Variations of Linear Polarization in Extragalactic Radio Sources

SINCE mid-1965 the linear polarizations of the stronger extragalactic variable radio sources have been monitored at 8 GHz using the University of Michigan 85-foot paraboloid equipped with a rotating, linearly polarized feed horn. Strong thermal and non-thermal sources were measured each observing day to determine the stability of the instrumental polarization. Five sources, 3C 120, 3C 273, 3C 279, 3C 345 and 3C 454·3, have exhibited significant changes in polarization, and three sources, 3C 84, NRAO 150 and 3C 446, are suspected of having variable polarizations. Preliminary observational results for several of these sources have been reported previously[1,2].

The general characteristics of the observed variations in polarization are as follows: (1) They do not mimic the variations in the total flux densities; (2) they occasionally have time scales as short as one week, which are much less than the time scales of the variations in the total flux densities of these sources; (3) their amplitudes are as large as 5–10 per cent of the amplitudes of the variations in total flux density; (4) large, rapid changes in polarization have been observed only when the total flux density was increasing or had reached a maximum; (5) variations in both the position angle of the plane of polarization and in the degree of polarization have been observed.

I wish to point out that these characteristics of the observed variations in polarization are consistent with expanding source type models (for example, ref. 3) and do not require any special source geometry except that the magnetic fields in these sources be relatively well ordered. In these models the low frequency cut-off in flux is produced by synchrotron self-absorption. As the source expands, the total absorption depth through the source decreases and the flux reaches a maximum at any frequency ν shortly after τ_ν (the absorption depth averaged over all polarizations) reaches unity in the source. Two processes which cause variations in polarization and which apparently have not been reported before occur as a result of this decrease of τ_ν with time.

Process I is the change with τ_ν of the intrinsic polarization of a synchrotron source. From the expressions for the emission and absorption coefficients of the synchrotron mechanism[4], it may be shown that when $\tau_\nu \gg 1$ the intrinsic degree of linear polarization is $3/(6\gamma+13)$ (ref. 5) with the plane of polarization parallel to the magnetic field. γ is the negative exponent in the electron energy-density power-law relation. This state of polarization is different from the case which is usually discussed of $\tau_\nu \ll 1$ when the intrinsic plane of polarization is perpendicular to the field, and the intrinsic degree of polarization is $(3\gamma+3)/(3\gamma+7)$. Studies of the variable sources 3C 120 (ref. 6) and 3C 273 (ref. 7) indicate that $\gamma \sim 1{\cdot}5$ for these sources. For this value of γ the intrinsic degree of polarization changes rapidly with τ_ν over the range $0{\cdot}5 \lesssim \tau_\nu \lesssim 10$ and equals zero (where the plane of polarization changes by 90 degrees) at $\tau_\nu \sim 5$. Thus even in the unrealistic case that the magnetic field was oriented in the same direction throughout the emitting region, an expanding source would exhibit variations in polarization as the source passes through the phase where $10 \gtrsim \tau_\nu \gtrsim 0{\cdot}5$. This phase occurs immediately before the expanding source reaches maximum flux output at the frequency ν.

Process II arises when the orientation of the magnetic field is not constant throughout the emitting region of the source. The observed polarization of a source is the average of the contributions of all polarized emitting regions within the source and thus depends upon the absorption depth of each region. As τ_ν decreases with time the contribution to the observed polarized radiation of emitting regions situated deep within the source increases. The observed polarization will then change because the states of polarization of different regions within the source are not the same. The rate of change of the observed polarization depends on the amplitude of $d\tau_\nu/dt$ and would generally be largest when $\tau_\nu \gtrsim 1$. Relatively rapid changes in polarization produced by this process do not require the magnetic field in the source to have small scale structure.

Both processes I and II are only important for $\tau_\nu \gtrsim 1$ and do not produce appreciable variations when $\tau_\nu \gg 1$ or $\tau_\nu \ll 1$. Thus the fact that large, rapid changes in polarization have been observed only during periods when $\tau_\nu \gtrsim 1$ (according to the expanding source model) strongly suggests that one or both of these processes are the chief cause of the observed variations in linear polarization. Neither process depends on changes in the structure of the radiating region (aside from overall expansion) or on any particular source configuration in order to produce polarization variations. Also the relatively well ordered structure of the magnetic field required to account for the large amplitudes of the polarization variations is not inconsistent with the rapid variations being produced by these processes. A detailed description of the observational results and the interpretation of the observed polarization variations is in preparation.

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Primordial Synthesis of Superheavy Nuclei in the Galaxy

ASTROPHYSICAL evidence in favour of the thesis that an appreciable amount of the heavy elements was produced in a giant explosion in the nucleus of the galaxy about 7×10^9 yr ago has been given by Unsöld[1]. Cosmochemical arguments could support Ambartsumyan's concept[2] of the presence of massive bulks of prestellar matter in the nuclei of the galaxies. The latter concept has now received further support from the calculations of Saakyan and Mnatsakanyan[3], who have reported on the possibility of hydrostatic equilibrium of superdense matter bulks of arbitrary mass in the framework of a slightly modified general relativity theory with variable gravitational constant G.

Synthesis of heavy elements in exploding massive bulks of prestellar matter may go preferentially through some kind of neutron capture process, similar in principle to those going on in stars. This synthesis occurs predominantly in the external layers of the body, where the density of matter drops below a subnuclear value of 10^{13} g cm^{-3} and the matter exists in the so-called "neA" phase (neutrons, electrons, nuclei). Synthesis of nuclei up to uranium in such high density conditions (without specifying whether this occurs in stars or in other objects) has been considered by Amiet and Zeh[4]. The shift of the valley of beta-stability of nuclei in the (Z,N) plane towards the N-axis at higher densities made it possible to bypass the