Spectroscopic view on the outburst activity of the symbiotic binary AG Draconis

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ABSTRACT
Variations of the emission lines in the spectrum of the yellow symbiotic star AG Dra have been studied for over 14 years (1997–2011), using more than 500 spectra obtained on the 1.5-metre telescope at Tartu Observatory, Estonia. The time interval covered includes the major (cool) outburst of AG Dra that started in 2006. Main findings can be summarized as follows: (i) cool and hot outbursts of AG Dra can be distinguished from the variations of optical emission lines; (ii) the Raman scattered emission line of O\textsc{vi} at $\lambda$ 6825 almost disappeared during the cool outburst; (iii) lower excitation emission lines did not change significantly during the cool outburst, but they vary in hot outbursts and also follow orbital motion; (iv) similarity of variations in AG Dra to those in the prototypical symbiotic star Z And allows to suggest that a "combination nova" model proposed for the latter object might also be responsible for the outburst behaviour of AG Dra.

Key words: stars: binaries: symbiotic – stars: individual: AG Dra

1 INTRODUCTION
AG Dra belongs to the subclass of so-called yellow symbiotic stars. Its cool component is of early K spectral class instead of M as in most other symbiotic stars. The hot component is a white dwarf with an effective temperature of $10^4$ K and a luminosity of $\sim 10^3 L_\odot$ (Mikołajewska et al. 1995) obtained from the IUE data. However, Sion et al. (2012) have derived $T_{\text{eff}} = 80 000$ K from the FUSE far-UV spectrum. The orbital period of the binary system is 550 days (Meinunger 1979; Smith et al. 1996; Fekel et al. 2000). A shorter period around 350–380 days has also been detected in photometric and spectroscopic variability of AG Dra (Bastian 1998; Gális et al. 1999; Friedjung et al. 2003). Gális et al. (1999) ascribed this period to the pulsations of the K giant.

By its photometric variability, AG Dra can be classified as a classical symbiotic star of Z And type. Its light curve, available since 1890 (Robinson 1969), shows frequent brightenings of about 1–1.4 magnitudes in the V/visual band and up to 2.3 and 3.6 magnitudes in the B and U bands, respectively. Major outbursts occur in intervals of 12–15 years (in 1936, 1951, 1966, 1980, 1994, 2006), and are usually followed by minor scale outbursts in intervals of about one year. González-Riestra et al. (1999) have distinguished between cool and hot outbursts of AG Dra. Major outbursts in the beginning of active phases are usually cool ones, during which the expanding pseudo-atmosphere of the white dwarf cools down and the He\textsc{ii} Zanstra temperature drops. In smaller scale hot outbursts, the He\textsc{ii} Zanstra temperature increases or remains unchanged.

The outburst activity of AG Dra over 120 years was studied in our recent paper (Hric et al. 2014), using mostly photometric observations. There are numerous other studies available, making use of optical spectroscopy as well as other methods of observations (see e.g. Tomov & Tomova 2002; Leedjärv et al. 2004; González-Riestra et al. 2008; Munari et al. 2009; Shore et al. 2010, and references therein). However, a lot of open questions remain concerning the nature and physical mechanism of the outbursts in particular. In the present paper, we study the variability of emission lines in the optical spectrum of AG Dra during almost 14 years (September 1997 to April 2011). This time interval includes the major outburst that started in July 2006. A brief description of the behaviour of AG Dra around this event was given by Leedjärv & Burmeister (2012). In the present paper, we undertake an analysis of AG Dra over a longer timeframe, and attempt to compare it with other symbiotic stars. Section 2 describes the observations. In Sect. 3 we present the main features of variability of the strongest optical emission lines. In Sect. 4 we attempt to find similarities of AG Dra to the prototypical symbiotic star Z And and other symbiotic stars. Discussion and conclusions are given in Sect. 5.
2 OBSERVATIONS AND DATA REDUCTION

Spectroscopic observations of AG Dra used in the present paper have been carried out on the 1.5-metre telescope at Tartu Observatory, Estonia. The equipment and methods of observations and their reductions are described by Leedjärv et al. (2004) (hereafter L04). Starting from March 2006, a new Andor Newton DU-970N CCD camera with 400 × 1600 pixels (pixel size 16 × 16μm) has been used. With this camera, dispersions ∼ 0.47 Å pix⁻¹ or ∼ 0.16 Å pix⁻¹ in the red spectral region, and ∼ 0.57 Å pix⁻¹ in the blue region were achieved. Test measurements have shown that the change of CCD detectors has no systematic effect on the obtained results.

Altogether 515 spectra of AG Dra, recorded between September 1997 and April 2011, are used in the present paper: 196 in the blue (Hβ) spectral region, 221 in the red (Hα) spectral region with lower dispersion, and 98 in the red region with higher dispersion. A few spectra have been sporadically recorded after April 2011, when the star was continuously in the quiescent stage Q6 (see Sect. 3), data from those spectra do not affect our analysis. Reductions of the spectra were done with the help of the ESO MIDAS software package, applying the standard procedures of subtracting the bias and sky background, calibrating into the wavelength scale, and normalizing to the continuum.

We focus on the strongest emission lines in the wavelength regions under study: the hydrogen Balmer lines Hα (λ 6563) and Hβ (λ 4861); the neutral helium HeI line at λ 6678, the ionized helium HeII line at λ 4686, and the Raman scattered OⅥ line at λ 6825. Equivalent widths (EWs), peak intensities relative to the continuum, and positions of these lines were measured. Uncertainties of the EWs were estimated from repeated test measurements of a few spectra, they range from about 3 per cent for the strongest lines to about 10 per cent for weak lines.

EWs may not be a good indicator of emission line variations when the underlying continuum is variable. Therefore, we have calculated absolute fluxes emitted in the lines, using the same photometric data as in Hric et al. (2014). In addition, data from Skopal et al. (2007) were applied. For interstellar reddening the value E(B−V) = 0.05 was adopted according to Mikolajewska et al. (1995). Interpolation of the photometric data in wavelength scale and in time brings along additional errors, and so uncertainties in the emission line absolute fluxes may reach up to 15–20 for the weakest lines.

3 CHARACTERISTICS OF THE EMISSION LINES FROM 1997 TO 2011

3.1 Variability and correlations with the brightness

In Fig. 1 we present the UBV light curves of AG Dra from 1990 to 2012, consisting of the quiescent and active stages. Individual events are marked, and these labels will be referred to throughout the paper. The EWs of the emission lines in the spectrum of AG Dra from April 2003 to April 2011 are presented in Table 1 (full table is only available online). In Table 1, we have applied the frequently used convention in which EWs of emission lines are given as positive numbers.

In Hric et al. (2014) we presented variability of the EWs together with the U light curve in fig. 8. Figure 2 shows the temporal variations of the absolute fluxes of the same emission lines. One remarkable feature of these variations is the brightening of all the lines during the outburst E10 in 2005. Even more noticeable is the deep minimum in the fluxes around JD 2 454 800 (2008–2009), after a major double-peaked outburst (F1, F2). At the same time, there are no peculiarities in the light curves; the U, B and V magnitudes correspond to their usual values in quiescence. The major (cool) outburst of AG Dra that started after JD 2 453 990 (July 2006, F1), is not specifically distinct in the fluxes of hydrogen and helium lines, but a weakening of the Raman scattered OⅥ line is clearly visible. Such a disappearance of the high excitation emission line in the spectrum of AG Dra during a major outburst was also observed by Munari et al. (2009) and Shore et al. (2010). Burmeister & Leedjärv (2007) detected a similar weakening of the OⅥ λ 6825 line in the spectrum of the prototypical symbiotic star Z And in summer 2006, when the star underwent a strong outburst accompanied by the ejection of bipolar jets. In the case of Z And, the HeII λ 4686 line also practically disappeared at the beginning of the outburst, while it did not display remarkable variations during the 2006 outburst of AG Dra.

In L04, we found a more or less linear correlation between the U magnitude and logarithms of the EWs (fig. 2 in L04). In Fig. 3 we present (in logarithmic scale) the dependence of the EWs of the emission lines on the U magnitude over a longer time span, including the cool outburst in 2006. Chronological connection of the points enables us to see the different behaviour of the EWs during hot and cool outbursts. We have also studied the dependence of the EWs on the B magnitude. Qualitatively they are almost congruent to those in Fig. 3. The EWs of all lines increase with the brightening in U(B), until U(B) reaches a value of 9.5−9.4(10.2−10.0). A different behaviour is seen at brighter magnitudes. The EWs of Hα and HeI 6678 remain more or less constant. In Hβ, a light decrease is seen for brighter U magnitudes. Finally, the high excitation HeII and OⅥ lines show a remarkable decline. Hence, the magnitudes U ∼ 9.4 and B ∼ 10.2 apparently mark the brightness limits above

| JD       | Hα  | Hβ  | HeI 6678 | HeII 4686 | OⅥ 6825 |
|----------|-----|-----|---------|-----------|---------|
| ~2 400 000 | 112.8 | 33.1 | 2.20 | 15.85 | 7.07 |
| 52 731.410 | 112.8 | 33.1 | 2.20 | 15.85 | 7.07 |
| 52 748.434 | 104.4 | 36.0 | 2.01 | 17.54 | 6.39 |
| 52 749.422 | - | 29.6 | 1.98 | 17.24 | 6.90 |
| 52 751.414 | 105.6 | 31.2 | 1.88 | 17.29 | 6.57 |
| 52 755.387 | 121.0 | - | 1.94 | - | - |
| 52 756.338 | 112.7 | - | 2.08 | - | - |
| 52 762.387 | 103.1 | 32.0 | 1.68 | 17.00 | 6.02 |
which the onset of a cool outburst of the hot component of AG Dra can be expected.

3.2 Ratio of the He\textsc{ii} $\lambda$ 4686 and H\textsc{$\beta$} lines

In L04 we reported that the average value of the EW ratio of the ionized helium line at $\lambda$ 4686 and the H\textsc{$\beta$} line (He\textsc{ii}/H\textsc{$\beta$}) was 0.79 $\pm$ 0.15 between 1997 and 2003, in accordance with González-Riestra et al. (1999). There has only been one short episode when this ratio slightly exceeded 1.0. Shore et al. (2010) confirm this result, but they have detected no epoch with He\textsc{ii}/H\textsc{$\beta$} $> 1.0$. Our measurements over the time interval from 1997 to 2011 are shown in Fig. 4. During four episodes the ratio marginally exceeds 1.0. A significant decrease to $\sim 0.2$ can be detected around JD 2 454 000 (major outburst F1), and there are a few more occasions when the ratio drops to 0.5 or slightly less. Due to these low values the long-term average of the line ratio over the period 1997–2011 was 0.70 $\pm$ 0.18.

The He\textsc{ii}/H\textsc{$\beta$} ratio can actually be considered as a proxy to the temperature of the hot component. Iijima (1981) has provided a simple formula for assessment of the effective temperature of a central source of ionizing photons from the nebular emission-line fluxes:

$$T_{\text{hot}}(\text{in } 10^4 \text{ K}) = 19.38 \sqrt{\frac{2.22 F_{4686}}{4.16 F_{\text{H}$\beta$} + 9.94 F_{4471}}} + 5.13,$$

(1)

Figure 1. $U$ (bottom), $B$ (medium), and $V$ (top) light curves of AG Dra from 1990 to 2012. Active stages E and F are confined between the vertical lines, with individual outbursts identified. The thin curves show a spline fit to the data points.

Figure 2. Absolute fluxes in the strongest emission lines of AG Dra together with the $U$ light curve. Thin lines show a spline fit to the data points.
where $F_{\text{H} \beta}$, and $F_{\lambda 4471}$ are the fluxes in the emission lines of He\textsc{ii} $\lambda$ 4686, H$\beta$, and He\textsc{i} $\lambda$ 4471, respectively. Sokoloski et al. (2006) have neglected the flux of the He\textsc{i} $\lambda$ 4471 line in the case of Z And, because $F_{\lambda 4471} \lesssim 0.1F_{\text{H} \beta}$. Approximately the same relation is valid for AG Dra. With a similar simplification, the EW ratio can be used instead of the flux ratio. So, we obtain:

$$T_{\text{hot}}(\text{in } 10^4 \text{K}) \approx 14.16 \sqrt{\frac{\text{EW}_{4686}}{\text{EW}_{\text{H} \beta}}} + 5.13. \quad (2)$$

Equation (2) yields a temperature of the hot component at about 170,000 K for the average line ratio of 0.70 as well as maximum (210,000 K) and minimum (108,000 K) values for the extrema 1.26 and 0.16, respectively. These temperatures are somewhat higher than those derived by González-Riestra et al. (1999), and in particular that by Sion et al. (2012). We are aware that by neglecting the He\textsc{i} line the temperature increases. At the same time, assumption of a radiation-bounded nebula made in the derivation of Eq. (1) may not be fully valid in the case of AG Dra. Nevertheless, Eq. (2) provides a useful indication of the temperature changes, and Fig. 4 can hence be regarded as representative for the temporal evolution of the hot component’s temperature variations. The temperature decrease during the major (cool) outburst F1 around JD 2454000 is clearly seen. Other episodes of low He\textsc{ii}/H$\beta$ values center around JD 2454480 (F2) and 2454840 (quiescence Q6). The latter episode coincides with the detection of the lowest flux values in both low- and high-excitation emission lines as presented in Fig. 2. Similar drops to $\sim 0.5$ can also be seen around JD 2451640 (possible quiescent episode between E5 and E6) and 2452750 (between E7 and E8). Some weakening of the Balmer and He\textsc{i} emission lines at the same times can be detected, but these are not comparable to the event at JD 2454840.

One can also notice a few exceptionally high He\textsc{ii}/H$\beta$ values, $> 1.0$ around JD 2451810 and 2452520, and about 1.2 around JD 2452940 and 2453620, respectively. Interestingly, three of those episodes can be associated with hot outburst type brightenings (E7, E8 and E10) were the $U$ and $B$ magnitudes reach the turning point in Fig. 3, while the first event took place during a short quiescence phase between the outbursts E5 and E6.

### 3.3 The O\textsc{vi} $\lambda$ 6825 line

Broad emission lines in the spectra of symbiotic stars at about 6830 and 7080 Å remained a mystery, until Schmid (1989) identified them as a product of Raman scattering of photons from the O\textsc{vi} resonance lines at 1032 and 1038 Å at atoms of neutral hydrogen. The formation of these lines requires specific physical conditions – simultaneous presence of a hot radiation source, capable of ionizing oxygen atoms five times, and enough neutral hydrogen atoms – which are met almost exclusively in symbiotic stars. Arrieta & Torres-Peimbert (2003) have identified the same lines in the spectra of a few planetary nebulae where also broad wings of the H$\alpha$ line are supposed to form in a similar process involving the Ly$\beta$ photons (Lee & Hyung 2000). Other Raman scattering processes can be expected, for example, the line at 4881 Å originating from the Ne\textsc{vii} $\lambda$ 973 photons, was recently identified in the spectrum of the Galactic symbiotic star V1016 Cyg (Lee, Heo & Lee 2014) and of symbiotic star candidates in the galaxy NGC 205 (Gonzalves et al. 2015). Very intriguing is the discovery of the Raman scattered O\textsc{vi} lines by Torres et al. (2012) in the spectrum of the massive
EW values than those in Shore et al. (2010), the correlation between the He\textsc{ii} and O\textsc{vi} lines remains more or less linear. Some discontinuity and deviations from linearity can be detected at EW(O\textsc{vi}) values between 10 and 15 Å. The He\textsc{i} line also roughly follows a linear correlation, but with a bigger scatter, especially at the highest EW values, and the data points from the cool outburst F1+F2 mostly deviate from a linear relation. A simple interpretation of these relations could be that during the cool outburst the temperature of the hot component considerably decreased, so that the high excitation O\textsc{vi} and He\textsc{ii} lines significantly faded and almost disappeared, but leaving the lower excitation He\textsc{i} lines mainly unaffected.

The ratios of the EWs of the high-excitation emission lines and the EWs of the nearby hydrogen Balmer lines could provide information on relative quantities of the correspondingly ionized atoms. Fig. 6 shows that these ratios from quiescence and hot outbursts occupy essentially the same region of the plot, only the scatter of the outburst points is somewhat larger. Data points from the cool outburst (squares) are located separately. They mostly occupy the lower left section of the plot. This result confirms that the number of the highly ionized He and O atoms decreased significantly during the cool outburst.

3.4 Orbital variations

It has long been debated whether the spectral lines of AG Dra vary regularly with orbital phase. From what is said above about the outburst variability of the emission lines, it is clear that such regularity should only be searched for in the quiescence data. Fig. 7 shows the emission line EWs in quiescence phased to the orbital period \( P = 549.73 \) (Gális et al. 1999) together with the \( U \) light curve. In the latter, the well known wave-like variability mentioned already by Meinunger (1979) is clearly seen. A very similar variability can be detected in the EWs of H\textsc{α} line, and to a lesser extent in H\textsc{β} and He\textsc{i} λ 6678 line. These low excitation lines most likely arise in an extended gaseous volume which also emits continuum radiation in the near-UV and optical spectral region. The high excitation He\textsc{ii} λ 4686 line practically does not vary with orbital motion. This line should have its origin close to the hot component. The EWs of the other high excitation line, O\textsc{vi} λ 6825, exhibit a large scatter because both the vicinity of the hot component and the extended volume of the neutral hydrogen are involved in the formation of this line. A possible relation of the occurrence of double-peaked H\textsc{α} profiles with the orbital motion requires further study and, thus, remains beyond the scope of this paper.

4 COMPARISON WITH OTHER SYMBIOTIC STARS

Symbiotic stars display a great variety of outbursts and active stages. A few symbiotic novae (Kenyon 1986; Belczyński et al. 2000) (like AG Peg, V1016 Cyg, PU Vul, RR Tel etc.) have shown only one large amplitude outburst during the observational history. A few symbiotic recurrent novae (Kenyon 1986; Anupama 2013) undergo outbursts with amplitudes up to \( \sim 7 \) magnitudes with a recurrence time of a few decades (RS Oph and T CrB are the best known luminous B[e] star LHA 115-S 18 in the SMC. Torres et al. (2012) have proposed two alternative explanations for the appearance of those spectral features: LHA 115-S 18 could be (1) a B[e] supergiant in a pair with a hot main-sequence star accreting mass, or (2) a Luminous Blue Variable (LBV) object.

Raman scattered O\textsc{vi} lines are always present in the spectrum of AG Dra, although they almost disappeared during the cool outburst in 2006 (Munari et al. 2009; Shore et al. 2010). Our observations confirm this finding. Fig. 5 shows the relation between the EWs of the helium and the O\textsc{vi} λ 6825 lines. With more data points and wider ranges of the
examples). Some symbiotics are quiescent with no recorded outbursts (RW Hya, EG And etc.), but the most widespread type of activity among symbiotic stars are the so-called classical or Z And type outbursts, which have amplitudes of about 1 – 3 magnitudes at optical wavelengths and recur in intervals of about one or a few years (e.g. AG Dra, Z And, BF Cyg, CI Cyg) or 10 – 15 years (e.g. AX Per) (AAVSO database, http://www.aavso.org).

A characteristic feature of some such outbursts is the weakening or disappearance of the high excitation emission lines, mentioned by Kenyon (1986), and followed in more detail in Hen 3-1341 (Munari, Siviero & Henden 2005), Z And (Sokoloski et al. 2006; Burmeister & Leedjärv 2007), and AG Dra (Munari et al. 2009; Shore et al. 2010, and present paper). As recent outbursts of the prototypical symbiotic star Z And have been extensively studied, we were tempted to quantitatively compare the behaviour of AG Dra and Z And. Extensive photometric time series for Z And are available in Skopal (1998); Skopal et al. (2000, 2002, 2004, 2007); Sokoloski et al. (2006); Tomov, Tomova & Taranova (2004). Using these data, we selected time intervals of about 3000 days from the U, B and V light curves of both AG Dra and Z And, and performed a cross-correlation analysis. The results of such analysis for curves with complex behaviour depend on the selection of a particular time interval. Therefore, we performed around 20 runs with different starting times and lengths of the analysed time intervals (1520 - 3066 days). In all runs, the cross-correlation functions manifested the significant maxima only for the time shift with a value around 2110 days. The time shifts for the maxima of the cross-correlation functions, the corresponding maximum values of these functions, and their errors for the light curves in the U, B and V filters are listed in Table 2. Such significant correlations might not be so surprising as we know that the U, B and V light curves of AG Dra correlate well between themselves during active stages (Hric et al. 2014), and the same can be concluded from the visual inspection of the light curves of Z And.

It would be more intriguing to find similar correlations in some spectroscopic features. Sokoloski et al. (2006) have published the EWs of the most prominent emission lines of Z And. We selected the OVI line at λ 6825 and performed a similar cross-correlation analysis of its EWs in AG Dra and Z And. In all runs, the maximum value of the cross-correlation function appeared for the time shift around 2290 days. Moreover, in many runs this maximum has a double-peaked structure with the second maximum around 2100 days. The maximum for time shift with value around 2970 days is also present in less than a half of the runs. The particular results of this analysis are listed in Table 2. The large value of the mean error for the time shift 2289.6 days...
is probably caused by the double-peaked structure of the maxima of the cross-correlation function.

These results show strong similarity of the photometric and spectroscopic behaviour of AG Dra and Z And. The difference between the time shift for the light and the EW curves (around 180 days) is not essential, because the value of the time shift for the EW curves lies indeed in the range 2100 - 2300 days, and its particular value depends only on the selection of the time interval. The correspondingly shifted U light curves and EW variability curves of AG Dra and Z And are shown in Fig. 8.

Those reasonable correlations could imply some similarity of the nature of the hot components and the mechanisms of the outbursts in AG Dra and Z And. Cool giants of these symbiotic stars are of rather different spectral types, K2–K3 and M4–M5, respectively. Available estimates of the mass of the hot component (WD) are similar for both stars, \( M_{\text{WD}} \approx 0.1 \) and 0.16 for the photometric and spectroscopic data, respectively. The 2 \( \sigma \) white level noise was about 0.1 and 0.16 for the photometric and spectroscopic data, respectively.

Table 2. The results of the cross-correlation analysis of the U, B and V light curves as well as the EW curves of the O\( \text{vi} \) line at \( \lambda 6825 \) of AG Dra and Z And. The 2 \( \sigma \) white level noise was about 0.1 and 0.16 for the photometric and spectroscopic data, respectively.

| Data set | Time shift | Cross-cor. function |
|----------|------------|---------------------|
|          | median     | error               |
| Filter U | 2 108.7    | 8.2                 | 0.76 | 0.05 |
| Filter B | 2 108.7    | 5.7                 | 0.84 | 0.03 |
| Filter V | 2 116.3    | 3.2                 | 0.82 | 0.04 |
| EWs      | 2 289.8    | 24.7                | 0.59 | 0.05 |
|          | 2 102.7    | 4.2                 | 0.49 | 0.08 |
|          | 2 972.3    | 6.4                 | 0.31 | 0.03 |

5 DISCUSSION AND CONCLUSIONS

It has been established long ago that a white dwarf alone is not capable of ionizing the nebulae of symbiotic stars to produce the characteristic emission-line spectrum. Quasi-steady thermonuclear shell burning on the surface of the WD can provide additional energy, and this phenomenon appears to be common in most of the symbiotic systems (Paczyński & Żytkow 1978; Iben 1982; Sion & Reddy 1992). An accretion rate of a few times \( 10^{-8} M_{\odot} \text{yr}^{-1} \) is sufficient to produce a luminosity of \( 10^{3} L_{\odot} \) by a thermonuclear shell burning (Sokoloski et al. 2006). The classical symbiotic outbursts, recurring every few years or decades, however, do not fit well into this picture. They are by far too frequent to be nova-like thermonuclear runaways like those in symbiotic recurrent novae (Iben 1982; Kenyon & Truran 1983; Mikołajewska et al. 1995). Even with the WD mass close to the Chandrasekhar limit, the recurrence times would be tens or hundreds of years (Sion, Acien & Tomeczyk 1979). But WDs in symbiotic systems seem to have a low mass (around \( 0.6 M_{\odot} \)) in most cases (Mikołajewska et al. 1995).

The “combination nova” model proposed by Sokoloski et al. (2006) seems to be a promising explanation, at least to the behaviour of Z And. Smaller scale hot outbursts (e.g. in 1997) are explained by the accretion disc instability model like in dwarf novae (Warner 1995). The 2000 – 2002 outburst of Z And was similar to the major (cool) outbursts of AG Dra. According to Sokoloski et al. (2006), the disc instability in this case triggered enhanced thermonuclear shell burning on the WD surface, thus resembling a classical nova outburst. For the 0.65 \( M_{\odot} \) WD, an average accretion rate of \( 5 \times 10^{-8} M_{\odot} \text{yr}^{-1} \) would be enough to both fuel the quasi-steady nuclear burning and accumulate enough material in the disc to trigger a combination nova event on time-scales of 10 years. The major (cool) outbursts of AG Dra occur on a similar time-scale (12 – 15 years). However, there is a fundamental difficulty because we do not have a firm evidence for the presence of an accretion disc in AG Dra. Radio observations of AG Dra have indicated bipolar outflows (Ogley et al. 2002; Mikołajewska 2002), but those can be explained hydrodynamically by a disc-like density condensation in the orbital plane (Gawryszczak, Mikołajewska & Różyczka 2003). No evidence of collimated bipolar jets like in Z And (Burmeister & Leedjärv 2007) neither short timescale flickering (Sokoloski, Bildsten & Ho 2001) has been found in AG Dra.

A “combination nova” model might be applicable to AG Dra, provided that a trigger mechanism for thermonuclear shell flashes can be found. Triggering of major (cool) outbursts seems to take place close to some critical threshold, as in some cases (active stages A and C in Hric et al. (2014)) there has been not enough power to ignite additional nuclear reactions required to initiate a cool outburst.

Our conclusions can be shortly summarized as follows:

– cool and hot outbursts of AG Dra can be clearly distinguished by the behaviour of the emission lines in the optical spectrum;
– the Raman scattered O\( \text{vi} \) line \( \lambda 6825 \) almost disappeared during the cool outburst confirming a drop in the hot component’s temperature as was also found from the variations of other emission lines;
– emission lines of hydrogen and neutral helium did not change significantly during the cool outburst. They are correlated with the orbital motion in quiescence and become stronger in hot outbursts;
– the similarity of the outbursts of AG Dra and Z And shows that a “combination nova” model might explain the outbursts of AG Dra. The presence of an accretion disc in the system still lacks confirmation.

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