IC 405 is the nebulosity around AE Aurigae (HD 34078), of type O9.5 V. This star is of considerable interest because it is one of the early type objects that are moving with high velocities away from the stellar association I Orionis. The association of AE Aurigae with the emission nebulosity of IC 405 appears, however, to be the result of a chance encounter, for the following reasons. First, the radial velocity of the star, +59 km/sec, differs substantially from the well-determined velocity of the bright-line nebulosity, which is about +22 km/sec according to Mayall, Osterbrock, and Courtès. Second, as has been pointed out by Blaauw and Morgan, emission nebulosity is conspicuously absent to the south of AE Aurigae, a fact leading to their suggestion that rapid northward motion of the star with respect to the nebulosity has somehow cleared this lane (see Plate I). Third, neither of the other high-velocity stars receding from the direction of Orion, μ Columbæ (O9.5 V) and 53 Arietis (B2 V), is known to be nebulous.

It was first noticed by Miss Gaze that the appearance of IC 405 differs strikingly on photographs taken in Hα light and in the ordinary photographic region. In the red, the outer parts are bright and an intricate structure of the nebulosity is apparent. In the blue, only the brighter parts of the Hα structure are conspicuous, while a broad streamer of nebulosity that is quite invisible on ordinary red exposures extends eastward from the immediate vicinity of AE Aurigae. The presence of this blue nebulosity is puzzling; Miss Gaze mentioned that it might be a pure reflection nebula, which would be most unusual because of the early spectral type of AE Aurigae, or that it might owe its luminosity to [O III] λ3727 emission. A third possibility, that non-thermal emission may be involved, has been discussed by Ambartsumian. For brevity, we shall here refer to the struc-

* Contributions from the Lick Observatory, Ser. II, No. 92.
The region of IC 405 (the very bright nebulosity above the center) and S 126 (the fainter nebulosity extending along the right side of the photograph) in Hα light. This photograph is part of Plate 14 of the *Atlas Gazovo-Pylevykh Tumannostei*, by V. G. Fesenkov and D. A. Rozhkovskii (Acad. Sci. Kazakh S.S.R., 1953). The area shown is 1°6 × 2°1; north is at the top and east to the left. The arrow indicates both the direction of the motion of AE Aurigae and the distance that the star moves in 50,000 years. In this photograph, the image of AE Aurigae is lost in the overexposed nebulosity of IC 405. Blaauw and Morgan have suggested that the sharp eastern boundary of S 126 may have been produced by AE Aurigae as the star moved northward.
The C nebulosity of IC 405, photographed with the Crossley reflector in the spectral region $\lambda \lambda 3800-5000$. AE Aurigae is the very bright star. Almost all of the bright nebulosity shown in this photograph has a continuous spectrum, except for some filaments north of the star that are the brighter parts of the E nebulosity. The field is $26' \times 33'$; north is at the top and east to the left. The area shown in Plates II and III lies in the overexposed region of IC 405 in Plate I.
The E nebulosity of IC 405, photographed with the Crossley reflector in the spectral region $\lambda\lambda 6300-6750$. This plate is centered somewhat farther north than Plate II, but the scale and orientation are the same. AE Aurigae is the bright star midway between the center and the lower edge. All of the nebulosity shown here has a predominantly emission spectrum: the C structure is very faint in this spectral region.
Representative spectrograms of three areas of IC 405, together with the spectrum of AE Aurigae (lower right). All these spectrograms were obtained with the nebular spectrograph of the Crossley reflector. The dispersion was 430 Å/mm at Hγ, and the slit was about 6′ long. The direct photograph was taken with the Crossley reflector on Kodak 103a-O emulsion, without a filter. The positions of the slit are indicated for the three spectrograms of the nebula. The strips of continuous spectrum are due to parts of the C nebulosity, while the hydrogen and [O II] lines arise in the E structure. The other emission lines and the continuum that extend over the entire length of the slit are due mainly to the night sky but also, to a lesser extent, to city lights. The faint, somewhat streaky continuum near the bottom of spectrogram CC′ is produced by scattered light in the diffraction pattern of AE Aurigae.
ture visible only on the blue-light photographs as the "C" nebulosity, and to that seen on the Hα exposures as the "E" nebulosity.

A number of slit spectrograms and color-filter photographs of IC 405 have been obtained with the Crossley reflector, and some are shown in Plates II, III, and IV. The details will be found in the captions. The direct photographs confirm and extend Miss Gaze's description. The spectrograms show clearly that the luminosity of the C nebulosity is due to a continuous spectrum, as surmised by Ambartsumian, and that there is no perceptible enhancement of the hydrogen or [O II] emission lines of the E nebulosity in the C structure. The spectrograms also show that the C continuum is at least as blue as AE Aurigae; the two lobes of C nebulosity just west of AE Aurigae seem definitely bluer than the star. It is possible, nevertheless, to isolate the C structure by photography in the λλ 4900–6300 region, which contains no important emission lines, by combining the Kodak 103a-D emulsion with a Schott GG 11 filter. However, the general appearance of IC 405 on such a photograph is very much the same as in the λλ 3800–5000 region (Kodak 103a-O plus Schott GG 13) since the latter interval contains only relatively weak emission lines of the E nebulosity. The reason that the C nebulosity is suppressed with respect to the E structure in the λλ 6300–6750 region (Kodak 103a-E(2) plus Schott RG 2) is the strength of the Hα, [N II], and [S II] lines of the E nebulosity relative to the blue C continuum, together with the narrowness of this wavelength interval.

One must next determine whether or not dust particles are involved in the C nebulosity. The crucial test for the presence of ordinary scattering would be whether the nebular absorption-line spectrum corresponds with that of AE Aurigae. Unfortunately, this test cannot be made with the present material because the hydrogen emission lines of the E nebulosity are present to some extent on all the spectrograms, so that one cannot see if the Balmer absorption lines of AE Aurigae appear in the C continuum (see Plate IV). The He I absorption lines in the star are probably also masked. However, an inspection of direct photographs shows that the distribution of stars in the vicinity of AE Aurigae is not at all uniform, and that in all cases the brighter
parts of the C structure coincide with lanes where there are deficiencies of faint stars.* Furthermore, some of the structure in the brightest parts of the C nebulosity can be seen faintly in silhouette against the E nebulosity on the red photographs (compare Plates II and III). These observations show that the C nebulosity is associated with material having an appreciable continuous opacity, probably dust particles. It is not known whether the C nebulosity shares the motion of AE Aurigae or not. This possibility seems rather unlikely because of the correlation of some of the C structure with obscuring lanes that seem to be traceable for some distance from the star. It should be possible to answer the question eventually by comparison of the nebulosity on large-scale photographs obtained some decades apart.

There appears no way to escape from the conclusion that the material responsible for the C nebulosity of IC405 has very little free gas associated with it. This conclusion immediately runs counter to the idea that dust particles are only trace condensates from gas, and hence should have a large amount of gas still associated with them since no efficient separation processes are known. Observations at 21 cm of IC 405 would be of considerable interest.

The next question is whether this dust nebulosity is to be considered as unusual or not. It seems improbable that the only known example of such a nebula should be associated quite by accident with a kinematically unusual object like AE Aurigae. It is possible that such clouds are more common than this example seems to indicate, but that the ordinary circumstances of the association of nebulae and stars mask the fact. Let us consider now how such a situation might arise.

It is well known that the continuous spectrum in ordinary emission nebulae is in general very much weaker than the scattered continuum of pure reflection nebulae. This difference is shown by the fact that, if both are photographed in a spectral region free of emission lines, the emission nebulae will fall well

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* This observation is based on a photograph taken in the $\lambda \lambda 5250-5850$ region, where both the C and E nebulosities are very faint and hence any photographic effect due to the superposition of nebulosity upon the stellar background is negligible.
off the Hubble relationship between the magnitude of the exciting star and nebular extension that is obtained from the reflection nebulae. Furthermore, as noted by Struve and Miss Story, reflection nebulae are in general associated with a greater degree of background obscuration than are emission nebulae. There is no obvious reason why stars earlier than about type B1 should be associated with systematically less opaque nebulae than those later than B1. It is very unlikely that there could be an intrinsic difference between the nebulae, since one often finds reflection nebulae surrounding later type stars that in turn lie within large emission nebulosities. It must therefore be presumed that this difference arises from the ability of very early type stars to modify somehow the properties of the material in their immediate vicinity.

The relative velocities of very early type stars and interstellar clouds are usually small. For this reason, a given cloud and a hot star will generally remain near one another for a rather long time, a condition giving ample opportunity for the properties of the nebular material to accommodate themselves to the influence of the star. It seems reasonable that the observed relationship between the spectral type of the illuminating star and nebular opacity has come about largely in this way. This relationship might break down if the time interval that measures the duration of the association of star with cloud became much shorter than the time required for the modification process to take place. Such a situation might well arise for a time when a newly formed star of large mass nears the main sequence in its contraction phase. It would also arise if a rapidly-moving star of very early spectral type moved swiftly into a dark nebula. It is suggested that the observability of the C nebulosity in IC 405 is due to the relatively short time that this dust structure has been exposed to the influence of AE Aurigae, on account of the high space velocity of that star. None of the C structure of IC 405 lies directly south of AE Aurigae; it may not have existed there originally or, since that is the direction from which the star has come, there may have been time for dust particles in that direction to have been modified by the star's radiation. The time required for such a process to take place must depend cru-
cially upon the separation of the star and the nebulosity, which is unknown in the case of IC 405. One can only note that the dust particles of the C structure southeastward of AE Aurigae have managed to survive exposure to the radiation of that star for some tens of thousands of years.

In summary, the following picture of the association of AE Aurigae and IC 405 is put forward. It is postulated that AE Aurigae in its northward motion has encountered two nebulae: (1) a large low-density gas cloud that the star has ionized and converted into the H II region prominent on Plates I and III, and (2) some dust streamers that only scatter the star’s light. Owing to the very rapid motion of the star, the dust has not had time to accommodate its properties to the new radiation field, and for that reason we have the apparently anomalous presence of a pure reflection nebula illuminated by a type O9.5 star. Given sufficient time, this nebula will presumably be modified to a major extent.