*** Chapter 1 ***

1.1 Introduction:

The mysteries and grandeur of the Universe fascinated mankind from long before the advent of the modern cosmology.From the time of earliest civilisations man has studied the movements of the heavenly bodies and from his observations has gradually built up ideas of the structure of the Universe.By ingenuity and perseverance through the centuries the nature of the Universe has gradually been unfolded.Man has acquired knowledge about the Universe entirely by interpretation of incoming radiation.Most astronomical information relies on measuring the electromagnetic radiation from space arriving at the earth.But there is another tool, which over the last few decades has become increasingly important - ***Cosmic Rays*** .

The Cosmic radiation is a very specific sample of matter , a highly isotropic flux of relativistic particles,that originates in the Cosmos. The study of cosmic rays originated approximately in the year 1900,as a result of observation of the ionisation in gases in closed vessels by *C.T.R. Wilson, Geitel and Elster*.In the year 1912 , Austrian scientist *Victor Hess* from his balloon flight experiment convincingly demonstrated that in closed vessel the air ionisation rate increases with height when moving away from the earth surface and he concluded that a very penetrating radiation is entering the atmosphere from outer space.However there was still another possibility that the observed radiation was gamma radiation from the radioactive substances present in the upper atmosphere. Hess results were confirmed in the subsequent observation by *Kohlhörster*. All doubts about the existence of a penetrating radiation from outside disappeared about 1927-28. *Millikan* gave the name *'Cosmic Rays'* to these penetrating radiations . *Hess* was later awarded the *'Noble prize'* in physics for his discovery of cosmic rays in 1936.

Cosmic rays are found in interstellar space of our own galaxy as well as in other galaxies. Thus cosmic rays are an important constituent of the Universe. The energy density of cosmic rays in our galaxy $\omega_{cr} \sim 10^6$ eV/m^3 , is of the same order as the energy density of the interstellar magnetic fields and as the energy density of the interstellar gas.The total estimated energy of the cosmic rays in the galaxy is about 10^{68} eV.

Cosmic rays are essentially extraterrestrial radiation having relativistic particles. The energy range of the cosmic ray particles are from 10^6 eV (super thermal energy) to about 10^{21}

deflection in the interstellar magnetic fields making it impossible to know the source direction. Stable electrically neutral particles are free from this problem.The commonly occurring neutral particles are neutrons , neutrinos and gamma ray photons. But neutrons are unstable and neutrinos , being weakly interacting, are not easy to detect.On the other hand gamma rays are ideal in view of both their production and interaction cross section being rather high and their being stable.

The starting point for gamma ray astronomy came from a paper by *Morrison* (5) in which he pointed out the prospects for gamma ray astronomy .Initially gamma ray detectors were carried by balloons.However high energy gamma ray astronomy was not to become established until satellites reduced the background problem and permitted long exposure. The successful flights of the *SAS-2* and *COSB* gamma ray experiments in the seventies established high energy gamma ray astronomy as a viable branch of astrophysics.

But the major problem at the UHE range is that the flux of UHE cosmic ray particles,in particular gamma rays, is so small that it can not be studied by balloons or satellites. As a result in the highest energy region cosmic ray observation are in general rather indirect. The only source of information about the highest energies is the '*Extensive Air Showers*' (EAS) .

<u>The Extensive Air Shower</u> :

Extensive Air shower is a phenomenon that results from the interaction of the high energy ($E > 10^{14}$ eV) primary cosmic ray particles with air nuclei in the earth's atmosphere.*Auger* and his colleagues first observed the phenomenon in the year 1938 (6).

When a high energy charged cosmic ray particle is incident on the top of the earth's atmosphere it interacts with the atmospheric nuclei.The products of this interaction are mainly charged and neutral pions with some kaons,nucleon , anti-nucleon pairs and other baryons.The secondary hadrons practically continue in the same direction of the primary and undergo further nucleon-nucleon collisions.Some of the charged pions and kaons interact while others decay to muons and neutrinos.Most of the muons survive to observation level.The neutral pions decay to gamma rays which initiate electromagnetic shower.In the electromagnetic cascade at each stage each gamma photon produces a pair of electrons which share its energy and each electron radiates nearly half of its energy as a bremsstralhung gamma ray.As a result the number of particles grow until the energy of the individual electrons drops to the point that other interaction (e.g. absorption) processes compete with particle production.The total number of secondaries created in this phenomena can be as high as many millions.Because of the large energy involved , the secondary particles are strongly beamed in the forward direction , and on the average retain the directionality of the primary.At each interaction level , the particles spread out laterally mainly because of multiple coulomb scattering of the charged secondary leptons in the influence of air nuclei so that by the time the shower reaches the detector level , it has a lateral spread of hundred of meters.If a high energy cosmic gamma ray is incident on the top of the atmosphere it produces an electromagnetic cascade.

Charged cosmic rays are highly isotropic whereas cosmic gamma rays are supposed to be directional.Hence, emission of gamma rays from a celestial source will be reflected in an excess number of showers from that direction of the celestial sphere.Since the convincing discovery of UHE gamma radiation from Cygnus X-3 by the Kiel group air shower arrays are extensively used in the search for point sources of cosmic rays.Several institutes have built new detector arrays or upgrade the existing ones to gather further information on gamma ray sources.In the last twelve years many observations of UHE gamma rays from various sources have been reported.However the present observational situation in UHE gamma ray astronomy is quite controversial.A brief review of the present status of observation of UHE gamma ray sources is described in next section.

1.2 Current status of observation of UHE gamma-ray sources :

In the year 1983 the Kiel group in Germany reported (1) detection of an excess flux of air showers of energies greater than 10^{15} eV from the direction binary x-ray source *Cygnus X-3*. That was the first positive observation of PeV radiation from a discrete source and with this observation a new era in gamma ray astronomy began.Since then many attempts have been made by different EAS groups to confirm the results of the Kiel group and to identify other discrete potential UHE gamma ray sources. Positive evidences of detection of UHE radiation were reported during last twelve years from several other sources e,g, *Crab nebula* , *Hercules X-1*, *Vela X-1* .

Search for UHE gamma rays from discrete sources started in the early sixties.For identification of gamma initiated showers against the large background of charged cosmic ray initiated showers it is essential to know the characteristics which distinguish gamma ray cascades from the charged cosmic ray initiated showers. Detailed calculation (2) have shown that air showers initiated by primary gamma rays should be deficient in muons by more than an order of magnitude compared to showers due to cosmic ray protons or heavier nuclei.The initial attempts to detect UHE gamma ray sources are based on looking for anisotropies in the cosmic ray flux using muon poor showers (3). But the initial attempts were unsuccessful.It was observed that cosmic rays in the PeV energy region are highly isotropic. Interest in UHE gamma ray astronomy was revitalized after the announcement of positive observation by the Kiel group. After many years of frustrating searches now a few sources in the UHE range , mostly of galactic origin , are established.

The summary of the status of observations can be represented by '*source catalog*'.Those sources which satisfy the criteria of at least three statistically significant independent observations are included in the source catalog which is presented in table 1.2.1 . The most numerous class of UHE gamma ray sources consist of x-ray binaries.The galactic x-ray sky is dominated by closed binaries in which one of the pair of stars is a compact object (white dwarf,Neutron stars or even black holes).The objects of most interest to gamma ray astronomy are the binaries that contain a neutron star. Most of these are found in massive systems in which the mass of the companion star is greater than $10M_0$. Supernova remnant is also found to be UHE gamma ray emitter which is expected.A brief discussion about the observation of the sources are described below.

Table 1.2.1

(UHE gamma ray source catalog)

Source	Type	Hemisphere	Co-ordinates Dec	RA	Distance from earth	Periodicity
Cygnus X-3	Binary X-ray source	N	40.9	307.8	> 11.4 kpc	4.8 hour
Hercules X-1	Binary X-ray source	N	35.4	254.0	~ 5 kpc	1.7 day, 1.24 s
Vela X-1	Binary X-ray source	S	-40.6	135.4	~1.4 kpc	8.96 day, 283 s
Crab nebula	Supernova Remnant	N	22.0	82.9	~ 2 kpc	Steady (33 ms ?)

Cygnus X-3 :

Cygnus X-3 is a very interesting astrophysical object.Cyg X-3 located at least 11.4 kpc away from the solar system , is a low mass x-ray binary system with a well known period of 4.8 hours which is normally interpreted as binary orbital period.Recent observations also indicate the presence of a fast pulsar of 12.6 ms pulsation in the TeV gamma range (4). The radio emission from Cyg X-3 is of particularly interesting as Cygnus X-3 displays flaring activity and occasionally exhibits large radio flares.

Cyg X-3 was first observed as x-ray source in the Cygnus constellation by a rocket borne x-ray telescope (5).The object has not seen at optical wavelengths.Cygnus X-3 was first observed as a TeV gamma ray source by Crimea astrophysical Laboratory (6) and subsequently observed by a number of other observations.

First attempts to observe UHE gamma rays from Cygnus X-3 were unsuccessful (7,8). The first report of successful detection of PeV gamma ray emission from any source came from the University of Kiel group (1). This result has a great importance in the UHE gamma ray astronomy.

The Kiel air shower array was consisted of 28 scintillation counters each of area $1m^2$. The sensitive area of the array was about 3000 m^2. Timing information were obtained from 11 fast timing detectors . The arrival direction was determined in this array with high accuracy (angular resolution better than 1^0).Showers with zenith angle less than 30^0 only were accepted for the analysis.The arrival direction of each showers was sorted into bins of right ascension and declination.They found a 4.4σ excess in the Cygnus X-3 direction compared to the background among the showers with age parameter greater than 1.1 (the mean age value in the Kiel observation) i,e, among the earlier developing showers. More significantly they found that event time exhibited a periodicity with peak emission at a phase 0.35 .They used P=0.1996814 d and P = 0 at an epoch t_0 = JD 2440949.9176 given by Parsignault et al (9) based on their x-ray data. The Kiel group also gave time average flux (integral flux) of $7.4 \pm 3.2 \times 10^{-14}$ photons $cm^{-2}s^{-1}$ above energies 2 PeV.For a distance to Cygnus X-3 of 11.4 KPc , this would corresponds to a luminosity of 2×10^{37} erg s^{-1}(considering the absorption effect due to interaction of UHE gamma rays with the 2.7^0 K black body radiation).They have also observed muons in the showers.When the data in the Cygnus X-3 bin were examined in terms of its muon to electron ratio this is found to be almost same ($0.67 \pm .09$) that obtained for a normal air showers initiated by a charged nuclei whereas the expected ratio would be ~0.10 (10).The detection of PeV signal from Cygnus X-3 was confirmed by Haverah Park group (11) within a few months of the publication of the Kiel results.Later positive evidence of UHE signal from the direction of Cygnus X-3 is reported by several groups (12,13,14,15) however negative results are also reported. Although the performance of the detectors improved with time, the significance of most of the published positive detection remained at a 3σ level.All the positive observation of Cygnus X-3 above TeV energy shown an excess close to two phases of the 4.8 hour orbital period at ~0.2 and ~0.6. However recent reports confirm only the emission at the second phase.Early observations of Cygnus X-3 provided the hope that the nature of 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. A summary of the results of some recent observations is presented in table 1.2.3.

Table 1.2.3

A Summary of some recent observations for UHE gamma-radiation from Cygnus X-3

Array Reference	Database	Observation
HEGRA EAS array (Located at the Canary Island La Palma 28.8°N 17.9°W,790 g cm^{-2}) (16)	Nearly 100 million events had been collected during 1989-91.Energy threshold of the array was 50 TeV.	No steady emission was observed but few short term excess was noticed . The largest short term excess on the 20 th January,1991 coincides with the huge radio flare. Phase analysis of the arrival times of the events of that day into the 4.8 hour phasogram shows enhancement of signal at a phase .2-.3. SOUDAN2 collaboration claims the detection of an increased muon flux from the direction of Cyg X-3 for the same day.
Chicago Air Shower Array (CASA) (17) (Located at Dugway Utah,USA .40.2° N, 112.8° W ,870 g cm-2)	About 1300 million events were collected by the array during 1991-93. 410 million events were taken for the analysis.	Search was made for steady and sporadic nature of emission with and without a cut on the muon content of the shower. No statistically significant excess was found.
EAS-TOP (18) (2005 m a.s.l., 42.45°N 13.56°E)	The database used in this analysis was taken during 1989-1990.	A search for possible periodic and sporadic emission had been performed.No significant excess was

		observed in any search.The upper limit to the DC flux was estimated F (>200 TeV) < 10^{-13} $cm^{-2}s^{-1}$
Ohya EAS array (19) (36.59^0 N,139.84^{0}E)	A total number of 2.5 x 10^6 shower events were taken in the period 1986 - 1993.	Muon less EAS from Cyg X-3 had been searched. A 4σ excess has been observed in the data set with the muon cut(R_μ<.2) and size cut less than 10^5.
GREX EAS array (20) (Located at Haverah Park,UK)	Between March 1986 and December 1990 21.3 million events were collected.	No positive observation.The upper flux limit(95% CL) was estimated as 5 x 10^{-14} $cm^{-2}s^{-1}$ (>900 TeV).
CYGNUS EAS array (21) (Located in Los Alamos New Mexico ,35.9^0 N)	Over 200 millions air shower events was recorded.	Negative results reported.The estimated upper flux limit is 4 x 10^{-14} $cm^{-2}s^{-1}$(>70 TeV).
Akeno Giant Air Shower Array(AGASA) (22)	Data collected during 1990-1991.	The array Looked for steady excess In EeV energy range. A 3.4σ excess has been found from the direction of Cygnus X-3 .The flux limit from the observation was estimated as F(>3 x 10^{17} eV) = (3.4 $\pm$ 1.0) x10^{-17} $cm^{-2}s^{-1}$.

One of the most striking feature of recent observation is the detection of EeV radiation from the direction of Cygnus X-3 by the Fly's Eye group (23) .The result is confirmed by the Akeno group (24) and also by Akeno Giant Air Shower Array (25) although such emission was not seen on Haverah Park data (26).

All these results make Cygnus X-3 a very interesting astrophysical object.

Hercules X-1 :

Hercules X-1 is considered to be the prototypical binary x-ray pulsar.The x-ray flux displays periodic variations with time scales of 1.24 s , ~1.7 d and ~ 35 d.The two shorter periodicities are interpreted as being due to rotation and occultation of an accreting neutron star that is located in a close binary system.The unusual 35 day flux modulation has an x-ray light curve that is composed of an 11 day high intensity state and a 19 day low intensity state that is interrupted midway between the 11 day high state by an intermediate high state (intensity ~40% of main high state) of 5 day duration.Hercules X-1 is not a radio source like Cygnus X-3.

Pulsed TeV gamma radiation from Hercules X-1 was discovered by the Durham group in 1983 at the array in Dugway(27) and subsequently observed by the Whipple observatory . Several observations of TeV gamma-ray emission have been reported (28) . One highlight was the observation of of a 42 sigma excess with the Pachimarhi Cherenkov detector in April 11 , 1986 in India (29). UHE pulsed gamma-ray emission was first observed at the Fly's Eye array (30).Observations at both PeV and TeV energies indicate the possibility that Hercules X-1 may be characterized by occasional transient blue-shifted emission of gamma-rays (14). No statistically significant long term steady PeV radiation from Hercules X-1 has been reported so far. Results of some recent observations are given in table 1.2.4.

Table 1.2.4

A summary of some recent observations for UHE gamma-radiation from Hercules X-1

Array Reference	Database	Observation
KGF EAS array (31)	The data was from about 400 days during 1985 - 1987.	There is a 2.8σ DC excess with a zenith angle cut of >28^0 but the orbital phase distribution of the excess is not uniform.
Ohya EAS array (32)	Five years of data(1986-1991) with large muon detector had been analyzed.	A slight muon cut (R_μ<1.0) was made and a 4.2σ excess at the pulsar period of 1.236 sec was observed.

CASA & MIA EAS array. (33)	Data collected during 1990-1991.	No evidence was found for any excess.
GREX EAS array (34)	A database of over 30 million events recorded during 1988-90 .	No sign for any excess.
Ooty EAS array (35)	A total of 6.9×10^5 events collected during 1984-87 .	Positive evidence was found for episodic emission from the source.
HEGRA EAS array (36)	During 1989-91 the array collected more than 100 million events.	No statistically significant excess was observed.
CYGNUS EAS array (37)	Over 200 millions EAS events were recorded.	No evidence for any steady or sporadic emission .

Vela X-1 :

Vela pulsar is the strongest GeV gamma ray source detected by the *COSB* satellite . This is a massive x-ray binary system, located comparatively close to the solar system (~1.9 KPc). It is believed to consist of a neutron star and a companion B-supergiant of 24 solar masses. Vela X-1 is originally discovered by the UHURU satellite experiment.It has been extensively studied at x-ray wavelenghts.Vela X-1 has a pulsed period 282.9 s and an orbital period 8.96 d.The orbital motion of the system is such that the pulsar is eclipsed for 20% of the total orbital period of 8.96 d.Being located in the southern sky it is accessible for observation only from sites in southern latitudes or near the equator.

Gamma radiation of UHE from Vela X-1 was first observed by the Bucland Park EAS array in Adelaide (38).The small array of 12 scintillation counters was operated at sea level.The muon density are not measured by the array.Background was discriminated using the value of age parameter.In the search for a flux from Vela X-1 only showers within 2^0 of source direction and having s>1.3 were selected.These events were folded with the 8.964 days orbital period into bins of width 0.02.In one of the phases (~0.33) there was 8 events where 1.5 are expected.The gamma ray flux (>3 PeV) was estimated as $10 \pm .3 \times 10^{-4}$ photons $cm^{-2}s^{-1}$ which implies a luminosity of 4×10^{34} erg s^{-1} of the source.Later the observation was supported by BASJE collaboration at Mt Chacaltaya after reanalyzing their data collected between 1963-64 (39).At TeV energies Vela X-1 would appear to be reasonably well established gamma ray source. At PeV energies the evidence is however not so compelling still now.

Crab nebula :

In the year 1054 AD a supernova explosion took place which is well documented in ancient Chinese records .The result of this explosion is a supernova remnant,the Crab Nebula.The Crab nebula is one of the most studied source in high energy astrophysics.

A 33 ms pulsar (PSR 0531 + 21) was discovered in the remnant by Staclin and Reifenstain.The discovery of the the pulsar PSR 0531 +21 in the Crab nebula confirmed the connection between Supernova explosions and pulsars and supported the suggestion that pulsars are rotating neutron stars.The Cab nebula is located about 2 KPc away from the solar system.

First detection of VHE gamma rays from the direction of Crab nebula was reported by Smithsonian Astrophysical Observatory group (40) after three years of observation.Further evidence for the detection of TeV emission from the Crab nebula was reported by Whipple observatory collaboration (41).Now Crab is firmly established as TeV gamma-ray source.

Using the database accumulated by the Lodz EAS array , Dzikowski et al (42) reported first detection of flux of gamma radiations of energy >10 PeV from the Crab pulsar.Support for the Lodz identification of the Crab nebula as a UHE gamma-ray emitter came from Fly's Eye experiment (43) and also from Tien Shan EAS experiment (44).However the serious conflict with the Lodz group claiming to have detected the Crab nebula as UHE gamma-ray emitter, came from the observations at Haverah Park (45).Alexeenko et al (46) first reported the observation of PeV burst from the direction of the Crab nebula during the period 14:00 - 19:00 on 23rd Feb ,1989 with their EAS array at Baksan.Latter TIFR group (47) and Gran-Sasso collaboration (48) reported observation of same PeV transient burst.Though none of the three detections individually correspond to transient emission of exceptional intensity however the three independent but correlated detection strongly suggest that the effect is real.

There is yet no clear conclusion about the PeV emission from Crab.Because of the importance of Crab nebula as an astrophysical laboratory ,these results must be verified.

Other potential UHE gamma-ray sources :

Besides these sources already discussed ,there exist a small number of galactic as well as extra-galactic objects which have attracted the attention of UHE astronomers in recent years.Several groups have reported for positive evidences of UHE gamma-ray emission from these sources.However the results are yet to be firmly confirmed. Observations relating to a number of these sources are summarized here.

Scorpius X-1(SCO X-1) :

This source is a galactic x-ray binary object at a distance of 500 Pc. The source is known to exhibit quasi-periodic x-ray oscillation.There has been a report by Matano et al (49) of impulsive emission at PeV energies observed in hadron poor showers with the SYS array at Mt. Chacaltaya .They have observed a significant excess in the number of hadron less showers arriving from within 7^0 of SCO X-1 during May 1986 over time scales of few weeks.In an independent experiment Ooty group (50) also observed similar kind of excess.These observations indicate SCO X-1,like Cyg X-3,is emitting PeV radiation with variable flux over a time period of few weaks.No significant evidence for continuous emission at UHE is observed from SCO X-1 till now.

4U 1145 -619 :

The South Pole Air Shower Experiment(SPASE) has observed (51) a 4.9σ steady excess of events from the direction of 4U 1145 -619 based upon analysis of 9.3 million showers detected between May and Sep 1988.TeV observation of this source have been made by Durham group during 1987-88 (52).The independent TeV and PeV observation of this source appear to suggest that 4U 1145 -619 be considered as a strong candidate of gamma-ray source.

PSR 1957 +20 :

This source is first observed in radio observation made at the Aricibo observatory (53) which is an eclipsing millisecond binary pulsar.The orbital period is 33000.9 s.The companion star is presumably a white dwarf which is being highly ablated as a result of intense energy transfer from the pulsar.KGF group reported (54) observation of 53 events against a background of 34 events amounting to a 3.3σ signal in the orbital phase interval 0.2-0.3 during the period 1984 to 1987.The Potchefstroom group have claimed a steady emission from this source at a 10^{-3}

confidence level (55).Ooty group (56) also looked for emission from this object during the same period (1984-1987) but no excess was found. There is no compelling evidence so far that PSR 1957 + 20 is a UHE gamma ray source.

Geminga :

The high energy gamma-ray source Geminga (2CG 195 +4) is the second strongest source in the COS-B catalog of sources.It was discovered by the SAS-2 satellite (57). Search for PeV radiation from Geminga is of particularly interest since the x-ray and gamma-ray detections indicate that it is similar to the Crab and Vela pulsar.Especially appealing for UHE experiments are the reported detection of periodicity at TeV energies (58,59). Observations with the GRAPES 1 array at Ooty during 1984-87 has shown evidence for emission of UHE radiation during one week interval in Oct 10-16,1986 (60).

Centaurus A :

This extra-galactic object is one of the brightest active radio galaxy located at a distance of nearly 6 MPc. As a source this is only visible in the southern hemisphere . Cen A was observed as a TeV radiation emitter by the Narrabri observatory (61). It is also visible in the x-ray region. Analysis of three years of operation of the Buckland Park at Adelaide shown a slight excess (2.7σ) in the box containing Cen A for energies > 1PeV (62).JANZOS collaboration (63) have reported observation of an excess over background between 14 April 1990 and 3 June 1990.The duration (48 days) and luminosity ($\sim 10^{43}$ erg s^{-1}) of the excess are similar to observed previously from x-ray outburst from Cen A. Further study is required to confirm the observation of UHE emission by Cen A.

LMC X-4, M 31 and few other extragalactic objects are also very appealing for UHE experiments. But there have been no reports of the detection of PeV gamma-rays from these extragalactic objects yet.

<u>Problems regarding the nature of UHE radiation from discrete point sources</u> :

Even if the sources are accepted as detected , it is not possible to conclude that the sources are emitting UHE gamma rays. Observation of excess flux of EAS was reported by several groups from the direction of *Cygnus X-3* , *Hercules X-1* and some other sources.The properties of the initiating particles of the detected excess showers are very tightly constrained.

The initiating particle should be neutral,stable ,rest mass at most a few MeV and interacting very much like a nucleon in the atmosphere. Charged particles could not travel such a long distance (~12kpc) without being deflected by the galactic magnetic field , neutrons can not survive such a long time required to travel such a long distance. So UHE gamma photons have to be assumed as primaries of such EASs. In the most of the positive observations the excess EASs from the direction of *Cygnus X-3* and *Hercules X-1* are observed in phase with the orbital motion of the respective systems and it appears that the excess EASs are due to gamma-ray photons.The main indicator of a photonic origin for a shower is the relative low *muon content* in that shower.However there are a number of detections of gamma-ray (?) sources in which showers from the source direction appear to have high muon content,close to that expected for hadron initiated showers.

Muon content of gamma-ray initiated showers :

The first idea of a search for showers initiated by UHE gamma-rays was based on the fact that these showers should contain much fewer muons than normal ones.The muon component in hadron initiated showers originate from decay of charged pions created in interactions of hadron with the atmospheric nuclei.There are two types of process involve in generation of muons in electromagnetic showers,direct creation of muon pairs and photoproduction.The direct production of $\mu^+\mu^-$ pairs by photons is analogous to the creation of $e^+ e^-$ pairs and in the asymptotic case of full screening of the nucleus field by the atomic electrons

$$\sigma_{\mu^+\mu^-}/\sigma_{e^+e^-} = (m_e/m_\mu)^2$$

which is very small.In the photoproduction muons are generated through production and subsequent decay of pimesons $(\pi^\pm - \mu^\pm \nu_\mu \bar{\nu}_\mu)$. The cross section for photoproduction is very small compare to Bethe-Heitler pair production $(\gamma - e^+ e^-)$ cross section.As a result gamma-ray initiated showers should be muon poor.*Wdowczyk* (2) first made detailed theoretical calculation and conclude that muon content in gamma-ray initiated showers should be more than one order of magnitude lower than that of normal showers.Monte carlo simulation results (64,65,66) also indicate that the muon content should be ~ 0.1 of that of proton initiated showers.From the simulation result Mckomb et al (67) concluded that only at energies around 10^{18} eV the photoproduction will significantly contribute to the number of low energy muons.However a number of experimental evidence from UHE gamma-ray observations of different point sources suggest that gamma-ray initiated EAS's are no means deficient in muons.*Samorski and Stamm* used the Kiel array to investigate the muon content in the excess air showers from the direction of Cygnus X-3.A neon hodoscope of effective area 21.5 m^2 under 880 gcm^{-2} of concrete was used as a muon detector for muons of energy > 2 GeV. They reported (1) that the muon content at the excess showers from the direction of Cygnus X-3 is only slightly less (67 %) than that obtained from a typical proton shower. Similar conclusions have been reached by the Los Alamos group (14). SOUDAN (68) and NUSEX (69) groups reported observations of 4.8 hour modulation in the flux of high energy muons arriving from the direction of *Cygnus X-3*. On the other hand, signals from *Cygnus X-3* detected by the Akeno group during 1986 depend upon the application of a muon poor cut(70).Ohya group (19) also observed UHE radiation from *Cygnus X-3* on the basis of muon poor cut.So it appears at least some of the showers from *Cygnus X-3* have much higher muon content than expected.Hence the situation is very confusing.

To resolve the discrepancy several proposals have been made so far.

i) Incomplete shielding of the muon detectors in the Kiel array allowed some photons *'punch-through'*.

ii) The observed excess EAS's was initiated not by gamma-rays but a new kind of particles (*Cygnet* ?).

iii)The cross section for hadronic interaction of photons is increasing in unexpected way with their energy.

Stanev et al (71) suggested that some of the penetrating particles in 'gamma-induced' EAS from *Cygnus X-3* observed by the Kiel group using a single layer of flash bulbs under 880 gcm^{-2} concrete may be 'punched-through' photons rather than muons.However they concluded that only 30 % of the muon density might be explained in terms of *'punched through'* photons assuming an overall detection efficiency for gamma-rays of 40 % for the neon flash bulbs.

Several authors (72,73 ,74) proposed that the experimental data require the introduction of a new particle. The properties of the initiating particles of the detected excess showers are very tightly constrained as discussed above.The Los Alamos experiment has seen a signal from *Hercules X-1* having a period of 1.24 s .Further the showers came in bursts and arrival time within each burst has periodicity that is characteristics of the period of *Hercules X-1*.This periodicity restricts the rest mast of the particle within few MeV.If the neutral particles are not photons then such low mass particles should have been seen at accelerators.

One possible explanation of the phenomena would be that the cross section for hadronic interaction of photons is increasing with their energy. Except for the differences in the magnitude of the cross-section , the photon-hadron elastic and inelastic reactions behave very similarly to the corresponding pion-hadron reactions at accelerator energies. This behavior can be well explained by theoretical model known as *Vector Meson Dominance* model of photon.The model assumes that photons interact with hadrons by first changing into neutral vector mesons ρ^0, ω^0 , ϕ^0 ,ψ^0 etc.Then the vector mesons that are created interact with the hadrons.The model is usefull in explaining the experimental photon-hadron interactions data.On the basis of the model Beznukov (75) approximated the energy dependence of the cross-section of photo-absorption of real photon by proton which is given by

$$\sigma_{\gamma p}(s) = 114.3 + 1.647 \ln^2(0.0213\ s)\ \mu b$$

where s is substituted in GeV.The photo-nuclear cross-section is in general extrapolated at the air shower energy using the above or similar expressions and used to predict the muon content in a EAS initiated by a gamma-ray photon of primary energy 10^{14} eV or more.But it may happen that gamma-rays have unexpectedly high photo-nuclear inteaction cross sections. A possible mechanism for that has been given by *Drees and Halzen* (76). According to them gluon structure of high energy photons can be the origin of large photoproduction cross section.*Wdowczyk and Wolfandale* (77) have studied the consequences of adopting this hypothesis for EAS. They found no experipental objection against the validity of the hypothesis and in certain cases the description of the experimental data is even better.However still at energies 10^{14} to 10^{16} eV the photoproduction cross section will remain very much small than that of pair production and as long as cross section of photoproduction is very much less than that of pair production the basic features of gamma-ray initiated showers will be unaltered (78). Recent *HERA* (79) results demonstrated that 100 TeV gamma ray initiated showers should in fact be muon poor.

The shower '*age*' is another possible distinguishing feature between gamma-ray initiated showers and hadronic showers.Though a number of authors opposed this idea.

Shower 'age' in gamma-ray initiated showers :

The shower '*age*' parameter, s,is used to characterise the shape of the lateral distribution of photon-electron component in EAS.It is usual to fit the same form of lateral distribution to all EAS's without regarding the nature of the primary particle.Showers that develop early in the atmosphere have on the average larger 'age' than late developing showers of equal primary energy. The energy in an electromagnetic cascade, as it penetrates the atmosphere is attenuated much faster (radiation length 37gmcm^{-2}) than that in a nuclear-electromagnetic cascade in which the energy is carried forward through the relatively stable hadrons (interaction length ~80 gmcm^{-2}).So it was thought that gamma-shower would look much older than normal showers.This philosophy was adopted in numbers of observations and also worked in many of those cases.The Kiel Group observed (1) that the signal from *Cygnus X-3* only in the high (.1.1) 'age' showers.Ooty group (13) obtained a 3.4σ excess in the *Cygnus X-3* direction only when a cut is made at s>1.4 (rejecting 66 % of the data). By selecting showers of age >1.3 an excess over background of 3.8 σ is observed by the MSU group(80) .The Adelaide group (38) made a similar 'age' cut and found the signal from Vela X-1. However no 'age' cut was used in the successful search by the Haverah Park group (11) for evidence of UHE emission from *Cygnus X-3*.

Fenyves (81) from his simulation results opposed the idea of making 'age cut' to discriminate gamma-induced showers from normal showers. *Hillas* (82) and *Cheung and Mackeown* (83) also reached at similar conclusion from their monte carlo simulation results.Thus making 'age cut' to differentiate gamma-ray initiated showers from large background of hadron initiated showers is a controversial question.

Thus a serious problem regarding the nature of the primaries of the observed excess EASs from the discrete point sources arises.

1.3 Aim of the present work :

The aim of the present work is twofold

i) an investigation on the muon component and electro-magnetic component of the EAS to study the nature of the initiating primary particles of the excess extensive air showers from the direction of celestial point sources as observed by several EAS groups.

ii) a search for celestial discrete UHE sources by the EAS technique.

As discussed in the previous section the nature of the radiation emitted by several observed discrete UHE point sources is very confusing. UHE gamma photons are assumed as primaries of such EAS but the excess EAS did not have the photonic signature.The muon content of the excess showers found to be comparable with that of the normal showers and those showers are characterised by high shower 'age' value.Since shower 'age' represents a measure of the longitudinal development of the EAS and muon number does not change much with the atmospheric depth after the maximum development of shower reaches while shower size decreases rapidly with the increase of shower 'age' there is a probability that the high muon content of the observed excess showers from point sources is due to high shower 'age' value.Considering this possibility the variation of the ratio muon density to particle density with shower age at particular radial distance from the shower core for a fixed shower size will be studied.

Monte carlo simulation results (1,2,3) show that 'ages' for gamma-ray initiated showers are nearly same as that of charged cosmic ray initiated showers though in many observations it is found that the signal from different discrete sources is contained only in high 'age' showers.In most of the observations the EAS 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.With the increase of zenith angle the atmospheric thickness increases , so it may happen that the high 'age' values of the excess showers from the direction of point sources is due to high zenith angle of the showers.Taking this possibility into consideration a variation of shower 'age' with zenith angle will be examined.

The present situation of the observation of the discrete UHE sources is also very confusing as discussed in the last section.A number of observations indicate the presence of UHE radiation from some point sources while negative evidences are also reported.Initial observations indicate a steady flux of EAS from the direction of Cygnus X-3 and few other sources.But most of the recent observations unable to detect such emissions. Some of the observations reported the nature of the emission as sporadic.The flux of emission of radiation from the point sources, particularly from Cygnus X-3 is reported to change by considerable amount during last fifteen years.The Cygnus X-3 is appeared as a variable source.To clearly understand the nature of emission from these sources it is necessary to observe the potential UHE point sources by a large number of EAS arrays spread over the surface of the earth .The NBU EAS array is capable (latitude 26.7^0) to observe the potential UHE point sources of northern hemisphere like Cygnus X-3 , Hercules X-1 , Crab nebula etc very effectively.In the present investigation a search has been carried out to observe continuous emission of UHE radiation from four potential UHE sources - Cygnus X-3 , Hercules X-1,Crab nebula and Geminga.The emission of flux from Cygnus X-3 and Hercules X-1 that has been observed previously as modulated by the orbital periods of the respective objects which are nearly 4.8 h for Cygnus X-3 and 1.7 day for Hercules X-1 has been reexamined.