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# THE HISTORICAL, 1889-2002, LIGHT CURVE OF THE ECLIPSING SYMBIOTIC BINARY AR Pav

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AR Pavonis is an eclipsing symbiotic binary with an orbital period of 605 days (Mayall 1937). It consists of a M5 III giant (Mürset & Schmid 1999) with a mass of $\sim 2\,M_\odot$ (Schild et al. 2001). The nature of the hot companion is under discussion. The presence of a large accretion disk around a main sequence star was suggested by Kenyon & Webbink (1984) and Skopal et al. (2000a), but, in contrast, Schild et al. (2001) considered a possibility that the hot component is a white dwarf and the red giant underfills its Roche lobe. According to the observed variations in the UV/optical continuum (e.g. Schild et al. 2001, Skopal et al. 2000a), the hot eclipsed object is highly variable in brightness, size and geometry. Photometric activity of AR Pav has been recorded since 1889 (Mayall 1937). The top panel of Fig. 1 shows its historical 1889.5–2001.8 photographic/$B$-band/visual light curve (LC). The $m_{\rm pg}/B$-band LC is characterized by about 2 mag deep minima – eclipses – and strong out-of-eclipse variations between about 12 and 10 mag, which peaked at $\sim 9^m$ in 1900 and 1935 active phases. The visual LC documents the evolution since 1982.2. It completely covers the 1985-1999 active phase. Dramatic out-of-eclipse variations in this part of the LC were interpreted as a result of variable mass transfer from the red giant (Bruch et al. 1994) and/or by an impact of the ejected material from the hot star to the facing red giant hemisphere (Skopal et al. 2000a).

Our new photographic magnitudes were obtained by measuring a total of 137 plates collected in the archive of the Bamberg Observatory. They cover the period 1963.5 to 1971.5. The magnitudes were estimated by eye at a microscope using the photoelectric sequence provided by Kilkenny (1988). For each plate we made a few independent estimates. It was possible to achieve an accuracy of about 0.1 mag. The data are summarized in Table 1 and plotted in Fig. 1. Compared are photoelectric $B$ magnitudes of Andrews (1974), which confirm the high accuracy of our photographic estimates. This suggests that variations of $\geq 0.1$ mag can be considered as real. Our data indicate rather irregular brightness changes from cycle to cycle with an increasing trend from epoch E=45 to E=48 (Fig. 2, left panel). We believe that a variable mass transfer governs this kind of irregular changes. In addition, a flat maximum can be recognized between 1969 and 1971 (Fig. 1, mid). This might be of the same nature as those observed in the Mayall's LC, suggesting a periodicity of 7-10 years (cf. Fig. 1, top).

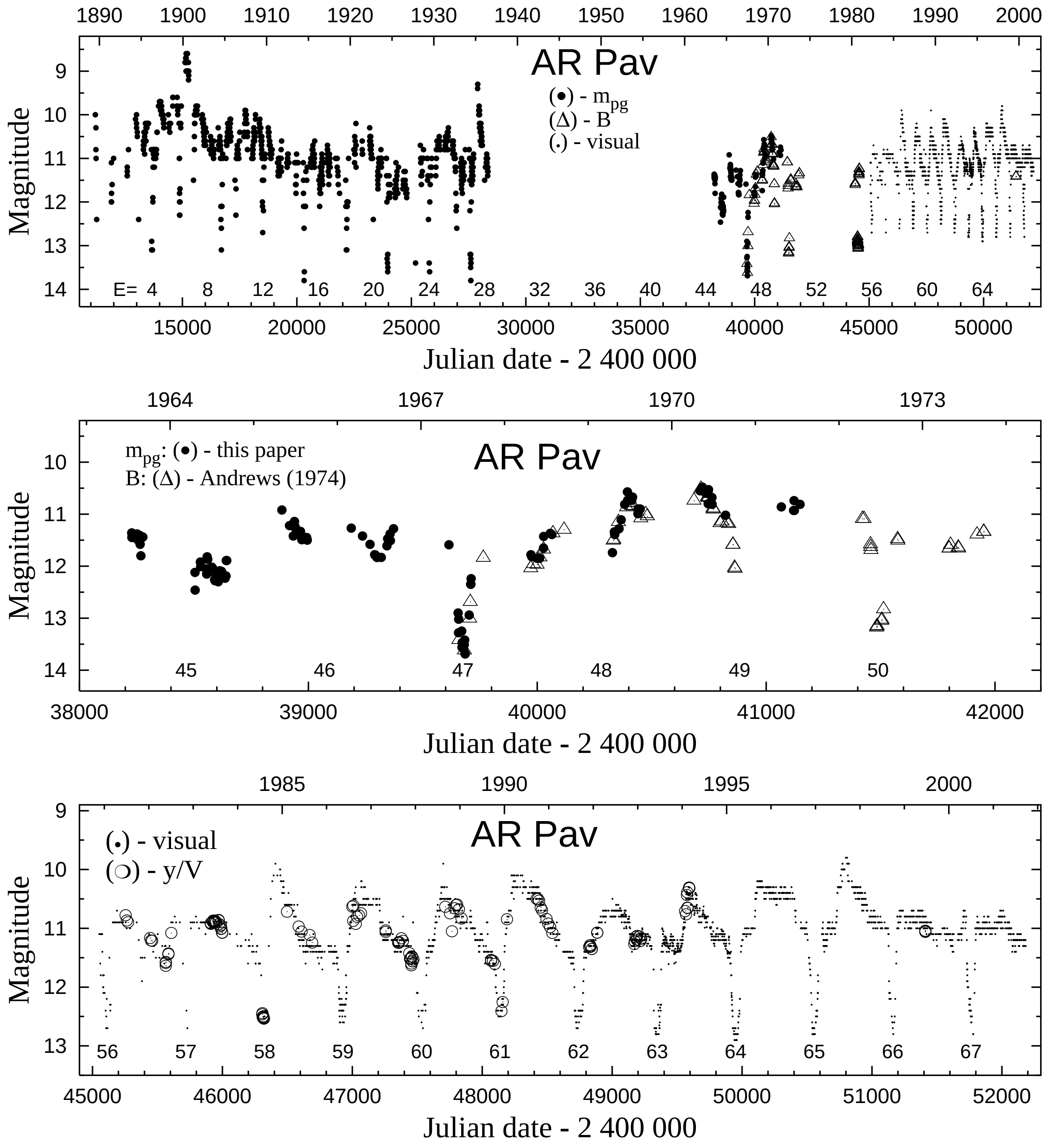


**Figure 1.** The historical 1889.5–2001.8 photographic/$B$-band/visual LC of AR Pav. It is compiled from photographic data of Mayall (1937), those presented in this paper, $B$-band photoelectric measurements as published by Andrews (1974) and Menzies et al. (1982), and the visual estimates made by one of us (AJ). **Middle:** A part of the LC between 1963.5 and 1973.7 composed of our photographic magnitudes and $B$-band photoelectric measurements by Andrews (1974). Note the very good agreement between these data sets. **Bottom:** Our visual estimates, which document the photometric evolution from 1982.2 to date. Compared are $y$-band photoelectric measurements obtained during the LTPV program at ESO (Manfroid et al. 1991, Sterken et al. 1993) and $V$-band photometry (around JD 2 451 410) published by Skopal et al. (2000b). Also in this case, agreement between these data sets is excellent. Epochs $E$ are given according to the average linear ephemeris of the minima, $Min = JD\ 2\,411\,265.9 + 604.46{\times}\mathrm{E}$ (Skopal et al. 2000a).

Our new visual estimates cover the period from epoch 66 (1998.9, cf. Fig. 1). They were carried out by one of us (AJ) with a private 12$''$.5 f/5 reflector using the comparison sequence of Kilkenny (1989). They are shown in the bottom panel of Fig. 1. Comparison of the photoelectric $y$ and $V$ magnitudes testifies the high quality of the visual observations. Our data show that the active phase of AR Pav suddenly ended at the beginning of epoch 66. No brightening was observed from this epoch to date. To demonstrate basic changes of the hot object between activity and the present quiescence, we folded the data according to the average ephemeris of the minima (Skopal et al. 2000a) and, as an example, selected those at E=62 and E=66 (Fig. 2, right panel). The E=66 minimum is narrower by about 16 days, deeper by $\approx 0.5$ mag with approximately the same level of minimum light, and shifted by about $-1.4$ days with respect to the minimum at E=62. In addition, a sharp profile of the recent minima at E=66 and 67 with a stillstand at $\varphi \sim 0.96$ is very similar to that observed during the quiescent phase between the epoch 0 and 28 (cf. Fig. 8 of Skopal et al. 2000a). Finally, we determined positions of the recent two minima to Min(66) = JD2 451 158.9±0.7 and Min(67) = JD2 451 762.8±0.7. Combining these positions with those published by Skopal et al. (2000a) allows us to slightly refine the average linear ephemeris of all available mid-points of eclipses between E=4 and 67 to

$$Min = JD\,2\ 411\,266.1 + 604.45(\pm 0.02) \times E.$$

The mid points of the last two minima suggest a period of $603.9 \pm 0.5$ days, which is consistent with the real period change derived by Skopal et al. (2000a). However, observations of further minima are needed to reduce the uncertainty.

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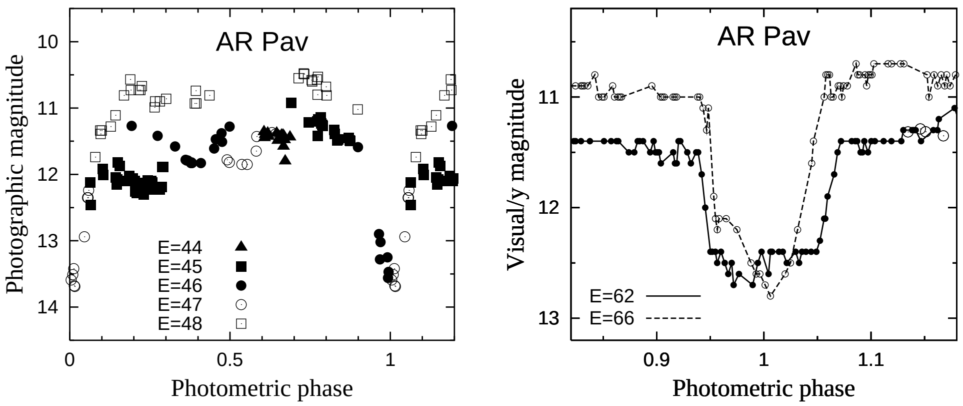


**Figure 2.** Phase diagrams of our photographic magnitudes (left) and visual estimates at E=62, 66 (right).

Table 1: New photographic magnitudes of AR Pav.

| JD 24... | $m_{pg}$ | JD 24... | $m_{pg}$ | JD 24... | $m_{pg}$ | JD 24... | $m_{pg}$ |
|---|---|---|---|---|---|---|---|
| 38228.366 | 11.36 | 38589.341 | 12.10 | 39236.440 | 11.42 | 40027.028 | 11.65 |
| 38229.363 | 11.45 | 38590.340 | 12.26 | 39269.497 | 11.58 | 40028.042 | 11.43 |
| 38230.364 | 11.40 | 38592.337 | 12.28 | 39289.447 | 11.78 | 40056.958 | 11.37 |
| 38233.310 | 11.42 | 38606.317 | 12.30 | 39291.434 | 11.79 | 40063.913 | 11.39 |
| 38234.360 | 11.40 | 38607.299 | 12.16 | 39293.431 | 11.79 | 40328.188 | 11.74 |
| 38235.326 | 11.38 | 38608.298 | 12.13 | 39299.431 | 11.83 | 40337.205 | 11.34 |
| 38236.319 | 11.43 | 38613.299 | 12.09 | 39300.410 | 11.82 | 40338.172 | 11.39 |
| 38252.269 | 11.38 | 38614.301 | 12.12 | 39301.419 | 11.83 | 40340.180 | 11.34 |
| 38254.274 | 11.49 | 38615.301 | 12.20 | 39318.358 | 11.83 | 40357.149 | 11.28 |
| 38257.267 | 11.45 | 38618.306 | 12.23 | 39343.309 | 11.61 | 40366.119 | 11.11 |
| 38258.267 | 11.46 | 38620.271 | 12.10 | 39346.267 | 11.47 | 40382.065 | 10.81 |
| 38260.270 | 11.46 | 38621.292 | 12.12 | 39357.254 | 11.38 | 40394.011 | 10.57 |
| 38261.269 | 11.41 | 38622.270 | 12.12 | 39358.237 | 11.51 | 40395.021 | 10.73 |
| 38264.225 | 11.41 | 38636.219 | 12.23 | 39372.236 | 11.28 | 40410.005 | 10.73 |
| 38265.223 | 11.58 | 38640.219 | 12.19 | 39614.547 | 11.59 | 40412.983 | 10.73 |
| 38266.269 | 11.43 | 38641.222 | 11.89 | 39654.042 | 12.90 | 40415.955 | 10.67 |
| 38267.221 | 11.48 | 38643.222 | 11.89 | 39656.042 | 13.28 | 40439.913 | 10.99 |
| 38268.226 | 11.80 | 38884.547 | 10.92 | 39657.028 | 13.02 | 40440.916 | 10.90 |
| 38277.224 | 11.44 | 38917.454 | 11.22 | 39669.994 | 13.25 | 40449.881 | 10.90 |
| 38504.572 | 12.12 | 38933.399 | 11.20 | 39671.014 | 13.56 | 40711.194 | 10.55 |
| 38505.574 | 12.46 | 38934.396 | 11.42 | 39672.021 | 13.47 | 40721.113 | 10.48 |
| 38528.513 | 11.92 | 38935.406 | 11.17 | 39677.969 | 13.59 | 40722.124 | 10.49 |
| 38529.514 | 12.01 | 38939.399 | 11.14 | 39680.979 | 13.51 | 40736.073 | 10.58 |
| 38553.462 | 12.05 | 38940.404 | 11.23 | 39682.990 | 13.42 | 40737.054 | 10.60 |
| 38555.461 | 12.15 | 38942.399 | 11.25 | 39683.999 | 13.68 | 40746.057 | 10.57 |
| 38556.463 | 12.08 | 38943.379 | 11.27 | 39684.958 | 13.69 | 40747.023 | 10.80 |
| 38557.463 | 11.82 | 38965.338 | 11.33 | 39702.938 | 12.94 | 40748.063 | 10.53 |
| 38560.419 | 11.87 | 38966.309 | 11.39 | 39708.896 | 12.35 | 40762.999 | 10.68 |
| 38562.423 | 12.10 | 38971.316 | 11.49 | 39709.886 | 12.35 | 40764.039 | 10.81 |
| 38578.377 | 12.02 | 38972.330 | 11.47 | 39710.896 | 12.24 | 40822.828 | 11.02 |
| 38580.383 | 12.10 | 38992.267 | 11.45 | 39972.198 | 11.78 | 41066.194 | 10.86 |
| 38583.381 | 12.06 | 38994.229 | 11.49 | 39976.177 | 11.82 | 41120.024 | 10.93 |
| 38584.381 | 12.10 | 38995.229 | 11.50 | 40000.090 | 11.85 | 41122.038 | 10.74 |
| 38585.381 | 12.06 | 39187.576 | 11.27 | 40010.063 | 11.85 | 41123.035 | 10.93 |
| | | | | | | 41147.917 | 10.81 |

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