C. JOINT DISCUSSION OF COMMISSIONS 27, 29, 35, AND 36
THE LITHIUM PROBLEM

(Monday, August 28, 1967)

Organizing Committee: K.H. Böhm (Chairman), W.K. Bonsack, J.L. Greenstein, G.H. Herbig, H. Reeves, A.B. Severny
Discussion Chairman: W.A. Fowler
Secretaries: W. Deinzer, H. Reeves

Contents:

https://doi.org/10.1017/S1539299600001192 Published online by Cambridge University Press

THE OCCURRENCE OF LITHIUM IN STARS

G. H. HERBIG

My task is to outline our present observational knowledge of the occurrence of lithium in stellar atmospheres. On account of the limited time, I shall not attempt to include a description of the situation in post-main sequence stars. Also for shortness of time, forgive me if I do not stop at each point to give due credit to the astronomers who have contributed to that topic.*

The youngest stars we know which are cool enough to exhibit neutral Li are the T Tauri stars, which are in the early stages of contraction toward the main sequence. All these objects that have been adequately observed are very abundant in Li: the range is between 50 and 400 times the so-called 'solar abundance', a convenient unit which corresponds to a H/Li ratio by number of atoms of about 10^{11}. It is significant that the average Li content of chondritic meteorites, which are often considered to be samples of the non-volatile, unprocessed material of the original solar nebula, is about 150 on this system, within the range observed in the TTauri stars.

As the TTauri stars contract toward the main sequence, the surface convection zone may be deep enough to circulate Li to a depth where it can be depleted by proton impact. But there is no completely convincing evidence that this does indeed take place. The most direct check would obviously be to observe stars between the TTauri phase, which is believed to occupy only the first 10–20% of the total contraction time, and the main sequence. Although there must be many such stars, no means has as yet been devised to find them, and so this important test has not been made.

There is now, however, a large amount of information on Li in main sequence stars, and it is clear that such objects contain much less Li than do the TTauri stars. The pattern of Li abundance vs. spectral type along the main sequence is shown in Fig. 1 of the *Ann. Astrophys.* reference. Between the early F and late G-type dwarfs, there is a major fall-off in the amount of Li; in K and M dwarfs, there is no Li detectable. Since the depth of the surface convection zone increases toward later types, the obvious explanation of this pattern is that it is simply the result of varying amounts of Li destruction by convection. It is the task of the theoretician to decide whether convective circulation is equal to this task, and if so, whether all the effect took place during contraction, or whether destruction must have gone on, on a much longer time scale, following arrival on the main sequence.

* Most of the major papers in the field are listed in *Ann. Astrophys.* 1966, **29**, 593.

Perek (ed.), Highlights of Astronomy, 230–232. © *I.A.U.*

It is clear from the data that at each spectral type there is a major spread in Li abundance: in the early F's, it is at least a factor of 10. In such early-type stars the surface convection zone is shallow, no major convective destruction is expected, and so one is inclined to regard this spread as a dispersion in the original, starting values of the Li content. But this factor of 10 contains also the effect of the evolutionary mass dispersion in a sample of field stars having the same spectral type. This particular source of confusion can be reduced by examination of stars all belonging to the same cluster, where the mass spread should be small. Such results suggest that the real spread in the starting Li abundances is only over a factor of 5.

For the sake of completeness, I should mention that pure convection may not be the only mechanism which affects the surface Li abundance. It is necessary also to consider the effect of mass loss, which in effect peels off the Li-rich surface layers and replaces them with Li-poor material from below. This phenomenon seems to be of special promise in understanding the variation in the abundance ratio of Li^6/Li^7 from star to star.

Where has this Li come from in the first place? Can it be that there is this much Li in the interstellar material from which stars are made? We are coming closer to a decision on this point, but the best observations to date are not yet quite adequate. The best place to search for interstellar Li I is surely in a cool interstellar cloud which is known to contain TTauri stars. An excellent example is the Sco-Oph dark clouds. There is now available a new analysis of the interstellar line spectrum of ζ Ophiuchi, which is seen through a substantial thickness of these clouds. The analysis for Li is best done differentially with respect to K I and Na I which have similar ionization potentials to Li I. The ionization correction can be made with some degree of confidence since good laboratory measurements of the photo-ionization cross-sections are now available. No interstellar Li I resonance line can be seen on good coudé spectrograms of ζ Oph, but the upper limit is still greater than the chondritic Li content by a factor of 9. Until this upper limit can be pressed down by another order of magnitude, we are unable to say whether there is enough free Li in the interstellar clouds to account for the abundances found in the TTauri stars.

Whether or not Li is present in the interstellar material, it can be argued that this amount of Li was not formed by nuclear processes in the TTauri stars after they became luminous. This point rests entirely on FU Orionis, which has been interpreted as a pre-TTauri star very near the beginning of its Hayashi track. Despite the fact that this star, which must be completely convective, flared up less than 30 years ago, it contains 80 times the solar Li abundance. The production of such an enormous amount of Li in such a short time by proton spallation of light elements would require a surface proton flux of 10^{11}–10^{12} times the present solar value, which seems to be inadmissable. Other possible sites where the Li may have originated will be discussed by later speakers in this program.

DISCUSSION

Feast: This seems a suitable opportunity to mention some work on the small but very interesting group of C-S stars of which UY Cen is probably the brightest example. Eight of these stars have now been examined at coudé dispersion and lithium found in all of them (in UY Cen itself measurements by Mr. R. Catchpole suggest that the lithium is mainly Li^7). In seven of the eight stars Li I 6708 is roughly the same strength as Ca I 6572 (an equivalent width of about 0·5 Å) indicating a lithium abundance of perhaps 10 times the solar value. However, in the remaining star Li I 6708 is exceptionally strong (equivalent width ~3 Å) although the rest of the spectrum is quite similar to that of the other stars. The abnormal lithium strength places this star in the same class as the three previously known lithium stars (WZ Cas, WX Cyg and T Ara). These three stars are all otherwise normal carbon stars, and it is very interesting therefore to find that extreme lithium overabundance can also occur in stars of lower C/O ratio.

Underhill: Is the relationship between line strength and abundance implicit in the use of 'lithium abundance' based on the simplified LTE theories of line formation?

Herbig: Yes.

L.H. Aller: Several recent investigations (Hollis Johnson, B.J. O'Mara) show that deviations from LTE are not very large for the sodium D-lines and are in fact quantitatively explained. The lithium and sodium lines have been handled theoretically in the same manner by Dr. Herbig. The effects of non-LTE give errors of maybe 20–30% and we are concerned with deviations of a factor of 50 or so! Non-LTE effects cannot be important in this context.

Biermann: For the question of mixing by convection or circulation the state of rotation of the stars would be of interest. Has the correlation of Be-, Li-abundance with rotation been investigated?

Herbig: Not as yet. The Li I λ6707 line becomes too wide to be seen at all if the rotational velocity becomes greater than about 50 km/sec, so such a test will be possible only at the lower rotations.

Hack: R. Lynds has found a non-identified line at λ 6708 in the solar spectrum. How much can this line, if present in stellar spectra, affect the Li abundance?

Herbig: In two dwarfs of spectral types F 8 (β Vir) and G 8 (τ Cet), there is no Li I line at λ6707 detectable with a dispersion of 4 Å/mm. Therefore in these stars we can examine the background on which the Li I line is superimposed for possible blending lines. At that dispersion, no other lines can be seen near 6707–8 Å, which corresponds to an upper limit on the equivalent width of perhaps 5 mÅ. Since in F-G dwarfs the equivalent width of the lithium line goes up to 100 mÅ, I hardly think that the contribution of a line weaker than 5 mÅ need concern us in the present rather rough analyses.