V725 Sagittarii: Unique, Important, Neglected

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Received June 15, 2020; revised June 30, 2020; accepted July 24, 2020

Abstract During the last century, V725 Sgr gradually changed from a 12-day Cepheid to an 85-day yellow semiregular giant. This paper presents wavelet analysis of AAVSO visual observations from 1982 to 2020, and Fourier analysis of ASAS-SN observations from 2016 to 2018. The results confirm that the previously-identified pulsation period has increased from about 50–60 days to 80–90 days since 1982. In the ASAS-SN data, there appear to be both a 82.6-day period and a possible 160.0-day period, though the latter is not prominent after pre-whitening. If it is real, however, the two periods could be interpreted as a first overtone period and a fundamental period, respectively. Evidence for two (or more) periods can also be seen in the ASAS-SN light curve, and in the visual data. The total V range is 1.1 magnitude. Since recent results in the literature indicate that V725 Sgr is a K4 yellow giant, it should be classified as a SRd variable. In view of its continuing changes, it needs and deserves to be monitored more systematically.

1. Introduction

Since 1926, V725 Sgr gradually changed from a 12-day Cepheid to a 85-day cool semiregular variable. Prior to 1926, it may have varied on a time scale of a few days. Between 1926 and 1935, its period increased smoothly from 12 to 21 days. In 1968–1969, its time scale was 45–50 days and, in 1973, it was about 50 days. Between 1985 and 2000, the period increased from 60 ± 2 days to 85 ± 3 days, the variability being semiregular. It is still listed as a Classical Cepheid in SIMBAD (Wenger *et al.* 2000). See Percy *et al.* (2006)—hereafter Paper 1—for a detailed account of its changing period, amplitude, and mean magnitude, and for additional references to the star.

Paper I pointed out that the behavior of V725 Sgr was consistent with a thermal flash and blue loop from the asymptotic giant branch (AGB) in the H-R diagram. It also noted that, since the behavior of the star might continue to change, and be semiregular, the star should be monitored regularly.

Unfortunately, that appears not to be the case. SIMBAD (simbad.u-strasbg.fr) records only one specific study of the star since 2006. AAVSO visual observations are sparse, and AAVSO CCD observations are apparently non-existent.

Battinelli and Demers (2010), however, obtained 32 VRIJHK observations of the star in 2008–2009. These indicate a semiregular variability with a time scale of about 70 days, and an amplitude of about one magnitude. Their multicolor photometry indicated that V725 Sgr had the colors of a K4 giant, so it should be classified as an SRd star, not as a pulsating red giant as Paper 1 did on the basis of limited spectroscopic information.

V725 Sgr was also observed in three surveys. It was observed by ASAS, the All-Sky Automated Survey (Pojmański 1997), between HJD 2451948 and 2455137 (2001–2009), a mean period of 78.06 days was derived. The phase diagram shows considerable scatter. It was also observed by Gaia, Data Release 2, from 2014 to 2016 (Gaia Collab. *et al.* 2018). The anonymous referee kindly determined a period of near 82 days from the Gaia data.

The star was also observed for 900 days from 2016 to 2018 by the All-Sky Automated Survey for Supernovae (ASAS-SN, Jayasinghe *et al.* 2018, 2019). The present paper presents an analysis of the ASAS-SN observations, and of the sparse visual observations in the AAVSO International Database (Kafka 2020) since JD 2445000 (1982).

2. Data and analysis

The ASAS-SN data and the AAVSO visual observations since JD 2445000 were analyzed using the Fourier and wavelet analysis routines in the AAVSO time-series analysis package VStar (Benn 2013).

3. Results

Figure 1 shows the ASAS-SN light curve of V725 Sgr. It is clearly not monoperiodic. It appears to be a superposition of at least two signals. The changes in amplitude from cycle to cycle suggest that the two periods are not close, but may differ by a factor of more like 1.5 to 3.

Figure 2 shows the Fourier spectrum of the ASAS-SN data. There are peaks at periods of 82.6 and 160.0 days, with comparable amplitudes of 0.23 and 0.22 mag, respectively. The amplitudes, as defined here, are the coefficients of the sine curves with the stated periods.

However, the anonymous referee has pointed out that, if the ASAS-SN data are pre-whitened for the 82.6-day period, the next significant period in the Fourier spectrum is 104 days, which is not prominent in Figure 2. The Fourier spectrum of the sparse AAVSO visual data, covering the same time interval as the ASAS-SN data, shows the 82.6-day period, but neither the 160.0-day period nor the 104-day period is prominent. So the situation is not clear. This is not surprising, given the limitations of the data, and the semiregularity of the star.

The Fourier spectrum of all the AAVSO visual measurements, since JD 2445000, shows a very weak peak at a period of 69.6 days, with an amplitude of 0.09 mag. There is also a peak at a period close to one year, which may be spurious. The data are rather sparse, they have limited accuracy, and any period present is likely to be changing. Therefore, it seemed more appropriate to carry out wavelet analysis, even in view of the limitations of the data.

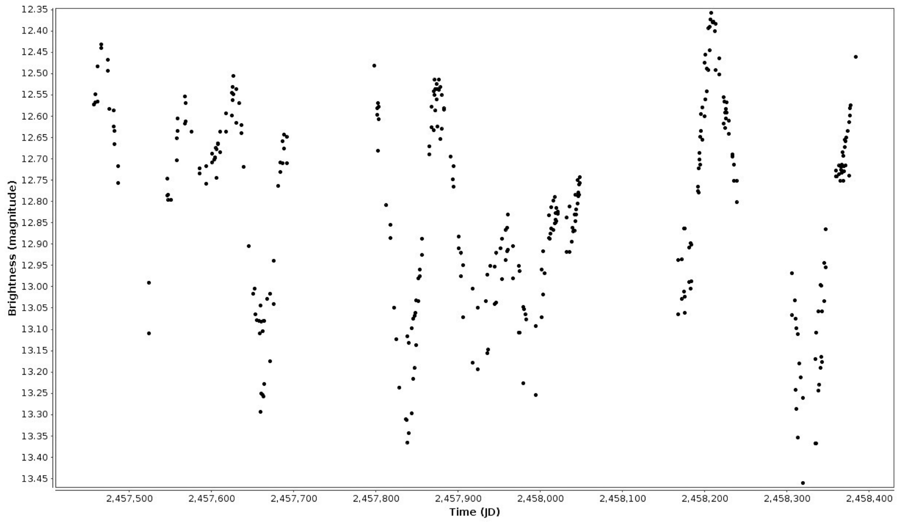

Figure 1. The ASAS-SN V light curve of V725 Sgr from 2016 to 2018.

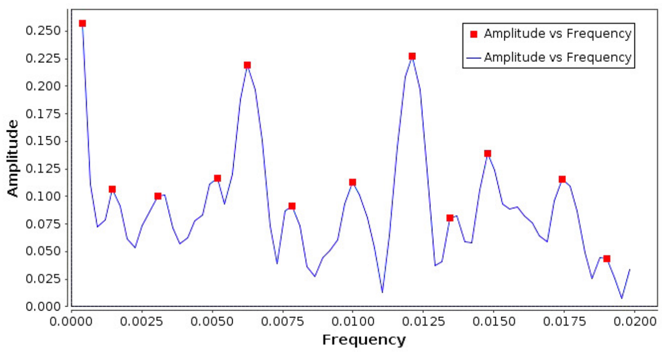

Figure 2. The Fourier spectrum of the ASAS-SN observations of V725 Sgr shown in Figure 1. It shows periods of 82.6 and 160.0 days.

Figure 3 shows the result. There appears to be a period, at the bottom of the graph, which increases from about 50 days at the beginning of the data to about 80 days at the end. This is the period that was identified in Paper 1. It is also consistent with the various periods already mentioned. There are also random signals at periods between 100 and 200 days. Given the sparseness of the data, it is not clear whether these additional signals are significant.

In particular, however, in the interval of the ASAS-SN data (JD 2457400–24584000), there are periods in Figure 3 which are consistent with those suggested in Figure 1, and shown in Figure 2, namely 82.6 and 160.0 days. It is therefore possible that the star was pulsating with those two different periods at that time.

4. Discussion

The primary period of V725 Sgr has persisted, and now has a value of about 85 days. It is not clear whether the period has stabilized.

The two periods in Figure 2 are in a ratio close to 1:2. The shorter period is not a harmonic; *if it is real*, then it is almost certainly an overtone. The ratio of the first overtone period to the fundamental period is close to 0.5 in pulsating red giants (Xiong and Deng 2007, Percy 2020), and in pulsating yellow giants (e.g. Fokin 1994). Indeed, such a ratio is one possible explanation for the alternating deep and shallow minima in RV Tauri stars, and the semi-regularity in SRd stars. If the longer period is actually 104 days, the interpretation is less clear, because the 82.6/104 ratio does not correspond to any obvious ratio of overtone periods.

Many red giants pulsate in the first overtone and the fundamental e.g. Mattei *et al.* (1997), Percy (2020). For pulsating yellow giants such as RV Tauri and SRd variables, double-mode pulsation also appears to be the case (Fokin 1994). The light curve in Figure 1 is typical of SRd variables.

The amplitude of the dominant pulsation period has varied as a function of time. This is normal; the pulsational amplitudes of pulsating red giants vary by factors of up to ten, on time scales of tens of pulsation periods (Percy and Abachi 2013). The same is true of yellow giants—RV Tauri and SRd variables (Percy 2015). Figure 3 clearly illustrates the complexity of the behavior of this star.

Paper 1 outlined the possible changes in the mean magnitude of the star but, given the miscellaneous sources of the data, and the complex variability, the reality of these changes are still uncertain. No changes are apparent in the AAVSO visual light curve since JD 2445000. Data before that are very scattered, but also very sparse.

Although the variability of V725 Sgr is now like that of a pulsating red giant, its (J–K) color, +0.869 according to SIMBAD, is not as cool as a typical red SR variable, namely +1.2. The (J–K) color quoted by SIMBAD is based on 2MASS data, and is consistent with the average values quoted by Battinelli and Demers (2010). These authors make a strong case that, at the time of their observations, V725 Sgr was a K4 giant. It should therefore be classified as an SRd variable. Its future is unclear. Which modes will be excited? Has the period stabilized, or will it continue to change? Will the star become cooler, and rejoin the AGB?

In view of the interesting and complex behavior of this star in the last few years, and the uniqueness of a star which is

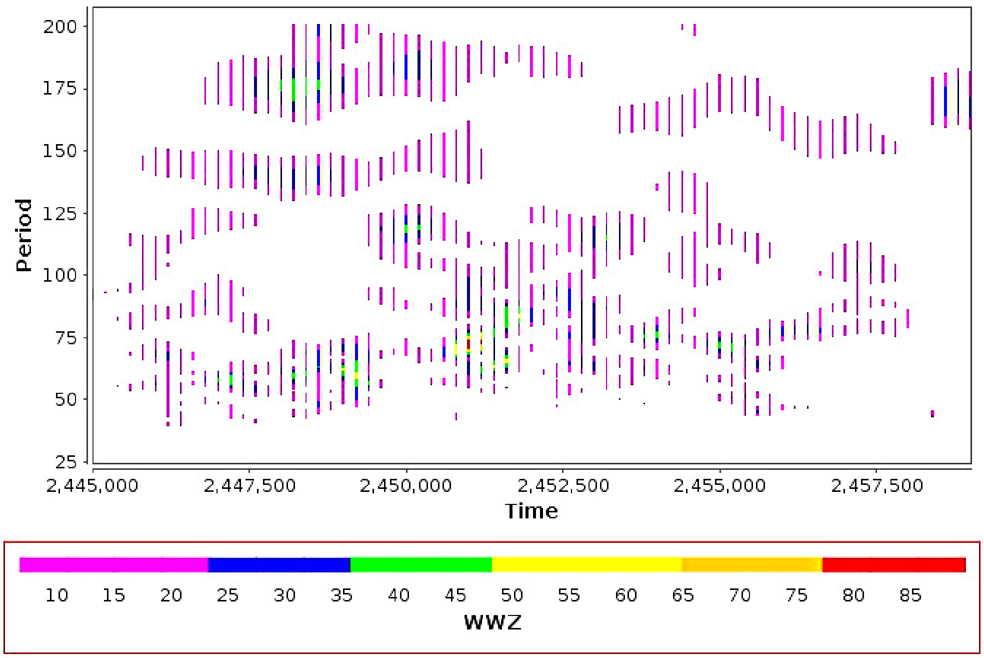

Figure 3. The wavelet diagram for the AAVSO visual observations of V725 Sgr. There is a period which slowly increases, with variable amplitude, from about 50 to 90 days. There are various longer-period signals, which may or may not be statistically significant. One strong signal is consistent with the 160-day period found by ASAS-SN between 2016 and 2018.

changing before our eyes, we again urge observers to monitor this star regularly, with CCD techniques and multicolor filters if possible. It needs and deserves such systematic monitoring.

5. Conclusions

A century ago, V725 Sgr was a Cepheid with a period of a few days. It is now a pulsating yellow giant with a period of about 85 days, and at least one longer period. These may represent two different pulsation modes. This star continues to change its physical and pulsation properties, rapidly and significantly, and needs and deserves to be monitored regularly—as regularly as more famous stars such as SS Cyg and R CrB.

6. Acknowledgements

We thank the ASAS-SN team for making their data and results publicly available. We also thank the AAVSO observers and staff for making and archiving the AAVSO data. We also thank the anonymous referee for suggesting significant improvements to this paper.

This project made use of the SIMBAD database, maintained in Strasbourg, France. The Dunlap Institute is funded through an endowment established by the David Dunlap family, and the University of Toronto.

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