A MODEL OF SURGE

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ABSTRACT

This paper reports on the application of a siphon flow model to the late stage of a surge observed in the UV radiation by the S055 experiment on board Skylab. The MgX λ625 and OVI λ1032 emissions from the density distributions occurring in flows which become supersonic at the top of the loop agree with the observations, indicating a pressure drop, along the loop, of a factor of 4 for the plasma emitting the OVI line, and of a factor of 2 for the plasma emitting the MgX line.

INTRODUCTION

The observation of large velocity fields in regions of high magnetic field in the solar transition region chromosphere-corona (Brueckner, 1976; Bruner et al., 1976; Doscheck et al., 1976; Athay, 1979; Brueckner, 1979; Lite, 1979) has drawn attention to the study of fast plasma flows in that region and in the corona above.

Steady coronal flows have been studied by Cargill and Priest (1979), and by Noci (1979), and a model based on such flows is here used to interpret the MgX and OVI emission of a surge. Similar flows for much lower temperature regions (T < 6000 K) had been investigated by Meyer and Schmidt (1968) as a model of the Evershed motions; Pikel'ner has also used a model based on flows, though limited to subsonic flows, to try to explain prominence formation (1971).

CHARACTERISTICS OF THE FLOW

In the region considered, the magnetic field is supposed to be constant in time and large enough to give β (plasma energy/magnetic energy) << 1; hence the flows are confined inside given magnetic tubes. No wave force is assumed to act upon the plasma; furthermore the run of density

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and temperature is assumed to follow a polytropic law and the cross-section of a magnetic tube to be constant.

The equations of the problem are clearly the same that apply to the problem of the solar wind. If s is a coordinate along the loop axis and s_m its value at the top of the loop, the topology of the solutions for the velocity is characterized by a critical point at s_m. Therefore, beyond solutions always subsonic, characterized by the same pressure at the two footpoints of the loop, there exists a subsonic-supersonic solution, characterized by a pressure decrease, which adjusts itself to the boundary condition at the second footpoint of the loop by a stationary shock. Large density decreases occur along the loop axis for these solutions, large density increases across the shock. These density variations should have a signature in large brightness variations along the loop.

THE SURGE OF OCTOBER 28, 1973 (Mc Math 584)

This model has been applied to the surge which followed the flare of October 28, 1973 at 1758 U.T. (UV max. time) in active region Mc Math 584. Observations were made by the Harvard spectrometer on board Skylab; I thank E. Schmahl for making the data available to me through a preprint (1979).

The application of the siphon model to a surge is prompted by the consideration that pressure unbalances should be produced by flares (that surges are driven by a pressure unbalance is suggested, e.g., by Schmahl, 1979). However, the model being a steady one, use has been made of observations sufficiently delayed from the flare maximum that subsequent observations did not show any evidence of travelling disturbances. Hence the neglect of the time dependent term $\partial v/\partial t$ in the momentum equation, compared with the stationary term $v\ \partial v/\partial s$, appears to be feasible.

The model assumes a shell structure of the loop, with temperature increasing from the interior towards the exterior. The polytropic parameter α has been taken equal to 1.1; ionization equilibrium has been assumed. The calculations have been therefore limited to the higher temperature ions for which the temperature decrease along the loop, in the siphon model, is small, namely MgX and OVI. (The temperature decrease is 7% in the shell producing the MgX emission, 14% in the cooler shell producing the OVI emission.)

The comparison of the model with the observations is shown in Figure 1. The data used are brightness values from just beyond the flare position (i.e., from the point P_o) to the footpoint of the loop. It is seen that the temperature is defined by the brightness gradient along the loop axis, and the density by the brightness itself. Two model curves are given for each ion to show the uncertainty of the parameter determination. It appears that the temperature, in the case of MgX, is strongly dependent on the weight one gives to the brightness distribution close to the flare position. Consequently the density is also affected, since the temperature value adopted determines the abundance of the ion: for MgX the increase

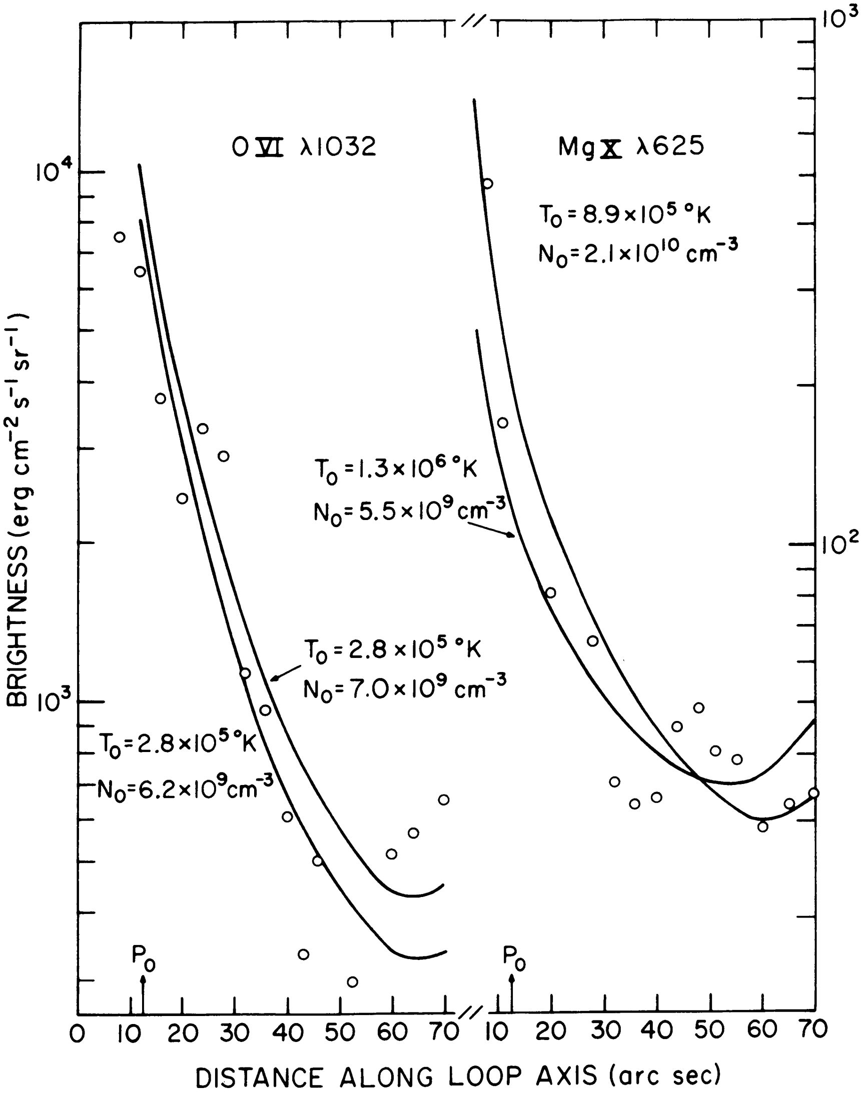

Figure 1. The surge of 28 October 1973, 18:09 (Mc Math 584). Observed (open circles) and calculated (curves) brightness distributions. T_o, N_o refer to point P_o (marked by an arrow, 13" from first footpoint). The thickness of the emitting shells has been assumed δ=1" (The diameter of the surge loop was ≲ 5").

in the density from the lower to the upper curve of Figure 1 compensates for the decrease in ion abundance due to the temperature decrease.

About the density values, it must also be noted that they depend on the assumed thickness (δ) of the emitting regions ($N_o^2 \sim 1/\delta$). It is worth

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remarking, however, that if the thickness of the two emitting shells is the same, the pressure increases from the core of the loop towards the surrounding corona.

Figure 1 shows that the agreement between theory and observations is good, hence these results support the view that surges are driven by a pressure increase, connected with a flare, at some point inside a magnetic tube.

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DISCUSSION

Lemaire: In your model you assume that the flux tube has a constant cross-section versus altitude! Is there experimental evidence that this is a reasonable hypothesis? What would happen if you would assume a more likely diverging magnetic field geometry?

Noci: According to the observations the cross-section of a coronal loop is approximately constant. In a situation of changing cross-section the topology of the solutions will be influenced. For example, for loops diverging with height, but still symmetric (with respect to the top), if the cross-section variation is not very large, the critical point remains at the top and the velocity gradient decreases.

Heinemann: In ordinary hydrodynamic flow without gravitational field the flow goes supersonic only at a minimum of the cross-sectional area of the flow tube, but the flow tube here has constant cross-section. What changes this requirement? I wouldn't expect the gravitational field to do it because the top of the loop is well below the Parker critical point.

Noci: Let us think of the topology which applies to the case of the Parker solar wind, where the heliocentric distance is the coordinate, and consider the class of solutions which fold themselves back to the solar surface after crossing the M (Mach number) = 1 line. If r_m is the heliocentric distance of the top of the loop, the solution of this class, which becomes sonic at r_m is the critical solution for the case of the loop: in terms of the s coordinate it is continuously growing, becoming sonic at s_m and supersonic in the "descending" branch of the loop.

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