A Bar/Bulge model for the Milky Way
for use with the Gaia Mock Catalogue

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The Boxy Bulge of the Milky Way

The Milky Way is thought to be a barred galaxy, first suggested by de Vaucouleurs (1964).

The fact that the MW has a clear boxy bulge, the asymetries in the COBE data (Dwek+95, Binney+97), the gas kinematic data (Englmaier & Gerhard 1999, Fux 1999) and microlensing (Hamadache 2006), have clarified the fact that we are living in a barred galaxy.


COBE Image

The boxy bulge in the MW has been identified and studied with star counts (Stanek et al. 1994, 1997, Lopez-Corredoira et al. 2005)

The boxy bulges are associated to bars through buckling instability and secular evolution (Combes et al. 1990, Raha et al. 1990), and observationally shown by Merrifield & Kuijken (1999) and Bureau & Freeman (1999).
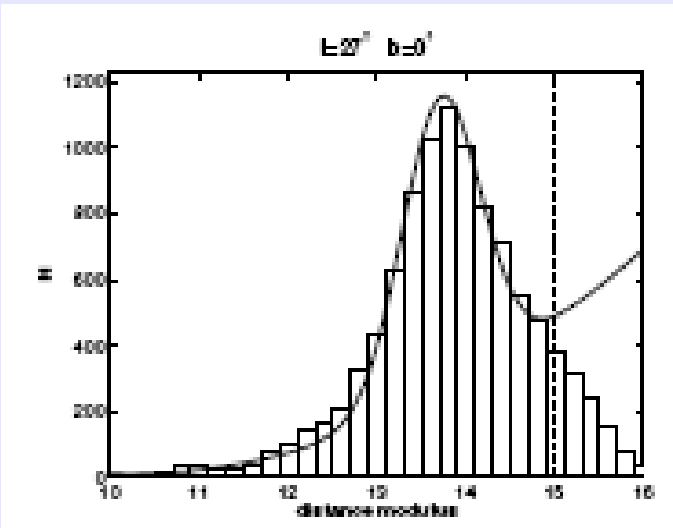
Long bar vs. bulge bar

- Hammersly 2000
- Benjamin et al. 2005, Churchwell et al. 2009 with GLIMPSE
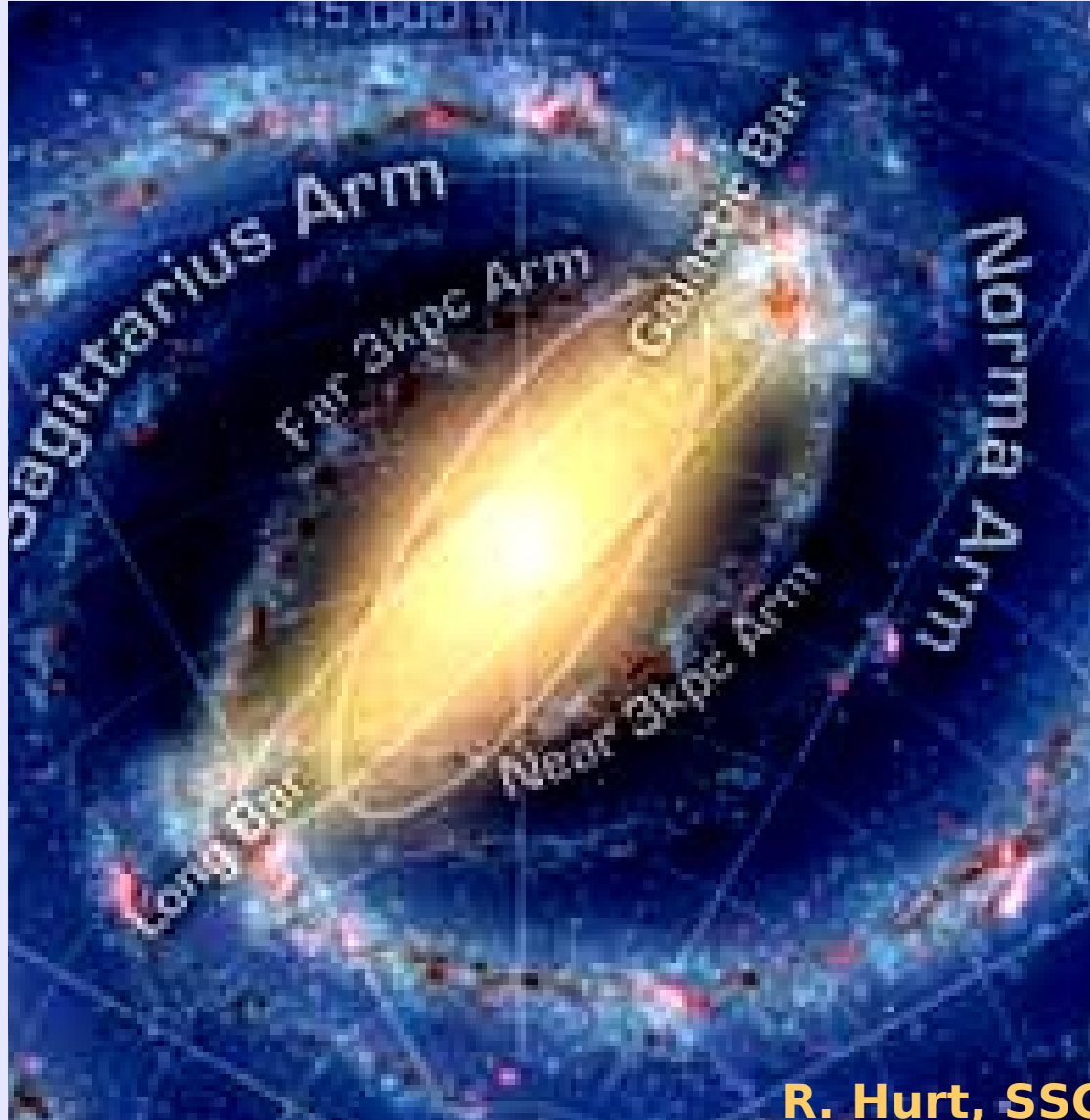
Cabrera-Lavers et al. 07, 08
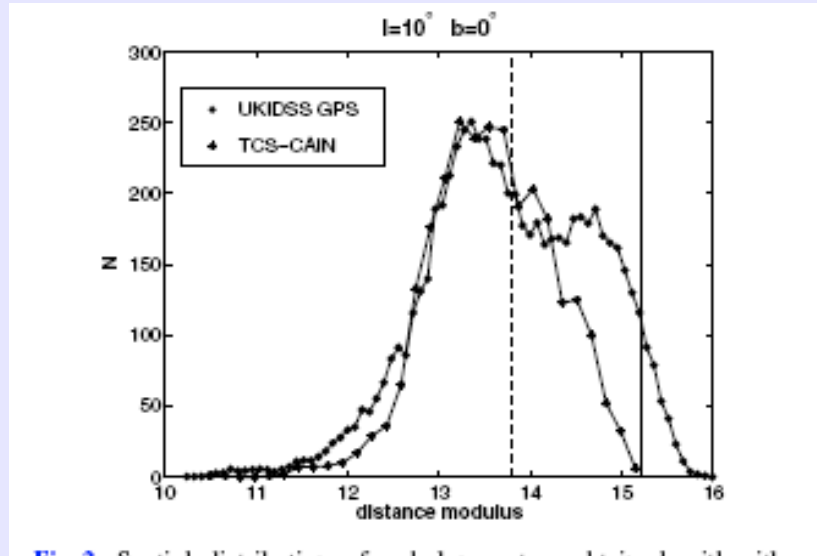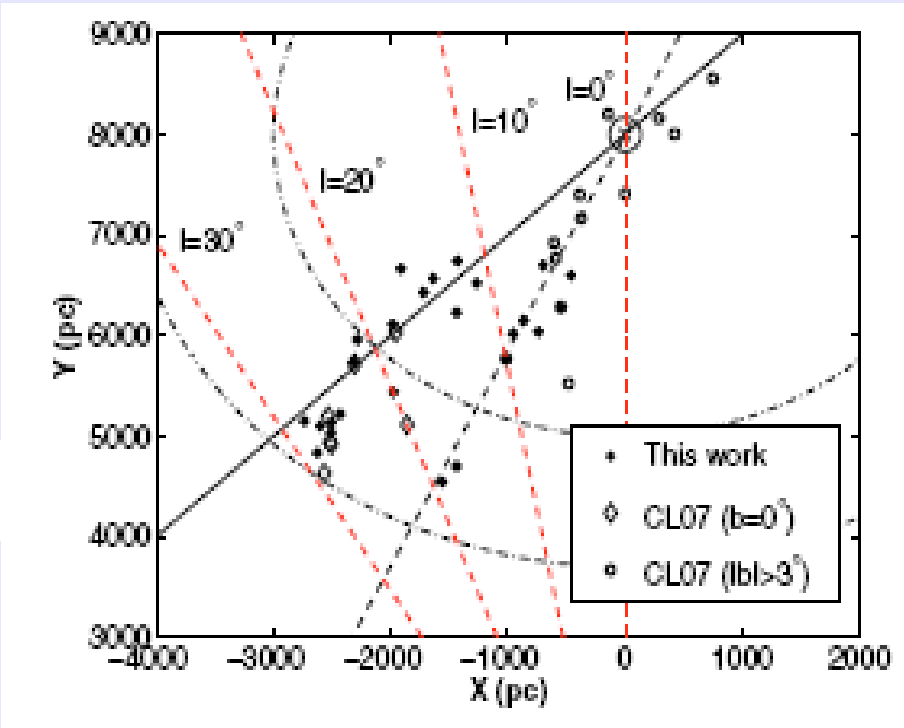
Red clump stars spatial distribution, comparing the magnitude limit for UKIDSS-GPS and TCS-CAIN.


2MASS data

Recent fidutial model for the MW.

http://www.space.com/5448-images-milky-loses-arms.html

R. Hurt, SSC.

We have used N-Body numerical simulations of barred galaxies to check this scenario of the two bars in the Milky Way.
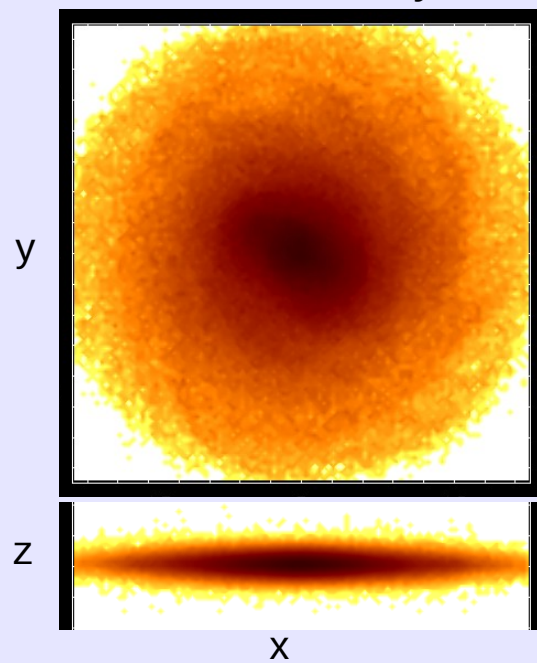
See also Romero-Gomez et al. 2011 (MNRAS, 418,1176) for an study with analytical potentials.
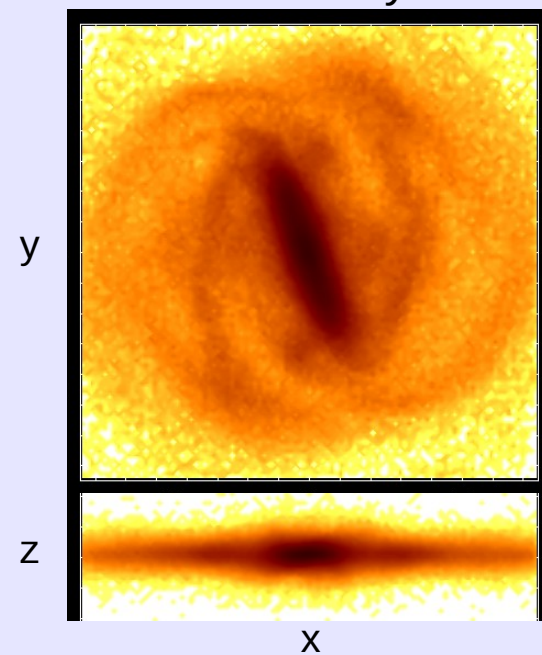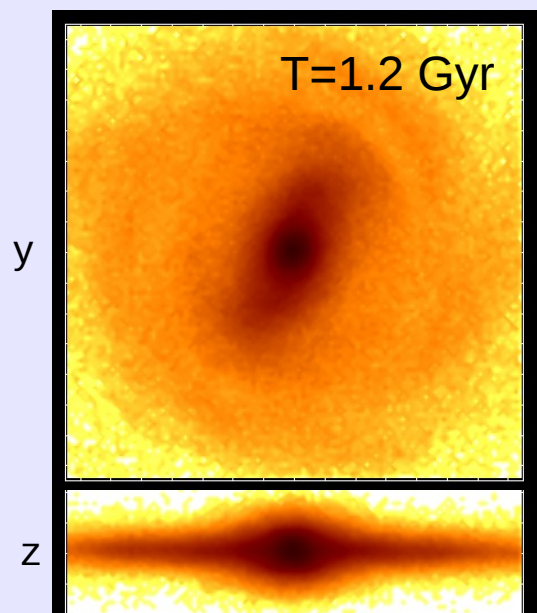
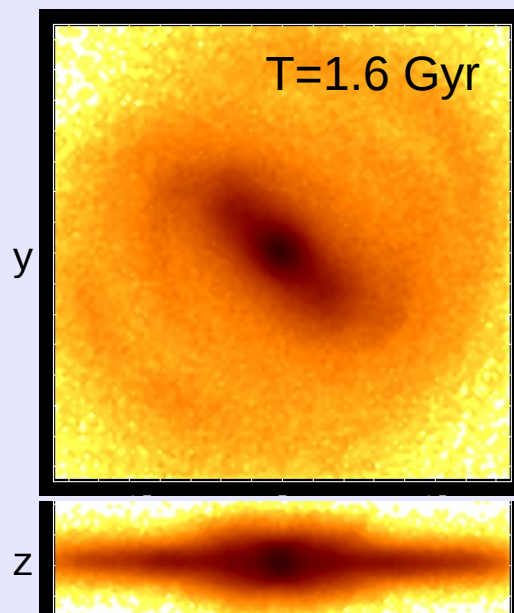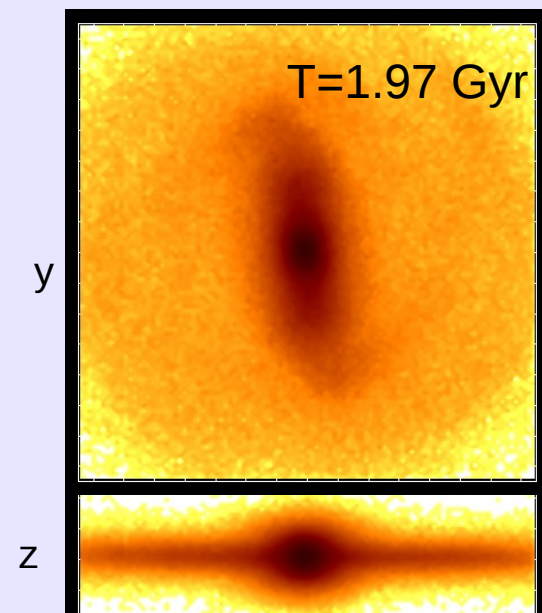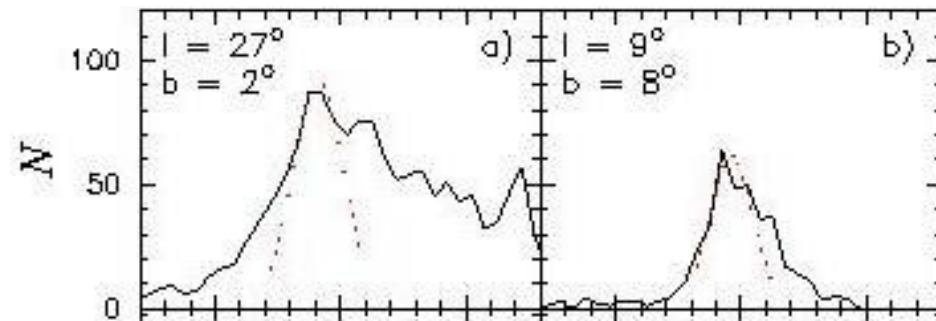# Evolution of the self-consistent numerical simulation
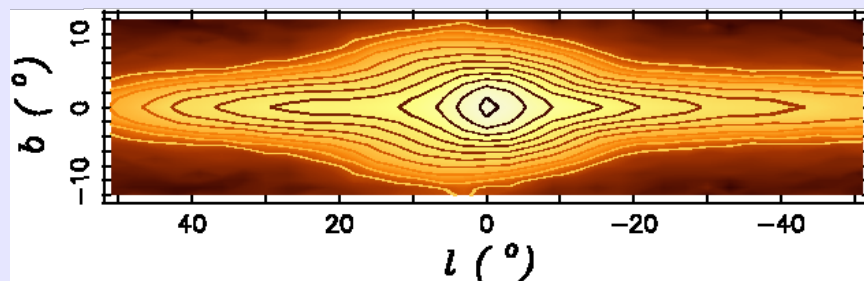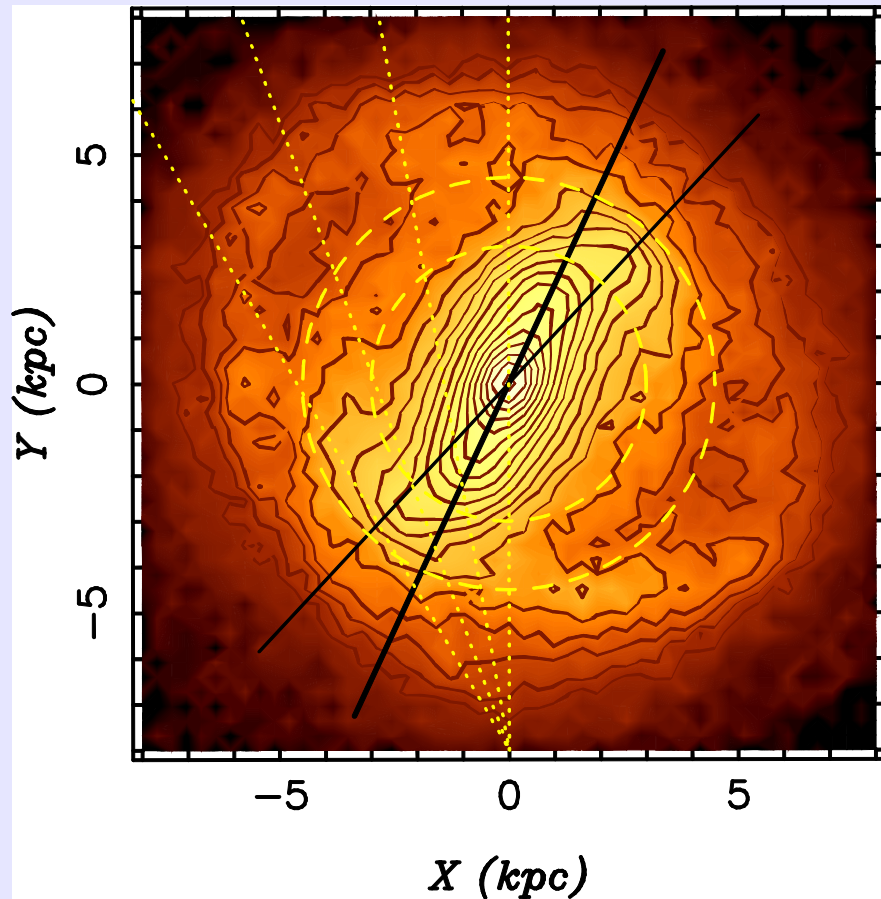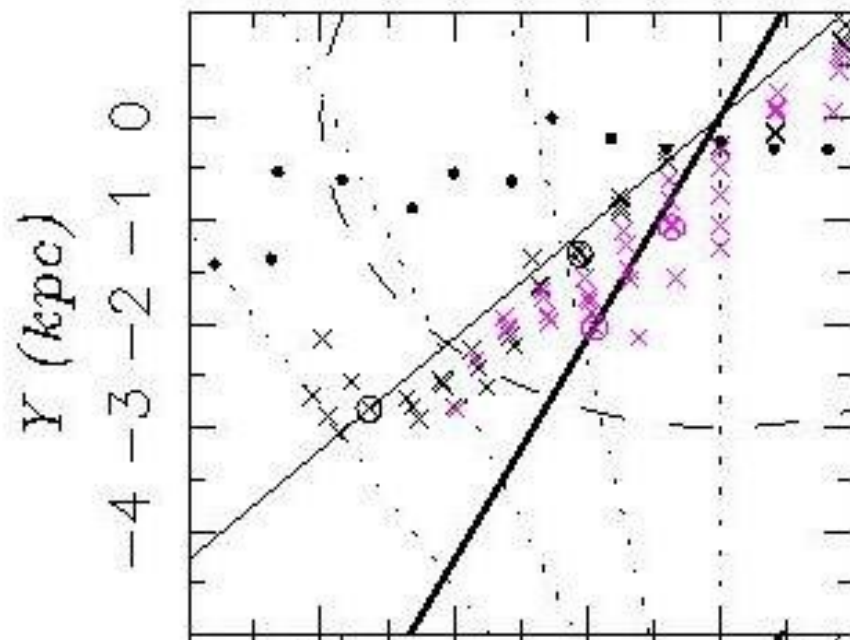
T=0 Gyr
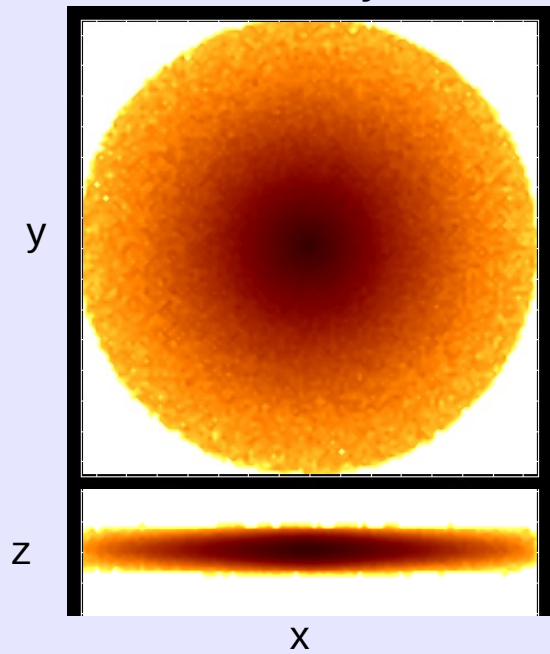
T=0.4 Gyr

T=0.8 Gyr

T=1.2 Gyr

T=1.6 Gyr

T=1.97 Gyr

First test on our model

Distance modulus

Quantitative reproduction of the observed data in the plane of the Milky Way

Martinez-Valpuesta & Gerhard, 2011, ApJ Letters, 734,20

Leading Ends of the bars in galaxies

- ✔ The leading, trailing ends of the bar are not exclusive of this simulation, as can be also seen in Fux (1997) and in Rautiainen & Salo (2000).
- ✔ In our simulations trailing and leading ends of bars are related to oscillations seen in the bar strength and in the pattern speed. This oscillations could be due to non-linear coupling modes between the bar and the spiral arms.
- ✔ Such oscillations are also seen in different N-body numerical simulations with disk and live dark matter halo (e.g., Dubinski et al. 2009).
- ✔ In this case the model goes from trailing, to straight, to leading and back for at least **1.2 Gyr, 40% of the time in leading phase.**

Similar structures also seen in real barred galaxies

NGC 3992
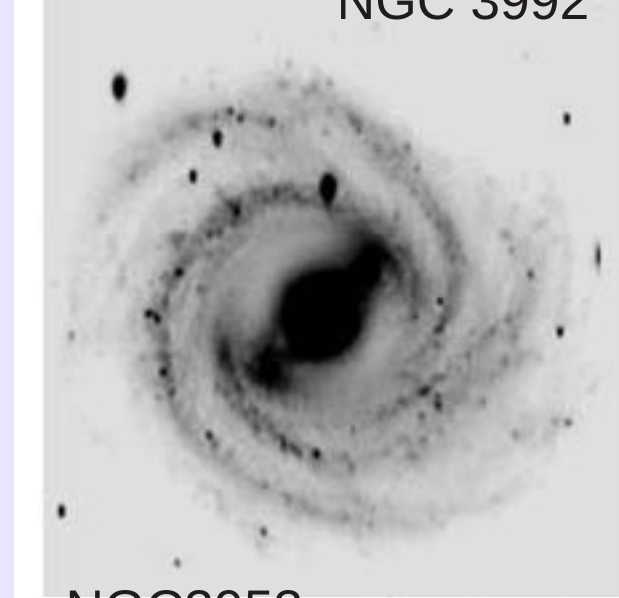
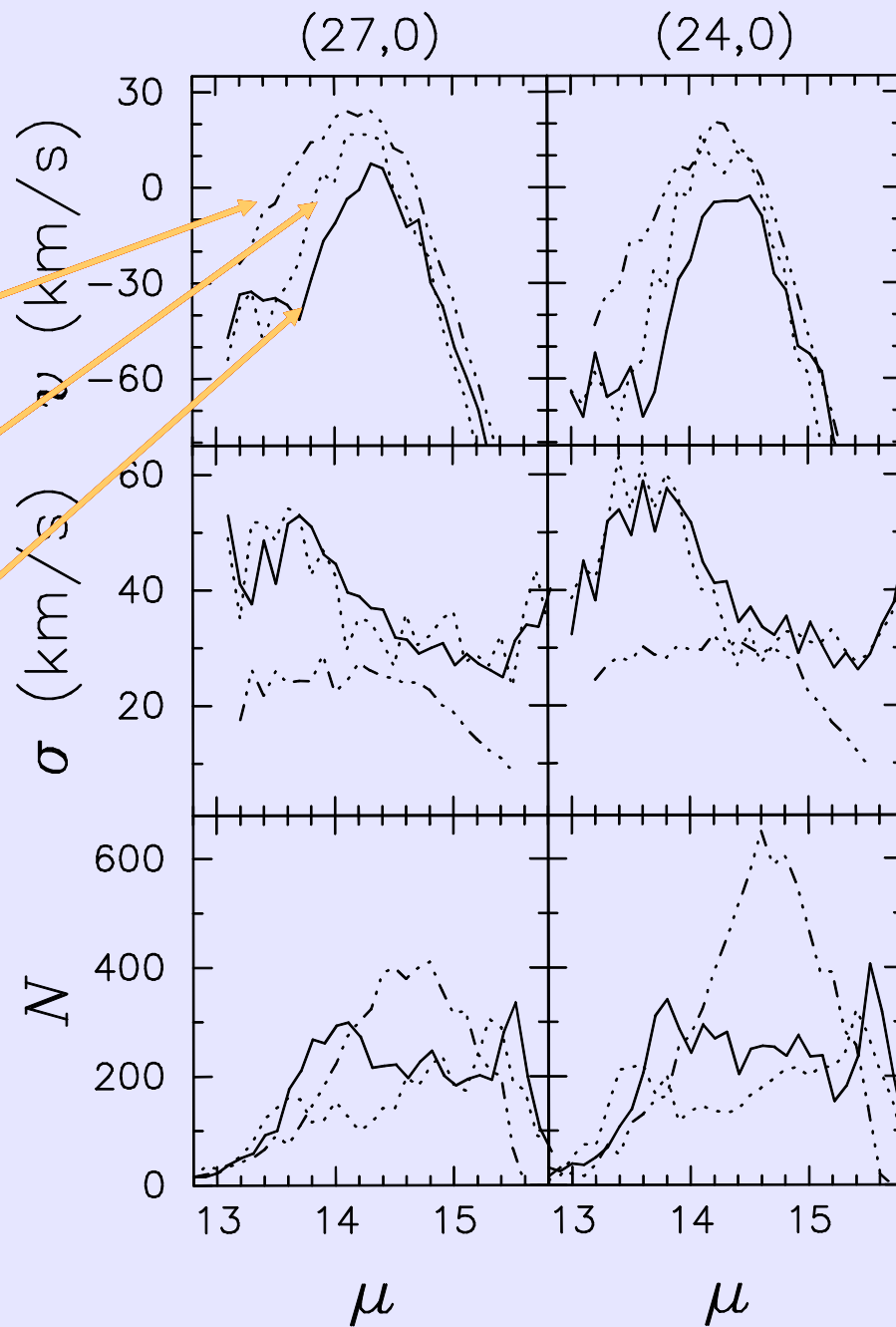

NGC3953

NGC 1073
NASA/ESA Hubble

Efremov 2011

Predictions for los-velocity distribution in the bar-disk transition zone
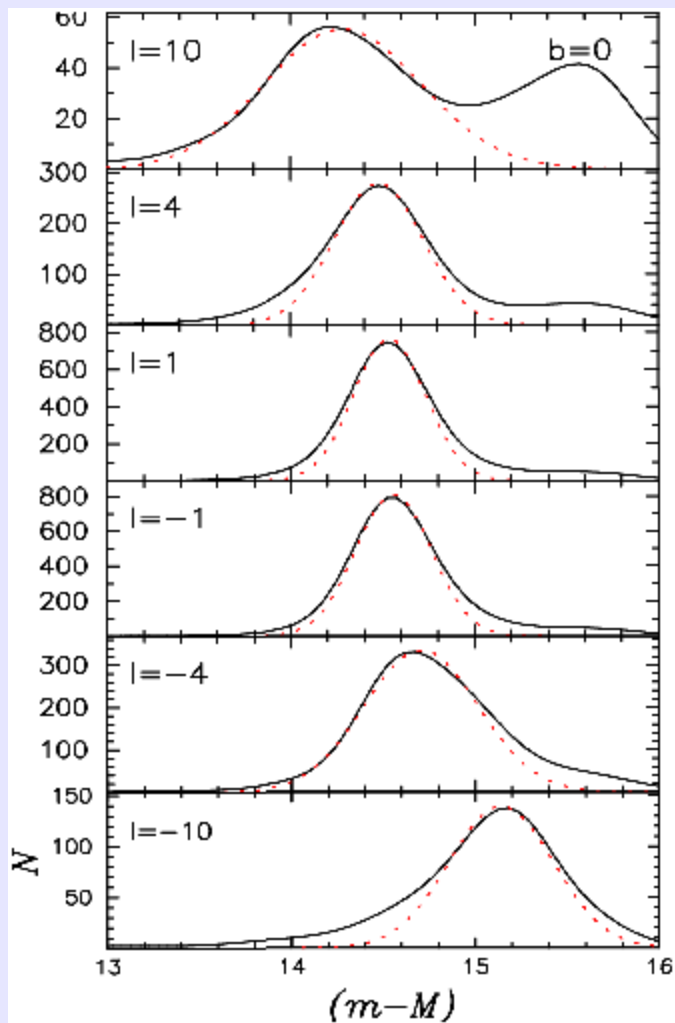
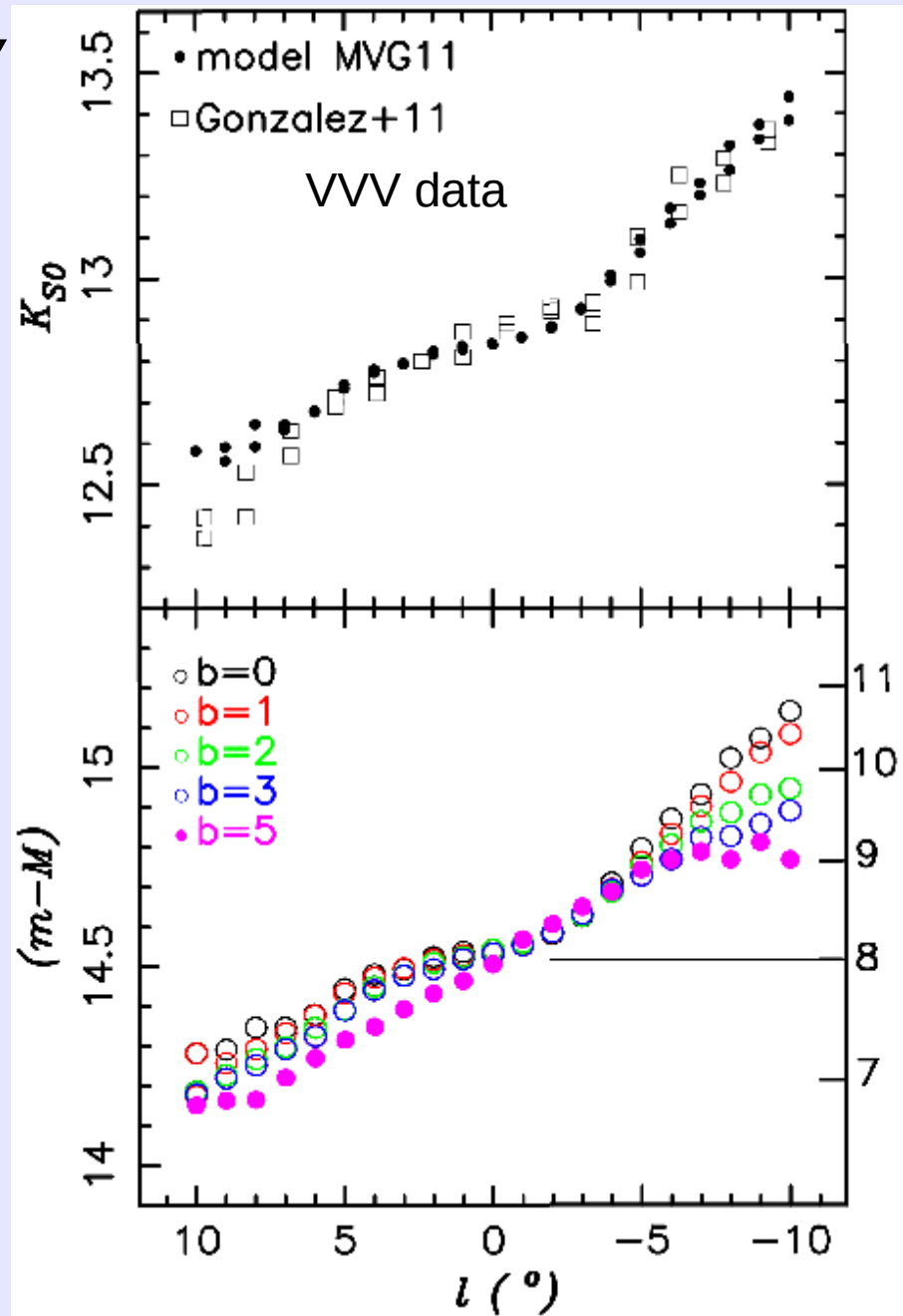Axisymmetric

Straight ends

Leading ends

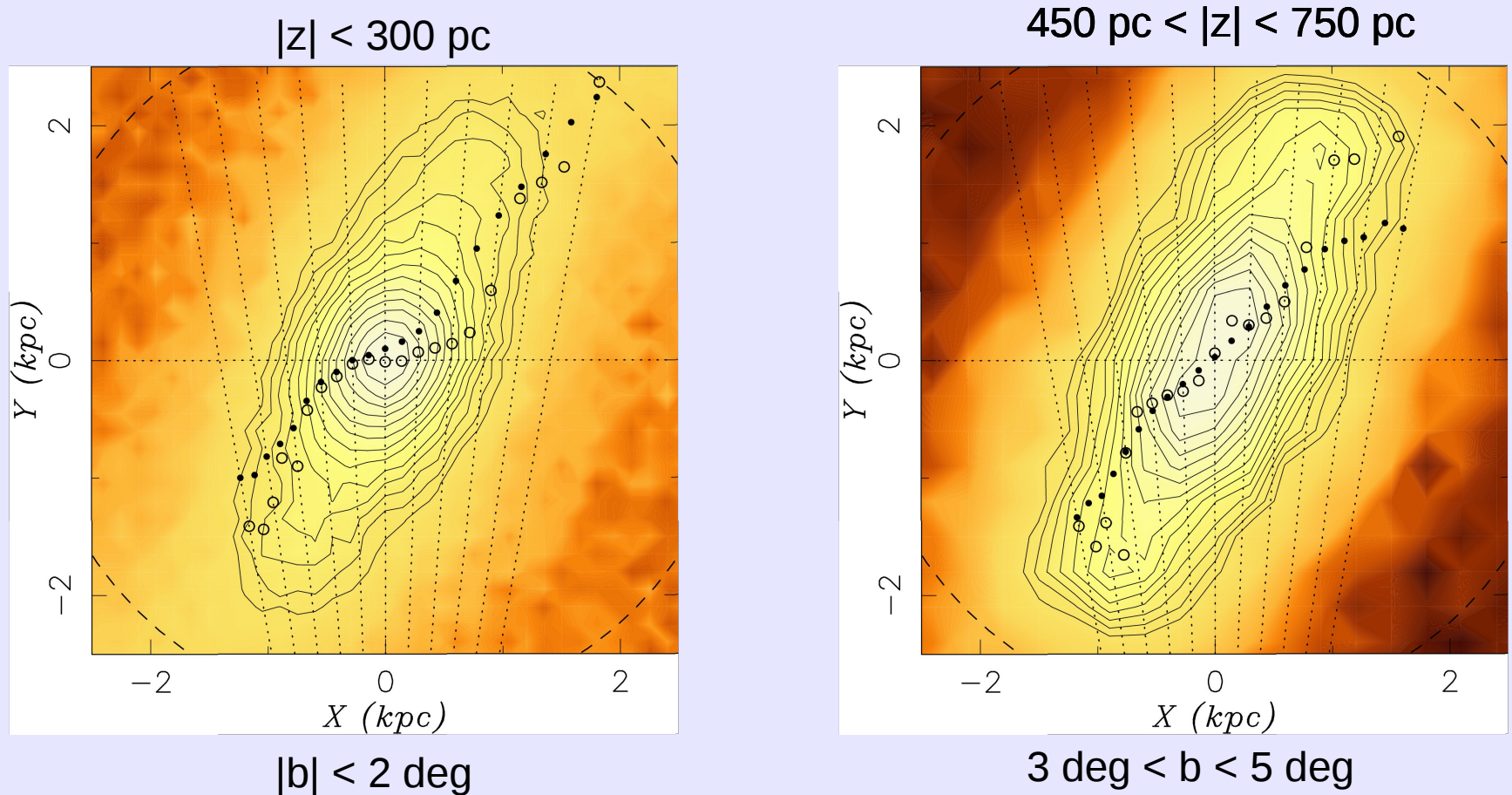With the new available surveys in the plane such as APOGEE, we will be able to test this scenario.

The inner region of the Milky Way

Simulated red clump
magnitude distributions

VVV data

Gerhard & Martinez-Valpuesta 2012, ApJLetter, 744, 8

Model inner bulge: structural change in inner kpcs

|z| < 300 pc

450 pc < |z| < 750 pc

|b| < 2 deg

3 deg < b < 5 deg

Open circles: Maxima of the line-of-sight density in stripes
Solid circles: Maxima of the line-of-sight density as seen in cones.

The long axis of the bar is at an angle bar = 25∘ relative to the line-of sight to the observer at the assumed galactocentric radius R0 = 8 kpc. Dotted lines show directions l = 0,±2,±4,±6,±8,±10∘, as seen from the observer's position.

Gerhard & Martinez-Valpuesta 2012, ApJLetter, 744, 8

Model describes structure of bulge well.
Next question is whether also the kinematics can be understood...
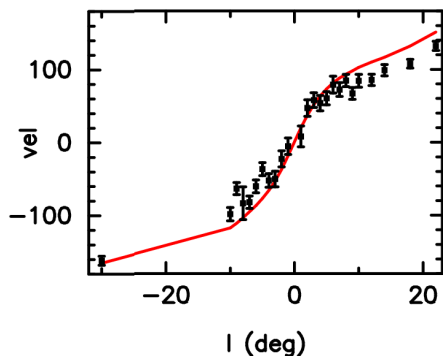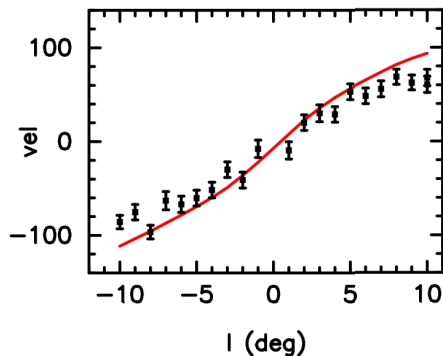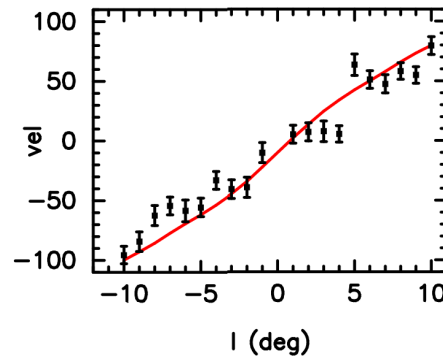
b=-4   b=-6   b=-8   Minor axis
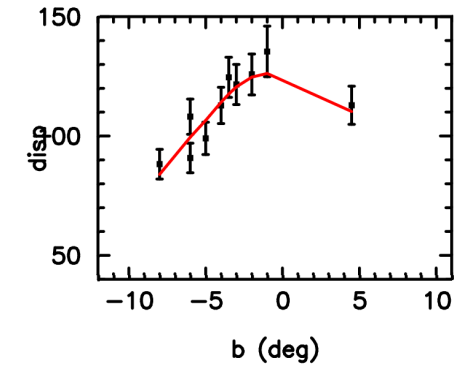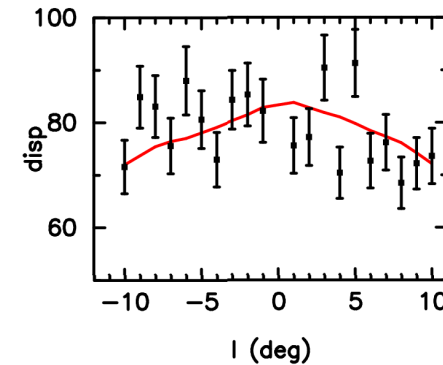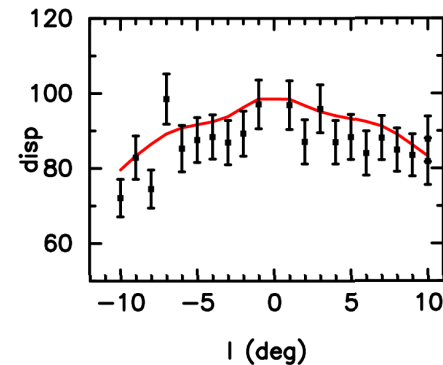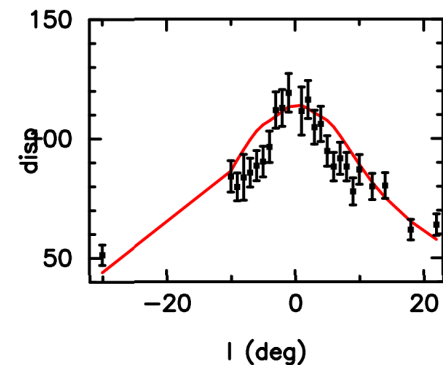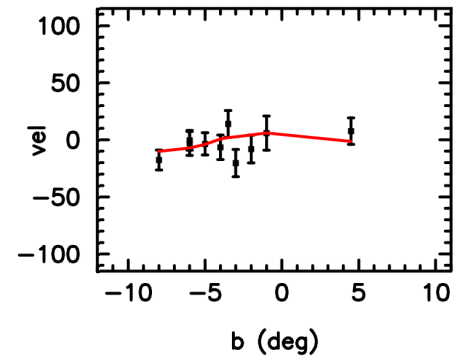
Time for dynamics models!!!

NMAGIC is a made-to-measure method (M2M) to construct particles models of stellar systems based on the observational data and taking into account observational errors (based on Syer & Tremaine 96, initially developed by de Lorenzi et al. 2007).

NMAGIC slowly changes the weights (probabilities) of the particles from an initial self-consistent model in order to fit the observational data provided.

NMAGIC has been greatly improved recently, buy changing the entropy scheme used, as you can see in Morganti & Gerhard (2012, astro-ph: 1202.2355). With this new scheme, the effective number of particles is under control.
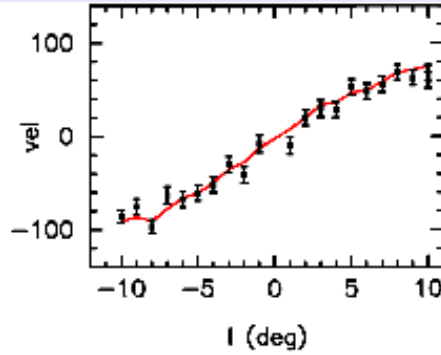
We can now apply it to barred galaxies, including our own Milky Way.

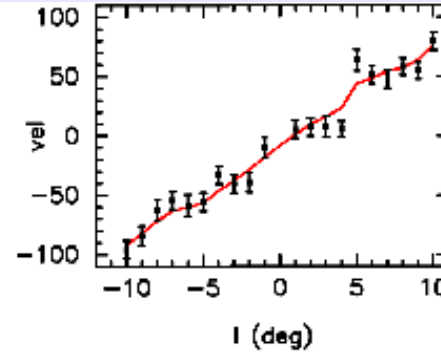**NMAGIC** starting with the previous model, fits and reproduces the kinematics of the Milky Way.
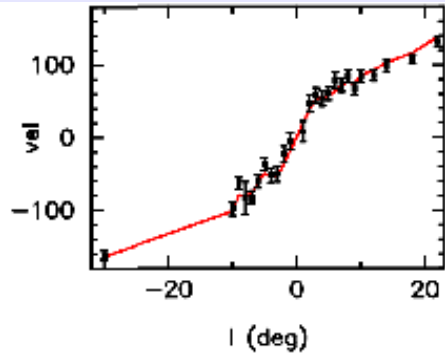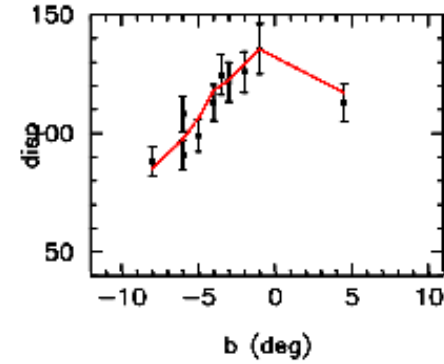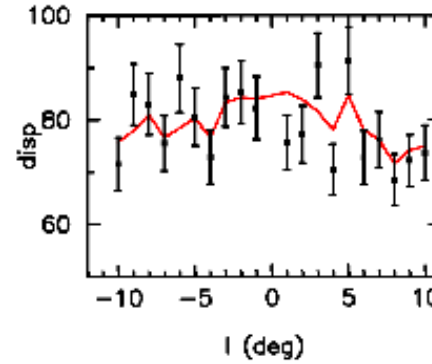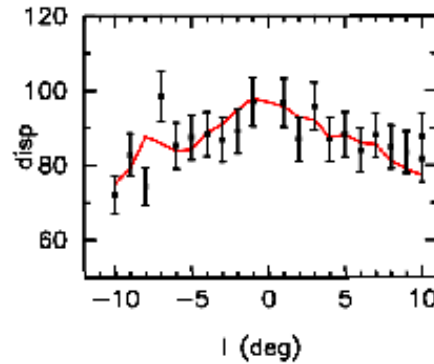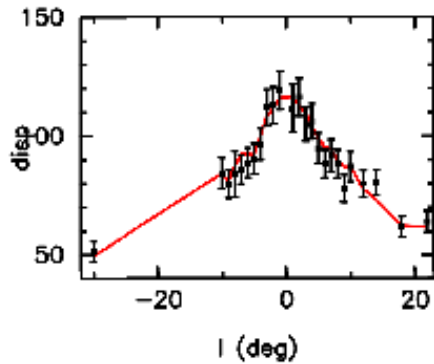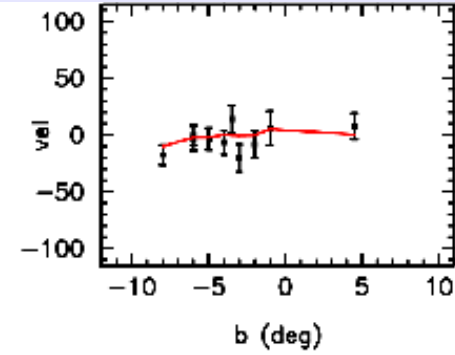

b=-4   b=-6   b=-8   Minor axis

Data points from the **BRAVA** survey Kunder et al. (2012)

The resulting model is slightly more boxy. Work in progress

Conclusions

✔ We have a model that reproduce observations of star counts near the galactic plane at the ends of the bar.

✔ We have a model which reproduces red clump longitudes profiles for the inner region of the Milky Way.

✔ We have a model that is a good starting point to obtain the right kinematics when using *NMAGIC*.

✔ All of this together makes this model a good candidate to be used with the GAIA mock catalog.

Thanks!!!!