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Exoplanet Orbit Database. II. Updates to Exoplanets.org

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ABSTRACT. The Exoplanet Orbit Database (EOD) compiles orbital, transit, host star, and other parameters of robustly-detected exoplanets reported in the peer-reviewed literature. The EOD can be navigated through the Exoplanet Data Explorer (EDE) plotter and table, available on the World Wide Web at exoplanets.org. The EOD contains data for 1492 confirmed exoplanets as of 2014 July. The EOD descends from a table provided by Butler and coworkers in 2002 and the Catalog of Nearby Exoplanets (Butler and coworkers in 2006), and the first complete documentation for the EOD and the EDE was presented by Wright and coworkers in 2011. In this work, we describe our work since then. We have expanded the scope of the EOD to include secondary eclipse parameters and asymmetric uncertainties and expanded the EDE to include the sample of over 3000 *Kepler* Objects of Interest (KOIs) and other real planets without good orbital parameters (such as many of those detected by microlensing and imaging). Users can download the latest version of the entire EOD as a single comma separated value file from the front page of exoplanets.org.

Online material: color figures

1. INTRODUCTION

Since the launch of NASA's *Kepler* mission (Borucki et al. 2010), the number of confirmed exoplanets has increased from about 300 to over 1490 as of 2014 July. *Kepler* contributed to a majority of these new discoveries (>800) while providing an additional sample of over 3000 exoplanet candidates (*Kepler* Objects of Interest, KOIs; e.g., Batalha et al. [2013]). The transit method has thus surpassed the radial velocity (RV) method to become the most fruitful means of detecting exoplanets. Meanwhile, great promise lies within the new and future exoplanet surveys and instruments with direct imaging (e.g., the Gemini Planet Imager, GPI, Macintosh et al. [2014]) and microlensing (e.g., the Wide-Field InfraRed Survey Telescope, WFIRST, Green et al. [2012]), while the fronts of RV and transit exoplanet searches keep expanding (e.g., the MINiature Exoplanet Radial Velocity Array, MINERVA, Wright et al. [2014]; the Habitable-zone Planet Finder, HPF, Mahadevan et al. [2012]; and the Transiting Exoplanet Survey Satellit, TESS, Ricker [2014]).

This paper describes our continuing efforts since Butler et al. (2002, 2006) and Wright et al. (2011) to maintain the Exoplanet Orbit Database[5] (EOD) and the Exoplanets Data Explorer (EDE), to keep track of exoplanet discoveries, and to better catalog orbital parameters and host star properties.

There are other entities devoted to similar efforts, including the Extrasolar Planets Encyclopaedia[6] (Schneider et al. 2011) and the NASA Exoplanet Archive[7] (Akeson et al. 2013). The natures of these efforts are largely complementary to the EOD, and to the degree that they are redundant, provide important cross-checking and validation. As described in Wright et al. (2011), the EOD is dedicated to cataloging properties of all robustly-detected exoplanets with well-determined orbital parameters published in peer-reviewed literature, and providing outstanding data exploration and visualization tools for these planets.

The EOD is hosted at the Web domain exoplanets.org, which also hosts the EDE, an interactive table with plotting tools for all the EOD exoplanets, in addition to other confirmed exoplanets without good orbital parameters, and KOIs (except for those with a "FALSE POSITIVE" disposition at the Exoplanet Archive). The entire dataset of exoplanets.org is available for download as a single comma separated value (CSV) file from the Web site front page.[8] An example of this CSV file is available with the electronic version of this paper (filename: exoplanets.csv).

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[5] See http://expoplanets.org.

[6] See http://exoplanet.eu.

[7] See http://exoplanetarchive.ipac.caltech.edu.

[8] At http://exoplanets.org/csv-files/exoplanets.csv.

The EOD is widely used in exoplanet research (e.g., Dawson & Murray-Clay 2013; Howard 2013; Kipping 2013; Kane 2014; Weiss & Marcy 2014), and the Web site exoplanets.org had over 47,000 visits[9] in 2013.

Since the documentation described in Wright et al. (2011), the EOD has expanded its scope: we now do not require the host star of an exoplanet to be a normal star (e.g., exoplanets around pulsars are now included). We now ingest more parameters describing the exoplanet systems and their host stars, and some parameters have been revised or deleted. We describe our updates to the EOD in § 2. The EDE at exoplanets.org has also expanded its scope and now includes the *Kepler* exoplanet candidates (KOIs). We describe these changes in § 3. The Web site exoplanets.org has gone through major back-end changes since Wright et al. (2011), which are described in § 4. We summarize the updates and possible future improvements in § 5.

2. UPDATES ON THE EOD

The scope of the EOD has expanded, and there are three major changes from what was described in Wright et al. (2011). Previously, we only included exoplanets orbiting the "normal stars," but now we are not limiting the type of host stars (e.g., we included exoplanets orbiting neutron stars). Furthermore, in Wright et al. (2011), we only included exoplanets that were discovered by the RV and transit methods in the EOD, but now we also include planets discovered via timing (including pulsar planets and those discovered by eclipse timing). We now include exoplanets discovered by any other methods with robust detections and good orbital parameters, such as β Pictoris b (Chauvin et al. 2012; Nielsen et al. 2014; Macintosh et al. 2014).

Previously, we used a generous mass cutoff, recognizing that any definition of "exoplanet" will not necessarily track with the formation mechanism for an object (which may, after all, be unknown or unknowable). Our previous mass cutoff was a minimum mass ($m \sin i$) smaller than 24 $M_{\rm Jup}$; to make this cutoff more relevant to a wide range of stellar masses and detection methods, we now require the measured planet-star mass ratio to be smaller than $24\ M_{\rm Jup}/M_{\odot}$ (<0.023).

The rest of the selection criteria for the EOD remain unchanged. We still require the planets to have robust detections and well-determined orbits (though these are not strictly quantitative and sometimes subjective; see § 2 of Wright et al. [2011]). If new evidence comes to light and we are no longer confident about a planet, we may remove it from EOD, even if the new evidence is not peer-reviewed. The rationale for this scheme is, as it has been since the Catalog of Nearby Exoplanets (Butler et al. 2002), that the EOD represents our best, expert effort to produce a clean set of trustworthy parameters. We do not report all the announced exoplanets, as we are not trying to provide "an encyclopedic presentation of every claimed detection of an exoplanet" (Wright et al. 2011). More comprehensive sets of planet parameters are available from other exoplanet compendia on the Web.

In the following subsections, we describe the newly added and revised fields since Wright et al. (2011), and list all fields in Table 1. We divide the fields into categories consistent with the individual planet page on exoplanets.org (Fig. 1 is an example of the individual planet page, which is presented to Web site users who click on a planet's name). Some fields are not explicitly tabulated on the page (e.g., the URLs for (e.g., the URLs for the papers providing the underlying data linked to their SAO/NASA Astrophysics Data System, i.e. ADS, entries) pages for papers providing the underlying data), but are explicitly listed in the downloadable .csv file (see § 1). Though we focus on the EOD in this section, the fields apply to all planets on exoplanets.org. We follow the definition of orbital elements in Wright & Gaudi (2013), unless indicated otherwise.

2.1. Discovery and References

We report general information of when, by whom, and how the planets were discovered and first reported and provide the references for underlying data. We describe the added or revised fields since Wright et al. (2011).

The DISCMETH field previously reported the method of discovery, which was either "radial velocity" or "transit." We have replaced DISCMETH with PLANETDISCMETH and STARDISCMETH to better report how exoplanet systems and individual exoplanets are first discovered. PLANETDISCMETH reports the discovery method for the planet, while STARDISCMETH reports the discovery method for the planetary system (i.e., the first discovered planet around the host star). These fields are stored in string format and have one of the following values: "RV," "Transit," "Imaging," "Microlensing," "Timing," or "Astrometry" (no planets have a value of "Astrometry" yet since no planet has yet been discovered via astrometry).

The MONTH field reports the integer month of the peer-reviewed paper publication date.

KEPID stands for *KEPler* identification, which is the integer Kepler Input Catalog index for a *Kepler* host star. KEPID is only available for unconfirmed KOI's imported directly from the Exoplanet Archive by the exoplanets.org backend.

KOI stands for *Kepler* Objects of Interest, which is an object with transit signals detected by *Kepler* that may or may not have been validated as being due to exoplanets. The KOI field defined by the *Kepler* team and shown on the Exoplanet Archive is stored as a floating point number, consisting of a whole number designated to the host star followed by a decimal portion denoting a candidate planet. For example, KOI 102 is a star suspected to host two exoplanets, KOI 102.01 is the inner planet candidate, and KOI 102.02 is the outer one. Once a candidate is confirmed, the NAME field of the planet is replaced by the official *Kepler* identification ("Kepler" followed by a hyphen, an

[9] Measured as "visits" by Google Analytics.

TABLE 1

FIELDS OF EXOPLANET ORBIT DATABASE

Field	Data type	Meaning	Related fields[a]	Ref.[b]
Discovery and References				
NAME	String	Name of planet	…	W11
OTHERNAME	String	Other commonly used name of star	…	2.1
DATE	Integer	Year of publication of FIRSTREF	…	W11
MONTH	Integer	Month of publication of FIRSTREF	…	2.1
PLANETDISCMETH	String	Method of discovery of planet	…	2.1
STARDISCMETH	String	Method of discovery of first planet in system	…	2.1
ORBREF	String	Peer-reviewed origin of orbital parameters	ORBURL	W11
FIRSTREF	String	First peer-reviewed publication of planetary orbit	FIRSTURL	W11
JSNAME	String	Name of host star used in the Extrasolar Planets Encyclopaedia	EPEURL	W11
ETDNAME	String	Name of planet used in the Exoplanet Transit Database	ETDURL	W11
EANAME	String	Name of planet used in the Exoplanet Archive Database	EAURL	2.10
SIMBADNAME	String	Valid SIMBAD name of host star (or planet, if available)	SIMBADURL	W11
KEPID	Long Integer	The unique *Kepler* star identifier	…	2.1
KOI	Float	KOI object number	…	2.1
EOD	Boolean	If true, planet is included in the EOD	…	2.1
MICROLENSING	Boolean	If true, planet was detected via microlensing	…	2.1
IMAGING	Boolean	If true, planet was detected via imaging	…	2.1
TIMING	Boolean	If true, planet was detected via timing	…	2.1
ASTROMETRY	Boolean	If true, planet was detected via astrometric motion	…	2.1
Orbital Parameters				
MSINI	Float	Minimum mass (as calculated from the mass function) in $M_{\rm Jup}$	-UL, -UPPER, etc.	W11
MASS	Float	Mass of planet in $M_{\rm Jup}$	-UPPER, etc.	2.2
A	Float	Orbital semimajor axis in AU	-UPPER, etc.	W11
SEP	Float	Separation between host star and planet in AU	-UPPER, etc.	2.2
PER	Double	Orbital period in days	-UPPER, etc.	W11
K	Float	Semiamplitude of stellar reflex motion in m s^{-1}	-UL, -UPPER, etc.	W11
ECC	Float	Orbital eccentricity	-UL, -UPPER, etc.	W11
I	Float	Orbital inclination in degrees	-UPPER, etc.	2.2
OM	Float	Argument of periastron in degrees	-UPPER, etc.	W11
BIGOM	Float	Longitude of ascending node in degrees	-UPPER, etc.	2.2
T0	Double	Epoch of periastron in HJD[c]	-UPPER, etc.	W11
DVDT	Float	Magnitude of linear trend in m s^{-1} day^{-1}	-UPPER, etc.	W11
LAMBDA	Float	Projected spin-orbit misalignment in degrees	-UPPER, etc.	2.2
TRANSIT	Boolean	Is the planet known to transit?	-REF,-URL	W11
Transit Parameters				
R	Float	Radius of planet in Jupiter radii	-UPPER, etc.	W11
TT	Float	Epoch of transit center in HJD[c]	-UPPER, etc.	W11
T14	Float	Time of transit from first to fourth contact in days	-UPPER, etc.	W11
B	Float	Impact parameter of transit	-UPPER, etc.	W11
AR	Float	(a/R_*)	-UPPER, etc.	W11
DEPTH	Float	Transit depth, or $(R_p/R_*)^2$ when depth is not given	-UPPER, etc.	W11
DENSITY	Float	Density of planet in g cm^{-3}	-UPPER, etc.	W11
GRAVITY	Float	$\log g$ (surface gravity) of planet in cgs units	-UPPER, etc.	W11
DR	Float	Distance during transit in stellar radii	-UPPER, etc.	2.3
RR	Float	(R_p/R_*)	-UPPER, etc.	2.3
Orbital Fit Properties				
CHI2	Float	χ^2_ν to orbital RV fit	…	W11
NOBS	Integer	Number of observations used in fit	…	W11
RMS	Float	RMS residuals to orbital RV fit	…	W11
FREEZE_ECC	Boolean	Eccentricity frozen in fit?	…	W11
TREND	Boolean	Linear trend in fit?	…	W11
NCOMP	Integer	Number of planetary companions known	…	W11
MULT	Boolean	Multiple planets in system?	…	W11
COMP	String	Component name of planet (b, c, etc.)	…	W11
Secondary Eclipse Depth				
SE	Boolean	If true, at least one secondary eclipse has been detected	-REF, -URL	2.4
SEDEPTHJ	Float	Secondary eclipse depth in J band	-UPPER, etc.	2.4
SEDEPTHH	Float	Secondary eclipse depth in H band	-UPPER, etc.	2.4

TABLE 1 (*Continued*)

Field	Data type	Meaning	Related fields[a]	Ref.[b]
SEDEPTHKS	Float	Secondary eclipse depth in K_S band	-UPPER, etc.	2.4
SEDEPTHKP	Float	Secondary eclipse depth in the *Kepler* photometry band	-UPPER, etc.	2.4
SEDEPTH36	Float	Secondary eclipse depth in *Spitzer* IRAC1 3.6 μm band	-UPPER, etc.	2.4
SEDEPTH45	Float	Secondary eclipse depth in *Spitzer* IRAC2 4.5 μm band	-UPPER, etc.	2.4
SEDEPTH58	Float	Secondary eclipse depth in *Spitzer* IRAC3 5.8 μm band	-UPPER, etc.	2.4
SEDEPTH80	Float	Secondary eclipse depth in *Spitzer* IRAC4 8.0 μm band	-UPPER, etc.	2.4
SET	Double	Epoch of secondary eclipse center in HJD[c]	-UPPER, etc.	2.4
Stellar Properties				
STAR	String	Standard name for host star	…	W11
BINARY	Boolean	Star known to be binary?	-REF, -URL	W11
MSTAR	Float	Mass of host star in solar mass	-UPPER, etc.	W11
RSTAR	Float	Radius of host star in solar radii	-UPPER, etc.	2.5
FE	Float	Iron abundance (or metallicity) of star	-UPPER, etc.	W11
TEFF	Float	Effective temperature of host star in Kelvins	-UPPER, etc.	W11
RHOSTAR	Float	Density of host star in g cm^{-3}	-UPPER, etc.	2.5
LOGG	Float	Spectroscopic $\log g$ (surface gravity) of host star in cgs units	-UPPER, etc.	W11
VSINI	Float	Projected equatorial rotational velocity of star in km s^{-1}	-UPPER, etc.	W11
GAMMA	Float	Systemic radial velocity in km s^{-1}	-UPPER, etc.	2.5
Stellar Magnitudes				
V	Float	V magnitude	-REF, -URL	W11
BMV	Float	$B-V$ color	…	W11
J	Float	J magnitude	…	W11
H	Float	H magnitude	…	W11
KS	Float	K_S magnitude	…	W11
SHK	Float	Mount Wilson Ca II S-value	…	2.9
RHK	Float	Chromospheric activity of star as $\log R'_{HK}$	…	2.9
KP	Float	*Kepler* bandpass magnitude	…	2.6
SPECREF	String	Source of most of the spectroscopic parameters	SPECURL	W11
Coordinates and Catalogs				
RA	Double	J2000.0 right ascension in decimal hours	…	W11
RA_STRING	String	J2000.0 right ascension in sexagesimal string	…	W11
DEC	Double	J2000.0 declination in decimal degrees	…	W11
DEC_STRING	String	J2000.0 declination in sexagesimal string	…	W11
PAR	Float	Parallax in mas	-UPPER, -LOWER, U-	W11
DIST	Float	Distance to host star based on parallax in parsecs	-UPPER, etc.	2.7
HIPP	Long Integer	*Hipparcos* catalog number of star	…	W11
HD	Long Integer	Henry Draper number of star	…	W11
GL	Float	GJ or Gliese catalog number of star	…	W11
HR	Integer	Bright Star Catalog number of star	…	W11
SAO	Long Integer	SAO catalog number of star	…	W11

REFERENCES.—(W11) Wright et al. 2011.

integer, a space, and finally a lower case letter). The KOI number is then used as OTHERNAME. For more information, see § 3.

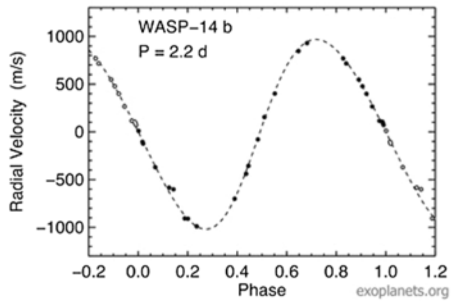
EOD is a Boolean that indicates whether an exoplanet is included in the EOD for having well-characterized orbital parameters, such as the orbital period (PER). We added this field because exoplanets.org now also includes robustly discovered planets that do not have well-characterized orbits, and also *Kepler* planet candidates (see § 3 for more details). Planets on exoplanets.org and appearing in the EDE that are not part of the EOD have EOD set to FALSE (i.e., zero).

MICROLENSING, IMAGING, TIMING, and ASTROMETRY are Boolean flags which indicate that a planet has been detected via these methods. For example, MICROLENSING = 1 means the planet is detected in a microlensing event. Note that planets may be detected with multiple methods.

2.2. Orbital Parameters

We report the orbital parameters that determine the shape of the planet's orbit. Depending on the detection methods, different sets of parameters are given by the literature. For instance, if a planet is detected by the radial velocity method, the semiamplitude, K, is reported, whereas the inclination of the orbit, i, is usually only known via the transit method (although planet-planet interactions and astrometry can also determine it). We describe the added fields since Wright et al. (2011) below.

WASP-14 b



Discovery and References

Other Name	2MASS J14330635+2153409
First Publication Date	2009
Method of discovery for the planet	Transit
Method of discovery of first planet in system	Transit
Orbit Reference	Joshi 2009
First Reference	Joshi 2009
EPE Link	WASP-14
ETD Link	WASP-14 b
Exoplanet Archive Link	WASP-14 b
SIMBAD Link	BD+22 2716
Kepler ID	*Unavailable*
KDE	✗
EOD	✓
Microlensing	✗
Imaging	✗
Timing	✗
Astrometry	✗

Orbital Parameters

Msin(i) [mjupiter]	7.65 ± 0.29
Planet Mass [mjupiter]	7.69 ± 0.29
Semi-Major Axis [au]	0.03677 ± 0.0007
Separation [au]	0.03677 ± 0.0007
Orbital Period [day]	$2.243752 \pm 1\times10^{-5}$
Velocity Semiamplitude [m/s]	993.0 ± 3
Orbital Eccentricity	0.0910 ± 0.003
Orbit Inclination [deg]	84.32 +0.67/-0.57
Argument of Periastron [deg]	253.37 +0.69/-0.68
BigΩ [deg]	*Unavailable*
Time of Periastron [jd]	2454462.33040 ± 0.00053
Velocity Slope [m/s/day]	*Unavailable*
Spin-Orbit Misalignment [deg]	-33.1 ± 7.4
Transit	✓

Transit Parameters

Planetary Radius [rjupiter]	1.281 +0.075/-0.082
Epoch of Transit Center	2454463.57583 ± 0.00053
Duration of Transit [day]	0.1275 +0.0028/-0.0031
Impact Parameter	0.535 +0.031/-0.041
a/R_*	5.929 ± 0.022
Transit Depth	0.01020 ± 0.00025
Planetary Density [g/cm^3]	4.66 +0.64/-0.99
Surface Gravity	4.045 ± 0.0112
Distance During Transit	*Unavailable*
RR	*Unavailable*

Orbital Fit Properties

Reduced Chi Squared	*Unavailable*
# of Observations	27
RMS of Velocities	10
Frozen Eccentricity Flag	✗
Flag for linear Trend	✗
Components	1

Secondary Eclipse Depth

Secondary Eclipse	1
Secondary eclipse depth in J band	*Unavailable*
Secondary eclipse depth in H band	*Unavailable*
Secondary eclipse depth in Ks band	*Unavailable*
Secondary eclipse depth in the Kepler photometry band	*Unavailable*
Secondary eclipse depth in 3.6 micron	$0.001870 \pm 7\times10^{-5}$
Secondary eclipse depth in 4.5 micron	0.00224 ± 0.00018
Secondary eclipse depth in 5.8 micron	*Unavailable*
Secondary eclipse depth in 8.0 micron	0.00182 ± 0.00022

Stellar Properties

Star Name	WASP-14
Binary Flag	✗
Mass of Star [msun]	1.31 +0.05/-0.1
Radius of Star [rsun]	1.310 ± 0.07
[Fe/H]	0.00 ± 0.2
T_{eff} [K]	6480 ± 100
Density of star [g/cm^3]	0.542 +0.079/-0.06
$\log_{10}(g)$	4.07 +0.043/-0.36
Vsin(i) [km/s]	4.9 ± 1
Gamma [km/s]	-5.63 ± 0.32

Stellar Magnitudes

V mag	9.8
B-V	0.46
2MASS J	8.9
2MASS H	8.7
2MASS K_S	8.6
S_{HK}	*Unavailable*
log R_{HK}	*Unavailable*
KP	*Unavailable*

Coordinates and Catalogs

RA (h:m:s)	14:33:06.355
DEC (d:m:s)	+21:53:40.9
Parallax [marcsec]	6.25 ± 0.56
Distance to Star [pc]	160 +15.6/-13.1
Hipparcos Catalog #	*Unavailable*
HD #	*Unavailable*
Gliese Catalog #	*Unavailable*
HR #	*Unavailable*
SAO Catalog #	83398

FIG. 1.—Example page for an individual exoplanet (WASP-14b in this case). The numbers listed in each field contain links to the reference on NASA ADS. In this example for WASP-14b, we provide the plot for the phased RVs, but we have yet to implement such a feature for all planets with available RV data. See the electronic edition of the *PASP* for a color version of this figure.

MASS is the mass of the planet in units of Jupiter mass. Previously, we only reported the minimum mass, ($m \sin i$, MSINI) of the planets. We now, additionally, report the best estimate of the true mass in a heterogeneous way. For example, if a planet is discovered by microlensing, we report the actual mass of the planet according to the literature. If a planet has both radial velocity and transit measurements, we calculate the mass from the minimum mass, $m \sin i$, and the orbital inclination, i. For convenience of plotting RV and other planets on a common mass scale (see § 3), MASS is set to MSINI if the orbital inclination is not known and the reference for MASS (MASSREF) is set to "Set to MSINI; I unknown."

Also, for plotting convenience, for transiting *Kepler* planets without $m \sin i$ measured, we estimate their mass using mass-radius relations from the literature. We follow a series of relations given by

$$M_p = \begin{cases} M_{\mathrm{WM}} & R < R_\oplus \\ (1-x)M_{\mathrm{WM}} + xM_{\mathrm{L}} & R_\oplus \leq R < 4\ R_\oplus \\ M_{\mathrm{L}} & 4\ R_\oplus \leq R < 6\ R_\oplus \\ \min\ (M_{\mathrm{M}}, M_{\mathrm{Jup}}) & 6\ R_\oplus \leq R < b \\ M_{\mathrm{Jup}} & R \geq b \end{cases},$$

where b is defined below, and we use the weight $x = (R_p/R_\oplus - 1)/3$ to smoothly transition between M_{WM} and M_{L} in their overlapping regions of validity. M_{WM} is from Weiss & Marcy (2014) and is given by:

$$\frac{M_{\mathrm{WM}}}{M_\oplus} = \begin{cases} 2.69\left(\frac{R_p}{R_\oplus}\right)^{0.93} & R < 1.5\ R_\oplus \\ 0.582\left(0.717 + \frac{R_p}{R_\oplus}\right)\left(\frac{R_p}{R_\oplus}\right)^3 & 1.5\ R_\oplus \leq R < 4\ R_\oplus \end{cases}.$$

M_{L} is given by $M_p/M_\oplus = (R_p/R_\oplus)^{2.06}$ from Lissauer et al. (2011), and M_{M} is given by:

$$\log_{10}\left(\frac{M_p}{M_0}\right) = -w\left(\frac{b}{(R_p/R_\oplus)} - 1\right)^{1/p}$$

from Mordasini et al. (2012), where

	$a/\mathrm{AU} \leq 0.1$	$a/\mathrm{AU} > 0.1$
$M_0[M_\oplus]$	1756.7	1308.7
$b[R_\oplus]$	11.684	11.858
w	1.646	1.635
p	2.489	2.849

Planets with masses estimated in this manner are so noted in the MASSREF field.

SEP is a separation between the host star and the planet in units of AU. For directly imaged and microlensing planets, the literature usually reports the projected separation and we report the value accordingly. If SEP is not directly measured, but the semimajor axis (A) is available, then we set SEP to A with its reference, SEPREF, set to "Set to A."

The parameter I reports the orbital inclination of the planet. Previously, only transiting systems had i measured, but now some nontransiting systems have dynamical or astrometric constraints on i (for example, the microlensing system OGLE-2006-BLG-109L by Bennett et al. [2010] and the imaged system β Pictoris by Lagrange et al. [2009]).

BIGOM is the longitude of the ascending node (Ω) in units of degrees. At the moment, only β Pictoris b has this quantity listed.

LAMBDA is the projected spin-orbit misalignment (λ) in the plane of the sky in units of degrees. At the moment, λ values are only available for the transiting systems, which are measured by either the Rossiter-McLaughlin effect (e.g., Winn et al. 2005) or planetary transits of star spots (e.g., Sanchis-Ojeda et al. 2012). The angle λ is used because the true spin-orbit angle, defined as the angle between the stellar spin axis and the orbital axis, is normally not directly measurable. We follow Fabrycky & Winn (2009), who defined the quantity as follows: the *z*-axis points toward the observer, the *x*-axis points along the intersection of the sky plane and the planet's orbital plane with the ascending node of the planet having $x < 0$, and the *y*-axis completes a right-handed triad. Lambda is measured clockwise on the sky from the *y*-axis to the projected stellar rotational axis. Lambda is not a newly added field to the EOD, but we describe it here because we did not previously report it consistently, since some literature report the "projected spin-orbit misalignment" as $\beta = -\lambda$ instead[10]. We have sorted these cases out and made sure that our λs are following the definition of Fabrycky & Winn (2009).

The MASSREF and MASSURL fields were used to report the reference and the URL of stellar mass, but now they are used for the planet's mass; MSTARREF and MSTARURL are now used for the stellar mass, MSTAR.

2.3. Transit Parameters

We have added two fields since Wright et al. (2011), which are used for KOIs incorporated from the Exoplanet Archive.

DR is the distance between the planet and the star during the transit in stellar radii. This is one of the parameters that goes into the transit light-curve modeling (see, e.g., Batalha et al. 2013).

RR is the ratio of the planetary radius and the stellar radius. If the transit depth (DEPTH) is not given, we calculate DEPTH by taking square of RR, but we do not calculate RR from DEPTH.

[10] In some cases, (e.g., Moutou et al. 2011), other conventions entirely appear to be used.

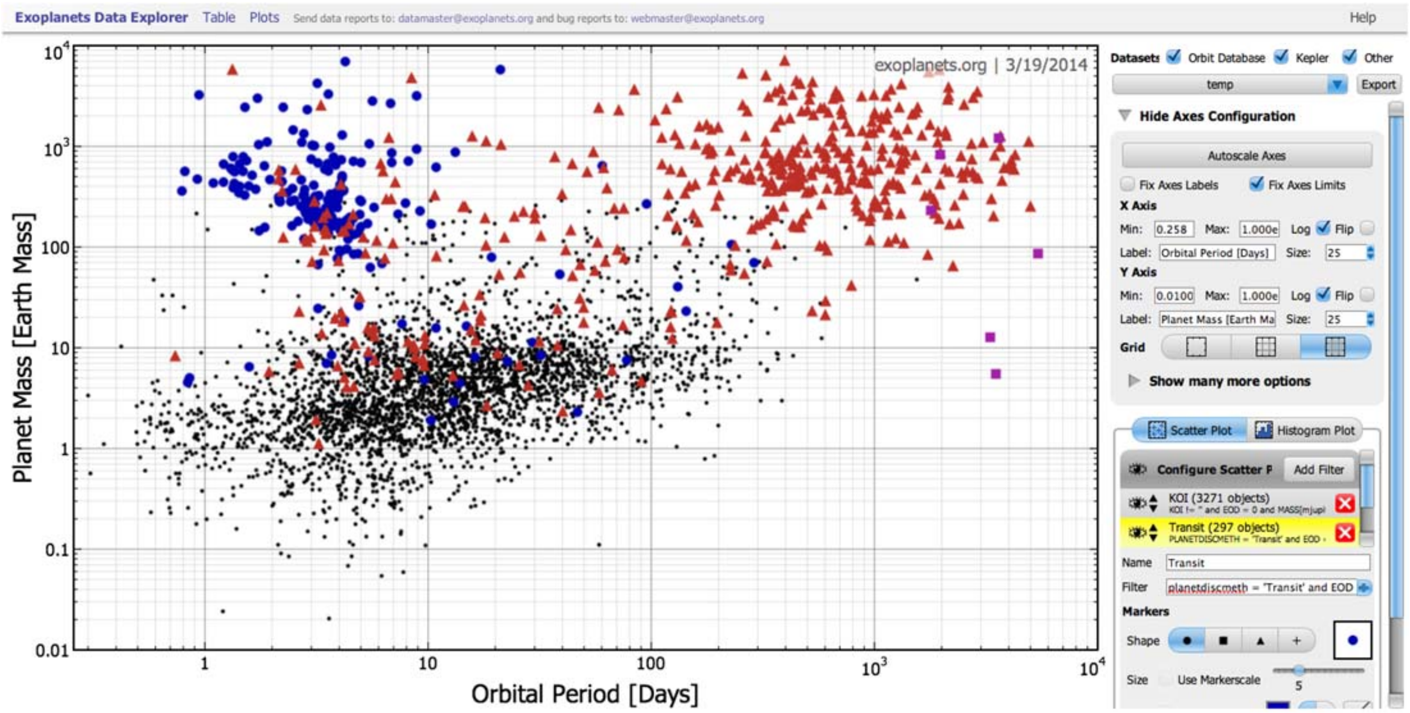


FIG. 2.—Example plot that demonstrates the current secondary eclipse measurements. Each planet has a set of circles that stand for its available secondary eclipse measurements in the database, including *Spitzer* 8.0, 5.8, 4.5, & 3.6 μm, and ground-based J, H, and K_s bands. *Kepler* secondary eclipse measurements are labeled as solid black dots. A few representative planets are also annotated (a feature not offered by the EDE plotter, but trivially implemented by other image or presentation software). The planet name will appear when the user points the cursor at the corresonding data point in the interactive plotting tools.See the electronic edition of the *PASP* for a color version of this figure.

2.4. Secondary Eclipse

We have added an entirely new set of fields for secondary eclipse depths. Previously, due to the limits of instrumentation and limited sample of exoplanets, there was not much secondary eclipse depth data available. Since Wright et al. (2011), as many different surveys have been launched, secondary eclipse depths at multiple bands have become available for many planets. Therefore, we added this entire new set of fields (see Fig. 2).

SEDEPTHX, where X stands for one of “J,” “H,” “KS,” “KP,” “36,” “45,” “58,” “80”: these fields are the secondary eclipse depth measured in the corresponding wavelength band. SEDEPTHJ, H, and KS are the depths measured in the Two Micron All Sky Survey (2MASS) wavelength bands in the near-infrared, centered at 1.25 μm, 1.65 μm, and 2.15 μm, respectively. KP is the depth measured in the *Kepler* photometric band, which spans 400 to 865 nm. The other four represent the *Spitzer* InfraRed Array Camera (IRAC) bands centered at 3.6 μm, 4.5 μm, 5.8 μm, and 8.0 μm.

The SE Boolean indicates whether the system has secondary eclipse depths measured in any band. Truth indicates the system has at least one secondary eclipse measurement in the EOD.

SET is the epoch of the secondary eclipse center, normally given in BJD, but (as with other fields) when the literature reports HJD or UTC JD, we do not attempt a conversion to BJD.

2.5. Stellar Properties

This set of parameters provides users the physical parameters of the exoplanet host stars. Most of the parameters are derived from the stellar models in the literature, and we provide the readers with the references. We describe added fields since Wright et al. (2011) below.

GAMMA (γ) is the radial velocity of the center of mass of the planetary system with respect to the barycentric frame and is reported in km s^{-1}. It is typically known to far less precision than K because it requires an absolute measurement of velocity.

RSTAR is the radius of the star in the solar units.

RHOSTAR is the density of the star in g cm^{-3}.

2.6. Stellar Magnitudes

We provide the brightness of the host star measured in different filters. We report optical magnitude and color (V and $B - V$), 2MASS J, H, and K_s magnitudes, and we have added KP for the *Kepler* photometric band. Note that the definitions of V and B in the literature vary and are often Hipparcos magnitudes.

2.7. Coordinates and Catalogs

We report the coordinates of the host star, as well as the host star's identification, as designated by different catalogs. We have added the DIST field since Wright et al. (2011), which is the distance to the host star in units of pc. If only parallax (PAR) is given, we calculate DIST based on PAR and vice versa. If the literature does not report DIST or PAR, then we obtain PAR from the Hipparcos dataset by van Leeuwen (2009) for stars with Hipparcos numbers. We naïvely translate the 1-σ errors in each into asymmetric uncertainties in the other.

2.8. Uncertainties

We have changed the way of reporting uncertainties, especially asymmetric ones, since Wright et al. (2011). We now report uncertainties for a certain field X as XUPPER, XLOWER, and UX. XUPPER and XLOWER store the upper and lower 1σ uncertainties, and they are different when the error bars are asymmetric. UX contains the 1σ uncertainty, and it equals $(\text{XUPPER} + \text{XLOWER})/2$. Fields that have XUPPER, XLOWER, and UX are: all the orbital parameters, all the transit parameters, all the secondary eclipse fields, and all the stellar properties and DIST and PAR.

2.9. References

The fields XREF and XURL store the peer-reviewed reference and link to the publication for the data in field X. Previously, we reported only general references for certain sets of fields (e.g., FIRSTREF, FIRSTURL, ORBREF, and ORBURL), but now we report the references for most of the fields on an individual basis.

The following fields do not have associated REF or URL fields. Except where we record these values directly from discovery papers, RA, DEC, and PAR are usually from the *Hipparcos* re-reduction of van Leeuwen (2009); the $B - V$ (BMV) values are from the *Hipparcos* catalog by Perryman & ESA (1997); stellar magnitudes J, H, and KS (i.e., K_s) are from the 2MASS catalog (Skrutskie et al. [2006]; as reported in SIMBAD), and the KP (i.e., K_P) magnitudes are from the Exoplanet Archive (Akeson et al. 2013).

SHK and RHK represent the Mount Wilson S and R'_{HK} chromospheric emission measures. These fields are poorly-maintained fields and unreferenced, at the moment. We plan to include proper reference in the future. Most of the SHK and RHK values are from Butler et al. (2006) and individual discovery papers.

2.10. Removed Fields

We removed two fields since Wright et al. (2011):

The SPTYPE field previously reported the stellar type of the host star. We have removed it since it can be difficult to verify with peer-reviewed references, and the field was not well maintained. We encourage users to use TEFF and BMV instead.

The NSTEDID field reported the identification of the host star in the NASA Star and Exoplanet Database (NStED), and now it is replaced by EANAME, which is the name of the star as appears on the NASA's Exoplanet Archive (Akeson et al. 2013).

3. INCLUSION OF THE KEPLER PLANET CANDIDATES AND OTHER EXOPLANETS ON EXOPLANETS.ORG

Since Wright et al. (2011), *Kepler* has discovered many exoplanet candidates, and more planets have been robustly discovered by various other methods, although not all have very well-characterized orbits. We have expanded the EDE to include those planets for the convenience of our users, and also to keep exoplanets.org complete in terms of confirmed exoplanets.

We now provide an option for users to include the KOIs discovered by *Kepler* in the EDE. Although KOIs are not counted as part of the EOD due to their status of being "candidates," we include them on our Web site so that these KOIs are put into the context of all confirmed exoplanets. We have used broad definitions for SEP and MASS so that they may be compared to EOD planets, even though they share few strictly defined parameters. The KOIs listed in our table include three *Kepler* data releases (as of 2014 July), and exoplanets.org always provides the most up-to-date release through a partnership with the NASA Exoplanet Archive.

To display the KOIs in the EDE table, users can check the "Kepler" option on the upper left of the table (the default selection only includes "Orbit Database," i.e., the EOD, and "Other"). They can also be displayed on plots with the interactive plotting tool of EDE (see Fig. 3 for an example plot). All KOIs with a disposition other than "FALSE POSITIVE" are included in the EDE.

We now also include robustly detected imaging, microlensing, and timing planets. Our criteria for a "robust detection" for these planets are the following:

Imaging planets:

1. Planet-star mass ratio $q < 0.023$ (<24 $M_{\rm Jup}$ for a solar mass star); and, in general, we require $(q + \sigma_q) < 0.023$, where σ_q is the uncertainty in q.
2. SEP < 100 AU $\times$ $(M_*/M_\odot)$, where SEP is the semimajor axis a, if a is known, and the projected separation otherwise.
3. Confidently detected: the detection is clearly of a real astrophysical source and will unlikely later be found to have been spurious.

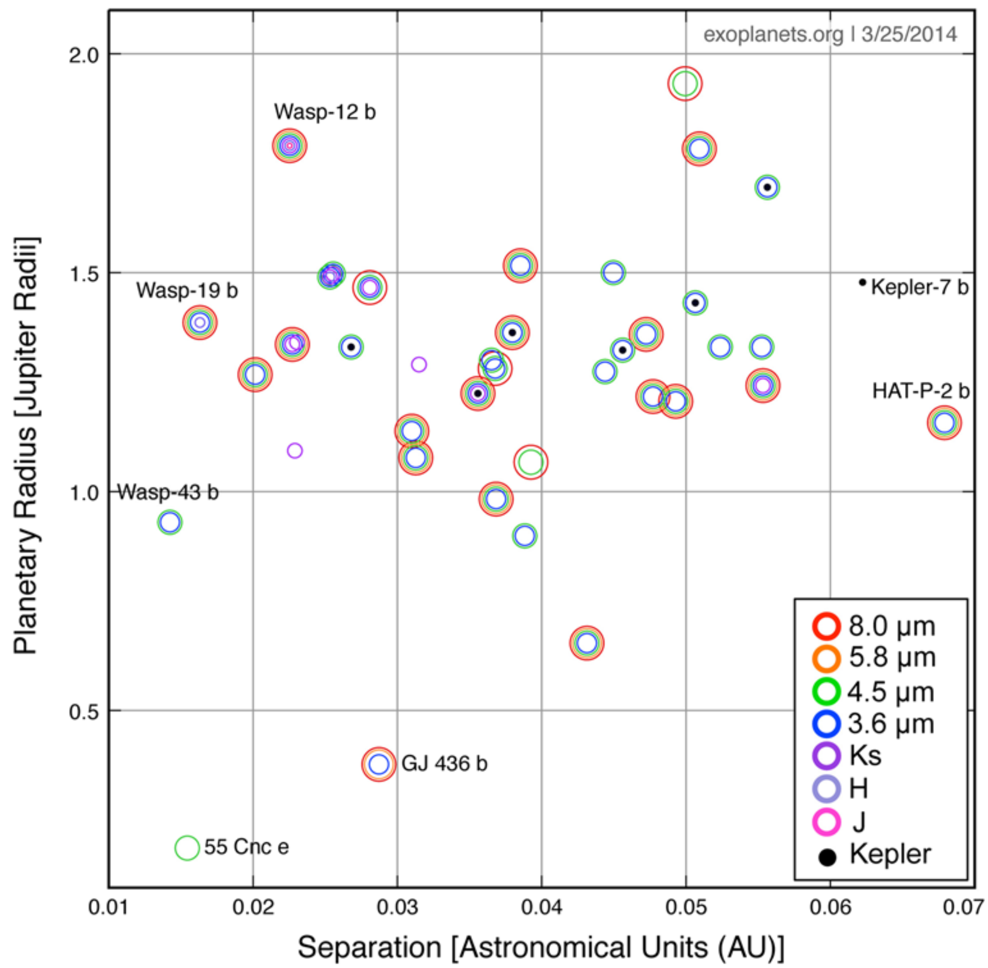


FIG. 3.—Example plot produced by the interactive plotting tools of EDE on exoplanets.org. The interactive plotting interface is shown on the right, with the mass-period plot shown on the left. The *x*-axis is planet orbital period in days and the *y*-axis is planet mass in Earth mass. The exoplanet samples being plotted are the ones in the EOD, including transit planets (*large blue dots*), RV planets (*red triangles*), and timing planets (*magenta squares*). The KOIs are plotted as small black dots, and their masses are calculated using their radii based on mass-radius relations from the literature (see § 2.2). Note the apples-to-oranges comparison enabled by the hybrid MASS field on the *y*-axis, which blends estimated masses, minimum masses, and true masses on a single plot.See the electronic edition of the *PASP* for a color version of this figure.

4. Confidently bound: object will clearly not be later found to be unbound or a chance alignment.

Microlensing planets.—We accept microlensing planets that appear in refereed journals as having unambiguously planetary masses (planet host mass ratio, $q < 0.023$).

Timing planets.—Timing planets must have dynamically stable orbits and, ideally, show multiple complete orbits (e.g., see Wittenmyer et al. 2012; Horner et al. 2012; Wittenmyer et al. 2013).

Some of the exoplanets that are primarily detected by these methods do not have well-determined orbital parameters, and thus they are categorized as "Other Planets" on exoplanets.org instead of being in the EOD. These planets can be displayed by checking the "Other" option for the EDE table. As of 2014 July, no microlensing or imaging planets (except β Pictoris) appear in the EOD, while several timing exoplanets have well-determined orbital parameters and are included in the EOD.

4. UPDATES TO THE WEB SITE SOFTWARE

The software stack powering the EOD remains largely unchanged from Wright et al. (2011). The back-end server is now written in Ruby, instead of Python, but the thin role it plays is largely unchanged. The JavaScript front end that runs on the browser has recently been optimized to support the larger datasets arising from the *Kepler* missions. In particular, the EOD table now only renders cells that are visible on-screen.

1. Plot parameters may be saved with browser cookies, so plots may be custom-reproduced easily with updated data later.

2. Tables may be generated and exported with custom fields computed.

3. Plots may be exported with a variety of resolutions and aspects, including publication-quality vector graphics (SVG format).

5. SUMMARY AND FUTURE WORK

We have had two major updates since Wright et al. (2011). First, we expanded the scope of the EOD. We removed the requirement for the host star being normal and included the planets discovered not only by RV and transit but also by various other methods (e.g., timing) in the EOD. We also have added some new fields; most notably, we now report the secondary eclipse depths. We removed obsolete fields and revised some fields as necessary. We have included SEP and MASS with broad definitions so all planets may be plotted on common axes.

Second, we included KOIs and other planets (the ones detected by microlensing, imaging, timing, and, in the future, astrometry but that do not have well-characterized orbits) on exoplanets.org. Although they are not included in the EOD, we reported them on our Web site since the users might find them useful for purposes of statistical studies and comparison.

In the future, we hope to include images of directly imaged planets and light curves for transits and microlensing planets. We plan to display RV curves whenever their RV data are available and include better incorporation of *Kepler* parameters in the EOD (such as KEPID).

We also plan to report the upper limits (XUL) for planet minimum mass (MSINI), eccentricity (ECC), and the radial velocity semiamplitude (K) when the literature reports them. For example, an upper limit for ECC is reported when the orbit is consistent with a circular one, and the upper limit for K is reported when there is only a null result from radial velocities. Since not all authors define the upper limits in the same way (e.g., 1σ or some fixed percentile), we encourage the users to refer to the original references for more information. We will also include proper rendering of upper limits in the EDE Table, proper upper limit symbols in the plotter, and proper handling of upper limits in filters and queries in both cases.

Omissions and errors to the EOD can be corrected by sending us an email at datamaster@exoplanets.org.

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REFERENCES

Akeson, R. L., et al. 2013, PASP, 125, 989
Batalha, N. M., et al. 2013, ApJS, 204, 24
Bennett, D. P., et al. 2010, ApJ, 713, 837
Borucki, W. J., et al. 2010, Science, 327, 977
Butler, R. P., et al. 2002, ApJ, 578, 565
Butler, R. P., et al. 2006, ApJ, 646, 505
Chauvin, G., et al. 2012, A&A, 542, A 41
Dawson, R. I., & Murray-Clay, R. A. 2013, ApJ, 767, L 24
Fabrycky, D. C., & Winn, J. N. 2009, ApJ, 696, 1230
Green, J., et al. 2012, preprint (arXiv:1208.4012)
Horner, J., Wittenmyer, R. A., Hinse, T. C., & Tinney, C. G. 2012, MNRAS, 425, 749
Howard, A. W. 2013, Science, 340, 572
Kane, S. R. 2014, ApJ, 782, 111
Kipping, D. M. 2013, MNRAS, 434, L 51
Lagrange, A.-M., et al. 2009, A&A, 493, L 21
Lissauer, J. J., et al. 2011, ApJS, 197, 8
Macintosh, B., Gemini Planet Imager Instrument Team. 2014 Planet Imager Exoplanet Survey, Gemini, & Observatory, Gemini 2014, AAS Meeting 223, 229.02
Mahadevan, S., et al. 2012, Proc. SPIE, 8446, 84461 S
Mordasini, C., Alibert, Y., Georgy, C., Dittkrist, K.-M., Klahr, H., & Henning, T. 2012, A&A, 547, A 112
Moutou, C., et al. 2011, A&A, 533, A 113
Nielsen, E. L., et al. 2014, preprint (arXiv:1403.7195)

Perryman, M. A. C., & ESA 1997, The HIPPARCOS and TYCHO Catalogues (ESA SP-1200; Noordwijk: ESA)
Ricker, G. R. 2014, J. AAVSO, 42, 234
Sanchis-Ojeda, R., et al. 2012, Nature, 487, 449
Schneider, J., Dedieu, C., LeSidaner, P., Savalle, R., & Zolotukhin, I. 2011, A&A, 532, A 79
Skrutskie, M. F., et al. 2006, AJ, 131, 1163
van Leeuwen, F. 2009, A&A, 497, 209
Weiss, L. M., & Marcy, G. W. 2014, ApJ, 783, L 6
Winn, J. N., et al. 2005, ApJ, 631, 1215
Wittenmyer, R. A., Horner, J., & Marshall, J. P. 2013, MNRAS, 431, 2150
Wittenmyer, R. A., Horner, J., Marshall, J. P., Butters, O. W., & Tinney, C. G. 2012, MNRAS, 419, 3258
Wright, J. T., et al. 2011, PASP, 123, 412
Wright, J. T., & Gaudi, B. S. 2013, in Planets, Stars and Stellar Systems, Vol. 3, ed. T. Oswalt, L. M. French, & P. Kalas (New York: Springer), 489
Wright, J., et al. 2014, AAS Meeting 223, 148.31