JASS Journal of Astronomy and Space Sciences

Observation of Three Variable Stars and an Asteroid Using Small Telescopes in the United Arab Emirates (UAE)

Mohammad Sh. Odeh[1,2†], Mashhoor Al-Wardat[1,3,4]

[1]Department of Applied Physics and Astronomy, University of Sharjah, Sharjah 27272, United Arab Emirates
[2]International Astronomical Center, Abu Dhabi 45015, United Arab Emirates
[3]Sharjah Academy for Astronomy, Space Sciences and Technology, University of Sharjah, Sharjah 27272, United Arab Emirates
[4]Department of Physics, Al al-Bayt University, Mafraq 130040, Jordan

We present the results of using small telescopes in the United Arab Emirates (UAE) for observing variable stars and asteroids. Two telescopes, namely, 5" apochromatic refractor and 14" Schmidt-Cassegrain, at Al-Khatim Observatory (M44) were used for the observations. The targets were the three variable stars RR GEM, AG LMi, and DL CMi and the asteroid 22 Kalliope. We found a good consistency between our light curves and published ones for the calibration targets, i.e., the asteroid 22 Kalliope and the variable star RR GEM. According to previous studies, AG LMi has two suggested periods, 16.3 hours and 32.62 hours. Our results clearly confirm the second one, with a period of 32.6175 hours. The star DL CMi has several suggested periods as per previous studies, such as 4.0173 days, 1.9606 days, and 2.0086 days. Our observations confirm the first one, with a period of 4.0159 days. These results demonstrate the effectiveness of using small telescopes for observing variable stars and asteroids. This work provides some recommendations on using small telescopes for such observations.

Keywords: variable stars, photometry, small telescopes in United Arab Emirates (UAE), AG LMi, DL CMi, Kalliope, Al-Khatim observatory

1. INTRODUCTION

To involve Al Kahtim observatory [International Astronomical Union (IAU) Minor Planet Center (MPC) code M44] in scientific work, we used its small telescopes to observe some variable stars and an asteroid. The observations were focused on covering the full period of the light curve for each target. The targets were the three variable stars RR GEM, AG LMi and DL CMi and the asteroid 22 Kalliope.

The asteroid 22 Kalliope and the variable star RR GEM were selected because they have well-established light curves. Hence, they were used to ensure that the equipment and the reduction method were accurate and yielded reliable results. On the contrary, the variable stars AG LMi and DL CMi were selected owing to disagreements between the catalogs regarding their parameters, which are discussed in this work. For example, the star AG LMi has a period of 32.6164224 hours in one of the catalogs (Watson et al. 2006) and a period of 16.308168 hours in another catalogue (Samus' et al. 2017). As for the star DL CMi, the period is 4.017282 days in one of the catalogs (Watson et al. 2006) and 1.960598 days in another catalogue (Watson et al. 2006).

2. METHODS

The following equipment was used to perform the photometry work.

2.1 Telescope

Two telescopes were used to conduct the work. Observations made from January 06 to February 08, 2022, were performed

using the following telescope:
- Explore Scientific 5" carbon fiber Triplet ED apochromatic refractor telescope
- Diameter: 12.7 cm
- Focal length: 952 mm
- Focal ratio: f/7.5

Observations made from February 18 to March 22, 2022, were made using a new telescope, as shown in Fig. 1, with the following specifications:
- Celestron 14" Aplanatic Schmidt–Cassegrain
- Diameter: 36 cm
- Focal length: 2,737 mm
- Focal ratio: f/7.7

2.2 Camera

QHY163C cooled color camera with the following specifications was used:
- Sensor: 4/3 inch CMOS
- Resolution: 16 Megapixels 4,656 × 3,522
- Pixel size: 3.8 μm
- Sensor size: 17.7 × 13.4 mm
- Temperature during the observations: –20°C

Fig. 1. The new equipment used to perform the photometry.

2.3 Software

After calibrating the images against the dark, flat, and bias frames and extracting the green channel, the software Tycho Tracker (Parrott 2020) was used to perform the photometry analysis. The software is quite powerful but easy to use, especially for selecting comparison stars and computing the variability period.

For all observed objects, some trials for the exposure time were conducted initially to ensure that the target is not saturated or in the nonlinearity zone. In addition, the comparison stars have magnitude and B–V values close to the target, and no variable star was selected as a comparison star.

The magnitude values of the comparison stars were obtained from the ATLAS catalogue, and the expressed magnitudes in the following graphs were M_v unless mentioned otherwise.

For AG LMi and DL CMi stars, to obtain accurate photometry measurements, the green channel was extracted to match an observation made with a mono camera using a V filter. As we used a color camera, the pixels of the sensor had three color filters, namely, red, green, and blue. The repeated pattern of these cameras comprised two green, one red, and one blue filters. Hence, to obtain standard results close to the green photometric filter, we used an image processing software to extract the results of the two green filters (channels) and combined them, which enabled us to obtain standard results as well as better signal-to-noise ratio (SNR) for our images.

2.4 Al-Khatim Observatory

The observatory was built by the International Astronomical Center (IAC) in the desert, approximately 60 km to the east of the United Arab Emirates (UAE) capital Abu-Dhabi, in an area called Al-Khatim. It is a robotic observatory, where the target objects are programed in advance. The roof opens automatically at the specified time, and after the observations are completed, it closes automatically too. The observatory is equipped with a weather station to close the roof in case of clouds or emergency.

The observatory was registered at the MPC of the IAU in February 2021 and was assigned the code M44. The objective of the observatory is to perform astrometry and photometry works, especially for asteroids and variable stars. Moreover, the observatory is involved in following the gamma-ray bursts and Kilonova events with an international team.

The observatory contains three telescopes: the main telescope, for three nights. Solar telescope, and a small telescope dedicated to lunar crescent observations. The

seeing conditions at the observatory location are generally good; the average value is approximately 1.3″, and the full width at half maximum of the stars is usually < 3″.

3. PARAMETERS OF THE OBSERVED ASTEROID AND VARIABLE STARS

3.1 Asteroid 22 Kalliope

It is a large main-belt M-type asteroid, which has the following parameters (Johnston 2022):
- Adopted phase slope parameter: G = 0.21
- Adopted absolute magnitude: H = 6.51
- Rotational amplitude: maximum = 0.53
- Period: 4.1482003 hours

3.2 RR GEM Variable Star

RR GEM variable star has the following parameters (Watson et al. 2006):
- Variability type: RR Lyrae (RRAB)
- Magnitude range: 10.62–11.99 V
- Amplitude: 1.37 magnitude
- Period: 9.53545 hours

3.3 AG LMi Variable Star

It is an eclipsing binary (Algol-Type; EA) star. There is no agreement on the amplitude and period of this variable star, and the following are some examples:

The International Variable Star Index (VSX) (Watson et al. 2006):
- Period: 32.6164224 hours
- Amplitude: 0.61

The ASAS-SN all-sky catalog of bright variable stars (Jayasinghe et al. 2020):
- Period: N/A
- Amplitude: 0.41

General catalogue of variable stars, version GCVS 5.1 (Samus' et al. 2017):
- Period: 16.308168 hours
- Amplitude: N/A

3.4 DL CMi Variable Star

It is an eclipsing binary star of type EA. There is no

agreement on the amplitude and period of this variable star, and the following are some examples:

The VSX (Watson et al. 2006):
- Period: 4.017282 days
- Amplitude: 0.59

General catalogue of variable stars, version GCVS 5.1 (Samus' et al. 2017):
- Period: 4.01732 days
- Amplitude: N/A

Catalogue of eclipsing variables, version 2 (Avvakumova et al. 2013):
- Period: 4.0173201561 days
- Amplitude: 0.59

The ASAS-SN all-sky catalog of bright variable stars (Jayasinghe et al. 2020):
- Period: 4.0174708 days
- Amplitude: 0.40

The first catalog of variable stars measured with ATLAS (Heinze et al. 2018):
- Period: 1.960598 days
- Amplitude: 0.375795

4. RESULTS AND DISCUSSION OF OBSERVATIONS

4.1 Asteroid 22 Kalliope

The asteroid was observed on three nights. Table 1 shows the number of images and the total observation time for each night. The exposure time was 15 seconds for each image. As the asteroid is a moving object, the comparison of stars varied from one day to another; however, the magnitudes of the comparison were always close to their magnitude.

After analyzing the images with Tycho Tracker, the phased light curve corrected for the light time was obtained, as shown in Fig. 2. Light time correction is needed when observing asteroids because the distance between the earth and the asteroid keeps changing.

Table 1. Observation details for the asteroid 22 Kalliope

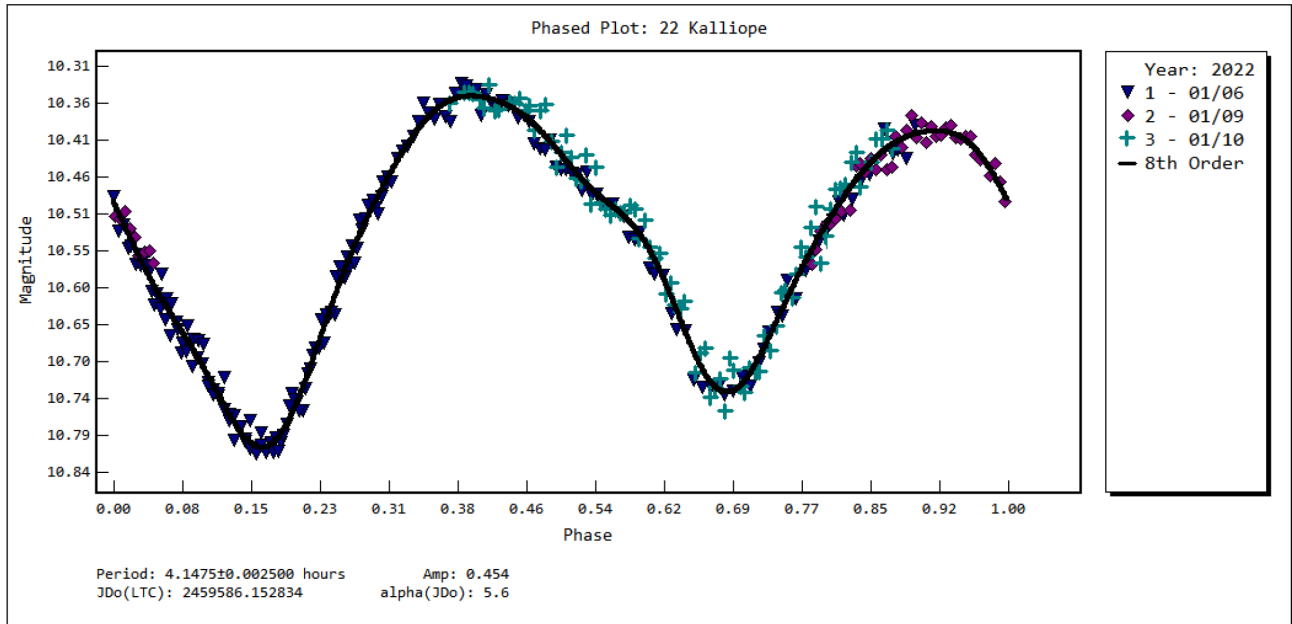| Date (local)	# of images	Total time
06 Jan. 2022	187	5.4 h
09 Jan. 2022	48	1.1 h
10 Jan. 2022	88	2.1 h

21

Fig. 2. Asteroid 22 Kalliope light curve.

We found that the period was 4.1475 hours and the amplitude was 0.454, which are both in agreement with the published data.

4.2 RR GEM Variable Star

The star was observed for six nights. Table 2 shows the number of images and the total observation time for each night.

The comparison stars that were used to determine the magnitude of the RR GEM variable star are listed in Table 3.

Table 2. Observation details for RR GEM

Date (local)	# of images	Total time
12 Jan. 2022	115	7.854 h
13 Jan. 2022	111	7.042 h
14 Jan. 2022	75	4.980 h
19 Jan. 2022	32	2.446 h
23 Jan. 2022	18	1.222 h
24 Jan. 2022	57	4.258 h

Table 3. The comparison stars used for RR GEM

R.A. (Deg.)	Dec. (Deg.)	Magnitude	B–V
110.525940	30.852305	10.725723	0.565000
110.620316	30.867854	10.729772	0.942000
110.310737	30.780406	10.713054	1.107000
110.213745	30.870511	10.846595	0.976000
110.352989	31.103558	10.826227	1.087000
110.355455	30.658417	11.185281	0.913000

After analyzing the images with Tycho Tracker, the phased light curve depicted in Fig. 3 was obtained.

We found that the period was 9.54 hours and the amplitude was 1.253, which are both in agreement with the published data.

4.3 AG LMi Variable Star

The star was observed for 16 nights. Table 4 shows the number of images and the total observation time for each night.

The comparison stars used to determine the magnitude of the AG LMi variable star are listed in Table 5.

After analyzing the images with the Tycho Tracker software, the best period obtained was 16.3188 hours, as shown in Fig. 4. This period had the lowest root mean square error (RMSE) value in the periodogram, as shown in Fig. 5.

This variability value agreed with that mentioned in the general catalogue for variable stars, as mentioned earlier. However, the light curve indicated the total disappearance of the secondary eclipse, which is possible if the secondary star is much fainter than the primary star.

Forcing the software to draw the light curve for the next period with the lowest RMSE value, we obtained a new light curve, as shown in Fig. 6, with a period of 32.6175 hours. Now, the primary and secondary eclipses were visible but identical, which can be explained only if the two stars are similar. Hence, we need more information on this binary to
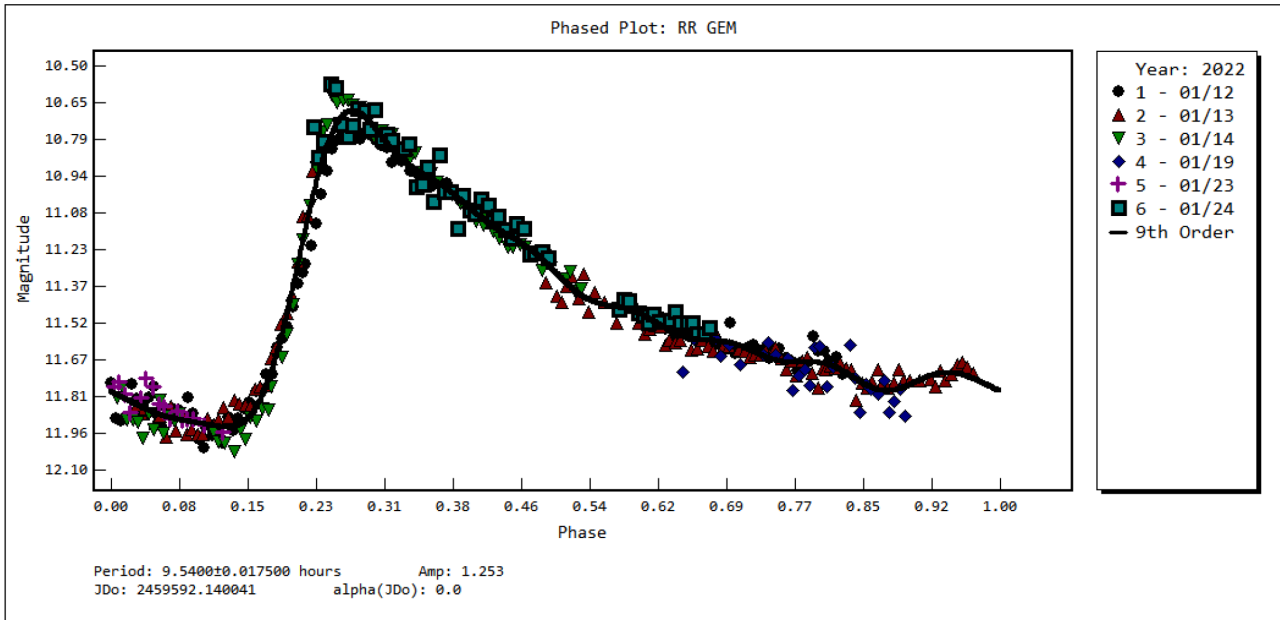
Fig. 3. RR GEM light curve.

Table 4. Observation details for AG LMi

Date (local)	# of images	Total time
31 Jan. 2022	61	4.881 h
01 Feb. 2022	21	1.484 h
02 Feb. 2022	45	3.491 h
03 Feb. 2022	75	5.714 h
04 Feb. 2022	78	5.634 h
08 Feb. 2022	53	4.041 h
18 Feb. 2022	21	1.288 h
19 Feb. 2022	50	3.684 h
20 Feb. 2022	22	2.027 h
21 Feb. 2022	21	1.505 h
22 Feb. 2022	20	1.273 h
24 Feb. 2022	79	6.628 h
25 Feb. 2022	25	1.666 h
01 Mar. 2022	21	48.750 min
03 Mar. 2022	46	3.613 h
08 Mar. 2022	27	1.296 h

Table 5. The comparison stars used for AG LMi

R.A. (Deg.)	Dec. (Deg.)	Magnitude	B–V
161.197345	33.318203	10.533301	0.849000
161.255536	33.496855	11.596925	0.986000
161.099427	33.173242	12.175591	0.988000
161.213201	33.388274	12.794548	0.591000
161.158367	33.348145	12.753027	0.659000
161.334452	33.472415	13.052693	0.661000

decide which of the two curves is correct.

This binary was studied by Mousavi-Sadr & Ebadi (2021), and we quote the following from their abstract:

"*The combined photometric and spectroscopic solutions indicate that the system is a detached eclipsing binary system that consists of two similar components with a mass ratio of q~0.983. The spectral type of each component was estimated as F8, and the effective temperatures of components were calculated as T1 = 6,240 ± 19K and T2 = 6,220 ± 21K for the primary and secondary stars, respectively.*"

As we now know that this binary system comprises two similar stars, we can exclude the first light curve and consider the second one with a period of 32.6175 hours and an amplitude of 0.57, which is in agreement with the published data in the VSX.

4.4 DL CMi Variable Star

This star was observed for 18 nights. Table 6 shows the number of images and the total observation time for each night.

The comparison stars used to determine the magnitude of the DL CMi variable star are listed in Table 7.

We analyzed the observations using the Tycho Tracker software. The period published by ATLAS (Heinze et al. 2018) in the first catalog of variable stars is 1.960598 days, which is plotted in Fig. 7 against our observations. The figure shows that this period cannot be accurate as the minima are continuously shifted.

Fig. 8 shows the period predicted by the other above-mentioned catalogs, i.e., 4.0 days. The analysis indicated
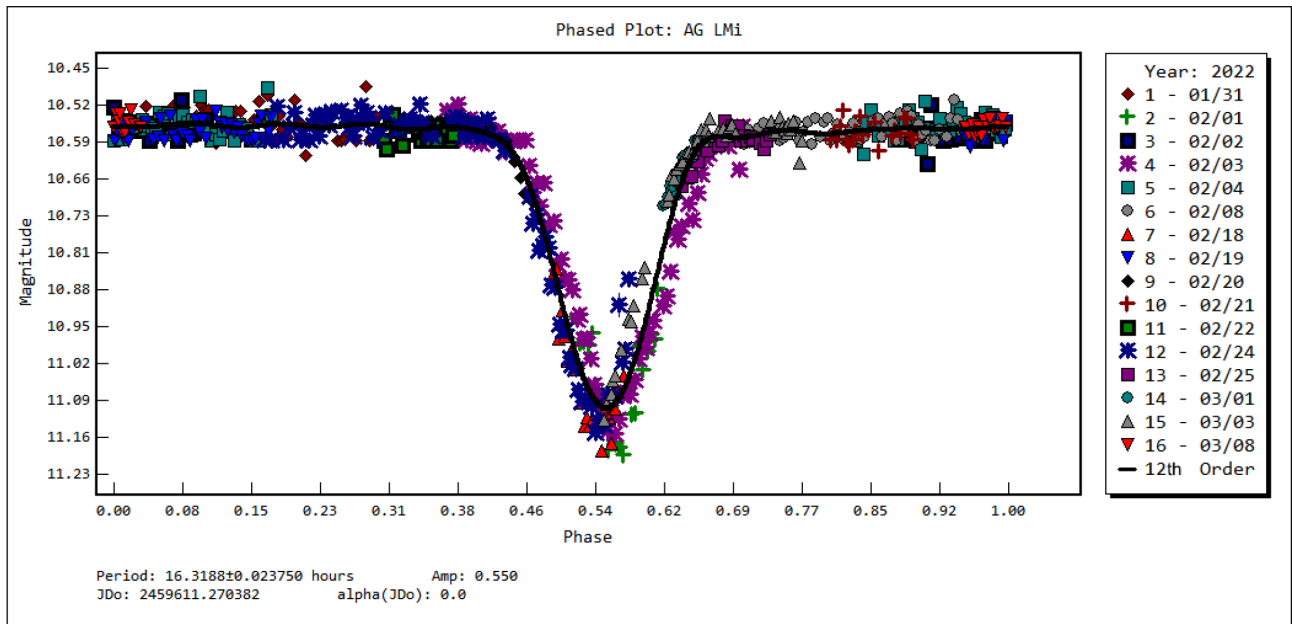
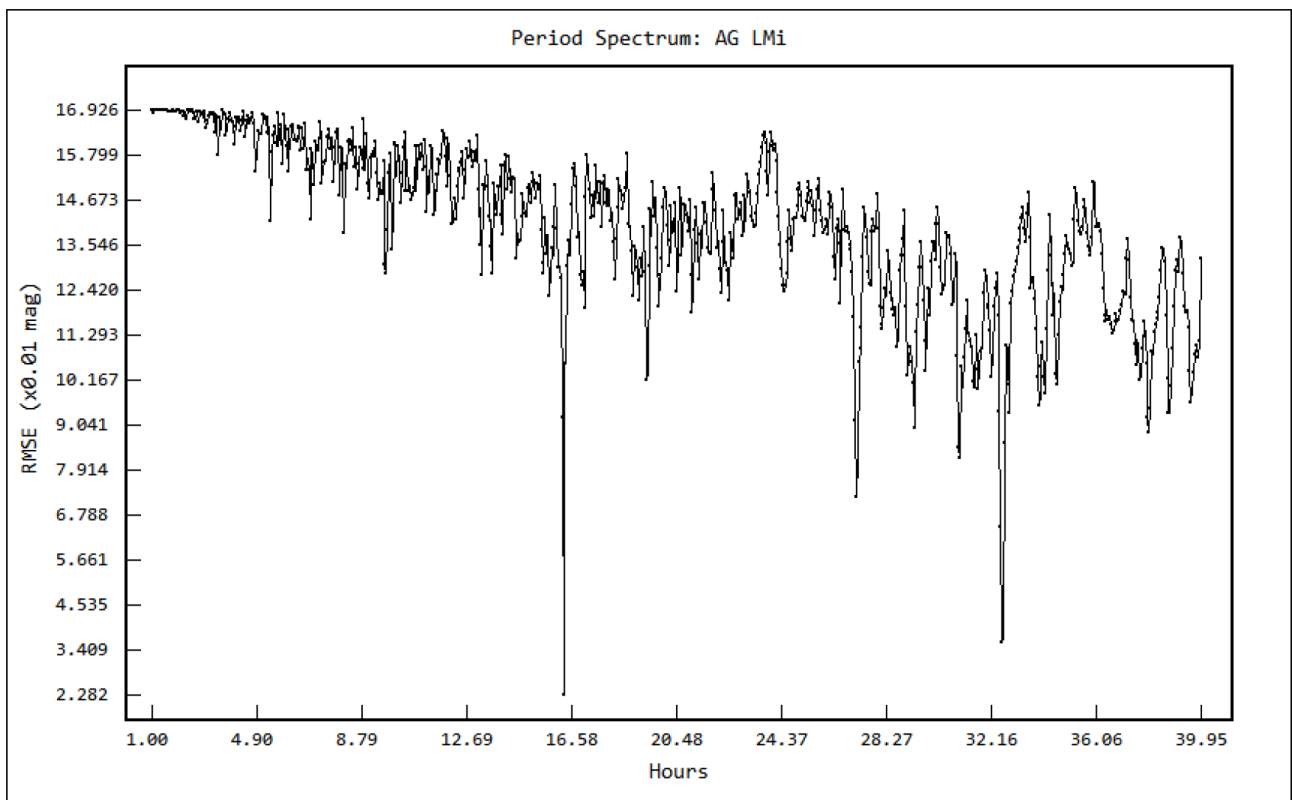**Fig. 4.** AG LMi light curve with a period of 16.3 hours.

Fig. 5. The period spectrum of the star AG LMi.

that the exact period is 4.0159 days with an amplitude of 0.6 mag, which is quite close to the period of 4.017 days specified in the mentioned catalogs.

Some studies have observed that the period of this star could be half of it, i.e., 2.008 days (Otero & Wils, 2005). As a test, Fig. 9 shows the light curve constructed assuming
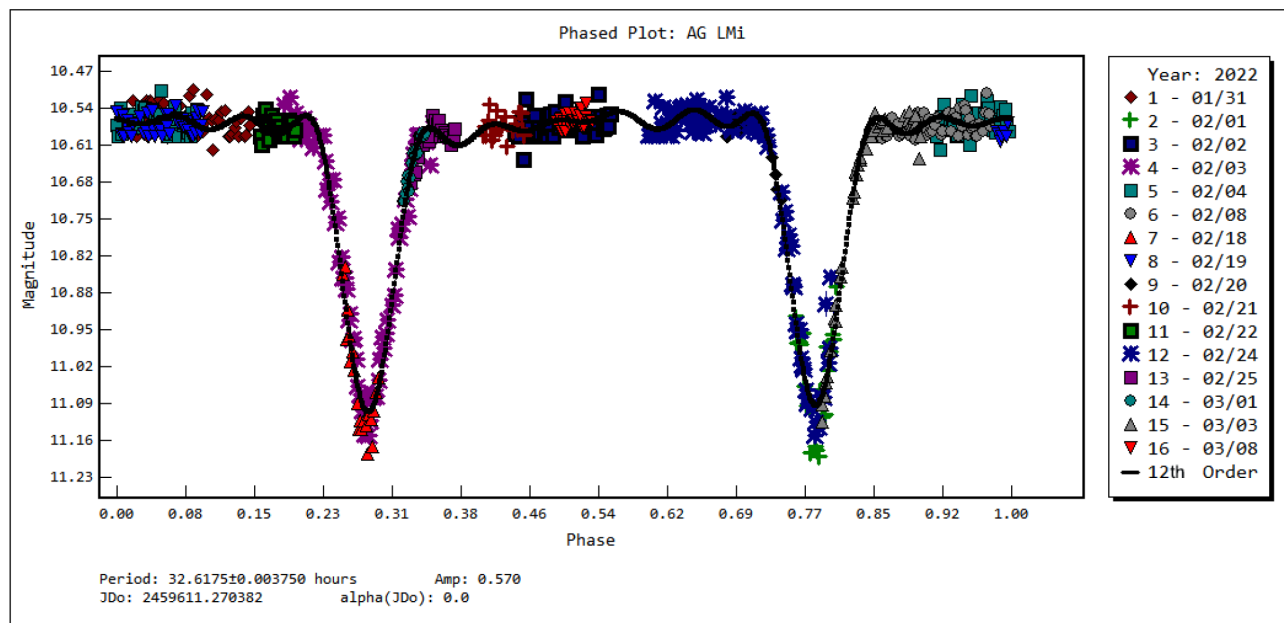
Fig. 6. AG LMi light curve with a period of 32.6 hours.

Table 6. Observation details for DL CMi

Date (local)	# of images	Total time
26 Jan. 2022	19	2.837 h
27 Jan. 2022	41	7.146 h
28 Jan. 2022	17	3.775 h
29 Jan. 2022	59	7.603 h
30 Jan. 2022	11	2.810 h
31 Jan. 2022	25	2.859 h
01 Feb. 2022	23	2.966 h
05 Feb. 2022	35	3.769 h
08 Feb. 2022	11	1.191 h
19 Feb. 2022	11	1.292 h
20 Feb. 2022	4	10.450 min.
21 Feb. 2022	6	17.183 min.
22 Feb. 2022	10	1.207 h
15 Mar. 2022	60	4.647 h
16 Mar. 2022	50	3.569 h
19 Mar. 2022	92	4.758 h
21 Mar. 2022	73	3.336 h
22 Mar. 2022	58	2.917 h

Table 7. Comparison stars used for DL CMi

R.A. (Deg.)	Dec. (Deg.)	Magnitude	B–V
116.243273	7.348734	12.271089	0.460000
116.160013	7.251670	11.961625	0.879000
116.086962	7.263701	11.743088	0.997000
116.158336	7.167091	12.177550	0.585000
116.049965	7.133821	12.413568	0.528000
115.957671	7.285905	12.445896	0.545000

this period, from which the total absence of the secondary eclipse is evident. Hence, we believe that the period of 4 days is correct.

As the two minima in Fig. 8 are quite close to each other, we conclude that the two stars are twin or very similar stars. Thus, a spectroscopic observation of the star is highly recommended to confirm this conclusion.

5. CONCLUSION

With accurate observation and data reduction, reliable results can be achieved using a small telescope, thereby enabling participation in scientific work.

Although a color camera is generally not preferred in astronomy work, it can be used in the photometry of bright objects with some advantages, such as extracting the two green channels and combining them to obtain a better image with less SNR. In addition, red and blue channels can be extracted to obtain simultaneous multiband observation for a certain target, which offers more data in a shorter time.

The parameters of variable stars in some catalogs are not definite and may need extra work to confirm them.

According to previous studies, AG LMi has two suggested periods, i.e., 16.3 hours and 32.62 hours. Our results clearly confirm the second one, with an exact period of 32.6175 hours.

The star DL CMi has several suggested periods as per previous studies, such as 4.0173 days, 1.9606 days, and 2.0086 days. Our observations confirm the first one, with an exact period of 4.0159 days.
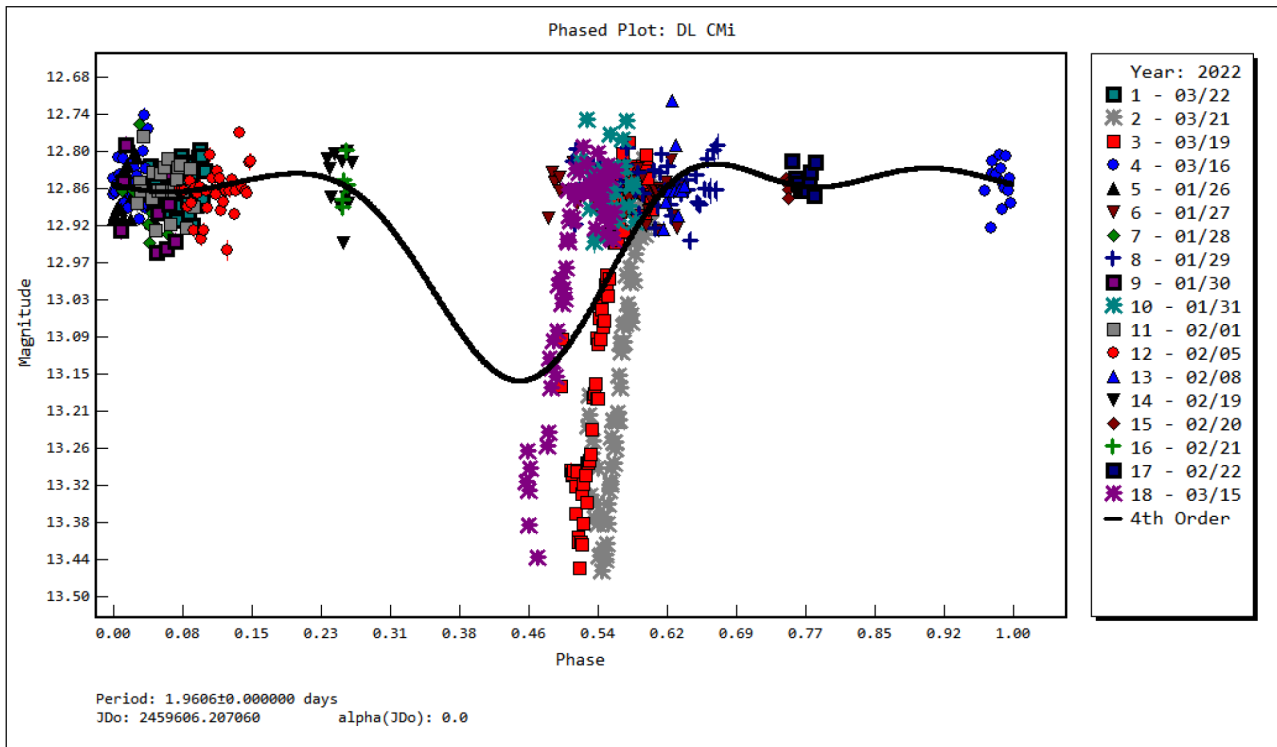
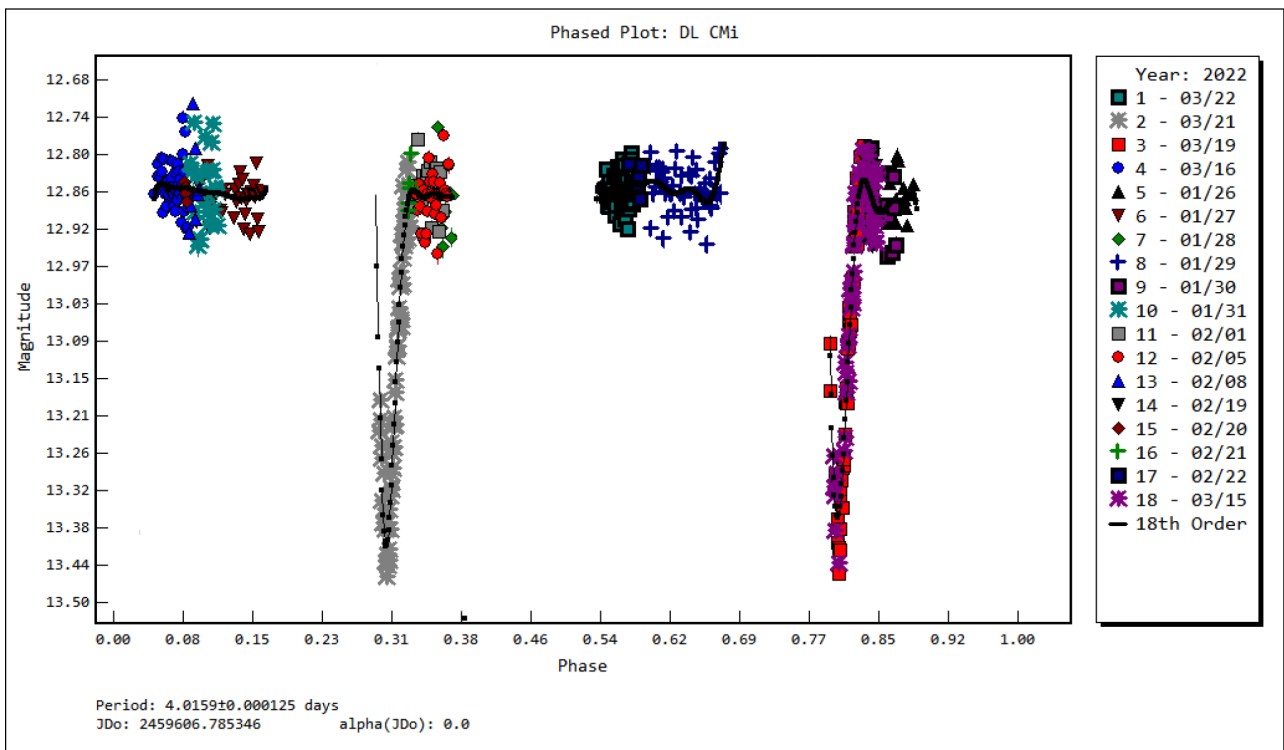**Fig. 7.** DL CMi light curve assuming a period of 1.960598 days.

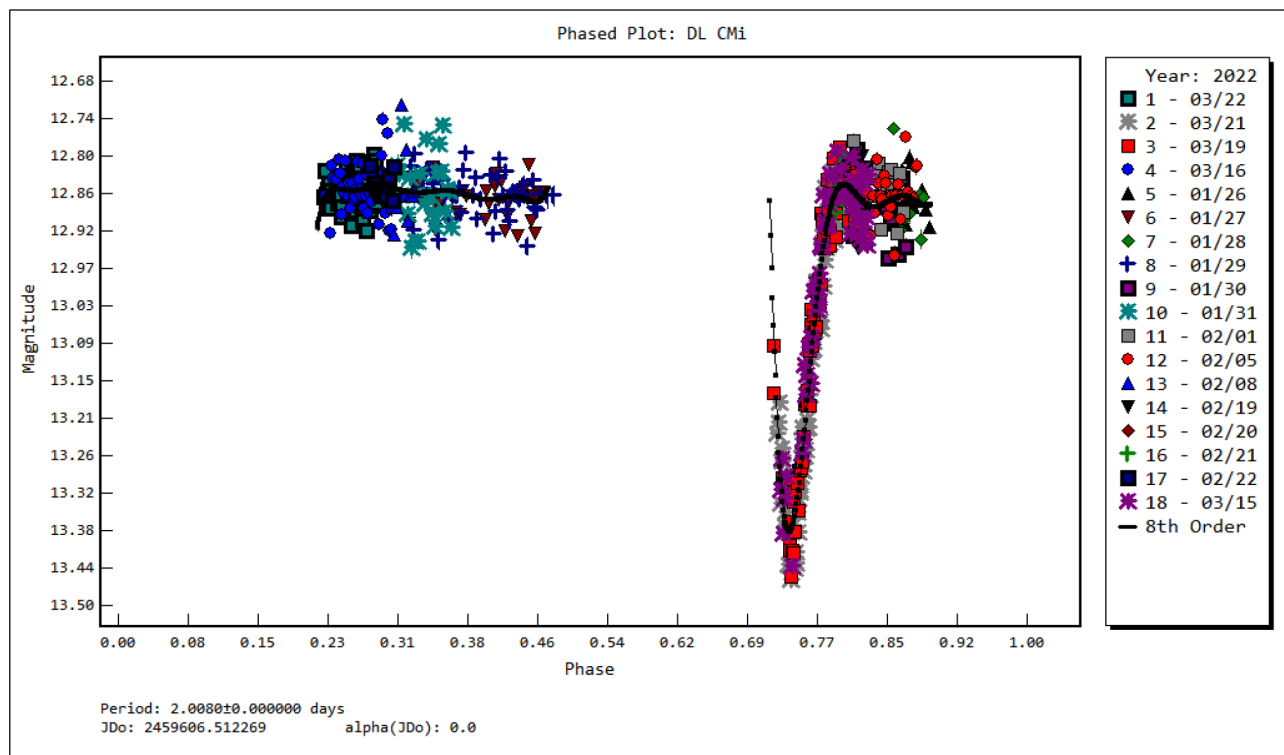**Fig. 8.** DL CMi light curve for a period 4.0159 days.

26

Fig. 9. DL CMi light curve with period of 2.008 days.

ORCIDs

Mohammad Sh. Odeh
https://orcid.org/0000-0002-8986-6681
Mashhoor Al-Wardat
https://orcid.org/0000-0002-1422-211X

REFERENCES

Avvakumova EA, Malkov OY, Kniazev AY, Eclipsing variables: catalogue and classification, Astron. Nachr. 334, 860-865 (2013). https://doi.org/10.1002/asna.201311942

Heinze AN, Tonry JL, Denneau L, Flewelling H, Stalder B, et al., A first catalog of variable stars measured by the asteroid terrestrial-impact last alert system (ATLAS), Astron. J. 156, 241 (2018). https://doi.org/10.3847/1538-3881/aae47f

Jayasinghe T, Stanek KZ, Kochanek CS, The ASAS-SN all-sky catalog of bright variable stars, Am. Astron. Soc. Meet. Abstr. 52 (2020).

Johnston WR, Asteroids with satellites database (2022) [Internet], viewed 2022 Dec 15, available from: http://www.johnstonsarchive.net/astro/astmoons/am-00022.html

Mousavi-Sadr M, Ebadi H, BVR photometric study and absolute parameters of the eclipsing binary AG LMi, New Astron. 89, 101625 (2021). https://doi.org/10.1016/j.newast.2021.101625

Otero SA, Wils P, New elements for 80 eclipsing binaries VII, Inf. Bull. Var. Stars. 5644, 1 (2005).

Parrott D, Tycho tracker: a new tool to facilitate the discovery and recovery of asteroids using synthetic tracking and modern GPU hardware, J. Am. Assoc. Var. Star Obs. 48, 262 (2020).

Samus' NN, Kazarovets EV, Durlevich OV, Kireeva NN, Pastukhova EN, General catalogue of variable stars: version GCVS 5.1, Astron. Rep. 61, 80-88 (2017). https://doi.org/10.1134/S1063772917010085

Watson CL, Henden AA, Price A, The international variable star index (VSX), in the Society for Astronomical Sciences 25th Annual Symposium on Telescope Science, Big Bear Lake, CA, 23-25 May 2006.