Bull. Astr. Soc. India (1993) **21**, 511-514

Some representative Cerenkov light images recorded by 144-pixel SHALON gamma-ray telescope

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Abstract. The 144-pixel SHALON imaging telescope was deployed on the nights of 1993 January 20 and 21 to record Cerenkov images of sample cosmic-ray events coming from the direction of zenith. Here, in this preliminary work, we present some typical examples of these images.

Key words : VHE γ-ray—SHALON imaging telescope—Cerenkov image parameters

1. Introduction

The unambiguous detection of TeV photons from the Crab Nebula (Vacanti *et al.* 1991), followed by the more recent detection of a similar signal from the active galaxy MK-421 (Punch *et al.* 1992), has convincingly demonstrated the power of the Cerenkov Imaging Technique in significantly augmenting the detection sensitivity in the field of VHE gamma-ray astronomy. Spurred on by this breakthrough, several groups, all over the world, are engaged in building generation-II TeV telescopes based on this promising new technique. This includes the 144-pixel SHALON telescope which has been recently commissioned at Tien Shan (690 g cm^{-2}, 43.04°N; 76.95°E).

2. SHALON telescope

A detailed description of this system is given by Nikolsky and Sinitsyna (1989); we refer here only its salient features. The telescope employs a 144-pixel Cerenkov imaging camera, placed in the prime focus of an alt-azimuth-mounted optical reflector (effective aperture = 3.57 m; focal length = 4.1 m). The camera pixels, each 0.62° × 0.62° in geometrical size, are tightly packed in a square matrix configuration to cover an overall geometrical field of 7.5° × 7.5°. The anode output of each photomultiplier detector in the camera is coupled to a charge-to-digital converter (CDC) channel, which has a dynamic range of ~ 1000 and an excellent pedestal stability. A master trigger is generated from the inner 64 pixels (8 × 8 matrix)

by demanding an output pulse amplitude which exceeds a certain preset level, leading to an event triggering rate of ~ 10 $\min^{-1}$ from the zenith direction.

Just before the start of observations each night, the overall gains of all the 144 photomultiplier channels were closely matched by adjusting their high voltages and using an LED lamp-based light pulser for calibration. In addition, pedestal data of all the CDC channels were recorded before and after observations. The threshold detection energy of SHALON is estimated to be $E_p^{(o)}$ ~ 10-25 TeV for a proton primary.

3. Image processing

A total of 6420 images were recorded in ~ 11h of observations. These raw images (figure 1a) were processed by subjecting them to the standard routine of CDC-pedestal subtraction. Figure 1b shows a typical pedestal file used for this purpose. Next the pixel counts are subjected to flat-fielding (gain normalization) and 'cleaning' routine, leading to the processed image as in figure 1c. The 'cleaning' routine involved setting the CDC count to zero in all those camera pixels where it was within 2 standard deviations of the combined CDC and sky pedestal dispersion. This practice helps to minimize errors in the estimation of the image parameters.

272	269	229	244	118	143	149	145	300	322	240	296
190	169	225	203	237	230	264	268	105	163	121	108
236	247	242	206	152	149	149	159	303	312	274	250
161	113	123	109	262	337	259	257	147	163	164	117
289	244	185	247	114	121	76	127	182	185	203	173
127	153	137	144	303	308	308	373	210	203	248	286
254	226	267	278	148	145	191	205	279	297	265	235
138	154	130	100	298	323	327	336	226	219	163	194
300	271	242	240	157	189	156	196	328	314	323	262
177	179	149	157	200	117	177	0	124	102	92	129
220	195	209	187	126	114	159	113	303	289	288	269
112	24	171	165	309	281	318	314	138	165	172	188

(a)

270	268	227	244	117	141	147	143	303	324	245	295
186	169	232	203	236	229	264	269	102	162	121	106
234	247	242	203	150	148	147	157	302	311	273	252
156	110	121	108	258	329	257	252	145	159	160	115
288	240	184	246	110	118	74	114	183	182	201	175
126	148	135	140	291	290	288	317	185	192	242	284
255	226	265	269	143	138	174	188	229	270	258	234
132	151	130	94	289	297	288	293	188	205	159	192
301	265	233	231	149	177	143	183	300	303	314	259
174	176	151	152	193	113	166	0	119	99	91	127
221	193	205	184	125	111	158	111	299	286	283	269
109	21	169	161	304	276	316	312	129	162	169	185

(b)

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	23	44	97	38	0	0	0
0	0	0	0	0	0	20	85	100	49	0	0
0	0	0	0	0	40	65	66	76	0	0	0
0	0	0	0	0	0	0	0	43	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

DISTANCE = 1.097°
LENGTH = 0.654°
WIDTH = 0 550°
MISS = 0.192°
FRAC2 = 0.264
AZWIDTH = 0.554°
ALPHA = 10.107°
ZONE = 3

(c)

Figure 1. Stepwise procedure to be followed for image processing: (a) raw image, (b) pedestal file, and (c) processed image.

The processed image-data were used to calculate image parameters first proposed by Hillas (1989), viz., LENGTH (L), WIDTH (W), DISTANCE (D), MISS (M), FRAC2 (F2) and AZWIDTH (A). These parameters define the shape and orientation of a recorded image and are intimately related with the details of actual development of the atmospheric cascades in the case of γ-ray and a hadron primaries. Figure 2a gives a schematic representation of

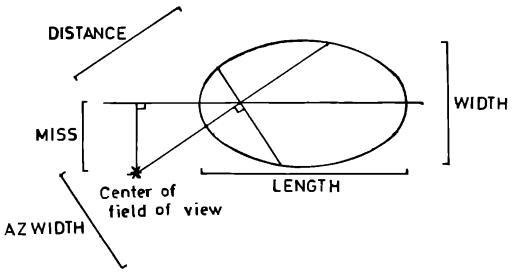


Figure 2a. Definition of 'Hillas image parameters'.

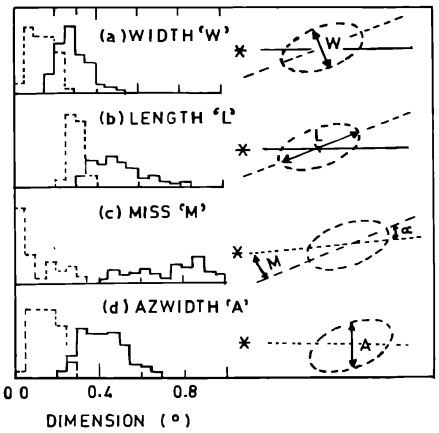
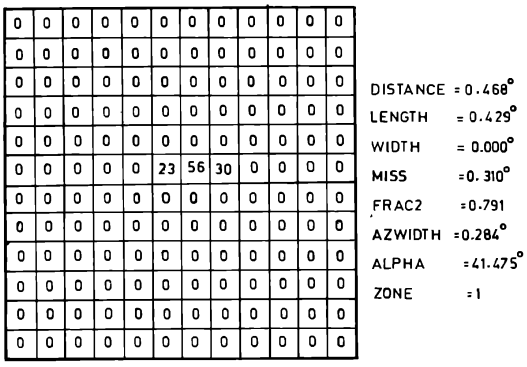
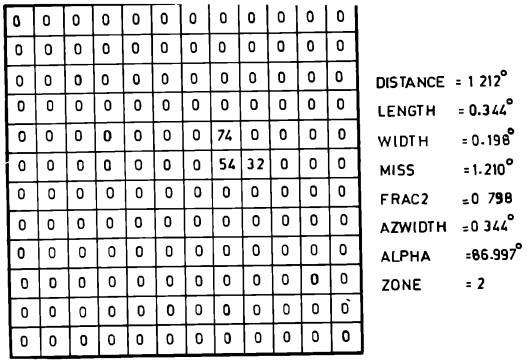


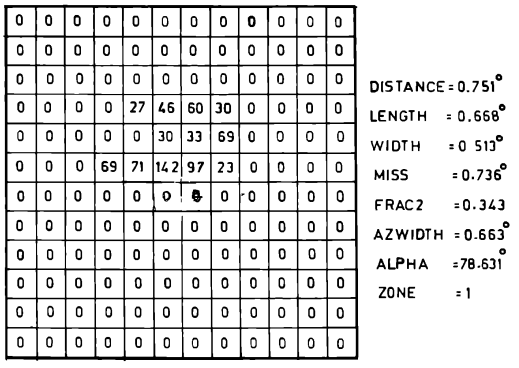
Figure 2b. Expected distribution of main image parameters for γ-ACE (-----) and p-ACE (——) events.



(a)



(b)



(c)

Figure 3. Examples of representative images recorded by SHALON : (a) Local muon origin, (b) local muon/γ-ray ACE(?), and (c) p-ACE image.

the 'Hillas' parameters while figure 2b shows their respective distributions for γ- and *p*-ACE predicted by cascade simulations. They are valid for the Low Resolution Whipple imaging system with a pixel size of ~ 0.5° (Weekes 1989).

4. Typical images

Here we limit ourselves to presenting a few examples of typical images; detailed results will be discussed elsewhere.

Figure 3a represents an event generated presumably by a local cosmic ray muon passing close through the camera pixels (W = 0). They constitute < 0.2% of the total processed images. Figure 3b represents another compact image whose size parameters (L and W) are consistent with both a local muon and a primary γ-ray origin. Some of the events of this type may belong to the γ-ray diffuse background but this point needs a more careful examination. Figure 3c (and also 1c) are representative of the rest of the sample. They are produced by the background cosmic-rays, as demonstrated by the distributions of the image parameters. They can thus constitute useful background reference data against which simulated γ-ray data can be compared to realistically assess the background filtering capability of SHALON.

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