An analysis of the continuum light in the 3500 – 8500Å region from a flare observed on the dwarf M star Gliese 234AB (= V577 Mon)

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Abstract: *Relative energies are given for the U, B, V, R and I bands for a 3.8 magnitude U-band flare observed on the dwarf dMe star Gl 234AB on 28 Feb 1985. This flare had a 45 second rise time and 20 minute decay time. The total flare energy from all five bands during the flare was* $7\ 10^{31}$ *erg,* 34% *of this total was from the U-band and* 20% *from the two near infrared R and I bands. The energy density (per frequency interval) implied a rising continuum towards the red, however this only lasted for approximately 20-40 seconds, i.e. during the impulsive phase, afterwhich the excess flare emission could not be detected in the near infrared bands. Of the various models fitted to the flare data (i.e. optical synchrotron, bound-free emission and free-free emission), bound-free emission seems the most promising.*

1 Introduction

Gl 234AB is a very close binary with a separation of 0.9" and a magnitude difference between components of 3.5. The combined system is classified as dM4.5e, with strong emission in the H and K lines of Ca II and Hα. The observations reported here were made in 1985 on a 75 cm telescope, with a photometer employing $UBV(RI)_{KC}$ filters. An automatic filter change system was used with integration times of 10, 3, 1, 1 and 1 seconds respectively for U, B, V, R and I. During the flare monitoring, a 3.8 mag. U-band flare was observed, showing an increase in all five photometric bands.

2 Results and Discussion

The flare of Feb. 28 1985 at 22:35 UT had a large impulsive component, with an increase in U of 3.8 magnitudes in approximately 45 seconds, and a decay time of at least 20 minutes. The total radiated energy from all five bands U, B, V, R and I during the flare was 7 10^{31} *erg*; of this, the R and I bands contributed ≈ 20% while the U-band contribution was 34%. Unfortunately, our time resolution does not permit us to determine the relative timing of the peak emission in the various bands, thus we can only conclude that the impulsive R and I band increase occurred before or at the same time as the impulsive U-band increase.

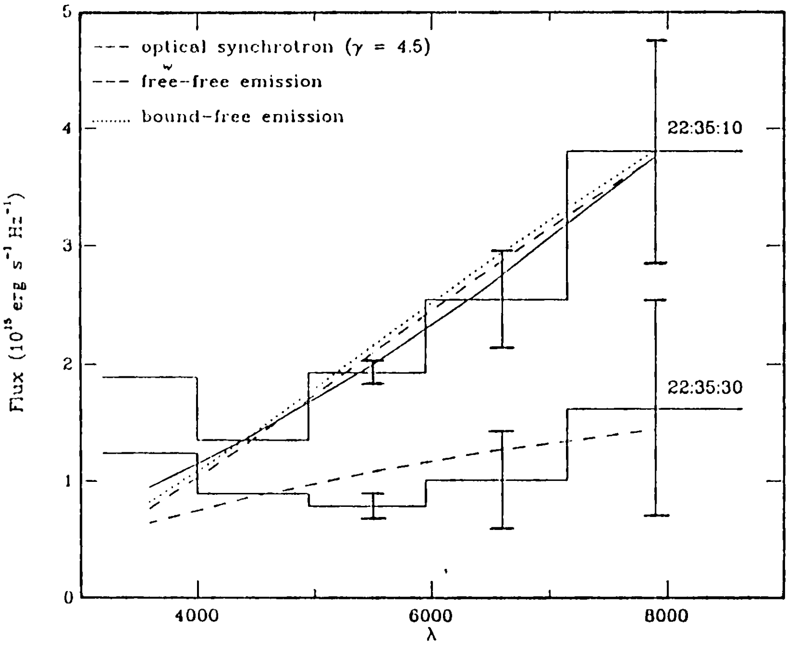

Fig. 3. The energy density (10^{15} *erg* s^{-1} Hz^{-1}) versus wavelength at two times during the impulsive phase of the flare of 28 Feb 1985. Note that since the U, B, V, R and I bands were not measured simultaneously, we have interpolated fluxes to a common time through straight line fits to successive points. Superimposed is the energy spectrum for optical synchrotron emission with a power-law energy distribution of $\gamma = 4.5$ (—), free-free emission model with $T = 1.4\ 10^4\ K$ (– –) and the bound-free emission model with $T = 1.4\ 10^4\ K$ (......) for the data at 22:35:10 UT. For the data at 22:35:30 UT we plot for $T = 3\ 10^4$ the free-free emission model.

In Fig. 1 we show the flare-only energy per frequency interval versus wavelength at two times during the peak of the flare. Note that since the observations in the five optical bands were not simultaneous we have interpolated straight lines fits between the observed points in order to plot the U, B, V, R and I energies at the same time. It is seen that during the first 20 seconds of the flare, the energy density (in $erg\ s^{-1}\ Hz^{-1}$) in I is a factor of three greater than that in B. This implies a rising flare continuum spectrum toward the red for this flare from at least 5000Å to 8000Å. Unfortunately we are unable to estimate the line contribution to the U and B-bands, however, an estimate for a flare observed on YZ CMi (Doyle *et al* 1988) found that ≈ 30% of the U-band flux came from Balmer emission lines. This value must be considered approximate as it is highly flare dependent.

Three models of the radiation mechanism responsible for the flare emission have been tested on this data; optical synchrotron, free-free and bound-free emission. The general shape of the flare energy distribution during the first 20 seconds (i.e. at 22:35:10 UT) can be reproduced by optical synchrotron emission from an isotropic distribution of electrons with a power-law energy distribution of $\gamma = 4.5$. Since the frequency spectrum scales as $\nu^{(1-\gamma)/2}$, the next observed distribution at 22:35:30 UT has $\gamma < 4.5$. Note that we have normalized the model spectrum to the B-band, assuming a 10% contribution due to emission lines. In addition, we have also fitted free-free emission. Taking the temperature to be $1.4\ 10^4 K$ and the expression for optically thin free-free emission, we find that this model also fits the continuum slope for the observations at 22:35:10 UT. A slightly higher temperature of $3\ 10^4\ K$ is required for the data taken at 22:35:30 UT. The energy distribution versus wavelength for both models is given on Fig. 3. In additional to the above mechanism, we consider bound-free emission, with again the best fit to the data been given by $T_e = 1.4\ 10^4 K$. The above analysis however considers only the spectral distribution of the emission, below we discuss the energy content and number density implied by the above three models.

For synchrotron radiation there is both a number and an energy problem since the required energy is several orders of magnitude larger than even the largest observed stellar flares. In order to have smaller values for the energy and particle content, one would require a magnetic field strength much greater than 1000G and/or a cut-off energy greater than the electron rest mass. Invoking free-free emission produces a total energy content which is somewhat greater than the radiated energy observed in the five bands, i.e. $7\ 10^{31}\ erg$. The derived electron density of $\approx 10^{11}\ cm^{-3}$ is perhaps small when compared to values obtained from chromospheric models of dMe stars, e.g. Giampapa *et al* (1982). Taking a slightly larger value of 10^{12} cm^{-3} gives an energy content close to the observed total radiative energy, a volume of 10^{31} cm^{3} and a number density of 1.5 10^{13}. This volume is still very rather large, since the stellar radius of Gl 234 is $\approx$ 1.9 10^{10} cm , therefore it is unlikely that free-free emission is the dominant mechanism.

Bound-free emission is a much more efficient mechanism than free-free; e.g. taking the equations for free-free and bound-free emission and the Saha equation we obtain

$$\frac{F_{\nu bf}}{F_{\nu ff}} = 2583\frac{g_{\nu bf}}{g_{\nu ff}}R_{01} \approx 4000 \qquad (1)$$

where $g_{\nu bf}$ and $g_{\nu ff}$ are respectively the bound-free and free Gaunt factors and R_{01} the ratio of the statistical weights g_0 and g_1. Similarly, the estimated volume is two orders of magnitude smaller than that estimated from free-free emission. The above analysis is very approximate since LTE conditions were assumed, however, it does serve to show that bound-free emission may be a more plausible emission mechanism for this flare. A more detailed paper has been submitted to *Astron. & Astrophys.*

References

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