

A highly unusual cosmic ray event at mountain altitude

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Search of rare massive particles in cosmic rays became an active field of research for several years. A recent theoretical study suggested the possible existence of strangelets in cosmic rays even at the mountain altitude. A common polymer, generally used as overhead projector transparencies, was identified as a solid state nuclear track detector (SSNTD) with a detection threshold $Z/\beta > 35$. Those polymer detectors were exposed to cosmic rays at an altitude of 2.2 km as a trial experiment for setting up a large area array of detectors, aiming at the search of rare massive cosmic ray particles at mountain altitude. During the analysis of one such OHP detector we have found a highly unusual event. In the present paper we report our observation.

1. Introduction

Even after the availability of high energy accelerators, cosmic rays (CR) still supply the highest energy particles with energies upto 10^{20} eV. With the development of astroparticle physics, it has become extremely important to analyze cosmic rays in search of exotic particles (like strangelets) and new interactions. A recent theoretical study [1] suggested the possible existence of strangelets in cosmic rays even at the mountain altitudes. To investigate these rare (5-10/100 $m^2/year$) events one requires large area exposures of a detector with a high detection threshold which can reduce the huge low-Z noise present in cosmic rays. Earlier we have identified a common polymer, generally used as overhead projector (OHP) transparencies, as a solid state nuclear track detector (SSNTD) with a detection threshold $Z/\beta > 35$ [2]. Henceforth we shall mention this polymer detector in this paper as the OHP detector. Regarding the standardization of this polymer, we have undertaken two simultaneous sets of investigations. On the one hand the response of the detector is being studied under different etching conditions and on the other hand the behaviour of the polymer to cosmic ray nuclei are being observed. The purpose of this second set of investigation is primarily to see whether this OHP detector can detect any CR nuclear track at all and secondly to see whether the quality of the recorded nuclear tracks in this material is sufficiently good for measurements of track parameters. Furthermore, the effects of daily and seasonal temperature fluctuations on this polymer in open air cosmic ray studies can also be studied. During the analysis of one such OHP detector we have found a highly unusual event. In the present paper we report our observation.

2. Experiment

In the present experiment three rectangular detector stands made of Perspex were placed at an altitude of 2.2 km at an atmospheric pressure of 765 hPa, in a row 3 ft apart from each other. The three holders were kept in such a way that the OHP detectors (21cm \times 30cm) fitted to them remain horizontal with a complete 2π exposure to the open air. In stand-I there was a 100 μm thick OHP film at the top, below which a CR39 (630 μm thick) was placed. In stand-II there was a 630 μm CR39 at the top, below which two sheets of OHPs (100 μm) were kept. In stand-III one OHP sheet of thickness 175 μm was placed. All the three stacks

were recovered after 171 days 4 hrs 40 mins and were duly cleaned and dried before etching. To see the quality of the nuclear tracks recorded, several small portions (4cm×4cm) from the top sheet of stand-I have been etched in 6.25N NaOH solution at 55.0 ± 0.1 °C for 3 hours. The etching condition was kept identical to our previous experiments with the same OHP detector [2]. Etch cones of different diameters and cone-lengths were seen on the etched plastic when viewed under a Leica DMR microscope, interfaced with a computer for automatic Image Analysis.

3. Results and Discussion

Scanning of area of 3.7×10^{-5} m² of the OHP detector, yielded a total of 194 circular etch pits. The diameters and cone-lengths were measured. When viewed under $\times 100$ dry objective of a Leica DMR Microscope there was generally only one track in a single projected image frame (actual area= 4.5×10^{-9} m²), for only 2% of the total scanned area. The projected image frames for the rest 98% of the scanned area had no track at all. However six almost identical nuclear tracks were found close to each other in a single image frame. Figure 1 shows the tracks in that particular image frame. The contours of the circular openings are sharp with an average diameter of 10.5 μ m.

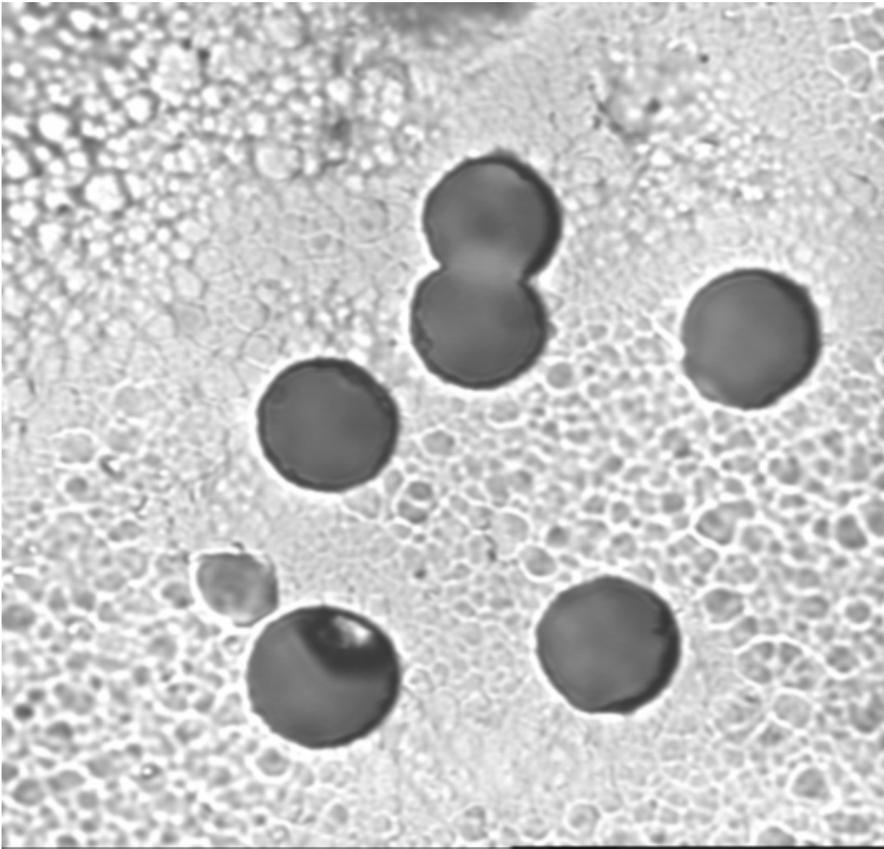


Figure 1. Six almost identical tracks in a single image frame

The diameter distribution of all 194 tracks are shown in Figure2.

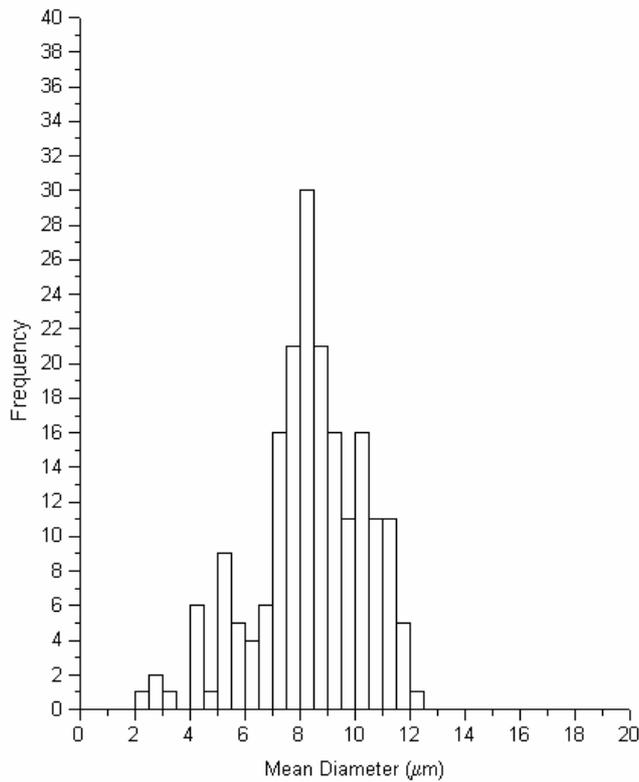


Figure 2. Diameter distribution of the surface openings of the nuclear tracks recorded in OHP detector

The unusual event lies under the right hand side peak in the distribution. The central question is what is the nature of this event.

In this mountain exposure for $\sim 1.5 \times 10^7$ secs, we have observed 188 etch cones corresponding to cosmic ray tracks of near normal incidence within an area $\sim 3.7 \times 10^{-5} \text{ m}^2$. They are different from the etch cones of this special event in that there is only one track in a single image frame, whereas this event has six almost identical tracks in one image frame. Besides this piece of detector where the unusual event has been found, we scanned three other pieces of the same size ($4\text{cm} \times 4\text{cm}$) from the same detector film in search of this unusual kind of event. But no other event of this type could be found. So, leaving open the possibility of a revision of our assessment of the situation, we may infer that there is only one event of this type over a detector area of $6.4 \times 10^{-3} \text{ m}^2$. So the flux of the general tracks found is at least $\sim 3 \times 10^4$ times higher than the unusual event. One can calculate the probability of six nuclear tracks passing through this element of area one by one at six different times during the entire course of exposure and it turns out to be $\sim 2.3 \times 10^{-13}$, which is very small. So, it could be that the particles came simultaneously and they may be emanated from a single vertex. The flux of the primary cosmic rays of Fe-group or Ultra-Heavy group (UH, $Z > 50$) at Darjeeling

altitude (atmospheric depth of 793 g/cm^2) are $J_{\text{Fe}}(E > 1 \text{ GeV/n}) \cong 10^{-52}/\text{m}^2\text{-sr-sec}$ and $J_{\text{UH}}(E > 1 \text{ GeV/n}) \cong 10^{-138}/\text{m}^2\text{-sr-sec}$ only, whereas the estimated flux of the unusual event is $\sim 1.1 \times 10^{-6}/\text{m}^2\text{-sr-sec}$, so this possibility is ruled out.

The other possibility is that they may be low energy heavy ions accelerated by the voltage difference (which can exceed 100 million Volts) responsible for lightning-strikes at any locality. But in that case there should be more of such events, not only one, and the polymer should get burnt instead of recording tracks of those energetic nuclei.

From the measured track parameters of the six etch cones, the angles of incidence are calculated following Henke and Benton [3]. The maximum and minimum diameters of each of the six etch pits and their respective angles of incidence are displayed in table-1.

Table 1. Track Parameters of the unusual event

Nuclear Track No.	Maximum diameter (D_a) (μm)	Minimum diameter (D_b) (μm)	Angle of incidence (i)
(a)	10.82 ± 0.26	10.40 ± 0.26	8.20 ± 0.89
(b)	11.32 ± 0.26	11.22 ± 0.26	8.56 ± 0.75
(c)	10.79 ± 0.26	10.63 ± 0.26	6.20 ± 0.75
(d)	10.69 ± 0.26	10.53 ± 0.26	4.05 ± 0.98
(e)	10.44 ± 0.26	10.27 ± 0.26	5.33 ± 0.96
(f)	10.35 ± 0.26	10.02 ± 0.26	9.57 ± 0.88

From table-1 it is seen that the angles of incidence of the six cones are within $\sim 4^\circ$ to 10° . So, there is a chance that they may correspond to particles radiating from a single vertex not very far from the detector. A least square fit calculation yields a vertex at the height of $506 \mu\text{m}$ above the OHP detector.

It is found that the diameter ($\sim 10.5 \pm 0.26 \mu\text{m}$) and cone length ($\sim 10 \pm 2 \mu\text{m}$) of each of the six etch cones are comparable with the corresponding figures (diameter = $8.5 \pm 0.26 \mu\text{m}$, cone length = $8.5 \pm 2 \mu\text{m}$) for the fission fragments from ^{252}Cf which were earlier detected in the same kind of OHP detector, as reported in ref.[2]. So, they are likely to be heavy ions with Z/β comparable to that of fission fragments, viz. $Z/\beta \sim 900$ to 1600 .

References

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