Reports

Search for Artificial Stellar Sources of Infrared Radiation

Abstract. If extraterrestrial intelligent beings exist and have reached a high level of technical development, one by-product of their energy metabolism is likely to be the large-scale conversion of starlight into far-infrared radiation. It is proposed that a search for sources of infrared radiation should accompany the recently initiated search for interstellar radio communications.

Cocconi and Morrison (*1*) have called attention to the importance and feasibility of listening for radio signals transmitted by extraterrestrial intelligent beings. They propose that listening aerials be directed toward nearby stars which might be accompanied by planets carrying such beings. Their proposal is now being implemented (*2*).

The purpose of this report is to point out other possibilities which ought to be considered in planning any serious search for evidence of extraterrestrial intelligent beings. We start from the notion that the time scale for industrial and technical development of these beings is likely to be very short in comparison with the time scale of stellar evolution. It is therefore overwhelmingly probable that any such beings observed by us will have been in existence for millions of years, and will have already reached a technological level surpassing ours by many orders of magnitude. It is then a reasonable working hypothesis that their habitat will have been expanded to the limits set by Malthusian principles.

We have no direct knowledge of the material conditions which these beings would encounter in their search for lebensraum. We therefore consider what would be the likely course of events if these beings had originated in a solar system identical with ours. Taking our own solar system as the model, we shall reach at least a possible picture of what may be expected to happen elsewhere. I do not argue that this is what *will* happen in our system; I only say that this is what *may have* happened in other systems.

The material factors which ultimately limit the expansion of a technically advanced species are the supply of matter and the supply of energy. At present the material resources being exploited by the human species are roughly limited to the biosphere of the earth, a mass of the order of 5×10^{19} grams. Our present energy supply may be generously estimated at 10^{20} ergs per second. The quantities of matter and energy which might conceivably become accessible to us within the solar system are 2×10^{30} grams (the mass of Jupiter) and 4×10^{33} ergs per second (the total energy output of the sun).

The reader may well ask in what sense can anyone speak of the mass of Jupiter or the total radiation from the sun as being accessible to exploitation. The following argument is intended to show that an exploitation of this magnitude is not absurd. First of all, the time required for an expansion of population and industry by a factor of 10^{12} is quite short, say 3000 years if an average growth rate of 1 percent per year is maintained. Second, the energy required to disassemble and rearrange a planet of the size of Jupiter is about 10^{44} ergs, equal to the energy radiated by the sun in 800 years. Third, the mass of Jupiter, if distributed in a spherical shell revolving around the sun at twice the Earth's distance from it, would have a thickness such that the mass is 200 grams per square centimeter of surface area (2 to 3 meters, depending on the density). A shell of this thickness could be made comfortably habitable, and could contain all the machinery required for exploiting the solar radiation falling onto it from the inside.

It is remarkable that the time scale of industrial expansion, the mass of Jupiter, the energy output of the sun, and the thickness of a habitable biosphere all have consistent orders of magnitude. It seems, then, a reasonable expectation that, barring accidents, Malthusian pressures will ultimately drive an intelligent species to adopt some such efficient exploitation of its available resources. One should expect that, within a few thousand years of its entering the stage of industrial development, any intelligent species should be found occupying an artificial biosphere which completely surrounds its parent star.

If the foregoing argument is accepted, then the search for extraterrestrial intelligent beings should not be confined to the neighborhood of visible stars. The most likely habitat for such beings would be a dark object, having a size comparable with the Earth's orbit, and a surface temperature of 200° to 300°K. Such a dark object would be radiating as copiously as the star which is hidden inside it, but the radiation would be in the far infrared, around 10 microns wavelength.

It happens that the earth's atmosphere is transparent to radiation with wavelength in the range from 8 to 12 microns. It is therefore feasible to search for "infrared stars" in this range of wavelengths, using existing telescopes on the earth's surface. Radiation in this range from Mars and Venus has not only been detected but has been spectroscopically analyzed in some detail (*3*).

I propose, then, that a search for point sources of infrared radiation be attempted, either independently or in conjunction with the search for artificial radio emissions. A scan of the entire sky for objects down to the 5th or 6th magnitude would be desirable, but is probably beyond the capability of existing techniques of detection. If an undirected scan is impossible, it would be worthwhile as a preliminary measure to look for anomalously intense radiation in the 10-micron range associated with visible stars. Such radiation might be seen in the neighborhood of a visible star under either of two conditions. A race of intelligent beings might be unable to exploit fully the energy radiated by their star because of an insufficiency of accessible matter, or they might live in an artificial biosphere surrounding one star of a multiple system, in which one or more component stars are unsuitable for exploitation and would still be visible to us. It is impossible to guess the probability that either of these circumstances would arise for a particular race of extraterrestrial intelligent beings. But it is reasonable to begin the search for infrared radiation of artificial origin by looking in the direction of nearby visible stars, and especially in the direction of stars which are known to be binaries with invisible companions.

FREEMAN J. DYSON
Institute for Advanced Study, Princeton, New Jersey

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Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].