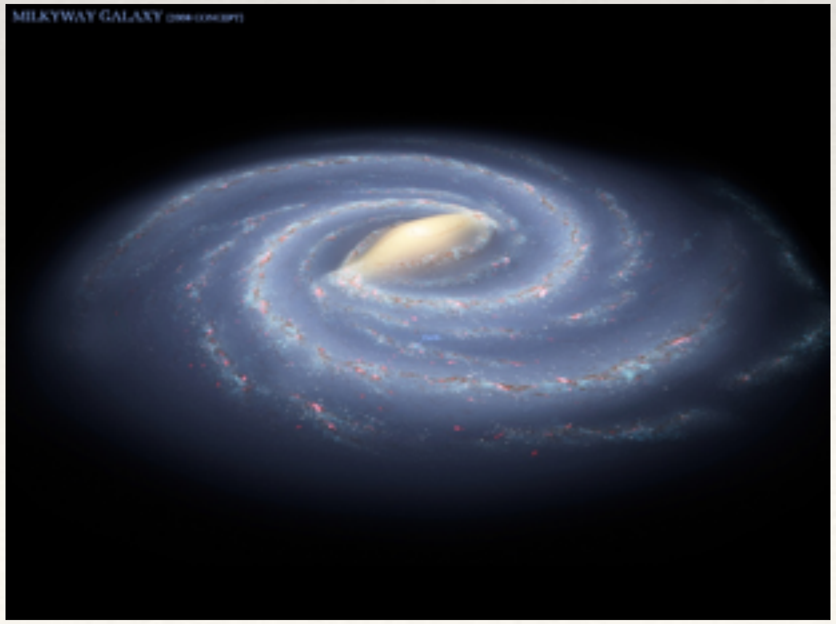
Besançon Galaxy Model (BGM): Structure and dynamics of the Milky Way

J. G. Fernández-Trincado

Under supervision of
A. Robin and C. Reylé
Institut Utinam, OSU Theta Franche-Comté-Bourgogne

In collaboration with
O. Bienaymé (Observatoire astronomique de Strasbourg, France)



Besançon - April 02, 2015

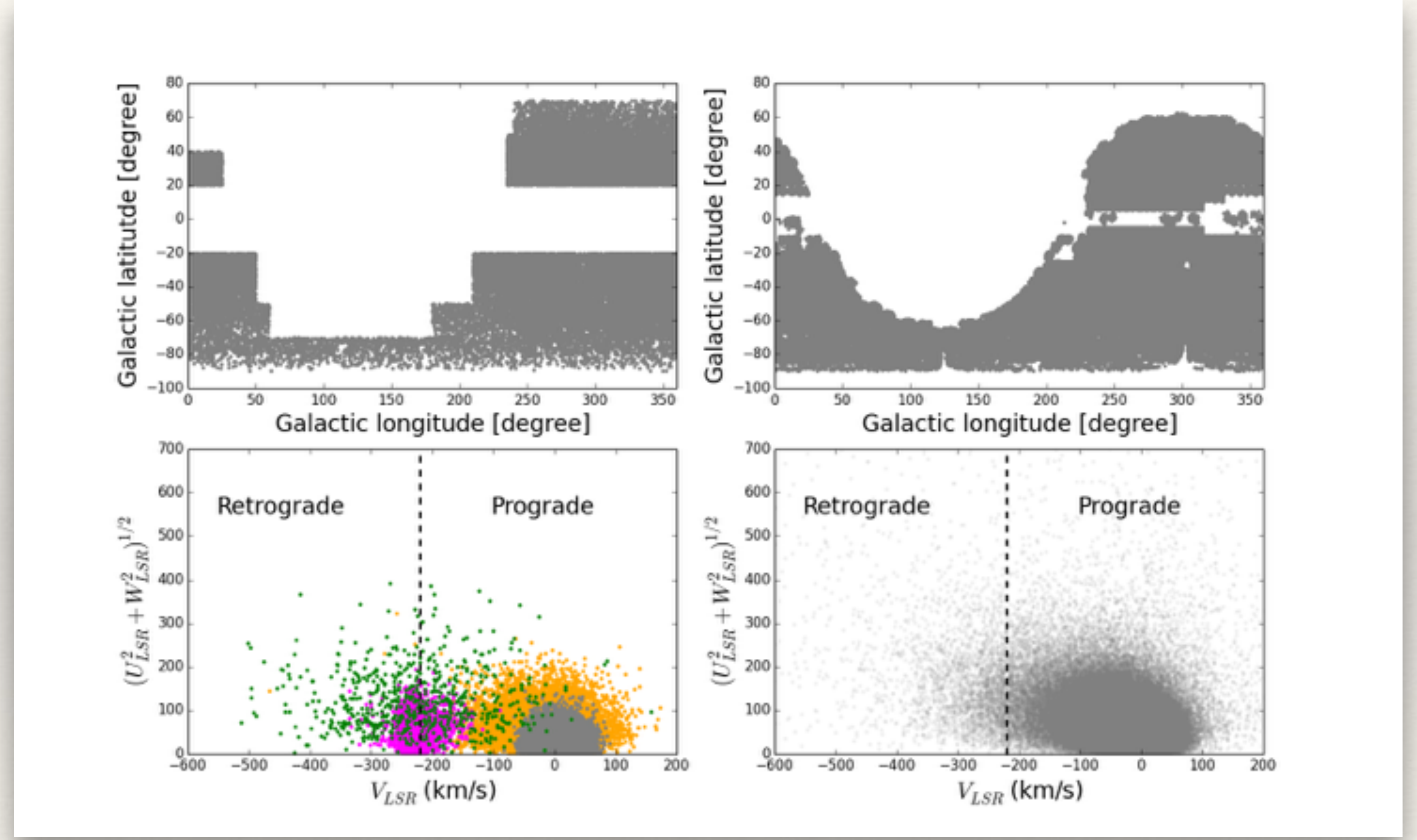
Inmediate objectives

- Construct a self-consistent dynamical model including triaxial structures (Galactic bar, “inner stellar halo”).
- Constraint on the physical parameters with the new Rotation Curve.
- Understand the structure and dynamical properties of the Milky Way under the new constraints.
- In the near future the population synthesis approach for using it for validation of GAIA data and for data analysis.

What is Besançon Galaxy Model (BGM)?

The Besançon Galaxy model is a semi-empirical model of the Galaxy, built to reproduce the stellar populations of the Milky Way (Robin et al. 1986, Robin et al. 2003).

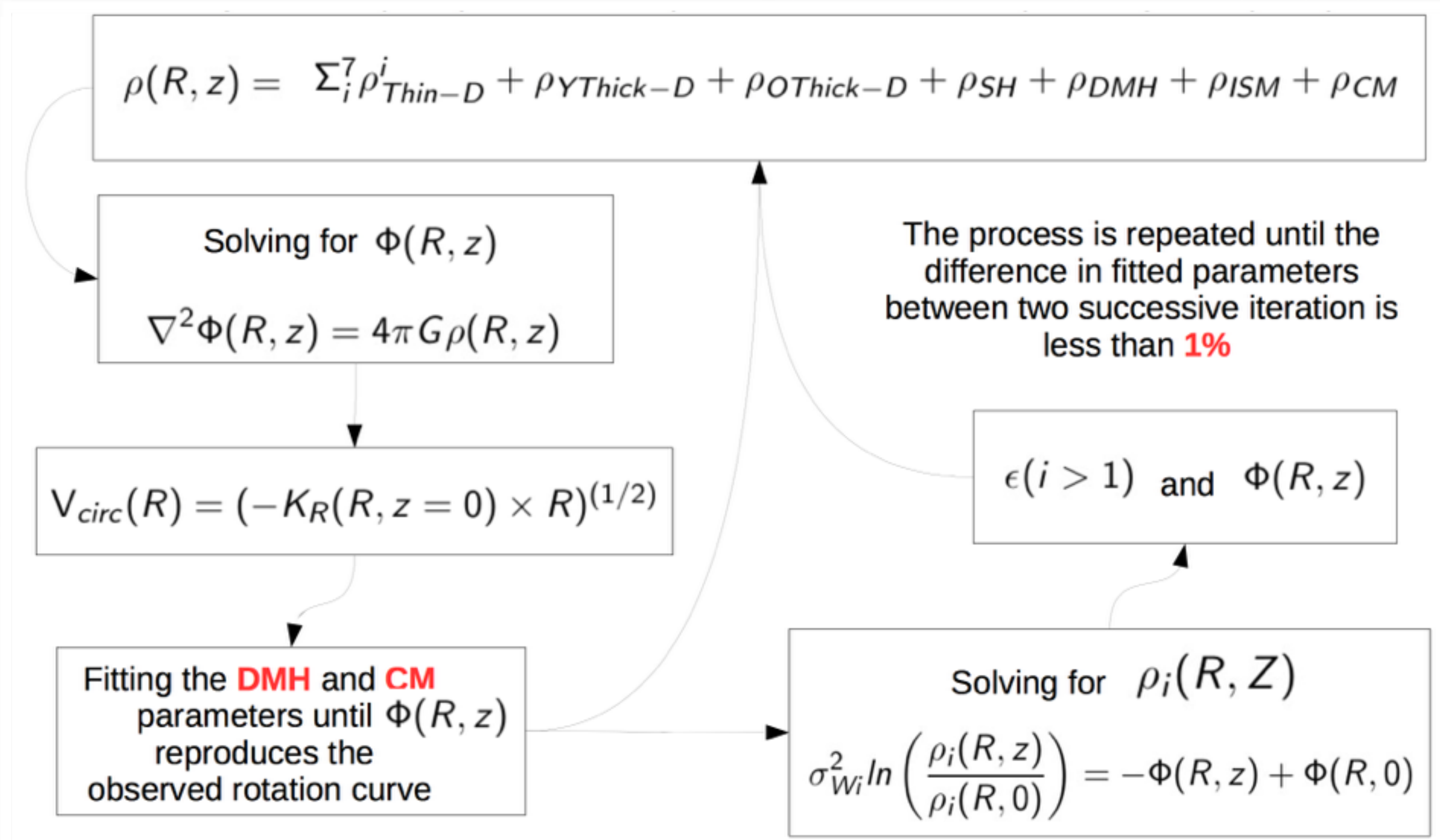
Example from the RAdial Velocity Experiment (RAVE-DR4) with an accuracy Vr < 2 km/s



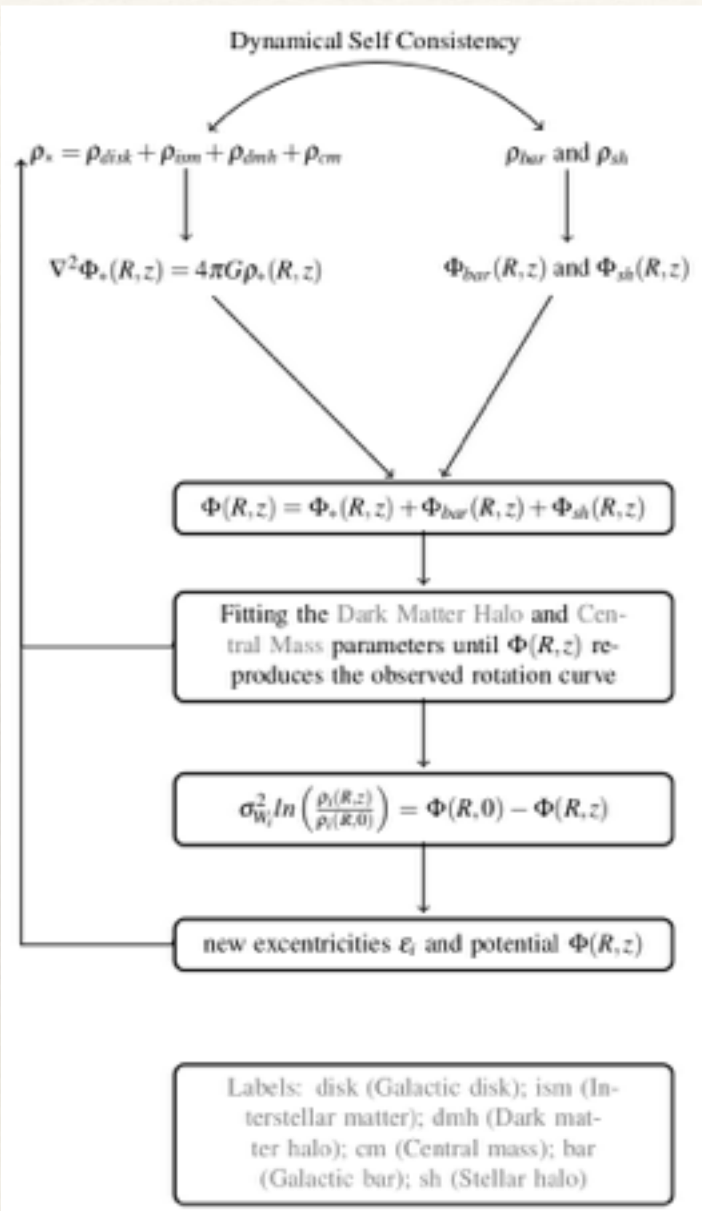
Fernández-Trincado et al. (2015, upcoming)
"RAVE stars ejected from Omega Centauri globular cluster"

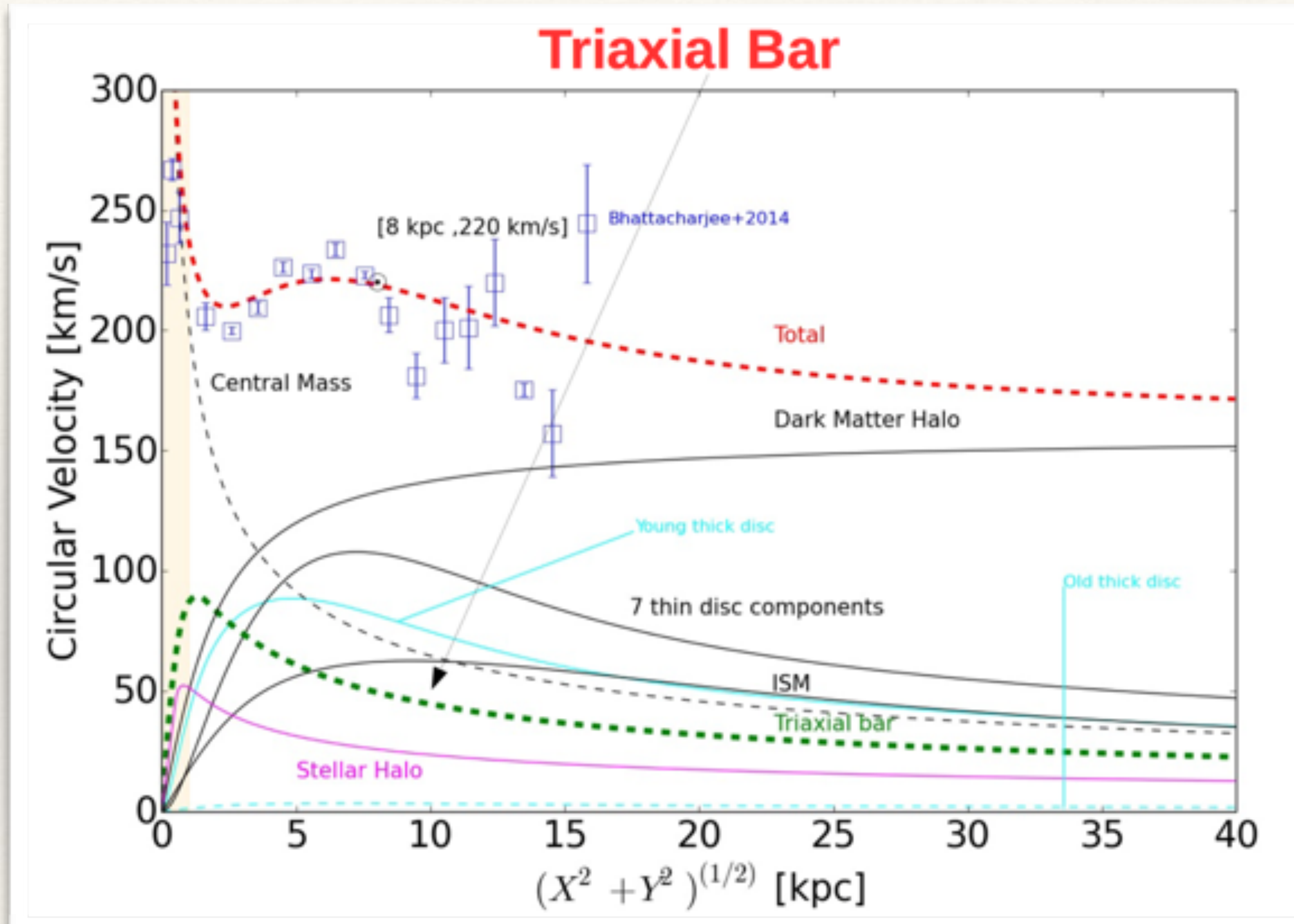
BGM: Dynamical self consistency

Bienaymé et al. (1986), Robin et al. (2003, 2012, 2014), Czekaj et al. (2013)



BGM: Dynamical self consistency including triaxial components
Similar scheme

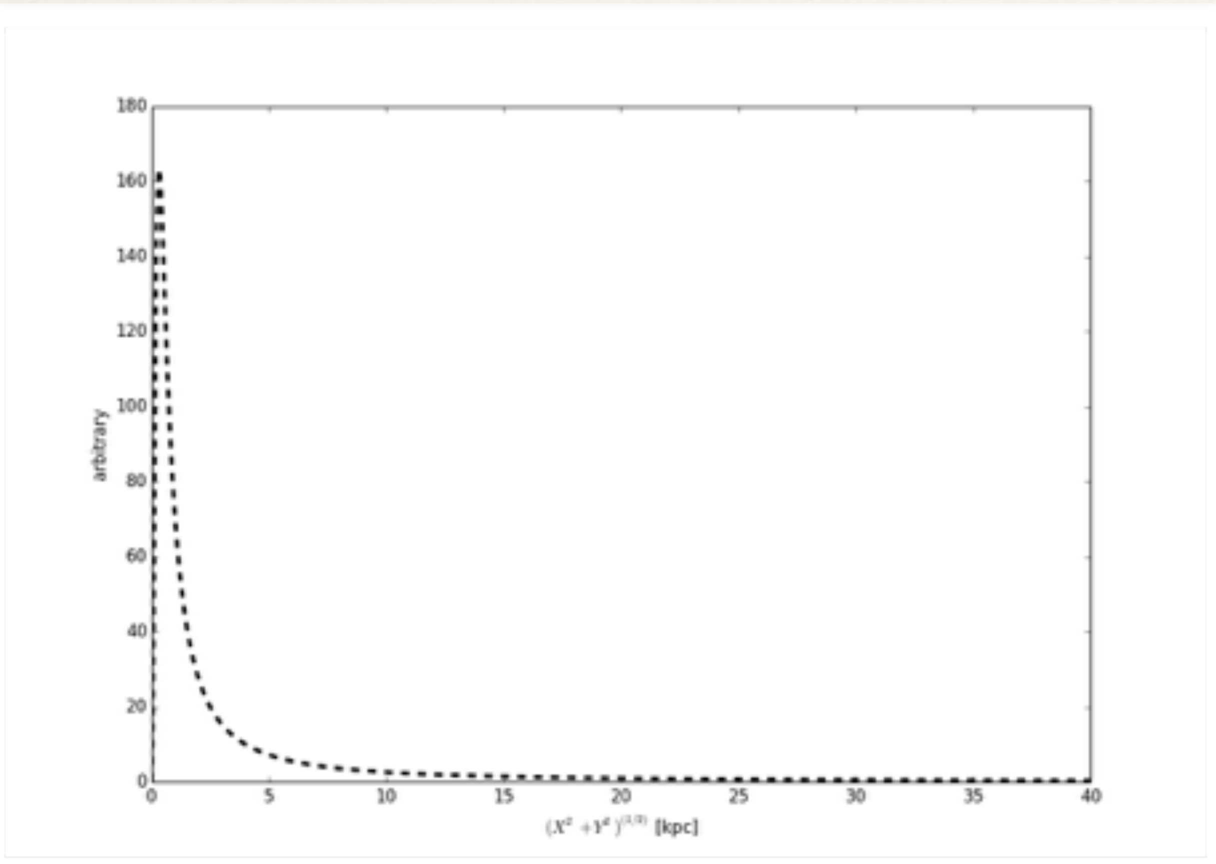


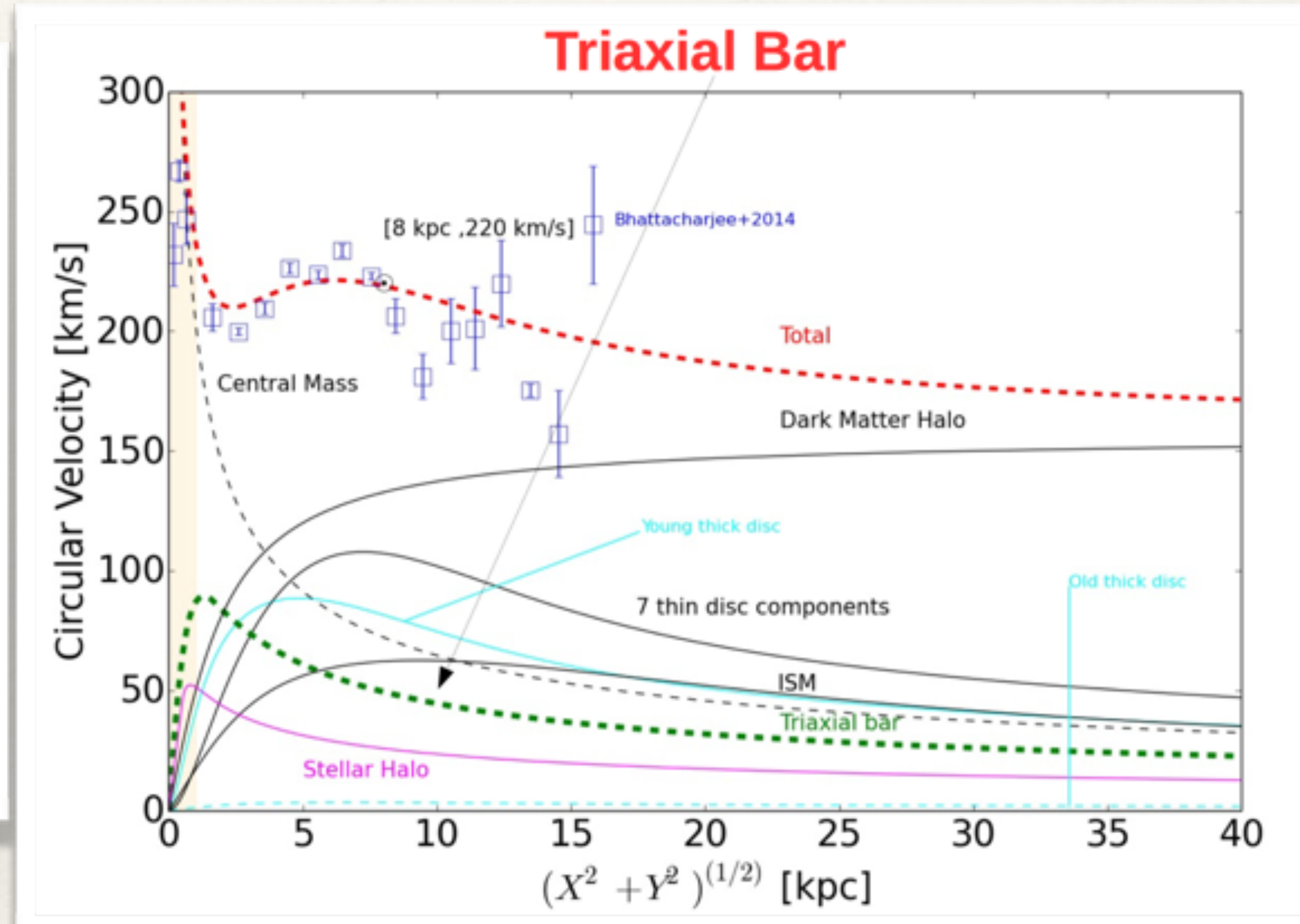


Fernández-Trincado et al. (2015b, in preparation)
“Besançon Galaxy Model: II. Dynamic update”

Rotation curve: Preliminary results

Figure: The rotation curve of our model Galaxy. The red dashed line is the total rotation curve, and the other indicate the partial contribution.





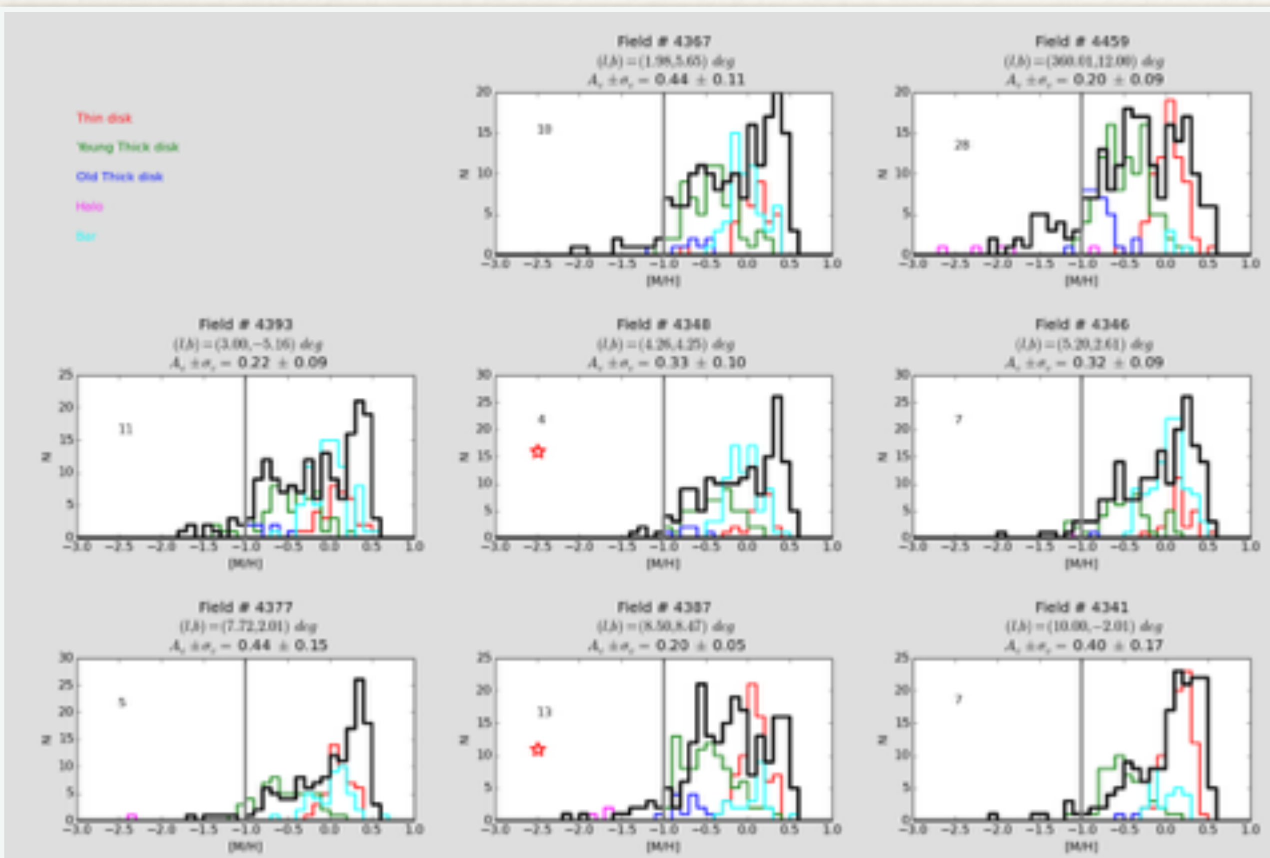
Preliminary results was presented in:

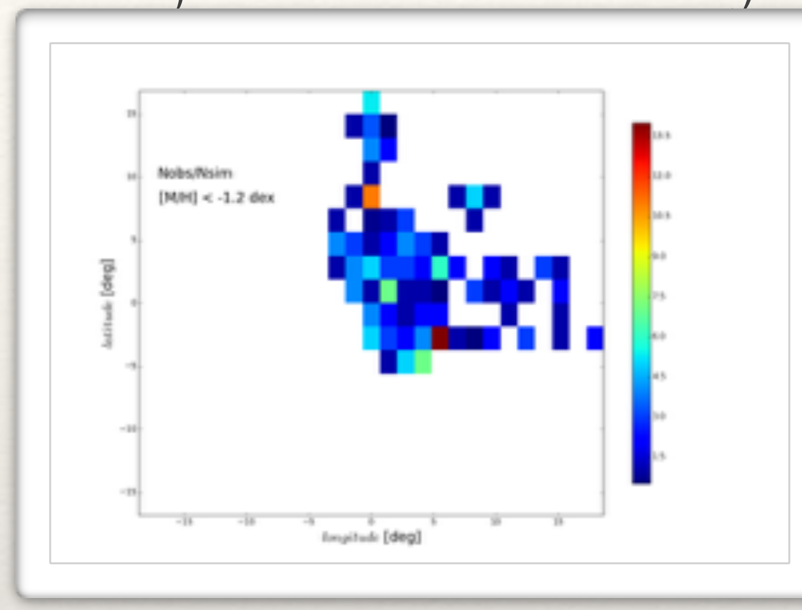
[1] Second Gaia Challenge Workshop - Germany, 27-31 October 2014.

[2] The Milky Way Unravelled by Gaia - Barcelona, 01-05 December 2015. Fernández-Trincado et al. (2015, proceeding)

Inner stellar halo

Constraining the density profile of the inner stellar halo from APOGEE survey

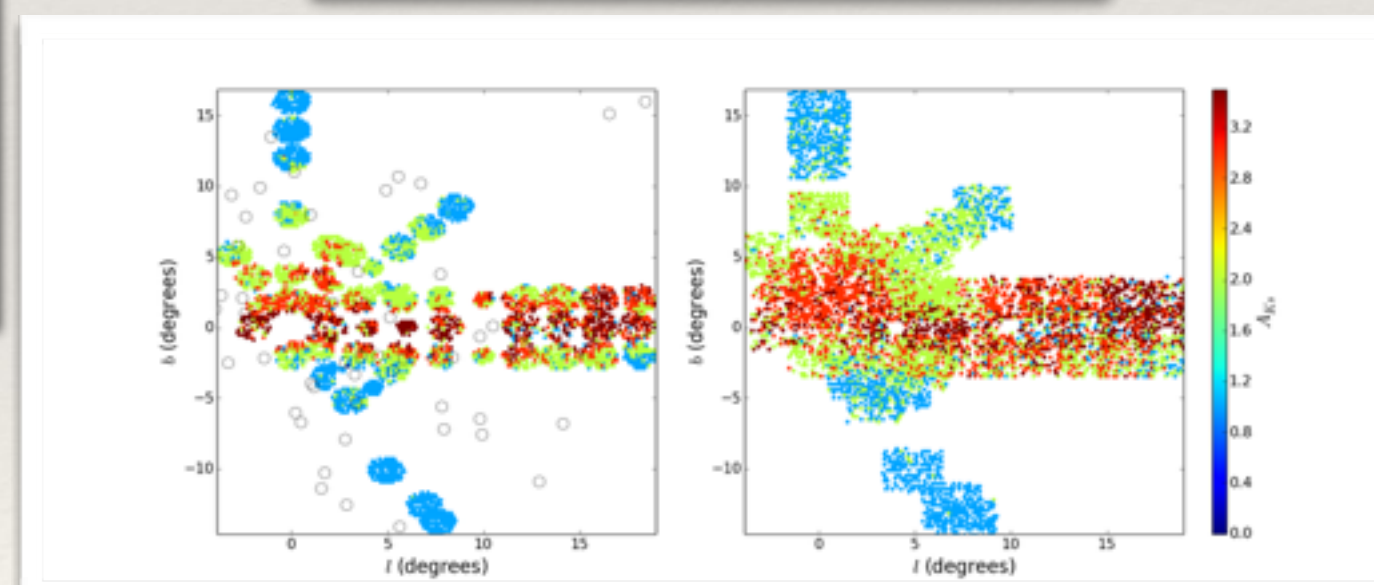




$$\rho(r) = \rho_0 \left(\frac{r}{r_{core}}\right)^{-\gamma} \left[1 + \left(\frac{r}{r_{core}}\right)^{\alpha}\right]^{(\gamma-\beta)/\alpha}$$

$$\Phi(r) = -\frac{4\pi G}{\alpha}\rho_0 r_0^2 \left[\frac{r_0}{r} \mathrm{B}\left(\frac{3-\gamma}{\alpha}, \frac{\beta-3}{\alpha}, \chi\right) + \mathrm{B}\left(\frac{\beta-2}{\alpha}, \frac{2-\gamma}{\alpha}, \chi\right)\right]$$

$$\chi = \frac{(r/r_0)^{\alpha}}{1+(r/r_0)^{\alpha}}.$$



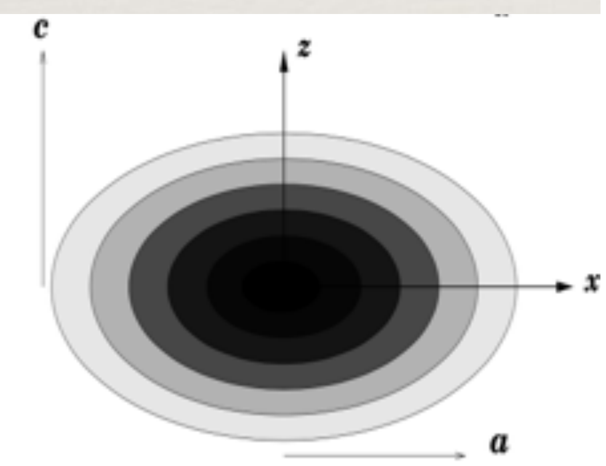
Fernández-Trincado et al. (2015a, in preparation)
"Besançon Galaxy Model: I. Constraining the density profile of the inner stellar halo of the Milky Way from SDSS and 2MASS"

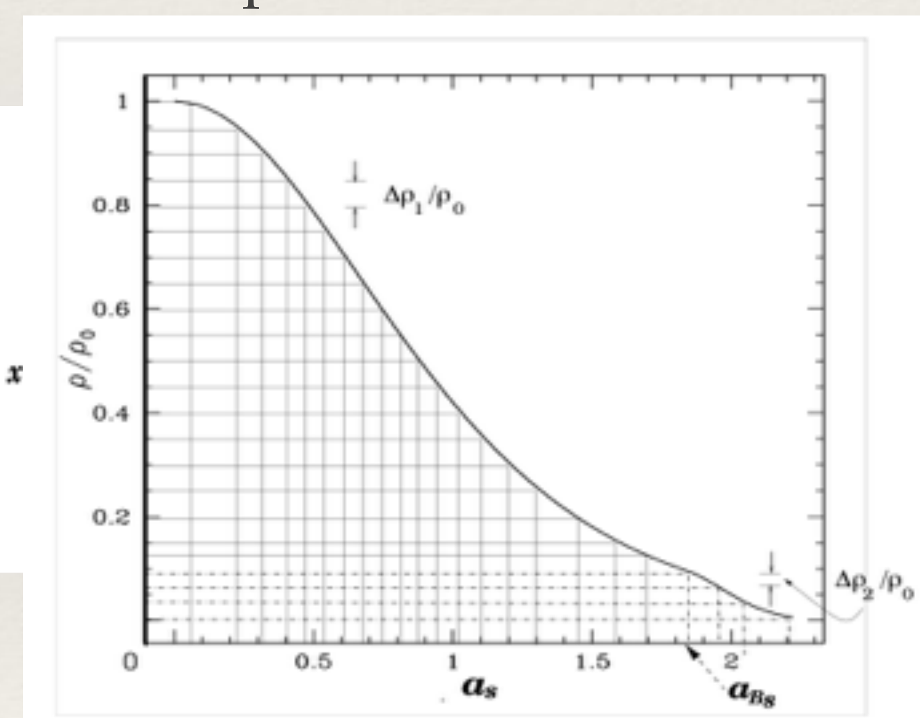
Triaxial bar

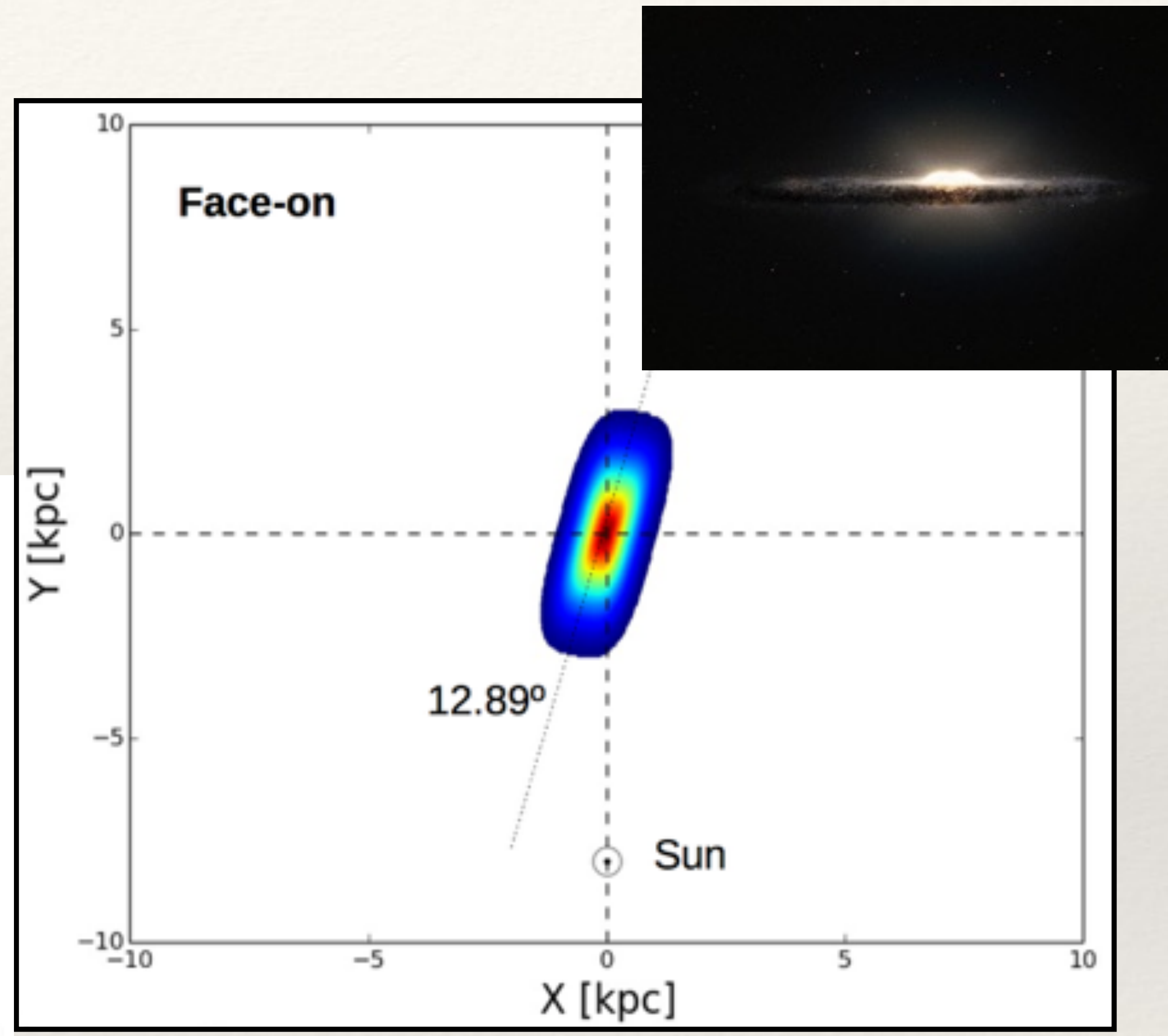
$$\rho(R_s) = \rho_o \times sech^2\left(\left[\left(\left|\frac{X}{x_0}\right|^{C_\perp} + \left|\frac{Y}{y_0}\right|^{C_\perp}\right)^{C_\parallel/C_\perp} + \left|\frac{Z}{z_0}\right|^{C_\parallel}\right]^{1/C_\parallel}\right)$$

$C_\parallel = 3.007$ and $C_\perp = 3.329$

Inhomogeneous ellipsoids from homogeneous ellipsoids







Pichardo model (Phd Thesis), Pichardo et al. (2004)

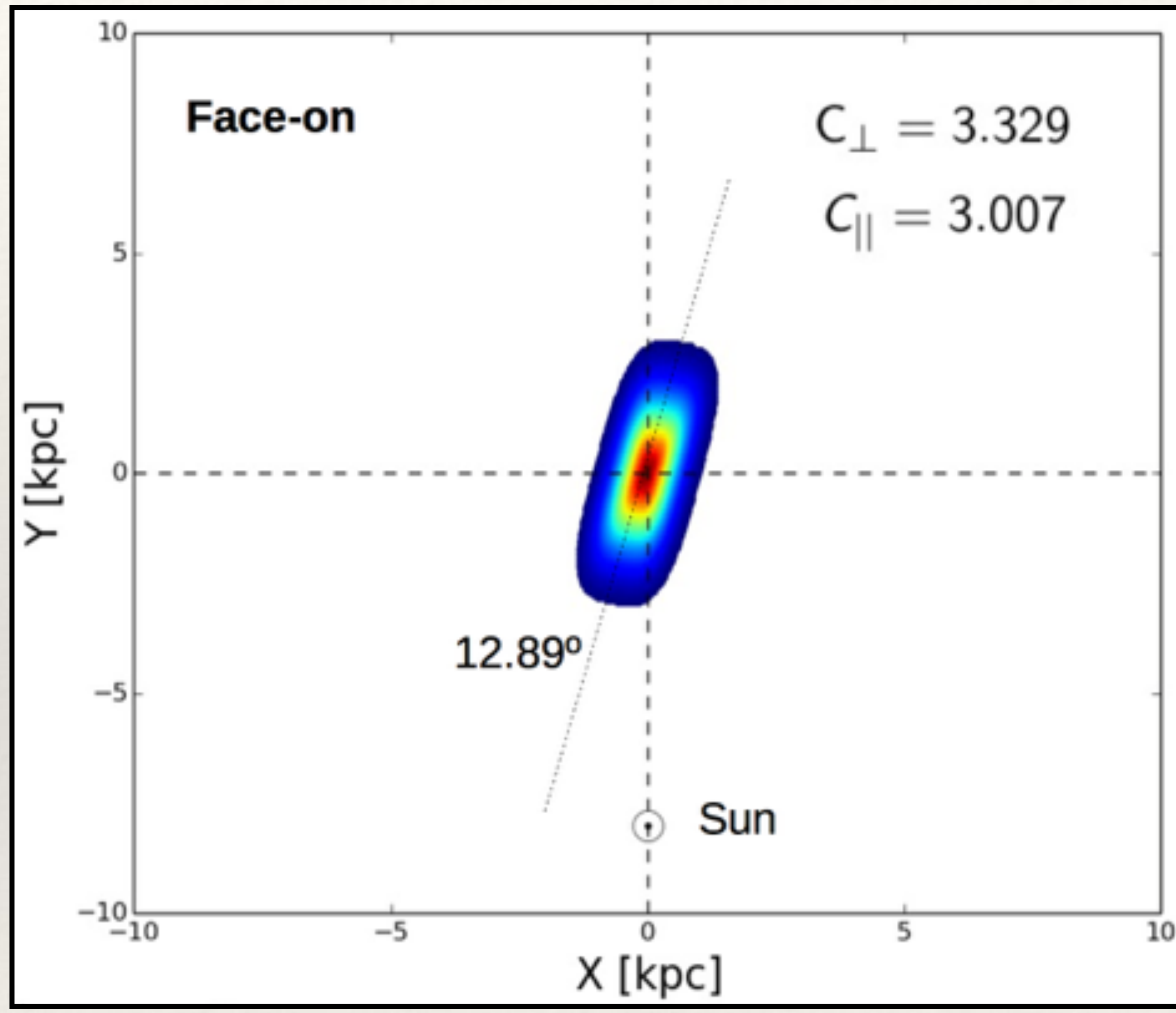
Fernández-Trincado et al. (2015b, in preparation)
"Besançon Galaxy Model: II. Dynamic update"

Triaxial bar

Inhomogeneous ellipsoids from homogeneous ellipsoids

$$
\begin{aligned}
(F_{x_B})_{elip} &= F_1 x \sum_{l=1}^{N_1+N_2\perp 1} \rho_l \{F(k,\theta_l) - E(k,\theta_l)\}, \\
(F_{y_B})_{elip} &= F_2 y \sum_{l=1}^{N_1+N_2\perp 1} \rho_l \{E(k,\theta_l) - k'^2 F(k,\theta_l) \\
&\quad -k^2(1-k^2 sen^2\ \theta_l)^{\perp 1/2} sen\ \theta_l \cos\theta_l\}, \\
(F_{z_B})_{elip} &= F_3 z \sum_{l=1}^{N_1+N_2\perp 1} \rho_l \left\{(1-k^2 sen^2\ \theta_l)^{1/2} \tan\theta_l - E(k,\theta_l)\right\} \\
(\Phi_B)_{elip} &= F_4 \sum_{l=1}^{N_1+N_2\perp 1} \rho_l a_l^2 F(k,\theta_l) - \frac{1}{2}\mathbf{r}\cdot(\mathbf{F})_{elip},
\end{aligned}
$$

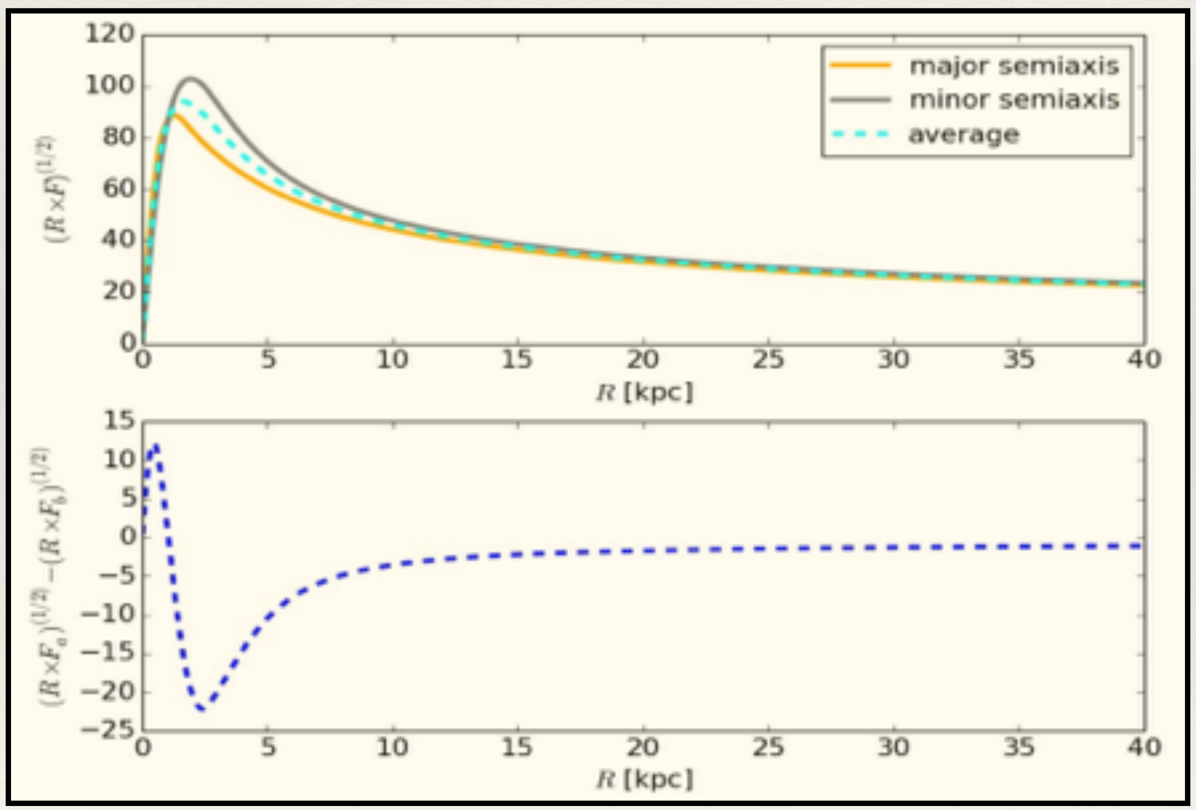
Kellog (1953) and Schmidt (1956)

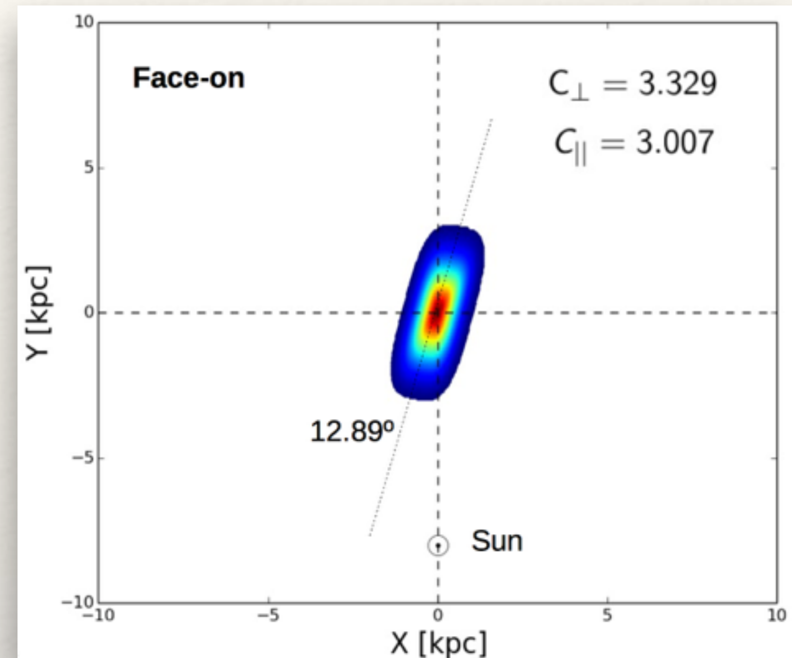


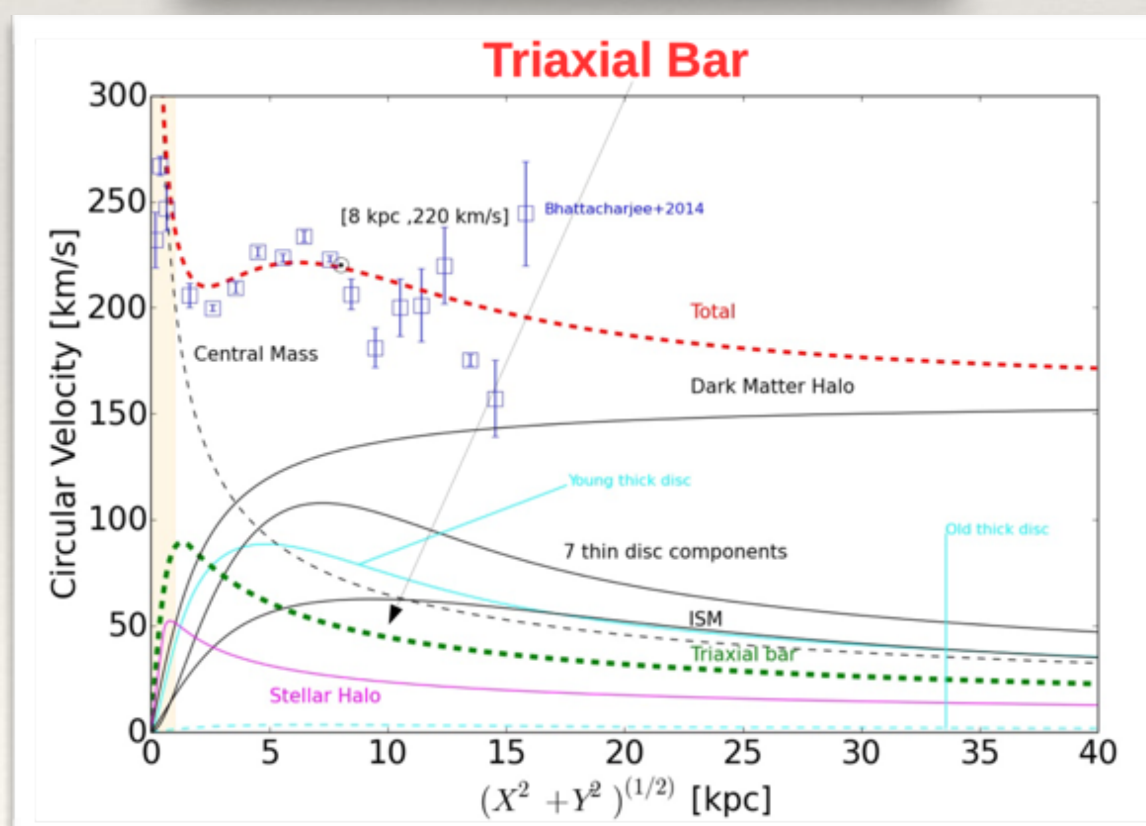
Fernández-Trincado et al. (2015b, in preparation)
"Besançon Galaxy Model: II. Dynamic update"

Triaxial bar

$$RC_{bar} = \frac{\sqrt{F_{x_0} \times R_{x_0}} + \sqrt{F_{y_0} \times R_{y_0}}}{2}$$







Fernández-Trincado et al. (2015b, in preparation)
"Besançon Galaxy Model: II. Dynamic update"

Summary

- We have applied the theory of potentials (Kellog 1953 and Schmidt 1956) to derive the field forces and potential for a triaxial bar according to the superposition model of Pichardo et al. (2004).
- It can be used to constraint the total mass in the Besançon Galaxy Model.
- New values for age-velocity dispersion relation are explored, from RAVE data (A. Robin; O. Bienaymé & J. G. Fernández-Trincado. 2015, in preparation).
- Test particles simulations will be generated to explore the bar effect locally and more generally derive the kinematics of the stars in a bar potential (Fernández-Trincado et al. 2015c, next step).
- 2016 and 2017, GAIA data analysis using modelling, (Fernández-Trincado et al. 2016, 2017, expectation).

Merci beaucoup