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EVIDENCES OF EPISODIC MASS ACCRETION IN LOW-LUMINOSITY EMBEDDED PROTOSTARS

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ABSTRACT

We present *Spitzer* IRS spectroscopy of CO_2 ice toward 19 young stellar objects (YSOs) with luminosity lower than 1 $L_\odot$. Pure CO_2 ice forms only at elevated temperatures, $T > 20$ K, and thus at higher luminosities. Current internal luminosities of YSOs with $L < 1$ $L_\odot$ do not provide such conditions out to radii of typical envelopes. Significant amounts of pure CO_2 ice would signify a higher past luminosity. We analyze 15.2 μm CO_2 ice bending mode absorption lines in comparison to the laboratory data. We decompose pure CO_2 ice from 12 out of 19 young low luminosity sources. The presence of the pure CO_2 ice component indicates high dust temperature and hence high luminosity in the past. The sum of all the ice components (total CO_2 ice amount) can be explained by a long period of low luminosity stage between episodic accretion bursts as predicted in an episodic accretion scenario. Chemical modeling shows that the episodic accretion scenario explains the observed total CO_2 ice amount best.

Key words: star formation; Spitzer IRS observation; conferences: proceedings

1. INTRODUCTION

The standard model explains that star formation is a continuous process (Shu et al., 1977). However, recent studies indicate that star formation does not occur continuously (Evans et al., 2009; Dunham et al., 2008). One possible scenario of non-continuous accretion models is the episodic accretion. If we can find imprints of past high luminosity/temperature at low luminosity YSOs, it can be evidence of episodic accretion.

In the interstellar dust, pure CO_2 ice formation requires at least 20 K. Dust temperature at an envelope of a YSO with $L_{int} = 0.7$ $L_\odot$ is lower than 20 K, which is too low to form pure CO_2 ice. If mass accretion occurs episodically, low luminosity YSOs can form pure CO_2 ice during burst stages, which does not disappear during quiescent stages. We tested this idea with *Spitzer* IRS Short-High mode observation and the chemical evolution modeling.

2. OBSERVATIONS, ANALYSIS AND MODELING

We detected the 15.2 μm CO_2 ice absorption line in all 19 sources. The observed flux is converted to optical depth, and fitted using 5 components of laboratory data (three different kinds of CO-CO_2 mixtures, pure CO_2 ice, water-rich CO_2; Pontoppidan et al., 2008). Then each optical depth is integrated to get the column density, N (see Figure 1).

The fraction of pure CO_2 ice is plotted against luminosity in Figure 2. YSOs with $L > 1$ $L_\odot$ have almost

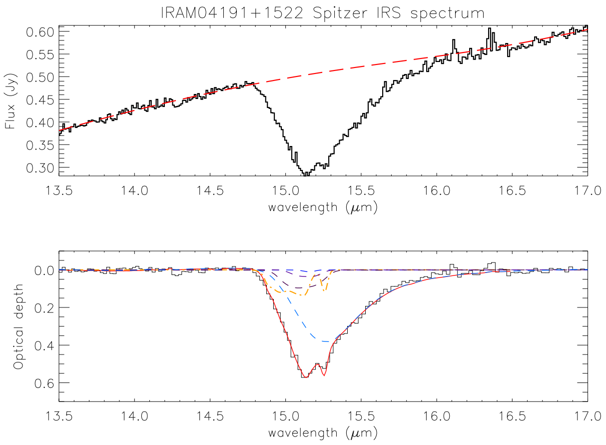

Fig. 1. A sample of *Spitzer* IRS spectrum of CO_2 ice absorption line and the laboratory data fit. The source is IRAM 04191+1522, a very low luminosity object, which has internal luminosity 0.08 $L_\odot$. Upper: Observed flux (black solid) and best fit continuum (red dashed). Lower: Optical depth(black solid), sum of all the ice components (red solid, best fit model), pure CO_2 (yellow dash-dot), H_2O-rich CO_2 ice (blue dashed), CO-CO_2 mixtures (purple dashed). Pure CO_2 ice double peak is observed in the source.

the same ratio as low luminosity YSOs. The fraction of pure CO_2 ice does not depend strongly on the luminosity. This supports that the currently existing central star is not the only heating mechanism of the envelope.

Using a chemo-dynamical model (Lee et al., 2004; Kim et al., 2011), we relate the amount of observed total CO_2 ice, including that in mixed ices, to the accretion scenario. We investigate 4 scenarios, continuous and episodic accretion with and without CO ice to CO_2 ice conversion. The scenario with episodic accretion and CO ice to CO_2 ice conversion explains the observed range of N and the luminosity spread of YSOs best.

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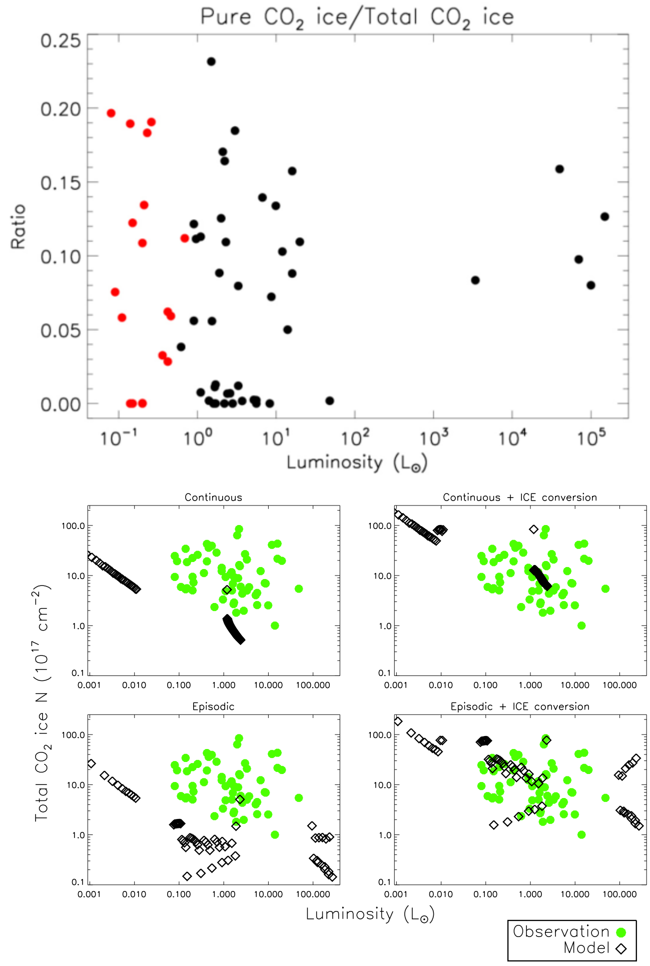

Fig. 2. Upper: The ratio of pure and total CO_2 ice vs luminosity. Red dots are from this work and black dots are from Pontoppidan et al. (2008). Lower: Total CO_2 ice N versus luminosity obtained from the chemical model and the observations (Kim et al., 2012).

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