N87-20872

SOME CRUCIAL CORONA AND PROMINENCE OBSERVATIONS

E. A. TANDBERG-HANSSEN
SPACE SCIENCE LABORATORY
MARSHALL SPACE FLIGHT CENTER, AL 35812

A number of theories and hypotheses are currently being developed to explain the often complex behavior of corona and prominence plasmas, and later today Parker will discuss some of the theoretical implications relevant to the topic of this workshop. In order to test the theories and hypotheses certain crucial observations are necessary, and I shall in this talk examine some of these observations and draw a few conclusions.

To set the stage let me remind you that already two thousand years ago Plutarch commented on an observation of crucial importance for coronal research when he wrote about solar eclipses: "There always appears around the circumference of the moon some light that does not permit total darkness." It took a long time before the proper theoretical explanation of that light was given. In a more lighthearted way Hirayama (1985) refers to crucial observations when he comments in his excellent review of Prominence Observations "Prominences are fascinating objects, abundant in variety, beautiful, and above all mysterious."

Prominence - corona mass balance

Since it is difficult to quantify "fascinating," "beautiful," and "mysterious," I shall start by looking at the material involved in the corona and prominence plasmas. The mass of the corona is, to an order of magnitude, given by

$$M_{cor} \approx n_p m_p A H , \qquad (1)$$

where A is the area of the solar surface (photosphere), $H \approx 10^{10}$ cm the coronal scale height, and n_p and m_p are the number density and mass respectively of hydrogen atoms. Eq. (1) gives, with $n_p = 3 \times 10^8$ cm^{-3}, the mass of the corona

$$M_{cor} \approx 4 \times 10^{17} \text{ g}.$$

A large quiescent prominence has a volume of roughly $V = 5 \times 10^8 \text{cm} \times 5 \times 10^9 \text{cm} \times 4 \times 10^{10} \text{cm} = 10^{29} \text{cm}^3$, and therefore a mass, taking $n_p \approx 3 \times 10^{11}$ cm^{-3},-

$$M_{prom} \approx n_p m_p V \approx 5 \times 10^{16} \text{g} . \qquad (2)$$

Consequently we find that half a dozen or so large prominences are as massive as the whole corona. From this one concludes that either a cycling of mass must continually be going on or the material must - more likely - come from lower, denser regions of the atmosphere. In either case we arrive at our first crucial observational consequence: <u>the dynamic nature</u> of the corona and prominence plasmas. Static models will no longer do. To understand the formation of prominences and their interplay with the corona a holistic approach is necessary. Figure 1 shows a sketch of the corona observed at the Nov. 12, 1966, eclipse (Saito and Tandberg-Hanssen, 1973), and two large quiescent prominences, seen as dark filaments on the disk, are situated under the helmet streamer at positions dictated by the coronal structure. To explore this situation further, we must look at solar magnetic fields.

PRECEDING PAGE BLANK NOT FILMED

Figure 1

Corona and Prominence Classifications

We are so used to looking at the changing shape of the corona from solar maximum to solar minimum conditions that is is easy to forget the important message this change carries. The classification of coronal shapes, the observation of helmet streamers and the more recent information on coronal holes and the solar wind point all to the crucial importance of the magnetic field configuration. It is the magnetic field that completely determines the shape and behavior of the coronal plasma; we are in a low-β plasma, ($\beta \equiv 8\pi nkT/B^2$), and a theory that does not include this aspect cannot be complete.

On the other hand classification of prominences reveals a practical scheme as given in Table 1.

Table 1
Prominence Classification

Quiescent	occur in queiscent regions subset: eruptive	Associated with Corona
Active	Occur in active regions subset: sprays	Associated with Sunspots
Loops	Occur in active regions	Associated with corona and/or flares
Surges	Occur in active regions	Often associated with subflares

Examining pictures of some of this objects, like active, sunspot prominences or loops, we again cannot doubt the decisive influence of the magnetic field structure on these prominences

This structure also plays an important part in quiescent prominences, and measurements of prominence magnetic fields (e.g. Leroy et al 1984) are crucial in distinguishing between models of prominences (Malherbe et al 1983a), taking the dynamic nature of these objects into account (Malherbe et al 1983b).

Prominence formation and stability

Prominences can, theoretically, form either by ejection of matter from below or by condensation of matter from the corona. Surges and sprays from according to the former mechanism; coronal rain and postflare loops seem to owe their existence to the latter. In the case of quiescent prominences it is often assumed that they form by condensation of coronal matter, and even though this process may take place, we have seen above that it is difficult to account for the material needed for a big quiescent prominence by this mechanism. Rather, an ejection or a siphon- type mechanism probably supplies matter into a pre-existing magnetic structure capable of supporting the prominence Pikel'ner (1971). The very stable nature of many quiescent prominences is also due to the action of the magnetic field, i.e. to its loop-shaped structure. Observations leave little doubt that it also is the loop-shaped magnetic field that accounts for the shape and stability of phenomena like coronal arches, postflare loop prominences, sprays, and transition region loops. We therefore arrive at another crucial observational consequence: The ubiquity of the magnetic loop. Table 2 illustrates this phenomenon, and shows the importance of loop structures on nearly all observable lengthscales on the Sun.

Table 2

Loops - a basic structure in solar physics

- o Coronal arches - interconnect active regions
- o Coronal loops, hot (> 10^6 k), cool (< 10^6 k)
- o Flare loops - relationship to coronal loops?
- o Loop prominences = post-flare loops
- o Loop structures in quiescent prominences
- o Transition-region loops, high and low
- o Bright points (X-rays, UV) = small loops?

Eruptive Prominences-Coronal Mass Ejection

The last crucial observation I want to direct your attention to is the disappearance of prominences during flares and the correlated coronal response. It seems that only a holistic approach will suffice to let us properly explain this complicated flare manifestation. Borrowing from work by Moore et al (1986), we can ascertain that the prominence eruption and the accompanying coronal mass ejection both are caused by an underlying change in the magnetic field - a global instability of the field configuration in the region where the flare occurs - and are not caused by the energy release in the flare. Fig. 2 illustrates both the change in hard x-ray intensity, showing the impulsive phase of the flare, and the eruption of the Hα prominence. We note that the eruption begins before the onset of the impulsive phase, probably caused by the same global instability in the magnetic field that also is responsible for the energy release that causes the flare.

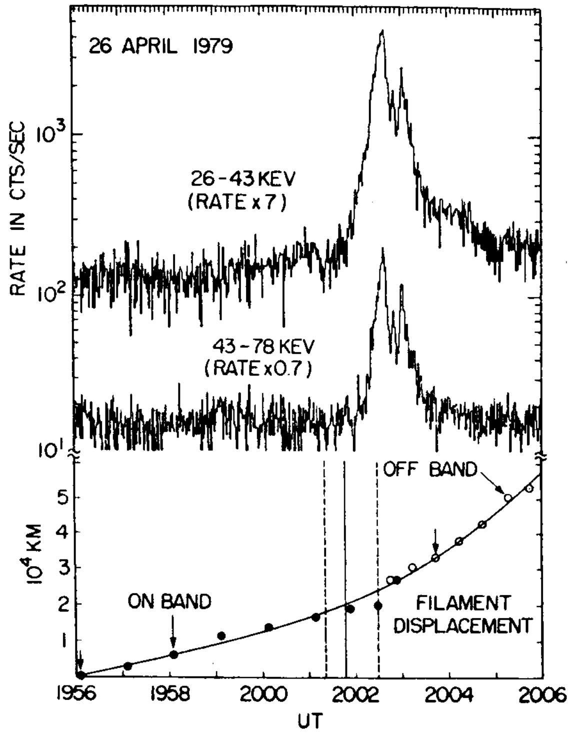

Figure 2

Other observations than the ones I have discussed may certainly be labeled crucial, and we are, for example interested in the diagnostic being discussed in Vial's and Lang's groups to furnish temperatures, densities, velocities etc. to properly model the observed prominences and coronal manifestations. However, the list of observations I have discussed and the preliminary conclusions drawn from them should form a basis from which we now can proceed to better explain the "fascinating" and "mysterious" objects that are among the topic of this workshop.

References

Hirayama, T. 1985, Solar Phys. 100, 415.

Leroy, J.L., Bommier, V., and Sahal-Brechot, S., 1984, Astron. Astrophys. 131, 33.

Malherbe, J.M., Priest, E.R., Forbes, T.G., and Heyvaerts, J. 1983a Astron. Astrophys. 127, 153

Malherbe J.M., Schmieder, B., Ribes, E., Mein, P., 1983b Astron. Astrophys. 119, 197.

Moore, R.L., Kahler, S.W., Kane, S.R., and Zirin, H. 1986, Bull. AAS 18, No.2.

Pikel'ner, S.B., 1971, Solar Phys. 17, 44

Saito, K. and Tandberg-Hanssen, E. 1973, Solar Phys. 31, 105.