Modelling the Milky Way's Contracted Dark Matter Halo

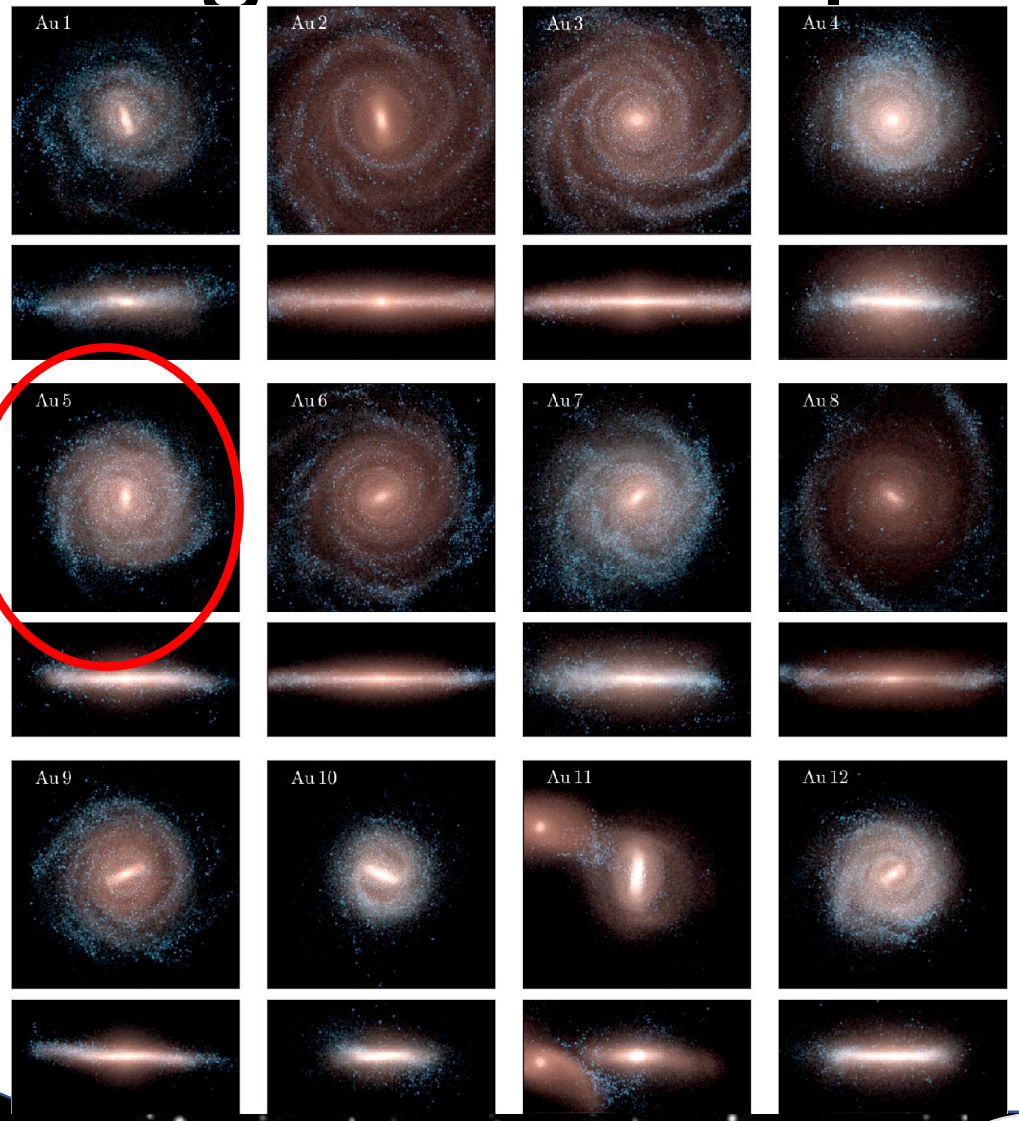
Tom Callingham

Marius Cautun, Alis Deason and Carlos Frenk

Durham University

ICC

Auriga Halo Sample



- Suite of MW like zoom-in simulations
- Lv4 resolution – 30 halos
- 17 Relaxed
- Range of Halo properties

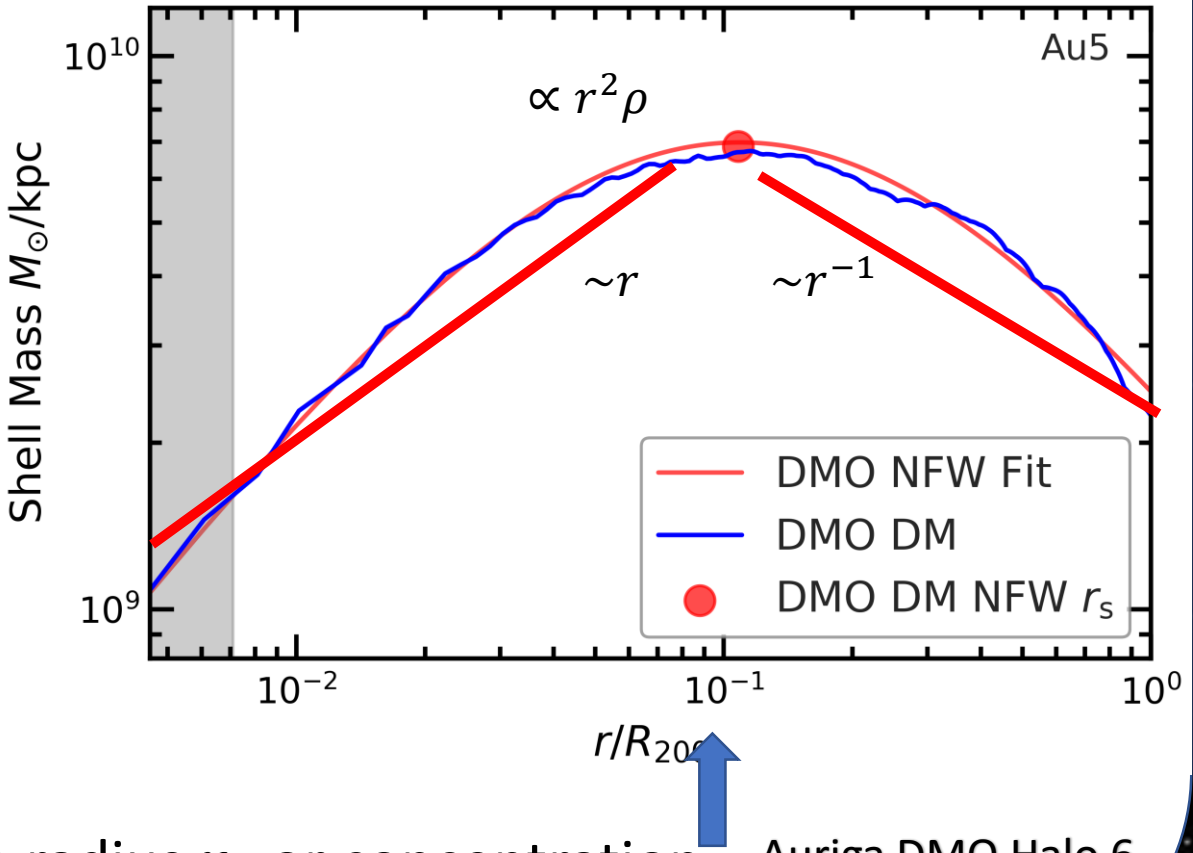
(Concentration, Mass)

- Compare DMO and Hydro halos

Dark Matter Universe - NFWs Everywhere

- Outcome of spherical collapse and hierarchal growth
- Density profile found in DM simulations across all mass ranges

$$\rho = \frac{\rho_0 \, {r_s}^3}{r(r_s + r)^2} \sim \begin{matrix} r^{-1} & \text{Inner Slope} \\ r^{-3} & \text{Outer Slope} \end{matrix}$$

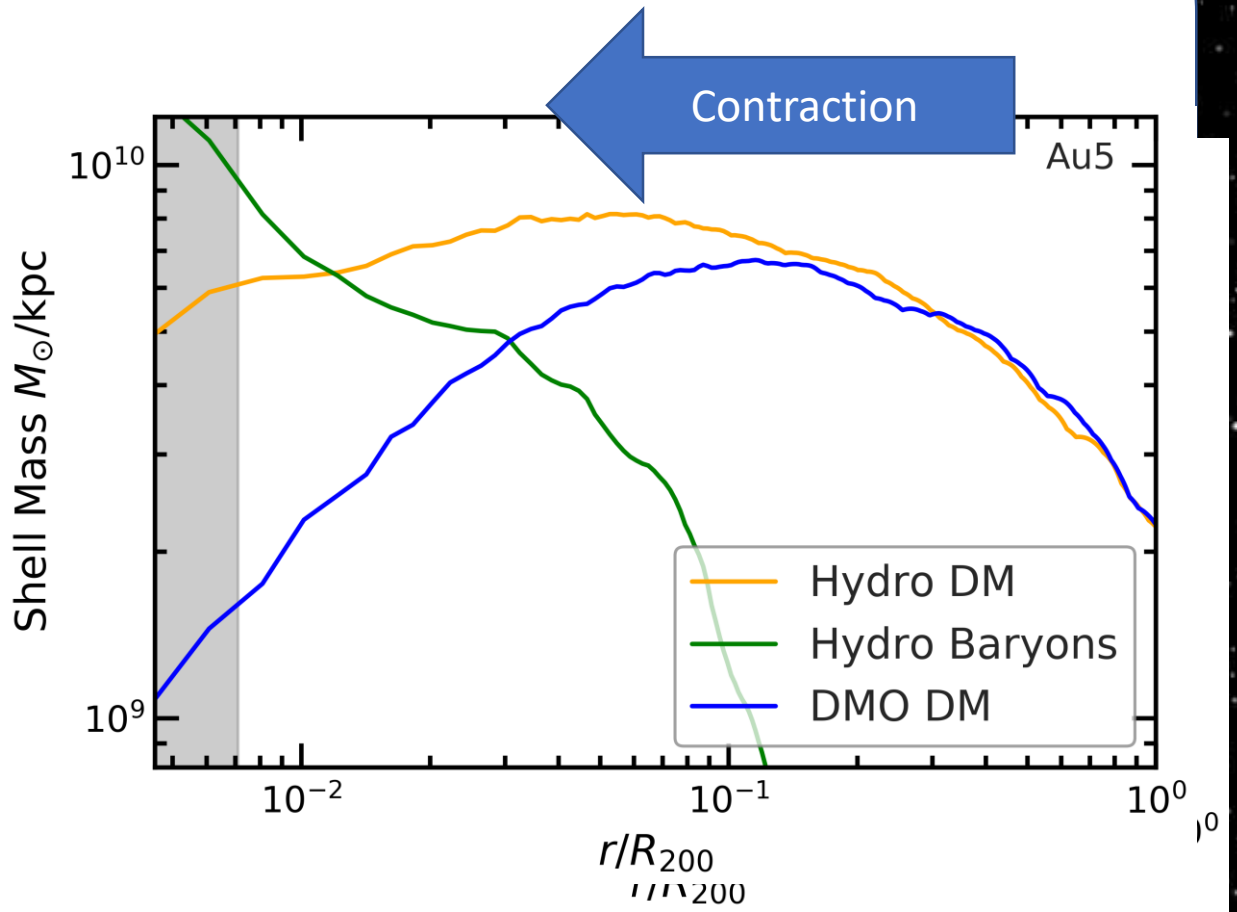


Only parameter is scale radius r_s or concentration (When scaled by mass)

Auriga DMO Halo 6

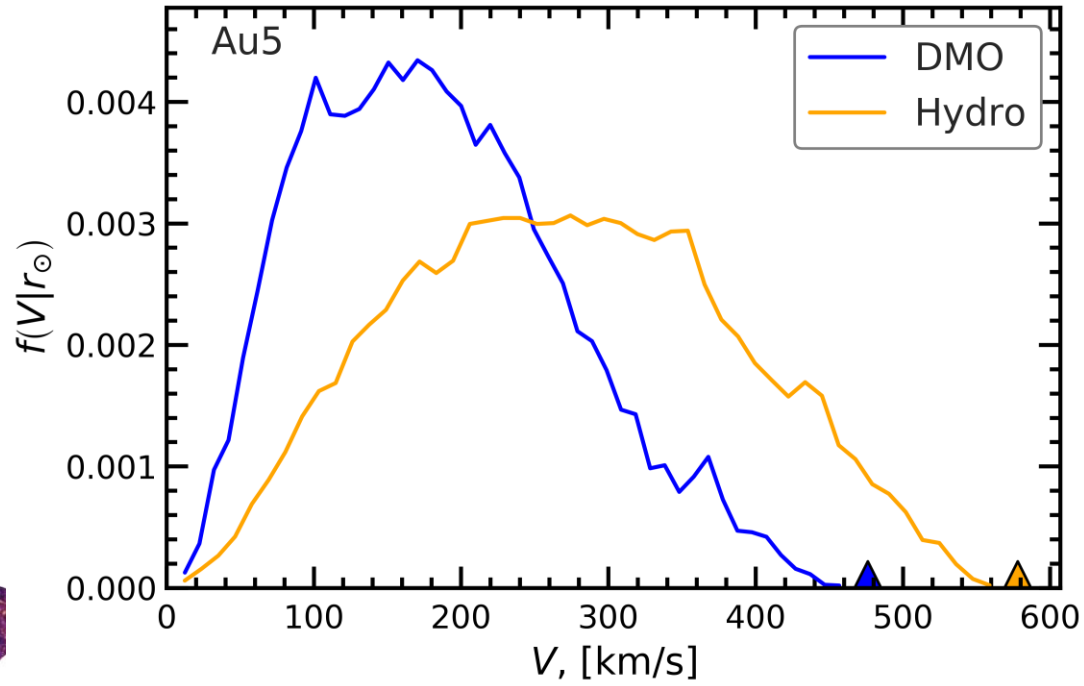
Baryons – Departure from NFW

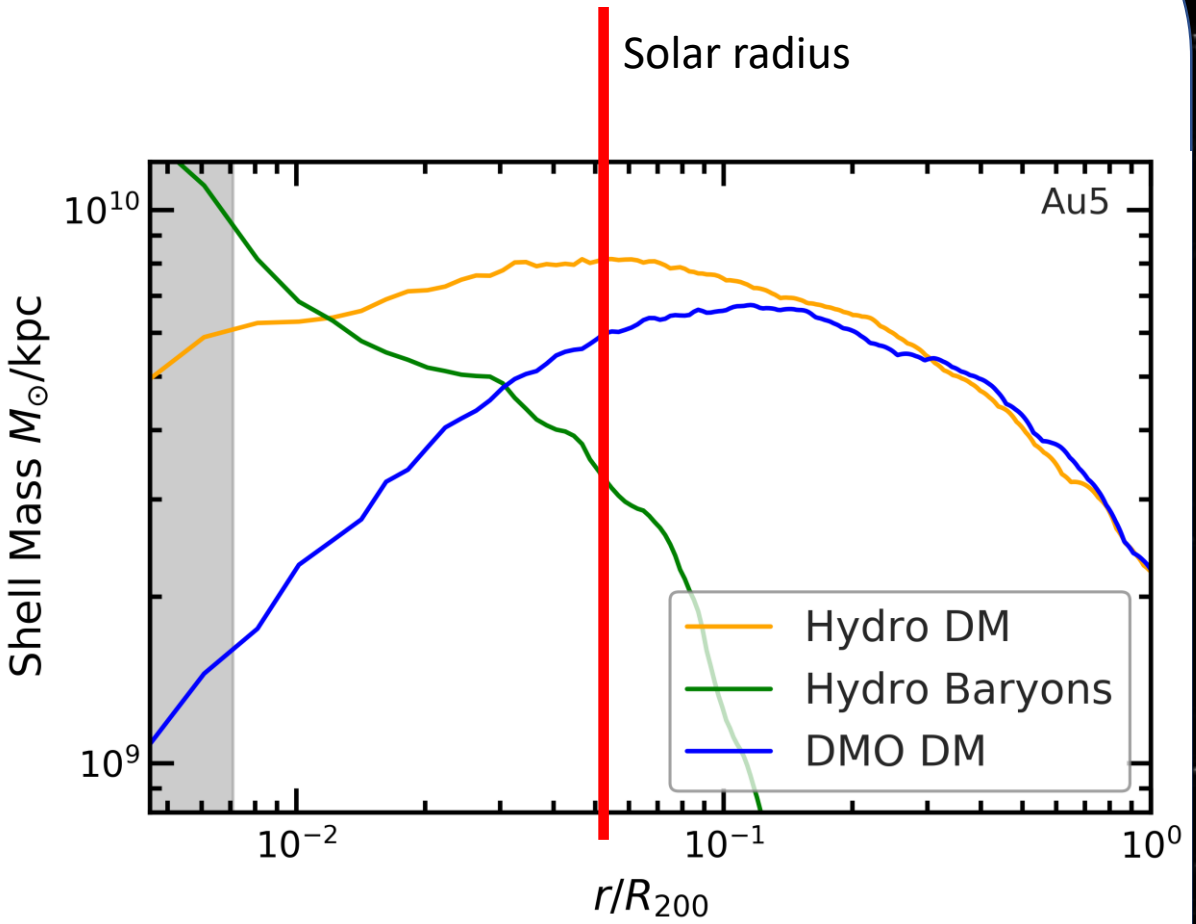
- Baryons collect in the centre of halos
- This gives a deeper galactic potential $(+\Phi_{Baryon})$
- Baryons Contract the Dark Matter Halo
- Denser central regions



DM Dynamics

- DM Halos comprised of orbiting particles
- Contraction effects (local) DM dynamics





Problems to solve

Can we satisfy Wyn?

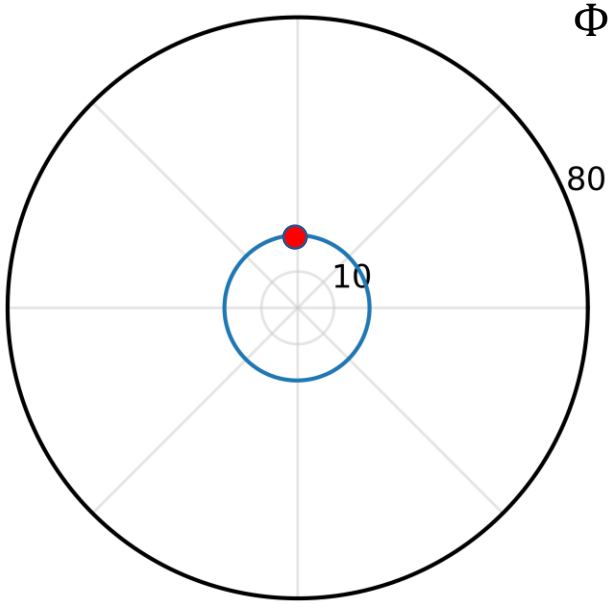
How to model….

- DM halo contraction? (To a known ρ_{Baryon})
- The dynamics of (Local) DM?
- Specifically our MW's own DM halo?

Spherical Action Angle Modelling!

- ~Model the DM halo as an Equillibrium distribution of orbits

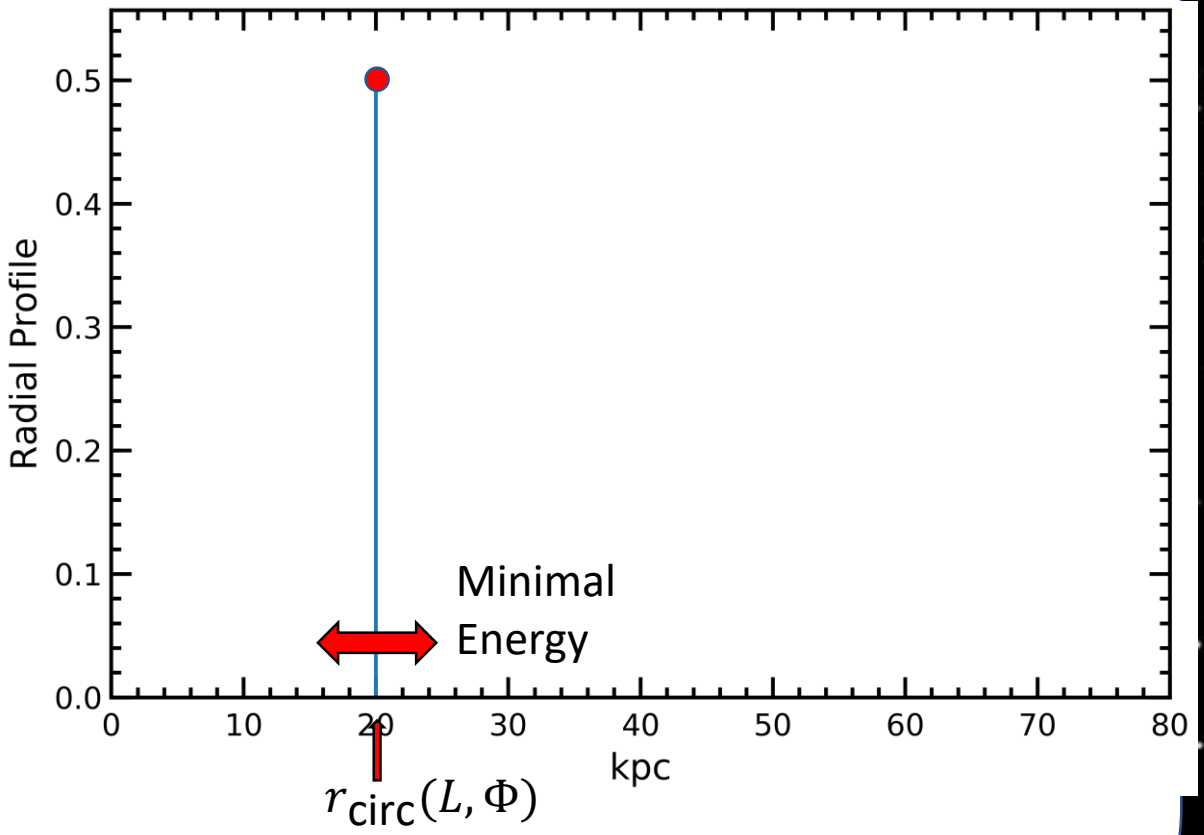
Constructing Orbits



$\Phi = \Phi_{Kepler}$

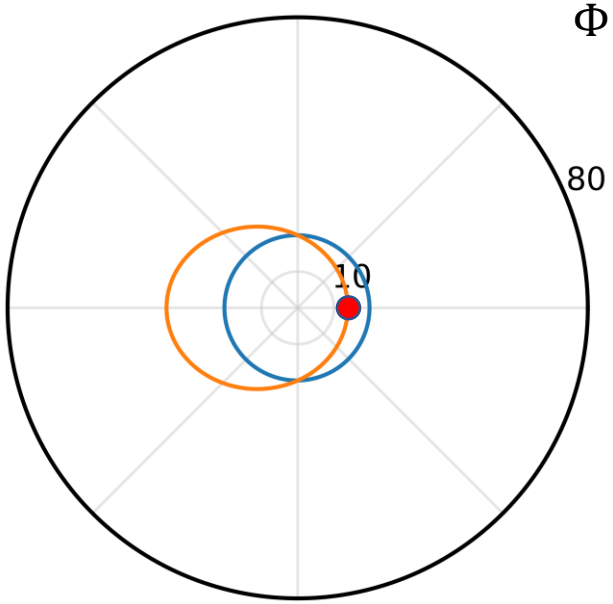
Fix Angular Momentum L ⟶ r_{circ}

Minimal Energy ⟶ Circular Orbit
(No Radial Energy)



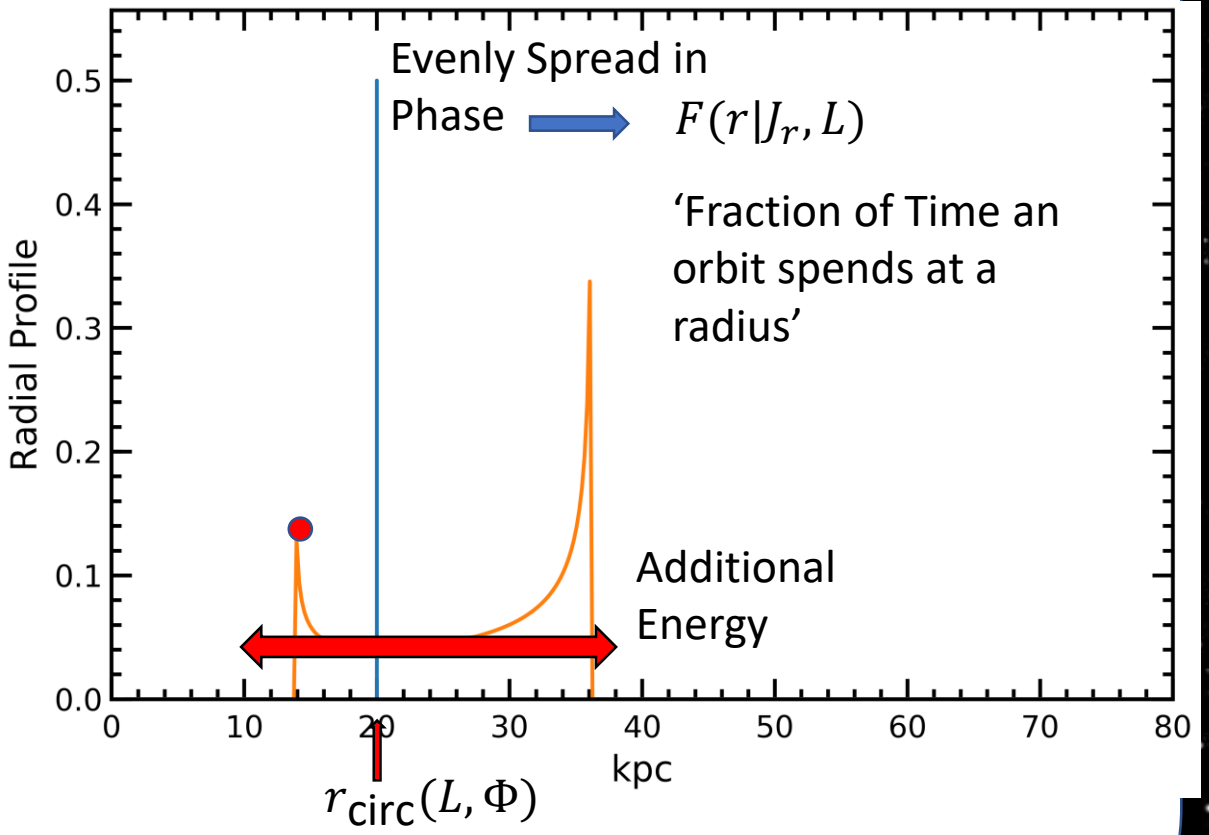
Constructing Orbits

$\Phi = \Phi_{Kepler}$



Fix Angular Momentum L ⟶ r_{circ}

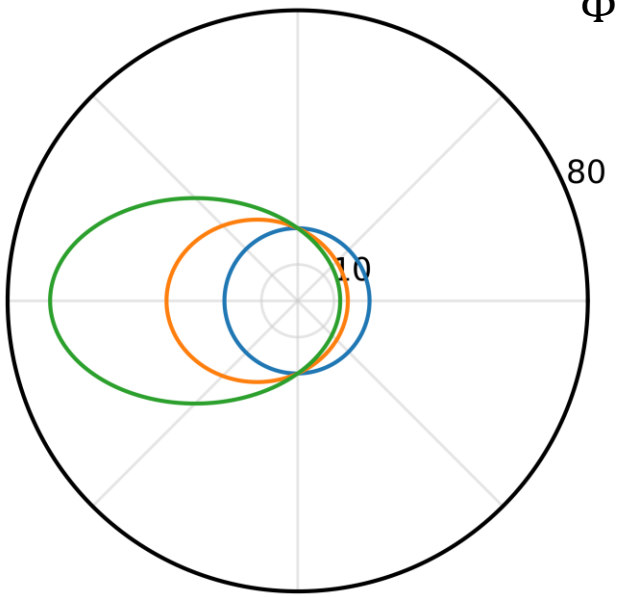
Add Radial Energy ⟶ Eccentric Orbit

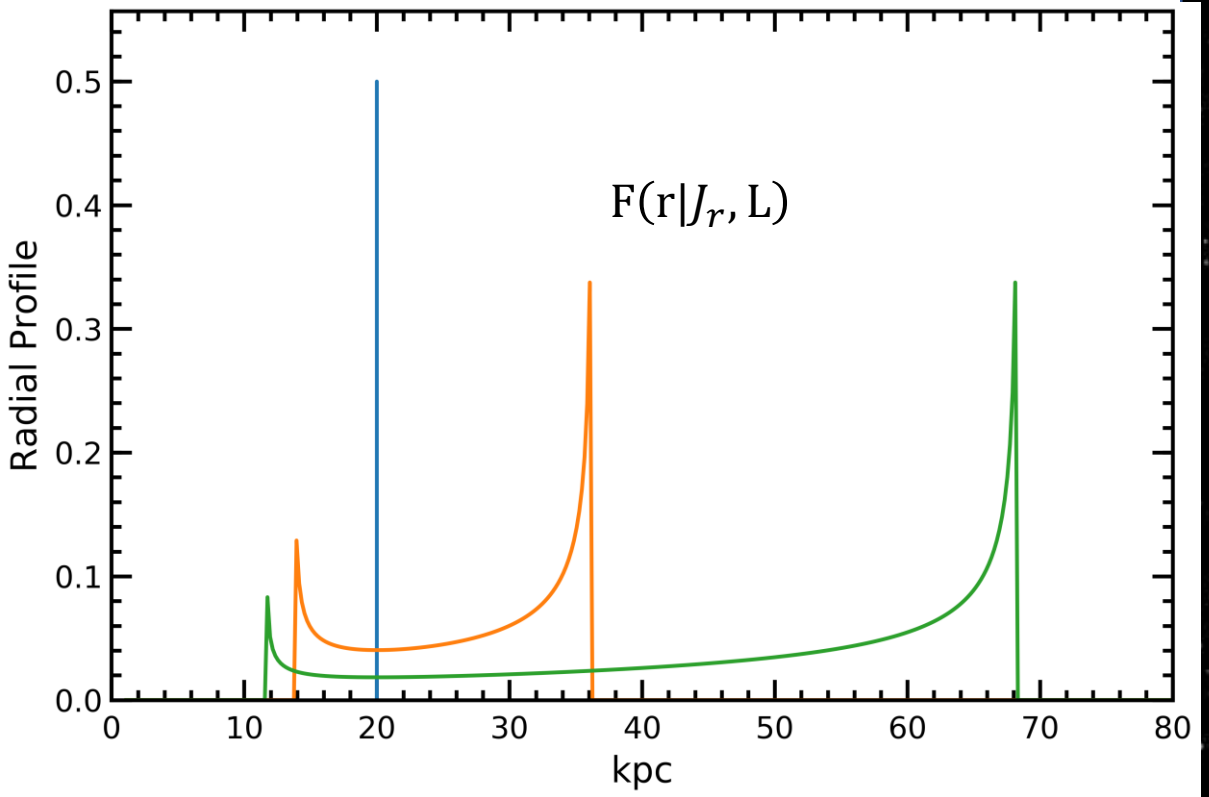


Radial Energy of Oscillation ~ Radial Action $J_r = \frac{1}{\pi}\int v_r dr$

Constructing Orbits

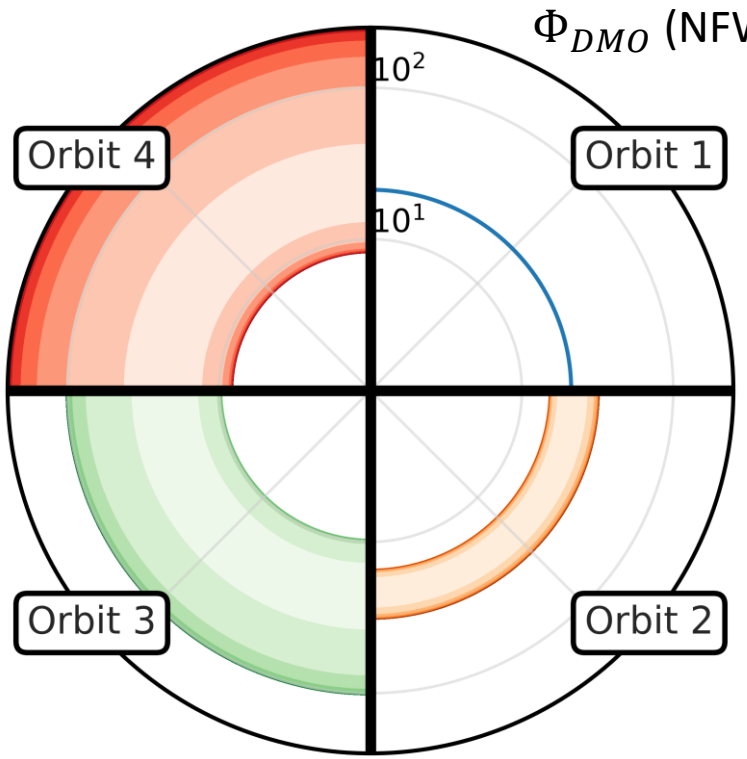
$\Phi = \Phi_{Kepler}$

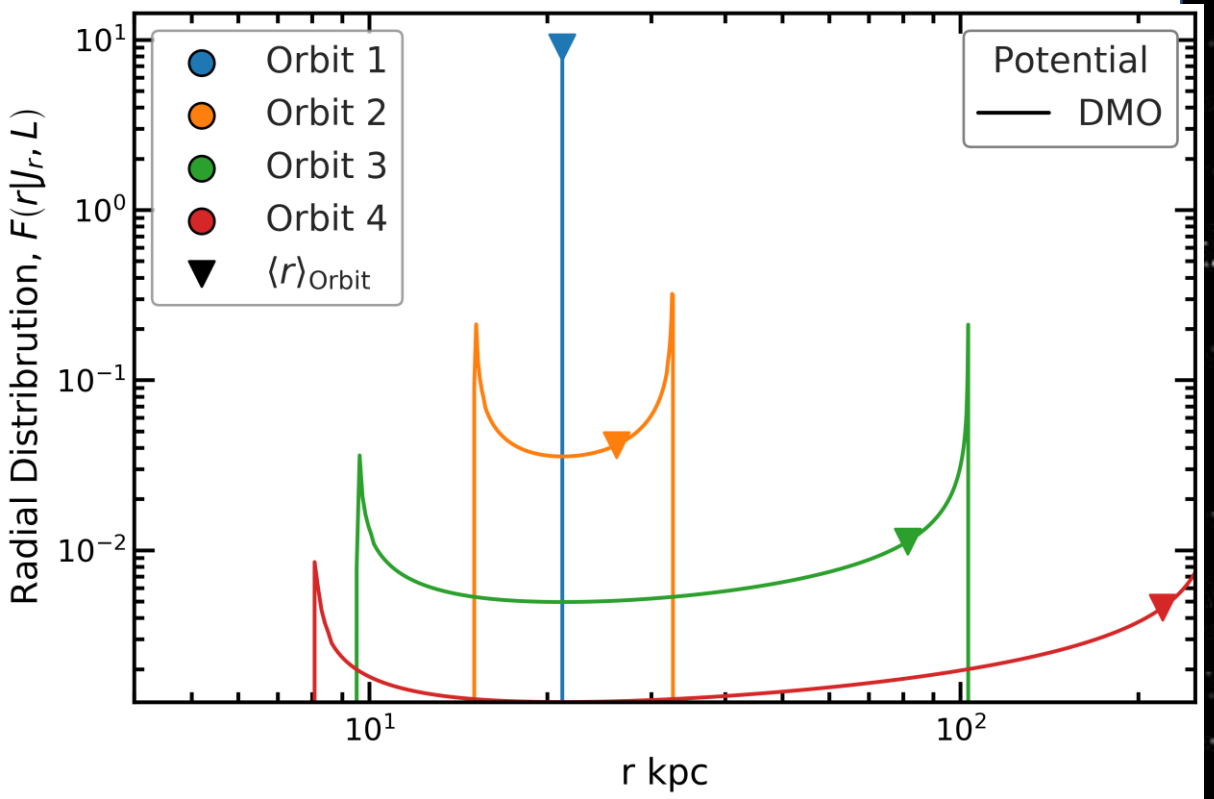




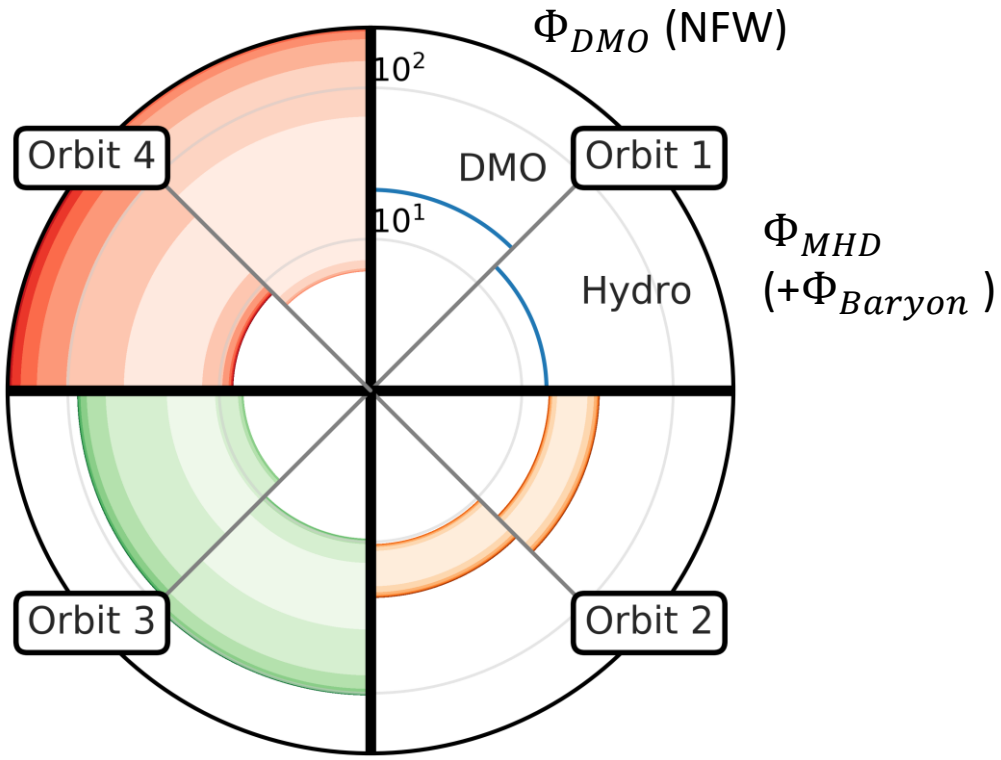
Varying L and J_r give different Radial Profiles $F(r|J_r, L)$

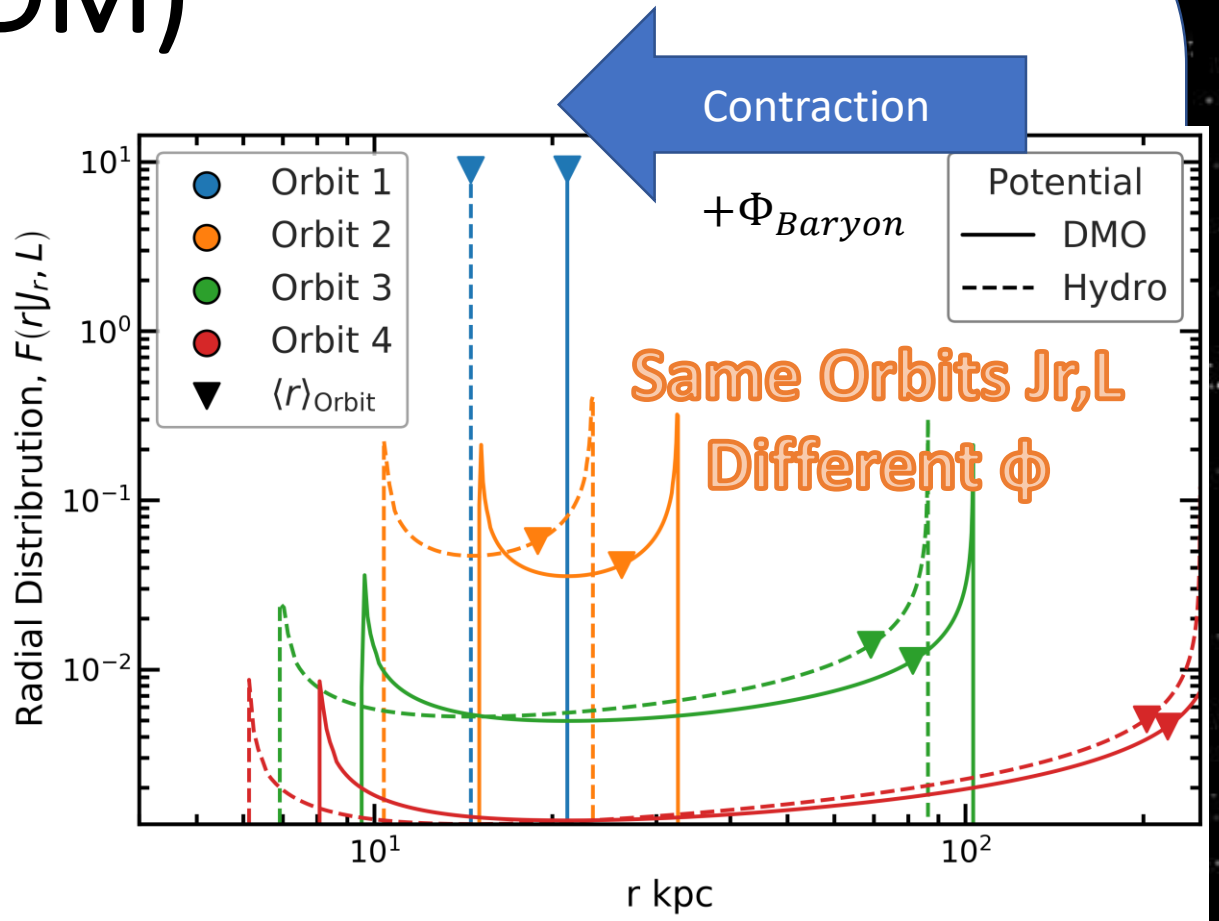
Constructing Orbits (DM)





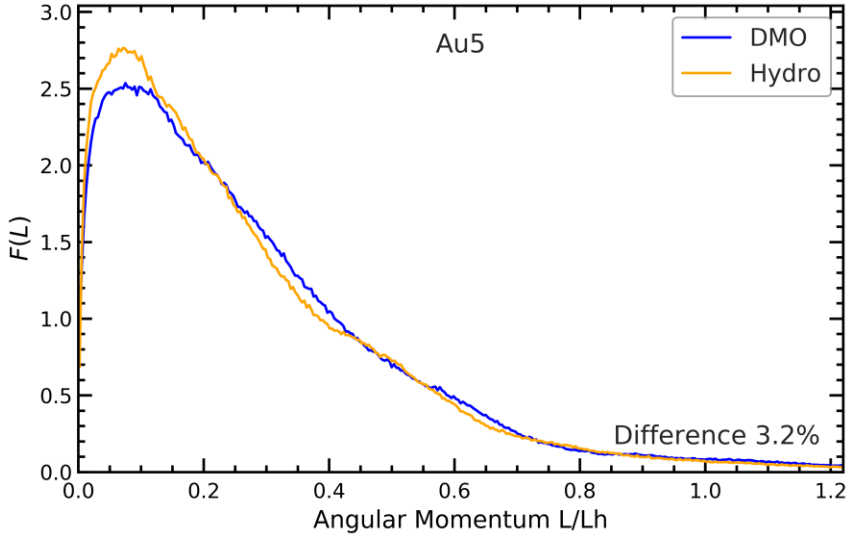
Constructing Orbits (DM)

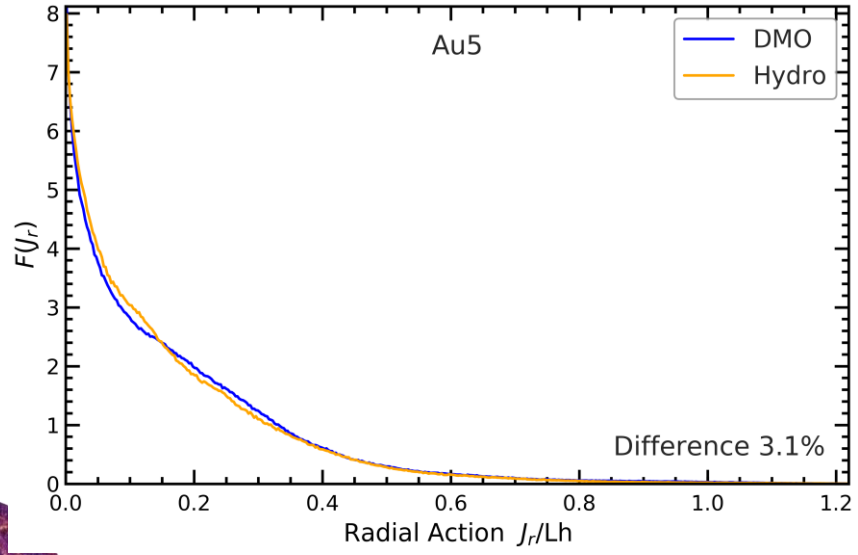




Do DMO and Hydro have the same orbits J_r, L ?

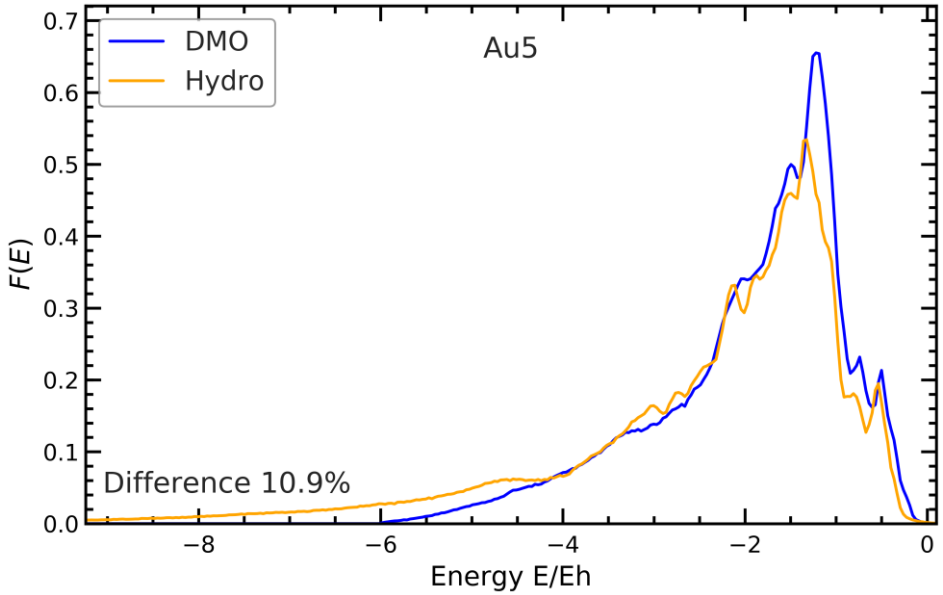
Orbital Distributions



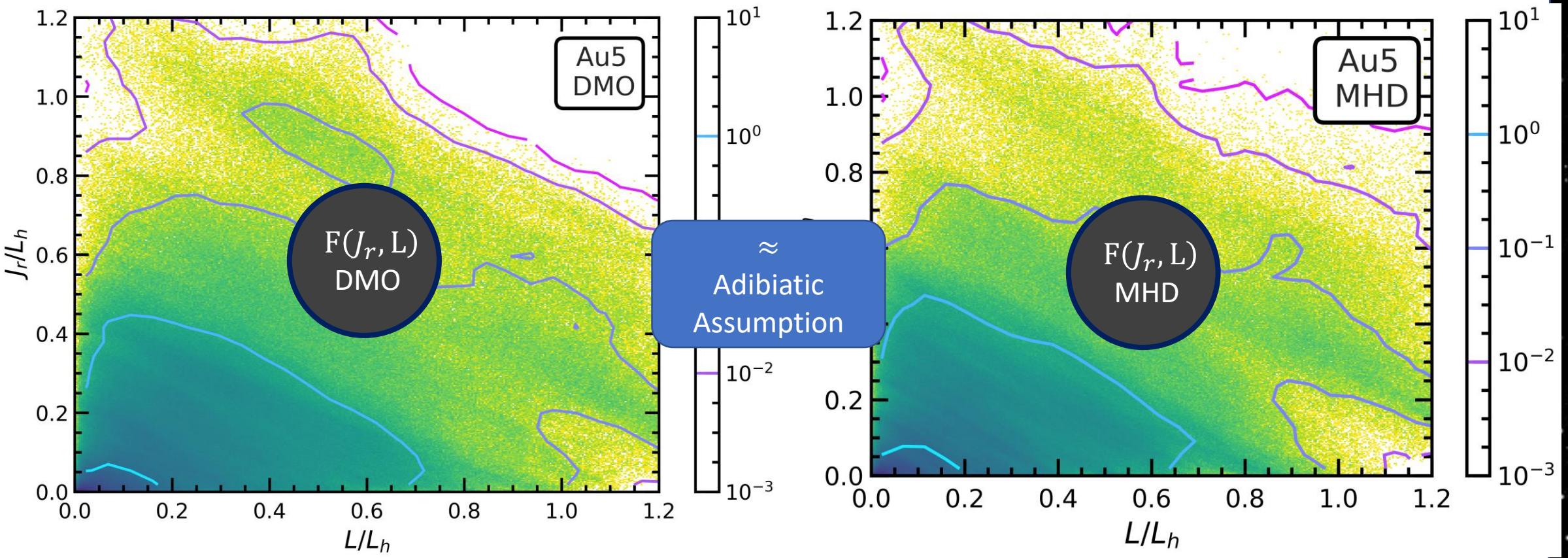


- Approximately yes!
- Actions L and J_r Adibiatic. Slow changes in potential approximately conserves L and J_r
- Assume accretion of baryons adiabatic process

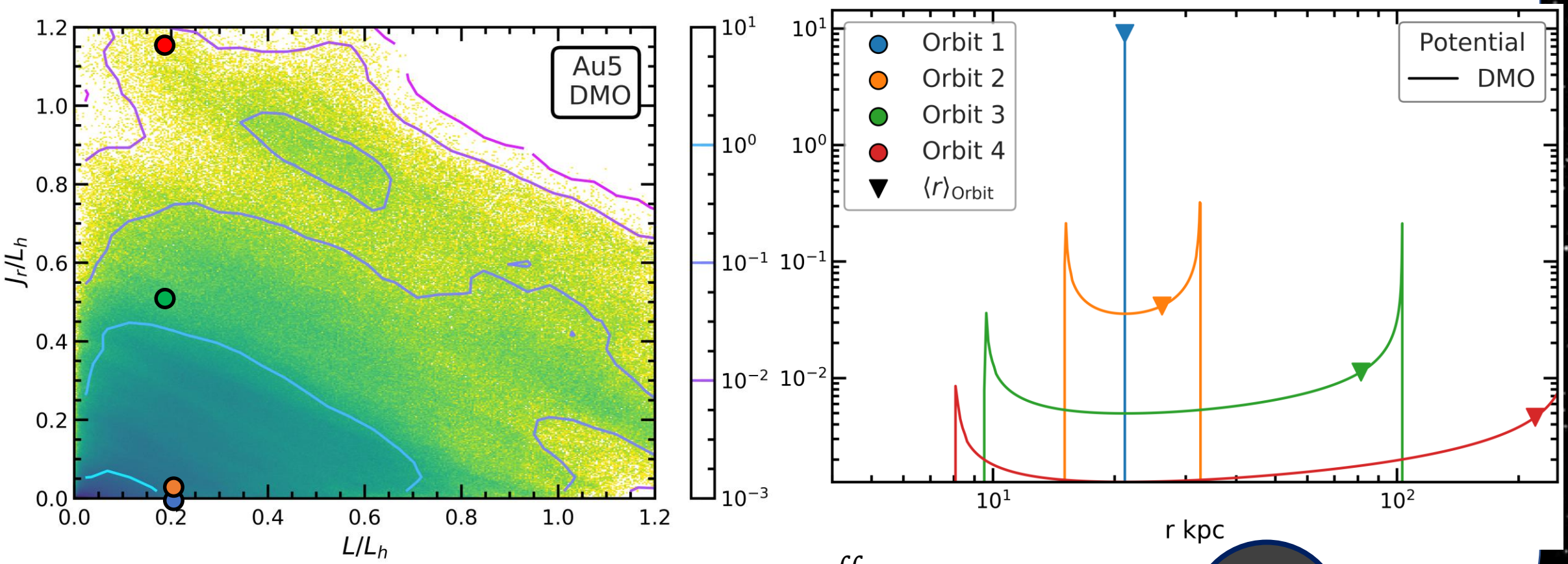
– How Adiabatic?



Action Distributions – Halo blueprints



Reconstructing the DM Halo

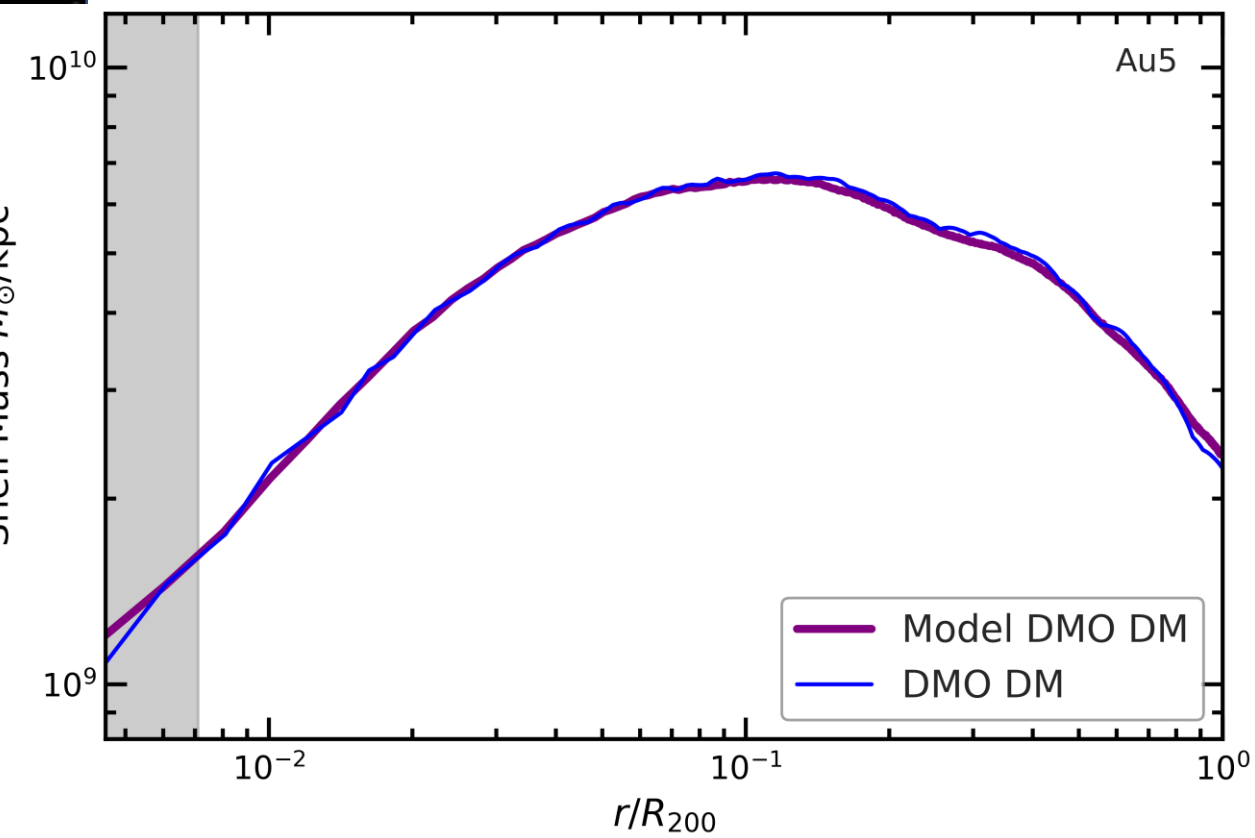


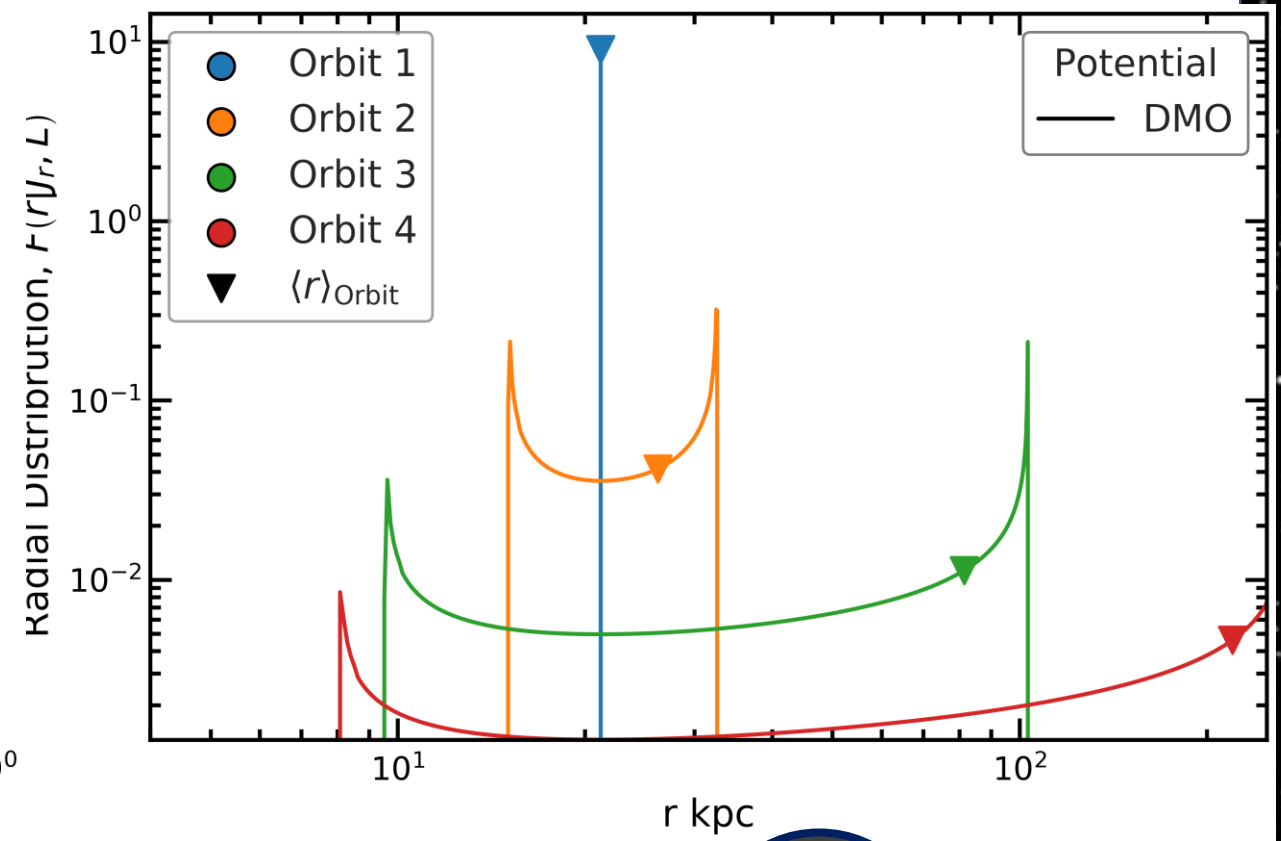
$$4\pi r^2 \rho(r) \propto F(r) \quad = \quad \iint F(r|J_r, L)\, \mathrm{F}(J_r, L)\, dJ_r dL$$

Density Profile = Action DF

$\mathrm{F}(J_r, \mathrm{L})$

Reconstructing the DM Halo





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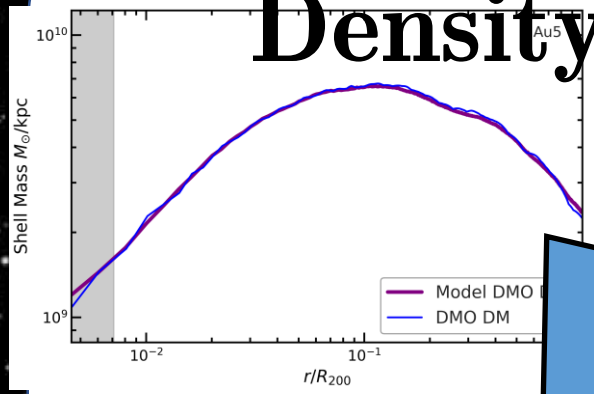
Density Profile = **Action DF**

$\mathrm{F}(J_r, \mathrm{L})$

$\rho_{DM}(r)$

Density



$\Phi_{DM}(r)$

Potential

$(+\Phi_{Baryon}$

A Self Consistent Converge Halo?

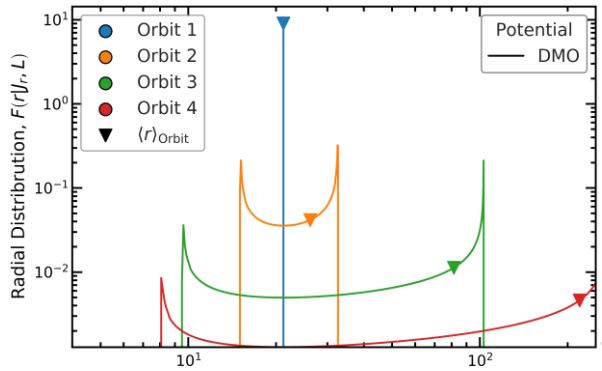
Integrate over Orbital Phase Space

$F(J_r, L)$

F(J_r, L)

Create Orbits

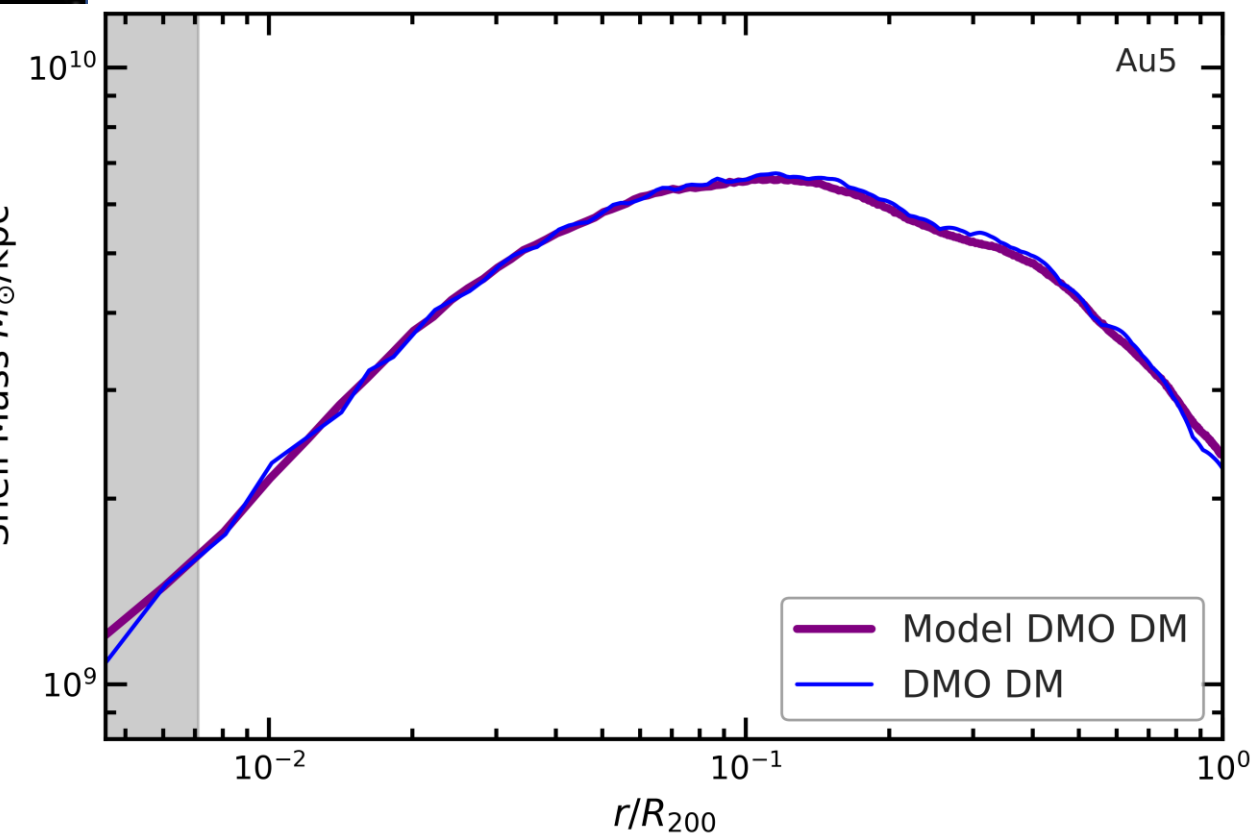
(J_r, L)

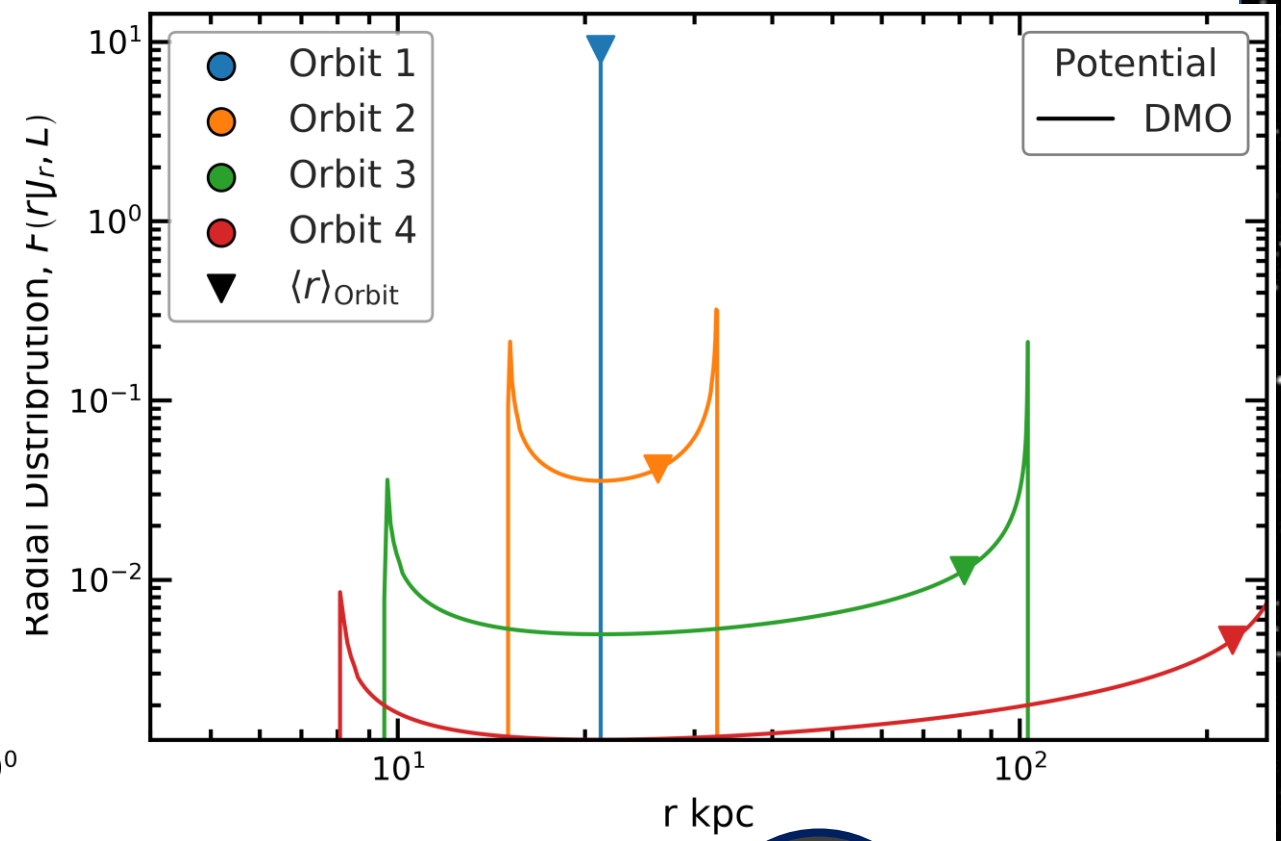


$F(r|J_r, L)$

Orbit Radial Profiles

Reconstructing the DM Halo





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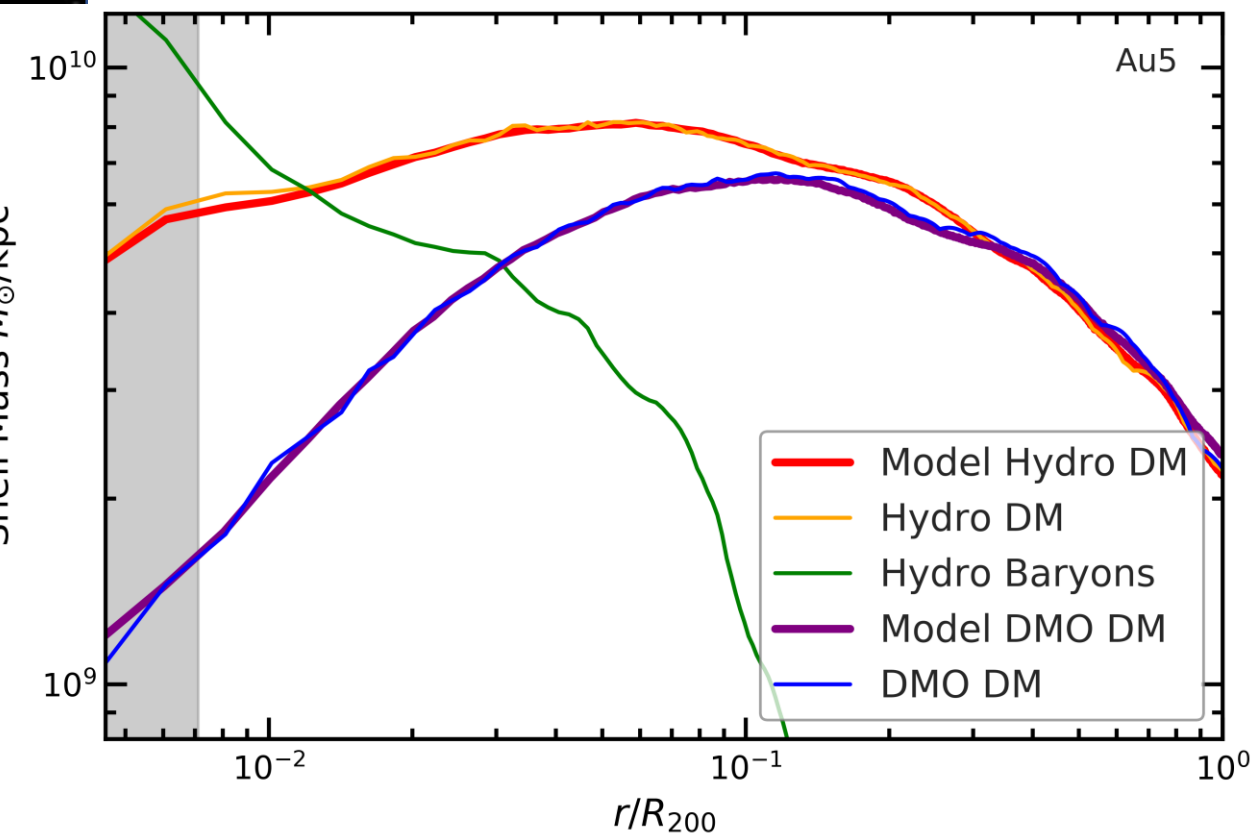
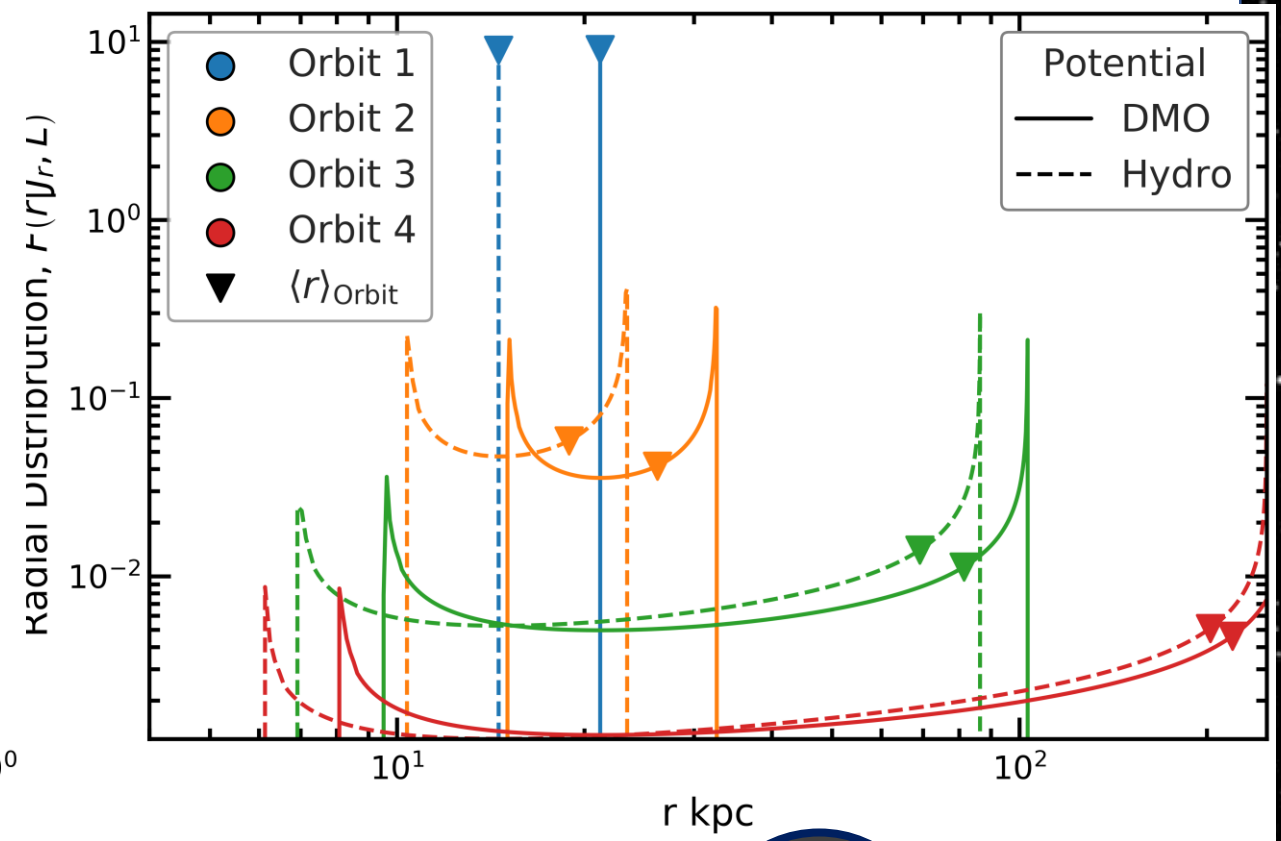
Density Profile = **Action DF**

$\mathrm{F}(J_r, \mathrm{L})$

Reconstructing the DM Halo





$$4\pi r^2 \rho(r) \propto F(r) \quad = \quad \iint F(r|J_r, L)\mathrm{F}(J_r, L)\, dJ_r\, dL$$

Density Profile = **Action DF**

$\mathrm{F}(J_r, \mathrm{L})$ $+\Phi_{Baryon}$

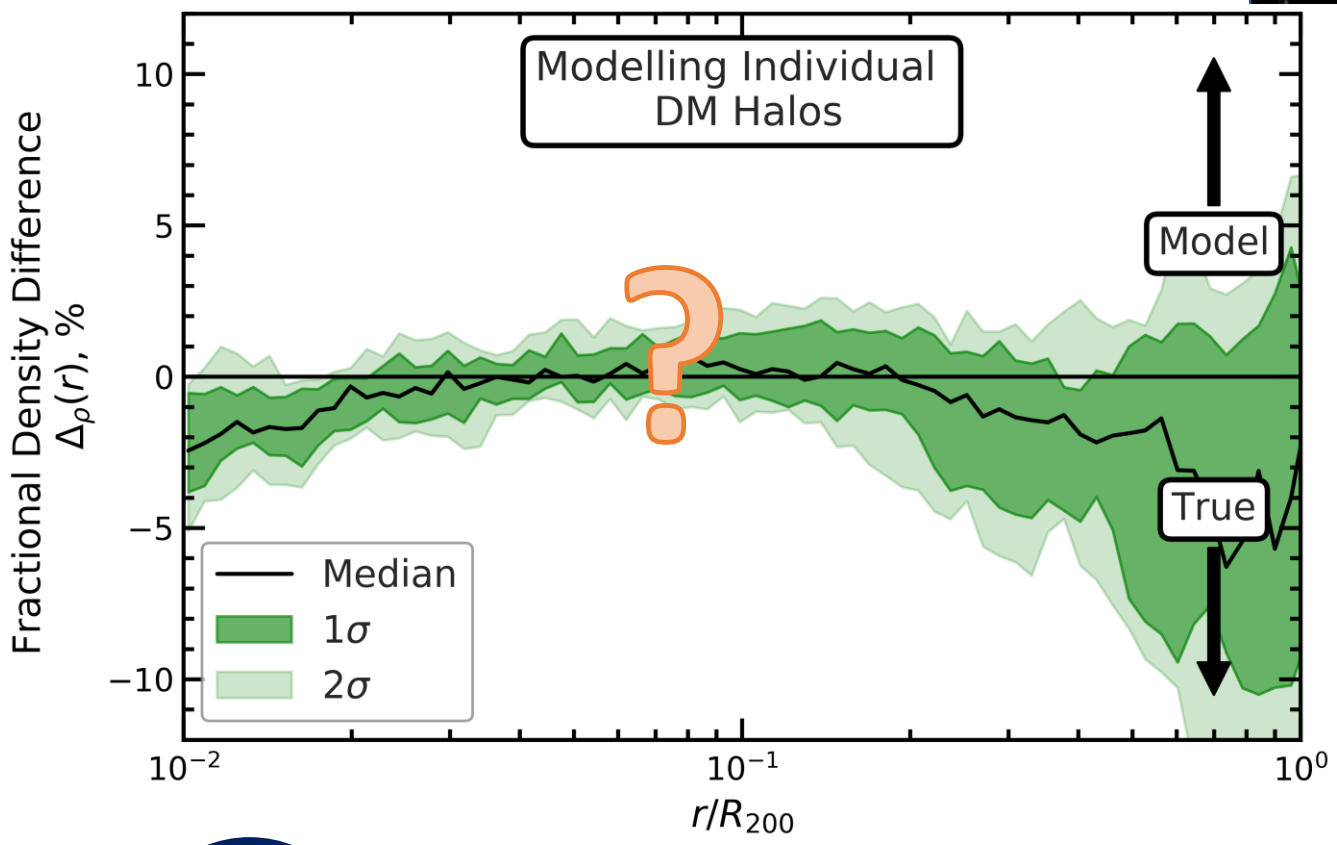
Testing on Auriga

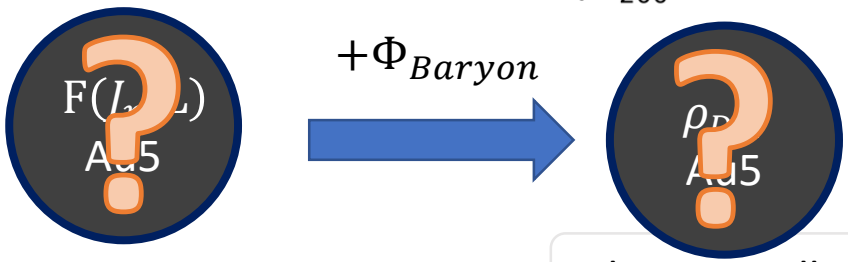
- Define Fractional density difference:

$$\Delta_\rho = \frac{2(\rho_{Model} - \rho_{True})}{(\rho_{Model} + \rho_{True})}$$

- Can recover Au5
- Can recover the relaxed sample of halos…

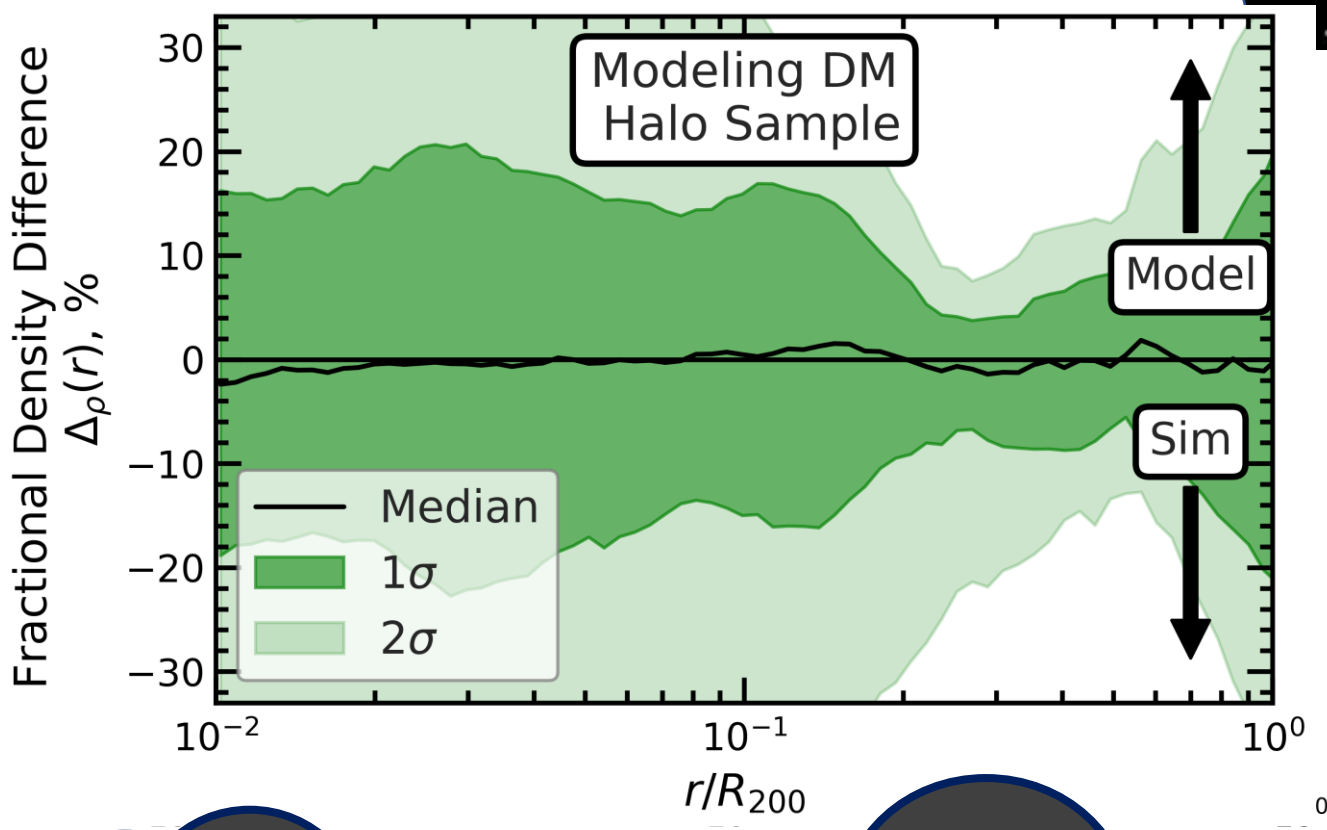
If we know the Action DF!

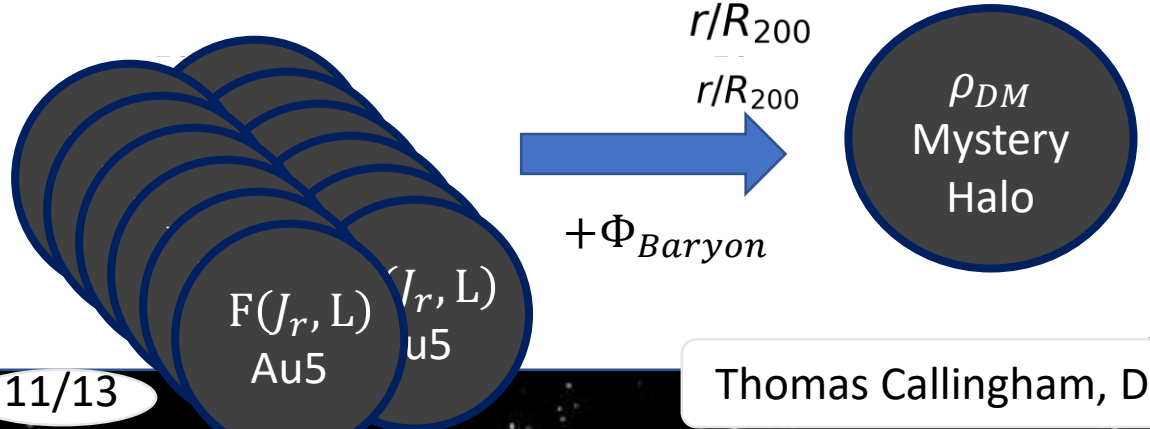




Testing on Auriga

- How can we model without a known distribution?
- Use the sample of Au halos
- Halo Scatter limits us to ~15% accuracy





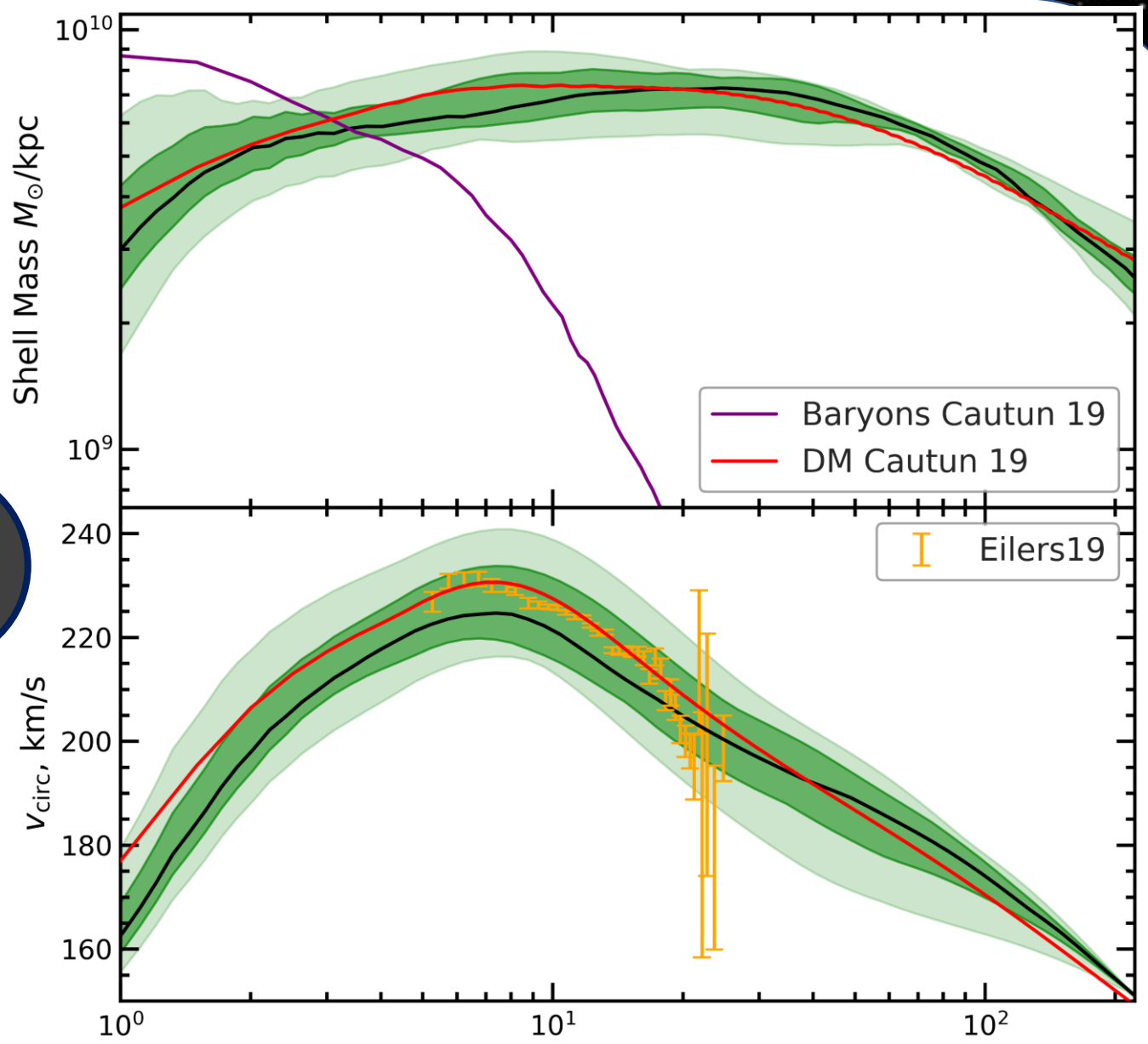
MW Models

- Use Cautun19 Baryons $(+\Phi_{Baryon})$

(M_{200} Callingham19)

- Contract our Auriga Sample F (J_r, L)
- We predict similar DM density profiles
- See scatter from our sample ~15% as expected

F(J_r, L) Au

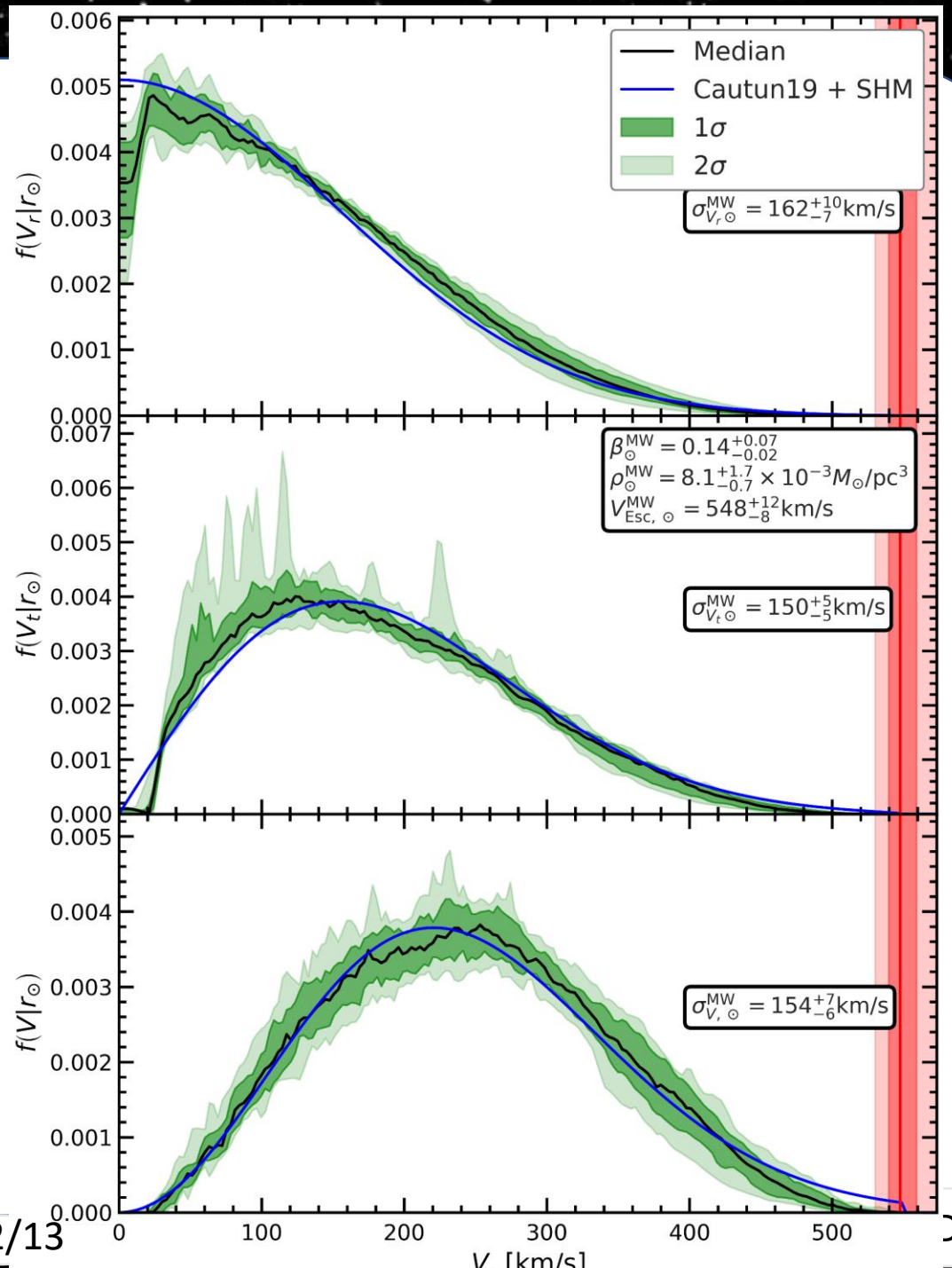


MW Models

- These models also predict the local DM dynamics

(OLD PLOT)

- This offers an improvement on SHM
- Comparable with literature



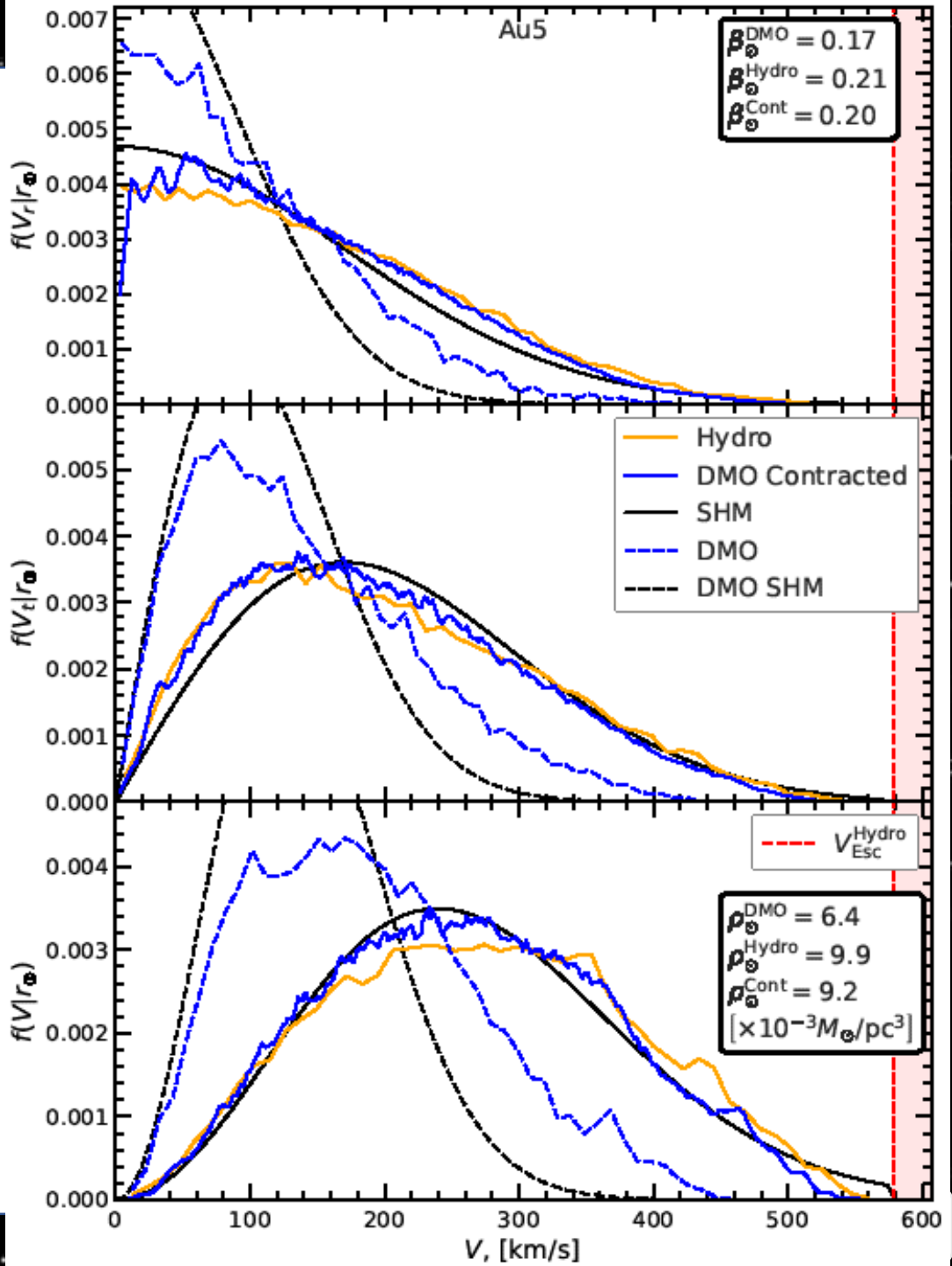
DM Halos

Conclusions

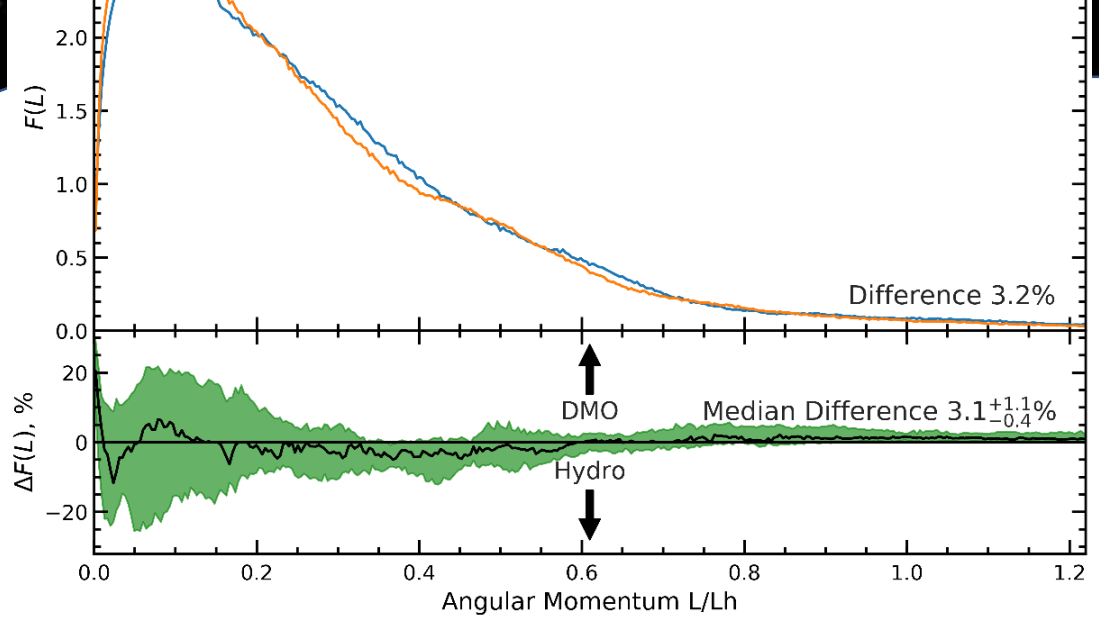
- Action Angle allows dynamical modelling of contracted DM halos
- Taking Action DFs from simulations helps us model the halo to halo scatter

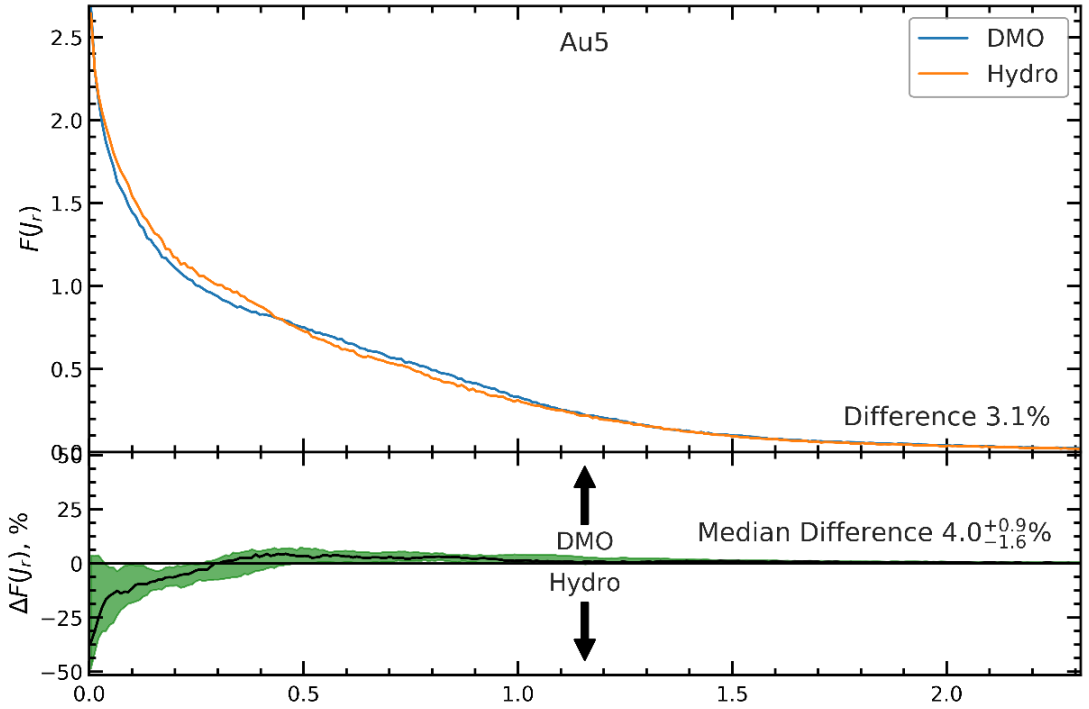
Future Work:

- Find our own baryon profile
- Can we predict the Action DFs from a halos merger history? (SAUSAGE?)
- How valid is the adiabatic assumption?
- Extend to axisymmetric modelling



Extra


F(L)
Difference 3.2%
ΔF(L), %
DMO
Hydro
Median Difference 3.1$^{+1.1}_{-0.4}$%
Angular Momentum L/Lh


Au5
DMO
Hydro
F(J_r)
Difference 3.1%
ΔF(J_r), %
DMO
Hydro
Median Difference 4.0$^{+0.9}_{-1.6}$%