

***** Chapter 4 *****

Conclusions :

The modern UHE gamma-ray astronomy is now about fifteen years old .But the situation of observation of UHE gamma radiation from discrete sources is still very confusing. Early observations of Cygnus X-3 provided the hope that the UHE radiation from this and similar sources could be studied regularly. However most recent observations have been unable to confirm the existence of such emission. The long standing problem regarding the nature of the primary particles responsible for the positive detections of excess EAS from the direction of the discrete point sources are yet to be solved.

To understand the muon anomaly associated with the subject from its birth in the present investigation the variation of the ratio of muon density to particle density with shower age for a particular shower size at a particular radial distance from the shower core is studied. It is observed that the ratio increases sharply with shower 'age'. It is expected because the muon number does not change much with the atmospheric depth traversed after the maximum development of shower reaches while electron component attenuates rapidly after the maximum development of showers. It is interesting to note that high muon content of the excess showers from the direction of Cygnus X-3 as observed by the Kiel group is also characterised by high 'age' values. Though, in Kiel observation the muon content of the excess showers is compared with the background also having high 'age' values but it may happen that the excess showers from the direction of Cygnus X-3 is characterised by even higher 'age' values. In several other experiments it was also observed that the excess showers from the direction of discrete point sources have high shower 'age' value. It is true that the amount of ^{muon} excess (67% instead of 10%) could not be explained by high shower age value alone but the present result indicate that the high muon content and high 'age' value may not be independent characteristics of the excess directional showers.

Discrimination of gamma-ray initiated showers from the large background of charged cosmic ray initiated showers based on shower 'age' has been used in several observations on the assumption that ,for same shower size, photon induced showers are older. Fenyves (1), Hillas (2), Cheung and Mackeown(3) from their monte carlo simulation results concluded that in 'age' the gamma-ray induced showers are not older than that of normal showers, though in several observations it is found that the excess showers from the direction of discrete point sources are

characterised by high 'shower age' value. Since in most of the observations the shower from point sources were observed at large angles during most of the observation time (due to high angle of transit of the sources at the arrays) so it may happen that high 'age' values of the excess EAS's are due to high zenith angle. To understand the problem, variation of shower 'age' with zenith angle is examined. It is found that the variation is slow, and up to zenith angle 30° , shower 'age' is practically independent of zenith angle. In the Kiel observation, showers with zenith angle less than 30° only were accepted for the analysis. So it is difficult to correlate the high 'age' value of the directional excess showers with zenith angle.

In the quest for UHE radiation from potential discrete point sources of the northern hemisphere four sources are studied in the present investigation, Cygnus X-3, Hercules X-1, Crab nebula and Geminga. We found no statistically significant excess of EAS from any of these sources. The Cygnus X-3 data set shows a steady excess of 1.79σ . The time average integral flux of particles responsible for the excess of showers seen from the direction of the object is obtained as $F(>8 \times 10^{14} \text{ eV}) = (4.10 \pm 1.28) \times 10^{-13} \text{ cm}^{-2} \text{ s}^{-1}$. The phase analysis of the event time of EAS from the direction of the Cygnus X-3 also indicates an excess of 2.11σ in the phase bin .5-.6. The statistical significance of the excess is not sufficient for any claim of a detection. A clearer picture will emerge only after analysis of more shower data. The Hercules X-1 database shows a marginal steady excess of 1.04σ which corresponds to a time average integral flux of $F(>8 \times 10^{14} \text{ eV}) = (2.42 \pm 1.08) \times 10^{-13} \text{ cm}^{-2} \text{ s}^{-1}$. The search for 1.7 day pulsed flux from Hercules X-1 has also been performed. No significant excess can be found at any phase. There is no statistically significant evidence for continuous emission from Crab nebula and Geminga.

There is considerable uncertainty about the present situation of the UHE gamma-radiations from celestial discrete point sources. Early claims of marginal statistical significance have not been substantiated by more recent observations. The performance of the detectors improved with time but the significance of most of the published positive observation remained at a 3σ level. The lack of clear identification of the gamma-ray signature of the positive signal is one of the reason to doubt the reality of the sources. However it is also true that positive evidences of UHE signal from discrete point sources is observed in several independent observations. Moreover the event times of the

excess showers from the direction of Cygnus X-3 are found to be modulated with a period 4.8 hour which is the orbital period of the object and similar to as observed from the x-ray data. Similar characteristics have been observed for few other sources too. So, it appears that the sources are real. But, it has now become clear that long term steady flux from Cygnus X-3 is much less than reported for late seventies and early eighties. These observations suggest that sporadic emission on a wide time of scale may be characteristics of Cygnus X-3 and many other UHE point sources.

Further observations are necessary to provide more information on the nature of the discrete UHE point sources. The present experiment is an ongoing experiment. The data analysis is continuing. It is expected that a clear picture of observation of UHE gamma-ray sources will emerge after analysis of few years data.