A QUANTITATIVE ANALYSIS OF THE SURGE OF MARCH 19, 1989

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(Received 20 July, 1995; in final form 10 May, 1996)

Abstract. A large surge event appearing in AR 5395 was observed at the Yunnan Observatory on March 19, 1989. Hα spectral profiles of the event are interpreted by using a two-cloud model and the contours of three parameters: excitation temperature, $T_{\text{exc}}$, microturbulent velocity, $V_t$, and column density of hydrogen atoms at the second level, $N_{\text{H}_2}$, are obtained, respectively. The question about the unique feature of the solution obtained by the fitting method is also discussed. The results show that the surge is composed of some conglomerated materials with higher temperature and density; the mass ejection is probably intermittent. Neither $T_{\text{exc}}$ nor $N_{\text{H}_2}$ vary with the height over the solar limb but decrease from the center to the periphery of the surge. $V_t$ varies from 10 to 30 km s$^{-1}$ and decreases with height. Some other important parameters, such as electron density, $n_e$, and electron pressure, $P_e$, etc., have also been estimated. In the surge, with $N_{\text{H}_2}$ about $2.0 \times 10^{12}$ cm$^{-2}$ and $T_{\text{exc}}$ about 8500 K on average, we obtained $n_e = 1.80 \times 10^{10}$ cm$^{-3}$ and $P_e = 0.023$ dyn cm$^{-2}$. The energy variations of the surge during the ascending phase are estimated.

1. Introduction

Surges are cool plasma ejections in solar active regions. They have a continuous distribution in size. Very small surges accompanying small, impulsive, chromospheric brightening are more frequent than large surges associated with major flares (Vorpahl and Pope, 1972; Roy and Leparskas, 1973; Sturrock, 1980; Schmieder et al., 1983, 1984, 1988). A typical surge has the shape of a straight or slightly curvilinear spike which grows upward from the chromosphere with velocities typically between 50 and 200 km s$^{-1}$. After reaching the maximum height (from 15 000 km to 200 000 km), the material is usually seen to descend, as it seems along the original trajectory (Švestka, 1976; Schmieder, Golub, and Antiochos, 1994). There are three phases for the whole motion path of surges: (a) Ascending and accelerating phase. This takes place at the primary stage of surges, and it lasts several minutes. The mean acceleration is about $1.2$ km s$^{-1}$, about 1--5 times the solar gravitational acceleration (Roy, 1973a; Platov, 1973; Cao, Xu, and Tang, 1979). (b) Ascending and decelerating phase. When the upward velocity reaches the maximum velocity (100--200 km s$^{-1}$), the velocity begins to decrease. (c) Descending phase. When the material in surges reaches the maximum height, it begins to return to the solar surface, and the descending acceleration is less than the gravitational acceleration. To explain the regularity of the motion in a surge, many dynamical theories have been proposed (Roy, 1973b; Altschuler et al., 1968; Uchida, 1969; Sturrock, 1972; Shibata et al., 1992). Cao, Xu, and Tang (1979) proposed that the material within a surge is accelerated not only by a magnetic gradient (the so-called 'melon seed' effect) but a magnetic tension as well. Furthermore, an expansion effect within the
surge is taken into account when the material ascends from a layer with higher pressure to one with lower pressure. This theory agrees with observational results very well.

Surges have a strong recurrence tendency and the surge ejections often repeat themselves at intervals of the order of 1 hour at apparently exactly the same place (Giovanelli and McCabe, 1958; Schmieder et al., 1984). A great number of observations and studies show that surges are composed of very-fine-structure threads (< 1") each thread being connected with a bright Ellerman bomb that lies above a small sunspot (Gopasyuk and Ogir, 1963; Rust, 1968a; Kiepenheuer, 1969; Roy, 1973a). During the last forty years, the morphology and characteristics of surges have been intensively studied in order to understand mechanisms of surges (Smith and Smith, 1963; Rust, 1968b; Ding and Xu, 1984; Schmieder et al., 1983, 1984, 1993; Schmieder, Golub, and Antiochos, 1994).

During solar cycle 22, a surge occurred in active region AR 5395 which is very well known for its great activity during its disk passage (11 X-class flares and 49 M-class flares (Hu and Zhang, 1990; Wang, 1990)). The surge we have mentioned occurred on March 19, 1989 and was visible on the west limb. In a previous paper (Gu et al., 1994) we studied its morphology and kinematic features, analysed its spectral data in Hα, and obtained many interesting results on the dynamics of the surge. In the present work, we are going to investigate this surge further quantitatively. On the basis of the results obtained in the previous paper, more information will be deduced. The validity of the solution deduced by using the two-cloud model method will also be discussed.

2. Studies of Contours of some Parameters

On March 19, 1989, a surge or mass ejection and other active objects were simultaneously observed by using the 26-cm high-resolution vacuum solar telescope and the two-dimensional multi-band spectroheliograph equipped with an Hα slit jaw monitor (Xuan and Lin, 1993) at the Yunnan Observatory. This surge overlapped different objects near the limb: a small loop system and an active object C (cf., Gu et al., 1994). The observed intensity along the line of sight is relevant in the integration of these different objects and the profile of the lines is found to be asymmetric (Figures 1 and 3). In the area where only the surge is observed, the classical cloud model method is applied (Beckers, 1964; Mein and Mein, 1988). The two-cloud model method has been applied to those asymmetrical profiles. Such a method has been developed by Luo (1987), Gu et al. (1992), and Li et al. (1993). By fitting theoretical profiles of spectral lines to the observational ones, we may derive four fitting parameters (Δλ0, ΔλD, τ0, and Sλ) for the surge, and in some places where the surge is overlapping other objects, four other fitting parameters (Δλ0, ΔλD, ... ) corresponding to the other objects can also be deduced.