Water Masers and YSOs in H II Regions: A Continuing Survey

Kevin R. Healy (Arizona State University), Mark J. Claussen (NRAO),
J. Jeff Hester (Arizona State University)

Abstract

We present the results of a second year of our search for water maser emission associated with young low-mass stars in H II regions using the NRAO Very Large Array. During March and May 2001 we reobserved two targets from our first survey year, M16 and M20, as well as observed NGC 6357 and S125. We detected new water masers in M16 to the east and to the north of cluster NGC 6611. We also detected new water masers in M20 around the massive core TC3. We detected no water maser emission from NGC 6357 or S125.

Introduction

Water maser emission at 22 GHz is a common and easily identifiable feature of low-mass star formation (Terebey, Vogel, and Myers 1992, Wilking et al. 1994). In addition, water masers are associated with the most active stage of accretion and outflow in protostar formation (Claussen et al. 1996, Furuya et al. 2001). The combination of these properties makes water maser emission a useful probe for very young, heavily embedded protostars in the molecular gas bounding H II regions. This provides complementary information to our optical and near infrared survey of H II regions.

Observations

All four H II regions were observed 2001 March 26 and 2001 May 18 with VLA using 127 channels of 0.33 km s^{-1} width. The total bandwidth of 42 km s^{-1} was centered on the H II region systemic velocities. Each pointing was observed for 6.5 minutes. The data were reduced and cleaned cubes constructed in AIPS. The resulting cubes had synthesized beam FWHM of approximately 1.0"x0.3" and rms noise values of 30 to 40 mJy. Spectra were extracted with ISPEC in AIPS.

Conclusions

Given the relative youth of M20 and the large number of young stars seen in M16 (Cernicharo et al. 1998, Hillenbrand et al. 1996), we initially expected to detect a large number of water masers. In four epochs spanning one year of observations, we have detected four sites of water maser activity in M16 and two sites in M20. The low number of detections suggests that we are witnessing the active role the massive stars of the central clusters in these H II regions play in the star formation in the surrounding molecular clouds.

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S125

S125 is part of our optical and near-infrared survey. Blitz & Lada (1979) found no water maser emission from this region to a limit of 6 Jy. Our search was negative to a limit of 0.15 Jy.

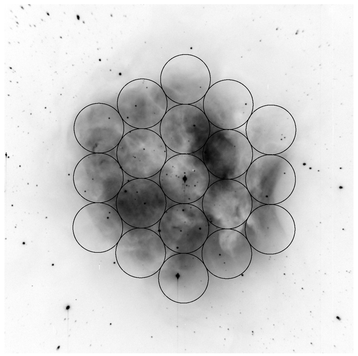

Figure 1. PFUEI Hα image of S125, centered on RA(J2000) = 21h53m30.1s and Dec(J2000) = +47d16m0.0s. Black circles indicate the VLA pointings observed in 2001.

NGC 6357

NGC 6357 is a target of our HST observations of H II regions. Batchelor et al. (1980) and Sakellis et al. (1984) found no water masers in this region to a limit of several Jy. Our search was negative to a limit of 0.15 Jy.

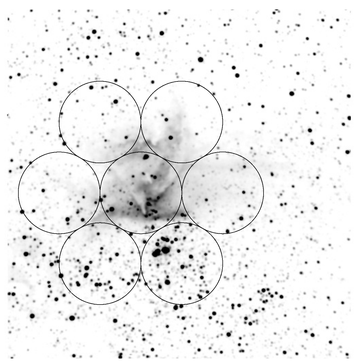

Figure 2. 2MASS K-band image of NGC 6357, centered on RA(J2000) = 17h24m42.0s and Dec(J2000) = -34d10m20.2s. Black circles indicate the VLA pointings observed in 2001.

M16

A combination of optical and infrared observations have shown M16 to be actively forming stars, with the most recent star formation occurring in the "elephant trunks" (Hester et al. 1996, Sugitani et al. 2002). We detected water maser emission only from the tips of the elephant trunks and the dark bay north of the cluster NGC 6611. These are locations of dense molecular gas that are slowly photoevaporating from the UV flux of NGC 6611. The protostars powering these masers will lose their envelopes on a timescale short compared to the accretion timescale. This suggests the star formation occuring in the M16 elephant trunks is being truncated by the nearby massive stars.

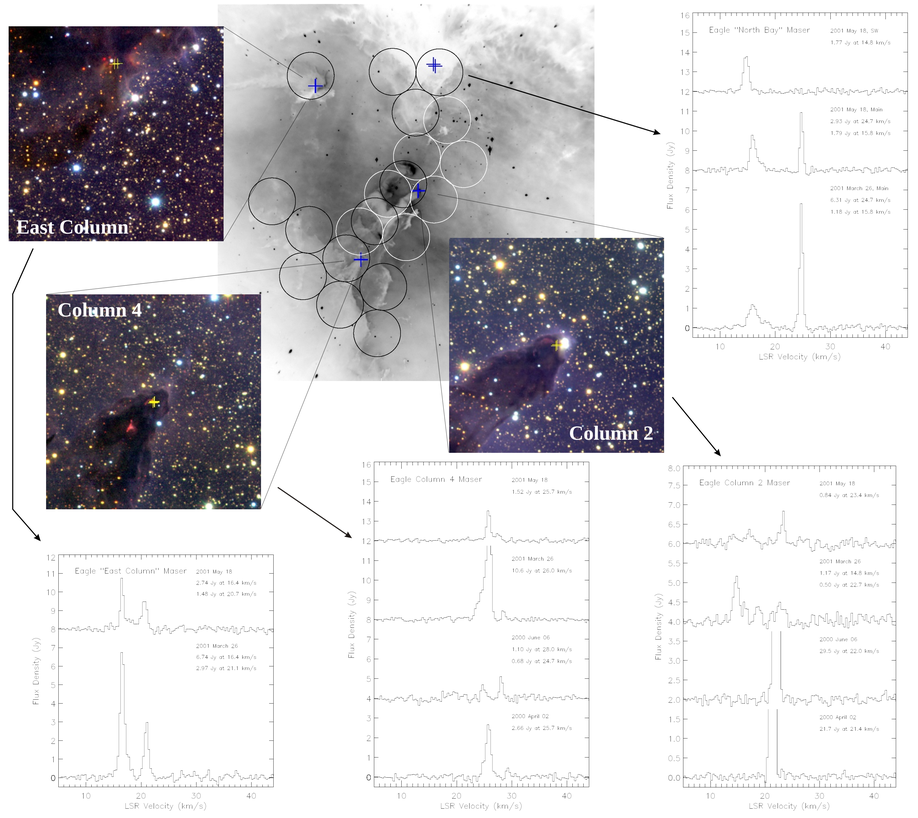

Figure 3. (center) PFUEI Hα image of M16, centered on the position RA(J2000) = 18h18m51.0s and Dec(J2000) = -13d49m53.4s. Circles indicate the VLA pointings observed (2000 in white, 2001 in black). Water maser positions are marked with blue crosses. (color insets) JHK images from the VLT ISAAC mosaic presented by McCaughrean & Andersen (2001). Yellow crosses mark the positions of the water masers in these images. (right, bottom row) Spectra of water masers in M16. East column only observed in 2001. Column 2 and column 4 observed in both years of survey. Despite strong variability, maser peaks persist with small velocity drift. North bay maser observed only in 2001. Note two distinct maser features were detected: Main and SW (top spectrum).

M20

M20 is one of the youngest H II regions known and contains a wide variety of star formation signatures (Cernicharo et al. 1998, Lefloch & Cernicharo 2000, Rho et al. 2001). We have detected water maser emission from two locations within this H II region. The first maser lies southeast of the H II region center, 0.6" from 2MASS 1802309-230549 and 15" from IRAS 17594-2305. Both of these infrared sources have colors indicative of a young embedded star. The other masers cluster around the massive core TC3 observed by Lefloch & Cernicharo (2000). It is not clear whether this object is collapsing to form a single massive star or fragmenting to form several smaller stars.

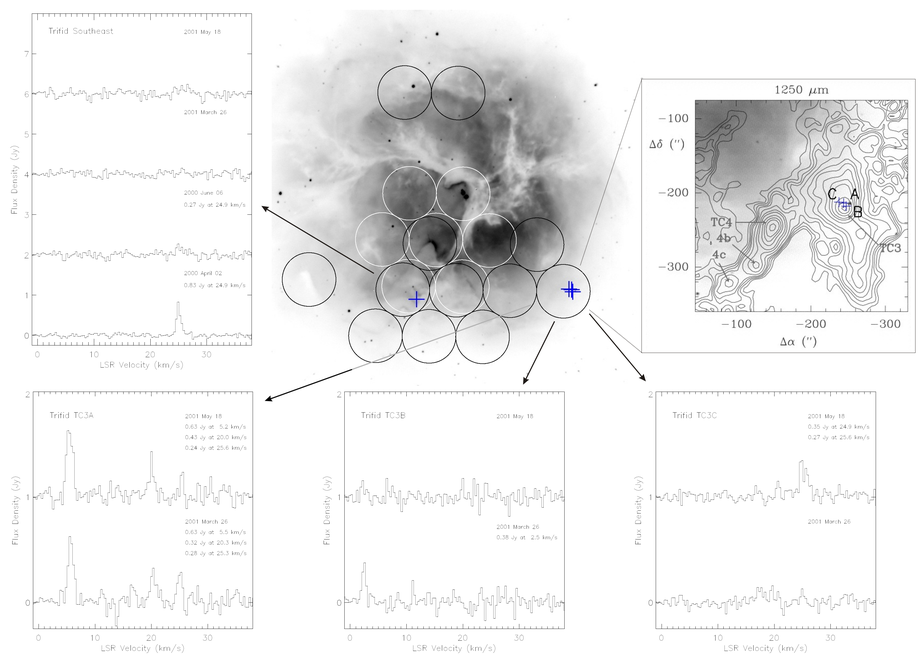

Figure 4. (center) PFUEI Hα image of M20, centered on the position RA(J2000) = 18h02m24.1s and Dec(J2000) = -23d02m00.3s. Circles indicate the VLA pointings observed (2000 in white, 2001 in black). Water maser positions are marked with blue crosses. (right) TC3 water masers plotted over 1.25 mm map from Lefloch & Cernicharo (2000). (left, bottom row) Spectra of water masers in southeast part of M20 and maser cluster around Tc3 in soutwest part of M20.

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