Short Time Variability OH Masers in the W3 Nebula

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We present data of three years observations of OH masers in W3(OH) that we developed with 32-m antenna of Svetloe observatory.

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1 Introduction

A characteristic feature of the emission of interstellar molecular masers is their strong variability. It is common to distinguish short (minutes, hours) and long (days, years) time scale variations of maser emission. W3 nebula is the brightest representative of class I OH masers. In December 2011 we started a program aimed at the study of the variability of OH and H2O masers with the 32-m radio telescope of "Quasar" interferometric network at Svetloe Radio Astronomical Observatory (Leningrad region). In this paper we report the results obtained during three years of these observations (2012–2014) on the sourse of W3(OH).

2 Equipment and technique

When operated at 18 cm wavelength the 32 m antenna [1] has a beam halfwidth of 20', effective area 480 m^2, and a flux sensitivity of 5.7 Jy K^{-1}. The radio telescope records both circular polarizations. The noise temperature of the system at about 50 K. The two-channel FFT spectral analyzer have 2048 spectral channels with halfwidth of 0.488 kHz (0.088 km s^{-1}). Subsequent reduction included averaging over time with chosen intervals ranging from 0.5 to 5 minutes. The mean squared fluctuation, which was automatically computed by the spectrum parts free of line emission, ranged from 2.44 to 0.78 Jy, respectively.

3 The results of observations

The following figures show the light curves of the profile features at the velocities of their maximum emission. Unfortunately, the emission in the wings of profile features cannot be separated, because many weak components at different radial velocities fall within our wide beam. Note that bright components too may actually be blends composed of the emission of two to three maser “dots”.

3.1 Outburst of January 23, 2012

Fig. 1 shows the light curves for January 23, 2012 with 30-s time integration. The brightness of feature at -46.2 km/s at about UT 03:27 increased by about a factor of seven (up to 170 Jy) over ≈ 90 s long interval and then returned to the initial level. The halfwidth of its profile was equal to 0.5 km s^{-1} and remained stable to within 5 % during the outburst. The signal at the same radial velocity in left circular polarization increased by only 34 %. However, of special interest is the fact that perturbations also spread to the neighboring components of the line profile: in the same time the brightness of components at 45 and 44 km/s decreased (!) in the right polarization and remained stable in the left polarization. The feature at -46.2 km/s showed very high activity in early 2012. During the next 2.5 years its flux remained at about 20 Jy level with no rapid variations observed.

3.2 Variability of OH Emission on Time Scales of Several Hours

Another strange phenomenon was noticed in the 2013–2014 light curves of the features of the OH line profile at 1665 MHz. Fig. 2 shows the results of measurements made on October 16, 2014 with 300 s time integration. As is evident from the figure, the flux of features -47 and -45 km/s varied significantly in both circular polarizations over 10 hours: the flux of feature first varied by a factor of three and 1.8 in the right and left polarization, respectively, and that of second feature, by 25 % and 30 % in the right and left polarization, respectively. The most interesting point is that the flux variations of these features in right and left polarization are evidently anticorrelated. As for other features, their emission was mostly stable. Ten such events have been recorded over two years (during a total of 30 days of observations).

The detailed discussion of possible instrumental defects, any effect of the Earth atmosphere and the eventual presence of narrow-band interference as well as effects of the interstellar medium on the emission of OH masers at 18 cm may be found in our paper [2].

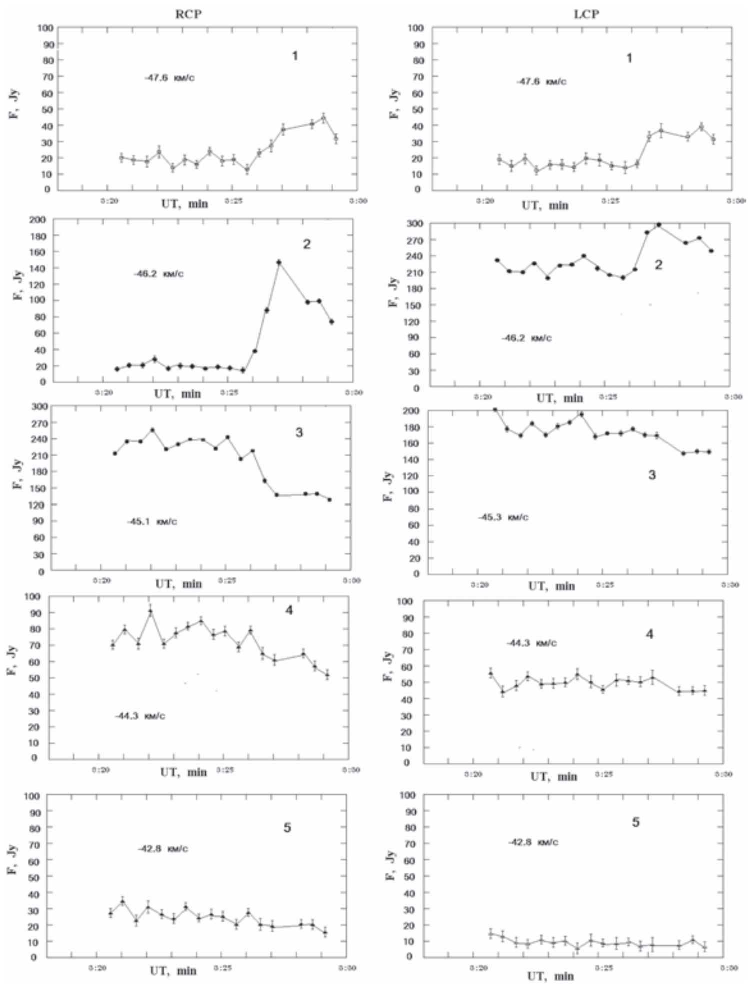

Fig. 1. -46.2 km/s feature outburst on January 23, 2012

4 Discussion of results

No such phenomena have ever been observed in the outburst of the OH maser that we recorded on January 23, 2012, however, we consider this event to be real. In this case its observed parameters allow some conclusions to be made concerning the physical properties of the emitting region. It is usually believed that the linear size of the emitting region Δl along the line of sight cannot be greater than $c\Delta t$, where c and Δt are the speed of light and the time scale of the variations of emission intensity, respectively. The observed time scale $\Delta t \approx 90$ s implies $\Delta l \approx 0.18$ AU, or 2.7×10^{12} cm.

The brightness temperature of the outburst for such angular size is of about 2×10^{16} K, which appears quite reasonable. The gain of the maser (if

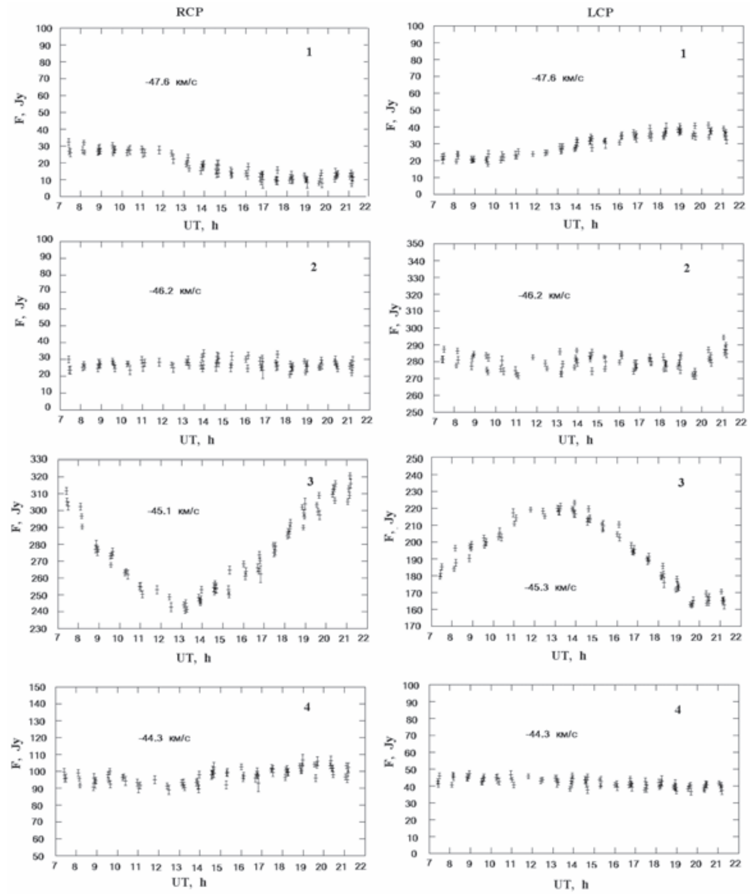

Fig. 2. -46.2 km/s feature outburst on January 23, 2012

we assume that the maser amplifies the continuum emission of the nebula) is of about 4.7×10^{12}, and its optical depth is $\tau \approx 29.2$ if the maser is in unsaturated mode. Note also that in the case of an unsaturated maser its gain depends exponentially on the parameters of the emitting region, and given the measured τ it should be increased by no more than 7 % to increase the maser brightness by a factor of seven.

References

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