Kepler: A Search for Terrestrial Planets

Kepler Archive Manual

KDMC-10008-005

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Document Change Log

Change Number	Change Date	Pages/Sections	Changes/Notes
001	Oct 17, 2011	Section 2.3.3	Description of FFI WCS coordinates
002	Oct 17, 2011	Section 2.3.4	Description of the Cotrending Basis Vectors
003	Oct 17, 2011	Section 2.3.5	Description of Pixel Response Functions
004	Oct 17, 2011	Section 2.2.1	How to Search for Custom Aperture Targets
005	Oct 17, 2011	Section 2.3.1.1	PDC-MAP and how it affects the PDC light curve, including keywords in the headers.
006	Oct 17, 2011	Table 2-3	Quality Flag updates
007	Oct 17, 2011	Section 1.10	Acknowledging Kepler in Papers
008	Oct 17, 2011	Section 2.3.1	Aperture Extension changes for light curve files.
009	Oct 17, 2011	Section 2.4	New keywords added to the keyword dictionary.
010	Oct 17, 2011	Section 2.3.3	Description of Uncertainties FFI
011	Oct 17, 2011	Table 3-2, Section 3.2.1	Data Tables now include Crowding, Flux Fraction and CDPP values.
012	Oct 17, 2011	p. 3	Added Change Log
013	Oct 21, 2011	Section D.2	Updated Acronyms
014	Oct 21, 2011	Appendix C2	Added FITS keywords for PRFs and CBVs
015	Mar 13, 2012	Section 2.3.6	Added Background FITS file description
016	Mar 13, 2012	Section 2.3.7	Added Collateral FITS file description
017	Mar 13, 2012	Section 2.3.8	Added ARP FITS file description
018	Mar 13, 2012	Table 2-1	Added Background, Collateral and ARP files
019	Apr 9, 2012	Section 3.3.5	Added CDPP retrieval section
020	Apr 9, 2012	Section 2.3.4	Removed details about CBVs
021	Apr 11,2012	Section 3.3.3	Added Section on Enhanced Kepler Searches
022	Apr 9, 2012	Section 3.3.4	Updated CasJobs Section
023	Apr 9, 2012	Table 1-1	Revise data release date
024	Apr 16, 2012	Section 1.8	Update data release text
025	Apr 16, 2012	p. 4	File Version Table

for KDMC-10008-005

026	Apr 16, 2013	Table 2-2	File Version Table
027	Apr 16, 2013	Section 2.4	Added PDC related Keywords
028	Apr 16, 2013	Section 2.3.1.1	Updated description of PDC
029	Apr 16, 2013	Table 2-3	Added Quality flags
030	Apr 17, 2013	Section A.1b	Updated FITS keyword list
031	Apr 17, 2013	Section D.2	Updated acronym list
032	May 28, 2013	Section 2.3.9	Reverse Clock Added
033	May 28, 2013	Section 3	Updates to MAST Tools
034	May 28, 2013	Section—Changing File Formats	Removed
035	Apr 23,2014	Section – Registering as User	Removed
036	Apr 23, 2014	Section – Data Rel. Schedule	Removed

File Version Numbers Described by this version of the Archive Manual

File Type	Version *	Archive Manual Section
Light Curves Files	5.0	2.3.1
Target Pixel Files	5.0	2.3.2
Full Frame Images	3.0	2.3.3
Background	2.0	2.3.6
Collateral/ARP	1.0	2.3.7 - 2.3.8
CBVs	1.0	2.3.4
PRFs	1.0	2.3.5

***See the keyword FILEVER in the header of each file.**

Table of Contents

Chapter 1 Introduction

Data from the *Kepler* mission are housed in the Archive at the Space Telescope Science Institute (STScI) and accessed through MAST (Mikulski Archive for Space Telescope). General information about *Kepler* may be found at the *Kepler* Mission http://www.kepler.arc.nasa.gov/ and the *Kepler* for astrophysicists' http://keplergo.arc.nasa.gov/ web sites.

1.1 Overview of Kepler

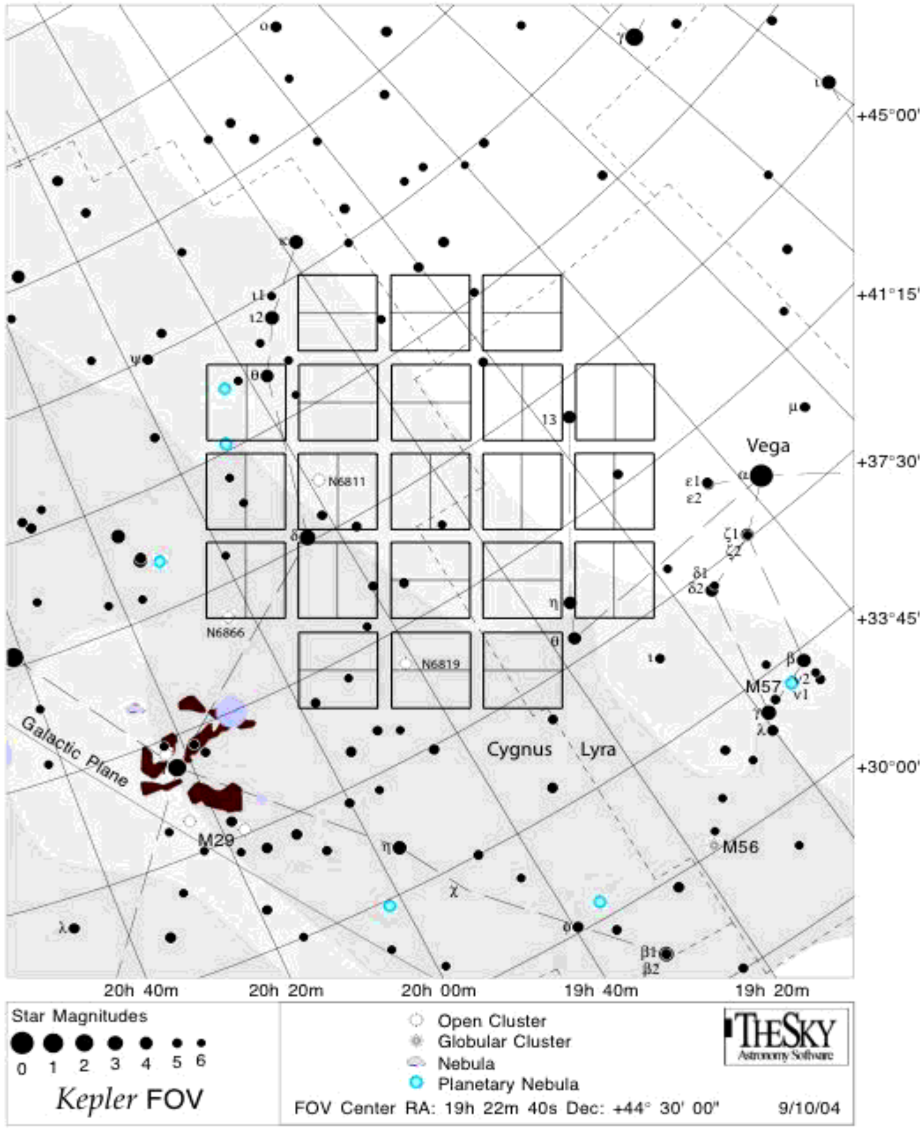
The *Kepler* mission is designed to survey a region of the Milky Way galaxy to detect and characterize Earth-size and smaller planets in or near the habitable zone by using the transit method of planetary detection.

The *Kepler* telescope has a 0.95-meter aperture and a 115.6 deg^2 field-of-view (FOV). It is pointed at and records data from the same region of the sky for the duration of the mission. The single instrument on board, a photometer, is an array of 42 CCDs arranged in 21 modules. Each CCD has 2 outputs. The half-maximum bandpass is 435 to 845 nm, with >1% relative spectral response as short as 420 nm and as long as 905 nm. Each 50x25 mm CCD has 2200x1024 pixels. The interval between reads of a given pixel of a CCD is composed of an exposure time set to 6.019802903 s and a fixed readout time of 0.5189485261 seconds. All pixels are read-out every integration, and temporally summed in the Science Data Accumulator (SDA). Target lists determined which of those SDA summed pixels are read out of the SDA and transmitted to the Solid State Recorder for later downlink. On average 32 pixels are read out of the SDA per target. The *long cadence* data are summed into onboard memory for 30 minutes (270 integrations), while the *short cadence* data are one-minute sums (9 integrations). Downlinks occurred approximately on a monthly basis.

The observed star field is near the galactic plane, centered on galactic coordinates l = 76.32°, b = +13.5° (RA=19h 22m 40s, Dec=+44° 30' 00'). Figure 1-1 shows the field with the *Kepler* FOV superimposed. The squares show the 5 square degree FOV of each of the 21 modules. The gaps between the modules are aligned so that about half of the 15 stars in the FOV brighter than m_V=6 fall in these gaps. The 42 CCDs cover a four-way symmetrical pattern on the sky such that most of the same stars stay visible during the mission, even after a quarterly 90° roll. In addition, the orientation of the rows and columns of each module's location on the sky is preserved for all roll orientations except for the center module, which is only 180 degrees symmetric. The roll is necessary to keep the solar arrays oriented towards the Sun and the radiator pointed towards deep space.

Kepler is in an Earth-trailing heliocentric orbit with a period of approximately 372.5 days. In this orbit the spacecraft slowly drifts away from the Earth and is at a distance of over 0.5 AU after 3.5 years. The orbit permits continuous pointing on a single region of the sky. Additional advantages are the very stable pointing attitude and the avoidance of the high radiation dosages associated with an Earth orbit.

Figure 1-1 Kepler Field of View



1.2 Overview of Data Flow

Data are downloaded from the spacecraft (S/C) through the Deep Space Network (DSN). The Mission Operations Center (MOC) at LASP receives the data and telemetry packets that are binned into files by data type. The data are then sent to the Data Management Center (DMC) at STScI, where they are archived. The data are then decompressed, sorted by cadence (long or short) and pixel type (target, background or collateral), and converted to the FITS (Flexible Image Transport System) format. The keyword values are populated. At this point in processing, the data are termed to be "original." The data are then sent to the Science Operations Center (SOC) at NASA Ames, where detailed calibration is performed and light curves and target pixel files are produced. The data are then returned to the DMC for archiving. The total time for one cycle (data dump from the S/C through archiving of the processed data) is nominally 4 months. For a given target, archive users can access the raw and calibrated pixel values in the target pixel files or the integrated flux values in the light curve files.

1.3 Related Documents

Documentation is available on-line for all archive holdings. The main archive page, http://archive.stsci.edu, provides links to a MAST tutorial, a general introduction to MAST and a "getting started" page. Each mission page has links to mission specific information, a mission specific "getting started" page and the MAST tutorial. The MAST Kepler page is located at http://archive.stsci.edu/kepler/. Other useful links for Kepler are http://keplergo.arc.nasa.gov/ and http://www.kepler.arc.nasa.gov/.

A reference description of *Kepler* may be found in the Kepler Instrument Handbook (KIH, KSCI-19033). The KIH describes the design, performance, and operational constraints of the Kepler hardware, and gives an overview of the pixel data sets available. A description of Kepler calibration and data processing is described in the Kepler Data Processing Handbook (KDPH, KSCI-19081-001) and in a series of SPIE papers published in 2010. Copies of the Kepler Instrument Handbook, the Data Processing Handbook and the SPIE papers may be downloaded from MAST. They are located under the Documentation item in the left gutter of the MAST/Kepler home page (http://archive.stsci.edu/kepler/documents.html).

Science users should also consult the special ApJ Letters devoted to early Kepler science (April 2010, ApJL, Vol. 713 L79-L207). This volume contains a description of the mission design (Koch et al. L79), an overview of the processing pipeline (Jenkins et al. L87), how the first Kepler planets were found (Borucki et al. L126; Dunham et al. L136), the long cadence data characteristics (Jenkins et al. L120), the short cadence data characteristics (Gilliland et al. L160), and a first use of these data for asteroseismology (Chaplin et al. L169).

Additional technical details regarding the data processing and data qualities can be found in the Kepler Data Characteristics Handbook (KDCH, KSCI-19040) and the Data Release Notes (DRN, KSCI-19042 to KSCI-19063), which are located in the left gutter of the MAST/Kepler home page. Data Release Notes accompany the data for each processing of each quarter.

1.4 Overview of MAST

The Mikulski Archive for Space Telescopes supports a variety of astronomical data archives, with the primary focus on scientifically related data sets in the optical, ultraviolet, and near-infrared parts of the spectrum. See http://archive.stsci.edu/missions.html for a full list of the missions hosted by MAST and http://archive.stsci.edu/hlsp/index.html for the high-level science products, surveys, and catalog data distributed by MAST. MAST is a component of NASA's distributed Space Science Data Services (SSDS).

The staff of the Archive Sciences Branch and the Mikulski Archive for Space Telescopes (MAST) provides:

- world-wide technical and scientific leadership in archive system design
- secure storage and reliable retrieval services for data from HST and all MAST-supported missions
- user-friendly and scientifically useful search and cross-correlation tools
- development and support for inter-archive communication and data transfer standards
- accurate and useful mission archive documentation
- helpful user support services with a 1 business day response time

MAST archives a variety of spectral and image data with a range of data characteristics. MAST provides a large suite of searches, including customized searches for each mission. It also provides several cross-mission search tools.

MAST also archives sets of community contributed High-Level Science Products (HLSPs). MAST actively solicits submission of High-Level Science Products related to our missions and we provide guidelines for contributing them to MAST.

The MAST Users Group provides essential user perspectives on archive operations and development, including suggesting priorities for short and long term operational and scientific enhancements to the archive.

User feedback is obtained via an annual survey. Send e-mail to archive@stsci.edu to participate in the next survey.

The archive website, http://archive.stsci.edu , is the best place to start learning about MAST and what it can do to enable your research. The web site should always be consulted for the most current information.

1.5 User Support Services

Archive Hotseat

Help or answers to any questions about archive issues may be obtained by sending e-mail to archive@stsci.edu, or by telephoning (410) 338-4547 Monday through Friday, 9 a.m. to 5 p.m. Eastern time.

The helpdesk staff will respond to questions concerning the archive and archive databases, and CDs, DVDs and hard disks provided by STScI. Helpdesk personnel also authorize accounts so that PIs and GOs can access their data. They will also provide advice concerning basic search strategies, and will investigate and document all problem reports. The archive helpdesk staff may not always know how to solve a problem, but they are responsible for finding out who does know the answer and for continuing to work with you until the problem is resolved. All initial communication from the user community to the archive should be directed to the archive helpdesk.

Questions and Comments

Communication regarding all aspects of the archive should normally be directed to the archive helpdesk (e-mail: archive@stsci.edu, or telephone (410) 338-4547). This will allow Archive staff to respond to your requests even when individual members of the group are away. If you feel your needs are not being adequately addressed through the helpdesk, place a message in the Suggestion Box located at http://archive.stsci.edu/suggestions.html.

1.6 Getting Your Data

Everyone may retrieve Kepler data via the MAST Kepler Data Search and Retrieval form http://archive.stsci.edu/kepler/search.php. Entering the proposal id in the Investigation_ID field and clicking on the "Search" button will return a list of the data in the archive for that proposal. You must include the wildcard character '%' to retrieve all data belonging to that proposal (e.g. enter "%GO1000%" instead of "GO1000") because some targets are shared between several proposals. Select the data to retrieve by clicking on the boxes in the "Mark" column. Note: there is a "Mark All" box. Click on the "Submit" button. The Retrieval Options page will be displayed. Fill out the required information, then click on the Submit button. E-mail will be sent acknowledging receipt of the retrieval request. A second e-mail will be sent when the data have been retrieved. Once the data have been retrieved to the staging disk, follow the directions in the e-mail to copy the data from staging. The data will remain on staging for a limited time before being automatically deleted. See Chapter 3 for more details on the MAST Kepler search forms.

All light curves and target pixel files are also available for direct download from the public ftp site, http://archive.stsci.edu/pub/kepler/. See Chapter 5 for non-search based data retrieval.

1.7 Publication Acknowledgement

Publications based on *Kepler* data should carry the following acknowledgement.

"This paper includes data collected by the Kepler mission. Funding for the Kepler mission is provided by the NASA Science Mission Directorate."

Those publications based on data retrieved from MAST should carry the following acknowledgment.

"Some/all of the data presented in this paper were obtained from the Mikulski Archive for Space Telescopes (MAST). STScI is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555. Support for MAST for non-HST data is provided by the NASA Office of Space Science via grant NNX13AC07G and by other grants and contracts."

See the MAST Data Use Policy http://archive.stsci.edu/data_use.html for the current MAST grant number.

This Kepler Archive Manual should be referenced as
S. E. Thompson & D. Fraquelli, 2014, Kepler Archive Manual (KDMC-10008-005), http://archive.stsci.edu/kepler/documents.html.

Chapter 2 *Kepler* Data Products

2.1 Introduction

A variety of different data products are archived for *Kepler.* These include science data of astronomical interest (light curves, target pixel data, and Full Frame Images (FFI)) and auxiliary data used to calibrate the images and determine the status of the spacecraft (focal plane characterization files, engineering data and telemetry data). The Science Operations Center (SOC) processes the data prior to it being archived.

Many *Kepler* specific terms are used to concisely and accurately describe the data and the processing. We have defined many of these terms in the glossary and list of acronyms in Appendix D.

2.1.1 Overview of Data in the Archive

Kepler's primary mission is to obtain flux time series of individual targets. As such, the majority of the *Kepler* science data is organized by target. Those interested in studying time variable phenomenon will find the light curve files and/or the target pixel files of interest. Additionally, *Kepler* downloads and calibrates a single cadence of the entire *Kepler* field each month. These Full Frame Images (FFIs) are not target specific and can be downloaded within months of acquisition from their own search and download page at MAST.

All science targets collected by *Kepler* each quarter are archived at the MAST. In rare cases some of the targets are not processed through the entire SOC pipeline. Primarily, this happens when the optimal aperture, re-calculated after the data are collected, reaches or exceeds the edge of the science pixels on the CCD leaving no valid pixels for aperture photometry. This may also happen if the target is declared an artifact. For each of these cases, no light curve file is available. Only pixel level data are available (i.e., the target pixel file).

Besides the astronomical data, *Kepler* archives much of the auxiliary data that either directly or indirectly affects the astronomical data products. Engineering data describes the state of the instrument and the spacecraft during data collection. Focal plane characteristic models, artifact removal pixels and collateral CCD data are used to calibrate and process the data.

2.1.2 Kepler Time System

The readout time for each cadence is recorded as a Vehicle Time Code (VTC). This timestamp is produced within 4 ms of the readout of the last pixel of the last frame of the last time slice (see glossary). When the data is downloaded to Earth, the Mission Operations Center converts VTC to Coordinated Universal Time (UTC), correcting for leap seconds and any drift in the spacecraft clock, as measured from telemetry. UTC times are converted to Barycentric Dynamical Time (TDB) then to BJD to correct for the motion of the spacecraft around the center of mass of the solar system. TDB is a time system that does not include the leap seconds that bedevil calculations of periods in the UTC system. TDB agrees with the time systems TDT and TT to better than 2 ms at all time. See Eastman et al. (2010, PASP 122, 935) for a recent discussion of the various time systems common in astronomy.

Note, due to an error in the Kepler pipeline, barycentric times reported in the Q0-Q14 data products with file version numbers prior to the versions listed in Table 2-2 are reported in UTC instead of TDB, and are in error by approximately 66 seconds (see KDCH).

Time stamps expressed in MJD or UTC are geocentric and not corrected to the TDB time system. Time is specified in the data files with an offset from BJD. The offset has a value of 2454833.0 and is specified in each file header (see BJDREF). The units are clearly defined in the headers of these files. The SOC uses SPICE kernels, which are calculated from the spacecraft telemetry, to calculate barycentric corrections. For more information on the SPICE kernels and SPICE tools visit http://naif.jpl.nasa.gov/naif/.

The quoted times for any cadence are believed to be accurate to within ±50 ms. This requirement was developed so that knowledge of astrophysical event times is limited by the characteristics of the event, rather than the characteristics of the flight system, even for high SNR events. Users who require temporal accuracy of better than 1 minute should read the Kepler Data Characterization Handbook (Section 6) and the associated Kepler Data Release Notes carefully. These documents contain additional details regarding the times, including accuracy, corrections for readout time slice offsets, change in units, etc.

2.1.3 FITS headers

Kepler science data use the FITS (Flexible Image Transport System) format to comply with astronomical data standards. Data headers use standard FITS keywords to formulate the data definition and comply with all FITS recommended keyword usage current at the time of header design. The primary headers contain keywords inherited by all subsequent extensions. Primary header keywords specify data processing inputs, data quality, observational modes (long cadence, short cadence, FFI), target information etc. The primary header/data units (HDU) do not contain a data array. FITS headers for cadence science data are specified in Appendix A.

2.2 File Name Syntax

Many file types are archived for *Kepler.* To prevent confusion, a standard syntax is used for *Kepler* filenames.

Kepler filenames have 3 components:

- **Rootname:** Usually a timestamp, for some file types the rootname contains other identifiers such as the Kepler Identification number (KepID) or the module/output (mod/out) number. The rootname begins with the character string ‘kplr’ followed by a time stamp of the form yyyydddhhmmss, where ddd is the day of year. If KepID or mod/out is present in the rootname, it precedes the timestamp (e.g., kplr<kepler_id>_<stop_time>). See Table 2-1 for a list of rootnames.

- **Suffix:** The suffix indicates the type of data in the file within the data set (short cadence light curve, target pixel background data, etc.) See Table 2-1 for a list of suffixes.

- **Extension:** The extension indicates the format of data contained in the file (fits or txt).

These three components are concatenated as shown to form the file name. This is the name of the file on disk.

kplr<rootname>_<suffix>.<extension>

In the archive, the data set name is the rootname.

Table 2-1 Filenames

Type of Data	Rootname*	Suffix	Extension
Calibrated Light Curves:			
LC calibrated light curves	<kepler_id>-<stop_time>†	llc	fits
SC calibrated light curves	< kepler _id>-<stop_time>†	slc	fits
Target Pixel Data:			
LC Target pixel data	< kepler _id>-<stop_time>†	lpd-targ	fits
SC Target pixel data	< kepler _id>-<stop_time>†	spd-targ	fits
Full Frame Image:			
FFI original data	<stop_time>	ffi-orig	fits
FFI calibrated data	<stop_time>	ffi-cal	fits
FFI uncertainties	<stop_time>	ffi-uncert	fits
Auxiliary Data:			
Background data	<modout>-<stop_time>†	bkg	fits
LC Collateral data	<modout>-<stop_time>†	coll/cols	fits
SC Collateral data	<modout>-<stop_time>†	cols	fits
Artifact Removal Pixel data	<modout>-<stop_time>†	arp	fits

* All rootnames begin with kplr.

† For historical reasons, the <stop_time> for time series files is given in local Pacific time for the last processed cadence of that quarter or month. All other stop times are given in UTC.

2.2.1 Custom Aperture Targets

Certain targets observed by Kepler, known as custom targets, have special apertures either because the target is not in the KIC or requires a special aperture to collect the appropriate pixels. The custom aperture targets are given a Kepler ID number greater than 100 million in order to distinguish them from the typical Kepler targets. These special ID numbers are used in the data file names, as the Kepler ID in the header, and for the Kepler ID field on the data search page at MAST. Thus, data searches by the traditional KIC identification number will not return the data files for the custom apertures of the specified target. The MAST has, however, linked the custom targets to the correct RA and Dec positions. To find custom apertures, perform a cone search around the RA and Dec position of the desired target.

There are two types of custom apertures of particular scientific interest to the general community. The first aperture type contains data from the open clusters NGC 6819 and NGC 6791. Each cluster is tiled with contiguous custom aperture files that may be placed side-by-side to create a 200 by 200 pixel block. The best way to find these targets is to search for an investigation ID of "STC" and a custom aperture number greater than 100 million. You can distinguish the clusters by the RA and Dec values. The second aperture type of interest is the background super aperture, which covers relatively dark regions of sky at a common location on all CCD channels. These data have been collected continuously since quarter 5. To find these data, do a data search for an investigation ID of "EXBA".

2.3 Data in the Archive

The general user will usually be interested in the light curves and the target pixel data. The full frame images (FFI) are useful for examining contamination near targets, but are not as useful for time series analysis of individual targets. A person intending to propose for *Kepler* time will be interested in the Kepler Input Catalog (KIC) and Characteristics Table (CT). These catalogs are discussed in Chapter 3. The specific file versions discussed in this archive manual are listed in Table 2-2. See the FILEVER keyword in the primary header to determine the version number of a specific file.

Table 2-2 File Version Numbers described in this Archive Manual

File Type	Version *	Archive Manual Section
Light Curves Files	5.0	2.3.1
Target Pixel Files	5.0	2.3.2
Full Frame Images	3.0	2.3.3
Background	2.0	2.3.6
Collateral/ARP	1.0	2.3.7 - 2.3.8
CBVs	1.0	2.3.4
PRFs	1.0	2.3.5

*See the keyword FILEVER in the header of each file.

2.3.1 Light Curve Files

Light curve files are produced for each target using simple aperture photometry. At any time, there will be more than 160,000 long cadence targets and up to 512 short cadence targets being observed. Short cadence targets are always observed at long cadence. Long cadence targets will be observed for at least a quarter and short cadence targets will be observed for at least a month (except for Q4 where targets on module 3 were lost due to a hardware failure). In the case where a target is observed at both long and short cadence, there will be one long cadence light curve and up to three short cadence light curves *for each quarter.*

As shown in Table 2-1, light curves are expected to have file names like kplr<kepler_id>-<stop_time>, with a suffix of either llc (long cadence) or slc (short cadence), and a file name extension of fits.

A light curve file contains time series data. Each data point corresponds to a measurement from a long or short cadence. Long and short cadence data are not mixed in a given light curve file. For each data point there are multiple flux and centroid values along with uncertainties. The value NaN is specified for any missing data values.

The light curves are packaged as FITS binary table files with a primary header, a light curve extension and an aperture extension. The FITS header is listed in Appendix A.1b.

Primary Header

The primary header contains information pertaining to the entire file, such as target information and version processing information. This header contains information about which CCD was used to collect these data, which quarter the data was collected, and which Data Release Notes apply to this processing of the data. The header contains keywords for the properties of the target star. Generally, these contain the static KIC values.

However, the *Kepler* Science Office has the option to replace these KIC values with updated better measurements as they become available from ground-based observations. The values in the header are those used by the *Kepler* pipeline. Primary header keywords are supplied to better understand the data processing and the target properties; they are not intended for publication without first understanding their source. Appendix A.2a contains a description of all the keywords in this header.

Light Curve Binary Extension

The binary table contains the following data columns:

TIME [64-bit floating point] – The time at the mid-point of the cadence in BKJD. *Kepler* Barycentric Julian Day is Julian day minus 2454833.0 (UTC=January 1, 2009 12:00:00) and corrected to be the arrival times at the barycenter of the Solar System. The pipeline uses the right ascension and declination of the object (found in the primary header), along with the location of the spacecraft at the time of the cadence to perform this calculation. This column can be converted to BJD using the following formula for each member of the series [i]:

$$BJD[i] = TIME[i] + BJDREFI + BJDREFF,$$

where BJDREFI and BJDREFF are given as keywords in the header.

TIMECORR [32-bit floating point] – The barycenter correction calculated by the pipeline plus the time slice correction. This column allows users to revert back to non-barycentric times, if required. To convert the times in the TIME column to the Julian Day of the observation, use the following formula:

$$\begin{aligned} JD[i] &= BJD[i] - TIMECORR[i] + time\_slice\_correction \\ &= BJD[i] - TIMECORR[i] + (0.25 + 0.62(5 - TIMSLICE))/(86400) \end{aligned}$$

where TIMSLICE is given in the header. To obtain the times in Julian Day reported by the spacecraft, subtract the TIMECORR column from the TIME column.

CADENCENO [32-bit integer] – The cadence number is a unique integer that is incremented by one with each cadence.

SAP_FLUX [32-bit floating point] – The flux in units of electrons per second contained in the optimal aperture pixels collected by the spacecraft. This light curve is the output of the PA module in the SOC pipeline.

SAP_FLUX_ERR [32-bit floating point] – The error in the simple aperture photometry as determined by PA in electrons per second. The reported errors for each cadence are a sum of the minimal error calculation (shot noise plus read noise) and an offset term to account for the extra error from the full propagation of errors.

SAP_BKG [32-bit floating point] – The total background flux summed over the optimal aperture. The background flux for each pixel is calculated by fitting a surface to the background pixels on each mod/out.

SAP_BKG_ERR [32-bit floating point] – The 1-sigma error in the simple aperture photometry background flux.

PDCSAP_FLUX [32-bit floating point] – The flux contained in the optimal aperture in electrons per second after the PDC module has applied its detrending algorithm to the PA light curve. To better understand how PDC manipulated the light curve, read Section 2.3.1.1 and see the PDCSAPFL keyword in the header.

PDCSAP_FLUX_ERR [32-bit floating point] – The 1-sigma error in PDC flux values.

SAP_QUALITY [32-bit integer] – Flags containing information about the quality of the data. Table 2-3 explains the meaning of each active bit. See the Data Characteristics Handbook and Data Release Notes for more details on safe modes, coarse point, argabrightenings, attitude tweaks etc. Unused bits are reserved for future use.

PSF_CENTR1 [64-bit floating point] – The column centroid calculated by fitting the point-spread function (PSF) combined with the modulation from pointing jitter and other systematic effects (also referred to as pixel response function fitting). This value is only calculated for selected stars, see discussion of PPA targets in the Kepler Data Processing Handbook.

PSF_CENTR1_ERR [32-bit floating point] – The 1-sigma error in PSF-fitted column centroid.

PSF_CENTR2 [64-bit floating point] – The row centroid calculated using the PSF fitting described above. This value is only calculated for selected stars.

PSF_CENTR2_ERR [32-bit floating point] – The 1-sigma error in PSF-fitted row centroids.

MOM_CENTR1 [64-bit floating point] – The column value for the flux- weighted centroid (first moment) position of the target at this cadence.

MOM_CENTR1_ERR [32-bit floating point] – The 1-sigma error in the column value for the first moment centroid position.

MOM_CENTR2 [64-bit floating point] – The row value for the flux- weighted centroid (first moment) position of the target at each cadence.

MOM_CENTR2_ERR [32-bit floating point] – The 1-sigma error in the row value for the first moment centroid position.

POS_CORR1: [array of 32-bit integers] – An array containing the column component of the local image motion for each background pixel calculated from the motion polynomials. We report the motion in pixels relative to the mid-cadence of the quarter.

POS_CORR2: [array of 32-bit integer] – An array containing the row component of the local image motion for each background pixel calculated from the motion polynomials. We report the motion in pixels relative to the quarter's mid-cadence.

Table 2-3 – Bits for the QUALITY and SAP_QUALITY data column.

Bit	Value	Explanation
1	1	Attitude Tweak
2	2	Safe Mode. Only the first cadence is marked.
3	4	Spacecraft is Not in Fine Point.
4	8	Spacecraft is in Earth Point.
5	16	Reaction wheel zero crossing
6	32	Reaction wheel desaturation event
7	64	Argabrightening detected across multiple channels on this cadence
8	128	Cosmic Ray was found and corrected in Optimal Aperture pixel
9	256	Manual Exclude. The cadence was excluded because of an anomaly.
10	512	Reserved
11	1024	SPSD detected. This bit is flagged on the last non-gapped cadence before the maximum positive change due to the detected SPSD.
12	2048	Impulsive outlier removed before cotrending
13	4096	Argabrightening event on specified CCD mod/out detected
14	8192	Cosmic Ray detected on collateral pixel row or column in optimal aperture
15	16385	Detector anomaly flag raised
16	32768	Spacecraft is in Coarse Point
17	65536	No Data Collected

Aperture Extension

The aperture extension contains a single image that describes which pixels were collected by the spacecraft, which pixels are contained in the optimal aperture and which pixels were used to calculate the centroids. Those pixels in the optimal aperture are used to create the SAP_FLUX light curve. The FITS standard requires a rectangular bounding box even though many target apertures are not rectangles. Therefore the image contains null pixels that were never collected (i.e., the image includes the extra pixels necessary to create a rectangular image). See Table 2-4 for a description for the reason each bit is set.

Table 2-4 – Aperture image bit descriptions for light curve files

Bit	Value	Meaning
1	1	pixel was collected by spacecraft
2	2	pixel is in the optimal aperture
3	4	pixel was used to calculate the flux weighted centroid
4	8	pixel was used to calculate the PRF centroid

2.3.1.1 The PDC light curves (PDCSAP_FLUX)

The primary purpose of the Presearch Data Conditioning (PDC) module of the Kepler data analysis pipeline is the removal of signatures in the light curves that are correlated with systematic error sources from the telescope and spacecraft, such as pointing drift, focus changes, and thermal transients. PDC tries to remove these errors while preserving planet transits and other astrophysically interesting signals. To do this, PDC uses a Bayesian Maximum A Posteriori (MAP) approach to establish a range of ``reasonable" robust fit parameters. These robust fit parameters are then used to generate a ``Bayesian Prior" and a ``Bayesian Posterior" probability distribution function which, when maximized, finds the best fit that simultaneously removes systematic effects while reducing the signal distortion and noise injection that commonly afflicts simple Least Squares (LS) fitting.

For data formatted as v5.0 and greater, Long Cadence PDC light curves use a msMAP (multiscale MAP) approach (Stumpe et al. 2014, PASP, 126, 100). msMAP is a wavelet-based band-splitting framework for removing systematics from the light curves. In each band, a subset of highly correlated and quiet stars is used to generate a cotrending basis vector (CBV) set. Each of the bands is handled differently where the options are: 1) perform a simple robust fit to the CBVs , 2) perform a MAP fit based on a Bayesian Prior (Smith et al. 2012, *PASP*, 124, 1000) or 3) perform no fit. The type of fitting performed in each band is specified in the FITS headers (see FITTYPE*j*). msMAP does not always perform better than regular, single-band MAP. PDC calculates both and provides the better of the two reductions, determined by examining the total PDC goodness metric. The keyword PDCMETHD in the FITS header indicates whether the 'multiscale MAP' or 'regular MAP' light curve was chosen. See Section 2.4 for more information on the keywords. (Note: The msMAP keywords were not populated for data release 21 of Q0-Q14.)

The Short Cadence PDC processing uses a single-band MAP fit. However, because of the limited number of short cadence targets, the CBVs are created by interpolating the long cadence basis vectors. Also, the Bayesian priors used to do the MAP fit are drawn from the long cadence priors.

PDC performs several other critical services. One is the identification and removal of Sudden Pixel Sensitivity Dropouts (SPSDs, or Discontinuities) that result in abrupt drops in pixel flux with short recovery periods. These corrections are described using the keywords NSPSDET and NSPSDCOR for the number of SPSDs detected and corrected, respectively. Another service is the adjustment of light curve fluxes to account for excess flux in the optimal apertures due to star field crowding and the fraction of the target star flux in the aperture.

PDC "protects" known transits from falsely being detected as Sudden Pixel Sensitivity Dropouts (SPSDs) or other types of outliers. Cadences containing known transits and eclipses are computed using the known epoch, period and duration of the events, and assuming a linear ephemeris. No SPSDs or outliers are flagged during the known transits. This helps preserve transit depths and shapes from corruption by the SPSD and outlier correction algorithms. Note, this only affects known transits. There is still the risk of transit corruption for as yet undetected transits. However, once the transits are detected and validated, subsequent data processing iterations will incorporate the new information.

Goodness metrics are also provided in the FITS headers for long-cadence PDC MAP data. These goodness metrics characterize the ``goodness" of the PDC cotrending with regard to four characteristics. A total goodness is also given as the geometric mean of the four components. The values range between 0 and 1, where 0 is poor and 1 is perfect goodness. Percentile values are also given for each component and the sum. While a percentile value is given for all targets, the statistical range is only generated for non-custom targets; this is to prevent custom targets from skewing the statistics for standard targets. Large values for all four componenets does not necessarily mean the resultant PDC light curve has been reliably corrected, only that it is good with respect to those metrics. For more information on the PDC goodness metrics and how they are defined see Stumpe et al. (2012, PASP, 124, 985).

The four goodness metrics and their percentiles found in the header of the light curve extension are as follows:

1) Correlation: Cotrending attempts to remove correlated systematics between the targets. Any residual correlation is characterized by a lower value. See keywords PDC_COR and PDC_CORP.
2) Variability: Using a Stellar Variability Estimation, any change in the intrinsic variability due to the cotrending will result in a lower value for this metric. A value of one 1 means the variability was perfectly preserved. See the keywords PDC_VAR and PDC_VARP.
3) Noise: Indicates if high frequency noise, just below the Nyquist Frequency, was added to the cotrended light curves. See keywords PDC_NOI and PDC_NOIP.
4) Earth Point: A value close to one means earth point thermal recovery signature was removed well. See keywords PDC_EPT and PDC_EPTP.

2.3.2 Target Pixel Data

For each target, *Kepler* only acquires the pixels contained within a predefined mask. These pixels are used to create the data found in the light curve files. Each target pixel file packages these pixels as a time series of images in a binary FITS table. The intent of these files is to provide the data necessary to perform photometry on the raw or calibrated data when needed (or desired) to understand (or improve) the automated results of the *Kepler* pipeline.

In the binary table, the pixel values are encoded as images. Each element in the binary table contains the pixels from a single cadence. Missing integer values are filled with the value -1, missing floating-point values are filled with the value NaN as described by the FITS standard, and keywords with missing values are either left as blank or filled with an empty string.

Each target pixel file has a primary header and two extensions: target table and aperture. The primary header describes the target and the processing software. The target table extension contains the flux time series for both the raw and calibrated pixels. The aperture extension describes the target pixel mask and optimal aperture.

Primary Header

The primary header contains information pertaining to the entire file, such as target information and version processing information. This header contains information about which CCD was used to collect these data, which quarter the data was collected, and which Data Release Notes apply to this processing of the data. The header contains keywords for the properties of the target star. Generally, these contain the static KIC values. However, the *Kepler* Science Office has the option to replace these KIC values with updated measurements as they become available. Primary header keywords are supplied to better understand the data processing and the target properties; they are not intended for publication without first understanding their source. Appendix A.2a contains a description of all the keywords in this header.

Target Table Extension

The target table extension contains pixel time series. It has 12 columns containing a series of either scalar values or images. The header defines these columns according to the FITS standard (see Pence et al. 2010 A&A, 524, A42). The keywords are explained in Appendix A.2b.

The image dimensions vary from target to target, however all images contained in a single target pixel file have the same dimensions. The location of the pixels on the specified CCD is provided in the header. The celestial World Coordinate System solutions for each image column is also specified, however not all FITS viewers support these keywords.

The definition of each column in the Target Table extension is as follows:

TIME [64-bit floating point] – The time at the center of the cadence in BKJD. This column is identical to the light curve file TIME column. *Kepler* Barycentric Julian Day is a Julian day minus 2454833.0 (UTC=January 1, 2009 12:00:00) and corrected to be the arrival times at the barycenter of the Solar System. The pipeline uses the right ascension and declination of the object (found in the primary header), along with the location of the spacecraft at the time of the cadence to perform this calculation. (For objects with no KIC number, this value is calculated for the RA and Dec at the center of the mask.) This column can be converted to BJD using the following formula for each member of the series [i]:

$$\mathrm{BJD}[i] = \mathrm{TIME}[i] + \mathrm{BJDREFI} + \mathrm{BJDREFF},$$

where BJDREFI and BJDREFF are given as keywords in the header.

TIMECORR [32-bit floating point] – The barycenter correction calculated by the pipeline plus the time slice correction. This column is identical to the light curve file TIMECORR column. This column allows users to revert back to non-barycentric times, if required. To convert the times in the first column to the Julian Day for the channel use the following formula:

$$\begin{aligned}\mathrm{JD}[i] &= \mathrm{BJD}[i] - \mathrm{TIMECORR}[i] + \mathrm{time\_slice\_correction} \\ &= \mathrm{BJD}[i] - \mathrm{TIMECORR}[i] + (0.25 + 0.62(5 - \mathrm{TIMSLICE}))/(86400)\end{aligned}$$

where TIMSLICE is given in the header. To obtain the times in Julian Day reported by the spacecraft, subtract the TIMECORR column from the TIME column.

CADENCENO [32-bit integer] – The cadence number is a unique integer that is incremented with each cadence. This column is identical to the light curve file CADENCENO column.

RAW_CNTS [2D array of signed 32-bit integers] – One image per cadence of the raw counts measured in each pixel downloaded from *Kepler*. To restore the values contained in this column to the Analog to Digital Units read off the photometer, subtract the appropriate "fixed offset", LC or SC (keywords LCFXDOFF and SCFXDOFF), and add the mean black level (keyword MEANBLCK) times the number of readouts (keyword NREADOUT). Then, each count represents one Analog to Digital Unit.

FLUX [2D array of 32-bit floating point] – One image per cadence of the measured flux in each pixel after processing by the pipeline module CAL, the removal of the interpolated background, and the removal of cosmic rays. The units are electrons per second. See Quintana et al. (2010 SPIE, 7740, 77401X, 12) on pixel level calibrations or the KDPH for more details on the processing. This column may be used, along with the optimal aperture, to reproduce the SAP_FLUX values found in the light curve file for this target by summing the values in the optimal aperture pixels for each cadence.

FLUX_ERR [2D array of 32-bit floating point] – An image of the 1-sigma error in the measured flux as calculated by CAL in electrons per second. This error includes the error from the background subtraction. This per pixel error does not, and cannot, include the pixel-to-pixel correlated background errors that are included in the errors calculated for the light curve files.

FLUX_BKG [2D array of 32-bit floating point] – An image of the background flux subtracted from the data in electrons per second. The background flux is calculated by interpolating a 2 dimensional surface from approximately 4500 dedicated background pixels on each channel.

FLUX_BKG_ERR [2D array of 32-bit floating point] – An image of the 1-sigma error in the background flux. This per pixel error does not include the pixel-to-pixel correlated background errors that are included in the error columns of the light curve files.

COSMIC_RAYS [2D array of 32-bit floating point] – An image of the cosmic ray flux identified by the module PA. The units are electrons per second. For most cadences, this image will be an array of NaNs to indicate that there were no cosmic rays. The quality flag, bit 8, indicates when a cosmic ray falls in the optimal aperture.

QUALITY [32-bit integer] – Flags containing information about the quality of the data. Table 2-3 explains what activates each bit. See the Data Characteristics Handbook and Data Release notes for more details on Safe Modes, Coarse Point, Argabrightenings, attitude tweaks etc. Unused bits are reserved for future use.

POS_CORR1: [array of 32-bit integers] – An array containing the column component of the local image motion for each background pixel calculated from the motion polynomials. We report the motion in pixels relative to the mid-cadence of the quarter.

POS_CORR2: [array of 32-bit integer] – An array containing the row component of the local image motion for each background pixel calculated from the motion polynomials. We report the motion in pixels relative to the quarter's mid-cadence.

Aperture Extension

The aperture extension contains a single image that describes which pixels were collected by the spacecraft and which pixels are contained in the optimal aperture. Those pixels in the optimal aperture are used to create the SAP_FLUX light curve described in Section 2.3.1. The FITS standard requires a rectangular bounding box even though many target apertures are not rectangles. Therefore the image contains null pixels that were never collected (i.e., the image includes the extra pixels necessary to create a rectangular image). The aperture mask is a 32-bit integer with a value between zero and three. Other bits are reserved for future use. See Table 2-5.

Table 2-5 – Aperture image bit descriptions

Bit	Value	Meaning
1	1	pixel was collected by S/C
2	2	pixel is in the optimal aperture

2.3.3 Full Frame Image

A Full Frame Image (FFI) contains values for every pixel in each of the 84 channels. Nominally three FFIs are taken each quarter and are used to confirm the proper orientation and placement of the detector on the sky and to assess photometer health. FFIs are available to the public once the processing is complete. The DMC process generates an FFI data file that contains the uncalibrated pixels (ffi-orig). The SOC produces the calibrated and uncertainty images (ffi-cal and ffi-uncert). The uncalibrated, calibrated, and uncertainty FFIs contain one extension per mod/out. A complete FFI dataset consists of 3 files, each with a filename like kplr<stop_time>_suffix. Tables 2-6 and 2-1 give details on the file names and data set.

Table 2-6 – FFI Data set and files

Data type	File suffix	Format
FFI – uncalibrated	ffi-orig	84 FITS image extensions
FFI – calibrated	ffi-cal	84 FITS image extensions
FFI – uncertainties	ffi-uncert	84 FITS image extensions

The original, or uncalibrated, FFI created by the DMC contains the raw counts collected from the spacecraft as well as the collateral (black and smear) data in units of electrons per cadence. The header keywords do not match the keywords of the calibrated FFI files created by the SOC. The calibrated FFI was processed through the CAL portion of the Kepler pipeline and has units of electrons per second. Standard calibrations, such as flat fields, blacks, and smears have been applied. For more details see the KDPH. The uncertainty file, also in units of electrons per second, contains the propagated uncertainties on the flux for each pixel in the calibrated FFI.

The FFIs contain a World Coordinate System (WCS) solution calculated from the motion polynomials. Since the pipeline does not calculate a motion polynomial directly from the FFI, the FFI WCS is based on the motion polynomial from the nearest long cadence. The WCS is stored in each extension header using the keywords specified by Greisen & Calbretta (2002, A&A 395, 1077) and Calbretta & Greisen (2002, A&A, 395, 1061). The distortion coefficients that describe non-linearities in the shape of the focal plane are accounted for using Simple Imaging Polynomials (SIP) outlined by Schupe (2005, ASPC, 347, 491). The WCS solution typically achieves an accuracy of 0.1 pixels (0.4 arcseconds).

2.3.4 Co-trending Basis Vectors

The co-trending basis vectors (CBVs) represent the set of systematic trends present in the ensemble flux data for each CCD channel. The CBVs are computed when creating the PDC time series and are provided as part of the quarterly delivery of data. The user may fit the CBVs to light curves to remove the common instrumental effects from the data when the PDC time series is insufficient for their target. More details on the method used to generate these basis vectors are given in the KDCH.

The publically available tool called *kepcotrend*, which is part of the PyKE package, can be used to fit these basis vectors to individual light curves (see http://keplergo.arc.nasa.gov/ContributedSoftwarePyKEP.shtml).

CBV Format

The Kepler mission creates one cotrending basis vector (CBV) file each quarter. The Co-trending basis vectors are named according to the following format: kplr <yyyydddhhmmss>-q<##>-d<##>_lcbv.fits. Where the time represents the stop time of the data set in UTC, the q<##> represents the quarter number and the d<##> represents the data release number. A new CBV file is created each time the data is reprocessed. The DATA_REL keyword in the header of the CBV file should match the same keyword in the data being co-trended.

The CBV consists of a primary header and 84 data extensions, one for each mod/out. Each data extension contains the following columns:

TIME [32 bit floating point] – The time at mid-cadence in modified Julian date.

CADENCENO [integer] – The cadence number is a unique integer that is incremented with each cadence.

GAPFLAG [integer] – This flag is set to a value of one when the PDC portion of the pipeline has gapped the data. This occurs because the spacecraft is in coarse point, safe mode, at earth point, during a momentum dump, a detector anomaly occurs, an argabrigtening event was detected on that mod/out, a manual exclude, or an attitude tweak occurs. The light curves are linearly interpolated across these gaps prior to creating the basis vectors. PA data do exist for many of these events; however, the use of CBVs on these gapped data points is not recommended.

VECTOR_1 [32 bit floating point] – The first co-trending basis vector. The file includes the first 16 basis vectors as the subsequent columns of this binary data table.

Warning: Currently, *Kepler* provides 16 basis vectors. However, using the vectors above eight generally does not provide much improvement to the co-trending and has been known to introduce non-physical signals into the light curve.

2.3.5 Focal Plane Characterization Models

At commissioning, data was taken to model the characteristics of the Kepler focal plane. These models are used for various calibration and diagnostic tasks in the Kepler pipeline. Currently only the Pixel Response Function (PRF) models are available to the general Kepler user. Others will be released as they are converted into a user accessible format.

2.3.5.1 Pixel Response Function

The Kepler Pixel Response Function (PRF) is determined from a combination of the Kepler optical point spread function (PSF) and various pointing and electronic systematics of the Kepler spacecraft during 14.7-minute long exposures. The PRFs were measured only once using data collected during spacecraft commissioning. For more information on the PRF, how it was measured, and how it is used in the Kepler pipeline, refer to the paper "The Kepler Pixel Response Function" (Bryson et al. 2011 ApJ 713 L97).

The PRF varies in size and shape across the Kepler focal plane. To describe this variation, the PRF model is comprised of five images per channel. These images describe the PRF in the four corners and the center of the channel. Each PRF was determined by using 10 stars near the corners (or at the center) of the CCD. For computational simplicity, each PRF may be assumed to be located exactly at the active CCD corner (or center). This approximation has negligible impact on the interpolated PRF across a channel.

The discrete PRF model is over-sampled by a factor of 50 to allow for sub-pixel interpolation. The model is comprised of a 550 x 550 (or 750 x 750) grid that covers an 11 x 11 (or 15 x 15) pixel array. The size of the PRF depends on the channel. The provided array is large enough to encompass all the light from an unsaturated point source collected by Kepler.

There are three primary uses of the PRF:

1) To predict (or model) pixel values due to a star at a specified pixel location with a specified magnitude.
2) To estimate a star's location based on its pixel values via non-linear PRF fitting. The PRF location and amplitude that produces the smallest chi-squared value between the pixel values estimated by the PRF and the observed pixel values provides the estimated location of the star.
3) To estimate the stellar magnitude resulting from the PRF fit.

Users may interpolate between the PRFs at a discrete set of points to capture the spatial variation of the PRF within a channel.

The Kepler Project provides the five PRFs for each channel as FITS (Flexible Image Transport System) formatted files with five image extensions. Each channel is stored in a separate file with names formatted as kplr<module>.<output>_<creation_date>. The creation date is formatted as <yyyyddd>. Note all the PRF files are bundled in a single tar file.

Each image extension within the file contains one of the five PRFs calculated for that channel. The first four image extensions contain the PRF for the four corners of the CCD and the last extension contains the PRF for the center of the array. The LOCATION keyword in conjunction with Table 2-7 may be used to determine the location of the center of each PRF. (These detector locations are zero-based and include the collateral row and columns.)

Table 2-7 -- The row and column values for the five locations in the PRF files.

Location	Column	Row
1	12	20
2	12	1043
3	1111	1043
4	1111	20
5	549.5	511.5

The FITS headers also contain physical WCS coordinates that can be used to determine these locations. The PRF grid spacing, which is the inverse of the over-sampling factor, is specified in the physical WCS keywords in each image header (CDELT1P and CDELT2P).

2.3.6 Background Data Files

Kepler observes a grid of 4464 background pixels on each channel at long cadence in order to remove the zodiacal light and the unresolved background stars from the data. The Kepler pipeline fits these pixels to determine the background applicable for each observed aperture. The results of this fit are available in the light curve and target pixel files for the specified mask. The pixel time series of these background data are contained in the background data files. Users interested in modeling the background for specific targets or in the flux variations of these small patches of sky should refer to these background data files.

The background data files contain the raw and calibrated background flux for all the background pixels on each mod/out. One file exists for each mod/out each quarter. The mod/out is found in the name of the file (see Table 2-1) as well as the primary header.

Primary Header

The primary header contains information pertaining to the entire file, such as quarter, season, channel, and pipeline version numbers.

Background Binary Extension

This data extension contains the background pixels as well as the results of fitting the background for the entire channel. The background pixels are not a continuous portion of the CCD, therefore the data are stored as arrays and not images. The Pixels binary extension describes the CCD location of each element in these arrays. The binary table in this extension contains the following columns:

TIME_MJD: [64-bit floating point] – The UTC time at mid-point of the cadence in modified Julian date.

BKJD_TIME: [array of 64-bit floating point] – An array of barycenter corrected times in BKJD. The barycenter correction was performed for the location of each background pixel. The right ascension and declination of each pixel are determined using the motion polynomial of each cadence and are specified in the header of the Pixels binary extension.

CADENCENO: [32-bit integer] – The cadence number is a unique integer that is incremented by one with each cadence.

RAW_CNTS: [array of 32-bit signed integers] – The raw flux for each background pixel in units of counts.

FLUX: [array of 32-bit floating point] – The calibrated flux for each background pixel in units of electrons per second.

FLUX_ERR: [array of 32-bit floating point] – The error in the calibrated flux for each background pixel in units of electrons per second.

BKG_CO: [array of 64-bit floating point] – The background polynomial coefficients determined by fitting the calibrated background pixels on the specified channel. The number of background polynomial coefficients for each cadence is given by $(K+1)*(K+2)/2$, where K is the order of the fit.

BKG_CO_ERR: [image of 64-bit floating point] – The covariance matrix that results from the background polynomial fit for the specified channel.

COSMIC_RAYS: [array of 32-bit floating point] – The cosmic rays identified and removed from each background pixel in units of electrons per second.

QUALITY: [32-bit integer] – Bit flag containing information about the quality of the data. See Table 2-3.

POS_CORR1: [array of 32-bit integers] – An array containing the column component of the local image motion for each background pixel calculated from the motion polynomials. We report the motion in pixels relative to the mid-cadence of the quarter.

POS_CORR2: [array of 32-bit integer] – An array containing the row component of the local image motion for each background pixel calculated from the motion polynomials. We report the motion in pixels relative to the quarter's mid-cadence.

Pixels Binary Extension

This extension describes the CCD row and column values for each background pixel found in the data array of the first binary extension (RAW_CNTS, FLUX, FLUX_ERR, POS_CORR1, POS_CORR2). The data column RAWX contains the column coordinate and the data column RAWY contains the row coordinate. The header of this extension contains the World Coordinate solution according to the FITS standard and is used to determine the values in BKJD_TIME, POS_CORR1 and POS_CORR2.

2.3.7 Collateral Data Files

The collateral data for each channel consists of masked and virtual smear columns along with trailing black rows. The short cadence collateral data also includes the overlap summed-pixels (black/masked and black/smear). See Figure 7 and Section 2.6.3 of the Kepler Instrument Handbook for a description of the collateral data. Users interested in calibrating raw pixel data will be interested in these data files. A description of how the Kepler pipeline uses the collateral data to calibrate the raw pixels can be found in the Kepler Data Processing Handbook, Section 5.3.

The number of row (or column) pixels that are summed on the spacecraft to create the smear and black data can be found in the respective headers (see keywords NROWVSMR, NROWMSMR, and NCOLBLK). The file contains a separate extension for each of the black, virtual smear, masked smear, and SC overlap pixels. Each of these extensions contains a pixel list that gives the row (or column) number of each element in the array.

Primary Header

The primary header contains information pertaining to the entire file, such as quarter, channel, and pipeline version numbers.

Binary Data Extensions

The following columns are found in the binary data extensions (BLACK, VIRTUALSMEAR, MASKEDSMEAR and SC2DCOLLATERAL):

<u>All Binary Data Extensions:</u>

TIME_MJD: [64-bit floating point] – The UTC time at mid-point of the cadence in modified Julian date.

CADENCENO: [32-bit integer] – The cadence number is a unique integer that is incremented by one with each cadence.

BLACK Binary Extension:
BLACK_RAW: [array of 32-bit signed integers] – The raw black co-added pixels used to estimate the black level correction for the specified channel in units of counts.

BLACK_RES: [array of 32-bit floating point] – The residuals of the co-added black pixels after removing a fit to the black and the cosmic rays. The units are counts per second.

BLACK_RES_ERR: [array of 32-bit floating point] – The error in the black residuals in units of counts per second.

BLACK_CR: [array of 32-bit floating point] – The cosmic rays identified and removed from the co-added black pixels in units of counts per second.

VIRTUAL SMEAR Binary Extension:
VSMEAR_RAW: [array of 32-bit signed integers] – The raw flux of the co-added, virtual smear pixels in units of counts.

VSMEAR_FLUX: [array of 32-bit floating point] – The calibrated flux of the co-added, virtual smear pixels in units of electrons per second.

VSMEAR_FLUX_ERR: [array of 32-bit floating point] – The error in the calibrated co-added, virtual smear pixels in units of electrons per second.

VSMEAR_CR: [array of 32-bit floating point] – The cosmic rays identified and removed from the co-added virtual smear pixels in units of electrons per second.

MASKED SMEAR Binary Extension:
SMEAR_RAW: [array of 32-bit signed integers] – The raw flux of the co-added, masked smear pixels in units of counts.

SMEAR_FLUX: [array of 32-bit floating point] – The calibrated flux of the co-added, masked smear pixels in units of electrons per second.

SMEAR_FLUX_ERR: [array of 32-bit floating point] – The error in the calibrated co-added, masked smear pixels in units of electrons per second.

SMEAR_CR: [array of 32-bit floating point] – The cosmic rays identified and removed from the co-added, masked smear pixels in units of electrons per second.

SC2DCOLLATERAL Binary Extension (only in SC files):
BMASKED_RAW: [signed 32-bit integer] – The raw counts for the sum of the pixels in the cross-sections of the trailing black columns and the masked smear rows in units of counts.

BMASKED_RES: [32-bit floating point] – The residuals of the masked black after removing the fit to the black, correcting for the number of co-added pixels, and correcting for the identified cosmic rays. The units are counts per second per pixel.

BMASKED_RES_ERR: [32-bit floating point] – The error in the residuals of the masked black in units of counts per second per pixel.

BMASKED_CR: [32-bit floating point] – The cosmic rays identified and removed from the masked black co-added pixels in units of counts per second per pixel.

BVIRTUAL_RAW: [signed 32-bit integer] – The raw counts for the sum of the pixels in the overlapping virtual smear rows and trailing black columns in units of counts.

BVIRTUAL_RES: [32-bit floating point] – The residuals of the virtual black values after removing the fit to the black, correcting for the number of co-added pixels and correcting for the identified cosmic rays. The units are in counts per second per pixel.

BVIRTUAL_RES_ERR: [32-bit floating point] – Error in the residuals of the virtual black in units of counts per second per pixel.

BVIRTUAL_CR: [32-bit floating point] – The identified and removed cosmic rays found in the virtual black region in units of counts per second per pixel.

Binary Pixel List Extensions

The pixel list extensions (BLACKPIXELLIST, VIRTUALSMEARPIXELLIST, and MASKEDSMEARPIXELLIST) describe the location (row or column) of the values in the arrays in the black and smear extensions. For short cadence data, these pixel lists are not contiguous because the collateral data is only read-out for those rows and columns that contain a collected pixel.

2.3.8 Artifact Removal Pixel Data Files

The Artifact Removal Pixels (ARPs) are individual pixels in the collateral data that are read-out at the long cadence rate. They are a set of pixels defined to sample the states of the fine guidance sensor (FGS) cross talk with the science CCD pixels. They are used to monitor the cross talk levels in both the pre-clocked bias region ("leading black") and the over-scanned bias region ("trailing black"). The pixels in the ARP files are not contiguous; therefore the data is stored in arrays instead of images for each cadence. ARP data are used by the pipeline for a dynamic 2-D black correction. See the KIH, Section 6.8, for further details.

Primary Header

The primary header contains information pertaining to the entire file, such as quarter, season, channel, and pipeline version numbers.

Artifact Removal Binary Extension

The following columns are found in this data extension:
TIME_MJD: [64-bit floating point] – The UTC time at mid-point of the cadence in modified Julian date.

CADENCENO: [32-bit integer] – The cadence number is a unique integer that is incremented by one with each cadence.

RAW_CNTS: [array of 32-bit integers] – The raw counts collected for each ARP pixel in units of counts.

FLUX: [array of 32-bit floating point] – The calibrated ARP pixels in units of electrons per second.

FLUX_ERR: [array of 32-bit floating point] – The error in the calibrated ARP pixels in units of electrons per second.

COSMIC_RAYS: [array of 32-bit floating point] – The cosmic rays identified and removed from the ARP pixels in units of electrons per second.

QUALITY: [32-bit integer] – Bit flag containing information about the quality of the data. See Table 2-3.

Pixels Binary Extension

This extension describes the CCD row and column values for each ARP pixel found in the data array of the first binary extension. RAWX contains the column coordinate and RAWY contains the row coordinate.

2.3.9 Reverse Clock Data Files

The Kepler CCD is reverse clocked several times every month to obtain a measure of the bias (see KIH, Section 5.0). These reverse clock data files are created by the DMC and are available at the MAST through the FFI and Engineering data download page. The reverse clock data set is comprised of the target pixels (lcs-targ), the background pixels (lcs-bkg) and the collateral pixels (lcs-col). Each file contains one extension per mod/out. Each extension contains one floating point array of all the reverse clock measurements in that mod/out. To determine the physical CCD location of each element of the array, refer to the pixel mapping file specified in the header. The primary header keywords LCTPMTAB, BKGPMTAB and LCCPMTAB give the name of the pixel mapping file associated with the target, background and collateral reverse clock data, respectively. The pixel mapping files are also available from the MAST.

2.4 Keyword Definitions

Several keywords in the headers of archive products cannot be explained very well in the 40 characters allotted for the comment field. Here we provide a short dictionary to clarify some of these keywords.

BACKAPP: This keyword is set to true if the background has been subtracted from the FLUX column of the target pixel file or the SAP_FLUX column of the light curve file. The background flux has not been subtracted for the FFIs causing BACKAPP to be set to false.

CDPP3_0: The root mean square CDPP (combined differential photometric precision) value calculated in 3-hour intervals by the Kepler pipeline. CDPP6_0 contains the 6-hour rms CDPP value and CDPP12_0 contains the 12-hour rms CDPP value for the same target. CDPP corresponds to the depth of a box-car test signal with a duration of N-hrs that results in a detection Signal-to-Noise of unity in the Transiting Planet Search (TPS) module. CDPP is calculated on a per cadence basis, thus the rmsCDPP only captures the first moment of the CDPP time series, and not its time evolution or distribution of CDPP values. See Section 8.3 of the KDPH (KSCI-19081-001) for more details on how rms CDPP is calculated by the pipeline.

CROWDSAP: The ratio of the flux from the target to the total flux in the optimal aperture as estimated from the sources available in the KIC.

DATA_REL: The version of the data release notes that corresponds to the data set. Each time data is processed it is associated with a new set of data release notes.

EQUINOX: The equinox of the celestial coordinate system used to describe the Right Ascension and Declination of the target.

FILEVER: File format version. This is incremented each time the FITS format of the light curve or target pixel file changes. This is specified as a string of the form "<major_update>.<minor_update>". Increments in the minor_update number should maintain compatibility with code written for that file type and major_update number.

FITTYPE*j*: The type of fit used by PDC for the band indicated by the integer j. Values include 'robustFit', 'priorFit' or 'none'. The number of bands is indicated by the keyword NUMBAND.

FLFRCSAP: Fraction of the target flux contained in the optimal aperture calculated by the target aperture definition portion of the pipeline using the sources available in the KIC.

GAIN: The value of the gain measured for the specified channel.

INT_TIME: The integration time for a single frame. Kepler sums 270 of these integrations to create one long cadence value and 9 of these for one short cadence value; see NUM_FRM.

LC_START: The time at the middle of the first cadence in modified Julian date.

LC_END: The time at the middle of the last cadence in modified Julian date.

LCFXDOFF: The value of the flight software black level added to the long cadence data by the spacecraft as part of the requantization processes prior to downloading the data. See the Instrument Handbook for more details (van Cleve & Caldwell 2009, KSCI-19033).

NPIXSAP: Number of pixels in the optimal aperture.

NPIXMISS: Number of pixels that should be in the optimal aperture, but were not collected by the spacecraft.

NUMBAND: Number of wavelet length-scale bands used by PDC to produce the PDCSAP_FLUX time series. The bands are listed in order from the longest length-scale (i.e., period) to the shortest.

NUM_FRM: The number of frames summed to create the data contained in the file.

PDCVAR: Measure of the variability as measured by PDC (see equation 11 of Smith et al. 2012 PASP, 124, 1000). This value is used to weight the prior relative to the probability distribution function.

PDCMETHD: The method used to calculate the PDC light curve provided in the file. The options include 'multiscaleMAP' or 'regularMAP'.

PR_GOOD*j*: The goodness of the PDC prior fit associated with the band indicated by the value *j*. The number of bands is indicated by the keyword NUMBAND (see equation 19 of Smith et al. 2012, PASP, 124, 1000).

PR_WGHT*j*: The prior weight used by PDC with the band indicated by the value *j*. The number of bands is indicated by the keyword NUMBAND.

RADESYS: The reference frame for all celestial coordinates reported by Kepler is in ICRS (International Celestial Reference System).

READNOIS: The value of the readnoise in electrons measured for the specified channel.

SCFXDOFF: The value of the flight software black level added to the short cadence data by the spacecraft as part of the requantization processes prior to downloading the data. See the Instrument handbook for more details (Caldwell et al. 2009, KSCI-19033).

TIERRELA: The relative timing error. All times are accurate relative to each other within 50 ms.

TIERABSO: The absolute timing error. The absolute error in the times for Kepler has not been externally measured and is not known at this time.

TSTART: The start time of the observations contained in the file measured at the beginning of the first cadence. The units are in BJD-BJDREF, where the keywords BJDREFI and BJDREFF make up the value of BJDREF.

TSTOP: The stop time of the observations contained in the file measured at the end of the last cadence. The units are in BJD-BJDREF, where BJEDREF is a keyword listed in the file.

Chapter 3 Searching the Archive for Kepler Data

Users can search for Kepler data in a multitude of ways. Common searches are based on position, time of observation, target name or kepler_id (Kepler Identification Number), but all catalog fields are searchable. MAST allows the upload of a file containing a list of up to 10,000 kepler_id's, coordinates and/or target names for desired searches. Cross correlation with catalogs is possible using CasJobs. Please note kepler_id and target name are different identifiers. MAST makes this distinction so that users may enter, say, NGC 6791 or TrES-2, as the target name and the Resolver will return the coordinates. The resolver does accept some planet names (e.g., Kepler-68 c) and KOI numbers as target names.

This chapter contains descriptions of the Kepler Data Search, the Kepler Target Search, the FFI Search, and the KIC Search Forms. These search pages rely on the Kepler Input Catalog (KIC), Characteristics Table (CT), the Kepler Target Catalog (KTC) as hosted by MAST, and the Kepler Target Table. The Kepler Target Table is a combination of the KIC, the CT, and a number of catalogs that cover all or part of the Kepler field of view (e.g., GALEX). It is supplemented with additional fields of interest. Users intending to propose for *Kepler* time should use the "Kepler Target Search" form to assist in selecting targets. Users interested in archived data should use the "Kepler Data Search & Retrieval" form to search the archive catalog for data of interest. A search form is also provided for users who wish to search the original KIC.

MAST has now released a new tool called Portal. Kepler light curves are available through the Portal. Access to the Portal is available via the main MAST web page or http://mast.stsci.edu/explore.

3.1 The *MAST Kepler* Catalogs

This section describes the primary catalogs used in creating the MAST Target Search Interface and the Data Search & Retrieval Interface.

The catalogs that form the basis for the Target Search table consist of the Kepler Input Catalog, the Characteristics Table, additional targets in the 2MASS catalogs (the KIC was incomplete in this respect), the Lucas (UK-IRT) survey in J (KIS), fluxes and colors from GALEX, Sloan (SDSS/DR9), Everett-Howell (UBV), and the Kepler Isaac Newton Telescope Survey (KIS). The KIS and UBV surveys are described in Greiss et al. 2012, AJ, 144, 24G and Everett, Howell, & Kinemuchi 2012, PASP, 124, 316E. See the Explanations and Caveats page http://archive.stsci.edu/kepler/kepler_fov/explanations.html for descriptions of the surveys and the rules used to form the color names. Cross correlation was done to match the KIC targets to each catalog or data set. Users are warned to combine KIC and KIS colors and magnitudes with care, as they are based on different zero point magnitude systems (AB and Vega/Johnson).

The KIC contains information on approximately 13 million sources, most of which are visible in or nearby the *Kepler* field of view. Creation of the KIC is discussed in Brown et al. (2011, AJ, 142, 112). Each source has an identification number, called the kepler_id, and a position (RA and Dec). Additional fields may or may not have values for each source.

The Characteristics Table (CT) contains parameters indicating if a given kepler_id is observable ("on silicon") by Kepler for each of the 4 seasons, as well as other characteristics. Not all sources in the KIC have values for all parameters. In fact, only about one third of the KIC entries are ever "on silicon." MAST does not provide a direct search capability for the CT. Instead, the CT fields have been included in the Kepler Target table. The Kepler Target Search form is used to search the Kepler Target table. Information about the CT parameters is given in the MAST help files, http://archive.stsci.edu/kepler/kepler_fov/help/search_help.html.

Facts about the KIC, CT and Kepler Target tables:

- The full KIC contains 13,161,029 rows (objects).
- The CT contains 6,569,466 rows (about half of the KIC total).
- The total number of targets in the Kepler Target table is > 15 million.
- The number of KIC targets on CCD every season is 4,353,971.

The fields in the Target Search Interface, along with a short description, a range of valid values and the data type is available via the "Fields Description" link on the page (at http://archive.stsci.edu/search_fields.php?mission=kepler_fov.

The search for data (actual observations) uses the archive tables, the KIC and the Kepler Target Catalog (KTC). The KTC contains all objects observed or scheduled for observation by *Kepler*. At launch, there were some 150,000 targets in the KTC. The KTC is updated on a quarterly basis and holds observation start and stop times for each target. The times are given in both Modified Julian Date (MJD) and standard date format (i.e., YYYY-MM-DD HH:MM:SS).

A list of the fields in the Data Search and Retrieval Interface is available via the "Fields Description" link, http://archive.stsci.edu/search_fields.php?mission=kepler, on the page.

For a given object, the kepler_id is the same in the KIC and the KTC. The one exception is for KIC targets observed with custom apertures (see Section 2.2.1): in this case, the kepler_id listed in the KTC is **not** in the KIC or the CT.

3.2 The MAST Search Forms

MAST provides separate forms for searching for targets to observe and for locating *Kepler* data in the archive. Each form serves a different purpose. When gathering targets for a Kepler Observing Proposal, perform a Target Search of the Kepler Target table from the "Kepler Target Search" form. Searches of the archive for existing data are called Kepler Data Searches, are done using MAST's "Kepler Data Search and Retrieval" form, and are based on the archive catalog and the KTC. These searches are done to locate and retrieve data from the archive. The forms function in the same manner, but the search fields are different because the underlying catalogs and database contain different information. The kepler_id is the same in both forms.

Additional MAST pages exist to download *Kepler* data. These include:

- FFI/Engineering data search page, http://archive.stsci.edu/kepler/ffi/search.php,
- co-trending basis vector download page, http://archive.stsci.edu/kepler/cbv.html,
- focal plane characteristics download page, http://archive.stsci.edu/kepler/fpc.html,
- KIC search page, http://archive.stsci.edu/kepler/kic10/search.php.

Check the "Search & Retrieval" page http://archive.stsci.edu/kepler/search_retrieve.html, for a current list of search and download options.

MAST provides standard forms, that is, forms that look and operate the same from mission to mission. On the "standard form", the top section consists of a place to enter a target name or coordinates and a Resolver. If a target name is entered, the coordinates will be resolved using SIMBAD or NED and these coordinates will be used in the search. The user can also choose the search radius (the default is 0.02 arcmin). Note the Resolver uses a standard MAST hierarchy, whose order is NED, SIMBAD, etc.

Note the **"file upload form"** link near the top right of the form. Clicking on the link brings up a version of the standard form that allows the upload of a user created file. The file must be an ASCII text file or table with one entry per line with one or more fields (e.g., RA and Dec) separated with one of the allowed delimiters. Searches are allowed on coordinates, target name or kepler_id. Other fields are allowed in the file, but are not searchable. Up to 10,000 lines are allowed. Several coordinate formats and delimiters are allowed. Check the on-line help for information. The name of the file is the name the file has on the user's disk. A browse button is provided.

The middle section of the search page contains mission specific fields, which can be used to qualify the search. Some user-specified fields are also provided. The menu (down arrow) next to each of these fields contains a complete list of the table columns. Select the desired field to add it to the search form. For more information about each field click on the link "Field Descriptions". This brings up a page of all the available columns, in tabular form. The table lists the database column name, the label, a description, an example or range of valid values in that field, and the data type.

The third section provides output options for the search results. On the left side is a list of columns that is displayed by default. Highlighting the column and clicking on the "remove" button to the right can remove columns. Choosing columns from the "select" box and clicking the "add" button to the left of the "select" box adds columns, click "Add All" to add all columns. Change the order by clicking on the field in the output columns box and click on the "up" or "down" buttons to the right. Clicking on the "reset" button will restore the default output columns settings. The output can be sorted by up to three columns. A 'null' option is available if no sorting is desired. When the no sort option is specified, the results are returned in the order in which they are stored in the database and for Kepler, this means in order of kepler_id. Note, when using the file upload option, if the upload contains more than 200 entries, the order of entries from the uploaded file **is maintained.** If the upload file contains less than 200 entries, the order in the uploaded file is **not preserved**.

The output format can be specified using the "Output Format" menu in the lower right of the form. Formats include HTML, comma separated value text, Excel spread sheet, VO table format, wget and more. The HTML format will give access to useful links and retrieval options. Since the astrophysical fields in the underlying catalogs are not populated for every object, searches that direct the results to an output file should use the Excel Spreadsheet output, or one of the CSV outputs that use a character (i.e., comma or semi-colon) as the delimiter. Use of a space delimited CSV format can result in non-interpretable results.

Output coordinates are displayed in sexagesimal by default, but decimal degrees or decimal hours can be specified. Click on the headings for additional help.

3.2.1 Kepler Target Searches (e.g., find objects to observe)

Figure 3.1 shows the Kepler Target Search form located at http://archive.stsci.edu/kepler/kepler_fov/search.php. The form allows searches based on kepler_id, position, target name and/or physical characteristics, where the available physical characteristics provided in the Kepler Target table are taken from the KIC. Note: since there are >12.5 million objects in the catalog searched by this form, it is not a good idea to submit an unqualified search. Indeed, such a search is likely to time out, with no results returned.

When doing a target search, several catalog values are listed by season, necessary because Kepler rotates quarterly. The planned start date for each season is given in Table 3-1. The seasons are numbered from 0 to 3, with 0 corresponding to Summer. Some targets are not on the CCD every quarter. The number of seasons the target is available is enumerated in this table.

Table 3-1 Planned Start Date for Seasons

Year	**Spring**	**Summer**	**Fall**	**Winter**
Quarters	**1,5,9,13,17**	**2,6,10,14**	**3,7,11,15**	**0,4,8,12,16**
Season	**3**	**0**	**1**	**2**
2009	May 13	Jun 18	Sep 17	Dec 17
2010	Mar 19	Jun 23	Sep 23	Dec 22
2011	Mar 24	Jun 27	Sep 29	Dec 29
2012	Mar 29	Jun 28	Oct 1	Jan 9,2013
2013	Apr 8	Jul 8		

Note on Contamination/Crowding values: Contamination is a floating-point number between 0 and 1 representing the fraction of light in the aperture due to the target star. We provide a rough estimate of the contamination for each KIC target and season in the MAST *target* search interface. **However, this contamination value is NOT to be used to correct *Kepler* flux light curves.** These values are intended only to facilitate the selection of isolated stars as targets. The contamination value relevant to a specific flux light curve can be substantially different from the predictive value. It varies because of changes in photometric aperture size, the pixel response function, optical throughput, and other position-dependent characteristics of the focal plane. The aperture for *Kepler* photometry is approximately defined before data collection, but is not finalized until post-processing is complete.

The contamination and flux fraction values used by the *Kepler* pipeline to create the PDC light curve are found in the headers of the individual files for light curve files of v2.1 and later. The MAST populates the *data* tables for individual data sets with these values.

Example Target Searches

See Figure 3-1 for an example of how to use the MAST Target Search Form. The Contamination, Teff and Log G fields have values entered to qualify the search. Note the use of carets, < and >, to provide starting or ending values. Also note that the input in the "Log_G" field, 3.0..3.5 specifies a range of values starting with 3.0 and ending with 3.5. A User-specified field, "r", was used to qualify on the Sloan r magnitude for the search. The default, KIC targets only, was taken for the "Catalogs" form element as only the KIC contains these fields. Finally, in the "Output Columns" box, a number of fields were removed to make the results more readable. This search was executed and the results are shown in Figure 3-2. More information on general usage of MAST search forms is provided in the on-line MAST tutorial, which is accessible via the (Help) link in the top right corner of the form.

Figure 3-1 MAST Kepler Target Search Form

Kepler_ID	2MASS ID	RA (J2000)	Data Availability Flag	Dec (J2000)	r	J	kepmag	Teff	Log_G
1571152	19234056+3709547	19 23 40.567	2	+37 09 54.76	9.229	8.547	9.268	7048	3.164
2166218	19305705+3730357	19 30 57.055	2	+37 30 35.78	9.433	8.768	9.465	7153	3.345
3760826	19394821+3853479	19 39 48.211	2	+38 53 47.90	8.789	8.477	8.758	8640	3.421
6668729	18535062+4210158	18 53 50.621	2	+42 10 15.82	8.597	8.089	8.590	7767	3.484
7060333	19541213+4233399	19 54 12.137	2	+42 33 39.92	9.081	8.532	9.088	7576	3.475
7119530	19291904+4238290	19 29 19.046	2	+42 38 29.08	8.536	8.002	8.517	7777	3.487
7273950	19170644+4249187	19 17 06.442	2	+42 49 18.77	9.356	8.696	9.389	7030	3.474
7827131	19334714+4331022	19 33 47.146	2	+43 31 02.24	8.012	7.623	7.986	8286	3.487
8649198	19572616+4446301	19 57 26.165	2	+44 46 30.11	9.251	8.727	9.253	7800	3.488
9812351	18461032+4637509	18 46 10.322	2	+46 37 50.99	7.949	7.451	7.934	7794	3.470
12055345	19105861+5030322	19 10 58.608	2	+50 30 32.22	9.420	9.134	9.379	8953	3.414
Kepler_ID	2MASS ID	RA (J2000)	Data Availability Flag	Dec (J2000)	r	J	kepmag	Teff	Log_G

Figure 3-2 Results of Target Search

The results in Figure 3-2 are in the default HTML form. Clicking on the column name at the top of a column will sort the input by that column. A second click will order the sort in the opposite direction. A click on the column name link at the bottom of the results will bring up a page that describes the column.

Other output formats are available and can be specified on the Search Form, see Figure 3-1, in the lower right. Consult the on-line tutorial for additional details.

Example Target Searches: Use Case 1

Upload a target list, e.g. of coordinate values. Return all objects within the default search radius having contaminations of less than 0.15. Include the 2MASS_ID in the output.

```
Before proceeding with the use case, the reader should note the fidelity of the contamination
value used in this search is poor compared to values based on actual apertures. Excluding
values of contamination here at 0.15 would in fact miss many real targets that have been
observed with realized contamination of order 0.01.
```

Start by creating a file that contains a table or list of coordinate values. The file must be an ASCII text file with either one entry per line (i.e., a target name, a Data ID, or a set of coordinates) or a table, with the values separated by one of the allowed delimiters (tab, comma, vertical bar or semicolon). Additional information may be available in the file/table. Only **one entry per line** is extracted. The file should reside on the user's disk. Below is the file that was input in this example.

```
 3830833, 18 58 29.93, +38 56 54.1
 8547781, 19 05 40.22, +44 37 26.4
 5127321, 19 54 09.98, +40 13 40.4
 8540791, 18 50 24.70, +44 38 39.9
12207020, 19 21 59.33, +50 49 27.1
 1571152, 19 23 40.57, +37 07 17.4
 8581320, 19 54 22.80, +44 40 20.4
 9667235, 19 52 56.74, +46 21 01.0
```

To upload the file, go the Kepler Target Search form, http://archive.stsci.edu/kepler/kepler_fov/search.php, and click on the "file upload form" link in the upper right corner of the form. This will bring up a similar looking MAST search form. Note the "Local File Name (required)" form element on the left hand side. Click on the "Browse" button next to the field in order to locate the file on the user's disk. Select it and click open. The location and name of the file will appear in the form element. Next, indicate the delimiter used in the file or table. In this case, comma (,) is the delimiter. Next, indicate which column holds the RA values, in this case column 2, and which column holds the DEC values, in this case, column 3. To add contamination qualifiers, the fields need to be added to the form. Go to "User-specified field 1" and click on the down arrow. A list of fields to add will be displayed. Scroll down to "Contamination season 0" and click on it. Enter the qualifier "<0.15" in the box labeled "Field Descriptions" to the right. Select "Contamination season 1" from "User-specified field 2" towards the right side of the page, and enter "<0.15" under its Field Descriptions box. Repeat for "Contamination season 2" and "Contamination season 3" in the user-specified fields 3 and 4." Adjust the output columns and select the output format. In this example, the output columns will be Kepler ID, 2MASS ID, RA, Dec and the contamination values, and the results will be displayed to the screen as comma-separated values. (The contamination fields were added to the output columns via the "add" box below the Output Column form element.) Figure 3.3 shows the Kepler Target Search form with the above information specified. Click the "Search" button to begin the search.

The results, as displayed to the screen, are shown below in Table 3-3. Note the 6th object in the input file did not return a result, because the contamination value was larger than the specified limit.

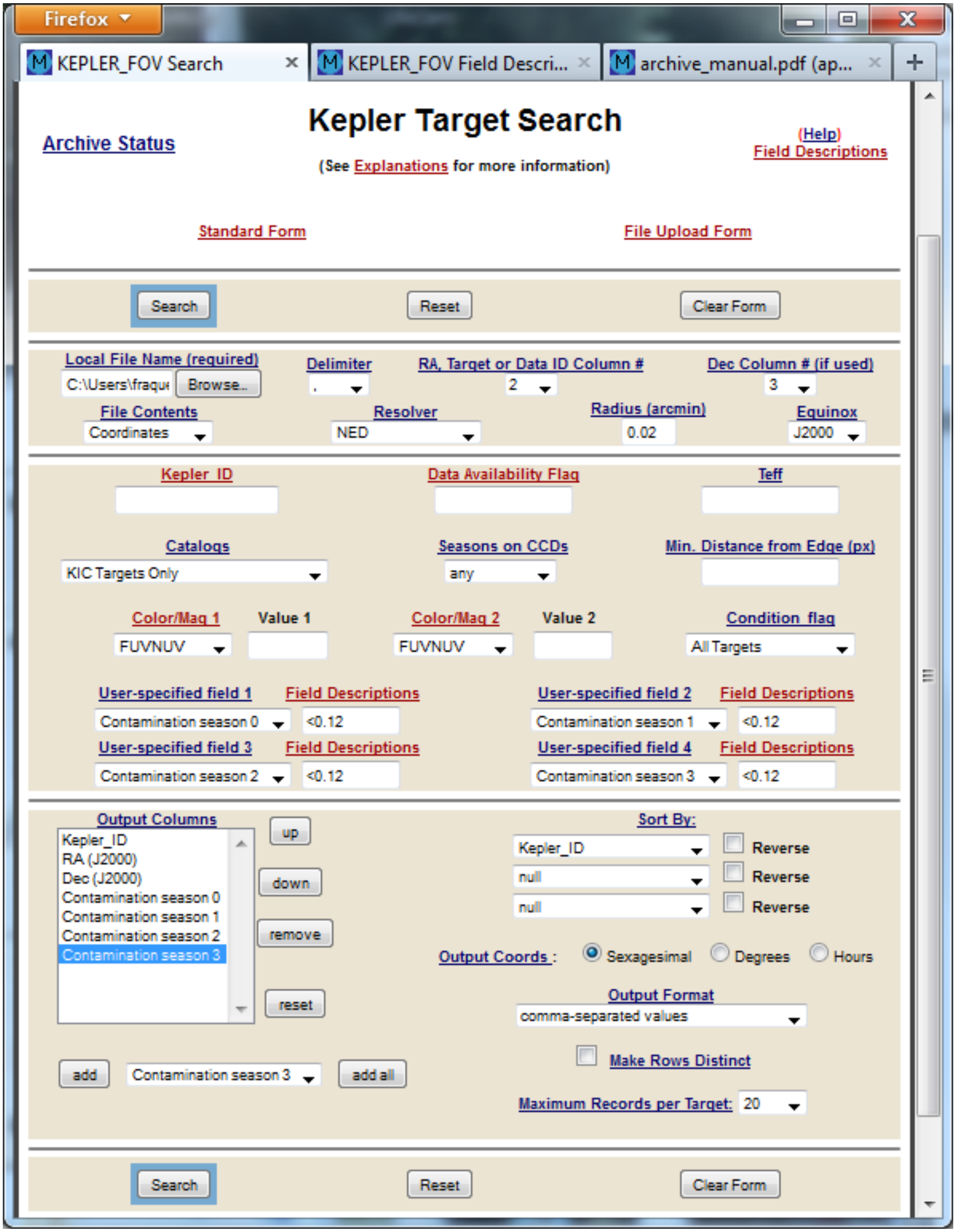


Figure 3-3 Use Case 1. Target Search Form Setup

```
Kepler_ID,RA (J2000),Dec (J2000),Contamination season 0,Contamination season
1,Contamination season 2,Contamination season 3
integer,ra,dec,float,float,float,float
8581320,19 54 22.802,+44 40 20.35,0.028,0.035,0.050,0.023

8547781,19 05 40.217,+44 37 26.40,0.026,0.028,0.030,0.038

3830833,18 58 29.933,+38 56 54.12,0.003,0.005,0.007,0.003

5127321,19 54 09.989,+40 13 40.37,0.029,0.036,0.040,0.035

12207020,19 21 59.327,+50 49 27.10,0.010,0.013,0.017,0.017

8540791,18 50 24.707,+44 38 39.91,0.028,0.015,0.039,0.025

9667235,19 52 56.734,+46 21 00.97,0.014,0.013,0.022,0.015
```

Table 3-3 Results for Use Case 1

Example Target Searches: Use Case 2

Return a list of all cool white dwarfs with large proper motions in the Kepler field of view: Teff < 7000K, log g >=5.0, and mu >0.5 arcsec/year.

Before proceeding with the use case, the reader should note there are many thousands of objects in the KIC for which no temperature, surface gravity or proper motion information is provided. Also, users of the KIC should become familiar with the accuracy and limitations of the values reported in this catalog (see http://www.cfa.harvard.edu/kepler/kic/kicindex.html) before searching for specific types of objects.

To obtain the desired list, the temperature and surface gravity criteria are entered on the search form. The total proper motion field is added as a "User-specified field" and added to the "Output Columns" menu. Most of the default columns have been removed from the "Output Columns" menu, and the order of the remaining values has been changed. The "Sort By" fields have been set to have the primary sort be done on the total proper motion, with the higher values displayed first. The secondary sort is on temperature and the tertiary search is on surface gravity. The "Output Format" is an HTML table. Finally, to allow the search to run more quickly, the "Seasons Target on CCDs" has been set to "unspecified". This field may be added to the "Output Columns" if the information is needed. Click on "Search." Only one object is found to satisfy the criteria (see Figure 3-5).

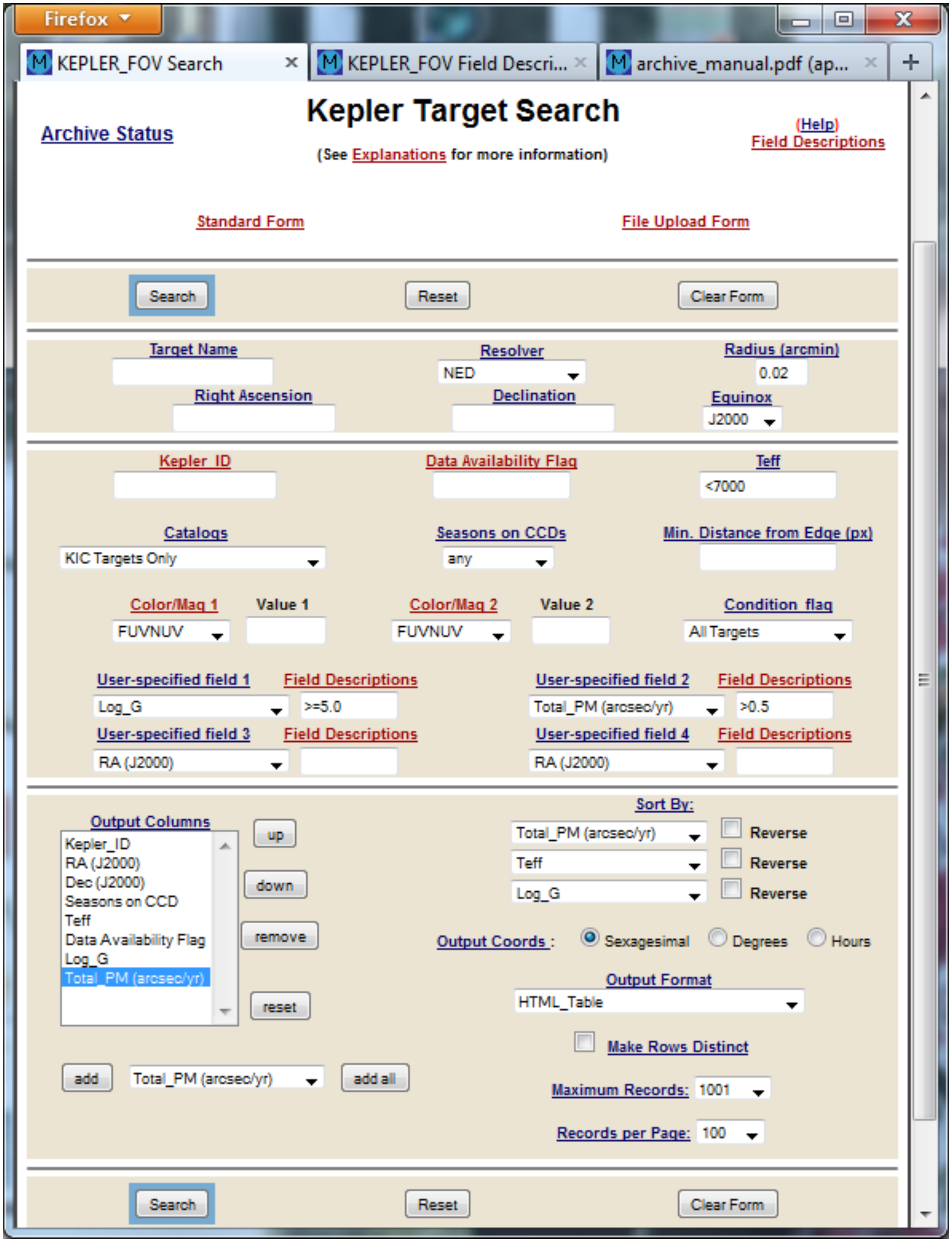


Figure 3-4 Search Form for Use Case 2


Firefox

KEPLER_FOV Search | KEPLER_FOV Field Descri... | archive_manual.pdf (ap...

Mission Search / Missions / Contacts / STScI / MAST Columns Help / Archive Status

Kepler Target Search Results

Edit Query

Display numeric columns graphically using VOPlot

number of rows returned = 1

Click on Data Availability Flag links (if any) to see available data
Click on Condition Flag entries for more information on flag definitions
Click on top column headers to sort the table on the column contents.
Click on bottom column headers for more information about the data in that column.

Kepler_ID	RA (J2000)	Dec (J2000)	Seasons on CCD	Teff	Data Availability Flag	Log_G	Total_PM (arcsec/yr)
10412357	19 39 15.437	+47 30 03.49	4	5685	0	5.060	0.576
Kepler_ID	RA (J2000)	Dec (J2000)	Seasons on CCD	Teff	Data Availability Flag	Log_G	Total_PM (arcsec/yr)

Top of Page
Copyright Notice http://archive.stsci.edu/kepler/kepler_fov/search.php
archive@stsci.edu
Modified: Sep 25, 2012 12:25

Figure 3-5 Search Results for Use Case 2

Example Target Searches: Use Case 3

Return the E(B-V)'s of all the KIC objects, whether they fall on the Kepler detectors or not.

This use case cries out for CASJobs (see Section 3.2.4) because of the large number of records that will be returned. Start by going to http://mastweb.stsci.edu/kplrcasjobs and setting up an account. **Read the help**.

Login to CasJobs. Click on "MyDB" in the menu bar. Select "Kepler" from the Context Box drop down menu. A list of the tables in the Kepler DB is displayed. Click on the table name to get documentation on that table. Select the kepler_input_catalog table (i.e., the KIC) by clicking on it. A list of the columns in the table is displayed in a box to the right. See Figure 3-6, which has an arrow pointing at the kepler_input_catalog in the list of tables.

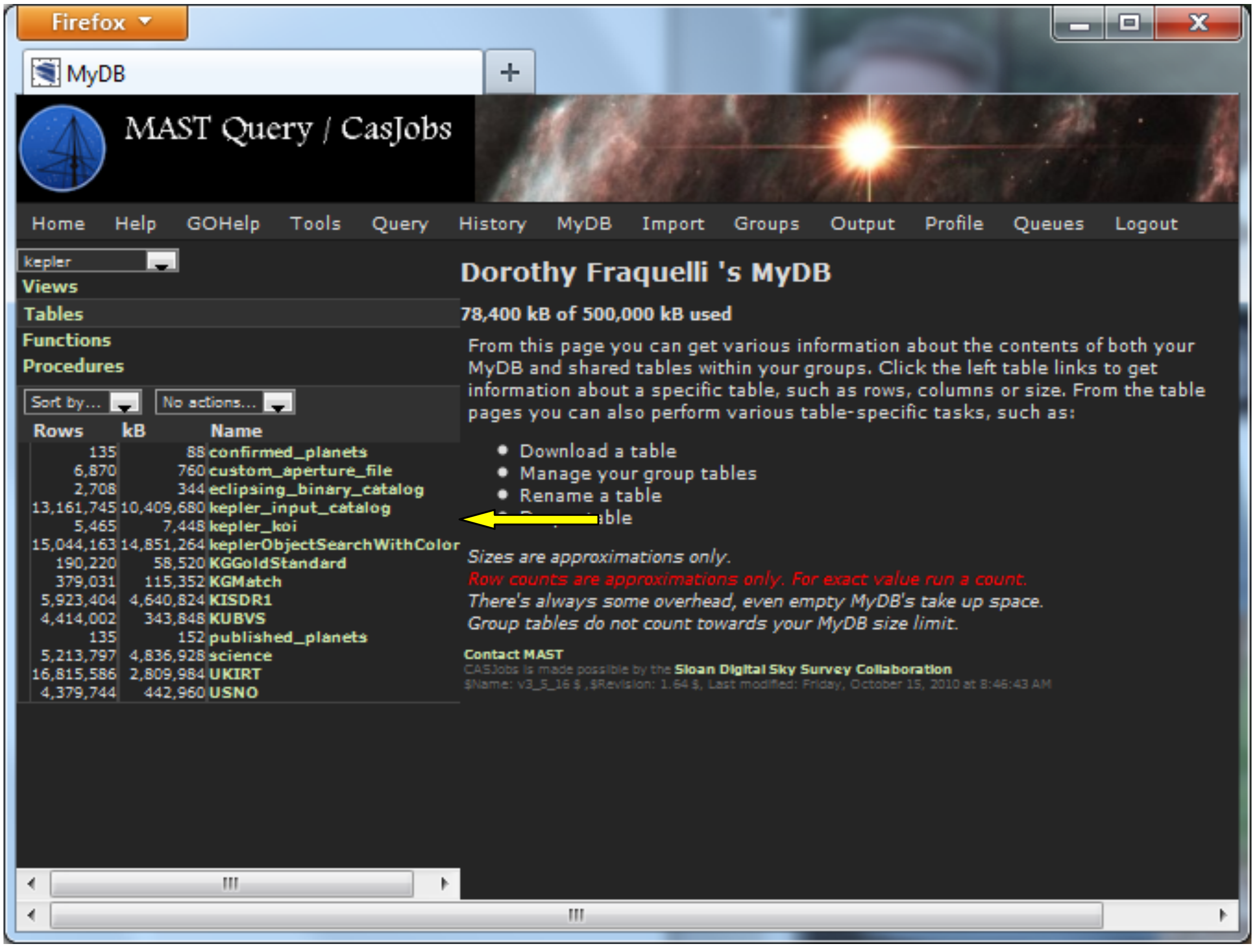


Figure 3-6 CasJob kepler database

For this use case, we will select the kepler_id, position and E(B-V) values from this table. We will ignore entries that do not have E(B-V) values. Also note we are querying the full KIC, so many of the returned targets will not be observable by Kepler.

To prepare a query, click the "Query" tab in the menu bar. Click in the window, then type or paste in the query

```
select top 20 kic_kepler_id,kic_ra,kic_dec,kic_ebminusv from kepler_input_catalog where
kic_ebminusv > 0
```

This is a test to ensure the query is correct. The "top 20" will limit the number of returned results. Click the "Syntax" button on the far right menu bar. After receiving acknowledgement that the query is syntactically correct, click on "Quick" in this same menu bar. The first 20 rows will be displayed in the lower portion of the screen.

The results from the test query are what we want. Next, remove the limit on the query ("top 20") and direct the output to a table in your database (MyDB). To do so, type in or paste in the following query:

```
select into MyDB.usecase3 kic_kepler_id,kic_ra,kic_dec,kic_ebminusv from kepler_input_catalog
where kic_ebminusv > 0
```

Make sure the "context" box is still Kepler. Note the use of "into MyDB.usecase3" to direct the results to a table named "usecase3" in database "MyDB." Again, check the syntax. Then click on "Submit" in the same menu bar. A screen similar to the one in Figure3-7 will be displayed. When the query is complete, the "Status" in the menu bar will change to “Finished.” Note that if you already have a table named "usecase3", you will need to go into the MyDB menu and "drop" the table before running your query. You do this by selecting the table in MyDB, then from the drop-down menu "All selected", choose Drop. Alternatively, you can choose to select your query into a new table by changing "usecase3" to something else."

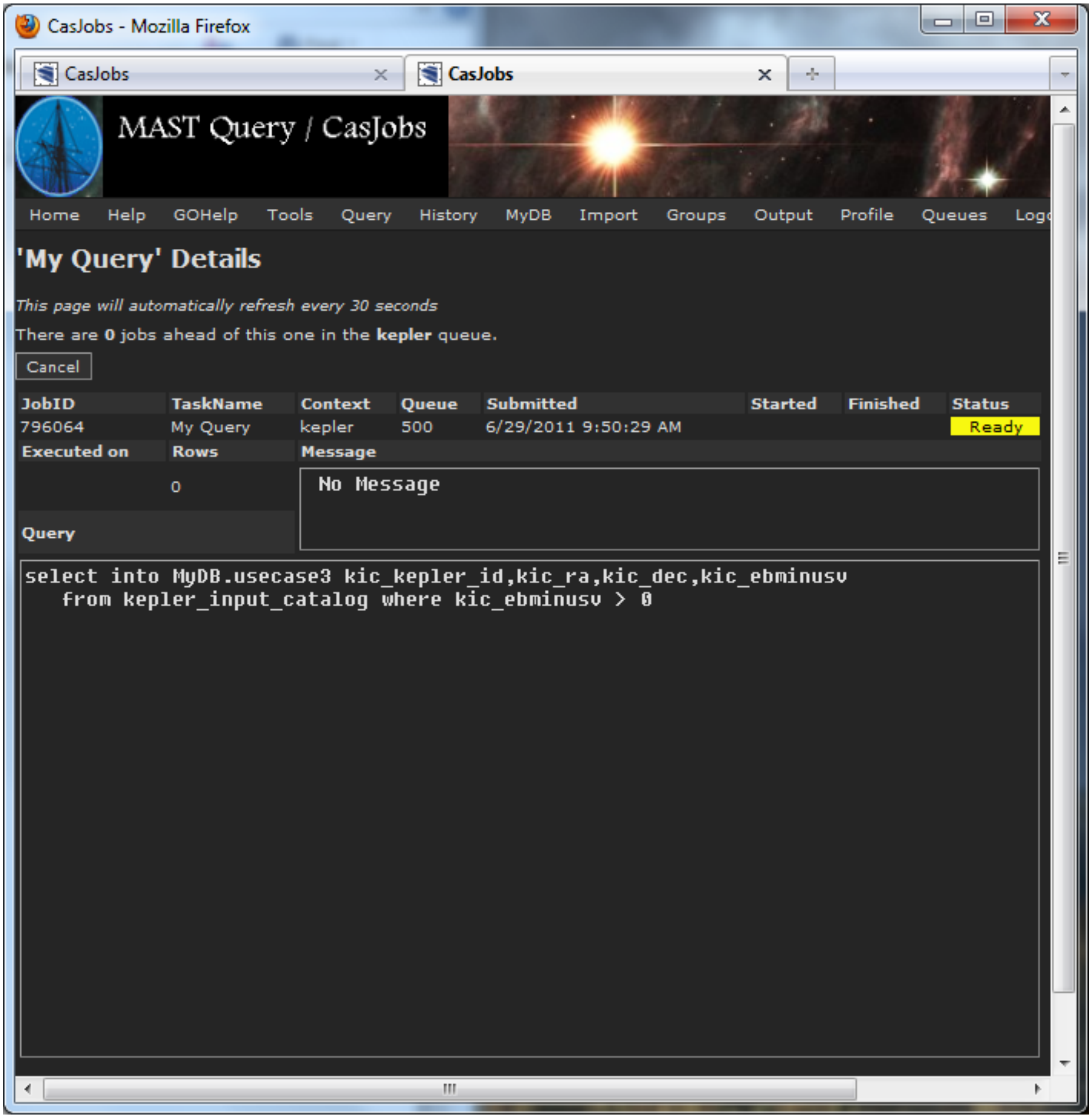


Figure 3-7 CasJob Query Status Page

To examine the results, click on “MyDB” in the menu bar. Use the drop-down menu to select the MyDB context. A screen similar to that shown in Figure 3.8 will be displayed. Note the table with the results, “usecase3.” It contains 2,106,821 records.

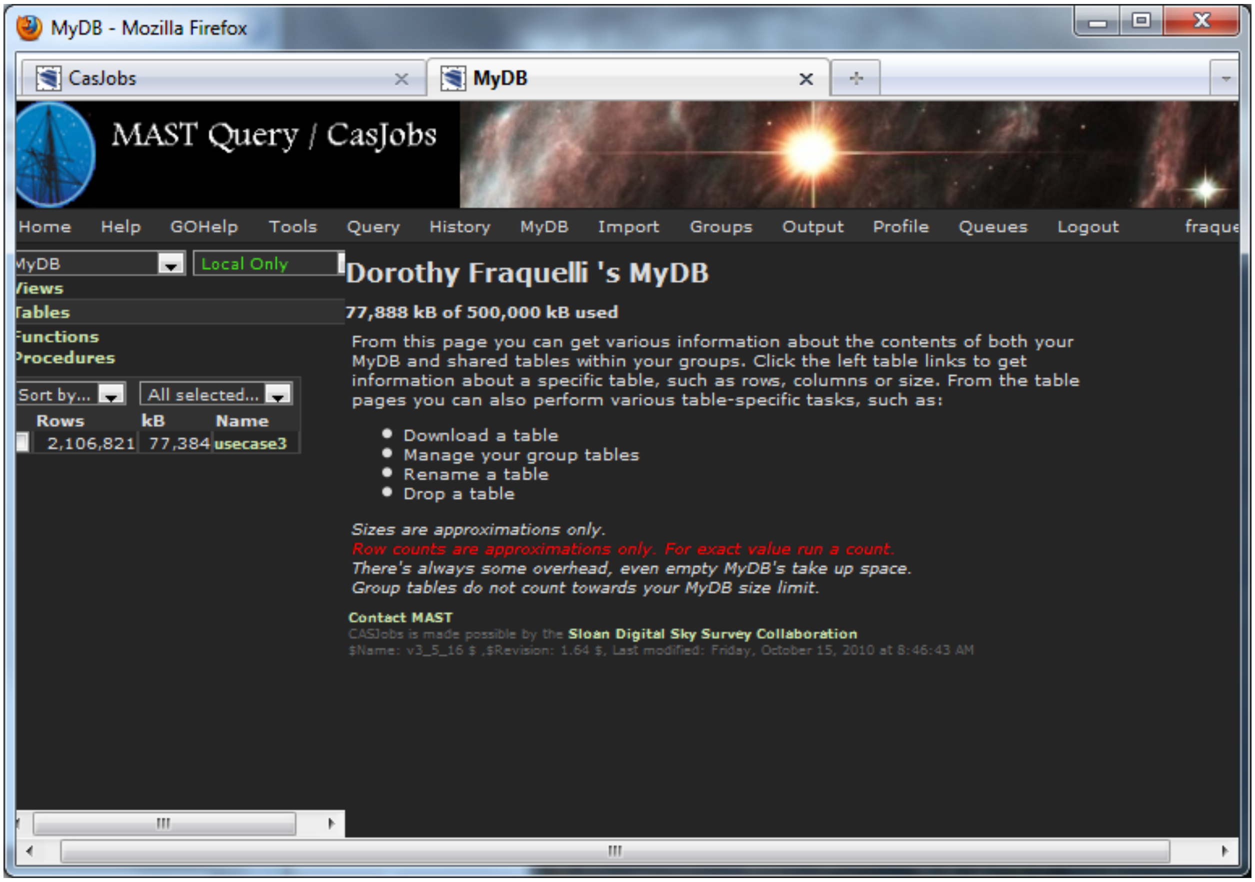


Figure 3-8 CasJobs MyDB page

Table "usecase3" may be queried, just like the kepler_input_catalog table, to examine the records it contains. To do so, click on "Query" in the menu bar. Set the context box to "MyDB" via the pull down menu. A simple query would be

```
select top 20 * from usecase3 where kic_ebminusv > 1.3
```

where the * means return the values in all the columns of the table, and the "where clause" says show me only those records where E(B-V) is greater than 1.3. The results are shown in Figure 3.9.

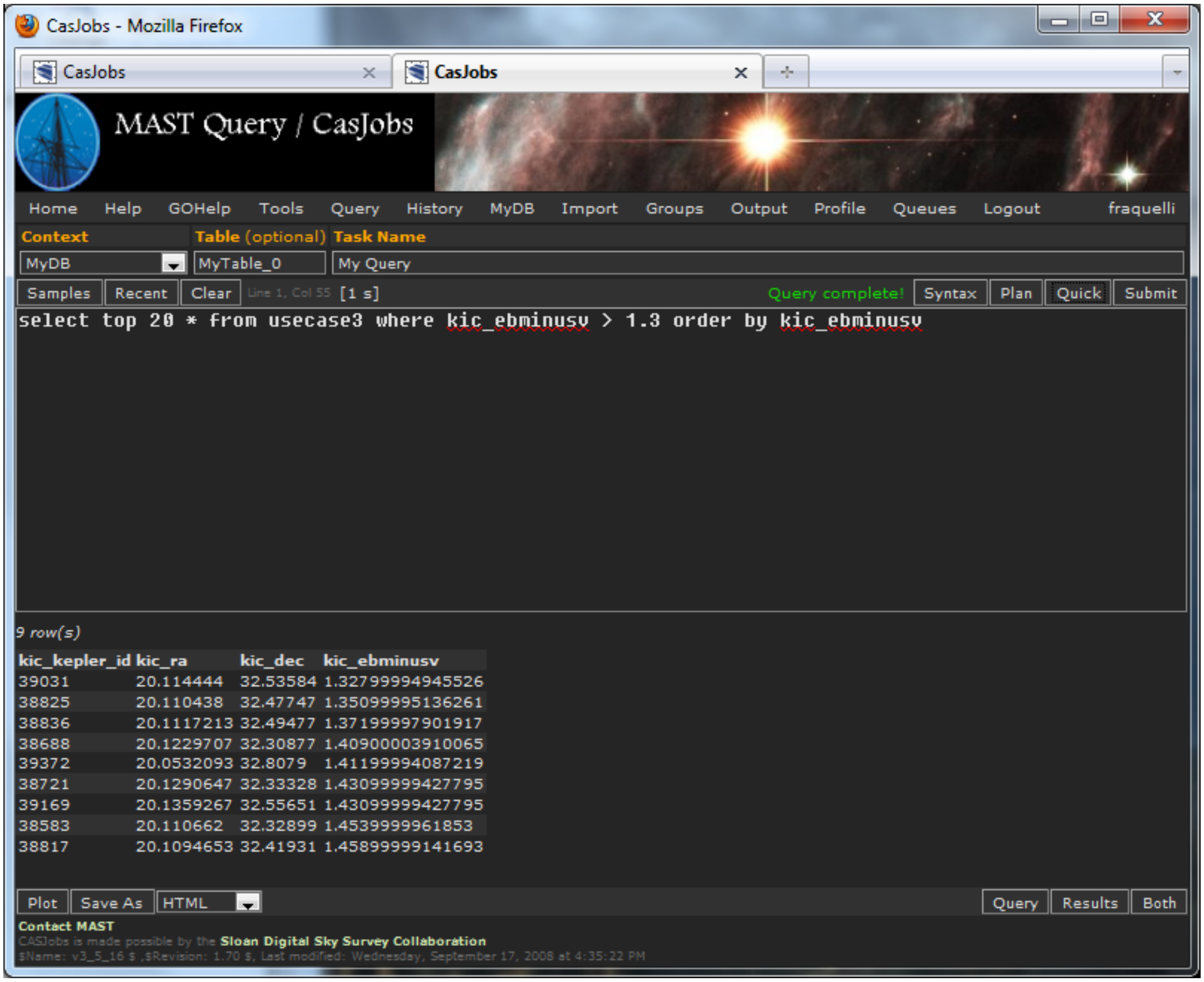


Figure 3-9 Results of search on MyDB table usecase3

Other options for Use Case 3:

Using the standard MAST/Kepler search form, while possible, will drive your graduate student insane. There are some 12.5 million records in the Kepler Target table, more than 13 million in the KIC, and the maximum number of results returned per search is 50,001. This means some 250 searches, or more, would be required to cover the full Kepler FOV.

MAST allows access to the catalog via scripts and http get requests. On-line help is available through the MAST services link on the MAST/Kepler home page. Taking advantage of the module/output structure of the Kepler detectors, http get requests may be issued for each mod/out. Below is an example of such a request. It is set up for mod/out 2.1, qualifies the "seasons target on CCD" as "unspecified," and requests the kepler_id and E(B_V) values be returned in a comma separated variable (CSV) format. Using this get request reduces the number of searches to 84, one for each mod/out.

http://archive.stsci.edu/kepler/kepler_fov/search.php?kct_module_season_0_value=2&kct_output_season_0_value=1&seasons=unspecified&max_records=400000&selectedColumnsCsv=kic_kepler_id,kic_ebminusv&outputformat=CSV&action=Search

A partial list of the output is listed here. The number of returned records for this get request is 101876

```
Kepler_ID,E(B-V)
integer,float
1862390,
1862391,
1862398,
1862400,
1862405,
1862421,
1862425,
1862437,
1862445,
1862446,
1862456,
1862458,
1862461,
1862462,
1862465,
1862467,
1862471,
1862472,
1862473,0.230
1862474,
1862475,
1862476,
1862479,
1862482,
1862485,
1862489,0.156
```

As can be seen, a significant number of the KIC entries do not have E(B-V) values. Perhaps a better search would be "give me the E(B-V)'s, where they exist, of all the KIC objects, whether they fall on the Kepler detectors or not." A check of the column help shows the range of E(B-V) in the KIC is 0.001 to 0.521. This allows us to add a simple qualifier to the get request: E(B-V) > 0, which is written as =%3E0.0 in the get request, below. The "%3E" is used for the > in the get request. Note the = sign must also be included in the qualifier. If it is not included, no qualification will be done on the E(B-V) value. A partial list of the output for the modified get request is listed below. The Ra, Dec and 2MASS id have been added to the output columns.

http://archive.stsci.edu/kepler/kepler_fov/search.php?kct_module_season_0_value=2&kct_output_season_0_value=1&seasons=unspecified&kic_ebminusv=%3E0.0&max_records=400000&selectedColumnsCsv=kic_kepler_id,kic_ebminusv,kic_degree_ra,kic_dec,kic_2mass_id&outputformat=CSV&action=Search

```
Kepler_ID,E(B-V),RA (J2000),Dec (J2000),2MASS ID
integer,float,ra,dec,string
1862473,0.230,19 20 10.42,+37 22 28.2,19201041+3722282
1862489,0.156,19 20 11.50,+37 23 49.8,19201150+3723498
1862518,0.130,19 20 13.05,+37 22 27.1,19201304+3722270
1862519,0.168,19 20 13.06,+37 23 34.2,19201305+3723342
```

If users truly want to search the KIC, they will need to use the CasJobs interface. This is because the mod/out values are not in the KIC, so the work around we used with the get request search of the Kepler Target table will not work for the KIC.

Example Target Searches: Use Case 4

The user wants to select likely extragalactic objects using a color cut. Most objects occupying the GALEX/Sloan color domain 0.3 < NUVg < 3.0, 0.8 < gi < 1.8 are galaxies (Bianchi et al. 2007, ApJS, 173, 659). Figure 3-10 gives an example of how to use the target search page to constrain the colors and magnitudes from the GALEX and Sloan catalogs. However, to insure that only distant objects are selected we add a faintness (magnitude) condition, g > 19.0. The table on the retrieval page for the combined color and faintness conditions gives 6700 KIC objects. Were we to remove the g > 19 faintness constraint, the number increases only to 7117. This shows that the color conditions alone do a good job of selecting only this class of objects.

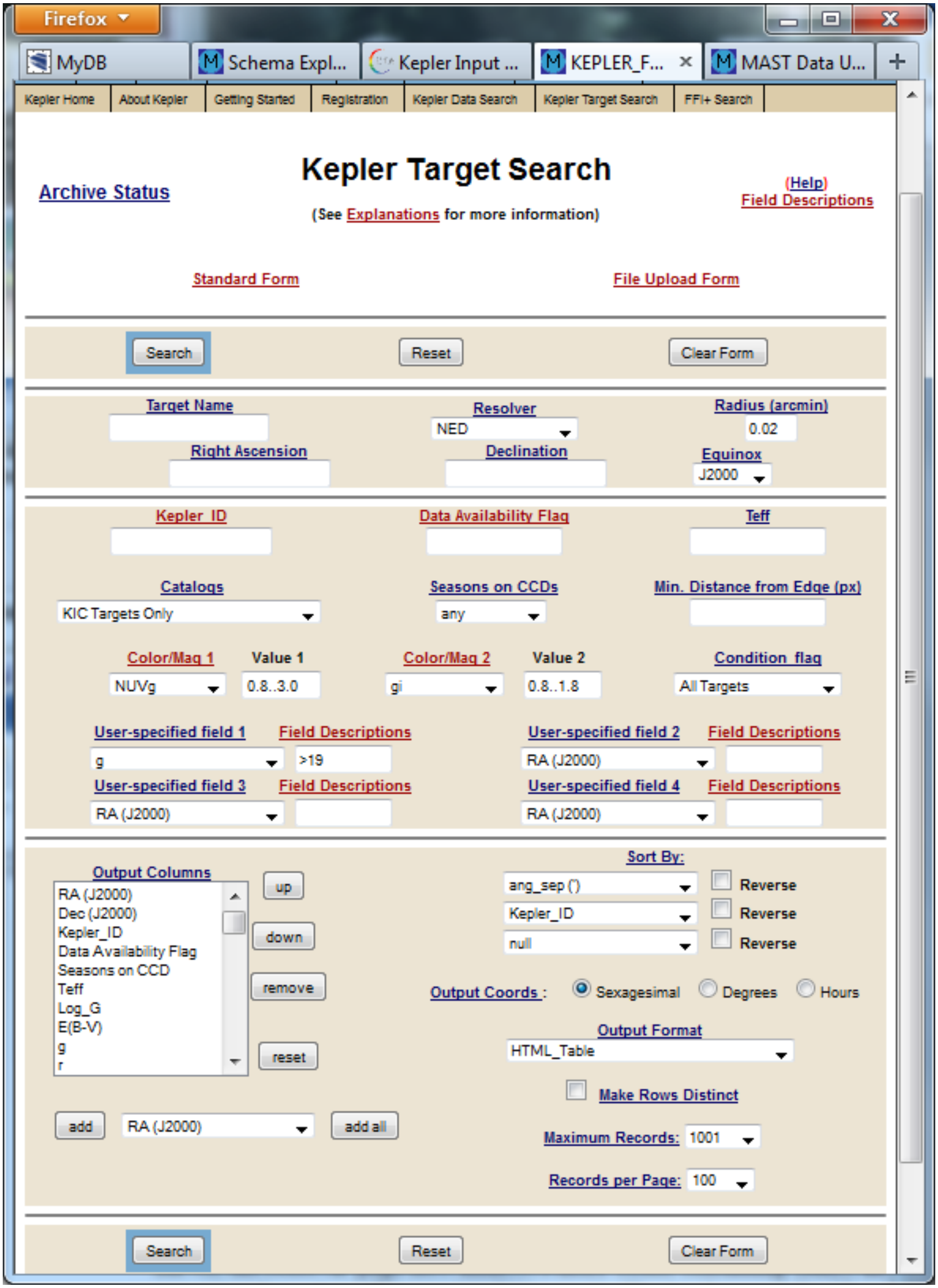


Figure 3-10: Target Search using Sloan/GALEX colors and magnitudes.

3.2.2 Kepler Data Searches

Users wishing to search for and/or retrieve Kepler data should use the Data Search and Retrieval Form, which is available at http://archive.stsci.edu/kepler/data_search/search.php. The features of this form are similar to those of the Target Search Form and function in the same way. On-line help is available. The search for data uses information from the archive tables, the KIC, and the KTC.

A note about target pixel files: Where a light curve has a matching target pixel file, users will only see the light curve file listed in the search results. However, the user may request the target pixel file be delivered with the light curve. If no light curve file is available, but a target pixel file exists, the target pixel file record will be included in the search results. The "Datasets Marked for Retrieval" page will show records for both light curve and target pixel files. The "Class" field on this page indicates if the record is for a light curve (archive class CSC or CLC) or a target pixel file (archive class TPL or TPS).

The Kepler data tables contain several values pulled directly from the archived light curve and target pixel files. These include the actual start time, the actual stop time, crowding, flux fraction, 3-hr CDPP, 6-hr CDPP, and 12-hr CDPP. A description of how to retrieve these CDPP values is described below.

Figure 3-11 shows the Data Search and Retrieval Form set up for a very simple search, with only the Kepler ID as a qualifier. The results of this search are shown in Figure 3-12. To send a retrieval request for these data, click the "Mark" boxes or click on "Mark all", as shown in Figure 3-13, then click on "Submit marked data for retrieval from STDAS." This will open up the Retrieval Options page, as shown in Figure 3-14.

The Retrieval Options Form is used for retrieval of public and proprietary data, and for anonymous retrievals of public data. For proprietary data, the user **must** enter their archive account username and password. For public or non-proprietary data, an archive account or anonymous retrieval is available. Enter anonymous for the "Archive Username" and your e-mail for the "Archive Password". For all requests, even anonymous, a valid e-mail account is necessary in order for the archive to send status information regarding the retrieval request.

Under Delivery Options, indicate how the data should be delivered. If requesting "FTP" delivery, fill out the boxes on the right side of the page, giving the name of the receiving computer, the location for the data, and a valid account name and password. Click on "Send retrieval request to ST-DADS." Some error checking is done for data that are to be ftp'ed, to ensure access to the computer and location for the data. A confirming e-mail is sent if the checks pass. If there is a problem, an e-mail reporting the problem is sent to the user.

If the "Stage" option is selected, the retrieved data are written to an Archive staging disk. The data will remain in this location for 2 days. The user is responsible for ftp'ing the data from the staging disk. After clicking on "Submit", the page shown in Figure 3-15 is displayed.

Standard ftp is used to retrieve data from the staging disk. Users are advised to issue `bin` (for binary) and, if using mget, `prompt` (to turn off prompting). Attempting to ftp the data from the staging disk before the retrieval is complete will result in incomplete datasets. The ftp should not be started until after the completion e-mail has been received.

For all retrievals, e-mail is sent confirming the retrieval request was received, where the data will be placed and what datasets will be retrieved. After the retrieval is complete, a second e-mail is sent listing the files that were delivered. If the "Stage" option was used, the location of the data is sent.

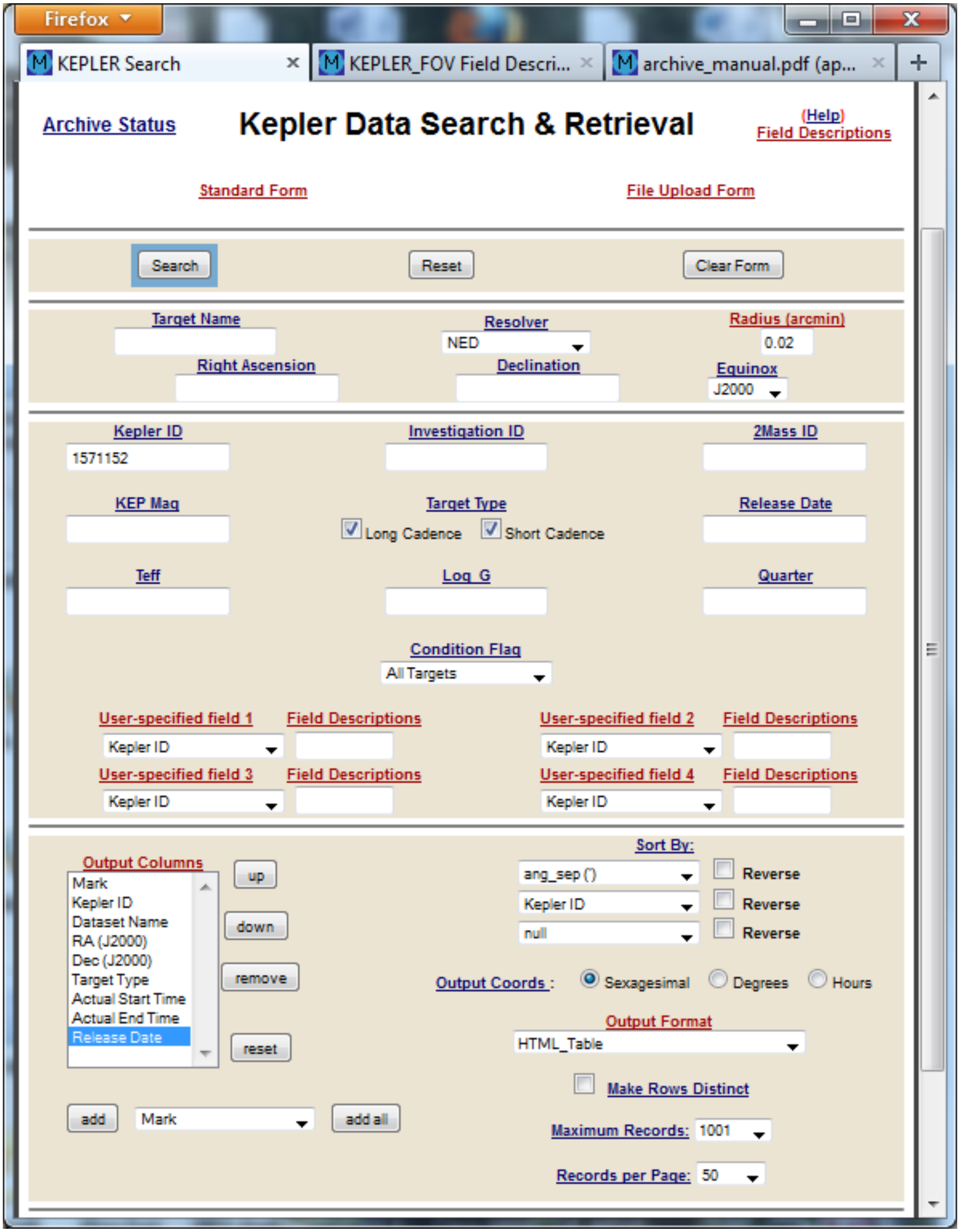
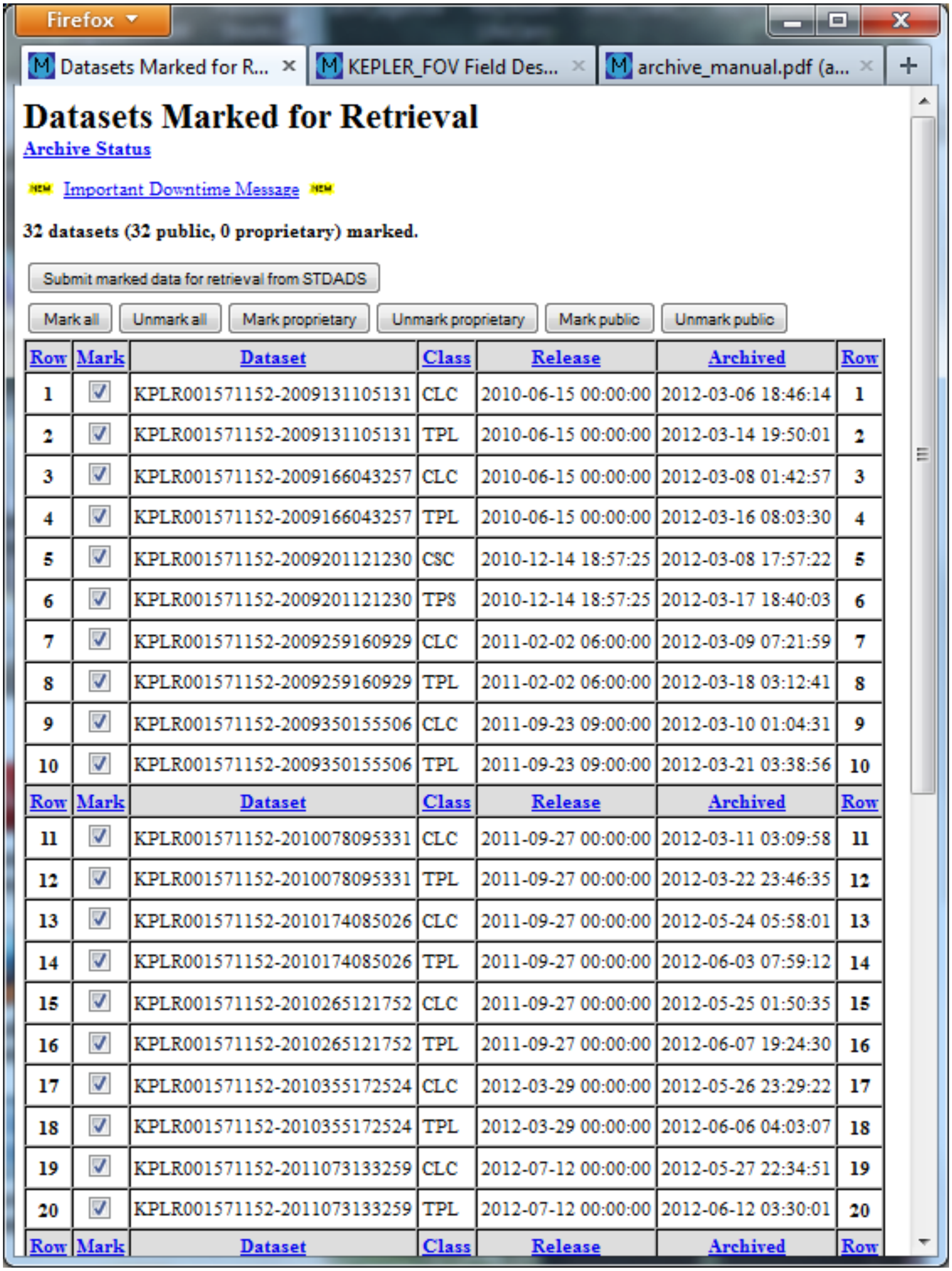

Firefox
KEPLER Search
KEPLER_FOV Field Descri...
archive_manual.pdf (ap...
Archive Status
Kepler Data Search & Retrieval
(Help)
Field Descriptions
Standard Form
File Upload Form
Search
Reset
Clear Form
Target Name
Resolver
NED
Radius (arcmin)
0.02
Right Ascension
Declination
Equinox
J2000
Kepler ID
1571152
Investigation ID
2Mass ID
KEP Mag
Target Type
Long Cadence
Short Cadence
Release Date
Teff
Log G
Quarter
Condition Flag
All Targets
User-specified field 1
Field Descriptions
Kepler ID
User-specified field 2
Field Descriptions
Kepler ID
User-specified field 3
Field Descriptions
Kepler ID
User-specified field 4
Field Descriptions
Kepler ID
Output Columns
Mark
Kepler ID
Dataset Name
RA (J2000)
Dec (J2000)
Target Type
Actual Start Time
Actual End Time
Release Date
up
down
remove
reset
add
Mark
add all
Sort By:
ang_sep ()
Reverse
Kepler ID
Reverse
null
Reverse
Output Coords :
Sexagesimal
Degrees
Hours
Output Format
HTML_Table
Make Rows Distinct
Maximum Records:
1001
Records per Page:
50

Figure 3-11 The MAST Data Search and Retrieval Form

Mark	Dataset Name	Archive Class	Quarter	Release Date
☑	KPLR001571152-2009131105131	CLC	0	2010-06-15 00:00:00
☑	KPLR001571152-2009166043257	CLC	1	2010-06-15 00:00:00
☑	KPLR001571152-2009201121230	CSC	2	2010-12-14 18:57:25
☑	KPLR001571152-2009259160929	CLC	2	2011-02-02 06:00:00
☑	KPLR001571152-2009350155506	CLC	3	2011-09-23 09:00:00
☑	KPLR001571152-2010078095331	CLC	4	2011-09-27 00:00:00
☑	KPLR001571152-2010174085026	CLC	5	2011-09-27 00:00:00
☑	KPLR001571152-2010265121752	CLC	6	2011-09-27 00:00:00
☑	KPLR001571152-2010355172524	CLC	7	2012-03-29 00:00:00
☑	KPLR001571152-2011073133259	CLC	8	2012-07-12 00:00:00
☑	KPLR001571152-2011177032512	CLC	9	2012-10-28 00:00:00
☑	KPLR001571152-2011271113734	CLC	10	2012-10-28 00:00:00
☑	KPLR001571152-2012004120508	CLC	11	2012-10-28 00:00:00
☑	KPLR001571152-2012088054726	CLC	12	2012-10-28 00:00:00
☑	KPLR001571152-2012179063303	CLC	13	2012-10-28 00:00:00
☑	KPLR001571152-2012277125453	CLC	14	2013-02-06 12:07:49

Figure 3-12 Data Search Results



Datasets Marked for Retrieval

Archive Status

NEW Important Downtime Message NEW

32 datasets (32 public, 0 proprietary) marked.

Submit marked data for retrieval from STDADS

Mark all | Unmark all | Mark proprietary | Unmark proprietary | Mark public | Unmark public

Row	Mark	Dataset	Class	Release	Archived	Row
1	☑	KPLR001571152-2009131105131	CLC	2010-06-15 00:00:00	2012-03-06 18:46:14	1
2	☑	KPLR001571152-2009131105131	TPL	2010-06-15 00:00:00	2012-03-14 19:50:01	2
3	☑	KPLR001571152-2009166043257	CLC	2010-06-15 00:00:00	2012-03-08 01:42:57	3
4	☑	KPLR001571152-2009166043257	TPL	2010-06-15 00:00:00	2012-03-16 08:03:30	4
5	☑	KPLR001571152-2009201121230	CSC	2010-12-14 18:57:25	2012-03-08 17:57:22	5
6	☑	KPLR001571152-2009201121230	TPS	2010-12-14 18:57:25	2012-03-17 18:40:03	6
7	☑	KPLR001571152-2009259160929	CLC	2011-02-02 06:00:00	2012-03-09 07:21:59	7
8	☑	KPLR001571152-2009259160929	TPL	2011-02-02 06:00:00	2012-03-18 03:12:41	8
9	☑	KPLR001571152-2009350155506	CLC	2011-09-23 09:00:00	2012-03-10 01:04:31	9
10	☑	KPLR001571152-2009350155506	TPL	2011-09-23 09:00:00	2012-03-21 03:38:56	10
Row	Mark	Dataset	Class	Release	Archived	Row
11	☑	KPLR001571152-2010078095331	CLC	2011-09-27 00:00:00	2012-03-11 03:09:58	11
12	☑	KPLR001571152-2010078095331	TPL	2011-09-27 00:00:00	2012-03-22 23:46:35	12
13	☑	KPLR001571152-2010174085026	CLC	2011-09-27 00:00:00	2012-05-24 05:58:01	13
14	☑	KPLR001571152-2010174085026	TPL	2011-09-27 00:00:00	2012-06-03 07:59:12	14
15	☑	KPLR001571152-2010265121752	CLC	2011-09-27 00:00:00	2012-05-25 01:50:35	15
16	☑	KPLR001571152-2010265121752	TPL	2011-09-27 00:00:00	2012-06-07 19:24:30	16
17	☑	KPLR001571152-2010355172524	CLC	2012-03-29 00:00:00	2012-05-26 23:29:22	17
18	☑	KPLR001571152-2010355172524	TPL	2012-03-29 00:00:00	2012-06-06 04:03:07	18
19	☑	KPLR001571152-2011073133259	CLC	2012-07-12 00:00:00	2012-05-27 22:34:51	19
20	☑	KPLR001571152-2011073133259	TPL	2012-07-12 00:00:00	2012-06-12 03:30:01	20
Row	Mark	Dataset	Class	Release	Archived	Row

Figure 3-13 Marked Datasets for Retrieval

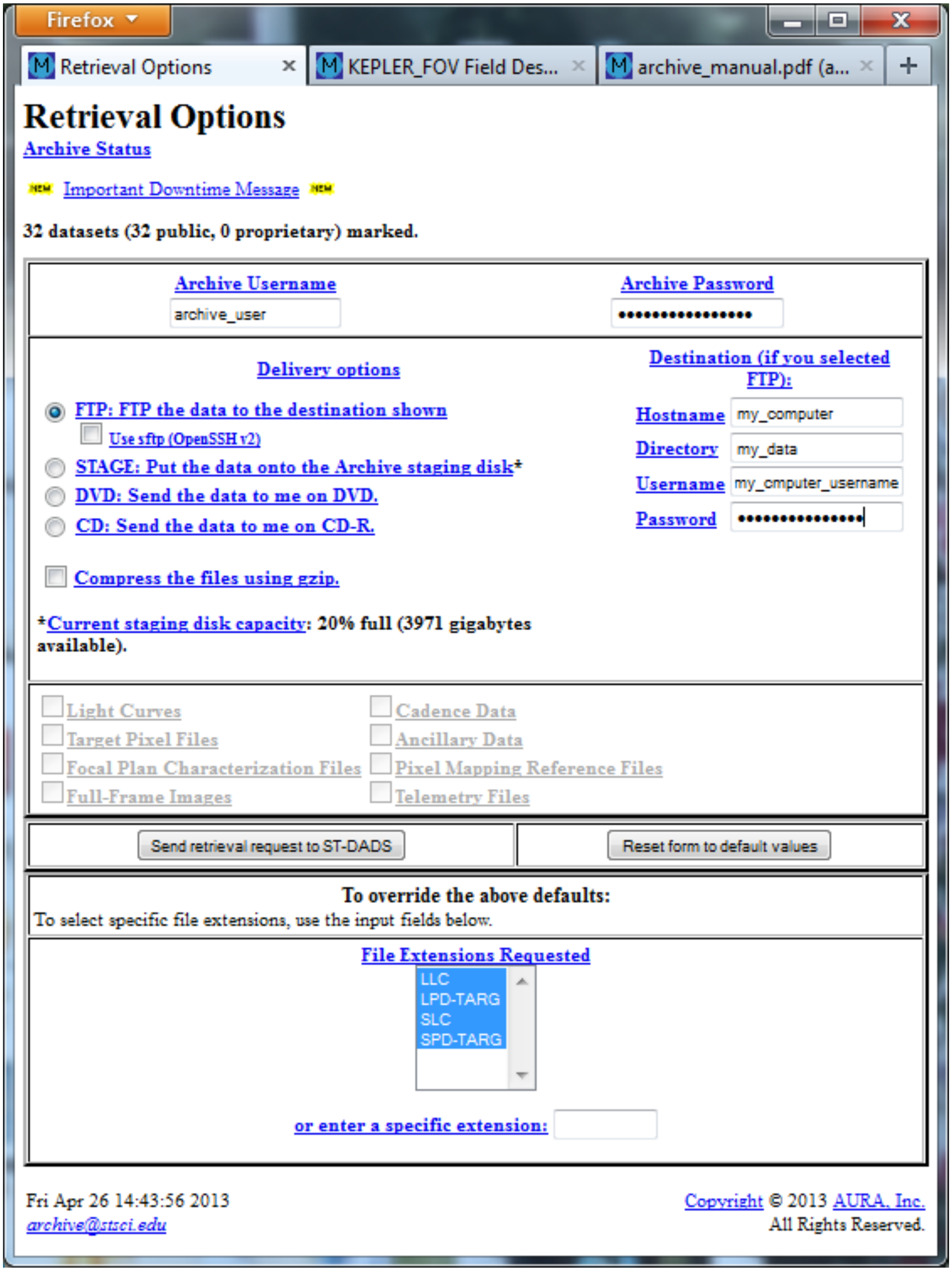


Figure 3-14 Retrieval Options Page

Figure 3-15 Confirmation Page

Example Data Searches

All searches for Kepler data are, by definition, searches of the KTC, and will use the MAST Data Search & Retrieval form, http://archive.stsci.edu/kepler/data_search/search.php . The ultimate purpose of a data search is retrieval of data from the archive. Check the fields listed in the "Output Columns" box. Also check the format in the "Output Format" box. By default, search results are displayed as an html table.

Example Data Searches: Use Case 1

I'm a Kepler GO and I want to download my data.

This is a simple procedure. Starting at the main MAST web site, http://archive.stsci.edu/ , under "Mission Search" in the bar across the upper portion on the page, select "Kepler Data." This will take you to the Kepler Data Search & Retrieval form, http://archive.stsci.edu/kepler/data_search/search.php.

Put the investigation id for your GO proposal in the box labeled "Investigation_ID." You should include a wild card on both ends of the investigation id, in case one or more of your targets are shared with another investigation. For example, enter %GO20025% instead of GO20025. Figure 3-16 shows the Data Search & Retrieval, qualified as stated and Figure 3-17 shows the results page. Follow the instructions in section 3.2.2 to retrieve the data.

Example Data Searches: Use Case 2

I want to know if there are Kepler data in the archive for cool giant stars.

The Kepler Team has provided a list of targets they identify as Red Giants. To find observations of these targets, use the "Condition Flag" on the "Kepler Data Search and Retrieval Page," as shown in Figure 3-18. A partial set of results is shown in Figure 3-19.

There may be other targets in the archive that are Red Giants. The KIC values for temperature and surface gravity may be used to perform a search for these data. Set up the Data Search & Retrieval form by putting the temperature and log g ranges in the "Temperature" and "Log G" boxes. Adjust the "Output Columns" and check the "Output Format." Click "Search" to initiate the search. See Figure 3-20 for the qualified form and Figure 3-21 for the search results.

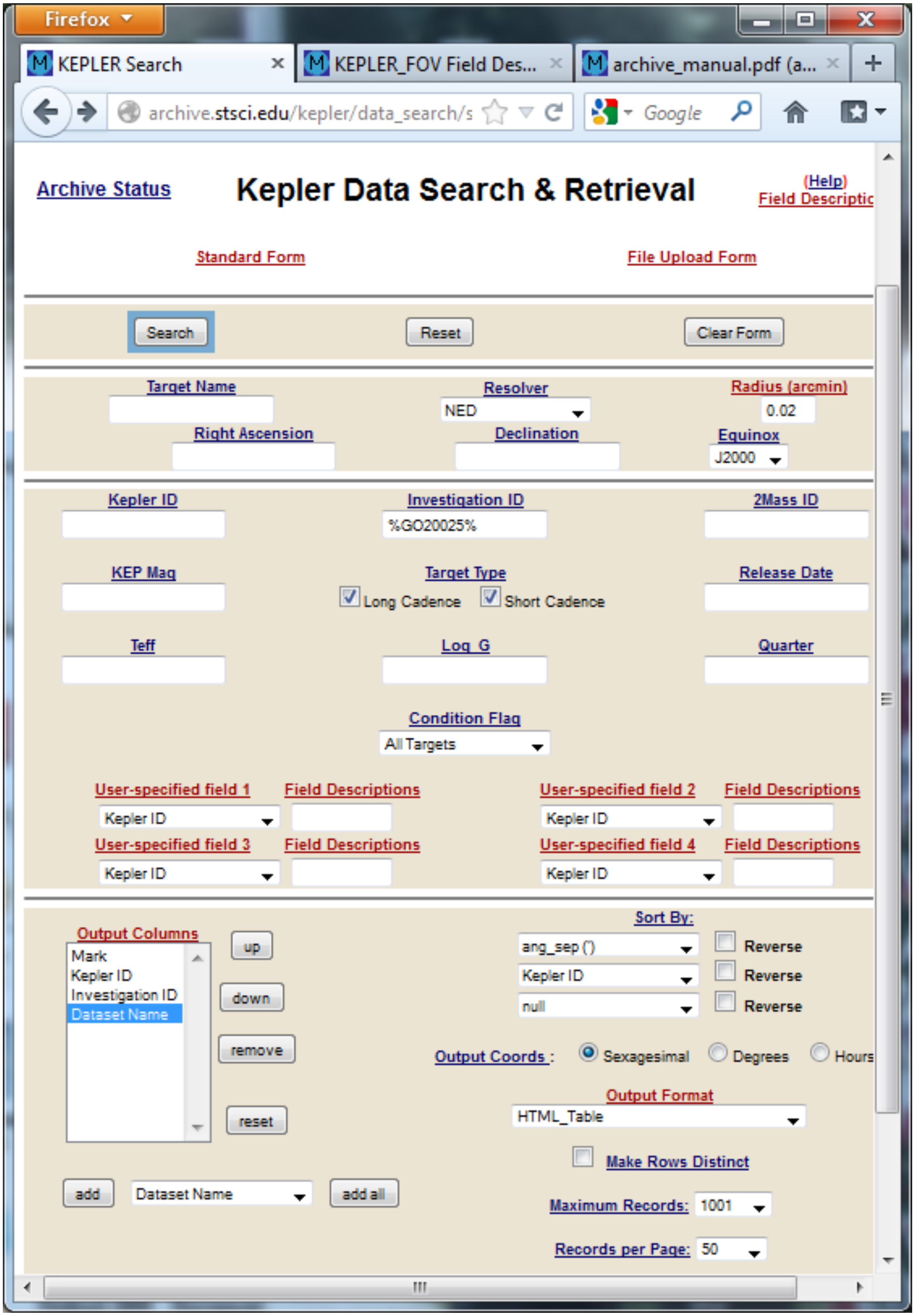


Figure 3-16 Use case 1 qualified search form

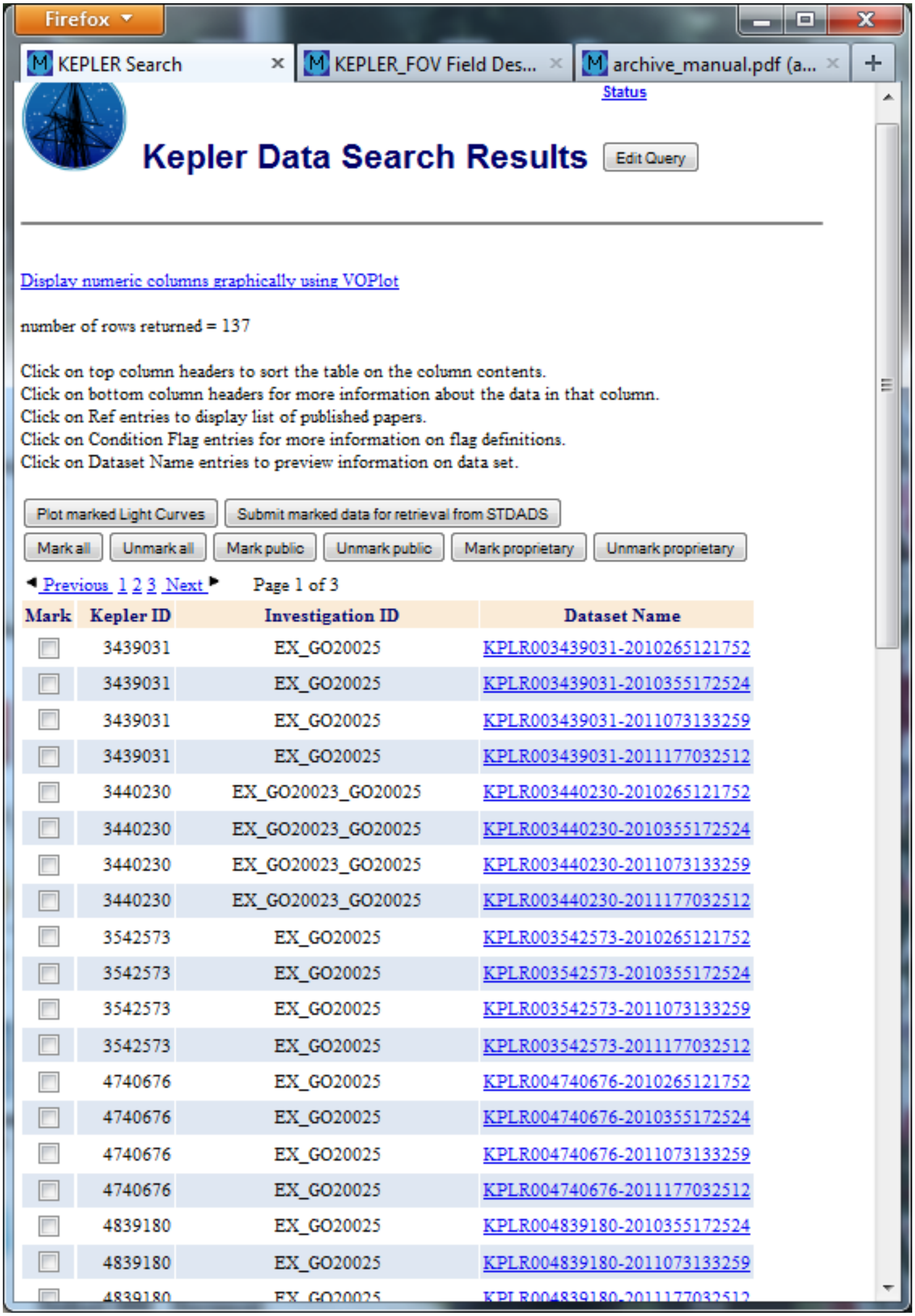


Figure 3-17 Use case 1 search results

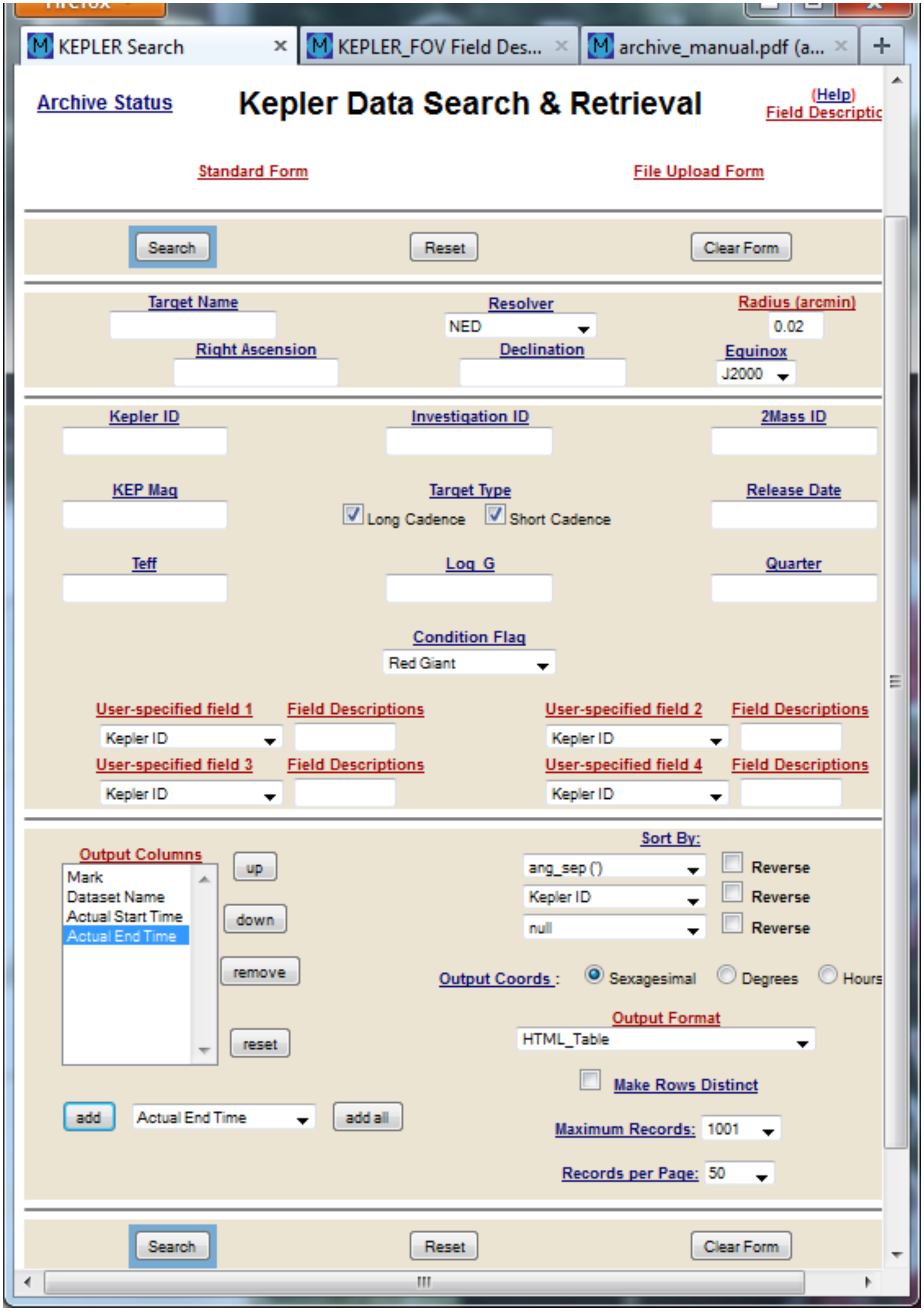
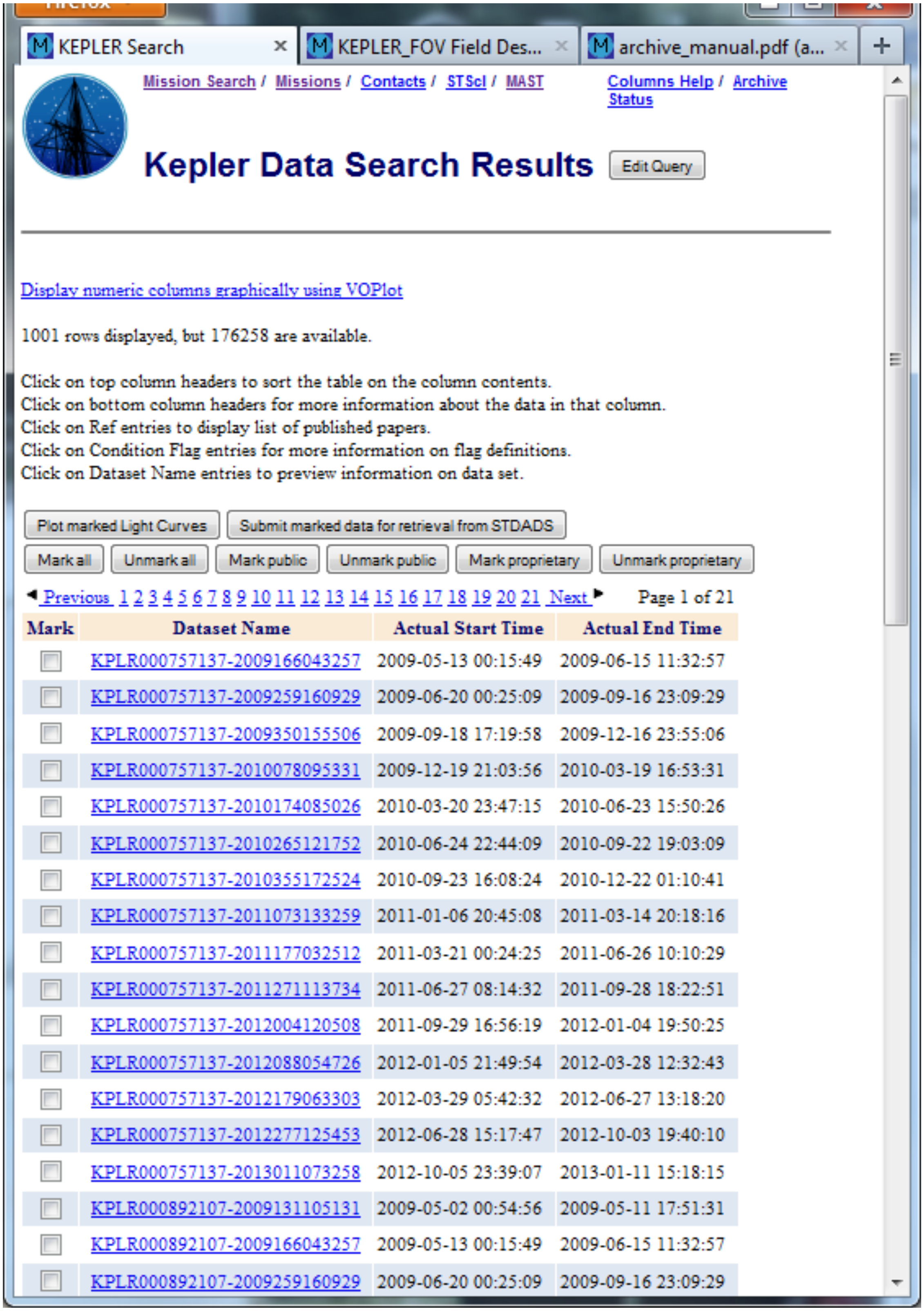


Figure 3-18 Red Giant Data Search Result



KEPLER Search | KEPLER_FOV Field Des... | archive_manual.pdf (a...

Mission Search / Missions / Contacts / STScI / MAST   Columns Help / Archive Status

Kepler Data Search Results

Edit Query

Display numeric columns graphically using VOPlot

1001 rows displayed, but 176258 are available.

Click on top column headers to sort the table on the column contents.
Click on bottom column headers for more information about the data in that column.
Click on Ref entries to display list of published papers.
Click on Condition Flag entries for more information on flag definitions.
Click on Dataset Name entries to preview information on data set.

Plot marked Light Curves | Submit marked data for retrieval from STDADS

Mark all | Unmark all | Mark public | Unmark public | Mark proprietary | Unmark proprietary

◄ Previous 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 Next ► Page 1 of 21

Mark	Dataset Name	Actual Start Time	Actual End Time
☐	KPLR000757137-2009166043257	2009-05-13 00:15:49	2009-06-15 11:32:57
☐	KPLR000757137-2009259160929	2009-06-20 00:25:09	2009-09-16 23:09:29
☐	KPLR000757137-2009350155506	2009-09-18 17:19:58	2009-12-16 23:55:06
☐	KPLR000757137-2010078095331	2009-12-19 21:03:56	2010-03-19 16:53:31
☐	KPLR000757137-2010174085026	2010-03-20 23:47:15	2010-06-23 15:50:26
☐	KPLR000757137-2010265121752	2010-06-24 22:44:09	2010-09-22 19:03:09
☐	KPLR000757137-2010355172524	2010-09-23 16:08:24	2010-12-22 01:10:41
☐	KPLR000757137-2011073133259	2011-01-06 20:45:08	2011-03-14 20:18:16
☐	KPLR000757137-2011177032512	2011-03-21 00:24:25	2011-06-26 10:10:29
☐	KPLR000757137-2011271113734	2011-06-27 08:14:32	2011-09-28 18:22:51
☐	KPLR000757137-2012004120508	2011-09-29 16:56:19	2012-01-04 19:50:25
☐	KPLR000757137-2012088054726	2012-01-05 21:49:54	2012-03-28 12:32:43
☐	KPLR000757137-2012179063303	2012-03-29 05:42:32	2012-06-27 13:18:20
☐	KPLR000757137-2012277125453	2012-06-28 15:17:47	2012-10-03 19:40:10
☐	KPLR000757137-2013011073258	2012-10-05 23:39:07	2013-01-11 15:18:15
☐	KPLR000892107-2009131105131	2009-05-02 00:54:56	2009-05-11 17:51:31
☐	KPLR000892107-2009166043257	2009-05-13 00:15:49	2009-06-15 11:32:57
☐	KPLR000892107-2009259160929	2009-06-20 00:25:09	2009-09-16 23:09:29

Figure 3-19 Red Giant Data Search Results

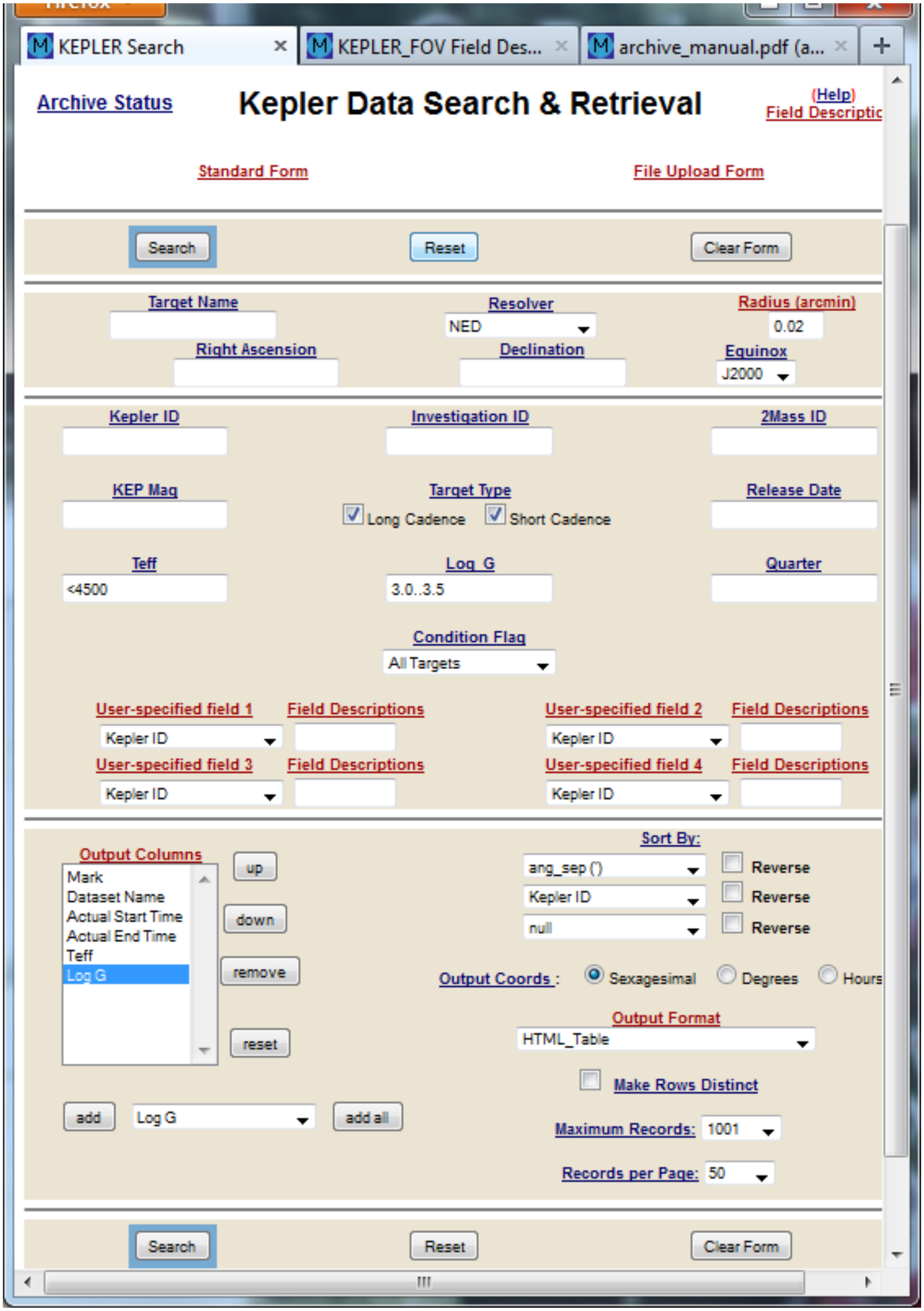


Figure 3-20 Use case 2 Red Giant Search

Display numeric columns graphically using VOPlot

number of rows returned = 334

Click on top column headers to sort the table on the column contents.
Click on bottom column headers for more information about the data in that column.
Click on Ref entries to display list of published papers.
Click on Condition Flag entries for more information on flag definitions.
Click on Dataset Name entries to preview information on data set.

Plot marked Light Curves | Submit marked data for retrieval from STDADS

Mark all | Unmark all | Mark public | Unmark public | Mark proprietary | Unmark proprietary

◂ Previous 1 2 3 4 5 6 7 Next ▸ Page 1 of 7

Mark	Dataset Name	Actual Start Time	Actual End Time	Teff	Log G
☐	KPLR001873513-2012277125453	2012-06-28 15:17:47	2012-10-03 19:40:10	3109	3.210
☐	KPLR001873513-2013011073258	2012-10-05 23:39:07	2013-01-11 15:18:15	3109	3.210
☐	KPLR002860885-2009166043257	2009-05-13 00:15:49	2009-06-15 11:32:57	4497	3.011
☐	KPLR002860885-2009259160929	2009-06-20 00:25:09	2009-09-16 23:09:29	4497	3.011
☐	KPLR002860885-2009350155506	2009-09-18 17:19:58	2009-12-16 23:55:06	4497	3.011
☐	KPLR002860885-2010265121752	2010-06-24 22:44:09	2010-09-22 19:03:09	4497	3.011
☐	KPLR002860885-2011271113734	2011-06-27 08:14:32	2011-09-28 18:22:51	4497	3.011
☐	KPLR002860885-2012277125453	2012-06-28 15:17:47	2012-10-03 19:40:10	4497	3.011
☐	KPLR003430205-2009131105131	2009-05-02 00:54:56	2009-05-11 17:51:31	4468	3.049
☐	KPLR003430205-2009166043257	2009-05-13 00:15:49	2009-06-15 11:32:57	4468	3.049
☐	KPLR003430205-2009259160929	2009-06-20 00:25:09	2009-09-16 23:09:29	4468	3.049
☐	KPLR003430205-2009350155506	2009-09-18 17:19:58	2009-12-16 23:55:06	4468	3.049
☐	KPLR003430205-2010078095331	2009-12-19 21:03:56	2010-03-19 16:53:31	4468	3.049
☐	KPLR003430205-2010265121752	2010-06-24 22:44:09	2010-09-22 19:03:09	4468	3.049
☐	KPLR003430205-2010355172524	2010-09-23 16:08:24	2010-12-22 01:10:41	4468	3.049
☐	KPLR003430205-2011271113734	2011-06-27 08:14:32	2011-09-28 18:22:51	4468	3.049
☐	KPLR003430205-2012004120508	2011-09-29 16:56:19	2012-01-04 19:50:25	4468	3.049
☐	KPLR003430205-2012277125453	2012-06-28 15:17:47	2012-10-03 19:40:10	4468	3.049
☐	KPLR003750264-2010174085026	2010-03-20 23:47:15	2010-06-23 15:50:26	3916	3.012
☐	KPLR003750264-2010265121752	2010-06-24 22:44:09	2010-09-22 19:03:09	3916	3.012

Figure 3-21 Partial list of search results for use case 2

3.2.3 FFI and Engineering Data Search and Retrieval or Download

Kepler Full Frame Image (FFI) and Engineering data are public. To search for a particular FFI, use the Kepler Full Frame Image (FFI) & Engineering Data Search page at http://archive.stsci.edu/kepler/ffi/search.php. The amount of metadata for FFIs is limited, with "start time", "end time" and "quarter" being the main fields. An example of the FFI Search form is given below in Figure 3-22.

To simply download the existing FFIs, go to http://archive.stsci.edu/pub/kepler/ffi/, either directly or from the MAST/Kepler home page. Click on the filename to download the file.

To display FFIs, without downloading them, go to the FFI display tool, either from the MAST/Kepler home page or directly at http://archive.stsci.edu/kepler/ffi_display.php. The opening page of this tool is shown in Figure 3-23, below.

This interface is also used to search for and retrieve engineering data and a variety of ancillary data files. The list of retrievable files is: Long and Short Cadence Collateral (COLL & COLS) files, Artifact Removal Pixel (ARP) files, Background Pixel (BKG) files, and Reverse Clock (RVC) files. To search for, say, Artifact Removal Pixel files, select Artifact Removal Pixel (ARP) from the pull down menu in the "Archive Class" form element. The page will change to include form elements appropriate for ARP data. For example, form elements for "quarter," "module" and others will appear. These elements may be qualified to see all ARPs for a given quarter, for a given mod, or both.

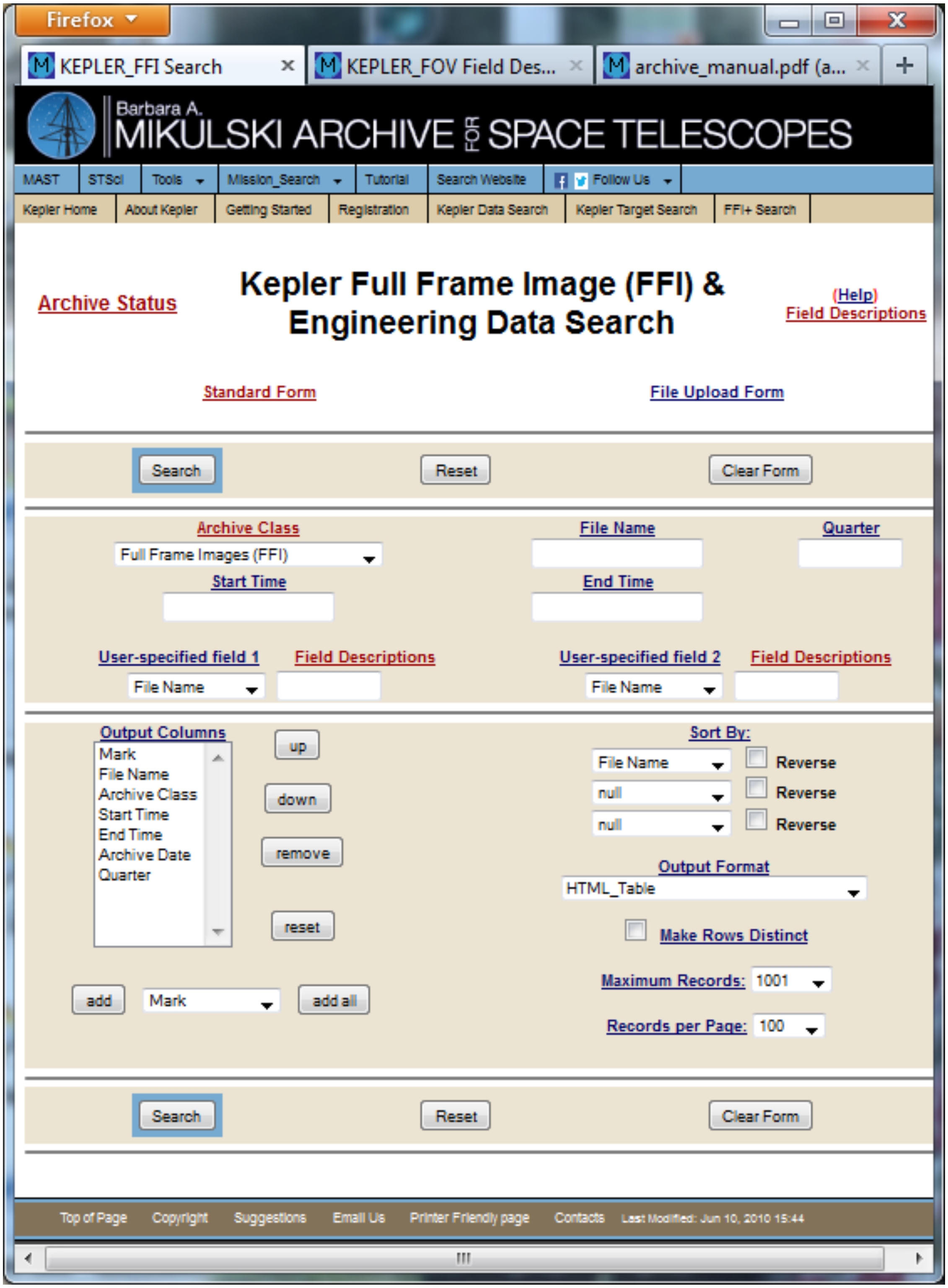


Figure 3-22 Standard FFI Search interface

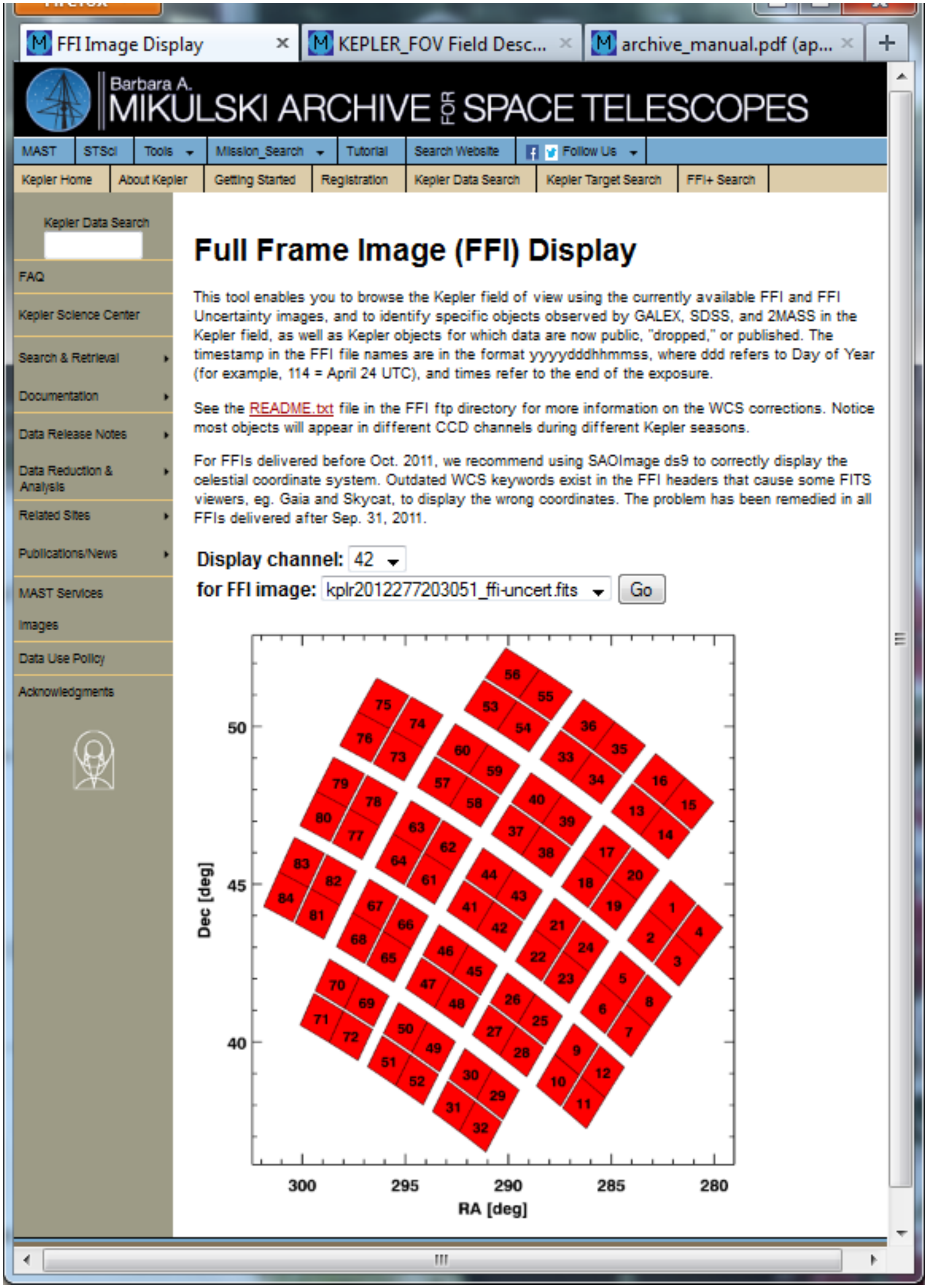


Figure 3-23 MAST's FFI Display Tool Opening Page

3.3 Other useful tools at MAST

The Kepler archive contains several other ways to retrieve useful data and tables. Here we describe a few that may of use to the Kepler user.

3.3.1 Kepler Object of Interest (KOI) Search Form

The Kepler Objects of Interest (KOI) table is produced by the Kepler project and provided to MAST by the NASA Exoplanet Science Institute (NExScI). The table lists planetary candidates, false positives, and confirmed exoplanets. Transit information, stellar parameters, and orbital information on possible exoplanets are included. The search form can be found at
http://archive.stsci.edu/kepler/koi/search.php

3.3.2 Confirmed Planets Search Form

Three separate search forms are available to search for Kepler confirmed Exoplanets. The first, Kepler Confirmed Planets KOI Information, at http://archive.stsci.edu/kepler/confirmed_planets/search.php, displays information obtained from the Kepler pipeline processing software. This information, which is also stored in the KOI table, describes the transit estimates and derived orbital parameters. Links are also provided to display available archived data and to query Simbad for the selected exoplanet. For non-KOI targets, these columns are blank.

Users should take care when entering values in the various KOI search forms. For example, Kepler-68c will return results if entered as the "Target Name." Other valid forms for the "Target Name" element are kepler-68c, kepler-68 c, and kepler 68 c. Note the spaces in these last two examples. However, for the "Planet Name" element, available in a "User-specified field," only the form kepler-68 c (**note the space**) yields any returns. Users are encouraged to wild card these values, for example, %68%, to reduce the error rate.

A second interface, Kepler Confirmed Planets Published Information, at http://archive.stsci.edu/kepler/published_planets/search.php lists the same set of confirmed planets but contains information extracted from the published papers by the staff at NExScI. The information available depends on the authors of each paper so many entries are left undefined, however this is the only table with information on non-KOI exoplanets. As above, the syntax for "Planet Name" is very specific, Kepler-68 c (**note the upper case K and the space**). Use of wildcards (%68 c or %68%) is encouraged.

Both forms should return the same list of exoplanets. Both search results include a link to see the results for the same entry from the other table.

A third form, Kepler KOI, at http://archive.stsci.edu/kepler/koi/search.php, provides access to the full list of KOIs and their dispositions as specified by the Kepler Team (FALSE POSITIVE, CANDIDATE, NOT DISPOSITIONED) and by NExScI (CONFIRMED, FALSE POSITIVE, CANDIDATE, NOT DISPOSITIONED). The table contains information about the detected transit event calculated from either the pipeline or from independent planetary model fits to the data.

3.3.3 Eclipsing Binaries

The current version of the Kepler Eclipsing Binary catalog, produced by the team at Villanova University, is available at http://archive.stsci.edu/kepler/eclipsing_binaries.html. Columns can be sorted by clicking the column headings, and links are provided for displaying archived data, displaying light curve plots from Villanova, or for seeing an overview of the target as produced by Villanova. Work on this catalog is still continuing and columns with missing data will be populated as the Eclipsing Binary team at Villanova finishes their analysis. Note a few targets with multiple periods have multiple entries. More information on the catalog can be found at http://keplerebs.villanova.edu/

3.3.4 The Kepler-GALEX Crossmatch

The Kepler-GALEX cross match (KGxmatch) was created to mitigate the problem of selecting blue objects from the KIC/Kepler Target tables by providing GALEX magnitudes as a substitute for u-band photometry, a value that does not exist in the KIC. Although GALEX observations do not cover the entire Kepler field of view, there is sufficient coverage to warrant performing a cross match.

MAST cross-matched the GALEX Release #6 “mcat” catalog, with the Kepler Target table version of the KIC. Our positional results are contained in two Kepler/Cross matched tables described below.

No extensive list of cross-matched objects observed by two missions is likely to be perfect. Our tables use as the criterion for matching the angular separation between positions of objects in the KIC and GALEX catalogs, and this criterion alone is not always sufficient. For example, the best apparent match to a KIC entry may be a GALEX catalog entry for which the closest match is some other KIC entry. To accommodate such ambiguities, MAST has generated two catalogs: a Complete (alternatively, “KGMatch”) and an Accurate (“GoldStandard”) table.

The Complete table gives all possible GALEX matches to each KIC entry within a search radius of 5". This table in general gives multiple matches (and reverse matches), ranked by increasing separation. The Complete table returns possible GALEX matches of Kepler entries out to 5”, and vice versa; all potential matches are ranked by distance from the Kepler entries.

The Accurate table gives all unique matches for search radii out to 2.5", both in the KIC-to-GALEX and GALEX-to-KIC match directions. Although this table is incomplete - because it misses those rare correct matches to GALEX entries with coordinates just beyond the 2.5” search radius - the matches are unambiguous. Note that while this table is designated “Accurate”, it can occasionally generate a false match if the correct match is to a Kepler entry that has a GALEX entry (and vice versa) that does not have the very closest coordinates. Such errors are common in crowded fields and for data collated from different bandpasses and at the edge of detectors where field distortions are greatest.

Note also that both tables are subject to the greatest errors for GALEX AIS (all sky) survey tiles, for which the exposures are short. There are 81 GALEX sky tiles (each a circle of radius ~0.6^{o}) that overlap the Kepler FOV, of which 79 were observed in both FUV and NUV bands. The user can expect that most GALEX objects will have both magnitudes represented. Users should note that the number of matched objects is limited by both the incomplete GALEX areal coverage and the brighter faint magnitude limit relative to the KIC’s.

Note: MAST plans to redo the Kepler-GALEX crossmatch using the final release of GALEX data for the Kepler FOV in the near future.

Kepler-GALEX Crossmatch interface form

MAST provides two interfaces to the KGxmatch results. One interface is a standard MAST web form that allows searches of either the complete or the accurate table, accessible at http://archive.stsci.edu/kepler/kgmatch/search.php. An example of this form is given in Figure 3-24. A portion of the results from the indicated search is shown in Figure 3-25. This interface will be familiar to most MAST users, and with the aid of a field description page, usage should be almost self-explanatory. The table allows uploading of target coordinates, and requires checking of either the Complete or Accurate table box. The default is Accurate. This form is recommended for relatively simple queries that do not require more filter conditions than those fields exhibited on the form. The returned fields include fluxes and colors from GALEX, SCP-Sloan, and 2MASS missions. The output is available in several formats.

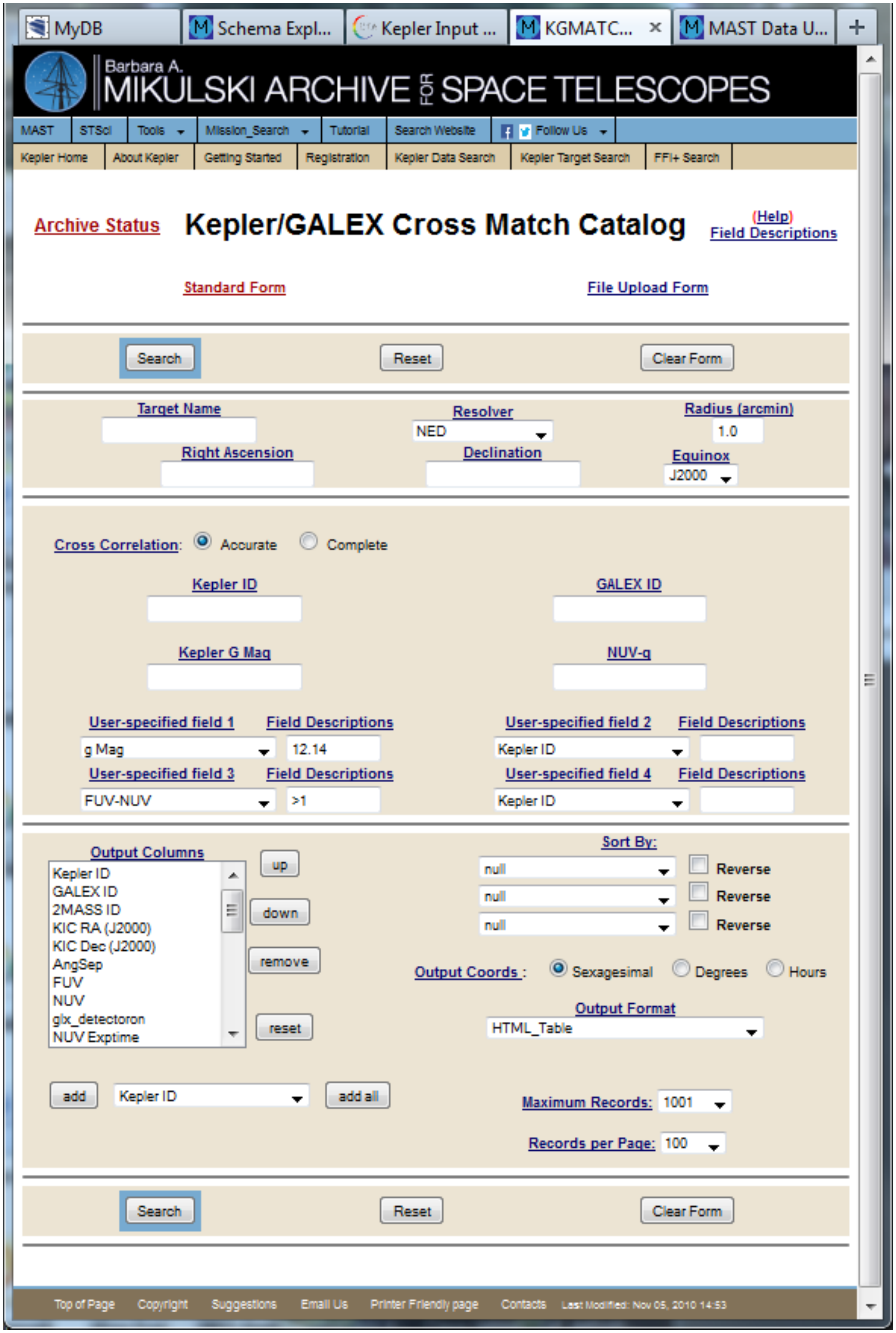


Figure 3-24 Standard MAST interface for the kepler-GALEX cross match tables

Mission Search / Missions / Contacts / STScI / MAST

Columns Help / Archive Status

KGMATCH Search Results

Edit Query

Display numeric columns graphically using VOPlot

```
SELECT  top 1001 kic_kepler_id, glx_objid, kic_2mass_id, kic_degree_ra, kic_dec, angsep, fuv, nuv, glx_detectoron, glx_nuvexptime, glx_fuvexptime, fuvnuv_color, nuvg_color, ki
FROM    keplersoc..kggoldstandard
WHERE   (kic_gmag BETWEEN 12 AND 14)
AND     (fuvnuv_color > 1)
```

1001 rows displayed, but 1947 are available.

◀ Previous 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 Next ▶ Page 1 of 21

Kepler ID	GALEX ID	2MASS ID	KIC RA (J2000)	KIC Dec (J2000)	AngSep	FUV	NUV	glx_detectoron	NUV Exptime	FUV Exptime	FUV-NUV
1701487	3154070188059526989	19043668+3717510	19 04 36.68	+37 17 51.0	0.963	21.697	15.911	FN	4537.950	4537.950	5.786
1849249	3154070188059527671	19043735+3723233	19 04 37.36	+37 23 23.3	0.390	21.598	16.577	FN	4537.950	4537.950	5.021
1849471	3154070188059526837	19045235+3719170	19 04 52.35	+37 19 17.0	0.524	23.081	17.407	FN	4537.950	4537.950	5.674
1849581	3154070188059527694	19050009+3723562	19 05 00.10	+37 23 56.2	0.463	23.532	16.801	FN	4537.950	4537.950	6.731
1995489	3154070188059529131	19043381+3729486	19 04 33.81	+37 29 48.7	1.053	21.212	15.884	FN	4537.950	4537.950	5.329
1995710	3154070188059527995	19045028+3725165	19 04 50.29	+37 25 16.6	0.671	21.295	16.995	FN	4537.950	4537.950	4.301
1995796	3154070188059528317	19045573+3727157	19 04 55.74	+37 27 15.8	0.728	22.345	16.431	FN	4537.950	4537.950	5.914
2140552	3154070188059529580	19035314+3732118	19 03 53.14	+37 32 11.9	0.774	23.144	17.048	FN	4537.950	4537.950	6.096
2140642	3154070188059529644	19040059+3734127	19 04 00.59	+37 34 12.7	0.575	20.909	16.211	FN	4537.950	4537.950	4.698
2140780	3154070188059528793	19041204+3732321	19 04 12.05	+37 32 32.2	0.379	23.310	21.660	FN	4537.950	4537.950	1.650

Figure 3-25 The Kepler/GALEX Crossmatch interface form and a results page. This example shows a request for all Kepler/GALEX matches within a rectangular sky region from the "Accurate" table part of the results listing.

3.3.5 The CasJobs Implementation

MAST has adapted the "CasJobs" tool constructed at Johns Hopkins University as an alternate method to download large data sets. Use of this tool, accessible at http://mastweb.stsci.edu/kplrcasjobs/, requires a one-time registration unless users have registered for the MAST/CasJobs tool already, (e.g., for bulk queries of GALEX data).

When should one use CasJobs? Here are several cases:

- **The query's target list is long**. The interface Form has a target limit of 25,001. Casjobs can be used in its "instant" or "query" (come back later) modes. In the later mode, there is no limit to the number of returns.
- **The use of customized filtering conditions.** The Form necessarily provides a limited number of computed columns, e.g. filter colors. Want to filter on objects with (FUV – i)? Can't find it on the form! Use CasJobs.
- **The query offers access to other** (non-Kepler provided or related) **database tables**. Queries can be constructed by imposing conditions or variables from other MAST database tables as well as the primary table used.
- **CasJobs provide the facility of "persistence."** This allows users to return to the MyDB tables and use them for two or more step queries. This can be helpful when you want to create a list of complicated sets of conditions and do not want to search a multi-million entry database – such queries can be extremely time-intensive and often fail in the first attempt. Moreover, the results from the first step may give the user ideas for additional queries to arrive at the final target list.
- **Submit queries using SQL.** Searches using the structured query language (SQL) provide more flexibility than a search form interface.

Because many users may not be familiar with SQL, this tool includes its own general help page, GO help page (http://mastweb.stsci.edu/kplrcasjobs/GOHelpKC.aspx#Part1), and SQL tutorial. It is essential to read the help pages to avoid common pitfalls, e.g. forgetting to change the 'context' tab (which points to a database table) from *kepler* to the user's own database area ("**MyDB**"). Users may also contact MAST personnel, via archive@stsci.edu, for help with CasJobs and in formulating their queries. In addition, the GO help page is updated whenever new features, such as a new catalog, is added to the CasJobs interface.

Figure 3-26 exhibits the "Query" page of the CasJobs/Kepler. After logging in, users can make queries by first consulting the relevant database tables. This is done by selecting the MyDB tab in the upper menu and the *kepler* context selection in the tables menu tab in the upper left (directly under "Home" and "Help" in the upper menu). This action will create an array of tables in the left pane. Most of the Kepler related tables can now be queried. Clicking "MyDB" will show a list of tables and documentation.

Once you are ready to write and submit a query, click on Query in the upper pane and an open query box will be created. A few SQL sample queries are shown in the indicated tab. These examples can be customized to return more refined lists without knowing too much about SQL syntax. Use of this query requires consultation of the column names of interest. These can be found in MyDB.

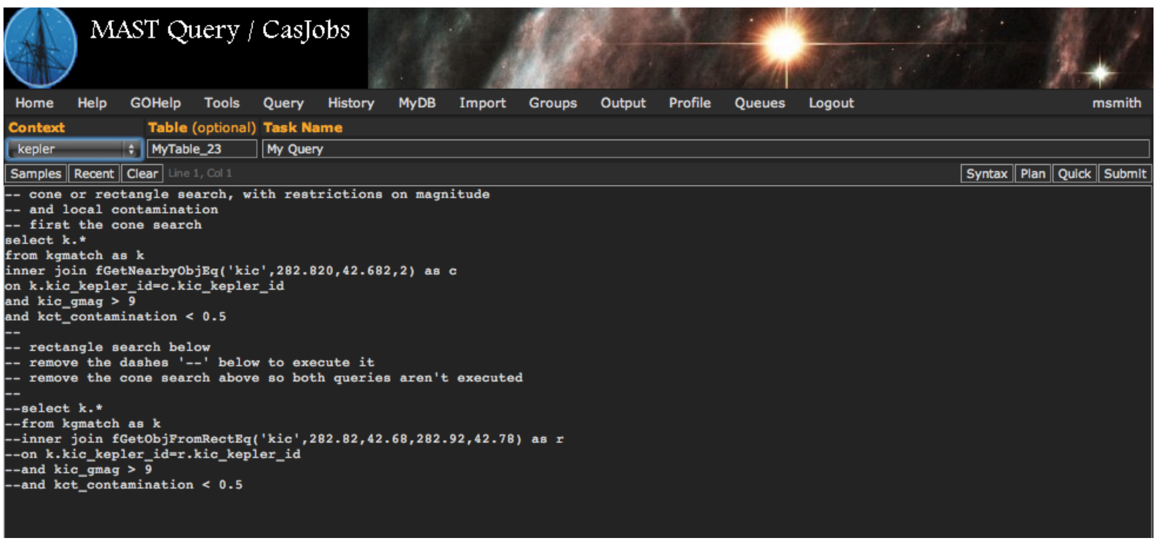


Figure 3-26 The Kepler/GALEX CasJob form. This page can be used to formulate sophisticated queries to constrain a class of objects. This example shows a comment-annotated query for selection of matching objects around a designated area in the sky from the Complete table.

3.3.6 Alternate Methods for Downloading Data

For archive users who do not wish to search for *Kepler* data, but rather simply download, say, all the public data, or their GO data, MAST provides some alternative means for downloading data. See the "Search & Retrieval" menu item in the left hand gutter of the MAST Kepler home page for a complete list of search and retrieval options. Below we describe how to access and download the quarterly-based tar files of public Kepler light curves.

Public Data Download

Kepler's public data have been staged in a directory area that is available through anonymous ftp or through a browser. These data are found at http://archive.stsci.edu/pub/kepler/lightcurves/tarfiles/. Each quarterly set of data has been broken into smaller files per quarter, each no larger than 5 GB. This was done because large tarfiles were presenting a significant problem for some users. The syntax for these smaller files is EX_QX_I.tgz, where X is the quarter and I is an integer starting at 1. The data are also tarred together by investigation ID (e.g. EX, STKS, GO) in the "teamfiles" directory for those looking for only a subset of the data.

To access the light curves do the following (X represents is the quarter number):

ftp archive.stsci.edu
login (as anonymous or with your archive user name and password)
cd /pub/kepler/lightcurves/tarfiles/QXteamfiles
bin
mget *QX*

A set of wget scripts is also provided that, when executed, will download the public light curves. These scripts are located in the same directory as the tarfiles, http://archive.stsci.edu/pub/kepler/lightcurves/tarfiles/. Consult the README file in their directory for details of the scripts.

There are subdirectories and tarfiles containing lightcurves for objects identified as Red Giants, Eclipsing Binaries and KOIs. Consult the README file for important information on the KOI version, as creation of the KOI tarfiles lags the Kepler Team announcement of a new KOI release. The subdirectories are at http://archive.stsci.edu/pub/kepler/lightcurves/tarfiles .

3.3.7 Retrieving CDPP values

The *Kepler* Mission provides the root mean square Combined Differential Photometric Precision (CDPP) values for every target observed. The values are calculated for various time scales, chosen to reflect typical transit durations. The CDPP values for the 3-, 6- and 12-hour time scales are provided each quarter. For more information on how this noise metric is calculated see Jenkins et al. (2010 ApJ 713 L120). These values are available in the light curve data headers and in the archive catalog. The CDPP values are dependent on the processing and will change with each reprocessing of the data. They cannot be used to assess the completeness of an arbitrary planet candidate list not directly associated with this processing.

For a small number of objects, users may obtain the CDPP values via the standard MAST/Kepler search form by adding cdpp3, cdpp6 and/or cdpp12 to the Output Columns. Users who desire the CDPP values for all observed objects may access gzipped ASCII files, which are grouped by quarter. The link to these files is found by **left clicking on the "Search & Retrieval" tab** in the left hand gutter of the MAST/Kepler home page, then, clicking on "Downloadable Catalogs" (http://archive.stsci.edu/pub/kepler/catalogs/). The files of interest are named cdpp_quarter#.txt.gz, where # is the quarter. The README_QUARTER file, in the same location, contains information on the content and format of the cdpp_quarter files. The data release number is reported along with the CDPP values to allow users to match the values with the data processing version number.

These CDPP catalogs, as well as several other ASCII catalog files, are available via ftp at archive.stsci.edu in pub/kepler/catalogs, and at http://archive.stsci.edu/pub/kepler/catalogs/.

For an intermediate number of objects, users should use an ***http get*** request (or, similarly using the GNU Wget unix command). Examples are available on line at http://archive.stsci.edu/vo/mast_services.html. In addition to the examples, the page contains links to field names for each mission. The field names are needed as part of the ***http get*** request. For the CDPP values, and any other data related search, use the "Kepler data" link. Any of the fields may be used to qualify the results of an ***http get*** request.

For example, what are the CDPP values for investigation GO20010? Note the use of "max_records" and "outputformat" in the request. A partial listing of the returns is given below the example.

http://archive.stsci.edu/kepler/data_search/search.php?ktc_investigation_id=GO20010&max_records=2000&selectedColumnsCsv=ktc_kepler_id,sci_data_quarter,sci_Cdpp3_0,sci_Cdpp6_0,sci_Cdpp12_0&outputformat=CSV&action=Search

```
Kepler ID,Quarter,,,
integer,integer
2968820,6,276.9526,251.3615,228.124
2968820,7,260.9334,240.7988,226.9803
2968820,8,188.7593,184.3977,177.6128
2968820,9,181.8454437255859,176.8077697753906,174.5309295654297
2984406,6,224.5499,205.8647,193.4872
2984406,7,223.7221,205.881,191.9032
2984406,8,153.0623,148.5383,146.9009
2984406,9,138.8018188476563,135.3896789550781,133.1756439208984
3096721,6,200.063,200.4038,190.1847
3096721,7,188.9354,189.2749,182.7877
3096721,8,145.2924,147.2329,144.5385
```

Magnitude and color cuts can also be specified. Here the search is for data where J>16 and (J-K) < 2. A partial list of results is shown below the example.

http://archive.stsci.edu/kepler/data_search/search.php?twoMass_jmag>16&twoMass_jkcolor<2&max_records=3000&selectedColumnsCsv=ktc_kepler_id,sci_data_quarter,sci_Cdpp3_0,sci_Cdpp6_0,sci_Cdpp12_0&outputformat=CSV&action=Search

```
Kepler ID,Quarter,,,
integer,integer
757076,0,107.1907272338867,87.06771087646484,74.18241882324219
757076,1,98.90160369873048,74.26993560791016,55.08943557739258
757076,2,107.1909103393555,84.28044128417969,66.48330688476562
757076,3,107.0135803222656,82.63387298583984,62.61486434936523
757076,4,105.0075378417969,80.99000549316406,63.43953704833984
757076,5,106.4529,76.9312,53.2947
757076,6,109.9427,80.9282,60.1158
757076,7,104.9784,77.6593,55.3902
757076,8,104.5721,79.6476,57.4747
```

3.3.8 Stellar Parameter Tables

MAST has created a search interface for the stellar parameters provided by the Kepler Stellar Working Group and used in the Kepler pipeline for the Q1-Q16 search for transiting planets. Access to the page is currently available at http://archive.stsci.edu/kepler/stellar16/search.php. A page also exists for the Q1-Q12 parameters at http://archive.stsci.edu/kepler/stellar12/search.php , but is available only by using the link address.

Appendices

Appendix A. Calibrated Data Headers – Light Curve and Target Pixel Files

A.1: Kepler Light Curve File Headers

A.1a: Light Curve File Primary Header

This header describes how the data was taken and processed along with information about the target contained in the file. These keywords describe the instrument and season the data was collected. CREATOR describes the code and version of the code that created the file. PROCVER describes the version of the pipeline that processed the data. DATA_REL relates which version of the data release notes describes these data. FILEVER contains the version of the file format.

Example Primary Header

```
SIMPLE  =                    T / conforms to FITS standards
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T / file contains extensions
NEXTEND =                    2 / number of standard extensions
EXTNAME = 'PRIMARY '           / name of extension
EXTVER  =                    1 / extension version number (not format version)
ORIGIN  = 'NASA/Ames'          / institution responsible for creating this file
DATE    = '2013-10-18'         / file creation date.
CREATOR = '558083 FluxExporter2PipelineModule' / pipeline job and program used t
PROCVER = 'svn+ssh://murzim/repo/soc/tags/release/9.1.4 r53267' / SW version
FILEVER = '5.0     '           / file format version
TIMVERSN= 'OGIP/93-003'        / OGIP memo number for file format
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBJECT  = 'KIC 7206837'        / string version of KEPLERID
KEPLERID=              7206837 / unique Kepler target identifier
CHANNEL =                   46 / CCD channel
SKYGROUP=                   62 / roll-independent location of channel
MODULE  =                   14 / CCD module
OUTPUT  =                    2 / CCD output
QUARTER =                   17 / Observing quarter
SEASON  =                    3 / mission season during which data was collected
DATA_REL=                   23 / version of data release notes for this file
OBSMODE = 'long cadence'       / observing mode
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           293.765570 / [deg] right ascension
DEC_OBJ =            42.737940 / [deg] declination
EQUINOX =               2000.0 / equinox of celestial coordinate system
PMRA    =               0.0000 / [arcsec/yr] RA proper motion
PMDEC   =               0.0000 / [arcsec/yr] Dec proper motion

PMTOTAL =               0.0000 / [arcsec/yr] total proper motion

PARALLAX=                      / [arcsec] parallax
GLON    =            75.711056 / [deg] galactic longitude
GLAT    =            10.706512 / [deg] galactic latitude
GMAG    =               10.021 / [mag] SDSS g band magnitude
RMAG    =                9.691 / [mag] SDSS r band magnitude
IMAG    =                9.661 / [mag] SDSS i band magnitude
```

```
ZMAG    =                9.648 / [mag] SDSS z band magnitude
D51MAG  =                9.865 / [mag] D51 magnitude,
JMAG    =                8.827 / [mag] J band magnitude from 2MASS
HMAG    =                8.628 / [mag] H band magnitude from 2MASS
KMAG    =                8.574 / [mag] K band magnitude from 2MASS
KEPMAG  =                9.769 / [mag] Kepler magnitude (Kp)
GRCOLOR =                0.330 / [mag] (g-r) color, SDSS bands
JKCOLOR =                0.253 / [mag] (J-K) color, 2MASS bands
GKCOLOR =                1.447 / [mag] (g-K) color, SDSS g - 2MASS K
TEFF    =                 6304 / [K] Effective temperature
LOGG    =                4.169 / [cm/s2] log10 surface gravity
FEH     =                0.140 / [log10([Fe/H])]  metallicity
EBMINUSV=                0.037 / [mag] E(B-V) redenning
AV      =                0.115 / [mag] A_v extinction
RADIUS  =                1.590 / [solar radii] stellar radius
TMINDEX =           1304921800 / unique 2MASS catalog ID
SCPID   =                      / unique SCP processing ID
CHECKSUM= '9fiGBciD9ciDAciD'   / HDU checksum updated 2013-10-18T19:39:21Z
END
```

A.1b: Light Curve File LIGHTCURVE Extension Header

This header describes the detector and the time period over which the data was collected.

Example LIGHTCURVE header

```
XTENSION= 'BINTABLE'           / marks the beginning of a new HDU
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                  100 / length of first array dimension
NAXIS2  =                 1556 / length of second array dimension
PCOUNT  =                    0 / group parameter count (not used)
GCOUNT  =                    1 / group count (not used)
TFIELDS =                   20 / number of table fields
TTYPE1  = 'TIME    '           / column title: data time stamps
TFORM1  = 'D       '           / column format: 64-bit floating point
TUNIT1  = 'BJD - 2454833'      / column units: barycenter corrected JD
TDISP1  = 'D14.7   '           / column display format
TTYPE2  = 'TIMECORR'           / column title: barycenter - timeslice correction
TFORM2  = 'E       '           / column format: 32-bit floating point
TUNIT2  = 'd       '           / column units: day
TDISP2  = 'E13.6   '           / column display format
TTYPE3  = 'CADENCENO'          / column title: unique cadence number
TFORM3  = 'J       '           / column format: signed 32-bit integer
TDISP3  = 'I10     '           / column display format
TTYPE4  = 'SAP_FLUX'           / column title: aperture photometry flux
TFORM4  = 'E       '           / column format: 32-bit floating point
TUNIT4  = 'e-/s    '           / column units: electrons per second
TDISP4  = 'E14.7   '           / column display format
TTYPE5  = 'SAP_FLUX_ERR'       / column title: aperture phot. flux error
TFORM5  = 'E       '           / column format: 32-bit floating point
TUNIT5  = 'e-/s    '           / column units: electrons per second (1-sigma)
TDISP5  = 'E14.7   '           / column display format
TTYPE6  = 'SAP_BKG '           / column title: aperture phot. background flux
TFORM6  = 'E       '           / column format: 32-bit floating point
TUNIT6  = 'e-/s    '           / column units: electrons per second
TDISP6  = 'E14.7   '           / column display format
TTYPE7  = 'SAP_BKG_ERR'        / column title: ap. phot. background flux error
TFORM7  = 'E       '           / column format: 32-bit floating point
TUNIT7  = 'e-/s    '           / column units: electrons per second (1-sigma)
TDISP7  = 'E14.7   '           / column display format
TTYPE8  = 'PDCSAP_FLUX'        / column title: aperture phot. PDC flux
TFORM8  = 'E       '           / column format: 32-bit floating point
TUNIT8  = 'e-/s    '           / column units: electrons per second
TDISP8  = 'E14.7   '           / column display format
TTYPE9  = 'PDCSAP_FLUX_ERR'    / column title: ap. phot. PDC flux error
TFORM9  = 'E       '           / column format: 32-bit floating point
TUNIT9  = 'e-/s    '           / column units: electrons per second (1-sigma)
TDISP9  = 'E14.7   '           / column display format
TTYPE10 = 'SAP_QUALITY'        / column title: aperture photometry quality flag
TFORM10 = 'J       '           / column format: signed 32-bit integer
TDISP10 = 'B16.16  '           / column display format
```

```
TTYPE11 = 'PSF_CENTR1'         / column title: PSF-fitted column centroid
TFORM11 = 'D       '           / column format: 64-bit floating point
TUNIT11 = 'pixel   '           / column units: pixel
TDISP11 = 'F10.5   '           / column display format
TTYPE12 = 'PSF_CENTR1_ERR'     / column title: PSF-fitted column error
TFORM12 = 'E       '           / column format: 32-bit floating point
TUNIT12 = 'pixel   '           / column units: pixel (1-sigma)
TDISP12 = 'E14.7   '           / column display format
TTYPE13 = 'PSF_CENTR2'         / column title: PSF-fitted row centroid
TFORM13 = 'D       '           / column format: 64-bit floating point
TUNIT13 = 'pixel   '           / column units: pixel
TDISP13 = 'F10.5   '           / column display format
TTYPE14 = 'PSF_CENTR2_ERR'     / column title: PSF-fitted row error
TFORM14 = 'E       '           / column format: 32-bit floating point
TUNIT14 = 'pixel   '           / column units: pixel (1-sigma)
TDISP14 = 'E14.7   '           / column display format
TTYPE15 = 'MOM_CENTR1'         / column title: moment-derived column centroid
TFORM15 = 'D       '           / column format: 64-bit floating point
TUNIT15 = 'pixel   '           / column units: pixel
TDISP15 = 'F10.5   '           / column display format
TTYPE16 = 'MOM_CENTR1_ERR'     / column title: moment-derived column error
TFORM16 = 'E       '           / column format: 32-bit floating point
TUNIT16 = 'pixel   '           / column units: pixel (1-sigma)
TDISP16 = 'E14.7   '           / column display format
TTYPE17 = 'MOM_CENTR2'         / column title: moment-derived row centroid
TFORM17 = 'D       '           / column format: 64-bit floating point
TUNIT17 = 'pixel   '           / column units: pixel
TDISP17 = 'F10.5   '           / column display format
TTYPE18 = 'MOM_CENTR2_ERR'     / column title: moment-derived row error
TFORM18 = 'E       '           / column format: 32-bit floating point
TUNIT18 = 'pixel   '           / column units: pixel (1-sigma)
TDISP18 = 'E14.7   '           / column display format
TTYPE19 = 'POS_CORR1'          / column title: column position correction
TFORM19 = 'E       '           / column format: 32-bit floating point
TUNIT19 = 'pixels  '           / column units: pixel
TDISP19 = 'E14.7   '           / column display format
TTYPE20 = 'POS_CORR2'          / column title: row position correction
TFORM20 = 'E       '           / column format: 32-bit floating point
TUNIT20 = 'pixels  '           / column units: pixel
TDISP20 = 'E14.7   '           / column display format
INHERIT =                    T / inherit the primary header
EXTNAME = 'LIGHTCURVE'         / name of extension
EXTVER  =                    1 / extension version number (not format version)
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBJECT  = 'KIC 7206837'        / string version of KEPLERID
KEPLERID=              7206837 / unique Kepler target identifier
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           293.765570 / [deg] right ascension
DEC_OBJ =            42.737940 / [deg] declination
EQUINOX =               2000.0 / equinox of celestial coordinate system
```

```
EXPOSURE=          29.27240151 / [d] time on source
TIMEREF = 'SOLARSYSTEM'        / barycentric correction applied to times
TASSIGN = 'SPACECRAFT'         / where time is assigned
TIMESYS = 'TDB     '           / time system is barycentric JD
BJDREFI =              2454833 / integer part of BJD reference date
BJDREFF =           0.00000000 / fraction of the day in BJD reference date
TIMEUNIT= 'd       '           / time unit for TIME, TSTART and TSTOP
TELAPSE =          31.79588440 / [d] TSTOP - TSTART
LIVETIME=          29.27240151 / [d] TELAPSE multiplied by DEADC
TSTART  =        1559.21557552 / observation start time in BJD-BJDREF
TSTOP   =        1591.01145992 / observation stop time in BJD-BJDREF
LC_START=       56391.72690412 / mid point of first cadence in MJD
LC_END  =       56423.50115222 / mid point of last cadence in MJD
DEADC   =           0.92063492 / deadtime correction
TIMEPIXR=                  0.5 / bin time beginning=0 middle=0.5 end=1
TIERRELA=             5.78E-07 / [d] relative time error
TIERABSO=                      / [d] absolute time error
INT_TIME=       6.019802903270 / [s] photon accumulation time per frame
READTIME=       0.518948526144 / [s] readout time per frame
FRAMETIM=       6.538751429414 / [s] frame time (INT_TIME + READTIME)
NUM_FRM =                  270 / number of frames per time stamp
TIMEDEL =     0.02043359821692 / [d] time resolution of data
DATE-OBS= '2013-04-09T17:12:01.786Z' / TSTART as UTC calendar date
DATE-END= '2013-05-11T12:16:22.281Z' / TSTOP as UTC calendar date
BACKAPP =                    T / background is subtracted
DEADAPP =                    T / deadtime applied
VIGNAPP =                    T / vignetting or collimator correction applied
GAIN    =               113.99 / [electrons/count] channel gain
READNOIS=            85.469702 / [electrons] read noise
NREADOUT=                  270 / number of read per cadence
TIMSLICE=                    5 / time-slice readout sequence section
MEANBLCK=                  717 / [count] FSW mean black level
LCFXDOFF=               419400 / long cadence fixed offset
SCFXDOFF=               219400 / short cadence fixed offset
CDPP3_0 =    22.56246566772461 / RMS CDPP on 3.0-hr time scales
CDPP6_0 =    21.24190330505371 / RMS CDPP on 6.0-hr time scales
CDPP12_0=   21.181299209594727 / RMS CDPP on 12.0-hr time scales
CROWDSAP=               0.9983 / Ratio of target flux to total flux in op. ap.
FLFRCSAP=               0.9958 / Frac. of target flux w/in the op. aperture
NSPSDDET=                    0 / Number of SPSDs detected
NSPSDCOR=                    0 / Number of SPSDs corrected
PDCVAR  =    7.627032279968262 / Target variability
PDCMETHD= 'regularMap'         / PDC algorithm used for target
NUMBAND =                    1 / Number of scale bands
FITTYPE1= 'prior   '           / Fit type used for band 1
PR_GOOD1=    0.616259753704071 / Prior goodness for band 1
PR_WGHT1=    45.86555480957031 / Prior weight for band 1
PDC_TOT =    0.960507869720459 / PDC total goodness metric for target
PDC_TOTP=   52.999935150146484 / PDC_TOT percentile compared to mod/out
PDC_COR =   0.9271799325942993 / PDC correlation goodness metric for target
PDC_CORP=    47.442523956298837 6.8239212036132 8 / PDC_COR percentile compared to
mod/out
```

```
PDC_VAR =   0.9998449087142944 / PDC variability goodness metric for target
PDC_VARP=    91.99235534667969 / PDC_VAR percentile compared to mod/out
PDC_NOI =   0.9558860063552856 / PDC noise goodness metric for target
PDC_NOIP=   60.222923278808594 / PDC_NOI percentile compared to mod/out
PDC_EPT =                      / PDC earth point goodness metric for target
PDC_EPTP=                      / PDC_EPT percentile compared to mod/out
CHECKSUM= 'BdbnBaZmBaamBaYm'   / HDU checksum updated 2013-10-18T19:39:21Z
END
```

A.1c Light Curve File Aperture Extension Header

The aperture extension describes the mask for the designated target in the file.

Example Aperture Header

```
XTENSION= 'IMAGE   '           / marks the beginning of a new HDU
BITPIX  =                   32 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   11 / length of first array dimension
NAXIS2  =                   20 / length of second array dimension
PCOUNT  =                    0 / group parameter count (not used)
GCOUNT  =                    1 / group count (not used)
INHERIT =                    T / inherit the primary header
EXTNAME = 'APERTURE'           / name of extension
EXTVER  =                    1 / extension version number (not format version)
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBJECT  = 'KIC 7206837'        / string version of KEPLERID
KEPLERID=              7206837 / unique Kepler target identifier
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           293.765570 / [deg] right ascension
DEC_OBJ =            42.737940 / [deg] declination
EQUINOX =               2000.0 / equinox of celestial coordinate system
WCSAXES =                    2 / number of WCS axes
CTYPE1  = 'RA---TAN'           / right ascension coordinate type
CTYPE2  = 'DEC--TAN'           / declination coordinate type
CRPIX1  =    5.734425136711934 / [pixel] reference pixel along image axis 1
CRPIX2  =    9.020901042644141 / [pixel] reference pixel along image axis 2
CRVAL1  =          293.7655695 / [deg] right ascension at reference pixel
CRVAL2  =             42.73794 / [deg] declination at reference pixel
CUNIT1  = 'deg     '           / physical unit in column dimension
CUNIT2  = 'deg     '           / physical unit in row dimension
CDELT1  =   -0.001103289223486 / [deg] pixel scale in RA dimension
CDELT2  = 0.001103289223486305 / [deg] pixel scale in Dec dimension
PC1_1   =   0.8574946837902978 / linear transformation element cos(th)
PC1_2   =  -0.5119469045520156 / linear transformation element -sin(th)
PC2_1   =  -0.5127083574373209 / linear transformation element sin(th)
PC2_2   =  -0.8600875986916059 / linear transformation element cos(th)
WCSNAMEP= 'PHYSICAL'           / name of world coordinate system alternate P
WCSAXESP=                    2 / number of WCS physical axes
CTYPE1P = 'RAWX    '           / physical WCS axis 1 type CCD col
CUNIT1P = 'PIXEL   '           / physical WCS axis 1 unit
CRPIX1P =                    1 / reference CCD column
CRVAL1P =                  229 / value at reference CCD column
```

```
CDELT1P =                  1.0 / physical WCS axis 1 step
CTYPE2P = 'RAWY    '           / physical WCS axis 2 type CCD row
CUNIT2P = 'PIXEL   '           / physical WCS axis 2 units
CRPIX2P =                    1 / reference CCD row
CRVAL2P =                  915 / value at reference CCD row
CDELT2P =                  1.0 / physical WCS axis 2 step
NPIXSAP =                   29 / Number of pixels in optimal aperture
NPIXMISS=                    0 / Number of op. aperture pixels not collected
CHECKSUM= 'lVohmUoZlUoflUoZ'   / HDU checksum updated 2013-10-18T19:39:21Z
```

A.2: Target Pixel File Headers

A.2a Target Pixel File Primary Header

This header describes how the data was taken and processed along with information about the target contained in the file. The data is processed in the Science Operations Center at NASA/Ames. CREATOR describes the code and version of the code that created the file. PROCVER describes the version of the pipeline that processed the data. DATA_REL relates which version of the data release notes describes these data.

Example Primary Header

```
SIMPLE  =                    T / conforms to FITS standards
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T / file contains extensions
NEXTEND =                    2 / number of standard extensions
EXTNAME = 'PRIMARY '           / name of extension
EXTVER  =                    1 / extension version number (not format version)
ORIGIN  = 'NASA/Ames'          / institution responsible for creating this file
DATE    = '2013-10-21'         / file creation date.
CREATOR = '562203 TargetPixelExporterPipelineModule' / pipeline job and program
PROCVER = 'svn+ssh://murzim/repo/soc/tags/release/9.1.4 r53267' / SW version
FILEVER = '5.0     '           / file format version
TIMVERSN= 'OGIP/93-003'        / OGIP memo number for file format
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBJECT  = 'KIC 7206837'        / string version of KEPLERID
KEPLERID=              7206837 / unique Kepler target identifier
CHANNEL =                   46 / CCD channel
SKYGROUP=                   62 / roll-independent location of channel
MODULE  =                   14 / CCD module
OUTPUT  =                    2 / CCD output
QUARTER =                   17 / Observing quarter
SEASON  =                    3 / mission season during which data was collected
DATA_REL=                   23 / version of data release notes for this file
OBSMODE = 'long cadence'       / observing mode
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           293.765570 / [deg] right ascension
DEC_OBJ =            42.737940 / [deg] declination
EQUINOX =               2000.0 / equinox of celestial coordinate system
PMRA    =               0.0000 / [arcsec/yr] RA proper motion
PMDEC   =               0.0000 / [arcsec/yr] Dec proper motion
PMTOTAL =               0.0000 / [arcsec/yr] total proper motion
```

```
PARALLAX=                     / [arcsec] parallax
GLON    =           75.711056 / [deg] galactic longitude
GLAT    =           10.706512 / [deg] galactic latitude
GMAG    =              10.021 / [mag] SDSS g band magnitude
RMAG    =               9.691 / [mag] SDSS r band magnitude
IMAG    =               9.661 / [mag] SDSS i band magnitude
ZMAG    =               9.648 / [mag] SDSS z band magnitude
D51MAG  =               9.865 / [mag] D51 magnitude,
JMAG    =               8.827 / [mag] J band magnitude from 2MASS
HMAG    =               8.628 / [mag] H band magnitude from 2MASS
KMAG    =               8.574 / [mag] K band magnitude from 2MASS
KEPMAG  =               9.769 / [mag] Kepler magnitude (Kp)
GRCOLOR =               0.330 / [mag] (g-r) color, SDSS bands
JKCOLOR =               0.253 / [mag] (J-K) color, 2MASS bands
GKCOLOR =               1.447 / [mag] (g-K) color, SDSS g - 2MASS K
TEFF    =                6304 / [K] Effective temperature
LOGG    =               4.169 / [cm/s2] log10 surface gravity
FEH     =               0.140 / [log10([Fe/H])]  metallicity
EBMINUSV=               0.037 / [mag] E(B-V) redenning
AV      =               0.115 / [mag] A_v extinction
RADIUS  =               1.590 / [solar radii] stellar radius
TMINDEX =          1304921800 / unique 2MASS catalog ID
SCPID   =                     / unique SCP processing ID
CHECKSUM= 'Nc8ZOc7ZNc7ZNc7Z'   / HDU checksum updated 2013-10-21T15:05:21Z
END
```

A.2b Target Pixel File TARGETTABLES Header

Format of binary table. Each column of the binary table is described with the FITS standard keywords TTYPE, TFORM and TUNIT. Columns are made of images and have the keyword TDIM to specify the dimensions of the image. Each image also contains keywords to specify the row and column values of the pixels on the specified channel.

Example TARGETTABLES Header

```
XTENSION= 'BINTABLE'           / marks the beginning of a new HDU
BITPIX  =                    8 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                 5308 / length of first array dimension
NAXIS2  =                 1556 / length of second array dimension
PCOUNT  =                    0 / group parameter count (not used)
GCOUNT  =                    1 / group count (not used)
TFIELDS =                   12 / number of table fields
TTYPE1  = 'TIME    '           / column title: data time stamps
TFORM1  = 'D       '           / column format: 64-bit floating point
TUNIT1  = 'BJD - 2454833'      / column units: barycenter corrected JD
TDISP1  = 'D14.7   '           / column display format
TTYPE2  = 'TIMECORR'           / column title: barycenter - timeslice correction
TFORM2  = 'E       '           / column format: 32-bit floating point
TUNIT2  = 'd       '           / column units: day
```

```
TDISP2  = 'E14.7   '           / column display format
TTYPE3  = 'CADENCENO'          / column title: unique cadence number
TFORM3  = 'J       '           / column format: signed 32-bit integer
TDISP3  = 'I10     '           / column display format
TTYPE4  = 'RAW_CNTS'           / column title: raw pixel counts
TFORM4  = '220J    '           / column format: image of signed 32-bit integers
TUNIT4  = 'count   '           / column units: count
TDISP4  = 'I8      '           / column display format
TDIM4   = '(11,20) '           / column dimensions: pixel aperture array
TNULL4  =                   -1 / column null value indicator
WCSN4P  = 'PHYSICAL'           / table column WCS name
WCAX4P  =                    2 / table column physical WCS dimensions
1CTY4P  = 'RAWX    '           / table column physical WCS axis 1 type, CCD col
2CTY4P  = 'RAWY    '           / table column physical WCS axis 2 type, CCD row
1CUN4P  = 'PIXEL   '           / table column physical WCS axis 1 unit
2CUN4P  = 'PIXEL   '           / table column physical WCS axis 2 unit
1CRV4P  =                  229 / table column physical WCS ax 1 ref value
2CRV4P  =                  915 / table column physical WCS ax 2 ref value
1CDL4P  =                  1.0 / table column physical WCS a1 step
2CDL4P  =                  1.0 / table column physical WCS a2 step
1CRP4P  =                    1 / table column physical WCS a1 reference
2CRP4P  =                    1 / table column physical WCS a2 reference
WCAX4   =                    2 / number of WCS axes
1CTYP4  = 'RA---TAN'           / right ascension coordinate type
2CTYP4  = 'DEC--TAN'           / declination coordinate type
1CRPX4  =    5.734425136711934 / [pixel] reference pixel along image axis 1
2CRPX4  =    9.020901042644141 / [pixel] reference pixel along image axis 2
1CRVL4  =          293.7655695 / [deg] right ascension at reference pixel
2CRVL4  =             42.73794 / [deg] declination at reference pixel
1CUNI4  = 'deg     '           / physical unit in column dimension
2CUNI4  = 'deg     '           / physical unit in row dimension
1CDLT4  =   -0.001103289223486 / [deg] pixel scale in RA dimension
2CDLT4  = 0.001103289223486305 / [deg] pixel scale in DEC dimension
11PC4   =   0.8574946837902978 / linear transformation matrix element cos(th)
12PC4   =  -0.5119469045520156 / linear transformation matrix element -sin(th)
21PC4   =  -0.5127083574373209 / linear transformation matrix element sin(th)
22PC4   =  -0.8600875986916059 / linear transformation matrix element cos(th)
TTYPE5  = 'FLUX    '           / column title: calibrated pixel flux
TFORM5  = '220E    '           / column format: image of 32-bit floating point
TUNIT5  = 'e-/s    '           / column units: electrons per second
TDISP5  = 'E14.7   '           / column display format
TDIM5   = '(11,20) '           / column dimensions: pixel aperture array
WCSN5P  = 'PHYSICAL'           / table column WCS name
WCAX5P  =                    2 / table column physical WCS dimensions
1CTY5P  = 'RAWX    '           / table column physical WCS axis 1 type, CCD col
2CTY5P  = 'RAWY    '           / table column physical WCS axis 2 type, CCD row
1CUN5P  = 'PIXEL   '           / table column physical WCS axis 1 unit
2CUN5P  = 'PIXEL   '           / table column physical WCS axis 2 unit
```

```
1CRV5P  =                  229 / table column physical WCS ax 1 ref value
2CRV5P  =                  915 / table column physical WCS ax 2 ref value
1CDL5P  =                  1.0 / table column physical WCS a1 step
2CDL5P  =                  1.0 / table column physical WCS a2 step
1CRP5P  =                    1 / table column physical WCS a1 reference
2CRP5P  =                    1 / table column physical WCS a2 reference
WCAX5   =                    2 / number of WCS axes
1CTYP5  = 'RA---TAN'           / right ascension coordinate type
2CTYP5  = 'DEC--TAN'           / declination coordinate type
1CRPX5  =    5.734425136711934 / [pixel] reference pixel along image axis 1
2CRPX5  =    9.020901042644141 / [pixel] reference pixel along image axis 2
1CRVL5  =          293.7655695 / [deg] right ascension at reference pixel
2CRVL5  =             42.73794 / [deg] declination at reference pixel
1CUNI5  = 'deg     '           / physical unit in column dimension
2CUNI5  = 'deg     '           / physical unit in row dimension
1CDLT5  =   -0.001103289223486 / [deg] pixel scale in RA dimension
2CDLT5  = 0.001103289223486305 / [deg] pixel scale in DEC dimension
11PC5   =   0.8574946837902978 / linear transformation matrix element cos(th)
12PC5   =  -0.5119469045520156 / linear transformation matrix element -sin(th)
21PC5   =  -0.5127083574373209 / linear transformation matrix element sin(th)
22PC5   =  -0.8600875986916059 / linear transformation matrix element cos(th)
TTYPE6  = 'FLUX_ERR'           / column title: 1-sigma calibrated uncertainty
TFORM6  = '220E    '           / column format: image of 32-bit floating point
TUNIT6  = 'e-/s    '           / column units: electrons per second (1-sigma)
TDISP6  = 'E14.7   '           / column display format
TDIM6   = '(11,20) '           / column dimensions: pixel aperture array
WCSN6P  = 'PHYSICAL'           / table column WCS name
WCAX6P  =                    2 / table column physical WCS dimensions
1CTY6P  = 'RAWX    '           / table column physical WCS axis 1 type, CCD col
2CTY6P  = 'RAWY    '           / table column physical WCS axis 2 type, CCD row
1CUN6P  = 'PIXEL   '           / table column physical WCS axis 1 unit
2CUN6P  = 'PIXEL   '           / table column physical WCS axis 2 unit
1CRV6P  =                  229 / table column physical WCS ax 1 ref value
2CRV6P  =                  915 / table column physical WCS ax 2 ref value
1CDL6P  =                  1.0 / table column physical WCS a1 step
2CDL6P  =                  1.0 / table column physical WCS a2 step
1CRP6P  =                    1 / table column physical WCS a1 reference
2CRP6P  =                    1 / table column physical WCS a2 reference
WCAX6   =                    2 / number of WCS axes
1CTYP6  = 'RA---TAN'           / right ascension coordinate type
2CTYP6  = 'DEC--TAN'           / declination coordinate type
1CRPX6  =    5.734425136711934 / [pixel] reference pixel along image axis 1
2CRPX6  =    9.020901042644141 / [pixel] reference pixel along image axis 2
1CRVL6  =          293.7655695 / [deg] right ascension at reference pixel
2CRVL6  =             42.73794 / [deg] declination at reference pixel
1CUNI6  = 'deg     '           / physical unit in column dimension
2CUNI6  = 'deg     '           / physical unit in row dimension
1CDLT6  =   -0.001103289223486 / [deg] pixel scale in RA dimension
```

```
2CDLT6  = 0.001103289223486305 / [deg] pixel scale in DEC dimension
11PC6   =   0.8574946837902978 / linear transformation matrix element cos(th)
12PC6   =  -0.5119469045520156 / linear transformation matrix element -sin(th)
21PC6   =  -0.5127083574373209 / linear transformation matrix element sin(th)
22PC6   =  -0.8600875986916059 / linear transformation matrix element cos(th)
TTYPE7  = 'FLUX_BKG'           / column title: calibrated background flux
TFORM7  = '220E    '           / column format: image of 32-bit floating point
TUNIT7  = 'e-/s    '           / column units: electrons per second
TDISP7  = 'E14.7   '           / column display format
TDIM7   = '(11,20) '           / column dimensions: pixel aperture array
WCSN7P  = 'PHYSICAL'           / table column WCS name
WCAX7P  =                    2 / table column physical WCS dimensions
1CTY7P  = 'RAWX    '           / table column physical WCS axis 1 type, CCD col
2CTY7P  = 'RAWY    '           / table column physical WCS axis 2 type, CCD row
1CUN7P  = 'PIXEL   '           / table column physical WCS axis 1 unit
2CUN7P  = 'PIXEL   '           / table column physical WCS axis 2 unit
1CRV7P  =                  229 / table column physical WCS ax 1 ref value
2CRV7P  =                  915 / table column physical WCS ax 2 ref value
1CDL7P  =                  1.0 / table column physical WCS a1 step
2CDL7P  =                  1.0 / table column physical WCS a2 step
1CRP7P  =                    1 / table column physical WCS a1 reference
2CRP7P  =                    1 / table column physical WCS a2 reference
WCAX7   =                    2 / number of WCS axes
1CTYP7  = 'RA---TAN'           / right ascension coordinate type
2CTYP7  = 'DEC--TAN'           / declination coordinate type
1CRPX7  =    5.734425136711934 / [pixel] reference pixel along image axis 1
2CRPX7  =    9.020901042644141 / [pixel] reference pixel along image axis 2
1CRVL7  =          293.7655695 / [deg] right ascension at reference pixel
2CRVL7  =             42.73794 / [deg] declination at reference pixel
1CUNI7  = 'deg     '           / physical unit in column dimension
2CUNI7  = 'deg     '           / physical unit in row dimension
1CDLT7  =   -0.001103289223486 / [deg] pixel scale in RA dimension
2CDLT7  = 0.001103289223486305 / [deg] pixel scale in DEC dimension
11PC7   =   0.8574946837902978 / linear transformation matrix element cos(th)
12PC7   =  -0.5119469045520156 / linear transformation matrix element -sin(th)
21PC7   =  -0.5127083574373209 / linear transformation matrix element sin(th)
22PC7   =  -0.8600875986916059 / linear transformation matrix element cos(th)
TTYPE8  = 'FLUX_BKG_ERR'       / column title: 1-sigma cal. background uncertain
TFORM8  = '220E    '           / column format: image of 32-bit floating point
TUNIT8  = 'e-/s    '           / column units: electrons per second (1-sigma)
TDISP8  = 'E14.7   '           / column display format
TDIM8   = '(11,20) '           / column dimensions: pixel aperture array
WCSN8P  = 'PHYSICAL'           / table column WCS name
WCAX8P  =                    2 / table column physical WCS dimensions
1CTY8P  = 'RAWX    '           / table column physical WCS axis 1 type, CCD col
2CTY8P  = 'RAWY    '           / table column physical WCS axis 2 type, CCD row
1CUN8P  = 'PIXEL   '           / table column physical WCS axis 1 unit
2CUN8P  = 'PIXEL   '           / table column physical WCS axis 2 unit
```

```
1CRV8P  =                  229 / table column physical WCS ax 1 ref value
2CRV8P  =                  915 / table column physical WCS ax 2 ref value
1CDL8P  =                  1.0 / table column physical WCS a1 step
2CDL8P  =                  1.0 / table column physical WCS a2 step
1CRP8P  =                    1 / table column physical WCS a1 reference
2CRP8P  =                    1 / table column physical WCS a2 reference
WCAX8   =                    2 / number of WCS axes
1CTYP8  = 'RA---TAN'           / right ascension coordinate type
2CTYP8  = 'DEC--TAN'           / declination coordinate type
1CRPX8  =    5.734425136711934 / [pixel] reference pixel along image axis 1
2CRPX8  =    9.020901042644141 / [pixel] reference pixel along image axis 2
1CRVL8  =          293.7655695 / [deg] right ascension at reference pixel
2CRVL8  =             42.73794 / [deg] declination at reference pixel
1CUNI8  = 'deg     '           / physical unit in column dimension
2CUNI8  = 'deg     '           / physical unit in row dimension
1CDLT8  =   -0.001103289223486 / [deg] pixel scale in RA dimension
2CDLT8  = 0.001103289223486305 / [deg] pixel scale in DEC dimension
11PC8   =   0.8574946837902978 / linear transformation matrix element cos(th)
12PC8   =  -0.5119469045520156 / linear transformation matrix element -sin(th)
21PC8   =  -0.5127083574373209 / linear transformation matrix element sin(th)
22PC8   =  -0.8600875986916059 / linear transformation matrix element cos(th)
TTYPE9  = 'COSMIC_RAYS'        / column title: cosmic ray detections
TFORM9  = '220E    '           / column format: image of 32-bit floating point
TUNIT9  = 'e-/s    '           / column units: electrons per second
TDISP9  = 'E14.7   '           / column display format
TDIM9   = '(11,20) '           / column dimensions: pixel aperture array
WCSN9P  = 'PHYSICAL'           / table column WCS name
WCAX9P  =                    2 / table column physical WCS dimensions
1CTY9P  = 'RAWX    '           / table column physical WCS axis 1 type, CCD col
2CTY9P  = 'RAWY    '           / table column physical WCS axis 2 type, CCD row
1CUN9P  = 'PIXEL   '           / table column physical WCS axis 1 unit
2CUN9P  = 'PIXEL   '           / table column physical WCS axis 2 unit
1CRV9P  =                  229 / table column physical WCS ax 1 ref value
2CRV9P  =                  915 / table column physical WCS ax 2 ref value
1CDL9P  =                  1.0 / table column physical WCS a1 step
2CDL9P  =                  1.0 / table column physical WCS a2 step
1CRP9P  =                    1 / table column physical WCS a1 reference
2CRP9P  =                    1 / table column physical WCS a2 reference
WCAX9   =                    2 / number of WCS axes
1CTYP9  = 'RA---TAN'           / right ascension coordinate type
2CTYP9  = 'DEC--TAN'           / declination coordinate type
1CRPX9  =    5.734425136711934 / [pixel] reference pixel along image axis 1
2CRPX9  =    9.020901042644141 / [pixel] reference pixel along image axis 2
1CRVL9  =          293.7655695 / [deg] right ascension at reference pixel
2CRVL9  =             42.73794 / [deg] declination at reference pixel
1CUNI9  = 'deg     '           / physical unit in column dimension
2CUNI9  = 'deg     '           / physical unit in row dimension
1CDLT9  =   -0.001103289223486 / [deg] pixel scale in RA dimension
```

```
2CDLT9  = 0.001103289223486305 / [deg] pixel scale in DEC dimension
11PC9   =   0.8574946837902978 / linear transformation matrix element cos(th)
12PC9   =  -0.5119469045520156 / linear transformation matrix element -sin(th)
21PC9   =  -0.5127083574373209 / linear transformation matrix element sin(th)
22PC9   =  -0.8600875986916059 / linear transformation matrix element cos(th)
TTYPE10 = 'QUALITY '           / column title: pixel quality flags
TFORM10 = 'J       '           / column format: signed 32-bit integer
TDISP10 = 'B16.16  '           / column display format
TTYPE11 = 'POS_CORR1'          / column title: column position correction
TFORM11 = 'E       '           / column format: 32-bit floating point
TUNIT11 = 'pixel   '           / column units: pixel
TDISP11 = 'E14.7   '           / column display format
TTYPE12 = 'POS_CORR2'          / column title: row position correction
TFORM12 = 'E       '           / column format: 32-bit floating point
TUNIT12 = 'pixel   '           / column units: pixel
TDISP12 = 'E14.7   '           / column display format
INHERIT =                    T / inherit the primary header
EXTNAME = 'TARGETTABLES'       / name of extension
EXTVER  =                    1 / extension version number (not format version)
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBJECT  = 'KIC 7206837'        / string version of KEPLERID
KEPLERID=              7206837 / unique Kepler target identifier
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           293.765570 / [deg] right ascension
DEC_OBJ =            42.737940 / [deg] declination
EQUINOX =               2000.0 / equinox of celestial coordinate system
EXPOSURE=          24.45655919 / [d] time on source
TIMEREF = 'SOLARSYSTEM'        / barycentric correction applied to times
TASSIGN = 'SPACECRAFT'         / where time is assigned
TIMESYS = 'TDB     '           / time system is barycentric JD
BJDREFI =              2454833 / integer part of BJD reference date
BJDREFF =           0.00000000 / fraction of the day in BJD reference date
TIMEUNIT= 'd       '           / time unit for TIME, TSTART and TSTOP
TELAPSE =          31.79588440 / [d] TSTOP - TSTART
LIVETIME=          29.27240151 / [d] TELAPSE multiplied by DEADC
TSTART  =        1559.21557552 / observation start time in BJD-BJDREF
TSTOP   =        1591.01145992 / observation stop time in BJD-BJDREF
LC_START=       56391.72690412 / mid point of first cadence in MJD
LC_END  =       56423.50115222 / mid point of last cadence in MJD
DEADC   =           0.92063492 / deadtime correction
TIMEPIXR=                  0.5 / bin time beginning=0 middle=0.5 end=1
TIERRELA=             5.78E-07 / [d] relative time error
TIERABSO=                      / [d] absolute time error
INT_TIME=       6.019802903270 / [s] photon accumulation time per frame
READTIME=       0.518948526144 / [s] readout time per frame
FRAMETIM=       6.538751429414 / [s] frame time (INT_TIME + READTIME)
NUM_FRM =                  270 / number of frames per time stamp
```

```
TIMEDEL =     0.02043359821692 / [d] time resolution of data
DATE-OBS= '2013-04-09T17:12:01.786Z' / TSTART as UTC calendar date
DATE-END= '2013-05-11T12:16:22.281Z' / TSTOP as UTC calendar date
BACKAPP =                    T / background is subtracted
DEADAPP =                    T / deadtime applied
VIGNAPP =                    T / vignetting or collimator correction applied
GAIN    =               113.99 / [electrons/count] channel gain
READNOIS=            85.469702 / [electrons] read noise
NREADOUT=                  270 / number of read per cadence
TIMSLICE=                    5 / time-slice readout sequence section
MEANBLCK=                  717 / [count] FSW mean black level
LCFXDOFF=               419400 / long cadence fixed offset
SCFXDOFF=               219400 / short cadence fixed offset
CDPP3_0 =    22.56246566772461 / RMS CDPP on 3.0-hr time scales
CDPP6_0 =    21.24190330505371 / RMS CDPP on 6.0-hr time scales
CDPP12_0=   21.181299209594727 / RMS CDPP on 12.0-hr time scales
CROWDSAP=               0.9983 / Ratio of target flux to total flux in op. ap.
FLFRCSAP=               0.9958 / Frac. of target flux w/in the op. aperture
CHECKSUM= '1Bq92Bo71Bo71Bo7'   / HDU checksum updated 2013-10-21T15:05:21Z
END
```

A.2c Target Pixel File Aperture Header

The aperture extension describes the mask for the designated target in the file. The physical coordinates of the bottom left pixel of the mask is given by CRVAL1P and CRVAL2P and the RA and Dec are provided as WCS keywords according to the FITS standard.

Example Aperture Header

```
XTENSION= 'IMAGE   '           / marks the beginning of a new HDU
BITPIX  =                   32 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   11 / length of first array dimension
NAXIS2  =                   20 / length of second array dimension
PCOUNT  =                    0 / group parameter count (not used)
GCOUNT  =                    1 / group count (not used)
INHERIT =                    T / inherit the primary header
EXTNAME = 'APERTURE'           / name of extension
EXTVER  =                    1 / extension version number (not format version)
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBJECT  = 'KIC 7206837'        / string version of KEPLERID
KEPLERID=              7206837 / unique Kepler target identifier
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           293.765570 / [deg] right ascension
DEC_OBJ =            42.737940 / [deg] declination
EQUINOX =               2000.0 / equinox of celestial coordinate system
WCSAXES =                    2 / number of WCS axes
CTYPE1  = 'RA---TAN'           / right ascension coordinate type
CTYPE2  = 'DEC--TAN'           / declination coordinate type
CRPIX1  =    5.734425136711934 / [pixel] reference pixel along image axis 1
CRPIX2  =    9.020901042644141 / [pixel] reference pixel along image axis 2
CRVAL1  =          293.7655695 / [deg] right ascension at reference pixel
CRVAL2  =             42.73794 / [deg] declination at reference pixel
CUNIT1  = 'deg     '           / physical unit in column dimension
CUNIT2  = 'deg     '           / physical unit in row dimension
CDELT1  =   -0.001103289223486 / [deg] pixel scale in RA dimension
CDELT2  = 0.001103289223486305 / [deg] pixel scale in Dec dimension
PC1_1   =   0.8574946837902978 / linear transformation element cos(th)
PC1_2   =  -0.5119469045520156 / linear transformation element -sin(th)
PC2_1   =  -0.5127083574373209 / linear transformation element sin(th)
PC2_2   =  -0.8600875986916059 / linear transformation element cos(th)
WCSNAMEP= 'PHYSICAL'           / name of world coordinate system alternate P
WCSAXESP=                    2 / number of WCS physical axes
CTYPE1P = 'RAWX    '           / physical WCS axis 1 type CCD col
CUNIT1P = 'PIXEL   '           / physical WCS axis 1 unit
CRPIX1P =                    1 / reference CCD column
CRVAL1P =                  229 / value at reference CCD column
CDELT1P =                  1.0 / physical WCS axis 1 step
```

```
CTYPE2P = 'RAWY    '           / physical WCS axis 2 type CCD row
CUNIT2P = 'PIXEL   '           / physical WCS axis 2 units
CRPIX2P =                    1 / reference CCD row
CRVAL2P =                  915 / value at reference CCD row
CDELT2P =                  1.0 / physical WCS axis 2 step
NPIXSAP =                   29 / Number of pixels in optimal aperture
NPIXMISS=                    0 / Number of op. aperture pixels not collected
CHECKSUM= '3W0d3V0a3V0a3V0a'   / HDU checksum updated 2013-10-21T15:05:21Z
END
```

Appendix B. Full Frame Image Headers

B.1: Calibrated Full Frame Image (FFI) Primary Header

The FFIs contain a primary header and 84 extension headers, one for each mod/out. The FFI are in units of electrons per second.

```
SIMPLE  =                    T / conforms to FITS standards
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T / file contains extensions
NEXTEND =                   84 / number of standard extensions
EXTNAME = 'PRIMARY '           / name of extension
EXTVER  =                    1 / extension version number (not format version)
ORIGIN  = 'NASA/Ames'          / institution responsible for creating this file
DATE    = '2011-08-26'         / file creation date.
CREATOR = '198129 ffiassembler' / pipeline job and program used to produce this
PROCVER = 'svn+ssh://murzim/repo/soc/branches/integ/8.1-i1 r44395' / SW version
FILEVER = '2.0     '           / file format version
TIMVERSN= 'OGIP/93-003'        / OGIP memo number for file format
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBSMODE = 'full frame image'   / observing mode
DATSETNM= 'kplr2009292020429'  / data set name
DCT_TIME= '2009292020429'      / data collection time: yyyydddhhss
DCT_TYPE= 'FFI     '           / data type
DCT_PURP= 'Monthly FFI'        / purpose of data
IMAGTYPE= 'SocCal  '           / FFI image type: raw, SocCal, SocUnc
QUARTER =                    3 / Observing quarter
DATA_REL=                      / SOC Data release version
SEASON  =                    1 / mission season during which data was collected
FINE_PNT=                    T / fine point pointing status during accumulation
MMNTMDMP=                    F / momentum dump occurred during accumulation
SCCONFIG=                   57 / commanded S/C configuration ID
PIXELTYP= 'all     '           / pixel type: target, background, coll., all
REV_CLCK=                    F / reverse clocking in effect?

VSMRSROW=                 1046 / collateral virtual smear region start row

VSMREROW=                 1057 / collateral virtual smear region row end
NROWVSMR=                   12 / number of rows binned in virtual smear
VSMRCOL =                   12 / collateral virtual smear region start column
VSMRECOL=                 1111 / collateral virtual smear region end column
NCOLVSMR=                 1100 / number of columns in virtual smear region
MASKSROW=                    6 / science collateral masked region start row
MASKEROW=                   17 / science collateral masked region end row
NROWMASK=                   12 / number of rows binned in masked region
MASKSCOL=                   12 / science collateral masked region start
```

```
MASKECOL=                 1111 / science collateral masked region end
NCOLMASK=                 1100 / number of columns in masked region
BLCKSROW=                    0 / science collateral black region start row
BLCKEROW=                 1069 / science collateral black region end column
NROWBLCK=                 1070 / number of rows in black region
BLCKSCOL=                 1118 / science collateral black region start
BLCKECOL=                 1131 / science collateral black region end column
NCOLBLK =                 1070 / number of columns binned in black region
OPERTEMP=             198129.0 / [C] commanded FPA temperature set point
FOCPOS1 =              -27.168 / [microns] mechanism 1 focus position
FOCPOS2 =              78.7336 / [microns] mechanism 2 focus position
FOCPOS3 =             -67.9754 / [microns] mechanism 3 focus position
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
EQUINOX =               2000.0 / equinox of celestial coordinate system
RA_NOM  =              290.667 /  [deg] RA of spacecraft boresight
DEC_NOM =                 44.5 / [deg] declination of spacecraft boresight
ROLL_NOM=                200.0 / [deg] roll angle of spacecraft
CHECKSUM= '6F7m6D6l6D6l6D6l'   / HDU checksum updated 2011-08-26T00:06:47Z
END
```

B.2 Calibrated FFI Channel Header

There are 84 extensions in total, one for each mod/out.

```
XTENSION= 'IMAGE   '           /  marks the beginning of a new HDU
BITPIX  =                  -32 / array data type
NAXIS   =                    2 / NAXIS
NAXIS1  =                 1132 / length of first array dimension
NAXIS2  =                 1070 / length of second array dimension
PCOUNT  =                    0 / group parameter count (not used)
GCOUNT  =                    1 / group count (not used)
INHERIT =                    T / inherit the primary header
EXTNAME = 'MOD.OUT 2.1'        /  name of extension
EXTVER  =                    1 / extension version number (not format version)
TELESCOP= 'Kepler  '           /  telescope
INSTRUME= 'Kepler Photometer'  /  detector type
CHANNEL =                    1 / CCD channel
SKYGROUP=                   53 / roll-independent location of channel
MODULE  =                    2 / CCD module
OUTPUT  =                    1 / CCD output
TIMEREF = 'SOLARSYSTEM'        /  barycentric correction applied to times
TASSIGN = 'SPACECRAFT'         /  where time is assigned
TIMESYS = 'TDB     '           /  time system is barycentric JD
```

```
MJDSTART=       55123.06602474 / [d] start of observation in spacecraft MJD
MJDEND  =        55123.0864583 / [d] end of observation in spacecraft MJD
BJDREFI =              2454833 / integer part of BJD reference date
BJDREFF =           0.00000000 / fraction of the day in BJD reference date
TIMEUNIT= 'd       '           /  time unit for TIME, TSTART and TSTOP
TSTART  =         290.56733021 / observation start time in BJD-BJDREF
TSTOP   =         290.58776377 / observation stop time in BJD-BJDREF
TELAPSE =           0.02043356 / [d] TSTOP - TSTART
EXPOSURE=           0.01881185 / [d] time on source
LIVETIME=           0.01881185 / [d] TELAPSE multiplied by DEADC
DEADC   =           0.92063492 / deadtime correction
TIMEPIXR=                  0.5 / bin time beginning=0 middle=0.5 end=1
TIERRELA=             5.78E-07 / [d] relative time error
INT_TIME=       6.019802903270 / [s] photon accumulation time per frame
READTIME=       0.518948526144 / [s] readout time per frame
FRAMETIM=   6.5387514294144005 / [s] frame time (INT_TIME + READTIME)
NUM_FRM =                  270 / number of frames per time stamp
FGSFRPER=       103.7897052288 / [ms] FGS frame period
NUMFGSFP=                   58 / number of FGS frame periods per exposure
TIMEDEL =           0.02043356 / [d] time resolution of data
DATE-OBS= '2009-10-19T01:35:04.537Z' /  TSTART as UTC calendar date
DATE-END= '2009-10-19T02:04:29.997Z' /  TSTOP as UTC calendar date
BTC_PIX1=                536.0 / reference col for barycentric time correction
BTC_PIX2=                567.0 / reference row for barycentric time correction
BUNIT   = 'electrons/s'        /  physical units of image data
BARYCORR=        1.3054676E-03 / [d] barycentric time correction
BACKAPP =                    F / background is subtracted
DEADAPP =                    T / deadtime applied
VIGNAPP =                    T / vignetting or collimator correction applied
READNOIS=            87.604748 / [electrons] read noise
NREADOUT=                  270 / number of read per cadence
TIMSLICE=                    4 / time-slice readout sequence section
MEANBLCK=                727.0 / [count] FSW mean black level
RADESYS = 'ICRS    '           /  reference frame of celestial coordinates
EQUINOX =               2000.0 / equinox of celestial coordinate system
WCSNAMEP= 'PHYSICAL'           /  name of world coordinate system alternate P
WCSAXESP=                    2 / number of WCS physical axes
CTYPE1P = 'RAWX    '           /  physical WCS axis 1 type CCD col
CUNIT1P = 'PIXEL   '           /  physical WCS axis 1 unit
CRPIX1P =                    1 / reference CCD column
CRVAL1P =                    0 / value at reference CCD column
CDELT1P =                  1.0 / physical WCS axis 1 step
CTYPE2P = 'RAWY    '           /  physical WCS axis 2 type CCD row
CUNIT2P = 'PIXEL   '           /  physical WCS axis 2 units
CRPIX2P =                    1 / reference CCD row
```

```
CRVAL2P =                    0 / value at reference CCD row
CDELT2P =                  1.0 / physical WCS axis 2 step
CTYPE1  = 'RA---TAN-SIP'       /  Gnomonic projection + SIP distortions
CTYPE2  = 'DEC--TAN-SIP'       /  Gnomonic projection + SIP distortions
CRVAL1  =    299.2617001144113 / RA at CRPIX1, CRPIX2
CRVAL2  =    44.01502810934495 / DEC at CRPIX1, CRPIX2
CRPIX1  =                533.0 / X reference pixel
CRPIX2  =                521.0 / Y reference pixel
CD1_1   =  -0.0005004780578635 / Transformation matrix
CD1_2   = 9.850651507779759E-4 / Transformation matrix
CD2_1   = 9.847518004452874E-4 / Transformation matrix
CD2_2   = 4.998471812902435E-4 / Transformation matrix
A_ORDER =                    2 / Polynomial order, axis 1
B_ORDER =                    2 / Polynomial order, axis 2
A_2_0   = 6.340797800196409E-7 / distortion coefficient
A_0_2   =   1.749990982371E-07 / distortion coefficient
A_1_1   = 5.382453881118889E-7 / distortion coefficient
B_2_0   =   1.175242752788E-07 / distortion coefficient
B_0_2   = 7.164025680025224E-7 / distortion coefficient
B_1_1   = 5.496396742485739E-7 / distortion coefficient
AP_ORDER=                    2 / Inv polynomial order, axis 1
BP_ORDER=                    2 / Inv polynomial order, axis 2
AP_1_0  =  3.76588935122466E-6 / inv distortion coefficient
AP_0_1  =  -4.851187332073E-06 / inv distortion coefficient
AP_2_0  = -6.40464415381175E-7 / inv distortion coefficient
AP_0_2  =  -1.767332402001E-07 / inv distortion coefficient
AP_1_1  =  -5.343953631364E-07 / inv distortion coefficient
BP_1_0  =  -2.637543835256E-06 / inv distortion coefficient
BP_0_1  =  -1.547946592422E-06 / inv distortion coefficient
BP_2_0  =  -1.064163345654E-07 / inv distortion coefficient
BP_0_2  =  -7.220223503958E-07 / inv distortion coefficient
BP_1_1  =  -5.404568839297E-07 / inv distortion coefficient
A_DMAX  =   0.3818408549009291 / maximum distortion, axis 1
B_DMAX  =  0.40086247834881306 / maximum distortion, axis 2
CHECKSUM= 'ZARXd8PXZAPXd5PX'   /  HDU checksum updated 2011-08-26T00:05:45Z
END
```

B.3. FFI Uncertainties Primary Header

The FFI uncertainties contain a primary header and 84 extensions.

```
SIMPLE  =                    T / conforms to FITS standards
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T / file contains extensions
NEXTEND =                   84 / number of standard extensions
EXTNAME = 'PRIMARY '           / name of extension
EXTVER  =                    1 / extension version number (not format version)
ORIGIN  = 'NASA/Ames'          / institution responsible for creating this file
DATE    = '2011-08-26'         / file creation date.
CREATOR = '198129 ffiassembler' / pipeline job and program used to produce this
```

```
PROCVER = 'svn+ssh://murzim/repo/soc/branches/integ/8.1-i1 r44395' / SW version
FILEVER = '2.0     '           / file format version
TIMVERSN= 'OGIP/93-003'        / OGIP memo number for file format
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBSMODE = 'full frame image'   / observing mode
DATSETNM= 'kplr2009292020429'  / data set name
DCT_TIME= '2009292020429'      / data collection time: yyyydddhhss
DCT_TYPE= 'FFI     '           / data type
DCT_PURP= 'Monthly FFI'        / purpose of data
IMAGTYPE= 'SocCal  '           / FFI image type: raw, SocCal, SocUnc
QUARTER =                    3 / Observing quarter
SEASON  =                    1 / mission season during which data was collected
FINE_PNT=                    T / fine point pointing status during accumulation
MMNTMDMP=                    F / momentum dump occurred during accumulation
SCCONFIG=                   57 / commanded S/C configuration ID
PIXELTYP= 'all     '           / pixel type: target, background, collateral, all
REV_CLCK=                    F / reverse clocking in effect?
VSMRSROW=                 1046 / collateral virtual smear region start row
VSMREROW=                 1057 / collateral virtual smear region row end
NROWVSMR=                   12 / number of rows binned in virtual smear
VSMRCOL =                   12 / collateral virtual smear region start column
VSMRECOL=                 1111 / collateral virtual smear region end column
NCOLVSMR=                 1100 / number of columns in virtual smear region
MASKSROW=                    6 / science collateral masked region start row
MASKEROW=                   17 / science collateral masked region end row
NROWMASK=                   12 / number of rows binned in masked region
MASKSCOL=                   12 / science collateral masked region start
MASKECOL=                 1111 / science collateral masked region end
NCOLMASK=                 1100 / number of columns in masked region
BLCKSROW=                    0 / science collateral black region start row
BLCKEROW=                 1069 / science collateral black region end column
NROWBLCK=                 1070 / number of rows in black region
BLCKSCOL=                 1118 / science collateral black region start
BLCKECOL=                 1131 / science collateral black region end column
NCOLBLK =                 1070 / number of columns binned in black region
OPERTEMP=             198129.0 / [C] commanded FPA temperature set point
FOCPOS1 =              -27.168 / [microns] mechanism 1 focus position
FOCPOS2 =              78.7336 / [microns] mechanism 2 focus position
FOCPOS3 =             -67.9754 / [microns] mechanism 3 focus position
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
EQUINOX =               2000.0 / equinox of celestial coordinate system
RA_NOM  =              290.667 /  [deg] RA of spacecraft boresight
DEC_NOM =                 44.5 / [deg] declination of spacecraft boresight
ROLL_NOM=                200.0 / [deg] roll angle of spacecraft
CHECKSUM= '6F7m6D6l6D6l6D6l'   / HDU checksum updated 2011-08-26T00:06:47Z
END
```

B.4 Uncertainties FFI Channel Header

```
XTENSION= 'IMAGE   '           /  marks the beginning of a new HDU
BITPIX  =                  -32 / array data type
NAXIS   =                    2 / NAXIS
NAXIS1  =                 1132 / length of first array dimension
NAXIS2  =                 1070 / length of second array dimension
PCOUNT  =                    0 / group parameter count (not used)
GCOUNT  =                    1 / group count (not used)
INHERIT =                    T / inherit the primary header
EXTNAME = 'MOD.OUT 2.1'        /  name of extension
EXTVER  =                    1 / extension version number (not format version)
TELESCOP= 'Kepler  '           /  telescope
INSTRUME= 'Kepler Photometer'  /  detector type
CHANNEL =                    1 / CCD channel
SKYGROUP=                   53 / roll-independent location of channel
MODULE  =                    2 / CCD module
OUTPUT  =                    1 / CCD output
TIMEREF = 'SOLARSYSTEM'        /  barycentric correction applied to times
TASSIGN = 'SPACECRAFT'         /  where time is assigned
TIMESYS = 'TDB     '           /  time system is barycentric JD
MJDSTART=       55123.06602474 / [d] start of observation in spacecraft MJD
MJDEND  =        55123.0864583 / [d] end of observation in spacecraft MJD
BJDREFI =              2454833 / integer part of BJD reference date
BJDREFF =           0.00000000 / fraction of the day in BJD reference date
TIMEUNIT= 'd       '           /  time unit for TIME, TSTART and TSTOP
TSTART  =         290.56733021 / observation start time in BJD-BJDREF
TSTOP   =         290.58776377 / observation stop time in BJD-BJDREF
TELAPSE =           0.02043356 / [d] TSTOP - TSTART
EXPOSURE=           0.01881185 / [d] time on source
LIVETIME=           0.01881185 / [d] TELAPSE multiplied by DEADC
DEADC   =           0.92063492 / deadtime correction
TIMEPIXR=                  0.5 / bin time beginning=0 middle=0.5 end=1
TIERRELA=             5.78E-07 / [d] relative time error
INT_TIME=       6.019802903270 / [s] photon accumulation time per frame
READTIME=       0.518948526144 / [s] readout time per frame
FRAMETIM=   6.5387514294144005 / [s] frame time (INT_TIME + READTIME)
NUM_FRM =                  270 / number of frames per time stamp
FGSFRPER=       103.7897052288 / [ms] FGS frame period
NUMFGSFP=                   58 / number of FGS frame periods per exposure
TIMEDEL =           0.02043356 / [d] time resolution of data
DATE-OBS= '2009-10-19T01:35:04.537Z' /  TSTART as UTC calendar date
DATE-END= '2009-10-19T02:04:29.997Z' /  TSTOP as UTC calendar date
BTC_PIX1=                536.0 / reference col for barycentric time correction
BTC_PIX2=                567.0 / reference row for barycentric time correction
BUNIT   = 'electrons/s'        /  physical units of image data
BARYCORR=        1.3054676E-03 / [d] barycentric time correction
```

```
BACKAPP =                    F / background is subtracted
DEADAPP =                    T / deadtime applied
VIGNAPP =                    T / vignetting or collimator correction applied
READNOIS=            87.604748 / [electrons] read noise
NREADOUT=                  270 / number of read per cadence
TIMSLICE=                    4 / time-slice readout sequence section
MEANBLCK=                727.0 / [count] FSW mean black level
RADESYS = 'ICRS    '           /  reference frame of celestial coordinates
EQUINOX =               2000.0 / equinox of celestial coordinate system
WCSNAMEP= 'PHYSICAL'           /  name of world coordinate system alternate P
WCSAXESP=                    2 / number of WCS physical axes
CTYPE1P = 'RAWX    '           /  physical WCS axis 1 type CCD col
CUNIT1P = 'PIXEL   '           /  physical WCS axis 1 unit
CRPIX1P =                    1 / reference CCD column
CRVAL1P =                    0 / value at reference CCD column
CDELT1P =                  1.0 / physical WCS axis 1 step
CTYPE2P = 'RAWY    '           /  physical WCS axis 2 type CCD row
CUNIT2P = 'PIXEL   '           /  physical WCS axis 2 units
CRPIX2P =                    1 / reference CCD row
CRVAL2P =                    0 / value at reference CCD row
CDELT2P =                  1.0 / physical WCS axis 2 step
CTYPE1  = 'RA---TAN-SIP'       /  Gnomonic projection + SIP distortions
CTYPE2  = 'DEC--TAN-SIP'       /  Gnomonic projection + SIP distortions
CRVAL1  =    299.2617001144113 / RA at CRPIX1, CRPIX2
CRVAL2  =    44.01502810934495 / DEC at CRPIX1, CRPIX2
CRPIX1  =                533.0 / X reference pixel
CRPIX2  =                521.0 / Y reference pixel
CD1_1   =  -0.0005004780578635 / Transformation matrix
CD1_2   = 9.850651507779759E-4 / Transformation matrix
CD2_1   = 9.847518004452874E-4 / Transformation matrix
CD2_2   = 4.998471812902435E-4 / Transformation matrix
A_ORDER =                    2 / Polynomial order, axis 1
B_ORDER =                    2 / Polynomial order, axis 2
A_2_0   = 6.340797800196409E-7 / distortion coefficient
A_0_2   =   1.749990982371E-07 / distortion coefficient
A_1_1   = 5.382453881118889E-7 / distortion coefficient
B_2_0   =   1.175242752788E-07 / distortion coefficient
B_0_2   = 7.164025680025224E-7 / distortion coefficient
B_1_1   = 5.496396742485739E-7 / distortion coefficient
AP_ORDER=                    2 / Inv polynomial order, axis 1
BP_ORDER=                    2 / Inv polynomial order, axis 2
AP_1_0  =  3.76588935122466E-6 / inv distortion coefficient
AP_0_1  =  -4.851187332073E-06 / inv distortion coefficient
AP_2_0  = -6.40464415381175E-7 / inv distortion coefficient
AP_0_2  =  -1.767332402001E-07 / inv distortion coefficient
AP_1_1  =  -5.343953631364E-07 / inv distortion coefficient
BP_1_0  =  -2.637543835256E-06 / inv distortion coefficient
BP_0_1  =  -1.547946592422E-06 / inv distortion coefficient
BP_2_0  =  -1.064163345654E-07 / inv distortion coefficient
```

```
BP_0_2  =  -7.220223503958E-07 / inv distortion coefficient
BP_1_1  =  -5.404568839297E-07 / inv distortion coefficient
A_DMAX  =   0.3818408549009291 / maximum distortion, axis 1
B_DMAX  =  0.40086247834881306 / maximum distortion, axis 2
CHECKSUM= 'EeGfGZ9dEbEdEZ9d'   /  HDU checksum updated 2011-08-26T00:05:45Z
END
```

Appendix C. Auxillary File Headers

C.1 Cotrending Basis Vector Headers

CBV Primary Header

```
SIMPLE  =                    T / conforms to FITS standard
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T
EXTNAME = 'PRIMARY '           / name of extension
EXTVER  =                  1.0 / extension version number
ORIGIN  = 'NASA/Ames'          / organization that generated this file
TELESCOP= 'Kepler  '           / telescope
DATE    = '2011-07-22'         / file creation date
CREATOR = '/Develop/designFITS/code/pdc-cbv/make_pdcfits.py r43962' / FITS SW
BVVER   = ' Prototype Uhat r43545' / basis vector software revision
DATAVER = 'q7_archive_ksop752/lc/mpe_true/pdc-matlab-4158-163239' / input data d
QUARTER =                    7 / quarter pertaining to this file
SEASON  =                    1 / mission season
DATA_REL=                   10 / version of data release notes
CHECKSUM= 'frDEho9CfoCCfo9C'   / HDU checksum updated 2011-07-22T10:44:30
DATASUM = '0       '           / data unit checksum updated 2011-07-22T10:44:30
END
```

Example Binary Extension

```
SIMPLE  =                    T / conforms to FITS standard
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T
EXTNAME = 'PRIMARY '           / name of extension
EXTVER  =                  1.0 / extension version number
ORIGIN  = 'NASA/Ames'          / organization that generated this file
TELESCOP= 'Kepler  '           / telescope
DATE    = '2011-07-22'         / file creation date
CREATOR = '/Develop/designFITS/code/pdc-cbv/make_pdcfits.py r43962' / FITS SW
BVVER   = ' Prototype Uhat r43545' / basis vector software revision
DATAVER = 'q7_archive_ksop752/lc/mpe_true/pdc-matlab-4158-163239' / input data d
QUARTER =                    7 / quarter pertaining to this file
SEASON  =                    1 / mission season
DATA_REL=                   10 / version of data release notes
CHECKSUM= 'frDEho9CfoCCfo9C'   / HDU checksum updated 2011-07-22T10:44:30
DATASUM = '0       '           / data unit checksum updated 2011-07-22T10:44:30
END
```

C.2 Pixel Response Function Headers

PRF Primary Header

```
SIMPLE  =                    T / conforms to FITS standard
BITPIX  =                    8 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T
EXTNAME = 'PRIMARY '           / name of extension
EXTVER  =                  1.0 / extension version number
```

```
ORIGIN  = 'NASA/Ames'          / organization that generated this file
DATE    = '2011-09-22'         / file creation date
CREATOR = 'MAKECALPRF'         / SW version used to create this file
PROCVER = 'svn+ssh://murzim/repo/so/trunk/Develop/designFITS/code/prf r44769'
FILEVER =                  1.0 / file format version
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler photometer'  / detector type
CHANNEL =                    3 / CCD channel
MODULE  =                    2 / CCD module
OUTPUT  =                    3 / CCD output
CHECKSUM= 'fAjdf3gdf9gdf9gd'   / HDU checksum updated 2011-09-22T01:43:48
DATASUM = '0       '           / data unit checksum updated 2011-09-22T01:43:48
END
```

Example PRF Image Extension Header

```
XTENSION= 'IMAGE   '           / Image extension
BITPIX  =                  -32 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                  750
NAXIS2  =                  750
PCOUNT  =                    0 / number of parameters
GCOUNT  =                    1 / number of groups
INHERIT =                    T / inherit primary keywords
EXTNAME = 'PRF_M2_O3_P1'       / extension name
EXTVER  =                  1.0 / extension version number
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler photometer'  / detector type
LOCATION=                    1 / code representing position on CCD channel
WCSNAMEP= 'PHYSICAL'           / name of world coordinate system alternate P
WCSAXESP=                    2 / number of WCS physical axes
CTYPE1P = 'RAWX    '           / physical WCS axis 1 type CCD col
CUNIT1P = 'PIXEL   '           / physical WCS axis 1 unit
CRPIX1P =                  375 / pixel image reference column
CRVAL1P =                11.99 / value at pixel image reference column
CDELT1P =                 0.02 / physical WCS axis 1 step
CTYPE2P = 'RAWY    '           / physical WCS axis 2 type CCD row
CUNIT2P = 'PIXEL   '           / physical WCS axis 2 units
CRPIX2P =                  375 / pixel image reference row
CRVAL2P =                19.99 / value at pixel image reference row
CDELT2P =                 0.02 / physical WCS axis 2 step
CHECKSUM= '3SS2APS16PS1APS1'   / HDU checksum updated 2011-09-22T01:43:48
DATASUM = '2365760863'         / data unit checksum updated 2011-09-22T01:43:48
END
```

Appendix D: Acronym and Definition List

D.1: Glossary of Terms

Cadence: A cadence is the frequency with which summed data are read out of the SDA. Short cadence is a 1-minute sum while long cadence is a 30-minute sum.

Channel: The sequential numbering, from 1 through 84, of the mod/outs. See Figure H.1 for the channel numbering.

Column: Each channel has 1132 columns and 1070 rows. There are 1100 science columns enumerated as columns 12 through 1111. Collateral data is enumerated as columns 0 through 11. Columns 1112 through 1131 are virtual columns used to measure electronic bias levels. These are not reported in the CT since an astronomical object located at that position would fall on the adjacent channel. A particular column is, therefore, an integer ranging from -205 through 1111. Negative values are enumerated in order to provide information on the distance of a target from a CCD channel.

Data Availability flag: A flag that indicates if data has been or will be observed by the Kepler photometer. A value of zero indicates that the target has not been observed. A value of one indicates that the target is either planned to be observed or has been observed but the data have not yet been archived. A value of two indicates that data for that target has been archived. Data availability flags are updated quarterly.

Data set: A group of one or more files that are related to each other. For example, a data set may consist of the calibrated cadence data, the corresponding collateral data and the processing history file. The files in a data set are archived as a group.

Data set name: The archive name for a group of one or more files that are archived as a group. Retrieval of a data set will result in retrieval of all files in the group.

Full Frame Image: Called FFI, this is a full readout of every CCD pixel. An FFI is typically taken at the end of each month. The FFI is formatted as a FITS image.

Light Curve: For each target, the SOC provides two calibrated light curves for each quarter. Both are the result of simple aperture photometry. One has been co-trended ("PDCSAP_FLUX") and the other has not ("SAP_FLUX"). Both light curves are contained within a single FITS formatted file.

Mod/out: Short for module/output, mod/out indicates which CCD recorded the data and which read amplifier was used to read out the detector. The values for modules start at 2 and run through 24, omitting 5 and 21. (Modules 1, 5, 21 and 25 are the fine guidance sensors.) The values of output range from 1 to 4. Although not used in this document, the syntax for mod/out is m.o, where m is the module number and o is the output number. Mod/out ranges from 2.1, 2.2, 2.3, 2.4, 3.1.. through 24.4, omitting 5 and 21. For a given target, the mod/out will change on a quarterly basis. See Figure D-1 for module and channel numbers.

Motion Polynomial: Two-dimensional polynomials are separately fit to the collection of row and column, flux-weighted, centroids of specified targets as a function of target right ascension and declination. The motion polynomials are computed cadence by cadence. In addition to providing seeds for PSF fitted centroids, motion polynomials are utilized elsewhere in the SOC Pipeline for focal plane geometry fitting, systematic error correction, attitude determination, and computation of instrument performance metrics. See the KDPH for more details.

Output: See Mod/Out

Pixel Mapping Reference Files: Called PMRF files, these files provide the key to identifying which data values in a given cadence data set belong to which targets. These files are produced at the DMC from the quarter-specific target and aperture definitions provided by the SOC. The PMRF files are non-proprietary.

Row: Each channel has 1132 columns and 1070 rows. There are 1024 science rows enumerated as rows 20 through 1043. Collateral data is enumerated as rows 0 through 19 and 1044 through 1069. ROW is an integer ranging from -232 through 1098. Values outside 0 through 1069 are enumerated in order to provide the location of a target in relation to a CCD channel.

Sky Group: As the spacecraft rolls from quarter to quarter (season to season), the stars fall on different CCD channels. The sky group (specified by Skygroup_ID at MAST) is an integer that groups stars together on the sky and, consequently, is time invariant. It is primarily used to specify custom apertures. The Skygroup_ID is equivalent to the channel number an object falls on (or near) during season 2. Stars very close to the boundary separating pixels on different channels can jump from one sky group to another from season to season. Only one sky group value is reported in the KIC. Users requiring sky groups for custom apertures should be especially careful for targets close to the channel boundary. The Skygroup_ID for a target near column 1111 can be misleading. One should consult the on-line pixel calculator for verification.

Target Pixel Data: For each target, the SOC creates a file that contains the individual data values for each pixel for each cadence. These target-based data are archived.

Time Slice: The readout of different modules is staggered in time as described in Section 5.1 of the KIH. Most modules have a readout time that is a 0.25--3.35 seconds **before** the recorded timestamp for the cadence. The magnitude of this difference, known as the time slice offset, is given by

$t_{ts} = 0.25 + 0.62(5 - n_{slice})$ seconds,

where n_{slice} is the module's time slice index. The (module dependent) value for n_{slice} is given in Figure 34 of the KIH. This value is included in BJD times seen by the end user. Because of the quarterly rotation of the spacecraft, a target will lie on a different module each quarter, and may therefore have a different time slice offset from quarter to quarter.

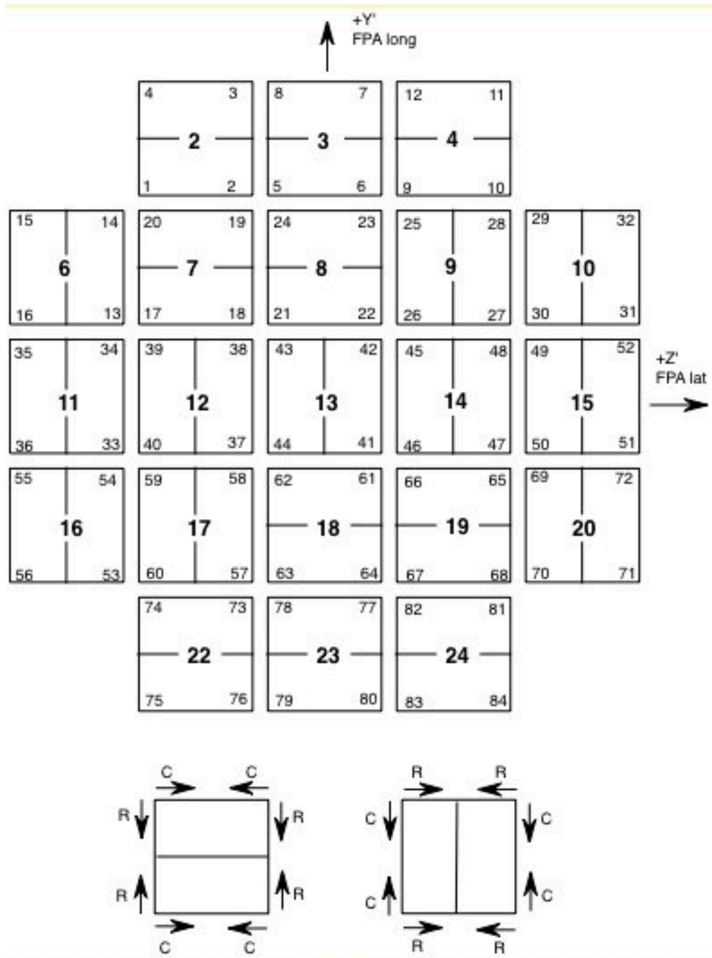


Figure D-1 Modules and channels with column and row directions. Each square shows 2 CCDs. The bold number in the each square is the module number. The smaller numbers in the corners of each square are the channel numbers. In the lower part of the figure, the column (C) and row (R) directions are indicated.

D.2 Common Acronyms

ARC	NASA Ames Research Center
BKJD	Barycentric Kepler Julian Date -- Equivalent to BJD minus 2454833.0
CAL	Pixel Calibration module
CBV	Co-trending Basis Vector
CCD	Charged Couple Device
CDPP	Combined Differential Photometric Precision
CR	Cosmic Ray
CRCT	Cosmic Ray Correction Table
CT	Characteristics Table
DIA	Differential Image Analysis
DMC	Data Management Center (for Kepler)
DSN	Deep Space Network (NASA)
FFI	Full Frame Image
FITS	Flexible Image Transport System
FOV	Field of View
GO	Guest Observer
HLSP	High Level Science Product
HST	Hubble Space Telescope
ICRS	International Coordinate Reference System
KDCH	*Kepler* Data Characterization Handbook (KSCI-19040)
KDPH	*Kepler* Data Processing Handbook (KSCI-19081-001)
KepID	*Kepler* Identification Number
KIC	*Kepler* Input Catalog
KIH	*Kepler* Instrument Handbook (KSCI-19033-001)
KRC	*Kepler* Results Catalog
KTC	*Kepler* Target Catalog
LASP	Laboratory for Atmospheric and Space Physics
LC	Long Cadence
MAP	*Maximum a Posteriori*
MAST	Mikulski Archive at Space Telescope
MJD	Modified Julian Date MJD = JD - 2400000.5 days
MOC	Mission Operations Center
NAIF	Navigation and Ancillary Information Facility (part of NASA's Planetary Sciences Division)
NED	NASA/IPAC Extragalactic Database
NASA	National Aeronautics and Space Administration
PA	Photometric Analysis module
PDC	Pre-search Data Conditioning Module
PDC-LS	Least Squares Pre-search Data Conditioning Module
PDF	Probability Distribution Function

PI	Principal Investigator
PMRF	Pixel Mapping Reference File
PSF	Point-Spread Function
PRF	Pixel Response Function
SAP	Simple Aperture Photometry
S/C	Spacecraft (i.e., Kepler)
SC	Short Cadence
SCP	Stellar Classification Program
SDA	Science Data Accumulator
SIMBAD	Set of Identifications, Measurements and Bibliography for Astronomical Data.
SOC	Science Operations Center
SPICE	Part of NAIF, SPICE is an information system designed for space instruments
SPSD	Sudden Pixel Sensitivity Dropout
SQL	Standard Query Language
SSDS	Space Science Data Services
STScI	Space Telescope Science Institute
TBD	To Be Determined
TDB	Barycentric Dynamical Time
TDT	Terrestrial Dynamical Time
TT	Terrestrial Time
UCD	Uniform Content Descriptor
WCS	World Coordinate System