Abstract. Homogeneous plane-parallel model atmospheres for solar flares have been constructed to approximately simulate observations of flares. The wings of the Ca II lines have been used to derive flare upper photosphere models, which indicate temperature increases of $\sim 100$ K over the temperature distribution in the pre-existing facula at a height of 300 km above $\tau_{5000} = 1$. In the case of flares covering sunspots the temperature rise seems to occur much higher in the atmosphere. We solve the transfer and statistical equilibrium equations for a three-level hydrogen atom and a five-level calcium atom in order to obtain the chromospheric flare models. The general properties of flares, including $n_e$, $N_2$, linear thickness, and Lyman continuum intensity are approximately reproduced. We find that with increasing flare importance the height of the upper chromosphere and transition region occur lower in the solar atmosphere, accounting for the factor of 60–600 increase in pressure in these regions relative to the quiet Sun. The Ca II line profiles agree with observations only by assuming a macro-velocity distribution that increases with height. Also the chromospheric parts of flares appear to be highly inhomogeneous. We show that shock and particle heated flare models do not agree with the observations and propose a thermal response model for flares. In particular, it appears that heating in the photosphere is an essential aspect of flares.

1. Introduction

In this paper we determine semi-empirical models for different types of flares, and then speculate concerning the nature of the heating mechanism. In Sections 2 and 3 we describe and reduce observations obtained at Sacramento Peak Observatory of the Ca II lines in a variety of flares. In Section 4 we investigate the photospheric structure of flares, which is at present relatively unknown, and then in Section 5 we build a grid of chromospheric flare models which approximately reproduces both the observed line profiles and the estimated parameters such as electron density, temperature and linear thickness. Since our models are homogeneous and plane-parallel they can only approximate what is clearly a dynamic and inhomogeneous phenomenon. The close agreement between our models and the observations suggests that our static models can be used as first order approximations to the physical properties in flares, and the basis for future dynamic and inhomogeneous models of flares.

2. Description of the Observations

The spectral observations described in this work were obtained with the Sacramento Peak Observatory 40-cm coronagraph and ‘universal’ spectrograph at a dispersion of

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TABLE I
Observational data

<table>
<thead>
<tr>
<th>Flare No.</th>
<th>Date</th>
<th>Importance</th>
<th>Region</th>
<th>log $F_K$</th>
<th>log $F_{6342}$</th>
<th>log $F_{6496}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1968 July 11</td>
<td>2B</td>
<td>C</td>
<td>6.53</td>
<td>6.73</td>
<td>6.60</td>
</tr>
<tr>
<td>2</td>
<td>1972 August 7</td>
<td>3B</td>
<td>C</td>
<td>6.69</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>1972 October 1</td>
<td>1N</td>
<td>C</td>
<td>6.30</td>
<td>6.63</td>
<td>6.54</td>
</tr>
<tr>
<td>4</td>
<td>1973 September</td>
<td>1N</td>
<td>C</td>
<td>6.47</td>
<td>6.70</td>
<td>6.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>6.03</td>
<td>6.37</td>
<td>(6.32)</td>
</tr>
</tbody>
</table>

C = region not over sunspots
P = region over penumbrae

1.6 Å mm$^{-1}$ in the blue region. From the observational material we selected four flares of importance 1N to 3B (see Table I). These flares were selected because they cover almost the entire range of flare importance classification, and because they show no evidence of moving material like surges and loop prominence systems which often accompany flares. The line profiles do show, however, the traditional red asymmetry observed in most flares (Svestka, 1972).

The spectra were taken nearly simultaneously in the wavelength intervals 3500–4200 Å and 6000–7800 Å. They include most of the Balmer spectrum, the H, K, and infrared lines of Ca II, and the strong CN $\lambda$ 3883 molecular band formed in the solar photosphere. In Figures 1 and 2 we can see some examples of the observed Ca II spectra in the selected events.

In these figures part of the flare is located in regions of penumbrae or umbrae of sunspots and part overlies plage regions. This is fortunate because, as has been noted by several authors (Malville et al., 1969; Svestka, 1972; Machado and Seibold, 1973), there is a strong difference in the shape and intensity of flare spectral lines observed over sunspots as compared to the normal flare spectrum.

3. Reduction and Calibration of the Observations

The photographic spectra were microphotometered, digitized, and reduced to relative intensities by means of a calibration wedge illuminated with the light of the solar disk center. Except for the 1972, August 7 flare, the intensities at the line center are not so bright as to fall into the saturation region of the calibration curve of the film.

Scattered light can be very important in the cores of strong absorption lines like H and K. In order to correct for this effect, we took several spectra of quiet Sun areas in the region of the Ca II lines and compared the observed residual intensities as a function of wavelength with the values given in the Kitt Peak double-pass photoelectric atlas (Brault and Testerman, 1972). We found that in general there was between 3 and