Study of long-term spectroscopic variability of symbiotic stars based on observations of the ARAS Group

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Content

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Selected symbiotic systems
AG Draconis

AG Dra is one of the best studied symbiotic systems.

- the cool component is a **red giant** of early spectral type (K0 – K4), with low metallicity and higher luminosity than that of standard class III (giant)
- the hot component is considered to be a **white dwarf** sustaining a high luminosity and temperature (Mikołajewska et al., 1995; Sion et al., 2012)
- the orbital period is **551 days** (Hric et al., 2014)
- the system undergoes characteristic symbiotic activity with **alternating quiescent and active stages**; the active ones consist of **several outbursts** repeating at about one-year interval
- after seven years of flat quiescence following the 2006-08 major outbursts, AG Dra **begun rising again in brightness** in the late spring of **2015**; we have observed series of **four minor outbursts** during the ongoing active stage

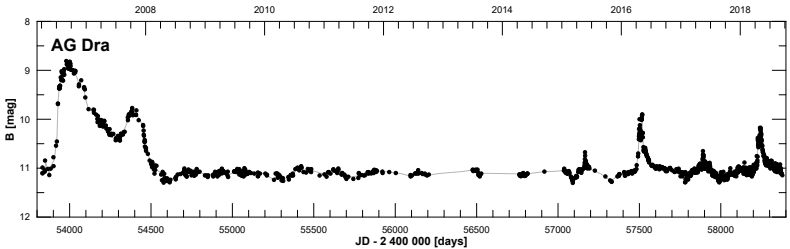

Figure: AAVSO light curve of AG Dra in B filter over the period 2006 - 2018.

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Selected symbiotic systems
Z Andromedae

Z And is the **prototype of the class** of classical symbiotic binaries.

- the binary consists of a **late-type M4.5 III giant** (Skopal, 2008) and a **white dwarf**
- orbital period of the binary system is **758 days** (Mikołajewska & Kenyon, 1996)
- during more than a hundred years of monitoring the system showed **several active stages** with changes ranging from **a few tenths of a magnitude to about three magnitudes** (Formiggini & Leibowitz, 1994; Skopal, 2008)
- the system is in the active stage since 2000 and **manifested the outburst** at the turn of the years 2017 and 2018

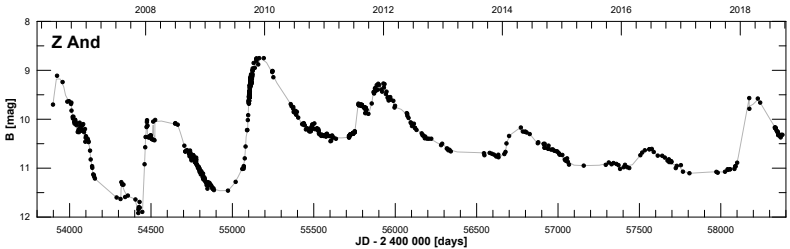


Figure: AAVSO light curve of AG Dra in B filter over the period 2006 - 2018.

Selected symbiotic systems
AG Pegasi

AG Peg is the **slowest symbiotic nova**, which showed Z And-type outburst 165 years after its nova-like flare-up.

- binary system consists of a **M3 III giant** (Schulte-Ladbeck, 1988) and a **white dwarf**
- the orbital period was determined to be **816.5 days** (Fernie, 1985)
- the brightness of the system began to be recorded **before 1820** (although with very low cadence) - its **nova-like outburst** began in 1850 and maximum brightness was reached around 1885 (Lundmark, 1921; Boyarchuk, 1967)
- during June 2015, the **Z And-type outburst** of AG Peg was observed

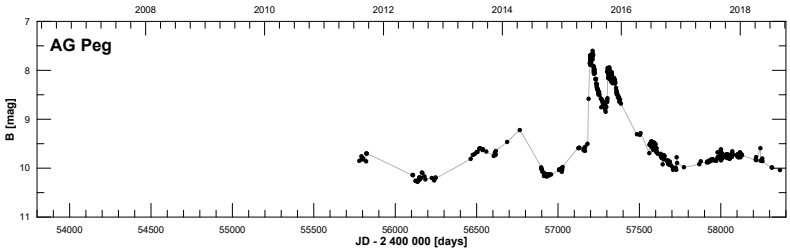


Figure: AAVSO light curve of AG Peg in B filter over the period 2006 - 2018.

ARAS Group

ARAS (Astronomical Ring for Amateur Spectroscopy) is an initiative dedicated to promotion of **amateur astronomical spectroscopy** and **pro/am** collaborations (more in F. Teyssier's talk).

- the observations of the group[1] focus on **novae** (34, to date) and **symbiotic binaries** (54, to date), moreover Be stars, cataclysmic variables, supernovae and other objects are observed
- the network consists of **independent small telescopes (20 to 60 cm)** with spectrographs of different resolution (500 to 15000), covering the range from 3500 to nearly 8000 Å
- the most important features of ARAS observations are **rapid response to alerts**, **long-term monitoring** and **high cadence** of observations

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

Observational data

We have used **medium resolution** spectra of selected symbiotic stars obtained by ARAS Group observers to study the **activity and overall behavior** of **AG Dra** during the ongoing active stage and to compare the recent evolution of prominent emission lines in the spectra to that of **Z And** and **AG Peg**.

	Spectra (used/all)	Observers[2]
AG Dra	274/477	17
AG Peg	111/235	15
Z And	61/127	6
	446/724	22

[2] **Observers in alphabetical order:** Paolo Berardi, Etienne Bertrand, Franck Boubault, David Boyd, Christian Buil, Francisco Campos, Valerie Desnoux, James Foster, Olivier Garde, Keith Graham, Joan Guarro Flo, Stéphane Charbonnel, Thierry Lemoult, Tim Lester, Dong Li, Jacques Montier, Umberto Sollecchia, Peter Somogyi, François Teyssier, Olivier Thizy, Michel Verlinden, Andrew Wilson

Observational data

AG Draconis observational campaign

After seven years of flat quiescence following the 2006-08 major outbursts, AG Dra **begun rising again in brightness** in the late spring of **2015** (more in R. Gális's talk).

- we have initialised the **observational campaigns** (AAVSO, ARAS, Tartu Observatory, Ondřejov Observatory) to study photometric and spectroscopic behaviour of recent active stage of AG Dra
- thanks to high cadence of low and medium resolution spectra which were obtained during our campaign by ARAS observers, we now have, for the first time, chance to **track changes in spectra** of AG Dra during the outburst almost on **daily time-scale**

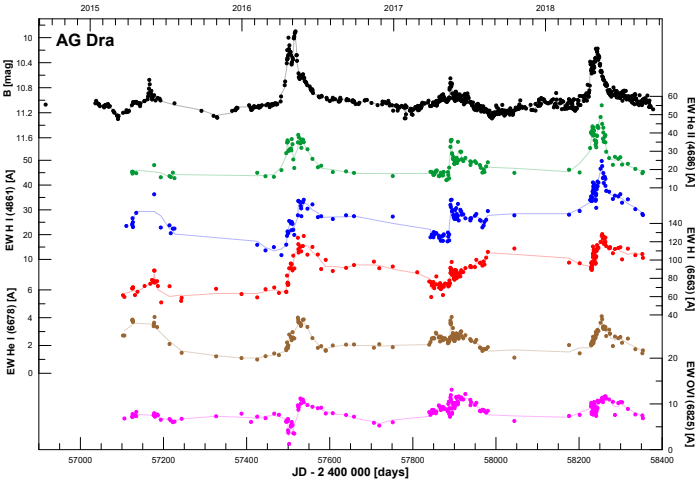
Recent outburst activity of the studied symbiotics

All three studied symbiotic binaries manifested **Z And-type outbursts** activity recently.

- AG Draconis entered a **new active stage** in 2015 and since then four outbursts have been observed so far; the brightness returned to **values typical for quiescence** during this summer (Merc et al., 2018b) (it does not mean that the active stage is over)
- Z Andromedae is in **the active stage** since 2000, the recent outburst was observed at the turn of the years **2017 and 2018**; since then the brightness is slowly declining
- AG Pegasi manifested **double-peaked outburst in 2015** with very slow decline in brightness lasting for more than a year

Recent outburst activity of the studied symbiotics

Variability and correlations with brightness



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Recent outburst activity of the studied symbiotics

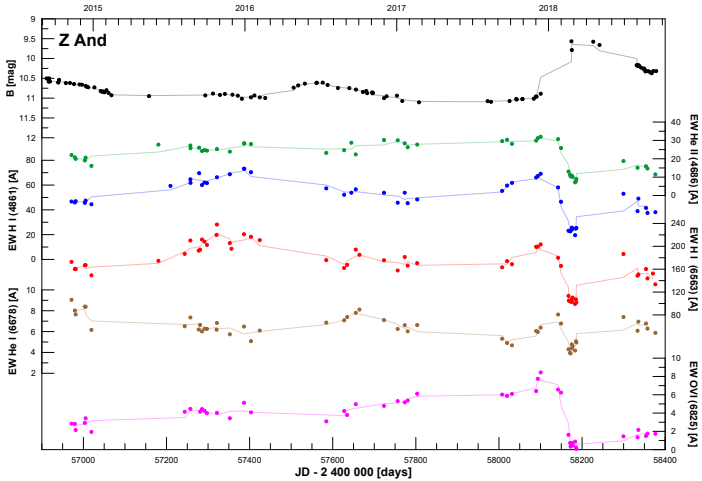
Variability and correlations with brightness

Characteristics of emission lines clearly confirmed the **presence of the two types** of outbursts in AG Dra: **cool** and **hot ones**.

- during the hot outbursts, brightness is more or less **linearly correlated** with variation of spectral characteristics (e.g. EWs)
- the increase of EWs was observed for all recent outburst indicating their **hot character**
- on the other hand, outbursts in the beginning of active phases of AG Dra are **usually major, cool ones**
- the activity during the ongoing active stage is very unusual

Recent outburst activity of the studied symbiotics

Variability and correlations with brightness



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Recent outburst activity of the studied symbiotics

Variability and correlations with brightness

The EWs of studied emission lines in spectra of Z And showed **significant decline** during the recent outburst.

- the EWs are **anticorrelated** with brightness changes during the outburst; in the case of AG Dra, such behaviour is typical for **cool outbursts**
- the Raman-scattered O VI lines **completely disappeared during the outburst** (and still not completely recovered); moreover also [Fe VII] disappeared during the outburst, but reappeared at the time when O VI lines remained undetectable
- similar behaviour of emission lines in the spectra of Z And **have been observed** during the outburst in 2006, when the star underwent a strong outburst accompanied by **the ejection of bipolar jets**; during that outburst, the He II line also practically disappeared (Burmeister & Leedjärv, 2007)
- despite the similarity of these two outbursts (2006 and 2018), **no sign of the jet components** around the H_α and H_β lines is observed in spectra during the recent one

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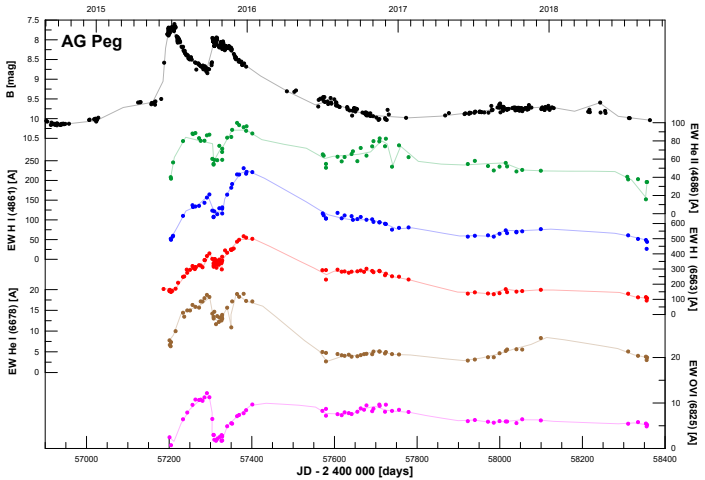
Recent outburst activity of the studied symbiotics

Variability and correlations with brightness



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Recent outburst activity of the studied symbiotics

Variability and correlations with brightness

AG Peg showed **Z And-type outburst** 165 years after its nova-like flare-up around the year 1850 (Skopal et al., 2017).

During the outburst of AG Peg, EWs of the studied emission lines **increased significantly** compared to the quiescence values.

- similar **double-peaked structure** as in light curves was observed in spectroscopy; on the other hand, observed increase of EWs was **not so steep** as the increase in brightness
- the Raman-scattered **O VI lines disappeared** from the spectra during both maxima of outburst

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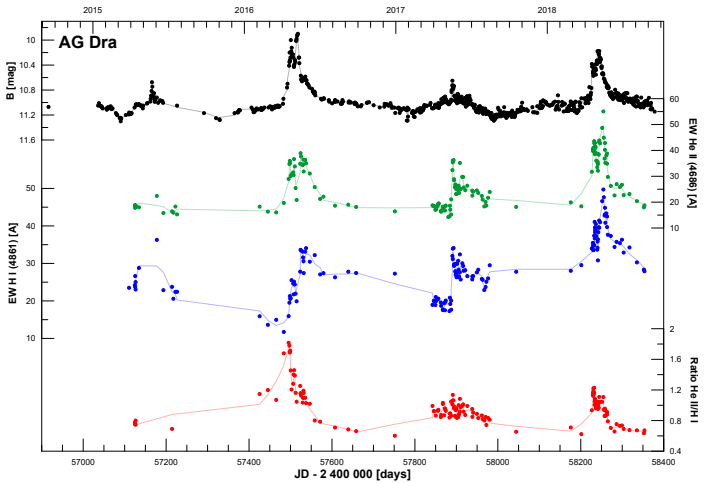
Temperature of the white dwarfs

Emission lines in the optical spectra can be used for the **estimation of the temperature** of the ionising source.

Having all **the implications** of using a simplified method of white dwarf temperature estimation in the mind (more in R. Gális's talk and Merc et al., 2018a), we can study the **temperature changes of white dwarfs** in selected symbiotic systems during their outbursts using the **ratio** of EWs of He II and H_β.

Temperature of the white dwarfs
AG Draconis



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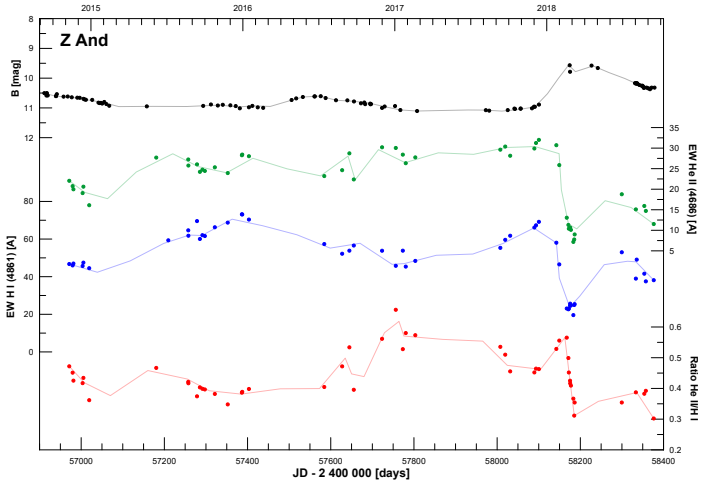
Temperature of the white dwarfs
Z Andromedae



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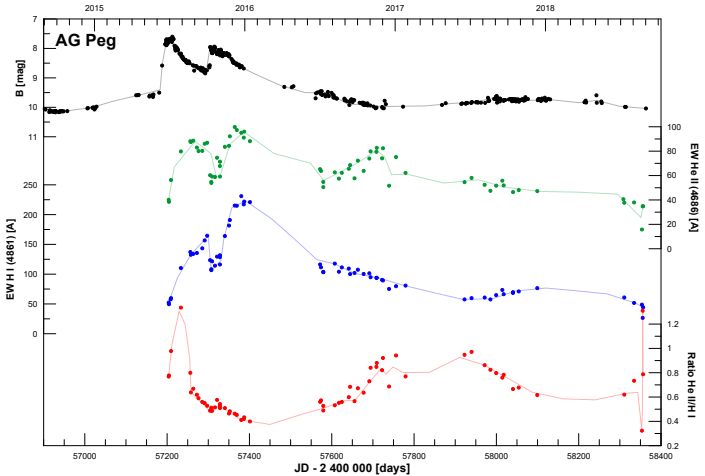
Temperature of the white dwarfs
AG Pegasi



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Temperature of the white dwarfs

Emission lines in the optical spectra can be used for the **estimation of the temperature** of the ionising source.

Having all **the implications** of using a simplified method of white dwarf temperature estimation in the mind (more in R. Gális's talk and Merc et al., 2018a), we can study the **temperature changes of white dwarfs** in selected symbiotic systems during their outbursts using the **ratio** of EWs of He II and H_β.

- all four recent outburst of AG Dra were of a **hot type**
- moreover, during the outburst G1 of AG Dra, **historical maximum** of the temperature have been observed
- the 2015 outburst of AG Peg was also accompanied by **the increase in temperature** of the white dwarf
- during and after last outburst of Z And a **decrease in temperature** was observed

The Raman-scattered O VI lines

Raman-scattered O VI lines are **broad emission lines** in the spectra at 6825 and 7082 Å which are a product of Raman-scattering of the photons of the O VI resonance lines at 1032 and 1038 Å off the atoms of neutral hydrogen (Schmid, 1989). They occur almost **exclusively** in the spectra of symbiotics.

Raman-scattered O VI 6825 Å almost **disappeared during the cool outburst** of AG Dra in 2006, confirming a drop in the hot component's temperature (Leedjärv et al., 2016).

- the outburst G1 manifested the **same vanishing** of the Raman-scattered O VI 6825 Å (Merc et al., 2017) although it was not of a **cool type**
- similar vanishing have been observed during the recent outbursts of AG Peg and Z And

The Raman-scattered O VI lines

The minima in the observed EWs of the Raman-scattered O VI lines in the case of Z And can be explained by **cooling of the ionising source**. On the other hand, the observations of AG Dra and AG Peg showed that the temperature of the white dwarfs in these systems **have been high** enough during studied outbursts. This **rejects** the usual interpretation for disappearance of O VI lines due to a cooling of the ionising source.

- during the outburst G1 of AG Dra the temperature reached the **historical maximum**
- in case of AG Peg the minimum of EWs of O VI lines was also observed at a **very high temperature**; Skopal et al. (2017) suggested that the transient weakening of the O VI lines is a result of an increase of mass-loss rate from the hot component which makes O VI zone optically thick
- probably a **similar effect** played a role in case of AG Dra

Conclusions

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Presented results showed not only the **importance of the long-term monitoring** of symbiotic stars, but also how important **pro/am collaborations** are. ARAS Group is a perfect example that such collaboration can be **very successful** and can bring important results.

- medium-resolution spectra of AG Dra, Z And and AG Peg were used to study the **variability and behaviour of prominent emission lines** in the spectra
- in addition, the **changes in profiles** of spectral lines were studied
- the high cadence of the obtained spectra allowed to study the **evolution of the temperature** of the white dwarf during the outbursts
- moreover, we have used the mid-res spectra of AG Dra for **radial velocity measurements** (more in R. Gális's talk)
- low-res spectra play not only an important role in **monitoring** but can be used for **spectral energy distribution modelling**

Thank you for your attention.