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Violent maser events in the circumstellar envelope of the pre-planetary nebula IRAS18276-1431

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Multi-epoch observations of the pre-planetary nebula IRAS18276-1431 (OH17.7-2.0) have revealed several narrow-band OH maser flares superimposed on the monotonic decay and rise of the integrated flux density at 1612/1665 and 1667 MHz, respectively. The flaring emission was highly polarized and came from well isolated and compact regions of the envelope. Generally the magnetic field prefers the orientation parallel to the axis of the bipolar lobes likely excavated in the envelope by tenuous bipolar winds.

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1. Introduction

IRAS18276-1431 is known as a strong 1612 MHz OH maser source since 1974 [1]. The central star has a spectral type earlier than K5 and effective temperature of 4 000 –10 000 K [8]. It has an optically thick, detached dust shell with a bimodal spectral energy distribution typical for a pre-planetary nebula (PPN). The 22 GHz water maser emission was gradually decreasing after 1987 and disappeared in 1991 [5]. The OH maser envelope shows a significant departure from spherical symmetry. MERLIN observations revealed a magnetic field of +4.6 mG and +2.5 mG at 1612 and 1667 MHz, respectively, that could be dynamically important for the shaping of the envelope [2]. Observations made in 2010 [7] revealed a weak SiO maser emission at 43 GHz, undetected before [10].

2. Maser variability

The OH maser emission at 1612, 1665 and 1667 MHz was monitored twice a month using the Nançay radio telescope (NRT) from 2002 to 2009 and in 2014. The NRT is a transit instrument (equivalent to a 93 m parabolic dish). The point-source efficiency was 1.4 K Jy^{-1}, the system temperature was 35 K. A spectral resolution of ∼0.07 km s^{-1} was used. The four Stokes parameters were provided by the system. Bursts of highly polarized OH maser emission were discovered in the three transition lines. The most prominent one appeared in the red-shifted part of the spectrum part at ∼73 km s^{-1} and lasted over ∼6 years (Wolak et al. in prep.). Its integrated flux density increased by a factor ∼3 during 2.5 years (Fig. 1). The integrated flux density of the red-shifted part of the spectrum excluding the bursting feature shows a linear decay similar to the blue-shifted part of the spectrum. Our observations supplemented with archival data confirm a linear decay of the 1612 MHz intensity over ∼36 years. Assuming a constant decrease rate, the 1612 MHz emission will fall below the detection limit before 2030. A monotonic decay and rise of the integrated flux density at 1665 and 1667 MHz, respectively, were also noticed (Wolak et al. in prep.). If the maser becomes unsaturated, the decrease may change to the exponential type and the disappearance will be faster.

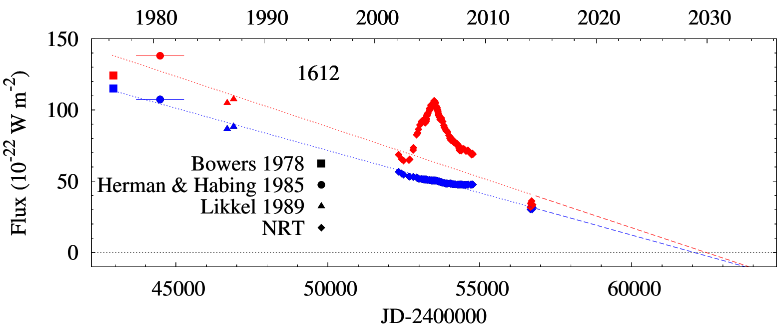

Figure 1: Secular changes of the OH total flux density at 1612 MHz. The red and blue symbols correspond to the total flux density of the red- and blue- shifted parts of the spectrum, respectively. The references to the archival data are given.

The 22 GHz observations using the Toruń 32 m radio telescope revealed a water maser emission of 25 Jy near 56.3 km s^{-1}. The system equivalent flux density was about 480 Jy and the spectral resolution was 0.03 km s^{-1}. Thus the emission reappeared after about 20 years. The emission feature has a nearly Gaussian shape and shows a velocity drift from 56.3 to 56.8 km s^{-1} during $\sim$1.5 year. [11].

3. Magnetic field structure

We have mapped the 1612 MHz emission in full polarization at two epochs (2006 and 2007) with MERLIN. The beam size for those observations was $\sim 0.''45 \times 0.''25$ and the spectral resolution was 0.18 km s^{-1}. The data calibration and reduction were carried out with AIPS using standard procedures for spectral line observations. Archival data from [2] were added for comparison. The spatial distribution of the electric vectors of the linearly polarized maser components globally confirms an ordered magnetic field in the envelope (Fig. 2). The long-lasting burst has occurred in the southern part of the envelope (magnified in Fig.'s 2 inset). In this region the mean polarization position angle (χ) of the maser components is $-57\pm15°$. It differs by $-110\pm10°$ from the mean χ angle of the remaining OH components.

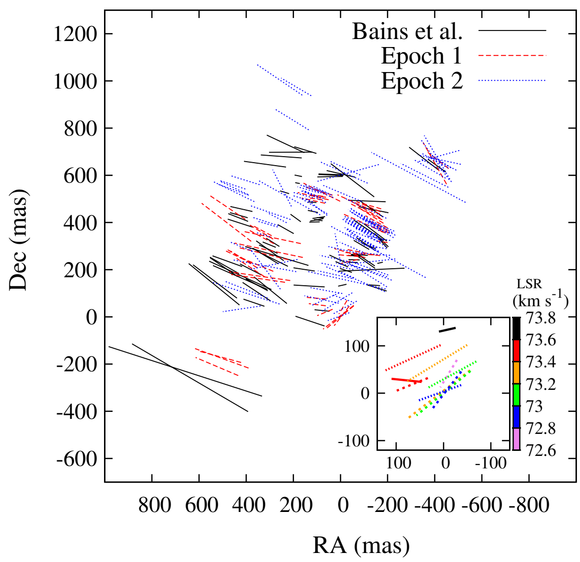

Figure 2: Distribution of the electric field vectors of the linearly polarized components at 1612 MHz. The vector lengths are proportional to the degree of linear polarization. Maps from three epochs are presented: 1999 May 18 - black solid lines [2], 2006 May 12 - red dashed lines and 2007 June 05 - blue dotted lines. The inset shows a magnification of the burst region with line colours corresponding to the velocity.

The orientation of the magnetic field vector is determined by the angles θ and χ, where θ is the angle between the line of sight and the magnetic field vector. If the ratio of Zeeman splitting to Doppler line width is > 1 then the degree of linear $m_{\rm L}$ and circular $m_{\rm C}$ polarization of the σ components are described by equations: $m_{\rm L} = \frac{sin^2\theta}{(1+cos^2\theta)}$ 100% and $m_{\rm C} = \frac{2cos\theta}{(1+cos^2\theta)}$ 100% [4]. The angle θ can be calculated from these two equations. Our preliminary study implies that the magnetic field vectors in the burst region do not change their orientation randomly but lie in a well defined plane (Wolak et al. in prep.). The size of the burst region is about 25 mas in diameter and is located close to the axis of infrared bipolar lobes reported in [3]. The magnetic field in the burst region is inclined at an angle of $\sim 50^\circ$ from the axis of the lobes.

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