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Time-delay and lens galaxy redshift in the doubly imaged quasar PS J2305+3714

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ABSTRACT

We present results from a seven-season (2018–2024) monitoring campaign of the gravitationally lensed quasar system `PS J2305+3714` using the 1.5-m Maidanak Telescope in the optical *R* band. We measure a time delay of $t_{\mathrm{AB}} = 52.2 \pm 2.5$ d, with the brighter image A leading. No significant microlensing variability is detected, with an upper limit on the amplitude of $\lesssim$10 mmag over a 7-yr time-scale. Long-slit `WHT/ISIS` spectroscopy refines the quasar redshift to $z_s = 1.791$ and provides the first measurement of the lens redshift, $z_d = 0.473$. The flux ratios of the quasar images in the Mg II λ2800 emission line and in the adjacent continuum are nearly identical, indicating minimal microlensing effects in the spectral domain, which is consistent with the very weak microlensing signal in the time domain. Using precise astrometry from recent *Hubble Space Telescope* (*HST*) imaging and the Mg II flux ratio, we also build two simple mass models for the lens system. The close agreement between the measured delay and the values predicted by the lens mass models, the measured redshifts, and a concordance Λ cold dark matter cosmology, supports the robustness of our results and highlights `PS J2305+3714` as a promising system for future time-delay cosmography.

Key words: gravitational lensing: strong – redshifts – quasars: individual: PS J2305+3714 – cosmology: observations.

1 INTRODUCTION

Gravitational lensed quasars can be used for the Hubble constant measuring. This idea was suggested a long ago (S. Refsdal 1964) but only in the last decade it is transformed into a powerful astrophysical tool known as 'Time Delay Cosmography' (S. Birrer et al. 2024) that is able to concurrent with other available methods and complement them. The characteristic feature of this method is the possibility to obtain useful constraints even from the analysis of a single target; however, for a more robust evaluation, a collection of well-studied objects is necessary. Such a set of six lensed quasars was used, e.g. in K. C. Wong et al. (2020), which led to a 2.4 per cent precision measurement in accordance with the local value of the Hubble constant. Certainly, the estimated value depends on details of the specific study and on the involved sample size, so the extension of a useful lensed quasar set is an actual problem.

Few hundred galaxy-scale gravitationally lensed quasars have already been confirmed, and forecast studies predict that upcoming wide-field synoptic surveys will expand the sample to thousands (M. Oguri & P. J. Marshall 2010; T. E. Collett 2015). The Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) alone is expected to deliver ~8000 lenses, while *Euclid* and the Nancy Grace Roman Space Telescope will add thousands more, especially at higher redshift.

Only a minority of these systems are suitable for precision 'Time Delay Cosmography' because they must exhibit clean, multiply imaged variability and permit accurate mass-model inference (D. Gilman, S. Birrer & T. Treu 2020). For each useful lens, the relative delays between quasar images need to be measured to better than about 5 per cent in order to keep the cosmological error budget competitive. The Strong-Lens Time-Delay Challenge showed that once this threshold is met, lens-model systematics –

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