thenoyltrifluoroacetone in benzene. The benzene solution was washed once with 4 M nitric acid to remove any of the aqueous phase which had been carried over with it, and evaporated on to an aluminum counting tray. The chemical separation of Pa was completed in 12 min.

The decay of the sample was observed with an end-window Geiger counter, using a 50-mg/cm^2 aluminum absorber to reduce the counting rate due to the 6.7-hr. Pa^{234}.

Three components were observed (Fig. 1), decaying with half-lives of about 1 min., 23±1.5 min., and 6 hr. These activities are attributed to 1.14-min. Pa^{234} (UX$_2$), Pa^{235}, and 6.7-hr. Pa^{234} (UZ).

A second extraction of Pa from the irradiated Th^{234} was carried out in one case 10 min. after, and in another case 25 min. after, the first. In neither case was any of the 23-min. activity observed. It is therefore concluded that substantially all of the Th^{235} had decayed to Pa^{235} during the 12-min. interval between removal of the samples from the pile and the first chemical separation of Pa.

Since the 6.7-hr. Pa^{234} could be used as a tracer for the Pa^{235}, it was not necessary to know either the initial amount of Th^{234} or the chemical yield in order to calculate the (n, γ) cross section of Th^{234} for the formation of Th^{235}. Values of 1.7 and 1.8 barns were obtained in two irradiations. The possibility that the Pa^{235} was produced directly by (n, γ) reaction in the small amount of 6.7-hr. Pa^{234} present or in 1.14-min. Pa^{234} is not considered likely, because the (n, γ) cross sections of the two Pa^{234} isomers would need to have the unusually large values of about 1.1×10^6 and 5×10^4 barns, respectively, to account for the quantity of Pa^{235} observed.

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Evidence Concerning the Existence of the New Unstable Elementary Neutral Particle

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ROCHESTER and Butler[1] in 1947 observed tracks in a Wilson cloud chamber which could be interpreted as the spontaneous decay of new types of elementary particles. They found two events selected from five thousand photographs, one of which consisted of two tracks which were copunctal, the particles producing the tracks having opposite signs and their momenta about 340 and 350 Mev/c, respectively. The second event consisted of a forked track produced by two positively charged particles of momenta 600 and 770 Mev/c. The first event could be interpreted as the decay of a neutral particle into two charged particles of opposite signs and the second event as the decay of a charged particle into a neutral and a charged particle. Recently Seriff *et al.*[2] have obtained similar results in cloud-chamber observations taken at a maximum altitude of 10,000 ft., and from a study of 11,000 cloud-chamber photographs they have obtained 34 forked tracks, 30 of which corresponded to the first event and 4 to the second event described by Rochester and Butler. In 15 of the results of the first kind the neutral particle could have originated in a nuclear disintegration, the plane of the decay tracks being approximately coplanar with the position of nuclear impact. It has recently been reported[3] that Butler using the cloud chamber has observed at an altitude of 9000 ft. an additional 9 events of the first and one of the second kind.

A result similar to the first event, a two-pronged star produced by a neutral particle, has been observed in a 400μ-thick Ilford G5 nuclear emulsion flown to an altitude of 70,000 ft.; and, fortunately, both tracks were of sufficient length to enable the masses of both particles to be identified. This has not been possible with the cloud-chamber observations. A facsimile drawing showing the position of the two-pronged star in relation to a large star of 29 prongs is shown in Fig. 1. The plane of the pair of tracks does not coincide with the center of the star, so it is concluded that if a high energy neutral particle disintegrated into the two-pronged star, it did not emanate from the large star. A summary of the data for the two prongs is given in Table I.

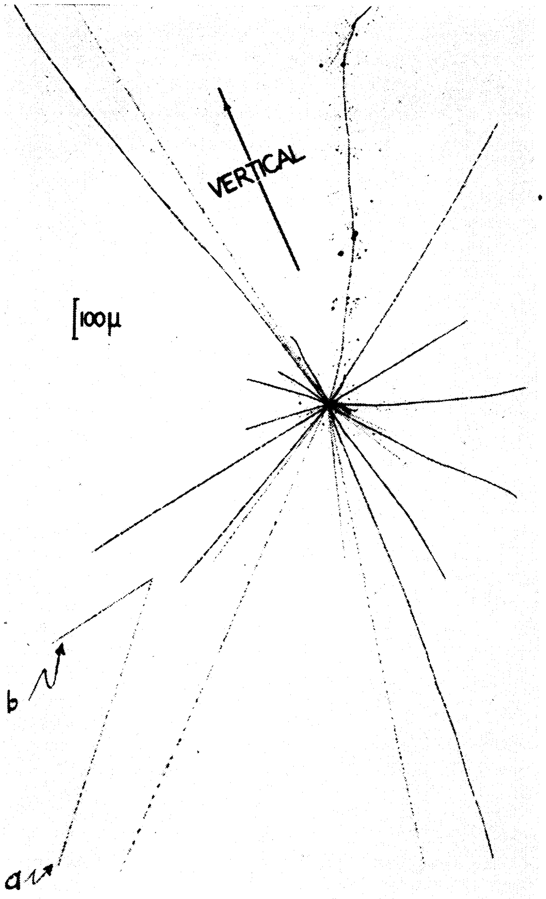

Fig. 1. Facsimile drawing which shows position of the two-pronged star relative to a large star. The plane of the two-pronged star does not coincide with the center of the large star. Track (a) corresponds to a meson and track (b) to a proton.

Neither of the tracks ended in the emulsion and there was no significant change in grain density along them. The grain-density of track (a) was slightly above the value of the grain-density corresponding to the minimum ionization particles for this emulsion which was 14.0 grains/50μ. α° is the average angular deviation between successive chords 100μ in length and was calculated by the method given by Fowler.[4] From the above results with the curves given by Fowler[4] the particles were identified as a meson and a proton. Both particles have approximately the same momenta as in the observations of Rochester and Butler for this type of event.

It is not possible from the above observations to identify the meson as either the π- or μ-type, but in the following calculations we have assumed it to be the π-meson. From the momenta and

Table I. Data on the two prongs.

Prong	Length in emulsion	Mean grain-density	Angle between the tracks	α°, Mean-deviation/100μ	Type of particle	Energy Mev	Momentum Mev/c
(a)	2600μ	16.3/50μ	40°	0.10°	Meson	215±30	329±30
(b)	400μ	50/50μ		0.3°	Proton	62±20	335±50

energies of these two observed particles and the angle between them, the rest mass of the neutral particle which could produce a π-meson and a proton by spontaneous transformation has been calculated as $2370\pm60m_e$. In this case the kinetic energy of the neutral particle would be 150±30 Mev and its momentum 620 ±80 Mev/c, the direction of motion of this neutral particle being inclined at 65° to the vertical. (If a μ-meson is used as a basis for the calculations, the rest mass of the neutral particle will be about $2300m_e$.) The calculated mass of the neutral particle is in agreement with one of the possibilities given by Seriff *et al.*, in which they have assumed that the decay particles are a proton and a π- or μ-meson. Unfortunately, they were unable to place limits on the mass of both charged secondary particles although they concluded that one of the charged particles was probably a meson. In the present investigation the identities of both particles are known more definitely.

We may consider the alternative suggestion that the event was a disintegration of a nucleus by a neutral particle with the emission of the two observed particles. Firstly, the disintegration of a light nucleus like oxygen, present in the emulsion, may be involved in the process. Assuming that the energy of the recoil fragment for oxygen is approximately 1/16 of the energy of disintegration, the range of the recoil fragment can be calculated according to the method of Harding.[5] This is about 7μ in the emulsion, the corresponding range in air being 1.4 cm. On the other hand, if a silver or bromine nucleus takes part in the reaction, the range, calculated in a similar manner, would be approximately 1.8μ in the emulsion. Normally, track lengths up to 0.5μ can be measured by the microscope. In the present event a single grain of average diameter 1.5μ having its center at the point of origin of the two tracks has been observed, and the range of the recoil nucleus, if it exists, must be less than 1μ. Unlike the present observation, other events of two- or three-pronged stars produced in the emulsion by neutral particles show definite indications of recoil fragments of length 1.0 to 2.0μ. It is thus unlikely that this type of process is involved. Moreover, in this type of nuclear process, where a large excitation energy of 275 Mev is involved, it is more probable that a larger number of particles would be emitted as a result of disintegration of a Br or Ag nucleus as observed in the many-pronged high energy stars. Further, in the observations of similar events with the Wilson cloud chamber, where the heaviest nucleus present is oxygen, the range of recoil fragment in this assumed process of nuclear disintegration would have been 1.4 cm of air. This, too, is against the assumption of the disintegration of a nucleus by a neutral particle. Thus, all the arguments seem to favor the process of decay of a neutral particle into two charged secondary particles, the mass of the neutral particle being 2370 $\pm60m_e$, assuming the decay products are solely the proton and π-meson observed.

Finally, we may consider to what extent some of the unusual nuclear reactions fit the present event. These may be:

$$\gamma+n=p^++\pi^-, \tag{1}$$

$$\pi^0+n=p^++\pi^-, \tag{2}$$

$$n+\pi^0=p^++\pi^-. \tag{3}$$

The first two processes do not satisfy the energy and momentum conditions, while the third process, the neutron colliding with a π^0-meson satisfies these relations. Such a reaction is difficult to imagine since the π^0-meson does not exist free in nature.

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Radioactive Nuclei Emitted in Cosmic-Ray Stars

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In a survey[1] of cosmic-ray stars formed in electron-sensitive photographic emulsions (Ilford G5) at about 85,000 feet we find that, in addition to $_3\text{Li}^8$ nuclei, characterized by the "hammer tracks," about an equal number of short range radioactive fragments are emitted. These are identified by the tracks of decay electrons with energies of a few Mev, originating from the end of the fragment. Unless heavy fragments are radioactive, it is difficult to distinguish their tracks from those of protons or α-particles in the emulsion unless they are of sufficiently long range to show either δ-rays or the characteristic thinning down in track width towards the end of the path. A mosaic of photo-micrographs illustrating a typical radioactive fragment is shown in Fig. 1.

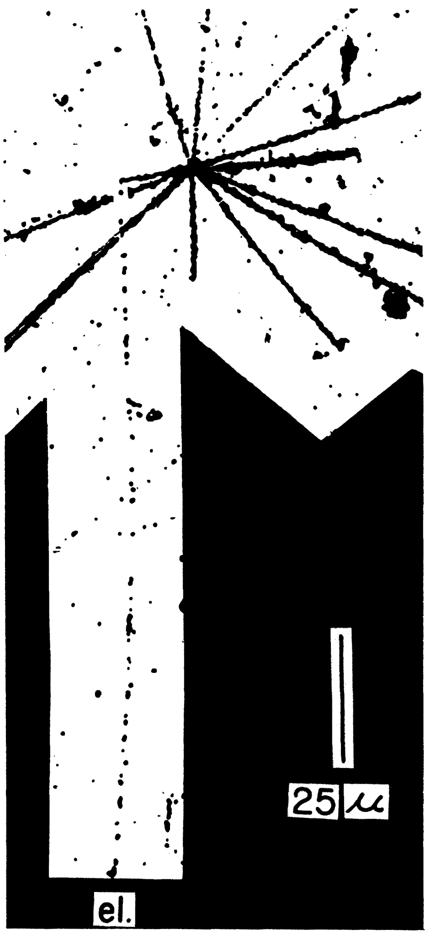

FIG. 1. Fifteen-pronged star with nucleus, from the end of which originates a decay electron.

Out of a total of about 4300 stars with more than 5 prongs[2] there were 31 stars with Li^8 fragments, and 32 with other radioactive fragments of ranges from a few microns to about 50 microns. The average range of the Li^8 nuclei was about 50 microns, being greater than the average range of the other radioactive nuclei. In one case of a 35-pronged star, two Li^8 nuclei were ejected; and in some cases there was at least one other non-radioactive nucleus, heavier than an α-particle.

There were also about 20 cases[3] in which electrons with energies

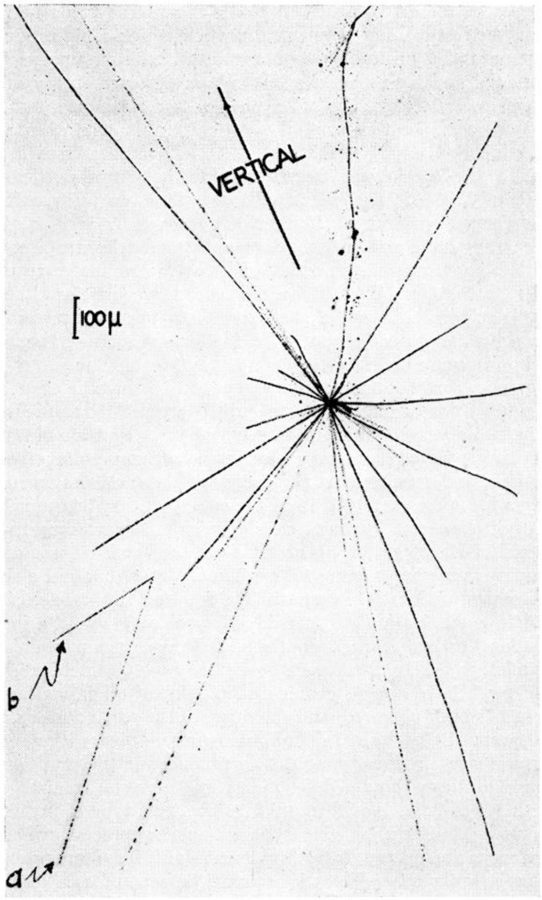

FIG. 1. Facsimile drawing which shows position of the two-pronged star relative to a large star. The plane of the two-pronged star does not coincide with the center of the large star. Track (a) corresponds to a meson and track (b) to a proton.