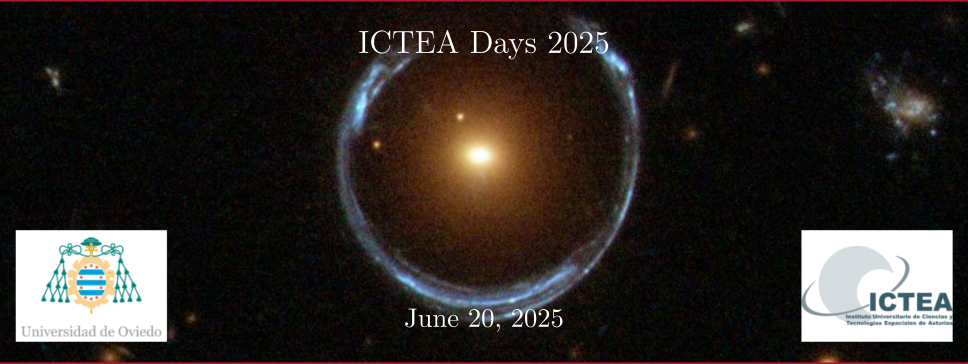
Candidate Gravitationally Lensed Submillimeter Galaxies in Herschel-ATLAS Associated with WISE Elliptical Counterparts



ICTEA Days 2025

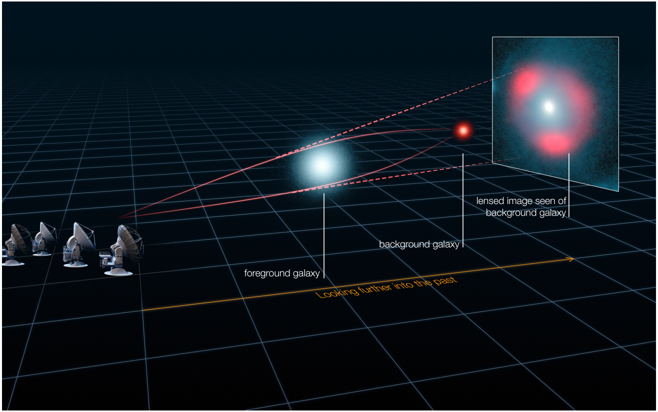
June 20, 2025

Juan Alberto Cano Díez (canojuan@uniovi.es)

on behalf of J. González-Nuevo, L. Bonavera, M.M. Cueli, T. Bakx, J.M. Casas, D. Crespo and R. Fernández Fernández

Introduction

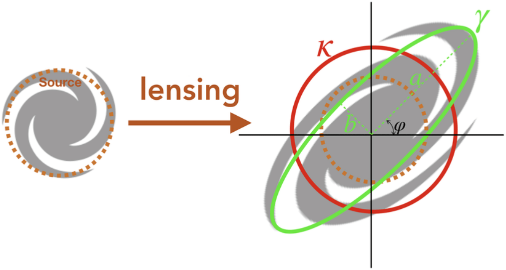
- Submillimeter galaxies (SMGs) are a population of high-redshift ($z > 1$), dust-obscured galaxies with extreme star formation rates.
- Ideal targets for gravitational lensing studies $\rightarrow$ cosmological tool.



Credit: ALMA (ESO/NRAO/NAOJ).

Introduction

- Submillimeter galaxies (SMGs) are a population of high-redshift ($z > 1$), dust-obscured galaxies with extreme star formation rates.
- Ideal targets for gravitational lensing studies → cosmological tool.
- Strong lensing: high magnification and distortion → case-by-case analyses.
- Weak lensing: mild magnification and distortion → statistical analyses.

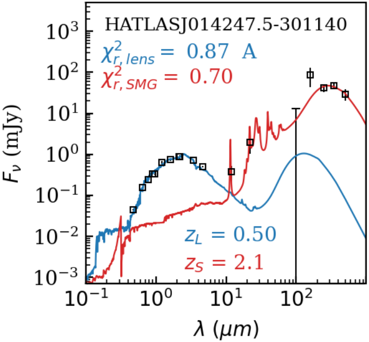


Magnification and distortion created by a lens over a circular source. Credit: Shuntov (2019).

Introduction

- Catalogs of confirmed strongly lensed galaxies in the sub-mm (e.g., Negrello et al. 2017; Bakx et al. 2024).
- We present a new method to identify gravitational lens candidates within the *Herschel*-ATLAS and AllWISE surveys.
- SED analysis performed with CIGALE code (Boquien et al. 2019).
- Estimation of their main physical parameters.

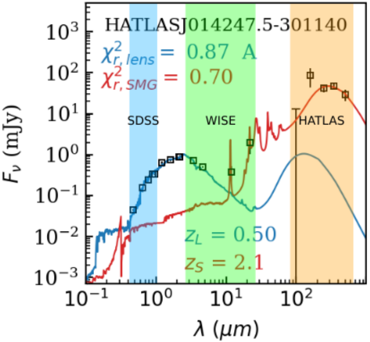
Survey	Filters
GALEX	*FUV*, *NUV*
SDSS	*u*, *g*, *r*, *i*, *z*
VST-ATLAS	*u*, *g*, *r*, *i*, *z*
Pan-STARRS1	*g*, *r*, *i*, *z*, *y*
VISTA-VIKING	J, H, K_s
UKIRT	*J*, *H*, *K*
2MASS	J, H, K_s
WISE	3.4, 4.6, 12, 22 (μm)
Herschel/PACS	100, 160 (μm)
Herschel/SPIRE	250, 350, 500 (μm)



Introduction

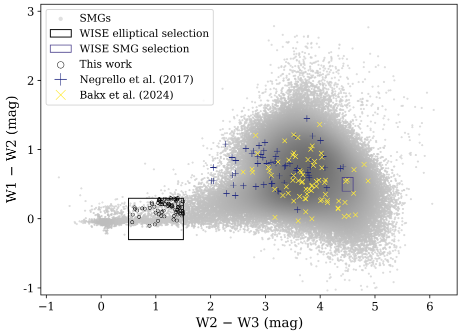
- Catalogs of confirmed strongly lensed galaxies in the sub-mm (e.g., Negrello et al. 2017; Bakx et al. 2024).
- We present a new method to identify gravitational lens candidates within the *Herschel*-ATLAS and AllWISE surveys.
- SED analysis performed with CIGALE code (Boquien et al. 2019).
- Estimation of their main physical parameters.

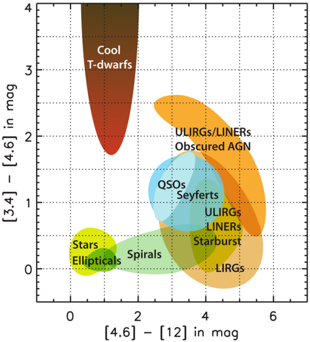
Survey	Filters
GALEX	*FUV*, *NUV*
SDSS	*u*, *g*, *r*, *i*, *z*
VST-ATLAS	*u*, *g*, *r*, *i*, *z*
Pan-STARRS1	*g*, *r*, *i*, *z*, *y*
VISTA-VIKING	*J*, *H*, K_s
UKIRT	*J*, *H*, *K*
2MASS	*J*, *H*, K_s
WISE	3.4, 4.6, 12, 22 (μm)
Herschel/PACS	100, 160 (μm)
Herschel/SPIRE	250, 350, 500 (μm)



Selection methodology

Wright et al. (2010)





- High-redshift SMGs in H-ATLAS: $1.2 < z_{smm} < 4.0$
- Elliptical galaxies in AllWISE: $0.5 < W2-W3 < 1.5$, $|W1-W2| < 0.3$
- Three possible explanations:
  - ▷ Those objects are actually the same.
  - ▷ Those objects are different, but they were identified as the same due to cross-match errors.
  - ▷ Those objects are different and form a gravitational lens.

Validation

Star/Galaxy separation:

- Ellipticals share similar WISE colours with stars.

Additional requirements:

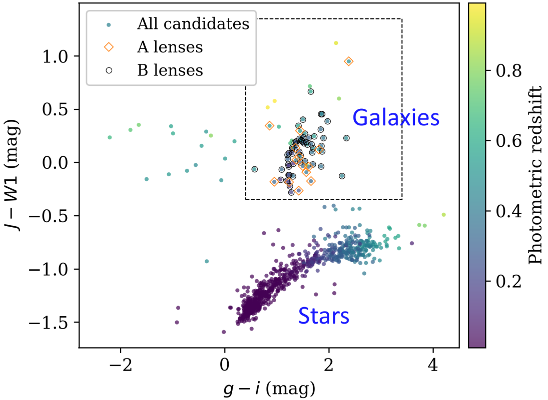
- ▷ $J - W1 > -0.35$ mag
- ▷ $g - i > 0.4$ mag
- ▷ $0.1 < z_{lens} < 0.6$

$\rightarrow$ 68 lens candidates

Best candidate selection:

- ▷ Ang. sep. < 5 arcsec
- ▷ $\chi^2_{r,\,\mathrm{lens}} < 10$

$\rightarrow$ 15 best candidates

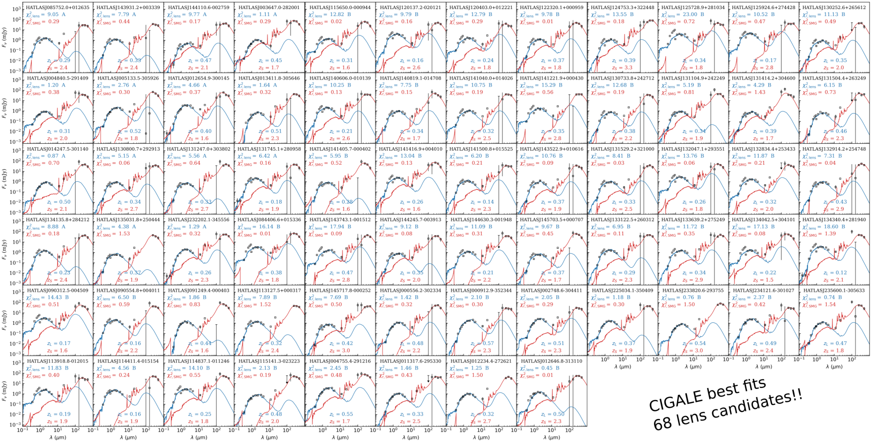


Other issues:

- Cross-matching errors (multiple counterparts, blending, etc).

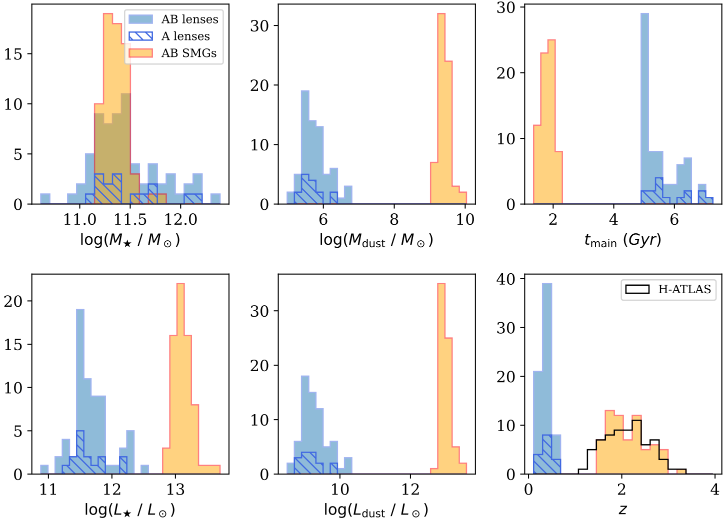
SED analysis results

- Independent analysis for the lens and sub-mm components of the SED.



SED analysis results

- Independent analysis for the lens and sub-mm components of the SED.



Magnification estimates

Assumptions:

- M_h: Stellar-to-halo mass relation from Moster et al. (2013).
- $M_{lens} = M_\star + M_{dust} + M_{gas} + M_h$.
- Halo model: Singular Isothermal Sphere (SIS).

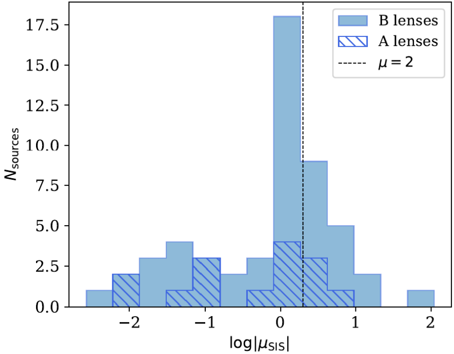
Einstein radius:

$$\theta_E = \frac{2\pi G M_{lens}}{c^2 r_{200}} \frac{D_{LS}}{D_S},$$

with $r_{200} = [3M_{lens}/(4\pi 200 \rho_c)]^{1/3}$

Magnification produced by the lens:

$$\mu_{SIS} = \frac{|\theta|/\theta_E}{|\theta|/\theta_E - 1}$$



Conclusions

Pros:

- A completely new method for selecting gravitational lens candidates.
- Not biased towards high sub-mm fluxes nor magnifications.
- 68 new candidates were found.

Cons:

- High stellar contamination.
- Cross-matching uncertainties.
- It assumes that the lenses are brighter than SMGs at MIR wavelengths.

Future steps

- High resolution observations.
- All-sky survey on the far infrared needed.

Conclusions

Pros:

- A completely new method for selecting gravitational lens candidates.
- Not biased towards high sub-mm fluxes nor magnifications.
- 68 new candidates were found.

Cons:

- High stellar contamination.
- Cross-matching uncertainties.
- It assumes that the lenses are brighter than SMGs at MIR wavelengths.

Future steps

- High resolution observations.
- All-sky survey on the far infrared needed.

Thank you very much for your attention!