Light Elements in the Universe

IAU Symposium 268

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Session 1 - Talks

Production of the light elements in the first minutes of the Universe

Historical perspective

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Constraints from cosmic microwave background experiments

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I will give a review of the current constrains on light element abundances from cosmic microwave background experiments, focusing on results from WMAP and discussing prospects from upcoming data from Planck and ground-based experiments. I will describe how the production of light elements affects the CMB anisotropies, and how we use the data to extract cosmological information that includes constraints on the baryon density, and primordial abundances.

Primordial nucleosynthesis: a cosmological probe

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During its early evolution the Universe provided a laboratory to probe fundamental physics at high energies. The relics from those early epochs, such as the light elements synthesized during primordial nucleosynthesis when the Universe was only a few minutes old, and the relic, cosmic background photons, last scattered when the protons (and alphas) and electrons (re)combined some 400 thousand years later, may be used to test the standard models of cosmology and of particle physics. The internal consistency of primordial nucleosynthesis is tested by comparing the predicted and observed abundances of the light elements and the consistency of the standard models is explored by comparing the values of the cosmological parameters inferred from primordial nucleosynthesis with those determined from studies of the cosmic background radiation.

The cosmic lithium abundances and physics beyond the standard model

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The standard scenario of Big Bang Nucleosynthesis (BBN), with its minimalistic assumptions about the composition and state of the Universe at around 1 second, predicts light-element abundances generally in approximate agreement with those observed. However, after an independent precise observational determination of the baryon density through observations of the cosmic microwave background radiation by the WMAP satellite, a significant discrepancy between the predicted and observationally inferred ^{7}Li/H ratio has emerged. This discrepancy may be due to ^{7}Li depletion in low-metallicity halo stars, though the details of such depletion remain uncertain. Alternatively, the discrepancy may be due to physics operating during the BBN epoch itself. This later possibility will be the main subject of this talk. I discuss the possibility of relic decaying or annihilating particles to explain the ^{7}Li anomaly and/or be the source of significant amounts of pre-galactic ^{6}Li. The effect of relic massive and charged particles through catalysis of nuclear reactions is also discussed. The possibility of a connection of the ^{7}Li problem to (a) the cosmic dark matter and (b) physics beyond the standard model of particle physics, such as super symmetry is stressed. Finally, the testability of such hypothetic scenarios at the LHC particle accelerator is contemplated.

Big Bang nucleosynthesis with long-lived strongly interacting relic particles

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The abundances of ^{7}Li in metal poor halo stars (MPHSs) is not in agreement with that predicted from standard big bang nucleosynthesis (BBN) model. The high ^{6}Li abundances measured for MPHSs also suggest a probable discrepancy between theory and observation. It has been suggested that relic long-lived strongly interacting massive particles (SIMPs, or X particles) existed in the early universe. We study effects of such long-lived SIMPs on BBN assuming that they existed during the BBN epoch, but then decayed long before they could be detected. The interaction strength between an X particle and a nucleon is assumed to be similar to that between nucleons. We then calculate BBN in the presence of the unstable neutral charged X^0 particles taking into account the capture of X^0 particles by nuclei to form X-nuclei. We also study the nuclear reactions and beta decays of X-nuclei. We find that SIMPs form bound states with normal nuclei during a relatively early epoch of BBN leading to the production of heavy elements that remain attached to them. Constraints on the abundance of X^0 particles are derived from observationally inferred limits on the primordial light element abundances. We find that particle models which predict long-lived colloured particles with lifetimes longer than 200 s are rejected based upon these constraints. We do not find a solution to the ^{6}Li or ^{7}Li problems in this paradigm. Since this scenario characteristically prefers the production of ^{9}Be and ^{10}B, there might remains its signature on primordial abundances of those light elements. New null results for primordial plateau abundances of observations of MPHSs would give stronger limits on the long-lived SIMPs.

Session 1 - Posters

Nucleosynthesis in multi dimensional universe

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We take an earlier solution of the present author about cosmological evolution in a higher dimensional (HD) spacetime to study the nucleosynthesis in an early HD universe. HD models are particularly relevant in the cosmological context before the universe underwent the compactification transition. The present study reveals that the dimensionality of spacetime has a significant effect on the process of element formation in the early universe. It is observed that the magnitude of the ratio Q/H, where Q is the reaction rate and H the expansion rate is crucially important in determining the nucleosynthesis. As temperature falls less rapidly in HD it takes relatively more time for the elementary particles to cool below their critical temperature. Further the ratio Q/H is more sensitive to temperature fluctuation in HD such that it takes relatively more time for the decoupling phase of the neutrinos to occur with possible astrophysical consequences. Moreover it may have its relics in the present day universe also.

Session 2 –Talks

Abundances of D, 3He and 4He (observations)

Improving the precision of the primordial Deuterium abundance to explore fundamental physics

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Standard Big Bang Nucleosynthesis now predicts the primordial abundances of the light nuclei with no free parameters when we take the baryon to photon ratio from the cosmic microwave background. We are working to improve the precision of the primordial deuterium abundance measurement to open a window on a wide range of new fundamental physics. Two examples - sterile neutrinos are required by popular schemes that explain the low masses of the light neutrinos and they may make detectable changes in the abundances from BBN, as could different numbers of neutrinos and antineutrinos (a net lepton number) in the universe.

Measurements of Deuterium in the Milky Way

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In this talk I will review what is known about the abundance of deuterium within the Milky Way and its extended gaseous halo. I will also discuss the processes by which the gas-phase deuterium abundance may be enhanced or depleted within the interstellar medium, compare and contrast the observational evidence for these processes, and place these results in the context of the values of D/H observed in the intergalactic medium.

The total deuterium abundance in the local Galactic disk and its implications

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Analyses of FUSE spacecraft spectra have provided measurements of D/H in the gas phase of the interstellar medium for many lines of sight extending to several kpc from the Sun. These measurements, together with the earlier Copernicus, HST, and IMAPS data, show a wide range of D/H values that have challenged both observers and chemical evolution modellers. I believe that the best explanation for the diverse D/H measurements is that deuterium can be sequestered on to carbonaceous grains and PAH molecules and thereby removed from the interstellar gas. Grain destruction can raise the gas phase D/H value to approximately the total D/H value. Supernovae and stellar winds, however, can decrease the total D/H value along lines of sight on time scales less than mixing timescales. I will summarize the theoretical and observational arguments for this model and estimate the most likely range for the total D/H in the local Galactic disk. This range in total D/H presents a constraint on realistic Galactic chemical evolution models or the primordial value of D/H or both.

What the D/O ratio tells us about the interstellar abundance of deuterium?

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The ionization balances for HI, OI, and DI being locked together by charge exchange, the deuterium-to-oxygen ratio is considered to be a good proxy for the deuterium-to-hydrogen ratio, in particular within the interstellar medium. As the DI and OI column densities are of similar orders of magnitude for a given sight line, comparisons of the two values is generally less subject to systematic errors than comparisons of DI and HI, which differ by about 5 orders of magnitude. Moreover, D/O is additionally sensitive to astration, because as stars destroy deuterium, they should produce oxygen. D/O measurements are now available for about 40 lines of sights in the interstellar medium, most of them from FUSE observations. I propose to review those measurements, what they tell about the interstellar deuterium abundance, and the questions they raise.

(Un)true Deuterium abundance in the Galactic disk

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Deuterium has a special place in cosmology, nuclear astrophysics, and galactic chemical evolution, because of its unique property that it is only created in the big bang nucleosynthesis while all other processes result in its net destruction. For this reason, among other things, deuterium abundance measurements in the interstellar medium (ISM) allow us to determine the fraction of interstellar gas that has been cycled through stars, and set constraints and learn about different Galactic chemical evolution (GCE) models. However, recent indications that deuterium might be preferentially depleted onto dust grains complicate our understanding about meaning of measured ISM deuterium abundances. For this reason, recent estimates by Linsky et al. (2006) have yielded a lower bound to the "true", undepleted, ISM deuterium abundance that is very close to the primordial abundance, indicating a small deuterium astration factor contrary to the demands of many GCE models. To avoid any prejudice about deuterium dust depletion along different lines of sight that are used to determine the "true" D abundance, we propose a model-independent, statistical Bayesian method to address this issue and determine in a model-independent manner the undepleted ISM D abundance. Presented will be preliminary results of Prodanovic, Fields & Steigman 2009 (in preparation).

D and 3He in the protosolar cloud

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For our understanding of the origin and evolution of baryonic matter in the Universe, the proto-solar cloud is of unique importance in two ways: 1) To this day, many of the naturally occurring nuclides have only been detected in the solar system. 2) Since the time of solar system formation, the Sun and planets have been virtually isolated from the galactic nuclear evolution, and thus the proto-solar cloud is a Galactic sample with a degree of evolution intermediate between the Big Bang and the present. The abundances of the isotopes of hydrogen and helium in the proto-solar cloud are primarily derived from composition measurements in the solar wind, the Jovian atmosphere and planetary noble gases in meteorites, and from densities in the Sun obtained by solar seismology. After discussing the changes in isotopic and elemental composition caused by processes in the solar wind, the Sun and Jupiter, proto-solar abundances of the four lightest stable nuclides will be given.

Measurements of ^{3}He in Galactic HII regions and planetary nebulae

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Abstract

Measurements of ⁴He in metal-poor extragalactic HII regions: the primordial Helium abundance and the DeltaY/DeltaO ratio

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I present a review on the determination of the primordial helium abundance, Y_p, based on the study of hydrogen and helium recombination lines in extragalactic HII regions. I also discuss the observational determinations of the increase of helium to the increase of oxygen by mass Y/O, and compare them with predictions based on models of galactic chemical evolution.

^{4}He abundances: Discrepancies between optical and radio recombination line measurements

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Accurate measurements of the ^{4}He /H abundance ratio are important in constraining Big Bang nucleosynthesis, models of stellar and Galactic evolution, and HII region physics. We discuss observations of radio recombination lines (RRLs) using the Green Bank Telescope (GBT) toward a small sample of HII regions and planetary nebulae. We report ^{4}He /H abundance ratio differences as high as 20%between optical and ratio data that are difficult to reconcile and challenge our ability to accurately measure primordial ^{4}He and the production of ^{4}He (DeltaY/Delta Z).

The primordial He abundance from a large sample of low-metallicity HII regions

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We determine the primordial helium mass fraction Yp using the large sample of low-metallicity extragalactic H II regions. This sample is selected from the Data Release 7 of the Sloan Digital Sky Survey, from European Southern Observatory archival data and from our own observations. It constitutes the largest data set for the determination of Yp. We have considered known systematic effects that may affect the He abundance determination. They include collisional and fluorescent enhancements of HeI recombination lines, underlying HeI and hydrogen stellar absorption lines, collisional excitation of hydrogen lines, temperature and ionization structure of the HII region. Monte Carlo methods are used to solve simultaneously the above systematic effects. We find a primordial helium mass fraction Yp = 0.2512 +/- 0.0006(stat.) +/- 0.0020 (syst.). This value is slightly higher than the value given by Standard Big Bang Nucleosynthesis (SBBN) theory.

The dominant terms contributing to the uncertainties in nebular He abundances

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I will discuss the results from recent work on attempts to reduce the uncertainties in nebular helium abundances. The emphasis will be on self-consistent, non-parametric analyses, and potentially improved observational strategies.

The quite complex Simple Stellar Populations of Globular Clusters

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The last few years have seen a dramatic change of perspective on Globular Clusters. When observed in details, with precision photometry and high-resolution spectroscopy, we understand that they are composed by multiple stellar populations (generations), distinct by the signature of proton-capture reactions in H-burning at high temperature. The main outcome of H-burning is always He, produced in an early generation of now-defunct massive stars. This signal may be recovered by photometric and spectroscopic observations of low mass stars in Globular Clusters, that show the fossil records of early enrichment processes in their properties. With a particular attention to He, we will review the huge progress recently made in this field of study and the resulting shift in our view of these -once considered simple- old stellar aggregates.

Revisiting the helium abundance from multiple main sequences in globular clusters

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Our recent study of the helium content in nearby K dwarfs has highlighted that at low metallicities the broadening of the observed Main Sequence is much narrower than expected from isochrones with standard DY/DZ = 2. A much higher value, of order 10, is formally needed to reproduce the observed broadening, leading to helium abundances in contrast with BBN. This result resembles, on a milder scale, the very high DY/DZ estimated from the multiple Main Sequences observed in some metal-poor globular clusters. We argue that a revision of low Main Sequence stellar models, suggested from nearby stars, could help to reduce the overwhelmingly high DY/DZ deduced so far for those clusters.

The helium contribution from massive AGBs

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Stars of intermediate mass pollute their environment via their low velocity winds, associated to the strong mass loss suffered during their Asymptotic Giant Branch phase. The most massive of these objects are strong helium producers, due to their deep second dregde-up experienced after the core helium-burning phase. Unlike the yields of the other elements, the helium abundance depends only on the strength of the second dredge-up, and not on the various uncertainties affecting the AGB description. The role that these stars may have played in the self-enrichment mechanism in Globular Clusters is also commented

He self-enrichment in globular clusters

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Globular clusters exhibit a peculiar chemical pattern where Fe and heavy elements stay constant inside a given cluster while light elements (Li to Al) show strong star-to-star variations. This pattern can be explained by a self-pollution due to the slow winds of fast rotating massive stars. Besides, several main sequences have been observed in several globular clusters which can be understood only with different stellar populations with distinct He content. Here we explore how these He abundances can constraint the self-enrichment in globular clusters.

Are the most iron-poor stars helium rich?

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At least 1 in 5 stars with [Fe/H] $\leq$ -2.0 exhibit [C/Fe] $\geq$ +1.0. These stars are known as C-enhanced metal poor stars (CEMP). The two most iron poor stars presently known ([Fe/H] equal to -5.96 and -5.4) are C-rich, they are called C-Rich Ultra-Metal Poor Stars (CRUMPS). The origin of their peculiar surface abundances is not well understood. We discuss the chemical composition of stars made of interstellar medium mixed with wind material of very metal poor massive stars, of wind and supernova ejecta and of material ejected by early AGB stars. Rotating and non-rotating models are considered. We find that the high nitrogen abundances observed in some CEMP stars imply that the material which is responsible for their peculiar abundance pattern must be heavily enriched in primary nitrogen. We show that rotating stars (both massive and intermediate mass stars) can produce the required amount of primary nitrogen, and can also account for the observed enhancements in C, O, Na, Mg and Al. CEMP stars formed from wind material of massive stars mixed with small amounts of pristine interstellar medium are He-rich, Li-depleted and present low $^{12}C/^{13}C$ ratios. By He-rich we mean stars that, at very low [Fe/H], present a helium mass fraction between 0.30 and 0.60.The fact that (at least some) CRUMPS stars are He-rich have deep consequences for obtaining their physical characteristics, as for instance, their mass and maybe their surface abundances. Some observational tests are proposed to test the “He--rich hypothesis"”.

Session 2 - Posters

He-rich and He-poor populations in globular clusters from the RGB

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There are several indicators of different He abundances in GCs based on the Horizontal Branch (HB extension, direct measure) or the Main Sequence (multipleMSs). However, also Red Giant Branches may be useful: even if the effects of different He are less visible than on the HB or on the MS, the RGB offers the advantage of being bright, so the properties and the abundances of the stars can be easily measured. In particular, stars with different He i) have different temperatures, so they have different colours, ii) display slightly different metallicities, and iii) have different level of the RGB bump. All these differences are small, so to be detected we need precision, good statistics, and homogeneity; these requirements are met by our study of stellar populations in Galactic GCs. With the idea of studying the Na-O anticorrelation and its relation with the HB morphology and other properties of the clusters, we obtained FLAMES@VLT spectra of RGB stars in 19 GCs, for a total of about 2000stars. I will show results of this work, focussing on the He values deduced from the different colours, [Fe/H] values, and RGB-bump levels.

Helium abundances in planetary nebulae of the inner Galaxy

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Planetary Nebulae can provide important information on the ISM structure and evolution, as well as on the Galaxy formation and evolution. Additionally, they can provide information on intermediate mass stars from which they are originated. Once the helium abundance is modified by dredge-up episodes along the evolution of the progenitor star, it is needed to apply individual corrections to the observed PNe abundances, in order to use helium as a tracer of the ISM structure. In this work, we report new helium abundances for a sample of planetary nebulae located in the inner Galaxy, aiming to derive their real values without the contamination of the progenitor stars. The results show that the correlation between log (N/O) and He/H has a positive trend, although there is no tight correlation between these quantities. Moreover, the distribution of helium abundances show a wide distribution, which results from the mass and age ranges of the progenitor stars that originate the PNe. We also show that helium abundances for a sample of planetary nebulae can be used as an additional constraint to Galaxy evolution models. They can be used to determine the galactocentric distance where, according to intermediate mass population, bulge and disk properties better separate.

Primordial helium abundance of the Small Magellanic Cloud: a view from intermediate mass stars

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We derived the chemical composition for a sample of planetary nebulae of the Small Magellanic Cloud. The derivation of helium abundances was as accurate as possible, including correction of collisional effects, using collision-to-recombination correction factors. Based on luminosities and effective temperatures derived for the central star of each nebula, the masses, and then ages of the progenitor stars were derived using isochrones and mass-age relationships. Using these results, helium abundances for each nebula were corrected for the contamination from the evolution of their progenitor stars as well as from the chemical evolution of the interstellar medium, by using yields for intermediate mass stars and a helium-to-heavy elements abundance ratio. Therefore we determined the helium enrichment in the SMC and used these results to estimate the pregalactic helium abundance of this galaxy. The derived results are compared to values derived from big bang nucleosynthesis and other determinations of primordial helium.

The helium content of stars in the globular cluster NGC6397

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In the new scenario for Globular Cluster stellar populations, the apparently "simple" NGC 6397 is a mainly "second generation" cluster and the helium abundance of its stars may be a bit larger than the standard Big Bang abundance Y~0.24. Can we derive constraints on the helium abundance from the analysis of the main sequence luminosity function? We try to answer this question making use of new models for main sequence down to the hydrogen burning minimum mass, adopting two version of an updated equation of state and making simulations of the theoretical luminosity functions for different choices of the mass function and of the initial helium content.

Diagnostics of dilution process in globular clusters: the Lithium test

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The traditional assumption of globular clusters (GCs) as simple stellar populations has proven to be too simplistic. In the last decades a lot of observational studies have revealed thepresence of anti-correlations between C, O, and Mg and N, Na, and Al, respectively, pointing out to dilution processes within GCs, and to the existence of multiple stellar generations. The Li abundances of GC stars can provide very powerful tracers of cluster formation and evolution, because this element is easily destroyed in the stellar interiors. Determination of Li variations in GCs allows us to uniquely constrain the nature and the extent of the dilution process between pristine and polluted material. We present our preliminary results on the GC 47 Tucanae.

The Galactic Deuterium gradient

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Independently of the model for chemical evolution, it is predicted that the D abundance (D/H) increases with Z if D is produced in stars, but decreases as Z increases if it is primordial: these correlations hold as a function of time and for gradients of abundances at the present time. A firm observation of the correlation of D/H with Z (e.g., a gradient in the Galaxy) would therefore tell whether D is mostly made during galactic evolution before most metals were synthesized; this test could not distinguish between production in the Big-Bang and production in the first generation of stars". (Audouze & Tinsely, Ann. Rev. A&A, v.14, 1976). Evidence for a positive Galactic D gradient, which implies that there are no significant Galactic sources of D, comes from observations of the D/H ratios in 15 molecular clouds with D/H = 2.4 ppm in the Galactic Centre region, D/H = 20 ppm at 10 kpc, and D/H < 32 ppm at 24 kpc. These results are consistent with the grain depletion corrected FUSE values of D/H ~ 23 ppm (FUSE data is 8 ppm < D/H < 23 ppm), the anticenter D/H = 21 ppm at 10 kpc (from 327 MHz DI), and D/H = 22 ppm in low-metallicity halo clouds. Some D is produced in the Galaxy because the 2.2 MeV n-capture gamma-ray lines have been detected in solar flares and high-energy (E > 10 GeV/nucleon) cosmic-ray deuterons from spallation reactions have also been detected. Additional sources of D nucleosynthesis (jets, cosmic-ray spallation reactions, flares) correlated with stellar activity should also be explored in order to explain the variation in the D abundances. Molecular clouds in the LMC do not have enhanced D (D/H ~ 20 ppm) while D has not been detected in molecular clouds in the Seyfert galaxy NCG 1068 (D/H < 15 ppm). The D/H = 26 ppm inferred from the WMAP, CMB, and QSO absorption systems (2.5 < z < 3.6) are surprisingly close to the Galactic D/H ratios. Better models of grain depletion, infall, astration, and astrochemistry are needed to explain the Galactic and cosmological D/H ratios while allowing large variation in the abundances of other elements. The best evidence to date is that D is primarily cosmological and that there are no significant non-cosmological sources of D.

Helium abundances in planetary nebulae: nucleosynthesis and chemical evolution

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Helium abundances can be accurately measured in planetary nebulae (PN), and reflect both the initial helium content of the progenitor stars plus the contribution of the products of nuclear processes dredged up to the outer layers of the star. As a result, the He/H ratios in PN comprise a relatively large range of values in different objects, depending on the initial mass of the progenitor stars. This ratio is typically in the range $0.07 < He/H < 0.15$, being usually larger for stars with masses near the upper limit of the intermediate mass stars that can still produce PN, essentially between 0.8 and 8 solar masses on the main sequence. We have obtained a large sample of PN with accurately determined helium abundances, with typical uncertainties of about 0.01, as well as abundances of several heavy elements. These objects are located in the solar neighbourhood, in the galactic bulge, disk and anticentre, and also in the Magellanic Clouds. In this work, these results are analysed both in terms of the nucleosynthesis of intermediate mass stars and the chemical evolution of the Galaxy. In particular, the He/H ratio plays a role in the evolution of the enrichment ratio between helium and the heavy elements, as represented by oxygen or nitrogen, and should match the pregalactic helium abundance as derived from low metallicity objects. On the other hand, correlations between the helium abundances and the abundances of elements such as N and O are important constraints of the nucleosynthetic processes occurring in the progenitor stars. Finally, a comparison of the variation of these abundances for objects in different galactic subsystems gives information on the chemical evolution of the different populations associated with these systems. (FAPESP/CNPq)

High-resolution spectroscopy of stars in the red giant branches of Omega Centauri

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We analyse a large sample of UVES and GIRAFFE spectra for more than 200 red giant branch stars in the Globular Cluster Omega Centauri. We determined abundances for Fe, Na, O, C, N, alpha and s-elements and coupled our results with high accuracy colour-magnitude diagrams obtained both with the Hubble Space Telescope and ground based telescopes. Our aim is to investigate the general properties of the multiple populations in Omega Centauri and to constraint the different scenarios on the origin and the chemical evolution of this peculiar globular cluster.

The effect of temperature variations on the primordial helium determination

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On the origin of the helium-rich population in the peculiar globular cluster Omega Centauri

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Making use of a complete model for the chemical evolution of the complex stellar system Omega Centauri and of up-to-date nucleosynthesis prescriptions, we discuss the origin of the extreme helium-rich stars that populate the blue main sequence of this Galactic globular cluster. The main purpose of this study is to explain the peculiarity of the chemical composition of the blue main sequence stars in the context of a model that reproduces well all the observed chemical properties of the cluster.

Session 3 – Talks

Abundances of LiBeB (observations)

LiBeB in the light of 3D hydrodynamical models and non-LTE line formation

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I will review the effects of 3D model atmospheres and non-LTE line formation on the derived abundances of Li, Be and B in late-type stars.

Li isotopes in metal-poor halo dwarfs

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In a post WMAP epoch, I will try to show the last results obtained about the ^{6}Li and ^{7}Li abundances in the most metal poor stars. These elements are important relics of primitive phases of the Universe, and are in principle observable in the atmosphere of old stars. In the old Universe ^{7}Li has been mainly produced by the primordial nucleosynthesis, ^{6}Li mainly by cosmic rays spallation. In the framework of the standard Big-Bang, the primordial nucleosynthesis depends only on the photons to baryons ratio, a constant which has been measured with high precision by WMAP. But difficulties appeared...The observations of the ^{7}Li abundance in the atmosphere of the oldest halo dwarfs lead to an abundance of lithium between two and five times lower than the abundance predicted by the standard Big-Bang. On the contrary, the "primordial" ^{6}Li could be much more abundant than the predictions of the primordial nucleosynthesis .I will try to summarize the main results obtained recently by the different teams working on this "hot" subject. I will present the observed trends of ^{6}Li and ^{7}Li with Teff and [Fe/H], and I will discuss the scatter of the lithium abundance at very low metallicity. Is the abundance of lithium measured in the stars as precise as we think (temperature scale)? Are we observing in the atmosphere of the warm halo dwarfs the primordial abundance of lithium or has it been modified (diffusion, mixing with deep layers...)? Is it possible to reconcile the observations with the predictions of the Standard Big Bang?

Depletion in the Spite plateau: solving the cosmological Li discrepancy

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We present new precise Li abundances for 73 stars in the metallicity range -3.5 < [Fe/H] < -1.0, employing accurate IRFM temperatures with improved E(B-V) values obtained mostly from interstellar NaD lines. The Li abundances were derived using precise equivalent widths with errors lower than 5%. We show that Li has been depleted in the Spite plateau stars. Models including diffusion and turbulence can reproduce the observed depletion assuming an initial Li abundance of A(Li) ~ 2.55-2.7, in excellent agreement with the primordial Li abundance predicted by Big Bang nucleosynthesis and WMAP data.

Convection and ^{6}Li in the atmospheres of metal-poor halo stars

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The spectroscopic signature of the presence of ^{6}Li in the atmospheres of metal-poor halo stars is a subtle extra depression in the red wing of the ^{7}Li doublet, which can only be detected in spectra of the highest quality. Based on high-resolution, high signal-to-noise VLT/UVES spectra of 24 bright metal-poor stars, Asplund et al.(2006) report the detection of ^{6}Li in nine of these objects. The average ^{6}Li^{7}Li isotopic ratio in the nine stars in which ^{6}Li has been detected is about 4 and is very similar in each of these stars, defining a ^{6}Li plateau at approximately n(^{6}Li) = 0.85 (on the scale n(H) = 12).A convincing theoretical explanation of this new ^{6}Li plateau turned out to be problematic: the high abundances of ^{6}Li at the lowest metallicities cannot be explained by current models of galactic cosmic-ray production. A possible solution of the so-called "second Lithium problem"' was proposed by Cayrel et al. (2007), who pointed out that the intrinsic line asymmetry caused by convection in the photospheres of cool stars is almost indistinguishable from the asymmetry produced by a weak ^{6}Li blend on a (presumed) symmetric ^{7}Li profile. Based on 3D hydrodynamical model atmospheres computed with the CO^{5}BOLD code and 3D non-LTE line formation calculations, we study the effect of the convection-induced line asymmetry on the derived^{6}Li abundance for a range in effective temperature, gravity, and metallicity. When the asymmetry effect is taken into account for the stars of the Asplund et al. sample, the resulting ^{6}Li ^{7}Li ratios are reduced by about 1.5 on average. This diminishes the number of certain ^{6}Li detections from 9 to 3 or 4, casting doubt on the existence of a ^{6}Li plateau. A careful reanalysis of individual objects is under way, in which additional spectral lines will also be considered for constraining the intrinsic line asymmetry and non-thermal Doppler broadening.

Beryllium and boron abundances in metal-poor stars

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Knowledge of lithium, beryllium, and boron abundances in stars of the Galactic halo and disk plays a major role in our understanding of Big Bang nucleosynthesis, cosmic-ray physics, and stellar interiors. Be9 and B10 are believed to originate entirely from spallation reactions in the interstellar medium (ISM) between alpha-particles and protons and heavy nuclei like oxygen, whereas B11 may have an extra production channel via neutrino-spallation. Both elements are observationally challenging: the main Be and B resonant doublets fall respectively at 313 nm (very close to the atmospheric cut-off) and at 250 nm (accessible only from space). At least for beryllium, the advent of 8-10m class telescopes equipped with highly (near-UV) sensitive spectrographs has opened up a new era of Be abundance studies, which are now routinely providing reliable and accurate determinations, so that the evolution of beryllium in the Galaxy can be better understood and constrained. Here, I will review and discuss the most interesting results of recent observational campaigns in terms of formation and evolution of these two light elements.

New Beryllium results in halo stars from Keck/Hires spectra

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We have obtained high-resolution, high signal-to-noise Keck spectra to determine beryllium (Be) abundances in over 100 stars in the Galactic halo. The stellar metallicities range from [Fe/H] = -0.50 to -3.50. Using this large sample, we have examined the trends of Be with iron (Fe) and Be with oxygen (O). In addition the large sample allows us to examine the reality of the observed spread in the Be abundance at a given Fe abundance. Our sample has been subdivided into accretive and dissipative categories to investigate the possible use of Be as a chronometer. We further examine the differences in Be abundance distribution in stars on extreme orbits with large retrograde motion and/or large apogalacticon distance from the Galactic centre. Our results show that the dominant production mechanism for Be changes as the Galaxy ages. In the early eras of the Galaxy, when massive stars become supernovae, Be is produced from the acceleration of energetic CNO atoms which bombard protons in the vicinity of supernovae. Later spallation reactions occur as high-energy protons bombard CNO atoms in the interstellar gas. The change occurs near [Fe/H] = -2.2. The results from our study not only illuminate the Galactic evolution of Be, but also the origin and evolution of the Milky Way through the Be distribution with stellar kinematics.

Boron abundances in diffuse interstellar clouds

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We present a comprehensive survey of B abundances in diffuse interstellar clouds from HST/STIS observations along 56 Galactic sight lines. Our sample is the result of a complete search of archival STIS data for the B II resonance line at 1362 angstroms, with each detection confirmed by the presence of absorption from other dominant ions at the same velocity. The data probe a range of astrophysical environments including both high-density regions of massive star formation as well as low-density paths through the Galactic halo, allowing us to clearly define the trend of B depletion onto interstellar grains as a function of gas density. Many extended sight lines exhibit complex absorption profiles that trace both local gas and gas associated with either the Sagittarius-Carina or Perseus spiral arm. Our analysis indicates a higher B/O ratio in the inner Sagittarius-Carina spiral arm than in the vicinity of the Sun, which may suggest that B production in the current epoch is dominated by a secondary process. The average gas-phase B abundance in the warm, diffuse ISM is consistent with the abundances determined for a variety of Galactic disk stars, but is depleted by 60 percent relative to the solar system value. Our survey also reveals sight lines with enhanced B abundances that potentially trace recent production of B-11 either by cosmic-ray or neutrino-induced spallation. Such sight lines will be key to discerning the relative importance of the two production routes for B-11 synthesis.

Boron abundances in the Galatic disk

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Boron, like lithium and beryllium, is a fragile element that is destroyed in stellar interiors at modest temperatures. Unlike Li and Be however, boron does not exhibit spectral lines in the optical, resulting in a relatively small number of boron abundances measured in stars in the Galaxy to date. The usable lines for deriving boron abundances all fall in the UV: in cool stars B I lines are found near 2500A, while in early-type stars one can measure both B II at 1362A and a B III resonance doublet at 2066A. In this presentation we will discuss published boron abundances from BI, BII and BIII lines observed in both disk stars and metal-poor halo stars. The discussion will focus on the possible origins of boron and its chemical evolution in the Galaxy.

Lithium in globular clusters: Dip, diffusion and dredge-up

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I shall review the current state of affairs regarding lithium measurements in individual globular-cluster stars. Questions to be addressed include:
* Do we have appropriate observational data?
* Can we describe the line-formation process of Li I 6707 quantitatively?
* Do we have appropriate stellar-structure models to compare the derived abundances with?
* Do we understand the evolution of lithium as a function of stellar mass and in relation to other elements?
While significant progress has been made in recent years, it is argued that the full complexity and indeed the potential of lithium as a probe of stellar physics has not yet been realized.

Main sequence and sub-giant stars in the globular cluster NGC 6397: the complex evolution of the lithium abundance

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Thanks to the high multiplexity and efficiency of Giraffe at the VLT we have been able for the first time to observe the Li I doublet in the Main Sequence stars of a Globular Cluster. At the same time we observed Li in a sample of Sub-Giant stars of the same B-V colour. Our final sample is composed of 84 SG stars and 79 MS stars. In spite of the fact that SG and MS span the same temperature range we find that the equivalent widths of the Li I doublet in SG stars are systematically larger than those in MS stars, suggesting a higher Li content among SG stars. This is confirmed by our quantitative analysis carried out making use of 3D hydrodynamical simulations of the stellar atmospheres. We find that SG stars show, on average, a Li abundance higher by0.1dex than MS stars. We also detect a positive slope of Li abundance with effective temperature, the higher the temperature the higher the Li abundance, both for SG and MS stars, although the slope is slightly steeper for MS stars. These results provide unambiguous evidence that the Li abundance changes with evolutionary status. The physical mechanisms that contribute to this are not yet clear, since none of the proposed models seem to describe accurately the observations. Whether such mechanism can explain the cosmological lithium problem, is still an open question.

The primordial lithium problem - Clues from old globular cluster stars

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The discrepancy remains between the BBNS+WMAP prediction of the primordial 7Li abundance in the universe and the lower abundances observed in halo (Pop II) dwarfs and subgiant stars. A possible solution to the problem is that the stars have undergone photospheric depletion of lithium. An important tool for constraining the physics responsible for the depletion is to accurately establish how the surface lithium abundance varies with stellar evolutionary phase. I will present a spectroscopic analysis of a very large sample of low-mass stars in the metal-poor globular cluster NGC6397, covering well all evolutionary phases from below the main sequence turn-off to high up the red giant branch. Aided by the Li as well as the Na abundances of our targets, we distinguish stars formed out of pristine material from stars formed out of material affected by pollution from a previous generation of more massive stars. Trends of lithium abundance with stellar luminosity and effective temperature are discussed, with focuses on the implications on stellar evolution and the prospects for solving the primordial lithium discrepancy.

Lithium in a metal-poor external galaxy: Omega Centauri

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Centauri is a massive stellar system which is currently going through the Galactic Halo. Its compact aspect and spheroidal shape have for a long time led to it being classified as a Globular Cluster. However the fact that its stars cover a wide metallicity range (-0.6 < [Fe/H] <-2.1), point to this object as an external galaxy, satellite of the Milky Way. Lithium among warm metal-poor stars shows a roughly constant abundance, the "Spite Plateau". This has been interpreted has evidence for a primordial origin of the lithium nucleus, at the time of nucleosynthesis. After the physical conditions under which nucleosynthesis occurred, have been constrained by the observations of the fluctuations of the Cosmic Microwave Background, we are facing a "cosmological lithium problem", namely the primordial lithium was a factor of three to four higher than what observed in the Spite plateau. Several avenues may be taken to solve this conundrum, either relying on fundamental physics or on stellar physics, however the realm of possibilities may be considerably narrowed by observing stellar populations in different galaxies, which have experienced different evolutionary histories. Some of the proposed "solutions" may be clearly ruled out, depending on the observation of lithium in the metal poor populations of external galaxies. Omega Centauri is the only external galaxy amenable to such an investigation in the era of 8m telescopes. We have pushed to its limits FLAMES at the ESO 8.2m telescope to obtain high resolution spectra of the LiI doublet in 92 Turn-Off and Sub-Giant stars at V~18 in Omega Centauri. We present our preliminary results on this data which suggest that the Li content in Omega Centauri warm stars is comparable to that observed in Galactic Halo field stars of similar metallicities and temperatures. This may effectively rule out a whole class of models, which invoke a severe Li depletion through processing of material in an early generation of massive stars.

Li, Be, and B in Population I dwarf stars

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Measurements of lithium, beryllium, and boron in Population I unevolved stars represent a key tool to address several topics, from stellar structure and internal mixing processes, to Galactic evolution, to age dating of young stars. I will review the status of the field, present recent observational results along with their implications, highlight open questions and problems, and discuss future perspectives.

Enhanced Lithium depletion in solar-type stars with exoplanets

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The depletion of lithium in the Sun discovered about 60 years ago remains the epitome of the lithium puzzle. A large dispersion in Li abundance observed in solar-type stars of the same age, mass and metallicity is inconsistent with classical models of stellar evolution. There are indications (Israelian et al. 2004, Gonzales 2008, Takeda et al. 2007, 2008, Chen & Zhao 2006) that Li is more strongly depleted in solar-type planet-host stars with effective temperatures (Teff) in the range 5600-5900 K than in stars of similar type but without planets. The formation and evolution of a planetary system could cause extra mixing in the surface convective zone of these type of stars and induce additional Li depletion. Recently we (Israelian et al. 2009, Nature, in press, under embargo until Nov 11, 2009) presented a homogeneous and unbiased study of lithium in solar analogue stars (solar effective temperature ± 80 K) with and without detected planets. We find that the planet-bearing stars have severely depleted lithium, retaining less than 1% of the original abundance, while 50% of solar analogues without detected planets have on average ten times more Li. Our observations reveal a connection between Li abundance and the presence of planets around solar type stars. So far, Li is the only chemical element with a different behaviour in stars with planets.

Light elements in stars with exoplanets

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It is well known that stars orbited by giant planets have higher abundances of heavy elements when compared with average field dwarfs. A number of studies have also addressed the possibility that light element abundances are different in these stars. In this presentation we will review the present status of these studies. The most significant trends will be discussed.

Observations of LiBeB in RGB and AGB stars

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Red giant stars in different evolutionary phases undergo a variety of processes that affect the surface abundances of the light elements, in particular that of lithium. Depending on which stage of evolution a star is in, lithium can either be destroyed or created. Variations in the observed lithium abundances in samples of stars on the giant branch, or on the asymptotic giant branch provide important clues and constraints on our understanding of both stellar evolution and light-element nucleosynthesis.
We will review all of the various ways that red giants modify their Li, Be, and B abundances and what these abundance variations reveal about stellar evolution up and down the red giant branches.

Mass loss and luminosities of S and C AGB stars with and without Li

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We present the preliminary results of an analysis performed on two samples of thermally pulsing Asymptotic Giant Branch stars from our Galaxy, the first made of Carbon rich sources and the second of S-type stars. We have estimated their absolute luminosities and updated rates of the stellar winds through methods linked with an improved study of their infrared spectrophotometry and updated estimates of their variability and distance. We then focus on those sources in our database showing Li in their spectra looking for correlations between the Li abundance and the other physical parameters, in the aim of establishing observational criteria for understanding the conditions for the occurrence of the deep mixing phenomena to which the production of Li is currently attributed.

Observations of light elements in massive stars

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Despite their small number and mass fraction, massive stars drive the chemical and dynamical evolution of the galaxies through nucleosynthesis and distribution of elements. Accurate galaxy evolution models require a detailed understanding of the internal and core properties of massive stars. The consideration of rotation in stellar evolution models predicts significant effects on the evolutionary tracks and surface abundances of massive stars.

Observations of light elements in massive stars are limited to few transitions of Boron in the satellite-UV; Li and Be are not observable. But because of its high sensitivity to the effects of rotational mixing, Boron abundance determinations in massive stars have excelled as the definite test for evolutionary models with rotation.

In this paper I will review the observational evidence for rotational mixing in massive stars and discuss alternative interpretations.

Session 3 - Posters

Lithium in super metal-rich dwarf stars

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We analysed 20 super metal rich stars, identified by Grenon (1999) with the characteristics of being old, and other bulge like indicators. The detailed is carried with two different codes, in order to validate their high metallicity. We derive Lithium in the few stars that show the line.

Survey along RGB: Super Li-rich K giant with anomalous low $^{12}C/^{13}C$ ratio

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Recently, we have undertaken a comprehensive survey of searching Li-rich K giants among low mass K giants. A sample of 1800 stars with accurate astrometry selected from Hipparcos catalogue covering the end of 1stdredge-up to all the way to the tip of the RGB on the HR diagram. The survey confirms the rarity of the Li-rich K giants, just under 1%, in the solar neighbourhood. This study increased the total number of Li-rich stars almost by two fold to the existing list. Results from the analysis of high resolution spectra of candidate Li-rich K giants showed that one of the candidate stars is highly enriched in lithium and also anomalous low carbon isotopic ratio, which is contrary to the first dredge-up, extra deep mixing associated with cool bottom processing, and other recent predictions for k giants on the RGB luminosity bump phase. Here, we discuss, in general, the survey and preliminary results and, in particular, the super Li-rich k giant with anomalous low carbon isotopic ratio.

A 3D-NLTE study of the 670 mn solar lithium feature

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The lithium abundance determination in solar-type, solar metallicity stars is more problematic than in metal-poor stars, because the Li 670 nm feature is immersed in a forest of lines whose atomic data are not well known. In contrast, the lines blending the Li feature have all disappeared in metal-poor stars, and hence the Li doublet is usually a prominent single feature in the spectra of these stars, which has well-known atomic parameters and has been studied in great detail. We derive the 3D-NLTE lithium abundance in the solar photosphere, by considering the Li I line at 670 nm as measured in several solar atlases. The Li abundance is obtained from line profile fitting with 1D/3D-LTE/NLTE synthetic spectra, considering several possibilities for the atomic parameters of the lines blending the Li feature. The 670 nm spectral region shows considerable differences in the two available disc-centre solar atlases, while the two disc-integrated spectra are very similar. We obtain A(Li)3D-NLTE=1.02. The 1D-LTE abundance is 0.08 dex smaller. Changing the atomic data of the blending lines does not affect the Li abundance. However, the line list giving the best fit for the Sun may fail for other stars. We need a better knowledge on the atomic parameters blending the Li feature, in order to be able to reproduce both the solar spectrum and the spectra of other stars. An improved line list is required to derive reliable estimates of the isotopic Li ratio in solar-metallicity stars.

Enhanced lithium depletion in Sun-like stars hosting exoplanets

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In this work we present a homogeneous set of lithium abundances for 451 stars from the HARPS GTO planet search program. We compare the abundances of stars with and without planets. For solar analogues, we find that the planet-bearing stars have severely depleted lithium, retaining less than 1% of the original abundance, while 50% of solar analogues without detected planets have on average ten times more Li. Our observations reveal a connection between Li abundance and the presence of planets around solar type stars. We also present here a extension of teh study of Be abundances in a sample of 70 stars hosting planets and 30 stars without planetary companions in order to find a possible explanation to the process of depletion and mixing of light elements of late type stars.

Lithium deficient halo stars

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While most warm halo dwarfs show lithium abundances at the level of the Spite Plateau, a very small number (~5%) have undetectable lithium lines [eg. 1,2]. These stars have long raised questions when interpreting the plateau abundances: are they an extreme example of a depletion mechanism that has affected the plateau stars, or do they have an entirely different history? The latter seems likely, at least in some cases, due to the high incidence of binarity and the presence of rotational line broadening for several stars [3]. In this presentation we discuss some observed properties of the lithium-poor stars, with a particular focus on abundance ratios and rotation characteristics, and consider possible origins for the lithium deficiency in this unique group of stars.[1] Spite, M., Maillard, J. P. and Spite, F., 1984, A&A, 141, 56[2] Thorburn, J. A., 1992, ApJ, 399, L83[3] Ryan, S. G., Gregory, S. G., Kolb, U., Beers, T. C., and Kajino, T.,2002, ApJ, 571, 501

Li-rich RGB stars in the Galactic bulge

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We present Lithium abundance determination for a sample of K giant stars in the galactic bulge. The stars presented here are the only 13stars with detectable Lithium line (6767.18 A) among ~400 stars for which we have spectra in this wavelength range, half of them in Baade's Window (b=-4) and half in a field at b=-6.The stars were observed with the GIRAFFE spectrograph of FLAMES@VLT, with a spectral resolution of R~20,000. Abundances were derived via spectral synthesis and the results are compared with those for stars with similar parameters, but no detectable Li line. We find 13 stars with a detectable Li line, among which 2 have abundances A(Li)>2.7. No clear correlations were found between the Li abundance and those of other elements. Except for the two most Li rich stars, the others follow a fairly tight A(Li)-Teff correlation. It would seem that there must be a Li production phase during the red giant branch (RGB), acting either on a very short timescale, or selectively only in some stars. The proposed Li production phase associated with the RGB bump cannot be excluded, although our targets are significantly brighter than the predicted RGB bump magnitude for a population at 8 kpc.

The first measurement of gas-phase Lithium in the Small Magellanic Cloud

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The cosmic abundance of lithium continues to represent a conundrum, as predictions from BBN theory are inconsistent with measurements in the atmospheres of the lowest-metallicity stars. While there are worries that systematic errors in the stellar abundance determinations or modifications of the stellar Li abundances may play a role in this discrepancy, no satisfactory solution has yet been found. We suggest an alternate approach to studying the cosmic abundance of Li: measurements of interstellar gas-phase Li in low-metallicity environments. We present the first measurement of gas-phase Li in the Small Magellanic Cloud (at >16 sigma detection significance). This is the first such measurement beyond the Milky Way. While the total Li abundance from this measurement has associated systematic uncertainties, they are completely independent of those associated with measurements in low metallicity stellar atmospheres. We also present the first limits on the isotopic $^{7}Li/^{6}Li$ ratio in the gas of the Small Magellanic Cloud. We discuss the implications of our measurements and prospects for future advances.

A very low upper limit for a Beryllium abundance of a Carbon-enhanced metal-poor star BD+44 493

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We report a low upper limit for a beryllium abundance of a very bright (V=9.1) carbon-enhanced metal-poor (CEMP) star BD+44 493.A 1D LTE chemical abundance analysis of the star was performed based on high-resolution, high signal-to-noise spectra obtained with Subaru/HDS. The star is shown to be a subgiant with an extremely low iron abundance ([Fe/H]=-3.7), while it is rich in C ([C/Fe]=+1.3) and O ([O/Fe]=+1.6). The abundance pattern of BD+44 493 implies that a first-generation faint supernova is the most likely origin of its carbon excess. From a high-quality spectrum in the near-UV region, we set an very low upper limit on this star ís beryllium abundance (A(Be) = log(Be/H)+12 <-2.0), which indicates that the decreasing trend of Be abundances with lower [Fe/H] still holds at [Fe/H]<-3.5. This is the first attempt to measure a Be abundance for a CEMP star, and demonstrates that high C and O abundances do not necessarily imply high Be abundances.

Lithium abundances in the Alpha Persei cluster

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New echelle spectra with the 2.7m telescope at McDonald Observatory and with the 4m telescope at KPNO have been analysed for 30 stars and Li abundances have been determined now in a total of 64 stars between 4000 K and 7000 K in the 50 Myr old open cluster Alpha Persei. The goal of our study was to determine whether the spread in Li that was earlier observed in a limited study of this cluster is real or whether it is due to inhomogeneous reddening across the cluster or chromospheric activity in the stars. The spectroscopic analysis for the 28 slowly rotating stars yielded an iron abundance of 7.42 +/- 0.10. Reddening was mapped across the cluster with the available uvby Hβ photometry and was found to be variable with Av ranging between 0.09 and 0.51. However when reddening-free photometric temperatures and spectroscopic temperatures were used to estimate Li abundances, the variation in Li abundance was consistent with measurement errors. The equivalent width of the KI 7699 Å line was measured in about 12 stars. The equivalent width was found to increase linearly with decreasing temperature and the spread in KI at a given Teff was much smaller than in Li I. Although based on sparse data, these results imply that the spread in Li at a given Teff is real and not an artefact of reddening or chromospheric activity. A comparison is made to published results of Li abundances in abundances in clusters younger and older than Alpha Persei.

Lithium in solar system twin candidates

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Recently, Melendez et al. and Ramirez et al. have shown that the chemical composition of the Sun departs from most solar twins, which are stars almost identical to the Sun. The chemical abundance pattern of the Sun seems to be related to the formation of planetary systems like our own. Therefore, solar twins with a solar abundance pattern are excellent solar system twin candidates. In the present work we present Li abundances in such a sample of stars in order to ascertain whether lithium is related to planet formation.

Li abundances and chromospheric activity of BY Dra type stars

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The studied stars were observed at high resolution, high signal to noise ratio with the ELODIE echelle spectrograph (OHP, France). Vsini were obtained with a calibration of the cross-correlation function. Effective temperatures were estimated by the line depth ratio method. Surface gravities log g were determined by two methods: parallaxes and ionization balance of iron. The parameters and Li abundance are found for 155 stars. Among them of about 60 stars are active stars with a big fraction of BY Dra type stars for which spectral peculiarities were investigated. The comparison the Li abundance and rotational velocities, and central intensity of Halpha line and the index of chromospheric activity GrandS was made. Among active stars, no clear correlation has been found between different indicators of activity for our sample stars.

Lithium in dwarfs of intermediate age open clusters

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Lithium abundance measurements in dwarf stars in open clusters are of crucial importance for our understanding of the mixing mechanism and have allowed us to achieve important conclusions on the matter. However, in order to shed more light on the mechanisms that drive lithium depletion, lithium abundance measurements have to be coupled with accurate temperature determinations, which are best achieved when the analysis of iron lines is employed. Effective temperature estimations from photometry, on the contrary, can be affected by errors as large as several hundred kelvins due to uncertain open cluster reddening, especially when studying old open clusters, which tend to be more distant. In this poster we present lithium abundances in 12 dwarfs belonging to 4 open clusters at ages between 0.8 and or 1.7 Gyr. The stellar effective temperatures, along with the other parameters, were estimated from the analysis of about 60 Fe I lines and 10 Fe II. Even though the few data points call for caution, we notice that stars in the open cluster IC 4651 seems to present a steep decline with temperature below 6000 K.

HD 232862: a magnetic and lithium-rich giant star

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We report on spectropolarimetric observations of the giant star HD 232862. We analyze these data to extract information on its magnetic character and lithium content, and we confront this information with predictions from stellar evolution models.

New results of spectral observations CP stars in Li I 6708A spectral region with BTA(6m) SAO Russia

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NEW spectral observations of some Ap-CP stars with echelle-spectrometer “NES” on BTA (SAO RAS) permitted us to discover several stars with abnormal (enhanced) lithium abundance...
I. Testing and monitoring CP stars with Doppler shift (Vsini >10 km/sec) show variable line lithium 6708A in spectra : 10 Aq l , 210027, HD169842, HD107612, HD65339,, HD49976, HD12098. Among these stars we distinguish especially one rapidly oscillating star HD 12098. The strong and variable lithium line was detect in spectrum of star and considerable difference in lithium abundance in opposite rotational phases corresponding different(opposite) regions on the star surface is similar to the lithium line behaviour from earlier observations stars HD83368 and HD60435 with lithium spots.. Special analysis spectra of HD12098 and model calculations present in POSTER: ìLi spots in the roAp star HD 12098î A.V. Shavrina, Yu.V. Glagolevskij, N.S. Polosukhina, N.A. Drake, D. Kudryavtsev (G. A. IAU august 2009) II. Some roAp - slowly rotating stars (vsini<10 km/sec) HD 134210 , HD139949 , HD 166473 ,)with strong and nonvariable Lithium line 6708A. Analysis of two Lithium lines 6708 A and LiI 6103 A in spectra of these stars shows enhanced abundance lithium (6103A shows higher Lithium abundance by(0.2-0.3 DEX) and high Li6/Li7 ratio (0.3-0.5) for studied stars. We propose lithium production (Li6) due to spallation reactions and the preservation of both isotopesLi6 and Li7 by strong magnetic field near poles of dipole magnetic field.

The metal-poor end of the Spite plateau

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The primordial nature of the Spite plateau in low metallicity stars has been strongly challenged recently: the WMAP satellite measurements imply a BBN Li production between four times higher than observed. Moreover, Li abundances in Halo stars around [Fe/H]=-3 hint of a disruption of the Li plateau for extremely metal poor stars, which appear to show low Li abundances along with an important abundance scatter. The determination of A(Li) is extremely sensitive to the adopted temperature scale, so that a Teff bias might mimic a trend in A(Li). At the same time, previous samples were limited below [Fe/H]=3. I will present VLT-UVES Li abundances for 28 Halo dwarf stars between [Fe/H]=-2.5 and -3.5, 10 of which have [Fe/H]<-3. Four different Teff estimators have been used. Direct infrared flux estimation has been produced on the basis of 2MASS infrared photometry. Halpha wings have been fitted against two synthetic grids computed by means of 1D LTE atmosphere models, assuming Barklem et al. (2000), or Ali & Griem (1966) self-broadening theories. Finally, a grid of Halpha profiles has been computed by means of 3D hydrodynamical atmosphere models. The Li I doublet at 670.8 nm has been used to measure A(Li) by means of 3D hydrodynamical NLTE spectral syntheses. The results I will show confirm that A(Li) does not show a plateau anymore below [Fe/H]=-3. A strong direct correlation with [Fe/H] appears, not influenced by the choice of the Teff estimator. From a linear fit, we obtain a strong slope of about 0.28 dex in A(Li) per dex in [Fe/H], significant to 2-3 sigma, and consistent within 1 sigma among all the four Teff estimators. Such slope is two times larger than before reported, indicating that the metallicity sensitivity of A(Li) increases at lower metallicities. The scatter in A(Li) increases dramatically towards lower metallicities, while the plateau appears very thin above [Fe/H]=-2.8.The disruption of the Spite plateau below [Fe/H]$$-3 appears established, but its cause is unclear. If the primordial A(Li) is the one derived from standard BBN, it appears difficult to envision a single depletion phenomenon producing a thin, metallicity independent plateau above [Fe/H]=-2.8, and a highly scattered, metallicity dependent distribution below. The fact that no star below [Fe/H]=-3 lies above the plateau might suggest that they formed at plateau level and underwent subsequent depletion.

Beryllium abundances along the evolutionary sequence of IC 4651

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We derived for the first time beryllium abundances along the whole evolutionary sequence of an open cluster. We focus on the well-studied open cluster IC 4651. These Be abundances are used together with previously determined Li abundances, in the same sample stars, to investigate the mixing mechanisms in a range of stellar masses and evolutionary stages. Beryllium is detected in all the main sequence and turn-off sample stars, both slow- and fast-rotating stars, including the Li-dip stars, but was not detected in the red giants. Confirming previous results, we find that the Li dip is also a Be dip, although the depletion of Be is more modest than that of Li in the corresponding effective temperature range. For post-main-sequence stars, the Be dilution starts earlier within the Hertzsprung gap than expected from classical predictions as does the Li dilution. A clear dispersion in the Be abundances is also observed. Theoretical stellar models including hydrodynamical transport processes are able to reproduce well all the observed features. These results show a good theoretical understanding of the Li and Be behaviour along the colour-magnitude diagram of this intermediate-age cluster for stars more massive than 1.2 Msun.

Lithium as an age indicator in F, G, and K stars

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A calibration of lithium is presented as a means of estimating the ages of pre-main sequence and early main sequence stars.

CNO abudances in RR Lyrae stars

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While carbon does not quite fall into the class of "light elements" that usually ends with boron, its abundance often provides evidence of mixing that is useful in modelling the effects of mixing on lighter elements. One of these is the long known evidence of mixing from the depletion of carbon and the enhancement of nitrogen as low mass stars evolve up the red giant branch in globular clusters. A recently recognized influence of mixing on carbon abundances has been the discovery of a few carbon rich RR Lyr stars by Wallerstein, Kovtyukh, and Andrievsky. We now have high res spectra of 25 additional stars that we will analyse for their C, N, O abundances. Prior to our detailed analysis with model atmospheres we have inspected our spectra in the 7115 A region to estimate the strength of the CI lines as well as at 7775 A for the OI triplet. The CI lines are strongest in the most metal-rich RR Lyrae stars as indicated byt heir delta-S values and with periods between 0.3 and 0.5 days. The issue of whether the key factor is the metallicity or the period is not yet clear because of the well known correlation of delta-S with period. The OI triplet is always present but its strength depends on NLTE effects and a full analysis will be necessary to derive the oxygen abundances. The over-all metallicity will be derived from the lines of FeII. Coauthors are Gisella Clementini (Bologna), Wenjin Huang (Washington)

Lithium in metal-poor red giants

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The lithium abundances are derived from Li I 6708 Å line by fitting the observed high-resolution spectra with synthetic spectra for seven metal-poor red giant stars in the metallicity range [Fe] from -1 to -3 dex.

Session 4–Talks

Sources and sinks of light elements

Light elements as diagnostics on the structure and evolution of low- and intermediate-mass stars

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In this talk, I will review the main physical mechanisms involved in the transport (or inhibiting the transport) of elements in low and intermediate mass stars and describe how light elements can be used as a diagnostic tool to disentangle their effects.

Rotational mixing and Lithium depletion

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I review basic observational features in Population I stars, which strongly implicate rotation as a mixing agent: these include dispersion and main sequence depletion for a range of masses at a rate that decays with time. New developments related to the possible suppression of mixing at late ages (through interactions with settling) and an alternate origin for dispersion in young cool stars are also discussed. I also argue that testing models of halo star lithium depletion requires understanding of their angular momentum evolution, and that the expected dispersion is sensitive to assumptions about the angular momentum loss rates in particular.

Effects of rotation and magnetic fields on the structure and surface abundances of solar-type stars

Patrick Eggenberger <patrick.eggenberger@unige.ch>
Geneva Observatory, Geneva University - Switzerland

The effects of shellular rotation on the modelling of solar-type stars (in particular internal structure, evolutionary tracks in the HR diagram, lifetimes, and surface abundances) will first be examined. Then the effects of a dynamo possibly occuring in the internal stellar radiative zone by imposing nearly solid body rotation will be discussed.

The light elements in an helio- (astero-)seismic perspective

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Helio and asteroseismology prove to be excellent tools to probe the internal structure of the sun and the solar-type stars. Comparisons between models and seismic observations lead to constraints that are connected to element abundances. Furthermore, the direct comparisons between observed and computed oscillation mode frequencies coupled with spectroscopic observations can lead to the helium abundances in solar type stars where it is not directly observable. It is also interesting in that respect to study the differences between exoplanet host stars and stars without detected planets.

Lithium production in evolved stars (AGB, novae)

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I review the role of AGB evolution and nova explosions as factories of production for the galactic lithium. In particular, I point out the fundamental role of mass loss in the determination of the total lithium produced by massive AGB stars and super-AGBs, and discuss the possible role of lithium production by these stars in the global understanding of the patterns of elemental abundances in Globular Clusters.

Lithium production by thermohaline mixing in low-mass, low-metallicity asymptotic giant branch stars

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Standard stellar evolution suggests that low-mass stars should deplete their surface lithium abundances as they evolve up the red giant branch. By the time a low-mass star reaches the end of its asymptotic giant branch (AGB), it should be severely depleted in Li. However, there have been several detections of lithium-rich carbon-enhanced metal-poor (CEMP) stars, like CS22964-121, which suggest that Li is present in substantial quantity in the ejecta of low-mass, low-metallicity AGB stars. A mixing mechanism capable of producing lithium on the AGB must therefore be sought. We investigate the consequence of including thermohaline mixing in simulations of low-mass, low-metallicity AGB stars. We find that thermohaline mixing can produce enhancements of lithium up to A(Li) = 2.5 in stars that are carbon-rich. We are thus able to account for the Li-rich CEMP stars that have been observed.

Light elements in massive single and binary stars

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We investigate the changes of the abundances of the light elements in massive single and binary stars as function of the evolutionary history of the star, and as function of the adopted stellar interior physics.

Session 4 - Posters

Lithium as a clock during the PMS

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By means of measurements of the Li abundances of 376 star members of nine associations with ages between 6 Myr and >~ 75 Myr, it has been possible to study the Li depletion in this period (see da Silva et al. in this conference). Here, we explore the constraints imposed by stellar rotation to the use of Li as a clock.

Age and mass of open cluster and field solar twins constrained by lithium abundance

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We analyze the non-standard mixing history of open cluster and field solar twins to determine as precisely as possible the mass and age. We computed a grid of evolutionary models with non-standard mixing at several metallicities with the Toulouse-Geneva code for a range of stellar masses. We choose the evolutionary model that reproduces the observed lithium abundances observed in the solar twins. Our best-fit model for each solar twin provides a mass and age solution constrained by their Li content and Teff determination. For the field, HIP 56948 is the most likely solar-twin candidate at the present time and our analysis infers a mass of 0.994 +/- 0.004 Msun and an age of 4.71 +/- 1.39 Gyr. For the open cluster M67 two stars 637 and 1787 are the most likely solar-twin and have both Teff determinations within 50 K from the solar values. Non-standard mixing is required to explain the low Li abundances observed in solar twins. Li depletion due to additional mixing in solar twins is strongly mass dependent. An accurate lithium abundance measurement and non-standard models could provide more precise information about the age and mass more robustly than determined by classical methods alone.

Boron depletion in rotating 9-15 solar mass stars

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Mixing in stellar interior is a 3D hydrodynamic effect, but since it is computationally very hard to perform 3D stellar evolution calculations mixing relies on theories reducing these effects to 1D. One of the main questions is how well the prescriptions for rotational mixing describe the real effects. Boron and nitrogen surface abundances together can constrain the mixing efficiencies in massive stars on the main sequence, because moderate mixing at the surface leads to a depletion of light elements such as lithium, beryllium and boron but only later to an enrichment in nitrogen. It is hard to explain this effect with binary mass transfer. This in turn could help to distinguish between effects due to binary mass transfer and mixing in rotating single stars. We tested the mixing prescriptions included in the Geneva stellar evolution code (GENEC) by following the evolution of surface abundances of light isotopes in massive stars. The GENEC contains a prescription for rotational mixing which includes as important feature the transport of angular momentum as an advection process and not as diffusion, like it is done in other stellar evolution codes including effects of rotation. We implemented an extended reaction network into this code including the light elements Li, Be and B, which allowed us to perform calculations testing the rotational induced mixing. We followed 9, 12 and 15 solar mass models with rotation from the zero age main sequence up to the end of He burning. The calculations show the expected behaviour with faster depletion of boron for faster rotating stars and more massive stars. The mixing efficiency at the surface is more efficient than predicted by prescriptions used in other codes. We found that the mixing prescription leads to strong enough surface mixing to reproduce the observations well while keeping the unique signature of single rotating stars.

Li survey in giant stars: Probing non-standard stellar physics

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Lithium has long been known to be a good tracer of non-standard mixing processes occurring in stellar interiors. Here we present the results of a large survey aimed at determining the surface Li abundance in a sample of about 800 giant stars with accurate parallaxes selected from the Hipparcos catalogue. We compare the observed Li behaviour with that predicted by stellar models including rotation and thermohaline mixing. We also discuss the case of the few "Li-rich" giants of our sample.

Boron depleting reactions studied through the Trojan Horse Method

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Boron, as well as lithium and beryllium, have been largely accepted as possible probe for stellar interior since its residual abundance in stellar atmospheres could reflect the action of non-standard mixing phenomena occurring inside stars. Its destruction mainly proceeds through nuclear (p, alpha) reactions induced at energies of about 10 keV and in such energy region nuclear measurements must be then performed. Trojan Horse Method provides a complementary tool to direct measurements to explore such energetic regions up to now only reached through extrapolations. The recent results about the boron depleting reactions will be then shown.

Lithium depletion by magnetic extra-mixing in main sequence stars

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We show calculations of lithium abundance and its time evolution in solar type stars, performed with standard stellar models together with magnetic extra-mixing. We compare them with observations from open clusters.

Extra-mixing and Li in Red Giants

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Thermally pulsing Asymptotic Giants Branch stars contribute to the synthesis not only of s-elements but also of light elements like Li, C, N, O. In particular, stars along the Red and Asymptotic Giants Branch show a wide range of Li abundances. This phenomenon is explained in literature in terms of deep not-convective mixing of different kinds, which determines a Li enrichment or destruction depending on the velocity profile. At present, none of the presented mechanism is able to provide Li production destruction at the same time. We present a possible scenario for the evolution of Li abundance along the RGB and AGB phase due to magnetically induced mixing, which can provide different velocity for the mass transport and so is able to provide a dilution as well as an enrichment of Li in the stellar envelopes.

Session 5 – Talks

Evolution of light elements in the Universe

Galactic evolution of D, ^{3}He, and ^{4}He

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After a short historical review of the subject, I focus on the uncertainties that still plague our understanding of the evolution of the light nuclides D, ^{3}He and ^{4}He in the Galaxy, as well as on possible ways out. The dispersion of the present-day values of the local D abundance can be reconciled with the predictions on D evolution from standard Galactic chemical evolution models, provided that the "true" local D abundance is correctly identified. The nearly constancy of the ^{3}He abundance with both time and position within the Galaxy implies a negligible production of this nuclide in stars, at variance with predictions from standard stellar models which, however, do agree with the scarce observations of ^{3}He in planetary nebulae. Advances in stellar modelling promise to hold solution for this conundrum, but we still wait for quantitative estimates of the actual ^{3}He yields. Much effort has recently been made to unravel the origin of the extreme helium-rich subpopulations discovered in some Galactic globular clusters. I briefly discuss the impact of extreme ^{4}He polluters on the evolution of ^{4}He in the Galaxy.

Thermohaline mixing in stars - Solving the long-standing ^{3}He problem

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The classical theory of stellar evolution predicts a very simple Galactic destiny to ^{3}He, dominated by a large production of this isotope in low-mass stars. As a consequence, one expects a large increase of ^{3}He with time in the Galaxy with respect to its primordial abundance. However, the ^{3}He content of Galactic HII regions is similar to that of the Sun, and very close to the BBN value. This is the so-called "^{3}He problem" that could be resolved if only ~ 10 % or less of the low-mass stars were releasing ^{3}He as predicted by classical stellar theory. In 2007 Charbonnel & Zahn showed that thermohaline mixing drastically reduces the ^{3}He production in low-mass stars. Here we present the predictions of stellar models over a broad range in mass and metallicity and including thermohaline mixing. Using the corresponding yields for ^{3}He, we are now able to explain the observed behaviour of this light element in our Galaxy.

Theoretical DY/DZ in the early Universe

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Population III stars initiated the chemical enrichment of the Universe. Chemical evolution models seem to favour fast rotators among the very low-metallicity population. When a star rotates fast, it ejects significant quantities of He and its nucleosynthesis is modified compared to the case without rotation. The value of DY/DZ is explored from a theoretical point of view through stellar models of zero- or very low-metallicity, with and without rotation.

Galactic evolution of ^{7}Li

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Lithium represents a key element in cosmology, as it is one of the few nuclei synthesized during the Big Bang. The primordial abundance of 7Li allows us to impose constraints on the primordial nucleosynthesis and on the baryon density of the universe. However, 7Li is not only produced during the Big Bang but also during galactic evolution: measures of stellar Li in our Galaxy suggest an almost constant Li abundance (the so-called Spite plateau) at low metallicities and a subsequent increase in the disk stars, leading to a Li abundance in T Tauri stars higher by a factor of ten than in Population II stars. This means that there must exist several possible stellar sources of 7Li: AGB stars, supernovae, novae, RG stars. 7Li is also partly produced in spallation processes while 6Li is entirely produced by such processes. All of these sources have been included in galactic chemical evolution models and constraints have been derived on the primordial 7Li and its evolution, as well on stellar models. I will review these models and their results and what we have learned about 7Li evolution. Some still open problems, such as the disagreement between the primordial 7Li abundance as derived by WMAP and as measured in Population II stars, and the uncertainties about the main sources of stellar 7Li will be discussed.

Lithium, Beryllium, and Boron Production in Core-collapse Supernovae

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Type Ic supernova (SN Ic) is the gravitational collapse of a massive star without H and He layers. It propels several solar masses of material to the typical velocity of 10,000 km/s, a very small fraction of the ejecta nearly to the speed of light. We investigate SNe Ic as production sites for the light elements Li, Be, and B, via the neutrino process and spallations. As massive stars collapse, neutrinos are emitted in large numbers from the central remnants. Some of the neutrinos interact with nuclei in the exploding materials and mainly ^{7}Li and ^{11}B are produced. Subsequently, the ejected material with very high energy impinge on the interstellar/circumstellar matter and spallate into light elements. The contributions of SNe Ic to the Galactic chemical evolution and the observed abundances of the light elements on some halo stars are discussed.

Light elements: Spallation production mechanisms

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- France

Galactic evolution of spallogenic light elements (Li6, Be9, B10 and B11)

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I will review the spallogenic production of Li6, Be9, B10 and B11 in the light of available observations of their abundances in the Milky Way, as well as the implications for the source sites of Galactic cosmic rays

Beryllium abundances and the formation of the halo and the thick disk

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The single stable isotope of beryllium is a pure product of cosmic-ray spallation. Assuming the cosmic-rays to be globally transported, the beryllium abundance should be roughly homogeneous throughout the early-Galaxy at a given time. Thus, it could be useful as a tracer of time. In an investigation of the use of beryllium as a cosmochronometer, abundances of beryllium were derived for a large sample of halo and thick-disk dwarfs. Using these abundances, and abundances of alpha-elements from the literature, we studied the evolution of Be in the early-Galaxy, its dependence on kinematic and orbital parameters, and the formation of the halo and the thick disk of the Galaxy. We found evidence that the halo stars separate into two components; one is consistent with predictions of evolutionary models, and another chemically indistinguishable from thick-disk stars. We also found evidence that the star formation rate was lower in the outer regions of the thick disk, pointing towards an inside-out formation. In this work, we present new results of the extension of this analysis using newly determined oxygen abundances. As oxygen can be considered a pure product of SNe II, it is a better tracer of star formation. It can thus be used to better constrain the evolution of star formation with time (Be) in the different components of the early-Galaxy.

Conclusions and open questions

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Session 5 - Posters

Cosmic rays changes the Universe

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It has been recorded that the key factors of changing the Universe are lying within the cosmic rays. During the Solar maximum and Solar minimum the influence of cosmic rays on the Sun has been observed. Sun-Earth environment has also been found under the influence of extra galactic and solar originated cosmic rays. Environment of the Earth has shown the fluctuation of cosmic rays before the occurrence of earthquake, tsunami, snowfall, rainfall and epidemic outbreak.

The nucleosynthesis in Sakurai's object from Li to Ba

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Sakurai's object (V4334 Sagittarii) is a post-AGB star that evolved through a very-late thermal pulse event. This H-ingestion variant of the He-shell flash is a proto-type example of convective-reactive nucleosynthesis where energetically relevant nuclear burning operates on the hydrodynamic time scale of convection (Damkohler number ~ 1). In particular, unprocessed material with a near-solar H abundance is mixed with the convectively unstable He-burning shell on top of electron-degenerate core. For Sukurai's Object Asplund et al. 1999 determined 28 elemental abundances ranging from light elements H, He and Li up to heavy elements Ba and La, plus the C isotopic ratio. These abundances are the key for a better understanding of the physics of H ingestion in He-shell flashes, and more in general for all convective-reactive episodes in stars. We present the results of detailed and highly resolved multi-zone nucleosynthesis simulations including all elements. We show that we cannot reproduce the observed abundances with the mixing evolution indicated by the one-dimensional stellar evolution models. On the other hand, we are able to reproduce most of the observed abundance trends by making mixing assumptions that are in line with expectations from hydrodynamic simulations.

Chemical evolution of D in the local disk

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Chemical features of the local disk have firmly established the picture for the formation of the Galactic disk that the star formation has proceeded under the continuous accretion of low-metallicity gas from the halo. It sets two processes for the evolution of deuterium (D), that is, the destruction of D in the interior of stars and the supply of new (nearly) primordial D associated with the gas infall. Standard Galactic chemical evolution (GCE) models predict that this scheme leads to a monotonic decrease in D/H with time, and the present-day D/H abundance $(D/H)_0$ lower than the recently observed estimates as a natural result of construction of the metal-rich local star plus gas system. Here we propose that the new GCE models make the system rich in both metals and D and compatible with the observed local disk features.