Chemical tracers of episodic accretion

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Introduction

The embedded phase of low-mass star formation (Class 0/I) is when most of the mass is accreted. This appears to happen at a highly variable rate [1,2], with long periods of weak accretion punctuated by brief bursts of strong accretion (Fig. 1). The luminosity is directly proportional to the accretion rate. Each accretion burst heats up the protostellar envelope for ~100 yr [3]. This disrupts the chemical balance for up to ~10^4 yr (Fig. 2). **The corresponding time evolution of certain molecular line ratios allows us to measure the time since the last accretion burst.**

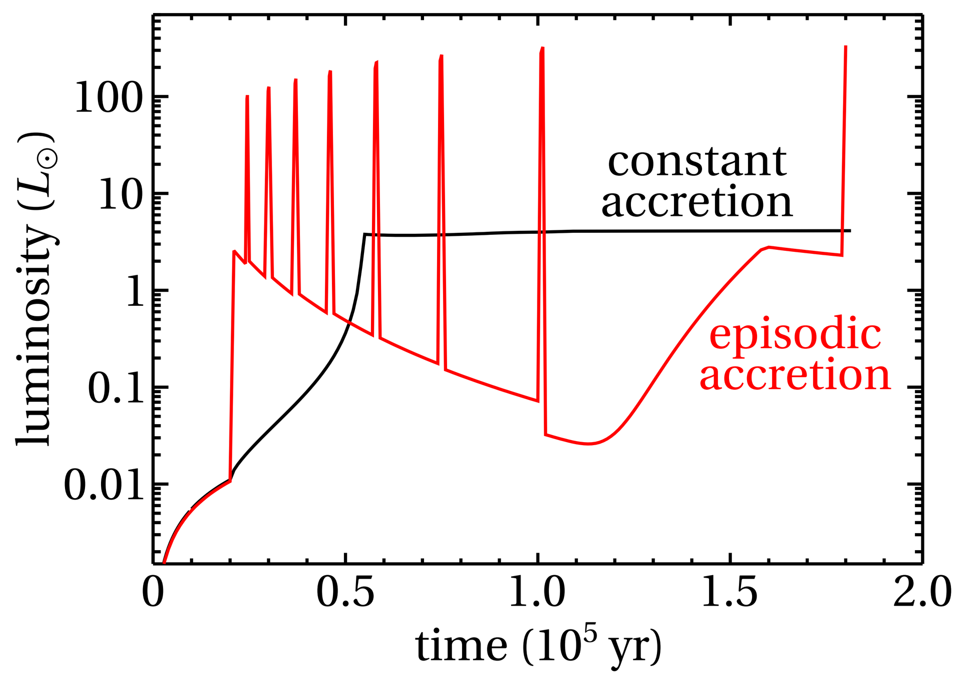


Fig. 1: Protostellar luminosity in models of constant accretion (black) and episodic accretion (red). (Taken from [4].)

Conclusions

1. Episodic accretion in embedded protostars leaves a long-lasting imprint on the chemical profile of the envelope
2. Line ratios like HCO^+ 7–6/$H^{13}CO^+$ 3–2 can be used to measure the time passed since the most recent burst
3. Normalization is required to filter out intrinsic source-to-source variations
4. Variability detected in multi-epoch water spectra is likely due to pointing uncertainties

Accretion bursts can have a long-lasting effect on the chemistry. Much of the chemistry is controlled by freeze-out and evaporation of major species like CO and H_2O. Evaporation during a burst is nearly instantaneous (<1 yr), but freeze-out after a burst can take more than 10^4 yr [5,6].

HCO^+ is a promising tracer of episodic accretion [7]. During a burst, evaporation of CO boosts HCO^+ in the outer envelope, while evaporation of H_2O destroys HCO^+ further in (Fig. 2). After the burst passes, the abundances slowly return to what they were before the burst.

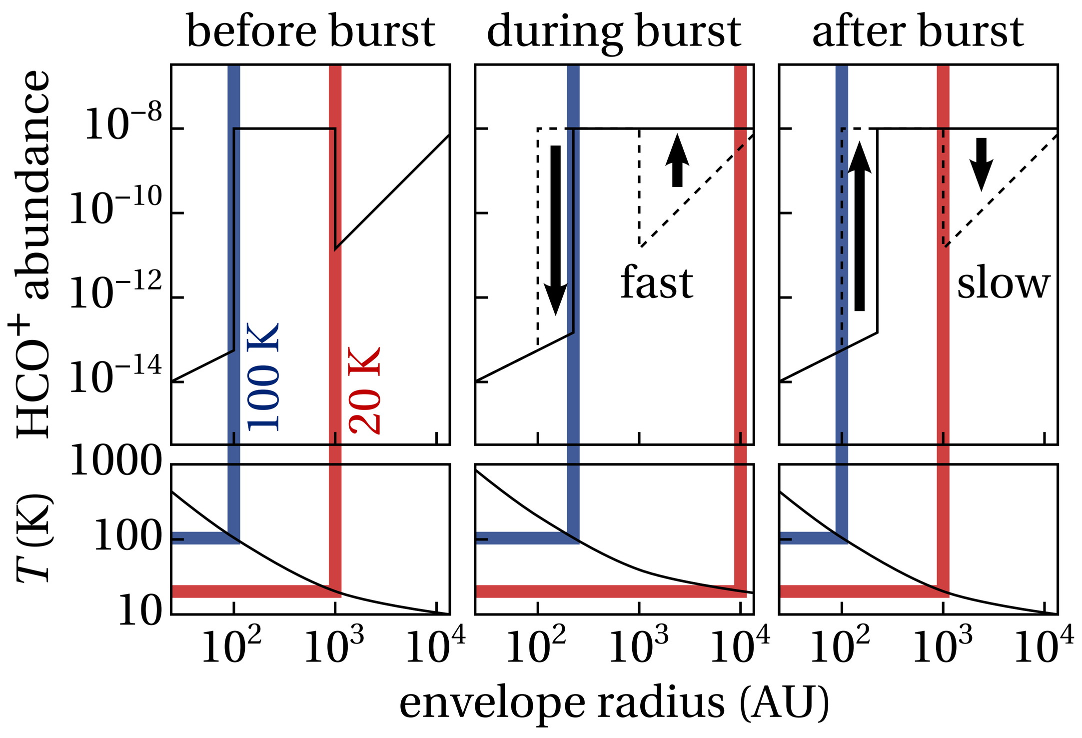
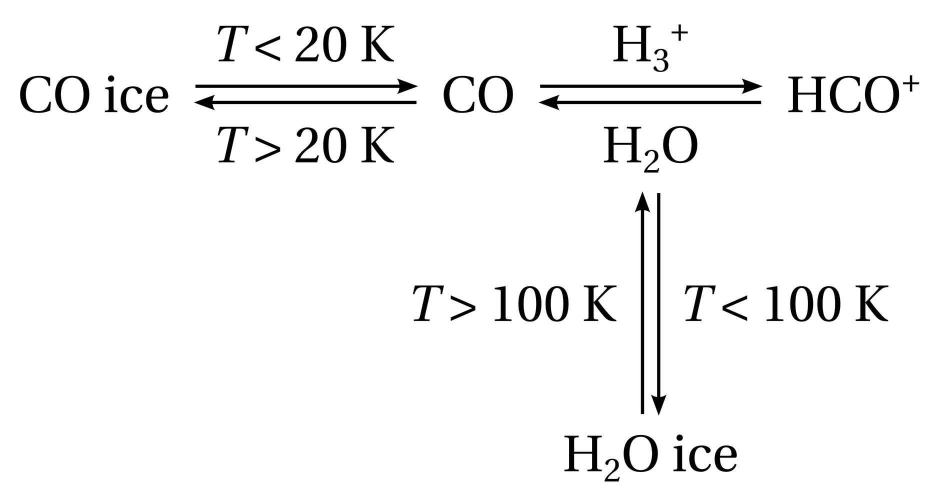
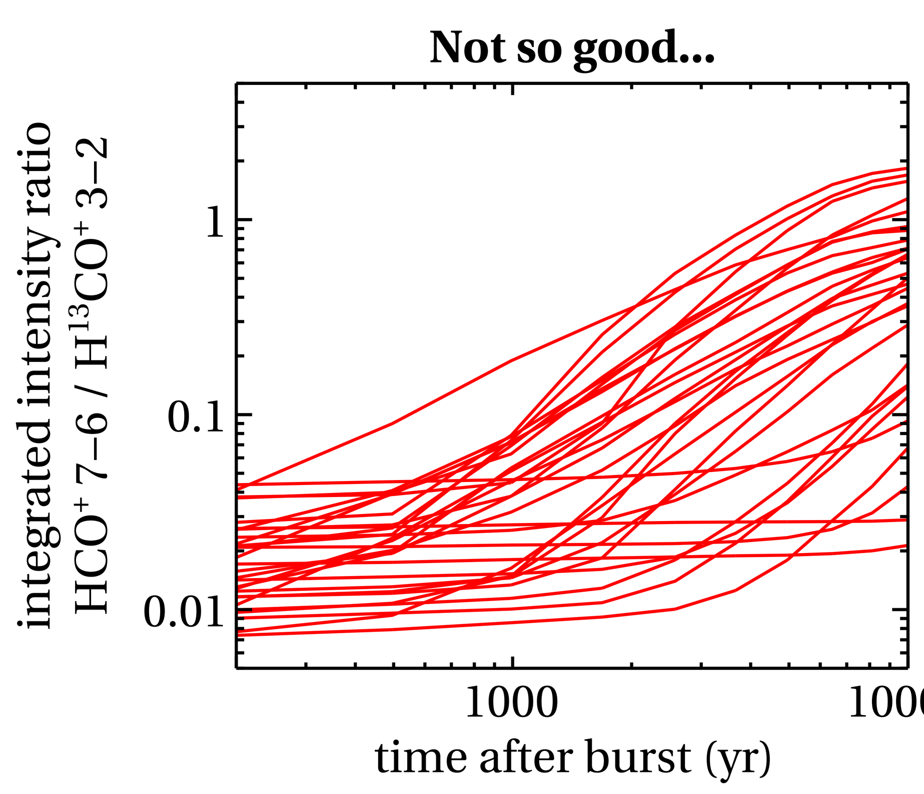


Fig. 2: Radial abundance profiles of HCO^+ before, during, and after an accretion burst.

HCO^+ chemistry



$T < 20$ K: freeze-out of CO reduces HCO+
20 K < T < 100 K: evaporation of CO enhances HCO+
T > 100 K: evaporation of H2O reduces HCO+



Can we use molecular lines to measure the time since the last burst?

$$t_{\rm freeze} = 10^4\,{\rm yr}\,\sqrt{\frac{10\,{\rm K}}{T}\,\frac{10^6\,{\rm cm}^{-3}}{n({\rm H}_2)}}$$

Normalize the horizontal axis by the freeze-out timescale

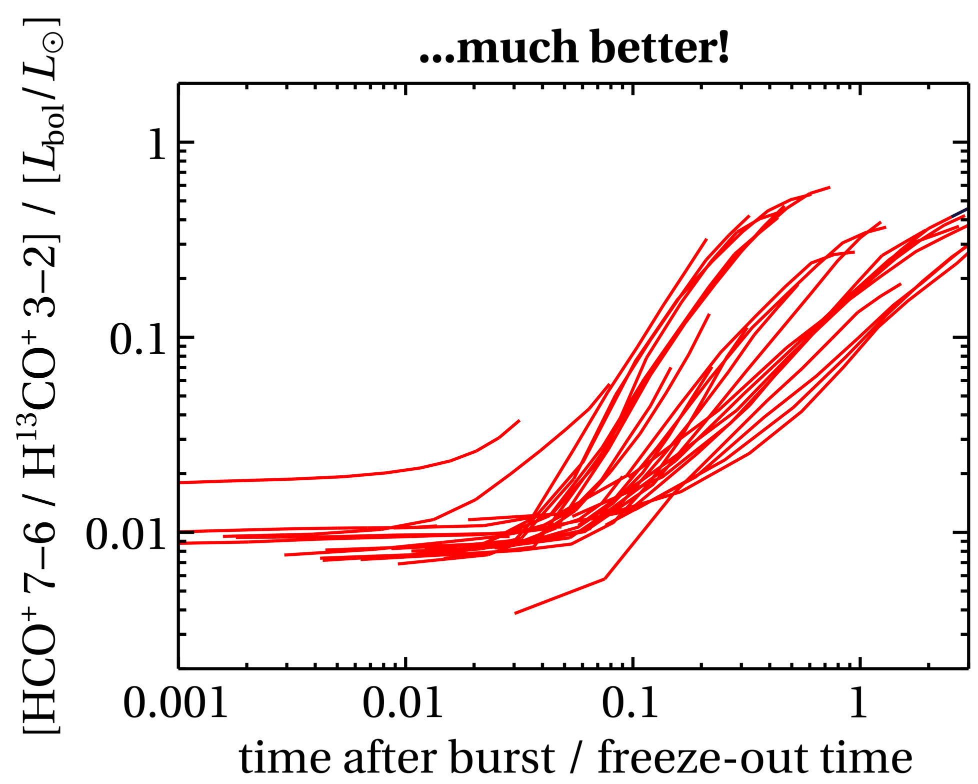
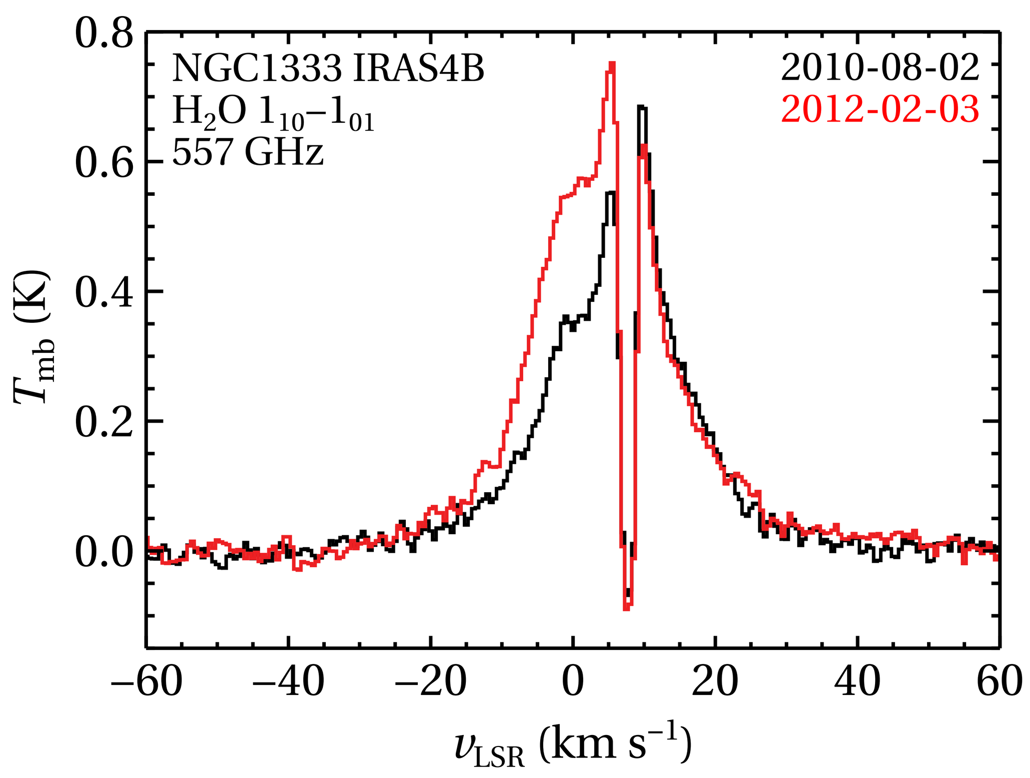


Fig. 3: Integrated intensity ratios of HCO^+ 7–6 and $H^{13}CO^+$ 3–2 for a sample of 29 low-mass protostars [8], obtained by radiative transfer on abundance profiles as in Fig. 2 [7]. The ratios are plotted as function of time after an accretion burst. On the left, the 29 sources span a wide range of values and the 7–6/3–2 ratio is of little diagnostic value. On the right, the horizontal axis is **normalized by the freeze-out timescale of CO** in each source, and the vertical axis by the bolometric luminosity. This greatly reduces the amount of scatter in the diagram, **turning the 7–6/3–2 ratio into a chronometer of when the most recent burst occurred.**

Time-variable water emission from dissociative shocks?

Fig. 4: This poster was going to present **time-variable water emission in low-mass protostars**. In some sources, multiple epochs of the pure rotational line at 557 GHz show distinctly different intensities. The spectral component seemingly showing variability is associated with shocks deep inside the protostellar cocoon [9,10,11].
We were eager to learn what was causing the variable emission and what this might mean for the interaction between shock and infalling envelope. Unfortunately, it appears now that **the variability can be explained by accidental mispointings**. If you want to know more, please ask me!



References
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