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New Detections of 321 GHz Water Masers toward Late-Type Stars

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Abstract. The SEST telescope has been used for a submillimeter water maser survey toward late-type stars. Six new 321 GHz water masers were detected. These, as well as the earlier reported sources, VY CMa and *o* Cet, were also observed in the vibrationally excited water maser line at 96 GHz. However, only VY CMa and *o* Cet showed the 96 GHz emission. The line velocity of *o* Cet is blueshifted, suggesting that the hot water vapor at 96 GHz takes part in the pulsation-shock motion of the Mira variable.

1. Introduction

Circumstellar water masers probe warm gas close to the star. The different water maser transitions observed toward late-type stars (e.g., Spencer et al. 1979; Lane et al. 1987; Menten & Melnick 1989, 1991; Cernicharo et al. 1990) trace different regions in the circumstellar shell depending on their excitation temperature. Menten & Melnick (1991) found that 22 GHz masers (upper energy level at 640 K) show a broader velocity range than the warmer 321 GHz masers (upper energy level at 1840 K). On the other hand, spectra of the ν_2 vibrationally excited water line at 96 GHz (upper energy level at 3065 K) differ considerably from corresponding 321 GHz spectra, because the 96 GHz masers reside in a much hotter region close to the stellar photosphere, where also SiO masers are found (Menten & Melnick 1991).

2. Observations

We have used the 15 m Swedish-ESO-Submillimeter-Telescope (SEST) for a 321 GHz survey toward late-type stars. In addition, as a backup program for less good weather, we observed the sources in the ν_2 vibrationally excited water line at 96 GHz.

The telescope and instrumentation are described by Booth et al. (1989). The half-power beam width of the antenna is 15" and 52" at 345 and 96 GHz,

respectively. The observations were performed in a beam-switching mode with an 11' throw in azimuth. In all observations we used two spectrometers with frequency resolutions of 80 kHz and 1.4 MHz, corresponding to a velocity resolution of 0.08 and 1.3 km s^{-1}, respectively, at 321 GHz. The data were calibrated with standard chopper-wheel technique. The aperture efficiency is 0.61 and 0.16 at 96 and 345 GHz, respectively. The antenna temperature, T_A^*, of 1 K corresponds to a flux density of 26 and 98 Jy at 96 and 321 GHz, respectively.

3. Results and Discussion

3.1. New 321 GHz Water Maser Sources

Figure 1 displays both the high-resolution (*a*) and low-resolution spectra (*b*) of the new 321 GHz water maser sources: U Dor, R Dor, L2 Pup, VX Sgr, T Lep, and X Pav. The signal-to-noise ratio exceeds 4.0 in the high-resolution spectra of the first four sources. For X Pav (T Lep) the signal-to-noise ratio is 3.7 (3.1) in the low-resolution spectrum. Gaussian fits to the spectra yield flux densities in the range 14 - 53 Jy for the high-resolution spectra of the first three sources and 8.5 - 16 Jy for the low-resolution spectra of the last three sources. The 321 GHz flux densities of *o* Cet and VY CMa (Fig. 2) are 100 and 80 Jy, respectively.

3.2. Pulsation-Shock of *o* Cet Traced by the 96 GHz Water Maser

The vibrationally excited 96 GHz water line was seen only in VY CMa (Fig. 2, bottom left) and in *o* Cet (Fig. 2, bottom right). The Mira variable *o* Cet is a new detection at 96 GHz. The flux densities of *o* Cet and VY CMa are 3.2 and 3.0 Jy, respectively. The Doppler velocity of VY CMa is redshifted by 3.7 km s^{-1} as compared to the stellar velocity. Generally, redshifted 96 GHz emission is interpreted as coming from regions, where the expansion of the cicumstellar shell has not yet begun and where infall motions may be present (Menten & Melnick 1989).

In contrast, the Doppler velocity of *o* Cet is blueshifted by 3.1 km s^{-1}, whereas the 321 GHz line is close to stellar velocity. This can be understood, if the 321 GHz emission (originating in cooler gas) does not take part in the pulsation-shock motion of the hotter gas, traced by the 96 GHz emission. During maximum light phase of the Mira variable, a pulsation shock moves outward and blueshifted, vibrationally excited maser emission is observed

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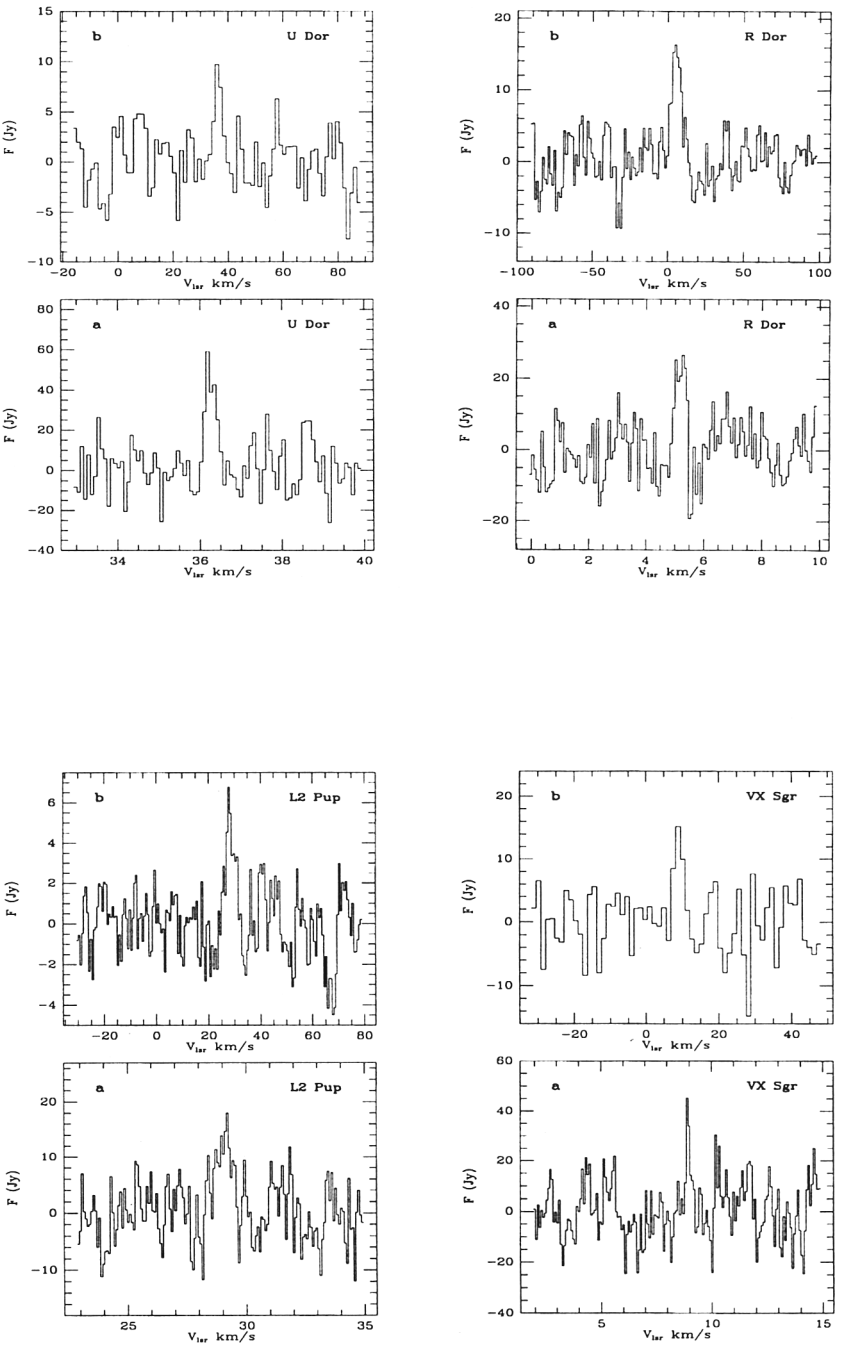

Figure 1. 321 GHz water maser spectra toward 6 late-type stars; (*a*) high-resolution spectrum, (*b*) low-resolution spectrum.

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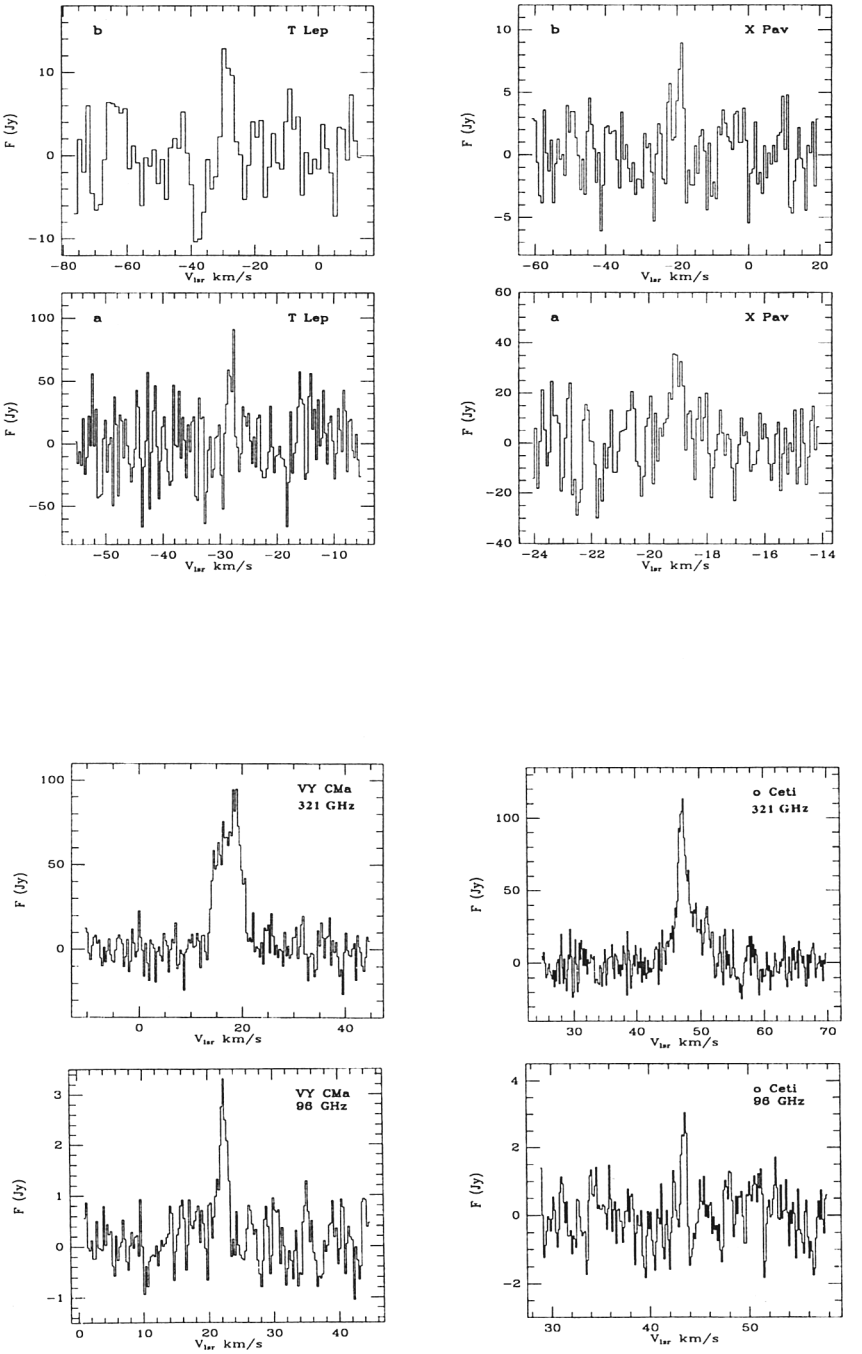

Figure 2. 321 and 96 GHz water spectra toward VY CMa and *o* Cet.

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