Kepler: A Search for Terrestrial Planets

Kepler Archive Manual

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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	Tabe 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

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Chapter 1 Introduction

Data from the *Kepler* mission are housed in the Archive at the Space Telescope Science Institute (STScI) and accessed through MAST (Multi-mission Archive at 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 (covering a 16.1 degree diameter of the sky) field-of-view (FOV). It is pointed at and records data from the same group of stars 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 determine 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 are expected to occur on an approximate monthly basis.

A star field near the galactic plane, centered on galactic coordinates l = 76.32°, b = +13.5° (RA=19h 22m 40s, Dec=+44° 30' 00'), is the "field." 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 location on the sky is preserved for all roll orientations. The center module is only 180 degree symmetric. The roll is necessary to keep the solar arrays oriented towards the Sun and the radiator pointed towards deep space.

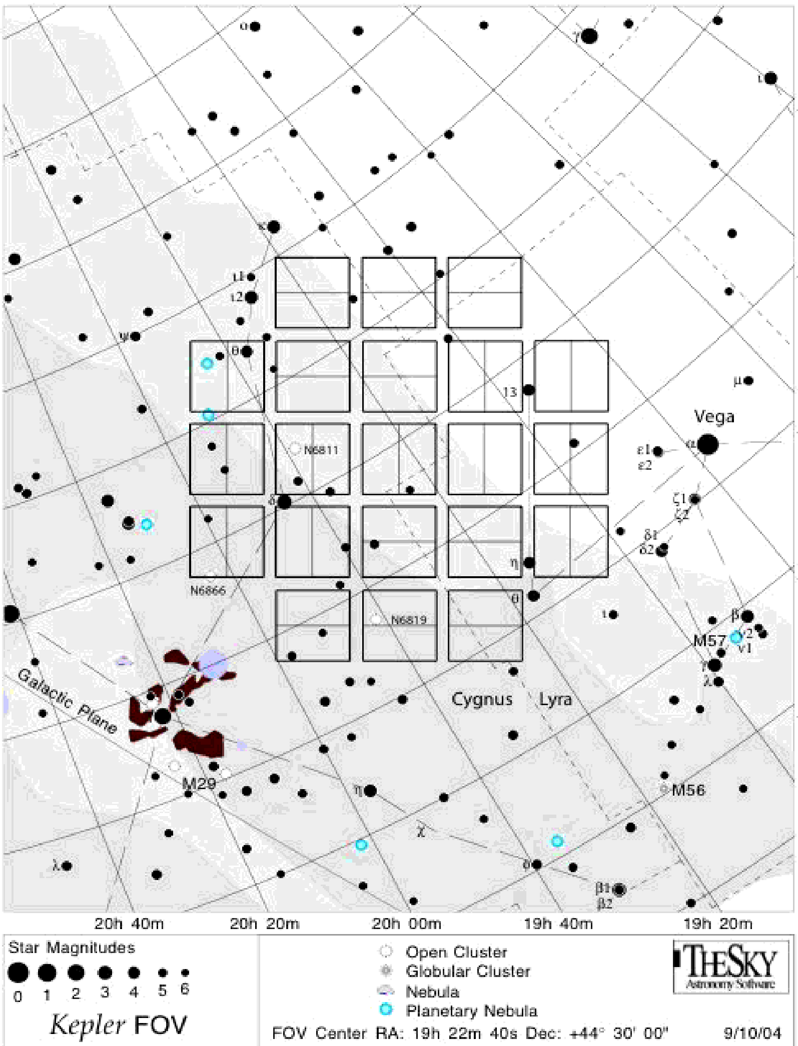
Kepler is in an Earth-trailing heliocentric orbit with a period of 372.5 days. In this orbit the spacecraft slowly drifts away from the Earth and is at a distance of over 0.5 AU after 3.5 years. The orbit permits continuous pointing on a single region of the sky. Additional advantages are the very stable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

1.2 Targets

At launch, ~150,000 targets were selected for observations by the mission. As the downlink data rate drops, one or more target "down selects" may occur. The data for these no-longer-observed targets will become public within 2 to 4 months.

Through MAST, users are able to search for existing targets of potential interest, determine when specific observations are available (consistent with proprietary restrictions) for access, and retrieve data. The community may propose to monitor additional objects of any nature that are in the *Kepler* FOV, such as variable stars or active galactic nuclei. In general, **proposals that duplicate the exoplanet project are not allowed.** See the Guest Observer (GO) Program website (http://keplergo.arc.nasa.gov/) for details on the proposal cycle.

Figure 1-1 Kepler Field of View



1.3 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 FITS. 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 curves.

1.4 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 Data Characteristics Handbook (DCH, KSCI-19040) and the Data Release Notes (DRN, KSCI-19042 to KSCI-19049), which are located in the left gutter of the MAST/Kepler home page. New Data Release Notes accompany the data for each processing of each quarter.

1.5 Overview of MAST

The Multi-mission Archive at STScI 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 Multi-mission Archive at STScI (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.

1.6 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 proprietary 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.

1.7 Registering as a User

Registration is not required to search the archive and/or retrieve public data. *Registration and authorization* is required to retrieve proprietary data, even for the Kepler Principal Investigator (PI) and Guest Observers (GOs). Only registered and authorized users can retrieve proprietary data. Register (create an archive account) by using the on-line form at http://archive.stsci.edu/registration. Be sure to enter your name and e-mail address as given in your Kepler proposal. Alternatively, send e-mail to archive@stsci.edu. Within two working days of the receipt of your e-mail, you will be notified by e-mail of your registration as an archive user and you will be provided with a username and a password. Note: The password can be changed from the registration page.

For proprietary users of Kepler data, authorization is handled automatically via quarterly receipt of an XML document from the Kepler Science Office. Archive users who find they are denied access to their proprietary data should have the PI or GO on the proposal send e-mail to archive@stsci.edu stating the investigation ID and the identities of anyone who should be able to retrieve the data.

KASC members do not have access to proprietary data through MAST. Instead, they should work through the KASC data archive maintained by the Kepler Asteroseismic Science Consortium. See http://astro.phys.au.dk/KASC/ .

To access proprietary Kepler data with a MAST account, the contact information and the e-mail of the user's archive account must match the contact information and e-mail provided to the Kepler Science Office. Users with existing archive accounts at STScI/MAST, created to retrieve data from other missions, do not need to create a new one. They may, however, need to update the contact information and/or change the e-mail address for the account. The GO office provides the MAST with the GO names and email addresses contained in the GO proposal. All information must match the MAST account information, or access will be denied. This means that a GO named Christopher E. Smith on the Kepler proposal, but registered as Chris Smith at the archive, will need to update his archive account contact information.

The direct link to the archive account update page is:
http://archive.stsci.edu/registration/index.html#acct_tools.

Near the bottom of the page is a section titled "How can I keep my account current?" In this section are links to

* Have your password sent to you
* Change your password
* Update your account information.

You will need your archive user name and password to access the Change Contact Info page.

These changes should be made BEFORE data are delivered to the MAST. This action is required because the links between the investigation ids and the proposer names are created before the data are ingested. If your data have already been delivered to MAST and you cannot access them, contact the archive help desk at archive@stsci.edu.

1.8 Proprietary Data Periods

The *Kepler* science team has exclusive access to the exoplanet data to perform follow-up ground-based observations on a data stream twice as long as is available to the public. Table 1-1 lists the data release dates for the exoplanet data for each quarter. A quarter is 3 months long. The table is based on a 3.5 year mission, so the release dates for quarters 7 and later will change if the mission is extended. Once data have been used for a refereed publication, that data will become public on the date of publication.

The Guest Observer Office will notify GOs of the availability of their data. It is the responsibility of the GOs to fetch their data from the archive. Unlike exoplanet data, GO data have a public release date set to one year from the time the light curves are archived. See http://keplergo.arc.nasa.gov for more information on the proprietary period for GO targets.

Archived data for mission targets dropped from the planetary search program will generally be made public within 4 months after being dropped from the target list. All data are public one year after the end of data acquisition from the mission.

Table 1-1 – Data Release Timeline for Exoplanet Program

Quarter	Data Release Date
1	6/15/2010
2	2/02/2011
3	9/23/2011
4	6/18/2012
5 and 6	6/18/2013
7 to 14	11/18/2013

Several types of *Kepler* data are non-proprietary, including the full frame images (FFIs) and the Kepler catalogs. The catalogs include the Kepler Input Catalog (KIC), the Characteristics Table (CT), the Kepler Target Catalog (KTC), the Focal Plane Characterization Models, the Co-trending Basis Vectors, and the Kepler Results Catalog (KRC). The catalogs contain metadata that will be staged through the Kepler archive interface at MAST. Information staged in these catalogs through MAST is public. The KRC is not yet available.

1.9 Getting Your Data

GOs on *Kepler* proposals and their authorized Co-Is may retrieve their 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. If the data were 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 and Chapter 5 for non-search based data retrieval.

1.10 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 Multimission Archive at the Space Telescope Science Institute (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 NNX09AF08G 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
D. Fraquelli & S. E. Thompson, 2011, Kepler Archive Manual (KDMC-10008-002), 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 auxillary 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.

Most science data products have a proprietary period in which they are only available to the *Kepler* Science Team or Guest Observer (GO) PIs. A general archive user can retrieve light curves and target pixel data after they are public. Light curve and target pixel files use the same rules to determine their release dates. FFIs are immediately public to all users once the MAST has ingested them. The auxiliary data is in development and is unavailable at this time.

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 C.

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 rapid 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 the S/C 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. 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 auxillary 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 and ancillary engineering CCD data are used to calibrate and process the data. Some of this information is available through the Data Release Notes Supplement; however, these data will be of less interest to the typical science user.

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.

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 S/C 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 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.

2.1.4 Disclaimer: Changing File Formats

The light curve file format changed significantly in June 2011. While the archive was updated in its entirety, if you have data processed and downloaded before that date you will need to refer to the previous version of the Archive Manual (KDMC-10008-001) for a description of the extensions, columns and keywords. This document aims to describe the current state of the data products and not their previous state. Given the additional information contained in the newly formatted light curve files, along with the improved consistency and clarity of the files, we highly recommend downloading the new version of the files. The file format of the light curve files, target pixel files and FFIs described in this document contain the keyword FILEVER in the primary header. For this version of the manual, we describe light curve files and target pixel files formatted as v2.1 and FFIs formatted as verion 2.0. The archive at MAST will not be entirely updated with these latest formats until July 2012.

Looking forward, we anticipate only small changes to the light curve and target pixel files. These changes will strive to only add and will avoid changing the existing columns, keywords and extensions of the FITS files. The keywords in the FFIs will change significantly by the end of 2011 in order to make them more consistent with the light curve and target pixel files. This change will be documented in a new version of the archive manual.

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 Science Data 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

* All rootnames begin with kplr.
🔒For historical reasons, the <stop_time> for target pixel and light curve 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 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 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 tiled together 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 distiguish the clusters by the RA and Dec values. The second aperture type of interest is the background super aperture, which are 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. Although the full frame images (FFI) are non-proprietary, they 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.

2.3.1 Light Curve Files

Light curve files are produced for each target using simple aperture photometry. At any time, there will be some 100,000 – 170,000 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 cuve 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 this 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. Generally, these contain the static KIC values. However, the *Kepler* Science Office has the option to replace these KIC values with 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. To convert the times in the TIME column to Julian Day use the following formula:

JD[i] = BJD[i] - TIMECORR[i] + time_slice_correction
= BJD[i] - TIMECORR[i] + (0.25 + 0.62(5- TIMSLICE))/(86400)

where TIMSLICE is given in the header.

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 error in the simple aperture photometry is only calculated directly every 24 cadences and then interpolated between the cadences. This is known to cause problems for highly variable targets.

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, argabrightening and attitude tweaks. 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 refered 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 [32-bit floating point] – The column local image motion calculated from the motion polynomials, which are a fit to the observed motion of bright stars on each channel. We report the motion in pixels relative to the mid-cadence of the quarter or month. This data column reports the size of the differential velocity aberration (DVA), pointing drift, and thermal effects applicable to the region of sky recorded in the file.

POS_CORR2 [32-bit floating point] – The row local image motion calculated from the motion polynomials, which are a fit to the observed motion of bright stars on each channel. We report the motion in pixels relative to the mid-cadence of the quarter or month. This data column reports the size of the differential velocity aberration (DVA), pointing drift, and thermal effects applicable to the region of sky recorded in the file.

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

Bit	Value	Explanation
1	1	Attitude Tweak
2	2	Safe Mode
3	4	Spacecraft is in Coarse 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
8	128	Cosmic Ray in Optimal Aperture pixel
9	256	Manual Exclude. The SOC operator excluded this cadence because of an anomaly.
10	512	Reserved
11	1024	Discontinuity corrected between this cadence and the following one
12	2048	Impulsive outlier removed after 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

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
0	1	pixel was collected by S/C
1	2	pixel is in the optimal aperture
2	4	pixel was used to calculate the flux weighted centroid
3	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. For data formatted as v2.1, Long Cadence PDC light curves use a Bayesian Maximum A Posteriori (MAP) approach where a subset of highly correlated and quiet stars is used to generate a cotrending basis vector set and 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 (PDF) 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.

Short Cadence PDC processing continues to use the Least-Squares method (PDC-LS) described in the Data Processing Handbook. The reference ensemble for the PDC-LS basis vectors is ancillary engineering data.

PDC performs several other critical services, including the identification and removal of Sudden Pixel Sensitivity Dropouts (SPSDs, or Discontinuities) that result in abrupt drops in pixel flux with short recovery periods and the adjustment of light curve fluxes to account for excess flux in the optimal apertures due to starfield crowding and the fraction of the target star flux in the aperture. These corrections are described using a bit flag. See the keyword called PDCSAPFL in the light curve extension. The flag values for this keyword are described in section 2.4.

Goodness metrics are also provided in the FITS headers for long-cadence PDC MAP data. However, these values are currently unreliable and the project does not recommend using them to determine the effectiveness of the PDC co-trending until they can be updated. These goodness metrics characterize the ``goodness'' of the PDC cotrending with regard to three characteristics. A total goodness is also given as the reciprocal sum of the three 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.

The three goodness metrics 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.
2) Variability: Using a Stellar Variability Estimation, any change in the intrinsic variability due to the cotrending. A value of 1 means the variability was perfectly preserved.
3) Noise: Indicates that noise was added to the cotrended light curves.

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 left blank.

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 this 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. Generally, these contain the static KIC values. However, the *Kepler* Science Office has the option to replace these KIC values with better measurements as they become available from ground-based observations. 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 second extension contains pixel time series. It has 10 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 for each target varies, however all images contained in a single target pixel file will 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. Only target pixel files updated after June 2011 will contain this information (see the DATE keyword in the primary header).

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]:

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

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 is identical to the light curve file TIMECORR column. To convert the times in the first column to Julian Day use the following formula:

$$JD[i] = BJD[i] - TIMECORR[i] + time\_slice\_correction$$
$$= BJD[i] - TIMECORR[i] + (0.25 + 0.62(5- TIMSLICE))/(86400)$$

where TIMSLICE is given in the header.

CADENCENO [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*. 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) 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. For each cadence one may sum the flux in the pixels contained in the optimal aperture to reproduce the SAP_FLUX value.

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, Argabrightening and attitude tweaks. Unused bits are reserved for future use.

POS_CORR1 [32-bit floating point] – The column local image motion calculated from the motion polynomials, which are a fit to the observed motion of bright stars on each channel. We report the motion in pixels relative to the mid-cadence of the quarter or month. This data column reports the size of the differential velocity aberration (DVA), pointing drift, and thermal effects applicable to the region of sky recorded in the file.

POS_CORR2 [32-bit floating point] – The row local image motion calculated from the motion polynomials, which are a fit to the observed motion of bright stars on each channel. We report the motion in pixels relative to the mid-cadence of the quarter or month. This data column reports the size of the differential velocity aberration (DVA), pointing drift, and thermal effects applicable to the region of sky recorded in the file.

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 from 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

Binary	Decimal	Meaning
00	0	data was not collected by S/C and is not in the aperture
01	1	data was collected by S/C
10	2	pixel is contained in the optimal aperture
11	3	pixel was collected by S/C and 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 non-proprietary and calibrated 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	FITS image
FFI – calibrated	ffi-cal	FITS image
FFI – uncertainties	ffi-uncert	FITS image

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 contained in this uncalibrated file are listed in the Appendix and 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 propogated uncertainties on the flux for each pixel in the calibrated FFI.

The v2.0 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).

For the FFIs prior to v2.0, we recommend using SAOImage ds9 to correctly display the celestial coordinate system. Outdated WCS keywords exist at the end of the FFI headers that cause some FITS viewers, eg. Gaia and Skycat, to display the wrong coordinates. This problem will be remedied when the FFIs are reprocessed in 2012.

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. Since most users do not have access to all the data neighboring their targets, they cannot take an ensemble approach to co-trending as described in Section 2.3.1.1. To mitigate this problem, the cotrending basis vectors are computed by the project. The user may fit them to light curves to remove the common instrumental effects from the data. More details on the method used to generate these basis vectors will be provided in the KDCH. Here is a summary of the method.

To create the initial basis set (the flux time series used to make the cotrending basis vectors):

1) The time series photometry of each star on a specific detector channel is normalized by its own median flux.
2) One (unity) is subtracted from each time series so that the median value of the light curve is zero.
3) The time series is divided by the root-mean square of the photometry.
4) The stellar variability is calculated for all normalized targets and only those targets below a threshold variability value are kept. This means only quiet targets are used when generating the Cotrending Basis Vectors.
5) The correlation between each time series on the CCD channel is calculated using the median and root-mean square normalized flux.
6) The median absolute correlation is then calculated for each star.
7) All stars on the channel are sorted into ascending order of correlation.
8) The 50 per cent of the most correlated stars are selected.
9) The median normalized fluxes (as opposed to the root-mean square normalized fluxes) are now used for the rest of the process.
10) Singular Value Decomposition is applied to the matrix of correlated sources to create orthogonal basis vectors.
11) The archived cotrending basis vectors are a *reduced-rank* representation of the full set of basis vectors and consist of the 16 leading columns. These vectors are sorted such that those with the strongest features are first.

The publically available tool called *kepcotrend*, which is part of the PyKE package, can be used to fit these basis vectors to individual data sets (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 pipeline has gapped the data. This occurs because the spacecraft is in coarse point, safe mode, at earth point, or an argabrigtening event was detected on that mod/out. The light curves were linearly interpolated across these gaps prior to creating the basis vectors. The use of CBVs on gapped data has not been explored.

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.

Currently, *Kepler* is providing 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 Functions

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 a point source collected by Kepler.

There are three primary uses of the PRF:

1) To predict (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. Our experience is that this generally does not provide an improvement over simple aperture photometry, though there may be exceptions.

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>.

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 the PRF. (These detector locations are zero-based.)

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	549.4	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).

2.4 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 and is indicated by the value of BACKAPP.

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. See Section 8.3 of the KDPH (KSCI-19081-001) for more details on how rms CDPP is calculated by the pipeline. 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.

CROWDSAP: The ratio of the flux from the target to the total flux in the optimal aperture.

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 compatability with code written for that file type and major_update number.

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

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.

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

PDCSAPFL: The integer value in this keyword represents a bit flag of different logical steps taken by PDC when processing the light curve.

Table 2-8 – The meaning of each flag in the PDCSAPFL keyword.

Bit	Value	Meaning
1	1	The target was initially flagged as variable at the pipeline specified threshold documented in the data release notes. (Used for PDC_LS, always false for PDC-MAP)
2	2	PDC processed this target as a variable target. (Always false for PDC-MAP)
3	4	Systematic errors were not corrected for this target.
4	8	Harmonic components were fitted successfully for this target.
5	16	Harmonic components were restored after systematic errors were corrected.
6	32	PDC detected one or more potential discontinuities, but was not able to correct for them.
7	64	PDC removed discontinuities
8	128	MAP Prior PDF used (i.e. if true, A proper Bayseian fit, if false, PDC-MAP reverted to a least-squares fit for this target)
9	256	MAP Requested (True if PDC-MAP was attempted. False if PDC-LS was used.)

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 1000 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. Existing Resolvers do not yet recognize kepler_id as a target name.

This chapter contains descriptions of the MAST Kepler Data Search and Retrieval, the MAST Kepler Target Search, the FFI Search, and the KIC Search Form. These search pages rely on the Kepler Input Catalog (KIC), Characteristics Table (CT), the Kepler Target Catalog (KTC) as hosted by MAST, and the Field of View (FOV) table (MAST's version of the KIC). The FOV table is a combination of the KIC and the CT, so it contains objects found in both catalogs. It is supplemented with additional fields of interest. Users intending to propose for *Kepler* time should search the FOV table for targets via the "Kepler Target Search" form. Users interested in existing 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.

3.1 The *Kepler* Catalogs as Presented at MAST

As of this writing, the 3 primary Kepler catalogs at MAST consist of the Kepler Input Catalog (KIC), the FOV table, which is the Kepler Input Catalog modified by the Characteristics Table (CT) and supplemented by additional fields provided by MAST, and the Kepler Target Catalog (KTC) with additional fields from the archive catalog.

The Kepler Input Catalog contains information on approximately 13 million sources, most of which are visible in or nearby the *Kepler* FOV. Creation of the KIC is discussed in Brown et al. 2011 (arXiv:1102.0342v1). 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. Table 3-1 lists the fields in the FOV table, along with a short description of the field. The non-KIC fields in Table 3-1 are flagged as either provided by MAST or taken from the CT. See the MAST help files at http://archive.stsci.edu/search_fields.php?mission=kepler_fov for more details.

Facts about the KIC, CT and FOV table:

- The full KIC contains 13,161,029 rows (objects)
- The CT (and likewise the FOV table) contains 6,569,466 rows (about half of the KIC total)
- The number of FOV table entries considered on CCD for at least one season is 4,412,616 (about a third of the KIC total)
- The number of FOV table entries on CCD every season is 4,237,550. .

The Kepler Target Catalog (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). Table 3-2 lists all columns of the KTC, including several from the archive catalog. For a given object, the kepler_id is the same in the KIC, the FOV table and the

KTC. The one exception is for KIC targets observed with custom apertures: in this case, the kepler_id listed in the KTC is **not** in the KIC or the CT. For more details on the columns see the MAST help files at http://archive.stsci.edu/search_fields.php?mission=kepler.

The Characteristics Table (CT) contains parameters indicating if a given kepler_id is observable ("on silicon" is the term used by the Kepler Science Team) 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 FOV table, which contains only those objects that have entries in both the KIC and CT. The Kepler Target Search form is used to search the FOV table. Information about the CT parameters is given in the MAST help files, http://archive.stsci.edu/kepler/kepler_fov/help/search_help.html.

The Kepler Results Catalog (KRC) will be hosted at MAST. The KRC contains results obtained for the mission targets. The **final** KRC will not be received until at least one year after mission end.

Table 3-1 Fields in the FOV Table as Displayed by MAST

Field name	Description
kepler_id	Kepler identification number
2mass_id*	2MASS catalog ID, a sexagesimal, equatorial position-based source name in the form: hhhmmssss+ddmmsss[ABC...]
tmid%	KIC provided 2 MASS designation, which is a unique identification number defined during 2MASS final processing, and known as the pts_kpy/cntr. See the User's Guide to the 2Mass All Sky Data Release, at http://www.ipac.caltech.edu/2mass/releases/allsky/doc/explsup.html for information on the pts_key/cntr field.
ra*	Right ascension of object in hours
dec	Declination of object in decimal degrees
pmra	Proper Motion in right ascension
pmdec	Proper Motion in declination
umag	U magnitude
gmag	G magnitude
rmag	R magnitude
imag	I magnitude
zmag	Z magnitude
gredmag	GRed magnitude
d51mag	D51 magnitude
Jmag	2MASS J magnitude
Hmag	2MASS H magnitude
Kmag	2MASS K magnitude
kepmag	Kepler magnitude
scpid	ID from the SCPKEY table
altid	ID from an alternate source
altsource	Source of alternate ID
Star/gal ID	Star/galaxy indicator.
blend	Is object a blend
variable	Is object variable
Data Availability flag	2= data in archive, 1 = planned to be observed or observed with no data in archive, 0 = not observed or planned to be observed

teff	Derived effective temperature
logg	Derived surface gravity
metallicity	Derived metallicity (Fe/H)
E(B-V)	Derived excess reddening E(B-V)
A_v	Derived extinction Av
radius	Estimate stellar radius
cq	Source of Kepler-band magnitude
pq	Photometry quality indicator
aq	Astrophysics quality indicator
Catalog key	Link to CATKEY table
SCP key	Link SCPKEY table
parallax	Parallax in arcseconds
Gal Lon	Galactic longitude
Gal Lat	Galactic latitude
pmtotal	Proper motion in arcsec/year
g-r color	(G-R) color
J-K color	(J-K) color
g-K color	(G-K) color
degree_ra	Right Ascension in decimal degrees
+sky_group_id	The channel where the target falls in season 2. Values will range from 1 to 84.
+crowding_season 0	The fraction of light in the aperture due to the target star during season 0. 1 means all the light is from the target, 0 implies all background. 0.5 means half the light is due to the target. This value is not intended for use in data analysis.
+crowding_season 1	The fraction of light in the aperture due to the target star during season 1. 1 means all the light is from the target, 0 implies all background. 0.5 means half the light is due to the target. This value is not intended for use in data analysis.
+crowding_season 2	The fraction of light in the aperture due to the target star during season 2. 1 means all the light is from the target, 0 implies all background. 0.5 means half the light is due to the target. This value is not intended for use in data analysis.
+crowding_season 3	The fraction of light in the aperture due to the target star during season 3. 1 means all the light is from the target, 0 implies all background. 0.5 means half the light is due to the target. This value is not intended for use in data analysis.
Seasons_on_CCD*	Number of seasons a target is on the detector
Contamination Season 0*	Measure of light contamination defined as 1-crowding. 0 implies no contamination, 1 implies all background. This value is not intended for use in data analysis.
Contamination Season 1*	Measure of light contamination defined as 1-crowding. 0 implies no contamination, 1 implies all background. This value is not intended for use in data analysis.
Contamination Season 2*	Measure of light contamination defined as 1-crowding. 0 implies no contamination, 1 implies all background. This value is not intended for use in data analysis.
Contamination Season 3*	Measure of light contamination defined as 1-crowding. 0 implies no contamination, 1 implies all background. This value is not intended for use in data analysis.
+Flux Fraction Season 0	The fraction of target flux that falls within the photometric aperture. A value of 1 means all the flux from the target falls within the aperture, while a value of 0 means no flux from the target falls within the photometric aperture.
+Flux Fraction Season 1	The fraction of target flux that falls within the photometric aperture. A value of 1 means all the flux from the target falls within the aperture, while a value of 0 means no flux from the target falls within the photometric aperture.

+Flux Fraction Season 2	The fraction of target flux that falls within the photometric aperture. A value of 1 means all the flux from the target falls within the aperture, while a value of 0 means no flux from the target falls within the photometric aperture.
+Flux Fraction Season 3	The fraction of target flux that falls within the photometric aperture. A value of 1 means all the flux from the target falls within the aperture, while a value of 0 means no flux from the target falls within the photometric aperture.
+SNR Season 0	The ratio of target flux collected within the photometric aperture to the statistical 1-sigma uncertainty in the collected target flux.
+SNR Season 1	The ratio of target flux collected within the photometric aperture to the statistical 1-sigma uncertainty in the collected target flux.
+SNR Season 2	The ratio of target flux collected within the photometric aperture to the statistical 1-sigma uncertainty in the collected target flux.
+SNR Season 3	The ratio of target flux collected within the photometric aperture to the statistical 1-sigma uncertainty in the collected target flux.
Edge_Distance_0*	The shortest distancefrom the detector edge to a pixel in the photometric aperture for season 0. Values of 0 or greater are observable..
Edge_Distance_1*	The shortest distancefrom the detector edge to a pixel in the photometric aperture for season 1. Values of 0 or greater are observable..
Edge_Distance_2*	The shortest distancefrom the detector edge to a pixel in the photometric aperture for season 2. Values of 0 or greater are observable..
Edge_Distance_3*	The shortest distancefrom the detector edge to a pixel in the photometric aperture for season 3. Values of 0 or greater are observable..
+Channel_season_0	Integer channel number for season 0.
+Channel_season_1	Integer channel number for season 1.
+Channel_season_2	Integer channel number for season 2.
+Channel_season_3	Integer channel number for season 3.
+Column_season_0	Column number for season 0.
+Column_season_1	Column number for season 1.
+Column_season_2	Column number for season 2.
+Column_season_3	Column number for season 3.
+Module_season_0	Integer module number for season 0.
+Module_season_1	Integer module number for season 1.
+Module_season_2	Integer module number for season 2.
+Module_season_3	Integer module number for season 3.
+Output_season_0	Integer output number per module for season 0.
+Output_season_1	Integer output number per module for season 1.
+Output_season_2	Integer output number per module for season 2.
+Output_season_3	Integer output number per module for season 3.
+Row_season_0	Row number for season 0.
+Row_season_1	Row number for season 1.
+Row_season_2	Row number for season 2.
+Row_season_3	Row number for season 3.

* Field added/modified by MAST.

+ Field taken from the Characteristics Table.

Column	**Description**

%Kepler Id	Running Kepler ID number
%Investigation_id	Investigation ID assigned by Project
+Pep_id	Unique integer value assigned by DMC
+Dataset Name	Dataset name for the exposure
+Quarter	The quarter in which the exposure was made.
*RA(J2000)	RA in decimal degrees
+Dec(J2000)	Dec in decimal degrees
%Target Type	Cadence – LC or SC
+Archive Class	Used to distinguish light curves (CLC,CSC) from target pixel files (TPL, TPS)
*Ref	Current number of known papers referencing this dataset.
Actual Observation Start Time	Actual start time
Actual Observation End Time	Actual end time
+Release Date	Date when data become public.
+data_rel	Release Notes
^ CDPP_3	3-hr rms CDPP value for the data set
^ CDPP_6	6-hr rms CDPP value for the data set
^ CDPP_12	12-hr rms CDPP value for the data set
Flux Fraction	The fraction of target flux obtained in the optimal aperture averaged for the specified data. This value is not to be confused with the Flux Fraction values given on the Target Search page that give predictive values.
Crowding	The ratio of target flux to total flux in optimal aperture. This value is not to be confused with the Crowding values given on the Target Search page that give predictive values.

Table 3-2 Fields in the MAST Data Search and Retrieval Interface

+ Field taken from data in the Kepler archive
* Field added by MAST
% Field taken from the KTC
^ CDPP values for Q1 are calculated from a later SOC pipeline processing than the data set currently held at the MAST. This will be remedied after the Q1 data are reprocessed in 2012.

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 FOV 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 an FFI search page, http://archive.stsci.edu/kepler/ffi/search.php, the co-trending basis vector download page, http://archive.stsci.edu/kepler/cbv.html, the focal plane characteristcs download page, http://archive.stsci.edu/kepler/fpc.html, and the previously mentioned KIC search page, http://archive.stsci.edu/kepler/kic10/search.php. Check the “Search & Retrieval” menu on MAST’s Kepler home page, http://archive.stsci.edu/kepler/, 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. The user can select a Resolver from the pull down menu. One of the options is ‘Don’t Resolve.’

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 5000 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. For Kepler, four user-specified fields are 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. Columns can be removed by highlighting the column and clicking on the “remove” button to the right. Columns are added by choosing columns from the “select” box and clicking the “add” button to the left of the “select” box. Change the order by clicking on 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. Note the following behavior when a sort option is used. 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**. 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.

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, and VO table format. The HTML format will give access to useful links and retrieval options. Since the astrophysical fields in the KIC 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 FOV table are taken from the KIC. Note: since there are ~7 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 3-4. 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 3-4 Planned Start Date for Seasons

Year	**Spring**	**Summer**	**Fall**	**Winter**
Quarters	**1,5,9,13**	**2,6,10,14**	**3,7,11,15**	**4,8,12**
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	

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. A value of 0 means all the light is from the target, 1 implies all background. 0.5 means half the light is due to the target. The user may enter a value for contamination or leave it unspecified. Contamination may be added via one of the user-specified field elements.

We provide our best estimates of the contamination for each 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. This version of the FITS files will be available starting in November 2011 and will completely populate the archive by July 2012. The values currently in the data tables at MAST have been separately provided by the mission and are based on the data currently available for download at the MAST.

Example Target Searches

See Figure 3-1 as 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 the input in the "Log_G" field, 3.0..3.5, which specifies a range of values starting with 3.0 and ending with 3.5. A User-specified field, "R_Mag", was used to qualify the R magnitude of the search. 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.

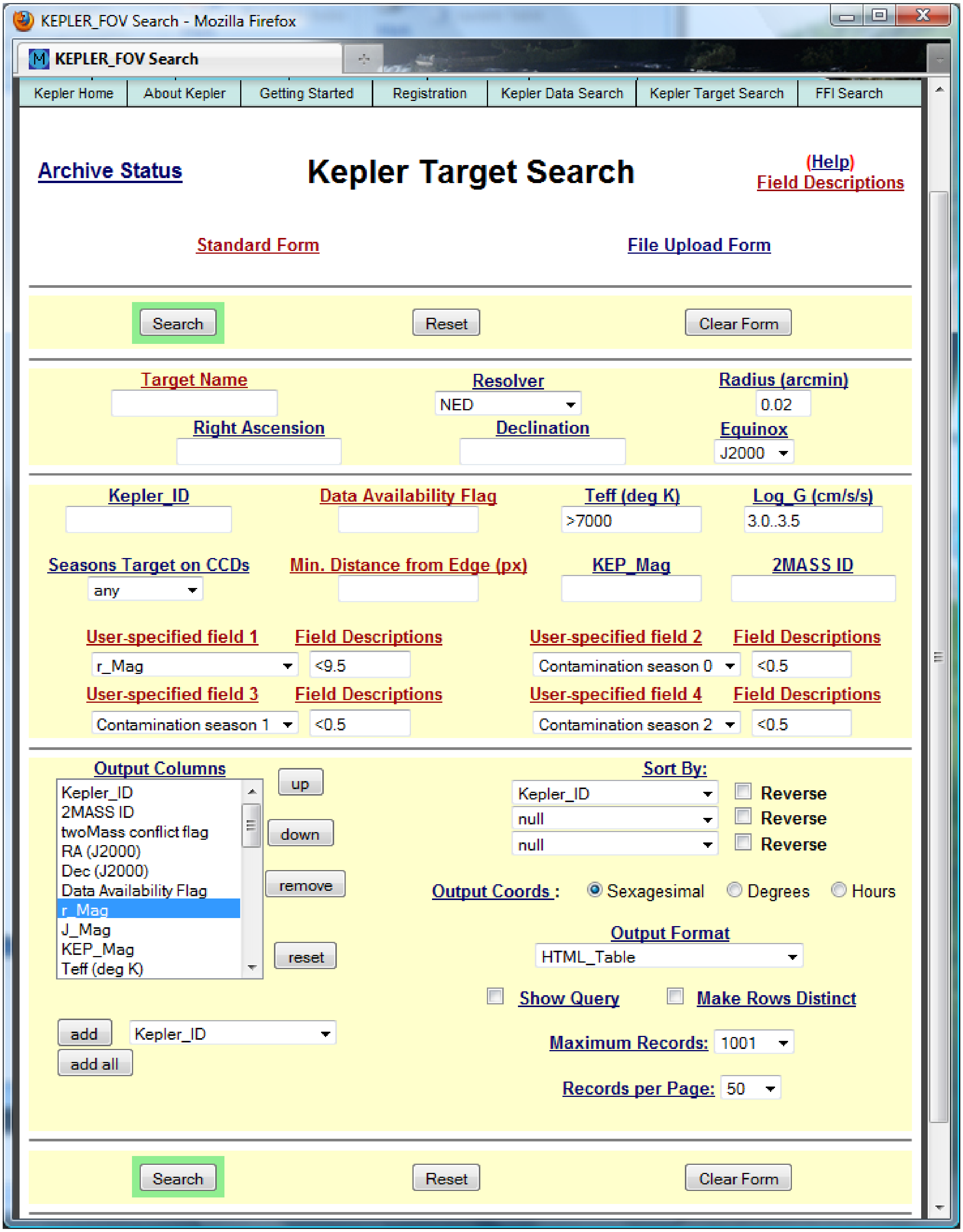


Figure 3-1 MAST Kepler Target Search Form

Kepler_ID	2MASS ID	RA_(J2000)	Dec_(J2000)	Availability Flag	R_Mag	J_Mag	KIC_Mag	Teff	Log_G
1571152	19234056+3709547	19 23 40.56	+37 09 54.8	2	9.229	8.547	9.268	7048	3.164
2166218	19305705+3730357	19 30 57.05	+37 30 35.8	2	9.433	8.768	9.465	7153	3.345
3760826	19394821+3853479	19 39 48.22	+38 53 47.9	1	8.789	8.477	8.758	8640	3.421
6668729	18535062+4210158	18 53 50.62	+42 10 15.8	2	8.597	8.089	8.590	7767	3.484
7060333	19541213+4233399	19 54 12.14	+42 33 39.9	2	9.081	8.532	9.088	7576	3.475
7119530	19291904+4238290	19 29 19.03	+42 38 29.1	2	8.536	8.002	8.517	7777	3.487
7273950	19170644+4249187	19 17 06.46	+42 49 18.8	2	9.356	8.696	9.389	7030	3.474
7827131	19334714+4331022	19 33 47.14	+43 31 02.2		8.012	7.623	7.986	8286	3.487
8649198	19572616+4446301	19 57 26.16	+44 46 30.1		9.251	8.727	9.253	7800	3.488
9812351	18461032+4637509	18 46 10.32	+46 37 51.0	2	7.949	7.451	7.934	7794	3.470
12055345	19105861+5030322	19 10 58.61	+50 30 32.2	2	9.420	9.134	9.379	8953	3.414
Kepler_ID	2MASS ID	RA_(J2000)	Dec_(J2000)	Availability Flag	R_Mag	J_Mag	KIC_Mag	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.

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 is created 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 to locate the file on the user's disk. Select the appropriate file from the user's computer and click open. Enter the location and name of the file 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 and click on it. Enter the qualifier, <0.15, in the box labeled "Field Descriptions." Repeat until the contamination for each season is added and qualified. 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 Figure 3.3. Note the 5th object in the input file did not return a result, because the contamination value was larger than the specified limit.

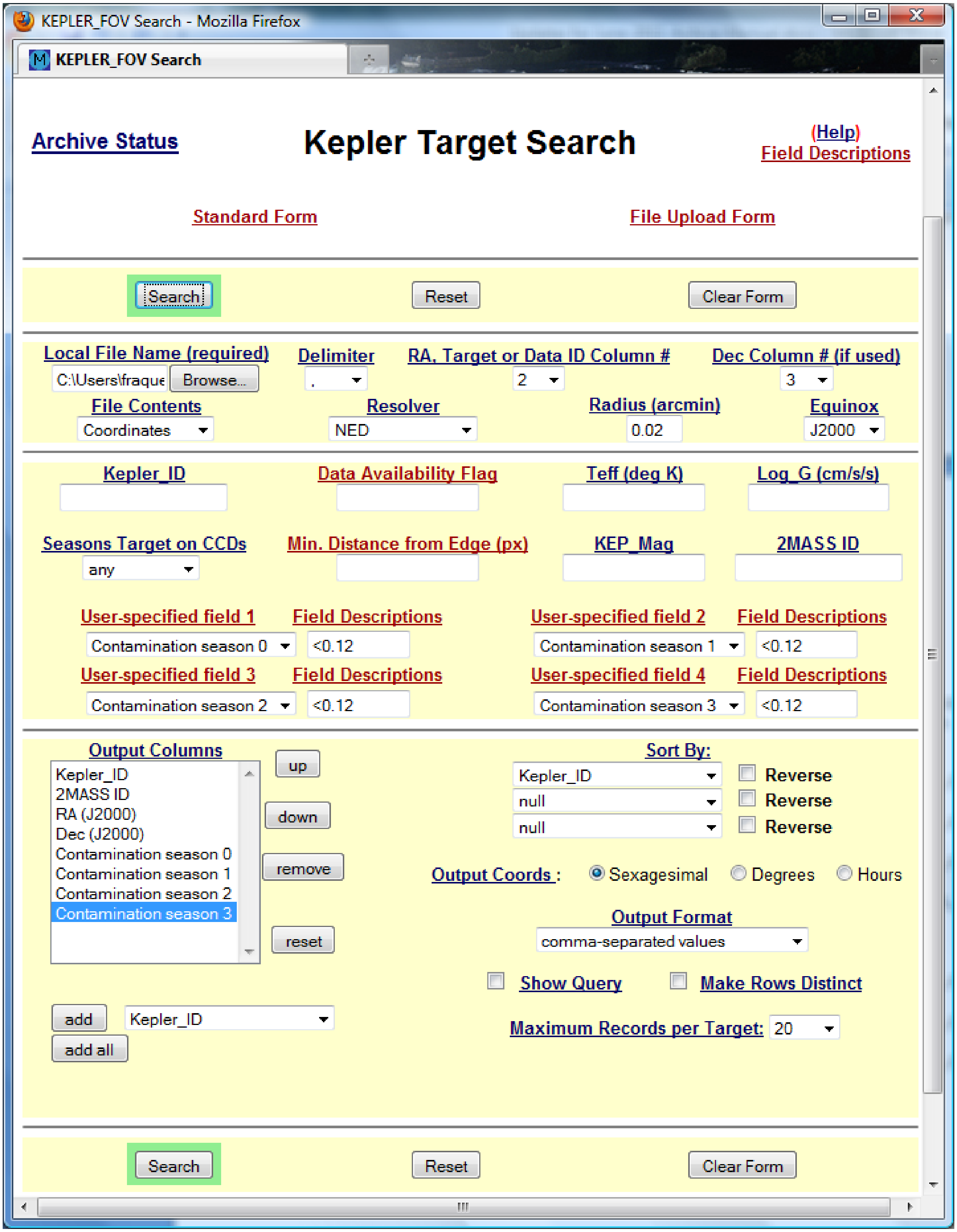


Figure 3-3 Use Case 1 Target Search Form Setup

```
Kepler_ID,2MASS ID,RA (J2000),Dec (J2000),Contamination season 0,Contamination season
1,Contamination season 2,Contamination season 3
integer,string,ra,dec,float,float,float,float

3830833,18582992+3856541,18 58 29.93,+38 56 54.1,0.003,0.005,0.007,0.003

5127321,19540999+4013403,19 54 09.99,+40 13 40.4,0.029,0.036,0.040,0.035

8540791,18502471+4438399,18 50 24.71,+44 38 39.9,0.028,0.015,0.039,0.025

12207020,19215932+5049271,19 21 59.33,+50 49 27.1,0.010,0.013,0.017,0.017

no rows found

8581320,19542280+4440203,19 54 22.80,+44 40 20.4,0.028,0.035,0.050,0.023

9667235,19525673+4621009,19 52 56.73,+46 21 01.0,0.014,0.013,0.022,0.015

9667235,19525673+4621009,19 52 56.73,+46 21 01.0,0.014,0.013,0.022,0.015
```

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.

The original use case specified a proper motion of greater than 1 arcsec/year. However, there are no objects in the KIC that meet the temperature and gravity criteria that also have a listed proper motion of more than 1 arcsec/year.

Before proceeding with the modified 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. The situation for the FOV table is similar, but for fewer objects. 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.

For the modified use case, 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.”

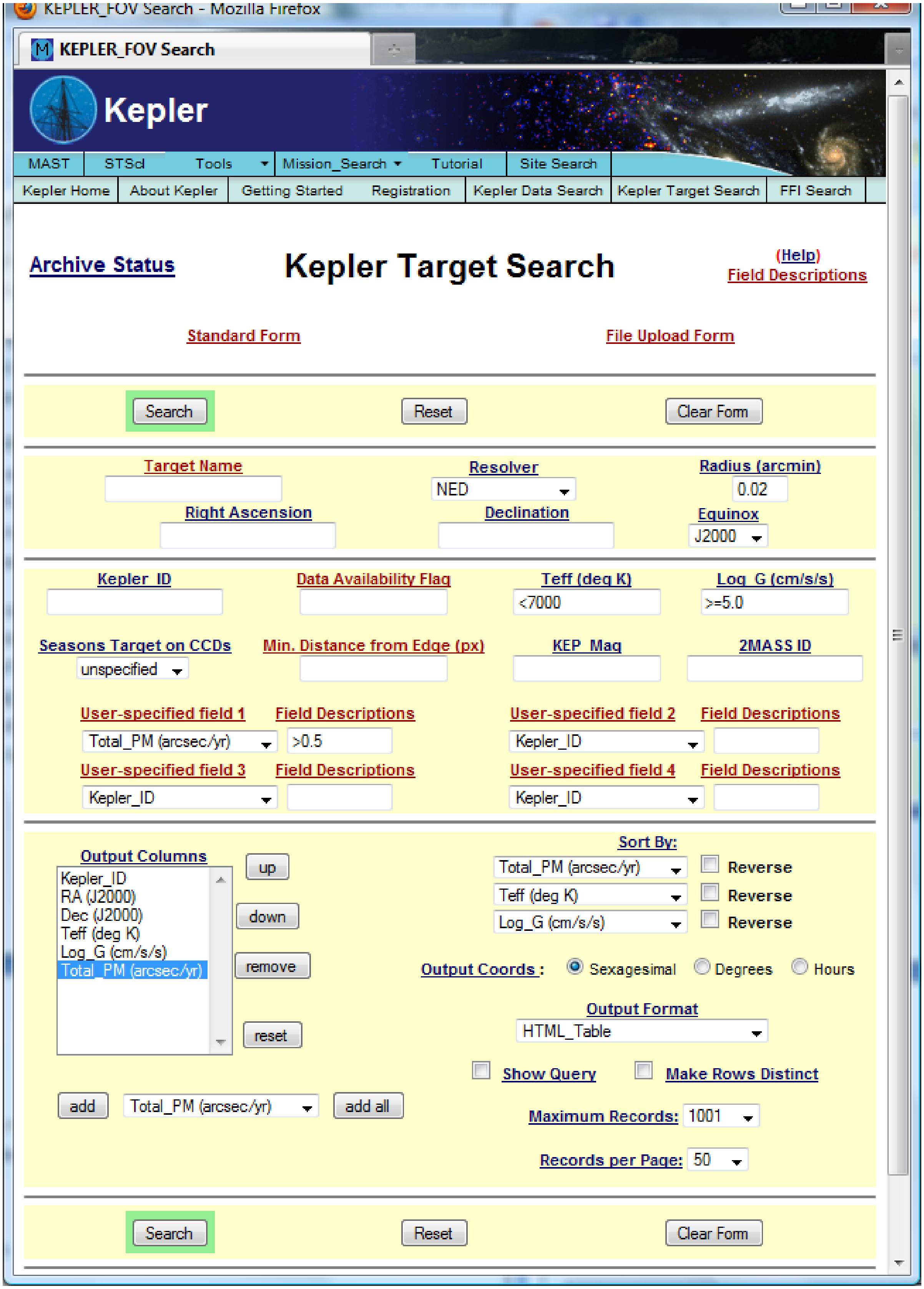


Figure 3-4 Search Form for Use Case 2

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 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. 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.

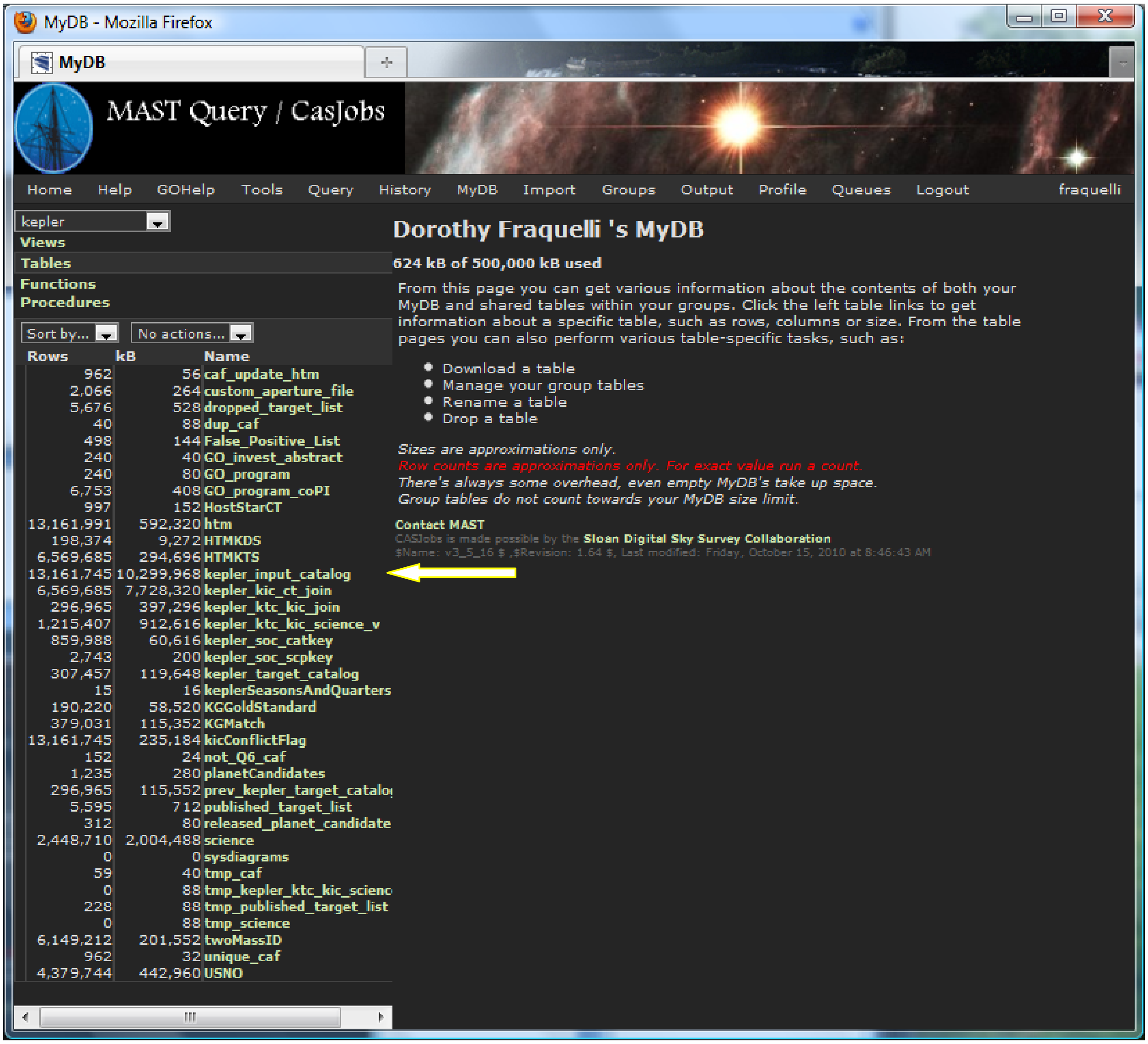


Figure 3-6 CasJob kepler database

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). 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."

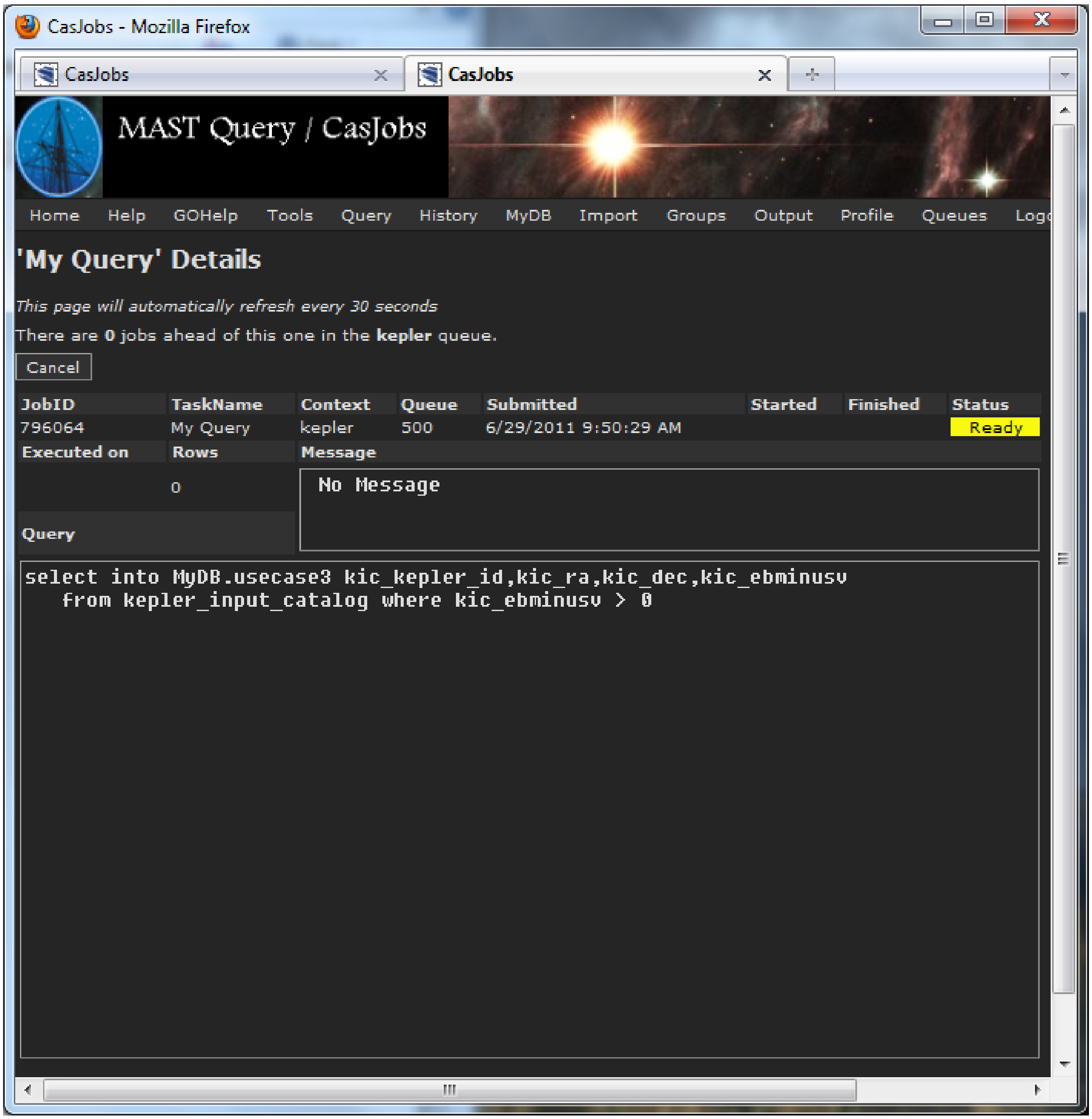


Figure 3.7 CasJob Query Status Page

To examine the results, click on "MyDB" in the menu bar. 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.

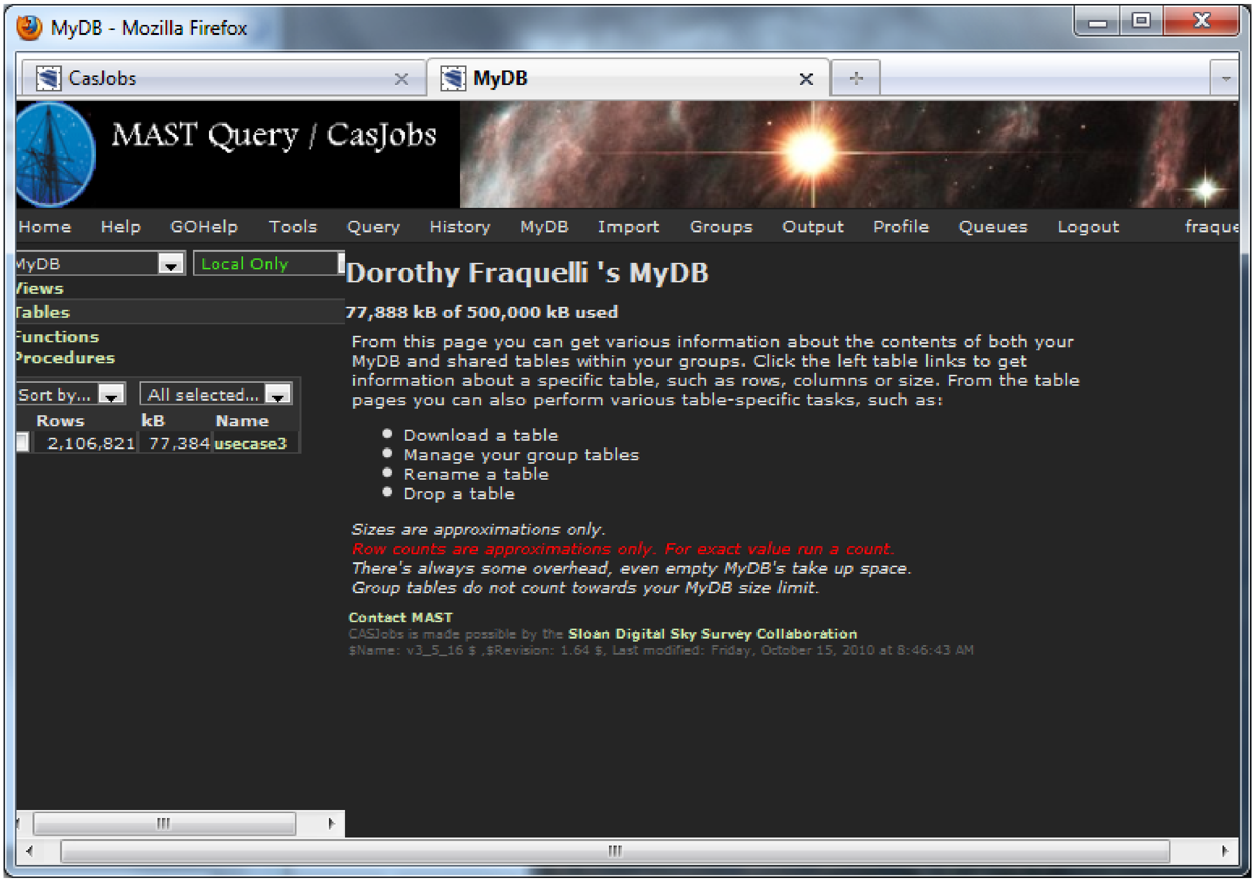


Figure 3.8 CasJobs MyDB page

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.

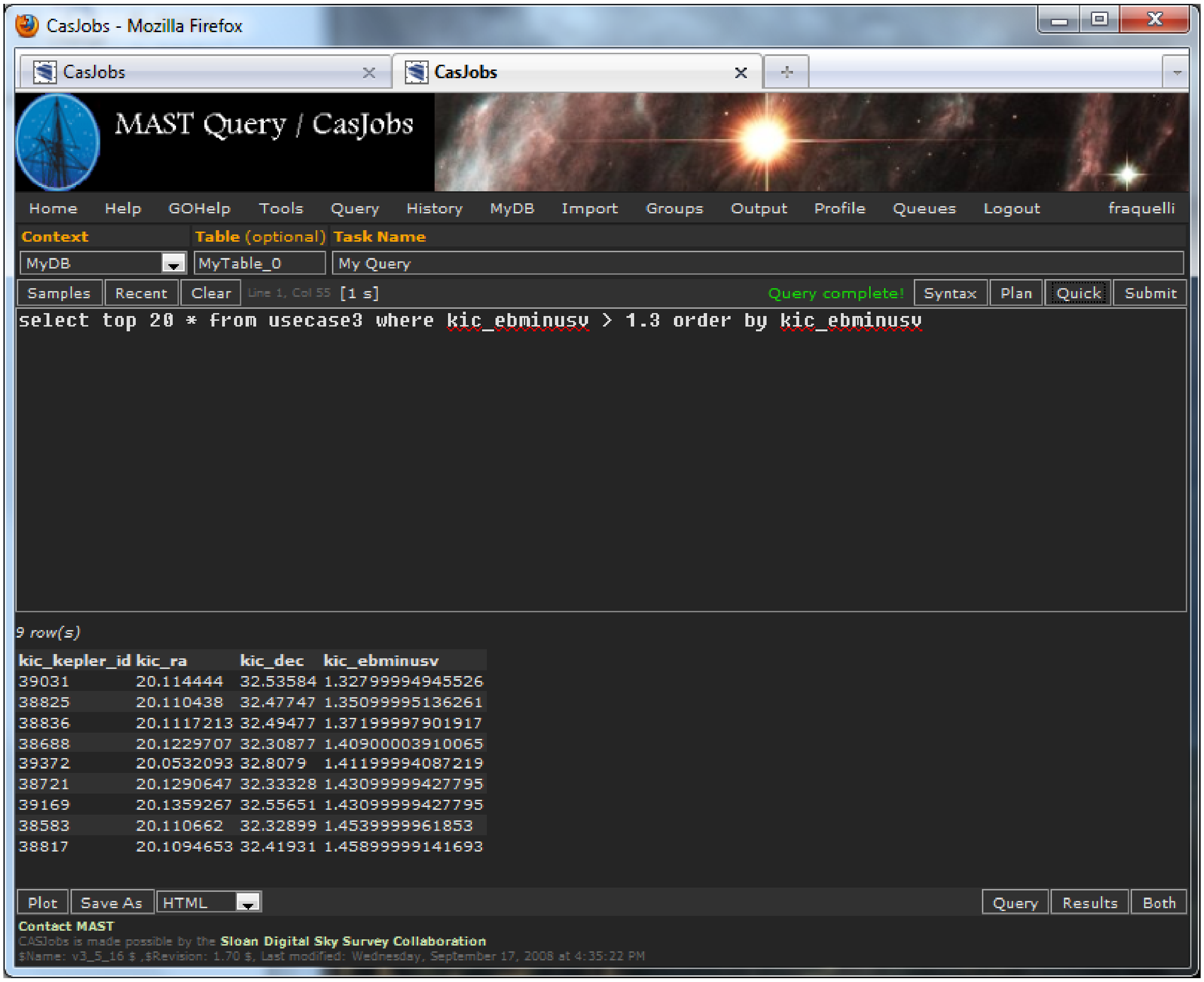


Figure 3.9 Results of search on MyDB table usecase3

Other options for usecase 3:

Using the standard MAST/Kepler search form, while possible, will drive your graduate student insane. There are some 7 million records in the FOV table, more than 13 million in the KIC, and the maximum number of results returned per search is 15001. This means some 438 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 the user truly wants to search the KIC, he will have to use the CasJobs interface when it becomes available. 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 FOV table will not work for the KIC.

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 is a search using information from the archive tables, the FOV table and the KTC.

A note about target pixel files: As of January 2011, target pixel files are being ingested into the archive. Where a light curve has a matching target pixel file, users will only see the light curve listed in the search results. However, the user may request the target pixel file be delivered with the light curve. If no light curve 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 curves 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. This includes the actual start time, the actual stop time, crowding, flux fraction, cdpp3, cdpp6, cdpp12. The values for the CDPP values, the crowding and flux fraction are only available in the FITS headers starting in November 2011.

Figure 3-10 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 3-11.

In the Search Results Form, use the "Mark" column to indicate the data to retrieve. When it is highlighted in yellow, the data are proprietary. Proprietary data may only be retrieved by the PI, and any authorized co-Is, of the proposal associated with that data. The release date column, at the far right, shows when these data become public. To send a retrieval request for these data, click the "Mark" boxes or click on "Mark all", as shown in Figure 3-12, then click on "Submit marked data for retrieval from STDAS." This will open up the Retrieval Options page, as shown in Figure 3-13.

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." The page shown in Figure 3-14 is displayed.

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 user is responsible for ftp'ing the data from the staging disk. After clicking on "Submit", the page shown in Figure 3-14 is displayed.

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.

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.

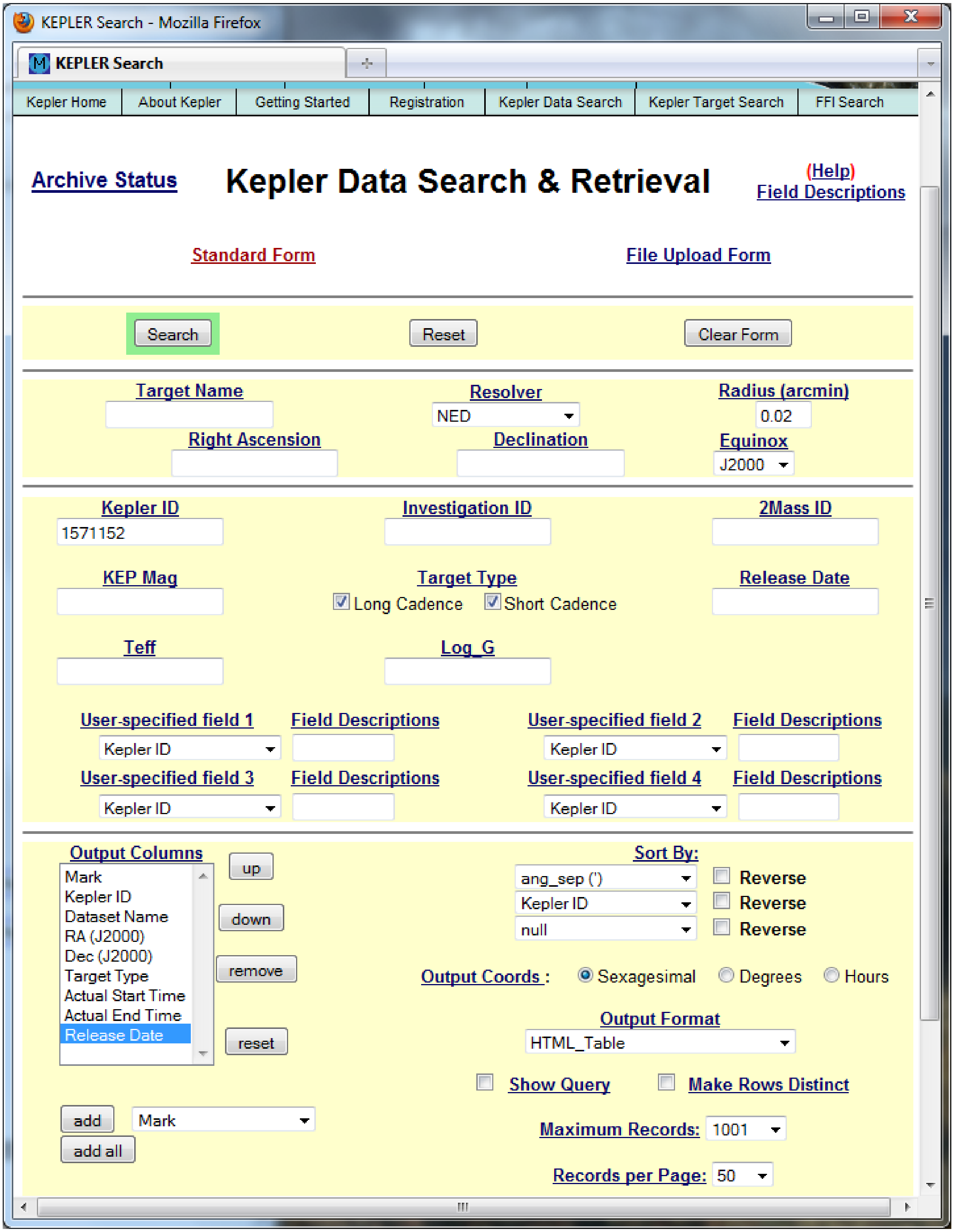


Figure 3-10 The MAST Data Search and Retrieval Form

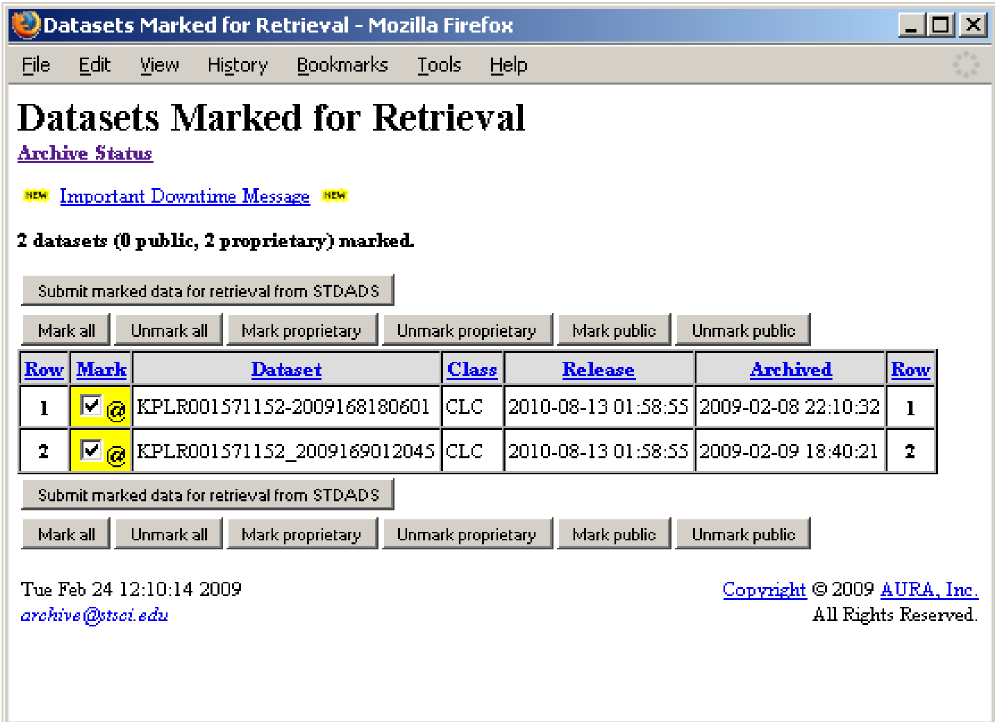


Figure 3-11 Data Search Results

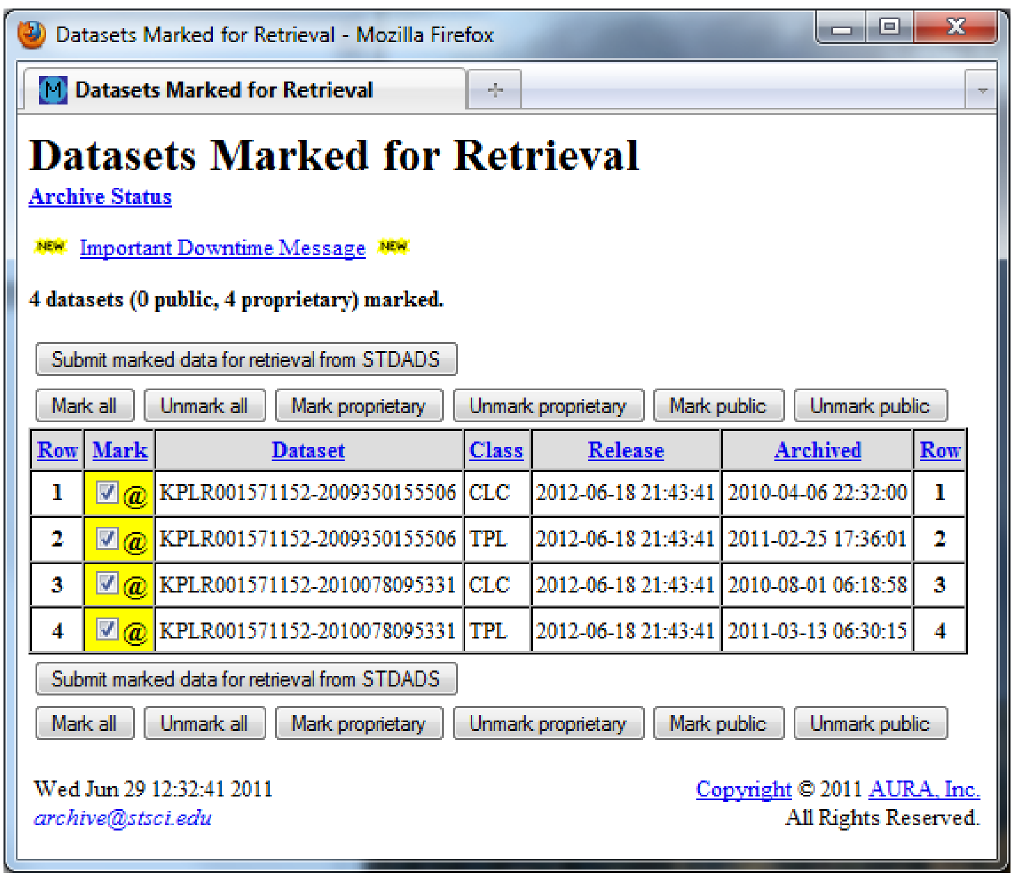


Figure 3-12 Marked Datasets for Retrieval

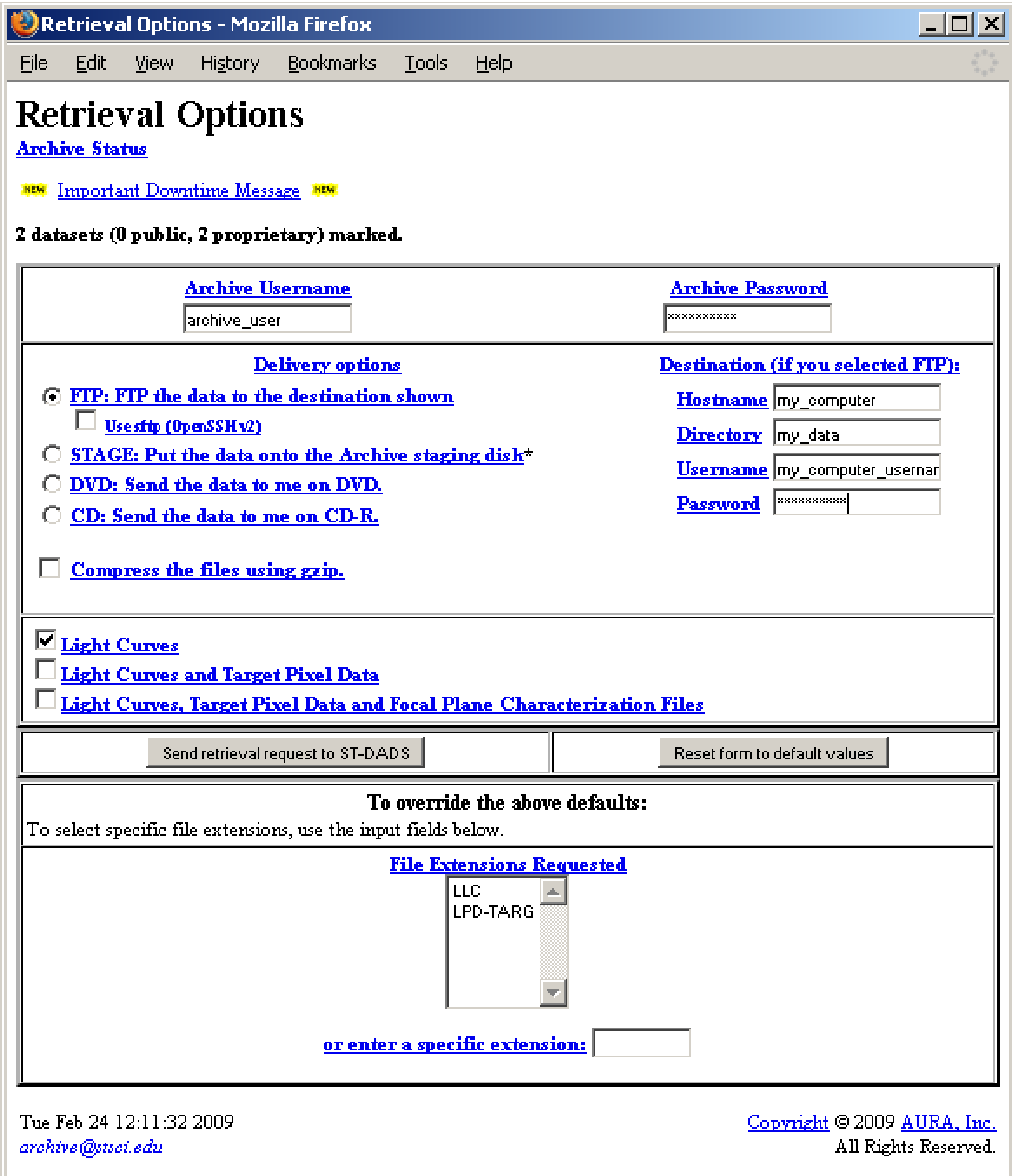


Figure 3-13 Retrieval Options Page

Figure 3-14 Confirmation Page

Example Data Searches

All searches for Kepler data are, by definition, searches of the FOV table 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 given as a 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 3-11 shows the Data Search & Retrieval, qualified as stated and Figure 3-12 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.

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 3-15 for the qualified form and Figure 3-16 for the search results. There are proprietary data included in the search results. Unless you are authorized to retrieve these data, any request for them will be denied. To eliminate proprietary date from the results, return to the Data Search & Retrieval page and add a qualification in the "Release Date" box. An example entry is "< 2010-Dec-03." Fewer results are returned, but all are public and may be retrieved.

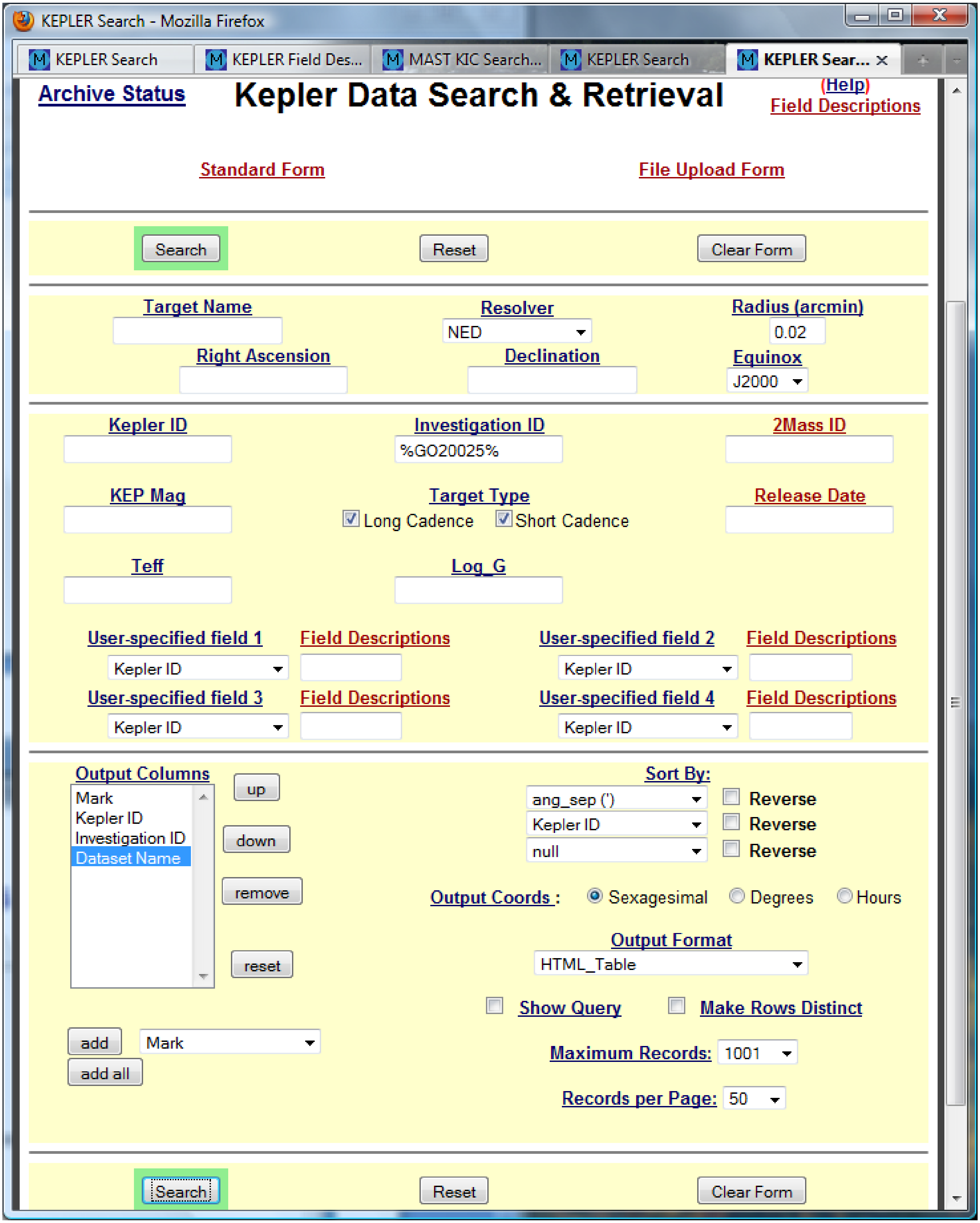
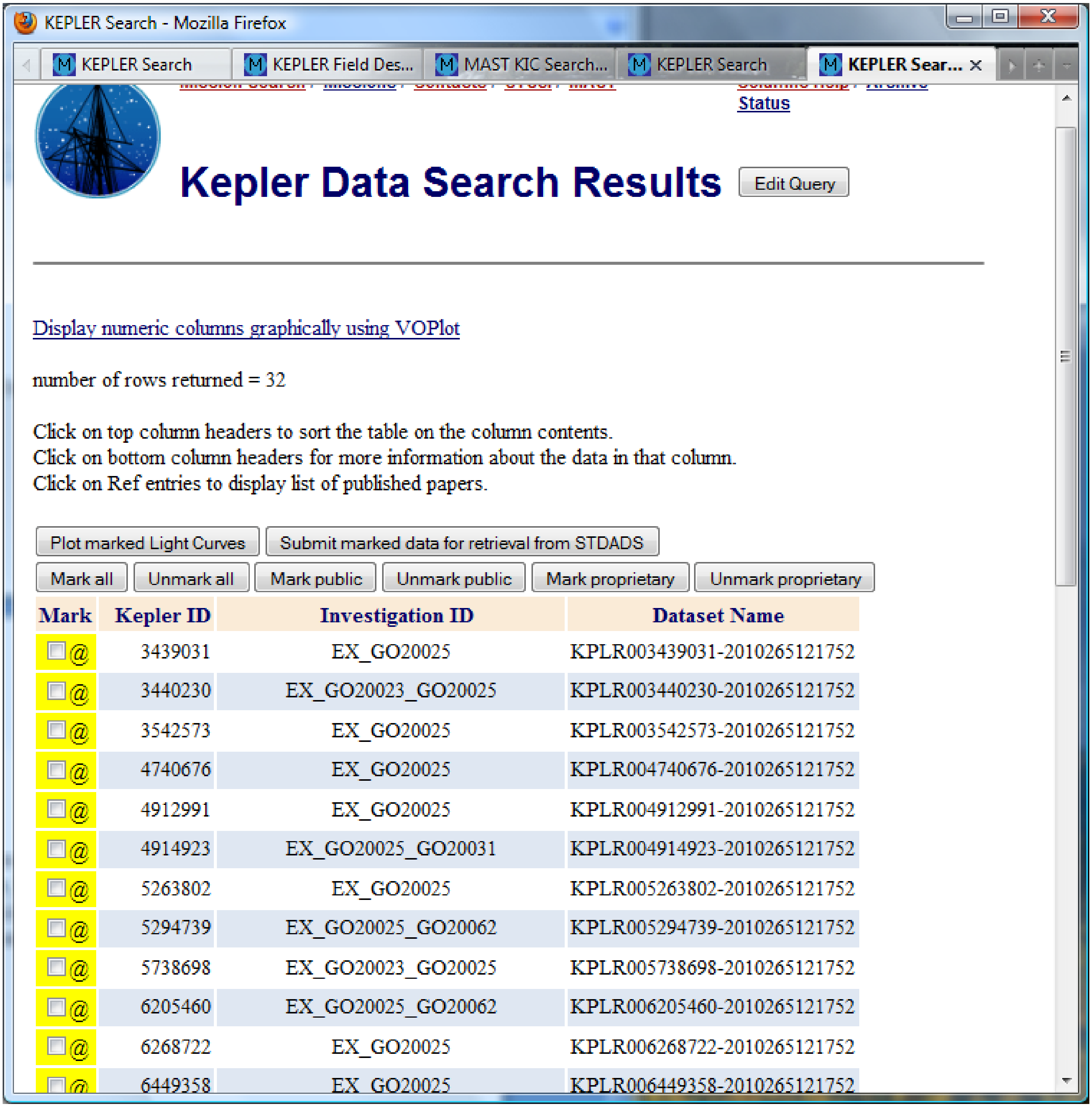

KEPLER Search - Mozilla Firefox
KEPLER Search
KEPLER Field Des...
MAST KIC Search...
KEPLER Search
KEPLER Sear...
Archive Status
Kepler Data Search & Retrieval
(Help)
Field Descriptions
Standard Form
File Upload Form
Search
Reset
Clear Form
Target Name
Resolver
NED
Radius (arcmin)
0.02
Right Ascension
Declination
Equinox
J2000
Kepler ID
Investigation ID
%GO20025%
2Mass ID
KEP Mag
Target Type
Long Cadence
Short Cadence
Release Date
Teff
Log_G
User-specified field 1
Field Descriptions
User-specified field 2
Field Descriptions
Kepler ID
Kepler ID
User-specified field 3
Field Descriptions
User-specified field 4
Field Descriptions
Kepler ID
Kepler ID
Output Columns
Mark
Kepler ID
Investigation ID
Dataset Name
up
down
remove
reset
Sort By:
ang_sep (')
Reverse
Kepler ID
Reverse
null
Reverse
Output Coords :
Sexagesimal
Degrees
Hours
Output Format
HTML_Table
Show Query
Make Rows Distinct
add
Mark
add all
Maximum Records:
1001
Records per Page:
50
Search
Reset
Clear Form

Figure 4-15 Use case 1 qualified search form



Mark	Kepler ID	Investigation ID	Dataset Name
@	3439031	EX_GO20025	KPLR003439031-2010265121752
@	3440230	EX_GO20023_GO20025	KPLR003440230-2010265121752
@	3542573	EX_GO20025	KPLR003542573-2010265121752
@	4740676	EX_GO20025	KPLR004740676-2010265121752
@	4912991	EX_GO20025	KPLR004912991-2010265121752
@	4914923	EX_GO20025_GO20031	KPLR004914923-2010265121752
@	5263802	EX_GO20025	KPLR005263802-2010265121752
@	5294739	EX_GO20025_GO20062	KPLR005294739-2010265121752
@	5738698	EX_GO20023_GO20025	KPLR005738698-2010265121752
@	6205460	EX_GO20025_GO20062	KPLR006205460-2010265121752
@	6268722	EX_GO20025	KPLR006268722-2010265121752
@	6449358	EX_GO20025	KPLR006449358-2010265121752

Figure 3-16 Use case 1 search results

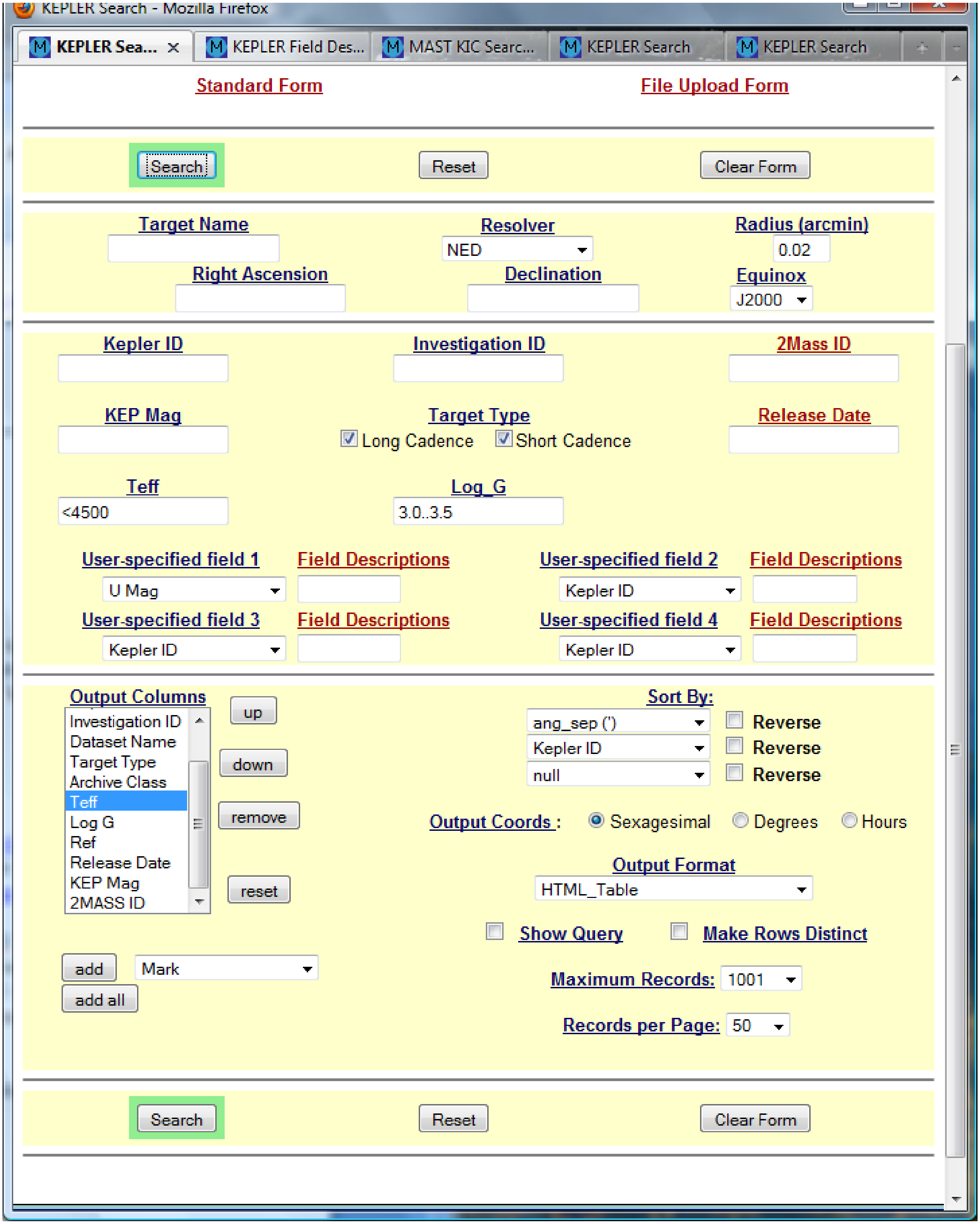
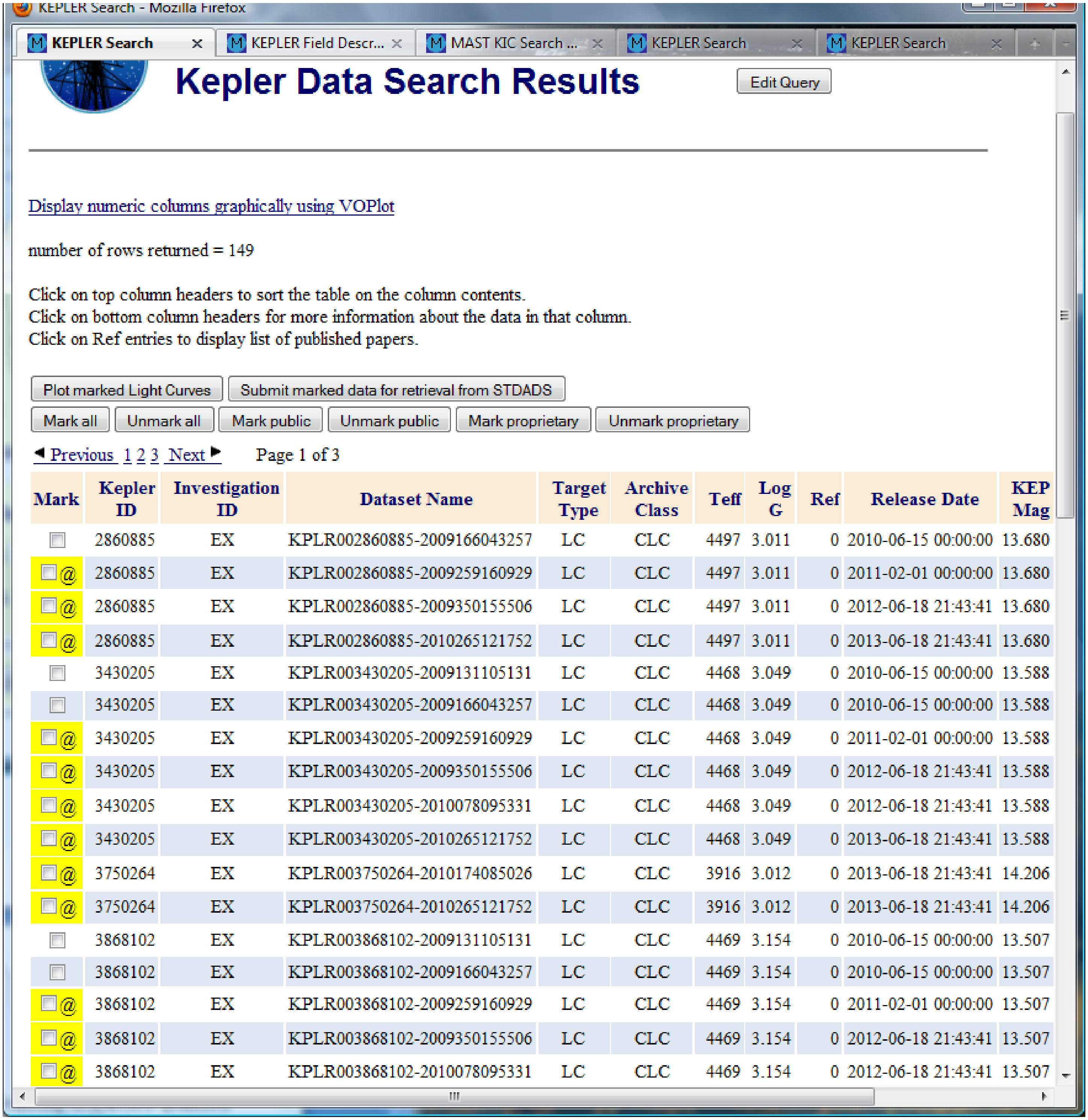

KEPLER Search - Mozilla Firefox
KEPLER Sea...
KEPLER Field Des...
MAST KIC Searc...
KEPLER Search
KEPLER Search
Standard Form
File Upload Form
Search
Reset
Clear Form
Target Name
Resolver
NED
Radius (arcmin)
0.02
Right Ascension
Declination
Equinox
J2000
Kepler ID
Investigation ID
2Mass ID
KEP Mag
Target Type
Long Cadence
Short Cadence
Release Date
Teff
<4500
Log_G
3.0..3.5
User-specified field 1
Field Descriptions
U Mag
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
Investigation ID
Dataset Name
Target Type
Archive Class
Teff
Log G
Ref
Release Date
KEP Mag
2MASS ID
up
down
remove
reset
Sort By:
ang_sep (')
Reverse
Kepler ID
Reverse
null
Reverse
Output Coords :
Sexagesimal
Degrees
Hours
Output Format
HTML_Table
Show Query
Make Rows Distinct
add
Mark
add all
Maximum Records:
1001
Records per Page:
50
Search
Reset
Clear Form

Figure 3-17 Use case 2 qualified search form



Mark	Kepler ID	Investigation ID	Dataset Name	Target Type	Archive Class	Teff	Log G	Ref	Release Date	KEP Mag
☐	2860885	EX	KPLR002860885-2009166043257	LC	CLC	4497	3.011	0	2010-06-15 00:00:00	13.680
☐@	2860885	EX	KPLR002860885-2009259160929	LC	CLC	4497	3.011	0	2011-02-01 00:00:00	13.680
☐@	2860885	EX	KPLR002860885-2009350155506	LC	CLC	4497	3.011	0	2012-06-18 21:43:41	13.680
☐@	2860885	EX	KPLR002860885-2010265121752	LC	CLC	4497	3.011	0	2013-06-18 21:43:41	13.680
☐	3430205	EX	KPLR003430205-2009131105131	LC	CLC	4468	3.049	0	2010-06-15 00:00:00	13.588
☐	3430205	EX	KPLR003430205-2009166043257	LC	CLC	4468	3.049	0	2010-06-15 00:00:00	13.588
☐@	3430205	EX	KPLR003430205-2009259160929	LC	CLC	4468	3.049	0	2011-02-01 00:00:00	13.588
☐@	3430205	EX	KPLR003430205-2009350155506	LC	CLC	4468	3.049	0	2012-06-18 21:43:41	13.588
☐@	3430205	EX	KPLR003430205-2010078095331	LC	CLC	4468	3.049	0	2012-06-18 21:43:41	13.588
☐@	3430205	EX	KPLR003430205-2010265121752	LC	CLC	4468	3.049	0	2013-06-18 21:43:41	13.588
☐@	3750264	EX	KPLR003750264-2010174085026	LC	CLC	3916	3.012	0	2013-06-18 21:43:41	14.206
☐@	3750264	EX	KPLR003750264-2010265121752	LC	CLC	3916	3.012	0	2013-06-18 21:43:41	14.206
☐	3868102	EX	KPLR003868102-2009131105131	LC	CLC	4469	3.154	0	2010-06-15 00:00:00	13.507
☐	3868102	EX	KPLR003868102-2009166043257	LC	CLC	4469	3.154	0	2010-06-15 00:00:00	13.507
☐@	3868102	EX	KPLR003868102-2009259160929	LC	CLC	4469	3.154	0	2011-02-01 00:00:00	13.507
☐@	3868102	EX	KPLR003868102-2009350155506	LC	CLC	4469	3.154	0	2012-06-18 21:43:41	13.507
☐@	3868102	EX	KPLR003868102-2010078095331	LC	CLC	4469	3.154	0	2012-06-18 21:43:41	13.507

Figure 3-18 Partial list of search results for use case 2

3.2.3 FFI Search and Retrieval or Download

Kepler Full Frame Image (FFI) data are public. To search for a particular FFI, use the MAST/Kepler FFI 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. Note that "quarter" was not available for FFIs prior to quarter 6. This will change when the FFIs are reprocessed. An example of the FFI Search form is given below in Figure 3-19.

To simply download the existing FFIs, go the 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 3-20, below.

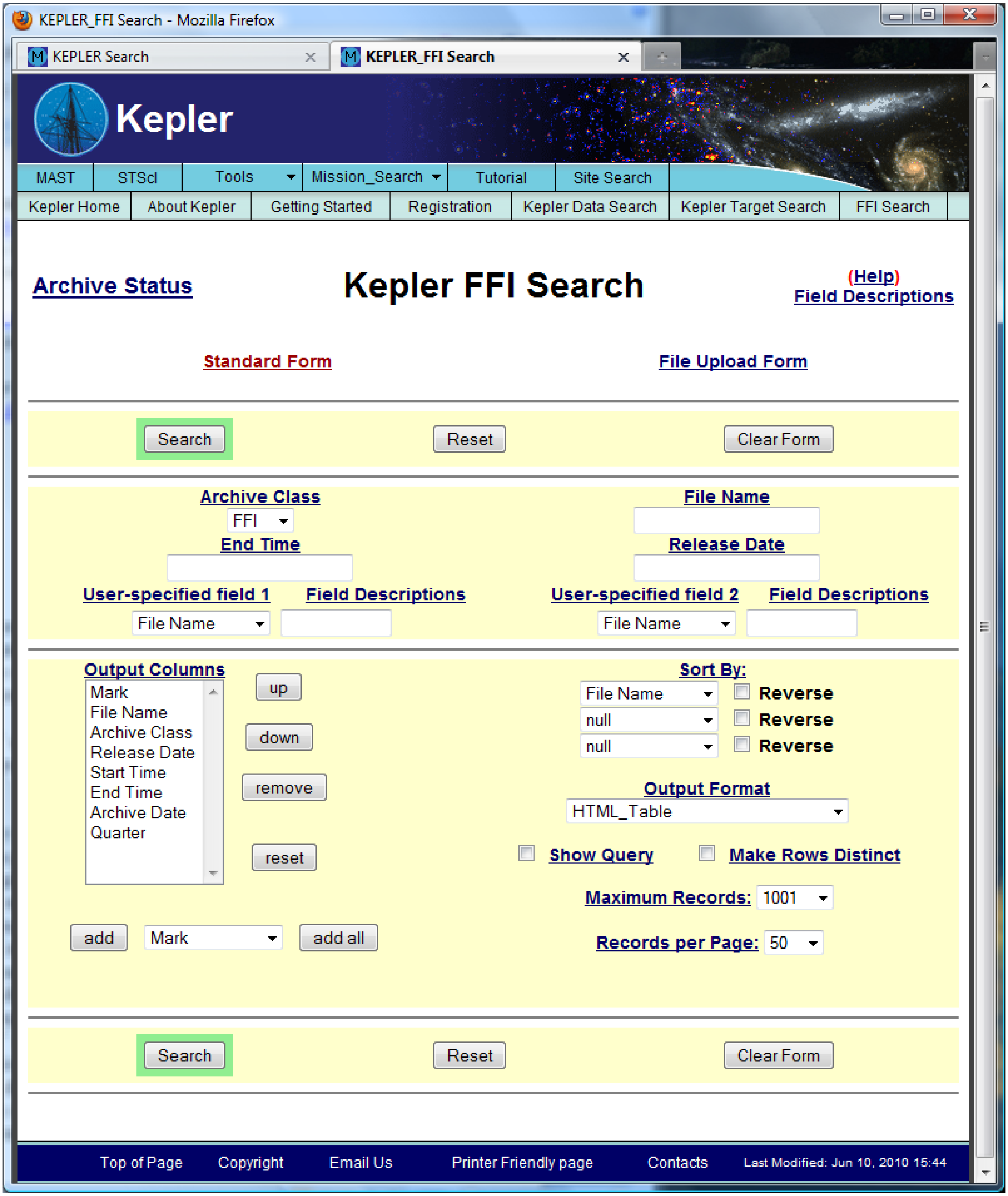


Figure 3-19 Standard FFI Search interface

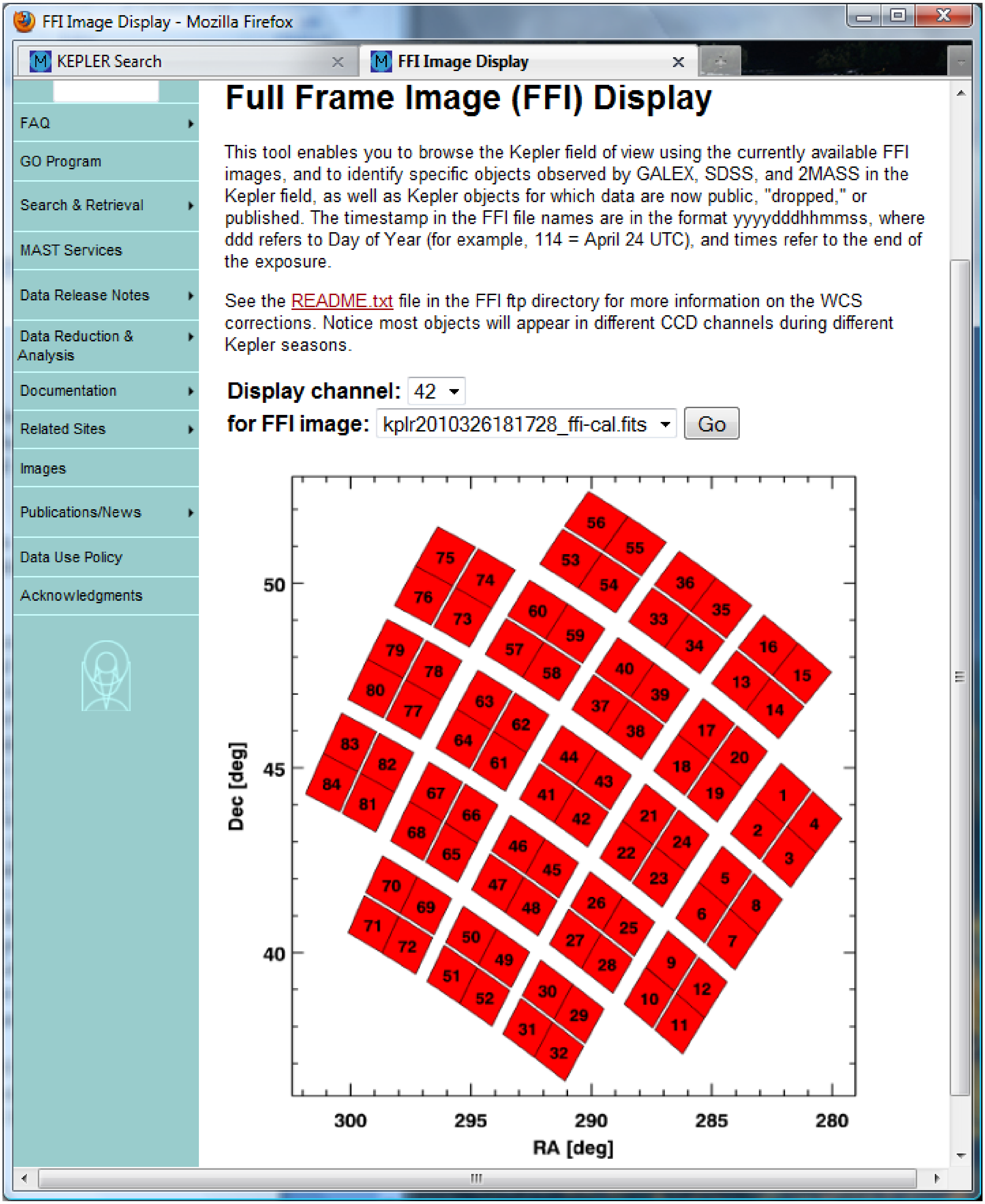


Figure 3-20 MAST's FFI Display Tool Opening Page

3.2.4 The Kepler-GALEX Crossmatch

The Kepler-GALEX cross match (KGxmatch) was created to mitigate the problem of selecting blue objects from the KIC/FOV 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 FOV 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 matchings 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 $\sim 0.6^{o}$) 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.

Kepler-GALEX Crossmatch interface form

MAST provides two interfaces to the KGxmatch results. The tables may also be downloaded by ftp from the gutter of the MAST/Kepler homepage.

One interface is a standard MAST web form that allows search 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 3-21. A portion of the results from the indicated search is shown in Figure 3-22. 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.

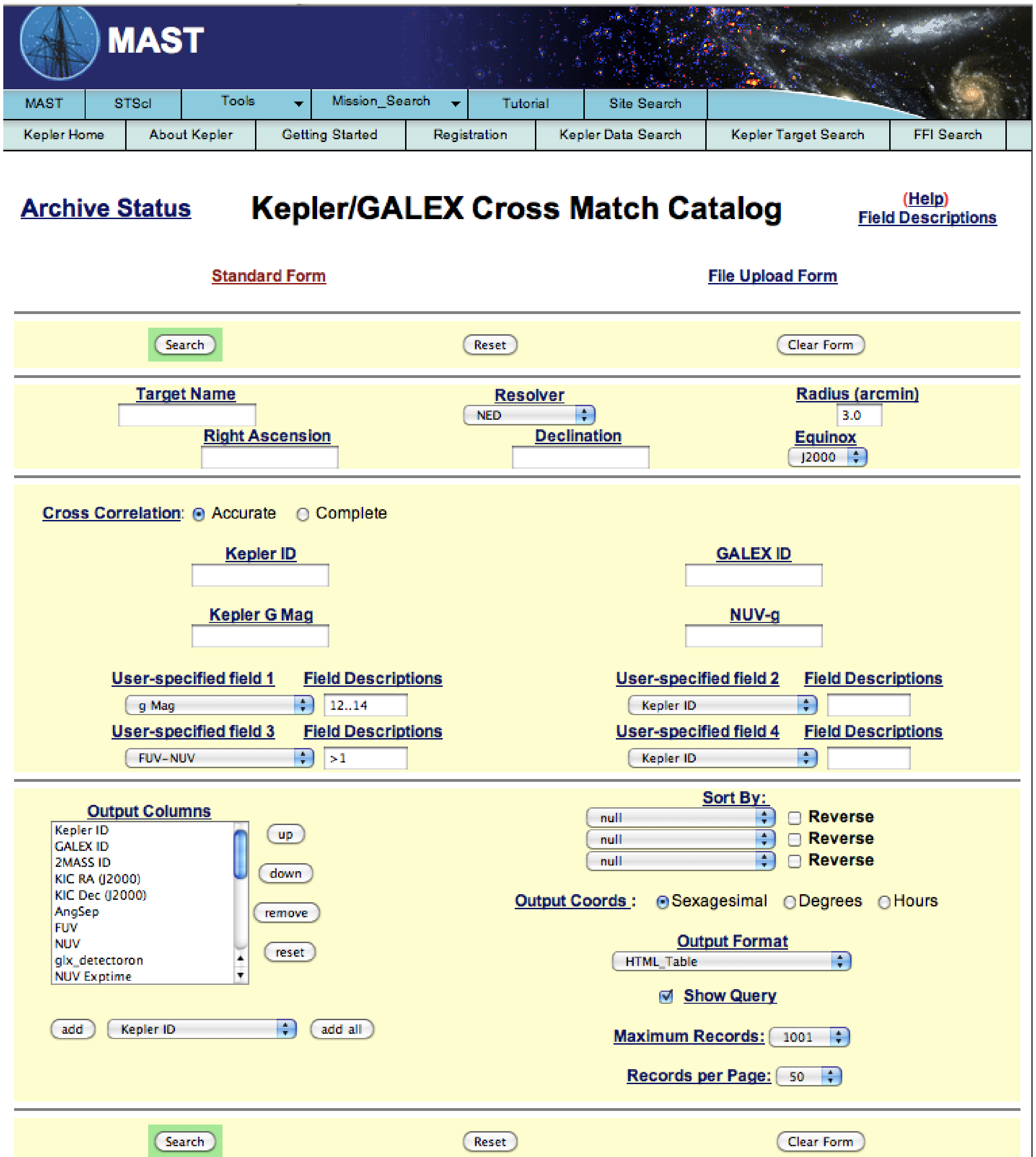


Figure 3-21 Standard MAST interface for the kepler-GALEX cross match tables

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 3-22 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.

The CasJobs implementation

MAST has adapted the "CasJobs" tool constructed at Johns Hopkins University and put it into use for serving long and complicated requests to GALEX tables in the archive and now for the Kepler-GALEX crossmatch tables. 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.

Use of the Casjobs form is recommended for users who wish to build their own more complicated queries using SQL and/or who want to leave their results for future work, e.g. for further cross-correlations with other catalogs or to collaborators. Because many users may not be familiar with SQL, this tool includes its own general help page, GO help page, and SQL tutorial. It is necessary 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**"). Figure 3-19 exhibits the "Query" page of the CasJobs/Kepler.

Because many users may not be experienced in SQL, a few SQL sample queries are shown in the indicated tab. The user can customize these examples to return more refined lists. Use of this query requires consultation of the column names of interest. These can be found in the *kepler* context tab and in the "Column Descriptions" Quick Link at the top of the GOHelp page.

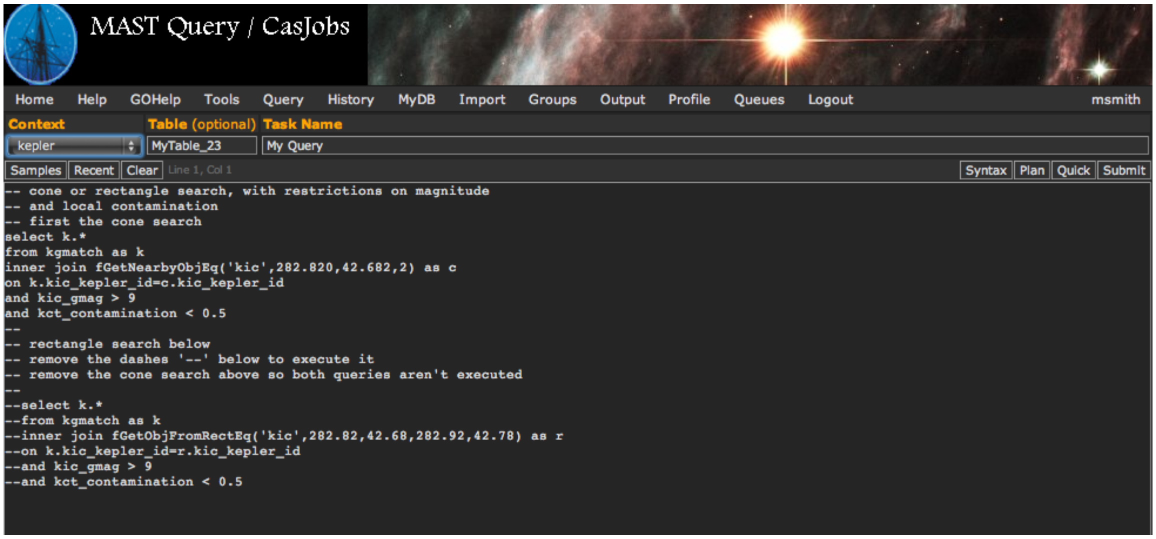


Figure 3-19 The Kepler/GALEX CasJob form. This page can be used to formulate sophisticated queries to constrain a class objects. This example shows a comment-annotated query for selection of matching objects around a designated area in the sky from the Complete table.

3.2.5 Alternate Methods for Downloading Data

As there are 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.

Public Data Download

Files tarred by quarter:
Kepler's public data have been staged in a directory area that is available through anonymous ftp or through a browser. For each quarter, the public files are tarred, by type, into one of three tarfiles. Within a quarter, data may be public for one of the following reasons.

- Dropped Target data
- Published Target data
- Other public data (e.g., the proprietary period has expired)

These data are found at http://archive.stsci.edu/pub/kepler/lightcurves/tarfiles/ and are also available via anonymous ftp from archive.stsci.edu in directory cd /pub/kepler/lightcurves/tarfiles.

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.

Individual Public Light Curve Files

All public data are also online as individual files. To see the directory through a browser go to http://archive.stsci.edu/pub/kepler/lightcurves/.

Note the data have been grouped by the first four digits of the Kepler ID, e.g. 0007, 0008....0129. Under each of these directories, there is a directory for each public Kepler ID, where all public Kepler lightcurves will be stored.

For instance, as of July 26, 2010, there are two datasets to be found in the directory: http://archive.stsci.edu/pub/kepler/lightcurves/0104/010480861/, each corresponding to a different quarter.

The path to these data via anonymous ftp is the same as for the public tar files:

```
ftp archive.stsci.edu
login as anonymous
cd /pub/kepler/lightcurves
```

Proprietary Data Download

As with the public data, MAST provides an ftp download option for proprietary data. In this case, data are collected by investigation id and access control is applied to the directories. Only users who are authorized to access the data for a given investigation can download data from these directories. See section 1.7 for information on registering to receive your proprietary data.

To access the data:

```
ftp archive.stsci.edu
login with archive username and password
ftp> cd /pub/kepler/tarfiles
```

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    = '2011-09-07'         / file creation date.
CREATOR = '208221 FluxExporter2PipelineModule' / pipeline job and program used t
PROCVER = 'svn+ssh://murzim/repo/soc/branches/release/8.0 r44589' / SW version
FILEVER = '2.1     '           / file format version
TIMVERSN= 'OGIP/93-003'        / OGIP memo number for file format
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBJECT  = 'KIC 12108312'       / string version of KEPLERID
KEPLERID=             12108312 / unique Kepler target identifier
CHANNEL =                   29 / CCD channel
SKYGROUP=                    1 / roll-independent location of channel
MODULE  =                   10 / CCD module
OUTPUT  =                    1 / CCD output
QUARTER =                    7 / Observing quarter
SEASON  =                    1 / mission season during which data was collected
DATA_REL=                   10 / version of data release notes for this file
OBSMODE = 'long cadence'       / observing mode
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           289.950761 / [deg] right ascension
DEC_OBJ =            50.657250 / [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    =            81.942394 / [deg] galactic longitude
GLAT    =            16.438763 / [deg] galactic latitude
GMAG    =               14.836 / [mag] SDSS g band magnitude
RMAG    =               14.278 / [mag] SDSS r band magnitude
IMAG    =               14.143 / [mag] SDSS i band magnitude
ZMAG    =               14.085 / [mag] SDSS z band magnitude
```

```
D51MAG  =               14.645 / [mag] D51 magnitude,
JMAG    =               13.137 / [mag] J band magnitude from 2MASS
HMAG    =               12.801 / [mag] H band magnitude from 2MASS
KMAG    =               12.698 / [mag] K band magnitude from 2MASS
KEPMAG  =               14.351 / [mag] Kepler magnitude (Kp)
GRCOLOR =                0.558 / [mag] (g-r) color, SDSS bands
JKCOLOR =                0.439 / [mag] (J-K) color, 2MASS bands
GKCOLOR =                2.138 / [mag] (g-K) color, SDSS g - 2MASS K
TEFF    =                 5474 / [K] Effective temperature
LOGG    =                4.786 / [cm/s2] log10 surface gravity
FEH     =               -0.206 / [log10([Fe/H])]  metallicity
EBMINUSV=                0.076 / [mag] E(B-V) redenning
AV      =                0.236 / [mag] A_v extinction
RADIUS  =                0.656 / [solar radii] stellar radius
TMINDEX =           1106839546 / unique 2MASS catalog ID
SCPID   =                      / unique SCP processing ID
CHECKSUM= '7ma2AjU27jZ2AjZ2'   / HDU checksum updated 2011-09-07T23:49:36Z
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  =                 4375 / 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  = 'D12.7   '           / 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  = 'E13.7   '           / 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  = 'E13.7   '           / 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  = 'E13.7   '           / 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  = 'E13.7   '           / 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  = 'E13.7   '           / 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  = 'E13.7   '           / 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 = 'E13.7   '           / 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 = 'E13.7   '           / 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 = 'E13.7   '           / 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 = 'E13.7   '           / 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 = 'E13.7   '           / 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 = 'E13.7   '           / 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 12108312'       / string version of KEPLERID
KEPLERID=             12108312 / unique Kepler target identifier
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           289.950761 / [deg] right ascension
DEC_OBJ =            50.657250 / [deg] declination
EQUINOX =               2000.0 / equinox of celestial coordinate system
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
TSTART  =         630.16377512 / observation start time in BJD-BJDREF
TSTOP   =         719.55816793 / observation stop time in BJD-BJDREF
LC_START=       55462.67250542 / mid point of first cadence in MJD
LC_END  =       55552.04909152 / mid point of last cadence in MJD
TELAPSE =          89.39439281 / [d] TSTOP - TSTART
LIVETIME=          82.29959973 / [d] TELAPSE multiplied by DEADC
EXPOSURE=          82.29959973 / [d] time on source
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= '2010-09-23T15:53:41.738Z' / TSTART as UTC calendar date
DATE-END= '2010-12-22T01:25:24.237Z' / TSTOP as UTC calendar date
BACKAPP =                    T / background is subtracted
DEADAPP =                    T / deadtime applied
VIGNAPP =                    T / vignetting or collimator correction applied
GAIN    =               112.32 / [electrons/count] channel gain
READNOIS=            80.690688 / [electrons] read noise
NREADOUT=                  270 / number of read per cadence
TIMSLICE=                    1 / time-slice readout sequence section
MEANBLCK=                  742 / [count] FSW mean black level
PDCSAPFL=                  384 / SAP PDC processing flags (bit code)
LCFXDOFF=               419400 / long cadence fixed offset
SCFXDOFF=               219400 / short cadence fixed offset
CDPP3_0 =   122.28099060058594 / RMS CDPP on 3.0-hr time scales
CDPP6_0 =    84.51203155517578 / RMS CDPP on 6.0-hr time scales
CDPP12_0=   61.956398010253906 / RMS CDPP on 12.0-hr time scales
CROWDSAP=               0.9570 / Ratio of target flux to total flux in op. ap.
FLFRCSAP=               0.8840 / Frac. of target flux w/in the op. aperture
CHECKSUM= 'CcarFbToCbZoCbZo'   / HDU checksum updated 2011-09-07T23:49:36Z
PDCVAR  =   0.8333725929260254 / PDC measure of target variability
PDCPRWT =   0.6917994022369385 / PDC prior weight detrending
PDC_TOT =   0.8609612584114075 / PDC total goodness metric for target
PDC_TOTP=    62.87252426147461 / PDC_TOT percentile compared to mod/out
PDC_COR =   0.9997266530990601 / PDC correlation goodness metric for target
PDC_CORP=    86.67927551269531 / PDC_COR percentile compared to mod/out
PDC_VAR =   0.9993423223495483 / PDC variability goodness metric for target
PDC_VARP=     88.4486083984375 / PDC_VAR percentile compared to mod/out
PDC_NOI =   0.8616523742675781 / PDC noise goodness metric for target
PDC_NOIP=   44.203914642333984 / PDC_NOI percentile compared to mod/out
```

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  =                    6 / length of first array dimension
NAXIS2  =                    5 / 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 12108312'       / string version of KEPLERID
KEPLERID=             12108312 / unique Kepler target identifier
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           289.950761 / [deg] right ascension
DEC_OBJ =            50.657250 / [deg] declination
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 =                  996 / 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 =                  811 / value at reference CCD row
CDELT2P =                  1.0 / physical WCS axis 2 step
WCSAXES =                    2 / number of WCS axes
CTYPE1  = 'RA---TAN'           / right ascension coordinate type
CTYPE2  = 'DEC--TAN'           / declination coordinate type
CRPIX1  =   3.9839181917794804 / [pixel] reference pixel along image axis 1
CRPIX2  =    3.356390699661233 / [pixel] reference pixel along image axis 2
CRVAL1  =          289.9507605 / [deg] right ascension at reference pixel
CRVAL2  =             50.65725 / [deg] declination at reference pixel
CUNIT1  = 'deg     '           / physical unit in column dimension
CUNIT2  = 'deg     '           / physical unit in row dimension
CDELT1  =   -0.001104958984605 / [deg] pixel scale in RA dimension
CDELT2  = 0.001104958984604746 / [deg] pixel scale in Dec dimension
PC1_1   =   0.8339658132919074 / linear transformation element cos(th)
PC1_2   =   0.5511153250248543 / linear transformation element -sin(th)
PC2_1   =  -0.5514383158387176 / linear transformation element sin(th)
PC2_2   =   0.8346791705857824 / linear transformation element cos(th)
NPIXSAP =                    8 / Number of pixels in optimal aperture
NPIXMISS=                    0 / Number of op. aperture pixels not collected
CHECKSUM= 'JfnXKZkVJfkVJZkV'   / HDU checksum updated 2011-09-07T23:49:36Z
```

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    = '2011-09-13'         / file creation date.
CREATOR = '222409 TargetPixelExporterPipelineModule' / pipeline job and program
PROCVER = 'svn+ssh://murzim/repo/soc/branches/release/8.0 r44694' / SW version
FILEVER = '2.1     '           / file format version
TIMVERSN= 'OGIP/93-003'        / OGIP memo number for file format
TELESCOP= 'Kepler  '           / telescope
INSTRUME= 'Kepler Photometer'  / detector type
OBJECT  = 'KIC 12108310'       / string version of KEPLERID
KEPLERID=             12108310 / unique Kepler target identifier
CHANNEL =                   29 / CCD channel
SKYGROUP=                    1 / roll-independent location of channel
MODULE  =                   10 / CCD module
OUTPUT  =                    1 / CCD output
QUARTER =                    7 / Observing quarter
SEASON  =                    1 / mission season during which data was collected
DATA_REL=                   10 / version of data release notes for this file
OBSMODE = 'long cadence'       / observing mode
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           289.949400 / [deg] right ascension
DEC_OBJ =            50.610740 / [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    =            81.897395 / [deg] galactic longitude
GLAT    =            16.421414 / [deg] galactic latitude
GMAG    =               16.066 / [mag] SDSS g band magnitude
RMAG    =               15.550 / [mag] SDSS r band magnitude
IMAG    =               15.398 / [mag] SDSS i band magnitude
ZMAG    =               15.337 / [mag] SDSS z band magnitude
D51MAG  =               15.871 / [mag] D51 magnitude,
JMAG    =               14.407 / [mag] J band magnitude from 2MASS
HMAG    =               14.130 / [mag] H band magnitude from 2MASS
```

```
KMAG    =               14.009 / [mag] K band magnitude from 2MASS
KEPMAG  =               15.598 / [mag] Kepler magnitude (Kp)
GRCOLOR =                0.516 / [mag] (g-r) color, SDSS bands
JKCOLOR =                0.398 / [mag] (J-K) color, 2MASS bands
GKCOLOR =                2.057 / [mag] (g-K) color, SDSS g - 2MASS K
TEFF    =                 5811 / [K] Effective temperature
LOGG    =                4.561 / [cm/s2] log10 surface gravity
FEH     =               -0.130 / [log10([Fe/H])]  metallicity
EBMINUSV=                0.136 / [mag] E(B-V) redenning
AV      =                0.421 / [mag] A_v extinction
RADIUS  =                0.893 / [solar radii] stellar radius
TMINDEX =           1106839401 / unique 2MASS catalog ID
SCPID   =                      / unique SCP processing ID
CHECKSUM= 'MlnGOllGMllGMllG'   / HDU checksum updated 2011-09-13T21:58:11Z
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  =                  508 / length of first array dimension
NAXIS2  =                 4375 / 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  = 'D12.7   '           / 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  = 'RAW_CNTS'           / column title: raw pixel counts
TFORM4  = '20J     '           / column format: image of signed 32-bit integers
TUNIT4  = 'count   '           / column units: count
TDISP4  = 'I8      '           / column display format
TDIM4   = '(5,4)   '           / 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  =                 1020 / table column physical WCS ax 1 ref value
2CRV4P  =                  777 / 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  =    3.824950985871965 / [pixel] reference pixel along image axis 1
2CRPX4  =   2.7870355338794752 / [pixel] reference pixel along image axis 2
1CRVL4  =   289.94939999999997 / [deg] right ascension at reference pixel
2CRVL4  =             50.61074 / [deg] declination at reference pixel
1CUNI4  = 'deg     '           / physical unit in column dimension
2CUNI4  = 'deg     '           / physical unit in row dimension
1CDLT4  =    0.001104405386536 / [deg] pixel scale in RA dimension
2CDLT4  =   -0.001104405386536 / [deg] pixel scale in DEC dimension
11PC4   =   0.8335381765495963 / linear transformation matrix element cos(th)
12PC4   =   0.5508653238178638 / linear transformation matrix element -sin(th)
21PC4   =  -0.5517328704972262 / linear transformation matrix element sin(th)
22PC4   =    0.835078120253523 / linear transformation matrix element cos(th)
TTYPE5  = 'FLUX    '           / column title: calibrated pixel flux
TFORM5  = '20E     '           / column format: image of 32-bit floating point
TUNIT5  = 'e-/s    '           / column units: electrons per second
TDISP5  = 'E13.6   '           / column display format
TDIM5   = '(5,4)   '           / 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  =                 1020 / table column physical WCS ax 1 ref value
2CRV5P  =                  777 / 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  =    3.824950985871965 / [pixel] reference pixel along image axis 1
2CRPX5  =   2.7870355338794752 / [pixel] reference pixel along image axis 2
1CRVL5  =   289.94939999999997 / [deg] right ascension at reference pixel
2CRVL5  =             50.61074 / [deg] declination at reference pixel
1CUNI5  = 'deg     '           / physical unit in column dimension
2CUNI5  = 'deg     '           / physical unit in row dimension
1CDLT5  =    0.001104405386536 / [deg] pixel scale in RA dimension
2CDLT5  =   -0.001104405386536 / [deg] pixel scale in DEC dimension
11PC5   =   0.8335381765495963 / linear transformation matrix element cos(th)
12PC5   =   0.5508653238178638 / linear transformation matrix element -sin(th)
21PC5   =  -0.5517328704972262 / linear transformation matrix element sin(th)
22PC5   =    0.835078120253523 / linear transformation matrix element cos(th)
TTYPE6  = 'FLUX_ERR'           / column title: 1-sigma calibrated uncertainty
TFORM6  = '20E     '           / column format: image of 32-bit floating point
TUNIT6  = 'e-/s    '           / column units: electrons per second (1-sigma)
TDISP6  = 'E13.6   '           / column display format
TDIM6   = '(5,4)   '           / 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  =                 1020 / table column physical WCS ax 1 ref value
2CRV6P  =                  777 / 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  =    3.824950985871965 / [pixel] reference pixel along image axis 1
2CRPX6  =   2.7870355338794752 / [pixel] reference pixel along image axis 2
1CRVL6  =   289.94939999999997 / [deg] right ascension at reference pixel
2CRVL6  =             50.61074 / [deg] declination at reference pixel
1CUNI6  = 'deg     '           / physical unit in column dimension
2CUNI6  = 'deg     '           / physical unit in row dimension
1CDLT6  =    0.001104405386536 / [deg] pixel scale in RA dimension
2CDLT6  =   -0.001104405386536 / [deg] pixel scale in DEC dimension
11PC6   =   0.8335381765495963 / linear transformation matrix element cos(th)
12PC6   =   0.5508653238178638 / linear transformation matrix element -sin(th)
21PC6   =  -0.5517328704972262 / linear transformation matrix element sin(th)
22PC6   =    0.835078120253523 / linear transformation matrix element cos(th)
TTYPE7  = 'FLUX_BKG'           / column title: calibrated background flux
TFORM7  = '20E     '           / column format: image of 32-bit floating point
TUNIT7  = 'e-/s    '           / column units: electrons per second
TDISP7  = 'E13.6   '           / column display format
```

```
TDIM7   = '(5,4)   '           / 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  =                 1020 / table column physical WCS ax 1 ref value
2CRV7P  =                  777 / 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  =    3.824950985871965 / [pixel] reference pixel along image axis 1
2CRPX7  =   2.7870355338794752 / [pixel] reference pixel along image axis 2
1CRVL7  =   289.94939999999997 / [deg] right ascension at reference pixel
2CRVL7  =             50.61074 / [deg] declination at reference pixel
1CUNI7  = 'deg     '           / physical unit in column dimension
2CUNI7  = 'deg     '           / physical unit in row dimension
1CDLT7  =    0.001104405386536 / [deg] pixel scale in RA dimension
2CDLT7  =   -0.001104405386536 / [deg] pixel scale in DEC dimension
11PC7   =   0.8335381765495963 / linear transformation matrix element cos(th)
12PC7   =   0.5508653238178638 / linear transformation matrix element -sin(th)
21PC7   =  -0.5517328704972262 / linear transformation matrix element sin(th)
22PC7   =    0.835078120253523 / linear transformation matrix element cos(th)
TTYPE8  = 'FLUX_BKG_ERR'       / column title: 1-sigma cal. background uncertain
TFORM8  = '20E     '           / column format: image of 32-bit floating point
TUNIT8  = 'e-/s    '           / column units: electrons per second (1-sigma)
TDISP8  = 'E13.6   '           / column display format
TDIM8   = '(5,4)   '           / 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  =                 1020 / table column physical WCS ax 1 ref value
2CRV8P  =                  777 / 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  =    3.824950985871965 / [pixel] reference pixel along image axis 1
2CRPX8  =   2.7870355338794752 / [pixel] reference pixel along image axis 2
1CRVL8  =   289.94939999999997 / [deg] right ascension at reference pixel
2CRVL8  =             50.61074 / [deg] declination at reference pixel
1CUNI8  = 'deg     '           / physical unit in column dimension
2CUNI8  = 'deg     '           / physical unit in row dimension
1CDLT8  =    0.001104405386536 / [deg] pixel scale in RA dimension
2CDLT8  =   -0.001104405386536 / [deg] pixel scale in DEC dimension
11PC8   =   0.8335381765495963 / linear transformation matrix element cos(th)
12PC8   =   0.5508653238178638 / linear transformation matrix element -sin(th)
21PC8   =  -0.5517328704972262 / linear transformation matrix element sin(th)
22PC8   =    0.835078120253523 / linear transformation matrix element cos(th)
TTYPE9  = 'COSMIC_RAYS'        / column title: cosmic ray detections
TFORM9  = '20E     '           / column format: image of 32-bit floating point
TUNIT9  = 'e-/s    '           / column units: electrons per second
TDISP9  = 'E13.6   '           / column display format
TDIM9   = '(5,4)   '           / 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  =                 1020 / table column physical WCS ax 1 ref value
2CRV9P  =                  777 / 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  =    3.824950985871965 / [pixel] reference pixel along image axis 1
2CRPX9  =   2.7870355338794752 / [pixel] reference pixel along image axis 2
1CRVL9  =   289.94939999999997 / [deg] right ascension at reference pixel
2CRVL9  =             50.61074 / [deg] declination at reference pixel
1CUNI9  = 'deg     '           / physical unit in column dimension
2CUNI9  = 'deg     '           / physical unit in row dimension
1CDLT9  =    0.001104405386536 / [deg] pixel scale in RA dimension
2CDLT9  =   -0.001104405386536 / [deg] pixel scale in DEC dimension
11PC9   =   0.8335381765495963 / linear transformation matrix element cos(th)
12PC9   =   0.5508653238178638 / linear transformation matrix element -sin(th)
21PC9   =  -0.5517328704972262 / linear transformation matrix element sin(th)
22PC9   =    0.835078120253523 / 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 = 'E13.6   '           / 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 = 'E13.6   '           / 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 12108310'       / string version of KEPLERID
KEPLERID=             12108310 / unique Kepler target identifier
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           289.949400 / [deg] right ascension
DEC_OBJ =            50.610740 / [deg] declination
EQUINOX =               2000.0 / equinox of celestial coordinate system
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
TSTART  =         630.16377718 / observation start time in BJD-BJDREF
TSTOP   =         719.55816403 / observation stop time in BJD-BJDREF
LC_START=       55462.67250542 / mid point of first cadence in MJD
LC_END  =       55552.04909152 / mid point of last cadence in MJD
TELAPSE =          89.39438685 / [d] TSTOP - TSTART
LIVETIME=          82.29959424 / [d] TELAPSE multiplied by DEADC
EXPOSURE=          80.75701975 / [d] time on source
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= '2010-09-23T15:53:41.738Z' / TSTART as UTC calendar date
DATE-END= '2010-12-22T01:25:24.237Z' / TSTOP as UTC calendar date
BACKAPP =                    T / background is subtracted
DEADAPP =                    T / deadtime applied
VIGNAPP =                    T / vignetting or collimator correction applied
GAIN    =               112.32 / [electrons/count] channel gain
READNOIS=            80.690688 / [electrons] read noise
NREADOUT=                  270 / number of read per cadence
```

```
TIMSLICE=                    1 / time-slice readout sequence section
MEANBLCK=                  742 / [count] FSW mean black level
PDCSAPFL=                  384 / SAP PDC processing flags (bit code)
LCFXDOFF=               419400 / long cadence fixed offset
SCFXDOFF=               219400 / short cadence fixed offset
CDPP3_0 =    262.5137023925781 / RMS CDPP on 3.0-hr time scales
CDPP6_0 =   172.92832946777344 / RMS CDPP on 6.0-hr time scales
CDPP12_0=   117.71680450439453 / RMS CDPP on 12.0-hr time scales
CROWDSAP=               0.9322 / Ratio of target flux to total flux in op. ap.
FLFRCSAP=               0.6985 / Frac. of target flux w/in the op. aperture
CHECKSUM= 'PgdaQZdZPddaPZdY'   / HDU checksum updated 2011-09-13T21:58:11Z
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  =                    5 / length of first array dimension
NAXIS2  =                    4 / 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 12108310'       / string version of KEPLERID
KEPLERID=             12108310 / unique Kepler target identifier
RADESYS = 'ICRS    '           / reference frame of celestial coordinates
RA_OBJ  =           289.949400 / [deg] right ascension
DEC_OBJ =            50.610740 / [deg] declination
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 =                 1020 / 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 =                  777 / value at reference CCD row
CDELT2P =                  1.0 / physical WCS axis 2 step
WCSAXES =                    2 / number of WCS axes
CTYPE1  = 'RA---TAN'           / right ascension coordinate type
CTYPE2  = 'DEC--TAN'           / declination coordinate type
CRPIX1  =    3.824950985871965 / [pixel] reference pixel along image axis 1
CRPIX2  =   2.7870355338794752 / [pixel] reference pixel along image axis 2
CRVAL1  =   289.94939999999997 / [deg] right ascension at reference pixel
CRVAL2  =             50.61074 / [deg] declination at reference pixel
CUNIT1  = 'deg     '           / physical unit in column dimension
CUNIT2  = 'deg     '           / physical unit in row dimension
CDELT1  =   -0.001104405386536 / [deg] pixel scale in RA dimension
CDELT2  =    0.001104405386536 / [deg] pixel scale in Dec dimension
PC1_1   =   0.8335381765495963 / linear transformation element cos(th)
```

```
PC1_2   =   0.5508653238178638 / linear transformation element -sin(th)
PC2_1   =  -0.5517328704972262 / linear transformation element sin(th)
PC2_2   =    0.835078120253523 / linear transformation element cos(th)
NPIXSAP =                    3 / Number of pixels in optimal aperture
NPIXMISS=                    0 / Number of op. aperture pixels not collected
CHECKSUM= 'kaaTmXaRkaaRkWaR'   / HDU checksum updated 2011-09-13T21:58:11Z
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 contains 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, .. 2.4, 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.

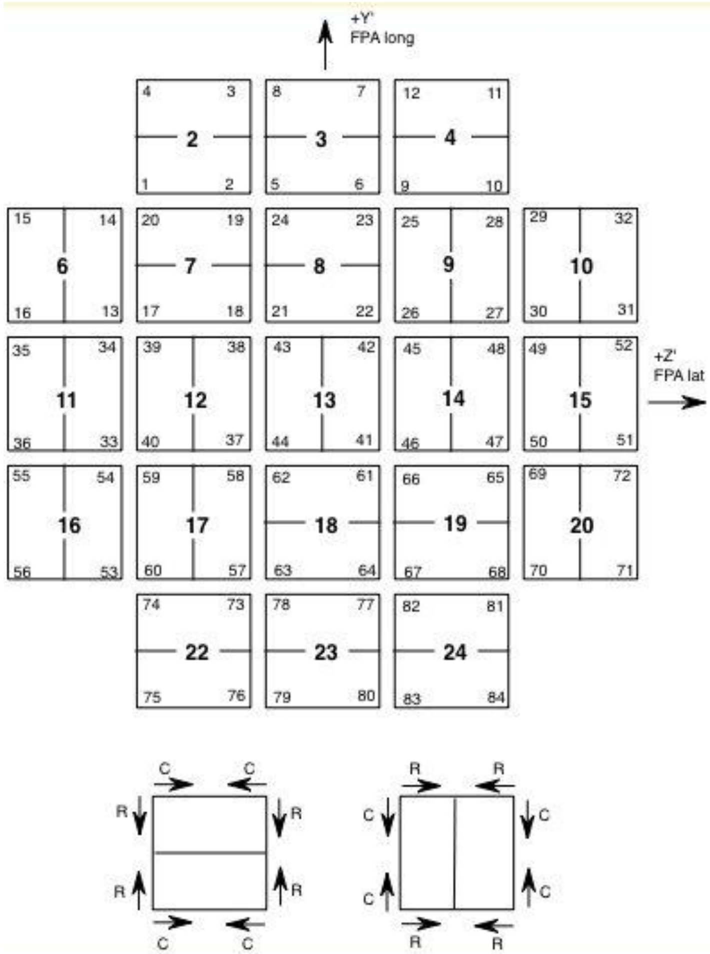


Figure D-1 Modules and channels with column and row directions. Each square shows 2 CCDs. The bold number in the each square is the module number. The smaller numbers in the corners of each square are the channel numbers. In the lower part of the figure, the column (C) and row (R) directions are indicated.

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
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
MAST	Multi-mission 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
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