NEWS AND VIEWS

A Record Cosmic Ray Primary?

An extremely large extensive air shower (EAS), caused by a cosmic ray particle incident on the atmosphere, has been observed by the air shower array of the Institute for Nuclear Study, University of Tokyo, and recently reported by K. Suga and colleagues (*Phys. Rev. Lett.*, **27**, 1604; 1971). Their analysis indicates that the total number of particles in the shower at sea level was $\sim 2\times 10^{12}$. This suggests that the energy of the primary particle that produced the EAS was $\sim 4\times 10^{21}$ eV.

The highest primary energies reported from other large EAS arrays have been $\sim 10^{20}$ eV at Volcano Ranch in the United States (J. Linsley, *Phys. Rev. Lett.*, **10**, 146; 1963), $\sim 10^{20}$ eV at Haverah Park, England (D. Andrews *et al.*, *Acta Phys.*, **29**, *Suppl.* 3, 343; 1970), and $\sim 2\times 10^{20}$ eV at Narrabri, Australia (R. G. Brownlee *et al.*, *Acta Phys.*, **29**, *Suppl.* 3, 377; 1970). The Japanese thus claim that their event has at least ten times more energy than any cosmic ray primary observed previously. The presence of such particles in the universe, even with an extremely low flux, is of considerable astrophysical and cosmological importance. But the processes by which particles can be accelerated to these enormous energies are unknown. Suga and colleagues point out that the directions of a pulsar, AP 2015+28, and a radio source, 3C409, are inside the uncertainty of the arrival direction of their event ($\pm 4°$). The direction of a cosmic ray proton of energy 4×10^{21} eV reaching the Earth from either of these sources would not be seriously affected by the intervening magnetic field.

Two chief problems arise in reaching an accurate value for the energy of the primary particle initiating an EAS. The central core of the EAS must be well located to enable the observed samples of particle density to be used to calculate accurately the total size of the shower. Certain assumptions must then be made about the nuclear processes in the atmosphere in order to obtain the relationship between shower size and primary energy.

The problem of the location of the core turns out to be the chief source of possible error. The density of particles falls off rapidly with distance R from the central core of the shower, roughly as $R^{-3.5}$. Thus an error in the location of the core can cause the size of the shower to be in error by a considerable amount. It has been pointed out that it is possible for large errors in the core location to occur if the core of the shower happens to land outside the perimeter of the detector array, such as is the case with the large event observed by the array at the Tokyo Institute for Nuclear Study.

At the time of the event three detector stations, each with a pair of 2-m^2 scintillators separated by 50 m, were being operated. The three stations made up a triangle with sides 1,890 m, 1,350 m and 850 m. A small but complex array of detectors, situated just inside one side of the triangle, 300 m from one of the stations, was also operating. This detector complex consisted of twenty-two unshielded scintillation detectors of 1 m^2 distributed over a circle of diameter 100 m, a 20-m^2 spark chamber and two 8-m^2 scintillation detectors underground at a depth of 5 m and 15 m to observe muons with energies above 1.5 GeV and 5 GeV. This particular EAS gave particle densities of 36 ± 9 m^{-2}, 80 ± 6 m^{-2} and greater than 281 m^{-2} at the three outer detector stations and a density of $2{,}050\pm 110$ m^{-2} averaged across the 100 m of the small array of detectors.

The direction of arrival of the shower with respect to the Earth's surface could be classified as near vertical (zenith angle $\theta=20\pm 4°$). The right ascension and declination of the arrival direction were $\alpha=20$ h 14.5 min and $\delta=24°$.

The location of the centre of the shower on the ground was estimated by assuming a form for the lateral density distribution of charged particles away from the core and took into consideration that the range of observed densities across the small 100-m array was comparatively flat. Their analysis places the core some 690 m from the centre of the small EAS array and about the same distance outside the triangle formed by the three outer stations. Assuming this core location to be correct, the total particle size of the shower was then calculated as $\sim 2\times 10^{12}$ particles.

The accuracy of the core location, well outside the array, must come under some suspicion. Moreover, the detailed distribution of particle density across the small array for this event which was presented by Suga and colleagues at the Twelfth International Conference on Cosmic Rays, Hobart, 1971 (not included in the conference proceedings) shows large fluctuations between neighbouring stations and cannot strictly be called uniform. Furthermore, the muon densities as measured by the underground detectors might indicate that the core is closer to the detectors than is claimed.

There is, however, no question that this is one of the largest showers ever recorded. Even ignoring the density measured at the detectors of the small array, the primary particle must be assigned an energy greater than 10^{20} eV independent of the location of the core. This shower must therefore be added to the increasing number of cosmic ray primaries observed with energy $\gtrsim 10^{20}$ eV. This is in apparent contradiction to the predicted cutoff in the energy spectrum of cosmic rays at $\sim 5\times 10^{19}$ eV due to interaction with the universal 3 K microwave radiation. The explanation might be that these very high energy cosmic rays are produced fairly locally, and it is interesting that the Haverah Park group point out that one of their highest energy events also comes from the general direction of a pulsar, PSR 2218+47 (D. Andrews *et al.*, *loc. cit.*). The total number of very large events is still rather small, however, and they give no evidence for a preferred galactic source. Only when more events have been recorded will it be possible to say whether or not the highest energy cosmic ray particles arrive preferentially from the centre of the galaxy and to comment on probable sources.—From a correspondent.