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HISTORIC FLARES OF THE CATACLYSMIC VARIABLE ASASSN-18AAN

Nesci, Roberto[1]; Tuvikene, Taavi[2]; Gualandi, Roberto[3]

1) INAF/IAPS, via Fosso del Cavaliere 100, 00133 Roma, Italy, roberto.nesci@inaf.it
2) Tartu Observatory, University of Tartu, Observatooriumi 1, Tõravere, Estonia, taavi.tuvikene@ut.ee
3) INAF/OAS, via Gobetti 93/3, 40129 Bologna, Italy

Abstract: The photometric variability of ASASSN-18aan has been studied on 93 pairs of B and I plates of the Asiago Observatory archive. The plates were taken with the Schmidt 65/90 telescopes from 1967 to 1975. The star was found generally around $B = 17.5$ mag, near the plate limit, but on four plates was definitely brighter. The I plates showed a light curve consistent with the B ones. We therefore confirm the cataclysmic-variable nature of this star, but the sampling is too sparse to firmly establish a recurrence time scale: a value of about 11 months is compatible with the present data. An X-ray counterpart was found in the Swift XRT archive, supporting the classification of the star. An optical spectrum taken in quiescence shows a clear emission at Hα, as expected for a cataclysmic binary.

1 Introduction

ASASSN-18aan (UCAC4 761-008050) was pointed out as a candidate cataclysmic variable on 2018-11-30.2 at $V = 15.28$, by the ASAS-SN collaboration (Shappee et al. 2014, Kochanek et al. 2017). The star's brightness increased from $g = 17.5$ mag to $g = 15.7$ mag in two days. The vsnet-alert network[1] invited the amateur astronomers community to monitor this star: observations by T. Vanmunster (2018) showed the star to be an eclipsing binary with a few hours period, suggesting a classification as UGSU+E type dwarf nova, with an eclipse amplitude about 0.45 mag. Further photometric studies (vsnet-alert 22825) confirmed the binary nature of the star, with a period of 3.586 hours and amplitude of 0.7 mag (Wakamatsu 2018). The star is located at RA=00:46:07.99 DEC=+62:10:04.9 (J2000), and is present in several all-sky catalogs: unfortunately it is not covered by the Catalina Sky Survey DR2. In the recent *Gaia* DR2 catalog (Gaia Collaboration 2016, 2018), the formal parallax of the star is 1.48 ± 0.07 mas, yielding a distance estimate of 664 pc, with lower and upper bounds of the confidence interval at 636 pc and 695 pc, respectively (Bailer-Jones et al. 2018). Given the low galactic latitude ($b = -0.7$) the extinction is likely rather patchy, so not easy to evaluate. From the paper by Sale et al. (2014), based on the IPHAS2 catalog, one can derive $A_V \sim 1$ mag at 1 kpc, so from the apparent *Gaia* G magnitude (16.8) the absolute magnitude is $G = +6.3$. From the *Gaia* color index, $G_{\rm BP} - G_{\rm RP} = 1.109$, a temperature of 5000 K is inferred, consistent with a star on the main sequence with subsolar mass, as expected for a cataclysmic variable.

To look for past flares of this star we searched in the Asiago and Heidelberg[2] plate archives. In the Asiago archive we found 93 pairs of blue and infrared plates, taken with

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[1] http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/22086
[2] http://dc.zah.uni-heidelberg.de/lswscans/res/positions/fullplates/form

Table 1: Sampling of the Asiago plate archive.

Season	Time span	Plates	Days
1967/68	203	15	13.5
1968/69	231	14	16.5
1969/70	262	14	18.7
1970/71	264	11	24
1971/72	139	8	17
1974/75	232	13	18
1975/76	176	13	13.5

the Schmidt 65/92 telescope. The plates were taken for a search of Mira variables in a field centered on Gamma Cas in the years 1967–1975 and were digitized at step of 1.52 arcsec/pixel for a previous paper (Nesci et al. 2018). The blue plates have Kodak 103aO emulsion, some with and some without the GG13 filter; the infrared plates have I-N emulsion and RG5, giving a good match respectively to the Johnson B and Bessel I photometric bands.

In the APPLAUSE DR3 archive[3] we found 12 plates of the Hamburg 80/120 cm Schmidt telescope taken on 11 different days in the years 1956 and 1958. Plates were taken in the U band (103aO+UG1), R band (OaO+RG1, Agfa H-alpha), and V band (OaO+GG5). Automatic photometry is available for all these plates, processed with the PyPlate software that were developed for the APPLAUSE project (Tuvikene et al. 2014). In no case the star appeared to be bright, with average values $U = 18.0$ mag, $V = 17.1$ mag. On the red plates the star was always near the plate limit, so its photometry is less reliable, but we can surely exclude a high state.

2 Plates photometry

The sampling of the Asiago light curve may be grouped into seven 'observing seasons', as given in Table 1: column 1 is the group number, column 2 the time span in days, column 3 the number of plates, column 4 is the average time interval between plates in the group. There are also a few plates outside these dense groups. From this Table appears that the sampling is not uniform, ranging from 13 days to 24 days. Outbursts shorter than the sampling may easily escape detection, while outbursts longer than 2 months should be detectable.

For the blue plates, a comparison sequence was first established using the stars of the UCAC4 catalog (Zacharias et al. 2013) within a radius of 6 arcmin, down to the catalog limit of $B = 17.1$ mag; aperture photometry of the stars was performed with IRAF/apphot with a 2 pixel (3 arcsec) radius. The calibration curve was fairy well fitted with a straight line only for stars below $B = 16$ mag, with RMS dispersion of 0.15 mag: our variable was very often fainter than $B = 17$ mag, so that its magnitude was extrapolated on the calibration curve.

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[3] `https://doi.org/10.17876/plate/dr.3`

We checked our results using the PanSTARRS DR1 catalog (Chambers et al. 2016) which is deeper than the UCAC4 and allows to reach stars near the limit of the Asiago plates: as comparison we used the g magnitudes, despite the not strict match of the passband with the Asiago emulsion/filter combination. From a comparison of the 224 stars in common in the two catalogs in this field we found that the PanSTARRS DR1 g magnitudes are on average 0.5 mag brighter than the UCAC4 B ones, and 0.5 mag fainter than the UCAC4 V ones.

The calibration curve was well represented by a straight line for stars fainter than $g = 15.6$ mag, giving a larger baseline for the fit than the UCAC4, with a typical RMS dispersion of the comparison stars of 0.12 mag. Besides a few underexposed plates, the limiting magnitude was about $g = 17.5$ mag. We did not find appreciable systematic differences in the comparison stars magnitudes between filtered and unfiltered plates.

The star was always detected, but often near the plate limit: only in four plates it was definitely brighter, two of them at a few days apart. The relevant data are reported in Table 2. We therefore detected three outbursts in the eight-year monitoring period of the Asiago plates.

For the Asiago I plates, photometric reduction was carried out with the PyPlate software, using the UCAC4 catalog for comparison: more details may be found in Nesci et al. (2018). The I plates were less deep, between $I = 16.0$ mag and $I = 16.5$ mag; as our star is among the bluest in the field, often it was not detected. For three of the four dates when the star was bright, there is a corresponding detection on an I plate, confirming the bright state, so excluding a blue plate defect.

In Table 2, we report the plate number in column 1, the Modified Julian Day in column 2, the g magnitude in column 3, its error in column 4, the I magnitude in column 5, the I error in column 6.

For completeness, in Table 3 we report the full list of available blue plates: column 1 is the plate number, column 2 the Modified Julian Day, column 3 the filter, column 4 the emulsion.

Finally, we have checked the Palomar Schmidt plates available from the STScI in the B, V, R, and I bands: in all these plates the star magnitude was similar to the values reported in the PanSTARRS DR1 catalog ($g = 17.5$ mag, $r = 16.8$ mag, $i = 16.6$ mag).

3 X-ray counterpart

We checked in the Swift archive available from the Italian Space Science Data Centre (SSDC)[4] if the source was serendipitously detected. The sky area was indeed observed several times in 2015 by Swift for an INTEGRAL follow-up program with the XRT and UVOT instruments. The four longest exposures ranged from 2500 to 4400 seconds, taken from February 18 to April 17. A faint source was always visible in the XRT instrument, consistent with the nominal position of ASASSN-18aan, with count rate about 0.005 c/s, constant within the accuracy limits. No spectral analysis is possible due to the low counts detected. The source was also seen by UVOT with the W2 filter (the only one used in

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[4] http://www.ssdc.asi.it

Table 2: Observed outbursts of ASASSN-18aan.

Plate	MJD	g	g_{err}	I	I_{err}
1898	40152.82	16.0	0.16	15.7	0.2
2544	40486.11	15.8	0.16	15.4	0.2
2548	40487.08	15.8	0.17		
3590	40822.91	15.6	0.15	15.4	0.2

Table 3: Available blue plates of the Schmidt 65/92 cm telescope in the Asiago archive. All plates have the emulsion 103aO.

Plate	MJD	Filter	Plate	MJD	Filter	Plate	MJD	Filter
729	39673	—	2503	40474.96	—	6602	41929.93	GG13
746	39682.07	—	2544	40486.11	—	6613	41931	GG13
765	39687.07	—	2548	40487.08	—	6622	41934.07	GG13
794	39704.99	—	2580	40502.87	—	6638	41952.91	GG13
820	39716.98	—	2656	40508.85	—	6650	41953.85	GG13
839	39739.04	—	2767	40535.78	—	6700	41960.1	GG13
850	39740.03	—	2856	40561.81	—	6755	41978.88	GG13
875	39760.95	—	2972	40588.74	—	7001	42059.81	GG13
885	39762	—	3099	40624.83	—	7098	42072.84	GG13
925	39767.02	—	3168	40673.79	—	7115	42098.81	GG13
940	39769.03	—	3451	40775.05	—	7142	42127.79	GG13
996	39788.74	—	3519	40801	—	7324	42274.03	GG13
1130	39828.98	—	3533	40802.86	—	7407	42302.02	GG13
1312	39875.79	—	3559	40805.02	—	7433	42304.01	GG13
1702	40042.02	—	3590	40822.91	—	7453	42306.01	GG13
1740	40059.01	—	3792	40885.88	—	7457	42306.1	GG13
1785	40119.07	—	4136	40950.89	—	7479	42317.08	GG13
1806	40124.98	GG13	4157	40977.87	—	7520	42338	GG13
1835	40144.82	—	4222	41003.78	—	7611	42370.86	GG13
1863	40149.83	GG13	4240	41009.78	—	7649	42388.87	GG13
1872	40150.8	—	4241	41010.78	—	7705	42397.85	GG13
1898	40152.82	GG13	4267	41039.81	—	7794	42424.87	GG13
1969	40184.89	—	4463	41133.97	—	7841	42450.77	GG13
2060	40209.87	—	4572	41178.93	—	8041	42659	GG13
2111	40228.79	—	4584	41180.09	GG13	8065	42662.94	GG13
2153	40242.78	—	4608	41182.96	—	8079	42680.84	GG13
2192	40262.76	—	4680	41216.94	—	11165	44912	GG13
2427	40412.01	—	4821	41247.74	—	11213	44928.9	GG13
2434	40413.05	GG13	4938	41272	—	11266	44939.86	GG13
2464	40417.02	—	5569	41547	—	12738	46059.79	GG13
2488	40428.05	—	6527	41895	GG13	15697	49333.88	GG13

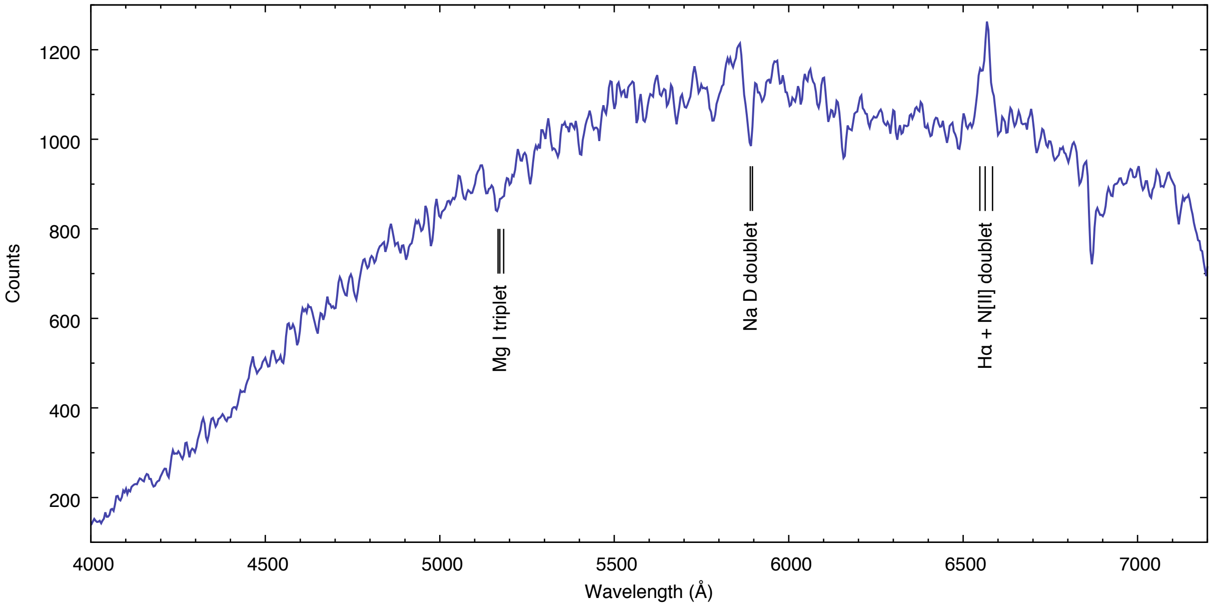

Figure 1: Spectrum of ASASSN-18aan calibrated in wavelength. Ordinate is in arbitrary counts.

those pointings, with effective wavelength of 200 nm) at a magnitude $W2 = 20.67 \pm 0.12$. We recall that at this wavelength the extinction may well be of 8–9 magnitudes. The X-ray and the far UV detection of ASASSN-18aan strongly supports its nature of cataclysmic variable.

4 Optical spectroscopy

To further check the nature of the star we made an optical spectrum at 4 Å resolution with the 1.5-m telescope of the Loiano Observatory on February 5, 2019, when the star was back in quiescence ($R = 16.7$ mag). The spectrum is shown in Fig. 1 and shows a broad emission at Hα, blended with the N[II] doublet 6548–6584 Å. The total equivalent width of the blend is 7.9 Å. No other emission lines are evident. The Mg b triplet and the Na D doublet, typical of G–K type stars, are present. A much higher signal-to-noise ratio would be necessary for a more accurate spectral type classification. Overall, the spectrum is compatible with that expected for the companion of an X-ray binary with subsolar mass, consistent with the absolute magnitude derived above from the *Gaia* parallax.

5 Tentative outburst recurrence estimate

There is an interval of 333 days between the first two high states, and of 336 days between the second and the third one, so a recurrence time scale of about 11 months could be inferred. If these outbursts were periodic, there should be nine high states, including the three detected, in the time span covered by our plates. We report in column 1 of Table 4 the expected dates; in column 2 the nearest available plate, MJD and magnitude;

Table 4: Periodicity check of ASASSN-18aan from the Asiago plates.

Expected MJD	Nearest plate MJD (plate, g-mag)	Preceding plate days before (plate, g-mag)	Following plate days after (plate, g-mag)
39820	39829 (1130, 17.2)	-25 (996, 17.5)	+55 (1312, 17.5)
40153	40153 (1898, 16.0)	-3 (1872, 17.2)	+31 (1969, 17.0)
40486	40486 (2544, 15.8)	-12 (2503, 16.8)	+16 (2580, 16.9)
40819	40823 (3590, 15.6)	-18 (3559, 17.2)	+62 (3792, 17.2)
41152	41134 (4463, 17.3)	-94 (4267, >17.5)	+44 (4572, 16.9)
41485	seasonal gap		
41818	seasonal gap		
42151	42128 (7142, 16.5)	-29 (7115, 17.1)	+146 (7324, 17.1)
42484	42451 (7841, 17.3)	-26 (7794, 17.3)	+208 (8041, 17.2)

in column 3 the distance in days of previous plate, the plate number and magnitude; in column 4 the same for the following plate. No plates are available for two dates of this Table due to the seasonal gap. Besides the well established high states reported in Table 2, a possible brightening may have happened around MJD 42128 (plate 7142, $g = 16.5$ mag).

About the outbursts duration, only loose upper limits can be derived for this Table. From the ASAS-SN public data we derive that the 2018 outburst duration was of the order of 20 days, fully compatible with our upper limits.

From the data in Table 4 we cannot exclude a recurrence of about 11 months for the outbursts of this source. The last 1000 days of ASAS-SN public data have large seasonal gaps, lasting about five months. The present outburst happened near the end of the observing season, so in principle previous outbursts at 11-month intervals might have been undetected due to falling in the seasonal gaps. Further monitoring of this star is necessary to establish the existence of a typical time scale for its outbursts. If the 11 months recurrence is true, the next outbursts are expected around the dates of 2019-10-30, 2020-09-30 and 2021-08-30.

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