Exoplanets - Group B

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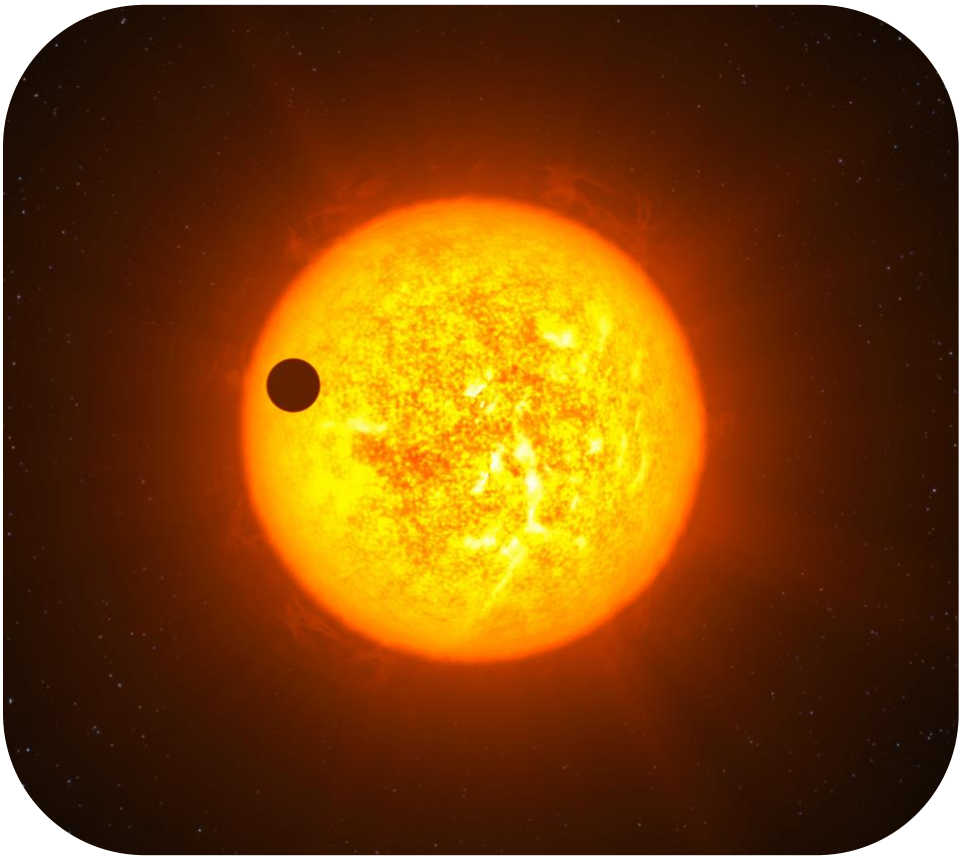

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Introduction

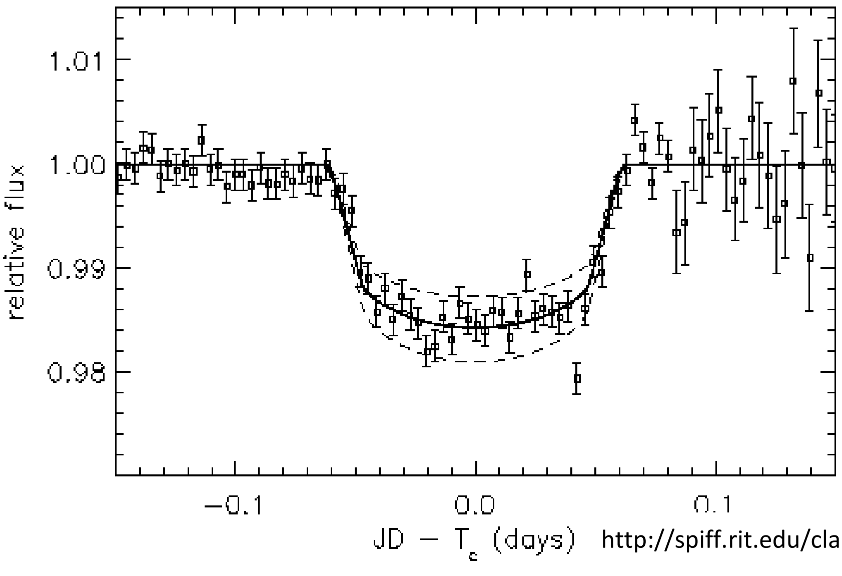
The HAT-P-5 is a G type star which is approximately 1100 light years away from earth. The star has an exoplanet transit which is the focus of our project.

An exoplanet is a planet which orbits a star other than the Sun. There are numerous methods for detecting exoplanets.

The most effective method with existing technology is Radial Velocity, which relies upon the fact that stars do not remain stationary when orbited by a planet. In response to the gravitational pull of its planet, a star moves instead in a small circle or ellipse. If a star is moving away from the observer on Earth, the light that it emits experiences a slight redshift. Similarly, if a star is moving towards the observer on Earth, the light that it emits experiences a slight blueshift. Using highly sensitive spectrographs, we can detect periodic shifts towards red and blue which we can analyse to obtain information about the exoplanet as regards its mass, its orbital period, etc.

To detect the exoplanet transiting the star HAT-P-5, we used an alternative method called Transit Photometry which works by measuring the minute dimming of a star. If the dimming is detected at regular intervals and lasts a fixed amount of time, then the likelihood is that a planet is orbiting the star and passing in front of it once every orbital period in what is a known as a planetary transit. Transit photometry is easier to use when the planet is closer to the star. Even though the flux drops by a tiny percentage as the planet transits, we are able to learn a lot more about the planet such as the radius of the planet, the orbital period, and the atmosphere of the planet in comparison to the radial velocity method.

When the brightness of a star is measured at regular intervals during a transit, then one would expect a graph of brightness (relative flux) against time to appear as follows (see next page).



http://spiff.rit.edu/classes/phys230/lectures/

A trough corresponds to the planetary transit. By measuring depth of a trough, we can determine an exoplanet's radius. The larger it is, the more light it blocks and hence the deeper the trough. By measuring the width of a trough, we can determine the time taken for a transit to take place and hence calculate an exoplanet's orbital period.

Target and Dataset

The observations our data came from were carried out on the Liverpool telescope in July 2009. It was taken over 4.5 hours using the RISE instrument. The data collected show the whole transit of the exoplanet with its parent star HAT-P-5.

The target of our research project was to identify which star from the data taken by the RISE camera at Liverpool Telescope had an exoplanet in transit. From the data gathered we would attempt to calculate the radius of the planet.

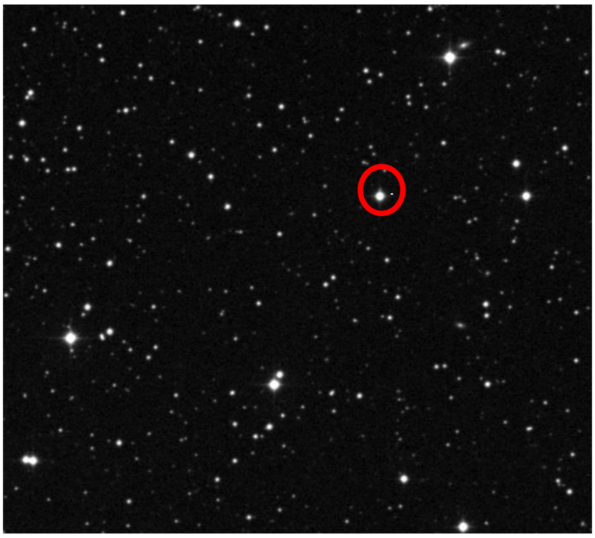
Method of Analysis

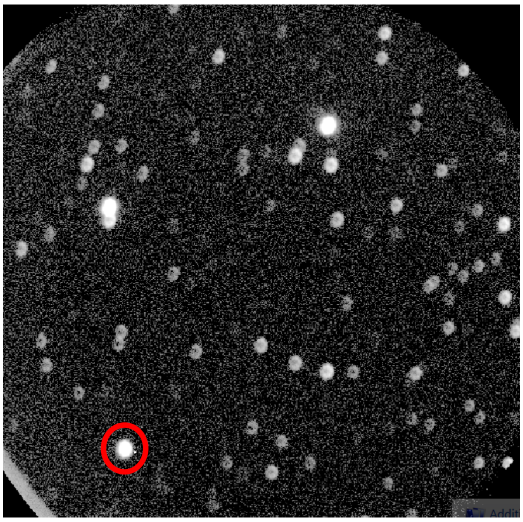
We conducted photometric measurements on the data by using LTImage. The images were first scaled to make them clearer for us to identify. We then measured the brightness of the 3 brightest stars in the data image 3 times for each star, in order to obtain a mean; this allowed us to reduce the effect of anomalous results, ensuring that our data is accurate making our results more reliable. After 7 images we couldn’t see a pattern because of the large amount of data, so we had to use another method to identify which star had the exoplanet. We used an image (Figure1) of the stars from DSS to compare our data from the LT (Figure2). This showed us which star we had to focus on. After we identified the exoplanet star, we decided to just measure the exoplanet and another bright star to compare our results. We decided to use star A to compare our exoplanet in transit to because it had higher counts than star B. Star B also had a very close star which could have affected our results because some of the brightness could have been obtained by the star next to it. We measured the brightness of the two stars 3 times in each exposure. We then entered the data from each star into an excel document in order to produce a results graph.

When we completed all of the measurements, we didn’t find a graph like we were expecting. Our results produced a graph showing no transit dip. In order to gain a better result we repeated the measurements by keeping the radius of the aperture the same each time, which made sure no light from nearby sources affected our results. We then took one reading for each of the two stars instead of 3. We then recorded our measurements in excel and produced another graph which was closer to our expected result. In the second attempt we only used half of the data. This affected the time resolution of our data, reducing the precision of our consequent calculations.

Figure 1-http://archive.stsci.edu/cgi-bin/dss

Figure 2- Exposure from the LT





Star C is circled showing where the exoplanet transit is taking place.

Results

Problems Encountered

We were given 100 images to analyse. After analysing the first 6 exposures, we noticed that it was very time consuming. Therefore we decided instead to analyse every other image, obtaining the following graph. (Figure 3)

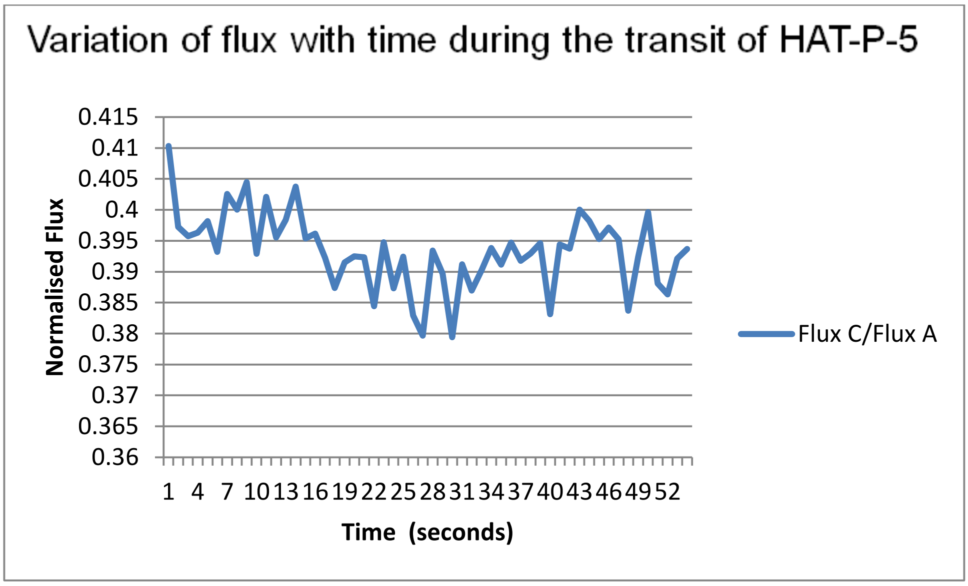


Figure 3- Graph obtained from data from HAT-P-5

This was neither the graph that we expected nor the graph that we had hoped for. Although there is a slight dip towards the middle, it fails to clearly show whether or not there is in fact a transit and where the transit starts and finishes. After speaking to our supervisor Chris, we decided to analyse the 50 images that we hadn't yet obtained data from. This time, however, we would keep the radius of the aperture constant throughout ensuring consistency between the measurements of brightness thus making our results more reliable. After doing this, we obtained another graph. (Figure 4)

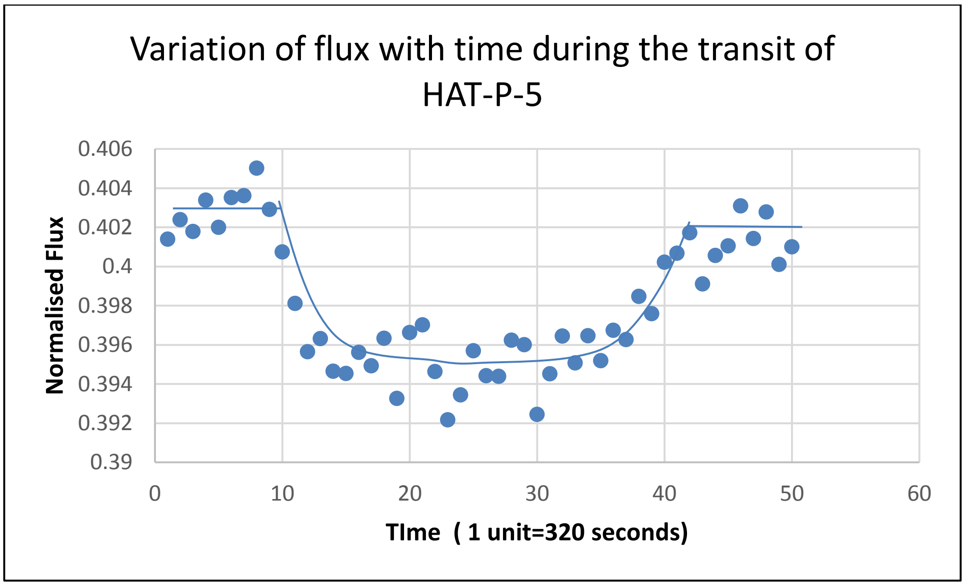


Figure 4- Graph obtained from data from HAT-P-5

This shows more clearly that a transit has taken place and although the points don't match up exactly with a transit curve, a rough transit curve can be sketched.

There are approximately 33 data points between the start and the end of the transit, which corresponds to 66 exposures. As these exposures are spaced 160 seconds apart, then the time of transit is:

66*160 = 10560 seconds

=10560/60 = 176 minutes

This is very close to the actual transit time of HAT-P-5b which is actually 175 minutes.

The depth of the dip caused by the transit can be used to calculate the radius of the star using the following equation:

$$\frac{\Delta F}{F} = \frac{R_p^2}{R_*^2}$$

$$R_p = \sqrt{\frac{(0.4025-0.395)*1.167^2}{0.4025}} = 0.159 \text{ solar radii}$$

In the equation above, ΔF is the change in flux caused by the transit, F is the initial flux, Rp is the planet's radius and R* is the star's radius in solar radii. The radius obtained, 0.159 solar radii, is equivalent to 1.59 Jupiter radii.

The distance of the planet from its star can be calculated using Kepler's 3rd Law which states that the distance squared is proportional to the planet's orbital period cubed. We calculated that the planet was 6.095 million kilometres away from its star.

Conclusions

From our data, we are able to conclude that there is an exoplanet orbiting Hat-P-5 as we have the characteristic dip in the graph where the planet has transited across the star. Even though there is a clear dip, it is not as prominent as we hoped for. This is due to the fact that the exoplanet causes a 1% drop in flux therefore it is quite difficult to produce an accurate curve. As well as this, the fluctuations seen on the graph could be caused by several factors such as cloud coverage or atmospheric distortion (seeing).

We have also found that the radius of the exoplanet is 1.59Rj (Jupiter radii) by using the equation. However from the star data provided, our data does not match up as it is 1.26Rj. This could be due to error within the graph used for calculations, however the data provided has an approximate 10% error therefore our calculations may be more accurate. At first, our radius of the exoplanet was 1.64Rj. This value is much bigger than the data provided so we used the average length of the dip from both sides. On the graph, the lines connecting the dip are at different heights which could be caused by the different wavelength of light after the exoplanet has transited. In order to make this more accurate, we could recalculate the points on the graph and use all of the data provided. The fact that the radius is 1.59Rj shows that it's a Jupiter-like planet. We were also able to calculate the distance from the star to the planet by using Kepler's 3rd Law to give the distance 6.095 million kilometres between the exoplanet and the star. Therefore, although it is a Jupiter-like planet, it is much closer to its star than Jupiter is to the Sun (128 times closer). This contradicts the traditional view that small, rocky planets form near to the Sun.

The main drawbacks of our results are the fact that the time resolution was halved as we only analysed every other image. With more time, we would have analysed every image to increase the accuracy of our calculations. We are also aware that the atmosphere of a planet can be analysed by transit photometry using various filters for different wavelengths. This would be the next stage in our project. Overall our results were well within the margins of error, however a closer value could have been obtained if we had more data and more signal to noise.

References

http://eclipse.gsfc.nasa.gov/transit/transit.html

Figure2- http://archive.stsci.edu/cgi-bin/dss_search?v=poss2ukstu_red&r=18+17+37.30&d=%2B36+37+16.9&e=J2000&h=15.0&w=15.0&f=gif&c=none&fov=NONE&v3=

http://www.schoolsobservatory.org.uk/astro/tels/lt

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http://telescope.livjm.ac.uk/About/

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