Light Curves with Salsa J

This activity was prepared on the framework of European Hands-on Universe by Roger Ferlet (IAP); Olivier Marco, Ester Aranzana Martinez, Sandra Greiss & Jeehae Chun (UPMC).

An extrasolar planet, or exoplanet, is a planet outside the Solar System.

As of 1 February 2023, there are 5,307 confirmed exoplanets in 3,910 planetary systems, with 853 systems having more than one planet.

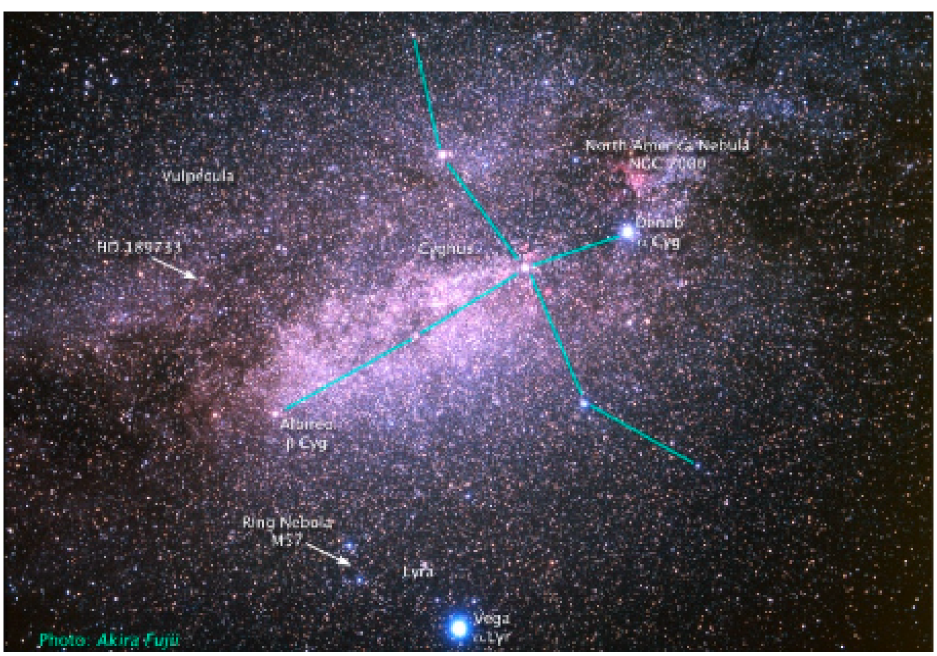
The vast majority of them have been observed through radial velocity and transit observations but other indirect methods also exist : astrometry, microlensing and timing among them.

At present, direct imaging is still difficult, even if lots of progress is being made. Anyway, most of the discoveries are about giant planets, thought to resemble giant Jupiters, orbiting near to their stars, where they are more easy to detect.

In this activity, we propose to unveil an extrasolar planet using the transit in front of its star.

The hunt for Exoplanet HD 189733b

The exoplanet orbiting the star HD 189733 was discovered on October 5, 2005 by transit method in France. The planet is classified as a hot Jupiter class Jovian planet, orbiting very close to its star with a period of 2.2 days. It's approximately 63 light-years away in the constellation of Vulpecula (the Fox). Its location is indicated in the deep (wide-angle) image of the sky below, centered on the northern constellation of Cygnus.

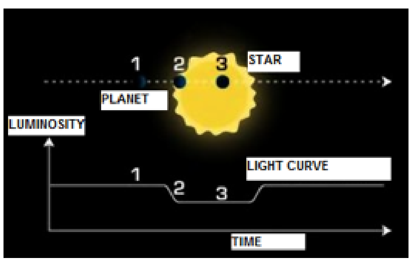


The physical characteristics of this planet are :

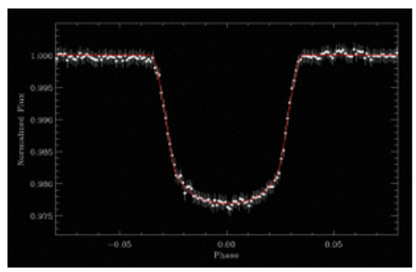
- mass: 1.13 MJ
- radius: 1.138 RJ
- surface gravity: 21.2 m/s²
- temperature: 1117K

Goals and objectives of this exercises:

You will dispose of a sample of 20 images of the same three stars obtained by the Spitzer space telescope: HD 189733 is among them. We will use SalsaJ to perform photometry measurements of each of the 3 stars, for all the 20 images. Over time, the flux of 2 stars will keep (roughly) constant while the flux of the 3rd star will drop, because of the planet's transit. Plotting the flux versus time of the 3 stars and comparing them, one should highlight the variation and thus discover the exoplanet !



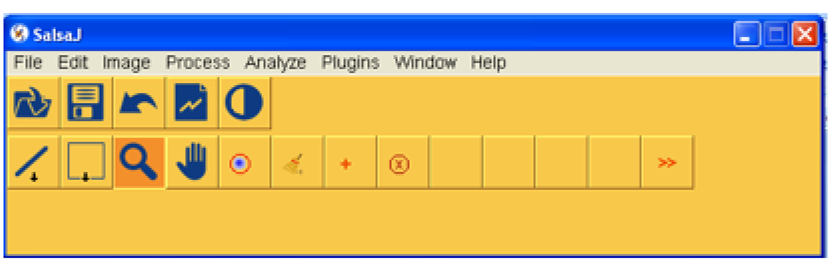
Outline of different phases of an exoplanet transit



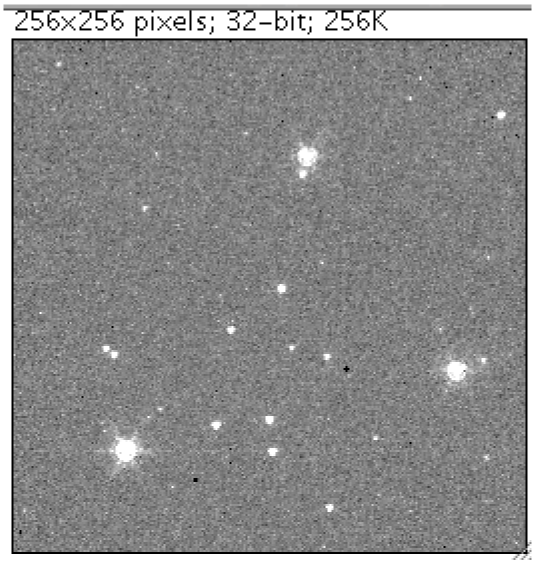
Light curve of an exoplanet transit observed by the Corot telescope in May 2007

Do it yourself!

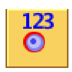
1. Open SalsaJ.



2. Open the 20 images taken with the NASA satellite Spitzer using the macro in "Pluging/macro/Extrasolar Planet transit" (this opens and tiles up all images). The images should be included in the SalsaJ installation ; if not, you can download them here : 20image_spitzer 4.77 Mb (you will have to open them manually).



3. On each image (in chronological order), identify the 3 main stars indicated here as Star1, Star2, Star3. Apparently, all images are identical : we will use SalsaJ photometry instrument and an Excel (or equivalent) spreadsheet to study their brightness variation over time.

4. Click on the Photometry icon 

: a photometry window will appear and your pointer will become a brightness sensor. As you click on some point of the image, the light intensity (in computer units) at that point will be stored in the photometry window.

5. Measure the intensity of Star1 on each image. The results will be stored in the photometry window (see image below).

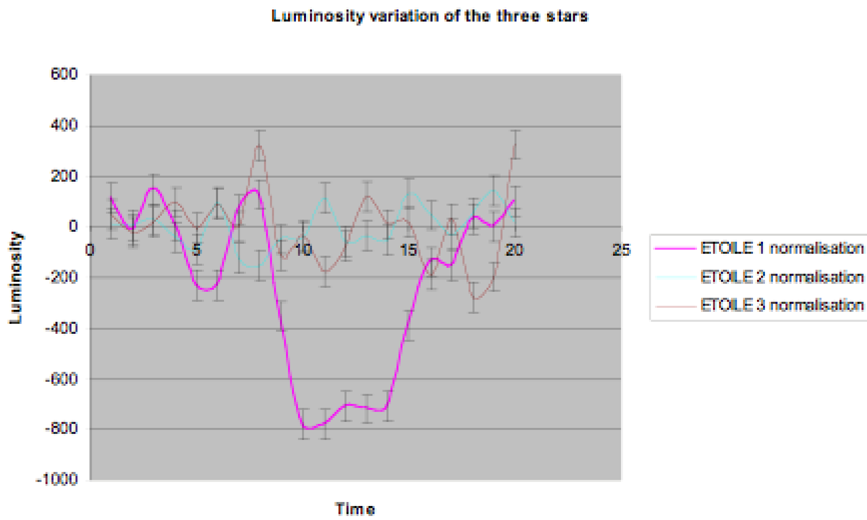
Index	Image	X	Y	Star's intensity	Star's radius	Sky's intensity	Sky's radius
5	SPITZER_I2_24538368_0400_0000_1_bcd.fits	146	58	33114	14	1	21
6	SPITZER_I2_24538368_0500_0000_1_bcd.fits	146	57	32976	14	1	21
7	SPITZER_I2_24538368_0600_0000_1_bcd.fits	146	58	33352	14	1	21
8	SPITZER_I2_24538368_0700_0000_1_bcd.fits	146	58	33572	14	1	21
9	SPITZER_I2_24538368_1100_0000_1_bcd.fits	146	57	32580	14	1	21
10	SPITZER_I2_24538368_1200_0000_1_bcd.fits	146	58	32549	14	0	21
11	SPITZER_I2_24538368_1300_0000_1_bcd.fits	146	57	32853	14	0	21

6. When you are finished with Star1, select all data in the photometry window and copy them in the "answerfile_transit.xls" (download answerfile_transit.xls). Since each image has been taken at a different time and conditions, we need to normalize our data : the mean intensity of our series is automatically calculated and subtracted from the intensity value. The variation over time of Star1 intensity is plotted. Save your answer file.

7. Use the function "Analyse/Clear Photometry Results" to reset the photometry window.

8. Now, repeat the operation for Star2 and Star3.

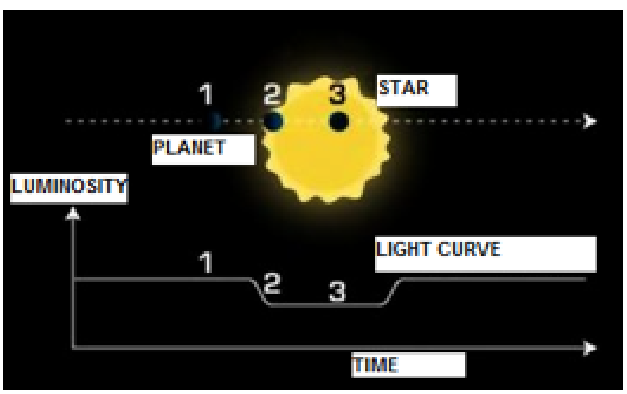
9. Once the operation is completed for the 3 stars, you should obtain something similar to the one below : each plot represents the normalized variation over time of the star intensity (in non physical computer units).



Interpretation

10. So, how do we interpret this result ?

The intensity of Star1 and Star3 seem roughly constant over time, while the intensity of Star2 shows a drop. Since all 3 stars are observed at the same time and our data are normalized, the drop could be a physical signal. In particular, a transit could have happened : some body may have transited between us and the star, hiding part of its surface to us.



During a transit we can define several "contacts", when the circumference of the planet coincides with the circumference of the star :

1) First contact: the planet is entirely outside the star, moving inward.

2) Second contact: the planet is partially inside the star, moving further inward.

3) Third contact: the planet is entirely inside the star, moving outward

11. Knowing this, what kind of estimate on the physical parameters of the planet can you derive from your measurements?

12. Knowing that the diameter of the star is 0.788+- 0.051 Rsun, estimate the diameter of the transiting body with respect to the Sun diameter. Speculate on the nature of the transiting body.

13. What can you say about the relative position of the Earth, star and transiting body?

14. You can now check your results on the Extrasolar Planets Encyclopedia (http://exoplanet.eu/).