An energetic flare on AT Microscopium

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Introduction

M-dwarfs are generally observed to be highly active objects displaying frequent enhancement of emission from chromospheric and coronal regions. The cause of the activity is now believed to be due to a magnetic dynamo effect coupled with high rotation rates and deep plasma convection. The most active of these M-dwarfs are the dMe stars which are characterized by their Balmer line emission. During flare activity both continuum and emission features become enhanced and observations have been made of very large asymmetric broadenings in the bases of chromospheric Balmer lines which are usually interpreted as mass flow events.

In this paper we present and discuss observations of an energetic mass flow event associated with a chromospheric flare observed on AT Mic. AT Mic is a dM4.5e star at 8.8 pc. The spectroscopic observations were made in May 1992 using the SAAO 1.9m telescope. The useful wavelength range covered was 3750 Å to 4150 Å incorporating the higher Balmer lines and CaII H and K lines.

Results

Figure 1 shows the CaII H and K lines for the AT Mic flare. Also plotted is the typical pre-flare quiescent spectrum. The hydrogen lines down to H11 as well as the CaII H and K lines are visible in emission. During the flare all the spectral lines display a prominent broadened and blue shifted component. Such large asymmetries in the CaII lines have not been observed previous to these results although Houdebine et al. (1993) indicated a blue-shifted component in the CaII K line of a flare on AD Leo, but with a somewhat smaller amplitude.

Line fluxes and widths were derived by fitting a series of gaussians to match the observed line profiles. The excess blue emission seen in the wings of the spectral lines can be interpreted as a bulk motion. This assymetric broad component was then used to derive mean and upper limits to the Doppler velocity of the flow component of this flare. The typical flow velocity was 250 kms^{-1}. We also estimated the total radiateive energy release due to the flare in the U-band at $\sim 10^{31}$ erg.

Plasma Modelling

In order to constrain the physical properties of the flare plasma associated with this event use has been made of escape probability (Drawin 1975) methods for optically thick lines. These estimates of plasma mass, volume and knietic energy are believed to be accurate to within an order of magnitude at a given optical depth.

A determination of the electron density in chromospheric flares is difficult but we have constrained this parameter by use of the relation derived by Kurochka (1967) for the variation of electron density with emission line half-widths. We found that the upper limit in electron density is about 10^{14} cm^{-3}.

Fig. 1. CaII and Hϵ lines from AT Mic during the flare (a quiescent spectrum is also shown). Notice the pronounced blue asymmetry.

The plasma mass estimate of 10^{12} kg does not vary by more than an order of magnitude for a large change in N_e. The plasma volume of $\sim 3\ 10^{24}$ cm^3 can change by two orders of magnitude while the kinetic energy E_k, which is well defined within the N_e range, is found to be $\sim 3\ 10^{29}$ erg. Unless the impulsive phase plasma velocities were much higher than those derived from the data this kinetic energy is much lower than that observed on, for example, AD Leonis ($E_k \sim 10^{32}$ erg) (Houdebine et al. 1993). The radiative energy release on the other hand is very high in comparison ($3\ 10^{31}$ erg). In this example of a dMe flare the kinetic energy is not a significant fraction of the total flare energy release,

Large uncertainties are likely to remain in these computed values, primarily due to lack of certainty in the plasma parameters and the assumptions made in the modelling. There is also the problem of the angle of flow direction which may have important consequences for the estimate of kinetic energy. The bulk motion itself may also consist of a very complex velocity field which would be difficult to model successfully.

Conclusions

One proposed model for chromospheric flare emission is that of an energetic particle beam directed down through the chromosphere from the apex of a magnetic loop (van den Oord 1988; Emslie 1978; Brown 1971). The beam interacts with lower level material, heating it and thus causing it to rise through the chromosphere in a bulk motion which can be observed as Doppler shifted spectral features.

We conclude that the heating of lower level material and its subsequent rising through the chromospheric layers has been observed in the excess blue emission seen in this flare on AT Mic. The CaII lines show clear evidence of a blue asymmetry and such a dynamic effect has not been previously observed in dMe CaII lines. We propose that this signifies a very deep penetration of an electron beam into the lower and cooler chromospheric layers where the CaII lines are formed. The presence of the blue shifted component in both Balmer and the CaII lines

could alternatively be explained if the emission was originating in the same rising plasma.

Together with order of magnitude estimates of electron density and plasma velcocity and assumptions on the hydrogen line formation, our model computations indicate that the kinetic energy of the flow is substantially less than the radiative energy release in the U-band.

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