HARVARD-SMITHSONIAN
CENTER FOR ASTROPHYSICS

Precursor Science for *WFIRST*'s Microlensing Program

Jennifer C. Yee
Sagan Fellow

What is Unique About WFIRST/AFTA?

- Systematic planet census at "snowline distances"
- Free-floating planets to Earth-mass and below
- Accurate planet masses for representative sample (i.e., subject to mild, well-understood selection)
- Accurate distances from here to Galactic Center (for representative sample): "Galactic distribution of planets"

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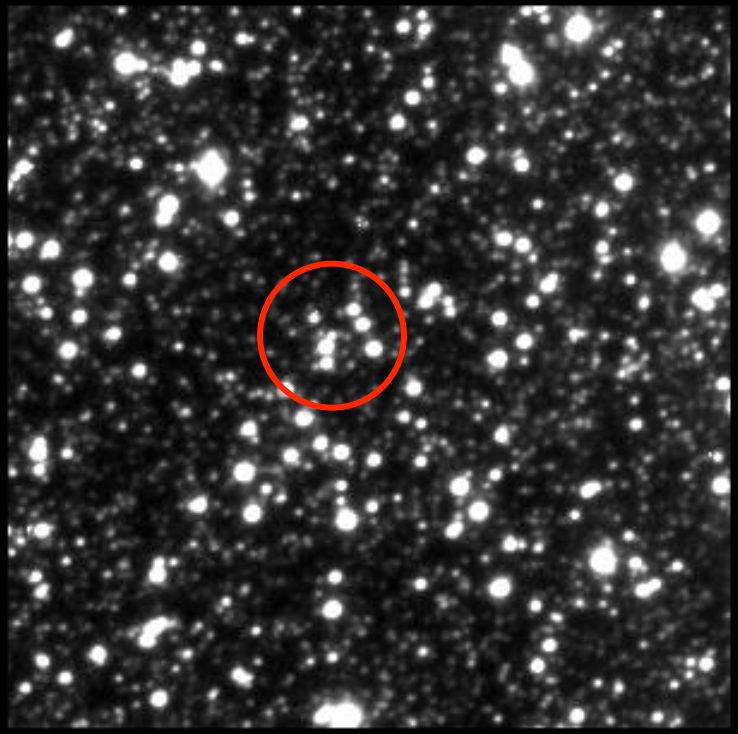
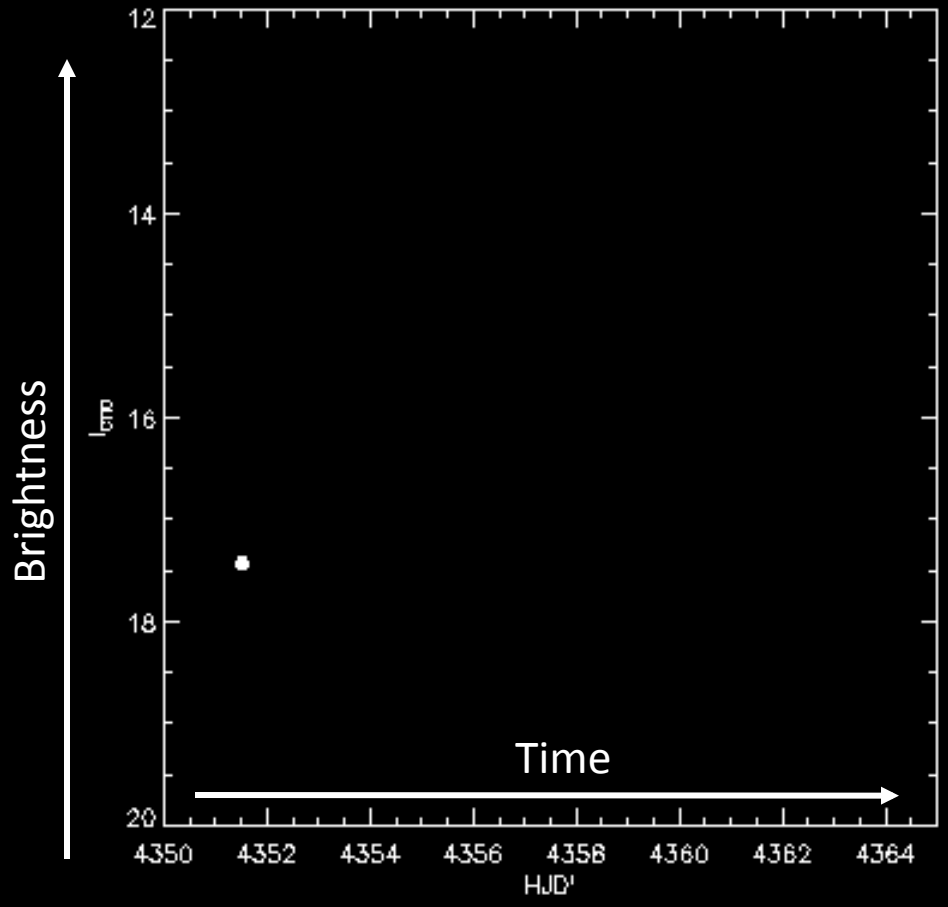
MASSES




Brightness
12
14
16
18
20
I_{STD}
Time
4350
4352
4354
4356
4358
4360
4362
4364
HJD'

Mass Ratio is the Primary Observable

Observable

$$q = m_p / M_{star}$$

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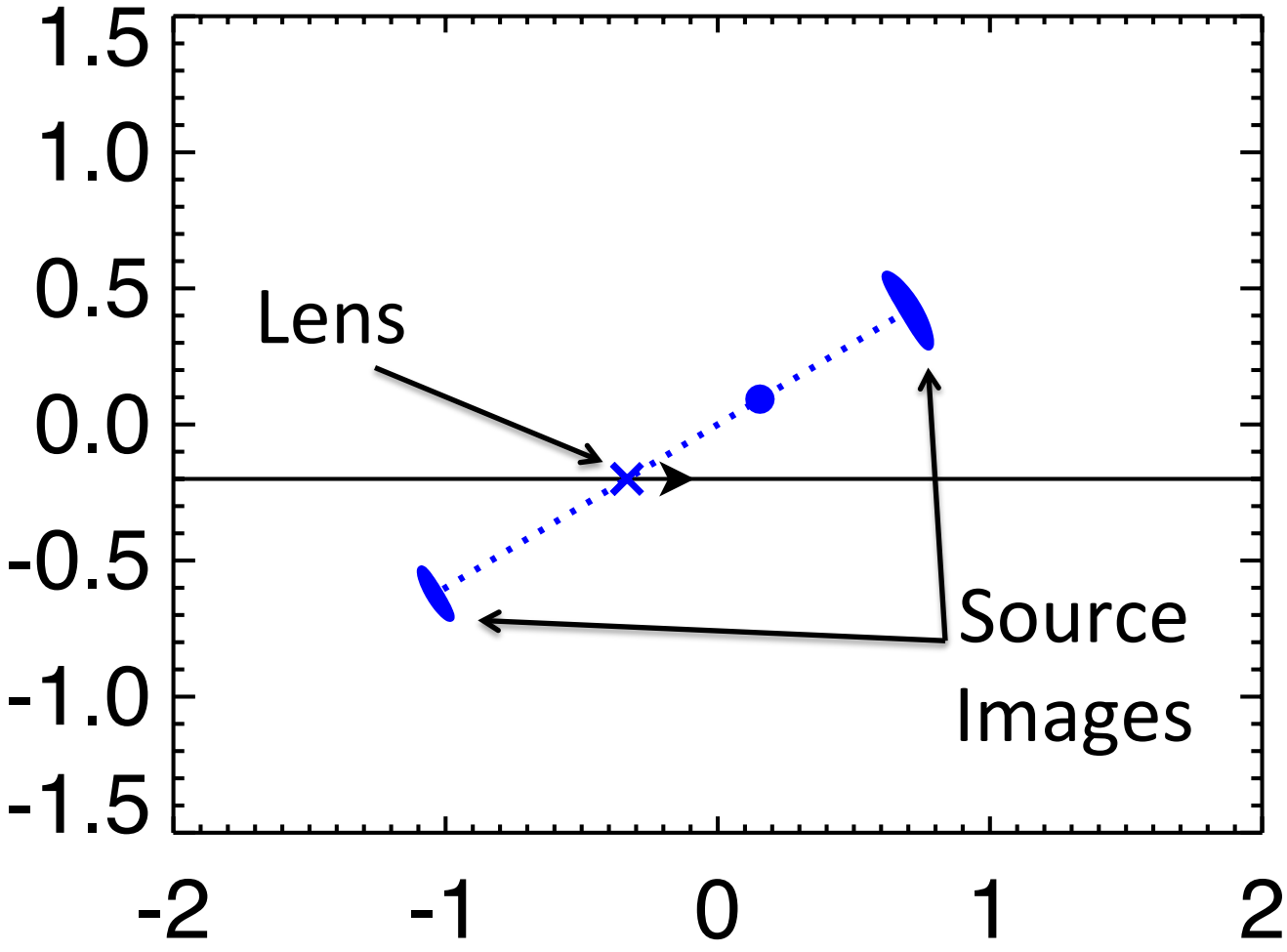
We *must* measure the mass of the lens star to measure the mass of the planet.

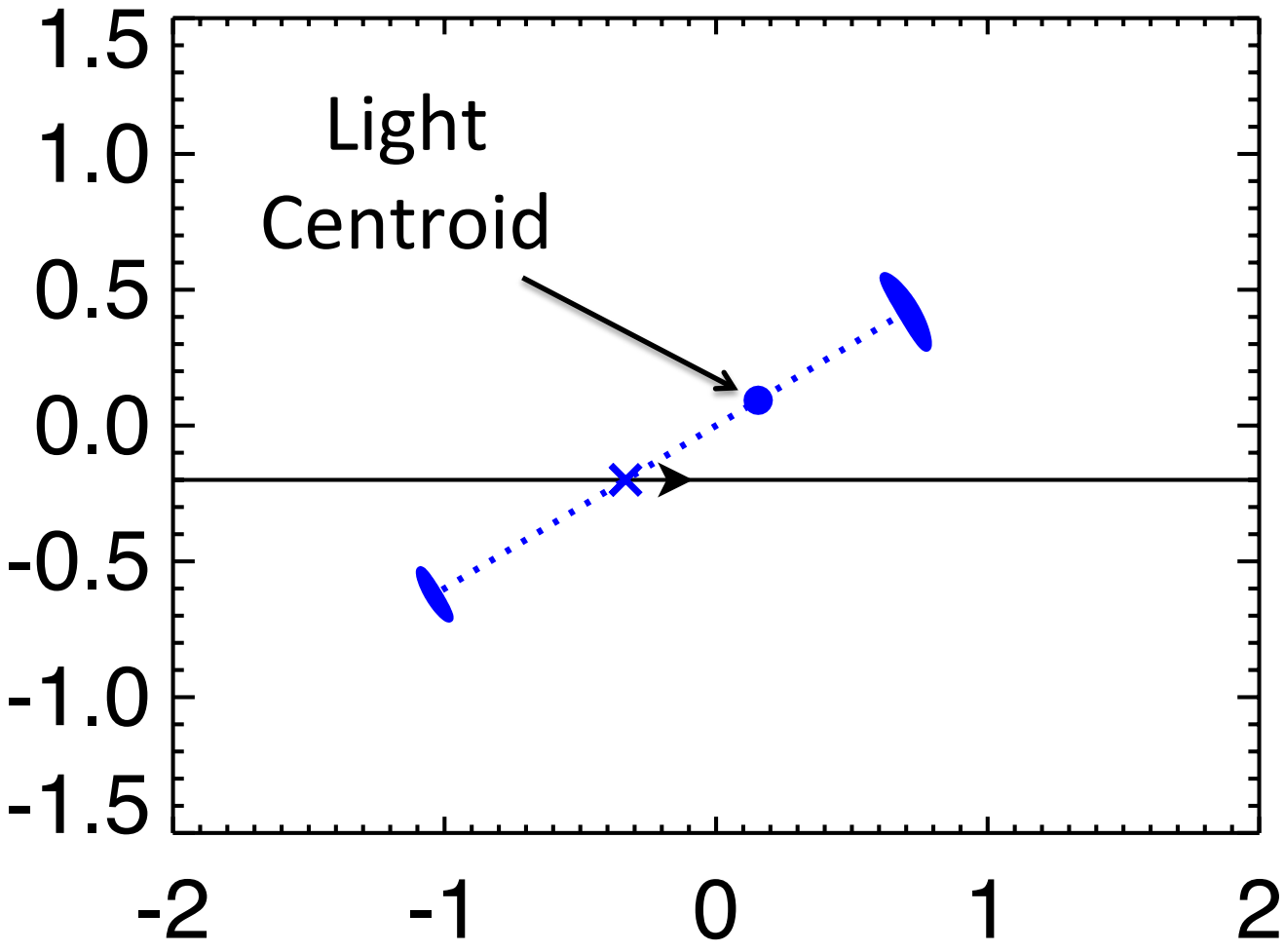
3 Ways WFIRST will Measure Lens Masses

1. Lens Flux
2. Microlens Parallax
3. Astrometric Microlensing

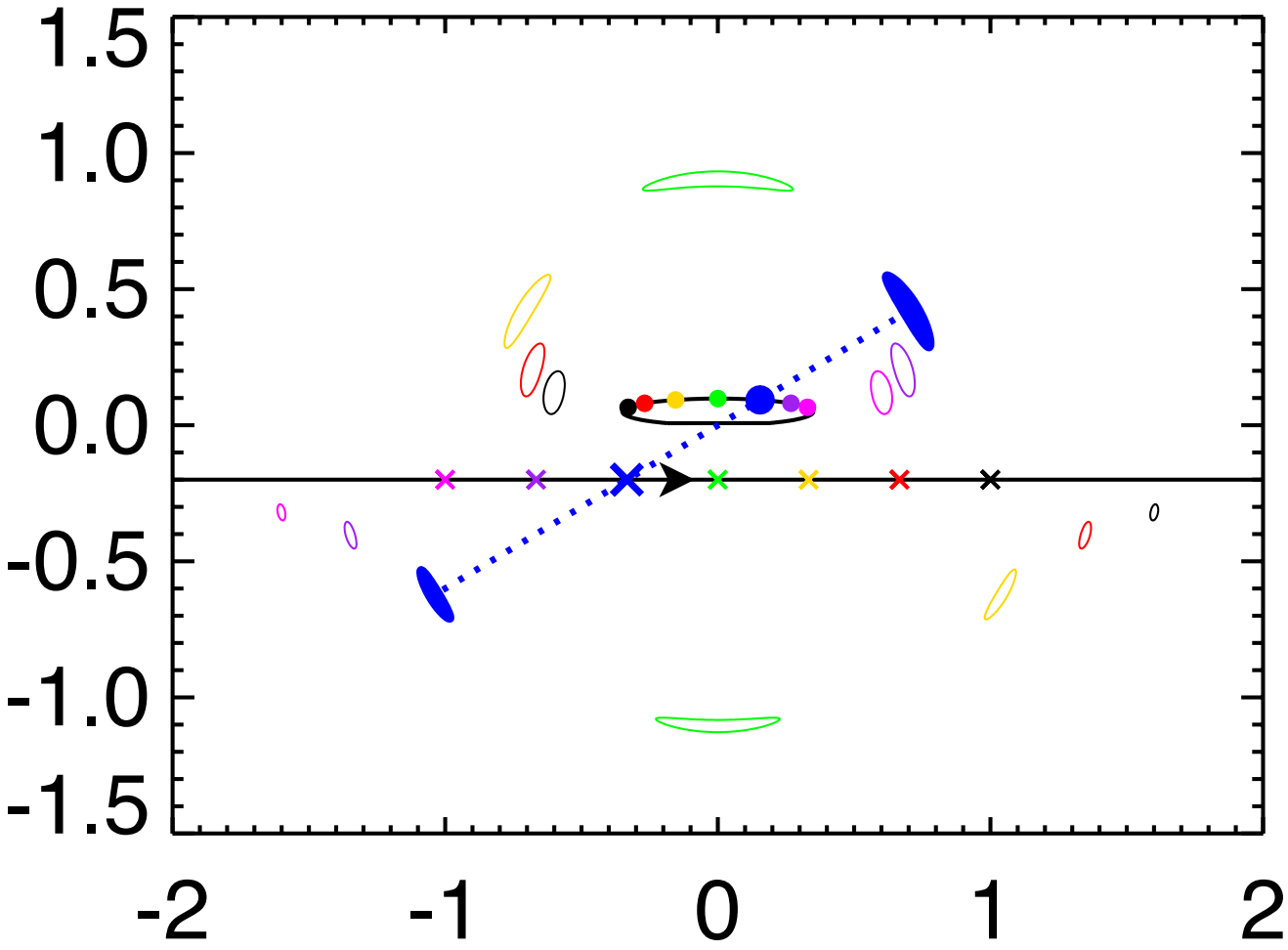
Astrometric Microlensing



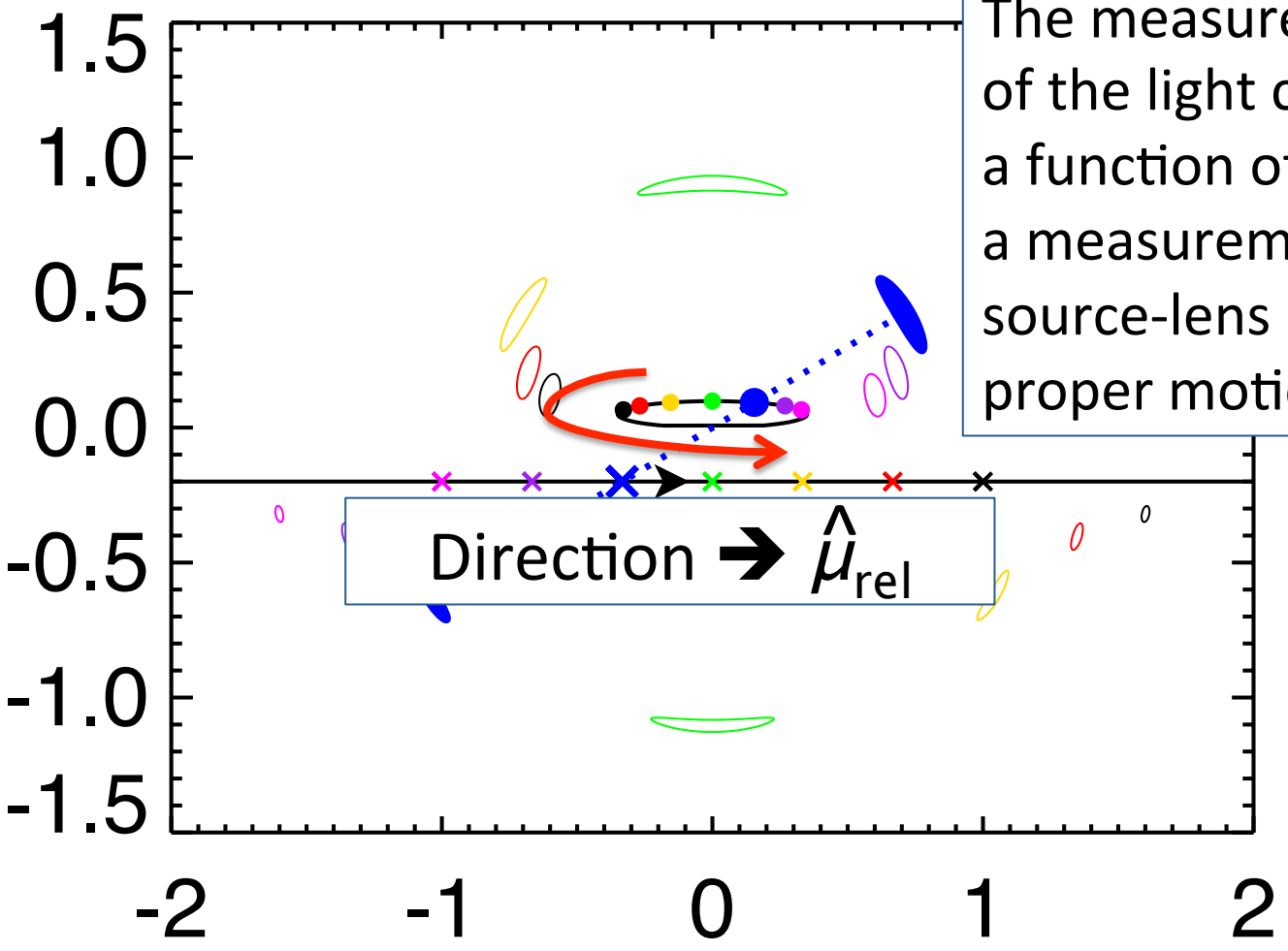
Astrometric Microlensing



Astrometric Microlensing



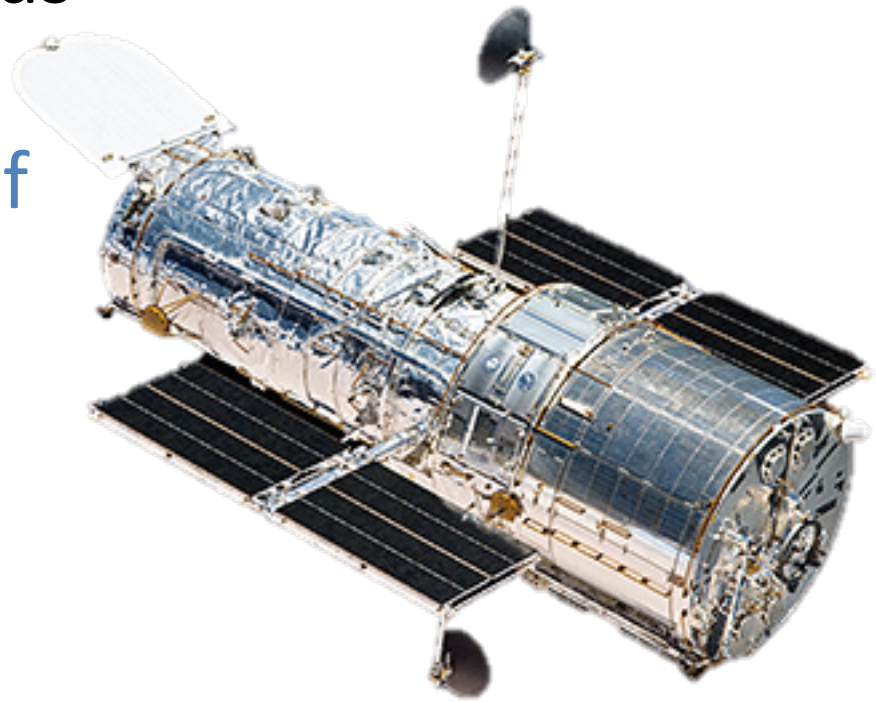
Astrometric Microlensing



The measured motion of the light centroid as a function of time gives a measurement of the source-lens relative proper motion.

Optical HST Imaging

An immediate, optical HST survey of the WFIRST fields will allow proper motion measurements for 22% of WFIRST stars → Direct verification of WFIRST microlens astrometry.

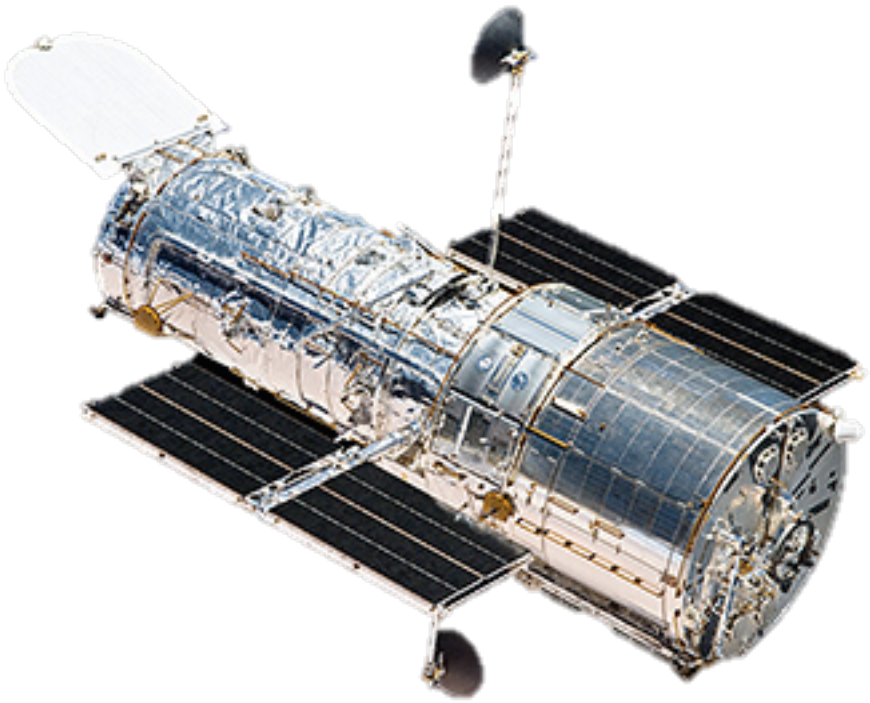


Reliable microlens astrometry measurements are vital to measuring planet masses with WFIRST.

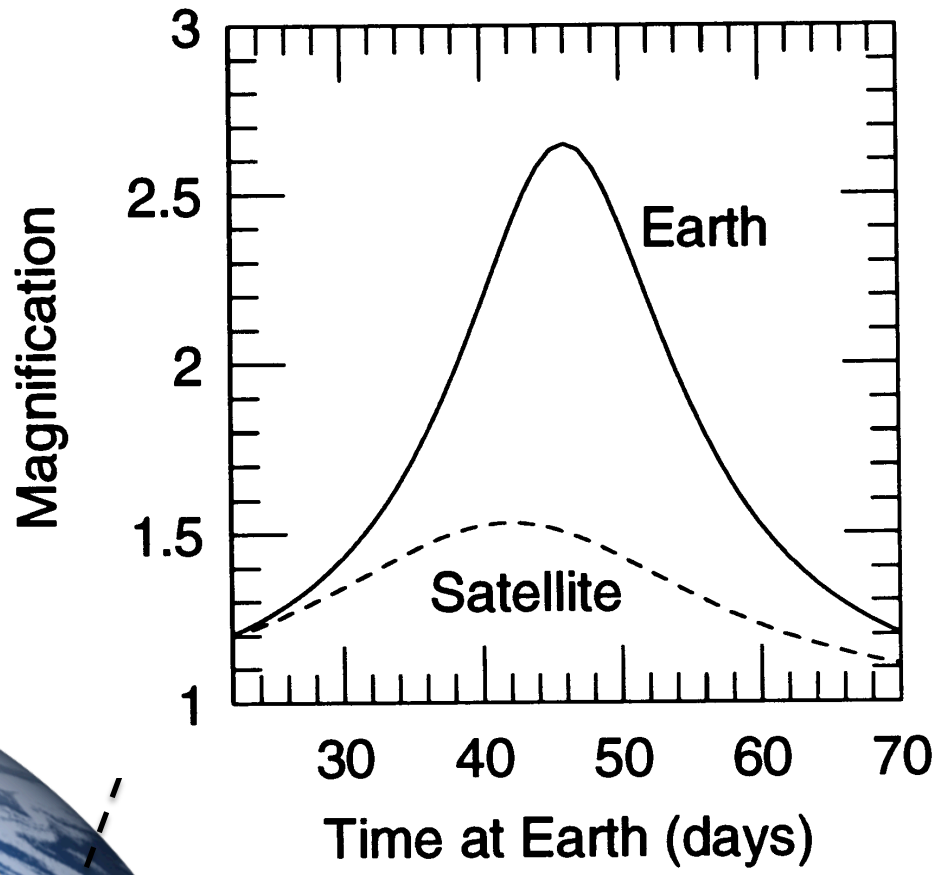
Optical HST Imaging

Colors of stars in WFIRST field → temperature, extinction, metallicity

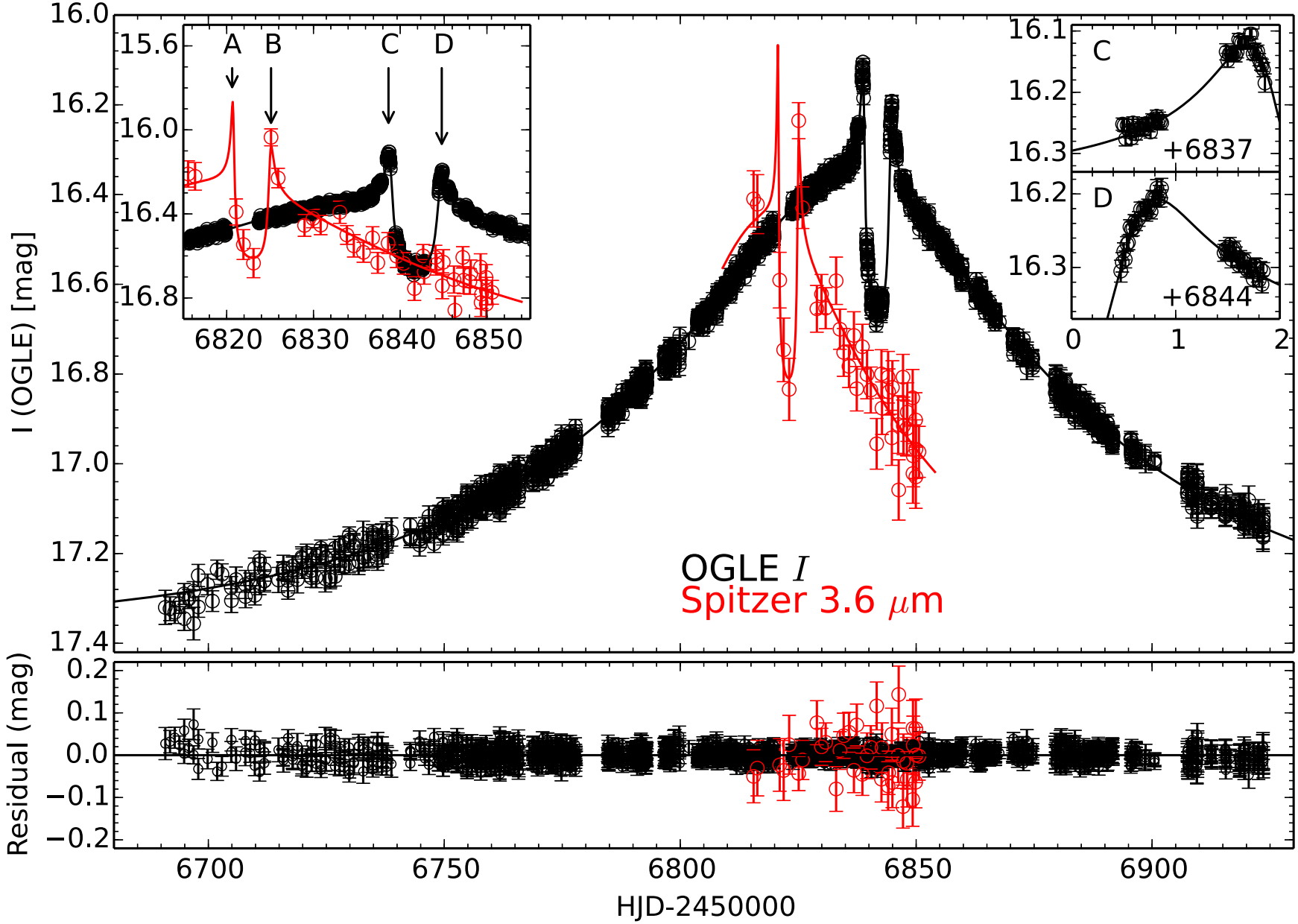
WFIRST relative astrometry + GAIA absolute astrometry + HST colors → Detailed structure of the galaxy



Gould 1994 ApJL, 421, 75



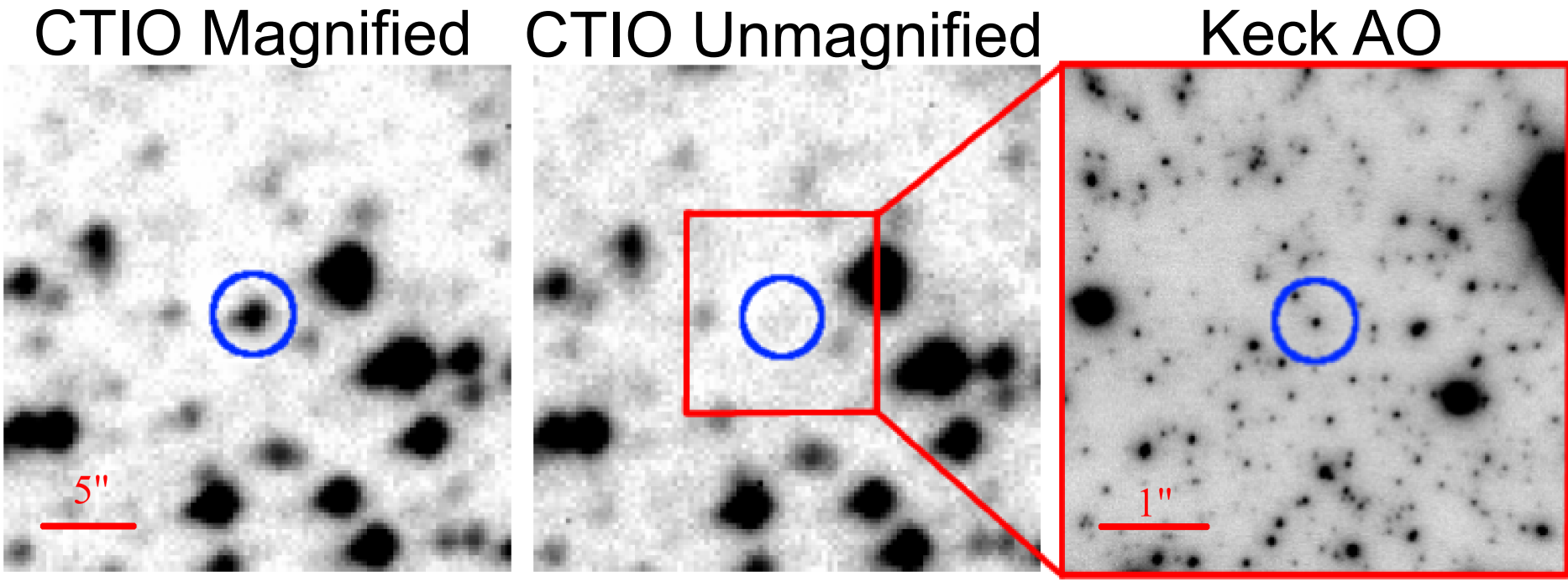
Gould 1994 ApJL, 421, 75



Udalski et al. 2014, ApJ, submitted, arXiv: 1410.4219

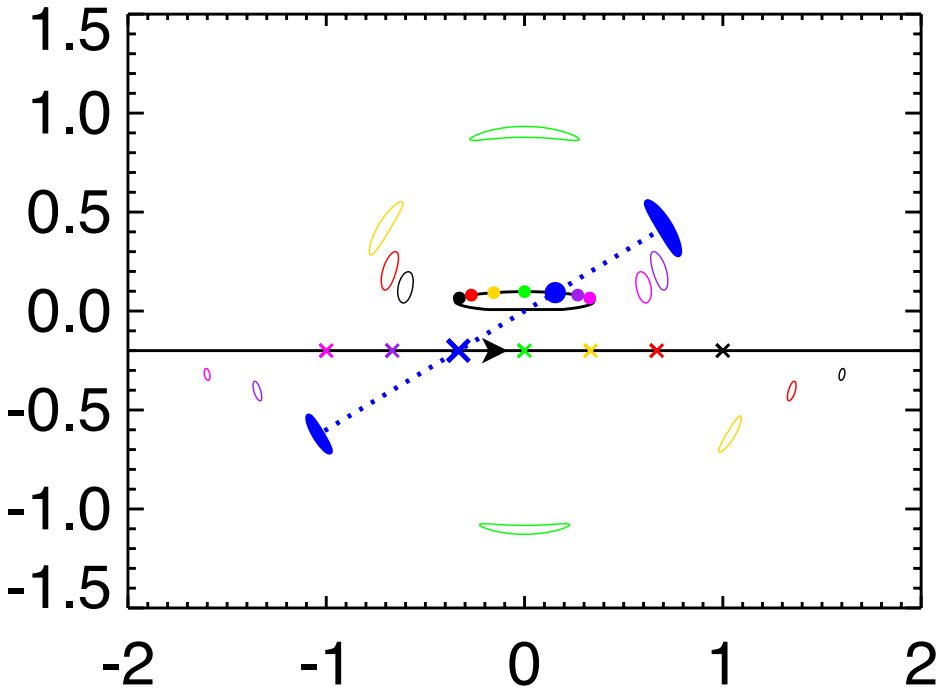
AO Observations

High-resolution imaging of known microlensing events can directly measure the lens flux (and mass).



Batista et al. 2014, ApJ, 780, 54

Microlens Astrometry of Black Holes

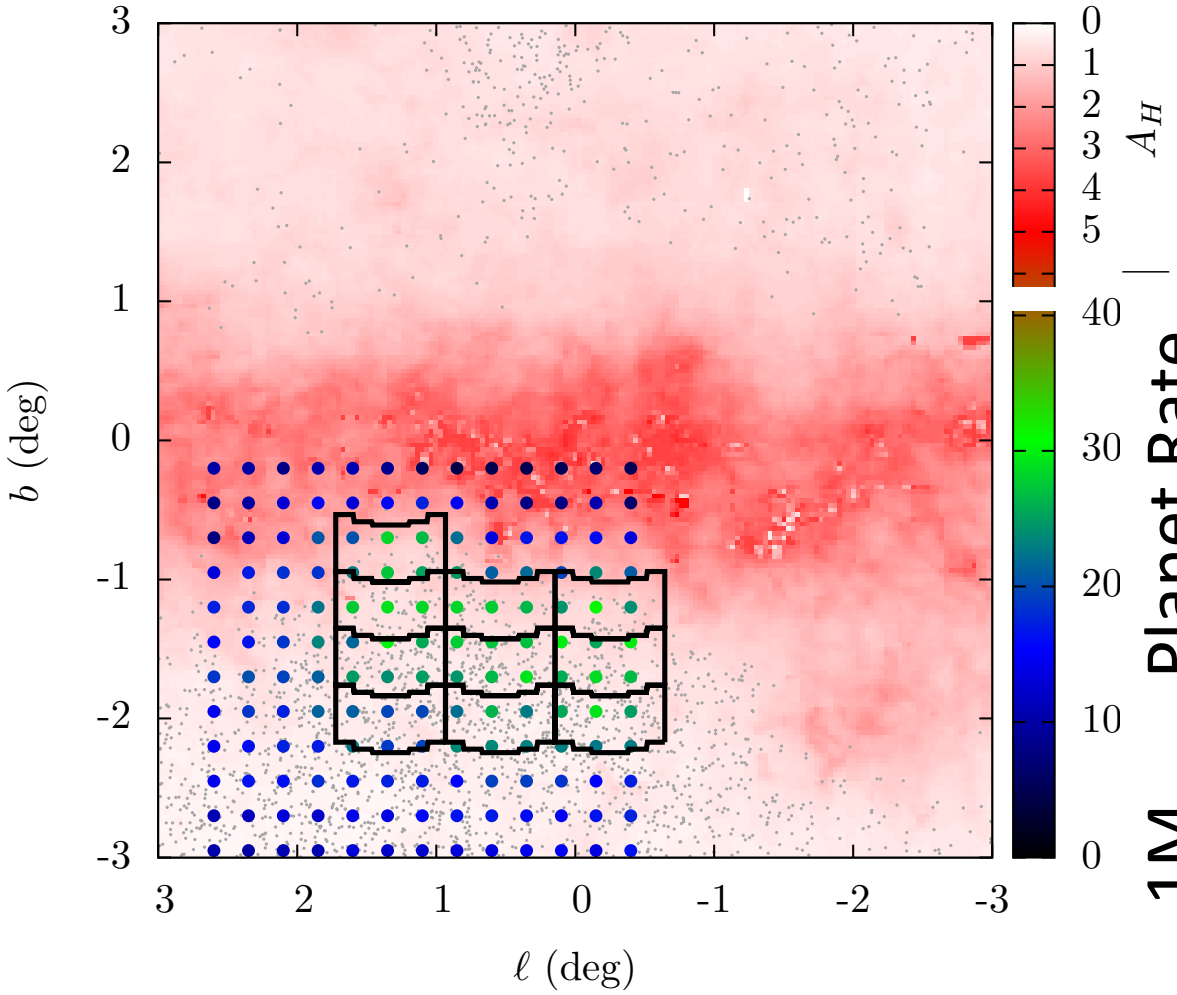


The astrometric microlensing effect for stellar mass black holes is large enough to measure with current capabilities.

$$M_{lens} \rightarrow D_{lens}$$

Measured distances can be used to probe the relative frequency of planets in the bulge and the disk.

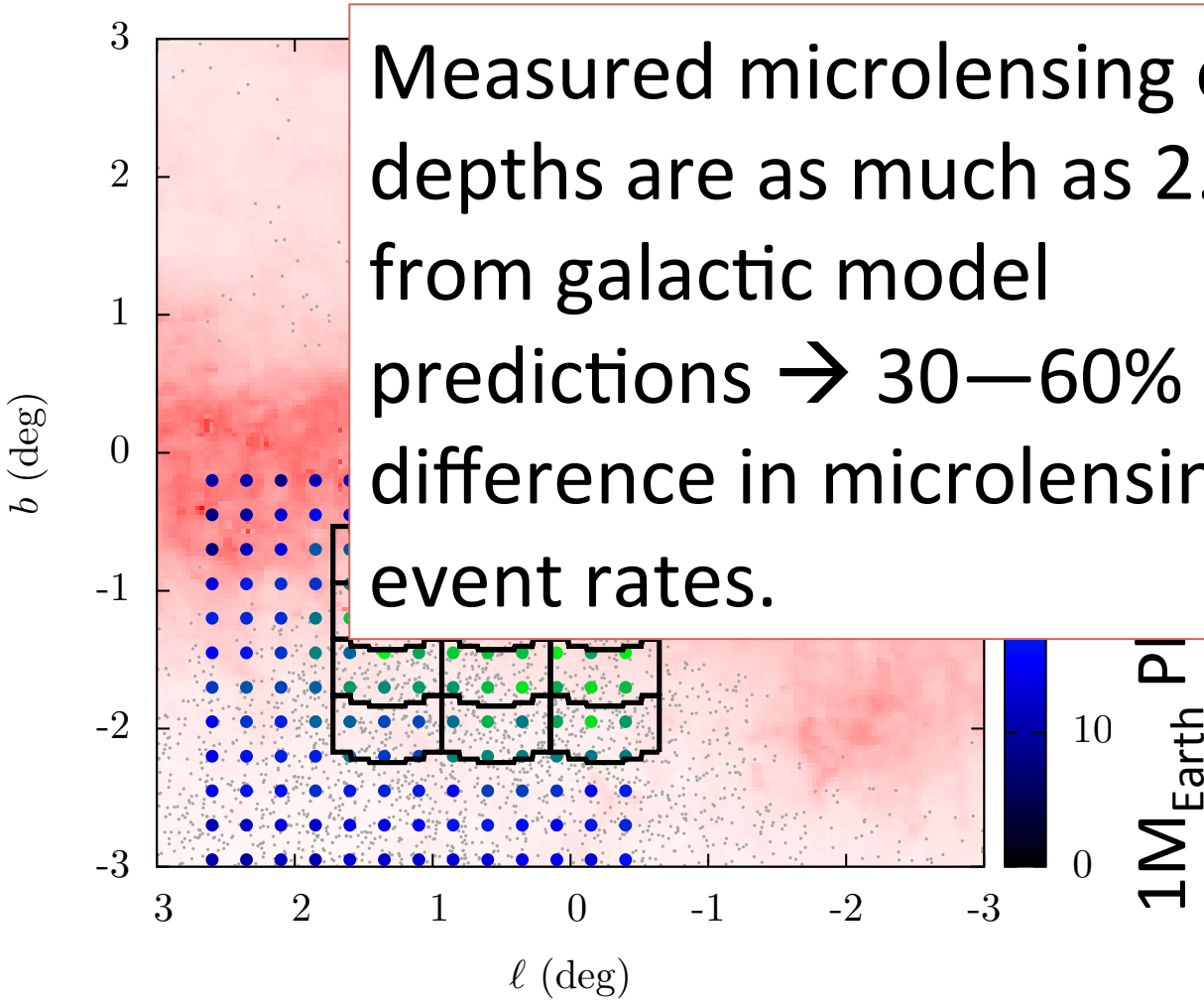
Ground-Based, Near-IR, Microlensing Survey



Extinction map: Gonzalez et al. 2012

Tentative WFIRST field based on our current understanding, extrapolations, and assumptions.

Ground-Based, Near-IR, Microlensing Survey



Measured microlensing optical depths are as much as 2.8σ off from galactic model predictions → 30—60% difference in microlensing event rates.

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Extinction map: Gonzalez et al. 2012

Major Observational Programs

- Directly support WFIRST science and reduce its scientific risk:
  - Early, optical, HST imaging of the WFIRST field
  - A preparatory, ground-based, microlensing survey in the near-IR
- Develop techniques for measuring (planet) masses:
  - Satellite parallax observations using Spitzer, Kepler, and TESS
  - HST or AO flux measurements of lenses in ground-based microlensing events
  - Measurements of microlens astrometry for black holes

SAG 11 Report: arXiv:1409.2759

Michael Albrow
Richard Barry
David Bennett
Geoff Bryden
Sun-Ju Chung
Scott Gaudi
Neil Gehrels
Andy Gould
Matthew T. Penny
Nicholas Rattenbury
Yoon-Hyun Ryu
Jan Skowron
Rachel Street
Takahiro Sumi
Jennifer C. Yee