DEEP GALEX UV SURVEY OF THE KEPLER FIELD. I. POINT SOURCE CATALOG

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ABSTRACT

We report observations of a deep near-ultraviolet (NUV) survey of the Kepler field made in 2012 with the Galaxy Evolution Explorer (GALEX) Complete All-Sky UV Survey Extension (CAUSE). The GALEX-CAUSE Kepler survey (GCK) covers 104 square degrees of the Kepler field and reaches a limiting magnitude of NUV $\sim 22.6$ at 3$\sigma$. Analysis of the GCK survey has yielded a catalog of 669,928 NUV sources, of which 475,164 are cross-matched with stars in the Kepler Input Catalog. Approximately 327 of 451 confirmed exoplanet host stars and 2614 of 4696 candidate exoplanet host stars identified by Kepler have NUV photometry in the GCK survey. The GCK catalog should enable the identification and characterization of UV-excess stars in the Kepler field (young solar-type and low-mass stars, chromospherically active binaries, white dwarfs, horizontal branch stars, etc.), and elucidation of various astrophysics problems related to the stars and planetary systems in the Kepler field.

Key words: catalogs – stars: activity – stars: chromospheres – techniques: photometric – ultraviolet: stars

Supporting material: machine-readable tables

1. INTRODUCTION

The fast growth of exoplanet detections has motivated the derivation of more accurate fundamental stellar properties (e.g., mass, radius, age, etc.) and the connection between these properties and those of their evolving planetary systems. The precision with which the exoplanets' parameters can be estimated directly depends on the precision associated with the properties of their stellar hosts. Of particular importance is the stellar age, since one of the major goals in the study of exoplanetary systems is to establish their evolutionary stage, and how this compares to the properties of our own solar system.

Reliably age-dating solar-type field stars is notoriously difficult. For these stars, alternative methods to isochrone fitting techniques have been explored. Chromospheric activity and stellar rotation are among the more reliable observables for stellar age estimation of Sun-like main sequence stars. The most common and accessible proxy for stellar activity has been the emission in the Ca II resonance line in the optical-ultraviolet spectral interval (e.g., Mamajek & Hillenbrand 2008). Alternative proxies have also been identified and include the high contrast emission of Mg II line in the ultraviolet (UV) and the continuum UV excess (e.g., Findeisen et al. 2011; Olmedo et al. 2013). For these stars, UV radiation originates in the hot plasma of the upper stellar atmospheres at temperatures of $\sim10^4$–$10^6$ K, heated by non-thermal mechanisms, such as acoustic and magnetic waves, generated by convection and rotation (e.g., Narain & Ulmschneider 1996; Ulmschneider et al. 2003). As the star ages, it loses angular momentum due to magnetic braking (Mestel 1968; Kawaler 1988), slowing the rotation and affecting the stellar dynamo, which in turn decreases the magnetic field leading to a decrement of the UV emission. In this first paper of a series aimed at investigating the UV properties of stars, we present a complete catalog of UV sources detected by the Galaxy Evolution Explorer (GALEX; Martin et al. 2005; Bianchi et al. 2014) in the field of the Kepler Mission (Bisri et al. 2005).

The Kepler field (i.e., the 100 square degree field of the original Kepler mission) has been fully surveyed at different optical and infrared bandpasses (Lawrence et al. 2007; Brown et al. 2011; Everett et al. 2012; Greiss et al. 2012). Its stellar content, mainly comprised of field stars, with over 450 confirmed exoplanet host stars, has rapidly become one of the most studied stellar samples and regions of the sky. The Kepler field and associated survey data comprise a potentially valuable resource for studying the age-activity-rotation relation for low-mass stars. Rotation periods (and ages) of stars in the Kepler field have been determined in a number of studies (e.g., Reinhold et al. 2013; Walkowicz & Basri 2013; do Nascimento et al. 2015; García et al. 2014; McQuillan et al. 2014; Meibom et al. 2015).

The GALEX UV space observatory was launched in 2003 and was operated by NASA until 2011 (Martin et al. 2005; Bianchi et al. 2014). Afterwards, the GALEX mission was managed by Caltech for about a year as a private space observatory, until the satellite was turned off in June 2013. GALEX is a 50 cm Ritchey–Chrétien telescope with a 1’25 wide field of view, equipped with a near-UV (NUV; 1771–2831 Å, $\lambda_{\text{eff}} = 2271$ Å) and a far-UV (FUV; 1344–1786 Å, $\lambda_{\text{eff}} = 1528$ Å) detectors. During its main mission, GALEX carried out the All-Sky, Medium, and Deep Imaging Surveys, with exposure times of $\sim$100, $\sim$1000, and $>$10,000 s, respectively, measuring more than 200 million sources (Bianchi et al. 2014). The continuation phase, called the GALEX Complete All-Sky UV Survey Extension (CAUSE), was funded by several consortia, with the main goal of extending observations in the NUV band to the Galactic plane, which was only scarcely

http://kepler.nasa.gov/ as of 2015 September 11.
mapped during the main mission, due to restrictions on the maximum target brightness.

In this work, we describe the creation of a deep NUV photometric catalog with nearly full coverage of the Kepler field using CAUSE observations. In Section 2 we introduce the observations and characteristics of the data. In Section 3 we explain the procedure for extracting the NUV point sources. Section 4 describes the point source catalog, and its crossmatch with the Kepler Input Catalog (KIC) and the Kepler Objects of Interest (KOI) catalog is presented in Section 5. Finally, the publicly available GALEX-CAUSE (GCK) catalog of NUV sources is described in Section 6.

2. OBSERVATIONS

As part of the CAUSE survey, Cornell University funded 300 orbits to complete the spatial coverage of the Kepler field through 2012 August–September (PI J. Lloyd). The data set of GCK field observations is composed of 180 tiles that cover the Kepler field (Borucki et al. 2003; Basri et al. 2005; Brown et al. 2005; Latham et al. 2005); each tile has 20 visits on average. These observations sample timescales from a millisecond to a month, and can be used to identify variable targets and exotic sources on such timescales. The GCK data set provides spatial coverage of the Kepler field in the GALEX NUV band.

The standard GALEX pointed observation mode adopted for the surveys during the primary NASA GALEX mission employed a 1.5 spiral dither pattern. This dither moves the sources with respect to detector artifacts and prevents a bright source to saturate one position on the detector, which is subject to failure if overloaded. The GALEX data pipeline processes the photon arrival times and positions with an attitude solution that reconstructs an image of the sky for a single tile, 1.2 in diameter around the pointing center.

In 2012, a drift mode was adopted, which scanned a strip of the sky along a great circle. For GCK observations, these scans run as long as 12°. The scan mode processing uses a pipeline adapted from the pointed mode observations.7 To adapt the scans to the standard tile processing pipeline, they are processed in tile sized images resulting in 9 and 14 images for the short scans (1−3 and 13−15) and long scans (4−12), respectively (shown in Figure 1). Thus for the 180 tiles of the GCK data, with each visited an average of 20 times, we have a total of ~3200 images.

The GCK data were processed with the GALEX scan-mode pipeline and subsequently delivered to Cornell in the form of packs of 5 images (see Table 1 for details) per visit for each tile. For details on these files or any technical information concerning the GALEX mission, see http://www.galex.caltech.edu/wiki/Public:Documentation.

A mosaic of the GALEX CAUSE NUV observations is shown on Figure 2. The superimposed blue box corresponds to the central CCD of the Kepler detector array. Most of the data exhibit the exquisite photometric and astrometric stability and reproducibility expected for a space observatory. However, the GALEX pipeline failed to correctly process a small fraction of the images. A thorough visual inspection showed that there are about 450 images affected by doubling or ghosting of sources. An example of this effect is illustrated in Figure 3. All these images were excluded from our analysis.

The final exposure time map is presented in Figure 4. Some tiles lack a single good visit and are located at the end of a scan, when the spacecraft was executing a maneuver. Because of this, the 13th image of scans 4, 5, 6, 9, and 10 were not included in the catalog construction (leaving a total of 175 tiles), representing a loss of no more than 0.5% coverage of the Kepler field. Within the main GALEX surveys, fractions of the Kepler field were partially surveyed (Smith et al. 2011). A cumulative distribution of the exposure time in function of sky coverage is shown in Figure 5 (solid blue line), and the orange dashed line corresponds to the GALEX release 6 (GR6).

Table 1

| Fits name              | Image type         | Units      |
|------------------------|--------------------|------------|
| nd-count.fits          | count image        | photons/pix|
| nd-rhr.fits            | effective exposure map | s pix$^{-1}$ |
| nd-int.fits            | intensity map      | photons s$^{-1}$ pix$^{-1}$ |
| nd-flags.fits          | artifact flags image | ...        |
| xd-mcat.fits           | catalog of sources | ...        |

3. ASSEMBLY OF A CATALOG OF NUV SOURCES

The construction of the GCK catalog can be summarized in four stages, each of which is discussed in this section. In the first stage, “Image Co-adding,” the available single epoch visits for each tile are co-added. Next, the “Background Estimation” is carried out from the intensity image using a modified σ clipping method. The “Source Extraction and Photometry” uses the software SExtractor (Bertin & Arnouts 1996) to first detect and then perform photometry on the background-subtracted intensity image for each tile obtained in the previous stage. In the final stage the catalogs from each of the 175 tiles are combined, and duplicate objects, low signal-to-noise ratio (S/N) sources, and other possible spurious sources are carefully removed.

http://galex.stsci.edu/GR6/?page=scanmode
3.1. Image Co-adding

Prior to co-adding all epochs for a given tile, each image was visually inspected, discarding visits presenting the source doubling or ghosting issue (Figure 3). Since the images already have an astrometric solution, and furthermore, each epoch for a given tile are aligned, co-adding only requires an arithmetic sum. For each tile, the process was as follows.

Figure 2. Intensity image mosaic of GALEX CAUSE NUV observations. The blue square corresponds to the central CCD of the Kepler telescope.

Figure 3. GALEX image corresponding to scan 1, image 2, visit 2, as an example of a failure of the pipeline processing: bright sources appear as double objects.

Figure 4. Mosaic of the effective exposure time of the GALEX CAUSE observations.
1. Construction of the co-added count image as the arithmetic sum of individual count intensity images (nd-count.fits).

2. Construction of the co-added effective exposure image as the arithmetic sum of individual effective exposure images (nd-rrhr.fits).

3. Construction of a combined flag image as the logic OR of the individual flag images (nd-flags.fits).

4. Calculation of the ratio of the co-added count and effective exposure images to obtain the final intensity image.

Table 2

| Number | Short name | Description |
|--------|------------|-------------|
| 1(1)   | edge       | Detector bevel edge reflection (NUV only) |
| 2(2)   | window     | Detector window reflection (NUV only) |
| 3(4)   | dichroic   | Dichroic reflection |
| 4(8)   | varpix     | Variable pixel based on time slices |
| 5(16)  | brtedge    | Bright star near field edge (NUV only) |
| 6(32)  | detector rim | Proximity (>0.6 degrees from field center) |
| 7(64)  | dimask     | Dichroic reflection artifact mask flag |
| 8(128) | varmask    | Masked pixel determined by varpix |
| 9(256) | hotmask    | Detector hot spots |
| 10(512)| yaghost    | Possible ghost image from YA slope |

Note. From the GALEX documentation, chapter 8 (http://www.galex.caltech.edu/wiki/Public:Documentation/Chapter_8). Artifacts 7, 8, 9 do not apply to the the GCK catalog.

Figure 5. Cumulative distributions of exposure time of the sky coverage of the GCK Kepler field (solid blue line). Observations from the GALEX release 6 (GR6) are represented with the dashed orange line.

Figure 6. Left panel: co-added intensity image for image 6 of scan 2. Right panel: the same image with source detected marked as red points. Note the absence of detection in the area affected by instrumental artifacts.

Figure 7. Distribution of NUV detections. Blue line is the distribution of objects on the GCK catalog, red line are the matched objects with the KIC. Dotted lines correspond to a sample of detections inside a the sky region defined on Figure 2.

Figure 8. NUV photometric error distribution for the GCK catalog. The color scale indicates the density of the sources in the plot.

Figure 9. Cumulative distributions of separations of the GCK—KIC cross-match.
3.2. Background and Threshold Estimations

The source extraction and photometry methodology follows that of the GALEX pipeline (reported in Morrissey et al. 2007).8 Prior to this step, background and threshold images are built, as required by SExtractor.

Background estimation: the construction of a background image consists of an iterative $\sigma$-$\kappa$ clipping method. The count image is divided into square bins 128 pix wide. In each bin, the local background histogram is built using the Poisson distribution (due to the low NUV background count rates), and the probability $P_k(x)$ of observing $k$ events for a mean rate $x$ is calculated. Pixels with $P_k(x) < 1.35 \times 10^{-3}$ (equivalent to a $3\sigma$ level) are iteratively clipped until convergence is reached. Then a $5 \times 5$ pix median filter is applied to decrease the bias by bright sources. The bin mesh is upsampling to the original resolution and divided by the effective exposure image to produce the final background image, which is subtracted from the intensity image to produce the background-subtracted intensity image.

Weight threshold image: this image provides the threshold for potential detections. The count image is again divided in 128 $\times$ 128 pix bins. In each bin the value of $k$, in counts/pix, which corresponds to probability level of $3\sigma$ is computed and stored to produce a threshold map. This map is upsampled to the original resolution and divided by the effective exposure image, in order to obtain a threshold image in counts s$^{-1}$ pix$^{-1}$. The final step is to compute a weight threshold image by dividing the background-subtracted intensity image by this last threshold image.

3.3. Source Extraction and Photometry

The detection and photometry process is carried out with SExtractor working in dual mode: the weight threshold image is used for detecting sources, while their photometry is computed on the background-subtracted intensity image. The SExtractor parameters THRESH_TYPE and DETECT_THRESH are set to “absolute” and “1”; in this way, SExtractor will consider all pixels with values above 1 in the weight threshold image as possible detections. SExtractor is executed for each of the 175 tiles in the GCK data, delivering detection and photometry of each source. The photometric error $dm$ in magnitude is calculated following the GALEX pipeline\textsuperscript{9}

$$
\frac{df}{t} = \sqrt{\left(\frac{f}{s\Omega}\right)^2 + t^2}, \quad dm = 1.086 \cdot \frac{df}{f},
$$

where $f$ is the flux from the source in counts s$^{-1}$, $s$ is the sky level in counts s$^{-1}$ pix$^{-1}$, $\Omega$ is the area over which the flux is measured, and $t$ is the effective exposure time in seconds.

3.4. Artifact Identification

In the GALEX imagery, there are various artifacts, not all of which are automatically detected by the GALEX pipeline. The worrisome non-flagged artifacts are large diffuse reflections within the field surrounding very bright stars. The shapes of these artifacts have quite different morphologies, however, the most common shapes are long thin cones, halos, and horse-shoe-shaped extended reflections. An example is shown in Figure 6. These artifacts bias the background and affect source detection, mainly producing false positives.

3.4.1. False Positives

In order to remove extended objects and spurious detections, caused by non-flagged artifacts in the images, we design suitable criteria to remove them, while at the same time minimizing the loss of genuine sources. The criteria were defined considering the geometric characteristics of the aperture fitted by SExtractor to the flux profile of detection and the S/N:

1. Semiminor axis $> 60''$;
2. Eccentricity $> 0.95$;
3. S/N $< 1.05$;
4. S/N $< 1.5$ and Semimajor axis $> 10''$.

The first two criteria are intended to remove large and/or extended sources, including false detections inside extended artifacts. The third criteria discards too low S/N detections, while the purpose of the fourth criteria is to remove detections at the border of images, where the flux inside the SExtractor apertures may not be reliable. We defined the above thresholds through a trial and error process, aimed at discarding most of the false positives, while minimizing the loss of real sources ones. The right panel of Figure 6 shows the source detections after removing false positives.

3.4.2. Artifact Flags

The GALEX pipeline produces a flag image for each tile. This image marks the pixels where the intensity image is affected by some artifacts or where artifacts were removed. Each detected source has the artifact\_flags keyword, that is a logical OR of the artifact flags for pixels that were used to compute its photometry. These flags are summarized in Table 2. The flags were developed for the dither mode observations and in some cases are not directly applicable to the scan mode.

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8 http://www.galex.caltech.edu/wiki/Public:Documentation/Chapter_104

9 Section 4 from: http://asd.gsfc.nasa.gov/archive/galex/Documents/GALEXPipelineDataGuide.pdf
observations. For example, in dither mode observations, only the outer region of any field is close to the detector edge, but in scan mode the detector edge crosses nearly the entire field for a fraction (but only a fraction) of the integration. The detector edge proximity flag (Flag 6) is therefore set by the pipeline, but it does not induce errors in the data quality. Flags 1 and 5 indicate the possible presence of reflections near the edge of the FOV. However, we have found that in many instances the regions affected by this latter artifact do not actually show any obvious problem. We therefore consider Flag 1 and 5 as non-aplicable to the scan mode observations in the same way as the dither mode observations. For example, in dither mode only the outer region of any field is close to the detector edge, but in scan mode the detector edge crosses nearly the entire field for a fraction (but only a fraction) of the integration. The detector edge proximity flag is therefore set by the pipeline, but it does not induce errors in the data quality.

4. THE GCK UV SOURCE CATALOG.

After processing each file through false positive removal and flagging, the 175 catalogs are combined to produce a single point source catalog for the whole GCK field. In the case of sources with multiple detections (due to small overlap between tiles), the measurement with the highest S/N was retained.

The resulting GCK catalog contains 660,928 NUV sources. The NUV brightness distribution of the GCK sources is shown in Figure 6, where one can distinguish arc-shaped features around the three brightest stars in the image. The GALEX pipeline flags were developed for the dither mode observations and in some cases are not directly applicable to the scan mode observations in the same way as the dither mode observations. For example, in dither mode only the outer region of any field is close to the detector edge, but in scan mode the detector edge crosses nearly the entire field for a fraction (but only a fraction) of the integration. The detector edge proximity flag is therefore set by the pipeline, but it does not induce errors in the data quality.

### Table 3
GCK Catalog Tags

| Tag Number | Tag Name | Description                                                                 | Unit      |
|------------|----------|----------------------------------------------------------------------------|-----------|
| 1          | gck_id   | GALEX CAUSE Kepler (GCK) Identifier                                         | number    |
| 2          | alpha_j2000 | Right ascension                                                          | Decimal degrees |
| 3          | delta_j2000 | Declination                                                             | Decimal degrees |
| 4          | nuv_mag   | Calibrated NUV magnitude                                                | AB magnitude |
| 5          | nuv_magerr | Error of the calibrated NUV magnitude                                     | AB magnitude |
| 6          | nuv_mag_cor | Corrected calibrated NUV magnitude with Camarota & Holberg (2014) calibration | AB magnitude |
| 7          | nuv_magerr_cor | Error of the corrected calibrated NUV magnitude                               | AB magnitude |
| 8          | nuv_flux  | NUV flux                                                                  | counts s⁻¹ |
| 9          | nuv_fluxerr | Error of NUV flux                                                         | counts s⁻¹ |
| 10         | nuv_sn2n  | Signal-to-noise ratio of NUV flux                                         | dimensionless |
| 11         | nuv_bkgrnd_mag | NUV background surface brightness at source position                     | AB magnitude |
| 12         | nuv_bkgrnd_flux | Background NUV flux at source position                                     | counts s⁻¹ arcsec⁻² |
| 13         | nuv_exptime | Effective exposure time at source position                               | s         |
| 14         | fov_radius | Distance of source from center of tile                                    | degrees    |
| 15         | artifact_flags | Logical OR of artifact flags                                              | number     |
| 16         | ktswkey   | Sequential number in CasJobs Kepler Colors Table of match                 | number     |
| 17         | kic_keplerid | Kepler Input Catalog identifier of match                                | number     |
| 18         | scan      | GCK scan number                                                          | dimensionless |
| 19         | image     | GCK image number                                                          | dimensionless |
| 20         | kep_name  | Kepler host star name                                                     | dimensionless |
| 21         | kic_kpnmag | Kepler-band magnitude                                                    | AB magnitude |
| 22         | kic_g     | g-band Sloan magnitude from the Kepler Input Catalog                      | AB magnitude |
| 23         | kic_r     | r-band Sloan magnitude from the Kepler Input Catalog                      | AB magnitude |
| 24         | kic_i     | i-band Sloan magnitude from the Kepler Input Catalog                      | AB magnitude |
| 25         | kic_z     | z-band Sloan magnitude from the Kepler Input Catalog                      | AB magnitude |
| 26         | twomass_j | 2MASS J-band magnitude                                                   | Vega magnitude |
| 27         | twomass_h | 2MASS H-band magnitude                                                   | Vega magnitude |
| 28         | twomass_k | 2MASS K-band magnitude                                                   | Vega magnitude |

10 Note that the correct C0 coefficient is 14.0821 for the IUE synthetic fluxes (L.Camarota 2015 private communication).
Table 4
GCK Catalog Sample

| Column | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|------|
| GCK J18461428 | 281.55948 | 44.34330 | 23.768 | 0.638 | −999 | −999 | 0.033 | 0.02 | 1.7 | 26.95 | 0.002 | 1013.0 | 0.843 | 32 | 792984 | 8344414 | 2 | 2 |
| +4420359 | | | | | | | | | | | | | | | | | | | |
| GCK J19531681 | 298.32004 | 49.44096 | 20.854 | 0.072 | −999 | −999 | 0.490 | 0.03 | 15.1 | 26.15 | 0.004 | 1262.5 | 0.754 | 32 | None | None | 15 | 4 |
| +4926274 | | | | | | | | | | | | | | | | | | | |
| GCK J19325850 | 293.24375 | 49.36697 | 20.038 | 0.055 | −999 | −999 | 1.040 | 0.05 | 19.8 | 26.60 | 0.002 | 692.6 | 0.497 | 17 | None | None | 12 | 5 |
| +4922011 | | | | | | | | | | | | | | | | | | | |
| GCK J19432870 | 295.86958 | 39.15869 | 14.803 | 0.003 | 14.681 | 0.220 | 129.076 | 0.35 | 366.7 | 25.79 | 0.005 | 1101.0 | 0.661 | 48 | 658168 | 4075067 | 9 | 14 |
| +3909313 | | | | | | | | | | | | | | | | | | | |
| GCK J19183283 | 289.63681 | 38.46219 | 22.907 | 0.285 | −999 | −999 | 0.074 | 0.02 | 3.8 | 26.34 | 0.003 | 1524.7 | 0.596 | 1 | 12145669 | None | 4 | 12 |
| +3827439 | | | | | | | | | | | | | | | | | | | |
| GCK J19145926 | 288.74693 | 44.89742 | 22.893 | 0.369 | −999 | −999 | 0.075 | 0.03 | 2.9 | 26.52 | 0.003 | 1372.3 | 0.197 | 4 | 4369546 | 8681571 | 7 | 7 |
| +4453507 | | | | | | | | | | | | | | | | | | | |
| GCK J19503417 | 297.64238 | 48.08325 | 22.789 | 0.251 | −999 | −999 | 0.083 | 0.02 | 4.3 | 26.01 | 0.004 | 1593.2 | 0.625 | 32 | 15256924 | None | 14 | 5 |
| +4804597 | | | | | | | | | | | | | | | | | | | |
| GCK J19290783 | 292.28261 | 45.72457 | 20.826 | 0.093 | −999 | −999 | 0.503 | 0.04 | 11.7 | 26.48 | 0.003 | 611.5 | 0.657 | 32 | None | None | 10 | 7 |
| +4543284 | | | | | | | | | | | | | | | | | | | |
| GCK J19550979 | 298.79079 | 41.86481 | 19.239 | 0.037 | −999 | −999 | 2.170 | 0.07 | 29.3 | 25.64 | 0.006 | 875.6 | 0.739 | 32 | 6369109 | 6469387 | 12 | 14 |
| +4151533 | | | | | | | | | | | | | | | | | | | |
| GCK J19523858 | 298.16074 | 44.37282 | 16.702 | 0.006 | −999 | −999 | 22.440 | 0.12 | 193.2 | 25.98 | 0.004 | 1819.6 | 0.415 | 20 | 14957236 | None | 13 | 8 |
| +4422221 | | | | | | | | | | | | | | | | | | | |

Note. Column number correspond to tag number in Table 3. A −999 value indicates unavailable datum.

(This table is available in its entirety in machine-readable form.)
### Table 5
NUV Magnitudes and Ancillary Data for *Kepler* Targets with Confirmed Exoplanets

| Column | (17) | (20) | (1)  | (2)  | (3)  | (4)  | (5)  | (6)  | (7)  | (10) | (21) | (22) | (23) | (24) | (25) | (26) | (27) | (28) |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 8359498 | *Kepler*-77 | GCK J19182585 +4420438 | 289.60772 | 44.34550 | 20.575 | 0.056 | −999 | −999 | 19.43 | 13.938 | 14.449 | 13.871 | 13.720 | 13.658 | 12.757 | 12.444 | 12.361 |
| 8644288 | *Kepler*-18 | GCK J19521905 +4444474 | 298.07939 | 44.74650 | 20.842 | 0.062 | −999 | −999 | 17.62 | 13.549 | 14.160 | 13.479 | 13.287 | 13.187 | 12.189 | 11.872 | 11.756 |
| 6616218 | *Kepler*-314 | GCK J19384180 +4204320 | 294.67418 | 42.07566 | 19.777 | 0.035 | −999 | −999 | 31.03 | 12.557 | 13.126 | 12.459 | 12.313 | 12.205 | 11.242 | 10.849 | 10.778 |
| 9821454 | *Kepler*-59 | GCK J19080950 +4638249 | 287.03957 | 46.64025 | 19.263 | 0.026 | −999 | −999 | 41.77 | 14.307 | 14.669 | 14.259 | 14.152 | 14.116 | 13.253 | 12.974 | 12.928 |
| 9595827 | *Kepler*-71 | GCK J19392762 +4617097 | 294.86508 | 46.28602 | 21.969 | 0.226 | −999 | −999 | 4.80 | 15.127 | 15.692 | 15.061 | 14.885 | 14.803 | 13.926 | 13.550 | 13.468 |
| 9884104 | *Kepler*-219 | GCK J19145734 +4645455 | 288.73890 | 46.76264 | 19.609 | 0.031 | −999 | −999 | 35.27 | 13.764 | 14.174 | 13.692 | 13.588 | 13.537 | 12.678 | 12.400 | 12.388 |
| 11121752 | *Kepler*-380 | GCK J18493471 +4845527 | 283.39464 | 48.75907 | 18.278 | 0.031 | −999 | −999 | 35.46 | 13.652 | 14.047 | 13.614 | 13.483 | 13.464 | 12.614 | 12.349 | 12.288 |
| 2302548 | *Kepler*-261 | GCK J19252754 +3736322 | 291.36477 | 37.60894 | 21.181 | 0.143 | −999 | −999 | 7.58 | 13.562 | 14.271 | 13.495 | 13.259 | 13.118 | 12.127 | 11.672 | 11.585 |
| 8572936 | *Kepler*-34 | GCK J19454460 +4438294 | 296.43583 | 44.64151 | 20.884 | 0.089 | −999 | −999 | 12.25 | 14.875 | 14.372 | 14.830 | 14.662 | 14.575 | 13.605 | 13.301 | 13.237 |
| 6850504 | *Kepler*-20 | GCK J19104751 +4220188 | 287.69795 | 42.33856 | 18.900 | 0.019 | −999 | −999 | 56.16 | 12.498 | 12.997 | 12.423 | 12.284 | 12.209 | 11.252 | 10.910 | 10.871 |

**Note.** Column number correspond to tag number in Table 3. A −999 value indicates an unavailable datum.

(This table is available in its entirety in machine-readable form.)
5. CROSSMATCH WITH KIC AND KOI

The positions of the GCK objects were cross-matched with the KIC (Brown et al. 2011), using a 2.5′ search radius. This value is compatible with the astrometric precision of GALEX observations, extending the crossmatch beyond this radius does not increase the number of matches more than 1%, as can be seen in the Figure 9. The cross-match resulted in 475,164 GCK objects with KIC counterparts. We would like to remark that a smaller search radius would significantly decrease the number of detections, while a larger radius would only increase the KIC sources to be associated with a single NUV source. In the final catalog we provide the identification of KIC counterparts.

The spatial location of these objects are plotted as red points in Figure 10, where they obviously coincide with the position of the Kepler satellite detectors. Their NUV brightness distribution is also shown in Figure 7. The constant ratio difference (up to NUV ~ 22.5 mag) between the GCK and KIC distributions seen in Figure 7 is due to incomplete coverage of the Kepler field (caused by the gaps between the Kepler mission detectors (Figure 10). In order to avoid this issue, we also show in Figure 7 the number distribution of GCK sources and their KIC counterparts of the objects on the central Kepler detector (see Figure 2); we can see that almost all GCK sources have KIC counterparts up to NUV ~ 22.5 mag.

We also cross-matched the GCK catalog with the KOI catalog available in MAST through the tool CasJobs11, and found 2614 candidate host stars (hosting 3390 planets) in common and 327 stars (hosting 768 planets) among the Kepler Confirmed Planets hosts. The GCK catalog should enable investigation of the UV excess as a function of stellar age, rotation, and metallicity, identification of UV-bright (potentially young) stars, and provide UV photometry for other astrophysically interesting systems in the Kepler field.

6. DESCRIPTION OF THE CATALOG FILE

Table 3 provides the description of the fields in the GCK catalog file (columns 1–19). The first keyword is the gck_id, the main identifier of the GCK catalog, with a sexagesimal, equatorial position-based source name (i.e., GCK Jhhmmss.ss +ddmmss.s). The second and third keywords are the coordinates of the NUV detection. The following keywords give the photometry in magnitudes and fluxes, with their corresponding errors. The keyword artifacts_flags provides the flags described in Table 2. For objects with a cross-match in the KIC the keywords ktswckey and kic_keplerid, are provided for the nearest counterpart. The keyword ktswckey is particularly useful to get data from the table keplerObjectSearchWithColors, also available in MAST through the tool CasJobs. This table contains the KIC catalog and other catalogs with coverage of the Kepler field. In Table 4, we show a portion of the GCK catalog. The column tags designates the keyword number that also appear in Table 3. The GCK catalog is approximately ~150 Mb (in ASCII format) and the table is available electronically with this paper.

As a useful reference for readers Table 3 provides 323 sources identified in the crossmatch between the GCK catalog and the Kepler targets with confirmed planetary companions. A segment of this table is illustrated in Table 5 and contains the information of columns 1–7, 10, 17, and 20–28 listed in Table 3.

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