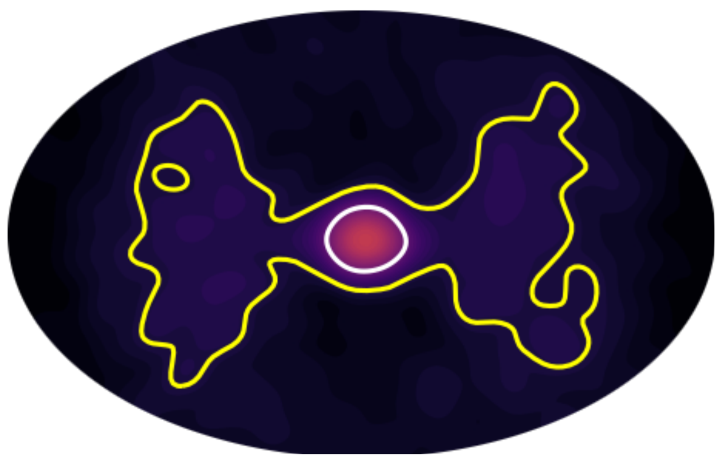


The chemistry of episodic accretion

Christian Rab[1], Elbakyan V.[2], Vorobyov E.[3], Güdel M.[3], Dionatos O.[3], Audard M.[4], Kamp I.[1], Thi W.-F.[5], Woitke P.[6], Postel A.[4]

[1]Kapteyn Astronomical Institute, University of Groningen; [2]Research Institute of Physics, Southern Federal University; [3]University of Vienna; [4]University of Geneva; [5]Max-Planck-Institut für extraterrestrische Physik; [6]SUPA, School of Physics & Astronomy, University of St. Andrews

Contact: rab@astro.rug.nl

Context

Protostars grow by accreting material from their circumstellar environment through their planet-forming 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 this luminosity bursts is most likely a dramatic increase of the mass accretion rate in the most inner region of the disk (see e.g. Zhu et al. 2007; Audard et al. 2014).

Such episodic accretion events heat the disk and envelope of the protostar and have a strong impact on the chemistry (e.g. Kim et al. 2012; Vorobyov et al. 2013; Visser et al. 2015). Due to the temperature increase, ices are released into the gas phase and ice lines are moved outwards. This might also influence the planet formation process as the movement of icelines affects dust evolution (e.g. Schoonenberg et al. 2017). After the luminosity burst has stopped the circumstellar material cools and molecules freeze-out again on timescales of 100 to 10^5 yr, much longer than the burst itself.

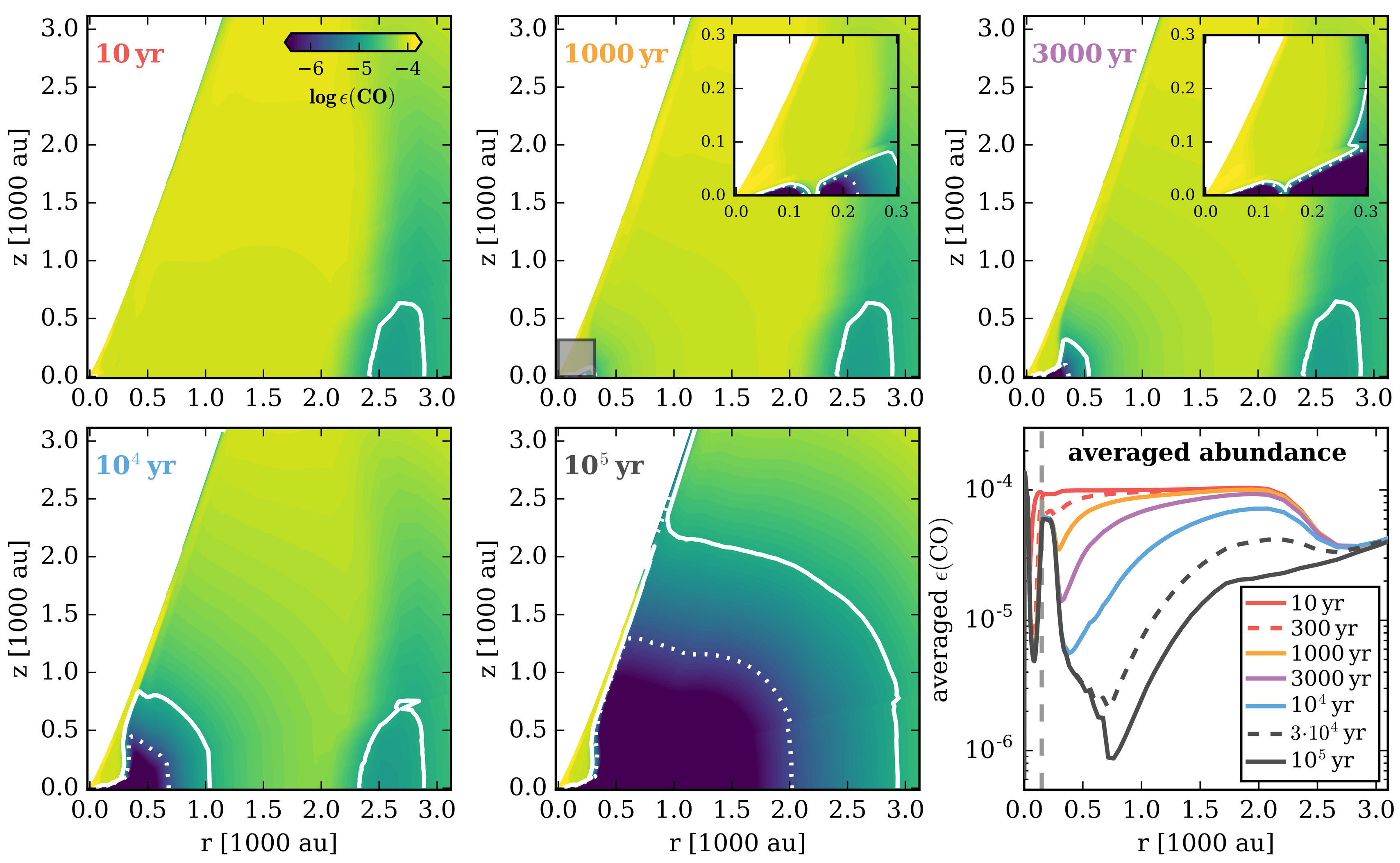
Method

We use the radiation thermo-chemical disk model ProDiMo (PROtoplanetary DIsk MOdel, (Woitke et al. 2009; Kamp et al. 2017; Rab et al. 2017) to study the impact of episodic accretion events on the chemistry and on observables, such as molecular line emission. ProDiMo self-consistently solves for the dust temperature (radiative transfer), the gas temperature (heating/cooling) and the chemical abundances for a fixed 2D disk/envelope structure (gas & dust).

Here we present models where we study the chemical evolution before, during and after the luminosity burst using a representative model of a young protostar still embedded in its envelope (Class I). Furthermore, we show first modelling results for the protostar V883 Ori, which is currently in a burst state. V883 Ori is especially interesting as as there are (indirect) observational constraints on the location of the water ice line (Cieza et al. 2016) and furthermore the detection of complex organic molecules were recently reported (van 't Hoff et al. 2018; Lee et al. 2019)

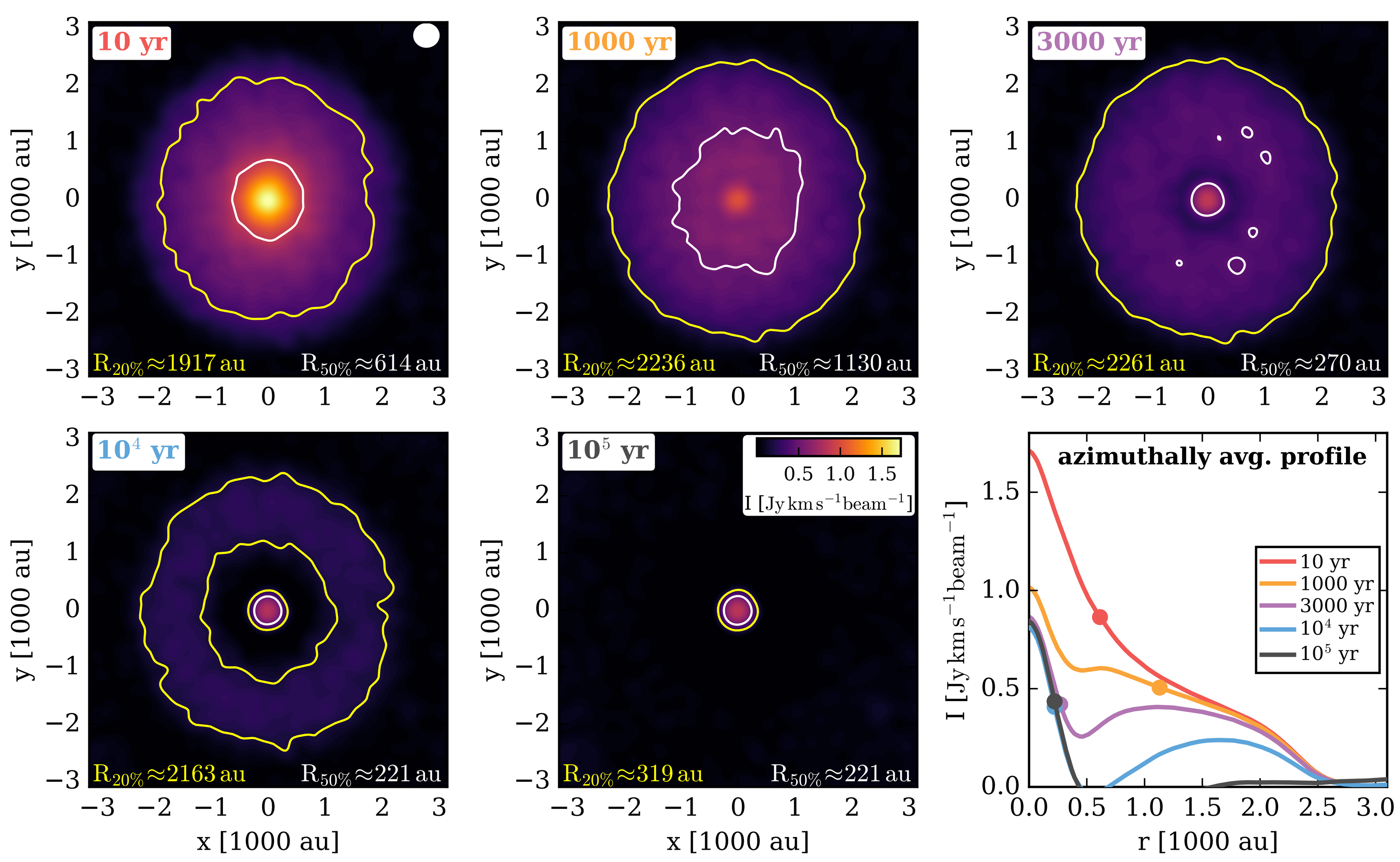
Chemical signatures of luminosity bursts

CO abundance



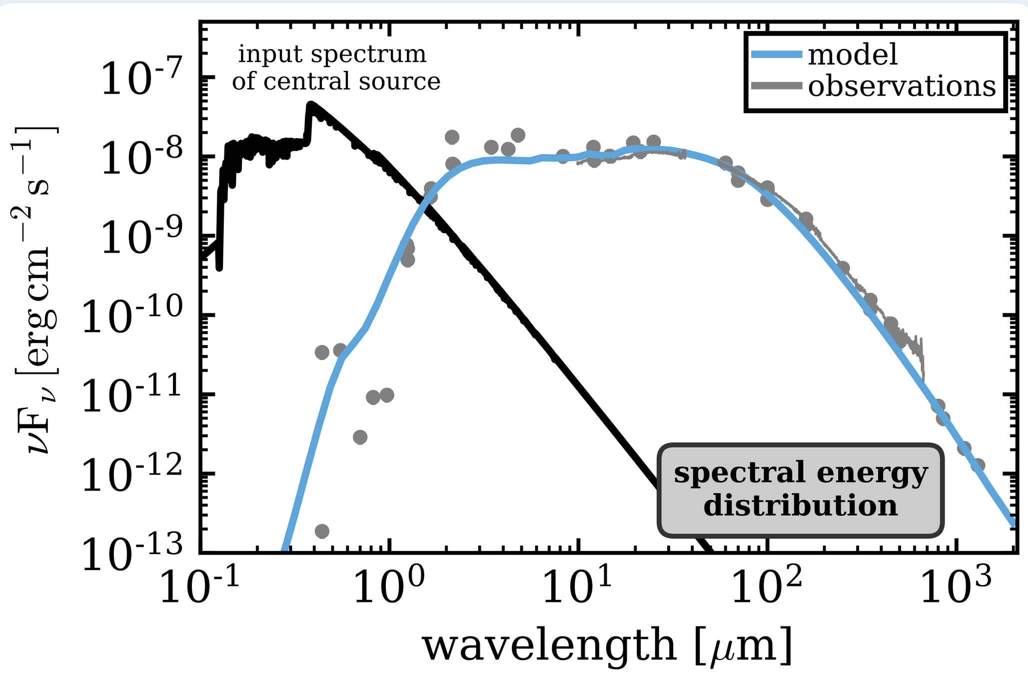
- representative model of a 100 yr luminosity burst with $L = 100\,L_\odot$ for a Class I protostar
- evolution of the CO abundance (left panel) and line emission (right panel) at t=10, 10^3, 3×10^3, 10^4, 10^5 yr after the burst stopped. At $t = 10^5$ the chemical structure is again (nearly) identical to the quiescent state (no burst, $L = 1\,L_\odot$).

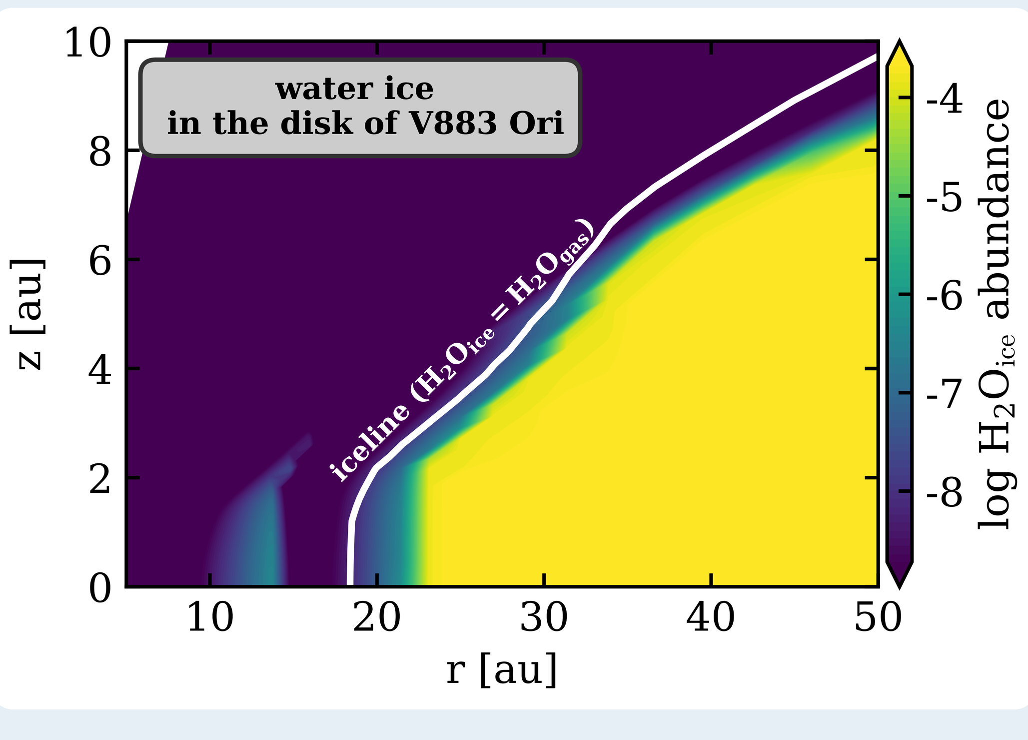
ALMA simulations of the $C^{18}O$ 2-1 line



- nearly all CO ice is desorbed during the burst, the freeze-out in the post-burst phase happens from inside out due to the radial density gradient (faster at higher densities)
- this produces distinct observational signatures in molecular line emission that allow to unambiguously identify an ancient burst (see Rab et al. (2017) for details).

A real object V883 Ori





- disk + envelope model for V883 Ori; by fitting the spectral energy distribution (SED) we can constrain the structure and physical conditions for the chemistry
- the current model is in good agreement with the observed SED (including new Herschel data, (Postel+, subm), resolved images for the disk (ALMA, dust&gas) and CO lines tracing the envelop (APEX, White+ 2019)
- the water ice line in the model is at $r \approx 20$ au, whereas observations suggest $r \gtrsim 40$ au; heating by the central luminosity source seems not to be sufficient, additional accretion heating in the disk might be required (if the water ice line is indeed at $r \gtrsim 40$ au)
- plan to model more complex molecules (e.g. methanol); that might provide additional constrains on the location of the ice line

Conclusions

With the presented model (Rab et al. 2017) we studied the impact of episodic accretion events on the chemistry in the disk and envelope of protostars. By consistently modelling the dust&gas and observables one can constrain both the physical structure/conditions and the chemical abundances of/in the circumstellar environment of young stars.

Signatures of luminosity bursts can be observed long after the burst has stopped. This allows to identify protostars that experienced episodic accretion events that otherwise are not observable anymore. This is crucial to answer the question if episodic accretion is a universal phenomenon in the star and planet formation process.

Episodic accretion events are a great possibility to study chemical evolution in young stars. Molecules that are released into the gas phase during the burst are observable, providing constraints on the ice composition (e.g Lee et al. 2019) and the thermal desorption process. Episodic accretion events can be seen as a kind of real life/large scale analogue of temperature programmed desorption (TPD) experiments. However, some patience is required due to the timescale of the order of 10 to 1000s yr. Nevertheless, observations with modern telescopes, such as ALMA, show already the great potential of episodic accretion chemistry to provide new constrains for astrochemistry in general.

References

• Audard, M., et al. 2014, Protostars and Planets VI, 387 • Cieza, L. A., et al. 2016, Nature , 535, 258 • Kamp, I., et al. 2017, A&A, 607, A41 • Kim, H. J., et al. 2012, ApJ, 758, 38 • Lee, J.-E., et al. 2019, Nat. Astronomy, 200 • Rab, C., et al. 2017, A&A, 604, A15 • Schoonenberg, D., Okuzumi, S., & Ormel, C. W. 2017, A&A, 605, L2 • van 't Hoff, M. L. R., et al. 2018, ApJ, 864, L23 • Visser, R., Bergin, E. A., & Jørgensen, J. K. 2015, A&A, 577, A102 • Vorobyov, E. I., et al. 2013, A&A, 557, A35 • Woitke, P., Kamp, I., & Thi, W.-F. 2009, A&A, 501, 383 • Zhu, Z., et al. 2007, ApJ, 669, 483

LaTeX TikZposter