MW-Gaia WG2/WG3 Workshop

Frontiers of Stellar Physics: the Theory-Observation Interface

Zagreb (Croatia), 21st-23rd January 2020

The workshop was Frontiers of Stellar Physics: the Theory-Observation Interface held at the Palace of Matica Hrvatska in Zagreb, Croatia, from 21st to 23rd January 2020.

This was the fourth workshop of the CA18104 COST Action MW-Gaia and the first (joint) WG2 and WG3 workshop.

Scientific motivation for the workshop

The recent data releases by the European Space Agency's Gaia survey reinvigorated the interest in stellar physics. Gaia's state-of-the-art astrometry and photometry combined with contemporary spectroscopic surveys and high-cadence photometric space missions allow stringent tests of the stellar evolution, pulsation and population synthesis models.

The aim of this workshop is to address the open questions related to the uncertainties in the theoretical models through a comparison with the observational data. The topics of the workshop include:

- ✓ Population synthesis: simulations of star counts, dependence on the uncertainties of the stellar models

- ✓ Stellar rotation: effects on the stellar evolution
- ✓ Stellar pulsations: comparison between the observational values and the theoretical light curves, luminosities, ages and colour
- ✓ High-cadence space missions: combining the Kepler, TESS and PLATO missions with Gaia and spectroscopic surveys to lift the degeneracies and provide key modelling parameters
- ✓ Spectroscopy: obtaining atmospheric parameters as a key ingredient of the models; Gaia benchmark stars
- ✓ Stellar ages: uncertainties in the models and their impact on the determination of ages
- ✓ Asteroseismology: importance of obtaining dynamical masses
- ✓ Distance scale: systematic errors in the determination of the distance scale as a result of the theoretical assumptions, ultimately affecting the determination of the Hubble constant

Day One

First day of the workshop started with the introductory talk of Nicolas Walton (Cambridge). He gave an overview of the COST action activities so far, presented the MW-*Gaia* work plan and the plan for the future workshops and activities. Second speaker was Giorgia Busso (Cambridge) who presented *Gaia* DR3 update. Her talk was divided in three parts. In the first part she presented the update of the *Gaia* mission and future plans for the mission. Second part was about *Gaia* EDR3 and DR3 and what the improvements will it have. The final part of her talk was about *Gaia* and comparison with other surveys. Rosanna Sordo (Padova) continued with *Gaia* DR3 updates and focused her talk on astrophysical parameters. She explained APSIS (Astrophysical Parameters Inference System) in great detail. Also, she added that CU8 will publish ~300 parameters in DR3 and since they have many modules treating the same source, multiple versions of parameters will be provided. Rosanna also explained the database structure and pointed out how all *Gaia* product must be validated before publication (CU8 and CU9 validation). The session continued with the invited talk on variable stars in *Gaia* DR3 by Gisella Clementini (Bologna). She gave an overview of *Gaia* and variable stars in general, variable stars in DR1 and DR2 and she explained that DR3 will provide variable star classifications together with the epoch photometry for 5-10 million variable stars of different types, and also that it will provide a pencil beam survey with integrated epoch photometry of all sources centred on the Andromeda Galaxy. That cone with 5.5-degree radius contains in total about 1 million sources both in M31 and the Milky Way. Also, Gisella presented her results for Cepheids and RR Lyrae, distance and H0 determinations she obtained using DR2.

After a short break, the session continued with another invited talk by Vardan Adibekyan (Porto) on frontiers of stellar spectroscopy and the precision – accuracy interface. At the beginning he explained the difference between precision and accuracy, why the accurate/precise parameters/abundances are important and he described main and less popular spectroscopy techniques. After showing the results he concluded that high precision parameters and abundances can be determined for solar-type stars using high quality spectra. Accuracy of these stellar parameters and abundances can be off by a small factor. High-quality spectroscopic information can help to improve the models, which will in turn help to improve the accuracy of spectroscopically derived parameters. Next on was Andrea Miglio's (Birmingham) invited talk was on stellar physics with combined astrometric and asteroseismic constraints, opportunities and caveats. In the introduction he explained basic principles of seismic inference and continued with

availability of the data. He described *Gaia's* contribution in asteroseismology and gave three examples: testing seismic determination of radius – he pointed out that seismic mass and radius are strongly correlated, testing models of stellar evolution and calibrating model parameters. At the end he added *Gaia's* influence on adding information about the kinematics.

First talk of the afternoon session was given by Marica Valentini (Potsdam) who continued the topic with combining asteroseismology, spectroscopy and *Gaia* for metal poor stars. She introduced the method for obtaining the ages of metal poor stars and also explained the identification of the good candidates. She presented her latest results and explained *Gaia's* contribution in her research with distance and proper motion data. Marica concluded her talk with listing the future developments in the field. Next, Diego Bossini (Porto) presented the work Bayesian tool PARAM that was utilised in conjunction with the *Gaia* parallaxes in order to derive new constraints for stellar ages and masses. Next speaker was Felix Iacob (Timisoara) whose topic was electron scattering in interstellar media. At the beginning, he gave a brief overview on plasma astrophysics and molecular species studied. He also pointed reasons why is the research in this field important and stressed importance of understanding the origin of matter, knowing the nature of the interstellar dust and chemical evolution. Felix also introduced methods and databases used. At the end he presented his results and announced the work in progress. Nicolina Pop's (Timisoara) was the final talk of the first day. Nicolina discussed the kinetic modelling in astrophysics. She presented her work on vibrational excitation and dissociative recombination of electrons with: H2 +, BeH+ and their isotopomers. First she introduced theoretical considerations, then continued with importance of rotational effects and later with H3+ dissociative recombination where she presented her latest work on three and two channel models. The first day was concluded with an open discussion of the topics that were presented.

Day Two

The first session of the second day was opened by Marcella Marconi (Naples) with her invited talk on theoretical constraints on the Hubble constant tension based on Cepheid models. She pointed out that the ESA *Gaia* mission will significantly contribute to reduce the uncertainties on the Cepheid-based local determinations of the Hubble Constant and the Hubble constant Tension and also for calibration of the extragalactic distance scale. Furthermore, she presented a theoretical approach to understand the residual systematics which is based on updated 1D nonlinear convective pulsation models. At the end of her talk she pointed another challenging aspect: the consistency between Cepheid and RR Lyrae distance scales. Richard Anderson (ESO) then presented his latest results related to the subject. He discussed the stellar association bias and how it affects H0. He concluded how there will be no solution to the discord related to H0 without improved systematic uncertainties. Next speaker was Louise Breuval (Paris) who presented her work on calibration of the Cepheid period-luminosity relation from *Gaia* DR2 visual binaries and its implications on the distance scale. She explained how, by using companion's parallaxes, it is possible to bypass the bias on *Gaia* DR2 Cepheid parallaxes and also calibrate the Leavitt law with non – HST (Hubble Space Telescope) parallaxes. Also, she described the re-scaling of H0 using *Gaia* DR2 parallaxes for Cepheid companions. In conclusion Louise added that they expect *Gaia* DR3 to provide a precise value of the parallaxes offset and also better Cepheids parallaxes. Last speaker before the short break was Giulia De Somma (Naples) whose talk was about modelling Galactic Cepheids in the *Gaia* photometric system. She explained how they obtained the individual distances and parallaxes from the *Gaia* light curves while obtaining the first theoretical PL, PLC, PW relations in the *Gaia* filters. At the end of her

talk she mentioned that these relations have been tested against *Gaia* DR2 parallaxes and that the results suggest a parallax offset for *Gaia* Cepheids consistent within the uncertainties with results published by other authors.

After a short break, Monika I. Jurković (Belgrade) gave a talk on Type II and Anomalous Cepheids in the Milky Way. She presented her results on Galactic kinematics for the *Gaia* DR2 sample of these types of stars where the results obtained for MW Bulge, Halo, Thick and Thin disc were presented separately. At the end she showed the distribution of Type II Cepheids in the Milky Way compared to their metallicity. Ivanka Stateva (Sofia) presented her results on modelling the binaries of W UMa type stars and *Gaia* distances. By using photometry and spectroscopy data together, they obtained simultaneous light curve and radial velocity curve solution which allowed them to determine the target distances from the global parameters of the targets. Calculated distances obtained of PHOEBE were compared to those of *Gaia* which proved the accuracy and adequacy of their model, used temperature and reliability of the PHOEBE itself. Last talk in the morning session was given by Krešimir Pavlovski (Zagreb) on quantitative spectroscopy of high mass stars in binary systems. His main topics were related to acquiring precise and accurate fundamental stellar quantities, discrepancy between dynamical and evolutionary mass of high-mass stars and the correlation with age and surface gravity. Furthermore, no pronounced changes in the surface CNO abundances are found, so far, for the high mass stars in binaries in a range of $M = 8 - 22\,M\odot$, contrary to single stars. An important question was raised as to what is suppressing the internal mixing and transport of CNO products to the surface layers in binary components.

First talk of the afternoon session was given by Ewa Niemczura (Wroclaw) who presented her results on chemically peculiar Am stars in the observations of TESS. Ewa described how the peculiarities arise from segregation of chemical elements under the influence of atomic transport processes. She used the data from TESS for variability, different spectroscopic surveys and *Gaia* data for parallaxes. Pablo Santos (Nice) presented his results on high-precision magnesium abundances in the metal-rich Galactic disk. They developed a method not depending on the stellar parameters that allowed them to use strong saturated lines, increasing the line-to-line precision. They also found decreasing trend in [Mg/Fe] even at supersolar metallicities, observational evidence of radial migration and no correlation [Mg/Fe] vs. Age. Tomislav Jurkić (Rijeka) gave a talk on symbiotic binaries in the era of large surveys. He explained the importance of the symbiotic stars in general and how *Gaia* distances, stellar parameters, radial velocities and photometry will greatly improve the research in this field. Stefan Cikota (Zagreb) then gave a review talk on determination of stellar radii by observing asteroid occultations with MAGIC. He pointed out that observations of diffraction fringes enable a direct measurement of the angular size of the star, even though that may be far below the imaging angular resolution limit of the telescope. He also presented his results on diffraction pattern for monochromatic and polychromatic stellar light and also his progress in convolution with 1D kernel to the fringes. Last talk of the second day was given by Milan S. Dimitrijević (Belgrade) and the topic was Stark broadening data for better stellar atmospheres and interiors modelling. He explained the needs for large line broadening data set and presented databases for Spectral Line Shapes, specially he presented the STARK-B database. The second day was concluded with a discussion session related to the presented topics.

Day Three

Last day of the workshop started with the invited talk of Léo Girardi (Padova) on stellar population models for the star counts in *Gaia* catalogue. He gave an overview of the

models that reproduce the stellar content of the Milky Way and a comparison with the *Gaia* DR2 HR diagram. Léo concluded that it is possible to make quite good models for star counts in *Gaia* DR2. He commented that with better modelling of parallax errors, IMF and extinction it could be possible to get the agreement <20% everywhere. A discussion of the current state of the models followed. Some important issues were pointed out (e.g. overshooting, rotation and asteroseismology of stars in field and clusters). He also pointed out that for binary evolution and TP-AGB, there is a clear avenue for improvement – GDR2 + data from present wide-area surveys of nearby galaxies are already being used. Matko Milin (Zagreb) gave a nice review talk about open problems in stellar nuclear astrophysics and also covered topics like instrumentation and techniques. He explained stellar nucleosynthesis from hydrogen, helium and carbon burning to the synthesis of the elements heavier than iron (S and R processes). At the end he gave prospects for future research. Since the next speaker, Petar Zečević (Zagreb) had to unexpectedly leave, Lovro Palaversa (Zagreb) presented his talk on the AXS, a framework for fast astronomical data processing based on Apache Spark. Although Spark already provides a significant fraction of functionality needed, AXS adds additional methods to make astronomers lives easier. It has two extensions to make cross matching and processing fast: specific data partitioning scheme and sort-merge join optimization. A plan for future developments was also laid out. The final speaker was Fran Jiménez-Esteban (Madrid) with his talk on determination of stellar physical parameters using VOSA. He explained in great detail how Virtual Observatory and its interfaces can enhance the research and how can they be used in the most efficient manner.

After a short break, there was a hands on session that concluded the workshop. Fran showed how VOSA works in practice. The participants followed a set of exercises that showcased the capabilities of VOSA.
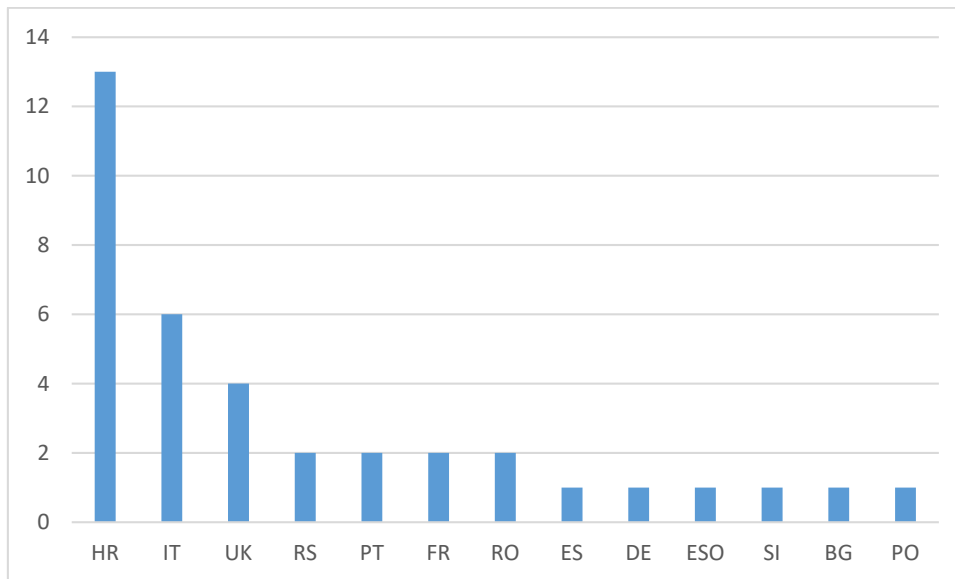
The workshop in numbers
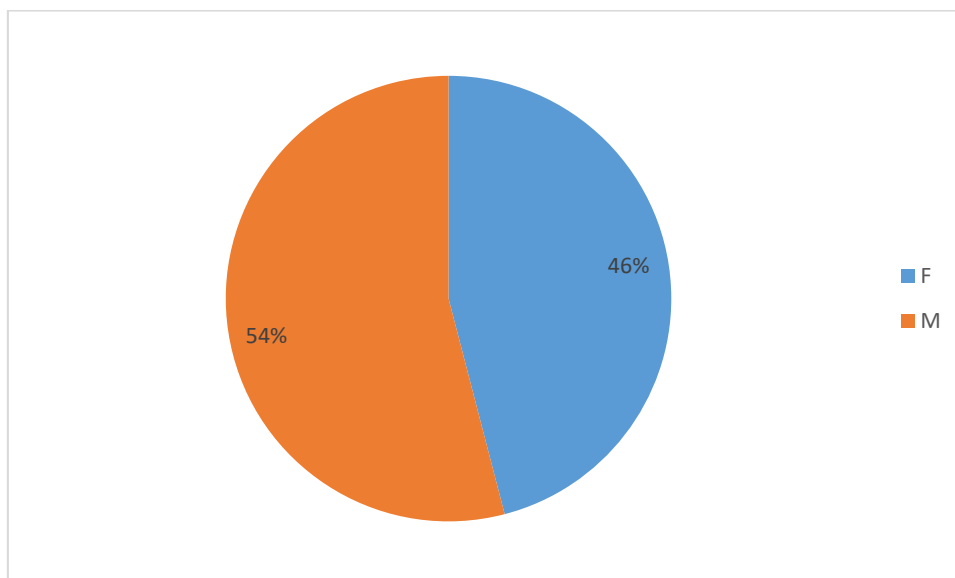
The workshop was attended by 37 researchers, 46% of them female.

The SOC and LOC had a 44 and a 50% of female researchers respectively.

From the total, 17 participants (46%, including invited speakers) had financial support by the COST Action.

There were researchers from 12 different countries in Europe (mostly Croatia).

There were 26 presentations. All female participants presented while 65% of male participants did. There were 6 Invited talks (33% female) and 20 Contributed talks (55% female).

Regarding career stage there were 10 PhD students and 6 Early Career Researchers (43% of young researchers).

Report prepared by Lovro Palaversa, Marta Fatović and Lola Balaguer-Núñez.