independent considerations. Towards the minimum of solar activity not only the growth of Δt exists but also that of ΔT, where ΔT is the duration of the geomagnetic disturbance. This growth of ΔT with the phase of solar cycle may be naturally explained if we admit the existence of a certain spectrum of velocities Δv in the stream. It follows from the graph connecting Δt and v, that for some fixed Δv the value of ΔT grows with the decrease of the mean velocity $\bar{v}$ of the corpuscles in the stream. It follows immediately from the graph connecting v and Δt that this effect is essential only for small velocities (from 100 km/sec to 300 km/sec) and this confirms independently their reality.

A careful inspection of geomagnetic disturbances observed before the years of minimum activity shows that often the mean *amplitude* of variations of the Earth's magnetic field strength is not changed sensibly with time (during the whole disturbance) or changes very slowly. Now if there exists a spread of velocities in the stream (even not a very large one) then it is natural to expect that this amplitude must be noticeably diminishing from the beginning till the end of the disturbance. Indeed, if all the energy of the corpuscles is mainly the kinetic energy of their translational motion (as it has been generally assumed), then the flux of this energy must be noticeably larger at the beginning of the disturbance than at the end. This contradiction led the author to consider that in many cases the total energy of the 'frozen' magnetic field of corpuscular condensations may considerably exceed the kinetic energy of their translational motion.

2. SOLAR FLARE COSMIC RAYS

J. A. SIMPSON

The rare solar flares which produce large quantities of cosmic rays arriving at the Earth enable us to study the acceleration of charged particles and their propagation in the solar system. The present paper discusses some of the main results derived from the most out-

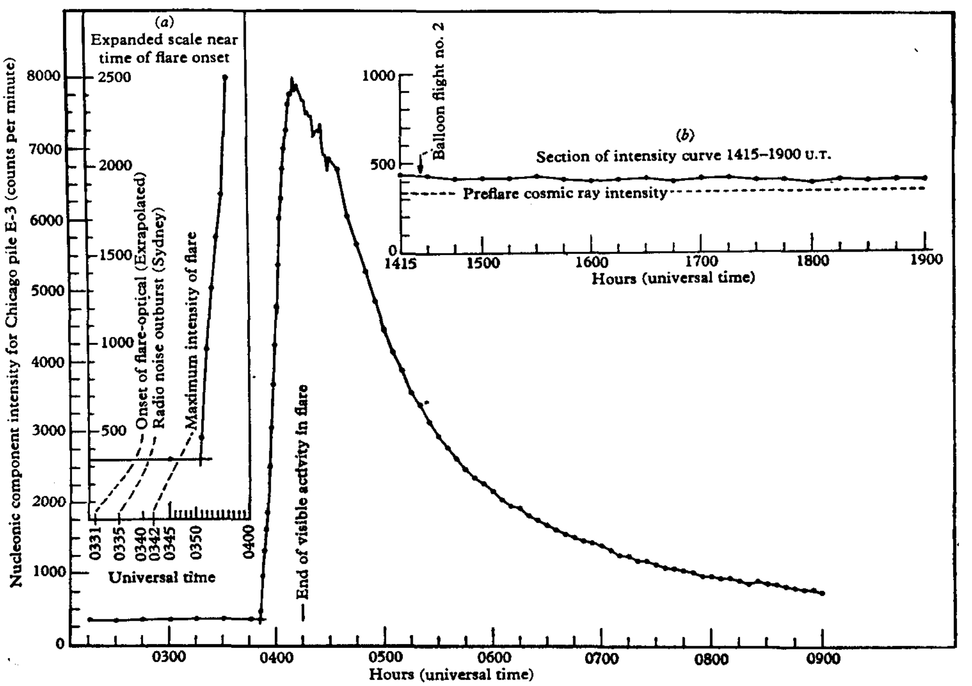

Fig. 1. Typical observation of flare cosmic rays arriving at the Earth.

standing of these events (the flare of 1956 February 23) and their bearing on astrophysical questions such as the total flare energy, the solar source for this energy, and the flare contribution to the prevailing level of cosmic radiation.

The main experimental results are summarized briefly as follows: Fig. 1 gives a typical observation of the flare cosmic rays arriving at the Earth as a function of time. Fig. 2

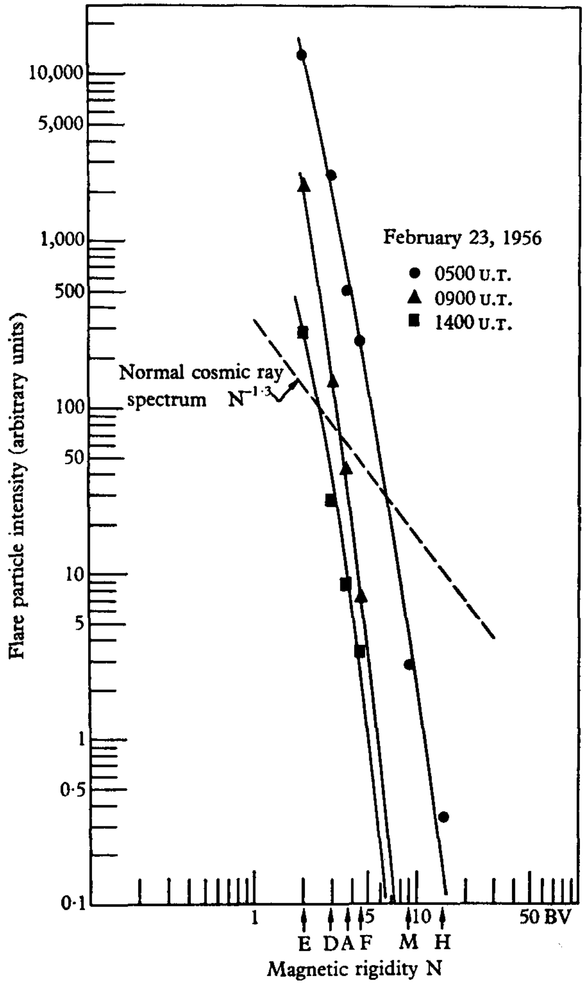

Fig. 2. The derived spectrum of protons in the vicinity of the Earth.

shows the derived spectrum of the protons in the vicinity of the Earth. The energy distribution extends from below 2 BeV to above 25 BeV. From these results, and the evidence that the excited region on the Sun had disappeared within one hour of the flare commencement, we concluded that the continued arrival of charged particles for an additional fifteen or eighteen hours requires the production of cosmic rays at the Sun for substantially less than an hour followed by their storage in interplanetary magnetic fields for the order of many hours. These observations provide the most direct evidence at the present time for the existence of magnetic fields in interplanetary space. The possible field configurations which satisfy the experimental observations are discussed elsewhere.

From the knowledge that these solar cosmic rays are stored, and from a determination of particle flux incident at the top of the atmosphere over the lifetime of storage, we determine the lower limit for the total kinetic energy in solar produced cosmic rays as $> 10^{30}$ ergs. The steep spectrum in Fig. 2 emphasizes that the main contribution is from particles $\leqslant 2$ BeV, or that $> 3 \times 10^{32}$ relativistic particles were produced and *not* captured by the Sun. Independently various estimates by Parker and others for the total energy released at the flare site based upon observed 'white light' or Hα emission yields $\geqslant 10^{32}$ ergs. Thus relativistic particle production is $\leqslant 1\%$ efficient.

From the volume of the optical flare it is clear that the average energy density available for the flare process exceeds 10^3 ergs/cm^3. Since such a high energy density cannot be created by drawing energy from surrounding regions of the Sun at the time of the flare, this energy must have been *in situ* prior to the flare. The only known energy storage is by magnetic fields. For fields of the order 10^3 gauss, only a portion of the field need be destroyed to provide the necessary energy. (At this conference Severny has shown striking magnetograph evidence for the partial destruction of magnetic fields which occupied the region of a flare.)

The acceleration of the particles in the unstable magnetic fields within the flare remains a major problem, although the Fermi mechanism is the most likely mode. A decision in this matter will come from a study of future flare cosmic ray increases to determine whether He^{++}, carbon, and heavier stripped nuclei are also accelerated to high energies in flares.

Although a solar origin for *all* low-energy cosmic rays is unlikely because of the observed short storage times in the solar system, there remains the question of whether the solar-flare effect contributes a sufficient yield of particles to the galaxy to be typical of the average injection required by stars for sustaining the galactic level of cosmic radiation. From a total kinetic energy for cosmic rays in the galaxy of approximately 10^{55} ergs, an 'average' star must inject nearly 5×10^{28} ergs/second in cosmic rays. The solar flare output is too small by a factor exceeding 10^6. Thus, if particle injection to the galaxy is by a flare mechanism, the Sun is not a typical injector. However, flares may not be the only possible mode of injection by the Sun.

3. DISCUSSION

REMARKS BY T. GOLD

The new results obtained by Van Allen in the U.S. and by U.S.S.R. scientists with the aid of satellites have much relevance to the discussion of magnetic storms and aurorae, and so has the new knowledge obtained by means of the cosmic ray investigations.

Van Allen concludes that there exists a flux of mean energy at least of the order of 10 ergs/cm^2 in the form of particles, probably both electrons and protons, mostly of the order of 50 keV particle energy but with a spectrum extending to several MeV. This flux commences at a height of 400 km and reaches the quoted intensity at the maximum height of the observation, namely 1600 km. At this height the intensity is still increasing with height, and therefore even higher values of the flux are expected. To date the observations have not been carried out for long enough to know much about variations in time; but as the flux is similar to that observed in the auroral regions at a lower level it is very tempting to think of this as associated with the auroral phenomenon, and thus variable in intensity. The occurrence of a bright aurora may then be caused by the flux being temporarily augmented and reaching down to lower levels.

Particles of this sort can be stored in the Earth's field, for there is a family of captured, stable orbits that go from one hemisphere to the other spiralling around the lines of force, and that suffer reflexion in the converging field at a height such that collisions with atmospheric gases is inappreciable. An intensification of such a flux of captured particles would account for the auroral phenomenon. But it is necessary to find the mechanism whereby particles can be put into these orbits.