PoR Meeting
September 2015

Tidal streams with PoR

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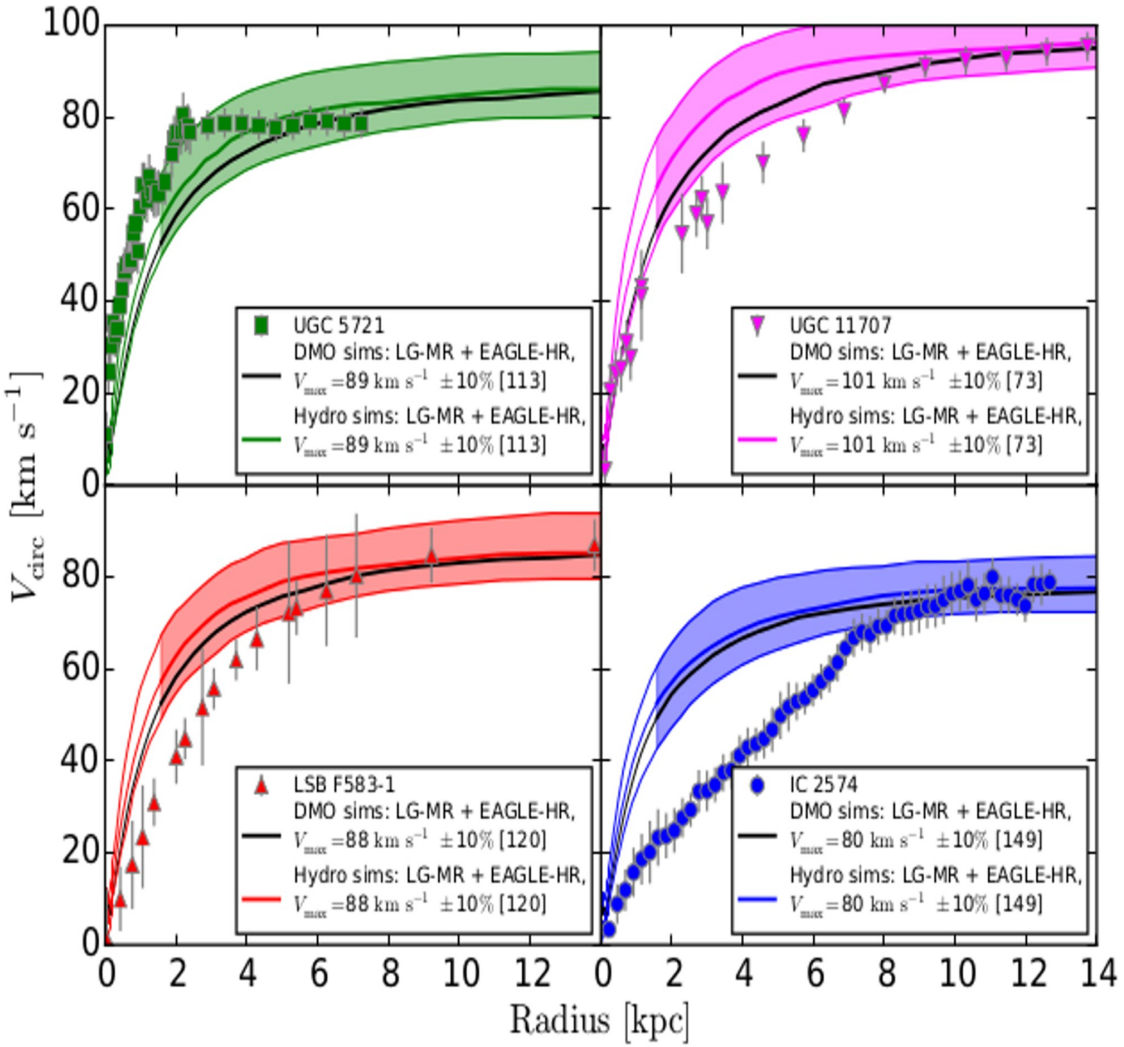
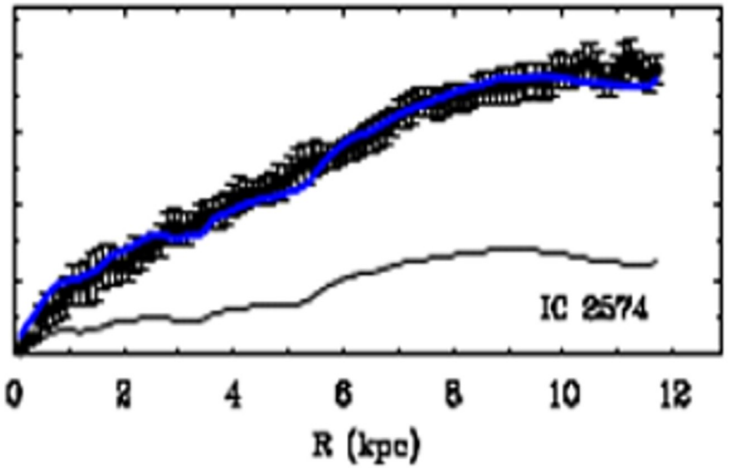
The rotation curve problem in the ΛCDM paradigm

Rotation curves in ΛCDM



Oman et al, 2015



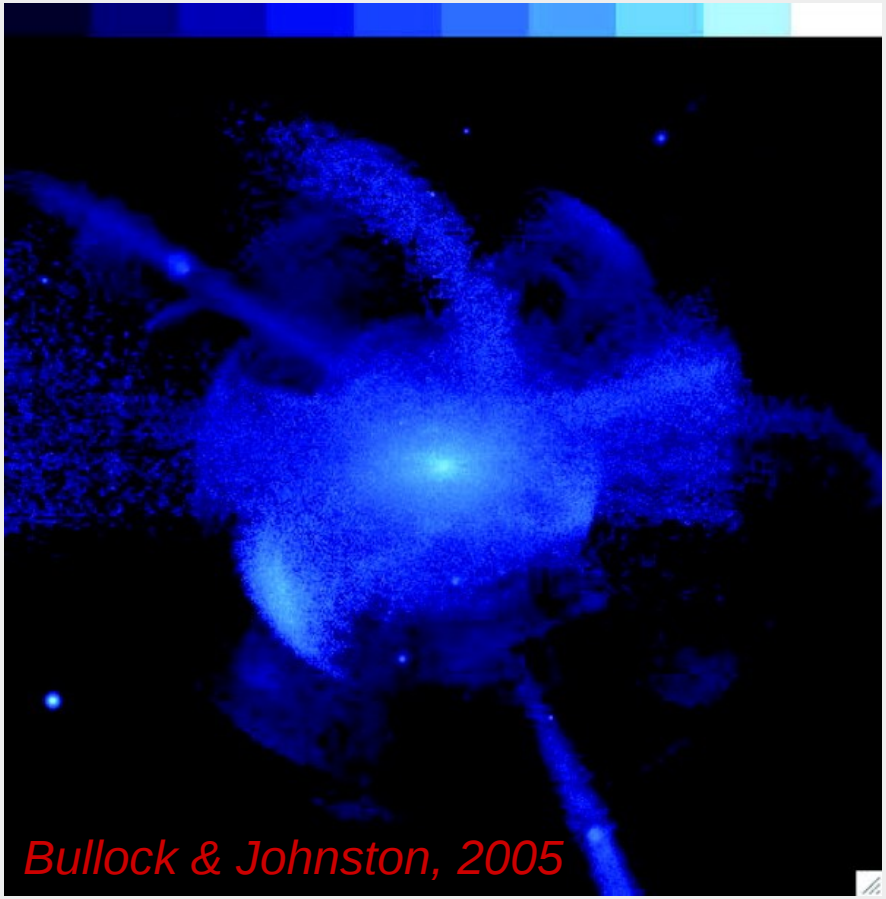
Famaey & McGaugh, 2012

What is a tidal stream ?

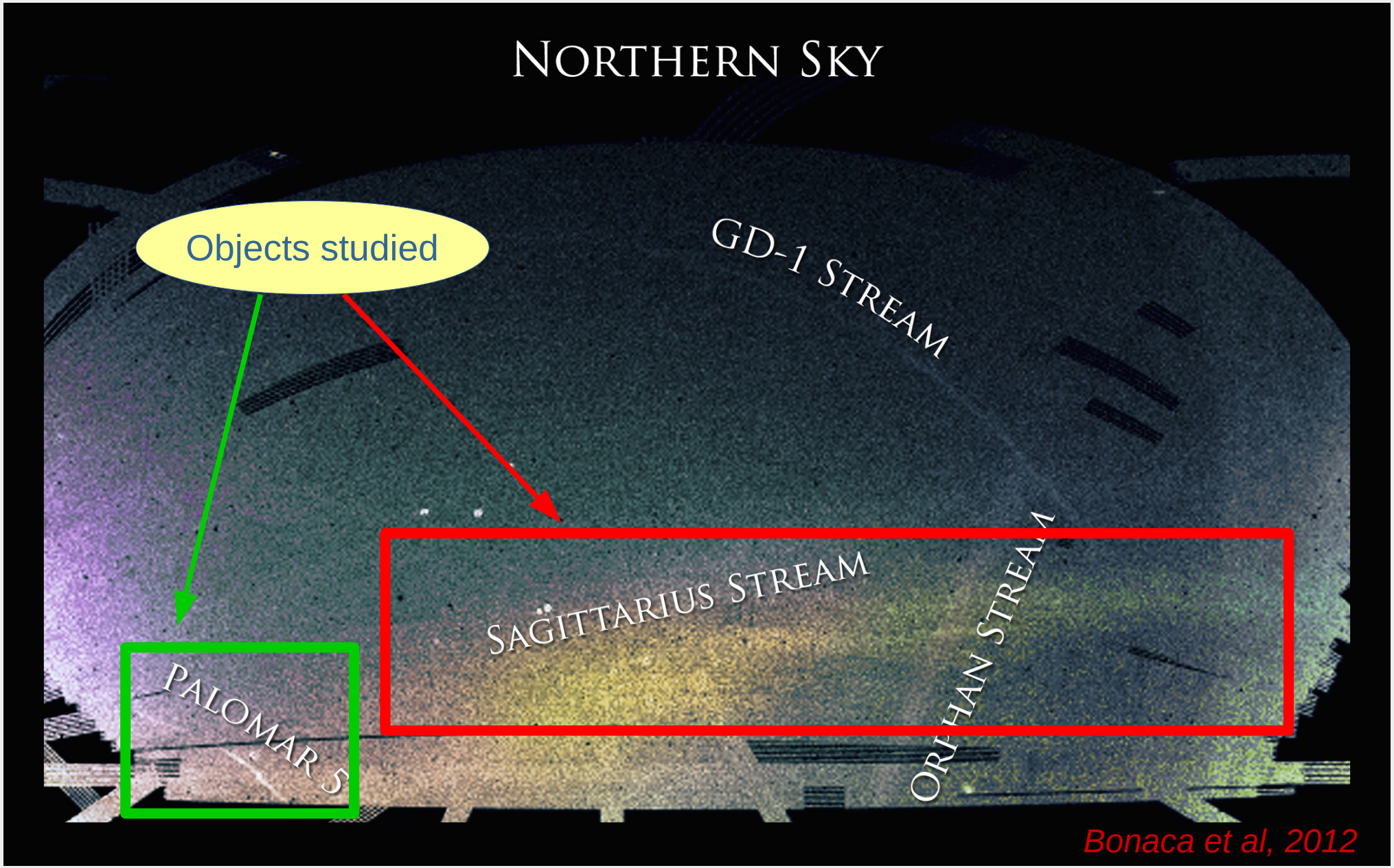
- Generated during the **accretion** of satellite galaxies or globular clusters by a host galaxy

- Composed of metal-poor old stars [Fe/H] ~ -3.0 – -0.5

- Streams are useful for :
  - **Record** the accretion history and the formation of the Milky Way
  - **Map** the galactic potential in 3D



SDSS's streams



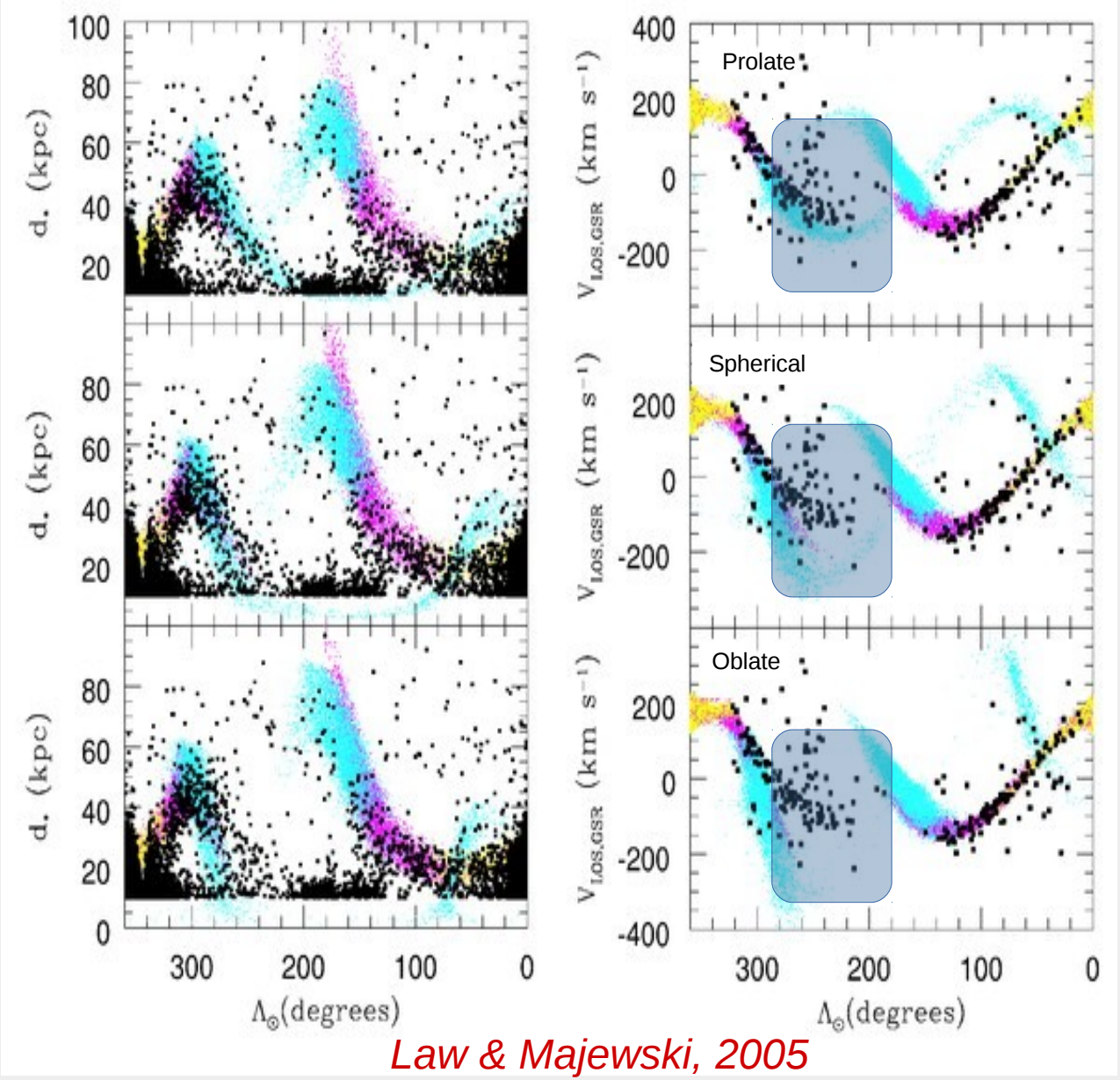
What about the streams in ΛCDM ?

What is the deduced shape of the Dark Matter halo ?

The Sagittarius stream

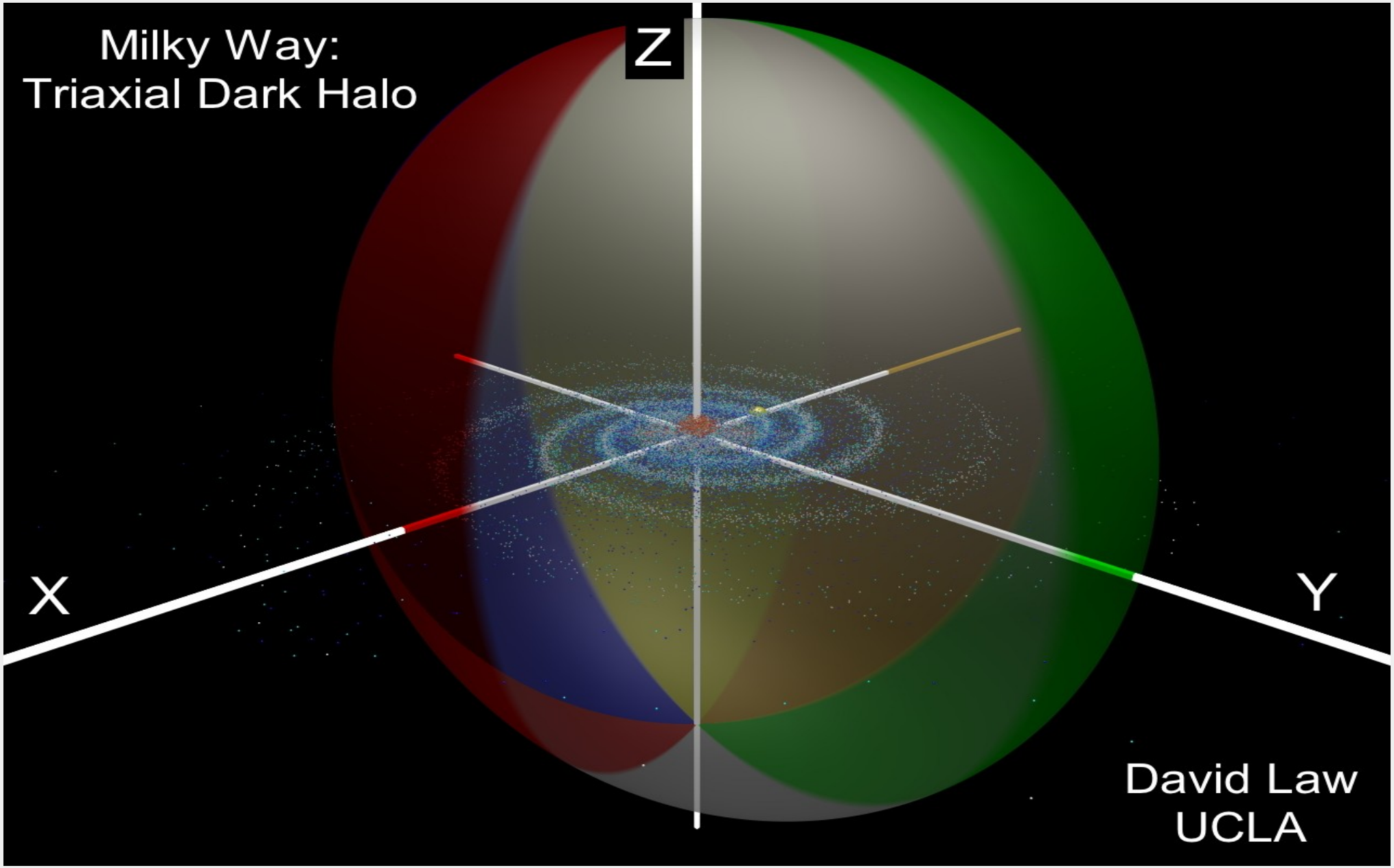
- Most extend stream in the sky (360°)
- Accreted for ~ 4 Gyr

➡ Needs a triaxial DM Halo

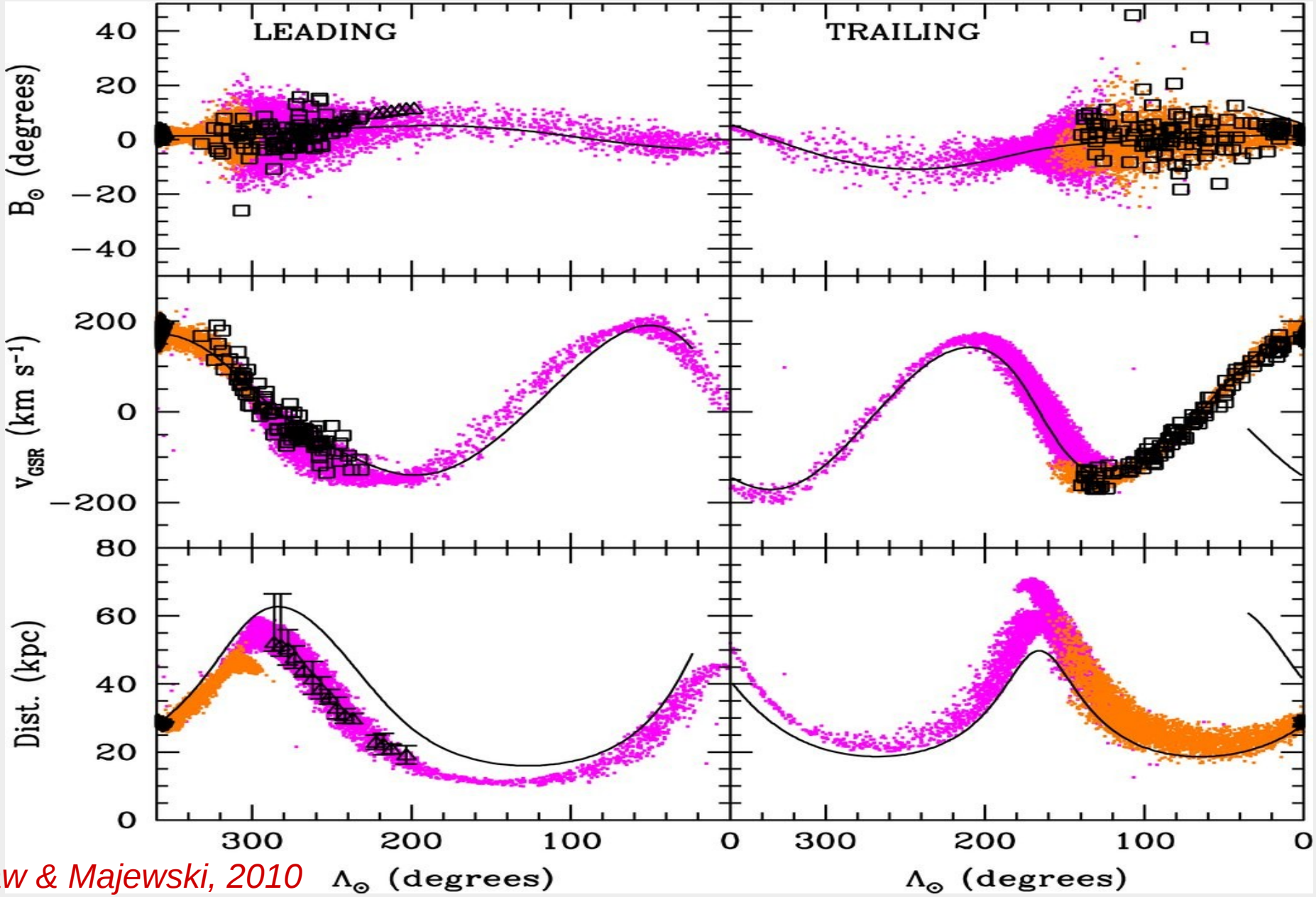


Law & Majewski, 2005

LM10's triaxial halo

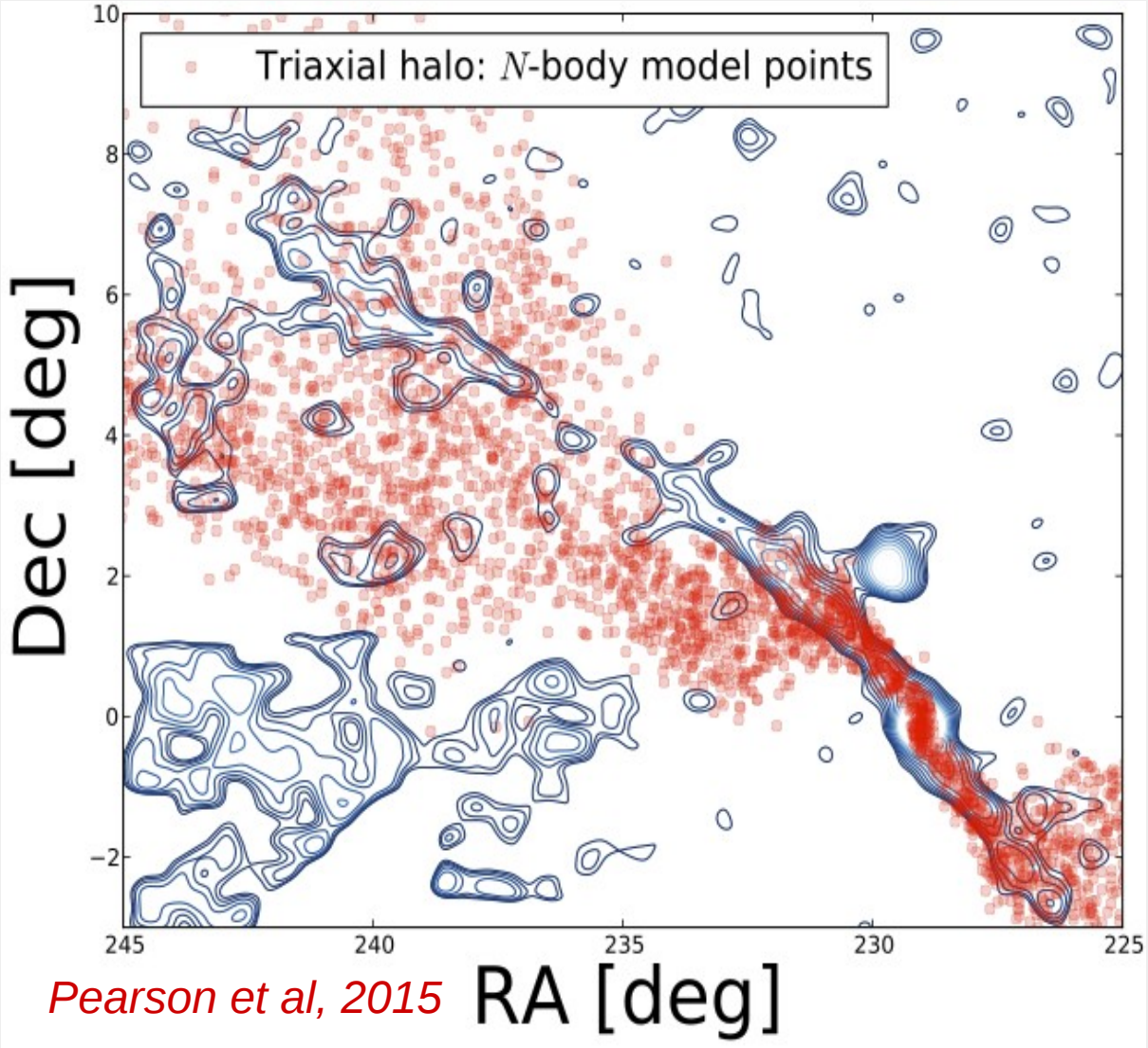


The Sagittarius stream



Law & Majewski, 2010

Palomar 5



Pearson et al, 2015

- 22° long and 0.7° width
- Dynamically cold
  (σ ~ 1 km/s)

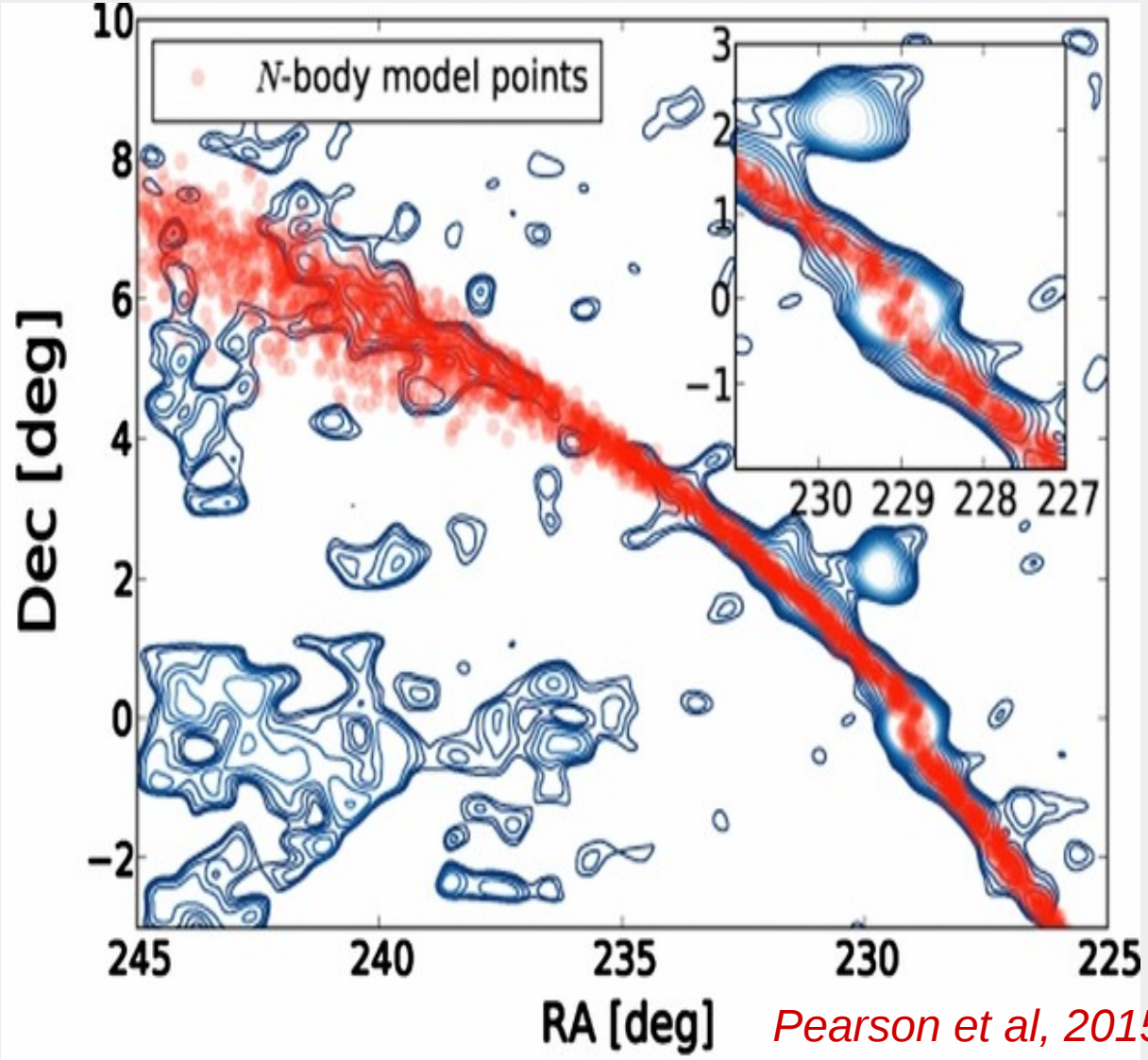
Triaxial Halo

→ **“fanning”** stream

Palomar 5

- 22° long and 0.7° width
- Dynamically cold
  (σ ~ 1 km/s)

Well reproduced
with a **spherical halo**



Pearson et al, 2015

What about the streams in MOND ?

What is the difference with ΛCDM ?

Stream in MOND

ΛCDM

- Problem with the shape of the DM halo
- Dynamical friction
- Accretion quite fast (~ 3 Gyr)

MOND

- No Dark Matter halo
- No Dynamical friction
- Accretion longer (~ 4 Gyr)
- Importance of the EFE

Read & Moore, 2005:

Precession of orbit in **MOND** similar than with a **spherical** DM halo

Needs a study on a full stream in MOND

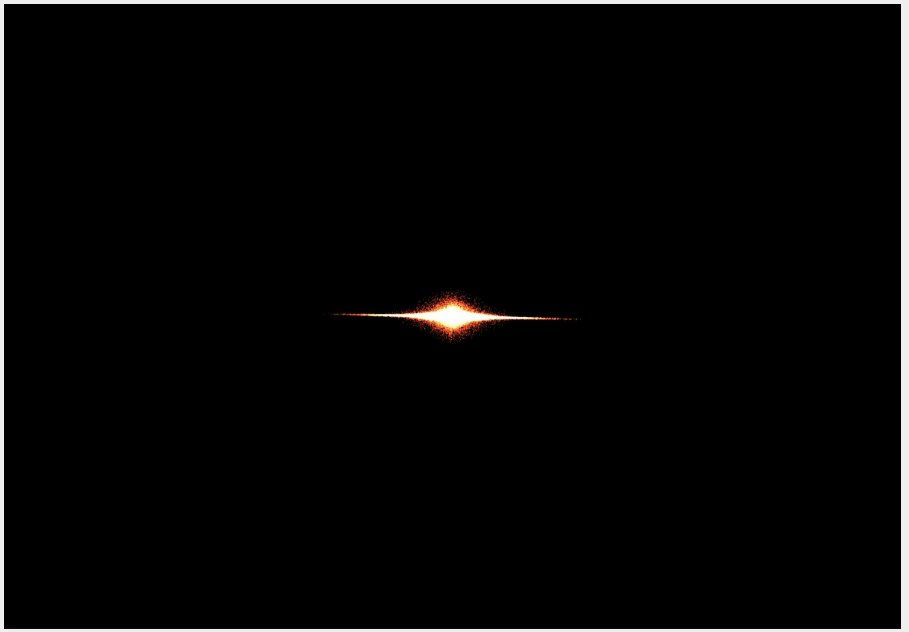
→ ***N-body simulation***

How I model accretion events with PoR?

Model of the Milky Way

- 1St model of **Dehnen & Binney, 98** without DM halo :
  - **ISM, thin and thick disk :**

$$\rho_d(R,z)=\frac{\Sigma_d}{2z_d}\exp\left(\frac{-R_m}{R_d}-\frac{R}{R_d}-\frac{|z|}{z_d}\right)$$



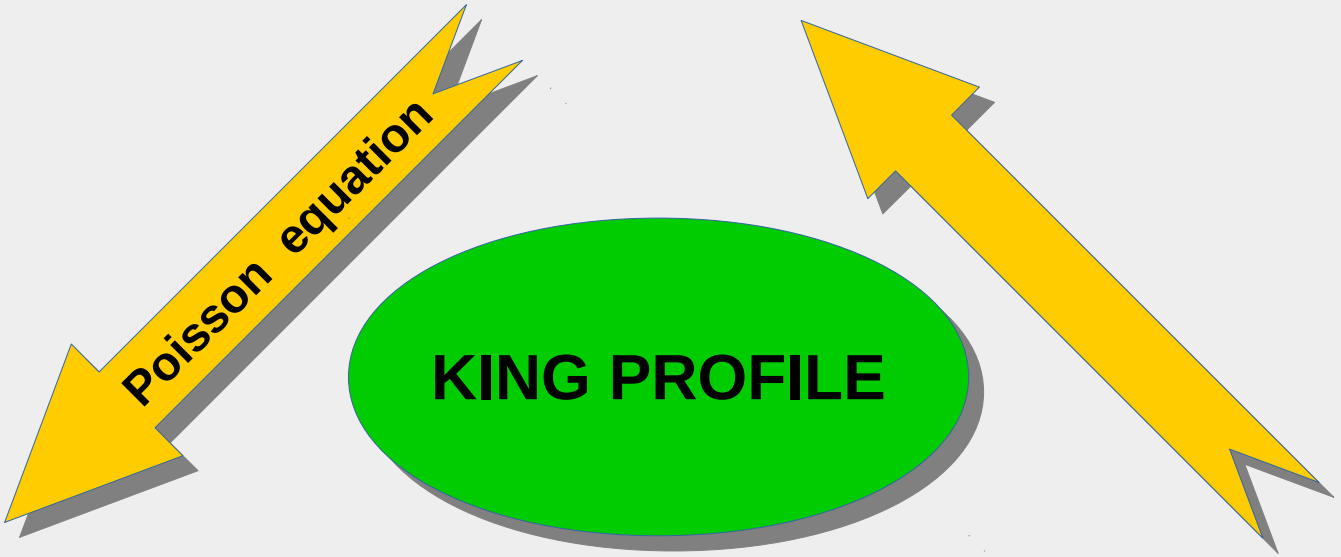
  - **Bulge** (and DM halo) :

$$\rho_s(R,z)=\rho_0\left(\frac{m}{r_0}\right)^{-\gamma}\left(1+\frac{m}{r_0}\right)^{\gamma-\beta}\exp\left(\frac{m^2}{r_t^2}\right)$$

$$\rightarrow \quad M_{MW} = 5.6 \cdot 10^{10}\, M_{\odot}$$

dSph Sgr with PoR

$$\rho_k \propto e^{\psi/\sigma^2}\, erf\left(\frac{\sqrt{\psi}}{\sigma}\right) - \sqrt{\frac{4\psi}{\pi\sigma^2}}\left(1+\frac{2\psi}{3\sigma^2}\right)$$



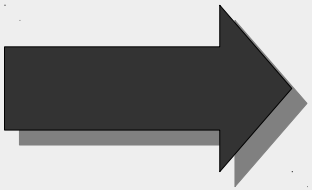
$$\nabla^2\psi_N = -4\pi G\rho_k$$

Spherical symmetry

$$\nabla\psi = \nu\left(\frac{\nabla\psi_N}{a_0}\right)\nabla\psi_N$$

The Sagittarius Stream

Observed



Sagittarius Dwarf Spheroidal (dSph Sgr)

- Discovered in 1994 by R. IBATA
- $M_* \sim 2 - 3.10^7 M_\odot$
- $R_h \sim 0.6$ kpc
- $D_{sun} \sim 25$ kpc
- $\sigma_c = 11$ km/s

Simulated

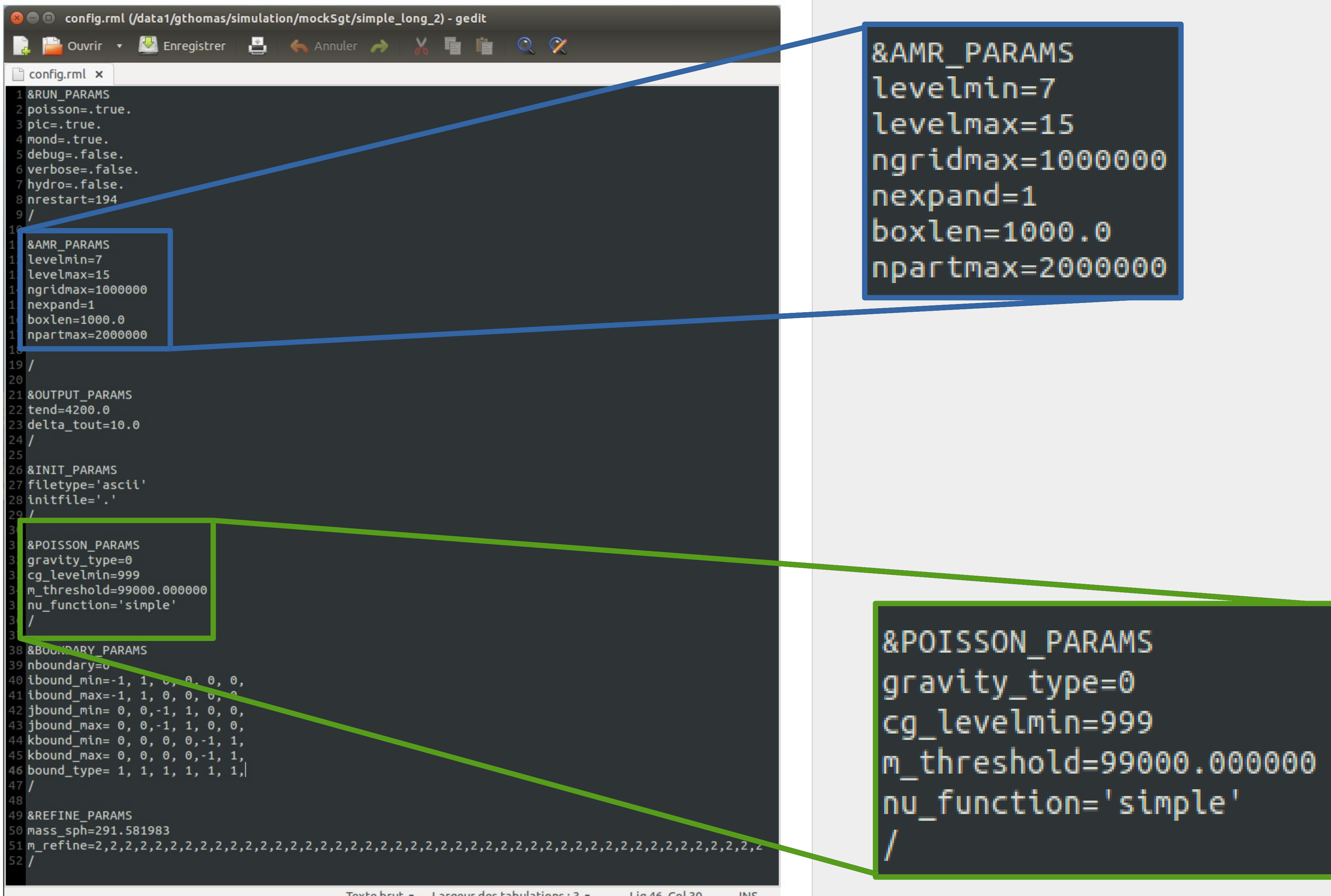
Initial MOND model

- King profile
- $M_{Sgr,dSph}(t=0\ Gyr) = 5.8\ 10^7 M_\odot$
- $r_h(t=0\ Gyr) = 0.41$ kpc

After 4 Gyr

- $M_{Sgr,dSph}(t=4\ Gyr) = 3.4\ 10^7 M_\odot$
- $r_h(t=4\ Gyr) = 0.62$ kpc
- $\sigma_c(t=4\ Gyr) = 11$ km/s

The Sagittarius Stream with PoR

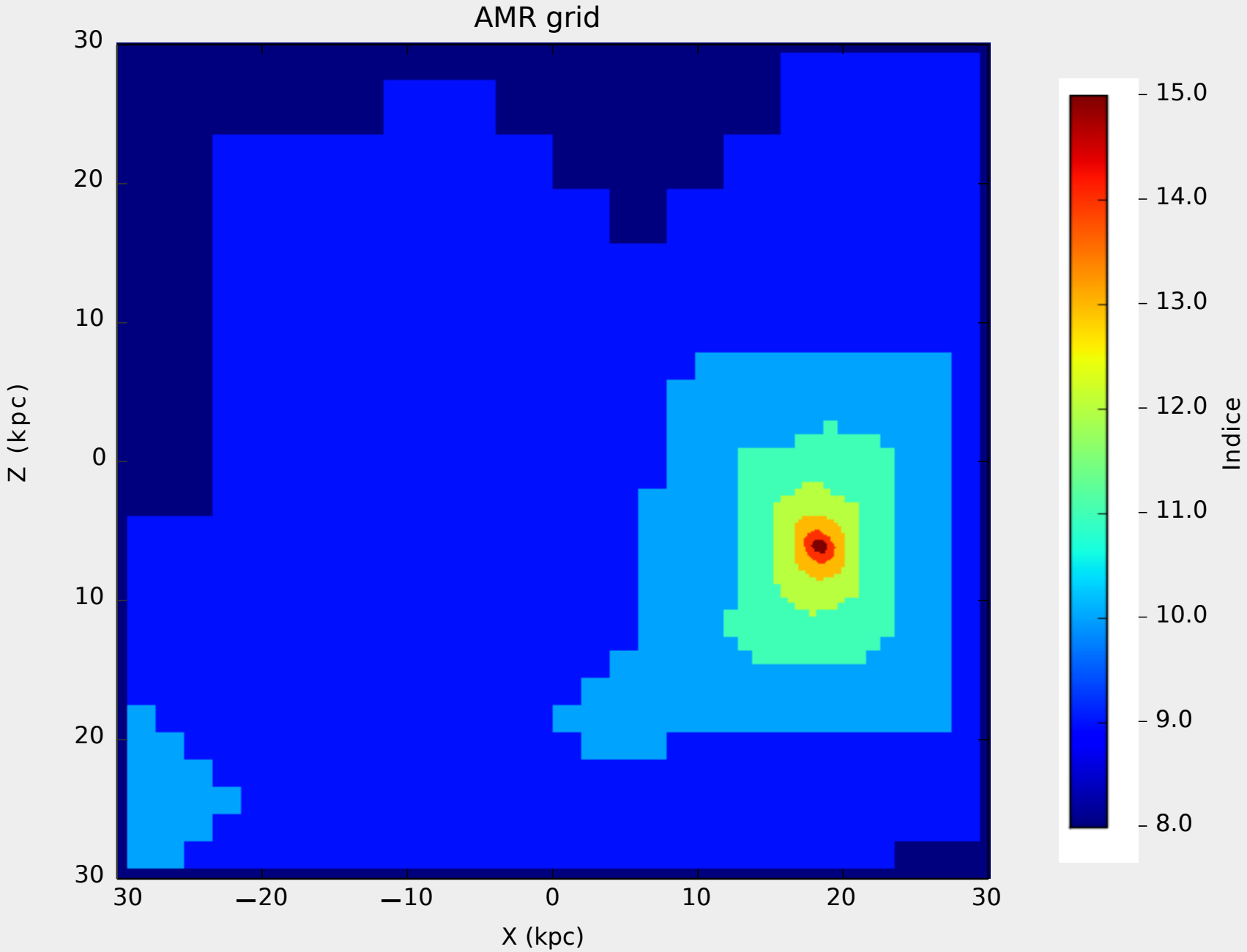


The Sagittarius Stream with PoR

25 kpc

(Movie sgr_dsph.avi)

The Sagittarius Stream with PoR



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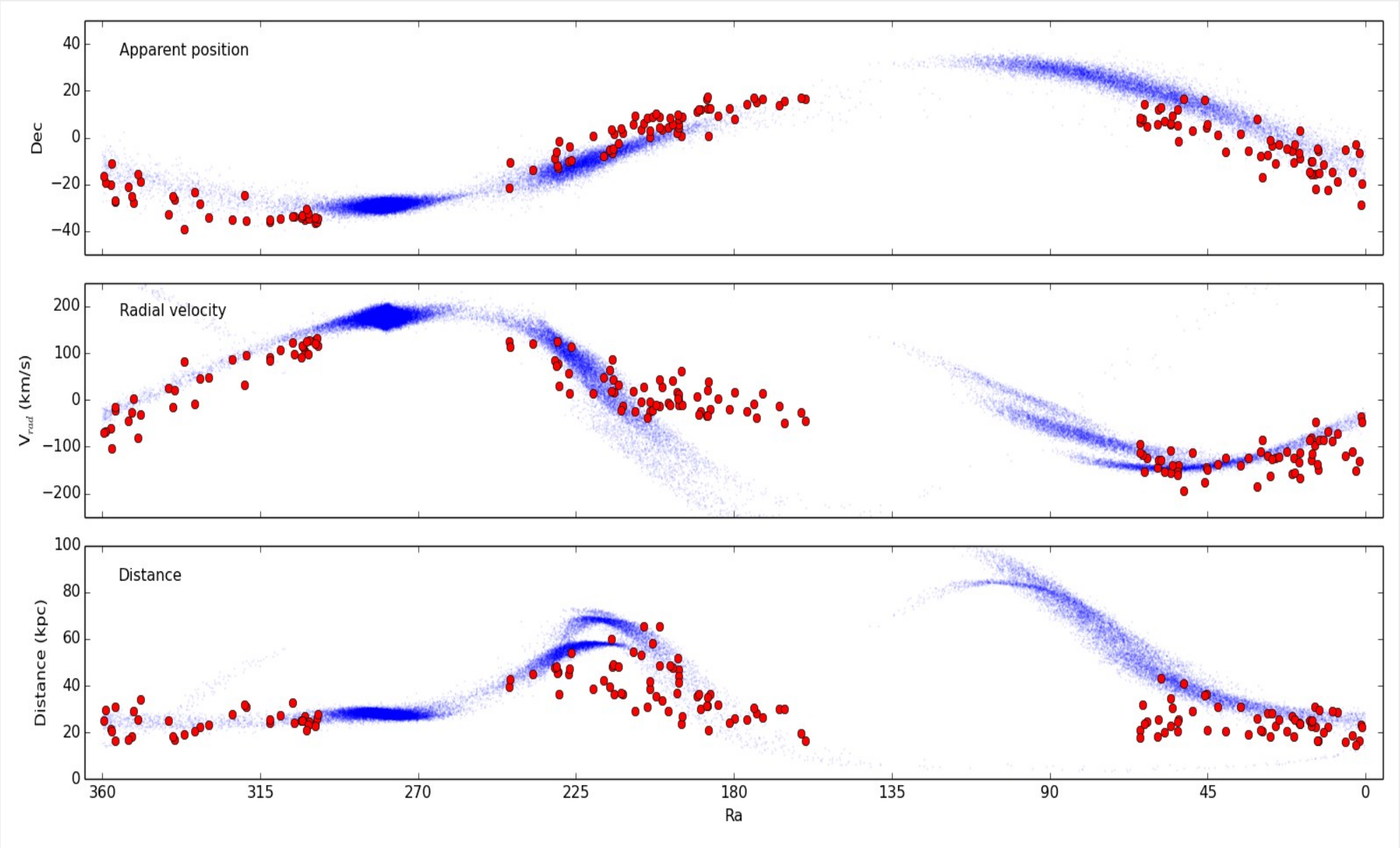
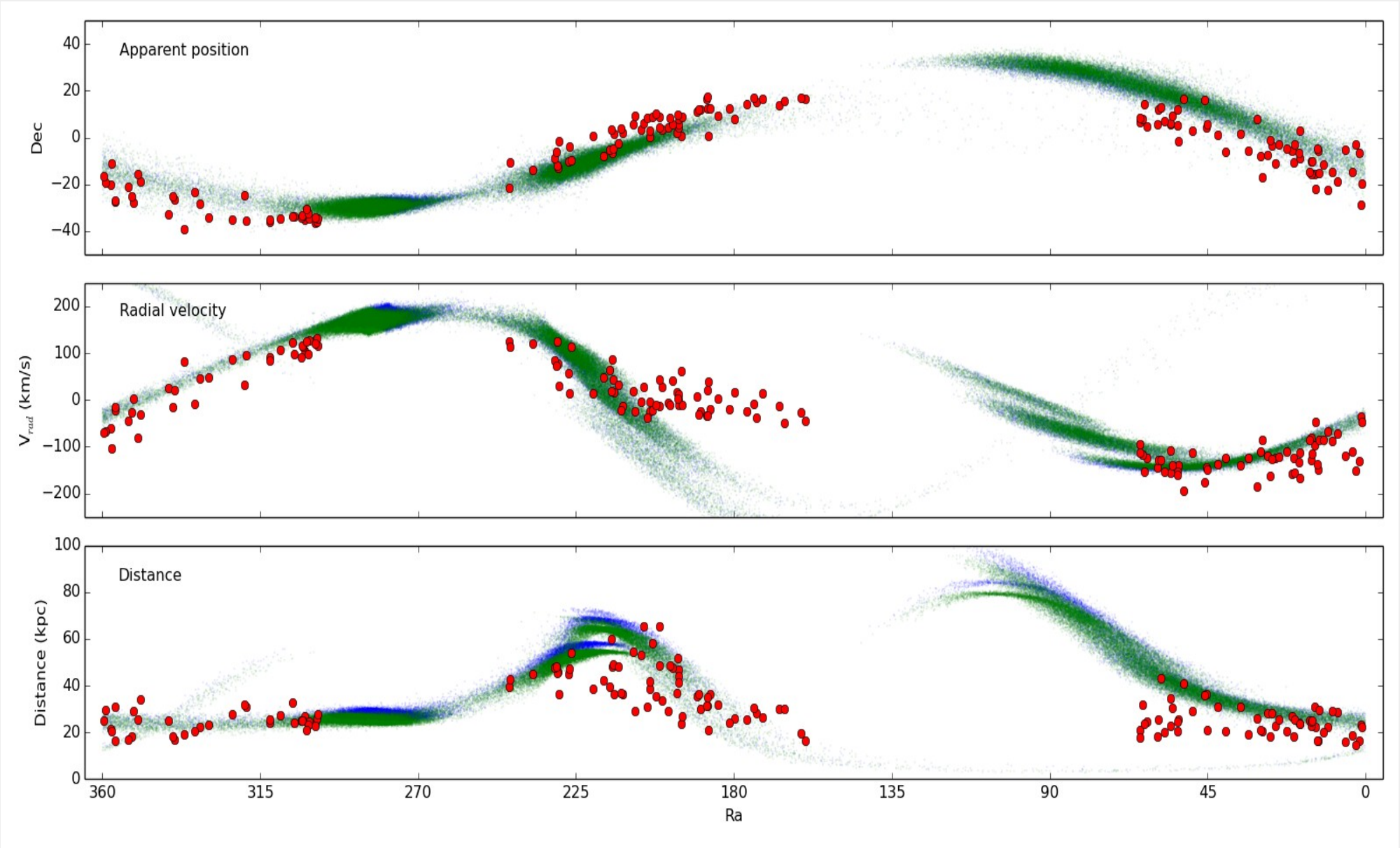


What configuration can explain the radial velocity ?

The resolution of the grid ?

The Sagittarius Stream with PoR



What configuration can explain the radial velocity ?

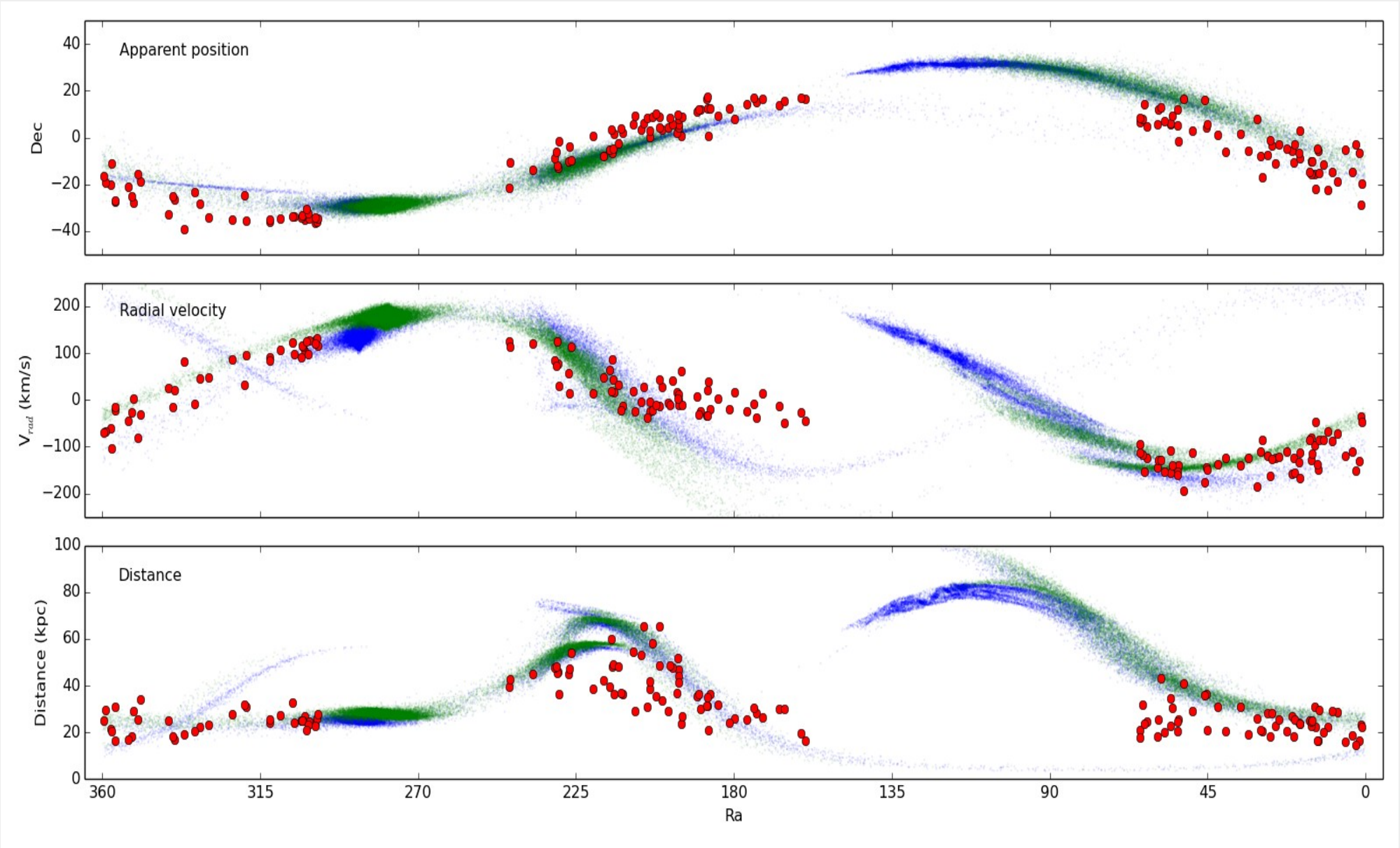
A rotating progenitor ?

A rotating progenitor ?

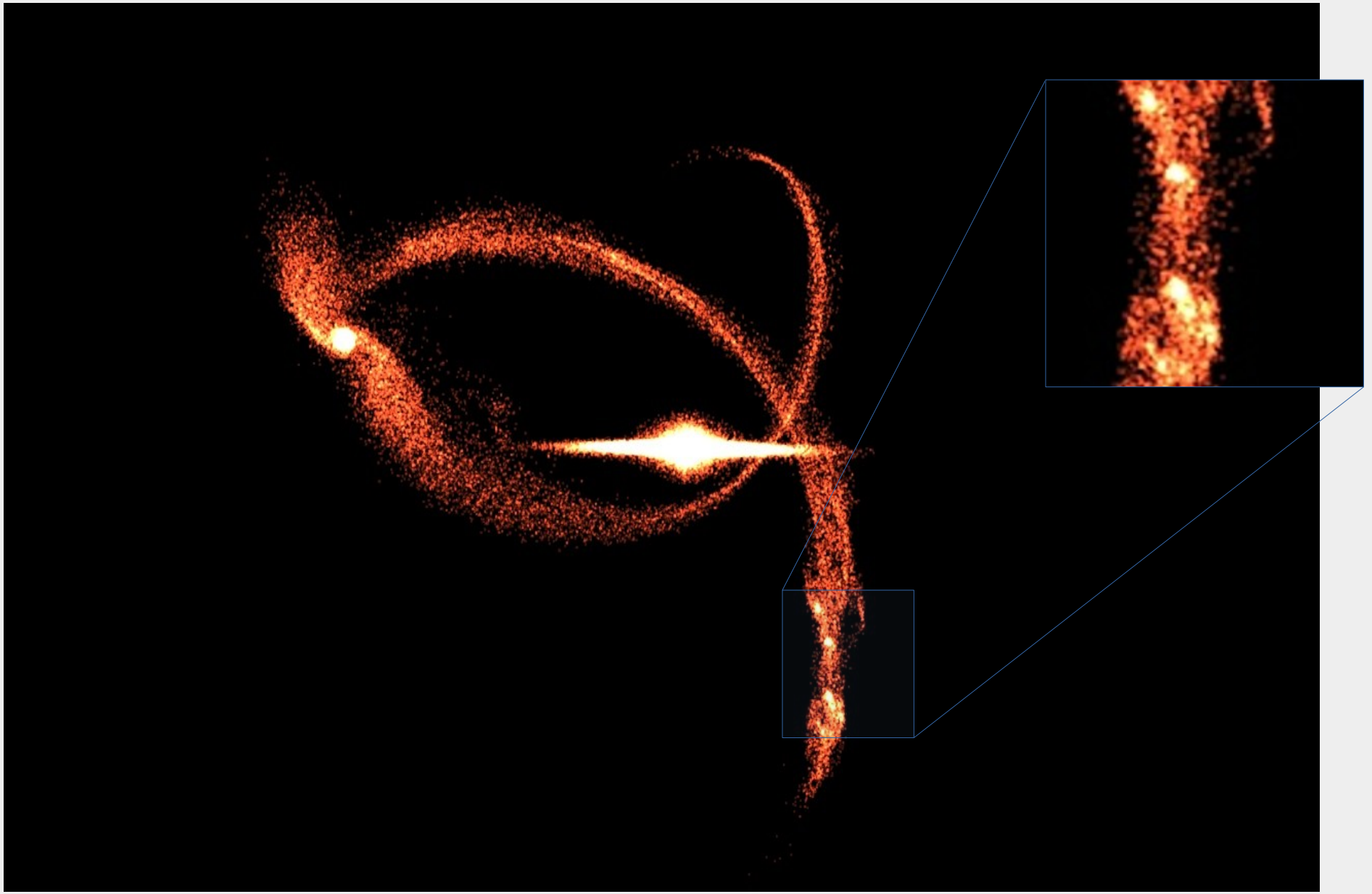
25 kpc

(Movie sgr_rotation.avi)

A rotating progenitor ?

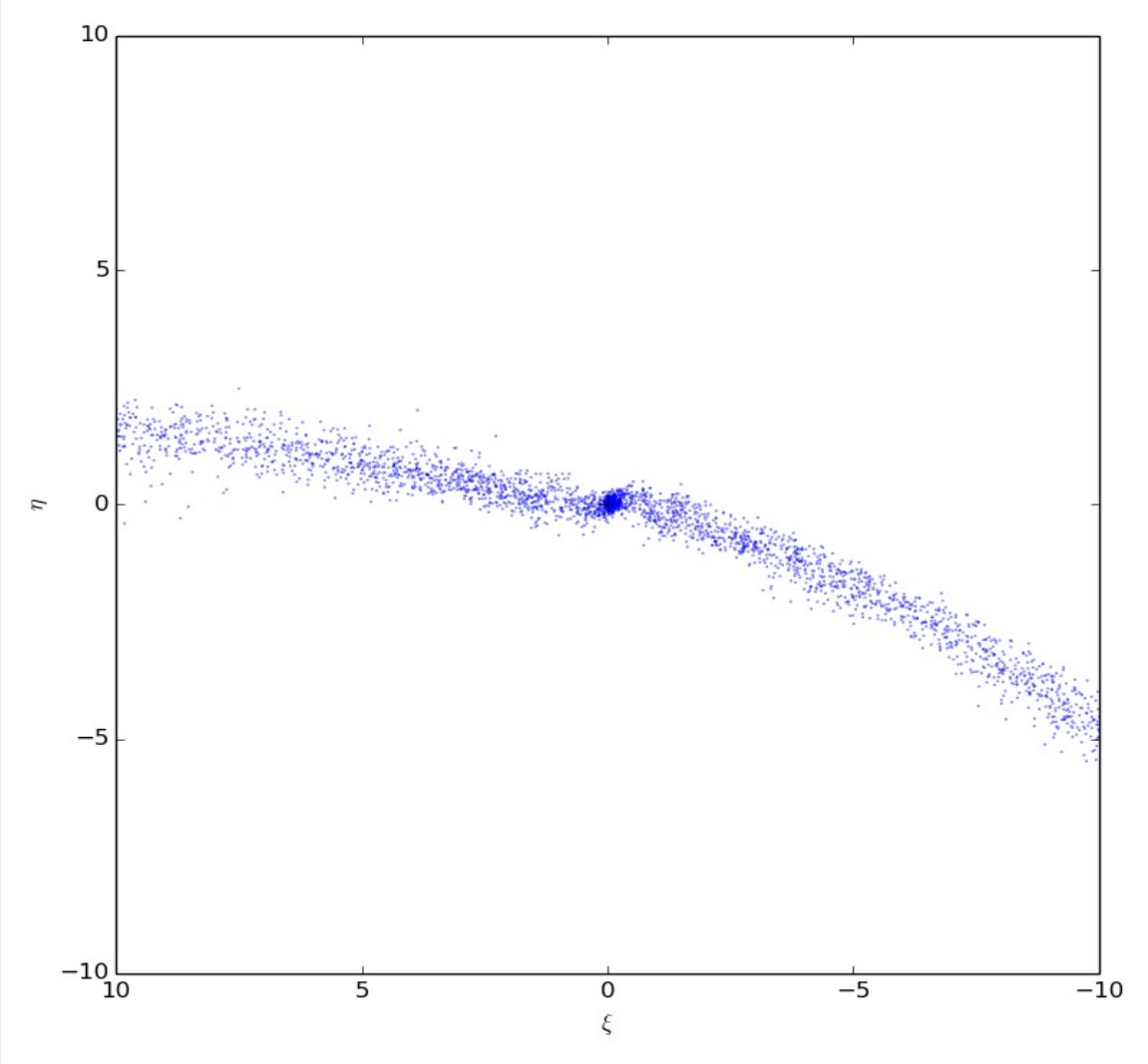


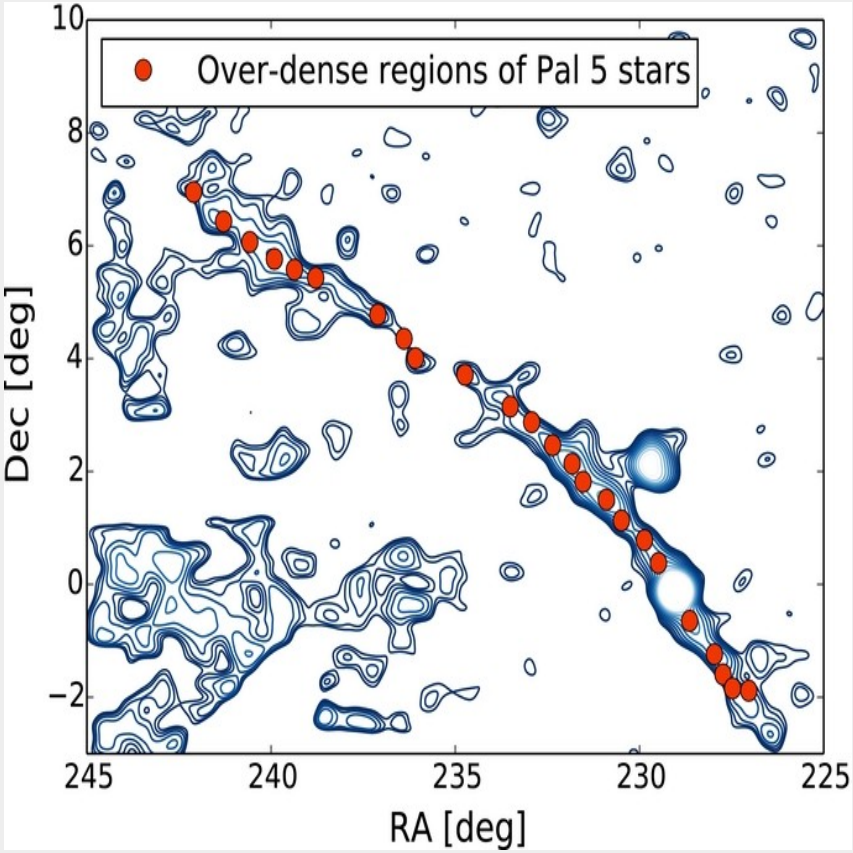
A rotating progenitor ?



The stream of Palomar 5

Palomar 5





Pearson et al, 2015

Comparaison between MONDian and ΛCDM simulations

Which DM halo gives the same orbit as MOND ?

Which DM halo ?

- We determine the **Shape** of DM halo by **reproducing the orbit** of the progenitor in MOND

- Using the ***NEMO*** software

➢ **DM halo**:

$$\rho_s(R,z)=\rho_0\left(\frac{m}{r_0}\right)^{-\gamma}\left(1+\frac{m}{r_0}\right)^{\gamma-\beta}\exp\left(\frac{m^2}{r_t^2}\right)$$

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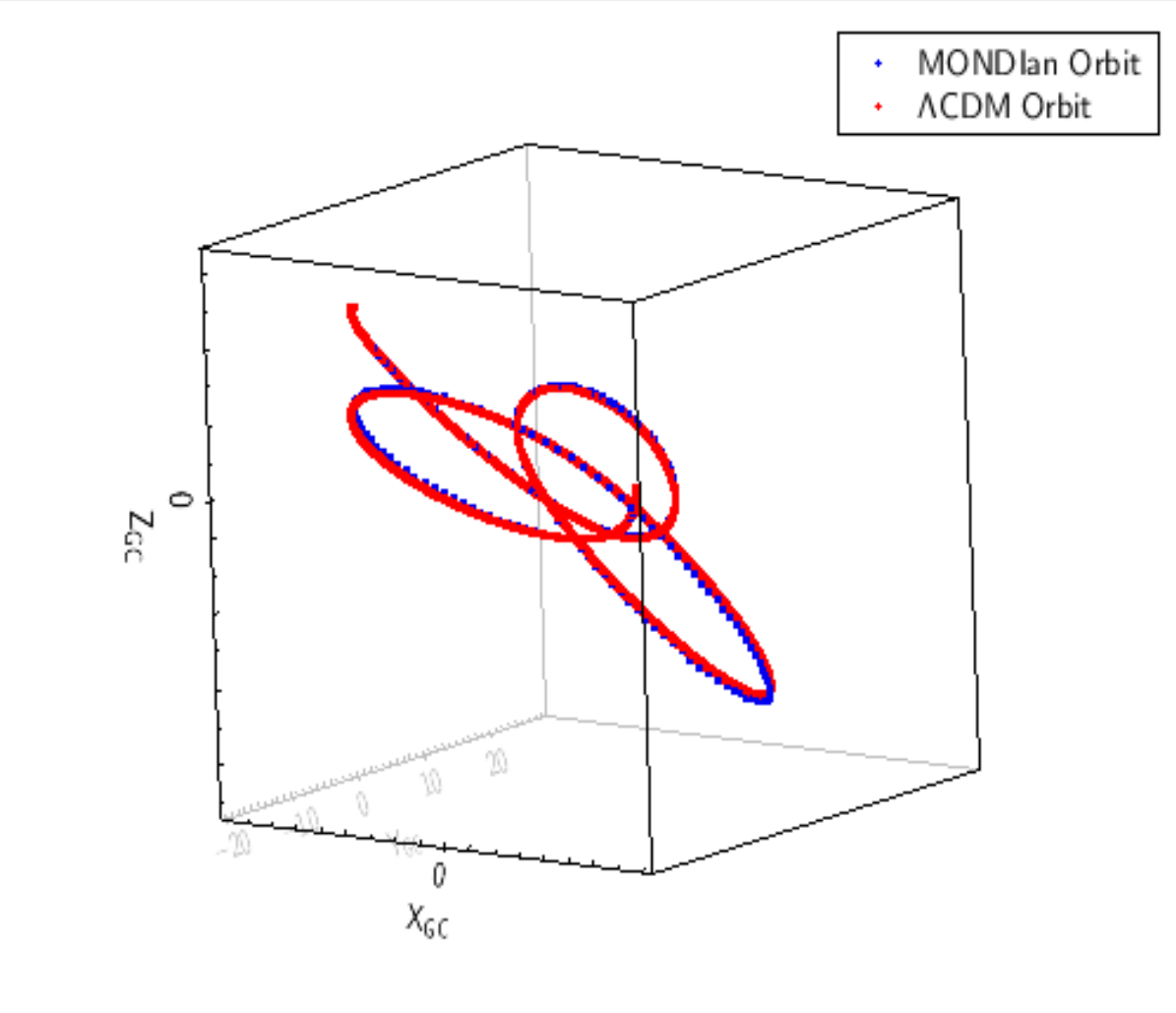

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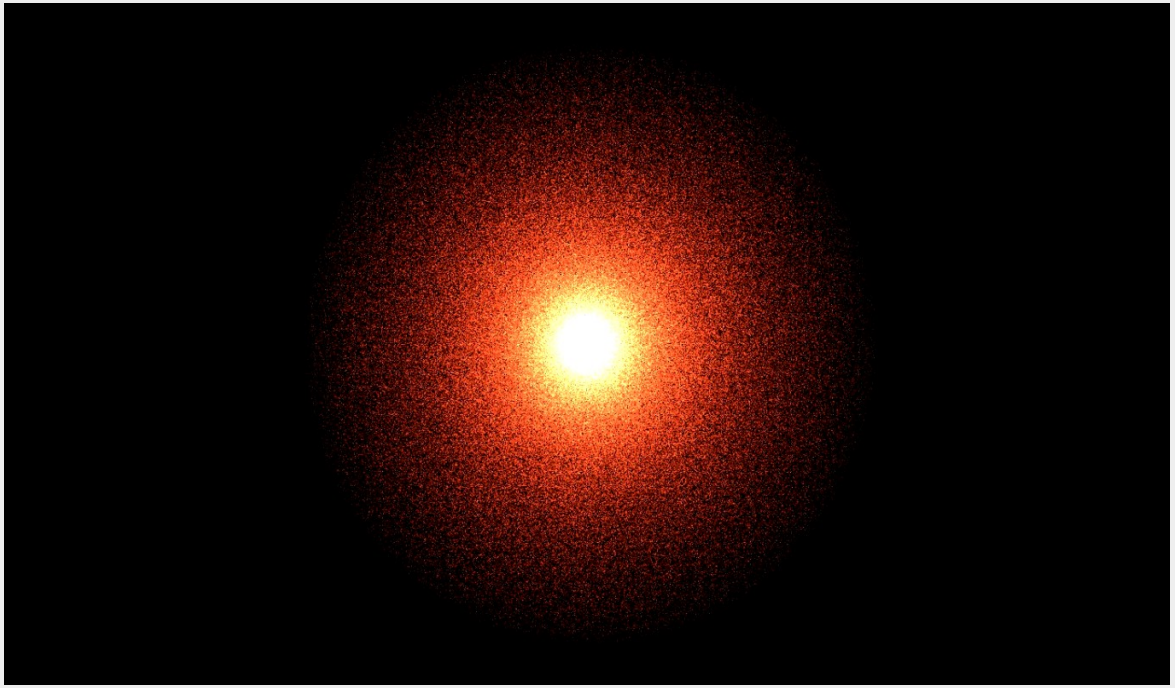
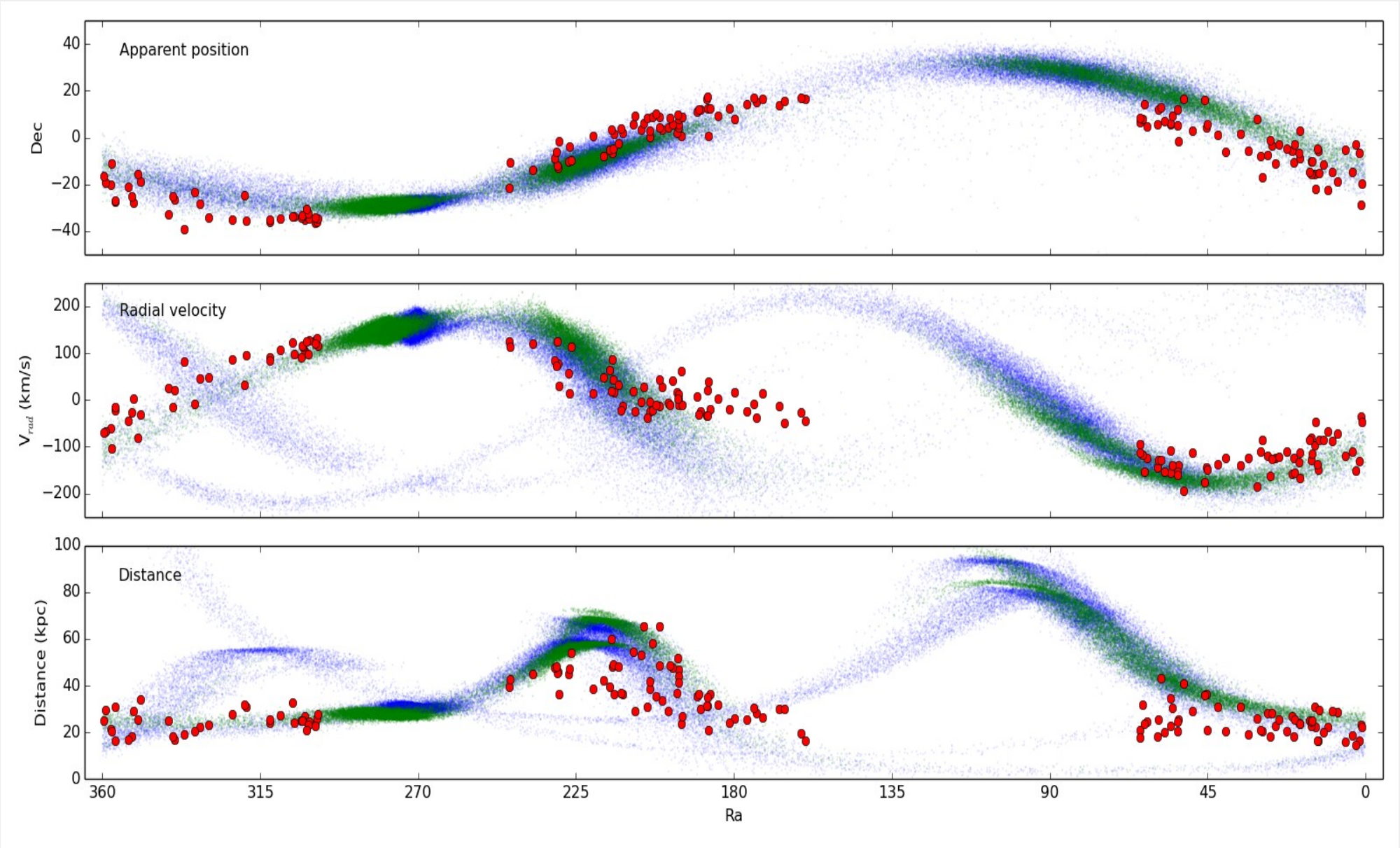


$M_{DM} = 1.42 \cdot 10^{12} M_{\odot}$

Sagittarius stream with DM halo



Conclusions

Conclusions & perspectives

MONDian simulations of the Sgr :

• **reproduce the spatial distribution** of the Sgr stream

… but still a **problem with Vrad** :

➔ Due to a peculiar feature of the Sgr ? (**Rotating dwarf spirale galaxy**)

➔ Or a more complex baryonic distribution of the MW ? (Influence of the **LMC** or a **non spherical hot gazous halo**)

• **Finish** simulation of **Pal 5**

• Search what **configuration** can explain the Sgr radial velocity (rotating progenitor)

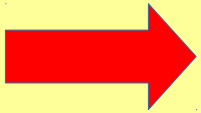
• Make direct comparaison between **MONDian and Newtonian predictions**

Thank you for your attention

Pympor

Python software for read the PoR outputs :

- **Part** (particles features)
- **Grav** (Acceleration and potential of the AMR grid)



https://filesender.renater.fr/?vid=6856dfcc-b5ce-10e8-1a93-0000434c41d2