

NOTE ON THE MOTION AND POSSIBLE ORIGIN OF THE O-TYPE STAR
HD 34078 = AE AURIGAE AND THE EMISSION NEBULA IC 405,

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The star HD 34078, O_{9.5}V, is found to have the high space velocity of 128 km/sec, showing both in the radial and in the tangential component. The surrounding emission nebula IC 405 seems to share this motion, which, moreover, is directed exactly away from the Orion association of O and B stars. It is suggested that HD 34078 was formed in a region of compression in this nebula, and is not older than a few million years at most; the nebula itself may have been pushed away from the Orion region.

1. HD 34078 = AE Aurigae, $m = 5.8$, Sp. O_{9.5}V¹⁾, is remarkable because of its high space velocity, which distinguishes it from the O-type stars in general. The radial velocity according to MOORE's catalogue²⁾ is $+59.3 \pm 0.7$ km/sec, this being the average of observations made mainly at Mount Wilson and Victoria in the years 1921 and 1922. Two more recent observations, made at the McDonald Observatory, give the same result: plate CQ 6392, 1947 Nov. 29: $+63$ km/sec ± 2.0 ; and plate CQ 6629, 1948 Jan. 4: $+55$ km/sec ± 2.0 . There is nothing in the spectrum of the star to suggest that the measured displacement does not refer to the star's real motion. Eliminating the standard solar motion, we find $V_r = +51$ km/sec.

The tangential velocity is found to be 117 km/sec, after correction for standard solar motion. This value is based on the photometric distance 525 ps and a newly determined proper motion. The distance modulus, $m_o - M = 8.6$ is derived from the adopted visual absolute magnitude, -4.2 , corresponding with the spectral type O_{9.5}V³⁾, and the apparent magnitude $m_o = 4.4$, corrected for interstellar absorption.

The proper motion is

$$\begin{aligned}\mu_\alpha \cos \delta &= -0''.0002 \pm 0''.0022 \text{ (p.e.)}, \\ \mu_\delta &= +0''.0401 \pm 0''.0024 \text{ (p.e.)}.\end{aligned}$$

Or, when corrected for the standard solar motion:

$$\mu_\alpha \cos \delta = -0''.002, \quad \mu_\delta = +0''.047.$$

The proper motion is almost exactly in the direction of increasing declination. In deriving this value, not only the early meridian observations used in B. BOSS' *General Catalogue* were considered, but also the more recent ones. Particularly valuable were: the series of 10 observations in the recently published *First Cape Catalogue for 1950* (mean epoch 1939.2), an unpublished series of 8 observations carried out at the Paris Observatory and kindly made available to us by Dr J. LEVY (mean epoch 1948.9), and a series of 5 observations at the U.S. Naval Observatory, kindly communicated by Dr F. P. SCOTT (mean epoch

1953.1). Dr SCOTT also very kindly carried through independently the computation of the proper motion. The value given above is the average of the systems of N₃₀ and FK₃ with precessional corrections applied.

The total space velocity derived from the radial and the tangential components is 128 km/sec.

2. HD 34078 is immersed in, and the exciting star of, the emission nebula IC 405. An excellent photograph of this nebula as observed in H α light is given on plate 4 of SHAJN and HASE's *Atlas of Diffuse Gas Nebulae* (issued by the Crimean Astrophysical Observatory, 1952). This photograph is reproduced here in Figure 1. It shows that the nebula extends considerably beyond the luminous central part in which HD 34078 is located and which is shown, for instance, on plate 30 of ROSS and CALVERT's *Atlas of the Milky Way*. But the nebula is especially remarkable because of its peculiar shape. It roughly resembles that of the figure 7, with HD 34078 somewhat below the centre of the horizontal bar, which is the most luminous part of the nebula, and the faint, vertical bar having a rather sharp edge at the eastern side. This edge runs exactly in the direction of the proper-motion component in declination of HD 34078.

This shape suggests that the fast motion of HD 34078 in declination is shared by a dense cloud surrounding the star, which has swept up the interstellar matter on its path and has left the matter at the western side of the sharp edge in its original position. If this interpretation is correct, we probably observe the accompanying cloud around HD 34078 in a state of collision with the interstellar matter north of it. The irregular shape of the bright emission features on the north side of HD 34078 compared to the smoother appearance of the nebula south of it, may well be due to this collision process⁴⁾.

At the north side of HD 34078, we also find luminous edges on some dark clouds at the side which faces HD 34078. This phenomenon, frequently observed in the dark clouds around associations of early-type stars, suggests either collisional excitation by matter pushed against these clouds in the direction of the motion of HD 34078 and the accompanying

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¹⁾ GC 6429, R. A. 5^h 13^m.0, Decl. $+34^\circ 15'$ (1950); $l = 139^\circ.8$, $b = -0^\circ.9$.

²⁾ *Publ. Lick Obs.* **18**, 1932.

³⁾ From unpublished preliminary calibration.

⁴⁾ This was suggested to us by Sr G. HARO.

cloud, or radiative excitation in these boundary regions of the dark clouds.

The radius of the bright "accompanying" cloud as judged from SHAJN and HASE's photograph is about 18' or 2.8 ps. A rough estimate of the hydrogen

density in this cloud from its size – assuming that the observed boundaries at the north side indicate the extension of the HII region – gives $N_H = 50$ ions per cubic centimeter, but regions of very much higher local density may well occur in this cloud. The extension

FIGURE 1

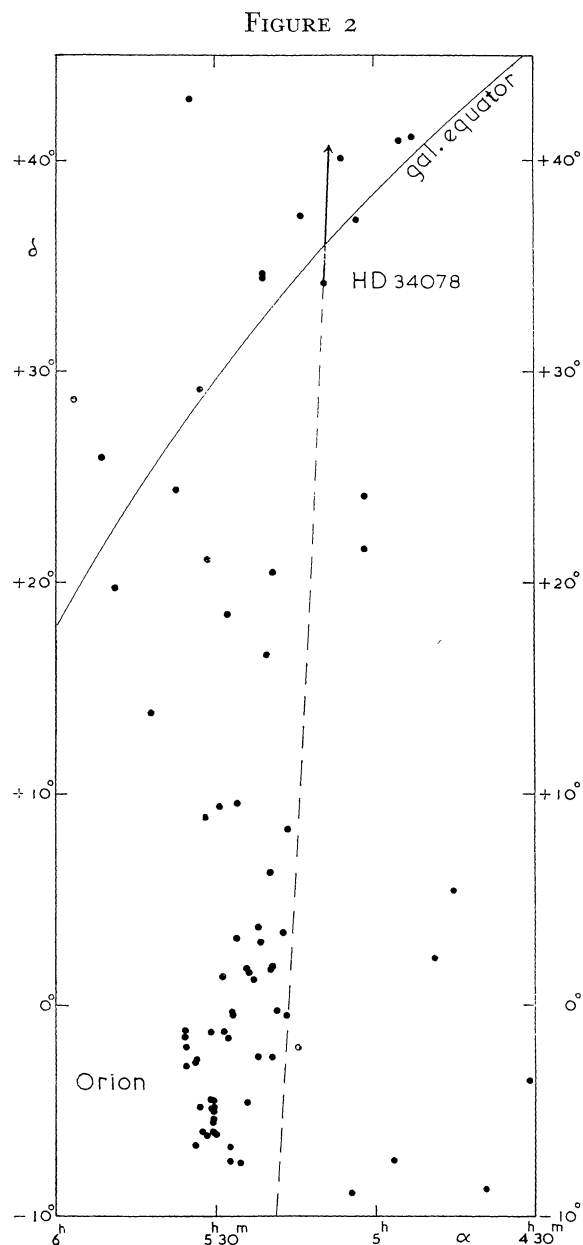


Reproduction of SHAJN and HASE's photograph in H α of the emission nebula IC 405 around the star HD 34078 (AE Aurigae), which is marked by the circle in the centre of the figure. North is up, East to the left. The scale is indicated below.

of the HII region south west of HD 34078 – the "uncleaned" part that is left of the original cloud – indicates a density of about one tenth of this value. Accurate photometry of the emission nebulae is required in order to improve these rough estimates.

3. The motion of HD 34078 – and possibly the motion of the accompanying cloud – has another

interesting property. It is directed almost exactly away from the Orion association of O and B stars. Figure 2 shows, in equatorial co-ordinates, the distribution of the O to B2 stars in this region of the sky. Only stars within 800 ps are represented. The arrow indicates the direction of the proper motion of HD 34078; its size corresponds to the motion in 5×10^5 years. The past path of HD 34078, shown by the dotted line,



The motion of HD 34078 = AE Aurigae with respect to the Orion aggregate. The arrow represents the projected motion in 5×10^5 years.

passes closely along the centre of the Orion group, which shows in the lower part of the figure. It seems as if HD 34078 or, perhaps, rather the cloud in which it was formed, originated in the neighbourhood of the Orion association and was pushed away with considerable force, causing its present rapid motion.

The observed radial velocity also fits in with this idea. Assuming 500 ps for the distance of the Orion association¹⁾ and, as before, 525 ps for HD 34078, we find that the space motion along the line connecting

the two objects in order that its tangential component be 117 km/sec, should have a radial component of +55 km/sec. This is almost exactly the observed value. It should be added, however, that the agreement is to some extent accidental, as a slight change in the assumed relative distances of HD 34078 and the Orion association strongly affects the predicted radial velocity. If we assume the distance modulus of HD 34078 to be 8.4 instead of 8.6, the predicted radial velocity becomes +33 km/sec. We might reverse the argument and say that the observed radial velocity of HD 34078 supports the adopted distance of this star.

4. The fast motion of HD 34078 is an excessive case in the class of high-velocity O-type stars, about the reality of which there has been some doubt in the past. This doubt now seems no longer justified, as the fast motions are found to appear both in the radial and in the tangential components. Another example is ζ Ophiuchi with a tangential motion of 31 km/sec²⁾. Also, the fast motion of ξ Persei³⁾ with respect to the centre of the ζ Persei group (49 km/sec), although derived mainly from the radial component, seems to fit so naturally in the general pattern of the fast motions in that association, that its reality appears quite plausible. MAYALL's recent measure of the radial velocity of NGC 1499, which is excited by ξ Persei, confirms this view⁴⁾. The fact that nearly all O-type stars are associated with O associations also lends some support to the assumption that HD 34078 is related to the Orion group. There is no other association along the past path of this star. The group of stars around $\alpha = 5^h 30^m$, $\delta = +20^\circ$ in Figure 2 is a loose association of B stars in Taurus at an average distance from the sun of about 350 ps.

The distance between HD 34078 and the Orion group is about 350 ps. With the space velocity of 128 km/sec this distance would have been travelled by the star in 2.7×10^6 years, and this might be considered as the "age" of HD 34078. However, it would seem more likely that the true age, considered as the time elapsed since the star began its motion as an independent unit, is somewhat shorter. If we suppose the cloud surrounding the star to be its birthplace, we can hardly imagine this cloud not to have lagged behind the star as a consequence of the obstruction by the interstellar medium. The fact that the star does not precede the cloud would rather point to an age of the order of one to two million years, similar to what was found for ξ Persei. It is tempting to think that the star actually originated in a dense compressed

²⁾ B.A.N. No. 433, 419, 1952.

³⁾ B.A.N. No. 433, 410, 1952.

⁴⁾ P.A.S.P. 65, 152, 1953.

¹⁾ S. SHARPLESS, *Ap. J.* 116, 251, 1952.

region of the cloud when this was blown away from the Orion region.

The assumption of common motion of HD 34078 and the part of IC 405 surrounding it, implies an unusually high velocity for this cloud. ADAMS has shown ¹⁾ that high interstellar K-line velocities occur in exceptional cases; his list gives 7 velocities between 50 and 100 km/sec. The explanation of these very high velocities presents a problem which has not yet been solved satisfactorily. Some progress has been made, however, by recent unpublished investigations of J. H. OORT and L. SPITZER, to whom we are indebted for this private information. These authors have found that very high velocities may be caused by the acceleration of clouds starting their motions from – or passing near by – HII regions in the immediate vicinity of O stars. The acceleration is explained as due to the one-sided ionization of the cloud by the O-type star, acting like a jet from a rocket. The Orion aggregate, with its accumulation of massive early-type stars, may well have presented in the past a suitable source of such ionization for the cloud surrounding HD 34078. It has also been suggested that the strong compression in the non-ionized parts of the clouds, which is likely to accompany the accelerations, would favour the formation of massive stars such as are found to share the motion of these fast clouds.

¹⁾ *Ap. J.* **109**, 354; *Mt Wilson Cont.* No. 760, 1949.

5. It will be of interest to derive from future observations the radial speed of the bright emission nebula around HD 34078, in order to check the hypothesis of the accompanying cloud. Also, studies of the absorption in the “cleaned” and in the remaining part of the large, originally present, cloud will be desirable.

HD 34078 has been listed as a double star in AITKEN's *Double Star Catalogue*, but the companion given there is spurious. It was taken from the *Astrographic Catalogue* measures in the Potsdam catalogue, but marked there as uncertain, and evidently had not been checked on the sky. We are indebted to Dr G. VAN BIESBROECK for this information.

HD 34078 is also known as the variable star AE Aurigae. The variability was announced by MOREHOUSE in 1923 ²⁾ and since that time the star has been more or less regularly observed visually by various observers, who report amplitudes of the variation of 0.2 or 0.3 magnitudes. More precise measurements of the star's brightness are desirable.

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²⁾ *Harvard Bulletin* No. 786, 1923.