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Is the Galactic Spiral Potential 2- or 4-arms?

Preben Grosbøl[1] † **and Giovanni Carraro**[2]

[1]European Southern Observatory,
Karl-Schwarzschild-Str. 2, D-85748, Garching, Germany
email: pgrosbol@eso.org

[2]Dipartimento di Fisica e Astronomia, Universita di Padova
Vicolo Osservatorio 3, I-35122, Padova, Italy
email: giovanni.carraro@unipd.it

Abstract. Young objects (e.g. OB-associations and HII regions) in the Galaxy outline a 4-armed spiral structure whereas the tangent points of arms observed in the near-infrared indicate a 2-armed pattern. The more important issue is whether the spiral potential in the Galaxy is 2- or 4-armed i.e. if all arms traced by young objects also have a significant mass perturbation associated to them. This can be tested by studying the mean radial velocity of a well defined stellar population across the spiral arms and thereby estimating the surface density change.

The current paper presents a preliminary analysis of the radial velocities of a sample of 736 early-type stars toward the Galactic center observed with FLAMES/VLT. A comparison with N-body models in a fixed spiral potential with 2 or 4 arms suggests that no significant mass is associated to the Sagittarius arm. The data are consistent with 2-armed models with pattern speeds in the range of 15-30 km s^{-1} kpc^{-1} and relative radial forces of less than 4%.

Keywords. Galaxy: structure, Galaxy: kinematics and dynamics, Galaxy: disk

1. Introduction

Whereas young objects in the Galaxy outline a 4-armed structure (Russeil *et al.* 2007, Ried *et al.* 2014), it is unclear if all arms are massive or only 2 of them (i.e. Perseus and Scutum-Centaurus) as indicated by near-infrared observations (Drimmel 2000). This issue can be resolved by mapping radial velocities of young stars across the Sagittarius arm toward the Galactic center since this direction minimizes the influence of Galactic rotation and the radial variation will show if a significant mass is associated to this arm.

2. Data

The FLAMES/Giraffe instrument with its 25′ field and 132 MEDUSA fiber system provides an excellent facility on the VLT for this purpose. Fifteen fields within 3° of the Galactic center were selected using candidates from Grosbøl (2016) and the VVV survey (Saito *et al.* 2012) with near-infrared colors suggesting that they were of early type. A total of 1726 spectra was observed with the LR02 grism yielding a resolution of ≈6000 in the spectral range of 396-457 nm. The standard reduced spectra provided by ESO were used for the further analysis after being normalized.

Radial velocities were estimated by cross-correlating the spectra with the UVBLUE grid of synthetic spectra (Rodriquez-Merino *et al.* 2005) with [M/H] = 0.3 after they had been re-binned to the resolution of the observed ones. Typical errors of the velocities were in the range 5-10 km s^{-1}. The correlation peak also yielded values for the effective

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temperature and surface gravity. With these value, intrinsic near-infrared magnitudes and colors were derived from the Padova ischrones with Z=0.03 (see Bressan *et al.* 2012 and Marigo *et al.* 2017). All source had near-infrared colors from VVV which allowed to calculate distances using the K-band extinction. The sample was reduced to 736 stars by limiting it to main-sequence stars (i.e. log(G)>3.5) and removing velocity outliers.

3. Models of radial velocities

A set of 2D N-body models in a fixed potential was calculated to estimate the radial variation of velocities toward the Galactic center for 2- and 4-armed patterns. The parameters for the axisymmetric potential were consistent with Bland-Hawthorn & Gerhard (2016). Both spiral potentials placed the Perseus arm at 9.9 kpc (Monguio *et al.* 2015). For the 2-armed pattern, the inner arm was Scutum at 5.0 kpc while for the 4-arms version it was the Sagittarius at 6.6 kpc (Ried *et al.* 2014) using a solar radius of 8.4 kpc. The pattern speeds 15, 30, and 40 km s^{-1} kpc^{-1} were considered. Models with spiral amplitudes yielding a relative radial force perturbations of up to 5% in the radial range of 5-9 kpc were computed. The models were populated with 10^6 particles in an exponential disk between 4.5 and 9.5 kpc using a velocity dispersion of 10 km s^{-1}. The spiral strength were increased over 0.6 Gyr and then kept constant to 2.0 Gyr.

4. Discussion and Conclusions

The preliminary reduction of the FLAMES spectra shows that the mean radial velocities relative to the Local Standard of Rest increases slowly with distance from the sun from slightly negative values to almost 10 km s^{-1}. One can exclude 4-armed potential models as they have negative velocity gradients. The best fits to the observed radial velocities are 2-armed models with pattern speeds of 15 and 30 km s^{-1} kpc^{-1}. The inclusion of a bar potential is not expected to give major changes close to the Sun. Many stars are expected to be double which would cause an underestimation of their distances. This would not change the velocity gradient measured nor the main conclusion.

The mean radial velocities of early-type stars as a function of their distances from the sun toward the Galactic center are slowly increasing to at least 2.5 kpc which is inconsistent with a significant mass perturbation associated to the Sagittarius arm. The exclusion of a 4-armed potential suggests that the star formation in the Sagittarius arm is associated to a gas compression due to the bar (Englemaier & Gerhard 1999) or a secondary shock (Yáñez *et al.* 2008).

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