SZ Lyn

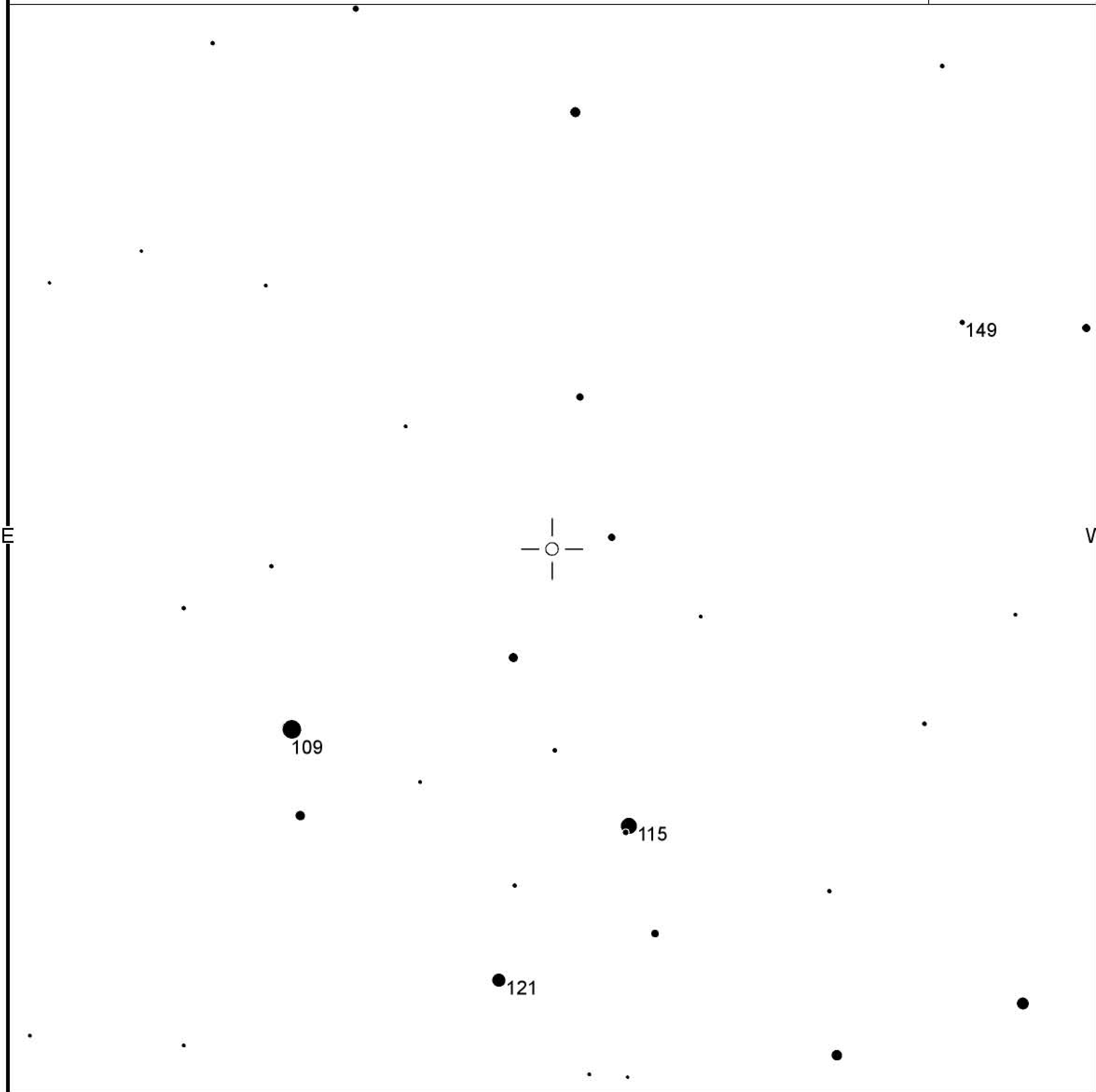
Magn: 9.08 - 9.72 V
Period: 0.12053492
Type: DSCT
Spec: A7-F2

SZ Lyn

(2000) 08:09:35.75 +44:28:17.6

AAVSO Chart

14651AI



FOV = 15.0'

Please use the photometry table for CCD observations.

http://www.aavso.org/vsp/

Field Photometry for SZ Lyn From the AAVSO Variable Star Database

Data includes all comparison stars within 0.12500° of RA: 8:09:35.75 (122.39896) & Decl.: 44:28:17.62 (44.47156).

AUID	RA.	Dec.	Label	U	B	V	B-V	Rc	Ic	J	H	K	Comments
000-BJR-415	8:09:55.81 [122.48254d]	44:25:48.6 [44.43017d]	**109**	-	11.701 (0.024)[18]	10.924 (0.016)[18]	0.777 (0.029)	10.481 (0.037)[18]	10.105 (0.041)[18]	-	-	-	
000-BJR-416	8:09:29.82 [122.37425d]	44:24:28.6 [44.40794d]	**115**	-	11.845 (0.033)[18]	11.456 (0.012)[18]	0.389 (0.035)	11.222 (0.024)[18]	11.002 (0.031)[18]	-	-	-	
000-BJR-417	8:09:39.83 [122.41595d]	44:22:21.5 [44.37264d]	**121**	-	12.689 (0.031)[18]	12.087 (0.024)[18]	0.602 (0.039)	11.743 (0.048)[18]	11.442 (0.060)[18]	-	-	-	
000-BKG-754	8:09:04.07 [122.26696d]	44:31:24.4 [44.52345d]	**149**	-	15.882 (0.045)[29]	14.918 (0.000)[29]	0.964 (0.045)	14.386 (0.056)[29]	13.890 (0.079)[29]	-	-	-	
Report this sequence as: **14651AK** in the *chart* field of your observation report.													

- **AUID** is the AAVSO Unique Identifier for the star. When reporting a problem, please include this AUID.
- Coordinates are in J2000 sexagesimal format, followed by decimal degrees
- Click here for a search of variable stars in this field via VSX
- **Label** is that star's label when plotted on an AAVSO chart, this is usually (but not always) its V magnitude rounded to the tenths.

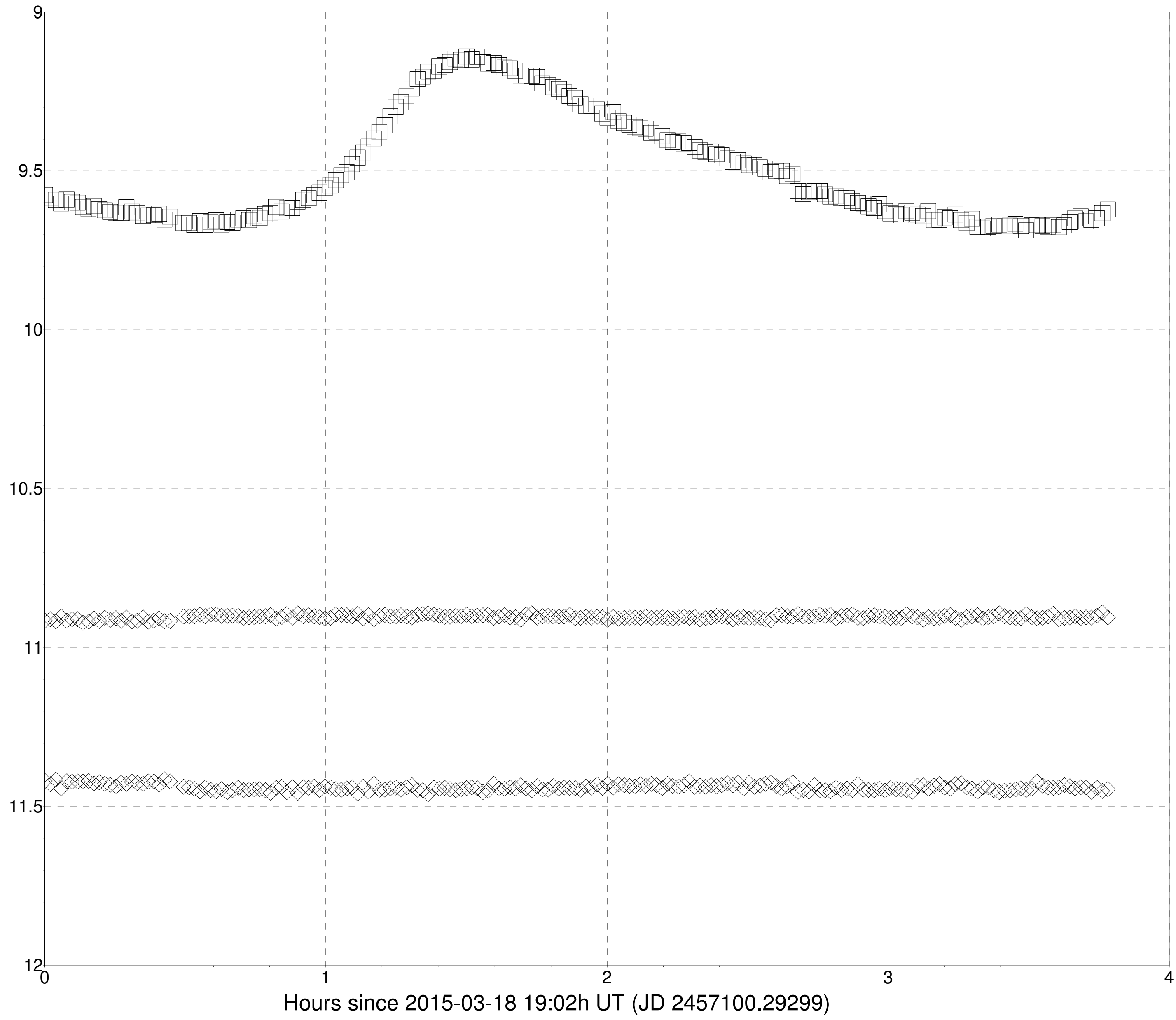
Source Reference Table

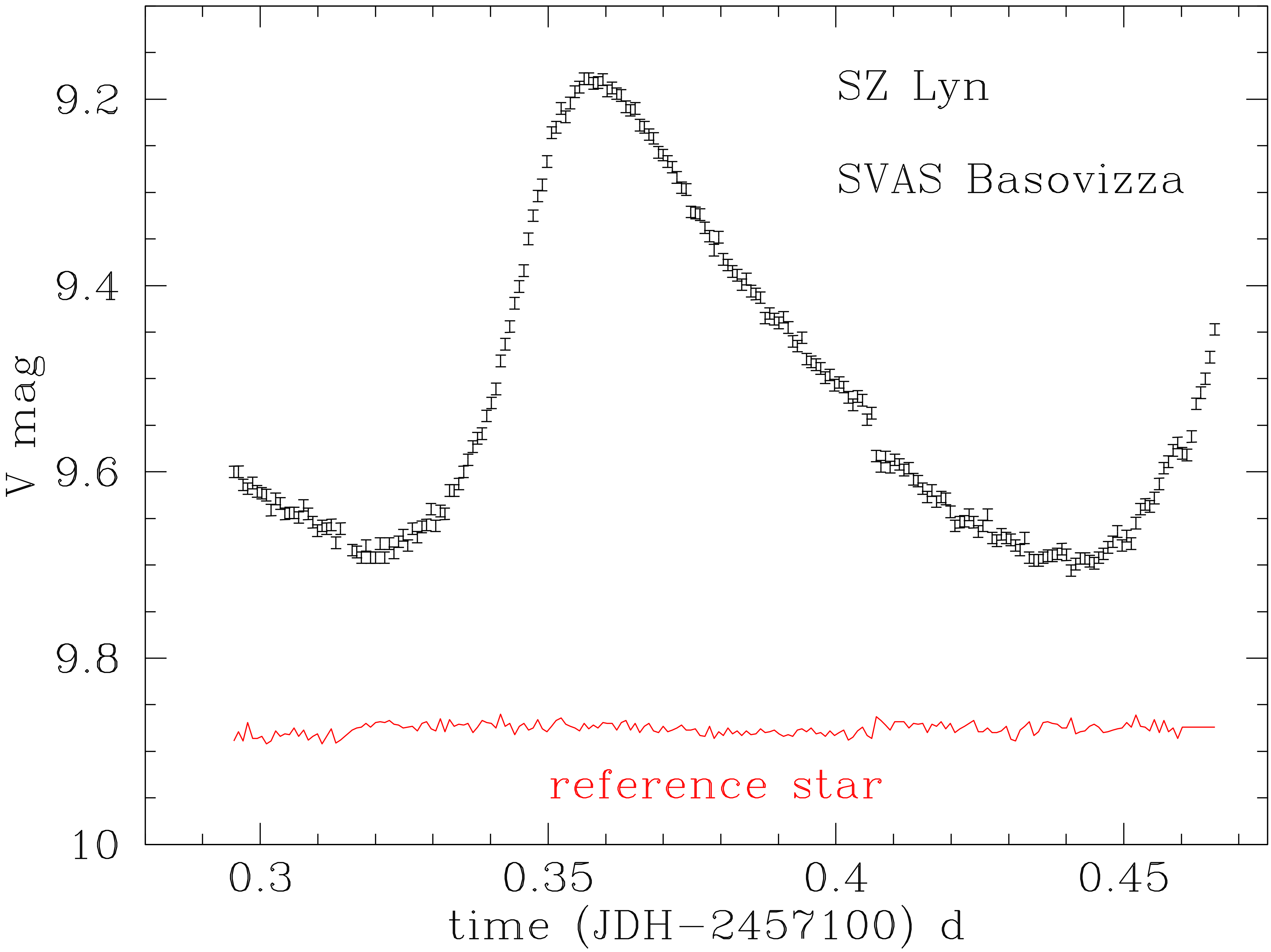
Footnote	Source
1	Tycho-2
2	GSC 1.2
3	GSC 2.2.1
4	USNO A2
5	USNO B1
6	GCVS
7	USNO Astrograph
8	2MASS
9	AAVSO Charts from ~2006-2008
10	Henden USNO 1m
11	CVCAT
12	Hipparcos
13	Draper, Draper Ext.
14	NSV

Footnote	Source
16	TASS
17	ASAS3
18	Sonoita Research Obs.
19	Other
20	GCPD
21	SDSS
22	BSC
23	B. Skiff's LONEOS
24	WBVR
25	DENIS
26	CMC14
27	RR Lyr Comp Star Database
28	Bright Star Monitor
29	APASS

Footnote	Source
31	Wright 30cm
32	Mt. John 60cm
33	Sonoita 50cm
34	K35
35	Landolt UBVRI 2007
36	Landolt UBVRI 2009
37	Bright Star Monitor - South
38	UCAC 3
39	UCAC 4
40	Bright Star Monitor - Hamren
41	Bright Star Monitor - Berry
42	Tortugas Mountain 0.61m Telescope
43	Variable Star Index
44	Coker 30cm

15	AAVSO Charts from <2006	30	Wright 28cm


9
9.5
10
10.5
11
11.5
12
0
1
2
3
4
Hours since 2015-03-18 19:02h UT (JD 2457100.29299)



SZ Lyn
SVAS Basovizza
reference star
V mag
9.2
9.4
9.6
9.8
10
0.3
0.35
0.4
0.45
time (JDH−2457100) d

THE HIGH AMPLITUDE DELTA SCUTI STAR SZ LYNCIS REVISITED

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(Received 20 April, 1988)

Abstract. Nine new times of light maximum are given for SZ Lyn and the time base of observations is herewith extended to 26 years. 154 light maxima have been used to calculate the orbital elements and the secular change in the period of the pulsating component. The results provided here support the post-Main Sequence, high mass hypothesis for the evolutionary state of this dwarf cepheid.

1. Introduction

SZ Lyncis (= BD + 44° 1718 = HD 67390) is one of the most thoroughly observed high amplitude δ Scuti stars. Ever since van Genderen (1967) discovered the strictly periodic variation in the O–C values of light maxima this star has become a major target for observers dealing with dwarf cepheids, because the only plausible explanation of this variation is the binary nature of the star. If a pulsating star is a member of a binary system, an independent estimate of the mass from stellar pulsation theory can be given.

The light variability of the star was discovered by Hoffmeister (1949a, b). Its type of variability was determined by Schneller (1961), while its pulsational period was first derived by Gefferth and Szeidl (1962) and by Notni (1962) independently. Since Schneller's first photoelectric observations a great number of photoelectric observations have been collected for the star. Apart from small (< 0.02 mag) cycle to cycle variations no irregularities have been found in the star's light variation and all attempts have failed to find double-mode pulsation.

van Genderen (1967) was the first to point out that the O–Cs produced by a linear ephemeris appeared to follow a sine-curve relation with a period of $P_B = 3.091 \pm 0.051$ years. Barnes and Moffett (1975) improved the period of the sine-curve relation to $P_B = 3.138 \pm 0.028$ years and interpreted this long-period variation as light travel time effect supposing SZ Lyn to be a member of a binary system with the orbital period P_B. Although they confirmed that the residuals from a constant period provided a good sine-wave fitting, Garrido *et al.* (1979) gave a slightly longer cycle length $P_B = 3.149 \pm 0.028$ years than did Barnes and Moffett. Utilizing all the photoelectric maxima available up to 1980, Szeidl (1983) came to the conclusion that the orbital period was significantly longer: $P_B = 3.203 \pm 0.009$ years allowing, for the first time, that the pulsation period of the star may change linearly. Soliman *et al.* (1986)

rediscussed the parameters of the light variation of SZ Lyn on an extended time base and obtained a longer orbital period $P_B = 3.213 \pm 0.006$ years.

Bardin and Imbert (1984) measured the radial velocities of SZ Lyn with high accuracy and high-time resolution. Their results fully confirmed the binary hypothesis and led to an orbit with a fairly large computed eccentricity and an even longer orbital period $P_B = 3.235 \pm 0.004$ years than was obtained from the O–C values of maximum light supposing circular orbit.

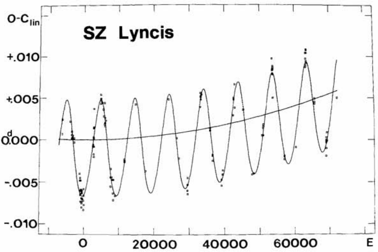

Fig. 1. The O–C values of light maximum have been computed by the linear ephemeris $C_{lin} = 2438124.39955 + 0^{d}.120534910E$. Equations (1)–(6) were used to fit in the times of the observed light maximum.

The discrepancy between the orbital periods obtained in the two independent ways is somewhat disturbing. One can speculate about its cause. Bardin and Imbert took into account the previous radial velocity observations including those of less accuracy; this might have led to a certain error in their period determination. Even so it is curious that the orbital period derived from the O–C values of light maxima assuming a circular orbit increases with the increasing time base covered by the observations. Of course, the underestimate of the orbital period may also be a consequence of the assumption that the orbit is circular or of the changes in the pulsation period not being properly taken into account.

The period changes of dwarf cepheids are characteristic of their evolutionary state. Szeidl (1983) was the first to try to determine the intrinsic, secular change in the

BVRI Observations of SZ Lyncis at the EKU Observatory

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Abstract Eastern Kentucky University (EKU) is a regional University serving the Kentucky part of Appalachia. In 2008 a small observatory was built and this work will describe the instrumentation and the site characterization. We have in fact measured the transformation parameters of the the telescope and camera combination and the first order extinction coefficients for our site. As an example of the capabilities of the observatory we have determined the pulsation period of the δ Scuti star SZ Lyncis and measured the standard magnitudes via BVRI and two color terms B–V and V–R.

1. Facilities

Eastern Kentucky University (EKU) is a regional comprehensive University located in the center of the Blue Grass region, in Richmond, Kentucky. Its service area includes much of the eastern part of Kentucky, commonly referred to as Appalachia. As such, Eastern has truly been a "school of opportunities" for the region.

In 2008 we had the opportunity to build a small observatory, for outreach and research. The facility, located at Lat. 37° 43' 35.92" N and Long. 84° 18' 0.67" W, consists of a 14-inch telescope (C-14 from Celestron), with a research grade tracking mount (Paramount ME), housed permanently in a two-room building. The observatory has a retractable roof, with the control room insulated against the elements, and is conveniently located near campus, but also away from city lights and vehicular traffic.

The instrument package consists of a SBIG STL-6303E CCD camera with filter wheel and full complement of photographic (Luminance, RGB), narrow-band, and photometric filters (H-alpha and Johnson-Cousins UBVRI). The camera's main CCD detector has an array of 3072×2048 pixels, with 9μm pixels, and is non anti-blooming (NABG). Binned 1×1, the combination of the telescope (an $f/11$ design) and camera results in a nominal image scale of 0.48 arcsec/pixel. This scale is rarely warranted by the prevalent seeing conditions, which range from 2 to 5 arcsec, and would produce unnecessary oversampling. This is solved by binning the CCD camera, with the twofold improvements of increased sensitivity and reduction of oversampling. While binned 3×3, the STL-6303 has been measured to produce an image scale of 1.23 arcsec/pixel, which is excellent for the local seeing conditions (approx. a

2 to 1 oversampling). A quick characterization of the CCD, using the routine in AIP4WIN (Berry and Burnell 2011), shows the camera, binned 3 × 3, to have a gain of 2.3 electrons/ADU, a readout noise of 28 electrons RMS, and a Mean Dark Current of 0.05 electrons/pixel/sec at –14.8°C. Camera and mount are controlled by the integrated package CCDSOFT-SKY X PRO from Software Bisque (2011).

2. Capabilities of the observatory and local conditions

The first step in precision photometry is the measurement of the CCD transformation coefficients, to be able to convert the raw instrumental magnitudes generated by the camera-telescope combination to standard magnitudes and to make comparison with other measurements possible. It also gives a means to assess the capabilities of the telescope-camera combination and its response through the photometric filters.

On four nights during March 2012 we imaged, through BVRI filters, Landolt standard fields centered at R.A. 07^h 24^m 15^s, Dec. –00° 32' 00"; R.A. 07^h 30^m 00^s, Dec. –02° 06' 00"; and R.A. 09^h 21^m 32^s, Dec. +02° 47' 00". These fields were identified by Smith (2002) as fields # 55, 56, and 61, respectively. Data were obtained with time integration between 60 and 240 seconds, binned 3 × 3. After standard data reduction (with dark, bias, and flat frames) and following the procedures recommended by Sarty (2008) and Gary (2006), we obtained the transformation parameters shown in Table 1. The quoted values are the results of a weighted average of the parameters obtained during the four nights and three fields.

An ideal system would have the first three parameters equal to 1 and the last two to zero. Our results indicate a certain lack of sensitivity of the system in the range identified by the band pass of the Johnson B filter (centered around 440 nm), which is not surprising as CCD cameras, unless expressly designed, are not very sensitive in this range.

Our second set of measurements was made to ascertain the kind of atmospheric conditions that could be expected at our location and to see if they were conducive to photometry. In Richmond, Kentucky, prevalent weather patterns seem to indicate that the best photometric nights would occur during mid-spring (April–May) and mid-fall (September–October) due to a higher percentage of clear nights with lower humidity. Summers are quite humid and hot, not very favorable conditions, while winters are wet with many cloudy nights.

We measured the first order extinction coefficients for the filters BVRI at our location using the comp star method as explained by Warner (2006). The final goal of this observing campaign was the study of the δ Scuti Star SZ Lyn (a target of choice of the American Association of Variable Star Observers, AAVSO). For that purpose, we used the AAVSO Variable Star Plotter (VSP, http://www.aavso.org/vsp) to plot a finder chart (Chart # 10399bsa) containing photometric star sequences for SZ Lyn. We identified three stars in this chart (AUID 000-BJR-415, 000-BJR-416, and 000-BJR-417) and their properties are presented in Table 2. These stars were present in all the images taken and were used for the comp star method.

Using the AIP4WIN magnitude measurement tool or MMT (Berry and Burnell 2011), we measured the instrumental magnitudes of the three stars through four standard photometric filters (BVRI), averaged their values, and plotted the resulting values as a function of the air mass. Given that in these measurements the air mass range covered was limited (1.1 to 1.5), and the three stars were of similar color, we assumed the second order extinction coefficient to be negligible. We fitted a straight line through the data, the slope of which will be the first order extinction coefficient for the particular photometric filter used. We performed these measurements during two nights (2012 April 6 and April 8).

The data are presented in Figures 1 through 4. Those two nights, while both clear and with good seeing, represent the range of variability in the local conditions. April 6 was clearly the better of the two nights, with smaller extinction coefficients across the board, while on April 8 the coefficients were all higher, probably due to high-lying cirrus clouds. Regardless, during the entire time of observation, the coefficients remained constant, thus making both nights “photometric nights.”

The values obtained during the two nights are clearly different, but they are self-consistent: the difference in B and V values, k'_{bv} (Warner 2006), between the two nights is of the order of 0.15 (0.11 and 0.14, respectively, in our case, while the difference between V and R, k'_{vr}, is small and positive as expected, equaling 0.06 and 0.07, respectively. If these measurements were done on a single star, the regression lines zero point intercepts (that is, the intercepts at zero airmass) would give the instrumental magnitude above the atmosphere, and therefore they should be the same for any filter, regardless of the slope. In our case they are very close, averaging to a difference of 0.05 magnitude. Based on this measurement, we therefore claim that our reported magnitudes will have an overall uncertainty of 0.050 mag.

3. SZ Lyn measurements

The variability of the extinction coefficients highlighted clearly indicates why absolute photometry is not for the faint of heart. It is much easier to perform differential photometry, in which the photometry of the star of interest is obtained by comparing it with stars within the same field.

We report below the measurements on SZ Lyn (R.A. 08^h 09^m 35.8^s, Dec. +48° 28' 18"), a variable star (Schneller 1961) belonging to the δ Scuti family and member of a binary system (Bardin and Imbert 1984; Gazeas *et al.* 2004). δ Scuti stars are short-period pulsating variables of A-F spectral types, located at the intersection of the main sequence and the instability strip in the HR diagram. Typical periods are of the order of a few hours with amplitudes less than 1 mag. In particular, SZ Lyn belongs to the high-amplitude δ Scuti (HADS) stars, which have V-band amplitude changes larger than 0.3 mag. (for a review of δ Scuti stars see Rodríguez and Breger 2001). SZ Lyn has received in-depth coverage because of its rapid pulsation rate and because is known to be a member of a binary system.

Over several nights from March to May 2012 we conducted measurements on SZ Lyn, using the AAVSO comparison star sequence. Measurements were performed using BVRI filters. The star field, reproduced in Figure 5, was imaged through our 14-inch telescope with integration times of 30 to 45 seconds, in a rapid sequence, B-V-R-I-B-V-R-I, etc., so as to follow the star pulsation as closely as possible.

Each CCD frame obtained was reduced via CCDSOFT (Software Bisque 2011). The reduced files were then uploaded to the AAVSO and the light curves were generated via the software package VPHOT (AAVSO 2012), an online tool for photometric analysis provided by the AAVSO. As a sequence, we used AUID 000-BJR-415 and AUID 000-BJR-417 as comparison stars and AUID 000-BJR-416 as check star (see Table 2). The magnitudes obtained were then transformed using our measured transformation parameters according to the method outlined by Sarty (2008).

In Figures 6, 7, and 8 we present the transformed magnitudes and the color terms as a function of phase. These phase plots were generated using the software package PERANSO (Vanmuster 2011), which was also used to determine the period of pulsation of SZ Lyn from our data. As summarized in Table 3, we obtained P = 0.1205353(81) d. This value is in excellent agreement with values from Gazeas *et al.* (2004) of P = 0.1205349 (41) d, and with Paparó *et al.* (1988) of P = 0.120534910 (13) d.

We compared these results with the period obtained by analyzing, again using PERANSO, the AAVSO database of SZ Lyn observations. So as to compare similar techniques, we arbitrarily selected all the CCD observations through the V-filter reported since January 2005. We obtained, with this much larger data set, a period P = 0.1205350(1) d.

The uncertainty we reported in our data is simply due to the spread of the values of the period obtained by using all the routines available in PERANSO, and it is approximately 0.7 second. This value seems much better to us than the typical accuracy of the computer clocks present in typical desktop PCs, especially considering that the measurements were done over the course of a few weeks. While we routinely, at the beginning of each observation run, synchronized the computer clock with internet time servers connected with NIST sites, we did so without really relying on any further refinements of our time base. The uncertainty quoted by Gazeas *et al.* (2004) is comparable to ours (0.35 s), and just as in our case, there is no mention of a particular effort to quantify the knowledge of the time base. Further, the uncertainties quoted by Paparó *et al.* (1988) and Gazeas and Niarchos (2005) appear to be approximately two orders of magnitude smaller (approx. 0.001 s).

The latter two results were obtained by fitting the times of all the light maxima observed over a span of 26 years and 34 years, respectively, all by different observers. It seems that all the quoted uncertainties, our case included, are simply an indication in the uncertainty of the computations to obtain the period (by Fourier transform techniques) of the time-series measurements. Unless a concerted effort is made, it is doubtful that the period of pulsation reported by Paparó *et al.*, this work, and Gazeas truly have the quoted uncertainty. We would categorize all these as lower limits of the uncertainty, probably superseded by larger uncertainties in the time base.

Given a large enough dataset, as in the case when we analyzed the AAVSO database, Fourier transform techniques pose a very small lower limit. The analysis of the AAVSO database, in fact, resulted in an uncertainty of approximately 0.09 second, but that should not be taken as the ultimate uncertainty, as the data were reported by a large number of individual observers over the course of many years. It is highly doubtful that all their clocks were all synchronized to within 0.09 second.

4. Conclusion

We performed measurements designed to characterize the instrumentation (telescope, camera, and filters) and the location. The former was achieved by determining the transformation coefficients of our telescope-camera combination, the latter by determining the extinction coefficients at our location. As an application, we determined the pulsation period of the δ scuti star SZ Lyn and its transformed standard magnitudes through the Johnson-Cousins BVRI filters. We found good agreement with values existing in the literature.

5. Acknowledgements

This work was supported in part by a grant from EKU's University Research Committee URC and a grant from the AAS Small Research Grant (SmRG) Program. We acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research. We also wish to thank Dr. M. Pitts for a careful reading of the manuscript.

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Table 1. Transformation parameters for the EKU observatory (March 2012).

Transformation Parameters	*Value and Uncertainties*
T_{bv}	1.445 ± 0.003
T_{vr}	1.006 ± 0.002
T_{ri}	0.945 ± 0.002
T_{v}	-0.054 ± 0.002
T_{r}	0.061 ± 0.003

Table 2. Sequence stars used (AAVSO Chart 10399bsa) to observe SZ Lyn.

AUID	*R.A.* h m s	*Dec.* ° ′ ″		
B	*V*	*Rc*	*Ic*	*Comments*
000-BJR-415	08 09 55.81	+44 25 48.6		
11.701(0.024)	10.924(0.016)	10.481(0.037)	10.105(0.041)	Comp. Star
000-BJR-416	08 09 29.82	+44 24 28.6		
11.845(0.033)	11.456(0.012)	11.222(0.024)	11.002(0.031)	Comp. Star
000-BJR-417	08 09 39.83	+44 22 21.5		
12.689(0.031)	12.087(0.024)	11.743(0.048)	11.442(0.060)	Check Star

Table 3. SZ Lyn pulsation period.

Observer	*Pulsation Period (d)*
Paparó *et al.* (1988)	0.120534910(13)
Gazeas *et al.* (2004)	0.1205349(41)
Gazeas and Niarchos (2005)	0.120535068(13)
AAVSO Database	0.1205350(1)
This work	0.1205353 (81)

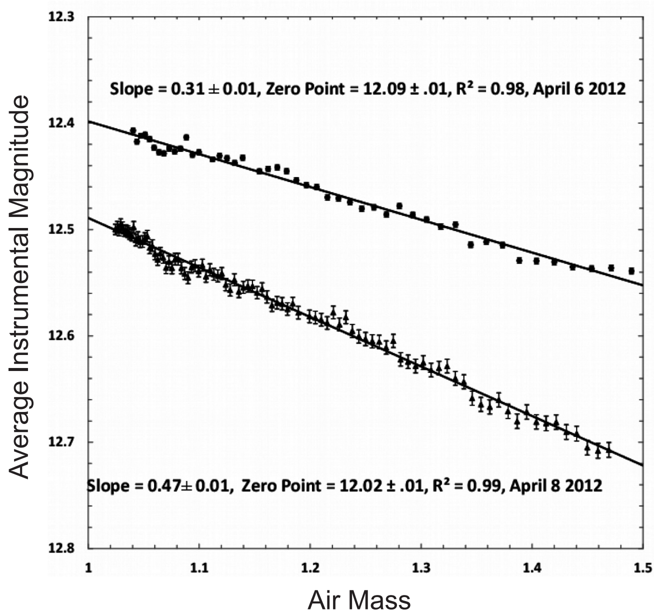

Figure 1. Extinction coefficient at EKU observatory through B filter.

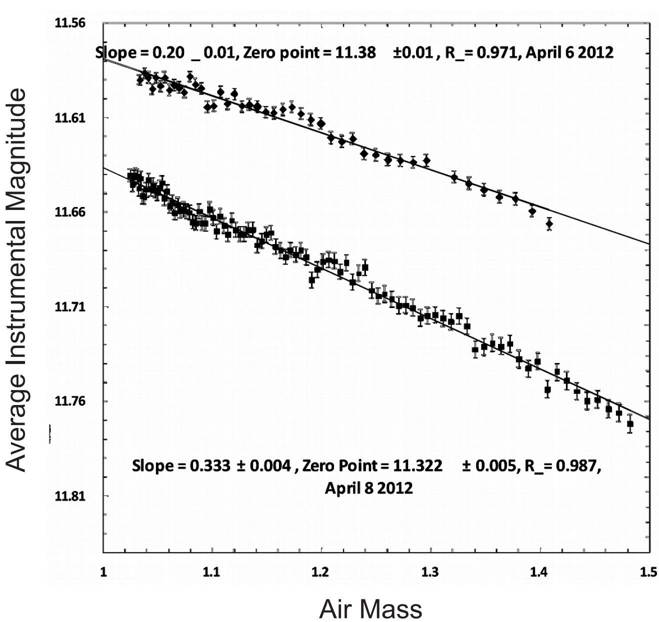

Figure 2. Extinction coefficient at EKU Observatory through V filter.

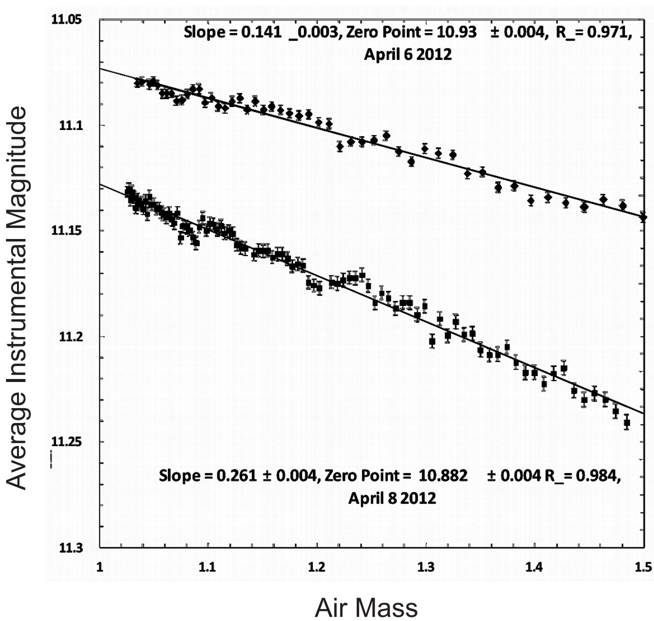

Figure 3. Extinction coefficient at EKU Observatory through Rc filter.

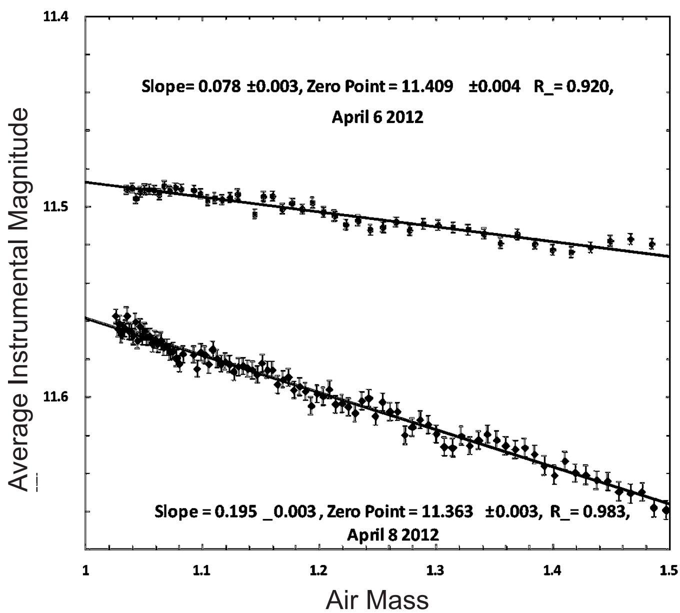

Figure 4. Extinction coefficient at EKU Observatory through Ic filter.

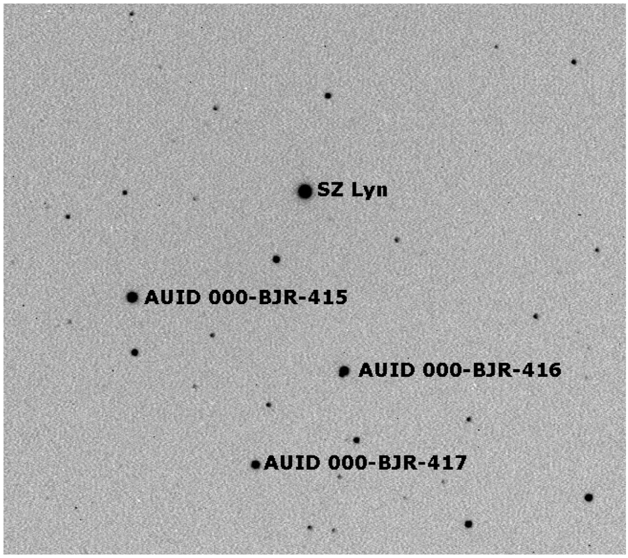

Figure 5. SZ Lyn and the sequence stars, as identified on AAVSO finder chart #10399bsa. This CCD image was obtained at the EKU Observatory on April 6, 2012. Image center is at R.A. 8^{h} 09^{m} 36.7^{s}, Dec. +44° 26' 48.0". Up, in this image, is 3° 12' West of true North. East is to the left. Scale size is 1.24 arcsec/pixel.

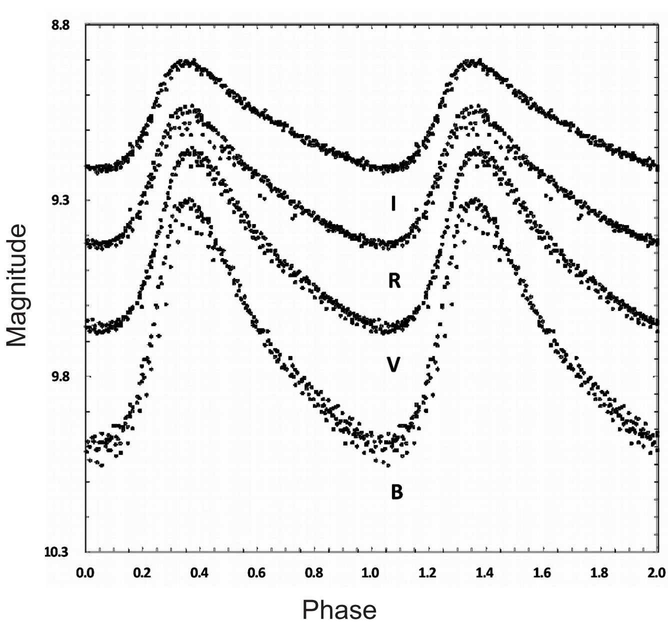

Figure 6. SZ Lyn phase plot.

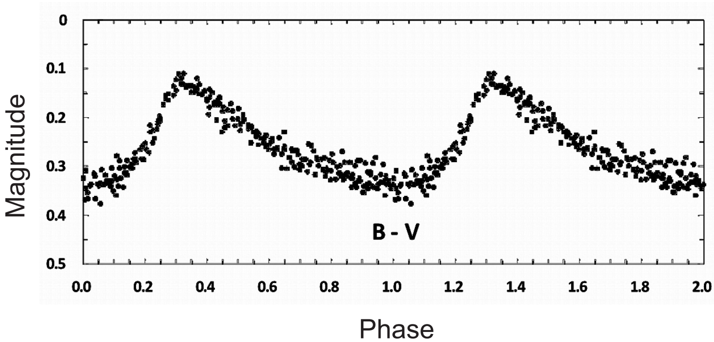

Figure 7. SZ Lyn B–V term.

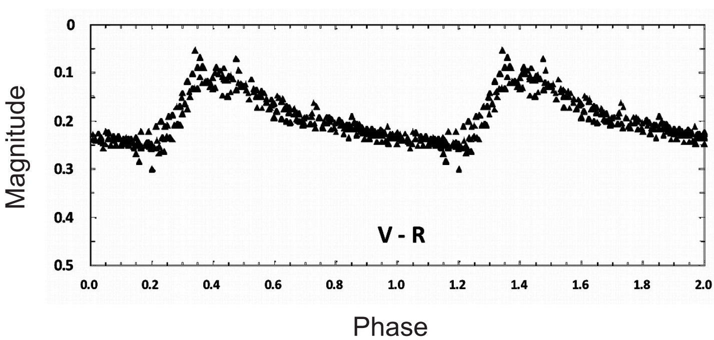

Figure 8. SZ Lyn V–R term.