Report on the ESO-Arcetri Workshop on

Chemical Abundances and Mixing in Stars in the Milky Way and its Satellites

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Between 13 and 17 September 2004, an ESO-Arcetri workshop took place in Castiglione della Pescaia, a middle age village in the south of Toscana, on the beautiful coast of Maremma.

Thanks to the advent of 8 m class telescopes and efficient high resolution spectrographs, detailed chemical composition can now be obtained for stars of different masses and evolutionary stages, both in our Galaxy and in its neighborhood satellites, and the VLT with FLAMES and UVES is providing a wealth of high quality data. Chemical abundance ratios and patterns represent key fossil records that can reveal the complex chemical history of the stellar aggregate out of which stars formed; if correctly interpreted, measured abundances will allow us to derive the star formation history and evolution of the host galaxies. As a crucial step, however, we must first ensure that the abundances presently observed in the stellar atmospheres are the pristine ones. We must therefore first understand stellar mixing, a phenomenon present in most stars which may affect not only the surface abundances of the fragile elements, such as lithium and beryllium, but also the most commonly studied heavier elements.

In this context, the workshop aimed to bring together theoreticians and observers to discuss the advancements of the last years both in observations and in the models. An impressive amount of new abundance data sets were indeed presented and the lively discussions which took place throughout the week testify that the interaction between observers and theoreticians was very successful. About 150 scientists were present; attendance by scientists from the ESO community was very high, complemented by a significant overseas participation. 70 talks were scheduled in the 6 sessions, complemented by more than 60 posters.

The first part of the programme of the 5 day long workshop addressed the chemical composition of the main components of the Galaxy: the Galactic disk, and the spheroidal components, the Halo and Bulge, respectively. The fragile light elements, Li and Be were discussed separately and the focus moved afterwards to chemical abundance measurements in Local Group neighborhoods. One day was then dedicated to the theory of mixing and to the analysis of the theoretical results, while the last session was devoted to chemical evolution models and to the implications for Big Bang Nucleosynthesis. We present here a selection from among the topics. The Proceedings will be published by Springer Verlag as part of the ESO *Astrophysics Symposia*.

The importance of Open Clusters as key probes of chemical evolution of the Galactic disk was emphasized, together with the fact that homogeneous, large, accurate data sets are required to achieve the goal. Available data on [Fe/H] and α elements suggest that the overall metallicity of a cluster depends more on the position in the disk than on its age. Indications have been found that the outermost clusters may deviate from the general abundance gradient and show enhanced α elements. New observations of several clusters are being obtained which will allow us to investigate these issues in greater detail. New, convincing arguments were presented, showing that the classical distance of the Pleiades cluster is favored with respect to the Hipparcos distance, eliminating the possible discrepancy with stellar evolution theory.

Detailed abundance studies of field disk stars now clearly indicate that stars belonging to different kinematical components (e.g. thin and thick disks) separate well when their elemental ratios are considered. For example, the thick disk appears more α enhanced than the thin disk. Based on currently available abundances and age determinations, the formation of the disk through a fast monolithic-like collapse appears problematic. On the other hand, a comparison of elemental ratios with similar ratios obtained for stars in nearby galaxies has so far revealed no chemical evidence that the thick disk was formed by the accretion of nearby dwarf galaxies. The production of α elements in all our neighborhood companions is much lower than what can be observed in the disk, suggesting that the rate of star formation in these galaxies is fairly slow.

There are, however, exceptions, the most noticeable being the Sagittarius dwarf, which is currently being swallowed by our own Galaxy and shows an interestingly high metal content and a relatively young population. It is also worth mentioning that the presence of multiple stellar populations, most likely spatially segregated and with extended halos, seems well established in nearby dwarf spheroidals.

A wealth of new results concerning the spheroidal component of the Galaxy were presented: Globular Clusters chemical anomalies and element-to-element anticorrelations (the most famous ones being the CN-CH and the O-Na anticorrelations) occur regularly, and it is now evident that internal mixing is not the main factor responsible for these. They are ubiquitous even on the main sequence and lower subgiant branch, where deep mixing can be ruled out; several observational examples instead favor the scenario of primordial pollution from a previous generation of stars. Whatever the polluters are, it is not trivial to quantitatively explain the observed abundance trends.

Field stars in the halo reveal instead extremely tight abundance and abundance-ratio patterns, down to the lowest levels of metallicity. It is also worth noting that bright giants in the halo show clear signatures of stellar CNO mixing even at the lowest metallicity which is now observed.

Finally, the difficulty of deriving accurate abundances for stars in the Galactic bulge was discussed in detail; available results show that chemical enrichment in the bulge of our Galaxy is not as extreme as in the most massive extragalactic spheroids.

A few talks were devoted to the light elements Li and Be. As far as Li is concerned, outstanding issues in the analysis and interpretation of the ^{7}Li plateau (commonly thought to be representative of the primordial Li abundance) have been examined. The virtually zero spread in the plateau has been confirmed, implying at most a small depletion in Li (<0.1 dex) in the Pop II hot dwarfs. In addition, recent UVES results suggest that we might soon be witness to the birth of a ^{6}Li plateau (a detection of ^{6}Li at [Fe/H]=–2.7 has also been reported) and of a Be plateau at the lowest metallicities. These are definitely topics to monitor in the coming months, especially if the disagreement between primordial Li abundances inferred from the Li plateau and values predicted by

BBN and WMAP values of the baryon density is not solved. The use of Be as a cosmochronometer for the early Galaxy has been successfully tested, and it has been shown that the observation of fragile elements is crucial to understanding globular cluster formation. New Li and Be observations have also been carried out in a variety of open clusters; models of pre-main sequence Li depletion still do not match observed patterns for solar-type stars, while a very good consistency is obtained for very low mass stars. The use of the lithium depletion boundary as an alternative and secure age indicator for young clusters has been stressed. The low level of Li in the Sun, one of the strongest factors of evidence for the existence of a non-standard mixing process on the main sequence (MS), remains unexplained and the depletion mechanism is still elusive. Whereas a few stars in old clusters share the low Li content of the Sun, the majority of solar-type stars intriguingly level out their Li content at an abundance of about a factor of 10 higher than solar. Finally, it has also been shown that planet-host stars, which are statistically more metal-rich than stars without planets, do not differ from the latter as far as the light elements are concerned. These results argue against pollution from planetary material as the key process leading to an overall metallicity excess, since in case of pollution an enhancement in Li and Be should also be observed.

A general word of caution is appropriate: whilst the 1D treatment of stellar atmospheres is fairly primitive, most recent solar abundances retrieved with the 3D treatment show a large discrepancy between several chemical element abundances in the Sun, oxygen in particular, and the independent constraints from helioseismology.

In summary, from the observational point of view, we now have clear observational evidence of internal extra-mixing processes (i.e., mixing mechanisms not predicted by standard stellar theories) both during the MS and even more for stars evolved off the MS. Differences of abundances in key elements are observed in massive stars in the Galaxy and in the Magellanic Clouds at different evolutionary stages, and CNO cycled material and isotope ratios show the presence of deep mixing among bright RGB stars. The mixing mechanisms are most likely related to stellar rotation, which is relevant for both hot, rapidly rotating stars and for lower-mass, more slowly rotating stars. It is worth noting that, whilst extra-mixing does not seem to affect red giant evolution, it has very important implications for different issues (e.g., Galactic evolution of ^{3}He). As far as massive stars are concerned, rotating models and mixing have important consequences for chemical yields and thus Galactic enrichment. We would like to stress that, perhaps for the first time, in addition to a large body of observations that provide abundances for several elements, for stars in a variety of evolutionary stages and environments, appropriate models are now available. By using fairly general treatments it is possible to reproduce quantitatively the behavior of observed chemical patterns for stars in a large range of masses.

Finally, models of Galactic evolution of Li and Be still have problems in reproducing the observed patterns, in particular the plateau at low metallicities. Galactic evolution models for heavier elements in our Galaxy and in its dwarf satellites have been presented. Whereas [α/Fe] ratios in dwarf spheroidals seem rather well reproduced, the evolution of elements such as N and C is less well constrained and appears critically dependant upon stellar evolutionary models and stellar yields. Nitrogen, for example, is overproduced in dwarf irregular galaxies.

Several of these aspects, including the bright future of these investigations, in particular with the advent of Gaia, were emphasized in the two summary talks.

A successful workshop benefits from the work of many. In addition to all the participants, special thanks go to the SOC and the whole LOC (C. Travaglio, E. Masini, D. Galli, P. Sestito, P. Bristow, G. Pace, C. Stoffer). Their excellent work made our stay not only interesting, but also pleasant.

ALMA Community Day

T. L. Wilson (ESO) and E. F. van Dishoeck (Leiden Observatory)

A major event has been the ALMA Community Day, held at ESO Garching 2004 September 24. This event was sponsored by ESO and RADIONET. There were more than 130 participants. Most of the members of the European Science Advisory Committee (ESAC) of ALMA actively participated in the organization of the Workshop and most were able to attend. The morning session opened with a greeting by the Director General. Then there was a review of the project by the Joint ALMA Office Director Massimo Tarenghi. This was followed by a series of 5 longer science samplers and 6 shorter presentations on topics relevant to ALMA. There was emphasis on how ALMA could further progress in these areas. After the lunch break there were 4 longer talks about plans for ALMA computing (from the users point of view), early science observing, and two talks on the ESO plans for the ALMA Regional Center (ARC) in terms of user support and science support. The meeting ended with a one hour discussion involving all of the participants. The Community Day agenda and presentations have been collected and are to be found on the website: http://www.eso.org/projects/alma/meetings/gar-sep04/. It was felt that there should be another, perhaps longer, Community Day meeting in about one year's time.

Within ESAC (for the current membership see http://www.eso.org/projects/alma/newsletter/almanews2/), there are plans for future meetings. Among the topics proposed are the SZ effect, for a meeting in Paris, spectral line searches with an emphasis on molecules of biological interest, for a meeting in Denmark, and modeling of sources at a workshop in Sweden. In conjunction with North America, there are plans for the next global ALMA Science meeting, to be held in Madrid in 2006.