

DISCUSSION

W. F. G. SWANN, *Bartol Research Foundation, Swarthmore, Pennsylvania*: There are a few points rather of interest in connection with the mechanism. In order to get these energies, one does not need to have a field of the order of magnitude of those in sunspots, one only has to have a suitable rate of change of field. Thus for example, in the calculations to which Dr. Vallarta referred, made some years ago, it was found that a charged particle attains an energy of 10^{10} volts in one second before the field had grown to more than 0.002 gauss. Now it doesn't matter which way the field is going, you still get this phenomenon. So even though you do not have sunspots, if you have magnetically disturbed areas over the sun, where the field is changing, you nevertheless have the conditions necessary for the production of these high energies. And you do not have to have fields which would be observable by the Zeeman effect or any other such effect.

Now over most of the sun, the main, dipole field would suppress the emission of cosmic rays produced by this mechanism. But I think it is perhaps interesting to meditate upon the possibility of cosmic rays produced by these local fluctuations emerging from polar regions where the difficulty in getting out is not so acute as it is in other places. When one meditates upon this thing perhaps happening in all the stars, it once more raises the question of the stellar origin of a large portion of cosmic radiation.

Finally, when Professor Vallarta referred to my former suggestion of the sunspot mechanism, and was so good as to christen the device a "cygnatron," I decided to tell you the complete story of this matter. Yes! Indeed, I did devise this machine. It was about the time when the Lucifer was turned out of Heaven. However, it was found, when the machine was put into operation, the eggs which this cygness laid were bad eggs because when they struck the earth's atmosphere, they disintegrated into mesotrons and things of that kind. It was for that reason that I was fired from my job and sent into purgatory, where I have remained until my present life. Following my discharge, the matter was put into the hands of the devil. Now the

devil had been my assistant in this matter, and I felt very badly about it because all that he knows he had from me. (I, of course, mean all that he knows about the machine.) However, the devil really didn't understand the problem. I had it all worked out so that we would have a very nice theory of cosmic rays which offered much consistency so the theoretical physicists of a later epoch would have a good time in harmonizing everything. Well, the first thing the devil did was to put a magnetic field on the sun which greatly complicated the process of getting the cosmic rays out. Then he put a magnetic field on the earth which further complicated matters terribly; and it is for such reasons as this that the subject of cosmic rays is in such a hell of a mess as it is today.

LEVERETT DAVIS, JR., *California Institute of Technology, Pasadena, California*: There is one point that I think should be made. If the sun does have a permanent magnetic of the order of 50 gauss at the poles and if it does rotate, then there must be electrostatic potentials of the order of 4 billion volts in the surrounding space. This is due to the charges induced on the moving, conducting sun. The reason that these potentials do not produce a constant outpouring of 4-billion volt cosmic rays from the sun is that the many ions in the neighborhood of the sun carefully distribute themselves so that the electric field produced by the combination of the induced charge and the space charge will always be perpendicular to the magnetic lines of force. Then nothing can come out. But if the magnetic field is suddenly changed, this equilibrium will be destroyed, and ions will be accelerated by the space charge along the lines of force of the new magnetic field. Thus, we have a subsidiary mechanism for the production of cosmic rays that must be considered in addition to the mechanisms proposed by Dr. Swann. Probably a more important aspect of the situation is that the 4-billion volt electrostatic field in the neighborhood of the sun will greatly complicate your calculations of orbits.

In connection with the stellar production of cosmic rays there is an additional point to be

considered. The total energy that we observe in cosmic rays is of the same order of magnitude as the energy that comes to us from the stars in the form of light. Hence, if cosmic rays are produced by the stars and travel essentially in straight lines, the stars must put energy into cosmic rays at the same rate that they put it into light. Since the only sufficiently large source of energy for starlight is nuclear energy, it follows that the energy for cosmic rays would have to originate from nuclear sources.

OLIVER R. WULF, *U.S. Weather Bureau, Washington, D. C.*: Are there not two terrestrial effects associated in general with solar flares that may in some measure influence the intensity of the penetrating component at the earth's surface; on the one hand the change in the earth's magnetic field concomitant with the solar flare, and, on the other hand, the change in the average height at which the mesotrons are produced, as a result of the heating in the atmosphere caused by the absorption of the excess radiation from the solar flare?

SCOTT E. FORBUSH, *Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D. C.*: Intense solar flares produce an increase in the strength of the upper atmospheric current system which is responsible for the diurnal variation in the earth's magnetic field. This increased strength of the current system, in the daylight side of the earth, is undoubtedly caused by an increase in upper atmospheric conductivity produced by the ultraviolet radiation from the flare. The normal diurnal variation in the Earth's field has, if anything, only a small effect on cosmic-ray intensity since the amplitude of the diurnal variation in cosmic-ray intensity is only 0.2

percent. Since a solar flare probably never increases the normal diurnal variation in the earth's field by more than a factor of two, it is evident that its effect on cosmic-ray intensity would be negligible compared to the increases we are discussing.

Regarding the possibility of these changes in cosmic-ray intensity, which arise from a change in the height at which mesons are produced, as a consequence of the heating effect of the flare-radiation on the atmosphere—it seems difficult to believe that such changes would occur simultaneously on the daylight and dark sides of the earth as would be necessary to explain the observed cosmic-ray effects.

The Latitude Effect of Cosmic Rays at 30,000 Feet

H. V. NEHER, *California Institute of Technology, Pasadena, California*: Through the co-operation of the Office of Naval Research and the Air Forces, a flight was made at 30,000 feet in May and June of 1948 from Hudson Bay to Peru following the 80th longitude. Part of the data taken on this trip included the measurement, with two completely independent cosmic-ray telescopes, of the ionizing radiation within $\pm 15^\circ$ of the vertical at that altitude. These measurements show no appreciable latitude effect at this altitude above 50° geomagnetic north and also no appreciable change from the geomagnetic equator to about 10° geomagnetic north. In between these latitudes the results show no pronounced deviation from a smooth curve. The total ionizing radiation at this altitude decreases by 36 percent from the northern plateau to the equator.

A more detailed account of these experiments will be published elsewhere.