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OH masers in semiregular variables: Insights from long-term monitoring

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Abstract. Drifts in radial velocities of OH maser features of the three semiregular variable stars R Crt, RT Vir and W Hya have been analyzed. The radial velocities of the extreme blue- and red-shifted features drifted by about $0.2\,\mathrm{km\,s^{-1}}$ to $1\,\mathrm{km\ s^{-1}}$ on time-scales of few months to several years. In the case of W Hya a blending effect of spectral features can account for those drifts. In the two other sources the velocity drifts are likely to be intrinsic to the clumps for which the velocities of peak emission vary due to appearance or disappearance of maser emission in the regions where circumstellar matter is still accelerated.

1. Introduction

OH masers are rarely associated with semiregular variable stars (SRs) and occur only in the reddest objects with the mass loss rates of about $10^{-7}\,\mathrm{M_\odot\,yr^{-1}}$ (Szymczak et al. 1995). SRs are likely to be progenitors of Mira variables on the asymptotic giant branch (Kerschbaum & Hron 1992). OH maser emission from SRs appears at main-line frequencies only and comes from small, thin envelopes as compared to those of Miras and OH/IR stars (Szymczak, Cohen, & Richards 1998; 1999), so that it can be characterized by non-regular and/or erratic variations. Indeed, long-term monitoring observations of three semiregulars have shown a variety of OH maser behaviour (Etoka et al. 2001). In this paper we present the radial velocity variations of maser features on time-scales from a few months to 10−14 years. Analysis of velocity drifts will help to describe the kinetics of outflows in the envelopes of SRs and to verify models of OH variations.

Observations of the 1665 and 1667 MHz maser lines towards R Crt, RT Vir and W Hya semiregular variables were made with the Nançay radio telescope. A dual channel receiver was used to measure both circular polarizations. The

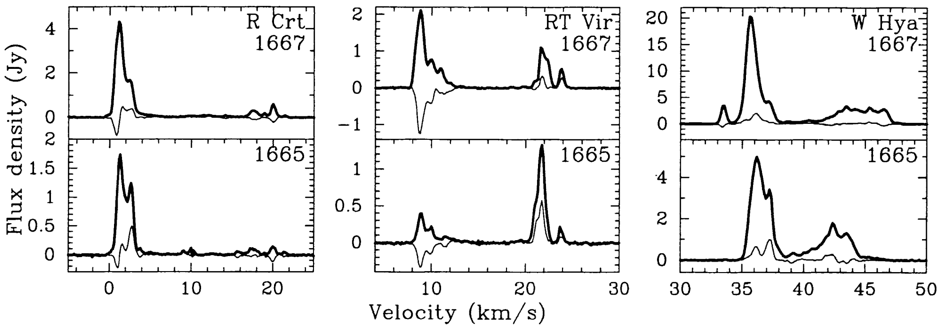

Figure 1. Average Stokes I (thick lines) and V (thin lines) profiles of OH maser emission at 1667 and 1665 MHz from the three semiregular variables.

system temperature was about 45 K. Typical velocity resolution was 0.07 or $0.14\,\mathrm{km\,s^{-1}}$ but sometimes spectra were obtained with a $0.28\,\mathrm{km\,s^{-1}}$ resolution. The noise level in the final spectra averaging the two polarizations was about 50 mJy for the highest spectral resolution. The targets were monitored over 10–14 years until 1995 November. Observing and data reduction procedures are described in detail by Etoka et al. (2001).

2. Results

The average OH maser profiles significantly deviate from standard double-peaked profiles (Fig. 1). Spectra are composed of 2–3 and 5–9 features at blue- and red-shifted velocities, respectively. The radial velocities of maser features were measured by fitting gaussian components to the maser profile.

The radial velocities of the 1667 MHz line of R Crt changed from 1.4 to $1.9\,\mathrm{km\,s^{-1}}$ and from 19 to $20\,\mathrm{km\,s^{-1}}$ for the extreme blue- and red-shifted features, respectively (Fig. 2). After $\mathrm{JD_m}$=4000 a $1\,\mathrm{km\,s^{-1}}$ drift over ~500 days was seen for the red-shifted feature. In this paper $\mathrm{JD_m}$=JD−2444950. The radial velocity of the blue-shifted feature at 1665 MHz varied in an irregular manner from 1.5 to $2.4\,\mathrm{km\,s^{-1}}$. The red-shifted feature at 1665 MHz exhibited moderate shifts in radial velocity (16.8 – $17.4\,\mathrm{km\,s^{-1}}$) prior to $\mathrm{JD_m}$=3800. Since $\mathrm{JD_m}$=4380 a new feature appeared near $21.3\,\mathrm{km\,s^{-1}}$ and its radial velocity drifted to $20.4\,\mathrm{km\,s^{-1}}$. A new feature also appeared on $\mathrm{JD_m}$=4500 at velocity $20.2\,\mathrm{km\,s^{-1}}$ and a systematic drift was observed until $\mathrm{JD_m}$=5000 (Fig. 2).

The amplitudes of velocity drifts of RT Vir features were lower than $1\,\mathrm{km\,s^{-1}}$ (Fig. 3). Weak systematic drifts of $0.2\,\mathrm{km\,s^{-1}}$ on time-scales of a few thousand days usually occurred but sometimes the maser features drifted by $0.5\,\mathrm{km\,s^{-1}}$ during ~150 days.

The radial velocity of the 1667 MHz very blue-shifted feature of W Hya at $33.8\,\mathrm{km\,s^{-1}}$ was very stable during 10 years. A similar behaviour was observed for the $36\,\mathrm{km\,s^{-1}}$ feature at 1667 MHz, while for the red-shifted feature a systematic drift of about $2\,\mathrm{km\,s^{-1}}$ occurred. The radial velocities of the extreme blue- and red-shifted features at 1665 MHz showed slow drifts by about $0.8\,\mathrm{km\,s^{-1}}$.

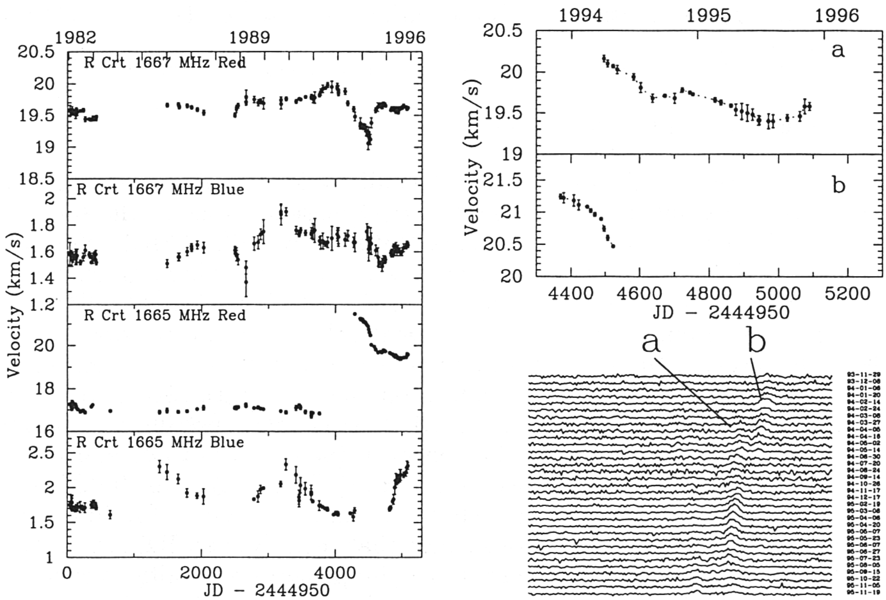

Figure 2. Left: Drifts of the radial velocity of the extreme red- and blue-shifted features of the 1665 and 1667 MHz spectra of R Crt. Right: Drifts of the radial velocity of the red-shifted feature of the 1665 MHz spectrum of R Crt from 1993 Nov to 1995 Nov (top). A set of the red-shifted spectra at 1665 MHz of R Crt (bottom).

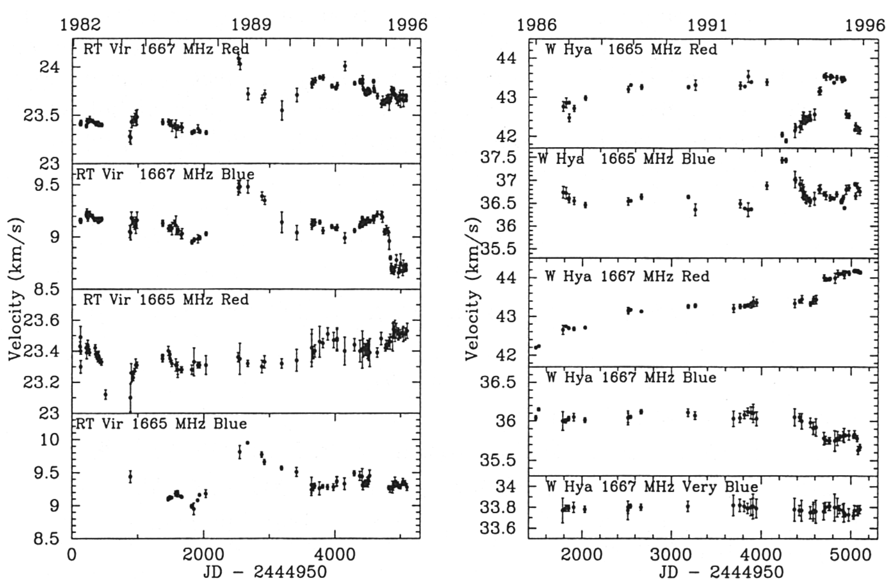

Figure 3. Radial velocity drifts of the blue- and red-shifted OH maser features of RT Vir (left) and W Hya (right).

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However, during the 2 last years of observations we observed $1-1.5\,\mathrm{km\,s^{-1}}$ drifts over 300–400 days.

3. Discussion and conclusions

This study shows considerable drifts in the radial velocities of OH maser features in SRs, which resemble the behaviour of H_2O masers. Because the spectra of R Crt and RT Vir are composed of a few features, we suggest that the velocity drifts are intrinsic to the clumps of outflowing material where maser amplification is sustained. Interferometric observation of R Crt has shown that OH emission comes from a few clouds in a small, thin envelope (Szymczak et al. 1999). Moreover, in the studied stars some maser features experienced eruptive variations during which maser amplification can be unsaturated (Etoka et al. 2001). Under unsaturated conditions OH masers may appear and disappear very quickly as a result of small differences in the density of OH molecules or the outflow velocity. Transient instabilities in the maser gain in the OH mainlines are expected as these lines arise from hot inner envelopes of radii 40–80 au (Szymczak et al. 1998; 1999). We suggest that in R Crt and RT Vir the radial velocity shifts are due to the appearance or disappearance of suitable conditions for masing in the inner regions of circumstellar envelope where the gas is still accelerated.

OH spectra of W Hya at velocities where some features show considerable drifts are very complicated. It is possible that strong blending effects occur in those parts of the spectra. Thus, the velocity drifts can be easily explained by different variations in the flux density of very close features (Peng 1989). This explanation appears to be supported by interferometric data (Szymczak et al. 1998), which revealed several maser components at virtually the same velocities.

The present study revealed drifts in the radial velocities of OH maser emission from R Crt and RT Vir. These drifts are likely intrinsic to maser appearance in clouds of different velocities in the accelerated regions of hot and thin envelopes. Monitoring of these SRs with high angular resolution is desirable to confirm this hypothesis.

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