PHYSICAL REVIEW VOLUME 75, NUMBER 4 FEBRUARY 15, 1949

Letters to the Editor

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Emissions of Mesons in Cosmic Stars in Photographic Emulsions

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January 3, 1949

ILFORD C2, boron, lithium, and deuterium loaded emulsions have been exposed to cosmic rays on trans-atlantic flights at an average height of 12,000–15,000 feet.[1] Meson tracks have been recorded in all these emulsions and one such event was previously reported.[2] Out of 1700 cosmic stars recorded with two or more prongs, including 600 with five or more prongs, there were 15 definite σ-mesons entering the emulsion, one $\pi-\mu$-event, where the μ-meson was entirely in the emulsion, two stars emitting σ-mesons, one star with a star producing fragment which is probably an α-particle, one or two stars emitting a particle which appears to be a meson ending without producing any visible disintegration, and 7 stars in which Li^8 nuclei are ejected[3] showing the characteristic hammer tracks. The numbers of these particular events produced within the emulsion relative to the total number of stars agrees fairly well, so far as we can judge with such small numbers, with the observations of the Bristol group[4] whose emulsions were exposed at about the same altitude, except that the number of π- and σ-mesons entering seems to be lower. Thus, in boron loaded emulsions, their estimated number of $(\pi+\sigma)$ mesons is about 17 percent of the number of stars with 5 prongs or more. Their observed number is less than this, but will be, however, greater than the observed 3 percent we get using varied emulsions as stated, but mainly boron loaded. The difference may be due to the smaller amount of extraneous material in the vicinity of the plates in the aircraft as compared with the mountain top experiments and would thus be a further strong indication that all such mesons are produced locally. Our figure is actually very similar to that given by Salant, Hornbostel, and Dollman[5] in balloon experiments at 100,000 feet. No estimate has been made yet of the number of ρ-mesons in our plates although these are present.[6]

The projected ranges of the two σ-mesons ejected from stars are 60μ and 700μ. The latter meson, which has an estimated energy of 5.2 Mev,[7] assuming mass 300 m, was emitted in a 3-pronged star, which shows also one short fragment, 4.5μ (probably an α-particle) and a lightly ionizing track which leaves the emulsion before it can be positively identified. A mosaic of photomicrographs of this event is shown in Fig. 1. The ejected meson is long; it suffers two large angle collisions and is finally captured at the end of its range, giving a nuclear disintegration in which only a small fraction of the energy available appears in visible charged fragments.

The initial ionization of the unidentified fragment in the primary star is seen to be very approximately the same as that of the meson. Hence, assuming it is not another meson,

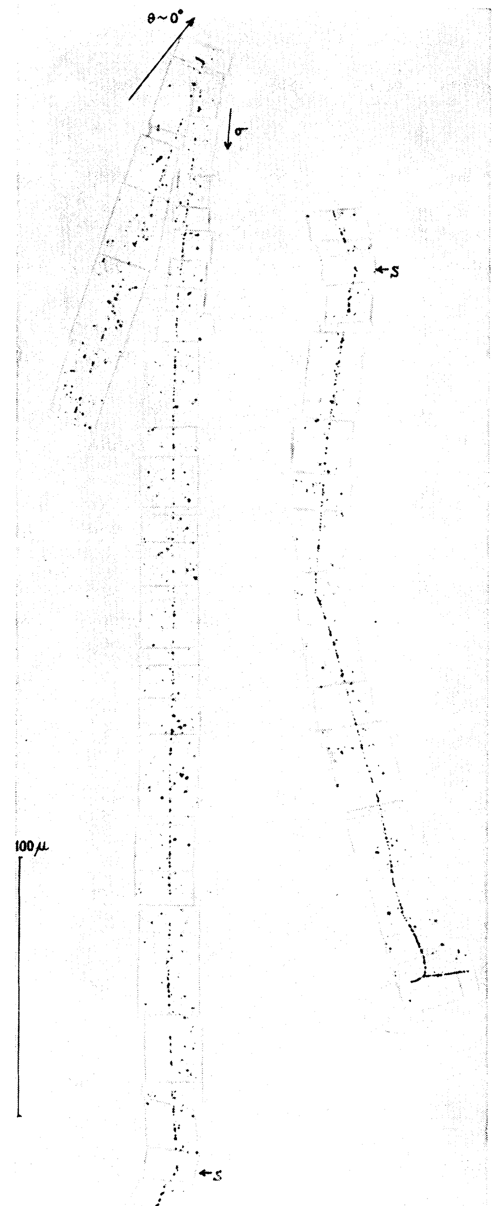

FIG. 1. Mosaic or photomicrographs showing meson ejected from star in Ilford C2, boron loaded emulsion (100μ thick). The meson track is shown in two parts, the points marked S being identical. The approximate direction of the zenith ($\theta=0°$) is indicated.

it could be a proton with energy about 30 Mev. The direction of the zenith (assuming this star to be formed while the aircraft was in level flight) is marked in Fig. 1, and so there is a downward momentum component for the visible fragments. The kinetic energy of the initiating radiation, if a nucleon, must have been more than 200 Mev.

Another point of interest in this event is the long range of the ejected meson. The chance of such a track lying wholly in the emulsion, so that identification is possible, is small. In view of this, and although very few events of this type have been reported yet,[4] we might speculate that an appreciable number of the cosmic stars observed give mesons which leave the emulsion before they can be identified, or are somewhat too energetic to leave a visible record (>about 7 Mev).[8]

We are indebted to the British Overseas Airways Corporation for carrying our plates, to Misses Joan Young, Shirley Young, and Beverly Mear for searching, and to Dr. W. J. Henderson for his interest in the above work.

[1] The plates were exposed on consecutive flights totaling about 400 hours over periods of about six weeks before development. The ceiling was about 25,000 feet.
[2] A. Morrison and E. Pickup, Phys. Rev. **74**, 706 (1948).
[3] Two of these seven events occured in an additional 160 stars of two or more prongs in C2, bismuth loaded emulsions, and one in some C2, unloaded emulsion.
[4] G. P. S. Occhialini and C. F. Powell, Nature **162**, 168 (1948) for σ-mesons from stars; C. F. Franzinetti and R. M. Payne, Nature **161**, 735 (1948) for Li^8 fragments; C. M. G. Lattes *et al.*, Nature **160**, 486 (1947), Table V for π- and σ-mesons.
[5] E. O. Salant, J. Hornbostel, and E. M. Dollman, Phys. Rev. **74**, 694 (1948).
[6] See U. Camerini *et al.*, Nature **162**, 433 (1948).
[7] Using the range energy relation given by Lattes, Occhialini, and Powell, Proc. Phys. Soc. **61**, 173 (1948), p. 181.
[8] We were able to trace back the longest σ-meson we have found, 1100μ with certainty. This corresponds to an energy of 6.8 Mev (for mass 300 m).

The Dielectric Behavior of $BaTiO_3$ Single-Domain Crystals

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December 27, 1948

The measurements of the dielectric constants of $BaTiO_3$ have up to now been made on sintered materials[1] and on multi-domain crystals.[2,3] Once having succeeded in growing single-domain crystals it was of great interest to establish the anisotropy of the dielectric constant by making measurements parallel (ϵ_c) and perpendicular (ϵ_a) to the polar axis. Such a measurement was made by Mason and Matthias[4] and gave the unexpected result that ϵ_a was about 500 times greater than ϵ_c not only in the Curie region but also above the Curie point in the cubic region, where the polar axis disappears.

We have, therefore, repeated these measurements on very thin single-domain crystals of area of the order of a few mm². The great majority of crystals have the polar axis perpendicular to the large faces (*c*-crystals), so that the measurements of ϵ_a could be made only on small crystals. As a check, measurements of ϵ_a were also made on *c*-crystals and the results agreed satisfactorily.

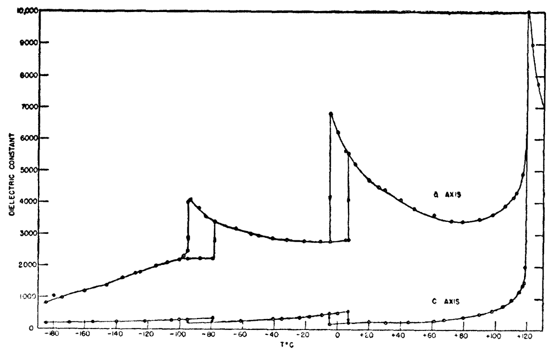


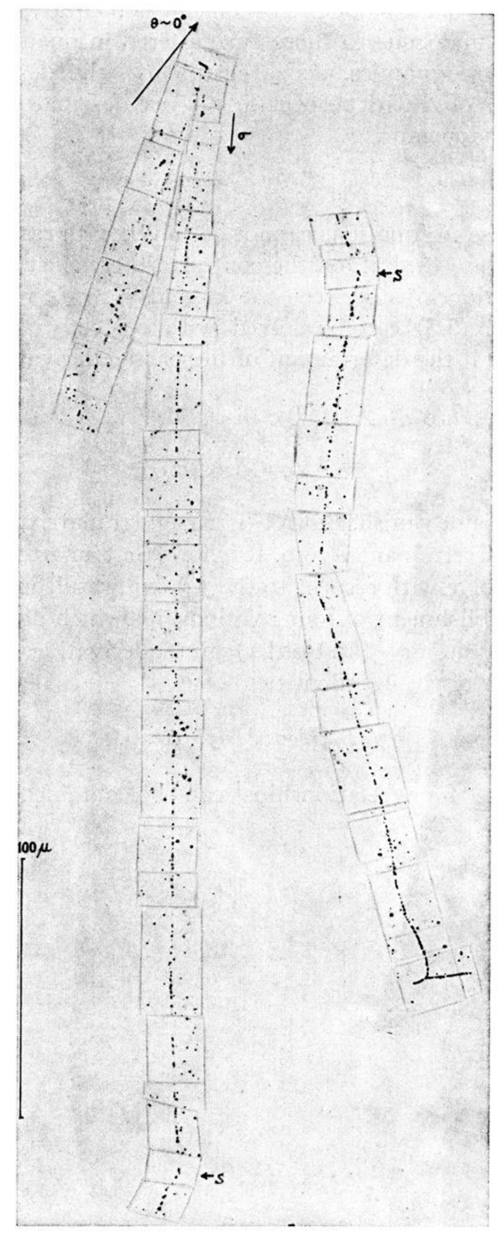
Fig. 1. Dielectric constant of $BaTiO_3$ single-domain crystals.

It is seen (Fig. 1) that ϵ_a is greater than ϵ_c but in a more reasonable ratio of about 20:1 at room temperature, and that in particular $\epsilon_a = \epsilon_c$ at the Curie point as required by the transition to the cubic modification. The different behavior of ϵ_a and ϵ_c between the Curie point and the transition point at about 0°C can be explained, as confirmed by optical observations, by the fact that the Ti ion in the oxygen-octahedra has an increasing tendency to displace itself from the eccentric position [001] toward [011], until at the transition point the [011] position becomes suddenly the most stable one. An analogous behavior of the dielectric constant is observed between the transition points at about 0°C and −85°C. Here the stable position of the Ti ion in the oxygen octahedra seems to become the direction of the body diagonal [111]. It is significant that domain formation occurs at both transition points.

Above −5°C, that is, in the tetragonal temperature region, where there are no domains, the results for all the measured crystals are very reproducible. (In Fig. 1 are plotted the values of ϵ_a for the crystal which gave the highest values.) It is not clear whether one should expect theoretically $\epsilon_a \neq \epsilon_c$ below −95°C. However, below the transition point at about 0°C the single-domain crystals break up into several domains. This domain structure varies from sample to sample as shown by optical evidence, and the slight variation of the measured results. The appearance of a large thermal hysteresis would seem to substantiate this argument.

In contrast to the result of Mason and Matthias,[4] we have found at room temperature no drop in ϵ_a up to 40 Mc/sec. Furthermore, our hysteresis loops are quite symmetric and saturation is obtained with fields of only about 1000 volts/cm. This indicates that our crystals are more free of internal stresses (at least above −5°C) and contain less impurities than the crystals of Mason and Matthias (mostly Pt impurities).

[1] v. Hippel, Breckenridge, Chesley, and Tisza, Ind. Eng. Chem. **38**, 1097 (1946).
[2] Blattner, Matthias, Merz, and Scherrer, Experientia **3**, 148 (1947).
[3] Bernd T. Matthias, Nature **161**, 325 (1948).
[4] W. P. Mason and B. T. Matthias, Phys. Rev. **74**, 1622 (1948).



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