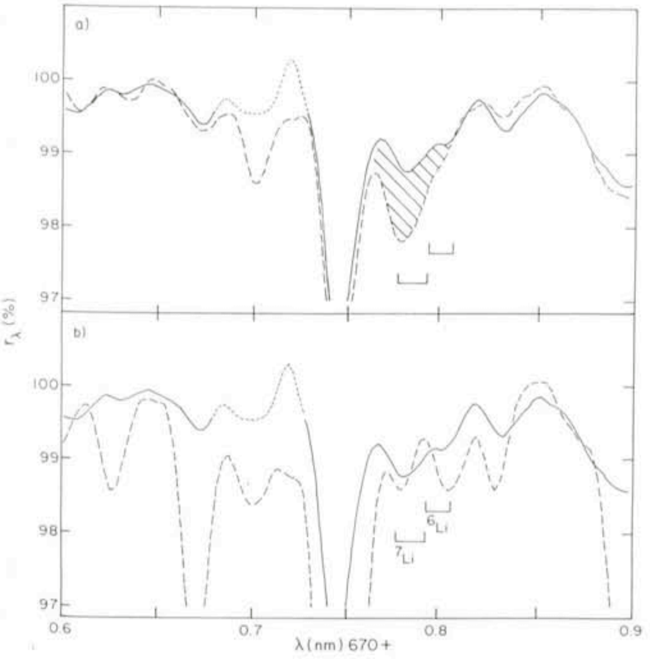

Fig. 1: *Data from the CAT/CES for lithium in α Centauri and the Sun. Note the vertical scale: only the top three percent of the spectrum is displayed. In both panels, the solid line shows a solar spectrum (the dotted section is a Reticon imperfection). Panel* a) *compares α Cen A to the Sun, while* b) *shows α Cen B. The expected wavelengths of the lithium lines are shown in the lower panel.* ^{6}*Li is rare – it constitutes less than 10 % of the total solar or terrestrial lithium. The* ^{7}*Li feature is a doublet, with the blueward component being twice as strong as the redward one. The shaded region in the upper panel shows the extra lithium absorption in α Cen A compared to the Sun.*

gradually runs out of hydrogen, and this causes the structure of the Sun to adjust in order to keep the nuclear reactions going. Because of all this, the Sun has grown a little warmer and larger over its main sequence lifetime.

We can use the same theory to determine the age of α Cen. The parallax and apparent magnitude together define the star's true luminosity. Determination of the temperature is then needed to get the age, since we know the mass (because it is a binary). This sounds straightforward, but is in reality difficult and uncertain. Because α Cen is in the south, it has not been as thoroughly observed as nearby stars that are in the north. Therefore the parallax and masses are not as well determined as we would like. The age one calculates depends on the composition of the star, and that is not known very well either. The best present estimates place α Cen at about 6 billion years old, just a little older than the Sun's 4.6 billion years.

For the purpose of understanding the lithium, it is sufficient to just compare α Cen A to the Sun. A great deal of effort is saved because it appears that they have the same temperature. Carefully determined spectral types for α Cen A and the Sun are identical. Comparing the spectra does not suffer from the usual problems of comparing the Sun to other stars: an excess of light that stellar equipment cannot handle. Another way of comparing temperatures is to compare Hα profiles. Again, α Cen A and the Sun appear to be indistinguishable.

If we assume that α Cen A and the Sun have exactly the same temperature, getting a lithium abundance is easy; we just need good measurements of the line strengths. An example of the lithium spectral region is shown in Fig. 1. You can see that the lithium spectral feature is a good deal stronger in α Cen A than it is in the Sun, but lithium is probably absent from α Cen B. These data indicate that α Cen A has about twice the solar lithium abundance. D. Dravins of Lund Observatory has also observed lithium in these stars, during the commissioning of the CAT/CES, and his data give the same result.

What does this mean? Remember that α Cen A is slightly more massive than the Sun (10 % more), while α Cen B is 9 % less massive. The depth of the convective envelope is extremely sensitive to a star's mass, so α Cen A should have a thinner convective zone than the Sun does. Therefore the lithium depletion will be slower, and α Cen A's greater lithium abundance is reasonable. Similarly, a star like α Cen B depletes lithium much faster than the Sun does, and it has none left.

There are other age-related properties that are being studied in these stars, such as the strength of their chromospheres and their rotation rates. They will have to be discussed another time.

The staff of ESO make observing there a real pleasure. I would particularly like to thank Sr. José Véliz for his help.

Ca II in HD 190073 Revisited

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In 1933, Paul W. Merrill, of the Mount Wilson Observatory, published, with the collaboration of Cora Burwell (Merrill and Burwell, 1933), a Catalogue of such attractive objects as the B and A stars that display emission lines in their spectra.

The classical model for the Be stars suggests that we are dealing with evolved (off the main sequence) objects and that the emisson arises because of a geometrical effect in the flat, extended envelope that surrounds them. This envelope would result from the shedding of matter through the equatorial bulge because of instability generated by the large rotational velocities that seemed to characterize our group of objects. Such a model is, however, vulnerable in many aspects, as recent studies, particularly those that cover the satellite ultraviolet wavelength region, have disclosed. Indeed, the apparent correlation of rotational velocity and emission is no longer an established fact, the mass loss rate does not seem to be related with velocity of rotation, and it does not seem to be necessarily true that the emission is observed because of a geometrical effect. The investigation of Be and Ae stars, in as an extended a wavelength range as possible is, therefore, most desirable if we wish to reach a full understanding of their nature and of the structure and extent of their gaseous envelope.

One of the particularly interesting stars of the group is the one listed under number 325 in Merrill and Burwell's (or Mount Wilson) Catalogue and known as MWC 325, or, more gener-

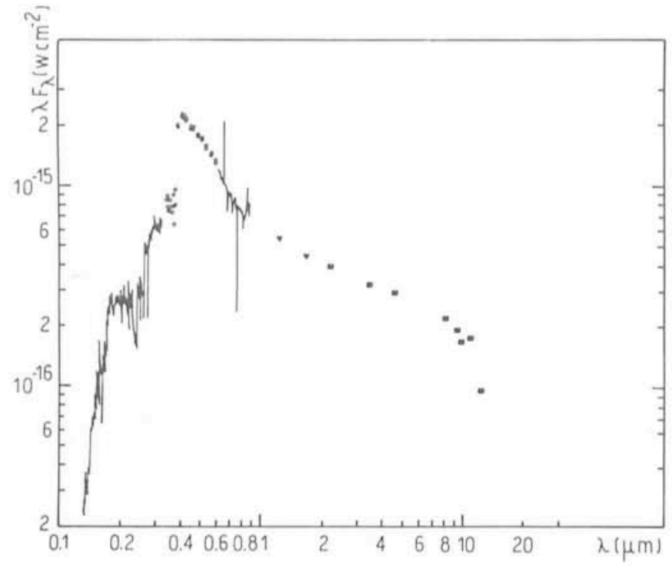

Fig. 1: *Energy distribution of HD 190073 (from Saitko et al., 1981).*

ally, as HD 190073, for its number in the *Henry Draper Catalogue*. The star is in the constellation of Aquila.

In their "Notes to the Catalogue", Merrill and Burwell pointed out that HD 190073, an A0 object, is characterized by a "most peculiar spectrum" where "the sodium $D_{1,2}$ lines are bright, and the structure of the H and K lines [of Ca II] are very remarkable". The discovery that the star's spectrum shows Hα in emission was made by Merrill in 1927, who also discovered a few years later the structure in Ca II.

HD 190073 is also characterized by the presence of a magnetic field. H.W. Babcock (1958) found that different elements or ions yielded different field intensities and polarity, namely,

Cr I, Fe I:	$+270 \pm 30$ gauss
Si II:	$+120 \pm 30$
Fe II, Ti II, Cr II:	$+ \quad 5 \pm 30$
Mg I:	0
Ca II:	-270 ± 30

and it may be significant that neutral metals yield larger field intensity than ionized metals, and that Ca II suggests a different polarity.

Another interesting feature of our star is that it has a large infrared excess, as was reported by S. L. Geisel (1970). Woolf, Stein and Strittmatter (1970) have shown that, in some cases, infrared excesses in Be stars can be accounted for by free-free radiation from an ionized hydrogen envelope with an electron temperature of the order of 10,000° K. In HD 190073 the infrared excess (H–K = 0.79 mag. and K–I = 1.20 mag.) cannot be understood purely in terms of Woolf et al.'s model. D. A. Allen (1973) suggests that in HD 190073 the infrared excess arises principally from thermal emission from grains in a circumstellar dust shell of a temperature little above 1,000° K that surrounds the object, and, in his paper on the "near infrared magnitudes of 248 early-type emission-line stars and related objects", illustrates eight cases of Be and Ae stars for which the infrared excesses can be similarly explained. An alternative—we should perhaps say, complementary—model of free-free emission from H I regions around the stars, where the electron temperatures are of the order of $1-8 \times 10^3$ K, has been proposed by Dyck and Milkey (1972). Actually, the flux from HD 190073 in the infrared suggests that we probably have contributions from an H II region, from an H I region and from a dust shell.

Fig. 1 depicts the energy distribution of HD 190073 from the IUE shortest UV wavelength through the infrared, as compiled by Sitko, Savage and Meade (1981). We can readily see that the energy distribution departs from a normal one.

In order to try to make a contribution towards a better understanding of the peculiar spectrum of the star, in particular of the structure in the lines of Ca II-H and K, in August 1982, we observed HD 190073 at La Silla with the coudé spectrograph of the 1.5 m telescope, in the blue, with a dispersion of about 12 Å mm^{-1}, and in the red region of the spectrum, the latter with a dispersion of about 20 Å mm^{-1}. The La Silla material was supplemented with IUE high dispersion images that existed in the NASA Goddard Space Flight Center archives and were partially studied by one of us (J. S.) with the use of the IUE RDAF (Regional Data Analysis Facility) in June–July 1983.

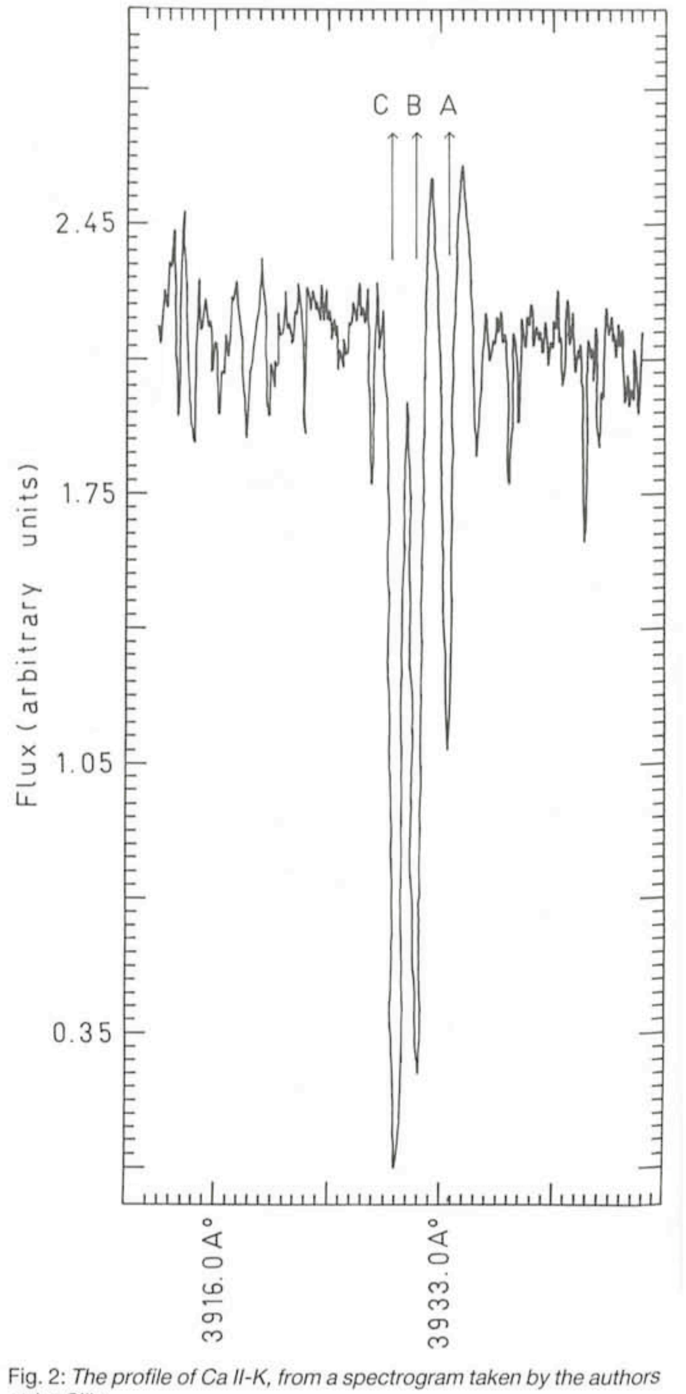

Fig. 2: *The profile of Ca II-K, from a spectrogram taken by the authors at La Silla.*

The spectrum of HD 190073 is most interesting and a detailed discussion of our results will be published in a professional journal. Here we would like to confine ourselves to the description and discussion of the profiles of the Ca II lines.

Fig. 2 illustrates the profile of the K line of Ca II at 3933.7 Å. We distinguish, going from shorter to longer wavelength, two narrow and deep absorptions (C and B on the figure, following Merrill's nomenclature) and an emission feature with a narrow and fairly deep absorption feature superimposed (A on the figure, following Merrill's nomenclature). Exactly the same is true for the Ca II-H line at 3968.5 Å.

Naturally, being so peculiar, the Ca II profiles have been extensively studied since their discovery, and some facts have been established. In the first place, Merrill was able to ascertain the constancy of the presence of the three strong and narrow absorptions A, B and C, and also the fact that, at times, components B and C are not single but display several subcomponents. More recently, J. Surdej and J.-P. Swings (1976, 1977) secured further observations and analyzed the spectra taken of the star during the interval of over 30 years, from 1943 through 1974. This work confirmed Merrill's conclusions and further disclosed that "the details of the H- and K-complex structure are correlated with the profiles of the Balmer lines".

On the observations we secured in 1982, we find the permanent absorption structure—and the emission—in the Ca II profiles, with no subcomponents. The derived radial velocities are 0, −180 and −300 km s^{-1} for components A, B and C, respectively.

Now a question arises. Are there lines of other elements or ions in the spectrum of HD 190073 that display the same profile as Ca II, or, at least, yield radial velocities of the same order as those derived from the absorption components in the profile of Ca II? An affirmative answer comes from the study of the material at our disposal.

On the spectra taken at La Silla, if we look at the Fe II lines that have stronger emissions, namely, those of multiplet 42, at 4924, 5018 and 5169 Å, we find that the line at 4924 Å displays a similar structure as Ca II. This is illustrated in Fig. 3, where we can see emission at about the normal position of the line, and absorptions A, B and C, yielding radial velocities of 0, −207 and −295 km s^{-1}, respectively, plus an additonal absorption between A and B, which we have called D in Fig. 3 and yields a radial velocity of −110 km s^{-1}. The line at 5018 Å does not show component C, and, at 5169 Å, component C is perhaps very weakly present. The Fe II lines of multiplet 42 display an additional feature, namely a sort of a bulge at the violet edge of the emission, which we will not discuss here.

The similarity in profile of the lines of Ca II and Fe II (42) and in the radial velocities of the common features suggest that perhaps these components of Ca II and Fe II are formed in the same regions of the gaseous envelope that surrounds the star. The question is as to whether we can say anything about the relative position of such regions. But before we try to take up this question let us add information from the IUE ultraviolet spectrum, of which we have, so far, analyzed only a few selected regions.

The IUE ultraviolet spectrum of HD 190073 displays only absorption features, except in the case of the resonance lines of Mg II at about 2800 Å, and is rich in Fe II lines, which are single and violet-displaced in the velocity interval −210 ± 35 km s^{-1}. The ultraviolet Fe II lines appear, therefore, to coincide with what we have called component B of Ca II and of Fe II (42) on the ground-based spectra. As a consequence, the first conclusion we can draw is that component B of Ca II and Fe II, which is devoid of emission, should form in a region located not too far from the stellar surface, and that component A,

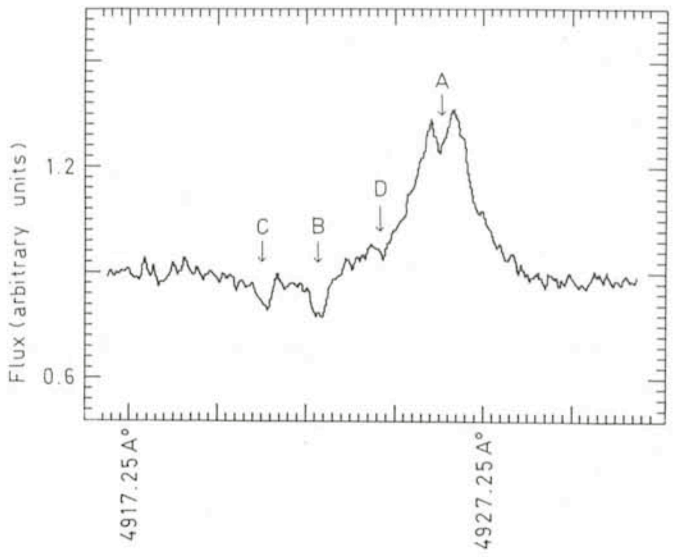

Fig. 3: *The profile of Fe II at 4924 Å, from a spectrogram taken by the authors at La Silla.*

which is associated with emission, should arise farther away, at a certain distance from the star. The latter assertion is supported by the fact that Na I displays a profile that, in all respects, is similar to that of component A and the associated emission.

Then, the subcomponents connected to component B that are observed at times, indicate that some kind of activity takes place close to the star. This conclusion, which finds further support in the similar conclusion that was reached in a recent study that we have carried out, jointly with other investigators, of the Be star V 923 Aquilae (Ringuelet et al., 1984), contributes to our knowledge and a better understanding of emission-line B and A stars.

Regarding component C, that, at times, also displays subcomponents and is devoid of emission, we can only say at present that the region of formation should be relatively close to the star, and should undergo variations in the local conditions with a time scale that could be, according to Surdej and Swings, even of the order of hours.

A complete analysis of the spectrum of HD 190073, in the photographic as well as in the satellite ultraviolet regions —which is near completion—and its possible interpretation in terms of a theoretical model, may improve our picture of the gaseous envelope around the star. The presence of the resonance lines of Si IV and of C IV in the IUE spectrum, that suggests the existence of a "transition region" in the envelope, and the information regarding the star's magnetic field are two important items that should then be taken into consideration.

Acknowledgements

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Determination of the Rotation Curve of Our Galaxy. Observations of Distant Nebulae

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For the derivation of the Galactic gravitational potential, a well calibrated rotation curve of a suitably selected class of objects is a valuable source of information. It gives us insight in problems of galactic dynamics and mass distribution.

This article describes the project currently carried out by the author, in collaboration with Dr. Jan Wouterloot (formerly with ESO) and Dr. Leo Blitz (University of Maryland). Its main purpose is to determine the shape and strength of the gravitational force that influences the motion of material in our Galaxy. We do this by turning our attention to the outer galaxy (third and fourth quadrant), where we try to figure out how the molecular material, and by inference the (young) stars that reside in the disk, moves in those outer reaches of our stellar system. Knowledge of the gravitational potential will give us insight in the way mass is distributed in the Galaxy.

The fact that the Galaxy rotates has been established by Lindblad and Oort in the mid 1920s. The rotation is differential, i.e. the Galaxy does not rotate as a solid disk (as for instance do the wheels of a car, fortunately), but has a different angular velocity at different distances R from the galactic centre (G.C). Furthermore it is found that different types of objects move in different ways, in the sense that the gas is constrained to move in nearly circular orbits around the G.C., whereas old stars (members of the so-called spheroidal component) move in highly eccentric orbits. The relation that gives the velocity of rotation in circular orbits with respect to the G.C. as a function of distance from the G.C. is called the rotation curve. Ever since the 1920s people have been trying to determine the rotation curve of our galaxy. There are several reasons why this relation is important. Matter in the Galaxy is distributed in a certain way, which determines the shape of the gravitational potential. This potential dictates the orbital parameters of the galactic constituents (stars and gas) and thus the rotation curve that we derive from our measurements of these constituents. Reversing the sequence, the rotation curve tells us how matter in the Galaxy moves and gives clues as to how it is distributed. A practical, and very important, use of a rotation curve is to estimate distances to gas clouds (either H I or H II regions for which the ionizing stars are too much obscured to be seen) by just measuring their velocity.

There are several ways to determine the rotation curve of our Galaxy, depending on the sector of the Galaxy that one investigates. For the inner Galaxy (l = 90°→0°→270°) a much used practice is to measure the velocity of the atomic or molecular gas (through respectively the 21 cm line of H I or the 115 GHz (or 230 GHz) line of CO). For a particular line of sight, the emission of the highest-velocity feature is then assigned to the location closest to the G.C., encountered along that line of sight. In this way a rotation curve for the part of the Galaxy inside the solar circle can be constructed. Another way to reach this goal is to use H II regions and their exciting stars. In that case, the velocities used are that of the ionized gas (e.g. via Hα, or H109α line measurements), of the stars (thought to be) associated with the nebulae, or of the molecular clouds associated with the H II regions. Distances are derived from optical observations (photometry and spectrography) of the exciting stars. Other galactic objects such as Cepheids and planetary nebulae can and have been used as well. From that combined work we now have a fairly good understanding of the rotation characteristics of the inner Milky Way. A disadvantage encountered in the inner Galaxy is that the line of sight samples each radius R twice. This situation is depicted in Fig. 1. Measuring a radial velocity of an object in that part of the Galaxy leaves one in doubt as to whether to assign it to the "near" or "far" distance. One then has to use circumstantial evidence (such as degree of extinction for H II regions or angular sizes of gas clouds in the direction perpendicular to the galactic plane) to solve this dilemma.

For the outer Galaxy (l = 90°→180°→270°) things are more straightforward as each velocity corresponds directly to

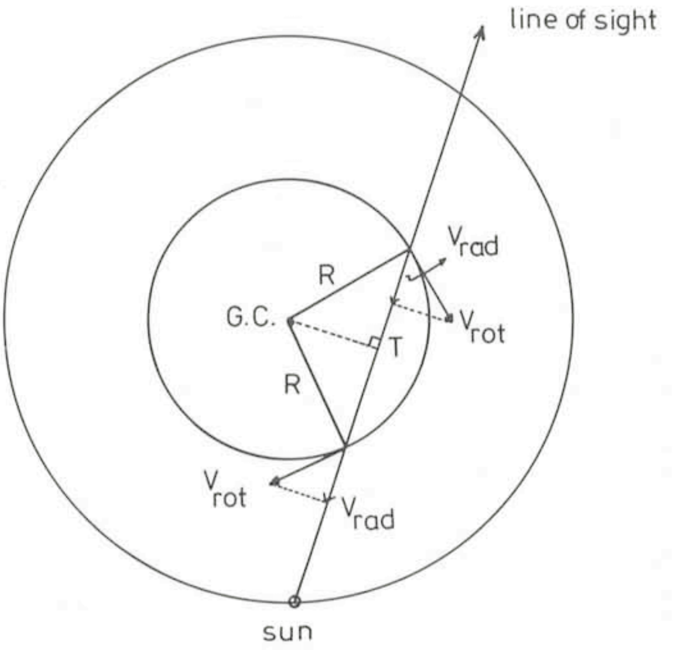

Fig. 1: *Distance ambiguity in the inner Galaxy. The line of sight intersects the circle that is the locus of points at a distance R from the G.C. twice. Objects at both intersections have the same velocity. It is assumed that the highest-velocity features along this line of sight are found at point T (= tangential point). V_{rot} and V_{rad} are rotational and radial velocity respectively.*