shown by a formula which describes the conditions for the dependence of the population on density and other parameters. The second argument against a position of the Trapezium deep in the central bright mass concerns a complete lack of a correlation between the radial velocities derived from the He I lines and the radial velocities derived from the emission lines close to the stars in the field. The emission lines have a very pronounced maximum at +20 km, whereas the He I components are distributed between + 23 km and − 31 km. These two arguments mentioned have together a weight strong enough to force abandonment of the idea that the Trapezium has a position deep in the bright central masses. Hence, a radial expansion of the central masses relative to the Trapezium stars is not supported by observational facts. The masses of the centre are on the contrary moving directly towards the Trapezium.

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DISCUSSION

G. Münch. I agree with Prof. Wurm regarding the incompleteness of the argument built up by Wilson, Münch, Flather, and Coffeen from the radial velocities of the He I nebular absorption lines. In fact, the reply by Wilson and myself (*Z. Astrophys.* **56**, 127, 1962) to Prof. Wurm's criticism probably is also not tenable, not on evidence provided by the Orion Nebula alone, but also on the basis of observations in other galactic and planetary nebulae. The point is that the observed weakness of the He I line in all cases, in comparison with theory assuming deactivation by electron collisions and two-photon decay, cannot be explained by the existence of density fluctuations. There must be some other very effective deactivating agent for the 2^3S level of He I. A brief calculation shows that if the optical depth in Lyman-α is greater than about 10^4, the energy density of $L\alpha$ radiation will be high enough to ionize He I from the 2^3S level much faster than it can be deactivated collisionally. The only evidence favouring this idea at present is that the only planetary nebula where He I absorption is observed with certainty on the central star is Campbell's hydrogen-envelope star, which has an expansion velocity larger than 100 km/sec; clearly, such a large expansion velocity favours the escape of trapped $L\alpha$ resonance radiation.

K. Wurm. By He I ionization from the metastable 2^3S level, it may be possible to reduce the population by a factor 2 to 5 or even 10. However, a reduction factor 100 to 1000, as is required to explain the low $\lambda 3889$ absorption in the Trapezium stars, must be regarded as impossible.

7. STRUCTURE AND KINEMATICS OF THE ORION NEBULA

G. Münch

The state of motion of the gases in the Orion Nebula has been studied from the profiles of the emission lines at a given point in the Nebula, and from the variation in the radial velocities of the lines from point to point over the Nebula. Additional information regarding velocity gradients and stratification is obtained from the comparison of spectrophotometric and radial velocity data for lines of ions with different states of ionization. The observations of line widths carried out at Hamburg-Bergedorf and the radial velocities determined at the Lick Observatory, were first interpreted by Von Hoerner in terms of the theory of isotropic turbulence for a homogeneous incompressible fluid of infinite Reynolds number. This theory predicts that the r.m.s. difference in radial velocity between two points in the Nebula separated by a distance d varies as $d^{1/3}$, for d greater than a certain critical distance d_c. Von Hoerner found that this functional dependence was approximately satisfied by the observations if the effective integration path along the line of sight was only about one-tenth the linear dimensions of the Nebula projected in the plane of the sky. But such a model is not self-consistent, for it is obvious that a thin nebula should produce lines with small turbulent widths. Because the earlier observational work did not have sufficient resolving power, we undertook with the 200-inch telescope an extensive observational program, the results of which were published sometime ago (1). We verified von Hoerner's findings regarding the $d^{1/3}$ law, and the inconsistency found if the line widths are interpreted in terms of the theory of isotropic incompressible turbulence. Our higher angular resolving power, however, revealed that the line widths were far from constant at the various points in the Nebula. Down to resolutions around 1 arcsec, the lines appeared broadened by mass motions, with r.m.s. values no less than about half their thermal values. In discrete regions, however, which may be as small as 5 arcsec, the lines may broaden up considerably and even become distinctly double, with separations up to 25 km/sec. We have arguments supporting the idea that the gas masses giving rise to such split lines are near by in space and that they represent truly supersonic motions. Because individual components always have widths in excess of the thermal value, we infer that the scale of the turbulent fluctuations producing the line widths are much smaller than our angular resolution. The radial velocity fluctuations, in contradistinction, are produced by the same large elements which produce in extreme cases the line doubling. The size distribution of the elements moving with various velocities does not seem and cannot be monotonic. We have related the origin of the supersonic velocity fluctuations to the interaction with the turbulent surrounding H I material against which the Nebula is expanding. The r.m.s. velocities measured in the 21 cm line are nearly the same as those needed to explain the widths of the emission lines at their narrowest, and this agreement would seem to indicate that the turbulence in the H II and in the H I regions is one and the same phenomenon. Because of the strong damping expected for supersonic motions in ionized gases, we can conceive that the large velocity fluctuations do not extend throughout the Nebula, but are confined to a relatively thin boundary layer. The observed characteristics of the radial velocity fluctuations and line widths are compatible with such a model. Problems remain, however, when we try to incorporate into the picture the observed stratification in radial velocity and ionization. Everywhere in the Nebula there is a difference of about 4 km/sec between the [O II] and the [O III] lines, with the hydrogen lines falling just about between. This is truly an ionization effect and not the result of a dependence on wavelength of optical depth, as the agreement between the radial velocities of the He I $\lambda 4471$ and [Ne III] lines with those of [O III] show. The model proposed above would demand that a gradient in velocity and ionization exists in the thin layer where the velocity fluctuations arise, since the systematic velocity difference between the [O III] and [O II] lines seems to persist even in individual components of double lines. Were this the case, then the systematic variation between the [O II] and [O III] line intensities, as function of distance to the apparent center of the Nebula, is a phenomenon completely unrelated to the difference in radial velocity just mentioned, and there also must be *small-scale* variations in the ionization equilibrium. The multicolor direct photographs of Wurm and Rosino suggest that such small-scale ionization gradients may exist, but obviously they should be investigated further by accurate spectrophotometry.

Because of the limited angular resolution of the observations of emission lines, the information provided by the nebular absorption of He I on the spectrum of the stars imbedded in the Nebula is of fundamental importance, not withstanding the very few stars (nine) on which it has been observed. With the exception of one component of He I $\lambda 3888$ observed in θ^1 Ori C, which has a very large negative shift, and may be related to the star itself, all other He I absorption components fall within the radial velocity range covered by the emission lines, and therefore could arise in the same region where the emission lines are being formed. The strongest evidence in favor of this idea is that two stars detached from the main body of the Huyghenian region, namely HD 37061 and HD 36982, showing the He I absorption line, have condensations of nebular material around them, while other stars at about the same distance from the Trapezium do not show it. Further work on the He I nebular absorption, mainly through observation of the λ 10830 line profile, will no doubt clarify the role which density and ionization fluctuations (Lyman-alpha energy density?) play in the dynamics of the nebular material.

REFERENCE

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DISCUSSION

S. von Hoerner. If we want to understand the velocity distribution of the gas in the Orion Nebula, we face the following severe problem. The Mach numbers in the Nebula are near and above unity, but we neither have a theory of supersonic turbulence nor do we have laboratory experiments of this type; there is actually nothing reliable to which the observations might be compared. If we try the theory of incompressible turbulence ($M \ll 1$), we may get a fair fit for the velocity distribution (i.e., the Kolmogoroff spectrum) but we encounter the difficulties just mentioned by Dr Münch. On the other hand, I have tried the other extreme, neglecting completely the usual concepts of turbulence and using a model of the Nebula which consists of plane-parallel random shock waves having no mutual correlation. This model gives a somewhat better fit for the velocity distribution, and avoids the difficulties connected with the line width (but should, of course, not be regarded as giving a true picture of the Nebula). The truth will be, as is always the case, somewhere between these two extremes.

8. THE STRUCTURE OF THE He I λ 10830 EMISSION LINE IN THE ORION NEBULA

A. H. Vaughan, Jr.

The structure and intensity of the infra-red helium triplet at 10830 Å in the Orion Nebula was recently investigated photoelectrically by means of a pressure-scanning Fabry-Pérot interferometer attached to the Kitt Peak 16- and 36-inch telescopes, at a spectral resolving power of 40 000 and spatial resolution of about 0·7 minute of arc. Eight regions within 4′ of θ^1 Ori were studied.

The $2^3P^\circ_{1,2} \rightarrow 2^3S_1$ fine structure components are blended because of thermal velocities and unresolved turbulence in the Nebula. This blend has an apparent heliocentric radial velocity systematically about 15 km/sec greater than the velocities of [O III] λ 5007 and He I λ 4471. The resolved $2^3P^\circ_0 - 2^3S_1$ fine structure component has an intensity relative to the blend of only about $\frac{1}{16}$, instead of $\frac{1}{8}$ (the ratio of statistical weights). The separation between the two observed components is about 1·5 Å, instead of 1·20 Å (the RMT value).

The r.m.s. velocity of unresolved turbulence in one dimension derived from the observed line widths is about 5·5 km/sec. This is significantly smaller than was found by Wilson, Münch *et al.* for [O III], [O II], and Hγ.

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