A Deep Learning Framework for Identifying Transit Anomalies

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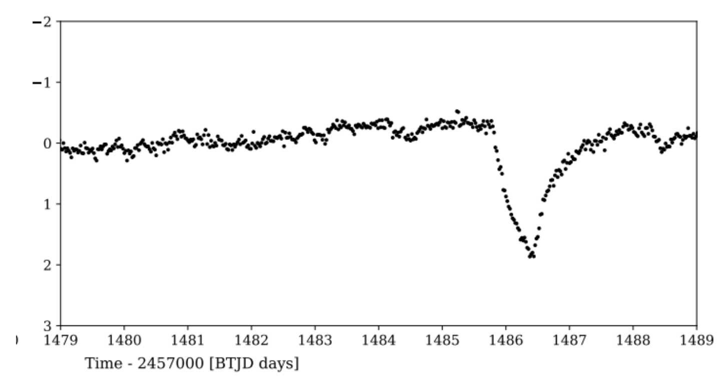
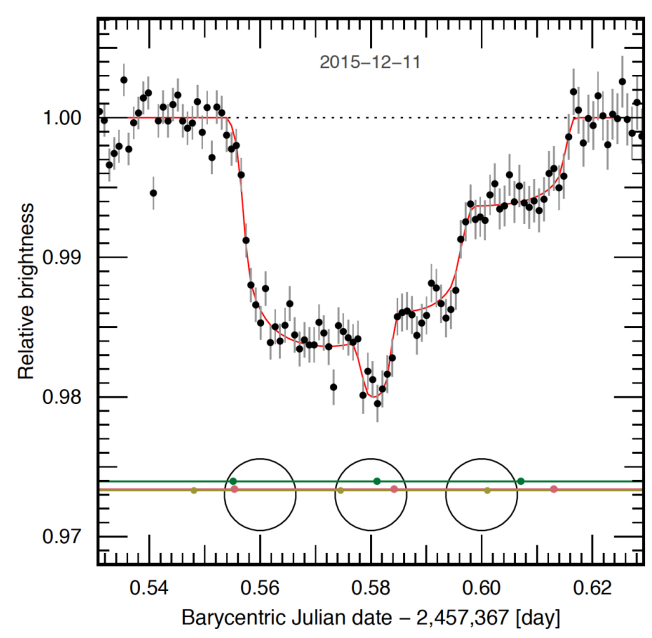
Transit detection missions are also sensitive to **any objects that cause periodic dimming of their host stars**, from exoplanets and other well-understood astrophysical phenomena (e.g., disintegrating worlds, exo-comets, complex multi-planet systems, etc.) to possible alien megastructures. Such objects **manifest as "anomalous" transit signals** that deviate from expected behavior due to a gravitationally bound spherical planet. Here we outline a **deep learning framework** for identifying non-spherical transiting objects in missions like Kepler and TESS.

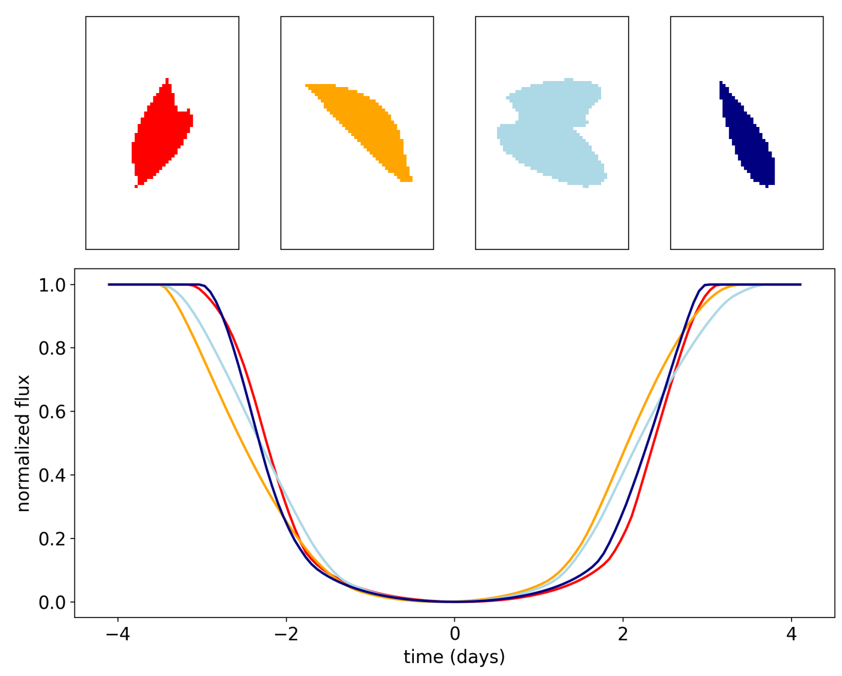
Sources of Anomalous Transit Signals



Exocomet tail from β Pictoris produces asymmetrical transit that is visibly different from circular transit models.(Zieba et al. 2020)



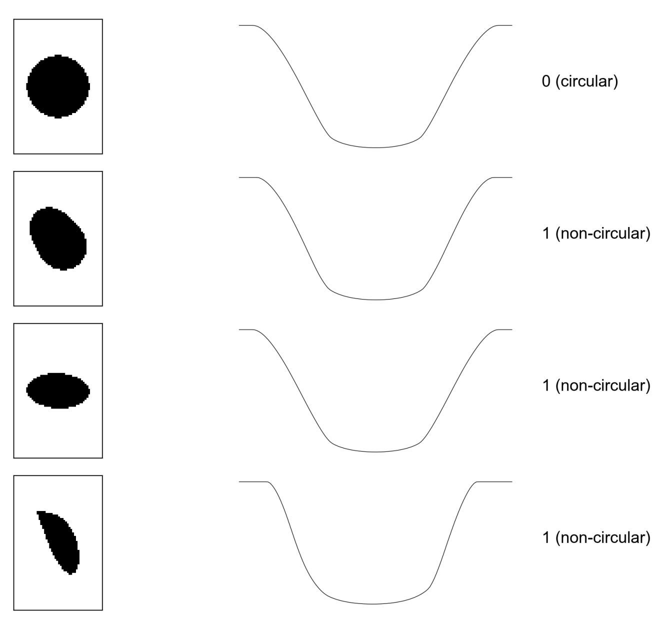
Co-occurring transits of three circular planets in TRAPPIST-1 produce anomalous transit shape (Gillon et al. 2017)

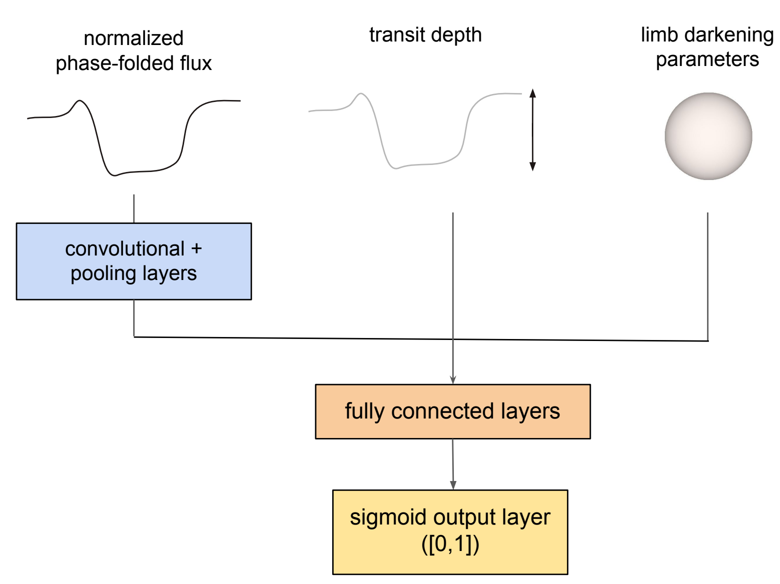


Transits of different occulting shapes simulated with EightBitTransit (Sandford & Kipping 2019). These objects show subtle deviations that are most prominent at ingress and egress (Angelo et al., in preparation)

A Deep Learning Framework for Identifying Non-Circular Transits

The analytic relationship between a transiting object's shape and its phase-folded light curve has degenerate solutions and is difficult to optimize. We can sidestep these issues by training a neural network to classify objects as circular and non-circular based on their light curves:





Left: *Simulated light curve examples of different shapes are paired with associated "circular" or "non-circular" classification as training data.* ***Right:*** *Diagram of our neural network structure. Our neural network learns the relationship between an object's shape and its light curve and host star properties.*

Data Challenges

There are a number of considerations we need to account for both in assembling representative training data and processing TESS data to analyze:

- TTV's
- ephemeris uncertainties
- stellar activity and instrumental effects

If you have experience treating these in phase-folded Kepler or TESS data, we'd love to hear from you!

References

S. Zieba, K. Zwintz, M.A. Kenworthy, et al. 2020, "Transiting exocomets detected in broadband light by TESS in the β Pictoris system"

M. Gillon, A. Triaud, B. Demory, et al. 2017, "Seven temperate terrestrial planets around the nearby ultracool dwarf star TRAPPIST-1"

E. Sandford & D. Kipping 2019, "Shadow Imaging of Transiting Objects"