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Defining and cataloging exoplanets: the exoplanet.eu database

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ABSTRACT

We describe an online database for extrasolar planetary-mass candidates, which is updated regularly as new data are available. We first discuss criteria for inclusion of objects in the catalog: "definition" of a planet and several aspects of the confidence level of planet candidates. We are led to point out the contradiction between the sharpness of criteria for belonging to a catalog and the fuzziness of the confidence level for an object to be a planet. We then describe the different tables of extrasolar planetary systems, including unconfirmed candidates (which will ultimately be confirmed, or not, by direct imaging). It also provides online tools: histograms of planet and host star data, cross-correlations between these parameters, and some Virtual Observatory services. Future evolutions of the database are presented.

Key words. catalogs – virtual observatory tools – planetary systems – planets and satellites: detection – planets and satellites: fundamental parameters

1. Introduction

The study of extrasolar planetary systems has become a very active field that will grow continuously in the coming years and decades. This new field of astronomy leads to two types of activities: (i) detection of new planets and new observations of known planets; and (ii) studies to understand the physical and dynamical processes of individual planets, planetary systems, and interactions of planets with their host stars.

These activities require precise knowledge of the characteristics of planets and of their parent stars, i.e. a well-documented catalog. Exoplanetology is developing so rapidly (and will even accelerate in the coming years) that any static catalog[1] becomes obsolete on time scales of a few months. An evolutionary online catalog through the Internet is better adapted to that situation. It has the advantage of permanently updating the data and of providing online tools for their pretreatments. Here we describe a freely accessible database consisting of a catalog and associated online services. In Sect. 2 we describe the purpose and philosophy of the database. In Sect. 3 we discuss criteria for including of objects in the catalog. In Sect. 4 we give the contents of the catalog in details. In Sect. 5 we describe the associated online services. The database is part of a wider portal, the Extrasolar Planets Encyclopaedia, offering other services, which we describe briefly in Sect. 6. We end by sketching future developments in Sect. 7.

2. Purpose of the catalog

A first online catalog, the Extrasolar Planets Catalog, was established at the dawn of the Web in February 1995 after suspicion of the discovery of γ Cep b (Campbell et al. 1988) and the confirmation of the first pulsar planets (Wolszczan 1994)[2]. It was followed some years later by the California and Carnegie Planet Search table at http://exoplanets.org/planet_table.shtml (Butler et al. 2006) and by the Geneva Extrasolar Planet Search Programmes table at http://obswww.unige.ch/~naef/planet/geneva_planets.html (Mayor, Queloz, Udry and Naef). The Extrasolar Planets catalog, available since then at http://exoplanet.eu/catalog.php (Martinache & Schneider 2004), has been upgraded in 2005 by the addition of several graphical and statistical online services (Le Sidaner et al. 2007). This new version has been followed by two other professional online databases: the NStED Database at http://nsted.ipac.caltech.edu and the Exoplanet Data Explorer at http://exoplanets.org (Wright et al. 2011), the later providing some online tools. The Exoplanet Data Explorer and the Geneva catalog have the advantage of providing firsthand data for some planets by the observers (and often discoverers) themselves. But as of February 2011 these catalogs list only planets discovered by radial velocity and by transits, whereas our catalog also lists planets discovered by astrometry[3], direct imaging, microlensing, and timing. It also gives a table of unconfirmed or problematic planets (see Sects. 3 and 4 for criteria of "confirmatio"). For completeness, there is also a fifth list, provided by the IAU Working Group on Extrasolar Planets at http://www.dtm.ciw.edu/boss/planets.html, but it only lists planet names and it is not maintained as of February 2011.

[1] Like the table of stellar and planet parameters by Fischer & Valenti (2005).

[2] Some older pages, back to 1999, are available at http://web.archive.org/web/*/http://www.obspm.fr/planets and at http://web.archive.org/web/*/http://exoplanet.eu.

[3] Although there is, as of February 2011, no planet discovered by astrometry; indeed, the planet VB 10 b claimed to be discovered by astrometry (Pravdo & Shakland 2009) has not been confirmed by radial velocity measurements (Bean et al. 2010).

As a final introductory remark, we point out that our catalog includes all planets that we estimate to be "reasonable" candidates, including a separate table of unconfirmed planets. Its aim is to be a working tool that is in progress permanently. This choice is made to provide the community of researchers all the available information at any time, allowing them to make their own judgement, to use the data for new observational or theoretical work and to confirm, or not, problematic candidates by complementary observations. It is also designed to help high-level amateurs (e.g., for transiting planets) and, since it is updated daily, to give the latest news for correct information for outreach activities. For that purpose it is multilingual (English, Farsi (Persian), French, German, Italian, Polish, Portuguese and Spanish). For comparison, the Exoplanet Data Explorer gives only "secure" planets in the sense that they are all published as such in refereed journals[4]. But as a counterpart it contains less candidates. We have chosen to provide a larger sample of candidates since each user can make her/his own mind up on their validity.

3. Criteria for including of objects in the catalog

The first task is to choose which objects to include in the catalog. The question is very simple, but the answer is delicate. It faces several problems for which one has to make choices. It therefore deserves a discussion to clarify all problematic aspects. The objective of making a catalog of exoplanets rests on the implicit prejudice that there is a definable category of objects sharing some common nature with Solar System planets. This purpose is necessary if the catalog is to be used to draw statistical features of planet characteristics. It is thus essential to establish criteria in order to decide which objects deserve the name "planet". As we will see, the ideal situation of criteria ruling all configurations without ambiguity cannot be realized.

3.1. "Definition" of a planet

The word "definition" refers to two different situations. First, it means an arbitrary convention, such as the neologism "pulsar". But the word "definition" also often designates an attempt to clarify the content of a pre-existing word for which we have some spontaneous preconceptions, regardless of their grounds, and to catch an (illusory) "essence" of what is defined. It is then made use of pre-existing plain language words which carry an a priori pre-scientific content likely to introduce some confusion in the reader's mind. In the clarification of pre-scientific conception versus scientific convention, some arbitrariness is unavoidable.

Here we do not try to catch some essence of planets but to find pragmatic criteria for including of objects in the catalog based on physical properties, if posssible, and on observable appearance. The complexity of the problem arises when one seeks to correlate these two approaches.

3.1.1. Physical nature of planets

Until 2001, a planet was defined as not having central deuterium burning. According to substellar interior models, this criterion enables a planet to be defined as having a maximum mass around 13 Jupiter mass (Burrows et al. 2001). But the discovery that the companion HD 168443 c with $M.\sin i = 18.1\ M_{\rm Jup}$ to the star

[4] It also provides more detailed planetary and stellar data (e.g., planet density, $V.\sin i$ for the star).

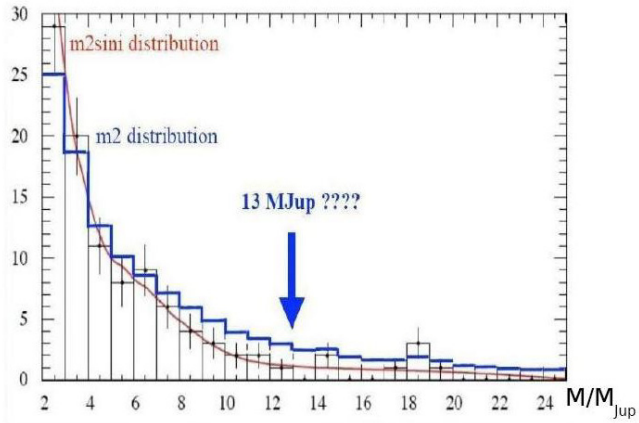


Fig. 1. Mass distribution of companions below 25 $M_{\rm Jup}$ (Udry 2010).

HD 168443 already has a companion with $M.\sin i = 8.2\ M_{\rm Jup}$ (Marcy et al. 2001) introduced a complication (see Sect. 4 for the labeling of planets). The idea emerged that a substellar companion with a mass higher than the 13 $M_{\rm Jup}$ limit could share a common "nature" with fewer than 13 $M_{\rm Jup}$ objects, whatever it may be. That there is no special feature around 13 $M_{\rm Jup}$ in the observed mass spectrum (Fig. 1 Udry 2010) reinforces the choice of forgetting this mass limit. But then an embarrassing problem arises: where set this limit (if a limit makes sense at all)?

Another approach is based on the formation scenario. The convention is then to call objects formed by accretion of planetesimals in a circumstellar dust disk "planets", just by analogy with Solar System planets, and to call objects formed by collapse in a gas cloud or circumstellar disk "brown dwarfs", by analogy with stars. We have chosen to follow this approach as much as possible. But it faces a major difficulty: for a given substellar companion, how do we know if it is formed by core accretion or by gravitational collapse since we cannot catch the formation process "in vivo", and it is not clear how to infer it from current observables. Unfortunately there is an overlap in the guessed mass distribution of planets and brown dwarfs (Baraffe et al. 2010; Spiegel et al. 2011). Baraffe et al. (2010) suggest that the brown dwarf mass function can go down to 6 $M_{\rm Jup}$. Therefore the companion mass can a priori not serve as a reliable criterion for deciding if it should be named a "planet" or a "brown dwarf". It is likely that these two categories have different statistical distributions, for instance, in the plane (M, a) (a being the semi-major axis), but this does not help for individual objects. One could make use of the bulk density of objects, beacause those formed by core accretion may have more heavy elements (Baraffe et al. 2010). But then one has to know their radius. As long as ultra-high angular resolution imaging cannot measure this radius directly, the latter is known only for transiting planets. In addition it is scrambled by the observed "radius anomaly", i.e. the abnormally large observed radius compared to models (at least for hot Jupiters, Baraffe et al. 2010). The companion mass value is finally the only simple pragmatic present criterion for the designation "planet" so we chose to rely on it. But we still have to choose a mass limit.

There is no theoretical prediction for the mass spectrum of brown dwarfs, but there is a dip around 25–30 $M_{\rm Jup}$ in the observed distribution in $M.\sin i$ of substellar objects (Udry et al. 2010, Fig. 2a). A closer look reveals a flat quasi-void between ~25–45 $M_{\rm Jup}$ (Sahlmann et al. 2011 – Fig. 2b). Since according to Baraffe et al. (2010) the likelihood of an object being a brown

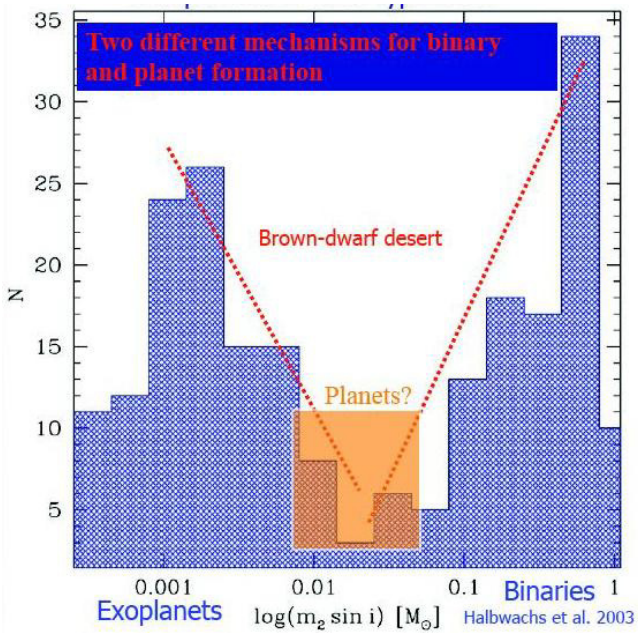


Fig. 2a. Mass distribution of substellar objects (Udry 2010).

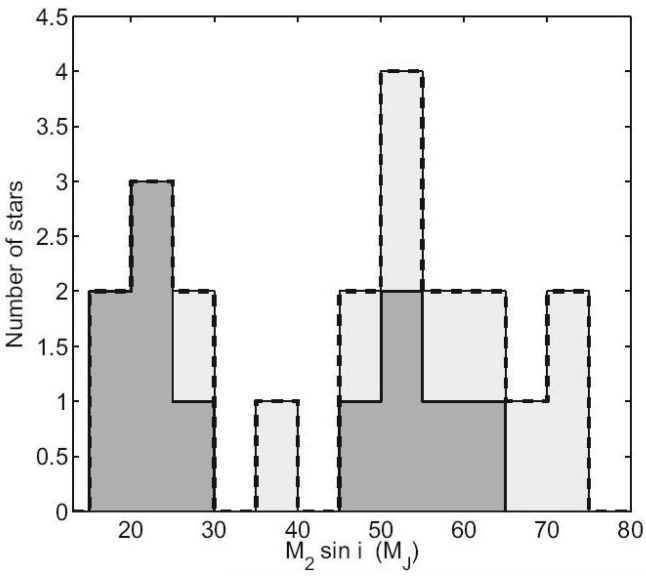


Fig. 2b. Zoom of the mass distribution around 25–40 $M_{\rm Jup}$ (Sahlmann et al. 2011).

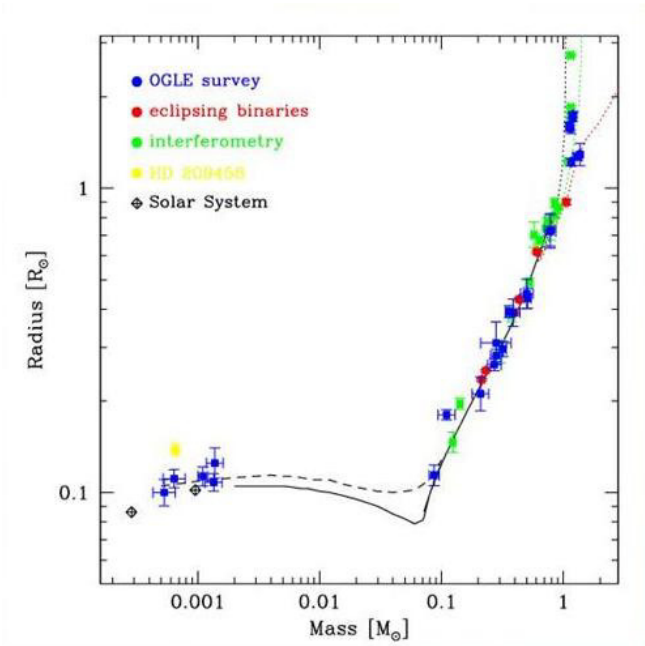


Fig. 3a. Radius distribution as a function of mass for substellar objects (Pont et al. 2005).

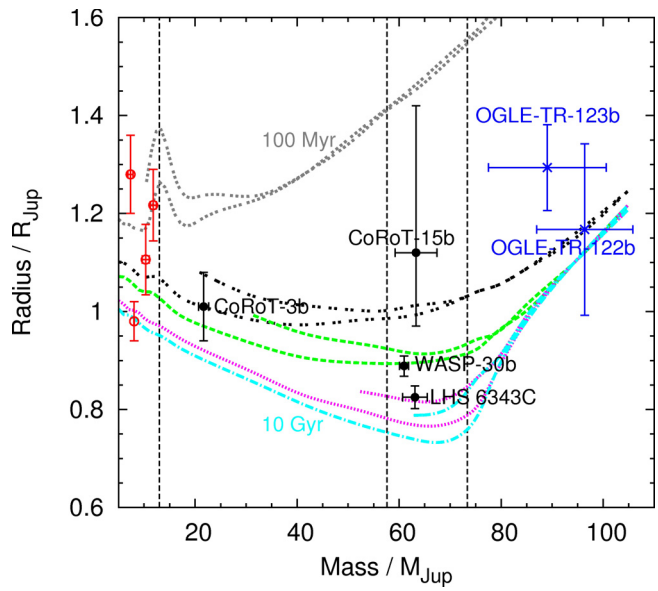


Fig. 3b. Zoom of the mass-radius distribution around 25–40 $M_{\rm Jup}$ (Anderson et al. 2011).

dwarf increases with mass and since the observed mass spectrum decreases from a few to 20 Jupiter mass, we attribute this decrease to the mass spectrum of planets. Finally since a threshold has to be chosen, we *arbitrarily* choose (and perhaps provisionally if new insights into the mass distribution emerge in the future) to priviledge at this stage a maximum mass of 25 $M_{\rm Jup}$.

There is also a break in the radius distribution as a function of substellar masses around 25 $M_{\rm Jup}$ (Fig. 3a Pont et al. 2005; Fig. 3b Anderson et al. 2011), suggesting a difference in physical nature below and above this mass.

These facts make it plausible that the population below around 25 $M_{\rm Jup}$ is essentially made of planets (in the above sense). Since in the 13–25 $M_{\rm Jup}$ region there are only about 5% of all objects with a mass below 25 $M_{\rm Jup}$, a possible confusion between planets and brown dwarfs is not statistically significant.

The word "superplanet" has sometimes been proposed for massive planets (e.g., Udry et al. 2002), but no clear definition was given in the literature. One could use it to designate objects between 13 and 25 $M_{\rm Jup}$, but since there is no special feature around 13 $M_{\rm Jup}$ in the observed mass spectrum of substellar objects (Fig. 1), it introduces an unnecessary complication so we discard it.

Another property of planets in the heliocentric view is that they are low-mass companions of a parent star. But a few isolated objects with a mass probably below ~10 Jupiter mass have been discovered (e.g., S Ori 70 Zapatero-Osorio et al. 2002). We therefore include an additional table of "free-floatting" planet candidates (called "rogue" planets by Abbot & Switzer 2011). Since some of these objects may be "true" planets ejected from

a circumstellar orbit, we avoid designating them by a new word, "sub-brown dwarfs", evoked by Spiegel & Burrows (2011).

The International Astronomical Union is attempting to establish an "official" definition of exoplanets (Boss et al. 2010), but we feel that it is premature since the situation is still evolving so any definitive definition is likely to be too rigid to adapt to new discoveries. We note that, with the exception of Solar System bodies, there is no other "official" definition of categories of objects in astronomy (e.g., of quasars), and it is better like this.

3.1.2. Observable parameters

A growing activity is and will be the spectro-polarimetric characterization of substellar companion atmospheres. The physics of atmospheres of gas giant planets and of brown dwarfs are essentially the same. Some users of the database are more interested by this aspect than by the internal structure resulting from a formation scenario. It is therefore useful for them to have a database that includes some brown dwarfs. It is another reason to have a "generous" upper mass limit of 25 $M_{\rm Jup}$.

Another concern is a lower mass limit for the planet. This is not very academic since objects transiting a white dwarf with a size 0.1 $R_\odot \approx 0.25\ R_{\rm Pluto}$ or companions to planets detected by transit time variations with a lower mass than the Moon (Sartoretti & Schneider 1999) may be detected any time in the nearby future. It is not certain that the IAU resolution B5 in 2006 defining a planet as "a nearly round object which has cleared the neighbourhood around its orbit" will be pertinent for exoplanets. For the present catalog we will not use any lower mass or size limit (and therefore include future "exo-moons"). We incidentally note that the planetary nature of PSR 1257+12b ($M = 1.8\ M_{\rm Moon}$) has never been contested in the literature.

As a provisional conclusion we therefore choose at this point to include all objects with a mass below 25 $M_{\rm Jup}$. One cannot exclude that this limit will change in the future. A sharp limit is somewhat absurd, since in the present case it excludes 25.1 $M_{\rm Jup}$ companions, but at the same time we see no pragmatic alternative to sharpness.

3.2. Confidence level of a planet

Once we have chosen a methodology to decide which objects are called planets, we have to decide whether a candidate fulfills these criteria or not. There are two aspects:

- is the suspected companion real or an artefact (stellar activity etc.)?
- is the companion, if confirmed, really a planet?

The ideal situation would be that authors give a clear confidence level for each candidate, so the task of a compiler would be to decide (arbitrarily) a threshold for a confidence level. But in most paper there is no clear confidence level, making the decision of confirmed/unconfirmed arbitray and subjective.

3.2.1. Companion or artefact?

There is first a well known problem with the confidence level of the interpretation of observations that is specific to each detection method. After the analysis of artefacts specific to each method, the planet candidate has a false alarm probability (FAP). The California Planet Survey team requires systematically a FAP below 5% to announce a planet discovery (Howard et al. 2010). But all authors do not give a clear estimate of their FAP (sometimes difficult to evaluate quantitatively), so in this respect the confidence level of planets is heterogeneous in the catalog. We therefore adopt, with only one exception (Gl 581 g – see special cases below), the criterion of being published in a refereed paper or presented in a professional conference or website as a "secure" companion. Without entering into a detailed discussion of all artefacts, let us recall some of their features:

- *Radial velocity (RV)*
  An apparent RV variation can be due to various phenomena in the stellar atmosphere. They are generally eliminated by the "bisector variation" test (Mandushev et al. 2005).
  Once the stellar wobble has been confirmed, it could still come from another mechanism than the pull by a companion. As shown by Schneider (1999) and confirmed by Morais & Correia (2010), it can be due to a distant binary star with the same orbital period as for the planet (false) candidate. But such events can only mimic low-mass planets on wide orbits, which are beyond the present detection capability. It does not apply to objects currently present in the catalog. It nevertheless represents a danger for future discoveries with the Gaia astrometric space mission (Schneider & Cabrera 2006).
  The final discrimination between this artefact and a real companion will be provided by the detection of the candidate by direct spectro-imaging. The same discussion holds for planets discovered by astrometry and by timing.
- *Transits*
  The main possible artefact is the presence of a background eclipsing binary (BEB) in the target point spread function. A first test is then to check, if possible, that the transit is at first sight achromatic (we leave aside the discussion of self-luminous transiting planets) and that a BEB is not seen in high angular resolution images. A second step is then to measure the radial velocity variations due to the suspected transiting object (after elimination of the bisector variation, Mandushev et al. 2005).
  We note that new approaches to consolidating the planetary nature of the transiting have recently emerged: indirect measurement of the object mass by transit time variation as for Kepler-11b–g (Lissauer et al. 2011) or the highly accurate achromaticity of the transit as for Kepler-10c (Fressin et al. 2011).
  Once the transit has been secured, it can still mimic a Jupiter-sized planet if it stems from a brown dwarf or a super-Earth if it is from a white dwarf. This case is removed by RV measurements that give the companion mass.
- *Direct imaging*
  The main possible artefact is confusion with a background star. It can easily be removed by verifying that the star and the companion have a common proper motion. Some authors nevertheless publish a planetary candidate "to be confirmed", prior to the check of common proper motion, when the probability of there being a background star in the target vicinity is "sufficiently" low (e.g., Lagrange et al. 2008 for β Pic b). There is no commonly accepted value of the FAP for these cases and the decision between "confirmed" and "unconfirmed" planet is arbitrary.

3.2.2. Planetary nature of the companion

Here again, there are two aspects:

- *Is the companion mass below the chosen 25 $M_{\rm Jup}$ limit?*
  Once the mass limit has been decided, an uncertainty remains since the measured mass suffers from various inaccuracies. It introduces a fuzziness on what objects to include in

the catalog. For all type of methods there is an instrumental uncertainty.
But in case of planets detected by RV or by timing there is an additional "sin i uncertainty", meaning that the only observable is then $M_{\rm pl}.\sin i$ instead of $M_{\rm pl}$ itself, due to the unknown orbital inclination i. The database lists all objects with $M.\sin i$ less than 25 $M_{\rm Jup}$. As is well know, this uncertainty does not hold for transiting planets since i is then derived from the shape of the transit light curve. For planets detected by imaging, constraints on their mass can be put thanks to multicolor photometry or spectroscopy and to atmosphere modeling. In that case the uncertainty is rather large (see for instance Neuhaeuser et al. 2005). The mass estimate then rests most often on the Baraffe et al. model (2010) correlating the mass to the spectrum and age. It is important to note that this model has not been tested yet for planets with a mass known from radial velocity measurements.

– *Is the less than 25 $M_{\rm Jup}$ companion a planet?*
For rigorous completeness one has to consider the possibility that less than 25 $M_{\rm Jup}$ compact objects are not planets. Presently there is no known category for such objects. But, at least in the early era of the first planet candidates when the abundance of exoplanets was completely unknown, one could wonder if a new class of objects had not been discovered instead. For instance, one could in principle invoke black holes or "X-stars", analogous to neutron stars, where X is some new type of particle. Planetary mass black holes have an evaporation time of $\tau_{\rm BH} = \tau_{\rm Planck}(M_{\rm BH}/M_{\rm Planck})^3 \approx 10^{63}(M_{\rm BH}/M_{\rm Jup})^3$ s (Yang & Chang 2009), so they survive evaporation over stellar lifetimes. But, having a (Schwarzschild) radius of a few meters, they are made implausible by the observed radius derived from transit events. X-stars would have a mass $M_{X*} = M^3_{\rm Planck}/M^2_X$, requiring a 30 neutron mass X particle for a 1 $M_{\rm Jup}$ object. This is not excluded by the zoo of "beyond the standard model" theories, but it would imply a discrete mass distribution with only a very few mass values (one per X-species). These perspectives are (or were) important given the philosophical significance of exoplanets and that "extraordinary claims require extraordinary proofs". But of course today the case is closed.

In conclusion, we have arbitrarily chosen a 25 $M_{\rm Jup} + \Delta M$ mass limit with a 1 sigma margin for ΔM. By having a "generous" mass limit, we allow the user to easily compare planets and brown dwarfs. Here again a sharp mass limit, even with a 1 sigma margin, is absurd since it excludes companions with $M - \Delta M = 25.1\ M_{\rm Jup}$.

3.3. Ambiguities and incorrect characteristics attribution

Some ambiguities are present in the interpretation of stellar wobbles. Anglada-Escude et al. (2010) warn that eccentric orbital solutions can hide two planets in a 2:1 resonance (and vice versa?). Other degeneracies are present for two-planet systems: exchange orbits (change in semi-major axis, Funk et al. 2011), eccentric resonances (change in eccentricity, Laughlin & Chambers 2002; Nauenberg 2002), Trojan planets (Dvorak et al. 2004), large moons or binary planets (Cabrera & Schneider 2007). These ambiguities will finally be resolved by the detection of the candidate by direct spectro-imaging.

For direct imaging, Kalas (2008) and Kennedy & Wyatt (2011) point out that the planet can be surrounded by a large dust cloud leading to a significant overestimate of its radius and albedo.

3.4. Special cases

Some special cases deserve a few comments.

– *Planets designated as "brown dwarfs"*
Some authors designate their discovered substellar companions as "brown dwarfs" even though they have a mass below the 25 $M_{\rm Jup}$ limit. This is, for instance, the case of HIP 78530 b ($M = 23.04 \pm 4\ M_{\rm Jup}$ (Lafrenière et al. 2011). We have included these allegated brown dwarfs in the main planet table.

– *Gliese 581 g*
The individual case of Gliese 581 g has deserved much attention because, as one of the first potentially habitable planets, it is emblematic. This news was published in a refereed paper (Vogt et al. 2010) and as such should normally be in the main table. It was challenged by Pepe et al. (2011) and by Gregory (2011), but as of February 2011 with no published additional RV data. We have chosen to transfer it (provisionally?) to the table of unconfirmed planets.

– *Objects with very high uncertainty on the mass*
Some objects have a published mass well beyond the 25 $M_{\rm Jup}$ mass limit, but with a very high uncertainty on the mass ΔM so that the value for $M - \Delta M$ is below the 25 $M_{\rm Jup}$ limit. This is, for instance, the case of HD 190228 b for which Reffert & Quirrenbach (2011) give a mass range 5.93–147.2 $M_{\rm Jup}$ at the 3σ level by using Hipparcos astrometric data. We have transferred them to the table of unconfirmed planets. The situation will be clarified around 2015 with the results of the ESA Gaia astrometric mission.
Some objects have completely unknown mass. We then use another criterion, the size; for some objects, such as SDSS J083008+4828 ($R = 0.61\ R_{\rm Jup}$ Tsuji et al. 2011), a radius based on the infrared flux has been determined. We include as unconfirmed planets, all objects with an upper radius provisionally set to 1.2 $R_{\rm Jup}$.

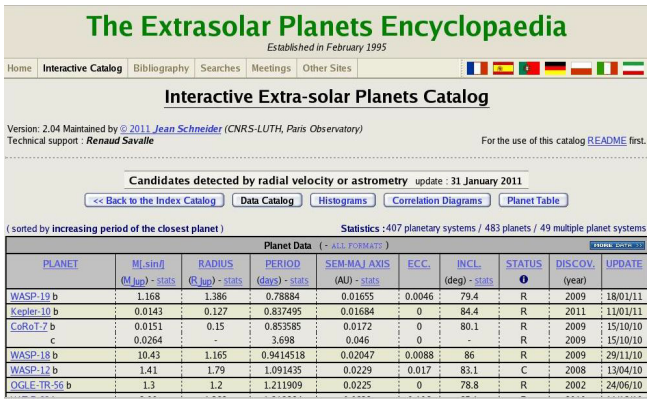
– *Planets declared unconfirmed by the discoverers*
These objects are naturally in the table "unconfirmed". Here again some borderline cases are inevitable, as is for instance the case as of June 2011, for Lupus-TR-3b (see the corresponding page "Notes for Lupus-TR-3b".

– *Suspected planets with no clear parameters*
Some candidates are suspected from a linear trend in RV monitoring, or because they sculpting a debris disk, or because they pollute a stellar spectrum. For the two first cases, the candidate will ultimately be confirmed, or not, by direct imaging. They are in the "unconfirmed" table.

4. Description of the catalog

We describe the catalog as it was in February 2011. It may evolve continuously. It is, provisionally, organized in eight tables, according to their discovery methods. We distinguish "detection" from "discovery"; e.g., some planets are discovered by RV and detected by transit afterwards. In the coming years, planets discovered by RV will be detected by direct imaging and vice-versa; therefore, this categorization is likely to change. The eight tables are

1/ all "confirmed" planets;
2/ planets discovered by RV and/or astrometry (note that as of February 2011 no confirmed planet has been discovered by astrometry, although a few of them have been observed in an astrometric monitoring after their discovery by RV);
3/ a subtable of the previous collects planets discovered first by transit and confirmed later by RV, and planets discovered first by RV with transits discovered afterwards;



The Extrasolar Planets Encyclopaedia

Established in February 1995

Home | Interactive Catalog | Bibliography | Searches | Meetings | Other Sites

Interactive Extra-solar Planets Catalog

Version: 2.04 Maintained by © 2011 Jean Schneider (CNRS-LUTH, Paris Observatory)
Technical support : Renaud Savalle

For the use of this catalog README first.

Candidates detected by radial velocity or astrometry update : 31 January 2011

<< Back to the Index Catalog | Data Catalog | Histograms | Correlation Diagrams | Planet Table

(sorted by increasing period of the closest planet)

Statistics : 407 planetary systems / 483 planets / 49 multiple planet systems

Planet Data (- ALL FORMATS)

PLANET	M[.sin/] (MJup) - stats	RADIUS (RJup) - stats	PERIOD (days) - stats	SEM-MAJ AXIS (AU) - stats	ECC.	INCL. (deg) - stats	STATUS	DISCOV. (year)	UPDATE
WASP-19 b	1.168	1.386	0.78884	0.01655	0.0046	79.4	R	2009	18/01/11
Kepler-10 b	0.0143	0.127	0.837495	0.01684	0	84.4	R	2011	11/01/11
CoRoT-7 b	0.0151	0.15	0.853585	0.0172	0	80.1	R	2009	15/10/10
c	0.0264	-	3.698	0.046	0	-	R	2009	15/10/10
WASP-18 b	10.43	1.165	0.9414518	0.02047	0.0088	86	R	2009	29/11/10
WASP-12 b	1.41	1.79	1.091435	0.0229	0.017	83.1	C	2008	13/04/10
OGLE-TR-56 b	1.3	1.2	1.211909	0.0225	0	78.8	R	2002	24/06/10

Fig. 4. Excerpt from the table of candidates discovered or detected by radial velocity or astrometry.

4/ planets discovered by microlensing;
5/ planets discovered by direct imaging;
6/ Planets discovered by timing (pulsar planets, timing of eclipses of eclipsing binaries (or planetary transits) or timing of stellar oscillations);
7/ Unconfirmed or retracted planets;
8/ "Free-floating" planets.

For each planet the tables list the planet and parent star characteristics. In addition there is an individual page for each planet and for each planetary system. It is accessible by clicking on the planet name in the table (Fig. 4).

The planet characteristics in the tables are given (when available) by Table 1. The parent star characteristics given by individual tables are shown in Table 2 and Fig. 5.

The individual pages for planets and planetary systems "Notes for planet xx" contain additional details, as listed.

- Quantities listed in Table 1 plus data listed in Table 3 (when available) and their errors;
- molecules detected in the planet atmosphere;
- specific remarks;
- bibliography relevant for the planet (sorted by author or publication date);
- links to professional websites associated with the planetary system (Data may be continuously refined on observers web pages, so we give a link to these pages);
- link to Simbad and ADS pages of the corresponding parent star.

Figure 6 gives as an example the individual page for HD 189733 b.

For multiplanet systems there is a synthetic page with all planets in the system and their characteristics (click on the star name in individual pages). Links to individual planet pages of the Exoplanet Orbit Database at exoplanets.org are under development.

4.1. Comments

- *Source of data:*
  Data are the latest known. They are updated daily. As of February 2011 they are taken from the

- latest published papers or preprints, or conference proceedings,
- first-hand updated data on professional websites. These presently are Anglo-Australian Planet Search at http://www.phys.unsw.edu.au~cgt/planet/AAPS_Home.html, California Planet Survey at http://exoplanets.org/, Geneva Extrasolar Planet Search Programmes at http://obswww.unige.ch/exoplanets, Kepler candidates at http://archive.stsci.edu/kepler/planet_candidates.html, SuperWASP at http://www.superwasp.org, and University of Texas – Dept. of Astronomy at http://www.as.utexas.edu.
- *References for data:*
  On each individual page there is a flag "ref" for each data point. By clicking on that flag, the user is directly connected to the reference paper giving the corresponding value. These references are updated as they appear in the literature.
- *Mass $M.[\sin i]$:*
  For planets detected by radial velocity and timing, only the product $M.\sin i$, where i is the orbit inclination, is known in general. For transiting planets, i, hence M, is known from the fitting of the transit ligh tcurve. For planets detected by astrometry, i is directly inferred from the parent star orbit. For planets detected by radial velocity in multiplanet systems, it can sometimes be inferred from the dynamical analysis of the planet-planet interaction (deviation from purely Keplerian orbits – e.g. Correia et al. (2010) for the GJ 876 system), and in a few years it will be inferred from direct imaging of some planets. The bracket in $[.\sin i]$ then means that it has to be ignored when the inclination is known and the value for $M.[\sin i]$ is the true mass value M.
- *Semi-major axis a:*
  When the semi-major axis a is not given in a detection paper, it is derived from the published orbital period and from the mass of the parent star through the Kepler law $P = 2\pi\sqrt{a^3/GM_\star}$.
- *Parent star coordinates and magnitudes:*
  If not given in a detection paper, they are taken from SIMBAD.
- *Orbit "misalignement" λ:*
  The precise definition of λ is the angle between the sky projections of the perpendicular to the planet orbit and of the star rotation axis (if the planet orbit is in the star equatorial plane, $\lambda = 0$). It is inferred from the measurement of the Rossiter-McLaughlin effect. Some authors give β instead of λ, with $\beta = -\lambda$. We then systematically convert the published β into $\lambda = -\beta$.
- *Units for mass and radius (see also "hints" below):*
  The default options for planet mass and radius units are the Jupiter mass and radius. In case a referenced paper gives the mass and radius in Earth units, the catalog automatically converts them into Jupiter units with the convention $1\ M_{\rm Jup} = 317.83\ M_\oplus$ and $1\ R_{\rm Jup} = 11.18\ R_\oplus$ (Allen 1976). The user can change units by clicking on "$M_{\rm Jup}$" and "$R_{\rm Jup}$" in the tables (Fig. 4).
- *Year of discovery:*
  The purpose is not to establish a priority among discoverers. This entry indicates the year of announcement in a professional meeting or the date of submission of a discovery paper. The date of publication is sometimes the year after the date of submission or announcement in a professional conference.
  The notion of "year of discovery" is problematic for a few objects: γ Cep b was more or less strongly suspected as a candidate in 1988 (Campbell et al. 1988), β Gem b was

Table 1. Planet parameters in planet tables.

Entity	Designation	Unit
Name	PLANET	
Mass	M[.sin i]	Jupiter and Earth mass
	(see comment below	*(see comment below)*
Radius	RADIUS	Jupiter and Earth radius
		(see comment below)
Orbital period	PERIOD	days and years
		(see comment below)
Semi-major axis	SEM-MAJ. AXIS	AU
Eccentricity	ECC.	
Inclination	INCL.	degrees
Publication status	STATUS	R, S, C, W
		(see comment below)
Year of discovery	DISCOV.	year
Date of data update.	UPDATE	dd/mm/yy

Table 2. Parent star parameters.

Entity	Designation	Unit
Distance	DIST.	pc
Spectral type		
Apparent	MAG. V	
magnitudes	MAG. I	
V, I, H, J, K	MAG. H	
	MAG. J	
	MAG. K	
Mass	MASS	$M_\odot$
Radius	RADIUS	$R_\odot$
Metallicity	[Fe/H]	
Right asc.	ALPHA	hh mm ss
Declination	DELTA	dd mm ss

strongly suspected in 1993 by Hatzes & Cochran (1993), γ Cep b was retracted in 1992 by Walker et al. (1992) and finally reconfirmed in 2003 with the correct mass and period (Hatzes et al. 2003), β Gem was finally confirmed in 2006 (Hatzes et al.). For these two objects we chose the date of final confirmation. HD 114762 b (~12 $M_{\rm Jup}$) was discovered as a confirmed companion in 1989 (Latham et al.), but it was not baptized as a planet at that time.

– *Status:*
R = refereed paper (accepted or published), S = submitted paper, C = announced in a professional conference, W = announced on a professional website.
– *Errors:*
The quoted errors are those given by the discovery paper or subsequent papers based on new observations. They generally refer to 1σ errors, with a few exceptions that are not always clearly documented in the literature. They are therefore only indicative. When a paper gives both the statistical and the systematic error we arbitrarily add the two errors in quadrature. Sometimes the most recent papers give a larger error than previous ones, based on a deeper analysis. We then take the most recently published error even if it is larger. Most important is that the reader can trace back the data through the referenced papers.
– *Unconfirmed and retracted candidates:*
This table stores candidates waiting for confirmation by later measurements. It includes definitely retracted planets for users who want to understand the reason of retraction. Details are given in the individual pages for each candidate.

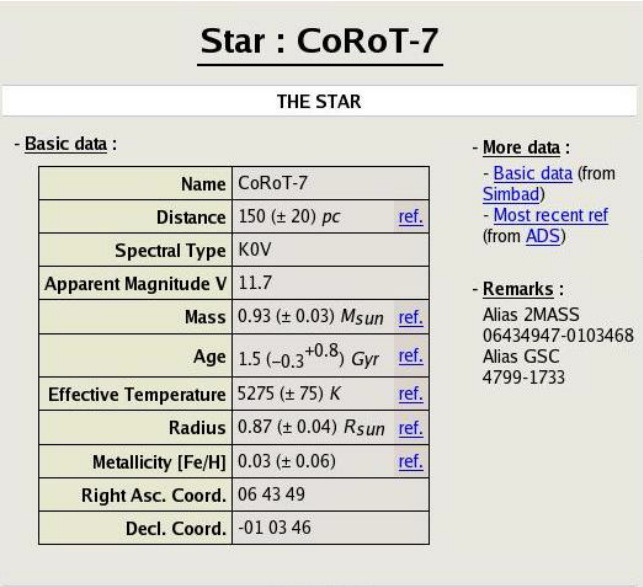


Fig. 5. Parent parameters given by individual tables (example of CoRoT-7).

Past experience shows that, since the announcement of the unconfirmed companion Lalande 21185 b (Gatewood 1996), only about 1.5% of candidates have been retracted. See also `http://obswww.unige.ch/~naef/planet/geneva_planets.html` #SPECIALCASES for special or spurious cases.

4.2. Some hints

– *Sorting*:
By default, Tables 1 to 7 sort the planetary systems by increasing period of the planet closest to the star. The user can sort the planets by increasing or decreasing values of each parameter by clicking on the parameter name at the top of each column.
– *Extended tables*:
The default option of Tables 1 to 7 only gives planet data. By clicking on "MORE DATA" the stellar parameters appear also (Fig. 7a), as well as the calculated value "ANG. DIST." for a/D (D = distance of the star – Fig. 7b); it gives a first evaluation of the star-planet angular separation. In a future version, we will calculate the angular separation online at maximum

Table 3. Additional star and planet parameters in individual pages.

Entity	Designation	Unit	Comment
Temperature of the star	Effective temperature	K	
Longitude of periastron	ω	deg.	For eccentric orbits
Longitude of ascending node	Ω	deg	
Orbit "misalignement"	λ	deg	For transiting planets *(see Sect. 4.1)*
Epoch of transit	$T_{\rm transit}$	JD	For transiting planets
Epoch of secondary transit	$T_{\rm sec-transit}$	JD	For transiting planets
Epoch of passage at periastron	$T_{\rm peri}$	JD	For eccentric orbits
Epoch of max. star velocity	$T_{\rm MaxRV}$	JD	For circular orbits

Planet : HD 189733 b

THE PLANET

- Basic data :

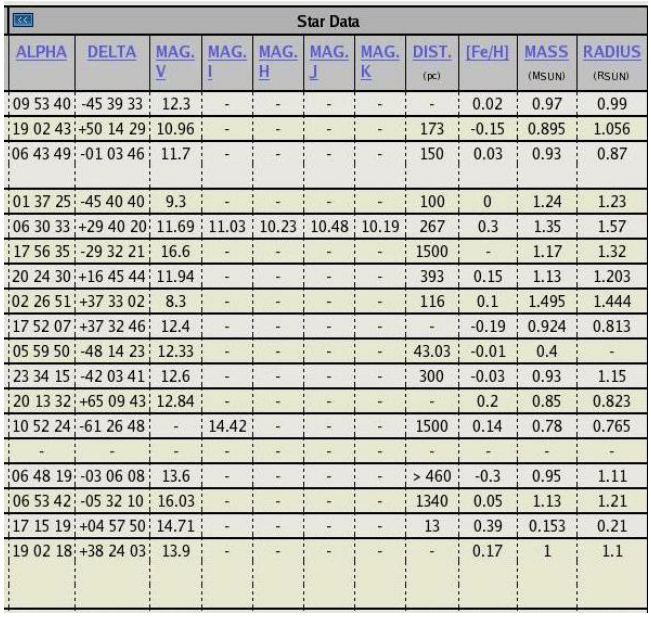
Name	HD 189733 b	
Discovered in	2005	
M.sin *i*	1.15 (± 0.039) *MJ*	ref.
Semi major axis	0.03142 (± 0.00052) *AU*	ref.
Orbital period	2.2185733 (± 2e-05) *days*	ref.
Eccentricity	0	
Radius	1.151 (± 0.038) *RJ*	ref.
Ttransit	2453988.80336 (± 0.00024)	ref.
Tsec-transit	2454038.72294 (± 0.00027)	ref.
Inclination	85.76 (± 0.29) *deg.*	ref.
λ	-1.4 (± 1.1) *deg.*	ref.
Update	13/12/10	

Fig. 6. Example of planet parameters given by individual pages for HD 189733b.

angular elongation for eccentric orbits for a given orbital inclination.

– *Planet names*
For single planetary companions to a host star, the name is generally *NNN b* where *NNN* is the parent star name. Since all stars have multiple names, we chose the name as given in the discovery paper: e.g., 51 Peg b instead of HD 217014 b. For planets with an alternate star name, the user can retrieve the planet through the star page at SIMBAD, which has a link to the present catalog (see Fig. 8. for β Gem, alias HD 62509).

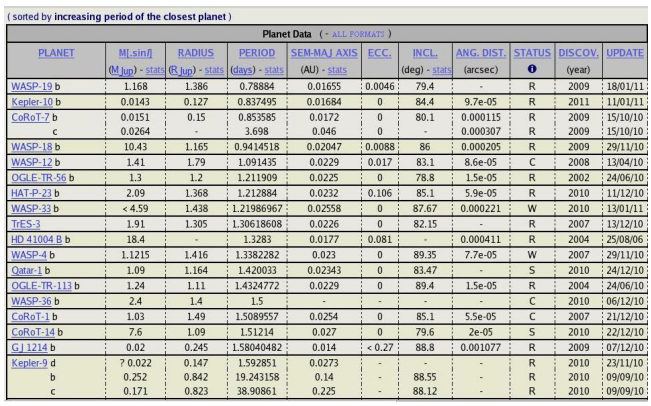
For multiplanet systems, the planet names are *NNN x* where *x* (= *b, c, d,* etc.) refers to the chronological order of discovery of the planet or to the increasing period for multiple planets discovered at the same time. Exceptions are possible for planets detected by transit like CoRoT, HAT-P, KEPLER, OGLE, Qatar, TrES, WASP, and XO planets or for planets detected by microlensing like MOA and OGLE, which are based on the name of the discovery facility. For some planets we arbitrarily shortened the name in the tables for aesthetic reasons: e.g., 2M1207 b instead of 2MASSWJ1207334-393254 b. The full name is then in the individual pages.



Star Data

ALPHA	DELTA	MAG. V	MAG. I	MAG. H	MAG. J	MAG. K	DIST. (pc)	[Fe/H]	MASS (MSUN)	RADIUS (RSUN)
09 53 40	-45 39 33	12.3	-	-	-	-	-	0.02	0.97	0.99
19 02 43	+50 14 29	10.96	-	-	-	-	173	-0.15	0.895	1.056
06 43 49	-01 03 46	11.7	-	-	-	-	150	0.03	0.93	0.87
01 37 25	-45 40 40	9.3	-	-	-	-	100	0	1.24	1.23
06 30 33	+29 40 20	11.69	11.03	10.23	10.48	10.19	267	0.3	1.35	1.57
17 56 35	-29 32 21	16.6	-	-	-	-	1500	-	1.17	1.32
20 24 30	+16 45 44	11.94	-	-	-	-	393	0.15	1.13	1.203
02 26 51	+37 33 02	8.3	-	-	-	-	116	0.1	1.495	1.444
17 52 07	+37 32 46	12.4	-	-	-	-	-	-0.19	0.924	0.813
05 59 50	-48 14 23	12.33	-	-	-	-	43.03	-0.01	0.4	-
23 34 15	-42 03 41	12.6	-	-	-	-	300	-0.03	0.93	1.15
20 13 32	+65 09 43	12.84	-	-	-	-	-	0.2	0.85	0.823
10 52 24	-61 26 48	-	14.42	-	-	-	1500	0.14	0.78	0.765
-	-	-	-	-	-	-	-	-	-	-
06 48 19	-03 06 08	13.6	-	-	-	-	> 460	-0.3	0.95	1.11
06 53 42	-05 32 10	16.03	-	-	-	-	1340	0.05	1.13	1.21
17 15 19	+04 57 50	14.71	-	-	-	-	13	0.39	0.153	0.21
19 02 18	+38 24 03	13.9	-	-	-	-	-	0.17	1	1.1

Fig. 7a. Stellar characteristics in the "extended table".



(sorted by **increasing period of the closest planet**)

Planet Data (- ALL FORMATS)

PLANET	M[.sin/] (M Jup) - stats	RADIUS (R Jup) - stats	PERIOD (days) - stats	SEM-MAJ AXIS (AU) - stats	ECC.	INCL. (deg) - stats	ANG. DIST. (arcsec)	STATUS	DISCOV. (year)	UPDATE
WASP-19 b	1.168	1.386	0.78884	0.01655	0.0046	79.4	-	R	2009	18/01/11
Kepler-10 b	0.0143	0.127	0.837495	0.01684	0	84.4	9.7e-05	R	2011	11/01/11
CoRoT-7 b	0.0151	0.15	0.853585	0.0172	0	80.1	0.000115	R	2009	15/10/10
c	0.0264	-	3.698	0.046	0	-	0.000307	R	2009	15/10/10
WASP-18 b	10.43	1.165	0.9414518	0.02047	0.0088	86	0.000205	R	2009	29/11/10
WASP-12 b	1.41	1.79	1.091435	0.0229	0.017	83.1	8.6e-05	C	2008	13/04/10
OGLE-TR-56 b	1.3	1.2	1.211909	0.0225	0	78.8	1.5e-05	R	2002	24/06/10
HAT-P-23 b	2.09	1.368	1.212884	0.0232	0.106	85.1	5.9e-05	R	2010	11/12/10
WASP-33 b	< 4.59	1.438	1.21986967	0.02558	0	87.67	0.000221	W	2010	13/01/11
TrES-3	1.91	1.305	1.30618608	0.0226	0	82.15	-	R	2007	13/12/10
HD 41004 B b	18.4	-	1.3283	0.0177	0.081	-	0.000411	R	2004	25/08/06
WASP-4 b	1.1215	1.416	1.3382282	0.023	0	89.35	7.7e-05	W	2007	29/11/10
Qatar-1 b	1.09	1.164	1.420033	0.02343	0	83.47	-	S	2010	24/12/10
OGLE-TR-113 b	1.24	1.11	1.4324772	0.0229	0	89.4	1.5e-05	R	2004	24/06/10
WASP-36 b	2.4	1.4	1.5	-	-	-	-	C	2010	06/12/10
CoRoT-1 b	1.03	1.49	1.5089557	0.0254	0	85.1	5.5e-05	C	2007	21/12/10
CoRoT-14 b	7.6	1.09	1.51214	0.027	0	79.6	2e-05	S	2010	22/12/10
GJ 1214 b	0.02	0.245	1.58040482	0.014	< 0.27	88.8	0.001077	R	2009	07/12/10
Kepler-9 d	? 0.022	0.147	1.592851	0.0273	-	-	-	R	2010	23/11/10
b	0.252	0.842	19.243158	0.14	-	88.55	-	R	2010	09/09/10
c	0.171	0.823	38.90861	0.225	-	88.12	-	R	2010	09/09/10

Fig. 7b. Planet table with "ANG. DIST".

Another configuration deals with planets orbiting a binary central star. It is the case of the binary NN Ser. We have followed the discoverer's designation NN Ser(ab)c and NN Ser(ab)d for the two companions (Beuermann et al. 2010). We follow the same type of designation for other candidates orbiting a binary star.

For "free-floating" planets, the name is the name given by the discoverers.

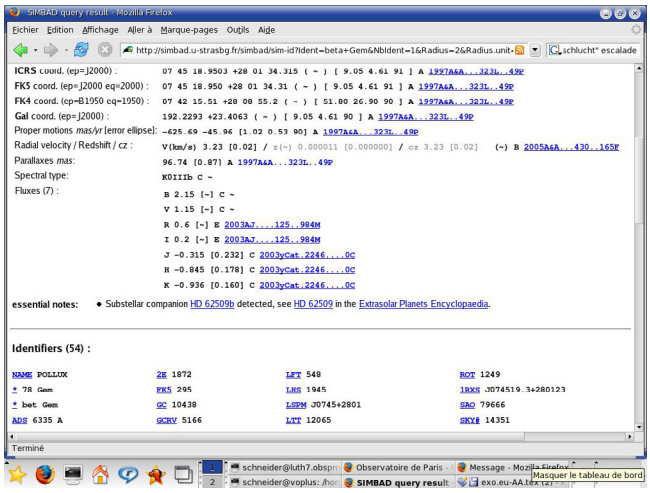


Fig. 8. Simbad page for β Gem.

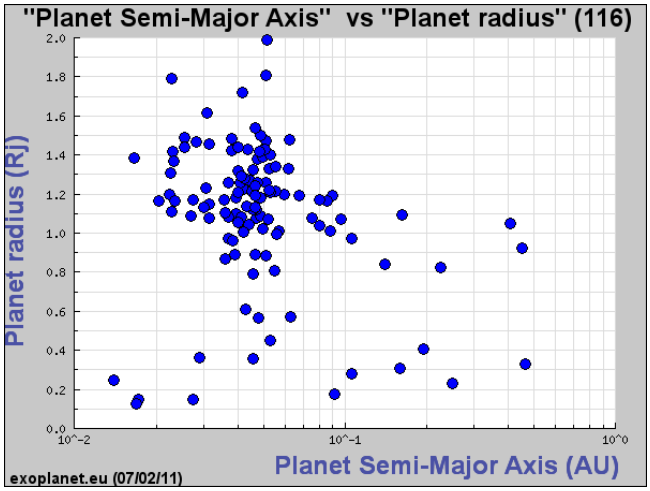


Fig. 9. Planet radius versus semi-major axis.

5. Interactive online tools

5.1. Statistics and output tables

The database provides online histograms and correlation diagrams. Click on "Histograms" and "Correlation diagrams" at the top of each of the eight tables. Some filters on data are provided, as well as the choice between linear scale and log scale.

They do not guarantee a solid scientific value, since the biases, leading to heterogeneous data, are not well documented in the literature. But they provide general trends and are useful for public presentations. We nevertheless note an interesting feature revealed by the $a - R_{\rm pl}$ correlation diagram: the scatter in $R_{\rm pl}$ for giant planets is reduced at large distance from the star. This is a first qualitative confirmation that the planet inflation stems from some influence of their nearby parent star, heating, tidal effects, or something else (Baraffe et al. 2010), see Fig. 9. It shows that a quick inspection of histograms and correlation diagrams can have at least some scientific meaning.

Output tables are provided in XML and CSV format. Click on "Planet Table" at the top of each of the eight tables.

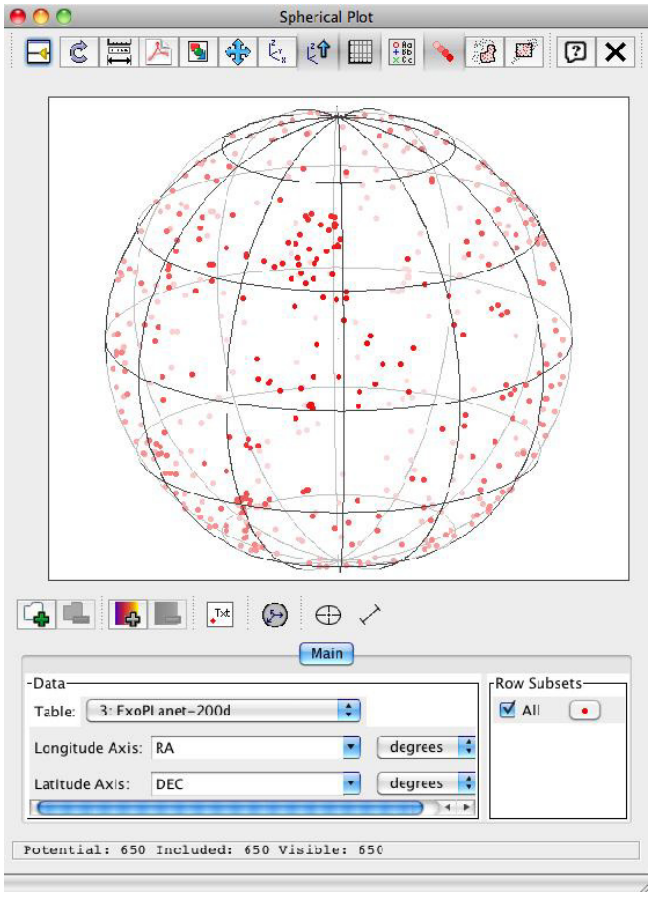


Fig. 10. Exoplanet catalog plotted on the sky in TOPCAT.

5.2. VO services

The first Virtual Observatory (VO) service implementing IVOA *ConeSearch*[5] interface for positional queries was introduced in the database in 2006. Since then it has been possible to locate and query the web service from the popular VO client applications like CDS ALADIN[6] or TOPCAT[7] (see Fig. 10) by querying VO registry with catalog keywords (e.g., "exoplanet"). The endpoint URL of this web service `http://voparis-srv.obspm.fr/srv/scs-exoplanet.php` leading to an .xml file which can be processed by any standard VO tool.

A web application also provides TAP (Table Access Protocol) services, which, as a successor of IVOA ConeSearch protocol, enables the user to query the dataset with arbitrary filters either from clients or using endpoint URL `http://voparis-srv.obspm.fr/srv/tap-exoplanet/` and custom software client optionally developed by users (see the Appendix).

All the present description of the database is summarized in the README.html file, which will be updated to account for future evolutions.

6. The Extrasolar Planets Encyclopaedia

The database is part of the Extrasolar Planets Encyclopaedia available at `http://exoplanet.eu`. It was designed since 1995 to encourage and facilitate the development of all exoplanet activities and communication between researchers. It

[5] `http://www.ivoa.net/Documents/latest/ConeSearch.html`
[6] `http://aladin.u-strasbg.fr/`
[7] `http://www.star.bris.ac.uk/~mbt/topcat/`

Fig. 11. Home page for the Extrasolar Planets Encyclopaedia.

gives the latest news, access to online tutorials and general papers, a list of current and projected ground and space searches for planets, an extended bibliography, a list of past and future meetings, and links to theory work and to other sites (Fig. 11).

The bibliography gives more than 8000 references (from Epicurus to today): articles in professional journals and preprints, books, conference proceedings, and PhD theses. It is updated daily and can be queried directly by author names, paper titles or both:
`http://exoplanet.eu/biblio-search.php?Authors=name`
`http://exoplanet.eu/biblio-search.php?mainWords=title`
`http://exoplanet.eu/biblio-search.php?mainWords=title`&Authors=name

7. Future developments

The database will be upgraded continuously in several aspects: addition of new planets, addition of new data for each planet, addition of new links and services.

- *New data:*
  We will add several new planet characteristics such as the position angle, number of planets in multiple systems, spectra, albedos, planet calculated and measured temperature, rings, moons, etc. By anticipation of the discovery of exomoon-like companions (and possibly binary planets, Cabrera & Schneider 2007), which can happen any time now by transits, we propose the following solution for their naming: NNN b1, b2 etc., if they have a similar semi-major axis and if the separation between the companions b1, b2, etc. is permanently less than the Hill radius, in order to distinguish with other types of 1:1 resonances like exchange orbits (Funk et al. 2010), eccentric resonances (Nauenberg 2002), and Trojan planets (Dvorak et al. 2004).
- *New links:*
  This includes links to NStED and Exoplanet Data Explorer individual pages for planets and to data tables at CDS.
- *New services and VO aspects:*
  We are preparing the management of multiple star names, multiple filters, etc. For the VO aspects of the database, we are preparing a new version of web applications distributing the catalog. We plan to implement an advanced cross-platform client toolkit for easy intercommunication with arbitrary VO applications by means of SAMP, Simple Application Messaging Protocol. The goal is to make a web browser act like a data browser that helps users locate datasets they need and send it flawlessly to dedicated VO tools launched before in a background, where in turn all scientific analysis takes place. This significantly enriches the user interaction with the data adding an opportunity to do sophisticated scientific analysis online.

To conclude, having two or more independent catalogs allows to have complementary services and each reader can check their mutual consistency. Comments and questions on the database can be addressed to `Jean.Schneider@obspm.fr`.

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Appendix

There are two ways to access Exoplanet Encyclopaedia data using VO protocols. The first one is manual access through a web browser using the VO-Paris Data Centre Portal at `http://voparis-srv.obspm.fr/portal/` and interfaces available for data discovery therein. Another option is to employ one of the available client applications. We give a brief step-by-step explanation using the example of the TOPCAT tool.

To access the exoplanet data one has to take the following steps.

1. Launch TOPCAT by opening the link to its Java WebStart version at `http://andromeda.star.bris.ac.uk/~mbt/topcat/topcat-lite.jnlp`. There must be a Java installed on the user's computer, including WebStart support in a browser. All modern operating systems now support this mainstream technology.
2. Go to *File* ⟶ *Open*, then in a raised window click on *DataSources* ⟶ *Cone Search* and type "exoplanet catalog" in the *Keywords* field of the last window opened and press *Submit Query* button. In this step the user has access to all the services related to the exoplanet catalogs available in the VO, searching yellow pages analogue, called "registry".
3. Click on the line with "ExoPlanet" label in the *shortName* (first) column in the query results section to select it. This indicates that the user is going to access The Exoplanet Data Encyclopaedia ConeSearch service.
4. Use the form below to fill in the details of your coordinate request. To load the whole catalog, for example, use query with RA = 0, Dec = 0, and Radius = 360. Press *OK* to retrieve the data.
5. To visualize the result, one can plot the all-sky distribution of the objects in the catalog by choosing *Graphics* ⟶ *Sky* item from the main menu.
6. For any other kind of plot go to *Graphics* menu and choose appropriate graphical representation from the list of available ones. With these options it is possible to plot any column of the data table.

The VO gives the ability to cross-correlate any quantities between different catalogs by using UCDs, Unified Content Descriptors, which associate the same physical parameters and their units with each other.

As an example of interoperability with other VO resources, one can plot another exoplanet catalog over the loaded one. To do so :

1. Do step 2 from the previous instruction.
2. Choose the line with the "EXOPLANETS" label in the *shortName* (first) column. It is taken from the NASA/HEASARC query tool of the Extrasolar Planet Encyclopaedia at http://heasarc.gsfc.nasa.gov/cgi-bin/W3Browse/w3query.pl?tablehead=name=heasarc_exoplanets/Action=More+Options/Action=Parameter+Search/ConeAdd=1
3. Do step 4 from the previous instruction, then select the first table from the *Table List* on the left of main TOPCAT window and then make step 5 from the previous instruction.
4. Press *Add a new dataset button* in the toolbox below the graph with all-sky distribution.
5. Select Table 2 in the drop-down menu *Table* in the *Data* section of the newly opened tab.
6. Click on the blue marker point on the right of the graph window in the section *Row Subset*.
7. In the raised window of marker properties, choose the open circle for a marker in a drop-down menu *Shape* on the left and increase its size up to 5 in the drop-down menu *Size* on the right. Press *OK* to apply changes.
8. Now you have two exoplanet catalogs overplotted on a sphere. You can move the sphere by holding your left mouse button and moving the mouse and zoom/unzoom it with your mouse wheel.

References

Abbot, D., & Switzer, E. 2011, ApJ, 735, L27
Allen, C. 1976, Astrophysical Quantities. Third edn (The Athlone Press), 140
Anderson, D., Collier Cameron, A., Hellier, C., et al. 2011, ApJ, 726, L19
Anglada-Escude, G., Lopez-Morales, M., & Chambers, J. 2010, ApJ, 709, 168
Baraffe, I., Chabrier, G., & Barman, T. 2010, Rep. Prog. Phys, 73, 016901
Bean, J., Seifahrt, A., Hartman, H., et al. 2010, ApJ, 711, L19
Beuermann, K., Hessman, F., Dreizler, S., et al. 2010, A&A, 521, L60
Boss, A., Lecavelier des Etangs, A., Mayor, M., et al. 2010, Transactions IAU, 6, Issue T27, 182
Burrows, A., Hubbard, W., Lunine, J., & Liebert, J. 2001, Rev. Mod. Phys., 73, 719
Butler, P., Wright, J., Marcy, G., et al. 2006, ApJ, 646, 505
Cabrera, J., & Schneider, J. 2007, A&A, 464, 1133
Campbell, B., Walker, G., & Yang, S. 1988, ApJ, 331, 902
Correia, A., Couetdic, J., Laskar, J., et al. 2010, A&A, 511, A21
Deleuil, M., Deeg, H., Alonso, R., et al. 2008, A&A, 491, 889
Dvorak, R., Pilat-Lohinger, E., Schwarz, R., & Freistetter, F. 2004, A&A, 426, L37
Fischer, D., & Velenti, J. 2005, ApJ, 622, 1102
Fressin, F., Torres, G., Desert, J.-M., et al. 2011, ApJ, accepted [arXiv:1105.4647]
Funk, B., Schwarz, R., Dvorak, R., & Roth, M. 2010, MNRAS, 410, 455
Gatewood, G. 1996, BAAS, 28, 885
Gregory, P. 2011, MNRAS, accepted [arXiv:1101.0800]
Hatzes, A., & Cochran, W. 1993, ApJ, 413, 339
Hatzes, A., Cochran, W., McArthur, B., et al. 2000, ApJ, 544, L145
Hatzes, A., Cochran, W., Endl, M., McArthur, B., et al. 2003, ApJ, 599, 1383
Hatzes, A., Cochran, W., Endl, M., Guenther, E., et al. 2006, A&A, 457, 335
Howard, A. Marcy, G., Johnson, A., et al. 2010, Science, 330, 653
Kalas, P., Graham, J., Chiang, E., Fitzgerald, M., et al. 2008, Science, 322, 1345
Kennedy, G., & Wyatt, M. 2011, MNRAS, 412, 2137
Lafrenière, D., Jayawardhana, R., Janson, M., et al. 2011, ApJ, 730, L42
Lagrange, A.-M., Gradatour, D., Chauvin, G., et al. 2008, A&A, 493, L21
Laughlin, G., & Chambers, J. 2002, AJ, 124, 592
Le Sidaner, P., Dubernet, M.-L., Simon, G., et al. 2007, in SF2A-2007: Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics held in Grenoble, France, July 2–6, ed. Bouvier, J. Chalabaev, A., & Charbonnel, C. 71
Lissauer, J., Fabrycky, D., Ford, E., et al. 2011, Nature, 470, 53
Mandushev, G., Torres, G., Latham, D., et al. 2005, ApJ, 621, 1061
Marcy, G., Butler, P., Vogt, S., et al. 2001, ApJ, 555, 418
Martinache, F., & Schneider, J. 2004 in SF2A-2004: Semaine de l'Astrophysique Francaise, ed. Combes, F. Barret, D. Contini, T. Meynadier, F., & Pagani L. (EdP-Sciences, Conf. Ser.)
Morais, M., & Correia, A. 2010, A&A, 525, A152
Nauenberg, M. 2002, AJ, 124, 2332
Neuhaeuser, R., Guenther, E., Wuchterl, G., et al. 2005, A&A, 345, L13
Pepe, F., Lovis, C., Ségransan, D., et al. 2011, Proc. The Astrophysics of planetary systems – formation, structure, and dynamical evolution (IAU Symp., 276), in press
Pont, F., Bouchy, F., Melo, C., et al. 2005, A&A, 438, 1123
Pravdo, S., & Shaklan, S. 2009, ApJ, 700, 623
Reffert, S., & Quirrenbach, A. 2011, A&A, 527, A140
Sahlmann, J., Ségransan, D., Queloz, D., & Udry, S. 2010, A possible dividing line between massive planets and brown-dwarf companions. in Proceedings of the IAU Symp. 276 [arXiv:1012.1319]
Sahlmann, J., Segransan, D., Queloz, D., et al. 2011, A&A, 525, A95
Schneider, J. 1999, 31st Annual Meeting of the DPS. 31, no 4, 5.02
Schneider, J., & Cabrera, J. 2006, A&A, 445, 1159
Spiegel, D., Burrows, A., & Milsom, J. 2011, ApJ, 727, 57
Vogt, S., Butler, P., Rivera, E., et al. 2010, ApJ, 723, 954
Udry, S. 2010, Detection and characterization of exoplanets: from gaseous giants to super-Earths. in Proceedings of "In the Spirit of Lyot", Paris October
Udry, S., Mayor, M., Naef, D., et al. 2002, A&A, 390, 267
Walker, G., Bohlender, D., Walker, A., et al. 1992, ApJ, 396, L91
Wolszczan, A. 1994, Science, 264, 538
Wright, J., Fakhouri, O., Marcy, G., et al. 2011, PASP, 123, 412
Yang, R.-J., & Chang, Sh.-N. 2009, Phys. Rev. D, 79, 124005
Zapatero-Osorio, M., Bejar, V., Martin, E., et al. 2002, ApJ, 578, 536