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The 1 mm spectrum of VY Canis Majoris: Chemistry in an O-rich envelope

Emily D. Tenenbaum[1], Stefanie N. Milam[2], Aldo J. Apponi[1], Neville J. Woolf[1], Lucy M. Ziurys[1], and Fredrik L. Schöier[3]

[1]Steward Observatory, Dept. of Chemsitry, University of Arizona
933 N. Cherry Ave. Tucson, AZ 85721 USA
email: emilyt@as.arizona.edu

[2]NASA Ames Research Center and SETI Institute
MS 245-6, Moffett Field, CA 94035-1000, USA

[3]Onsala Space Observatory, SE-439 92, Onsala, Sweden

Abstract. We present preliminary results of an unbiased spectral survey at 1 mm of the oxygen-rich supergiant, VY CMa. A number of exotic molecules have been detected, including NaCl and PO, and a relatively rich organic chemistry is observed. Results of the survey will be compared with carbon-rich stars.

Keywords. Stars: individual (VY Canis Majoris, IRC +10216), circumstellar matter, astrochemistry, submillimeter

1. Introduction

Although numerous spectral band surveys have been carried out for carbon-rich circumstellar shells, an oxygen-rich counterpart has never been studied in equivalent detail. In 2006, with the goal of more deeply investigating oxygen-rich circumstellar chemistry, we began a spectral survey of the oxygen-rich supergiant VY CMa. This star is one of the brightest objects in the near-infrared sky, with an unusually large mass loss rate of $\sim 5 \times 10^{-4}$ solar masses per year (Muller *et al.* 2007). Unlike less massive AGB stars such as IRC + 10216, which have uniformly expanding shells, the mass loss in this object is very sporadic, resulting in a clumpy, structured envelope consisting of arcs, knots and jets (Humphreys *et al.* 2007). The main goal of our survey is to observe a continuous spectrum from 215 to 280 GHz towards VY CMa using the Arizona Radio Observatory 10 m Sub-millimeter Telescope (SMT) on Mount Graham, Arizona. The SMT is equipped with a new side-band separating 1 mm receiver, giving system temperatures ranging from 150 to 400 K over the survey band. In addition, a simultaneous survey of IRC +10216 is being conducted in the same 1 mm band.

2. Results

Currently, the data-taking phase of the survey is 60% complete and it should be finished by November 2008. Seventy-five emission lines have been detected so far, including 12 unidentified lines. Eighteen molecules have been detected in VY CMa and of these, eight were first detected in VY CMa by our survey. In particular, the species NaCl, NS, HCO^+, and PN were detected for the first time in an oxygen-rich shell (Ziurys *et al.* 2007), and PO has been identified - the first interstellar molecule with a P-O bond (Tenenbaum *et al.* 2007).

Six carbon-containing molecules have been observed towards VY CMa. Emission from CO, CS, HCO^+, HCN, and HNC has been modeled using the non-LTE large velocity gradient code developed by Bieging & Tafalla (1993). Sample spectra of these molecules are shown in Figure 1. Emission from CS and HCN arises from regions close to the star, suggesting that shock-induced chemistry plays a role in the formation of these species. Our findings are in agreement with theoretical work by Cherchneff (2006) which predicts that non-TE shocked regions above the photosphere are areas of active carbon-chemistry.

3. Future Work

After the data-taking phase of the survey is complete, the observed emission will be modeled using a 3–*D* Monte Carlo radiative transfer code for circumstellar envelopes (Schöier & Olofsson 2001). From the modeling we will gain additional information about molecular abundances and envelope kinematics. When both the VY CMa and IRC +10216 surveys are complete, we will compare the chemistry in *C*-rich versus *O*-rich circumstellar envelopes. Interferometry observations of molecular emission from VY CMa will be critical to understanding the morphology of the circumstellar envelope. SMA observations of CO and SO emission have recently been published (Muller *et al.* 2007) and the envelope of VY CMa will be an optimal target for observations with ALMA.

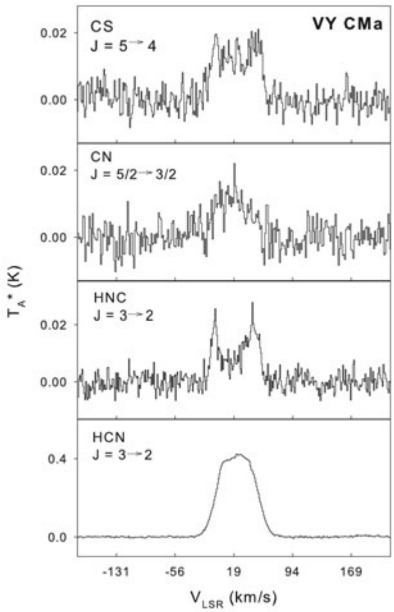

Figure 1. Emission from carbon-bearing molecules in VY CMa observed with the SMT.

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