WFIRST Community Science Team

WFIRST
WIDE-FIELD INFRARED SURVEY TELESCOPE
ASTROPHYSICS • DARK ENERGY • EXOPLANETS

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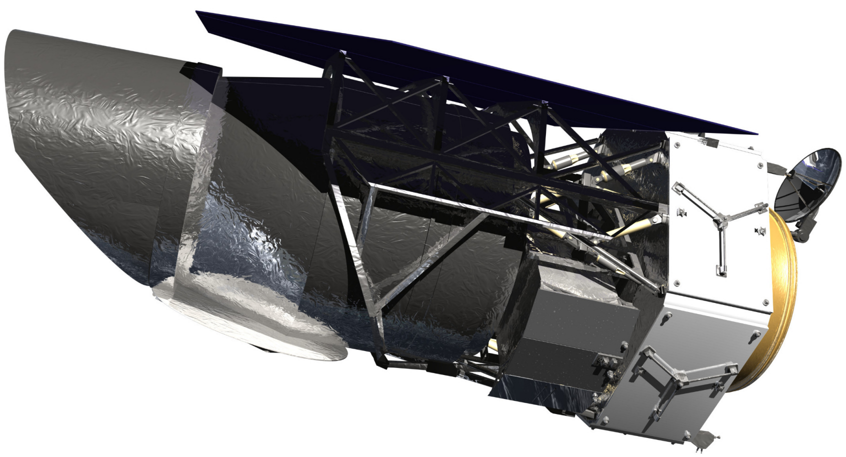
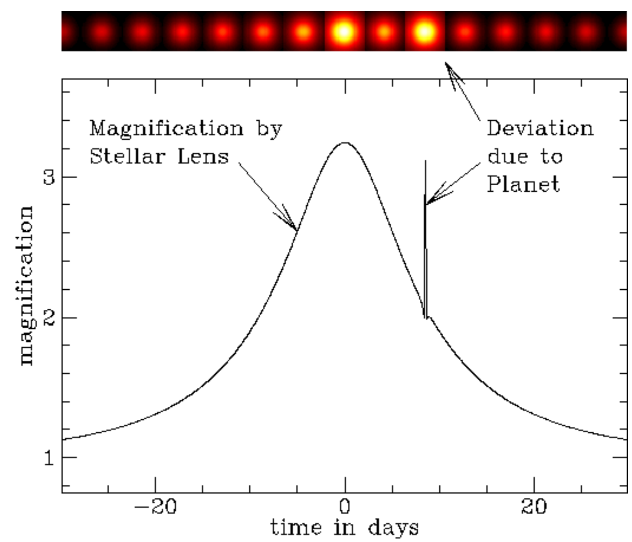




Why Do We Need Exoplanet Demographics?

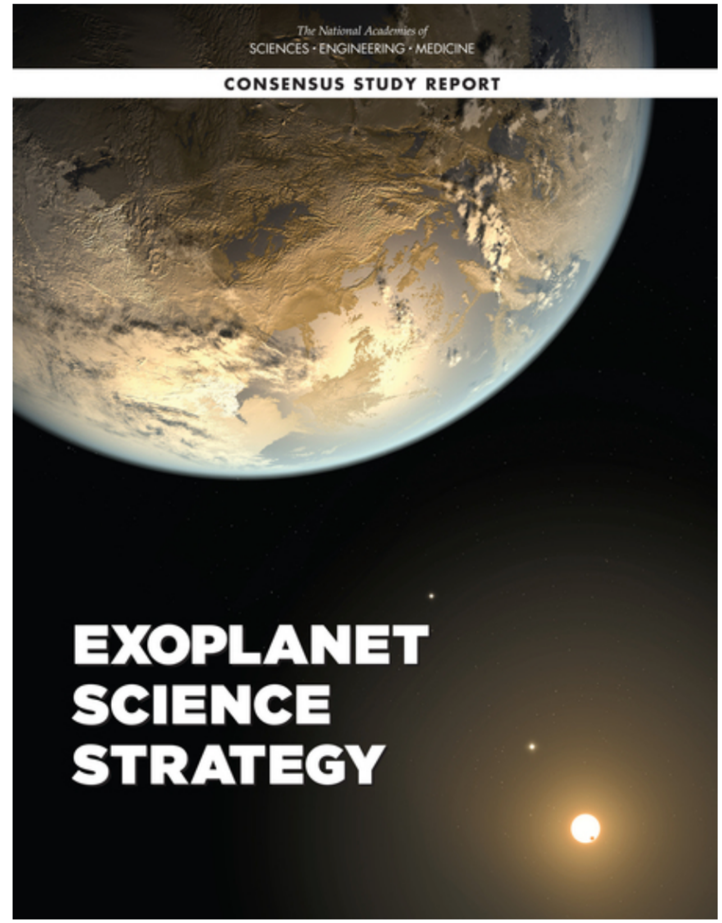
The National Academy's

2018 Exoplanet Science Strategy Report

Recommendation:

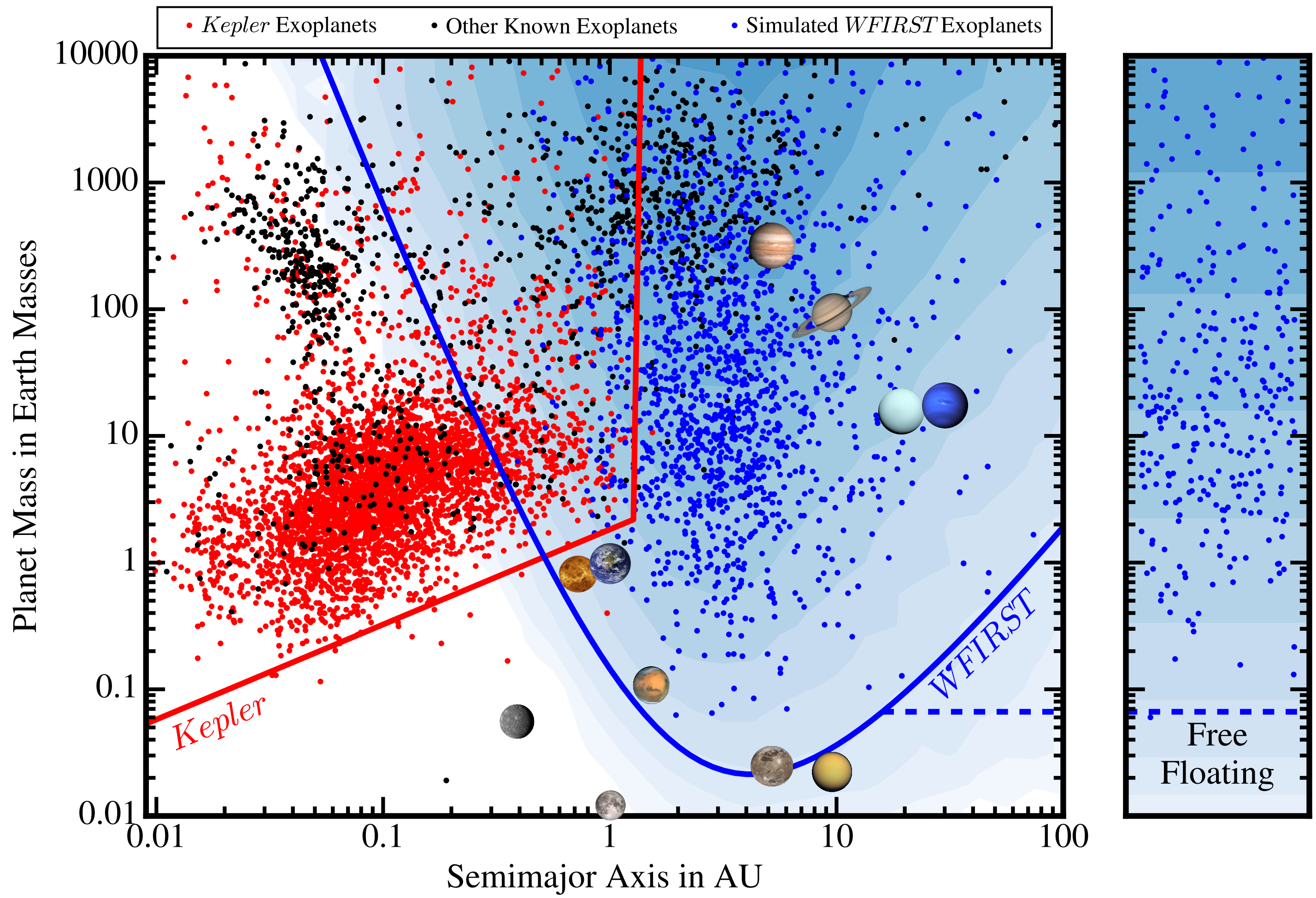
"NASA should launch WFIRST to conduct its microlensing survey of distant planets and to demonstrate the technique of coronagraphic spectroscopy on exoplanet targets.**"**

The New Worlds of the Astro2010 Decadal Survey are Microlens Worlds



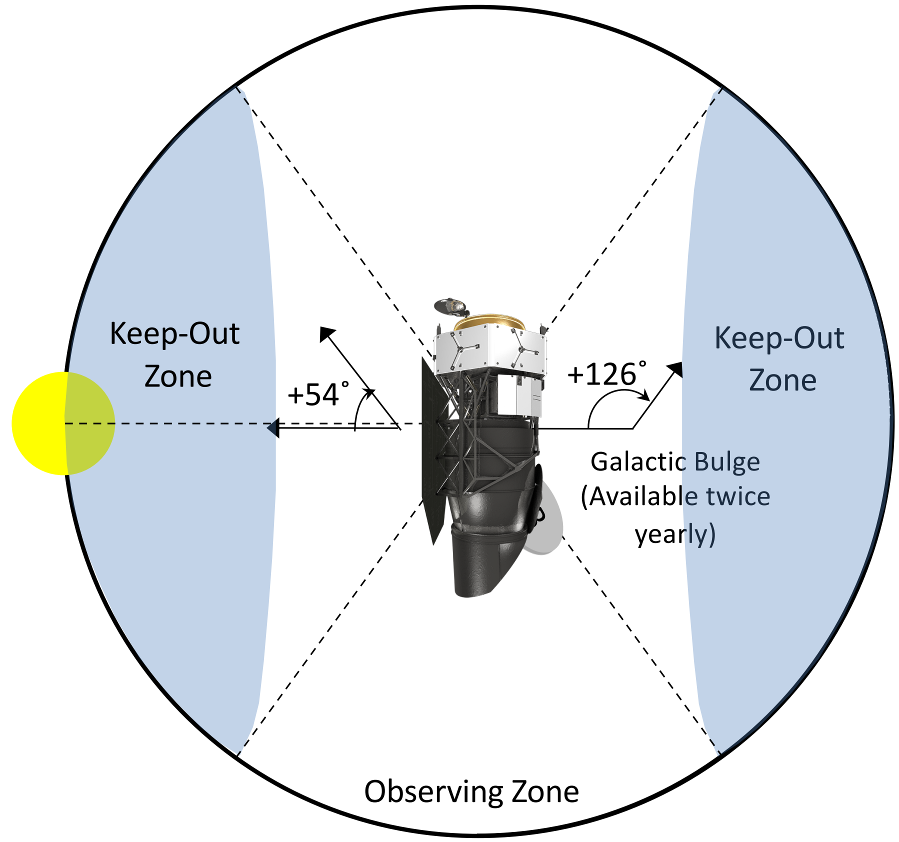
Exoplanet Demographics from WFIRST

Comparison of NASA's 2 Exoplanet Demographics Missions: Kepler and **WFIRST**



WFIRST's μLensing Seasons

- Solar panels restrict range of Sun-spacecraft angle to ~72º range
- Can observe bulge for 72 days twice a year
- 6 ⨉ 72 days = 432 days
  - Nominal microlensing observing allocation
  - Uses 6 of 10 available bulge observing seasons



Optimal time for microlensing parallax observations: acceleration is ⊥ line-of-sight

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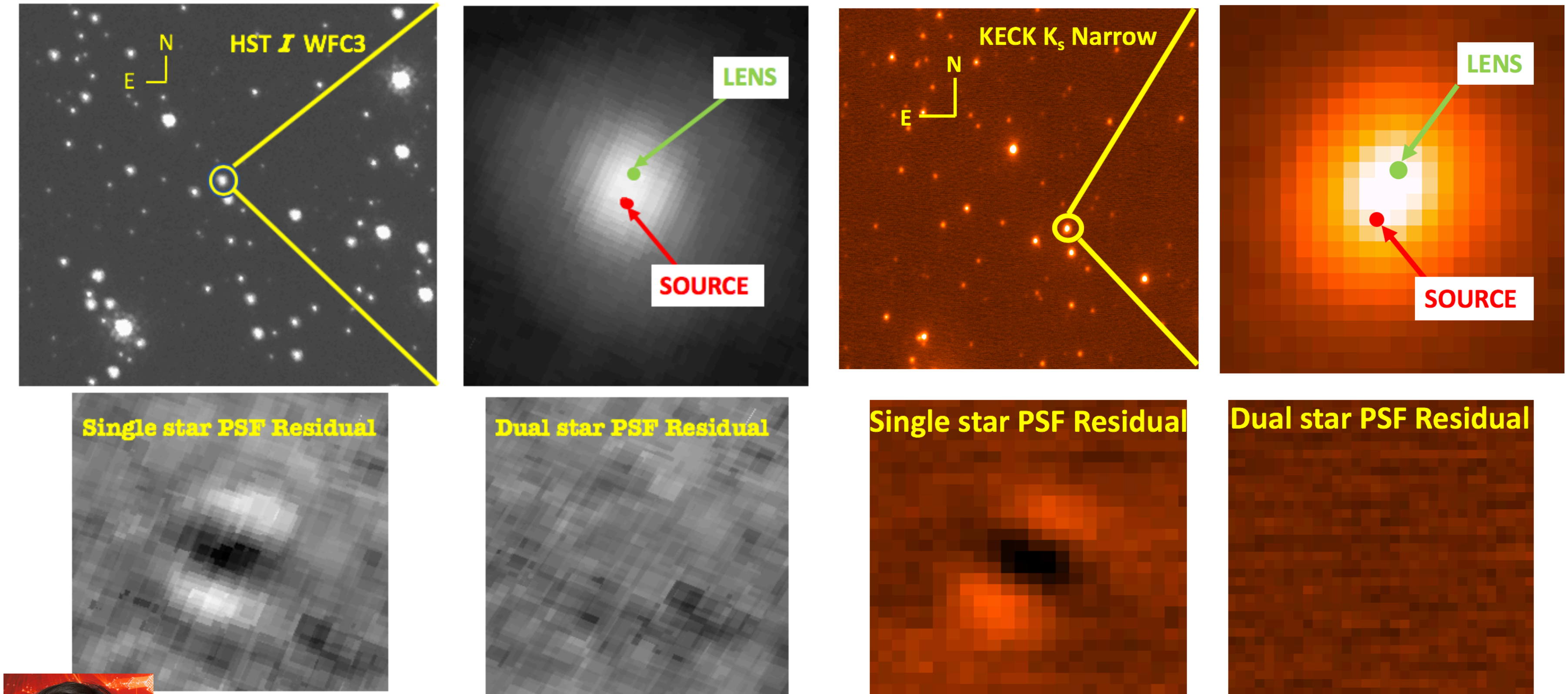
OGLE-2012-BLG-0950 HST I-band vs. Keck K-band



Co-added, dither HST I-band image

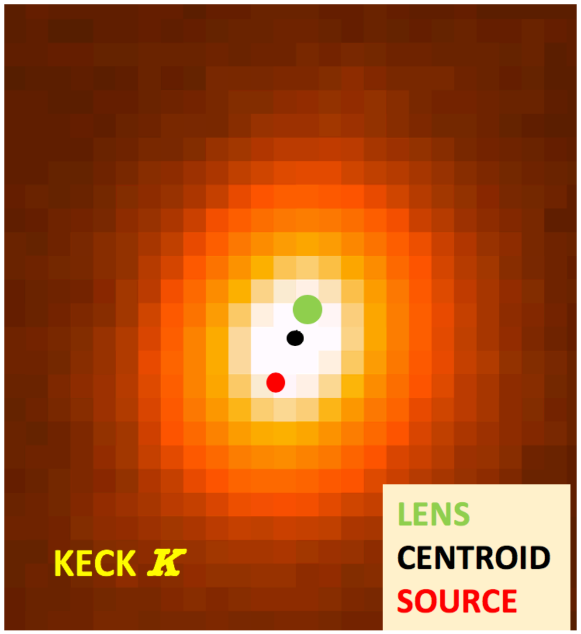
Co-added Keck K_s-band image

Lens & Source not resolved, but slightly elongated and centroid is offset

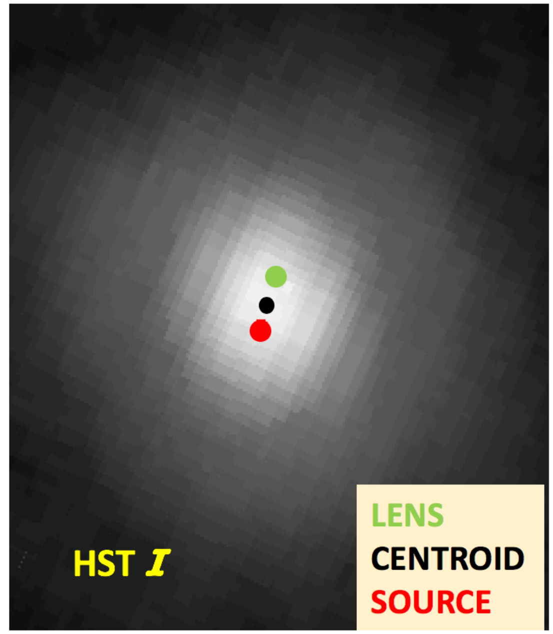
Lens-Source separation = 34.2 ± 0.8 mas

Aparna Bhattacharya

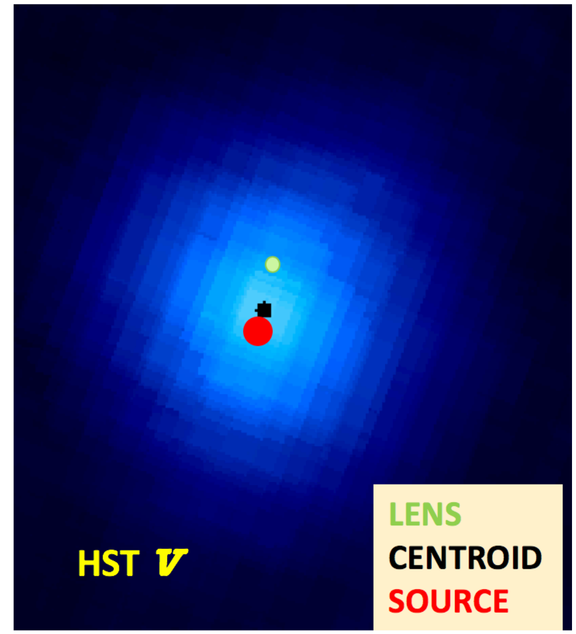
OGLE-2012-BLG-0950 Keck K-band vs. HST I & V-band



Co-added, dithered HST V-band



Co-added, Dithered HST I-band



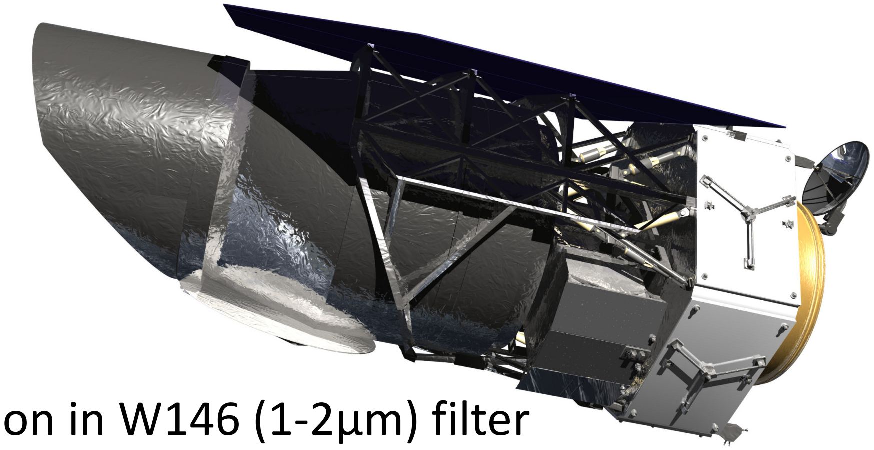
Co-added Keck K_s-band image

Lens & Source not resolved, but slightly elongated and centroid is offset

Aparna Bhattacharya

At smaller separations, relative offset of blended source+lens centroid in different passbands gives stronger signal of lens-source separation. Requires near simultaneous Keck & HST observations.

Host Star Identification with WFIRST



- ~6000 dithered images per 72-day season in W146 (1-2μm) filter
  - 750 × more than our HST examples
  - 20 × more photons per exposure
- ~144 dithered images per 72-day season in R062 or Z087 and F184 filters
  - 18 × more than our HST examples
  - 2-5 × more photons per exposure
- 3-4 Year separation between lensing events and first or last observing season.
- Fainter lens stars
- Expect high efficiency for detecting host stars

WFIRST Microlensing Data Products

- Raw Images are public immediately
- Microlensing Image Pipeline Outputs
  - Time series photometry of all variable objects
    - Released daily with major updates after each season
  - Stellar positions, proper motion for all stars, including those with separations as small as ~10mas, release after each observing season
    - Possibly, image “moments”, (elongation, skewness …) for events with unresolved companions
- Microlensing Models for all single, binary, and (hopefully) triple lens microlensing events
  - Preliminary single and binary models in real time
- Microlensing Detection Efficiencies
  - For single and binary lensing events
  - Reliability of detections may be so high that we do not need reliability estimates
  - But, we will give probabilities for degenerate microlensing events
- These Data Products must be funded! (as was done late in the Kepler mission)

WFIRST Microlensing Science Implementation Team

- 2021 – end of prime mission (2030)
- Develop Microlensing photometry/astrometry pipeline algorithms
  - Including catalog of known stars
  - Final implementation of this pipeline will be done by IPAC
- Produce end-of-season star catalogs with parallaxes and proper motions of each star
- Develop and implement microlensing event detection code
- Develop and implement microlensing modeling algorithms and code
- Develop detection efficiency algorithm
- Produce all high level data products

Proposed WFIRST Community Science Team

- WFIRST Implementation Science Teams will be selected 4-5 years before launch
  - The WFIRST pre-selected survey science should not be limited to this team!
    - This would be inconsistent with the broad community participation expected for a Flagship mission.
  - Community participation should not be limited to post-launch developments
    - Allow community to learn state-of-the-art microlensing analysis methods prior to launch
    - Provide opportunity for improved analysis methods from the community, in collaboration with the Implementation Science Team
    - Enable improved non-exoplanet and non-microlensing science with volunteers working with the Implementation Science Team
- WFIRST Microlensing Community Science Team
  - Open to volunteers
  - Only requirement is that members can work productively with the Implementation Science Team
    - Implementation Team might have to approve membership, but the aim would be accept any reasonable membership request
    - No actual work expected from unpaid members

WFIRST Community Science Team Member Ideas

- Photometry/astrometry pipeline development
  - Community science team members might be able to improve the pipeline design
  - Work with Science Implementation team with access to the Implementation Team's pipeline – so improvements of only part of the pipeline can be made
  - Improvements might be incorporated in later pipeline releases
- Auxiliary photometry/astrometry pipeline or light curve modeling pipelines
  - These would address different science goals than exoplanet microlensing
  - Example: automated modeling and classification of CV light curves
  - Example: Detect and determine orbits for newly discovered asteroids or KBOs moving through WFIRST fields
  - Example: improved microlensing light curve modeling methods (say for triple and quadruple lens events)
- Funding!
  - Community Science Team members should have access to funding for major contributions
  - Perhaps through ROSES or a Participating Scientist Program

WFIRST Community Science: Astrometry

- WFIRST microlensing survey needs precise relative astrometry on <1 pixel scale (< 110 mas)
- Safest dither pattern for microlensing survey is very compact, 1-2 pixel spread.
- Global astrometry is subject to “beam walk” errors
  - The full focal plane is sensitive to the same imperfections in the primary mirror
  - But, different parts of the focal plane see different parts of the secondary and tertiary mirrors. (As you move across the field the beam “walks across the secondary and tertiary)
- Beam walk calibration requires dithering on the ~20” or ~200 pixel scale.
  - This could compromise photometry if sub-pixel scale sensitivity variations change over scale of ~200 pixels (5% of the detector width).
- Can we optimize microlensing photometry and wide field astrometry?
  - Caltech’s Precision Projector Laboratory will soon be measuring sub-pixel scale sensitivity variations on WFIRST flight-like detectors
  - It would be useful to have some help in understanding this test data from those interested in WFIRST astrometry

Development of Creative GO Programs

- The details of the WFIRST time allocation have yet to be worked out
- Some have proposed modifications of the WFIRST Exoplanet Microlensing Survey plans to address additional science goals
  - These would typically hurt the sensitivity of the exoplanet microlensing survey
  - But, this could be overcome by increasing the time allocation for the exoplanet microlensing survey
  - The community science team might be able to work out a joint program that would add the new science without affecting the prime survey science. This would allow experts on the different science topics to evaluate the different science programs instead of having the Microlensing Implementation Science Team have a direct role in the selection of such programs

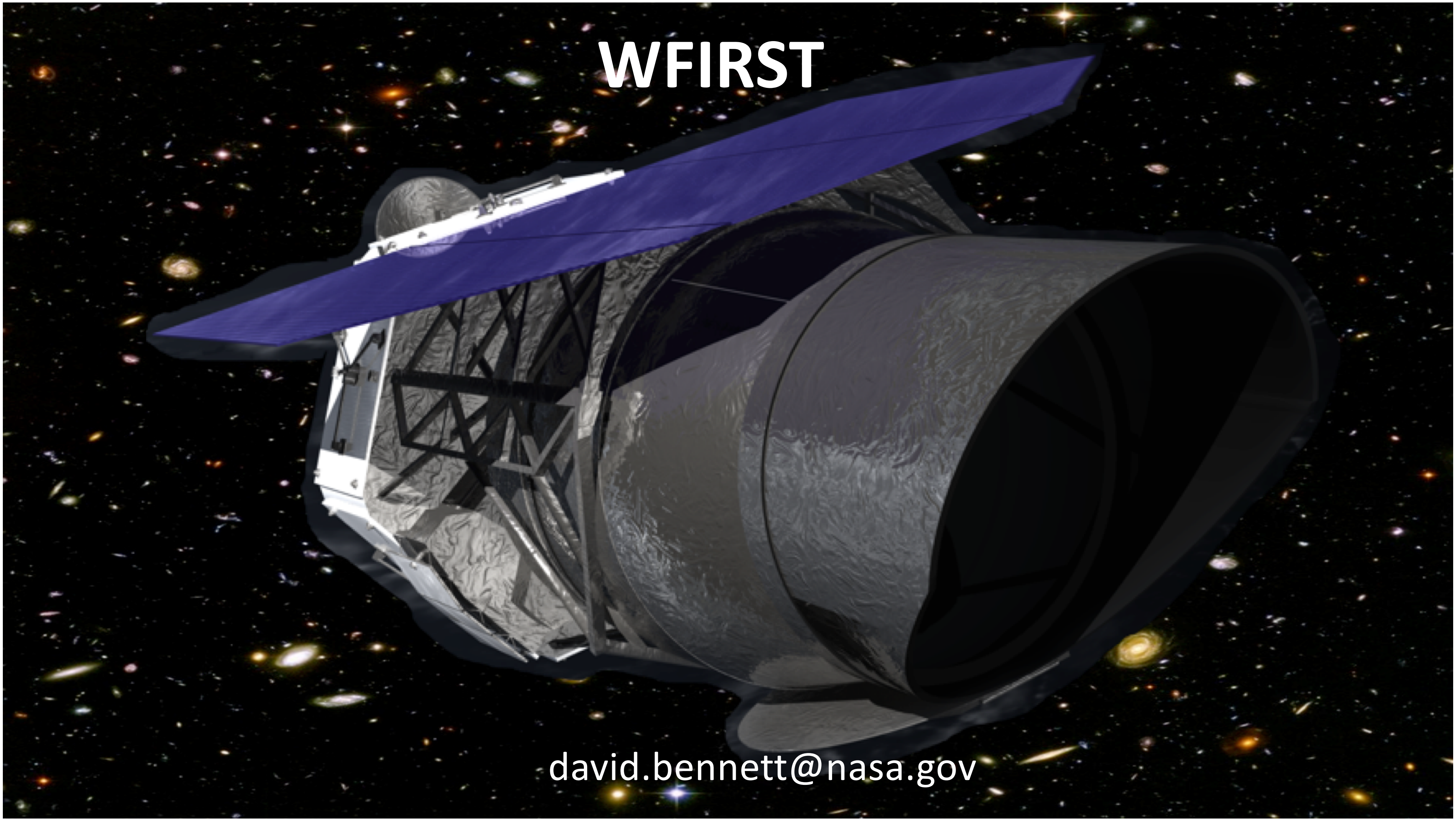
Kepler, K2 and TESS Examples

- Thanks to developments with Kepler, K2 and TESS, the exoplanet community now expects high level exoplanet data products and a community science team
- Kepler and TESS are PI-led missions that have historically left most of the science to the PI teams (e.g. WMAP)
- But, much of the success of these programs depends on
  - High level data products (detection efficiencies, reliability, high quality light curves, etc.)
  - Community Science Team
    - Auxiliary science
    - Follow-up of Kepler, K2, and TESS discoveries

Help!

- We need your help to develop a proposal for these programs!
- Space mission Program Managers do not necessarily see the need for much science funding prior to launch
- Current WFIRST plans call for high level data products, but it is unclear if Project Management plans adequate funding
- There are no current plans for a WFIRST Exoplanet Microlensing Community Science Team

- **”Project White Paper to the Astro2020 Decadal Survey on Community Involvement in the WFIRST Exoplanet Microlensing Survey**
  - NOI already submitted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