VIBRATIONALLY EXCITED SILICON MONOXIDE MASERS

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ABSTRACT

Published data on a select group of SiO maser sources have been analyzed for velocity variations as a function of phase. No apparent correlation was found to a level of about 2 km/s. This places constraints on the location of the maser molecules. Such a correlation should be present at some level. The implications for future high resolution infrared measurements are discussed.

We have carefully analyzed published data on the stellar maser sources R Leo, chi Cyg, W Hya, o Ceti and R Cas to learn more about the environment of SiO masers. The intent is to find the probable properties of infrared spectral lines of SiO that are to be observed in the near future with an infrared heterodyne spectrometer, and to determine what new information the infrared measurements may yield.

Most published SiO maser spectra have been carefully analyzed. The velocity of the emission peak and the velocity extent (width) of emission have been examined as a function of stellar phase; there were no apparent correlations to within 2 km/s. This result is somewhat surprising since Hinkle (1978) has measured velocity pulsations of 16 and 27 km/s of the 2 micron OH and CO emission from the star R Leo. There are two tentative conclusions to be drawn:

1. The agreement of the velocity of the narrow SiO maser feature with that of the ground state SiO centroid and with center of the OH peaks, plus the apparent lack of correlation noted above, suggests that the narrow SiO features are tangentially amplified, and should therefore mark the stellar velocity to within a few km/s.

2. Further, the apparent lack of an observable systematic effect in the line wings (maximum and minimum extent) is consistent with the apparent lack of a blue shift of the wings (or "broad feature") with respect to the peak. This implies that the maser feature

B. H. Andrew (ed.), Interstellar Molecules, 537–538.

https://doi.org/10.1017/S0074180900073186 Published online by Cambridge University Press

originates far enough from the star that geometrical blockage of emission from the far side is negligible. It is interesting in this regard that each successive vibrational state ought to be excited closer to the star. The observations of Scalise and Lepine (1978) and Snyder et al. (1980) of simultaneous v=1,2, and 3 maser SiO lines show the v=3 to be substantially blue shifted from v=1 and 2. Could this be an example of geometrical blockage?

Consideration of the above plus the dynamical scale height would appear to imply that the SiO emission originates at radial distances greater than about 1.8 stellar radii in typical type I objects. In principle limits can also be placed on the maximum distance from the stars at which maser emission can occur. Under average conditions of uniform mass loss near the star, the gas density should decrease as R^{-2}. When the dust grains condense, they are accelerated and carry the gas along. Conservation of mass implies that the gas density will decrease even more sharply in this accelerated region, i.e. as R^{-3}. In addition, the fractional abundance of gaseous SiO is expected to drop dramatically as SiO condenses onto dust grains. Thus there should be far less gaseous SiO beyond the grain condensation radius, so that the maser would be expected to occur within this region.

Therefore these two lines of inquiry indicate that the SiO maser originates somewhere roughly beyond the dynamical scale height but not significantly further than the grain condensation radius. Quantitatively this should be about 2-3 stellar radii for type I sources.

The lack of observable velocity pulsations is very convenient for the infrared heterodyne measurements, which have inherently high resolutions. However, such correlations of velocity with phase are expected at some level. It would appear that the rotational level populations for each vibrational state should be directly determinable from the infrared measurements, so that the range of possible pumping mechanisms would be tightly constrained. It also appears probable that the infrared measurements will supply a wealth of data on the stellar environment.

REFERENCES

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