10-1-2014

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Recommended Citation

Szkody, P., Everett, M., Howell, S., Landolt, A., Bond, H., Silva, D., & Vasquez-Soltero, S. (2014). Follow up observations of SDSS and CRTS candidate cataclysmic variables. *Astronomical Journal, 148* (4)
https://doi.org/10.1088/0004-6256/148/4/63

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Followup Observations of SDSS and CRTS Candidate Cataclysmic Variables*

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ABSTRACT

We present photometry of 11 and spectroscopy of 35 potential cataclysmic variables from the Sloan Digital Sky Survey, the Catalina Real-Time Transient Survey and vsnet-alerts. The photometry results include quasi-periodic oscillations during the decline of V1363 Cyg, nightly accretion changes in the likely Polar (AM Herculis binary) SDSS J1344+20, eclipses in SDSS J2141+05 with an orbital period of 76±2 min, and possible eclipses in SDSS J2158+09 at an orbital period near 100 min. Time-resolved spectra reveal short orbital periods near 80 min for SDSS J0206+20, 85 min for SDSS J1502+33, and near 100 min for CSS J0015+26, RXS J0150+37, SDSS J1132+62, SDSS J2154+15 and SDSS J2158+09. The prominent He II line and velocity amplitude of SDSS J2154+15 are consistent with a Polar nature for this object, while the lack of this line and a low velocity amplitude argue against this classification for RXS J0150+37. Single spectra of 10 objects were obtained near outburst and the rest near quiescence, confirming the dwarf novae nature of these objects.

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*Based on observations obtained with the Apache Point Observatory (APO) 3.5-meter telescope, which is owned and operated by the Astrophysical Research Consortium (ARC).

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1. Introduction

The observational identification of close binaries involving mass transfer from a late main-sequence star to a white dwarf (cataclysmic variables or CVs) has always been hampered by selection effects. The first wide field surveys like the Palomar-Green (Green et al. 1982) concentrated on bright (<16 mag) blue-color objects and so found many high accretion, novalike type systems. The Hamburg Survey (Hagen et al. 1995) used low resolution spectra to identify emission line objects (targeted for quasars) and was able to reach fainter (<17.5 mag) objects with strong emission lines. The Sloan Digital Sky Survey (York et al. 2000) pushed to 21st-22nd magnitude in 5 filters and to about 20th mag in medium resolution spectra and so was able to identify the faintest, shortest period dwarf novae as well as extremely low accretion systems with magnetic white dwarfs (summary in Szkody et al. 2011). While this latter survey and its followup on individual objects provided a means to counter previous biases due to brightness and provide a test of population models (Gänsicke et al. 2009), it suffered from incompleteness and a concentration on CVs out of the galactic plane.

Besides photometric colors and emission lines, the other way to characterize CVs is by their variability, both long term via outbursts and high/low states in novalikes, and short term via orbital variability due to hot spots, eclipses, flickering (a summary of general properties of CVs is contained in Warner 1995). This aspect is being pursued with the recent and ongoing Catalina Real-Time Transient Survey, CRTS (Drake et al. 2009a) which uses 3 different telescopes: a 0.7m Schmidt in the Catalina mountains (CSS) and a 1.5m Cassegrain on Mt. Lemmon (MLS) to cover the northern skies, and a 0.5m Schmidt at Siding Springs (SSS) for the south. The CRTS also avoids the galactic plane but accomplishes long term light curves down to about 20-21st mag. The candidate CVs are made public by the CRTS on their website[1]. Two other all sky surveys that use small wide-field cameras but only reach objects that brighten at outburst are the All Sky Automated Survey (ASAS; Pojmanski (1997), and the Mobile Astronomical System of the Telescope Robots, MASTER (Lipunov et al. 2010). Information about the CV systems discovered in these surveys is usually dispersed via vsnet alerts[2].

While these surveys provide the database to identify CV candidates, the confirmation and specific nature of the type of CV requires detailed followup observations using spectroscopy and orbital lightcurves. These followup data determine whether an accretion disk

[1]crts.caltech.edu/

[2]http://ooruri.kusastro.kyoto-u.ac.jp/pipermail/vsnet-alert/

or the underlying stars contribute most of the light, whether the system is a high excitation novalike showing He II, if it contains a magnetic white dwarf (Polar) showing cyclotron or Zeeman splitting features, and if the the orbital period is long or short. This type of information for a large unbiased all sky survey allows a comparison of observed numbers of CVs in each period range and each category with expectations from population models.

Several groups are now accomplishing followup studies of the available candidate CVs. Woudt et al. (2012) and Coppejans et al. (2014) have published their photometry of 40 southern objects, Thorstensen & Skinner (2012; hereafter TS) have published spectra and photometric colors of 36 northern systems and Breedt et al. (2014; hereafter B14) accomplished spectroscopic identification of 85 additional systems along with a discussion of the CRTS light curves. Since many of the candidates were discovered during outbursts, most are relatively faint for followup at quiescence. TS and B14 compared the available results from CRTS to the SDSS and Ritter-Kolb samples and concluded that the CRTS is biased toward large outburst amplitudes, missing objects that are not dwarf novae. However, the large number of new discoveries shows that there are still many CVs being missed.

Our group has continued to obtain followup photometry and spectroscopy of both the SDSS sample and the CRTS and vsnet alerts to further the task of identifying the nature of the large number of available CV candidates. Our results from 2010-2013 are presented here, which include photometry of 11 CVs (8 from SDSS, one from CRTS and two from vsnet) and spectroscopy of 35 (8 with SDSS spectra, 14 from CRTS that have only SDSS photometry, and 13 from CRTS, MASTER and ASAS that are not in the SDSS database). Time-resolved spectra of 8 objects were obtained, with tentative fits to a sine-curve solution available for seven. Our observations have six overlaps with objects studied by TS: we have spectra of 3 objects that TS have only photometric colors, while their spectral studies of the other 3 occurred during different years/outburst states. As done by the other groups, for simplicity we identify all objects by their 2000 RA and Dec coordinates in Tables 1 and 2 (which allows them to be found in their respective databases) and abbreviate these coordinates in the following text discussion.

2. Observations

Most of the photometric observations were conducted on the KPNO 2.1 m telescope during 2011 May and June. The STA2 CCD was used with either a V or a BG39 filter. Data were also acquired on three nights during 2013 July and October with the UW 0.76m telescope at Manastash Ridge Observatory using a Spyder CCD with a BG40 filter. The data are summarized in Table 1. Reductions were accomplished using IRAF[3] routines under *ccdproc* to flat-field and bias correct the images. Magnitudes of the variables and comparison stars on the same images were then measured using *qphot* and used to construct differential light curves on each night. Due to relatively long readout times and faintness of the targets, the time resolution of most of the light curves is on the order of a minute.

Spectroscopy was primarily accomplished during 2010-2013 using both the KPNO 4 m telescope and the 3.5 m telescope at Apache Point Observatory (APO). At KPNO, the RC-Spectrograph was used with the 2048 CCD T2KA and a 1 arcsec slit. The second order of grating KPC-22b produced a focussed spectrum over 3800-4900Å with a resolution of 0.7Å pixel^{-1}. FeAr lamps were used to calibrate the wavelengths and flux standards were observed. At APO, the Double-Imaging Spectrograph was generally used in high resolution mode to provide simultaneous blue and red spectral coverage with a resolution of 0.6Å pixel^{-1} for blue wavelengths of 3900-5000Å and red wavelengths of 6000-7200Å. On one night (2010 October 2), the low resolution gratings were used, resulting in a resolution of 1.2Å from 3400-9500Å. Flux standards and HeNeAr lamps were used for calibration. On one other night (2010 September 18), the Double Beam Spectrograph on the 5m telescope at Mt. Palomar provided a spectrum with a resolving power of 7700 in the blue and 10000 in the red, with wavelength coverage of 3500-5000Å in the blue and 6200-6800Å in the red. Standards and FeAr and HeNeAr lamps were used for calibration. In all cases, IRAF tasks under *ccdproc*, *apall* and *onedspec* were used to correct the images, extract the spectra to 1-d and calibrate them. For the time-resolved spectra, velocities of the Balmer emission lines were measured with the centroid *e* routine in *splot* and an IDL program was used to find the least-squares fit to a sine-curve. A summary of the spectroscopic observations is given in Table 2 and the radial-velocity fits are summarized in Table 3. A montage of the available useful spectra is shown in Figure 1. As both the KPNO and APO data cover the blue region of the spectrum, Figure 1 is plotted for the region that is common to all spectra.

3. Results for Systems with Light Curves

The following sections provide the photometric and spectroscopic results obtained for the 11 systems with observed light curves (Table 1).

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[3]IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, under cooperative agreement with the National Science Foundation.

3.1. V1363 Cyg

This CV has a peculiar nature which has defied classification. It was classified as a dwarf nova when it was discovered (Miller 1971) but the light curve was peculiar in showing long periods at quiescence near 17.5 mag and also what appeared to be standstills about one magnitude below maximum light that would classify it as a Z Cam star (Warner 1995). Bruch and Schimpke (1992) obtained spectra which showed the typical Balmer emission lines of a CV. Outbursts are relatively rare and have not been well-studied in the past. In 2011 May, V1363 Cyg underwent its first outburst since 1952 as reported by vsnet (Oshima 2011a). Quasi-periodic oscillations (QPOs) from 8.5-10.5 min and amplitude of 0.05 mag were reported from May 8-June 1. On May 30, a longer QPO at 28.8 min was observed (Oshima 2011b). Our light curves in May (Figure 2) show the QPOs, with changes in amplitude noticeable in the longer lightcurves of May 13 and 24.

3.2. RXS0150+37

This counterpart to an x-ray object in Andromeda was found by MASTER and reported by Denisenko (2013a) with archival images showing variability from 15-19th magnitude. A further alert (Denisenko 2013b) reported unusual behavior at a mid-state between 2013 Sept 16-25 that could be indicative of an active Polar. Our 2.8 hrs of photometry on 2013 Oct 29 (Figure 3) show a double-humped modulation at a period of 109 min. The velocities measured from our 1.5 hrs of APO time-resolved spectra on 2013 Oct 2 give a best fit to a sinusoid with period of 103 min and semi-amplitude of 54 km s^{-1} (Table 3 and Figure 3). The lack of the high excitation line of He II, combined with the low semi-amplitude of the radial velocity curve argue for this object being a normal low inclination dwarf nova rather than a Polar.

3.3. SDSS1219+20

This 19th magntitude CV was observed in order to search for possible white dwarf pulsations, as its SDSS spectrum (Szkody et al. 2011) showed broad Balmer absorption lines flanking the emission lines. This type of spectrum is typical in the 16 known accreting white dwarf pulsators. However, our 4 light curves in 2011 May did not reveal any periodic feature that could be ascribed to either pulsation or orbital motion.

3.4. SDSS1344+20

The SDSS spectrum of this 17th magnitude object showed weak Balmer emission lines and a broad hump feature near 5200Å that implied an origin as a cyclotron harmonic from a magnetic white dwarf (Szkody et al. 2011). Time-resolved spectra revealed a large (∼400 km s^{-1}) semi-amplitude variation of the Hα and Hβ lines with an orbital period of 110 and 122 minutes respectively, which was consistent with a Polar nature. Our 3 nights of photometry in 2011 June shown in Figure 4 corroborate this Polar identification, but also show interesting changes during the week timespan. On June 5, a very large (2 magnitude) hump is visible. This feature is typical of an accretion pole passing through the line of sight such as occurs in the Polar VV Pup (Warner & Nather, 1972; Liebert et al. 1978), but the light increases after the passage of the pole. The next night, June 6, shows the hump with less amplitude but longer duration, while 4 days later on June 10, the system has transtioned to most of the time spent in the bright state. This is somewhat reminiscent of the light curves of the Polar CSS071126+440405 (Thorne et al. 2010) which was interpreted as sporadic mass transfer. If the increased mass transfer moves the accretion zone so that it is no longer eclipsed by the white dwarf, the light curve would not have the low segment visible on June 5. The changes in the light curve make the determination of a photometric orbital period difficult, but the features present on June 5 and 6 are most consistent with a period near 100 min.

The spectra obtained in 2011 May and June (Table 2 and Figure 1) also reveal significant changes in accretion. On May 15, the system was in a low state with a featureless spectrum, while the spectra on June 9 and 10 show a flux increase by a factor of 2 as well as increased Balmer line strengths over those in the SDSS spectrum. If the broad hump around 4200Å is a cyclotron hump, its presence together with the one at 5300Å in the SDSS spectrum would imply a field strength of ∼65 MG for harmonics of 4 and 3 (Wickramasinghe & Ferrario 2000).

3.5. SDSS1604+41

While the SDSS spectrum of this g=17.7 mag source shows strong He II (Szkody et al. 2005), the light curve obtained over 1.4 hrs on 2013 July 26 shows no prominent feature, only flickering of a few tenths magnitude.

3.6. SDSS1605+20

The SDSS spectrum of this 19.9 magnitude object (Szkody et al. 2009) shows Balmer absorption surrounding its emission lines. The 5 nights of photometry in 2011 May-June (Figure 5) show a broad feature with an amplitude near 0.08 magnitudes and a period of 75-78 minutes.

3.7. SDSS1659+19

This g = 16.8 mag system also shows a prominent He II line in its SDSS spectrum (Szkody et al. 2006). Its light curve on 2 nights in 2013 July (the longest timespan is shown in Figure 6) shows 10% amplitude flickering as well as a possible hump but further photometry is needed to resolve if this is a periodic occurrence.

3.8. SDSS2052-02

This object was discovered in outburst at V=14 as ASASSN-13cg on 2013 Aug 27 and matched with a blue SDSS g=18.3 object (Stanek 2013), while later vsnet posts suggested a possible AM CVn object. Observations by Littlefield reported by Kato (2013b) revealed a superhump period of 1.4 hrs and shallow (0.1 mag) eclipses. Our light curve 2 months later (2013 Oct 29) obtained near quiescence (Figure 7) shows some variability near 37 min with an amplitude of 0.4 mag although better S/N and a longer timespan will be needed to ascertain if this is related to the orbital period.

3.9. SDSS2141+05

This g = 18.9 mag CV appears in DR10 of the SDSSIII release. The SDSS spectrum is shown in Figure 8. The deep absorption in the Balmer lines, along with the broad absorption flanking the emission is indicative of a system at high inclination and with a low mass transfer rate. Our followup photometry during 2011 June (Figure 9) confirms the high inclination by showing 2 eclipses on each night. While the eclipses are not well-resolved at our time resolution of 194 sec between exposures, the combination of the two nights yields an orbital period of 76±2 minutes.

3.10. CSS/SDSS2154+15

An outburst of this CRTS CV on 2013 June 4 at 17.5 mag was reported by vsnet (Kato 2013a). A light curve showed a prominent single hump feature with a period of 96.9 min. Our light curve 4 months later (Figure 10) shows a similar feature. The large amplitude (1.5 mag) is indicative of a Polar nature for this object.

Our KPNO spectra obtained on 2013 Sept 5 (Figure 1) shows a prominent He II line. The velocities from the 82 min time-resolved spectra were fit to a sine-curve with the period fixed at 96.9 min (Figure 10). The resulting large K amplitudes near 300 km s^{-1} (Table 3) are consistent with a polar. The SDSS photometry obtained in 2009 October gives a fainter magnitude ($g = 18.65$) and blue colors (u-g=0.10, g-r=0.02) which are not consistent with the usual red colors of a polar. However, the system may have been in a low state at the time of the SDSS observations, similar to the low state in EF Eri when the white dwarf dominates the optical light (Wheatley & Ramsay 1998). Polarimetric measurements would confirm that this object harbors a magnetic white dwarf.

3.11. CSS/SDSS2158+09

The CSS light curve of this object shows a bright measurement at 13.2 on June 15, 2010. The rest of the time it resides near 17.6 mag, with a large scatter indicative of orbital variability. This object exists in the SDSS photometric database with blue colors (g=17.51, u-g=0.08, g-r=-0.10). Calibrated V, R, I images by TS provide a comparable V magnitude of 17.48 and V-R=0.13. Our KPNO spectra obtained in 2010 Sept (Figure 1) show prominent deep central absorption in the Balmer emission lines indicative of a high inclination. Our KPNO photometry obtained 9 months later (Figure 11) reveals a large amplitude (0.3 mag) hump feature followed by dips (near UT times of 9 and 10.7 hr) which hint at eclipses but the 4 min integration times do not allow resolution of this feature. A periodogram of these data gives a period of 104 minutes. Using the 12 time-resolved spectra obtained over 2 hrs on 2010 Sept 16, we attempted a radial velocity solution using centroids, gaussians and the line wings of Hβ. Due to the complexity of the line shape and the less than ideal S/N, a good solution could not be determined. The values obtained by fixing the period at values between 100-120 min are listed in Table 3. The semi-amplitudes are typical for dwarf novae but improved data will be needed to pin down the period. Spectra in the red can determine if the secondary is visible.

4. Time-Resolved Spectra of Systems without Light Curves

In addition to the time-resolved spectra for the 3 objects with light curves described above, radial velocities were also obtained for five other systems.

4.1. CSS0015+26

Drake et al. (2009b) identified this 18th mag ROSAT source as a CV when the CSS measured it at 13.3 mag in 2009 Sept. Our KPNO blue spectra over 73 min reveals a typical dwarf nova (Figure 1) with a period near 100 min and a K semi-amplitude near 70 km s^{-1} (Figure 12, Table 3).

4.2. CSS/SDSS0206+20

The CSS identifies a one magnitude variation in this $g = 15.58$ mag SDSS object. The blue colors ($u - g = 0.06, g - r = 0.10$) are consistent with a CV. The KPNO blue spectra obtained in 2013 Sept show the strong Balmer emission lines of a dwarf nova and the 11 time-resolved spectra over 113 min on 6 Sept are fit with a period near 80 min and a K semi-amplitude near 60 km s^{-1} (Table 3, Figure 13). While the photometric amplitude is very low, the other characteristics are typical of a a dwarf nova. It is possible that the variation caught by CSS was not an outburst but just a sporadic accretion event, as objects with such short orbital periods often have outburst frequencies that are tens of years.

4.3. SDSS1132+62

This $g = 18.5$ system showed strong Balmer emission lines in its SDSS spectrum (Szkody et al. 2004). Our 82 min of time-resolved spectra on 2013 Feb 5 reveals a low K semi-amplitude and an orbital period near 100 min (Figure 14, Table 3).

4.4. SDSS1224+18

The SDSS spectrum of this bright 16th mag system shows broad absorption with central narrow emission and was suggested as a possible pre-CV (Szkody et al. 2011).Our 126 min of time-resolved spectra on 2011 May 16 showed no significant radial velocity variation during that interval. The system likely has a long orbital period and/or a low inclination.

4.5. SDSS/CSS1502+33

This object was identified in the SDSS spectra at quiescence (Szkody et al. 2006) as a high inclination, eclipsing system with a period of 84 min. A vsnet alert by Maehara (2011) reported the CSS detection of this system at an outburst mag of 15 (2.5 mag brighter than quiescence) on 2011 June 11. We obtained 4 spectra on June 13 and 8 on June 14 in order to search for a line component that could be from the irradiated secondary star and yield the velocity amplitude of the secondary. The spectra (Figure 1) show much stronger Balmer lines and a much larger flux in the He II line than the quiescent spectra. The Hβ/He II flux and equivalent width ratios on June 13 were 1.25 and 1.29 whereas they were 15 and 7 in the quiescent SDSS spectra. On June 13, the He II line does show a prominent red peak when the Balmer lines have a prominent blue peak (Figure 1). However, the 4 spectra were not enough to resolve a velocity curve and the next night, the peaks in the lines are similar in phase. The radial velocity curves from June 14 (Table 3) have higher amplitudes than the quiescent data (a factor of 2 for Hβ), implying an origin closer to the white dwarf.

5. Spectra at Outburst

Ten of the objects listed in Table 2 and shown in Figure 1 were observed close to their maximum reported brightness. Most of the ones near outburst peak show the typical optically thick accretion disk that is the signature of outburst, with a rising blue continuum and shallow Balmer absorption (ASAS0011+04, CSS0514+08, SDSS0754+38, SDSS0757+22, PNV1915+07, MASTER2355+42). Of these, only CSS0514+08 shows the presence of He II. TS have 3 spectra from 4700-6700Å for this object taken in 2011 January at quiescence which show Hα and Hβ in emission. Three other systems (CSS0353-03, SDSS0518-02 and SDSS2100-02) have flat or decreasing continua in the blue, which may be indicative of large reddening. The presence of emission cores in the Balmer lines of SDSS0518-02 indicates the disk is not at the peak outburst state.

The most interesting outburst spectrum exists for CSS0104-03. The CSS has one recorded outburst of this system in 2009 but (Ohshima 2013) reported an ASAS detection at 16.4 (about 3 mags above the SDSS and CSS quiescent magnitudes) on 2013 Aug 27. The CSS lightcurve does not cover this period of time, but the large spread of magnitudes at quiescence indicates a possible eclipsing system. Our KPNO spectra on 2013 Sep 03 show strong emission lines when the system was still brighter than quiescence.

6. Systems with Strong He II

Figure 1 shows 5 systems with a strong He II emission line (SDSS0756+30, SDSS1232+22, SDSS1502+33, SDSS1519+06, CSS2154+15). Previous sections have discussed SDSS1502+33 and CSS2154+15. The remaining 3 systems were first presented in Szkody et al. (2011). Additonal spectra were taken to determine any changes that would indicate the nature of these objects. All spectra are similar to the past SDSS data, with weak broad Balmer and He II emission lines.

7. Comments on Remaining Spectra

7.1. CSS/SDSS0000+33

CSS found an outburst of this object on 2010 Sept 10. Our KPNO spectrum on Sept 12 shows the typical Balmer absorption lines of an accretion disk at outburst while the Palomar spectrum on Sept 18 shows the lines in emission, indicating that it was a short outburst and the system was already declining to quiescence. The SDSS quiescent g magnitude is 20.5. While the integration time is long, so there is likely velocity smearing, the asymmetric nature of the lines may indicate a prominent hot spot, but a larger telescope is needed for orbital resolution.

7.2. CSS0051+20

The spectrum of this system near quiescence shows an interesting sharp peak in the broad Balmer emission lines. This could be indicative of irradiation of the companion or a hot spot on the accretion disk.

7.3. CSS/SDSS0058+28, CSS0650+41 and CSS1740+41

While these objects are very faint at quiescence, broad lines of Hβ and Hγ are visible. The quiescent g magnitude of SDSS0058+28 is 19.2.

7.4. SDSS0344+09

Szkody et al. (2011) identified this object as a possible CV but with very narrow Balmer lines and a very blue continuum. The KPNO spectrum is very similar to the SDSS one, but extends blueward by 100Å. It is possible that this system is a hot star with an irradiated companion.

7.5. CSS/SDSS0422+33

The asymmetric line shape with a sharp narrow component is typical of CVs with a prominent hot spot. The SDSS quiescent g magnitude is 19.8.

7.6. CSS0501+20

This object also displays the asymmetric profiles and peaks associated with a hot spot component. TS have time-resolved red spectra obtained 4 months after our KPNO data from which they obtained an orbital period of 1.8 hr.

7.7. CSS0647+49

TS obtained time-resolved red spectra in 2011 March that determined an orbital period of 8.9 hrs. Our spectrum shows the blue wavelengths of this source.

7.8. CSS/SDSS2156+19

The spectrum shows prominent, very broad and doubled Balmer emission, indicating a fairly high inclination system. TS obtained 4 images on 2011 June at V=20.83 showing very blue colors (B-V=-0.96). The SDSS photometry shows g=18.5.

7.9. CSS/SDSS2243+08, CSS/SDSS2325-01, CSS/SDSS2338+28

One year after their outbursts, these objects display typical CV spectra with strong, broad Balmer emission. The SDSS photometry provides g magnitudes of 19.6, 18.9 and 18.5

for these 3 objects.

8. Conclusions

Our photometric and spectroscopic observations of CV candidates discovered from SDSS, CRTS and vsnet-alerts have resulted in the confirmation of objects as dwarf novae, novalikes or Polars as well as the determination of unusual properties of a few systems. Our photometry revealed QPOs following the outburst of V1363 Cyg, eclipses in the short period system SDSS2141+05 and likely eclipses in CSS/SDSS2158+09. Our spectra confirm the Polar nature of CSS/SDSS2154+15, show interesting nightly changes in the accretion of the likely Polar SDSS1344+20 and refute the Polar classification of RXS0150+37. These results present systems where further detailed followup is necessary to understand the physical parameters of the binaries. This work also portends the impending problems in accomplishing the necessary followup for future ever larger surveys such as LSST. It will be very difficult to determine the precise nature of the CVs discovered without obtaining both time-resolved spectra and photometry. A single spectrum at quiescence can confirm the CV nature through the Balmer emission lines and the width of the lines and their single or double-peaked nature gives information about the inclination while the strength of He II indicates a high excitation novalike or a magnetic white dwarf. However, the time-resolved data are necessary for the determination of the orbital period through the periodic presence of a hot spot or eclipses in the light curves, or its determination through radial velocity curves which also provide the masses of the underlying stars. These physical parameters are necessary for formulating the correct evolution and population model for close binaries.

PS and SV-S acknowledge support from NSF grant AST-1008734. AL acknowledges NSF grant AST-0803158. H.E.B. thanks the STScI Director's Discretionary Research Fund for travel support. All authors thank the visionaries who created the National Observatory that served the community so well for so many years.

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Table 1. Summary of Photometric Observations

UT Date	Object	Type,P(hr)[a]	Obs	UT	Exp(sec)	Filter	State
2011 May 12	V1363 Cyg	DN	KPNO	10:52-11:46	10	BG39	outburst
2011 May 13	V1363 Cyg	DN	KPNO	09:16-11:48	10	BG39	outburst
2011 May 24	V1363 Cyg	DN	KPNO	09:16-11:26	20	BG39	decline
2013 Oct 29	CSS/SDSS215427+155938	P,1.6	MRO	05:44-07:46	60	BG40	low
2011 Jun 28	CSS/SDSS215815+094709	DN,1.7	KPNO	07:59-11:21	240	V	quies
2013 Oct 29	RXS015017+375614	DN,1.7	MRO	08:14-11:20	35	BG40	quies
2011 May 12	SDSS121913+204938	DN	KPNO	04:33-06:06	30	BG39	quies
2011 May 13	SDSS121913+204938	DN	KPNO	05:15-06:02	30	BG39	quies
2011 May 26	SDSS121913+204938	DN	KPNO	04:49-05:36	30	BG39	quies
2011 May 27	SDSS121913+204938	DN	KPNO	03:28-07:56	60	BG39	quies
2011 Jun 05	SDSS134441+204408	P,1.7	KPNO	04:00-06:25	30	V	quies
2011 Jun 06	SDSS134441+204408	P,1.7	KPNO	03:35-05:59	30	V	quies
2011 Jun 10	SDSS134441+204408	P,1.7	KPNO	03:46-07:12	30	V	quies
2013 Jul 26	SDSS160450+414328	...	MRO	08:26-09:44	60	BG40	quies
2011 May 25	SDSS160501+203056	DN,1.3	KPNO	04:58-05:3	50	BG39	quies
2011 May 25	SDSS160501+203056	DN,1.3	KPNO	08:01-10:02	50	BG39	quies
2011 May 26	SDSS160501+203056	DN,1.3	KPNO	07:51-09:58	50	BG39	quies
2011 May 27	SDSS160501+203056	DN,1.3	KPNO	08:13-09:54	50	BG39	quies
2011 Jun 08	SDSS160501+203056	DN,1.3	KPNO	07:43-08:53	50	BG39	quies
2011 Jun 10	SDSS160501+203056	DN,1.3	KPNO	07:27-09:28	50	BG39	quies
2013 Jul 26	SDSS165951+192745	...	MRO	06:07-08:14	60	BG40	quies
2013 Jul 28	SDSS165951+192745	...	MRO	06:09-07:49	60	BG40	quies
2013 Oct 29	SDSS205252-023952	E,1.4	MRO	03:44-05:22	60	BG40	quies
2011 Jun 29	SDSS214140+050729	E,1.3	KPNO	09:00-11:20	60	V	quies
2011 Jun 30	SDSS214140+050729	E,1.3	KPNO	07:19-09:15	60	V	quies

[a]Provisional type of Dwarf Nova (DN), Polar (P), Eclipsing (E), and orbital period if determined

Table 2. Summary of Spectroscopic Observations

UT Date	Coords	Type,P(hr)[a]	Source	Obs	UT start	Exp(sec)	State
2010 Sep 12	000025+332543	DN	CRTS,SDSS	KPNO	08:27	900	outburst
2010 Sep 18[b]	000025+332543	DN	CRTS,SDSS	Pal	09:26	1200	decline
2013 Sep 03[b]	001133+045122	DN	ASASSN-13ck	KPNO	09:38	900	outburst
2013 Oct 03	001133+045122	DN	ASASSN-13ck	APO	04:37	600	outburst
2010 Sep 14	001538+263657	DN,1.7	CRTS	KPNO	09:04	900	quies
2011 Aug 26[b]	001538+263657	DN,1.7	CRTS	KPNO	11:10	900x3	quies
2011 Aug 29	001538+263657	DN,1.7	CRTS	KPNO	10:29	600x8	quies
2010 Sep 15	005153+204017	DN	CRTS	KPNO	08:27	1200	quies
2013 Jan 16	005825+283004	DN	CRTS,SDSS	APO	02:01	900	quies
2013 Sep 03	010411-031341	DN	CRTS,SDSS	KPNO	10:45	1200x2	outburst
2013 Oct 03	015017+375614	DN,1.7	MASTER	APO	04:55	600x8	high
2013 Sep 01	020633+205707	DN,1.3	CRTS,SDSS	KPNO	11:01	900	out
2013 Sep 05	020633+205707	DN,1.3	CRTS,SDSS	KPNO	11:06	600x5	out
2013 Sep 06[b]	020633+205707	DN,1.3	CRTS,SDSS	KPNO	09:39	600x11	out
2010 Sep 15	034420+093006	...	SDSS	KPNO	09:01	1200	quies
2013 Jan 16	035318-034847	DN	CRTS	APO	03:13	900	outburst
2013 Jan 16	042218+334215	DN	CRTS,SDSS	APO	04:41	900x3	decline
2010 Sep 12	050124+203818	DN,1.8	CRTS	KPNO	11:40	900	quies
2013 Jan 16	051458+083503	DN	CRTS	APO	04:12	600	outburst
2013 Sep 01	051815-024503	DN	CRTS	KPNO	11:51	900	outburst
2010 Sep 12	064729+495027	DN,8.9	CRTS	KPNO	11:00	900	quies
2013 Sep 03	065037+413053	DN	CRTS	KPNO	11:39	750	quies
2013 Feb 05	075418+381225	DN	CRTS,SDSS	APO	02:27	600x2	outburst
2011 May 15	075648+305805	...	SDSS,CRTS	KPNO	03:38	600x2	quies
2013 Apr 01	075713+222253	DN	CRTS,SDSS	APO	03:40	600	outburst
2013 Feb 05	113215+624900	DN,1.7	SDSS	APO	04:39	600x8	quies
2011 May 16	122405+184102	...	SDSS	KPNO	03:50	600x12	quies
2011 Jun 12	123255+222209	...	SDSS	KPNO	03:56	900x3	quies
2011 May 15	134441+204408	P,1.7	SDSS	KPNO	04:40	900x3	low
2011 Jun 09[b]	134441+204408	P,1.7	SDSS	KPNO	04:14	900	high
2011 Jun 10	134441+204408	P,1.7	SDSS	KPNO	04:06	900x2	high
2011 Jun 13[b]	150240+333423	DN,1.4	SDSS,CRTS	KPNO	04:09	600x4	decline
2011 Jun 14	150240+333423	DN,1.4	SDSS,CRTS	KPNO	03:48	480x8	decline
2011 May 16	151915+064529	...	SDSS	KPNO	03:28	600	quies
2011 Jun 11[b]	151915+064529	...	SDSS	KPNO	03:49	600x5	quies
2013 May 05	174033+414756	DN	CRTS	APO	05:49	600x5	outburst
2013 Jun 12	174033+414756	DN	CRTS	APO	05:52	900	decline
2013 Oct 03[b]	174033+414756	DN	CRTS	APO	01:59	900x2	quies
2013 Jun 12	191501+071847	DN	PNV	APO	06:38	300	outburst
2013 Oct 03	210016-024258	DN	CRTS,SDSS	APO	04:13	900	outburst
2013 Sep 01[b]	215427+155713	P,1.6	CRTS,SDSS	KPNO	09:49	1200	out
2013 Sep 05	215427+155713	P,1.6	CRTS,SDSS	KPNO	09:18	600x8	out
2010 Oct 02	215636+193242	DN	CRTS,SDSS	APO	03:26	900	quies
2010 Sep 14[b]	215815+094709	DN,1.7	CRTS,SDSS	KPNO	08:26	900x2	quies
2010 Sep 16	215815+094709	DN,1.7	CRTS,SDSS	KPNO	07:07	600x12	quies
2010 Oct 02	224348+080927	DN	CRTS,SDSS	APO	03:48	900	quies

Table 2—Continued

UT Date	Coords	Type,P(hr)[a]	Source	Obs	UT start	Exp(sec)	State
2010 Oct 02	232551-014024	DN	CRTS,SDSS	APO	05:17	600	quies
2010 Sep 12	233849+281955	DN	CRTS,SDSS	KPNO	10:18	900	decline
2013 Sep 03	235503+420010	DN	MASTER	KPNO	09:57	1200x2	outburst

[a]Provisional type of Dwarf Nova (DN), Polar (P), Eclipsing (E),and orbital period if determined

[b]For multiple observations, denotes spectrum shown in Figure 1

Table 3. Radial Velocity Fits

Object	Line	P(min)	γ(km s^{-1})	K (km s^{-1})	σ (km s^{-1})
001538+26	Hβ	103	-66±3	71±10	19
001538+26	Hγ	99	-53±2	78±9	16
015017+37	Hα	103	96.9±0.4	54±3	5.5
015017+37	Hβ	103[a]	88±1	38±11	21
020633+20	Hβ	81	-58±2	58±8	18
113215+62	Hα	100[a]	-0.7±0.5	34±6	11
113215+62	Hβ	100[a]	-7.2±0.5	20±7	12
113215+62	Hγ	102	-4.8±0.8	29±9	15
150240+33	Hβ	84.83[a]	6±2	104±26	36
150240+33	He II	84.83[a]	13±1	142±14	19
215427+15	He II	97	-44.4±0.1	311±10	17
215427+15	Hβ	97[a]	-2±1	293±51	89
215815+09	Hβ	100-120[a]	-4–14	71-76	27-21

[a]Period fixed at this value

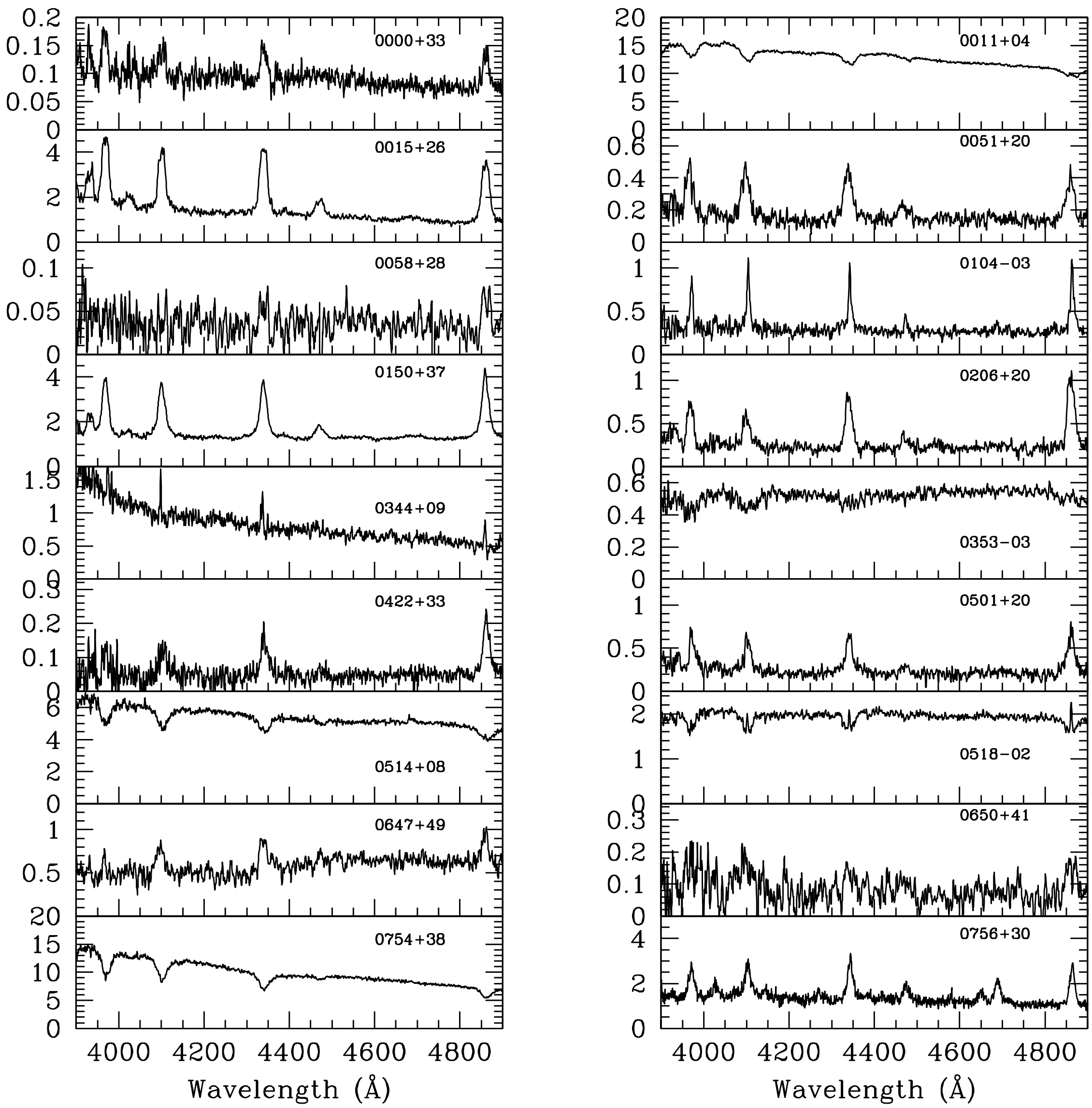


Fig. 1a.— Blue region spectra of sources listed in Table 2. Vertical axes are F_λ in units of 10^{-15} ergs cm−2 s^{-1} $Å^{-1}$. Objects are labelled with first digits of RA and Dec as given in Table 2.

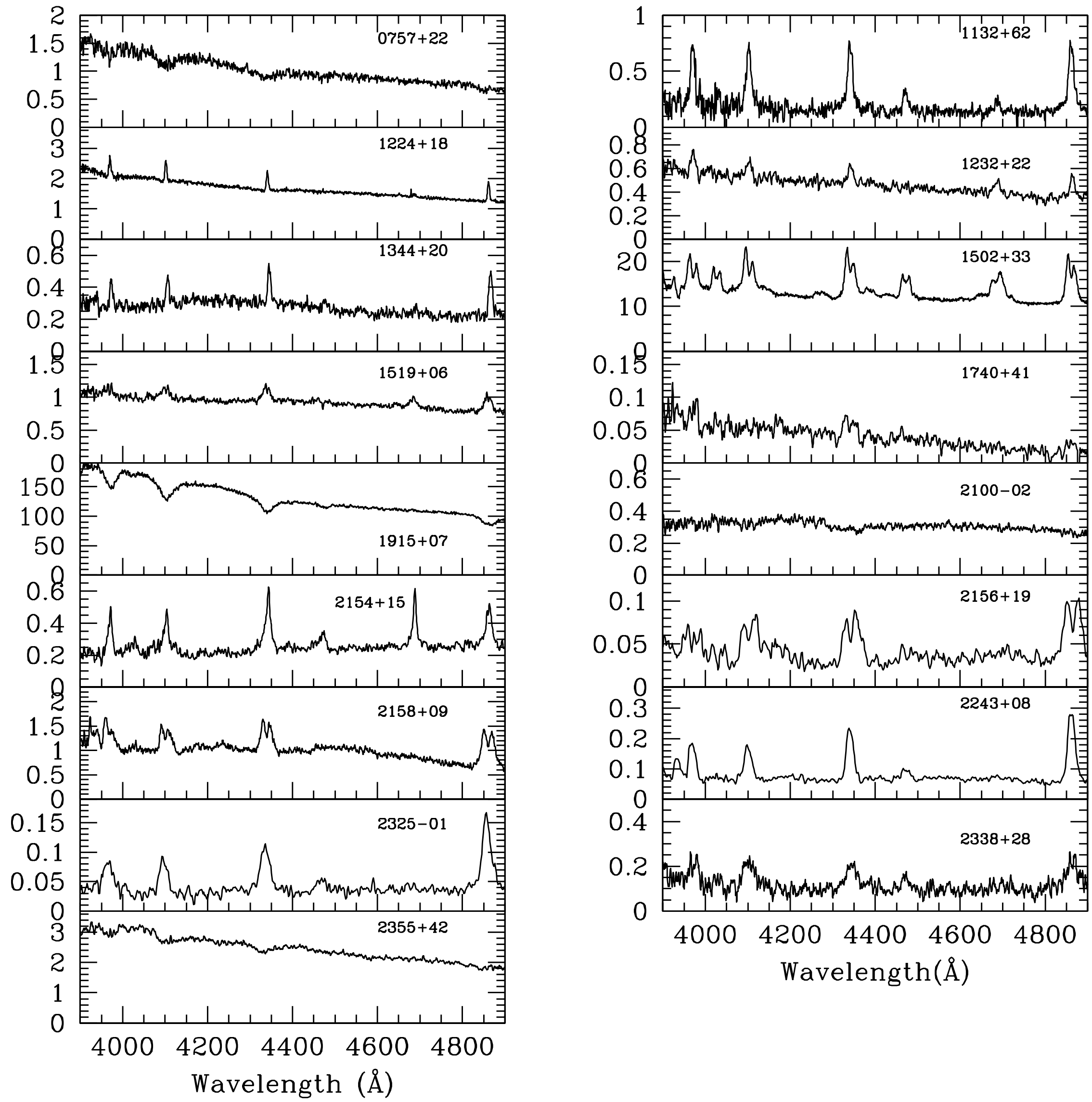


Fig. 1b.— Figure 1 continued.

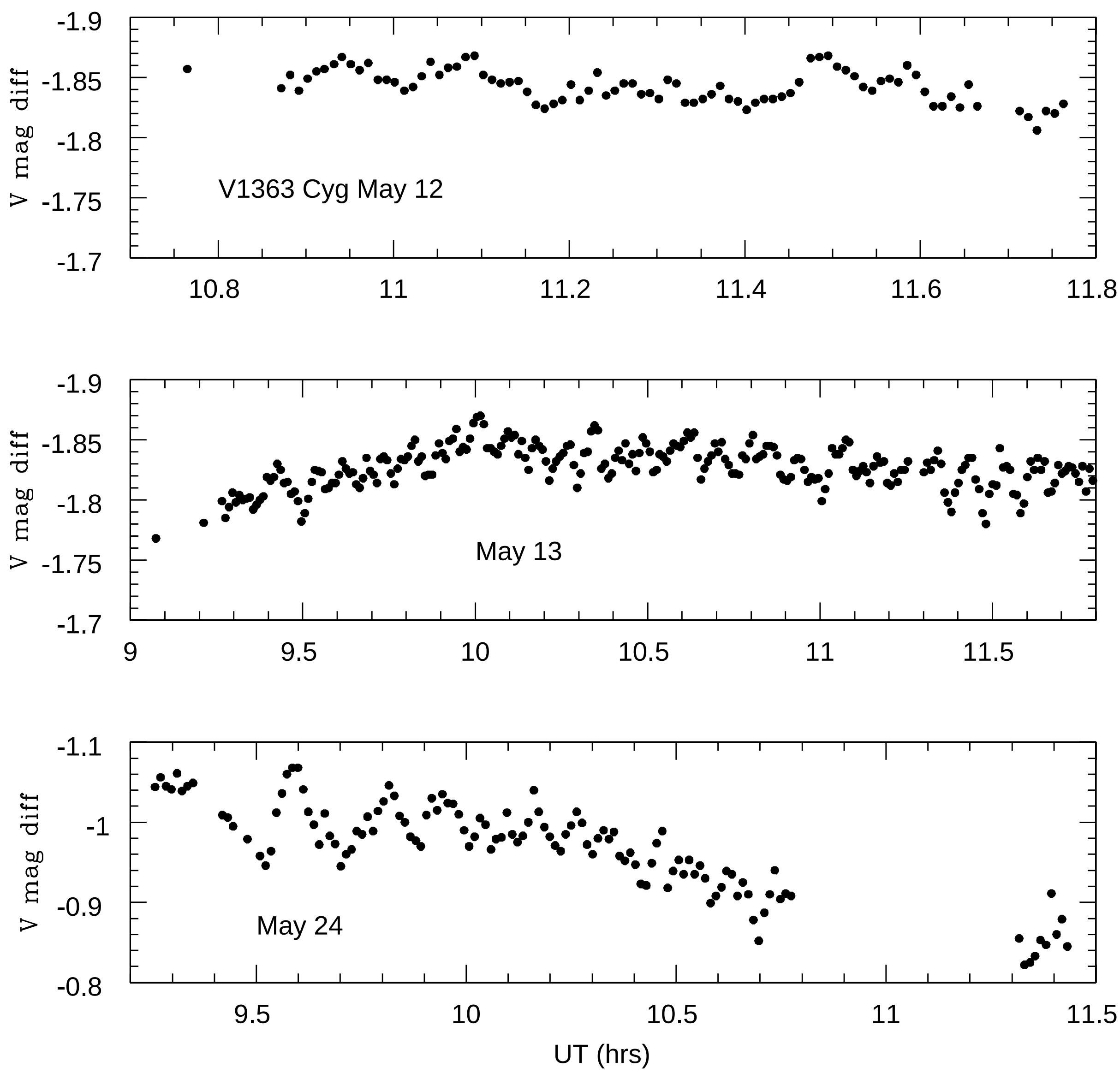


Fig. 2.— KPNO 2011 May data showing the changing oscillations of the dwarf nova V1363 Cyg as the system declined from outburst.

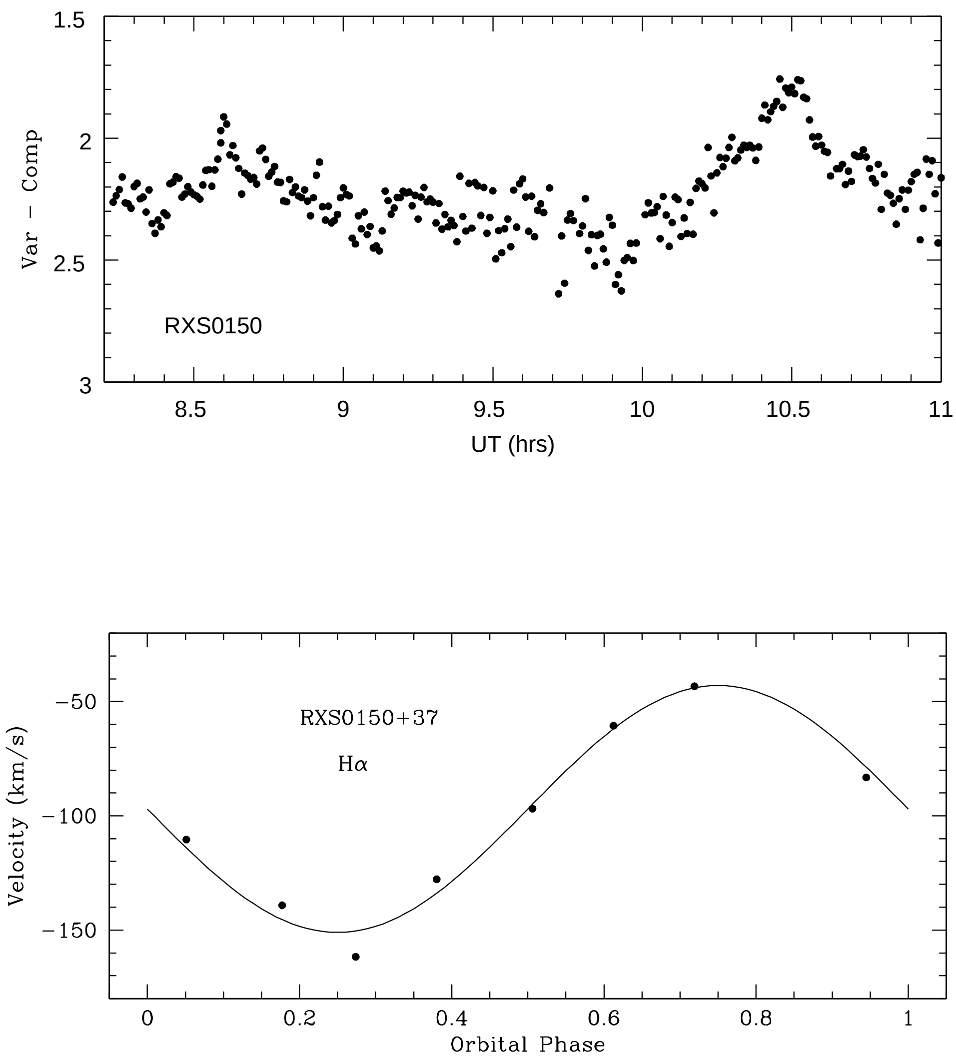


Fig. 3.— Light curve of the dwarf nova RXS0150+37 on 2013 Oct. 29 (top) and radial velocity curve (bottom) from 2013 Oct. 3. Velocity curve is phased with a period of 103 min and best fit sine curve is shown with parameters from Table 3.

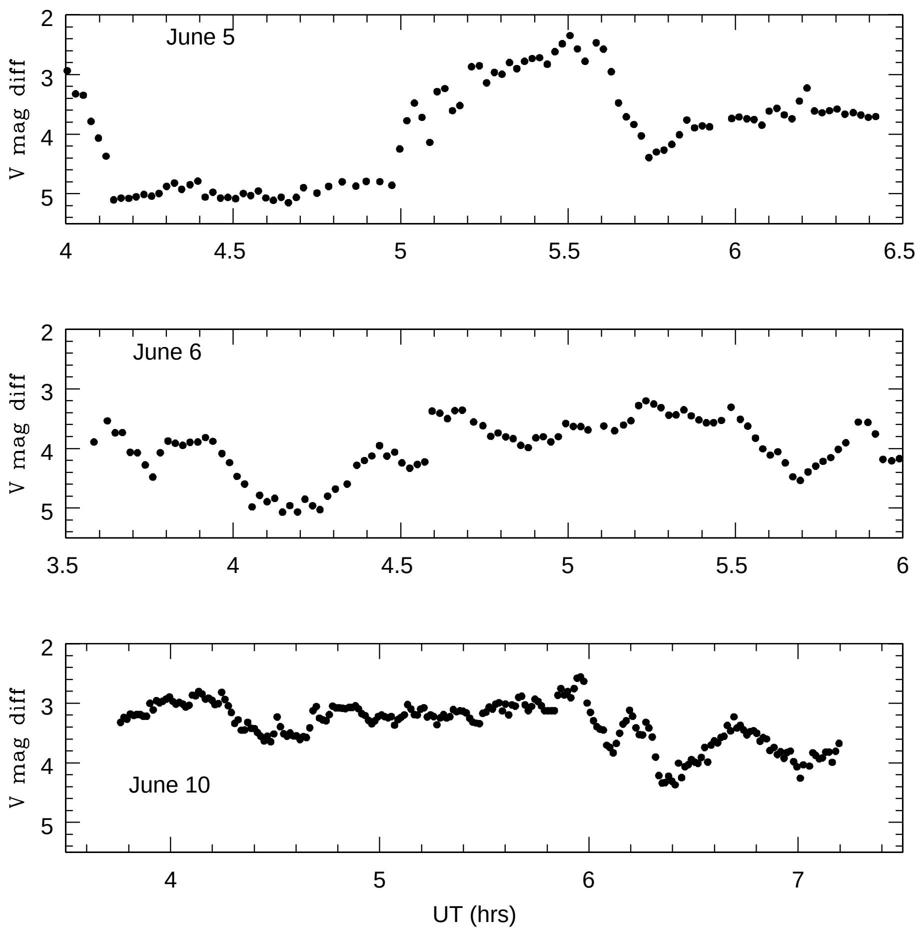


Fig. 4.— KPNO data from 2011 June showing the large changes in the light curve of the likely Polar SDSS1344+20 during the course of a week.

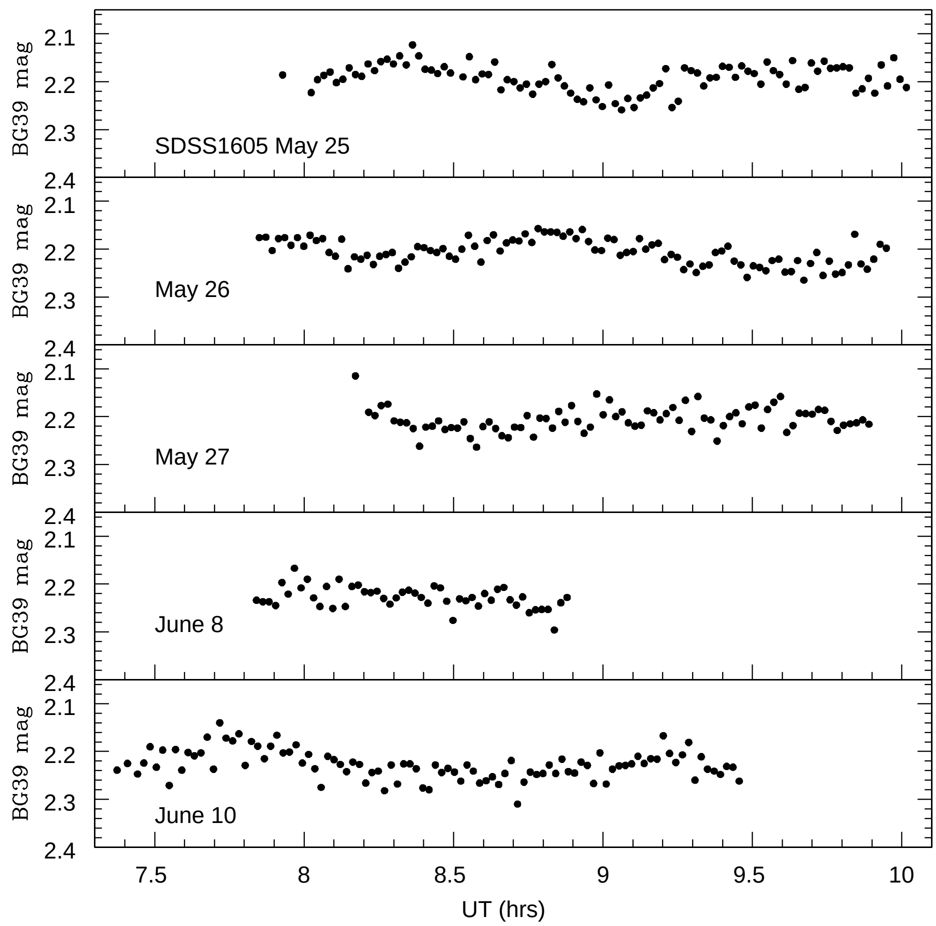


Fig. 5.— KPNO data from 2011 May-June showing the 76 min orbital modulation in the light curves of the dwarf nova SDSS1605+20.

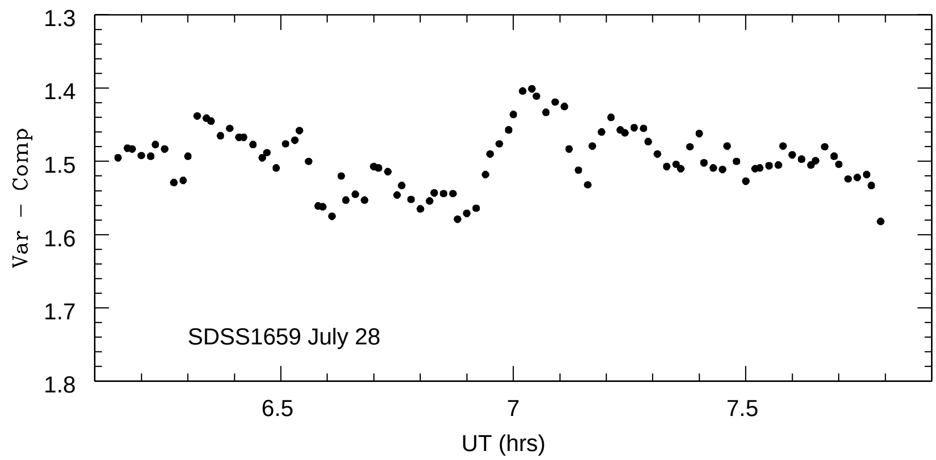


Fig. 6.— MRO light curve of the suggested AM CVn system SDSS1659+19 obtained 2013 July 28.

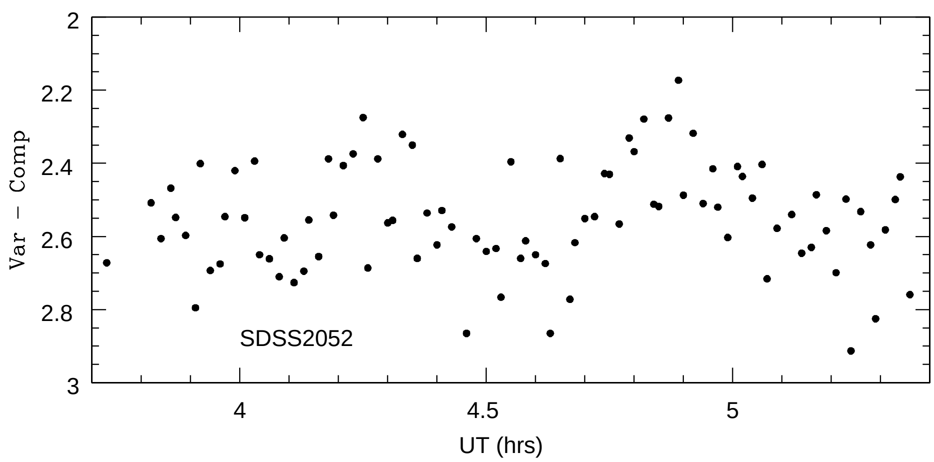


Fig. 7.— MRO light curve of SDSS2052-02 obtained 2013 October 29.

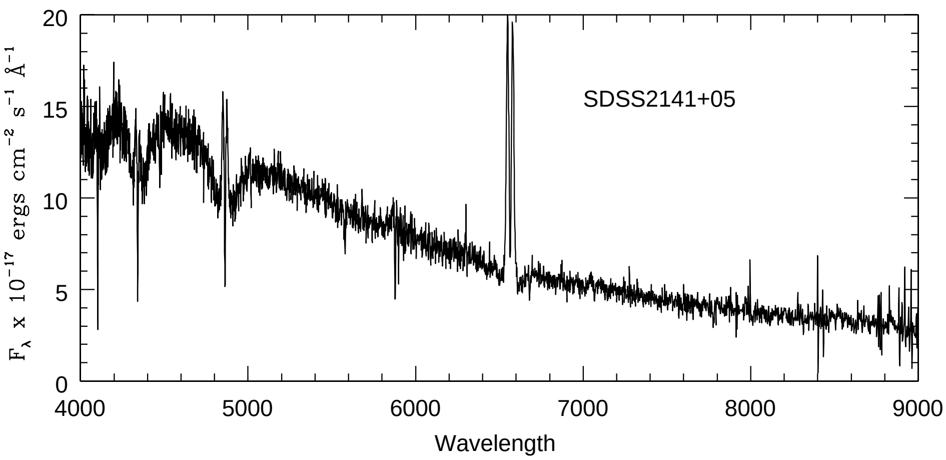


Fig. 8.— SDSS spectrum from DR10 showing the prominent doubled emission lines with central and flanking absorption indicative of a high inclination CV.

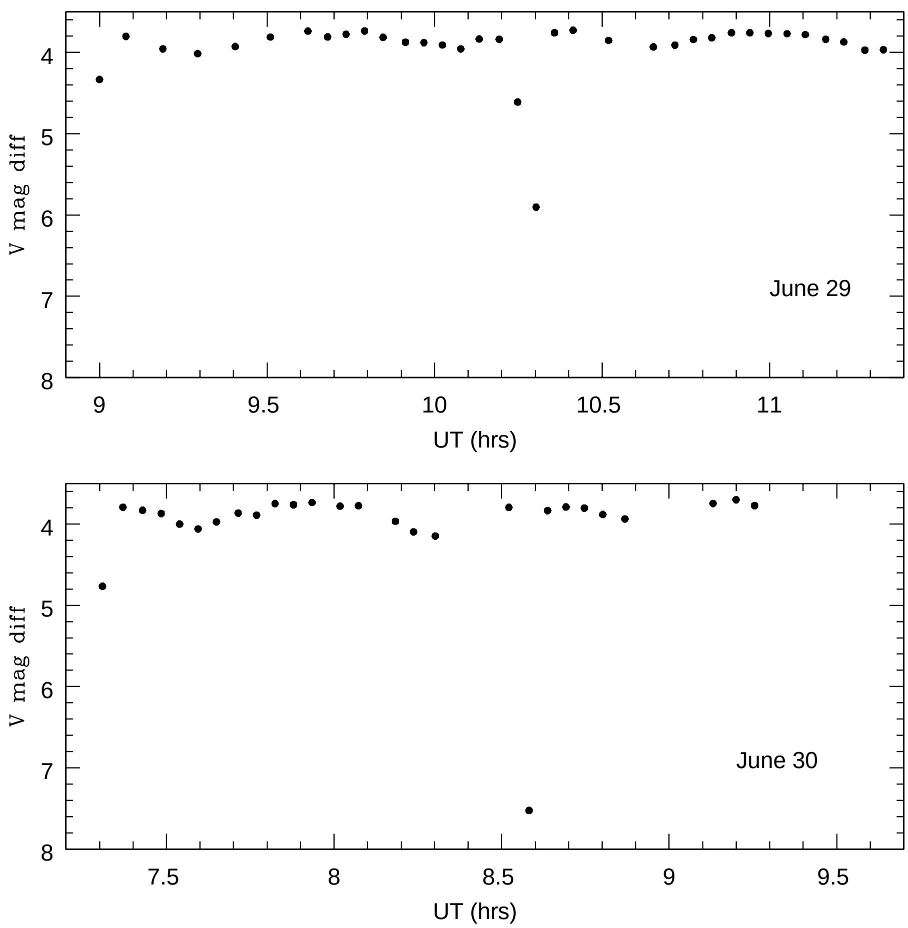
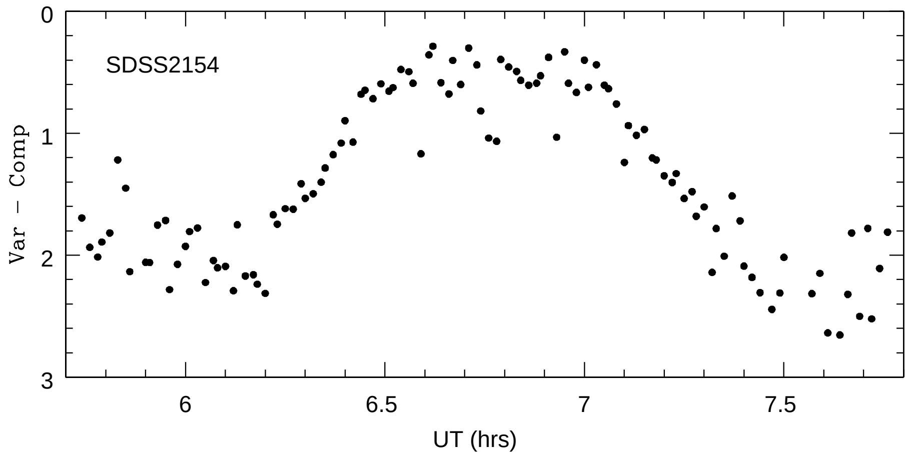


Fig. 9.— KPNO data from 2011 June showing 2 eclipses and 2 egresses from eclipse in SDSS2141+05.



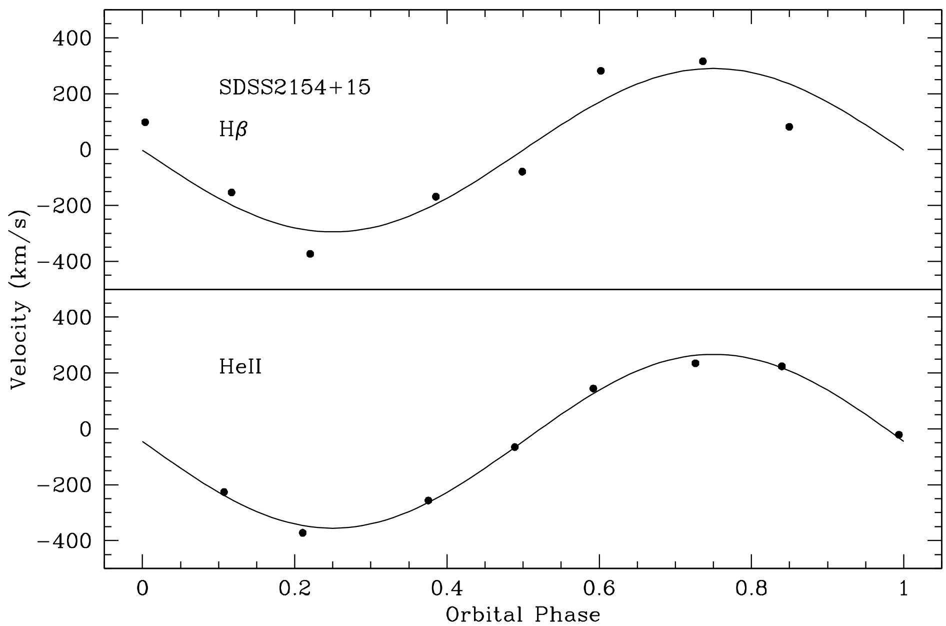


Fig. 10.— MRO light curve of the likely Polar CSS/SDSS2154+15 obtained 2013 October 29 (top) and the velocity curve from 2013 September 5 (bottom), phased with a period of 97 min and showing the best-fit sine curve with parameters from Table 3.

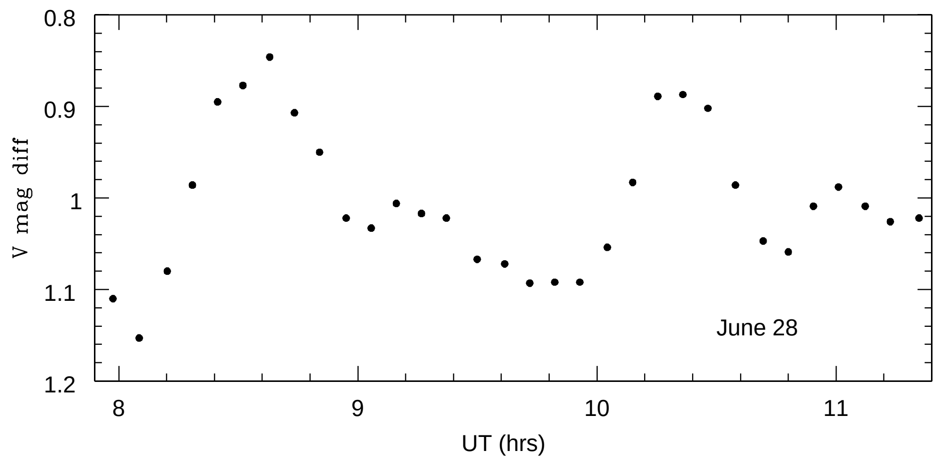


Fig. 11.— KPNO light curve of the dwarf nova CSS/SDSS2158+09 obtained 2011 June 28, showing a possible orbital period near 104 min with hints of eclipses.

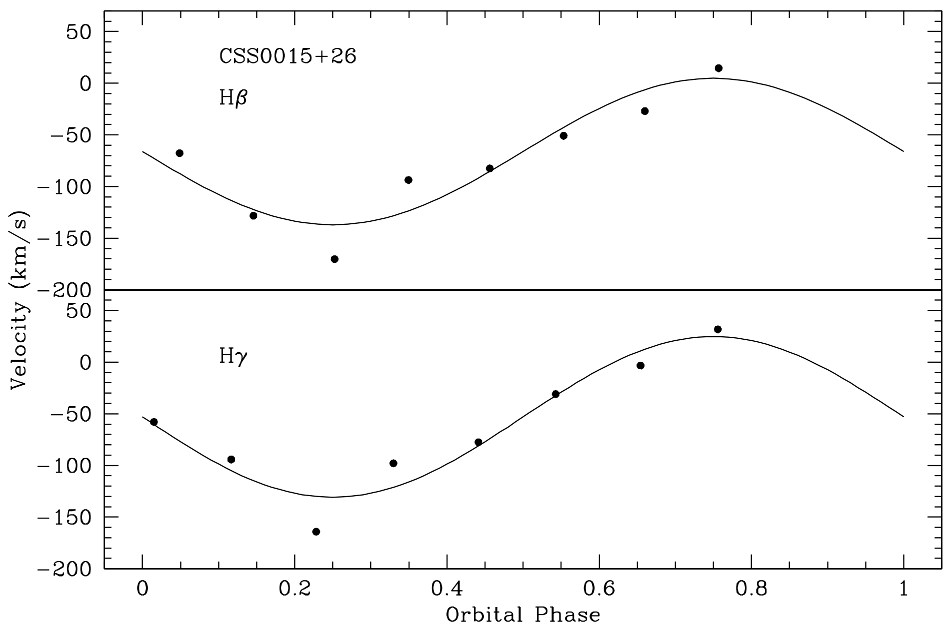


Fig. 12.— Velocity curves of Hβ and Hγ obtained for the dwarf nova CSS0015+26 on 2011 August 26. Hβ is phased with a period of 103 min and Hγ with a period of 99 min. Best fit sinusoids are shown with parameters listed in Table 3.

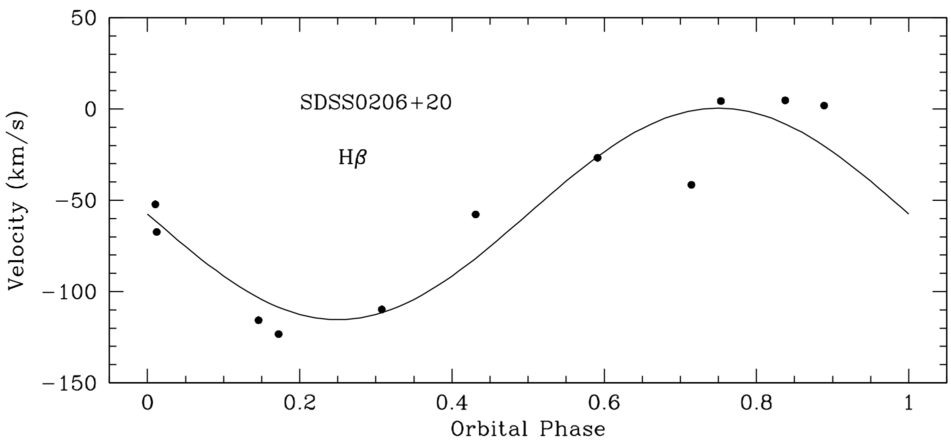


Fig. 13.— Hβ velocity curve of the dwarf nova CSS/SDSS0206+20 obtained on 2013 September 6, phased with a period of 81 min and showing the best fit sine curve with parameters from Table 3.

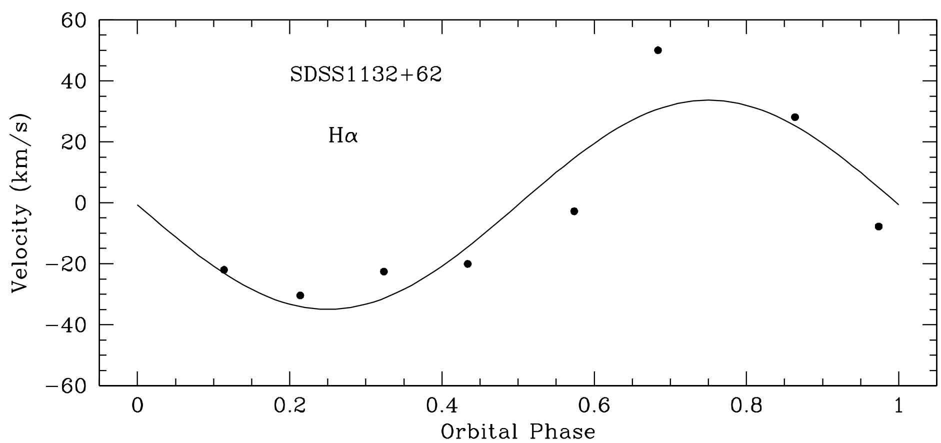


Fig. 14.— Hα velocity curve of the dwarf nova SDSS1132+62 obtained on 2013 February 5, phased with a period of 100 min and the best fit sine curve with parameters from Table 3.