Modelling CO Bandhead Emission of Massive Young Stellar Objects from the RMS Survey

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Abstract

High resolution spectra over the CO first overtone bandhead of twenty massive young stellar objects (MYSOs) have been obtained. The CO bandhead emission traces hot, dense gas - exactly the conditions expected in circumstellar discs. We fit the data with models of accretion discs to determine the MYSO's currently unknown accretion rates. Determining this key parameter will provide insight into the formation scenario of massive stars.

In contrast to low mass star formation, the formation mechanism of high mass stars (> 10 $M_\odot$) is poorly understood. The Red MSX source (RMS) survey (Urquhart et al. 2007) is the largest collection of MYSOs to date, which utilised an extensive multiwavelength campaign to yield over 500 candidate MYSOs throughout the Galaxy. These MYSOs have a short lifetime, and thus reach the main sequence while still embedded in their natal molecular cloud, obscuring them from observations at optical wavelengths.

To discover more about these objects, we must look at other wavelengths. We observed 40 MYSOs using the CRIRES spectrograph on the VLT to obtain high resolution NIR spectra, 20 of which showed a CO bandhead feature. Figure 1 shows the spectrum of one of these objects - IRAS 08576-4334.

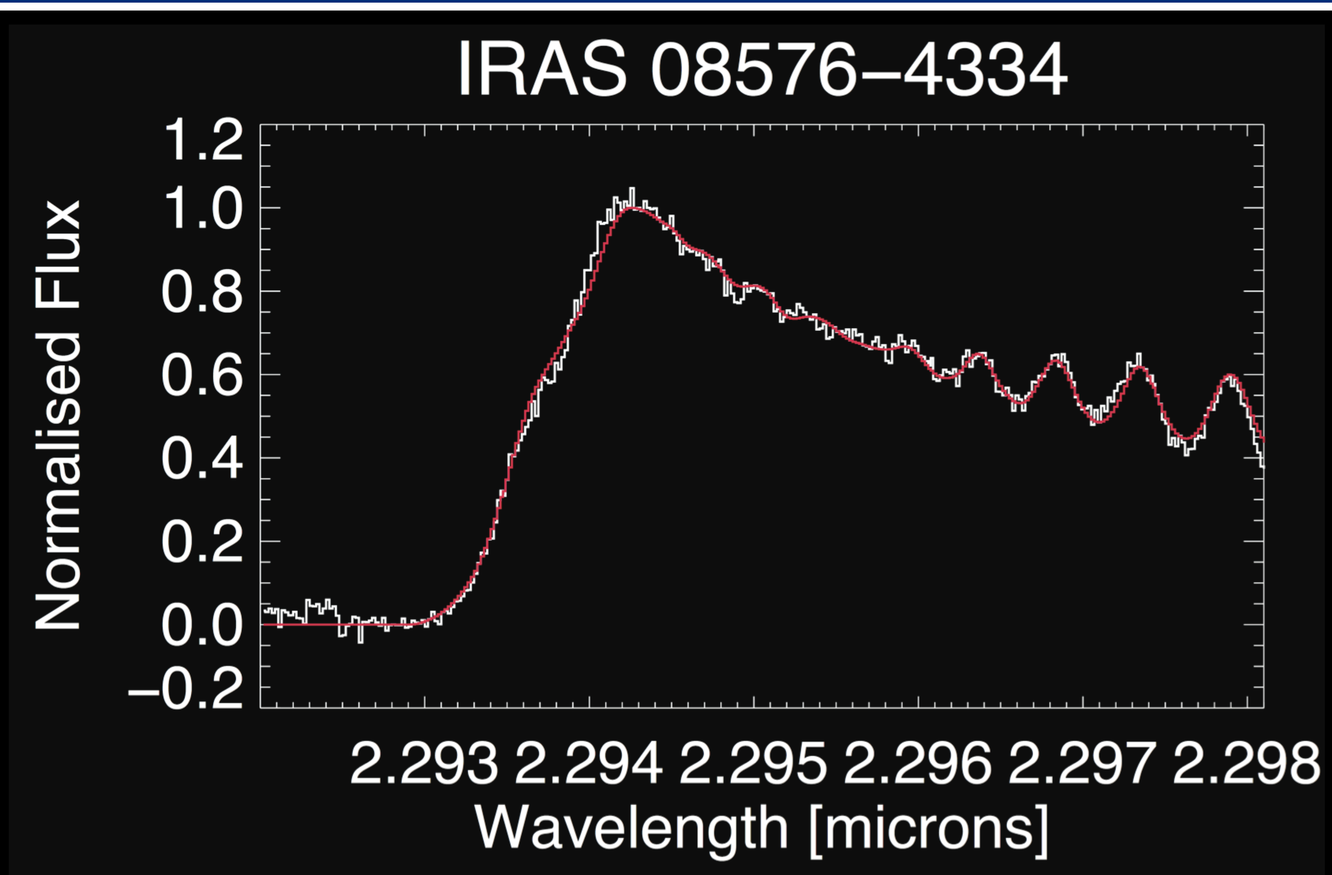

Figure 1) Spectrum of IRAS 08576-4334 (white) with best fitting model (red). The best fitting parameters are a mass accretion rate of 6.3×10^{-5} $M_\odot$ per yr, an inclination of 57.9 degrees, and a linewidth of 16.4 km s^{-1}

The CO bandhead traces hot (2500-5000 K) and dense (> 10^{11} cm^{-3}) neutral gas, precisely the conditions expected in a circumstellar accretion disc.

To model this emission, we adopt the same method as Wheelwright et al. (2010) and Kraus et al. (2000), but use the physical disc model of Vaidya et al. (2009). The main source of heating in the disc is assumed to be via viscosity. The best fitting model is determined using a downhill simplex algorithm, with the free parameters being the mass accretion rate ($\dot{M}$), the disc inclination (i) and the instrinsic linewidth (Δv). Figure 2 shows the reduced X^2 map of the fit to the IRAS 08576 data.

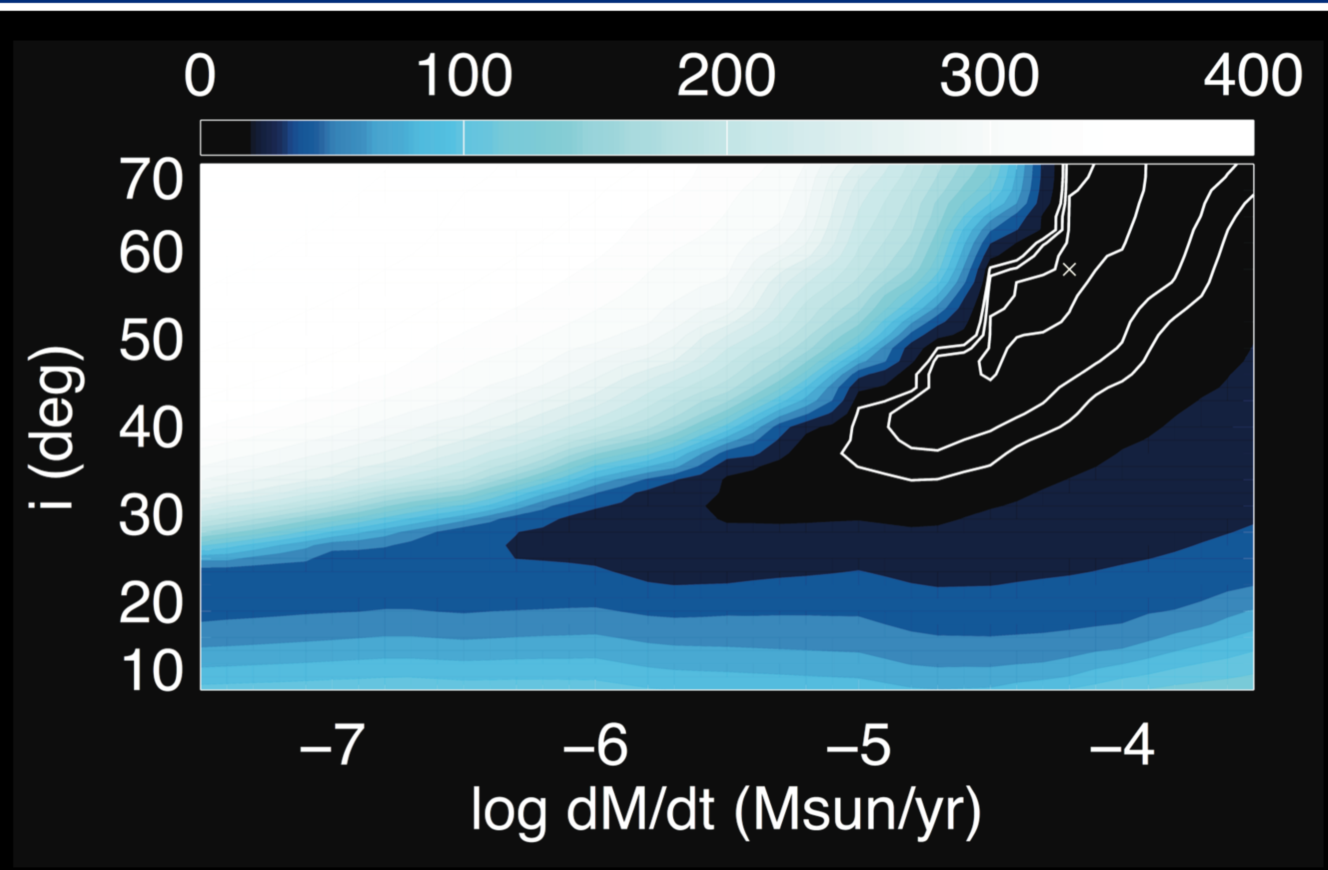

Figure 2) Map of the reduced X^2 statistic for the model fit shown in Fig. 1 (at Δv = 16.4 km s^{-1}) with contours at 1-, 5- and 9-σ. It is clear that there is only one minimum over the explored parameter space, correctly identified by our fitting routine (marked X).

From Figs. 1 & 2 it can be seen that the observations are well fit with our model of a rotating Keplerian disc with a relatively high mass accretion rate, suggesting that MYSOs do indeed form through disc accretion.

We plan to apply this method to the nineteen other objects with CO emission, which will allow us to investigate the relationship between mass accretion rate and other astrophysical quantities, and draw statistically significant conclusions that we hope will lead to a better understanding of massive star formation.

References:

Kraus et al. 2000, A&A, 362, 158

Vaidya et al. 2010, ApJ, 702, 567

Urquhart et al. 2007, A&A, 461, 11

Wheelwright et al. 2010, MNRAS, 408, 1840

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