EVIDENCE FOR LITHIUM DESTRUCTION AND SYNTHESIS IN MAIN-SEQUENCE AND SUBGIANT STARS OF ABOUT SOLAR MASS

M. W. FEAST
(Radcliffe Observatory, Pretoria, South-Africa)

Herbig's extensive work on lithium abundances in solar-type stars on and near the main sequence, suggested to him that for these stars the lithium abundance might be some simple, decreasing function of age. If this were the full story we should expect a low lithium abundance in subgiants of about solar mass. However, already in Herbig's work there were one or two stars with lithium abundance about 10 times the Greenstein-Richardson solar value whose trigonometrical parallaxes showed them to be possible subgiants. Other subgiants with high lithium abundances have been found by Wallerstein and at Pretoria. These results suggest that solar-mass stars are able to synthesise fresh lithium in or just prior to their subgiant phase.

A study (Feast, 1966) of the Li^6/Li^7 isotope ratios also provided evidence for lithium synthesis during evolution off the main sequence. Freshly synthesised lithium is expected to have a high value of Li^6/Li^7 (close to 0·5, the laboratory spallation ratio). Older lithium which has undergone depletion by convection to regions of high temperature should have a lower isotope ratio. In fact the few stars with a high ratio (all of them close to 0·5) are all subgiants well above ($\sim 1^m.4$) the main sequence. Of course, lithium preserved in old stars in which convection has been inhibited by magnetic fields (as Wallerstein has suggested) would also be expected to have a high Li^6/Li^7 ratio, but we should also expect to find similar high Li^6/Li^7 stars on the main sequence in that case, and so far none have been found. Main sequence stars seem to contain old depleted lithium which is consistent with Herbig's idea that this is the remnant of an earlier, extremely lithium-rich stage.

A detailed study of the total lithium abundances yields some interesting results. Stars with known lithium abundance which also have absolute magnitudes and colours (C) corrected for blanketing (Eggen, 1964) have been plotted in an HR diagram and evolution studied using Iben's (1967) theoretical tracks. For the present purpose the region with C between 0·50 and 0·65, which is roughly centred on Iben's one solar-mass track, is of particular interest. This track, suitably shifted, has been used to define the region shown in Figure 1. Only stars between the two tracks shown will be considered and those parts of the tracks that lie below the Hyades' main sequence are considered to be on the main sequence at the same colour. For any star

Perek (ed.), Highlights of Astronomy, 233–236. © *I.A.U.*

in this region the distance above the main sequence (ΔM) is a simple measure of its state of evolution. Some of the main-sequence stars in this region may of course be going to evolve to places outside the region in which we are interested, but this will not affect any of the conclusions drawn.

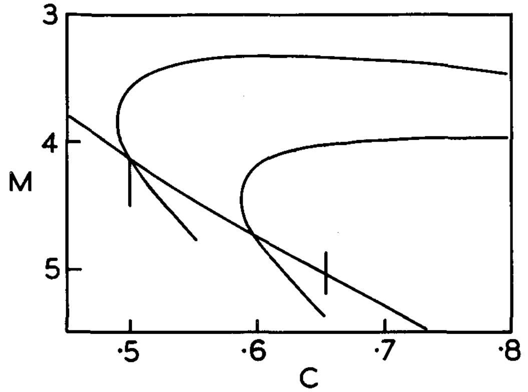

FIG. 1. *HR diagram. The Hyades' main sequence is shown. The tracks are Iben's one solar-mass track displaced to define the main sequence limits in C of 0·50 and 0·65. In the discussion of stars above the main sequence, only those stars between the two tracks are considered.*

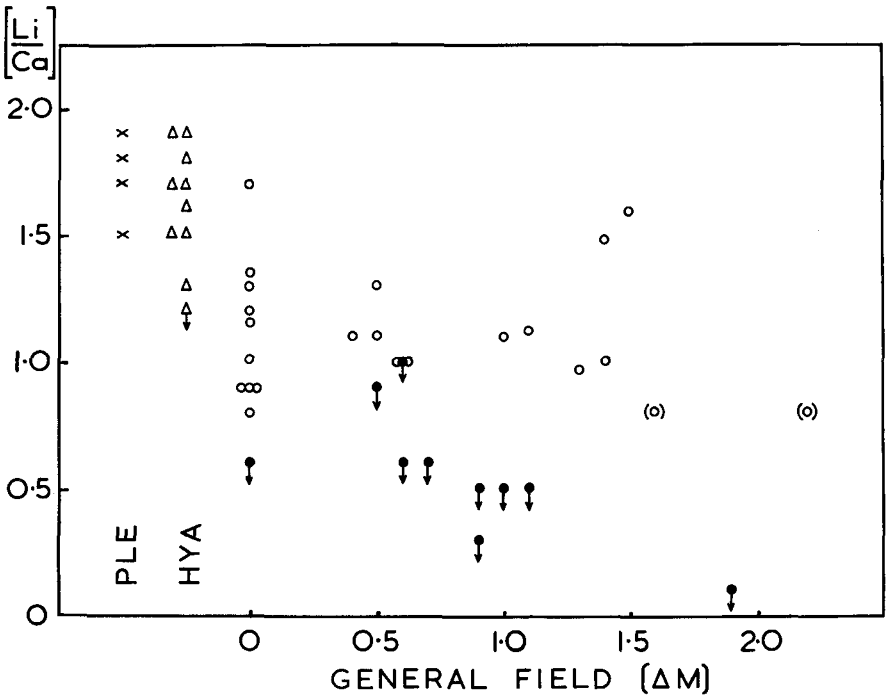

FIG. 2. *Lithium abundance as a function of distance above the main sequence for stars in the region defined by Figure 1. Arrowed points denote upper limits only. See text for further discussion.*

For field stars in this region, Figure 2 shows the log of the lithium abundance plotted against distance above the main sequence. The main-sequence Pleiades and Hyades stars in this region are also shown and arrowed points denote upper limits. Perhaps the most important feature of this diagram is the indication that low lithium (say less than 0·6 in the log) is preferentially concentrated between the main sequence $\Delta M = 0$ and the subgiants at $\Delta M \sim 1^{m}.4$. It is interesting that the one possible case of low lithium on the main sequence is 20 Leo Min which is a main sequence star in Eggen's paper but which others have considered to be above the main sequence. The greater average abundance of lithium in the Pleiades and Hyades stars is consistent with the field stars being on the average older and more depleted in lithium. The absence, or low frequency of low lithium on the main sequence suggests that depletion is not anything like complete during main-sequence life. The stars of intermediate ΔM appear to demand considerable post-main-sequence depletion. The subgiants, $\Delta M \sim 1^{m}.4$ on the other hand contain only lithium-rich stars consistent with the idea of synthesis here. The more evolved subgiants such as μ Her A with $\Delta M \sim 2{\cdot}0$ (the two bracketed points are just outside the region studied) can possibly be interpreted in terms of Iben's ideas on convective dilution as Herbig and Wolff have suggested (though if e.g. δ Eri has passed through a post-main-sequence lithium production phase, it is difficult to see how convective dilution can have produced the observed more or less pure Li^7).

These conclusions are supported by the histogram of Figure 3. Here the stars have been divided into high lithium (solid line) and low lithium (dotted line) and divided

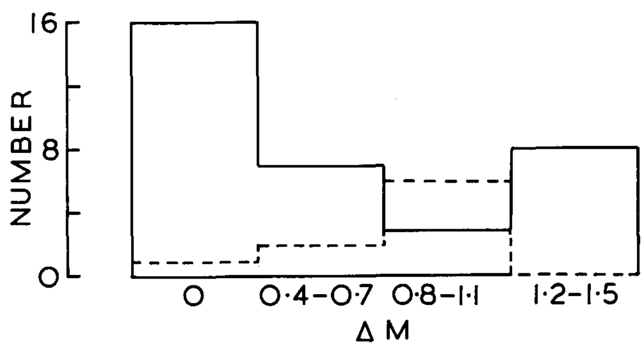

FIG. 3. *Lithium abundance as a function of distance above the main sequence for field stars. Solid line, lithium-rich stars* ([Li/Ca]> 0·6). *Dotted line, lithium-poor stars.*

into groups according to distance above the main sequence. The data differ from the last slide in that I have included several additional stars (including unpublished work) for which there are, as yet, no detailed abundances available but for which the line strengths give an adequate measure of the class to which the star belongs. 20 Leo Min is still the only low lithium star on the main sequence. In the intermediate region

https://doi.org/10.1017/S1539299600001209 Published online by Cambridge University Press

there is a clear fall in high lithium and a rise in low lithium and there are still, as yet, no subgiants with $\Delta M \sim 1\overset{m}{.}4$ with low lithium.

Thus, for stars in this range the lithium abundances as well as the isotope ratios suggest a scheme in which there is both pre-main-sequence and post-main-sequence depletion with fresh synthesis in the subgiant region.

References

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