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Analysis of bipolar outflow parameters, magnetic fields and maser activity relationship in EGO sources

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Abstract. The interferometric and single-dish observations of the Extended Green Objects sample have been carried out in order to check the possible common pumping mechanism of class I methanol maser (cIMM) and OH(1720 MHz) maser and their identification with a front of bipolar outflow as a source of interstellar shock stimulating collisional pumping of the molecules. High spatial and spectral resolution observations of OH masers allow us to investigate structure, kinematics, and magnetic field configuration of the inner region of the source, i.e., the outflow ejection region. Analysis of magnetic field strength in a disk area is crucial to understanding of the outflow origin.

Keywords. ISM: evolution, masers, magnetic fields

1. Introduction

Recently a promising new sample of about 300 massive young stellar objects (MYSOs) was identified on the base of excess of extended emission in the 4.5μm – green in the IRAC/*Spitzer* camera color scale (GLIMPSE-I survey, Churchwell *et al.* 2009). These objects were named EGO, i.e., Extended Green Objects (Cyganowski *et al.* 2008). The sample has been chosen for our study keeping in mind EGOs' association with active protostellar outflows, cIMMs (Cyganowski *et al.* 2009) and OH(1720 MHz) masers (Litovchenko *et al.* 2012).

2. Observations and Data Reduction

• The Karl Jansky Very Large Array (JVLA) (NRAO, USA): interferometric observations of 20 EGOs were carried out in 2013 using C-configuration with an angular resolution of about 12″ and spectral resolution of 0.34 km/s in all four OH lines at frequencies of 1612, 1665, 1667, and 1720 MHz.

• The Nançay decimetric radio telescope (NRT) (Observatoire de Paris, France): high-spectral resolution polarimetric single-dish study were made in 2015 with a 3.5′×19′ beam and spectral resolution of 0.07 km/s at frequencies of 1665, 1667, and 1720 MHz.

Position, $V_{\rm LSR}$, integrated and peak flux density for each maser feature detected at JVLA in the RCP and LCP data-cubes were obtained for the EGOs. In order to identify

Zeeman patterns, we searched through detected maser features for groups with opposite circular polarization that coincide spatially to within OH spot sizes in the frames of the positional uncertainties (following the method discussed in, e.g., Fish *et al.* 2003). Magnetic field strength was calculated based on OH lines Zeeman splitting values estimated in Davies (1974). The polarization parameters such as the degree of circular and linear polarization, flux density in linear polarization, and polarization angles were obtained from NRT data.

3. Conclusions

- With the JVLA in the direction of 20 EGOs maser emission at 1665/1667 MHz was detected in 50% of the sample.
- Spatial association of cIMMs and OH(1720 MHz) masers was not detected – it may indicate the absence of the conditions necessary for excitation of OH(1720 MHz) masers in the interaction region of bipolar outflow and interstellar medium.
- OH masers at 1665 and 1667 MHz were detected within $\sim 0.1''$ from the continuum source – ejector of bipolar outflow found in e.g. Cyganowski *et al.* (2011), Towner *et al.* (2017).
- The magnetic field strength was obtained for spatially coincident possible Zeeman pairs, which were identified in 50% of 10 EGOs: the values range from -8.4 to $+13.2$ mG, that indicates the possible predominance of strong magnetic fields in the OH maser spots in EGOs.
- The velocity gradient indicating an association of the OH maser spots with the rotating discs, previously observed in thermal lines of CS and NH_3 molecules, was observed in $\sim$40% of the sources.
- Orientation of OH maser spot cluster in 70% of cases is perpendicular to the plane of propagation of the bipolar outflow.
- The direction of magnetic field and outflow is almost parallel: an analysis of linear polarization angle distribution in OH spot clusters shows it in the majority of the cases (assuming a magnetic field perpendicular to the polarization angle).

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