THE KEPLER SPACE TELESCOPE

The Search for Other Worlds
A search for Earth-like planets around Sun-like stars

Kepler is a space observatory launched by NASA on March 7, 2009, to discover Earth-size planets orbiting other stars in the Cygnus-Lyra region.
Named after astronomer Johannes Kepler, the spacecraft was launched into an Earth-trailing heliocentric orbit.
The Kepler spacecraft provides the power, pointing and telemetry for the photometer.

Pointing at a single group of stars for the entire mission greatly increases the photometric stability and simplifies the spacecraft design.
Other than the small reaction wheels used to maintain the pointing and an ejectable cover, there are no other moving or deployable parts.

The only liquid is a small amount for the thrusters which is kept from slosh by a pressurized membrane.

This design enhances the pointing stability and the overall reliability of the spacecraft.
THE PHOTOMETER

- The Kepler photometer is a simple single purpose instrument.
- It is basically a Schmidt telescope design with a 0.95-meter aperture and a 105 square degree (about 12 degree diameter) field-of-view.
- It is pointed at and records data from just a single group of stars for the duration of the mission.
The photometer is composed of an array of 42 CCDs (charge coupled devices).

Each 50x25 mm CCD has 2200x1024 pixels.

The CCDs are read out every three seconds to prevent saturation.

Only the information from the CCD pixels where there are stars brighter than about R magnitude of 16 is recorded.
THE CONCEPT

- By observing the slight drop in brightness of a distant star as a planet moves in front of it, astronomers can determine the size or radius of the planet.
Once detected, the planet's orbital size can be calculated from the period (how long it takes the planet to orbit once around the star) and the mass of the star using Kepler's Third Law of planetary motion.

The size of the planet is found from the depth of the transit (how much the brightness of the star drops) and the size of the star.

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P^2 = \left[ \frac{4\pi^2}{G(M + m)} \right] a^3
\]
From the orbital size and the temperature of the star, the planet's characteristic temperature can be calculated.

From this the question of whether or not the planet is habitable (not necessarily inhabited) can be answered.
Since Kepler launched in 2009, 21 planets less than twice the size of Earth have been discovered in their star's habitable zone - the region in a planetary system where liquid water might pool on the surface of an orbiting planet.

This is often referred to as “The Goldilocks Zone”
These planets are plotted relative to the temperature of their star and with respect to the amount of energy received from their star in their orbit in Earth units.

The sizes of the exoplanets indicate the sizes relative to one another.

The light and dark green shaded regions indicate the conservative and optimistic habitable zone.
DISASTER!

- Between July 2012 to May 11, 2013, two of the spacecraft reaction wheels failed.
- Reaction wheels, similar to gyroscopes, allow very precise adjustments of a spacecraft’s attitude without the need for heavy rockets and fuel.
The loss of the reaction wheels severely hampered Kepler’s ability to maintain its position and thus prevented the stability required for precise observations needed to detect transiting exoplanets.

With the May 2013 failure of the second reaction wheel, Kepler’s original mission was ended.
K2 – KEPLER’S SECOND MISSION

A Community Driven Mission
AN ELEGANT SOLUTION

- Operating in the ecliptic plane minimizes the torque exerted on the spacecraft by solar wind pressure, reducing pointing drift.

- By utilizing the two remaining reaction wheels, and the spacecraft’s thrusters, the spacecraft attitude can effectively be controlled and stabilized to continue scientific observations.
K2 – A PLAN TO EXTEND THE MISSION

- K2 became fully operational in June 2014 and is expected to continue operating until late 2018.
- The K2 mission entails a series of sequential observing "Campaigns" distributed around the ecliptic plane and offers a photometric precision approaching that of the original Kepler mission.
CAMPAIGNS

- Each ecliptic Campaign is limited by Sun angle constraints to a duration of approximately 80 days.
- Therefore, four to five K2 Campaigns can be performed during each 372-day orbit of the spacecraft.
Kepler’s Second Light: How K2 Will Work

When the spacecraft is balanced, the telescope is stable enough to monitor distant stars in search of transiting planets. A specific portion of the sky is studied for approximately 83 days, until it is necessary to rotate the spacecraft to prevent sunlight from entering the telescope. There are approximately 4.5 viewing periods or campaigns per orbit or year.
GUEST OBSERVER PROGRAM

- K2 is an entirely community-driven mission.
- All K2 targets are proposed by the community through the Guest Observer program.
- The program welcomes proposals addressing compelling scientific questions in any area of astrophysics and planetary science providing the required observations are amenable to the operational characteristics and constraints of the mission.

Rob Leathley March 2018
The science motivation may include, but is not limited to, exoplanet detection, stellar astrophysics, galactic and extragalactic astrophysics, and solar system science.

All K2 proposals must meet several criteria to justify the need for new observational data rather than utilizing the stored data from the original Kepler observations.

Funding is available for qualified Principal Investigators affiliated with US institutions at two levels based upon the number of “targets” to be observed.
THE DISCOVERIES

- **Kepler mission:**
  - Candidate exoplanets: 4,496
  - Confirmed exoplanets: 2,341
  - Confirmed exoplanets less than twice Earth-size in the habitable zone: 30

- **K2 mission:**
  - Candidate exoplanets: 622
  - Confirmed exoplanets: 197
KEPLER MISSION

FIRSTS

Kepler-186f: Earth-like planet in the habitable zone of its star
April 2014

Kepler-00: Star with seven transiting planets
November 2013

Kepler-62 & f:
Super-Earth-size planets in the habitable zone
April 2013

Kepler-40b, c & d:
Three smallest planets
January 2012

Kepler-20b & f:
Earth-size planets
December 2011

Kepler-22b:
Habitable zone planet around a sun-like star
December 2011

Kepler-18b:
A planet with two suns
September 2011

Kepler-10b:
A rocky planet
January 2011

www.nasa.gov

For more information, visit: www.nasa.gov/kepler or kepler.nasa.gov
With the fuel remaining, the spacecraft’s scientific future continues to look unexpectedly bright.

Kepler’s field of view surveyed just one patch of sky in the northern hemisphere. The K2 ecliptic field of view provides greater opportunities for Earth-based observatories in both the northern and southern hemispheres, allowing the whole world to participate.
"The new approach of letting the community decide the most compelling science targets we’re going to look at has been one of the most exciting aspects. Because of that, the breadth of our science is vast, including star clusters, young stars, supernovae, white dwarfs, very bright stars, active galaxies and, of course, exoplanets."

Steve Howell, Kepler and K2 project scientist at Ames.
REFERENCES

- Kepler & K2 Science Center
  - https://keplerscience.arc.nasa.gov/

- NASA Kepler & K2 Missions

- Kepler Space Telescope: Exoplanet Hunter
  - https://www.space.com/24903-kepler-space-telescope.html

- Kepler (Spacecraft)