Revista Mexicana de Astronomía y Astrofísica Serie de Conferencias, 60, 211-212, (2026)

OPEN ACCESS https://doi.org/10.22201/ia.14052059p.2026.60.183

"XVII LARIM", Montevideo, Uruguay, November 27 - December 1, 2023.Volume Editors: Gonzalo Tancredi, Cecilia Mateu & Juan José Downes

Constraints on modified gravity from follow-up observations of 20 Strong Lensing systems

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Keywords: *gravitational lensing: strong*

Strong Lensing (SL) systems can be used to set constraints on deviations from General Relativity (GR), quantified through the so-called Post-Newtonian parameter γ, which is equal to 1 in GR. In particular, for galaxy-galaxy SL systems, this can be done by combining the lensing derived mass modeling and the kinematics of the lens galaxy (obtained through the velocity dispersion σ_v). In this work, we present the first estimation of γ from purely ground-based data. To this end we conducted spectroscopic follow-up observations of systems selected from wide-field imaging surveys using the Southern Astrophysical Research (SOAR) and the Gemini Telescopes. In order to model these lenses, we employed the Source Lens and Lens (SLaM) modeling pipeline. With 20 strong lensing systems in our sample, we obtained a value of $\gamma = 1.13^{+0.21}_{-0.25}$, consistent with the value expected from GR at 68% confidence level.

Mass modeling of strongly lensed galaxy-galaxy systems is the backbone of different applications in cosmology. The SL modeling of such systems is generally carried out on space-based imaging data (usually from HST), strongly limiting the number of systems available for these studies. On the other hand, hundreds of thousands of these systems are expected to be discovered in the forthcoming Vera Rubin Observatory Legacy Survey of Space and Time (LSST Collett, 2015).

As a preparation for these upcoming data, our group has collected approximately 30,000 SL candidates, among which hundreds are expected to be suitable for modeling with available imaging from ground-based data. We refer to this comprehensive compilation of gravitational lenses as "the Last Stand Before Rubin" (LaStBeRu, Oliveira and Makler, in prep.). In order to derive γ from purely ground-based imaging data, we conducted follow-up observations of 20 lens systems selected from this sample on the SOAR and the Gemini Telescopes. The spectra where reduced with the standard pipelines and analysed using the `pPXF` (Cappellari, 2017) code to derive σ_v.

To model these systems, we have developed a semi-automated modeling pipeline that interactively reconstructs the noise-map and PSFs in the image cutouts available from the LaStBeRu compilation. The modeling is performed using an updated version of SLAM, which builds up upon Etherington et al. (2022). This pipeline consists of a multi-modeling connected layer in order to guarantee convergence during the lens parameters inference. Our best model fits the lens light as a Multi-Gaussian Expansion light profile, with a Power-Law density distribution. The source light is fitted by an adaptive pixelization in a Voronoi mesh. This pipeline is currently implemented using features of `PyAutoLens` (Nightingale et al., 2021).

We follow the analysis of Schwab et al. (2010) (see also Cao et al., 2017, and subsequent works) to combine the results from our SL modeling and our measurements of the lens velocity dispersion to set a constraint on γ. From our sample of 20 strongly lensed systems, we obtain a result of $\gamma = 1.13^{+0.21}_{-0.25}$, consistent with GR at 68% confidence level. Although the error bars are significantly larger than the current estimates in the literature, due to the sample size, these results show the potential for using ground-based data to test gravity. They are also the first constraints on γ from a sample entirely independent from the ones uses in the previous works.

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