Galactic archeology : The outskirts of the Milky Way disk

In the last years, extragalactic observations have revealed all the complexity of the outer regions of galaxy disks: truncated/anti-truncated surface brightness profiles (Erwin et al 2012), breaks in metallicity profiles (Bresolin et al 2012), U-shaped age profiles (Yoachim et al. 2010, 2012; Roediger et al 2012). The origin of all these characteristics is still largely debated. They may be the result of dynamical processes, such as radial migration (Roskar et al 2008; Minchev et al 2012) or heating of satellites (Younger et al 2009), or the result of in-situ star formation (Sánchez-Blázquez et al 2009), and related to the accretion history of the Milky Way.
The boundaries of the outer disks themselves are questioned : where do they end and where the stellar halos begin (Martín-Navarro t al 2014)?

For the Milky Way, its outer regions are still largely unknown. We know that they are rich of (in situ or accreted?) substructures, but a global picture of the outer disk is still missing: what is its general structure ? How was it shaped over time ? What are its kinematical and chemical characteristics ?

Currently, there are only very few studies of the detailed chemical abundances of field stars in the outer Galactic disk, that is at R > 10 kpc from the Galaxy center. Most of our knowledge of the detailed chemistry of the outer MW regions comes currently from open clusters (e.g. Lepine et al 2011, Yong et al. 2012) or from studies of outer disk stars found at the solar vicinity (Haywood et al 2013). Both approaches seem to indicate that the Sun is at the transition between the inner (R < 6 kpc) and the outer disk (R > 10 kpc) and that, in particular, the outer regions of the Milky Way have followed a chemical enrichment pattern different from that of the inner disk, with stars in the outer disk being, at all ages, more alpha-abundant, and less metal-rich than coeval stars of the inner disk (Haywood et al 2013). The chemical differences between inner and outer disks have also been recently confirmed by the analysis of APOGEE data (Nidever et al 2014), which has allowed to extend this investigation to stars at few kpc from the Sun. However, it is clear that our knowledge of the characteristics of the MW outer regions is still very fragmentary and incomplete. To overcome this fragmentariness, we need a survey able to go beyond 12 kpc from the galaxy center (distances already covered by APOGEE and accessible by WEAVE), where the transition regime visible in the metallicity profile ends (Lepine et al 2011) and the outer metal-poor disk begins.

MSE is the most adapted instrument for this science. Currently, no large field of view, HR spectroscopic survey is operating or planned to study detailed abundances possible out to ~10 kpc from the Sun and beyond. HR spectroscopy of an extensive sample of dwarfs and subgiants at magnitudes V=17-19 from 5 to more than 10kpc from the Sun, and giants to several tens of kpc from the Galaxy center is essential to quantify the boundaries of the MW disk and its assembling history. A survey around the anticenter direction will allow also to probe a number of known substructures (Anticenter stream, the Monoceros Ring, .. ), linking them to the characteristics of the surrounding disk, and discover new ones.

Such a survey will allow to address a number of fundamental questions :

1. What is the structure of the outer disk ? (Note that at distances greater than 4-5 kpc from the Sun, Gaia parallaxes have errors > 30% for a G=17 star. At higher distances, photometric distances will become competitive with Gaia estimates).

2. At what epochs did the outer disk start to form ? HR spectroscopy on dwarfs would allow determination of ages at up to almost 10 kpc from the Sun (through logg-logTeff diagrams) and to measure to what extent did the MW grow following an inside-out formation scenario.

3. Model the chemical history of the outer disk, understanding how it is related to the evolution of the inner disk. Possibly, reconstruct the accretion history of the Milky Way in its outskirts.

4. What is the degree of inhomogeneity of the outer disk? How many substructures are identifiable in chemical space ? and how do they relate to known structures like Canis Major, Monoceros, the stellar warp, .. ? More generally, how much is the outer disk the deposit of unmixed structures, of all scales ?

5. What will the Milky Way tell us about the external regions of extragalactic disks?