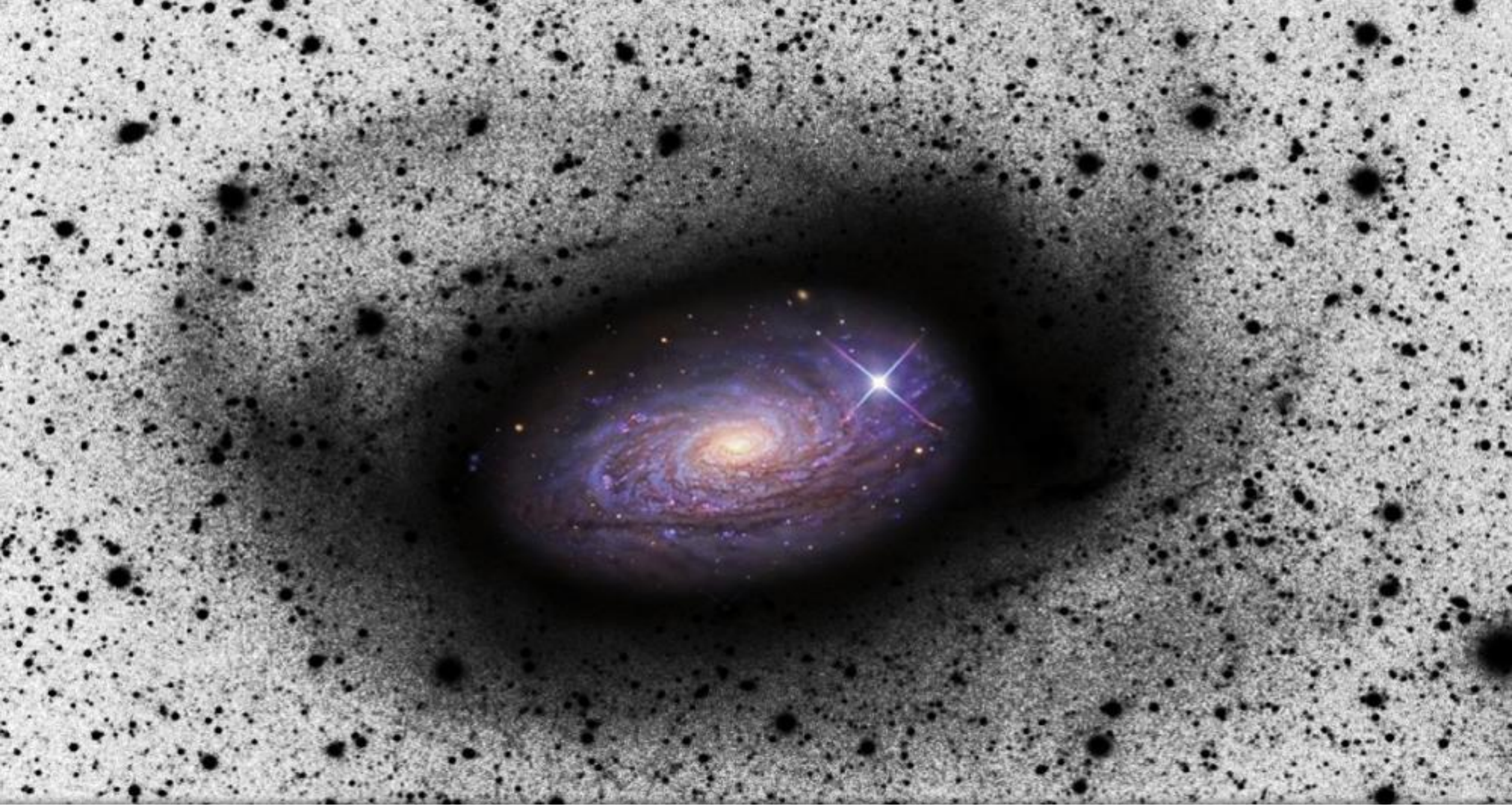


Modelling the time evolution of a galaxy's potential and the effect on stellar streams

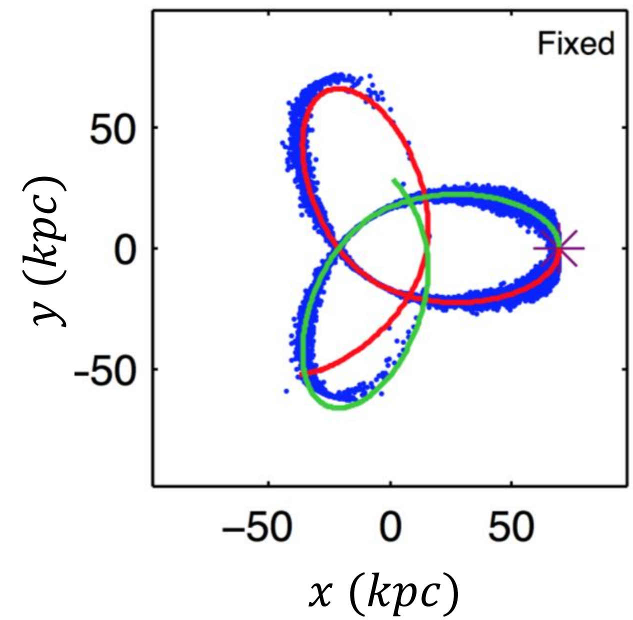
Hans J.T. Buist

Introduction

Cosmology: significant evolution in mass of galaxy and DM halo

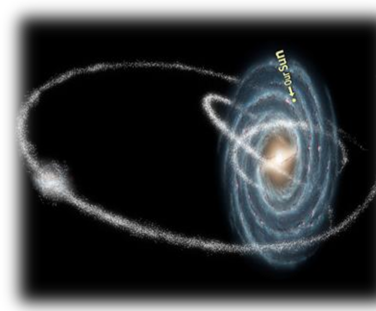
- Use stellar streams:
  - Consist of stars stripped from infalling dwarf galaxies (and globular clusters)
  - These stars orbit in host potential
  - Stream is proxy to progenitor orbit

    (See Eyre & Binney 2009, Gomez & Helmi 2010)
- Streams as probe for time-evolution of the gravitational potential:

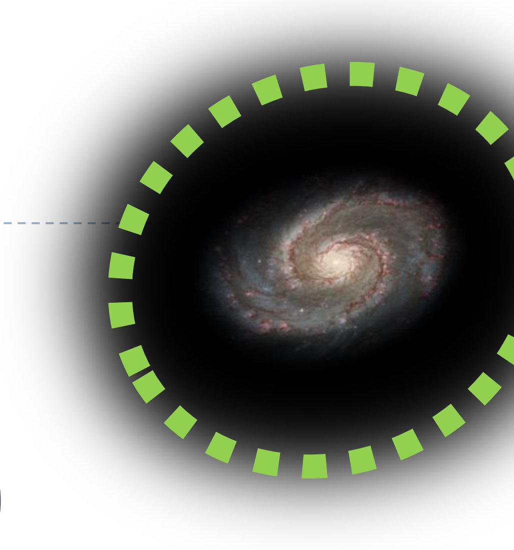


Study behaviour of streams in the halo for evolving potential

- Need realistic time-dependent potential



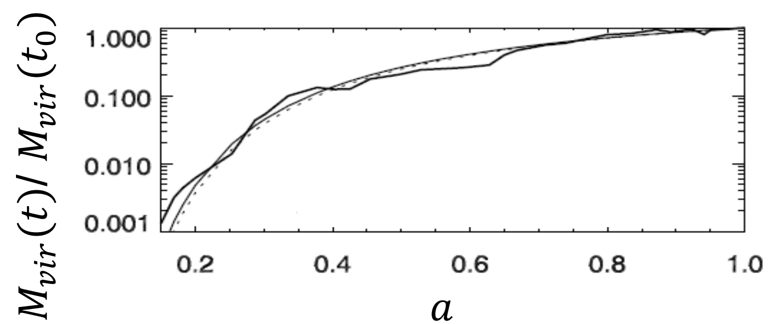
Evolution of dark matter halos



LCDM Cosmology: dark matter halos form inside out

(See Helmi et al. 2003; Wang et al. 2011)

- Inner regions form first; growth on outskirts
- No major mass redistribution (without major mergers)



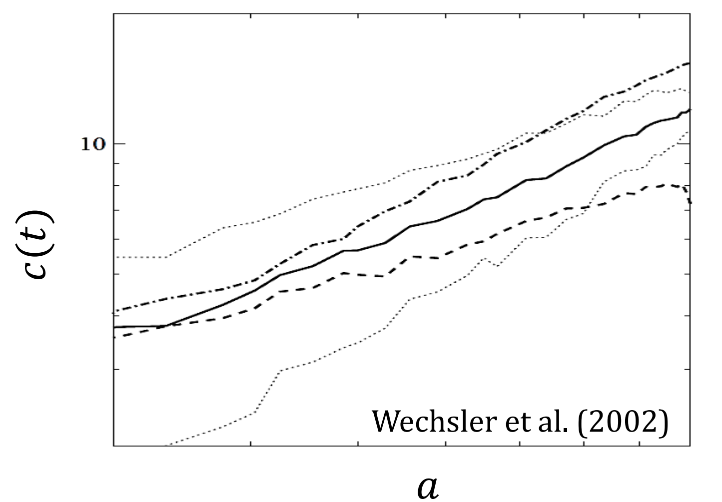
Two parameters to describe mass profile

- Need characteristic mass and radius
  - Dark matter halos: $M_{vir},\ c = \frac{r_{vir}}{r_s}$
- Most widely used model by Wechsler et al. (2002):

  $$M_{vir}(t) \propto \exp(-2a_c z)$$

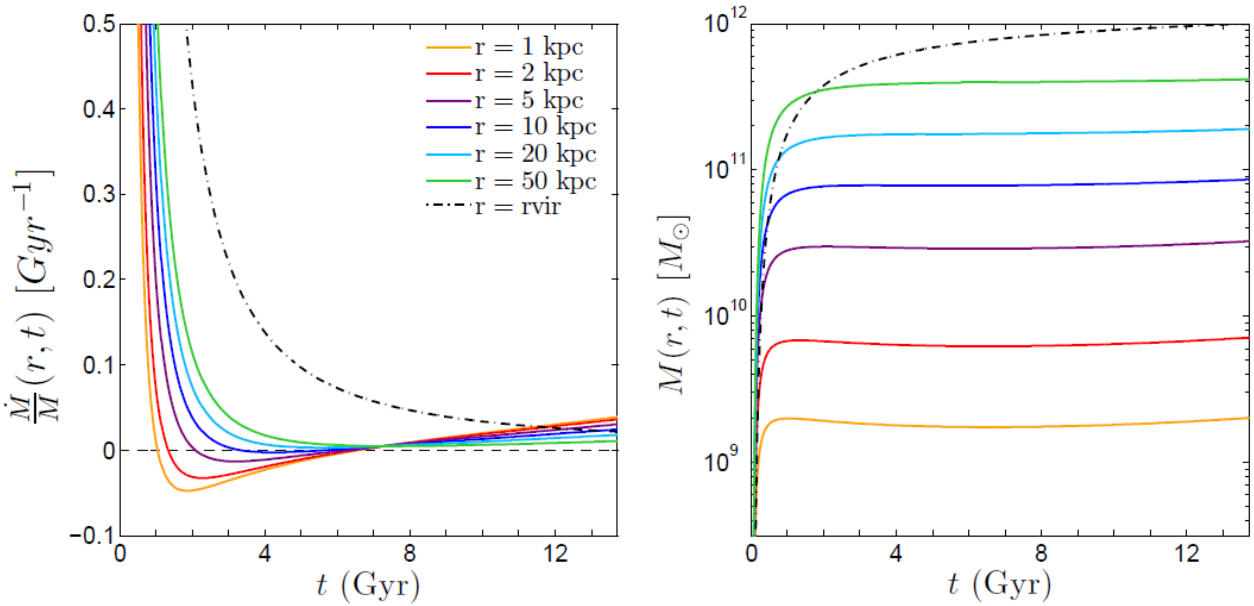
  $$c(t) \propto \frac{a}{a_c} \qquad a_c{\sim}0.1 - 1.0$$

  - But: statistical model, not for individual halo



Wechsler model: Evolving mass profile

Example case: $M_{vir} = 10^{12} M_{\odot}$; $a_c = 0.15$



Issues with evolution track

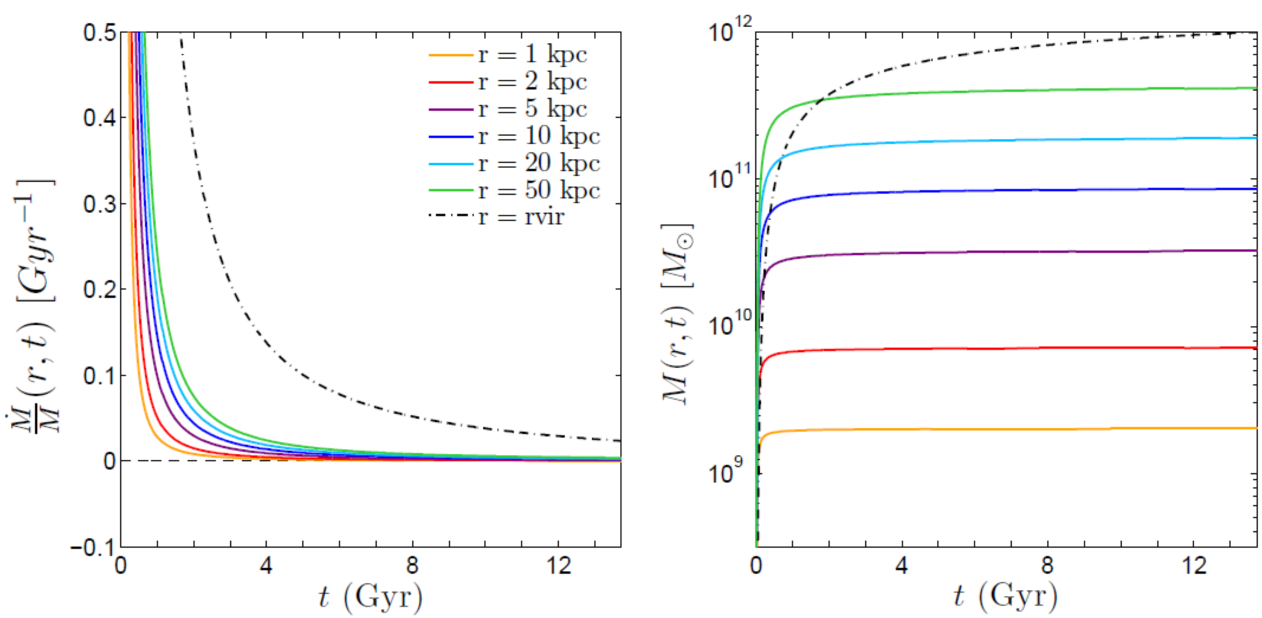
- Mass growth rate decreases as expected. But negative at some radii/times?
- Inner mass shells take over growth of outer shells at later time
  - Unexpected: halos form inside out?
- Detailed calculation: evolution of cosmological background density in M_{vir}

Alternative mass evolution model

Use functional form that guarantees inside-out growth

- Instead of M_{vir} and c we use M_s and r_s: (Buist & Helmi 2014, published in A&A)
  - Same form as Wechsler M_{vir} function: $M_s \propto \exp(-2a_g z)$
  - Power-law relation between $M_s(t)$ and $r_s(t)$: $r_s \propto \exp\left(-2\frac{a_g}{\gamma}z\right)$ $(\gamma \geq 2)$ *Inside-out growth*

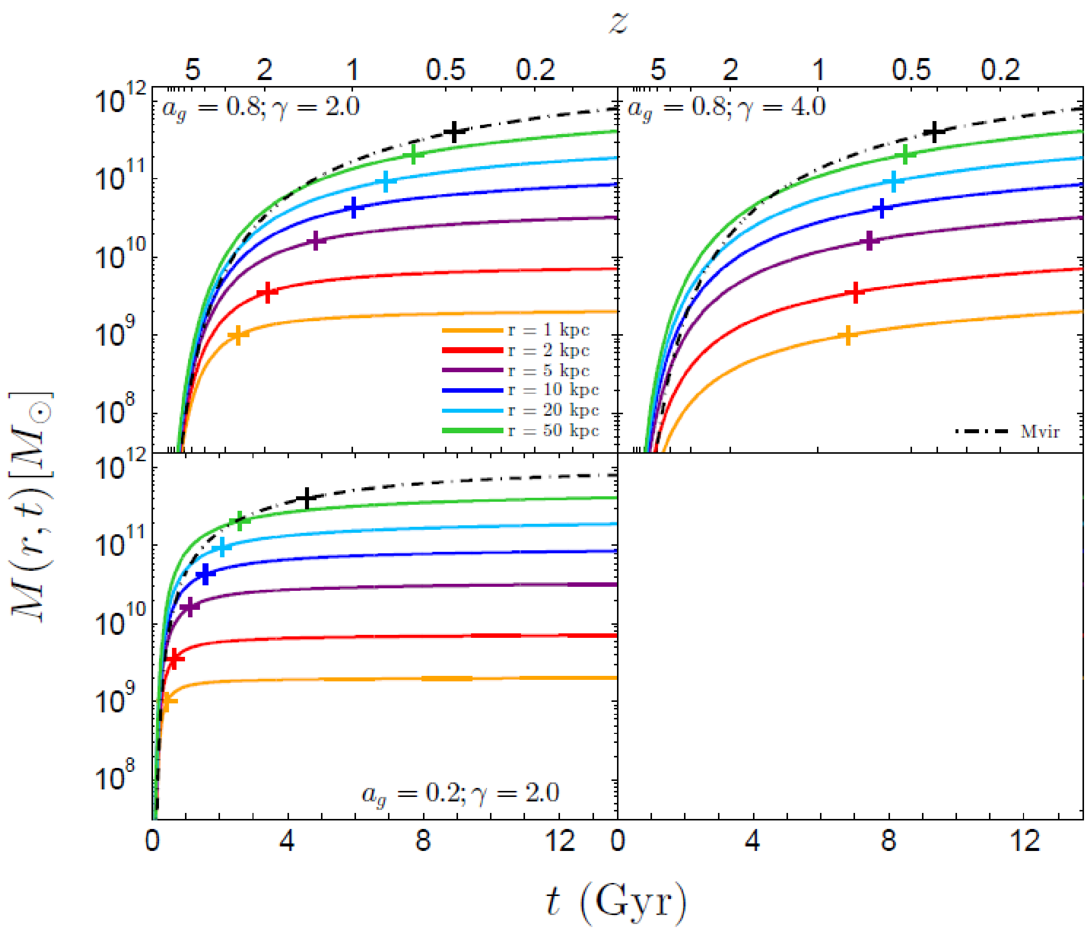
Example: halo with same final M_{vir} and r_s ; $\gamma = 2$; $a_g = 0.04$



Alternative model: Parameters

Two main free parameters

- Power law slope γ ~ relative growth of shells
- Growth parameter a_g ~ controls halo assembly time

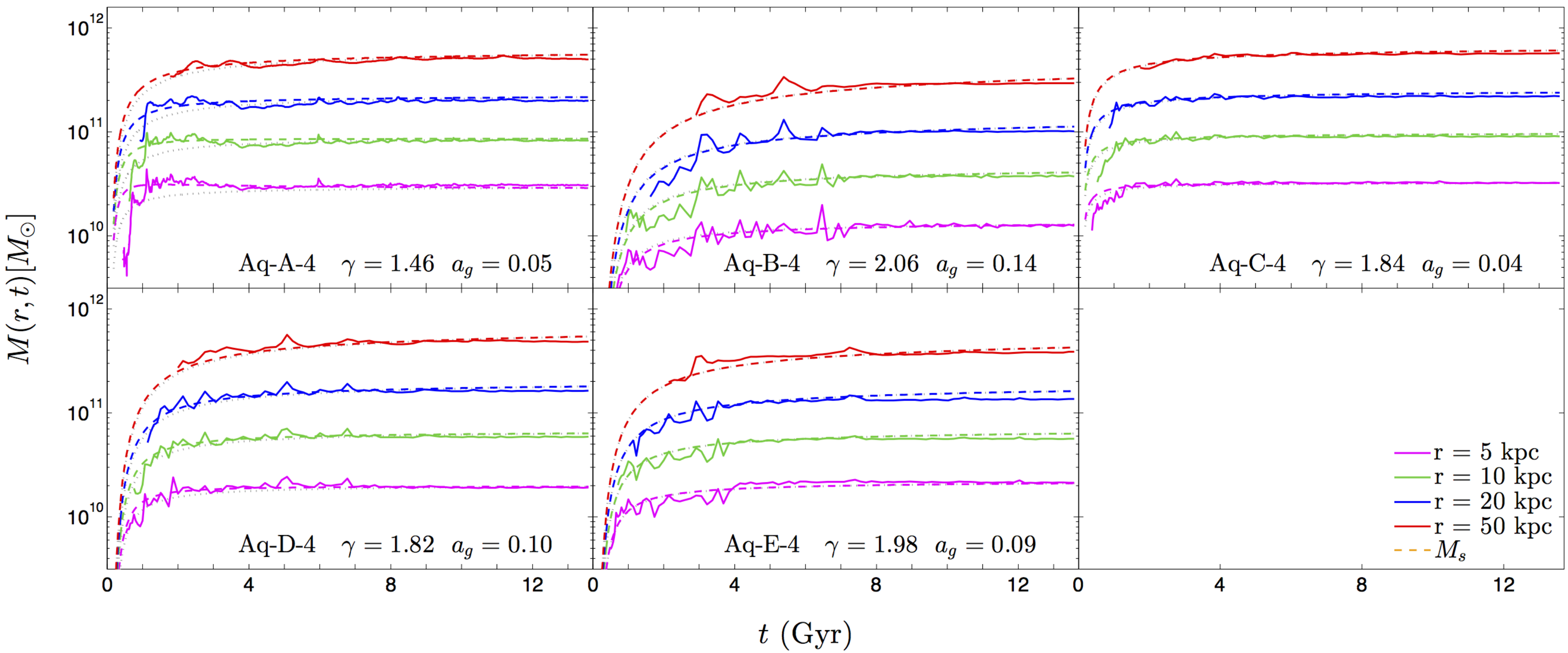


+ Half mass time

Comparison with Aquarius simulations

Aquarius dark matter simulations: Milky-Way like halos (Springel et al. 2008)

- Fit spherically averaged mass profile: $M_s(t)$, $r_s(t)$
  - Then fit our model to find γ and a_g
- We find $\gamma \lesssim 2$, but consistent with $\gamma = 2$

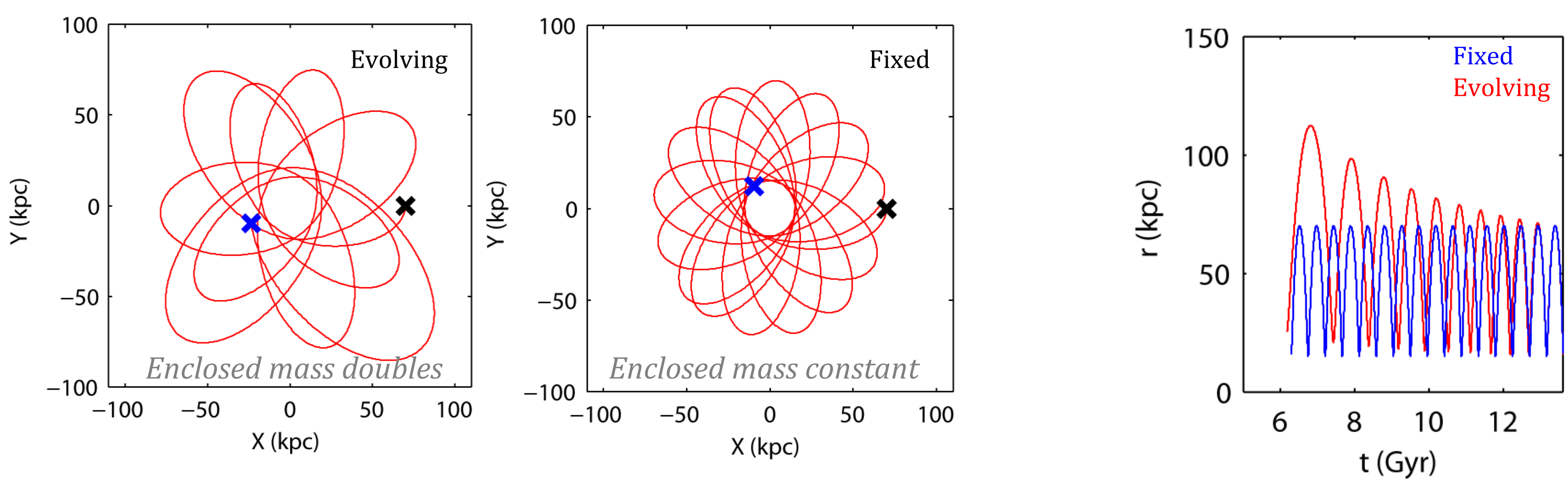


Evolution of streams in the model

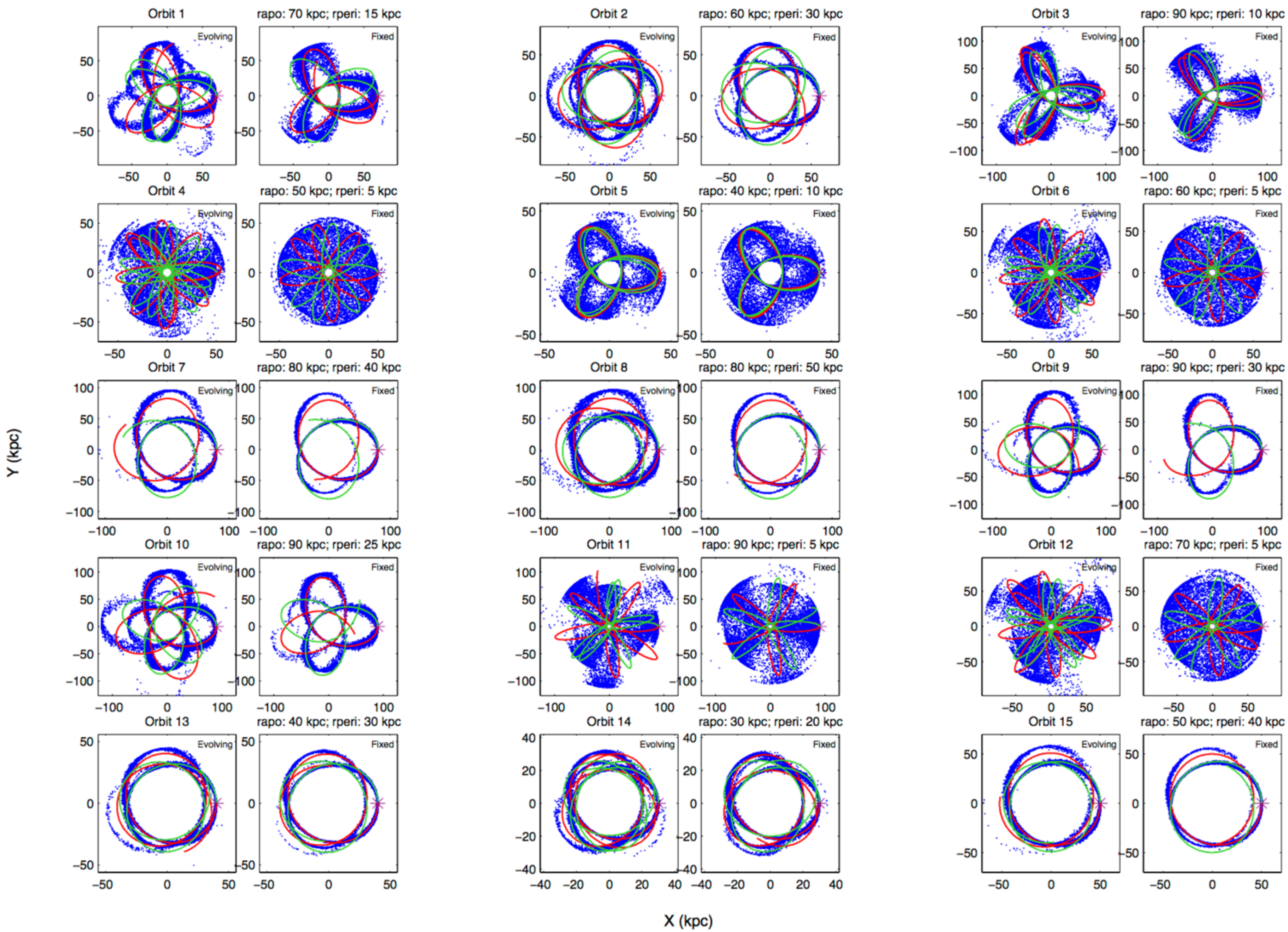
Simulation setup:

- Test-particles evolved in different time-dependent potentials
  - "Sculptor"-like progenitor ($\sigma_x = 300$ pc; $\sigma_v = 10$ km/s)
  - "Carina" -like progenitor ($\sigma_x = 100$ pc; $\sigma_v = 5$ km/s)

- Interested in effect on stream observed today
  - Same final halo (M_s, r_s)
  - Same final position/velocity for progenitor orbit
  - Backwards integration central orbit for ~ 8 Gyr, then forwards (blue to black 'x')



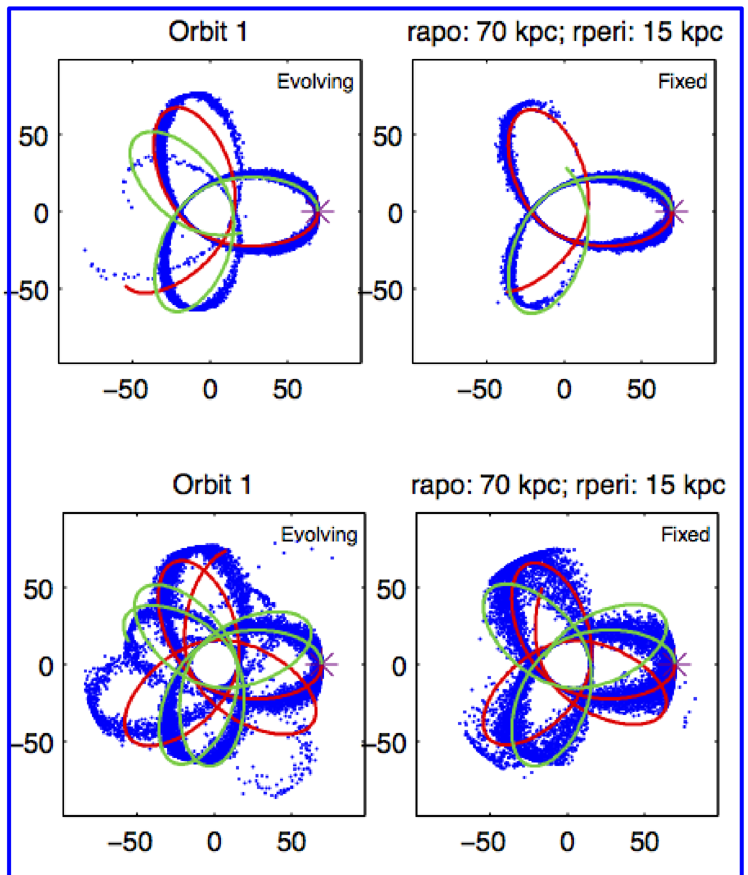
Evolution of streams in the model: overview



Evolution of streams in the model: zoom

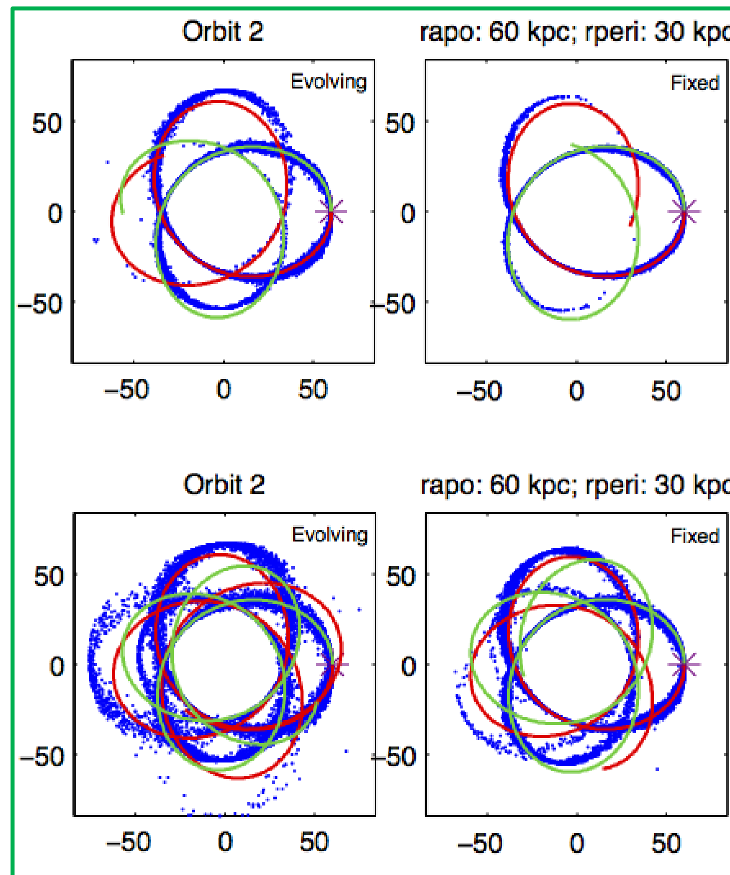
Differences:

- Evolving case: longer streams (also by larger progenitor)
- Differences between stream and progenitor orbit



“Carina”

“Sculptor”



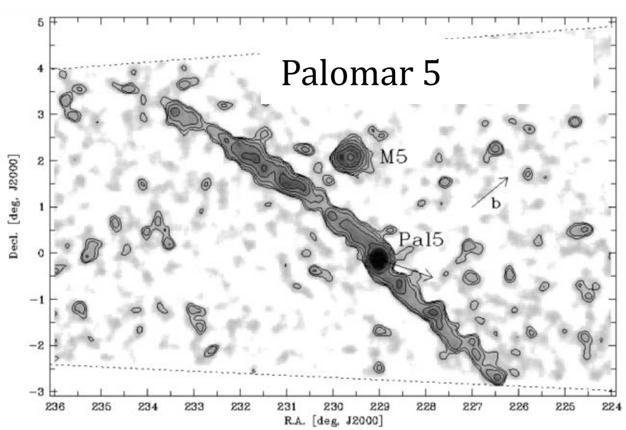
Evolution of streams in the model

Close to progenitor, stream approximately traces progenitor orbit

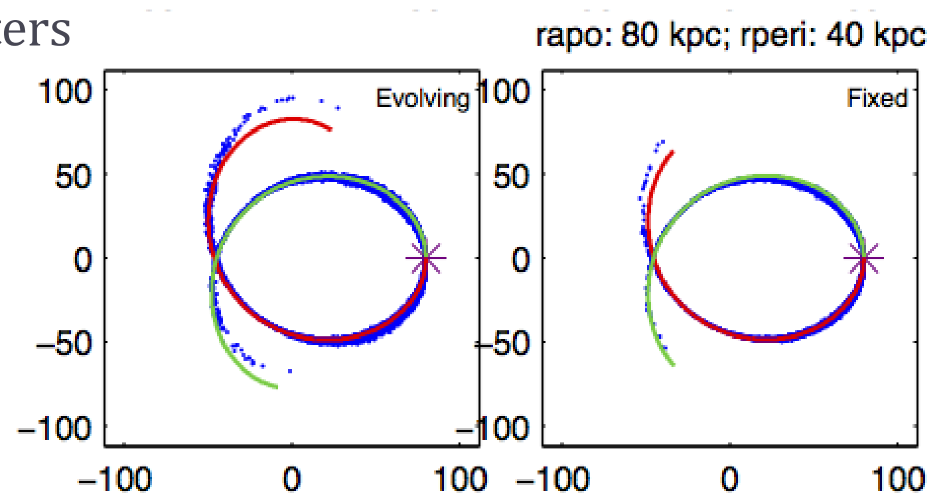
- Need only ~ 1-2 Gyr of central orbit to trace stream (v.s. 8 Gyr for stream)
- How well stream traces progenitor orbit depends on orbit and on evolution of potential

Need long enough stream to see differences (~1-2 radial periods)

- Too short stream does not allow comparison with progenitor orbit
- Not suitable for globular clusters



Odenkirchen et al. 2003



Summary

Need realistic time-dependent host-potential to evolve streams

Galaxies/DM halos expected to grow inside out

- Model by Wechsler et al. (2002)
- For certain choices of parameters inside-out growth not guaranteed

Alternative model

- Power-law relation between $M_s(t)$ and $r_s(t)$
- Exponential in $M_s(t)$
- Fits halos from Aquarius simulations well

Main effects on streams of a time-evolving potential

- Length of streams
- Differences in how well streams are traced by progenitor orbit