Tools for searching resonant moving groups in galactic disc simulations

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Abstract

One of the most plausible explanations for the origin of the moving groups is the orbital and resonant regions related to the large scale structure (bar and spiral arms) of the Milky Way (Antoja, 2010). This study has been up to now restricted to the solar radius. Here we propose to investigate the origin and evolution of these structures through the analysis of the velocity distribution in the full galactic plane, discussing the link between the kinematic substructures, overdensities (bar and spiral) and resonant regions. To facilitate the analysis of the density function (DF) on the phase space of the simulated galactic discs, we are implementing statistical tools like EM-WEKA and FoF clustering algorithms, and moments of the distribution function (vertex deviation and third order moments).

Tools

Moments of the DF:

-Vertex deviation:

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

-Third order moments:

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

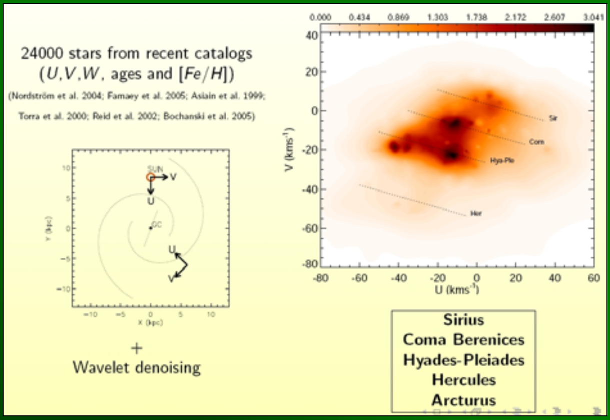
$$\sigma_{\varphi\varphi\varphi} = \frac{\iiint_\infty (V-\langle V\rangle)^3 f\, dUdVdW}{N} = \mu_{030}$$

Clustering algorithms:

- EM-WEKA: Parametric (gaussian fitting), slow, doesn't need a previous knowledge about cluster number.

- FoF: Non parametric, fast, needs neighbouring distance and a starting point.

Moving groups in the solar neighbourhood



24000 stars from recent catalogs
$(U,V,W$, ages and $[Fe/H])$
(Nordström et al. 2004; Famaey et al. 2005; Asiain et al. 1999; Torra et al. 2000; Reid et al. 2002; Bochanski et al. 2005)

+
Wavelet denoising

Sirius
Coma Berenices
Hyades-Pleiades
Hercules
Arcturus

N-body simulations

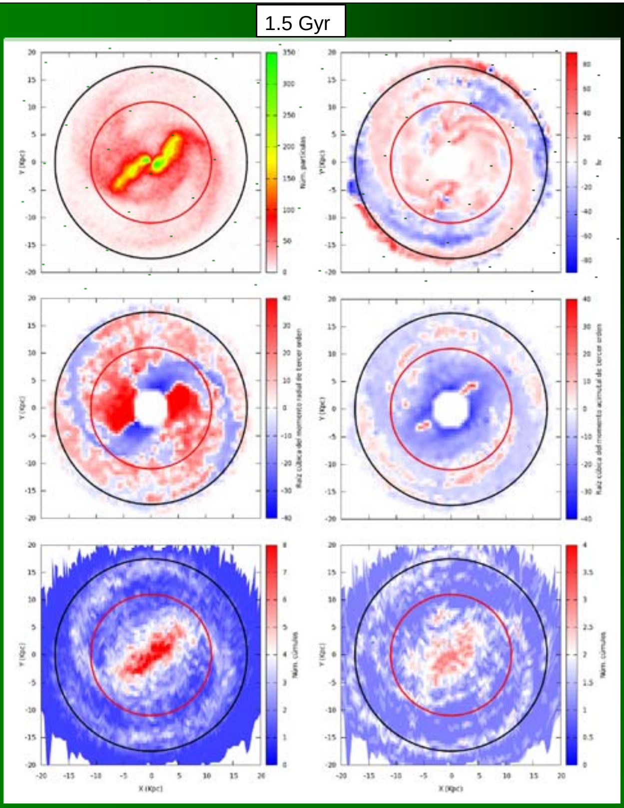
Simulations provided by Inma Martínez-Valpuesta

N-body code used is based on FTM (Fast Tree Method) v.4.4 and includes FalcON force solver. It also applies a 160 pc softening.

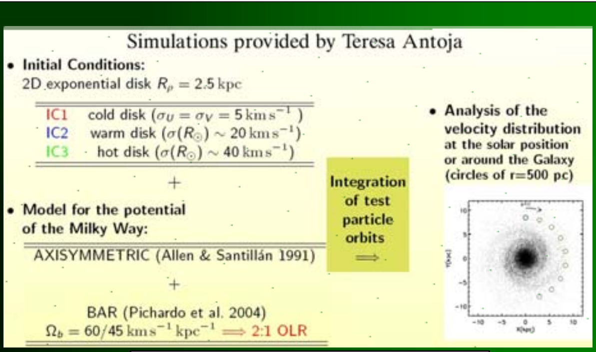
Initial Conditions:

- 3D exponential disk with H=0.5 and R=2.85 Kpc, and cut-off at 25 Kpc.
- Halo with a cut-off at 30 Kpc.
- Kinematic initial conditions using Fall & Efstathiou 1980.
- 10^6 particles: 75 % disk, 25 % halo.

1.5 Gyr



Test particle simulations



Simulations provided by Teresa Antoja

- **Initial Conditions:**
  2D exponential disk $R_\rho = 2.5\,\mathrm{kpc}$

IC1	cold disk $(\sigma_U = \sigma_V = 5\,\mathrm{km\,s^{-1}})$
IC2	warm disk $(\sigma(R_\odot) \sim 20\,\mathrm{km\,s^{-1}})$
IC3	hot disk $(\sigma(R_\odot) \sim 40\,\mathrm{km\,s^{-1}})$

+

- **Model for the potential of the Milky Way:**

AXISYMMETRIC (Allen & Santillán 1991)

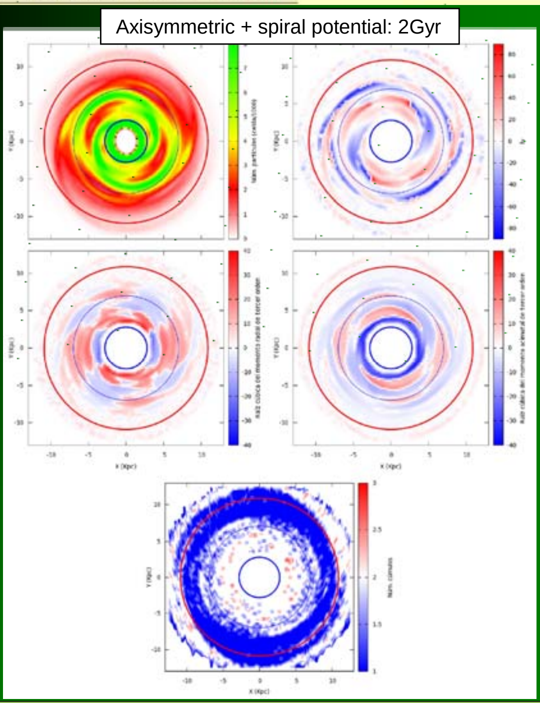
+

BAR (Pichardo et al. 2004)
$\Omega_b = 60/45\,\mathrm{km\,s^{-1}\,kpc^{-1}} \Longrightarrow$ 2:1 OLR

Integration of test particle orbits $\Longrightarrow$

- **Analysis of the velocity distribution at the solar position or around the Galaxy (circles of r=500 pc)**

Axisymmetric + spiral potential: 2Gyr



Conclusions

-We show that second and third order moments of the velocity distribution and statistical methods such as expectation maximization (EM) of the WEKA statistical package and FoF clustering are able to detect kinematic substructure in the galactic disc.

-With the developed algorithms, we are able to trace the regions of the Galactic disc where particles present a kinematic structure similar to the one observed in the Solar neighbourhood.

- We confirm that the vertex deviation and the third order moments are good tracers of the spiral perturbation.

TOOLS ARE READY!

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