Dark matter in low-mass dwarf galaxies

Lauren Cooke
Holton-Arms School
Rebecca Levy, Prof. Alberto Bolatto

Image Credit: L. Raffensperger & G. Schilling (Discover Magazine)

Galaxies

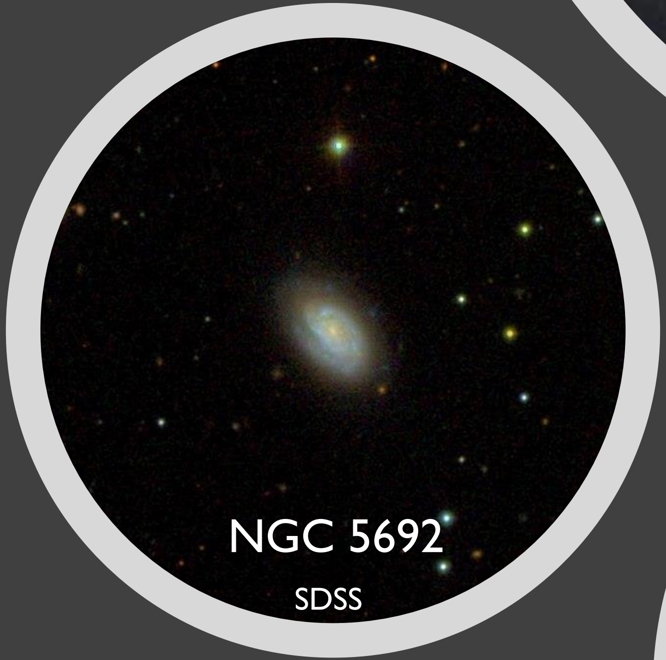
- Groups of stars, gas, dust, and dark matter
- Held together by gravity
- They Rotate!

NASA, ESA & A. van der Hoeven

Dwarf Galaxies

- Most abundant, low luminosity, low mass, small size
  - NGC 4451 ~ 16,304 ly in diameter
  - Milky Way ~ 100,000 ly in diameter
- Hard to spot
- Dominated by dark matter

NASA, ESA, HST, STScI, ST-ECF, CADC, NRC, CSA
NGC 4451



NGC 5692
SDSS

NGC 6106
SDSS

Dark Matter History

1884

Lord Kelvin estimates mass of galaxy to differ from the mass of visible stars = presence of dark bodies

1906

Henri Poincaré coins the term “dark matter” when describing Kelvin’s work

1922

Jacobus Kapteyn suggests dark matter exists from stellar velocities

1933

Fritz Zwicky obtained evidence of dark matter from galaxy clusters

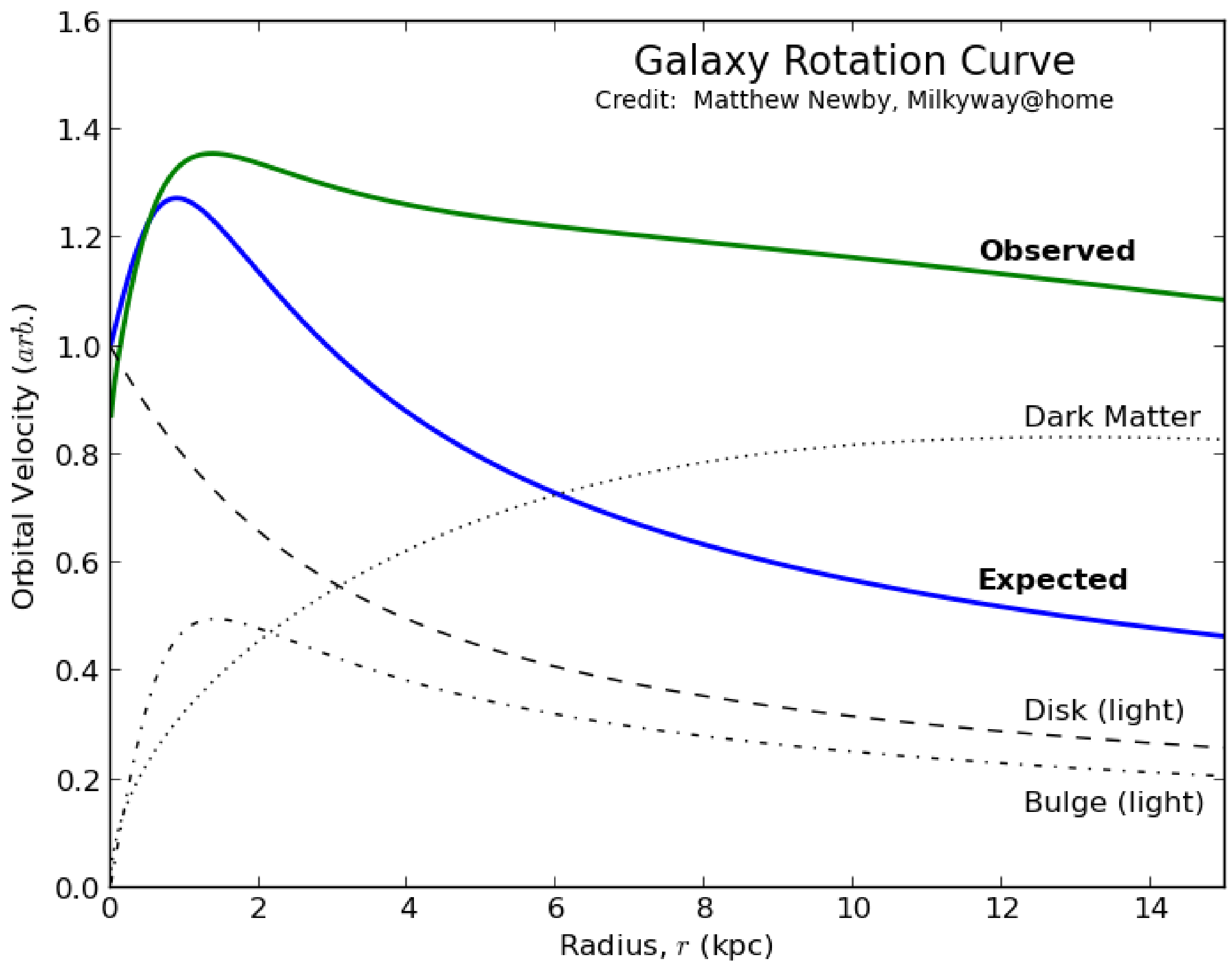
1976

Vera Rubin provides evidence for dark matter from galaxy rotation curves

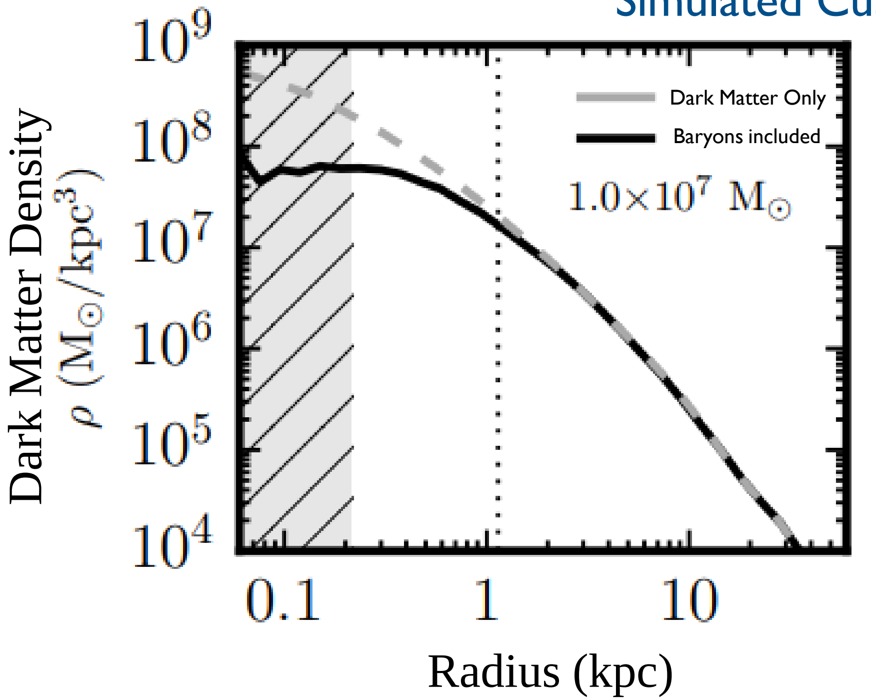
(Carnegie Institution of Washington via Associated Press)

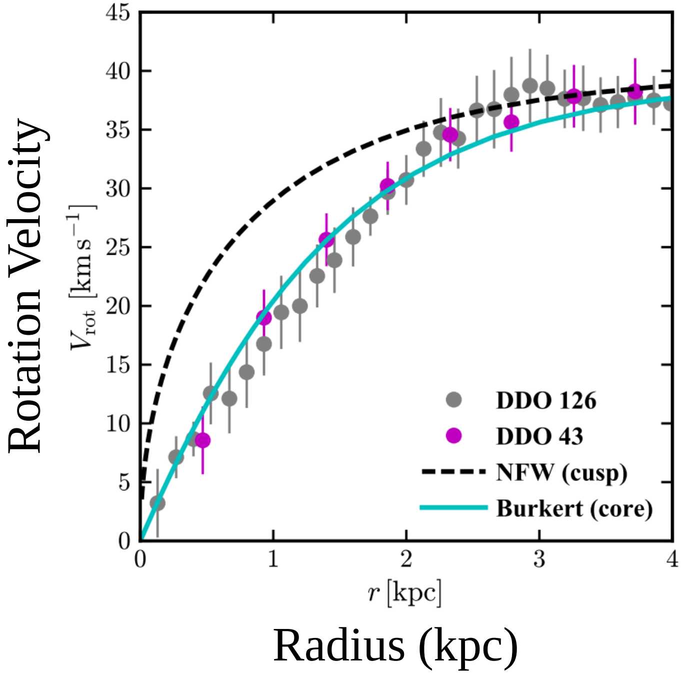
Dark Matter

- Expected velocity from observed mass
- But larger velocity observed
- Must be more unseen mass
- Dark matter: only known to interact with gravity



Simulated Cusp, Observed Core





$$\rho \propto \left(\frac{v}{r}\right)^2$$

Adapted from Bullock & Boylan-Kolchin et al. 2017

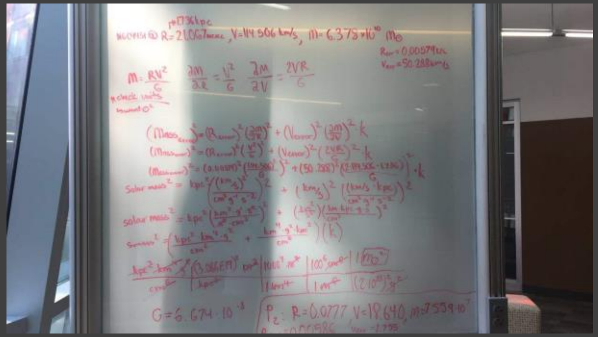
Core-Cusp Problem

Possible Causes:

- Dark matter functions differently than we understand
- Baryonic physics

Chronology and My role

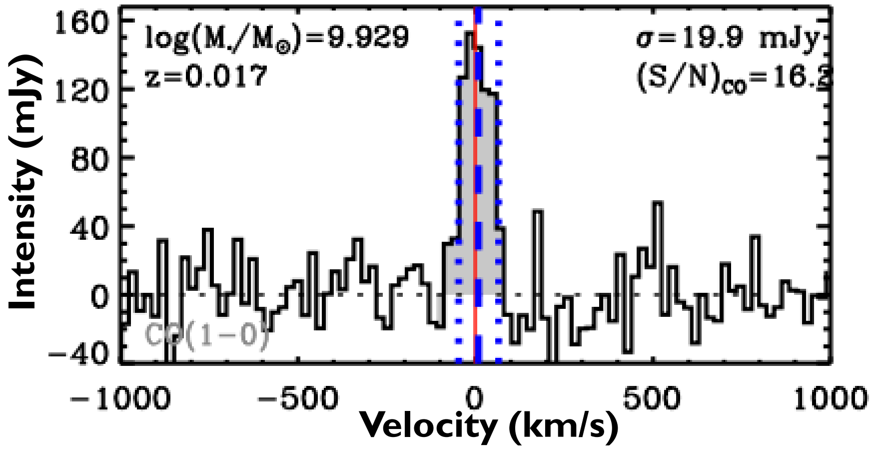
1. Setup, astronomy & scientific python overview
2. Plot CO velocity fields and rotation curves
3. Read papers, compare CO data to Hα data, cleanup code
4. Determine error to CO rotation curves using Monte Carlo method, find dynamical mass
5. Compare rotation curve geometric parameters between datasets, find inner slope of dark matter density and dark matter rotational velocity
6. Start final presentation and paper, fix error on fits, plot comparisons between observed and simulated data, compare dark matter concentrations to other galaxy parameters
7. Finalize graphs and code, write presentation
8. Finish presentation and poster

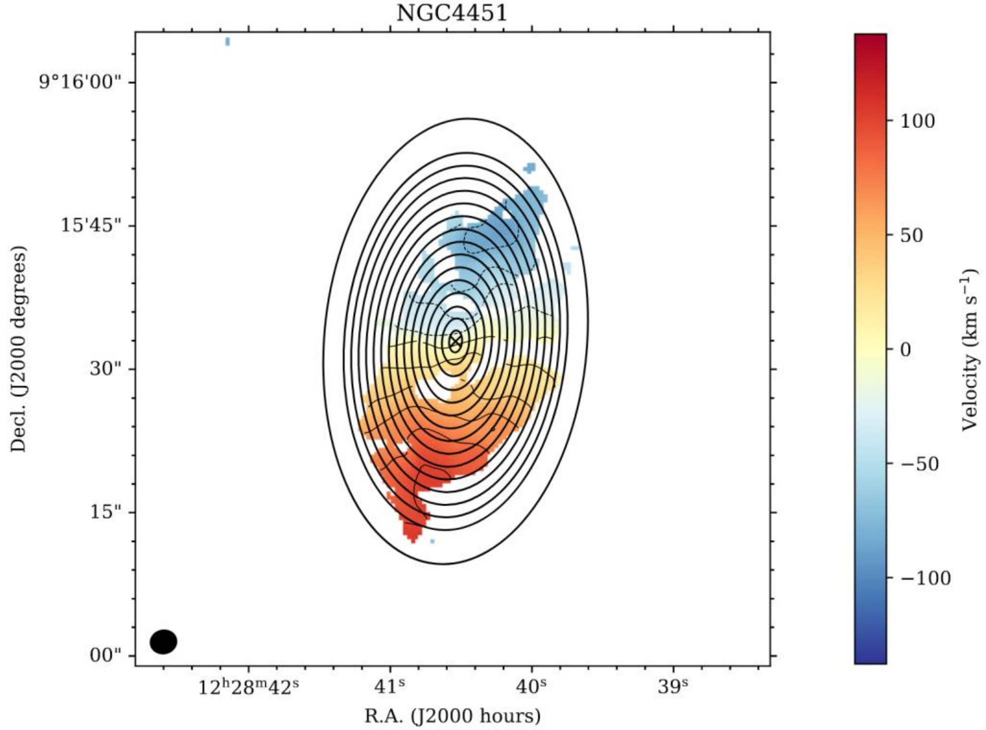


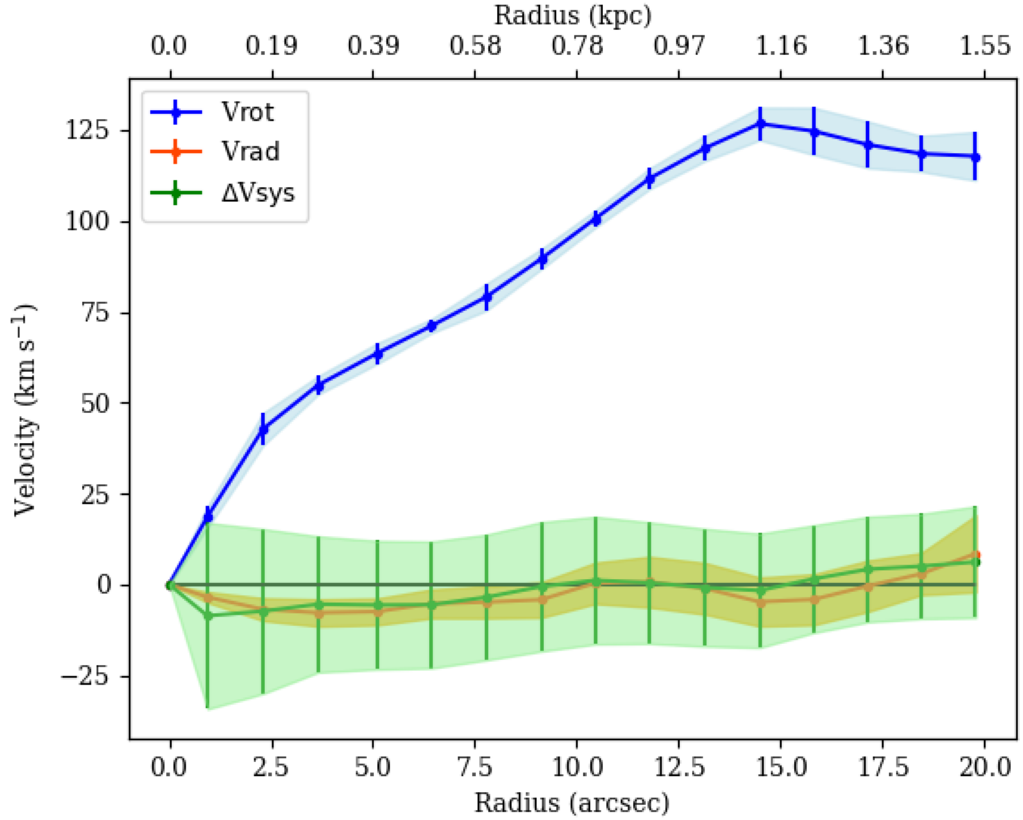
Data

- ALMA
- Carbon Monoxide (CO)
- Measuring the spectrum: amount of light emitted by that molecule at different frequencies

Saintonge et al. 2017



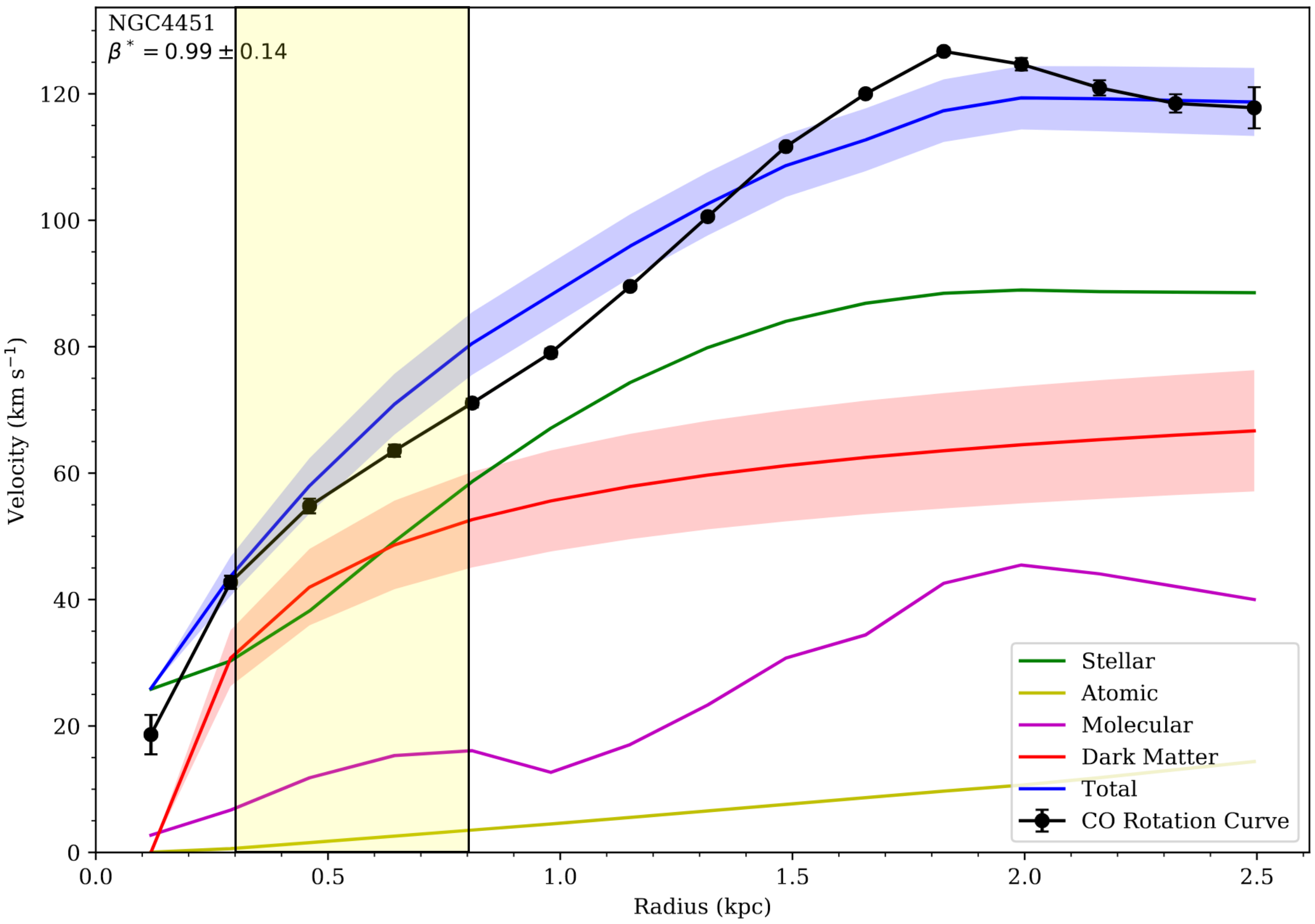


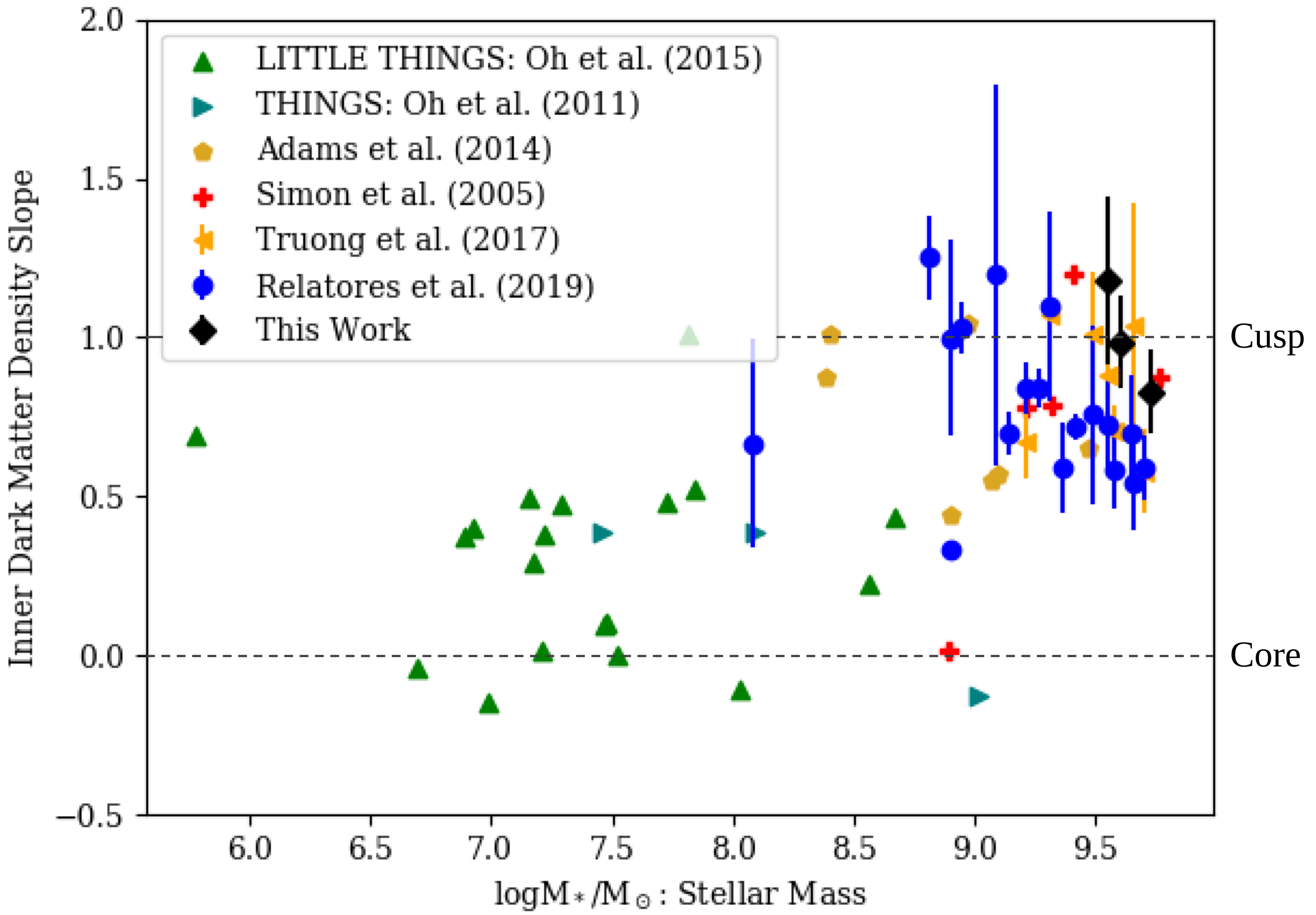


Velocity Fields and Rotation Curves

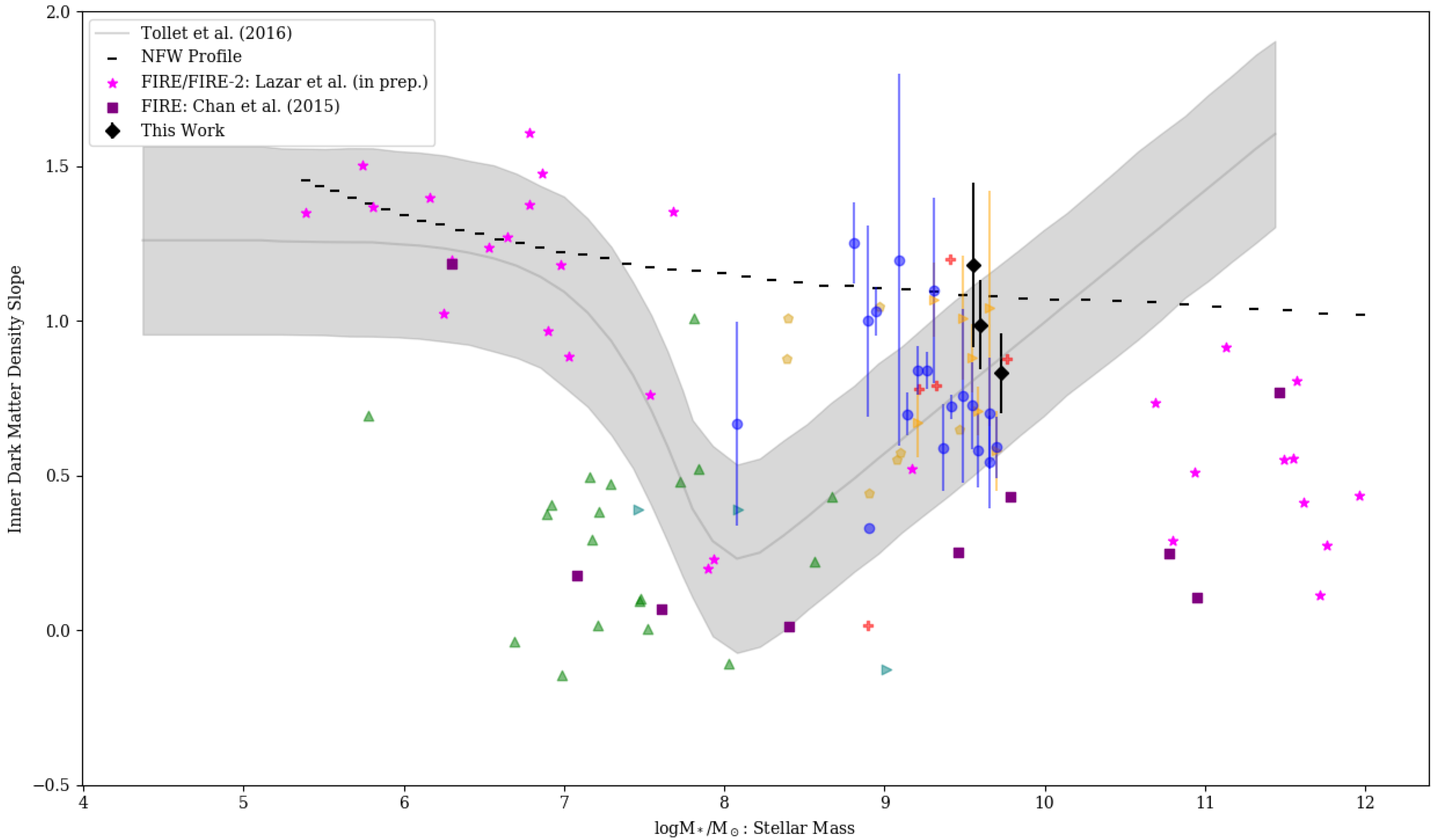
Dynamical Mass & its Breakdown

$$M = \frac{Rv_{rot}^2}{G}$$

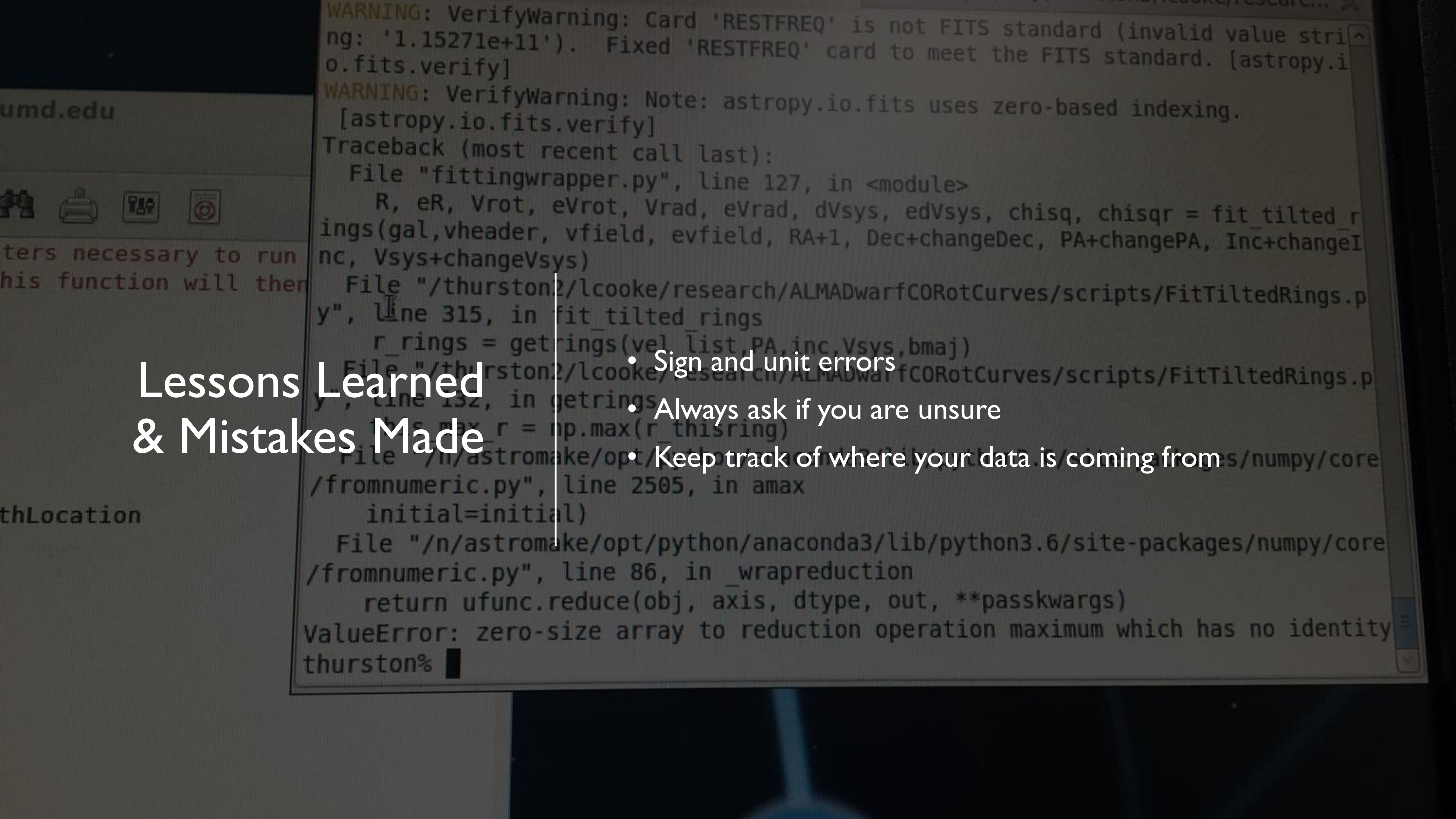




LITTLE THINGS: Oh et al. (2015)
THINGS: Oh et al. (2011)
Adams et al. (2014)
Simon et al. (2005)
Truong et al. (2017)
Relatores et al. (2019)
This Work
Cusp
Core
Inner Dark Matter Density Slope
logM* /M⊙ : Stellar Mass
2.0
1.5
1.0
0.5
0.0
−0.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5



Tollet et al. (2016)
NFW Profile
FIRE/FIRE-2: Lazar et al. (in prep.)
FIRE: Chan et al. (2015)
This Work
Inner Dark Matter Density Slope
2.0
1.5
1.0
0.5
0.0
−0.5
4
5
6
7
8
9
10
11
12
logM∗/M⊙: Stellar Mass



Lessons Learned & Mistakes Made

- Sign and unit errors
- Always ask if you are unsure
- Keep track of where your data is coming from

Future Work

Decompose mass of galaxies where we have robust rotation curves

Paper

Acknowledgements

- Rebecca Levy
- Prof. Alberto Bolatto
- Elizabeth Tarantino
- University of Maryland Astronomy Department
- Dr. Hannah Krug

UMD ASTRO

Conclusions

1. Dark matter distribution is affected by feedback

2. Simulations agree best with observations when baryonic physics are included

3. Core-Cusp problem in dwarf galaxies may be explained with baryonic physics