PROCEEDINGS OF SCIENCE

Ultra-compact structures in galactic masers observed in the RadioAstron project

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H_2O masers associated with the massive star formation region W49N were observed in frames of the Space-VLBI project RadioAstron. Ultra-compact structures in the masers were detected on space-ground baselines up to 9.6 Earth diameters. The flux density of ultra-compact features does not exceed a percent of the single dish flux density. Some results of the data processing for three observing sessions performed in 2014-2015 are presented. The lower limit of minimal brightness temperatures and estimates of angular sizes of the brightest features corresponding to the ultra-compact maser spots of the W49N complex are obtained.

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Table 1: Observing sessions summary.

Epoch	Ground telescope array	Observing time	Band	Baseline length	Fringe spacing
2014 May 18	Effelsberg 100-m	1 hour	22 GHz	3.0 ED $\sim$38 000 km	74 μas
2015 April 27	Effelsberg 100-m Yebes 40-m Torun 32-m Hartebeesthoek 26-m	1 hour	22 GHz	9.6 ED $\sim$122 000 km	23 μas
2015 May 22	Green Bank 100-m Effelsberg 100-m Medicina 32-m Torun 32-m	50 min	22 GHz	8.6 ED $\sim$110 000 km	26 μas

1. Introduction

The high-mass star-forming region W49N (G43.16+0.1) is a part of W49A, which is the most massive and luminous star-forming complex in our Galaxy. The region W49N is located in the Perseus arm near the solar circle in the first Galactic quadrant at the distance from the Sun of 11.11$\pm$0.8 kpc [1]. The distance to W49N from the Galactic mid-plane is only 3 pc. This region contains numerous 22 GHz H_2O masers forming the most luminous maser set ($\sim$1 $L_\odot$) in the Galaxy. This makes the W49N region an excellent target for RadioAstron maser observations.

RadioAstron (RA) is the international space VLBI project involving the 10-m Space Radio Telescope (SRT) on board the satellite Spektr-R and ground radio telescopes [2]. The SRT was launched in 2011 on elliptical orbit whose plane is evolving with time with an apogee of up to 370 000 km and operates at frequencies of 22, 5, 1.6, and 0.3 GHz [3]. W49N was observed as part of the RadioAstron maser survey during 2014-2015 [4]. The highest angular resolution of 23 μas for galactic masers was achieved in W49N observations on a baseline of 9.6 Earth diameters (ED).

2. Observations

We conducted three observing sessions of W49N as listed in the Table 1. Left- and right-hand circular polarization data were recorded with a total bandwidth of 32 MHz per polarization. Cross-correlation data were obtained in a frequency channel spacing of 7.81 kHz. The antenna pointing and phase-tracking center for all W49N observations in Table 1 was set to RA= $19^h10^m13.4096^s$, DEC= $09^\circ06'12.803''$, where the most luminous UCHII region G in the W49N complex is located.

3. Results

The H_2O maser in W49N is known as a highly variable source demonstrating high-velocity bright features arising from time to time in a range of several hundred km/s. Such features may have flux densities up to several thousand Jy and then disappear. The main part of the W49N H_2O maser spectrum around the systemic velocity at $\sim$ 0 km/s was always observable and had a stably high flux density. Since RadioAstron can observe in the bandwidth of 32 MHz, the central frequency in all observations of W49N was chosen so that the main part of the spectrum fell into the

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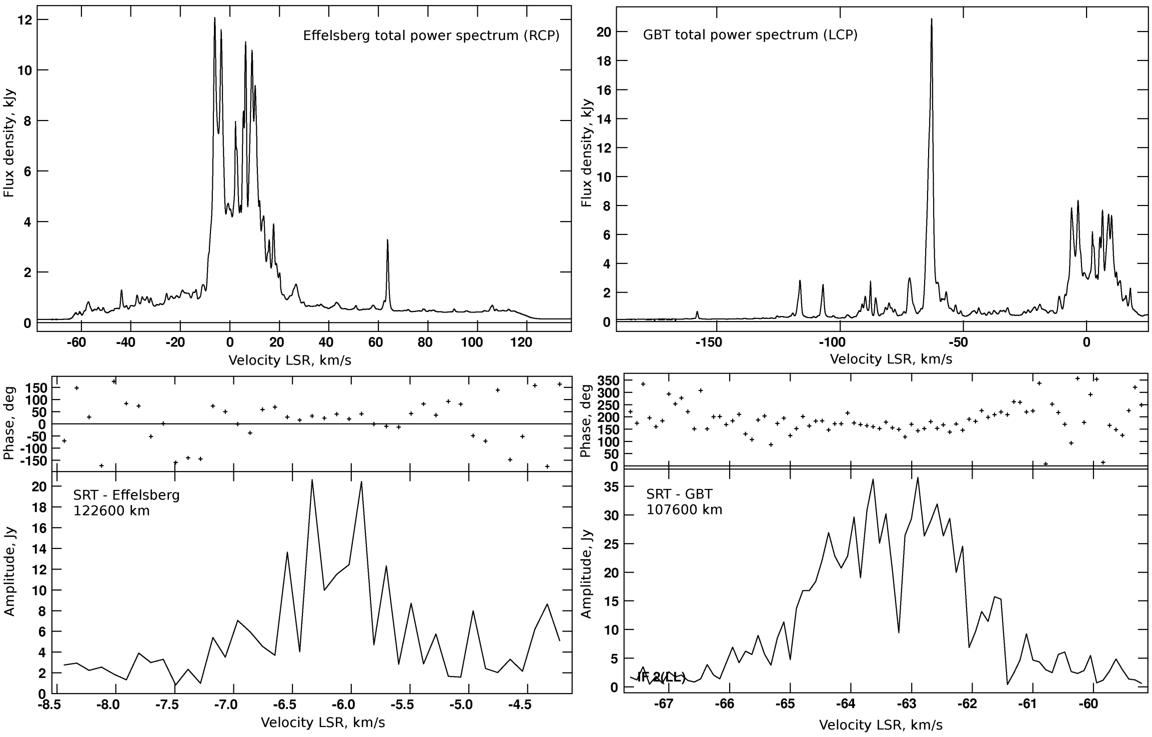

Figure 1: *Top panel*: Autocorrelation spectra of W49N obtained in the RadioAstron observations on April 27, 2015 (left) and May 22, 2015 (right). Telescopes are indicated on the figures. V_{LSR} ranges correspond to the upper side band used in these observing sessions with central frequency of 22228 MHz and 22236 MHz respectively. *Bottom panel*: Cross-correlation spectra of W49N maser features detected on space-ground baselines obtained in the RadioAstron observations. Corresponding length of baselines and telescopes are indicated on the figures.

band. Nevertheless, during the observing session on 27 April 2015 a short-living feature at 64 km/s was observed (see Figure 1, top left panel). According to monitoring on the Effelsberg 100-m radio telescope [5], this feature appeared a few weeks before the observation on RadioAstron and disappeared in a few months later. During the observation on 22 May 2015 a bright feature at −63 km/s was observed (see Figure 1, top right panel). The results of the post correlation data processing for these two sessions are shown on Figure 1. Amplitude calibration of the data was carried out using T_{sys} measurements obtained during observations.

Fringes on a space baseline of ∼3 ED between RA and 100-m RT in Effelsberg were found in the first session on May 18, 2014 for two spectral features at −6 km/s and at 6 km/s (see Figure 2). Lack of the intermediate length baselines does not allow us to explore the structure of the features so as to distinguish the flux density contributions from different structural components. With a given angular resolution we can obtain only a lower limit of the brightness temperature of a component as was suggested in [6]. Thus, for the brightest feature at −6 km/s we obtained $T_{b,min}$ ∼6.1e+14 K.

In the second session on April 27, 2015, the brightest feature at the velocity −6 km/s was detected at the RA-Effelsberg baseline at the fringe spacing 23 μas, what is the record fringe spacing achieved for galactic masers (see Figure 1, bottom left panel). The minimal brightness temperature of the corresponding maser spot is $T_{b,min}$ ∼5.7e+14 K. The short-living feature at

64 km/s has a fringe only on ground baselines up to the longest baseline Effelsberg-Hartebeesthoek.

In the third session on May 22, 2015, fringes at the space baseline RA-GBT were found for a group of features at VLSR -63 km/s (see Figure 1, bottom right panel). Weak fringe was also found for feature at -72 km/s. The minimal brightness temperature of the brightest feature at -63 km/s is $T_b \sim 1.1e{+}15$ K.

It is quite interesting that the three brightest components detected at space baselines in three experiments contain only 0.006, 0.001 and 0.002 of the total flux densities, respectively. Fringe spacings given in the last column of the Table 1 can be considered as nominal estimates of actual sizes of these components. Another thing, which should be taken into account, is that we could see the refractive scattering floor caused by interstellar scintillation when observing at such long baselines up to 9.6 ED [7].

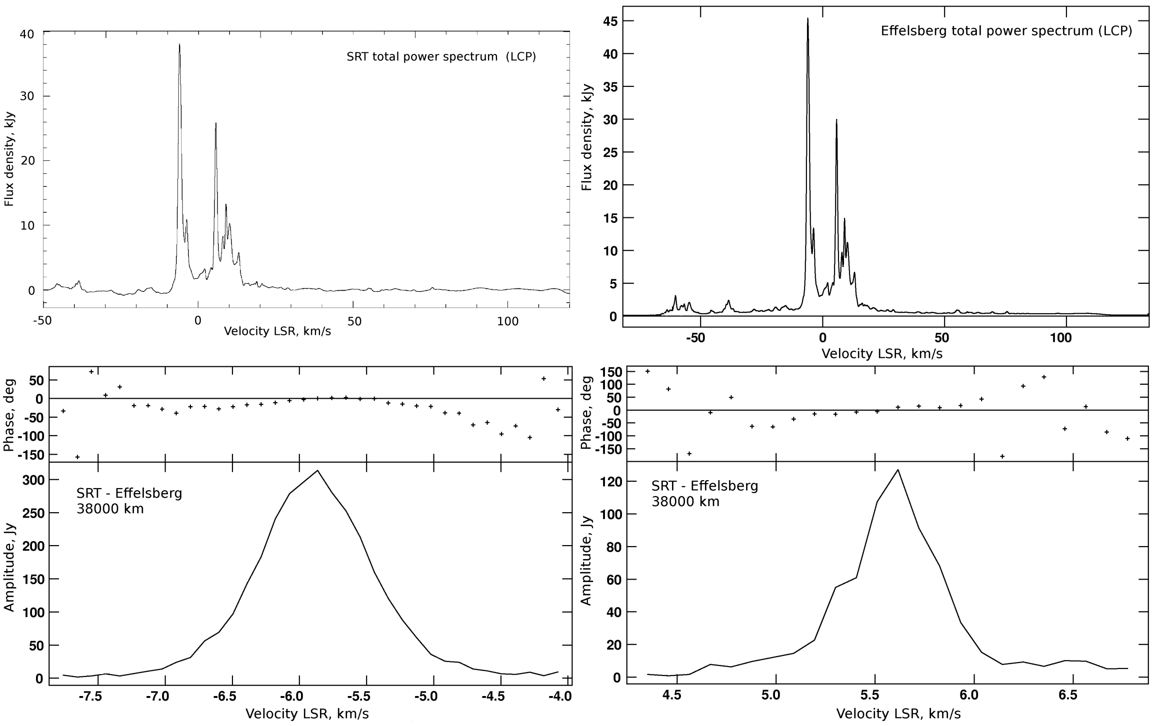

Figure 2: *Top panel*: Autocorrelation spectra of W49N obtained on the 10-m SRT (left) and 100-m Effelsberg (right) in the RadioAstron observation on May 18, 2014. V_{LSR} range at Effelsberg spectrum corresponds to the upper side band used in this observing session with central frequency of 22228 MHz. *Bottom panel*: Cross-correlation spectra of two W49N maser features detected on space-ground baseline between SRT and Effelsberg. Telescopes and corresponding length of baseline are indicated on the figures.

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