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The activity pattern on MM Herculis: spots and faculae

G. Taş, S. Evren, and C. İbanoğlu

Ege University Observatory, Bornova, İzmir, Turkey (tas, sevren, ibanoglu@alpha.sci.ege.edu.tr)

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Abstract. The RS CVn type eclipsing binary MM Herculis was observed using B, V, and R filters in 1997 and the light and colour curves were obtained. The long-term (1976–1997) variations in the brightness and colour of the system were revealed by examining 12 light and colour curves. The reason for the variations in the B–V colour curves may be the photospheric bright facular structures that surround starspots. The system is bluest when at its faintest. Migration periods of 5.8 and 5.9 years have been found for the two spots or spot groups, which are located on the cooler component. The spots that are located within the longitude difference of 180° seem to approach each other with a period of six years. In this case the amplitudes of the light curves increase, the system's mean brightness decreases and its mean colour becomes bluer.

Key words: stars: activity – stars: individual: MM Her – stars: late-type – stars: starspots

1. Introduction

The RS CVn type eclipsing binary MM Her was first observed photometrically by Tsesevich (1954) and its light variations were obtained later by Oliver (1974), Hall et al. (1977), Popper (1980), Sowell et al. (1983) and Evren (1985, 1987a, 1987b). The system has also been studied spectroscopically by Imbert (1971). Evren (1985) has given the detailed history of MM Her. The migration period of the wave-like distortion at outside eclipses was calculated to be 7.5 years by Sowell et al. (1983), 3.57 years by Evren (1987a) and finally 7.6 years by Heckert & Ordway (1995) using the Information Limit Optimization Technique (ILOT) of Budding & Zeilik (1987) to model the spot longitude, latitude, and radius for each published and archived light curve. They found spot lifetime to be about 1 year for MM Her. The system's primary eclipse was obtained as a partial eclipse by Sowell et al. (1983), while Evren (1985) observed a total eclipse lasting about two hours. Evren (1987a) reported that the change in the secondary minimum was not clear and the depth of the primary minimum continued to decrease between 1983 and 1985.

The first section of this paper contains the B, V, and R observations obtained in 1997 and the variations appeared in the light and colour (B–V, V–R) curves. In the second section, the variations in the light curve (V filter) and colour curves are presented and a comparison with the previous observations is given. The contribution of the dark and bright regions in the photosphere, to the light and colour were examined. We tried to account for the variations of the mean brightness and colour of the system.

2. Observations

MM Her (BD +22° 3245) was observed with the 48-cm reflector of Ege University Observatory between July 16 and September 22 and 94 observational points were obtained for each colour in B, V and R filters over 21 nights in 1997. The Hamamatsu R 4457 PMT was used during the observations. BD +21° 3274 was taken as a comparison star and BD +22° 3250 as a check star. The observations were corrected for the atmospheric extinction and it was seen that the light of the comparison star didn't change. Later on the brightness and colour of the comparison star were transformed to the standard system and the following values were found: $V = 8\overset{\text{m}}{.}463 \pm 0\overset{\text{m}}{.}005$; $B - V = 0\overset{\text{m}}{.}714 \pm 0\overset{\text{m}}{.}005$; $V - R = 0\overset{\text{m}}{.}539 \pm 0\overset{\text{m}}{.}001$.

The nightly mean standard observations of MM Her are listed in Table 1. The first column in this table indicates the heliocentric times and the second column the orbital phases corresponding to these times. The light elements of the system have been taken from Evren (1985) as:

$$Min\,I = J.D.(Hel)\,24\,45551.4336 + 7\overset{\text{d}}{.}960358\,E.$$

Zero phase corresponds to the conjunction with the cooler and active component in front. These elements have been used in all the calculations pertaining to the observations. The third, fourth and fifth columns give the standard magnitudes in the V band, B-V and V-R colours, respectively. The standard deviation of each observational point for each colour in B, V, and R is about $\pm 0\overset{\text{m}}{.}005$. Since the orbital period of MM Her is almost eight days, its light curve could not be completely obtained in 1997. Only eight sections of the light curve were observed from our observatory in the 1997 observing season. A total of 8 mean points were formed from 94 observations for each colour. The light and colour curves consisting of the mean points of MM Her

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Send offprint requests to: S. Evren (sevren@alpha.sci.ege.edu.tr)

Table 1. The nightly mean standard magnitudes and colours of MM Her for 1997.

JD 2450000.+	Phase	V (mag)	B-V (mag)	V-R (mag)
646.3582	0.0372	9.525	0.880	0.648
650.3361	0.5369	9.516	0.887	0.649
651.3291	0.6617	9.497	0.890	0.651
658.3251	0.5405	9.512	0.892	0.655
659.3298	0.6667	9.477	0.884	0.659
660.3346	0.7929	9.468	0.887	0.643
665.2903	0.4155	9.549	0.858	0.657
667.3086	0.6690	9.486	0.894	0.662
668.3015	0.7937	9.469	0.902	0.659
686.2731	0.0514	9.542	0.888	0.646
687.2831	0.1783	9.570	0.859	0.654
688.2880	0.3045	9.573	0.865	0.675
690.2861	0.5555	9.515	0.873	0.665
691.3086	0.6839	9.489	0.884	0.669
692.2944	0.8078	9.465	0.895	0.647
700.2867	0.8118	9.482	0.883	0.659
701.2808	0.9367	9.504	0.883	0.664
702.2939	0.0639	9.543	0.876	0.645
703.2861	0.1886	9.562	0.874	0.658
704.2841	0.3140	9.562	0.845	0.685
714.2416	0.5648	9.514	0.883	0.664

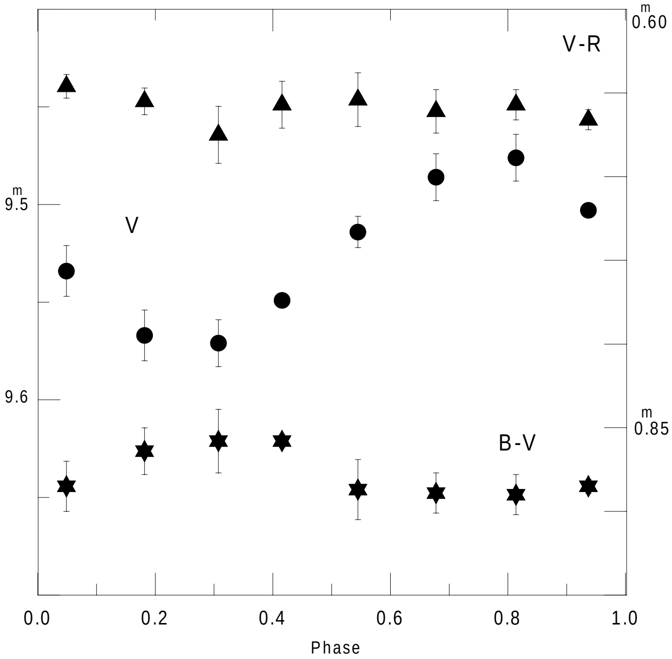

Fig. 1. The mean light and colour (B–V and V–R) curves of MM Her for 1997. The vertical bars represent the standard deviations.

obtained in 1997 are shown in Fig. 1. The eclipses of the system were deliberately not observed as we wanted to investigate the relation between brightness and colour variations at outside the eclipses. As seen from Fig. 1, the mean light curve of the system obtained in the V band in 1997 shows very clearly the sine-like distortion which is characteristic of the RS CVn type stars. The light of the system indicates a minimum at phase 0.26 and a maximum at phase 0.80.

The amplitude of the variation is approximately $0\stackrel{\rm m}{.}1$. The colour curves reveal an interesting phenomenon. The B–V colour curve reaches a maximum during the phase that the light is faintest, in other words the colour of the system appears bluer when the system is fainter. However, the V–R colour is seen redder at the same phase. The amplitudes of the B–V and V–R colour curves are $0\stackrel{\rm m}{.}03$ and $0\stackrel{\rm m}{.}02$, respectively. The values that are found for the amplitudes of the light and colour curves are in agree well with those given by Henry et al. (1995) for the stars around K0 IV. If the mean brightness changes entirely as a result of changes in surface brightness rather than changes in stellar radius, amplitudes in B–V should be only about one-fourth as large as amplitudes in V.

3. Photometric variations

3.1. The light and colour curves (1976–1985)

Observations of MM Her in B and V bands from 1976 to 1985 were collected and comparatively interpreted. The observations obtained between 1976 and 1980 (set A–K) were taken from Sowell et al. (1983) and the observations between 1983 and 1985 from Evren (1986). A total of 12 light and B-V colour curves including the 1997 observations were obtained. The 1976–1985 light and B–V colour curves were represented as free hand curves, and the values of the brightness and the colour were read at 0.05 phase intervals from each curve. We assume that one spot or spot groups on the surface of the cooler star can produce a sine-like light variation. The light variations due to the spot or spot groups should be symmetrical in shape. If the light variations have two minima in a period these may be a clue to the existence of more than one spot since the light and colour curves are asymmetrical in shape. Therefore, it is assumed that the star has at least two separate spots or spot groups. The phases of the minima of light variation were then read directly from the light variation in a period. While we call the spot that causes more light loss as the first spot, we think that other light loss is originating from the second one. The effect of two spots or spot groups is seen in all of the curves except three. The photometric parameters obtained from these curves are given in Table 2. The first column of the table presents the data sets taken from different references, whereas the second column presents the epochs of these sets. In the third column the mean brightnesses are given together with their standard deviations in the V band, whereas in the fourth column the values of minimum brightness are indicated; in the 5th column the amplitudes of these curves are given. The 6th and 7th columns of the table consist of the values related to the B–V colour of the system. In the 6th column, the mean colour values of the system are given together with their standard deviations. The values in the 7th column are the colour values at the phase that the system appears faintest. The phases of the maximum effects, due to the spots that cause distortions on the light curves are seen in 8th and 9th columns. If the values in the 9th column are considered, it appears that the system did not have a second spot effect in the years 1978 (set G), 1980 (set J) and 1997. Heckert & Ordway (1995) used almost the same data set (1976–1984). They analysed these data sets in order to study long-term spot activity on the star and somewhat different results were obtained. In the last column the phase differences between two spot groups are given. When the light (V) and colour (B–V) curves are examined, it is seen that the variations are similar to those we obtained in 1997. The system's B–V colour at the phases that the light curves have minimum values is bluer by 0.02–0.04 mag. For example, in the B, D, G, K and 1983, 1984, 1985 observation sets, this phenomenon is much clearer.

3.2. The migration period

If a star has a longitudinally asymmetric surface brightness distribution and is not exactly viewed pole-on, the brightness will vary as the star rotates. This variation is commonly called '$wave$' and can appear in the light curve superimposed on additional variability, which might result from eclipses, ellipticity, or reflection. Photometry of the wave can yield remarkably accurate rotation periods (Hall 1992). If two spots exist simultaneously, the light curve can take on quite a complex shape, depending on the latitude, longitude, and area of each spot and the inclination of the rotation axis. The long-time span of photometric observation makes them attractive for searching long-lived active-longitude structures on spotted stars. Tracing the wave minima in time could provide information on migration of the active regions with no assumptions about their structures, shapes, areas, temperatures, and latitudes (Berdyugina & Tuominen 1998). The light curve does not give any information on the latitude of the spots, or spot groups directly, and even detailed light curve modelling may not do so (Raveendran & Mohin 1995). However, information on the longitude can be obtained reliably from the light curve. The phases of the light minima (θ_{min}) directly indicate the mean longitudes of the dominant spot groups. Due to differential rotation, spots at different latitudes would give rise to different migration rates for the associated θ_{min} (Raveendran & Mohin 1995).

The migration of the minimum of wave-like distortions in the light curves versus the years was taken as a clue that the photometric period is different from orbital one (Hall 1992). The displacements of the phases of the first and second spots were plotted against years and are shown in Fig. 2. Applying linear fit to the shift of the phases, the following results were obtained:

$$\begin{array}{rcl} \text{First Spot } \theta_{min} & = & -0.173 \times (t-1900) + 17.21 \\ & & \quad \pm 3 \qquad\qquad\qquad\quad \pm 5 \\ \text{Second Spot } \theta_{min} & = & -0.170 \times (t-1900) + 16.32 \\ & & \quad \pm 9 \qquad\qquad\qquad\quad \pm 9 \end{array}$$

where t is in years. Using these equations, we found migration periods of about 5.8 ± 0.1 years and 5.9 ± 0.3 years for the first and the second spots, respectively. The photometric period is shorter, about 0.03 days, than the orbital one. These migration periods, being so close to each other, indicate that the spots located at different longitudes rotate with almost same velocities. Heckert & Ordway (1995) stated that the corotating latitude for MM Her is less than 50°. Since the photometric period we found is shorter than the orbital one, the spot or spot groups should locate on the stars' latitude lower than 50°. Only one spot seems to appear on the light curve obtained for 1997. Therefore the data used for the calculation of the migration period for spot1 cover a time span twice as long as those of spot2. The migration period values are different from those published previously. Sowell et al. (1983), Evren (1987a) and Heckert & Ordway (1995) obtained migration periods of 7.5, 3.57 and 7.6 years, respectively. The rate of migration period for the second spot was not quoted in the previous papers. The observed minimum phases of MM Her are well arranged in two permanent strips with approximately the same slope, which can be naturally interpreted as two long-lived active longitudes. Recently, the similar permanent structures were found on four RS CVn stars: EI Eri, II Peg, Sigma Gem, and HR 7275 (Berdyugina & Tuominen 1998). From the Fig. 2 we found two migrating active longitudes with a separation of about 0.4 in phase.

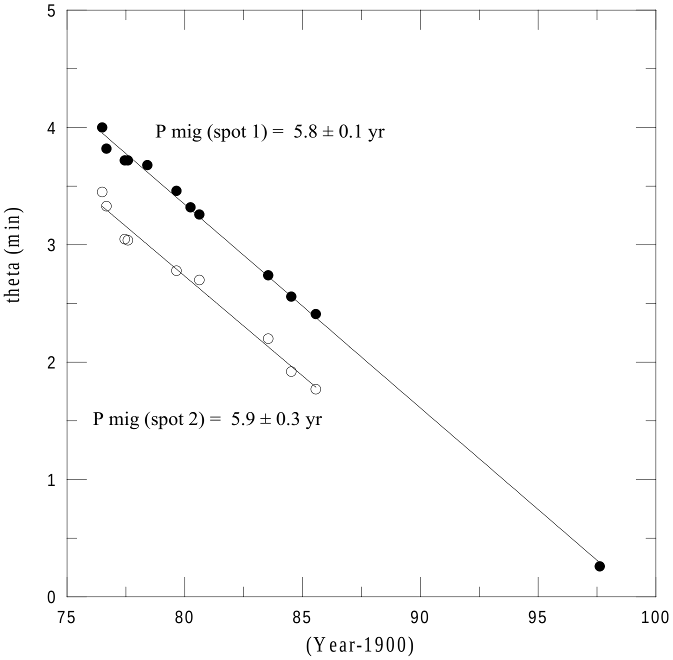

Fig. 2. The migration curves of MM Her spot 1 and spot 2.

3.3. Distribution of the spots and their effects

The spots located on the surface of the cool star displace with time, as discussed in the preceding section. We stated that two spot groups existing on the MM Her between 1976 and 1985 show their effects in different orbital phases. In this case, the following question may be asked: Do spot or spot groups approach each other with time? The change in the differences between the existing phases of each spot group will answer this question. If the phase difference between the spot groups lo-

Table 2. The photometric parameters for MM Her.

Data set	Mean epoch	Mean (V mag)	Minimum (mag)	Amp. (mag)	Mean (B-V)	Blueing (mag)	Spot1 (phase)	Spot2 (phase)	Difference of phase
Set A	1976.49	9.531 ±15	9.562	0.052	0.899 ±2	0.903	0.00	0.45	0.45
Set B	1976.67	9.533 ±30	9.572	0.074	0.890 ±13	0.882	0.82	0.33	0.49
Set D	1977.45	9.519 ±42	9.589	0.130	0.866 ±15	0.853	0.72	0.05	0.33
Set F	1977.58	9.540 ±46	9.612	0.127	0.875 ±8	0.863	0.72	0.04	0.32
Set G	1978.40	9.522 ±40	9.567	0.108	0.880 ±8	0.865	0.68	–	–
Set H	1979.64	9.515 ±30	9.563	0.093	0.880 ±8	–	0.46	0.78	0.32
Set J	1980.24	9.510 ±39	9.572	0.112	0.884 ±11	0.875	0.32	–	–
Set K	1980.61	9.508 ±27	9.560	0.080	0.881 ±11	0.870	0.26	0.70	0.44
Evren	1983.54	9.537 ±42	9.600	0.135	0.849 ±15	0.853	0.74	0.20	0.46
Evren	1984.52	9.537 ±48	9.615	0.153	0.848 ±9	0.833	0.56	0.92	0.36
Evren	1985.56	9.541 ±55	9.623	0.158	0.847 ±12	0.831	0.41	0.77	0.36
This study	1997.62	9.528 ±35	9.578	0.100	0.875 ±12	0.859	0.26	–	–

Set A-K: IAU Com. 27 Data File Number 110 (Sowell et al. 1983)
Evren: Evren (1986)

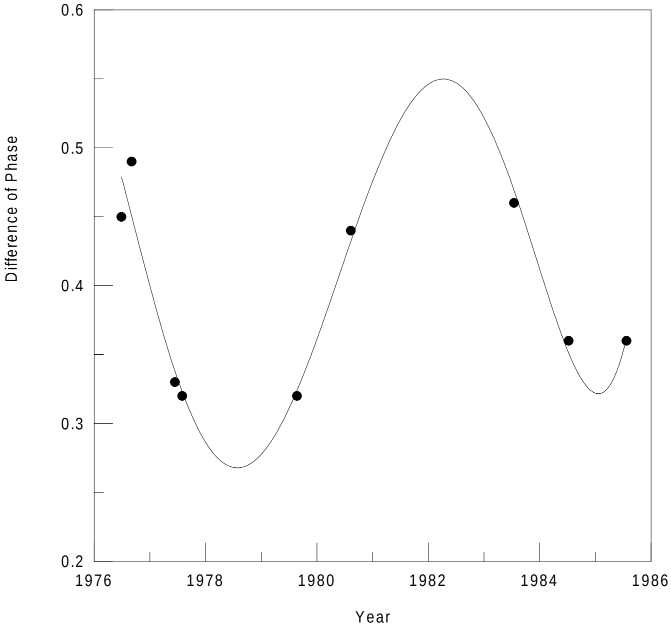

Fig. 3. The change of the differences between the phases in which the spot groups appeared on different longitudes versus years.

cated on the different longitudes does not change, the spots will continue to exist on the star's surface with the same longitude difference. But it has been seen that the spot groups on MM Her come closer to each other by time. The change in the differences between the phases in which the spot groups appeared on different longitudes versus years is shown in Fig. 3. As seen in Fig. 3, the phase difference between the spot groups becomes smaller reaching a value of 0.3 (108°) between 1978–79 and in 1985. In the years 1976 and 1982, the separation between the spot groups was 0.5 phase (180°). The period of this sine-like variation is about 6 years and this is the same value as the spot migration period. While the spots located on different latitude move to the equator due to the differential rotation, those located on lower latitudes move down faster to the equator than the rest; so their longitudinal displacement will be faster than the other spots. Hence, two spot groups in different latitudes but longitudinally close enough to each other will be observed.

When we investigate the shape variations in the light curves, in the years that the spot groups get closer to each other, we obtain some important results. The first result is that in the years, which the spot groups appear at neighbouring longitudes, the amplitude of the light curves increases. The amplitude variations of the light curves of MM Her obtained in V band versus years are shown in Fig. 4. In the years 1977–78 and 1985 the amplitude reached maximum values $0\overset{\mathrm{m}}{.}14$ and $0\overset{\mathrm{m}}{.}16$, respectively, while it was $0\overset{\mathrm{m}}{.}06$ in 1982.

A second effect is that the relative motion of active regions causes the variation in the mean brightness of the system. The variations of the mean brightness and colour for MM Her were

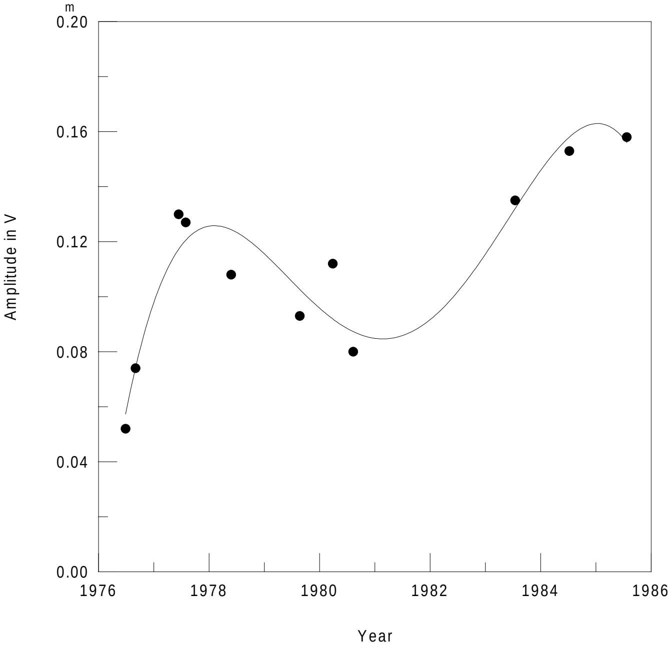

Fig. 4. The amplitude variations of the light curves of MM Her obtained in V band versus years.

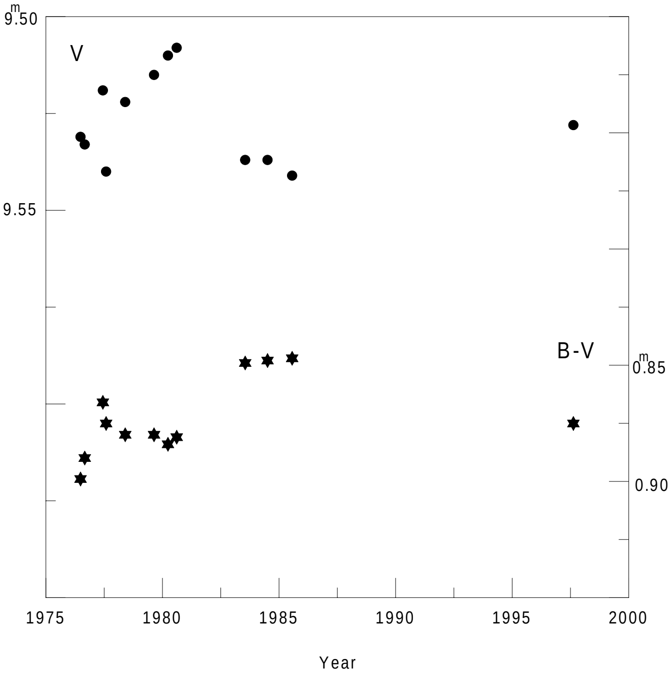

Fig. 5. The variations of the mean brightness and colour for MM Her versus years.

plotted against the years and are shown in Fig. 5. While the system was the faintest in 1977–78 and 1985, it appeared brightest in 1982, in other words, in the years which the spot groups approached each other, the system's activity increased and the system was seen fainter. In this case, if we look at the mean colour of the system, we see that it changed, more or less at the same time, in the opposite direction with respect to the mean brightness. The approaching active regions make the system's colour bluer. When the system is at its faintest, it is bluest and vice versa. This phenomenon can be understood by assuming that the blueing originates from the facular network or the facular structure, which surrounds the spots, and is hotter than the photosphere.

4. Results and discussion

The light and colour curves of the system obtained in B, V and R filters over 21 nights in 1997 were evaluated together with previous light and colour curves. The long-term variations of light and colour at outside eclipses were then obtained. The system has wave-like distortion in the light curves, which is one of the main characteristics of the RS CVn type binaries. In general the light and colour variations are in phase in these types of binary. When the light is at its minimum the colour of the system is redder. On the contrary, when the light of the system is at its minimum the colour of the system is bluer in some binaries. Similar behaviour has been detected in the non-eclipsing, double-lined spectroscopic binary UX Ari. In this system at the light minimum in V band, the colours of the system in both U–B and B–V get bluer. This anti-correlation between the V light curve and colour variations was attributed to the continuous flaring activity associated with the spots on the active component or to the presence of bright plage-like regions by Rodono & Cutispoto (1992). On the other hand, an attempt at explaning this behaviour has been met, using a different approach, by Mohin & Raveendran (1989) and later Raveendran & Mohin (1995). They interpreted this anti-correlation between the V band light and B–V curves seen in UX Ari as a result of the variable fractional contribution by the hotter component to the total light at shorter wavelengths. This interpretation depends on the spectroscopic indications that have been obtained by Carlos & Popper (1971). They found that the G-type component dominates in the photographic region and the K-type in the visual region.

The amplitude of the light curve (in V) of MM Her is about $0\overset{\mathrm{m}}{.}1$. When the system is at its minimum brightness B–V colour gets $0\overset{\mathrm{m}}{.}03$ bluer, while the V–R colour gets $0\overset{\mathrm{m}}{.}02$ redder. If the distorting effects were only due to the cool spots would the colour get redder at the phases where the brightness is minimum? But this reddening is seen only in the V–R curve. The star MM Her is a double-lined eclipsing binary. The maximum brightness of the system obtained in 1983 is $9\overset{\mathrm{m}}{.}465$ in the V band. On the other hand, the light curve analysis gives reliable fractional contributions of the components to the total light. Since the proximity effects are very small for MM Her, the wave-like distortion on the light curve obtained in 1983 was subtracted and the cleaned light curves were analysed by Evren (1987b). The ratios of fractional luminosities of the hotter G and the cooler K star were found to be L_G / L_K = 2.145 in blue and 1.451 in the V band. Using these values and total brightness of the system at maximum we obtain $((B-V)_K$= $1\overset{\mathrm{m}}{.}136$ and $((B-V)_G$= $0\overset{\mathrm{m}}{.}712$. Since the G component has the same effective temperature as that of the Sun and a radius of 1.56 $R_\odot$

(Evren 1987b) the absolute visual magnitude was found to be $3\overset{m}{.}82$ and its distance to be 181 pc. The absolute magnitude of the cooler component was estimated to be $4\overset{m}{.}15$. The absolute magnitudes of the components given in CABS (Strassmeier et al. 1993) seem to be written in reverse order. Also, Imbert (1971) noted that only the H&K lines of CaII belonging to the K star are visible in the composite spectrum of the system. If we use a colour excess of 0.06 in B-V as proposed by Sowell et al. (1983) these colours are agree well with the spectroscopic results obtained by Popper (1988). The maximum amplitude of the wave-like distortion obtained up to now is $\Delta V_{total} = 0\overset{m}{.}158$. It corresponds to $0\overset{m}{.}438$ intrinsic variation of the K star in V band. Whereas for the smallest amplitude light variation, i.e. $0\overset{m}{.}052$, the intrinsic variation in the brightness of the active component is about $0\overset{m}{.}132$. All the light curve analyses made by different investigators reveal that the fractional luminosity of the hotter star is larger than those of the K star both in B and V bands. Using the colour difference of $-0\overset{m}{.}424$ between the components, it is easy to copute the colour variation of the K star due to the spots or spot groups. This computation indicates that the intrinsic variation of about $0\overset{m}{.}438$ in the brightness of the K star does not produce any change in its colour. Therefore, the reason for the blueing in B-V should not be related to the cool spots. The blueing in B–V colour may arise from the photospheric bright facular structures that surround starspots. As it is obvious, that for the Sun the faculae are hotter than the photosphere, they are more dominant in the B–V colour. When we examine the light and colour curves obtained in previous years, we can see the blueing in B–V curves. In the phases that the light curve is at its minimum, the system's B–V colour curve is bluer by $0\overset{m}{.}02$–$0\overset{m}{.}04$. Unfortunately, we could not obtain V–R colour from our observations, except in 1997. Consequently, we can not develop an argument concerning the V–R colour variation.

Excesses in the mean global blue colours of some young open cluster stars have been detected for some time now. Turner (1979) measured UV excess in the members of the young open cluster Pleiades. He explained this as being due to an effect of metallicity. Stauffer (1980) examined the "$turn - on$" point of pre-main sequence objects in the Pleiades. He explained this ultraviolet excess as being due to flaring. He reasoned that, since many of these stars are flare stars, this might affect the blue colours, making them look bluer and, thus, producing the excess.

This UV excess has been observed in some other types of stars and, up to now, there have been a few attempts at explaining it. In the study published by Amado & Byrne (1997), they examined several classes of chromospherically active late-type stars for evidence of an effect of activity on the mean global photospheric colours. The question that immediately arises from their study concerns the mechanism responsible for this UV excess. They considered the following possibilities: *flaring, chromospheric emission, X-ray back-heating, faculae*.

In an active star, where the brightness and temperature of the faculae and plages are greater than those of the photosphere, there is an effect on the colours. They can produce a UV excess and the star will be appeared bluer. This effect, of course, will be more enhanced for stars with lower effective temperature for which the contrast between the faculae and the photosphere will be larger.

In nine out of the 12 light curves, it appears that the distortions originate from the effect of two spots or two spot groups. First and second spots migrate toward decreasing phases with periods of 5.8 and 5.9 years. In previous years, only the migration period of the first spot was calculated and found to be 7.5 years by Sowell et al. (1983), 3.57 years by Evren (1987a), and 7.6 years by Heckert & Ordway (1995).

Migration motions of the spot groups located at different longitudes were detected over the years and it was found that the minimum separation of the spot groups was 0.3 phase in 1978.5 and 1985. In the years 1976 and 1982 the spot groups appeared farthest from each other, the difference in phase between two spots was 0.5 phase, this is the maximum difference. According to the results of Henry et al. (1995), there had been recent observational evidence that starspot formation was restricted to regions of stellar longitude 180° apart, which would be an indication that active longitudes form a long-lived, rigid structure, in the form of quadrants that are active, inactive, active, and inactive. Differential rotation can cause subsequent migration in longitude, which can carry a given spot far from its site of emergence. There has also been recent observational evidence that this rigid structure, if the active longitudes are defined with respect to the line of centers in a binary system, remains stationary. This effect would be called preferred longitudes (Henry et al. 1995). The spots seem to approach each other at a time interval of about six years in the MM Her system. The period of these variations is almost equal to the migration period. We determine that the spot groups get closer to each other, as *Active Regions Mutual Approach* (ARMA). The effects of ARMA on the amplitude of the light curve, the mean brightness and colour of the system allow us to obtain the following results:

- *The amplitude of the light curves increases by* $0\overset{m}{.}08$,
- *The system is the faintest*,
- *The system is the bluest*.

These properties may be taken as an indication of photospheric structures like spots and faculae. The network structure between these regions is more dominant with ARMA.

Dorren & Guinan (1990) gave an interesting example of evidence for an activity pattern in an active RS CVn star V711 Tauri. Fig. 5 in this paper shows a plot of the seasonal mean values of Hα index, V-magnitude, colour index, and C IV λ1550 emission line flux over time. The light variation appears to show a systematic increment and decrement suggesting the presence of an activity cycle with a period of 11–13 years. However, the Hα index and colour index measured for this binary do not seem to correlate well with the observed brightness changes. Moreover, the C IV λ1550 emission flux, which arises from the transition region, appears to rise and fall a few years out of step with the star's luminosity. This study indicates that the star was the brightest when the activity levels inferred from the transition region lines were the greatest. This effect is opposite to what would be expected if the starspots were the only contribution to the long-term brightness variations.

These results are interpreted as evidence of a significant facular (white light faculae) contribution to the star's luminosity. They suggest that the C IV λ1550 line emission yields a more direct measure of magnetic activity and that long-term light variation is produced by competition between the blocking effect of the dark starspots and enhancements in luminosity from white light faculae and a facular network similar to that observed in the Sun.

Dorren & Guinan (1990) believe that it is possible to have a clearer understanding of these results in light of the work of Foukal & Lean (Foukal & Lean 1986, 1988; Foukal 1987; Lean & Foukal 1988) on the factors affecting the solar irradiance. They showed conclusively that sunspot area is not the only factor affecting solar luminosity in the visible band. The contributions of the active region faculae and the facular network are at least as important in augmenting the solar emission as the spots are in diminishing it. Indeed, they showed that during the solar activity maximum (cycle 21) the irradiance was also a maximum. If the spots were the sole factor affecting the visible band luminosity a minimum would be expected. The loss of light due to the increased spot area at the peak of activity was more than compensated for by the growth of the contribution of the faculae and facular network. During the decline of activity from 1981 to 1984 following solar maximum, the solar irradiance also declined; they showed that this was due to a decline in both the active region faculae and in the facular network. A study of the last three solar cycles, 19–21, led these authors to conclude that the Sun is consistently brighter at the solar maximum, due to the faculae and facular network overcompensating for the reduced emission from the spots. They also found that the evolution of large active facular complexes is responsible for variations in the time scale of a few months.

In future, photometric and spectroscopic studies will explain the mystery of MM Her as well. Long-term sensitive UBVRI measurements will clarify the variations in the brightness against the colour. The variations which appeared as irregularities in such a system's colour curves should be investigated to reveal the effect of the facular structures. If we manage to find out not only the spots' contribution but also the contribution of spots and facular regions separately then we may be able to understand the photospheric distribution of these structures. The blueing in the colours of the system seems to prefer phase 0.5. This matter will be a subject of another paper.

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