Light Curves and Analyses of the Eclipsing Overcontact Binaries V1033 Her and V1044 Her

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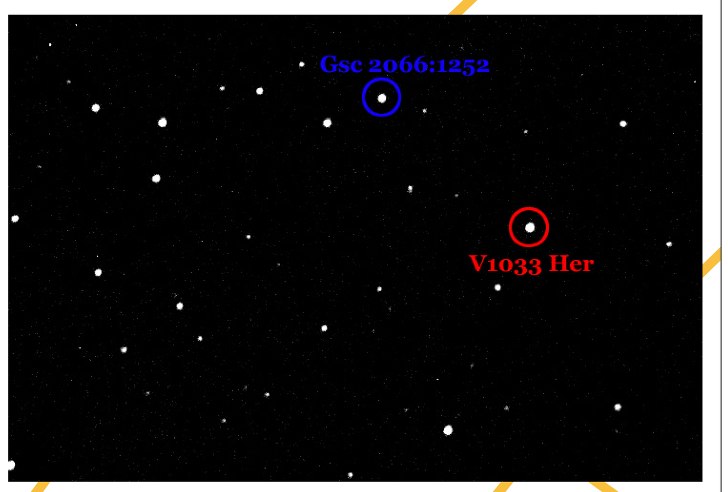
New precision V & R_c light curves of the eclipsing binaries V1033 Her and V1044 Her have been obtained using the 41-cm telescope at the Eastern University Observatory equipped with an SBIG ST-10XME CCD.

V1033 Her (GSC 2066:1210, P = 0.2981 days, m = 11.2) has only one published unfiltered light curve (Blattler and Diethelm 2001a) with significant scatter in the data. The system was observed on seven nights from 15 Jun - 26 Jul 2006, accumulating approximately 900 observations in both V and R_c. All published times of minimum light were analyzed resulting in the refinement of the star's ephemeris to 2452056.4134(5) + 0.29805021(11)E. Since monitoring began in 1999 the period of the system has been constant. The light curves show distinctly that the system is totally eclipsing. Analysis via Wilson-Devinney (1971;1992) differential corrections (DC) indicates that that binary is W-type (the larger, more massive star is the cooler component), has a mass ratio of 0.287, small temperature difference between the stars of 374° K, and a fillout of 0.294. The complete list of parameters is given in a table below.

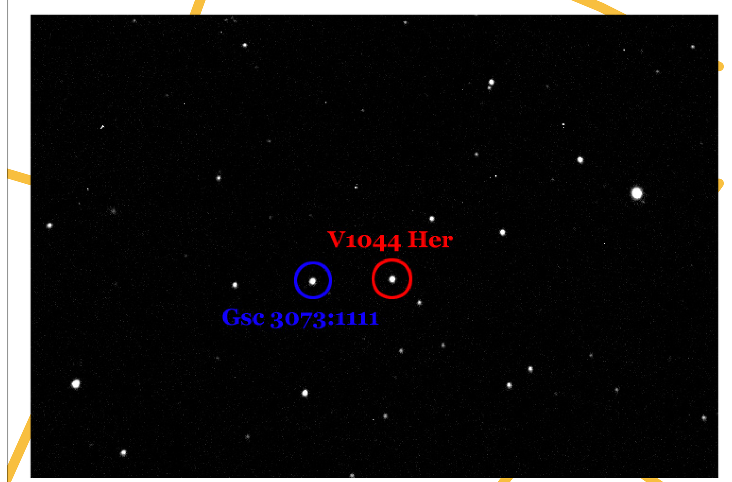
V1044 Her (GSC 3073:837, P = 0.2406 days, m = 12.5) is a partially eclipsing overcontact system of very short period and relatively deep eclipses of 0.6 mag in R_c. The previously published unfiltered light curve given by Blattler and Diethelm (2001b) had too much scatter for reliable analysis. V1044 Her was observed on eleven nights from 5 Jun - 10 Jul 2005, accumulating more than 800 observations in both V and R_c. All published times of minimum light were analyzed resulting in the refinement of the star's ephemeris to 2452065.5004(3) + 0.24064028(7)E. Since monitoring began in 2001 the period of the system has been constant.

Determining a unique mass ratio from partially eclipsing light curves is nearly impossible. Even with a fairly deeply eclipsing system like V1044 Her, the range of possible mass ratios is extensive. This is shown in the "Q-method" graph below which plots mass ratio versus the sum of the squares of the residuals as determined from Wilson-Devinney differential corrections (DC). Each dot represents a different mass ratio which was held constant while varying other parameters (inclination, T_2, omega, L_1) in order to achieve a best fit (the infamous "q-method"). In each case the DC program converged to a robust solution where the suggested parameter corrections were usually smaller than their formal probable errors. The result of this clearly demonstrates that the mass ratio is **indeterminate** from the light curves. Essentially any mass ratio from 0.55 to 1.60 gives nearly the same fit. Interestingly, although most of the parameters cannot be uniquely determined, the inclination and temperature difference between the two stars hardly varied at all within this mass ratio range. So the inclination of the system (~81°) and the temperature difference (~200° K) are fairly well determined.

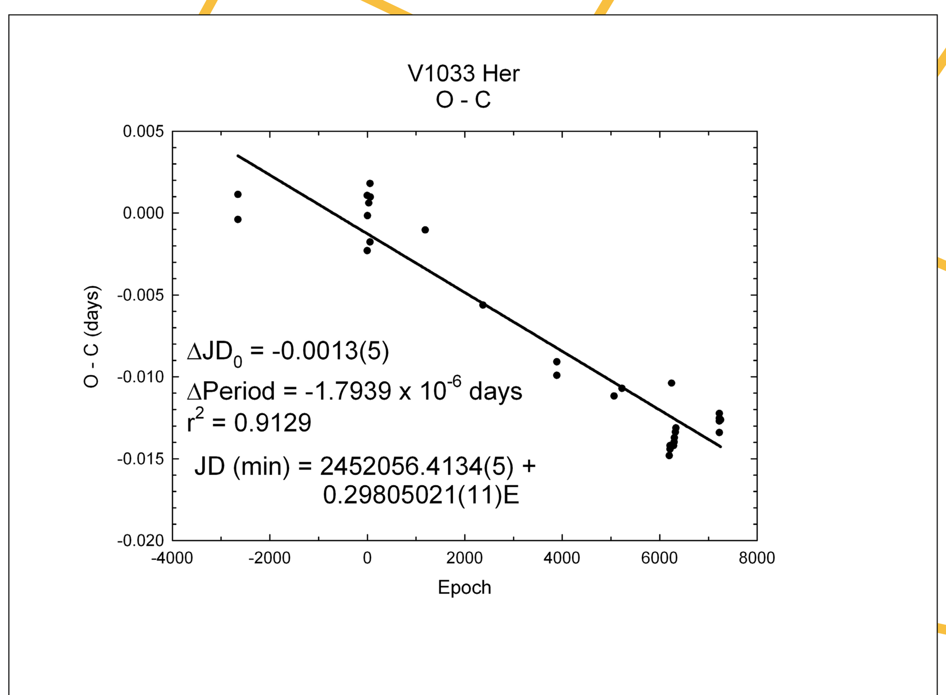
To show how close the solutions actually are, we plot the "best" fit (mass ratio = q = 0.55 which by definition is an A-type overcontact system, not to be expected from such a short period binary) as well as a "typical" mass ratio of (q = 1.35) which is far more likely for a W-type solution of this very short period system. The resulting light curves from the two solutions are virtually indistinguishable to the eye. Obviously the final solution to this overcontact binary must await a spectroscopic study and radial velocity solution in order to uniquely determine the mass ratio as well as absolute parameters.



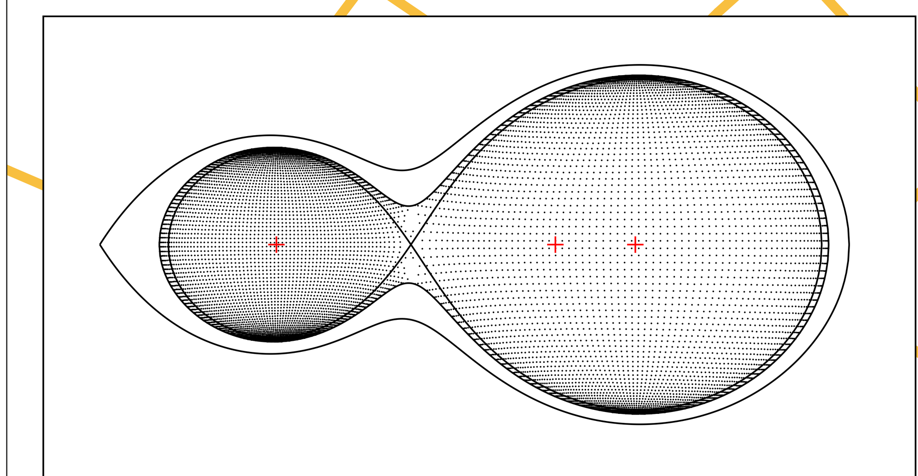
V1033 Her



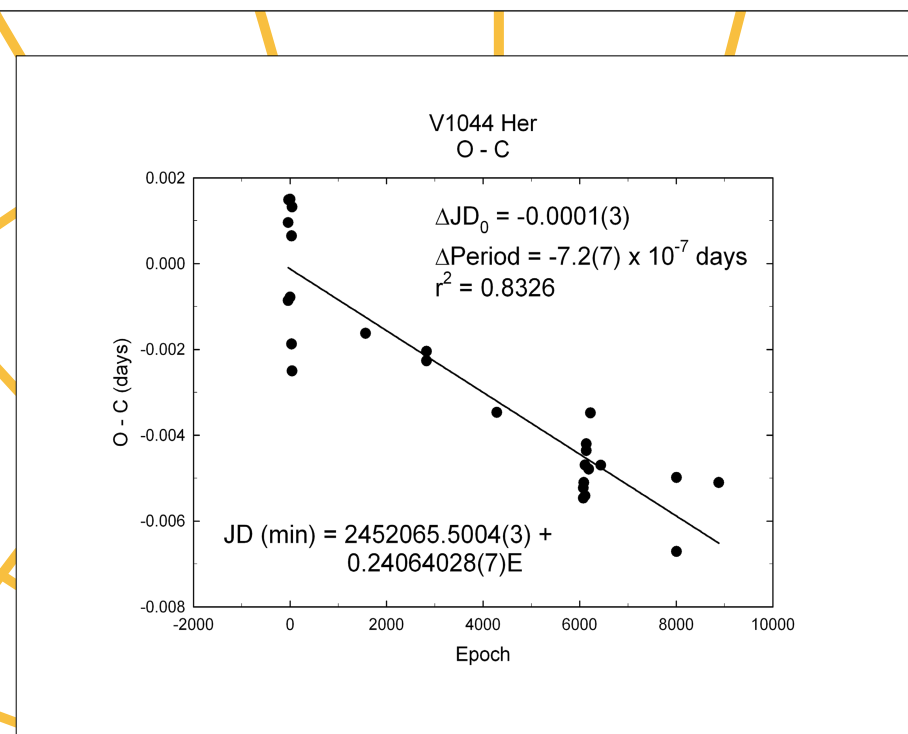
V1044 Her



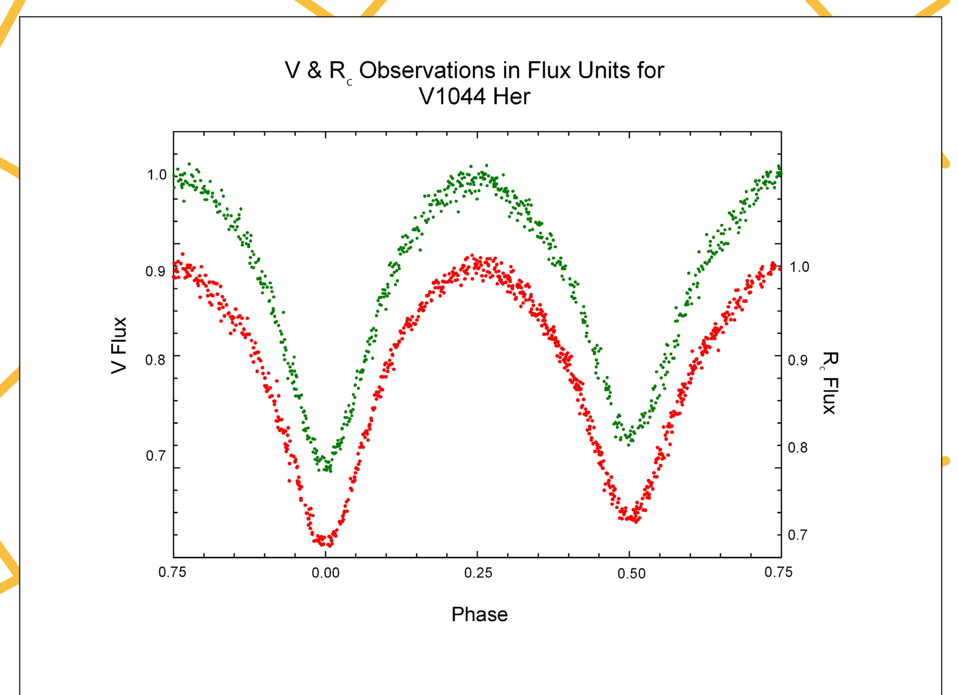
Linear fit to the O-C residuals of V1033 Her indicating that the published period was too long. The corrected ephemeris is shown in the bottom left hand corner.



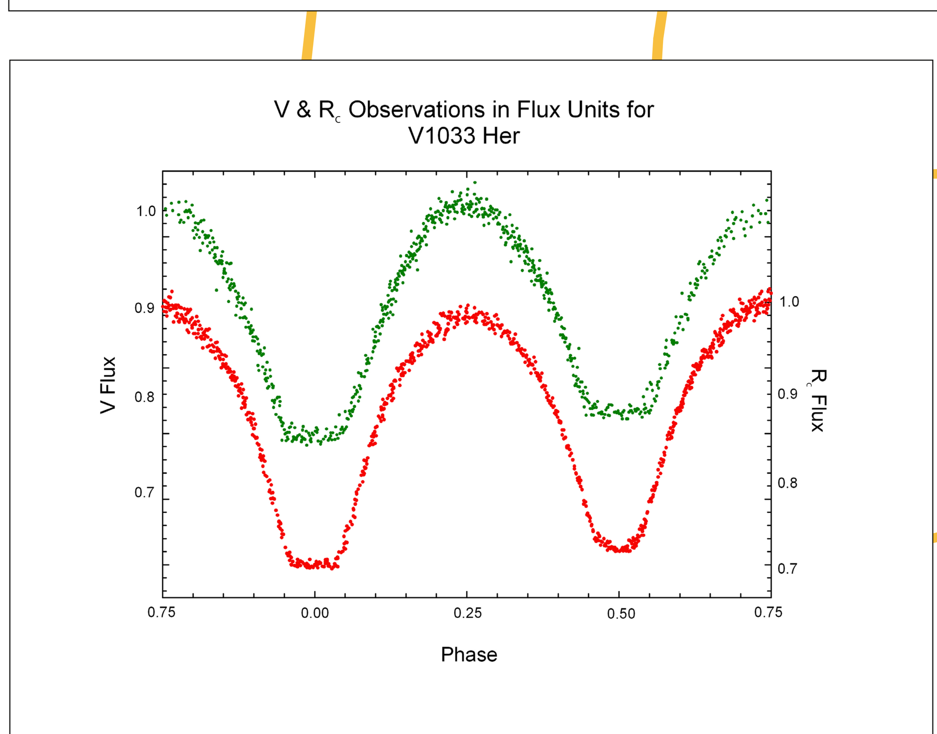
V1033 Her with inner and outer Lagrangian surfaces



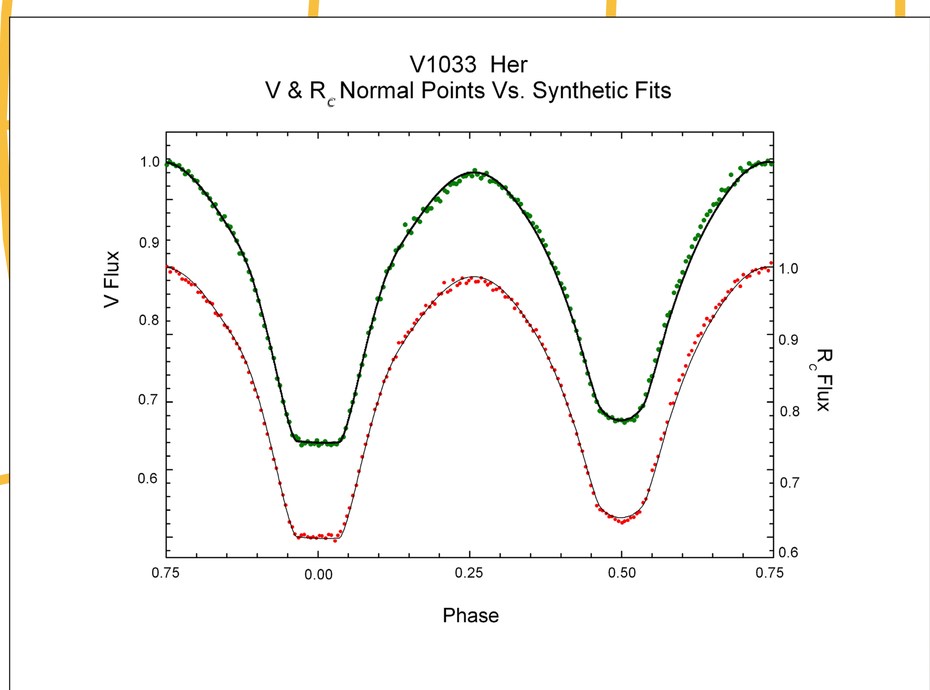
Linear fit to the O-C residuals of V1044 Her indicating that the published period was too long. The corrected ephemeris is shown in the bottom left hand corner.



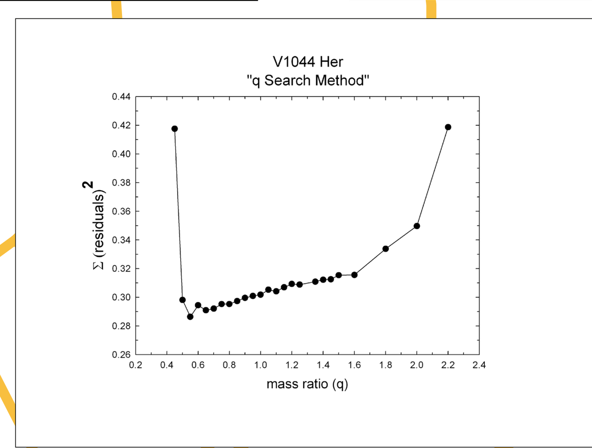
Individual V (green dots) and R_c (red dots) observations of V1044 Her



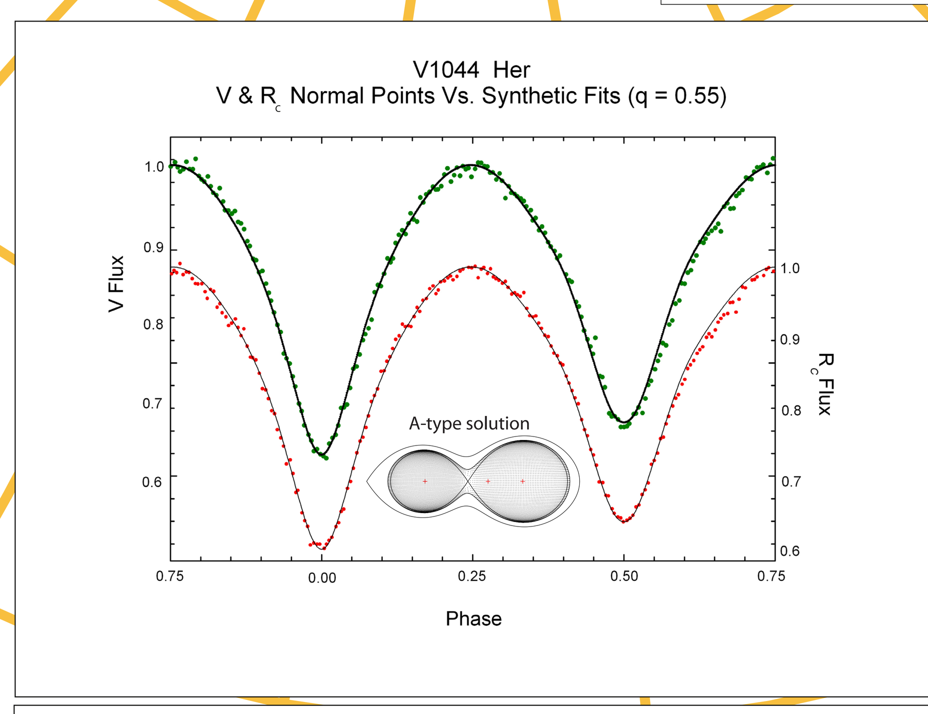
Individual V (green dots) and R_c (red dots) observations of V1033 Her



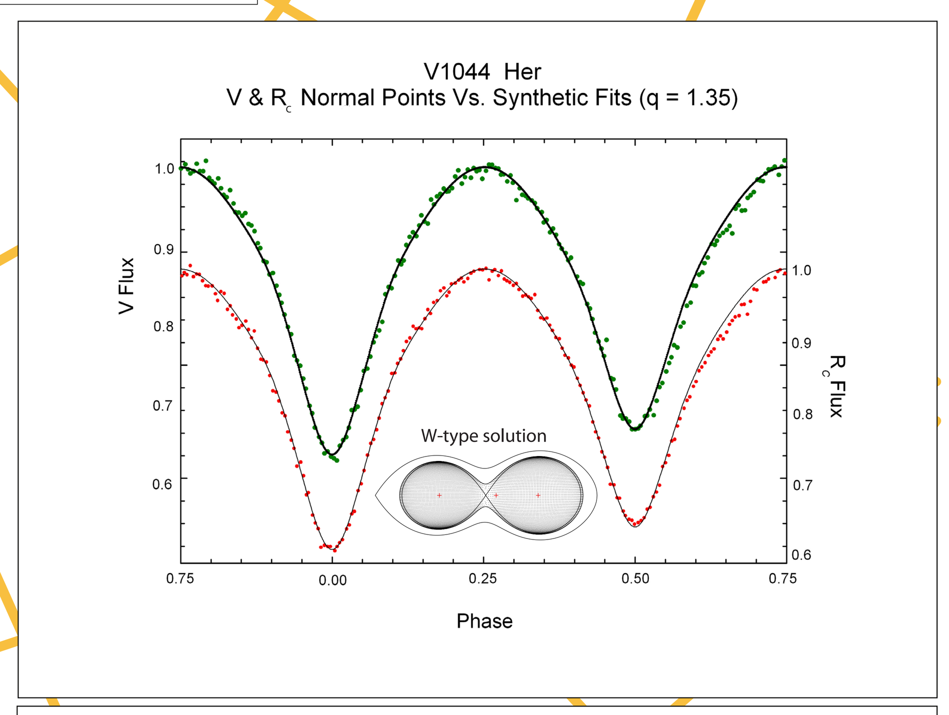
V and R_c synthetic Wilson-Devinney fits (solid curves) to normal points of V1033 Her



Plot of mass ratio vs. sum of the squares of the residuals for various trial solutions of V1044 Her using Wilson-Devinney DC. These results indicate that essentially equivalent fits can be achieved using any mass ratio between 0.55 and 1.60. This demonstrates the ambiguity in solving partially eclipsing systems.



V and R_c synthetic Wilson-Devinney fits (solid curves) to normal points of V1044 Her for mass ratio of q = 0.55. Note that this solution is virtually indistinguishable from the light curve generated using q = 1.35 shown in the graph to the right.



V and R_c synthetic Wilson-Devinney fits (solid curves) to normal points of V1044 Her for mass ratio of q = 1.35. Note that this solution is virtually indistinguishable from the light curve generated using q = 0.55 shown in the graph to the left.

Light Curve Parameters for V1033 Her

(Formal probable errors are given in parentheses)

mass ratio	= 3.489 (10)
Surface potential $\Omega_1 = \Omega_2$	= 7.0723 (100)
Fillout	= 0.294
Mean density ρ_1	= 1.29 g/cm³
Mean density ρ_2	= 1.95 g/cm³
Inclination	= 88.40 (35)
Temperature T_1	= 5626 ºK (3)
Temperature T_2	= 6000 ºK (assumed)
Albedo $A_1 = A_2$	= 0.5 (assumed)
Luminosity 1 = L_1 (5500 Å)	= 0.6929
Luminosity 2 = L_2 (5500 Å)	= 0.3071 (5)
Limb darkening $x_1 = x_2$ (5500 Å)	= 0.594 (assumed)
Luminosity 1 = L_1 (6400 Å)	= 0.7011
Luminosity 2 = L_2 (6400 Å)	= 0.2989 (5)
Limb darkening $x_1 = x_2$ (6400 Å)	= 0.510 (assumed)
Gravity brightening $g_1 = g_2$	= 0.32 (assumed)

Stellar Radii

r_1 back	= 0.53868 (41)	r_2 back	= 0.32637 (107)
r_1 side	= 0.50991 (25)	r_2 side	= 0.28285 (131)
r_1 pole	= 0.47072 (16)	r_2 pole	= 0.26999 (107)

Spot Parameters for Star 1

Latitude	Longitude	Spot Radius	Temperature Factor
60.0	90.0	10.0	0.70

Light Curve Parameters for V1044 Her (q = 0.55)

(Formal probable errors are given in parentheses)

mass ratio	= 0.55 (assumed)
Surface potential $\Omega_1 = \Omega_2$	= 2.8842 (32)
Fillout	= 0.266
Mean density ρ_1	= 2.32 g/cm³
Mean density ρ_2	= 2.83 g/cm³
Inclination	= 82.92 (9)
Temperature T_1	= 5600 ºK (assumed)
Temperature T_2	= 5454 ºK (5)
Albedo $A_1 = A_2$	= 0.5 (assumed)
Luminosity 1 = L_1 (5500 Å)	= 0.6582 (11)
Luminosity 2 = L_2 (5500 Å)	= 0.3418
Limb darkening $x_1 = x_2$ (5500 Å)	= 0.641 (assumed)
Luminosity 1 = L_1 (6400 Å)	= 0.6544 (9)
Luminosity 2 = L_2 (6400 Å)	= 0.3456
Limb darkening $x_1 = x_2$ (6400 Å)	= 0.552 (assumed)
Gravity brightening $g_1 = g_2$	= 0.32 (assumed)

Stellar Radii

r_1 back	= 0.48409 (509)	r_2 back	= 0.38173 (386)
r_1 side	= 0.44922 (342)	r_2 side	= 0.33886 (196)
r_1 pole	= 0.42066 (253)	r_2 pole	= 0.32213 (151)

Light Curve Parameters for V1044 Her (q = 1.35)

(Formal probable errors are given in parentheses)

mass ratio	= 1.35 (assumed)
Surface potential $\Omega_1 = \Omega_2$	= 4.1815 (40)
Fillout	= 0.208
Mean density ρ_1	= 2.53 g/cm³
Mean density ρ_2	= 2.79 g/cm³
Inclination	= 80.36 (9)
Temperature T_1	= 5405 ºK (5)
Temperature T_2	= 5600 ºK (assumed)
Albedo $A_1 = A_2$	= 0.5 (assumed)
Luminosity 1 = L_1 (5500 Å)	= 0.5245
Luminosity 2 = L_2 (5500 Å)	= 0.4755 (12)
Limb darkening $x_1 = x_2$ (5500 Å)	= 0.641 (assumed)
Luminosity 1 = L_1 (6400 Å)	= 0.5301
Luminosity 2 = L_2 (6400 Å)	= 0.4699 (10)
Limb darkening $x_1 = x_2$ (6400 Å)	= 0.552 (assumed)
Gravity brightening $g_1 = g_2$	= 0.32 (assumed)

Stellar Radii

r_1 back	= 0.45420 (195)	r_2 back	= 0.40234 (557)
r_1 side	= 0.41816 (111)	r_2 side	= 0.36260 (329)
r_1 pole	= 0.39403 (80)	r_2 pole	= 0.34423 (260)