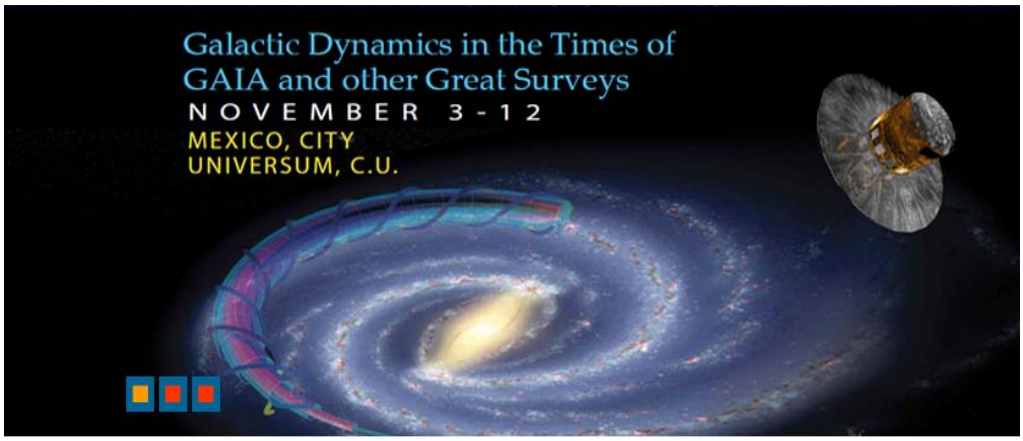
Research Networking Programmes

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*: Galactic Dynamics in the Times of Gaia and other Great Surveys**
International School, November 3-12, 2013, Mexico City

Application Reference N°: 5086



Web page of the school: http://www.astroscu.unam.mx/gaiaschoolmex/
Internal web page of the school: http://www.astroscu.unam.mx/gaia-software/[1]
Video of the school: http://www.youtube.com/watch?v=s-t3TCFk47s

1) Summary (up to one page)

The raison d'être for the school has been the Gaia astrometric mission. The promise of the availability of positional, kinematic and even stellar atmospheric information for a significant fraction of stars in our Galaxy (~1%), at a level of precision never before attained in such a global scale, promises to be a major landmark in the characterization of our galaxy and the study of its evolution. One of the disciplines that most likely will see a profound impact due to the Gaia database is Galactic Dynamics. The massive availability of data will allow us to use the traditional modeling procedures at an unprecedented degree of refinement. Even more exciting, new and powerful theoretical tools will be able to be applied for the first time.

The goal of the school has been to introduce students to some of the modeling tools (old and new), that are likely to be relevant in the Gaia era. Our aim has been understanding over formal lectures, and we recognize that practice is an important tool for understanding: from doing something is that familiarity arises. So, our school has been designed with a two pronged approach: lectures in the mornings and exercises in the afternoons. The lecturers have taken the time to design exercise sessions that have introduced students to numerical tools that they have used to work out concepts seen

[1] user is: gaia2013, password: Ga14scho0l

during the morning lectures. In the second half of the school, students have work on some projects on their own, but with lecturer advice available. In these projects, students have used the theoretical concepts and numerical tools covered before.

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

2.1 Lectures and exercises developed during the school.

Lectures by **Dr. Luis A. Aguilar** (IAUNAM/México)
Basic Galactic Dynamics in a rush
I. Hamiltonian Dynamics
- Why Hamiltonian Dynamics?
- The starting point: The least Action Principle
- Hamilton's equations and phase space
- Canonical transformations and generating functions
- Hamilton-Jacobi and the search for a simpler picture
- The promised land: Action-angle space

II. Galactic Dynamics
- The collisionless Boltzmann equation: what it is and what it means
- Orbits as the fundamental building blocks of DF's
- Isolating integrals as shapers of orbits
- An interesting family tree: regular and irregular orbits
- The misfits: sensible dependence on initial conditions and chaos
- Putting everything together: Self-gravitational, relaxation and selfconsistency
- What exactly does "relaxed" mean?
- Difference between test-particle and full N-body simulations.

Lectures and exercises by **Dr. Daniel Carpintero** (La Plata/Argentina)
Galactic Dynamics basic building bricks: Orbits
I. Regular and chaotic orbits
- Regular and chaotic orbits
- Poincare's sections
- Lyapunov exponents

II. Refining the orbital classification
- Other indicators of chaos: SALI, MEGNO, FLI, OFLI
- Regular families
- Classification of regular orbits: Spectral analysis

1 Exercise: Numerical laboratory for orbits.
- Poincare sections and Lyapunov exponents
- Chaos indicators and spectral analysis.

Lectures and exercises by **Dr. Francesca Figueras** (U. de Barcelona/Spain)
I. **Ingredients for a Galaxy model**
How do we go about building a model of the galaxy
II. **The Gaia mission**
An in depth but quick introduction to the Gaia mission
III. **The Gaia mock catalogues: GUMS and GOG**
Description of two very powerful tools to immerse into the Gaia Universe
2 Exercises:
I. How to install and use GOG
II. Derivation of the local force perpendicular to the galactic plane with a Gaia mock catalogue.

Lectures and exercises by **Dr. Daisuke Kawata** (UCL/UK)
I. **N-body/SPH simulations of our Galaxy**
II. **The Physics behind sub-grid modeling**
Exercise:Plugging N-body data into the Gaia universe. A barred galaxy simulation.

Lectures and exercises by **Dr. Paul McMillan** (Oxford/UK)
Actions, angles and approximations
I. Availability of exact actions for a limited set of potentials. Torus modeling: Key principles
II. Other approximations for actions
III. Use of angle-action approximations in Galactic modeling.
Exercise: Angles and actions in practice.

Lectures and exercises by **Dr. Bárbara Pichardo** (UNAM/México)
The influence of non-axisymmetric galactic structures: A Galaxy with spiral arms and a central bar.
I. Morphological description of spiral arms and bars in disk galaxies in general and in our Galaxy. First potential models for the Milky Way
II. More advanced models for the Galaxy. The dynamical effect of the! non-axisymmetric structure
III. Stellar dynamics under the influence of the non-axisymmetric structure of the galaxy.
Exercise: A numerical laboratory to study the effect of non-axisymmetric structure on the orbital structure of our Galaxy.

Lectures and exercises by **Dr. Justin Read** (U. of Surrey/UK)
Dark matter in the Galaxy
I. The local dark matter density
- Definition and some history
- Two approaches: rotation curve vs. local measurements
- Critique of both approaches. Power of combined approach
- Theoretical background: what to expect from Cosmology

II. Jeans vs. DF modeling
- Collisionless Boltzmann equation and its meaning
- Moments and derivation of Jeans' equations in cylindrical coords.
- Advantages and disadvantages of full Jeans vs. DF and mixed modeling
- Tests on mock N-body data

III. The latest results
- Application to real data: a census of results so far.
- The meaning of the results: spherical halo or dark disk?
- The future: Gaia and large surveys
- Remaining challenges and outlook

Exercise: Generate 1D mock data from Gaussian velocity distribution and recovery of original distribution using Markov Chain Monte Carlo.

Lecture by **Dr. Octavio Valenzuela** (UNAM/México)
N-body simulations of our Galaxy

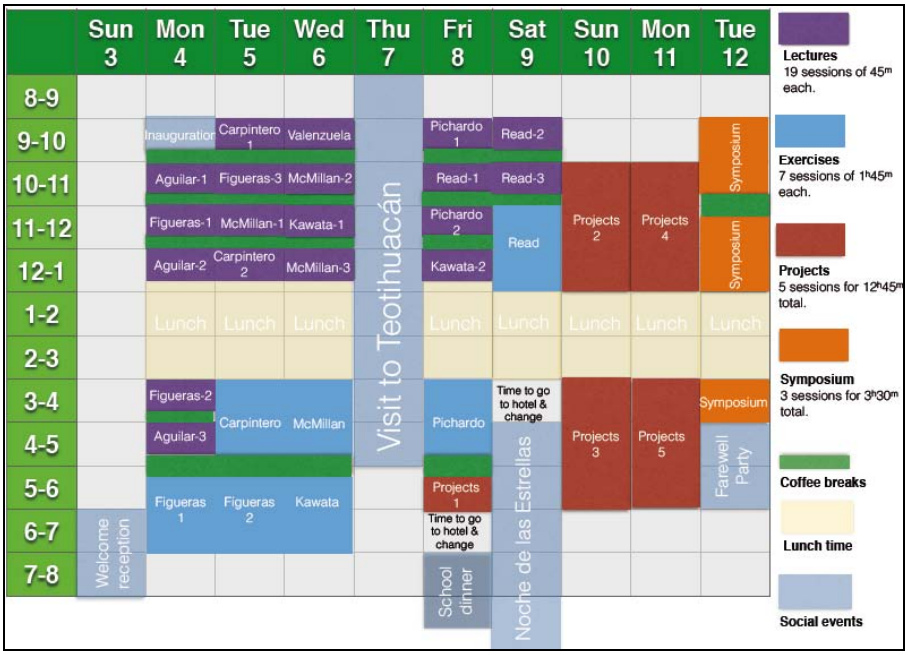


Figure 1 Schedule of the School

2.2 Projects developed by the students

The approach has been the following:

- At the first project session (friday afternoon), some lecturers have presented possible projects for the students to develop

- The students have had 1 day to decide what project to work on. They can propose projects by their own. It has strongly advised to set projects that use the concepts seen during the lectures and numerical tools used during the exercise sessions.
- The students have work in teams of 4 on their projects.
- They have had a total of 12 hours split in 4 sessions to work on their projects. On 2 of the sessions, the lecturers have been available to advise. On the remaining two, students have work on their own.
- On the last day of the school, we have switched to "symposium mode". The students have presented the results achieved on their projects as in a symposium. Lecturers have commented on the results and suggested possible continuations.

The proposed exercises and all the material provided to the students have been compiled in the following web page:
http://www.astroscu.unam.mx/gaia-software
user is: gaia2013
passwd: Ga14scho0l

The projects developed by the students and presented in the Symposium (see Fig. 1) can be found in the same web:

- Gaias View on the Metallicity of the Milky Way Galaxy
- Effect of Gaia Errors on Orbital Classification
- Angles and Actions of Red Clump Stars in the Solar Neighborhood
- Modelling Sun's Siblings in the Times of Gaia
- Orbital Chaotic Behavior in the Solar Neighborhood towards the Galactic Centre
- Searching the Origin of the Pleiades Cluster
- Detection of Spiral Arms and Bar with and without the Gaia errors

We tried to publish this work in the Mexican Journal of Astronomy but its board declined. They answered these were really nice projects but with too little work yet. They invited teachers and students though to finish them as publishable papers there.

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

We, as lecturers, have encouraged all students to strongly interact with us, either during the lecture or exercise sessions, or during the recesses, even after the school. We have been in the school room during most of the school, and not just for our participation. The reason has been for us to be available to the students. We have encouraged them to feel at ease during the school and feel free to ask, or comment as much as they deem necessary. We think we have successfully reached these goals.

Soon we will have the evaluation of the *questionaire* filled by the students at the end of the school (work is in progress to process them). Please find in this link a video of the Gaia School that was interviewing some teachers and students along the School (more than 300 visits up to now): http://www.youtube.com/watch?v=s-t3TCFk47s

The experience was great so we will work to repeat the school in 2014 and if possible in 2015. Tentative locations for the school are: Barcelona University, Santiago de Chile (ESO) and Beijing (work in progress).

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

Annex 4a: Programme of the meeting

The programme has been detailed in Section 2)

Annex 4b: Full list of participants

Lecturers
Luis Aguilar (UNAM/ Mexico)
Daniel Carpintero (La Plata/Argentina)
Francesca Figueras (U. of Barcelona/Spain)
Daisuke Kawata (UCL/UK)
Paul McMillan (Oxford/UK)
Barbara Pichardo (UNAM/Mexico)
Justin Read (U. of Surrey/UK)
Octavio Valenzuela (UNAM/Mexico)

The list of the 34 predoc and postdoc students, from all around the world, can be found in the following table (next page)

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