


The *Kepler* False Positive Table

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The *Kepler* False Positive Working Group
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Contents

1	Introduction	5
1.1	False Positives and False Alarms	5
1.2	Differences Between the FP and KOI Tables	6
2	The FPWG Vetting Process	7
3	The False Positive Table	12
3.1	Identification Data	12
3.2	KOI False Positive Flags	12
3.3	High-Level FPWG dispositions	13
3.4	Flux-Based Observational Flags	13
3.5	Offset Observational Flags	16
3.6	Period-Epoch Match Flags	17
3.7	False Alarm Observational Flags	18
3.8	Ground-Based Observational Flags	18
3.9	External False Positive Identification	19
3.10	Supporting Observational Information	20
3.11	Comments	21

1 Introduction

This document describes the *Kepler* false positive table hosted at the Exoplanet Archive¹, herein referred to as the “FP table”. This table is the result of detailed examination by the *Kepler* False Positive Working Group (FPWG) of declared false positives in the *Kepler* Object of Interest (KOI) tables (see, for example, Batalha et al. (2012); Rowe et al. (2015); Burke et al. (2014); Mullally et al. (2015); Coughlin et al. (2015b)) at the Exoplanet Archive. A KOI is considered a false positive if it is not due to a planet orbiting the KOI’s target star. This table contains all KOIs that have a disposition of “FALSE POSITIVE” in any KOI table, even if the disposition is “CANDIDATE” or “CONFIRMED” in a later KOI table.

The purpose of the FP table is to provide a list of *certified* false positive KOIs. A KOI is certified as a false positive when, in the judgement of the FPWG, there is no plausible planetary interpretation of the observational evidence, which we summarize by saying that the evidence for a false positive is compelling. This certification process involves detailed examination using all available data for each KOI, establishing a high-reliability “ground truth” set. The FP table can be used to estimate the reliability of, for example, the KOI tables which are created using only *Kepler* photometric data, so the disposition of individual KOIs may differ in the KOI and FP tables. Follow-up observers may find the FP table useful to avoid observing false positives.

The FP table is a work in progress: while all KOIs that were ever dispositioned as false positives have an entry in the table, the time and effort required to certify a false positive means that certifications will be taking place through 2017. The initial release of the FP table contains over 1600 certified FPs, which is about half of the KOIs ever dispositioned as false positive in the KOI tables. Table columns indicate which KOIs have been examined by the FPWG and their resulting status as certified false positives. In some cases KOIs are marked “PENDING”, which means at the time of table delivery further examination is required for certification. Updates to the FP table will occur regularly as more KOIs are examined. Once a KOI is certified as an FP, we expect changes to its certification status to be very rare.

1.1 False Positives and False Alarms

The *Kepler* mission finds exoplanets by observing transit events on particular target stars, analyzing the flux falling on pixels around each target star (Koch et al., 2010; Jenkins et al., 2010). For each target star, the flux of several pixels is summed to create that star’s flux light curve which is searched for transit events. Repeated transit events are indicative of an exoplanet around the target star, and are called “transit like”. Broadly speaking, there are two ways in which a KOI can be a false detection of a planet:

- **False Positives** are detections of transit-like signals present in the data that are not due to planetary transits (Brown et al., 2003). These are always due to objects in the sky, and are typically one of the following:

¹<http://exoplanetarchive.ipac.caltech.edu>

- **Eclipsing Binaries** (EBs) where the transit-like event is due to a stellar companion orbiting the target star. The KOI table includes eclipsing binaries where the eclipse depth is clearly not planetary, but in some cases, particularly grazing EBs or hierarchical multiple systems, the eclipse depth may mimic that of a planetary transit. EBs are identified through analysis of the target star’s flux light curve, including transit shape, the appearance of a secondary eclipse and light-curve phase variations.
- **Background Eclipsing or Transiting Object** where a background eclipsing binary or transiting planet is blended with the target star. The typical case is a background eclipsing binary (BGEb) where a deep eclipse on the BGEb itself is diluted to mimic a planetary transit by the usually brighter target star. When the separation of the background source from the target star is large enough, the transit source location can be identified by observing an offset between the target star and the transit signal. Background transiting planets are considered false positives because they are not transits on the target star.
- **False Alarms** are spurious detections caused by features in the target star’s light curve that are not transit like. There are several causes of false alarms, including astrophysical stellar variability and non-astrophysical instrumental artifacts.

The FP table uses “false positive” to refer only to transit-like signals that are not planetary transits. In the FP table false positives are distinct from false alarms. This nomenclature differs from the KOI tables, where false alarms are considered a type of false positive, which is labeled “not transit-like”.

In most cases KOIs in the FP table that have been examined by the FPWG are certified as false positives or false alarms, and evidence driving each false positive/alarm certification is given. In a few cases the FPWG has determined that the evidence for a false positive or false alarm is insufficient and recommends that the KOI be returned to planet candidate status. The KOI tables, however, are based on uniform analysis of *Kepler* data, so individual dispositions in the KOI tables will not change because of information in the FP table. The FP table will only be used to improve the analysis performed to create the KOI table dispositions.

1.2 Differences Between the FP and KOI Tables

The differences between the dispositions in the FP table and those in the KOI tables are due to several factors:

- The FPWG uses all available data when evaluating a possible false positive, including ground observation and detailed, low-level examination of *Kepler* data. The KOI table dispositions are determined under the constraint that only *Kepler* data are used, and only certain high-level data products were used to determine a KOI’s disposition (Coughlin et al., 2014a).
- The FPWG generally applies a higher-level of scrutiny, whereas time constraints in the creation of the KOI table at times did not allow deep investigation of a particular KOI.

This is particularly true of the later KOI tables, where disposition is an automated process with a known accepted error rate (Coughlin et al., 2015b).

- The FPWG has different criteria of when a KOI is declared a false positive because more data are used in the determination. An example is the use of derived planetary radius as described in §3.

In addition, the FP table provides more detailed information about why a KOI is declared a false positive than the KOI tables.

2 The FPWG Vetting Process

The threshold for the certification that a KOI is a false positive or false alarm is that the evidence for such a certification is compelling. In this section we describe the overall FPWG vetting process, leaving the details to the description of the FP table in §3. The FPWG vets KOIs using a variety of observational metrics, most of which are based on *Kepler* data. These observational metrics are used to determine the reason that the KOI should be considered a false positive. The FPWG vetter sets Boolean true or false values for the observational characteristics indicating the false positive nature of the KOI. Once a cause to consider the KOI a false positive has been indicated, the required vetting is complete and it is up to the vetter whether or not to further classify the KOI by setting other observational characteristics. Therefore the FP table only provides the reason that a KOI is certified to be a false positive, and does not provide a complete characterization of the KOI. In addition the vetter can indicate cause for a certified false positive/alarm that is not included in the standard observational characteristics, with an explanation in a comment.

FPWG vettors bring uncertain cases to group discussion, where the expertise and experience of the full FPWG is brought to bear on the KOI in question. This has often resolved cases where a particular vetter is uncertain.

The KOI is certified to be a false positive or false alarm only if required observational characteristics are indicated. This is determined by applying a logical analysis to the observational characteristics indicated by the FPWG vetter. The vetter does not directly certify that a KOI is a false positive or false alarm, but the vetter can prevent a false positive/alarm certification by indicating that though certain observational characteristics are set they are not sufficiently compelling. This conservative approach sets a high bar for the certification of a false positive/alarm while allowing the vetter to indicate possible issues with the KOI that are short of compelling evidence.

There are three independent logical analyses on the observational characteristics: one each for EBs, offsets and false alarms. The EB logical analysis is shown in Figure 1, the offset analysis in Figure 2, and the false alarm analysis in Figure 3. In each figure the square boxes give the observational characteristics set by the vetter. In the vetting process, when appropriate, the vetter indicates that the evidence is not compelling and, for example, the “stellar parameters not trustworthy”. The opposite polarity of these parameters is given in the figures for clarity. So, for an example using Figure 1, if the vetter indicates that there

is an observed secondary, that the secondary is self-luminous, and indicates nothing else then the KOI is determined to be an EB, whereas if the vetter were to also check “stellar parameters not trustworthy”, then the KOI would not be determined to be an EB.

Each box in these figures has a column in the FP table. Several additional observational characteristics are given in the table that provide interesting information, but do not determine a false positive/alarm. These characteristics are described in §3.

The result of these logical analyses is three Booleans: eb, offset and false alarm. The high-level certification of a false positive is determined by the following logic: false positive = ((eb true) OR (offset true)) AND (false alarm false). In addition to the observational characteristics checked by the FPWG, a KOI can become a certified false positive/alarm because of published analysis. In these cases the FPWG reviews the publication, and indicates its concurrence in the FP table.

If none of the observational characteristics required to determine a false positive or false alarm are indicated, then the KOI is a possible planet candidate. Such KOIs are brought before special sessions of the FPWG and given full scrutiny, including a literature search. If no compelling evidence for being a false positive/alarm is found, then the KOI is given the disposition “possible planet”.

Finally, the vetter has the ability to mark a KOI as pending, which means that the available evidence is ambiguous and there is a reasonable expectation that data available in the near future will provide better evidence. This data can include future group discussion, final pipeline processing, or promised ground-based observations.

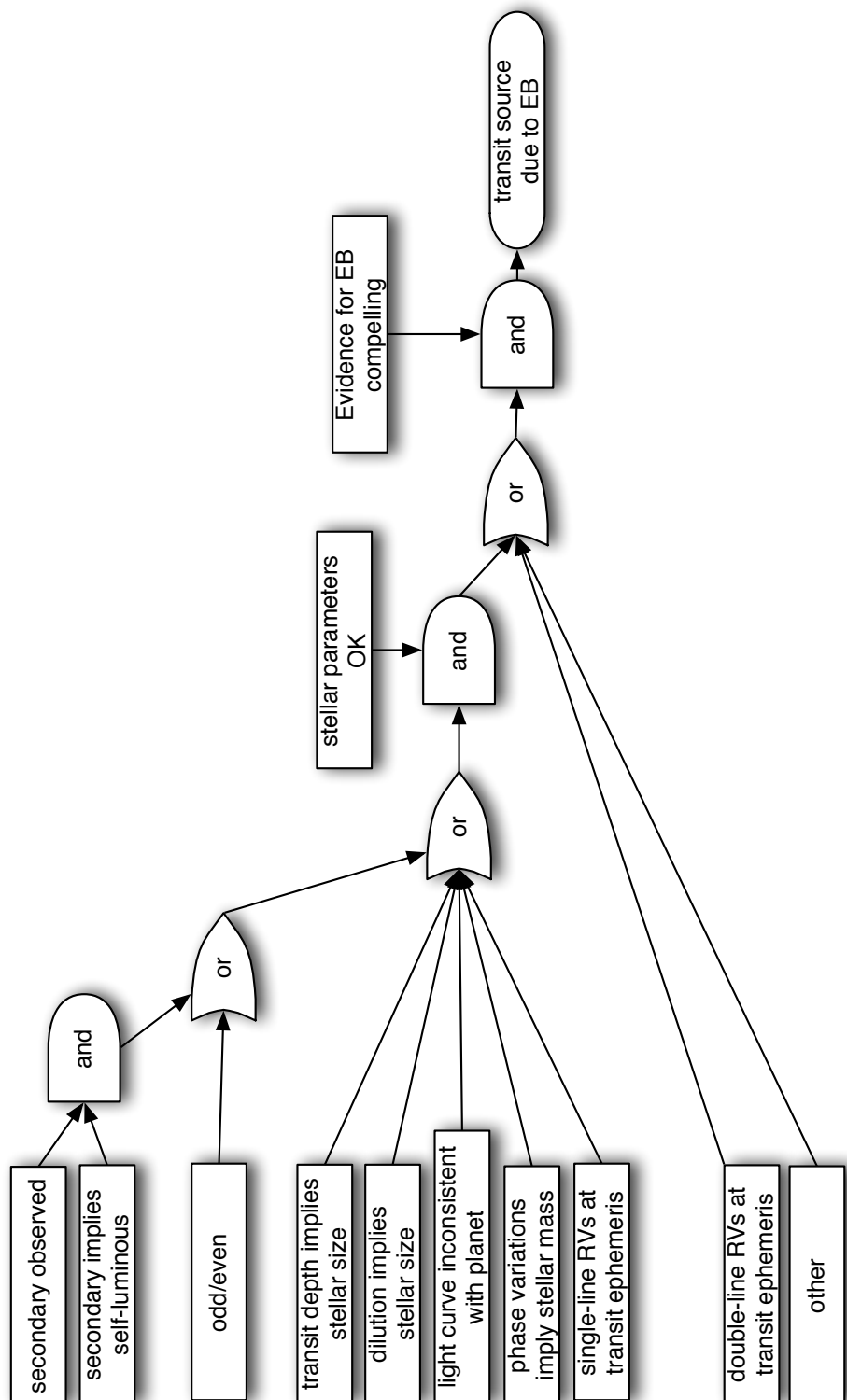


Figure 1: The logical analysis leading to the certification of an EB false positive

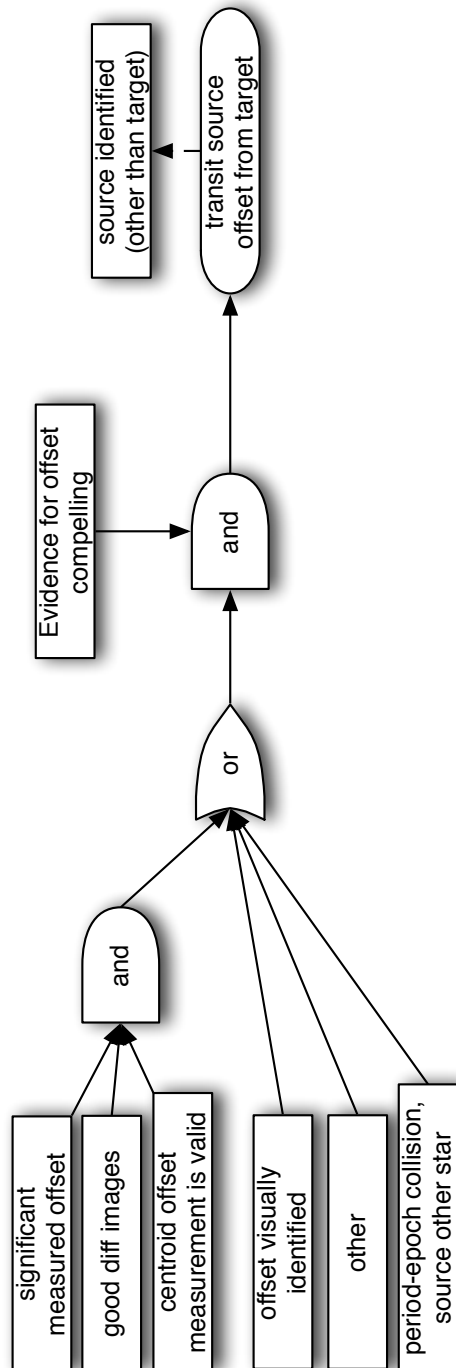


Figure 2: The logical analysis leading to the certification of an offset false positive

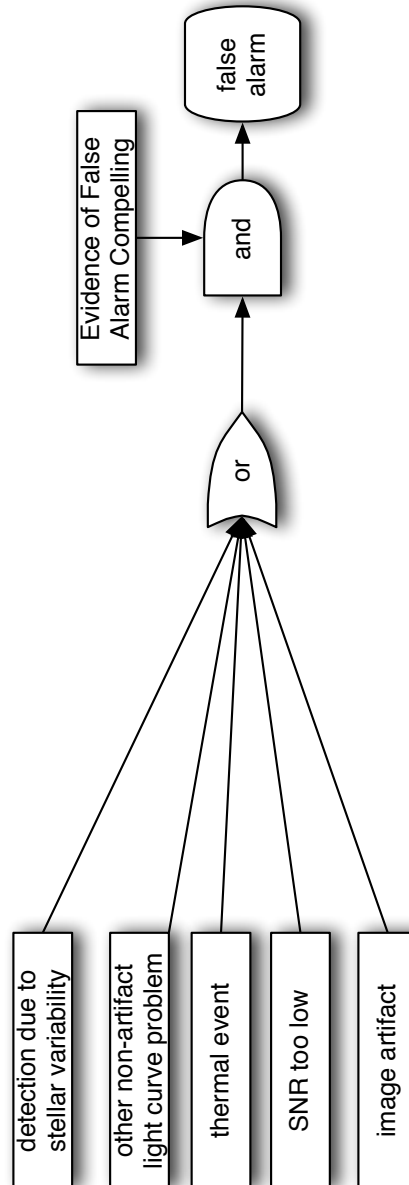


Figure 3: The logical analysis leading to the certification of a false alarm

3 The False Positive Table

This section describes the *Kepler* false positive table in detail. Many of the table entries are Boolean flags determined by inspection of various metrics as described in §2. Many of these metrics are described in detail in Coughlin et al. (2014a, 2015a), which describes the report used for vetting by the Threshold Crossing Event Review Team (TCERT). We provide detail about those metrics not described in Coughlin et al. (2014a, 2015a) or other references. The archive variable name for each entry is given in parentheses.

The FP table has several distinct groupings, which we describe in separate subsections.

3.1 Identification Data

- **Kepler ID** (*kepid*), the Kepler Input Catalog number of the target star for this KOI.
- **KOI name** (*kepoi_name*)
- **KOI period** (*fpwg_koi_period*), the period in days used in FPWG vetting. This period may not agree with that in the KOI table, for example when the period reported by automated analysis and vetted by the FPWG is half the correct period. This is typically the case when there is a strong odd/even effect (see §3.4).

3.2 KOI False Positive Flags

In the KOI table, a KOI with a false positive disposition has four flags giving the type of false positive. These TCERT flags are repeated in the FP table for convenience.

- **TCERT False Positive Flag** (*fpwg_tcert_fp*), a Boolean indicating that the TCERT has determined that this KOI is a false positive.
- **Not Transit-Like Flag** (*fpwg_tcert_fa*), a Boolean indicating that the TCERT has determined that this KOI is a false alarm.
- **Significant Secondary Flag** (*fpwg_tcert_eb*), a Boolean indicating that the TCERT has determined that this KOI has a secondary eclipse or occultation event. This can include planetary occultations, in which case the TCERT False Positive Flag will not be set.
- **Ephemeris Match Indicates Contamination Flag** (*fpwg_tcert_perep*), a Boolean indicating that the TCERT has determined that this KOI is the child of a period-epoch match (Coughlin et al., 2014b).
- **Centroid Offset Flag** (*fpwg_tcert_offst*), a Boolean indicating that the TCERT has determined that this KOI is due to a source offset from the target star, usually indicating a background eclipsing binary.

3.3 High-Level FPWG dispositions

This group contains the high-level FPWG dispositions, arrived at by applying the logical analysis described in §2.

- **Disposition** (*fpwg_disp_status*), a character string indicating the overall disposition of this KOI. This string will have one of the following values:
 - **NOT EXAMINED:** This KOI has not been examined by the false positive working group.
 - **CERTIFIED FALSE POSITIVE:** The FPWG has determined that this KOI is a false positive. This value is set when either the eclipsing binary flag or the offset flag is set and the false alarm flag is not set.
 - **CERTIFIED FALSE ALARM:** The FPWG has determined that this KOI is a false alarm.
 - **PENDING:** The FPWG determination is pending further investigation using expected future data or analysis.
 - **POSSIBLE PLANET:** The FPWG has determined that there is not sufficiently compelling evidence that this KOI is a false positive or false alarm.
- **Target is source** (*fpwg_disp_source*), a Boolean indicating that the transit signal is likely due to the target star. This flag is set when neither the offset nor the period-epoch match flags are set.
- **EB** (*fpwg_disp_eb*), a Boolean indicating that the transit signal is likely due to an eclipsing binary. If the offset flag is false then the eclipsing binary is likely the target star.
- **Offset** (*fpwg_disp_offst*), a Boolean indicating that the transit signal is likely offset from the target star.
- **Period-Epoch Match** (*fpwg_disp_perep*), a Boolean indicating that this KOI is the child of a period-epoch match (Coughlin et al., 2014b).
- **Other FP** (*fpwg_disp_other*), a Boolean indicating that this KOI is a false positive or false alarm for reasons not covered above. Details are given in the comments.

3.4 Flux-Based Observational Flags

This group contains observational characteristics determined through manual examination of the target star’s flux light curve, usually used to identify eclipsing binaries.

- **Secondary Observed** (*fpwg_flux_ss*), indicating that the flux light curve shows a secondary eclipse or occultation event. This does not, by itself, imply an eclipsing binary

because the secondary may be due to reflected light from a planet. An observed secondary can be detected through the various light curve displays such as the DV summary, the odd/even metric, or the model shift uniqueness test. The odd/even metric and the model shift test are applied to several types of light curve detrending, including the whiteners applied by the pipeline, median detrending and so-called alternate detrending. For details see Coughlin et al. (2014a).

In some cases the displays described in Coughlin et al. (2014a) are not sufficient and other flux light curve displays are used, such as those available at the Mikulski Archive for Space Telescopes (MAST)².

- **Secondary Implies Self Luminous** (*fpwg_flux_slflum*), a Boolean indicating that the secondary event indicates that the eclipsing object is self-luminous, implying an eclipsing binary. Two metrics are used to indicate that the secondary implies a self-luminous object:
 - **Estimated Albedo** computes the albedo of the orbiting object as

$$A_{\text{obs}} = D \frac{a^2}{R_p^2}$$

where D is the measured secondary fractional depth, a is the semi-major axis computed via Kepler’s third law using the KOI period and mass of the target star, and R_p is the planetary radius computed from the radius ratio in the KOI table and the stellar radius (see eqn. 5 of Coughlin and López-Morales (2012)). The stellar parameters are from Huber et al. (2014).

- **Observed Temperature** computes an estimate of the temperature T_{obs} using eqn. 4 of Coughlin and López-Morales (2012), assuming the albedo is 0.3, and a theoretical maximum planetary temperature T_{max} using eqn. 3.

When $A_{\text{obs}} \geq 1$ or $T_{\text{obs}} \gg T_{\text{max}}$ the secondary is taken as self-luminous. These metrics require stellar parameters and are sensitively dependent on them. When stellar parameters are not available this flag is not checked.

- **Significant Odd/Even** (*fpwg_flux_oedp*), a Boolean indicating that the transit signal shows alternating depths, indicating primary/secondary events with twice the inferred orbital period. If the primary and secondary depths are very similar it is very likely that the implied secondary is self luminous.
- **V-shaped** (*fpwg_flux_vshape*), a Boolean indicating that the transit signal is V-shaped, indicating a possible grazing eclipsing binary. This is an information-only field and does not determine a false positive.

²http://archive.stsci.edu/kepler/data_search/search.php

- **Depth Implies Stellar Size** (*fpwg_flux_depth*), a Boolean indicating that the depth of the transit signal is not consistent with a planetary interpretation. The depth is used to estimate the planetary radius from the stellar radius. The FPWG has adapted a threshold of $30 R_{\text{Earth}}$, above which the transiting object is considered stellar. The radius estimate is sensitively dependent on stellar parameters. When stellar parameters are not available, this flag may be set due to very deep transits.
- **Dilution Implies Stellar Size** (*fpwg_flux_dilutn*), a Boolean indicating the depth of the transit signal is not consistent with a planetary interpretation after accounting for dilution due to flux from other stars. This flag is most likely to be set when high-resolution imaging shows that the target star is actually a multiple star system, because crowding from known field stars is accounted for when computing the planetary radius (Wu et al., 2010).
- **Light Curve Inconsistent With Planet** (*fpwg_flux_lcurve*), a Boolean indicating that the flux light curve is generally inconsistent with a planet interpretation for reasons not covered in the other flags.
- **Phase Variations Imply Stellar** (*fpwg_flux_oovvar*), a Boolean indicating that the flux light curve shows phase variations inconsistent with a planetary interpretation. This flag is most likely to be set when the phase variations are large and phased with the transit signal. In some cases a fitted model of the phase variation provides a mass of the orbiting object (Faigler, S. and Mazeh, T., 2014).
- **Transit Correlated Flux Variations** (*fpwg_flux_corvar*), a Boolean indicating that the flux light curve shows flux variations correlated with the transit signal. This is an information-only field and does not determine a false positive.
- **Other Flux Issues** (*fpwg_flux_other*), a Boolean indicating that the flux light curve is inconsistent with a planetary interpretation for reasons not captured in other flags. Details are given in the comments.
- **Stellar Parameters Not Trustworthy** (*fpwg_flux_stellr*), a Boolean indicating that the stellar parameters used to infer transit properties are too uncertain to be used to reach conclusions about the nature of the transiting object. This flag is set only when stellar parameters are present and they are judged to be not trustworthy by the vetter. Setting this flag overrides essentially all other flux-based observational flags as shown in Fig. 1.
- **Evidence For EB Not Compelling** (*fpwg_flux_noteb*), a Boolean indicating that there is not compelling evidence that this KOI is a flux false positive regardless of the settings of other flux-based observational flags. This allows the vetter to set other flags to indicate issues with the flux light curve, but determine that those issues are not compelling.

3.5 Offset Observational Flags

This group contains observational characteristics determined through manual examination of the centroid offset analysis described in Coughlin et al. (2014a). This examination uses a variety of methods to determine whether the transit signal source is co-located with the target star, with particular focus on the difference image PRF fit method. For each quarter, the difference image PRF fit method fits the *Kepler* Pixel Response Function (PRF) to both averaged direct pixel images and averaged difference images formed by subtracting the in-transit pixel values from the out-of-transit pixel values. The PRF fit to the direct pixel image gives the position of the target star if it is well isolated. The PRF fit to the difference image gives the position of the transit signal source when the transit signal to noise ratio is large enough. The difference between these positions gives the offset of the transit source from the target star. Alternative methods provided for computing the offset are 1) taking the difference of the PRF fit to the difference image from the target star catalog position, and 2) inferring the transit source position from the photometric centroid shift in transit. All of these methods are vulnerable to several sources of error, but on average the difference image PRF fit method is the most robust. For further details see Bryson et al. (2013). High-resolution imaging, particularly UKIRT imaging (Lawrence et al., 2007), can play a prominent role in offset identification: when the offset indicates that the transit source is co-located with a detected star, we have increased confidence that the offset analysis is correct.

- **Significant Measured Offset** (*fpwg_offst_sig*), a Boolean indicating that difference image PRF fit measurements imply that the transit source is offset from the target star by more than 3 times the uncertainty, indicating that the transit source is not co-located with the target star.
- **Bad Difference Images** (*fpwg_offst_badim*), a Boolean indicating that difference images used to compute centroid offsets are not of sufficient quality to support the measurement. This is determined by visual inspection of the difference image, and is set when the difference image does not resemble a stellar image, causing a meaningless PRF fit. Bad difference images are typically caused by very shallow transits with low signal to noise. Setting this flag overrides the Significant Measured Offset flag.
- **Centroid Offset Not Valid** (*fpwg_offst_inval*), a Boolean indicating that the measured centroid offsets are not valid. This is determined by visual inspection of the direct and difference image, and can be due to several causes such as bright nearby stars in the direct image or the target star being highly saturated. Another common case of invalid offsets is that of small but significant spurious offsets due to nearby stars causing the PRF measurement of the target star position to be biased, leading to the mistaken identification of an offset. Spurious offsets caused by such biases can be detected by examining the results of modeling described in Bryson and Morton (2015).
- **Offset Visually Identified** (*fpwg_offst_vis*), a Boolean indicating that visual inspection determined that the transit source is offset from the target star, usually by inspec-

tion of the difference image. This is usually set when the measured centroid offsets are unavailable or invalid but the difference images are available and indicate an offset.

- **Star Detected At Transit Location** (*fpwg_offst_star*), a Boolean indicating that a star other than the target star is found at the offset transit source location, increasing confidence in the reality of the transit source offset. This is an information-only field and does not determine a false positive.
- **Quarterly Depth Variations** (*fpwg_offst_qvars*), a Boolean indicating that the transit depth depends on quarter, possibly indicating that the transit source is offset from the target star and is near the edge of the pixels obtained for this target star. Quarterly depth variations can have other causes, however, such as a bright star near the edge of the pixels contributing different amounts of dilution in different quarters, so this is an information-only field and does not determine a false positive.
- **Other Offset Evidence** (*fpwg_offst_other*), a Boolean indicating that the transit source is offset from the target star based on evidence not captured in other flags. Details are given in the comments.
- **Evidence For Offset Not Compelling** (*fpwg_offst_nooff*), a Boolean indicating that the transit signal is likely not offset from the target star regardless of the settings of other offset observational flags. This allows the vetter to set other flags to indicate issues with the offset analysis, but determine that those issues are not compelling.

3.6 Period-Epoch Match Flags

This group gives the results of the period-epoch match analysis of Coughlin et al. (2014b). Many of these matches are with parent stars in the pixels obtained for this KOI's target star, and are detected as offsets. But several of these matches are due to bright eclipsing binaries that can be very distant on the *Kepler* focal plane.

- **Match To Parent** (*fpwg_perep_match*), a Boolean indicating that this KOI is the child of a known period-epoch match parent. Setting this flag can cause the high-level offset flag to be set.
- **Direct PRF Contamination** (*fpwg_perep_direct*), a Boolean indicating that the period-epoch match is due to being in the wings of the parent PRF. This is an information-only field and does not determine a false positive.
- **Column Effect** (*fpwg_perep_col*), a Boolean indicating that the period-epoch match is due to a parent in the same CCD column. This is an information-only field and does not determine a false positive.
- **Optical Ghost** (*fpwg_perep_ghost*), a Boolean indicating that the period-epoch match is due to optical ghosting of the parent. This is an information-only field and does not determine a false positive.

- **Video Crosstalk** (*fpwg_perep_video*), a Boolean indicating that the period-epoch match is due to video crosstalk of the parent on another channel. This is an information-only field and does not determine a false positive.
- **Reflected Light** (*fpwg_perep_ref*), a Boolean indicating that the period-epoch match is due to light from the parent reflected off the structure of the *Kepler* photometer. This is an information-only field and does not determine a false positive.

3.7 False Alarm Observational Flags

This group gives the results of false alarm analysis, which involves visual inspection of the various flux light curves described in §3.4.

- **Stellar Variability** (*fpwg_fa_starvar*), a Boolean indicating that transit detection is due to stellar variability, not a transiting or eclipsing body. This is based on expert examination of the flux light curve.
- **Transit Not Unique** (*fpwg_fa_unique*), a Boolean indicating that the detected transit signal is not obviously different from other signals in the flux light curve. Very shallow planetary transits on noisy stars can, however, have this behavior so this is an information-only field and does not determine a false alarm.
- **Thermal Event** (*fpwg_fa_thermal*), a Boolean indicating that the detected transit signal is caused by an identified thermal event in the flux light curve.
- **Not Transit Like** (*fpwg_fa_ntl*), a Boolean indicating that the detected transit signal is not consistent with a transit or eclipse.
- **Image Artifact** (*fpwg_fa_artifact*), a Boolean indicating that the detected transit signal is due to an image artifact such as a sudden pixel sensitivity dropout. See Christiansen et al. (2013) for a discussion of various image artifacts.
- **Other False Alarm Evidence** (*fpwg_fa_other*), a Boolean indicating that the detected transit signal is a false alarm for reasons not captured in other flags. Details are given in the comments.
- **Evidence For False Alarm Not Compelling** (*fpwg_fa_notfa*), a Boolean indicating that the transit signal is likely not a false alarm regardless of the settings of other false alarm observational flags. This allows the vetter to set other flags to identify issues indicating a possible false alarm, but determine that those issues are not compelling.

3.8 Ground-Based Observational Flags

This group gives false positive evidence found in the results of ground-based observation, usually from the Kepler Community Follow-up Observing Program (CFOP)³.

³<https://cfop.ipac.caltech.edu/home/>

- **Single-Line Radial Velocities At Transit Ephemeris** (*fpwg_fop_rvs1*), a Boolean indicating that single line spectroscopic radial velocities have been measured at the transit ephemeris that are not consistent with a planetary interpretation. Because these are only single line spectra, with no clear evidence of a stellar companion, this is an information-only field and does not determine a false positive.
- **Double-Line Radial Velocities At Transit Ephemeris** (*fpwg_fop_rvs2*), a Boolean indicating that double line spectroscopic radial velocities have been measured at the transit ephemeris that are not consistent with a planetary interpretation.
- **Radial Velocities Detected** (*fpwg_fop_rvs3*), a Boolean indicating that spectroscopic radial velocities indicating a stellar binary have been measured but it is not known if they match the transit ephemeris. This is an information-only field and does not determine a false positive.
- **Composite Spectrum** (*fpwg_fop_dblline*), a Boolean indicating that spectroscopy indicates more than one star at the target star location. This is an information-only field and does not determine a false positive.
- **HighRes Image Examined** (*fpwg_fop_imexam*), a Boolean indicating that high-resolution imaging has been examined for this KOI.
- **HighRes Image Shows Blend** (*fpwg_fop_imblend*), a Boolean indicating that high-resolution imaging shows one or more stars very close to the target star. This is an information-only field and does not determine a false positive.

3.9 External False Positive Identification

This group provides information about false positives identified by the astronomical community, typically through peer-reviewed publications. When the FPWG has examined and concurs with the false positive determination, then other appropriate flags will be set for this KOI, resulting in a high-level false positive certification. The purpose of this group is to properly credit the discovery of the false positive evidence.

- **Publicly Identified FP** (*fpwg_efp_public*), a Boolean indicating that a publication has declared this KOI to be a false positive. Citation(s) are given in comments. By itself this flag does not determine a certified false positive in the FP table.
- **Examined By FPWG** (*fpwg_efp_pubexam*), a Boolean indicating that the FPWG has examined the publication(s).
- **Accepted As FP By FPWG** (*fpwg_efp_accept*), a Boolean indicating that the FPWG agrees with the publications conclusion that this KOI is a false positive. When set, other flags will be set for this KOI to document the evidence for the false positive determination.

3.10 Supporting Observational Information

This group provides information that may be of interest when studying the population of false positives or false alarms. The information in this group is not expected to be available for all KOIs.

The following fields provide information about offset false positives. The offset values are from the difference image PRF fit as computed by the *Kepler* pipeline’s Data Validation module (Wu et al., 2010).

- **Offset in Right Ascension from target star** (*fpwg_obs_ra*): Measured RA offset from the target star in arcsec.
- **Offset RA Uncertainty** (*fpwg_obs_ra_err*): RA offset uncertainty in arcsec.
- **Offset in Declination from target star** (*fpwg_obs_dec*): Measured Dec offset from the target star in arcsec.
- **Offset Dec Uncertainty** (*fpwg_obs_dec_err*): Dec offset uncertainty in arcsec.
- **Offset From Target Star** (*fpwg_obs_offst*): Measured two-dimensional offset from the target star in arcsec.
- **Offset Uncertainty** (*fpwg_off_err*): Measured two-dimensional offset uncertainty in arcsec.
- **Offset From Target Star in Units of Uncertainty** (*fpwg_obs_uncunit*): Measured offset from the target star divided by the measurement uncertainty.
- **ID of Star at Transit Location** (*fpwg_obs_kepid*): Identifying information about the star, if any, found at the transit source location.
- ***Kepler* Magnitude of Star at Transit Location** (*fpwg_obs_kepmag*): *Kepler* magnitude of the star found at the transit source location.
- **Modeled Depth of Star at Transit Location** (*fpwg_obs_depth*): The depth of a transit or eclipse on the background star required to match the observed KOI depth after accounting for dilution, computed as described in Bryson and Morton (2015).
- **Provenance of Star at Transit Location** (*fpwg_obs_idprov*): Identification of the source of information about the star at the transit source location.

The following fields provide information about observed secondaries consistent with the KOI’s ephemeris.

- **Secondary depth** (*fpwg_obs_secdep*): Measured depth of the observed secondary in ppm.
- **Albedo** (*fpwg_obs_albedo*): Albedo inferred from the observed secondary in the flux light curve, computed using the formula described in §3.4.

3.11 Comments

The comment field (*fpwg_comment*) gives the vetter the opportunity to point out interesting aspects of the KOI. Some flags, when set, also require explanatory comments. A comment may be truncated in the online table at the Exoplanet Archive. All comments can be obtained in their entirety by downloading the FP table.

References

- Batalha, N. M., et al. 2012, ApJS 204, 24
- Brown, T. M., et al. 2003, ApJ 593, L125
- Bryson, S. T., et al. 2013, PASP 125, 889
- Bryson, S. T., and Morton, T. 2015, *Planet Reliability Metrics: Astrophysical Positional Probabilities*, KSCI-19092
- Burke, C. J., et al. 2014, ApJS 210, 19
- Christiansen, J., et al. 2013, *Kepler Data Characteristics Handbook*, KSCI-19040
- Coughlin, J., and López-Morales, M. 2012, AJ 143, 39
- Coughlin J., et al. 2014a, *Description of the TCERT Vetting Products for the Q1-Q16 Catalog Using SOC 9.1*, KSCI-19103
- Coughlin, J., et al. 2014b, ApJ 147, 119
- Coughlin, J., et al. 2015a, *Description of the TCERT Vetting Products for the Q1-Q17 DR 24 Catalog*, KSCI-19104
- Coughlin, J., et al. 2015b, *in preparation*
- Faigler, S., and Mazeh, T. 2014, ApJ 784, 45
- Huber, D., et al. 2014, Proc. ApJS 211, 2
- Jenkins, J., et al. 2010, Proc. SPIE, Vol. 7740, 77400D
- Koch, D. et al. 2010, ApJ 713, L79
- Lawrence, A., et al. 2007, MNRAS 379, 1599
- Mullally, F., et al. 2015, ApJS 217, 31
- Rowe, J. F., et al. 2015, ApJS 217, 16
- Wu, H., et al. 2010, Proc. SPIE, Vol. 7740, 774019