WFIRST-AFTA
Exoplanet Microlensing Precusor Observations

David Bennett
University of Notre Dame
Recommended Precursor Observations

- IR microlensing survey from the ground to measure lensing rate and select WFIRST-AFTA microlensing fields
- HST survey of selected fields (WFC3/IR + ACS in parallel?) for proper motion measurements
  - Early observations allow precise lens-source relative proper motion measurements
- HST/WFC3/IR time series observations for photometry/astrometry code development
- HST and AO follow-up of current planet detections
- Kepler (K2) and Spitzer parallaxes
- ExoPAG – SAG-11 led by Jennifer Yee to address this
Measure the Microlensing Rate in Target Fields with an IR Survey

MOA-II microlensing rate maps

MOA-II measurements show maximum lensing rate at $l = 1^\circ$, but this depends on extinction. Existing models are too simplistic to capture the detailed rate structure in $l$ and $b$. 

WFIRST–NRO Fields & Extinction Map

WFIRST–AFTA Fields
central MOA fields

scale

rate per star

rate per deg\(^2\)
New Photometry/Astrometry code needed

- These images are from MACHO fields with low extinction
- WFRIST-AFTA fields will be closer to the plane with 2-3 × the stellar density
- Proper motion of neighbor stars will be a significant source of photometry errors
- A time series of HST/WFC3/IR data will allow us to test photometry code
Blow-up of HST/WFC3/IR Image

HST J-band
Microlensing Survey Stars Will Not Be Isolated

• Proper motion of neighboring stars will contribute to photometry noise
• We need astrometry information for our determination of host star properties
• We want a WFIRST-AFTA exoplanet microlensing pipeline that generates
  • Photometry
  • Astrometry
  • A catalog of detector defects

• Develop exoplanet microlensing photometry+astrometry pipeline pre-launch using HST/WFC3/IR data
Lens Star Identification from Space

- Lens-source proper motion gives $\theta_E = \mu_{\text{rel}} t_E$
- $\mu_{\text{rel}} = 8.4 \pm 0.6 \text{ mas/yr}$ for OGLE-2005-BLG-169
- Simulated HST ACS/HRC F814W (I-band) single orbit image “stacks” taken 2.4 years after peak magnification
  - 2× native resolution
  - also detectable with HST WFPC2/PC & NICMOS/NIC1
- Stable HST PSF allows clear detection of PSF elongation signal
- A main sequence lens of any mass is easily detected (for this event)

Simulated HST images:
- $M_L = 0.08 M_\odot$
- $M_L = 0.35 M_\odot$
- $M_L = 0.63 M_\odot$

raw image  PSF subtracted  binned
Stacked HST I-band Image of OGLE-2005-BLG-169 Source

Source looks elongated relative to neighbors
PSF for a Single Star Subtracted

Residuals in X when we subtract a PSF from each image and stack...
Fit and Subtract Two Stars: Source & Lens

Very good subtraction residuals when we fit for two sources
Lens+Source Solution:

- Offset consistent in the F814W, F555W, and F438W data:
  - \( \Delta x = 1.25 \) pixels = 50 mas
  - \( \Delta y = 0.25 \) pixel = 10 mas
  - FLUX: (left) (right)
    - F814W: \( 3392 \) e\(^-\) \( 3276 \) e\(^-\)
    - F555W: \( 2158 \) e\(^-\) \( 3985 \) e\(^-\)
    - F438W: \( 338 \) e\(^-\) \( 1029 \) e\(^-\)
    - \( f_I = 0.51 \)
    - \( f_V = 0.35 \)
    - \( f_B = 0.25 \)

HST BVI observations imply
\( M_* = 0.63 \, M_\odot \)
\( M_p = 17 \, M_\oplus \)

observed separation of 51 mas confirms planet model prediction of 54.3\( \pm \)3.7 mas