A Study of the LPM 201 Double Star System

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Abstract

In this paper, we studied the LPM 201 double star system with WDS number 05023-1932 and discoverer code LP 776-61. The system was astrometrically measured to determine if it was optical double or gravitationally bound. The target was first queried off the Washington Double Star Catalogue, and then cross-referenced with Gaia Data Release 3 (DR3) to make sure it is targetable. The system is then imaged with the Prompt 5 telescope at Cerro Tololo Inter - American Observatory and measured using Afterglow. Calculations were performed to determine its likelihood of being gravitationally bound. Historical Right ascension and Declination data points of the system were also graphed to compare with calculated findings. It was determined that LPM 201 is physically related but not gravitationally bound due to its relative proper motions significantly exceeding its system escape velocity. Furthermore, there is an absence of an orbiting trend to the historical data, indicating a lack of gravitational relationship.

1. Introduction

Double stars describe a pair of stars in the sky that appear close together in its Right Ascension (RA) and Declination (Dec) value as viewed from Earth. However, not all double stars are physically close in space. Visual doubles are pairs of stars which appear close as viewed from earth but in reality are very far apart from each other (Fraknoi et al., 2016), while physical doubles are pairs of stars which both appear close together and are in physical proximity to each other. They travel together in space and have most likely emerged from a common point of origin at around the same time (Fraknoi et al., 2016). These physically related pairs of stars are then further subdivided into either being gravitationally bound (Binary stars) to each other or simply a common proper motion pair (Fraknoi et al., 2016).

The LPM 201 binary star system is located at Ra 05:02:20.19 and Dec -19:32:04.4. The system consists of two high proper motion (PM) stars, LP 776-61 (primary) and LP 776-62 (secondary). Both LP 776-61 and LP 776-62 are main sequence stars (Luyten, 1979), with LP 776-61 residing in the dwarf region of the H-R diagram (Cruzalèbes et al., 2019). This is reinforced by another study classifying the primary as a dwarf (Twarog and Anthony-Twarog, 1995) and further classified as a K4 spectral type (Bidelman, 1985). The high PM of this binary system makes it especially exciting as LPM 201's orbital movement, if it exists, will be more apparent when graphed against past data.

2. Target selection

Given a clear filter and an exposure duration between 3 and 60 seconds, the primary star must be fainter than 9th while the secondary star must be brighter than 18th. Also, the delta magnitude must be less than 5 so the primary star does not overpower the secondary star leading to unresolvable images. The separation between stars needs to be between 5 to 20 arcseconds, and this will be determined based upon past observational data because in general stars that are closer together will be orbiting faster. An optical telescope will be used to obtain the images, and photometric date. So, they should not be so close as to make it impossible to resolve and measure, nor too close to the sun to be obscured and physically observed with an optical telescope. The Washington Double Star Catalogue was used as a preliminary filter to find a list of physical double stars to select targets from for observation. Querying the Stelle Doppie Washington Double Stars Database using the above requirements, the binary system LPM 201 was selected.

3. Observation

The primary star, LP 776-61, is selected as the imaging target while LP 776-62 will be imaged along with the primary as shown in figure 1. Observation was made using the Prompt 5 telescope located at the Cerro Tololo Inter - American Observatory, Chile.

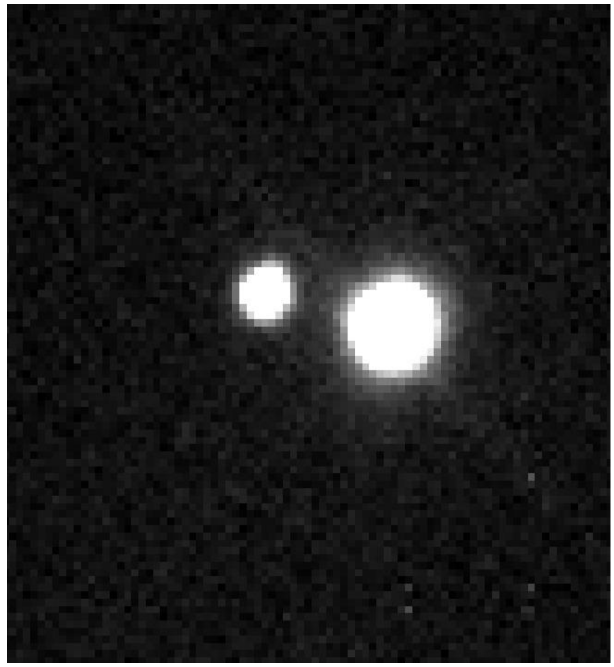

Figure 1: Stacked image of LP 776-61 (right) and LP 776-62 (left)

Table 1. Prompt 5 telescope specifications.

Telescope Properties	Measurement
Aperture	0.4 m
Focal length	4576.0 mm
F ratio	11.3
CCD Size	1024 x 1024 (13 um pixels)
Exposure duration per image	24.39 seconds

The Prompt 5 is a f/11.3 telescope with auto target tracking and an aperture of 0.4 metres which is acceptable for this study. To avoid burn-in while imaging the system, which would affect the telescope's ability to take accurate measurements, the telescope is also dithered with a 3x3 grid and 10 arcsecond spacing. The exposure duration is first determined to be 20 seconds for a generic 16 inch back illuminated CCD telescope, then converted to fit the specifications of the Prompt 5. The Cerro Tololo site is located on the Cerro Pachón mountain with an elevation of 2286 metres. At this altitude astronomical seeing is greatly reduced since there is simply less atmosphere in the way. As a designated observatory, light pollution is also reduced to a minimum, making it an ideal site for imaging this pair of double stars. The resulting images were then first calibrated and aligned using available WCS solutions. Finally, they were stacked in Afterglow, an astrophotography tool, to obtain a single image which was used in the analysis.

We were able to obtain an adequately resolved image of the LP 776-61 double star system as expected. Looking at figure 1, the two stars are nicely separated from each other, and the primary also did not overpower the secondary star. From this stacked image, accurate extraction of each star's physical details such as its Ra and Dec is possible using Afterglow.

4. Measurement and analysis

More detailed information about LP 776-61 and LP 776-62 was extracted from the stacked images using photometry tools in Afterglow. Additional information that was not part of our observation but critical to the analysis was obtained by referencing the Gaia database and is recorded below (Gaia Collaboration et al., 2022k).

Table 2. Summary of measurement.

System	Date	Number of images	Position angle (°)	Standard error position angle	Separation (")	Standard error separation
LPM 201	2023.1041	5	74.37	0.046	10.618	0.012

Table 3. Gaia data for LP 776-61 and LP 776-62.

Properties	LP 776 - 61 (Primary)	LP 776 - 62 (Secondary)
Magnitude	11.8	14.6
Parallax (mas)	17.90181	15.8243
Proper Motion Ra (mas/yr)	531.41681	531.78434
Proper Motion Dec (mas/yr)	-424.63062	-426.19923
Radial Velocity (km/s)	85.43	88.92
Colour (B - R)	1.35372	2.11329
Gmag	11.27676	14.01093

Table 4. Calculated values.

Properties	LP 776 - 61 (Primary)	LP 776 - 62 (Secondary)
Absolute Gmag	7.5412	10.0076
Estimated mass (solar masses)	0.6	0.3
Rounded distance (pc)	55.9380	63.1940
System escape velocity (m/s)	33	
Relative transverse motion (m/s)	427	
Relative radial motion (m/s)	3490	
Relative 3D velocity (m/s)	3516	
rPM	0.002	
rPM Classification	CPM	

From figure 1, it is clear that the system is indeed a visual binary, making it a double star. However, to determine whether the system is gravitationally bound, some calculations are needed. The pair is first assumed to be gravitationally bound and its system escape velocity is calculated using the equation

$$V_{esc} = \sqrt{\frac{2G\ (M_1 + M_2)}{r}}$$

where r is the 3D separation between the two stars, G is the Newtonian gravitational constant and $(M_1 + M_2)$ is the mass of the two stars.
The 3D separation is given by

$$R_{transverse} \approx \frac{sep}{p_1} \cdot \frac{1^\circ}{3600''} \cdot \frac{2\pi}{360^\circ}$$

$$r = \sqrt{\left|\frac{1}{p_1} - \frac{1}{p_2}\right|^2 + R^2{}_{transverse}}$$

with p being the parallax.
The relative proper motion (rPM) of the two stars is another indicator that can be used to determine if the two stars are gravitationally bound. It is defined to be the magnitude of the delta PM between the stars divided by the magnitude of the PM of the primary or secondary star, whichever is larger (Harshaw, 2016).

$$rPM = \frac{||PM||}{\sqrt{PM^2{}_{Ra} + PM^2{}_{Dec}}}$$

The rPM classification is represented by the piecewise function

$$rPM\ Classification$$

$$= \begin{cases} rPM < 0.2 & CPM; stars\ are\ moving\ through\ space\ in\ a\ similar\ way \\ 0.2 \le rPM < 0.6 & SPM; stars\ are\ moving\ through\ space\ in\ a\ similar\ way \\ 0.6 \le rPM & DPM; stars\ are\ moving\ through\ space\ in\ a\ similar\ way \end{cases}$$

From the above calculations, the relative motion of the stars indicates that they are not gravitationally bound as they greatly exceeded the system escape velocity. This makes the LPM 201 a visual binary system.

5. Plot

To further confirm that the calculated results were not due to observational or instrumental errors and that the LPM 201 system is indeed not gravitationally bound, historical observations of LPM 201 are plotted in figure 2. Historical data points provided by the Washington Double Star Catalogue are labelled blue and the new observation in red. Data points are first converted from polar into cartesian coordinates and then plotted. The primary star lies at the origin of the graph, while the data points indicate the movement of the secondary star with respect to the primary. From figure 2, there are three groups of data points, with two singular points residing on either side of the graph and a main cluster of points in the middle. Immediately to the right side of the graph is a point taken on 2000 with a RA of roughly 10.7 mas and Dec of -2.55 mas. We can say with confidence that this point is an outlier in the data set by simply comparing it to other historical data. The two closest points taken in 1999.827 and 2000.7748 all reside in

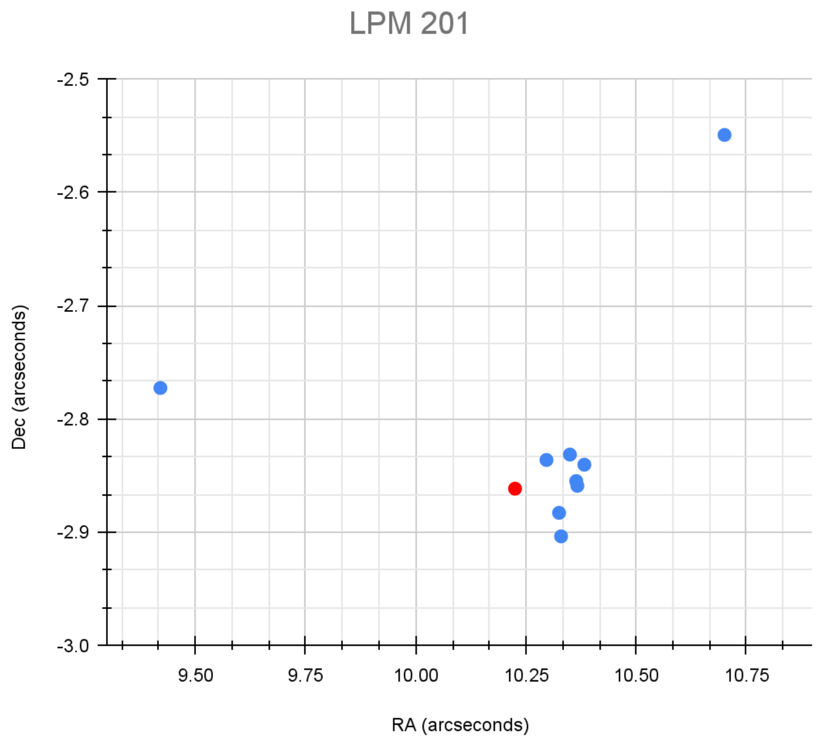

Figure 2: Historical data alongside new observations

the main grouping in the middle. Considering that the star has a high PM it is very unlikely that the difference is as great as the data indicates. Therefore, it is probable that the point taken on 2000 is an outlier in our data set. On the left of the graph is the very first recorded data point of the 2 stars taken in 1939.85. The star has a RA of roughly 9.42 mas and Dec of -2.77 mas. However, the next closest observation was taken 59 years later on 1998.2661 with a RA of roughly 10.33 mas and Dec of -2.88 mas. This large time span makes it unclear if this data set is an outlier or if the star actually travelled that far in that time period. Considering that LP 776-62 is a high PM star, this is a possibility. Another consideration is that the newest point, taken in 2023.1041 resides in the same grouping as the point recorded in 1998.2661. In the 25 years, which is almost half of the 59 year gap, LP 776-62 has not made much progress compared to the measurement taken in 1939.85. Thus, it is difficult to conclude whether the point taken in 1939.85 should be considered as an outlier. The main group itself also does not seem to suggest any visible trends to the PM of the system. Ignoring the two possible outliers, the plot suggests that the two stars are not orbiting around each other as otherwise there should be an orbital trend in the graph. We were also unsuccessful in obtaining a solved orbit for the system which seems to align with the conclusion that LPM 201 is not gravitationally bound.

6. Conclusion

From our computations as discussed in sections 4 and 5, we conclude that the LPM 201 double-star system is a visual binary. First computing the system escape velocity as discussed in section 4 and comparing it to the system's relative transverse motion, relative radial motion and relative 3D velocity, they exceeded the escape velocity by factors of approximately 13, 106 and 107 respectively. Furthermore, by examining the historical data values and comparing them to our observation there does not appear to be a trend that would indicate the two stars are orbiting around each other. Therefore, the LPM 201 double star system is concluded to be a visual binary that could have possibly formed from the same gas cloud. In this study we did not take into account extinction during calculation, and this may have affected our calculations to some extent. At a distance of 56 pc, the extinction would have had a non-trivial impact on the result. However, since the calculation would be consistently skewed by the amount described by the extinction value, it will not affect the conclusion in any significant way.

7. Acknowledgements

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This work makes use of observations taken by the 0.4 metre Prompt 5 telescope of the Skynet Robotic Telescope Network located in Cerro Tololo Inter - American Observatory.

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