SECTION II

THE SEARCH FOR OTHER PLANETARY SYSTEMS

II. THE SEARCH FOR OTHER PLANETARY SYSTEMS

INTRODUCTION

It is generally agreed that planets are the cosmic wombs where life may start and develop, sheltered in the hospitable, rich in nutrients, protective environments of certain planets. Though other alternatives can not be completely excluded, the physics, chemistry, and the abundances of chemical elements, strongly concur in favor of a planetary origin of life. This makes the search for extrasolar planetary systems the first step in the search from extraterrestrial life, but unfortunately we do not yet know whether a planetary system like ours represents a rarity or a common occurance among the billions of stars of our Galaxy. The reason is that the detection of planets around other stars is technically a very difficult problem, something like trying to see a firefly flying near the edge of a powerful searchlight.

In recent years, however, new instruments and new techniques for obtaining and analyzing data have brought new excitement in this field. The Infra-Red Astronomy Satellite (IRAS), launched on January 25, 1983, was able to detect envelopes of particles around a considerable number of young stars, possibly indicating planetary formation from preplanetary disks. The first such star, found in 1983 by the IRAS, was Vega (alpha Lyrae, 25 l.y.), which was soon followed by Fomalhaut (alpha Piscis Austrini, 23 l.y.), epsilon Eridani (11 l.y.), and beta Pictoris (50 l.y.). Soon after, Bradford Smith and Richard Terile using a coronograph and a CCD electronic camera with the 100-inch telescope of the Las Campanas Observatory in Chile, obtained in 1984 some high resolution pictures which after being computer processed revealed that the particle envelope around beta Pictoris was actually a tilted preplanetary disk. Preplanetary disks have also been detected using speckle interferometry and image processing techniques (maximum entropy image reconstruction), around several T-Tauri stars, such as HL Tauri, which are pre-main sequence (10^5 - 10^6 years old), Sun-like stars, as well as in infrared sources, such as the one known as IRS-S L1551, where a disk was discovered using the 45 m Nobeyama radio telescope of Japan.

Another important recent discovery in 1984 was made by Donald McCarthy, Frank Low and Ronald Probst, who using infrared speckle interferometry were able to observe a massive object, 20-50 times the mass of Jupiter, around the star Van Biesbroeck 8 (VB 8, 21 l.y.) which has been named VB 8B. (Objects with masses in this intermediate range belong into a special category between stars and planets and are called Brown Dwarfs). It must be pointed out, however, that the discovery of a single massive planet or brown dwarf does not imply the existence of a

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planetary system, because it might only be a common binary star system consisting of a star and a low mass companion. Still the detection of VB 8B was an important astronomical discovery, because it was the first brown dwarf ever to be observed.

The search for extrasolar planetary systems is rapidly becoming one of the most exciting fields of astronomy where in the next 10-20 years we may witness initially the discovery of Jupiter-like extrasolar planets and later on the detection of extrasolar planetary systems. As this search will progress, we will begin to compile statistics on planetary system such as, frequency of planetary systems by spectral type and rotational period of stars, mass and distance distribution of planets relative to the mass of the star, etc. This information, as pointed out by David Black in the first paper of the Section, is essential in order to understand the origin of our own solar system as well as the formation of stars and planets in general. It is also, as mentioned above, a fundamental link in the search for extraterrestrial life.

The different planetary detection techniques currently in operation or in the planning stages can be divided into two categories, direct and indirect. Direct methods are very difficult because, as shown in the diagram in David Black's review paper, the emission of a Sun-like star exceeds the emission of a Jupiter-like planet by a billion times in the visible and by 10.000 - 100,000 in the microwave and infrared regions. In addition, their separation is only 1 arcsecond at a distance of 17 l.y. Consequently only the 2.4 m Hubble Space Telescope, which by avoiding the seeing and airglow problems of the atmosphere will have a much higher resolution and will be able to see much fainter objects, might be able to make some direct detections of planets when it goes into orbit in 1986.

The indirect techniques try to deduct the presence of a large planet from the motions it induces to the star. Astrometric techniques study the wobbling motion in the path of the star (typically changes of less than 1 milliarcsecond) and are most effective for large planets far away from the star. Spectroscopic techniques, on the other hand, study the Doppler shifts in the orbital velocity of the star around its bary-center with the planet (typically changes of less than 10 m/sec) and are most effective for large planets close to the star, which produce more pronounced effects. Photometric methods, which try to detect minor changes in the luminosity of the star due to the eclipsing of a large planet are very difficult and might have a better chance with the high speed photometer of the Space Telescope.

Several groups around the world are working now on these problems perfecting instruments and techniques and getting close to initiating long term systematic searches. With all these new technological developments, the IRAS results, and the prospect of the Space Telescope, this has become a very exciting field. So was also the corresponding first Session of our Symposium, which was chaired by Carl Sagan of Cornell University and Jun Jugaku of the Tokyo Observatory, on which this Section of the Proceedings is based.

This Sections opens with a review paper by David Black of NASA-Ames, who has been coordinating and overseeing practically all the activities in this field for many years. He discusses the rationale for planetary searches, reviews the different techniques and the prospects for the Space Telescope, and concludes by saying that detecting and understanding extrasolar planetary systems is one of the more significant undertakings of all time, "the final step in the Copernican revolution" as he calls it.

H. H. Aumann of JPL, who with F. Gillett were the first to discover from IRAS data the particle envelope around Vega, reports in the next paper that of the 335 confirmed stars observed with the IRAS within a distance of 25 pc (80 l.y.), 68 i.e. about 20%, showed a significant infrared excess beyond 12 microns, i.e. at 25 and at 60 microns, indicating the presence of cold particle envelopes around a significant fraction of stars, especially A and F stars. From the fact that we see a large 60 micron excess in about half of the type A stars, which typically have a life span of 1-5 x 10^8 years, one can conclude that this cool infrared excess lasts for only about half of their lives, i.e., about 10^8 years, which coincides with the accretion time for large planets. It is interesting to note that if our solar system was observed now from a large distance, it would show an insignificant (less than 1%) and most likely undetectable infrared excess.

Steven Beckwith of Cornell University, a leader in ground-based observations of particle disks around very young stars, estimates that the mass of solid matter around HL Tau is at least equal to the mass of the Earth, and since in interstellar space the ratio of hydrogen mass to solid matter is approximately 100, one can infer a mass of gaseous hydrogen around HL Tau of at least 100 Earth masses, which approaches the total mass of our planetary system which is about 400 Earth masses. From the fact that the introduction of new techniques have yielded so many cases of preplanetary disks so fast, he concludes that preplanetary disks and therefore planetary systems are probably quite common in our Galaxy.

David Staelin and M. Colavita of MIT and Michael Shao of the Smithsonian A.O. report on their optical astrometric interferometer. They started several years ago with a one color instrument, based on a conventional Michelson Stellar Interferometer, which has now been upgraded to a two color system (red and blue) which permits corrections for atmospheric turbulence every few milliseconds. Observations with a prototype have yielded accuracies of 0.02 arcsec for one second samples, still a considerable distance from the one milliarcsec accuracies needed for the detections of Jupiter-like planets.

George Gatewood, John Stein and their collaborators from the Allegheny Observatory of the University of Pittsburgh, now the leading Observatory for astrometric planetary searches, report on the modernization of their 30-inch Thaw refractor telescope, including a new objective lens, which will be ready in the summer of 1985. Combined with their Multichannel Astrometric Photometer (MAP), they expect to achieve accuracies of 0.002 arcsec per hour and plan to start soon a comprehensive search for Jupiter-like planets in 100 to 200 stars in the neighborhood of the Sun. This project is expected to take 10-20 years because of the anticipated 10 or more year periods of such large planets.

Jane Russell of the Space Telescope Science Institute, and previously of the Allegheny Observatory, gives a comprehensive description of the five dedicated instruments to be carried on the Hubble Space Telescope (Faint Object Camera, Wide Field/Planetary Camera, High Speed Photometer, Faint Object Spectrograph, High Resolution Spectrograph), which together with the Fine Guidance System (3 star selections, two of which are continuously needed for guidance while the third might be used for astrometric planetary searches) offer considerable opportunities for planetary searches. The Faint Object Camera, which has a coronographic finger of 0.8 arcsec and an apodizing mask, might be used for direct searches. The Wide Field/Planetary Camera which operates with a CCD detector might be used for astrometric studies with a 0.002 arcsec accuracy. The High Speed Photometer, which has a dynamic range of 20 magnitudes with an accuracy of 0.001 magnitudes may be used for planetary detections during occultations by minor planets. The two spectrographs have also some potential, but have not yet been fully explored for planetary searches. The greatest problem for planetary searches with the Space Telescope is expected to be the availability of observing time, because the requests for time on the Space Telescope exceed already the available time by a factor of 15.

Thornton Page of the NASA Johnson Space Center complements the descriptions of Russell. In his paper he discusses some research projects developed in a class he taught on the potential use of the Space Telescope for extrasolar planetary searches.

This Sections closes with the description of two new proposed technique which might prove of considerable usefulness in the search for extrasolar planetary systems. Pierre Connes of the CNRS of France discusses his idea for a stellar accelerometer to measure radial stellar velocities with a potential accuracy of 1m/sec. It is based on a Fabry-Perot interferometer which tracks several spectral lines of the star and monitors their Doppler shifts with lasers. The other technique, proposed by Laurance Doyle of NASA-Ames would combine speckle interferometric measurements of CaII H and K emission from active stellar regions with stellar rotation periods to determine the orientation of the stellar axis of rotation. This information would establish the inclination of the planetary orbits and therefore would be an important criterion in selecting the proper method for a search for planets around that star.

THE EDITOR

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