News on gravitationally lensed supernovae

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R. Marques-Chaves (Univ. of Geneva), R. Shirley (MPE),

Z. Delgado-González, and C. Jaén-Martín (ULL)

and

LensWatch, SGLF, Herschel SPIRE, HeRMES, H-ATLAS, Bells Gallery,

EP-IAC supernovae, ULL-ASTRO-MASTER, etc.

UNDARK kick-off meeting, IAC, 11 October 2024

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Overview

- Some applications of gravitational lensing in Astronomy
- Herschel lenses
- Bells Gallery: lensed Lyman Alpha Emitters
- Icarus
- Tiny Galaxy at z = 9.5
- SN Zwicky
- SNe Requiem and Encore
- Supernovae and Gravitational Lenses Follow up (SGLF)
- Plans for the Vera Rubin LSST
- Other related projects
- Transients and teaching of astronomical techniques

Applications of gravitational lensing in Astronomy

- Strong lensing: galaxy-galaxy, massive lensing clusters
- Weak lensing, e.g Euclid
- Caustic crossing events in galaxy clusters, e.g. Icarus, Earendel, …
- New application: gravitationally lensed SNe with multiple images
- etc

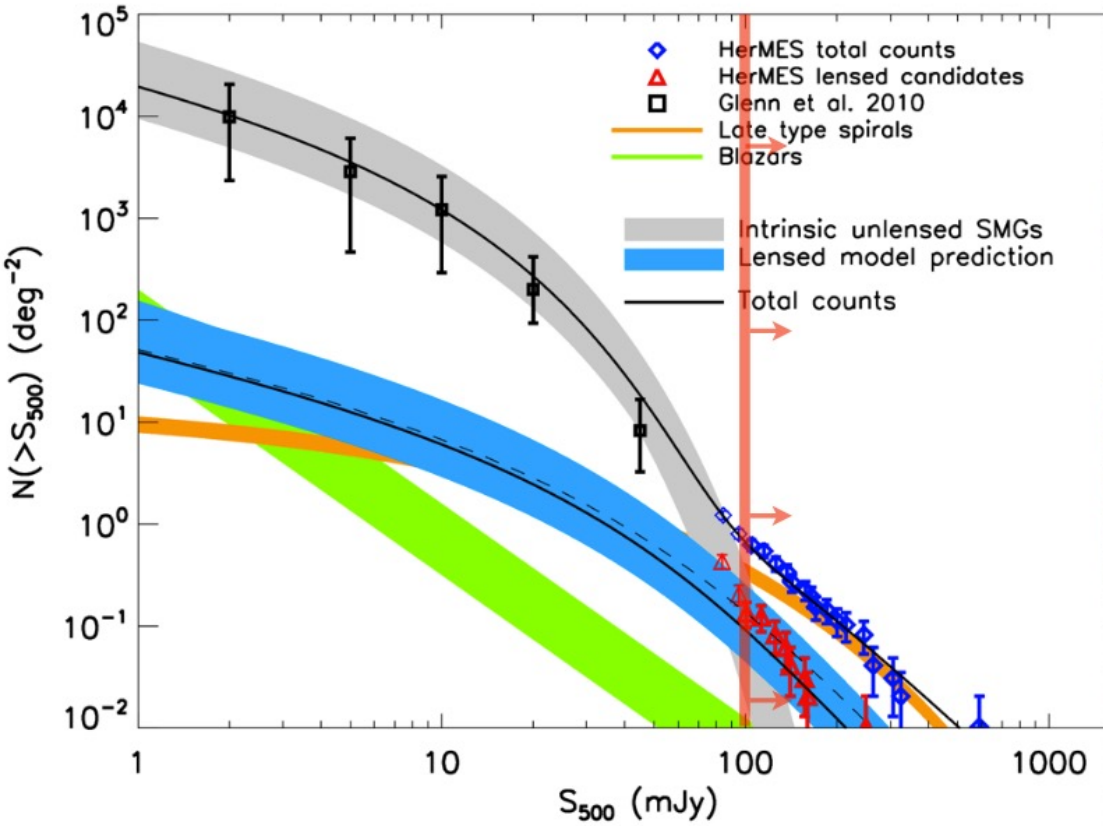
Herschel lenses

- Prediction: bright Herschel SPIRE galaxies are strongly lensed by foreground massive galaxies

- Confirmation in the many Herschel SPIRE surveys (e.g. HerMES and H-ATLAS) and high-resolution follow up with SMA, NOEMA, and ALMA

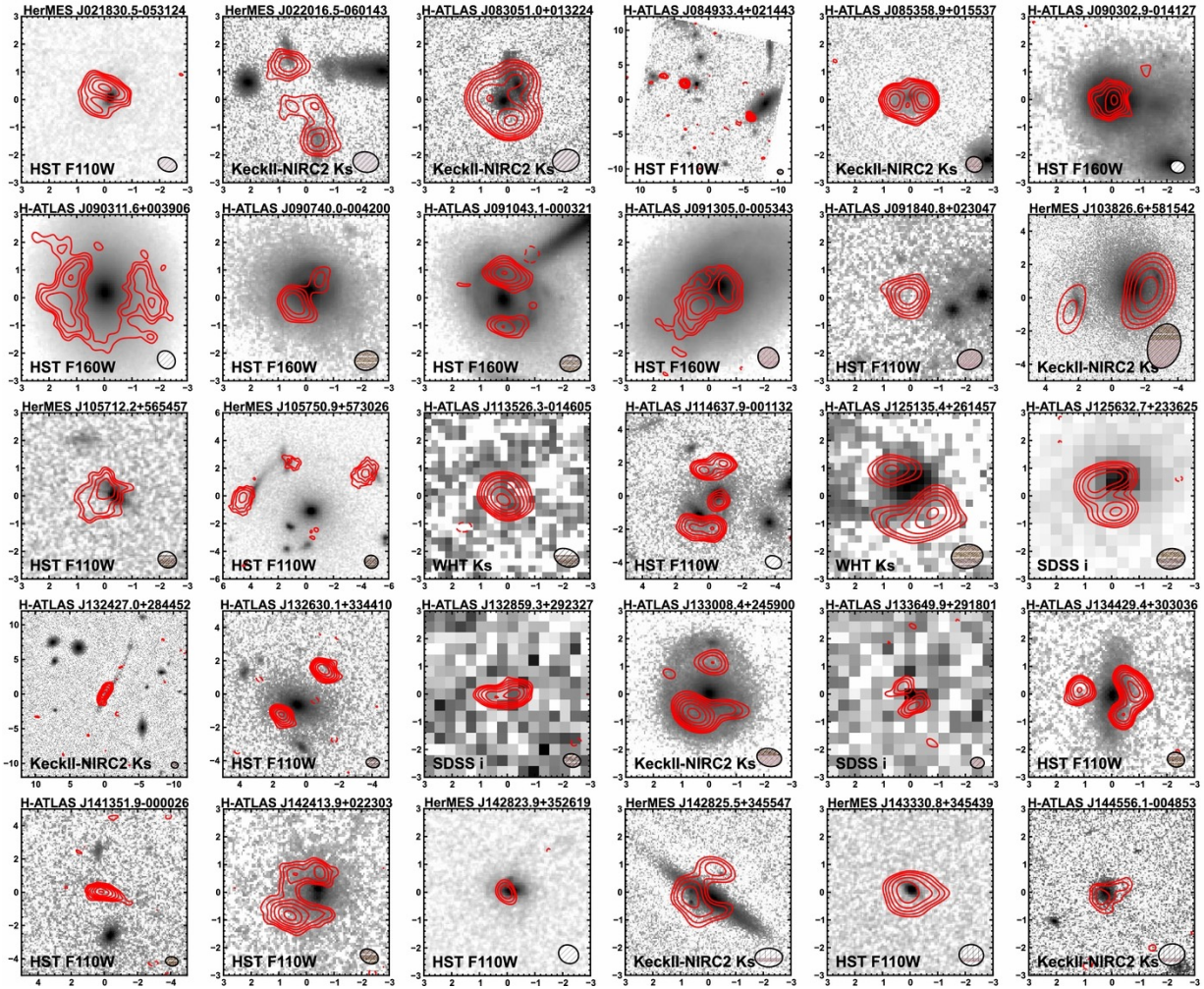
HerMES lens candidates

S_{500}>100mJy & no blazars or local spirals



Candidates: ~0.15 deg^{-2}

Wardlow et al. 2013



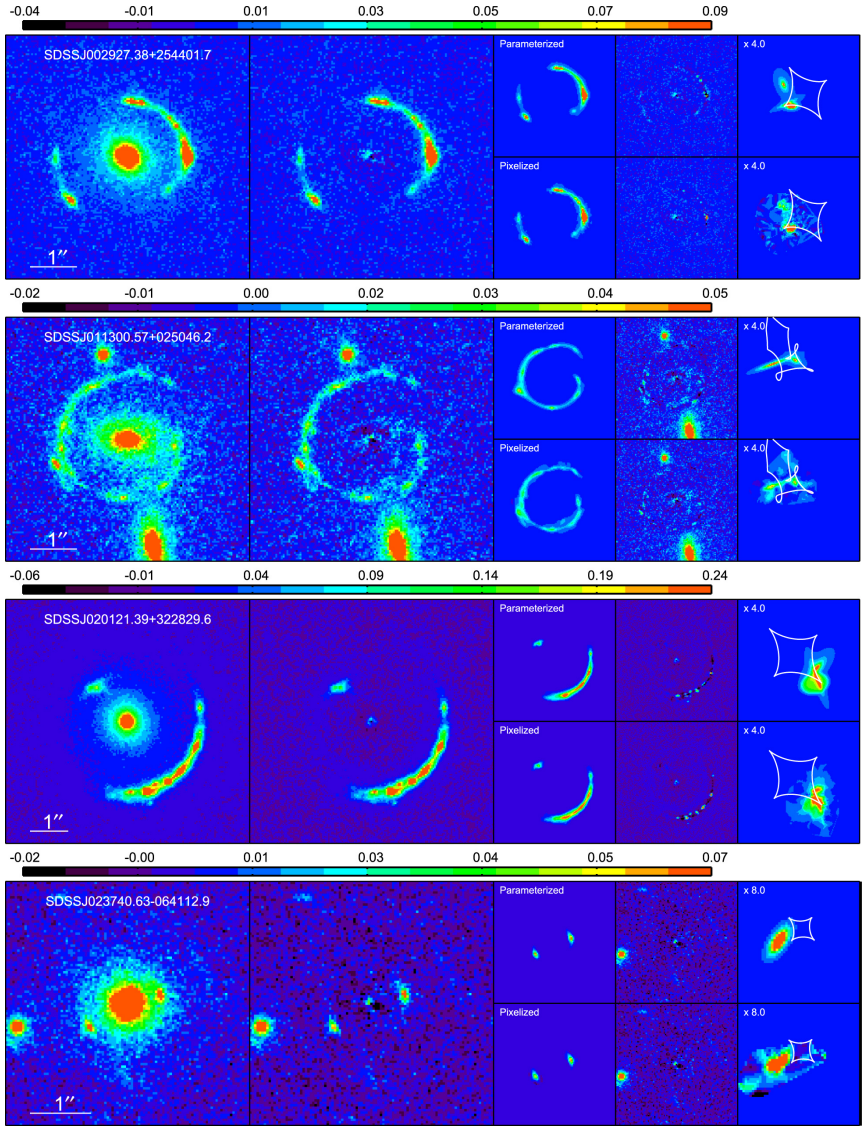
Gravitational lens models of Herschel galaxies at z > 1.5

Bussmann, IPF et al. 2013

Bells Gallery: lensed Lyman Alpha Emitters

Shu et al., Marques-Chaves et al., Cornachione et al.

- z = 2-3 Lyman Alpha Emitting galaxies gravitationally lensed by luminous red galaxies (LRG)
- Discovered in SDSS spectroscopy of LRGs
- Follow-up with HST
- Spectroscopy with GTC
- High-resolution imaging of LAEs thanks to HST+lensing

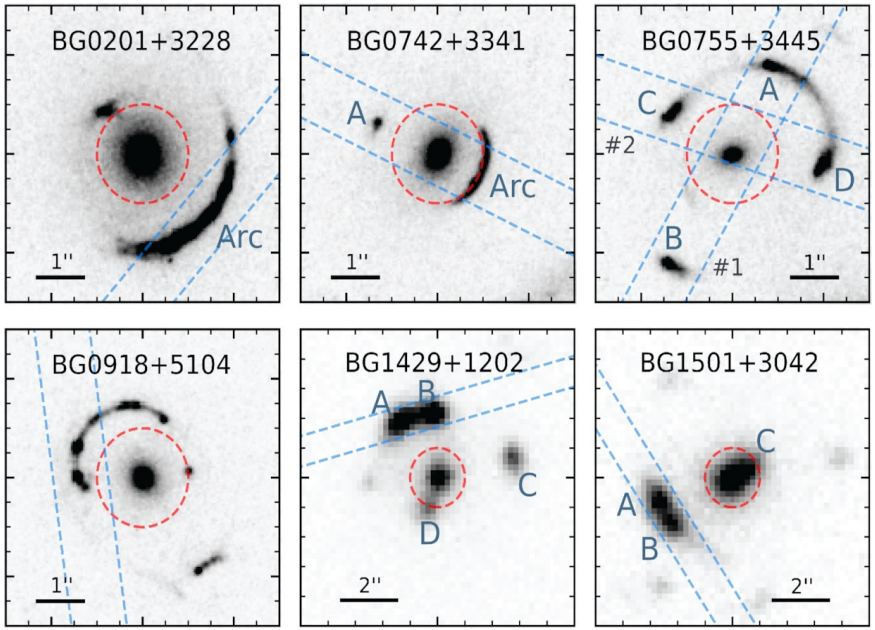


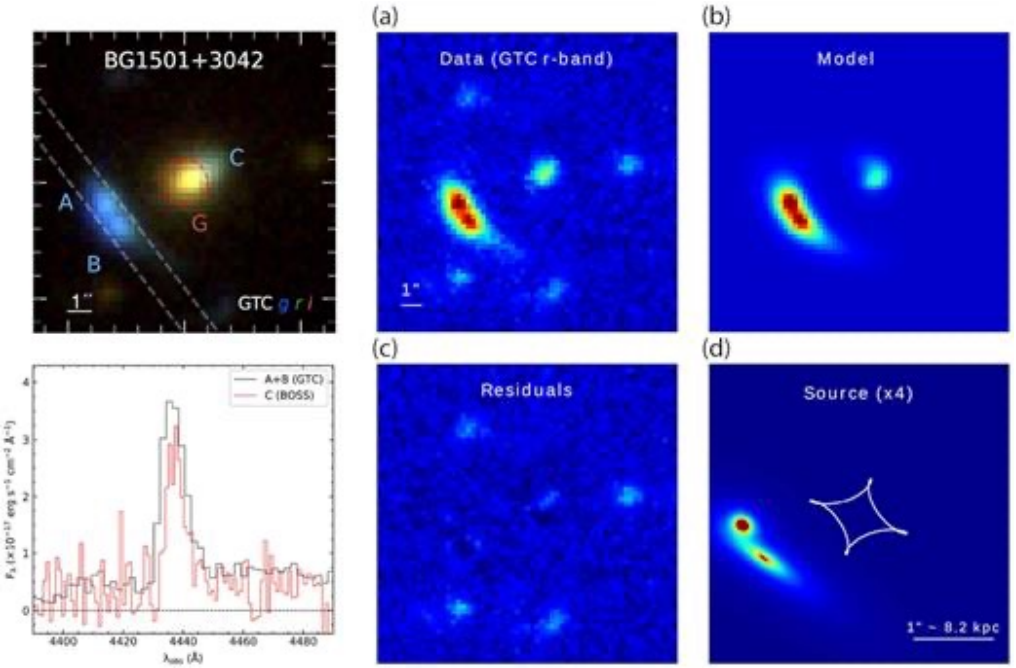
Examples of smooth lens models for the BELLS GALLERY grade-A lenses. The observational data, foreground-subtracted image, predicted lensed image, final residual, and the background source model are shown from left to right, respectively. For each system, the results of the two source models are split into two rows with the parameterized source model on the top and the pixelized source model on the bottom. The white lines in the last panels are the caustics of the lens model. All the images are orientated such that north is up and east is to the left. The source plane panels are magnified by factors of four or eight relative to the image plane panel as indicated in each panel. The color bars indicate the intensity levels in units of electrons per second per pixel^2.

Shu et al. 2016

Rest-frame UV properties of luminous strong gravitationally lensed Lyα emitters from the BELLS GALLERY Survey

Marques-Chaves, IPF et al. 2019





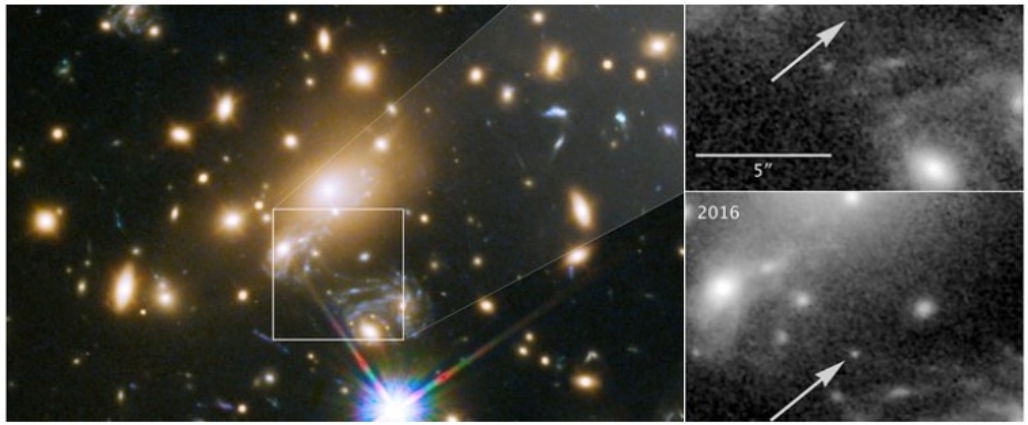
Icarus, the first distant (z = 1.5) star, Kelly et al. 2018

heic1807 — Science Release

Kids

Hubble uses cosmic lens to discover most distant star ever observed

2 April 2018

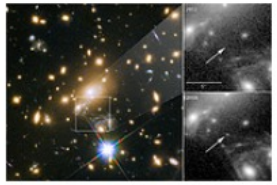


Astronomers using the NASA/ESA Hubble Space Telescope have found the most distant star ever discovered. The hot blue star existed only 4.4 billion years after the Big Bang. This discovery provides new insight into the formation and evolution of stars in the early Universe, the constituents of galaxy clusters and also on the nature of dark matter.

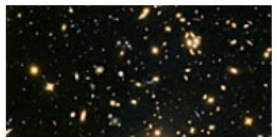
About the Release

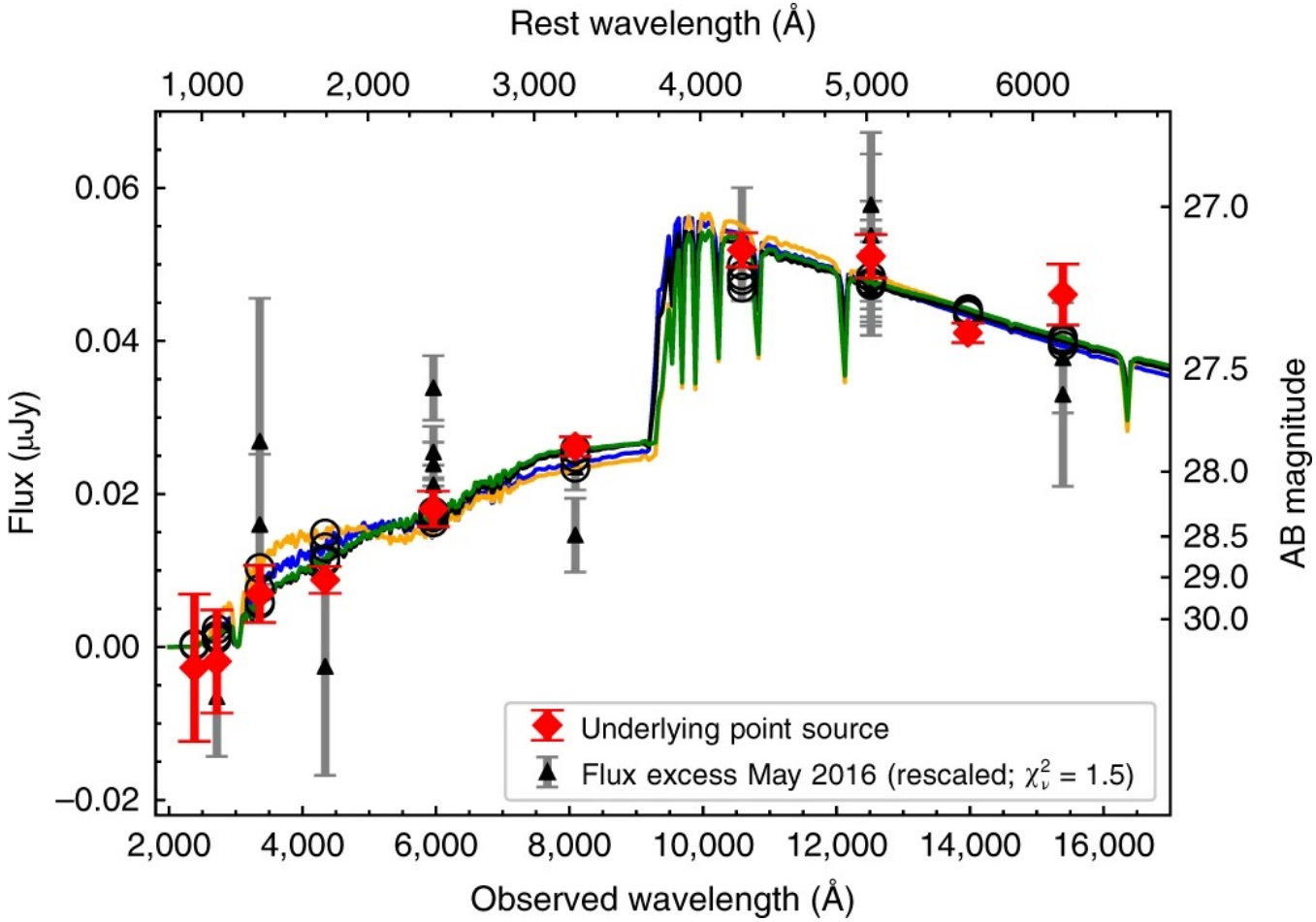
Release No.:	heic1807
Type:	Early Universe : Star : Spectral Type : B
Facility:	Hubble Space Telescope
Instruments:	WFC3

Images



PR Image heic1807a
Appearance of the most distant star





SED of Icarus

Kelly et al. 2018
Nature Astronomy

Extreme magnification of an individual star at redshift 1.5 by a galaxy-cluster lens

RESEARCH ARTICLE | GALAXIES

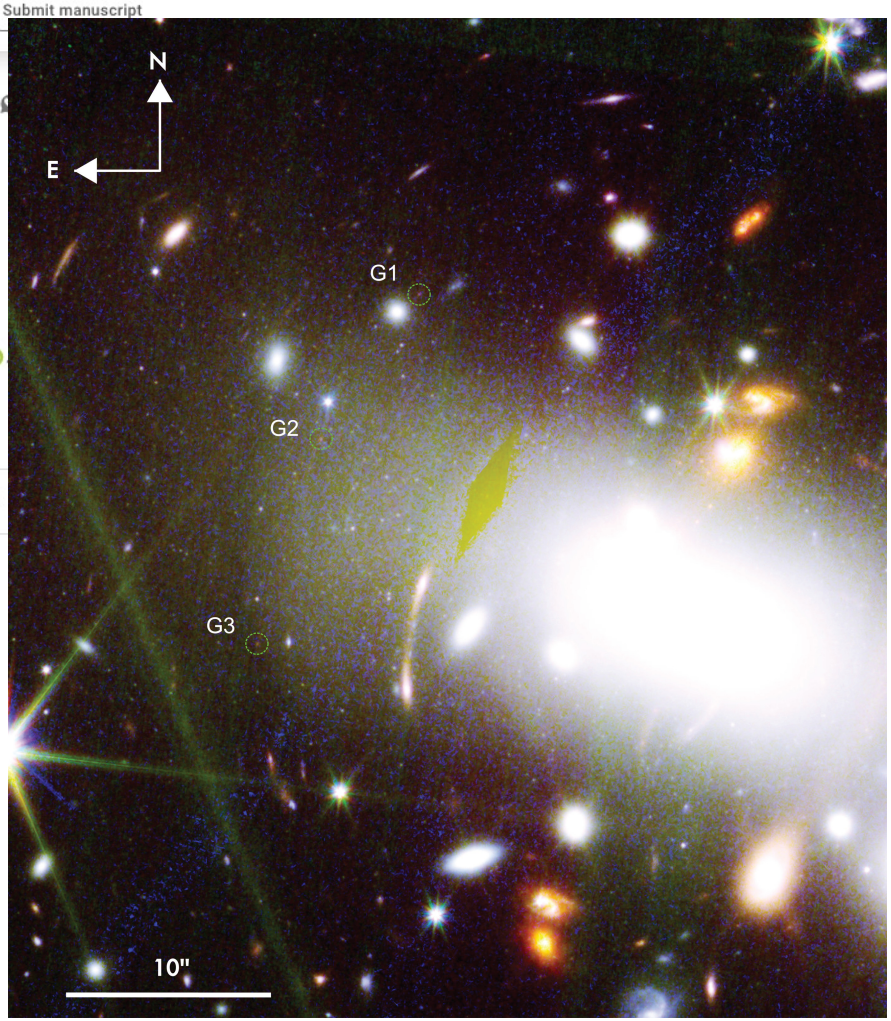
A magnified compact galaxy at redshift 9.51 with strong nebular emission lines

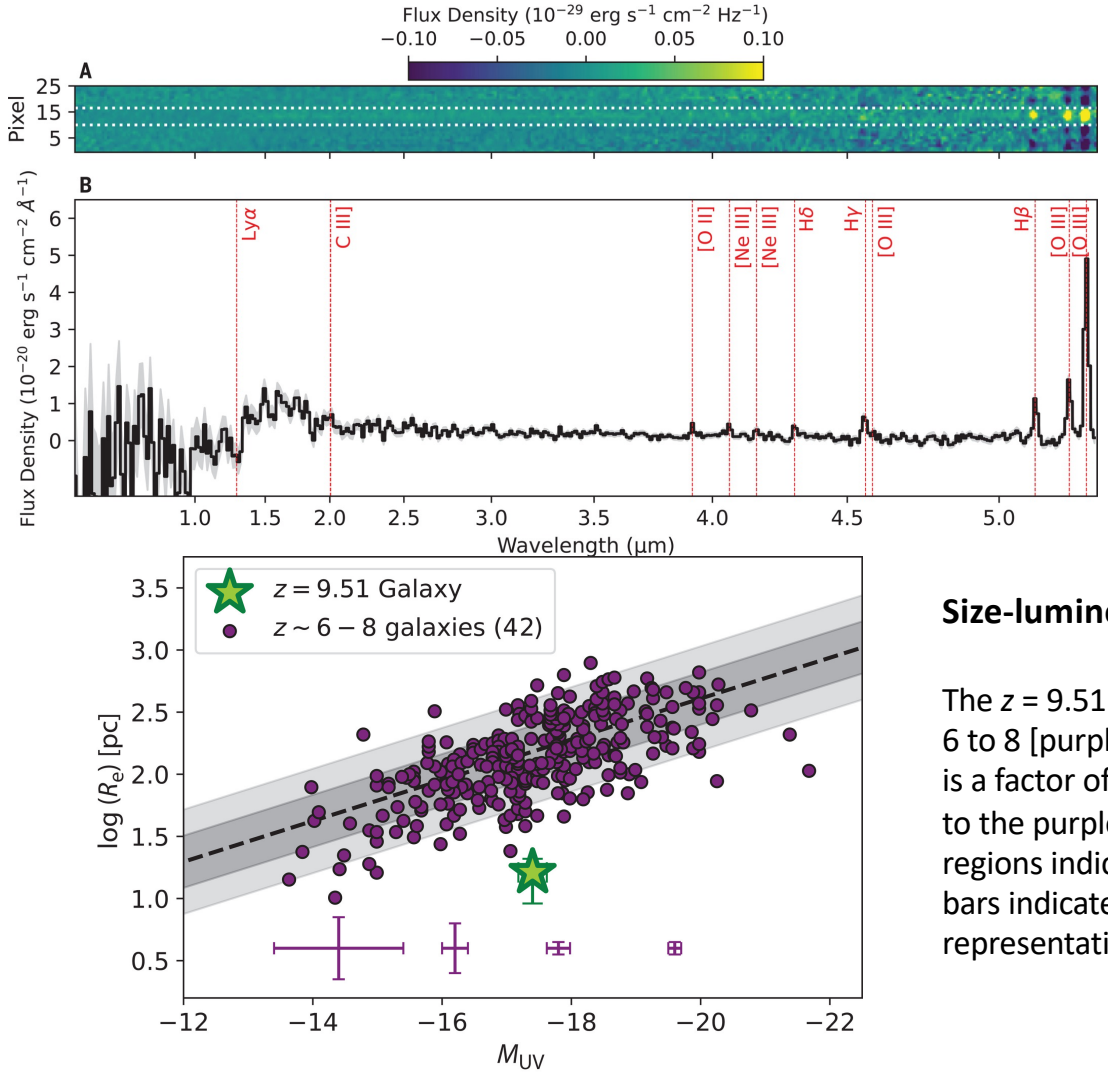
HAYLEY WILLIAMS, PATRICK L. KELLY, WENLEI CHEN, GABRIEL BRAMMER, ADI ZITRIN, TOMMASO TREU, CLAUDIA SCARLATA, ANTON M. KOEKEMOER, MASAMUNE OGURI, YU-HENG LIN, JOSE M. DIEGO, MARIO NONINO, JENS HJORTH, DANIAL LANGEROODI, TOM BROADHURST, NOAH ROGERS, ISMAEL PEREZ-FOURNON, RYAN J. FOLEY, SAURABH JHA, ALEXEI V. FILIPPENKO, LOU STROLGER, JUSTIN PIEREL, FREDERICK POIDEVIN, AND LILAN YANG fewer Authors Info & Affiliations

SCIENCE • 13 Apr 2023 • Vol 380, Issue 6643 • pp. 416-420 • DOI: 10.1126/science.adf5307

Editor's summary

The expansion of the Universe causes the light from distant galaxies to be redshifted to longer wavelengths. Candidate distant galaxies can be identified using imaging, but confirming their redshift requires spectroscopy. Williams *et al*. used near-infrared imaging and spectroscopy to identify a galaxy at redshift 9.5, corresponding to about 500 million years after the Big Bang. Little is known about galaxies at that early time. Emission lines in the spectrum allowed the authors to determine some of the galaxy's physical properties, such as its abundance of elements heavier than helium, and they found that it is very compact and has a high density of star formation. —Keith T. Smith





Williams et al. 2023, Science

A magnified compact galaxy at redshift 9.51 with strong nebular emission lines

JWST spectrum

Size-luminosity relation.

The z = 9.51 galaxy (green star) compared with galaxies at redshifts 6 to 8 [purple circles]. The half-light radius of the z = 9.51 galaxy is a factor of (3.5σ) smaller than the size-luminosity relation fitted to the purple points (dashed line, with dark and light gray shaded regions indicating its 1σ and 2σ uncertainty ranges). The purple error bars indicate the typical 1σ uncertainties for the z = 6 to 8 galaxies at representative values of M_{UV}.

Some ongoing projects on astrophysical transients that are being carried out at the IAC

- Superluminous supernovae (Fred Poidevin´s talk on Tuesday)
- Gravitationally lensed supernovae (LensWatch and SGLF)
- Discovery and classification of supernovae using the LSST/ZTF brokers (SGLF)
- Fast X-ray transients (from Einstein Probe) and GRBs
- Core-collapse supernovae in nearby galaxies
- Teaching astrophysical techniques and multiwavelength astronomy with transients

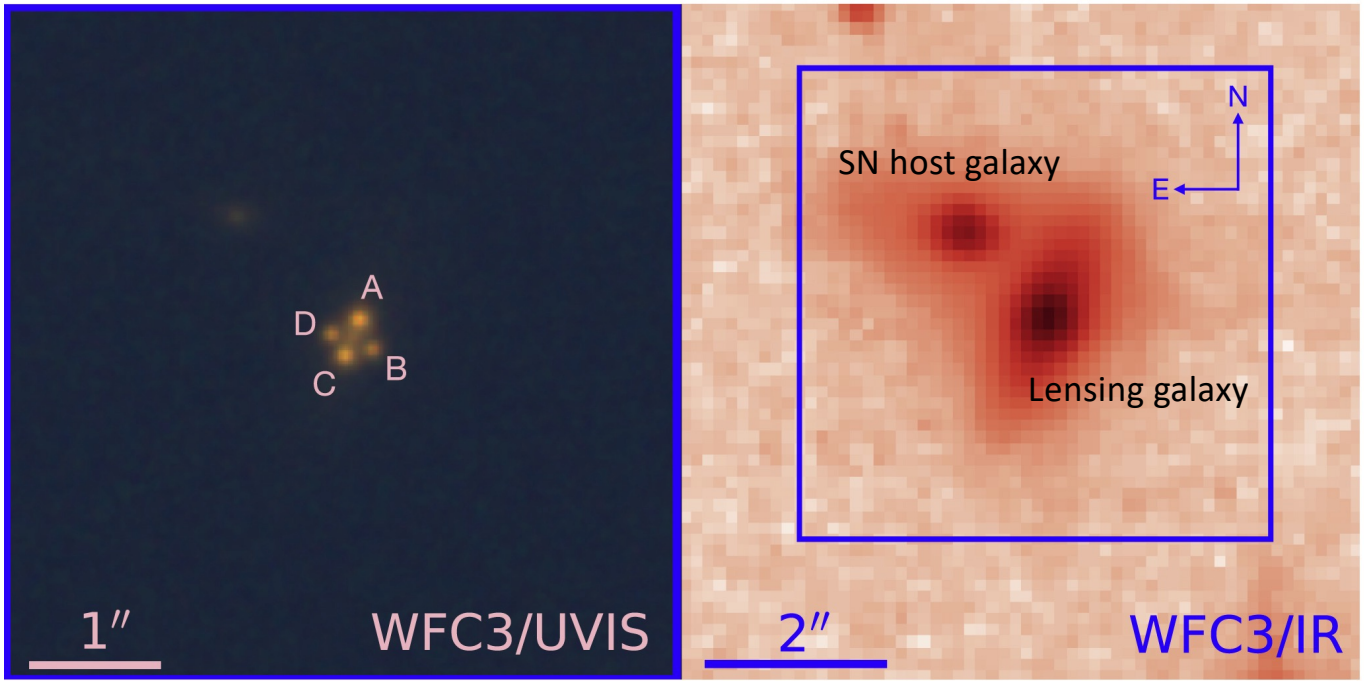
Gravitationally lensed supernovae with multiple images

- Pre-LSST monitoring programs of known lenses (Craig+ 2024, Jiménez Ángel PhD 2023)
- Search for gravitationally lensed supernova with multiple images in time-domain surveys (Zwicky Transient Facility) and HST & JWST observations of massive lensing clusters

    Galaxy-galaxy lenses: SN Zwicky

    Cluster lenses: SN H0pe, SN Encore, …

SN Zwicky (SN 2022qmx, ZTF22aaylnhq)



ZTF-discovered transient

Goobar+ 2023
Pierel+ 2024
Larison+ 2024 submitted

z (lens) = 0.2
z (SN and host galaxy = 0.4)

Small time delays (days)

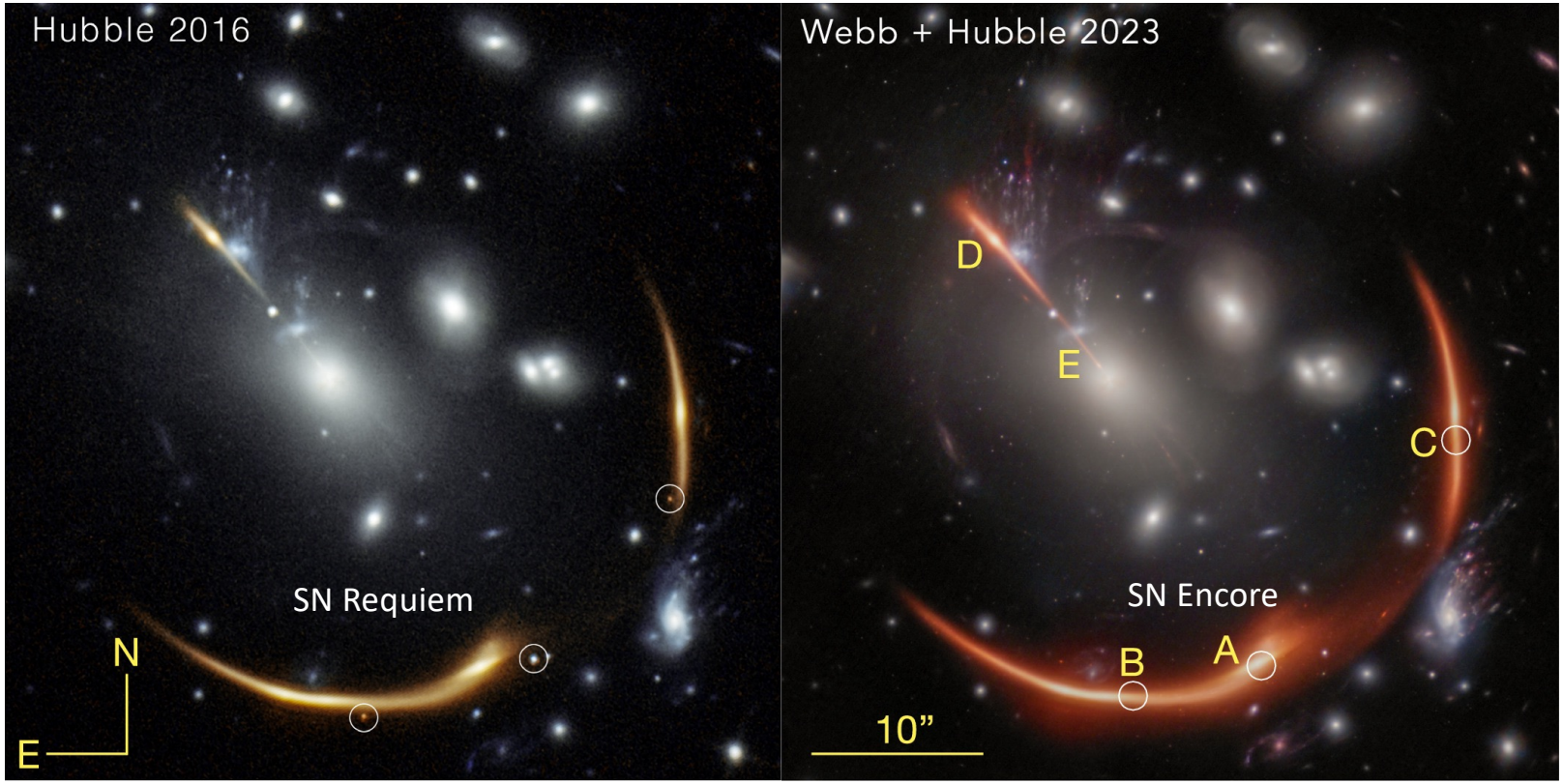
Lens models cannot reproduce well all SN fluxes

SN Requiem (2016) and SN Encore (2023)

two SNe Ia with multiple images in the same lensed massive galaxy

Rodney+ 2021, Pierel+ 2024

z (SN Encore and Requiem) = 1.95

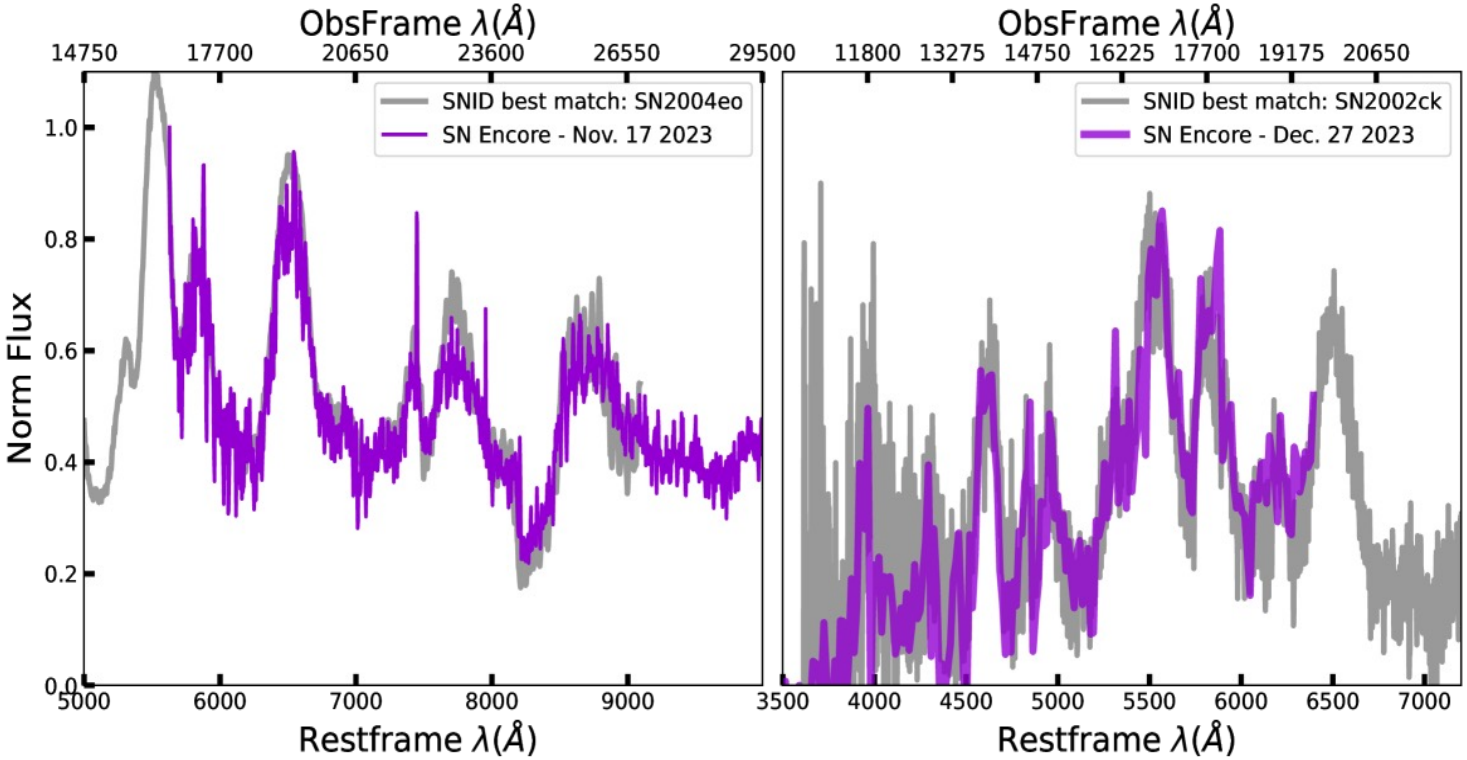


SN Encore, JWST spectra

Dhawan+ 2024

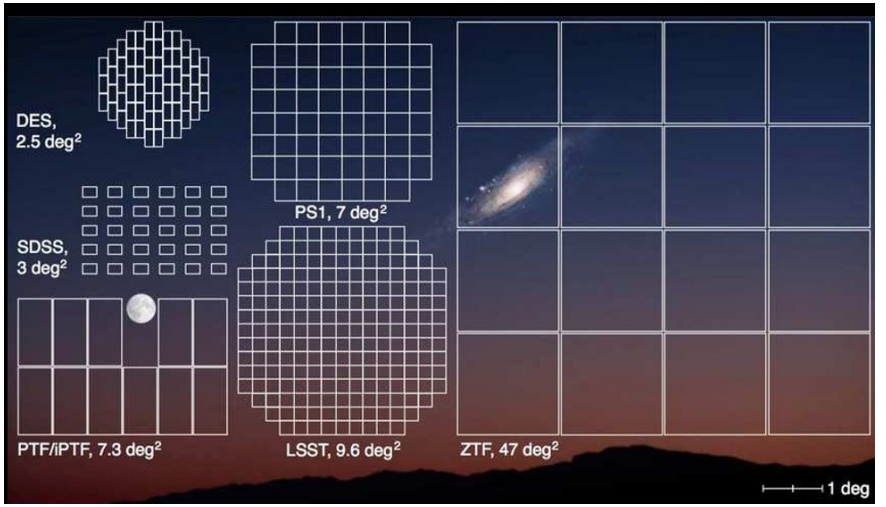
SN Encore, two JWST epochs

Spectra are very similar to low-z SNe Ia



Zwicky Transient Facility (ZTF)

The largest (47 sq. deg) optical camera for time-domain astronomy



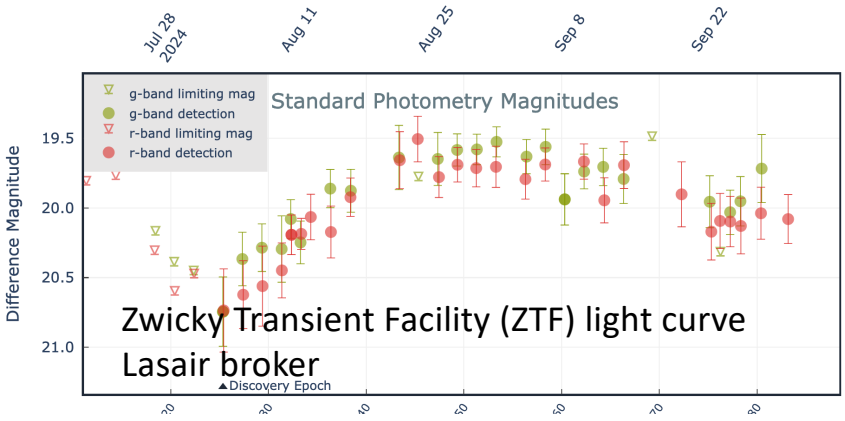
Credit:
ZTF, Caltech, and
Palomar Observatory

Supernovae and Gravitational Lenses Follow up (SGLF)
discovery and classification of ZTF supernovae using the LSST/ZTF brokers

- A significant fraction of ZTF-selected possible supernovae are not reported to the Transient Name Server (TNS) by the ZTF brokers or are not reported quickly
- We have developed methods that combine the tools available at the ZTF/LSST brokers, mainly using ALeRCE, Lasair, Lasair Sherlock, and ATLAS forced photometry, to search for new supernovae, report them to TNS and spectroscopically classify some of them (using the Liverpool, NOT and GTC telescopes)
- Forced photometry (included recently in the ZTF alerts) can help in many cases
- > 2100 TNS discovery reports (TNS group SGLF)
- > 150 TNS classification reports (TNS groups SGLF and SIRAH)
- 11 SLSNe discovered by SGLF
- 20 SLSNe classified by SGLF
- 1 TDE discovered by SGLF
- SNe with precursor emission
- Strongly-interacting SNe
- SN Factories
- SN Siblings
- etc

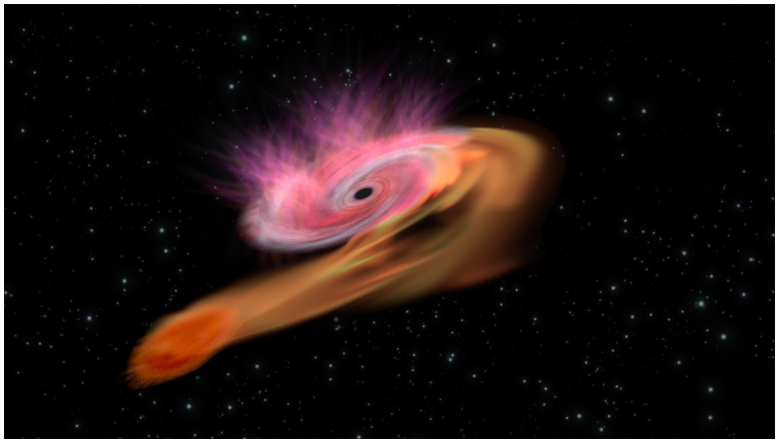
Tidal Disruption Event (TDE) AT 2024rny

Pérez-Fournon+, TNS discovery report

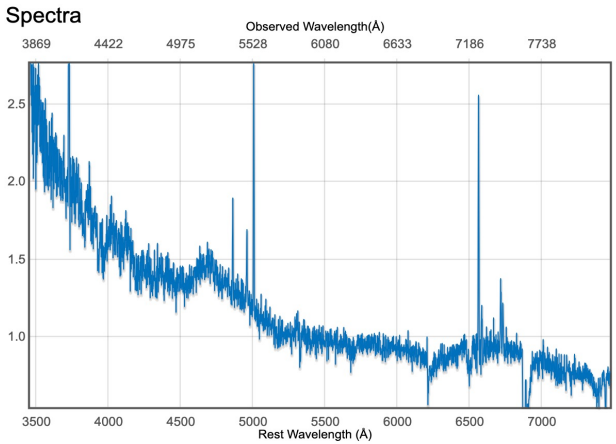


Zwicky Transient Facility (ZTF) light curve

Lasair broker



Credit: SRON



TNS Classification spectrum

Gómez et al.

z = 0.1055

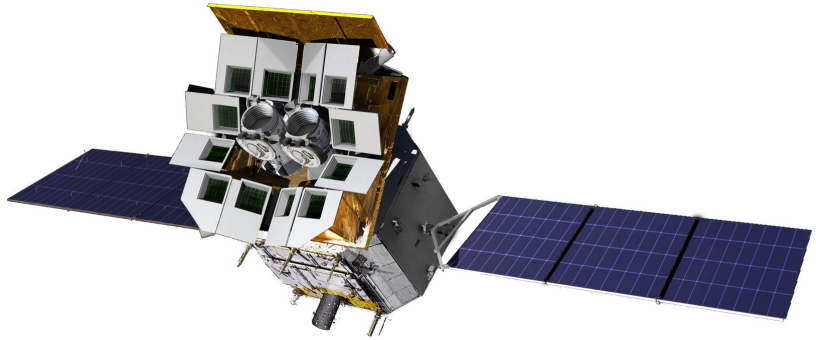
PanSTARRS, 30”x30”

Plans to follow up LSST transients

- Superluminous supernovae up to redshift 2
- Gravitationally lensed supernovae: spectroscopic classification and photometric and spectroscopic follow up
- Discovery and classification of supernovae using the LSST brokers, TBD % will not be reported to TNS by the brokers
- Medium-depth transient survey? Similar to ZTF Bright Transient Survey, to fainter magnitudes.
- New types of transients
- Transients and teaching of astronomical techniques

VRO: 289E, 30S
ORM: 342E, 28.7N
OT: 343E, 28,3N

Fast X-ray transients
from Einstein Probe



- New program to study core-collapse SNe detected by the new Einstein Probe mission with GTC, NOT and LT (collaboration with Nincheng Sun, D. Aguado, A. López-Oramas, J. Acosta-Pulido, D. Nespral, F. Acero, and others)

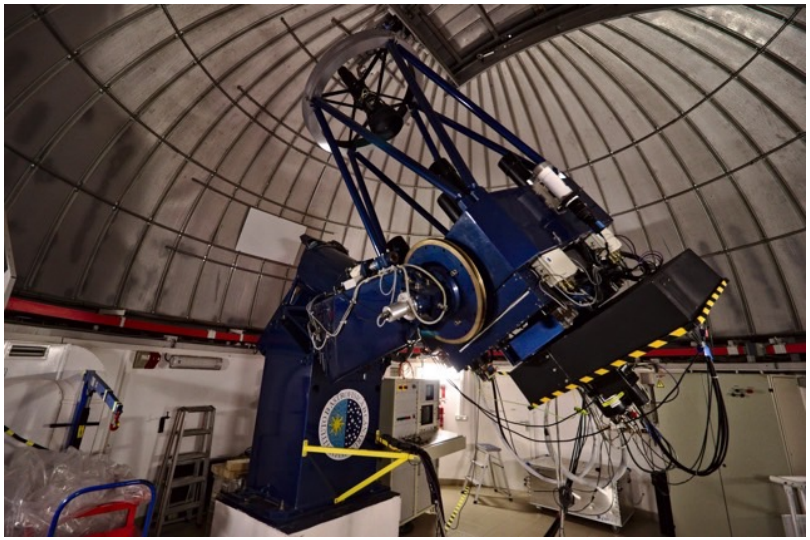
- Study of GRBs and EP Fast X-ray Transients (FXT) with Las Cumbres Observatory (robotic) telescopes

- Early results: LCOGT optical afterglow detections of recent EP FXTs and a GRB,

GCN circulars 37007, 37038, 37080, and 34746.

Transients and teaching of astronomical techniques

ULL-ASTRO-MASTER



IAC80, Teide Observatory, Tenerife
80-cm

Las Cumbres Observatory global telescope network

10 x 40-cm telescopes in six observatories:

Siding Spring, Sutherland, Tenerife, Cerro Tololo, McDonald, and Haleakala

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New! Circulars over Kafka, Heartbeat Topic, and Schema v4.1.0. See news and announcements

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GCN Circular 37692

Subject GRB 241002B: ULL-ASTRO-MASTER LCOGT 0.4m + QHY600 detection of the GOTO optical counterpart candidate AT 2024xbg / GOTO24gpc
Date 2024-10-03T12:45:46Z (8 days ago)
From Ismael Perez-Fournon at Instituto de Astrofisica de Canarias <ipf@iac.es>
Via Web form

M. Torreiro Martínez, B. Armas-Chinea, F. Dobrindt, P. Escudero-Coca, G. Fernández-Rodríguez, Á. García Lozano, A. Huertas Ferrer, C. Méndez-Lapido, I. Ortega-Casas, Guillermo Villa (ULL), S.R. Berlanas, and I. Pérez-Fournon (IAC and ULL)

We report on optical follow-up observations of the GOTO optical counterpart candidate AT 2024xbg / GOTO24gpc (Kumar et al. GCN 37676) of the FERMI long GRB GRB 241002B (Fermi GBM Team, GCN 37368, trigger 749542463.76265 / 241002260, trigger time 2024-10-02T06:14:18 UT).

We observed the field of AT 2024xbg with one of the Las Cumbres Observatory Global telescope network (LCOGT) 40-cm telescopes located at the LCOGT node at Siding Spring Observatory (Australia). Observations were performed using one of the LCOGT Planewave Delta Rho 350 telescopes equipped with QHY600 CMOS cameras in the SDSS g´and r´filters, with 500 sec exposures in each of the filters. We detect a faint source at the position of AT 2024xbg (GOTO24gpc) with magnitudes g'= 20.18 +/- 0.3 at 2014-10-02T12:26:41 UT and r´ = 19.90 +/- 0.25 at 2014-10-02T12:35:09 UT, calibrated using stars from the catalog of Gaia DR3 synthetic photometry generated from the Gaia BP/RP mean spectra (Gaia collaboration 2022) and without corrections for Milky Way extinction.

These results are based on observations made with the Las Cumbres Observatory's education network telescopes that were upgraded through generous support from the Gordon and Betty Moore Foundation (programme IAC2024B-010), as part of a course on Astrophysical Techniques of the Master in Astrophysics of the Universidad de La Laguna, Tenerife, Spain.

Detection of AT 2024xbg / GOTO24gpc (possible afterglow of GRB 241002B) with one of the LCOGT 40.cm telescopes

Torreiro Martínez et al., GCN Circular 37692
ULL-ASTRO-MASTER

Illustration of a gamma-ray burst erupting from a dense environment around a collapsing massive star (Image credit: NASA, ESA and M. Kornmesser)

- **Many thanks for your attention!**