Comparison of Relative Flux Density of Procyon in Visible Band

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ABSTRACT

We present the photometric analysis of Procyon in FITS format using Aladin 9.0 by studying the luminous flux collected by a 16 inch Meade LX200GPS Schmidt-Cassegrain telescope placed at B.P. Koirala National Observatory, Nagarkot, Nepal on April 18, 2017. The maximum and minimum diameters along the maximum and minimum flux regions are constructed. A graph is plotted using a Python custom program for the relative flux density along the two diameters. The flux density varies from the region of extremities of the diameters constructed from 0.25 to a peak of 248.50 in the relative unit. A significant bulging towards the north-eastern portion of Procyon is observed. While moving from the region of maximum flux towards the edge of the north-eastern section, we noticed the bulge prominently. The south-western portion and the other two directions do not show much variation. A possible explanation of the result is discussed.

Keywords: Procyon, Schmidt-Cassegrain telescope, Flux density variation

1. INTRODUCTION

Procyon (Fig. 1) is one of the brightest stars in the night sky. Close inspection of the star reveals it to be a binary star comprising of spectral type F5 IV-V subgiant Procyon A with a near-ending main sequence by Eggenberger *et al.* (2005) and a white dwarf Procyon B.

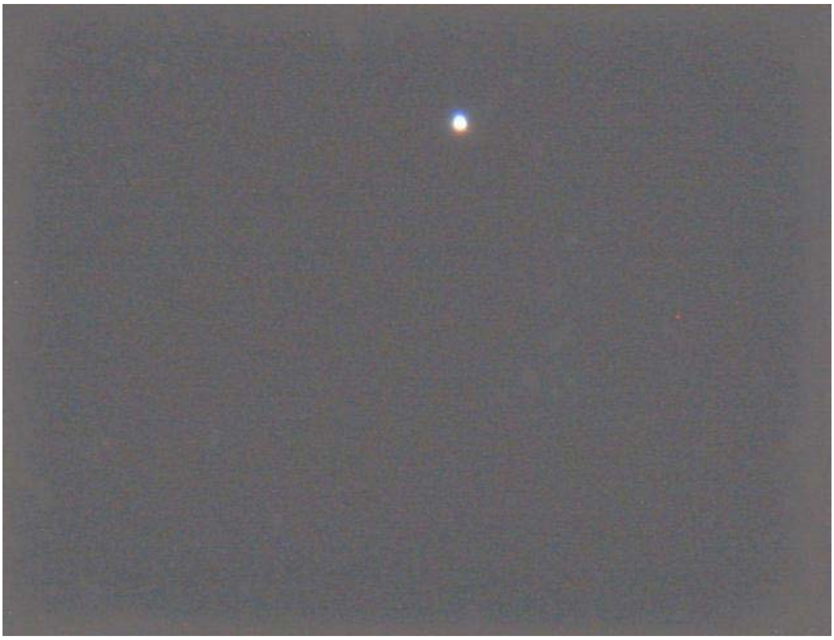

Fig. 1: JPEG image of Procyon captured at 9:23 PM on April 18, 2017

According to Bond *et al.* (2015) the two stars keep on orbiting each other for around 40.84 years. The scientific designation of Procyon A is Alpha Canis Minoris. The co-ordinate of 07 39 18.1 RA and +05 13 29.2 Dec obtained from SIMBAD Astronomical Database - CDS (Strasbourg) keeping 'Procyon' as a search keyword, Procyon A's apparent magnitude is found to be 0.34(V). On the basis of analysis done by Bond *et al.* (2015) with the Hubble Space Telescope data over two decades, Procyon A's mass was found to be 1.478±0.012 Msun and that of Procyon B to be 0.592±0.005 Msun.

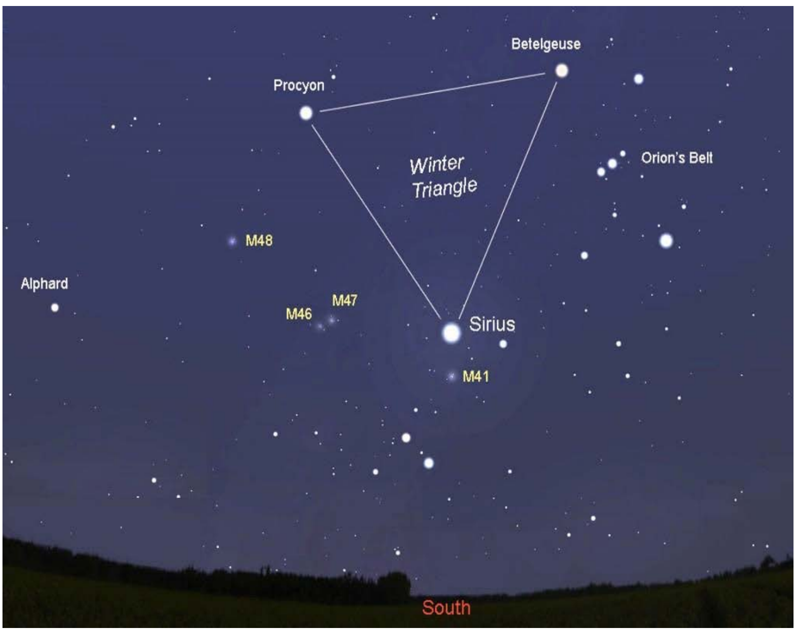

Fig. 2: Procyon position in the sky, source: http://www.sacredsitesproject.com

Considering the high amount of core overshoot, Procyon A's age was found to be 2.7 Gyr according to the core overshoot model by Bond *et al.* (2015). However, Procyon A's age was calculated to be 1.72±0.30 Gyr by Eggenberger *et al.* (2005). Similarly, Aufdenberg *et al.* (2005) calculated the star's luminosity as log(L\Lsun)=0.83±0.04 and the sufficient temperature as 6543±84 K.

Photometric study of stars such as Betelgeuse by Koju *et al.* (2012) and Sirius by Pant *et al.* (2013) has been concluded using the images obtained from 16 inch Meade LX200GPS Schmidt-Cassegrain telescope located at B.P. Koirala National Observatory, Nagarkot, Nepal. The relative flux of the stars was analyzed from the data obtained from the said telescope. Similarly, the asymmetric structure of Betelgeuse was verified by using the images and the data obtained from the same telescope by Koju *et al.* (2012). This research project intends to study the relative flux of Procyon in visible bands obtained from the images from the telescope at the B.P. Koirala National Observatory. This research also intends to analyze the symmetry of Procyon from the study of the image obtained.

2. MATERIALS AND METHODS

2.1 Observation

On April 18, 2017, Procyon was observed from B.P. Koirala National Observatory in Nagarkot, Nepal.

Fig. 3: B.P. Koirala National Observatory in Nagarkot, Nepal

This is the only location in Nepal till date, under the Government of Nepal facility, which has a telescope and can be used for astronomical observations. The government of Nepal has established B.P. Koirala Memorial Planetarium, Observatory, and Science Museum Development Board in Nepal in 1992 to conduct and facilitate research activities in Astronomy, Astrophysics, and Cosmology. The observation deck is located in a very peaceful environment at Nagarkot (Fig. 3) at a Latitude of 27°42'06" N and Longitude of 85°31'00''E (Parajuli *et al.* 2015).

Fig. 4: Meade 16 inch LX200GPS Schmidt-Cassegrain telescope

This Observatory constitutes a two-story building in which the 16-inch LX200GPS Schmidt-Cassegrain telescope (Fig. 4) has been installed.

The telescope has the values of relative flux density of 2,50,000 pixels. The telescope's reference frame was set up by tracking two prominent stars-Betelgeuse and Sirius (Fig. 2) through the tracking feature in the Autostar II. When Procyon was in the field of view, by replacing eyepiece with webcam, photographs in FITS (Fig. 5) and JPEG format (Fig. 1) were taken through the software Autostar suite 3.08. Multiple images of the star were captured. At 9:23 PM, the image (Fig. 5) was obtained, which we selected for our research.

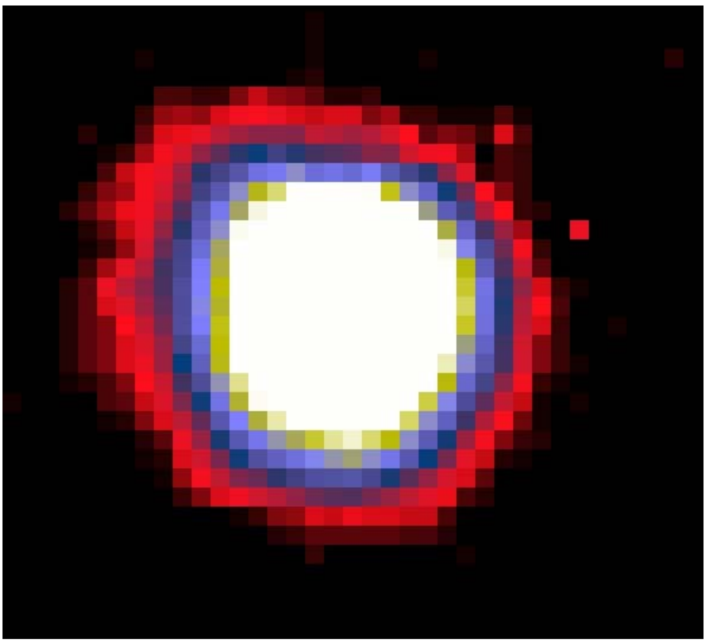

Fig. 5: FITS Format image of Procyon star obtained on April 18, 2017, from 16 inch Meade LX200GPS located at B.P. Koirala National Observatory, Nagarkot, Nepal.

2.2 Analytical Method

Procyon's photographic image in FITS format was processed in the data reduction software Aladin 9.0 to generate information about relative flux density. For the image obtained from 16 inch Meade LX200GPS telescope, four contour levels were constructed (Fig. 6), among which the contour level '142' in the relative unit was chosen as reference for the study of the asymmetrical feature since the area behind this contour towards the outside seems to be dispersing from circular symmetry. The other remaining contours in respective order from the outermost level to innermost levels are 142, 51, and 5 in the relative unit. These contours were drawn so that the regions with similar relative flux densities could be isolated. We identified the pixel of maximum flux density and bisected the image's major and minor axis along with it.

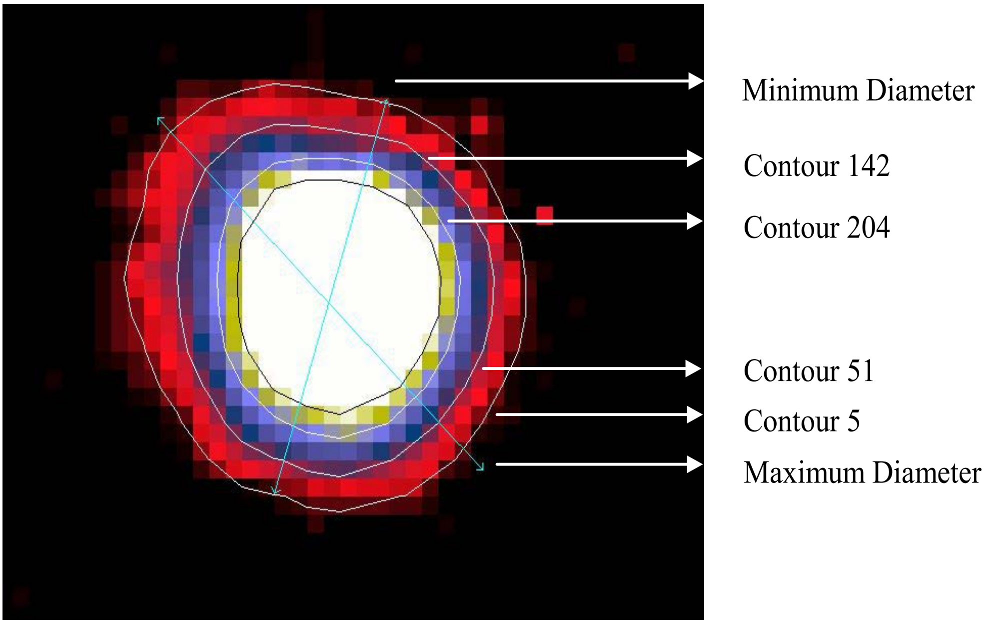

Fig. 6: Description of contours and Diameter lines for the image from B.P. Koirala National Observatory's Telescope

Relative flux densities along the maximum and minimum diameter were noted along with their respective distances from one of the diameter line extremities to create a CSV format file. These data were then fed into a custom-created program in Python software to obtain a fitted curve for maximum and minimum diameters for both the images.

The relative flux densities for all pixels in each bisected region were calculated and summed up to obtain the total relative flux densities for the regions so that the symmetry of the star could be analyzed.

3. RESULTS AND DISCUSSION

The study of relative flux densities showed variations in the total flux. The area on one half of the bisected region where the contour seems to disperse from the circular symmetry towards the north-east region contains more numbers of relatively brighter pixels and hence more flux. This derives inference that Procyon's atmosphere is undergoing evolution towards the north-eastern region, leading to an asymmetrical structure. The relative flux density plot versus the distance from one of the extremities of minimum or maximum diameter line shows a nearly perfect Gaussian fit in Equation 1.

$$y = \frac{A}{2\pi\omega} e^{\frac{-(x-\sigma)^2}{2\sigma^2}} \quad (1)$$

3.1 Maximum Diameter Lines as a Reference

For the telescope at B.P. Koirala National Observatory, the relative flux density and distance in the arcmin unit from the top (North-west) portion of the maximum diameter line are presented in Table 1. Table 1 is represented graphically by figure 7.

Table 1 Relative flux density versus the distance from top (North-west) portion along the maximum diameter line

Distance from an extremity	Relative Flux Density	Distance from an extremity	Relative Flux Density	Distance from an extremity	Relative Flux Density
1.2	1.25	10.13	132.2	18.61	155.8
1.49	3.25	10.37	145.2	19.49	123
2.39	4.75	11.76	178.8	20.15	108.8
3.61	6.75	11.93	197.2	21.07	70.5
4.43	11.25	13.21	229.8	22.2	30.75
4.9	14.25	13.96	248.5	23.1	20.75
5.56	25.25	14.44	255	23.66	13.75
7.07	42	14.82	232.5	24.52	7.75
8.11	74.5	16.01	215.2	25.46	3.25
8.65	79.5	17.07	197.8	26.07	2
9.17	99.75	17.99	184.5	27.39	0.5
-	-	-	-	27.68	0.25

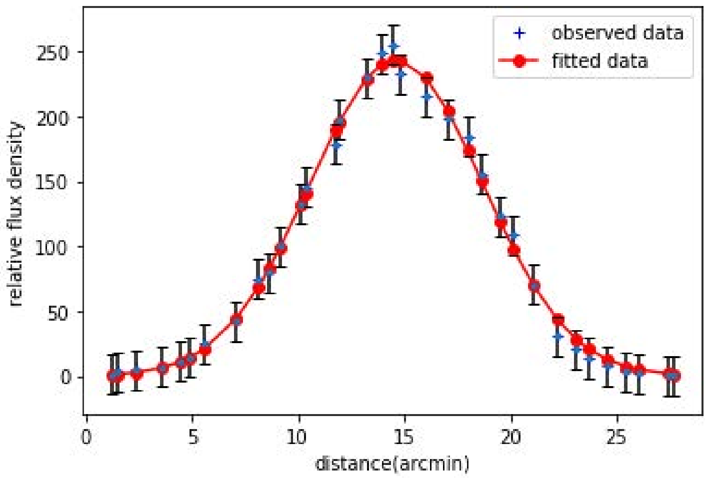

Fig. 7: Curve along the maximum diameter line

By analyzing the plot of Table 1, we found that the curve narrows at the peak (Fig. 7) with approximately equal exposure of the relative flux densities from the center, which includes the pixel with the highest relative flux density as shown by the curve with a standard error of 15.20 (Table 2). This refers to the idea that the top diameter line contains relatively less luminous flux, with the brightest at the near center. Thus, along this line, the bulging is not prominently observed, providing information about the near symmetry along the north-west and south-east region, which are the edges of the maximum diameter line.

The following parameters were obtained from the curve analysis for the telescope from B.P. Koirala National Observatory.

Table 2 Curve analysis for Gaussian fit of relative flux density along the maximum diameter line

Amplitude (A)	149.39 ± 3.23
Position of Peak (ω)	14.63 ± 0.05
Gaussian Width (σ)	4.08 ± 0.05
Standard Error along y	15.2

3.2 Maximum Diameter Lines as a Reference

For the telescope at B.P. Koirala National Observatory, the relative flux density and distance from the top (North-east) portion of the minimum diameter line are presented in Table 3. Here, we noticed that a single pixel of FITS formatted image in Aladin 9.0 for our image represented a single value of the flux density; we introduce the pixel count in this table from the extremity of the minimum diameter line.

Table 3 is represented graphically by figure 8.

Pixel Count	Relative Flux Density	Pixel Count	Relative Flux Density	Pixel Count	Relative Flux Density
1	1.75	10	228.2	19	109.2
2	4	11	228.8	20	83.5
3	14.5	12	229	21	34.75
4	25.5	13	255	22	14.25
5	48	14	255	23	8.75
6	72.25	15	248.5	24	3.5
7	110	16	236.5	25	0.75
8	150.8	17	214.2	26	0.25
9	189.2	18	163.8		

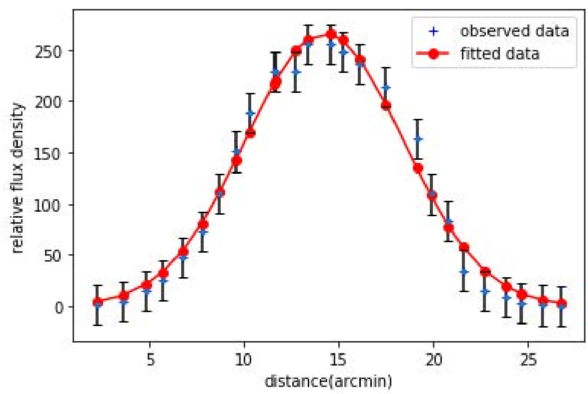

Fig. 8: Curve along the minimum diameter line

By analyzing the plot of Table 3, we found that the curve slightly widens at the peak (Fig. 8) in comparison with the maximum diameter line with approximately greater exposure of the relative flux densities towards the left of the curve from the center, which includes the pixel with highest relative flux density as shown by the curve with standard Error of 19.48 (Table 4). This refers to the idea that the minimum diameter line contains relatively more luminous flux near to the brightest at the near center starting from the north-east region. Thus, along this line, the bulging is prominently observed, providing information about the asymmetry along the north-east and south-west regions, which are the edges of the minimum diameter line.

Table 4 Curve analysis for Gaussian fit of relative flux density along the minimum diameter line

Amplitude (A)	158.89 ± 6.44
Position of Peak (ω)	14.24 ± 0.11
Gaussian Width (σ)	4.20 ± 0.10
Standard Error along y	19.48

3.3 Symmetrical Analysis

The sum of relative flux densities for each hemisphere divided by the minimum and maximum diameter for the telescope from B.P. Koirala National Observatory is obtained in Table 5.

Table 5 Total flux in the relative unit along with maximum and minimum diameter line for the hemispheres

Hemisphere along the maximum diameter line		**Hemisphere along the minimum diameter line**	
Top	14515.41	**Right**	13826.25
Bottom	10694	**Left**	11464.58

Since all the pixels obtained from the B.P. Koirala National Observatory's telescope are of the same size, the numerical figure and the plot from the data analysis through the maximum and minimum diameter lines imply that the north-east region area is relatively more extensive than south-west region. This information helps deduce the asymmetry of Procyon towards the north-east region, and hence the relative flux density values are most important to study the asymmetrical nature. The asymmetry can be seen in the outer region of the Procyon. Thus, the symmetrical analysis should be done significantly in the uppermost region of the Procyon, enveloping the pixels which address the bulging due to their more amount. The atmosphere of Procyon is extended in the north-eastern region with intermediate values in the other three regions. The variation of the plot in the diameter lines suggests much more variation of relative flux density in the north-east region than the south-west region concerning the distance from the core. In our study, the image seems to be present with a broader bulge according to the plot we took, referring to the maximum and minimum diameter and the relative flux density. Since Procyon was low on the horizon and the light pollution of Bhaktapur district affected the picture, the more atmospheric effect had been incurred in Procyon's picture. We report this change observed through 16 inch Meade telescope from B.P. Koirala National Observatory in Nepal.

4. CONCLUSION

From the plot obtained as seen in the results, we can conclude that the data for the relative flux density fits into the gaussian for maximum and minimum diameter lines for the image obtained from the telescope of B.P. Koirala National Observatory. It shows that the Procyon star system is isolated and has minimal effects from outside sources. The outer atmosphere of Procyon is observed to bulge towards the north-east direction suggesting the asymmetrical feature strongly. Monitoring Procyon using the same telescope to attain further concrete evidence regarding the asymmetry to substantiate further this research is highly encouraged. However, we have to consider that the peaks obtained from the images in gaussian fit could be different in sharpness due to the property of resolution of images obtained due to the telescope's nature. Similarly, this result can also be used to compare the image obtained from this telescope located in Nepal with the larger version of other Schmidt telescope images such as that obtained from Digitized Sky Surveys 1 and 2 (9), which may facilitate to enhance the upgrading of various telescope properties or components in this Observatory too.

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