KiDS0239-3211: A new gravitational quadruple lens candidate

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INTRODUCTION

Strongly lensed quasars (SLQSOs), particularly quadruply lensed systems, are very rare (Oguri & Marshall 2010), but very valuable probes of cosmology and extragalactic astrophysics.

With the KiDS Strongly lensed QUAsar Detection project (KiDS-SQuaD, Spiniello et al. 2018, hereafter S18) we have started a systematic census of lensed quasars in the Kilo Degree Survey (KiDS, de Jong et al. 2015), taking advantage from the high spatial resolution of VST ($0.2''$/pixel) and its stringent seeing constraints ($< 0.8''$ in r-band).
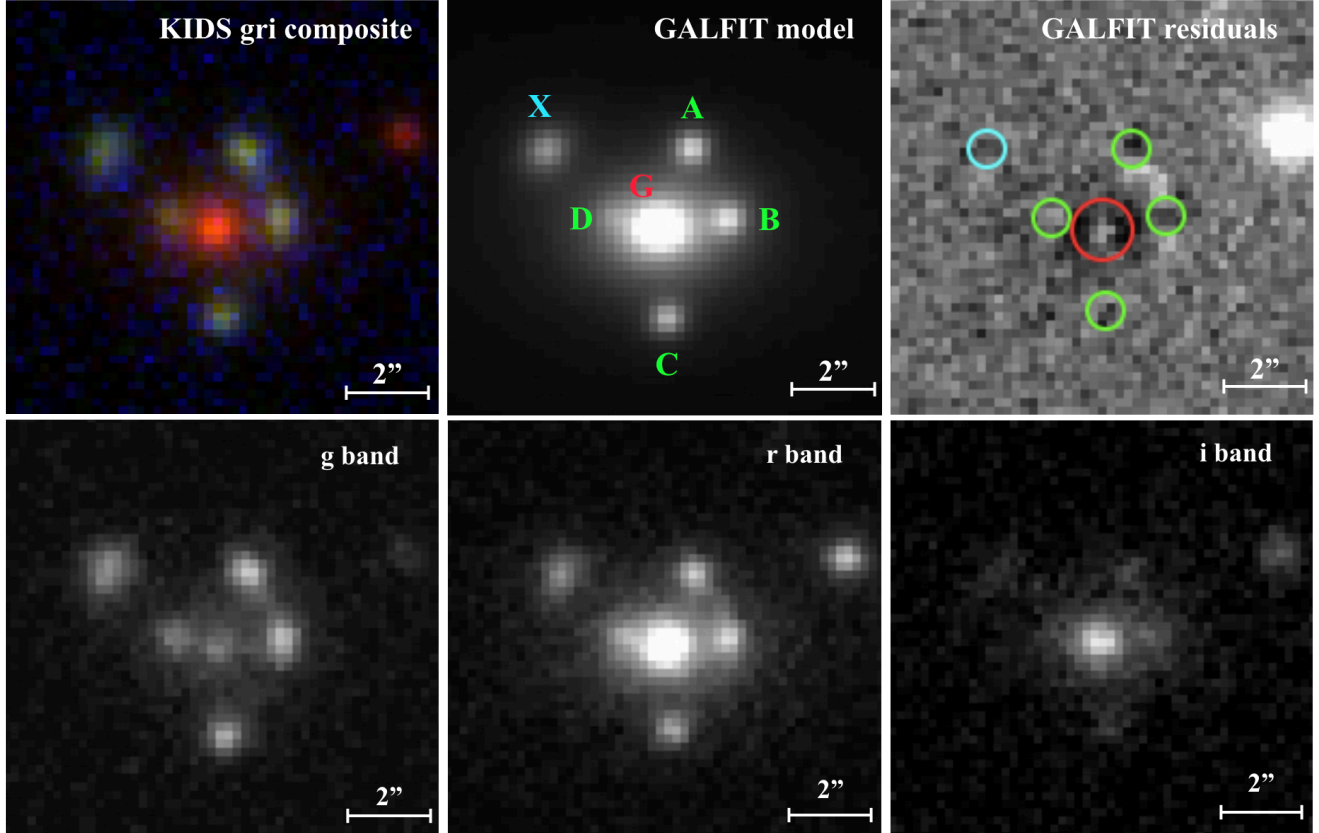
In S18 we selected qso-like objects based on infrared and optical colors and then used different methods to identify multiple systems, that we then visually inspected. However, with these methods, the number of candidates highly depends on the (somehow arbitrary and often calibrated on previous finding) selection criteria. Generally this number is of the order of thousands every 100 deg^2, making the visual inspection long and tedious. Thus, to make our research more effective and suitable to deal with larger amount of data coming with future data releases and new wide-sky surveys (e.g. Euclid or LSST), we developed a new method based on machine learning. These techniques have the great advantage to explore, with little computing time, large amount of candidates with less stringent pre-selections and with reasonably high precision (recovery rate) and little contamination (spurious detection). These have been applied already for the search of strong gravitational arcs in KiDS (Petrillo et al. 2018) and SLQSOs in other wide-sky Surveys (Agnello et al. 2015).

MINING STRONG LENSED QUASARS WITH MACHINE LEARNING

Although the combination of near-infrared and optical colours is the most effective way to separate quasars from stars within photometric surveys (Akhmetov et al. 2017), infrared information is not always available and often not deep enough. For this reason, we developed a machine learning based method to separate QSOs from stars using only 4 photometric optical bands (u,g,r,i). We used Random Forests classifier (self-written python code) with spectroscopically confirmed stars $(622,052)$ and QSOs $(484,372)$ from SDSS DR14 (Abolfathi et al. 2018). We worked in the 6-dimensional colour space, made of all possible differences of magnitudes in the different bands. The classification was performed with a 5-fold cross-validation, obtaining 99% of purity and 65% of completeness of the quasar validating sample. We thus apply this procedure on the KiDS-DR3 catalog and then select QSO-like multiple sources (with a separation $\leq 10''$). We ended up with 3187 candidates, for which we inspected the combined ugr KiDS cutouts. A detailed presentation of the method will be presented in a future publication.

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KIDS 0239-3211

KiDS 0239-3211 (Ra: 02:39:29.69, Dec: −32:11:29.66) is without doubt the most promising candidate we found in the public KiDS-DR3.

Comp. Name	δx (arcsec)	δy (arcsec)	g (mag)	r (mag)	i (mag)	$g - r$ (mag)	$g - i$ (mag)	$r - i$ (mag)
G	0	0	20.68 ± 0.07	19.04 ± 0.04	18.58 ± 0.04	$+1.64 \pm 0.08$	$+2.09 \pm 0.08$	$+0.46 \pm 0.06$
A	$+0.71 \pm 0.07$	$+1.81 \pm 0.07$	22.51 ± 0.15	22.52 ± 0.18	22.6 ± 0.2	-0.01 ± 0.2	-0.09 ± 0.25	-0.08 ± 0.27
B	$+1.55 \pm 0.07$	$+0.20 \pm 0.07$	22.71 ± 0.19	22.8 ± 0.2	22.6 ± 0.2	-0.09 ± 0.27	$+0.11 \pm 0.27$	$+0.2 \pm 0.28$
C	$+0.36 \pm 0.05$	-2.06 ± 0.05	22.72 ± 0.17	22.6 ± 0.2	22.6 ± 0.2	$+0.12 \pm 0.26$	$+0.12 \pm 0.26$	$+0.0 \pm 0.3$
D	-1.1 ± 0.3	$+0.30 \pm 0.3$	23.3 ± 0.3	23.4 ± 0.9	23.1 ± 0.7	-0.1 ± 0.9	$+0.2 \pm 0.7$	$+0.3 \pm 1.1$
X	-2.57 ± 0.08	$+1.77 \pm 0.08$	22.19 ± 0.13	22.02 ± 0.16	22.04 ± 0.15	$+0.17 \pm 0.2$	$+0.15 \pm 0.2$	-0.02 ± 0.22

In the figure we show the combined gri KiDS cutout of the quad, as well as single band images and GALFIT model and residuals. The system is composed by a red galaxy in the middle (G) surrounded by five blue blobs within few arcsec distance (listed in the Table) We obtained differential photometry directly from GALFIT, calibrating the zero-point with a reference star from the KiDS catalog. We note that all blobs have consistent colors, within the errors, which support the lensing hypothesis.

Given the geometry, colors and shape of the blobs, we believe that four of them are multiple images of a point-like source (A, B, C, D in green) whereas the fifth, more distant one is a contaminant (X in cyan). This hypothesis is further confirmed by the machine learning based estimate of the photometric redshifts ($z \sim 0.5$ for G and X and $z \sim 1.6 - 2.0$ for A and C, from the catalog in de Jong et al. 2017 and derived using the Multi Layer Perceptron with Quasi Newton Algorithm technique presented in Cavuoti et al. 2015).

DISCUSSION AND CONCLUSIONS

The discovery of KiDS 0239-3211, missed by other methods, demonstrates that our machine learning set-up, although still preliminary, represents a considerable step further to effectively find new SLQSOs in present and future public wide-sky photometric surveys.

Nevertheless, to unambiguously confirm the lensing nature of the system and to translate the 'geometric' lens model results (e.g. Einstein radius) into physical measurements of luminous and dark masses, the redshifts of the source and of the deflector are needed. We are therefore setting up a systematic, multi-site, multi-facility campaign for spectroscopic observation of the best candidates in KiDS, including KiDS 0239-3211, but the publication of the object coordinates and fluxes is meant to encourage the community to help out with this task.

ACKNOWLEDGMENTS

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