Research Networking Programmes

Short Visit Grant or Exchange Visit Grant

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online <u>within one month of the event</u>. It will be published on the ESF website.

<u>Proposal Title</u>: The role of bar and spiral arms in modeling the Milky Way

<u>Application Reference N°</u>: 4657

1) **Purpose of the visit**

The purpose of the visit was to produce samples of a “mock Milky Way”, i.e., a numerically simulated galaxy similar, for its structure and kinematics, to the stellar disk of the Milky Way. These mock data will be used to test methods to retrieve important properties of the Milky Way, that will be later applied to real data (especially to the Gaia data). In particular, the mock data were tailored to take in account the effect of bar and spiral arms on the kinematics of the stars in the Milky Way.

The methods that we would like test in a future on the simulated Galaxy aim to retrieve the fundamental parameters of the Milky Way (Sun's peculiar motion, Sun's distance from the center of the Milky Way, the circular velocity of the Milky Way at the Sun's position).

2) **Description of the work carried out during the visit**

During the visit we implemented the codes necessary for the numerical experiments mentioned in the previous point.

In particular, the first of these codes generates the initial positions and velocities (“initial conditions” or “IC”) for the particles in the simulations, roughly similar to those observed for the stars in the Galactic disk, in the surroundings of the Sun.

Such IC are drawn from a Shu distribution function, built on the integrals of motion of a potential similar to the Milky Way's potential (described below). The IC generated in this way are in equilibrium with the potential (i.e., the statistical properties of the particles' position and velocities do not evolve with time as the particles move in the gravitational field of the simulated Galaxy). We generated 3 different samples of particles that, for their kinematics and structures, are similar to the stars that populate the Galactic disk, with ages in the ranges 0.15-1 Gyr, 2-3 Gyr, and 3-5 Gyr respectively (following Robin et al. 2003).

We then implemented a model for the gravitational forces, that should resemble those of the Milky Way. The contribution to the forces was divided in two parts: a part due to the axisymmetric mass distribution of the Galaxy (the “background”) and the other due to the non-axisymmetric components (bar and spiral arms).

To represent the axisymmetric background we took Model III of Irrgang et al. (2013) (a recent fit of some of the observed properties of the Milky Way, well suited for numerical experiments).

We modeled the Galactic bar as a rotating pure qudrupole perturbation as in several works of the past (Weinberg 1994; Dehnen 2000; Fux 2001, however, the model for the first time is extended to the 3 dimensions). The parameters for the bar (pattern speed, angle between the long axis of the bar and the line connecting the Sun and the Galactic center) were taken from the best fit values obtained by Antoja et al. (2014) for the description of the velocity of the Hercules moving group. The spiral arms were instead described with the tight winding approximation, with the best fit model obtained by Siebert et al. (2012) and its the vertical extension described in Faure et al. (2014).

Once generated the axisymmetric IC, we integrated them forward in time in the gravitational field described above (“test particles simulations”). The length of the integrations were chosen to correspond with the mean age of the integrated population.

3) Description of the main results obtained

The main result that we obtain are the outcomes of the 3 simulations, that mock the effects of the bar and spiral arms on the Galactic disk's stars.

In particular, it is in the kinematics of the particles that the effects of the bar and spiral arms' perturbations are most evident, especially where the stars' orbital frequencies are in resonance with the bar and spiral arms' rotation frequencies. In particular, near the position of the Sun in the simulations, the most important resonances are the outer Lindblad resonance of the bar and the 1:4 inner resonance of the spiral arms. These resonances induce, near the Sun, streaming motions and kinematic gradients similar to those observed in the solar neighborhood (e.g., the bar's outer Lindblad resonance is responsible for a group of particles that tends to moves outwards and lag the Sun's rotation, similar to the Hercules moving group).

To be properly compared with the observations, these mock data has to be convolved with realistic models for the errors and selection function (keeping in account, e.g., the dust absorption). In Barcelona it was developed a code to implement, in simulations, errors and selection function similar to those expected from the Gaia mission (this code was recently updated for the new Gaia error models). Moreover, this code takes in account the dust extinction (obtained using the Drimmel et al. 2003 3D extinction maps). Using the error/extinction code we retain those particles in the 3 simulated samples that Gaia would most likely observe and “shift” them in position and velocity, of an amount comparable with the Gaia's error in their determination (error convolution).

Some of these simulations could be presented/used during the GREAT Gaia Challenge meeting in Heidelberg at the end of October.

4) **Future collaboration with host institution (if applicable)**

In a near future we want to collaborate to use the simulated samples for their original purpose, i.e., to test the methods for retrieving the fundamental Galactic parameters of the Milky Way.
In particular, we would like to test the classical method for retreving the the peculiar motion of the Sun and Local Standard of Rest (LSR), that uses the asymmetric drift relation for an axisymmetric Galaxy. This method, the most widely used for the estimation of these parameters, is incorrect when non-axisymmetric perturbations (like bar and spiral arms) are present.
Using the classical method on a non-axisymmetric (simulated) Galaxy, we hope to asses the biases induced by bar and spiral arms on the determination of LSR and peculiar motion, and estimate if they are significant, taking in account the precision of the data produced by the Gaia mission.

5) **Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)***

A publication should follow after the planned future collaboration, described in the previous point, with topic the classical method for retrieving LSR and Sun's peculiar motion and the biases induced by bar and spiral arms in this estimate.

6) **Other comments (if any)**