UNIVERSITY OF COPENHAGEN
Niels Bohr Institute
Cosmic Dawn Center
NOT - a telescope for the future

A Complete CENSUS of Quasars

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Introduction

- Nowadays, there are significant selection effects in the search for quasars, which are produced by different color criteria. The most widely used criteria are the UV band excess (UVX) selection [1], the K band excess (KX) selection [2], the WISE color selection [3], and so on.
- These color criteria can lead to an incomplete or even biased quasar population due to the limited samples from which they originated, and the inevitable imprecision caused by the degeneracy of spectral information in photometry.
- One example of WISE color selection is displayed in Fig. 1, in which the objects with color W1 [3.4] – W2 [4.6] ≥ 0.8 [Vega] are selected to be quasars. However, the classification of targets in the red elliptical curve is not trustworthy. In our opinion, the so-called red quasar candidates are all possible to be quasars, despite a large number of blue dots in this region.

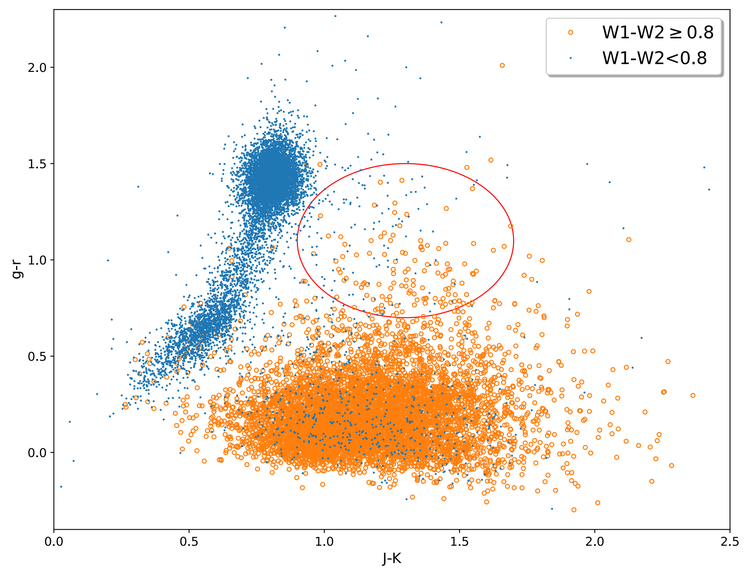

Figure 1. The g-r, J-K diagram of objects observed by multiple surveys. The orange circles appearing blue in the optical bands (with small g-r values) are credible to be quasars (the bottom clump), and the blue dots form the stellar locus.

Methods

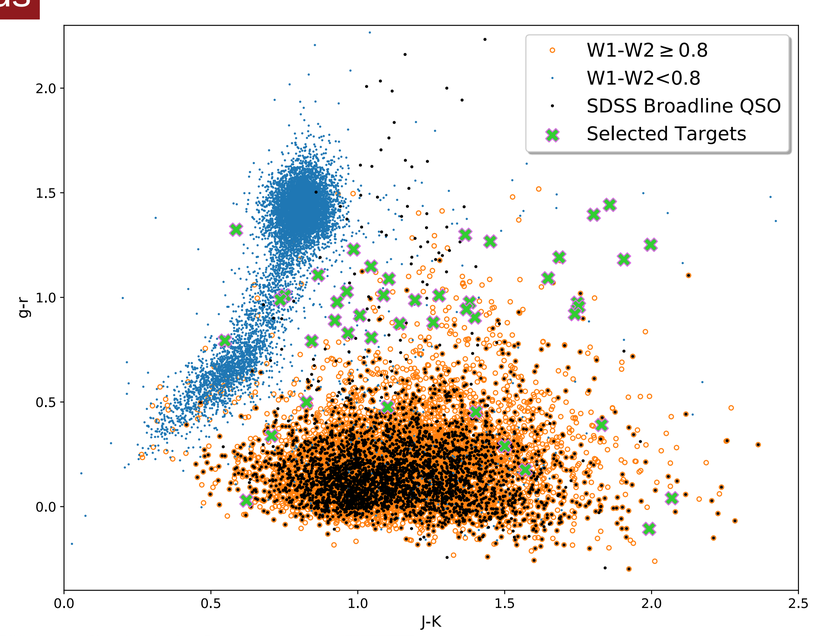

Figure 2. The selected 50 quasar candidates with abnormal colors, most of which (30) are red quasar candidates. We obtained their spectra with the Nordic Optical Telescope (NOT; bottom left) and the Gran Telescopio Canarias (GTC; bottom right). **Source**: https://www.wikipedia.org.

Spectral analysis

Figure 3. Example spectra of a normal quasar, a BAL quasar, a detached BAL quasar, an M5 star, and a peculiar quasar (from the left to the right and from the first row to the second).

Results

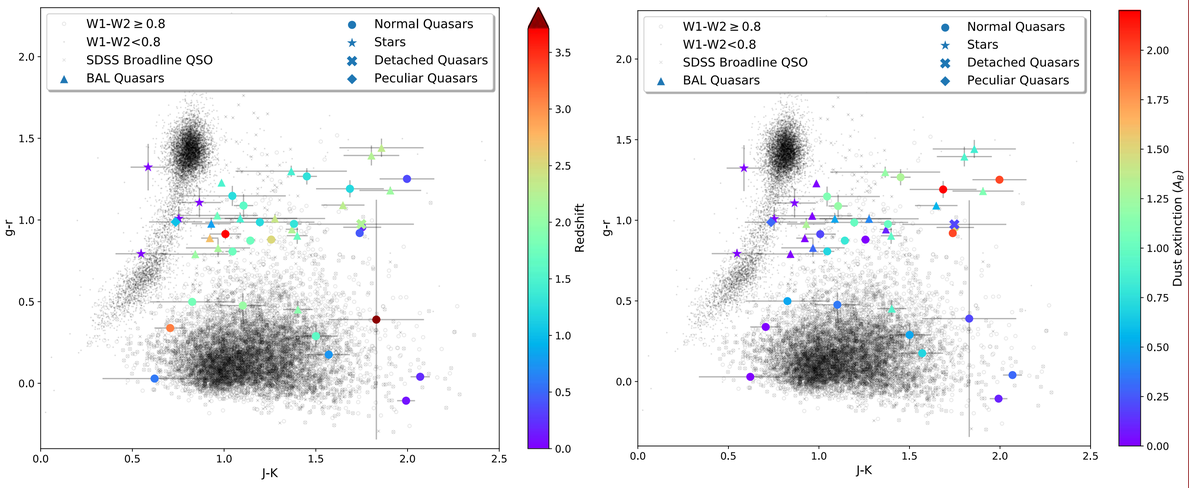

Figure 4. The classification of selected targets, with color scales based on their redshifts and estimated amount of dust extinction respectively. Most of the red quasar candidates are indeed quasars, which are reddened by the combined effect of the redshift and dust extinction.

Detached BAL quasars

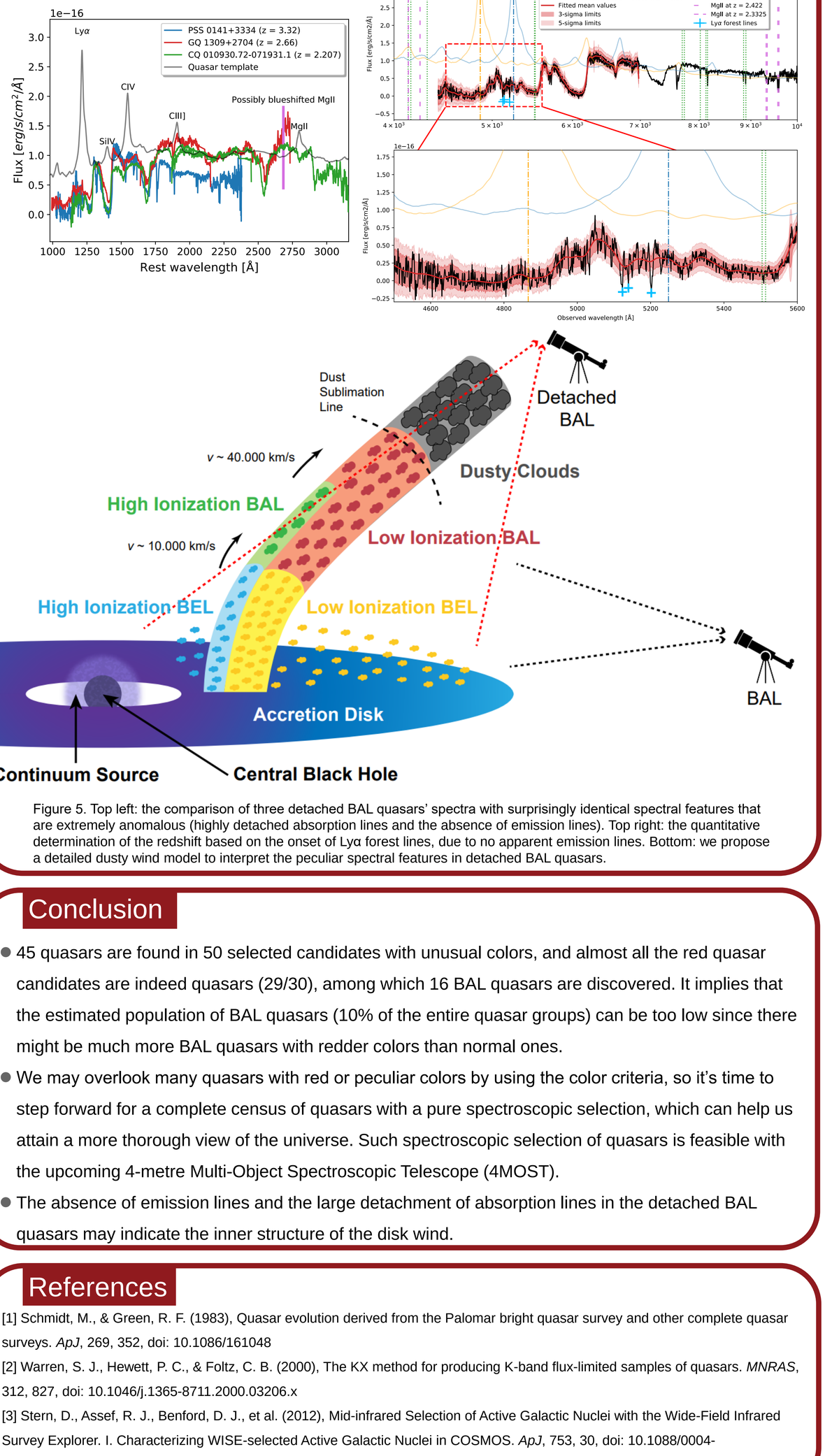

Figure 5. Top left: the comparison of three detached BAL quasars' spectra with surprisingly identical spectral features that are extremely anomalous (highly detached absorption lines and the absence of emission lines). Top right: the quantitative determination of the redshift based on the onset of Lyα forest lines, due to no apparent emission lines. Bottom: we propose a detailed dusty wind model to interpret the peculiar spectral features in detached BAL quasars.

Conclusion

- 45 quasars are found in 50 selected candidates with unusual colors, and almost all the red quasar candidates are indeed quasars (29/30), among which 16 BAL quasars are discovered. It implies that the estimated population of BAL quasars (10% of the entire quasar groups) can be too low since there might be much more BAL quasars with redder colors than normal ones.
- We may overlook many quasars with red or peculiar colors by using the color criteria, so it's time to step forward for a complete census of quasars with a pure spectroscopic selection, which can help us attain a more thorough view of the universe. Such spectroscopic selection of quasars is feasible with the upcoming 4-metre Multi-Object Spectroscopic Telescope (4MOST).
- The absence of emission lines and the large detachment of absorption lines in the detached BAL quasars may indicate the inner structure of the disk wind.

References

[1] Schmidt, M., & Green, R. F. (1983), Quasar evolution derived from the Palomar bright quasar survey and other complete quasar surveys. *ApJ*, 269, 352, doi: 10.1086/161048

[2] Warren, S. J., Hewett, P. C., & Foltz, C. B. (2000), The KX method for producing K-band flux-limited samples of quasars. *MNRAS*, 312, 827, doi: 10.1046/j.1365-8711.2000.03206.x

[3] Stern, D., Assef, R. J., Benford, D. J., et al. (2012), Mid-infrared Selection of Active Galactic Nuclei with the Wide-Field Infrared Survey Explorer. I. Characterizing WISE-selected Active Galactic Nuclei in COSMOS. *ApJ*, 753, 30, doi: 10.1088/0004-637X/753/1/30