

## Carbon star CGCS 673 identified as a semi-regular variable star

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**Abstract** This study reports that the carbon star CGCS 673 is a semi-regular (SR) variable star with a period of 135 d and an amplitude of 0.18 mag in the *V*-band. The light curve obtained by this study correlates well with the SR classification as the photometric data obtained show noticeable periodicity in the light changes of CGCS 673 that is occasionally interrupted by a period of irregular variability. The derived period and colour index obtained from our data and those from professional databases indicate that the attributes of this star fall within the parameters of the SR class of variable stars. Following our notification of the discovery that this star is a variable source, CGCS 673 has received the AAVSO Unique Identifier of (AAVSO UID) 000-BMZ-492.

**Key words:** techniques: photometric — stars: variables: semi-regular variable — stars: individual: CGCS 673

### 1 INTRODUCTION

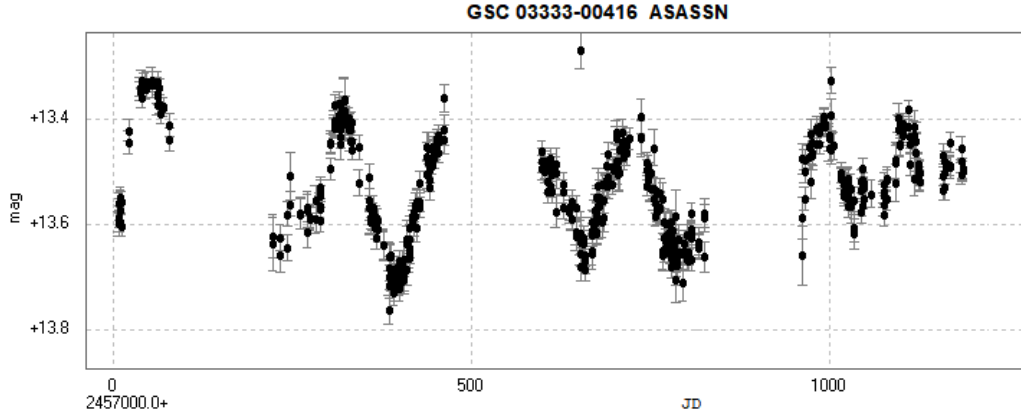
Carbon stars share some of the characteristics of giant stars. Both reside at a late phase of stellar evolution. What makes a carbon star different from their more common counterparts is the fact that the carbon to oxygen ratio in their atmosphere is much higher, hence the appropriate name. Carbon stars reside within the Asymptotic Giant Branch (AGB) of the Hertzsprung-Russell (H-R) diagram and their placement indicates that these old stars are in a phase that precedes the ejection of their atmospheres to form a planetary nebula. This phase of their lives has long been of interest to astronomers. [Alksnis et al. \(2001\)](#) compiled a catalogue of Galactic Carbon Stars (CGCS) that contains 6891 candidates. [Nesci et al. \(2018\)](#) report that out of the CGCS population, 851 were classified as variable stars within the General Catalogue of Variable Stars (GCVS, [Samus' et al. 2017](#), CDS B/gcvs) with around 45 percent of these manifesting a period of variability reported. The AAVSO VSX catalog ([Watson et al. 2016](#)) features over 958 CGCS variables with associated periods, hence only a minority of carbon stars are known to be variable sources. Thanks to the monitoring of a suspected variable star UCAC4 690-

029948 that resulted in a new variable star discovery by Brincat and Hills<sup>1</sup>, further investigation revealed that within the same field of view lies the carbon star GSC 0333-00416. Results of the data retrieved through data mining affirm that the carbon star CGCS 673 is also a variable source.

CGCS 673 (also designated as GSC 03333-00416) was first described as a carbon star by [Nassau & Blanco \(1954\)](#). They identified this star as CASE 72 (entry 72) in their list of carbon stars near the Galactic equator. [Stephenson \(1973\)](#) also listed the star in his paper with a second revision published in 1989 ([Stephenson 1989](#)). [Soyano & Maehara \(1991\)](#) mentioned the star CGCS 673 through their findings on 226 cool carbon stars that were derived from *V*-band plates within the Perseus-Camelopardalis region. Many stars in this list were identified by the authors as the same carbon stars as in the [Stephenson \(1989\)](#) general catalogue. [Chen et al. \(1993\)](#) also identified CGCS 673 within their candidate list. The General Catalog of Galactic Carbon stars by [Stephenson \(1989\)](#) was published through an updated and revised version by [Alksnis et al. \(2001\)](#) where information

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<sup>1</sup> <https://www.aavso.org/vsx/index.php?view=detail.top&oid=684054>.



**Fig. 1** CGCS 673 light curve including ASAS-SN data. The light curve affirms that the star is SR in nature as regular cycles are interrupted by periods of irregularity.

**Table 1** Brightness Readings of CGCS 673

Catalogue	Photometric Bands			Sources
2MASS	$J = 6.814 \pm 0.02$	$H = 5.450 \pm 0.02$	$K = 4.856 \pm 0.02$	<a href="#">Skrutskie et al. (2006)</a>
APASS DR9	$B = 16.935 \pm 0.09$	$V = 13.412 \pm 0.03$	$g = 15.131 \pm 0.11$	<a href="#">Henden &amp; Munari (2014)</a>
Gaia DR2	$G = 11.1198 \pm 0.0036$	$BP = 13.4479 \pm 0.0141$	$RP = 9.7842 \pm 0.0061$	<a href="#">Brown et al. (2018)</a>

**Table 2** Equipment Used

Observatory (Location)	Observer	Telescope	Passband	CCD Sensor	FoV (arcmin)/Binning	Pixel Scale (arcsec pixel <sup>-1</sup> )
Tacande Observatory (El Paso, La Palma, Spain)	Hills K.	0.500-m ASA Astrograph	$V$	FLI ML3200/KAF 3200ME	35.7×24.1	0.98
Flarestar Observatory (San Gwann, Malta)	Brincat S. M.	0.254-m SCT	$V$	Moravian G2-1600/KAF 1603 ME	25.5×17.0/1×1	0.99
Znith Observatory (Malta)	Galdies C.	0.200-m SCT	$V$	Moravian G2-1600/KAF 1603 ME	30.0×20.0/1×1	1.17

such as coordinates, magnitudes, spectral classification and references was updated.

## 2 OBSERVATIONS

CGCS 673 (C\* 205 = CSI+47-04201 = 2MASS J04234199+4753050 = Case 72 = IRAS 04200+4746 & UCAC2 47715951 = GSC 03333-00416 = Kiso C5-190 = UCAC3 276-65568 = UCAC4 690-029995 = AAVSO AUID 000-BMZ-492) is located at RA 04 23 41.996 and DEC +47 53 5.06 (J2000) in the constellation of Perseus.

The brightness readings of CGCS 673 through different catalogues ranging from the near infrared to the optical region are displayed in Table 1.

The Gaia Data Release 2 (DR2) catalogue lists the star as ‘257953644153609344’ ([Brown et al. 2018](#)) with a stellar effective temperature of about 3300 K. The

reddening at this location due to interstellar extinction is expressed as  $E(EB-RB)\text{mag} = 2.25$ .

We discovered the variability of CGCS 673 during a study of the neighbouring object UCAC4 690–029948. A large colour index (CI) was uncovered through application of the  $V$  (551 nm) and  $I$  (806 nm) bands. This finding prompted further research to reveal that CGCS 673 is a known carbon star.

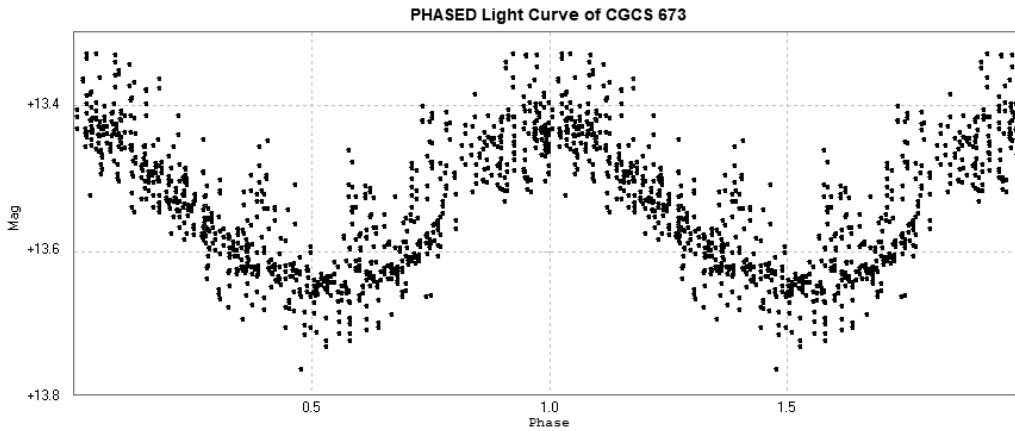
As a number of carbon stars have been identified as variable stars, a search was conducted through the ASAS-SN survey that can depict data through light curves ([Kochanek et al. 2017](#)). This search confirmed that the star is a variable source (Fig. 1). The data downloaded covered a time span of 1444 d during the period from 2014 December 1 (JD 2457007.88) to 2018 November 29 (JD 2458451.95). The ASAS-SN images utilised by this research were those taken through  $V$  and  $G$  bands.  $G$  band

**Table 3** Observer Contribution

Observer	Number of Observations	Band	Range Start (HJD)	Range End (HJD)	Span (d)
BrinCAT S.M.	112	V	2458467	2458585	117.97
Galdies C.	9	V	2458549	2458573	24.04
Hills K.	227	V	2458405	2458505	100.78

**Table 4** Comparison Stars Used for the Observation of CGCS 673 that were Based on the APASS Catalogue

AUID	RA	DEC	Label	V	B – V
000-BMT-664	04:23:35.54 [65.89808655°]	47:58:43.0 [47.97861099°]	142	14.215 (–0.04)	0.659 (0.071)
000-BMT-665	04:23:39.81 [65.9158783°]	47:59:58.3 [47.99952698°]	146	14.629 (0.051)	0.989 (0.097)
000-BMT-666	04:24:27.34 [66.11391449°]	47:46:28.0 [47.77444458°]	149	14.930 (0.035)	0.972 (0.077)

**Fig. 2** Phased light curve of CGCS 673 (Epoch: HJD 2457050.369) with data displayed from the ASAS-SN Survey and data obtained by the observers listed in Table 3.

photometry was transformed into  $V$  magnitudes through an offset that was applied for all of our analysis.

The ASAS-SN survey obtained photometric magnitudes through differential aperture photometry with zero-points calibrated to the APASS catalog (Henden et al. 2016). The ASAS-SN survey initially relied on four 14 cm aperture Nikon telephoto lenses as telescopes. Each of the four telescopes utilised a 20482 ProLine back-illuminated CCD camera by Finger Lakes Instruments. ASAS-SN imaged the area of CGCS 673 in batches of two or three images per night with a frequency interval ranging from 1 to 5 d. Occasionally, a longer interval occurred due to unfavourable weather conditions.

In order to determine additional physical characteristics of this carbon star, we have gathered more photometry through  $V$  (visual) band taken from the observatories listed in Table 2 and their contributions in Table 3.

Differential aperture photometry was considered to obtain brightness readings. The magnitudes of comparison stars were referenced from AAVSO, for the neighbouring star NSV 1536. The list of comparison stars shown in Table 4 was used by all observers except for the ASAS-

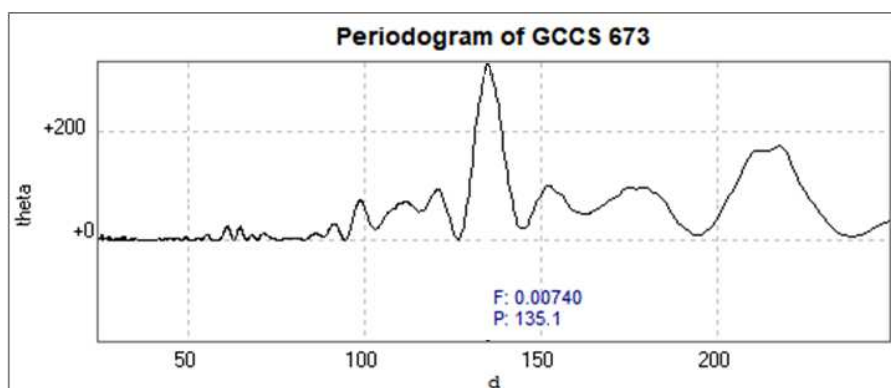
SN data that utilised the same APASS source but possibly different comparison stars.

### 3 DATA ANALYSIS

In order to investigate the periodic behaviour of CGCS 673, we performed a period search employing Fourier analysis through the software PERANSO - version 2.60 (Paunzen & Vanmunster 2016).

Period analysis was conducted applying the Phase Dispersion Minimisation (PDM) algorithm (Stellingwerf 1978), ANOVA algorithm (Schwarzenberg-Czerny 1996) and Lomb-Scargle algorithm (Lomb 1976; Scargle 1982).

Through the algorithms mentioned above, the analysis of our observations along with those from the ASAS-SN Survey revealed the following periodicity within our dataset. The combined period of CGCS 673 was determined as  $135.10\text{d} \pm 1.3\text{d}$  with a mean amplitude (derived through a polynomial fit) in  $V$ -band of 0.188 mag (Fig. 2). Figure 3 depicts the periodogram of the Lomb-Scargle algorithm that shows identical results as obtained through the PDM algorithm and ANOVA algorithm.



**Fig. 3** Periodogram of CGCS 673 as obtained through the Lomb-Scargle algorithm featuring the peak at the derived period of 135.1 d (0.0074 c/d).

#### 4 CONCLUSIONS

Our observational campaign to monitor CGCS 763 was concluded on 2019 April 11, yielding a total number of 348 observations gathered by the observatories displayed in Tables 3 and 4 for which several cycles were recorded. Our analysis of ASAS-SN data combined with those of our own observations indicate that the carbon star GCCS 673 is a semi-regular (SR) variable star with a period of 135 d with amplitude of 0.18 mag in the *V*-band. The light curve obtained by this study correlates well with the SR classification as the photometric data obtained show the classical SR morphological features in the changes of CGCS 673 that are occasionally interrupted by a period of irregular variability. The derived period and CI obtained from professional databases indicate that the attributes of this star fall within the parameters of the SR class of variable stars. Following our notification that this star is a variable source, this star received the AAVSO Unique Identifier of (AAVSO UID) 000-BMZ-492.

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