A SEARCH IN THE INFRARED TO MICROWAVE FOR ASTROENGINEERING ACTIVITY

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ABSTRACT. Huge space power plants (Dyson Spheres) utilizing most of a star's energy should be detectable as infrared or microwave sources. A recent far infrared all-sky survey has revealed many sources with a spectrum peaking on this region which is characteristic of the thermal emission of the hypothetical Dyson spheres. The possibility of confusing them with thick circumstellar dust shells around evolved red giant stars is discussed. Microwave detection of cool extended Dyson Spheres by all-sky surveys searching for microwave background fluctuations is also considered.

1. THE SPECTRA OF DYSON SPHERES

One of the likely forms of astroengineering activity seems to be the construction of huge space power plants utilizing most of the energy of the star, as proposed by F. Dyson. Such "Dyson Spheres" (DS) would intercept most of the stellar flux and reemit it at longer wavelengths. Effective use of the energy of the star would be accomplished when the temperature of the DS is much lower than the effective temperature of the star. The thermodynamic efficiency η is:

$$\eta = 1 - \frac{T(DS)}{T(star)} \tag{1}$$

For T(star) = 6000 K and T(DS) = 300 K, $\eta = 0.95$. The lower limit for the temperature of a Dyson sphere is set by the microwave background radiation temperature T_o = 2.7 K, while the upper limit must be somewhere around 300 K, both for reasons of the efficiency η and for providing a comfortable environment. Since both the heating and the cooling of the sphere are radiative, the sphere must effectively absorb most of the star's radiation in the optical region and emit it at wavelengths around the maximum of the black-body spectrum of the respective temperature, i.e., between 15 microns and 2 mm (Kardashev, 1979).

M. D. Papagiannis (ed.), The Search for Extraterrestrial Life: Recent Developments, 315–319.

For a terrestrial observer it will look as a far infrared - submillimeter - millimeter wavelength source with a peaked, nearly black body spectrum, without any optical counterpart, or at best with a very weak one. Thus, the search for DS must be a survey of the sky at several wavelengths in the far infrared - millimeter region for sources with a nearly blackbody spectrum. The flux density at the peak of the DS spectrum is:

$$S_{max} = \frac{2.84\ k^3 L}{4h^2 c^2 \sigma T D^2} \tag{2}$$

or

$$S_{max} = \frac{35}{T}\left(\frac{D}{1\ \mathrm{kpc}}\right)^{-2} \frac{L}{L_\odot}\ \ \mathrm{Jy} \tag{2*}$$

where T is the temperature of the DS, D the distance to the DS, L and $L_\odot$ the luminosities of the star and the Sun, k the Boltzmann constant, h the Planck constant, c the speed of light, and σ the Stefan-Boltzmann constant.

2. A SEARCH IN THE FAR INFRARED

One survey relevant to the search for DS was just completed by the IRAS team (Neugebaner et al., 1984). The satellites's far infrared telescope was equipped with four detectors sensitive at 12, 25, 60, and 100 microns, and made an almost full-sky survey down to a flux density of about 0.1 Jy. 200,000 sources were detected, most of them previously unknown. As follows from (2), all DS with temperatures between 50 and 400 K within 1 kpc from the Sun should have been detected by the IRAS. There are many sources having spectra peaking in the spectral range of the IRAS survey. Several examples are shown in Figure 1.

0507+528 P05 (IRAS Circular No. 5). Bright source with a peak at 18 microns, corresponding to T = 290 K. It might be a DS around a star of 1 $L_\odot$ at 22 parsec from the Sun. Available observations show that an OH/IR maser and the highly reddened spectral type M10 star NV Aur coincide in position with this source. Far infrared fluxes at 10.6, and 21 microns, measured from the ground are consistent with the IRAS measurements. The star, at a distance of 820 parsecs (Engels, 1979), is a red giant variable, not a DS.

0453+444 P03 (IRAS Circular No. 3). The spectrum corresponds to T = 350 K, and the maximum flux density to a DS of 1 $L_\odot$ at a distance 32 parsec. Longmore et al. (1984) with the UKIRT found a near infrared source at 1.6, 2.2, 3.5, 11.6, and 21 microns with a flux at 11.6 and 21 microns which is consistent with the IRAS data. At shorter wavelengths the flux is far in excess of the flux of a 350 K blackbody. Longmore et al. (1984) report a strong 3.05 micron ice absorption band. The object seems to be similar to 0507+528 P05.

0536+467 P05 (IRAS Circular No. 5). The spectrum corresponds to T = 300 K, and the maximum flux density to a DS of 1 $L_\odot$ at a distance 24 parsec. No other observations are available.

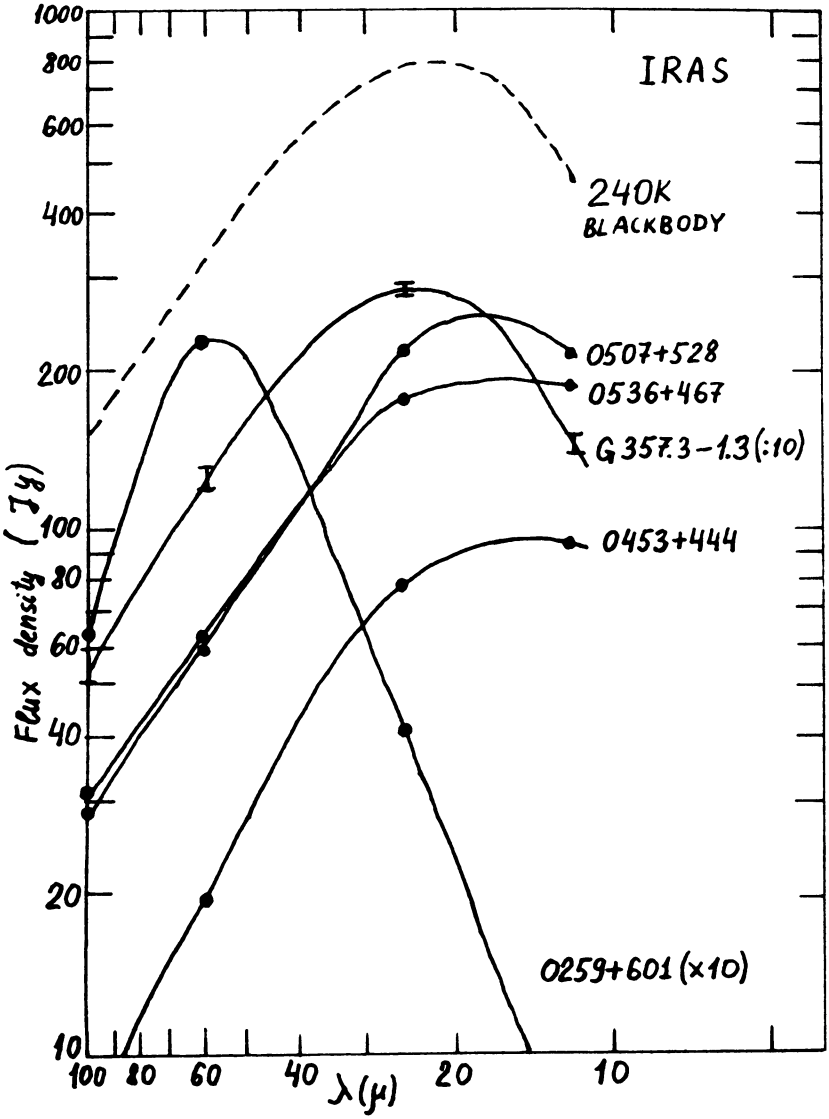

Figure 1. IRAS sources with maxima in the IRAS spectrum (IRAS Circulars No. 1, 2, 3, 5, 10, Nature (1983-84)). The flux density has been corrected for a blackbody spectrum according to the IRAS calibration (Neugebauer et al., 1984).

G 357.3-1.3 (Gautier et al., 1984). A very strong source with a $T = 220$ K blackbody spectrum. May be a DS of 1 L_O at a distance of only 7 parsec. No counterpart in the optical or in the microwave region is known.

0259+601 P02 (IRAS Circular No. 2). A cooler object with T=85 K, which could correspond to a DS of 1 L_O at 130 parsec. Compared to a blackbody, the spectrum shows excess at short wavelengths and is deficient at long wavelengths. The spectrum resembles that of the planetary nebula NGC 6302 (IRAS Circular No. 1).

All these sources are within 10° from the galactic plane. A search for sources with spectra peaking in this range but away from the galactic plane ("Minisurvey", IRAS Circular No. 10) produced only one case, out of 179 sources, object 1647-113 P10 with $T = 200$ K which could correspond to a DS of 1 L_O at 190 parsec.

The small distances obtained for 1 L_O DS are incompatible with their preferential position close to the galactic plane. Assuming a half width of 3400 pc for the Z-distribution of the Galaxy, one can find that they must be at much larger distances of about 1 kpc and have luminosities of 10^3-10^4 L_O, which is the luminosity of a typical late type red giant star. The confusion between red giants with thick circumstellar dust envelopes and possible DS in the IRAS survey is a serious problem, and to differentiate between the two we need additional data.

3. A MICROWAVE SEARCH

In the IRAS survey one might find only those sources with a peaked spectrum that correspond to an effective temperature above 60 K. DS of lower temperatures must be searched for in the submillimeter and in the microwave regions. For very large DS, with radii approaching a fraction of a parsec or more, the temperature will be close to the universal background temperature $T_b = 2.7$ K. In the limit when $T - T_b = \Delta T < T_b$ we get,

$$\frac{\Delta T}{T_b} = \frac{10^{-8}}{D^2_{kpc}\,\Omega} \frac{L}{L_O} \qquad (3)$$

where D is the distance to a DS, and Ω the solid angle subtended by the DS from the Earth. This relation defines an angular spectrum of the background temperature fluctuations as measured by a radio telescope with beam of solid angle Ω. The search, therefore, for such cold DS in the microwave region may utilize the same technique used for measurements of the fluctuations of the microwave background radiation. One recent satellite experiment conducted at 8 mm has covered all the sky with a sensitivity $\Delta T/T \sim 10^{-2}$ and $\Omega = 10^{-2}$ (Strukov and Skulachev, 1984). Preliminary results indicate that no cold DS of 1 L_O within 100 pc was detected, provided it had a blackbody spectrum at 8 mm. The requirement for a blackbody spectrum in the Rayleigh-Jeans region does not seem to be very strict. The optical depth of a DS must be greater than unity only in the spectral regions where the emission of the star (optical) and of the DS ($\lambda \sim 5000/T$ microns) peak. Outside of these regions the DS may be transparent and emit less than a blackbody. In this case the DS could be detected only near their spectral peaks, and relation (3) will represent only an upper limit.

4. CONCLUSIONS

I. Astroengineering activity aimed at utilizing most of the energy emitted by a star of 1 solar luminosity $L_{\odot}$ can be detected by current astronomical surveys in the infrared to microwave regions of the spectrum out to distances of 1 kiloparsec.

II. Analysis of the published extracts from the IRAS survey has revealed several possible candidates for such activity, but they can easily be confused with thick circumstellar dust shells around red giant stars. The confusion may be resolved by additional data from observations of OH and SiO emission, infrared spectra, proper motions, etc.

III. Future work may involve surveys at millimeter and submillimeter wavelengths with high angular resolution, a search through the full IRAS catalogue for sources with peaked spectra and subsequent supporting astronomical observations to reveal their nature.

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