Lab #5: Aperture Photometry

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Abstract

We present the photometric observations of 2MASS J16142029-190648, a T-Tauri star in Upper Scorpius, with the goal of understanding its inherent variability. Nine observations were taken with various LCOGT based telescopes over the course of a month. After conducting aperture photometry on these images, the apparent magnitude is determined via the distance modulus equation. In the end, it is determined that higher cadence observations are needed to fully understand the stellar variability observed.

Introduction

Upper Scorpius (US) is a highly studied region located approximately 470 light-years away in the Scorpius-Centaurus Association. US is the youngest of 3 sub-components in the Scorpius-Centaurus Association, and home to many Younge Stellar Objects (YSOs). Star formation began in this region only—approximately—5 Myr ago (Mathews et al., 2013).

We present photometric observations of 2MASS J16142029-1906481, a T-Tauri type star located in US (Cody et al. (2014), Preibisch and Mamajek (2008)). For the sake of simplicity, this star will be referenced as the *target star*. The goal of these observations is to calculate the magnitude of target star intermittently to quantify its variability.

The magnitude of the target star will be calculated using the following relation,

$$m_A - m_B = (-2.5)\log_{10}\left(\frac{F_A}{F_B}\right) \tag{1}$$

$$\Rightarrow m_A = (-2.5)\log_{10}\left(\frac{F_A}{F_B}\right) + m_B \tag{2}$$

where F_A is the detrended flux of the target star, m_B is the apparent magnitude of a reference star, F_B is its associated detrended flux. See Table 1 for the background of the target and reference star.

Star ID	RA	DEC	Apparent Magnitude
Target	243.584583	-19.113361	TBD
Reference	243.58713	-19.101305	13.5

Table 1: Observational background of the target star and a reference star of known magnitude located within the field-of-view.

Observations

The observations were conducted with various telescopes a part of the *Los Cumbres Observatory Global Telescope* (LCOGT) network. See Table 2 for the observation times and locations. The observations on this object were conducted intermittently over the course of about 1 month.

Observatory	Gain	Observation Date	
Siding Spring	1.4	2014-06-07	22:33:39
		2014-06-07	22:34:10
		2014-06-07	22:19:14
SAAO	1.4	2014-06-07	07:55:38
		2014-05-26	08:28:40
		2014-05-26	08:37:51
McDonald	1.4	2014-06-07	14:27:58
Cerro Tololo	1.0	2014-06-23	16:14:55
		2014-06-25	15:59:51

Table 2: Observational Background of the target, with dates of observations noted.

Outline of Analyses

Within each image, a square aperture was drawn around the target star. Similarly, another region, devoid of stars, was also selected to serve as the background region. The background signal is approximated by the median signal within that region. See Fig. 2 in the Appendix for an example showing the aperture, and background selection for an image. For each pixel in the target aperture, the background signal is subtracted then the resulted array is then summed and multiplied by the given *Gain* value. Summarized in the following equation:

$$\text{Detrended Flux} = \left[\Sigma_i^N(\text{Pixel}_i - \text{Background})\right] \times \text{Gain}$$

Recall that the flux follows poisson statistics, therefore the error in the detrended flux can be approximated as,

$$\sigma = \sqrt{\text{Detrended Flux}}$$

In a similar fashion, the detrended flux of the reference star and its associated error is obtained. Then, using Eq. 2, we will obtain a result for the apparent magnitude of the target star—recall that the reference star has a fixed magnitude of 13.5.

Results

Using Eq. 2, the resulting detrended flux and magnitudes for the star in each image is tabbed in Fig. 3. With those magnitudes, a plot depicting the magnitude as a function of time is shown in Fig. 1.

Dates [mjd]	Detrended Flux	Apparent Magnitude
56815.3762592	$(1.1008\pm0.0033)\times10^{05}$	13.304 ± 0.005
56815.3847391	$(1.1215\pm0.0033)\times10^{05}$	13.296 ± 0.005
56815.6192169	$(1.411\pm0.004)\times10^{05}$	12.868 ± 0.005
56814.9708378	$(7.112\pm0.027)\times10^{04}$	13.046 ± 0.006
56803.0094263	$(8.02\pm0.09)\times10^{03}$	14.329 ± 0.015
56803.0858539	$(8.03\pm0.09)\times10^{03}$	14.437 ± 0.014
56815.2927424	$(7.603\pm0.028)\times10^{04}$	13.487 ± 0.006
56831.2619646	$(1.275\pm0.004)\times10^{05}$	13.969 ± 0.004
56833.2621304	$(1.333\pm0.004)\times10^{05}$	14.110 ± 0.004

Table 3: Resulting detrended flux and apparent magnitude calculations for the target star.

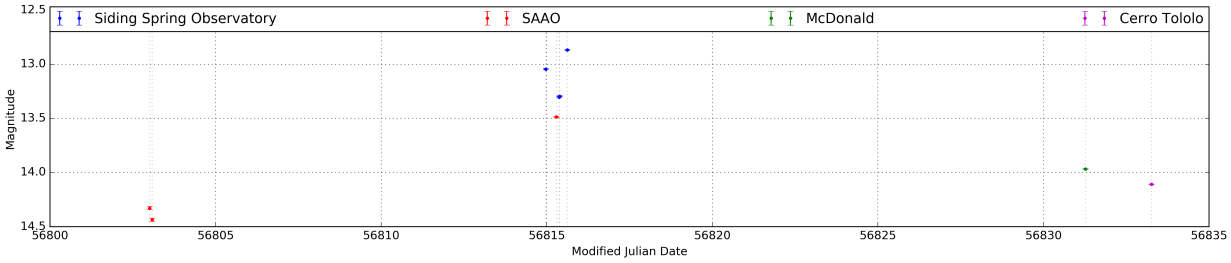

Figure 1: Apparent magnitude as a function of time, for the target star. Data is taken intermittently over the course of approximately 1 month. Measurements were taken via a variety of observatories, noted by color.

Discussion / Conclusion

Upon inspection of Table 3 and Fig. 1, it can be seen that the magnitude is highly variable in the target star. Unfortunately, there is not enough data given to quantify the frequency, or nature of the star's variability. Despite the lack of data, it can be inferred that this object is a T-Tauri type star with variability on a time scale of hours—which can especially be seen around day 56815. In summary, more observations with a higher cadence are needed in order to fully understand the variability seen in Fig. 1.

References

Cody, A. M., Stauffer, J., Baglin, A., Micela, G., Rebull, L. M., Flaccomio, E., Morales-Calderón, M., Aigrain, S., Bouvier, E., Hillenbrand, L. A., Gutermuth, R., Song, I., Turner, N., Alencar, S. H. P., Zwintz, K., Plavchan, P., Carpenter, J., Findeisen, K., Carey, S., Terebey, S., and Hartmann, L. (2014). CSI 2264: Simultaneous Optical And Infrared Light Curves of Young Disk-Bearing Stars In NGC 2264 with COROT AND SPITZER Evidence for Multiple Origins of Variability .

Mathews, G. S., Pinte, C., Duchêne, G., Williams, J. P., and Ménard, F. (2013). Astrophysics A Herschel PACS survey of the dust and gas in Upper Scorpius disks. *A&A*, 558.

Preibisch, T. and Mamajek, E. (2008). The Nearest OB Association: Scorpius-Centaurus (Sco OB2). *Bo Reipurth*.

Appendix

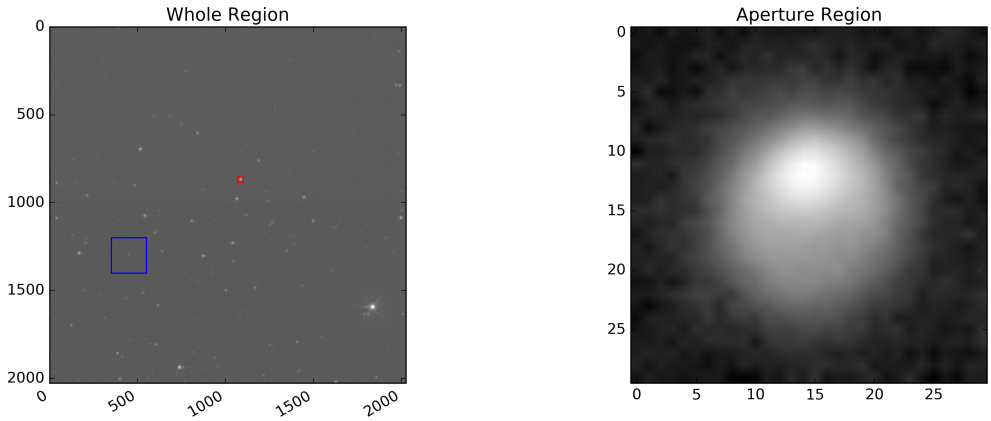

Figure 2: Example of Aperture Photometry. (Left) the full region is shown with the selected aperture (red) and the background (blue) noted. In this example the aperture is a 30×30 pixel box. (Right) Zoomed-in view of the target star in the aperture.