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Sinks of Light Elements in Stars - Part II

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Abstract.

See the abstract given in Part I (Deliyannis, Pinsonneault, Charbonnel, hereafter DPC, in these proceedings). In Part II we discuss the lithium data for metal-poor stars and the constraints it places on stellar depletion. There are a variety of indicators that place interesting bounds on the degree of stellar depletion, and in contrast to the other two sections the data for Population II stars provides weaker evidence for stellar lithium depletion. We review both the theoretical studies and the observational data, and critically evaluate the degree of stellar depletion consistent with the data.

1. Introduction

The study of lithium in metal-poor stars has implications for stellar structure, galactic chemical evolution, and Big Bang nucleosynthesis (BBN). There has thus been considerable observational and theoretical effort on this question, and we will therefore attempt to draw together the main themes and outstanding questions rather than undertake a detailed analysis of the fine points. This paper will be organized as follows. In section 2, we recall the main trends of the theoretical expectations. In section 3, we discuss the major features of the observational data; in particular we stress the similarities and differences with the population I pattern. Section 4 is devoted to the comparison of different classes of theoretical models with the data, and our conclusions are summarized in section 5.

2. Main Trends of the Theoretical Expectations

Let us first briefly recall that the so-called standard case refers to models which exclude any kind of transport processes of the chemicals in the radiative zones, and thus consider only convection as a mixing mechanism. Lithium is destroyed at moderate temperature by stellar interior standards; for typical main sequence (MS) and pre-MS densities, Li^6 burns at a time scale comparable to or shorter than the evolutionary time scale at around 2 million K and Li^7 burns at around 2.6 million K. Both beryllium and boron are less fragile, with characteristic burning temperatures of order 3.5 million K and 5 million K respectively. Because the observational data points to modest lithium depletion in halo stars (and even this conclusion is controversial!) we will restrict our discussion of light element depletion to lithium.

The major predictions of classical (sometimes referred to as standard) stellar evolution models for halo stars are summarized in Deliyannis et al. (1990). They depend mainly on the variations of the depth of the stellar convective envelope (and thus of the temperature at its base) with the stellar mass, metallicity and evolutionary stage. Pre-MS depletion increases with decreased mass, and there will therefore be a strong decrease of lithium with decreased T_{eff} for cool stars. Main sequence depletion is predicted to be minimal for all but the coolest stars; the absolute degree of lithium depletion decreases with decreased metal abundance. The net effect predicted is that hot halo dwarfs should exhibit little or no dependence of their surface lithium abundance on effective temperature, and for the lowest metal abundances there should be a minimal dependence on [Fe/H], in the sense that lower abundances would be predicted for higher metallicities. This implies a small dispersion in lithium at fixed effective temperature; in the Population I case, it also implies a weak dependence of lithium on age which can be tested in open clusters.

Classical stellar models neglect some physical processes which are known to be important for interpreting the surface lithium abundances of stars. The linked phenomena of gravitational settling and thermal diffusion, which are solidly based in our knowledge of plasma physics, are among the most important. Atomic diffusion is a fundamental process which must occur in the stellar gas unless some macroscopic motions counteract it, causing heavy elements to sink with respect to light ones under the conditions applicable for halo dwarfs. The time scale for this process decreases as the depth of the surface convection zone decreases.

Theoretical models which include pure atomic diffusion[1] (see Michaud et al. 1984 for the first computations for halo stars) therefore predict that lithium sinks below the surface convection zone for the conditions appropriate for subdwarfs, and furthermore that the degree of diffusion increases with increased T_{eff}. Microscopic diffusion will not generate a dispersion in abundance at fixed T_{eff}, and the effects at a given surface temperature are not strongly metallicity dependent.

[1] By "pure atomic diffusion" we mean that it is not counteracted by any macroscopic process in the stellar radiative zones.

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Stellar winds can counteract and prevent atomic diffusion without leading to nuclear destruction (Vauclair & Charbonnel 1995). The corresponding mass loss necessary in the hottest halo stars is in excess of the value inferred from an extrapolation of the solar Mdot to halo stars by a factor of about 10 to 30, but not by a degree that can be ruled out observationally. For even larger mass loss rates the outer layers containing lithium can be removed; as noted by Swenson & Faulkner (1992) the finite depth of the surface convection zone must be accounted for and models with strong (stronger than inferred by Vauclair & Charbonnel 1995) mass loss alone are incompatible with the Population I lithium pattern. For hot halo stars the combined effect of diffusion and mass loss produce both lithium depletion and a small dispersion in abundance.

There are known mechanisms for mild mixing in the radiative envelopes of low mass stars. The two most frequently studied are rotationally-induced mixing and turbulence induced by gravity waves (see Pinsonneault 1997 for a review and DPC). Gravity waves can be produced by turbulence in the surface convection zone; because the convection zone depth is a strong function of mass, this can produce mass-dependent lithium depletion that is a function of time on the main sequence. It would not produce a dispersion in abundance for a sample of uniform age and composition, but abundance differences could be generated by a range of age and composition as seen in field halo stars.

The degree of rotational mixing depends on several major factors. Low mass Population I stars are observed to have a range of surface rotation rates and stars of the same mass, composition, and age could therefore have different initial angular momenta, different rotation rates as a function of time, and different degrees of rotational mixing. A dispersion in surface lithium abundance, even at fixed effective temperature in clusters, is therefore expected. However, the observed distribution of rotation rates in young clusters is nongaussian which strongly affects the expected lithium depletion pattern. We also cannot directly observe the initial conditions for Population II stars. To predict the detailed distribution of abundances the best we can to is to infer the distribution of initial conditions from young open cluster stars (see Pinsonneault et al. 1999, hereafter PWSN). The degree of mixing is also directly linked to the internal transport of angular momentum (e.g., Zahn 1992, Maeder 1995). Rotational mixing can also be inhibited by gradients in mean molecular weight - induced by nuclear burning in the cores of stars and possibly also by gravitational settling of helium in their outer layers (see also Michaud and Vauclair in these proceedings). In contrast with classical models, more modern models including mild mixing below the envelope on the main sequence can simultaneously produce modest depletions of species, such as lithium and beryllium, that burn at very different temperatures. Rotational mixing will also be a function of age, and some classes of models predict trends with [Fe/H] and effective temperature that can be tested in halo stars.

Realistic models should include the possible interactions between the above, since mass loss can counteract atomic diffusion and diffusion can interact with mixing (also see Michaud, these proceedings). We note that Vauclair (these proceedings) has proposed a nonlinear interaction between mixing and microscopic diffusion which would permit negligible halo star lithium depletion; note, however, that the details of such an interaction need to be computed and that such a cancellation would still have to be consistent with the globular cluster and Population I star data.

3. Observational Pattern

As we have just seen the surface lithium abundances of stars are sensitive to a variety of effects, both those accounted for in classical stellar models and those caused by physically well-motivated but still so-called non-standard effects. Uniqueness is thus a real issue when interpreting the observational data. We will therefore begin with the overall conclusions from studies of Population I stars, and then proceed to the current status of the observational data for Population II stars.

3.1. Population I Properties

The properties of Population I stars are summarized in DPC. Here we briefly recall those that are important for the problem of lithium depletion in Population II stars. In progressively older open cluster stars there is clear evidence for increased lithium depletion with age and a dispersion in abundance at fixed T_{eff} which is inconsistent with classical models. The predicted dropoff of lithium for cool stars from pre-MS burning is clearly seen. The overall properties favor mild mixing below the envelope on the MS; there is also evidence for microscopic diffusion playing a role for F stars and in the helioseismic inversions of the solar sound speed relative to theoretical models (see Guzik & Cox 1993, Richard et al. 1996, Basu et al. 2000). Large enough amounts of mass loss to directly cause lithium depletion are inconsistent with the observed population I pattern (Swenson & Faulkner 1992). As of this time a single theoretical model capable of explaining all of the Population I data has not yet been found (Talon & Charbonnel 1998, PWSN).

3.2. Overall Population II Properties

Beginning with the pioneering work of Spite & Spite (1982), there have been a series of progressively more sophisticated observational studies of lithium in halo field stars; the largest sample is that of Thorburn (1994). Ryan et al. (1999, hereafter RNB) obtained a smaller sample with a lower formal error ($\sigma \sim 0.036$ dex) than the errors in earlier studies ($\sigma \sim$ 0.07-0.09 dex). There have also been preliminary studies of small samples of stars near the turnoff in globular clusters. Different investigators of field stars agree on some general properties:

1. Halo stars hotter than 5800 K exhibit a weaker dependence on T_{eff}, [Fe/H], and a smaller dispersion than seen in Population I stars. There is vigorous debate about the existence and magnitude of any dispersion in the field star case, and there are active controversies about trends with T_{eff} and [Fe/H].

2. Turnoff globular cluster stars were first studied by Molaro & Pasquini (1994), who reported a Li abundance for a turnoff star in NGC 6397 consistent with the halo plateau abundances. These are technically challenging observations owing to the faintness of the stars and the need for high resolution spectroscopy. A subsequent Keck study of the globular cluster M92 (Deliyannis et al. 1995, Boesgaard et al. 1998) revealed a large scatter, similar in morphology to the old open cluster M67. The sample, however, is small (seven stars,

including only three with S/N greater than 40). Pasquini & Molaro (1997) also observed a range of Li abundances in three turnoff stars in the intermediate metal abundance globular cluster 47 Tuc. Any successful theory must explain both the cluster and field star patterns; more data is clearly needed for the globular cluster stars (see also Part III, Charbonnel, Deliyannis & Pinsonneault).

We now turn to a summary of the most recent data on the important global features in field halo stars.

3.3. Trends with T_{eff}

There has been a spirited debate about the existence and magnitude of trends in the halo star data with metallicity and effective temperature. The slope with metal abundance is important for constraining the galactic chemical evolution contribution to the observed lithium abundances, and it may also contribute to the small scatter in the data at fixed effective temperature. Trends with effective temperature are important as a diagnostic of the mass dependence of any physical processes which affect the surface abundances. Thorburn (1994) reported evidence for a positive slope of lithium with respect to T_{eff}; this conclusion was challenged by Molaro et al. (1995). Subsequently Ryan et al. (1996) reanalyzed their data, claiming confirmation of the original results; see also Bonifacio & Molaro (1997). The existence of a modest rising trend with increased T_{eff} is only predicted in the models including atomic diffusion and stellar winds (Vauclair & Charbonnel 1995). However, what is even more important than the existence of a mild mean trend is the thing which is *not* seen : any evidence for a decline in lithium among the hottest stars.

As discussed above, models which include only microscopic diffusion predict a decline in surface lithium for the hottest halo stars; models with strong depletion from mixing also predict a downwards trend in lithium for the hottest stars (Chaboyer & Demarque 1994). This observational fact therefore constitutes an important limit on lithium depletion in halo stars.

3.4. Trends with [Fe/H]

The existence of trends of lithium with metallicity is a signature of galactic chemical evolution, and it could also contribute to the dispersion observed in halo stars. The majority of the observational investigations have looked for a correlation between [Li] and [Fe/H]; in parallel to the controversy over trends with effective temperature, there have been conflicting results on metallicity trends. Both Thorburn (1994) and Ryan et al. (1996) found some evidence for an increase in [Li] with [Fe/H] with a slope of order 0.1. This was disputed by Molaro et al. (1995) and Bonifacio & Molaro (1997). RNB obtained a sample with a small intrinsic range in effective temperature, but a wider range in metallicity. They could therefore evaluate metallicity but not effective temperature trends, and found a slope of [Li] with respect to [Fe/H] consistent with the Thorburn (1994) level. Chemical evolution trends should most logically be evaluated in the linear Li - linear Fe/H plane (see Olive and Matteucci, these proceedings).

A general feature of the derived chemical evolution trends is that they are sensitive to the source used for the metallicity, the subset of the data which is used, and the treatment of outliers in the fit. Ryan et al. (1996) also noted that the evidence for trends in the data with T_{eff} and [Fe/H] is more convincing in a bivariate analysis than when either variable is treated separately. The existence and magnitude of metallicity trends is also important for the interpretation of the dispersion in abundance (see below). The metallicity dependence of any rotational mixing is small (PWSN) and would be difficult to disentangle from chemical evolution effects.

3.5. Dispersion

The dispersion in the lithium abundances of halo plateau stars has been the subject of a number of studies. This is largely because the existence or absence of a detectable range in abundance at fixed metallicity and T_{eff} is the best direct test and constraint on the transport processes of chemicals in these stars. Lithium abundances can be studied as a function of age in the Population I case, which makes it easier to unambiguously distinguish between different classes of theoretical models (or at least rule bad models out). All of the metal-poor stars that we observe are old, and we therefore cannot directly reconstruct the depletion of lithium by sorting stars of progressively increased age into an evolutionary sequence.

Studies of the dispersion tend to fall into two groups. Some investigators (Deliyannis et al. 1993, Thorburn 1994) found evidence for a dispersion at a low level; others (Spite et al. 1996, Bonifacio & Molaro 1997) placed bounds on the dispersion consistent with their observational errors. The level of dispersion inferred by Deliyannis et al. (1993) is not inconsistent with the latter two studies (greater than 0.04 dex as compared with less than 0.08 and 0.07 dex respectively). In a recent paper, RNB have claimed a more stringent constraint on the overall dispersion. We examine this most recent data set below; a comparison of models including rotational mixing with the Thorburn (1994) data set was performed by PWSN.

The formal dispersion of the RNB data set is 0.053 dex, greater than their observational error of 0.036[2]. They attribute this to a correlation between metallicity and lithium abundance, e.g. chemical evolution rather than stellar depletion. There is a substantial overlap between the RNB and Thorburn (1994) data sets, and the markedly lower dispersion inferred by RNB can be traced directly to differences in equivalent width measurements. In Figure 1 we illustrate and compare the properties of the RNB sample (excluding one upper limit) with the stars in common as measured by Thorburn (1994); both have been shifted to the same effective temperature scale. There are both significant zero-point shifts and a marked difference in the overall dispersion of the sample. RNB attribute this to possible scattered light and sky subtraction issues in the Thorburn (1994) data set. We note, however, that similar differences appear in samples in common with other investigators[3]. The systematic differences between various observational data sets therefore require more scrutiny, especially given the relatively small sample size of the RNB data set and the small number of overdepleted stars expected for modest stellar depletion.

[2]Not 0.033 as claimed by RNB.

[3]e.g. compare G64-12 and CD -33 1173 as measured by both Thorburn 1994 and Spite & Spite 1993 to their relative abundances in RNB.

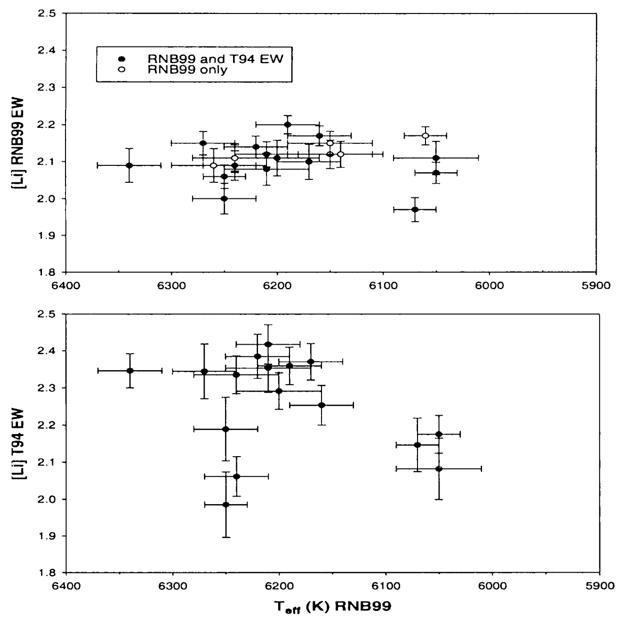

Figure 1. Data from RNB (top panel) compared with data for stars in common with Thorburn (1994) corrected to the same effective temperature (bottom panel).

We compare the theoretical distribution of the lowest depletion case of PWSN to the RNB data in Figure 2. The majority of young low mass stars in open clusters are slow rotators, which implies that they should have experienced similar rotational histories and similar degrees of rotational mixing. However about 1/5 of the stars in open clusters are observed to be rapid rotators and these should manifest themselves as overdepleted objects, producing an excess dispersion which is measureable. The existence of a core in the sample with minimal internal dispersion therefore does not by itself rule out more modest stellar destruction (as noted by RNB). The existence and number of outliers is a more stringent test. In the raw RNB sample there are three stars more than 0.1 dex below the median, one of which has an upper limit of 1.36 for its abundance; this simulation would predict $\sim$ 4 depending on the criterion for defining what constitutes an overdepleted star. It is legitimate to question whether the highly overdepleted star is produced by the same mechanism as the other stars, but in any case the sample size is small and it is certainly difficult to make a persuasive case against modest depletion factors based on the data without chemical evolution corrections.

RNB placed more stringent constraints than the above based upon attributing some of their small dispersion to galactic chemical evolution. RNB fitted the data for a trend with [Fe/H] and concluded that there was a 10 % probability that as few outliers (one) as observed would be present by chance. This conclusion depends on the usage of a logarithmic, rather than a linear, rela-

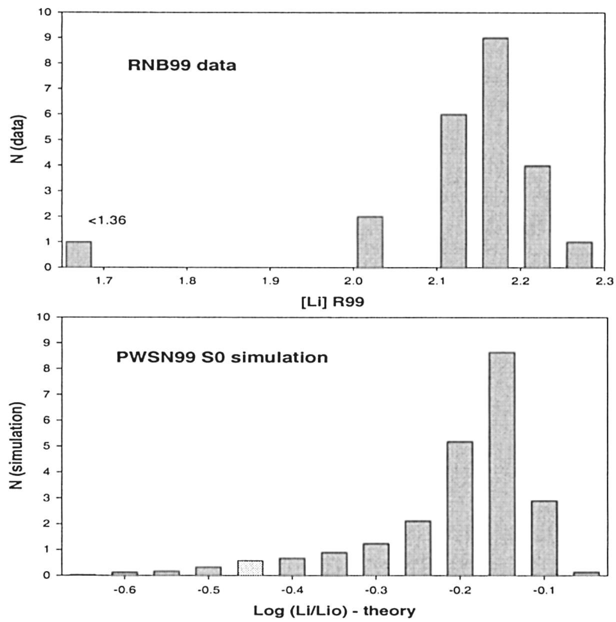

Figure 2. Data from RNB (top panel) compared with the theoretical simulation of PWSN for their low depletion case. The theoretical distribution has been convolved with an observational error of 0.03 dex.

tionship between lithium abundance and metallicity (Pinsonneault et al. 2000). In conclusion, the RNB data places more severe constraints on the dispersion in abundance than previous studies, and depending on the treatment of trends with metal abundance it may either be consistent with modest stellar depletion factors or places a bound of order 0.1 dex on the absolute depletion from the class of rotational mixing models considered by PWSN.

The existence of stars above the plateau may also provide some important clues; they could either be underdepleted or they could have experienced lithium production. Stars with very low initial angular momentum would experience much less rotational mixing than the norm and would therefore appear as underdepleted. However, there are strong observational selection effects against detecting very slow rotators in open clusters, and it is therefore difficult to estimate the fraction of such objects that would be expected in rotational mixing models. An alternative explanation would be differential lithium production. King et al. (1996) examined the most prominent such star, BD+23:3912, and found no evidence for lithium production in the abundances of other elements that would be affected by the main mechanisms (see King et al. 1996 for a detailed discussion and caveats).

3.6. Li^6/Li^7

Li^6 is more fragile than Li^7 and it is not produced in significant quantities in standard BBN models. The detection of Li^6 in halo stars can therefore be used

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to set powerful constraints on the absolute depletion of Li^7, with the caveat that the initial Li^6 abundance must be inferred from chemical evolution models. Smith et al. (1993) first claimed a detection of Li^6 in the halo star HD 84937. This was confirmed in subsequent studies by different investigators who added two more possible detections and a number of upper limits (see Cayrel et al. 1999, Hobbs et al. 1999, Nissen et al. 1999 for recent work on the subject and Nissen in these proceedings). The detected amount of Li^6 is small, but it appears to be secure. The amount is greater than would be expected from the beryllium and boron data, suggesting that alpha-alpha fusion may contribute to the production of Li^6.

One important uncertainty in the usage of Li^6 data is therefore what the initial abundance of the species could be; for example, Lemoine et al. (1996) and Cayrel et al. (1999) obtained bounds of a factor of four and three respectively on the absolute depletion of Li^6 in HD 84937. PWSN argued that an even higher initial abundance could not be excluded, and considered the extreme limiting case where the halo Li^6 abundance could have been as high as the solar system value.

The second uncertainty is the ratio of Li^6 to Li^7 depletion. Nuclear burning in the convective envelope in standard models would produce strong Li^6 depletion before any Li^7 depletion occurred; this has been used to argue that any detected Li^6 implies negligible Li^7 depletion (e.g. Lemoine et al. 1996). Both models with microscopic diffusion and models with mild envelope mixing, however, predict simultaneous detectable depletion of both isotopes to varying degrees, with Li^6 being more sensitive but not infinitely so (see PWSN). Nonetheless, the Li^6 data does provide one of the best independent checks on any stellar depletion of Li^7, and it indicates that large depletion factors are very unlikely to be consistent with the observed detections (see below.)

4. Theoretical Constraints on Lithium Depletion

In light of the observational data above, what can we infer about the depletion of lithium in halo stars? The first and most generally agreed-upon conclusion is that a variety of observational tests make a large depletion factor unlikely. There have been three major features of the halo data which have been used to constrain the absolute depletion: the degree of dispersion in the halo plateau, the detection of Li^6 in some halo stars, and the absence of a decline in surface Li for hotter halo stars.

4.1. Bounds from the Dispersion in the Plateau

PWSN inferred a range of 0.2-0.4 dex depletion factors from models including rotational mixing; the lower end of the range was more consistent with the dispersion inferred from the Thorburn (1994) data set, while the upper end of the range permitted the rare highly overdepleted stars to be explained within the framework of rotational mixing. As discussed above, the most recent data set of RNB is marginally consistent with the lower end of the depletion range in PWSN (of order 0.2 dex.) Other investigators (e.g. Bonifacio & Molaro 1997, RNB) have claimed more stringent limits of order 0.1 dex on the absolute depletion based upon the small (or, in their view, nonexistent!) dispersion in the halo Li data. We will return to this claim after reviewing other measures based upon the detection of Li^6 and the absence of the observed signature of pure microscopic diffusion in halo stars.

4.2. Bounds from Li^6 / Li^7 Measurements

PWSN set a less severe, but firm, limit of 0.5-0.6 dex Li^7 depletion from the measured Li^6 / Li^7 abundance ratios in halo stars under the assumption that the halo stars did not have a Li^6 abundance higher than the solar system value. Lemoine et al. (1996) derived a bound of a factor of 4 on the absolute Li^6 depletion of HD 84937, which in the rotationally mixed models of PWSN would imply a bound of 0.25 dex on the Li^7 depletion, while Cayrel et al. (1999) used the lithium data in the same star to set a bound of 0.1 dex on its Li^7 depletion; both of these calculations, however, are dependent on the chemical evolution model which is used. We note that if the Cayrel et al. (1999) bound of a factor of three Li^6 depletion is used in conjunction with the PWSN models, an absolute Li^7 depletion of 0.15 dex is inferred for HD 84937 rather than an upper limit of 0.1 dex.

4.3. Bounds from the Flatness of the Plateau

Vauclair & Charbonnel (1998) used a different set of properties to infer a stellar depletion factor. Pure microscopic diffusion in halo models would produce a strong decrease in surface lithium with increased T_{eff} which is not observed. It is therefore clear that something must be inhibiting microscopic diffusion, especially given the improved agreement with helioseismology from the inclusion of micrscopic diffusion in solar model calculations. They noted that there is a subsurface peak in the Li^7 abundance of the pure diffusion models which does not vary greatly across the plateau.

Vauclair & Charbonnel (1995) (see also Swenson 1995) argued that mass loss at a rate 10-30 times greater than the solar value could counteract the effects of diffusion if the rate was tuned across the lithium plateau. This would have the effect of exposing a uniform abundance across the plateau, with an absolute depletion of 0.15 dex. Vauclair & Charbonnel (1998) noted that in the presence of sufficiently mild mixing the height of this peak could be preserved, implying that a uniform depletion of order 0.15 dex could apply if the absence of a measurable surface signature of diffusion arose from either the competing effects of mass loss or the interaction of diffusion and mild mixing. As noted by Chaboyer & Demarque (1994), sufficiently strong mixing can cancel the effects of diffusion while not preserving the height of the peak; however, models with the high degree of depletion inferred by that latter paper are difficult to reconcile with the other observational tests of lithium depletion.

4.4. Is There Any Depletion?

In light of the remarkable observed properties of the halo lithium plateau, it is reasonable to ask whether there is in fact any depletion at all. In other words, are we directly seeing the primordial lithium abundance (e.g. Bonifacio & Molaro 1997) or is the primordial lithium abundance in fact *lower* than the observed values because of a significant contribution from galactic chemical evolution (RNB)?

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"Standard" stellar models are sometimes invoked as evidence against significant depletion. These classical models, however, achieve this prediction by simply neglecting known physics rather than by demonstrating that it is unimportant. For example, one could construct stellar models which ignore the CNO cycle, and they might even agree with some data, but it does not follow that these should be placed on an equal physical basis with models that include the known nuclear physics. In particular, atomic diffusion cannot be excluded arbitrarily from the computations, on the pretext that it produces unobserved features. This disagreement is a simple signature of some macroscopic motions (mass loss or rotation-induced motions) which counteract the diffusion process.

Any model predicting zero stellar depletion in halo field stars must be reconciled with the apparent scatter in the globular cluster turnoff stars. If both the halo stars and the globular cluster stars are depleted by (say) mild mixing, it is possible to explain the difference in the abundance patterns by a different set of initial angular momenta. Such a difference could arise in the context of the currently popular model for the origin of the range of rotation rates, namely that the lifetime of accretion disks determines the rotation rate, if globular cluster stars experienced more frequent interactions which disrupted their accretion disks early in their lifetimes relative to the lower density systems that the halo stars arose from. It is more challenging, however, to explain why stars with similar thermal structures should experience completely different depletion histories.

The *complete* absence of depletion in Population II stars would also have to be reconciled with the strong evidence for depletion in Population I stars which is not predicted by standard models.

At the same time, it is also clear that none of the existing theoretical models provide a complete description of the complex lithium abundance pattern seen in stars. Although the most recent classes of rotational models are reasonably successful at reproducing the observed angular momentum evolution of low mass Population I stars, they do not reproduce the solar rotation profile as inferred from helioseismology. They also require an extrapolation of the initial conditions from Population I to Population II stars, which may introduce systematic errors in the calculations. Further theoretical work is clearly needed, and a more refined set of models could potentially alter the inferred degree of stellar depletion.

5. Summary

We have compared theoretical models with the observational Population II lithium data to obtain bounds on stellar lithium depletion. From a combination of the dispersion in the data, the detection of Li^6, and the flatness of the halo plateau interesting bounds can be set on the stellar depletion of lithium in Population II stars. The majority of tests are roughly consistent with depletion at the 0.15-0.2 dex level, with a firm upper bound of 0.5-0.6 dex from a combination of the detected Li^6 abundance in HD 84937 and an extreme chemical evolution model. The most recent data set of RNB places the most severe observational constraints on the dispersion of lithium in halo stars. It is marginally consistent with the least depleted set of models of PWSN including rotational mixing; a larger statistical sample would permit a more definitive test of the limits on depletion from mixing in halo stars. There are unexplained differences between the equivalent width measurements of Thorburn (1994) and RNB which need to be understood; indeed, the systematic differences between investigators on the absolute level of the plateau are approaching the uncertainty in the inferred degree of stellar depletion.

A new generation of theoretical models is needed to further refine our understanding of light element depletion in stars. The interaction between different physical mechanisms, such as microscopic diffusion, mass loss, and rotational mixing, and a better physical description of each of them, may prove important in this context.

Finally, any stellar lithium depletion has implications for BBN. PWSN discussed the implications of a higher primordial lithium abundance; see Olive (these proceedings) for the case of negligible stellar depletion. If the preliminary data from the BOOMERANG mission is confirmed (Lange et al. 2000), we note that there may be a disagreement between the stellar lithium abundances and the predictions of standard BBN as well as the low deuterium results of Tytler (these proceedings). This is significantly relaxed if stellar lithium depletion has occured.

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