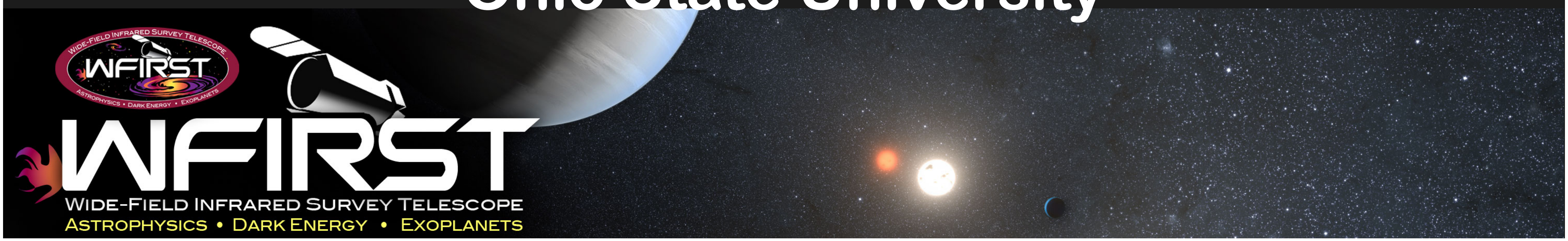
‘Auxiliary’ Science with the WFIRST Microlensing Survey:

Measurement of the Compact Object Mass Function over 10 Orders of Magnitude; Detection of $\sim 10^5$ Transiting Planets; Astroseismology of $\sim 10^6$ Bulge Giants; Detection of $\sim 5\times10^3$ Trans-Neptunian Objects; and Parallaxes and Proper Motions of $\sim 6\times10^6$ Bulge and Disk Stars.

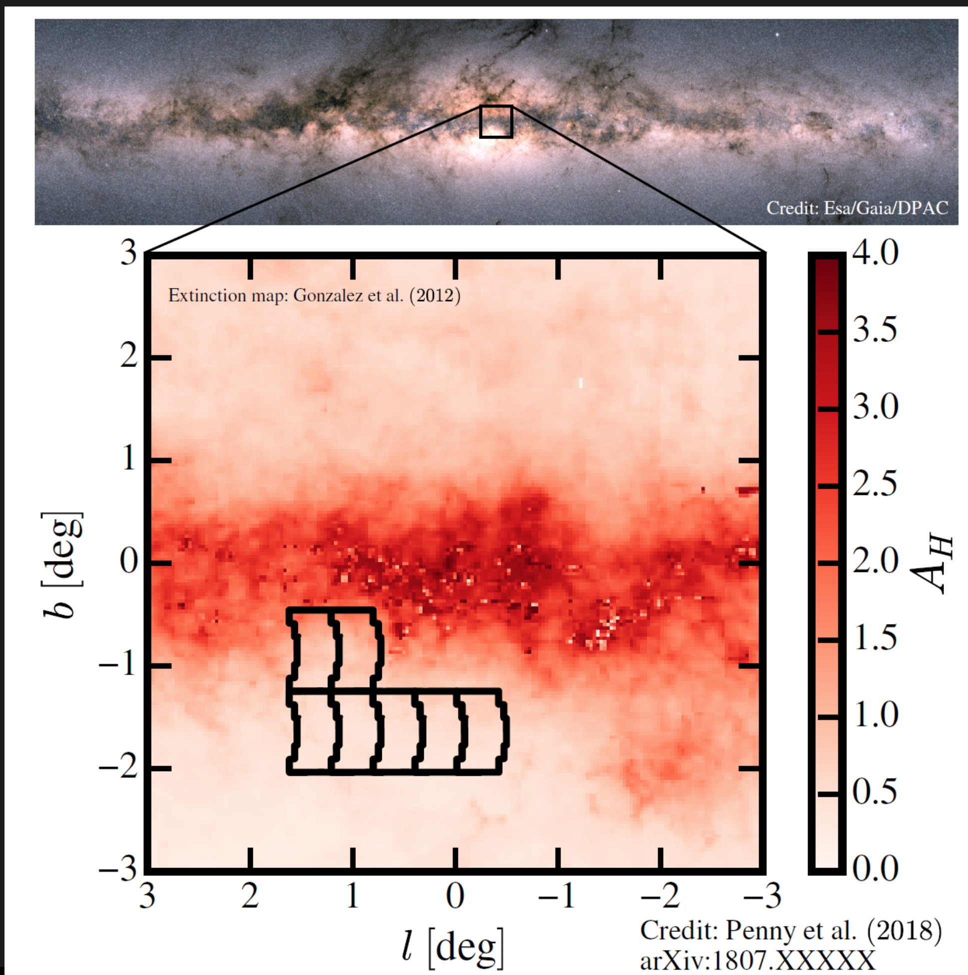
Science in our Own Backyard with WFIRST

June 18, 2019

Scott Gaudi
(many figures/numbers taken from Matthew Penny)
Ohio State University



WFIRST's Microlensing Survey Strategy. (preliminary)



- 7 fields for a total of ~2 deg^2
- Wide $W149_{AB}$ (0.93-2 μm) filter*.
- 15 minute cadence.
- 50s exposures.
- Observations every at least 12 hours in at least one other filter
- (e.g., Z087,F184), 900 total obs.
- 6 x 72 day seasons.
- ~41,000 exposures in $W149_{AB}$.
- ~432 total days spread over 5 year mission.

Penny et al. 2019

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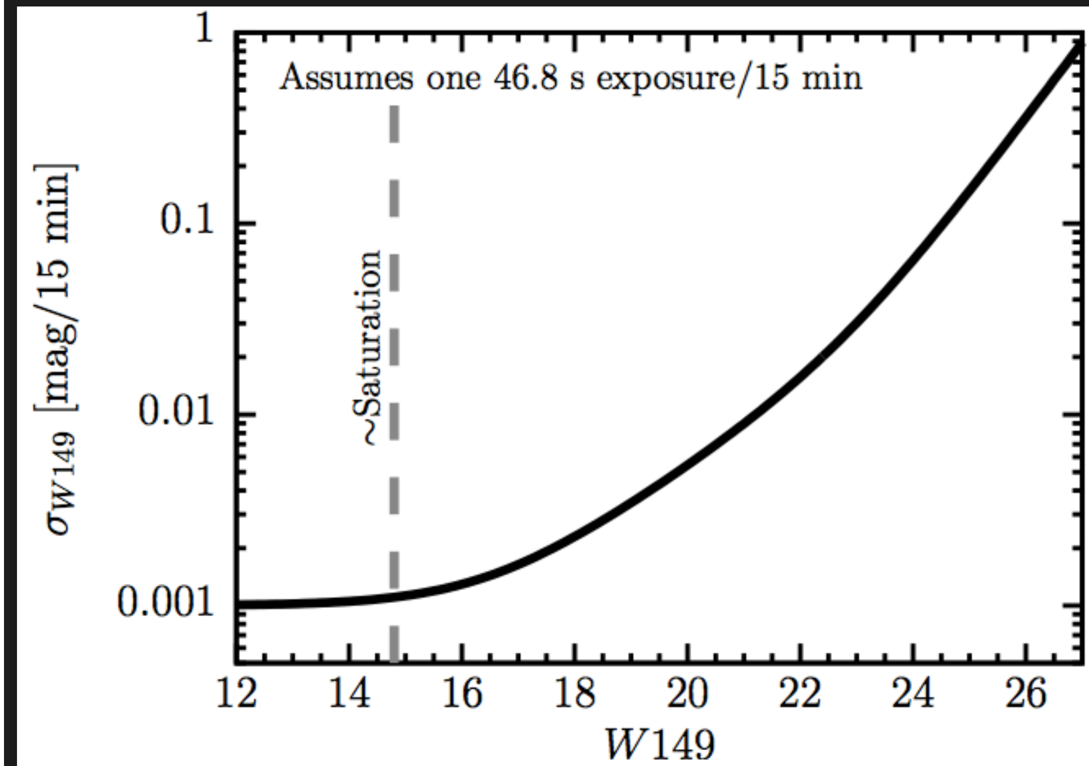
*One photon per second for $W149_{AB}$ ~27.6

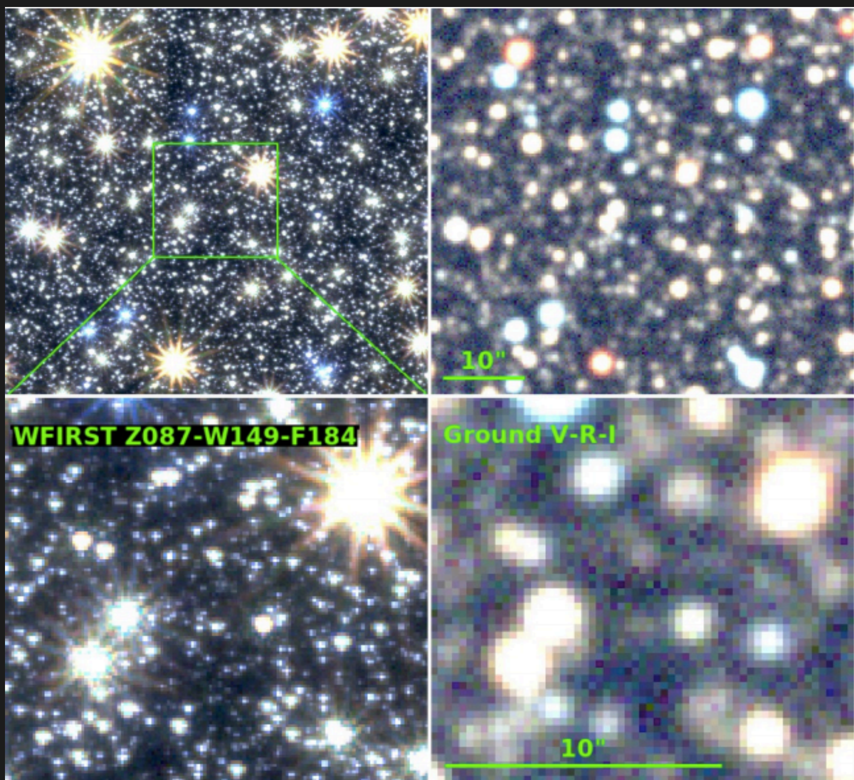
Statistical Power.



- For a $W149_{AB}$~21.15 star:
  - Photon-noise relative photometric precision of σ~0.01 mag per exposure.
  - Total of ~10^9 photons over the survey.
  - Saturation @ $W149_{AB}$ ~14.8.
- Root N: $\sqrt[2]{41{,}000} \sim 200$.

Penny et al. 2019

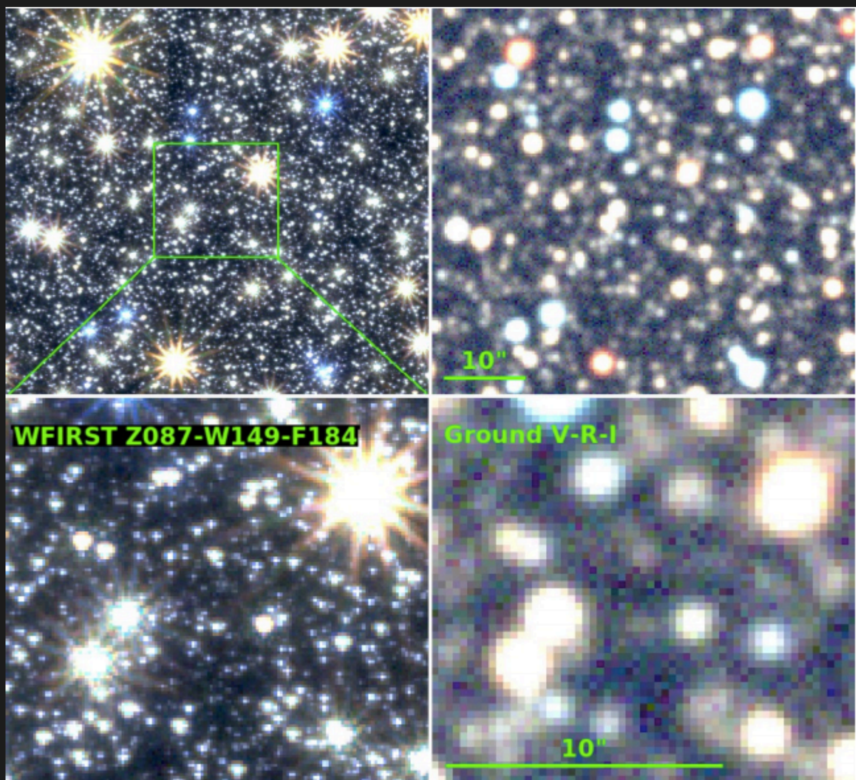
Sample Size and Microlensing Events.



Stars ($W149 < 15$)	$\sim 0.3 \times 10^6$
Stars ($W149 < 17$)	$\sim 1.4 \times 10^6$
Stars ($W149 < 19$)	$\sim 5.8 \times 10^6$
Stars ($W149 < 21$)	$\sim 38 \times 10^6$
Stars ($W149 < 23$)	$\sim 110 \times 10^6$
Stars ($W149 < 25$)	$\sim 240 \times 10^6$
Microlensing events $\|u_0\| < 1$	$\sim 27,000$
Microlensing events $\|u_0\| < 3$	$\sim 54,000$

Penny et al. 2019

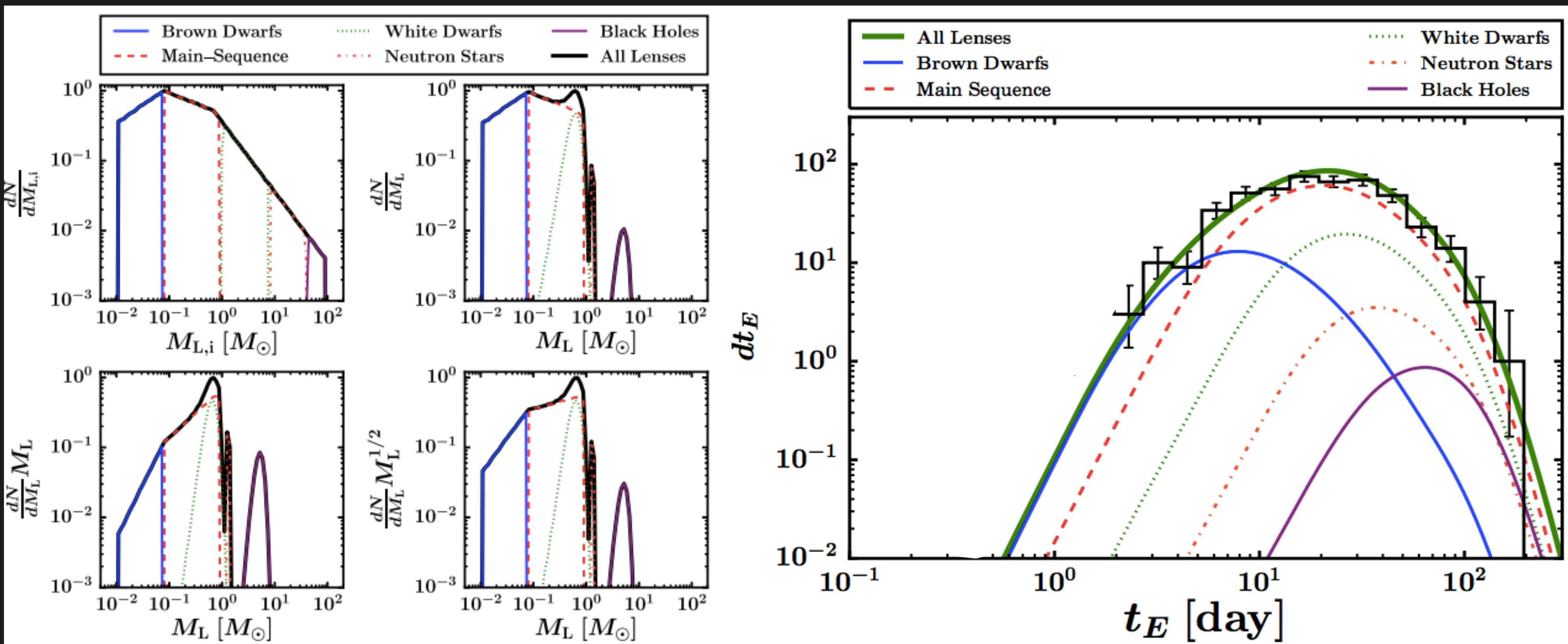
Photometric and Astrometric Precision.
(Relative, Poisson Noise Only)



H_{AB}	# of Stars	Relative photometric precision (per exp.)	Astrometric precision (per exp.)
<19	6×10^6	~0.8%	~0.6 mas
<21	40×10^6	~1%	~1.5 mas

Penny et al. 2019

Probe the Compact Object Mass Function from ~30 $M_\odot$…



Clanton & Gaudi 2017

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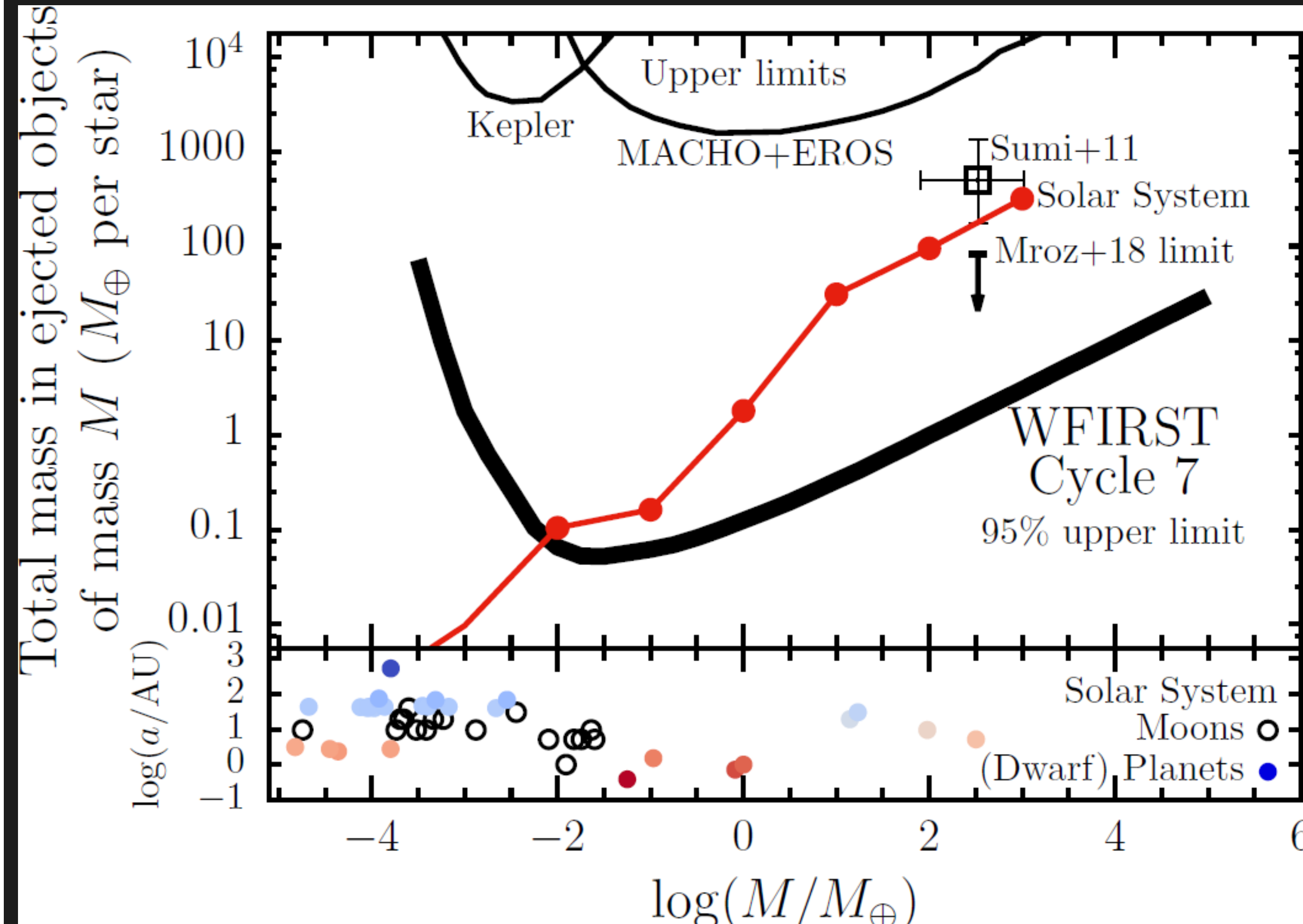
…down to the mass of Pluto!



- Wide-orbit & free floating planets.
- Wide sensitivity to measure mass budget in range down to $1M_\oplus$ Earth-masses per star down to $0.001M_\oplus$.

Johnson et al., in prep.

Log10(30 x mass of the sun/mass of Pluto) ~ 10!

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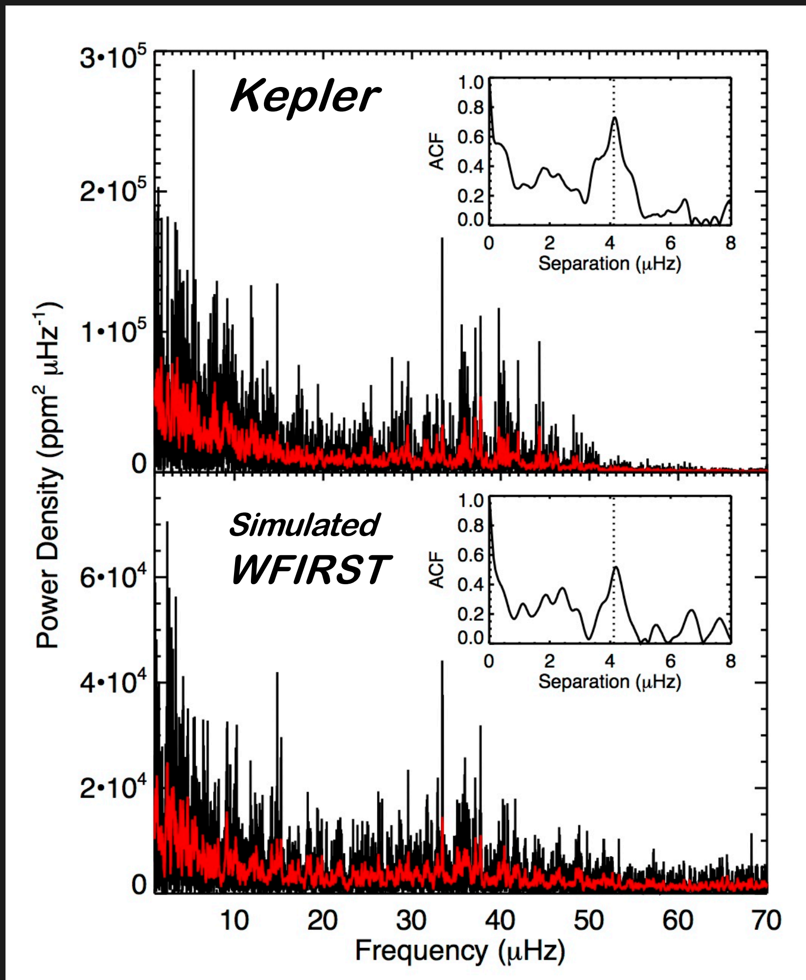
Asteroseismology of 10^6 giants.



- WFIRST will be able to measure ν_{max} and $\Delta\nu$ for the ~10^6 H_{AB}<14 red giant stars in the survey fields.
- Only measure ν_{max} for fainter stars.
- Will also be able to measure precise (~0.3%) distances to these stars via parallax (if photon-noise limited).

Gould et al. 2015

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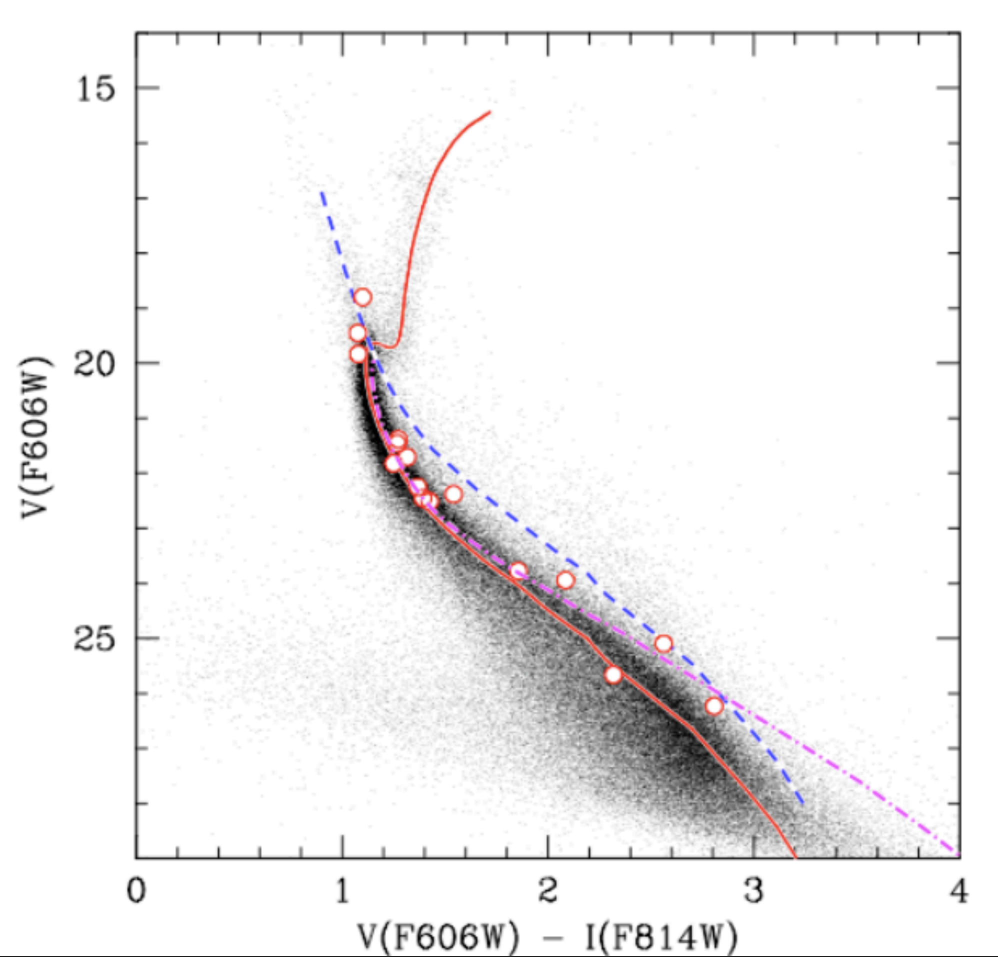
Resolved Stellar Populations.



- WFIRST will obtain one of the deepest fields ever taken.
  - ~$2x10^6$s in W149.
  - ~$3x10^5$s in Z087.
- Compare to the SWEEPS $9x10^4$s in F606W (V) and F814W (I).

Sahu et al. 2006

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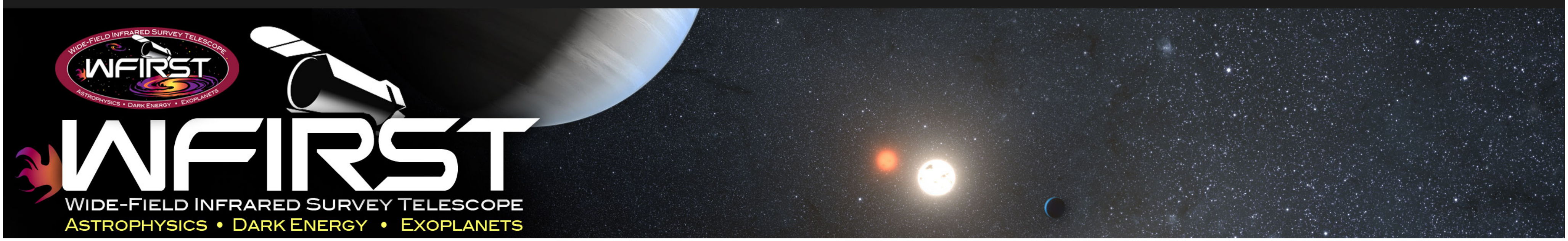
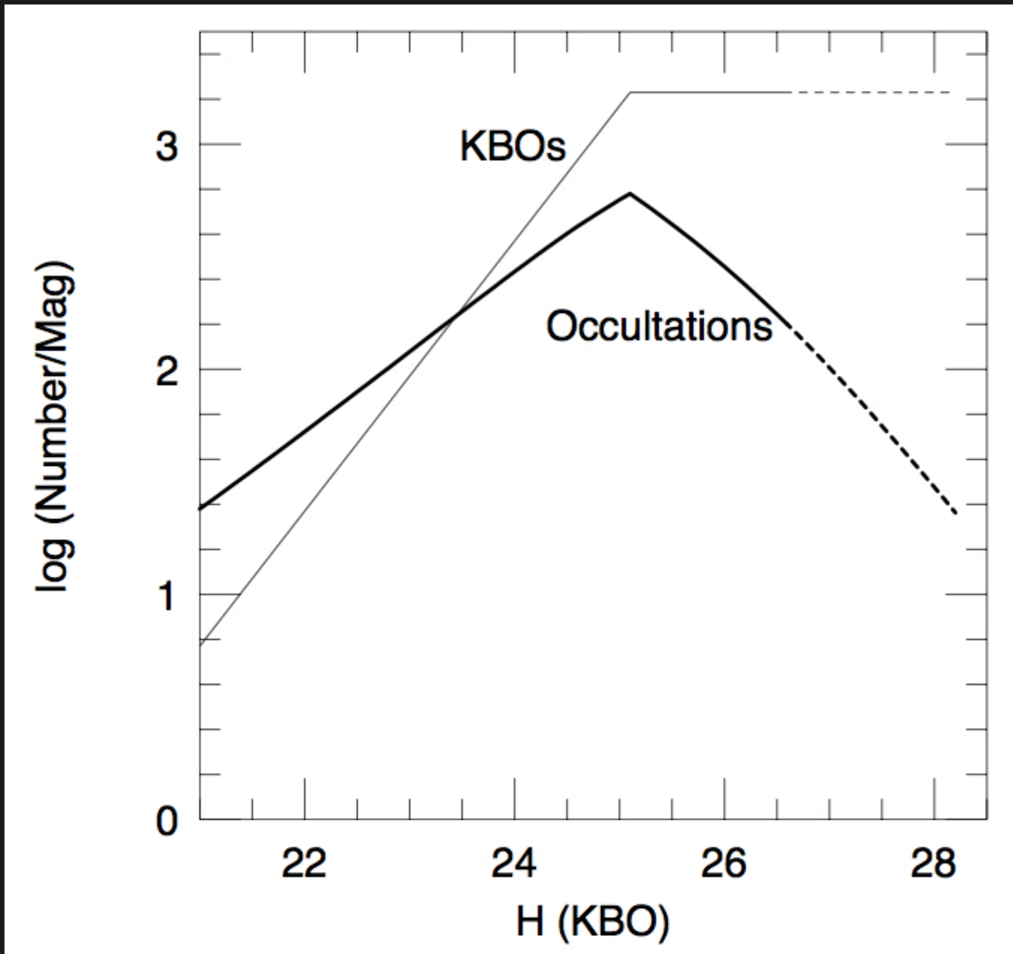
Galactic Structure.

- Photon noise-limited parallaxes of <10% and proper motion measurements of 0.3% (0.01 mas/yr) for ~4×10^6 bulge and disk stars with $W149_{AB}<21$.
- Deep multicolor photometry in a least one bluer filter (e.g., Z087) for these stars.
- Shallow photometry in all filters.
- With this dataset, it will be possible to:
  - Estimate T_{eff}, [M/H], Age, Luminosity, and A_H for all these stars.
  - Probe the disk and Galactic bulge mass and velocity distribution (including Galactic bar structure).
  - Probe the metallicity and age distribution of the disk and bulge.
  - Create an exquisite extinction map in the survey area.



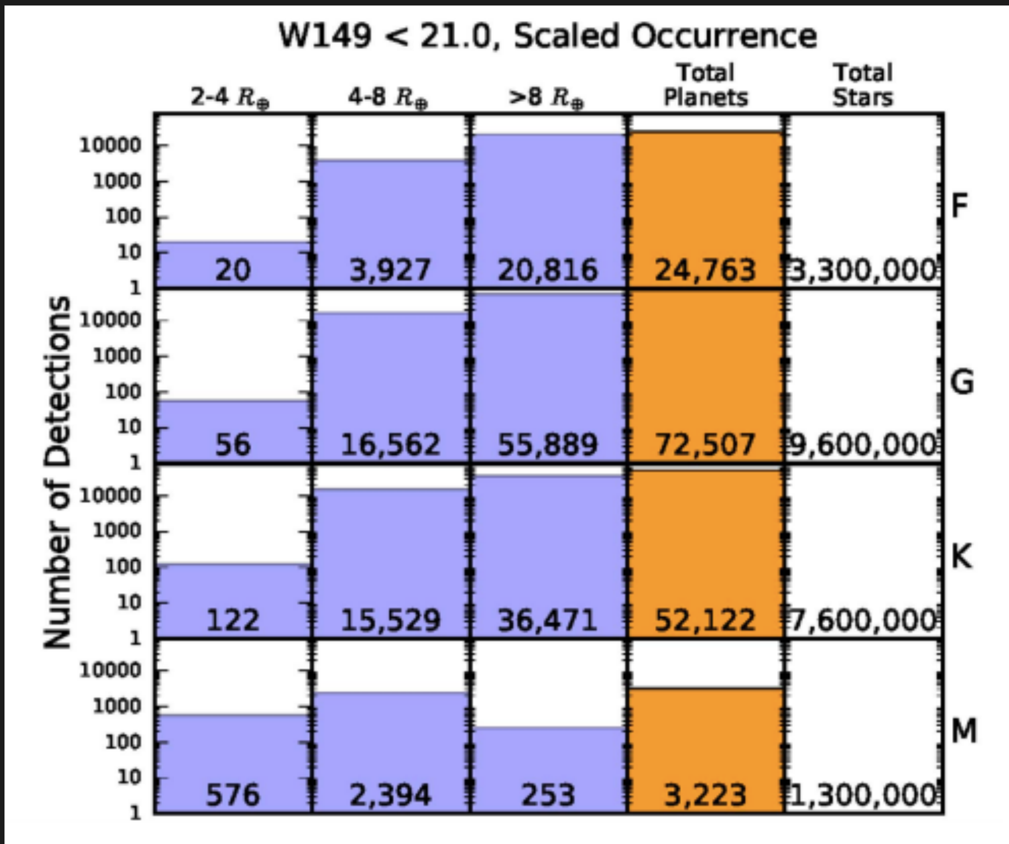
Solar System Science.



- WFIRST will detect ~5000 TNOs down to $W149_{AB}<30$ (corresponding to D~10 km) of 17 deg^2.
  - Substantially below the collisional break.
- Orbital elements will be determined to a few %, allowing for dynamical classification.
- ~1000 of these will occult stars, and several dozen will occult more than one star.

Gould 2014

10^5 Transiting Planets



Expected yield of transiting planets orbiting dwarfs with $W149_{AB}$<21 (Montet et al. 2017)

- WFIRST will detect ~10^5 transiting planets with radii down to ~2R⊕.
- Most host stars will have measured distances.
- Several thousand can be confirmed by the detection of their secondary eclipses.
- Some systems will have measured transiting timing variations.

Bennett & Rhie 2012
Montet et al. 2017

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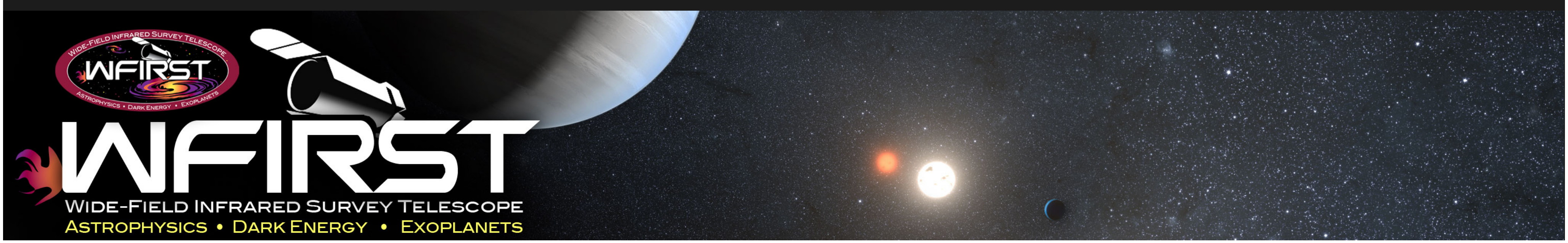
Control of Systemics: Detector Characterization.

- Many of these applications will require new data reduction algorithms in order to realize their full science potential.
- *Excellent-to-exquisite* control of systematics will be required for many of these applications.
- The extent to which systematics can be controlled in unclear.
- However, with its ~4×10^4 dithered images of ~10^8 mostly constant point sources of known fluxes, positions, and colors, the microlensing survey may provide the best dataset to characterize the WFI detectors, including artifacts such as:
  - Persistence, Inter-pixel Capacitance, Count Rate Nonlinearity, and Intra-pixel Response Variations.



‘Auxiliary’ Science.

- Measurement of the Compact Object Mass Function over 10 Orders of Magnitude.
- Detection of ~10^5 Transiting Planets.
- Astroseismology of ~10^6 Bulge Giants.
- Detection of ~$5x10^3$ Trans-Neptunian Objects.
- Parallaxes and Proper Motions of ~$6x10^6$ Bulge and Disk Stars.
- Oh and some planets founds by microlensing too…