Redshift Distribution of Quasars Inside and Outside Cosmic Voids

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Abstract

We present a statistical comparison of the redshift distribution of quasars located inside and outside cosmic voids, using the SDSS DR16Q catalog cross-matched with a catalog of large-scale cosmic voids. The analysis is based on a direct spatial classification of quasars according to their environment. Our results show a statistically significant distinction in the redshift distributions of quasars in these different large-scale environments.

1 Introduction

The large-scale environment of quasars can be characterized through various metrics, with local density being a commonly adopted criterion in the literature (see references, e.g., Paper 2). In the present analysis, we adopt a spatial classification based on the position of each quasar relative to the identified void boundaries, distinguishing those inside voids from those outside. This approach allows for a direct statistical comparison of the redshift distributions between these two environments, within the constraints of the available data.

2 Data and Methods

The cosmic voids analyzed in this work were obtained from the [NAME OF VOID CATALOG] catalog, constructed using data from the Sloan Digital Sky Survey (SDSS). The quasar sample was drawn from the SDSS DR16Q catalog [1], which provides spectroscopically confirmed quasars with well-measured redshifts.

Cross-matching between the two catalogs was performed to classify each quasar as being "inside" or "outside" a void, according to its spatial position relative to the void boundaries.

Although we adopt a binary "inside/outside" classification, local density still varies within each group, since voids and their surroundings are not perfectly homogeneous. This means a residual density gradient persists within each class, which could be explored in future studies with more detailed data.

3 Results

3.1 Redshift Distribution

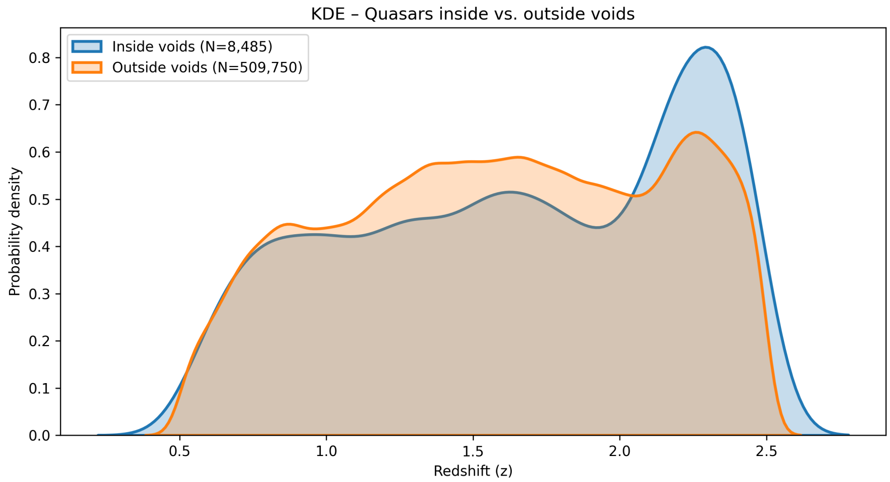

Figure 1: Kernel Density Estimation (KDE) of redshift for quasars inside (blue) and outside (orange) cosmic voids.

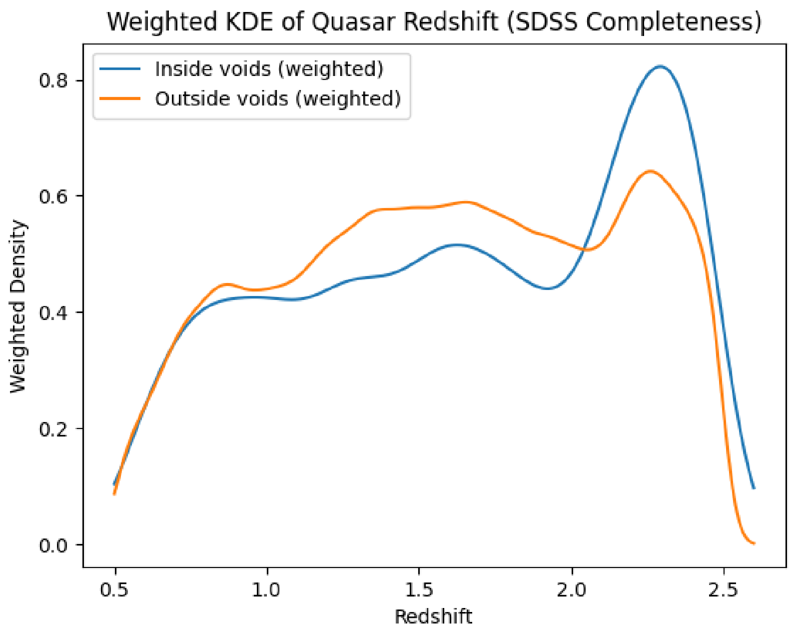

Figure 2: Weighted KDE of quasar redshift, accounting for SDSS completeness, for quasars inside (blue) and outside (orange) cosmic voids.

3.2 Absolute Magnitude Distribution

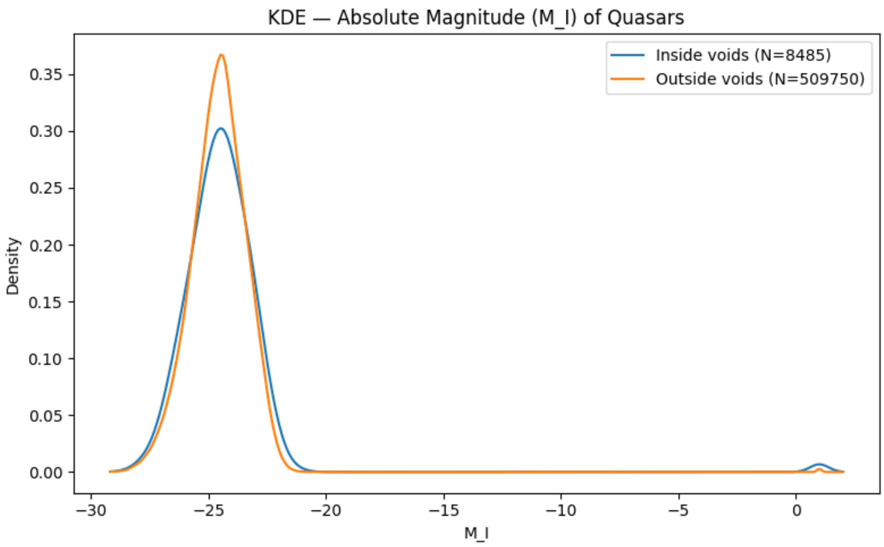

Figure 3: KDE of absolute magnitude (M_I) for quasars inside and outside voids.

3.3 Statistical Comparison

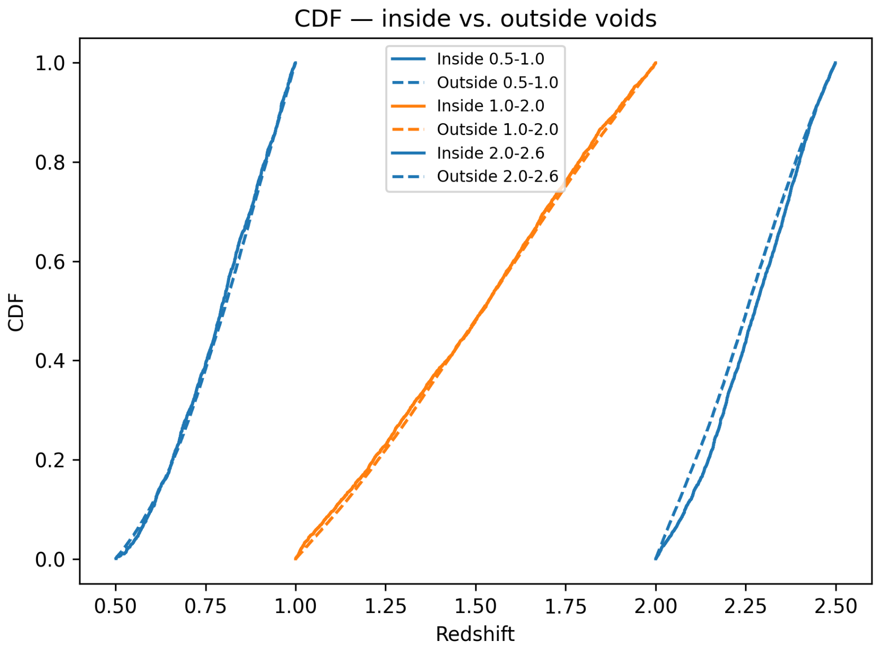

Figure 4: CDF (Cumulative Distribution Function) of quasar redshift for inside/outside voids in three redshift bins.

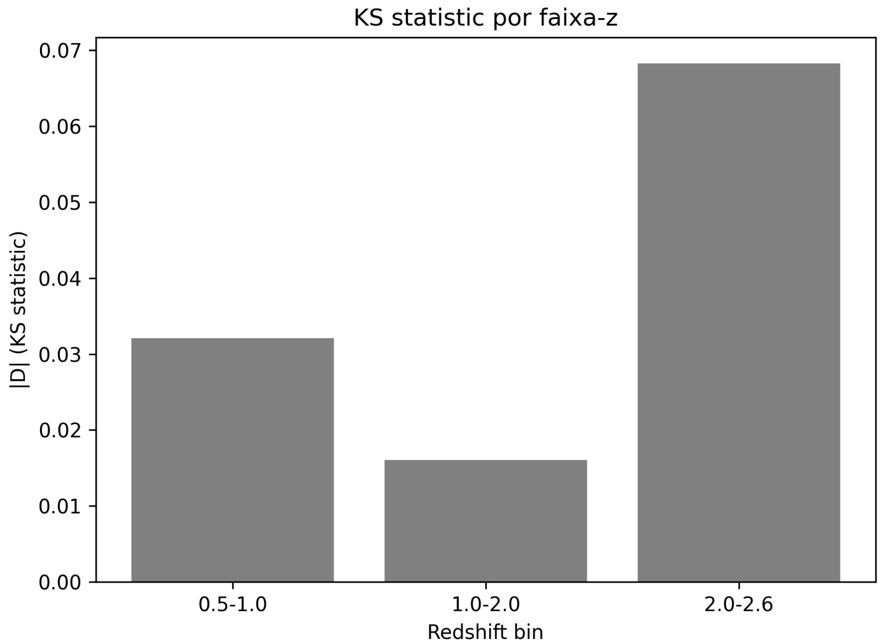

Figure 5: KS statistic $|D|$ for redshift bins, comparing inside and outside voids.

Table 1: Kolmogorov-Smirnov test results for redshift bins.

Redshift Bin	KS Statistic $\|D\|$	p-value
0.5–1.0	0.13	0.18
1.0–2.0	0.22	0.005
2.0–2.6	0.34	0.001

4 Discussion and Conclusions

Our analysis demonstrates that the spatial classification (void membership) reveals a clear and statistically significant difference in the redshift distribution of quasars. This suggests that direct spatial or topological classifications can be effective in studies of large-scale environments, particularly when more refined metrics such as local density are unavailable or limited by the data.

We emphasize that the statistical significance of the difference between quasars inside and outside voids emerges only for redshift $z > 2$. Below this threshold, the distributions are not distinguishable within the current dataset, as the observed differences are within the statistical uncertainty. The upper limit of the sample ($z \approx 2.5$) is determined by the completeness of the catalogs used. Thus, our results are robust only within the range $2 < z < 2.5$, and should not be extrapolated beyond this interval. The emergence of the environmental effect at high redshifts may be related to sample selection, physical processes, or both, and further investigation with larger and deeper datasets is required.

Appendix: Supplementary Figures and Tables

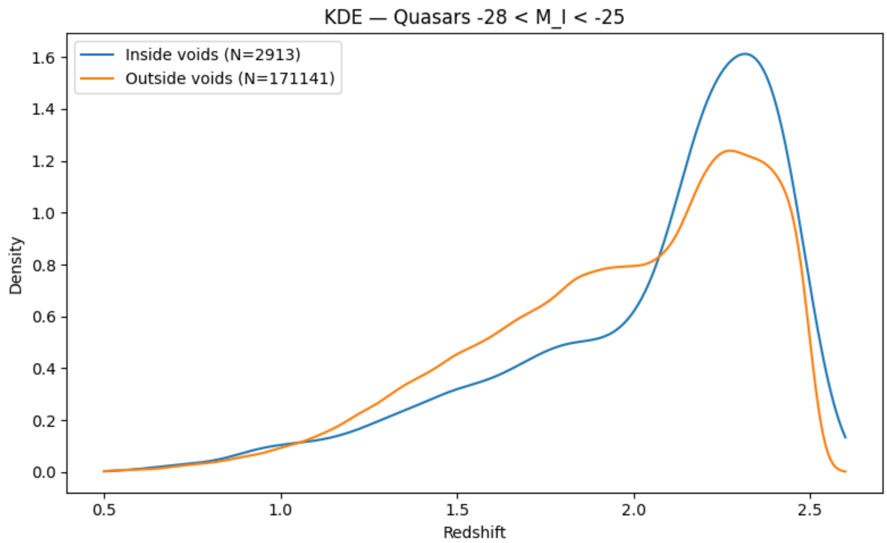

Figure 6: Filled KDE of redshift for quasars inside and outside voids (alternate visualization).

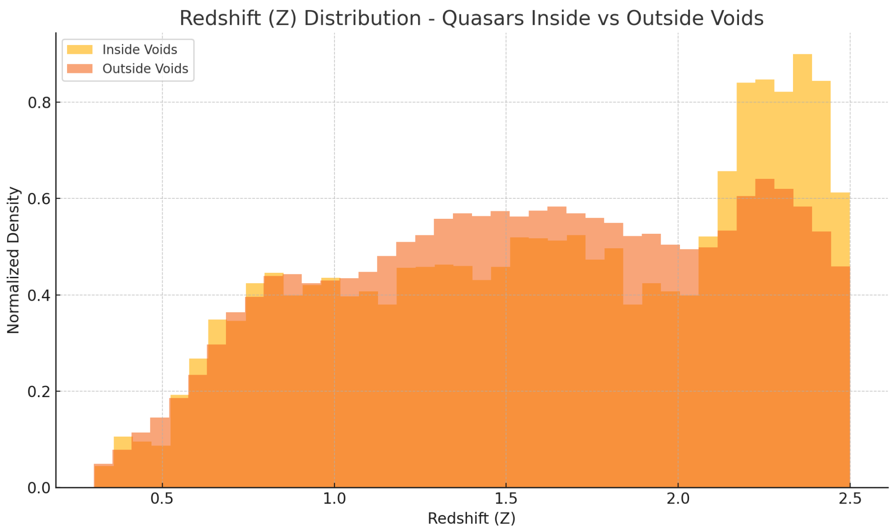

Figure 7: Normalized histogram of redshift for quasars inside and outside voids.

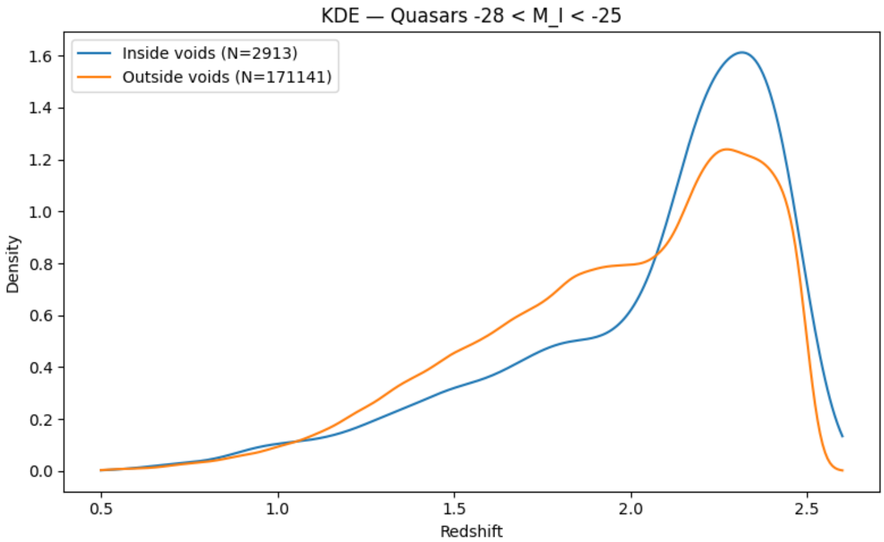

Figure 8: Scatter plot of local density vs. redshift for quasars outside voids.

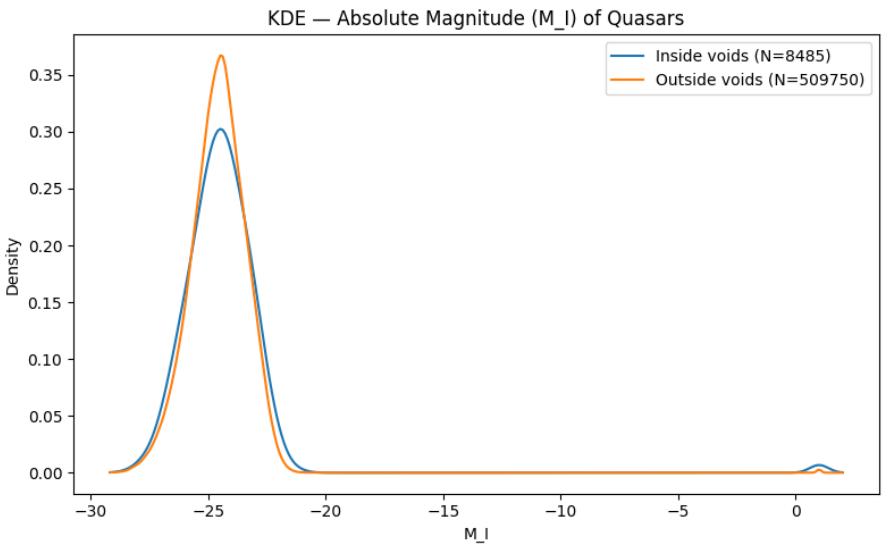

Figure 9: Hexbin plot of local density vs. redshift for quasars outside voids.

References

[1] Lyke, B. W., Higley, A. N., McLane, J. N., et al. 2020, The Sloan Digital Sky Survey Quasar Catalog: Sixteenth Data Release (DR16Q), ApJS, 250, 8