# Exoplanet detection using transit method

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## Abstract

*We conducted differential photometry on the star wasp 49 which is host to the planet wasp 49-b using the software AstroImageJ. We collected a series of images during the transit using the SBIG 0.4-meter telescope of Las Cumbres Observatory. The measurements obtained from these images were plotted and we were able to establish a definite light curve.*

## Introduction

An exoplanet or extrasolar planet is a planet outside the solar system. Man has constantly been searching for life elsewhere in the universe which has fueled the search for exoplanets. In this paper we present evidence for the detection of Wasp 49-b by conducting transit photometry of the host star Wasp 49.

There are many methods used for exoplanet detection. One such method is the transit method which is the measuring of the dimming of a star when its tiny planet passes between it and our telescopes. The transit method has been very useful for detecting a "hot Jupiter," namely a large planet whose orbit is close to its host star and where the planet passes directly in front of the star from the perspective of an observer on Earth. Figure 1 shows an ideal light curve obtained during a transit.

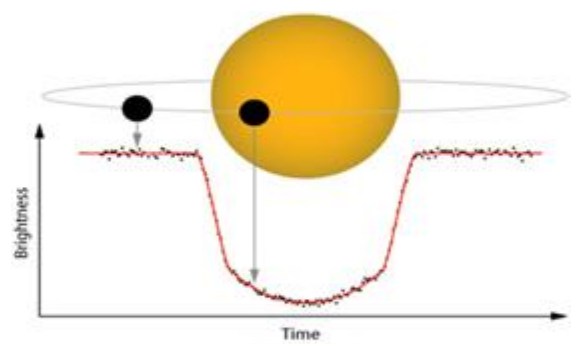



Figure 1

To observe our host star we used the telescope of Las Cumbres Observatory. The data obtained is analysed using a free software tool named AstroImageJ to obtain a light curve.

## Instrumentation

We used the 0.4-meter (diameter) telescope that use SBIG STL6303 cameras at the Cerro Tololo observatory in Chile.

These telescopes are wholly modified Meade telescopes with custom equatorial mounts and high-quality CCD cameras. A CCD (charge coupled device) is a tiny microchip onto which the light that the telescope collects is focused.

0.4 m telescope in Chile

When light falls onto one of the pixels, electrons are released from atoms in the pixel. To measure the amount of light that fell onto each pixel, the number of electrons released is counted.

Based on the transit predictions obtained from the exoplanet transit database, an observation was scheduled and the camera was aimed at the target stars region of the sky. The images before, after, and during the predicted transit of the exoplanet are processed to obtain the necessary dataset.

## Software used

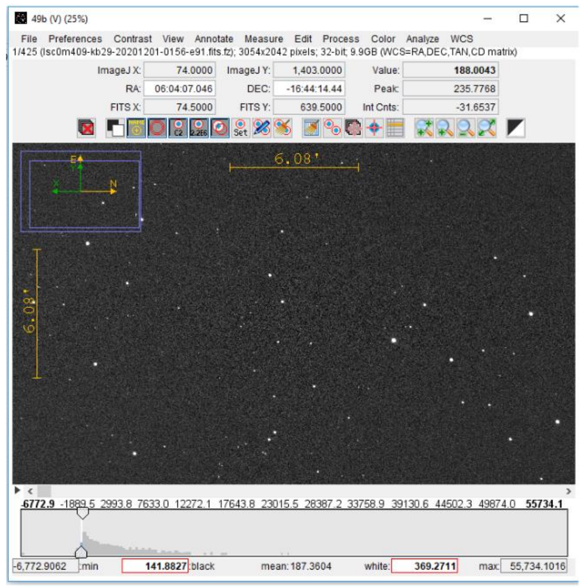
AstroImageJ (AIJ) is an interactive, simple and powerful image analysis software is built on ImageJ (IJ), which is used extensively in the field of biology and bioinformatics. AIJ and IJ are public domain Java image processing programs inspired by NIH Image for the Macintosh.

The transit method relies on differential photometry. Differential photometry technique is used to determine the changes in brightness (flux) of the exoplanet's host star that might indicate an exoplanet transit. That is, we compare the relative difference between the brightness of the host star and one or more (assumed to be non-variable) comparison stars during the imaging session. The data points that represent the star's relative change in brightness are then used to model the exoplanet transit.

## Data Analysis

We obtained 425 raw images of the exoplanet Wasp 49-b transit on 02/12/2020 (center of transit 2459185.72708 Julian date) based on the transit prediction by Nasa. Since the data obtained from LCO is already calibrated we started with the analysis of the flux of the star Wasp 49 in AstroImageJ.

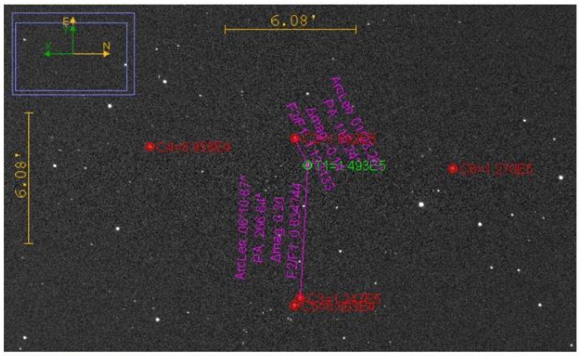
These images are arranged into a stack (and input as a sequence into the program.




Stack of calibrated images

First we calibrate the aperture of the target and comparison stars. The purpose of this is to adjust any uncertainties located in the aperture region(circle around the star), such as background sky noise. AIJ has the ability to detect and adjust for any faint stars that might happen to be in the annulus (ring shaped region surrounding the aperture) and therefore bias the background sky counts. The initial radii settings can be determined using the Seeing Profile screen associated with the target star.

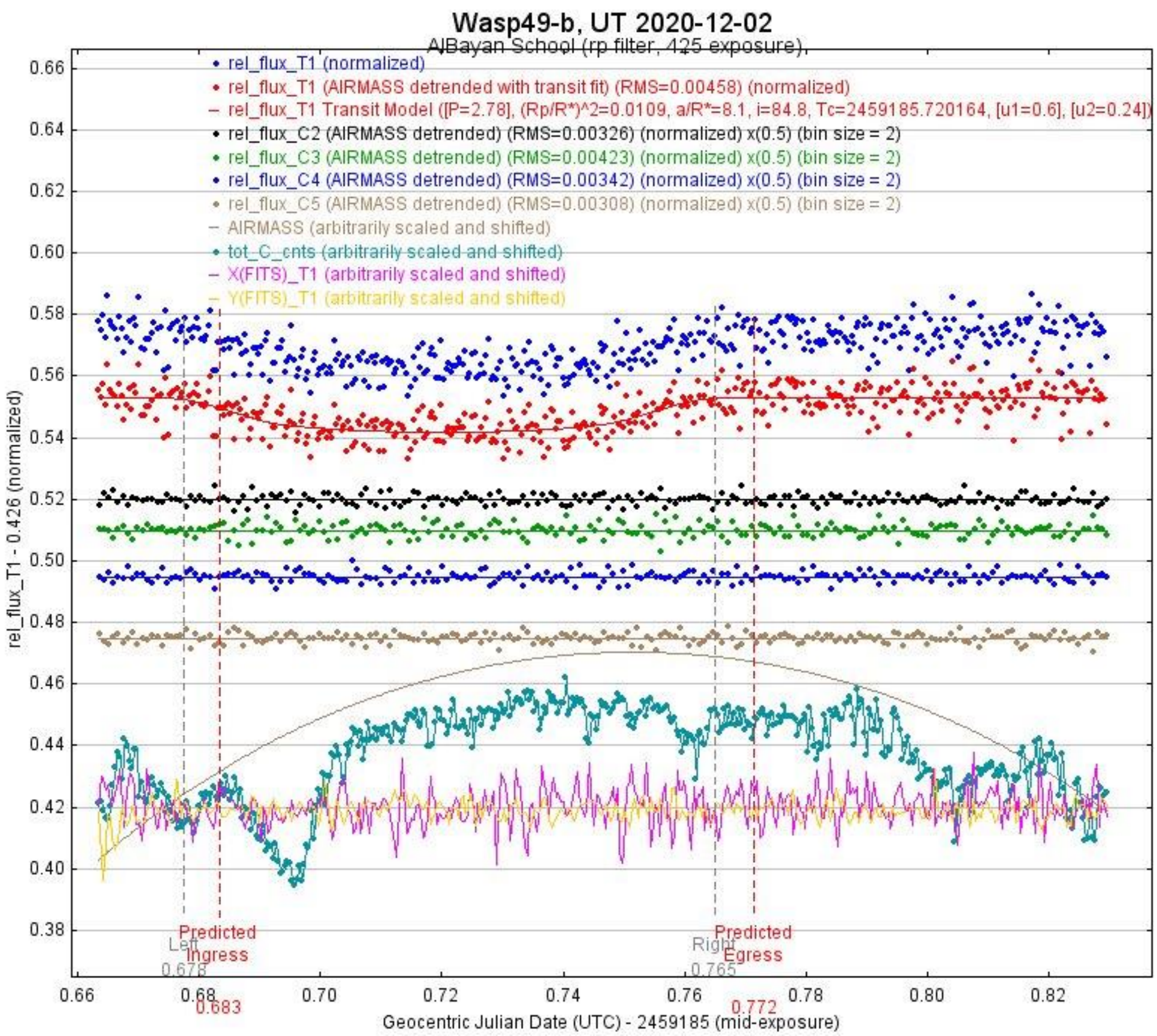
After that the target and comparison stars are selected. We selected one target star and many comparison stars. Stars whose magnitudes were as close as possible to the target star were selected as comparison stars. The software then evaluates each image in sequence and plots the flux.




Selected target and companion stars

## Transit fit

Performing a transit fit onto the data points helps us to learn more about the transiting planet. The host star parameters $R_{sun}$ and $R_{star}$ are specified first. The period of transit for Wasp 49b, which is 2.78 days is also input. The following curve is obtained from the software.




rel_flux_T1
User Specified Parameters (not fitted)
Orbital Parameters
Period (days) 2.7817387
Cir
Ecc 0.0
ω (deg) 0.0
Host Star Parameters (enter one)
Sp.T. G5V
Teff (K) 5758
J-K 0.394
R* (Rsun) 0.976
M* (Msun) 0.960
ρ* (cgs) 1.083
Transit Parameters
Enable Transit Fit
Auto Update Priors
Extract Prior Center Values From Light Curve, Orbit, and Fit Markers
Parameter Best Fit Lock Prior Center Use Prior Width Cust StepSize
Baseline Flux (Raw) 0.291413156 0.291482405 0.058296481 0.1
(Rp / R*)2 0.010865149 0.011067614 0.005533807 0.011067614
a / R* 8.105519080 11.202305634 7.0 1.0
TC 2459185.720164189 2459185.72125 0.015 0.01
Inclination (deg) 84.760834329 86.9 15.0 1.0
Linear LD u1 0.599000000 0.599 1.0 0.1
Quad LD u2 0.235000000 0.235 1.0 0.1
Calculated from model
b 0.740
t14 (d) 0.090050
t14 (hms) 02:09:40
t23 (d) 0.055386
tau (d) 0.017332
ρ* (cgs) 1.3007
(e)SpT G5V
Rp (Rjup) 0.99
Detrend Parameters
Use Parameter Best Fit Lock Prior Center Use Prior Width Cust StepSize
AIRMASS 0.003593231817 0.0 1.0 0.1
Width_T1 0.0 1.0 0.1
Sky/Pixel_T1 0.0 1.0 0.1
X(FITS)_T1 0.0 1.0 0.1
Y(FITS)_T1 0.0 1.0 0.1
tot_C_cnts 0.0 1.0 0.1
0.0 1.0 0.1
Meridian_Flip 0.0 1.0 0.1
Fit Statistics
Fit Statistics
RMS (norm) 0.004580
chi²/dof 1.889540
BIC 865.4929
dof 419
chi² 791.7174
Plot Settings
Show Model
Show in legend
Line Color red
Line Width 1
Show Residuals
Show in legend
Show Error
Line Color magenta
Line Width 1
Symbol dot
Symbol Color magenta
Shift 0.0
Fit Control
Fit Control
Fit Update Options
Auto Update Fit
Update Fit Now
Fit Tolerance 1.0E-10
Max Allowed Steps 20,000
Steps Taken 819

## Analysis of the plotted data

As we can see there is a 1.09% dip in the flux of the target star. This is obtained from the $(R_p/R_*)^2$ value. The flux of the comparison stars are relatively linear. This indicates that a large body has transited in front of the star.

## Evaluation and Conclusion

A comparison of the data obtained from the model fit and the actual published values show that the model fit data are very close to the actual data.

The quality of data depends on the actual observing conditions prevailing during the observing night. The $\chi2$ / d.o.f is 1.88 indicates that the fit is not perfect, however the shape of the curve clearly shows a transit. With the results obtained we can conclude that Wasp 49-b is a close orbiting hot Jupiter.

| | **Published data** | **From the transit fit** |
|---|---|---|
| **Spectral type of the host star** | G5V | G5V |
| **$R_{planet}$ [$R_J$]** | 1.115 ± 0.047 | 0.99 |
| **Inclination** | 84.89 | 84.76 |
| **$\Delta F = (R_p/R_*)^2$ (transit depth)** | 0.01376 ± 0.00038 | 0.0108 |
| **$T_{[14]}$(d) (first to fourth contact transit duration** | 0.08832 ± 0.00080 | 0.09005 |
| **b ( impact parameter)** | 0.745 ± 0.014 | 0.740 |

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## References

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