Supporting Online Material for

Kepler Planet-Detection Mission: Introduction and First Results

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Correction: The article title on the cover page has been edited to conform to *Science* style.

SUPPORTING ONLINE MATERIAL
<u>TEXT</u>
SOM 1. Instrument description
The instrument is a differential photometer with a wide (115 square degrees) field-of-view
(FOV) that continuously and simultaneously monitors the brightness of approximately 150,000
main-sequence stars. The instrument is designed for a useful range of visual magnitudes ranging
from 9 to 15. Although saturation occurs for stars brighter than mv=11.5, measurements show
excellent photometric performance from magnitude 7 through 17 (*S1*) when the photometric
aperture is sufficiently large to measure the overflow. The photometer is based on a modified
Schmidt telescope design that includes field flattening lenses near the focal plane that
accommodate the flat detectors on the curved focal surface associated with the large FOV. The
photometer uses a corrector with a 0.95 m aperture and a 1.4 m diameter f/1 primary. The 0.95 m
aperture is sufficient to reduce the Poisson noise to the level required to obtain a 4σ detection for
a single transit from an Earth-size planet passing in front of a $V=12^{th}$ magnitude G2 dwarf (i.e.,
Sun-like stars) with a 6.5 hour transit. The focal plane is composed of forty-two 1024x2200
backside-illuminated CCDs with 27 μm pixels. The 5% band pass wavelengths are 423 nm and
897 nm.

Two cadences are available for data acquisition; ~1 minute and ~30 minutes which are summed
onboard the spacecraft from 6.02 second exposures. A maximum of 170,000 targets can be
accommodated at the 30 minute cadence and 512 at the 1 minute cadence. The shorter cadence is
used for high resolution measurements needed for transit timing variations, eclipsing binary
timing, and for asteroseismology.

SOM 2. Target Selection
To remove the many giant stars in our FOV from the target list, a 5 year program of ground
based multi-band photometric observations of $6x10^6$ stars in the FOV classified each star. The
results were assembled into the *Kepler Input Catalog (KIC)* that is now available to the public.
This catalog provides the effective temperature and surface gravity which can be combined to
estimate the size of the star and to distinguish dwarfs from giant stars. The target stars are chosen
from the $4.5x10^6$ stars that are imaged onto active silicon of the detector array (S2). Most giant
stars are avoided, as the stellar size and variability make it much more difficult to detect small
planets. On average, only about 38 pixels for each star are sent to the ground where the
photometry is done. (*S2*)

SOM 3. Identification of False Positive Events
 To accurately determine the frequency of planets, *Kepler* must identify false-positive events;
i.e., transit-like signals that are not caused by a transiting planet. There are two general types of
false positive events; statistical or systematic fluctuations in the time series and astrophysical
phenomena that produce similar signals. The *Kepler* pipeline applies a series of tests to avoid
statistical false positives (*S3, S4*). Rejecting astrophysical false positives requires a combination
of *Kepler* data and observations from the *Kepler* Follow-up Observation Program. (*S5*).

The *Kepler* data-processing pipeline reduces the photometric observations of each star and searches each time series for threshold crossing events (TCE), a pattern of transits that exceed a 7.1-σ threshold (*S6*) and might be caused by a planetary transit. The TCE then undergo a series of tests to determine if some astrophysical process is present such as a small star orbiting the target star, or an eclipsing binary is present in the aperture, or there is a third star that is diluting the amplitude of the transit.

To identify stellar companions and background false-positive objects and to measure the masses of the planets; radial velocity, active optics, and speckle observations were conducted at the Keck I, Hobby-Eberly, Harlan J. Smith 2.7m, Hale, WIYN, MMT, Tillinghast, Shane, and Nordic Optical Telescopes. Similar to the results of the CoRoT Mission, many events were found to be false positives (*S5*); usually background eclipsing binaries (*S7*).

SOM 4. Determination of the Characteristics of Discovered Planets
Once a planet has been identified, the semi-major axis can be derived using Kepler's 3rd Law, the orbital period from *Kepler* photometry, the mass of the host star. There is a weak dependence on planet mass, but this is rarely substantial and can be accounted for when radial velocity (RV) observations measure the planet mass. The planet's equilibrium temperature can be estimated from the size of the star, its effective temperature, and its semi-major axis. Formally, the equilibrium temperature also depends on the orbital eccentricity and the albedo, but these are modest effects except for large eccentricities and high albedos. If this temperature is consistent with the possibility of liquid water on the surface of the planet, then the planet is deemed to be in the habitable zone; i.e. in a temperature regime favorable to the evolution of life. Of course, a planet's actual surface temperature also depends on the greenhouse factor which is a function of the mass of the planet and the properties of its atmosphere.

The ratio of the planet area to the star area can be directly measured from the transit depth (after accounting for dilution by starlight from nearby stars, the orbital inclination, and limb darkening effects). Therefore it is critical to estimate the sizes of the stars hosting planets. If the orbital eccentricity of the planetary orbit is known, then precise measurements of the transit duration and orbital period provide an excellent determination of the mean stellar density (*S8, S9*). When combined with spectroscopic measurements and stellar modeling, the stellar size and mass can be determined. While RV observations and/or measurements of the occultation can be used to measure the eccentricity, it is important to have independent measurements of the stellar size. Asteroseismology analysis is being used to determine the mean stellar density and to estimate the size, mass, and age of target stars. Then these parameters are used to derive the size and age of the planets.

Although asteroseismic analysis of the optical flux variations of bright target stars provide the best estimate of stellar size, other methods are needed for the large number of dimmer stars. Astrometry on the image centroids can measure the parallax and thus distance to the star (*S10*). When this distance is combined with photometric measurements (e.g., those from KIC), spectroscopic observations and stellar modeling, one can estimate the stellar luminosity, temperature, size and mass.

FIGURES AND LEGEND

SOM 5. Light curves and RV observations of the first planets detected by *Kepler*.
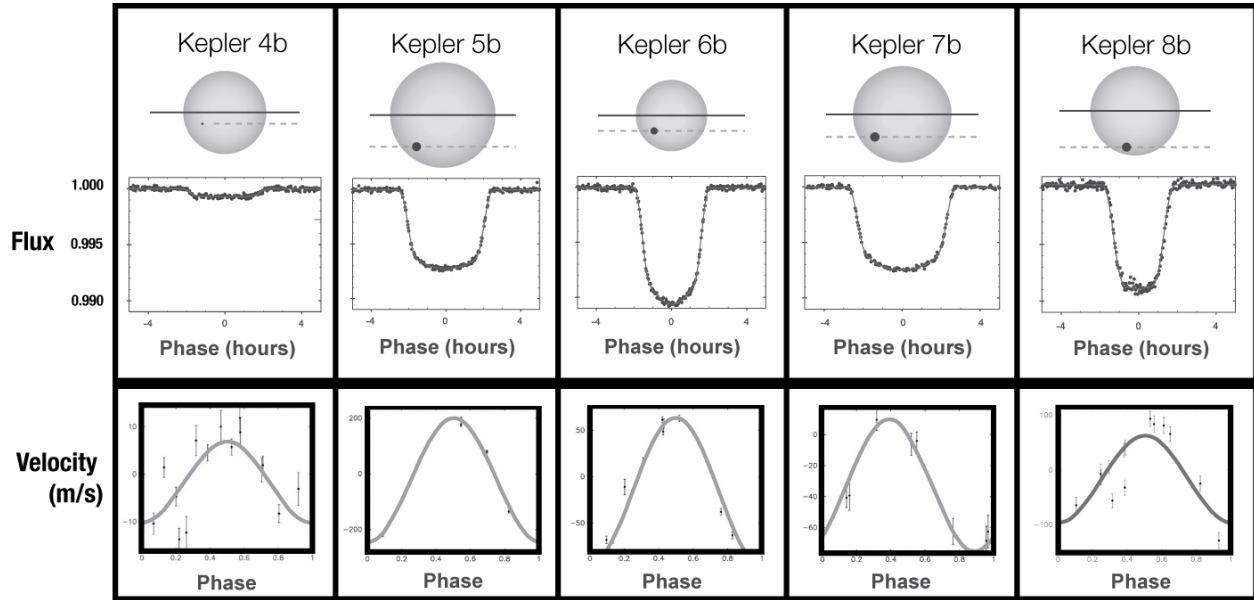
S1. Light curves and RV observations of the first planets detected by *Kepler*. All parameters, such as stellar size, depth and duration of transit, and impact parameter use the same relative scale.

References:

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