

**DIVISION H**  
**COMMISSION 33**

**STRUCTURE AND DYNAMICS**  
**OF THE GALACTIC SYSTEM**  
*STRUCTURE ET DYNAMIQUE*  
*DU SYSTÈME GALACTIQUE*

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**Introduction**

Research on the structure and dynamics of the Galactic System covers a large field of research, from formation scenarios to long-term evolution and secular processes. Today we speak of near-field cosmology where the oldest parts of the Galaxy are used to probe back to early times, e.g. studying the chemical signatures of the oldest star clusters and dwarf galaxies to learn about the byproducts of the first stars. Some of the most detailed work relates to the structure of the dark matter and baryons in order to compare with expectation from N-body models. Secular processes have been identified (e.g. stellar migration) where material within the Galaxy is being reorganized by dynamical resonances and feedback processes.

During the past triennium, much work has been devoted to ground-based, high-resolution spectroscopic and photometric observations. The Sloan Digital Sky Survey (SDSS) headed by the US creates three-dimensional maps, with multi-color images of at least one third of the sky, and provides spectra for millions of astronomical objects (SEGUE). Other important imaging surveys include Skymapper, Panstarrs, VST, VVV, etc. are either ongoing or just beginning. Plans for even larger photometric surveys e.g. the LSST, are ongoing, but this will have to wait until the next decade. After the success of the Geneva-Copenhagen survey, similar resolution and size surveys have targetted the bulge (BRAVA, ARGOS). The RAVE survey has now completed providing the biggest spectroscopic survey of the disk (550,000 stars). RAVE identified 3D streaming patterns in the local disk which may be associated with the local spiral arms. The SDSS successor to SEGUE is the near-infrared APOGEE survey (R=20,000) which targets 150,000 stars over the inner Galaxy and provides the first uniform CNO abundances for disk stars. This has led to a clean separation of the thin and thick disk through its C/N signature.

The Australians have made excellent progress with the one-million star survey (GALAH) to measure 30 chemical elements; to date, 180,000 stars have been observed in the first two years. The LAMOST in China started its first year of regular operations and several other wide field instruments will survey various parts of the Milky Way. Investment in Galactic archaeology is ongoing with multiobject spectroscopic experiments

including 4MOST/VISTA and MSE/CFHT expected to be operational before the end of the decade, with WEAVE/WHT starting in the next few years.

Our community is particularly excited by the successful launch of the ESA Gaia mission in December 2013. The Gaia satellite will deliver precision astrometry with an accuracy of about 20 microarcseconds as for more than one billion stars. It will also measure radial velocities and abundances as well as parallaxes for about 200 million stars to better than 10%. This remarkable instrument will revolutionize our understanding of the Galaxy over the next decade, particularly in terms of accurate values for the total baryonic and dark matter mass distribution. Even today, the radial scale length of the disk and total Galaxy mass are uncertain to 30% or more.

Figure 1 shows a Star density map of the Milky Way and the Magellanic Clouds made from housekeeping data from the Gaia satellite. For further information see: <http://sci.esa.int/gaia/56123-counting-stars-with-gaia/>, and [http://www.esa.int/spaceimages/Images/2015/07/Stellar\\_density\\_map](http://www.esa.int/spaceimages/Images/2015/07/Stellar_density_map).

Another exciting facility is the Atacama Large Millimeter/submillimeter Array (ALMA) which studies light in the sub-mm waveband. ALMA comprises 66 high-precision antennas, spread over distances of up to 16 kilometres. This global collaboration is the largest ground-based astronomical project today and is now in full operation. It will map essentially all of the main cold gas phases in the Galactic disk.

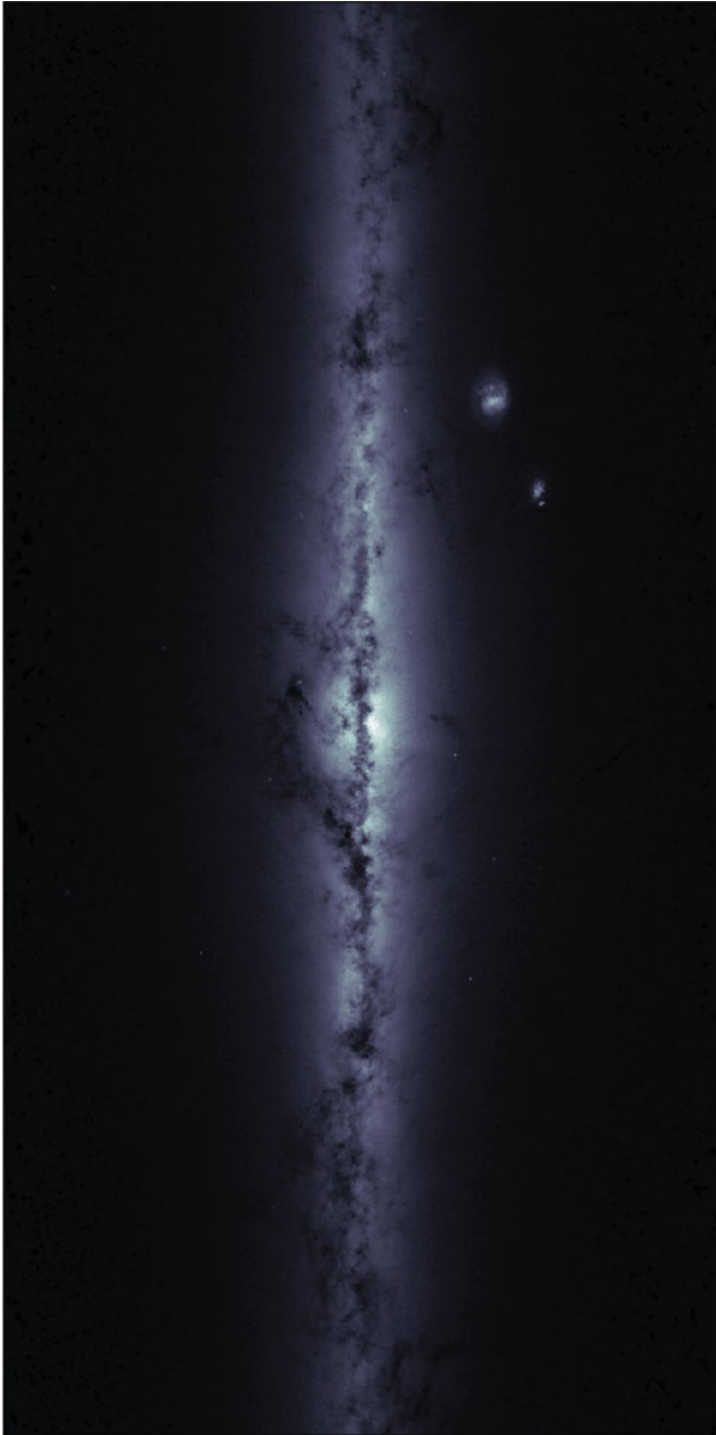
The large surveys, both spectroscopic and photometric, provide excellent datasets for testing predictions from chemo-dynamical models of Galactic stellar populations. The increased capabilities of large computers have made it possible to explore detailed numerical simulations of thousands of individual galaxies to predictions for typical galaxies like the Milky Way. In the past few years, independent N-body simulation groups have managed to produce reasonable synthetic approximations of the Galaxy which has led to new lines of enquiry (e.g. baryon/dark matter fraction at the Galactic Centre). Such very wide-ranging research is of relevance for the Galactic System.

The detection of increasing numbers of satellite galaxies within the Large Group has been taken into account in the definition of the new Commission “Local Universe” which succeeded Commission 33 at the IAU General Assembly in August 2015.

Meetings of most direct relevance to the Galactic System (see also <http://www2.cadc-ccda.hia-ihp.nrc-cnrc.gc.ca/meetings/>) are given below as well as a brief summary of publication statistics.

## 1. Past meetings

- The General Assembly of Galaxy Halos: Structure, Origin and Evolution, IAUS 317, 3-7 Aug. 2015, Honolulu, USA
- Formation, evolution, and survival of massive star clusters, IAUS 316, 11 - 14 Aug. 2015, Honolulu, USA
- Stellar Physics in Galaxies throughout the Universe, FM 7, 12 -1 4 Aug. 2015, Honolulu, USA
- Reconstructing the Milky Way’s History: Spectroscopic Surveys, Asteroseismology and Chemodynamical Models, 1 - 5 June 2015, Bad Honnef, Germany
- The Milky Way Unraveled by Gaia, 1 - 5 Dec. 2014, Barcelona, Spain



**Figure 1.** The Figure shows a Star density map of the Milky Way and the Magellanic Clouds made from housekeeping data from the Gaia satellite (July 2015). For further information see: [http://www.esa.int/spaceinimages/Images/2015/07/Stellar\\_density\\_map](http://www.esa.int/spaceinimages/Images/2015/07/Stellar_density_map). Credit: ESA/Gaia-CC BY-SA 3.0 IGO

- The Milky Way as a Laboratory for Galaxy Formation, 22 July - 9 Aug. 2013, Aspen Center for Physics, Colorado, USA
- Galaxies in 3D across the Universe, IAUS 309: 7 - 11 July 2014, Vienna, Austria
- Setting the scene for Gaia and LAMOST - the current and next generations of surveys and models, IAU 298, 20 - 24 May, 2013, Lijiang, China Nanjing
- Overcoming Great Barriers in Galactic Archaeology 2 27-30 May 2014, Alamanda at Palm Cove, Queensland, Australia
- Galaxies: Origin, Dynamics, Structure, 14-18 May 2013, Sochi, Russia
- Galactic Archaeology Surveys: Past, Present and Future, 23 - 27 July 2012, Sydney, Australia
- A Window to the Formation of the Milky Way, 20 May - 9 June 2012, Aspen Center for Physics, USA
- Stars Without Borders: Radial Migration in Spiral Galaxies, 21 - 24 May 2012, Medena, Slovenia

The business meeting of Commission 33 was held at the IAU GA in Honolulu together with the Science meeting of Division H and well attended. Many of the presentations from the meeting are provided on the Division website at <https://www.strw.leidenuniv.nl/IAU-H/iauga2015.php>.

## 2. Future meetings

- The Multi-Messenger Astrophysics of the Galactic Centre IAUS 322, 18 - 22 July 2016, Cairns, Australia
- 6th Gaia Science Alerts Workshop Meeting 10 - 13 November 2015, Liverpool, UK
- Astrometry and Astrophysics in the Gaia sky IAUS 330, 5 - 9 Dec. 2016, Nice, France

## 3. Publications

As noted above, the research into the Milky Way overlaps that of other commissions. Use of the key words 'Milky Way', in the abstract field of the SAO/NASA Astrophysical Data Service interface, results in 2,176 papers published in refereed journals in the period from 1 October 2011 - 31 October 2015. During the same period those papers were cited 36,754 times in refereed journals.

**Reviews** related to the Galactic System that appeared in the SAO/NASA Astrophysical Data Service from 1 October 2011 to 31 October 2015 include:

- Perryman, M., 2011, 'EAS Tycho Brahe prize lecture 2011. Hipparcos: a retrospective', *A&ARv* 19,45
- Kennicutt, R. C. Jr.,<sup>1</sup> & Evans, N. J. II<sup>2</sup>, 2012, 'Star Formation in the Milky Way and Nearby Galaxies', *ARA&A* 50, 531
- Gratton, R. G.; Carretta, E. & Bragaglia, A., 2012, 'Multiple populations in globular clusters. Lessons learned from the Milky Way globular clusters', *A&ARv* 20, 50
- Ivezić, Z, Beers T.C. & Juric, M., 2012, 'Galactic Stellar Populations in the Era of the Sloan Digital Sky Survey and Other Large Surveys', *ARA&A*, 50, 251
- Rix, H-W. & Bovy, J., 2013, 'The Milky Way's stellar disk. Mapping and modeling the Galactic disk', *A&ARv* 21, 61
- Nomoto, K., Kobayashi, C. & Tominaga, N., 2013, 'Nucleosynthesis in Stars and the Chemical Enrichment of Galaxies', *ARA&A*, 51, 457
- Frebel, A. & Norris, J. E., 2015, 'Near-Field Cosmology with Extremely Metal-Poor Stars', *ARA&A*, 53, 631

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