certainly very young objects that have recently arrived at the main sequence or are approaching it. The spectra of these stars in the Li region resemble very closely those of the rapidly rotating K stars in the Pleiades as well as those of naked T Tauri stars. Moreover, two of these stars (AB Dor and PZ Tel) have already been shown on kinematic grounds to belong to the Pleiades moving group.

5. Conclusions

Our survey has shown that chromospherically active K stars have a definite Li excess with respect to inactive stars of similar spectral type. This excess cannot simply be an age effect, since it is also present in many RS CVn binaries and other supposedly evolved stars. It cannot be due either to an enhancement of the Li line by large cool spots since observations of a few stars at different phases have shown no rotational modulation of the Li line. We have suggested that a combination of thin convective zones in their main-sequence progenitors, together with little angular momentum loss during the evolution of these tidally-locked rapidly rotating stars, may qualitatively explain the lower Li depletion. It is not easy however to disentangle the various relevant effects in a highly heterogeneous sample as the present one, which may also contain young, rapidly rotating single stars.

More work needs to be done for a proper understanding of the Li problem in chromospherically active stars. First of all, a separation of the total sample in smaller, more homogeneous subsamples is necessary. Secondly, it is desirable to extend the observations to northern stars since most "classical" well-studied RS CVn binaries, with better determined masses and evolutionary states, are located at northern declinations. Third, the metallicity of the various stars in the sample should be accurately determined. Finally, we should be careful in identifying very young stars and possibly pre-main sequence objects in the sample by studying their kinematic properties and surface activity. Research along these lines is currently being carried out by us; the results are expected to provide essential clues for the understanding of Li abundance in chromospherically active stars.

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Lithium in Carbon Stars

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Carbon Stars

Carbon stars (C stars in the following) are characterized by a surface carbon to oxygen ratio (C/O ratio) greater than unity (detected by the presence of strong molecular bands of C_2, CN and CH) and an excess of heavy elements (presence of ZrO molecular bands instead of TiO bands, as seen in M giants, and presence of enhanced atomic lines of Sr, Y, Ba), as well as a huge mass loss.

Those stars are located on the poorly known asymptotic giant branch (AGB) of the H-R diagram. This branch constitutes the locus of intermediate mass ($0.8 \leq M/M_{\odot} \leq 8$) stars in which hydrogen and helium burn alternately in shells around an electron degenerate carbon-oxygen core (Iben and Renzini, 1983). These stars are also characterized by the occurrence of thermal pulses. After each thermal pulse, the carbon and the s-process isotopes, made in the convective helium-burning zone, can be brought to the surface of the stars by convective dredge-up. Therefore, it is believed that along the AGB, a star evolves from spectral type M (i.e. $C/O < 1$) to S ($C/O \approx 1$) and finally C ($C/O > 1$) when it experiences more and more thermal pulses.

The presence of the unstable s-element technetium in the spectra of some C stars (Peery 1971) is a clear indication that an intense nucleosynthesis is taking place in those stars and that the freshly synthesized material is brought to the surface. The exact mechanism by which this processed material comes to the surface, as well as the conditions present in the pulses, however, are not very well known. Therefore, it is of prime importance to study the Li in AGB stars, as the great sensitivity of this element to the physical conditions makes it a good tracer to constrain those conditions prevailing in the stellar atmospheres.

Lithium

Lithium is a fragile element, easily destroyed by proton captures in the stellar envelopes at temperatures higher than $2.5\ 10^6$ K. In fact, in main-sequence stars, Li only survives in the outer 2 to 3% (in mass) of the stars, its surface abundance depending on the depth of the convective envelope in this phase, itself depending mainly on the effective temperature and metallicity of the star. Observations in main-sequence stars generally show that the abundance of Li correlates strongly with the effective temperature, in the sense of lower abundance for decreasing temperature (from F to G-K dwarfs). But, if phenomena as semiconvection, diffusion or mass loss are also active in this phase, the surface Li abundance will be reduced even more, either by exposing Li to energetic protons, or by removing it from the star. During the ascent of the red giant branch, the convective mixing (first dredge-up) dilutes the surviving Li with Li-free material from the interior. After this process, the expected surface abundance of Li is at most 1/30 of the initial abundance in the stars, that value depending on the initial mass of the star.

In general, the observations of red giants are not in agreement with the theoretical predictions: either the Li abundance is higher than predicted, as is the case for some G-K giants (Brown

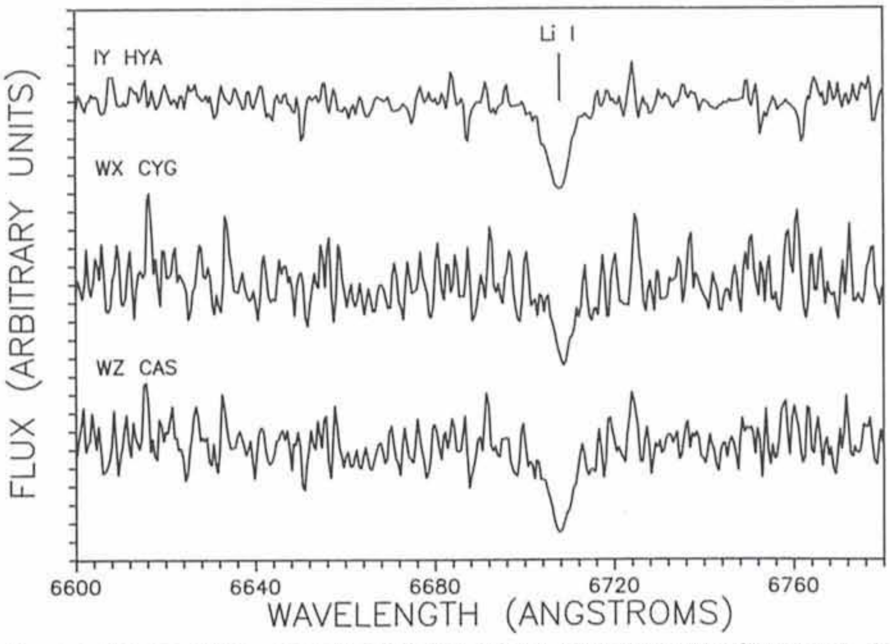

Figure 1: *Spectra of three super Li-rich C stars obtained at the La Palma Observatory. The peculiar nature of IY Hya was discovered in the course of this programme.*

et al. 1989) and for weak G-band stars, or, in the majority of giants, it is lower. In AGB stars, the successive dredge-up episodes will still decrease the Li abundance at the surface of those stars. As an example, Kipper and Wallerstein (1990) found a mean value of log N(Li)≈− 0.5 for a sample of SC stars.

However, the existence of AGB stars with Li abundance higher than 1.5 (Boesgaard, 1970) shows that things are not so simple. More surprisingly are the few AGB – either S or C stars – showing Li abundances about two orders of magnitude higher (Boesgaard, 1970) than the cosmic log N(Li) = 3.1 abundance. This enormous abundance of Li (log N(Li) ≈ 5) is an evidence that those peculiar AGB stars, called super Li-rich stars, might produce this element in their interiors. Different models have been proposed to explain this fact, the majority of them being based on the idea of Cameron and Fowler (1971): under certain circumstances, which remain to be defined and modelled, some of the ^{3}He present in the envelope could be injected into ^{4}He-rich zones. If the temperature of these zones exceed 4 10^7 K, some of this ^{3}He is transformed into ^{7}Be. The ^{7}Be will then capture an electron to give ^{7}Li, but this must occur after ^{7}Be has been transported by convection to regions where the temperature is such that the reaction ^{7}Li(p, α)^{4}He is slow enough for Li not to be completely destroyed. The application of this mechanism to AGB has been proposed by Scalo and Ulrich (1973): they assume that, as a consequence of thermal pulses, the convective envelope penetrates into the He-burning shell. In that case ^{3}He might be transformed in ^{7}Be and this isotope, by convective mixing, transported to cooler and outer regions where the ^{7}Be(e$^-$,ν)^{7}Li can occur. After a certain number of pulses, the star becomes enriched in Li.

Another possible scenario (Sackmann et al., 1974) is the hot-bottom burning: some hot nuclear burning at the base of the convective envelope can induce surface enrichment of Li, following the same sequence of reactions as quoted above. Although both models are able to produce Li in the proportions which are observed in super Li-rich stars, these models, however, lack the required self-consistency concerning the treatment of the concomitant nucleosynthesis and convection. Also, mass loss, which is very important in those stars, has not been included in those calculations.

As we see, theory is not yet really able to explain the existence of super Li-rich stars. Improved models are thus required which should satisfy those observational constraints. In the same way, new observations should be done to try to better define those constraints.

Observations

We have started a programme of observations of Li in a large sample of C stars, both at ESO and at the observatories of La Palma and Calar Alto (Spain). Our aims are twofold: First, we want to determine the abundance of Li in each star C/O ratios, mass loss . . . This is why we have preferentially devoted ourselves to study stars from the catalogue of Claussen et al. (1987) which has the property of being a homogeneous flux-limited sample of galactic C-stars and which gives some characteristics of the stars. Secondly, we hope to discover new super Li-rich stars, as well as to determine the real percentage of such stars among C stars and, if possible, what other peculiar characteristics those stars share.

The observations at La Silla were made using the CES on the 1.4-m CAT, with an RCA CCD. The spectral range covered was about λλ 6680–6739 Å and the resolving power was 45,000, giving a resolution of 0.15 Å. This wavelength range gives access to the Li I doublet line at λ 6707.8 Å, as well as to the Ca I line at λ 6717.7 Å. At La Palma, the observations were made with the 2.5-m INT with CCD. The spectral range observed was 280 Å around the Li I, doublet and the resolution was 0.45 Å. At Calar Alto, we used the 3.5-m telescope with the double spectrograph and a CCD. The resolution achieved was about 0.4 Å. For most of the spectra, the S/N ratio was higher than 100.

Until now, about 80 stars were observed at La Silla, 120 at La Palma and 80 at Calar Alto. In Figure 1, we show the spectra taken at La Palma of 3 super Li-rich C stars, one of which was discovered in the course of this programme (IY Hya). The very large line of Li is clearly visible. For comparison, we show in Figure 2 the spectrum of another C star, V Aql, which has a much weaker Li line. Note the higher resolution of this spectrum, which was obtained at La Silla.

Determination of the Lithium Abundance

As clearly shown by Gustafsson (1989), the analysis of cool stars such as C stars is one of the most difficult things to accomplish in spectroscopy. This is mainly due to the fact that model atmospheres of C stars are highly sensitive to composition, that the spectra of those stars are overcrowded by atomic and molecular lines, preventing a good determination of the continuum, and that the parameters of stars (effective temperature, gravities, microturbulence, CNO abundances, . . .) are generally not well known.

This means that if one wants to achieve the best determination of the Li abundance in C stars, synthetic spectra are really necessary. We calculate those synthetic spectra in the LTE approximation, using a grid of models of atmospheres for C stars of Gustafsson et al. (private communication). This grid contains models in T_{eff} from 2500–3000 K in steps of 100 K, log g = 0.0 and solar metallicity ([Fe/H] = 0). For a given effec-

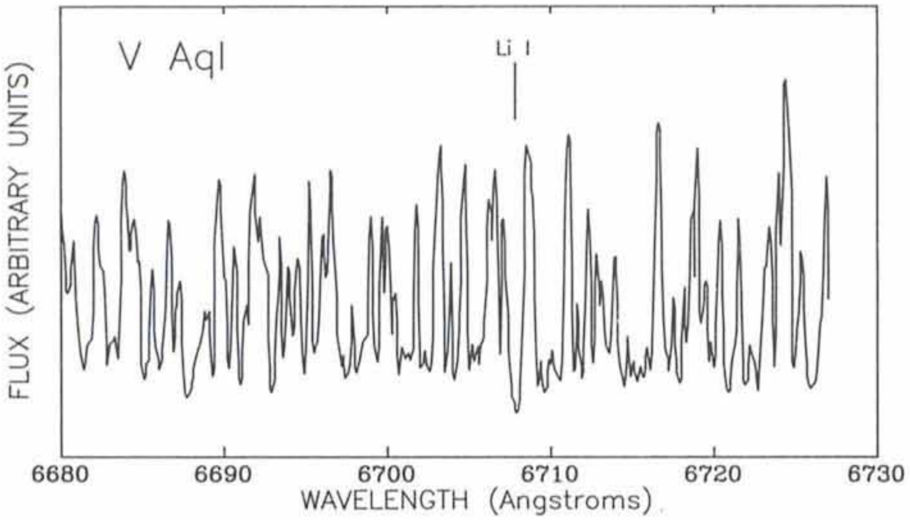

Figure 2: *Spectrum of the C star V Aql taken at La Silla with the CAT. The equivalent width of the lithium line, calculated by integrating the synthetic spectrum, is 300 mÅ. This seems to imply an abundance larger than expected from the standard theory of nucleosynthesis in AGB.*

tive temperature there are also several models with different values of the ratios C/N/O. The spectral region synthesized is between 6685 and 6725 Å. This spectral region contains the doublet of Al I at λλ 6696–6698 Å and the Ca I line at λ 6718 Å. The theoretical fit to these lines was used as an indicator of the metallicity of our stars although it is expected that the metallicity of these intermediate mass stars does not differ too much from the solar one. Neither Al nor Ca are expected to be destroyed in the atmospheres of the AGB stars, thus [Al, Ca/Fe] ≈ 0.0 must be true in our stars. This is verified in galactic stars, at least until [Fe/H] = −0.5.

When possible, we derive the effective temperature from the J-K index. Otherwise, its determination is done from the spectral appearance itself. The uncertainty in the temperature is therefore of the order of 200 K, but this does not bring a very large error in the Li abundance determination. The adopted gravity is log g = 0.0 and the microturbulence is generally taken as 3 kms^{-1}. The major problem in the derivation of the Li abundance is in fact the knowledge of the C, N and O abundances. A few studies have been made in some C stars (see Gustafsson, 1989), but unfortunately the errors are as large as 0.25 dex. This allows a very large range of variation. As the model atmospheres are very sensitive to those abundances, this is the largest uncertainty in our derived Li abundance. Indeed, in the wavelength range we use, a variation of 0.05 dex in the C abundance does not give any noticeable differences in the spectrum, except for the Li line, so that another value of the Li abundance is needed to fit the observed spectrum. As a matter of fact, a change of 0.05 dex in the C abundance induces a variation of 0.3 dex in the Li abundance. We are therefore obliged to admit that our error in the Li abundance must be about 0.5 dex, when all the sources of uncertainty are taken into account. This seems to be the best one can do presently. Indeed, Kipper and Wallerstein (1990), in their study of Li in SC stars, obtained a comparable error.

We show in Figure 3 the observed spectrum of WZ Cas, as well as the synthetic spectrum we find as the best fit. One can see that, even if there is a relatively good agreement, not all of the lines are well fitted. We think that this is mainly due to a lack of accuracy in the atomic and molecular data. The derived Li abundance for this star is log N(Li) = 5.3 ± 0.3. More quantitative results will be published soon in *Astronomy and Astrophysics.*

Chemical Evolution of the Galaxy

In addition to the consequences for nucleosynthesis and stellar evolution, the fact that some AGB stars have such extreme abundances of Li is perhaps more important by their implications on the galactic evolution of the Li abundance. Although there is still a great debate on that subject, it is often claimed that the pregalactic (i.e. from the Big-Bang) abundance of Li was about log N(Li) ≈ 2.1. This fact seems to be confirmed by the observed Li abundance in very metal-poor (unevolved) F-stars of the galactic halo. Since the actually observed maximum Li abundance (in the interstellar medium and in pre-main-sequence stars) is log N(Li) ≈ 3.1, it is evident that a mechanism of Li production, complementary to the Big Bang, is required to explain this increase of the Li abundance in the course of the life of the Galaxy.

Several models of chemical evolution of the Galaxy have shown that, if one takes into account the astration, the well-known galactic mechanism for Li production (i.e. the bombardment of He and CNO nuclei by galactic cosmic rays in the interstellar medium) is not enough to explain such an increase in the abundance of Li from the pre-galactic value (see e.g. Reeves et al. [1990] for a wider discussion on the topic). The proposed mechanisms are of stellar origin: novae, supernovae or red giant stars, but until now only the red giant stars (AGB C stars) are firm candidates. In fact, they are the only objects in which there is a clear observational evidence of stellar Li production.

Furthermore, an inspection of a compilation of Li abundances in unevolved stars suggests how the abundance may have grown with the metallicity: log N(Li) ≈ 2.1 at [Fe/H] ≤ −1, log N(Li) ≈ 2.3 at [Fe/H] ≈ −0.5, to log N(Li) ≈ 3.1 at the present time (near solar metallicity). This behaviour with metallicity suggests a continuous and slow increase of the Li abundance in the galaxy. This fact is more compatible with the AGB evolutionary lifetimes than with those of the pre-SN II or novae. Given the usually long characteristic time for the appearance of the nova phenomenon, a sudden increase of the Li abundance at late epochs in the life of the galaxy would be expected. On the other hand, in the supernova scenario, one would expect the opposite: i.e. a strong increase of the Li abundance at very early epochs. Neither of these facts are observed.

However, even in the AGB stars Li production scenario, there are still many questions to be answered: Will all the AGB stars become super Li-rich stars, or is it rather a random phenomenon? In the former case, what is the range in stellar mass for Li production? What is the amount of Li produced and what

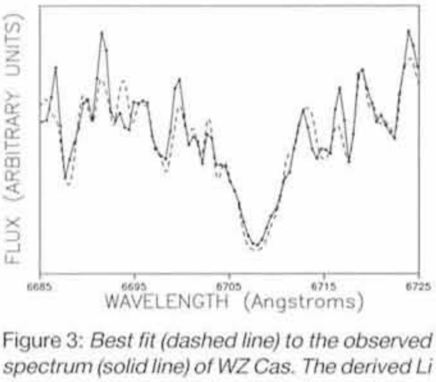

Figure 3: *Best fit (dashed line) to the observed spectrum (solid line) of WZ Cas. The derived Li abundance is log N(Li) = 5.3. The equivalent width computed with the synthetic spectrum is 4 Å.*

percentage of it really survives and is ejected into the interstellar medium? What is the characteristic life-time for AGB stars' Li production scenario? These and others are some of the questions we would like to answer with our observational and theoretical studies of Li in AGB stars.

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Saturn's Bright Spot

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A very large, white spot has recently appeared on the giant planet Saturn. It is probably a great storm in the planet's atmosphere, which has been initiated by upwelling of clouds from the lower layers into the uppermost regions. The spot began as a small, white feature in Saturn's northern hemisphere and has since developed rapidly so that it now appears to completely encircle the planet's equatorial regions. "Great White Spots" have been seen on Saturn in 1876, 1903, 1933 and 1960 (see below), but the present one seems to be the biggest of them all.

At this moment Saturn is situated in the southern constellation of Sagittarius and is therefore best observed with southern telescopes. It has been monitored at the ESO La Silla Observatory since early October. Most of the observations have been made with the ESO NTT (both EFOSC 2 and EMMI) and later, with the ESO/MPI 2.2-m telescope.

As Saturn is a very bright object, the main problem was to avoid saturation of the CCD. This was solved by using very short exposure times and/or narrow-band filters. Table 1 gives the observational data. Isophotal contours have been plotted, and transferred to the coordinates system of Saturn (using a perspective scale grid as described in [1]). As this planet has a strong differential rotation (the period varies from 10 hrs 10 min to 10 hrs 50 min, depending on the latitude), the longitude definition is not an easy problem. The "System I" [2] was chosen; it is fixed to the equatorial belt, and its period of rotation is 10 hrs 14 min. As the spot is located in that region, this system is rather well suited. The longitudes were taken from the Astronomical Almanac 1990 [3].

For each image, the isophotes of the region of latitude between −30° and +30° are plotted in Figure 1. The limbs of the planet and the position of the rings are also indicated. Saturn presents an important limb darkening, which affects of course also the spot's isophotes. This effect has not been corrected. The visual observations reported in the IAU telegrams (# 5109, 5111 and 5115) are also plotted.

Development of the Spot

The new phenomenon was first reported on September 25, 1990 by astronomers at the Las Cruces Observatory in New Mexico, USA, as a white spot at northern latitude +12°. It was watched by many amateur astronomers in various countries as it slowly grew in size to about 20,000 km on October 2. Further observations determined the spot's rotation period to about 10 hrs 17 min, that is somewhat slower than the surrounding atmosphere.

During the next days the spot became longer and longer and by October 10, its length was approximately half of Saturn's visible diameter. After that it continued to expand and on exposures made at ESO from October 23 onwards it encircles the entire planet as a bright equatorial band. At the same time, several new intensively bright spots have been sighted inside the larger feature; they are now being followed with great interest. There is no indication yet that the phenomenon has started to fade away.

Earlier Spots

New spots on Saturn are not so common: only a few dozens have been observed from the Earth during the past 200 years and only about ten of them were enough contrasted and lasted long enough to give good positional measurements [4]. Most of them were quite small (5000 to 15,000 km), brown,

TABLE 1: *Selected Observations*

Date	Hour (UT)	Telescope	Instrument	Filter	Exp. time
10 01	22:49	*			
10 02	19:36	*			
10 03	05:44	*			
10 04	02:18	*			
10 08	00:00	NTT	EFOSC2	U	0.5s
10 10	02:40	NTT	EFOSC2	U	0.5s
10 16	00:00	NTT	EMMI-B	HeII	1s
10 17	00:04	NTT	EMMI-B	HeII	1s
10 19	02:47	NTT	EMMI-R	SII	1s
10 21	00:00	2.2-m	Adapt.	NU	15s
10 21	23:45	2.2-m	Adapt.	NU	10s
10 23	00:01	2.2-m	Adapt.	NU	10s

Comments: * Visual observation reported in IAU Circulars. – U: Johnson filter. – HeII: Narrow band around 4686 Å. – SII: Narrow band centred around 6732 Å. – NU: Narrow band centred around 3875 Å.