Concurrent Microlens Observations with ULTIMATE-Subaru

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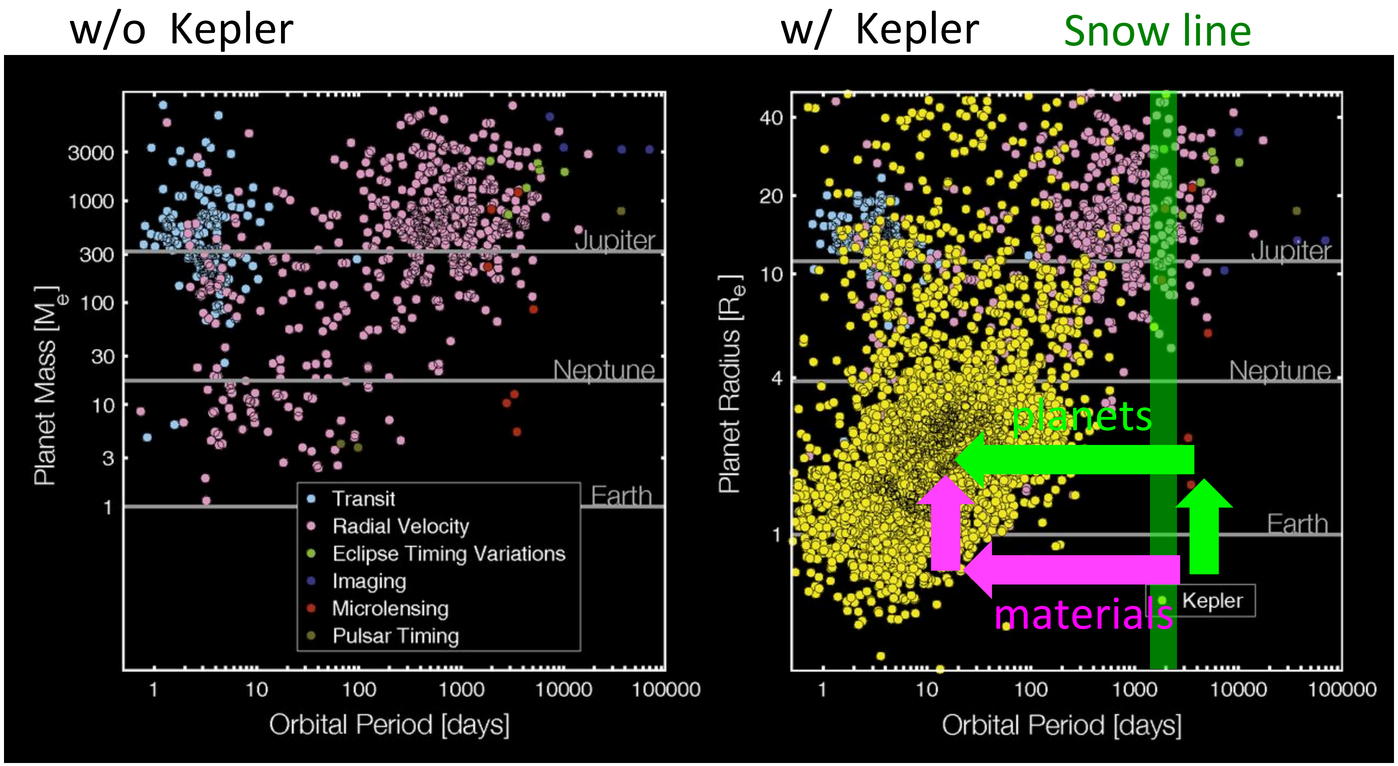
Other Science Cases for Microlensing

- Concurrent observations of microlensing events using ULTIMATE-Subaru
- NIR spectroscopy of bulge dwarfs through high magnification microlensing

Kepler's Discovery and Open Question

Exoplanet distribution as of 2014



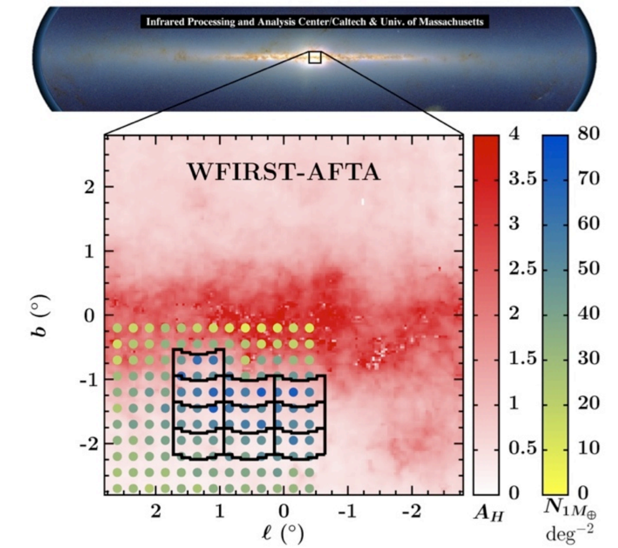
Batalha et al. 2014

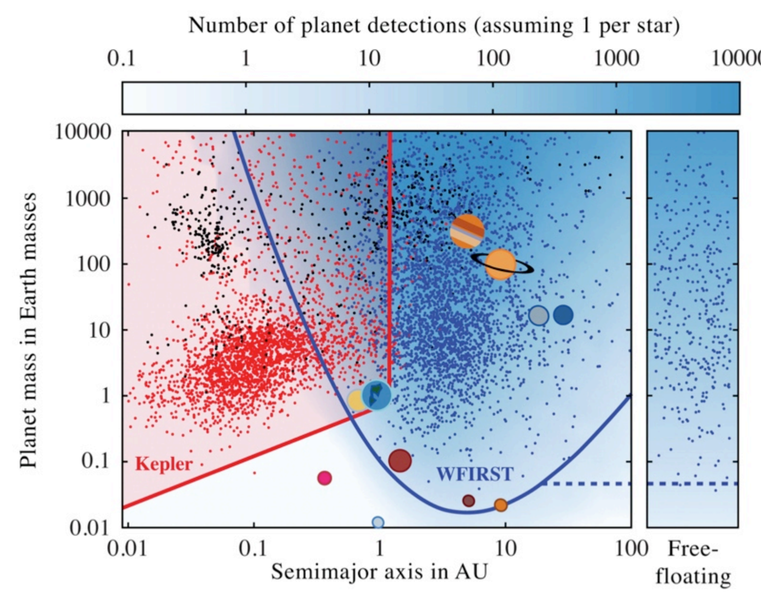
- Kepler discovered thousands of close-in exoplanets smaller than Neptune
- Their formation mechanism is still an open question:
    - Originally formed outside the snow line, then migrated inward, or
    - formed inside the snow line
- Promising way is to survey exoplanets outside the snowline

WFIRST Microlensing Survey

- WFIRST will probe the planetary birth place
  - WFIRST will discover thousands of planets outside the snow line with the mass down to 2x moon
  - The mass distribution can be a strong test for planetary formation/evolution theories

- Precise mass measurements (~10% accuracy) are required
  - The mass-distance degeneracy has to be solved



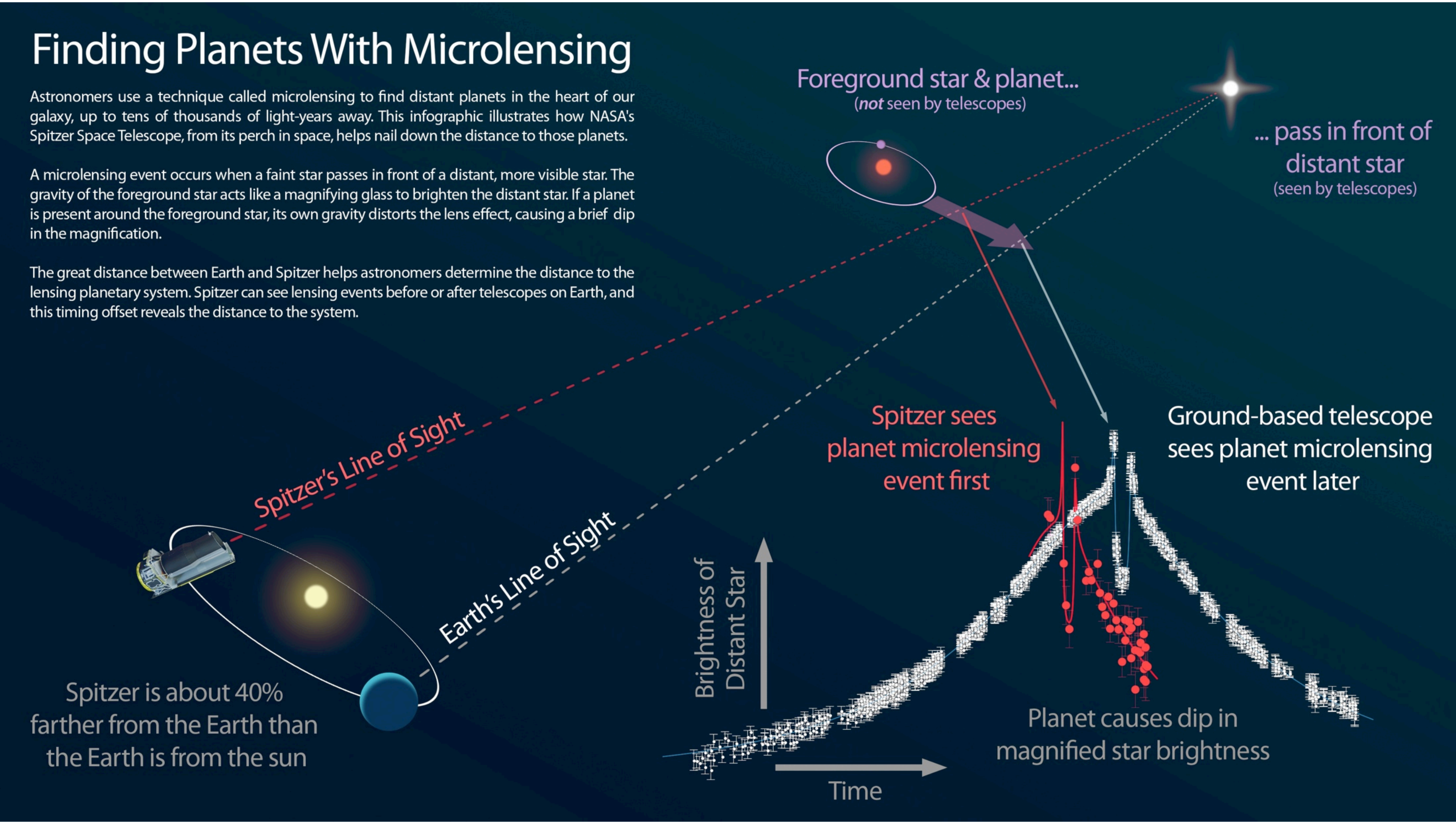


From WFIRST-AFTA 2015 report

Toward Precise Mass Measurements

- WFIRST itself has several solutions to solve for the mass-distance degeneracy
  - Finite source effect
  - Direct proper motion measurement
  - Astrometric image shifts
  - Orbital parallax
  - Lens flux
- Only a subset of events will allow precise (~10%) mass measurements
  - More difficult for farther lenses
- Ground-based follow-ups are important to maximize the yields of WFIRST

Toward Precise Mass Measurements

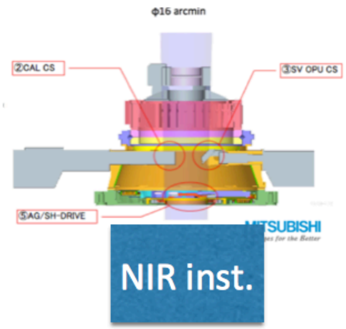


Concurrent Observations using ULTIMATE-Subaru

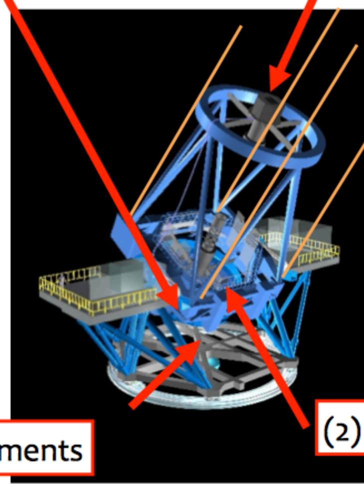
ULTIMATE-Subaru

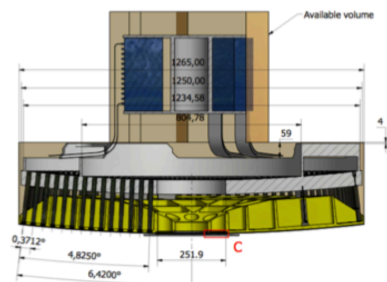
(3) Wavefront Sensors

4x LGS
> 8x8 Shack-Hartmann for each
3 x Tip/Tilt NGS
2x2 Shack-Hartmann for each



(1) Adaptive Secondary Mirror





Preliminary Subaru ASM designed by Microgate with ~1000 actuators

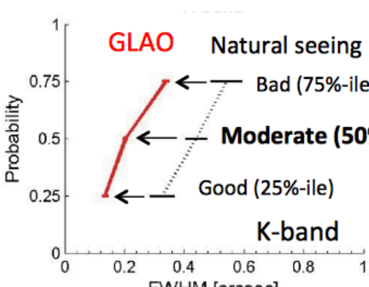
(2) Laser Guide Star system

TOPICA 20W CW fiber laser(589nm) x 2
Generate 4 laser guide stars

(4) Wide-field NIR instruments

- Imager
- Multi-Object Slit spec.
- Multi-Object IFU spec.

FoV~16arcmin max.
at Cs. focus



Band	Natural Seeing (")			GLAO(")		
	Good	**Moderate**	Bad	Good	**Moderate**	Bad
J	0.38	**0.50**	0.71	0.17	**0.26**	0.44
H	0.38	**0.46**	0.60	0.15	**0.23**	0.39
K	0.33	**0.44**	0.54	0.14	**0.20**	0.34

- FWHM ~ 0.2-0.3'' for φ15' @K-band
- Completion will be ~2025

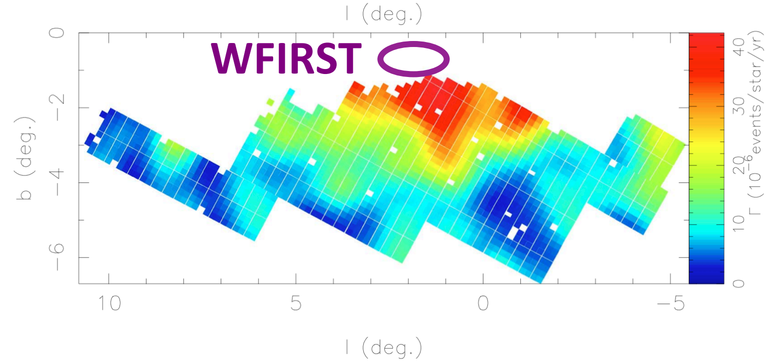
From fact sheet: https://www.naoj.org/Projects/newdev/ngao/20170316/materials/fact_sheet.pdf

Concurrent Observations using ULTIMATE-Subaru

Advantages

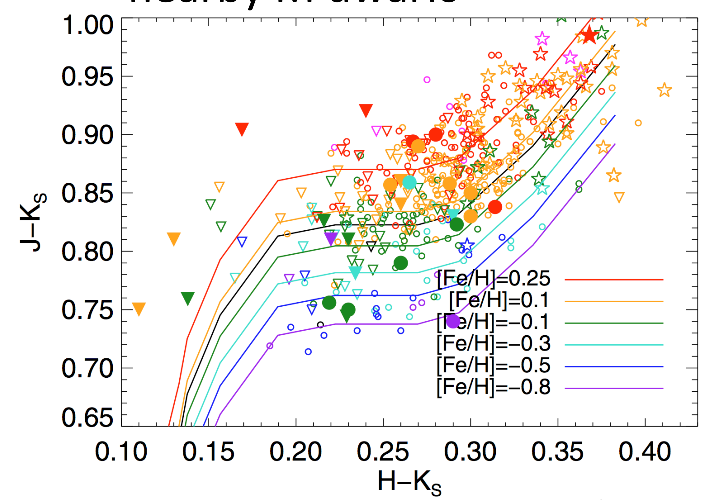
- NIR -> can go closer to central bulge
  - Higher event rate
  - Complement to LSST/HSC
- High resolution -> less blending
  - Fainter events
  - Lens flux
- K band capability -> lens' colors
  - Complement to WFIRST (< H band)
  - (Z087 – K) and (W149 – K) colors
  - Metallicity of M-dwarf host stars can be estimated

Event rate toward the galactic bulge



Sumi & Penny 2016

NIR color-color diagram of nearby M dwarfs



Newton et al. 2014

Concurrent Observations using ULTIMATE-Subaru

Disadvantages

- Smaller FOV than HSC (~1/33)
- Long overheads (~10-15 min for AO setup?)

Proposed Observation

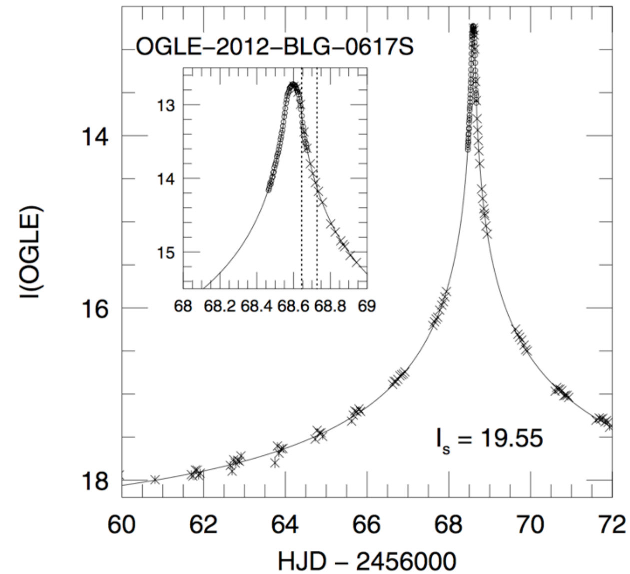
- Low cadence monitoring of the WFIRST fields in K-band
  - 1-several points per night for selected WFIRST fields
  - Unique and complementary observation

Issues

- The instrument availability around 2025 is unclear
- Need study of figure of merit relative to HSC

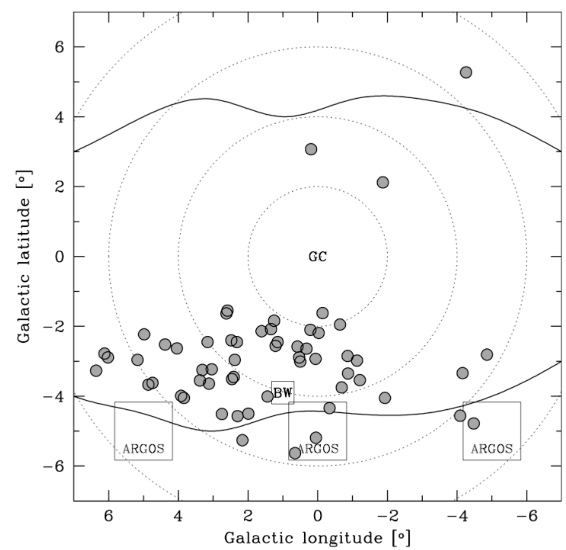
NIR Spec. of Bulge Dwarfs through High-mag μlens

- Environment study of the central bulge
  - WFIRST can examine the dependency of planet abundance on the stellar properties (e.g., stellar age, metallicity, and kinematics)
  - Recent studies support the presence of younger (~a few Gyr) populations



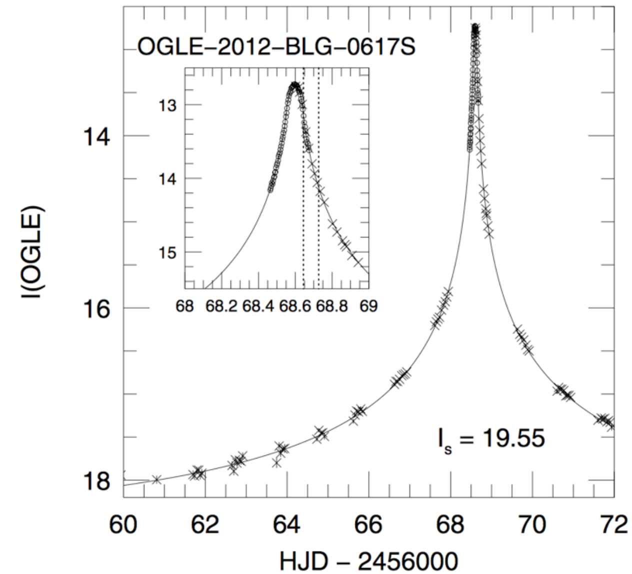
- High-mag (A_{max}>50) μlensing events will allow IR spectroscopy of bulge dwarfs
  - A_{max} > 50: H=19 ⇒ H < 14.8, mid R w/ IRCS (or PFS)
  - A_{max} > 500: H=19 ⇒ H < 12.3, high R w/ IRCS or IRD

(This idea is also proposed by N. Matsunaga @Univ. of Tokyo)



Bensby et al. 2013

NIR Spec. of Bulge Dwarfs through High-mag μlens



- ToO is required
  - Low event rate
    - A_{max} > 50: ~50 events/year
    - A_{max} > 500: several/year
  - Short peak time scale
    - ~one day

- PRIME will provide targets before WFIRST
  - PRIME: new 1.8m wide-field IR telescope @SAAO for microlensing (2019~)
  - Good to start with PRIME

Summary

We would like to propose additional two science cases:

- Concurrent observations of microlensing events using ULTIMATE-Subaru
  - Toward precise mass measurements of planetary systems outside the snowline

- NIR spectroscopy of bulge dwarfs through high magnification microlensing
  - To study the properties of the central bulge dwarfs