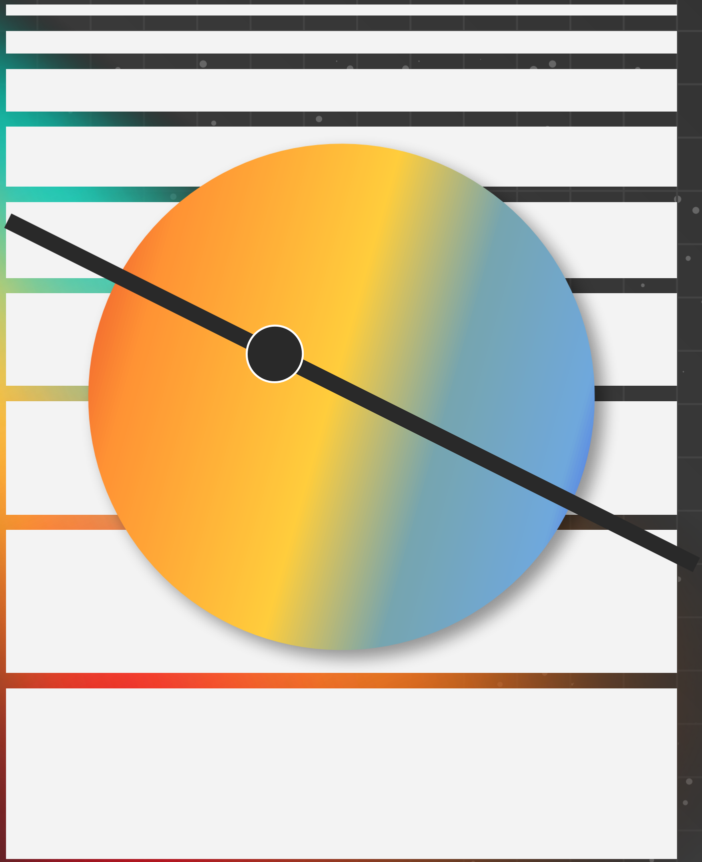

Panopticon

Detecting transits in PLATO lightcurves

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Team Meeting – IPAG – 15/03/2024

Context

PLATO

- Exoplanet hunter
- Transit method
- High cadence (25s), long period (~2years)
- 24 cameras, targeting multiple stars
- Launch: 2026

Issues

Transit detection is tedious

- Detrending the light curve
- Shallow signals are easily missed
- Transits are short
- Long period planets lead to few events

Detecting Earth analogs is a challenge

Objectives

Bypass Detrending

- Instrument noise
  - Aging
  - White noise
- Stellar activity
  - Variation at different timescale (minutes to years)

Analysis must be done for various timescale

Detect unique events

- Remove periodicity requirement (BLS)
- Provide early classification of event (Planet, EB, BEB)

Model must work as a classifier

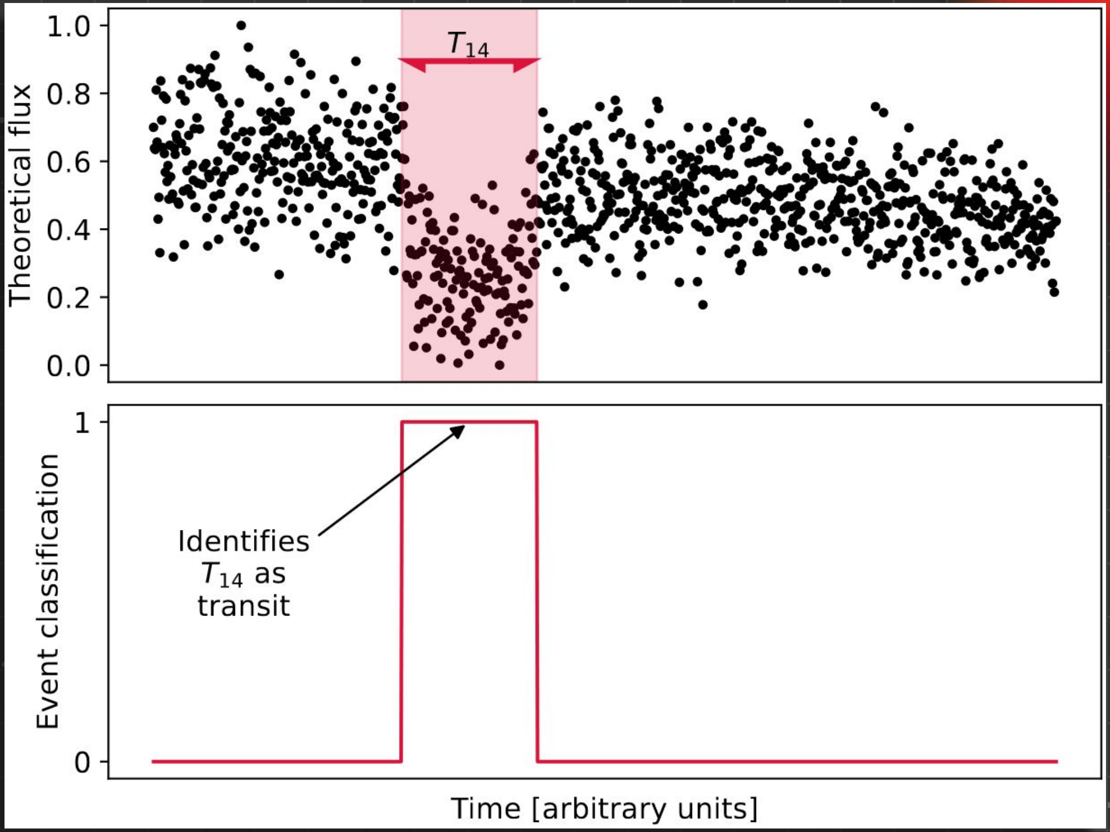
The theory

What we **don't know *a priori***:

- Number of transits
- Number of planets
- Does it have a companion?
- Is there a background contaminant?
- Duration of each of the events
- And (obviously) their locations

Step up from a simple vetter, or from simply raising a flag: we want to **pinpoint** where the transits are.

Because we need individual transit detection capabilities, we want to construct a *"likelihood map"*



Dataset

Plato launches in 2026: we use **PlatoSim** (Jannsen et al. 2023):

Not perfect, but should include all effect that are expected

- ➔ Instument noise
- ➔ Telescope jitter
- ➔ CCD aging
- ➔ Stellar activity
    - ◆ Spots
    - ◆ Plages
    - ◆ Flares
    - ◆ Granulation
- ➔ And then some

We have roughly 15000 light curves to train on

Astronomy & Astrophysics manuscript no. jannsen2023platosim ©ESO 2023
March 31, 2023

PlatoSim: An end-to-end PLATO camera simulator for modelling high-precision space-based photometry

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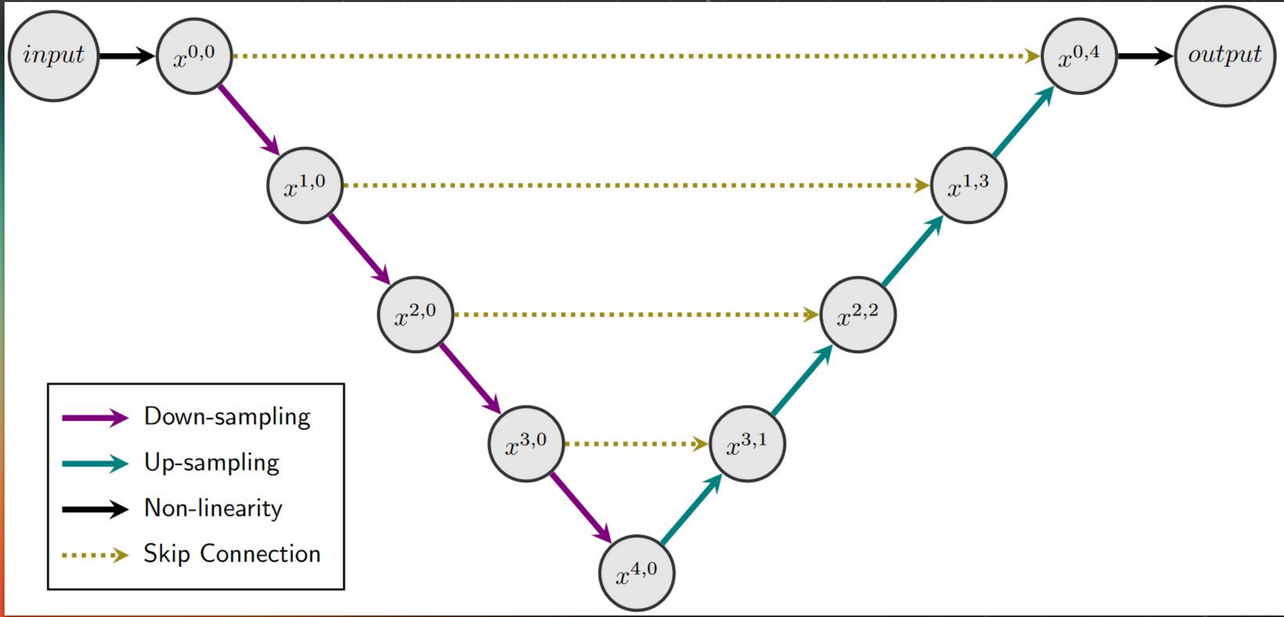
March 31, 2023

ABSTRACT

Context. PLAnetary Transits and Oscillations of stars (PLATO) is the ESA M3 space mission dedicated to detect and characterise transiting exoplanets including information from the asteroseismic properties of their stellar hosts. The uninterrupted and high-precision photometry provided by space-borne instruments such as PLATO require long preparatory phases. An exhaustive list of tests are paramount to design a mission that meets the performance requirements, and as such, simulations are an indispensable tool in the mission preparation.
Aims. To accommodate PLATO's need of versatile simulations prior to mission launch – that at the same time describe accurately the innovative but complex multi-telescope design – we here present the end-to-end PLATO simulator specifically developed for the purpose, namely PlatoSim. We show step-by-step the algorithms embedded into the software architecture of PlatoSim that allow the user to simulate photometric time series of CCD images and light curves in accordance to the expected observations of PLATO.
Methods. In the context of the PLATO payload, a general formalism of modelling, end-to-end, incoming photons from the sky to the final measurement in digital units is discussed. According to the light path through the instrument, we present an overview of the stellar field and sky background, the short and long-term barycentric pixel displacement of the stellar sources, the cameras and their optics, the modelling of the CCDs and their electronics, and all main random and systematic noise sources.
Results. We show the strong predictive power of PlatoSim through its diverse applicability and contribution to numerous working groups within the PLATO Mission Consortium. This involves the on-going mechanical integration and alignment, performance studies of the payload, the pipeline development and assessments of the scientific goals.
Conclusions. PlatoSim is a state-of-the-art simulator that is able to produce the expected photometric observations of PLATO to a high level of accuracy. We demonstrate that PlatoSim is a key software tool for the PLATO mission in the preparatory phases until mission launch and prospectively beyond.

Key words. Methods: numerical – Space vehicles: instruments – Instrumentation: photometers – Planets and satellites: detection

Architecture: Unet family



Step 1 - **Encoder**:

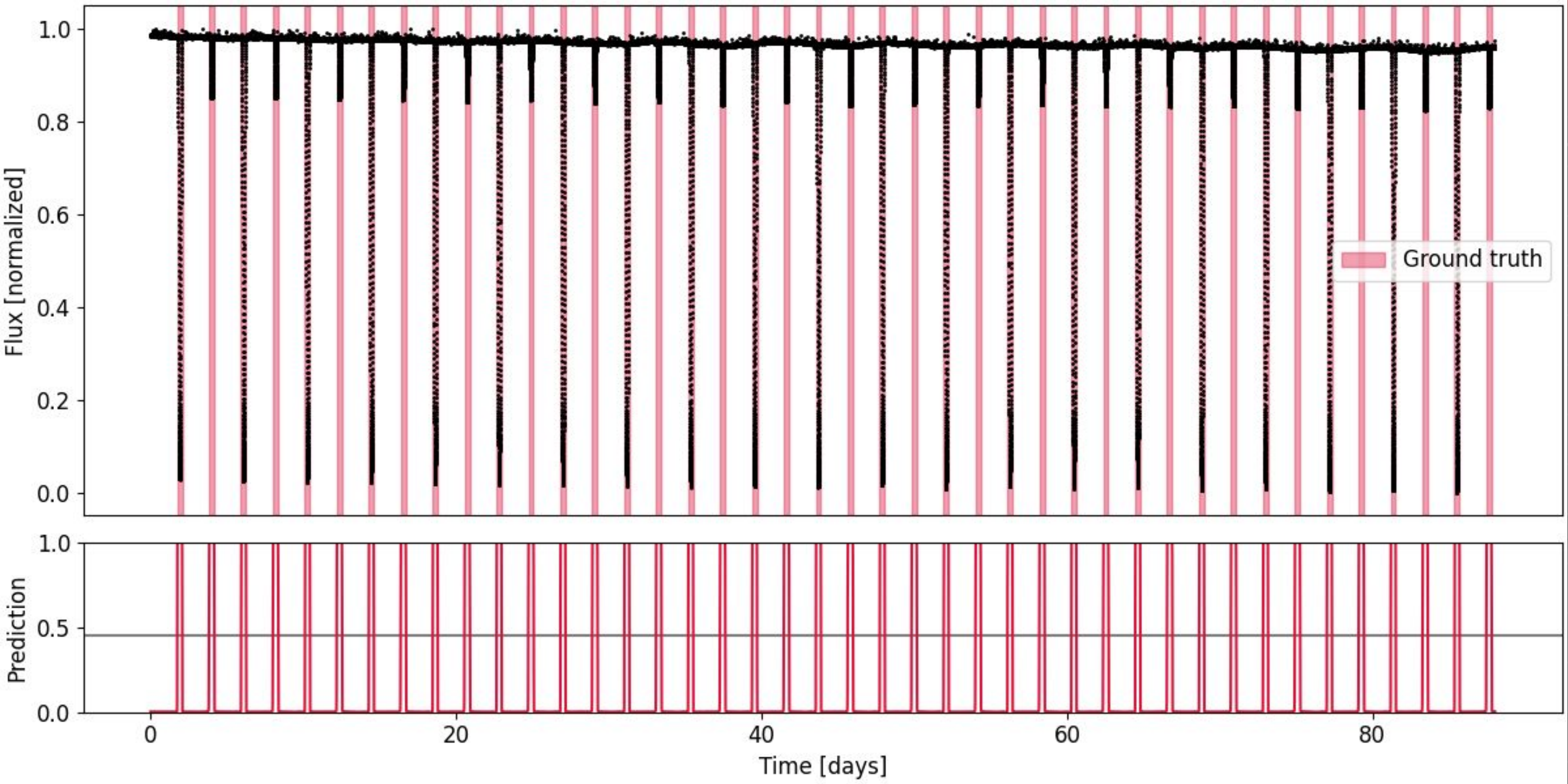
- Extract N features with given kernel size of convolution
- Downsample signal
- Repeat

Step 2 - **Decoder**:

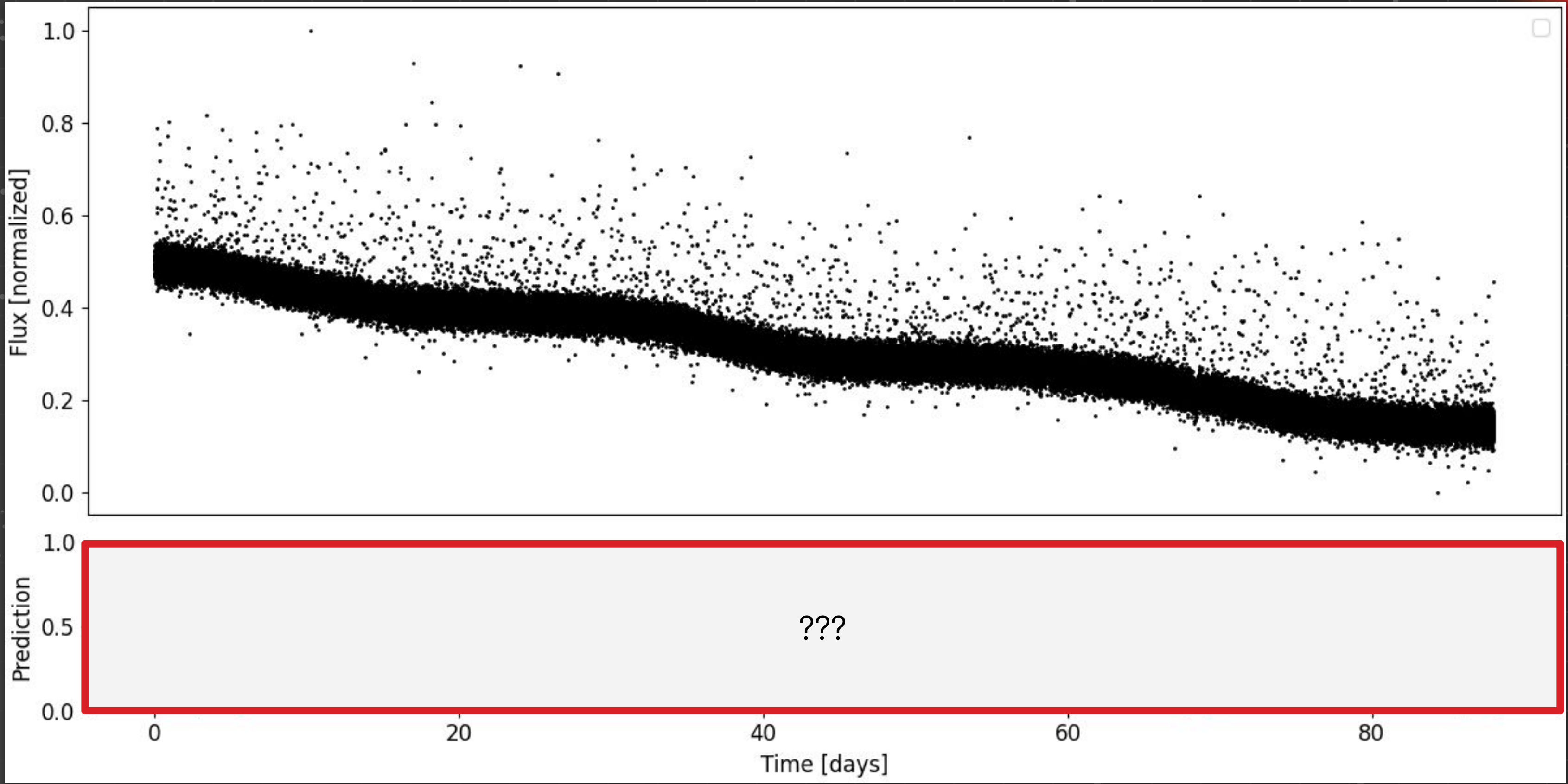
- Upsample signal
- Concatenate with equivalent feature map from encoder
- Convolve together
- Repeat

Step 3 - Profit!

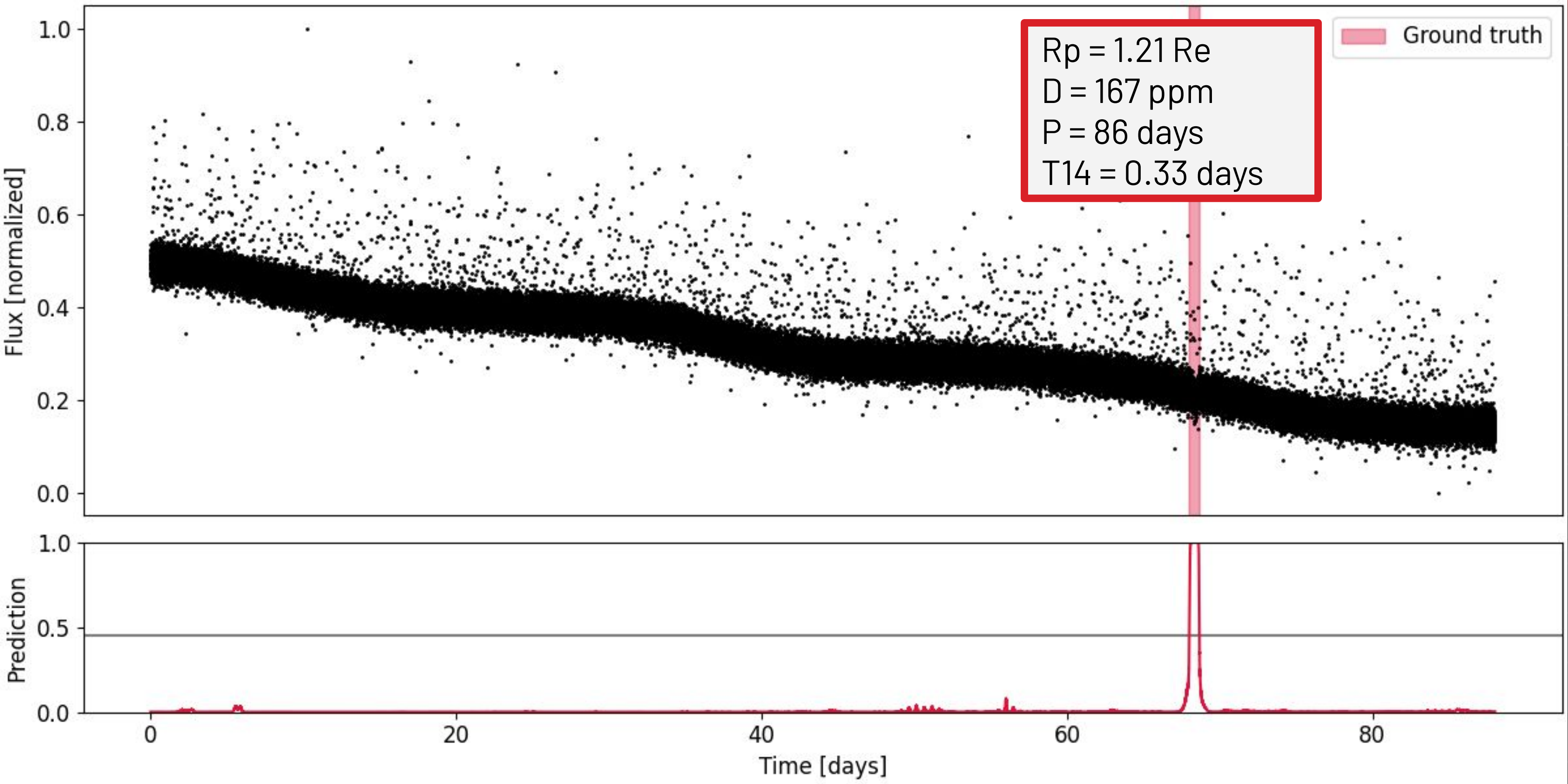
Principle, but in practice - binary



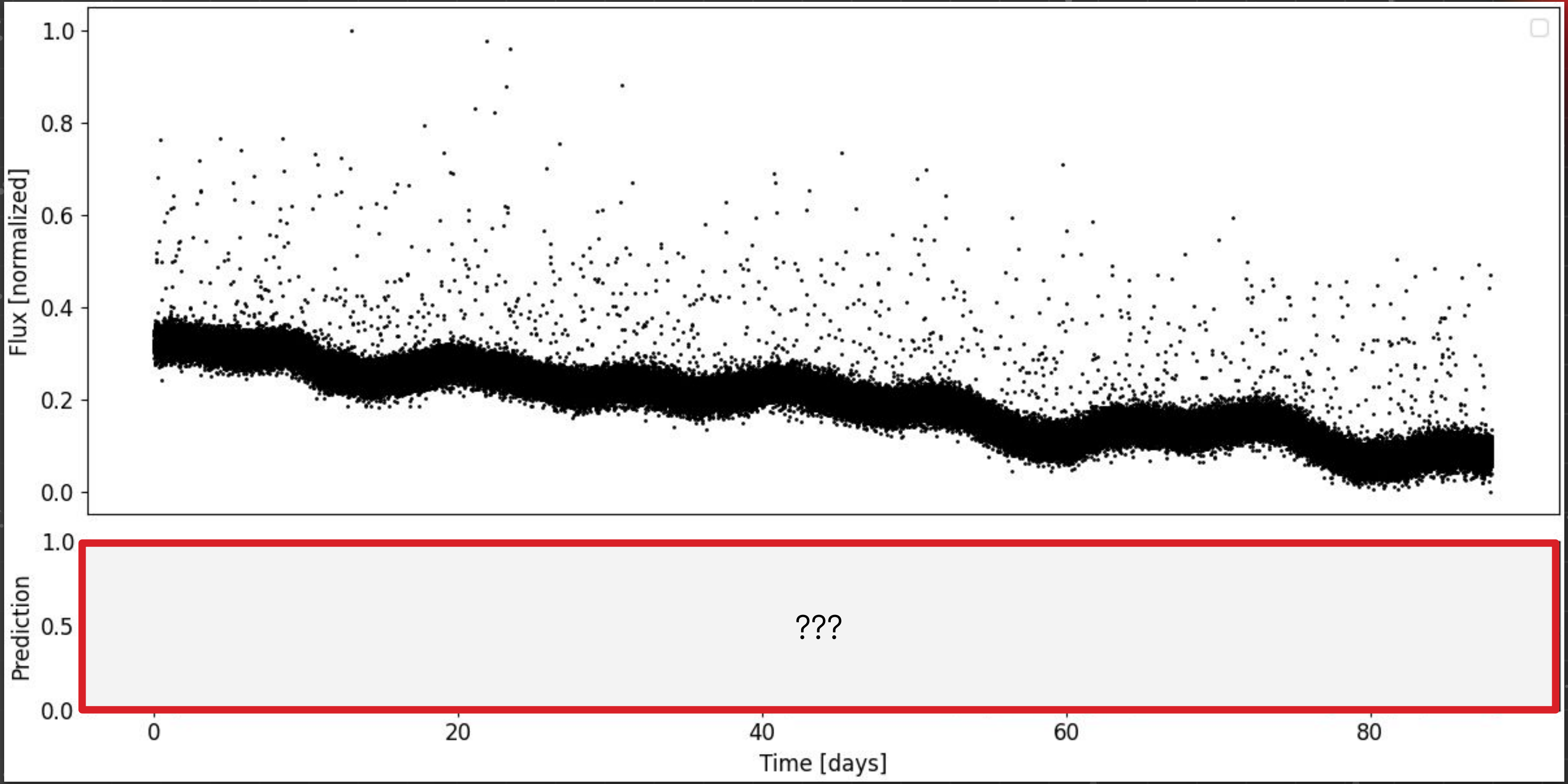
Principle, but in practice - planet



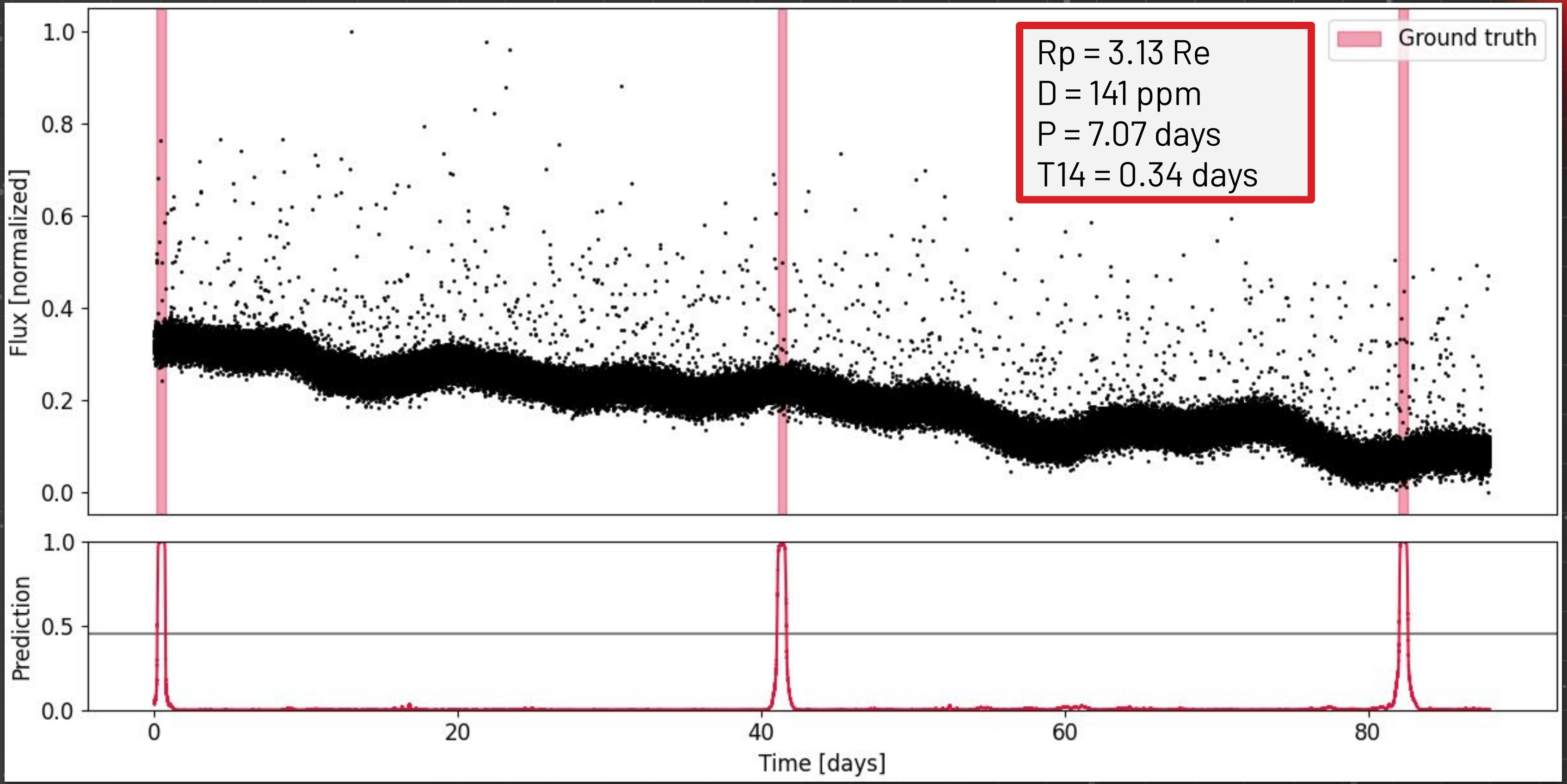
Principle, but in practice - planet



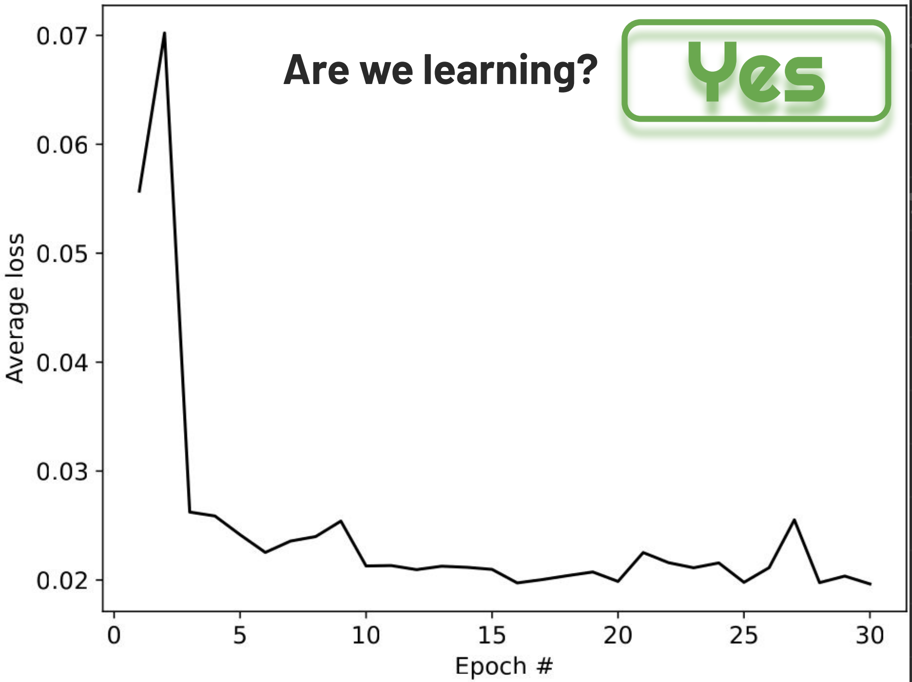
Principle, but in practice – one last

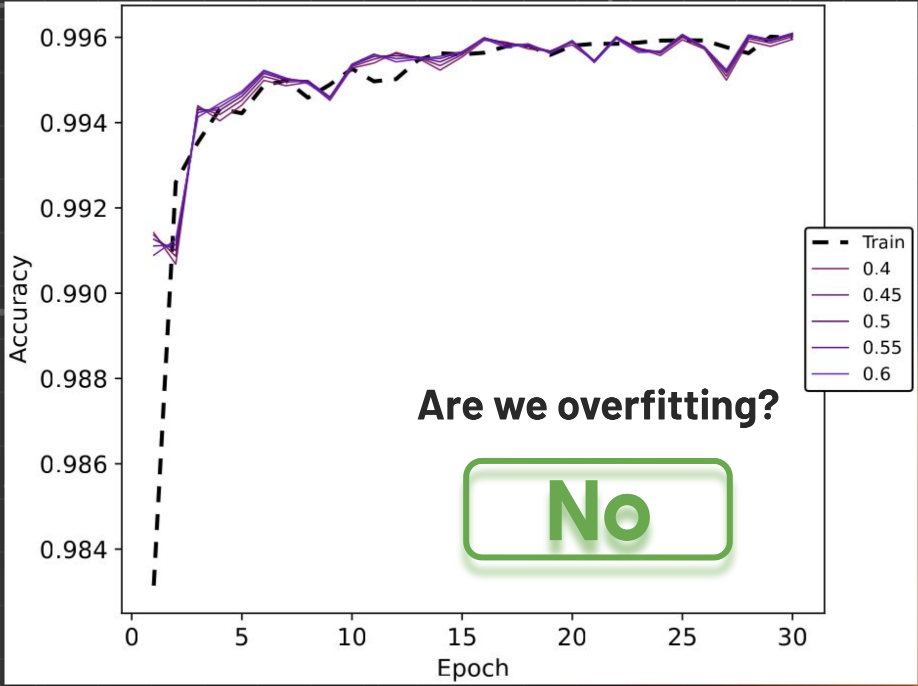


Principle, but in practice – one last

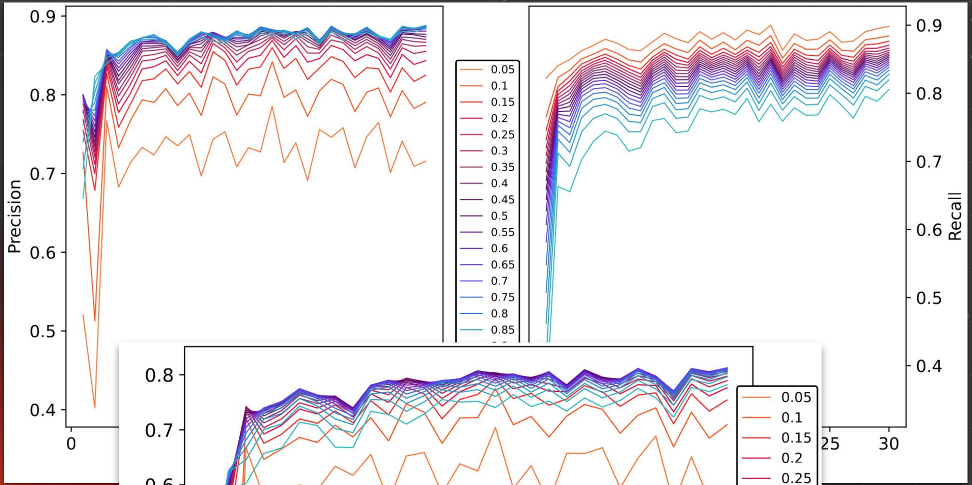


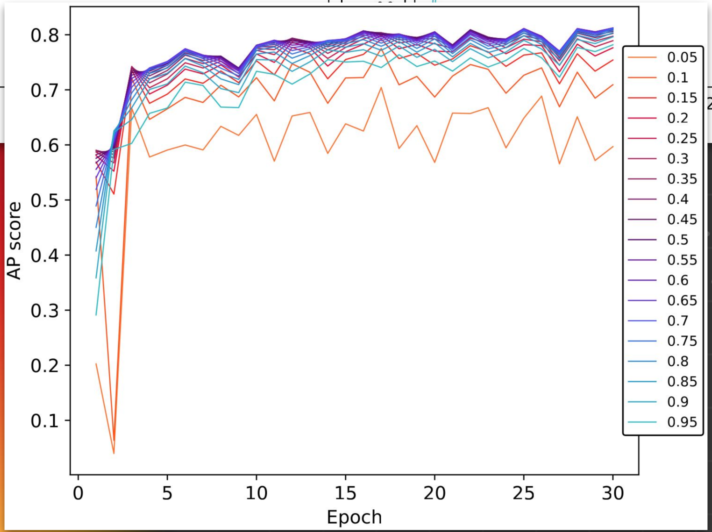
Verifying that's it's OK

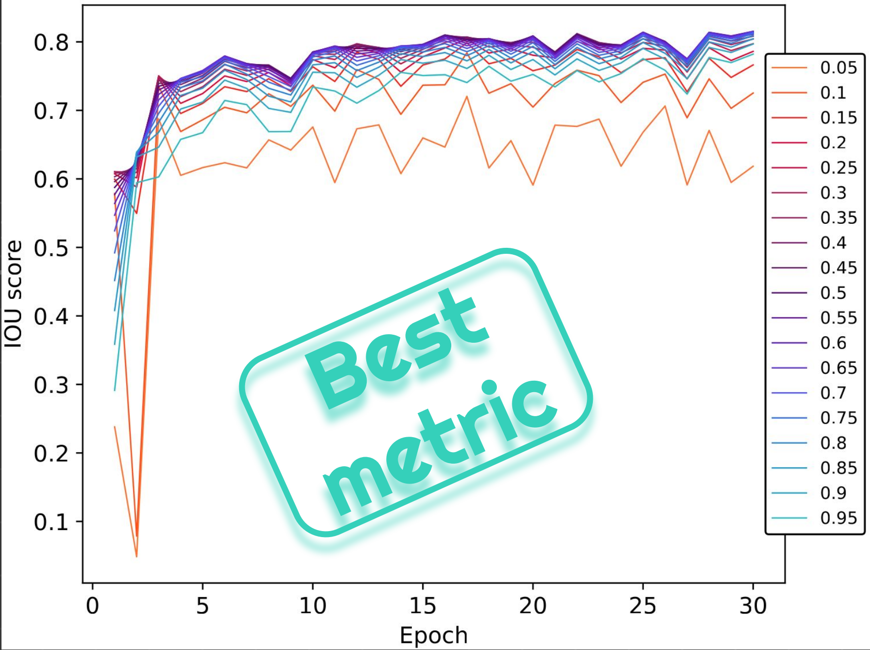




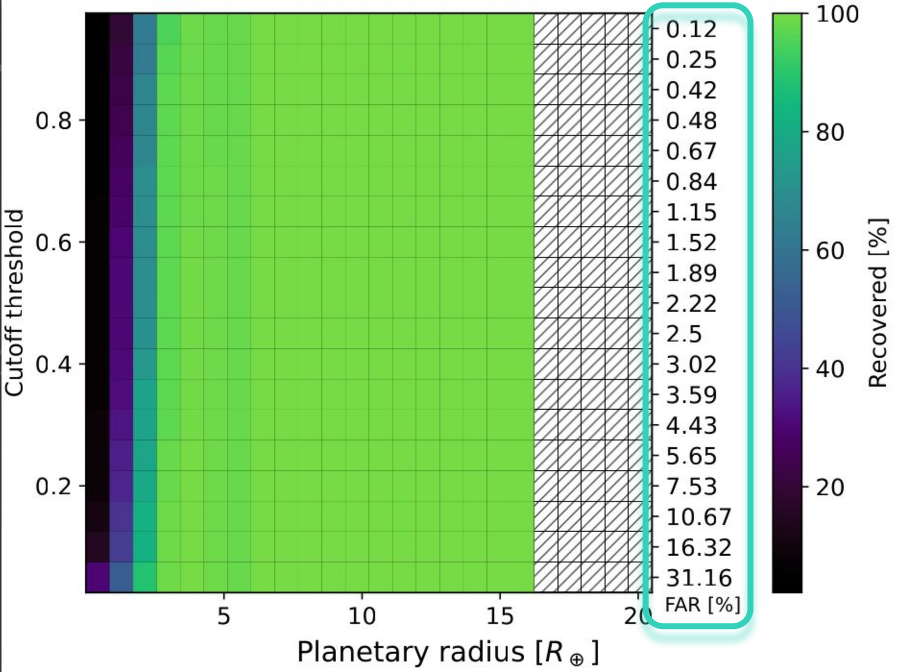
Basic performance estimation

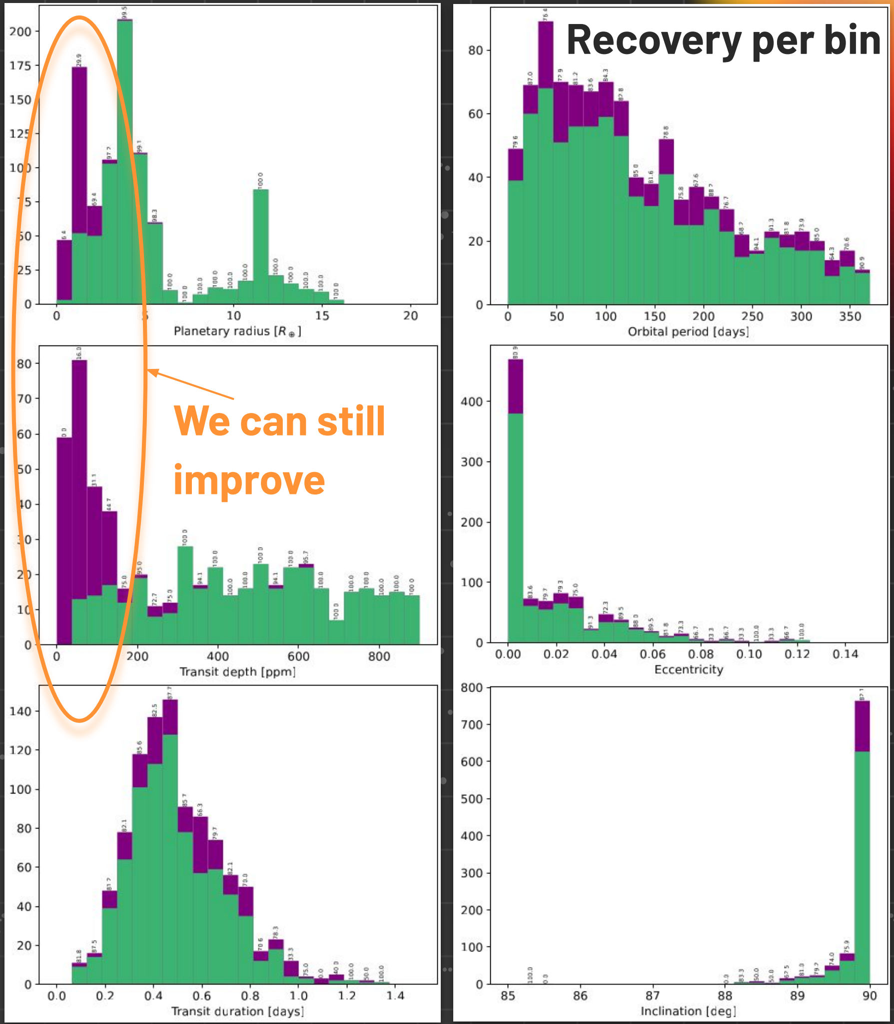






But what does it mean, really?

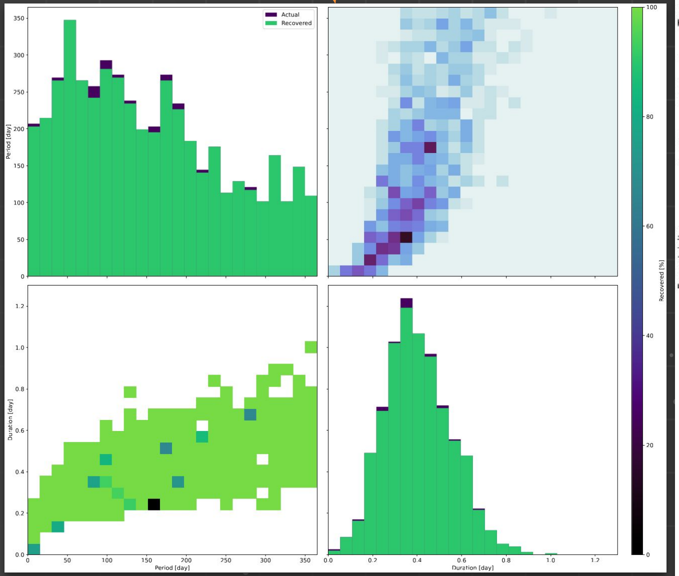


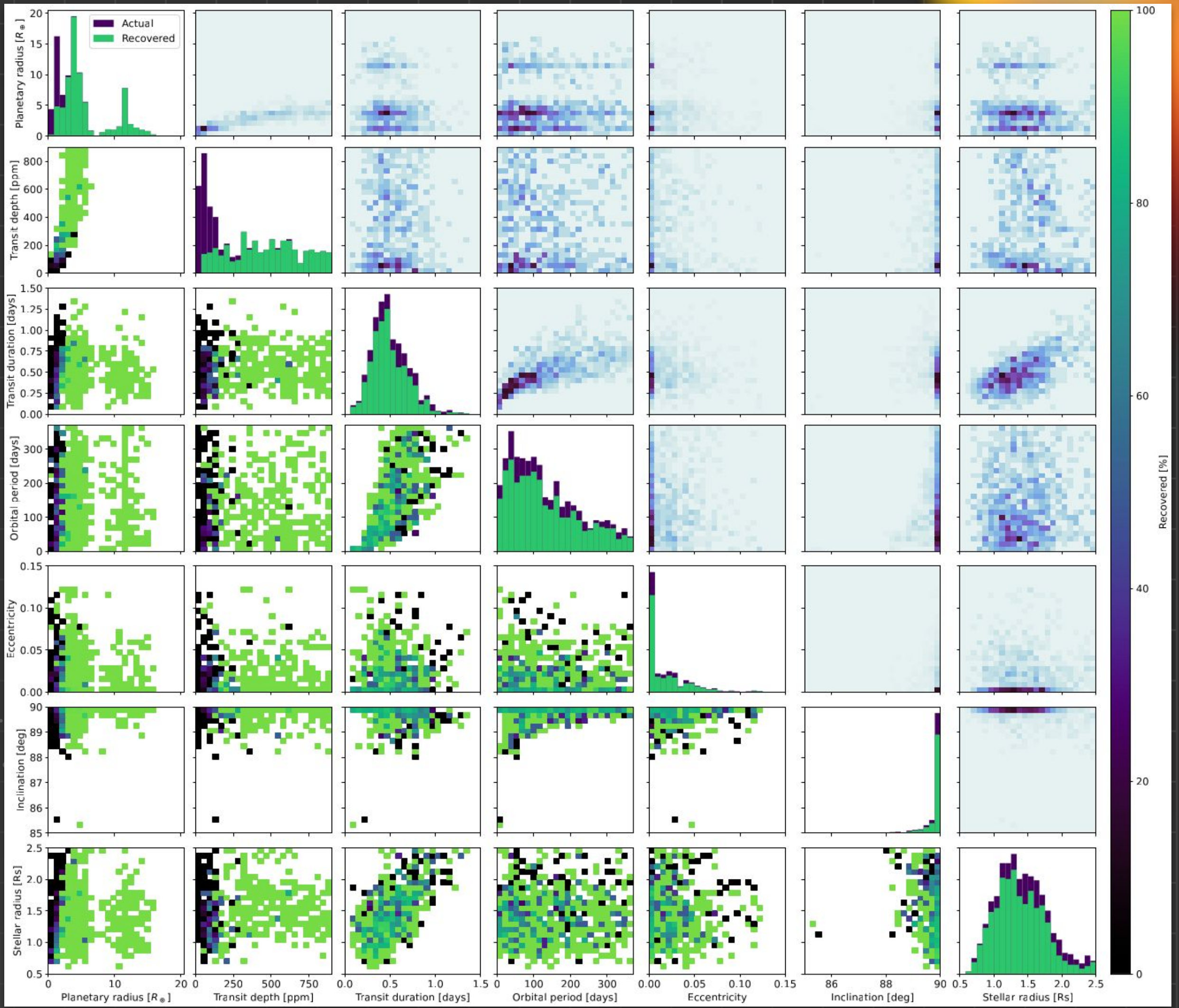


Corner plot

Planets

Binaries





Conclusion and prospects

I will be available starting spring 2025!

Paper in prep, will be submitted soon!

- We are able to bypass filtering
- We are able to detect unique events (no periodicity dependency)
- Need to better characterize the performances
- Shallow signals remain problematic

Improving the model:

- Addition of centroids for classification & recovery
- Adding stellar physical parameters (PINN)

Testing on real data: internship with TESS (and maybe Kepler)

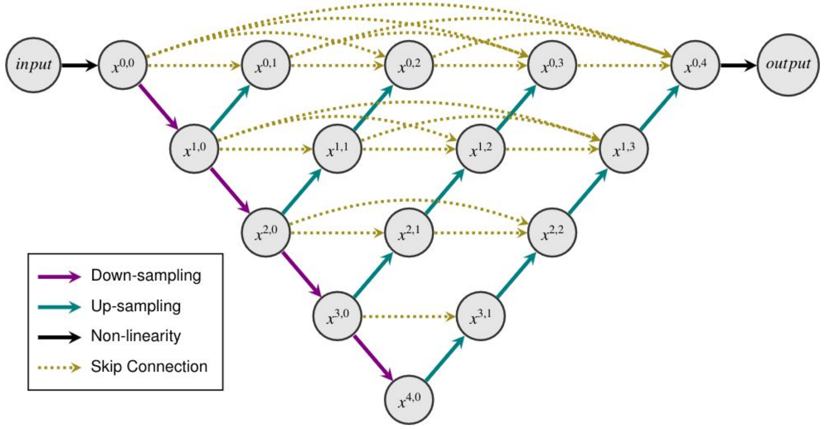


Fig. A.2. The Unet++ architecture of same depth as Fig. A.1. This version introduces a more complex recombination during decoding. Each encoding level is up-sampled individually and combined in nested dense skip connections. This gives a better merging of various feature sizes when creating the output.

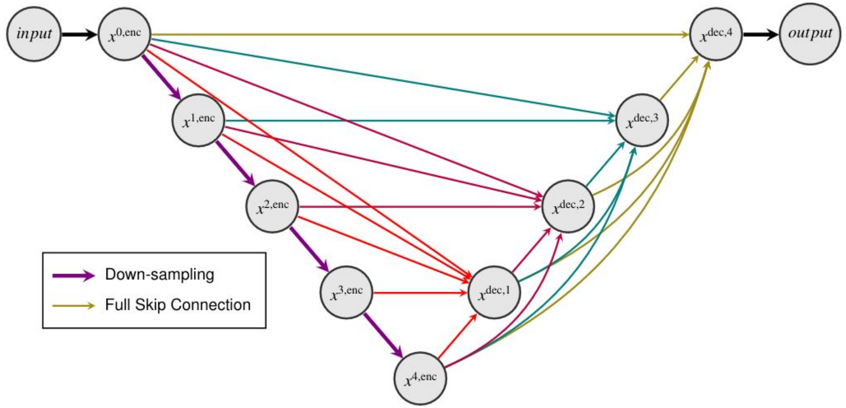
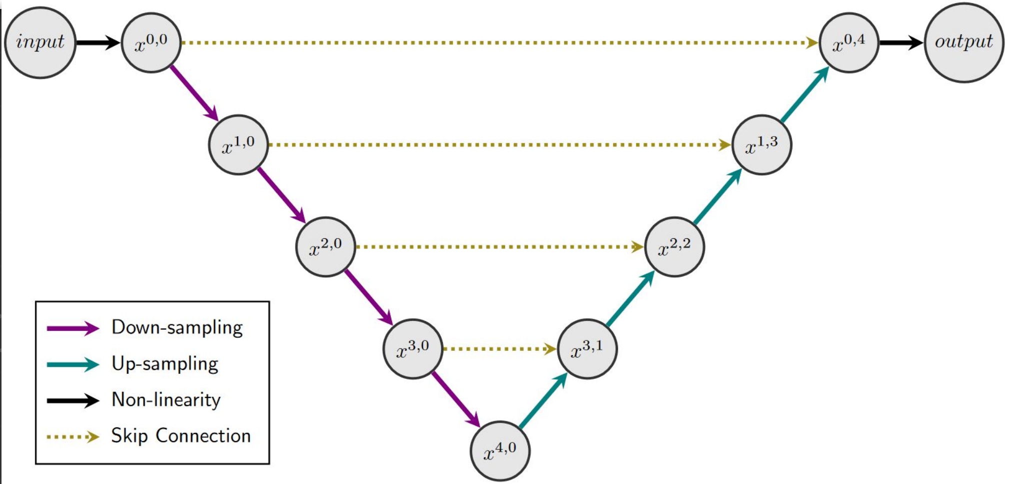
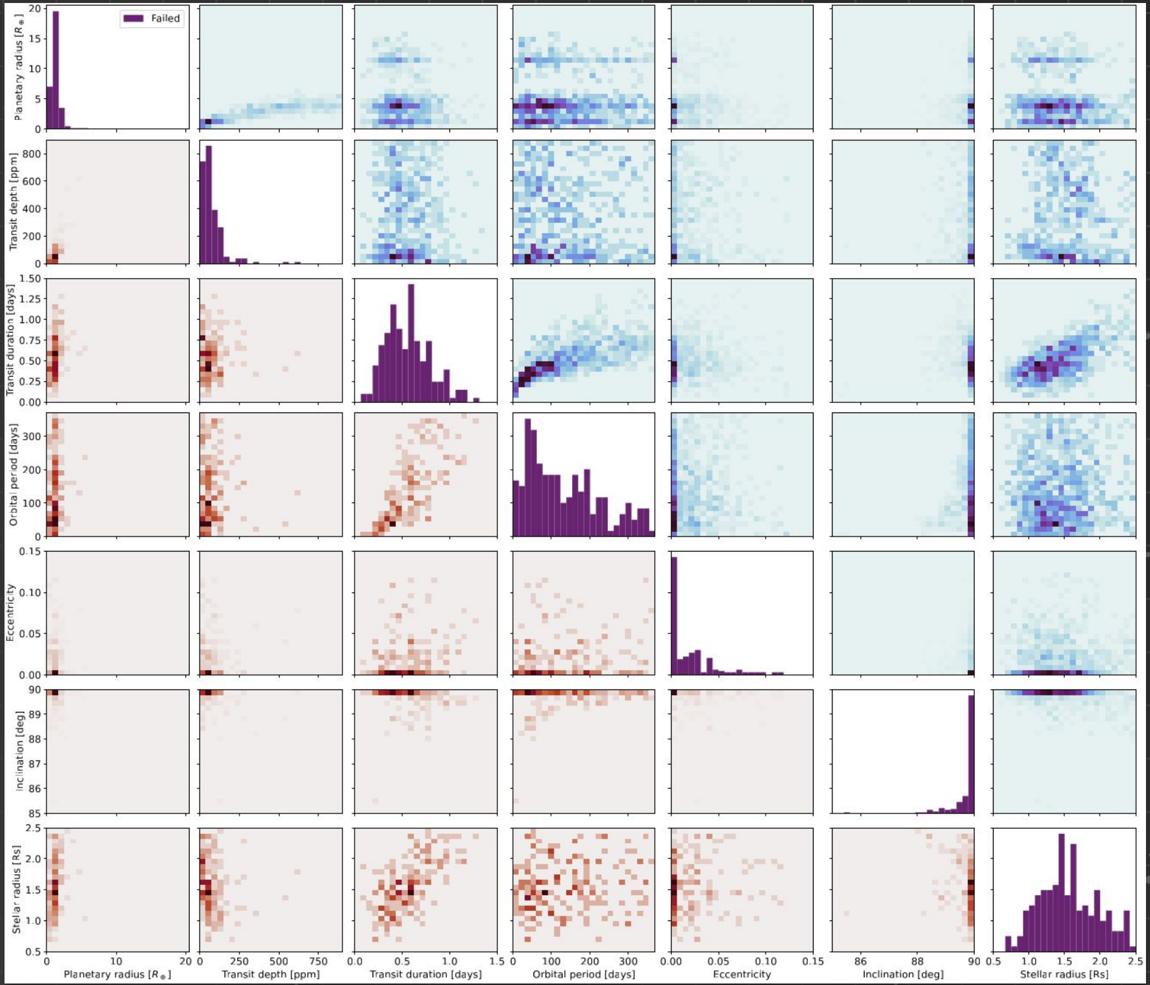


Fig. A.3. The Unet3+ architecture of same depth as Figs. A.1&A.2. The skip connections are here not up-sampled for each encoder level, but are included directly when computing the decoder levels, and merged with previous decoder levels. This creates a simpler decoding process, limiting the number of free parameters compared to Unet++, as there are no in between convolution layer.



Unets et al.

What do we miss?



Some more metrics