Probing the precessing bar model for the Galactic warp origin

C. Pardo-Araujo[1]

TFM Supervisors: M. Romero-Gomez[2] P. Sánchez-Martin [3]

[1] Universidad Politécnica de Cataluña [2]Universidad de Barcelona [3]Universidad de Zaragoza

Abstract: About 50% of external galaxies present a warped disc when they are seen edge-on, and our galaxy is also one of them. It was first detected in dust and gas, and recent works also show it in the stellar component using different tracers: Cepheids, young stars in star-forming regions, Red Giants. The origin of such deformation in the disc is not clear yet, though. Among the different theories found in the literature, we focus on a recent one that involves precessing bar models. In this approach, we explore a model where the bar is precessing due to a misalignment of the angular velocity vector and the angular momentum vector of the system. In this work, we further explore the viability of this theory for the formation of the warp in our Galaxy, by quantifying the effect of a precessing bar in the proper motions of stars near the Galactic bar using Gaia mock catalogs and comparing the expected result with proper motions coming from Gaia data.

Context of the research

- $\sim 50 - 70\%$ of spiral disc galaxies present stellar warped discs. In the Milky way these were detected:
  - First with 21-cm observations of the HI gas Burke (1957)
  - Later by Two Micron All Sky Survey infrared data in dust and gas, López-Corredoira+ (2002)
- Although the formation of these warps is still unknown, some theories try to tackle this challenge:
  - Tidal interaction with satellites due to the closeness of the Large Magellanic Cloud to our galaxy. However, López-Corredoira+ (2002) show that this theory would lead to low amplitude warps.
  - Our approach is similar to the work made by Sánchez-Martín+ (2016), where they reproduced the galactic warp introducing a small misalignment between the angular momentum and angular velocity vectors of the system.

Description of the work

- Model:
  1. Disc + Bar (2 Ferrer ellipsoids) + Halo. (M. Romero-Gomez+, 2015)
  2. Misalignment of angle ε of the angular momentum and angular velocity which will make the bar precess. (P. Sanchez-Martin+, 2016)
- We worked as follows:
  1. Test particle simulations:
     1. Traditional model: $\varepsilon = 0$ rad.
     2. Precessing model: $\varepsilon = 0.2$ rad.
  2. A classifier based on the Fast Fourier Transform to extract x1 like orbits from the rest of the stars in the galaxy. Then its proper motions in the both models are compared.
  3. A study of the error of Gaia along the mission to conclude if we would be able to see in proper motions the effect of the precessing bar.

FFT classifier of X1 orbits

- We focus on quasi-periodic orbits which oscillate close to the x1 family with a similar shape.
- To extract such stars from our simulation we apply the Fast Fourier transform.
- Figures 1 and 2 show an orbit classified by our algorithm as a x1 like orbit and its Fast Fourier Transform (FFT) respectively.

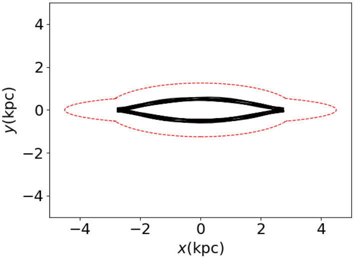

Figure 1: Orbit in the x-y plane. The red dashed line denote the contour of the bar.

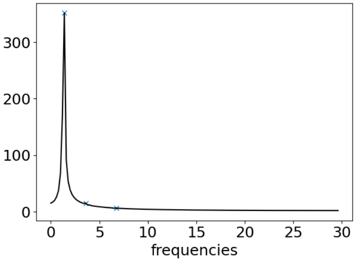

Figure 2: The FFT of the orbit at the left. The blue crosses denote when the gradient sign changes.

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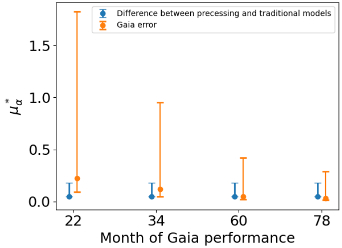

Figure 3: The orange and blue lines denote the errors in Gaia data and the difference between models respectively in μ_α.

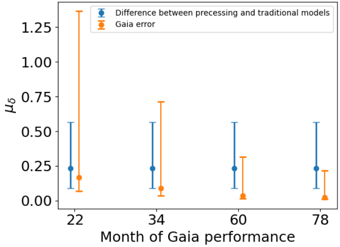

Figure 4: The orange and blue lines denote the errors in Gaia data and the difference between models respectively in μ_δ^*.

- To validate our results we need that the difference between the two models to be significant compared to Gaia uncertainty for these stars.
- This will be possible for μ_δ at R4 (60 months).

Impact and prospects for the future

- **Impact:** New theory for the formation of galactic warps, testable with Gaia for the Milky Way.
- **Further studies:**
  1. Same analysis for galactic coordinates.
  2. The same study did for the bar will be done for the disc.
  3. When the data of Gaia will be accurate enough (60 months) these results will be checked with observational data.