ZEEMAN FEATURES FROM ACCRETION COLUMNS IN AM HERCULIS-TYPE SYSTEMS

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Abstract

Absorption features seen in the bright phase spectra of E1405-451 are identified with Zeeman features of H_α originating from cool ($T \sim 10^4$-10^5 °K) material surrounding the accretion shock. The presence of apparently unshocked material surrounding the cyclotron emission region is surprising and may indicate that accretion occurs onto a larger fraction of the stellar surface than had previously been thought possible.

Introduction

The spectra of AM Herculis type systems are known to be highly variable and to exhibit a range of diverse characteristics. We note in particular the discovery of cyclotron emission features in the bright phase spectrum of VV Puppis (Wickramasinghe and Visvanathan (1981)) and of Zeeman features in the low state spectra of AM Herculis (Latham, Liebert and Steiner (1981)), CW1103+254 (Stockman et al (1983)) and H0139-68 (Wickramasinghe, Visvanathan and Tuohy (1984)). While the cyclotron features originate from the accretion shock, the Zeeman features that have so far been identified are of photospheric origin.

Paper presented at the IAU Colloquium No. 93 on 'Cataclysmic Variables. Recent Multi-Frequency Observations and Theoretical Developments', held at Dr. Remeis-Sternwarte Bamberg, F.R.G., 16–19 June, 1986.

Astrophysics and Space Science **131** (1987) 601–606.

In this paper we present spectropolarimetric observations of E1405-451 which show absorption features which cannot be identified either with cyclotron emission features from the accretion column or with photospheric Zeeman features. We argue that the stronger features are Zeeman components of H_α arising from cool unshocked material surrounding the cyclotron emission region.

Observations and discussion

Circular spectropolarimetric observations of E1405-451 were obtained on 1985 May 11 using the Anglo-Australian Telescope with the Pockels Cell spectropolarimeter. The instrument and reduction procedures have been described by McLean et al (1984). The data obtained at a spectral resolution of 10Å and covering 5 cycles were folded modulo the 101.52 m orbital period into 10 phase bins. A broad band light curve derived by summing all the counts in each of the 10 phase bins is displayed in Figure 1. The centre of the broad photometric minimum agrees with the predicted time (arrow) of minimum light based on the ephemeris of Cropper et al (1986).

We present in Figure 2 the summed bright phase spectra (bins 1, 2, 3) and faint phase spectra (bins 6, 7 8). The circular polarisation spectra have been averaged over wavelength bins of size 41Å . In addition to the emission features due to H , He I and He II the mean bright phase intensity spectrum shows broad absorption features which require explanation. The strongest feature is the minimum centered at 6050Å which is present in each of the individual bright phase spectra (bins 1-6, 9-10) . A weaker feature seen at 5500Å is present in individual spectra near maximum light (bins 1-3) . In addition there is evidence of a narrow absorption feature in the blue wing of the H_α emission feature. None of these features are seen in the summed faint phase spectrum.

We note that the absorption features are seen only during the bright phase and in a strongly polarised cyclotron continuum similar to the situation in which

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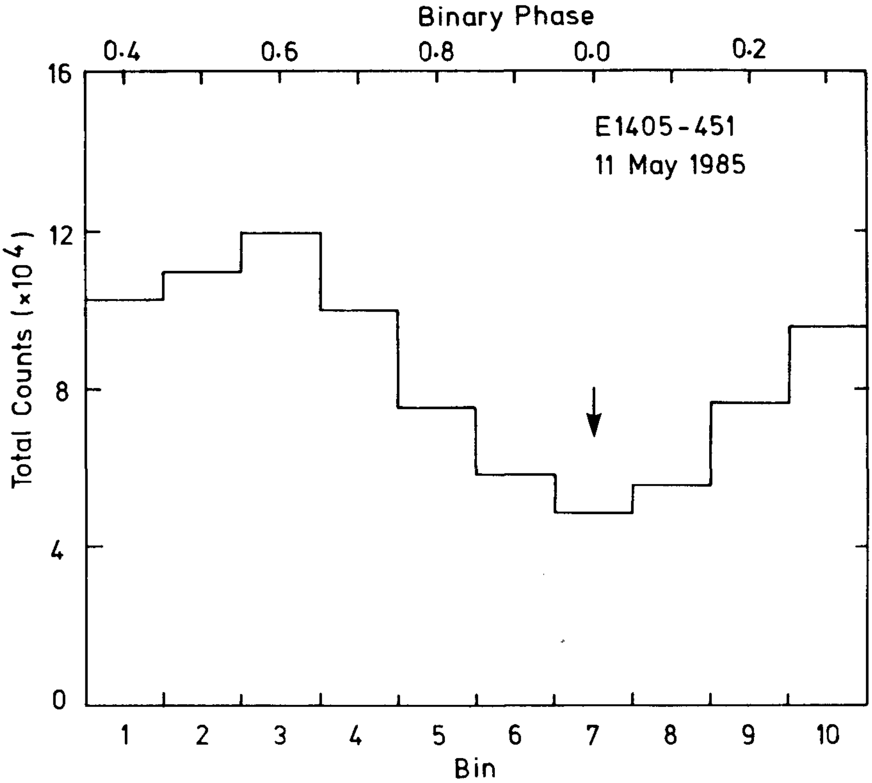

Figure 1 Broad-band (3500-7800 Å) light curve of E1405-451 obtained by folding the data modulo 101.52 minutes. Binary phase and the predicted time of photometric minimum (arrow) are indicated.

cyclotron harmonic features were seen in VV Puppis (Wickramasinghe and Visvanathan (1981)). On a cyclotron interpretation the intensity minima seen in E1405-451 would have to be identified with regions between successive cyclotron emission peaks (Wickramasinghe and Meggitt (1982)). We have investigated and rejected this possibility for the following reasons. The viewing geometry of E1405-451 is well established (Cropper et al (1986)) and indicates that the emission region is viewed over a wide range of angles ($\theta \sim 50$ - $85°$) with respect to the field direction during the bright phase ($\phi = 0.3$-0.7) . For such a large variation in θ , the theory of cyclotron emission predicts large and easily detectable shifts in the positions of harmonics which should be seen as shifts in the positions of the absorption troughs (Wickramasinghe and Meggitt (1982)). The data show no detectable change in the positions of the 6050Å and 5500Å features with phase.

A clue as to the origin of the absorption features comes from an inspection of the bright phase circular polarisation spectrum (Figure 2) which shows a narrow circular polarisation feature centered at 6511 ± 3Å coincident with one of the absorption features. The wavelength and polarisation of this feature suggests an identification with a π component of H_α. From Kemic (1974) we may identify the 6511Å feature with a blend of the π components (2p+1 - 3d+1) and (2p-1 - 3d-1) at a field of 22 MG. At this field the σ^- components (2p0 - 3d+1), (2p+1 - 3d+2) and (2p-1 - 3d0) occur at 6096Å, 6076Å and 6148Å respectively suggesting that the 6050Å feature may be a blend of σ^- components. The data of figure 2 shows a broad minimum in circular polarisation at this wavelength. The sign of circular polarisation of this feature relative to that of the continuum is consistent with a Zeeman absorption interpretation provided the visible pole is the magnetic south pole and the continuum radiation is optically thin cyclotron radiation. A more detailed analysis shows that the width and central wavelength of the 6050Å feature implies the presence of magnetic fields in the range 20-25 MG.

A photospheric Zeeman interpretation is untenable since on this model one would expect the Zeeman components to be strongest during the faint phase (near θ_{min}). In fact the features are observed to be strongest during the bright phase (near θ_{max}) when the cyclotron intensity is at a maximum. The inevitable conclusion appears to be that the Zeeman absorption features arise from cool material in the accretion column which surrounds the cyclotron emission region. With this hypothesis the following observations find a natural explanation :

a) The low values of circular polarisation of the 6511Å feature is explained by radiative transfer of circularly polarised cyclotron radiation through an accretion halo that is optically thick to the π components of H_α.

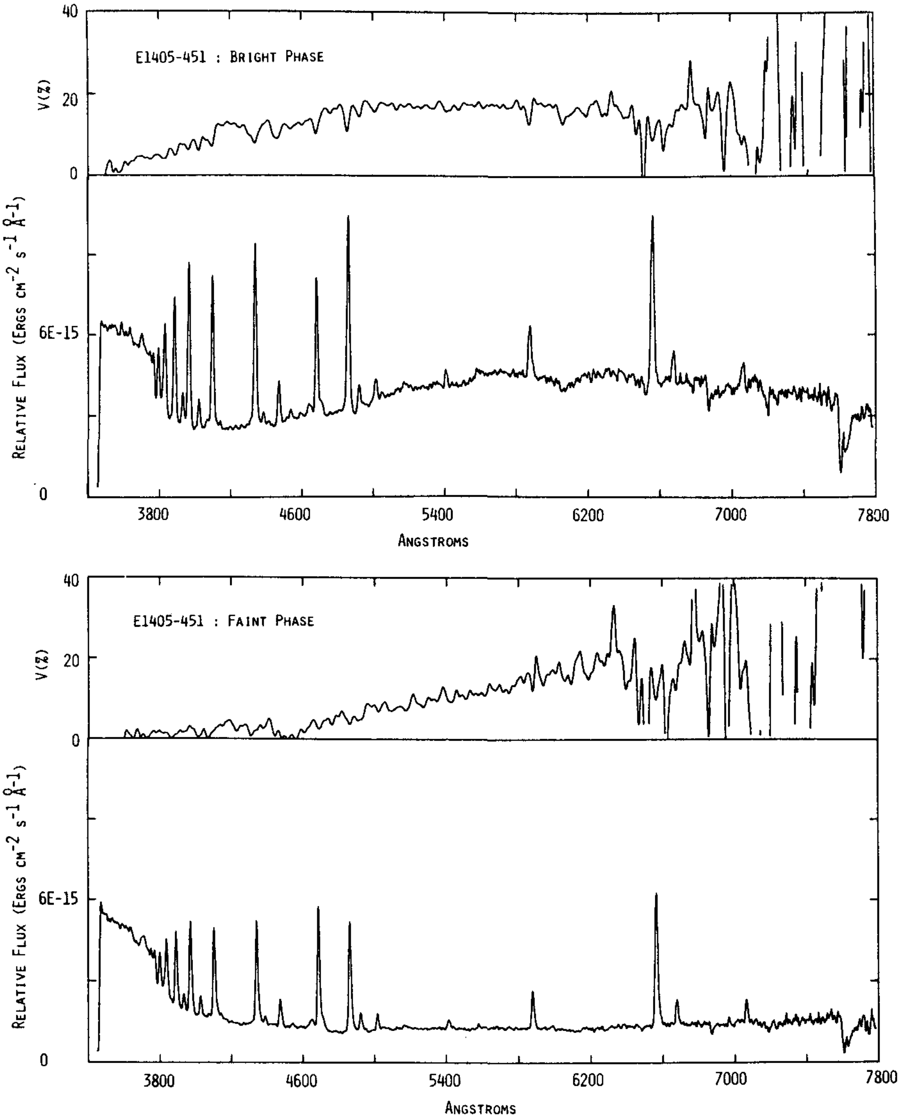

Figure 2 Bright state and low state intensity and polarisation spectra for E1405-451 derived by summing the data in Bins 1-3 and 6-8 respectively.

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b) The weakening of the Zeeman features as θ decreases below θ_{max} is explained by the increase in relative importance of background sources of radiation with decrease in θ.

The feature at 5500Å remains unexplained and could be of cyclotron origin.

Conclusion

We conclude that the strongest absorption features seen during the bright phase of E1405-451 can be identified with Zeeman components of H_α in a field of 20-25 MG originating from cool (10^4-10^{5}°K) material surrounding the accretion shock. The presence of cool apparently unshocked material surrounding the cyclotron emission region is somewhat surprising and appears to indicate that

a) accretion occurs onto a larger fraction of the stellar surface than had previously been thought possible.

b) at sufficiently low rates of accretion material may settle on the stellar surface without the formation of a shock.

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