On the Radio and Optical Luminosity Evolution of Quasars

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We calculate simultaneously the radio and optical luminosity evolutions of quasars, and the distribution in radio loudness, using a flux limited data set containing 636 quasars with radio and optical fluxes. It is imperative to first determine the true correlations among the variables, not those introduced by the observational selection effects, before obtaining the individual distributions of the variables. We use the nonparametric methods which are designed to obtain unbiased correlations, distributions, and evolution with redshift from a data set truncated due to observational biases.

We find that there is a strong luminosity evolution with redshift in both wavebands, with significantly higher radio than optical evolution. We compare the distribution of the radio loudness parameter *R* obtained from careful treatment of the selection effects and luminosity evolutions with that obtained from the raw data without such considerations. We find a significant difference between the two distributions and no clear sign of bi-modality in the true distribution.

Data truncations and variable correlations

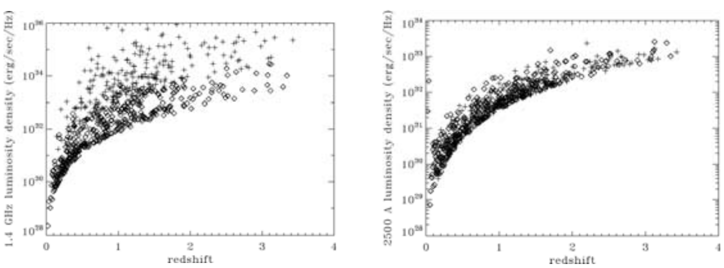

Figure 1: Radio and Optical luminosities vs. redshift of the White et al. sample

To demonstrate the concepts, we use the FIRSTxPOSS-I 1.4 GHz radio and R-band optical dataset of White et al.[2] With any flux-limited dataset, the truncations inherent in the data and the correlations among parameters (e.g. the radio and optical luminosity) introduce biases in the determinations of the distributions of parameters.

Luminosity and redshift correlations

First we remove the correlation between radio and optical luminosity by forming a 'correlation reduced' radio luminosity (L_{crr}) with the best fit correlation between the two removed. Then we determine the redshift dependence of the L_{opt} and L_{crr} using a power law parameterization $L_i \sim (1+z)^{k_i}$.

Both determinations use the Spearman rank test (SRT) with the method of associated sets.[3,4] In the later determination, we must simultaneously determine both luminosity-redshift correlations.

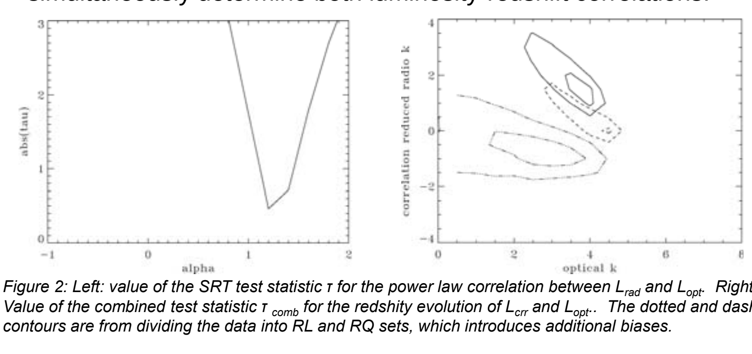

Figure 2: Left: value of the SRT test statistic τ for the power law correlation between L_{rad} and L_{opt}. Right: Value of the combined test statistic τ_{comb} for the redshity evolution of L_{crr} and L_{opt}. The dotted and dashed contours are from dividing the data into RL and RQ sets, which introduces additional biases.

Luminosity evolutions

We find that with the parameterization $L_i \sim (1+z)^{k_i}$, the best fit values are $k_{opt}=3.75\pm0.5$ and $k_{rad}=6.55\pm0.45$ as shown in Figure 2. These redshift evolutions do not change significantly with a different, more complicated power law parameterization for this redshift range. We also find that dividing the data into radio loud (RL: *R*>10) and radio quiet (RQ: *R*<10) sets introduces an additional truncation which skews the determination.

Distribution of Radio Loudnesses

The raw observed distribution of the radio loudness *R* (defined as the ratio of 1.4 GHz to 2500 Å luminosity) is quite different than the one we reconstruct taking into account all of the truncations, correlations, and redshift evolutions. The inherent distribution shows no sign of bi-modality.

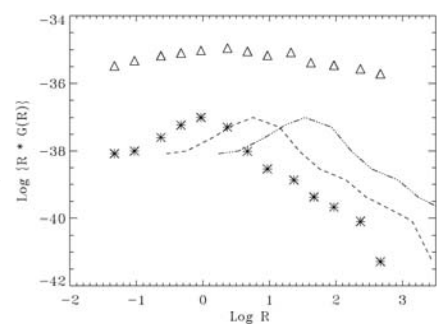

Figure 3: Raw observed (triangles) and reconstructed inherent (stars) distribution in radio loudness $G_R(R')$. Also shown are the redshift evolved distributions at z=1 and z=3.

Conclusions

Our results indicate, somewhat surprisingly, that radio loud and radio quiet quasars do not form two distinct populations, and that there is no critical switch in the efficiency of the production of disk outflows/jets between very radio quiet and very radio loud quasars, but rather a smooth transition.[5] The differing evolutions in radio and optical luminosity have implications for estimates of the fractional integrated contribution of quasars to the cosmic radio background. For a complete treatment, see [1].

References: [1]J. Singal, V. Petrosian, L. Stawarz, & A. Lawrence, 2011, *ApJ*, submitted (arXiv: 1101:2930); [2]R. White et al. 2000, *ApJ*, 126, 133; [3]B. Efron, & V. Petrosian,1992, *ApJ*, 399, 345; [4]V. Petrosian,1992, in Statistical Challenges in Modern Astronomy, 173; [5]M. Sikora, et al,. 2007, *ApJ*, 658, 815