Modeling the Chemical Impacts of Luminosity Outbursts in Protostellar Envelopes

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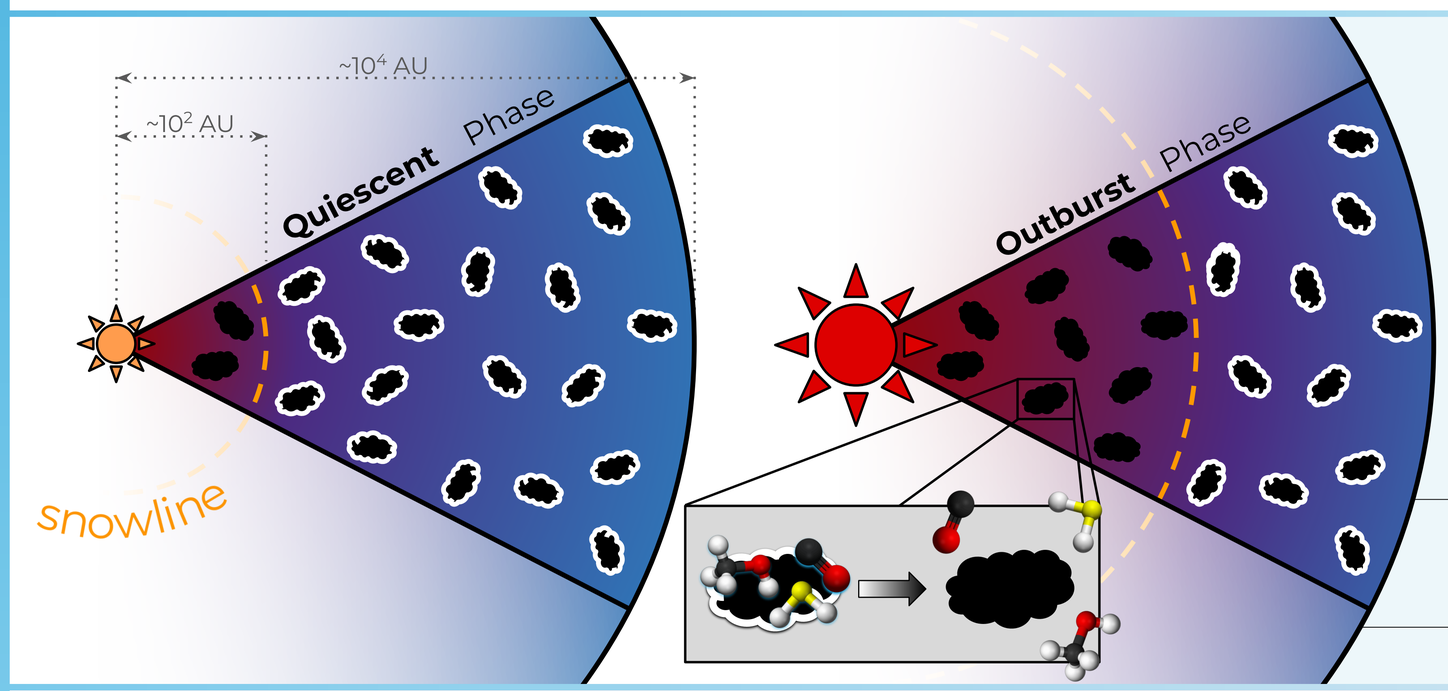
ABSTRACT

More and more large spectral surveys are carried out in the radio/submm/mm range to characterize the molecular composition of star forming regions. The observational studies carried out so far seem to indicate that the chemical content differs between protostars. With chemical models, it is possible to test different scenarios and better understand the possible origins of these differences. In this study, we investigate the impact of luminosity outbursts on the chemical composition of solar-type protostars. Accretion bursts and consequently luminosity outbursts are experienced by some young stellar objects. The sudden rise in temperature caused by luminosity outbursts can sublimate the molecules frozen on the dust grains. The release of new molecules into the gas phase with the temporary increase in temperature could affect the long-term evolution of the chemical composition of protostellar systems. We used the dynamic physical APE code (Marchand et al. 2025) to calculate the 1D evolution of particles in a protostellar envelope. We also ran models implementing luminosity outbursts by modifying the previously determined temperature. The physical evolution of the density and temperature was then used as inputs of the Nautilus gas-grain chemistry code (Ruaud et al. 2016) (updated to take into account a better description of the complex organic molecules) to predict the evolution of the molecular abundances from the cold outer regions to the warm inner regions. This poster summarize our results on the predicted impact of luminosity outbursts on the chemical composition of protostellar envelopes.



Sketch representing the impact of a luminosity outburst on the protostellar envelope.
Snowlines of chemical species are pushed away from the protostar, leading to the release of molecules into the gas phase (desorption).
Left: quiescent phase; Right: outburst phase

CONTEXT

Different chemical compositions are **observed** among low-mass protostars. Are some of these discrepancies due to **episodic accretion**?

➜ We need to **model** the **impact** of a luminosity **outburst** on the **chemistry.**

MODEL

Amplitude of the outburst: $L_{outburst} = L_{quiescent} \times 100$

Outburst **duration**: 100yr

Impact only the temperature: $$\frac{T_{outburst}}{T_{quiescent}} = \left(\frac{f\ T_*^4 \left(\frac{R_*}{r}\right)^2 + T_{mc}^4}{T_*^4 \left(\frac{R_*}{r}\right)^2 + T_{mc}^4}\right)^{\frac{1}{4}}$$

with f = 100, T_{mc} the temperature of the surrounding molecular cloud
T_* and R_* are respectively the temperature and the radius of the protostar

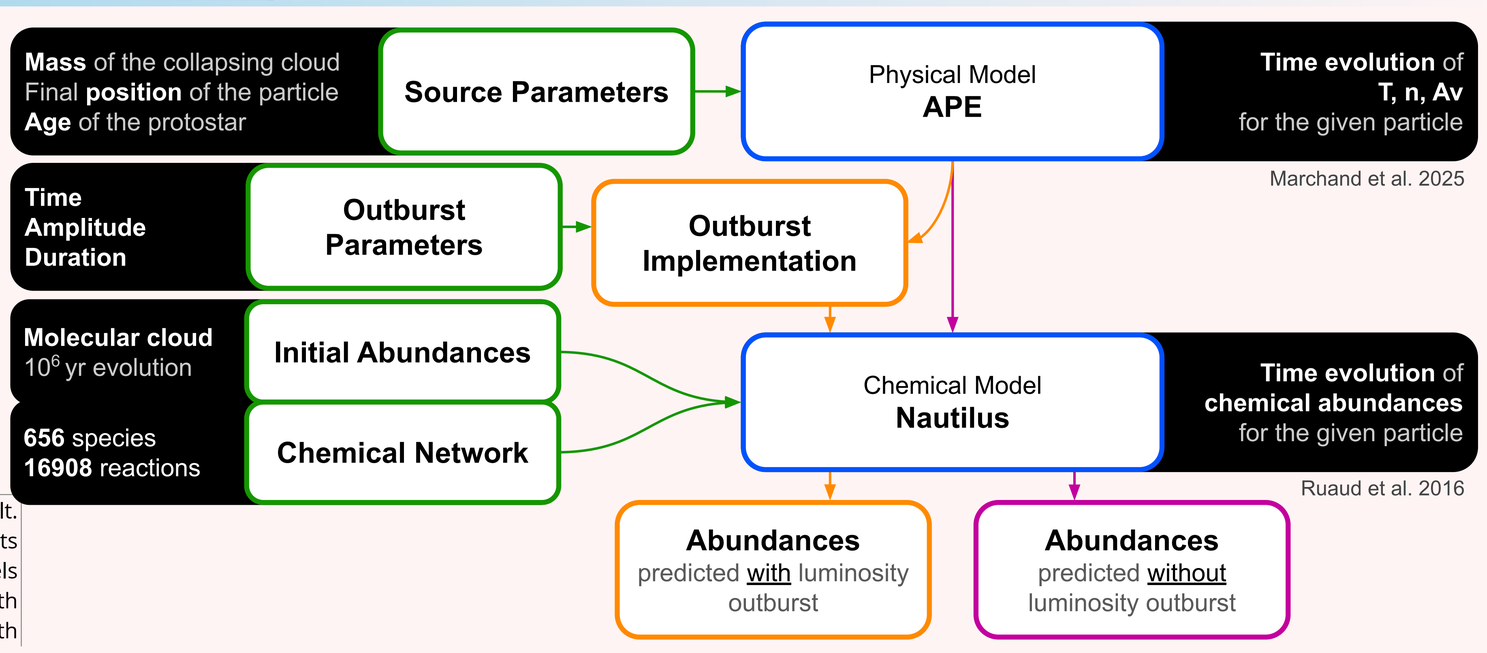
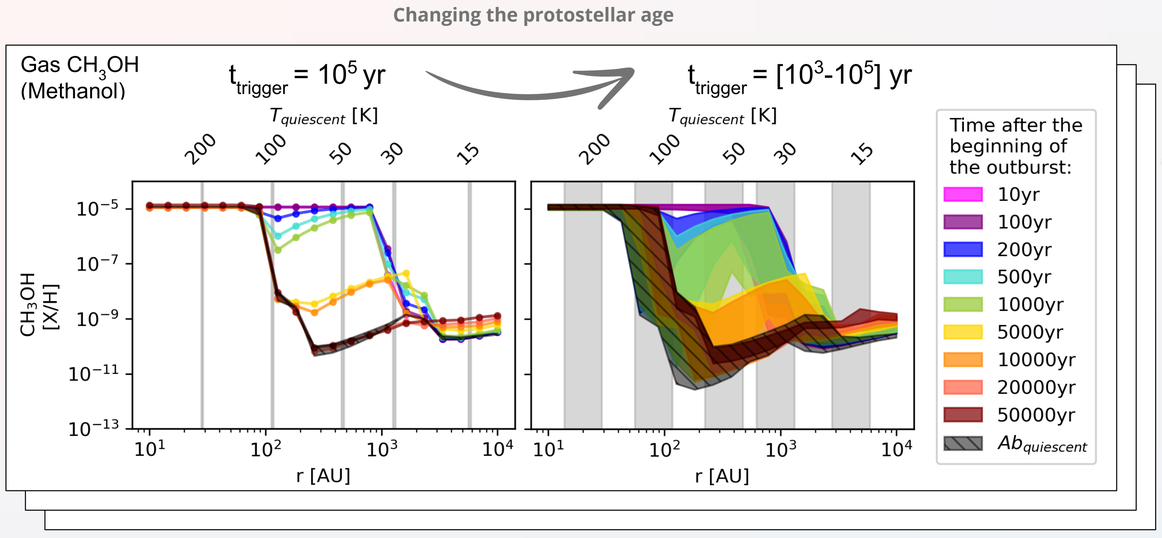


Diagram representing how the model used in this study is built.
Green: Inputs
Blue: Physical and chemical models
Orange: Outburst path
Purple: Quiescent path

Changing the protostellar age

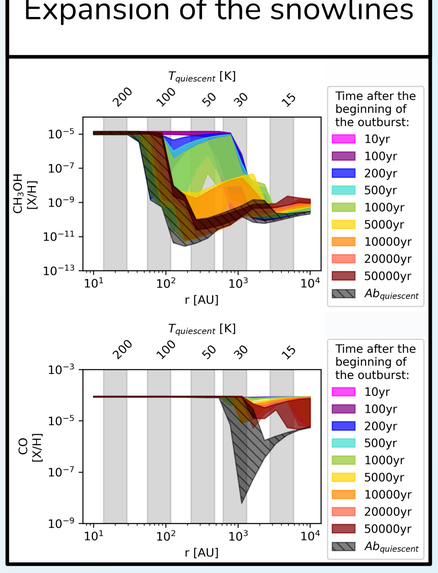


For all the species of the chemical network

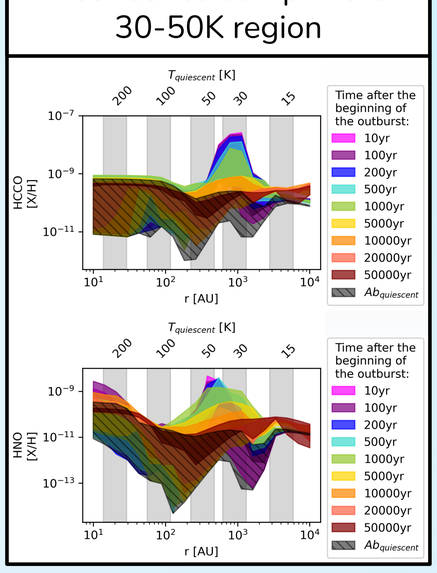
RESULTS

Classification of molecules
Impacted?
In which region(s)?
How long?
How much?
Not impacted?

Expansion of the snowlines

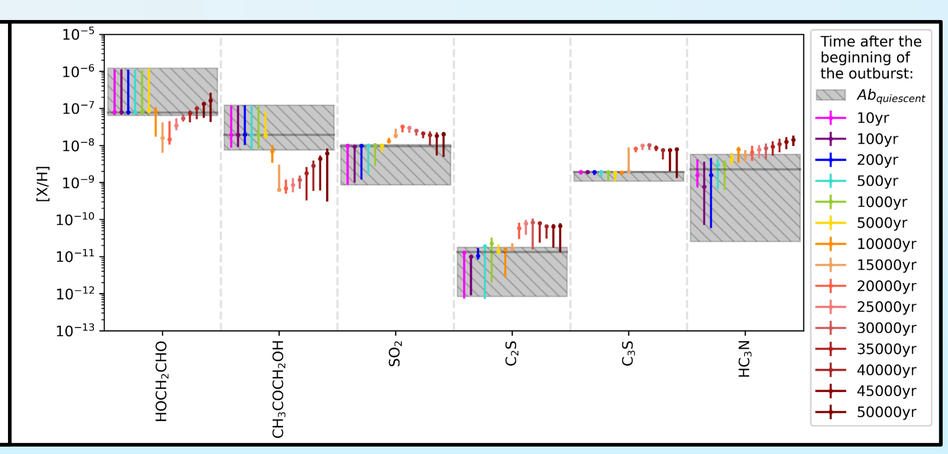


Abundance bump in the 30-50K region



- Most of the molecular abundances exhibit spatial variations in response to the outburst 55/79
- Some gas-phase molecular abundances are only impacted in the 50-30K region on the envelope 6/79
- Few molecules manifest differences in the inner region of the envelope a long time after the outburst occurred (few tens of kyr) 6/79

Late inner impact in the inner region (at 10AU)



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