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Discovery of a binary quasar at z=1.76

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Abstract. We present the serendipitous discovery of a physical pair of quasars with estimated cosmological redshift $z = 1.76$. Long-slit spectroscopic observations of the candidate quasar GQ 1114+1549A were conducted with the OSIRIS instrument at the Gran Telescopio Canarias. The orientation of the slit allowed OSIRIS to also capture the spectrum of GQ 1114+1549B, an object with angular separation of $\Delta\theta = 8.76$ arcsec from GQ 1114+1549A. Spectral analysis on the Si IV and C IV, C III] emission lines confirmed the quasar nature of GQ 1114+1549A, as well as that of its newly discovered companion. The relative intensity for the emission lines and the shape of the continuum of the two objects were found to be significantly different, rendering the hypothesis of the system being a gravitationally lensed quasar highly unlikely. The projected physical distance between the two quasars was therefore estimated to be 75 kpc.

Key words: quasars: general: emission lines, spectroscopy – quasars: individual: GQ 1114+1549, binary quasar

1. Introduction

Small-scale clustering of quasars has been object of debate for at least two decades, as it provides insight into cosmological tests of the Λ-Cold Dark Matter model and enhanced astrophysical activity of individual pairs of objects (see e.g. Mortlock et al., 1999; Sergeyev et al., 2016; Shalyapin et al., 2018, and references therein). In this project we analysed optical spectra of quasar candidates, selected based on photometry from a range of public surveys as well as astrometric information from Gaia following the prescription of Heintz et al. (2018); Geier et al. (2019). In synergy with the SDSS photometric selection, the Gaia-assisted method was able to reliably identify extra-galactic sources from their parallax consistent with zero (Geier et al., 2019). Such selection, presented by Geier et al. (2019), resulted in a catalogue of candidate quasars, which were then spectroscopically observed, in order to confirm or confute their extra-galactic nature. GQ 1114+1549 was included in the catalogue constructed by (Geier et al., 2019) and its quasar nature spectroscopically confirmed.

In the present work, we analysed the spectral data relative to GQ 1114+1549 and found evidence of a second unknown quasar, GQ 1114+1549B, separated by 8.76 arcsec from its companion. The determination of systemic redshifts, as well as emission and broad absorption lines, indicate that GQ 1114+1549 is highly likely to be a gravitationally bound quasar pair, which is the object of our study.

2. Observations and results

The primary quasar has equatorial coordinates $RA = 168.6417$ deg, $Dec = +15.8292$ deg (J2000.0) (see also Heintz et al., 2018; Geier et al., 2019) and it is hereafter identified as GQ 1114+1549A. The spectra used in the project originate from a project (PI S. Geier) running at the Gran Telescopio Canarias (GTC), which allowed the observation of GQ 1114+1549A on December 4, 2018, when two exposures with 400 second integration time were secured. The Grism 1000B, combined with a 1.23 arcsec slit, provided a resolution of $\mathcal{R} = 500$ and a spectral range of 3750–7800 Å. The atmospheric conditions presented a seeing of 1.2 arcsec, which allowed the observation of the target at an air mass of 1.46 using a parallactic slit angle.

Alongside with the spectrum of GQ 1114+1549A, two other objects were covered by the slit, as shown in the top panel of Figure 1. The unidentified faint source located above the main target in the slit was found to display the broad emission lines typical of quasars. Due to the low signal-to-noise ratio for this source, the spectrum is plotted using a larger bin size, in order to enhance the visibility of the emission lines. In the two bottom panels of figure 1 we show the 1-dimensional spectra of the main target GQ 1114+1549A and its weaker companion, which we henceforth refer to as GQ 1114+1549B. The redshift for both objects, $z = 1.76$, was computed based on the presence of emission lines from Si IV and C IV, and C III].

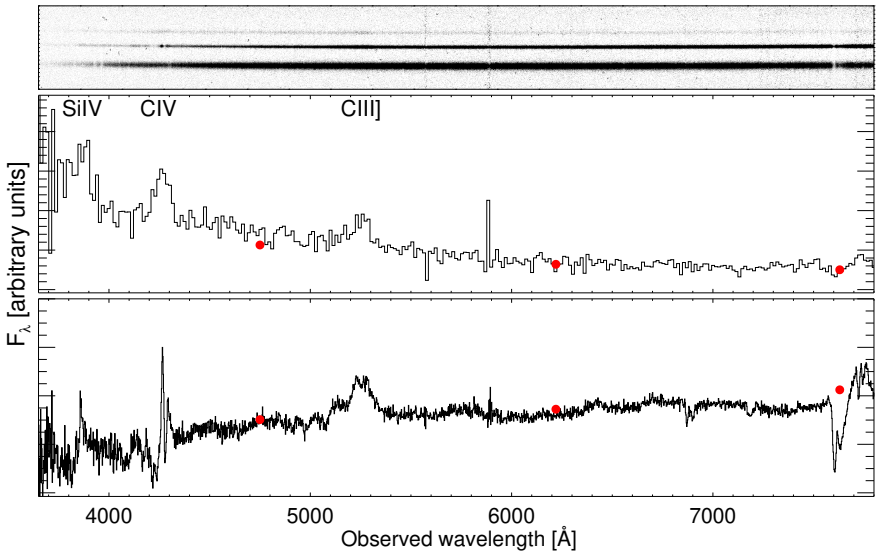

Figure 1. This figure presents the GTC spectra, where the Si IV and C IV, C III] lines are indicated. The top panel shows the section of a 2-dimensional spectra with three objects on the slit. The bottom trace is a star, the central trace is the primary target and the upper trace is the serendipitously discovered quasar. The two bottom panels display the 1-dimensional quasar spectra of GQ 1114+1549A (below) and B (above). Due to a misalignment between the B-object and the slit, the flux of the B-spectrum was suppressed by a factor of ~ 10 and was therefore binned by a factor of seven for better visibility. The red circles represent the g, r, and i-band photometry from the SDSS (York et al., 2000), which sets the scale for the photometric information.

3. Discussion and conclusion

By using images from the Sloan Digital Sky Survey (SDSS; York et al., 2000), centred on GQ 1114+1549A, we have inferred that GQ 1114+1549 A and B appear as two point sources separated by 8.76 arcsec. The slit orientation only marginally covers the position of GQ 1114+1549B, which explains the low signal-to-noise ratio for the GQ 1114+1549B spectrum. However, both the GTC spectra and the SDSS photometry allowed to identify significant differences in spectral shapes between the two objects. In particular, GQ 1114+1549A is a reddened source with strong associated absorption lines, whereas GQ 1114+1549B appears to be a blue quasar. The pair is therefore highly unlikely to arise from a gravitationally lensed quasar and the projected physical separation between GQ 1114+1549 A and B was hence found to be 75 kpc.

Further observations and analyses of this quasar pair will be presented in an upcoming paper.

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