

# Modeling the Chemical Impacts of Luminosity Outbursts in Protostellar Envelopes

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The CHEMical TRail In Protostars: From the deeply embedded phase to the planet-forming disk



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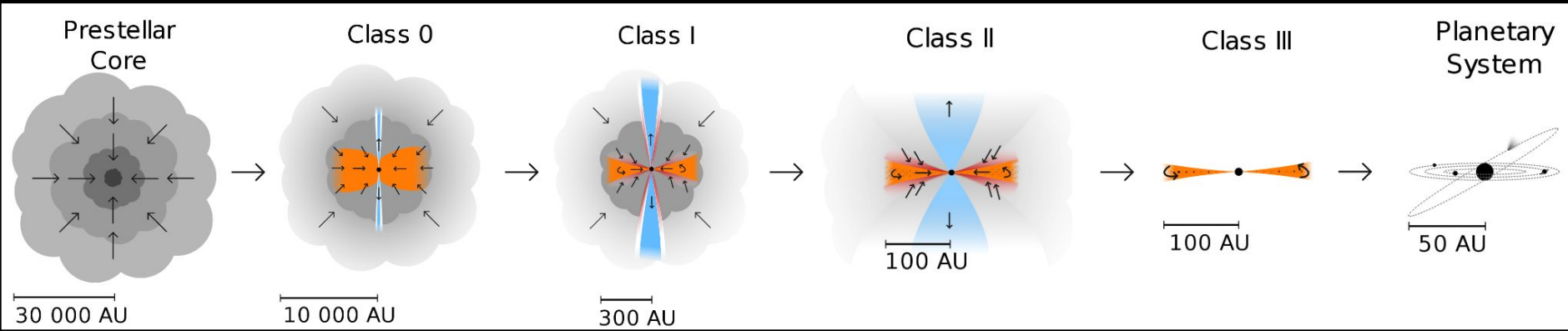
Credit: NASA/CXC/M. Weiss

**Spectral surveys** in the **radio/submm/mm** → **molecular composition** of **star-forming regions**

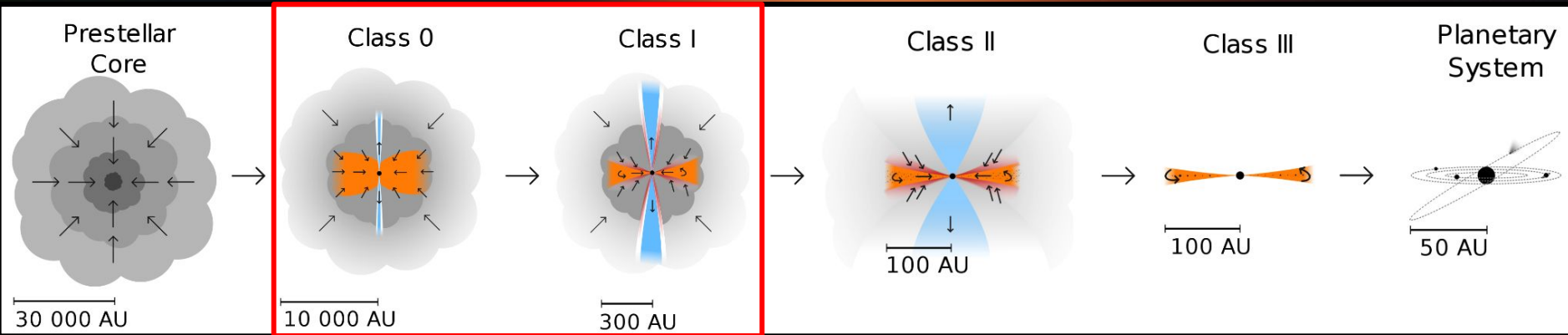
**Observational studies** → **chemical content** may differ between **protostars**

⇒ **Physico-chemical models** are used to **understand the origins** of these differences

Source: M. Persson



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**Focus of this study**

Some **young stellar objects** undergo **episodic accretion**

- **long periods + low accretion rate**  $\Rightarrow$  **quiescent** phase
- **short periods + high accretion rate**  $\Rightarrow$  **outburst** phase

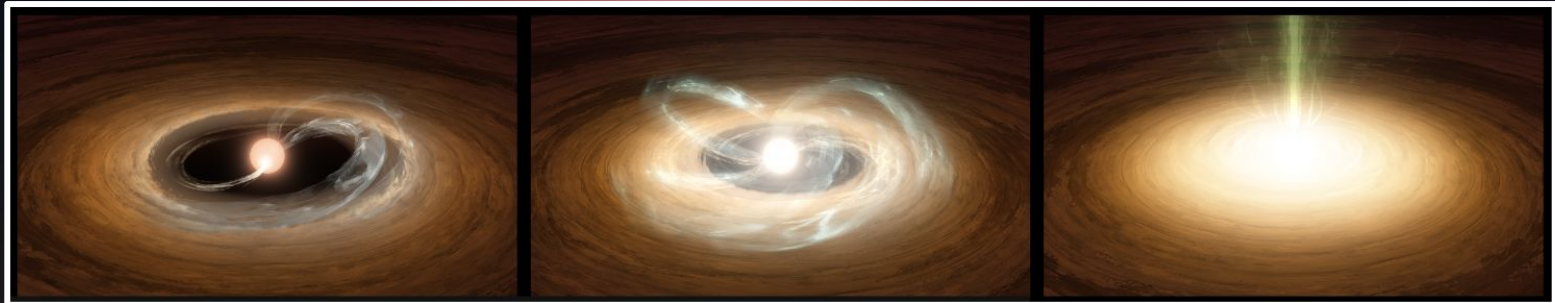
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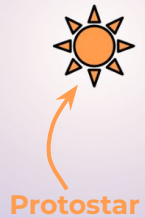
- **long periods + low accretion rate**  $\Rightarrow$  **quiescent** phase
- **short periods + high accretion rate**  $\Rightarrow$  **outburst** phase

**Episodic accretion**  $\rightarrow$  **Luminosity outbursts**

Quiescent

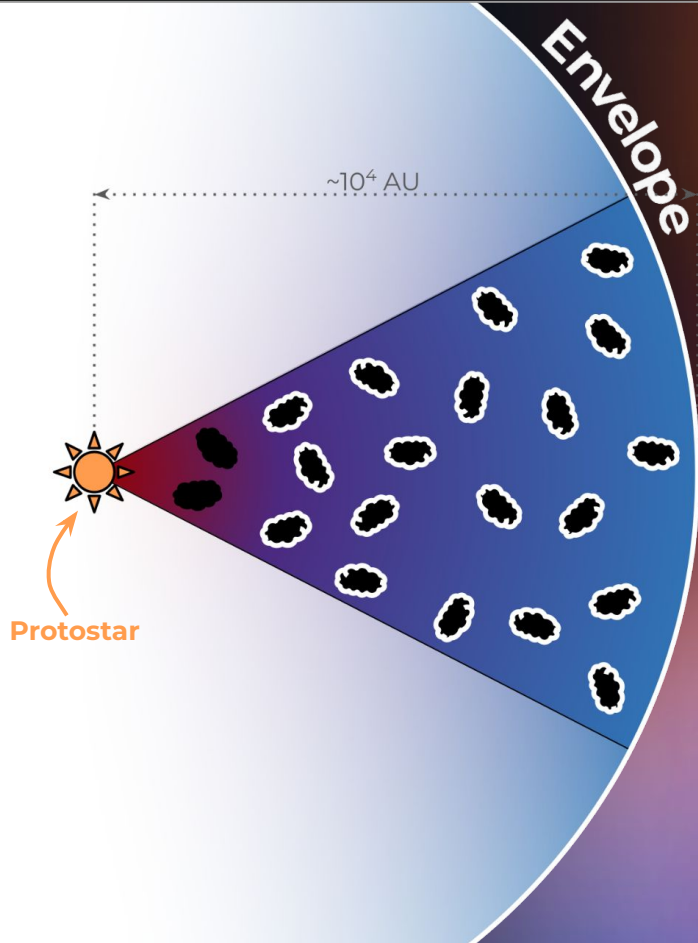
Outburst





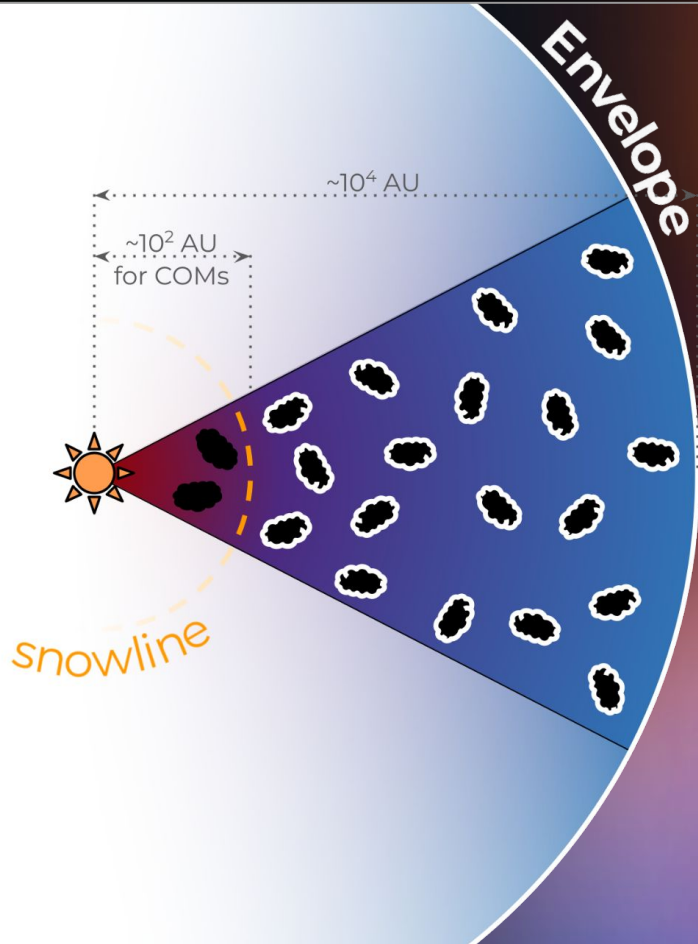
What is the impact of **luminosity outbursts** on the **chemical composition** of **solar-type protostellar envelopes**?

- warm inner regions
- cold outer regions



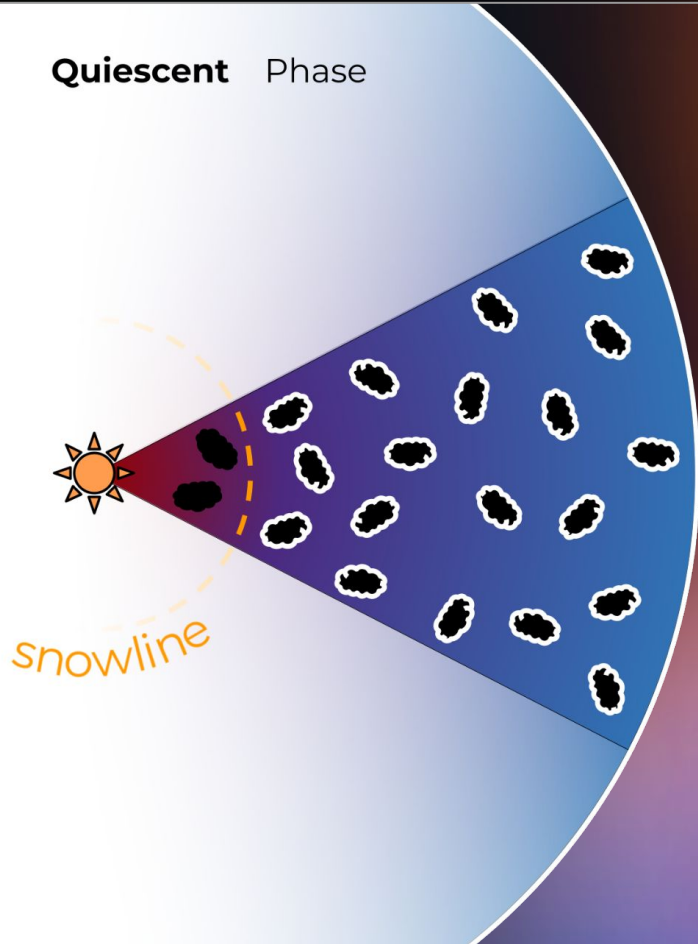
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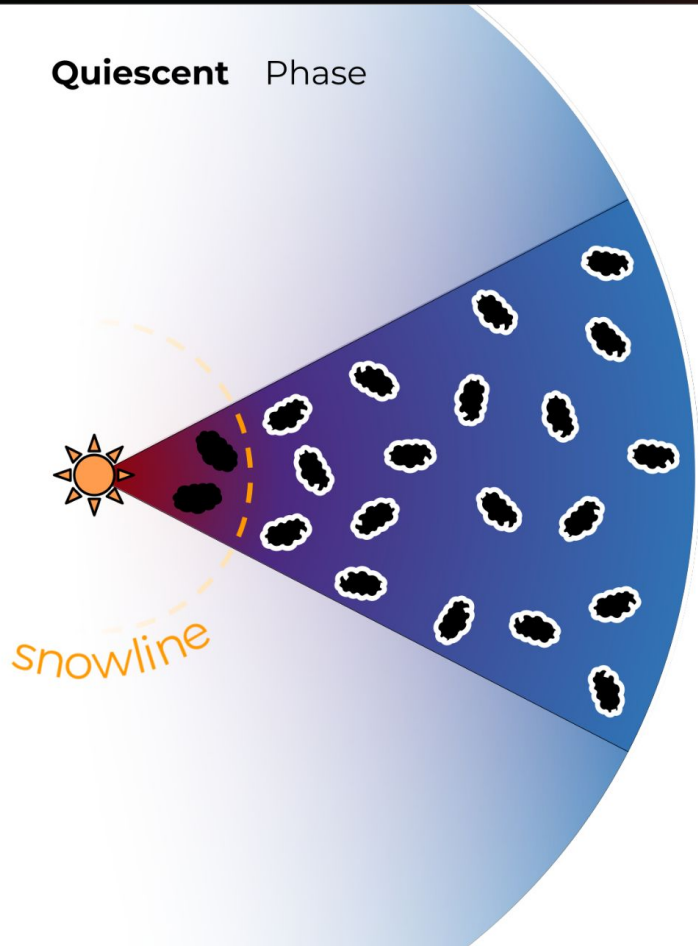
- warm inner regions
- cold outer regions



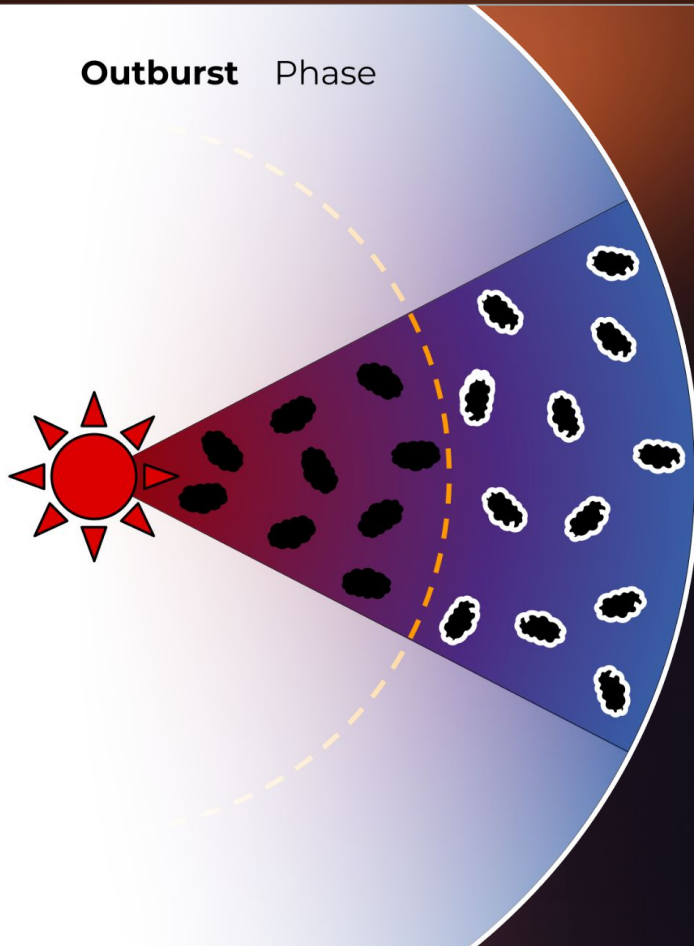
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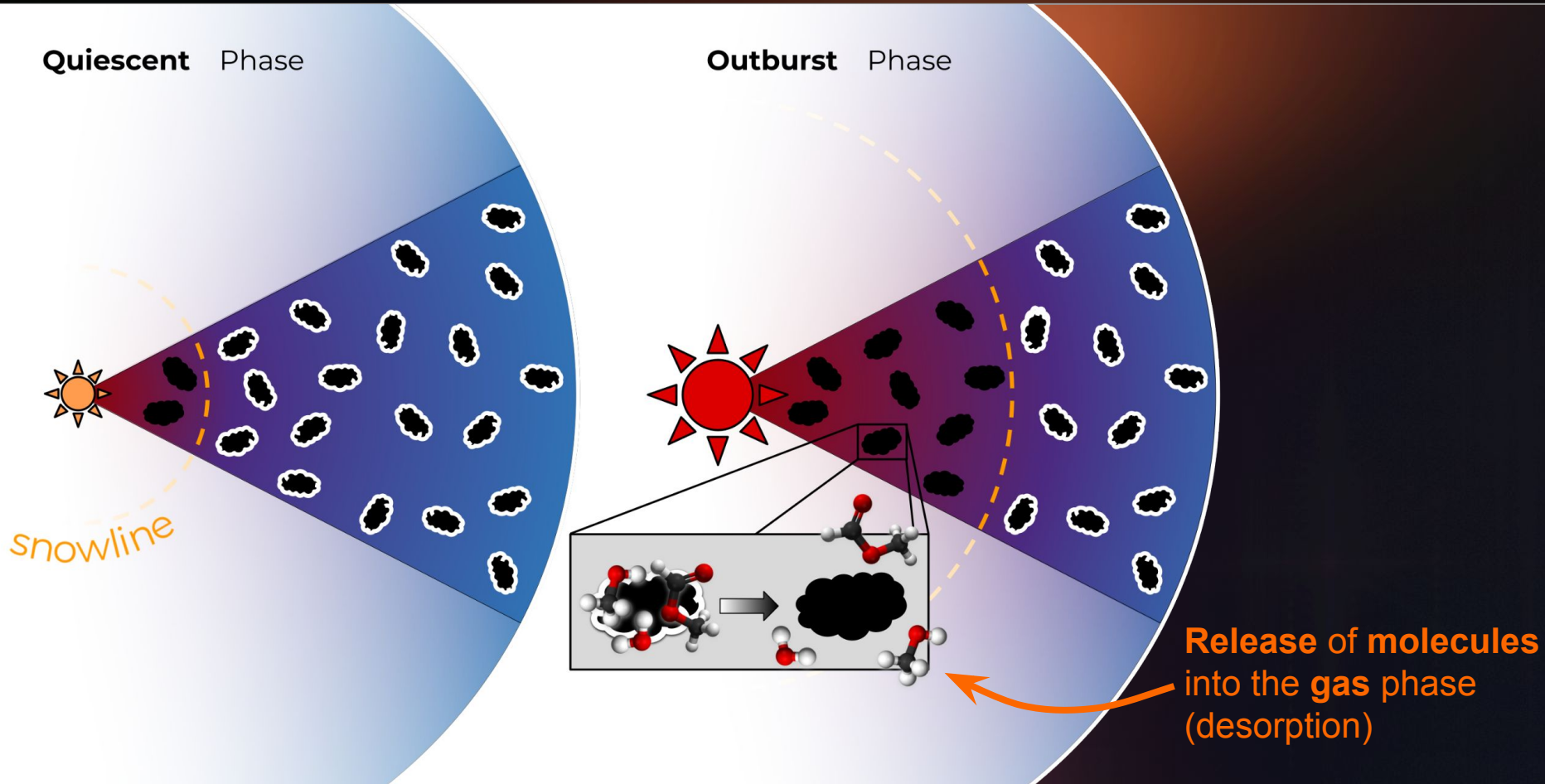
- warm inner regions
- cold outer regions

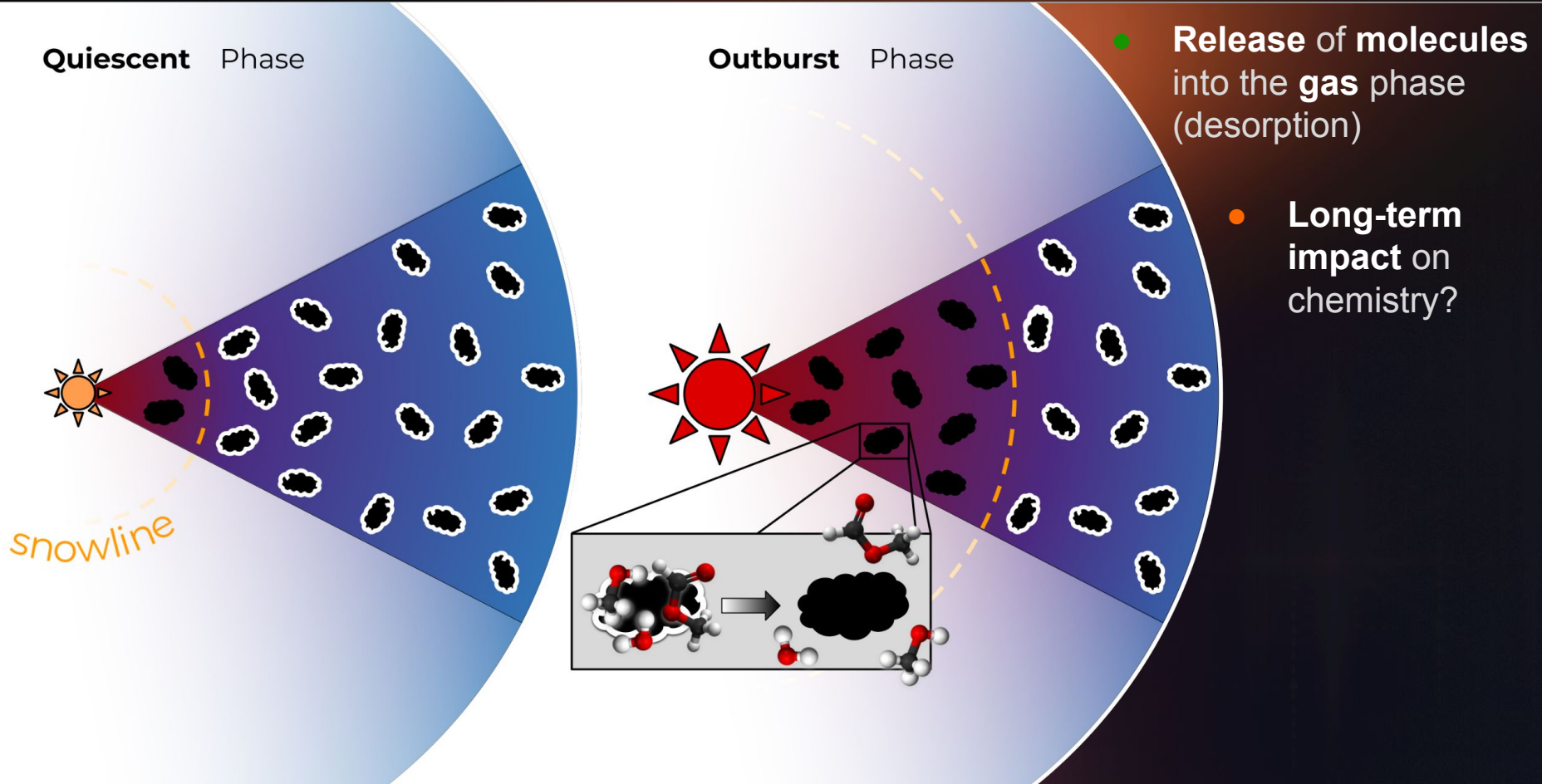
**Quiescent Phase**

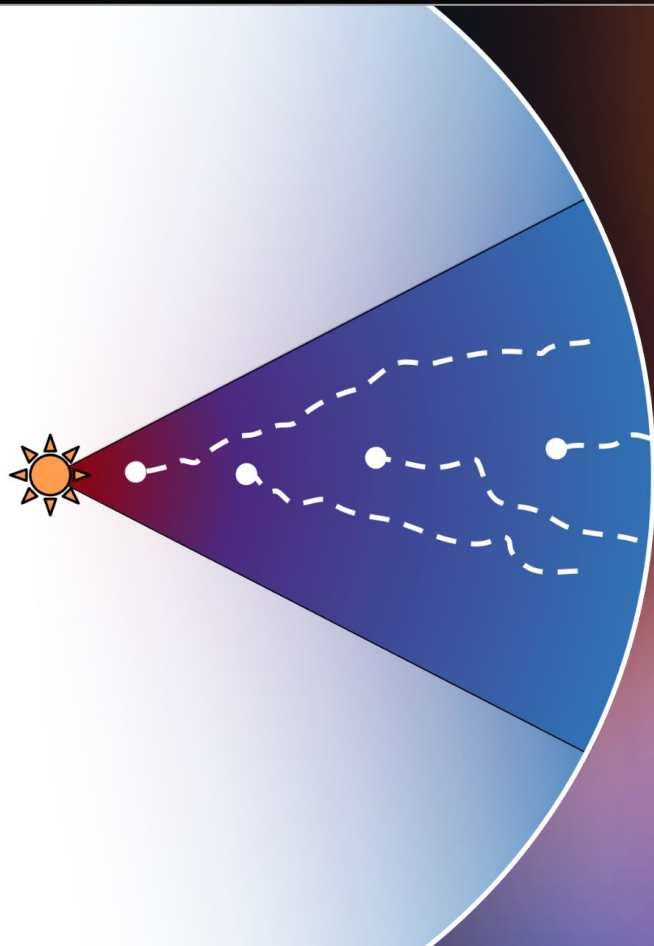


**Outburst Phase**



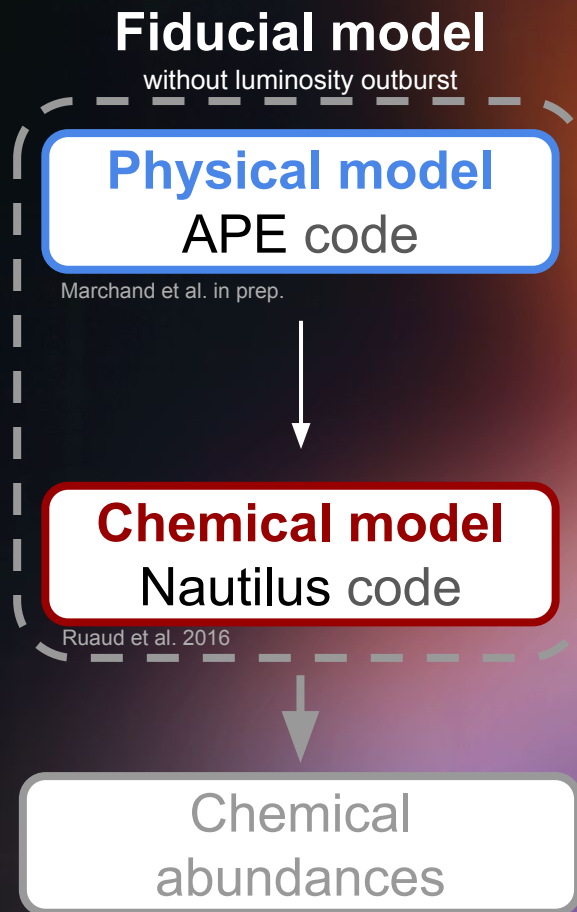


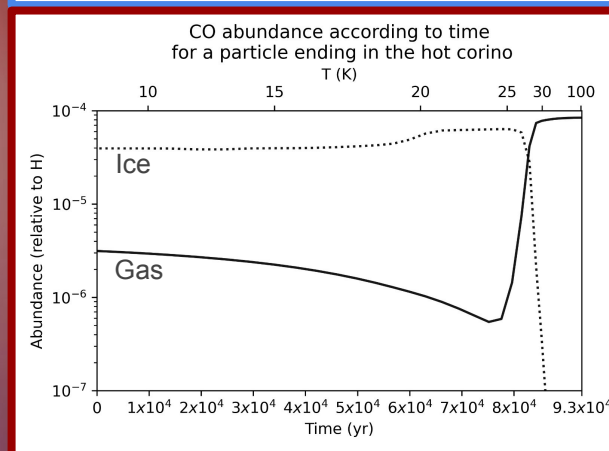
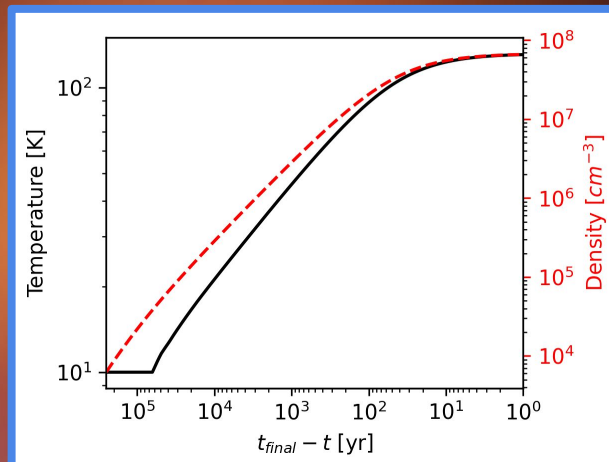
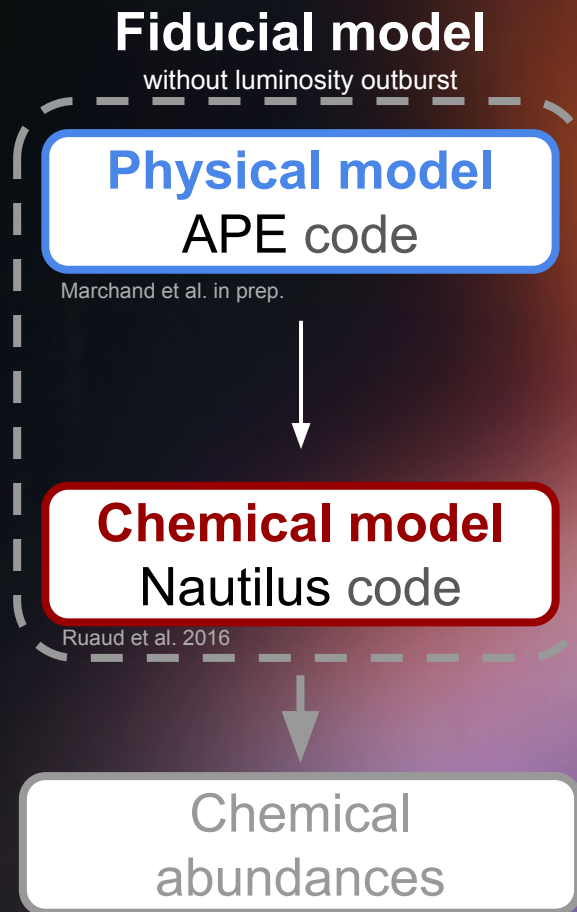


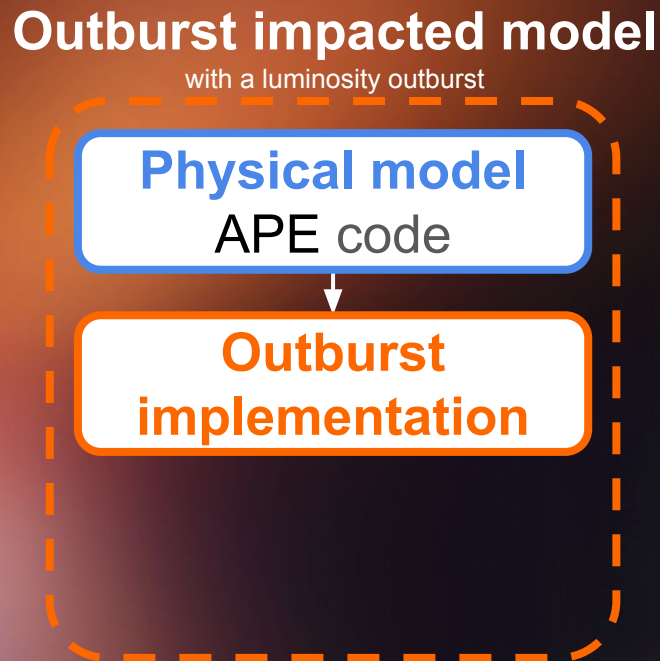
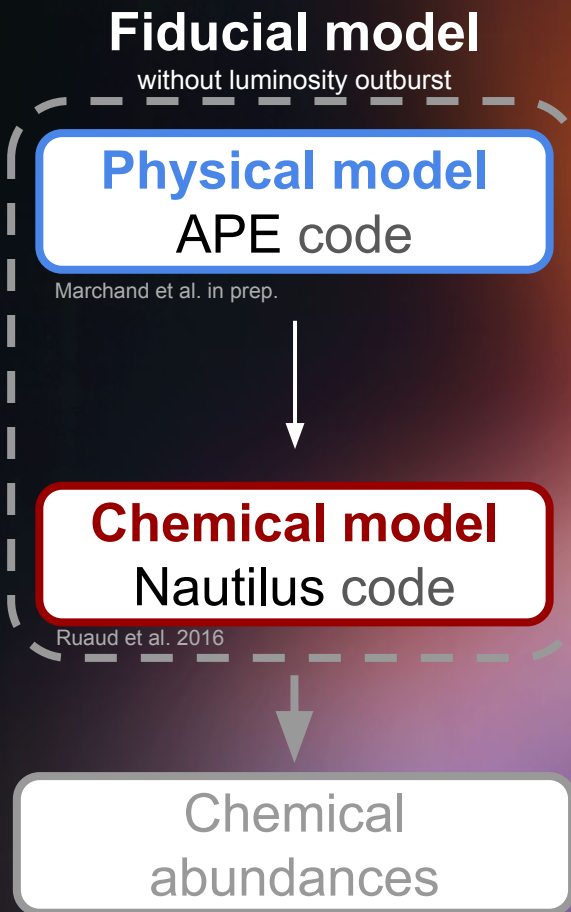


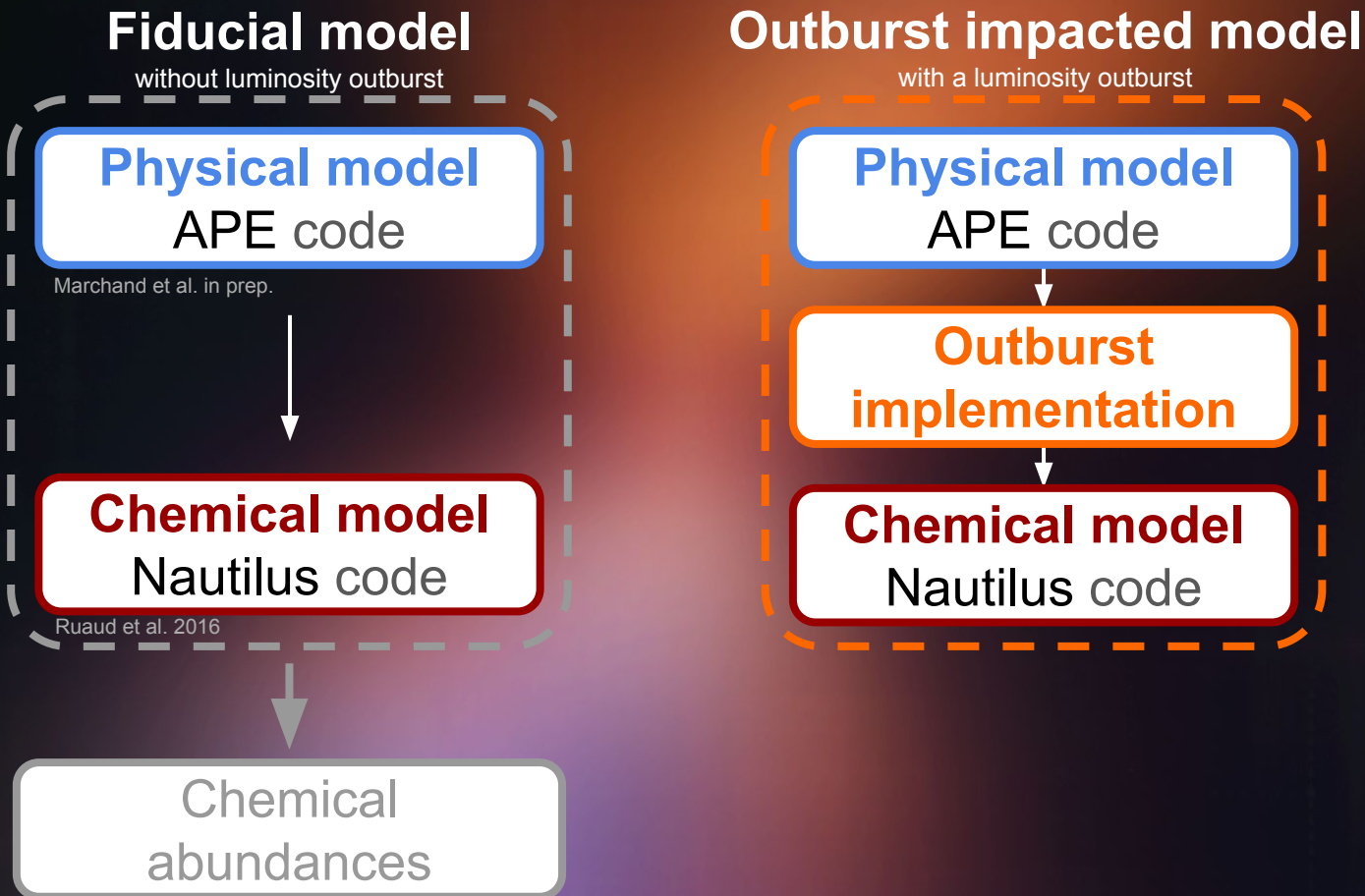
### Simulation of material infall in the envelope

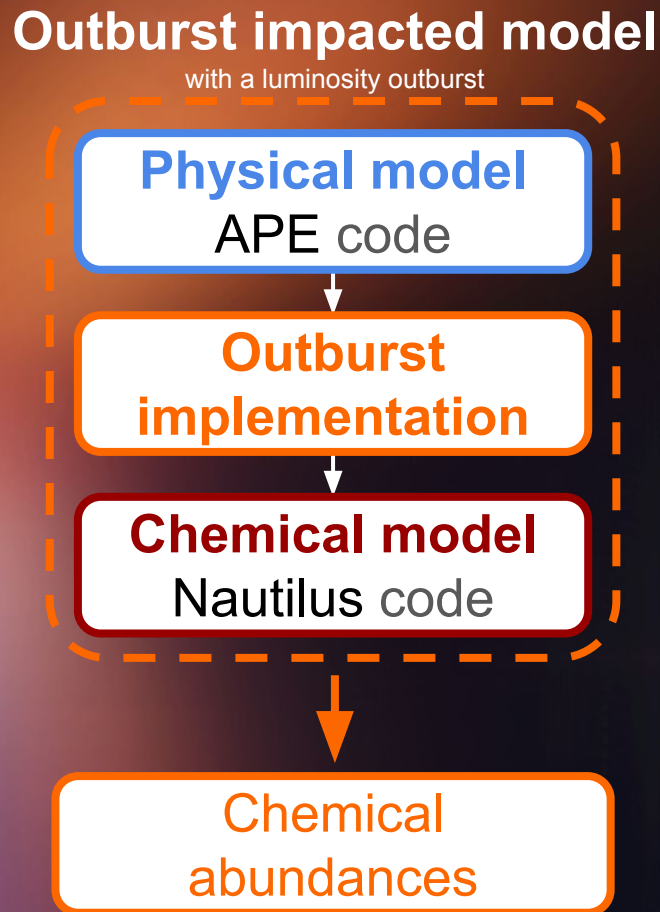
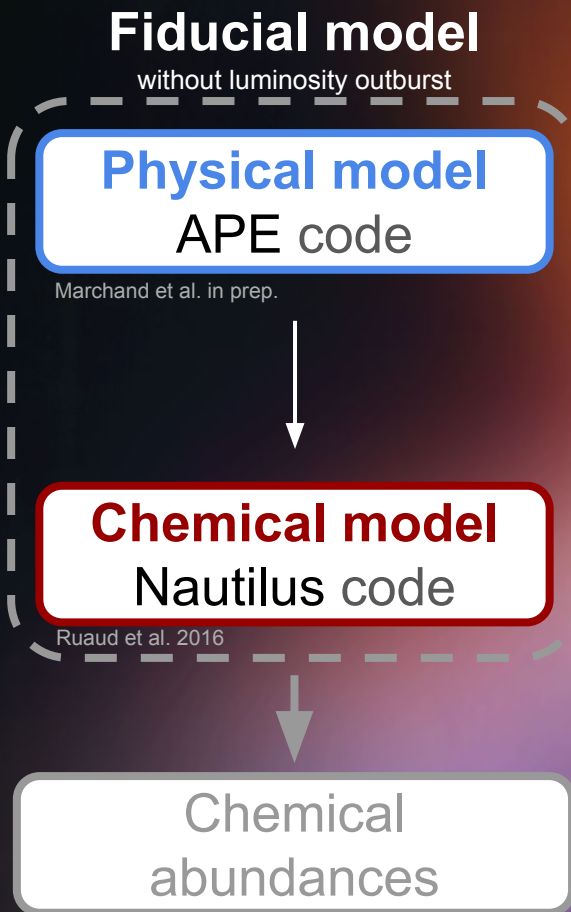
- different trajectories
- particles experience the outburst at different points in their trajectories

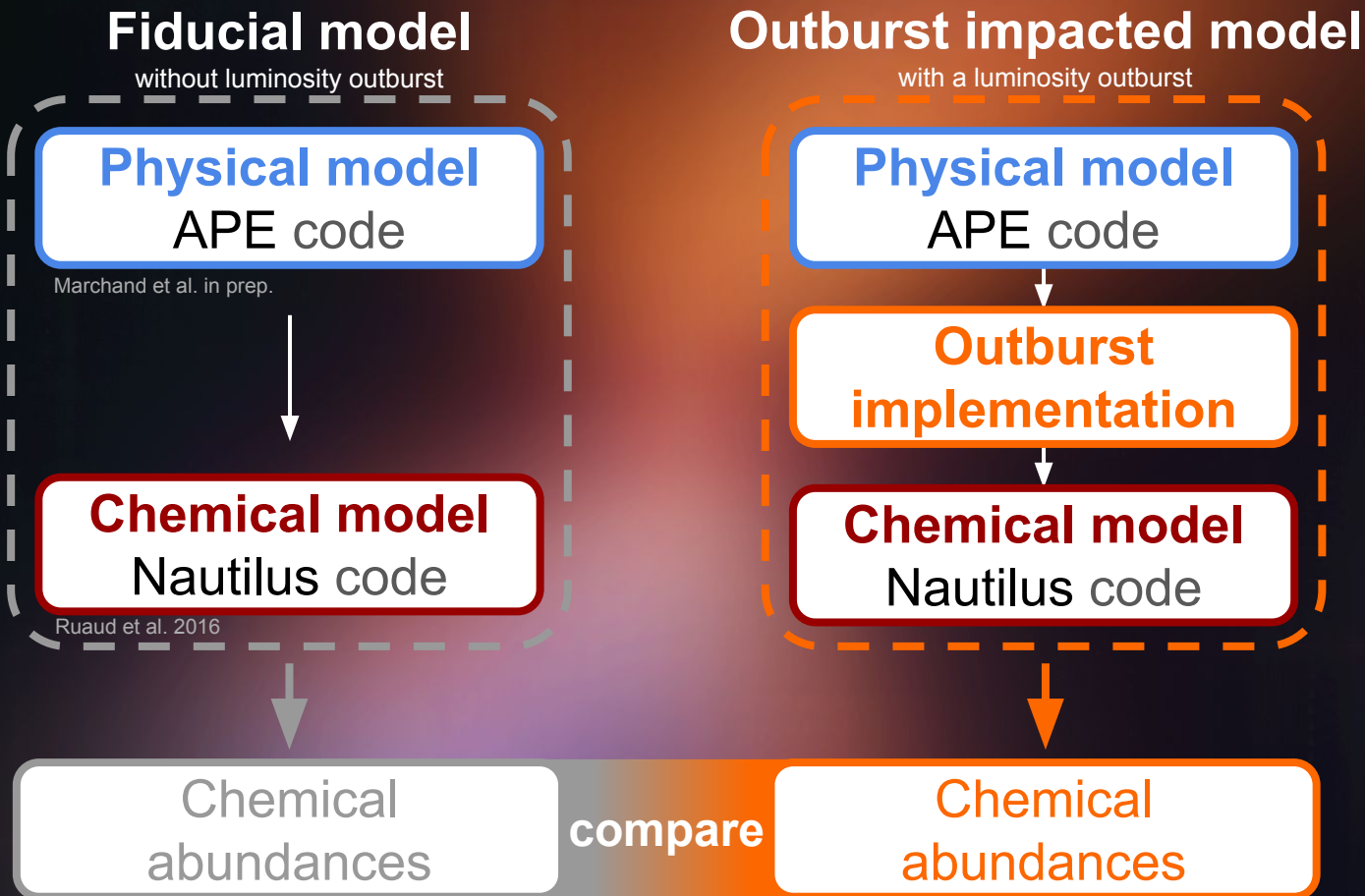


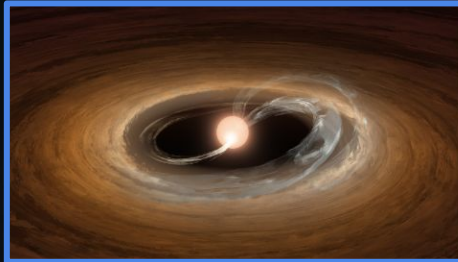




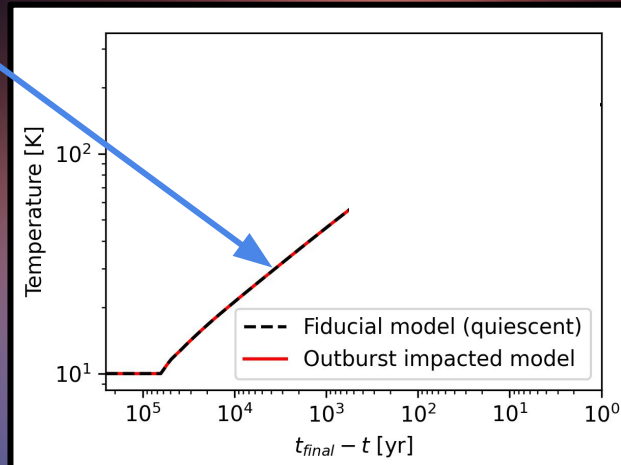


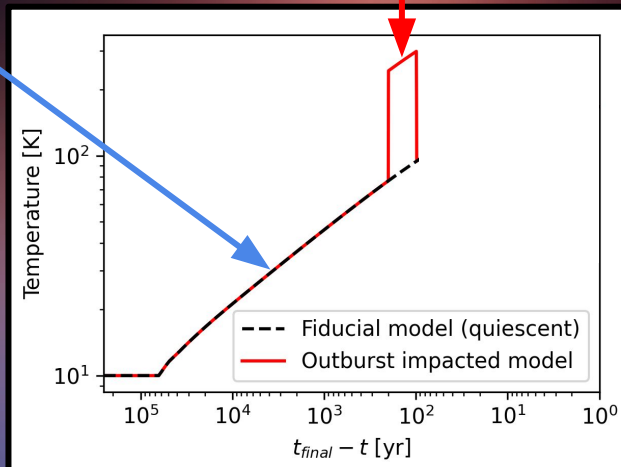
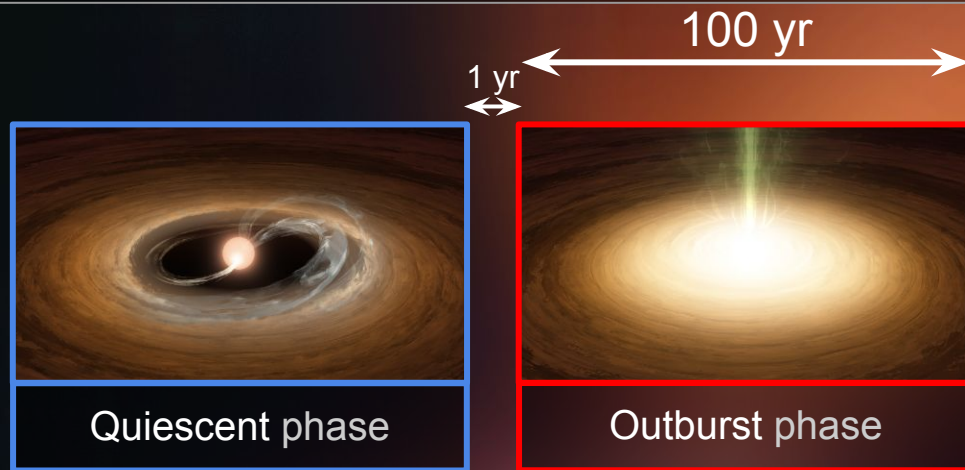




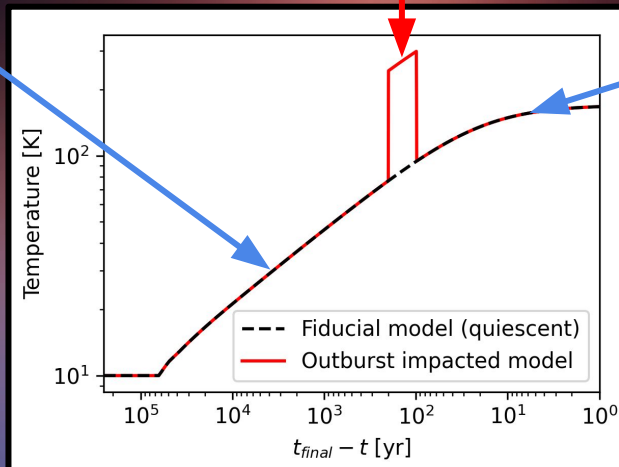
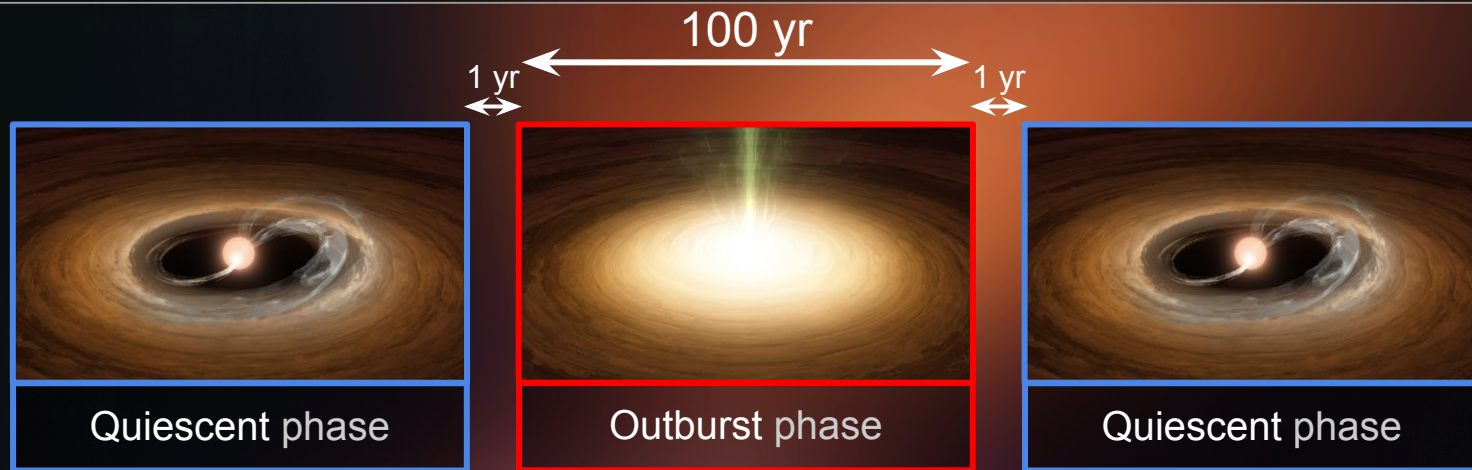


Quiescent phase





- $L_{\text{outburst}} = 100 \times L_{\text{quiescent}}$
- Only impacts the temperature



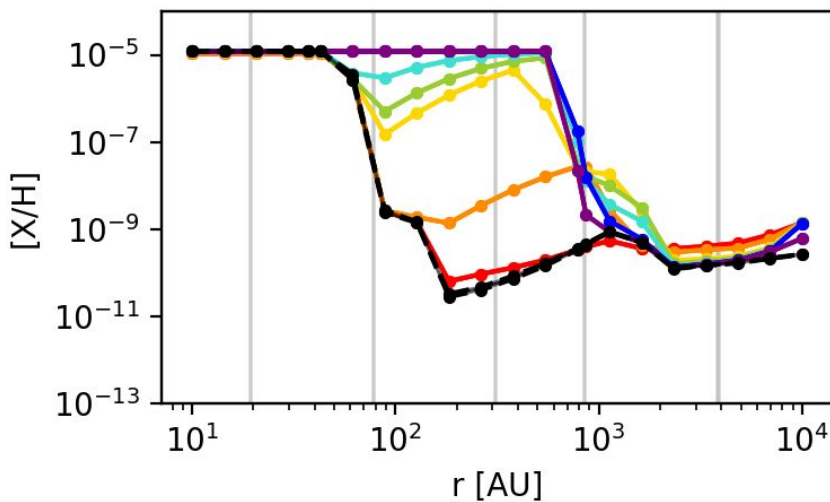
- $L_{\text{outburst}} = 100 \times L_{\text{quiescent}}$
- Only impacts the temperature

Gas CH<sub>3</sub>OH  
(Methanol)

$t_{\text{outburst}} = 10^5 \text{ yr}$

$T_{\text{quiescent}} \text{ [K]}$

200 100 50 30 15



Time after the beginning of the outburst:

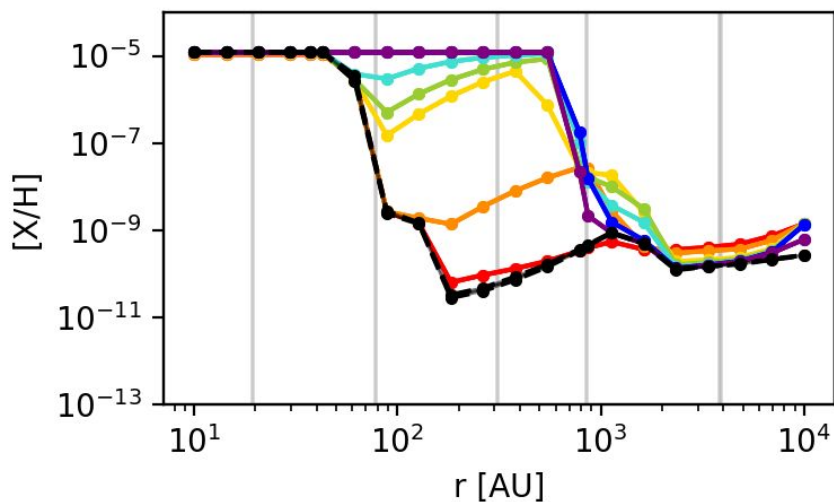
- 10yr
- 100yr
- 200yr
- 500yr
- 1000yr
- 5000yr
- 10000yr
- $Ab_{\text{quiescent}}$

Gas CH<sub>3</sub>OH  
(Methanol)

$t_{\text{outburst}} = 10^5 \text{ yr}$

$T_{\text{quiescent}} \text{ [K]}$

200 100 50 30 15



During the outburst

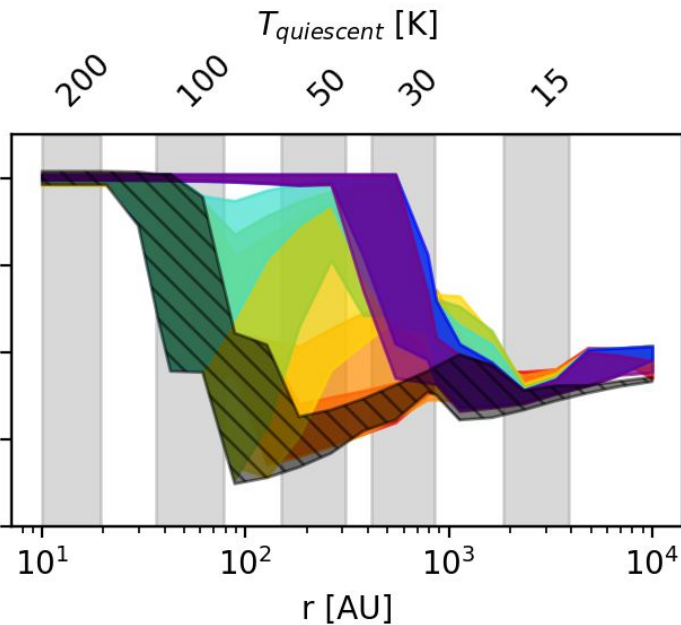
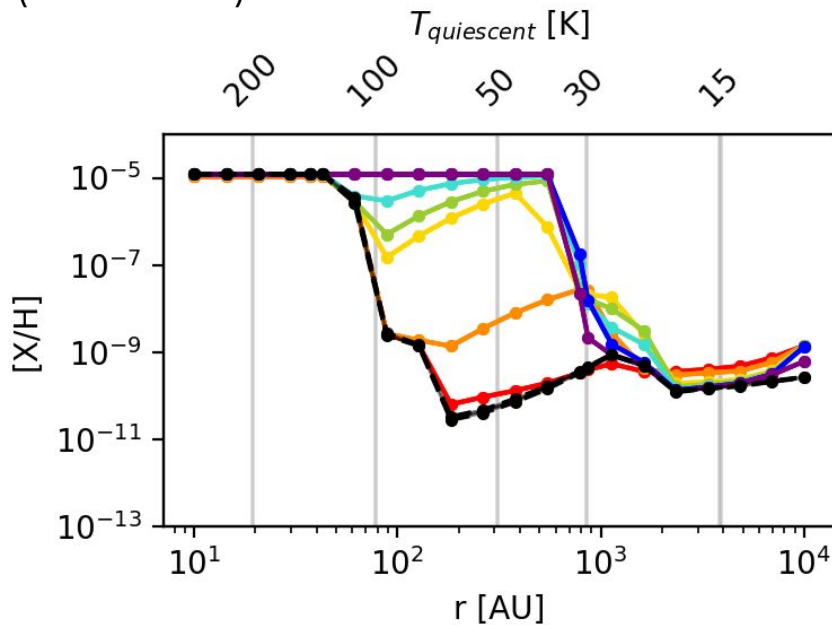
Post outburst

Gas CH<sub>3</sub>OH  
(Methanol)

$t_{\text{outburst}} = 10^5 \text{ yr}$

changing the time at which  
the outburst is triggered

$t_{\text{outburst}} = [10^3 - 10^5] \text{ yr}$



- Time after the beginning of the outburst:
- 10yr
  - 100yr
  - 200yr
  - 500yr
  - 1000yr
  - 5000yr
  - 10000yr
  - $Ab_{\text{quiescent}}$

## II Method

Grid of particles (varying  $r_{\text{final}}$ ,  $t_{\text{final}}$ ,  $t_{\text{outburst}}$ )

10

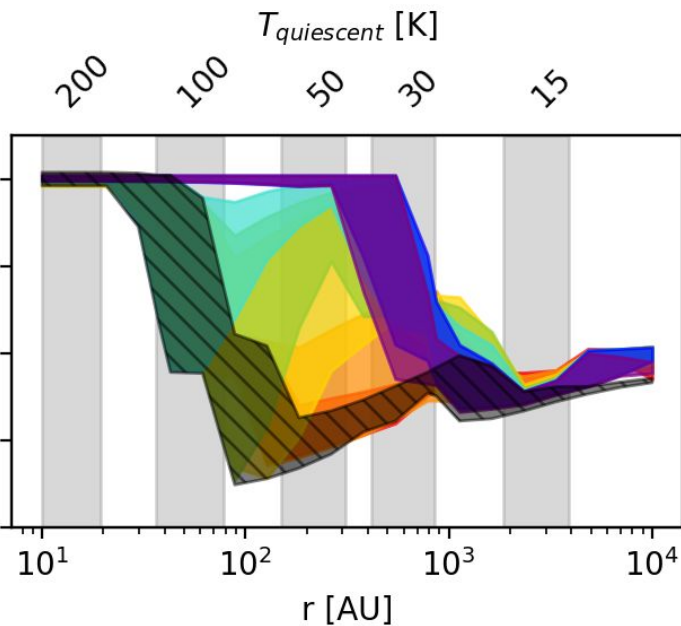
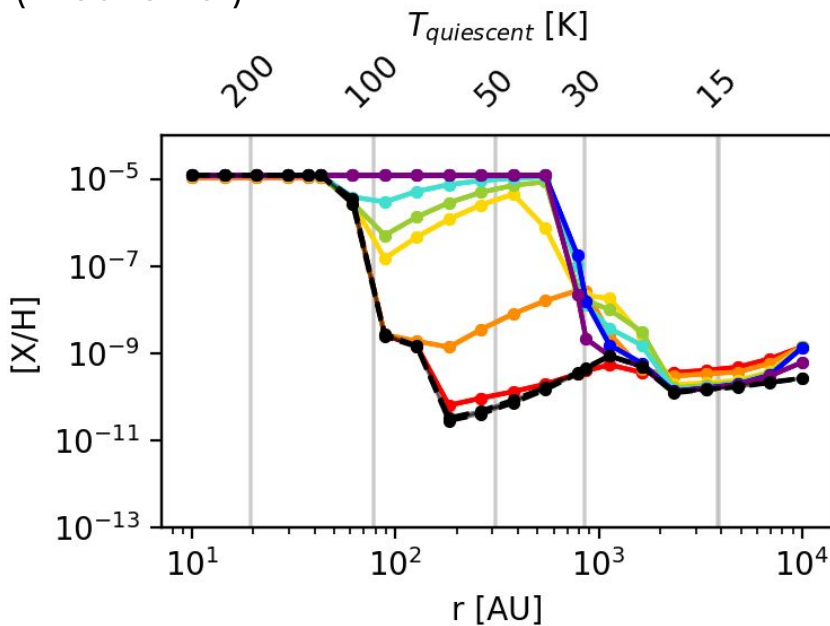
For all the species of the chemical network

Gas  $\text{CH}_3\text{OH}$   
(Methanol)

$t_{\text{outburst}} = 10^5 \text{ yr}$

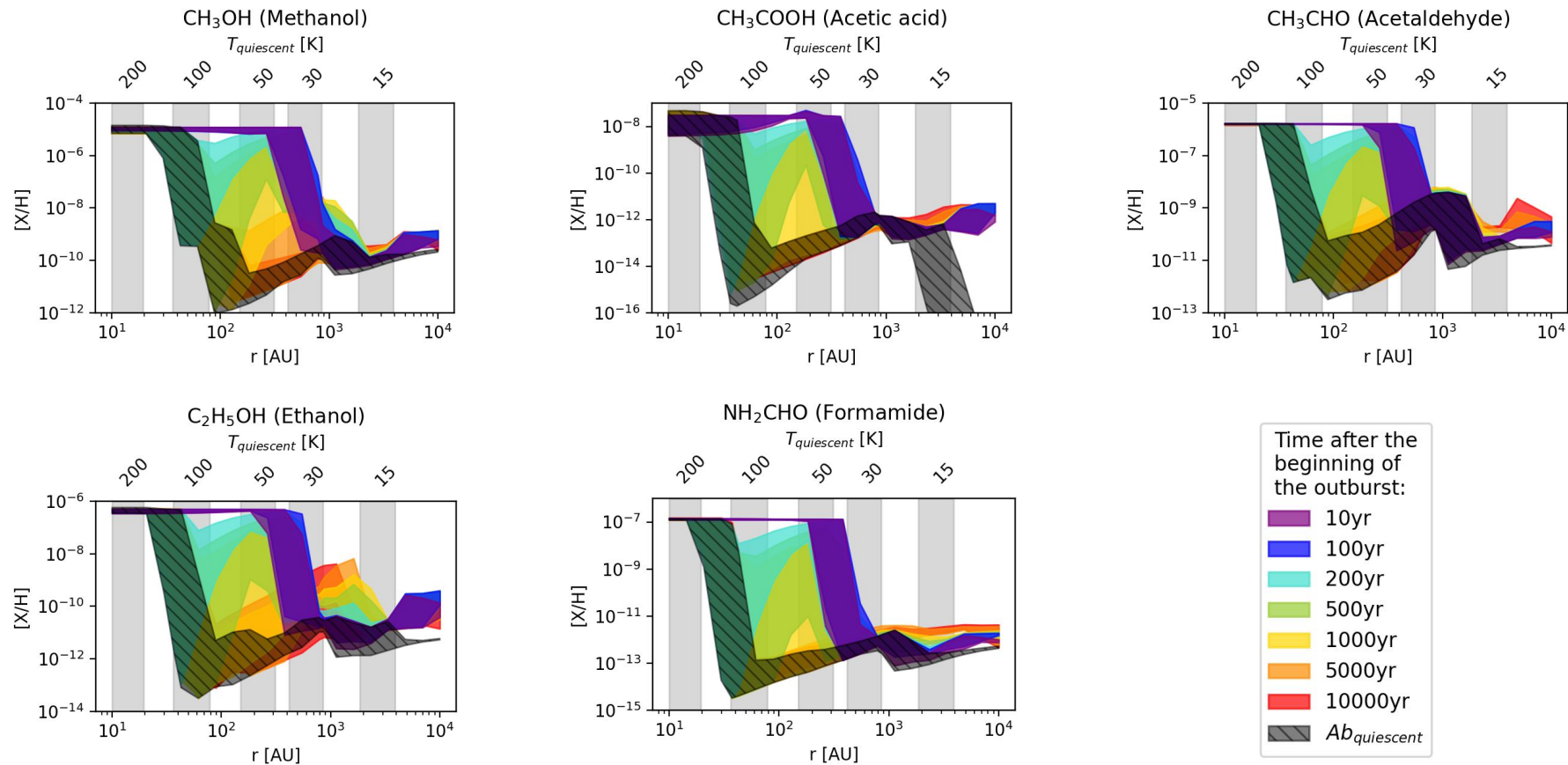
changing the time at which  
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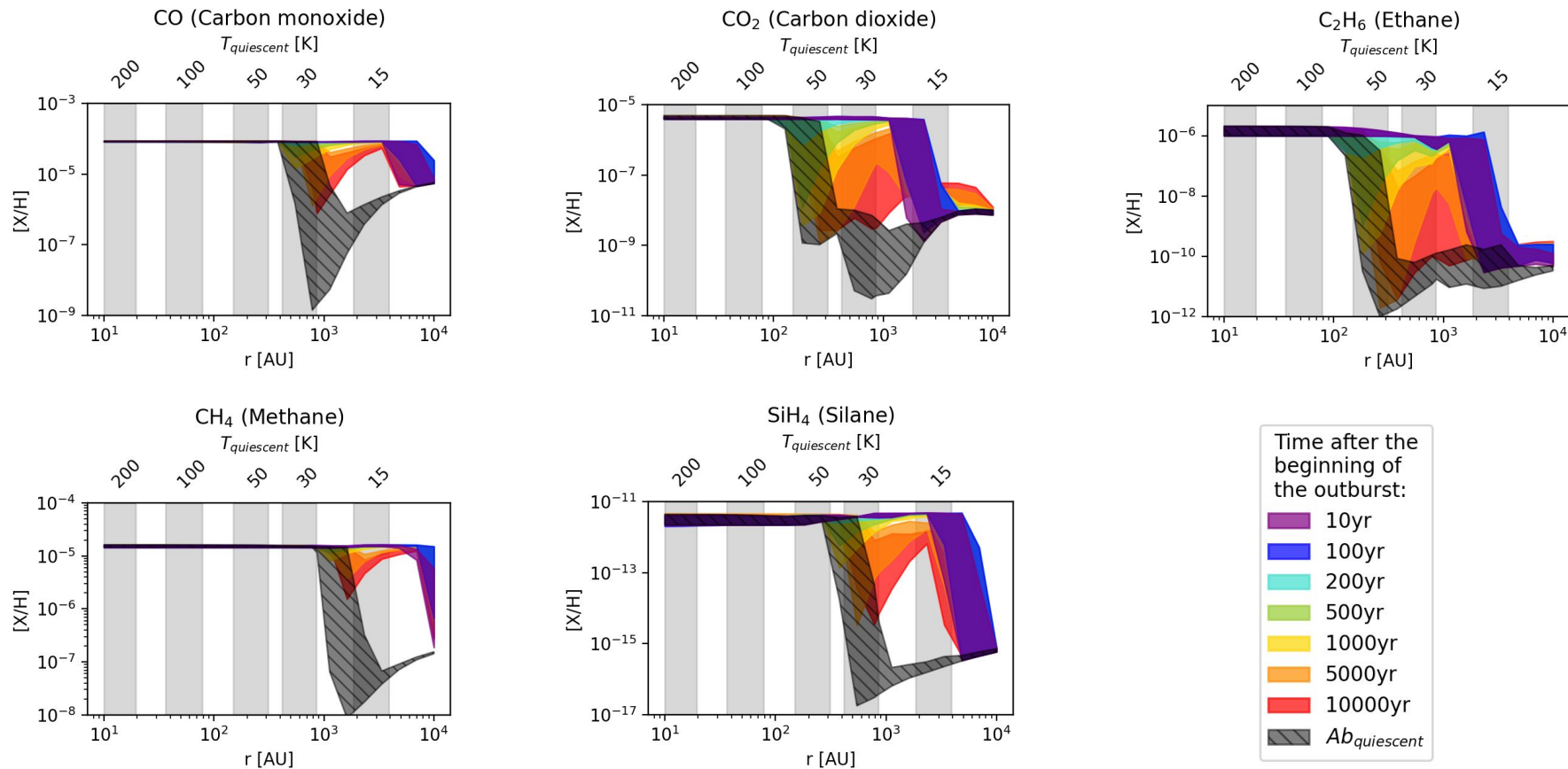
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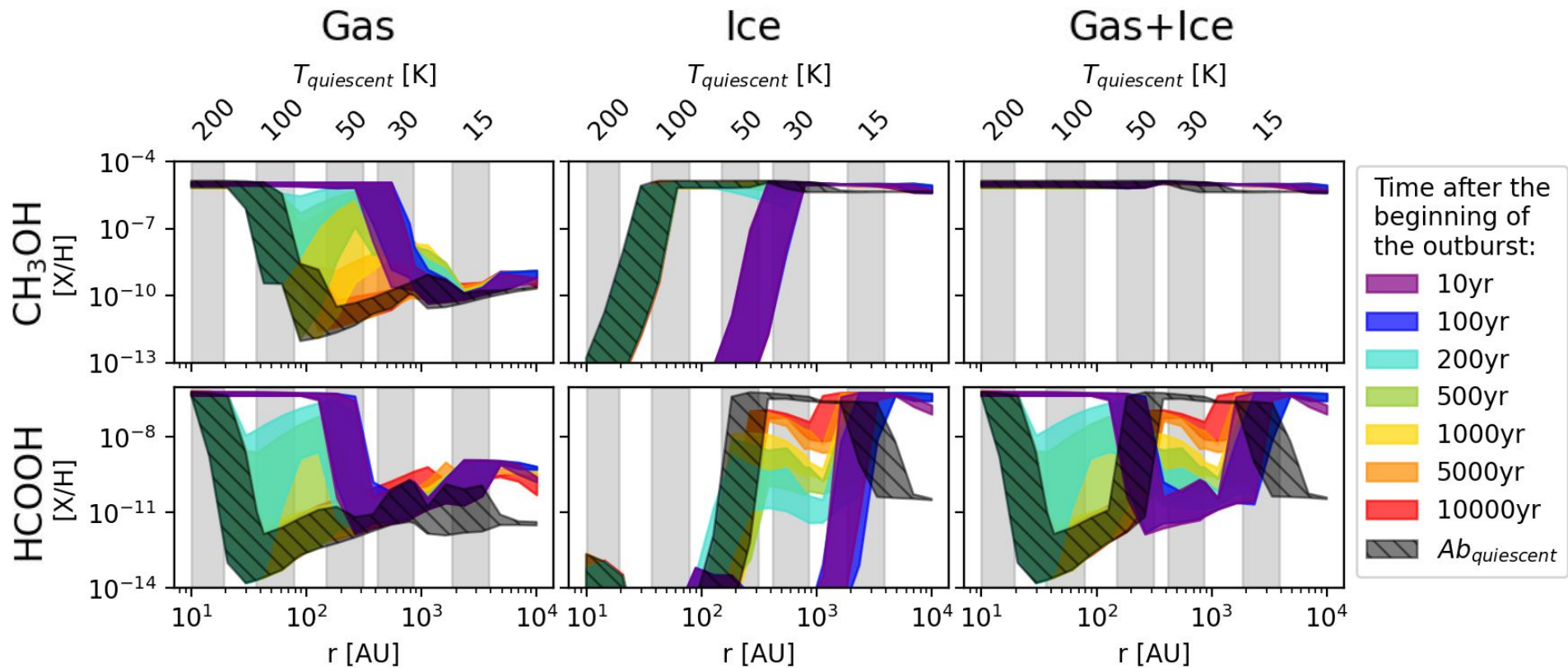


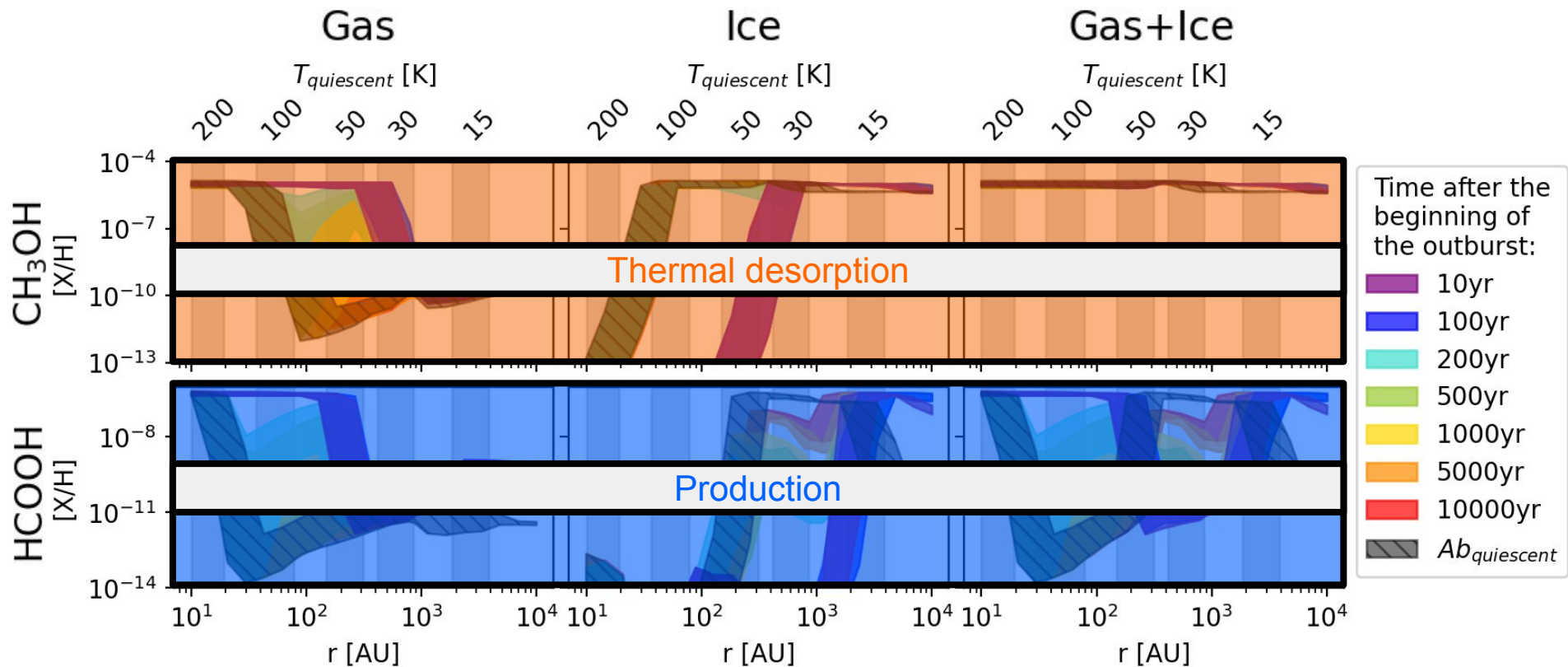
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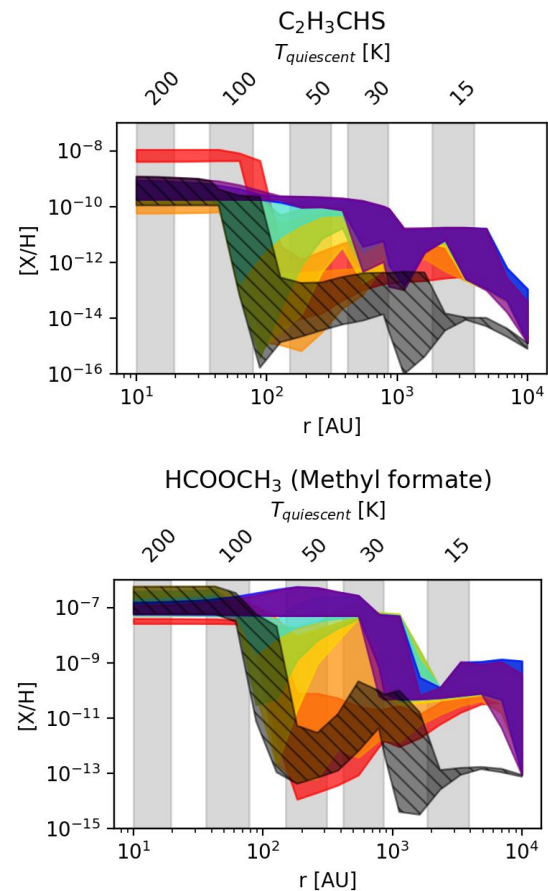
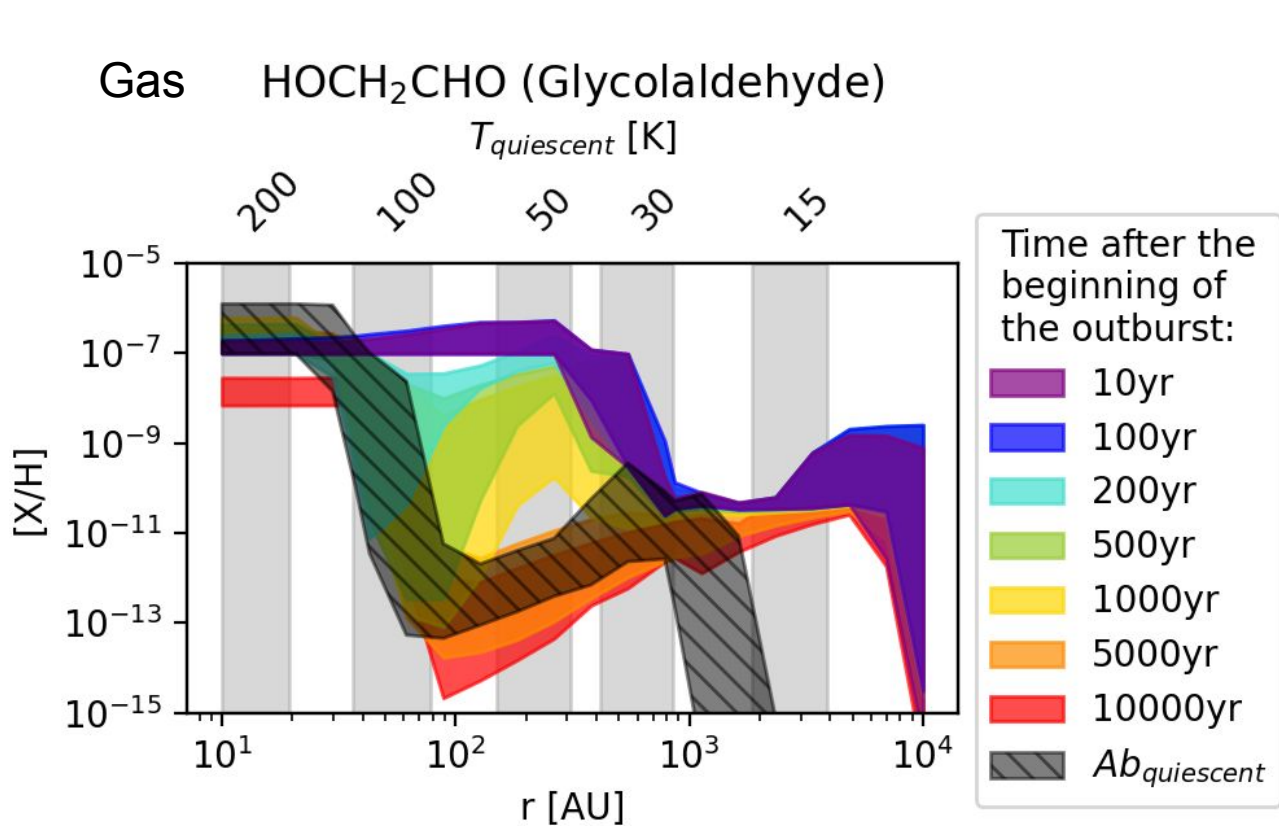
- 10yr
- 100yr
- 200yr
- 500yr
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- 10000yr
- $Ab_{\text{quiescent}}$

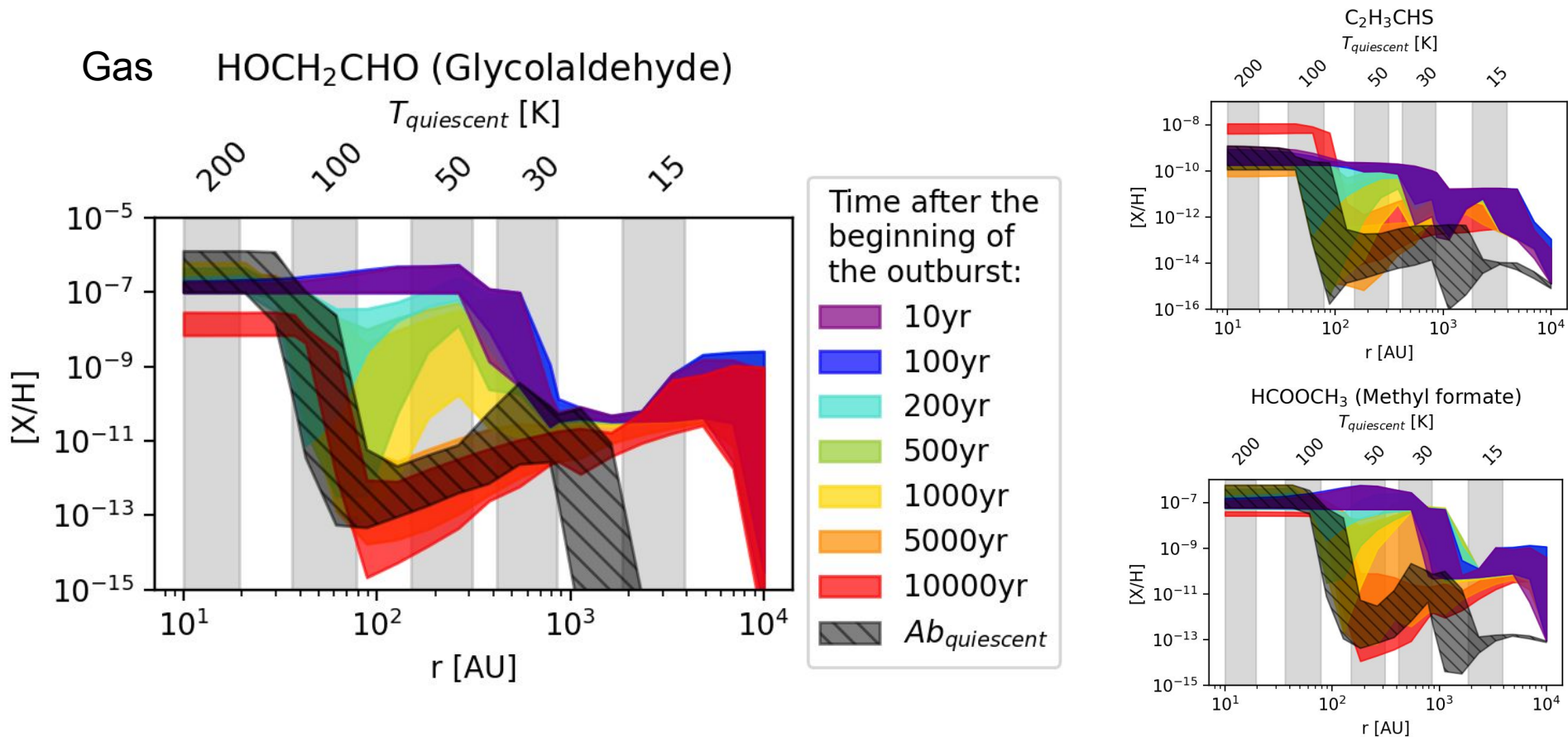


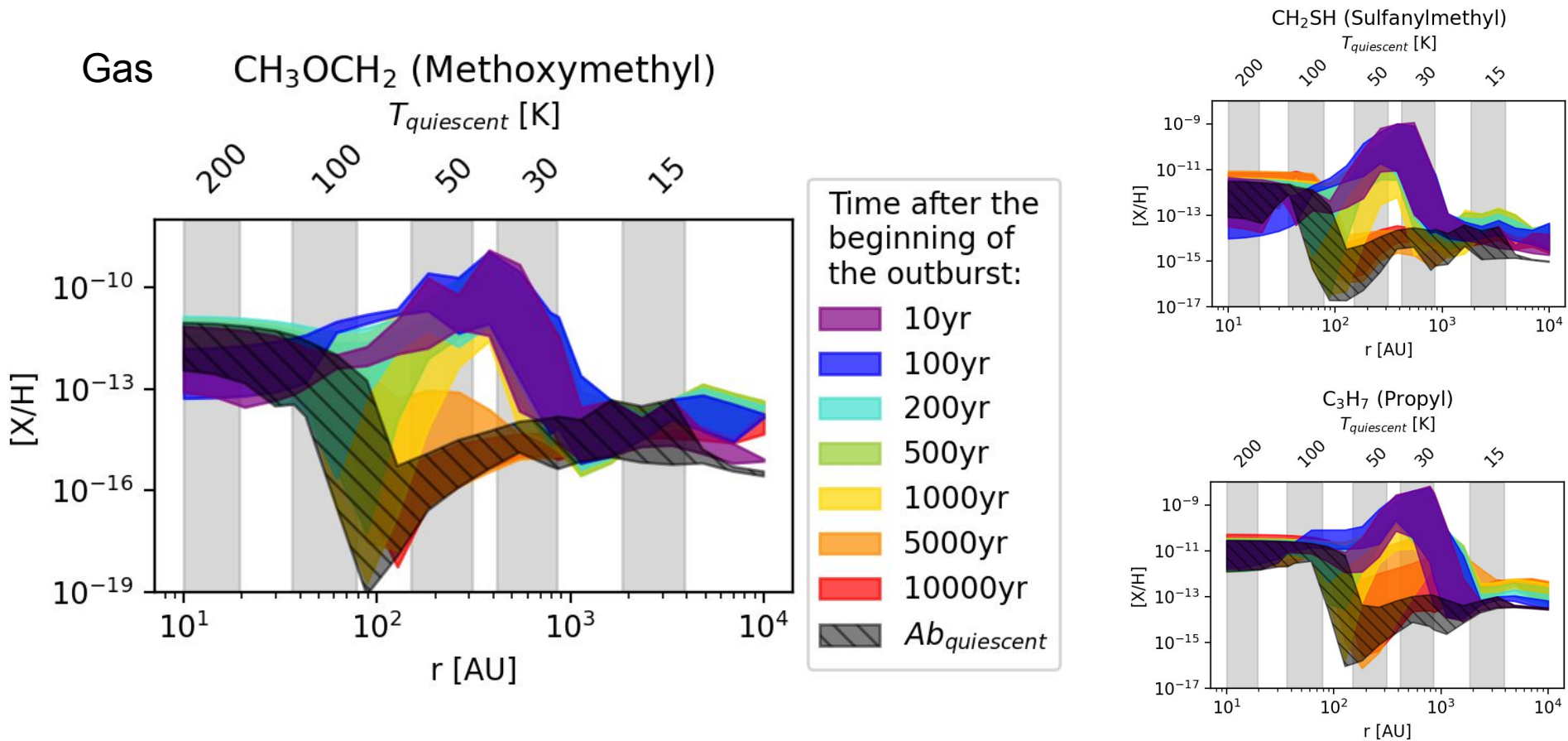






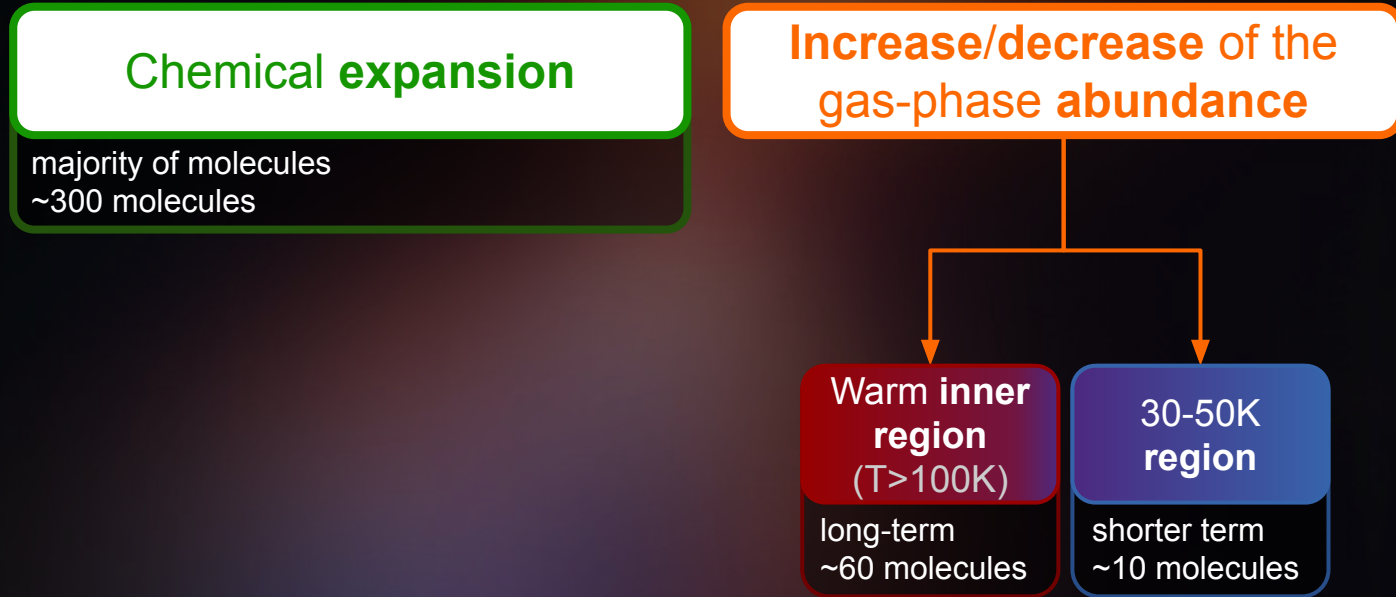






Espagnet et al. in prep.

- Modeling the chemistry of protostellar envelopes: APE + Nautilus
- Study the impact of a luminosity outburst on the chemistry



Thank you for your attention!



The CHEMical TRail In Protostars: From the deeply embedded phase to the planet-forming disk



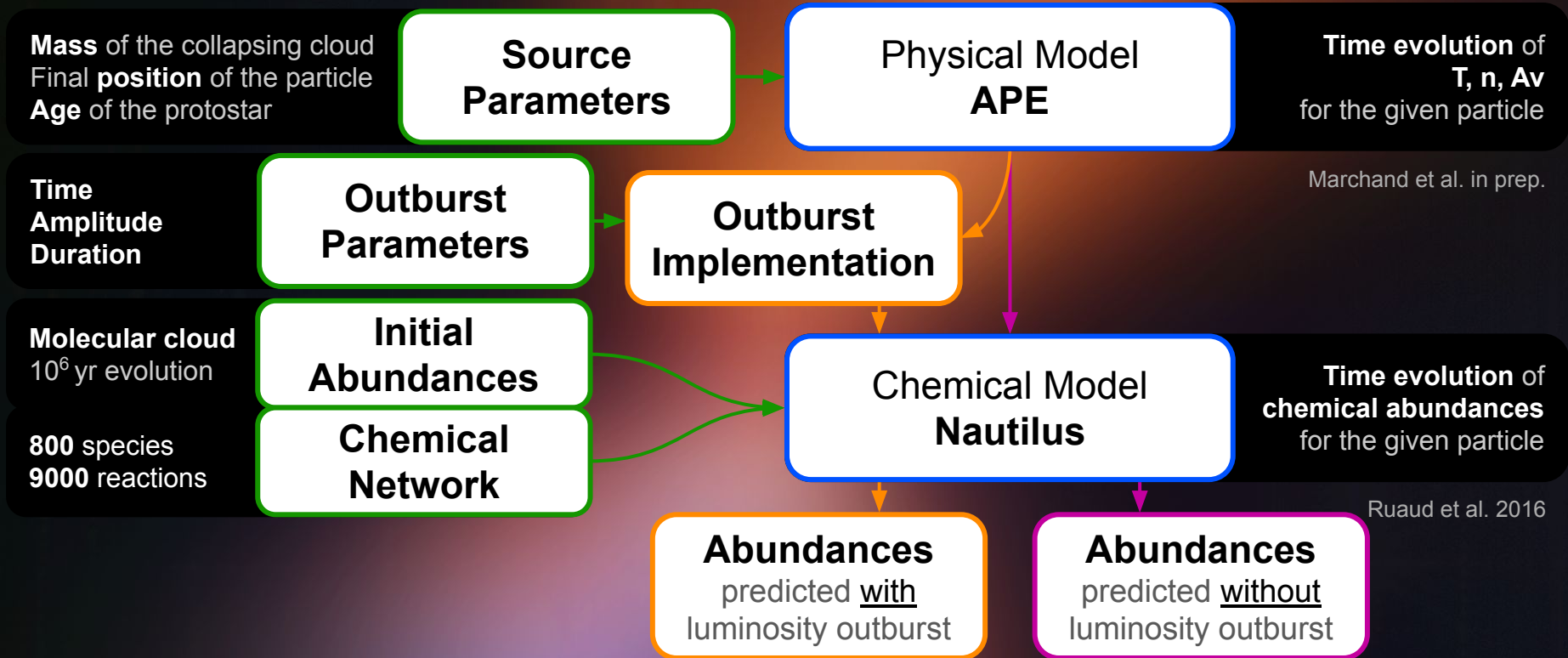
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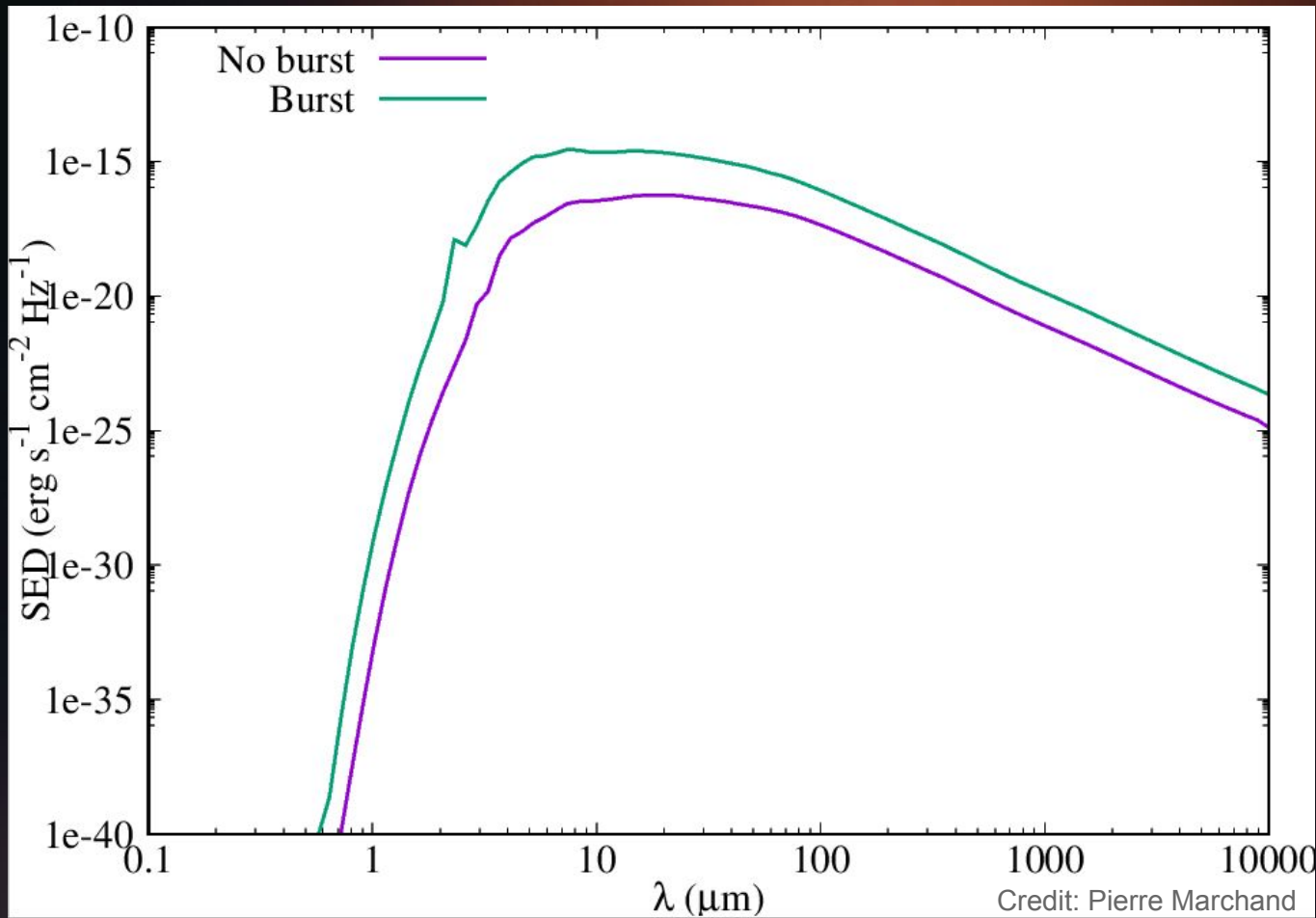


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Backup slides





Credit: Pierre Marchand

Flux density received at 10au.

## II. Method

# Chemical model

- Chemical model: **Nautilus**

(Ruard et al. 2016)

3 phase gas-grain chemical code

- Chemical network

(developed by Jean-Christophe Loison)

- 800 species
- 9000 reactions

- Provides time evolution of chemical abundances →

