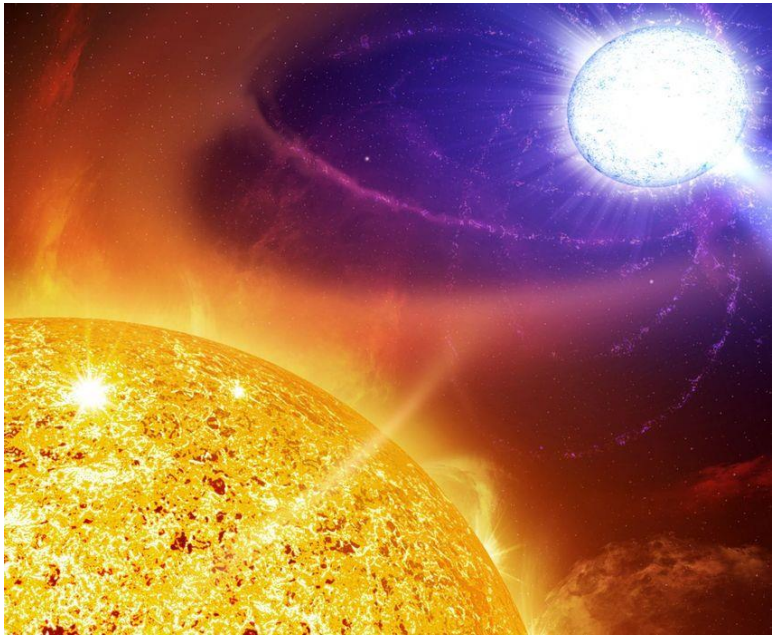
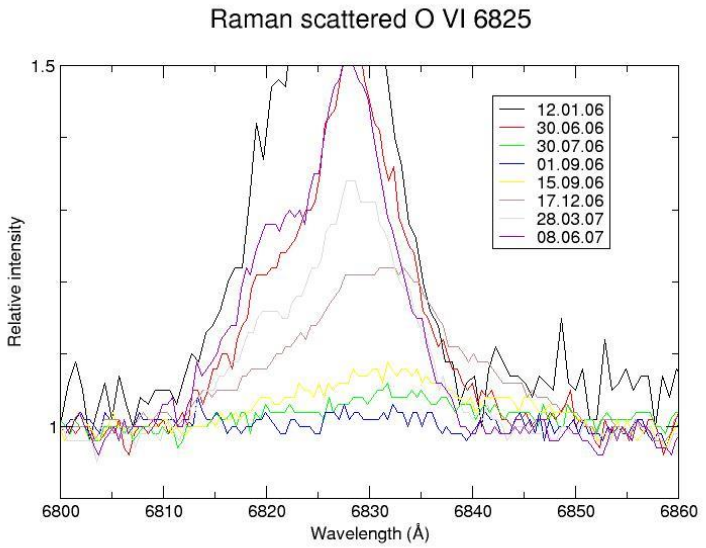
Spectroscopic view on the outburst activity of the symbiotic binary AG Draconis





Laurits Leedjärv

Astronomy Seminar at Tartu Observatory
May 20, 2015

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Outburst activity of the symbiotic system AG Dra

MNRAS (September 11, 2014) Vol. 443, 1103-1112, doi:10.1093/mnras/stu1162
First published online July 22, 2014

- Analysis of the light curves from 1889 to 2012

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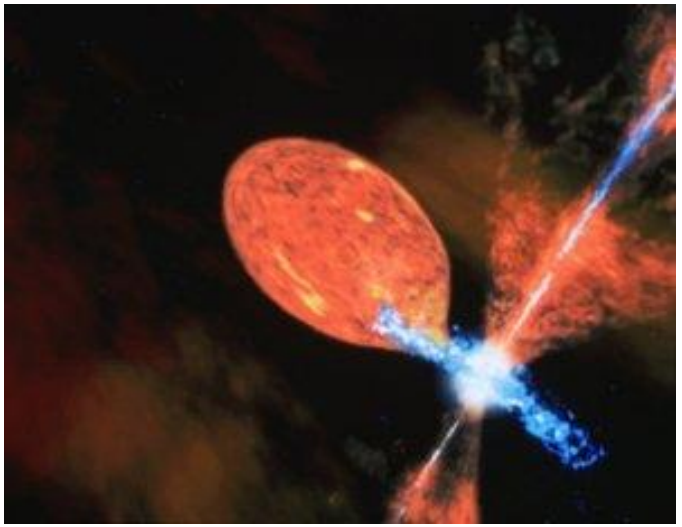
Spectroscopic view on the outburst activity of the symbiotic binary AG Dra

MNRAS
To be submitted in June 2015

- Analysis of the spectroscopic observations done at Tartu Observatory mostly from 1997 to 2011

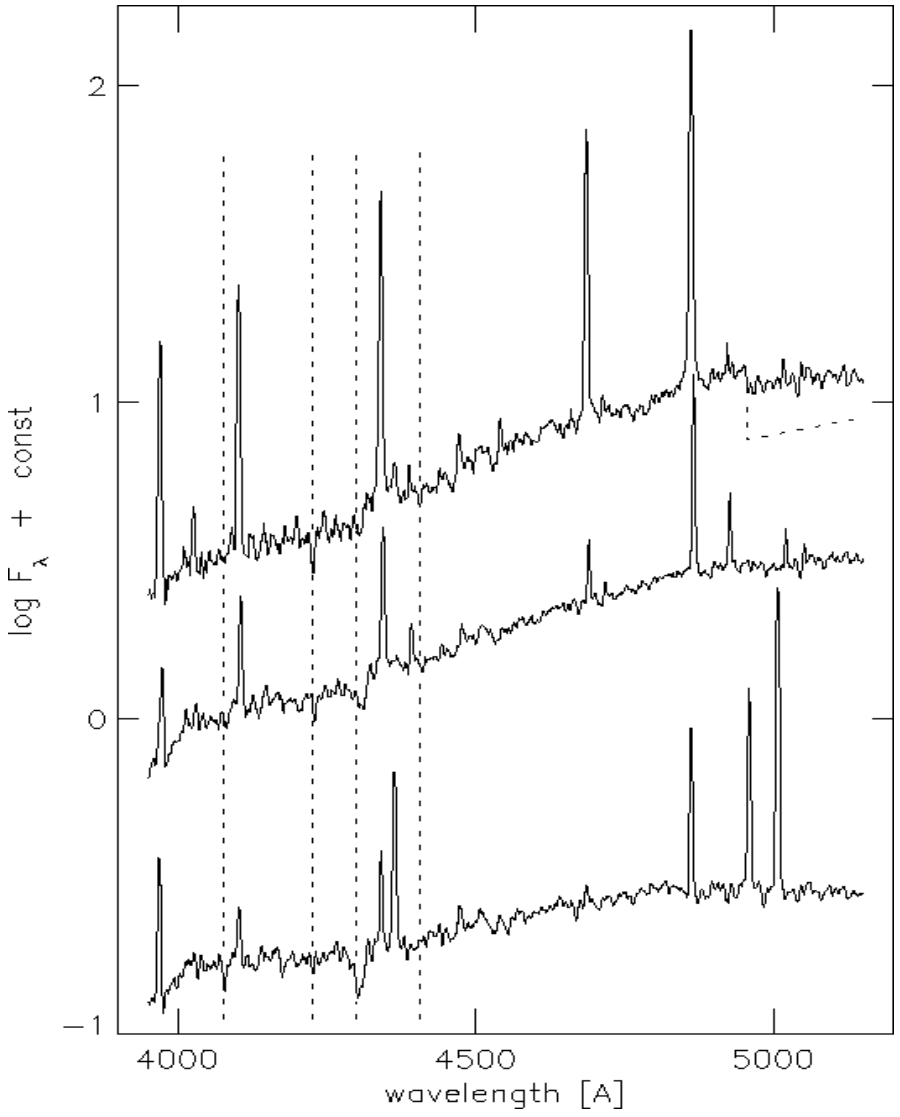
Symbiotic stars (SS):

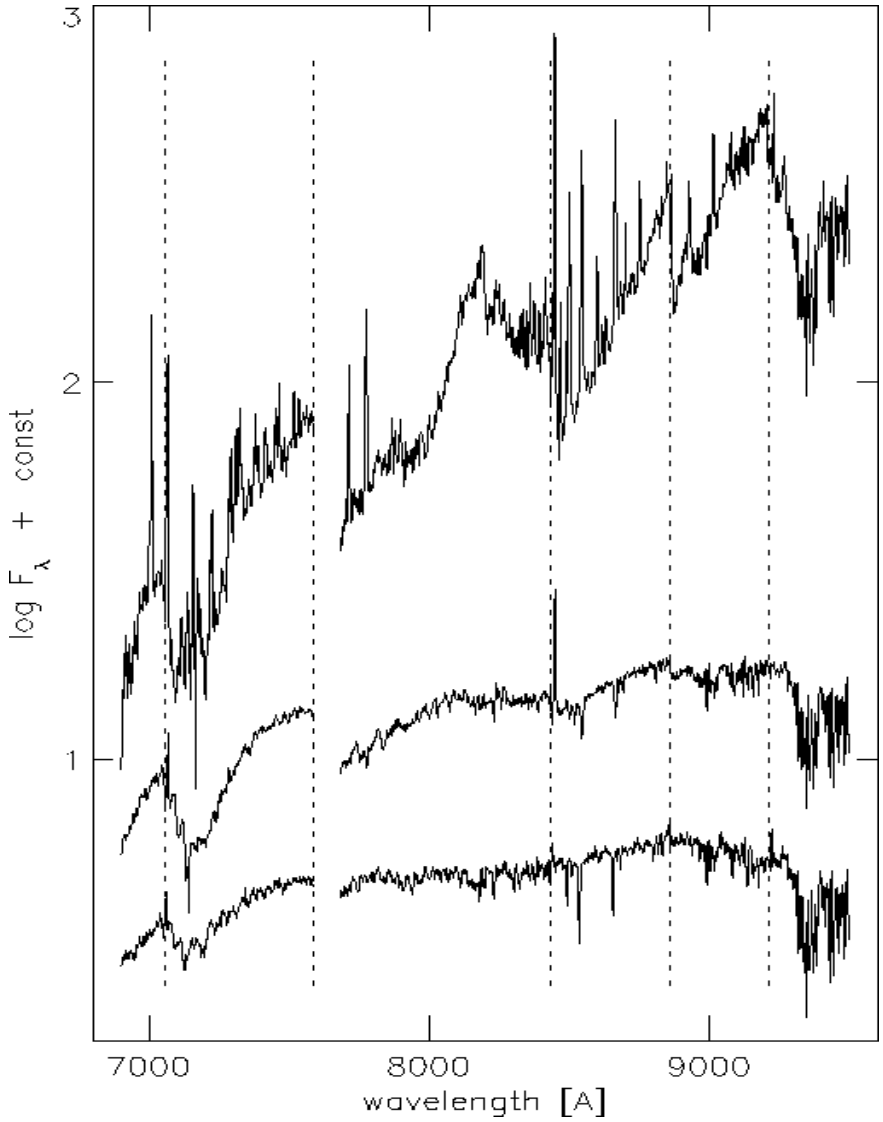


Interacting binary systems consisting of a red giant (in general not filling its Roche lobe) and a white dwarf (usually accreting matter from the red giant's wind, sometimes through an accretion disk)

Both components are embedded in a gaseous nebula, partly ionized by the hot component

Typical SS spectrum with absorption bands of TiO and high excitation emission lines





About 230 SS known:

A Catalogue of Symbiotic Stars Belczyński *et al*. 2000, A&ASS, 146, 407
Corradi *et al*. 2010, A&A, 509, A41
Miszalski *et al*. 2013, MNRAS, 432, 3186
Gonçalves *et al*. 2015, MNRAS, 447, 997

Classification to S and D types

S (Stellar): normal M giant, orbital periods 200–2000 (5700) days

D (Dusty): Mira type cool component, orbital periods in tens of years

Yellow (S – without dust, and D' – dusty): F, G or K type giant, orbital periods like in S-type

Carbon

Classification of SS based on the nature and variability of the hot component:

Classical (Z And type) SS

- about 1–3 mag eruptions at irregular intervals (a few years)

Symbiotic novae

- one about 6–10 mag outburst recorded

Symbiotic recurrent novae

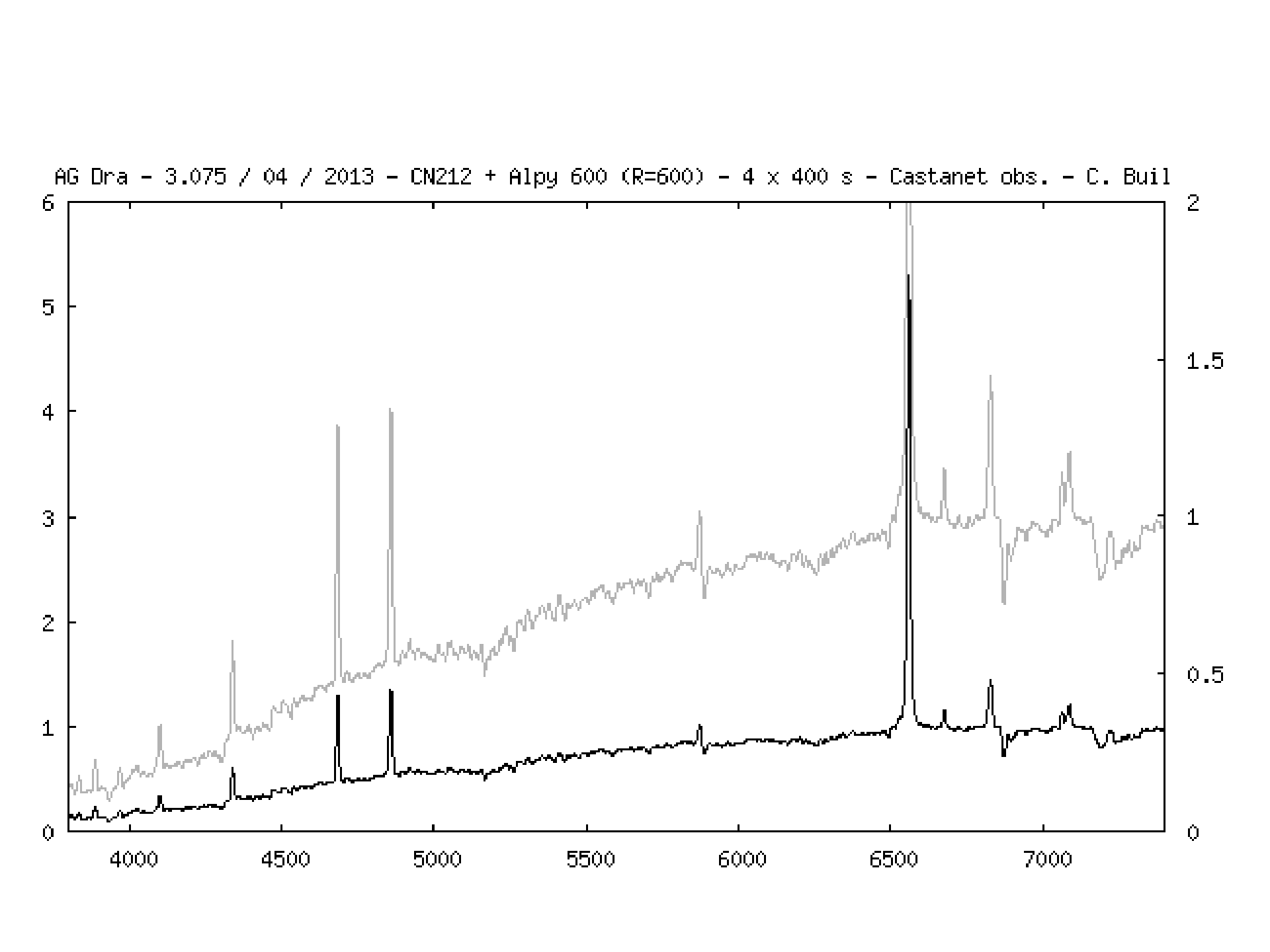
- repeating outbursts (~2–10 mag) at ~10–100 years intervals

Quiescent SS

- no outburst related brightness variations

AG Dra – a yellow symbiotic star:

- **S type**
- **early-type cool component (K0–K3 II–III)**
- **Galactic latitude 41°, velocity –148 kms^{-1},**
  [Fe/H]= -1.3 ➔ Galactic halo
- **orbital period P_{orb} = 550 d**
- **major outbursts start at about 12–15 years intervals**
- **minor activity in about one-year cycle**
- **pulsation (?) period P_{puls} = 350–380 d**
- **strong supersoft X-ray source**


AG Dra - 3.075 / 04 / 2013 - CN212 + Alpy 600 (R=600) - 4 x 400 s - Castanet obs. - C. Buil
6
5
4
3
2
1
0
2
1.5
1
0.5
0
4000
4500
5000
5500
6000
6500
7000

Optical spectroscopy at Tartu Observatory:

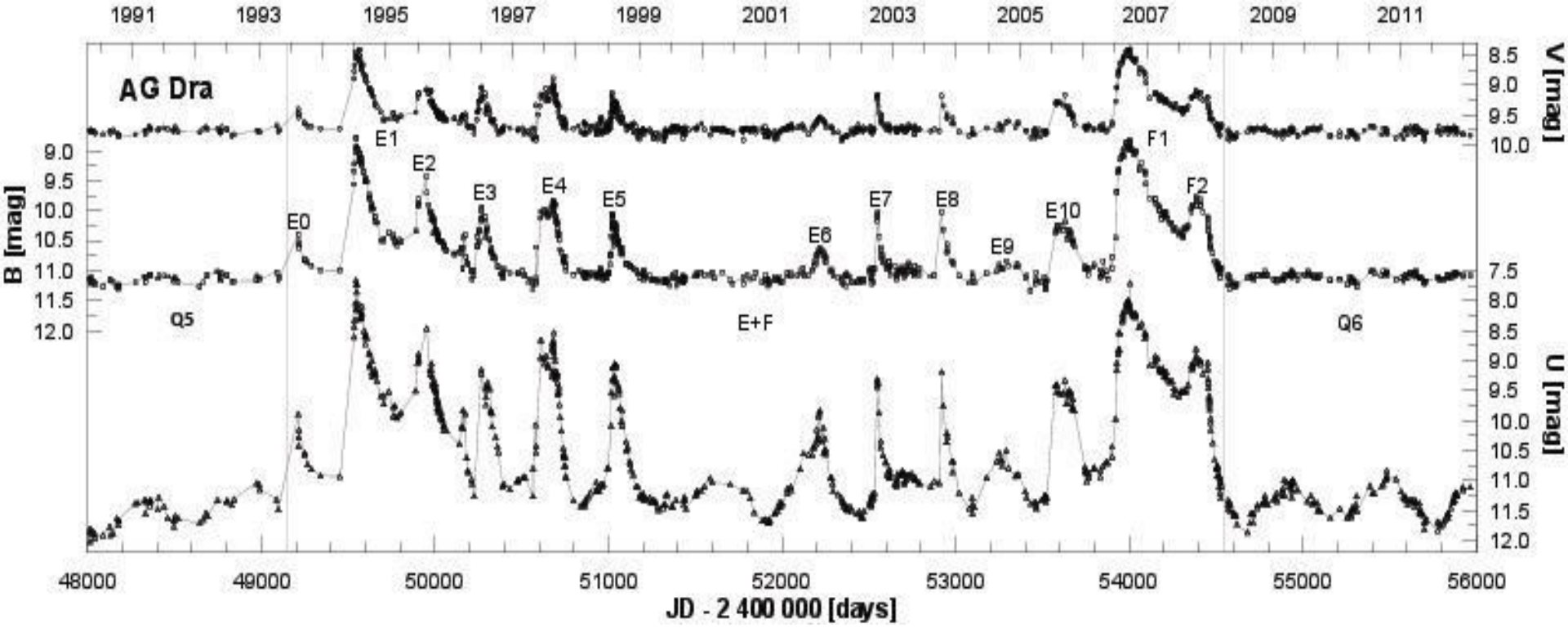
1.5-meter telescope AZT-12,
Cassegrain focus spectrograph

Blue spectra: He II 4686 – Hβ	**0.86 Å/pix**
Red spectra:	
Hα - He I 6678–O VI Raman 6825	**0.66 Å/pix**
Hα	**0.26 Å/pix**

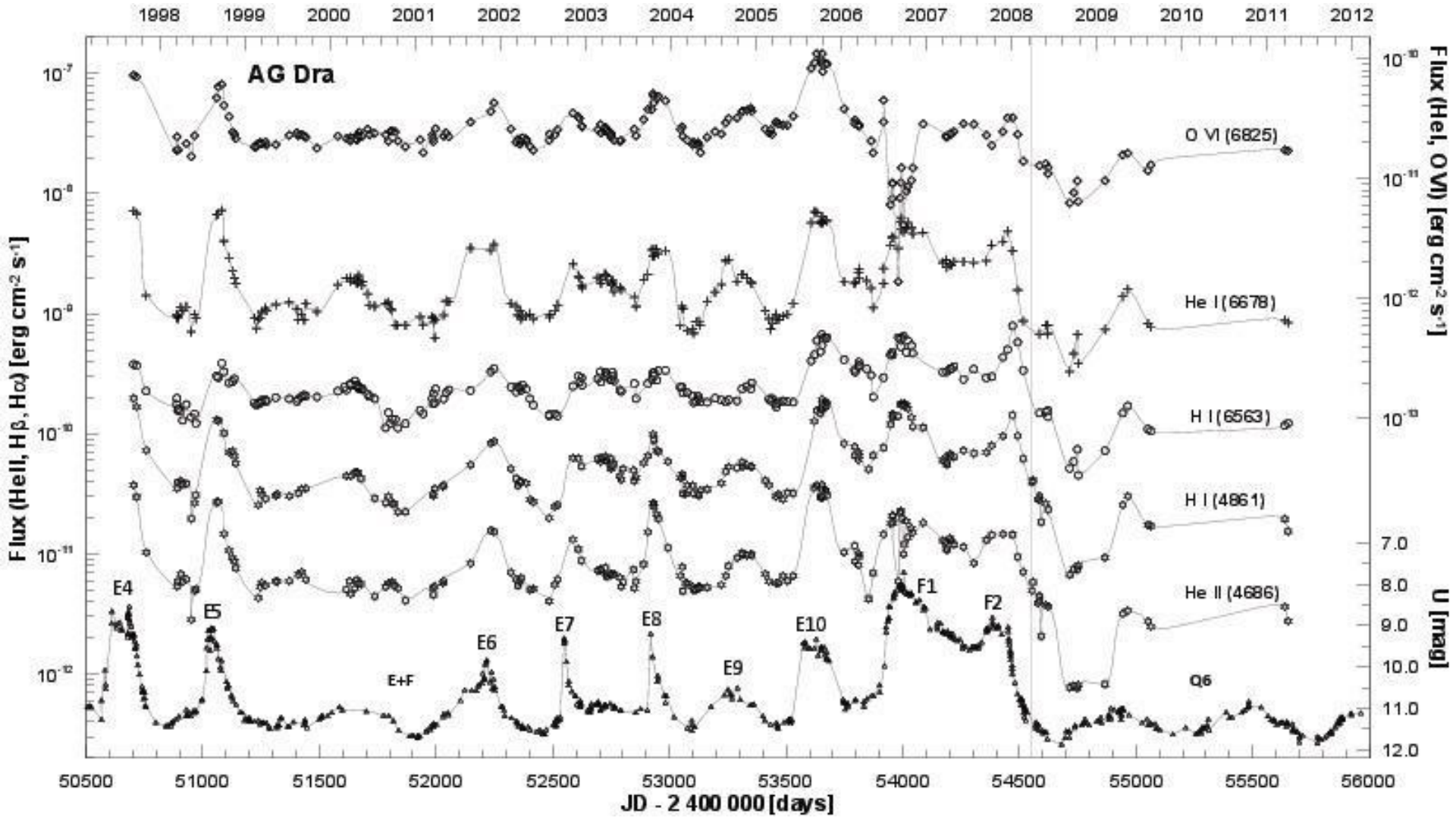
Altogether about 520 spectra from 1997 to 2011 (2014)

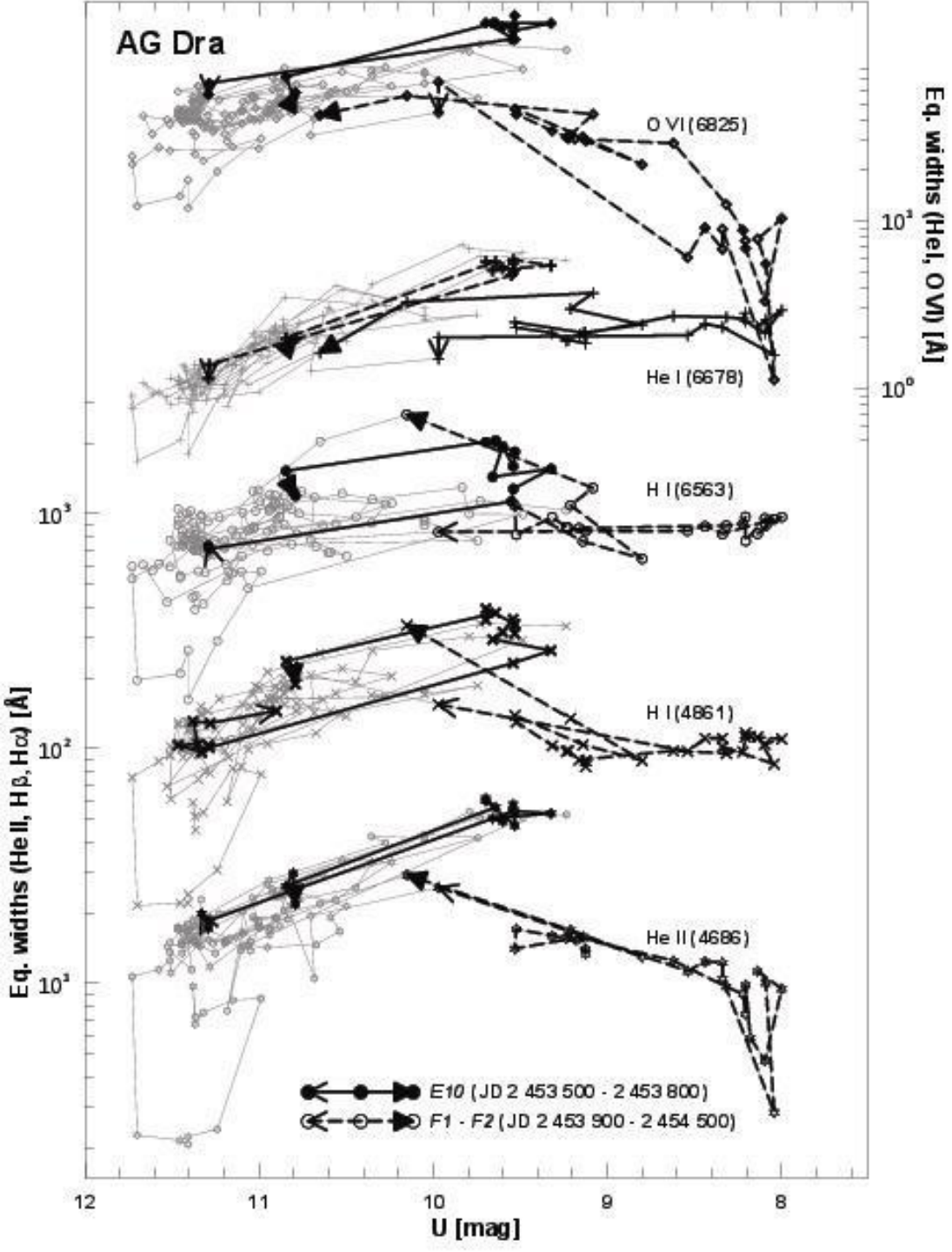
Thanks to Kalju Annuk, Alar Puss, Anti Hirv …

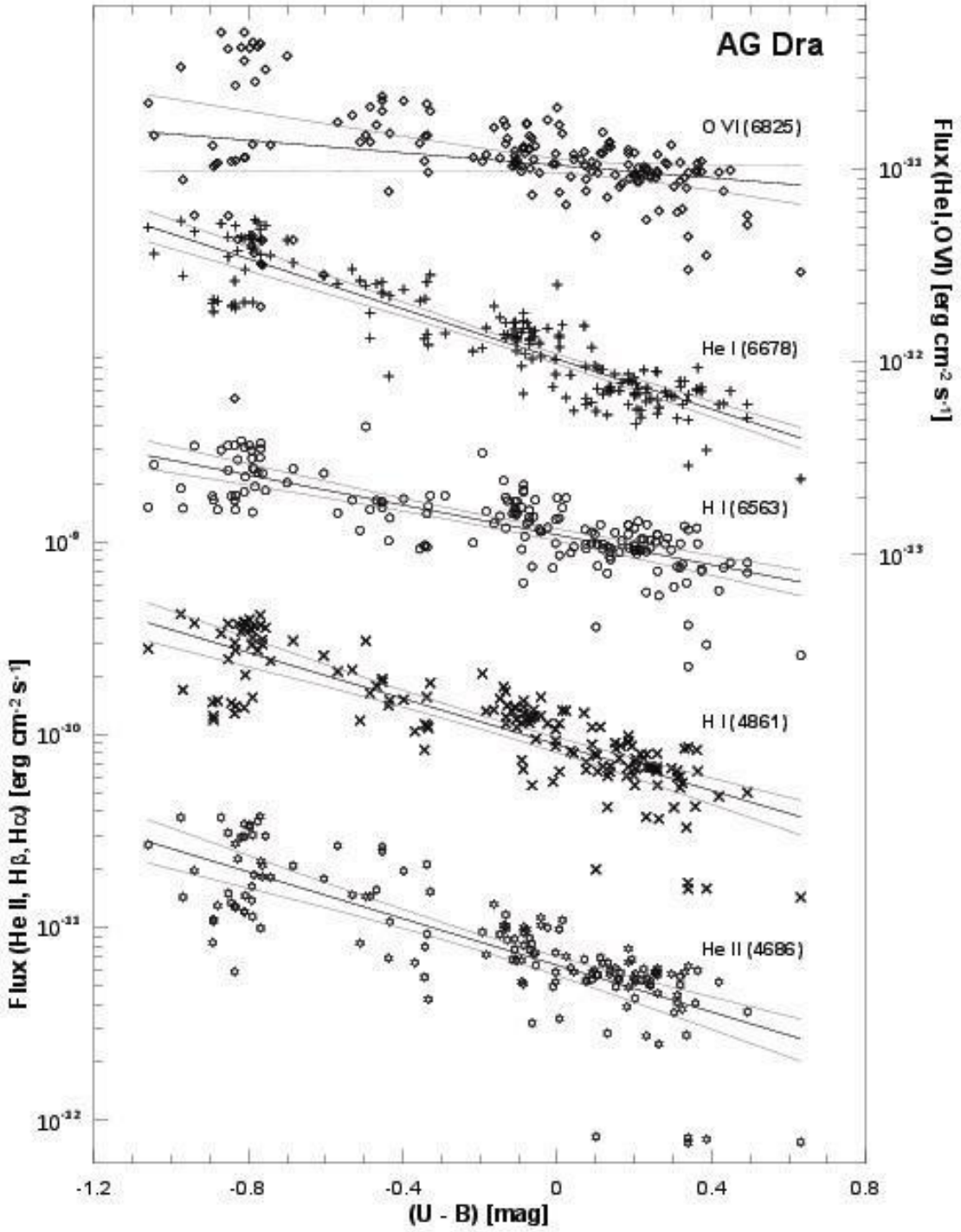
UBV light curves of AG Dra from 1990 to 2012



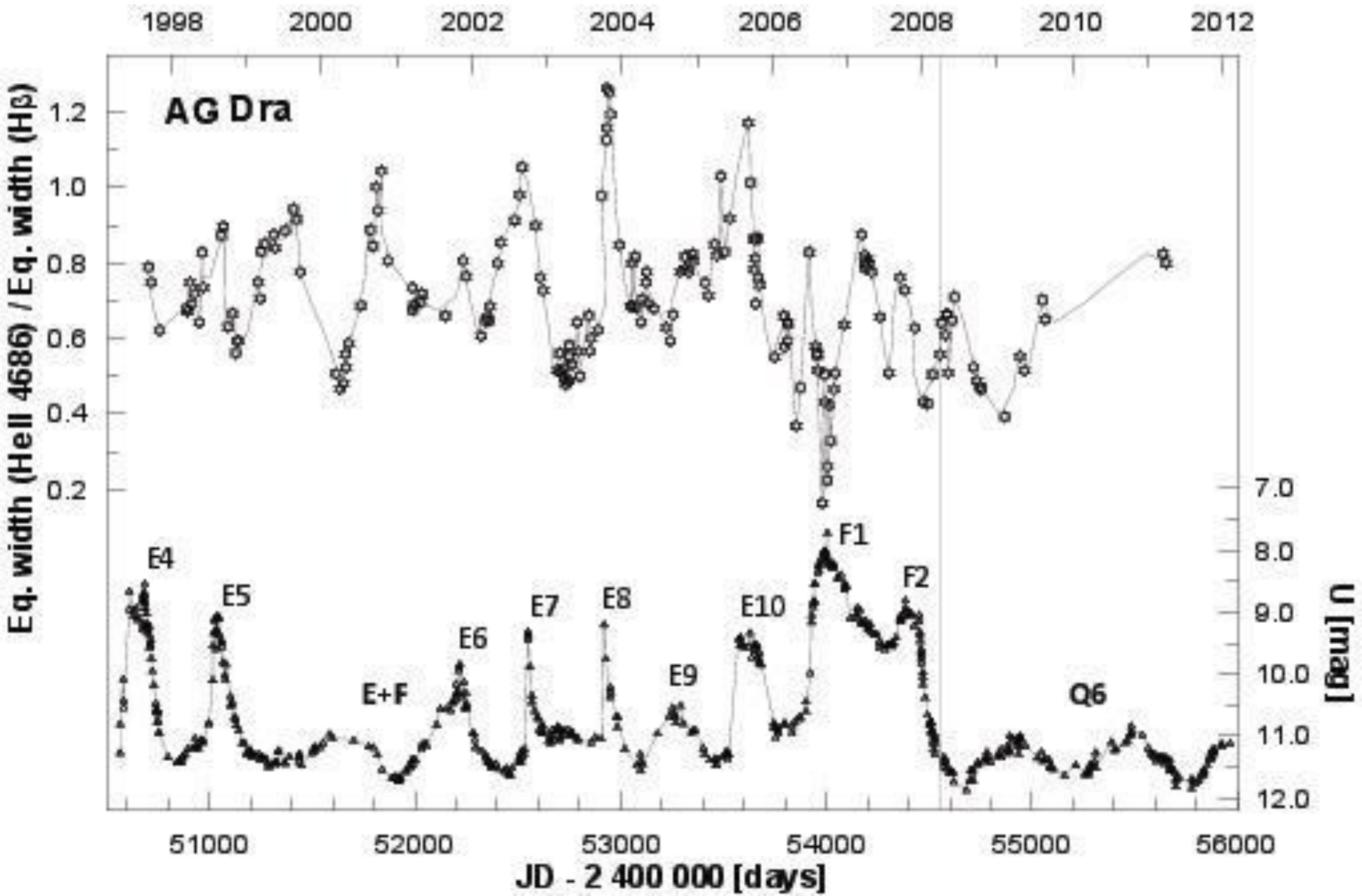
Fluxes emitted in the most prominent emission lines (together with the *U* light curve)

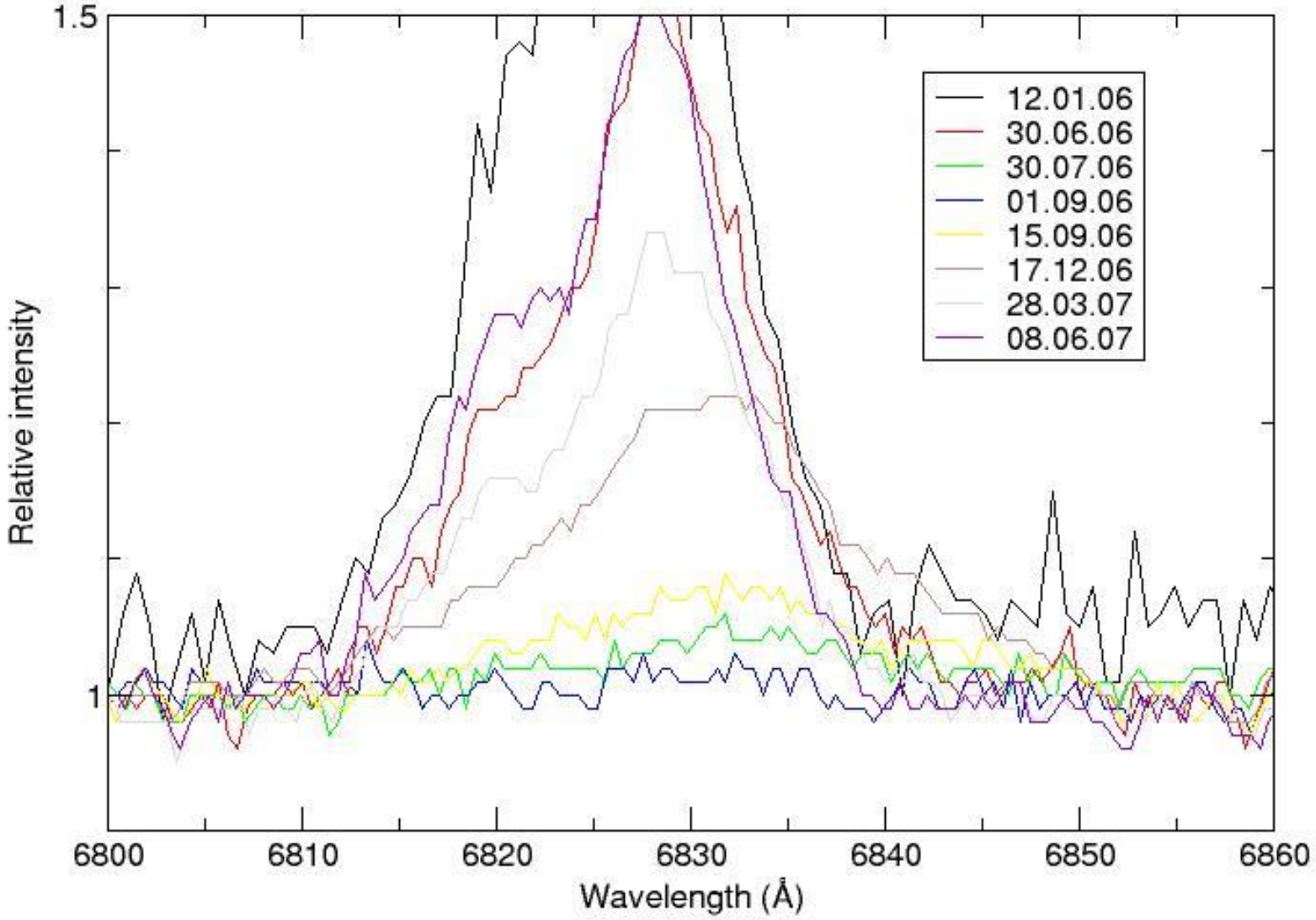


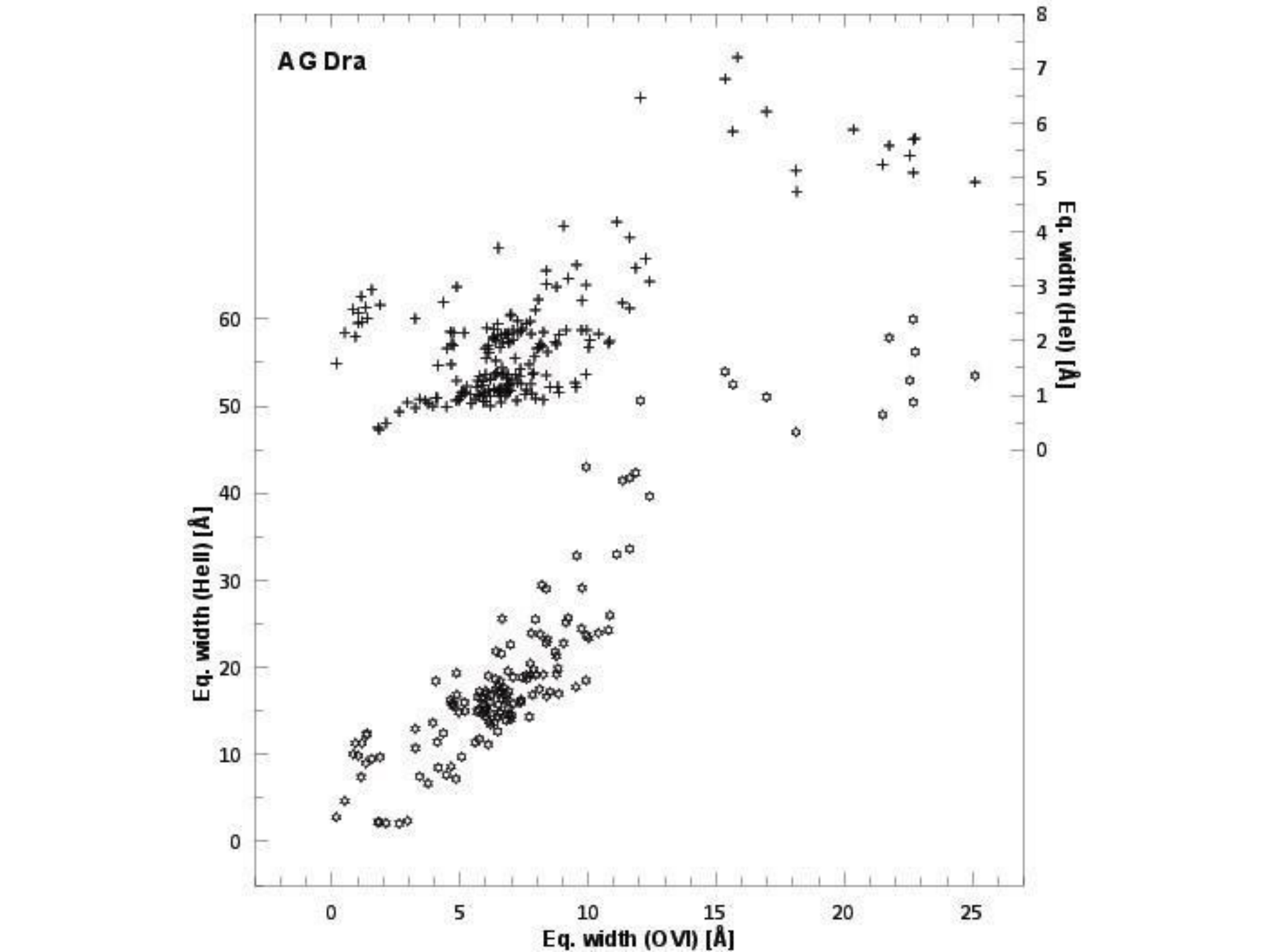

AG Dra
O VI (6825)
He I (6678)
H I (6563)
H I (4861)
He II (4686)
Eq. widths (He II, Hβ, Hα) [Å]
Eq. widths (He I, O VI) [Å]
U [mag]
12
11
10
9
8
E10 (JD 2 453 500 - 2 453 800)
F1 - F2 (JD 2 453 900 - 2 454 500)


AG Dra
O VI (6825)
He I (6678)
H I (6563)
H I (4861)
He II (4686)
Flux (He II, Hβ, Hα) [erg cm⁻² s⁻¹]
Flux (HeI, OVI) [erg cm⁻² s⁻¹]
(U - B) [mag]
-1.2
-0.8
-0.4
0
0.4
0.8

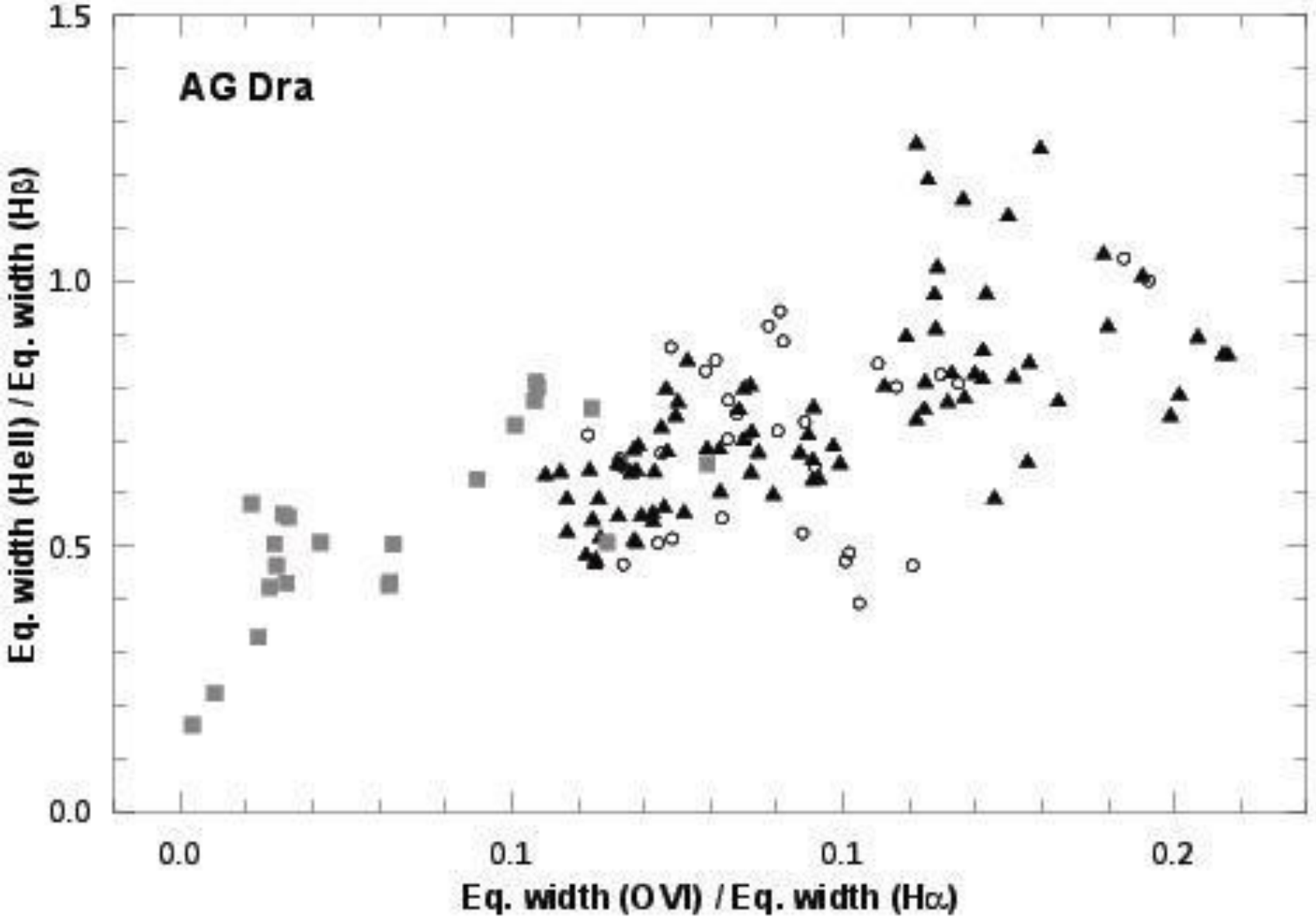
EW(4686)/EW(Hβ) approximating T_{hot}

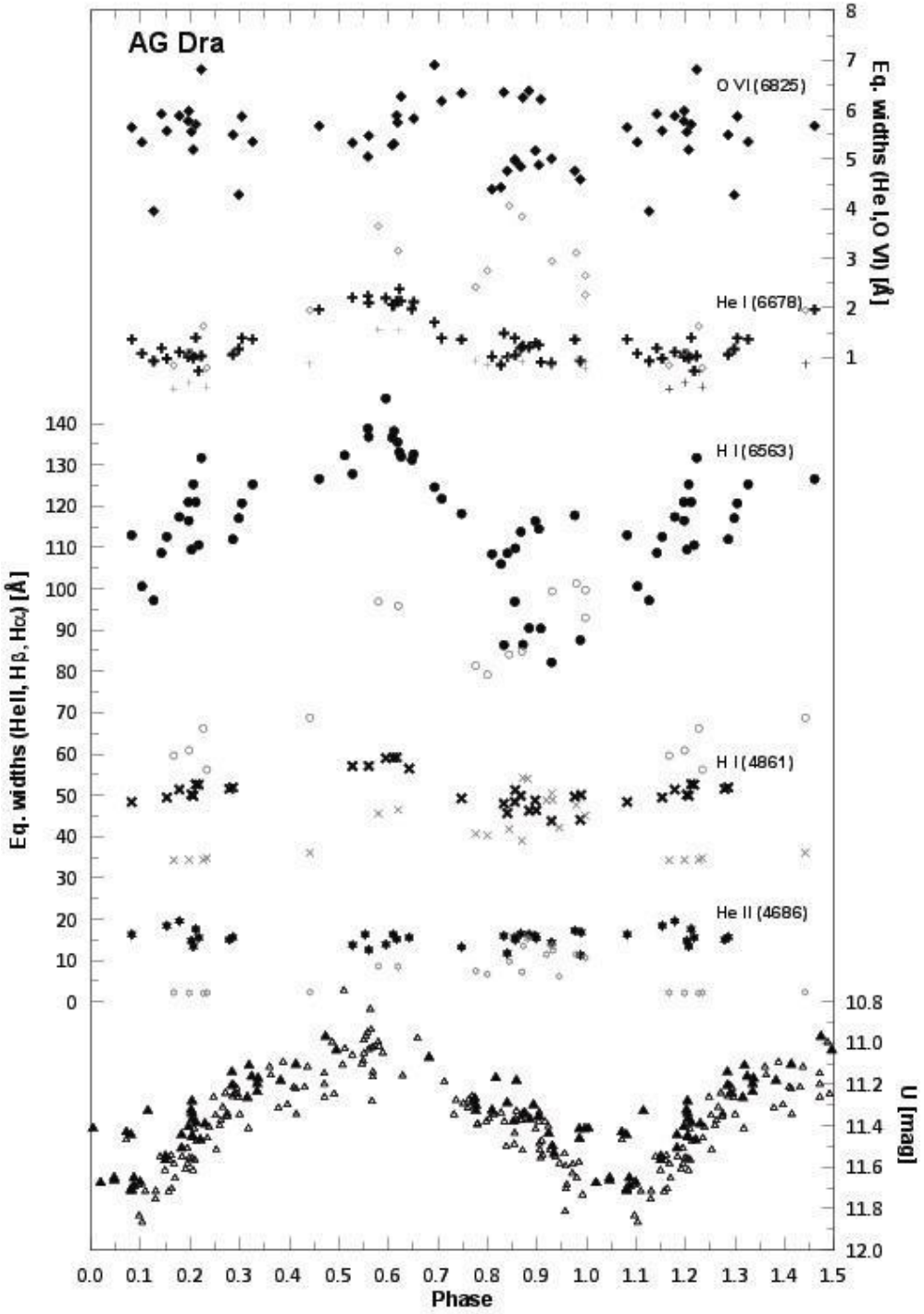



Raman scattered O VI 6825
1.5
1
Relative intensity
6800
6810
6820
6830
6840
6850
6860
Wavelength (Å)
12.01.06
30.06.06
30.07.06
01.09.06
15.09.06
17.12.06
28.03.07
08.06.07

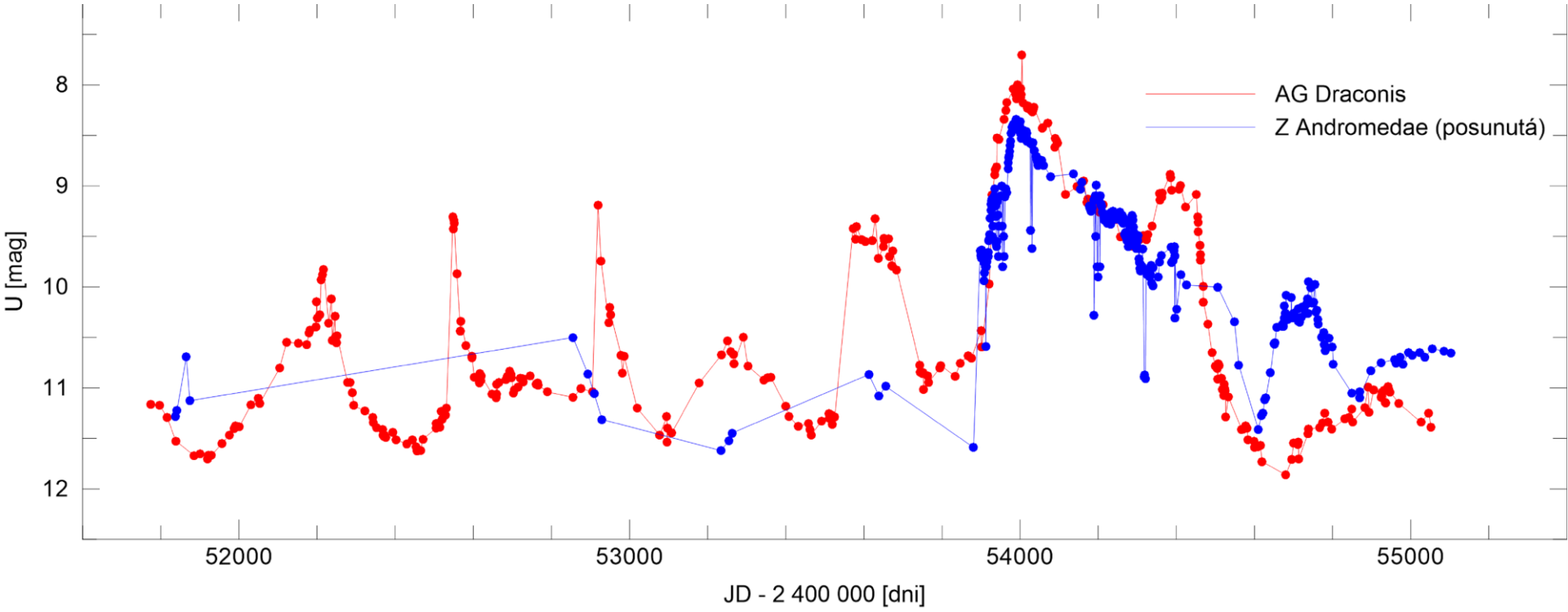

AG Dra
Eq. width (HeII) [Å]
Eq. width (HeI) [Å]
Eq. width (OVI) [Å]
0
10
20
30
40
50
60
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25

Separating cool and hot outbursts

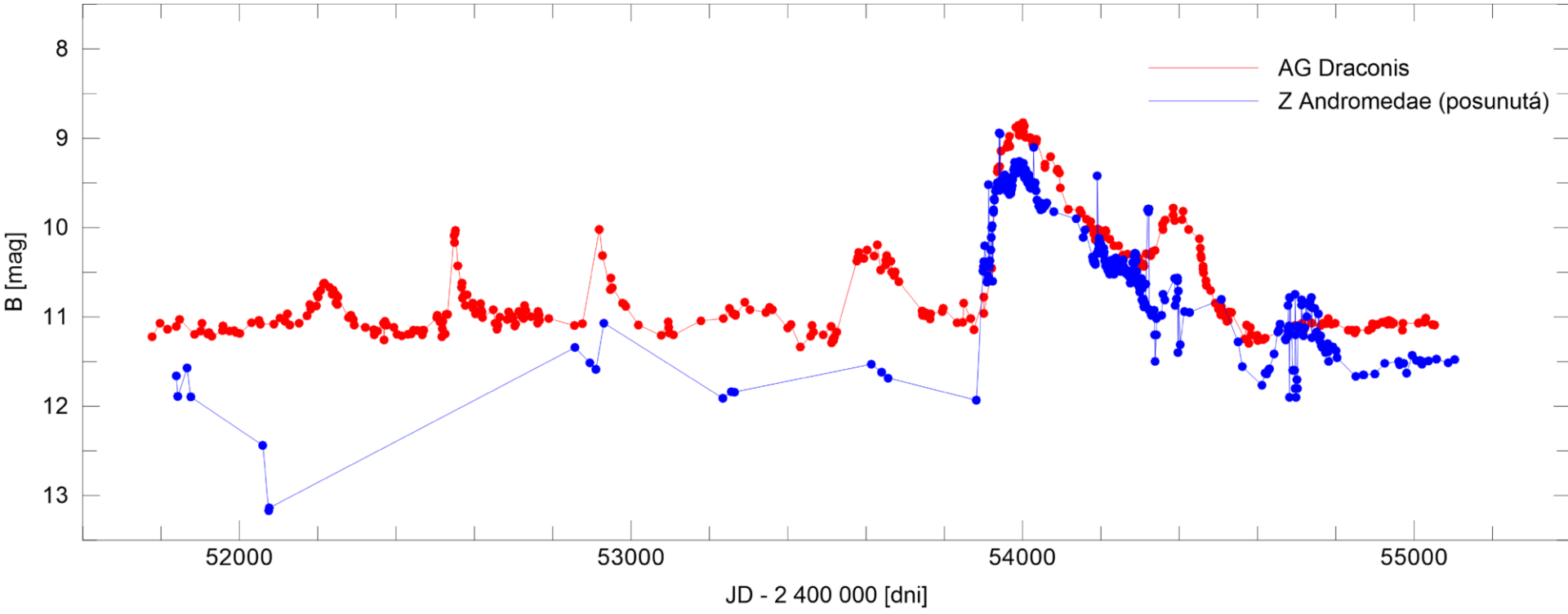



AG Dra
O VI (6825)
He I (6678)
H I (6563)
H I (4861)
He II (4686)
Eq. widths (HeII, Hβ, Hα) [Å]
Eq. widths (He I,O VI) [Å]
U [mag]
Phase

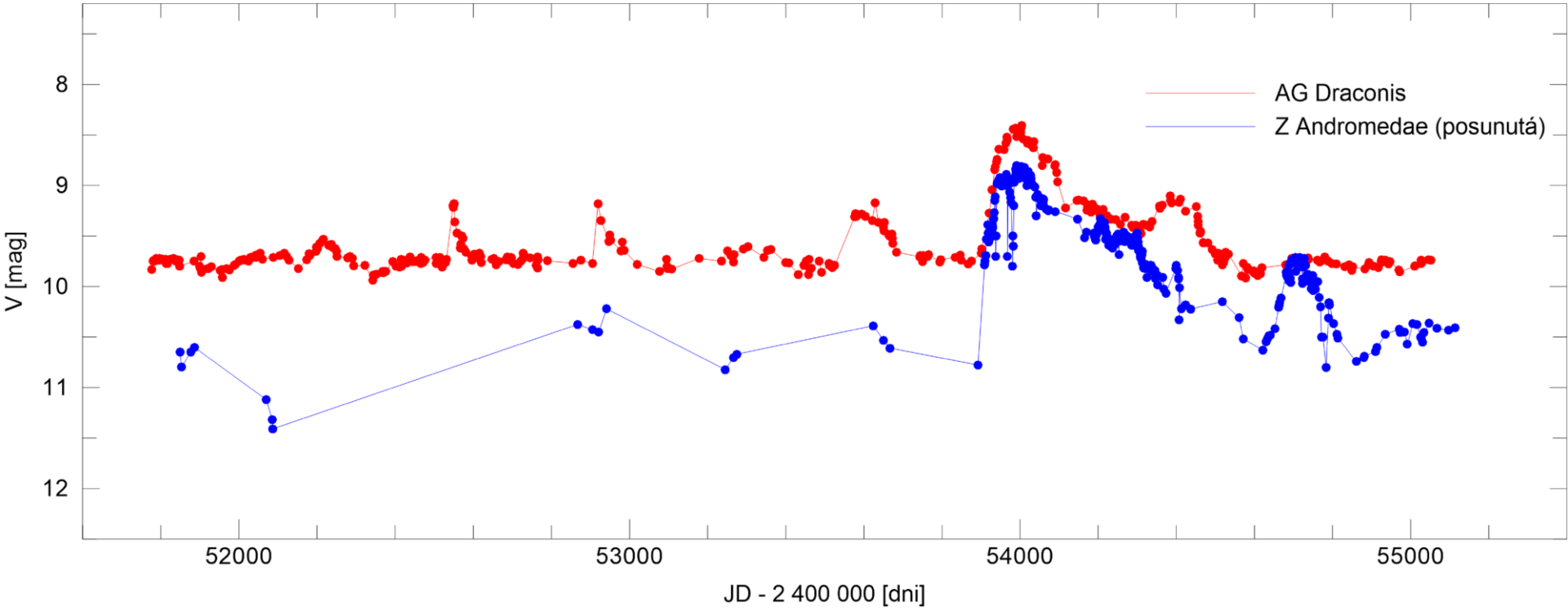
Correlation of the long-term *U* light curves of AG Dra and Z And, shift = 2103.4 days, *r* =0.70



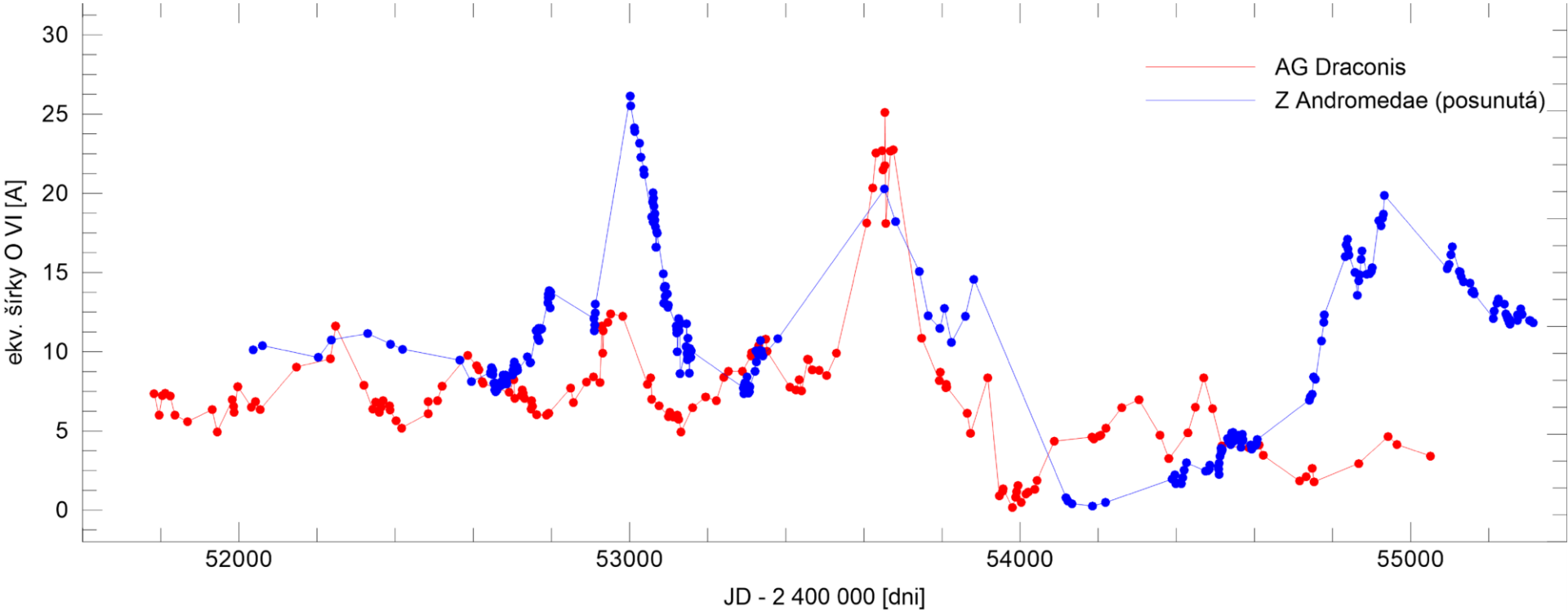
B light curves, shift = 2104.6 days, *r* =0.77



V light curves, shift = 2115.0 days, *r* =0.74



EWs of the Raman scattered O VI 6825 line
shift 2960.0 days, maxima, r =0.48
2311.2 days, minima, r =0.45



(Preliminary) conclusions:

- **In hot outbursts, emission lines strengthen with increasing brightness of the star**

- **At a certain magnitude (*U* ~9.4, *B* ~10.2), this trend breaks down – low excitation lines (H I, He I) strengthen only slightly or remain ~constant, high excitation lines (He II, O VI) start to weaken**

- **Time scales and amplitudes of the cool outburst occurring in AG Dra in 2006 are similar to those in the prototypical symbiotic star Z And – a similarity of the physical conditions and mechanism?**

Conclusions (continued):

- **Neither accretion processes nor thermonuclear reactions on the surface of the WD alone are capable to explain frequency and amplitude of the 1 – 3 magnitude outbursts of classical symbiotic stars occurring at a few years intervals**

- **A *combination nova* model proposed by Sokoloski et al. (ApJ, 636, 1002, 2006) for Z And is promising: disk instability causing smaller scale (hot) outbursts, at a certain threshold an increased accretion rate triggers thermonuclear flash**

- **However, presence of the accretion disk in AG Dra is not certain**