Extremely High Energy Hadron and Gamma-ray Families(III)

--- Core Structure of The Halo of Superfamily ---

Yamashita, S., Ohsawa, A. *, Chinellato, J.A. **, Shibuya, E.H. **

Science and Engr. Research Lab., Waseda University, Japan
* Institute for Cosmic Ray Research, University of Tokyo, Japan
** Instituto de Fisica, Universidade Estadual de Campinas, Brazil

Abstract

The study of the core structure seen in halo of Mini-Andromeda III(M.A.III), which was observed in Chacaltaya emulsion chamber , is presented. On the assumption that lateral distribution of darkness of the core is exponential type, i.e. $D=D_0\exp(-r/r_0)$, subtraction of D from halo darkness is performed until the cores are gone. The some quantity on cores obtained by this way are summarized. The analysis is preliminary and is going to be developed.

1 Introduction

Since one of the most powerful event , Andromeda(E_{halo} = 21,000 TeV), was observed in 1969, eight events with halo were detected by Brazil-Japan emulsion chamber collaboration experiment, at Mt. Chacaltaya, 5200 m at sea level, in Bolivia(1)(2)(3)(4)(5). The detailed study of halos tells the existence of various pattern of the core structure in halo, i.e., single core structure and/or multi-core structure.

Pamir group of emulsion chamber experiment, already, paid attention to this multi-core structure of halo and has derived the important results such as relative P_t of each core and alignment of the cores, etc.(6)(7).

On the other hand, Chacaltaya group has pointed out that the cores in halo correspond to the Jet-clusters obtained by the clustering analysis for individual high energy shower-particles and to the vestige of the nuclear interaction(5). Then in this article, we pick up the M.A.III for example of typical multi-core event and investigate the characteristic of the core structure in halo. The detailed description on M.A.III is presented elsewhere(5).

2 Method

2-1) Core structure of the halo

Fig.1 shows the two-dimensional distribution of darkness of halo in RR type X-ray film at 10 c.u. on M.A.III. The figure is processed by the micro-computer after getting the data by automatical photometry measurement at Institute for Cosmic Ray Research, University of Tokyo. The measurement is carried out by the square slit with the size of 300 μm and number of steps of measurement are 80 to both horizontal and vertical direction, i.e., the figure is made of the darkness of 80 x 80 cells. The numerals in the figure show the darkness $D(D=-\log_{10} I/I_0)$, where I_0 and I, respectively, express flux of the incident and transmitted light. In the figure, four cores are recognized and are named as H, I, J and L, respectively. The center of halo, $\vec{R}_G$, is defined by the following way to be presented by a mark of + . $\vec{R}_G = \Sigma \vec{r}_i D_i / \Sigma D_i$, where D_i and $\vec{r}_i$, respectively, represent the darkness and position vector of each cell.

2-2) Determination of incident direction

As an air family generally comes into the chamber with inclined direction and halo looks like a elliptical shape which extends to the incident direction, the correction for inclined incidence must be made. For the correction, we make the following way. One subtracts the $D=D_0(x_0,y_0)\exp(-r/r_0)$, (x_0,y_0) is the position of halo center and r_0 is arbitrary, from the all D_i of the cell. As the function, $D=D_0\exp(-r/r_0)$, is a circular symmetrical one on r, subtraction of this function from elliptical halo makes the plus area in both edge of long axis of ellipse and the minus area in both edge of short axis of ellipse when we chose suitable size of r_0. If we can get a line which is joined at two plus area, we determine the direction of the line as incident one and correction for inclined direction is made along the direction. In fact, the coefficient of correlation, R_{xy}, of the first degree is calculated and in the case when absolute value of it is greater than 0.5, we consider there is a linear correlation on x and y and determine the line of incident direction by the least square method.

2-3) Subtraction of the core from halo

We assume that the lateral distribution of the darkness of the core is $D(r,x,y,r_0)dr=D_0(x,y)\exp(-r/r_0)2\pi r dr$, and we input the position of the core,(x,y), and its mean spread, r_0. D_0 is the darkness of the core center and we can get the electron density, ρ_0 (1/cm^2) at r=0 by transforming D_0 to ρ_0 .

The distribution, $D(r,x,y,r_0)$, thus defined is subtracted from the darkness of halo made of 80 x 80 cells(contour map) at each r in order of the magnitude of the core size and new contour map is constructed. In this time, correction for inclined incidence is made with the way described in preceding paragraph. Fig.2 shows the new map thus obtained by subtraction of the highest energy core L on the assumption of r_0=1.5 mm. In the figure, we can see the core L disappears and H, I and J cores survive. The same procedures are applied to the second highest core J with r_0= 1.5 mm and to the cores H, I with r_0=0.5 mm, respectively and the new map are shown in Fig.3. In the figure we can see all the four cores disappear.

3 Discussion

Table 1 shows the summary of some quantity on cores H, I ,J and L thus obtained. In the Table 1, ρ_0 and R_0 present electron density of the cores at r=0 and mean lateral spread of the cores, respectively. R is the distance from the center of halo to the core and Ne is a total electron number in the core obtained by $Ne=\int_0^\infty \rho_0 e^{-r/r_0} 2\pi r dr$. According to the simulation calculation by Makio Shibata, we can get the energy of core by transforming the number of electrons in core at 10 c.u. to the energy(8). E in Table 1 shows the energy of each core thus estimated. R_{ij} is a relative distance among each core and Z_{ij} is a quantity induced by Pamir group as $Z_{ij}=R_{ij}(1/N_i+1/N_j)^{-1}$, which is connected with the relative transverse momentum of each core(6)(7). ER_{ij} is the relative lateral spread of each core obtained by $R_{ij}(1/E_i+1/E_j)^{-1}$ using the energy of the cores instead of N_i. Fig.4 shows the scatter plot of the cores in E-R diagram together with that of computer-constructed A-jets. The triangles with capital letters H,I,J and L show the plots of the cores of M.A.III and the closed circles with small letter i,j and l show the A-jets of M.A.III which should correspond to the cores I,J and L as seen in ref.(5). The cores J and L well correspond to the A-jets j and l but correspondence of the core I to A-jet i is not so good. We suppose it is caused by using the unfit r_0. The core H is originated from hadronic component as seen in ref.(5) and the shower development does not still reach the maximum at 10 c.u..

This report is preliminary one and shows the new method of investigation of the core structure. There remain problems to be solved, such as the way of determination of r_0, the order of subtraction of the cores and derivation of the P_t from Z_{ij}, etc.. These problems are under considerations and we will make the answer on their problems in separate publication.

Acknowledgment

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Figure captions

Fig.1: Contour map of halo in RR-type X-ray film at 10 c.u. on M.A.III. Cores H, I, J and L are recognized in it. Darkness are shown by numerals in figure.

Fig.2: Contour map of halo on M.A.III after subtracting the core L form Fig.1 with R_0=1.5 mm.

Fig.3: Contour map of halo on M.A.III after subtracting the core J from Fig.2 with R_0=1.5 mm and the cores H and I with R_0=0.5mm.

Fig.4: Scatter plot of the cores in E-R diagram together with that of computer-constructed A-jet. Marks are $\triangle$ for the cores of M.A.III, ○ for A jet of Andromeda, $\times$ for A-jet of Ursa Maior and ● for A-jet of M.A.III.

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Table 1

#	$\rho_0(1/cm^2)$	R_0(mm)	R(mm)	N_e	E(TeV)
L	2.63×10^7	1.5	1.65	3.72×10^6	580
J	1.91×10^7	1.5	0.55	2.69×10^6	420
H	2.27×10^7	0.5	2.84	3.56×10^5	56
I	6.25×10^6	0.5	1.86	9.81×10^4	15

#--#	R_{ij}(mm)	Z_{ij}(els.mm)	ER_{ij} (TeV.mm)
L--J	2.20	3.44×10^6	536
L--H	3.67	1.19×10^6	187
L--I	3.13	2.99×10^5	46
J--H	2.66	8.37×10^5	131
J--I	1.54	1.46×10^5	22
H--I	1.24	9.58×10^4	14

Fig.1

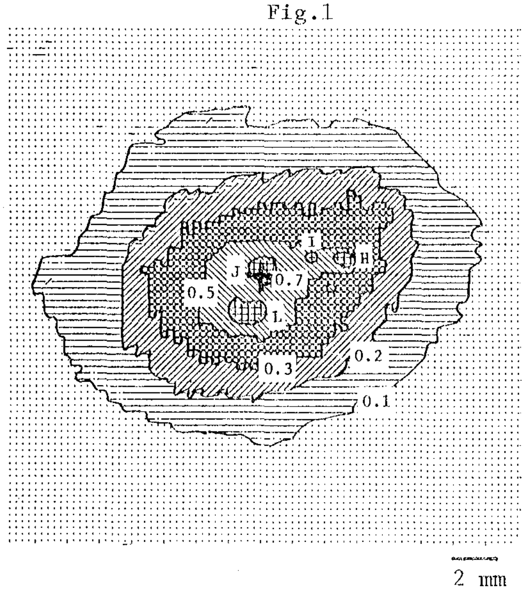

Fig.2

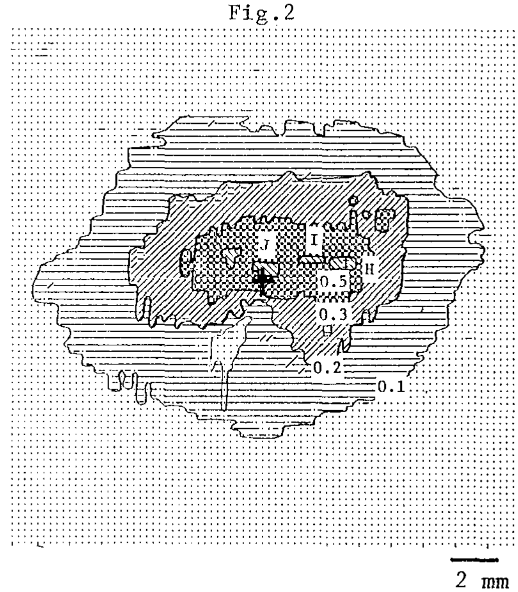

Fig.3

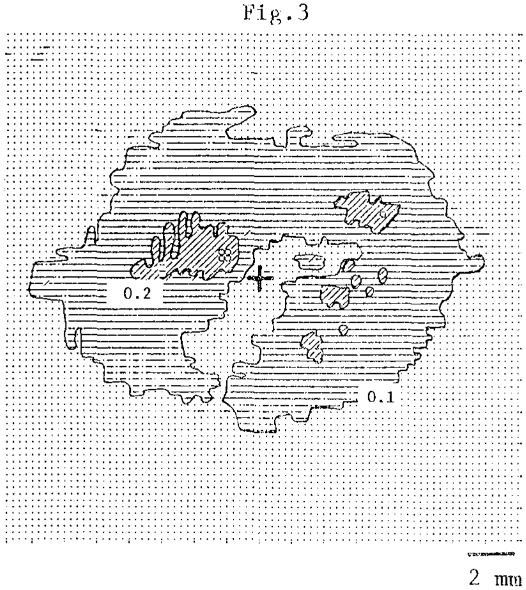

Fig.4