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**: Helios and Helium : what is wrong with them ?*

***Application Reference N°:* 5374**

1) Summary

The ESF-sponsored meeting "Helios and Helium : what is wrong with them?" was held in Geneva (Switzerland) on Wednesday-Thursday 2-3 July 2014 as a Special Session within the European Week of Astronomy and Space Science (EWASS 2014). The scientific program included 7 invited talks and 11 contributed talks.

The meeting gathered experts from various fields, to discuss synergies between different techniques at the dawn of the Gaia era, as well as advances and puzzles in our understanding of the Sun, Main Sequence stars and their helium content. The first part of the meeting, on Wednesday July 2nd, was dedicated to ***Gaia-asteroseismology synergies*** (invited speakers: Antonella Vallenari and Andrea Miglio) and was the natural extension of the preceding Gaia Symposium. On Thursday, July 3rd, we discussed ***Asteroseismology of low mass stars*** (invited speaker: Aldo Serenelli), ***Low mass stellar models*** (invited speaker: Santi Cassisi) and ***Stellar model atmospheres and chemical abundances*** (invited speakers: Remo Collet and Maria Fernanda Nieva). The meeting ended with a **Summary and Discussion** led by Achim Weiss (invited).

With about 30 attendees, the participation to the meeting fulfilled our expectations. We received positive feedback from our colleagues about the scope and the quality of the meeting. Although there will be no proceedings, our web-site will collect the PDF copies of the 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 invited speakers, and of a young PhD.

Organizers : Laura Portinari, Luca Casagrande and Orlagh Creevey
Scientific Organizing Committee : Martin Asplund, William Chaplin, Andreas Korn, Antonella Vallenari, Achim Weiss

http://eas.unige.ch/EWASS2014/session_display.jsp?id=Sp2

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

We are living exciting times for stellar and Galactic astrophysics, aided by present and upcoming space borne missions, and theoretical advances.

Realistic 3D model atmospheres are drastically changing our view on the outer layers of stars, while asteroseismology is routinely using global oscillation frequencies to infer their fundamental properties. Both fields are proving very successful, yet not all pieces of the puzzle are falling into place. The latest solar abundance determinations wreak havoc with the standard solar model; while asteroseismology cannot fit moderately metal poor Main Sequence stars, unless using unphysically low helium abundances. This conundrum was already suggested by older studies of the fine structure of the HR diagram in the low Main Sequence.

The situation is especially worrying since Main Sequence models are the simplest and traditionally most secure ones. Stellar models, via HR diagrams and population synthesis, are one main tool to interpret the Milky Way and external galaxies out to cosmological distances. This is particularly important at the dawn of the Gaia Era, where the synergy between different techniques has the potential of delivering exquisite stellar parameters, and reliable models are thus needed.

The purpose of this meeting was to gather experts from different fields, to highlight successes, discuss problems and failures as well as new ideas to proceed forward.

1st segment : Gaia-Asteroseismology synergies

The meeting started, following the Gaia symposium, by discussing the perspectives of combining Gaia data with asteroseismic studies, to fully characterize stellar populations.

Antonella Vallenari (invited) reviewed the status of the Gaia commissioning phase, and the expected Gaia deliveries for bright stars, in terms of photometry, astrometry, and spectroscopy. The nominal bright magnitude limit for Gaia is G=5.7 (H_P =6), limiting the detection up to G=3. Bright stars are observed through gates as they are saturated. The first Gaia data release is expected in mid 2016; the spectra will be released at the end of the mission. 2000 bright stars will be observed.
The classification is based on photometry, spectrometry and parallaxes. Multi-library stellar templates have been computed (MARCS, PHOENIX, BASEL). The Gaia catalogue validation procedure includes internal validation (correspondence of photometric and spectroscopic classification) and validation upon open clusters.

Andreas Korn reviewed the tools developed in the Gaia Coordination Unit 8 to derive astrophysical parameters of single stars, especially of F, G, K type. Constraints on some parameters (e.g. log$g$) will require parallaxes and/or additional (non-Gaia) data. Parameter accuracy is secured by extensive calibrations, relying also on seismic results. *Æneas*, a Bayesian analysis tool including HR diagram priors, will provide parameters with accuracy ΔT_{eff}=100-200 K, Δ[Fe/H] and $\Delta\log g$ =0.2-0.3 dex and extinction ΔA=0.1 mag. Stellar parameters can be obtained for $G\leq13$ (10^6 stars) and radial velocities for $G\leq15$ (10^7 stars).
The limited spectroscopic capabilities of Gaia will be complemented by ground-based surveys: GES, and the future WEAVE and 4MOST (northern and southern hemisphere, respectively) will observe 10-20 million stars down to V≈17 at $R\approx150.000$.

Andrea Miglio (invited) discussed the complementary role of astrometric and asteroseismic constraints. Combining Gaia distances with asteroseismic ages is the key

to reconstruct the formation and evolution of the Milky Way. The *Plato* mission, observing 10^6 stars over 50% of the sky, will be the asteroseismic complement of Gaia.
Seismology *per se* yields a highly correlated mass/radius solution; Gaia distances + angular diameters will provide radiii and solve the degeneracy.
As to helium measurements, the helium content of the Sun is obtained from an acoustic glitch, related to the helium ionization layer. For Kepler stars, the data are not good enough for that (with the exception, so far, of one Red Giant in a cluster) and helium is obtained via global oscillation modelling.
The *AsteroSTEP* European program is dedicated to apply seismic results to stellar population studies.

Orlagh Creevey discussed how Gaia distances will provide stellar luminosities and radii, that combined with asteroseismic data can disentangle mass and initial helium abundance, to better determine mass and age. The *Asteroseismic Modelling Portal (AMP)* has been developed to analyze homogeneously large numbers of stars.

2nd segment : Asteroseismology of low mass stars

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

Aldo Serenelli (invited) reviewed the determination of the surface abundance of helium in the Sun, from the location of the partial HeII ionization zone, that causes a depression in the Γ1 adiabatic exponent, and an acoustic glitch. The resulting Y_{sur}=0.246-0.249 indicates that helium has been depleted by diffusion. The corresponding initial helium abundance depends on the solar model. With “classic” solar abundances (Grevesse & Sauval), Y_{sur}=0.2485 and Y_{ini}=0.2724; with the Asplund abundances, Y_{sur}=0.2319 and Y_{ini}=0.2620. The scatter in the Y_{sur}-Y_{ini} relation produces a 3% uncertainty on Y_{ini}.
For other stars, grid-based fits to the global oscillation properties currently lead to "best-fit" solutions with a clear deficit in helium abundance (often sub-primordial). More direct techniques are based on frequency modulations caused by acoustic glitches, analogous to those used for the Sun. This approach was applied to the 16 Cyg system; acoustic glitches are now being studied in other Kepler stars.

Patrick Eggenberger presented the modelling and effects of transport processes of angular momentum and chemicals in the radiative zones of stars; and the constraints provided by asteroseismology. Rotation counteracts atomic diffusion, and the rotation rates of young solar type stars can help constrain the efficiency of the process. Asteroseismology is investigating internal differential rotation, finding that slow rotators present strong differential rotation, while fast rotators have little differential rotation.

Laura Portinari reviewed past studies of helium abundance and $\Delta Y/\Delta Z$ from the broadening of the low Main Sequence in the HR diagram. The results anticipated the "sub-primordial helium problem" now encountered in asteroseismology. Various solutions for stellar models discussed at the time (diffusion, mixing length, boundary conditions, opacities) are the subject of this meeting.

3rd segment : Low mass stellar models

The meeting continued discussing status and perspectives of low mass stellar models.

Santi Cassisi (invited) reviewed the state of the art of low-mass Main Sequence stellar models, emphasizing the main uncertainties still affecting the them. The Equation Of

State affects stars with M_V=5-7; uncertainties in opacity computations and boundary conditions are cancelled out by the solar calibration, but could still affect (differentially) low metallicity models. Diffusion could be less efficient at low Z, as found by globular cluster studies; radiative acceleration seems especially efficient at low Z. He concluded that nothing is wrong with helium, as there is ample room to improve the models.

Stefano Pasetto presented a new analytical formulation of stellar convection that does not require the mixing length parameter. The motion of stellar convective cells is expressed in their non-inertial comoving frame, in a non-local and time dependent formalism. The analytical solution follows from the physical behaviour of the cells themselves and the surrounding medium, without any free parameter. The predictions of the new theory compare well with those of the mixing-length paradigm.

4th segment : Stellar model atmospheres and chemical abundances

The last segment of the meeting was dedicated to stellar model atmospheres (also as boundary conditions for stellar models) and the related chemical abundance determinations, especially for helium.

Remo Collet (invited) reviewed the status of 3D stellar atmosphere models for late type dwarfs. 3D, time dependent simulations solve the hydrodynamic conservation equations coupled with a realistic treatment of radiative transfer, and follow convection with no tunable parameters. Cooling at the surface triggers convection, that quickly reaches a quasi steady-state regime. 3D models provide self-consistent wavelength shifts and line asymmetries. The difference between 3D and 1D stratification is significant at low metallicities, reaching a factor of 10-20 around [Fe/H]=-3.
For the Sun, 3D models result in far better limb-darkening corrections and line profiles than 1D models. Different 3D models (e.g. *STAGGER* vs. *COB^{5}OLD*), albeit yielding different metallicities, agree in the temperature stratification. Mean stratifications from 3D simulations can be implemented into 1D stellar models.

Zazralt Magic presented the *STAGGER* grid of 3D atmosphere models for late-type stars, and its application to improve stellar structure and evolutionary models. Convection consists of hot, rarefied bulk upflows and cool, dense, narrow downdrafts. 3D simulations consistently model undershooting and the amplitude and shape of the super-adiabatic region. The *STAGGER* grid was used to calibrate the mixing length free parameter α and its variations: α increases at decreasing T_{eff} (i.e. in cool dwarfs).

Hans Ludwig presented the work of the *COB^{5}OLD* team on the oxygen triplet in the solar spectrum. The derived abundance A(O) correlates with the S_H parameter of neutral collisions. The Asplund group finds A(O)=8.68 with S_H =0.85, while the *COB^{5}OLD* team derives A(O)=8.79 with S_H=2. Horizontal homogenization also induces a difference between “true” value A(O)=8.79 and averaged <3D> value A(O)=8.61. 1D-NLTE analysis is inadequate for the oxygen triplet, hampering studies of Galactic chemical evolution.

Karin Lind discussed NLTE effects on the helium lines of metal-poor stars. Horizontal Branch stars are hot enough to measure the NIR HeI line at 5876 Å. However, NLTE effects are very large, deepening the core of the line and decreasing the derived abundance. NLTE effects increase with T_{eff} (due to the larger UV flux) and the NLTE correction is up to ΔY=0.1; its uncertainty, dominated by H bound-bound collisions (S_H factor), is ΔY~0.02. NLTE effects are much smaller in bluer lines (e.g. He lines around 4000 Å) that originate in deeper layers of the atmosphere.

Sofia Alexeeva discussed carbon abundances based on 1D, NLTE CI line formation. NLTE leads to stronger CI lines, and thus lower C abundances. NLTE corrections do not exceed 0.41 in absolute value for the Sun, are less significant in metal-poor dwarfs (HD84937), and negligible in cool giants (HD122563). The atomic and molecular lines (CH and C_2) give consistent abundances. For the Sun: logε(C)=8.43±0.04.

Maria Fernanda Nieva (invited) reviewed the current status of helium abundances in massive stars of the solar vicinity from the literature and own work. Sample selection is crucial to obtain results meaningful for Galactic chemical evolution: the useful T_{eff} range is 15-35.000 K (4-20 $M_{\odot}$), to avoid large mass loss. Once binaries, chemically peculiar stars, fast rotators etc. are properly excluded, only 40% of the observed stars are useful for He determinations. As to spectroscopic analysis, 1D-LTE atmospheres + NLTE line formation is adequate for OB stars. The procedure consists of a preliminary fit based on only H and He, and then a full fit including all the elements. Consistency tests are made comparing spectroscopic versus astrometric (Hipparcos) distances, and the mass-radius and mass-luminosity relations. Internal mixing of helium and CNO elements alters ε(He) by 0.2 dex; these objects must be also excluded. Altogether, the present-day helium abundance in massive stars is estimated to be Y=0.276.

Antonino Milone reviewed the helium abundance of multiple populations in Globular Clusters. Combination of ultraviolet, visual, and near-infrared photometry has revealed that the CMD of any globular cluster is made of interwined sequences (two to five or more), that can be followed continuously from the bottom of the Main Sequence up to the Subgiant Branch, the Red Giant Branch and even the Horizontal Branch. They correspond to generations of star with different abundance of helium and light elements, but very similar age as the turn-off is typically very narrow.
Robust helium estimates from MS splitting are obtained by constraining metallicities from UV and FUV photometry (affected by molecular lines), and then analyzing optical photometry which is sensitive to Y. The helium range ΔY correlates with the mass of the cluster; in extreme cases ΔY~0.13 and the He-rich population approaches Y~0.40.

Anna Marino reviewed the impact of helium on the second parameter problem of the Horizontal Branch morphology. For M4, a connection exists between the Na-O anticorrelation and the distribution along the HB: stars on the blue side of the RR-Lyrae gap are Na enhanced, and stars on the red side are both Na-rich and Na-poor. The Na-rich material has undergone high-temperature H-burning, and is also enriched in Helium; indeed, He-enhanced stars are expected to populate the blue end of the HB. FLAMES/GIRAFFE spectra have provided direct empirical evidence for this: in NGC2808 the blue HB is populated exclusively by very He-rich stars with Y=0.34±0.01.

Conference Summary

Achim Weiss (invited) presented the conference summary, emphasizing the interrelation between seismology, spectroscopy, stellar structure and atmosphere models, and atomic physics. He reviewed a collection of He abundance measurements in the literature, from various methods. The results vary widely: for instance recent helium indicators related to the RGB bump, can lead to high Y values in the Bulge (Y~0.4; Nataf et al. 2011, 2012) to very low (sub-primordial) Y values in globular clusters (Y=0.2, Troisi et al. 2011). The “R factor” is also used but its physical meaning and calibration should be rediscussed based on updated models. He concluded that nothing is wrong with helium: differences are due to the use different methods and the need to improve the theory and models behind them.

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

The meeting fulfilled our goal to gather about 30 experts of different sub-fields, to discuss synergies of various techniques (especially Gaia deliveries and asteroseismic results) to characterize stellar parameters and stellar populations, and their helium content. We revised the status and limits of asteroseismology, low mass stellar models, model atmospheres and spectroscopic chemical abundance analysis.
We received positive feedback from the participants, about both the quality and the scope of the meeting, as the “helium problem” is rarely discussed. It was particularly important to convey to the community at large, the present and future effective capabilities of asteroseismic techniques, to measure the helium content – along with other stellar parameters.
Being asked by our colleagues “What is next year's topic?” (after Fundamental Stellar Parameters at EWASS 2013, and Helios and Helium at EWASS 2014) was to us the best acknowledgement of the success and interest of the meeting.

Final discussion

The meeting closed with a discussion chaired by Achim Weiss. The meeting clearly highlighted the interrelation between seismology, spectroscopy, stellar structure and atmosphere models, and atomic physics. Synergy is a circular process: advances in one field affect all the other fields.
The assembly convened that it is often unclear whether published chemical abundances are to be considered absolute or relative (solar-scaled) values. Solar-scaled abundances or parameters are affected by the Solar Model problem, which still persists with the revised lower abundances. Also, the scaling from observed metallicity [Fe/H] to the theoretical global metallicity Z is often a source of confusion. More clarity in future literature, on all these points, would be beneficial.
Spectroscopic chemical abundances are more sensitive to NLTE effects in 3D than in 1D models; therefore it is not obvious that 3D models are always an advantage over 1D models, as sometimes the results of simple 1D+LTE treatment is close to 3D+NLTE.
Andrea Miglio underlined that proper Y measurements from asteroseismology are those based on glitch-dependent frequencies, not on global fitting. Giants are promising targets, and they are not affected by diffusion. As to dwarfs, many will be observed by Plato but it is unclear if the quality of the data will allow helium measurements.

Conclusions

Helium, in spite of being the second most abundant element in the Universe, is very elusive and in most cases only indirect approaches can be used to measure it. The discrepancies in the results, provocatively termed as “the helium problem”, in fact highlight the need to improve on the basic modelling underlying the various methods.
We exited the meeting with a much raised awareness of the current achievements and limitations in the various methods; and of where progress is foreseen, either internally within a method, or in combination with other techniques.

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

Annex 4a: Programme of the meeting

Helios and Helium : what is wrong with them ?

Special Session 2 @EWASS 2014

Wednesday 2nd of July		
16.00-16.05	Welcome	
	16.05-17.40 - Chair : Joris De Ridder	
Gaia-Asteroseismology synergies		
16.05-16.30	**Antonella Vallenari (I)**	*Bright stars in Gaia*
16.30-16.45	Andreas Korn	*Astrophysical parameters from Gaia*
16.45-17.10	**Andrea Miglio (I)**	*Synergy between Asteroseismology and Gaia*
17.10-17.25	Orlagh Creevey	*Gaia, asteroseismology and initial helium abundance*
17.25-17.40	*Open discussion*	

Thursday 3rd of July		
	11.00-12.45 - Chair : Frederic Thevenin	
Asteroseismology of low mass stars		
11.00-11.30	**Aldo Serenelli (I)**	*Asteroseismic studies of the Sun and Main Sequence stars*
11.30-11.45	Patrick Eggenberger	*Transport processes in low mass stars constrained by asteroseismic measurements*
11.45-12.00	Laura Portinari	*Helium abundance and DY/DZ in low Main Sequence stars*
Low mass stellar models		
12.00-12.30	**Santi Cassisi (I)**	*Low-mass Main Sequence Stars: the theoretical framework*
12.30-12.45	Stefano Pasetto	*Theory of stellar convection: Removing the Mixing-Length Parameter*
12:45-14:00	*Lunch*	
	14.00-15.30 - Chair : Ulrike Heiter	
Stellar model atmospheres and chemical abundances		
14:00-14:30	**Remo Collet (I)**	*Three-dimensional model stellar atmospheres: a review of the current status and a look into the next challenges*
14.30-14.45	Zazralt Magic	*Steps towards improved stellar structure and evolutionary models*
14.45-15.00	Hans-G. Ludwig	*The photospheric oxygen abundance of the Sun according to CO5BOLD*
15.00-15.15	Karin Lind	*NLTE effects in the Sun and metal-poor stars*
15.15-15.30	Sofya Alexeeva	*Carbon abundances on the basis of 1D model atmospheres. Non-LTE line formation of C I*
15:30-16:00	*Coffee break*	
	16.00-17.30 - Chair : Corinne Charbonnel	
16.00-16.30	**Maria Fernanda Nieva (I)**	*Present-day helium abundances in the Solar Vicinity*
16.30-16.45	Antonino Milone	*The helium abundance of multiple populations in Globular Clusters*
16.45-17.00	Anna Marino	*Second parameter problem on the horizontal branch morphology in globular clusters: the impact of helium*
17.00-17.30	**Achim Weiss (I)**	*Summary and Discussion*

Annex 4b: Full list of speakers and participants

Speakers :

Sofya Alexeeva	Institute of Astronomy RAS, Moscow, Russia
Santi Cassisi (I)	INAF – Osservatorio Astronomico di Teramo, Italy
Remo Collet (I)	Australian National University, Canberra
Orlagh Creevey (organizer)	Institut d'Astrophysique Spatiale, Paris-Sud, France
Patrick Eggenberger	Observatoire de Geneve, Switzerland
Andreas Korn	Uppsala University, Sweden
Karin Lind	Uppsala University, Sweden
Hans-G. Ludwig	Landesternwarte, Universität Heidelberg, Germany
Zazralt Magic	Max-Planck Institut für Astrophysik, Germany
Anna Marino	Australian National University, Canberra
Andrea Miglio (I)	University of Birmingham, UK
Antonino Milone	Australian National University, Canberra
Maria Fernanda Nieva (I)	University of Innsbruck, Austria
Stefano Pasetto	University College London, UK
Laura Portinari (organizer)	Tuorla Observatory, University of Turku, Finland
Aldo Serenelli (I)	Institute of Space Sciences, Bellaterra, Spain
Antonella Vallenari (I)	INAF – Osservatorio Astronomico di Padova, Italy
Achim Weiss (I)	Max-Planck Institut für Astrophysik, Germany

Other participants :

Conny Aerts	Katholieke Universiteit Leuven, Belgium
Corrado Boeche	Astronomisches Rechen-Institut, Germany
Luca Casagrande (organizer)	Australian National University, Canberra
Corinne Charbonnel	Observatoire de Geneve, Switzerland
Joris De Ridder	Katholieke Universiteit Leuven, Belgium
Joao Fernandes	Universidade de Coimbra, Portugal
Ulrike Heiter	Uppsala University, Sweden
Paula Jofre	Institute of Astronomy, Cambridge, UK
Norbert Przybilla	University of Innsbruck, Austria
Victor Silva Aguirre	Aarhus University, Denmark
Frederic Thevenin	Observatoire de la Côte d'Azur, France
Eline Tolstoy	Kapteyn Astronomical Institute, Netherlands