The Little Books of Gaia

THE SEARCH FOR PLANETS

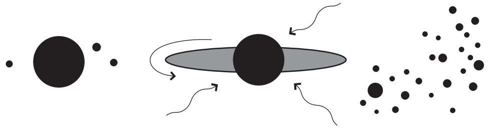
June 2009

The confirmation that the Earth was not at the centre of the Universe, but that it was orbiting the Sun together with 7 other planets, revolutionised mankind's understanding of the Universe. In recent years, the discovery of more than 350 extrasolar planets in our Galaxy constitutes a major scientific advance. It ends an era of speculation about the existence of worlds similar to ours orbiting stars other than the Sun.

Understanding how our Solar System formed, and finding out if there are other planets capable of supporting life, are major driving forces for continuing planet search programmes.

How did planets and our Solar System form?

Our current understanding is that stars and planets form as a result of the collapse of rotating interstellar clouds of gas and dust. These dense clouds (A) contract under self-gravity giving rise to a central star with a surrounding disc of material (B). The particles of dust and gas in this flattened disc may eventually form planets that orbit the central star (C).



Terrestrial planets in our Solar System (Mercury, Venus, Earth and Mars) have a relatively small size and are primarily made of rock and metals. They are thought to form by **core accretion**, which involves dust particles in the disc sticking together to form increasingly larger bodies or planetesimals, that eventually form planets by collisional growth.

Giant planets (Jupiter, Saturn, Uranus, Neptune) orbit further from the Sun and consist of a solid core surrounded by a gaseous envelope. Planetesimal accretion can also explain the formation of these cores, which subsequently capture gas from the surrounding disc.

Most of the new extrasolar planets discovered have minimum masses ranging from about 0.1 to 10 Jupiter masses. They orbit very close to their parent star and generally have large eccentricities. Planetary formation theories predicted instead nearly circular orbits and giant planets formed far from the star, just as for our own Solar System.

A mechanism called **orbital migration** has been introduced to account for the displacement of giant planets from their formation site far from the star to small orbital radii. The large eccentricities of new candidate planets are still not clearly understood by present theories.

To advance our knowledge of how planetary systems really form, we need to observe a statistically significant number of stars and planets and classify the observations taking into account the orbital parameters of the planet (eccentricity, period, inclination), its mass, and the type of parent star it is orbiting.

Are there other planets apart from Earth capable of supporting life?

If life elsewhere follows what we know about life on Earth, it requires liquid water and a solid-liquid interface to develop. The only objects in space where these conditions can be fulfilled are terrestrial planets in the **habitable zone**, i.e. solid planets at the appropriate distance from the star to allow for liquid water.

Complex life may only have developed on planets orbiting solar-type stars. These stars are old enough that complex organisms would have had time to evolve and they possess a relatively stable energy output which permits stable conditions in the orbiting planet.

The simultaneous existence of at least one massive planet orbiting far from the star and a terrestrial planet orbiting in the habitable zone may be a favourable configuration for the presence of complex life on the inner planet, as it would be protected from collisions by comets, events that could destroy life.

No planets satisfying all the above requirements have yet been found. But detection techniques are becoming more and more sophisticated, and we can expect the discovery of habitable planets in the near future. Furthermore, it is now reasonable to plan for telescopes that will look at the spectra of planetary atmospheres to find any indications for the presence of life in the form of absorption features of water or ozone.

Future perspectives

Whether the aim is to understand the formation of planets or to look for extraterrestrial life, more observational and theoretical work is needed.

The quest for extrasolar planets will be revolutionised by Gaia, an astrometric satellite that the European Space Agency will launch in spring 2012. Gaia will **detect about 15000 Jupiter-mass planets**, depending on details of the detection and orbital distribution hypotheses. Such a large sample would be fundamental for testing theories of the formation and evolution of planetary systems.

Gaia

Gaia could also play a role in the search for habitable worlds, not by directly detecting terrestrial planets, but by finding systems with a giant planet orbiting far from a solar-type star, a condition that would increase the possibility of finding an inner terrestrial planet harbouring life.

Increasingly more powerful computers will allow numerical simulations of planetary formation and evolution to develop rapidly, providing an invaluable tool for theoretical studies in this field.

Detection Methods

There are a number of different methods through which planets are being searched for:

★Dynamical Perturbation of the Star by the Planet: When a planet orbits a star, it exerts a gravitational pull over it, inducing a reflex motion of the star with respect to the common centre of mass of the system. The star will thus describe a small elliptical orbit with the same period as that of the planet.

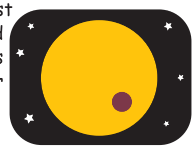
Two methods aim at detecting this star wobble:

* Radial Velocity: Measurements try to detect the periodic variation of the star's radial velocity induced

by the presence of a planet. Most of the extrasolar planets presently known have been discovered by this technique. It is most sensitive to massive planets orbiting close to the star; Earth mass planets cannot be detected through radial velocity techniques.

* Astrometry: Measurements look for the angular change in position of a star due to the pull of an orbiting planet. This technique is most sensitive to high mass planets with large periods orbiting nearby low-mass stars. The great advantage of this method is that it allows the determination of the mass and orbital inclination of the planet. Astrometric measurements are affected by the Earth's atmosphere, so planet hunting by this method will require satellites like Gaia going to space to gather the data.

★Photometry (occultations): This method measures the decrease in the brightness of a star when a planet passes in front of it. For a Jupiter-sized planet the dimming represents about 1% of the starlight. This method is most effective for large planets orbiting very close to the star. The first planetary transit to be observed by a ground-based telescope was for the planet orbiting the star named HD 209458.



ESA's COROT planet-hunting space telescope is already at work. From its polar orbit, it is looking for rocky planets several times larger than Earth around nearby stars.

★ Gravitational Lensing: A planet can produce a temporary gravitational amplification of the light of background stars. This is due to the peculiar propagation of light in curved space-time. One planet detection has been claimed to date with this method.

★ Imaging: Planets generally emit no light, but they reflect that of their parent star. This method aims at detecting this reflected light. It is a very difficult task because the nearby star is so bright that it overwhelms the image and hides the much fainter planet. Planned satellites like the ESA/NASA Darwin/Terrestrial Planet Finder mission will use imaging techniques to look for terrestrial planets in the habitable zone.

We are living in an exciting age, where discovering other worlds similar to our own, understanding how our Solar System formed, and even observing planets where life may be present, is now within our reach.

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More detailed information can be found on the Gaia web site: http://sci.esa.int/Gaia