Evidence for Higher Black Hole Spin in Radio-loud Quasars

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One of the major unsolved questions on the understanding of the AGN population is the origin of the dichotomy between radio-quiet and radio-loud quasars, i.e. why does the majority of AGN feature only weak core radio emission, while about 10 % of them have powerful relativistic jets with high bulk Lorentz factor. The most promising explanation is provided by the spin paradigm, which suggests radio-loud quasars have higher black hole spin. However, the measurement of black hole spin remains extremely challenging.

To address this question, we proposed a novel approach to probe the mean radiative efficiencies of both populations as direct tracers of black hole spin. For this goal, we used a large well-defined statistical quasar sample drawn from SDSS [1] at $0.3<z<0.8$, separated into radio-loud and radio-quiet quasars. A radio loud quasar is here defined by their radio-to-optical flux density ratio R either above 10 (or above 80). We used the [O III] luminosity as an indirect average tracer of the ionizing continuum in the extreme-UV regime where differences in the SED due to black hole spin are most pronounced. We found that the radio-loud sample shows an enhancement in [O III] line strength by a factor of at least 1.5 compared to a radio-quiet sample matched in redshift, black hole mass and optical continuum luminosity L_{5100} or accretion rate (see Fig. 1).

We do not see evidence that the observed trend is driven by star formation or jet-driven outflows (see e.g. Fig. 2). A remaining uncertainty we cannot fully resolve given current observations lies in our assumption of similar average NLR structures between radio-loud and radio-quiet quasars. However, we find a similar enhancement in both narrow and broad high ionization lines (in particular broad He II $\lambda 4686$) which suggests that our result is not driven by NLR physics.

We argue that the most plausible explanation for the observed [O III] equivalent width enhancement is an intrinsic difference in ionizing continuum, thus in SED, meaning higher average bolometric luminosities at fixed accretion rate in the radio-loud population. This suggests that the radio-loud quasar population has on average systematically larger radiative efficiencies and therefore higher black hole spin than the radio-quiet population. Assuming a standard average radiative efficiency of 0.1 for radio-quiet quasars (a = 0.67), radio-loud quasars would have an efficiency of 0.15 and thus a = 0.89, which is high but not yet close to maximum spin.

Our results provide new observational support for the black hole spin paradigm [2].

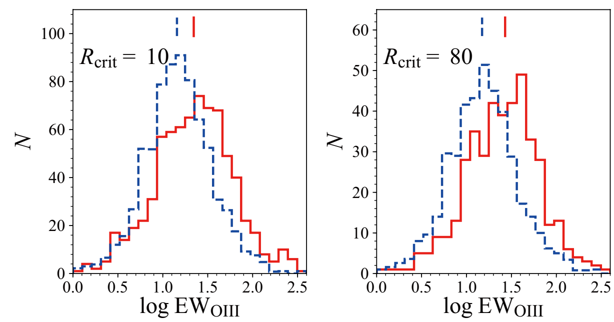

Figure 1: Histogram of [O III] equivalent width for the radio-loud quasar sample (solid red lines) and the matched radio-quiet sample (dashed blue lines), in the left panel for defining radio-loud quasars by a radio loudness parameter $R>10$ and in the right panel using a more conservative threshold $R>80$.

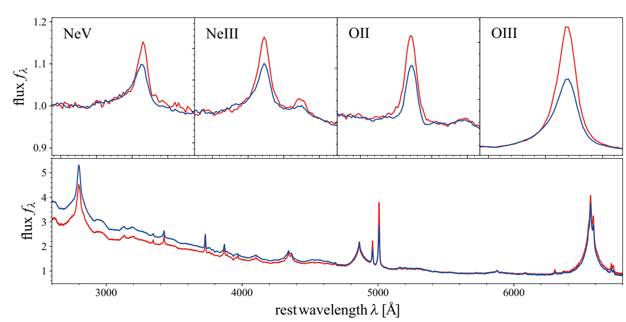

Figure 2: Composite spectra of the radio-loud (red) and matched radio-quiet (blue) quasar sample, where the composite spectra are normalized at 5100 Å, for the full spectrum (lower panel) and several prominent narrow high-ionization lines (upper panels).

References

[1] Shen, Y., et al.: 2011, *ApJS*, **194**, 45.
[2] Schulze, A., et al.: 2017, *ApJ*, **849**, 4.