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Life in Outer Space

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INTRODUCTION

Whether there is life in space elsewhere than on the earth is one of the most appealing questions for the mind to dwell on and in former centuries, as now, there was much explicit speculation. Many quotations can be given.

> *Empty space is like a kingdom, and heaven and earth no more than a single individual person in that kingdom. Upon one tree are many fruits, and in one kingdom many people. How unreasonable it would be to suppose that, besides the heavens and earth which we can see, there are no other heavens and no other earths?*
>
> Teng Mu, 13th century philosopher

> *And so what mainly makes me believe that the planets have intelligent beings is that the superiority of our earth over those others would be too great if the beings had unique features so far beyond all other living beings, not to mention the plant kingdom.*
>
> Christian Huyghens,
> 17th century physicist

> *Observe how system into system runs;*
> *What other planets circle other suns;*
> *What varied being people every star.*
>
> Alexander Pope,
> 18th century poet

> *Homo sapiens has recently flattered and frightened himself by conceiving that, though perhaps he is not the sole intelligence in the cosmos, he is at least unique, and that worlds suited to intelligent life of any kind must be extremely rare. This view proves ludicrously false.*
>
> W. Olaf Stapledon,
> 20th century writer

> *"You s'pose there are Mars worms? Jupiter worms? Venue worms? Porfirio?"*
>
> *"Panchito! It'd be gross conceit to imagine that in all those awesome endless galaxies we are the only worms!"*

Gus Arriola,
20th century cartoonist

The current surge of discussion, which began around 1960, differs in an important way from the discussion of earlier times: the philosopher of today is expected not to violate known laws of physics and to keep his scenarios compatible with the great many facts of astronomy and astrophysics that are now known. Although these restrictions make it difficult to say anything at all about life in space, nevertheless a substantial body of literature has arisen. A principal topic deals with action that humans might take to find out whether there is life elsewhere. In this category we should include the planning and execution of the Mars landings, but to reach beyond the solar system is far more difficult. A well known proposal is to listen by means of a sensitive radio receiver connected to a large radio telescope pointed in the direction of nearby stars. Project Ozma and the Cyclops design study will be recalled as exercises in this direction and some listening activity is being pursued at the present time, for example by Kraus and Dixon at Ohio State University. There is a remote chance of success so I am in favour of this enterprise but very little total effort will be exerted because most people with suitable equipment will judge that their time will be more productively spent on other endeavours. The situation would change if a very large antenna system, much larger than anything now available, could be constructed – the Cyclops study group contemplated 10,000 large radio telescopes massed together.

As it has come to be realized that direct listening is not 1 ikely to yield quick success and is likely to be very expensive, action-oriented thinking has turned to other directions. A new thought is to look for nonsolar planets rather than for life directly. If planets were discovered it would mean a big step forward for direct listening both as regards the enthusiasm for listening that would be generated and as regards the actual chance of successful detection of life. Not only intelligent life is in point. Although reception of radio communication signals from a planet would convincingly evidence the presence of technological life it is conceivable that lower forms of life could reveal their presence over interstellar distances in some other way. We must remember that the conspicuous blue of our planet as seen from the moon is due to our oxygen, which is a by-product of organic life. To a sophisticated outside observer, if there is one who can see our planets, the blue of Earth, contrasted with the white of Venus and the red of Mars would speak volumes.

We have become so accustomed through fiction to the plurality of planets belonging to other stars and even to stars of other galaxies that it is a shock to some to learn that even today there is no generally accepted evidence for the existence of any planets in the Universe other than the nine in our own solar system. There is certainly evidence for dark companions but they are objects much more massive than Earth or even than Jupiter. If a coordinated search were to be made for nonsolar planets it would be a step forward in the search for life in outer space but would also be certain to provide other sorts of astrophysical knowledge. This is important, for the general assent of the scientific community is necessary for the general assent of the scientific community is necessary for the initiation of large projects and the broader the prospective returns the wider the assent is likely to be. Therefore I am confident that there will be a surge in activity aimed at detection of nonsolar planets in coming years. Furthermore, I have a technique to propose. First let us consider two orthodox proposals as a background for two new ideas that space-age technology permits us to contemplate.

ASTROMETRY

One of the great traditions of astronomy is the preparation of star catalogues, an activity that was pursued by the Babylonians and the Chinese, by Hipparchus (second century B.C.) and Claudius

Ptoleniaeus (second century A.D.). The earliest substantial work that is extant records the positions of 1028 stars as determined by Ptolemy, whose system of classifying stars into first and second magnitude and so on is the one still in use today. A by-product of this activity was the discovery that the stars are not fixed on the celestial sphere but appear to move slowly, some faster than others. Sirius, the brightest star, has always appeared in the catalogues as they grew in length and over the years became more refined, so that by 1844 Friedrich W. Bessel (1784-1846) was able to announce a very peculiar thing about Sirius. Over the course of 50 years Sirius not only moves south by 66 seconds of arc, a very noticeable distance, but does so in a sinuous path, weaving to each side by 8 seconds of arc. Bessel announced that Sirius must possess a dark companion which if visible, would be seen on a wavy path interwoven with that of Sirius as they each revolved about their common center of mass. Thus did the first white dwarf make its presence known. Years later in 1862 it was seen arid ultimately, many years later, it was photographed. It has about the same mass as our Sun, is only twice the size of the Earth and has a density of 150,000 relative to water.

This fragment of history exemplifies all the technical background needed to follow the method of astrometry as a technique for discovering nonsolar planets. A planetary companion must produce the same sinuous motion of its parent star but less in excursion according to its mass. Let us imagine a star S like our Sun possessing a planet J like Jupiter but situated 33 light years away. This distance is chosen because it is a standard distance in astronomy (the distance on which the system of absolute magnitudes is based). There are about 300 stars in a sphere of 33 light years radius. We now ask, what will the lateral excursion of S be, as we observe it year by year from Earth, wider the influence of its revolving planet J. The answer is 0.5 milliseconds of arc or 16,000 times less than for Sirius under the influence of its dark companion. The technical feat that would be required to detect such a small displacement in the sky is clearly If the greatest difficulty and may seem impossible. Bear in mind that Jupiter takes 12 years to orbit the Sun so the detection of planet J if it has a similar period would require sustained attention for many years and a means of assuring that small displacements, if detected, were the result of planetary motion and not of some instrumental change over the years. In addition remember that a star image dances about by 100 milliseconds of arc or more due to irregular refraction or twinkling of the starlight as it passes through the earth's atmosphere. In view of the difficulties imposed by the atmosphere and year-to-year changes in astrometric telescopes it is surprising to learn that the precision attainable in current astrometry, when a year's observations are combined, is 3 milliseconds of arc.

RADIAL VELOCITY

As star S rotates about the mass center not only does it weave from side to side as seen from Earth, but it also approaches and recedes. Such radial, or line-of-sight motion is not apparent as a displacement of the star on the celestial sphere, but it changes the stellar spectrum, which is subjected to Doppler shift. Under the influence of planet J, star S acquires a radial velocity of 12 metres per second on top of its mean velocity of approach or recession (which is likely to be in the range of tens of kilometres per second). Radial velocity measurement is a vigorous discipline that is practised both on stars and external galaxies but because the velocities to be measured are relatively high, great precision has not been in demand. At present precisions of about one kilometre per second are standard and 250 metres per second has been attained on the Palomar 5 metre telescope. So there is a substantial gap between current practice and what would be necessary to detect the radial velocity variation due to an orbiting planet. An encouraging aspect is that current work is done on faint stars chosen because of some characteristic such as stellar type whereas the first candidates for planetary search would be the nearby stars which are much brighter. For this reason, and taking account of foreseeable instrumental developments it is thought that a precision of 10 metres per second is technically feasible, though great effort will be required.

In the radial velocity approach, as with astrometry, observations sustained over many years will be required so that the changing effect due to the planet's orbital motion can exhibit itself. Radial velocity has the interesting feature of being independent of distance whereas the astrometric displacement falls off as distance increases. The two established procedures are thus in a sense complementary, astrometry being more favorable for the closer stars and radial velocity taking over at some as yet undetermined distance.

APODIZATION

Why cannot a nonsolar planet be photographed through a large telescope with a time exposure sufficient long to develop a planetary image? The difficulty is attested to by the fact that the dark companion of Sirius, known as Sirius B, resisted photography until quite recently. This was partly because Sirius gives 10,000 times more light than Sirius B. But that is not the full story because Sirius B is, even so, equivalent to a twelfth magnitude star which can be photographed readily with an exposure time of minutes. The other important factor is the proximity of Sirius. As is quite noticeable on photographs of star fields, brighter stars produce larger images than fainter stars. This means that as the exposure time is increased the photographic image of a star grows in diameter and tends to obliterate any faint object in the neighbourhood. Thus the image of Sirius easily reaches a radius of 8 seconds of arc in the time necessary to bring up a detectable image of Sirius B which is then lost in the glare. The explanation of this phenomenon lies partly with light scattered through small angles of just seconds of are by atmospheric particles, partly with imperfections of the telescope and partly with diffraction of the starlight.

While Sirius is 10^4 times stronger than Sirius B, we calculate that star S is log times stronger than planet J. Furthermore, while Sirius B is 8 seconds away from Sirius, planet J is only half a second away from its star, as viewed from 33 light years. Thus direct photography seems unattractive. But, action is needed, so we should take an optimistic attitude and ask what would be needed to change the situation to a favourable one. There is an answer. First, the earth's atmosphere must be eliminated, a step which the space age has rendered feasible. Indeed, sizable telescopes of several kinds have already been launched successfully into earth orbit. That deals with atmospheric scattering. Secondly, much better parabolic surfaces must be made than were manufactured for today's great working telescopes, some of the best of which date back decades. That is a matter of technology and seems to present no insuperable obstacle in principle but will present a significant engineering challenge. Finally, there is the diffraction of light which is inherent in wave propagation and describes the ability of light to go round corners as studied long ago by Francis M. Grimaldi (1619-1663), who coined "diffraction", and by Isaac Newton (1642-1727). Because of this proclivity of light rays to bend, starlight falling on a parabolic mirror is not all directed to the geometrical focal point, which is where the photographic plate is placed, but a certain amount arrives in the neighbourhood. One can calculate strictly how the light intensity falls off. As we know, it is still very strong half a second of arc away in the location of the planetary image (if such there be). Apodization is a method of reducing the strength of the diffracted light by eliminating the sharp boundary of the cylindrical beam of starlight that falls on the parabolic mirror. If the light intensity can be made to fall off from center to edge continuously instead of cutting off abruptly, there is a dramatic reduction in the amount of light that is bent away from the focus and further improvement is attainable the more smoothly the light intensity tapers off. As with the indirect methods of detection already described the indications are that in principle apodization can succeed but effort and inventive ability will be required. A major difference is this. Direct photography will not require 12 years of sustained attention. If planet J is there it will be detected promptly.

SPINNING INFRARED INTERFEROMETER

While there are three avenues open, any of which could lead to successful detectin of nonsolar planets, as far as we know now, there are significant technical unknowns which might block or delay progress. There is therefore scope for new ideas going beyond the improvement of already known methods.

Let us ask first whether visible light is the best or only way to go. Planets not only reflect the light of their sun but also emit electromagnetic radiation in their own right because of the heat they contain. In the case of Jupiter, whose temperature is -145°C, heat radiation would not seem to be of great importance because the planet is so cold. Its radiation is faint and peaks up at an infrared wavelength of about 40 micrometres. Perhaps surprisingly, the stellar radiation at this wavelength is also not very strong, in fact it is only 10,000 times stronger than that of planet J. Merely by jumping to another wavelength we therefore immensely improve the problems caused by glare at visible wavelengths where the star outshines the planet by a factor 10^9.

With this encouraging beginning we are stimulated to seek a new principle to discriminate between star and planet. The answer is interferometry. A special infrared telescope can be imagined which collects infrared radiation from the star through two apertures about one metre in diameter and 10 metres apart. The two beams can be brought together and caused to interfere destructively if crests of one wavetrain superimpose upon troughs of the other. Radiation from the planet, on the other hand, not coming from precisely the same direction, can give rise to constructive interference and a maximum of intensity. This will happen if one of the apertures is one half wavelength closer to the planet than the other aperture, a condition that will arise automatic~ ally if the spacing is 10 metres as proposed. A star is almost a point source but not quite. The angular diameter of star S at 33 light years is one millisecond of arc. The consequence is that only a diameter of the star can be nulled out and points to each side, while they will be heavily discriminated against, are in fact not entirely suppressed. When allowance is made for the imperfect suppression, it is found that the planetary emission exceeds that of the star by 20 times.

If the beam on which the collecting apertures are mounted is allowed to spin around an axis passing to the star, the planetary signal will rise and fall at a precisely known frequency and sensitive techniques of synchronous detection may be used to detect the presence of the planet against the unchanging stellar background signal. This very simple set of concepts offers a fourth approach and warrants careful study.

Already many features have been examined. For example, the infrared instrument must operate outside the earth's atmosphere which is a stronger source of heat than the planet. All heat radiation that can be screened off, particularly solar and terrestrial heat, must be blocked by shades and thermal insulation. Heat radiation from the optical parts, mostly mirrors, and the walls of the satellite containing the detector must be stringently reduced by operating at extremely low temperatures, such as the boiling point of helium. Techniques of this sort are already established for space vehicles of other kinds but a cryostat of the necessary size is not a trifle. Elaborate laser servos are needed to keep the infrared optics in adjustment and a star tracker to keep the interferometer spin axis aimed at the star. Although these elements are already well understood also, successful operation will demand the highest traditions of instrument design.

As with direct detection by apodization, the spinning infrared interferometer does not require 12 years of observation but the time required may well be many months. The reason for this would not be easily foreseen. In the vicinity of the Earth, and more or less in the plane of its orbit, there are solid particles about one micrometre in diameter and about one kilometre apart, on the average, that give rise to the zodiacal light, scattered sunlight that can be seen stretching out along the zodiac when the sun is just below the horizon. Because of smog, very few people are familiar with the zodiacal light these days. The best time to look is on a clear autumn evening when there is no moon. In spite of the sparsity and fineness of the particles, they are at about Earth temperature and it is thought that there are enough in the field of view of the infrared instrument to limit the sensitivity. The quality of the infrared detectors themselves is not likely to be limiting unless in future years infrared interferometers are launched out of the ecliptic plane or on voyages well beyond Mars where the particles have proved to be undetectable.

Many fascinating problems are presented by this novel concept. As yet it is too early to estimate the relative costs and relative chances of success of the four approaches that have been described. If history is any guide, however, we may be sure that all of these projects, which represent substantial advances on current instruments, are likely to produce discoveries of phenomena more conspicuous than the minute planetary effects that are sought but too faint to have been noticed hitherto.

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