Similarities in the structure of the circumstellar environments of B[e] supergiants and yellow hypergiants

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Spectroscopic survey of emission-line stars

1. **Goal**
   Explore the frequency and origin of [Ca II] and [O I] lines and study physical conditions traced by these lines

2. **Objects**
   Emission-line stars surrounded by dense circumstellar material

3. **Instrument**
   Coudé spectrograph @ Ondřejov 2 m telescope, Czech Republic:
   - ▷ H α: 6250–6760 Å – $R \simeq$13 000 (H α + [O I] $\lambda\lambda$6300, 6364)
   - ▷ [Ca II]: 6990–7500 Å – $R \simeq$15 000 ([Ca II] $\lambda\lambda$7291, 7324)
   - ▷ IR: 8470–8980 Å – $R \simeq$18 000 (Ca II $\lambda\lambda$8498, 8542, 8662)

Survey: overview of the results

Sample of 58 objects:

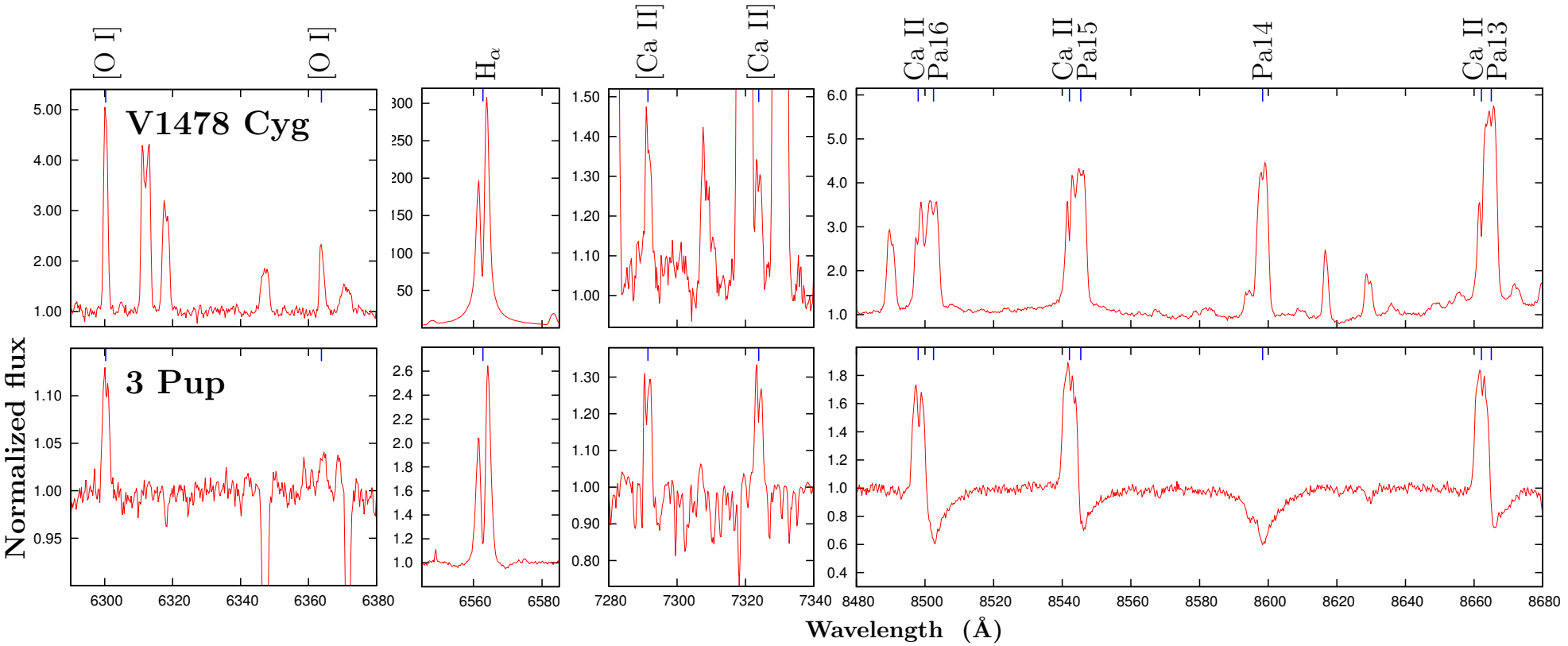
9 B[e] stars*, 4 YHGs, 1 post-AGB star, 2 peculiar objects with dense disks,
30 Be stars, 3 emission-line stars of O–B types,
9 pre-main-sequence stars (Herbig, T Tau, FU Ori).

Class	[O I]	[Ca II]
B[e]SG	**+**	**+**
low-mass B[e]	+	–
YHG	**+/–**	**+**
post-AGB	+	+
peculiar	+/–	+
Be	–	–
O–B em	–	–
pre-MS B[e]	+	+/–

*Aret et al. 2016, MNRAS 456, 1424

Survey: B[e] supergiants V1478 Cyg and 3 Pup

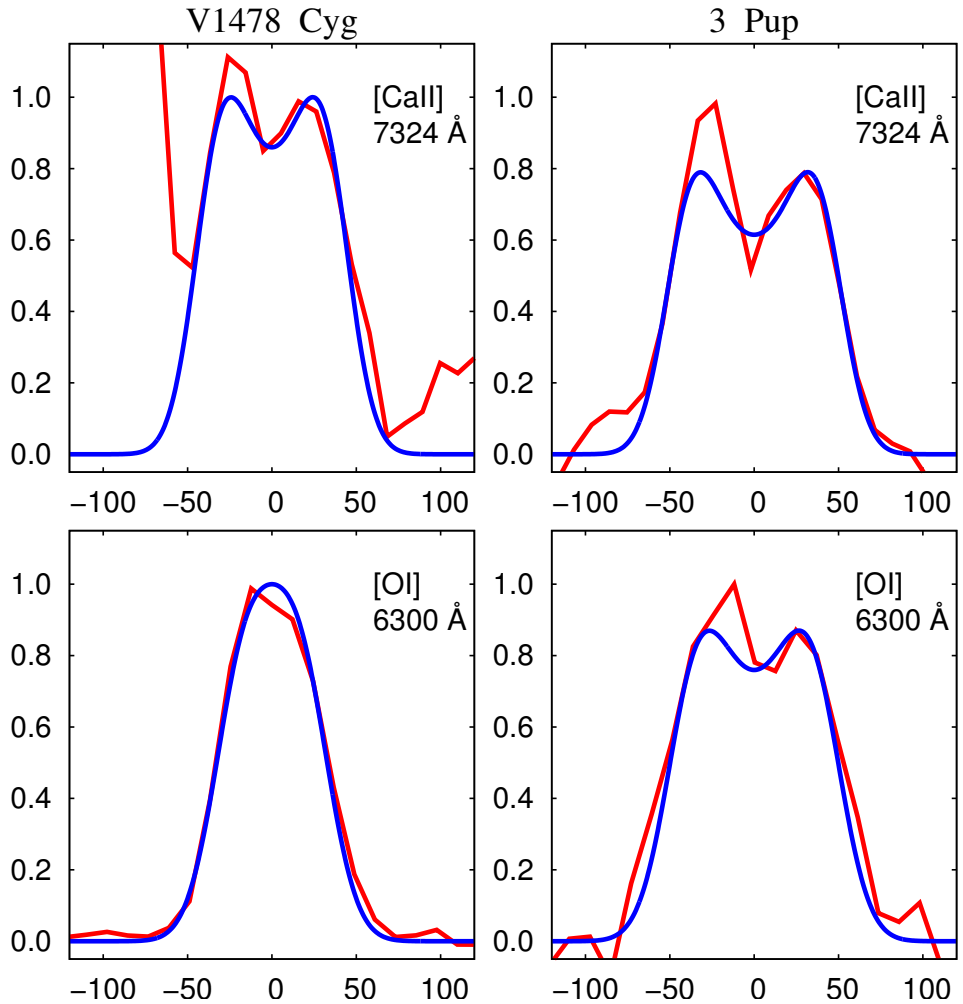
MWC 349A HD 62623



[O I] $\lambda\lambda$6300,6364 Hα [Ca II] $\lambda\lambda$7291,7324 Ca II IR $\lambda\lambda$8498,8542,8662

Survey: B[e] supergiants V1478 Cyg and 3 Pup

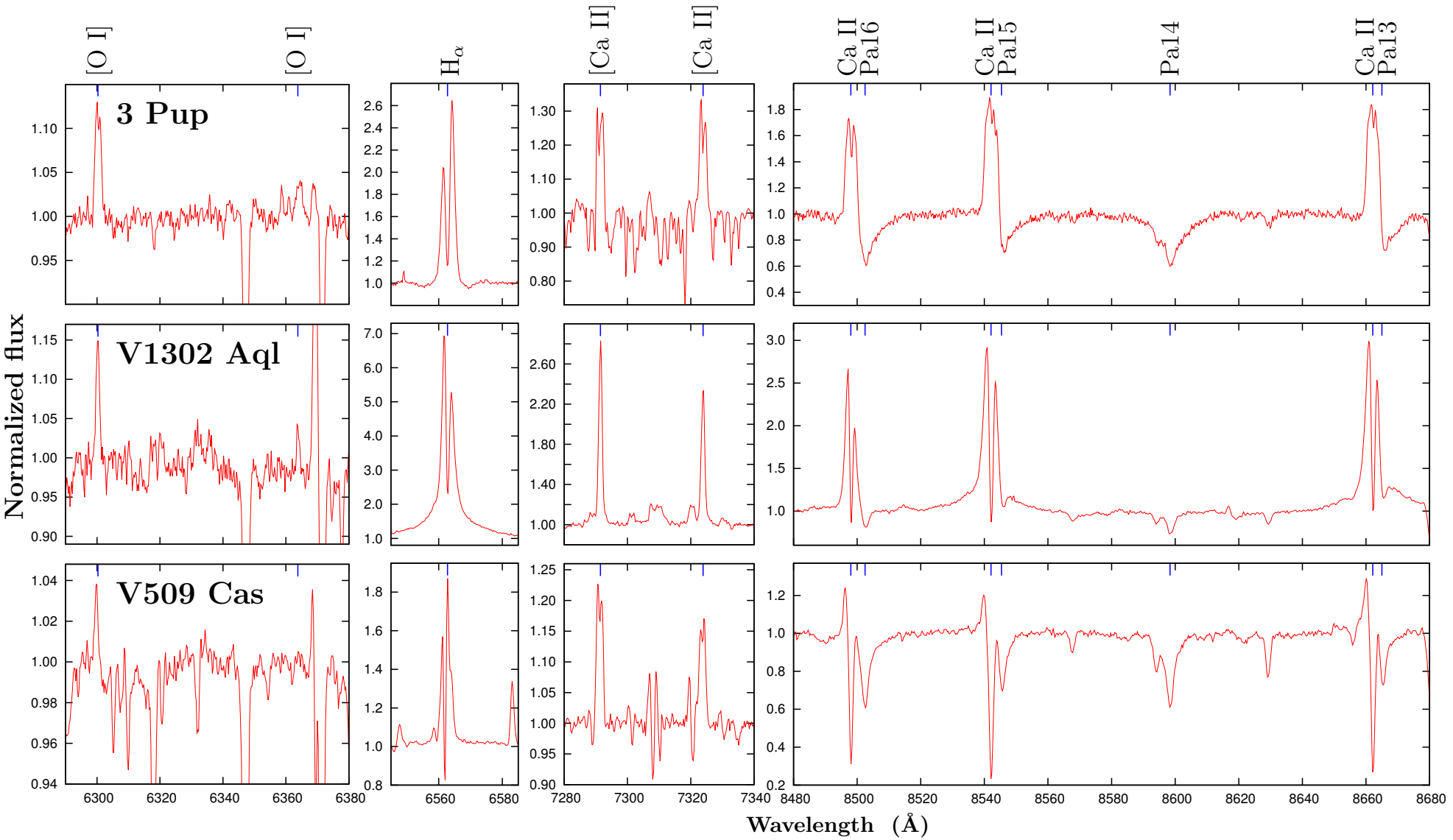
Kinematics obtained from the [O I] and [Ca II] line profiles agrees with an origin of the lines in the **Keplerian rotating rings**



Survey: B[e]SG *vs* YHG

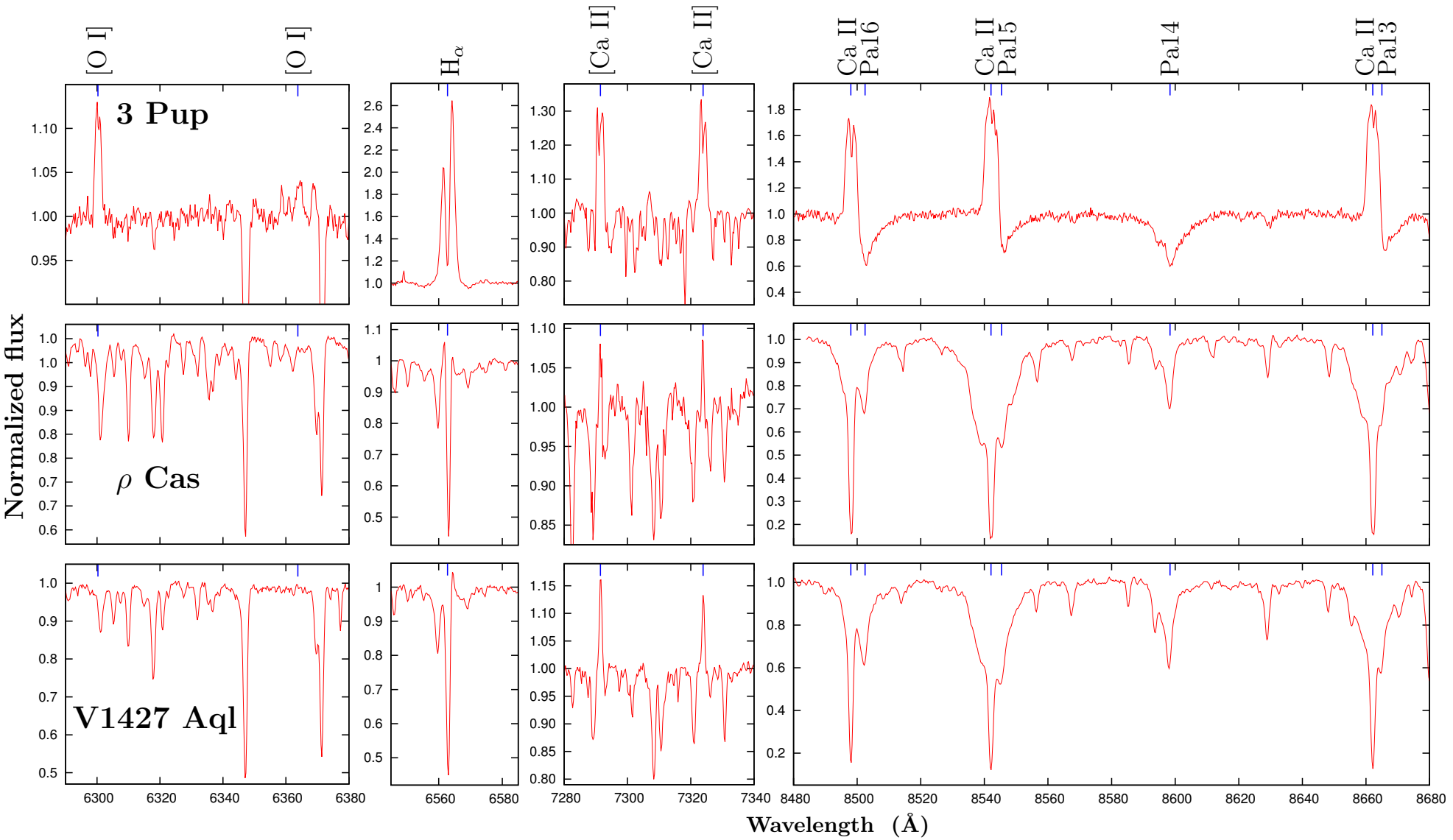
	Object		Sp.type	[O I]	[Ca II]	Ca II IR
B[e]SG	V1478 Cyg	MWC 349A	B0-B1.5 I	+	+	emis
	3 Pup	HD 62623	A2.7 Ib	+	+	emis
YHG	V1302 Aql	IRC +10420	A2-F8Ia	+	+	emis
	V509 Cas	HR 8752	A7-G5Ia	+	+	emis/abs
	ρ Cas	HD 224014	F0-G7Ia	–	+	abs
	V1427 Aql	HD 179821	F3-G5Ia	–	+	abs

B[e]SG 3 Pup *vs* hot YHGs V1302 Aql & V509 Cas



[O I] λλ6300,6364 Hα [Ca II] λλ7291,7324 Ca II IR λλ8498,8542,8662

B[e]SG 3 Pup *vs* cool YHGs V1302 Aql & V509 Cas



[O I] $\lambda\lambda$6300,6364 Hα [Ca II] $\lambda\lambda$7291,7324 Ca II IR $\lambda\lambda$8498,8542,8662

General similarities (Galactic & extragalactic objects)

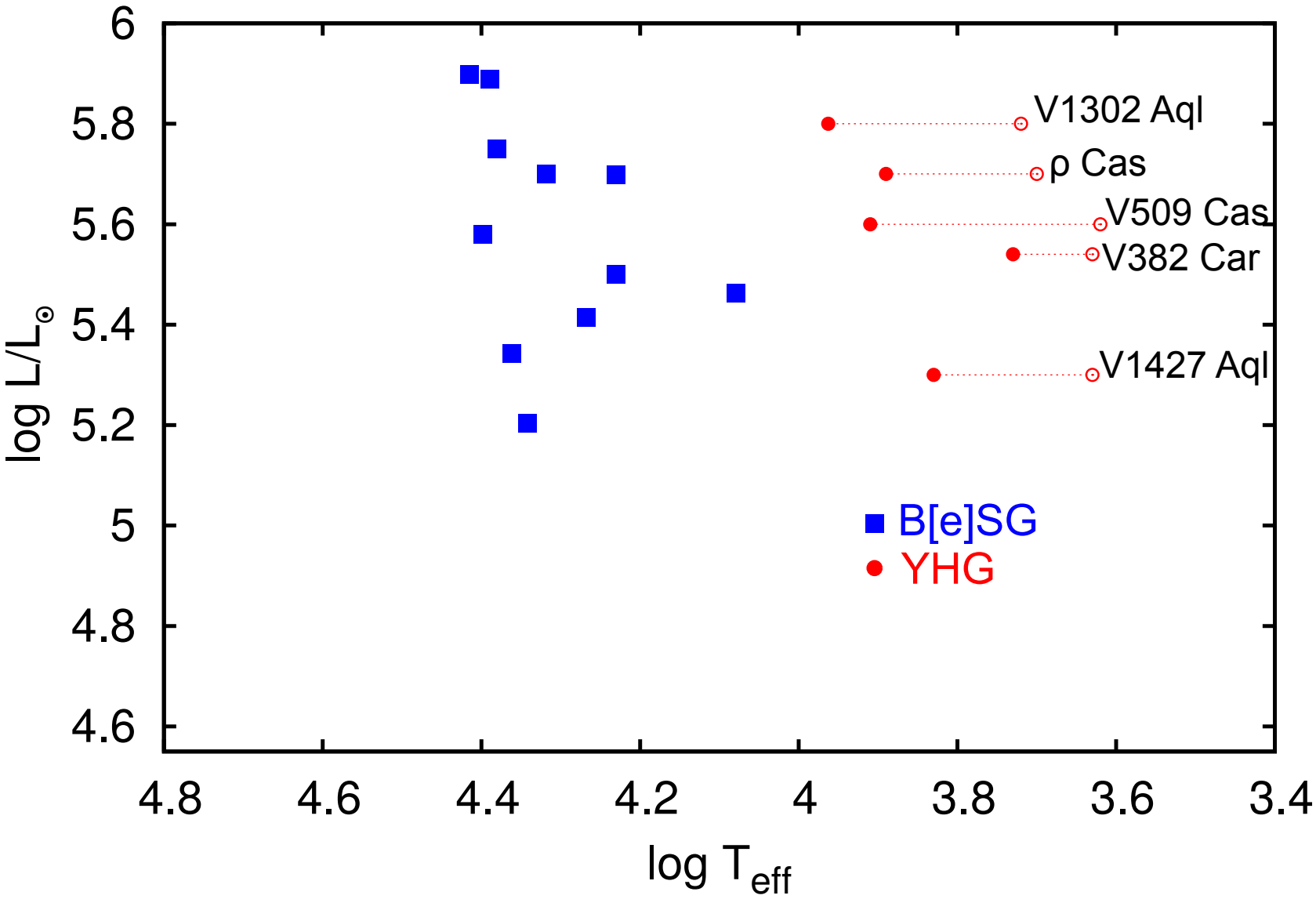
	B[e]SG	YHG
[Ca II]	all	all
[O I]	all	hotter
CO band (variability)	most (some)	most (all)
IR excess / dust	all	many
CMS structure	disc[a]/ring[b]	disc[c]/shell
Mass loss mechanism	pulsations?[d]	pulsations[e]

[a] e.g. Leinert 1986; Millour et al. 2011; [b] Maravelias et al. this conference; [c] Oudmaijer & de Wit 2013

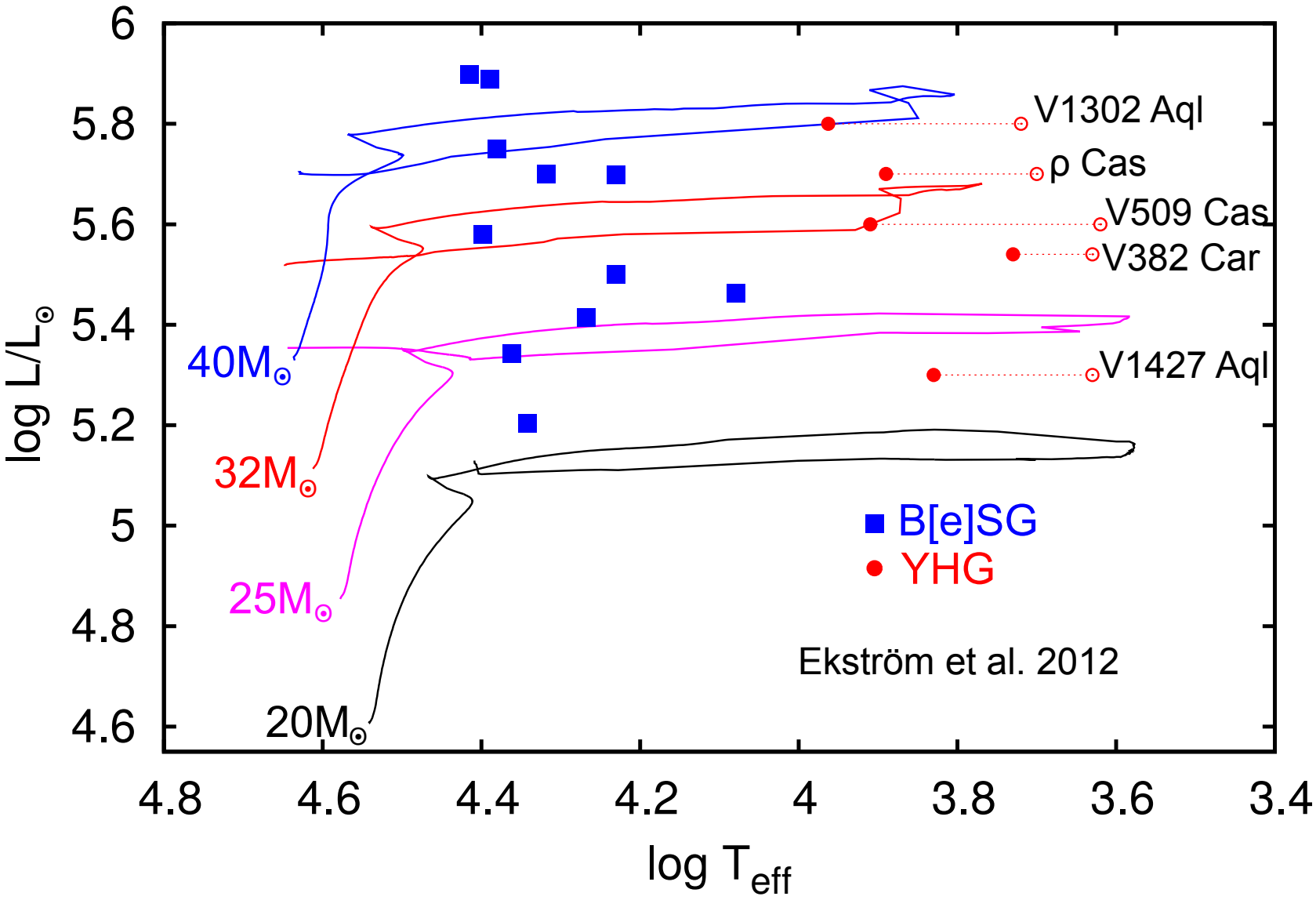
[d] V743 Mon: Borges Fernandes et al. 2012; LHA 120-S 73: Kraus et al. 2016; [e] overview by de Jager (1998)

Zickgraf (1998): Is V1302 Aql a pre-B[e] supergiant?

Evolutionary connection



Evolutionary connection



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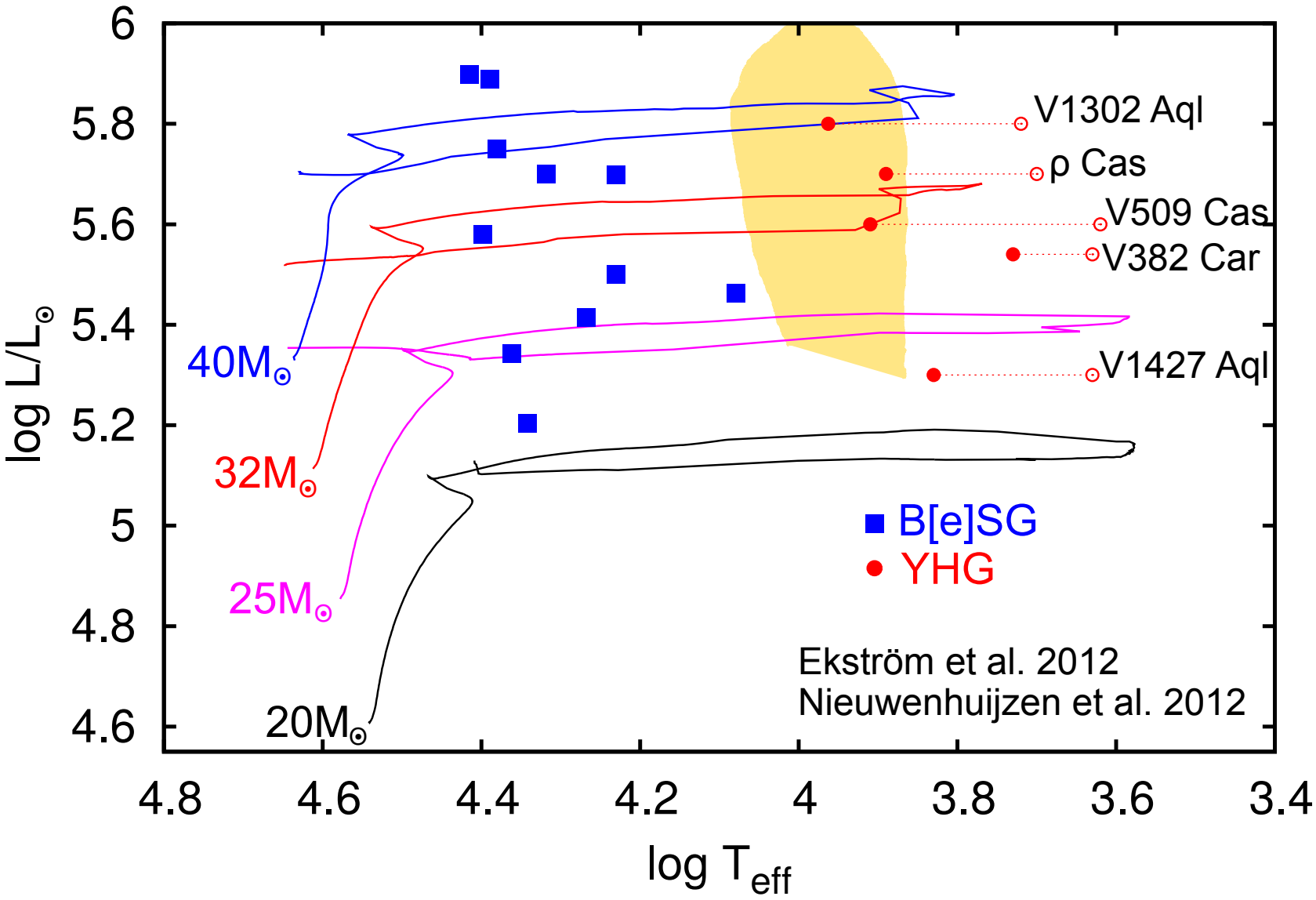
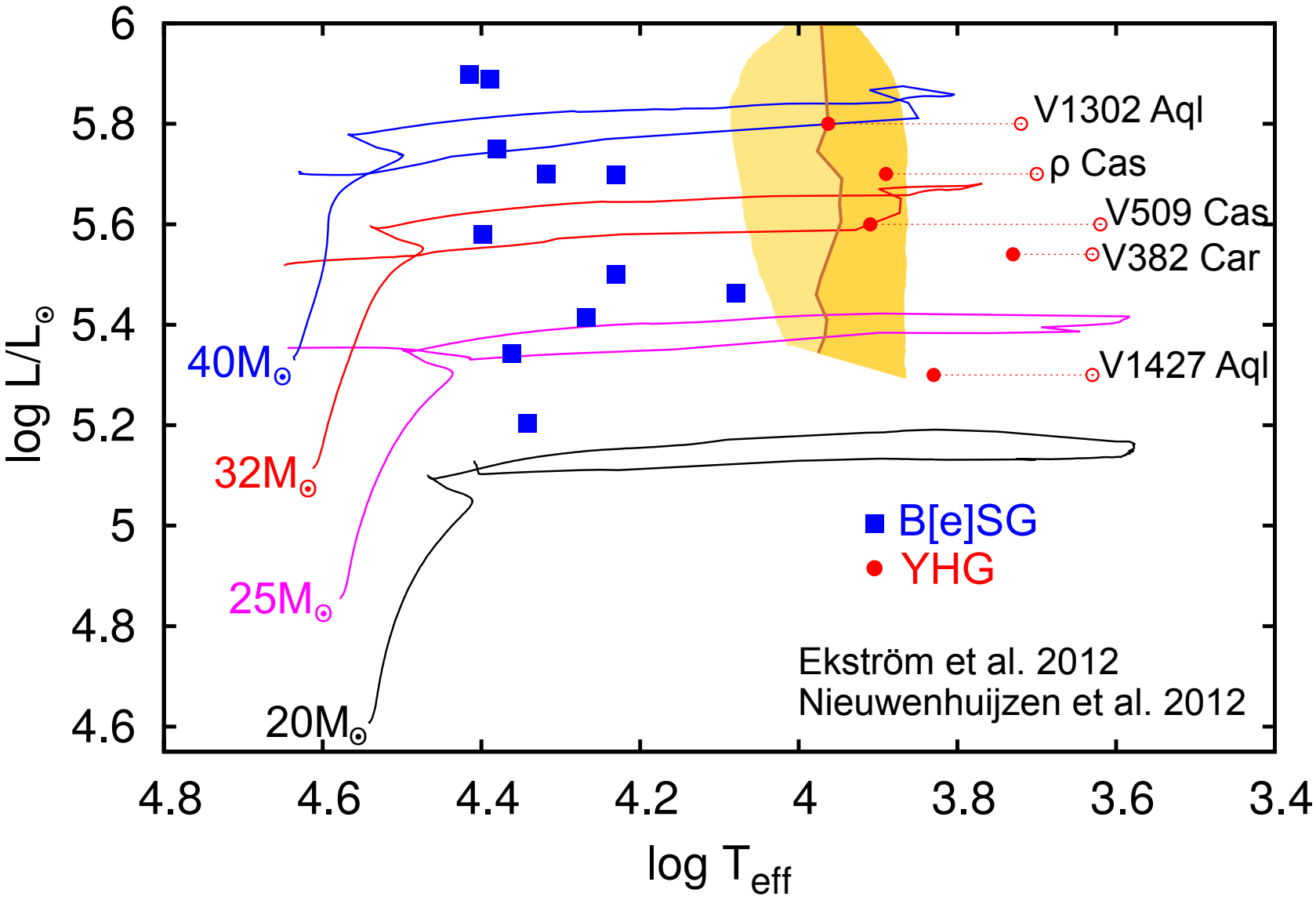


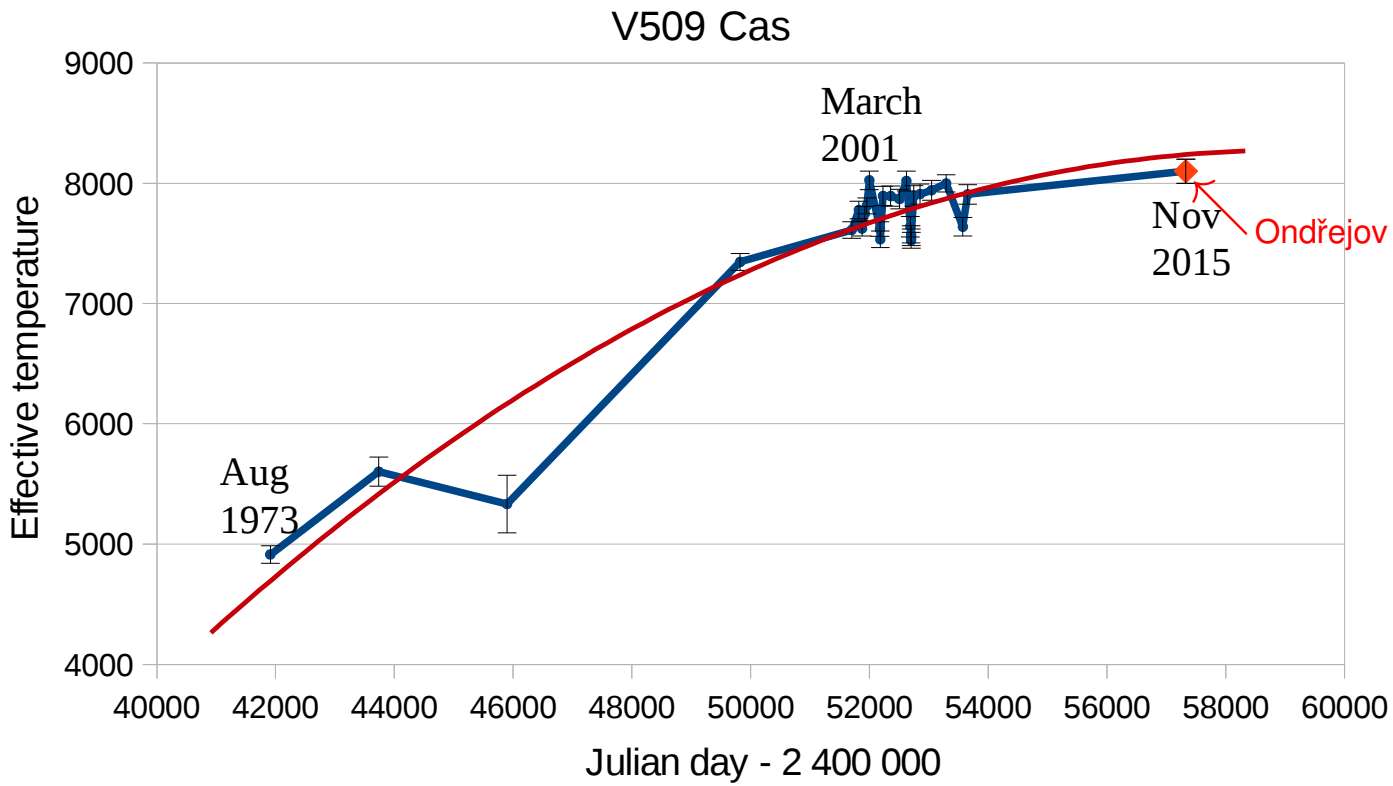
Evolutionary connection



YHGs: bluewards evolution across the HRD

V1302 Aql – F8[1] $\Longrightarrow$ A2[2]: increase in $T_{\rm eff} \sim 120$ K/yr in 1973–2002
Klochkova et al. 2016: $T_{\rm eff}$ does not increase any further

V509 Cas – Nieuwenhuijzen et al. 2012: Fast growth of $T_{\rm eff}$ in 1973–2005



[1] Humphreys et al. 1973; [2] Klochkova et al. 2002

Conclusions

1. Forbidden lines of [O I] and [Ca II] provide an ideal tool to identify objects with similar circumstellar environments
2. Appearance of [Ca II] lines requires environments of high density and large emitting volume
3. Both sets of lines are detected in B[e]SGs and hot YHGs, Ca II IR triplet is in emission
4. [Ca II] are detected also in cool YHGs, Ca II IR triplet is in absorption
5. Fast heating of V509 Cas has slowed down

Similarities between B[e]SGs and YHGs indicate possible evolutionary connection