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THE AGE OF α CENTAURI

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ABSTRACT

The rotational velocity, Li content, and Ca II emission intensity are used to determine the age of the α Cen triple system by comparison with Skumanich's decay curves. High-dispersion (1.7–3.4 Å mm^{-1}) spectrograms have been obtained of α Cen A (G2 V), α Cen B (dK1), and the Sun. The rotational velocity of α Cen A is apparently 10 percent greater than that of the Sun, which gives an age of 3.6×10^9 years. An upper limit of 6.2 mÅ on the equivalent width of the Li line results in a lower limit for the age of 4×10^9 years. The Ca emission intensity is comparable to that of the Sun and not more than 50 percent greater than the solar intensity; this value gives a lower limit of 2×10^9 years. We conclude that α Cen A is at least 3 billion years old, which is inconsistent with the expected age of 4×10^8 years for α Cen C, a dM4e flare star.

Subject headings: Ca II emission — emission-line stars — flare stars — stars, individual — visual double or multiple stars

I. INTRODUCTION

The nearest star, α Centauri, is a triple system. The star α Cen itself is a visual binary, consisting of α Cen A, a G2 V star like the Sun, and α Cen B, a dK1 star. The third star, Proxima Cen (V645 Cen), is a common-proper-motion companion, separated from the other components by about 2°. Its orbital motion is not great enough to have yet permitted the determination of a reliable orbit, but the association is clearly indicated by the spatial closeness and the proper motion.

Proxima Cen is a dM4e flare star. Haro and Chavira (1964) have determined that no flare star should be found in any group of stars older than 10^9 years. They give an estimate for the age of flare stars in the solar neighborhood of 4×10^8 years. If the three members of this stellar system had a common origin, then α Cen is significantly younger than the Sun. Several observational correlations with age have been found for main-sequence stars. These can be applied to the components α Cen A and B to determine if their ages are consistent with that for a flare star.

Wilson (1963) has established a correlation between ages and intensity of emission in the core of the H- and K-lines of Ca II in late-type main-sequence stars. For stars of a given spectral type, the more intense the emission, the younger the star. Ca II emission is an indicator of chromospheric activity, which decreases with age.

There is also thought to be a correlation between Li abundance and age. Herbig (1965) suggests that after a late-type star reaches the main sequence, its Li is depleted on a long time scale. This rate of Li depletion is also a function of spectral type (Conti 1967).

Kraft (1967) has studied the rotation of late F and early G dwarfs and found that rotational velocity decreases with increasing age. This dependence is believed to be due to magnetically coupled stellar winds which carry off the star's angular momentum. The generation of these winds is thought to be a chromospheric phenomenon occurring in stars with hydrogen convection zones just below the surface.

Van den Heuvel and Conti (1971) and Skumanich (1972) give quantitative results for these age correlations. Both Ca emission and rotation decay by a square-root law, and the Li abundance decays by a square-root law as far as the Hyades age but then decays exponentially with an e-folding time of 1.1×10^9 years. Use of these data has provided us with quantitative limits on the age of α Cen.

Because these three phenomena vary with spectral type, we are fortunate that α Cen A is of exactly the same spectral type as the Sun, and the two stars may be directly compared.

II. OBSERVATIONS

Although α Cen is at $-60°$ declination, it is possible to observe it from Mauna Kea. In order to study the Ca emission, five heavily exposed spectrograms were obtained of α Cen A on baked IIa-O emulsion at 3.3 Å mm^{-1} with the 244-cm focal length camera of the coudé spectrograph of the 224-cm reflector at Mauna Kea Observatory. The spectra were widened to 1.0–1.3 mm on the plate. The same grating and camera combination was used to take two exposures of α Cen B to examine the H and K emission. Two spectrograms of the daytime sky were obtained with this equipment for direct comparison of α Cen A and the Sun.

These same spectrograms were also used to measure the line half-widths for the rotational velocity. In addition, two exposures of α Cen A were made at 1.7 Å mm^{-1} with the 488-cm focal length camera on baked IIa-O emulsion and widened to 1.2 mm. One spectrogram of the daytime sky was also obtained at this higher dispersion.

Three spectrograms were taken at 5.1 Å mm^{-1} on 103a-F emulsion with the 244-cm camera to look for Li in α Cen A. Since Li could not be detected at this dispersion, a spectrogram at 3.4 Å mm^{-1} was obtained with the 488-cm camera, and this spectrogram also

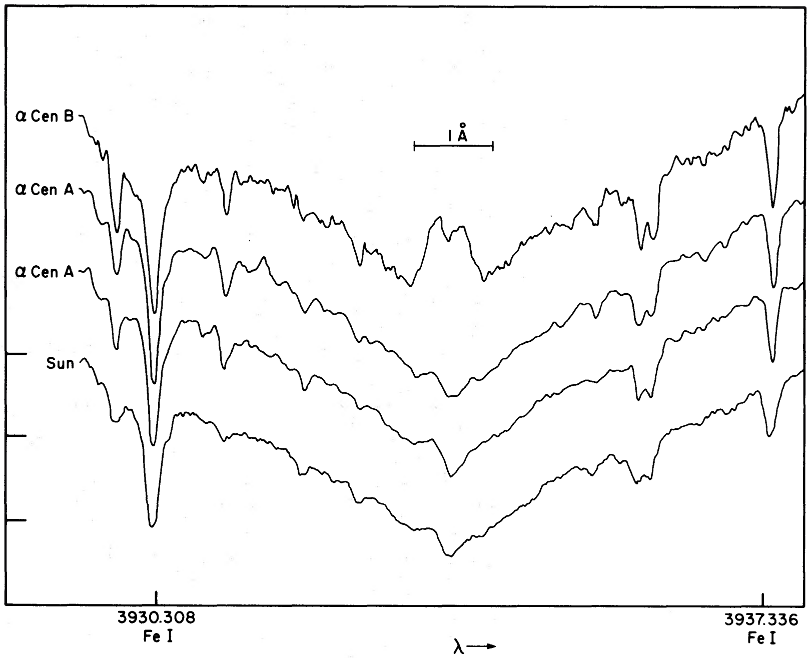

FIG. 1.—Two microphotometer tracings of the K line of α Cen A, and one each of α Cen B and the Sun. Note the similarity in the emission of α Cen A and the Sun, and the stronger emission in α Cen B.

showed no Li feature. Two spectrograms were taken of α Cen B on 103a-F emulsion at 5.1 Å mm^{-1}; no Li was detected on either plate.

III. RESULTS

a) *Calcium Emission*

Microphotometer tracings were made of all H and K plates and the Ca emission examined. Figure 1 reproduces several tracings of the core of the K line of α Cen A and B and the Sun. No significant difference is visible between α Cen A and the Sun. If the emission intensity in α Cen A were 50 percent greater than that of the Sun, the difference would be detectable.

The Ca emission intensity of α Cen B has been estimated as 2 on Wilson and Bappu's 1957 scale (Warner 1969). This star does not appear unusually young or old when compared with other K stars. It should be noted that in this binary system, the cooler star has stronger Ca emission, as would be expected (Wilson 1963).

b) *Lithium Abundance*

A depression in the continuum at λ6707.8 was measured to determine an upper limit on the equivalent width of Li I. The value thus found is $W \leq 6.2$ mA. Herbig (1965) has determined Li abundances for late-type stars using a dispersion of 4 Å mm^{-1}. His results for G0–G5 V stars are plotted in figure 2. We have fitted a straight line through his points to allow a determination of the Li abundance for α Cen A. Our value of ≤ -6.03 for log W/λ yields an upper limit on the abundance of +0.2 for [Li/Ca]. (The solar equivalent width used by Herbig is 3.7 mÅ from the work of Greenstein and Richardson 1951.)

c) *Rotation*

Half-widths of about 120 lines were measured on microphotometer tracings of four spectrograms of α Cen A and one of the Sun at 3.4 Å mm^{-1}, and no difference in rotational velocity was detectable. How-

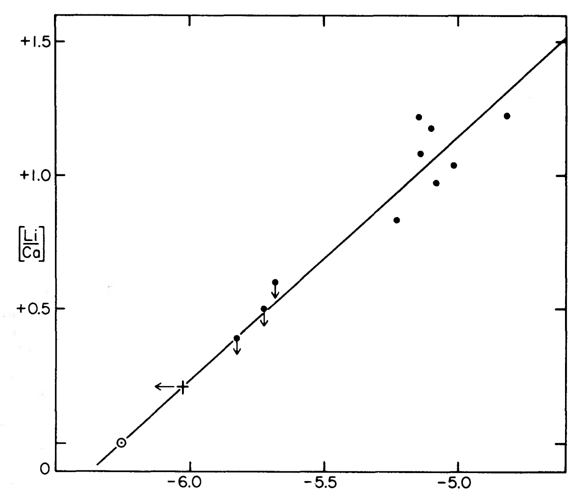

FIG. 2.—Li abundance as a function of equivalent width for G0–G5 V stars from Herbig (1965). The circled dot represents the Sun, and α Cen A is marked by a plus sign.

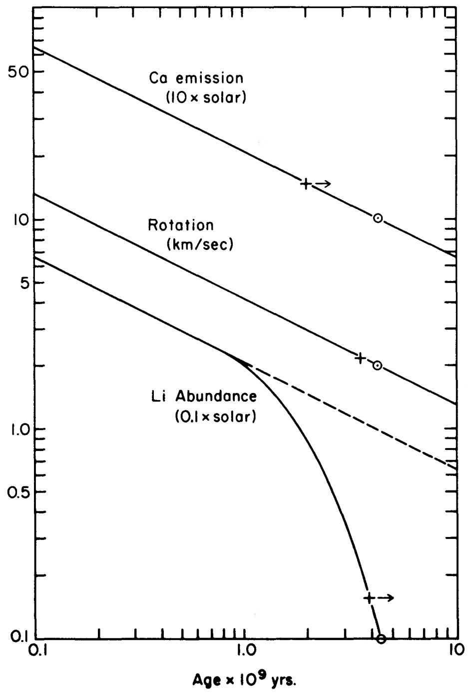

FIG. 3.—Skumanich's (1972) decay curves. The Sun is represented by the circled dots, and α Cen A by plus signs.

ever, two spectrograms of α Cen A and one of the Sun taken at 1.7 Å mm^{-1} revealed a 10 percent greater width for α Cen A. We interpret this increased width as an increased rotational velocity.

The plane of the orbit of α Cen A and B is inclined at 79° to the line of sight (Finsen and Worley 1970). It is reasonable to assume that the rotational plane will be the same, so that a measured $v \sin i$ will be essentially the same as the actual equatorial rotational velocity, v.

IV. CONCLUSIONS

We have added our values for α Cen A to Skumanich's (1972) decay curves which are reproduced in figure 3. We believe that the Ca emission intensity of α Cen A is no more than 50 percent greater than that of the Sun. This yields a lower limit for the age of α Cen A of 2×10^9 years. The upper limit on the Li abundance of ≤ 1.6 times the solar value corresponds to a lower limit for the age of about 3.9×10^9 years. Rotation 10 percent faster than that of the Sun yields an age of 3.6×10^9 years.

These three independent age determinations have given us consistent results for the age of α Cen A. That is, it must be at least 3 billion years old. However, this is not consistent with the age derived for flare stars by Haro and Chavira (1964). Assuming Proxima Cen formed at the same time as its companions, we have observational evidence for a flare star older than 10^9 years. This new age for Proxima Cen may be used to give the pre–main-sequence lifetime of low-mass dMe stars.

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