FRONTIER DEVELOPMENT LAB | 2018

Automatic Classification of Transiting Planet Candidates with Deep Learning

Megan Ansdell[1]

Hugh Osborn,[2] Yani Ioannou,[3] Michele Sasdelli,[4] Jeff Smith,[5,6] Doug Caldwell,[5,6] Chedy Raissi,[7] Daniel Angerhausen,[8] Jon Jenkins[5]

[1]**UC Berkeley, Center for Integrative Planetary Science;** [2]Laboratoire d'Astrophysique de Marseille; [3]University of Cambridge, Machine Intelligence Lab; [4]University of Adelaide; [5]NASA Ames Research Center; [6]SETI Institute; [7]Institut National de Recherche en Informatique et en automatique; [8]University of Bern, Center for Space & Habitability

EXOPLANETS

ADASS XXVIII, College Park, 13 Nov. 2018

FDL

NASA Frontier Development Lab (FDL)

Space Scientists

Machine Learning Researchers

Silicon Valley Partners

FDL 2018

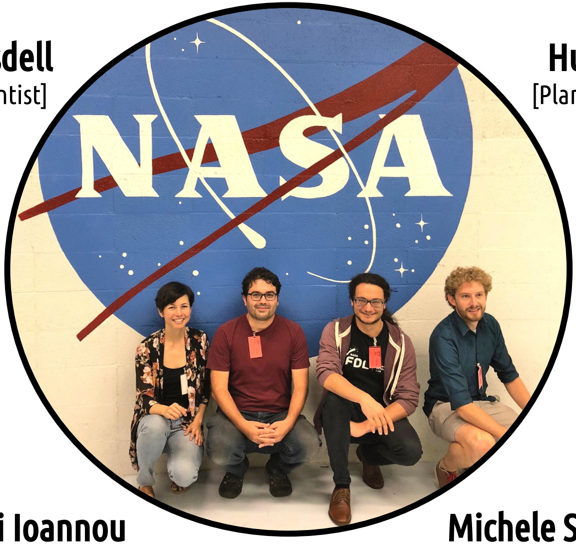
- 8 week research accelerator hosted at NASA Ames & SETI
- 9 projects across 5 areas proposed by lead mentors

Innovative Solutions to Space Science Problems

2018 NASA FDL Exoplanet Team

Megan Ansdell
[Planetary Scientist]
UC Berkeley

Hugh Osborn
[Planetary Scientist]
LAM, Marseille



Yani Ioannou
[Deep Learning Expert]
University of Cambridge

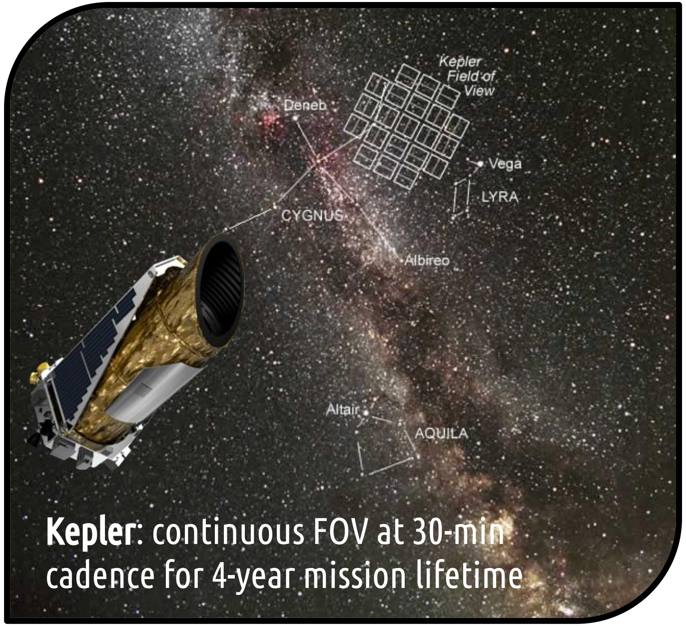
Michele Sasdelli
[Deep Learning Expert]
University of Adelaide

2018 FDL Exoplanet Team Mentors:

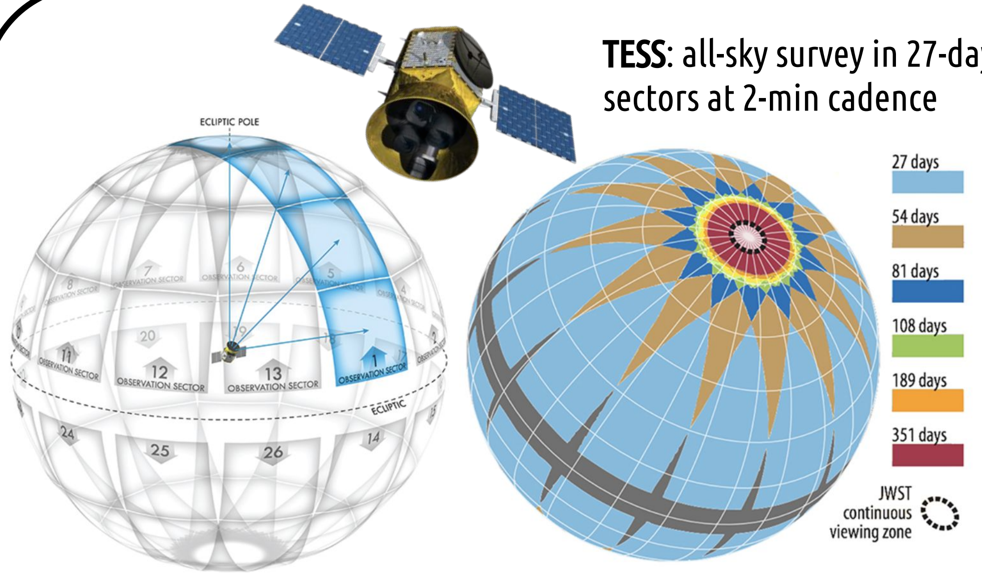
- *Science Expertise* → J. Smith, D. Caldwell, J. Jenkins (NASA Ames / SETI Institute) Daniel Angerhausen (University of Bern / CSH)
- *Machine Learning* → C. Raissi (INRIA), Yarin Gal (Oxford)
- *Compute Power* → Massimo Mascaro (Google Cloud)

Challenge: increase the efficacy and yield of exoplanet transit detections with deep learning

The Data: Kepler & TESS Light Curves

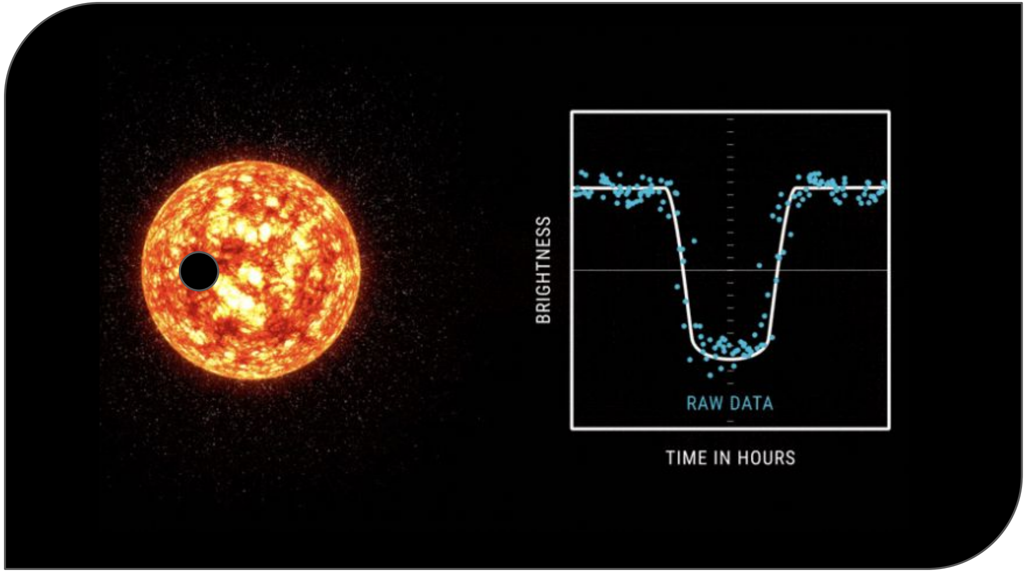


Kepler: continuous FOV at 30-min cadence for 4-year mission lifetime



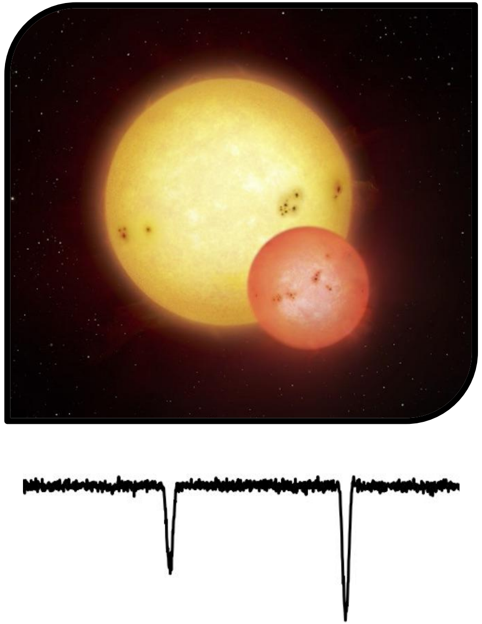
TESS: all-sky survey in 27-day sectors at 2-min cadence

The Data: Kepler & TESS Light Curves

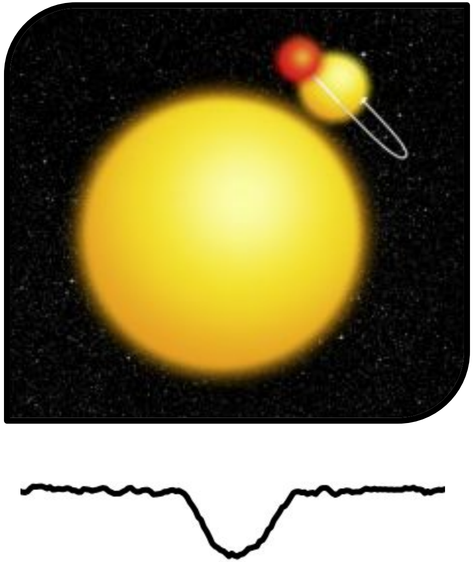


- Orbiting exoplanets transit host star
- Distinct box-shaped transit
- Very shallow 0.01%–1.0% flux dips

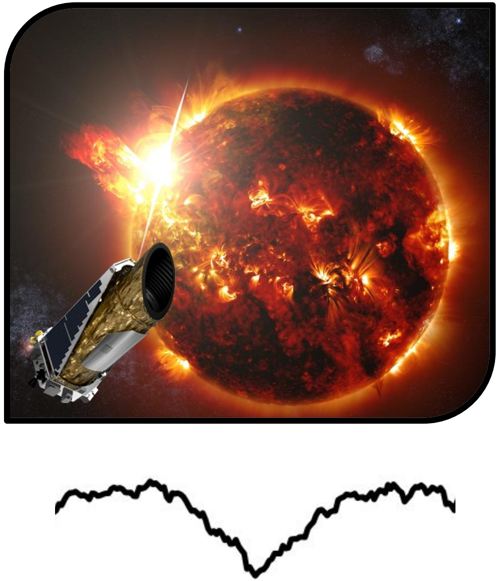
The Data: False Positives



Eclipsing Binaries (EBs)



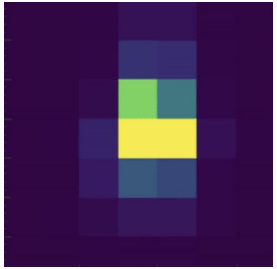
Background Eclipsing Binaries (BEBs)



Stellar Variability / Instrumental Noise

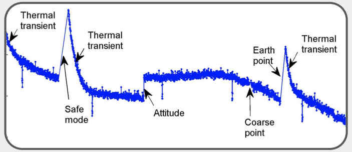
Kepler/TESS Science Processing Pipelines

Target Pixel File (TPF)



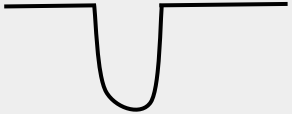
Smith+2012, Stumpe+2012

Aperture photometry & Sysetmatics Correction



Jenkins+2010, Seader+2013

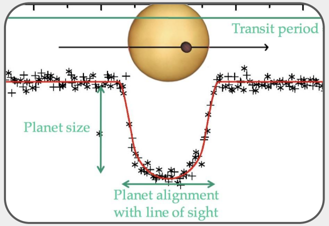
Transiting Planet Search (TPS)



Threshold Crossing Event (TCE)

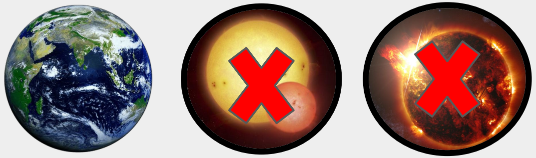
Wu+2010

Data Validation (DV)

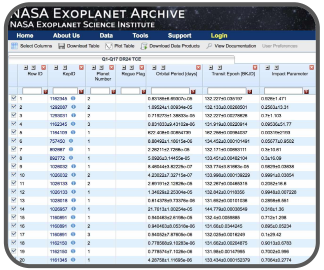


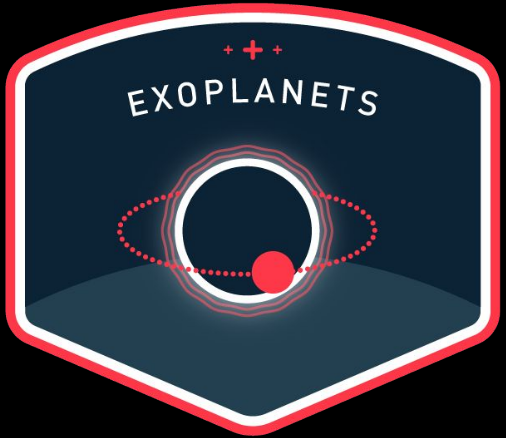
Batalha+2013, Burke+2014, Rowe+2015, Mullally+2015

Kepler TCE Review Team [human vetting]



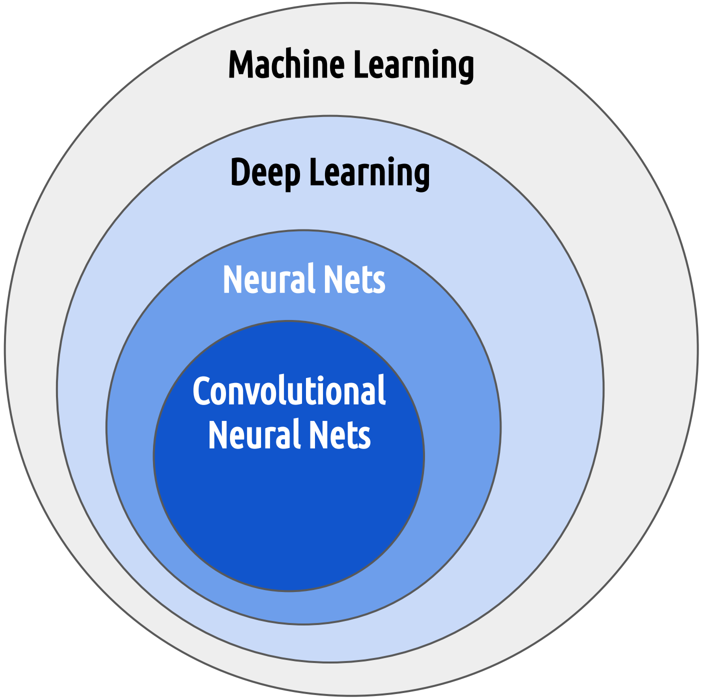
Exoplanet Catalogues

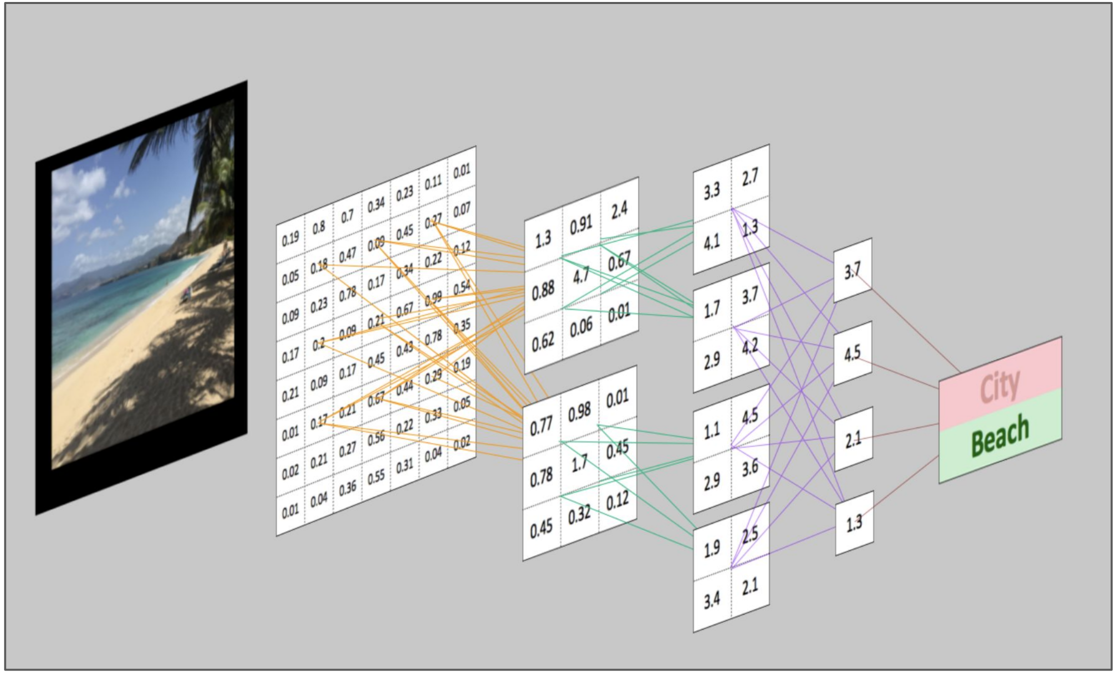




Challenge: increase the efficacy and yield of exoplanet transit detections with deep learning

Classifying Transits with Deep Learning





Classifying Transits with Deep Learning

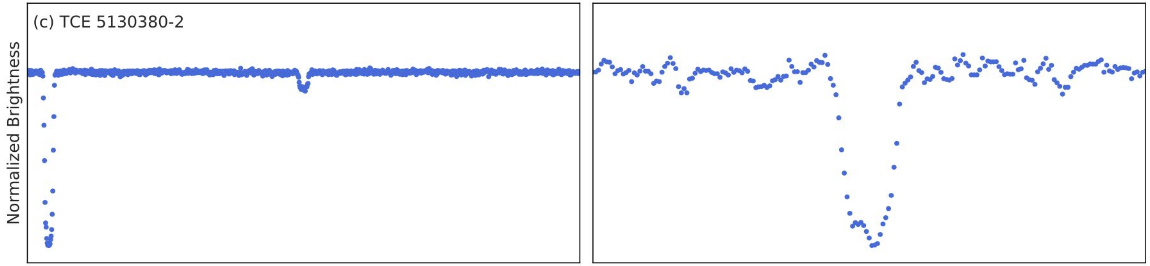
- **Quick** → trained models take seconds/minutes to apply to new data
- **Systematic** → important for calculating exoplanet occurence rates
- **Upgradable** → re-doing analysis with upgrades is easy/quick
- **Quantifiable** → can assign probabilities/uncertainties to planet candidates

Classifying Transits with Deep Learning

Astronet

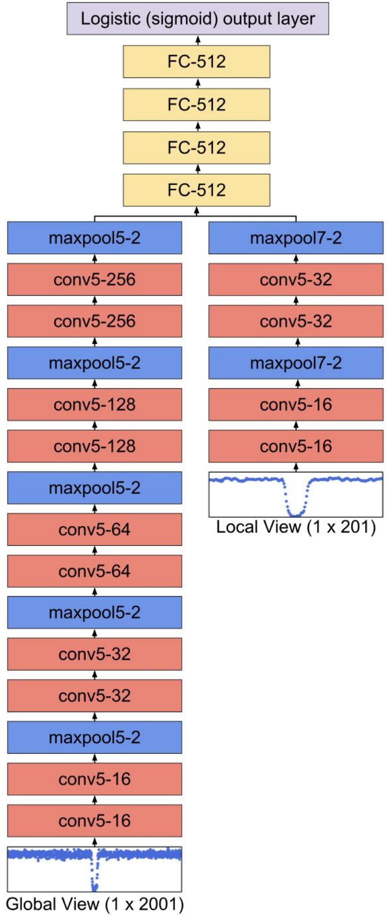
Shallue & Vanderburg (2018)

- Deep Convolutional Neural Net written in TensorFlow
- Inputs are "local" and "global" transit view of each TCE
- Two disjoin 1D convolutional columns + 4 fully connected layers
- Output is binary classifier in the range [0,1]



Global View

Local View



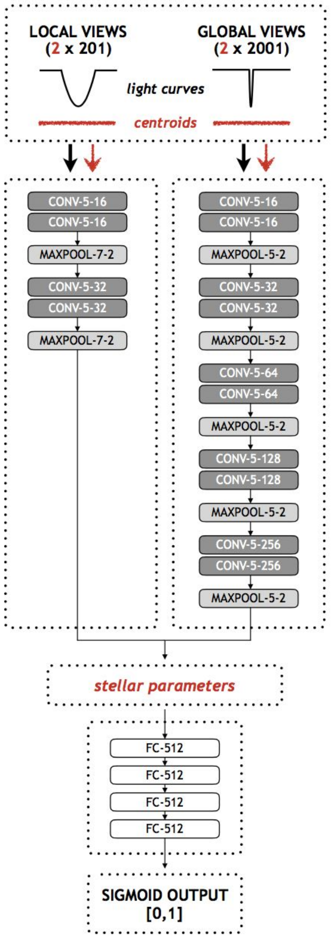
Classifying Transits with Deep Learning

Exonet [Astronet + Scientific Domain Knowledge]

Ansdell, Ioannou, Osborn, Sasdelli, et al. (2018)

- Re-implemented Astronet in PyTorch
- Added "scientific domain knowledge" to architecture + inputs
- Improved overall model performance by ~1–3%
- 15-20% higher recall for lowest SNR transits (Earth-sized planets)

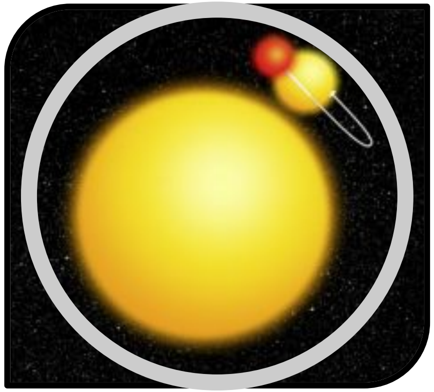
arXiv: 1810.13434
https://gitlab.com/frontierdevelopmentlab/exoplanets

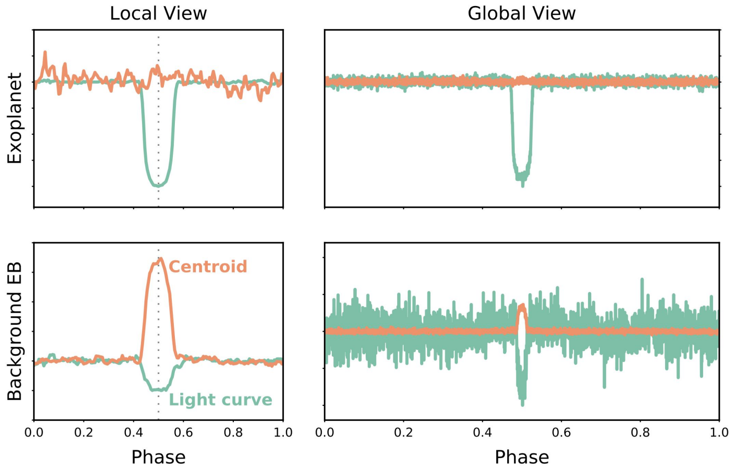


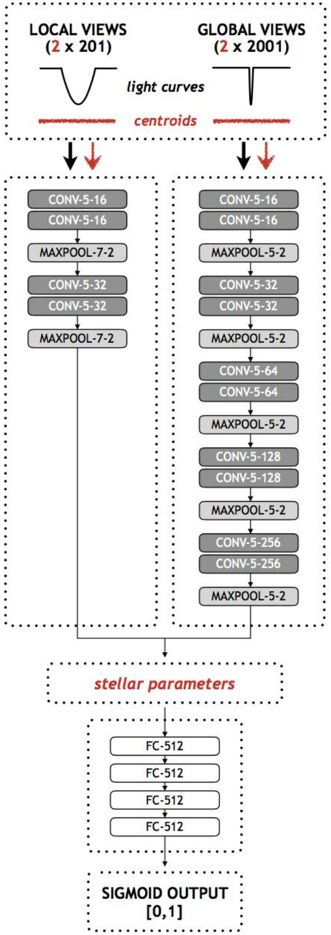
Scientific Domain Knowledge

Centroid Time-series

- Position of center of light in TPF as function of time
- Important for identifying EBs and BEBs



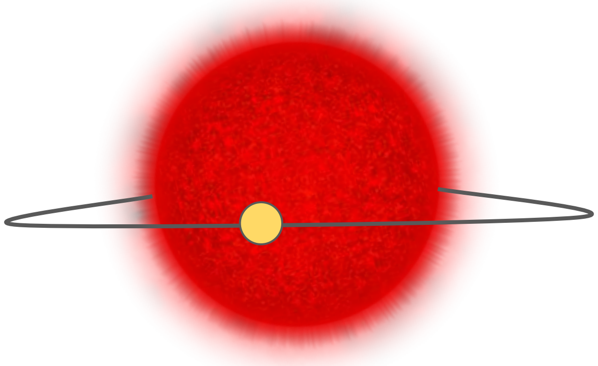


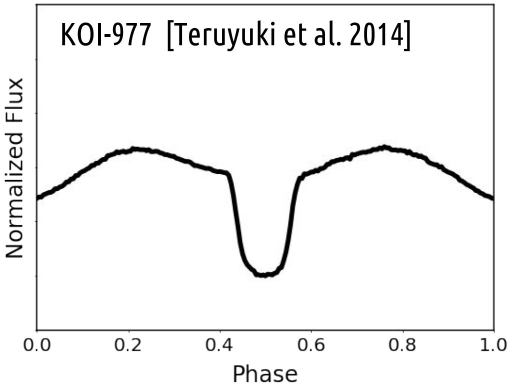


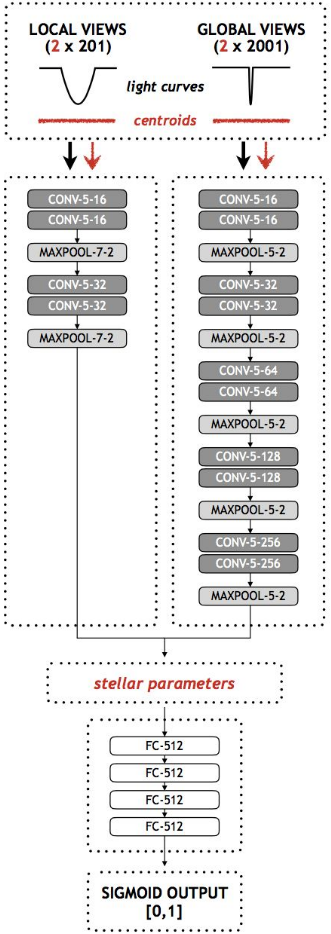
Scientific Domain Knowledge

Stellar Properties

- From KOI catalog: mass, radius, density, surface gravity, metallicity
- Important for identifying, e.g., giant star eclipsing binaries





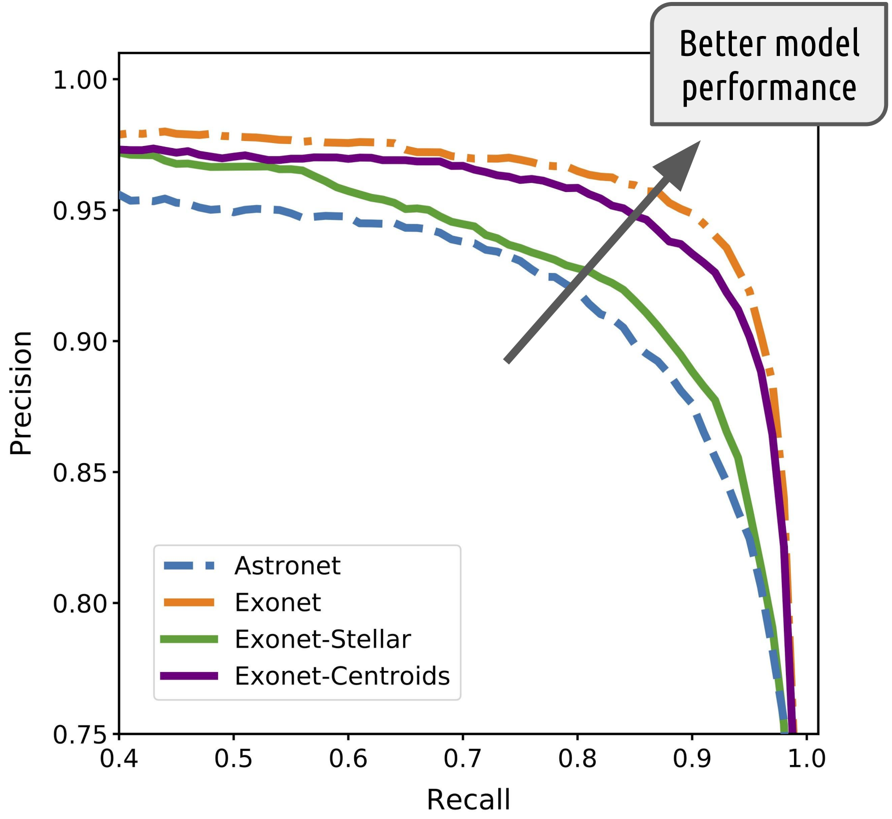


Scientific Domain Knowledge

Improved Overall Performance

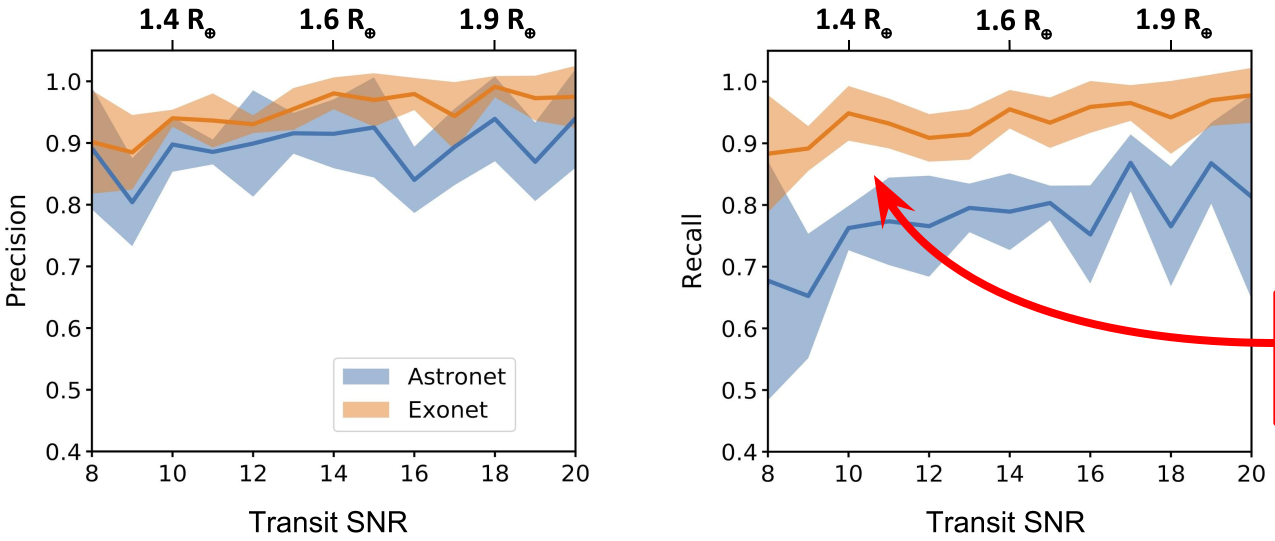
	Accuracy	Avg. Precision
Astronet	95.8%	95.5%
Exonet	**97.5%**	**98.0%**

- Accuracy = % of correct classifications
- Precision = % of classified planets that are true planets
- Recall = % of planets recovered by model



Scientific Domain Knowledge

Improved Performance for Lowest SNR Transits



Future missions like TESS & PLATO will focus on small planets

15-20% gains in recall for Earth-sized planets

Scientific domain knowledge improves exoplanet transit classification with deep learning

Questions?

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gitlab.com/frontierdevelopmentlab/exoplanets

Megan Ansdell, CIPS Postdoctoral Fellow, UC Berkeley
ADASS XXVIII, College Park, 13 Nov. 2018