LITHIUM IN THE COSMOS

Poster Abstract Booklet

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D. Bemmerer and C. Gustavino for the LUNA collaboration

Study of the 2H(alpha,gamma)6Li nuclear reaction producing 6Li in standard big bang nucleosynthesis

The 2H(alpha,gamma)6Li reaction dominates the production of lithium-6 in standard big bang nucleosynthesis. Due to its exceedingly low cross section, this reaction has never been studied experimentally at the relevant energies, and consequently the adopted reaction rate depends on uncertain extrapolations. A direct study of the 2H(alpha,gamma)6Li cross section is currently underway at the LUNA 400 kV accelerator, located deep underground in the Gran Sasso laboratory, Italy. The expected data lie directly at big-bang energies. It is hoped that they help constrain non-standard lithium-6 production scenarios, by putting the standard Big Bang production on a solid experimental footing.

K. Cunha, S. Schuler, L. Ghezzi, J. King, V. Smith

Constraints on Li6/Li7 ratios in a Sample of Planet Hosting Stars

The measurement of the isotopic ratio Li6/Li7 is challenging and, in particular, the analysis of Li6 in solar type stars has many uncertainties. We present constraints on Li6 measurements for a sample of planet hosting stars from the analysis of very high resolution and very high signal-to-noise ratio spectra obtained with the Hobby Eberly Telescope at McDonald Observatory. The target stars were selected as they exhibit large slopes of element abundance versus condensation temperature. The possible detection of Li6 in planet hosting stars could be a signature of accretion of solid material. Li6/Li7 ratios will be presented and results will discussed.

B. Kumar Yerra

Study of Li-rich K giants: Evolution of Li, far-IR excess, and rotation in low mass giants

A few low mass giants in the red giant branch are found to have anomalous high Li in their atmospheres. Adding to this anomaly, some of the Li-rich giants show far infrared excess and high rotation. Origin of overabundance of Li and associated peculiarities in Li-rich K giants are not well understood. To understand the underlying physical process for excess Li and to increase the sample size of Li-rich K giants, we have initiated a low resolution spectroscopic survey of 2000 K giants along the red giant branch covering all the way from base of the RGB to post-luminosity bump. This is the first major survey for Li-rich K giants which resulted in 15 new Li-rich K giants including 3 new super Li-rich ones. Survey resulted in increasing the total number of Li-rich K giants by a factor of two, and confirmed the rarity of the Li-rich K giants, just under 1%, in the solar neighbourhood. A significant result from the survey is finding of no Li-rich K giants before and after the luminosity bump. Importantly, all the Li-rich K giants occupy a narrow luminosity range in the HR diagram suggesting their connection to internal changes in the star. High resolution spectroscopic study suggests no correlation between Li enhancement, and C, N, O abundances or 12C/13C isotopic ratios. Abundances of C,N,O and values of 12C/13C suggest that the Li-rich K giants are normal and have undergone expected 1st dredge-up and extra-mixing. Infrared properties of Li-rich K giants may suggest a correlation between Li and mass-loss. Distribution of rotational velocities of stars from main sequence to giants indicate that a few stars among Li-rich K giants may have inherited high rotation from main sequence. In this presentation, we will describe the survey and the results which strongly favour internal nucleosynthesis to any other scenarios such as planet engulfment or preservation.

W. J. Maciel, R. D. D. Costa

Lithium abundances and metallicities: trends from metal-poor and AGB/RGB stars

Recent determinations of Li abundances in the Galaxy resulted in two important conclusions: first, there is a significant discrepancy between the predicted values by Standard Big Bang Nucleosynthesis (SBBN) and the observed values, reaching about 0.6 dex for the oldest, most metal-poor stars; second, for these stars there seems to exist an almost linear relationship between the Li abundances relative to H and the metallicity as given by the Fe abundances relative to the Sun. Concerning higher metallicity objects, present results show that a larger dispersion of Li abundances is observed for a given metallicity up to about [Fe/H] = 0.5. In the case of RGB and AGB stars, most of the objects analyzed have probably destroyed most of the pristine lithium. However, there is a number of galactic AGB and RGB stars which show clear signs of Li enhancements, in particular those for which the Li abundance relative to H is higher than 1.5 dex, which are generally known as Li-rich giants. Part of the Li observed in these objects may have been produced by Hot Bottom Burning (HBB), or by other mechanisms. Since the metallicities of the Li-rich giants are generally known, it is interesting to investigate whether or not the trend presented by the metal-poor stars can also be observed in their metal-rich counterparts. This will provide a better understanding of the chemical evolution of lithium during the galactic lifetime, as well as place constraints on the Li production in AGB stars. In this work, we consider a large sample of AGB and RGB stars for which accurate Li abundances are available, and investigate the existence of any trends between the Li abundances and the metallicities. It is concluded that, in average, Li-rich AGB stars maintain the same average increase of Li abundances at higher metallicities, so that a similar slope is obtained both for metal-poor and metal-rich stars. This fact possibly has some consequences on the mechanisms of Li production in AGB stars.
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T. Mishenina

Li abundance in the stars with the solar-like type of activity

Li abundances, atmospheric parameters and rotational velocities for 150 dwarfs have been determined from the high resolution echelle spectra, obtained with the ELODIE spectrograph at the OHP (France). Among them, there are 100 stars with a determined level of activity. The level of chromospheric and coronal activity of the target has been evaluated through the log R'HK index and X-ray flux. The behavior of the lithium abundance with Mbol, Teff, [FeH], vsini and the level of activity was considered. The Li is detected in 62% stars with the high level of solar-type activity whereas it is only detected in 31% of stars with the weak level of solar-type activity. Some correlations between the Li abundances, and of the level of chromospheric activity and rotational velocities vsini have been found. The correlation of the Li abundances and the index of chromospheric activity log R'HK was not established. The obtained results confirm that the principal causes of the formation of high activity and detectable Li abundance are determined mainly by fast axial rotation and younger age, respectively.

T. Nordlander, A.J. Korn, O. Richard, K. Lind

Li in globular clusters: Significant systematics

Atomic diffusion is known to introduce significant depletion of lithium in the surface layers of Spite plateau stars. In current stellar modelling, however, atomic diffusion effects need to be moderated by a free parameter referred to as turbulent mixing. To better constrain this parameter, and the primordial lithium abundance, we have reinvestigated high-resolution UVES spectra of 18 stars in the metal-poor globular cluster NGC 6397 (Korn et al. 2007). The stars range from just above the turnoff-point to the RGB below the bump.In our updated analysis, we adopt a temperature scale supported by recent calibrations on the infrared flux method (Casagrande et al. 2010). Additionally, we have determined and corrected the Mg abundances for the effects of intra-cluster pollution. The evolution of surface abundances are found to be in good agreement with stellar model predictions with atomic diffusion and a turbulent-mixing efficiency parameter in the range T5.95-6.15. For the optimal T6.0 model, we deduce an initial lithium abundance in our sample of stars of A(Li) = 2.57 +- 0.1, in reasonable agreement with the WMAP-calibrated BBN prediction of the primordial lithium abundance, A(Li) = 2.71 +- 0.06. We expect that correcting for the remaining biases in our estimate would lead to a higher initial lithium abundance, and thus consider our result conservative. These biases, each responsible for an underestimation by as much as 0.05 dex, are the effects of intra-cluster pollution on lithium, the precise choice of the turbulent-mixing efficiency, and spectroscopic modelling shortcomings (3D NLTE effects).

G. Pace

Lithium in M67: from the main sequence to the red giant branch

Lithium abundances in open clusters have been widely used as probe of mixing processes in the sun. The open cluster M67 is especially interesting in that its age and metallicity make it a perfect tool to help understand the large depletion of lithium in the sun. Despite M67 have been studied several times, a homogeneous global analysis of lithium in stars from subsolar up to the most massive members, was never accomplished for a large sample based on high-quality spectra. We collected literature data to follow, for the first time in a homogeneous way, NLTE lithium abundances of all observed single stars in M67 more massive than about 0.9 solar masses, and we then used these data to test our non-standard models. Our grid of evolutionary models were computed with non-standard mixing at metallicity [Fe/H] = 0.01 dex, using the Toulouse-Geneva evolution code.

A. Palacios

The puzzling weak G band stars

The weak G-band subclass includes about thirty cool and luminous stars that exhibit very weak or no G-band of the CH. In addition to their apparently very strong carbon deficiency a large number of these stars are also lithium-rich (A(Li) $>$ 1.4 dex). In this presentation, we will review the evolutionary status and the possible explanation of the weak G-band phenomenon, and propose some clues to their lithium enrichment in the light of new stellar evolution models and abundance determinations.

N. Polosukhina, A. Shavrina, N. Drake, M. Smirnova

Lithium in roAp stars with strong magnetic fields

Last time we study the problem of Lithium and the Li6/Li7 ratio in the atmospheres of some sharplined roAp stars with magn.fields Our synthetiic spectrum calculations take into account magnetic splitting and other line-brouding effects. Lithium everabundances were found in the atmospheres of the some roApstars based on our analysis of both lines 6103 and 6708A lithium lines, with high values of the Li6/Li7 ratio (0.2-0.5) This can be explaned if Lithium produced in spallation reactions and Li 7 and Li6 is preserved by strong magnetic fields in upper layers atm. around magnetic poles!

M. Pospelov, N. Afshordi

Lithium diffusion after recombination

We revisit the cosmological history of Li after the recombination, when the gravitational settling of elements in the potential wells of the dark matter overdensities leads to the diffusion-driven differentiation of their abundances. Lithium is the only element that remains in the ionized state after all other primordial elements become neutral. This was missed in previous analyses that led to incorrect conclusion about the direction of lithium diffusion relative to hydrogen. In this presentation, we show that lithium (relative to hydorgen) diffuses out of overdensities and speculate that this might be a cause of its deficit in the Milky Way relative to BBN/WMAP prediction.

T. Prodanovic

Lithium Production in Galactic Flybys

Unlike Li-7 plateau which is expected but observed with a level that is difficult to explain, Li-6 observations in low-metallicity halo stars also reveal a plateau which is completely unexpected within the standard picture of Li-6 origin in galactic cosmic-ray interactions. This indicates the existence of a new pre-galactic Li source, however all considered sources (e.g. supernovae, shocks due to structure-formation etc.) either completely fail to explain the observed abundance or require some fine-tuning. Here we present another possible source of lithium ■ cosmic rays that arise due to galactic flybys. Gravitational interaction between two galaxies flying by each other could result in weak, but large-scale, short-lived shocks that would give rise to a new, low-energy cosmic-ray population. Such cosmic-ray population would result in a homogeneous increase of Li-6 (and Li-7) abundance, but would not be accompanied with increased metallicity or with increased gas content. The details, of course, depend on interacting galaxies. In our preliminary results we consider close flybys between Milky Way and Small Magellanic Cloud (SMC), and analyze impact on resulting lithium abundances. Our results are discussed in the light of the new lithium abundance measurements and gamma-ray observations of the SMC.

N. Prantzos

Production and evolution of Li, Be, and B isotopes in the Galaxy

We reassess the problem of the production and evolution of the light elements Li, Be and B and of their isotopes in the Milky Way, in the light of new observational and theoretical developments. We find that the adopted GCR source composition accounts naturally for the observations of primary Be and helps understanding why Be follows closer Fe than O. We find that GCR produce 70% of the solar 11 B/ 10 B isotopic ratio; the remaining 30% of 11 B presumably result from neutrino-nucleosynthesis in massive star explosions. We find that GCR and primordial nucleosynthesis can make at most 30% of solar Li. At least half of solar Li has to originate in low-mass stellar sources (red giants, asymptotic giant branch stars or novae), but the required average yields of those sources are found to be much larger than obtained in current models of stellar nucleosynthesis. For the first time we present radial profiles of LiBeB elemental and isotopic abundances in the Milky Way disk. We argue that the shape of those profiles - and the late evolution of LiBeB in general - reveals important features of the production of those light elements through primary and secondary processes.

A. Ritchey

Lithium isotope ratios near the supernova remnant IC 443

The rapid rise in the Li-7 abundance for stars of near solar metallicity requires the existence of one or more stellar sources of Li-7. Likely candidates include red giant and asymptotic giant branch stars, which produce Li-7 via the Cameron-Fowler mechanism, and Type II supernovae, in which Li-7 is synthesized by neutrino-induced spallation. Direct evidence of the neutrino-process remains elusive, yet could be provided by detailed studies of Li isotope ratios in interstellar gas surrounding supernova remnants. Here, we present the results of the first such investigation, based on high-resolution measurements of Li I along four lines of sight through the supernova remnant IC 443. While our observations probe material presumably contaminated by the ejecta of a core-collapse supernova, we find no evidence of Li-7 synthesis by neutrino-induced spallation. Rather, our results indicate that the abundance of Li-6 relative to Li-7 has been enhanced by interactions between shock-accelerated cosmic rays and the molecular cloud surrounding the remnant. Future observations will help to establish unequivocally the role that neutrino spallation plays in Li-7 production.

G. Ruchti

Li-Production as Probed by Metal-Poor Li-Rich Giants in RAVE

The abundance of Li in stellar atmospheres is a very sensitive probe of the structure of the stellar interior and the physical processes taking place there. Understanding the processes whereby lithium is created and destroyed is critical to clarifying tension with standard big bang nucleosynthesis. Li is expected to be readily destroyed in giant stars, however, Li-rich giants have been found in both the field and globular clusters. In a recent paper, we reported on the discovery of eight lithium-rich field giants found in a high-resolution spectroscopic sample of metal-poor stars ([Fe/H] $<$ -0.5) selected from the Radial Velocity Experiment survey. The majority of the Li-rich giants in our sample are very metal-poor ([Fe/H] $<$ -1.9), and have a Li abundance between 2.30 and 3.63, well above the typical upper RGB limit. We further discovered a new Li-rich giant in the globular cluster, M68. We performed a detailed abundance analysis of all stars, finding that the majority of our sample stars have elemental abundances indistinguishable from those of Li-normal halo giants. I will discuss these abundance properties, as well as other observational properties, of the Li-rich giants in our sample and compare to predictions made by present theories of Li-production in giant stars.

J. Schober

Implications of Primordial Lithium for the Origin of Magnetic Fields

The primordial element abundances regulate the ability of the gas to cool, as well as its overall ionization degree. Detailed calculations show that at densities above $10^9 cm^{-3}$, Li^+ becomes the main charge carrier and thus determines the magnetic properties of the gas. We use a detailed chemical network to determine the evolution of the abundances during the collapse of a primordial halo. We study the amplification of the magnetic field by the small-scale dynamo, which depends on the turbulent properties as well as the Ohmic resistivity (Schober et al. 2012). Finally, we calculate the evolution of the small-scale magnetic field during the collapse for the two extreme cases of turbulence (incompressible and highly compressible turbulence). We find that in both cases, equipartition is reached very quickly. Thus, the presence of primordial lithium is particularly important to maintain this magnetic field at high densities.

S. Theado, S. Vauclair

Metal-rich Accretion and Thermohaline Instabilities in Exoplanet-host Stars

The early evolution of planetary systems is expected to depend on various periods of disk matter accretion onto the central star, which may include the accretion of metal-rich matter after the star settles on the main sequence. When this happens, the accreted material is rapidly mixed within the surface convective zone and induces an inverse mean-molecular-weight gradient, unstable for thermohaline convection. The induced mixing, which dilutes the metal excess, may also have important consequences on the light elements abundances. We model and analyze this process, and present the results according to various possible accretion scenarios. We give a detailed discussion of the different ways of treating thermohaline mixing, as proposed by previous authors, and converge on a consistent view, including the most recent numerical simulations. We show how the observations of light elements in stars can be used as tracers of such events.

S. Degl'Innocenti, E. Tognelli

Lithium seven abundances in pre-MS open cluster stars

The disagreement between theoretical predictions and observations for surface lithium abundance in stars is a long-standing problem not settled yet. Indeed, despite the large amount of lithium observations in isolated stars, binaries, and clusters, and the strong effort done from the theoretical point of view, the unsatisfactory agreement with the data is a challenging issue for stellar modellers. Thus, it is meaningful to examine the old lithium problem under the light of the new improvements both on models and observations. In the talk we perform a consistent and quantitative analysis of the theoretical uncertainties affecting the models and compare our predictions on lithium abundance against the observations available for five young open clusters, of different ages and chemical composition, namely, Ic 2602, α Per, Blanco1, Pleiades, and Ngc 2516. We present also the comparison for lithium observations available in four detached double-lined eclipsing binary systems. Finally we investigated and discuss the possibility of adopting a a different convection efficiency during the pre-MS and MS phase.

F. Villante

The cosmological lithium-7 problem from a nuclear physics perspective

We discuss the cosmological Lithium-7 problem from the nuclear physics perspective. In order to do this, we introduce an efficient method to calculate the response of the 7Li primordial abundance to an arbitrary modification of the nuclear reaction rates. We, then, apply our approach to the various possible Beryllium destruction channels. We improve with respect to previous analysis by introducing a better description of the nuclear processes. As a results of this, the parameter space for a nuclear physics solution of the Lithium-7 puzzle is considerably reduced.