Are we alone in the universe?

Seeking for EXO-planets

Are we alone in the universe? Not very likely! On one, or several of the billion celestial bodies in the Universe there has got to be some kind of life. Intelligent peoples like us might exist, although it may sound like utopia. However, how do we find out?

What is life and how find it?

Until now, scientists have not been able to clearly define what life is, thus it makes it hard to look for something or somebody indefinable. Until recently the conclusion has been to primarily look for bodies around other stars with similar conditions known to mankind, thus making it easier to expect to find similarities of some kind.

This has been the basis for today's search for exo-planets. (Planets outside our Solar System are referred to as exoplanets and solar systems outside our own are referred to as extrasolar systems) Parts of the scientific communities now spend enormous recourses through theoretical and practical investigations of our galaxy and more distant galaxies, to find bodies where life may exist. However, the extrasolar planets found until now are only hot gas planets of Jupiter size and on gas planets life cannot exist.

How to find extrasolar planets

There are three main detection techniques that can be used to find extrasolar planets; the radial velocity method, the astrometry method, and the transit method. All of them rely on detecting a planet's effect on its parent star, to infer the planet's existence and all are referred to as 'indirect' methods.

The three techniques are simple in principle, but difficult in practice, because extreme precision is needed to register the planet's effect on the much larger star. This is also difficult from Earth because the atmosphere distorts our view of the stars and limits the accuracy of the observations. Space missions overcome this problem and most of the search is based on space instruments. However detecting from Earth is possible, using a network of telescopes scattered across the globe, astronomers recently discovered a new extrasolar planet from Earth, significantly more Earth-like than any other planet found so far.

Eventually, astronomers hope to be able to isolate; either the light being reflected by exoplanets or the thermal infrared radiation emanating from the planetary surface itself. These techniques are known as 'direct' detection methods.

Direct detection and imaging methods

The ultimate aim of this research method is to make direct observations of planets around other stars, so that astronomers can analyse the light from the planet itself, determine the chemical composition and assess physical state of these distant worlds. This is an extremely challenging task, but doable. Scientists at Goddard Space Flight Center, USA, using the Spitzer Space Telescope, recently obtained a spectrum of a planet orbiting another star. Using spectroscopy, they were able to identify silicon dust in clouds on a planet, but unfortunately it was still a gas planet of Jupiter size.

In visible wavelengths, a star like the Sun will outshine a planet like the Earth by ten thousand million times. Different methods of direct observations are constantly considered, but to detect a small planet without its own light close up to a large and bright star is very difficult. Some methods are possible in theory, but nonetheless expensive due to the need for large and very accurate instruments, some of which are Doppler isolation, Polarimetry and Nulling Interferometry.

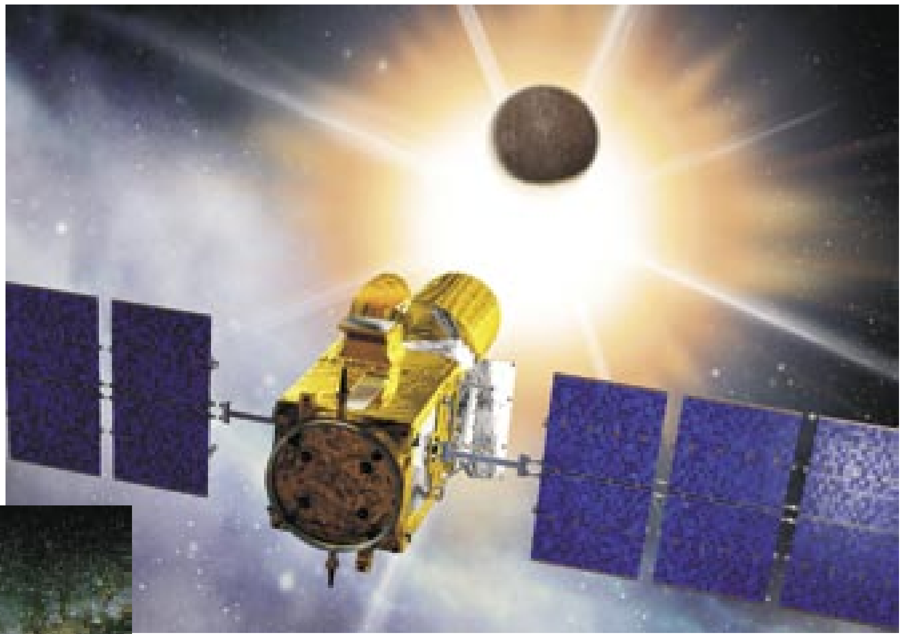
One of the telescopes at the European Southern Observatory at La Silla, Chile.

Photo: ESO

Baard Kringen, NordicSpace

Radial velocity using telescopes

So far, most planetary detections have been achieved using the radial-velocity technique from ground-based telescopes. The method requires the light from a star to be passed through a prism and split into a spectrum. This technique is limited, because it will never be able to detect small, Earth-sized worlds. With the best spectroscopes, astronomers can confidently detect motions of about 15 metres per second. However, Earth only forces the Sun to move at 0.1 metres per second.



Artist's view of Corot. Figure: CNES/D. Ducros

Gaia mapping the stars of the Milky Way. Figure: Medialab

Astrometry using Gaia

Another technique, related to the radial-velocity detection, is to precisely measure the position of a star, so that any wobbling can be directly detected. Such observations are known as astrometry. ESA's next astrometry mission, Gaia, is designed to be the most precise astrometry satellite ever created and will survey thousand million stars after its launch, early next decade. Among a great many other scientific goals, Gaia is expected to find between 10 000 and 50 000 gas giant planets beyond our Solar System. Once again, the wobbling motion caused by an Earth-sized planet will be too small to be detectable, even by Gaia.

Transits using Corot

A more promising method for detecting small worlds is to look for the drop in brightness they cause when they pass in front of their parent star. Such a celestial alignment is known as a transit. From Earth, both Mercury and Venus occasionally pass across the front of the Sun. Through this method more than 10 planets have now been detected, but only large gas planets. To detect 'rocky' Earth-like worlds one needs go to space. This has happened with CoRoT (Convection, Rotation and Transit) satellite, launched early 2007.

Nulling Interferometry Using Darvin

The Nulling Interferometry will be used at the European Darvin mission and is a method that uses light from individual telescopes combined to simulate collection by a much larger telescope. This technique is called interferometry and was pioneered using radio telescopes. For ESA's Darvin mission a sophisticated flotilla of spacecraft will use the so-called nulling interferometry method to isolate the light from Earth-like extrasolar planets.

What is life?

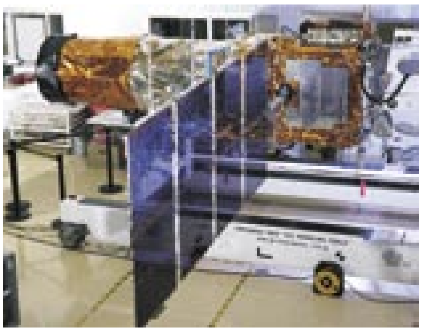
Amino acids are complex organic molecules present in all living organisms known so far; they make up the proteins, by attaching to each other according to the 'orders' dictated by the genetic code of every organism - the famous DNA molecule.

But amino acids themselves are not life, and it is not even clear whether they are 'essential' for life. Their existence only demonstrates that a complex organic chemistry is at work - 'organic' meaning only that the element carbon is present. In principle, a living system should at least be able to replicate and consume energy, but what happens for example with viruses and other micro-organisms that can stay silent and inactive, apparently dead for very long periods of time?

COROT discovers its first exoplanet

COROT has provided its first image of a giant planet orbiting another star and the first bit of 'seismic' information on a far away, Sun-like star, with unexpected accuracy.

The first planet detected by COROT, now named 'COROT-Exo-1b', is a very hot gas giant, with a radius equal to 1.78 times that of Jupiter. It orbits a



COROT during test before launch. Photo ESA.

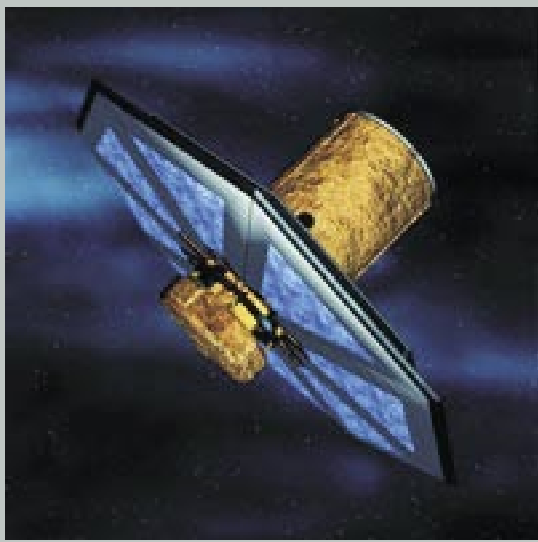
yellow dwarf star similar to our Sun with a period of about 1.5 days. 'COROT-Exo-1b' is situated roughly 1500 light years from us, in the direction of the constellation Unicorn (Monoceros). Coordinated spectroscopic observations from the ground have also allowed the determination of the mass of the planet, equivalent to about 1.3 Jupiter masses.

This first exoplanet was detected with an error of only 0.03% during one hour of observation. On applying all the corrections to the light curves, the error will be reduced to only 5 parts out of 100 000.

As a consequence, small planets down to the size of our Earth – three times smaller than initially thought possible - will be in the grasp of COROT. The satellite may also be able, in specific circumstances, to detect subtle variations in the stellar light reflected by the planet itself. This would give an indication of its chemical composition.

Press release:
www.esa.int/esaCP/

ESA' missions for searching life



One of Darwin's telescopes that is a part of four-spacecraft flotilla.

Figure: ESA/Medialab

The search for life must be carried out step by step. Firstly, find the stars that have planets. Next, one has to decide what kinds of planets one is looking for, and then find the planets similar to ours.

The joint CNES/European mission Corot will be the first spacecraft capable of detecting large rocky planets in short-period orbits around nearby stars. It will use its 30-centimetre telescope to look at several thousand stars and monitoring changes in their brightness caused by planets crossing in front of them.

Such rocky worlds are smaller than the gas giants but several times larger than the Earth, itself the biggest rocky planet in the Solar System. Such planets would represent a new, as yet undiscovered, class of world that astronomers believe exists. With COROT, astronomers expect to find 10-40 of them, together with tens of new gas giants, in each star field COROT will observe. Every 150 days COROT will move to a new field and begin observing again.

ESA will continue the search into the second decade of the century with the Darwin mission. Darwin's main objective is to find the most likely places for life to develop - at least as one knows it! Darwin will make observations in the infrared since life on Earth leaves its mark in our atmosphere at these wavelengths. On Earth, biological activity produces gases that mingle with our atmosphere.

For example, plants give out oxygen and animals expel carbon dioxide and methane. This flotilla of spacecrafts will survey 1000 of the closest stars, looking for rocky planets and analysing their atmospheres for this evidence of possible life.

The programme will start in 2015 with one of the most challenging telescopes ever designed. Darwin will be able to separate the bright starlight from the faint planet light by performing a technique called 'nulling interferometry'. The idea is that all telescopes will point towards the same star at the same time, and retransmit the light they detect to the central spacecraft.

In the central spacecraft the light from the individual telescopes is combined in a certain way and it results in the light from the bright star being cancelled out, leaving only the light from the possible planet around the star. The trickiest part of all this is that the distances between the telescopes and the central hub have to be controlled to about a millionth of a metre. This 'formation flying' will be demonstrated by another ESA mission, LISA Pathfinder (previously called SMART-2) although it will not perform nulling interferometry.

Searching for Exoplanets from Earth

The Danish 1.5 m telescopes at ESO La Silla. Photo : ESO

It is not always necessary to search for exoplanets from telescopes placed in space. New and advanced techniques developed for the ground based telescopes provide possibilities to search from Earth, and, surprisingly, the most Earth-like exoplanets found up until now are detected from Earth.

Using a network of telescopes scattered across the globe, including the Danish 1.54 m telescope at ESO La Silla (Chile), astronomers discovered a new extrasolar planet significantly more Earth-like than any other planet found so far. The planet, which is only about 5 times as massive as Earth, circles its parent star in about 10 years. It is the least massive exoplanet around an ordinary star detected so far and also the coolest. The planet most certainly has a rocky/icy surface. Its discovery marks a groundbreaking result in the search for planets that support life.

The new planet, designated by the unglamorous identifier of OGLE-2005-BLG-390Lb, orbits a red star five times less massive than the Sun and located at a distance of about 20,000 light years, not far from the centre of our Milky Way galaxy.

Its relatively cool parent star and large orbit implies that the likely surface temperature of the planet is 220 degrees Centigrade below zero, too cold for liquid water. It is likely to have a thin atmosphere, like Earth, but its rocky surface is probably deeply buried beneath frozen oceans. It may therefore more closely resemble a more massive version of Pluto, rather than the rocky inner planets like Earth and Venus.

"This planet is actually the first and only planet that has been discovered so far that is in agreement with the theories for how our Solar System formed," says Uffe Gråe Jørgensen (Niels Bohr Institute, Copenhagen, Denmark), member of the team. Furthermore, he says that it is a very small team within the institute that is working with the search for exoplanets. It was the Danish telescope that discovered the satellite, but the discovery is verified by four other ground-based telescopes. The telescope could not undertake any further detailed investigation of the planet, but will instead look for new objects.

Contrary to most exoplanets discovered, the Earth-like planet was indeed found using the "microlensing" technique, based on an effect noted by Albert Einstein in 1912. "One does not see the planet, or even the star that it's orbiting, one just sees the effect of their gravity."

The microlensing technique is most probably the only method currently capable of detecting planets similar to Earth.

European Southern Observatory (ESO)

ESO created in 1962, is the foremost intergovernmental European Science and Technology organisation in the field of ground-based astrophysics supported by eleven European countries.

ESO operates the La Silla Paranal Observatory at several sites in the Atacama Desert region of Chile. The first site is at La Silla. It is equipped with several optical telescopes with mirror diameters of up to 3.6 metres.

Whilst La Silla remains one of the scientifically most productive observation sites in the world, the Very Large Telescope array (VLT) is the flagship facility of European astronomy. One of the most exciting features of the VLT is the possibility to use it as a giant optical interferometer, VTLI. This is done by combining the light from several of the telescopes.

The Atacama Large Milimeter Array (ALMA), during construction at 5000 m altitude in Chile, will be one of the largest ground-based astronomy projects of the next decade, and is a major new facility for world astronomy. ALMA will be comprised of a giant array of 12-m submillimetre quality antennas, with baselines of several kilometres. An additional, compact array of 7-m and 12-m antennas is also foreseen. Construction of ALMA started in 2003 and will be completed in 2012 and will become incrementally operational from 2010 onwards. The ALMA project is a partnership between Europe, Japan and North America in cooperation with the Republic of Chile. The Chajnantor site is also home for the 12-m APEX sucmm/mm telescope, operated by ESO on behalf of the Onsala Space Observatory, Sweden, the Max Planck Institute for Radio Astronomy, and ESO itself.