Convolutional Neural Networks for Microlensing Detection within Photometric Light Curves

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Abstract

Wide-field telescope surveys, like the one conducted by the **Microlensing Observations in Astrophysics** (MOA) collaboration, consistently monitor millions of celestial objects, accumulating extensive datasets over the years. While mining this vast volume of data to identify microlensing exoplanetary signatures already poses challenges, an even greater hurdle awaits. The Nancy Grace Roman Space Telescope (Roman) promises to collect hundreds of millions of precise light curves, an even greater data influx. Neural networks have emerged as potent tools to address this challenge. In this presentation, we propose using convolutional neural networks to facilitate gravitational microlensing detection. Our ongoing project uses the nine-year MOA dataset, containing 2.4 million light curves, of which 23 thousand received human-inspected labels. **Our strategy uses only raw photometric light curves as input for our neural network pipeline, which, after training, can detect microlensing signals in the light curve in milliseconds.** This approach aims to provide an alternative pipeline to accelerate the identification of potential microlensing exoplanets.

The MOA 9-year Data Set

Soon: Python tool for reading, downloading, and visualization

- First high-cadence microlensing survey towards the Galactic bulge.
- **2.4 million light curves from 2006 to 2014.**
  - **Fully available on the NASA Exoplanet Archive** since December 2023.
- **23,000 human-inspected labels.**
- **6,105 gravitational microlensing events** - single lens fitting biased.
- Suzuki et al. 2016 provided statistical analysis for planetary signals discovered using gravitational microlensing.
- Sumi, …, Ishitani Silva, et al 2023 predicted ~21 free-floating planets per star.

Current Method

10 times - Cross-validation

MOA Dataset 549,444 Light Curves with Labels

Training set: 80%
Validation set: 10%
Test set: 10%

Flux only
train

Convolutional Neural Network

pip install qusi

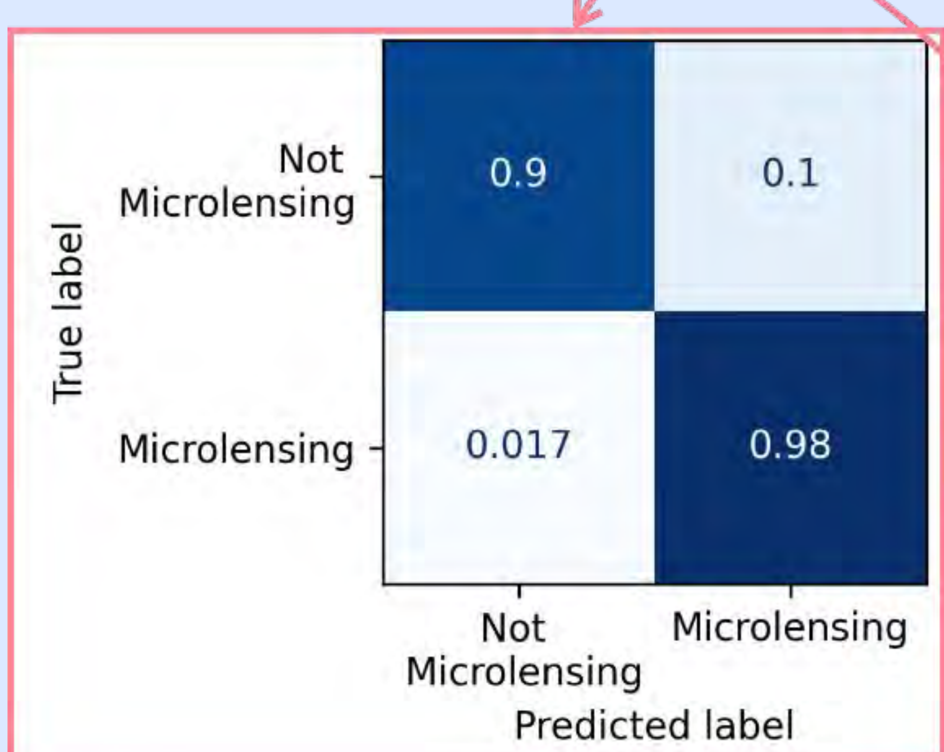
Once trained, it is fast!
infer each lightcurve in milliseconds

List of Neural Network Confidence Scores for Each Light Curve

Score: 0 to 1

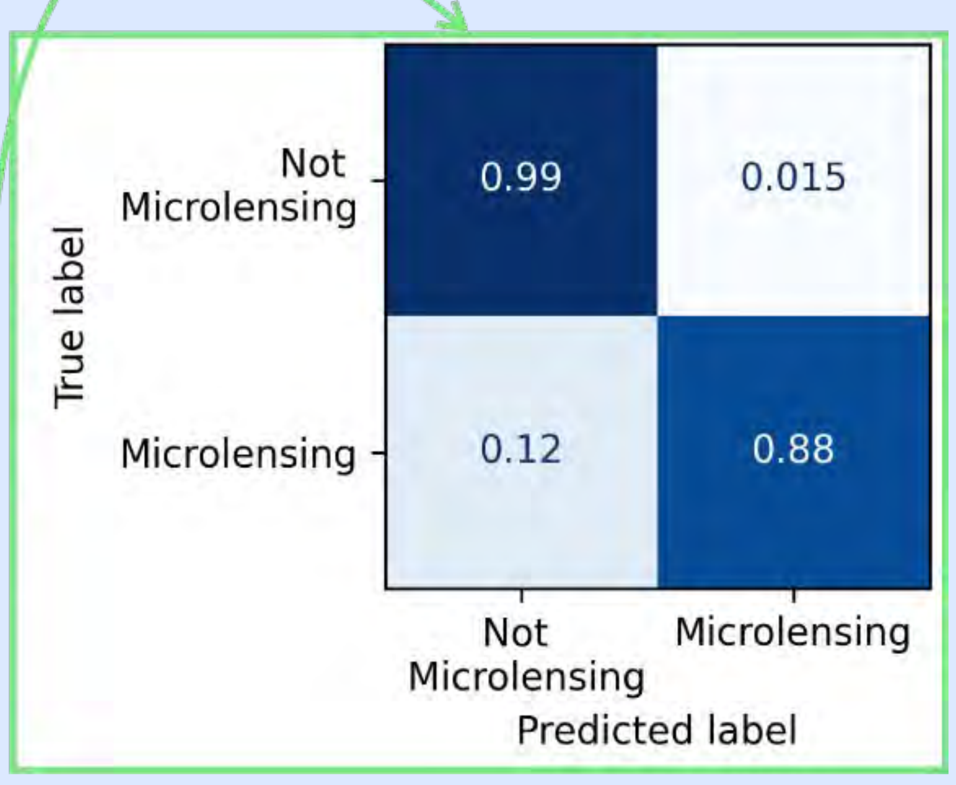
Results

Lower threshold = miss less microlensing events

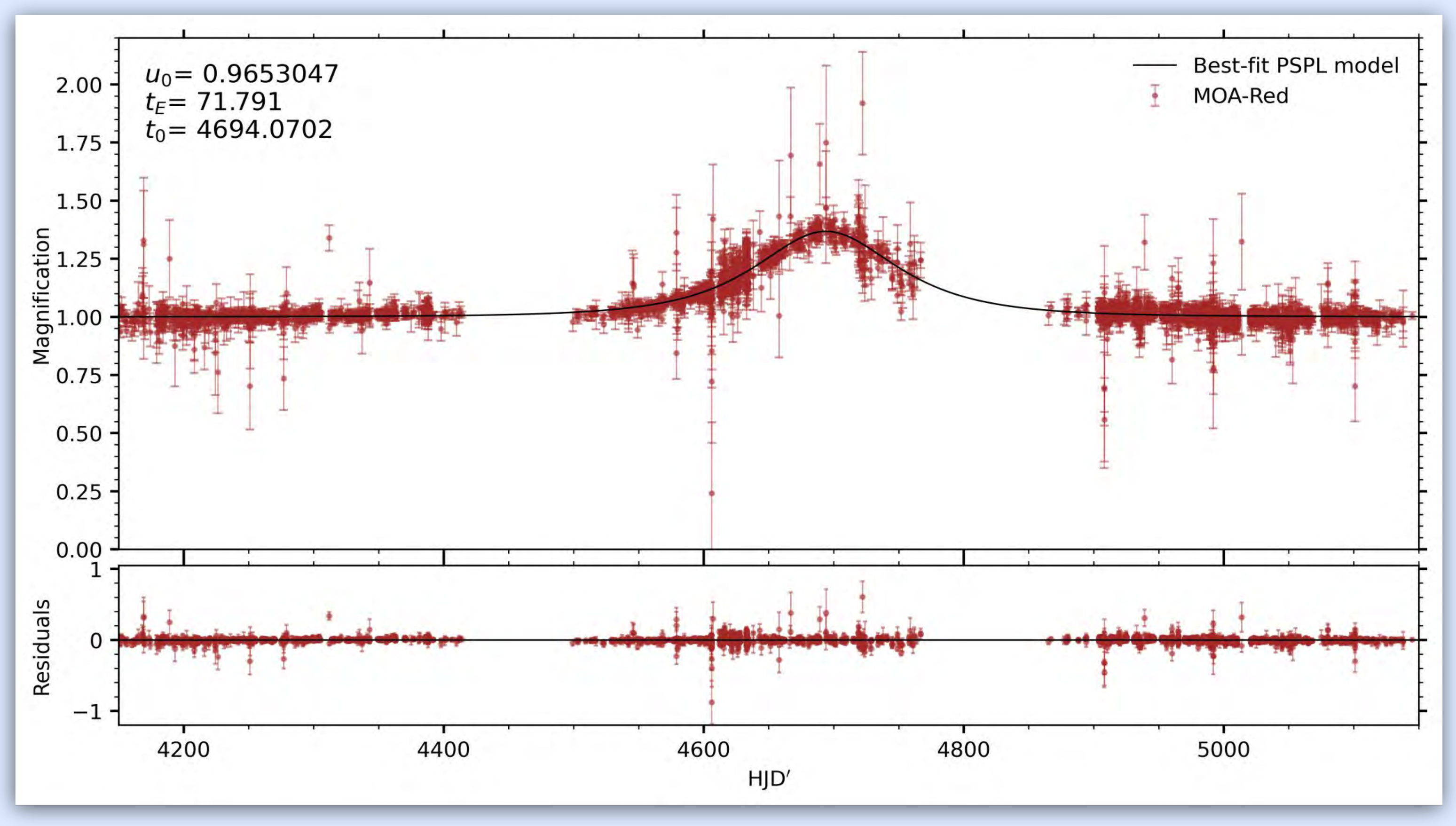


Thresholds	True positives	False positives	True negatives	False negatives
0.1	6068	150830	392509	37
0.2	6003	55592	487747	102
0.3	5930	34384	508955	175
0.4	5826	23194	520145	279
0.5	5632	14685	528654	473
0.6	5348	7895	535444	757
0.7	5122	3827	539512	983
0.8	4948	2019	541320	1157
0.9	4718	1339	542000	1387

Higher threshold = less false positives



Capability to detect previously missed events



A microlensing event that was previously missed by the MOA collaboration, but identified by our NN with a confidence level of 94%.

Next Steps

- Train and infer on the entire dataset.
- Use **synthetic data** to enhance the quality, diversity, and emphasis (e.g., **multiple lens events**) of the training dataset.
- Extend this work to detect multiple lens events vs single lens.
- Perform **archival searches** with the network to identify previously undetected events.
- Utilize the coherence of our pipeline to determine the **sensitivity of the MOA survey,** contributing to statistical studies of **exoplanets, brown dwarfs and binary star distributions.**
- Train and evaluate the neural network as an **alternative pipeline for the Roman mission.**

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