IONIZATION OF THE INTERSTELLAR MEDIUM

The theories of ionization of the interstellar medium have undergone revision in the last couple of years since ultraviolet observations with the Copernicus satellite did not reveal the expected high ionization states. During the same time observational data accumulated on free electrons outside visible ionized regions. Besides pulsar dispersion measures which indicated the existence of ionized hydrogen in all pulsar lines of sight, a faint diffuse Hα background was also discovered in all directions within about 25° of the galactic equator (Reynolds, Roesler and Scherb *Ap. J.*, **192,** L53, 1974). The uniformity of this background suggests a uniform distribution of electrons over distances of the order of a kiloparsec, the dust absorption mean free path. The adjacent [N II] λ6584 line has also been seen in all directions in this Hα survey. The occurrence of this line is suggestive of phenomena commonly taking place in H II regions and planetary nebulae. The intensity of this line relative to H_α is dependent upon the electron kinetic temperature and the observed value indicates a temperature of a few thousand degrees in the regions of space where this emission is observed. In a recent catalogue of galactic O stars Cruz-Gonzălex et al. (*Rev. Mexicana Astr. Ap.*, **1,**211,1974) found that a large fraction of O stars (∼ 47%) are outside detectable nebulosities on Palomar Sky Survey plates. It further strengthened an earlier suggestion that much of the low density intercloud medium is an extensive HII region photoionized by O and B stars not contained in conspicuous nebulosities. The consequences of this suggestion have been investigated in detail by Elmergreen (*Ap. J.*, **198,** L31,1975; *Ap.J.*, **205,**405, 1976).

The Hα emission survey by Reynolds, Roesler and Scherb revealed a number of brighter localized Hα features superposed on the diffuse galactic background. The emission measures of these features (EM = 16 — 184 cm^{-6} pc) are much higher than the low intensity background (EM = 4 — 12 cm^{-6} pc). In a diagram with the galactic O stars having absorption less than $2.^m0$ at Hα superposed on the Hα contours, Elmergreen (1975) finds that most of the bright features correlate with the stars. The bright H α features are therefore a smooth extension of the HII regions surrounding the O stars, the lower emission measures being a consequence of the low density of the embedding medium. The rms electron densities of these regions obtained by Elmergreen are of the order of 2.0 cm^{-3}. Close to the plane of the Galaxy $\langle n_e^2 \rangle^{1/2}$ may be as high as 3.3. cm^{-3} .

The H α background could be atrributed similarly to ionized regions around other O stars in yet more tenuous media. The uniformity is easily explained by postulating that the line of sight intersects regions of overlapping Strömgren spheres surrounding these stars. Since the size of the Strömgren spheres should increase with decreasing density such a situation could arise if O stars existed in the low density intercloud medium (ICM) for significant lengths of time without altering the density distribution. Earlier Torres-Peimbert, Lazcano-Araujo and Peimbert (*Ap. J.*, **191,** 401,1974) had shown that the Lyc photons from OB stars not associated with emission nebulae were sufficient to maintain the ionization of an ICM at a temperature of 8000°K with an rms density less than 0.2 cm^{-3}. Elmergreen (1976) questions the possibility of such extensive intercloud ionization by O stars excepting in very special circumstances. In fact he has shown that an O star cannot exist in a medium of density less than unity for any appreciable length of time. In almost all circumstances O stars should be surrounded by unit density ($n_e = 1$ cm^{-3}) H II regions and thus be prevented from causing widespread ionization of the ICM.

The interaction of O stars with the interstellar medium has been analysed in steps by Elmergreen. The basic idea underlying all the different situations is that of cloud destruction through the process of ionization. An O star located in a low density medium with clouds sparsely distributed around it will photoionize the clouds and heat them at the same time. An ionization front will get into a cloud ; the velocity of the front will be determined by the available flux and the density of the material to be ionized. When most of the ionizing flux is absorbed in the outer layer of the cloud, the front will slow down and the future evolution of the configuration is influenced by the expansion of this hot ionized boundary layer (IBL). The expansion produces two major effects: (i) the remaining cloud is accelerated away from the star, (ii) part of the ionized material is moved toward the star in the form of exhaust. The outward acceleration tends to expel the cloud from the Strömgren sphere of the star ; at the same time the ionized cloud debris increases the density of the material surrounding the star. An O star is able to produce a cloud-free ionized region in its vicinity during its own lifetime, the size of such a region being dependent more on the cloud-intercloud parameters than on the type of the ionizing star. If clouds far from the star are partially obscured by other nearby clouds and survive longer the ability of the O star to produce a cloud-free region is only moderately reduced. The efficiency increases when the cloud acceleration by rocket effect is taken into account in the calculations and it is found that more than 60% of the original Strömgren radius of the star can be fully ionized during the lifetime of the star. However, due to the increase in the density of the material in the neighbourhood of the star the Strömgren radius shrinks to a fraction of its original value. Thus the ionized debris regulates the ambient Lyc flux prevents further destruction of clouds in the stellar lifetime. It also reduces the ability of the O stars to ionize regions far from their location. It is interesting to note that in the absence of any other major effect this series of processes is just enough to create the unit density H II regions surrounding the O stars as observed in the galactic H α survey.

The situation is different when the ionizing star has a large velocity relative to the clouds. If the star has a high velocity (∼ 100 km sec^{-1}) it may produce ionization of the low density medium through which it is moving. The ionized debris will collect around the star but the star will move away faster from the debris. It is doubtful if a substantial fraction of O stars would have such high peculiar velocities. If the star has a low velocity (20 km sec^{-1}) the ionized debris will collect more efficiently and the unit density H II region will form around the O star and the entire pattern will move with the stellar velocity. Depending upon the stellar velocity and the material density O stars with peculiar velocities may contribute to the ionization of the intercloud medium.

Elmergreen has also considered regions of the Galaxy where the O star density is sufficiently high so that a cloud in such a region is exposed to a uniform background of ionizing radiation. The lifetime of a remote cloud in such a situation may equal or be greater than the stellar lifetime. Where the stellar density is sufficiently high the lifetime of a cloud may be as low as $1 - 4 \times 10^6$ yrs and intercloud ionization by O stars would indeed be possible but for the ionized cloud debris which will still prevent the Lyc flux to flow to and cause ionization of all the neutral material in such regions. In any case such special situations cannot explain the very general problem of ionization of the ICM.

All this may be substantially modified if supernova shocks periodically clear away the cloud-expelled material from the ICM to produce new clouds. In the absence of such a sweeping mechanism by another agent the onus of maintaining the ionization in ICM has to rest on B stars and nuclei of planetary nebulae. Since these weaker agents are such less effective in destroying clouds through ionization and acceleration, the clouds in turn will not affect the ICM ionization so drastically as in the case of O stars.

The analyses reported by Elmergreen have involved many assumptions and many features of the ionization of the interstellar medium have yet to be explained. The pulsar dispersion measures and the diffuse Hα background may correctly be explained by postulating ionization by the less luminous stars. A wealth of ultraviolet data has been collected in the recent years and they need to be fully understood in the framework of such a theory. Dust will conceivably play a very major role and theoretical investigations are needed to study phenomena in a dusty ISM. Observations of weaker emission lines in the so-called unit density H II regions will certainly improve our understanding of the ionization mechanisms. Last but not the least is the question of the electron temperature of the clouds and the ICM and we hope that future investigations will address themselves to determining values of this quantity in the various components of the ISM.

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TWO KINDS OF BL LAC TYPE OBJECTS ?

Among the new kinds of celestial objects recognized during the nineteen sixties are the BL Lacertae type objects named after their prototype, the variable star BL Lacertae, which was suggested as the optical identification for the radio source VRO 42.22.01 (Schmidt, *Nature*, **218,** 663, 1968; Macleod and Andrew, *Ap. Letters*, **1**, 243, 1968). The distinguishing characteristics of this class of objects, also known as Lacertids, are (Strittmatter et al., *Ap. J. Letters*, **175**, L7, 1972; Pollock, *Ap. J. Letters*, **198,** L53, 1975; Usher, *Ap. J. Letters*, **198**, L 57, 1975) :

(a) Continuous, featureless optical spectra or weak or transient line optical spectra,
(b) flat or centimetre excess radio spectra,
(c) rapid variations in intensity at radio, infrared and visual wavelengths

and

(d) strong and rapidly varying polarization at visual and radio wavelengths.

Altschuler and Wardle (*Nature*, **255,** 306, 1975) define a BL Lac type object as one that exhibits strong and rapidly varying nonthermal radiation at optical wavelengths and has a very small line to nonthermal continuum ratio.

These objects have been presumed to be extragalactic although no certain distance determination to any of these objects has been possible till 1974. However, the determination of the redshift of 0.07 of BL Lac by Oke and Gunn (*Ap. J. Letters*, **189** L5, 1974) and its confirmation by Thuan, Gunn and Oke (*Ap. J.*, **201**, 45, 1975), and also by Kinman (*Ap. J. Letters*, **197**, L49, 1975) seems to indicate that the BL Lac objects may be extragalactic.

Perhaps, suggesting that all BL Lac type objects are extragalactic on the basis of the redshift of BL Lac may be too much of a generalization. Recently, Webster and Ryle (*M.N.R.A.S.*, **175**, 95, 1976), on the basis of a series of observations made at the Mullard Radio Astronomy Observatory of the variable radio source, CL4, in the direction of the Cygnus Loop with their 5-km and one-mile telescopes find that this source exhibits properties which are remarkably similar to BL Lac. According to these authors,

(a) Both (i.e. BL Lac and CL4) have spectra increasing with frequency to 3 GHz and constant at higher frequencies.

(b) The variations of flux density above 3 GHz: Both show a quasi-periodic variation of amplitude of about 25% on a time scale of a few months, superimposed on long period variations. At lower frequencies the variability becomes less marked.

(c) Neither source is strongly linearly polarized.

and

(d) Both sources are associated with compact optical objects having power law optical spectra rising steeply to the red. Neither is known to be an X-ray source, and the spectra from radio to optical frequencies are similar.