Flexible Scheduling: A New Technique for Maximizing Scientific Output from Exoplanet Observations

Thematic Areas (Check all that apply):

☐ (Theme A) Key science themes that should be prioritized for future JWST and HST observations
☒ (Theme B) Advice on optimal timing for substantive follow-up observations and mechanisms for enabling exoplanet science with HST and/or JWST
☐ (Theme C) The appropriate scale of resources likely required to support exoplanet science with HST and/or JWST
☐ (Theme D) A specific concept for a large-scale (∼500 hours) Director's Discretionary exoplanet program to start implementation by JWST Cycle 3.

Summary: We propose a more flexible and collective approach to scheduling transit/eclipse observations with JWST, driven by the desire to accelerate and maximize scientific output. Often, in the course of attempting to answer a single scientific question, the wrong number of observations are scheduled. It may be too few or too many, depending on uncertainties in planet properties, stellar variability, and telescope systematics. We propose that instead of approved programs being allocated a set number of transits, an *approximate* and *malleable* number should be scheduled. This approximate number of transits should be determined conservatively by the proposing team, without overly optimistic estimates of error bar size. There should be a collective pool of unused time, in which programs can donate or borrow time depending on whether more or fewer transits are needed, respectively. While we recognize this is an unusual proposition, it has the potential to vastly increase the collective scientific knowledge we gain from the telescope. We only have one JWST. Should we not utilize its time as wisely and efficiently as possible?

Anticipated Science Objectives: It is becoming increasingly apparent that our estimates of the number of transits/eclipses needed to answer a scientific question are often wrong. This is particularly true in the search for atmospheres on rocky planets, in which atmospheric scale height, albedo, and surface composition are entirely unknown, yet they all impact the transit or eclipse depth. Beyond this, uncertainties in our systematic detrending parameters, as well as stellar variability, have led to spectra which are not as constraining as initially anticipated (e.g., [1]).

We advocate for a revamping of how observations are scheduled. Instead of a set-in-stone number of transits dedicated to each approved program, programs should be scheduled with an *anticipated* number of transits needed to answer the science case. This number, which will be carefully and conservatively estimated by the proposing team, should be malleable and transferable between observing programs. While this is unorthodox, it is the best way to maximize our *collective* scientific output from JWST.

This technique is illustrated in Figure 1 using the example of a search for an atmosphere on a rocky exoplanet. After each transit, a "quick look" reduction team should examine the data to determine whether an additional transit is needed to reach statistically significance. For example, if ~ 6 transits are needed to detect $\mathrm{CO_2}$ at 3σ assuming a high mean molecular weight atmosphere, 6 transits should be scheduled. However, this number should be reassessed after each successive transit until a 3σ detection/non-detection is reached. If the number of transits needed is less than 6, the remaining transit(s) should be "donated" to a pool of unused time, which can be allocated out to other programs in which MORE transits are needed than originally anticipated. In this system, the goal is to maximize the scientific understanding coming out of each program, and not to simply achieve the set number of transits/eclipses originally scheduled.

Urgency: The exoplanet community has the opportunity to increase the efficiency and volume of scientific output per cycle. To do so, we need to make these changes as early as possible in the telescope's lifetime.

Risk/Feasibility: There is no denying that this is logistically complicated. The greatest risk comes if proposers are overly optimistic about the number of transits needed, which would put the community in a net "deficit" of time. However, with the help of STScI scientists, this scheduling system is feasible.

Timeliness: This system could be implemented in a small pilot program for Cycle 3 to test its effectiveness.

Cannot be accomplished in the normal GO cycle: N/A.

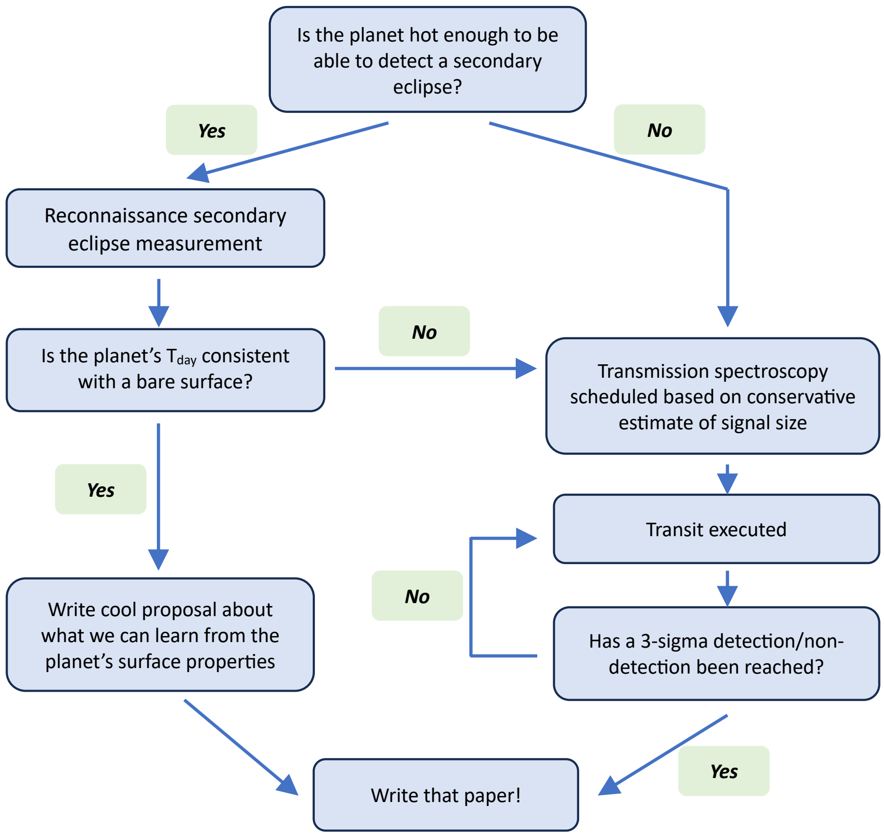

Figure 1: Example flowchart for searching for atmospheres on rocky planets with JWST. First, if the planet is hot enough for its secondary eclipse to be detectable, reconnaissance emission photometry should probe whether it is likely to have an atmosphere. If it is too cold for emission photometry, or its measured T_{day} is inconsistent with a bare rock, transits should be scheduled in a optimizable manner. These transits should continue on a given target until statistical significance is reached, whether that be a detection or non-detection.

References

[1] Sarah E. Moran et al. "High Tide or Riptide on the Cosmic Shoreline? A Water-rich Atmosphere or Stellar Contamination for the Warm Super-Earth GJ 486b from JWST Observations". In: 948.1, L11 (May 2023), p. L11. DOI: 10.3847/2041-8213/accb9c. arXiv: 2305.00868 [astro-ph.EP].