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LIGHT CURVES FOR R ARAE

R Arae has recently been the subject of considerable effort, including the work of Nield (1987), Nield *et al.* (1986), Forbes *et al.* (1988), Forbes (1990a,b), Banks (1989a,b), and the recent international observing campaign organised by Dr. Guinan. Light curve modelling of this system is complicated by third light (HD 47930B being only 4" distant), and broadband light curve fluctuations of about 0.1 magnitudes, which possess timescales of the order of a night (Nield, 1987). The latter, in addition to other irregularities such as abnormal radial velocities, apparent Balmer line doubling (Sahade, 1952), and a gradual period increase (Forbes, 1990b) are now considered to be typical indicators of Interactive Algols.

Nield (1987) modelled UBV light curves using Budding's (1972) eclipsing binary computer program, finding that the secondary component's radius appeared to be well within its Roche Lobe, although increasing the third light contribution helped slightly, enlarging the radius. Banks (1989b) attempted unsuccessfully, in a Budding and Zeilik (1987) style analysis, to reach a semi-detached status using a mass transfer stream impact "hot spot" to account for the light curve asymmetry. The purpose of the present bulletin, a continuation of this previous effort, is to demonstrate that a light curve solution of the desired status can be reached by the introduction of orbital eccentricity (although see Kondo *et al.* (1984)). It is hoped that this brief analysis will be of benefit to the current work by other researchers on R Arae.

The final effective stellar temperatures of Nield (1987) and Sahade's (1952) mass ratio were adopted for an initial fit of the amalgam V band of Nield's (1987) and Forbes' (1990a) data, binned in the manner described by Budding and Zeilik (1987). Only the features expected in a standard eclipsing binary's light curve were modelled in this fit (see Figure 1). The following photometric parameters were reached :

Primary Radius $r_1 = 0.214 \pm 0.029$

Secondary Radius $r_2 = 0.282 \pm 0.068$

Inclination $i = 86.2 \pm 6.8^{\circ}$

Primary Luminosity $L_1 = 32.6 \pm 6.5$ %

Secondary Luminosity $L_2 = 15.3 \pm 7.5$ %

Eccentricity $e = 0.43 \pm 0.06$

Mean Anomaly at Phase zero = $2.4 \pm 1.1^{\circ}$

The difference curve (see Figure 2), obtained by subtracting this initial model from the original light curve, was then modelled as being due to a mass transfer stream "hot spot". The ratio of the spot flux relative to the primary component's photosphere was arbitrarily set to double, while the

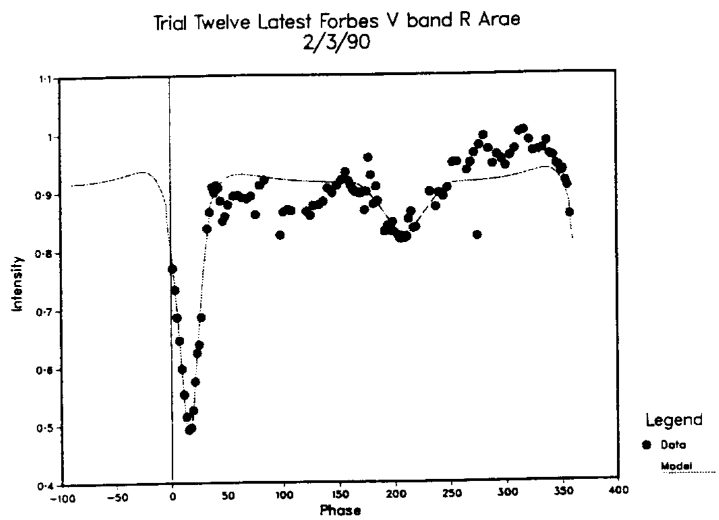

Figure 1: The binned data points (circles) are plotted with the best initial fit model (the line).

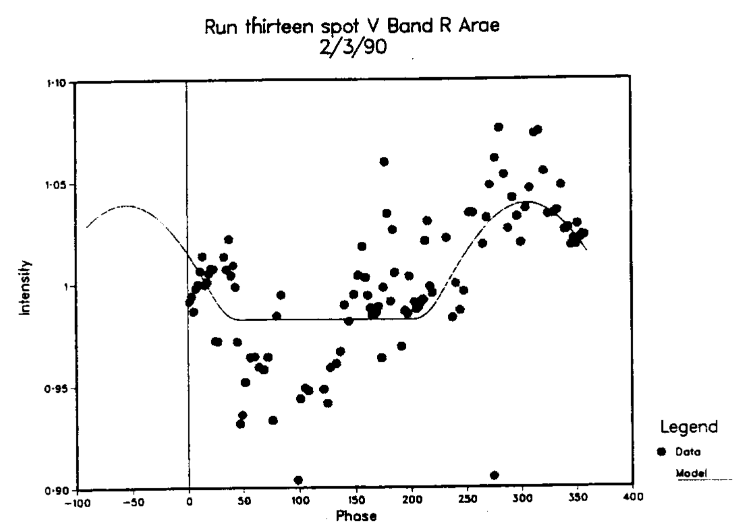

Figure 2: The residuals from the inital fit (circles) were modelled by a mass transfer impact site hot spot (the smooth line).

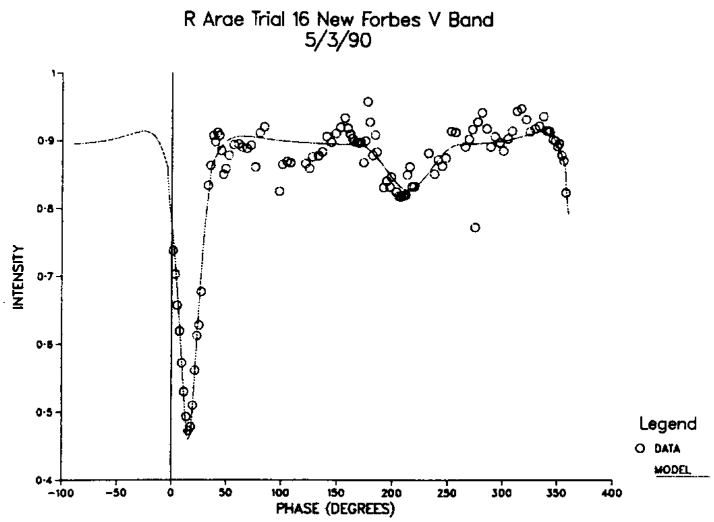

Figure 3: The final light curve data and best fit model.

spot's latitude was set to zero, being the likely region for impact.

The resulting equatorial spot parameters were longitude 304.9 ± 6.3 ° and radius 13.9 ± 0.8°, slightly smaller than Banks' (1989b) results which did not account for eccentricity. The azimuthal extension lends support to the existence of a circumstellar disk.

The final light curve (see Figure 3) was then formed by removing the calculated spot effects from the orginal data. This was then modelled as a standard eclipsing binary producing the following parameters :

Primary Radius $r_1 = 0.214 \pm 0.005$

Secondary Radius $r_2 = 0.277 \pm 0.011$

Inclination $i = 84.1 \pm 6.2\,^\circ$

Primary Luminosity $L_1 = 36.66 \pm 0.05$ %

Secondary Luminosity $L_2 = 14.03 \pm 0.07$ %

Eccentricity $e = 0.43 \pm 0.05$

Mean Anomaly at Phase zero = $7.1 \pm 3.8\,^\circ$

These generally better constrained values are not dramatically different from those of the initial fit, which could be expected as the "spot" is located around second quadrature. The eclipsing binary synthetic light curve program therefore runs a "mean" line through the spot's influence on the light curve. This bulletin's results are more physically possible for the system than previous work, as the secondary component reaches its Roche Lobe (see Kopal, 1959), and could now be responsible for the mass transfer.

R Arae's eccentricity will result in its Roche Geometry altering during an orbit, presumably along with the mass transfer rate, that could help explain the rapid light curve variations noted above (see also Banks, 1989b). However there is an urgent need for observations of this bright system, especially around the rather elusive secondary minimum, which would aid considerably further synthetic light curve modelling. In addition the question of third light needs to be definitively addressed. Nield (1987) estimated the V band contribution to be about 40% of the total system's light. This estimate was obtained by moving R Arae out of the telescope diaphragm, and taking readings of the companion star alone. CCD Imaging, at a longish focal ratio perhaps, could be the best method of resolving this issue.

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References:

Banks, T.,*Unpublished M.Sc Thesis*, Victoria University of Wellington, 1989a.
Banks, T., *Southern Stars*, **33**, 188, 1989b.
Budding, E., *Unpublished PhD Thesis*, Victoria University of Manchester, 1972.
Budding, E., and Zeilik, M., *Astrophys. J.*, **319**, 827, 1987.
Forbes, M.C., in *"Proceedings of the Blenheim 1989 PEP-3 Conference"*, in press, 1990a.
Forbes, M.C., *Unpublished M.Sc Thesis*, Victoria University of Wellington, 1990b.
Forbes, M.C., Budding, E., and Priestly, J., *IBVS Number 3278*, 1988.
Kondo, Y., McCluskey, G.E., and Parsons, B.B., *Astrophys. Spa. Sci.*, **99**, 281, 1984.
Kopal, Z., *Close Binary Systems*, Chapman and Hall, 1959.
Nield, K.M., *Unpublished M.Sc Thesis*, Waikato University, 1987.
Nield, K.M., Budding, E., and Priestly, J., *IBVS Number 2941*, 1986.
Sahade, J., *Astr. J.*, **116**, 27, 1952.