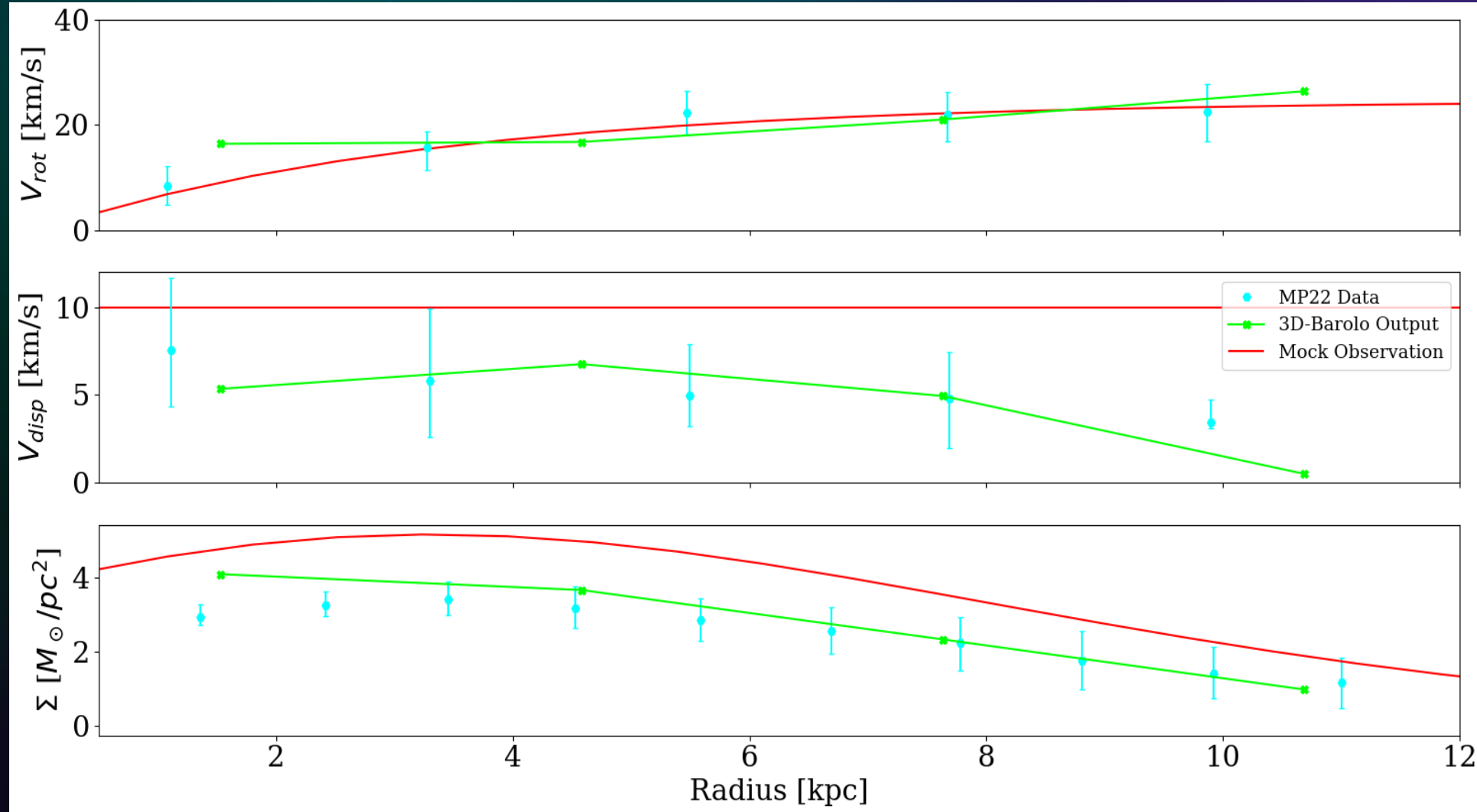
What happens when you put in a MP22-like mock model into 3D-Barolo?

- V_{disp} is underestimated by 2.5 - 4.5 km/s
- Inner Surface density is slightly underestimated



Finding AGC 114905's Properties

- V_{disp} and $\Sigma(r)$ are increased within the mock galaxy
- The quality of fits between 3D-Barolo and MP22 data increases dramatically



Conclusions

- The velocity dispersion of AGC 114905 is likely higher than what is published in ref. [2] by 3.5 ± 1 km/s
- This suggests that AGC 114905 could require a DM halo to explain the velocity of matter within it