Propagation of the Cosmic Radiation through Interstellar Space

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The purpose of this short note is to present an additional evidence that the cosmic radiation passes through only a small thickness of intersteller matter. This has already been suggested through studies on primary heavy nuclei. Bradt and Peters[1] found in the primary cosmic radiation a negligible amount of Li, Be and B, which could be produced by the collisions of heavier nuclei with intersteller matter. Their passage is, therefore, limited within a few gcm^{-2} of matter. Dainton et al[2]. however, obtained an evidence which contradicts the former result. In spite of this discrepancy between above two experiments, the existence of heavy nuclei, such as C, O, Ne and Fe, may set the upper limit of about 10 g cm^{-2} to the amount of intersteller hydrogen traversed, as pointed out by Dainton et al[2]. provided the assumption of cosmic elements and the velocity spectra of nuclei at the origin are accepted.

This concept disagrees with the speculation of Fermi[3] and Unsöld[4], who assumed the cosmic radiation as confined in our galaxy due to the galactic magnetic field, avoiding a difficulty that the cosmic radiation takes up too great energy in the universe. According to these authors, the cosmic radiation possesses a mean life time in the galaxy, corresponding to the absorption mean free path in the matter. Then the mean free path for cosmic ray protons is the order of 100g cm^{-2}, which seems to be long enough to produce an appreciable amount of secondary rays. Most of them are unstable and turn eventually into electrons and photons. The photons escape the galaxy and give a very small intensity observed. The electrons are, however, stored in the galaxy due to the magnetic field and may be observable on the earth, if they could not be eliminated during their travel through the galaxy.

The intensity of the electrons relative to that of protons may be estimated in the following way. Most of the electrons should mainly come from the decay of muons which are the daughters of pions, At the geomagnetic latitude 55^0 N, where experiments referred are carried out, the minimum energy of electrons for vertical incidence is 1,7 Bev. An electron of this energy can be produced through the decay of a muon of average energy of 5 Bev, consequently of a pion of 6 Bev. The minimum energy of a proton that can produce a pion of this energy due to a collision with hydrogen is 10 Bev. Taking into account the recoil of nucleons and the production of neutral pions, we may safely set the minimum energy of a proton which can effectively produce an observable electron as 20 Bev. Thus about 5% of protons are responsible to observable electrons.

As seen above, we would expect an appreciable amount of electrons in the primary cosmic radiation, unless there were any efficient absorption process for the electrons. This problem has been studied by Donahue[5], asking whether or not the electrons originally accelerated together with nuclei could be eliminated during their passage through intersteller space. The result of this author can be applied to our case. The mean life time of electrons determined by the Compton scattering with galactic photons is estimated as about 4×10^{15} sec for an electron of energy 10 Bev losing a half of its energy. This life time is longer than the collision mean time for protons, about 7×10^{14} sec, and the intensity of electrons must be multiplied by the ratio of these life times. Thus the electron intensity turns out to be about 30% of the proton intensity. (This figure gives only a crude order of magnitude due to our meager knowledge on the pion production at high energies and may allow an uncertainty of factor two.) This definitely contradicts the experimental evidence on the absence of primary electrons[6].

On account of the inefficiency of eliminating electrons in the galaxy, we are led to the conclusion that protons should not travel in the galaxy for such long time as to produce electrons more than 0.6% of the total intensity. This set the upper limit of the path length for protons that they must not traverse more than 3 g cm^{-2} of hydrogen.

This evidence together with those mentioned above on heavy nuclei leads us to the presumption that the cosmic radiation passes through a very small amount of matter from its origin to entry. We are then inclined to reject the assumption that the cosmic radiation is confined in our galaxy for long time, but to adopt that it originates somewhere out of our galaxy and travels along a straight way. In this case one expects the siderial time variation of heavy primaries, because the earth locates far from the center of the galaxy and the amount of hydrogen traversed by the cosmic radiation coming through the center is about 0.6g cm^{-2}. In the passage through this thickness secondary particles are scarcely produced except photons which are due to the decay of neutral pions. The intensity of the secondary photons are estimated as about 0.1% of the total intensity at the geomagnetic latitude 55^0, but as nearly 1.5% at the equator. In the latter case this effect would be detectable.

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1) H. L. Bradt and B. Peters, Phys. Rev. **77** (1950), 54; **80** (1950), 943.
2) A. D. Dainton, P.H. Fowler and D.W. Kent, Phil. Mag. **42** (1951), 317; **43** (1952), 729.
3) E. Fermi, Phys. Rev. **75** (1951), 1169.
4) A. Unsöld, Phys. Rev. **82** (1951), 857.
5) T. M. Donahue, Phys. Rev. **84** (1951), 972.
6) C.L. Critchfield, E. P. Ney and S. Oleska, Phys. Rev. **85** (1952), 461.