4.2.2.2 The InfraRed Space Interferometer (IRSI)

Introduction

The survey committee for the Horizon 2000+ programme identified the topic of Infrared Interferometry as a potential Cornerstone candidate. They also added the recommendation of using interferometry for the direct detection of Earth-like planets in orbit around other stars. This topic, of course, is one of the ‘Big Questions’ that have not only an intrinsic scientific interest, but also a great cultural and philosophical value. As a consequence of the recommendation, ESA is studying the feasibility of such a project, and identifying the technologies requiring development before an IR space-based interferometer can be realised.

There is a significant collaboration between, principally, European space scientists aimed at the detection of terrestrial exoplanets. It was the original proposal of this ‘DARWIN’ group, in response to a call for proposals for Horizon 2000+, that resulted in the recommendation of the survey committee.

The study

ESA initiated preparatory work in 1997 for the study by forming a Science Advisory Group (SAG), consisting of R. Liseau (S), D. Queloz (CH), C. Schalinsky (D), J.-M. Mariotti (F), H. Roettgering (NL), A. Penny (UK) and F. Cappccioni (I). The task of this group was to prepare the grounds for an industrial, system-level study by identifying model missions. The result formed the basis for an Invitation To Tender (ITT) in August 1997. The objectives of the model missions can be summarised as:

- To detect in 10 h and with a signal-to-noise of 5, an Earth-like planet orbiting a G2V star at a separation compatible with it being in the ‘life-zone’, and at a distance of 10 pc from the Earth. Further, to characterise physically any planet discovered, especially its potential for life as we know it.
- To perform imaging at 5-28 mm with a spatial resolution at least an order of magnitude better than that expected from the Next Generation Space Telescope (NGST), and with a spectral resolution of 100-1000 km/s.

Two technical solutions illustrating the problems were included in the ITT. The contractor was also asked to study a combined mission. Aerospatiale was the successful bidder, and the work began in January 1998. The study will be completed towards the end of 1998, generating a set of recommendations on how to proceed.

Initial solutions

The technical solutions provided by the SAG as input for this study concern two separate missions:

- A planet-finding mission using a ‘nulling’ interferometer;
- An imaging mission using a ‘normal’ Michelson-type interferometer.

The problem of detecting an Earth-type planet circling another star is basically one of contrast. The primary star will be a billion times more luminous than the planet, which will also be very close to the star. Even with ‘normal’ interferometric methods increasing the spatial resolution by several orders of magnitude, the contrast problem remains. Going into the IR region, the contrast problem decreases by some orders of magnitudes, but the contrast is still somewhere between 10^5 and 10^6, and the spatial resolution becomes worse. The recent solution is to use a ‘nulling’ interferometer. In this arrangement, a different phase delay is introduced between each pair of telescopes in the array. Each pair is thus designed to produce a deep null in the centre of the synthesised beam. In this way, the strong flux emanating from the primary can be cancelled out. If, at the same time, the arrangement produces positive interference at

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Further information on IRSI can be found at http://astro.estec.esa.nl/IRSI/

positions in the synthesised beam where one expect the target planet to be, it can in principle be detected.

In the model mission described above, the objective was to detect the Earth in the Solar System removed to a distance of 10 pc. This is, of course, used only to set the requirements on the mission and does not exclude any of the nearby stars as targets.

The requirement that the planets should also be considered as abodes of life means that they must (as far as we understand life) reside within the life zone. This is the orbital range in which the planet's surface water is liquid. The life zone's size and the planet's distance from the primary depends on the stellar type, both parameters being smallest for the faintest M-type dwarfs.

Different arrangements of 3-9 telescopes (circular, triangular, elliptical configurations) are being evaluated to determine which produces the deepest null and the best sampling of the life zone around different types of nearby stars. Telescope mirror diameters of 1.5 m are found to best suit the target systems. In order to reduce the contrast problem, we have chosen to work at wavelengths of about 10 μm. However, it has been found that this introduces a different problem. Our Solar System is immersed in dust, which produces the zodiacal light. The thermal emission from the zodiacal light 1 AU from the Sun peaks at around 10 μm. The flux is so large that it would drench the faint signal from an exoplanet, leading to impossibly long integration times for the (relatively) small telescopes. There are two obvious solutions: use bigger telescopes or fly the interferometer further from the Sun where the dust temperature has dropped sufficiently for the emission peak to move out of the planet-finding wavelength band, and possibly where there are lower dust densities (although this is poorly known at the moment).

Both of these 'solutions' have their own problems. It is found that flying a planet-finder at a distance of 1 AU, as in an L2 orbit, requires at least 4 m-class telescopes. On the other hand, the poorly-known distribution of larger (1-10 μm) particles in the outer Solar System means that we do not know whether to fly at 3 AU, 5 AU or possibly even further from the Sun. The consequences of such a distant mission, in terms of power, communication, etc are being investigated.

The other, 'imaging', option has been specified to provide order-of-magnitude improvements over monolithic telescopes (including NGST) within the near- and mid-IR bands. Free-flying telescopes with kilometric separations provides milli- and micro-arcsecond spatial resolution. This would generate breakthroughs in almost every branch of astronomy. Although technically less complicated than the planet-finding mode, there are also problems with this scenario. For example, obtaining sufficient sampling over a kilometric baseline requires a large number of satellites or a small number in a reconfigurable formation with consequently longer observing times.

The possibility of combining the two missions is being investigated. Combined planet-finding and imaging would not only generate excellent science, but it would also require technical developments applicable in many other areas of science and technology.