# The Venus Transit 2004

**... Extended InfoSheet E1**

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## The Detection of Extrasolar Planets [1]

The Transit of Venus gives us the opportunity to see how transits make it possible to detect extrasolar planets, i.e. planets orbiting stars other than the Sun, and also, to give a progress report on these new worlds.

### Why should we be interested in extrasolar planets?

It is natural to wonder whether life exists elsewhere than on the Earth. Epicurus raised the question already in 300 BC (in his Letter to Herodotus; moreover he answered positively with no hesitation).

Life can, *a priori*, take extremely different forms from our own. Within this unlimited range we do not know where to look first, which does not help much. To make research more effective, we start by searching for forms of life that share with us the characteristics that we think are - if not universal - at least rather widespread: to be based on organic chemistry, to develop in an environment, if not aqueous at least sufficiently wet, and finally, to have at its disposal a source of permanent luminous energy. The most favoured environments for such conditions are solid planet surfaces (or liquids) located a fair distance from their star. They are called "habitable" planets.

In other words, it is necessary first to detect other planetary systems. This condition also answers other questions such as: how many planetary systems are there in the Galaxy? How are their characteristics distributed (number of planets, masses, orbits etc.), how are they correlated with the type of star?

### How to detect other planetary systems?

The most obvious method would be to take a picture of a planetary system where the planets are close to the host star. This is also the most promising method because it would be possible to see the colours of planets, to deduce the characteristics of their atmospheres and of their surfaces, and to detect signs of possible life. Unfortunately, it is also the most difficult to implement because stars are a billion times more brilliant than planets and they dazzle the observer.

We should start then with indirect approaches since direct imaging will not be possible before about 2007, and the instruments to make the observations are still being prepared.

### Indirect methods:

*Disturbance of the trajectory of a star by a planet*

When the planet orbits its host star, in fact it turns around the centre of gravity of the star-planet pair, and so does the star.

This movement of the star, which we want to detect, is periodic, with a much smaller orbit than the planet's and with a radius "a" given by the centre of gravity law:

$$a = A (m/M)$$

where:
A is the star-planet distance
m is the mass of the planet
M is the mass of the star

This results in some periodic variations of three measurable quantities:

- The "radial " velocity V of the star (component of the speed of the star in the line of sight star-observer). The amplitude of this variation is 13 m/s for a planet similar to Jupiter, located, like Jupiter, at five astronomical units (A.U.) from its star.
- The star-observer distance (measured by the variation of the times of arrival of periodic signals emitted by the star, as in the case of pulsars for example)
- The position of the star on the sky ("astrometric" method) since the star turns around the centre of gravity of the star-planet pair.

*Disturbance of the luminosity of the star (transits)*

A planet can slightly and temporarily darken the star around which it is orbiting (transit). This is the transposition to stars of the method for transit of Venus across the Sun. It is nevertheless quite different: whereas in the case of Venus we can see an image of the planet in front of the solar disk, in the case of a extrasolar planet the star is seen as a point and all that one can observe is a very small drop in the intensity of the star during the transit. The relative fall of luminosity is proportional to the surface area of the planet.

This drop of luminosity is 1% for a giant planet like Jupiter and 0.01% for a planet of the size of the Earth.

A disadvantage of this method is the low geometric probability (p = R/A where R is the radius of the star) for the orbit of the planet to be correctly oriented to produce a transit. This probability is around 0.5% for a planet located at one A.U. from its star; in other words, if all the stars have a planet at one A.U., it is necessary to follow 200 of them to see a transit. If 10% of stars have a planet at one A.U., then in order to detect ten stars, 20 000 need to be followed photometrically.

**Assessment of the discoveries**

The method of radial velocity shifts has made possible the detection of 103 planetary systems (as of November 2003), of which 13 are multiple, giving in all 118 planets. These detections indicate that at least ~7% of stars are accompanied by at least one planet. Extrapolated to the entire galaxy, this proportion means that our galaxy contains at least 7 billion planets. The masses of the detected planets range from 36 Earth masses to 13 Jupiter masses. The lower limit comes from the limitation of instrumental precision. The higher limit is fixed by the definition adopted for a planet: above 13 Jupiter masses, a body has its own source of energy due to central thermonuclear activity: it is thus a star. The distances from the detected planets to their stars ranges from 0.02 A.U. to 4.8 A.U. Curiously, half of the detected orbits are rather elliptic (strong eccentricity) contrary to what happens in the solar system where all the planets (except Mercury and Pluto) have quasi-circulars orbits. This phenomenon is not yet understood.

Among the 118 planets detected by their radial velocity shifts, one (HD 209458 b) also produces a transit every four days. The Hubble Space Telescope observed such an event. Spectroscopic observations during transits of this planet already provided indications of the chemical composition of its atmosphere. It is necessary to add also the planet OGLE-TR-56 B, which was detected by the transit method (and confirmed later by radial velocity measurements). There is in this case a transit every 30 hours which implies, if the interpretation of the observations is correct [2], a very tight orbit (only five times the radius of the Sun).

All these planets are giant planets and would not be able to sustain a form of life similar to terrestrial life.

**Future space missions to search for planets**

During the coming years, most observatories will continue to develop systematic planet research programmes based on the radial velocity shift (spectroscopy) method, on transits, on astrometry or on direct imagery. In parallel a large harvest is expected from several telescopes already in orbit and operational, being built or only being designed:

- The Hubble Space Telescope observed, in June 2003, 50 000 stars with the aim of seeking planetary transits. A hundred planets are expected from this; the results of the analysis will be available in 2004.
- The satellite CoRoT [3], will follow 60 000 stars over two and an half years to llok for planetary transits. It will be launched by the CNES (French Space Agency) in June 2006. We expect that it will find the first "big Earths" (approximately twice the radius of the Earth) in the Galaxy, some being likely to harbour a form of life.
- The American satellite Kepler (launch planned for 2008) should detect by the same method a few hundreds planets of a size similar to Mars.
- The U.S. satellite SIM (Space Interferometric Mission), scheduled for launch in 2009, should detect using the astrometric method, at least a few tens of planets, primarily giants. The much more ambitious European project GAIA (launch foreseen in 2011) will follow a billion stars with the same goal. A harvest of a few tens of thousands of planets is expected.
- The U.S. satellite JWST (with a European contribution to detect planets) will try to seek giant "hot" planets by imagery. With a little bit of luck it could find a few tens of them.
- Finally, two parallel projects (Darwin for Europe, TPF for the USA) are being studied to detect habitable planets by imagery. In the second phase a spectroscopic study of these planets will seek, around 2020, signs of biological activity, such as the presence of oxygen or colours characteristic of vegetation. In the meantime, NASA studies precursors to TPF with more modest ambitions.

We are living at a time when a question, unresolved from antiquity, will find an answer: near 2020, a great change will take place in the history of astronomy. It may be important for humanity, too.

To find out more, look at the books section from The Extrasolar Planets Encyclopaedia at Paris Observatory.

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**Notes**

[1] Written by Jean Schneider, Paris Observatory.
[2] It is necessary to be sure that the transits are not artefacts due to a binary star with its own eclipses.
[3] CoRoT means "Convection Rotation and planetary Transits" since this satellite will also study the rotation of the stars.

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