Research Networking Programmes

Science Meeting – Scientific Report

Scientific report (one single document in WORD or PDF file) should be submitted online within two months of the event. It should not exceed seven A4 pages.

Proposal Title:

"The Galaxy, Stellar Compositions and Dynamics"

Application Reference N°: 4730

1) Summary (up to one page)

This school has addressed the understanding of the Milky Way as a holistic system, one of the key challenges in astrophysics for the coming decade. Our Galaxy is a complex system, a late-type spiral, with major structural elements being the bar and bulge, the halo, and the disk. The largest contributor to the mass of the Galaxy is likely the dark matter halo, with stars offering crucial insight on important epochs of the history of the Galaxy and keeping a fossil record of its chemical evolution.

The Milky Way is a rich laboratory that we can use to explore how stars and galaxies form, how they evolve, and which processes shape their present states. Stars harbour planets, and our planetary system provides pointers to extra-solar worlds. Making linkages from the local solar neighbourhood, to planetary systems, open clusters, the disk, and our Galaxy as a whole, is the key to our understanding of the wider evolution of the Universe — from the Big Bang to its eventual cold and lonely demise.

The topic by itself has been very timely. Not only because the school has taken place at about the same time as the launch of the Gaia spacecraft, but also due to the abundant and important on-going research on the Milky Way as a galaxy: the two phases of the Galactic disk, the structure of the stellar halo, the detailed morphology of the inner regions, the connection between the long bar and the bulge, etc. In addition, there is an ever increasing interest in surveying the Galaxy from many different angles – consider the large area surveys being devoted to the Milky Way since the last decade: 2MASS, APOGEE, SEGUE, RAVE, Gaia, the Gaia-Eso Survey, and others.

It is as part of the training programme of GREAT-ITN that we have organised this school in Tenerife (Canary Islands, Spain) devoted to provide the students with a deep

knowledge on the several topics described below. In addition, the participants will have the opportunity to present their research topics and discuss with a panel of distinguished senior researchers.

2) Description of the scientific content of and discussions at the event (up to four pages)

The broad topic of the school can be better understood if separated into areas, as described below. It has to be stated from the beginning that this school is very tightly linked to the scientific exploitation of the Gaia mission.

The Stellar Constituents of the Milky Way. Unravelling the structure, formation, and evolutionary history of the Milky Way builds on a detailed understanding of the stars that make up our Galaxy. The school will focus on two central aspects of this: 1) where do the stars form and 2) what are their astrophysical properties. Gaia's contribution to these fields will be enormous, as the mission will directly observe 1000 million stars and measure their astrophysical properties. This enables a detailed interpretation of the phase space data in terms of specific events that have shaped the Milky Way as well as a detailed discussion of how and where star formation took place.

Based on the study of star forming regions, stars are thought to form primarily in open clusters or associations. This scenario may explain a large part of the stellar population of the thin disk. However, the formation of the thick disk is still hotly debated with at least five different scenarios currently being discussed in the literature: accretion, heating, radial migration, gas-rich mergers, and the conversion of unstable young disks into a thick disk and bulge system. The current data for the Milky Way disks and bulge are not able to distinguish between these scenarios with any accuracy, at least given the available analysis tools. Gaia data will hopefully unravel the origin of the Milky Way’s disk stars through a detailed study combining the 6D phase space information with accurate elemental abundances from Gaia's instruments and supporting surveys (Gaia-ESO, APOGEE, HERMES, etc.). The school aims at getting the next generation of scientists ready for this data revolution, and to ensure that the potential of Gaia, and its complementary observations, is fully realized.

Galactic Dynamics are best traced by the motions of the Milky Way’s stars and gas. Gaia will focus on stellar motions, which are key for uncovering the properties of the different stellar components of our Galaxy, such as their size, mass, and density. Galactic dynamics are an excellent means for deriving the detailed mass distribution of the Milky Way and constraining the distribution and amount of dark matter. Dynamics are also a vital tool for uncovering stellar streams in phase space and for finding signatures of ancient accretion events. A key challenge will be to create a realistic Galaxy model based on Gaia's 1000 million star catalogue. This school will underline the most useful dynamical tracers in the Milky Way, focusing on getting students ready for squeezing the most out of the Gaia data, and connecting observations in the Milky Way with other galaxies with more complex dynamics.

The broad ideas outlined above have been developed in full by a set of distinguished speakers in a series of lectures that have covered with great detail the many aspects involved in the overall description of the Milky Way as a complex system, including

different approaches and techniques to tackle problems present in the Galactic research.

Prof. L. Girardi developed the topic of Stellar Distribution Models, starting from the basis and reaching till the most demanding simulations. The lectures included several practical exercises to be developed by the students.

Prof. F. Primas was in charge of the very hot topic of Chemical Abundances, on which a rather observational approach was selected. As a conclusion, the derivation of the light element abundances was included as a practical demonstration of the different methods and tools introduced in the lectures.

Prof. O. Gerhard made a very complete introduction on Galactic Dynamics, where he run over the classical formalism for the conceptual description and included also made-to-measure models as examples. The dynamics of the Milky Way was then described by the sum of its main morphological components.

Prof. C. Allende, which doubled also as organiser, made an extensive description of the modern survey projects aimed at mapping the Galaxy covering an ample range of scientific goals and using different observational techniques and instrumentation. That serves as a good complement to the rather theoretical approach of most of the other lectures.

Prof. J. Sellwood devoted his lecturing to the topic of N-body simulations on which he offered a very detailed review of the many aspects involved in the setting of a useful N-body model. A large set of practical examples were spread throughout the lectures.

And finally Prof. K. Freeman developed the complex topic of Stellar Populations: chemical composition, kinematics, morphology. This matter has very commonalities with several other lectures given by different professors, which required some in advance work of sorting out the duplicities. At the end, the result was excellent.

3) Assessment of the results and impact of the event on the future directions of the field (up to two pages)

We, the organizers, are fully satisfied with the outcome from the school as extracted from our own attendance and from the direct contact with lecturers and students. The high number of attendees, which overrun our most optimistic expectations, posed some logistic problems in the organisation, which were quickly fixed with the help of the IAC staff. But that rather high number of student proved to be very adequate to promote discussions and interchange of ideas all over the school.

Most of the lectures have been recorded in video and the full set of presentations are available as pdf files in the school web site, http://www.iac.es/congreso/itn-gaia2013. The high number of access since the closure of the school can provide an estimate of the usefulness and adequacy of the event.

4) Annexes 4a) and 4b): Programme of the meeting and full list of speakers and participants

Annex 4a: Programme of the meeting

Stellar distribution models

-- Leo Girardi (Osservatorio Astronomico di Padova, INAF, Italy)

1- The basics

- overview of stellar evolution as a function of mass and metallicity

- from evolutionary tracks to isochrones

- quick overview of chemical changes at the stellar surface

2- More on isochrones

- bolometric corrections and Teff-color relations

- populating isochrones, and the IMF

- simulating star clusters

- simulating apparent and detached binaries

- simulating interacting binaries

3- From star clusters to external galaxies

- basic methods

- age and metallicity distribution functions for different stars,

including main sequence, red clump, RGB, AGB

4- From external galaxies to the Milky Way

- basic equation of stellar statistics, computational methods

- overview of available MW codes

- expected populations X photometric depth and galactic coordinates

5- Some current problems and opportunities

- simulating kinematics

- simulating variables

- simulating non-solar scaled populations

- simulating rare and extreme populations (e.g. X-ray sources, PNe,

hot-WDs, AGB-manque', C stars, IR-emission by mass-losing stars)

- opportunities opened by asteroseismology

Chemical Abundances

-- Francesca Primas (European Southern Observatory)

1- Basic principles of stellar nucleosynthesis

- main stellar nucleosynthetic processes, from the light/alpha and iron-peak elements to heavy elements

- main transitions of each element

2- Methods and available tools

- how stellar abundances can be derived, starting from basic input parameters (stellar parameters, lines identification, line lists) to the actual measurement of equivalent widths and computation synthetic spectra.

- examples of both methods applied to different spectra (in terms of quality and/or spectral region of interest)

3- Interpretation of the results

- interpretation of the derived abundance ratios

- comparison between the Milky Way and other galaxies

4- A specific application

- the "light elements", Li Be and B.

- big bang nucleosynthesis and 'mixing' in stars

Dynamics of the Milky Way

-- Ortwin Gerhard (Max-Planck-Institut fuer extraterrestrische Physik, Germany)

1- Fundamental stellar dynamics

- relaxation, collisionless dynamics

- distribution functions, Jeans eqs, etc.

2- Stellar orbits and dynamical models

- orbits in various potentials, Jeans Thm, DF models, Schwarzschild, M2M

3- Galactic disk dynamics

4- The Galactic bulge

- structure

- dynamics

- origin

5- The Galactic halo

- mass, extent, shape

- substructure, inner/outer halo

Galactic Surveys: astrometry, photometry and spectroscopy

-- Carlos Allende Prieto (Instituto de Astrofísica de Canarias, Spain)

1- Astrometry and photometry

- Hipparcos, Gaia, full-sky and large-area photometric surveys

- fitting models to data

- algorithms and tools

2- Spectra

- APOGEE, RAVE, SDSS/SEGUE/BOSS, Gaia-ESO

- Spectral classification

- radial velocities

- automated data analysis

3- Other spectroscopic surveys and analysis strategies

- eBOSS, BigBOSS, HETDEX, WEAVE, 4MOST

- data mashup: astrometry, photometry and spectroscopy together

- reconstructing the Galaxy

- 'observing' galaxy simulations

- discovery and follow-up of interesting/exotic targets: HVS, UMPS, CEMPS, RCrBs...

Simulations: N-body, etc.

-- Jerry Sellwood (Rutgers University, USA)

1- The use and abuse of N-body codes

- relaxation in spheres and disks, collective enhancement

- code structure, block time steps

2- Poisson solvers

- trees

- fixed and adaptive grids

- parallelization

3- Setting up equilibrium models

- choosing from a DF, Jeans equations and their limitations

- disk-bulge-halo models

4- Analysis "on the fly"

- code testing

- made-to-measure

5- SPH basics

- numerical viscosity

- Kelvin-Helmholtz instabilities

- other problems and their amelioration

Stellar Populations: chemical composition, kinematics, morphology

-- Ken Freeman (Australian National University, Australia)

1- Overview of the structure of our Galaxy in the context of other galaxies

- the basic components

- dark matter properties

- general ideas about galaxy assembly

2- The thin disk.

- observational issues with the star formation history and the dynamical evolution of the thin disk.

- continuing gas accretion

- theoretical ideas about the formation and evolution of the thin disk.

3- The thick disk in the context of other disk galaxies

- systematics of thick disks in other galaxies

- chemical, structural and dynamical properties of the Galactic thick disk

- ideas about how thick disks form

4- The stellar halo of the Galaxy

- more on dark matter in the Galaxy

- chemical tagging and reconstructing the star formation history of the Galactic disk.

5- The Galactic bulge

- observational status on bulge kinematics and chemical properties in the context of other bulges

- ideas about the formation of the bulge

Annex 4b: Full list of speakers and participants

Speakers:

- Leo Girardi (Osservatorio Astronomico di Padova, INAF, Italy)
- Francesca Primas (European Southern Observatory)
- Ortwin Gerhard (Max-Planck-Institut fuer extraterrestrische Physik, Germany)
- Carlos Allende Prieto (Instituto de Astrofísica de Canarias, Spain)
- Jerry Sellwood (Rutgers University, USA)
- Ken Freeman (Australian National University, Australia)

Participants:

- Abedi, Hoda, Univ. Barcelona, Spain
- Balbinot, Eduardo, Univ. Fed. Rio Grande do Sul, Brazil
- Blanco Cuaresma, Sergi, CNRS, Bourdeaux, France
- Brauer, Dorothée, Leibniz Inst. Astrophysik, Postdam, Germany
- Chatzopoulos, Sotiris, MPE, Garching, Germany
- Choudhury, Omar, AIP, Postdam, Germany
- Clarke, Adam, Univ. Lancashire, U.K.
- Clavero, Rosa, IAC, Tenerife, Spain
- Compère, Paul, IAC, Tenerife, Spain
- de Bokx, Richelle, Mullard Space Sci. Lab., London, U.K.
- del Pino Molina, Andrés, IAC, Tenerife, Spain
- Díaz García, Simón, Univ. Oulu, Finland
- Dorda, Ricardo, Univ. Alicante, Spain
- Fabbian, Damian, IAC, Tenerife, Spain
- Faure, Carole, Obs. Strasbourg, France
- Fernández Alvar, Emma , IAC, Tenerife, Spain
- Feuillet, Diane, New Mexico State Univ., U.S.
- Fu, Xiaoting, SISSA, Trieste, Italy
- Gkouvelis, Leonardos, Univ. Valencia, Spain
- Guiglion, Guillaume, Obs. Côte d'Azur, France
- Henault-Brunet, Vincent, Univ. Surrey, U.K.
- Hernitschek, Nina, MPIA, Heidelberg, Germany
- Herpich, Jakob, MPIA, Heidelberg, Germany
- Holl, Berry, Geneva Obs., Switzerland
- Howes, Louise, Mount Stromlo Obs., Australia
- Hunt, Jason, Mullard Space Sci. Lab., London, U.K.
- Irrgang, Andreas, Bamberg Observatory, Germany
- Laevens, Benjamin, Strasbourg, France and MPIA, Germany
- Lapenna, Emilio, Univ. Bologna, Italy
- Libralato, Mattia, Univ. Padova, Italy
- Liu, Cheng, Lund Observatory, Sweden
- López Fernández, Rafael, IAA, Granada, Spain
- Martínez Vázquez, Clara Eugenia, IAC, Tenerife, Spain
- Martins, André, Besancon Obs., France
- Molgó, Jordi, GRANTECAN, Tenerife, Spain
- Murareva, Tatiana, Obs. Bologna, Italy
- Palaversa, Lovro, Geneva Observatory, Switzerland
- Portail, Matthieu, MPE, Garching, Germany
- Rodrigues, Thaíse, Obs. Padova, Italy
- Roeck, Benjamin, IAC, Tenerife, Spain
- Rojas, Álvaro, Obs. Côte d'Azur, France

- Rybizki, Jan, ZAH, Heidelberg, Germany
- Sancho Miranda, Maider, Univ. of Central Lancashire, UK
- Sans Fuentes , Sara Alejandra, Inst. Astron. Leuven, Belgium
- Sampedro Hernández, Laura, IAA, Granada, Spain
- Serra, Ana Laura, Obs. Turin, Italy
- Sibbons, Lisette, Univ. Hertfordshire, U.K.
- Silva, Manuel, Univ. Lisbon, Portugal
- Simion, Iulia, Inst. Astronomy, Cambridge, U.K.
- Süveges, María, Univ. Geneva, Switzerland
- Tailo, Marco, Univ. La Sapienza, Rome, Italy
- Thygesen, Anders Overaa, ZAH, MPIA, Heidelberg, Germany
- Tian, Hao, Kapteyn Astron. Inst., Groningen, Holland
- Trick, Wilma, MPIA, Heidelberg, Germany
- Vasquez, Sergio, Pontificia Univ. Católica/ESO, Chile
- Wang, Yue, ESO
- Wegg, Chris, MPE, Garching, Germany
- Ziegerer, Eva, Bamberg Observatory, Germany