Poster contribution to IAU Symposium 170, *CO: Twenty-five Years of Millimeter-wave Spectrocopy*, 29 May – 2 June 1995, Tucson, Arizona

Mass Loss from OH26.5+0.6

K. Justtanont (NASA/Ames Research Center), C.J. Skinner (Space Telescope Science Institute), A.G.G.M. Tielens (NASA/Ames Research Center), M. Meixner (University of Illinois), F. Baas (Leiden Observatory and Joint Astronomy Center, Hawaii)

We present a self-consistent model for the dust and gas outflows from the extreme OH/IR star, OH26.5+0.6. The source has a deep 10 μm absorption, inferring a very high mass loss rate ($\dot{M} = 5.5 \times 10^{-4} M_\odot/yr$) while the CO J=1-0 and 2-1 lines suggest a more tenuous mass loss rate in the past ($\dot{M} = 10^{-6} M_\odot/yr$). From these observations plus the recent observations of CO J=3-2 and 4-3 transitions, we have concluded that the star has entered the superwind phase when the mass loss rate increases dramatically during the past 200 yrs.

INTRODUCTION

A star loses a significant fraction of its mass when it is on the Asymptotic Giant Branch (AGB) due to pulsation. The gas is driven to its terminal velocity by radiation pressure on dust grains which condense from the outflow. Stars with $C/O > 1$ have signature of SiC at 11.3 μm in their spectra. For stars with $C/O < 1$, condensates are expected to be silicates with spectral features ate 9.7 and 18 μm. These stars often exhibit OH maser emission.

It is of interest to know how stars terminate the AGB phase. It has been suggested that mass loss slowly increases as stars evolves up the AGB (Baud & Habing 1983). Alternatively, mass loss can abruptly increase at the end of the AGB in a form of superwind (Renzini 1981; Bowen & Willson 1991).

OBSERVATIONS

The infrared observations were done on the 3.8-metre UKIRT. We obtained 10 and 20 μm spectra using the Cooled Grating Spectrometer 3 (CGS3, see Justtanont et al. (1994) for details) while the mid-IR images were obtained using the Berkeley/LLNL mid-IR array camera (Arens et al. 1987).

We observed CO J=3-2 and 4-3 with the 15-metre JCMT using receivers B3(i) and C2(i) at the rest frequencies of 345 and 461 GHz, respectively. Unfortunately, the interstellar contamination is not completely cancelled out in the spectrum of J=3-2 transition.

Table 1: Input parameters for OH 26.5+0.6

M_*	8 $M_\odot$
T_{eff}	2200 K
R_*	6.0×10^{13} cm
R_{in}	4.5 $\times10^{14}$ cm
R_{COphot}	5.95 $\times10^{16}$ cm
$\dot{M}_d$	2 $\times10^{-6}$ $M_\odot$ yr^{-1} for $r < 8 \times 10^{15}$ cm
	3.6 $\times10^{-9}$ $M_\odot$ yr^{-1} for $r > 8 \times 10^{15}$ cm
$\dot{M}_d/\dot{M}_g$	3.6 $\times10^{-3}$
v_{exp}	15.4 km s^{-1}
D	1.37 kpc
f_{CO}	3 $\times10^{-4}$

MODELLING THE ENVELOPE OF OH26.5+0.6

We have developed a self-consistent model which can explain both infrared and sub-millimeter observations. The mid-IR images are unresolved, placing the upper limit on the emitting region at 10μm to $\leq 0.5''$. The IR spectrum suggests a presence of optically thick dust shell while CO J=2-1 observations implies a tenuous outer region of the envelope ($T_{MB} \sim 1.4$ K, Heske et al. 1990). From this information, the mass loss must have recently increased, but this has not propagated to the outer part where CO J=1-0 and 2-1 originate from.

The Spectral Energy Distribution

We have successfully modelled the IR energy distribution of OH 26.5+0.6, using a radiative transfer code based on the work by Haisch (1979). The input parameters are listed in Table 1. We took a cut off of the superwind radius to be 8×10^{15} cm where the mass loss rate is 2×10^{-6} $M_\odot$/yr, and suddenly drops to 3.6×10^{-6} $M_\odot$/yr in the outer part. Note that in Fig 1, the dashed curve is for a constant mass loss rate of 2×10^{-6} $M_\odot$/yr which is much higher than the observed photometric fluxes. The distance to the object has been obtained by van Langevelde et al. (1990) using the phase lag technique.

Modelling CO lines

We have calculated the radiative transfer in molecular lines using a Newton-Raphson method developed by Schönberg & Hempe (1986) which does not assume the Sobolev approximation.

We have found that for a high mass loss rate, the main parameter affecting the calculated antenna temperature is the gas kinetic temperature. We can use this to constrain the calculated J=3-2 and 4-3 transitions which originate from the super-wind region. The gas kinetic temperature is calculated from the energy balance (see Goldreich & Scoville 1976; Justtanont et al. 1994). From the dust mass loss rate of 2×10^{-6} $M_\odot$/yr, the dust-to-gas mass ratio required to drive the wind to 15.4 km/s is 3.6×10^{-3}, giving the gas mass loss rate of 5.5×10^{-4} $M_\odot$/yr. The mass loss rate in the outer part is assumed to be 10^{-6} $M_\odot$/yr. The resulting line profiles are plotted in Fig 2.

CONCLUSION

From our model of OH26.5+0.6 both in the IR and sub-millimeter, we conclude that OH26.5+0.6 has recently entered the superwind phase when mass loss rate suddenly increases. The radius of the superwind is 8×10^{15} cm and with the expansion velocity of 15.4 km/s, this increase in the mass loss occurred 200 yrs ago. This small superwind region is consistent with our mid-IR images which put the upper limit at 0.5″ for the emitting region.

References

Arens, J.F., Jernigan, J.G., Ball, R., Peck, M.C., Gaalema, S., & Lacy J. 1987, in Infrared Astronomy with Arrays, ed. C.G. Wynn-Williams & E. Becklin (Honolulu:University of Hawaii), p 256

Baud, B., & Habing, H.J. 1983, A&A, 127, 73

Bowen, G.H., & Willson, L.A. 1991, ApJ, 375, L53

Goldreich, P., & Scoville, N. 1976, ApJ, 205, 144

Haisch, B.M. 1979, A&A, 72, 161

Heske, A. Forveille, T., Omont, A., van der Veen, W.E.C.J., & Habing, H.J. 1990, A&A, 239, 173

Justtanont, K., Skinner, C.J., & Tielens, A.G.G.M. 1994, ApJ, 435, 852

Renzini, A. 1981, in Physical Processes in Red Giants, eds. I. Iben, Jr & A. Renzini, (Dordrecht:Reidel), p431

Schönberg, K., & Hempe, K. 1986, A&A, 163, 151

van Langevelde, H.J., van der Heiden, R., & van Schooneveld, C., 1990, A&A, 239, 193

Figures

Fig 1 The IR energy distribution of OH26.5+0.6. Open circles are our observed CGS3 spectra and other photometric points are published data The solid curve is our model with the two-density regime while the dash line is for a constant mass loss rate.

Fig 2 The calculated line profiles for CO J=3-2 and 4-3 compared to our JCMT observations.