UV AND OPTICAL OBSERVATIONS OF AT MICROSCOPI

T. R. Ayres
CASA
University of Colorado
Boulder, Col. 80309, USA

S. Elgarsey
P. Jorés
ing Institute of Theoretical Astrophysics
University of Oslo, Blindern
N-0315 Oslo 3, Norway

ABSTRACT

The red dwarf binary AT Mic was observed in 1985 in the UV and optical wavelength regions. In the U-band flares were observed at a rate of about 1 per hour. In the UV region, surface line fluxes are enhanced compared to those of the quiet Sun and show closer relation to values which are characteristic of very active regions on the Sun. Hot lines (C IV, Si IV) show larger broadening and negative frequency shifts whereas cooler lines (Fe II, Mg II) are less broadened and reveal small negative or positive line shifts. Improved radial velocity determinations of AT Mic are essential for the interpretation of the results.

Keywords: Red dwarfs, Chromospheres, Ultraviolet spectra.

1. INTRODUCTION

Main sequence stars of spectral type M are among the most important classes of late type stars for the understanding of the energization mechanisms of stellar chromospheres and coronae. The surface fluxes in C IV emission ($10^5$K) and soft X-rays ($10^6$K) of the dMe subclass of red dwarfs are among the largest observed despite the low mass and the small bolometric luminosities of these stars.

The X-ray coronae, chromospheric activity, starspots and flares on the red dwarfs can be viewed as basically solar-type magnetic phenomena exaggerated by the fully convective interior structure of the low mass stars (Ref. 1). But the manifestation of the solar-like phenomena can be so extreme on the dMe stars that one may ask whether the detailed processes occurring on the Sun and the red dwarfs truly are so close to one another as their superficial similarity would seem to suggest.

Unfortunately the detailed study of red dwarfs is severely limited by their comparative faintness. Only one red dwarf star - AU Mic (dM 1.6e) - has previously been observed at high dispersion by the IUE in the SW (1150 - 2000 Å) and the LW (2000 - 3000Å) regions with sufficient signal-to noise ratio to record the profiles of the important emission features (Ref. 2). We therefore have undertaken a very long exposure with the IUE in order to study, at high dispersion, the far-ultraviolet emission of a prototype flare-star binary, AT Mic ($\delta$M 4.5e+5M 4.5e, Ref. 3).

In the following some results from the observations are presented. A full account of the analysis is to be published elsewhere (Ref. 4).

2. OBSERVATIONS

The flare-star binary AT Mic was monitored with the International Ultraviolet Explorer on three days in 1985; Sep. 15, 16 and 17. Observations were also carried out in the visible region at SAAO, South Africa, Mt. John, New Zealand and CTIO, Cerro Tololo. Further data on the observations are given in table 1.

The long SWP and LWP exposures were started only after the IUE spacecraft had been allowed to stabilize thermally at the proper orientation for the AT Mic observations. The star image was repositioned within the large spectrograph aperture (10"x20") relative to the guide star every 2 hours during the SWP exposures. The purpose was to attain the highest possible wavelength stability and accuracy. The wavelength calibration was further checked by taking the platinum hollow cathode emission line lamp spectrum immediately after the SWP high resolution exposure. The wavelong image was taken through the small aperture with the large aperture closed.

The IUE/SWP and LWP echellograms were reduced by using the procedures of the British Starlink program presently in use at the image processing laboratory of Institute of Informatics, University of Oslo.

The small aperture platinum lamp exposures were extracted with the same dispersion constants as for the large aperture exposures of AT Mic. The inferred velocity correction from the wavecal exposure was subtracted from the velocity scale of the high resolution SWP and LWP exposures of the star, thereby adjusting them to the reference frame of the spectrograph. The correction to the measured wavelengths were $+32(19)$ mÅ and $+20(19)$ mÅ for the short and the long wavelength ranges respectively. The final wavelength scale was corrected for the IUE spacecraft velocity in the direction of the star.

An observational goal was to obtain a thirty-
hour exposure of AT Mic with the position angle of the orbit as nearly perpendicular to the dispersion axis of the SW echelle mode as possible. Because of technical difficulties with the IUE satellite at the time of observation this was only approximately accomplished; a 25 hour exposure time was reached and the position angle was inclined by about 45° to the dispersion axis during exposure.

3. OBSERVATIONAL RESULTS

3.1 Flare activity

Ground based optical monitoring of AT Mic was done simultaneously with some of the IUE observations. Photometric data were taken through Johnson U-filters with time resolutions of 2 - 5 seconds. Both components of the binary were always included in the diaphragm. During 19.7 hours of monitoring 23 flares were detected. On the average AT Mic emitted $1.6\times10^{48}$ ergs/s of U-filter flare light. The quiescent system emits $1.8\times10^{49}$ ergs/s. Accordingly 8.8% of the received flux was generated by flare activity.

3.2 Surface fluxes

Observed fluxes may be converted to surface fluxes when the parallax and radius of the emitting object are known. In the present contribution the same factor as that used by Linsky et al. (Ref.5) has been adopted, i.e. $2.73\times10^{17}$, based on a parallax of 0"122 and a radius of 0.48 $R_\odot$. It is furthermore assumed that both components contribute with equal amounts to the recorded flux.

In table 2 surface fluxes of some prominent lines in the spectrum of AT Mic are listed and compared with surface fluxes on the Sun as given by Butler et al., Ref.6). The chromospheric and transition region lines of AT Mic are strongly enhanced as compared with the quiet Sun. Surface flux values for active (AR) and very active (VAR) regions on the Sun relative to quiet Sun values have also been included. It appears that AT Mic may be characterized as comparable to "extremely active" regions on the Sun. Only the SI II lines are less enhanced. One notes that AT Mic follows the same pattern as AU Mic (Ayres et al., Ref.2). Surface fluxes of AT Mic amount to roughly 75% of those of AU Mic (Ref.6).

3.3 Line shifts and line widths

From the SWP and LWP high resolution spectra line shifts for the more prominent lines may be determined. Heliocentric values have been derived after appropriate corrections.

In addition to line shifts, line widths (FWHM values) have been found. In Figure 1 line width is plotted against line shift. Figure 2 shows line temperature against line shift. Errors in the line shifts range from 1-3 km/s. The figures reveal an interesting property: The hot transition zone lines show larger nonthermal broadening and larger negative line shifts whereas the cooler chromospheric lines are less broadened and show smaller
Table 2
Surface fluxes at AT Mic and the Sun.

<table>
<thead>
<tr>
<th>Ident</th>
<th>Surface flux (10^4 cgs)</th>
<th>AT Mic</th>
<th>Quiet Sun</th>
<th>AT Mic</th>
<th>AR</th>
<th>VAR</th>
<th>AT Mic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>QS</td>
<td>QS</td>
<td>QS</td>
<td>QS</td>
<td>QS</td>
<td>QS</td>
</tr>
<tr>
<td>O I</td>
<td>1304.9</td>
<td>3.8</td>
<td>0.40</td>
<td>9.5</td>
<td>3.9</td>
<td>5.4</td>
<td>1.8</td>
</tr>
<tr>
<td>C II</td>
<td>1334.5</td>
<td>3.8</td>
<td>0.46</td>
<td>8.3</td>
<td>4.5</td>
<td>7.0</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>1335.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Si IV</td>
<td>1393.7</td>
<td>3.0</td>
<td>0.17</td>
<td>17.6</td>
<td>4.1</td>
<td>5.9</td>
<td>3</td>
</tr>
<tr>
<td>C IV</td>
<td>1548.2</td>
<td>10.6</td>
<td>0.58</td>
<td>18.3</td>
<td>4.4</td>
<td>4.0</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>1550.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>He II+</td>
<td>1640.5</td>
<td>5.2</td>
<td>0.13</td>
<td>40.0</td>
<td>15.6</td>
<td>22.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Fe II</td>
<td>1808.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Si II</td>
<td>1816.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Si II</td>
<td>1817.4</td>
<td>4.2</td>
<td>1.61</td>
<td>2.6</td>
<td>2.1</td>
<td>3.1</td>
<td>0.88</td>
</tr>
</tbody>
</table>

negative or positive shifts. For the interpretation of the above results, knowledge of the radial velocity of AT Mic is important. According to Giese (Ref.7) one has radial velocities of 445 km/s and -325 km/s for the A and B component respectively. From Abt (ref.8) it is seen that the scatter in the derived values of radial velocities is large, amounting to more than 30 km/s, and they must be regarded as quite uncertain.

Regardless of radial velocity the results in Figures 1 and 2 reveal systematic flows. However, when one wants to relate these flows to the stellar surface, it becomes necessary to know the radial velocity with a higher degree of accuracy than is presently available. Depending on the radial velocity (v_r) the following possibilities may be pointed out:

a. If it is assumed that v_r=4 km/s, the observed line shifts imply that cooler material (Mg II, Fe II) flows towards the stellar surface whereas hot material (Si IV, C IV) flows away from the surface. This may be explained by a "surge-type" model in which hot material is ejected upwards and is permitted to cool somewhat before it falls back down. The contribution to the hot lines may therefore be greatest from the upstreaming gas whereas the

![](image1.png)

*Figure 1. Line width plotted against line shift for UV lines observed in AT Mic.*

![](image2.png)

*Figure 2. Line shift versus temperature of formation of the lines.*

© European Space Agency • Provided by the NASA Astrophysics Data System
cooler lines largely come from the downfalling and redshifted material.

b. If \( v_c \) is positive and amounts to a few km/s, Mg II is stationary with respect to the stellar surface, whereas the other lines reveal outstreaming motion. If \( v_c \) is positive and larger than the shift of Mg II, all lines give outward flow, the velocity increasing with temperature. This leads to the suggestion of "wind-type" models. Dissipation in the outward directed flow might lead to the increase in line width with flow velocity.

c. A third variant may be seen to occur if \( v_c \) is negative and larger than the shift of C IV. Then there is a downdraft with cool lines revealing faster stream velocity than the hot ones. This would imply that the highest velocities are associated with lines formed in the chromosphere, which seems rather unlikely.

4. REFERENCES