ABSOLUTE PHOTOMETRY OF AN ECLIPSING BINARY

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ABSTRACT

This report utilizes photometry and reduction of data from a CCD Image in order to define magnitudes for an extinction and variable star located within the Orion Nebula. Through analyzing the data, we can then estimate the amount of interstellar reddening occurring as the energy from the star radiates light years away and is absorbed and scattered both through the Earth's atmosphere and the optics within the telescope.

1. INTRODUCTION AND PURPOSE

Binary stars frequently occur in our universe, as one star rotates around another - usually heavier - star. Occasionally, the geometry between Earth and this binary star system is just right that we can observe the periodicity of one star revolve around its host. With the passing of one object around the other, there is a perceived 'dip' in the magnitude of the host star as it blocks some of the light radiating in our direction. This phenomena, when applying photometry to find the light curves, is a common method to detect and verify possible binary star systems. The measure of the intensity of light from these object as its energy shifts with travelling distances and obstacles is covered by the subject of photometry. All in all, photometry is a critical subject in astronomy by measuring energy outputs of stars through their emitted wavelengths and yielding constraints on stellar structure models of its measured stars.

In this report, we are observing and analyzing the transit of the eclipsing binary of stars located in the Orion Nebula, specifically the θ Ori A system, as shown in Figure 1.

2. DATA DESCRIPTION AND REDUCTION

The general steps of photometry are quite simple. First, you observe the celestial objects you want to see and acquire these observations empirically or visually, such as on a CCD image chip. Then, it is relevant to calibrate the chip to be as close to the accurate image as possible. This step of reductions can involve many calibration options. Then, the analysis of the data takes place. Here, you can create tables/graphs/etc. to emphasize and illustrate the astronomical purpose of the observations. Then, as scientists aspire to, the dream of communicating the idea to a published journal is hopefully made true.

The reduction steps performed for these images included a bias level, dark current, and flat field. Ultimately the goal is that the pictures we take should be as accurate to what's in space as possible. The sensors on cameras and the telescopes can collect issues over time that can effect the resulting image.

Figure 1. Credit: NASA/ESA/AURA/Caltech, https://www.sun.org/images/m45-the-pleiades

The first reduction step involves correcting for the bias using a 'bias frame'. The bias frame utilizes the exposure with the least length as possible with the shutter closed. The image can be used to recognize the specific signal-to-noise ratio within each pixel. These ratios should be consistent for each image taken, so with the bias frame taken, we can compare these ratios with each image to subtract out as much noise as possible.

Another issue with sensors is due to the heat produced when taking long exposure images. This is known as the 'dark current'. To calibrate for this, an exposure image is taken with almost the same conditions and criteria as the observed images, though without any light striking the CCD image. With this frame, there is an expected similar consistency of the dark current heating some pixels more than others that can be subtracted out to a neutral image. The temperature of the pixels has an incredibly significant effect of the pixels, so the importance of the dark current corrections cannot be underestimated.

Finally, we focus on the different raw sensitivity to light in each pixel with the Flat-Field Calibration. Occasionally, dust can find a way onto these sensors forming 'dust donuts' - muddying the image along with the innate sensitivity errors from each pixel. Similarly, the flat-field frame is created through an exposure taken with a uniform light source, exposing the base of the sensors image.

After pre-processing the images, the data from the CCD images can be taken. By using AstroImageJ, we can mark each star observed and collect the data, such as the 'flux'. The FITS files can have many different versions of flux, some incorporating the different light emissions from the source and the dark sky around it, some averaging the value over the exposure, and some stating the peak value of the flux during the exposure. For our purposes, the 'mean' value will be used. Given this flux value, we can find the instrumental magnitude using the light-flux ratio and relationship, detailed in Equation 1.

$$\frac{F_1}{F_2} = (10^{\frac{2}{5}})^{(m_2 - m_1)} \tag{1}$$

$$\log(\frac{F_1}{F_2}) = 0.4(m_2 - m_1) \tag{2}$$

$$m_1 - m_2 = -2.5\log(\frac{F_1}{F_2}) \tag{3}$$

This can be generalized to our situation as shown in Equation 4, where the magnitude of the star given our data from the CCD chip.

$$m = -2.5\log(\text{mean flux}) \tag{4}$$

The data and values from these equations are then tabulated as shown in Table 1.

Another important note is that the filters used in the processing can also affect the calibrations. With this data, only one filter is used (Y Stromgen) throughout, so the corrections are simple and the equations used later only require one related to the filter that is similar to the V filter. This factor will be more relevant in the calculations later performed in the report.

Table 1. Instrumental Magnitudes

FITS-DATE-OBS	Mean Flux$_{var}$	Mean Flux$_{ext}$	m$_{var}$	m$_{ext}$
$59895 - 0146_out.fits$	479.8679	862.8717	−15.434	−16.901
$59895 - 0147_out.fits$	506.9473	879.3290	−15.571	−16.948
$59895 - 0148_out.fits$	487.8636	841.0725	−15.475	−16.837
$59895 - 0149_out.fits$	484.2110	870.2698	−15.456	−16.922
$59895 - 0150_out.fits$	476.3384	870.2478	−15.415	−16.922
$59895 - 0151_out.fits$	494.3003	812.9238	−15.508	−16.752
$59895 - 0152_out.fits$	468.3937	852.9822	−15.373	−16.872
$59895 - 0153_out.fits$	509.2025	893.4444	−15.582	−16.988
$59895 - 0154_out.fits$	483.4070	813.3825	−15.452	−16.753
$59895 - 0155_out.fits$	507.5427	833.6437	−15.574	−16.815
$59895 - 0156_out.fits$	487.2995	815.7004	−15.472	−16.760
$59895 - 0157_out.fits$	495.9738	787.5421	−15.516	−16.672

Table 1 *continued on next page*

Table 1 *(continued)*

FITS-DATE-OBS	Mean Flux_{var}	Mean Flux_{ext}	m_{var}	m_{ext}
$59895-0158_out.fits$	526.4410	884.4604	−15.665	−16.962
$59895-0159_out.fits$	523.2727	878.2342	−15.650	−16.945
$59895-0160_out.fits$	497.9527	841.9432	−15.526	−16.839
$59895-0161_out.fits$	507.0991	867.9947	−15.572	−16.915
$59895-0162_out.fits$	521.3667	856.6248	−15.641	−16.883
$59895-0163_out.fits$	510.5818	848.8578	−15.589	−16.860
$59895-0164_out.fits$	494.4714	827.0293	−15.509	−16.795
$59895-0165_out.fits$	519.7636	852.5618	−15.633	−16.871
$59895-0166_out.fits$	489.0908	811.0072	−15.481	−16.746
$59895-0167_out.fits$	519.5344	826.7615	−15.632	−16.794
$59895-0168_out.fits$	540.8448	886.9930	−15.733	−16.970
$59895-0169_out.fits$	539.9943	935.7803	−15.729	−17.103
$59895-0170_out.fits$	534.0649	898.4543	−15.701	−17.002
$59895-0171_out.fits$	542.8158	931.2497	−15.742	−17.091
$59895-0172_out.fits$	541.4358	851.1942	−15.736	−16.867
$59895-0173_out.fits$	504.2070	787.3616	−15.557	−16.672
$59895-0174_out.fits$	526.2632	846.9648	−15.665	−16.854
$59895-0175_out.fits$	506.0306	808.5955	−15.566	−16.738
$59895-0176_out.fits$	496.9190	762.1895	−15.521	−16.590
$59895-0177_out.fits$	493.1002	832.0503	−15.502	−16.810
$59895-0178_out.fits$	543.6758	929.5013	−15.746	−17.087
$59895-0179_out.fits$	572.5504	938.5070	−15.875	−17.111
$59895-0180_out.fits$	588.5721	963.8776	−15.944	−17.177
$59895-0181_out.fits$	564.5563	930.4865	−15.840	−17.089
$59895-0182_out.fits$	550.4689	951.4416	−15.777	−17.145
$59895-0183_out.fits$	575.5192	968.6924	−15.888	−17.190
$59895-0184_out.fits$	562.4950	948.7778	−15.831	−17.138
$59895-0185_out.fits$	576.6255	986.5016	−15.893	−17.235
$59895-0186_out.fits$	558.4220	979.7865	−15.813	−17.218
$59895-0187_out.fits$	581.5826	953.4733	−15.914	−17.150
$59895-0188_out.fits$	568.7637	929.3498	−15.859	−17.086
$59895-0189_out.fits$	591.4057	977.1149	−15.956	−17.212
$59895-0190_out.fits$	573.7927	961.9327	−15.881	−17.172
$59895-0191_out.fits$	588.0350	1004.7041	−15.942	−17.281
$59895-0192_out.fits$	589.9619	970.6651	−15.950	−17.195
$59895-0193_out.fits$	599.8420	990.8232	−15.992	−17.246
$59895-0194_out.fits$	593.1209	997.5603	−15.963	−17.263
$59895-0195_out.fits$	589.3604	990.2017	−15.948	−17.245

Table 1 *continued on next page*

Table 1 *(continued)*

FITS-DATE-OBS	Mean $Flux_{var}$	Mean $Flux_{ext}$	m_{var}	m_{ext}
$59895-0196_out.fits$	590.9404	975.5468	−15.954	−17.207
$59895-0197_out.fits$	606.1793	1001.7416	−16.018	−17.274
$59895-0198_out.fits$	606.2723	987.5660	−16.018	−17.238
$59895-0199_out.fits$	617.1858	991.8328	−16.063	−17.249
$59895-0200_out.fits$	605.1111	983.4879	−16.014	−17.228
$59895-0201_out.fits$	605.1111	983.4879	−16.014	−17.228
$59895-0202_out.fits$	609.3076	978.1097	−16.031	−17.214
$59895-0203_out.fits$	978.1097	621.1817	−17.214	−16.079
$59895-0204_out.fits$	967.2943	609.4075	−17.186	−16.031
$59895-0205_out.fits$	963.3624	595.2174	−17.176	−15.972
$59895-0206_out.fits$	936.1607	618.8080	−17.104	−16.069
$59895-0207_out.fits$	982.5850	606.9913	−17.225	−16.021
$59895-0208_out.fits$	960.6686	645.5421	−17.169	−16.175
$59895-0209_out.fits$	1007.5025	631.1052	−17.288	−16.119
$59895-0210_out.fits$	999.8634	613.1574	−17.269	−16.047
$59895-0211_out.fits$	1023.1527	609.0953	−17.327	−16.030
$59895-0212_out.fits$	993.7697	618.0680	−17.254	−16.066
$59895-0213_out.fits$	986.2998	610.9792	−17.235	−16.038
$59895-0214_out.fits$	1018.4517	630.3217	−17.315	−16.116
$59895-0215_out.fits$	991.0608	632.3963	−17.247	−16.124
$59895-0216_out.fits$	1061.2911	634.7964	−17.418	−16.133
$59895-0217_out.fits$	1040.1238	633.2618	−17.368	−16.127
$59895-0218_out.fits$	1013.8391	641.6999	−17.304	−16.160
$59895-0219_out.fits$	997.3573	649.2667	−17.263	−16.190
$59895-0220_out.fits$	1027.3980	635.4702	−17.337	−16.136
$59895-0221_out.fits$	1024.8550	646.9450	−17.331	−16.181
$59895-0222_out.fits$	983.5207	639.4188	−17.228	−16.151
$59895-0223_out.fits$	1015.3344	637.9721	−17.307	−16.146
$59895-0224_out.fits$	1025.3197	653.9083	−17.332	−16.207
$59895-0225_out.fits$	1052.0212	639.8180	−17.396	−16.153
$59895-0226_out.fits$	1022.4483	666.3695	−17.325	−16.255
$59895-0227_out.fits$	1029.3879	656.8936	−17.342	−16.219
$59895-0228_out.fits$	1017.8667	642.7945	−17.314	−16.165
$59895-0229_out.fits$	1041.6562	651.9698	−17.371	−16.200
$59895-0230_out.fits$	1037.6561	648.3564	−17.362	−16.186
$59895-0231_out.fits$	1029.9037	672.7953	−17.343	−16.279
$59895-0232_out.fits$	1035.3604	655.4539	−17.356	−16.213
$59895-0233_out.fits$	1055.1987	656.2266	−17.404	−16.216

Table 1 *continued on next page*

Table 1 *(continued)*

FITS-DATE-OBS	Mean Flux$_{var}$	Mean Flux$_{ext}$	m$_{var}$	m$_{ext}$
$59895 - 0234_out.fits$	1041.8107	661.1859	−17.372	−16.235
$59895 - 0235_out.fits$	1032.1877	664.4044	−17.349	−16.247
$59895 - 0236_out.fits$	1075.7106	649.7204	−17.452	−16.191
$59895 - 0237_out.fits$	1055.9380	664.1897	−17.405	−16.246
$59895 - 0238_out.fits$	1058.7409	680.7205	−17.412	−16.308
$59895 - 0239_out.fits$	1049.5578	680.1835	−17.390	−16.306
$59895 - 0240_out.fits$	1057.0321	680.1835	−17.408	−16.306
$59895 - 0241_out.fits$	1057.0321	666.1720	−17.408	−16.254
$59895 - 0242_out.fits$	1060.5211	676.2429	−17.416	−16.291
$59895 - 0243_out.fits$	1060.2335	681.1115	−17.416	−16.309
$59895 - 0244_out.fits$	1064.5007	675.6345	−17.426	−16.289
$59895 - 0245_out.fits$	1047.5997	657.2683	−17.386	−16.220
$59895 - 0246_out.fits$	1050.3681	701.1746	−17.392	−16.382
$59895 - 0247_out.fits$	1067.3756	703.6989	−17.432	−16.391
$59895 - 0248_out.fits$	1058.0418	684.2518	−17.410	−16.321
$59895 - 0249_out.fits$	1083.5847	653.4393	−17.470	−16.206

3. ANALYSIS

Another factor that effects our observations of these stars is looking through the Earth's atmosphere. No matter how clear the seeing is, the light from stars will always be scattered and absorbed by the atmosphere and effect our observational data. Astronomers have derived equations that can 'correct' these values to 'above-atmospheric' values. To do this, we must find the airmass variation. The airmass, represented by X, can be found using Equation 5.

$$X = \sec(z) = \frac{1}{\sin(\phi)\sin(\delta) + \cos(\phi)\cos(\delta)\cos(H)} \tag{5}$$

Here, z represents the Zenith Distance, given in the FITS files, making the calculations much easier. Additionally, the variables δ represents the star's declination and ϕ represents the observer's latitude. Additionally, the hour angle, H is also found in the equation to account for the positional geometry of the observer to the star.

The air mass is a critical value in determining the shift in the light of our image from the star, gleaning important information to consider for our data.

3.1. *Extinction Star*

For the extinction star, we compute the values for its airmass. We tabulate the extinction star's Heliocentric Julian Date (HJD), instrumental magnitudes, and its airmass in Table 2

[h]

Table 2. Extinction Star Magnitudes

HJD	Instrumental Mag	Airmass
2459895.710	−16.901	1.512
2459895.710	−16.948	1.512
2459895.710	−16.837	1.739
2459895.710	−16.922	1.739
2459895.710	−16.922	2.076
2459895.710	−16.752	2.076
2459895.711	−16.872	2.679
2459895.711	−16.988	2.679
2459895.711	−16.753	3.715
2459895.711	−16.815	3.715
2459895.712	−16.760	79.540
2459895.712	−16.672	79.540
2459895.712	−16.962	−9.327
2459895.712	−16.945	−9.327
2459895.713	−16.839	−4.636
2459895.713	−16.915	−4.636
2459895.713	−16.883	−3.109
2459895.713	−16.860	−3.109
2459895.714	−16.795	−2.311
2459895.714	−16.871	−2.311
2459895.714	−16.746	−1.539
2459895.714	−16.794	−1.539
2459895.715	−16.970	−1.371
2459895.715	−17.103	−1.371
2459895.715	−17.002	−1.241
2459895.715	−17.091	−1.241
2459895.716	−16.867	−1.155
2459895.716	−16.672	−1.155
2459895.716	−16.854	−1.092
2459895.716	−16.738	−1.092
2459895.717	−16.590	−1.010
2459895.717	−16.810	−1.010
2459895.717	−17.087	−1.001

Table 2 *continued on next page*

Table 2 *(continued)*

HJD	Instrumental Mag	Airmass
2459895.717	−17.111	−1.001
2459895.718	−17.177	−1.003
2459895.718	−17.089	−1.003
2459895.718	−17.145	−1.020
2459895.718	−17.190	−1.020
2459895.718	−17.138	−1.049
2459895.718	−17.235	−1.049
2459895.719	−17.218	−1.185
2459895.719	−17.150	−1.185
2459895.720	−17.086	−1.283
2459895.720	−17.212	−1.283
2459895.720	−17.172	−1.416
2459895.720	−17.281	−1.416
2459895.721	−17.195	−1.622
2459895.721	−17.246	−1.622
2459895.721	−17.263	−1.900
2459895.721	−17.245	−1.900
2459895.722	−17.207	−3.339
2459895.722	−17.274	−3.339
2459895.722	−17.238	−5.461
2459895.722	−17.249	−5.461
2459895.723	−17.228	−13.496
2459895.723	−17.228	−13.496
2459895.723	−17.214	27.912
2459895.723	−16.079	27.912
2459895.723	−16.031	6.443
2459895.723	−15.972	6.443
2459895.724	−16.069	2.533
2459895.724	−16.021	2.533
2459895.725	−16.175	2.027
2459895.725	−16.119	2.027
2459895.725	−16.047	1.684
2459895.725	−16.030	1.684
2459895.725	−16.066	1.474
2459895.725	−16.038	1.474
2459895.726	−16.116	1.324
2459895.726	−16.124	1.324
2459895.727	−16.133	1.119

Table 2 *continued on next page*

Table 2 *(continued)*

HJD	Instrumental Mag	Airmass
2459895.727	−16.127	1.119
2459895.727	−16.160	1.066
2459895.727	−16.190	1.066
2459895.727	−16.136	1.028
2459895.727	−16.181	1.028
2459895.728	−16.151	1.008
2459895.728	−16.146	1.008
2459895.728	−16.207	1.000
2459895.728	−16.153	1.000
2459895.729	−16.255	1.031
2459895.729	−16.219	1.031
2459895.729	−16.165	1.067
2459895.729	−16.200	1.067
2459895.730	−16.186	1.119
2459895.730	−16.279	1.119
2459895.730	−16.213	1.192
2459895.730	−16.216	1.192
2459895.731	−16.235	1.291
2459895.731	−16.247	1.291
2459895.732	−16.191	1.707
2459895.732	−16.246	1.707
2459895.732	−16.308	2.028
2459895.732	−16.306	2.028
2459895.732	−16.306	2.533
2459895.732	−16.254	2.533
2459895.733	−16.291	3.431
2459895.733	−16.309	3.431
2459895.733	−16.289	5.414
2459895.733	−16.220	5.414
2459895.734	−16.382	−15.577
2459895.734	−16.391	−15.577
2459895.734	−16.321	−5.768
2459895.734	−16.206	−5.768

Moreover, by graphing the airmass against the instrumental magnitude, the slope from the line of best fit can be used in future calculations.

The slope from Figure 2 is $k = -8.12 * 10^{-6}$.

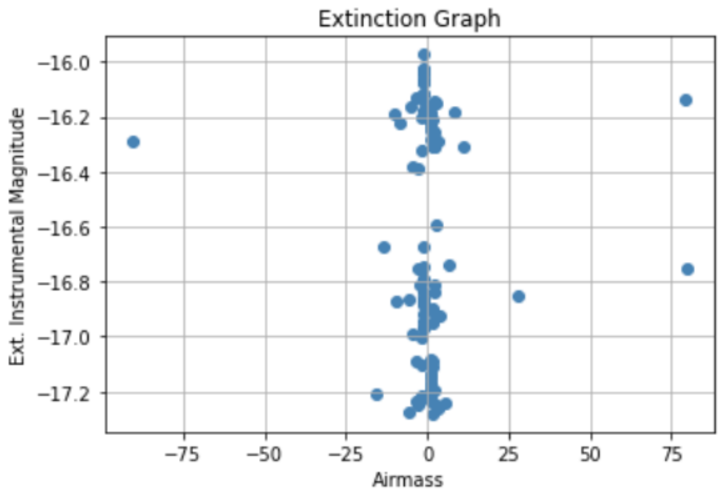

Figure 2. Caption

3.2. *Variable Star*

With the corrections made to the sensors, and now with more knowledge on the atmospheric conditions, we can 'transform' the magnitude to above-atmospheric values, closer to values we'd find by measuring in space. The transformed magnitude, v_0 can be calculated as shown in Equation 6.

$$v_0 = v - k * X \tag{6}$$

The transformed magnitude should also consider the zero-point magnitude given by Dr. Sowell, as 14. Thus, the equation is:

$$t = v_0 + 14 \tag{7}$$

We can analyze how our perspective of the star in our sky can affect the perceived magnitude by plotting the HJD against the transformed magnitude. As expected, Figure 3 shows a negative linear relationship, as the star gets closer to horizon and more of its light scatters in the atmosphere, dimming the magnitude we are able to detect.

Table 3. Extinction Star Corrections

HJD	Instrumental Mag	Airmass	Corrected Mag	Transformed Mag
2459895.710	−16.901	1.512	−16.901	−2.901
2459895.710	−16.948	1.739	−16.948	−2.948
2459895.710	−16.837	2.076	−16.837	−2.837

Table 3 *continued on next page*

Table 3 *(continued)*

HJD	Instrumental Mag	Airmass	Corrected Mag	Transformed Mag
2459895.711	−16.922	2.679	−16.922	−2.922
2459895.711	−16.922	3.715	−16.922	−2.922
2459895.712	−16.752	79.540	−16.751	−2.751
2459895.712	−16.872	−9.327	−16.872	−2.872
2459895.713	−16.988	−4.636	−16.988	−2.988
2459895.713	−16.753	−3.109	−16.753	−2.753
2459895.714	−16.815	−2.311	−16.815	−2.815
2459895.714	−16.760	−1.539	−16.760	−2.760
2459895.715	−16.672	−1.371	−16.672	−2.672
2459895.715	−16.962	−1.241	−16.962	−2.962
2459895.716	−16.945	−1.155	−16.945	−2.945
2459895.716	−16.839	−1.092	−16.839	−2.839
2459895.717	−16.915	−1.010	−16.915	−2.915
2459895.717	−16.883	−1.001	−16.883	−2.883
2459895.718	−16.860	−1.003	−16.860	−2.860
2459895.718	−16.795	−1.020	−16.795	−2.795
2459895.718	−16.871	−1.049	−16.871	−2.871
2459895.719	−16.746	−1.185	−16.746	−2.746
2459895.720	−16.794	−1.283	−16.794	−2.794
2459895.720	−16.970	−1.416	−16.970	−2.970
2459895.721	−17.103	−1.622	−17.103	−3.103
2459895.721	−17.002	−1.900	−17.002	−3.002
2459895.722	−17.091	−3.339	−17.091	−3.091
2459895.722	−16.867	−5.461	−16.867	−2.867
2459895.723	−16.672	−13.496	−16.672	−2.672
2459895.723	−16.854	27.912	−16.854	−2.854
2459895.723	−16.738	6.443	−16.738	−2.738
2459895.724	−16.590	2.533	−16.590	−2.590
2459895.725	−16.810	2.027	−16.810	−2.810
2459895.725	−17.087	1.684	−17.087	−3.087
2459895.725	−17.111	1.474	−17.111	−3.111
2459895.726	−17.177	1.324	−17.177	−3.177
2459895.727	−17.089	1.119	−17.089	−3.089
2459895.727	−17.145	1.066	−17.145	−3.145
2459895.727	−17.190	1.028	−17.190	−3.190
2459895.728	−17.138	1.008	−17.138	−3.138
2459895.728	−17.235	1.000	−17.235	−3.235
2459895.729	−17.218	1.031	−17.218	−3.218

Table 3 *continued on next page*

Table 3 *(continued)*

HJD	Instrumental Mag	Airmass	Corrected Mag	Transformed Mag
2459895.729	−17.150	1.067	−17.150	−3.150
2459895.730	−17.086	1.119	−17.086	−3.086
2459895.730	−17.212	1.192	−17.212	−3.212
2459895.731	−17.172	1.291	−17.172	−3.172
2459895.732	−17.281	1.707	−17.281	−3.281
2459895.732	−17.195	2.028	−17.195	−3.195
2459895.732	−17.246	2.533	−17.246	−3.246
2459895.733	−17.263	3.431	−17.263	−3.263
2459895.733	−17.245	5.414	−17.245	−3.245
2459895.734	−17.207	−15.577	−17.208	−3.208
2459895.734	−17.274	−5.768	−17.274	−3.274
2459895.735	−17.238	−3.566	−17.238	−3.238
2459895.735	−17.249	−2.603	−17.249	−3.249
2459895.735	−17.228	−2.070	−17.228	−3.228
2459895.735	−17.228	−2.070	−17.228	−3.228
2459895.736	−17.214	−1.460	−17.214	−3.214
2459895.737	−16.079	−1.315	−16.079	−2.079
2459895.737	−16.031	−1.201	−16.031	−2.031
2459895.738	−15.972	−1.125	−15.972	−1.972
2459895.738	−16.069	−1.071	−16.069	−2.069
2459895.739	−16.021	−1.007	−16.021	−2.021
2459895.739	−16.175	−1.000	−16.175	−2.175
2459895.740	−16.119	−1.005	−16.119	−2.119
2459895.740	−16.047	−1.023	−16.047	−2.047
2459895.740	−16.030	−1.055	−16.030	−2.030
2459895.741	−16.066	−1.190	−16.067	−2.067
2459895.742	−16.038	−1.290	−16.038	−2.038
2459895.742	−16.116	−1.426	−16.116	−2.116
2459895.742	−16.124	−1.616	−16.124	−2.124
2459895.743	−16.133	−1.891	−16.133	−2.133
2459895.744	−16.127	−3.205	−16.127	−2.127
2459895.744	−16.160	−4.857	−16.160	−2.160
2459895.744	−16.190	−10.288	−16.190	−2.190
2459895.745	−16.136	79.057	−16.135	−2.135
2459895.745	−16.181	8.174	−16.181	−2.181
2459895.746	−16.151	2.819	−16.151	−2.151
2459895.747	−16.146	2.197	−16.146	−2.146
2459895.747	−16.207	1.817	−16.207	−2.207

Table 3 *continued on next page*

Table 3 *(continued)*

HJD	Instrumental Mag	Airmass	Corrected Mag	Transformed Mag
2459895.747	−16.153	1.566	−16.153	−2.153
2459895.748	−16.255	1.390	−16.255	−2.255
2459895.749	−16.219	1.158	−16.219	−2.219
2459895.749	−16.165	1.094	−16.165	−2.165
2459895.749	−16.200	1.049	−16.200	−2.200
2459895.750	−16.186	1.022	−16.186	−2.186
2459895.750	−16.279	1.005	−16.279	−2.279
2459895.751	−16.213	1.012	−16.213	−2.213
2459895.751	−16.216	1.033	−16.216	−2.216
2459895.752	−16.235	1.069	−16.235	−2.235
2459895.752	−16.247	1.123	−16.247	−2.247
2459895.753	−16.191	1.197	−16.191	−2.191
2459895.753	−16.246	1.469	−16.246	−2.246
2459895.754	−16.308	1.655	−16.308	−2.308
2459895.754	−16.306	1.948	−16.306	−2.306
2459895.754	−16.306	1.948	−16.306	−2.306
2459895.755	−16.254	2.404	−16.254	−2.254
2459895.755	−16.291	3.096	−16.291	−2.291
2459895.756	−16.309	11.258	−16.309	−2.309
2459895.756	−16.289	−90.444	−16.290	−2.290
2459895.757	−16.220	−8.281	−16.220	−2.220
2459895.757	−16.382	−4.367	−16.382	−2.382
2459895.757	−16.391	−3.077	−16.391	−2.391
2459895.758	−16.321	−1.822	−16.321	−2.321
2459895.759	−16.206	−1.588	−16.206	−2.206

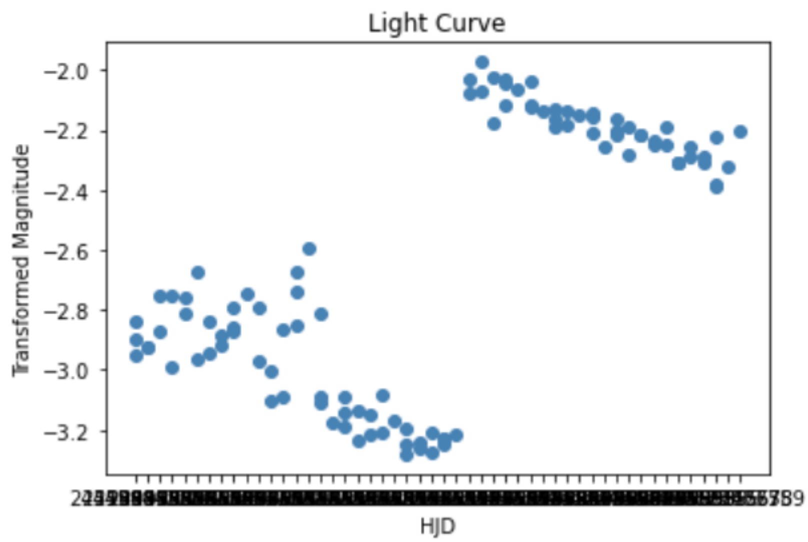

Figure 3. Light Curve

4. CONCLUSIONS

The obstacles that light encounters to reach our telescopes many light years away is an incredibly journey, and the corrections we make are quite a scientific feat. Through the calibrations and power of photometry, we can get a full picture of the astronomical observations and the data that we can gather from these observations. Even when correcting for some image-processing variables, the interactions between light even through our atmosphere can have a huge effect on the calculations for the magnitude of an object. I would additionally be curious to understand some possible aspects of cosmology - where it is a common factor to include that the wavelengths become red-shifted due to the expansion of the universe and the impact of this phenomena on our understanding of magnitude.