Thomas Lewton

Is there anybody out there?

Scientists are hoping to shine light on the age old question of life's existence elsewhere in the Universe using a new space-based telescope named Kepler. Launched on 6 March 2009, Kepler is searching the sky for small, rocky, Earth-like planets within our galaxy. This will reveal how common it is for other solar systems to contain planets with the right conditions for life.

Key words
telescope
extra-terrestrial life
extra-solar planet
transit

The Kepler spacecraft lifts off aboard a Delta II rocket from Cape Canaveral, Florida.

NASA Associate Administrator Ed Weiler has called it a historic mission. "It really attacks some very basic human questions that have been part of our genetic code since that first man or woman looked up in the sky and asked the question: Are we alone?".

Kepler will orbit the Sun for at least three years observing the same outstretched-hand-sized patch of sky. Though it may seem small, this is an unusually large field-of-view for a telescope, containing more than 4.5 million detectable stars. However, only 300 000 of these are the right age and composition to host Earth-like planets. Kepler will monitor many of these for periodic dips in brightness that occur when an orbiting planet transits a star.

The drop in a star's brightness during a planetary transit is barely perceivable – equivalent to watching a flea cross a car's headlights many miles away. "Being able to make that kind of a sensitive measurement over a very large number of stars is extremely challenging," Kepler project manager James Fanson said.

However, Kepler boasts a highly sensitive 95 mega-pixel camera, enabling accurate measurements of the size, period and transit time of planets hundreds of light years away. No wonder Fanson is so proud of the telescope, calling it a "crowning achievement" for NASA.

From these measurements a surprisingly large amount of information can be determined about any detected planets, enabling the potential alien worlds to be sifted out from the uninhabitable.

A planet's size is calculated by the amount of light it blocks– the larger the planet, the greater the drop in the star's brightness during a transit. Kepler will only pick out planets below several Earth masses as potentially habitable because planets much bigger than this will be gaseous, rather than rocky, and so can't support life.

Johannes Kepler (1571-1630) discovered the laws of planetary motion – these laws apply equally to planets orbiting distant stars.

The distance from a star at which a planet orbits can be calculated from a planet's measured period and the corresponding star's mass. A famous law of German astronomer Johannes Kepler, who the telescope is named after, relates these three quantities in a simple formula:

$$p^2 = \frac{4\pi^2}{GM} a^3 \qquad \text{Kepler's 3rd law}$$

p = period
a = orbital distance
M = star mass
G = gravitational contant

Some definitions

Transit: The passage of a planet in front of its host star.

Period: The time it takes a planet to orbit its star exactly once.

Field-of-view: The angular area of the sky that a telescope can observe at any one time.

Box

Calculating Earth's orbital distance

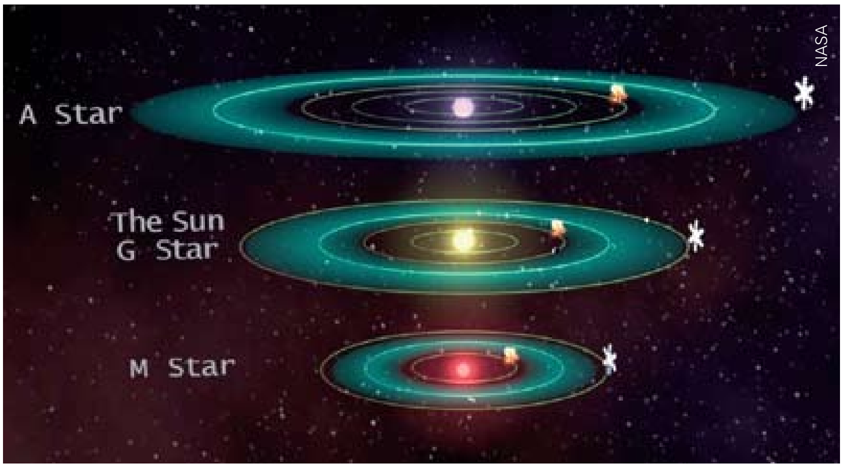
Earth has a period of 365 days.

The Sun has a mass of 2×10^{30} kg.

Using Kepler's 3rd law we can calculate our distance from the Sun to be:

$$\frac{p^2 \times G \times M_s}{4\pi^2} = a^3$$

$$a = 1.5 \times 10^{11}\text{m}$$



The habitable 'Goldilocks' zone around a star, shown here in green, is further out for a bigger, hotter star.

From the orbital distance of a planet and the temperature of its star the characteristic planet temperature can be calculated. Planets further from the star will be colder than those closer to the star. There is only small range of distances in which a planet can orbit so that it has a temperature suitable for the formation of life; this is called the 'habitable zone' of a solar system.

Not so simple

Many planets have already been detected in far off solar systems, but the telescopes used so far have only been powerful enough to detect mostly uninhabitable gas giants, similar to Jupiter. The abundance of these giant planets, however, has given scientists high hopes for the number of Earth-sized planets that Kepler might find.

"We think it's harder to build a Jupiter than to build an Earth," explains William Borucki, science principal investigator for the Kepler mission, because it takes less matter to form smaller planets.

However, there is a huge leap to go from finding Earth-sized planets to finding life elsewhere in the Universe. Out of the many small, rocky planets Kepler is expected to find, only a fraction will be found in the habitable zone. Even these planets are still unlikely to harbour any life because of many other special conditions needed for the formation of life. Perhaps most importantly, a planet also has to be composed of the right chemical elements.

For example, although the Earth exists in our solar system's habitable zone, the energy the Earth's surface absorbs from the Sun should only amount to a surface temperature of -18°C. This is too cold for life to form as water, an important solvent in which life forming reactions are played out, will be frozen. So what else is going on?

The answer lies in the chemical make-up of the Earth's atmosphere, which contains greenhouse gases such as carbon dioxide and water vapour. These gases absorb the infrared radiation that the Earth emits (the Earth itself heated by the Sun) and re-radiates some of the energy back down to the Earth's surface. The resulting natural greenhouse effect raises the surface temperature of the Earth up to 14°C, making it inhabitable.

Just the right balance of greenhouse gases is needed in the atmosphere to maintain the right temperature for life. Global warming is an example of what happens when the delicate balance is disrupted, in this case resulting in a runaway heating effect.

Water is more than just a greenhouse gas: Earth's vast oceans also act as a climate stabiliser because of their ability to store vast amounts of heat. A balance, however, is needed – too much water could lead to a 'water world' with no continents and few nutrients for the development of life.

What's next?

Future space telescope missions will look even closer at the planets Kepler has identified as potentially inhabitable, searching for signs of these essential molecules. Alan Boss, an astrophysicist, has called Kepler a 'step one' in the search for inhabitable worlds.

"NASA will be able to build space telescopes that can actually go out and take a picture of that nearby 'Earth' and measure the elements and compounds in its atmosphere of the planet and give us some hint as to whether or not it's got life," he said.

A delicate balance of extraordinary circumstances is needed to create the right conditions for life; it is likely most of the planets Kepler finds won't have all the necessary characteristics. However, Kepler is searching only a very small region of our galaxy which itself is only one of billions of galaxies in the Universe. Even finding a significant number of Earth-sized planets will be a huge accomplishment, raising the probability of life's existence elsewhere in the Universe. As Borucki notes, "If we find that many, it certainly will mean that life may well be common throughout our galaxy, that there is an opportunity for life to have a place to evolve."

Who knows, on one of these planets an alien may be aiming his telescope towards the Sun and, as he picks up the faint annual bleep of the Earth's transit, pondering: Are we alone?

Thomas Lewton is studying Physics at Oxford University

See details of the Kepler spacecraft overleaf.

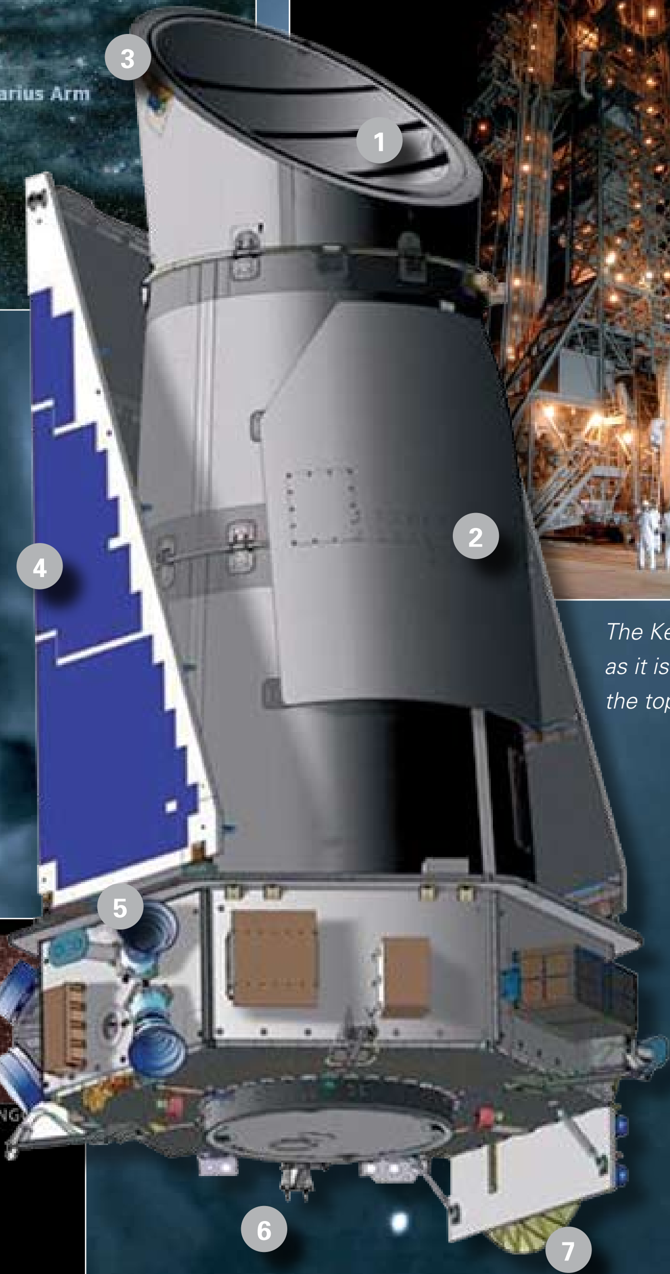
The Kepler spacecraft

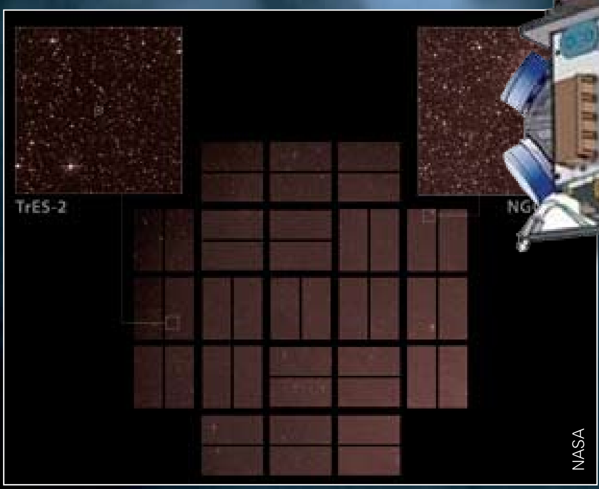
Looking for life beyond the Solar System

An artist's impression of the region of space in which Kepler will search for extra-solar planets.

The Kepler spacecraft, seen as it is about to be lifted to the top of its launch rocket.

The array of CCDs which capture Kepler's images.





An early image from Kepler, showing the patch of sky it will be studying. Highlighted are TrES-2, a known Jupiter-like planet 750 light years away which transits its star every 2.5 days, and NGC 6791, a cluster of stars 13 000 light years from Earth.

1 Photometer: gathers light from distant stars
2 CCD: records the image
3 Sun shade: blocks direct light from the Sun, which would overwhelm the instrument
4 Solar array: generates electricity from sunlight
5 Star trackers: monitor the craft's orientation in space
6 Thrusters: rotate the spacecraft
7 Antenna: sends data back to Earth