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The chemistry of episodic accretion

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Abstract. Episodic accretion is an important process in the evolution of young stars and their surroundings. A consequence of an episodic accretion event is a luminosity burst, which heats the protostellar environment and has a long lasting impact on the chemical evolution of the disk and envelope of young stars. We present a new model for the chemistry of episodic accretion based on the 2D radiation thermo-chemical disk code ProDiMo. We discuss the impact of an episodic accretion burst on the chemical evolution of CO and its observables. Furthermore we present a model for the outbursting source V883 Ori where we fitted available observational data to get an accurate physical structure that allows for a detailed study of the chemistry.

Keywords. stars: pre–main-sequence, accretion, accretion disks, (stars:) circumstellar matter, astrochemistry, radiative transfer, methods: numerical

1. Introduction and Method

Protostars grow by accreting material from their circumstellar environment through their disks. However, mass accretion is not a steady process. Observations of young stars show sudden increases in their luminosity by several orders of magnitude that can last for 10-100 yr (e.g. FU Orionis). The origin of these luminosity bursts is most likely a dramatic increase of the mass accretion rate in the most inner region of the disk (e.g. Zhu *et al.* (2007); Audard *et al.* (2014)). Episodic accretion events heat the disk/envelope of the protostar and have therefore a strong impact on the chemistry (e.g. Kim *et al.* (2012); Vorobyov *et al.* (2013); Visser *et al.* (2015)).

We developed a new model for the chemistry of episodic accretion based on the 2D radiation thermo-chemical disk code ProDiMo (PROtoplanetary DIsk MOdel, Woitke *et al.* (2009)). ProDiMo self-consistently solves for the dust temperature, the gas temperature and the chemical abundances for a fixed gas and dust density structure. With the new extension also disk+envelope structures are possible (Rab *et al.* (2017)). Furthermore the code produces synthetic observables such as spectral energy distributions (SED) and molecular line emission.

Here we present two applications of this model. We study the chemical evolution and the impact on observables after the luminosity burst and we show first modelling results for the outbursting source V883 Ori. V883 Ori is especially interesting as observational

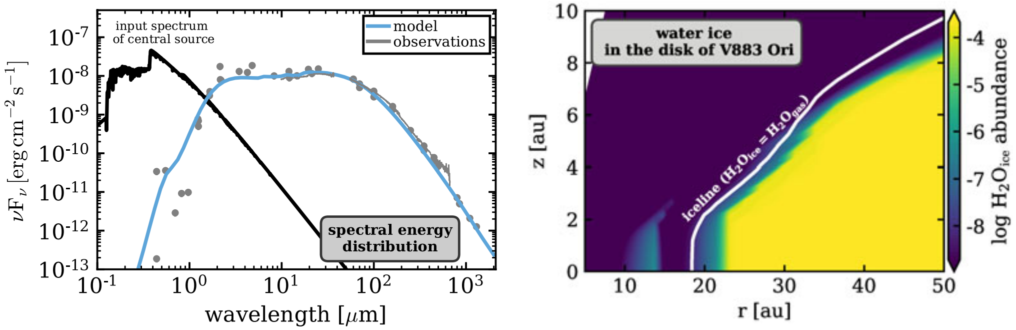

Figure 1. *Left panel:* Fitted spectral energy distribution for V883 Ori. *Right panel:* The resulting water ice abundance and the location of the water ice line in the disk of V883 Ori.

constraints on the location of the water ice line exist (Cieza *et al.* (2016)) and complex organic molecules were detected (van't Hoff *et al.* (2018); Lee *et al.* (2019)).

2. Results and Conclusions

For a representative Class I protostar a burst with a luminosity of $L = 100\,L_\odot$ sublimates CO ice in the disk and envelope out to $r \approx 3000$ au. After the burst stops, CO freezes out from inside-out due to the radial density gradient (faster freeze-out closer to the center). This produces clear observational signatures in the line emission such as rings and distinct features in radial intensity profiles. As the the freeze-out of CO lasts up to 10000 yr, such observational signatures allow to identify targets that experienced a luminosity burst long after the burst stopped. Based on these models we developed a simple method, that does not require chemical modelling, to identify such post-burst objects by fitting observed radial intensity profiles (see Rab *et al.* (2017) for details).

In Fig. 1 we show the modeled SED of V883 Ori. The data used includes new photometric and spectroscopic data from the Herschel Space Observatory (Postel *et al.* (2019)). The model is also consistent with spatially resolved ALMA data for the disk and APEX CO observations of the envelope (White *et al.* (2019)). The water ice line in the model is at $r \approx 20$ au (Fig. 1). This indicates that the additional heating by the burst is not sufficient to shift the ice line out to $r \gtrsim 40$ au, as suggested by observations (Cieza *et al.* (2016)). Accretion heating in the disk (not included in the model) might solve this discrepancy.

Episodic accretion events provide an excellent testbed to study chemistry in young stars (e.g. molecules sublimate during the burst, become observable and provide constraints on the ice composition, Lee *et al.* (2019)). Observations with state-of-the-art instruments (e.g. ALMA) show already the great potential of episodic accretion chemistry to shed new light on the complex processes governing astrochemistry. Models, like the one presented here, are crucial for the interpretation of such observations.

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