A phylogenetic view of the Eigenvector 1 of quasars

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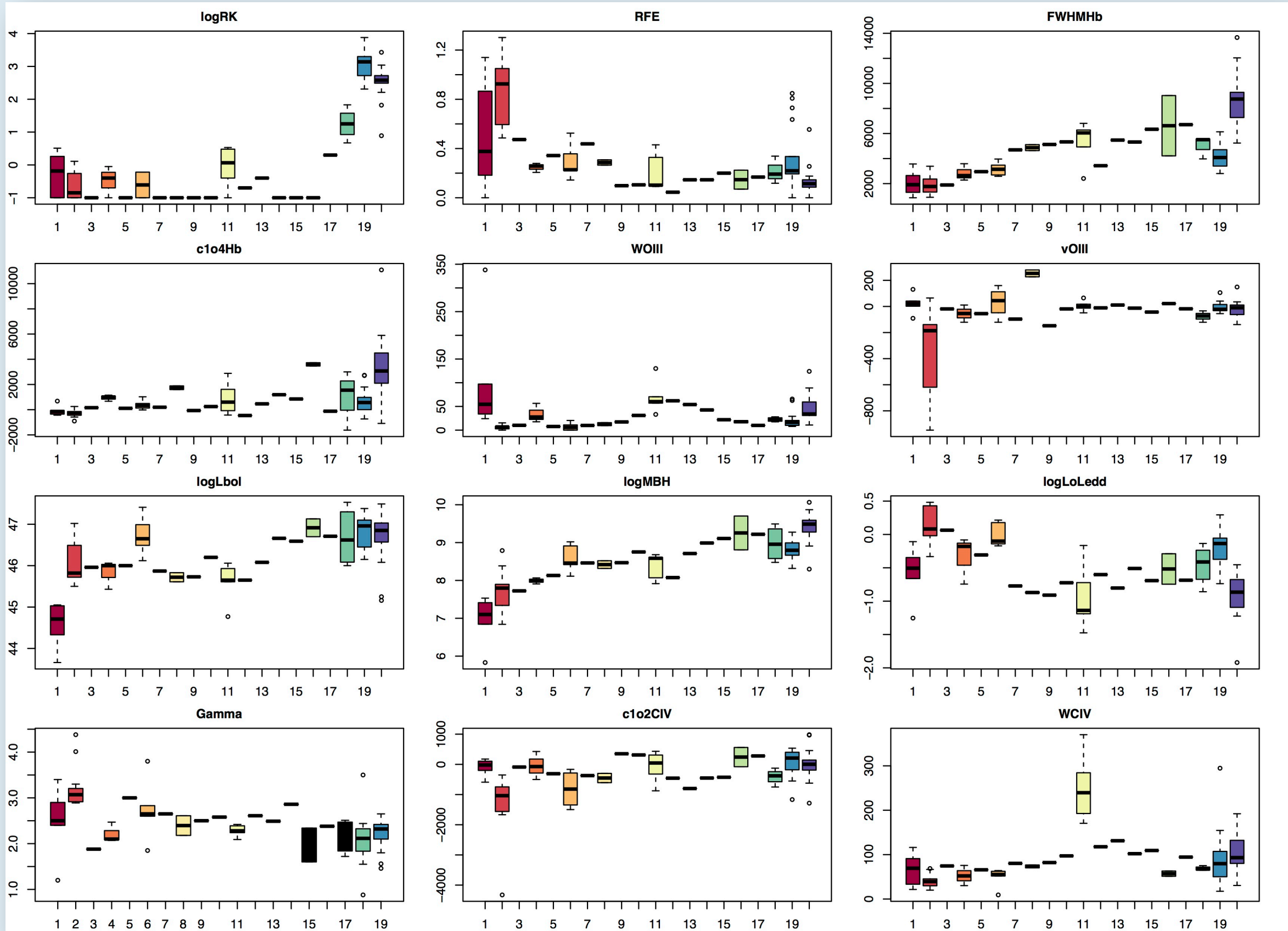
ABSTRACT

A cladistic analysis on samples of low-*z* quasars ($z<0.7$) separates sources radiating at higher Eddington ratios values, as well as radio-quiet (RQ) from radio-loud (RL) quasars. The analysis properly distinguishes also core-dominated and lobe-dominated quasars, in agreement with the basic tenet of radio-loud Unification schemes, and suggests a black hole mass threshold for powerful radio emission. Considering that the black hole mass then provides a sort of "arrow of time" of nuclear activity, an evolutionary interpretation becomes possible if cladistic trees are rooted on black hole mass. More massive radio-quiet Population B sources at low-*z* become a more evolved counterpart of Population A i.e., wind dominated sources, to which at least part of the "local" Narrow-Line Seyfert 1s belong. In this scheme, powerful radio-loud sources may be seen as sources belonging to a most evolved quasar population.

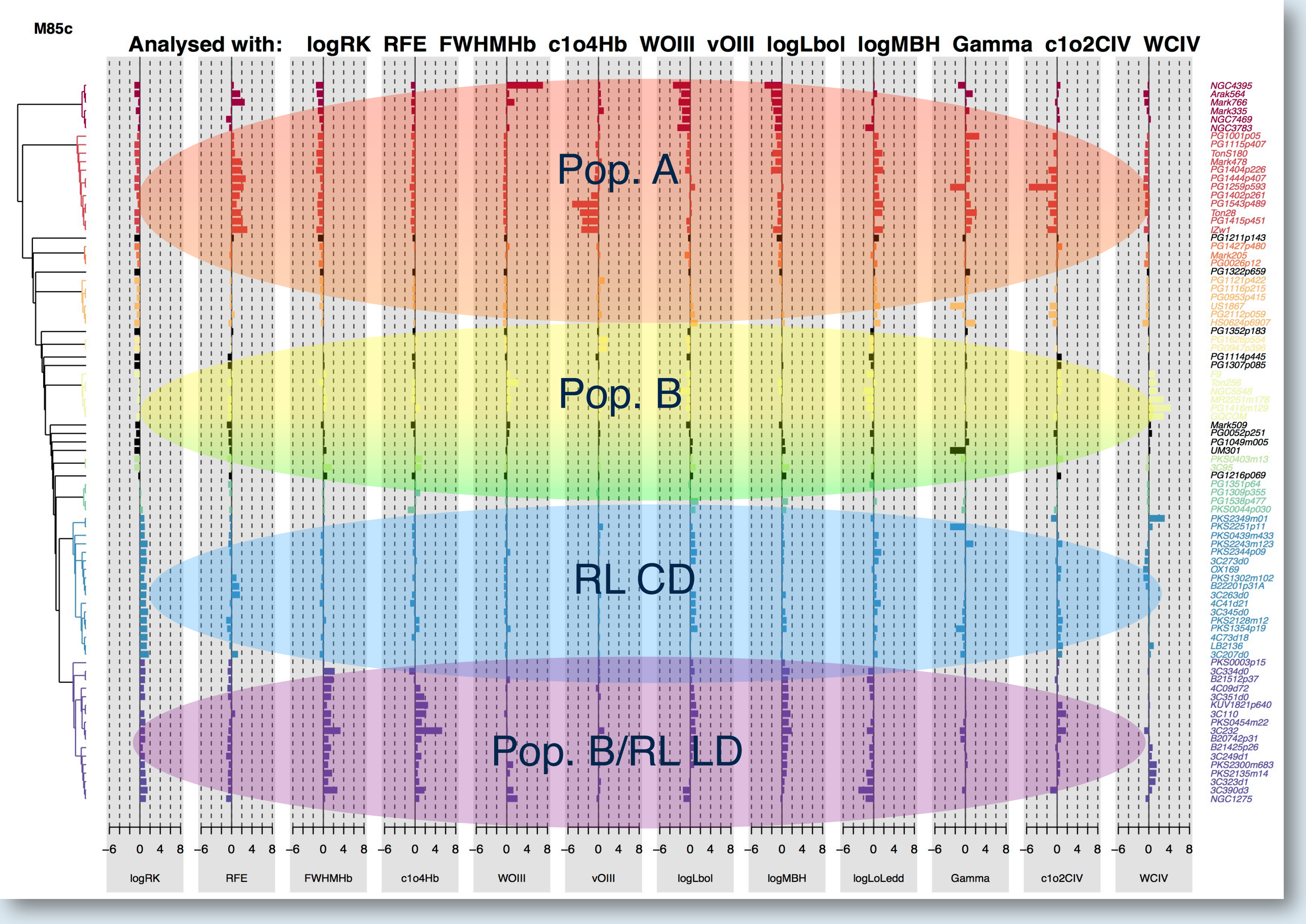
WHAT IS ASTROCLADISTICS

Astrocladistics aims at introducing phylogenetic tools in astrophysics. Among these tools, cladistics, also called Maximum Parsimony, is the most general and the simplest to implement. It uses parameters, and not distances, to establish relationships between the species by minimizing the total evolutionary cost depicted on a phylogenetic tree. The trees that result from cladistic analysis should not be interpreted as genealogic trees: here, as the trees do not indicate ancestor or descendant objects, each quasar supposedly represents a species (i.e., a class). In this phylogenetic sense, the trees can be "rooted" according to a parameter that may have an evolutionary meaning. More information and links to introductory and review papers are available at https://astrocladistics.org.

A cladistic analysis of a low-z quasar sample



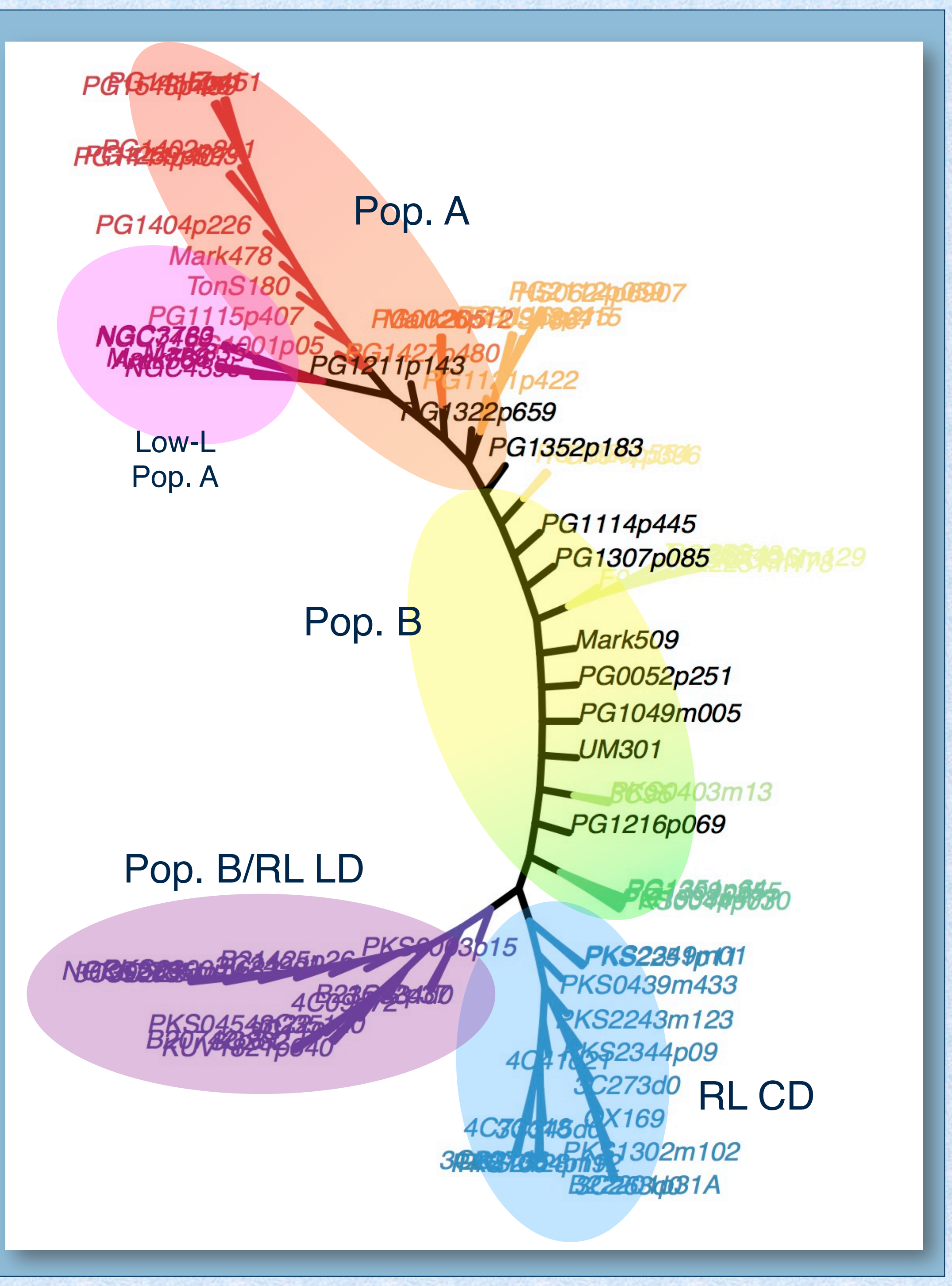
The boxplots aside show the radio loudness parameter R_K, R_{FeII}, FWHM(Hβ), the line centroid displacement of Hβ at quarter maximum (c1o4Hb), W([OIII]λ5007), the peak shift of [OIII]λ5007, the bolometric luminosity L_{bol}, M_{BH}, the Eddington ratio, the soft X-ray photon index (Gamma), the centroid displacement of CIVλ1549 at half maximum (c1o2CIV), W(CIVλ1549) for a sample of 85 low-*z* (<0.7) quasars with coverage of both CIVλ1549 and Hβ), as grouped following the cladistic analysis.



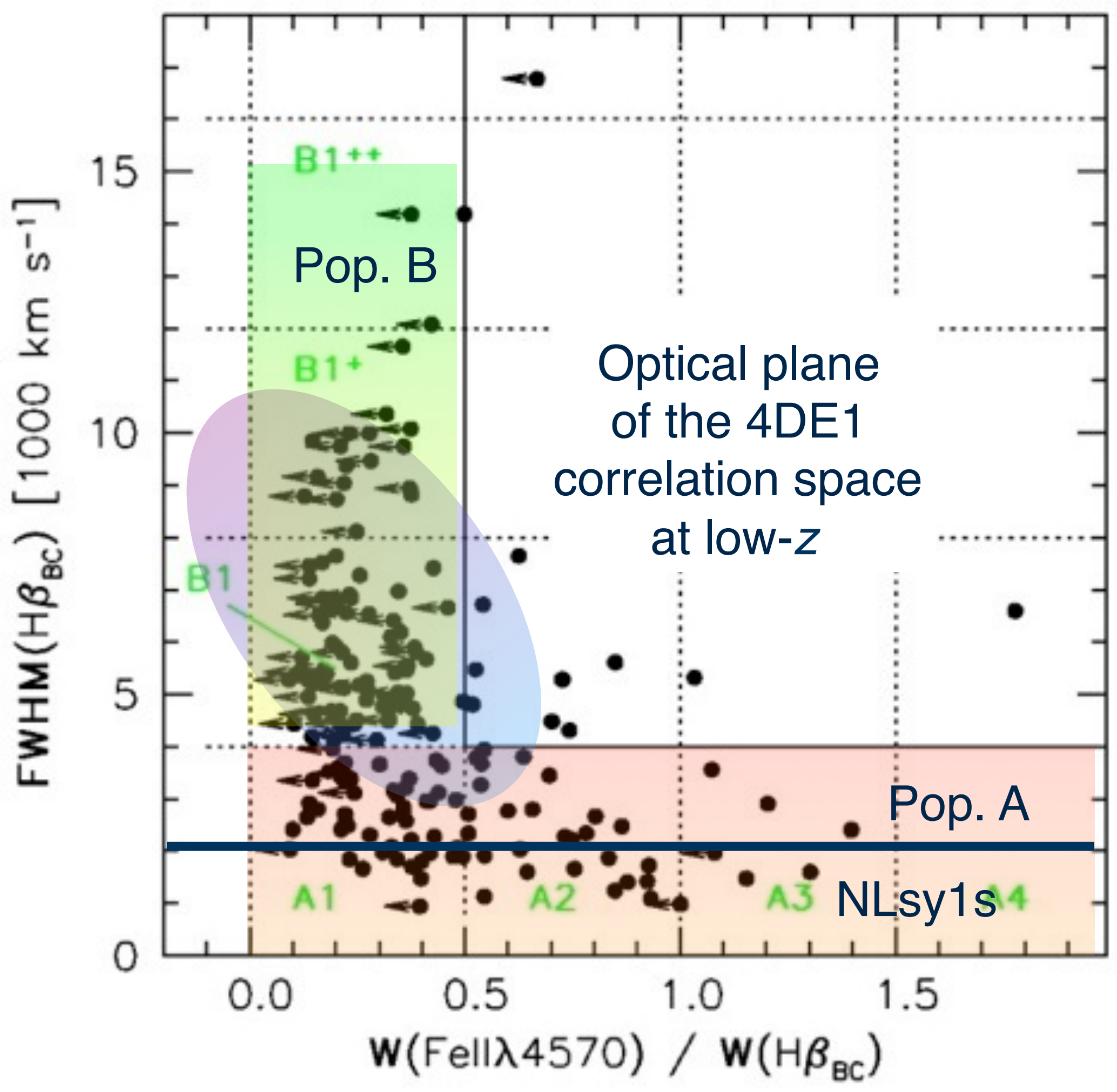
The cladogram traces the relation between individual objects belonging to the seven groups identified by the cladistic analysis. While no evolutionary inference should be inferred, it is interesting to note that there is a sequence of relationships going from extreme Pop. A and Pop. B. The bottom groups are core-dominated and lobe-dominated RL sources, which are monophyletic groups.

The cladistic tree

In the case of quasars, a parameter that can root the cladistic tree is black hole mass (M_{BH}), since M_{BH} can only grow as a function of cosmic time: the only way a black hole can disappear is through emission of Hawking's radiation which is tremendously inefficient for massive black holes. A rooted tree shows a clustering consistent with evolution from less massive to more massive sources (as shown by the arrow diagram in the grey panel). Powerful RL sources appear in our low-*z* sample only above a mass threshold, and CD and LD are separated because of an intervening role or orientation (in phylogenetic terms, they belong to different monophyletic groups). The quasar sample contains a population of massive quasars which are "more evolved" and a population of less-massive quasars that are radiating at a higher L/L_{Edd}. While L/L_{edd} remains the physical factor governing E1, high-M_{BH} quasars may have resembled low-M_{BH} quasars in an earlier stage of their evolution.



The 4DE1 sequence: an evolutionary interpretation?

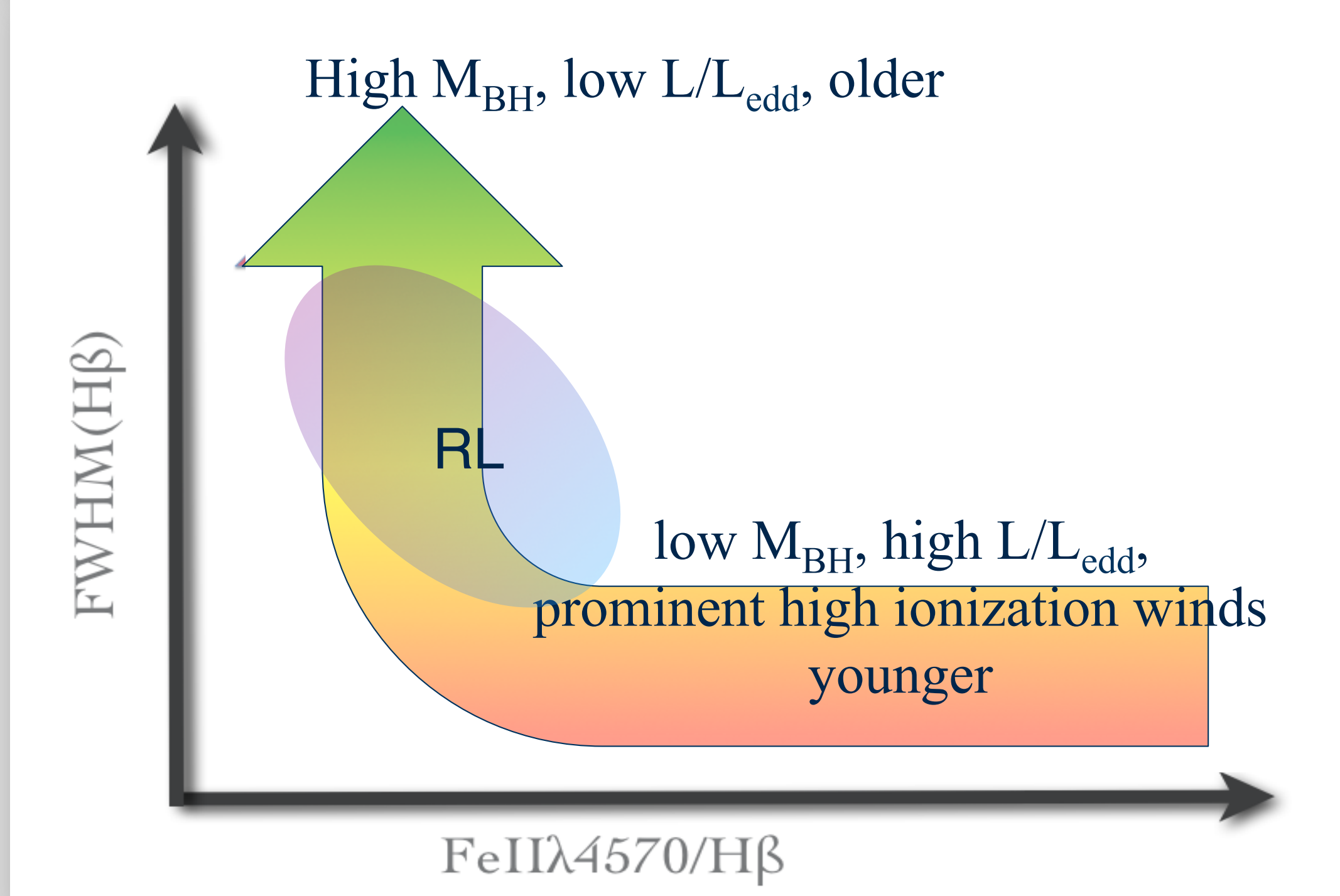


The radio, IR, optical, UV, and X properties of low-*z* quasars (listed in Table 1) can be organized along the sequence defined by FeII prominence (R_{FeII}= I(FeIIλ4570)/I(Hβ)) and FWHM of broad Hβ (the optical plane of the 4D eigenvector 1 space, 4DE1, Sulentic & Marziani 2015). The most relevant physical parameter appears to be Eddington ratio, and to a second extent, orientation (Marziani et al. 2001). A discontinuity may occur at FWHM ~ 4000 km s^{-1} (the Pop. A/B limit), probably associated with a discontinuity in accretion mode. RL quasars are predominantly found in the bluish area where RQ quasars are also found with similar accretion parameters (log L_{bol} ~ 45.5 [erg s^{-1}], log M_{BH} ~ 8.5, L/L_{Edd}~0.1). At the other end, extreme Pop. A sources are high accretors which show evidence of strong radiation driven winds (Sulentic et al. 2016).

Table 1. Main trends along the 4DE1 sequence. (from Sulentic et al. 2011)

Parameter	Pop. A	Pop. B	References
FWHM(Hβ_{BC})	800–4000 km s^{-1}	4000–10000 km s^{-1}	1,2
$R_{Fe II}$	0.7	0.3	1
c($\frac{1}{2}$) C IV λ1549$_{BC}$	–800 km s^{-1}	zero	3,4
Γ_S	often large	rarely large	1,5
W(Hβ_{BC})	~80 Å	~100 Å	1
Hβ_{BC} profile shape	Lorentzian	double Gaussian	6,7,9
c($\frac{1}{2}$) Hβ_{BC}	~zero	+500 km s^{-1}	7
Si III / C III]	0.4	0.2	10,11
FWHM C IV λ1549$_{BC}$	(2–6) ·10^3 km s^{-1}	(2–10) ·10^3 km s^{-1}	3
W (C IV λ1549$_{BC}$)	58 Å	105 Å	3
AI (C IV λ1549$_{BC}$)	–0.1	0.05	3
X-ray variability	extreme/rapid common	less common	12,13
Optical variability	possible	more frequent/higher amplitude	14
Probability radio loud	~3–4%	~25%	15
Broad absorption lines (BALs)	extreme BALs	less extreme BALs	16,17
log density^1	>11	~9.5–10	10
log U^1	–2.0/–1.5	–1.0/–0.5	10
log M_{BH}	6.5–8.5	8.0–10.0	7,8
L/L_{Edd}	0.1–1.0	0.01–0.5	7,8

1. Sulentic et al. 2000a; 2. Collin et al. 2006; 3. Sulentic et al. 2007; 4. Baskin & Laor 2005; 5. Wang et al. 1996 6. Veron-Cetty et al. 2001; 7. Marziani et al. 2003; 8. Peterson et al. 2004; 9. Sulentic et al. 2002; 10. Marziani et al. 2001; 11. Wills et al. 1999; 12. Turner et al. 1999 13. Grupe et al. 2001; 14. Giveon et al. 1999; 15. Zamfir et al. 2008; 16. Reichard et al. 2003; 17. Sulentic et al. 2006.



References

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