Resolving the Lens of Macho 97-BLG-28 ?

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MACHO-97-BLG-28 (ALBROW ET AL. 1999)

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- Binary microlensing event, mass ratio q=0.234 and separation d=0.686
- First limb darkening parameters determined by Microlensing (we do it better now...)

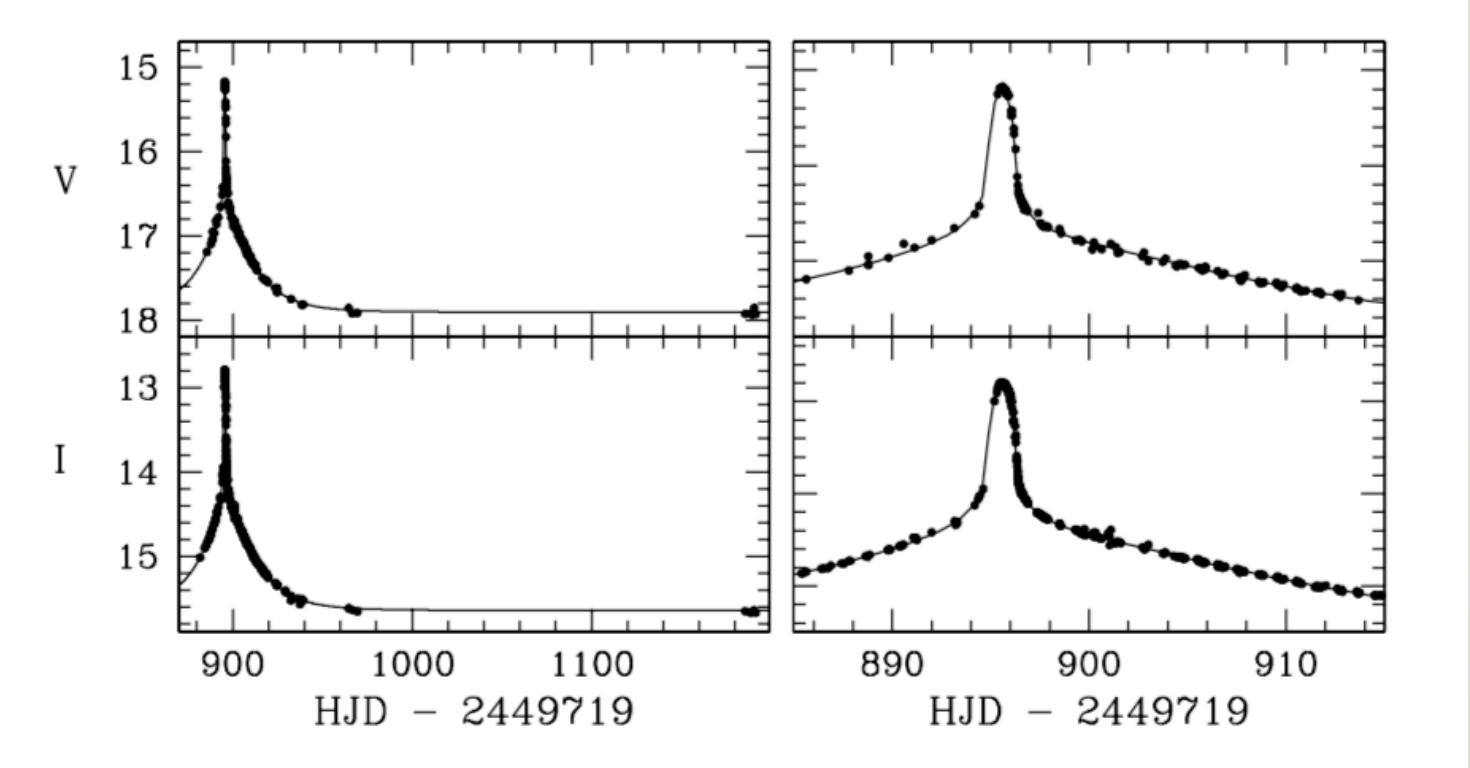
MACHO-97-BLG-28 (ALBROW ET AL. 1999)

- Alert: May 29 1997, peak @ June 10 97
- Six weeks following

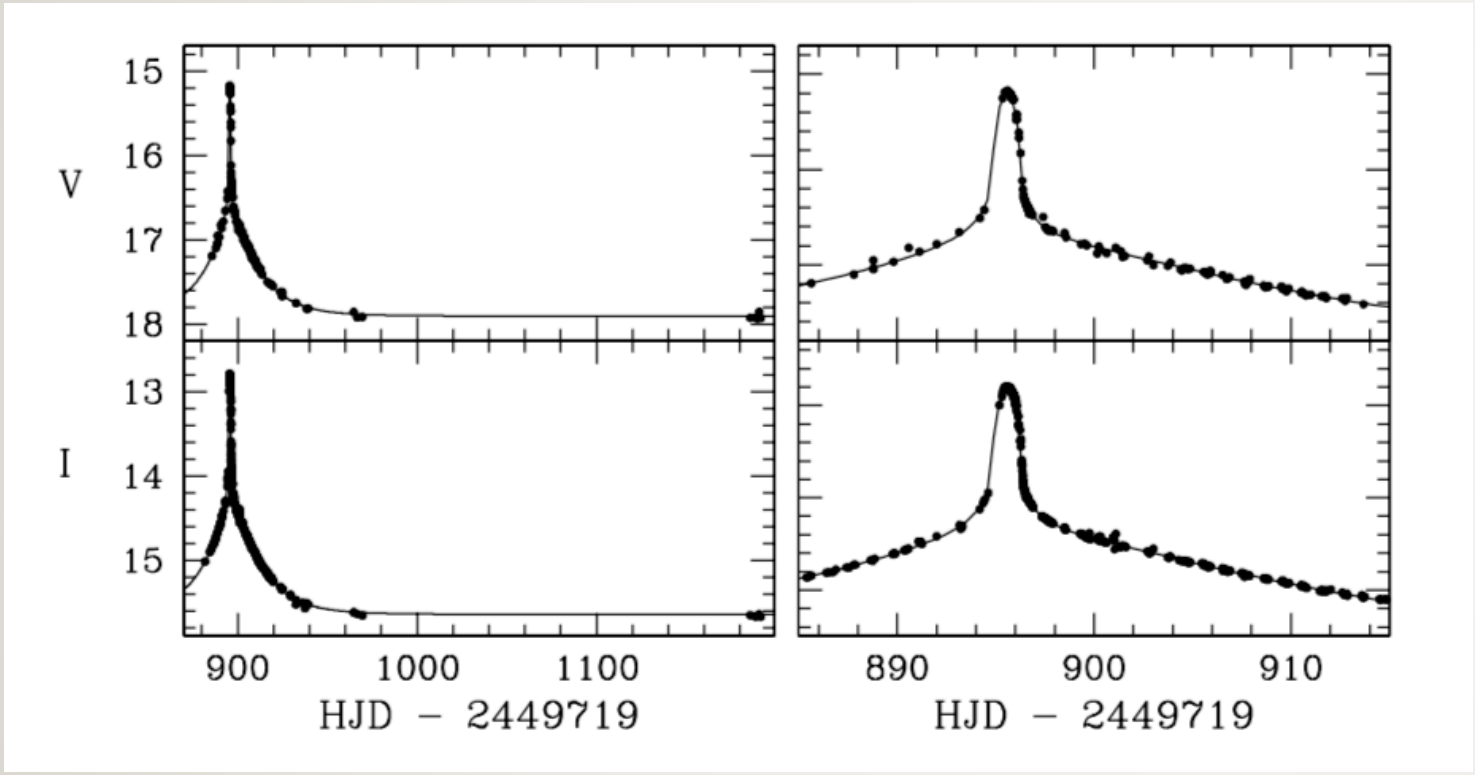
ESO 3.6m La Silla

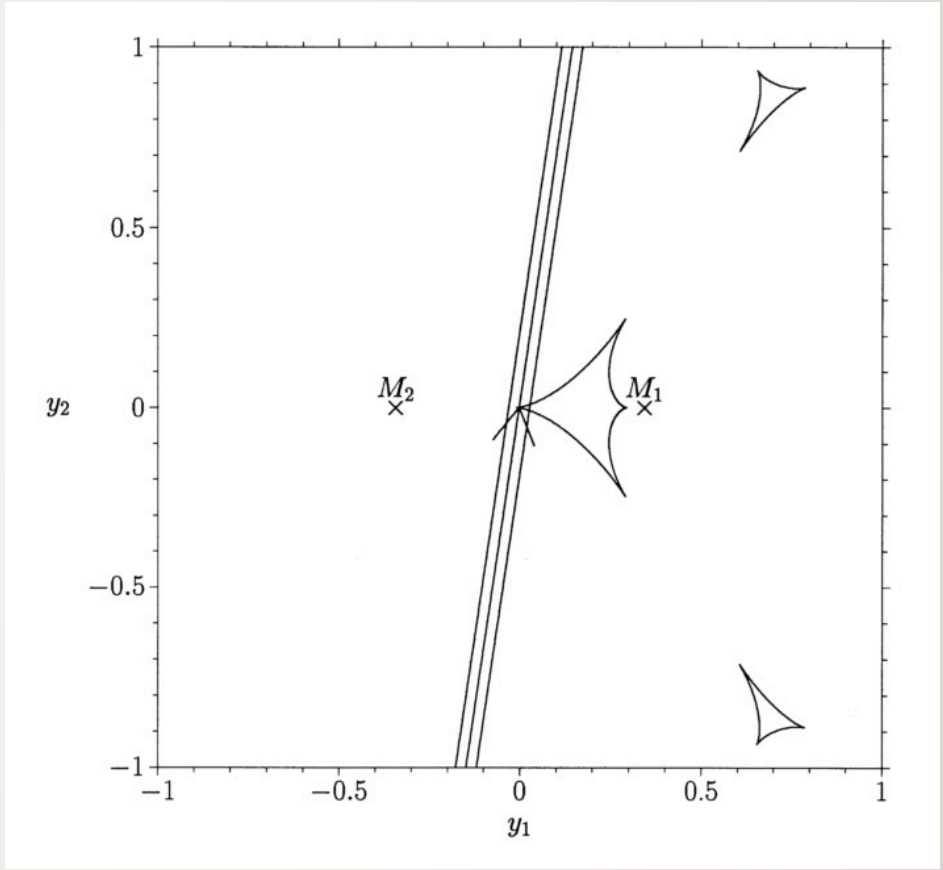
Canopus 1m

Sutherland 1m



MACHO-97-BLG-28 (ALBROW ET AL. 1999)





MACHO-97-BLG-28 (ALBROW ET AL. 1999)

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- Conclusion not entirely certain:
- For a lens in the Galactic bulge:

  Stellar binary of separation 1-2AU.
- If the lens is in the disk:

  One or both the objects are brown dwarfs.

Which is it?

Approach

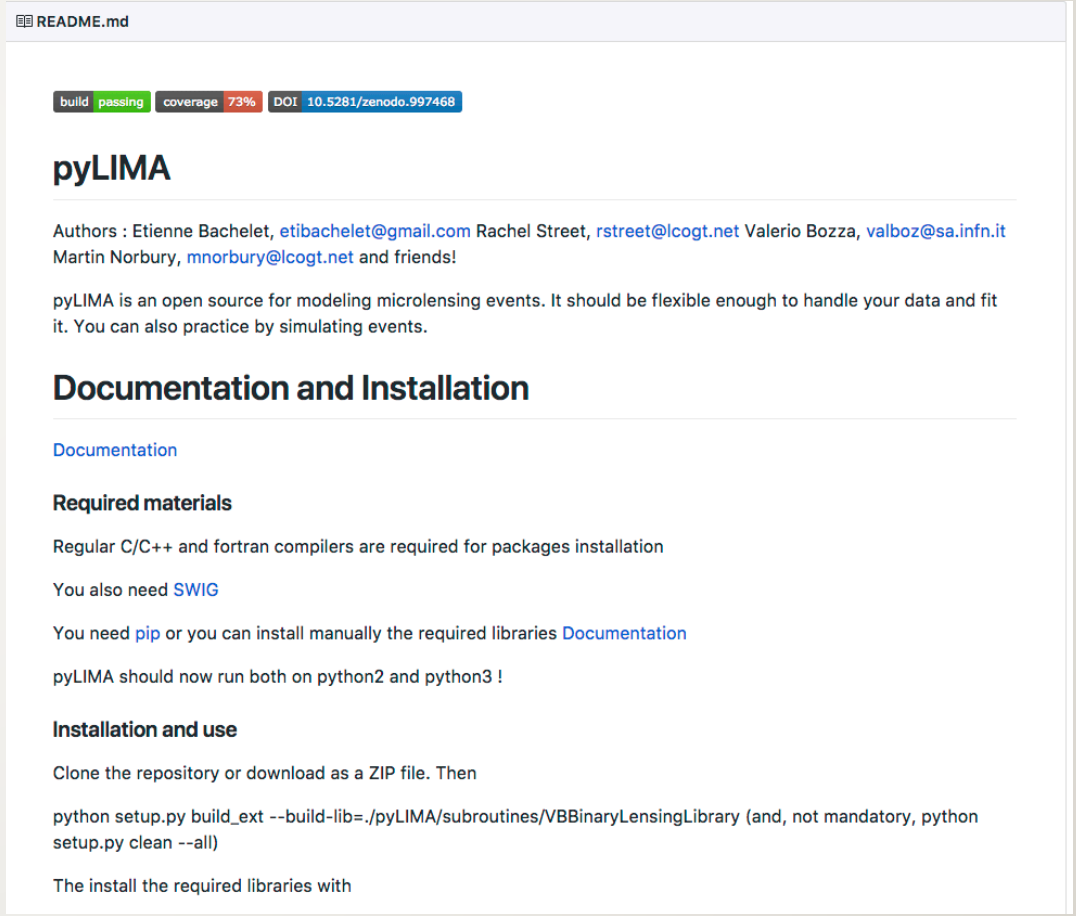
1. Use pyLIMA (Bachelet et al. 2017) to remodel the event curve using original data + MSO 74” data.
2. Use Adaptive Optics observations from KECK (2013) to determine the lens flux and constrain the physical parameters of the system.

See: Batista et al. (2013) + Beaulieu et al. (2016)
MOA-2011-BLG-293Lb OGLE 2012-BLG-0026

1. Use pyLIMA (Bachelet et al. 2017) to remodel the event curve using original data + MSO 74” data.

Differential Evolution USBL/FSBL fit

Used Linear Limb Darkening parameters from Claret (2000).



README.md

build passing coverage 73% DOI 10.5281/zenodo.997468

pyLIMA

Authors : Etienne Bachelet, etibachelet@gmail.com Rachel Street, rstreet@lcogt.net Valerio Bozza, valboz@sa.infn.it Martin Norbury, mnorbury@lcogt.net and friends!

pyLIMA is an open source for modeling microlensing events. It should be flexible enough to handle your data and fit it. You can also practice by simulating events.

Documentation and Installation

Documentation

Required materials

Regular C/C++ and fortran compilers are required for packages installation

You also need SWIG

You need pip or you can install manually the required libraries Documentation

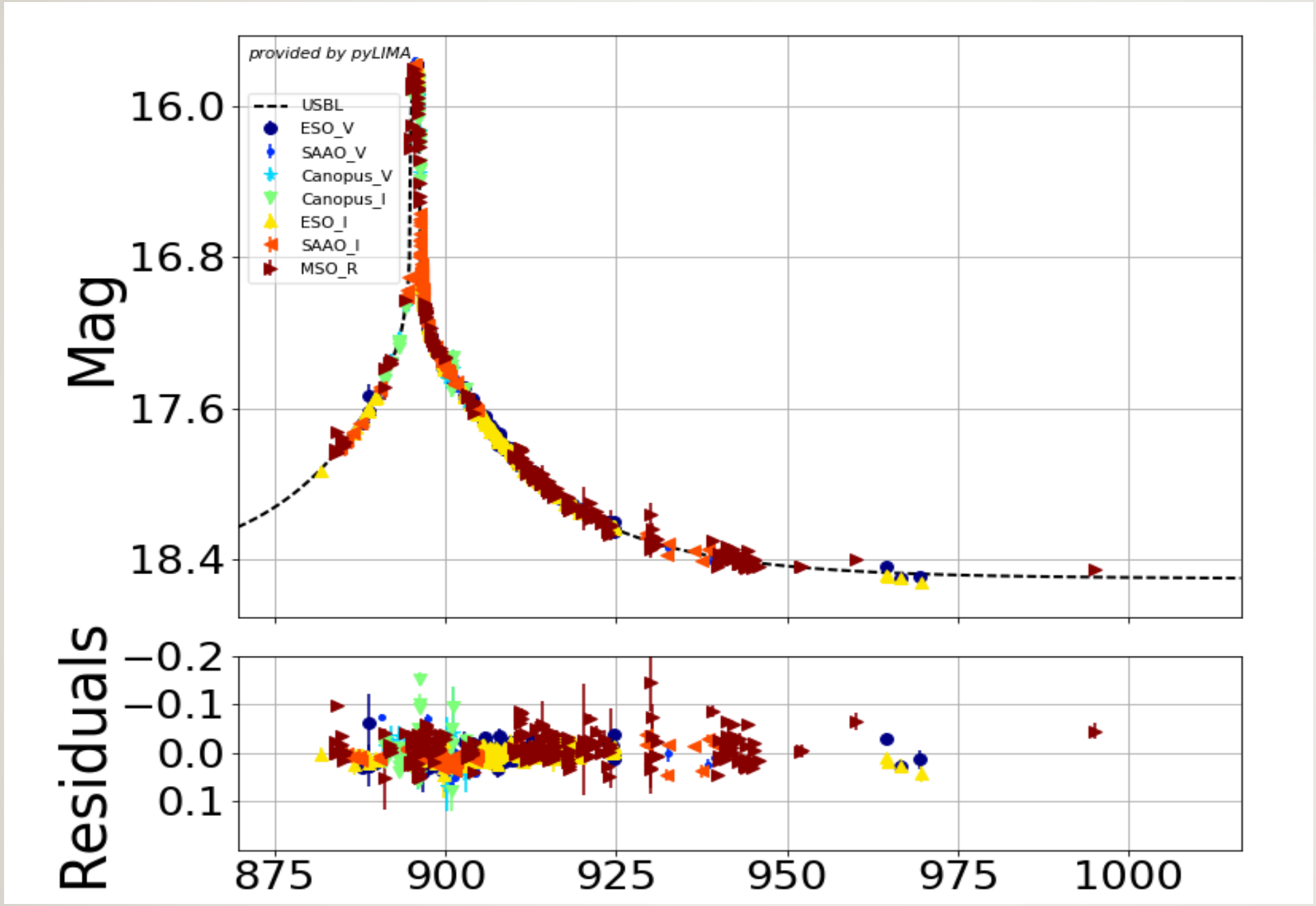
pyLIMA should now run both on python2 and python3 !

Installation and use

Clone the repository or download as a ZIP file. Then

python setup.py build_ext --build-lib=./pyLIMA/subroutines/VBBinaryLensingLibrary (and, not mandatory, python setup.py clean --all)

The install the required libraries with



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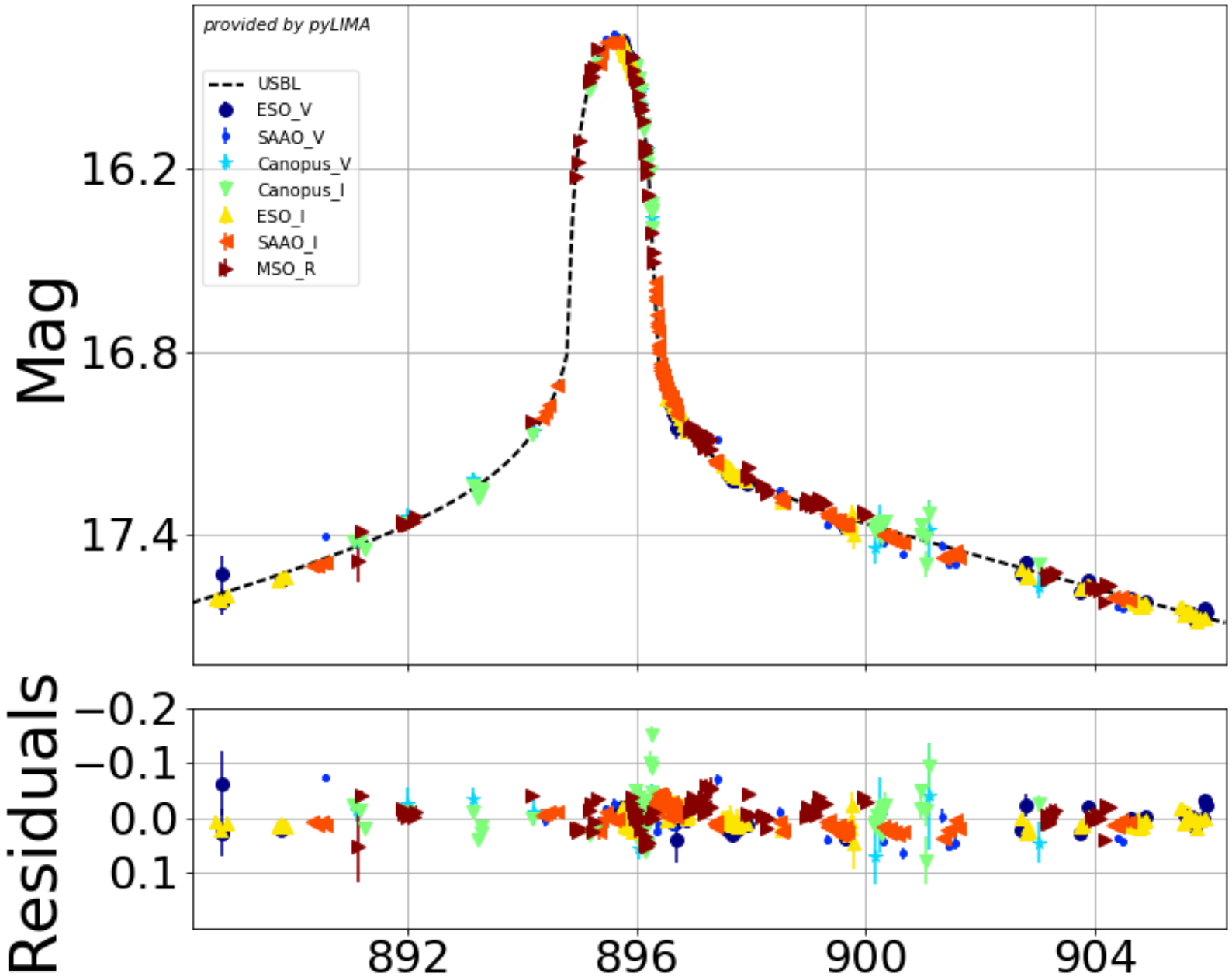
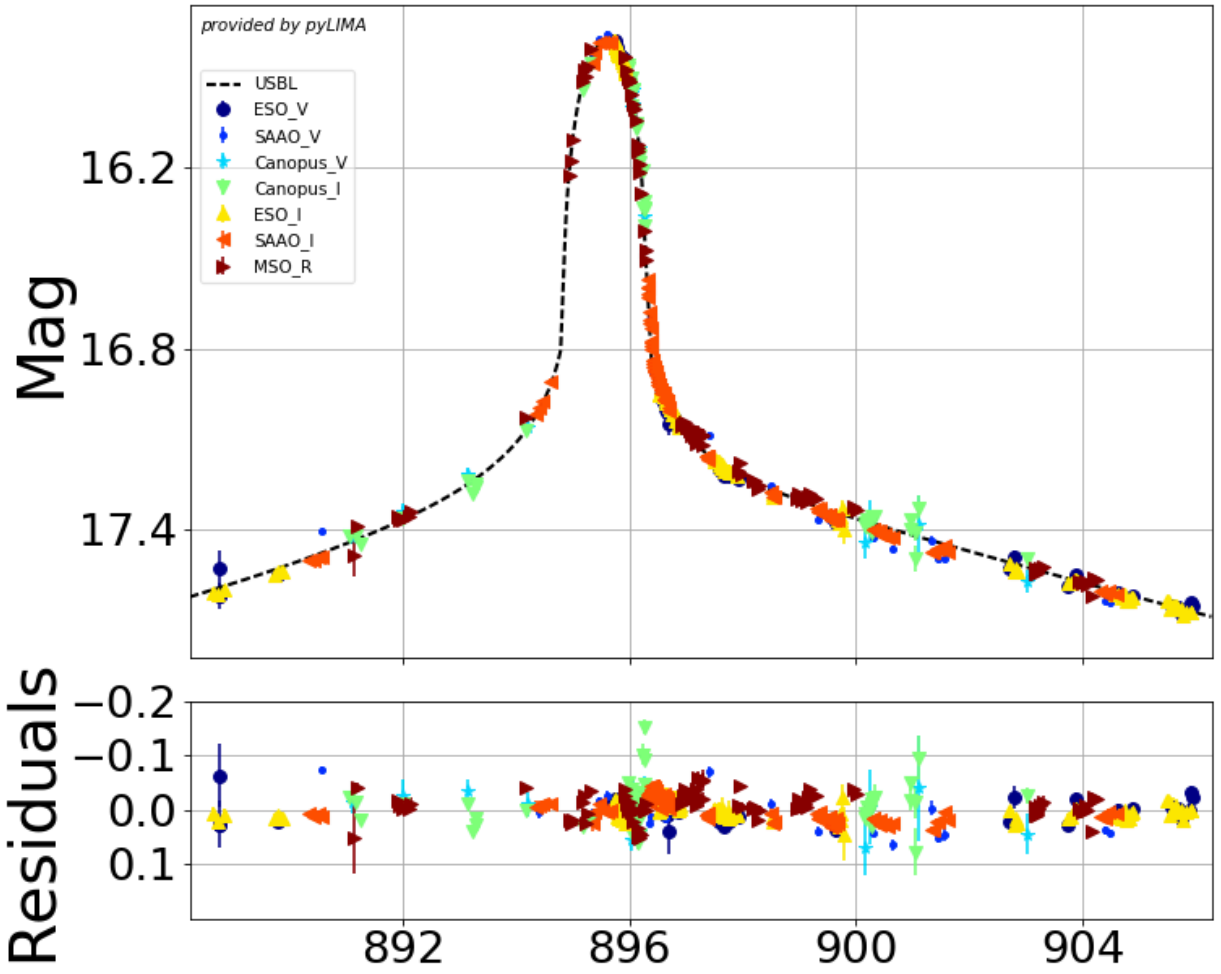
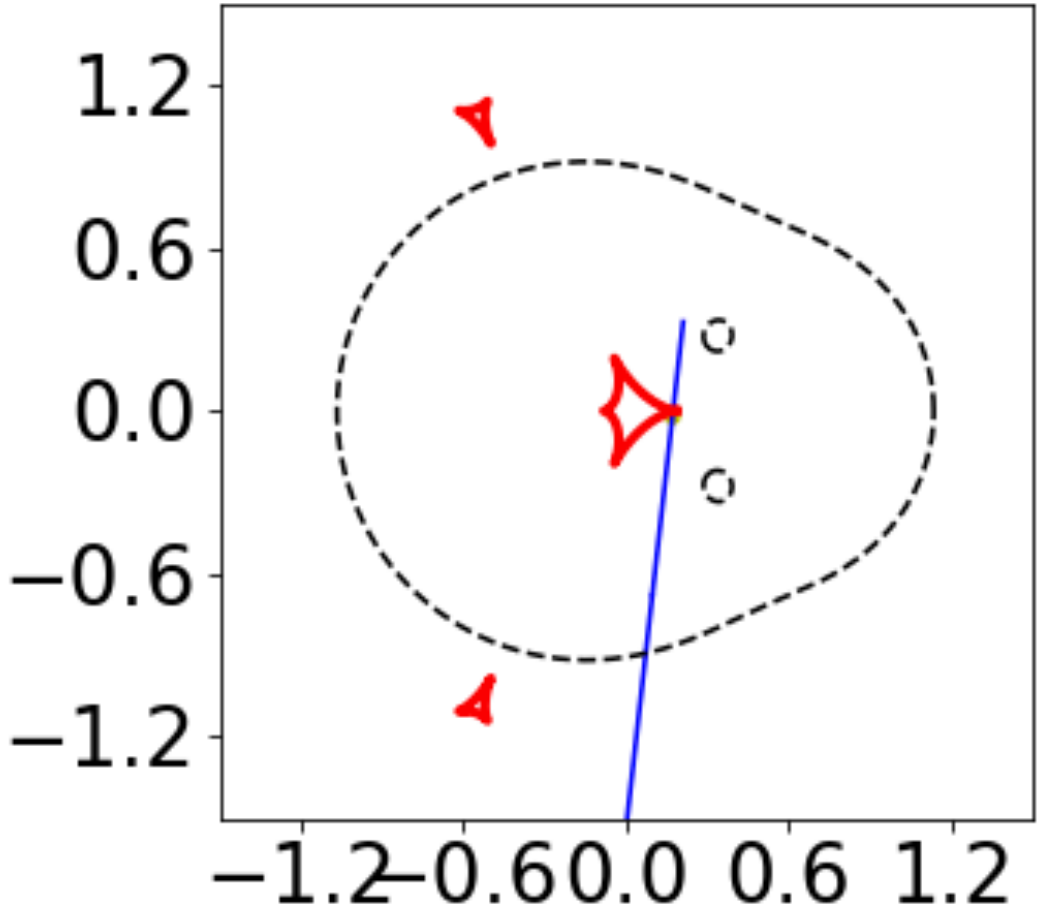

provided by pyLIMA
USBL
ESO_V
SAAO_V
Canopus_V
Canopus_I
ESO_I
SAAO_I
MSO_R
Mag
16.2
16.8
17.4
Residuals
−0.2
−0.1
0.0
0.1
892
896
900
904

Fitted Light Curve and Geometry





Fitted Light Curve and Geometry

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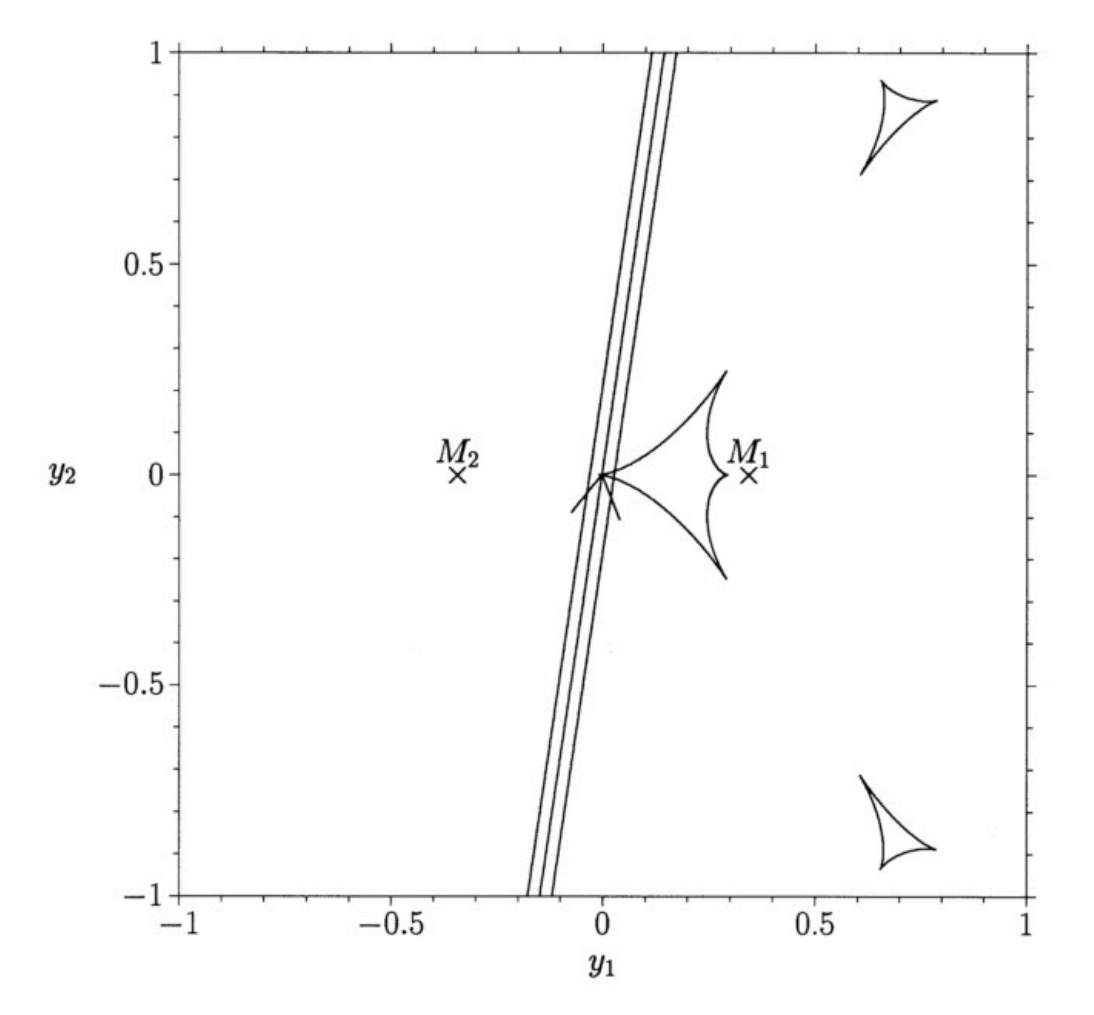

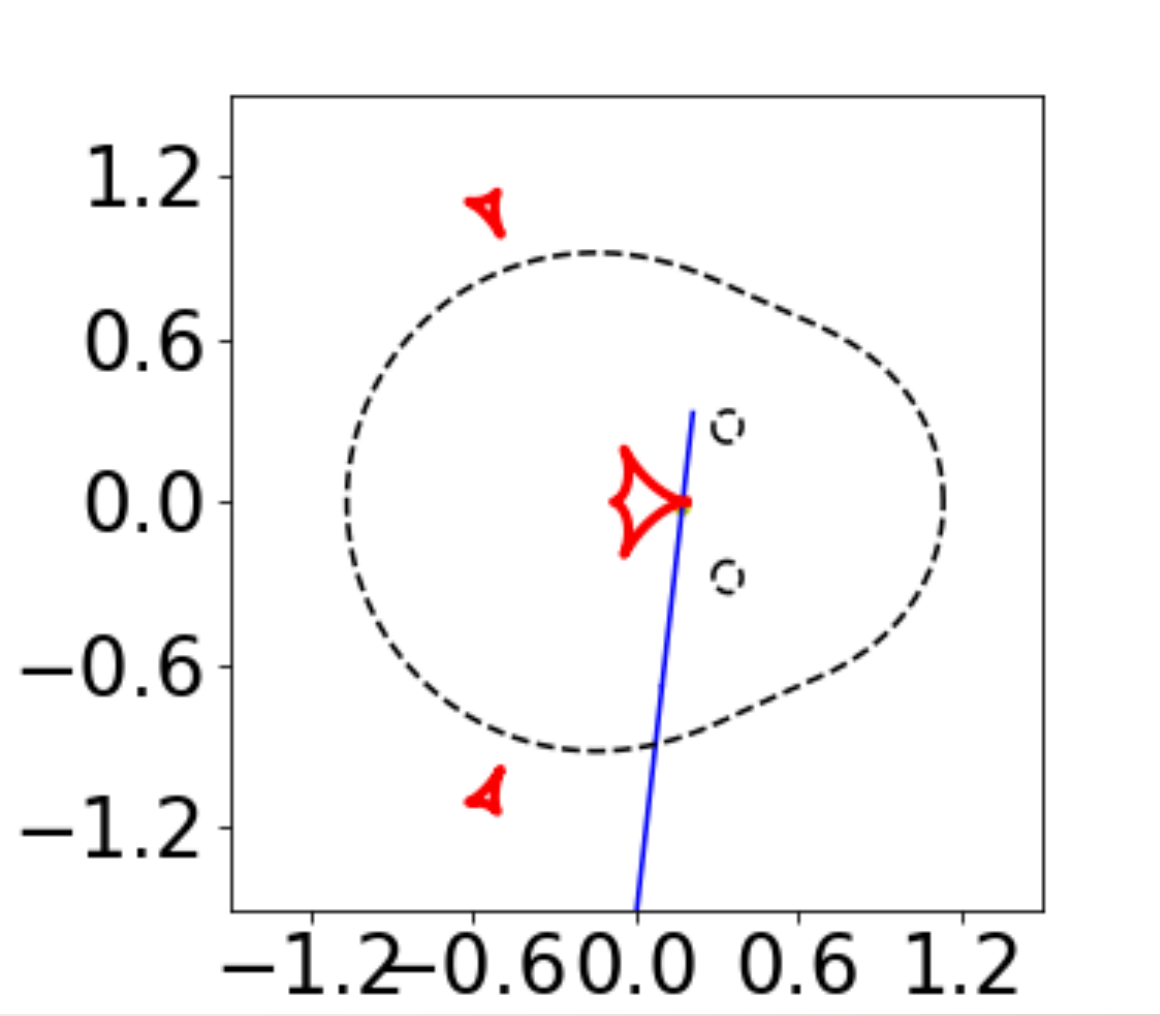

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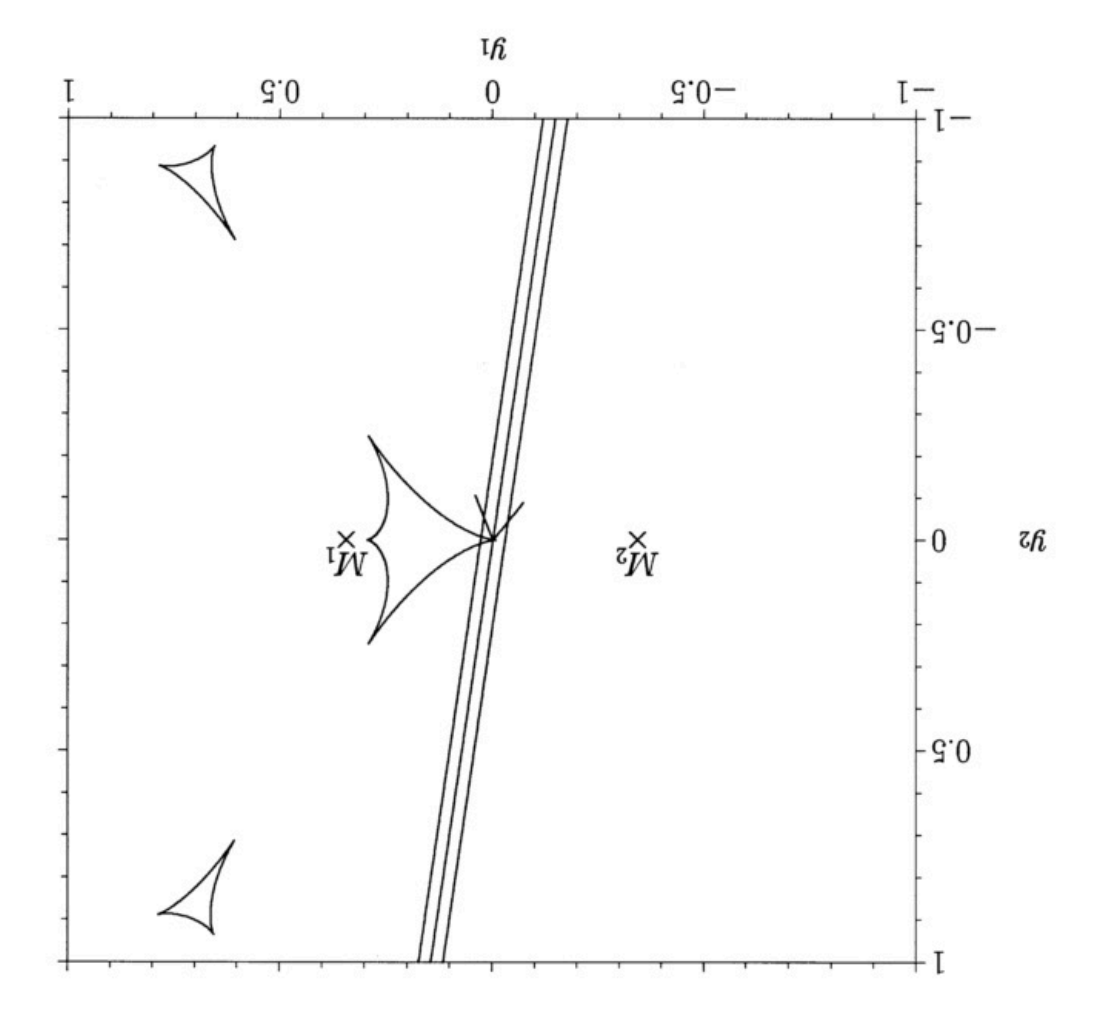

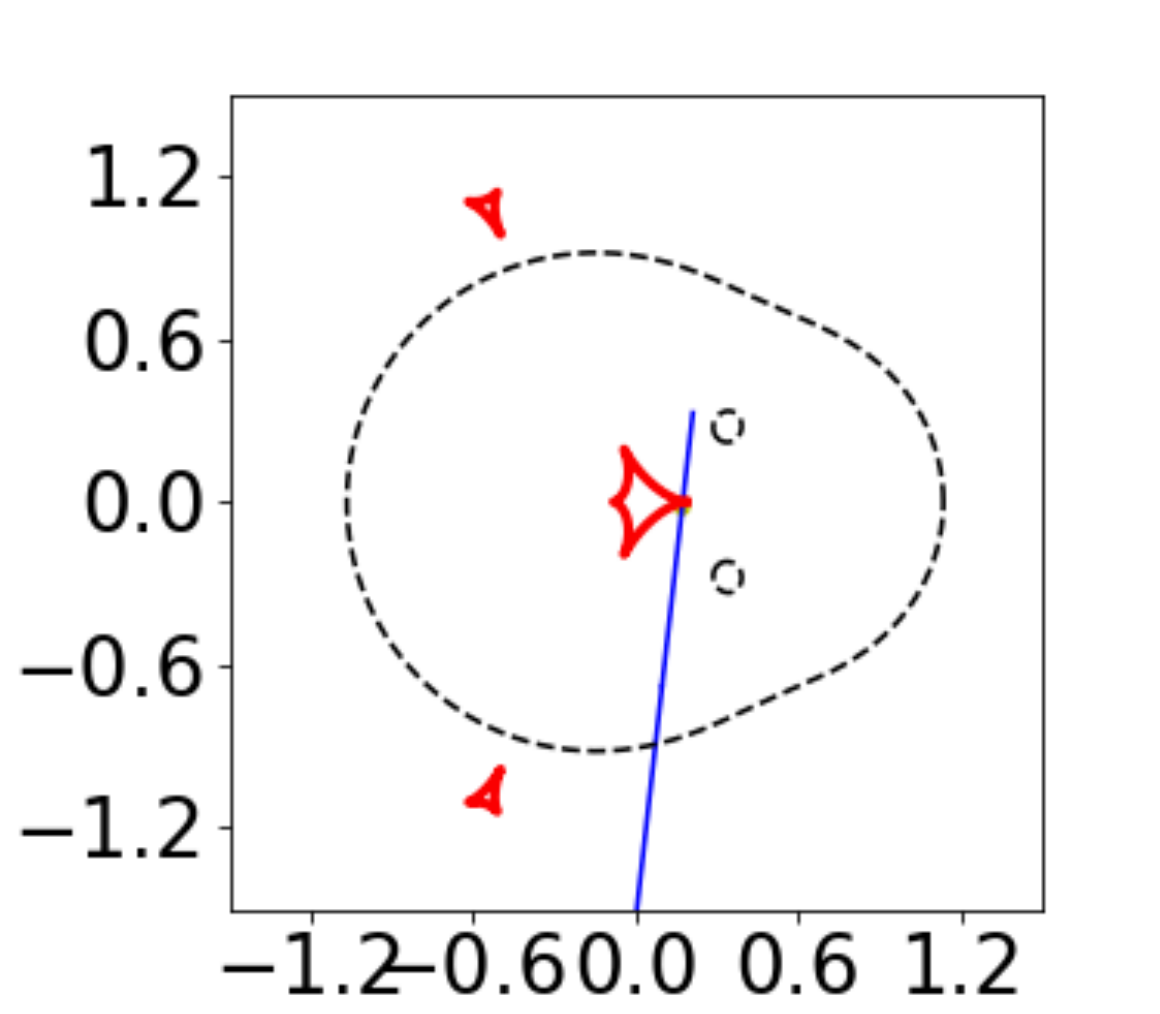

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Model Parameters

Parameter	LD2 Model Fit (Albrow 1999)	FSBL pyLIMA
$t_E\ (days)$	27.3	29.5 ± 0.15
$t_0\ (days)$	895.58	896.31 ± 0.03
u_0	0.0029	0.183 ± 0.005
ρ_*	0.0286	0.0254 ± 0.0005
d	0.686	0.636 ± 0.004
q	0.234	0.252 ± 0.005
α	1.426	-1.704 ± 0.001

Source Star: Size and Colour

Baseline source magnitude of evidence the source (Albrow et al. 99)

$$V = 17.91 \pm 0.05$$
$$I = 15.66 \pm 0.05$$

Using extinction estimates from Gonzalez et al. (2012) and intrinsic colour information from Bessel/Brett (1988) we recalculate the colours:

$$(V - I)_0 = 0.93$$

resulting in angular size of $\theta_* = 7.9 \pm 0.1\ \mu as$**.**

Source Star: Size and Colour

G4/G6 giant | $R_{\text{source}} = 13.6 \pm 0.2\ R_{\odot}$ (Blackman et al. 2018)

K2 III giant | $R_{\text{source}} = 15 \pm 2\ R_{\odot}$ (Albrow et al. 1999)

Source Star: Size and Colour

Lens source relative proper motion

$\mu = 3.9 \pm 0.3\ mas\ yr^{-1}$ (Blackman et al. 2018)

$\mu = 4.1 \pm 0.5\ mas\ yr^{-1}$ (Albrow et al. 1999)

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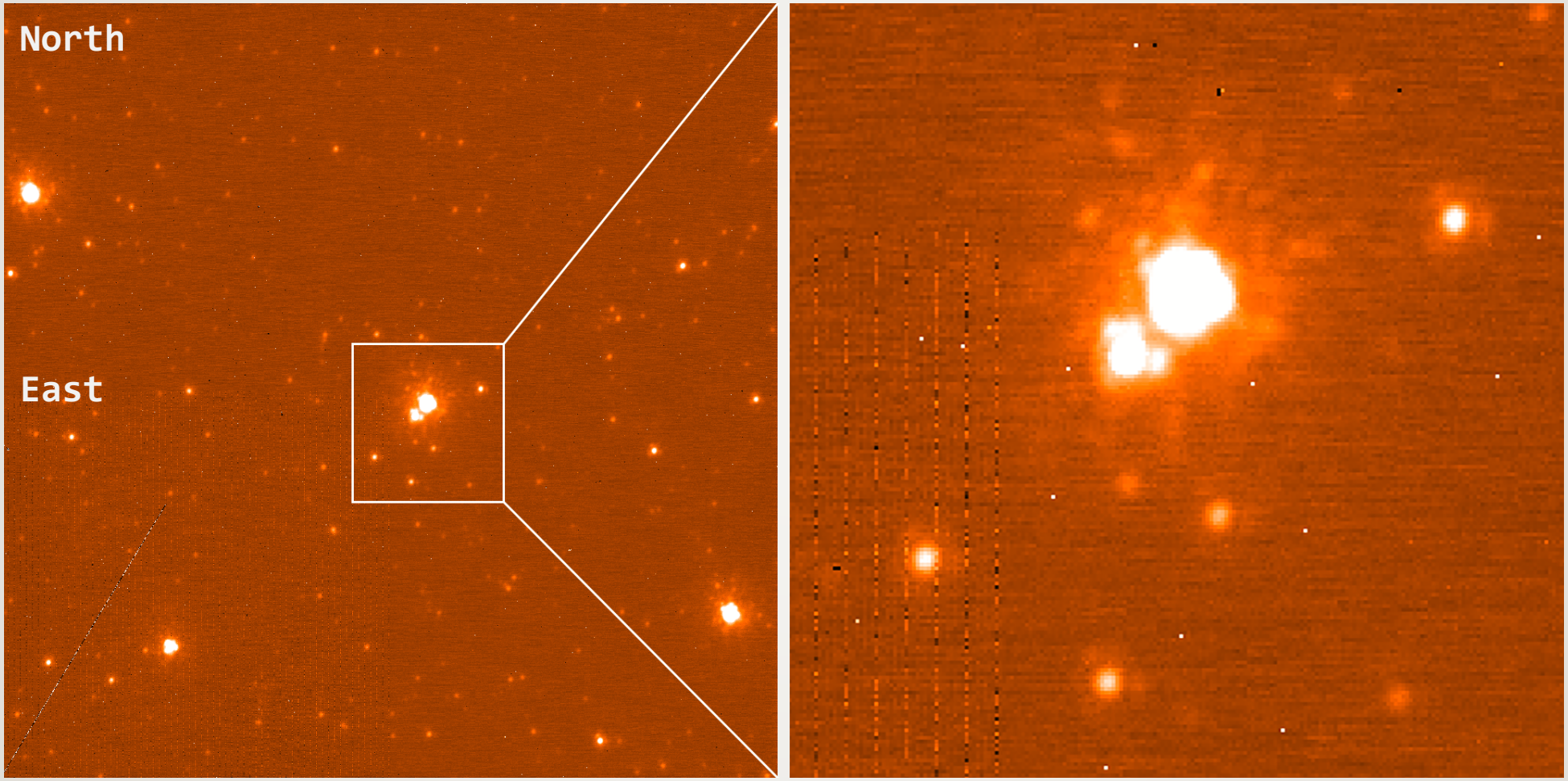
Approach

1. Use pyLIMA (Bachelet 2017) to remodel the event curve using original data + MSO 74” data.
2. Use Adaptive Optics observations from KECK (2013) to determine the lens flux and the amplitude and direction of the lens-source proper motion.

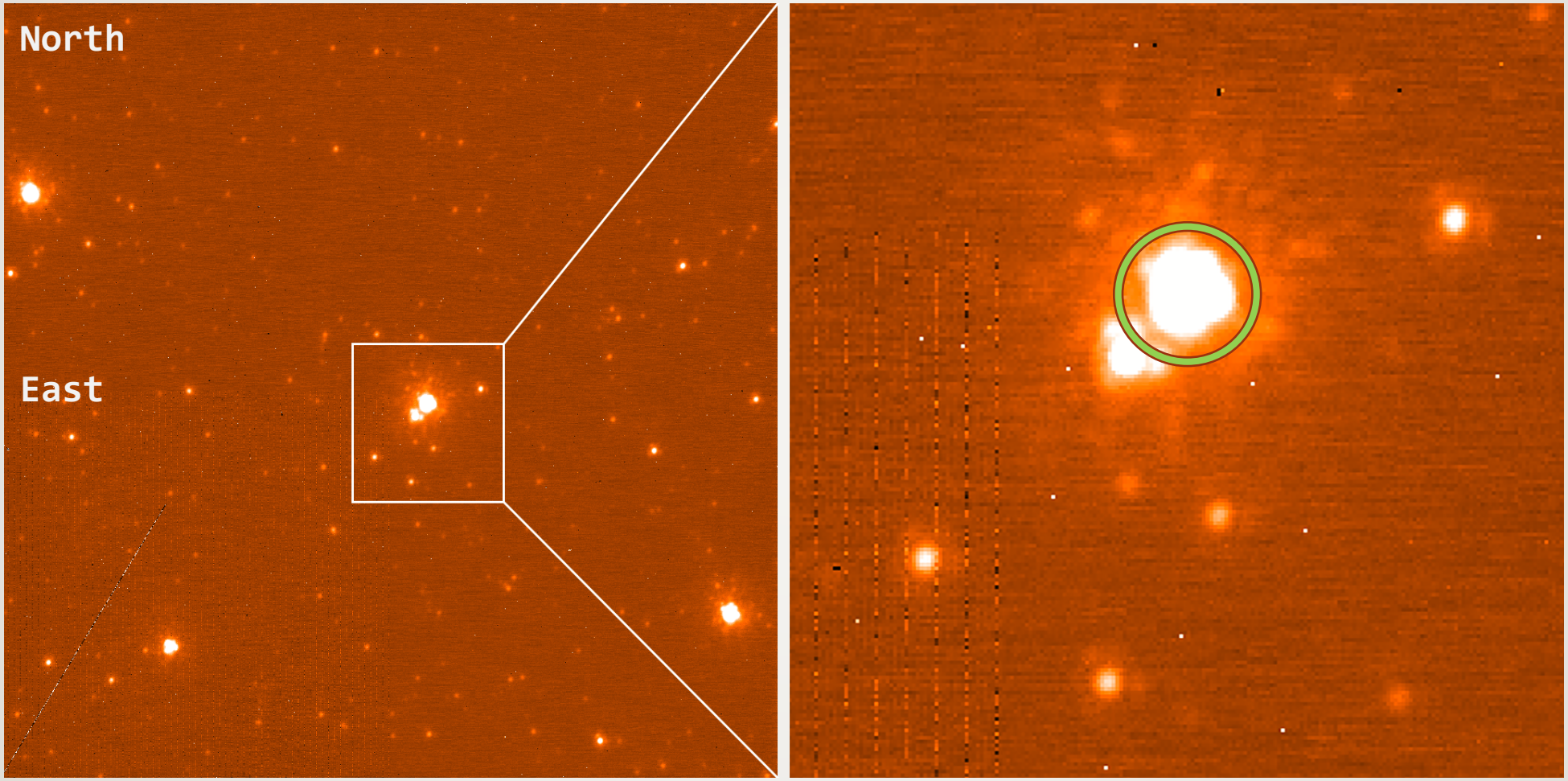
Keck Images



K-Band NIRC2 image, 10 arcsec
13 July 2013 (HJD = 2456487.291)

2 arcsec

Keck Images



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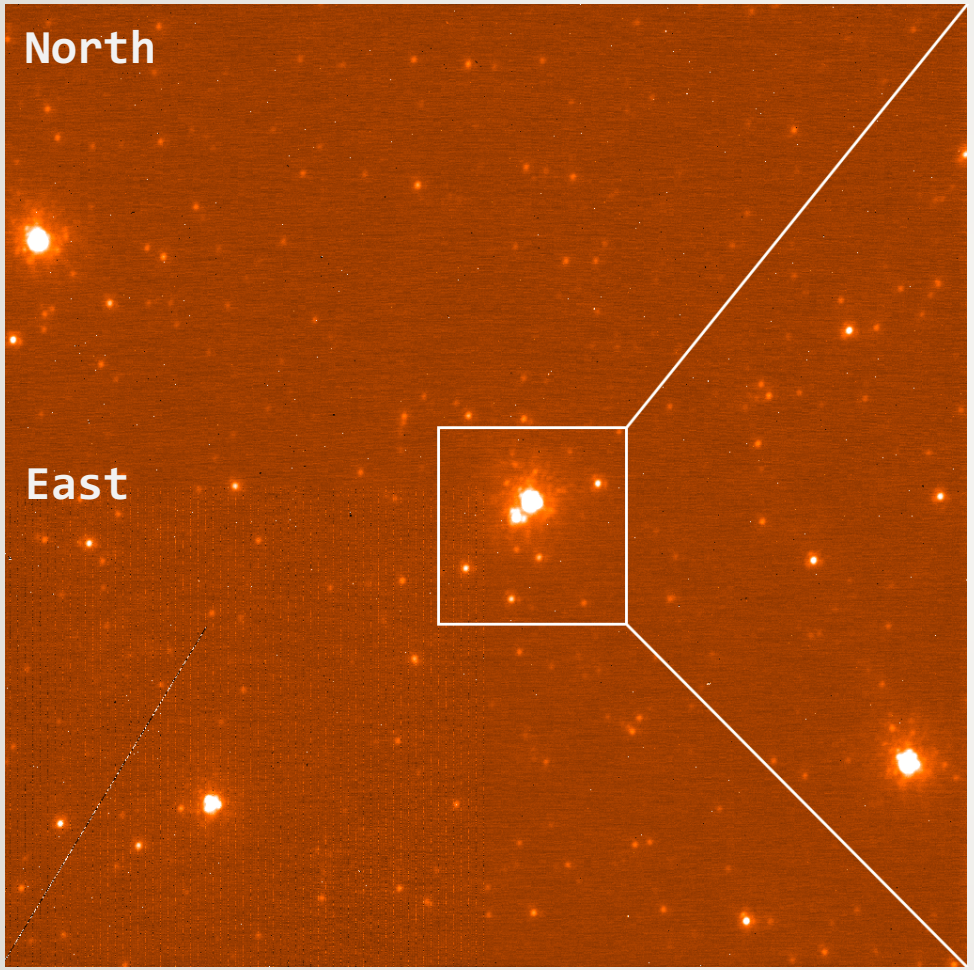

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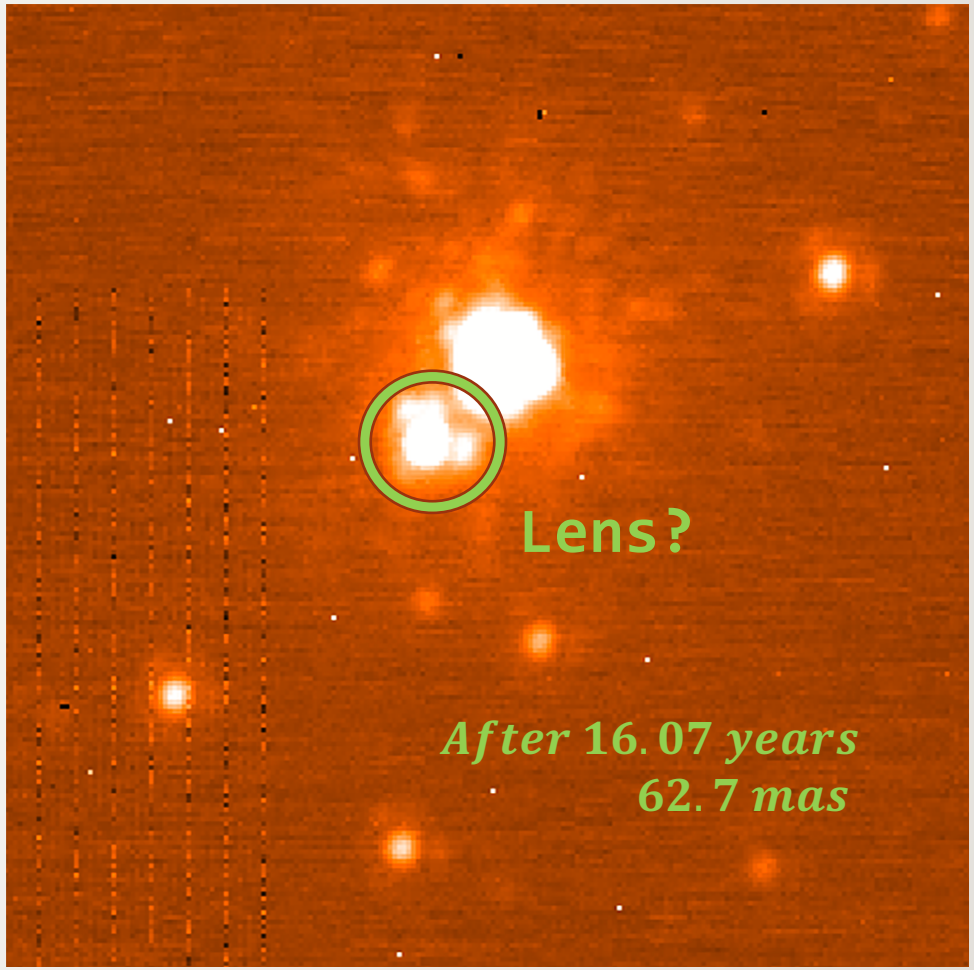
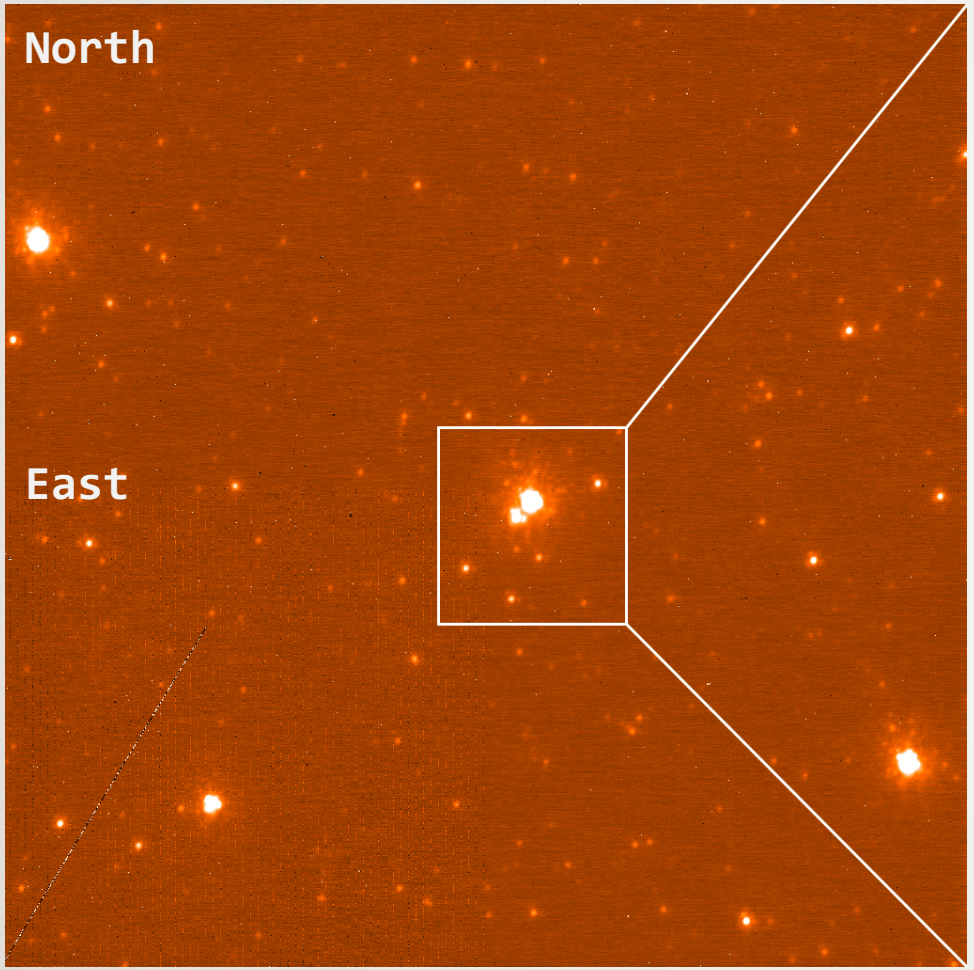


2 arcsec

Keck Images



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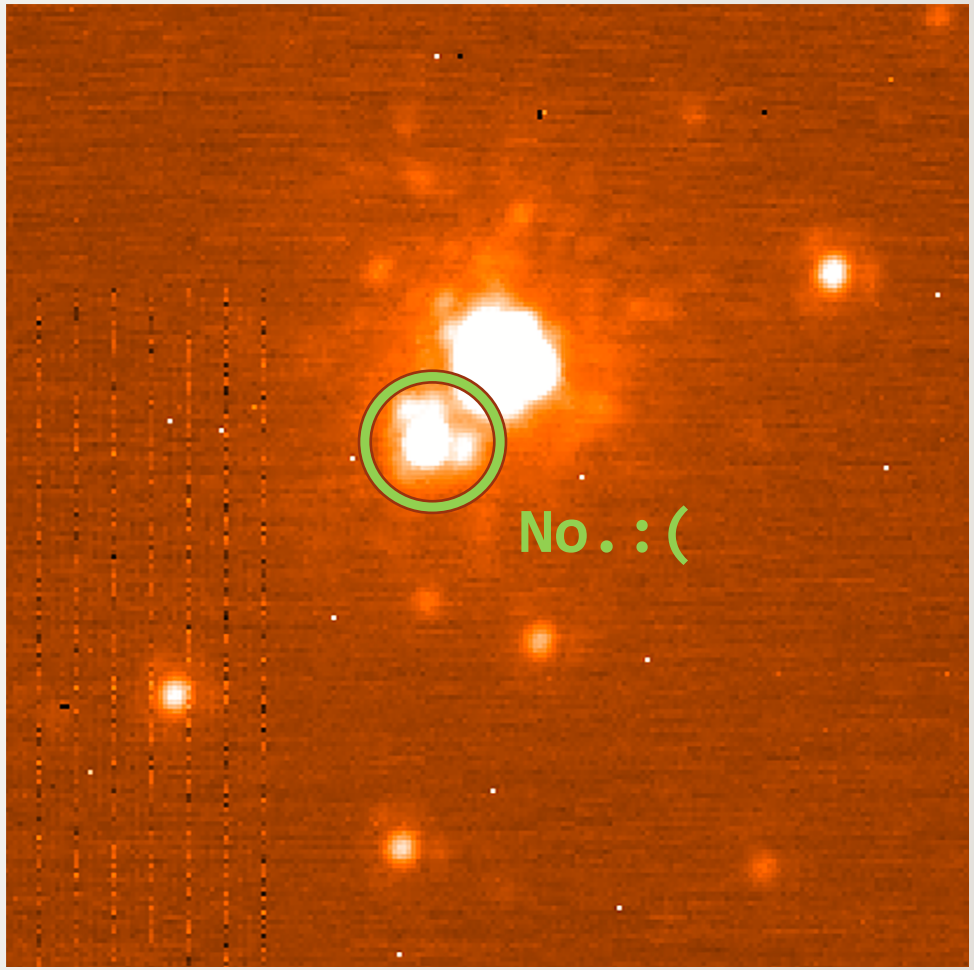

2 arcsec

AO Observations

- Images were reduced following the procedure in Beaulieu et al. (2016) and Batista et al. (2014).
- Tools: Sextractor | Topcat | Swarp | Gaia.
- VVV Catalog was used for astrometry. The object at the source position had magnitudes:

$$K_{Keck} = 12.86 \pm 0.05 \qquad J_{Keck} = 13.52 \pm 0.05$$

- Predicted source mag from fit is $K = 13.18$, which results in:

$$K_{lens} = 14.34 \pm 0.1$$

Done

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- Constrained source G4/G6 star, smaller than original paper
- Confirmed the geometry and model parameters with the addition of MSO R-band data
- Modelling implies Macho-97-BLG-28 is a binary – question still remains about size – for now.

To Do

- The blend is quite bright. We need to double check if this is from the lens, a companion to the source, or a companion to the lens (but not involved in the lensing).
- Plot mass-distance relation with Einstein ring and stellar isochrones constraints to determine the possible D_L. Maybe in the bulge
- Fit with galactic model to determine the physical parameters of the system