COMMISSION 27 OF THE I. A. U.
INFORMATION BULLETIN ON VARIABLE STARS
Number 2305

Konkoly Observatory
Budapest
30 March 1983
HU ISSN 0374-0676

EXTREME SURFACE ACTIVITY ON THE COOL COMPONENT OF THE ECLIPSING BINARY FF AQUARII

The binary nature of FF Aqr (=BD-3°5357) was discovered by Dworetsky et al. (1977) when UBV photometry revealed a sharp occultation eclipse lasting about 13 hours in which the time of ingress/egress is only 24 minutes. No secondary eclipse was observed and an orbital period of $9^{d}.21$ was found. An analysis of the photometric and spectrographic observations showed that FF Aqr is an eclipsing binary which consists of a G8 III-IV component with strong Ca II H+K emission, and a less massive, hot subdwarf having a radius of about $0.1R_{\odot}$. In addition, Dworetsky et al. observed a relatively large light variation outside the eclipse (with a V amplitude ≈0.35 mag) which originally was tentatively attributed to the heating of the inner hemisphere of the G8 star by the subdwarf (i.e. the reflection effect). Ultraviolet observations of the system have been made inside and outside the eclipse with the IUE satellite (Dorren, Guinan and Sion 1982) and these observations indicate that the hot component is a sdOB star with $T_e \approx$ 35,000K and log $g \approx 6.0$). The UV spectrum of the cool star alone (obtained during the total eclipse of the subdwarf) reveals the presence of strong chromospheric emissions such as Mg II h+k and very strong chromospheric-corona transition region emission lines such as N V, C IV, C II, etc. The level of surface activity observed on the G8 star is generally consistent with its tidally induced rapid rotation of 50-60 km s^{-1}, indicated by the rotationally broadened line profiles measured by Dworetsky et al.

Photoelectric observations of FF Aqr were made on 33 nights from 1977 July through 1978 August at Biruni Observatory, Shiraz, Iran. The data were obtained with the 51-cm reflector, using a photometer equipped with an unrefrigerated RCA 4509 photomultiplier. The v, b, and y filters of the Strömgren intermediate-band uvby system were used. The star was too faint to observe in the ultraviolet bandpass.

Typically about one hour of observations was obtained per night, except during ingress and egress when more observations were obtained. BD-3°5353 and BD-3°5362 were observed as the comparison and check stars, respectively. The effects of differential atmospheric extinction were removed from the data using mean extinction coefficients, but these corrections were insignificant because of the close angular proximity of the comparison and variable stars. The observations were combined to form nightly means, except during ingress/egress when the individual observations were not averaged.

The differential Δb magnitudes are plotted in the figure against orbital phase where the phases were computed using the ephemeris of Dworetsky et al.:

$$\text{Min I} = \text{HJD } 2442752.9577 + 9^{d}.207755E. \qquad (1)$$

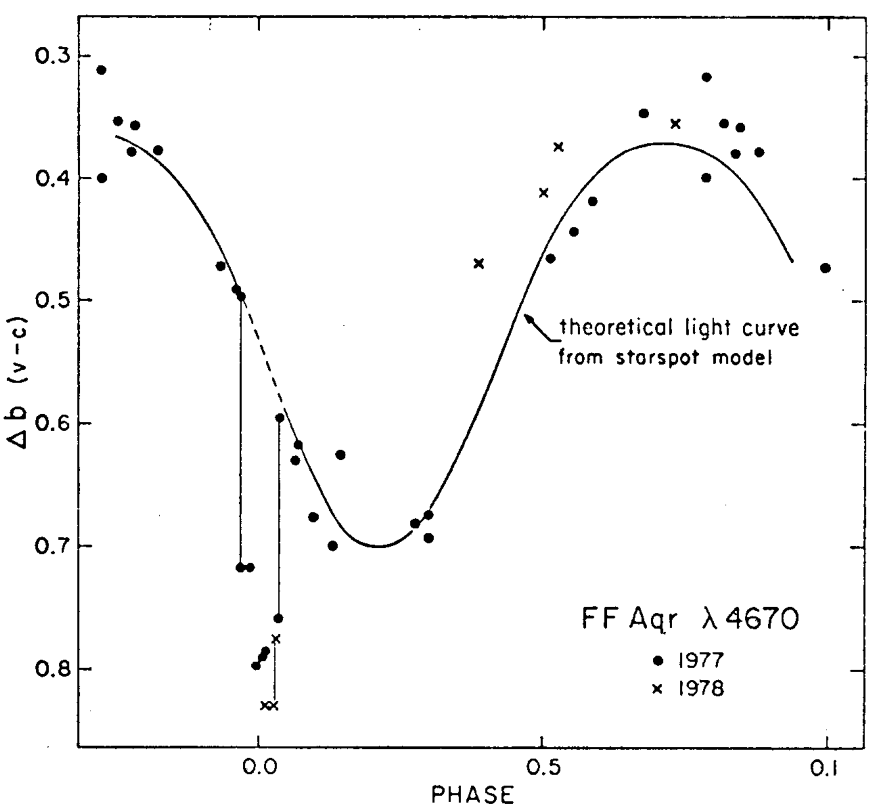

Figure 1

The Δb observations of FF Aqr obtained during 1977 and 1978. Individual observations obtained during ingress/egress are numerous and are represented by straightlines. The solid curve drawn through the data is a theoretical light curve computed with the starspot model.

As shown in the figure, the light curve is characterized by a wavelike light variation with an amplitude of about 0.33 mag, in which the minimum and maximum of the wave occur at about 0.18P and 0.7P, respectively. The primary eclipse is clearly seen at 0.0P about half way down the descending branch of the photometric wave.

The eclipse depth, wave amplitude and orbital phase of the wave maximum for the v, b, and y bandpasses are given in Table I along with the corresponding values determined by Dworetsky et al. from their 1975 UBV data.

Table I

Photometric Parameters of FF Aqr

Bandpass	λ_{eff}(Å)	Eclipse Depth	Wave Amplitude	Phase of Wave Max.
		1975 Dworetsky et al.		
V	5500	$0\overset{m}{.}15$	$0\overset{m}{.}35$	0.66
B	4400	0.4	0.33	0.55
U	3650	1.2	0.22	0.53
		1977		
y	5480	$0\overset{m}{.}11$	$0\overset{m}{.}35$	0.73
b	4670	0.22	0.33	0.72
v	4110	0.49	0.29	0.68

As shown in the table, the eclipse depths and amplitudes of the outside eclipse light variation generally are consistent between two sets of observations. The orbital phase of light maximum, however, appears to occur on the average about 0.13P later in 1977 than in 1975. In addition our 1978 observations suggest that the phase of light maximum occurs near 0.55P. Lastly, light variations as large as 0.10 mag occur from cycle-to-cycle. These cycle-to-cycle variations are particularly noticeable at the bottom of primary minimum. Dworetsky et al. also found that the light curve did not repeat closely. Similar variations are found in the v and y observations, and it appears that these brightness changes arise from the cool component.

The phasing of maximum and minimum light as well as the large amplitude of the photometric wave cannot be explained by the usual binary star interaction effects. This light variation is very similar to the quasi-sinusoidal photometric waves commonly observed for RS CVn variables, which appear to arise from an uneven distribution of subluminous regions (starspots) over the surface of the rotating star (Hall 1976). This possibility was also noted by Etzel et al. (1977).

Spectroscopically the G8 star appears similar to the active RS CVn variables, and it seems reasonable to suppose that the photometric wave observed in FF Aqr also arises from surface inhomogeneities. Following the same analytical procedure used by Dorren et al. (1981) to analyze the light curves of the RS CVn star -- V711 Tau, we find that the present light curves can be fit with the starspot model. The preliminary results of the analysis indicate that about 42% of the cool giant star's surface is covered with large subluminous regions which are about 800K cooler than the photosphere.

Thus, the cool component of FF Aqr rivals or surpasses most of the RS CVn stars in terms of surface activity. In addition, the presence of a cool giant and subdwarf in an eclipsing system provides an unusual opportunity to determine the physical properties of each star, which may play an important role in stellar evolutionary theory.

J.D. DORREN
M.J. SIAH
Biruni Observatory
Shiraz, Iran
and
Dept. of Astronomy
and Astrophysics
Univ. of Pennsylvania
Philadelphia, PA 19104

E.F. GUINAN
Biruni Observatory
Shiraz, Iran
and
Harvard-Smithsonian
Center for Astrophysics
60 Garden St.
Cambridge, MA 02138

References:

Dorren, J.D., Guinan, E.F. and Sion, E.M., 1982, in Advances in UV Astronomy: Four Years of IUE Research, edited by Y. Kondo, J.M. Mead and R.D. Chapman, NASA Conf. Publ. 2238, p. 517

Dorren, J.D., Siah, M.J., Guinan, E.F. and McCook, G.P., 1981, Astron. J. 86, 572

Dworetsky, M.N., Lanning, H.H., Etzel, P.B. and Patenaude, D.J., 1977, M.N.R.A.S. 181, 13

Etzel, P.B., Lanning, H.H., Patenaude, D.J., and Dworetsky, M.M., 1977, P.A.S.P. 89, 616

Hall, D.S., 1976, In Multiple Periodic Phenomena in Variable Stars, IAU Colloq. No. 29, Part I, edited by W.S. Fitch (Reidel, Dordrecht).