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**: Fundamental Stellar Parameters - Special Session @ EWASS 2013*

***Application Reference N°: 4729***

## 1) Summary

The ESF--sponsored meeting on ``Fundamental Stellar Parameters'' was held in Turku (Finland) on Monday July 8th, 2013 as a Special Session within the European Week of Astronomy and Space Science (EWASS 2013). The scientific program included 6 invited talks, 9 contributed talks and 13 posters.

The meeting gathered experts to review the latest results on fundamental stellar parameters from various techniques, in view of application to existing and upcoming Galactic surveys. The first segment of the meeting discussed ***Interferometry and Asteroseismology*** (invited speakers: Pierre Kervella, Orlagh Creevey, William Chaplin). The second segment presented the status of ***Photometric and Spectroscopic Scales*** (invited speaker: Andreas Korn). The third segment discussed ***Galactic Surveys and Reddening*** (invited speaker: Tomaz Zwitter). The meeting ended with a ***Conference Summary and Final Discussion*** led by Bengt Gustafsson (invited).

With over 30 scientists attending and contributing, the participation to the meeting fulfilled our expectations. We received very positive feedback from our colleagues about both the scope and the quality of the meeting. Although there will be no proceedings, we collected and made available on our website the PDF copies of the oral and poster presentations, as record and legacy of a fruitful meeting. All details about the program can be found on the web-site indicated below.

The sponsorship of the GREAT programme of the European Science Foundation is duly acknowledged on the web-site and was also acknowledged in the welcome speech introducing the meeting. The 3.000 EUR funding was used to support the attendance of the 6 invited speakers.

**Organizers** : Laura Portinari and Luca Casagrande
**Scientific Organizing Committee** : William Chaplin, Sofia Feltzing, Chris Flynn, Bengt Gustafsson, Pierre Kervella, Birgitta Nordström, Antonella Vallenari

*http://users.utu.fi/lporti/EWASS2013/Fundamental/SpecialSession3-EWASS2013.html*

## 2) Description of the scientific content of and discussions at the event

Extensive high precision surveys of stellar populations in our Galaxy (the CoRoT, Kepler and Gaia space missions, the Gaia-ESO spectroscopic Survey) are a major investment of the European astronomical Community for the next few years. To make best use of them, it is urgent to pin down the fundamental scale that translates stellar observables into physical parameters. Different methods and approaches might diverge by 100~K in temperature and 0.1~dex in metallicity, seriously limiting high accuracy stellar and Galactic astrophysics. Fundamental stellar parameters are also a crucial complementary information for asteroseismology, which is providing an entirely new view on stellar populations.

This meeting aimed to present the latest results on fundamental stellar parameters from different methods: spectroscopy, photometry, interferometry, asteroseismology; review their current precision and uncertainties; highlight remaining discrepancies and ways to settle them.

### *1st segment : Interferometry and Asteroseismology*

The meeting started by discussing the most direct and fundamental way to characterize stellar parameters: the measurement of their angular diameters via interferometry.

**Pierre Kervella (invited)** reviewed the extant capabilities of interferometry to determine stellar radii and masses. The current "hard" accuracy limit on the angular diameter $\theta$ is 0.2%; translating $\theta$ into radius requires the distance, adding an error of 0.2% for Hipparcos distances. This will not improve with Gaia: its bright magnitude limit ($V$=7) is too faint for interferometric targets.
Combining interferometry and asteroseismology can yield the stellar mass (e.g. 61 Cyg A&B). Interferometric radii can be compared to asteroseismic ones to test scaling relations (Procyon). Interferometry can also reconstruct the visual orbit of eclipsing binaries to provide the mass ratio and the distance (δ Vel).
The forefront facilities are CHARA and VLTI (with GRAVITY in 2014); not all classes of stars are however within the reach of current interferometers.

**Orlagh Creevey (invited)** highlighted how interferometry can provide effective temperatures but also gravities (via the radius), setting constraints on spectroscopic estimates, non-LTE effects etc.
Stellar models are found to overestimate temperatures and underestimate radii, especially for metal--poor stars. In a program with VEGA@CHARA dedicated to metal poor stars, the diameter of the benchmark giant HD122563 has been measured, indicating again a discrepancy with models and suggesting a change in mixing length with respect to the solar calibration ($\alpha<\alpha_\odot$). The same conclusion was reached from a sample of stars ascending the Red Giant Branch (Piau et al. 2011).

**Kaspar von Braun** reviewed the results of the extensive CHARA survey of Main Sequence stars by Boyajian et al. The $(V-K) - T_{\rm eff}$ relation does not depend on metallicity (within -0.5<[Fe/H]<0.5 dex). Their diameters have a typical uncertainty of 2%; the main uncertainty on the temperatures is from SED fitting of literature photometry, to recover the bolometric fluxes.
Finally, he presented results on some specific planet-host stars and their habitable zones (55 Cnc, GJ581, GJ436, GJ876).

**Gerard van Belle** warned against using “classic” radius–$T_{\rm eff}$ relations (e.g. Allen's reference book on Astronomical Quantities), superseded by modern interferometric results.
A massive amount of PTI data on 250 giant stars is now being analyzed, with expected precision of 1% in radii and 25–40 K in temperatures, and significant improvement e.g. on colour–$T_{\rm eff}$ relations. The sample includes a number of carbon stars, that appear to be non-spherical: possibly they are rapid rotators, spun-up by planet ingestion.
Finally he presented the upgrade of the Navy Precision Optical Interferometer.

In recent years asteroseismogical studies, originally devised to study the interior of our Sun, have extended to other stars: we can now probe stellar interiors and fundamental parameters via their oscillation properties.

**William Chaplin (invited)** presented the results and capabilities of asteroseismology from the Corot and Kepler missions (about 600 solar--type stars and 20.000 Red Giants). Frequency analysis allows, for instance, to discriminate H--shell burning giants from core--He burning giants.
Asteroseismic studies are possible out to few hundred pc. They can constrain spectroscopy, by comparing seismic gravities to spectroscopic ones. Independent estimates on $T_{\rm eff}$ and [Fe/H] are needed as input to aid the asteroseismic analysis.
For large samples (thousands of stars), detailed frequency analysis is unfeasible, but scaling relations have been thouroghly tested and can now be applied.
For planet-host stars, Transit Time Variations combined to asteroseismology is able to characterize also very complex, multiple systems.

**Pieter DeGroote** presented the open--source code Phoebe to generate consistent observables (multicolour photometry, radial velocities, light curves, spectroscopic line and Stokes profiles, interferometric visibilities) from stellar models including pulsations, spots, magnetic fields, multiplicity, differential rotation, accretion disks, planetary systems. Some example applications were illustrated.

**Piergiorgio Prada Moroni** presented the Scepter code to compute stellar parameters by interpolation over a grid of theoretical stellar models, and discussed the related uncertainties due to input physics: nuclear reaction cross sections, assumed $\Delta Y/\Delta Z$ law, or microscopic diffusion. Errors on masses and radii are around 1%; 4% on the mass of low mass stars, when neglecting microscopic diffusion.

## *2nd segment : Photometric and Spectroscopic Scales*

The meeting continued reviewing photometric and spectroscopic methods to determine stellar parameters : though less ``fundamental'' than the techniques discussed in the first segment, these methods are of paramount importance to analyze large sets of data and understand Galactic stellar populations at large.

**Luca Casagrande** reviewed the status of photometric methods, in particular the InfraRed Flux Method. Recent advancements, fostered by the all-sky homogeneous 2MASS NIR survey and the improved precision of the absolute flux calibration, render this technique competitive in setting stellar diameters and temperatures at an accuracy of 1%.

**Juliet Datson** presented a new method to test the calibration of a catalogue, based on strictly differential analysis of the spectra of Sun-like stars versus a reference solar spectrum. Devised and applied specifically to the Geneva--Copenhagen Survey – revealing an offset in its temperature and metallicity calibration – the method can be extended to other catalogues and surveys, as well as to other benchmark stars besides the Sun.

**Andreas Korn (invited)** reviewed the current status and strategies to derive parameters for stellar populations in the Gaia and GES Galactic surveys. With a resolution of 3700 at magnitudes fainter than V=10, GAIA is not suited to derive detailed chemical information: it will have a precision of only 200 K in temperature and 0.2 dex in metallicity. Hence it is being complemented by the Gaia-ESO Survey (GES) of 5000 stars in the Galactic plane at high resolution, and 100.000 stars at higher latitudes at medium resolution.
The data will be analysed with a variety of methods: classic Equivalent Width analysis, spectral synthesis, and projection onto pre-computed spectral grids (MATISSE). These are independently applied by different groups, based on a homogeneoud line list and stellar atmosphere models, for the sake of comparison. Results appear to converge when S/N > 30. The calibration is based on 40 FGKM and 20 OB ”benchmark stars” having fundamental parameters from interferometry and asteroseismology.
For the future, 4MOST@ESO--VISTA is foreseen to yield even more radial velocity and chemical abundance data, to complement the Gaia survey.

**Gregory Ruchti** presented a spectroscopic analysis of data from the RAVE survey, comparing the standard LTE approach on the ionization–excitation balance of iron lines, to non-LTE analysis. NLTE effects are non-negligible, but what really drives the results is the adopted $T_{\rm eff}$ scale, especially in the metal-poor regime; temperatures based on Balmer lines proved to give the best results.

**Remo Collet** presented the new grid of 200 stellar model atmospheres from the Stagger 3D code, and discussed the differences with respect to standard 1D models. Important discrepancies appear at low metallicities due to different stratification in the atmosphere, leading to differences of 0.2 dex in the estimated [Fe/H]. Molecular bands are especially affected, with difference of up to 1 dex in the resulting abundance.
The Stagger team will release both the full 3D model spectra, and temperature stratifications to be implemented in standard 1D model atmospheres.

### 3rd segment : Galactic Surveys and Reddening

The last segment was dedicated to discuss data treatment in Galactic surveys, and the problem of reddening determination in particular.

**Tomaz Zwitter (invited)** reviewed the experience gained with the RAVE survey. The FIR−based Schlegel map provides only an upper limit for reddening, which is significant also out of the Galactic plane, and is not easily corrected for, from simple two-colour plots. Reddening is also an opportunity to learn about the InterStellar Medium.
The best method to estimate reddening is a Bayesian analysis combining spectroscopic temperature (unaffected by reddening) to photometric colours and a distance prior.
Some Diffuse Interstellar Bands (DIB) are correlated with reddening and can provide an alternative estimate.
For future surveys, the experience with RAVE indicates that only 90\% of stars can be classified as “normal”; 10% is “peculiar” due to binarity or chromospheric activity

producing strong emission lines. Galactic surveys thus allow also a large-scale mapping of the ISM and population studies of stellar activity.

**Ralph Schönrich** argued that modern surveys need probabilistic Bayesian analysis to derive all stellar parameters in a self-consistent way and avoid systematic biases. For example, knowledge of temperature and gravity already sets the (most probable) metallicity, from the density of isochrones in the temperature–metallicity plane.
He presented a public platform for Bayesian analysis.

## ***Conference Summary***

**Bengt Gustafsson (invited)** presented the summary of the meeting. He remarked the need to derive stellar parameters to an accuracy of 1% or better, in order to fully harvest the scientific potential of Galactic studies. Model limitations are what currently sets the accuracy today; improving on this will need very accurate work on a number of selected stars.
As large datasets are to be analyzed with automatic methods, it is imperative that they are able to handle anomalies.
Finally, a number of basic assumptions underlying our current models may be misplaced, for instance stars may not be fully mixed when they are born.

## ***Posters***

There were 13 posters presented at the meeting, on display for the whole week of EWASS. The posters were about : codes and methods to determine chemical abundances (**Corrado Boeche**), the helium content in globular clusters and in nearby stars (**Marcella Di Criscienzo, Joao Fernandes**), stellar parameters and chemical abundances in specific stars or clusters **(Natalia Drake, Leticia Ferreira, O.J. Katrime Santrich, M.M. Rojas Garcia, Sergey Zubarev)**, novel techniques to improve interferometric measurements **(Anders Jorgensen)**, photometric methods to estimate stellar parameters (Nadia Kaltcheva, Laura Portinari), mass determination methods (**Fernando Pinheiro**).

## 3) Assessment of the results and impact of the event on the future directions of the field

The meeting fulfilled our goal to gather over 30 experts of different sub-fields, to discuss the status and perspectives of various techniques to determine Fundamental Stellar Parameters. We received very positive feedback from the participants, about both the scope and the quality of the meeting; one colleague praised it as ”a marker for emphasizing the importance of fundamental parameters”. It was particularly important to raise, among the larger community involved in Galactic surveys, the awareness of the tremendous potential of asteroseismology, so far championed by relatively small groups.

## Final discussion

The meeting closed with a lively discussion chaired by Bengt Gustafsson, who asked the attendees to comment on the most striking thing that, in their opinion, emerged over the meeting.
There was a discussion (Korn, Casagrande, Gustafsson) whether stellar parameters can really be set at 1% level, as the results from different groups differ by much more than that; and on whether Balmer line analysis can ever yield a 1% accuracy in absolute temperatures (in relative temperatures, such accuracy is already achieved).
William Chaplin reminded the basic importance of steadily comparing results from independent groups, as different results can be achieved even when adopting the same input models and methods.
Interferometric experts (van Belle and von Braun) remarked that, even with excellent angular diameters, a 10 K accuracy in temperature is hardly achieved due to uncertainties in the absolute fluxes; and lamented the scarcity of high quality, modern photometric data available for the bright stars targeted with interferometry. Their wish is to abandon the obsolete magnitude scale in favour of actual physical fluxes.
To the general dismay, it emerged that the Gaia mission will not improve the accuracy of fundamental parameters for nearby stars, as its bright magnitude limit is too faint for this purpose. Orlagh Creevey remarked, more in general, upon the crucial gap between bright nearby stars with well-determined parameters, and the fainter stellar populations typically sampled by modern Galactic surveys.
Gustafsson concluded that, when aiming at a 1% accuracy, we should be aware that even within stellar clusters, chemical abundances may differ by 0.01 dex due to physical effects such as diffusion, stellar activity etc. He challenged the paradigm that stars with same temperature, gravity, [Fe/H] and [α/Fe], would have the same stellar continuum : age and activity may also influence the Spectral Energy Distribution and this still needs to be tested.

## Conclusions

We exited the meeting with a much raised awareness of the current achievements and limitations in the various methods; where progress is foreseen and what instead impedes advancement in each technique. Determining fundamental parameters at a 1% accuracy appears within reach, but that will prompt us with new challenges for additional physical effects come into play at such level of accuracy. Also, particular care must be taken, when linking and comparing results from various methods that probe different ranges and objects, with different systematics; and especially to secure the calibration of modern surveys onto well--studied benchmarks.

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

### Annex 4a: Programme of the meeting

# Fundamental Stellar Parameters

## Special Session 3 @ EWASS 2013

Monday, July 8th (11.45-18.00)

| | | |
|---|---|---|
| 11.45-11.50 | Welcome | |
| **Interferometry and Asteroseismology** | | |
| 11:50-12:10 | **Pierre Kervella (I)** | *Stellar radii and masses from long-baseline interferometry* |
| 12.10-12.30 | **Orlagh Creevey (I)** | *Improving fundamental parameters of stars through stellar modelling with interferometry* |
| 12.30-12.45 | Kaspar von Braun | *Fundamental Stellar Parameters of Main Sequence Stars with an Eye on Exoplanets* |
| 12.45-13.00 | Gerard van Belle | *The PTI Giant Star Survey* |
| 13.00-13.20 | **William Chaplin (I)** | *Asteroseismic estimation of fundamental stellar properties* |
| **13:20-14:30** | *Lunch* | |
| 14.30-14.45 | Pieter DeGroote | *Consistent modeling of stars* |
| 14.45-15.00 | Pier Giorgio Prada Moroni | *Stellar models uncertainties and grid-based estimates of stellar parameters* |
| **Photometric and Spectroscopic Scales** | | |
| 15:00-15:20 | Luca Casagrande | *Fundamental stellar parameters from photometry* |
| 15.20-15.35 | Juliet Datson | *Testing the temperature and metallicity scales* |
| 15.35-15.55 | **Andreas Korn (I)** | *Stellar parameters in the Gaia-ESO and Gaia surveys* |
| 15.55-16.10 | Gregory Ruchti | *High-Precision Spectroscopy and Fundamental Parameters of Cool Stars* |
| **16:10-16:30** | *Coffee break* | |
| 16.30-16.45 | Remo Collet | *The Stagger-Grid project: a grid of 3D model stellar atmospheres for high-precision spectroscopy* |

| Galactic Surveys and Reddening | | |
|---|---|---|
| 16.45-17.05 | **Tomaz Zwitter (I)** | *Galactic Spectroscopic Surveys, stellar parameters and reddening* |
| 17.05-17.20 | Ralph Schönrich | *Probabilistic methods of stellar parameter determination* |
| 17:20-17:30 | **Bengt Gustafsson (I)** | *Conference Summary* |
| **17:30-18:00** | **Final discussion** | |

## POSTERS

| | |
|---|---|
| Corrado Boeche | *SPACE: a new code for stellar parameters and chemical abundances estimations* |
| Marcella Di Criscienzo | *The initial Helium content of galactic globular cluster stars* |
| Natalia Drake | *Chemically-peculiar low-metallicity stars BD+03 2688 and HD 55496: fundamental parameters, chemical abundances and evolution states* |
| João Fernandes | *DY/DZ from binary stars: metallicity dependence and helium saturation* |
| Leticia Ferreira | *Chemical Abundance Scale in Giant and Dwarf stars* |
| Anders Jorgensen | *High-Precision Stellar Diameters from Coherent Integration of NPOI Data* |
| Nadia Kaltcheva | *A precision photometry study of Galactic star-forming sites* |
| O.J. Katime Santrich | *Giant stars in the young open cluster NGC 3114: fundamental parameters and chemical abundances* |
| Fernando Pinheiro | *Mass inference of solar type stars: comparison between methods* |
| Laura Portinari | *The importance of appearing right* |
| M.M. Rojas Garcia | *Fundamental parameters and abundance patterns of a sample of debris-disks and planet-hosting stars* |
| Sergey Zubarev | *The effective temperature and entropy production as a function of star age* |
| Sergey Zubarev | *Homogenized HR diagram for the open cluster NGC 188* |

**Annex 4b: Full list of speakers and participants**

**Speakers :**

| | |
|---|---|
| Luca Casagrande (organizer) | Australian National University, Canberra |
| William Chaplin (I) | University of Birmingham, UK |
| Remo Collet | Australian National University, Canberra |
| Orlagh Creevey (I) | Institut d'Astrophysique Spatiale, Paris-Sud, France |
| Juliet Datson | Tuorla Observatory, University of Turku, Finland |
| Pieter DeGroote | Instituut voor Sterrenkunde, KULeuven, Belgium |
| Bengt Gustafsson (I) | Uppsala University, Sweden |
| Pierre Kervella (I) | LESIA, Observatoire de Paris, France |
| Andreas Korn (I) | Uppsala University, Sweden |
| Pier Giorgio Prada Moroni | Università di Pisa, Italy |
| Gregory Ruchti | Lund Observatory, Sweden |
| Ralph Schönrich | Ohio State University, Columbus, USA |
| Gerard van Belle | Lowell Observatory, Flagstaff, USA |
| Kaspar von Braun | Max-Planck-Institute für Astronomie, Germany |
| Tomaz Zwitter (I) | University of Ljubljana, Slovenia |

**Other participants :**

| | |
|---|---|
| Thomas Bensby | Lund Observatory, Sweden |
| Corrado Boeche | Astronomisches Rechen-Institut, Germany |
| Piercarlo Bonifacio | GEPI, Observatoire de Paris, France |
| Elisabetta Caffau | ZAH, Landessternwarte, Heidelberg, Germany |
| Marcella Di Criscienzo | INAF-Osservatorio di Capodimonte, Napoli, Italy |
| Natalia Drake | St. Petersburg State University, Russia |
| Leticia Dutra Ferreira | European Southern Observatory, Germany |
| Sofia Feltzing | Lund Observatory, Sweden |
| Joao Fernandes | Universidade de Coimbra, Portugal |
| Jussi Harmanen | Tuorla Observatory, University of Turku, Finland |
| Anders Jorgensen | New Mexico Tech, Socorro, USA |
| Nadia Kaltcheva | University of Wisconsin Oshkosh, USA |
| Birgitta Nordström | Copenhagen University, Denmark |
| Fernando Pinheiro | Universidade de Coimbra, Portugal |
| Laura Portinari (organizer) | Tuorla Observatory, University of Turku, Finland |
| Sergey Zubarev | Ural Federal University, Ekaterinburg, Russia |