

2nd WGA1 workshop - Galaxy Modelling with a Gaia mock catalogue

Universitat de Barcelona, Spain, 29 February-2 March 2012

Summary

The Gaia launch day is around the corner. We are excited by the unprecedented accuracy and amount of the data that Gaia will provide us. Furthermore, the ground-based chemodynamical spectroscopy survey projects progress strongly and will add more values to the Gaia data. To extract the maximum useful information about Galaxy dynamics and formation from the enormous data set, the generation and elaboration of theoretical models are crucial. A question is "are we ready?"

Gaia will produce the unprecedentedly large amount of the data for order of billion stars with many dimensions of information. The accuracy of the information of each dimension will depend on apparent magnitude, distance, population, location in the sky due to the dust extinction, crowding and so on, i.e. observational "selection function". On the other hand, theoretical models are never like the real Galaxy, and some simplification and/or coarse sampling are always applied. To quantitatively compare such theoretical models with the upcoming Gaia data, we need to be well prepared and exercises with a Gaia mock catalogue would be crucial for the theorists.

The workshop discussed how to use Gaia mock catalogue for Galaxy modelling. We invited researchers working for DPAC (Data Processing and Analyzing Consortia) and GAP (Gaia Archive Preparation WG) who are experts on accuracies of the Gaia data and mock catalogue and active researchers in the field of Galaxy modelling. The aim of this workshop is to stimulate discussion and establish collaboration among these participants. The expected outcome of this workshop were:

- establishing a close link between Galaxy modelling community to the DPAC teams.
- identifying challenge of generating and using a Gaia mock catalogue.
- providing input and feedback, including the use cases of a Gaia mock catalogue, from the Gaia modelling community to the DPAC teams.
- setting the tasks for the participants to work by the next workshop.

Due to excellent talks by speakers and stimulus discussion by participants, we think that we meet these targets. Based on discussion at the workshop, we are planning a follow-on workshop in about one year from now.

Scientific Content and Discussion

In first session, we had a series of talks by researchers who are actively working for Gaia DPAC, and they overview what we will see in the Gaia era. Anthony Brown presented the status of Gaia and the data release plan. He showed us an overview of the Gaia survey, the current status of satellite and the launch site (with many nice and exciting pictures), and a current plan of early data release. Jos de Bruijne told about the Gaia's astrometric performance in detail. Annie Robin presented the state-of-the-art Gaia Universe Model Snapshot (GUMS) and overviewed the "ingredients" of the Universe model that was an input catalogue of the current Gaia mock catalogue. Xavier Luri presented the Gaia Object Generator (GOG). GOG is the tool to generate Gaia mock catalogue

from input "Universe data" like GUMS. He explained that GOG can handle any input source catalogue, and this tool could be a core tool for Galaxy modelling community to generate their own Gaia mock catalogue. Wil O'Mullane showed us how the Gaia data will be archived and how we can access the data. He welcome feedback from community for archive format and how people want to access the data. Coryn Bailer-Jones summarised one of DPAC CU8 activities, deriving stellar parameters from Gaia's spectrophotometer. Carine Babusiaux gave us a nice summary of ground-based survey related to Gaia. Especially she showed an updated status of Gaia-ESO survey.

These talks nicely showed the fact that Gaia is around the corner and it was an important wake-up call for theorists working for Galaxy modeling. Particular attentions are paid for the early data release plan. Led by Gerry Gilmore we had an intensive discussion about the early data release. Anthony Brown summarised what is the constraints of the data release, and indicate one of the issue is the man power and funding. Gerry Gilmore stressed that applying simple modelling study is an effective way to find out systematics in the data, and therefore encourages to release the data in earliest possible. DPAC CU9 is being created for this purpose. However, modelling community may also want to take seriously this issue.

On the next day, we had a series of the talk from Galaxy modelling researchers. James Binney presented an opening talk and reviewed Galaxy model, in particular dynamical modelling. He summarised what challenges we are facing, and stressed that we need to fit distribution function to data in space of observables. Paul McMillan presented his Torus model development. They are intending to publically release a mock catalogue constructed from the Torus model of a known distribution function, which would be valuable for testing different modelling technique. Ralf Schönrich showed a new way of measuring the Galactic rotation from the heliocentric radial velocity data. Jorge Peñarrubia presented a new way of measuring the potential of the Milky Way without using dynamical model, but using the tidal stream data. Victor Debattista presented their χ^2 Made-to-Measure (M2M) modelling and successful application to the inner region of the Milky Way and extra-galaxies. Annie Robin showed the current contents of Besançon model and the ongoing updates. Especially the bar/bulge region's fit is significantly improved and she discussed the implication from the model. Doug Marshall presented his 3D extinction map of the Milky Way and on-going efforts and expectation for the Planck and Gaia era.

Then, we had a series of 5minutes presentations. Esko Gardner presented his plan to apply their M2M model to Besançon model, and demonstrated an application to a simple Milky Way model as a first step. Teresa Antoja presented the moving groups identified in the different disc position within about 1 kpc from the Sun from RAVE data. These will be an important indicators of non-axisymmetric structures of the Milky Way, and she also demonstrated the Gaia observables expected from her spiral arm models. Octavio Valenzuela discussed the spiral arms seen in their barred and unbarred galaxy simulations. He showed the spiral arm pattern speed is flatter when the bar is stronger. However, he also pointed out that the complication of measuring the pattern speed, and pointed out the challenge of measuring the pattern speed of the Milky Way's spiral arm. Oleksiy Golubov showed his compilation of asymmetric drift and rotation curve from the various survey data. Stefano Pasetto presented his developing tool to generate synthetic CMD, which will be useful to generate Gaia mock catalogue from N-body simulations. Richard Hanson showed their development of 3D extinction models from Gaia data. Brigitte Rocca-Volmerange showed low and high resolution galaxies libraries for Gaia based on PEGASE. Antonella Vallenari stressed that open clusters are the good indicators of Galactic disc and showed the status of the Gaia-ESO survey of the open clusters.

In the afternoon, we had several talks about modelling the inner region of the Milky Way. Lia Athanassoula gave a review of N-body modelling of the bar/bulge, and showed some comparison with the Milky Way data. She described that the bar can have a short boxy/peanut and thinner and longer bar, which nicely explain the current observed features of the inner region of the Milky

Way. Inma Martínez-Valpuesta presented their N-body simulations of a bar and demonstrated that the bar can have leading and trailing ends, which can explain the feature of the double bar claimed from the observations. She also show the prediction of line-of-sight velocity distribution around the end of the bar. She also mentioned their application of M2M to the observation of the bar region of the Milky Way. Then, we had two 5 min short presentations. Merce Romeo-Gómez showed her manifold model and prediction of the kinematics in the bar region. She also demonstrated their estimate of the Gaia error for the kinematics of red-clump stars in the region of the connection of bar and spiral arm. Andres Moitinho overviewed VA-4D project, Visual Analysis of 4-Dimensional Fields, Process & Dynamics to design a conceptual model for an intelligent visual analysis tool for large datasets of 4D fields.

We then had a session to explore the Gaia mock catalogue. Daniel Tapiador, ESAC, kindly set up a mock catalogue including Gaia-like observations, up to $G = 17$ from GOG simulator. The participants had an opportunity to play with the Gaia mock catalogue and examples of accessing and processing the data. LOC prepared several portable HD to copy all the software and the data to the participants's laptops, which was very helpful.

On the third day, we had a series of the talks related to N-body modelling. Luis Aguilar gave an opening talk. He nicely reviewed how N-body simulations can be useful for exploring the large and complex observational data. He also stressed that we need to compare the model with the observation in observable space, and showed their pioneering works of generating mock observations from N-body simulations. Rok Roškar discussed how we can interpret observations with the aid of N-body simulations. He also showed their development of pyNbody tool to generalise analysis of N-body simulations with a python-based software package. Andreea Font also showed her idea of using N-body simulation to help understanding the observational data, and demonstrate a comparison of age-velocity dispersion relation between their GIMIC cosmological simulations and the observations of solar neighbourhood stars, stressing the gas dissipation process. Justin Read presented their work for measuring the dark matter density in solar neighbourhood. He also discussed how we can use N-body model to understand the biases of measurements. He suggested galaxy modelling challenge where he can provide mock data from N-body models of stable sphere and/or disc or more complicated systems, and the participants try to reconstruct the input N-body model using their favourite methods. Paola Di Matteo discussed minor mergers, interaction and secular evolution of the disc and possible observable signatures. She also discussed that we need to construct mock catalogue to make observables and robust prediction from the different formation and evolution scenarios. Then, we have to be extremely cautious about how the mock catalogue could be sensitive to the assumption for input stellar population models, dust extinction map and etc. Chiaki Kobayashi showed their chemodynamical models taking into account chemical yields of many different elements, and stressed the power of chemical tagging. Cristina Chappini and Ivan Minchev overviewed the proposed 4MOST instrument and their science feasibility studies using numerical modelling and GALAXIA. Ivan Minchev focused on the disc sciences. He showed how 4 MOST will add the values to the Gaia data to reconstruct full velocity space. He also demonstrated their prediction of the observable features of minor mergers and comparison with the SDSS dwarf data.

Results and impact of the event on the future direction of the field

Again our expected outcome of this workshop were:

- establishing a close link between Galaxy modelling community to the DPAC teams.
- identifying challenge of generating and using a Gaia mock catalogue.
- providing input and feedback, including the use cases of a Gaia mock catalogue, from the

Gaia modelling community to the DPAC teams.

- setting the tasks for the participants to work by the next workshop.

We had many feedback from the participants of Galaxy modelling community that it was useful for them to know what is developed by DPAC and who are working for. We had many lively discussion and people are also making discussion during coffee breaks (we had many coffee breaks between the sessions, which was successful in stimulating discussion). In discussion session, led by Wil O'Mullane, we discussed again the archive, and he welcome the feedback about data access. Modelling community also recognise that GOG and the other software developed by DPAC are extremely useful for them to create their own mock catalogue from their own models. People from DPAC team mentions that they are happy to let to use their software. After these discussion, we identify the following challenges for Galaxy modelling.

- How to compare models with the real observations?
- There are complicated selection function of the Gaia and complementary data. How to take them into account?
- We will have unprecedentedly huge and complex data set of the Milky Way.

To tackle these challenges, we proposed the following two activities of GREAT WGA1.

A Building a tool to generate a mock catalogue from (N-body) simulations.

B Galaxy modelling challenge.

Activity A: In this workshop, several speakers stressed that we need to compare the models and observational data in observable space. Therefore, it would be extremely useful for community, if there is a tool to build a mock catalogue from model prediction or numerical simulation results. We learned from the first day talks, especially the one by Xavier Luri that there are DPAC developed tools, such as GOG. If we have input star catalogue, GOG can generate a mock catalogue, taking into account the Gaia's measurement accuracy. Luri also demonstrated that we can take off the stars from the GUMS input, and add our own star catalogue to GOG. Therefore, we think that the missing part is generating star catalogue from N-body (or any simulation) models. Since such model does not have resolution to resolve individual stars, it often requires to assume an IMF and stellar population model to generate star catalogue (e.g. talk by Stefano Pasetto and GALAXIA used by Ivan Minchev's talk). In addition, we need a 3D extinction map (e.g. Dough Marshall's talk) to generate observable star catalogue. Although it is challenging to develop such tools, in the community there are expertise and experiences in these fields and DPAC team went all the steps based on the Besançon model. We hope that we can fascilitate this activity and start organising the collaborations.

Activity B: This is the idea suggested by Justin Read, and he also agreed to set up a wiki page for this activity. We first set a fake observables from N-body models, and ask the participants to fit their model and reconstruct the input N-body model. This activity must be useful to identify Pros and Cons of different technique and also useful for the participants to improve their model. People interested in this activity suggested that we should take step-by-step challenges. We will probably start from a simple spherical N-body model. Then, more complicated systems, like triaxial systems, systems with disc and spheroid, and adding bar and spiral arms. We hope that eventually mock catalogues created from activity A will be one of target model for this modelling challenge.

To support these two activities, we are discussing to organise a follow-on workshop in the next year, and planning to apply GREAT ESF fund, again. We thank GREAT ESF for supporting this workshop to initiate these activities. We hope that GREAT ESF continuously support the activity of GREAT working group A1: Gaia model.

Meeting Programme

29 February 2012

Session 1: What we want to do with a Gaia mock catalogue

14:00-15:45

Anthony Brown: Gaia Status and data releases

Jos de Bruijne: Detailed astometric performances predictions

Annie Robin: The Gaia Simulator: scientific contents

Xavier Luri: The Gaia Object Generator (GOG): future scientific exploitation

William O'Mulane: Serving a simulated Gaia Catalogue from ESAC/GAP

16:15-18:00

Coryn Bailer-Jones: Astrophysical Parameter accuracy from low resolution spectra

Carine Babusiaux: Related surveys to the Gaia mission

Summary and Discussion led by Gerry Gilmore

1 March 2012

Session 2: What we need/want to do with Gaia mock catalogue

9:00-10:10

James Binney: Gaia Modelling

Paul McMillan: Analysing observations using orbital torus models

Ralf Schoenrich: Simple measurements of Galactic rotation

Jorge Peñarrubia: Measuring the Milky Way potential without dynamical models

10:40-12:05

Victor Debattista: Particle Dynamical Modelling the Milky Way

Annie Robin: Update on the development of the Besançon Galaxy Model and implications for Gaia simulations

Douglas Marshall: From Planck to Gaia - exciting perspectives for the interstellar medium

5 minutes short talks:

Esko Gardner: The Milky Way, made-to-measure

Teresa Antoja: Disk kinematic groups with Gaia

Octavio Valenzuela: Milky Way Spiral Arms History

Oleksiy Golubov: Asymmetric drift of the thin disc main sequence stars

Stefano Pasetto: Millions stars synthetic CMD generator: a novel technique to exploit Gaia photometric catalogue

Richard Hanson: Building a 3D extinction model

Brigitte Rocca-Volmerange: Synthetic galaxy libraries at low and high spectral resolution for Gaia

Antonella Vallenari: Open clusters as disk tracers

Discussion led by James Binney

Session 3: What we need/want to do with Gaia mock catalogue

13:30-14:40

Lia Athanassoula: The bar/bulge model for the Milky Way

Inma Martínez-Valpuesta: A bar/bulge model for the Milky Way to be compared with the Gaia Mock Catalogue

5 minutes short talks:

Merce Romeo-Gómez: Kinematics of the Galactic Bar: Gaia capabilities

Andres Moitinho: What will the visualization of the Gaia Catalogue be?

Session 4: Mock Catalogue

15:00-17:45

Practical work with GUMS ("ideal" error-free catalogue, up to $G=20$) and GOG (actual catalogue simulation including Gaia-like observations, up to $G=17$) led by Daniel Tapiador

19:30- Workshop dinner

2 March 2012

Session 5: What we need/want to do with Gaia mock catalogue

9:00-10:40

Luis Aguilar: Digging out substructure in the galactic halo with Gaia. What has been done and what needs to be done

Rok Roškar: Interpreting Observations with the aid of N-body Simulations

Andreea Font: Reconstructing merger histories from local disc observables. Insights from cosmological simulations

Justin Read: Measuring the local dark matter density: the utility of N-body mock data

11:00-12:20

Paola Di Matteo: Signatures of secular processes and accretion events in the Milky Way disk

Chiaki Kobayashi: Chemodynamical simulations and stellar yields

Cristina Chiappini: Future ground-based spectroscopy surveys: adding value to the Gaia data and constraining theoretical models

Ivan Minchev: Milky Way chemodynamics in the Gaia era

Discussion led by Luis Aguilar

12:20-13:00

Session 6: What we need/want to do with Gaia mock catalogue

Gaia Archive Discussion led by William O'Mullane

Grand Challenge Discussion led by Francesca Figueras and Daisuke Kawata

Meeting end: 13:00

Participants

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Luis Aguilar	ICC-UB, UNAM (Mexico)	Spain
Teresa Antoja	Groningen	Netherlands
Lia Athanassoula	LAM, Marseille	France
Carine Babusiaux	GEPI, Obs. de Paris	France
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Andre Martines	Besançon	France
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Jorge Peñarrubia	Granada	Spain
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Annie Robin	Besançon	France
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Rok Roškar	ETH Zürich	Switzerland
Robyn Sanderson	Groningen	Netherlands
Ralf Schönrich	OSU	USA
Christos Siopis	Bruxelles	Belgium
Gabriel Stoöckle	ZAH-ARI Heidelberg	Germany
Daniel Tapiador	ESAC	Spain
Jordi Torra	ICC-UB	Spain
Octavio Valenzuela	IA-UNAM	Mexico
Antonella Vallenari	INAF, Padova	Italy

Organisers

Teresa Antoja (Groningen), James Binney (Oxford), Anthony Brown (Leiden), Victor Debattista (UCLan), Francesca Figueras (Barcelona, Convenor, LOC Chair), Andreea Font (Cambridge), Amina Helmi (Groningen), Daisuke Kawata (MSSL, Convenor), Xavier Luri (Barcelona, LOC), Ivan Minchev (Potsdam), William O'Mullane (ESAC), Celiné Reyle (Besançon)