CHANGES OF THE CHROMOSPHERE MODEL DURING "UMBRAL FLASHES"

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ABSTRACT. We have carried out calculations, showing how the thermodynamical structure of the sunspot umbra atmosphere varies during two stages of the oscillatory process of "umbral flashes".

1. INTRODUCTION

There have been a large number of publications in which the observed properties of oscillation spectra are used both to refine umbra atmosphere models and to search for the oscillation source itself. As far as our knowledge goes, no calculations have been done yet, which would show how the atmospheric structure changes in different phases of the dynamical process and how this affects spectral line profiles usually used as indicators of this process.

The purpose of this note is to make a quantitative estimate of the change in the thermodynamical state of the umbra chromosphere which leads to the observed behaviour of CaII lines during two stages of the most pronounced oscillatory process of umbral flashes (UF), whose period is of ≈3 min.

2. OBSERVATIONAL CONSTRAINTS

Our choice of atmosphere models for the UF maximum stage was based on the following observational data. When UF show maximum brightness, the intensity in the core of lines H and K CaII increases by factors of 4 to 5.5 (Beckers and Tallant, 1969; Kneer et al., 1981; Turova et al., 1983). In this case line profiles for sunspots located at the disk center look like a single-peaked emission reversal with a steep blue and gentle red wing, while for sunspots far from the disk center they are two-peaked reversal with a higher blue peak. The ratio of central intensities $I(K_3)/I(H_3)$ is 1.25 (Firstova, 1980) and remains the same in all UF stages (Turova, 1983). IR-lines at the time of greatest UF brightness change over from absorption to emission (the peak-to-peak brightness variation being ≈3 (Kneer et al., 1981), and the emission

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is usually a single-peak one, shifted to the blue side. The brightening of the entire core of lines H and K and IR-line changes indicate that the UF process occurs within a considerable height range.

3. SET OF MODELS

A "quiet" stage of the process was represented by Staude's (1982) umbra model, except for one parameter, namely the microturbulence velocity taken from the "Sunspot" model (Avrett, 1981). In order to imitate the stage of UF maximum, we calculated a number of "disturbed" models, by varying the temperature behaviour and the mass scale. Thermodynamical quantities (electron and gas pressure, density, etc.) were determined by a method suggested by Cram and Giampapa (1987) and modified by us (Grigoreyeva et al., 1989). In order to calculate line profiles, we used the LINEAR code (Auer et al., 1972) with some modifications (Staude, 1982; Grigoryeva, 1989). Profiles of five lines Ca II (H, K, X, Y, Z) were computed, however below we shall confine our attention to the discussion of lines H and Y as well as the ratio $I(K_3)/I(H_3)$.

4. RESULTS

It has appeared that four of 15 disturbed models of the sunspot umbra we have calculated meet best the requirements imposed. Three of them, which are rather close to each other, are notable for increased mean chromospheric temperatures and for increased mean temperature gradients as compared with the quiet umbra model; in the fourth model the point of temperature minimum is displaced and the mean chromospheric temperature is increased (Figure 1). H-line profiles calculated from these models, are intensified, as compared with an undisturbed profile, by factors of 4.4 to 7.8 and have shallow gaps which can be easily masked by systematic mass flows. Y-line profiles for these four models are emission ones, one of them being a single-peaked profile. The ratios $I(K_3)/I(H_3)$ are close to the ratio obtained for the quiet umbra model (1.2). They lie within the range 1.26-1.37.

We have calculated the height run of gas pressure for the undisturbed and disturbed models (Figure 2). Beginning from the temperature minimum the gas pressure for disturbed models was found to be increased, i.e., at the phase of UF maximum the atmosphere is compressed. It seems likely that the atmosphere at heights from the temperature minimum to the beginning of the upper chromosphere is involved in the UF process as a whole so that there exist no compression wave nodes within this range.

According to our estimates made for observed profiles (Turova, 1983; Grigoryeva, 1988), radiative losses corresponding to the time of UF maximum, are $\approx 8.5 \times 10^6$ erg cm^{-2} s^{-1}, thus exceeding by a factor of ≈ 3.3 those for the quiet umbra. Radiative losses calculated for a theoretical profile of the quiet umbra, are $\approx 2.6 \times 10^6$ erg cm^{-2} s^{-1}, and $\approx 1 \times 10^7$ erg cm^{-2} s^{-1} for the UF maximum. This is, of course, only a rough estimate because there are uncertainties associated with both

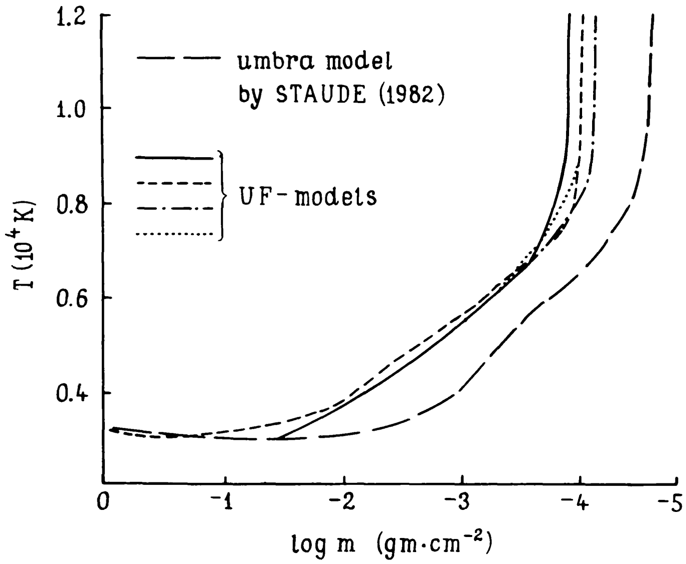

Fig. 1. The umbra chromosphere models simulating the maximum phase of UF.

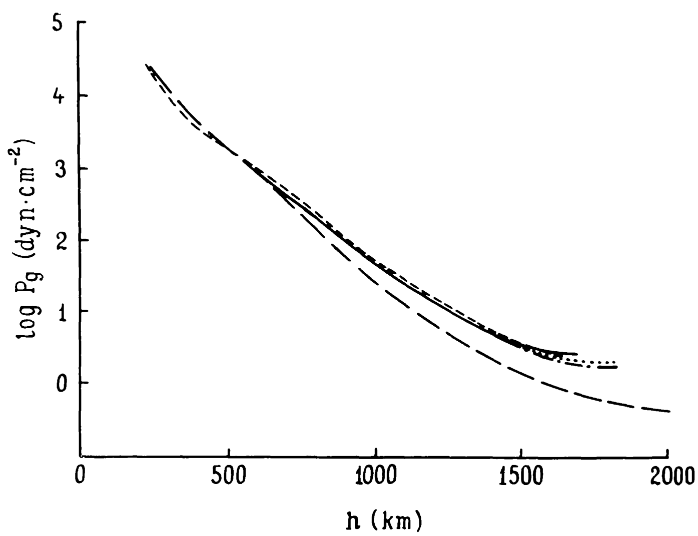

Fig. 2. The height variation of gas pressure. Symbols same as in Fig. 1.

observations (limited spatial resolution and small statistic of observations) and calculations (the adopted Doppler absorption profile and CRD).

Both facts - pressure increase throughout the entire chromosphere and the approximately fourfold increase of radiative losses - should be taken into account when identifying the oscillation mode that is responsible for umbral flashes. It seems to us that the results obtained here lend support to the Lites' (1984) view that "umbral oscillations must be providing a nontrivial amount of mechanical energy to the sunspot chromosphere".

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