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ASASSN-22ak: *La Belle au bois dormant* in a hydrogen-depleted dwarf nova?

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Abstract

ASASSN-22ak is a transient discovered by the All-Sky Automated Survey for Supernovae and by Gaia in 2022 January. Although this object had been in deep quiescence at least for seven years before this outburst, it has been showing relatively regular long (35–40 d) outbursts with intervals of 132–188 d after the 2022 January outburst. This "waking up" phenomenon appears similar to the very unusual (hydrogen-rich) WZ Sge star V3101 Cyg. Time-resolved photometry during the 2023 outburst detected low-amplitude (0.05 mag) superhumps with a period of 0.042876(3) d. ASASSN-22ak appears to be very similar to CRTS J112253.3−111037, which is known to have a very low mass ratio and is considered to be an object evolving close to AM CVn stars as inferred from the low hydrogen and high helium content. ASASSN-22ak is likely yet another object having an evolved core and strongly depleted hydrogen in the secondary. The case of ASASSN-22ak strengthens the idea that a considerable fraction of AM CVn stars are formed from evolved cataclysmic variables. Both ASASSN-22ak and V3101 Cyg before the initial outbursts were probably in dormant states with low quiescent viscosity or low mass-transfer rates. The current "high" states of ASASSN-22ak and V3101 Cyg may have been induced by radiation during the initial outburst or these objects are simply returning to ordinary states, either in terms of quiescent viscosity or mass-transfer rates. We also provide updated superhump period and estimated mass ratio for CRTS J112253.3−111037.

1 Introduction

In the famous fairy tale *La belle au bois dormant* (the Beauty in the Sleeping Forest or the Sleeping Beauty), a princess was cursed by an evil fairy to sleep for a hundred years before being awakened by a prince (Perrault 1697). This tale produced one of the world most famous ballets composed by Pyotr Tchaikovsky (Tchaikovsky 1889)[1]. The similar things appear to have happened in the world of dwarf novae. The giant outburst and subsequent superoutbursts in V3101 Cyg = TCP J21040470+4631129 (Tampo et al. 2020; Hameury and Lasota 2021) could

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[1] The reference refers to the earliest publication of this work in the form of a score of Aleksandr Ziloti's arrangement for solo piano according to Tchaikovsky's letter (<https://en.tchaikovsky-research.net/pages/The_Sleeping_Beauty>). The premiere at the Mariinsky Theatre was performed in 1890.

be a signature of long "dormant" phase before the initial outburst. MASTER OT J030227.28+191754.5 (Tampo et al. 2023; Kimura et al. 2023) might be another such example. Here, we report on an instance of ASASSN-22ak, which may be the first similar case in a cataclysmic variable (CV) with an evolved core in the secondary.

2 ASASSN-22ak

ASASSN-22ak was discovered as a dwarf nova by the All-Sky Automated Survey for Supernovae (ASAS-SN: Shappee et al. 2014) at g=15.0 on 2022 January 7.[2] The object further brightened and reached the peak of g=13.2 on 2022 January 8. The object apparently faded rapidly after this (there was a 6-d gap in observation in ASAS-SN). When the object was observed again on 2022 January 16 by Gaia (=Gaia22afw)[3], the object faded to G=15.16. This outburst was announced in VSNET (Kato et al. 2004) by Denis Denisenko (vsnet-alert 26518)[4]. According to this, this outburst was also detected by MASTER-OAFA (Lipunov et al. 2010) at 13.8 mag on 2022 January 9. The object underwent another outburst at 15.4 mag on 2022 July 20 detected by one of the authors (RS) (vsnet-alert 26875)[5] and 16.2 mag on 2022 December 18 (by RS, vsnet-alert 27223)[6]. After these two outbursts, the unusual light curve of this object received attention (vsnet-alert 27224).[7] The ASAS-SN light curve suggested that all outbursts were superoutbursts. Although the similarity to V3101 Cyg and the possibility of an AM CVn star, as judged from the short recurrence time of long outbursts, were discussed, the nature of the object remained elusive. One of the authors (BM) obtained a single-night run during the 2022 January outburst and a possible period of 0.044 d was suggested (vsnet-alert 27225).[8] This period, however, did not comfortably fit what is expected for a WZ Sge star and the reality of the period remained to be confirmed. During the 2022 December outburst, one of the authors (FJH) obtained time-resolved photometry, which also suggested a period of 0.0412 d (vsnet-alert 27243).[9] This suggestion of a period, however, remained unconfirmed since the object faded soon after these observations and the amplitudes of the variations were small. The sudden fading of 1.8 mag (corresponding to more than 2.0 mag d^{-1}) on 2022 December 29 was sufficient to convince us that the 0.0412 d, but not its double, is the true period (vsnet-alert 27258).[10]

These outbursts, however, left us important lessons and we started observations following the detection of another outburst at 15.2 mag on 2023 April 29 by RS. FJH obtained time-resolved photometry. The sampling rate, however, was initially insufficient to detect a period. After increasing the sampling rate on 2023 May 13, the detected period was confirmed to be the same as in the previous outbursts. The log of observations is summarized in table 1.

3 Long-term behavior

The long-term light curve of ASASSN-22ak using the survey data and visual observations by RS is shown in figure 1. During Gaia observations between 2015 and 2021, the object very slowly faded. This trend was different from V3101 Cyg before the first outburst (Tampo et al. 2020). The four outbursts starting from 2022 January are seen in the right part of the figure. The quiescent brightness between these outbursts were brighter than Gaia observations before the first outburst. The enlarged light curves of these outbursts are given in figure 2. Near the termination of the third and fourth outbursts, there were a short (less than 1 d in the third and 2 d in the fourth) dip and rebrightening. The presence of such a short dip indicates that the long outbursts were indeed superoutbursts of a system with a short orbital period, not long outbursts seen in SS Cyg stars. We should note that the post-outburst observations after the 2022 December outburst (third panel in figure 2) were biased brighter since aperture photometry could measure the object only on limited number of frames. The true magnitudes should be fainter (see the fourth panel in figure 2, which were observed under more ideal conditions).

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[2] <https://www.astronomy.ohio-state.edu/asassn/transients.html>.
[3] <http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia22afw/>.
[4] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/26518>.
[5] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/26875>.
[6] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27223>.
[7] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27224>.
[8] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27225>.
[9] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27243>.
[10] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27258>.

Table 1: Log of observations of ASASSN-22ak.

Start*	End*	Mean mag.	Error	$N^\dagger$	Observer	Filter
59598.2841	59598.3620	2.235	0.010	216	MLF	C
59935.5072	59935.6519	16.046	0.010	53	HaC	CV
59936.5080	59936.6481	16.048	0.008	52	HaC	CV
59937.5084	59937.6458	16.132	0.010	51	HaC	CV
59938.5085	59938.6430	16.155	0.007	50	HaC	CV
59939.5086	59939.6400	16.267	0.009	49	HaC	CV
59940.5093	59940.6373	16.341	0.009	47	HaC	CV
59941.5090	59941.6354	16.458	0.011	47	HaC	CV
59942.5094	59942.6304	18.287	0.065	45	HaC	CV
59943.5101	59943.6251	18.603	0.085	25	HaC	CV
59944.5240	59944.6141	18.968	0.086	16	HaC	CV
59945.5244	59945.6241	19.013	0.083	15	HaC	CV
59946.5282	59946.6212	18.933	0.091	15	HaC	CV
59947.5178	59947.5941	18.674	0.146	10	HaC	CV
59949.5672	59949.5847	18.393	0.224	4	HaC	CV
59950.5702	59950.6130	17.830	0.209	6	HaC	CV
59951.5256	59951.6045	18.293	0.104	13	HaC	CV
60065.8612	60065.9208	15.366	0.029	12	HaC	CV
60066.8591	60066.9203	15.431	0.017	11	HaC	CV
60067.8564	60067.9177	15.523	0.012	11	HaC	CV
60069.8509	60069.9176	15.571	0.020	13	HaC	CV
60070.8480	60070.9215	15.670	0.019	13	HaC	CV
60071.8453	60071.9189	15.690	0.026	13	HaC	CV
60072.8425	60072.9221	15.686	0.011	14	HaC	CV
60073.8382	60073.9208	15.728	0.011	19	HaC	CV
60074.8355	60074.9227	15.755	0.015	20	HaC	CV
60075.8342	60075.9208	15.785	0.025	16	HaC	CV
60076.8298	60076.9222	15.747	0.012	21	HaC	CV
60077.7851	60077.9234	15.951	0.003	178	HaC	CV
60078.7822	60078.9245	15.992	0.003	183	HaC	CV
60079.7794	60079.9239	16.012	0.003	186	HaC	CV
60080.7767	60080.8968	16.005	0.003	155	HaC	CV
60081.7739	60081.8964	16.077	0.037	151	HaC	CV
60082.7711	60082.8968	16.041	0.003	162	HaC	CV
60083.7690	60083.8965	16.063	0.004	84	HaC	CV
60085.7670	60085.9041	15.901	0.004	99	HaC	CV
60086.7615	60086.9034	15.962	0.004	89	HaC	CV
60087.7579	60087.9040	15.921	0.004	202	HaC	CV
60088.7551	60088.9048	15.920	0.002	244	HaC	CV
60089.7523	60089.9052	15.903	0.003	249	HaC	CV
60090.7495	60090.9050	15.956	0.009	232	HaC	CV
60092.8064	60092.9059	16.005	0.003	164	HaC	CV
60093.7412	60093.9065	16.077	0.003	270	HaC	CV
60094.7384	60094.9061	16.160	0.002	274	HaC	CV
60095.7357	60095.9062	16.242	0.003	278	HaC	CV
60096.7328	60096.9070	16.294	0.003	284	HaC	CV
60097.7301	60097.9073	16.317	0.004	289	HaC	CV
60098.7273	60098.9071	16.300	0.004	293	HaC	CV
60099.7245	60099.9079	16.209	0.005	299	HaC	CV
60100.7217	60100.9077	16.122	0.004	303	HaC	CV
60101.7190	60101.9078	16.133	0.004	308	HaC	CV
60102.7162	60102.9082	16.261	0.004	313	HaC	CV
60103.7134	60103.9086	18.188	0.024	315	HaC	CV

*BJD−2400000.

†Number of observations.

Table 1: Log of observations of ASASSN-22ak (continued).

Start*	End*	Mean mag.	Error	$N^\dagger$	Observer	Filter
60104.7108	60104.9081	19.279	0.031	171	HaC	CV
60105.4868	60105.6093	16.652	0.009	75	HaC	CV
60106.4773	60106.6080	16.698	0.007	80	HaC	CV
60107.8310	60107.9077	19.809	0.042	66	HaC	CV
60109.9030	60109.9059	19.834	0.332	3	HaC	CV
60110.8900	60110.9064	19.841	0.096	15	HaC	CV
60111.8828	60111.9063	19.681	0.078	19	HaC	CV
60112.8835	60112.9057	19.863	0.081	20	HaC	CV
60113.8873	60113.9123	19.694	0.082	24	HaC	CV
60114.8995	60114.9265	19.957	0.095	18	HaC	CV
60117.9123	60117.9315	19.857	0.088	13	HaC	CV
60118.8955	60118.9272	20.018	0.074	23	HaC	CV
60119.8928	60119.9246	20.002	0.067	22	HaC	CV
60120.8901	60120.9267	19.943	0.069	34	HaC	CV
60121.8871	60121.9266	19.993	0.058	29	HaC	CV
60122.8845	60122.9269	19.978	0.075	31	HaC	CV
60124.8790	60124.9262	19.924	0.071	30	HaC	CV
60125.8780	60125.9261	19.903	0.074	34	HaC	CV

*BJD−2400000.

†Number of observations.

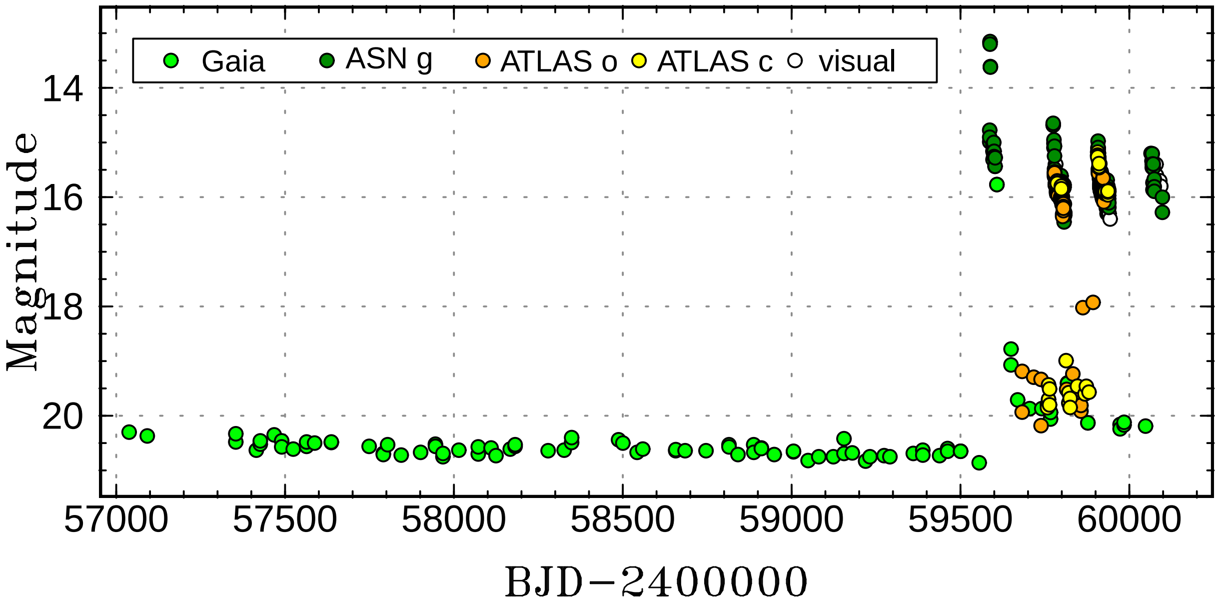

Figure 1: Long-term light curve of ASASSN-22ak.

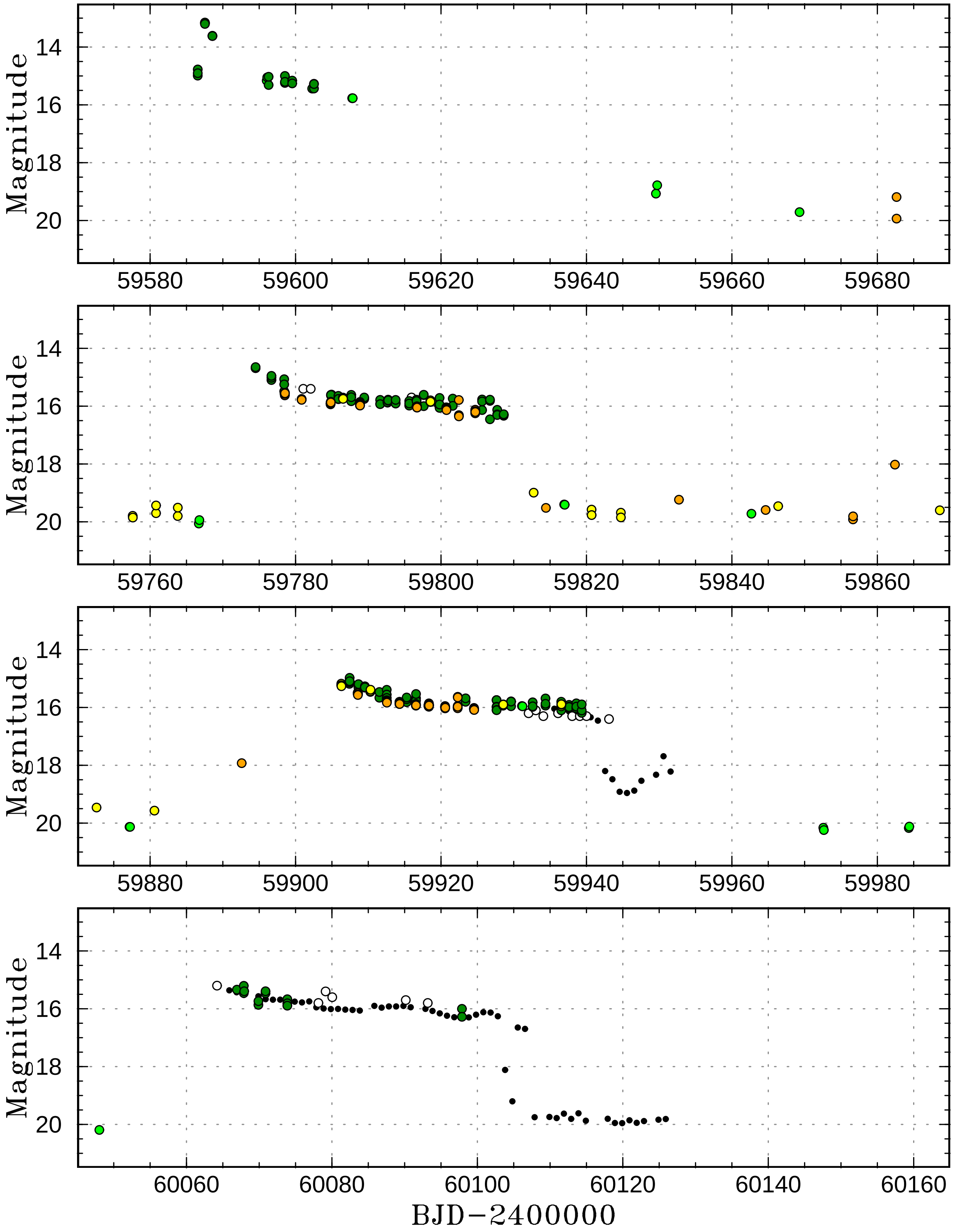

Figure 2: Light curves the outbursts of ASASSN-22ak. The peaks of the outbursts are not aligned to show the existing data between the outbursts better. The symbols are the same as in figure 1. The small dots represent nightly averaged unfiltered CCD magnitudes by FJH. Near the termination of the third and fourth outbursts, there were a short (0.5–2 d) dip and rebrightening. ASAS-SN did not detect the object 1-d before the initial detection (upper limit 17.0 mag).

4 Superhumps

We analyzed the best observed 2023 outburst. We used locally-weighted polynomial regression (LOWESS: Cleveland 1979) to remove long-term trends. The periods were determined using the phase dispersion minimization (PDM: Stellingwerf 1978) method, whose errors were estimated by the methods of Fernie (1989); Kato et al. (2010). The result before the dip (2023 June 8, BJD 2460103), after excluding the scattered data on 2023 May 17 (BJD 2460081–2460082) is shown in figure 3. The period obtained by this analysis is 0.042876(3) d. The variation of the profiles in 2023 is shown in figure 4. The amplitude of the variations increased on BJD 2460088 (2023 June 23), which corresponded to temporary brightening from the fading trend (see figure 2). Based on the amplitude variation correlated with the overall trend similar to SU UMa stars (Kato et al. 2009) and the gradual shift in the phase of peaks, we identified these variations to be superhumps, not orbital variations.

An analysis of less observed outburst in 2022 December during the plateau phase is shown in figure 5. Note that these 7-night observations recorded only the terminal portion of the outburst and the statistics were not ideal. The phase plot assumes a period of 0.042876 d, which is allowed as one of the aliases as seen in the PDM analysis.

5 Discussion

5.1 Comparison with hydrogen-rich WZ Sge stars

As we have seen, there was no evidence of an outburst in ASASSN-22ak before 2022 (at least for seven years based on ASAS-SN and Gaia observations). The object suddenly became active and repeated superoutbursts with cycle lengths of 132–188 d. No very similar object has been known. V3101 Cyg is somewhat analogous in that it repeated four superoutbursts (up to the time of the writing) following the 2019 large outburst. The case of V3101 Cyg is different in that short rebrightenings were also observed (Tampo et al. 2020). The initial (2019) outburst of V3101 Cyg showed a relatively rapidly fading phase, which is the viscous decay phase characteristic to WZ Sge stars (Kato 2015). The initial (2022 January) outburst of ASASSN-22ak had a similar feature, reaching $\sim$2 mag brighter than subsequent outbursts and which apparently faded rapidly. The second and third outbursts of ASASSN-22ak had similar, but less distinct, features. The same feature was almost lacking in the fourth outburst (figure 2). These features suggest that the first outburst of ASASSN-22ak was a strong WZ Sge-type one and that the second and third ones were weaker WZ Sge-type ones, although early superhumps (Kato 2015) were not directly observed during any of these outbursts.

The superhump period of 0.042876 d should be close to the orbital period (see also discussions later). This period is rather too short for a hydrogen-rich CV. If ASASSN-22ak is a hydrogen-rich CV, the orbital period should break the record of 0.0462583 d in OV Boo (Littlefair et al. 2007; Patterson et al. 2008; Uthas et al. 2011; Ohnishi et al. 2019), which is considered to be a population II CV. We consider the possibility of ASASSN-22ak being a population II CV less likely since the transverse velocity of ASASSN-22ak is 20% of OV Boo (Gaia Collaboration et al. 2022) (but still with a 28% 1-σ error in the Gaia parallax) and because of the difference in the light curve (lack of short rebrightenings, long durations of superoutbursts compared to supercycles) from the hydrogen-rich V3101 Cyg. ASASSN-22ak would then be more likely a hydrogen-depleted CV. There are two possibilities. It could be either an EI Psc star (CV with an evolved core in the secondary but still with considerable surface hydrogen) or an AM CVn star in which the surface hydrogen of the secondary is almost lost. We consider these possibilities in more detail.

5.2 Comparison with EI Psc stars in general

EI Psc has an orbital period of 0.0445671(2) d (Thorstensen et al. 2002) very similar to ASASSN-22ak. EI Psc, however, has a hot, luminous secondary (Thorstensen et al. 2002), whose quiescent color (Gaia $GP-RP$=+0.88) is much redder than in ASASSN-22ak ($GP-RP$=+0.16). Another EI Psc-type object V418 Ser [superhump period 0.04467(1) d] has $GP-RP$=+0.52 and this object shows outbursts similar to hydrogen-rich CVs (Kato et al. 2015; Vogt et al. 2021). The properties of V418 Ser look different from those of ASASSN-22ak. CRTS J174033.4+414756 (orbital period 0.045048 d) has $GP-RP$=+0.43 and the outburst behavior (Kato et al. 2014, 2015; Chochol et al. 2015; Imada et al. 2018) appears moderately similar to ASASSN-22ak. CRTS J174033.4+414756 indeed showed a bright WZ Sge-type outburst in 2023 February after 5-yr quiescence (vsnet-alert 27373).[11] Not sufficient time has

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[11] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27373>.

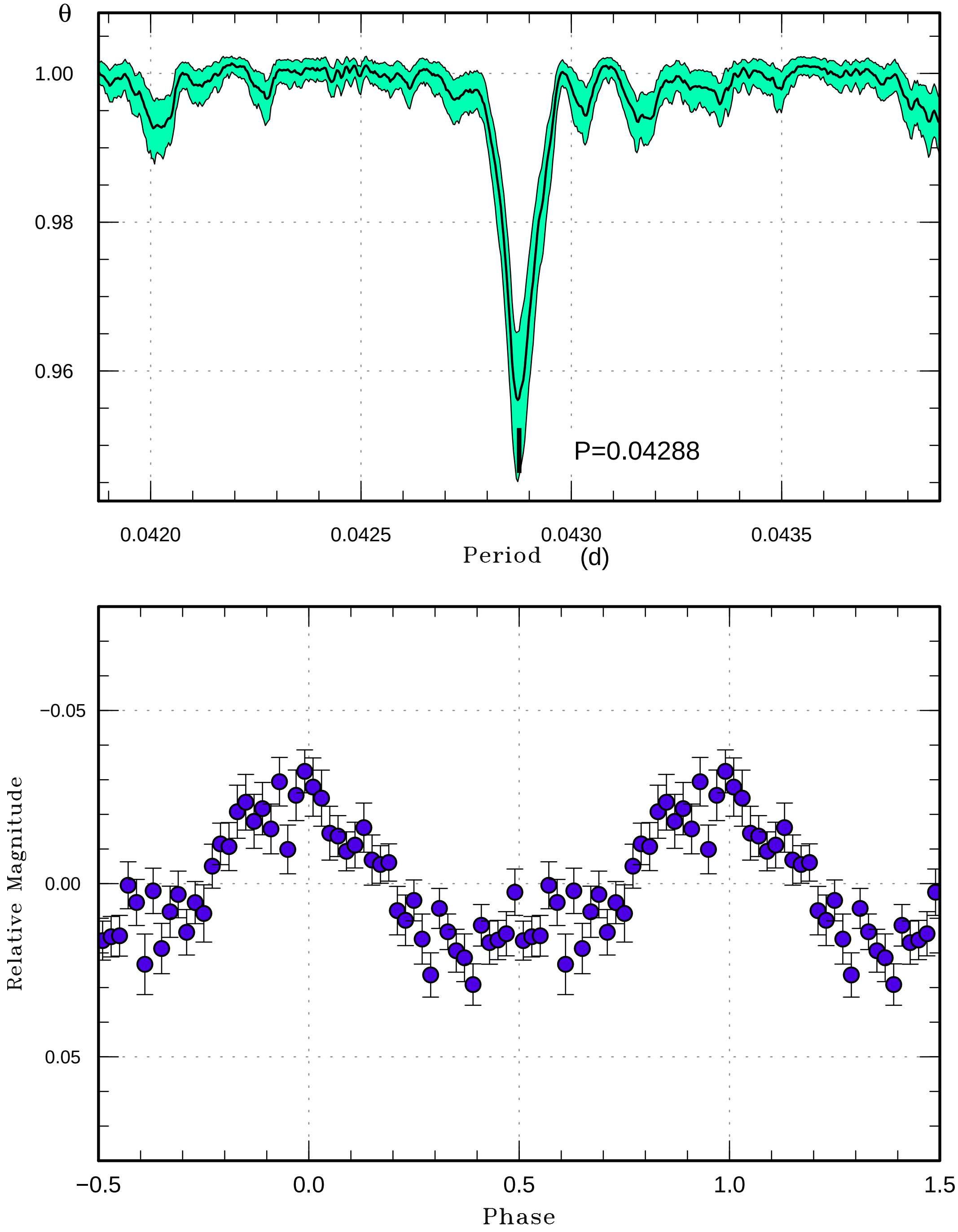

Figure 3: Superhumps of ASASSN-22ak in 2023. (Upper): PDM analysis. The bootstrap result using randomly contain 50% of observations is shown as a form of 90% confidence intervals in the resultant θ statistics. (Lower): Phase plot.

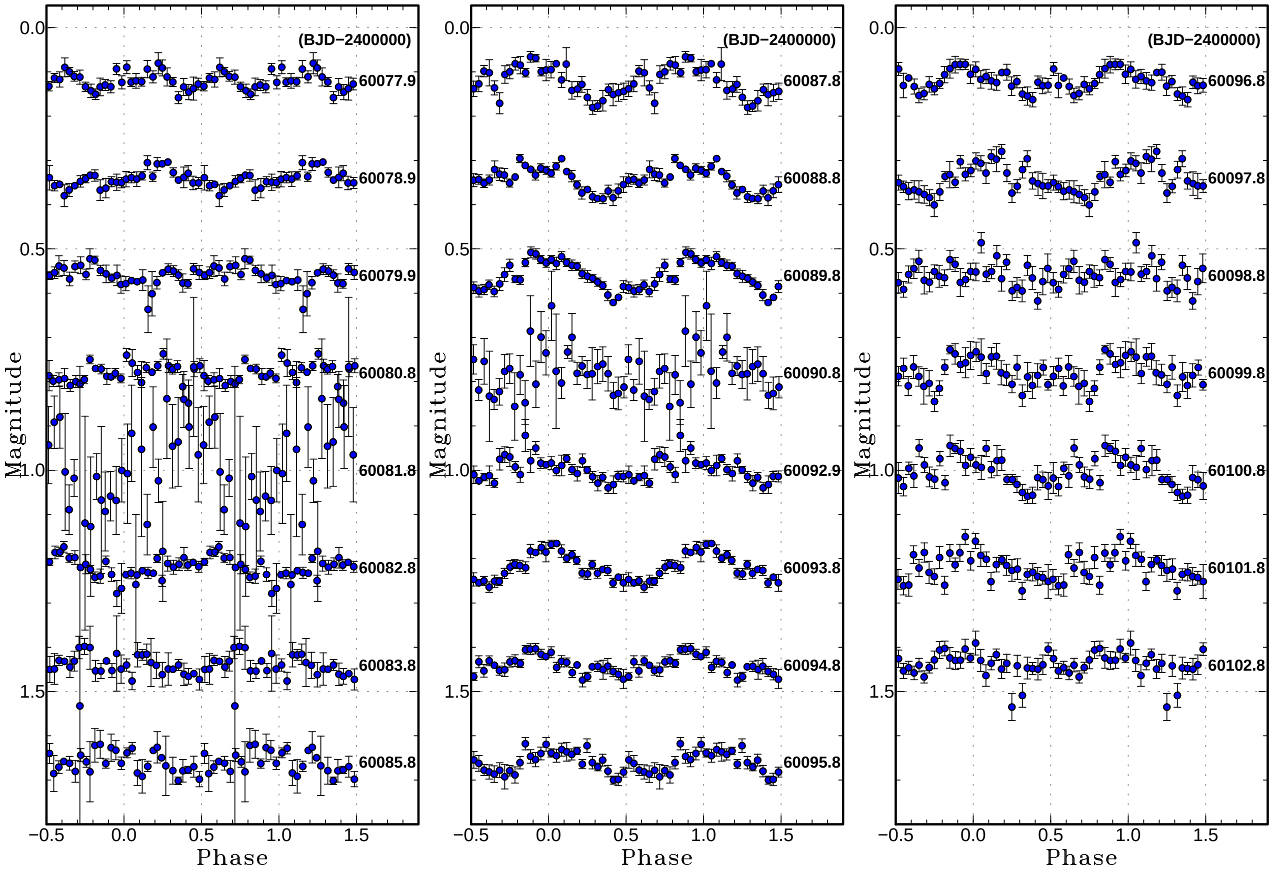

Figure 4: Variation of the superhump profile in 2023. Superhumps of ASASSN-22ak in 2023. The epoch is arbitrarily assumed to be BJD 2460089.800 and the period of 0.042876 d is used.

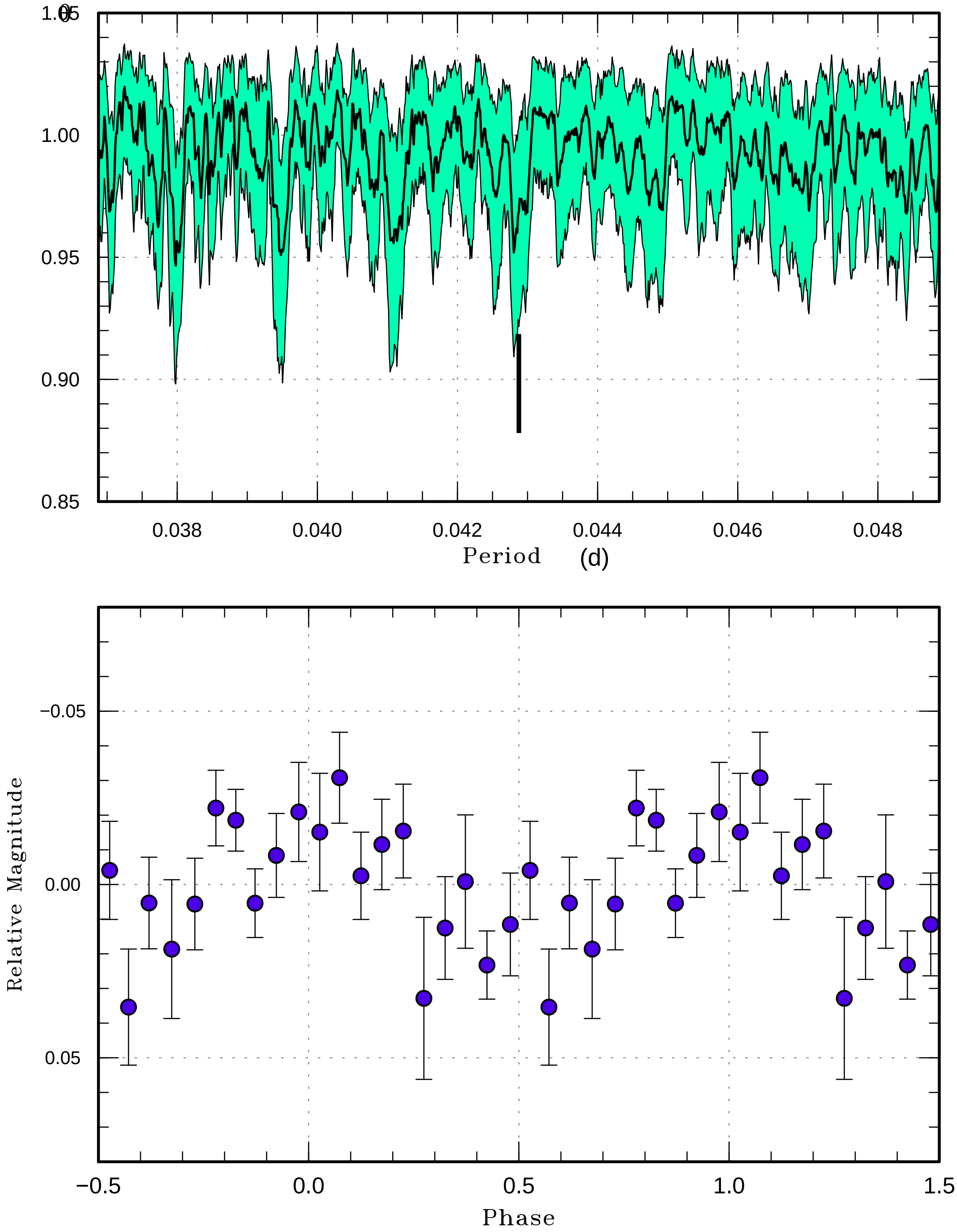

Figure 5: Superhumps of ASASSN-22ak in 2022 December. (Upper): PDM analysis. The tick is shown at the superhump period obtained by the 2023 observations. (Lower): Phase plot.

passed since this outburst and it is unknown whether CRTS J174033.4+414756 behaves like ASASSN-22ak. The known differences between CRTS J174033.4+414756 and ASASSN-22ak are that the former shows superhumps with much larger amplitudes, which suggests a higher mass ratio [q=0.077(5) was obtained by (Imada et al. 2018)], and the redder color in quiescence. Although CRTS J174033.4+414756 would be a good candidate for an already known object having properties similar to ASASSN-22ak, particularly with a bright superoutburst after 5-yr quiescence, the secondary in ASASSN-22ak appears to be fainter and less massive.

5.3 Comparison with CRTS J112253.3−111037

The object most similar to ASASSN-22ak appears to be CRTS J112253.3−111037 (Breedt et al. 2012). This object has an orbital period 0.04530 d and a very small fractional superhump excess $\epsilon \equiv P_{\rm SH}/P_{\rm orb} - 1$, where $P_{\rm SH}$ and $P_{\rm orb}$ represent superhump and orbital periods, respectively. The secondary in CRTS J112253.3−111037 was undetected in contrast to other EI Psc stars. The Gaia color $GP - RP$=+0.10 is also very similar to that of ASASSN-22ak. Although $P_{\rm SH}$ was reported in Kato et al. (2010), this value is vital to this discussion and we re-analyzed the data in Kato et al. (2010), in which the modern de-trending method was not yet employed. The resultant period was 0.045409(9) d (figure 6). This value corresponds to ϵ=0.0024(2). In the treatment by Breedt et al. (2012), old ϵ-q calibrations, which did not consider the pressure effect, were used and they obtained an exceptionally small q. Using the modern calibration in table 4 of Kato (2022) considering the pressure effect (but calibrated using hydrogen-rich systems), this ϵ corresponds to q=0.043(1) assuming stage B superhumps [for superhump stages, see Kato et al. (2009)]. There remains a possibility that the observed superhumps were stage C ones since observations only recorded the final part of the outburst. The periods of stage B superhumps are generally longer by 0.5% than those of stage C superhumps in hydrogen-rich systems (Kato et al. 2009). If stage B superhumps were missed and we only observed stage C superhumps, this q value would be an underestimate. By artificially increasing the superhump period by 0.5%, the resultant q becomes 0.058(1), which should be regarded as the upper limit. In actual WZ Sge stars, stage C tends to be missing (Kato et al. 2009; Kato 2015), and we consider that the first value [q=0.043(1)] is expected to be closer to the real one.

CRTS J112253.3−111037 is also similar to ASASSN-22ak in terms of the low frequency of outbursts (Breedt et al. 2012). There was no information how the 2010 outburst in CRTS J112253.3−111037 started due to an ∼50 d observational gap in the CRTS data (Drake et al. 2009) and it is unknown whether CRTS J112253.3−111037 showed a sharp peak or a viscous decay phase. No repeated superoutbursts like ASASSN-22ak, however, appear to have been present since then. It might be interesting to note that ATLAS and ASAS-SN data show that CRTS J112253.3−111037 showed brightening with a broad peak reaching g=17.8 around 2022 June 6 (BJD 2459737). The entire event lasted ∼15 d and this may be similar to the enhanced quiescent activity in the AM CVn star NSV 1440 (Kato and Stubbings 2023), possibly signifying the similarity to AM CVn stars.

The small amplitude of superhumps (0.05 mag) in CRTS J112253.3−111037 is also similar to ASASSN-22ak (0.05 mag), implying a similarly low q in ASASSN-22ak.

Breedt et al. (2012) suggested a possibility that CRTS J112253.3−111037 had already evolved past its period minimum based on Podsiadlowski et al. (2003) and that its secondary can be semidegenerate. Although this conclusion was apparently partly based on q smaller than the one obtained in the present paper, we agree that both ASASSN-22ak and CRTS J112253.3−111037 are evolving close to AM CVn stars since the properties of these objects are very different from other EI Psc objects with similar orbital periods (subsection 5.2). ASASSN-22ak may have already lost hydrogen and it may even be an AM CVn star. If this is the case, ASASSN-22ak breaks the longest record of orbital periods in AM CVn stars showing a genuine superoutburst [see also the discussion in Kato and Stubbings (2023); superhump period of 0.0404–0.0415 d in ASASSN-21au = ZTF20acyxwzf (vsnet-alert 25369;[12] Isogai et al. 2021; Rivera Sandoval et al. 2022)]. Another AM CVn star with a long orbital period [PNV J06245297+0208207 in 2023 (Maehara 2023): superhump period 0.035185(8) d (vsnet-alert 27353[13])] showed a superoutburst very similar to ASASSN-21au. This morphology of superoutbursts appears to be common to AM CVn stars with long orbital periods and the possibility of ASASSN-22ak as being an AM CVn star might be less likely. We leave this question open since the outburst properties were so unusual in ASASSN-22ak. In any case, spectroscopy of ASASSN-22ak to determine the hydrogen and helium content and to determine the orbital period is very much desirable. The addition of ASASSN-22ak seems to strengthen the idea that cataclysmic variables could be the dominant progenitors of AM CVn binaries (see, e.g., Sarkar et al. 2023; Belloni and Schreiber 2023).

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[12] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/25369>.

[13] <http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/27353>.

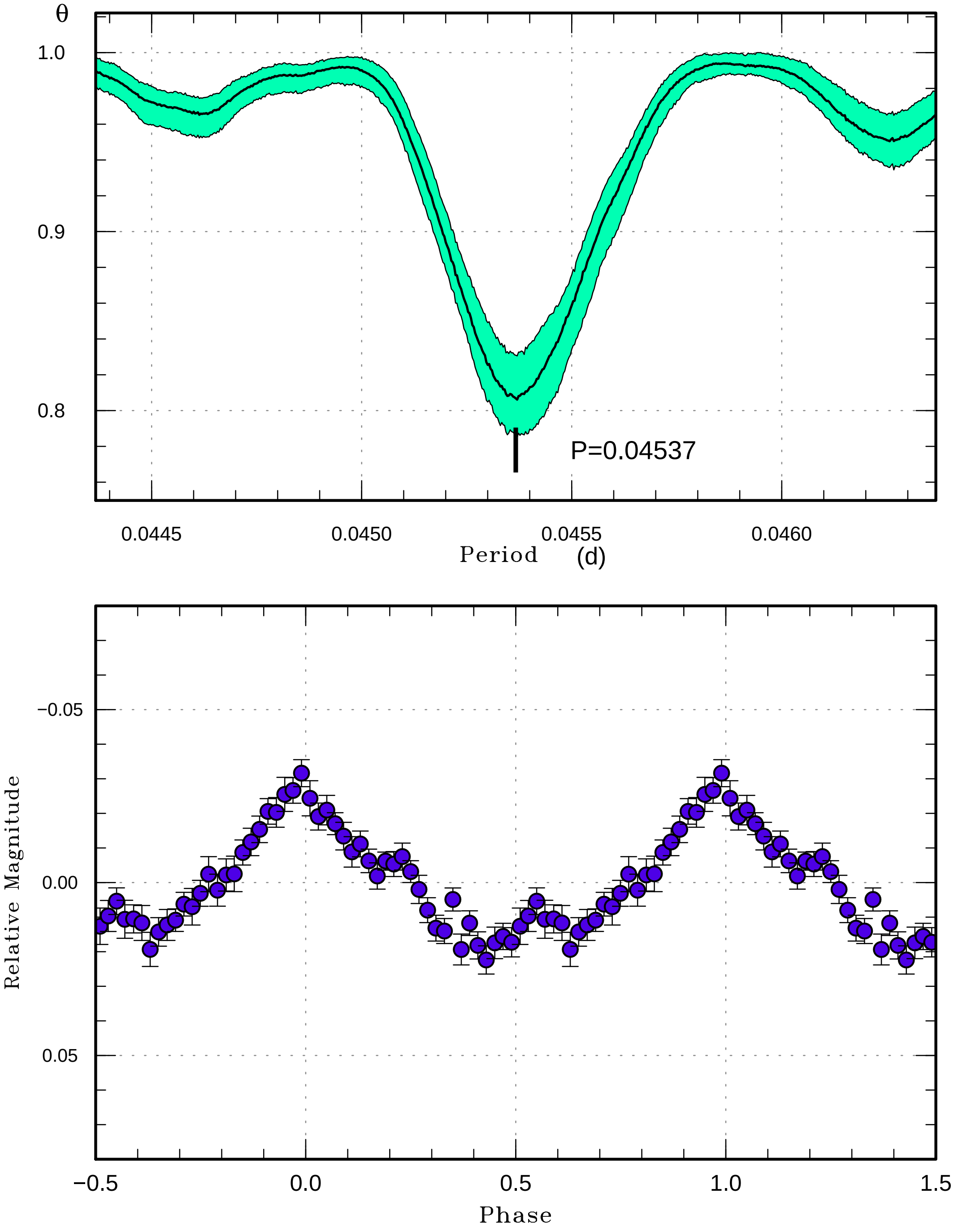

Figure 6: Superhumps in CRTS J112253.3−111037 during the 2010 superoutburst. (Upper): PDM analysis. (Lower): Phase plot.

Table 2: Comparison of objects treated in this paper.

Object	Period (d)*	$BP-RP$	M_G	$q^\dagger$	Superhump amplitude (mag)
EI Psc	0.0445671	+0.88	10.0	0.171	0.16
V418 Ser	0.04467(1)$^{\mathrm{S}}$	+0.52	10.3(5)	–	0.06
CRTS J174033.4+414756	0.045048	+0.43	11.0(3)	0.077(5)	0.17–0.03
CRTS J112253.3−111037	0.04530(1)	+0.10	11.1(10)	0.043(1)	0.05
ASASSN-22ak	0.042876(3)$^{\mathrm{S}}$	+0.16	12.1(5)	–	0.05

*Superscript s refers to superhump period.

†Value estimated from ϵ assuming stage B.

The EI Psc-type objects treated in this paper for comparisons with ASASSN-22ak are summarized in table 2. The mean superhump amplitude for EI Psc was obtained from the data in Uemura et al. (2002). The superhump amplitudes for V418 Ser and CRTS J174033.4+414756 were from Kato et al. (2015) and Imada et al. (2018), respectively. Although CRTS J174033.4+414756 showed the initial phase of large superhump amplitudes (Imada et al. 2018), no such a phase was recorded in ASASSN-22ak. The q values from ϵ assuming stage B were obtained by the method in Kato (2022).

5.4 Pre-outburst dormancy and repeated superoutbursts

Repeated long superoutbursts with short recurrence times is the unique feature of ASASSN-22ak. In the case of (hydrogen-rich) V3101 Cyg, some of post-superoutburst rebrightenings may have been caused by the matter in the disk left after the main superoutburst (Tampo et al. 2020). Repeated superoutbursts appear to be more easily explained if the mass-transfer rate increased after the initial outburst (Hameury and Lasota 2021). This increase in the mass transfer may either have been caused by irradiation of the secondary by the initial outburst (Hameury and Lasota 2021), or it could have been that the quiescent viscosity of the disk before the initial outburst was simply extremely low to accumulate a large amount of mass in the disk and that the mass-transfer rate and the quiescent viscosity is simply returning to the normal value of this object after the initial outburst.

In the case of ASASSN-22ak, the initial outburst was not as strong as in V3101 Cyg, although the peak was bright, and the mechanism may be different from the case of V3101 Cyg. In ASASSN-22ak, q would be smaller than in V3101 Cyg (as inferred from the smaller amplitude of superhumps and from the analogy with CRTS J112253.3−111037) and the weaker tidal effect would make it more difficult to maintain superoutbursts in contrast to V3101 Cyg. Although there have been a suggestion that smaller q can lead to premature quenching of superoutbursts (see e.g., Hellier 2001), there is no established theory when superoutbursts end. Although this premature quenching of superoutbursts might explain the repeated superoutbursts with relatively short intervals, the lack of post-superoutburst rebrightenings in ASASSN-22ak might be problematic. It may be that the hydrogen depletion in the disk of ASASSN-22ak is not as strong as AM CVn stars and long superoutbursts are easier to maintain than in almost pure helium disks. A combination of effects of all these circumstances, unusual for ordinary CVs, should be a challenging target for theorists working with the disk-instability model.

The pre-outburst dormancy might be easier to explain in ASASSN-22ak. In contrast to V3101 Cyg, which is expected to have a fully convective secondary, ASASSN-22ak has an evolved core and a magnetic dynamo can still work (see e.g., Sarkar et al. 2023) and is probably necessary to form the observed AM CVn stars within reasonable time. With such a dynamo, the instantaneous mass-transfer rate can be different from the secular average, as seen in the spread of absolute magnitudes in CVs above the period gap (Dubus et al. 2018) and the presence of VY Scl stars. There is also a possibility that the quiescent viscosity of the disk before the initial outburst was simply very low and the viscosity increased after the outburst as proposed by Osaki et al. (2001); Meyer and Meyer-Hofmeister (2015) for hydrogen-rich WZ Sge stars. This explanation, however, might face a difficulty to realize a very quiet, low-viscosity disk when the secondary has a seed magnetic field, which may increase the quiescent viscosity of the disk via the magneto-rotational instability (cf. Meyer and Meyer-Hofmeister 1999; but see also Ishioka et al. 2001). High and low states in polars (AM Her stars: Cropper 1990) may provide additional insight. EF Eri has a brown-dwarf secondary (Schwope and Christensen 2010, and the references therein) and a strong magnetic activity cycle as in CVs above the period gap is not expected. This object showed (and still showing) a long-lasting high state (just like “awakening”) starting from 2022 December (vsnet-alert 27205).[14] Since polars do not have an accretion disk, storage of mass in the disk before the active (high) state, as in WZ Sge stars, is impossible. There could be a reservoir of additional angular momentum other than the disk, and this might also explain the dormany/waking-up phenomena in dwarf novae.

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List of objects in this paper

OV Boo, AM CVn, SS Cyg, V3101 Cyg, EF Eri, AM Her, EI Psc, VY Scl, V418 Ser, SU UMa, WZ Sge, NSV 1440, ASASSN-21au, ASASSN-22ak, CRTS J112253.3−111037, CRTS J174033.4+414756, Gaia22afw, MASTER OT J030227.28+191754.5, TCP J21040470+4631129, ZTF20acyxwzf

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