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IRAS[1] OBSERVATIONS OF OH / IR STARS

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ABSTRACT

We present the preliminary results of *IRAS* survey observations of a sample of 40 very evolved stars, all detected originally as OH maser emission sources. In several cases, the spectrum is very much redder than for those sources identified from the ground. Color-color plots show that there is a continuous sequence from classical Mira variables to the reddest OH/IR stars. However, the reddest stars differ somewhat: they pulsate only weakly or not at all. Probably, they have reached the end of their evolution on the asymptotic giant branch.

Subject headings: infrared: spectra — masers — stars: late-type

I. INTRODUCTION

OH/IR stars are characterized by double-peaked 1612 MHz OH maser lines, and they have very red energy distributions with near-infrared color temperatures around 500 K. They are stars in the latest stages of evolution on the asymptotic giant branch with mass loss rates of typically 10^{-5} $M_{\odot}$ yr^{-1} (e.g., Baud and Habing 1983).

The majority of OH/IR stars have been discovered during systematic 1612 MHz OH surveys along the galactic plane (e.g., Baud *et al.* 1981). Subsequent near-infrared observations yielded identifications for most stars observed, but in a few cases the IR counterpart remained undetected (e.g., Jones *et al.* 1982).

Herman (1983) found for the OH/IR stars a flux density ratio between 35 μm and 1612 MHz of about 3, confirming the prediction by Elitzur, Goldriech, and Scoville (1976). This means that all OH/IR stars should easily be detected in the *IRAS* survey.

In this *Letter* we report on the preliminary *IRAS* results for a sample of relatively bright OH/IR stars, for which extensive OH variability data are also available.

II. OBSERVATIONS AND REDUCTION

The *IRAS* survey instrument used for these observations is described in Neugebauer *et al.* (1984, hereafter Paper I). We used the data produced by the quick-look facility in Chilton, England. The internal photometric errors are approximately 10%, and the band-to-band calibration uncertainty is of the same order.

The sample consists of the 43 OH/IR stars in Baud's catalog (Baud *et al.* 1981) between galactic longitudes 10° and 90° with an OH peak flux density larger than 4 Jy. All these stars have been monitored in OH for a period of 3–5 years with the 25 m Dwingeloo dish (Herman 1983) in order to study their variability.

Using only positional information, we identified the *IRAS* counterparts of 40 OH/IR stars. In all these cases, only one *IRAS* source (position uncertainty 45″ by 9″, see Paper I) coincides with the OH or ground-based IR position (uncertainties less than 15″). In one case, the star lies very close to an H II region which dominates all the *IRAS* bands, and in two other cases the positions were not good enough to make an identification. The flux densities at the standard wavelengths of 12, 25, and 60 μm were calculated taking into account the spectral energy distributions of the sources (see Paper I). We do not use the results at 100 μm because we suspect confusion problems for most sources, which are all in the galactic plane.

III. RESULTS

In Figure 1, we show the spectra of two OH/IR stars for which we also have ground-based or airborne data. OH 26.5+0.6 is a typical large-amplitude OH/IR star that has been observed out to 50 μm by Werner *et al.* (1980) at about the same phase. OH 17.7−2.0 is the reddest OH/IR star detected from the ground (Herman 1983); it varies little, if at all.

Figure 2 shows the color-color diagram for 31 OH/IR stars detected in all three bands. We have added 18.5+1.4, for which only an upper limit was found at 12 μm. For comparison, we have also indicated with crosses a number of OH/IR stars that were first known in the optical or infrared (optical Mira variables and IRC and AFGL sources with OH maser emission). The line indicates the position of blackbodies at various temperatures.

IV. DISCUSSION

Figure 1 shows that the energy distribution of OH 26.5+0.6 is very wide with color temperatures from 500 K in the

[1]The *Infrared Astronomical Satellite* was developed and is operated by the Netherlands Agency for Aerospace Programs (NIVR), the US National Aeronautics and Space Administration (NASA), and the UK Science and Engineering Research Council (SERC).

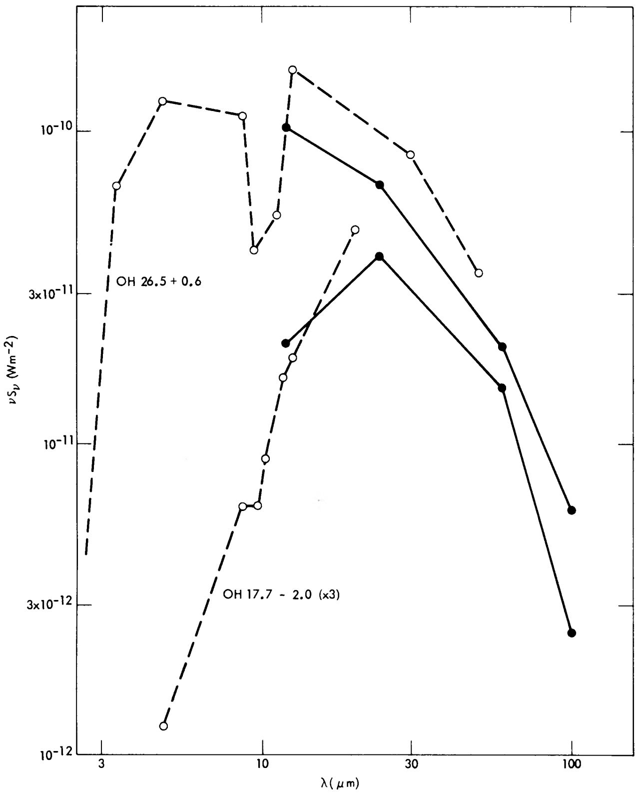

FIG. 1.—The infrared spectra of OH 26.5+0.6 and OH 17.7−2.0 composed of *IRAS* data (*filled circles*) and ground-based data (*open circles*: Werner *et al.* 1980; Herman 1983).

near-infrared to 150 K in the far-infrared. The other four OH/IR stars observed by Werner *et al.* (1980)—all large-amplitude variables—have similarly wide energy distributions. The spectrum of OH 17.7−2.0 is much narrower with color temperatures between 250 and 150 K.

Figure 2 clearly shows a continuous band from optical Mira variables with OH emission, at color temperatures around 2000 K, through the IRC and AFGL sources at about 40 K, to the large-amplitude OH/IR stars, and finally to the extremely red, small-amplitude OH/IR stars reaching down to about 100 K. Of course, these color temperatures have little physical meaning because the dust emission that dominates the spectrum is not like that of a blackbody and because of the strong temperature gradient in the dust envelope.

This large range in redness can be explained only by a large range in column density of the circumstellar shell. Since the flow velocity changes less than a factor of 2 from object to object, this implies a large range in the mass loss rate. The bluer OH/IR stars are known to lose mass at about 10^{-5} $M_\odot$ yr^{-1}, and the extremely red ones must have mass loss rates in excess of 10^{-4} $M_\odot$ yr^{-1}. If our current ideas are right, these stars must soon become planetary nebulae.

Most remarkable in Figure 2 is the apparent break in variation properties around a 12 μm to 25 μm ratio of 1. All stars with bluer colors have fairly large amplitudes (similar to the Mira variables), and redder stars have small amplitudes, if any. This dichotomy is all the more remarkable because there is no continuous correlation between amplitude and color in the data. Herman (1983) suggests that the weakly pulsating stars have reached the end of their evolution. Baud and

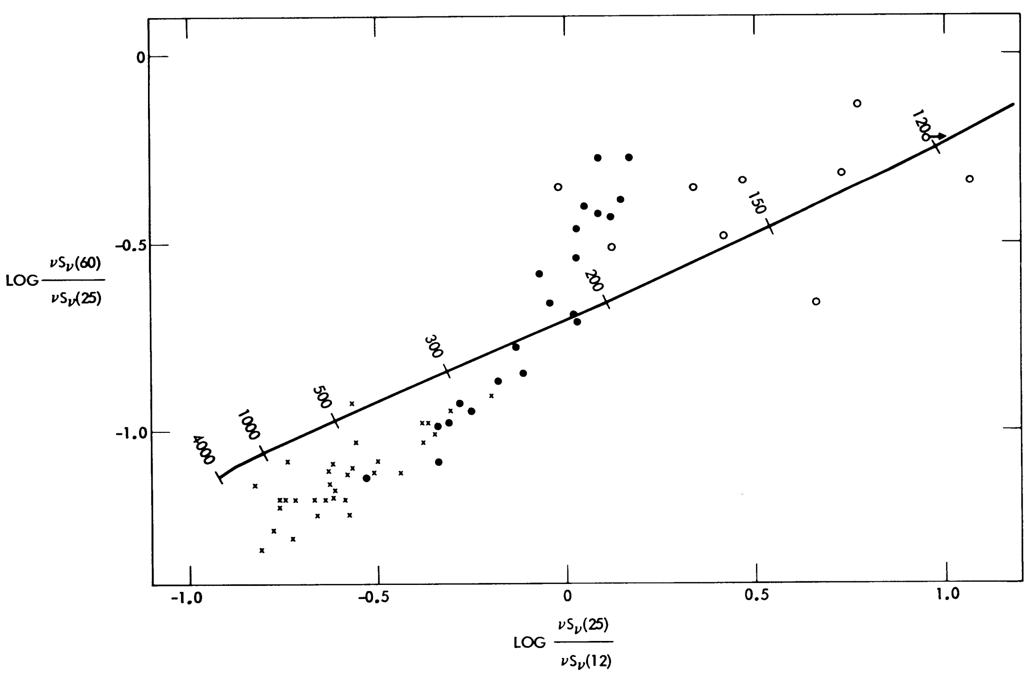

FIG. 2.—Color-color diagram of the (νS_ν) ratios between 12, 25, and 60 μm. The open circles indicate the OH/IR stars with a peak-to-peak OH amplitude of less than 0.30 mag, and the filled circles refer to those with larger amplitudes. The crosses indicate optical Mira variables and IRC and AFGL sources with OH emission. The line gives the locus of blackbodies at various temperatures.

Habing (1983) suggest that the mass loss rate is largest at the end of the evolution. This is consistent with the very red color observed for the weakly variable sources.

All sources have large signal-to-noise ratios at 25 μm. Some objects are very distant, 8 kpc or more (Herman 1983). The *IRAS* survey will find hundreds of weaker specimens of the same kind. Their identification offers the possibility of interesting studies of galactic structure, especially when the radial velocities are measured through follow-up detection as OH masers.

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