Light curve fitting project for JWST/ERS Workshop
Instructor Prof. Björn Benneke

Scenario:

Your team detected a planet candidate in the data from the Transiting Exoplanet Survey Satellite (TESS). The data is very noisy, but you are confident that the planet would be a great target to be characterized with JWST.

Based on the TESS data, you can predict that the next transit will be between the time t = 1.212 days and t = 1.362 days. The TESS data also tell you that the radius of the planet is between 1% and 10% the radius of the star. Unfortunately, you don't know where the planet crosses the star, i.e. the impact parameter is largely unconstrained between 0 and 1.

You wrote a proposal and successfully convinced the time allocation committee of the James Webb Space Telescope (JWST) to obtain new very precise data for you. YAY!!!

You receive the data in JWST_Transit_Data.csv

From these data, you want to determine new estimates with uncertainties for the planet-to-star radius ratio and simultaneously fit the transit time and the impact parameter.

Following the 5 steps below, set up a well-organized analysis to fit the JWST data and evaluate different fitting models.

Step 1: Define the physical model
Write a function for your physical "forward" model that takes in a vector with these three parameters

Step 2: Define the Bayesian analysis
1. Code the given prior information as
    1. a log-prior function
    2. a prior transform
2. Write a log-likelihood function
3. Write a log-probability function

Step 3: Only now: solve the problem numerically
Determine new estimates with uncertainties of the transit time, the planet-to-star radius ratio, and the impact parameter
1. Using Emcee. Make all possible plots and quantitative assessments to convince the reviewer that your results are converged
2. Using Dynesty. Make all possible plots and quantitative assessments to convince the reviewer that your results are converged

Step 4: Investigate whether you model is a good fit to the data

Investigate the residuals. What do you think? Quantitatively and graphically assess whether your model is a good fit to the data.

Step 5: Refine your physical model

1. What could explain your findings in Part 4. Tip: When a distant observer sees a transit of the Earth in front of the sun, would it only be the Earth that is transiting at that time?
2. Code a new physical "forward" model and log-likelihood function that better explains the data.
3. Use Dynesty to find the constraints of both objects. Treat the moon like another body transiting shortly before or after. Use the same prior for the moon. That makes six parameters.
4. Make plots to convince the reviewer that your results are converged
5. Determine quantitatively whether the model justifies applying this more complex model? How confident are you that you detected a moon?
6. Summarize your results for the parameters for each object?
7. Why do you get a multi-modal solution? What could you do to avoid this in this simple example?