

Chemical modeling of FU Ori protoplanetary disks

Tamara Molyarova¹, Vitaly Akimkin¹, Dmitry Semenov²,
Péter Ábrahám³, Thomas Henning², Ágnes Kóspál^{2,3},
Eduard Vorobyov⁴ and Dmitri Wiebe¹

¹Institute of Astronomy, Russian Academy of Sciences, 119017, 48 Pyatnitskaya st., Moscow, Russia

email: molyarova@inasan.ru

²Max Planck Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany

³Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Konkoly-Thege Miklós út 15-17, 1121 Budapest, Hungary

⁴Research Institute of Physics, Southern Federal University, Stachki 194, Rostov-on-Don, 344090, Russia

Abstract. Luminosity outbursts of the FU Ori type stars, which have a magnitude of $\sim 100 L_{\odot}$ and last for decades, may affect chemical composition of the surrounding protoplanetary disk. Using astrochemical modelling we analyse the changes induced by the outburst and search for species sensitive to the luminosity rise. Some changes in the disk molecular composition appear not only during the outburst itself but can also retain for decades after the end of the outburst. We analyse main chemical processes responsible for these effects and assess timescales at which chemically inert species return to the pre-outburst abundances.

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Young stars of the FU Ori type are objects experiencing sudden luminosity outburst, associated with increased accretion rate (Dunham & Vorobyov 2012). These outbursts are thought to be episodic and could happen to many young protostars (Audard *et al.* 2014). Anomalous abundances of specific molecules in disks around quiescent stars may indicate past luminosity outbursts (Rab *et al.* 2017). Our goal is to point out the chemical species useful for this purpose.

We use ANDES astrochemical model by Akimkin *et al.* (2013), adjusted to the case of variable accretion rate. We consider disk with the mass $M_{\text{disk}} = 0.01 M_{\odot}$ and characteristic radius $R_c = 100$ au around a young sun-like star ($1 M_{\odot}$, $0.9 L_{\odot}$). Dust size distribution is described by a power-law with the index of -3.5 , $a_{\text{min}} = 5 \cdot 10^{-7}$ cm and $a_{\text{max}} = 2.5 \cdot 10^{-3}$ cm. The outburst is simulated as an increased accretion luminosity lasting for ≈ 50 yr, with the profile shown in Fig. 1. The detailed description of this model as well as chemistry of different disk models can be found in Molyarova *et al.* (2018).

The patterns of chemical behavior during the outburst are shown in Figure 1. Most of gas-phase species grow in abundance during the outburst due to the thermal evaporation of their ices (the first three panels). For CO the increase is not very significant due to the chemical depletion of its ice (Molyarova *et al.* 2017, Bosman *et al.* 2018). Abundant volatiles, such as CH_3OH and C_3H_4 , follow closely the luminosity profile and immediately return to their quiescent abundances after the end of the outburst. The species shown in the last three panels of Fig. 1 are found to stay overabundant after the outburst for the longest timescales, from decades to thousand years.

Different mechanisms are responsible for time-dependent chemistry of the selected species. While H_2CO , NH_2OH , CH_3CHO , HCOOCH_3 , and CH_3OCH_3 are evaporated

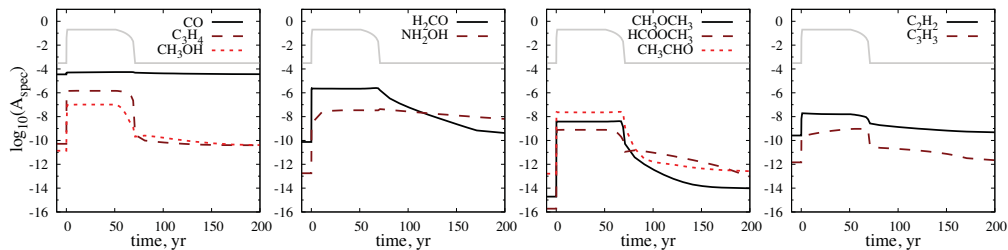


Figure 1. Disk total abundances (with respect to H_2) of selected species changing with time. The solid grey line denotes the luminosity profile (in $1000 L_{\odot}$).

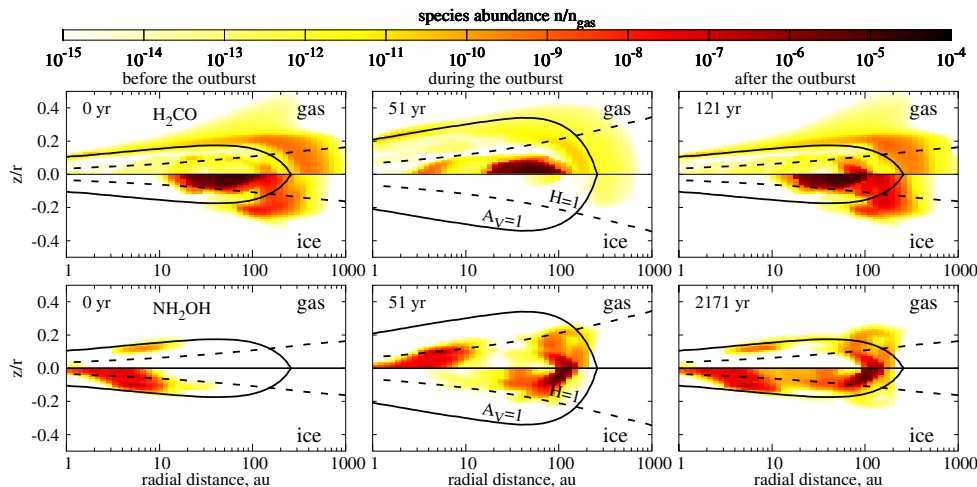


Figure 2. 2D distribution of H_2CO and NH_2OH in gas (upper half-plots) and in ice (lower half-plots) at specified time moments after the beginning of the outburst. Solid and dash black lines show the surface of $A_v = 1$ and scale height equal to unity, correspondingly.

from ice, C_3H_3 and C_2H_2 are formed directly in the gas. Fig. 2 shows spatial distribution of H_2CO and NH_2OH , which are the most promising post-outburst tracers. Their abundances are determined mostly by the evaporation, although NH_2OH is also actively formed on ice during the outburst. The times of returning to the quiescent values are defined by freeze-out timescales, which are long in the outer disk regions.

The abundances of H_2CO and NH_2OH jump for several orders of magnitude during the outburst and stay elevated for $10^2 - 10^3$ yr after it. This makes them the most suitable candidates for recent outburst tracers.

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