Water released in a recent protostellar accretion burst

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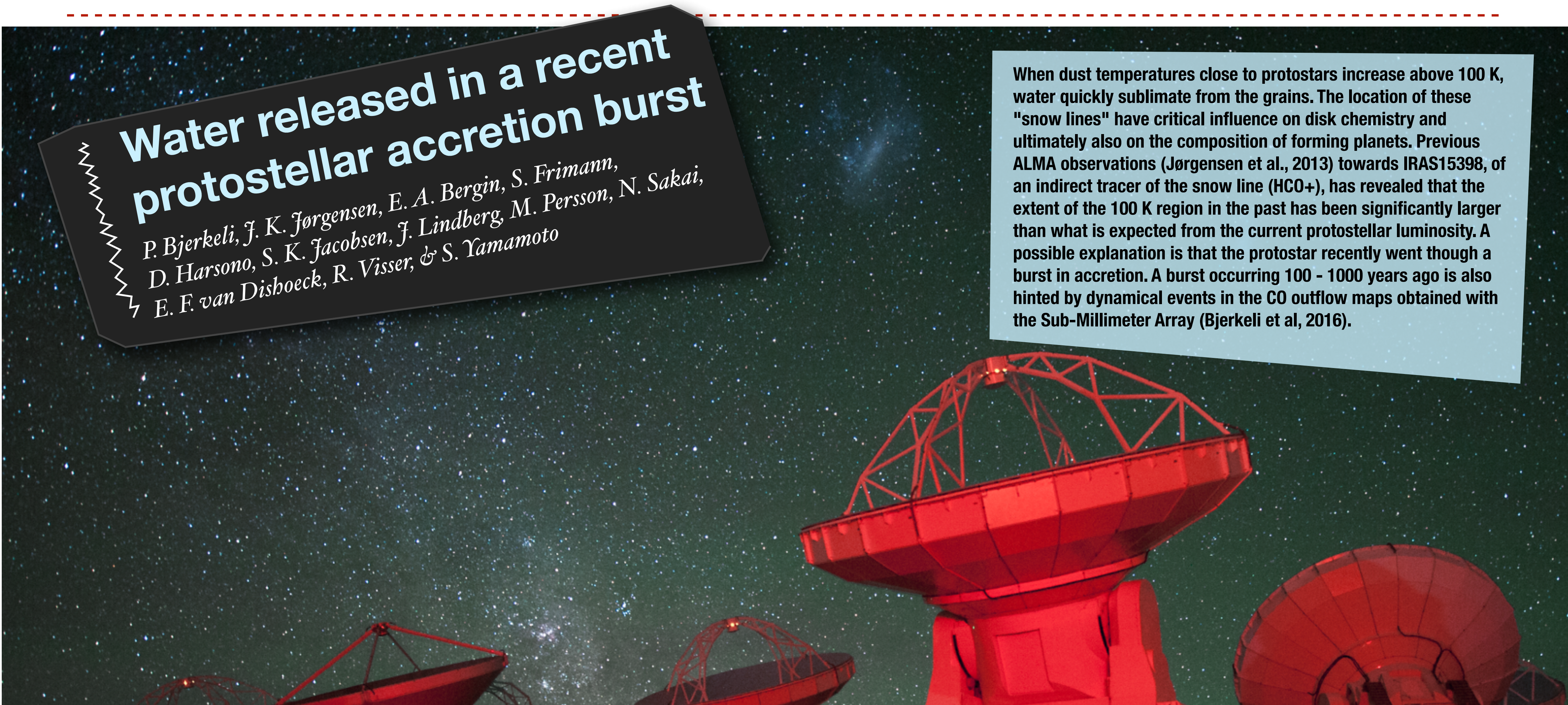

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When dust temperatures close to protostars increase above 100 K, water quickly sublimate from the grains. The location of these "snow lines" have critical influence on disk chemistry and ultimately also on the composition of forming planets. Previous ALMA observations (Jørgensen et al., 2013) towards IRAS15398, of an indirect tracer of the snow line (HCO+), has revealed that the extent of the 100 K region in the past has been significantly larger than what is expected from the current protostellar luminosity. A possible explanation is that the protostar recently went though a burst in accretion. A burst occurring 100 - 1000 years ago is also hinted by dynamical events in the CO outflow maps obtained with the Sub-Millimeter Array (Bjerkeli et al, 2016).

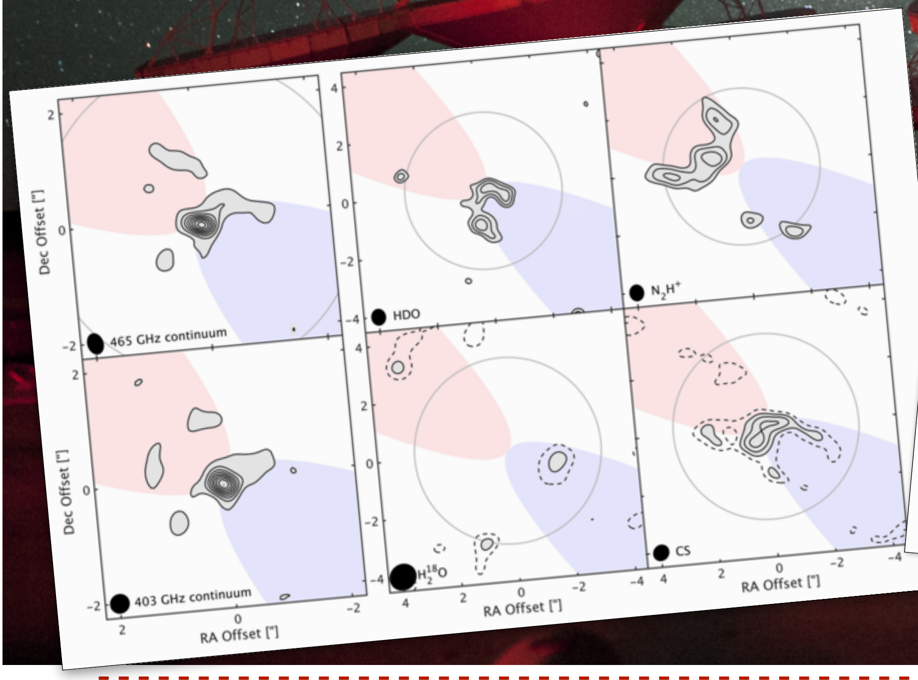

Fig. 1. Continuum and integrated line emission maps towards IRAS15398. HDO is detected close to the protostar while $H_2{}^{18}O$ is not detected. Red and blue shaded regions mark the directions of the outflow cones (same geometry as the RADMC-3D model).

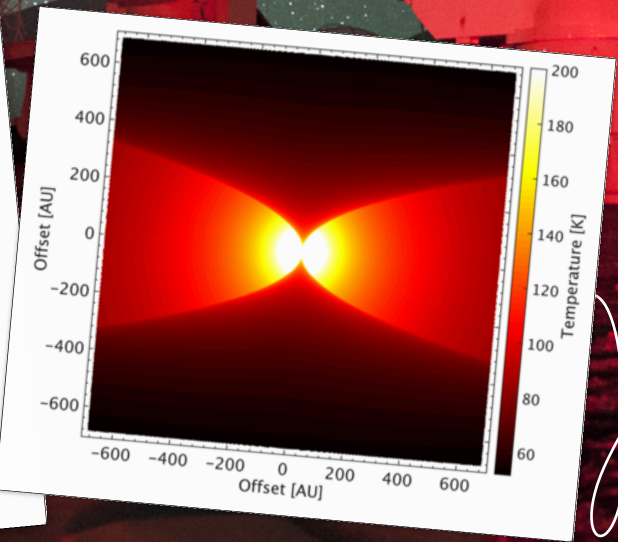

Fig. 2. Dust temperature map computed with RADMC-3D. The density in the outflow is constant at $n_{H_2} = 10^5$ cm^{-3} and the luminosity of the protostar is increased by two orders of magnitude.

Ice sublimation during a recent accretion burst?

RADMC-3D temperature maps show that the 100 K radius is shifted outwards whenever a low density outflow cone is present.

THE EMISSION FROM IRAS 15398

Here, we present high-resolution ALMA observations of warm water towards the IRAS15398 system. We observed the emission from two isotopologues, viz. HDO (1_{01}-0_{00}) at 465 GHz and $H_2{}^{18}O$ (4_{14}-3_{21}) at 390 GHz. HDO is detected towards the protostar and in the outflowing gas at distances up to 500 AU from the protostar. $H_2{}^{18}O$ is, on the other hand, not detected in the imaged region. The non-detection of $H_2{}^{18}O$, and the detection of HDO, is consistent with a post-burst scenario (Jørgensen et al., 2013) where current envelope temperatures are low. The two lines have very different excitation temperatures (22 K for HDO and 322 K for $H_2{}^{18}O$) and we thus not expect $H_2{}^{18}O$ to be highly excited in these environments. Even though temperatures likely are low, HDO is also detected in the outflow component at larger distances from IRAS15398. The presence of water on these scales can, however, not easily be explained by outflow chemistry, since velocities are too low. Also, HDO emission is not detected at large distances from the protostar.

To calculate the dust radiative transfer, we use RADMC-3D, which allows us to take all relevant components into account. We conclude that the presence of an outflow, where the density is lower than in the surrounding envelope, can have profound influence on the dust temperature distribution, and therefore also the location of snow-lines. In the case of IRAS15398, the 100 K radius is likely located at distances larger than 500 AU, when the protostar undergoes a burst. In addition to the water observations, we also present detailed maps of other species, e.g. CS(8-7) and N_2H^+(5-4). These emission maps reveal signs of a rotating flattened envelope and the detailed kinematics and morphological structure of the outflowing gas.

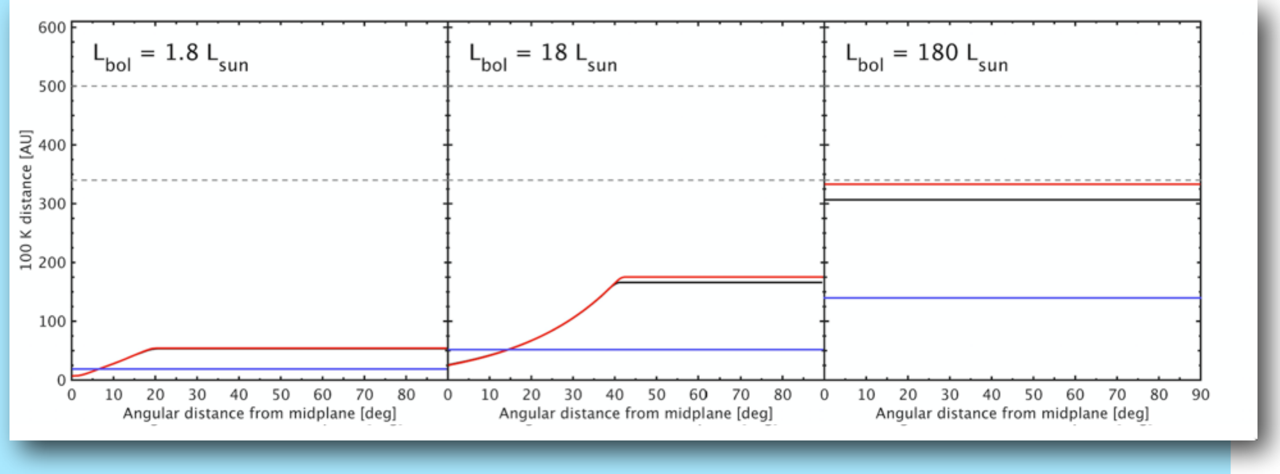

Fig. 3. 100 K distance from the protostar as a function of angle to outflow axis. The blue curve shows the results for a pure envelope density profile. For the black curve, an outflow cone, where the density is constant at 10^5 cm^{-3} is added to the model. The red curve is for the same geometry as in the second scenario but with an outflow density of 10^4 cm^{-3}. The left panel shows the result for the current luminosity (1.8 L_{sun}) and the middle and right panels show the same curves when the luminosity is increased by one and two orders of magnitude. Dashed grey lines indicate the maximum distance to the emission peaks for the blue-shifted and red-shifted emission.

MAIN CONCLUSIONS

- The observed velocities and spatial distribution of the HDO emission suggests that it is not due to shock chemistry. It is also not likely that water was released from the grains and transported outwards by the outflow.
- RADMC-3D models of a geometry containing an infalling envelope and an outflow at low density show that the 100 K distance can be shifted outwards to 500 AU.

Centre for Star and Planet formation (STARPLAN)
The Centre for Star and Planet formation is a multidisciplinary research centre for cosmochemistry, astrophysics and astronomy funded by the Danish National Research Foundation and is located at the Natural History Museum of Denmark, University of Copenhagen.

References:

Bjerkeli, P., et al. 2016, A&A, 587, 145
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