National Aeronautics and Space Administration

Setting the WFIRST Microlensing Fields: Analysis of the UKIRT Precursor Survey

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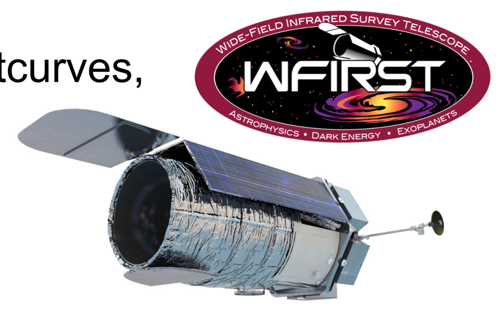
Program: Topical Area R&TD

The Wide Field Infrared Survey Telescope (WFIRST) flagship mission is scheduled to launch in the mid-2020's, with more than 1 year of its lifetime dedicated to a microlensing survey. This survey will discover ~1000 exoplanets via their microlensing lightcurves, enabling a Kepler-like statistical analysis of planets ~1-10 AU from their parent stars and revolutionizing theories of planet formation.



Our goal is to prepare for WFIRST in two ways:

1) **Determine the optimal target fields for the WFIRST microlensing survey**.
2) Develop data analysis tools to enhance the science return of the survey.

Project Objectives:

- Extract lightcurves for the tens of millions of stars in our near-IR UKIRT survey.
- Identify microlensing events in the lightcurves, distinguishing them from intrinsic stellar variability or spurious instrumental artifacts.
- Map the microlensing event rate near the center of the galaxy.

Approach:

Unlike all previous microlensing surveys, *WFIRST will operate in the near-IR*. In order to map the unknown near-IR event rate, we are performing a near-IR survey with **UKIRT, a 3.8-m telescope on Mauna Kea in Hawaii**. Over three years, we have imaged ~11 square degrees around the center of the Milky Way. The survey contains ~40 million lightcurves, with ~100 epochs each.

Our preliminary analysis was very successful, detecting the first five microlensing events ever discovered in the infrared (Shvartzvald et al. 2017)

MACHINE LEARNING

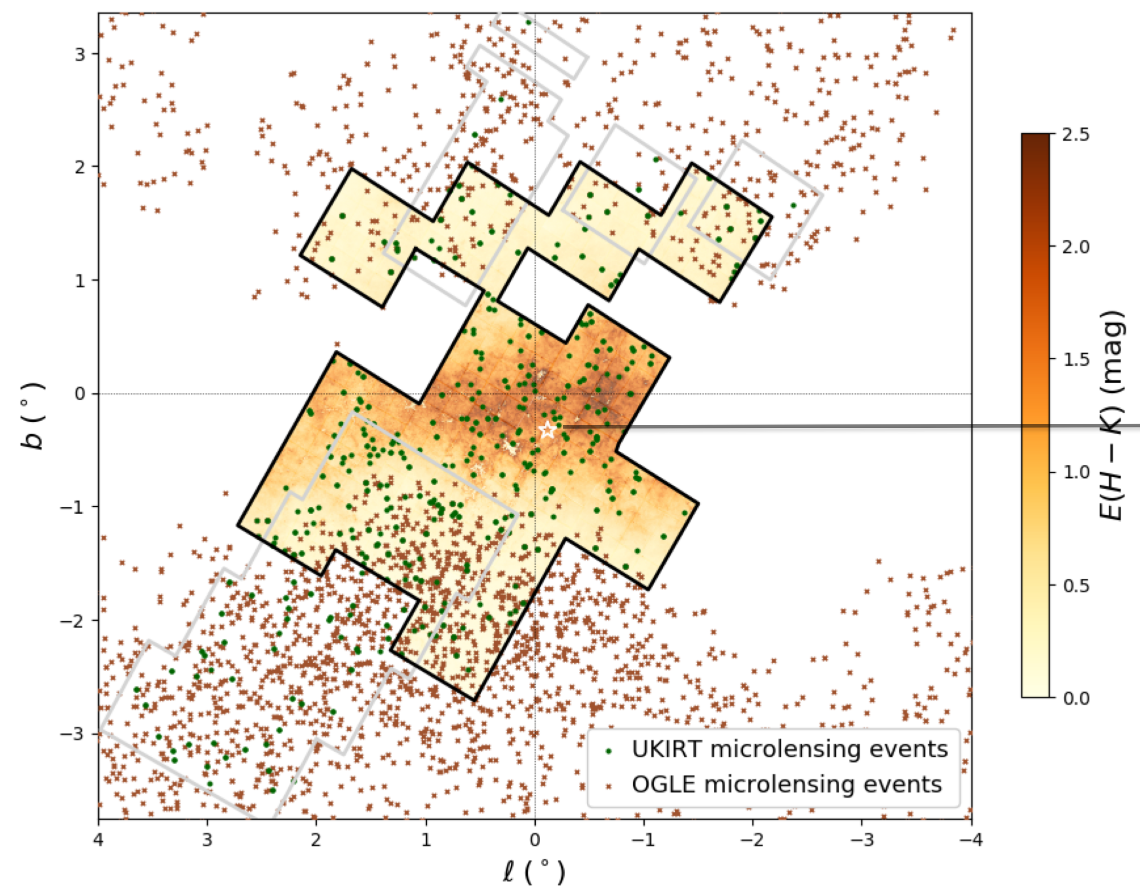
We have taken advantage of JPL's expertise in machine learning to advance the state-of-the-art in lightcurve classification. While we still need to vet a subset of lightcurves by eye (for use as a training set), we have developed a classification scheme that can automatically classify the overall dataset and can robustly quantify the likelihood that each lightcurve is microlensing. Having an automated procedure will not only be necessary for the eventual processing of WFIRST's much larger dataset, but is also immediately required, to determine our detection efficiency and thereby map the underlying event rate across the potential WFIRST fields.

We have focused on two technical aspects of the classification scheme:

1) Determination of the best classifier (random forest) and parameter optimization.
2) Identification of a set of lightcurve features that can distinguish between different types of stellar variability.

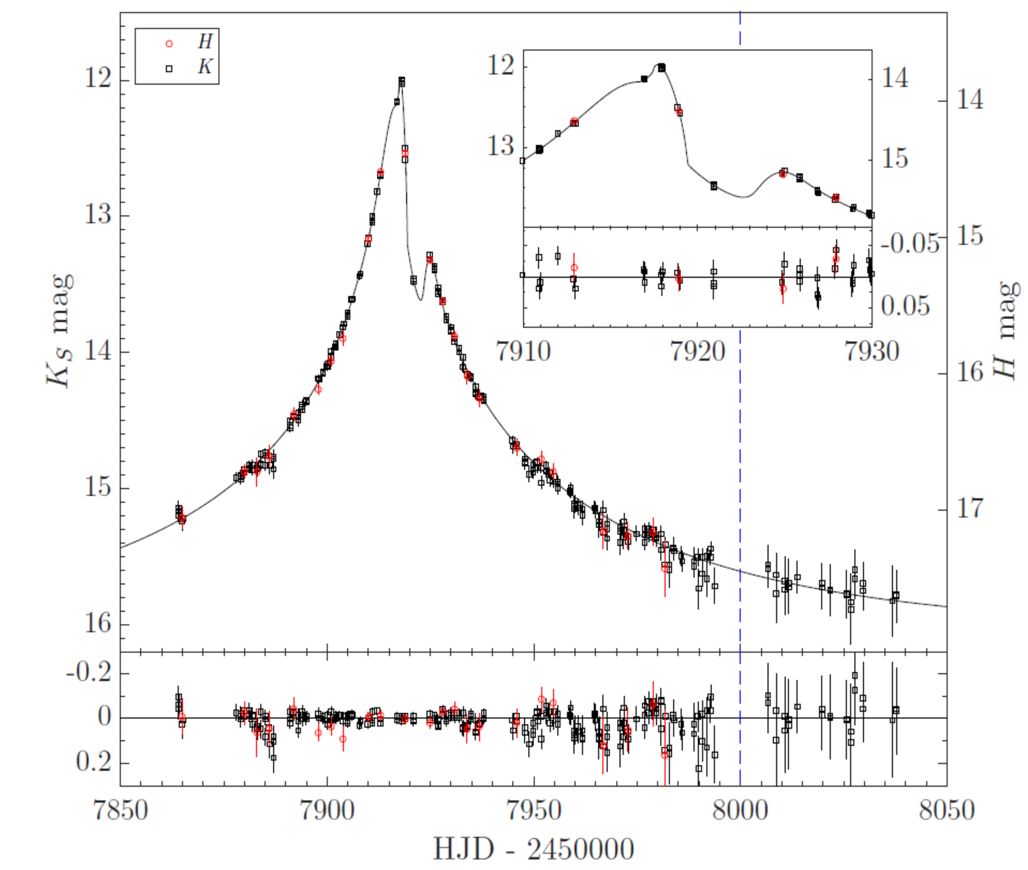
Results: Detection of Microlensing Events

the Moon (for scale)



We have now detected more than 500 microlensing events. Within ~1° of the Galactic center, there is too much dust for optical surveys to detect microlensing events (e.g. OGLE, the brown points). Our infrared survey has no difficulty in detecting many events (green points) close to the center of the Galaxy, including a discovered planet (white star). Based on the infrared colors of stars in our observed fields, we can also map the dust extinction in these regions (color scale).

Results: Detection of New Exoplanets



This is *not* an exoplanet survey; the goal is to map the *stellar* microlensing rate, for WFIRST. Still, our *discovery of a Jupiter-mass planet orbiting at ~4 AU* around a solar-type star (Shvartzvald+ 2018) highlights our successful identification of many high-quality UKIRT microlensing events. Because it is embedded in a region of high dust extinction, no other microlensing survey could detect this event.

Benefits to NASA and JPL:

The results of this project will feed directly into NASA's WFIRST mission. The specific impact of this work is two-fold, along the lines of our two original goals:

First, the resulting event rate map will be used to determine the optimal target fields for WFIRST's exoplanet survey. The best fields will be decided by a trade between event rate and dust extinction; the center of the galaxy has many stars/events (good), but has more dust (bad). The WFIRST microlensing Science Investigation Team (SIT) already has detailed models predicting the number and type of planets that WFIRST will detect. Including our UKIRT event rate and our UKIRT dust extinction measurements into these existing Design Reference Mission simulations will enable us to optimize the overall mission yield.

Second, the machine learning algorithm developed here will be incorporated into the WFIRST data pipeline. We have already tested it on simulated WFIRST data, as part of a data challenge organized by the WFIRST SIT. We are now in the process of writing pipeline flowcharts and documentation for the formal mission requirements.

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References:

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Publications:

Shvartzvald, Y. et al. (2018) Astrophysical Journal 857, L8, "*UKIRT-2017-BLG-001Lb: A Giant Planet Detected through the Dust*"

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