Optical variability patterns of radio-quiet and radio-loud quasars

E. Bon[1], A. Grieco[2], P. Marziani[3], N. Bon[1], D. Dultzin[4], A. Del Olmo[5], M. D'Onofrio[6]
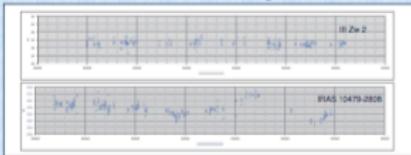
[1]Belgrade Observatory, Serbia; [2]Via Carpane 78, Vigonza, Italia; [3]INAF, Osservatorio Astronomico di Padova, Padova, Italy; [4]Instituto de Astronomia, UNAM, Mexico; [5]Instituto de Astrofisica de Andalucia (IAA-CSIC), Granada, Spain; [6]Università di Padova, Padova, Italy

ABSTRACT

We analyzed the light curves of several radio-quiet and radio-loud quasars belonging to the same parameter space volume in the 4D Eigenvector 1 (4DE1) quasar sequence, using light curves (LCs) from the Catalina Real-time Transient Survey (CRTS). We report preliminary results on detected variability pattern, and discuss possible mechanisms.
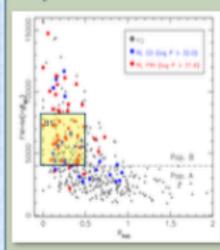
The origin of the radio-quiet / radio-loud (RL/RQ) dichotomy is still not understood. The most-widely accepted mechanism for producing powerful relativistic radio jets i.e., the Blandford-Znajek (1977) mechanism, relies on the strong dependence of the jet radiative power on the black hole specific spin angular momentum a/M. A different black hole spin distribution (the "spin paradigm;" e.g., Wilson & Colbert 1995) is probably not sufficient to explain the RQ/RL dichotomy, as it is not consistent with a/M values which imply maximally rotating black holes for undistinguished RQ sources (such as MGC -06-30-15; Sulentic et al. 1998). In the present contribution, the optical variability patterns of RQ and RL low-z (<0.6) quasars are compared in the region of RL source maximum occupation along the 4DE1 sequence of Sulentic et al. (2000). Periodical variability may ultimately indicate the presence of a sub-parsec supermassive binary black hole (SMBBH) in RL sources. As preliminary tests to this hypothesis, we analyze whether RL and RQ quasars show systematic differences in variability measures, and consider best candidate cases for periodic variability.

Quasar V-band variability in the CRTS

The CRTS covers ~ 33,000 square degrees of the sky (Drake et al. 2009). The survey provided V-band magnitudes at 200 – 400 epochs for our sample of 77 "B1" quasars (31 RL, see panel aside), over a time span of ~ 3000 d. The data allow for the computation of variability statistics as well as of the auto-correlation (ACF) and structure function (SF) of individual sources. Two examples of LCs are shown above. Some past studies even resorted to the computation of sample averages which is not correct. Quasars apparently show an optical LC consistent with damped random walks, a stochastic process that doesn't satisfy the ergodicity condition.
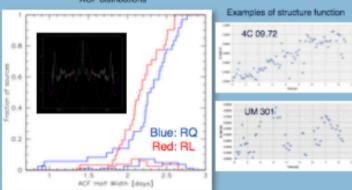
Sample Definition: RL and RQ in the 4DE1 Sequence

Eddington ratio, and, to a second extent, orientation and black hole mass change along the sequence defined by FeII prominence (R_{FeII} = I(FeIIλ4570)/I(Hβ)) and FWHM of broad Hβ (the optical plane of the 4DE1). RL quasars are not distributed uniformly along the sequence, but are predominantly found in the shaded area (B1) where also RQ quasars are found with similar accretion parameters (log $L \sim 45.5$ [erg s^{-1}], log M_{BH} ~ 8.5, L/L$_{Edd}$~0.1).

The RL and RQ variability patterns: Two sample comparison

ACF distributions

Blue: RQ
Red: RL

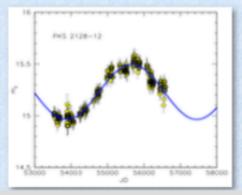### Examples of structure function

4C 09.72

UM 301

The variability patterns RQ and RL sources in the 4DE1 spectral bin B1 were compared using the excess variance, and the estimator ΔV defined as the standard deviation of $(V(t) - <V>)/\delta V$, where δV is the 1σ error. The two measures are correlated variability indicators. A source was considered variable if $\Delta V > 1.4$. These distributions of these estimators are not statistically different in the RL and RQ samples according to Kolmogorov-Smirnov tests. The rest-frame ACF 0 peak half-width (ACF-HW) was used as an indicator of variability time scale. Two extreme cases are shown in the black inset: the white one (III Zw 2) is associated with no variability, the second one (PKS2128-12) shows a high degree of correlation between distant observations. The ACF-HW distribution is marginally different (at slightly less than 2σ confidence level; at 2σ if the ACF-HW is normalized by the black hole mass). It is important to stress that large ACF-HW (> 500d) are possible for RL and RQ alike, which may indicate a stochastic process with a "red" frequency spectrum, or relatively long time-scale deterministic physical processes. The structure functions slopes (two examples are are shown above) are also not statically different, even if RQ sources more often show an irregular multi-peaked SF than RL ones (as in the case of UM 301, above).
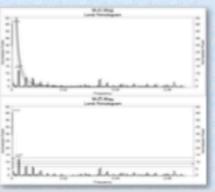
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Red noise and the issue of periodicity

PKS 2128-12

The visual inspection of several LCs hint at a periodic behavior. The best case in our sample is PKS 2128-12 (above), with a light curve similar to the one of PKS 1302-102 hailed as a SMBBH candidate by a recent work (Graham et al. 2015), and of the compact-steep spectrum (CSS) radio source 3C 57 (Sulentic et al. 2015). A naïve application of the Lomb-Scargle periodogram indicates that a large fraction of sources exhibit periodicity to some extent. In the case of PKS 2128-12 the peak corresponding to a period P ~ 3550 d is highly significant against white noise (associated with measurement errors) but not against red noise. A damped random walk implies that the stochastic variability amplitude grows larger at lower frequencies, literally creating the illusion of periodic curves (Vaughan et al. 2016). A longer time span is needed to confirm periodicity, as for NGC 5548 (Bon et al. 2016, and references therein). The temporal coverage of the CRTS is entering the domain of the dynamical timescales of physical processes that can give rise to a periodic signal. The very possibility of damped red noise as an appropriate statistical description of LCs may be called into questions as time coverage increases.

Conclusion

The CRTS data made possible an empirical comparison of the *V* band LCs for RQ and RL sources with similar distributions of accretion parameters. We found no strikingly strong differences between RQs and RLs. However, it is intriguing that the best candidates for periodicity are RL (including 1 CSS source which can be interpreted as "rejuvenated" after a merger). Further photometric and spectroscopic monitoring is needed to trace behaviors which may provide evidence for sub-pc SMBBHs.