Contrib. Astron. Obs. Skalnaté Pleso **49**, 197 – 203, (2019)

The current active stage of the symbiotic system AG Draconis

R. Gális[1], J. Merc[1,2] and L. Leedjärv[3]

[1] *Institute of Physics, Faculty of Science, P. J. Šafárik University, Park Angelinum 9, 040 01 Košice, Slovak Republic*

[2] *Astronomical Institute, Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, 180 00 Prague, Czech Republic*

[3] *Tartu Observatory, Faculty of Science and Technology, University of Tartu, Observatooriumi 1, Tõravere, 61602 Tartumaa, Estonia*

Received: November 15, 2018; Accepted: February 12, 2019

Abstract. AG Dra is a strongly interacting binary system which manifests characteristic symbiotic activity of alternating quiescent and active stages. The latter ones consist of the series of individual outbursts repeating at about one-year interval. The current activity of AG Dra was initiated by a minor outburst in May 2015. The new stage of activity of this symbiotic system was confirmed by the following three outbursts in April 2016, May 2017 and in April 2018. The photometric and spectroscopic observations suggest that all these outbursts are of the *hot* type. Such behaviour is considered to be unusual in almost 130-year observation history of this object, because the major outbursts at the beginning of active stages are typically *cool*. In the present work, the current activity of the symbiotic binary AG Dra is described in detail.

Key words: symbiotic stars – outbursts – photometry – spectroscopy

1. Introduction

AG Dra is one of the best studied symbiotic systems. Its cool component is a metal-poor cool giant of spectral type K3 and higher luminosity than that of standard class III (Smith et al., 1996). The hot component of AG Dra is considered to be a white dwarf sustaining a high temperature of $(1 - 1.5) \times 10^5$ K and luminosity of $(1 - 5) \times 10^3\,L_\odot$ due to the stable hydrogen burning of the accreted matter on its surface (Mikolajewska et al., 1995; Sion et al., 2012). The giant under-fills its Roche lobe and the WD accretes from the stellar wind of the cool giant. A fraction of the giant's wind is ionised by the WD, which gives rise to the symbiotic nebula (Seaquist et al., 1984).

The period analysis of long-term photometric and spectroscopic observations confirmed the presence of two periods in AG Dra (Hric et al., 2014). The longer one (≈ 550 d) is related to the orbital motion and the shorter one (≈ 355 d) could be due to pulsation of the cool component of this symbiotic system.

AG Dra regularly undergoes quiescent and active stages which consist of several outbursts repeating with about 360 d interval. UV and X-ray observations showed that there are two types of outbursts: *cool* and *hot* ones (González-Riestra et al., 1999). In the previous work, we demonstrated that the outbursts of AG Dra can also be clearly distinguished according to the behaviour of the prominent emission lines in optical spectra (Leedjärv et al., 2016).

2. Observational data

In this study, we analysed the photometric and spectroscopic observations that cover the ongoing active stage of AG Dra. New photometric measurements were obtained during 261, 155 and 560 nights from Karpov (2017), Vrašťák (2018) and the *AAVSO International Database* (Kafka, 2018), respectively.

Spectroscopic observations of AG Dra were acquired by *ARAS Group*[1] observers mostly in the framework of two observing campaigns which we initiated and coordinated in 2017 and 2018. Although the spectra were obtained with small telescopes (25 - 35 cm, $R \approx 1800$ - 11 000), they provided us valuable information about the recent activity of AG Dra. In total, we used 274 spectra covering the time interval from JD 2 456 765 (April 17, 2014) to JD 2 458 353 (August 23, 2018). Moreover, we analysed new intermediate-dispersion spectra obtained at the Tartu Observatory in Estonia (4 spectra, a 1.5-m telescope, $R \approx 6000$ and 7000) and at the Observatory of the Astronomical Institute of ASCR in Ondřejov (16 spectra, a 2.0-m telescope, $R \approx 13\,000$).

Our analysis was focused on the prominent emission lines in the wavelength regions under study: the hydrogen Balmer lines Hα ($\lambda\,6563$) and Hβ ($\lambda\,4861$), the neutral helium He I ($\lambda\,6678$) line, the ionised helium He II ($\lambda\,4686$) line, and the Raman-scattered O VI line at $\lambda\,6825$.

3. Recent outburst activity of AG Dra

After seven years of quiescence following the 2006-08 major outbursts, the symbiotic system AG Dra started to become brighter again toward what appeared to be a new minor outburst during May 2015 (Fig. 1). The outburst activity of AG Dra was definitely confirmed by the following three outbursts in April 2016, May 2017 and in April 2018 (Gális et al., 2018).

3.1. Photometric behaviour

The first, less prominent outburst (G0) was observed in May 2015. The maximum brightness was achieved around JD 2 457 166 (10.7 and 9.6 mag in the B and V filters, respectively). It turned out that it was a minor outburst of AG Dra, a precursor of its activity as it was observed in some of the previous active stages.

[1] http://www.astrosurf.com/aras/Aras_DataBase/Symbiotics.htm

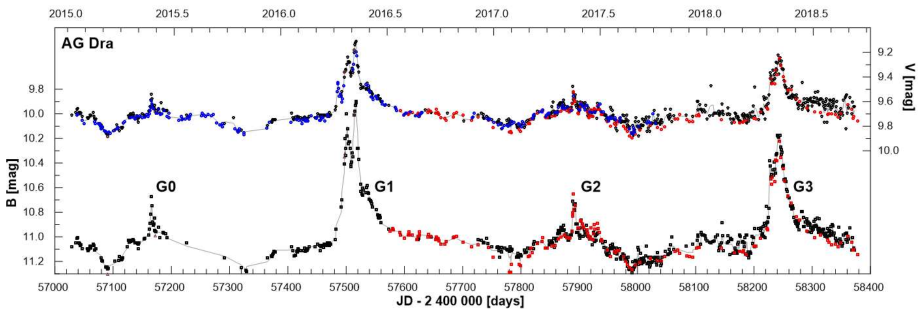

Figure 1. The light curves of the symbiotic system AG Dra during the recent active stage (2015-18) constructed on the basis of the B and V band observations. The photometric measurements depicted by blue, red and black colour were obtained from Karpov (2017), Vrašťák (2018) and *AAVSO* (Kafka, 2018), respectively.

During the second, more prominent outburst (G1), the brightness around JD 2 457 517 (May 8, 2016) reached the maximum of 9.9 and 9.1 mag in the B and V filters, respectively. As in the case of previous outburst (G0), its amplitude ranks this brightening to the minor outbursts of AG Dra.

Such photometric behaviour of the active stage is very unusual. More often, the pre-outbursts of AG Dra are followed by major outbursts, during which the brightness can reach around 8.8 and 8.4 mag in the B and V filters, respectively. A major outburst was not observed only during the activity stage in 1963-66, which was the shortest one in the almost 130-year photometric history of this strongly interacting symbiotic system (Hric et al., 2014).

In May 2017, the third brightening (G2) during the recent activity of AG Dra was detected. It was a very sharp and short-lasting outburst of the *hot* type. Maximal brightness was reached at JD 2 457 890 (10.7 and 9.5 mag in the B and V filters, respectively), similarly to the case of G0.

According to our statistical analysis of photometric observations, we found that time intervals between outbursts of AG Dra vary from 300 to 400 d (without an apparent long-term trend), with a median of ≈ 360 d. Therefore we expected the next outburst in the interval from April 21, 2018 (JD 2 458 230) to May 31, 2018 (JD 2 458 270).

Actually, AG Dra manifested the fourth outburst of the ongoing activity stage on May 4, 2018, i.e. 353 days after previous one. The maximum was reached at JD 2 458 243 with brightness of 10.2 and 9.5 mag in the B and V filters, respectively. At the end of July 2018, the brightness of AG Dra almost returned to values typical for quiescence (11.4, 11.1 and 9.8 mag in U, B and V filter, respectively), so the fourth outburst has finished (Merc et al., 2018).

The photometric behaviour suggests that all four recent outbursts of AG Dra belong to the minor, *hot* type. Such classification is also supported by the EW increase of the studied emission lines detected during all these events.

3.2. Spectroscopic behaviour

We analysed variability of selected emission lines in the optical spectrum of AG Dra during almost 14 years (1997-2011) using own intermediate-dispersion spectroscopic observations (Leedjärv et al., 2016). One of the most interesting features of this variability is the significant increase of the EWs of all the five emission lines considered, but in particular that of Hα and Raman-scattered O VI (λ 6825), during some minor outbursts of this symbiotic system.

On the other hand, the major, *cool* outbursts of AG Dra (e.g. in July 2006) are not specifically distinct in the EWs of hydrogen and helium lines, but the weakening of the Raman-scattered O VI (λ 6825) line is very well seen. A simple interpretation of this behaviour could be that during the *cool* outburst, the temperature of the hot component of the symbiotic system decreased considerably, so that the high excitation original O VI (λ 1032) line faded considerably and its Raman-scattered O VI (λ 6825) counterpart almost disappeared, however leaving the lower excitation emission lines of hydrogen and helium mainly unaffected.

Direct comparison of the spectra of AG Dra obtained during the quiescence stage Q6 (JD 2 456 906) and the recent active stage G (JD 2 457 176) reveals significant increase of the EWs of all studied emission lines during the pre-outburst G0 (Fig. 2). Such spectroscopic behaviour is typical for the *hot* outbursts of this symbiotic system. Moreover, the absorption component observed in the profiles of the emission lines He I (λ 6678), Hα and Hβ completely disappeared during this outburst, which again justifies its *hot* character.

The EWs of emission lines Hα, Hβ, He I (λ 6678) and He II (λ 4686) manifest an even more prominent increase during the minor outburst G1. Such behaviour would suggest that this brightening belongs also to the *hot* outbursts of AG Dra. On the other hand, the EWs of the Raman-scattered O VI (λ 6825) line dropped to deep minimum during this outburst, which was observed only during the major, *cool* outbursts. In this way, the outburst G1 manifested the spectroscopic behaviour of both *hot* and *cool* outbursts of AG Dra (Merc et al., 2017). The open question remains whether it is a new type of outburst or some kind of transition between (or combination of) the *hot* and *cool* outbursts?

Although the third outburst G2 during the recent active stage of AG Dra was similar to the pre-outburst G0 in its brightness, we detected the same prominent increase of all the emission line EWs as in the case of brightening G1. The only exception was the Hα line: its EWs were comparable to ones during the G0 pre-outburst. Other interesting feature of this outburst was a weakening of hydrogen emission lines just before the G2 outburst. Overall, spectroscopic behaviour ranks this brightening to the *hot* outburst of AG Dra.

The last outburst of AG Dra detected in April 2018 was also of the *hot* type. The maxima of the EWs were either comparable to the values reached during

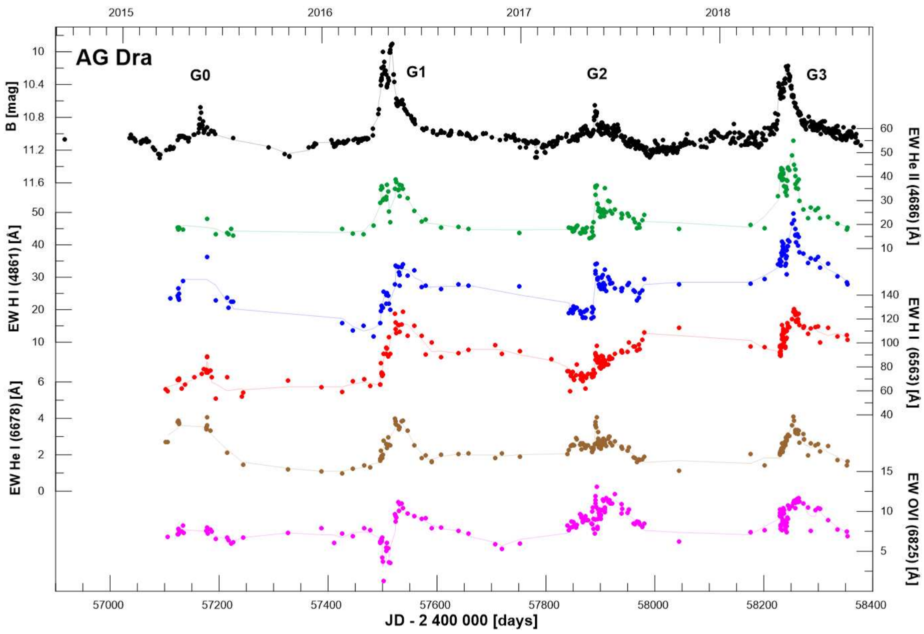

Figure 2. The light curves of AG Dra during the recent active stage in the B band together with the EWs of the studied emission lines. The spectroscopic measurements were obtained from *ARAS* database.

previous outbursts (in the case of Hα, He I ($\lambda\,6678$) and Raman-scattered O VI ($\lambda\,6825$) lines) or demonstrated the highest values detected during the ongoing active stage (Hβ and He II ($\lambda\,4686$) lines).

4. Conclusions

To sum it up, photometric as well as spectroscopic behaviour suggest that the last four outbursts of AG Dra belong to the minor, *hot* type. Such classification is also supported by the results of our analysis of the hot component's temperature during the ongoing active stage of this symbiotic system (more details are given in Merc et al., 2019). On the other hand, some specific effects observed during the outburst G1 (e.g. the almost disappearance of the Raman-scattered O VI lines) are more typical for the *cool* outbursts, despite the fact that the WD's temperature reached the historical maximum during this event.

The future evolution of AG Dra is an open question. Can we expect (finally) a major, *cool* or (again) minor, *hot* outburst? Another possibility is that the symbiotic system will return to quiescence as we already detected such behaviour during the weak activity stage 1963-66. On the basis of our statistical analysis of photometric observations, we are able to predict the time of the next outburst of AG Dra in the interval from JD 2 458 581 (April 7, 2019) to JD 2 458 625 (May 21, 2019).

In any case, AG Dra clearly demonstrates the importance of a pro/am co-operation in long-term monitoring of symbiotic stars in order to disentangle the nature and mechanisms of their active stages and outbursts.

Acknowledgements. This work was supported by the Slovak Research and Development Agency grant No. APVV-15-0458 and by the Estonian Ministry of Education and Research institutional research funding IUT 40-1. We are grateful to all ARAS members that contributed their spectra to this paper. We acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research.

References

Gális, R., Merc, J., Vrašťák, M., et al., The fourth outburst during the present active stage of symbiotic binary AG Dra. 2018, *The Astronomer's Telegram*, **11559**, 1

González-Riestra, R., Viotti, R., Iijima, T., & Greiner, J., IUE observations of the high-velocity symbiotic star AG Draconis. III. A compendium of 17 years of UV monitoring, and comparison with optical and X-ray observations. 1999, *Astron. Astrophys.*, **347**, 478

Hric, L., Gális, R., Leedjärv, L., Burmeister, M., & Kundra, E., Outburst activity of the symbiotic system AG Dra. 2014, *Mon. Not. R. Astron. Soc.*, **443**, 1103, DOI: 10.1093/mnras/stu1162

Kafka, S. 2018, Observations from the AAVSO International Database, https://www.aavso.org

Karpov, S. 2017, private communication

Leedjärv, L., Gális, R., Hric, L., Merc, J., & Burmeister, M., Spectroscopic view on the outburst activity of the symbiotic binary AG Draconis. 2016, *Mon. Not. R. Astron. Soc.*, **456**, 2558, DOI: 10.1093/mnras/stv2807

Merc, J., Gális, R., & Leedjärv, L., Recent outburst activity of the super-soft X-ray binary AG Draconis. 2017, *Contributions of the Astronomical Observatory Skalnaté Pleso*, **47**, 192

Merc, J., Gális, R., & Teyssier, F., Study of long-term spectroscopic variability of symbiotic stars based on observations of the ARAS Group, *Contributions of the Astronomical Observatory Skalnaté Pleso*. 2019, *Contributions of the Astronomical Observatory Skalnaté Pleso*, **49**, 228

Merc, J., Gális, R., Vrašťák, M., & Leedjärv, L., The Fourth Outburst during the Ongoing Active Stage of AG Draconis has Finished. 2018, *Research Notes of the American Astronomical Society*, **2**, 142, DOI: 10.3847/2515-5172/aad807

Mikolajewska, J., Kenyon, S. J., Mikolajewski, M., Garcia, M. R., & Polidan, R. S., Evolution of the Symbiotic Binary System AG Draconis. 1995, *Astron. J.*, **109**, 1289, DOI: 10.1086/117361

Seaquist, E. R., Taylor, A. R., & Button, S., A Radio Survey of Symbiotic Stars. 1984, *Astrophys. J.*, **284**, 202, DOI: 10.1086/162399

Sion, E. M., Moreno, J., Godon, P., Sabra, B., & Mikolajewska, J., On the Nature of the Hot Component in the Symbiotic, Supersoft X-Ray Binary AG Draconis. 2012, *Astron. J.*, **144**, 171, DOI: 10.1088/0004-6256/144/6/171

Smith, V. V., Cunha, K., Jorissen, A., & Boffin, H. M. J., Abundances in the symbiotic star AG Draconis: the barium-symbiotic connection. 1996, *Astron. Astrophys.*, **315**, 179

Vrašťák, M. 2018, private communication