The WFIRST Exoplanet Microlensing Survey

VST in the era of the large sky surveys
5-8 June 2018
INAF – Osservatorio Astronomico di Capodimonte

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Caltech/IPAC

thanks to the WFIRST MicroSIT (PI: S. Gaudi), in particular to M. Penny

Layout

- Wide Field Infrared Survey Telescope, a NASA flagship mission
  - ✓ Timeline
  - ✓ Science
  - ✓ The mission
- Gravitational microlensing and exoplanets
- The WFIRST microlensing survey
  - ✓ Physics of (bound) Planets Beyond the Snow Line
  - ✓ Free floating planets
- VST: WFIRST microlensing survey concurrent ground-base observations

WFIRST - Timeline

- ✓ 2010: Decadal Survey top ranked recommendation
- ✓ 2011-2012: Initial designs (1.1m-1.5m: Green et al, 2011, 2012)
- ✓ 2012: 2.4-m telescope WFIRST-AFTA (Dressler et al 2012, Spergel et al, 2013, 2015)
- ✓ February 2016: Phase A – Mission Concept Technology Development
- ✓ May 2018: Phase B – Preliminary Design & Technology Completion
- mid-2020: launch

WFIRST - Science

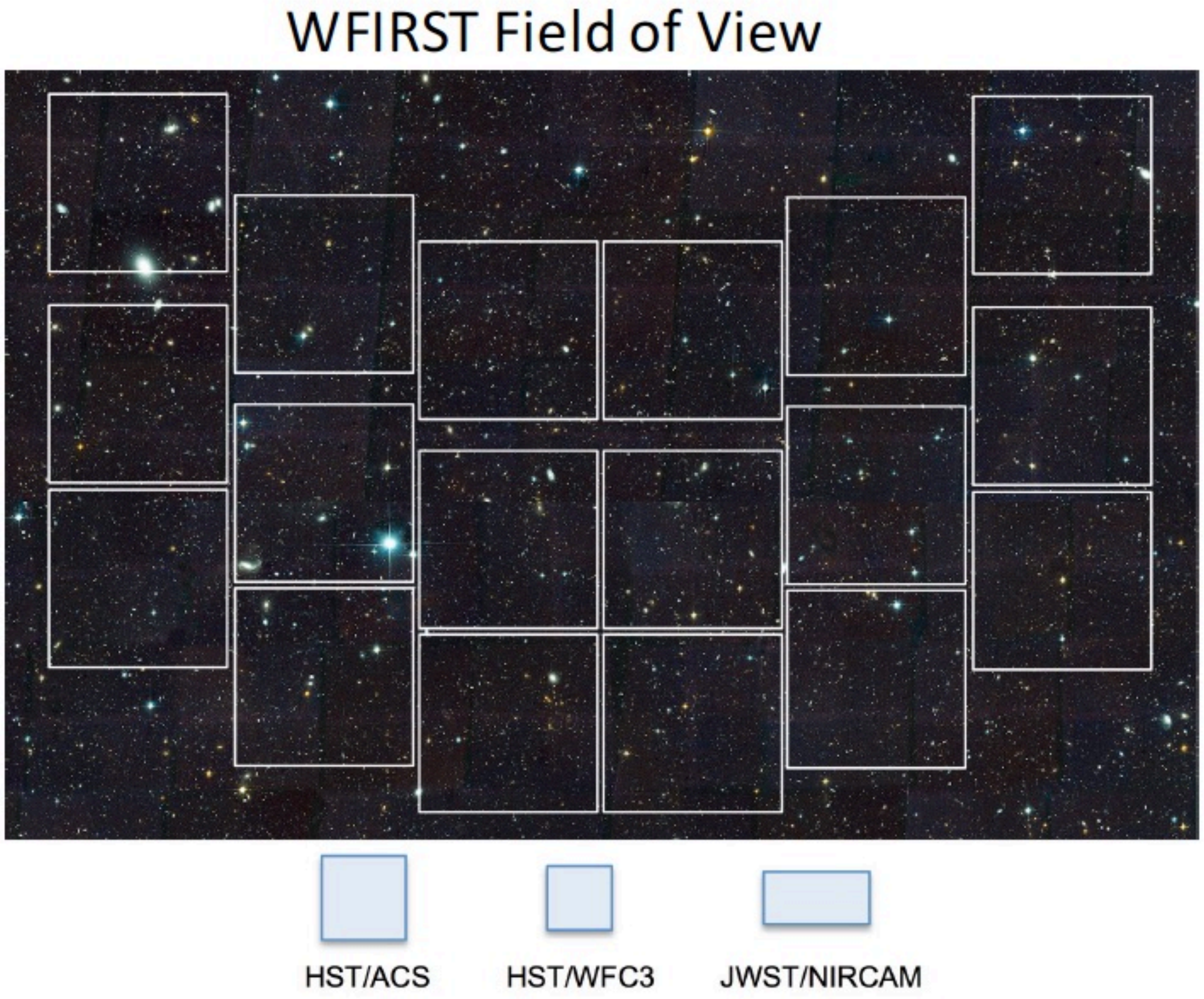
- Dark Energy Program (JDEM-OMEGA, *Gehrels, 2010)*
  - Baryonic acoustic oscillations
  - Cosmic shear and Weak lensing of galaxies
  - Type Ia supernovae
- Near Infrared Sky Survey (*Stern et al 2010*)
- Exoplanets
  - **Microlensing survey** (MPF, *Bennet et al 2010)*
  - CGI characterization of nearby exoplanets
- Guest Observer Program

Spergel et al, 2015

WFIRST – The mission

- Telescope: 2.4m aperture
- Instruments:
  - Wide Field Imager/Grism
  - Internal Coronagraph
- Orbit: Sun-Earth L2
- 5 years primary mission
- Starshade compatible

WFIRST – The Wide Field Instrument



Imaging

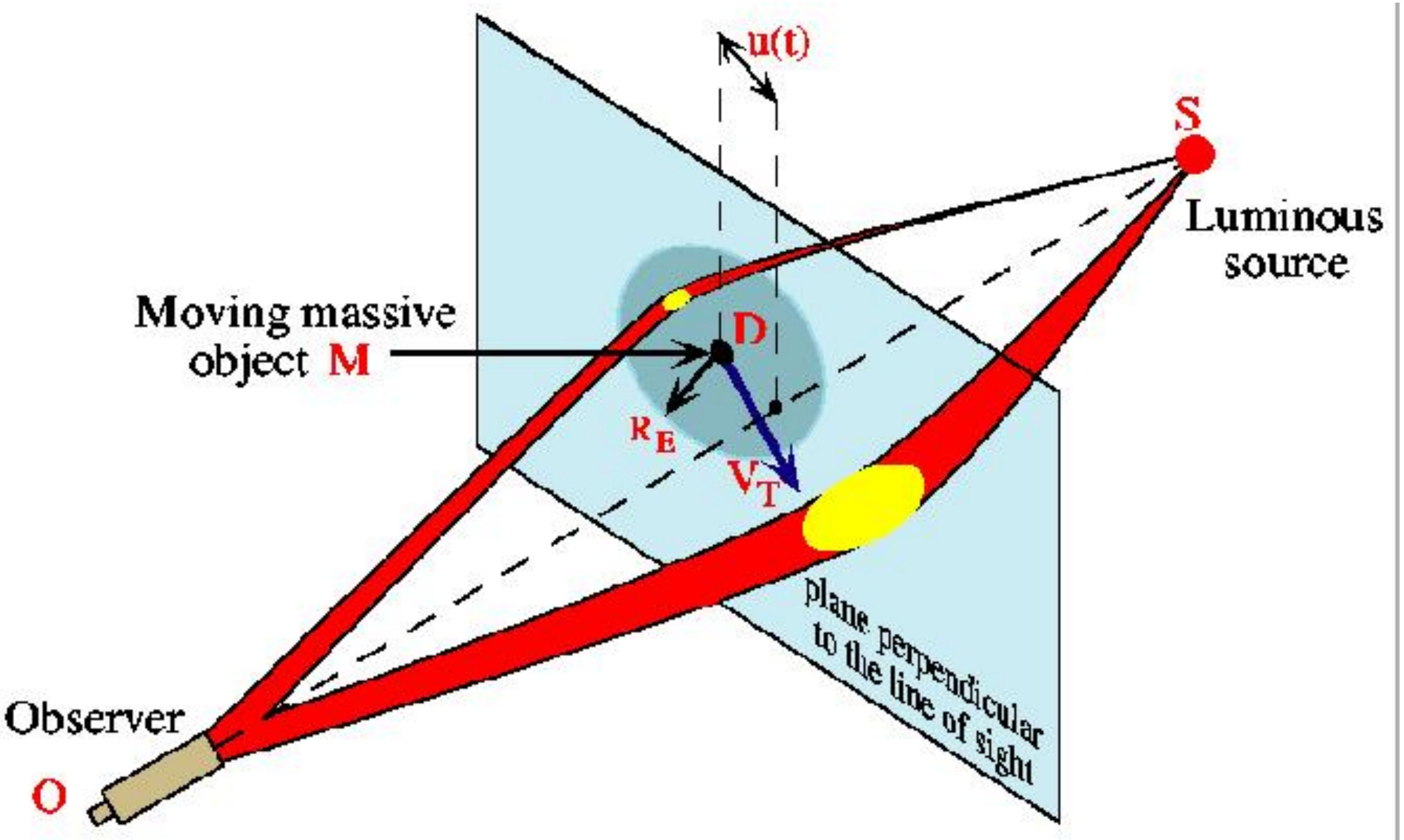
- ❖ 0.76-2.0 μm
- ❖ 18 4k x 4k HgCdTe detectors
- ❖ 10 μm pixels - 0.11” pixel scale
- ❖ 0.281 square degree active area

Slitless Grism

- ❖ 1.0-1.93 μm
- ❖ R: 435-865

Gravitational Microlensing

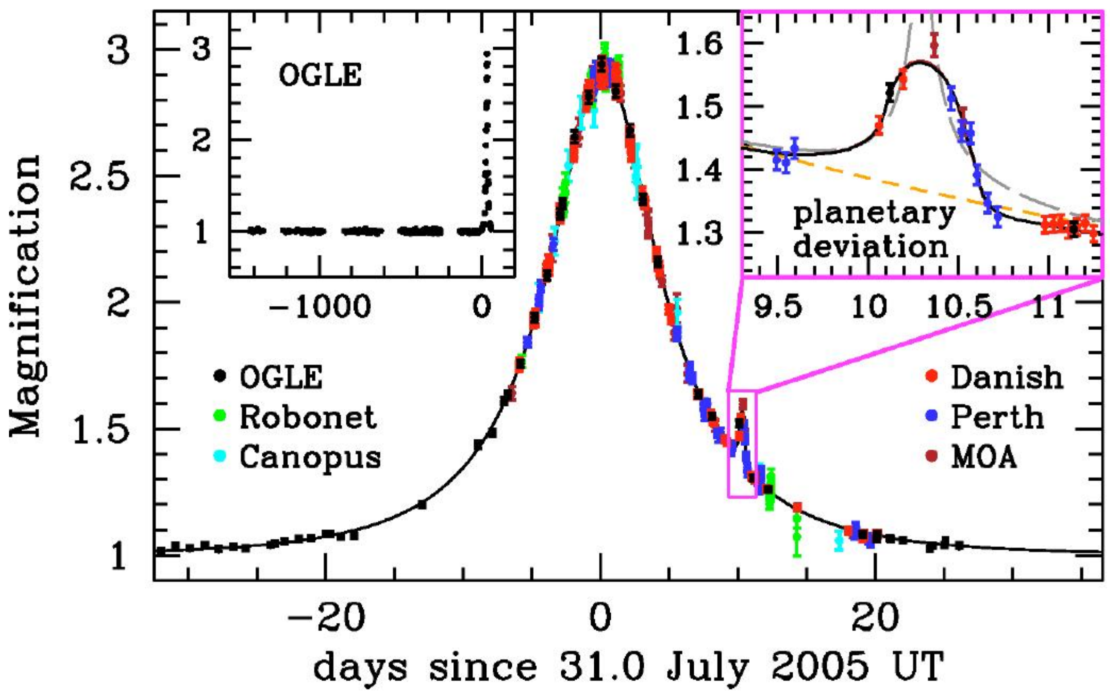
Gravitational deflection of light: for sources in the Bulge, image separation of order few mas



Transient source's brightening, duration $\propto \sqrt{lens\ mass}$

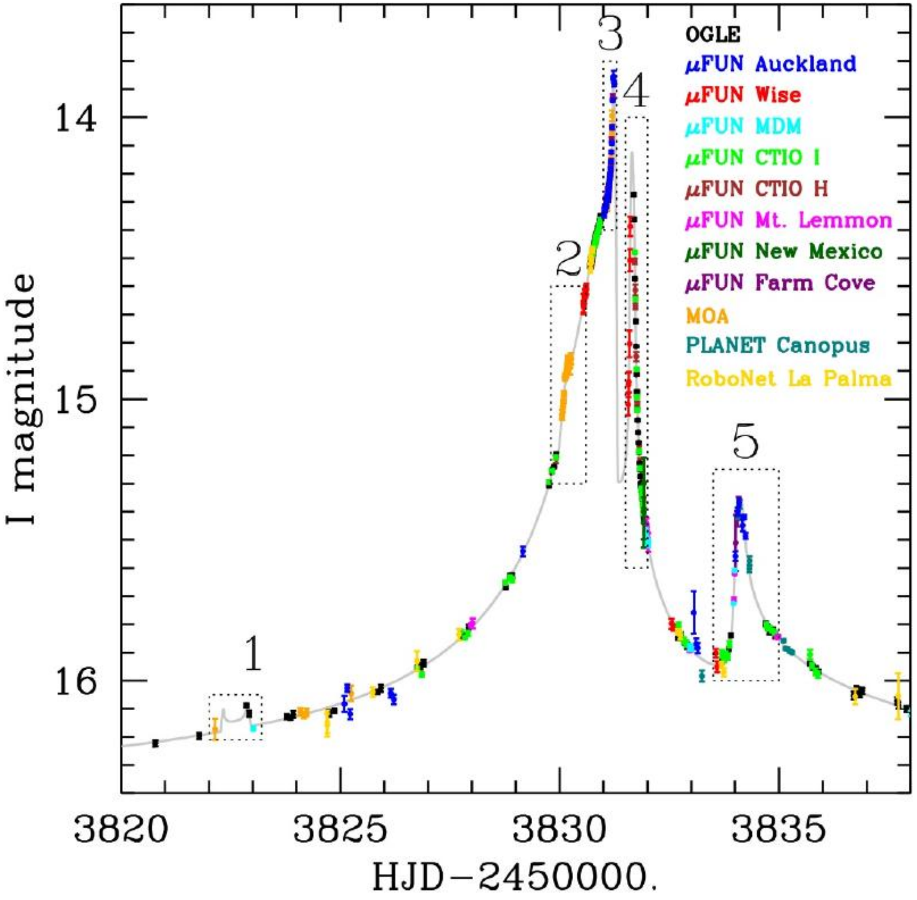
Microlensing exoplanet signal

Anomaly characterization ⇨ Microlensing parameters ⇨ Physical parameters



Beaulieu et al, Nature 2006

A 5.5 Earth mass planet orbiting a 0.2 M-dwarf, With about 3 AU separation, at 7 kpc

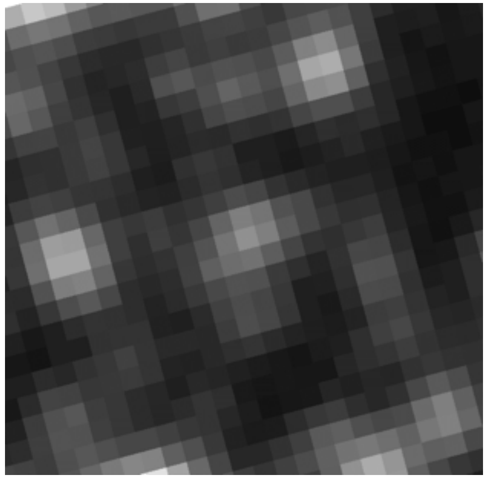


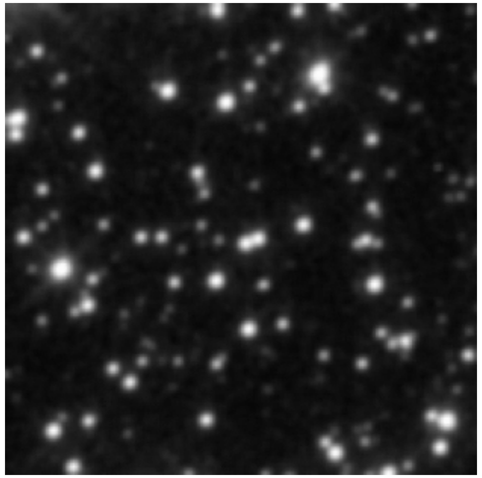
Gaudi et al, Science 2008

A Jupiter-Saturn analog around a 0.5 M-dwarf at 1.5 kpc

Microlensing Survey: Ground vs Space

Down to Earth mass planets and below: need to resolve main sequence sources in the Bulge



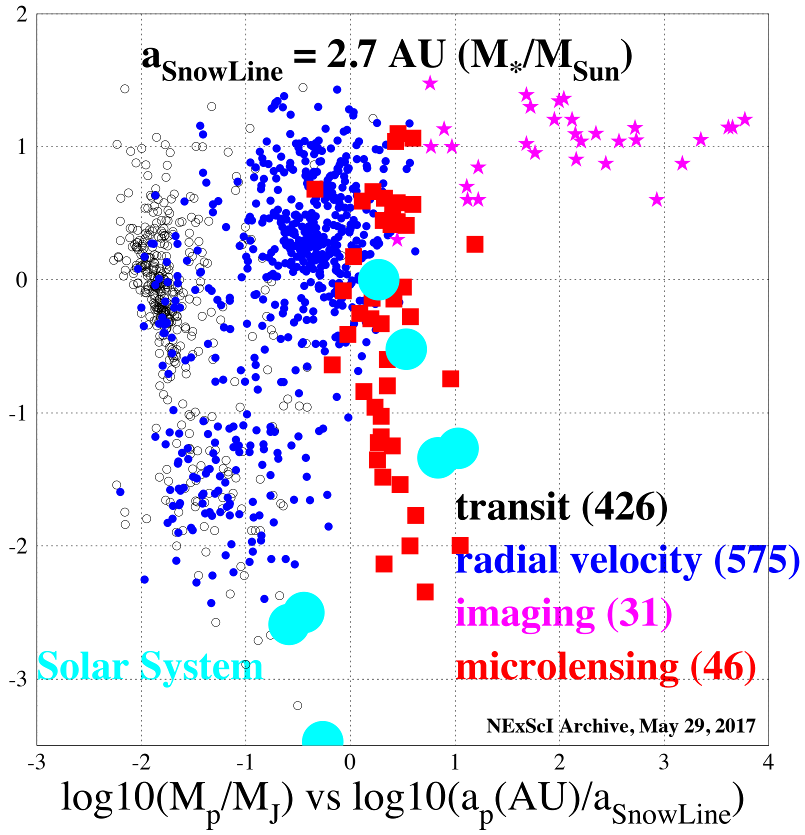


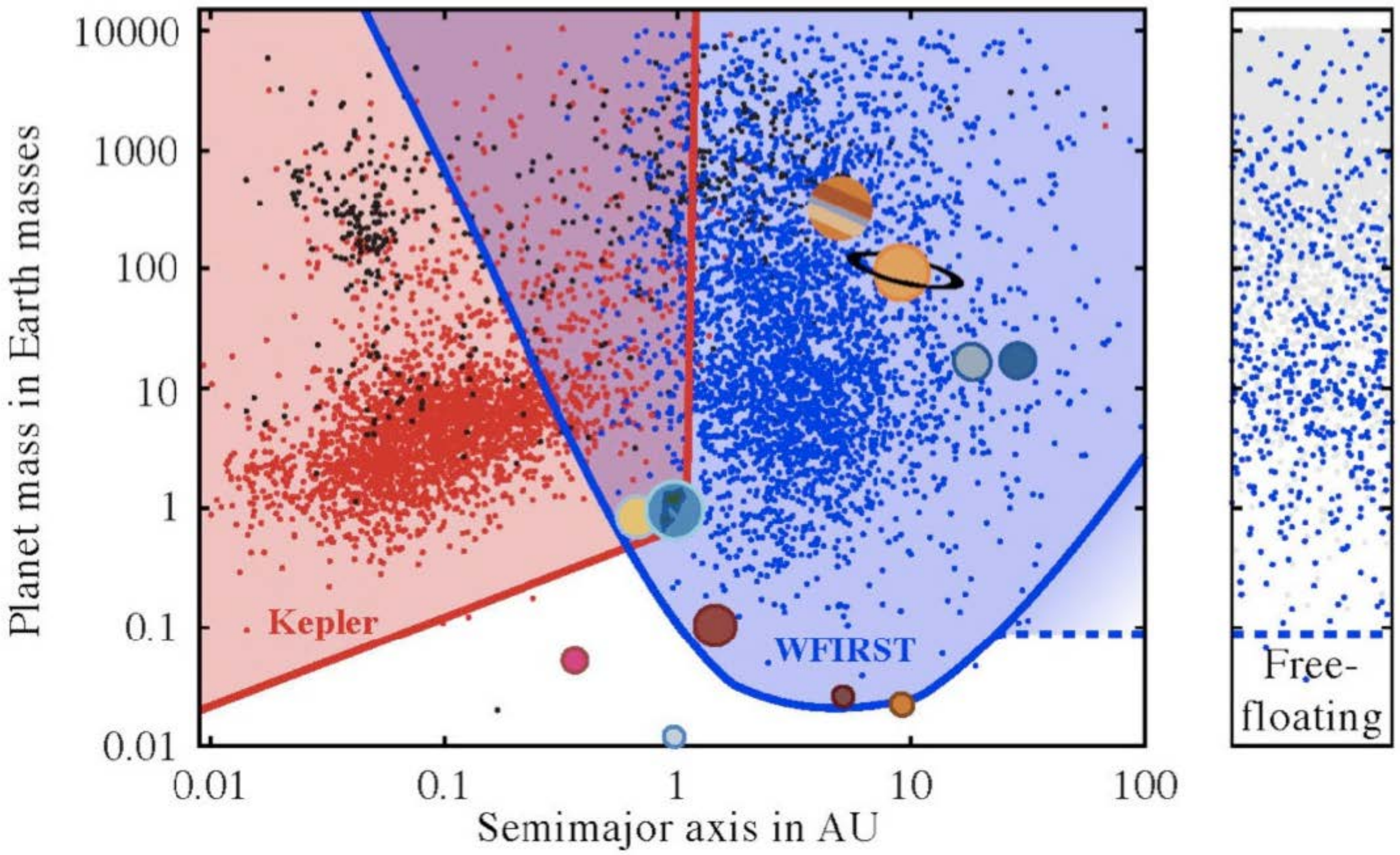
The field of microlensing event MACHO-96-BLG-5 (Bennett & Rhie, 2002)

- ✓ Continous monitoring $\sim 10^8$ Bulge stars
- ✓ Relative photometry few %
- ✓ Stable conditions / Control of the systematics
- ✓ Resolve main sequence source stars: beat finite source size effect for the detection of small mass planets
- ✓ Infrared observations: monitoring dense highly extincted region towards the Bulge
- ✓ Resolution: isolate light from the lens star for primary mass determination
- ✓ Astrometry: relative lens-source proper motion
- ✓ Astrometry: astrometric microlensing ?

The WFIRST Microlensing Survey

Physics of Planets Beyond the Snow Line





Penny et al, in prep

The WFIRST Microlensing Survey-II

Layout

- ❑ Area 1.96 square degree
- ❑ Baseline 4.5 years
- ❑ Season 6 x 72 days
- ❑ W149 15 min cadence
- ❑ W149 $\sim$41,000 images/field
- ❑ Z087 $\lesssim$12 hours

Expected signal

- ❖ Microlensing events $|u_0| < 1$ $\sim$27,000
- ❖ Microlensing events $|u_0| < 3$ $\sim$54,000
- ❖ Planet detections $(0.1 - 10^4 M_\oplus)$ $\sim 1,400$
- ❖ Planet detection $(< 3\ M_\oplus)$ $\sim$200
- ❖ **Free-floating planets (~ hundreds)**

Planet characterization: from Microlensing to physical parameters

- Finite source size
- Orbital parallax
- Motion relative to the source
- Lens flux
- Color-dependent centroid shifts
- **Space-based Earth-L2 parallax**

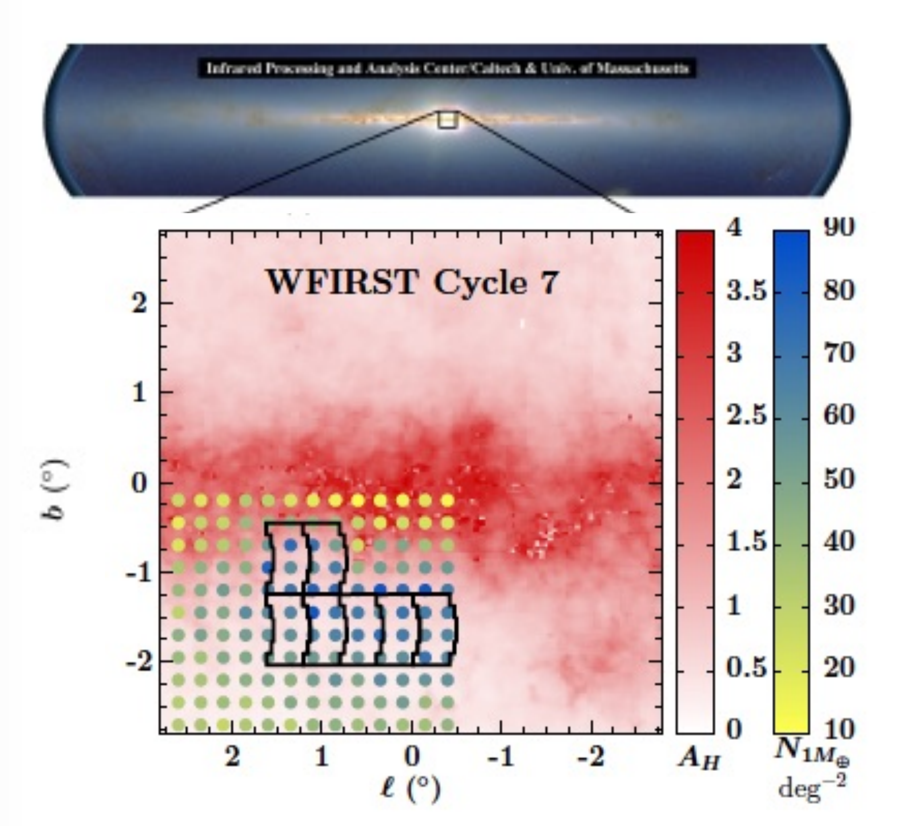
WFIRST alone

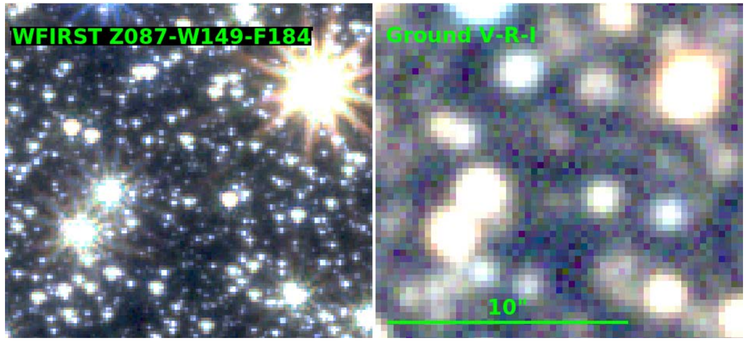
lens flux

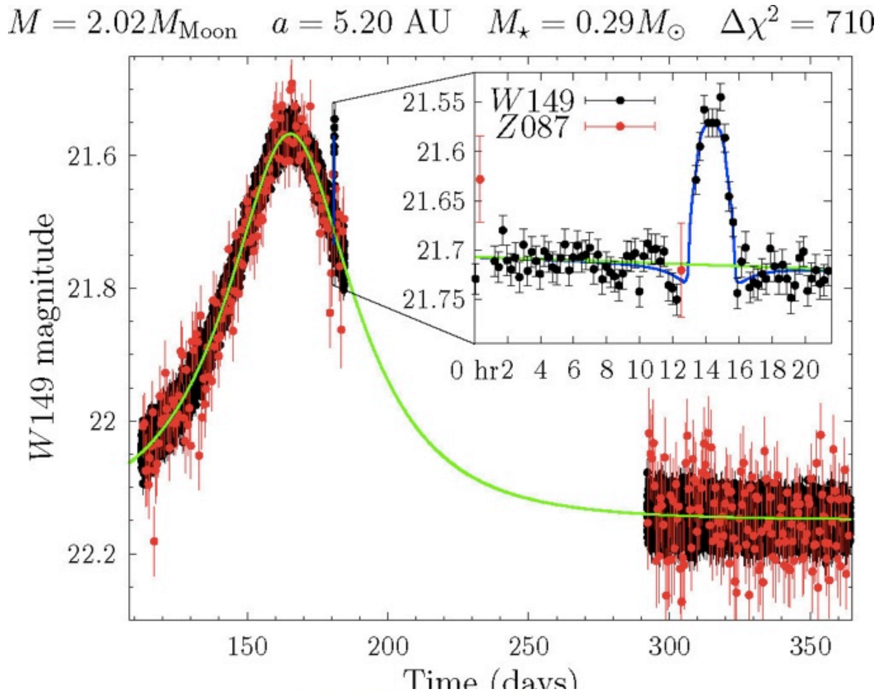
Simultaneous survey from ground to measure the lens mass, through the microlens parallax, for free floating planets and other dark lenses

Penny et al, in prep.

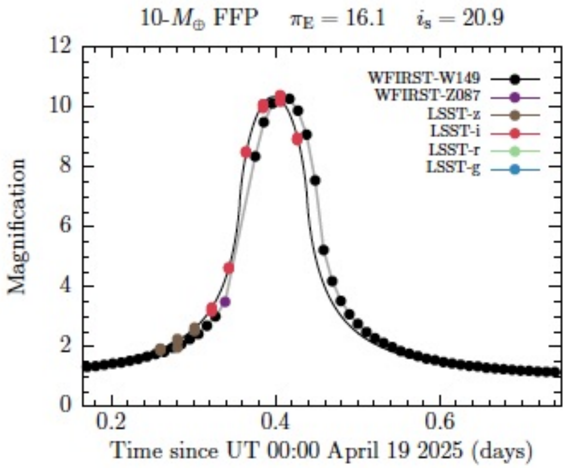
The WFIRST Microlensing Survey-III







From (down to very low mass) bound planets…



…to free-floating planets

Penny et al, in prep.

Simultaneous Ground-base Microlensing Surveys

- Earth-L2 space-based parallax measurement
  - dark lenses and in particular free-floating planets
  - cross check for WFIRST-alone characterization
- Determination of primary lens parameters
  (WFIRST "seasons" last 72 days only)
- **a VST Microlensing Survey in 2025 ?**

The Microlensing Data Challenge

contact: Rachel Street, LCO

Entering the Challenge

http://microlensing-source.org/data-challenge

Mailing list: microlensing-data-challenge@lco.global

Github organization: https://github.com/microlensing-data-challenge

Microlensing Source

Overview | Learning | Glossary | Resources | Interactive | Opportunities | Software | Data Challenge

Microlensing Data Challenge

The analysis and modeling of microlensing events has always been a computationally-intensive and time-consuming task, requiring a powerful computer cluster as well as well sampled lightcurves. While the number of interesting events with adequate data remained fairly low, it has been practical to perform a careful interactive analysis of each one, often with the aid of a powerful computer cluster. Even so, a number of challenges remain, particularly concerning the analysis of triple lenses.

This is expected to change with next-generation surveys, especially with the launch of WFIRST. This mission is expected to detect thousands of microlensing events, including hundreds of planetary events. Clearly, our analysis techniques need an upgrade to fully exploit this dataset, and we encourage people from outside the current microlensing community to bring in diverse expertize.