very beautiful cinematographic pictures of the coronal formations actually moving out of the way momentarily to let the bubble of gas go through. Then what can be said about the space further out? Let me just summarize what was discussed earlier. It is clear that the fields from the region where the gas originates will be drawn out into space by the moving gas. A big bulge of magnetic fields sticking into outer space must be formed. A magnetic region will be produced in space in which the particle velocity of the streaming gas will be mainly outward away from the sun as a consequence of the big explosion, but in which the magnetic lines of force will retain the configuration, at least for a while, that corresponds to drawing out the initial field.

From this point of view one can understand why flares don't have much of an east-west effect on the sun. The gas streams out more or less radially, therefore the central meridian is the best place from which it should come in order to reach the earth. On the other hand, there is strong evidence now that the fields after the outbursts do get twisted up by the rotation or an effect connected with the rotation of the sun, and one supposes it is much the same as with a water hose squirting out water, with individual water particles moving radially, but where the locus of the points on which are the successive particles is the shape of a spiral.

Now the last point I would like to mention is the recent evidence obtained by the MIT plasma probe and by the magnetometer used by the NASA group on Explorer X. This showed the medium out in space, at least on this occasion and possibly on other occasions to be very broken up. It seems to be broken up in such a way that there are individual regions in which either the magnetic pressure or the gas pressure dominates. It is perhaps possible to suggest, although of course the evidence is not yet conclusive, that by and large the situation is one of pressure balance across the lines of force, so that the magnetic field and gas pressures balance. This aspect is one that will require a great deal of further work experimentally and theoretically, before it is really understood. But it seems to me that it is a glimpse that we have of the detailed "solar system meteorology" which will no doubt become a large subject.

Particles in the Magnetosphere

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Thermal Particles

The bulk of the particles in the magnetosphere up to some 10–15 earth radii have thermal energies corresponding to the temperature at the base of the exosphere, about 1500 degrees.

Observational information is limited to rather low altitudes. The distribution of mass density below 800 km is known from analysis of satellite drag (King-Hele, 1959). The *integrated* thickness of the neutral hydrogen cloud around the earth is known from analysis of the profile of solar hydrogen Lyman-α (Purcell and Tousey, 1960). Electron densities up to 1500 km are known from rocket measurements (Berning, 1960). The electron density to several earth radii is inferred (with some uncertainty) from whistler observations (Smith and Helliwell, 1960; Allcock, 1959).

On the other hand the *relative* distributions of the neutral constituents can be deduced from a theory of the exosphere (Öpik and Singer, 1961). The neutral components describe ballistic orbits without collisions about the base of the exosphere (530 km) and the distribution of concentration with altitude is calculable in a fairly straightforward manner. The ionized components (having much larger cross section because of Coulomb interaction) are distributed according to the barometric formula (Johnson, 1960). In each case the slope (or scale height) is determined by the temperature at the base of the exosphere. Using the data referred to above for normalization, it is possible to construct a model of the exosphere (Singer, 1960). This model is shown in Table I.

Table I. Concentration of major constituents in the terrestrial exosphere (cm^{-3}).

r/R	O	O^+	H	H^+
1.100	1.2×10^7	5×10^5	10×10^3	—
1.200	2.7×10^4	2.5×10^4	6.6×10^3	9×10^3
1.300	1.7×10^2	1.7×10^3	4.4×10^3	6.6×10^3
1.400	1	1.3×10^2	3.1×10^3	5×10^3
1.500	—	11	2.3×10^3	3.7×10^3
1.75		$<.1$	1.25×10^3	2.1×10^3
2.00			8×10^2	1.3×10^3
3.00			2×10^2	3.5×10^2
4.00			82	1.5×10^2
5.00			43	85
6.00			25	51
7.00			16	33
8.00			12	23
9.00			9.1	17
10			6.5	11

Although the main features of the exosphere are well understood, there still exist some uncertainties and controversies. Some problems still remain: the question of helium and helium ions in the exosphere; the relative distribution of H^+ and O^+, and their interaction with electric fields; the H^+ distribution at high altitudes, which has never been placed on a firm theoretical basis; the "ducts" and curious condensations along lines of force in the H^+ exosphere; the question of the existence of neutral hydrogen atoms in bound orbits. The dynamics of the exosphere has never been treated nor has the diurnal variation or "hot spot" been extrapolated to higher altitudes.

Fast Particles

The fast particles which relate to the magnetosphere are those which are trapped in the geomagnetic field. (The fast particles which simply traverse the field are generally discussed as "cosmic rays".) Among the trapped particles we may distinguish the high energy protons ranging from a few Mev to a few hundred Mev; high energy electrons in the range of 100 kev; and low energy electrons, up to perhaps 50 kev. In addition we have the particles responsible for the magnetic storm ring current, which have not been directly identified.

High Energy Protons. These particles are confined to rather low altitudes, between about 500 kilometers and 6,000 kilometers and to low and moderate latitudes. At the heart of the proton belt, in the equatorial plane at 3000-4000 km altitude, the maximum flux is $\sim10^4\ cm^{-2}\ sec^{-1}$. All of the features of the proton belt observed so far can be well explained in terms of the neutron albedo theory. (See the discussion by Singer on this subject; paper II-2-P3).

A remarkable feature is the fact that these protons seem to produce no known geophysical effects. Another remarkable feature is the extremely long lifetime which they must have in order to yield the observed intensities, up to a few hundred years. This long term stability of the proton belt is really quite surprising in view of the many large and rapid changes of the earth's magnetic field.

A special feature is the sudden injection of low energy protons into this belt during solar flare cosmic ray events (which also cause PCA's). (See paper II-2-7 by Lenchek and Singer.)

High Energy Electrons. It is not impossible that their existence can be explained in terms of the neutron albedo theory. The data are not yet good enough to tell us whether electrons of energy greater than 780 kev (the end-point of the β-spectrum) are present. This is one of the crucial questions that needs to be settled.

Low Energy Electrons. In the maximum of the electron belt (at 3-4 earth radii) the flux is of the order of $10^9\ cm^{-2}\ sec^{-1}$. It is quite clear that the spatial distribution does not accord well with the neutron albedo theory and that we are dealing here with electrons which have been accelerated locally in the earth's magnetic field by processes which derive their energy ultimately from the sun.

The bulk of electrons has energies below 100 kev and these certainly cannot be accounted for in terms of the neutron albedo mechanism. Sometimes two maxima (E_2 and E_3) can be identified; sometimes the structure is even more complicated. The intensity changes and motions of the peaks are not well explained. One puzzling aspect, for example, is the fact that the maximum stays relatively fixed during a *large* magnetic storm and moves inward during a *small* storm (Fan, Meyer and Simpson, 1961) while lines of force are moving outward. The electrons may be dumped into the atmosphere in the subauroral zone at times, there to produce auroral X-rays observed by Brown (1961), Anderson (1958), Winckler (1960) etc. (during bays and pulsations discussed by Kato). The usual aurora in the auroral zone, on the other hand, does not correlate well with the outer radiation belt (Winckler) but seems to be produced by quite low energy electrons of the order of 10–20 kev which have not been particularly well studied in satellite and space probe experiments.

Magnetic Storm Belt Particles. Satellite observations, as well as theory, seem to fix the position of magnetic storm belt particles at distances of 4–8 earth radii, but their nature is by no means certain. The most widely held point of view is that they consist of 20 kev protons, injected into the geomagnetic field through field perturbations or locally accelerated (Dessler, Hanson, and Parker, 1961) or accelerated by convection currents (Axford and Hines, 1961). As has been pointed out during this Conference (see discussion I-3-P1 by Singer on Magnetic Storm Theories) it is quite likely that these particles are low energy electrons. For a variety of reasons we identify them closely with the auroral electrons of about 10 kev although it is quite possible that the bulk of the particles responsible for magnetic storms have energies which are very much less. Clearly a direct experimental decision between protons and electrons is called for.

One of the puzzling features is the inward motion of the magnetic storm belt as brought out by Kellogg; it is very hard to understand this and direct determinations with magnetometers in eccentric orbit satellites would be most desirable.

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