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Excited OH Masers in Late-Type Stellar Objects

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Abstract. The final stages of low-mass stellar evolution are characterized by significant mass loss due to stellar pulsations during the AGB phase, which lead to the development of planetary nebulae. Molecular masers of H_2O, SiO, and ground state OH transitions are commonly detected in oxygen-rich late-type stars (OH/IR objects). In contrast, *excited* OH maser transitions are rare. We discuss our study of the carbon-rich pre-planetary nebula CRL 618 (a prototypical post-AGB star). Observations conducted in May 2008 with the 305m Arecibo Telescope resulted in the first detection of a 4765 MHz OH maser line in a late-type stellar object; the detection was confirmed a few months later also with Arecibo. Subsequent observations in 2015 and 2017 resulted in non-detection of the 4765 MHz OH line. Our observations indicate that the 4765 MHz OH maser in CRL 618 is highly variable, possibly tracing a short-lived phenomenon during the development of a pre-planetary nebula.

Keywords. masers, stars: AGB and post-AGB, circumstellar matter, stars: individual (CRL 618)

1. Introduction and Observations

Late-type solar-like stars evolve from asymptotic giant branch (AGB) to the planetary nebula phase. The transition between AGB stars and planetary nebulae is important in the development of asymmetries observed in many planetary nebulae. This phase of evolution is known as pre-planetary nebula (PPN, also known as post-AGB stars).

We observed the PPN CRL 618 to investigate the presence of excited OH masers. The observations were conducted with the 305m Arecibo Telescope in 2008, 2015 and 2017. In addition to the 4765 MHz OH line, we searched for emission/absorption of all other OH transitions between 1 and 9 GHz in October 2008 and 2015.

2. Results and Discussion

An excited 4765 MHz OH emission line was detected in May and October 2008. The 4765 MHz OH emission line was not detected in 2015 or 2017 (Figure 1). No other OH

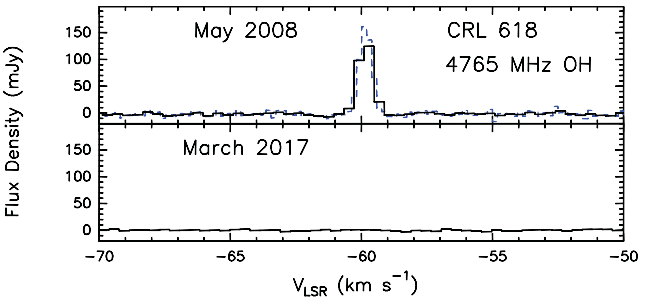

Figure 1. Example spectra from two epochs, first detection (upper panel; see observation details in Araya *et al.* 2015) and 2017 (lower panel) non-detection. The upper panel shows a high spectral resolution spectrum (blue-dashed) and the smoothed spectrum (black-solid).

transition was detected at rms levels of $\lesssim$5 mJy. Excited OH transitions in late-type stellar objects are extremely rare. Before this work, the only confirmed excited OH masers were toward the young planetary nebulae Vy2-2 and K3-35 (6035 MHz OH, Desmurs *et al.* 2010). Unconfirmed detections include the 4750 MHz OH line in the Mira star AU Gem, and the 6030 and 6035 MHz OH lines in the hypergiant NML Cygni (Zuckerman *et al.* 1972, Claussen & Fix 1981, Jewell *et al.* 1985, Sjouwerman *et al.* 2007). In CRL 618, the velocity difference between the 4765 MHz line (-60 km s^{-1}) and the systemic velocity (-21.5 km s^{-1}, Sánchez Contreras *et al.* 2004) suggests that the OH maser is associated with the bipolar outflow. The production of the OH could be from photo-dissociation of H_2O (e.g., Netzer & Knapp 1987). In K3-35, the OH maser likely occupies the same region as the H_2O masers and the masers have similar velocities (Miranda *et al.* 2011).

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