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Radiation from the Crab

For millennia, human beings have obtained a view of the universe in the visible part of the electromagnetic spectrum because nature has endowed them with eyes which senses only light. In the last few decades, man has built for himself instruments sensitive to invisible wavelengths. These extend his 'vision' from the infrared to microwaves and radio waves on the one side and the ultraviolet, X-rays and gamma rays on the other. He has also lifted these instruments into space to study the radiations which are normally absorbed by the earth's atmosphere.

The inspiration to do gamma-ray astronomy came when Philip Morrison suggested in 1958 that objects like supernovae and supernova remnants could produce high-energy gamma rays. This electrically neutral radiation is unaffected by the galactic magnetic fields and hence travels in straight lines like light. A triumphant confirmation of Morrison's predictions was made when the satellite SAS-II detected gamma-ray emission from several sources in the sky including the Crab and Vela nebulae. Gamma rays are known to be associated with some of the most energetic and enigmatic processes in the universe like solar flames, nova and supernova explosions, white dwarfs, neutron stars, black holes, dense interstellar clouds in the Milky Way, cores of active galaxies and quasars. Gamma rays are also ideal for the study of such phenomena as they can penetrate dense regions of space that normally obscure emissions at other wavelengths.

Unfortunately, there are no simple ways to detect gamma rays of energies less than a billion electron volts (10^9 eV) as the earth's atmosphere absorbs them (without producing any easily detectable secondaries).

Workers at the University of Kiel (Stamm and Manfred) had set up arrays of air-shower detectors consisting of scintillators which emit a flash of light when energetic particles enter them and which in turn can be detected by photomultiplier tubes. They discovered mysterious particles with energies exceeding 10^{15} eV coming from the direction of Cygnus X-3. Obviously, the incoming primary radiations could not have been charged cosmic-ray particles (the trajectories would then have been scrambled by the galactic magnetic field). The primary radiation therefore should have been either electrically neutral particles or gamma rays. Thus these observations became of vital importance as they opened up a window to some of the highest-energy processes that occur in the universe.

When the high-energy gamma-ray photons hit the earth's atmosphere, they generate secondary particles and air showers that are similar to those caused by cosmic rays. It is certain that the Kiel workers detected these air showers.

The secondaries arising from the 10^{11}-eV primaries do not have sufficient energy to reach the earth's surface. But there is a cunning way by which they can be detected on earth. Some of these particles travel at speeds greater than that of light in the air but less than that of light in vacuum. Such particles emit characteristic pulses of blue light (Cerenkov radiation) which can be detected by simple parabolic mirrors with photomultipliers at their foci.

Are the primary radiations coming from the Crab, Vela, Cygnus and Hercules gamma-ray photons? Cosmic rays also produce air showers and amongst them there is an abundance of muons (heavy and highly penetrating relatives of electrons). Gamma-ray primaries would trigger muon-poor showers. Most of the air showers observed so far appear to be muon-rich. This is most puzzling.

As stated earlier, primaries must be electrically neutral. Is there a new type of neutral particle involved? We must remember that data are still inadequate as very-heavy-energy gamma rays are extremely rare; typically only a few of them strike a given square metre of the earth per month.

Trevor Weekes of the Smithsonian Astrophysical Observatory reports that at the Whipple Observatory using the direct array at the prime focus of the 10-metre reflector his group has established that the Crab nebula is a steady source of gamma rays at energies greater than 10^{12} eV, so steady that observers can calibrate their instruments using this radiation from the Crab. Some astrophysicists feel that through all the stages of travel of the 10^{12}-eV gamma-ray photons from the supernova remnant to the earth's atmosphere they have understood the actual processes of interaction and these are in accordance with theoretical predictions. This is definitely not so for many other sources, e.g. Cygnus X-3 and Hercules X-1. M. V. S. Rao and B. V. Sreekantan who are a part of the TIFR group working at Ooty and Pachmarhi, using many of the techniques described, review (page 617) the problems associated with energetic radiations coming from the Crab.