Comments and Discussion

Biermann, L.: Supplementing the discussion of subject B – transmission of solar particle radiation through interplanetary space – to which part of Dr. Gold's contribution and that of Dr. Rossi referred – I would like to draw attention to the fact, that the comet tails provide useful background information for any synthetic theory of the earth storms (see also Dr. Lüst's contribution to plenary session IP of September 9). Evidently to the extent to which we understand what is going on in the comets, we can regard them as space probes provided by nature: we have observations of many past comets, and these cover indeed long periods of time both at high and at low level of solar activity. It is fortunate, that this recent observation from Explorer X allow to test, which predictions based on comet observations were verified and otherwise.

Since the accelerations of the plasma tails of comets had to be ascribed to the interaction with the solar corpuscular radiation, the most direct conclusions pertained to the radial direction and to the continuous character of the particle flux from the sun. The detailed discussion, especially of the correlation with solar activity gave furthermore information on the average velocity of solar particle streams, on the spiral pattern of the recurrent streams from active ("M") region and on the particle density (from considerations on the mechanism of ionization). As to the question of the prevailing mechanism of interaction, by which momentum is being transferred from the solar stream to the comet tails, no final choice between the several theoretical possibilities could be made from the observations of comets alone.

The results obtained from Explorer X confirmed in a general way most of the points made above, only the particle density was found to be lower than expected and the magnetic fields seem to play a more important rôle in the transfer of momentum than had appeared likely before.

As a consequence it appears possible to regard the comets tails already as probes for the velocity field of the solar corpuscular radiation in interplanetary space. The interpretation of those features in the comet tails, which indicate the action of magnetic fields, is not yet unambiguous, only further work will reveal, to which extent they can be used in a similar way.

Roederer, J. G.: I would like to bring up again our results on the sweeping away effect of plasma clouds on a pre-existing, trapped solar particle flux. It would be interesting to search systematically on whether this sweeping effect does or does not occur simultaneously for low energy particles, such as measured in PCA events or high altitude exposures. I think that the experimental results on this point would probably give quite definite information on the "roughness" parameter of the magnetic field in the plasma bottles, or on scale parameters of the field which govern the blast wave propagation. Further I would like to bring up a further point on which we have been working in Buenos Aires, and that is the superposition effect on galactic cosmic ray modulation of successively emitted plasma clouds or blast waves. I think that the experimental results found with respect to this point, *must* be taken into account and explained by any model for Forbush decrease mechanism.

Cole, K. D.: In the bulk of theory related to this topic the propagation of disturbance downwards from the magnetosphere to the ionosphere is considered. I wish to draw attention to general problem of the reaction, produced by the ionosphere, which affects the magnetosphere. Specifically, I wish to mention three points.

1. Those currents flowing in the ionosphere which produce geomagnetic disturbance cause joule heating. Supposing a uniform distribution of electron density as a function of height, it follows that this heating peaks at 150 km height. This heating covers as many orders of magnitude as geomagnetic disturbance. However at moderate disturbance in the auroral zone, temperature increases of order 1000°K at and above 150 km appear feasible. This heat source would affect scale heights above about 130 km and

would cause a geomagnetic disturbance fluctuation in them, especially at the auroral zone. These increased scale heights would result in the gradual lowering of mirror points of geomagnetically trapped particles. The $j \times B$ (the Lorentz) force could, at times of moderate disturbance, support a pressure at (say) 200 km equal to that at perhaps 130 km at lower latitudes.

2. Hydromagnetic waves emitted upwards by fluctuating filaments of current in the auroral ionosphere would appear greatly Doppler shifted to trapped particles (Cole, this conference). The violation of conditions for adiabatic invariance may be effected by these waves especially for protons.

3. Those electric fields in the ionosphere causing disturbance electric current may cause, in the magnetosphere, motion patterns principally near the 6h meridian plane. This is a slight variation on the general theme introduced earlier by Gold.

Hines, C. O.: Professor Singer has pointed out a disagreement between theory and experiment in the matter of the distribution of ionization and neutral gas at great heights. It is easy to show that the polarization field of the quiet-day dynamo system, when extrapolated to the magnetosphere, introduce forces which are quite comparable to the gravitational and centrifugal forces that have so far been included in the theory. This statement corresponds exactly to that which Professor Gold has been making, that magnetospheric convection must be considered. The enhanced polarization fields at times of storms would further affect the problem, and can in fact also alter the distribution of neutral gas.

Academician Vernov has suggested that two mechanisms are required to provide both the storm-time and the background outer radiation belt. I would like to suggest, instead, that one mechanism would suffice if a quiet-day solar breeze exists in addition to the storm-time solar plasma clouds. Injection by a single mechanism would then provide for the observations, simply by a change in effectiveness of the process depending on the flux of the available solar particles. Such a mechanism, employing the intermediary of a ring current, is incorporated in the theory developed by Dr. Axford and myself, and is discussed in our full paper (Canadian Journal of Physics, **39**, 1433-1464 (1961)).

Sekido, Y.: About the origin of the interplanetary disturbance magnetic field, Dr. Gold mentioned that at present we cannot know whether it is due to the sunspot field brought out or pre-existing interplanetary field compressed. I would like to suggest that the latter case may be ruled out, because Forbush decrease of cosmic ray takes place only when there was solar flare associated with type IV radio outburst. According to the latter assumption of pre-existing field, we must expect Forbush decrease when there is large solar flare even if there is no type IV radio outburst. This is not the case. And the explanation of geomagnetic storm, as discussed in this session, need not the existence of magnetic field in the interplanetary plasma, but only particle density. Now, I think we can conclude that magnetic field brought out from the sun is responsible for Forbush decrease, on the other hand particle flow from the sun is responsible for magnetic storms.

Simpson, J. A.: My comments are concerning the interesting contributions of Prof. Vernov and Prof. Hayakawa on the outer belt electrons.

1. Prof. Vernov suggests that the tendency for the outer belt electron intensity to return to roughly its pre-storm level indicated that two kinds of acceleration processes are operative in the outer belt. I would point out, however, that Explorer VI experiments show the mirror-point distribution along a line of force in the outer belt (after having been concentrated at the equator due to an irreversible acceleration process) gradually returns to the undisturbed mirror-point distribution while irreversible energy loss in the belt is taking place. This suggests that there is some dissipative process which acts strongly during enhanced intensities, but is not effective for the quiet period mirror-point distribution. For example, an instability or synchrotron effect might be operative.

If so, only one local acceleration process need be invoked to account for all the observation so far.

2. Prof. Hayakawa has remarked on the

possibility that local acceleration in the outer belt might occur during times of high geomagnetic disturbances. From Explorer VI we find that an irreversible energy gain of about a factor two in the belt energy takes place near the end of the magnetically disturbed period, and we tried to agree that small scale magnetic fluctuations are intimately connected with this acceleration. For example, it is possible that protons are first accelerated in the initially larger scale magnetic disturbances (*viz.* the early increase of the scintillator counter intensity on Explorer VI) followed in time by electron acceleration as the magnetic irregularities inevitably decrease in scale size (*viz.* the later increase in the electron flux in Explorer VI).

3. Finally the proof that large increases of electron intensity at the equator may take place while no appreciable change is detected at the high latitude "tips" of the belt until days later emphasizes the danger in analysing and interpreting data on the outer belt derived from low latitude satellites, which do not reveal what is going on in the center of the outer belt near the equator.

Kellogg, P. J.: None of the speakers have mentioned the observations of solar proton magnetic cutoff at Minnesota, and their interpretation. I would like to emphasize the importance of these observations for understanding the behavior of the radiation belts and of magnetic storms. Briefly, the geomagnetic cutoff at Minneapolis, Minnesota is much reduced during the *main phase* of a storm. These observations are best explained, without any new assumptions, by attributing the reduced cutoff to a ring current. When this is done, new information about the ring current, namely its radius, is obtained, and further, it is necessary that the ring move in late in the storm. It seems very likely that this represents the supply of energy to the outer Van Allen zone. Since changes of total energy in the trapped radiation are reflected in the earth's surface field, the storm must represent the only time when extra energy is added to the trapped radiation. (Although a steady supply of energy, balanced by a steady energy loss, would not show in observations of the surface field).

Gold, T.: I would like to refer briefly back to the point made by Dr. Vernov and Dr. Simpson concerning the question whether two mechanisms are needed to account for the steady background level of the outer radiation belt or whether only one mechanism might be sufficient. One has to realize that the pressure of captured particles in the magnetic field would not need at all to be comparable with $H^2/8\pi$, but could be great deal less than this value, and still will be responsible for producing a convective motion in the magnetosphere. It is therefore not to be excluded that the flux itself will arrange for an instability of the plasma, which in turn will redistribute the flux, so that it sets itself up to a particular stable pattern. In that case one injection mechanism would suffice. If the decay is not an exponential one due to collisions but is due to the rearrangement of the magnetosphere into a particular stable configuration, the stable background level might then just correspond to the steady configuration. An important point is that even though the fluxes are small compared with $H^2/8\pi$, they can still be perfectly large enough to be responsible for such a rearrangement.

Singer, S.F.: Dr. Kellogg has mentioned that the ring current seems ot move inward during a storm, i.e. as it decays. On the other hand, if the current is due to protons which are removed by charge exchange, then the current should move *outward*. If electrons are responsible for the current, then its motion during decay is still an open question.