Data Analysis Question 1 - solution

1) The star is a W UMa type, so both primary and secondary minima were observed. If the depth of the minimum isn't given, there is no way of decifing which (primary or secondary it is).

2) From the data, the can be seen that on four nights more than one minimum was observed. This allows us to estimate half the period based on the difference between pairs of observations:

minima	Δ T	average
2-1	.1367	Σ/5=.1367
4-3	.1372	Period P = obtained average x 2 = **0.2734**
10-9	.1364	
11-10	.1373	
12-11	.1359	

3) For a first approximation of the elements, we chose an initial epoch (M_0), for example the first observed minimum 2454092.4111 The approximate elements are then:
$M_{calc} = 2454092.4111 + 0.2734 \cdot E$

4) For an exact determination of the the elements we draw an O-C diagram. The data for making the O-C diagram are calculates as follows:

No	(M_{obs}) 2454000 +	$E = (M_{obs} - M_0)/P$	E (rounded to the nearest whole or half integer)	M_{calc} 2454000.0+	O-C = M_{obs}-M_{calc}
1	092.4111	0	0,0	092,4111	0,0000
2	092.5478	0,5	0,5	092,5478	0.0000
3	367.3284	1005,5497	1005,5	367,3148	0,0136
4	367.4656	1006,0516	1006,0	367,4515	0,0141
5	388.5175	1083,0519	1083,0	388,5033	0,0142
6	388.6539	1083,5508	1083,5	388,6400	0,0139
7	704.8561	2240,1061	2240,0	704,8271	0,0290
8	776.4901	2502,1178	2502,0	776,4579	0,0322
9	835.2734	2717,1262	2717,0	835,2389	0,0345
10	847.3039	2761,1295	2761,0	847,2685	0,0354
11	847.4412	2761,6316	2761,5	847,4052	0,0360
12	847.5771	2762,1287	2762,0	847,5419	0,0352

5) The O-C diagram should be plotted on graph paper

6) From the diagram, it can be seen that over 2762 epochs the value of (O-C) increased by 0.0355 days, therefore over one cycle (one epoch) the period was too short by:

$$0.0355/2762 = 0.0000129$$

and the estimated period P should be increased by this value.Taking into account that the graph can be read to 3 significant figures, the correction should also be to 3 significant figures.
$P' = 0,2734 + 0,0000129 = 0,2734129$
thus the corrected light elements of V1107 Cas are:

$M_{calc} = 2454092.4111 + 0.2734129 \cdot E$

7) The correction of the period could also be determined directly from the table, using the mean value of O-C for the initial epoch (E=0; 0,5) and the final epochs (E=2761; 2761,5; 2762)

8) To calculate the ephemeris, we need to know the JD of a given day. Since dates and JD numbers are given in the observations, we can calculate that, for example on 1 January 2008 r. at 12:00 the JD was 2454467.0, while on 1 January 2011 at 12:00 it was 2455563.0.
Since 1 September 2011 is the 243-rd day of the year, thus at 12:00 on that day JD 2455806.0 begins.

9) On 1 September 2011 at 18:00 (JD 2455806.25) there have been 1713.8389 days or 6268.3176 epochs since the inital epoch M_0 (2454092.4111). Thus the nearest (secondary) minimum which agrees with these elements will be:

JD 2454092.4111 + 0,2734129 · 6268,5 =2455806,2999 = **$19^h\ 12^m$ UT**

The next (primary) minimum will be :

JD 2454092.4111 + 0,2734129 · 6269 = 2455806.4366 = **$22^h\ 29^m$ UT**

The next (secondary) minimum will be on the same night, at:

JD 2455806,4111 + 0,2734129 · 6269,5 = 2457520,5733
that is on 2 September at **$1^h\ 46^m$ UT**

Earlier and later minima can be determined by adding or subtracting half a period, or 3^h17^m

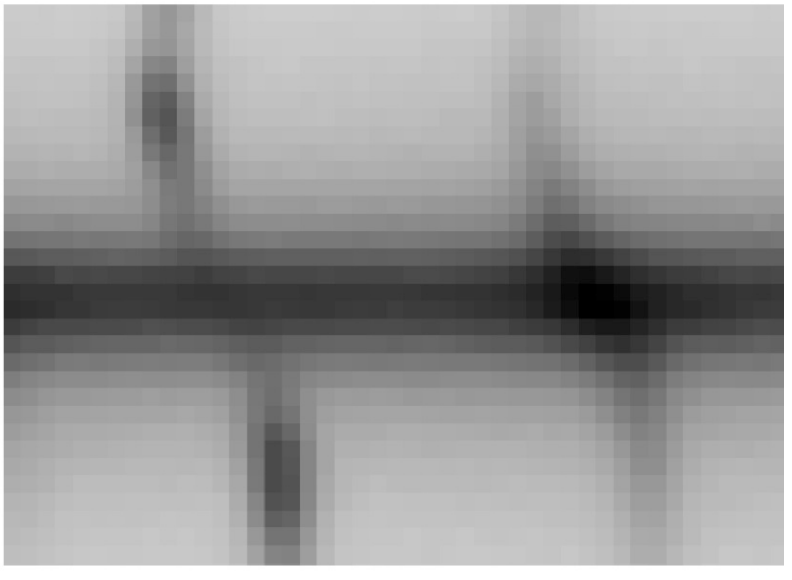
Data Analysis questions - points

1. Minima

Max 25 points

Correct determination of the approximate elements by	
using double the difference of successive minima	[2]
using the average of several pairs of minima	[2]
correct calculation	[1]
Correct calculation of the points for the O-C diagram	
correct calculation of epochs	[3]
correct calculation of (O-C)	[3]
either Correctly drawn diagram	
Each correct axis	[1+1]
Correctly and carefully drawn points	[2]
Correct calculation of the period correction and giving the corrected elements	
Using cumulative error / no. of epochs to correct period	[1]
correct cumulative O-C error	[1]
correct no. of epochs	[1]
correct period correction result	[1]
or calculation of period correction from the table of O-C without drawing O-C diagram	[4]
corrected elements	[1]
error estimate for elements	[1]
Incorrect significant figures in final ephemeris:	[-2]
Calculation of JD for 1 Sept 2011	[1]
Correct calculation of the ephemeris for the given night	[3]
Missing the second and third minima of the night	[-1 each]

Data Analysis Question 2 - solution



Solution:

$\Delta\lambda = \lambda_1 - \lambda_2 = 20$ Å

distance on picture $=22$ pixels ± 2 > horizontal scale $20/22 = 0.9091$ Å/pixel

Doppler shift from spectrum between upper and lower arm: $\Delta\lambda = 7$ pixels $\pm 1 = 6.3636$ Å

$2V_{radial} = c \cdot \Delta\lambda/\lambda$ ($c \approx 300\,000$ km/s) $= 290.8$ km/s

Inclination problem: (i – angle between line of sight and galactic disc)

Size of galaxy image: $a = 11.5 \pm 0.5$ cm, $b = 6.5 \pm 0.5$ cm > $i = \arcsin(b/a) \approx 35^o$

$\cos(i) = V_{radial} / V_{rotation}$ > $V_{rotation} = V_{radial}/2 \cdot \cos(35^o) = 216.7$ km/s

Vertical scale (pixel to distance-from-centre conversion)

For 1 pixel: angle 0.82" corresponds to $2 \cdot 40$ Mpc$\cdot$tg(0.82"/2) = 159 pc in galactic distance

Mass determination:

From Kepler's law: $M = V^2 \cdot R / G$

$R \approx 10$ pixel $= 1590$ pc$\cdot 3.09 \cdot 10^{16}$ m/pc $= 4.9 \cdot 10^{19}$ m

$M = 3.4 \cdot 10^{40}$ kg > $1.7 \cdot 10^{10}\ M_\odot$ ($M_\odot \approx 2 \cdot 10^{30}$ kg)

2. Weighing a galaxy

Max 25 points

estimation of horizontal scale (pixel/Å)	[1]
calculation of $\Delta\lambda$ distance between lines	[1]
calculation of scale in Å/pixel	[1]
estimation of scale error	[1]
Vertical scale	
Calculation of distance from galactic centre or rescaling from "/pixel to pc/pixel	[2]
Estimation of disc inclination based on pictures of galaxy :	
measuring the vertical and horizontal size of galaxy image	[2]
calculating the inclination of galactic disc	[1]
calculating the error of inclination estimation	[1]
estimations of position of line in pixels	[1]
calculations of Doppler shift in Å	[1]
calculations of radial velocity using proper formula and constants	[1]
calculations of velocity for inclination	[1]
proper draw the rotation curve:	
if picture will show: -'solid body' rotation in bulge	[1]
- two arms (blue and read shifted)	[1]
- symmetry between arms	[1]
- more then 10 point per arm	[1]
- fluctuation of "constant level"	[1]
calculation of mass of bulge of galaxy based on Kepler's law	
- using the proper formula	[2]
- using the proper place (end of the bulge) for bulge mass determination	[2]
- estimation of error base of scale and inclination error	[2]