Potential of the Galaxy from the Besançon Galaxy Model including the triaxial bar

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Gaia Challenge 2014 'Discs', Germany

Image by: ESO/NASA/JPL-Caltech/M. Kornmesser/R. Hurt.

General Idea

1. Construct a self-consistent dynamical model (Besançon Galaxy Model) including the "Non-axisymmetric Potential" produced by a triaxial bar and a more realistic density distribution for the stellar halo (potential corresponding to a Hernquist model).

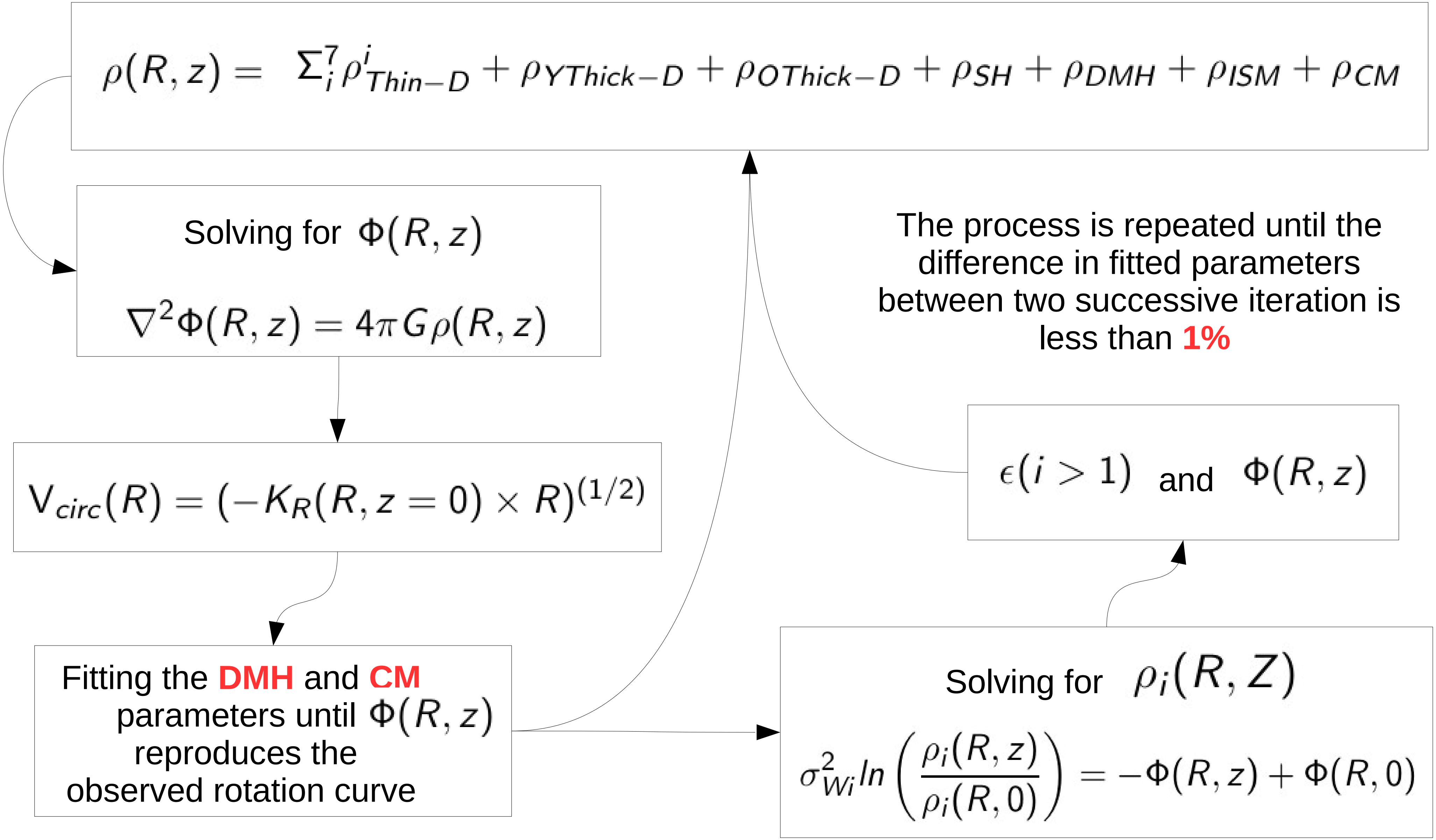
2. Constraint on the physical parameters with the new Rotation Curve.

3. Understand the structure and dynamical properties of the Milky Way under the new constraints.

4. In the near future the population synthesis approach for using it for validation of GAIA data and for data analysis.

GENERAL SCHEME FOR DYNAMICAL SELF CONSISTENCY
BESANCON GALAXY MODEL

Bienaymè et al. (1987), Robin et al. (1986, 2003, 2012, 2014), Czekaj et al. (2013)



$$\rho(R,z) = \Sigma_i^7 \rho^i_{Thin-D} + \rho_{YThick-D} + \rho_{OThick-D} + \rho_{SH} + \rho_{DMH} + \rho_{ISM} + \rho_{CM}$$

Solving for $\Phi(R,z)$

$$\nabla^2\Phi(R,z) = 4\pi G\rho(R,z)$$

$$V_{circ}(R) = (-K_R(R,z=0) \times R)^{(1/2)}$$

Fitting the **DMH** and **CM** parameters until $\Phi(R,z)$ reproduces the observed rotation curve

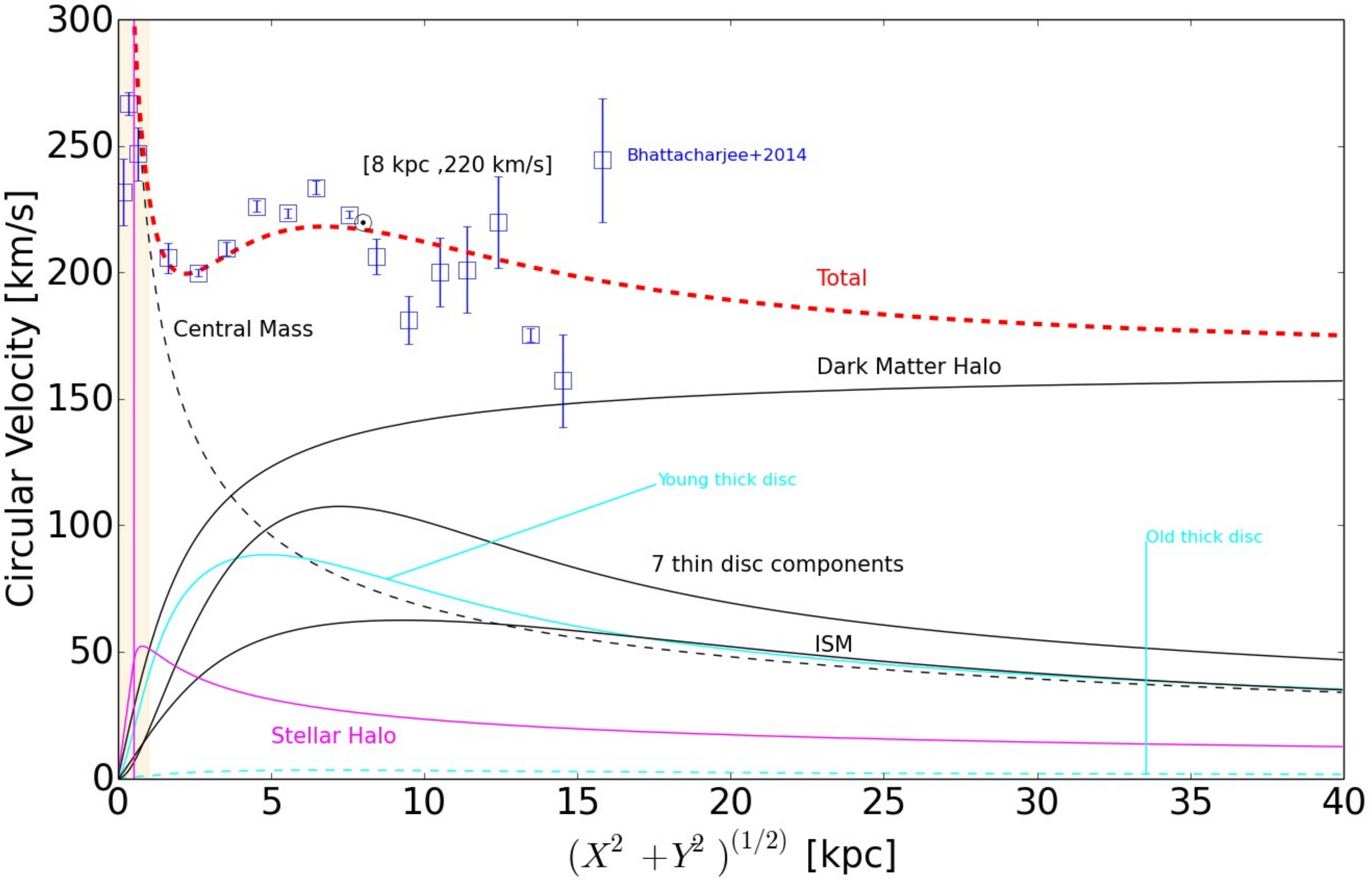
Solving for $\rho_i(R,Z)$

$$\sigma^2_{Wi} ln\left(\frac{\rho_i(R,z)}{\rho_i(R,0)}\right) = -\Phi(R,z) + \Phi(R,0)$$

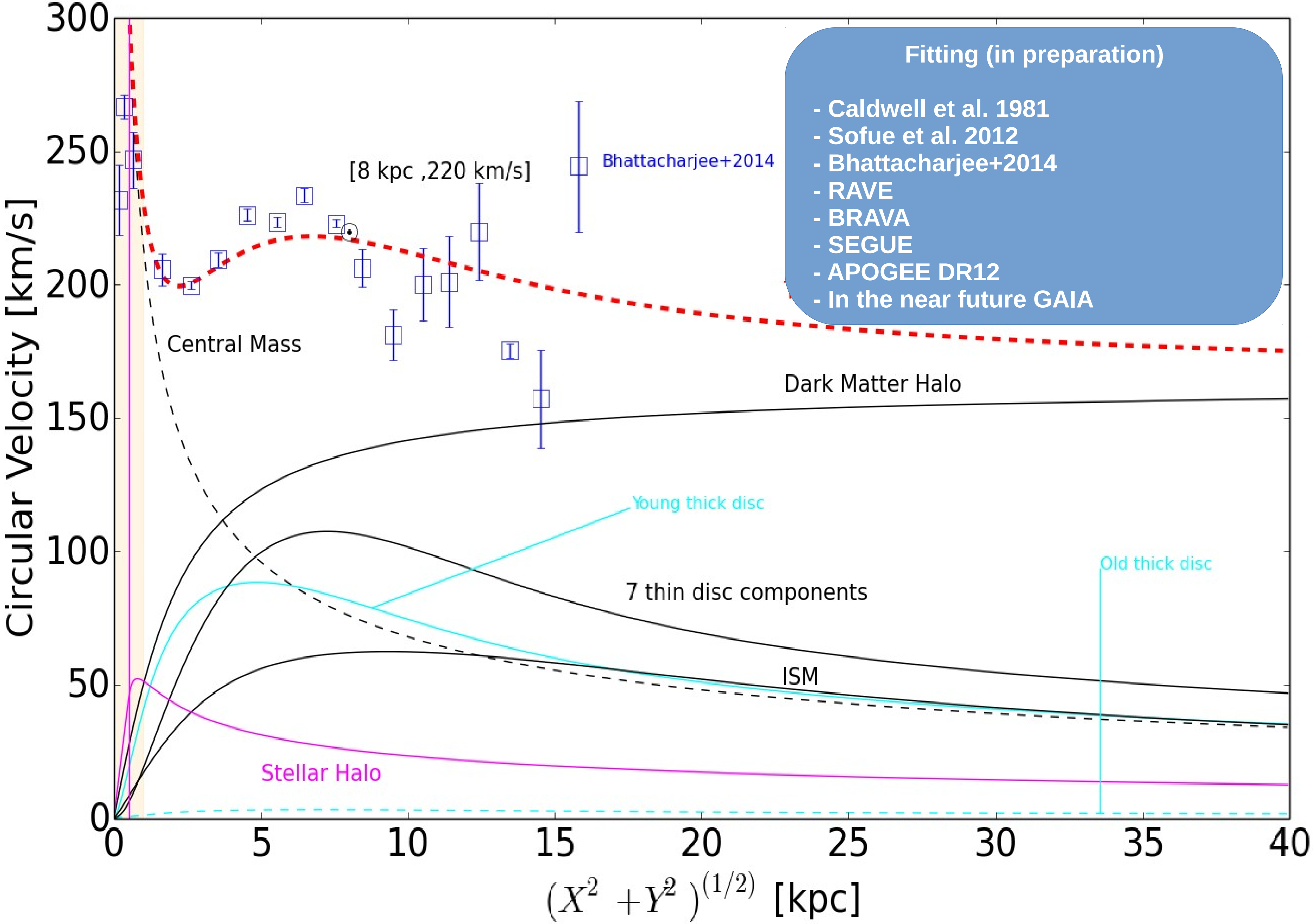
$\epsilon(i>1)$ and $\Phi(R,z)$

The process is repeated until the difference in fitted parameters between two successive iteration is less than **1%**

The Rotation Curve of the Milky Way



The Rotation Curve of the Milky Way



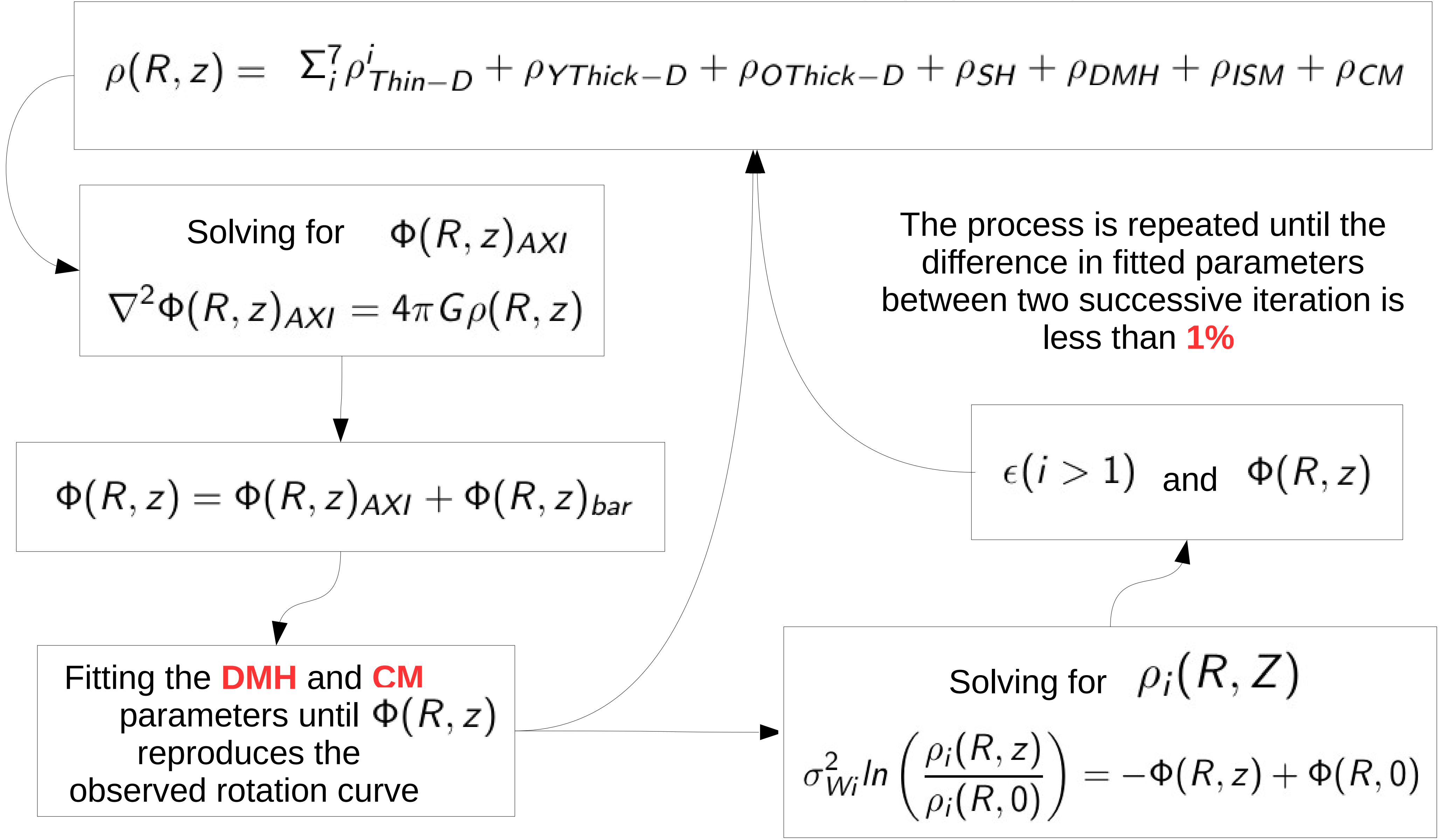
Fitting (in preparation)

- **Caldwell et al. 1981**
- **Sofue et al. 2012**
- **Bhattacharjee+2014**
- **RAVE**
- **BRAVA**
- **SEGUE**
- **APOGEE DR12**
- **In the near future GAIA**

GENERAL SCHEME FOR DYNAMICAL SELF CONSISTENCY

AXISYMMETRIC $\Phi(R,z)_{AXI}$ **+ NON-AXISYMMETRIC** $\Phi(R,z)_{bar}$

Fernández-Trincado et al. (in preparation)



$$\rho(R,z) = \Sigma_i^7 \rho^i_{Thin-D} + \rho_{YThick-D} + \rho_{OThick-D} + \rho_{SH} + \rho_{DMH} + \rho_{ISM} + \rho_{CM}$$

Solving for $\Phi(R,z)_{AXI}$

$$\nabla^2\Phi(R,z)_{AXI} = 4\pi G\rho(R,z)$$

$$\Phi(R,z) = \Phi(R,z)_{AXI} + \Phi(R,z)_{bar}$$

Fitting the **DMH** and **CM** parameters until $\Phi(R,z)$ reproduces the observed rotation curve

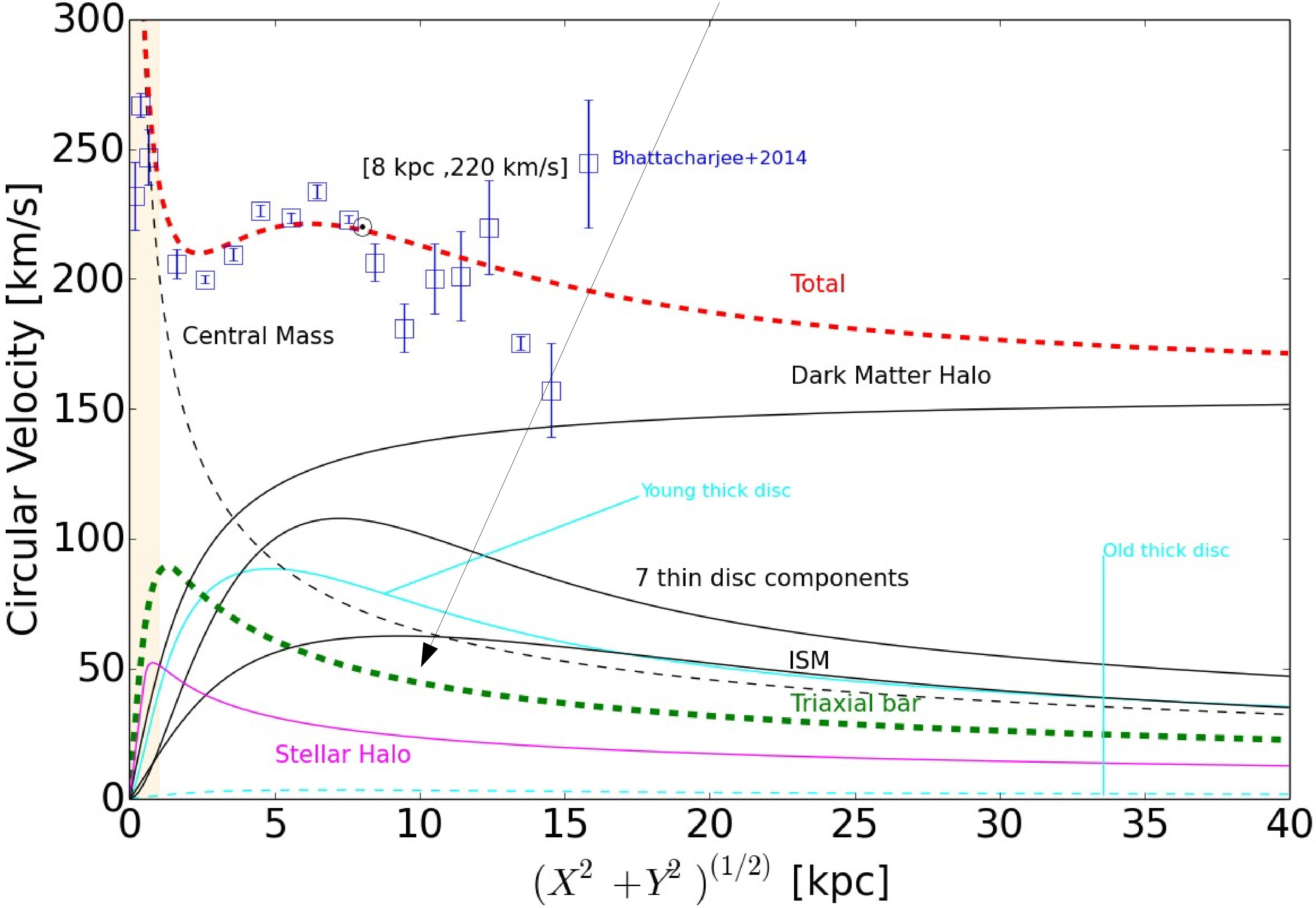
Solving for $\rho_i(R,Z)$

$$\sigma^2_{Wi} ln\left(\frac{\rho_i(R,z)}{\rho_i(R,0)}\right) = -\Phi(R,z) + \Phi(R,0)$$

$\epsilon(i > 1)$ and $\Phi(R,z)$

The process is repeated until the difference in fitted parameters between two successive iteration is less than **1%**

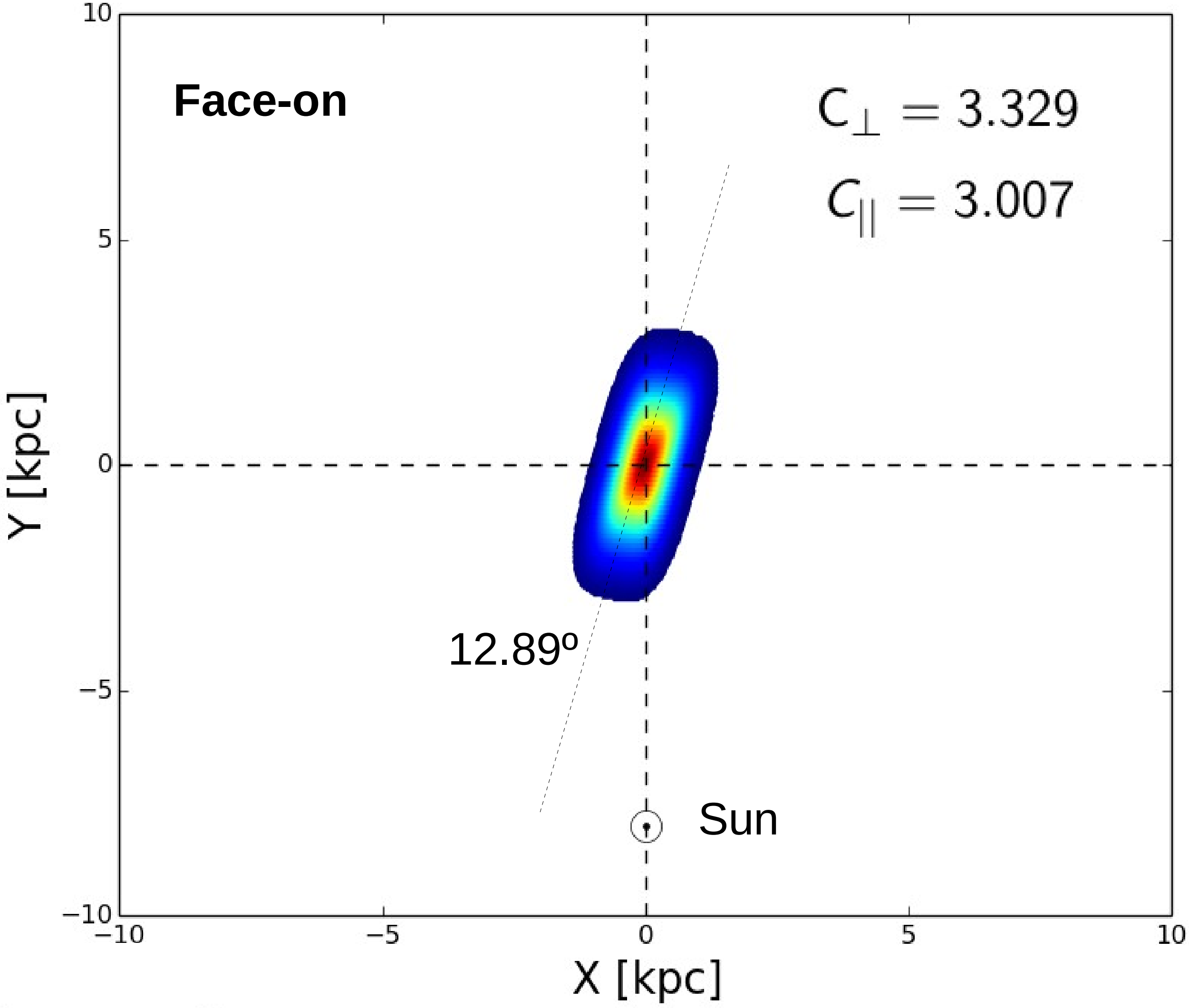
The Rotation Curve of the Milky Way + Triaxial Bar



Triaxial Bar

Robin et al. (2012)

$$\rho_{bar} = \rho_0 sech^2(-R_s)$$



$$Rs^{C_{||}} = \left[\left|\frac{X}{X_0}\right|^{C_\perp} + \left|\frac{Y}{Y_0}\right|^{C_\perp}\right]^{C_{||}/C_\perp} + \left|\frac{Z}{Z_0}\right|^{C_{||}}$$

Face-on

Edge-on

$C_{||} = 3.007$ and $C_\perp = 3.329$ **Fitting** $C_{||} = 2$ and $C_\perp = 2$

Triaxial Bar

Superposition of four inhomogeneous ellipsoids

Pichardo et al. (2004) model

N-homogeneous ellipsoids

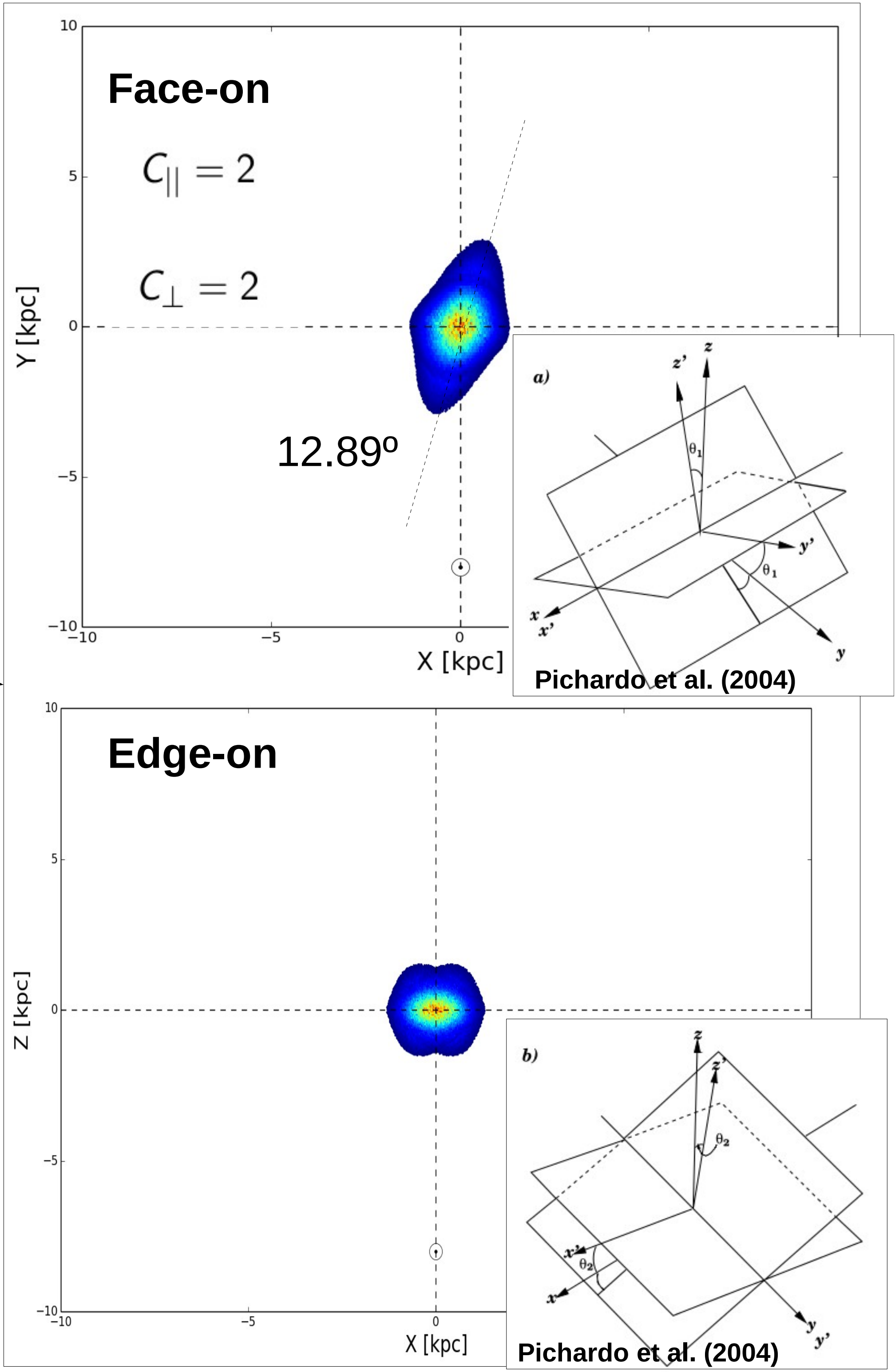
$$M_{\rm bar} = \frac{4}{3}\pi\zeta\xi\rho_0\left(\Delta_1\sum_{i=1}^{N_1-1}a_i^3 + \Delta_2\sum_{j=0}^{N_2-1}a_{N_1+j}^3 + \Delta_3\sum_{k=0}^{N_3-1}a_{N_1+N_2+k}^3\right)$$

Schmidt (1956)

$$\Phi(R,z) = \Phi(R,z)_{AXI} + \Phi(R,z)_{bar}$$

Effective potential for the triaxial bar in the rotating system

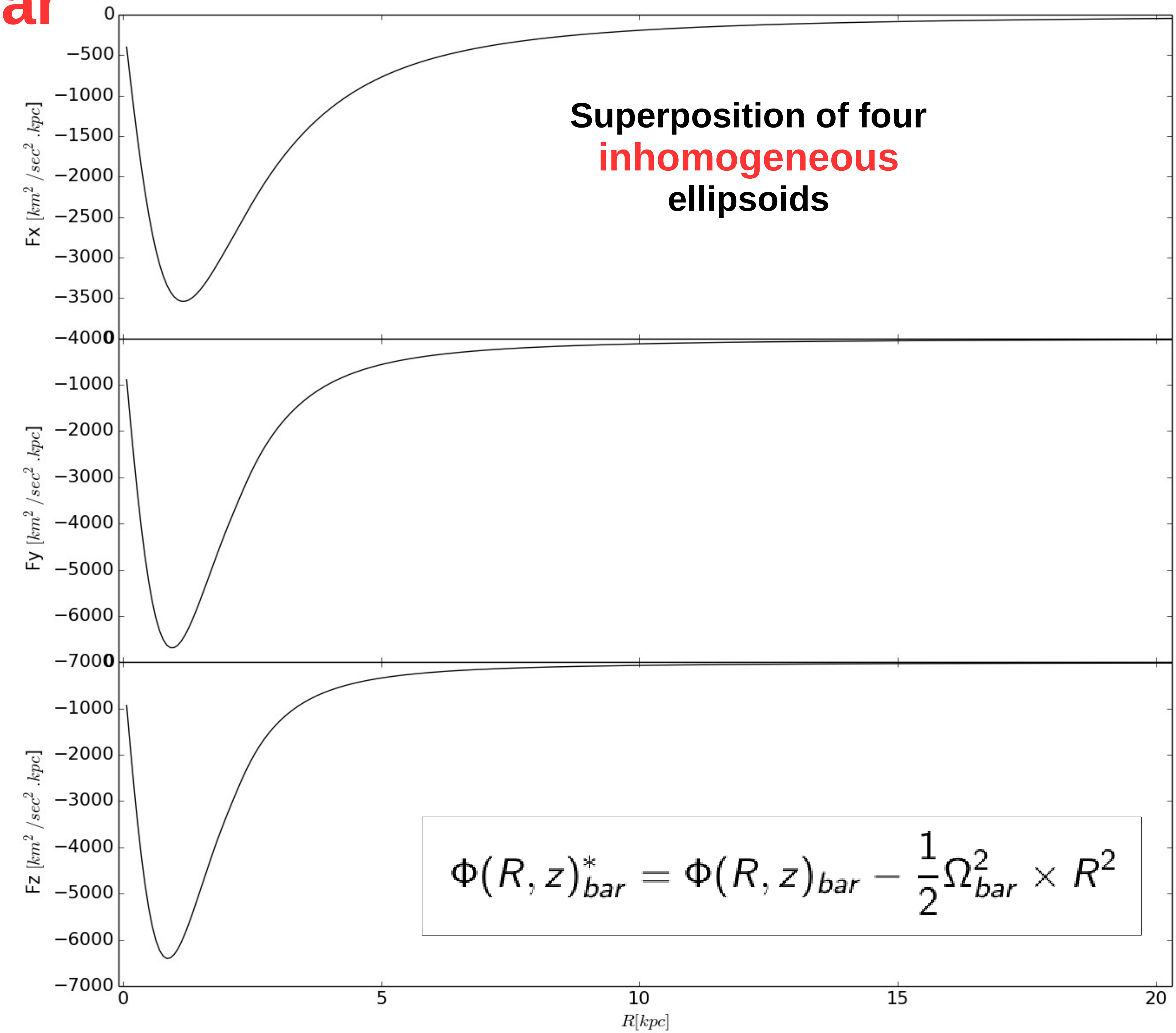
$$\Phi(R,z)^*_{bar} = \Phi(R,z)_{bar} - \frac{1}{2}\Omega^2_{bar} \times R^2$$



Pichardo et al. (2004)

Pichardo et al. (2004)

Triaxial Bar



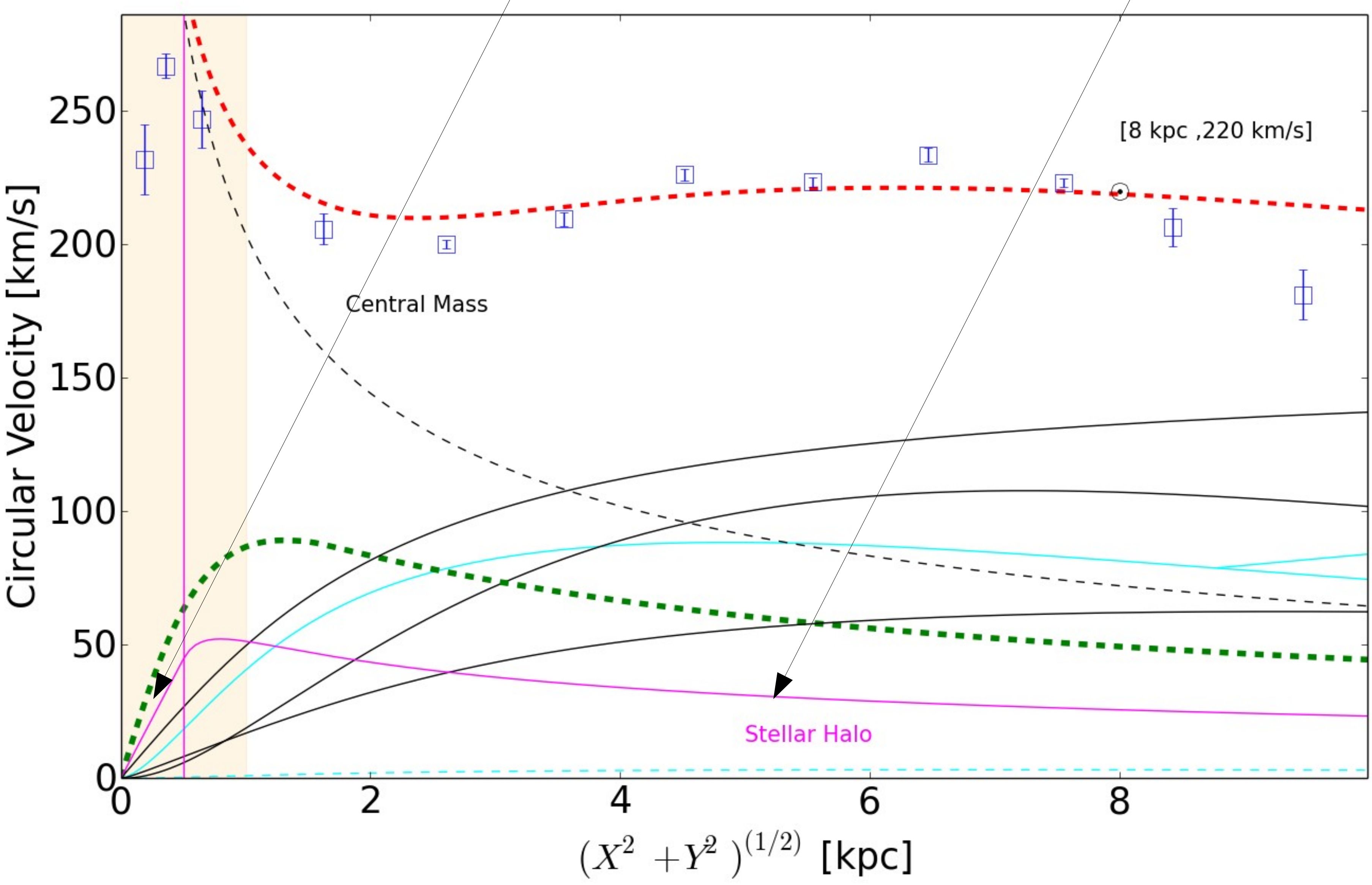
Superposition of four inhomogeneous ellipsoids

$$\Phi(R,z)^*_{bar} = \Phi(R,z)_{bar} - \frac{1}{2}\Omega^2_{bar} \times R^2$$

Stellar Halo

$$a^2 = R^2 + \frac{z^2}{\epsilon^2}$$

Robin et al. (2003) → $\rho_0/d_0 \times \left(\frac{a_c}{R_\odot}\right)^{-2.44}$ $\rho_0/d_0 \times \left(\frac{a}{R_\odot}\right)^{-2.44}$



Stellar Halo

"A pure power-law system can not exit in nature"

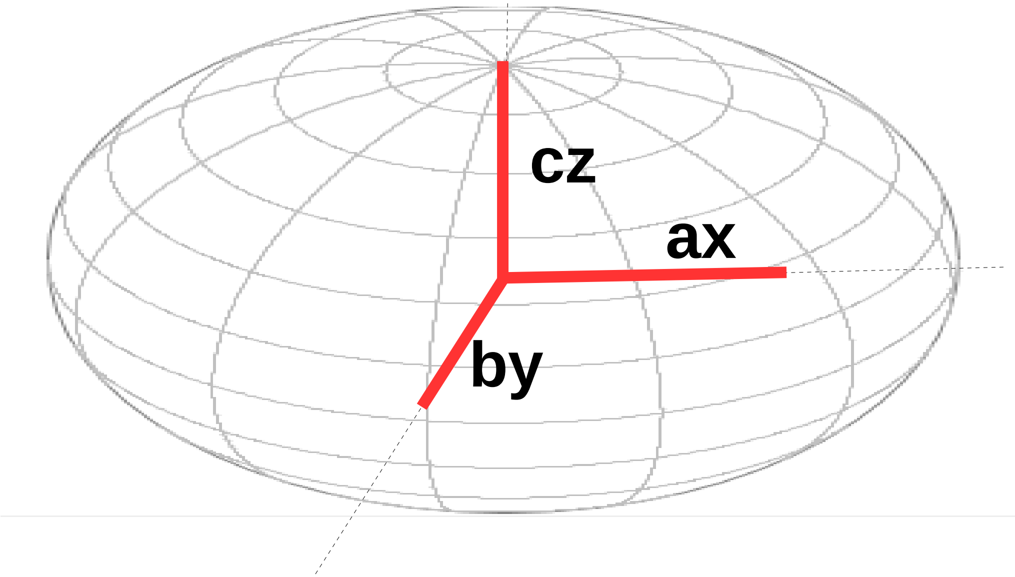
$$\rho_0/d_0 \times \left(\frac{a}{R_\odot}\right)^{-2.44}$$

Robin et al. (2003)

$$a^2 = R^2 + \frac{z^2}{\epsilon^2}$$

Oblate Spheroid

ax = by > cz



"A Hernquist law is a more realistic density distribution"

$$\rho_{SH}(R, z) = \rho_0 \times \left[\frac{1}{R_a \times (R_{core} + R_a)^n}\right]$$

2.1 kpc

2.76

Robin et al. (2014)

$$R_a = \sqrt{x^2 + \frac{y^2}{p} + \frac{z^2}{q}}$$

0.77

1. $p \neq 1$
2. $p = 1$

Triaxial Hernquist halo

In preparation

$\Phi_{SH}(R, Z)$

$K_R(R, z)$

$K_z(R, z)$

1. $R_a >> R_{core}$
2. $R_a << R_{core}$

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).**

- The potential and field forces for a Hernquist law (stellar halo) are in preparation.

- New values for age-velocity dispersion relation are explored, from RAVE data (**in preparation**).

- It can be used to constraint the total mass in the Besançon Galaxy Model (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.