Project – Transit of HAT-P-5b

Background
The detection of orbiting planets was slow to progress, with the first discovery not being confirmed until 1992; 4 years after the first published assumed discovery of the planet orbiting Gamma Cephei. This first confident discovery of two planets orbiting the pulsar PSR 1257$_{+}$12 was discovered by radio astronomers Aleksander Wolszczan.[i]

HAT-P-5
HAT-P-5 is a star alike to our on sun in sharing the same classification, type G which is situated 340 (± 30) parsecs away. Observations from the HAT Net transit search programmes lead to arising suspicion of the potential orbiting of a transiting planet around this host star; a hypothesis which was later verified by spectroscopic observations.[ii] The planet causing the transit that we have been observing and analysing is called HAT-P-5b and was discovered on 9th October 2007.[iii]

Data
The images we used for analysis were obtained from the Liverpool Telescope using the RiSE instrument on the evening of 09/07/2009-10/07/2009. The telescope recorded data over a period of 4.5 hours in order to obtain images for the whole planetary transit and an image was recorded with intervals of 2 minutes and 40 seconds. The field of view of the lens of the telescope from which our data was obtained had a field of view of 9.2 by 9.2 arcmins and a “V+R” single fixed filter.[iv] In order to collect our data, we measured the relative brightness of the target star, HAT-P-5 and two comparative stars, C1 and C2, using the programme LTimage to confirm the transiting planet of HAT-P-5b. When measuring the brightness, we used a radius of 11.3 (±0.3) pixels because it was a large enough radius in order to encompass all three stars and make for reliable readings. We measured the brightness of C1 and C2 as stable stars in order to calculate the difference between both of these stable stars and HAT-P-5 in order to confidently verify the correct host star (as depicted below). Through this comparison we were able to confirm that the planetary transit was the cause of the decreasing brightness rather than another external factor as the other relative brightness’ did not differ as much in relation to the host star HAT-P-5.

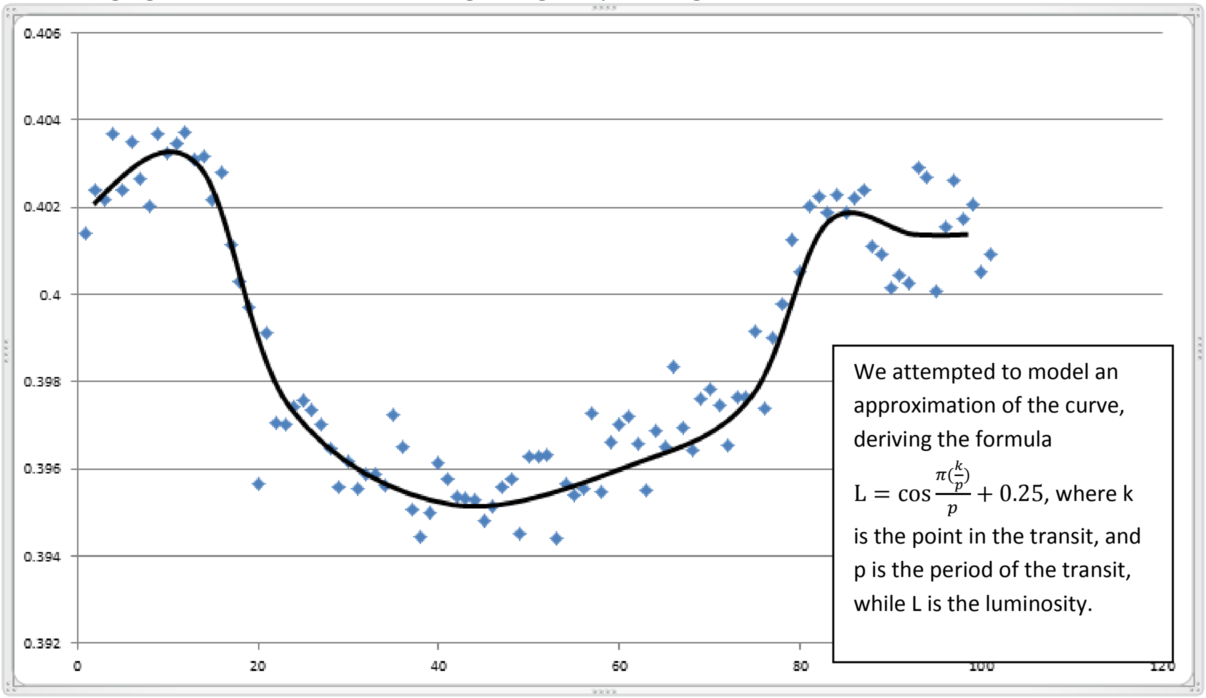
Method
Our project was to conduct photometric measurements on a subset of that data, with a view to tracking changes in brightness as the planet passes in front of its parent star.To detect the star, we found the coordinates on SIMBAD and analysed images of these coordinates. Using the known co-ordinates of the location of HAT-P-5 (RA: 18hr: 17min: 51.799sec Dec 36°: 35’: 25.01”), we used the programme Stellarium in order to locate the host star and compared it to the image created by SIMBAD for this star with dimensions of 9.2. This comparison enabled us to locate which star on our telescopic images was the host star of the planet we were observing in transit.
We tracked the positions of two stars, which we later used to compare the brightness of HAT-P-5 with, to find the position of HAT-P-5 itself.

In order to gather the data, namely the luminosity of the stars HAT-P-5, C1, and C2, we used the programme LT imager’s brightness function on 101 images of the stars and measured the photon counts which we inserted into a table using Microsoft excel, which we used to calculate the differences in brightness between HAT-P-5 and the other two stars. We used this information and a function on excel to plot the graph used earlier to display graphically the relationship between the changing brightness of Hat-P-5 and S/C1 (HAT-P-5/C1 Brightness’).

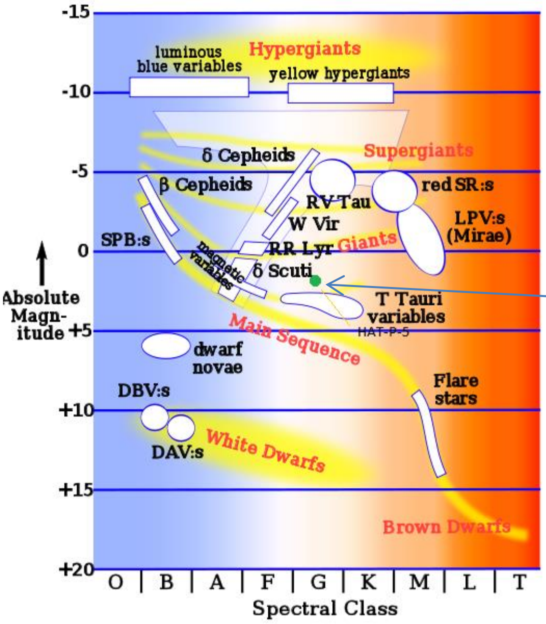
We then compared our graph to the model graph of which you would expect from the luminosity of a host star with a planetary transit. Through observing the graph displaying this relationship and the change in brightness, we were able to confirm the star originally depicted as HAT-P-5 does in fact have a planet in orbit, HAT-P-5b.

Analysis

When plotted on a scatter graph, the results obtained from monitoring the relative luminosity of the star HAT-P-5b form a curve that displays a slight increase from 22:58:49 when the survey began until 23:25:22, when the star was at its brightest. This, however, is not the notable feature of the curve yielded by the results; from 23:25:22, the luminosity of the star began to decrease gradually before increasing again after 01:25:48, forming a large 'dip' in brightness:



Two other stars, hitherto referred to as 'C1' and 'C2', were monitored alongside HAT-P-5 as a comparison, and their luminosities were divided by HAT-P-5's and the results plotted on this graph. Assuming the stars C1 and C2 had an almost uniform luminosity, which they did, there must be some cause for the variation in the luminosity of HAT-P-5. There could be a number of reasons for this; HAT-P-5 could be a variable star; for example, an eclipsing binary such as β Persei (Algol), as the variation in brightness exhibits periodicity. We could detect no evidence of another star orbiting HAT-P-5, eliminating the possibility of it being an eclipsing binary. We also plotted HAT-P-5 onto a Hertzsprung-Russel diagram displaying the positions of other variable stars, in order to confirm that HAT-P-5 was not any other type of variable star.



The small green dot is HAT-P-5

By proving HAT-P-5 is not a variable star, we can assume that there is something obstructing the light detectable to us. Since we have also proven that there is no companion to HAT-P-5, we can draw as the most likely conclusion that there is a non-luminous object in orbit of the star. By calculating roughly via the total decrease in luminosity of the star, we derived that the object obscuring the star was approximately 0.1 solar radii. Although later proven incorrect, we can draw the important conclusion the body is not a brown dwarf either, but a planet, and judging by the calculated radius of the planet, one approximately the size of Jupiter. The extremely rapid period of the transit indicates that the planet, hitherto referred to as HAT-P-5b, has a very short orbit and therefore a very close periastron and apastron. Many such planets, sharing a similar mass and radius to Jupiter and a very close position to their star, have been found, referred to as pegasids (or 'hot Jupiters') after the first of their kind (and incidentally the first extrasolar to be detected around a sun-like star) .

Using the measurements of brightness from LTimage along with known data about the host star HAT-P-5, we were able to calculate the radius of the planet orbiting it with an accuracy of 92.6%. The given mass of the star was 1.16 solar masses (=$2.31\text{x}10^{30}$kg) and the known radius was 1.167 Solar radii ($8.12\text{x}10^{8}$m). Using our graph we calculated the percentage of brightness covered by the transit to be 1.03%; therefore the area of the planet was 0.01 x the area of the host star HAT-P-5, i.e. area of star: π x $8.12\text{x}10^{8}$= $2.07\text{x}10^{18}$
Area of planet: $2.07\text{x}10^{18}$ x 0.0103= $2.07\text{x}10^{16}$
Rearranging the formula for area making radius the subject, we calculated the planet radius to be $8.17\text{x}10^{7}$m (=0.1167 solar radii); with a high degree of accuracy in comparison to the approximate suggested radius of the planet is 0.126 solar radii.

In conclusion, by measuring the luminosity of three neighbouring stars and comparing such measurements, we have found that there is a planet, HAT-P-5b, which orbits the host star HAT-P-5 and this planet has a radius of approximately 0.1167 solar radii.

Bibliography

[i] https://en.wikipedia.org/wiki/Extrasolar_planet#Confirmed_discoveries
[ii] http://en.wikipedia.org/wiki/HAT-P-5
[iii] http://en.wikipedia.org/wiki/HAT-P-5b
[iv] http://telescope.livjm.ac.uk/Info/TelInst/Inst/RISE/