A SEARCH FOR SiO MASERS IN ORION-LIKE REGIONS

RICHARD BARVAINIS
National Radio Astronomy Observatory,[a] Edgemont Road, Charlottesville, Virginia 22903-2475

DAN P. CLEMENS
Five College Radio Astronomy Observatory and Department of Physics and Astronomy, University of Massachusetts, Amherst, Massachusetts 01003
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ABSTRACT

A sensitive search for SiO maser emission toward objects possessing high-velocity flows and/or disk geometries has revealed no Orion-like sources. The ratios of the luminosity limits reported here to the Orion SiO maser luminosity range from 0.04 to 0.0002, indicating that the Orion masers are associated with a unique set of physical conditions and not any widespread phenomena, even at a weak level. We report detection of a new SiO maser toward the reflection nebula OH231.8 + 4.2, exhibiting characteristics typical of the SiO masers seen toward late-type stars.

I. INTRODUCTION

The SiO masers in Orion appear to be unique. Unlike all other known SiO masers, which exist in the vicinity of late-type stars, the masers in Orion are located in a region of star formation. They appear to be closely associated with IRc2 (Wright and Plambeck 1983), an infrared source thought to be powered by a young O or B star, and their velocity profile shows a double-peaked structure reminiscent of OH masers in expanding shells. This overall profile shape has been relatively stable for the past 10 yr, unlike the variable profiles of late-type star masers.

Sensitive searches for SiO masers in other star-forming regions have yielded negative results (Genzel *et al.* 1980; Jewell *et al.* 1984). However, these searches did not use as selection criteria two recently discovered characteristics of the Orion phenomenon: The high-velocity bipolar outflow from IRc2 (Erickson *et al.* 1982; Wright *et al.* 1983) and the presence of a molecular disk or torus surrounding IRc2 (Plambeck *et al.* 1982). Barvainis (1984) has modeled the Orion SiO masers as originating in a disk which is rotating and expanding.

Here we report the results of a search for Orion-like SiO masers in 12 regions where the presence of a disk or torus might be inferred, either through direct observation (e.g., S106, Bally, Snell, and Predmore 1983), from the presence of bipolar outflow (e.g., L1551), or from other considerations (the bipolar reflection nebulae; see, e.g., Morris 1981). No Orion-like masers were found; however, we did detect a weak new SiO maser in the bipolar reflection nebula OH231.8 + 4.2, a maser probably associated with the long-period variable star at the nebula's center.

II. OBSERVATIONS

The search for $v = 1, J = 2 - 1$ SiO emission at 86.243 28 GHz was conducted using the FCRAO* 14-m telescope, on 1983 February 26. The cooled Schottky receiver gave total SSB system temperatures in the range 400–700 K, depending on the rather variable weather conditions encountered during the run. Telescope sensitivity was 50 Jy/K, derived from measurements of the planets, and antenna temperatures were calibrated using the standard chopper wheel method. Pointing was checked using Venus and the R Leo maser, and did not change by more than 10″ (~1/6 of a beamwidth) during the observations. The velocity windows searched were 445 km s^{-1} in a 512×250 kHz filterbank, and 890 km s^{-1} in a 256×1 MHz filterbank. We reobserved the OH231.8 + 4.2 maser on 1983 June 8, with similar system parameters.

Our results are summarized in Table I. Upper limits quoted are twice the rms noise in 1-MHz filters. In the last column of Table I, we compare our upper limits to the source luminosity to the Orion maser luminosity. If any masers are present in the star-forming regions searched, they must be intrinsically weaker than Orion by factors of 10^2 to 10^4.

Two observations, taken about three months apart, of the new maser in OH231.8 + 4.2 are presented in Fig. 1. The June spectrum may need to be scaled by a factor 1.3–1.4, due to the possibility of a small pointing offset during that observation, but it is nonetheless apparent that the maser varied considerably in profile shape and intensity between the measurements.

III. DISCUSSION

To date, some 48 regions of star formation have been searched for SiO maser emission, most with moderate to high sensitivity (Genzel *et al.* 1980; Jewell *et al.* 1984; this paper). Although many of these regions do not exhibit high-velocity outflow or disk-like structure, at least 13 of the 16 (excluding Orion) bipolar high-velocity outflow sources listed by Bally and Lada (1983) have now been searched, all with negative results. It is thus difficult to avoid not only the oft-reached conclusion that the presence of SiO masers in Orion makes this source unique among star-forming regions in general, but now also among a recently elucidated subset of regions whose geometric and kinematic properties closely resemble Orion. Possible reasons for the extreme rarity of such masers are discussed by Downes *et al.* (1981) and, within the context of a detailed model, by Elitzur (1982).

Although bipolar reflection nebulae are thought to be associated with evolved stars, we included four such objects in our source list because like Orion, they exhibit molecule-bearing disks and axisymmetric outflow. Three of these contain O or B stars (M2-9, M1-92, and GL 2789; see Morris 1981 and references therein), and exhibited no detectable SiO emission. The fourth, the interesting and unusual nebula

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TABLE I. SiO maser search results.

Source	α (1950)	δ (1950)	Flux density[a] (Jy)	D (kpc)	L/L_{Orion} [b]
			Star-Forming Regions		
CRL 437	3 03 32.0	58 19 13.5	<2.8	0.5	$<4\times10^{-3}$
GL 490	3 23 38.8	58 36 39.5	<2.0	0.9	$<9\times10^{-3}$
L1551	4 28 40.0	18 01 52.5	<1.6	0.14	$<2\times10^{-4}$
NGC 2071	5 44 31.1	0 20 55.5	<1.5	0.5	$<2\times10^{-3}$
CRL 961	6 31 59.0	4 15 9.5	<2.8	1.6	$<4\times10^{-2}$
S106IR	20 25 33.8	37 12 50.5	<2.0	0.5	$<3\times10^{-3}$
LHα234	21 41 57.5	65 53 07.5	<1.0	1.0	$<6\times10^{-3}$
CEPH A	22 54 21.9	61 46 06.5	<1.4	0.7	$<4\times10^{-3}$
			Bipolar Reflection Nebulae		
OH231.8 + 4.2	07 39 58.9	− 14 35 44.5	9.0 (2/26/83) 3.8 (6/8/83)	2.0[c]	
M2-9	17 02 54.0	− 10 04 00.5	<1.6	0.9[d]	$<7\times10^{-3}$
M1-92	19 32 21.0	29 19 30.5	<1.3	<4.5[e]	<0.2
GL 2789	21 38 23.0	50 01 12.5	<3.0	7.5[d]	<1.0

[a] upper limits are 2σ.
[b] assumes $S_{Orion} = 700$ Jy, $D_{Orion} = 0.5$ kpc.
[c] Morris, Bowers, and Turner 1982.
[d] Calvet and Cohen 1978.
[e] Herbig 1975.

OH231.8 + 4.2, contains a late-type long-period variable star, possibly a Mira-type variable (Feast *et al.* 1983; Bowers and Morris 1984). Our detection of an SiO maser in this object probably does not indicate Orion-like conditions, since the maser has only a single spectral component rather than a double-peaked "shell" profile like that seen in Orion; rather, it is likely a "normal" stellar maser.

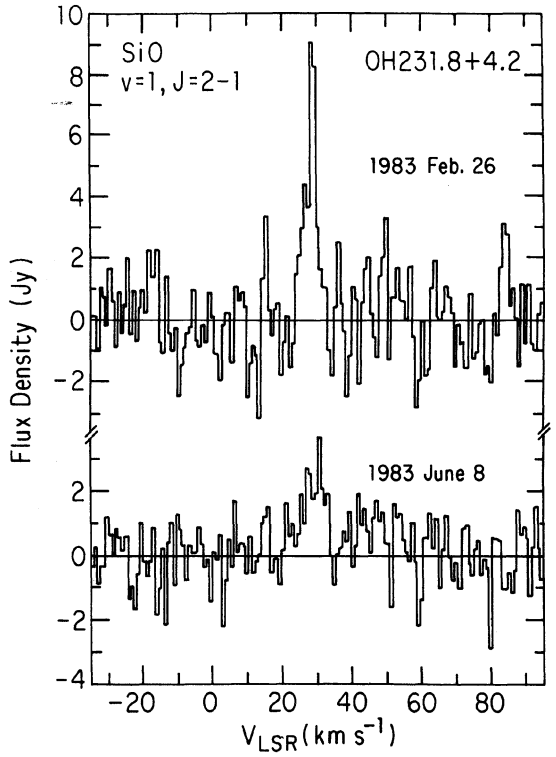

FIG. 1. Spectra obtained toward a new SiO maser in OH231.8 + 4.2.

OH maser emission in OH231.8 + 4.2 is characterized by a very wide (100 km s^{-1}) and flat profile with a single intense spike on the negative-velocity side of the profile center. Based on VLA maps, Morris, Bowers, and Turner (1982) modeled the OH emission as arising from radially expanding material concentrated toward the system's equatorial plane. The spike may be due to radio continuum from the central star amplified at velocities along the line of sight (Morris and Bowers 1980). The systemic velocity of the star would be expected to be the velocity of the center of the broad profile, at about 30 km s^{-1}. This is also the mean LSR velocity of H_2S emission (Ukita and Morris 1983), and corresponds to the peak of the SiO maser profile, reinforcing the notion that this maser is of the ordinary late-type star variety. The SiO photon luminosity, as derived from the February spectrum, is $\sim 10^{43}$ s^{-1}, a value fairly typical of SiO masers associated with Mira variables (Lane 1982).

IV. SUMMARY

Among objects possessing many of the same star-forming characteristics of the Orion source IRc2, such as bipolar high-velocity outflow and disk or torus geometries, no SiO maser emission was detected to mimic the Orion masers. The large ratios of the Orion SiO luminosity to the luminosity limits imply that the Orion masers are indeed unique, even under the close scrutiny obtained here. SiO masers in star-forming regions must require *more* than just IR sources, disks, and gas outflows.

Our detections of SiO masers in OH231.8 + 4.2 provide additonal evidence that the exciting star of this nebula is a typical late-type variable star.

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