

A Planet Hunters Search of the Kepler TCE Inventory

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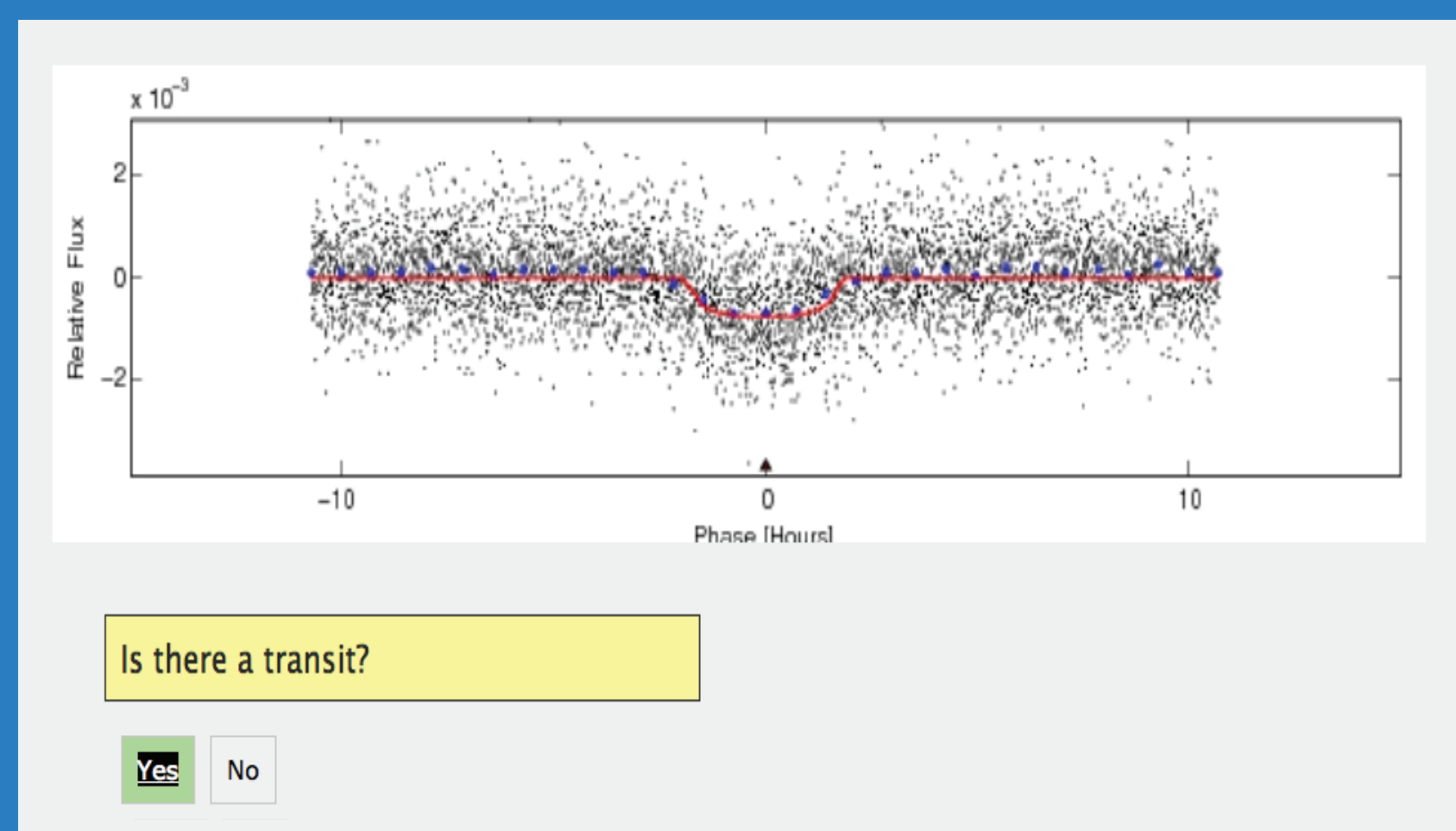
Introduction:

NASA's Kepler spacecraft has spent the past 4 years monitoring ~160,000 stars for the signatures of transiting exoplanets. Planet Hunters (<http://www.planethunters.org>), part of the Zooniverse (<http://www.zooniverse.org>) collection of citizen science projects, uses the power of human pattern recognition via the World Wide Web to identify transits in the Kepler public data. We have demonstrated the success of a citizen science approach with the project's discoveries including PH1 b, a transiting circumbinary planet in a four star system., and over 20 previously unknown planet candidates.

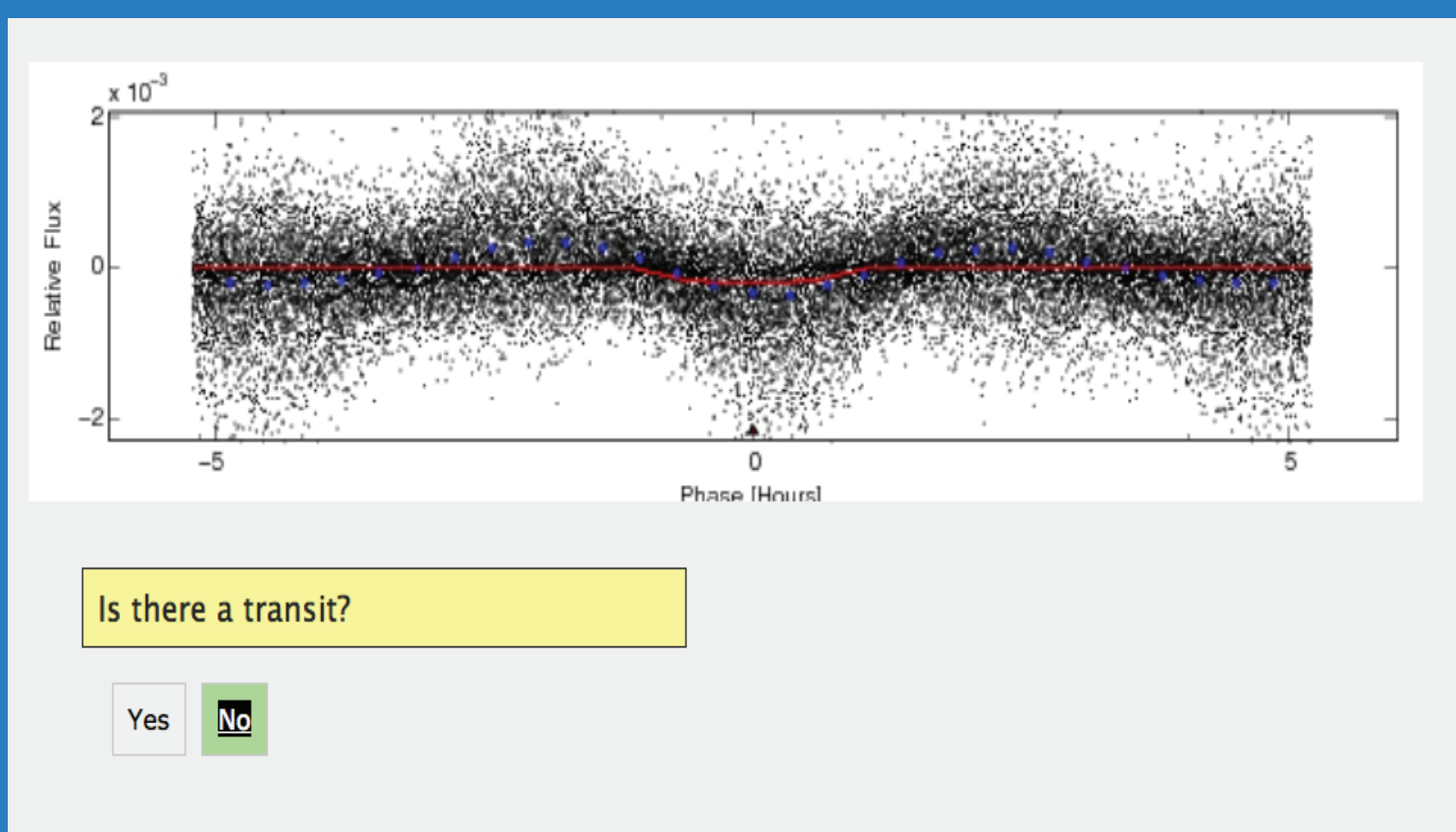
The Kepler team has released the list of 18,406 potential transit signals or threshold-crossing events (TCEs) identified in Quarters 1-12 (~1000 days) by their automated Transit Planet Search (TPS) algorithm. The majority of these detections found by TPS are triggered by transient events and are not valid planet candidates. To identify planetary candidates from the detected TCEs, a human review of the validation reports, generated by the Kepler pipeline for each TCE, is performed by several Kepler team members.. **We have undertaken an independent crowd-sourced effort to perform a systematic search of the Kepler Q1-12 TCE list. With the Internet we can obtain multiple assessments of each TCE's data validation report. Planet Hunters volunteers evaluate whether a transit is visible in the Kepler light curve folded on the expected period identified by TPS. We present the first results of this analysis.**

Classification Interface:

The interface displays the folded zoomed in light curve from the Kepler Data Validation Summary Report. Volunteers are asked to confirm there is a visible transit in the folded light curve identified by TPS ("Is there a transit? yes or no") and determine whether the red line matches the light curve ("Does the red line fit the data? yes or no").



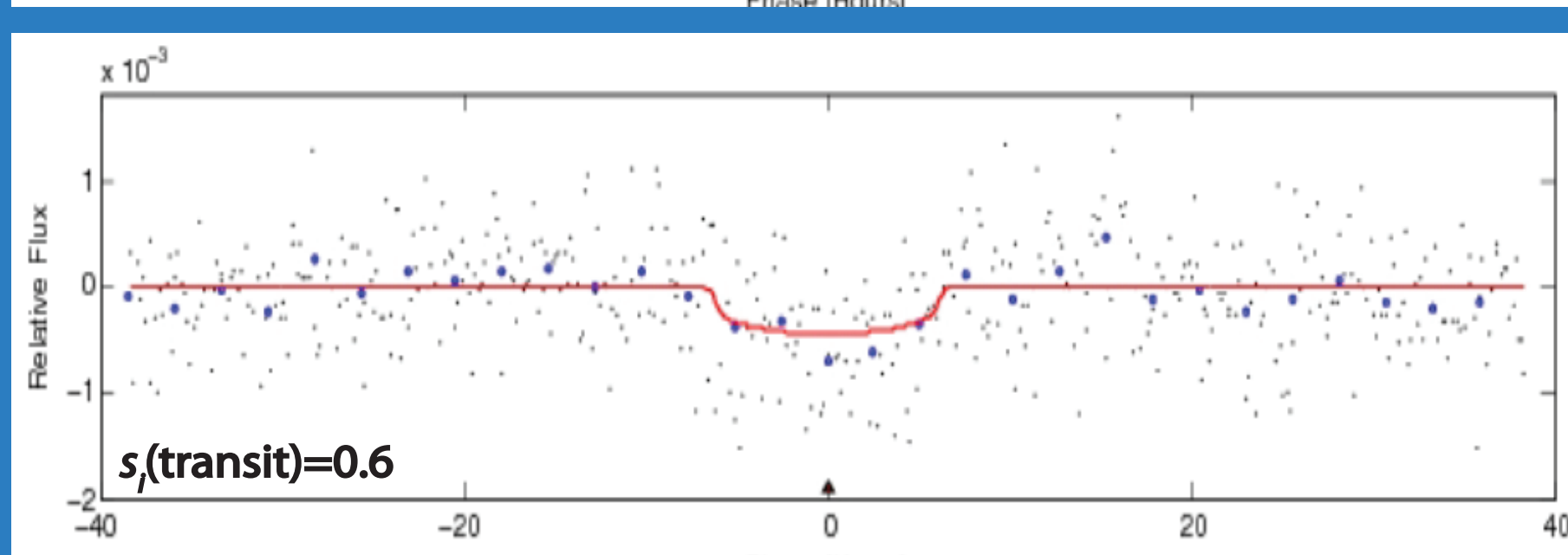
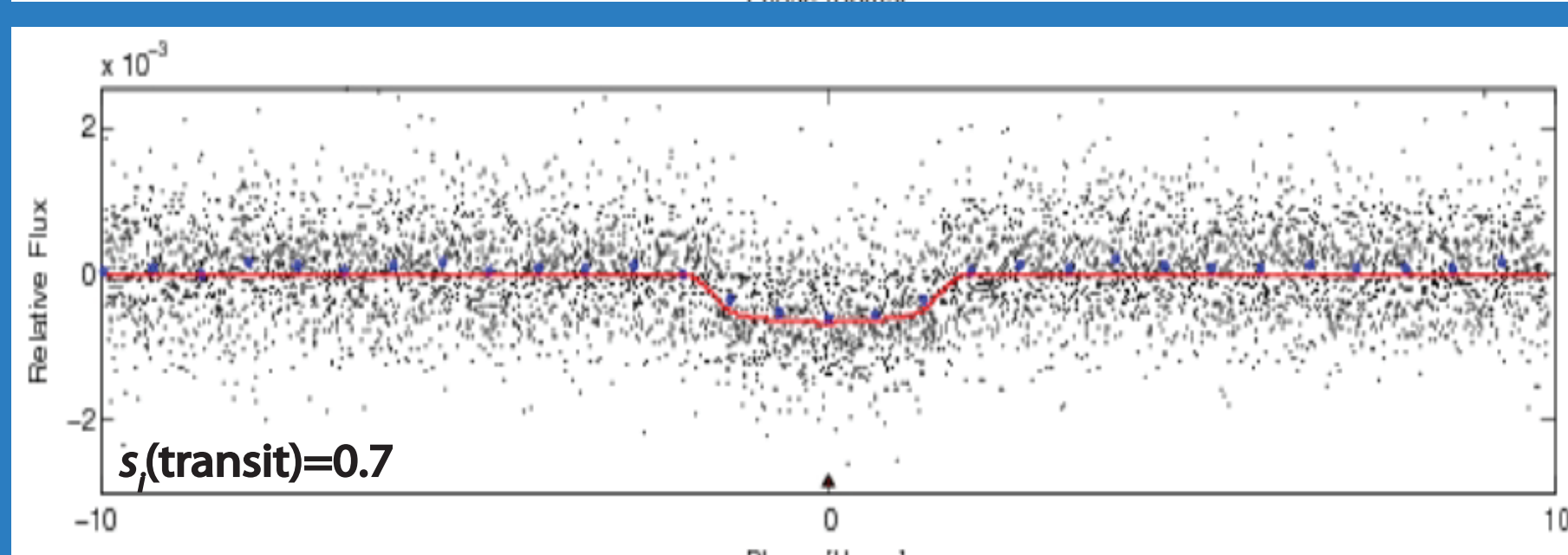
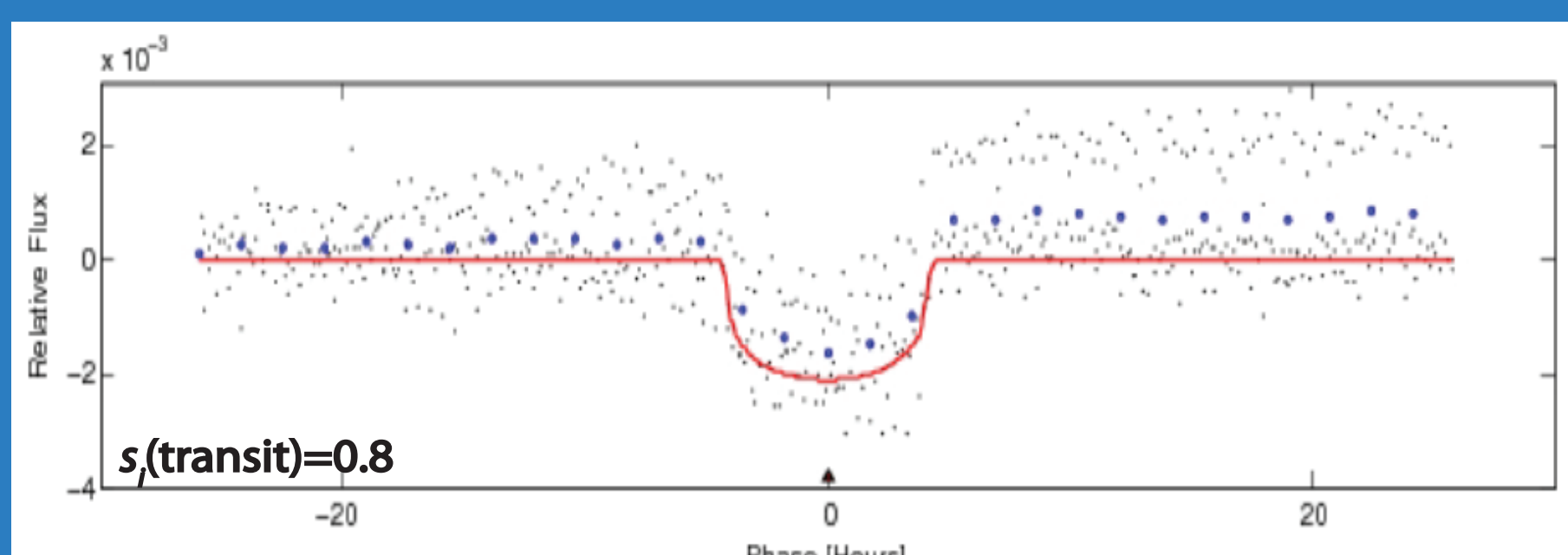
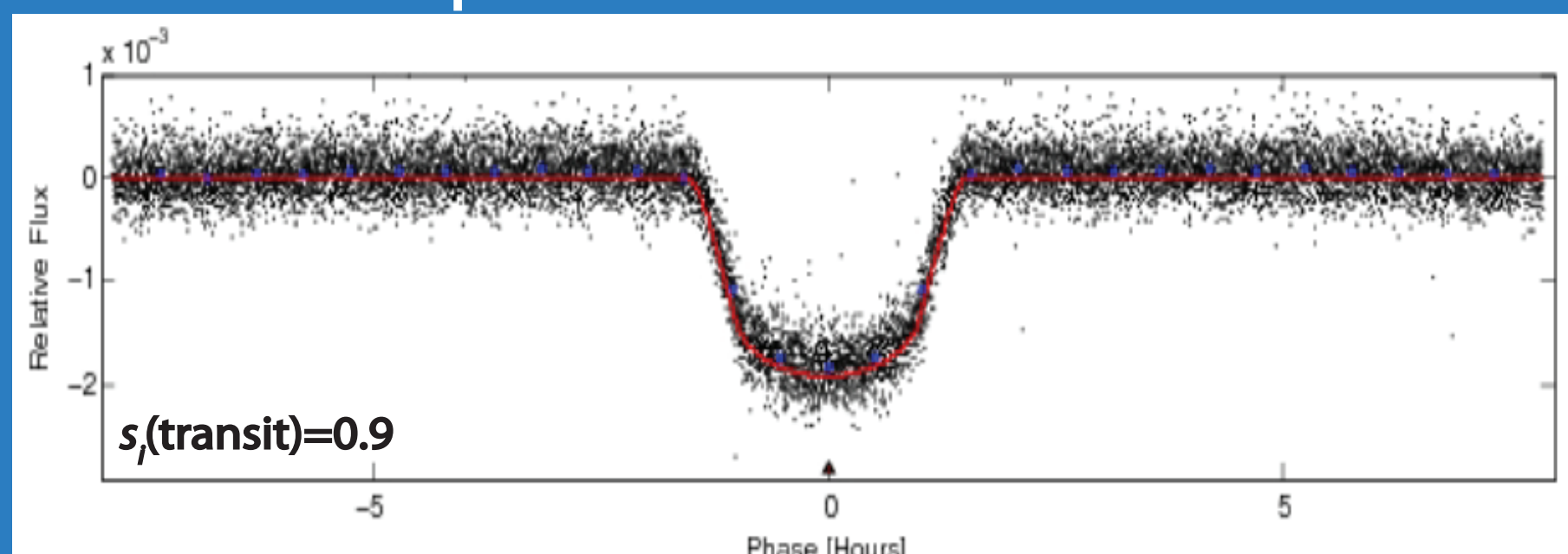
Planet Hunters TCE Review Interface with a transit-like TPS detection



Planet Hunters TCE Review Interface with a TPS false positive detection

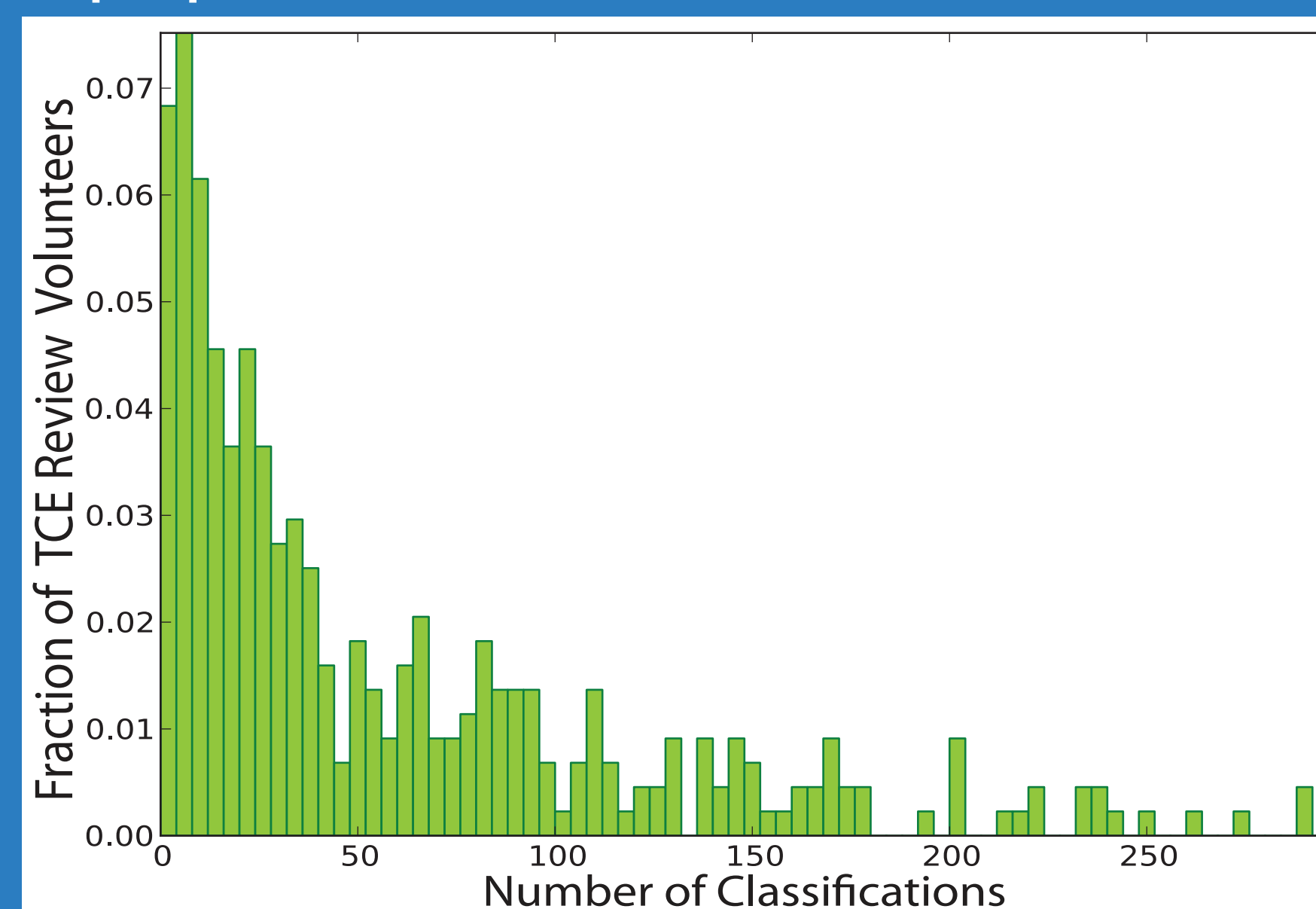
Transit-shaped TCEs identified:

Applying a cut on $s_t(\text{transit})$ at 0.5, 4666 TCEs with transit-like shapes remain.



Classifier Statistics:

Each of the 18,406 TCEs received 10 independent assessments in the review interface. Classifications were obtained over a 2 month period. 439 Planet Hunters volunteers contributed classifications to the TCE review with a median of 54 and average of 423 classifications per person.



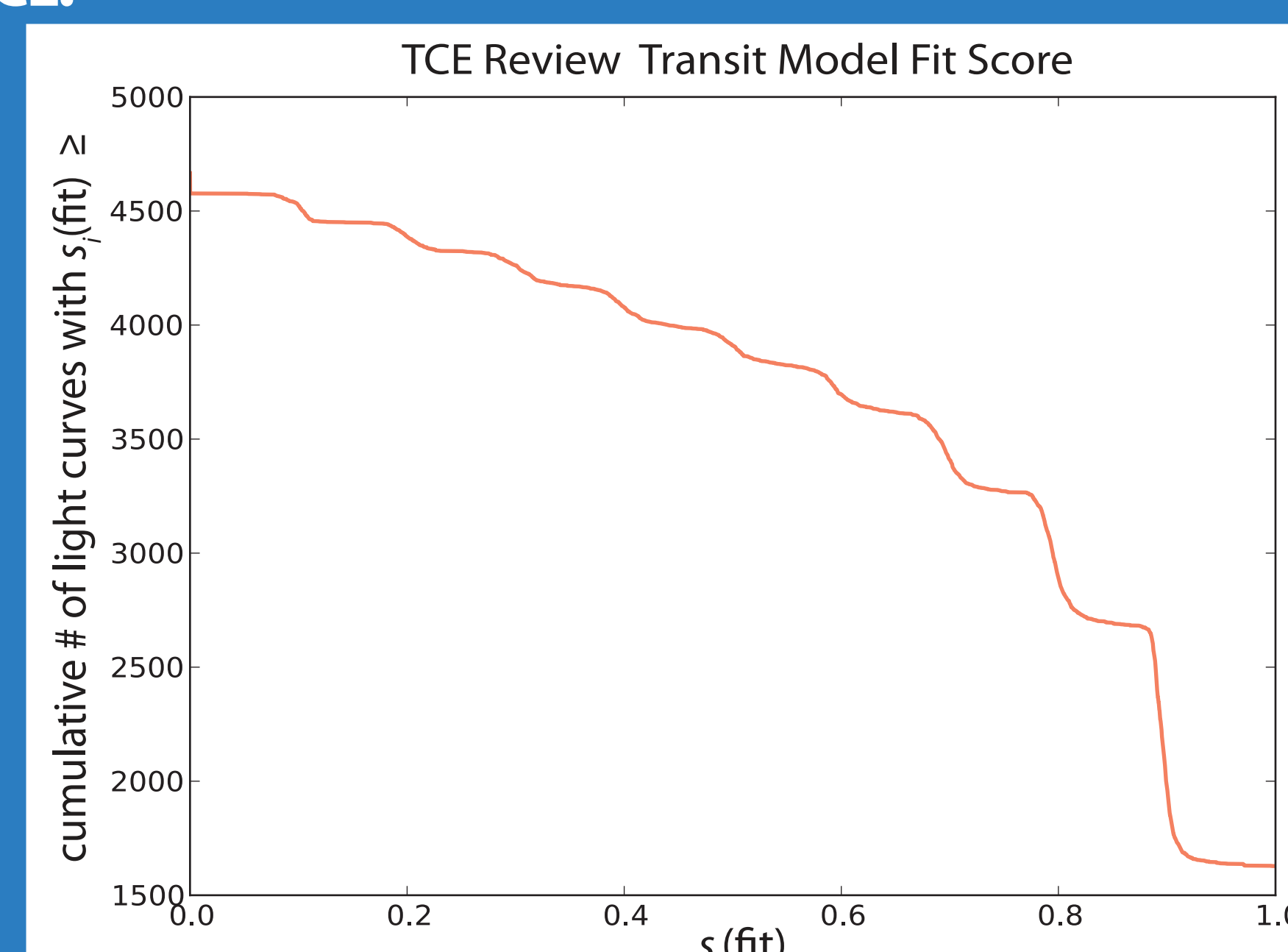
Distribution of classifications used in TCE analysis per registered Planet Hunters volunteer with a bin size of 4. The plotted distribution is truncated at 300 classifications for resolution. Only 20% of all registered volunteers make more than 300 classifications.

Iterative Weighting Scheme:

The classifications are processed through a pipeline to assess the capabilities of individual classifiers. Weightings are assigned to individual classifiers, and an iterative process is used to converge on final assessments on whether TCE events are transit-shaped. We assign a transit score, $s_t(\text{transit})$, for each TCE as the sum of the classifier weights who answered yes to the transit question divided by the sum of the weights for all who classified the given TCE.

Transit Model Fit Assessment:

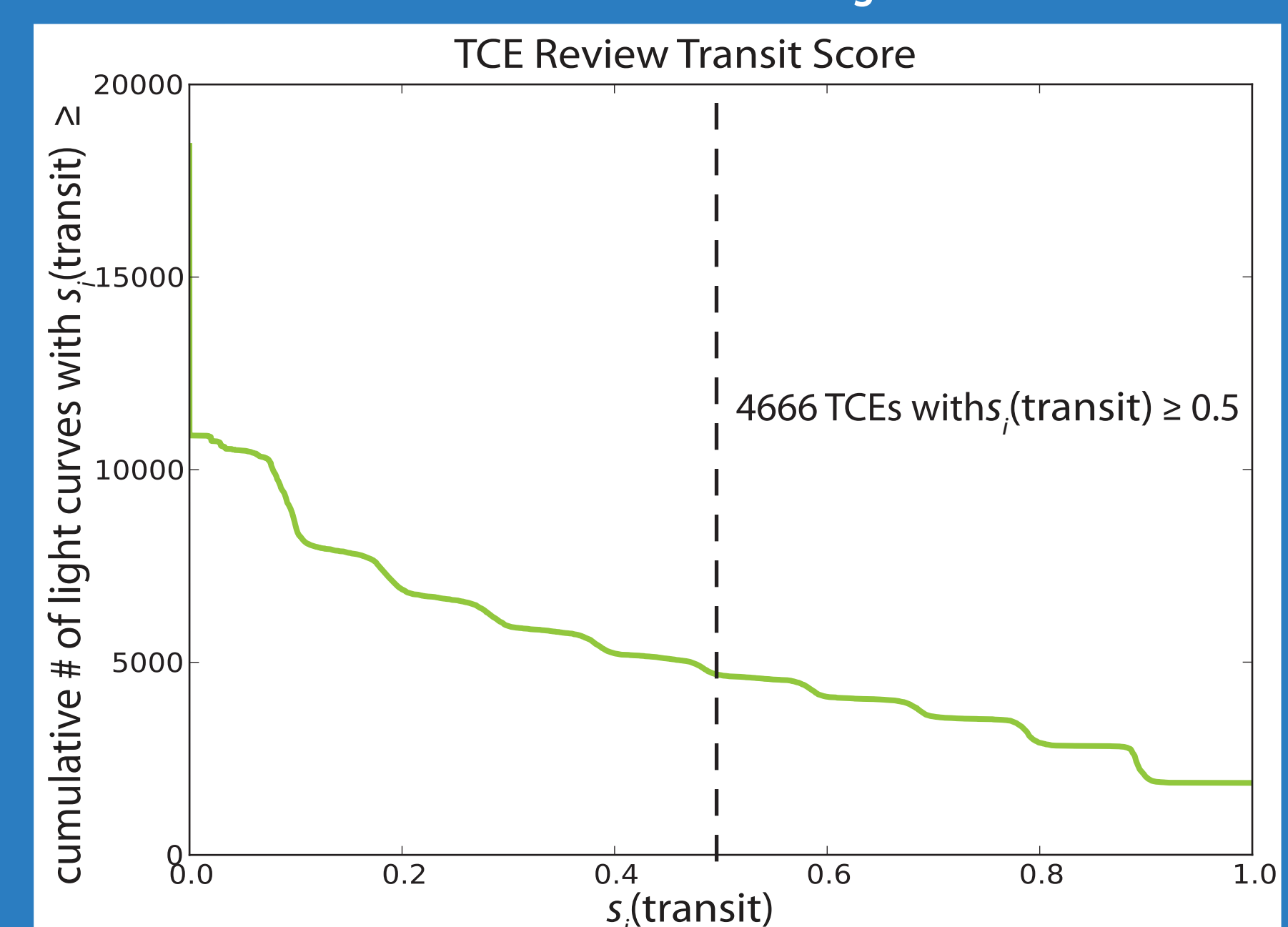
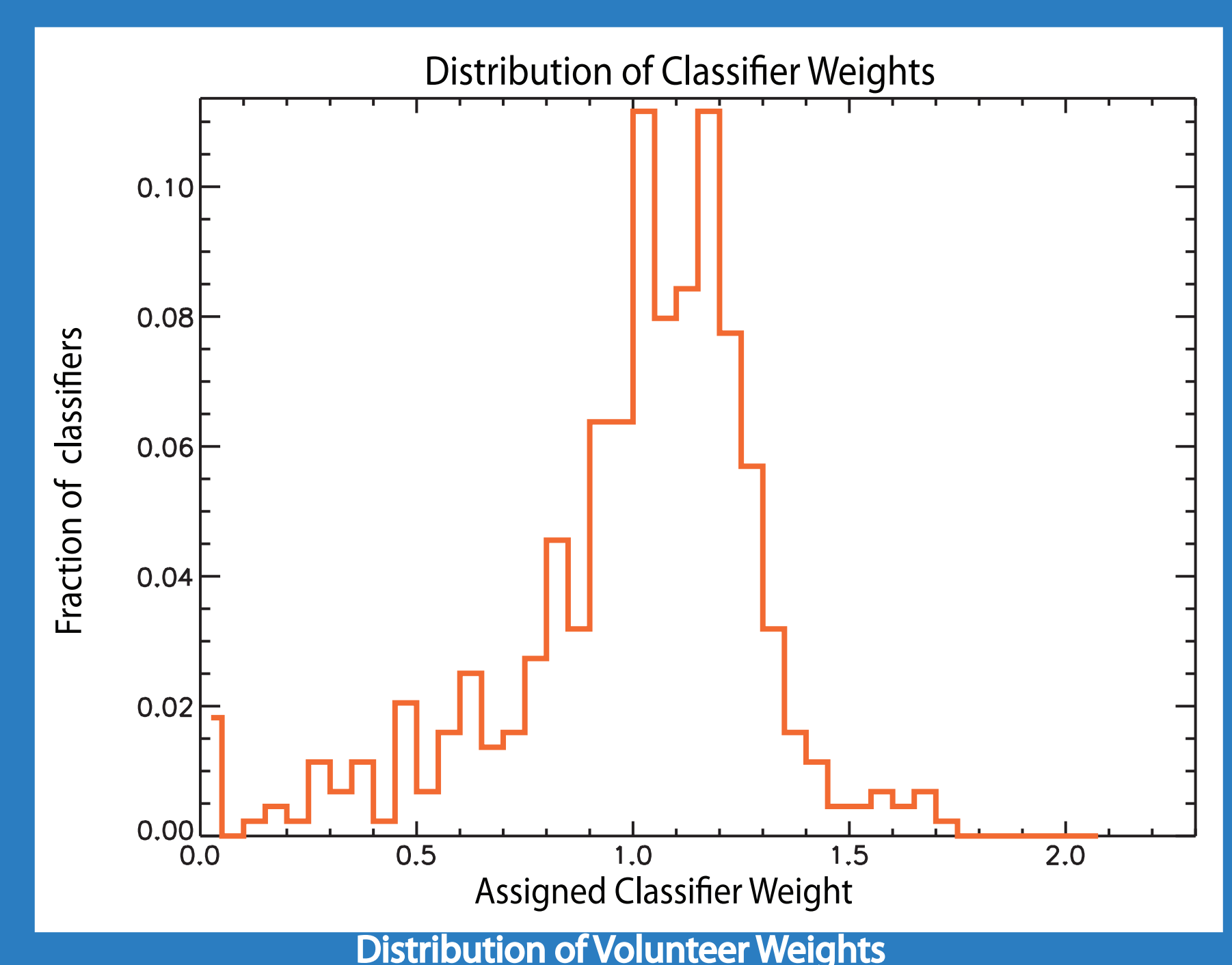
To assess how well the transit model fits the data, we use the previously computed classifier weights. We assign a transit model score, $s_t(\text{fit})$, for each TCE as the sum of the classifier weights who answered yes to the 'Does the red line fit the data?' question divided by the sum of the weights for all who classified the TCE.



Cumulative Distribution of Transit Model Fit Scores for Kepler TCEs.

We apply a conservative cut at 0.3 for $s_t(\text{fit})$ to determine how well the transit model fits the folded light curve. **4261 TCEs remain after this cut.**

Weighting Scheme Results:



Cumulative Distribution of Transit Scores for Kepler TCEs. Applying a threshold of at 0.6, 4666 TCEs remain on the list

In and Out of Transit Pixel Offsets & Removing Other False Positives:

- The odd-even transit statistic (computed by the Kepler Data Validation pipeline) is used to remove non-eccentric eclipsing binaries. 27 TCEs are rejected at 90% or higher likelihood of being a binary star.
- Long period detached eclipsing binaries are identified by comparing TPS detections around the same star and removing those with orbital periods less than 0.5 days apart. 523 TCEs are rejected.
- Pixel offset were checked requiring both difference image shifts and relative to star catalog position shifts in and out of transit be less than 4-sigma.
- Our preliminary list contains 3148 potential planet candidates compared to the ~3000 Kepler Object of Interests (KOIs) currently dispositioned as planet candidates and 1358 yet to be dispositioned.

Future Work:

Here we have presented preliminary results from our on-going analysis of the Planet Hunters TCE review. Further work will include refining our cuts, a detailed comparison to the Kepler KOI list, an improved method for removing long period detached eclipsing binaries, and more refined assessment of the pixel offset metrics.

planethunters.org

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