# REMARKS ON COSMIC-RAY COMPOSITION

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Theories which place the origin of all cosmic rays within this galaxy might barely be able to account for the largest air showers ($>10^{10}$ particles), but could do so only if all of the most energetic primaries were nuclei as heavy as iron.[1] In the preceding Letter evidence is given that the primaries of energy $>10^{17}$ eV are nearly all protons. It follows that a correct theory of cosmic-ray origin must allow for a metagalactic component. Once primary particles of energy $>10^{19}$ eV are accepted to be metagalactic, there is no reason to draw the line so high. The following model is suggested by the new evidence on composition and other recent observations:

(A) The presence of heavy nuclei is characteristic of cosmic rays produced within ordinary galaxies. The metagalactic cosmic rays consist entirely of protons.[2]

(B) The composition of galactic cosmic rays is independent of rigidity, but there is a rigidity cutoff corresponding to an energy of $\sim 2\times 10^{15}$ eV/nucleon.

(C) Galactic and metagaletic components are equal at about $10^{16}$ eV/nucleus.

Point (B) is a well-known suggestion by Peters.[3] As he has pointed out, the existence of such a cutoff would explain the rather abrupt change in slope of the air shower spectrum at $N \sim 10^5$.[4] For our choice of cutoff rigidity the limiting energy per nucleus for iron nuclei would be $\sim 5\times 10^{16}$ eV, so the transition between galactic and metagalactic components would have to occur at a lower energy than that. On the other hand, one would prefer to hold the energy density of metagalactic cosmic rays to the minimum which is consistent with other requirements, so one would prefer not to have the transition take place at too low an energy. Other recent evidence suggests anisotropy for primary heavy nuclei at $10^{16}$-$10^{17}$ eV/nucleus.[5] Anisotropy might be expected in the region approaching cutoff. It could be objected that there is a high degree of overall isotropy at $10^{15}$-$10^{16}$ eV, where we suggest that galactic protons and alpha particles experience cutoff. The objection might be met if the protons and alpha particles are produced by collisions of heavier nuclei outside of the acceleration region. It can also be objected that the primary spectrum should show a break in the region of transition between galactic and meta-galactic components.[1] We agree that where structure in the spectrum is observed there is probably a mechanism which accounts for it, but we do not agree that absence of structure observable by present methods is an argument against the existence of a transition. Finally, we note that on this model an interesting situation would occur in the energy range $\sim$(1 to 5) $\times 10^{16}$ eV/nucleus. Primary cosmic rays would be either protons (metagalactic) or nuclei belonging to the $H$ and $VH$ groups (mass numbers mostly greater than 20). With such a favorable composition it should be possible to resolve the components rather completely, by existing techniques.

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[1] V. Ginzburg and S. Syrovatsky, Suppl. Progr. Theoret. Phys. Japan 20, 1 (1961). A comprehensive review of theoretical and experimental work.

[2] This could be a matter of difference in acceleration mechanism or could result if heavy nuclei disintegrate in transit. Photodisintegration could be important in the metagalaxy, according to N. M. Gerasimova and I. L. Rozental', Zhur. Eksp. i Teoret. Fiz. 41, 488 (1961) [translation: Soviet Phys. – JETP 14, 350 (1961)].

[3] B. Peters, Proceedings of the Moscow Cosmic-Ray Conference, 1960 (Publishing House of Scientific and Technical Literature, Moscow, 1960), Vol. III, p. 157.

[4] S. Fukui, H. Hasegawa, T. Matano, I. Miura, M. Oda, K. Suga, G. Tanahashi, and Y. Tanaka, Suppl. Progr. Theoret. Phys. Japan 16, 1 (1960).

[5] H. Hasegawa, T. Matano, I. Miura, M. Oda, G. Tanahashi, Y. Tanaka, S. Higashi, T. Kitamura, Y. Mishima, M. Miyamoto, K. Shibata, and Y. Watase, Phys. Rev. Letters 8, 284 (1962).