New insights on the dynamical evolution of the MW galactic disc

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Goal:

To constrain the characteristics of non axisymmetric structures of the Milky Way Galactic disc, using the phase space distribution function (DF) of the stellar component, as seen by Gaia.

Methodology and Tools to be developed:

- Analytical potentials (time dependent) / map of the orbital structure
- Hybrid models: N-body simulations & Chemo-dynamical models
- Gaia simulated data (Gaia Object Generator, GOG)
- Tools and interfaces to compare DF from galactic models and Gaia simulated data

First basic training with a time dependent potential: The analysis of Gaia capabilities to trace the dynamics of the warp

Test Particle Simulation

We use test particle simulations, which is the numerical integration of test particles on a given potential. Here, we integrate the orbits of a set of test particles distributed in a 3D disc for a potential model for the Milky Way.

The Axisymmetric Potential

- The galactic model is taken from Allen & Santillan (1991).
- It consists of a bulge, a disc and a massive spherical halo.
- The bulge and disc are modeled as Miyamoto-Nagai potentials (Miaymoto & Nagai 1975).
- The halo is built as a spherical potential

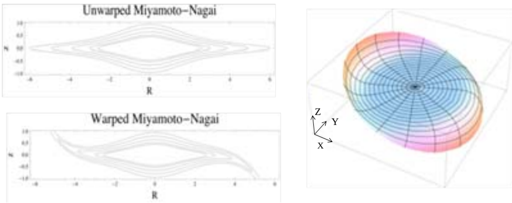
Distance Sun – Galactic center	$R_\odot = 8.5$ kpc
Local circular velocity	$V_c(R_\odot) = 220$ kms^{-1}
Local total mass density	$\rho = 0.15\ M_\odot$ pc^{-3}
Rotation curve	Clemens (1985)

Our Warp Model

To warp this system, we bend the potential of the disc using a simple geometry transformation; we rotate the coordinates along Y-axis by an angle and specify this tilt angle as a function of the cylindrical R coordinate. For this, we use the following function:

$$\Psi(R;R_1,R_2,\psi_2,\alpha) = ((R-R_1)/(R_2-R_1))^{\alpha}, \qquad R > R_1$$

The tilt is applied beyond R_1. The resulting warp is such that the tilt angle increases as a power law whose exponent is α and such that at R_2 it has a value equal to Ψ_2 .



Initial Conditions

•Initial conditions of test particles are obtained as discussed by Hernquist (1993)

•We consider two different types of initial conditions; cold ones which are the young star population and warm ones, like for example, the red clump stars. For all of them, we assume an exponential disk scale length with $R\rho = 2.5$ kpc.

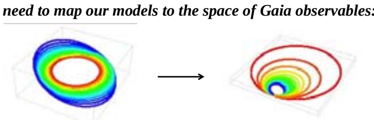
•The velocity dispersion has an exponential profile with scale length $R\sigma = 7.5$ kpc. Local normalization $\sigma_U(R_\odot)$ for cold and warm population are respectively 10 km/s and 30 km/s. A vertical scale height of 100 pc for cold ones and 300 pc for warm ones are used.

Numerical Experiments

- ***Control Case***: Each test particle is exposed to the axisymmetric unwarped potential for about 4 Gyr.
- ***Warp Case: To help preserve stability, the warp is produced adiabatically while the test particles are being integrated. It is not clear that a statistical equilibrium configuration can exist for the warped model. We integrate the test particles further in time after the warping has finished to verify this.***

Strategy

- ***Compare control and warped configurations, simulate Gaia astrometry from both and check level of significance of difference between them.***
- ***We need to map our models to the space of Gaia observables:***



Open Questions

- ***At what significant level*** can Gaia detect a kinematic signature of Milky Way warp?
- what is the systematic vertical motion we expect to have?

An example:
Besançon Galaxy Model predictions for Red Clump to be used for warp analysis

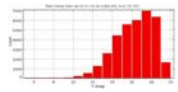


Figure: V magnitude distribution of 3.5 x 10⁴ RC stars - Mbol = [0.20, 0.80] and Teff=[4200, 4800] – up to V=20 in the direction of rotation l=[89,90] and b=[-15,+15].

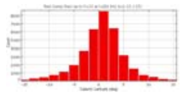


Figure: Galactic Latitude distribution of the RC stars up to V=20 in the direction of rotation l=[89,90] and b=[-15,+15]. The asymmetry due to the warp in the BGM can be observed

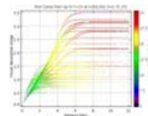
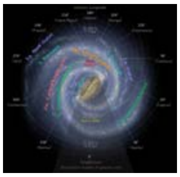


Figure: Visual absorption against distance colored with V magnitude distribution

Training from the IR surveys: Internal disc components & Gaia

Goals:

- Structure and kinematics of the galactic bar (s) What can Gaia tell us?
- The role of stellar streams in the Gaia Sphere to constrain the galactic bar(s) potential
- First scientific exploitation linking Gaia & IR spectroscopic data (EMIR)



Does our Galaxy have one or two galactic bars?

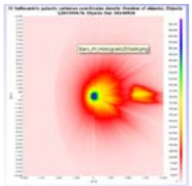
Method:

IR star counts & Spectroscopy + Gaia proper motions on parallax for Red Clump Stars

Open questions to answer:

Can we see the edge of the long bar with Gaia? Which kinematic signatures from proper motions near the edge of the long bar?
Some insights on the kinematics of the galactic bar at low extinction regions l=[10-20] and b < 3º?

EMIR, infrared Multiobject Spectrograph at GTC (2014)



Which kinematic signatures from the bar are we expecting in the Gaia sphere?

Method:

Analysis of the resonant effects in the velocity distribution function due to the bar in the Gaia Sphere

Tools:

- Analytical potential & test particle integration
- Characterization of the orbital structure
- Identification of resonant family orbits
- Map of the orbital structure
- Identification of the orbits populated in the Gaia sphere
- Identification of kinematic signatures through the large scale analysis of the moving group in the galactic disc

Training from gas-dynamics and chemical enrichment codes:

Goals:

- New insights on the age-kinematic-Metallicity relation in/out of the spirals
- The role of stellar streams in the prediction of the growth of the non axisymmetric components

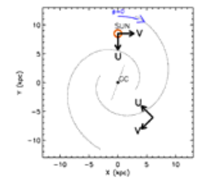
Method:

Simulations of Milky Way type galactic disks can map the evolution of the stellar large scale kinematic response to the bar and spiral structure.

Second and third order moments of the velocity distribution function prove to be good indicators of both, the velocity ellipsoid misalignment near the arms and the bar, and the degree of kinematic substructure in the UV W plane, that is, the presence of moving groups in the Gaia Sphere.

A large scale analysis all through the galactic disk will allows us to establish the kinematic behavior near resonances and the correlation between the kinematic parameters and properties of the non-axisymmetric components, such as its transient nature or its mass overdensity

Only a massive computation will allow enough resolution to analyze the kinematic-metallicity relation.



Vertex deviation and 3 order moments

$$l_v \equiv \frac{1}{2}\arctan\left(\frac{2\sigma^2_{R\varphi}}{\sigma^2_{RR}-\sigma^2_{\varphi\varphi}}\right)$$

$$\sigma_{RRR} = \frac{\iiint_\infty (U-\langle U\rangle)^3 f dUdVdW}{N} = \mu_{300}$$

$$\sigma_{\varphi\varphi\varphi} = \frac{\iiint_\infty (V-\langle V\rangle)^3 f dUdVdW}{N} = \mu_{030}$$

Simulations:

GCD+ is a three-dimensional tree N-body/Smoothed Particle Hydrodynamics (SPH) code which incorporates selfgravity, hydrodynamics, radiative cooling, star formation, supernova feedback and metal enrichment.

References:

Kawata D., Gibson B., 2003, MNRAS, 340, 908

Kawata D., Okamoto T., Cen R., Gibson B., 2009, ...