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ON THE ORBITAL PERIOD OF FO AQUARII

Patterson and Steiner (1983) identified the 13^{th} magnitude cataclysmic variable FO Aquarii as the optical counterpart of the X-ray source H2215–086, and found strictly coherent large-amplitude pulsations in the light curve, with a period of 21 minutes. In addition they found a shallow modulation recurring at the same period with which the emission lines move, which appeared to be 0.16802 days. This period has been adopted as the fundamental orbital period in all later studies, but we shall see below that it is probably incorrect, being a 24-hour alias of the true orbital period.

Tables 1 and 2 contain all available information on the two signatures of the orbital motion: the timings of "orbital dips" in the light curve, and the timings of inferior conjunction of the emission-line source. as revealed by radial velocity studies. The photometric data are sufficient to establish that the dips follow one of the following ephemerides:

(a) Minimum light $= JD_{\odot}\, 2,44782.867 + 0\overset{d}{.}202060E$

(b) Minimum light $= JD_{\odot}\, 2,44782.888 + 0\overset{d}{.}168017E$

In Table 1 we give cycle counts and $O-C$ residuals for the timings under each of these alternatives. The $O-C$ diagrams are shown in Figure 1, which shows that ephemeris (a) provides an excellent fit with an rms scatter of only 0.03 cycles, while ephemeris (b) is much less satisfactory, with an rms scatter of 0.09 cycles. Still a third cycle count, corresponding to $P = 0.1680466\ d$, was suggested as a possibility by Semeniuk and Kaluzny (1988), but Figure 1 shows that this is not possible.

This evidence ***strongly*** favors the longer period. Normally we would consider this evidence decisive, but the three spectroscopic timings, given in Table 2, supply contrary evidence. They occur at a consistent orbital phase according to ephemeris (b), but not according to ephemeris (a). This strongly favors the shorter period.

We can envision 3 solutions to this confusing problem:

TABLE 1 – Orbital "dips" in the light curve

Time	Observatory	ephemeris (a)		ephemeris (b)		Source
($JD_{\odot}$ 2, 440, 000+)		E	$O-C$ (cycles)	E	$O-C$ (cycles)	
4782.871	KPNO	0	+.02	0	−.10	Patterson and Steiner 1983
4787.914	KPNO	25	−.02	30	−.09	Patterson and Steiner 1983
4789.938	KPNO	35	−.01	42	−.04	Patterson and Steiner 1983
4790.953	KPNO	40	+.02	48	+.00	Patterson and Steiner 1983
4791.969	KPNO	45	+.05	54	+.05	Patterson and Steiner 1983
4834.801	CTIO	257	+.02	309	−.03	Patterson and Steiner 1983
4873.789	KPNO	450	−.02	541	+.02	Patterson and Steiner 1983
4881.673	KPNO	489	−.01	588	−.05	Patterson and Steiner 1983
4882.685	KPNO	494	+.00	594	−.03	Patterson and Steiner 1983
5117.881	ESO	1658	−.01	1994	−.20	Pakull 1986
5505.029	UKIRT	3574	−.00	4298	+.02	Sherrington, James & Bailey 1984
5613.733	KPNO	4112	−.02	4945	+.01	This paper
5919.867	KPNO	5627	+.04	6767	+.05	Mateo 1985
5929.142	AAO	5673	−.06	6822	+.25	Berriman *et al.* 1986
(6931.67)	KPNO	7962	+.01	9575	+.11	This paper
(6682.64)	CTIO	9402	+.02	11307	−.10	Semeniuk and Kaluzny 1988
6684.655	CTIO	9412	−.00	11319	−.10	Semeniuk and Kaluzny 1988
6685.665	CTIO	9417	−.00	11325	−.09	Semeniuk and Kaluzny 1988
6695.574	CTIO	9466	+.03	11384	−.12	This paper
6704.625	McDonald	9699	−.01	11652	+.02	Shafter and Macry 1987

TABLE 2 – Times of inferior conjunction of emission lines

Time	Observatory	ephemeris (a)		ephemeris (b)		Source
($JD_{\odot}$ 2, 440, 000+)		E	$O-C$ (cycles)	E	$O-C$ (cycles)	
4791.939	McGraw-Hill	45	−.10	54	−.13	Williams 1981
4872.939	Lick	446	−.23	536	−.04	Shafter and Macry 1987
5915.475	KPNO	5605	+.30	6741	−.09	Mateo 1985

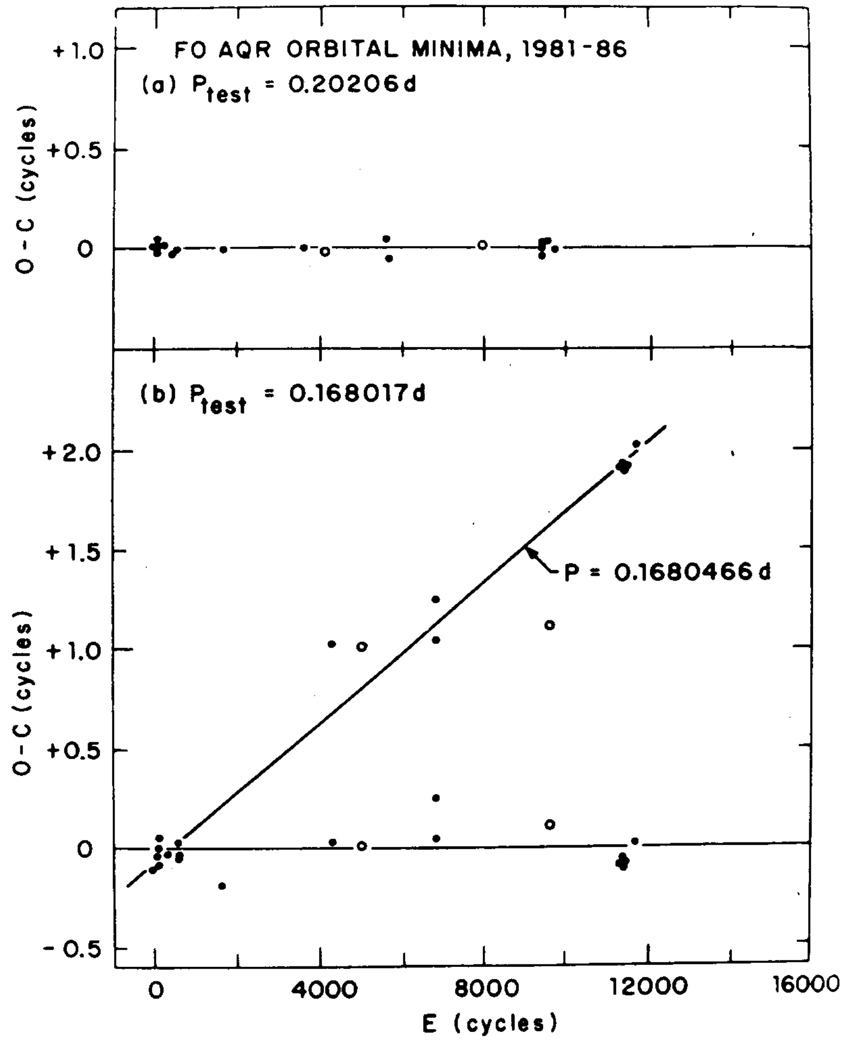

Figure 1. $O - C$ diagrams of the orbital dips, relative to three candidate ephemerides. The scatter about ephemeris (a) is by far the least, suggesting that it is the correct choice.

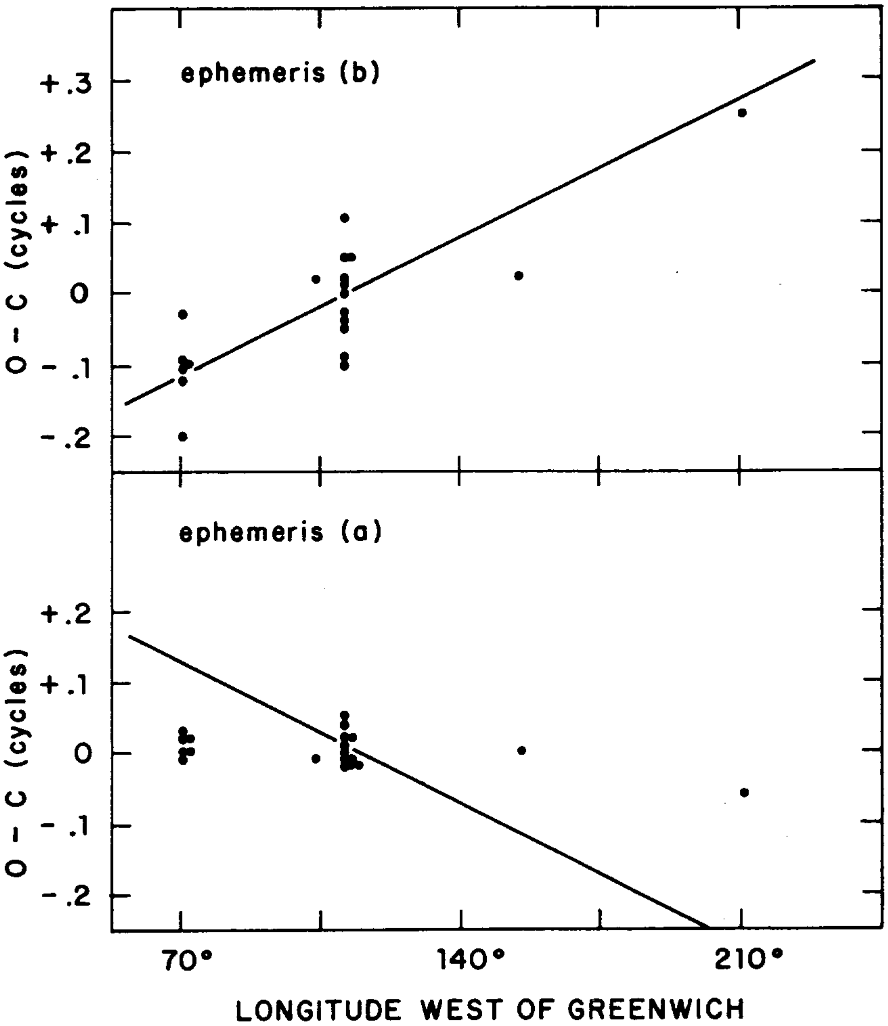

Figure 2. Dependence of dip timings on observatory longitude. No dependence is seen for ephemeris (a), but ephemeris (b) shows a systematic trend with longitude - in agreement with the solid line, which shows the trend expected if a cycle count error is present.

(1) The photometric period is really 0.20206 days, but the spectroscopic period is slightly different, sufficient to cause the inconsistent $O - C$ residuals in Table 2.

(2) Both photometric and spectroscopic periods are really 0.168017 days, but the uncertainties in the timings conspired by accident to give a substantially better fit to the longer, incorrect period.

(3) Both periods are really 0.20206 days, but at the time of Mateo's (1985) spectroscopy, the dominant emission-line source switched from its normal location by ~ 180°.

While none of these can be entirely excluded, we suspect that (3) is the correct answer. The accreting white dwarf in the system is a strong X-ray source which may cause a significant emission-line luminosity from the secondary and/or the hot spot region, due to the reprocessing of X-rays. This would be significantly out of phase with the motion of the accretion disk, normally the site of emission lines in cataclysmic variables. It's possible that a small rise in X-ray luminosity might shift the dominant role in the emission lines away from the accretion disk.

In principle, it might be possible to find the orbital frequency by finding an optical modulation at the sideband frequency ($\nu_x - \nu_{\mathrm{ORB}}$) caused by X-ray heating of surfaces fixed in the orbital frame. Such a modulation appears to be intermittently present, seen in the power spectra published by Patterson and Steiner (1983; $P = 1370 \pm 15$ sec) and Semeniuk and Kaluzny (1988; $P = 1374 \pm 4$ or 1351 ± 4 sec). The 0.168 d orbital period predicts $P_{\mathrm{SIDE}} = 1373$ sec, while the 0.202 d orbital period predicts $P_{\mathrm{SIDE}} = 1352$ sec. Hence this evidence, though far from conclusive, slightly favors the shorter period.

A better test, in our opinion, is to look for a systematic dependence of the $O - C$ residuals on the observer's terrestrial longitude. Figure 2 shows that such an effect does exist with ephemeris (b), but not with ephemeris (a). As Figure 2 demonstrates, the observed sign and magnitude of the effect provides strong support for the hypothesis we favor, that ephemeris (a) is correct.

Finally, it's worth noting that any lingering uncertainty about the photometric period could be dispelled by a single, high-quality timing obtained in Europe, Africa, or Asia. This will break the 24-hour alias which is the root of the problem.

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