K2: Extending Kepler's Power to the Ecliptic

Ecliptic Plane Input Catalog

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DOCUMENT CHANGE LOG

CHANGE DATE	PAGES AFFECTED	CHANGES/NOTES
February 5, 2014	all	Original Release for Campaign 1 (C1)
April 8, 2014	15-18	Added three new columns to EPIC, provided some provenance information in Figures 3 and 4, and included two new references for Campaigns 2 & 3

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1. Introduction

This document describes the Ecliptic Plane Input Catalog (EPIC) for the K2 mission. The primary purpose of this catalog is to provide positions and *Kepler* magnitudes for target management and aperture photometry. A secondary goal is to provide estimates of stellar properties to facilitate target selection. The Ecliptic Plane Input Catalog is hosted at MAST (http://archive.stsci.edu/kepler) and should be used for choosing targets when ever possible.

2. Input Sources and Cross-Matching

Input sources are the Hipparcos catalog (van Leeuwen 2007), the Tycho-2 catalog (Høg et al. 2000), the fourth US Naval Observatory CCD Astrograph Catalog (UCAC4, Zacharias et al. 2013), the Two Micron All Sky Survey (2MASS, Skrutskie et al. 2006), and data release 9 of the Sloan Digital Sky Survey (SDSS DR9, Ahn et al. 2012). Each catalog was downloaded from Vizier (http://webviz.u-strasbg.fr/viz-bin/VizieR) using a search radius of 12 degrees centered on a K2 campaign field. The following quality cuts and transformations were applied to the observables:

(a) Tycho-2: BT and VT photometry were converted into the Johnson BV by interpolating Table 2 in Bessell et al. (2000).

(b) UCAC-4: g'r'i' photometry (which is adopted from the AAVSO Photometric All-Sky Survey, http://www.aavso.org/apass) was transformed to the SDSS gri system (http://www.sdss.org/dr7/algorithms/jpeg_photometric_eq_dr1.html). Uncertainties in the BVgri bands which are set to zero or formal uncertainties set to 0.01 mag were replaced with typical uncertainties calculated from original APASS values as a function of g, r and i magnitude.

(c) 2MASS: All sources brighter than J < 5 mag were discarded due to known saturation problems, and all sources with a J-band quality flag worse than C were removed.

(d) SDSS DR9: Only targets with clean photometry, r magnitudes lower than 20, and photometry errors lower than 0.5 mag were retained.

Note that future deliveries may also include photometry in the WISE bands.

Each catalog was cross-matched for overlapping sources. Published matches (Hipparcos-Tycho, UCAC-Tycho-2MASS) were adopted when available, otherwise sources were matched by finding the closest object within 3 arcseconds of the proper-motion-corrected coordinates provided by Vizier. To eliminate serendipitous matches due to background objects, the V or g band magnitude of the target and matched source were required to agree within 1.5 mag, which is the typical maximum 3σ uncertainty in a given passband. For cross-matches without common passbands (such as Tycho-2MASS, or 2MASS-SDSS), the V and g band magnitudes of the matched source were estimated using Johnson-2MASS-Sloan transformations by Bilir et al. (2005) and Bilir et al. (2008). For transformed magnitudes, the matching criteria were conservatively set to 2 mag for g-band magnitudes estimated from BV, and 4 mag for g-band magnitudes estimated from JHK. While this procedure should eliminate most erroneous cross-matches, it may result in duplicate entries. Visual inspection of sky images from the STScI digitized sky survey (http://archive.stsci.edu/cgi-bin/dss_form) showed that duplicate entries are relatively rare.

For each source, the following observables were cataloged (see Table 1): Right Ascension (RA), Declination (DEC), Johnson BV, 2MASS JHK, Sloan ugriz, proper motion in RA, proper motion in DEC, parallax, and associated uncertainties. For sources with photometry in multiple catalogs, Tycho BV and UCAC gri were prioritized over APASS BV and SDSS gri. Cross-matched identifiers of all catalogs were also recorded. Additionally, extended sources identified in either 2MASS or SDSS were flagged in the "Objtype" identifier.

Column Name	Unit	Description
EPIC	none	K2 Identifier
HIP	none	Hipparcos Identifier
TYC	none	Tycho-2 Identifier
UCAC	none	UCAC-4 Identifier
2MASS	none	2MASS Identifier
SDSS	none	SDSS Identifier
Object type	none	Object Type Flag [STAR, EXTENDED]
Kepflag	none	*Kepler* Magnitude Flag [gri, BV, JHK, J]
RA	degrees	Right Ascension (JD2000)
Dec	degrees	Declination (JD2000)
pmra	milliarcseconds/year	Proper Motion in RA
pmdec	milliarcseconds/year	Proper Motion in DEC
plx	milliarcseconds	Parallax
Bmag	magnitude	Johnson B band magnitude
Vmag	magnitude	Johnson V band magnitude
umag	magnitude	Sloan u band magnitude
gmag	magnitude	Sloan g band magnitude
rmag	magnitude	Sloan r band magnitude
imag	magnitude	Sloan i band magnitude
zmag	magnitude	Sloan z band magnitude
Jmag	magnitude	2MASS J band magnitude
Hmag	magnitude	2MASS H band magnitude
Kmag	magnitude	2MASS K band magnitude
KepMag	magnitude	*Kepler* magnitude (Kp)

Table 1: Ecliptic Plane Input Catalog columns. Bracketed items list the possible values for catalog flags (see text for details).

3. *Kepler* Magnitudes

Kepler magnitudes (Kp) were calculated in different ways, depending on the available photometry for a given source. The identifier "KepFlag" keeps track of which photometry was used to calculate the *Kepler* magnitude of each source. The following prioritization scheme was adopted:

(a) Kepflag = [gri]: Kp was calculated from gri magnitudes using Equations (2)-(5) in Brown et al (2011).

(b) Kepflag = [BV]: Sloan gr was estimated from Johnson BV using the transformations by Bilir et al. (2005):

$$g-r = 1.124\ (B-V) - 0.252, \text{ and} \tag{1}$$

$$g = V+0.634\ (B-V) - 0.108. \tag{2}$$

Kp was then calculated from gr using Equation (2) in Brown et al. (2011).

(c) Kepflag = [JHK]: Kp was calculated using the polynomial J-K relations by Howell et al. (2012). Given x=J-K these transformations are:

$$Kp = 0.42443603 + 3.7937617\ x - 2.3267277\ x^2 + 1.4602553\ x^3 + K, \tag{3}$$

for all stars with J-H > 0.75 and H-K > 0.1 (approximate color cut for giants), and

$$Kp = 0.314377 + 3.85667\ x + 3.176111\ x^2 - 25.3126\ x^3 + 40.7221\ x^4 - 19.2112\ x^5 + K, \tag{4}$$

for all remaining stars. The above relations are calibrated for -0.2 < J-K < 1.2 for giants and -0.2 < J-K < 1.0 for dwarfs.

(d) Kepflag = [J]: For sources outside the color limits of Equations (3) and (4) or sources which only have a valid J-band magnitude, a rough estimate of Kp calculated from the J-band magnitude using the relations by Howell et al. (2012):

$$Kp = -398.04666 + 149.08127\ J - 21.952130\ J^2 + 1.5968619\ J^3 - 0.057478947\ J^4 + 0.00082033223\ J^5 + J, \tag{5}$$

for J = 10 – 16.7 and

$$Kp = 0.1918 + 1.08156\ J \tag{6}$$

for J > 16.7.

Figure 1 compares *Kepler* magnitudes calculated from UCAC gri, APASS BV, 2MASS JHK, and 2MASS J to original Kp values for a random sample of 5000 stars in the original *Kepler* field. The values show good agreement for the first three methods (panels a-c), with a median offset and scatter of -0.01±0.09 mag for UCAC gri, -0.03±0.13 mag for APASS BV, and 0.01±0.12 mag for 2MASS JHK. Users should be aware that *Kepler* magnitudes based on J (panel d) are very approximate since the transformation is based on the average colors of stars in the *Kepler* field. Deviations of up to 1 mag can be observed for very blue or red sources.

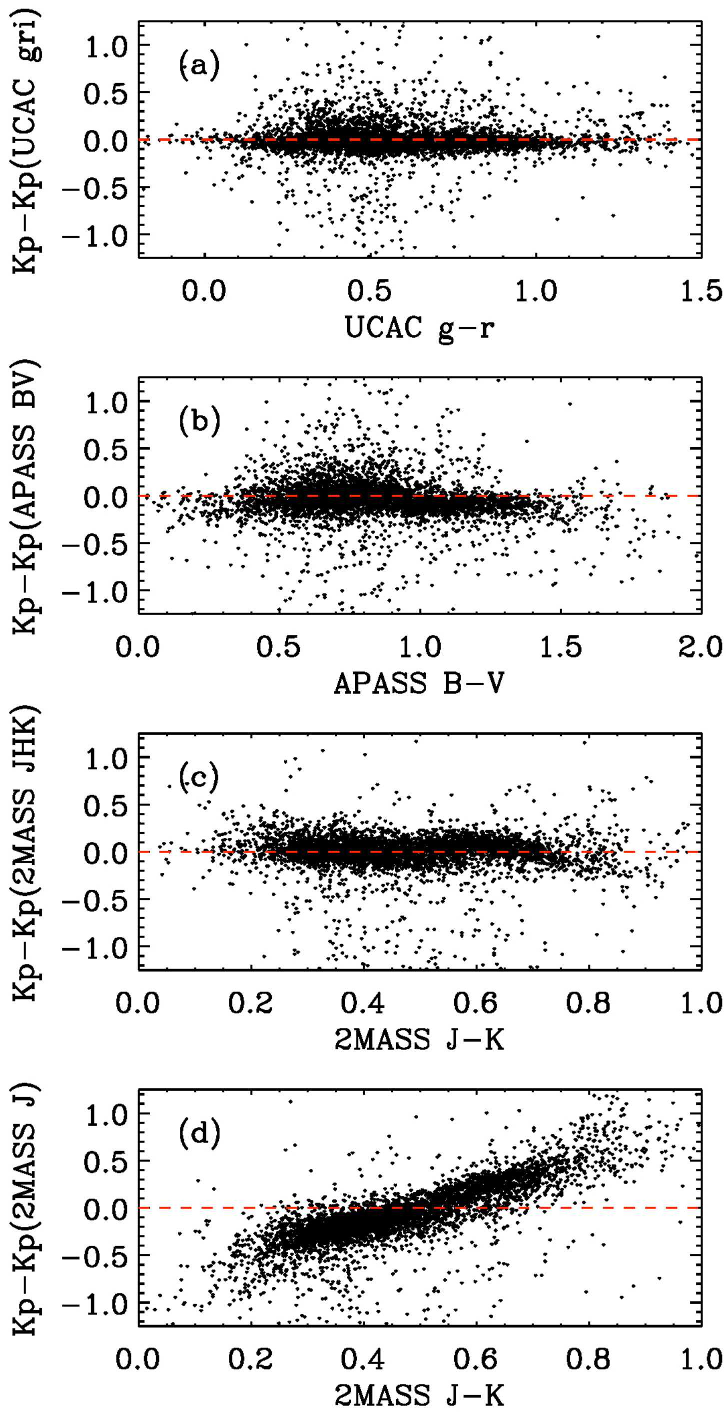

Figure 1: Difference between *Kepler* magnitudes calculated from UCAC gri (panel a), APASS BV (panel b), 2MASS JHK (panel c), and 2MASS J (panel d) as a function of color.

Figure 2 shows the *Kepler* magnitude distribution for sources in a ~80 square degree field in campaign 1 covered by both 2MASS and SDSS. The steep drop-off at Kp ~ 20 mag is caused by the r < 20 mag cut in SDSS DR9. For coordinates not covered by SDSS the completeness is set by 2MASS sources. The right panel in Figure 2 shows the distribution on a logarithmic scale, illustrating that the catalog includes a small number of objects with Kp > 25. These are predominantly galaxies identified in SDSS.

Visual inspection of field images showed that the catalog should be complete to at least Kp ~ 18 mag for areas covered by SDSS, and Kp ~ 16 mag for areas only covered by 2MASS. Completeness for fields only covered by 2MASS may be significantly reduced for sources that are blue and faint. It is emphasized that observers can propose targets that are fainter than the typical completeness limits and/or are presently not included in the Ecliptic Plane Input Catalog. Such targets may be added to the catalog in future deliveries.

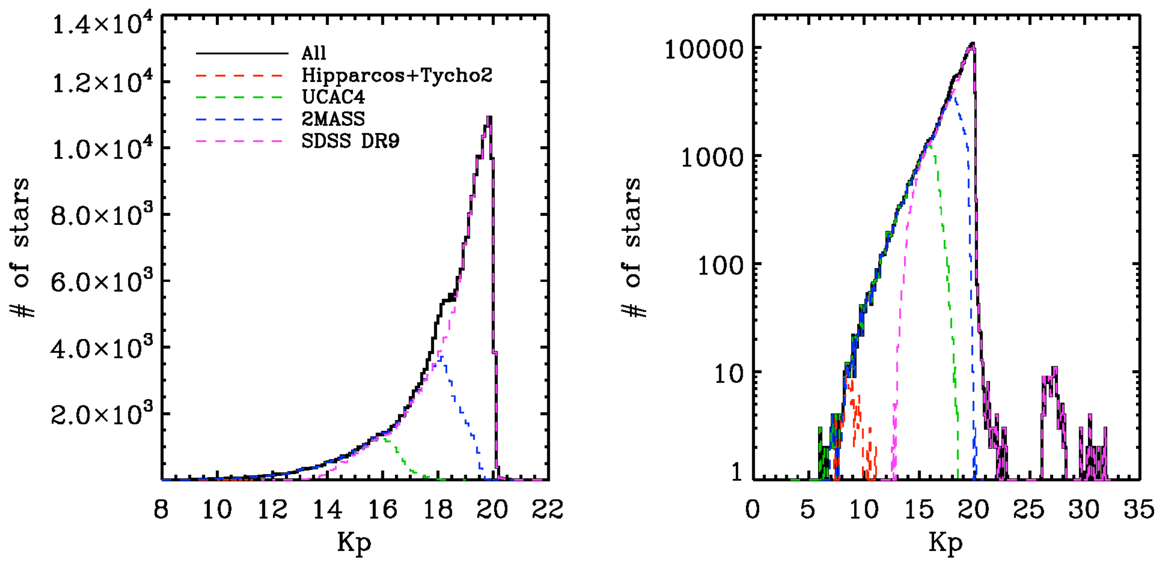

Figure 2: Histogram of *Kepler* magnitudes for sources in a ~80 square degree field in campaign 1 covered by both SDSS and 2MASS on a linear scale (left panel) and logarithmic scale (right panel). Colors show the individual contributions from different catalogs.

4. Stellar Properties

Validation of stellar properties (temperatures, surface gravities, metallicities, radii, masses, etc.) determined using parallaxes, proper motions and colors is currently in progress and results of these classifications are expected be added to the Ecliptic Plane Input Catalog at a later stage. Users are encouraged to make use of the observational data provided in the catalog to identify interesting sources for K2 observations.

5. Changes Implemented for Campaigns 2 & 3

The following changes to the EPIC have been implemented for Campaigns 2 & 3:

(a) Proper motions were supplemented with the NOMAD-1 catalog (Zacharias et al. 2005) to increase completeness for faint high-proper motion stars. NOMAD values were only used for 2MASS cross-matched sources for which no other proper motions were available (i.e., NOMAD does not override Tycho, UCAC, or SDSS).

(b) A small fraction of the bright near-infrared sources (J<10) do not have optical photometry and fall outside the J(HK) calibration range in Howell et al. (2012). Such sources were previously ignored, but are now included with a Kepler magnitude equal to their J-band magnitude. This affects <0.1% of all sources in the EPIC.

(c) Three new columns have been added to the EPIC:

Column Name	Unit	Description
NOMAD	none	NOMAD-1 Identifier
Mflg	none	2MASS Flags [Qflg-Rflg-Bflg-Cflg-Xflg-Aflg]
prox	arcseconds	2MASS nearest neighbor distance (i.e., proximity)

Details on the 2MASS flags can be found in the 2MASS documentation (Cutri et al. 2003). The new columns are listed at the end of the original columns defined for Campaign 1.

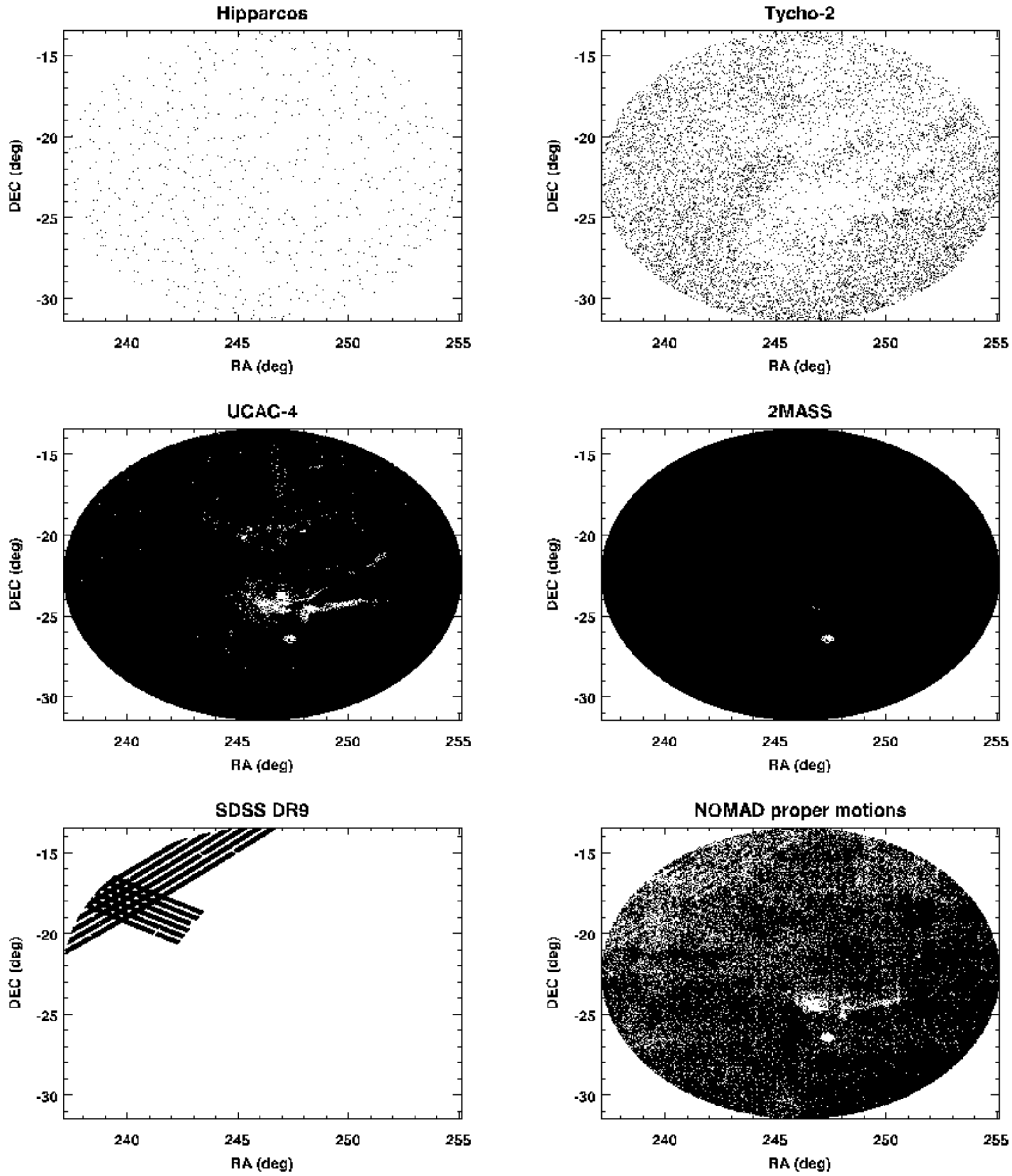

Figure 3: The distribution of sources in the Campaign 2 FOV subdivided into the different input catalogs. Each black point corresponds to a single source in the EPIC. Note that the lack of sources near the field center is due to dust extinction. The hole at RA ~ 247.4 degrees and Dec ~ -26.4 degrees is caused by alpha Sco (V ~ 0.9 mag).

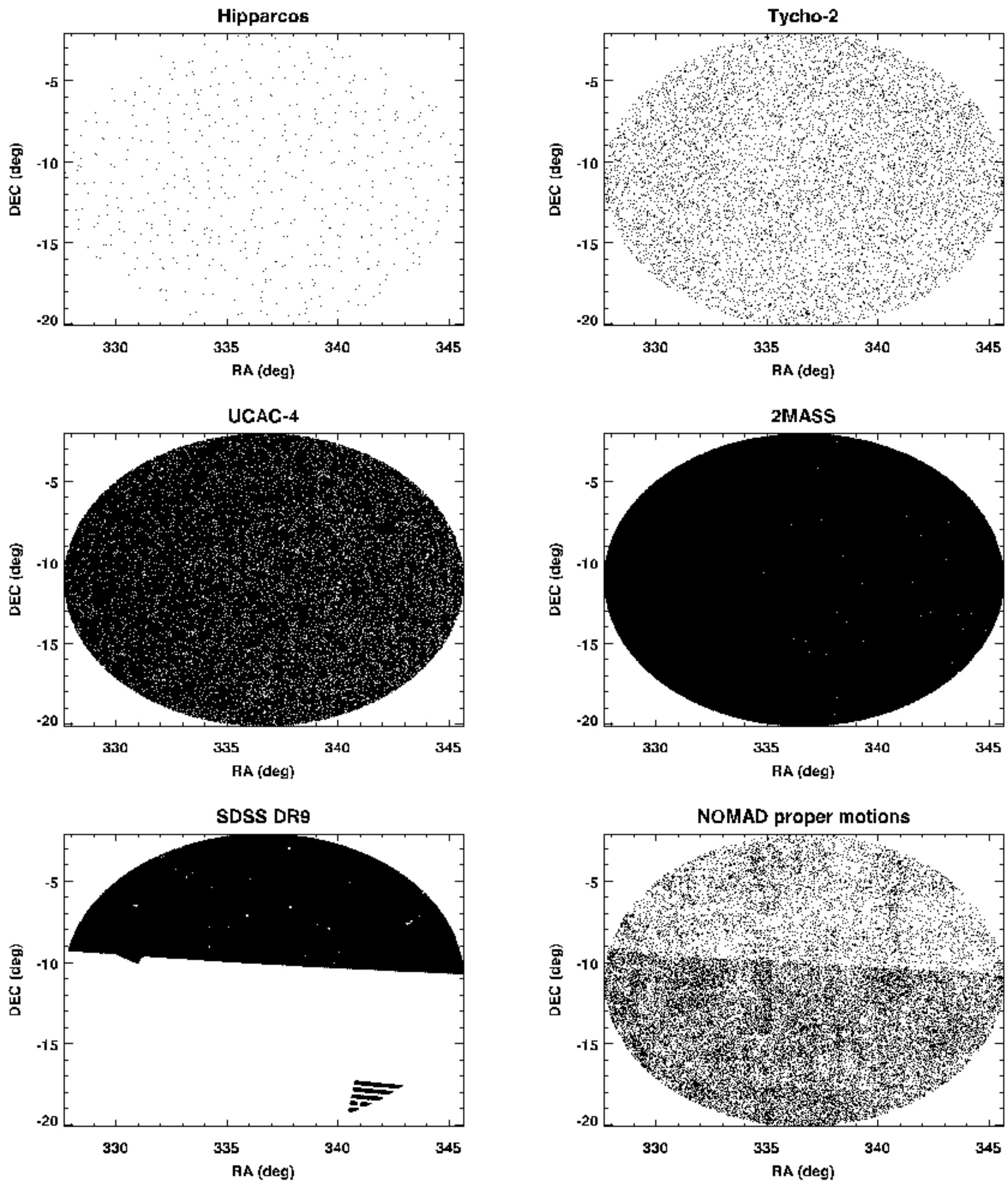

Figure 4: The same as Figure 3, but for Campaign 3. The bimodal distribution in the bottom right panel is caused by the fact that NOMAD proper motions are only used for 2MASS cross-matched sources that do not have proper motions listed in Tycho, UCAC or SDSS.

6. References

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