A Massive Protobinary in the Hot Core W3(H_2O)

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Using the Berkeley-Illinois-Maryland-Association (BIMA) array, we have observed a nearby hot core, W3(H_2O), in both the continuum and methyl cyanide (CH_3CN) line emission. We obtained the best angular resolutions that have been observed for this hot core at millimeter wavelengths. Our continuum observations at wavelengths of 1.4 mm and 2.8 mm resolved the core into two principle components. By fitting Gaussians with the five *K* components of the CH_3CN $J = 12\rightarrow11$ transitions, a radial velocity difference of 2.8 kms^{-1} is found towards the two continuum peaks. Interpreting the two sources as binary components in orbit about one another, we find a minimum mass of 22 $M_\odot$ for the system. Radiative transfer models are constructed to explain both the continuum and CH_3CN emission of each source. Density distributions close to the free-fall profile, $r^{-1.5}$, are found for both components, suggestive of continuing accretion. The luminosity estimates of (0.9-1.8)×10^4 $L_\odot$ suggest that the two sources have equivalent zero-age main sequence (ZAMS) spectral type B0.5-B0. The nebular masses derived from the continuum models are about 5 $M_\odot$ for source A and 4 $M_\odot$ for source C. A velocity gradient previously detected by Wyrowski et al. (1997) may be explained by unresolved binary rotation with a small velocity difference.

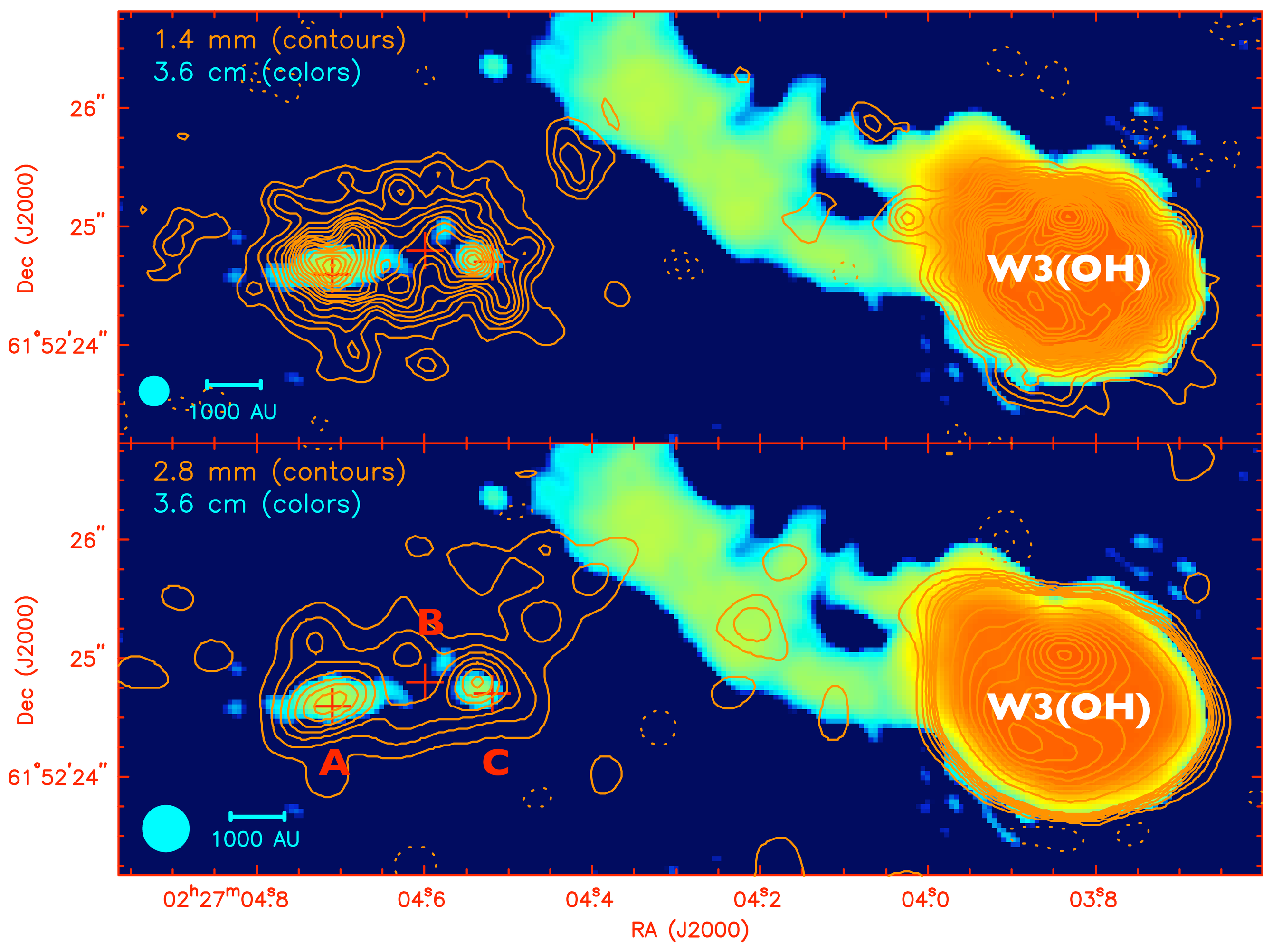
Introduction

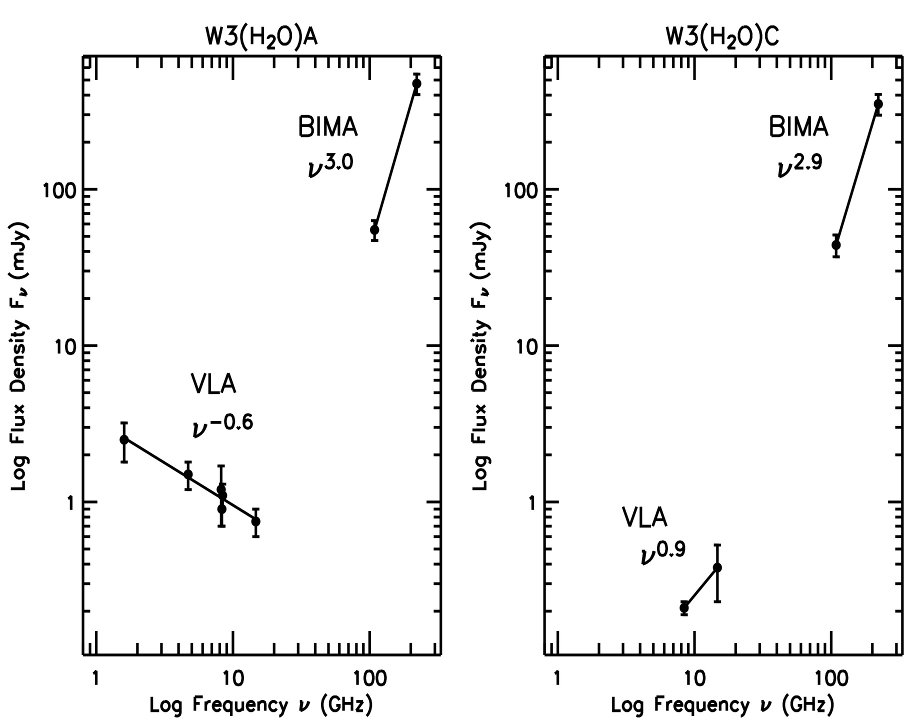
Hot molecular cores (HMCs) are warm ($T \gtrsim 100$ K), dense ($n \gtrsim 10^6$ cm^{-3}), molecular clumps of high luminosities ($L \simeq 10^{4-5}$ $L_\odot$) often found in the vicinity of ultracompact HII regions (Kurtz et al. 2003). The lack of detectable Strömgren spheres suggests on-going accretion and further places hot cores in an evolutionary stage earlier than UC HII regions.

The hot molecular core, W3(H_2O), located 6" east to W3(OH), was first discovered by Turner & Welch (1984) in HCN emission. Subsequent millimeter interferometric observations (Turner & Welch 1984; Wilner, Welch, & Forster 1995; Wyrowski et al. 1997, 1999) estimated a luminosity of 10^4 $L_\odot$ and a mass of 10-20 $M_\odot$, suggesting the presence of obscured protostellar objects equivalent to early B type ZAMS stars.

Continuum Observations

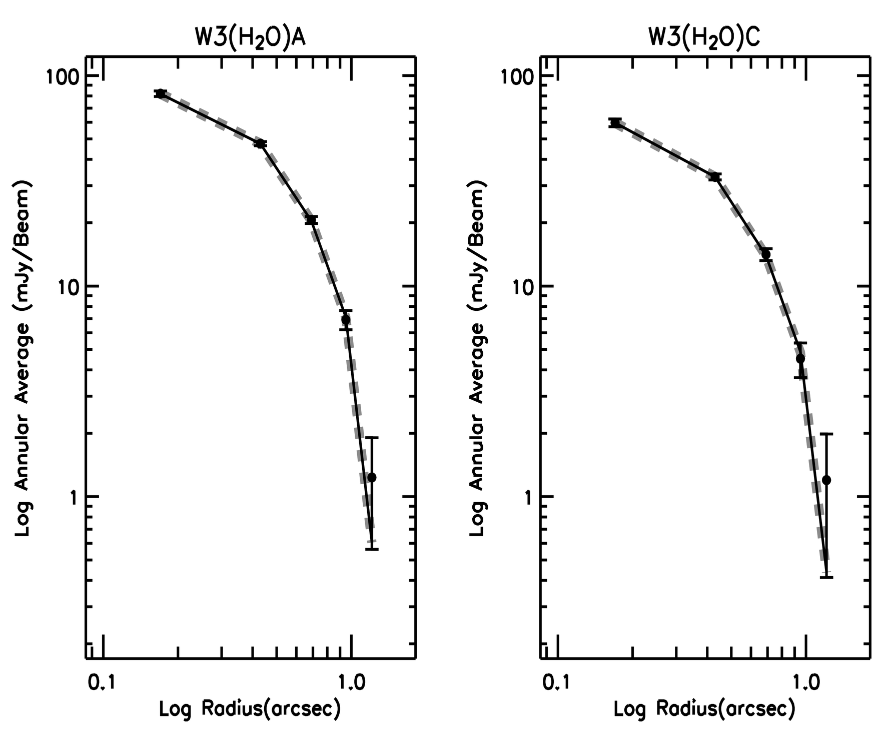
Our line-free continuum observations resolved W3(H_2O), which shows a double-peaked morphology with peak positions coinciding well with those in the 3.6 cm map. The beam size is 0.26" at 1.4 mm and 0.4" at 2.8 mm. We adopt the notation of Wyrowski et al. (1999), who identified three peaks, A, B, and C (indicated by three red crosses). The angular separation between source A and C is 1.19", corresponding to 2.43×10^3 AU if a distance of 2.04 kpc is assumed.





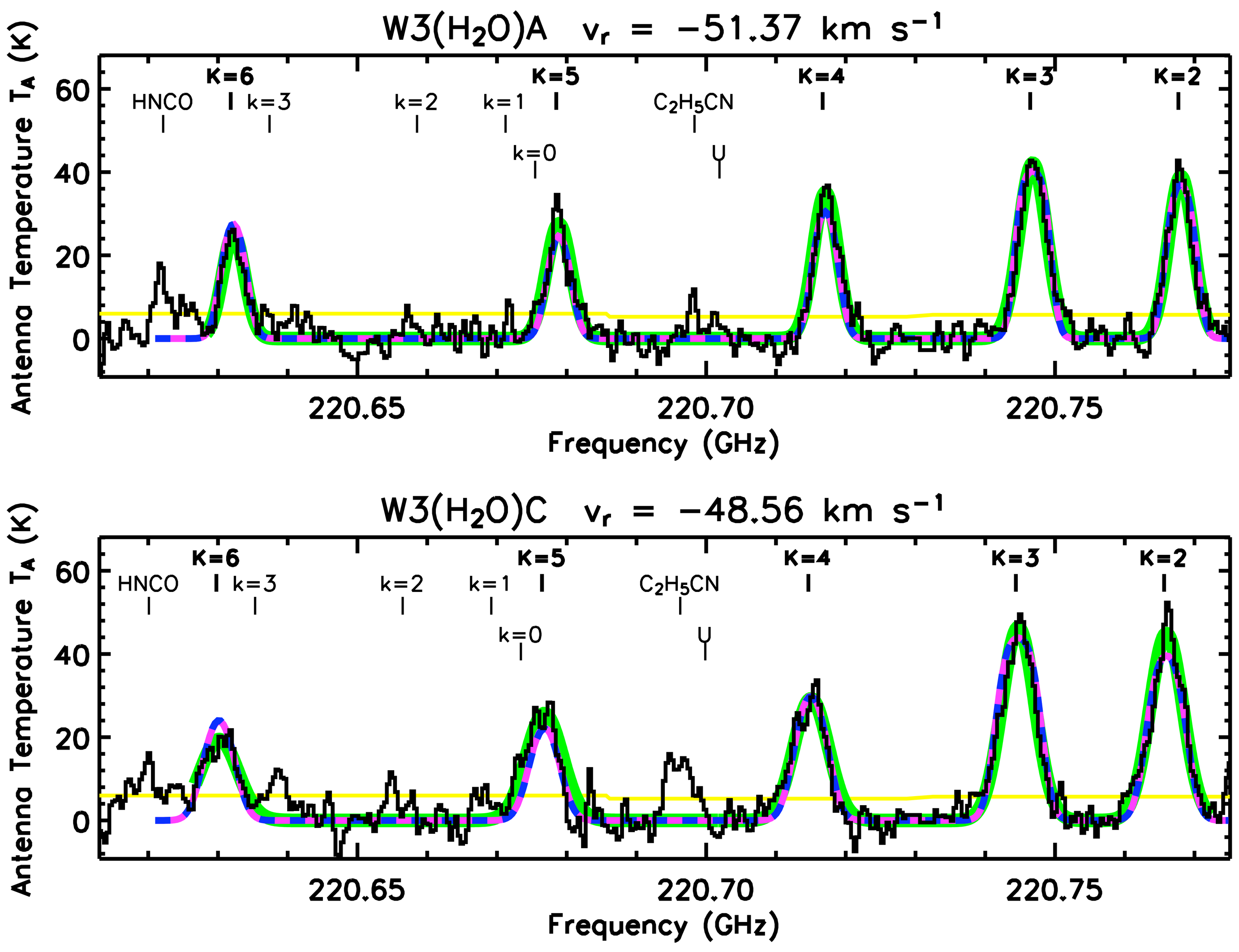
Continuum spectra of the two components in W3(H_2O) show rising spectra between 1.4 mm and 2.8 mm with spectral indices of 3.0 and 2.9, corresponding to a dust opacity law of $\beta=1$. The spectral indices are much smaller than the canonical value of 2 in the diffuse interstellar medium. Our continuum models suggest the optical depths at 1.4 mm for both components are less than 0.1. Hence the small spectral indices should be the result of grain growth.

Assuming the temperature profiles follow $r^{-0.4}$, the optimized continuum models (solid lines) fit the 1.4 mm emission profiles with underlying density distributions of a power-law radial dependence of $r^{-1.52}$, close to the free-fall density profile of $r^{-1.5}$. The cutoffs at large radii are caused by the finite sizes of the dust distributions while the turnovers at the innermost radii result from a combined effect of the central cavities and the convolution with the beam.



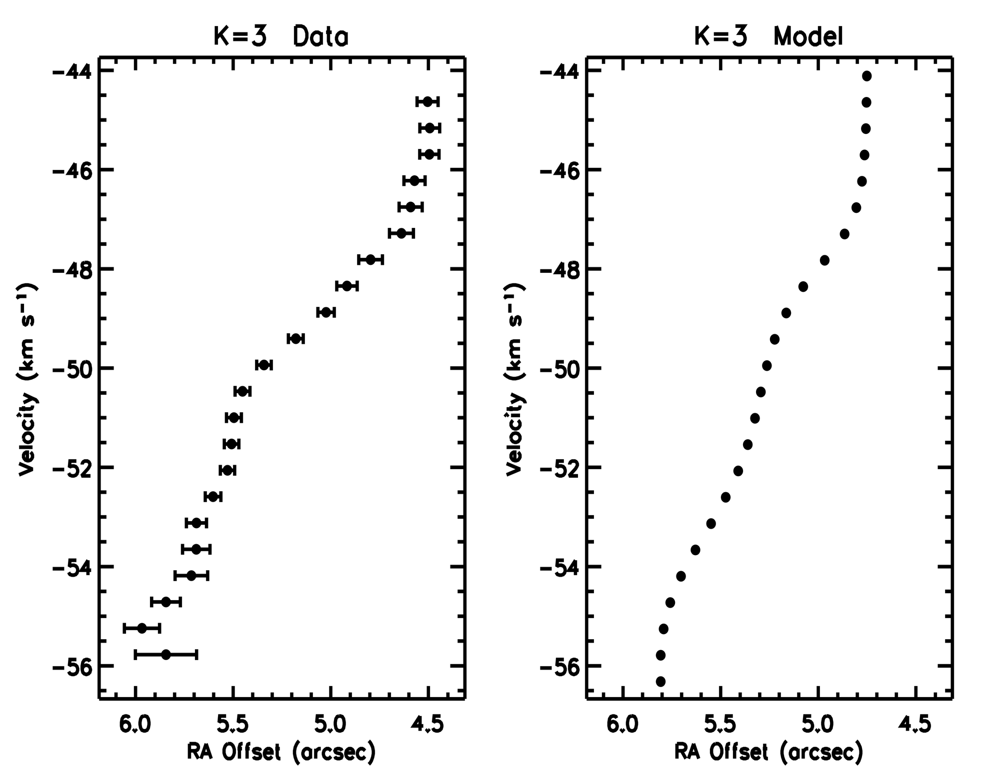
Methyl Cyanide Line Observations

We have observed *K*=2,3,4,5, and 6 components of the CH_3CN $J=12\rightarrow11$ transitions to study the kinematics as well as the temperatures of the two sources. By fitting 5 Gaussians with the 5 *K* components simultaneously, we find a velocity difference of 2.8 kms^{-1} (green curves), which gives a minimum mass of 22 $M_\odot$ if the two sources are in binary rotation. Assuming the Boltzmann population of levels, our radiative transfer models can fit the spectra well (blue and red curves) and explain the suppression of the *K*=3 components with large optical depths. The temperature given by the optimized models is about 200 K for source A and 182 K for source C. The estimated luminosity for source A is about (1.5-1.8)×10^4 $L_\odot$ and (0.9-1.4)×10^4 $L_\odot$ for source C. These numbers correspond to ZAMS spectral type B0.5-B0. Since a star of spectral type earlier than B3 will produce an observable HII region, we expect each member of the binary to develop its own HII region in the future.



The Nature of the Velocity Gradient

Wyrowski et al. (1997) have observed an intriguing velocity gradient spanning about 10 kms^{-1} in W3(H_2O) along the east-west direction over an angular range of about 1". This gradient was found by plotting the positions of maximum emission derived from channel maps in several lines. We applied the same method to our *K*=3 component and the result is shown in the left panel. In general, we detected a similar velocity gradient but with more important details. Our position drift shows turnovers, where the peak positions stay unchanged at the two ends, and a twitch, where the velocity has a larger increment at 5.5" east to the reference position. These irregular behaviors in the velocity gradient can result from two velocity clumps with a small radial velocity difference. The same Gaussian fitting to our model images, which are made by adding linearly the CH_3CN models for the two binary members, shows similar irregularities that support our hypothesis (right panel).



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