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Editorial: Galactic Dynamics in the Solar Neighborhood

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Editorial on the Research Topic

Galactic Dynamics in the Solar Neighborhood

This volume of Frontiers in Astronomy brings 6 interesting articles on the spiral structure of the Galaxy and on the stellar dynamics in the solar neighborhood. The spiral structure presented by Monteiro et al., derived from open clusters with astrometric positions from GAIA DR2, and the one by Hou, based on giant molecular clouds, high-mass star-formation region masers, HII regions, and O stars, both in this volume, have similar results. There is no more doubt about the position of the arms in the solar neighborhood. The arms that we see in this region are the most visible part of the complete galactic arms structure, as revealed by VLBI maser observations that were published in recent years. The VLBI sources show that the Milky Way has a grand design spiral structure with four arms, that are about equally spaced, at least in the Galactic quadrants containing the Solar neighborhood. It is a little surprising that this better knowledge of the geometry of the arms has not been followed by a consensus concerning the physics or nature of the spiral arms. It seems that the Galactic Dynamics community is divided in two main tendencies: 1) those who believe that the spiral arms are long lived (a few billion years), and 2) those who think that the arms are short lived (about hundred Myr). However, there is not a real debate going on about this important question.

The corotation radius is the radial distance from the Galactic center at which the rotation curve of the material of the disk (gas, stars) rotate at the same velocity of the spiral arms. For the followers of the intermittent behavior of the arms, the corotation radius is not an interesting parameter. Corotation can be anywhere, many corotation radii can exist simultaneously. For the followers of the long-lived arms hypothesis, the corotation radius has a fundamental importance, since it is the location of the strongest resonance of the Galactic disk.

The question, then, comes about: is there something special at the corotation radius that is effectively observed? The answer comes by means of a technique which is quite simple, much used in Celestial Mechanics, but most often ignored in Galactic Dynamics. Since we have precise measurements of stellar positions and space velocities provided by GAIA DR2 and DR3, for millions of stars situated within a distance of about 2 kpc from the Sun, all what is needed to integrate the orbits of the stars is available. You can discover for each star if its orbit is normal (well behaved) or chaotic (departs strongly from the expected path). This is the technique of Dynamic Maps (Barros et al. in this volume). It is known from Celestial Mechanics that there is a concentration of chaotic stars at the frontiers of a resonance region. A strong resonance can be seen in the dynamic maps of the Solar neighborhood. Its position almost coincides with the solar radius. A direct determination of the spiral pattern speed, based on the birthplace of open clusters (Monteiro et al., this volume), shows that the corotation is at this same radius.

Is this enough to settle the debate? No! First, there is many papers (tens of them) that attribute the dynamical anomaly to a resonance of the Galactic bar without consensus on what resonance exactly

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is the best choice. For a given choice, the authors adjust the rotation speed of the bar, so that the chosen resonance happens to be at the Solar radius. A weakness of these models is that there is no independent measurement of the bar rotation speed to support their choice. Also, there are two well behaved spiral arms, Sagittarius-Carina and Scutum, between the extremity of the bar and the Sun, that do not seem to be perturbed by the potential of the bar. This puts limits on the strength of the bar. Second, another type of phenomenon, has been added to the list of candidates to produce anomalies in the solar vicinity: the infalling clouds or dwarf galaxies that may have reached the Galactic disk in a recent past.

These ideas are the consequence of an influential paper published in the journal Nature some 2 years ago, in which the authors claim to have discovered a kind of spiral structure in phase space including the Z direction. There was only one paper expressing some doubts about the reality of this spiral structure, while tens of papers accepted it as real and discussed different possibilities of infalling objects.

Finally, as another line of attack against the well-behaved grand design picture of the Galaxy, some work claim that there are arms that rotate with different velocities. If true, this would kill the grand design and long-lived picture. There cannot be strong spiral arms rotating at different velocities because the epicycle frequency can have only one value at a given radius, and the rotation speed of the arms is a combination of the frequency of the rotation curve and frequency of the epicycle.

In summary, nowadays, some authors believe that the Galaxy has a grand design style, and others believe that it is more like a flocculent Galaxy. New ways of thinking are needed. In their review on Astrochemistry, Mendoza et al. (this volume) shows in their Section 2 that the presence of a step in the metallicity distribution in the Galactic disk is an indication of a long-lived structure. Amores and Levenhagen (this volume) suggest a new way, still in a preliminary development, to precisely map the spiral arms and the stellar population contained in them.

It seems it may be too early to say if a revival of the old theory of Marochnik, concerning the very narrow belt of life where we are, described in the last section of Barros et al. (this volume) will happen.

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