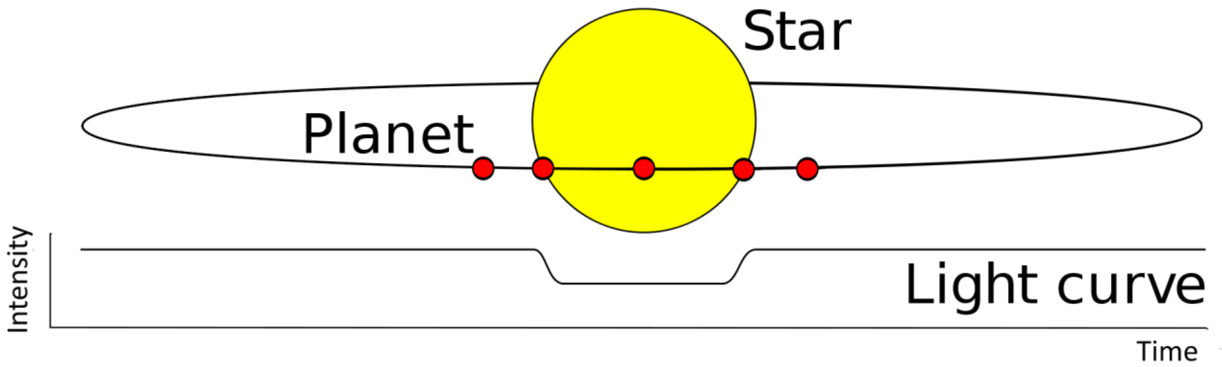
Detecting the exoplanet HD189733b

Kyriaki Iosifidou



Class 11

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1. Introduction

The school project course in Astronomy gave me a unique opportunity to gain astronomical experience. I am very excited about exoplanets and the development of our solar system compared to other planetary systems. So, I decided to conduct a project about exoplanets and then participate in the *ESO Catch a Star*.

We focus on the detection of the exoplanet HD189733b with the 0.5m telescope of our school. The transit method allows the detection of a dip of the star's intensity, when the exoplanet passes in front of its parent star.

My motivation was the question "what might come up, if we try to detect an exoplanet with our school's latest set up telescope equipment".

Further, I give some information about the exoplanet HD189733b itself, the technical equipment and the weather condition. After that, the calibration of the raw images, such as the evaluation of the light curve is explained. With the results, we manage to calculate the exoplanet parameters, such as its size and radius.

2. Exoplanet facts

An exoplanet or extrasolar planet is not under the gravitationally influence of our sun. Up to current date 3886 exoplanets have been detected in 2897 planetary systems. Most of them have been detected by the transit method. 158 of them tend to be earth like and super earths[1]. Only Jupiter like exoplanets can be detected through small telescopes, like our school telescope.

3. Information about the exoplanet HD189733b

The exoplanet HD189733b was discovered in 2005 by the satellite *Hipparchos* and then further investigated by the *Spitzer (SST)* and the *Hubble Space Telescope (HST)*. It is a so-called "Hot Jupiter", 1.15 times the mass of Jupiter and orbits the yellow dwarf HD 189733, which is almost 10' (arc minutes) away from the *Dumbbell Nebula* M27 (figure 1). Figure 1 shows the star position by Stellarium[2].

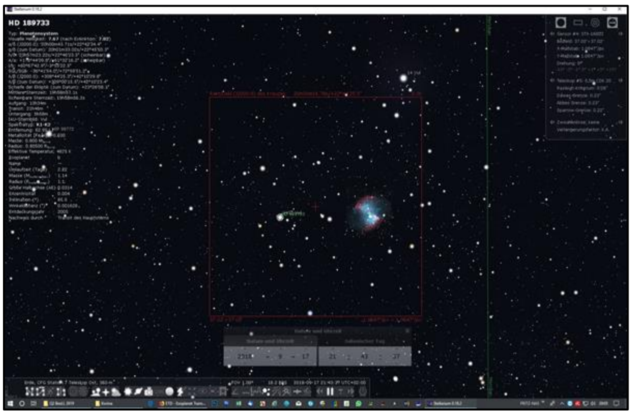

Figure 1: Artificial representation of the star position with *Stellarium*

The yellow dwarf HD 189733 is about 63 light-years apart from earth and has an apparent magnitude of 7.67mag, with only 0.028mag transit depth. The absolute magnitude of the star is about 6.3mag. Comparably to our 4.83mag sun, it is two third less luminous. The surface temperature of the star is about 5000K and the sun's temperature 5778K.

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[1] https://de.wikipedia.org/wiki/Liste_extrasolarer_Planeten

[2] http://stellarium.org/

The exoplanet orbits in 2.22 days (53h) in a distance of 0.0312 AU (4.6 Million Kilometers), which means that the planet is almost 92% closer to its star than Mercury to our sun (57.9 Million Kilometers). He has an orbital speed of 152.5km/s [3], which is very fast compared to Jupiter (13.07 km/s) [4].

The planet probably turns one side towards its parent star, because of the high tidal forces between them, called tidal locking. HD189733b is still a more unpleasant world than Mercury. Its surface temperature is up to 3000K. Through observations of the planet by the *HST* and the *SST*, astronomers detected his atmospheric composition. The chemical elements in his atmosphere show an organic link[5].

At first, they detected heavy molecules, like carbon dioxide and carbon monoxide. The detection of methane on the atmosphere of the exoplanet, is responsible for the several biological processes, such as the digestive tract of cattle. Hydrocarbons are found on celestial bodies, such as Titan, the biggest Saturn moon. In addition, traces of water molecules were discovered in his atmosphere, where it could be present only in the form of gas (water vapor). By creating a temperature map by the *HST*, the color of the planet was detected for the first time. It is azure (figure 2), since the exoplanet seems to reflect the light in blue wavelength at most.[6] Responsible for this color are fine floating particles of molten silicate minerals.

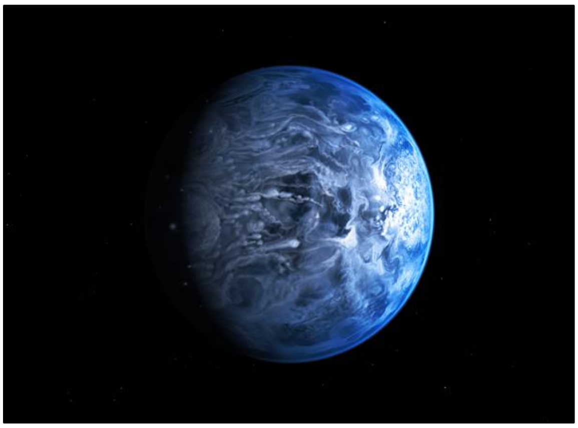

Figure 2: Artist´s impression of the planet´s blue color

Although these candidates would be very suitable for the existence of life, scientists are firmly convinced that there could be no life on the exoplanet because of his enormously high surface temperatures. However, this conviction was strengthened, after another transit observation revealed a blue shift in the sodium double-line. This shift indicates that there are blowing winds through his atmosphere with a speed of 2km/s (30,000 km/h). Those are twenty times faster than the 500 km/h (138m/s) winds on the earth's atmosphere and seven times faster than the speed of sound[7]. So, any form of life, as we know it, could be excluded, because HD189733b is an "infernal" such as highly undesirable world in our imagination.

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[3] https://en.wikipedia.org/wiki/HD_189733_b

[4] https://en.wikipedia.org/wiki/Jupiter

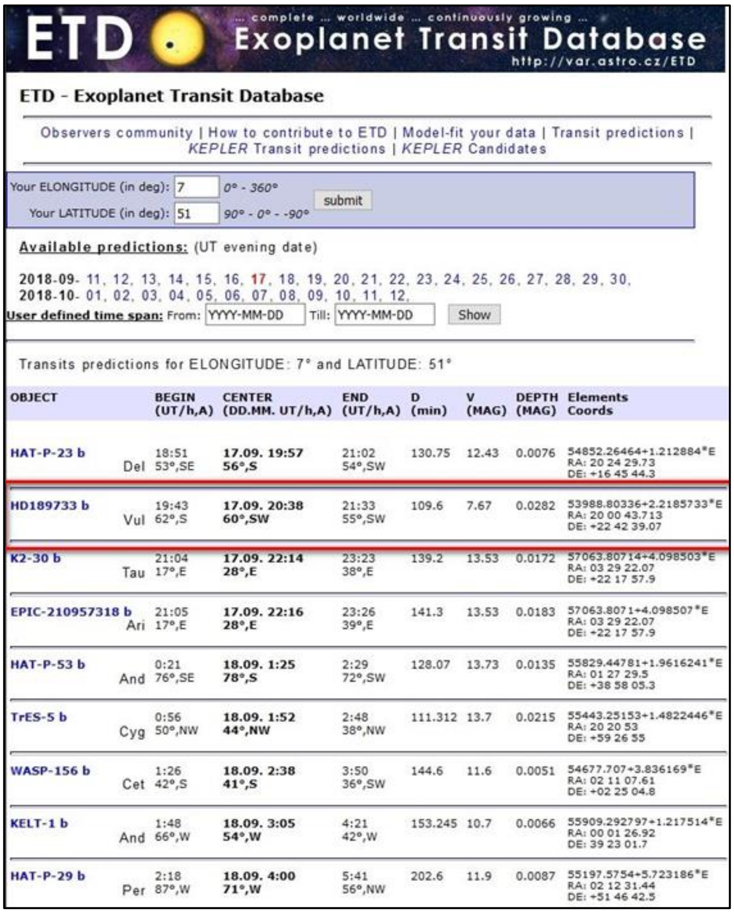
[5] https://www.wissenschaft.de/astronomie-physik/methan-auf-hd-189733b/

[6] https://de.wikipedia.org/wiki/HD_189733_b#/media/File:Artist%E2%80%99s_impression_of_the_deep_blue_planet_HD_189733b.jpg

[7] https://www.nasa.gov/image-feature/rains-of-terror-on-exoplanet-hd-189733b

3.1 Prediction of the exoplanet HD189733b

With the help of the transit method, we detected the exoplanet HD189733b with the 0.5m *CDK 20 Planewave* telescope of our school. Due to the *Exoplanet Transit Database (ETD)* website[8] the transit of HD189733b, for the 17th of September, began at 19.43 UTC and ended at 21.33 UTC (figure 3).


... complete ... worldwide ... continuously growing ...
ETD Exoplanet Transit Database
http://var.astro.cz/ETD

ETD - Exoplanet Transit Database

Observers community | How to contribute to ETD | Model-fit your data | Transit predictions | *KEPLER* Transit predictions | *KEPLER* Candidates

Your ELONGITUDE (in deg): 7 0° - 360°
Your LATITUDE (in deg): 51 90° - 0° - -90°
submit

Available predictions: (UT evening date)

2018-09- 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30,
2018-10- 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12,
User defined time span: From: YYYY-MM-DD Till: YYYY-MM-DD Show

Transits predictions for ELONGITUDE: 7° and LATITUDE: 51°

OBJECT	BEGIN (UT/h,A)	CENTER (DD.MM. UT/h,A)	END (UT/h,A)	D (min)	V (MAG)	DEPTH (MAG)	Elements Coords
HAT-P-23 b Del	18:51 53°,SE	17.09. 19:57 56°,S	21:02 54°,SW	130.75	12.43	0.0076	54852.26464+1.212884*E RA: 20 24 29.73 DE: +16 45 44.3
HD189733 b Vul	19:43 62°,S	17.09. 20:38 60°,SW	21:33 55°,SW	109.6	7.67	0.0282	53988.80336+2.2185733*E RA: 20 00 43.713 DE: +22 42 39.07
K2-30 b Tau	21:04 17°,E	17.09. 22:14 28°,E	23:23 38°,E	139.2	13.53	0.0172	57063.80714+4.098503*E RA: 03 29 22.07 DE: +22 17 57.9
EPIC-210957318 b Ari	21:05 17°,E	17.09. 22:16 28°,E	23:26 39°,E	141.3	13.53	0.0183	57063.8071+4.098507*E RA: 03 29 22.07 DE: +22 17 57.9
HAT-P-53 b And	0:21 76°,SE	18.09. 1:25 78°,S	2:29 72°,SW	128.07	13.73	0.0135	55829.44781+1.9616241*E RA: 01 27 29.5 DE: +38 58 05.3
TrES-5 b Cyg	0:56 50°,NW	18.09. 1:52 44°,NW	2:48 38°,NW	111.312	13.7	0.0215	55443.25153+1.4822446*E RA: 20 20 53 DE: +59 26 55
WASP-156 b Cet	1:26 42°,S	18.09. 2:38 41°,S	3:50 36°,SW	144.6	11.6	0.0051	54677.707+3.836169*E RA: 02 11 07.61 DE: +02 25 04.8
KELT-1 b And	1:48 66°,W	18.09. 3:05 54°,W	4:21 42°,W	153.245	10.7	0.0066	55909.292797+1.217514*E RA: 00 01 26.92 DE: 39 23 01.7
HAT-P-29 b Per	2:18 87°,W	18.09. 4:00 71°,W	5:41 56°,NW	202.6	11.9	0.0087	55197.5754+5.723186*E RA: 02 12 31.44 DE: +51 46 42.5

Figure 3: Time of the Transit (UTC) from the ETD-website

3.2 Transit geometry

In order to define the radius of the star, we need to consider the relationship of the planet radius and the star radius, with the intensity I, and the total flux F of the star. The total flux describes the total energy flux of a celestial body that is emitted or absorbed in the form of light. The star emits light. During the transit, a part of the flux F of the star is covered by the planet. From the flux ratio, which results from the occultation of the star by the planet, the radius of the planet can be later calculated.

The general formula for the total flux F of a celestial body with Radius R, in our case the parent star, is

$$F = \pi R^2 * I$$

First, we study the flux difference during the transit. The flux difference is described by the following formula

[8] http://var2.astro.cz/ETD/

$$\Delta F = \frac{Fs - Fp}{Fs} = 1 - \frac{Fp}{Fs}$$

Fs is the flux the star radiates and Fp, the part of the starlight the exoplanet absorbs. From the formula of the flux ratio and the general formula of the total flux, we get following results for the relationship between the star and the planet radius

$$\Delta F = 1 - \frac{\pi Rp^2 Is}{\pi Rs^2 Is} = 1 - \left(\frac{Rp}{Rs}\right)^2$$

Is is the intensity of the star during the transit, Rp the planet radius and Rs the star radius. The following formula shows the substitution of ΔF by Δm (difference of apparent magnitude)

$$\Delta m = -2.5 * lg[1 - (\frac{Rp}{Rs})^2]$$

We then solve the formula for Rp and use the individual values. For Δm, we use the specified catalog value at 0.0247mag. We take the planet radius from an exoplanet catalog[9]. It is given in 0.805 solar radii (*Rs*). We must convert this value to kilometers, so that we can later convert the radius of the planet into Jupiter radii. This is recommended, in order to compare the planet and its star with our solar system. To convert the value from Rs to km, we multiply 0.805 with 696,342km, the radius of sun

$$Rs = 0.805[Rsun] = 0.805 * 696{,}342\text{km} = 560{,}555\text{km}$$

The above formula of the magnitude difference can be formed according to the radius of the planet by mathematical transformation

$$\Delta m = -2.5 * lg\left[1 - \left(\frac{Rp}{Rs}\right)^2\right]$$

$$Rp = \sqrt{\left[-10^{\left(\frac{-\Delta m}{2,5}\right)} + 1\right]} * Rs$$

[9] http://exoplanet.eu/catalog/hd_189733_b/

4. Experimental setup

In the following chapters, we give some information about the experimental setup while recording and afterwards about the calibration of the images.

4.1 Telescope and Camera

In order to detect the exoplanet, we used the 0.5m CDK20 Planewave Telescope and the monochrome CCD camera SBIG STX-16803 (figure 4).

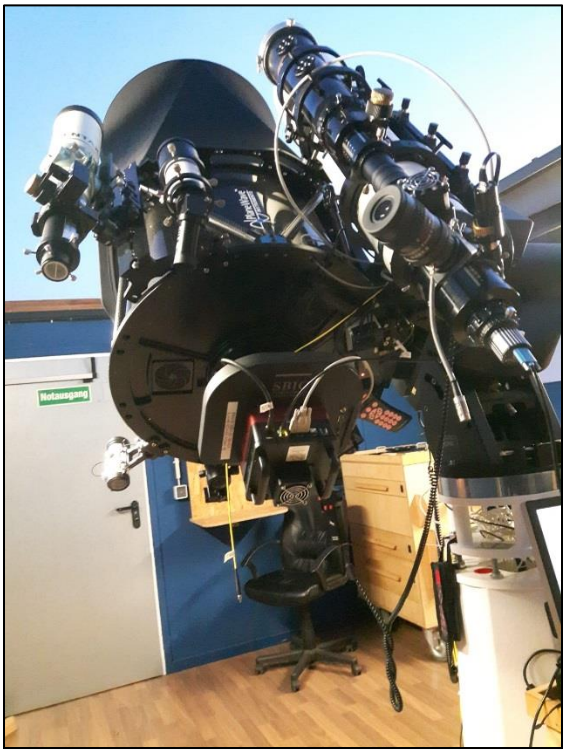


Figure 4: 0.5m CDK20 Planewave telescope

The CCD camera is ideal for a precise photometric measurement. It has a built-in LRGB-filter wheel, which allows the camera sensor to detect light in different wavelengths. To reduce noise, the camera sensor was cooled down to -30°C. Additionally, we used a Celestron Skyris 274M video camera at the co-aligned TEC160FL refractor for autoguiding (figure 4). Table 1 gives information about technical data of the telescope and cameras

	Raw images	**Flatfield**	**Darkframes**
CCD Camera	CCD STX-16803	CCD STX-16803	CCD STX-16803
Autoguider camera	Celestron Skyris 274M	-	-
Telescope	CDK 20	CDK 20	CDK 20
Exposure	20 s	10 s	20 s
CCD temperature	-30 °C	-30 °C	-30 °C
Filter	Baader LRGB red	Baader LRGB red	-
Pixel size	9 µm	9 µm	9 µm
Number of images	271	20 (Autodark, Masterflat)	26 (Masterdark)

Table 1: Technical data

Telescope and cameras controls are shown in figure 5.

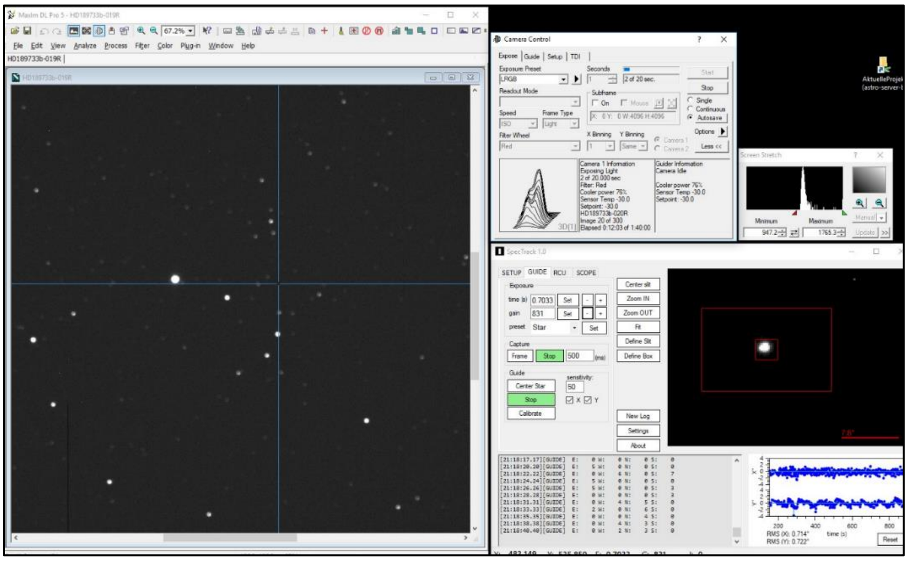


Figure 5: Telescope control. Left: Camera control by MaxIm DL. Lower right: Autoguiding by *SpecTrack* software

4.2 Images of HD189733b

Before start taking pictures, a few presets are significant. We synchronized the computer clock and the clock of the telescope mount by means of an internet time server controlled by the application *Dimension 4*. After pointing at the star HD189733b in *Stellarium,* the telescope slewed to the requested position in the sky. By using *MaxImDL* we checked the intensity of the star. We slightly defocused the stars to avoid saturation. We used a red filter to reduce the influence of clouds and moonlight. To avoid instrumental image shifts during the transit, we attached a video camera for autoguiding.

During the transit, which lasted 109min., we took 271 exposures, exposed for 20s each. We started taking pictures at 19.06 UTC, more than half an hour before the transit began, and ended up about 20min. after the transit ended, at 21.52 UTC. This procedure is necessary to record the intensity of the star before and after the predicted transit.

We created a Masterdark from 26 dark frames. They were taken with the same exposure time (20s) and sensor temperature (-30°C) like those of the raw images of the star field, with the camera shutter closed. The dark frames are used to reduce image noise and hot pixels. We also took 10s flatfields with a flat field unit[10] to eliminate vignetting and donuts created by dust particles on the sensor (table 1, 2).

19.06 UTC	HD189733b	Begin of recording
19.43 UTC	HD189733b	Begin of transit
21.33 UTC	HD189733b	End of transit
21.52 UTC	HD189733b	End of recording
21.53 UTC – 22.08 UTC	Darkframes	
22.18 UTC – 22.27 UTC	Flatfields	

Table 2: Time table

[10] https://www.astroshop.de/flatfieldmasken/gerd-neumann-jr-aurora-flatfield-leuchtfolie-420mm-220v/p,46383

4.3 Sky condition

The weather on Monday 17th evening was cloudy because some cirrus clouds came up[11] (figure 6). The first quarter moon (60%) brightened the night sky (figure 7).

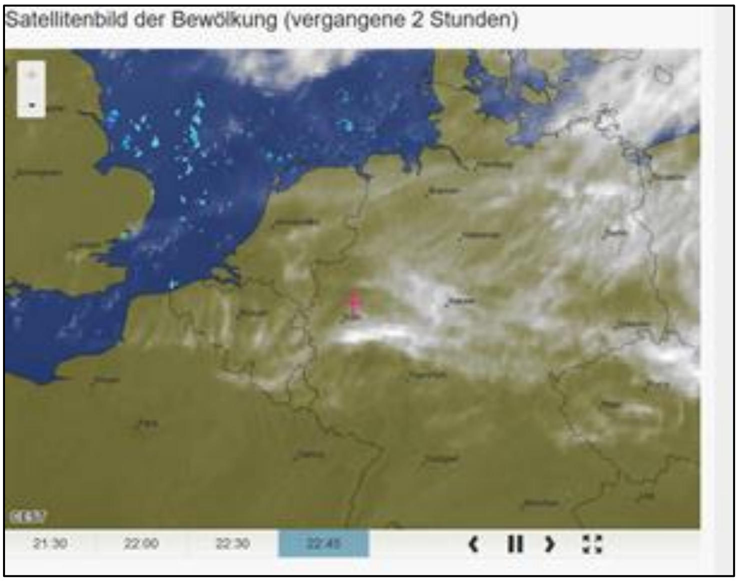


Figure 6: Satellite picture revealing cirrus clouds

Figure 7: Light of first quarter moon interfering (*Stellarium*)

[11] https://www.meteoblue.com/en/weather/forecast/week/wuppertal_germany_2805753

4.4 Calibration of the images

When calibrating raw images, it is about correcting the image errors that occurred during exposure (dust, noise), so that no information about the brightness of the star is lost later in the evaluation of the light curve. Firstly, we remove noise by subtracting a Masterdark from each raw image. Then, the dark corrected raw image is divided by the Masterflat, already corrected by an Autodark (table 1). The Masterdarkflat was not needed. Thus, donuts and vignetting are fixed. The formula for calibrating each image is

$$\frac{Raw\ image - Masterdark}{Flatfield - (Masterdarkflat)}$$

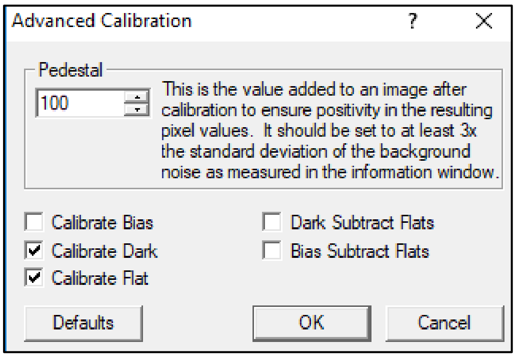


Figure 8: Advanced calibration window

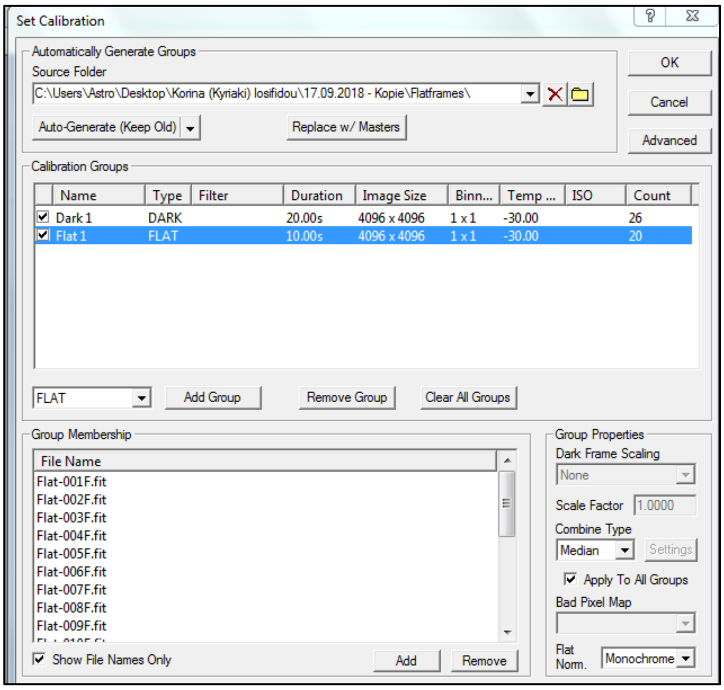


Figure 9: Set calibration

In order to create the Masterdark and subtract it from all raw images, we use *MaxImDL*. We open the window **set calibration** (figure 8, 9). Then we choose **auto generate (clear old)** for the creation of Masterdark and Masterflat.

Finally, we klick **Replace w/Masters** and the masters will be created.

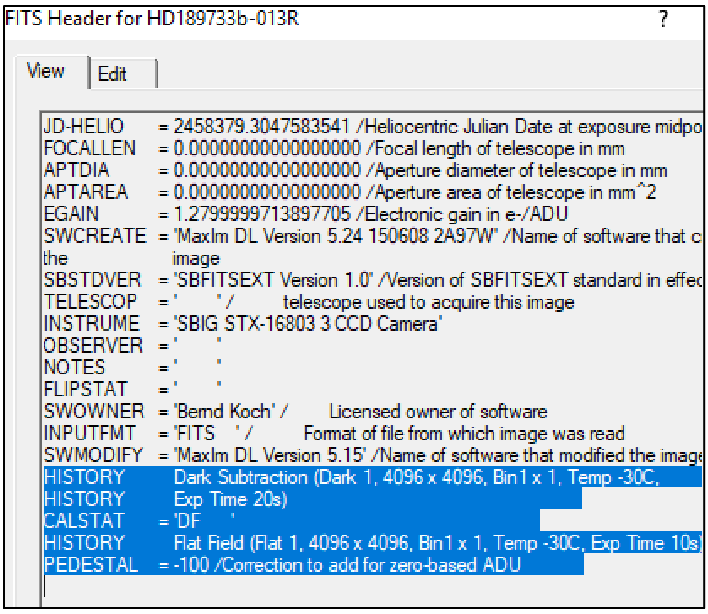


Figure 10: FITS Header

The calibration will be started by the command **Calibrate All.**

After finishing, we control the calibration by looking at the FITS Header (figure 10), to secure if dark subtraction and flat field correction are correct.

A minor problem was a partially defective camera column, which was obvious as a vertical dark line at the left side of the images. We choose the command **Remove Bad Pixels** (figure 11). We then choose **save map** and **process** and the defective camera column will be corrected (figure 12, 13). This had been done for each of the 269 calibrated images.

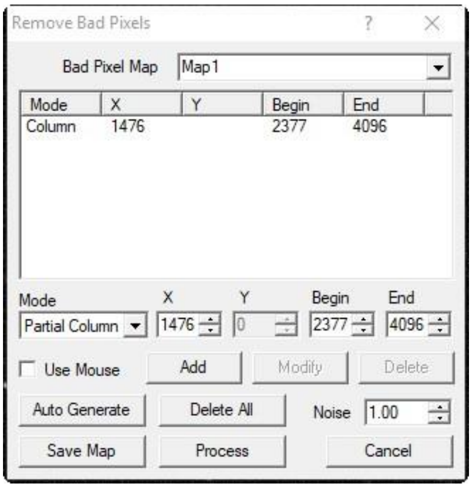


Figure 11: Remove bad pixels

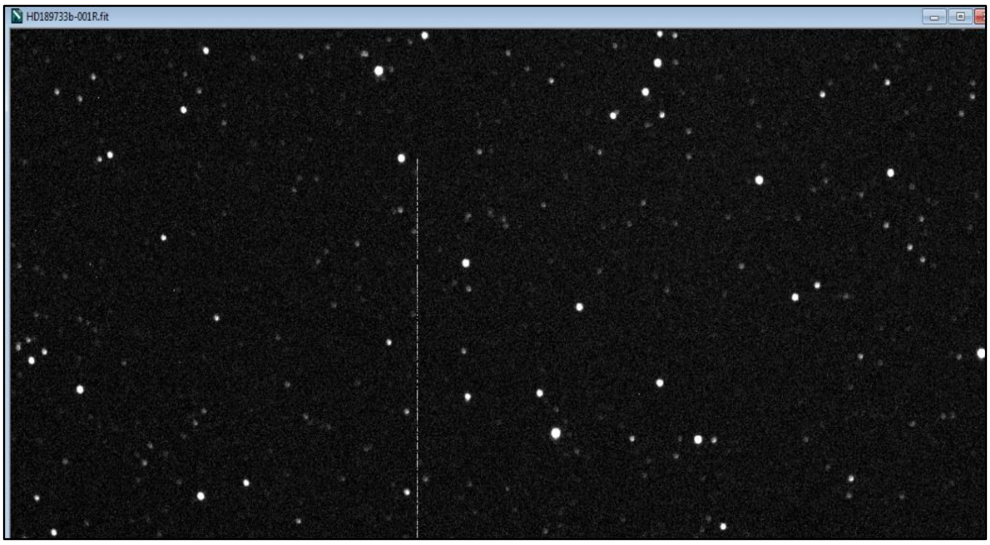


Figure 12: Calibrated image before column correction

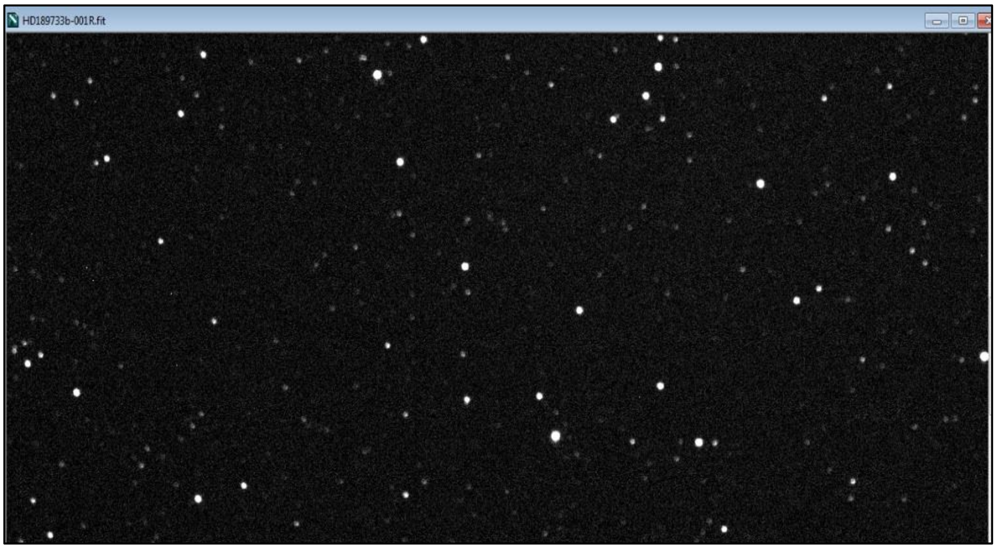


Figure 13: Calibrated image after column correction

Last step prior to creating the light curve, we had to align (register) the raw images with *MaximDL*.

5. Photometry of the data set

With the help of *Muniwin*[12], an ideal astronomical software for photometric measurements, we can create the light curve. We open the software, define the name of the project (HD189733b) and start loading the aligned images.

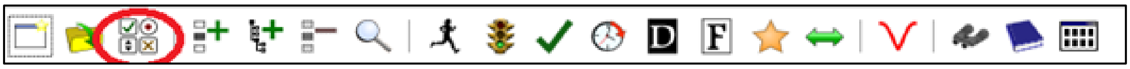


Figure 14: Menu task bar

After adding them to the project, we decided to remove the images 142 and 224, because there was an airplane track as well as a satellite track in those images and we wanted to avoid any kind of artifacts in the creation of the light curve.

Afterwards, we converted the files into a working format by clicking **convert input files to working format** (figure 14, green checkmark). After that, we click **photometry**, where we must adjust how the stars should be recognized in the images and set some photometry options. We choose the **star detection options** and set the Filter width (FWHM) at 8.00px. We set the detection threshold (minimal star-brightness) at 4.00px. We then set the maximum number of stars, that should be recognized in the images, at 400 (figure 15).

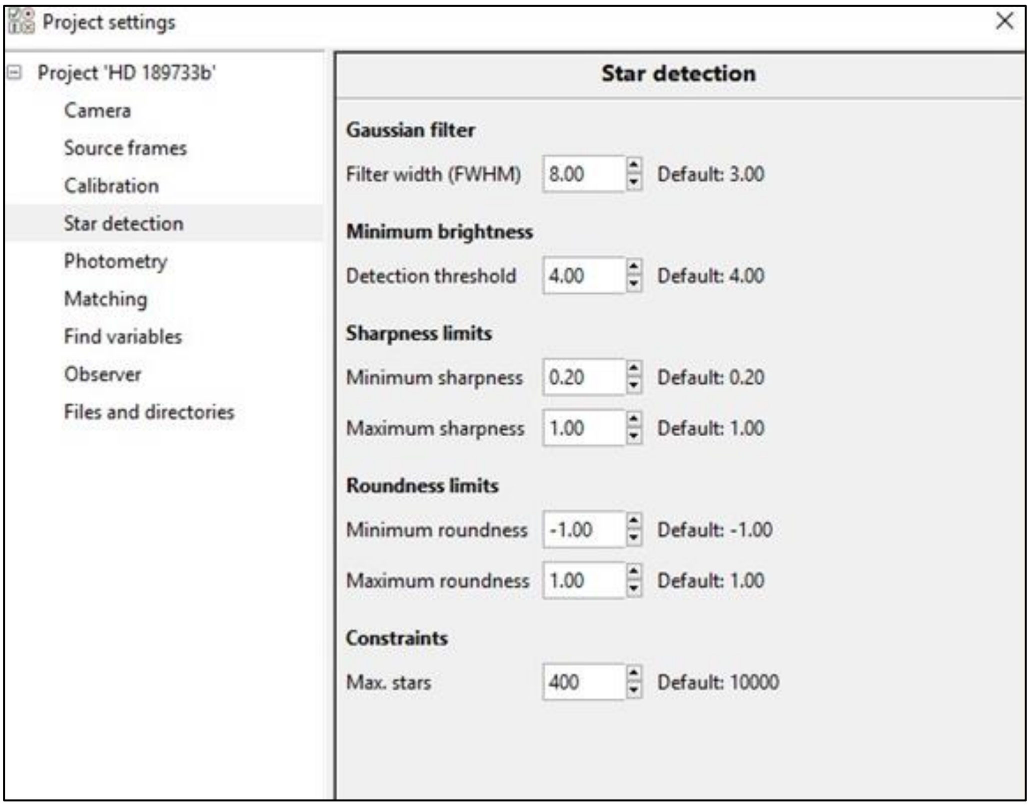


Figure 15: Star detection

[12] http://c-munipack.sourceforge.net/

5.1 Setting the parameters

Now we set the photometry options (figure 16) for the orifice to be wider than the apparent diameter of the star, so that no part of the complete starlight will get lost. In order to check the size of the star and choose a suitable aperture we click on the variable star. We can see that the radius of the star is 8.7px. We pick 32px for the inner circle and 39px for the outer circle. Those two circles determine the brightness of the sky to be subtracted from the star's intensity. We choose 24px (green circle) to measure the star.

Now, we define our observer's location at CFG Wuppertal. The longitude for our school is 7° 08' 28'' E and the latitude 51° 13' 52'' N.

After that, we click OK and the images will be processed. We can now move on by matching the stars, when clicking **find cross references between photometry files**.

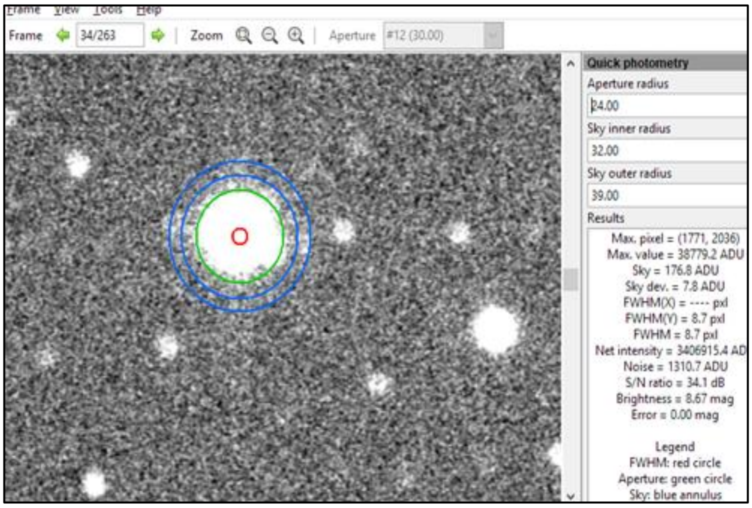


Figure 16: Quick photometry window

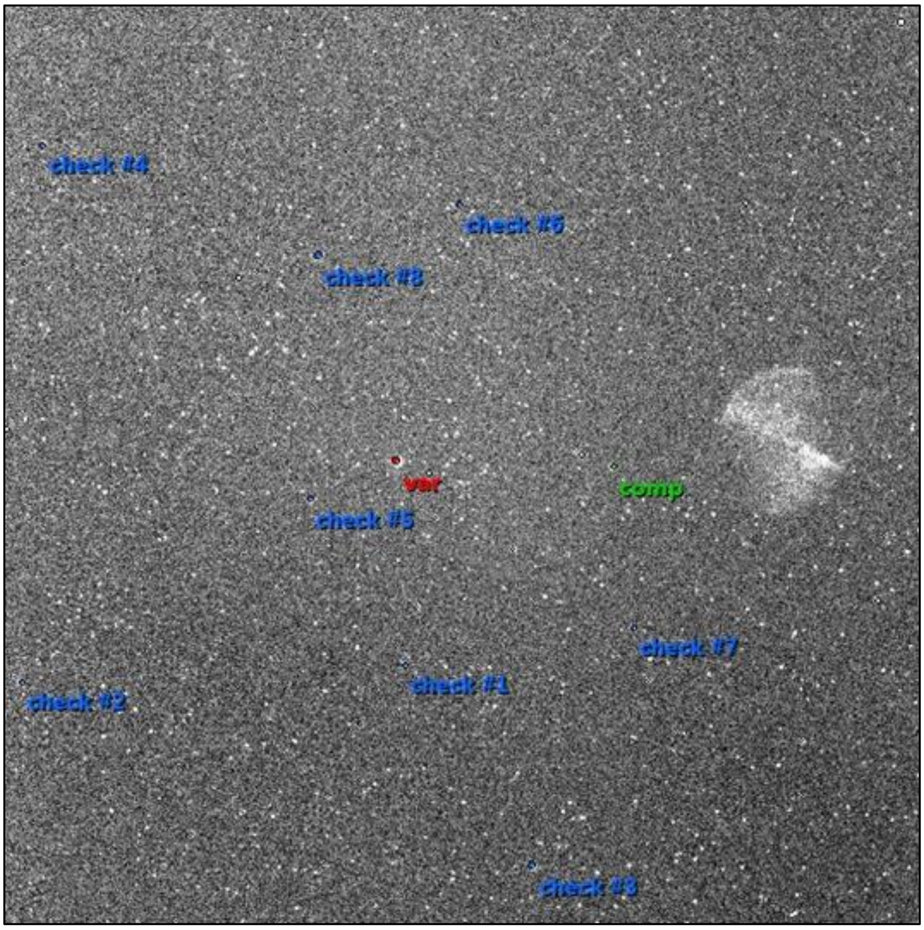


Figure 17: Selected Stars

5.2 Transit light curve

To create the heliocentric light curve, we define the target star (var), a comparison star (comp), and a couple of check stars (check). We choose eight check stars (figure 17).

After that, we choose a value for the measurement aperture. The aperture should provide the lowest measurement errors. We choose the aperture number 9 with a value of 18px size. The light curve (figure 18) is created and shows the magnitude difference between the variable and the comparison star or to another check star (differential photometry). By comparing two other check stars, the magnitude difference is depicted as a constant line.

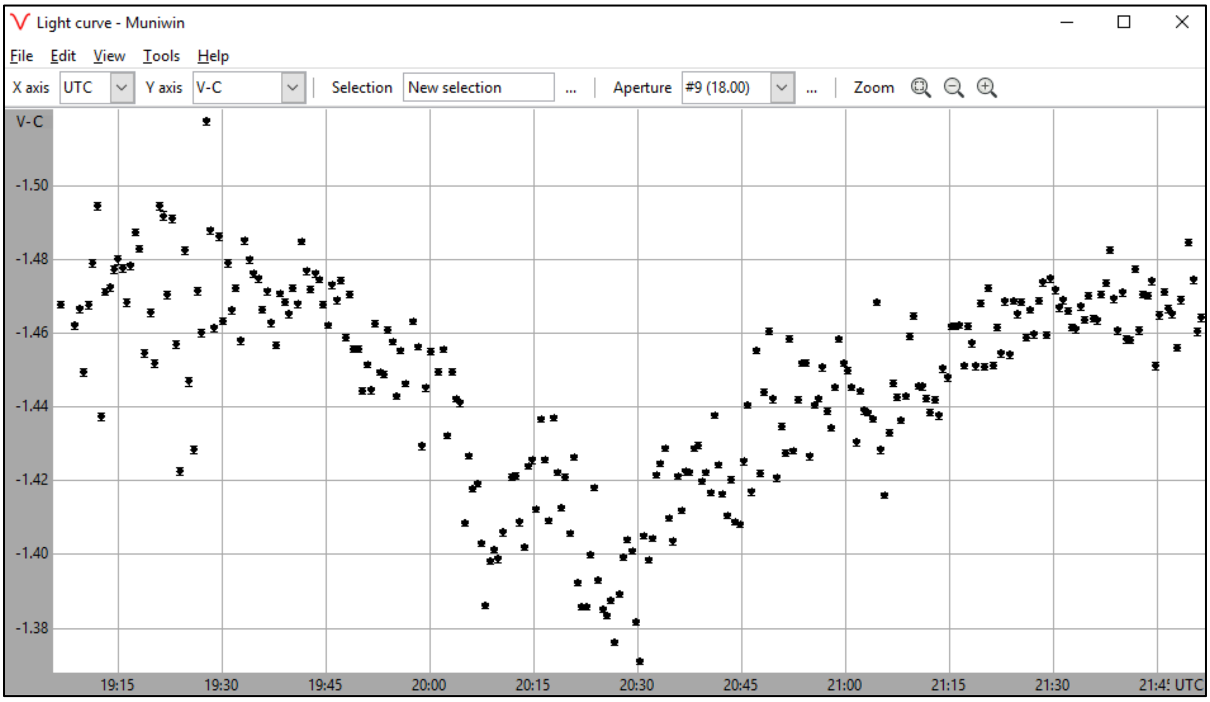


Figure 18: HD 189733 Transit light curve V-C (UTC, heliocentric). Brightness error is 0.027mag for each star.

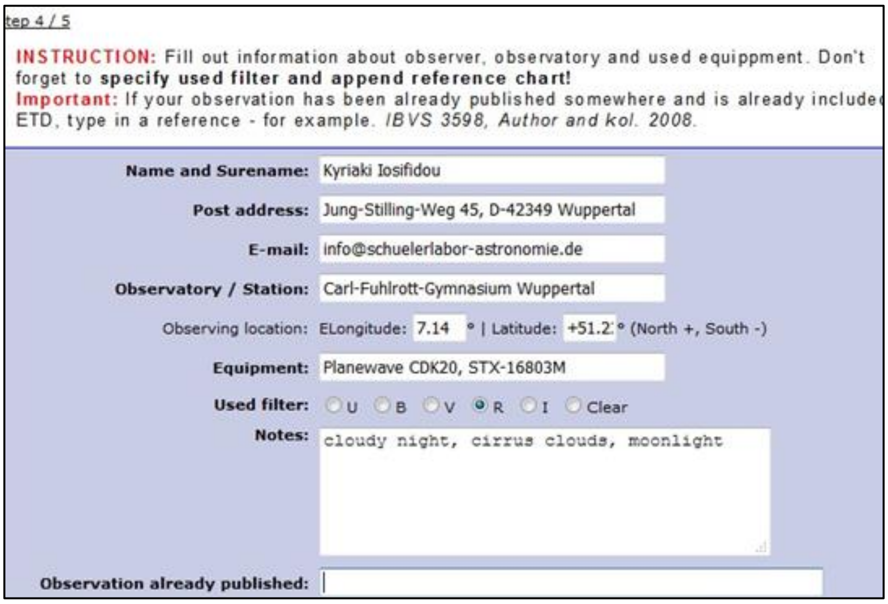


Figure 19: Observer's data

5.3 Calculation of the exoplanet parameters on ETD-Website

On ETD website we upload transit data to be fitted for parameters like planet radius and orbit. And we can compare with results of different observers. Figure 19 gives information about our school observatory and technical equipment.

We only choose the HJD midtransit to be fitted (figure 20, 21), because transit duration and depth could not be fitted to the same precision with our own data (see error discussion in chapter 5.4)

Figure 22 and table 3 show the star's catalogued and measured geometry.

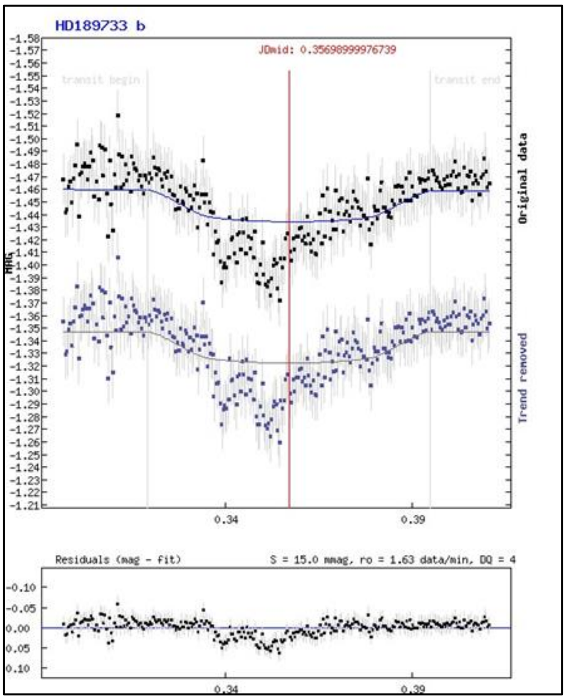


Figure 20: Fitted light curve (top), Residuals (bottom)

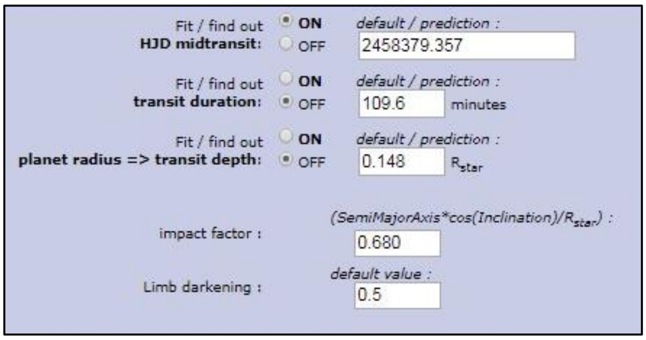


Figure 21: Selected options for fitted parameters

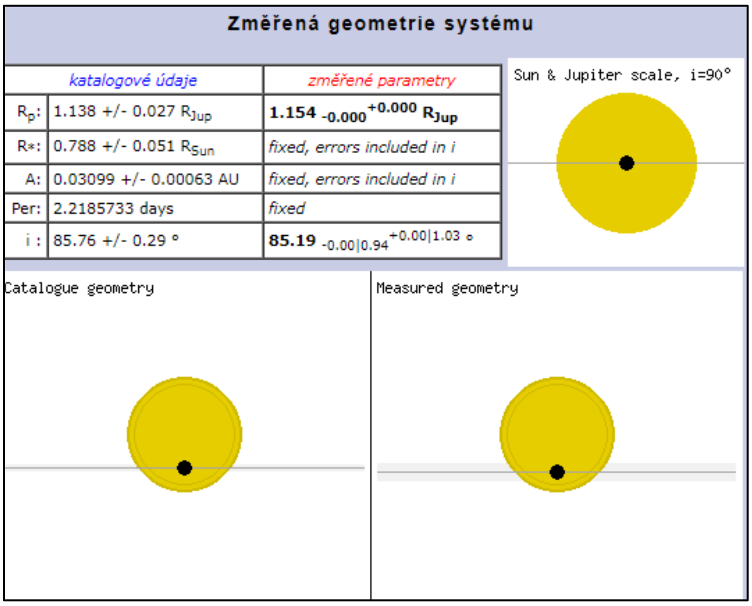


Figure22: Star geometry

	Catalogued geometry	Measured geometry
Rp:	1.138 $RJup$	1.154 $RJup$
Rs:	0.788 $Rsun$	
A:	0.03099 AU	
Per:	2.22 days	
i:	85.76 °	85.19°

Table 3: geometry

After publishing our light curve, we compared our results with different observers on the ETD-Website (figure 23) [13]. The comparison light curves obviously are different to ours, but there is no information available to explain the differences.

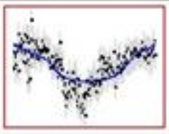
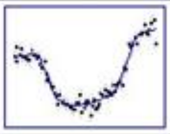
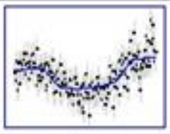
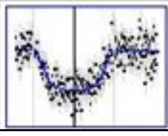
#	HVĚZDA	FILTR	STŘED TRANZITU	KŘIVKA	POZOROVATEL, STANICE / VLOŽENO
168	HD189733 b	R	2018-09-17 20:36:10 Ukaž v ETD		**Kyriaki Iosifidou** Carl-Fuhlrott-Gymnasium Wuppertal 2018-11-05
167	HD189733 b	Clear	2018-10-27 19:09:29 Ukaž v ETD		**lionel rousselot** Vierzon 2018-10-28
166	HD189733 b	Clear	2018-08-28 21:29:56 Ukaž v ETD		**Jan Schilhab** Hodice 2018-08-29
165	HD189733 b	V	2018-08-20 00:25:37 Ukaž v ETD		**Pere Guerra** Observatori Astronomic Albanyà 2018-08-24

Figure 23: Our own light curve on the Czech ETD-Website

5.4 Error discussion

In this chapter, we are dealing with possible measurement errors that could come up while recording due to the creation of the light curve (figure 18).

Looking at the light curve, obviously the transit begins at 19.45 UTC (245879.32 JD) and it ends at about 21.30 UTC (245879.38 JD). The mid-point of the transit (minimum of the light curve) should be at 20.30 UTC (245879.35 JD).

It should be noted that, at the beginning of the light curve the measuring points scatter. This is probably because the signal-noise-ratio was too low at the beginning due to strong cirrus clouds in the sky. Light pollution of the city of Wuppertal could also influence our measurement. Therefore, we could not precisely measure the brightness of the stars between 19.15 UTC (245879.30 JD) and 19.30 UTC (245879.32 JD).

Also, there is a strong variation in brightness between 20.10 UTC (245879.34 JD) and 20.20 UTC (245879.35 JD) just before minimum, such as after the minimum between 21.00 UTC (245879.375 JD) and 21.14 UTC (245879.384 JD). We presume that cirrus clouds could cause this variation in a not ideal night for precise photometric measurements. We conclude that, if this was the reason, then the variation should also be seen in all the light curves of check stars.

[13] http://var2.astro.cz/EN/tresca/transits.php

But when looking at the light curves of two check stars (figure 24, 25), they look identical regarding the brightness variations. That means that, all stars are affected in the same way by cirrus clouds. Besides, there is no variation between 20.10 UTC and 20.20 UTC, such as between 21.00 UTC and 21.14 UTC, except from a tiny one.

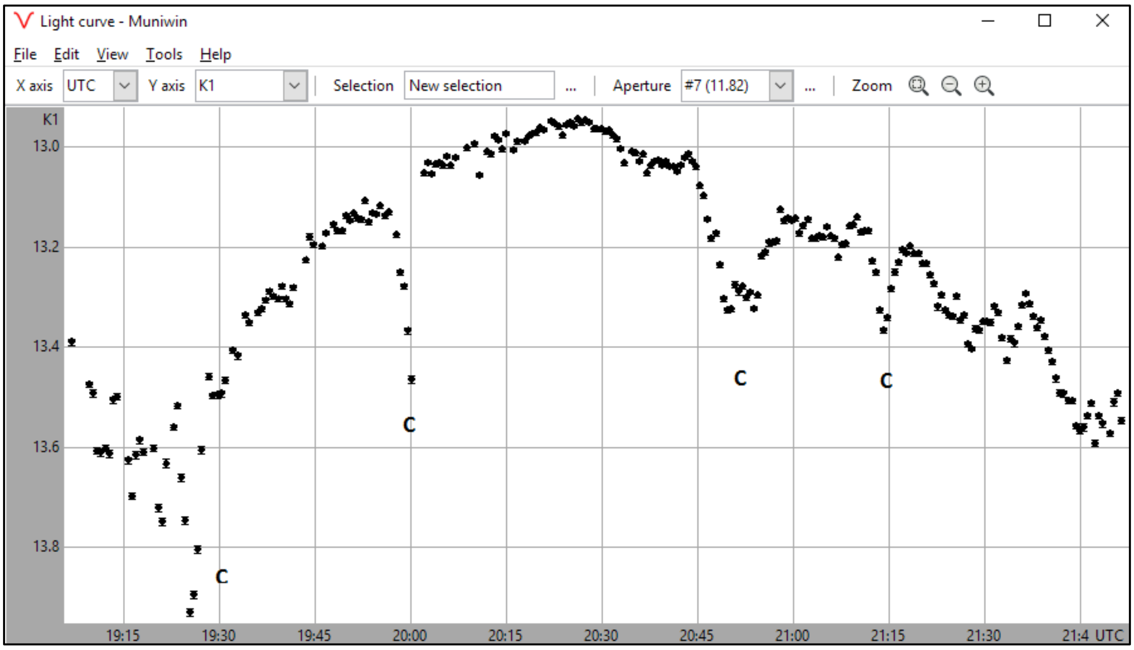


Figure 24: Light curve K1 (check 1), Clouds are indicated by a C

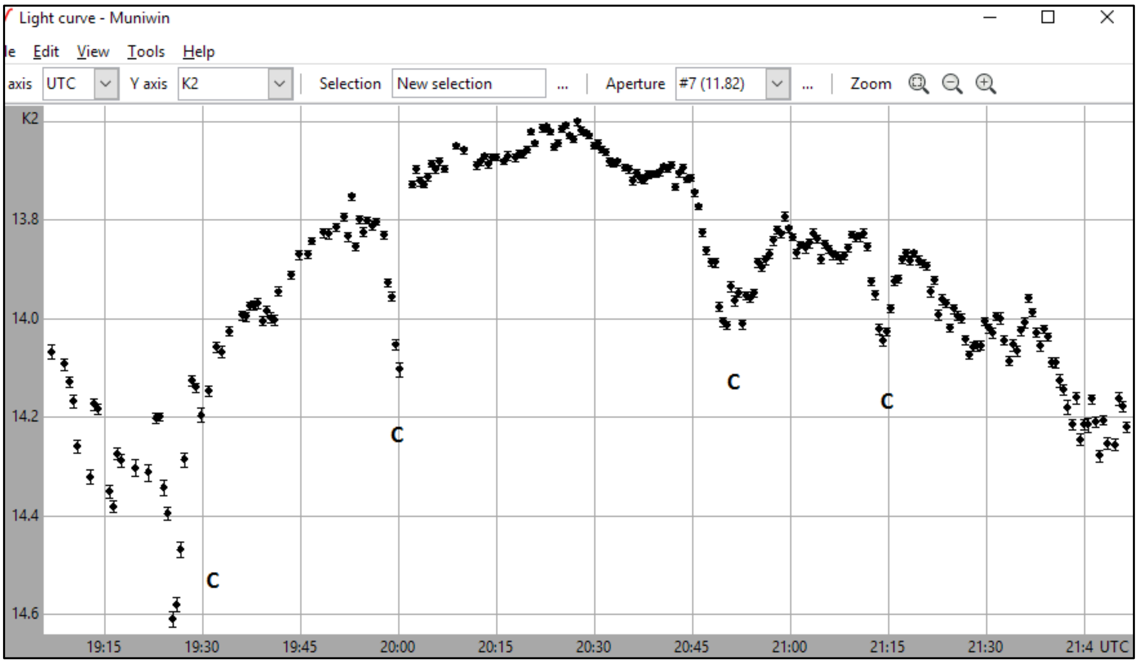


Figure 25: Light curve K2 (check 2), Clouds are indicated by a C

Now we calculate the difference between the two check stars K1 and K2 (figure 25). Between 19.30 UTC and 21.40 UTC the magnitude difference between both check stars appears to be constant (figure 26).

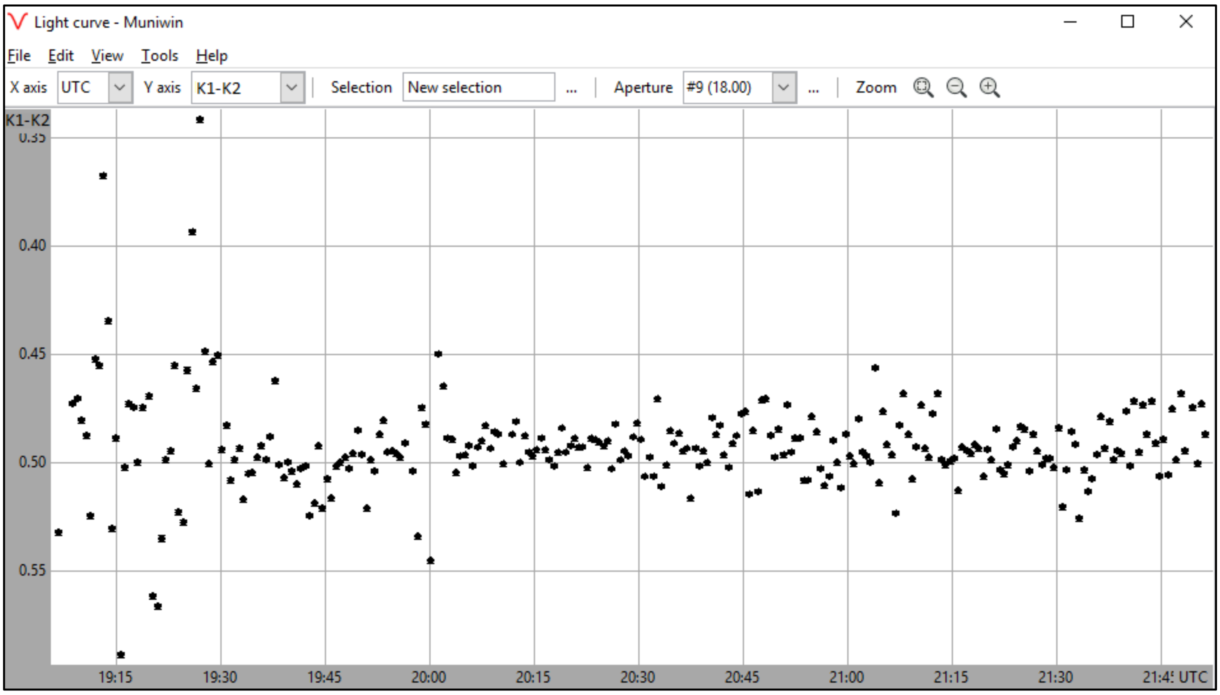


Figure 26: Difference photometry K1-K2

Therefore, we cannot explain the reason for the variations near transit minimum. We must assume, that our measurement was not as exact as expected, although we eliminated all possible errors in our setup. For example, we defocused the star images to avoid saturation.

When fitting transit midpoint and depth, the values for duration and depth differed significantly from the catalog values (figure 27). We got a value of 0.06mag for the depth instead of the published value 0.024mag. This greater depth leads to a greater star radius. However, we got a better data quality (2) with smaller residuals.

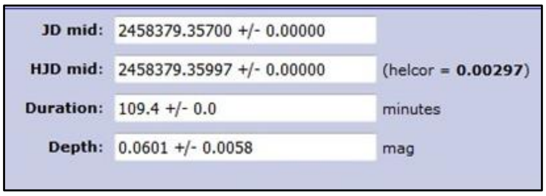


Figure 27: Parameters of the fitted light curve DQ2

This again raises the question: Why do our own measurements deviate although those are not directly justified by the weather. When we compare our light curve with other light curves, published in recent years, such deviations, for example caused by starspots, obviously do not exist. The following figure (28) proves that[14]:

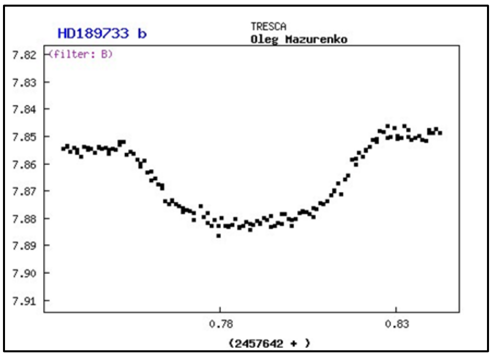


Figure 28: Comparison light curve of Oleg Mazurenko

[14] Published on ETD Website at 27.12.2016, best data quality.

5.5 Calculation of the exoplanet parameters

We use the values from chapter ***3.2. Transit geometry*** to get the star radius in kilometers and set them in the following formula:

$$Rp = \sqrt{\left[-10^{\left(\frac{-0.0247}{2.5}\right)} + 1\right]} * 560{,}555\text{km} = 84{,}069.7\text{km}$$

Lastly, we must convert the radius into Jupiter radii by dividing the value by the Jupiter radius (given in km). The value for the radius of Jupiter is 71,492km.

This is shown in the following equation:

$$Rp[Rj] = \frac{Rp[km]}{Rj[km]} = \frac{84069.7}{71492} = 1.2Rj$$

So, we get the catalog value of the planet radius, because we used the magnitude depth value from the *ETD-Website*. However, if we use our own measured value for the depth, the radius would be much larger than the given value. Our measured value of depth is 0.0601mag.

Then we would get:

$$Rp = \sqrt{\left[-10^{\left(\frac{-0.0601}{2.5}\right)} + 1\right]} * 560{,}555 = 130{,}080\text{km}$$

The calculated value is 130,080km. This value is approximately 46,000 km larger than the catalog value. If we convert this value into Jupiter radii, we get:

$$Rp[Rj] = \frac{130{,}080}{71{,}492} = 1.8Rj$$

This corresponds to approximately 1.5 times the catalog value (1.2Rj), a deviation of 60%. This is a huge difference and results from brightness fluctuations around minimum, which was already discussed.

5.6 Conclusion

Although our results were not as well as expected, we feel encouraged to study this star again, in order to investigate the origin of our quite different results.

6. Attachment

6.1. Bibliography

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6.2. Acknowledgement

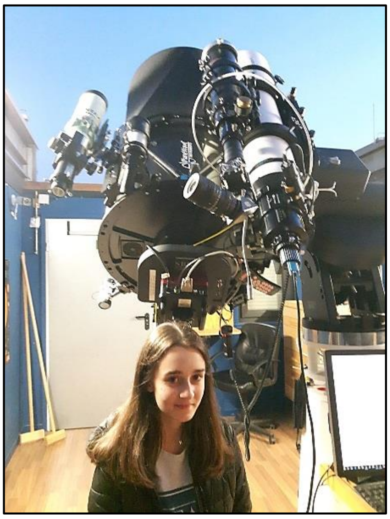
I would like to thank all those who contributed to the realization of this project and their commitment to our school observatory.

But most of all, I would like to thank Mr. Bernd Koch, who supported me and taught me most important astronomical basics needed for exoplanets. He spent hours helping me to develop my project and answering the questions that came up, while working through it.

Also Mr. Michael Winkhaus, who encouraged me to participate in the astronomy course and to launch an own project.

6.3. Final declaration

I hereby declare that the project work entitled ''Detecting the exoplanet HD189733b'' submitted to *ESO Catch A Star*, is an original work done by me under the guidance of Mr. Bernd Koch at the school observatory of Carl-Fuhlrott-Gymnasium Wuppertal, Germany.



Kyriaki Iosifidou

11.12.2018