



Optimizing Radial Velocity Follow-up Strategies for Single-Transit Exoplanet Candidates

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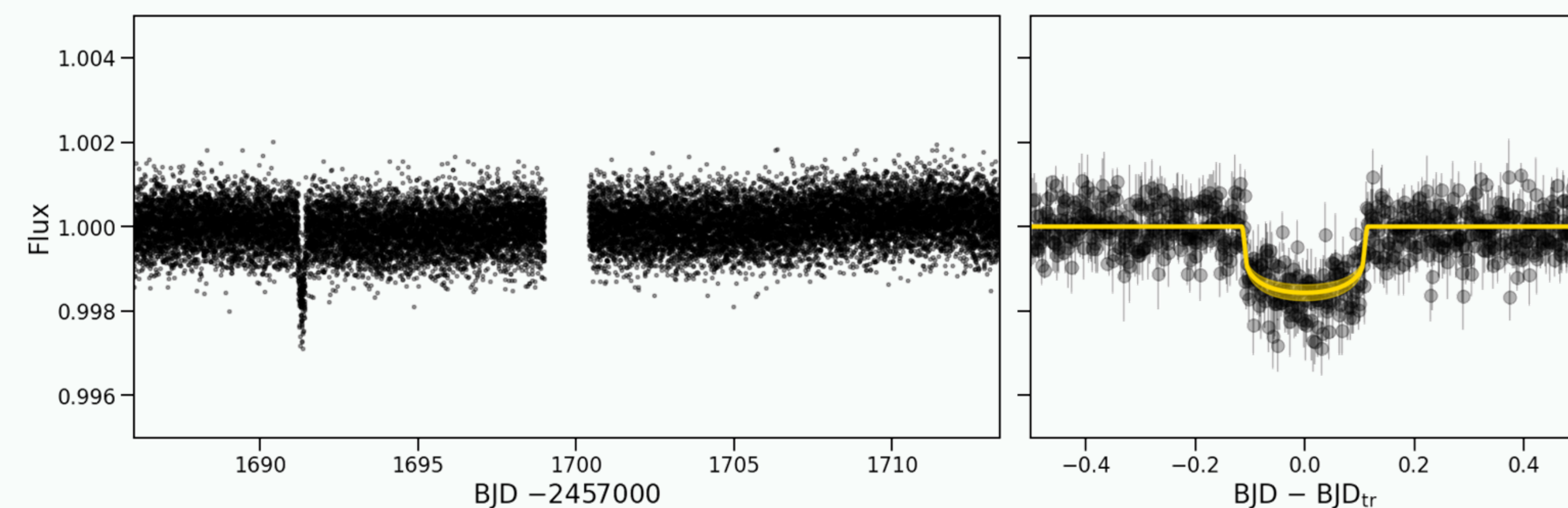


TESS Single-Transit Planet Candidates

TESS “single-transit planet candidates” (STPCs) have the potential to provide a valuable window into the relatively unexplored population of long-period exoplanets. Yet with just a single transit and an unknown orbital period, it is difficult and expensive to confirm these candidates. Here, we present a framework for leveraging exoplanet population statistics and the information contained in isolated transit profiles to **design and implement efficient RV follow-up strategies** for STPCs.

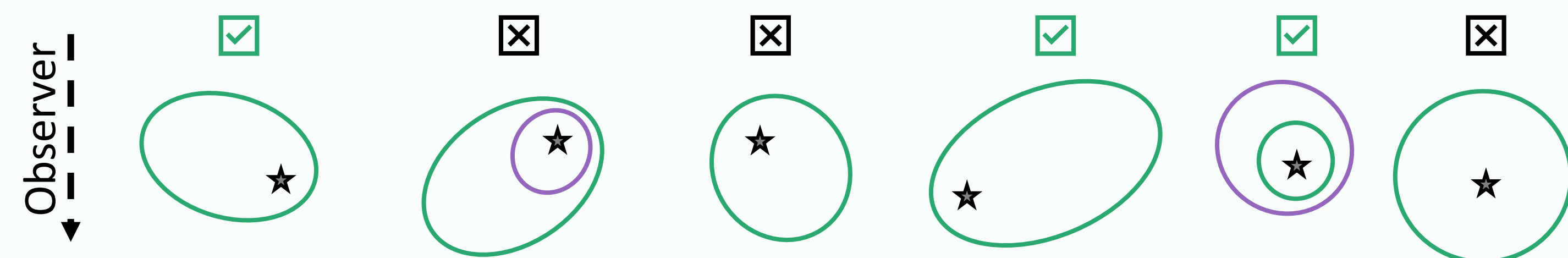
1 Fit the transit profile

- We fit the observed transit signal to place constraints on the radius and orbit of the STPC



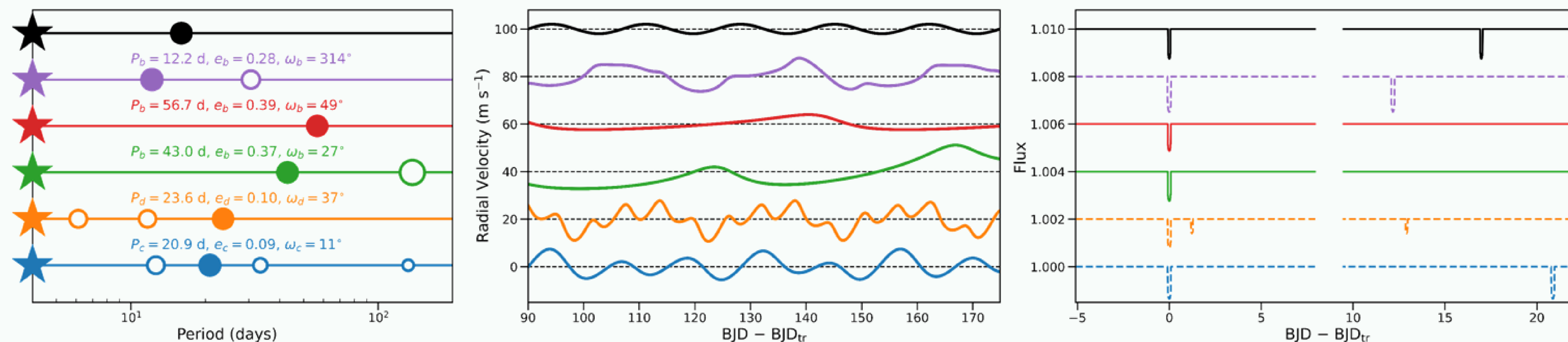
2 Generate exoplanet systems

- We generate a catalog of exoplanet systems for each STPC host star using SysSim, a planetary system modeling code that reliably reproduces Kepler statistics (see [He et al. 2019](#), [He et al. 2020](#))
- From this catalog, we identify systems containing exoplanets with radii and orbital parameters consistent with the observed transit profile



3 Generate model radial velocity curves

- We integrate orbits of from the time of transit (BJD_{tr}) to predict the radial velocity signal we might expect to observe for each simulated exoplanet system
- A sliding window function is used to calculate the probability that no other transits would have been detected while TESS was monitoring the star



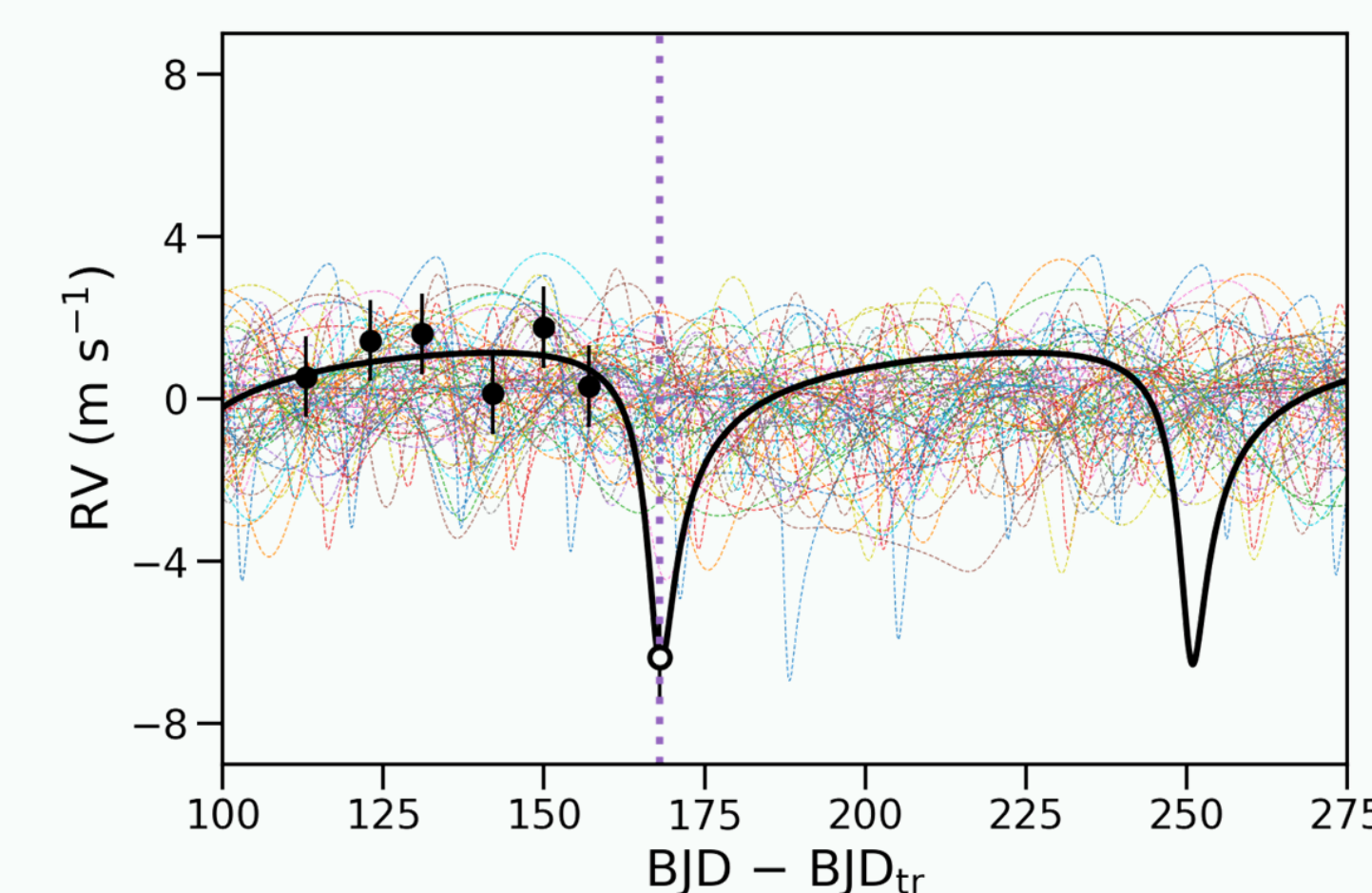
Orbit plots (**left**), modeled RV curves (**middle**), and modeled light curves coincident with the TESS baseline (**right**) are shown for a sample of simulated systems corresponding to a single STPC. Filled circles represent the STPC in each system, and dashed light curves indicate systems in which either a second transit or additional transiting planets would have been detected.

4 Reconnaissance radial velocity observations

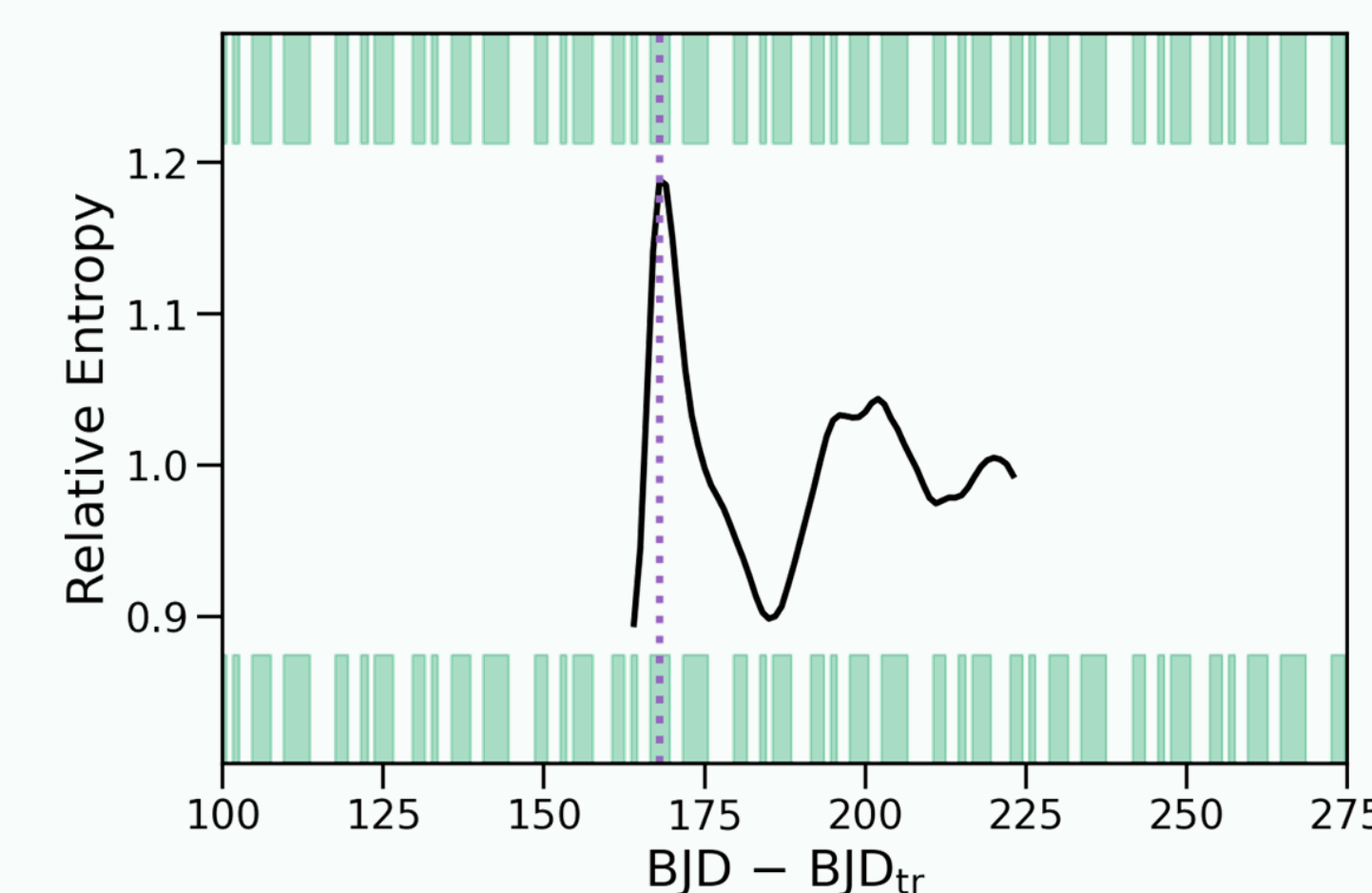
- A set of 3-6 reconnaissance observations are obtained to evaluate the level of radial velocity variation

5 Maximum entropy sampling

- We use our simulated RV models and initial data to calculate the information entropy of future observations as in [Ford 2008](#)
- Future observations are scheduled near the time of maximum entropy, accounting for practical limitations such as weather conditions and telescope and instrument availability
- As new data are made available and the set of viable models thins out, the information entropy is recalculated to facilitate adaptive scheduling of additional observations
- We repeat this process until we identify a *qualitatively unique* orbit for the STPC, at which point phase sampling follow-up strategies can be employed (e.g., [Burt et al. 2018](#))



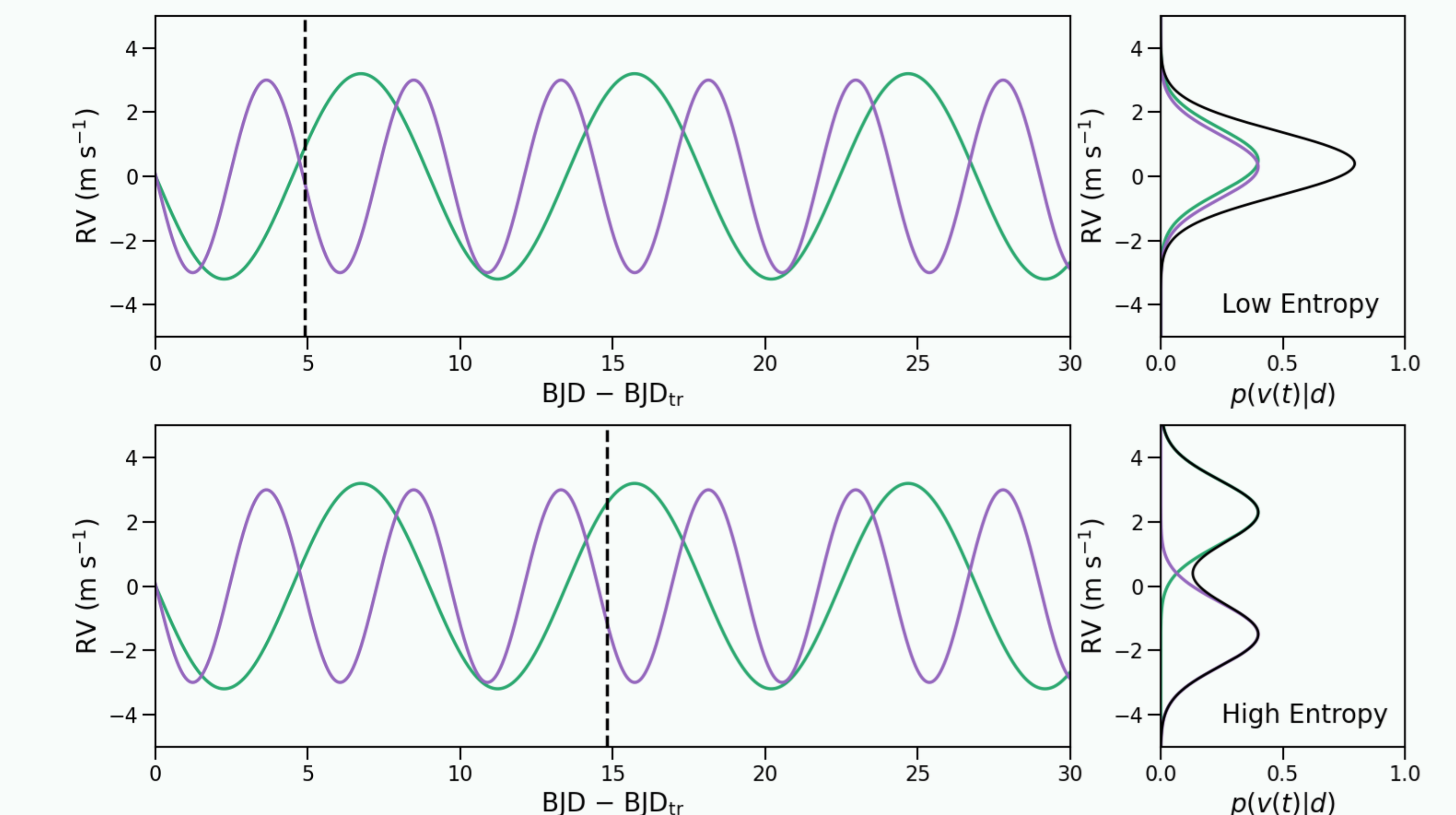
Top: Modeled RV curves (colored lines), reconnaissance RV observations (black points), and the true RV curve for a simulated eccentric warm Neptune STPC. The next observation (white point) should be scheduled as close as possible to the time of maximum entropy (dashed purple line).



Bottom: Information entropy (black line) of potential future observations from one week to two months after the final reconnaissance observation. The dashed purple line indicates the time at which the information content carried by a new observation is expected to be greatest, allowing us to more easily distinguish between competing models for the orbit of the STPC. Green bars indicate telescope and instrument availability, which constrain exactly when future observations may be scheduled.

Maximum Entropy Sampling

The Shannon entropy, or **information entropy**, of an observation is the average level of uncertainty contained in the set of possible measurement outcomes.

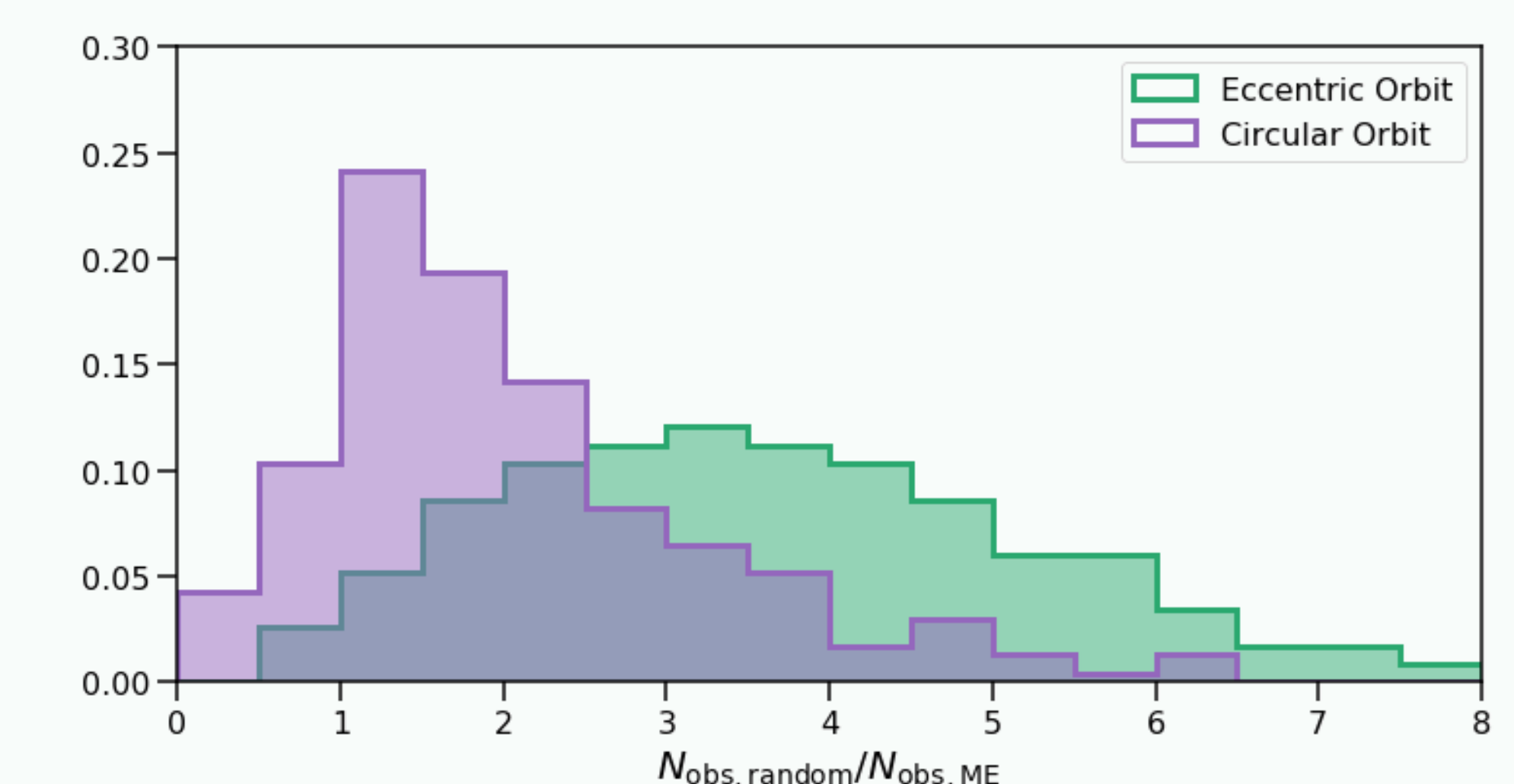


In the simple case of two competing models, a *low-entropy* observation (**top**) does little to distinguish between these models, whereas a *high-entropy* observation (**bottom**) is much more informative. In the low-entropy case, for which the two models predict similar radial velocity values at the time of observation, new data is likely to be equally consistent with both models. In the high-entropy case, the predicted velocity probability distribution is bimodal, and a new measurement is more likely to prefer a single model.

Sampling Efficiency

Maximum entropy (ME) sampling can be used to identify a qualitatively unique orbital solution with **fewer observations** than random sampling on the same timescale.

Simulations indicate a **more significant gain in efficiency for STPCs on highly eccentric orbits**, for which random sampling is more liable to miss large radial velocity shifts.



See poster by **Matthias He** for more on RV follow-up of TESS exoplanet candidates with SysSim



Center for Exoplanets and Habitable Worlds