

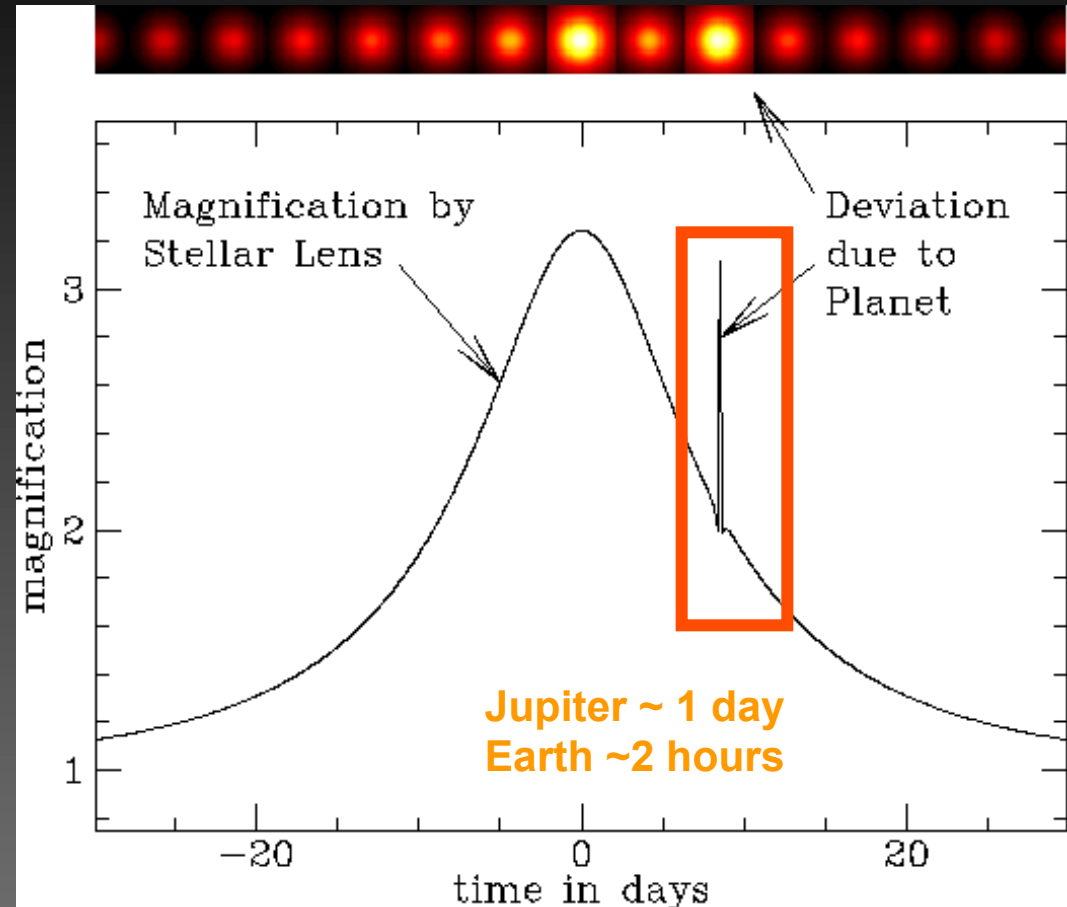
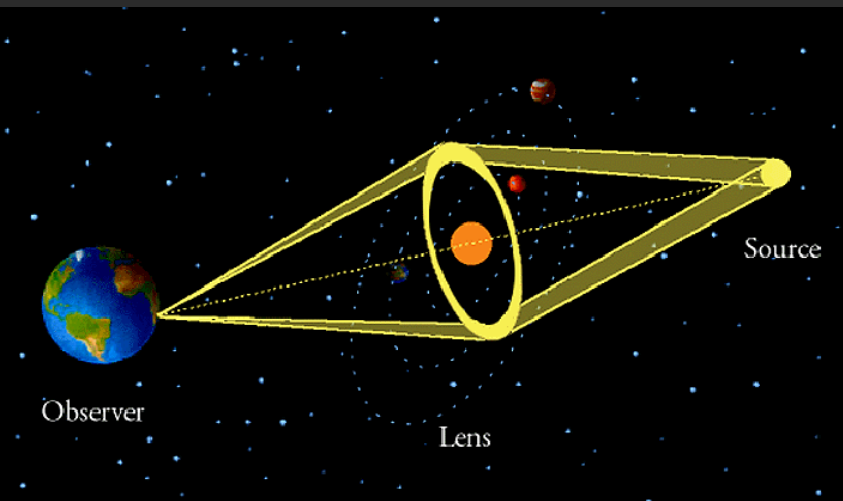
EUCLID microlensing planet hunting

A/ EUCLID microlensing survey yields
B/ Using ground-space parallax.

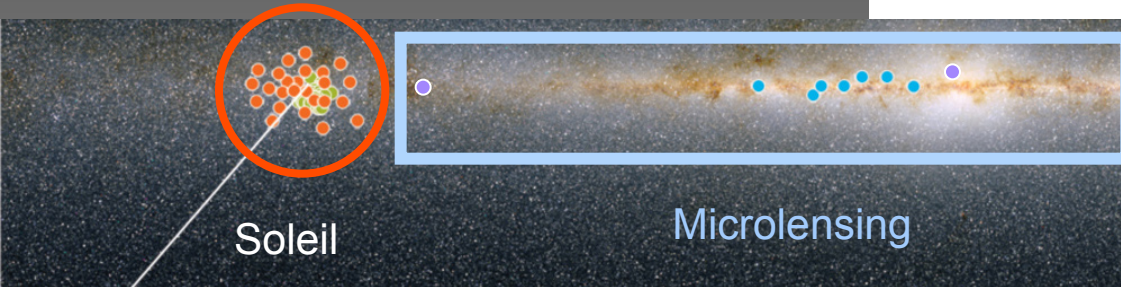
Jean-Philippe Beaulieu,
Institut d'Astrophysique de paris,

In collaboration with E. Kerins, M. Zapatero, V. Batista, , A. Cassan, P. Tisserand,
P. Fouqué, M. Penny, C. Coutures, J.B. Marquette, and the
EUCLID Science Working Group on exoplanets

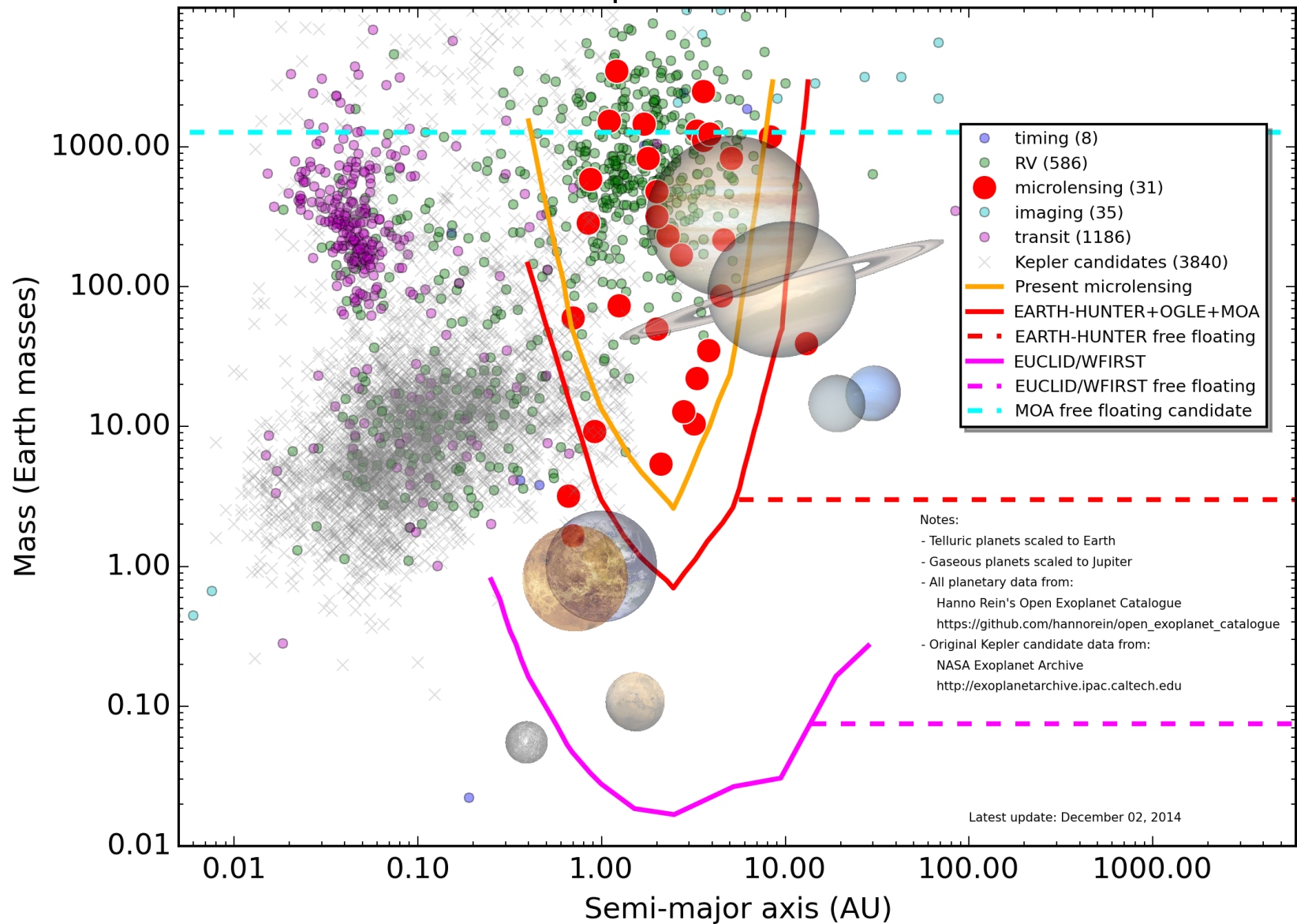
How to detect a planet via microlensing



Radial velocities & Transit



Exoplanet discoveries



Astro-2010 Decadal Survey

“The Kepler satellite ... should be capable of detecting Earth-size planets out to almost Earth-like orbits.”

“As microlensing is sensitive to planets of all masses having orbits larger than about half of Earth’s, WFIRST would be able to complement and complete the statistical task underway with Kepler, resulting in an unbiased survey of the properties of distant planetary systems.”

EUCLID 2020

WFIRST 2025+



Microlensing already in DUNE proposal Legacy science in 2007...

EUCLID microlensing

Telescope parameters

| | |
|------------------------|---------|
| Diameter (m) | 1.2 |
| Central blockage (m) | 0.4 |
| Slew + settle time (s) | 85(285) |

Detector parameters

| Instrument | VIS | | NISP | |
|--|----------------------|-------------------|--------------------|-------------------|
| Filter | <i>RIZ</i> | <i>Y</i> | <i>J</i> | <i>H</i> |
| Size (pixels) | 24k × 24k | | 8k × 8k | |
| Pixel scale (arcsec) | 0.1 | | 0.3 | |
| PSF FWHM (arcsec) | 0.18 | 0.3* | 0.36* | 0.45* |
| Bias level (e ⁻) | 380 [†] | | 380 [†] | |
| Full well depth (e ⁻) | 2 ¹⁶ | | 2 ¹⁶ | |
| Zero-point (ABmag) | 25.58* | 24.25** | 24.29** | 24.92** |
| Readout noise (e ⁻) | 4.5 | 7.5* | 7.5* | 9.1* |
| Thermal background (e ⁻ s ⁻¹) | 0 | 0.26 | 0.02 | 0.02 |
| Dark current (e ⁻ s ⁻¹) | 0.00056 [◇] | | 0.1* | |
| Systematic error | 0.001 [†] | | 0.001 [†] | |
| Diffuse background (ABmag arcsec ⁻²) | 21.5 [‡] | 21.3 [‡] | 21.3 [‡] | 21.4 [‡] |
| Exposure time (s) | 540(270) | 90 | 90 | 54 |
| Images per stack | 1 | 3(1) | 3(1) | 5(2) |
| Readout time (s) | < 85 | | 5 [†] | |

Besançon model

Microlensing simulator
3 fields, 270 sec per pointing,
5x2 months observing

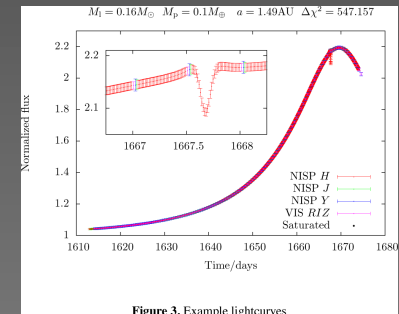
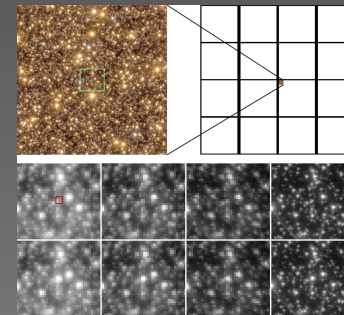


Figure 3. Example lightcurves

Penny, Kerins, Rattenbury, Beaulieu, et al., 2014, MNRAS
PhD Matthew Penny

ExELS

Approx location of
3 ExELS fields

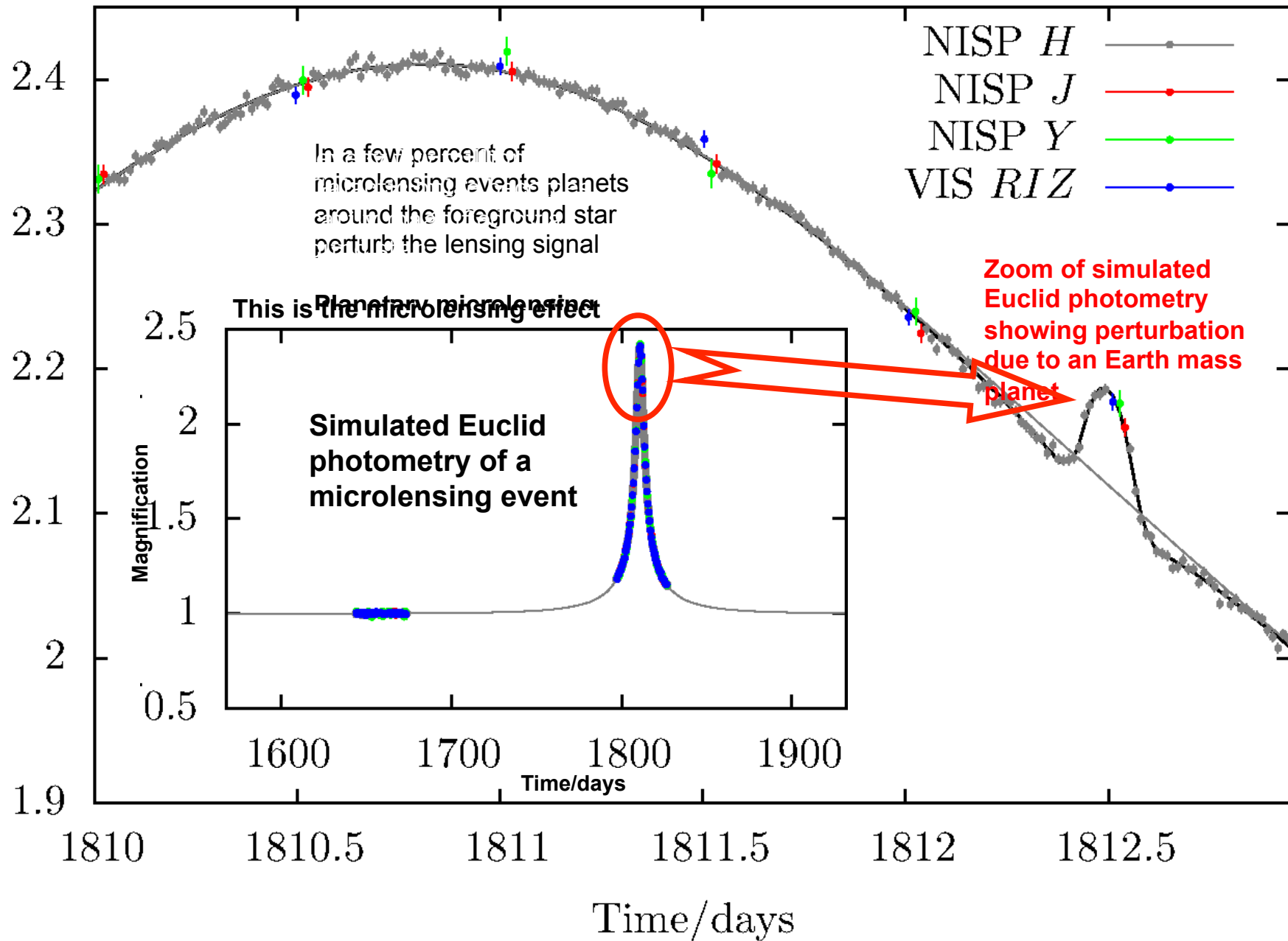


Simulated Euclid H band image
from a single 2k x 2k NISP array

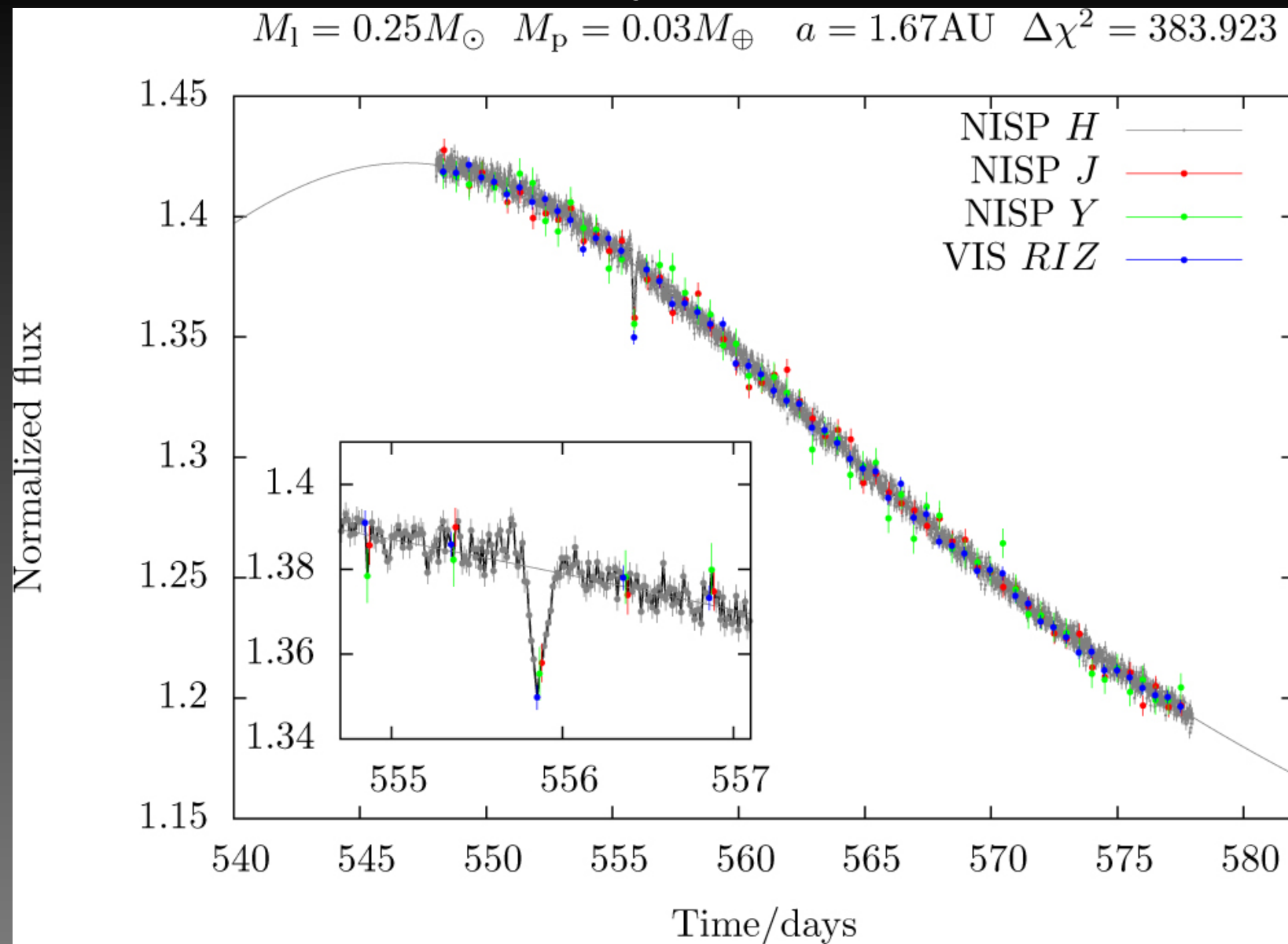
Detailed image-level simulation of ExELS
photometry carried out by SWG (Penny et al
2013)

$$M_1 = 0.86 M_\odot \quad M_p = 1 M_\oplus \quad a = 2.4 \text{ AU} \quad \Delta\chi^2 = 1526.96$$

Normalized flux

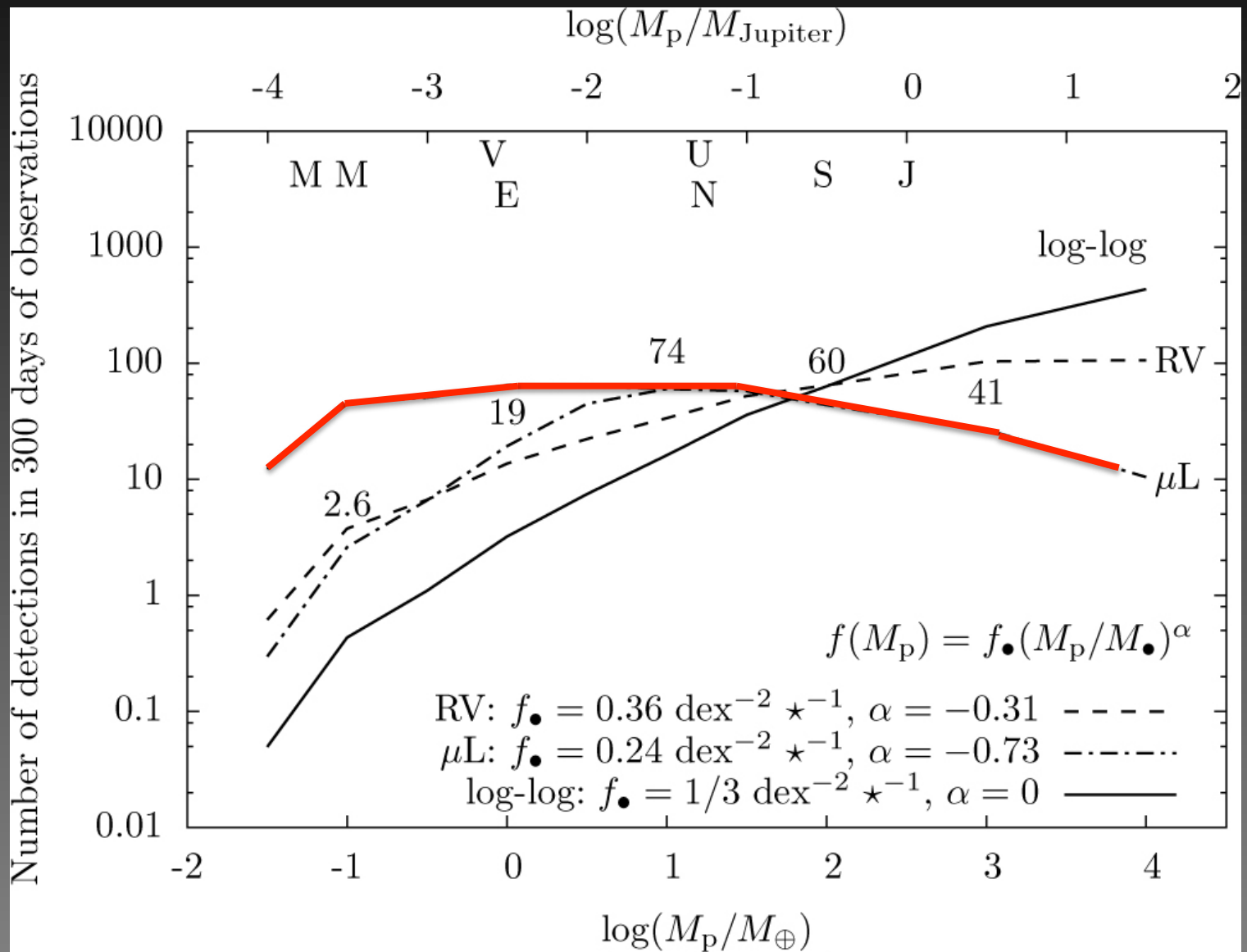


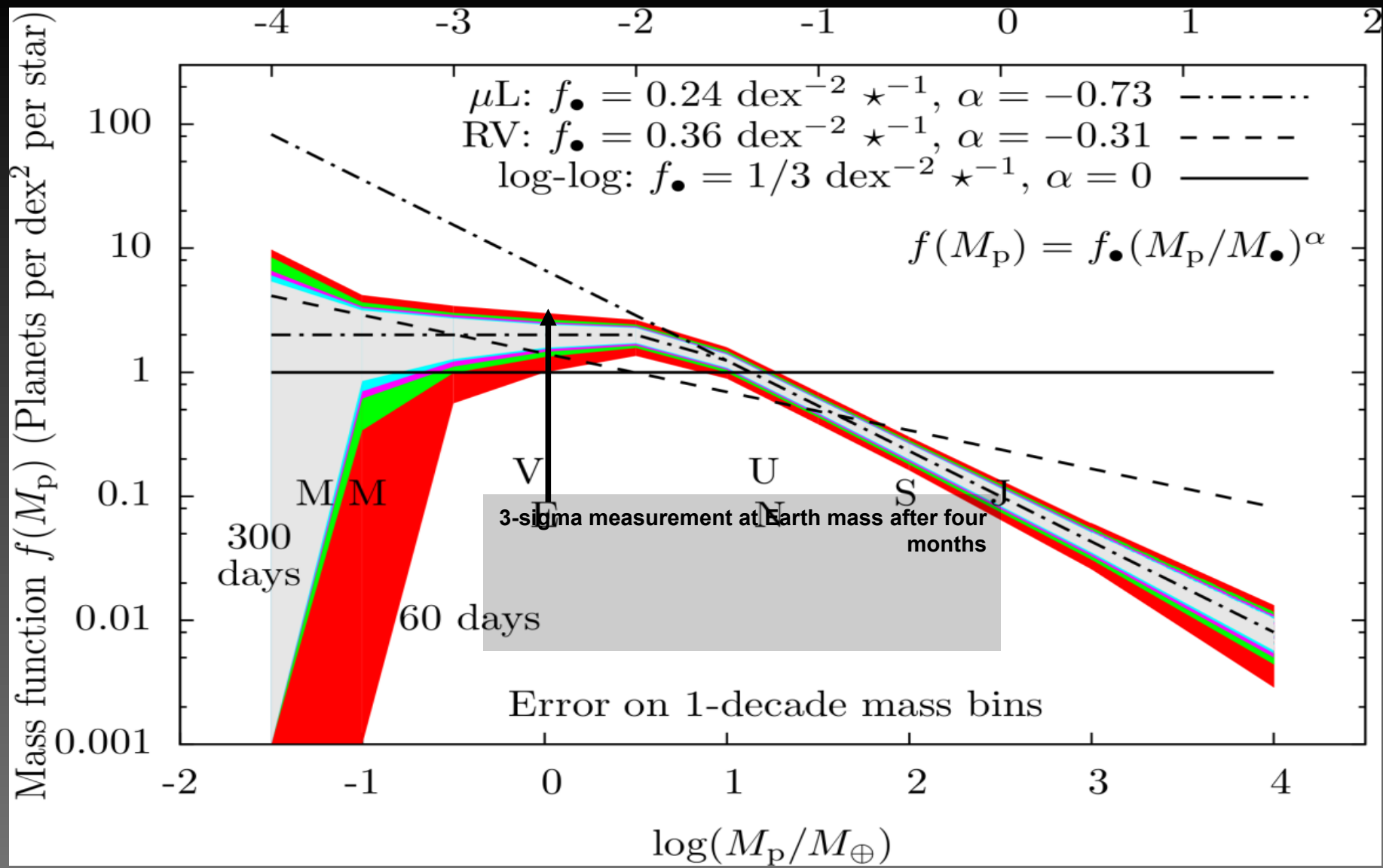
EUCLID will detect very low mass planets



(d)

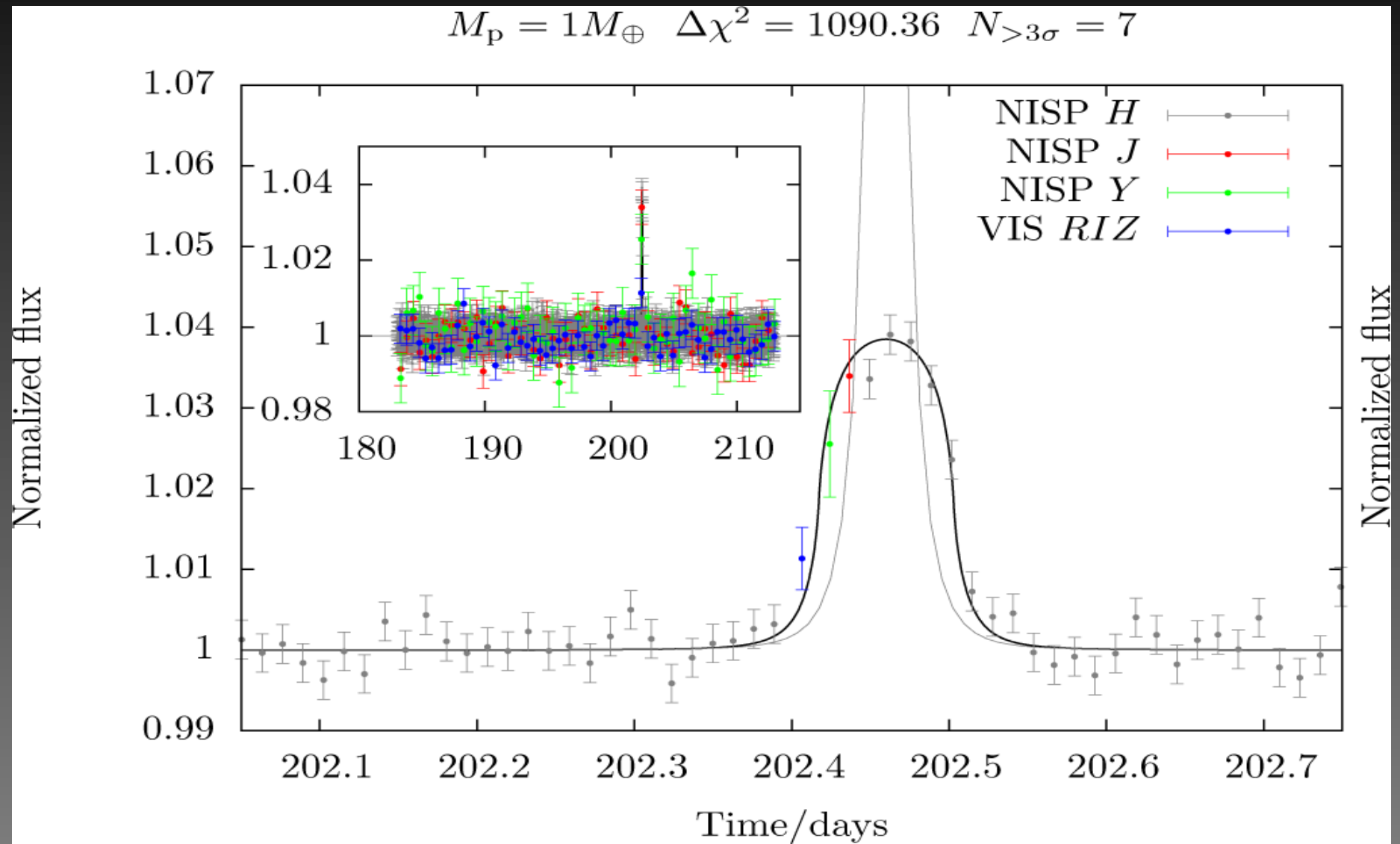
EUCLID's planet catch



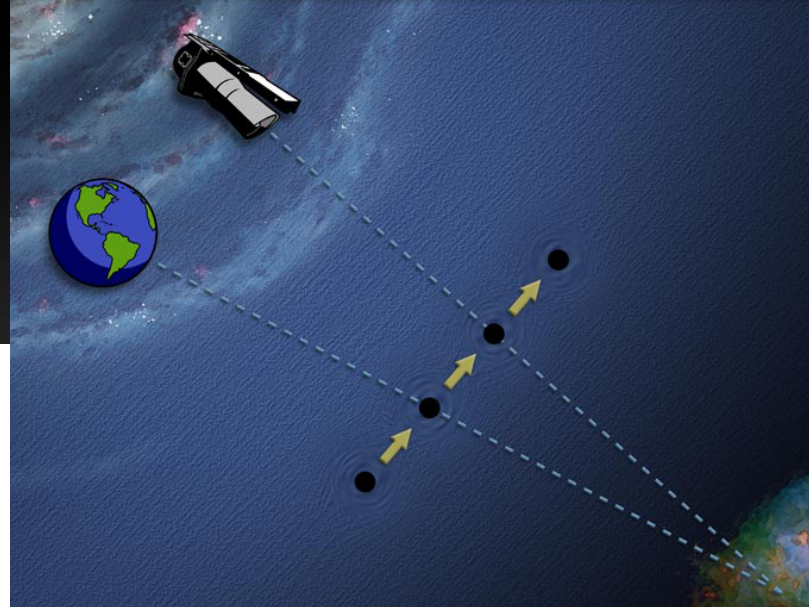
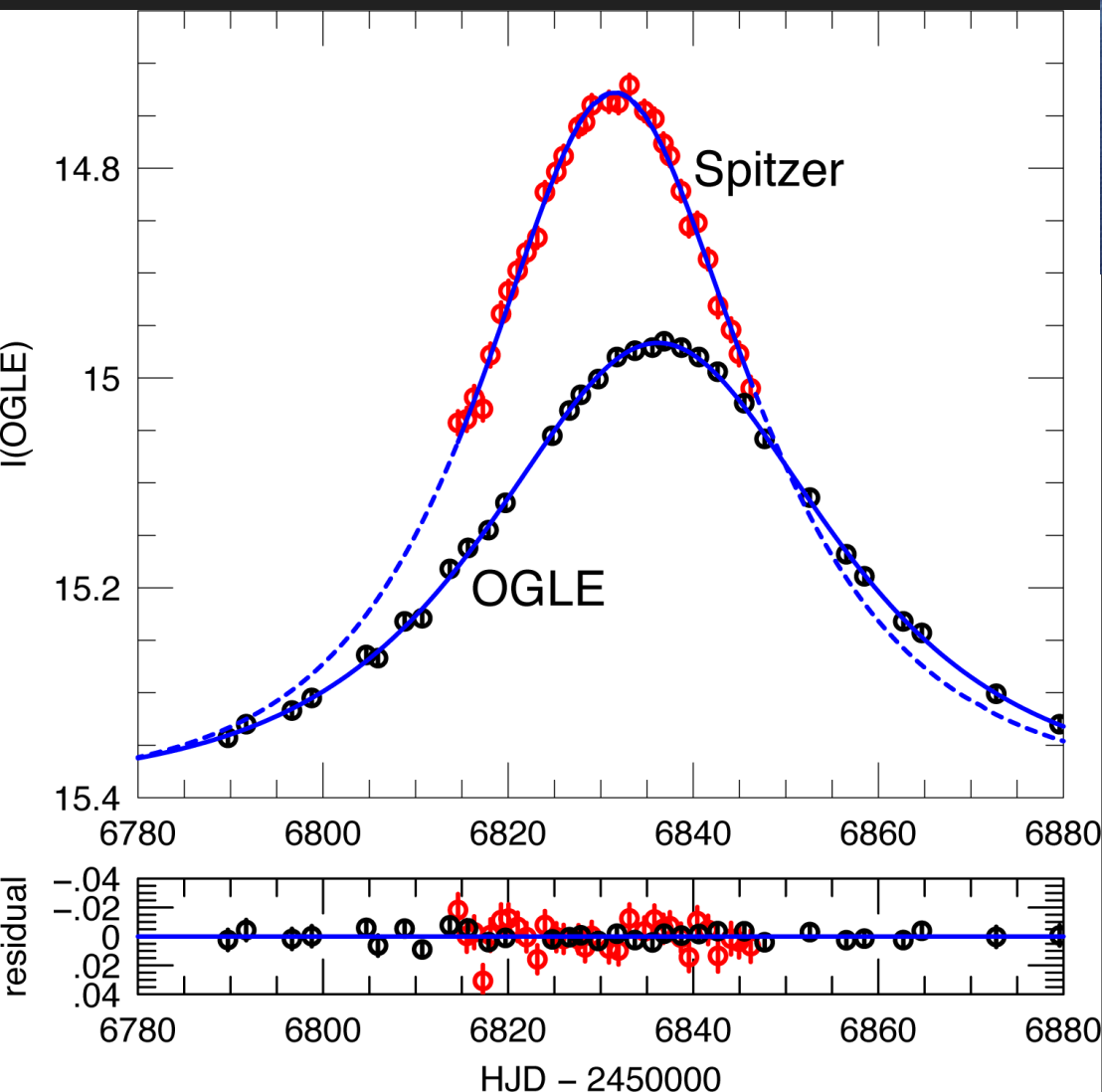


Abundance measurement sensitivity versus planet mass for different extrapolations of measured exoplanet mass functions and survey lifetimes

Free floating planets



Parallax Ground-Space



Spitzer at 1 AU from us

We can measure the mass
And distance of the lens.

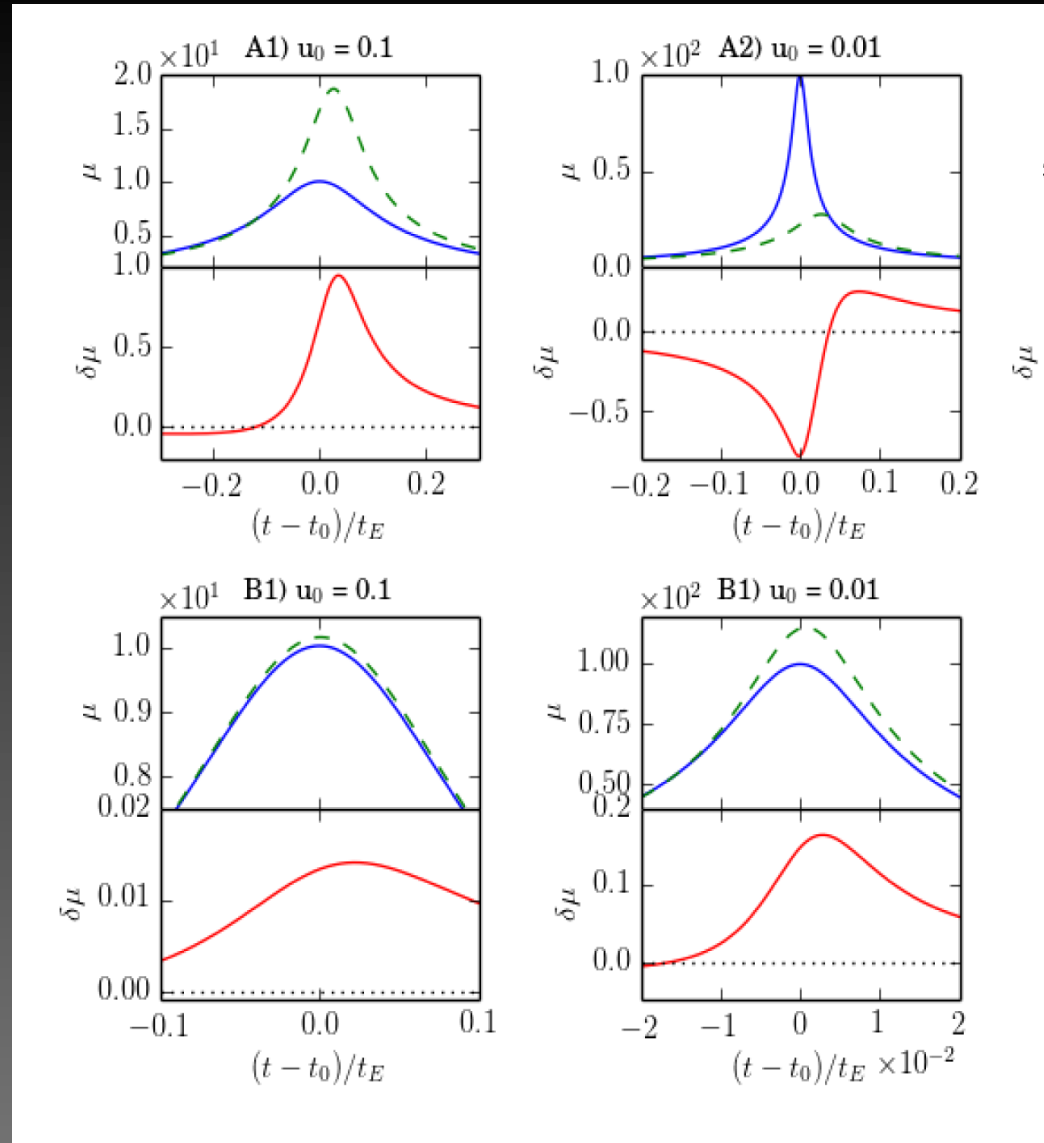
Yee et al., 2014, *astroph*

Ground-space parallax (EUCLID + VISTA)

Mogavero & Beaulieu, 2014, in prep

Jupiter at 500 pc

Brown dwarf at 4 kpc



In a significant number of cases, we will get masses directly !

Microlensing program on board the EUCLID Dark Universe Probe

- Measuring cold Earth abundance and mass function with 4 months of survey
- Getting free floating planets down to the mass of Earth
- Habitable Earth around G stars would require larger survey (300+ days, WFIRST)
- EUCLID/ML complements parameter space probed by RV and KEPLER
- Currently in additional science. Decision in 2015
- EUCLID understood the excellent synergy cosmic shear/microlensing requirements

Penny et al., 2014, MNRAS, « ExELS: an exoplanet legacy science proposal for the ESA Euclid mission I. Cold exoplanets

Beaulieu et al., 2010, “EUCLID : Dark Universe Probe and Microlensing planet Hunter”, arXiv:1001.3349

Conclusion, 2 major science results with 4 months of EUCLID

I/ Cold planet mass function down to the mass of the Mars.

~35 planets / month (5 Earth / month, 15 Neptune / month)

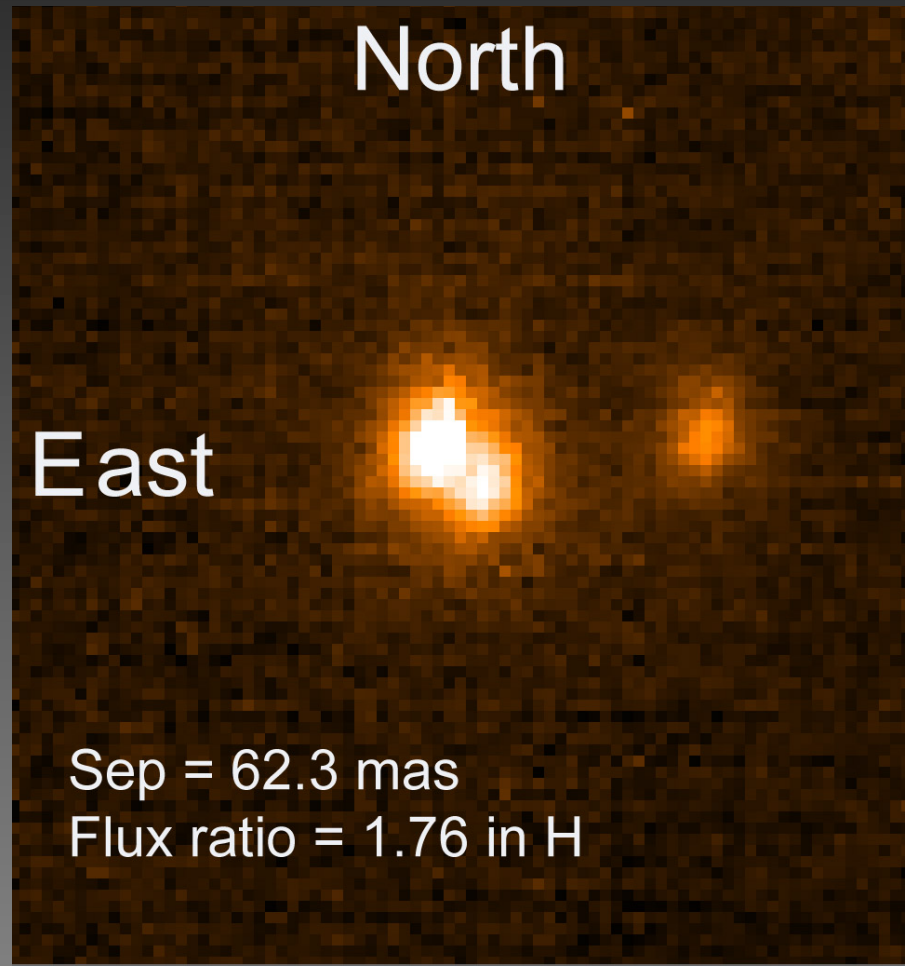
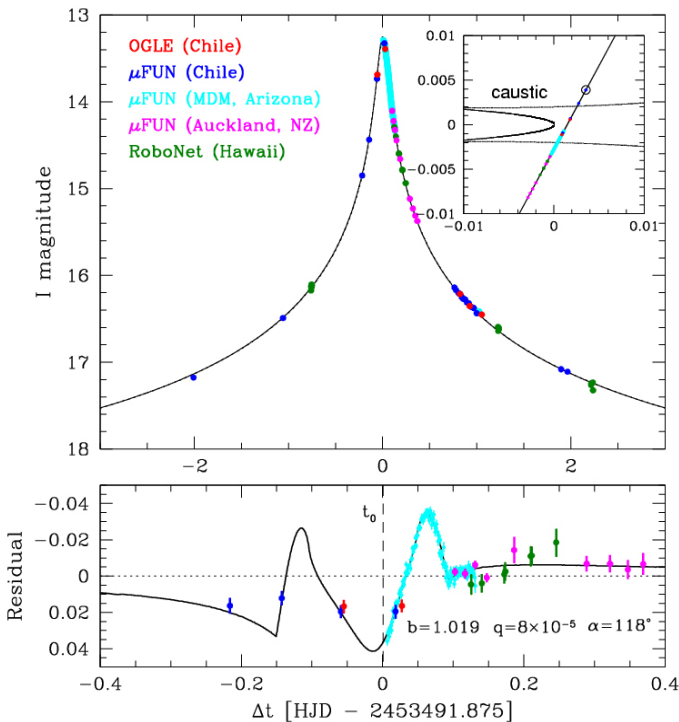
II/ Abundance of free floating planets down to the mass of Earth

~15 free-floating planets / month

WFIRST will do it, so let's do it before them !

OGLE-2005-BLG-169Lb : a $\sim 13 M_{\oplus}$ planet

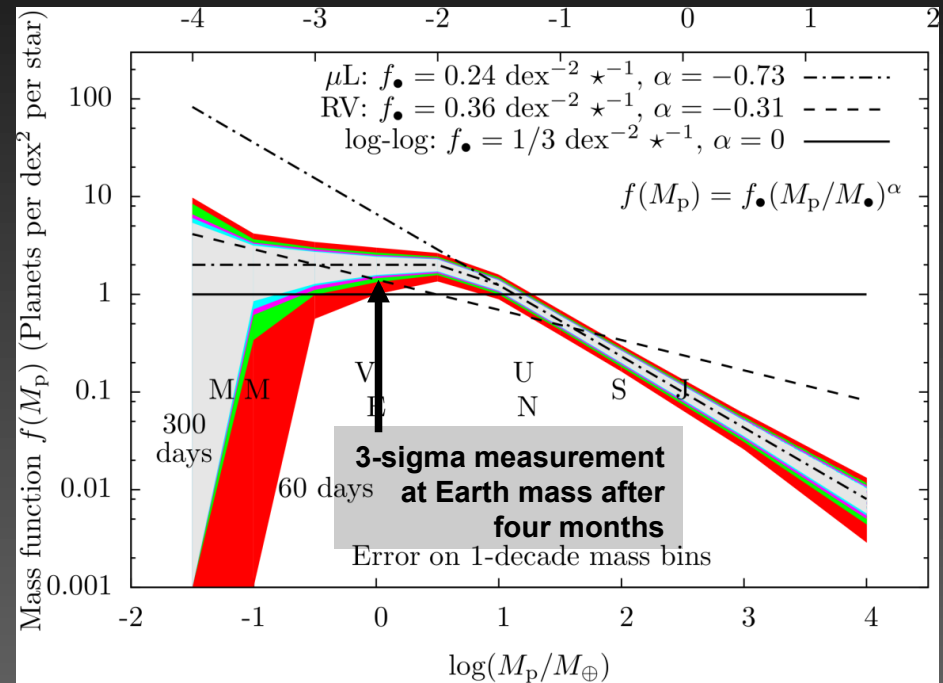
With KECK, detecting the lens in 2013
Measuring proper motion



Sep = 62.3 mas
Flux ratio = 1.76 in H

Survey constraints

- Observability of the Gal Centre limited by design of Sun shield and the constraint on Solar aspect angle. This fixes the times when the bulge is observable with Euclid. ExELS could get squeezed if these times are used up for primary science calibration or other surveys.
- Current simulations based on Red Book Euclid design indicates that ExELS requires 4 months of observing time in order to achieve the primary science objective of measuring the abundance of cold Earth mass planets with at least 3-sigma precision.



Abundance measurement sensitivity versus planet mass for different extrapolations of measured exoplanet mass functions and survey lifetimes