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A Natural $\gtrsim 100\times$ Telescope: Discovery of the Strongly Lensed Type II SN 2025mkn at $z = 1.37$

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Abstract

We present the discovery of SN 2025mkn, a gravitationally lensed Type II supernova. First detected as a blue transient in Zwicky Transient Facility (ZTF), 0".83 from a $z = 0.42$ elliptical galaxy, the follow-up SNIFS/UH2.2 m and LRIS/Keck spectra revealed absorption lines at $z = 1.371$. Later JWST NIRCам imaging shows that the bright transient is a close pair of point sources separated by $\sim 0".07$, and a 30 times fainter counterimage opposite the lens, for which NIRSpec reveals strong $H\alpha$ emission also at $z = 1.371$. The lightcurves and spectra are consistent with the Type II supernova source being magnified $\gtrsim 100$ times, with ~ 250 required to reconcile its luminosity with that of nearby events such as SN2023ixf. Lens models are consistent with such high magnifications, and always show that the faint image arrived first (undetected in earlier ZTF imaging), consistent with the later spectral phase of this fainter image. A fourth image is also predicted and possibly detected in the NIRSpec data. Lightcurve-based time-delay measurements are not possible due to the first image being the faintest; however, the resolved NIRSpec spectra offer a future opportunity for time-delay cosmography through supernova phase measurements.

Unified Astronomy Thesaurus concepts: [Strong gravitational lensing \(1643\)](#); [Type II supernovae \(1731\)](#); [Supernovae \(1668\)](#)

1. Introduction

Strong gravitational lenses are unique astrophysical tools: they allow direct probes of total masses within the Einstein radius (e.g., A. J. Shajib et al. 2024), reach resolutions impossible for unlensed sources thanks to the associated magnification (e.g., parsec scales at $z = 2$, E. Vanzella et al. 2022), and provide multiple subkiloparsec lines of sight to study spatial variations in kinematics and chemistry in galaxies (e.g., S. Cristiani et al. 2024), among many other uses. Nearly all strong lens systems discovered to date have galaxy or quasar sources (C. Lemon et al. 2024), the latter of which are time variable, opening up additional science cases such as microlensing studies to probe compact matter fractions in lensing galaxies (e.g., G. Vernardos et al. 2024), and time-

delay cosmography, in which the time delays between image pairs are measured and used to constrain the Hubble constant (S. Refsdal 1964). For the latter application, S. Refsdal (1964) originally proposed supernova sources, but only in recent years have such systems been discovered (R. M. Quimby et al. 2013; P. L. Kelly et al. 2015; A. Goobar et al. 2017). These lensed supernovae (SNe), despite only providing time-domain information during the lifetime of the supernova, offer several advantages over lensed quasars: (i) time-delay measurements are often easier due to the known shape of the supernova lightcurve; (ii) time delays can be measured independently from spectral phases (J. Bayer et al. 2021; J. Johansson et al. 2021; W. Chen et al. 2024); (iii) some SNe are “standardizable,” providing absolute magnifications to break degeneracies of lens modeling (L. Weisenbach et al. 2024); and (iv) after the supernova has faded the lensed host galaxy can be used to constrain the lensing potential without the noise and systematics of overlapping bright point sources (as used for iPTF16geu in, e.g., E. Mörtzell et al. 2020).

While cluster-scale lensed supernovae have already been used for time-delay cosmography (e.g., J. Vega-Ferrero et al. 2018; P. L. Kelly et al. 2023; M. Pascale et al. 2025;

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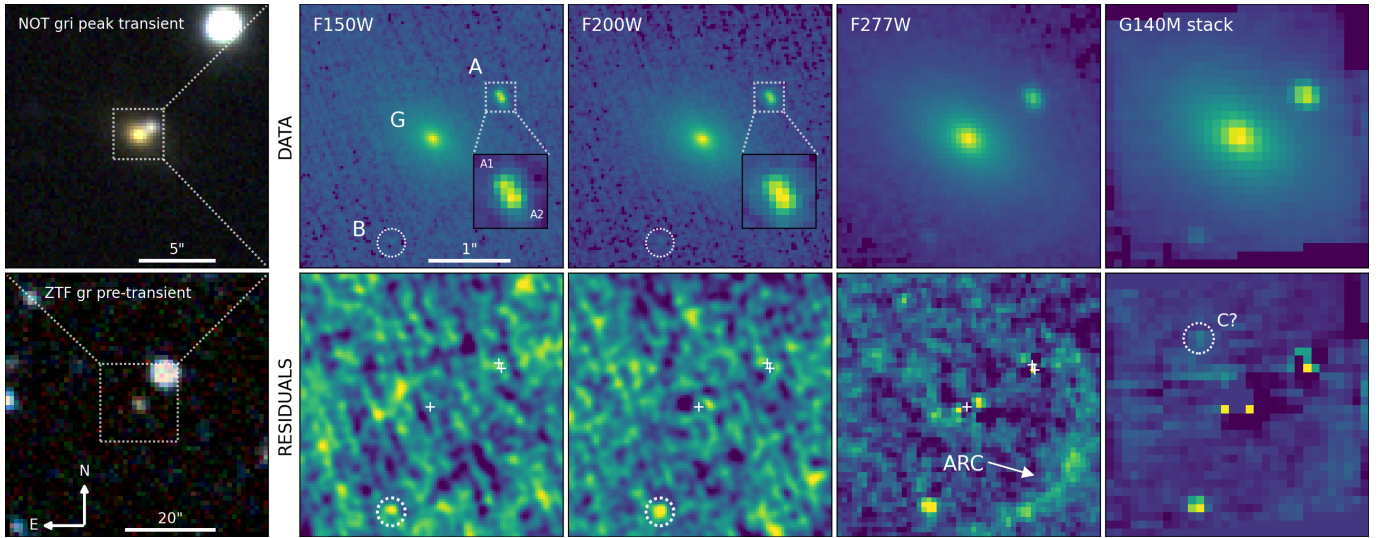


Figure 1. Left: ZTF *gr* image of the field before the transient (bottom) and NOT *gri* image during the peak of the lightcurve (top). Right: NIRCam F150W, F200W, and F277W images, alongside the NIRSpect G140M white light image (top), and subtractions after modeling the lensing galaxy, G, and image A (bottom). Note the inset showing that image A is well modeled as two PSFs separated by $\sim 0''.07$. The F277W and G140M residuals show an arc to the south west of the galaxy, as well as a hint of another image, which we label C.

J. D. R. Pierel et al. 2025), the mass models are complex and do not completely use the information of the lensed arcs. Galaxy-scale lensed supernovae offer a promising route to the Hubble constant, thanks to their simple lens mass distributions, though the first examples discovered had time delays too short to offer competitive cosmological constraints (A. Goobar et al. 2017, 2023a). Recently J. Johansson et al. (2025) and S. Taubenberger et al. (2025) reported a lensed Type I superluminous supernova at $z = 2.01$ with a maximum image separation of $4''.9$.

In this Letter, we report the discovery of SN 2025mkn at $z = 1.371$, a Type II supernova that is multiply imaged by a foreground galaxy at $z = 0.42$, with lens coordinates of R.A., decl. (J2000) = 16:42:11.47, +55:31:02.45. In Section 2, we outline both ground-based and JWST imaging and spectra, and in Section 3 we present analysis of the source, the lensing galaxy, and present a simple lens model of the system. We discuss the data, model, and implications in Section 4, and conclude in Section 5. Throughout this work, we adopt a flat Λ CDM cosmology with $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, and $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$. Magnitudes are reported in the AB system.

2. Observations

Previous galaxy-scale lensed supernovae have been discovered through an inferred magnification. This requires a redshift and expected absolute magnitude. Ideally, spectra will provide both the redshift and supernova type (and thus expected intrinsic brightness); however, spectra are costly and rare for these types of events. To expand the search, photometric redshifts of potential host galaxies are used so photometric candidates can also be vetted (D. A. Goldstein & P. E. Nugent 2016). In the case of lensing, even though the lensing galaxy will be incorrectly assumed to be a host, it still provides a lower redshift limit with which to search for overly bright supernovae. Our search for lensed supernovae is based on the cadenced survey by the Zwicky Transient Facility (ZTF; E. C. Bellm et al. 2019; D. A. Duev et al. 2019;

M. J. Graham et al. 2019; A. Mahabal et al. 2019; F. J. Masci et al. 2019; M. T. Patterson et al. 2019; R. Dekany et al. 2020).

During our daily automatic crossmatch of new ZTF transients to photometric redshifts, SN 2025mkn—internally named ZTF25aasjeza—was alerted as a transient with an intrinsic magnitude of $M = -22.4 \pm 0.1$ given the nearby photometric redshift of $z = 0.39 \pm 0.02$ (Legacy Survey; R. Zhou et al. 2021). A Dark Energy Spectroscopic Instrument (DESI; DESI Collaboration et al. 2016, 2022; J. Guy et al. 2023; E. F. Schlafly et al. 2023; T. N. Miller et al. 2024; C. Poppett et al. 2024; M. Abdul Karim et al. 2025; A. G. Adame et al. 2025; DESI Collaboration et al. 2026; S. Bailey et al. 2026, in preparation) spectrum of the galaxy confirmed it to be $z = 0.4203 \pm 0.0001$. The spectrum was taken from the internal release “Loa”, which will be released as part of DESI DR2 in 2027.⁷³ The transient was also reported by the Asteroid Terrestrial-impact Last Alert System (ATLAS; J. L. Tonry et al. 2018).

An early classification spectrum of the transient by the Spectroscopic Classification of Astronomical Transients (SCAT) survey (M. A. Tucker et al. 2022; J. Hinkle 2025) showed a nearly featureless blue spectrum. However, upon closer inspection, narrow absorption lines are present at two distinct redshifts, $z = 1.256$ and $z = 1.371$. This provides a new lower limit for the supernova redshift of 1.371, implying a rest-frame UV absolute magnitude $M \sim -25$ mag, which is several magnitudes brighter than the most extreme superluminous supernovae; thus, a lensing magnification is required, which was reported in A. Goobar et al. (2025). This led to the triggering of a JWST program, involving imaging that resolves the multiple lensed images (see Figure 1) and spectroscopy, both of which we present in this section, alongside a ground-based follow-up. We also obtained Karl G. Jansky Very Large Array (VLA; A. R. Thompson et al. 1980; R. A. Perley et al. 2011) observations to investigate the source as a possible Luminous Fast Blue Optical Transient (LFBOT), which yielded a nondetection.

⁷³ DESI spectrum ID 39633329464544708, available in DESI DR2.

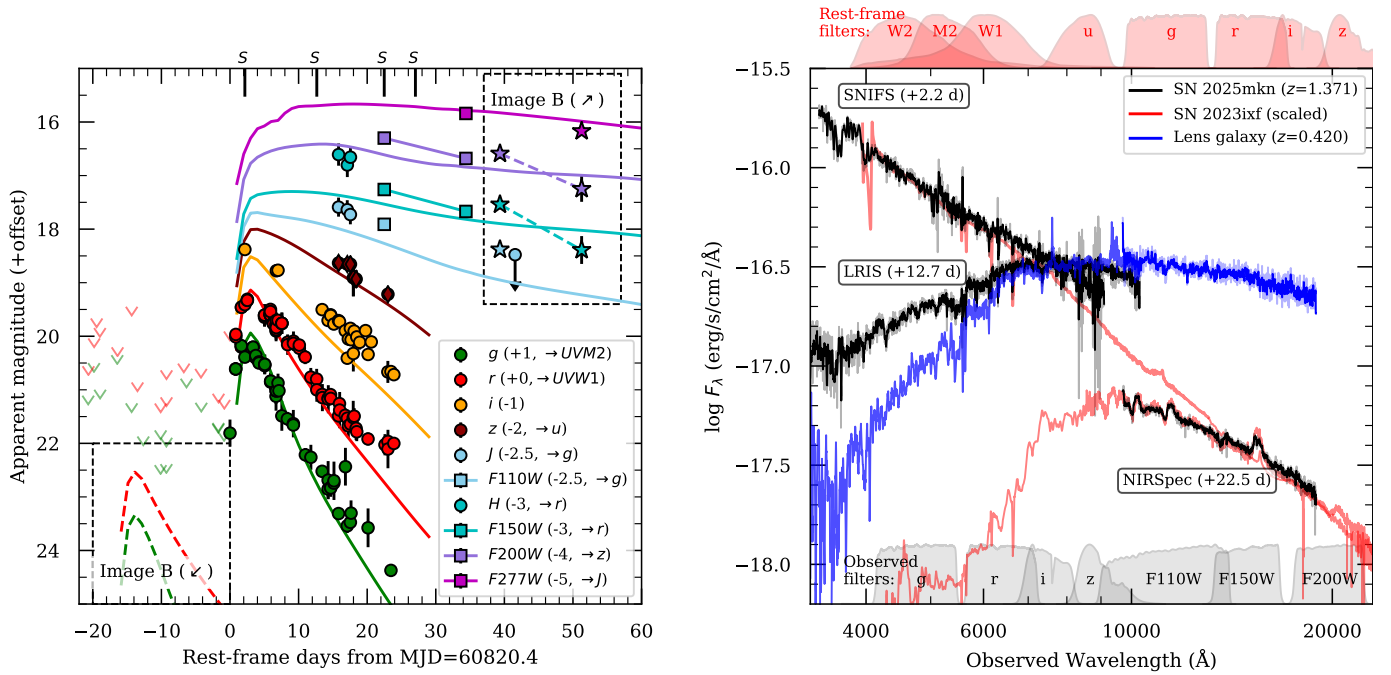


Figure 2. Left panel: compilation of ground-based (circles) and JWST (square symbols) photometric observations of SN 2025mkn (Image A). The solid lines show the lightcurves of SN 2023ixf in matching rest-frame filters or synthetic photometry on spectra indicated in the legend. The star symbols and dashed lines show the photometry for image B (shifted both in time and magnitude, corresponding to a fiducial time delay and differential magnification). The observation dates of the spectra are marked along the top with "S" symbols. Right panel: optical and near-IR spectra (black lines) of SN 2025mkn (Image A). The shaded red lines show SN 2023ixf redshifted and scaled to match SN 2025mkn with magnifications of 250 and 15 (for A and B respectively) at similar phases (reported in rest-frame days). The blue line is a combined Keck/LRIS and JWST/NIRSpec spectrum of the lens galaxy.

The long-wavelength JWST/NIRCam data (Figure 1) clearly resolve both the lensing galaxy and the transient seen north west of the galaxy. They also show a second point source $1''.3$ south east of the galaxy. We label the two point sources A and B, respectively, and note that B is approximately 30 times fainter than A. We postulate that B is another image of the transient, and provide supporting evidence in the next section.

2.1. Ground-based Imaging

The ZTF *g*- and *r*-band lightcurves of SN 2025mkn are supplemented by *gri* photometry from both the Spectral Energy Distribution Machine (SEDMA; N. Blagorodnova et al. 2018; M. Rigault et al. 2019; Y.-L. Kim et al. 2022) on the Palomar 60-inch telescope and the Alhambra Faint Object Spectrograph and Camera (ALFOSC) on the Nordic Optical Telescope, and *griz* observations with the IO:O camera on the Liverpool Telescope (LT), and *grzJH* imaging with the Fraunhofer Telescope at Wendelstein Observatory (FTW) using the Three Channel Imager (3KK; F. Lang-Bardl et al. 2016).

For the optical *griz* data we use archival Pan-STARRS (K. C. Chambers et al. 2016) images for subtractions. For 3KK, the optical CCD and near-infrared (NIR) CMOS data were reduced using a custom pipeline (C. A. Gössl & A. Riffeser 2002; M. Busmann et al. 2025). For the astrometric calibration of the images, we used the Gaia EDR3 catalog (Gaia Collaboration 2020; Gaia Collaboration et al. 2021; L. Lindegren et al. 2021). Tools from the AstrOmatic software suite (E. Bertin & S. Arnouts 1996; E. Bertin et al. 2002; E. Bertin 2006) were used for the coaddition of each epoch's individual exposures (as well as for the IR imaging described later). We use the Saccadic Fast Fourier Transform (SFFT; L. Hu et al. 2022) algorithm for image subtraction.

For the near-IR *J*- and *H*-band data, we follow the same image subtraction process as for the optical imaging, but calibrate against the 2MASS Catalog (M. F. Skrutskie et al. 2006). For 3KK, we use templates from the United Kingdom Infrared Telescope (UKIRT; S. Dye et al. 2018).

Due to the high decl. of SN 2025mkn, ZTF observations of the field have short seasonal gaps of ~ 55 days. In the discovery season, data starting ~ 170 days before peak are available in the *g* and *r* bands with a median cadence of ~ 2 – 3 days. In these data, we search for any preceding images, and in the case of a nondetection, place upper limits on the brightness.

We download all epochs of available *g* and *r* imaging from ZTF through the IRSA ZTF application programming interface (API), to build a scene model of the pretransient system, using *lightcurver* (F. Dux 2024) and *STARRED* (K. Michalewicz et al. 2023). After subtracting the best-fit constant model (the lensing galaxy and a nearby star), the residuals are inspected for signs of leading images. No detection is seen in any epoch before image A first appears. 5σ nondetections are shown in Figure 2. The photometric datasets were collated using *fritz* (S. van der Walt et al. 2019; M. W. Coughlin et al. 2023).

In Figure 2 we show all of the available photometry for this system, with the lightcurves of the nearby Type II supernova, SN 2023ixf, overlaid, with discussion on the nature of the source in Section 3.1.

2.2. Ground-based Spectra

On 2025 May 30, a classification spectrum was taken with the SuperNova Integral Field Spectrograph (SNIFS; B. Lantz et al. 2004) on the University of Hawaii 2.2 m telescope SCAT (M. A. Tucker et al. 2022). SNIFS covers the full optical range

Table 1
Synthetic Photometry from NIRSpec (MJD = 60873.7) and Photometry from NIRCImaging (MJD = 60901.9)

Object	NIRSpec [MJD = 60874]			NIRCImaging [MJD = 60902]			Astrometry + Lens model				
	F110W	F150W	F200W	F150W	F200W	F277W	$-\Delta R.A.\cos\delta$ (arcsec)	$\Delta\text{Decl.}$ (arcsec)	κ	γ	μ
A	$20.41^{+0.05}_{-0.05}$	$20.26^{+0.05}_{-0.05}$	$20.30^{+0.05}_{-0.05}$	$20.67^{+0.01}_{-0.01}$	$20.68^{+0.01}_{-0.01}$	$20.84^{+0.01}_{-0.01}$	...	...	...	...	...
A1	...	...	...	$21.33^{+0.02}_{-0.02}$	$21.33^{+0.03}_{-0.03}$	...	$0.843^{+0.003}_{-0.003}$	$0.474^{+0.003}_{-0.003}$	0.482	0.508	101
A2	...	...	...	$21.53^{+0.02}_{-0.02}$	$21.54^{+0.03}_{-0.03}$	...	$0.809^{+0.003}_{-0.003}$	$0.540^{+0.003}_{-0.003}$	0.492	0.518	-97
B	$24.28^{+0.05}_{-0.05}$	$23.94^{+0.05}_{-0.05}$	$23.99^{+0.05}_{-0.05}$	$24.79^{+0.26}_{-0.18}$	$24.65^{+0.24}_{-0.20}$	$24.57^{+0.09}_{-0.07}$	$-0.49^{+0.01}_{-0.01}$	$-1.24^{+0.01}_{-0.01}$	0.332	0.346	3.1
G	$18.53^{+0.05}_{-0.05}$	$18.12^{+0.05}_{-0.05}$	$17.90^{+0.05}_{-0.05}$	$18.16^{+0.01}_{-0.01}$	$17.95^{+0.01}_{-0.01}$	$18.00^{+0.01}_{-0.01}$	$0.000^{+0.003}_{-0.003}$	$0.000^{+0.003}_{-0.003}$	...	...	...
A/B flux ratio	~35	~30	~30	48^{+13}_{-9}	39^{+6}_{-5}	32^{+3}_{-2}	68				

Note. Uncertainties are based on the 16th and 84th percentile intervals for NIRCImaging and we estimate 0.05 for NIRSpec based on agreement of the galaxy magnitude with NIRCImaging. The galaxy photometry is based on a $1''$ -radius aperture. We also present F200W image astrometry with a fiducial lens model (including convergence, κ , shear γ , and image magnification μ), for which a fourth image is also predicted, at $(-0''55, 0''82)$, with $\kappa = 0.632$, $\gamma = 0.606$, and $\mu = -4.3$. The F110W and F200W synthetic magnitudes are based only on the wavelength range overlapping with the NIRSpec Spectrum.

with both a blue (320—560 nm) and a red (520—1000 nm) channel. The SNIFS spectrum was taken in good conditions, with a seeing of $\approx 0''.8$, and had an exposure time of 1800 s. The data were reduced with the custom SCAT reduction pipeline, which incorporates wavelength-dependent tracing across each channel and aperture extraction from the reconstructed data cubes (see M. A. Tucker et al. 2022, for more details).

SN 2025mkn was later observed with the Low Resolution Imaging Spectrometer (LRIS) on the 10m-class telescope Keck I on the nights of 2025 June 24, July 25, and 28, with a $1''$ wide slit using the B400/3400 grism and R400/8500 grating at a parallactic angle. Two exposures of 600 s were taken, and spectra were reduced and extracted using LPipe (D. A. Perley 2019).

2.3. JWST NIRCImaging

JWST/NIRCImaging (program 3468, A. Goobar et al. 2023b) was taken in simultaneous short- (SW) and long-wavelength (LW) mode on module B with the FULL subarray, using RAPID readout (two groups per integration; one integration per exposure); the SW channel used F150W and F200W, each paired with F277W in LW. We applied an intramodule SMALL-GRID-DITHER (four dithers with sub-pixel steps), obtaining four integrations of 21.5 s each, for a total of 86 s in each of the SW filters, and 172 s in the LW filter. We note that the pixel scales for the SW and LW images are 0.0312 and 0.0629 pix^{-1} , respectively. The standard pipeline data showed clear $1/f$ (flicker) noise (H. Bushouse et al. 2023), evident as horizontal banding in the SW images, so the pipeline was rerun with `clean_flicker_noise` turned on in stage 1, and the `skymatch` process in stage 3 (B. J. Rauscher 2024). The data for the system are shown in each filter in the top row of Figure 1.

2.3.1. Light Modeling

As previously mentioned, the F277W data show the bright transient, A, as well as a fainter point source, B, south east of the lens, which we postulate as another image of the source. We also note that A is elongated in the tangential direction, and appears to be consistent with two point spread functions (PSFs) in the F150W and F200W data. We therefore consider these two images—A1 and A2, as labeled in Figure 1—for the purposes of fitting. To determine galaxy profile parameters and

point-source positions, we fit three point sources and two concentric Sérsic profiles, convolved by the same point-source model. We use the STPSF DET_DIST extension as our PSF model (M. D. Perrin et al. 2014); although this product is formally intended to match detector-coordinate images (e.g., individual rate exposures), we use it here as an approximation for the drizzled PSF. Given the low signal-to-noise of our data, we expect this PSF estimate to be robust for our current analysis. The galaxy- and A-subtracted residuals (after Gaussian smoothing with widths of 2, 2, and 1 pixels respectively) are shown in the bottom row of Figure 1.

While image B is immediately obvious in the F277W data and the NIRSpec white light image, it is also detected at 5.1σ and 5.3σ significance in the F150W and F200W data respectively, even when allowing its position to vary. We report the photometry and astrometry with their 16th and 84th percentile intervals in Table 1. We also note the presence of an arc-like structure in the south west of the system only seen in the F277W filter of the imaging data, which we postulate to be the lensed host galaxy of the source supernova.

2.4. JWST NIRSPEC IFU

Through program 3468 (A. Goobar et al. 2023b), JWST/NIRSpec integral-field spectroscopy was obtained using the G140M grating with the F100LP filter in Integral Field Unit (IFU) mode, providing observer-frame spectral coverage from $\lambda \simeq 0.97$ to $1.89 \mu\text{m}$ ($R \sim 1000$). The data were taken in the NRS_FULL_IFU aperture as part of a 4-POINT-DITHER pattern (a box of $\sim 0''.4$ on a side), in NRSRAPID readout with $N_{\text{INT}} = 7$ integrations and $N_{\text{GROUP}} = 12$ groups per integration, resulting in an effective exposure time of $t_{\text{exp}} = 3600$ s. The data were reduced with the standard JWST NIRSpec pipeline (H. Bushouse et al. 2023), and the spatial pixel scale is 0.10 spaxel^{-1} .

In many slices, artefacts with diamond-shaped patterns were present—with the same shape as the dither pattern—and were masked by hand. For each slice of the combined product with north up, background striping oriented along one axis of the instrument frame is seen. Therefore, in the following modeling process, we fit a varying background perpendicular to this direction, such that at each pixel step along this perpendicular direction, a degree of freedom for a constant background is allowed.

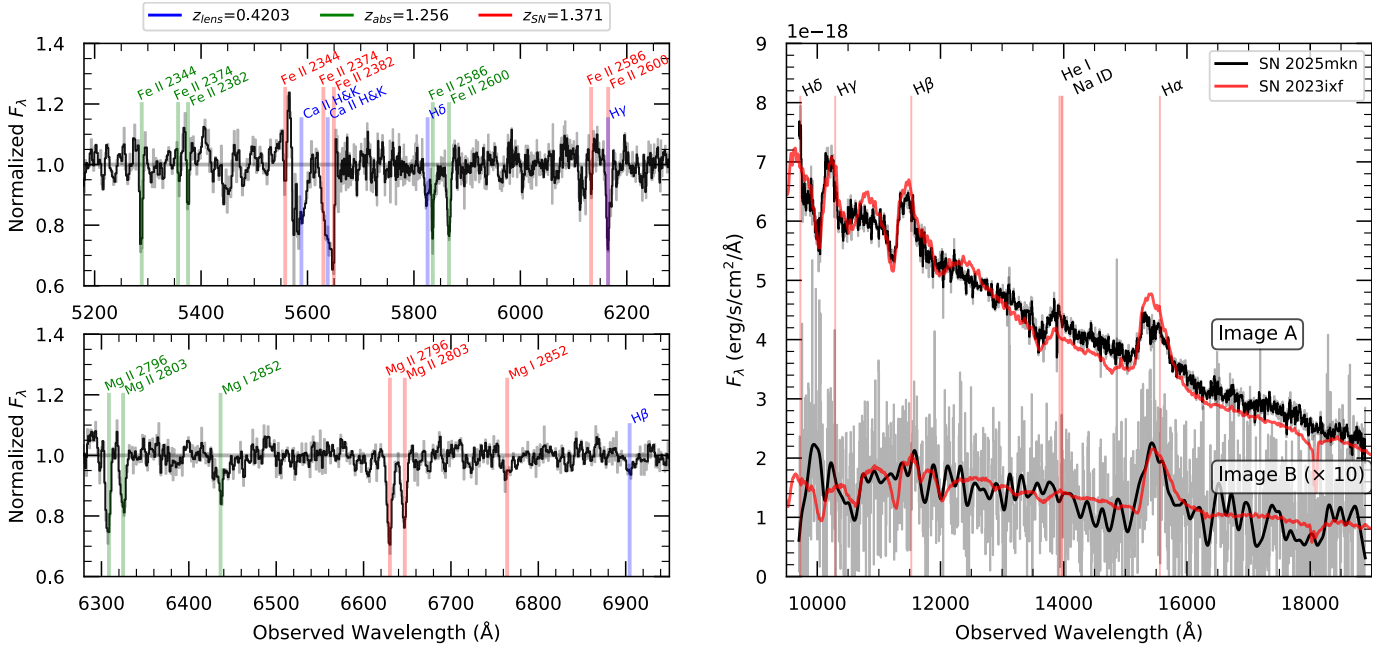


Figure 3. Left panel: selection of narrow absorption features seen in the LRIS spectrum of SN 2025mkn (here showing the continuum normalized Keck/LRIS spectrum from 2025 June 24). The spectrum shows absorption features from the lens galaxy at $z = 0.420$ (blue lines), as well as from systems at $z = 1.256$ (green) and $z = 1.371$ (red lines). Right panel: JWST/NIRSpec spectra of SN 2025mkn Images A and B (black lines). The red lines show SN 2023ixf, redshifted to $z = 1.371$ and scaled to match SN 2025mkn.

In the white light image of the cube (see Figure 1), image B is clearly detected. Image A is unresolved in the NIRSpec image so we extract it with a single PSF, and include another PSF for image B—as well as a Sérsic profile convolved by that same PSF for the lensing galaxy. The PSF is generated using the STPSF package (M. D. Perrin et al. 2014). We use the relative positions as measured from the NIRCAM imaging, only fitting for the galaxy position, so our model at each slice contains two positional degrees of freedom, five for the Sérsic profile, and ~ 40 for the varying background. The signal of image B is below the noise in most slices, so we repeat the fit by stacking slices in bins of 10 to extract our final spectrum of B. The 2D stacked data (white light) and residuals are shown in Figure 1, and we note the presence of the arc, which is also seen in the F277W NIRCcam data, as well as a possible extra source, which we label as C. The 1D spectrum of A is shown in Figure 2, and the spectra of A and B are compared in more detailed in Figure 3.

The spectrum of B shows a peak at the wavelength of $H\alpha$ expected at $z \sim 1.37$, which now firmly establishes its nature as another image of the source. We therefore also expect that it is fading between the NIRSpec and NIRCcam observations (which are separated by 28 days), so we perform synthetic photometry on the NIRSpec 1D spectra of both A and B and present the values in Table 1. We note that the extraction is reliable as we recover the same value for the F150W magnitude of the lensing galaxy in a $1''.0$ circular aperture within 0.05 mag. We take this error as an estimated systematic error on our synthetic photometry. We indeed do see that images A and B fade between the observations, and we discuss this further in Section 4.

2.5. VLA Observations

We obtained VLA data of SN 2025mkn under Director’s Discretionary Time program VLA/25B-366 (PI: A.Y.Q. Ho). The observation started at 2025 September 2 23:29 UT and lasted

2.5 hr at midfrequencies of 10 GHz (X-band, 4 GHz bandwidth) and 15 GHz (Ku-band, 6 GHz bandwidth). We calibrated the data using the automated pipeline in Common Astronomy Software Applications package version 6.5.4–9 (CASA; CASA Team et al. 2022) and imaged using standard techniques. We use the pwkit/imtool program (P. K. G. Williams et al. 2017) to measure the flux density and image rms. The foreground lensing galaxy is radio bright, and has a 10 GHz flux density of $205 \pm 60 \mu\text{Jy}$ and a 15 GHz flux density of $128 \pm 30 \mu\text{Jy}$. There is no apparent emission at the location of the SN 2025mkn images, and the rms is measured at $\lesssim 4 \mu\text{Jy}$ at 10 GHz and $\lesssim 5 \mu\text{Jy}$ at 15 GHz.

3. Analysis

3.1. Spectra and Lightcurves

The early SNIFS spectrum exhibits a steep blue continuum with an inferred blackbody temperature of $\sim 27,000$ K and an absence of obvious broad supernova features.

Superimposed on the two first spectra are multiple narrow absorption lines. As shown in the left panel of Figure 3, we identify prominent Fe II lines and the Mg II $\lambda\lambda 2796, 2803$ doublet at two distinct redshifts, $z_1 = 1.256 \pm 0.001$ and $z_2 = 1.371 \pm 0.001$. Additional absorption features at $z_{\text{lens}} = 0.420$ correspond to the foreground lensing galaxy.

The higher redshift $z_2 = 1.371$ is adopted as the SN redshift, based on the broad hydrogen features in the JWST/NIRSpec spectrum of image A. At a rest-frame phase of +22.5 days, the spectrum displays broad $H\alpha$, $H\beta$, and $H\delta$ emission features, unambiguously identifying SN 2025mkn as a Type II supernova. The NIRSpec spectrum of image B likewise exhibits broad $H\alpha$ emission at the same redshift, firmly establishing it as a second lensed image of the same explosion. The presence of fading between the NIRSpec and NIRCcam epochs further confirms the transient nature of image B.

The photometric evolution of image A is shown in Figure 2, combining ground-based optical and near-infrared data with resolved JWST photometry. The lightcurves exhibit a close resemblance in shape to those of Type II supernovae, the nearby IIP/IIIL SN 2023ixf in particular (E. A. Zimmerman et al. 2024), when compared in matched rest-frame filters. Motivated by this striking similarity, we use SN 2023ixf as a local analog to estimate the magnification of SN 2025mkn.

Under the assumption that SN 2025mkn follows the intrinsic luminosity evolution of SN 2023ixf, the observed peak brightness of image A implies a magnification of $\Delta m_A \sim 6$ mag, corresponding to $\mu_A \sim 250$. Independent estimates from spectral scaling yield consistent results: matching the flux-calibrated spectra of images A and B to SN 2023ixf at similar phases implies magnifications of $\mu_A \sim 250$ and $\mu_B \sim 15$, respectively. It should be noted that SNe II show significant peak-brightness scatter ($\sigma \sim 1$ mag), limiting the precision of magnification estimates based on their luminosity. Hence, next we estimate the magnification independent of the assumption that SN 2023ixf and SN 2025mkn are exact analogs in Section 3.3 through lens modeling.

The spectral comparison further reveals that image B appears at a later phase than image A, consistent with a significant time delay between the two images. Although the leading image was not detected in archival ZTF data (see inset dashed lines in Figure 2), the relative spectral phases provide an independent handle on the time delay, an approach that will be explored in detail in a forthcoming companion paper (J. Johansson et al. 2026, in preparation).

3.2. Lens Galaxy

Estimating the total mass and properties of the lensing galaxy is an important step in prioritizing follow-up of lensed supernova candidates. In particular, the mass of the lensing galaxy provides an estimate of the image separation of potential multiple images.

We derive the stellar mass of the system using Pan-STARRS *grizy* (K. C. Chambers et al. 2016; H. A. Flewelling et al. 2020; E. A. Magnier et al. 2020), 2MASS *JHK_s* (M. F. Skrutskie et al. 2006), and WISE W1–W4 (E. L. Wright et al. 2010) photometry, taken from *blast* (D. O. Jones et al. 2024). The measured fluxes before extinction correction are $(11.57 \pm 0.71, 48.56 \pm 1.01, 83.84 \pm 1.03, 115.61 \pm 2.51, 133.13 \pm 5.32, 191.52 \pm 86.72, 487.82 \pm 131.79, 477.98 \pm 152.5, 263.7 \pm 11.76, 184.48 \pm 13.24, 31.84 \pm 29.59, -103.5 \pm 258.64)$ μ Jy in (*g*, *r*, *i*, *z*, *y*, *J*, *H*, *K_s*, W1, W2, W3, W4). We apply a Milky Way reddening correction using the K. D. Gordon et al. (2023) UV–mid-infrared extinction law, with $E(B - V) = 0.012$ mag from the E. F. Schlafly & D. P. Finkbeiner (2011) dust map, with $R_V = 3.1$. We perform a Bayesian spectral energy distribution (SED) fit using the *prospector* modeling framework (B. D. Johnson et al. 2021) with a stellar population synthesis (SPS) model based on the Flexible Stellar Population Synthesis code (FSPS; C. Conroy et al. 2009, 2010; C. Conroy & J. E. Gunn 2010), and a parameterization based on *Prospector- α* (J. Leja et al. 2017, 2019b). We use a G. Chabrier (2003) stellar initial mass function, and a seven-bin star formation history with bins logarithmically spaced in lookback time (J. Leja et al. 2019a, 2019b). Nebular emission is included based on the *cloudy* (G. J. Ferland et al. 2013) model grid from N. Byler et al. (2017). We carry out posterior sampling using the *dynesty* (J. S. Speagle 2020) nested sampler, with a sampling

strategy based on J. Skilling (2004, 2006), F. Feroz et al. (2009), and E. Higson et al. (2019). We estimate a lens mass of $\log_{10}(M/M_\odot) \approx 11.4 \pm 0.1$, which provides an estimated Einstein radius of $(1.04 \pm 0.12)''$ (ignoring aperture corrections and the presence of dark matter).

We can independently determine the Einstein radius using the velocity dispersion from the DESI spectrum: 281 ± 50 km s^{−1}. Given the redshifts of the lens and source, and under the assumption of an isothermal mass profile, we constrain $\theta_E = (1.38 \pm 0.45)''$, in agreement with the estimate from the stellar mass estimate.

Multiple images in strongly lensed systems are typically separated by twice the Einstein radius—therefore, at least $2''$ in the case of SN 2025mkn. Given that image A lies only $\sim 0.8''$ from the galaxy, another more distant image is expected opposite the lens. Coupled with the magnification argument from the source intrinsic magnitude, our Einstein radius estimate convincingly demonstrated a case of strong lensing, which was borne out by the discovery of image B in the JWST datasets.

3.3. Lens Model

Before we discuss the nature of the system based on the above analysis, we will provide a lens model based on the astrometry of the SW NIRC*am* imaging.

As previously discussed, image B is a counterimage of the supernova due to the Einstein radius estimates, spectroscopic redshift from NIRS*pec*, and its transient nature (fading between datasets). We also take A1 and A2 to be separate images of the transient since they are each consistent with point sources, and have the same F200W–F150W color based on the resolved JWST NIRC*am* imaging.

To elucidate the nature of the system, we fit a simple lens model of a singular isothermal ellipsoid with external shear to recover these three images using *lenstronomy* (S. Birrer & A. Amara 2018; S. Birrer et al. 2021), but do not place any constraints on the required flux ratios. We only have 6° of freedom (from three image positions), so we fix the lens mass to that measured from the light, i.e., the centroid and flattening parameters—150° north of east with an axis ratio of 0.634—and only fit for five parameters: the Einstein radius, external shear strength and position angle, and a source position.

We show our best-fit lensing model in Figure 4, demonstrating the recovery of the image positions and large magnifications of images A1 and A2. The reduced χ^2 is 2.1. We note that in all models a fourth image is predicted, which we label C, and note that the time delays are similar to those of images A1 and A2, and thus should be closer to peak than image B. Even ignoring this phase, the lens model predicts it to be brighter than image B; however, it is not seen in any of the imaging data. Its predicted position is compatible with a potential detection in the NIRS*pec* white light residuals (see Figure 1), as described in Section 2.4. Values for the convergence, shear, and magnifications are provided in Table 1. The total magnification of our best-fit model is ~ 200 , and the predicted flux ratio of A (A1+A2) to B is ~ 65 . While this is at odds with the observed upper limit of 30 from the NIRS*pec* flux ratio, we find that much lower total magnifications are possible when the lens mass is allowed to deviate from the light. We discuss alternative explanations for this in Section 4, while keeping the lens mass and light aligned.

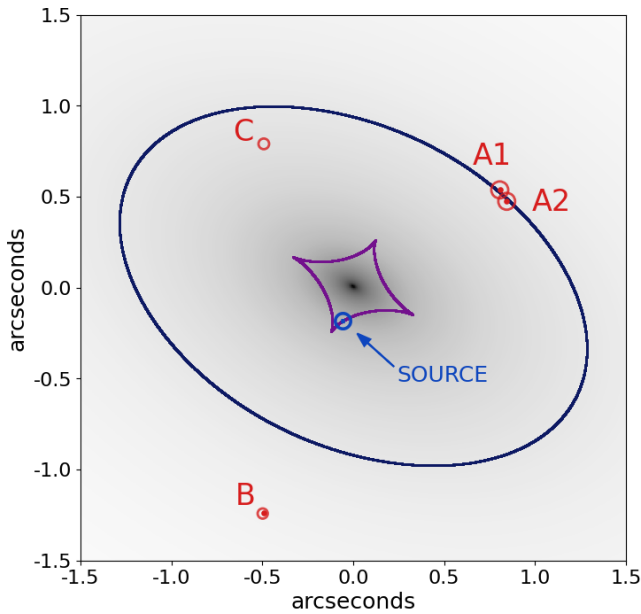


Figure 4. Best-fit elliptical power law with external shear mass model for SN 2025mkn, with predicted image positions as open red circles. The model recovers the observed positions (red dots) of A1, A2, and B, but also predicts a fourth image, C. The source lies close to the astroid caustic (purple), and the high-magnification images of A straddle the critical curve (dark blue).

The model Einstein radius is $\sim 1''.12$, and the external shear strength is 0.03 at 128° north of east. This small external shear gives confidence to our assumption that the lens mass follows the light. While our model predicts a time delay of weeks between images A and B, we do not report an exact value here for the sake of blinding any potential time-delay measurements from spectral phase matching of the spectra of images A and B. However, we do note that the predicted time delay between images A1 and A2 is approximately 1 minute—not measurable.

More detailed lens models, which include the information in the lensed host galaxy arc, will be presented in an upcoming paper alongside the spectral time-delay measurements.

4. Discussion

The magnification estimate of $\times 250$, based on the assumption of a SN 2023ixf analog, is in agreement with the light-mass-aligned lens models, which can predict total magnifications up to 300. However, there are two problems when confronting the lens model to the data: (i) image C is predicted to be brighter than B but is not seen in the imaging data (an upper limit from the F277W data for C is around 0.25 times the brightness of B, or 1.5 magnitudes fainter); and (ii) the flux ratio of A (A1+A2 combined) to B is measured to be around 25 accounting for the time delay, but predicted to be ~ 65 from the lens model. These discrepancies can be explained by a different lens model in which the lens mass is allowed to deviate from the light. Such models (while underconstrained with just the three image positions) can reproduce the observed A to B ratio of 25–30, though C is still expected at a similar brightness to B.

We can resolve flux ratio problems in either case by invoking microlensing of a combination of images B and C. Images A1 and A2 are unlikely to be significantly affected by microlensing due to their similar flux ratio—as predicted by

the model. From the NIRSpec white light image we estimate that the brightness of the potential detection of image C is around 25% the brightness of B, consistent with the lack of detection in the NIRCам imaging. We therefore require the B/C brightness to be boosted by a factor of ~ 4 . While reducing the flux of image C can explain this, also boosting the flux of image B can help explain the A/B ratio in the mass-light-aligned models.

We generate microlensing maps given the best-fit κ - γ values from our model (J. Jiménez-Vicente & E. Mediavilla 2022), assuming a smooth matter fraction of 0.5 (typical for images of similar lenses) and stellar masses of $0.2 M_\odot$ (such that the Einstein radii match the photospheric scale of a type II supernova 40–50 days post-explosion). Image C is demagnified by 0.8 mag or more in 49% of cases (demagnification is common for saddle points; P. L. Schechter & J. Wambsganss 2002), while B is only magnified by 1 mag or more in 6% of cases. By drawing random realizations of the microlensing in images B and C, and comparing the relative probability of these cases to the most probable case, we find that requiring the above (de)magnifications is more probable than 20% of such realizations.

This shows that the observed flux ratios can be satisfactorily explained with microlensing, though the exact reliance on this requires a better-constrained mass model, which will be the focus of future investigations using the information of the extended host arc, and possibly by extracting a position constraint from image C.

5. Conclusions

We have presented the discovery of SN 2025mkn as a gravitationally lensed Type II supernova, with a magnification of $\times 100$ or larger, potentially reaching ~ 250 if interpreted as a near-perfect analog of SN 2023ixf. This system is unique not only as the most magnified supernova yet discovered, but as the first single galaxy lensed supernova with a time delay of weeks. These extreme magnification events are expected in magnitude-limited surveys, such as the previous galaxy-scale spectroscopic discoveries (A. Goobar et al. 2017, 2023a); however, in this case the flux ratio between images is extreme, and might not be expected in mock catalogs that require several, or leading, images to be brighter than a certain threshold (e.g., M. Oguri & P. J. Marshall 2010). The striking photometric and spectroscopic resemblance with SN 2023ixf, one of the best studied Type II supernovae in the local Universe, from the rest-frame far-UV to the near-IR, emphasizes the power of lensing magnification to constrain evolutionary effects in stellar explosions over 9 Gyrs. Such detailed comparisons for unlensed supernovae are at the limits of observing capabilities of existing telescopes, as demonstrated by the study of a lensed Type II supernova at $z = 5$ (D. A. Coulter et al. 2026). Triggering follow-up for such systems as soon as possible is key to maximizing their scientific use. Robust photometric or spectroscopic redshifts of early type galaxies, and estimates of Einstein radii from stellar mass estimates or velocity dispersions help to prioritize the limited spectroscopic follow-up.

One major difficulty of turning this system into a cosmographic probe is the leading image being too faint to obtain a resolved lightcurve. Despite only triggering follow-up long after it faded, spectroscopic phase retrieval offers a way to measure the time delay, especially in the case of an archival local analog with well-sampled UV spectra. In an upcoming

paper we will present detailed lens models including modeling of the extended arc, alongside time-delay measurements from the resolved JWST NIRSpec spectra, and any associated cosmological constraints.

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Data Availability

Some of the data presented in this Letter were obtained from the Mikulski Archive for Space Telescopes (MAST) at the Space Telescope Science Institute. The specific observations analyzed can be accessed via doi:[10.17909/bs3w-2z02](https://doi.org/10.17909/bs3w-2z02).

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