Water released in a protostellar accretion burst

Per Bjerkeli

J. K. Jørgensen, E. A. Bergin, S. Frimann, D. Harsono, S. K. Jacobsen, M. Persson, J. Lindberg, N. Sakai, E. F van Dishoeck, R. Visser, S Yamamoto

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National Gallery of Denmark

Outline

1. Background / Episodic accretion

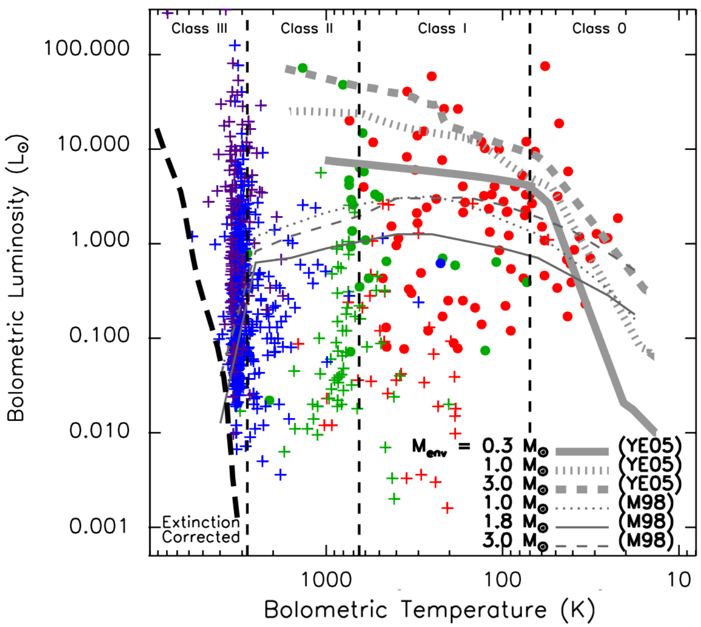
2. Observations of IRAS15398 with ALMA

3. Conclusions

Episodic accretion

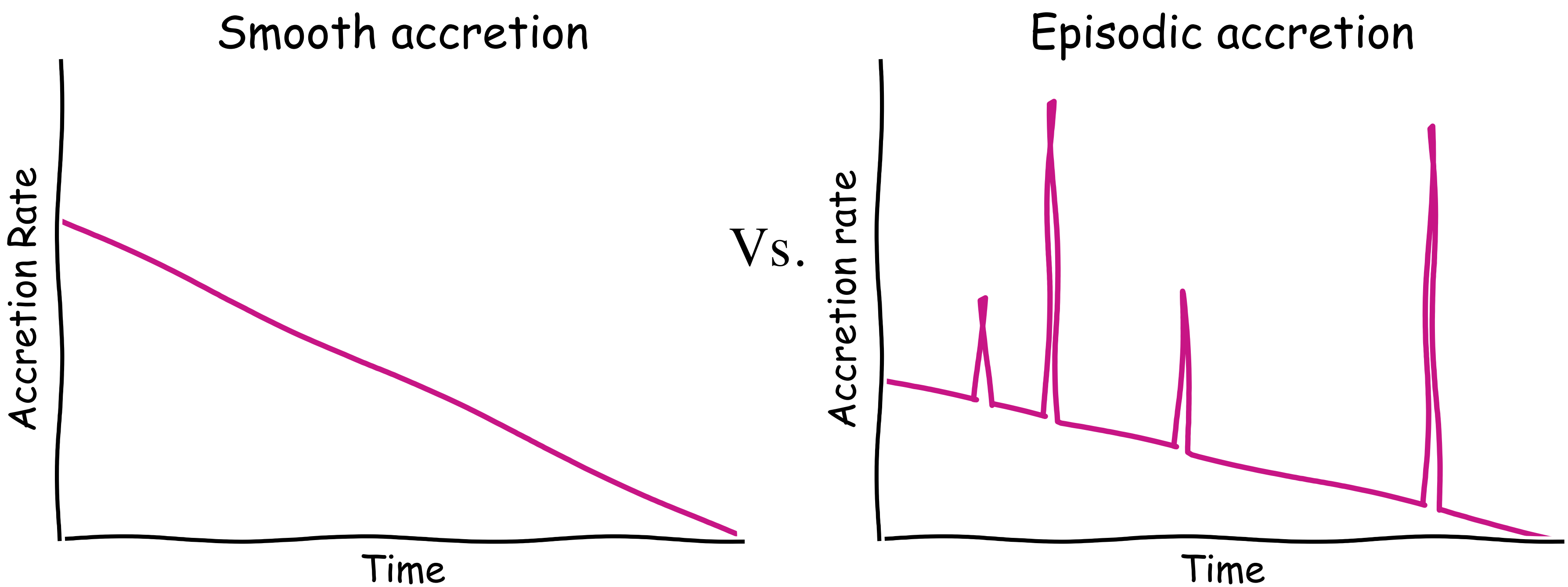
If accretion rate constant

- Protostars at same evolutionary stage should have roughly the same luminosity.
- Protostars in different evolutionary stages should have different luminosities.
  - **episodic accretion**
  - d*M*/d*t* decrease with time



Evans et al. 2009

Episodic accretion

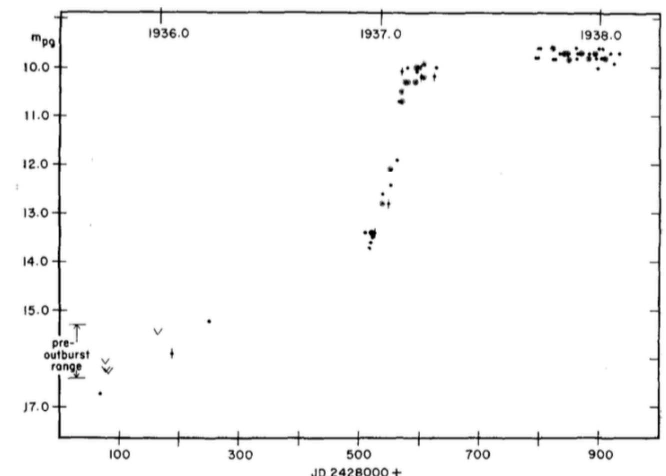


The mode of accretion has a large impact on the physical and chemical evolution of the system

Credit: S. Frimann

Episodic accretion

Material falls towards the disk. The accretion from the disk towards the protostars occurs in a series of burst events! A possible solution to the luminosity problem.

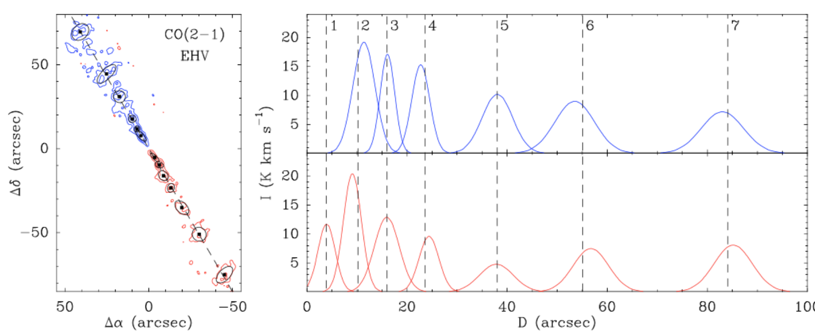


Herbig (1966)

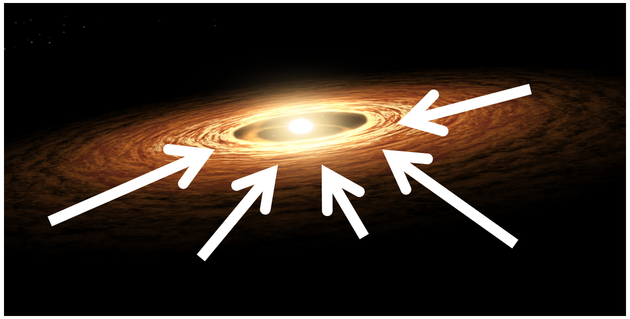
Observational evidence

- FU Orionis objects (accretion bursts)
- Periodic shocks along protostellar jet axis
- Chemical traces
- Linked to disk instabilities

Simulations

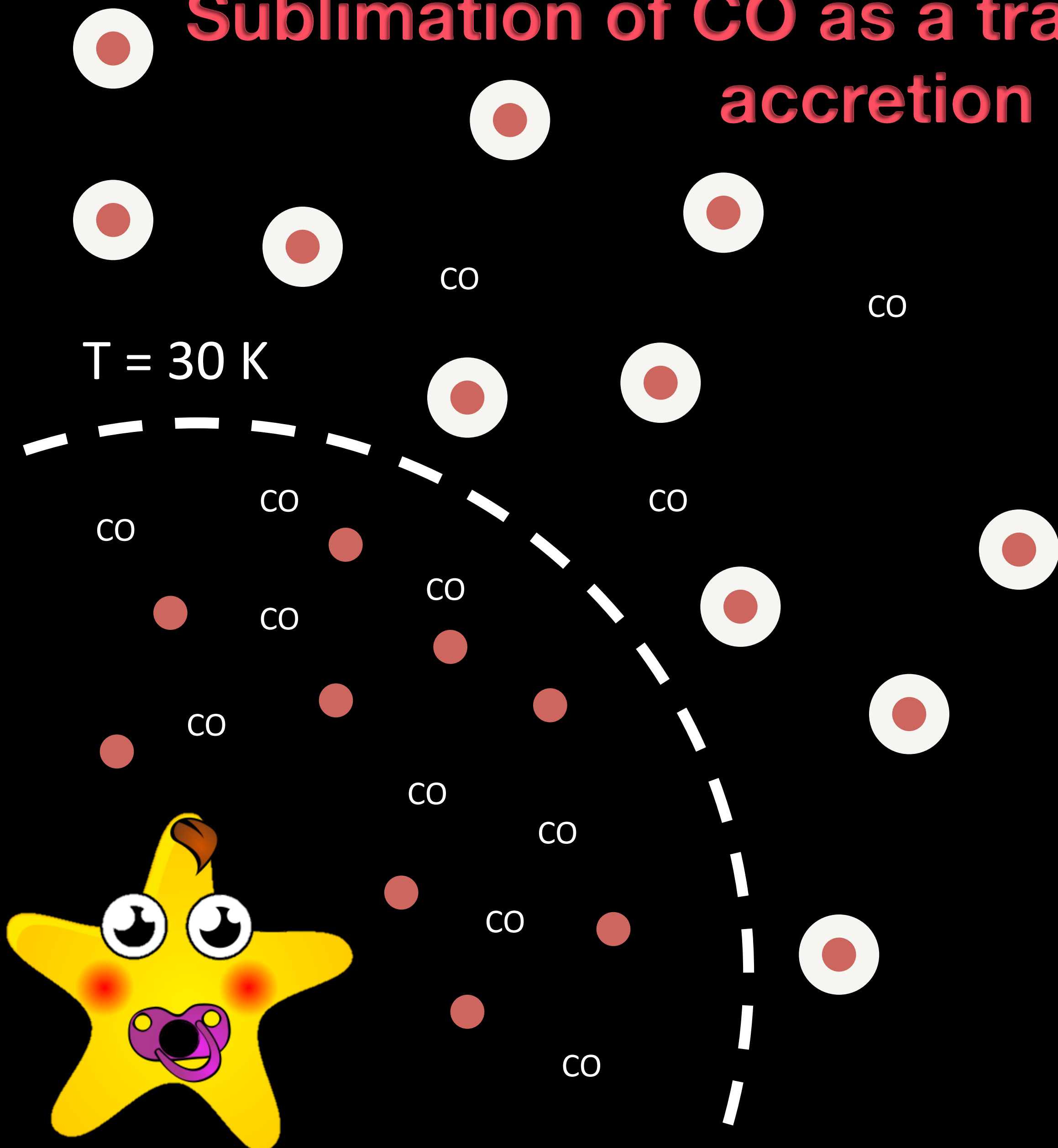


IRAS04166:Santiago-García et al. 2009



Credit: S. Frimann

Sublimation of CO as a tracer of episodic accretion



Basic idea

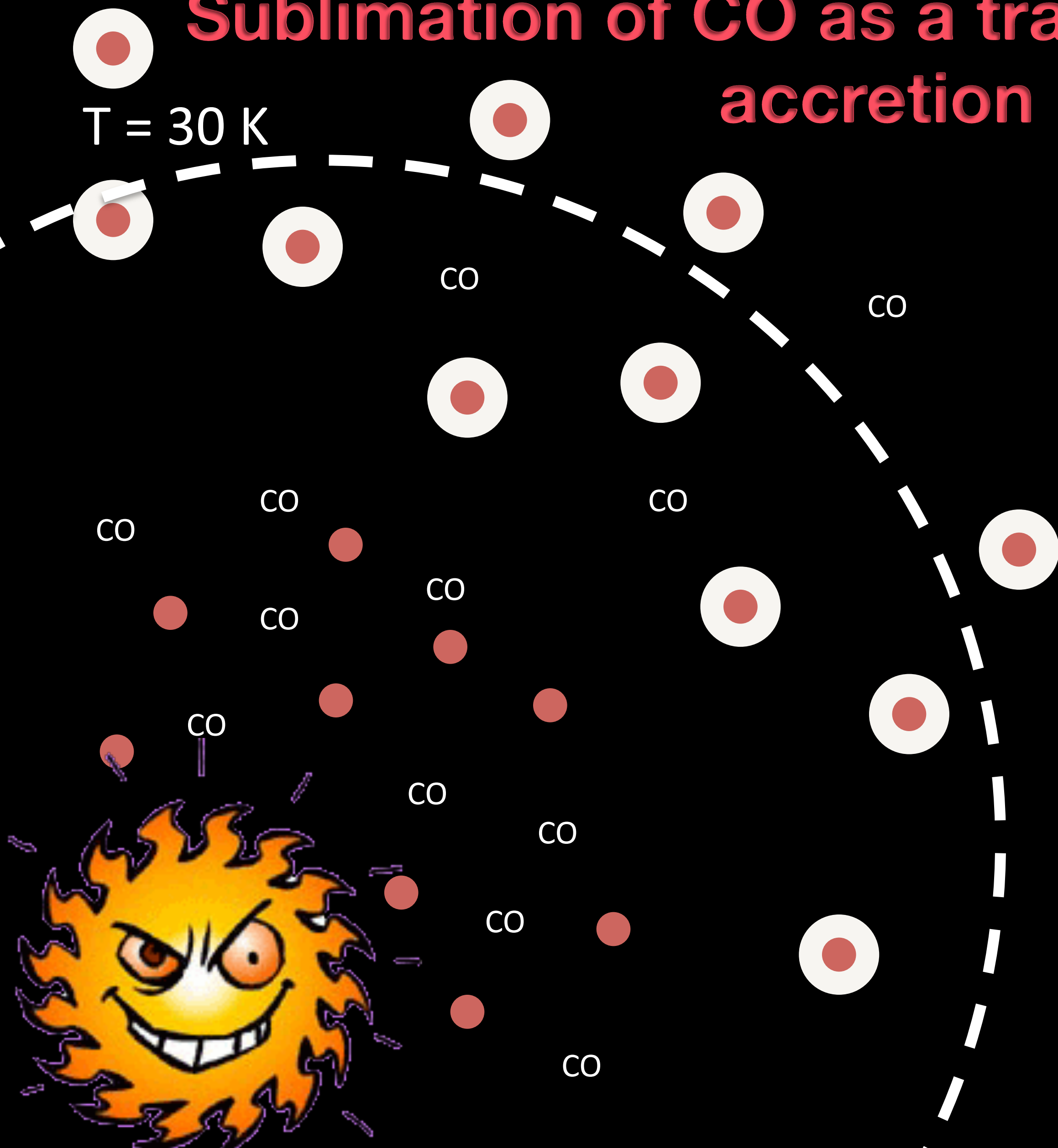
The protostar is surrounded by gas and dust

CO is in gas phase for T > 30 K
CO is frozen out for T < 30 K

t = 0 yr

Credit: S. Frimann

Sublimation of CO as a tracer of episodic accretion



Basic idea

The protostar is surrounded by gas and dust

CO is in gas phase for T > 30 K
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When luminosity increase the 30 K radius moves outward

0 yr < t <≈ 100 yr

Credit: S. Frimann

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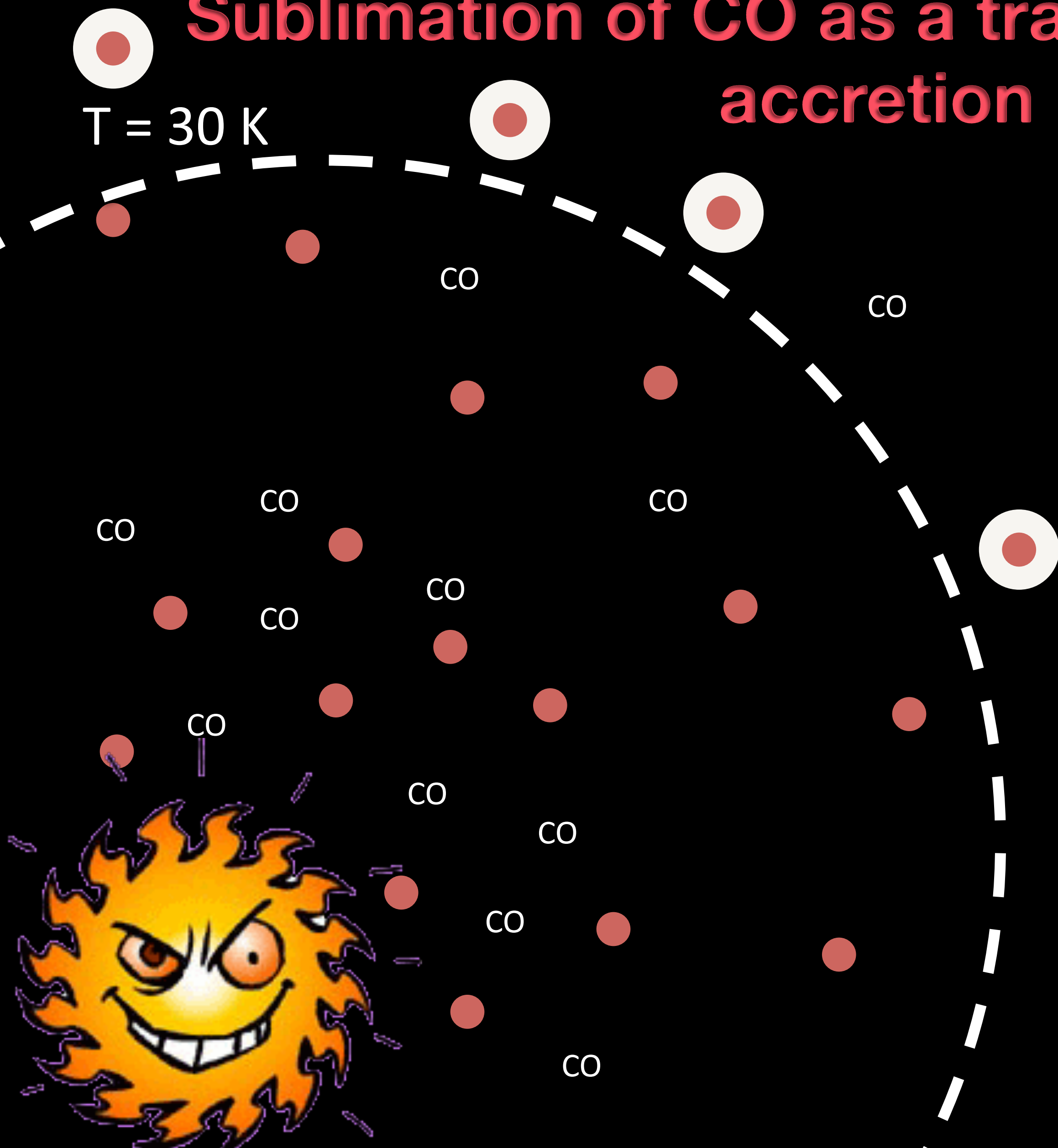

Basic idea

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CO is in gas phase for T > 30 K
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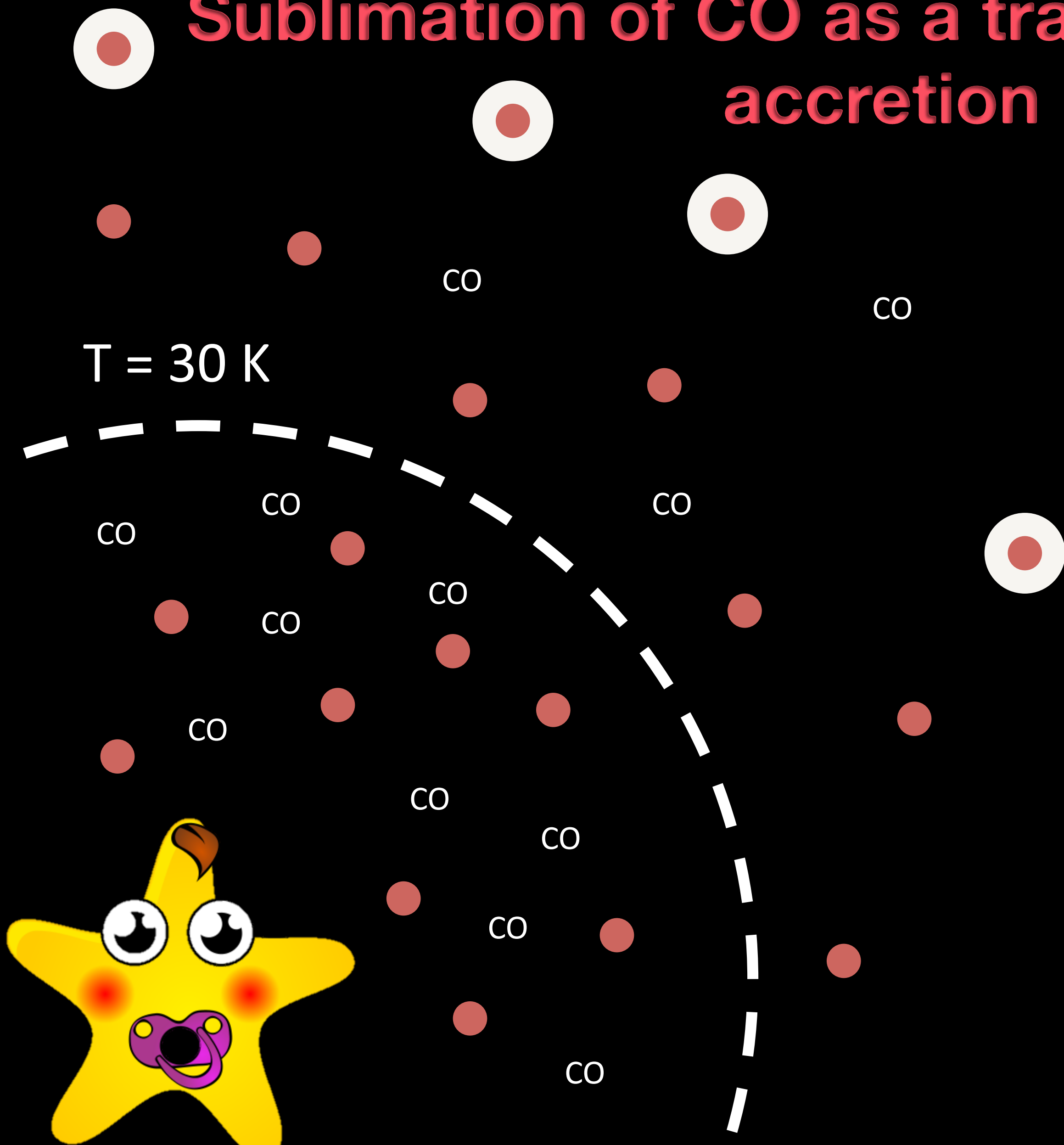
When luminosity increase the 30 K radius moves outward

The dust grains loose their ice mantles on time scales < 1yr

0 yr < t <≈ 100 yr

Credit: S. Frimann

Sublimation of CO as a tracer of episodic accretion



Basic idea

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CO is in gas phase for T > 30 K
CO is frozen out for T < 30 K

When luminosity increase the 30 K radius moves outward

The dust grains loose their ice mantles on time scales < 1yr

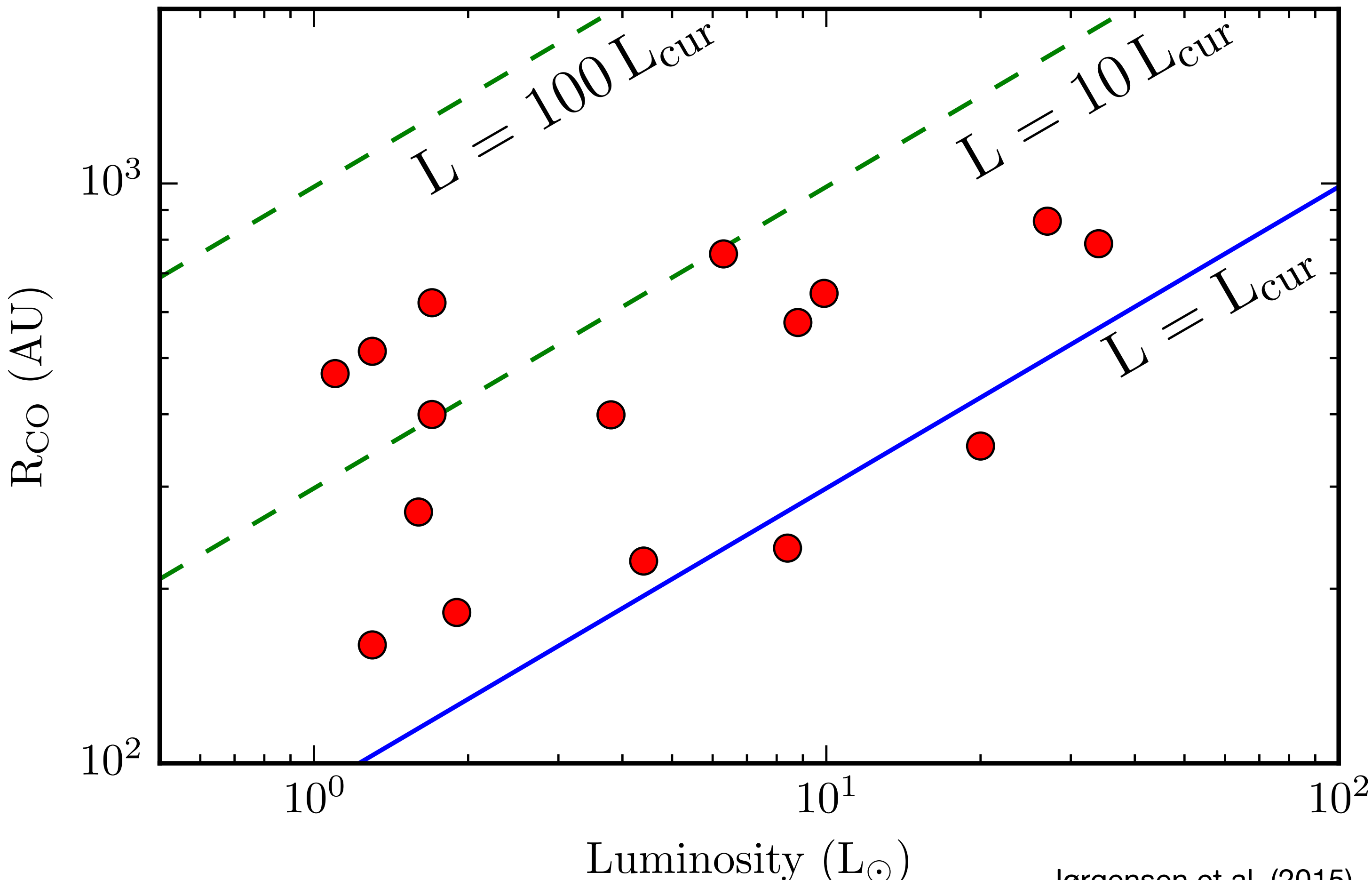
CO stays in the gas-phase when luminosity decreases

$0 \text{ yr} < t <\approx 10^4 \text{ yr}$

Credit: S. Frimann

Episodic accretion

CO extents toward 16 protostars compared to their current luminosity



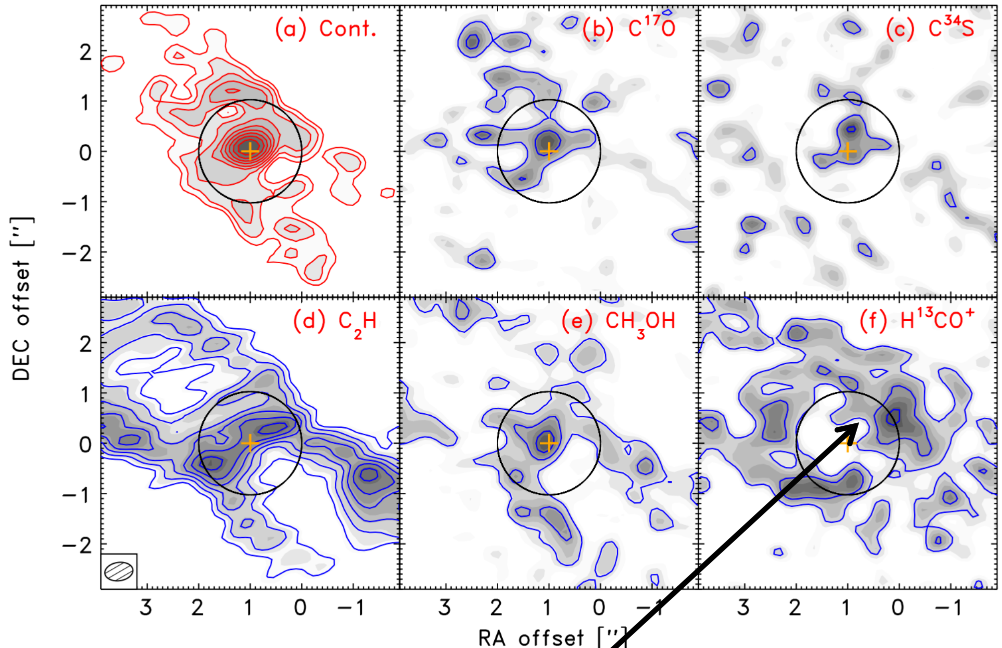
Jørgensen et al. (2015)

Observations of IRAS15398

ALMA & SMA

Detected species

- ^{12}CO, ^{13}CO, $C^{17}O$, $C^{18}O$, $C^{34}S$, C_2H, CH_3OH, HCO^+, $H^{13}CO^+$, N_2H^+, N_2D^+



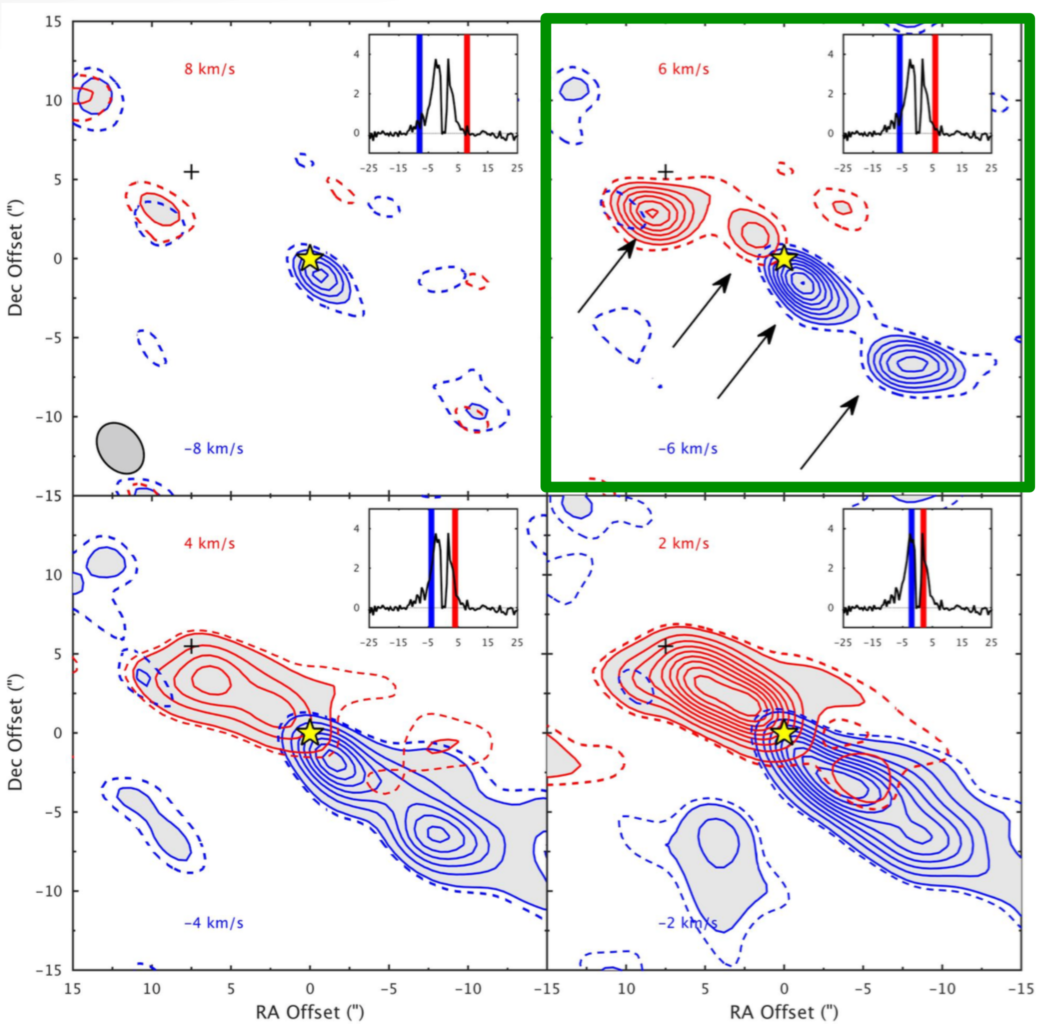
Jørgensen et al. 2013

HCO⁺ ring

HCO^+ destroyed through reactions with H_2O

Observations of IRAS15398

ALMA & SMA



Bjerkeli et al. (2016)

Signs of episodic accretion

- HCO^+ ring
- ”Knots” in the jet
- Distribution of HDO?

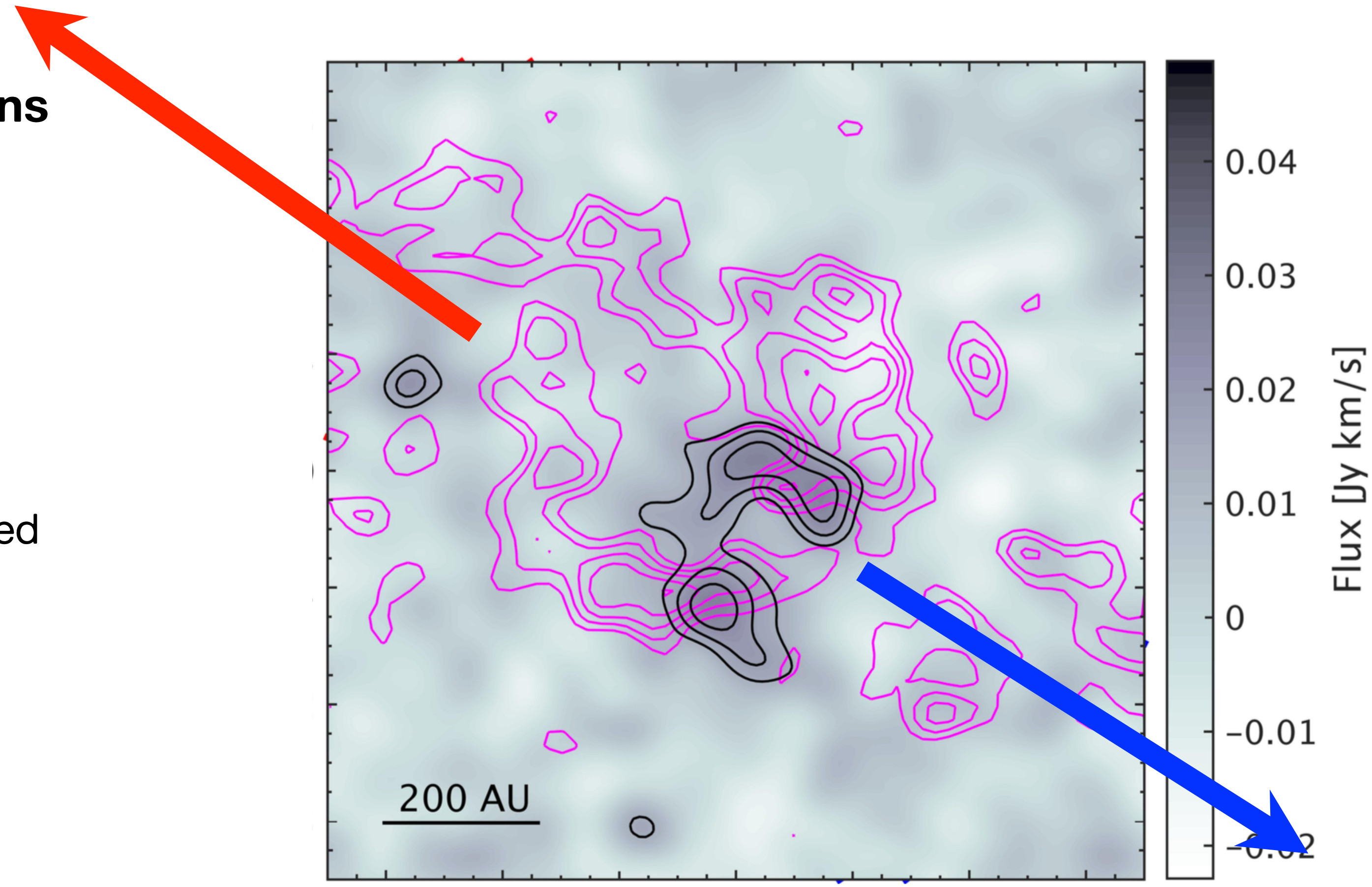
Data consistent with a scenario where the star increased its luminosity by up to two orders of magnitude 100 – 1000 years ago.

Observations of IRAS15398

ALMA

Water observations

- HDO (1_{01}-0_{00})
  - 465 GHz
  - E_{up} = 22 K
- $H_2{}^{18}O$ ($4_{14} - 3_{21}$)
  - 391 GHz
  - E_{up} = 390 K
- Only HDO detected



Observations of IRAS15398

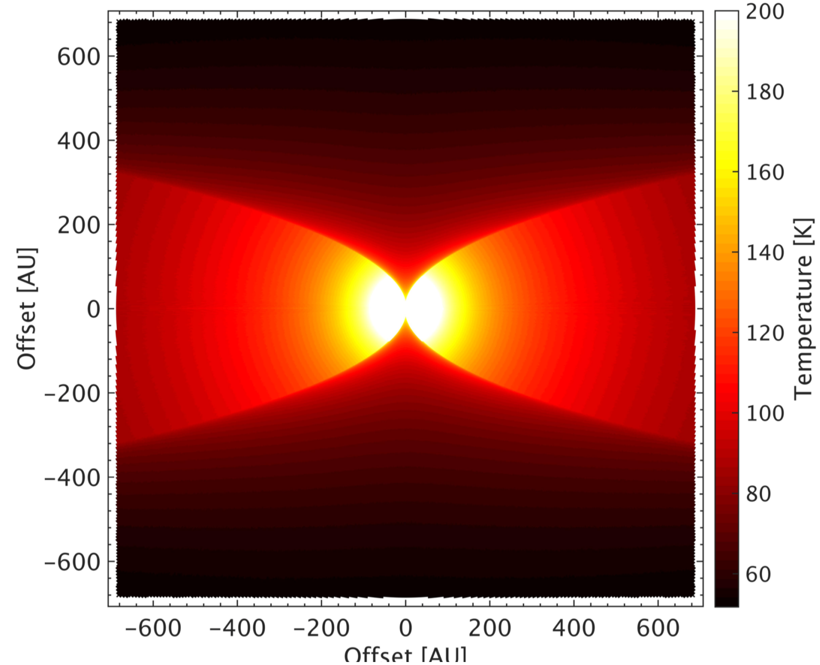
RADMC-3D

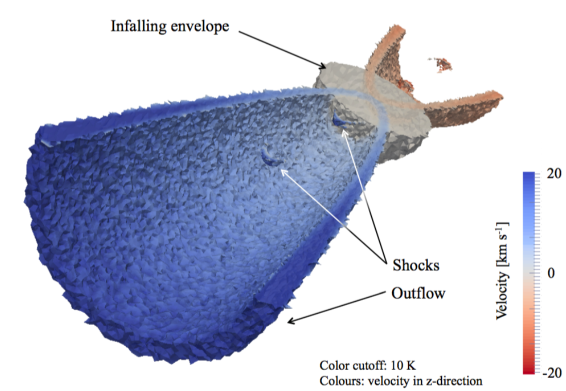
Shock origin?

- $nt > 10^{11}$ cm^{-3} K to excite the $H_2{}^{18}O$ line
- FWHM < 1 km s^{-1}
- Only emission close to the protostar

Ice sublimation during recent accretion burst?

1. **Water sublimation in a spherical envelope?**
2. **Water sublimation close to protostar and shifted by outflow motions?**
3. **Water sublimation in low-density outflow?**





Observations of IRAS15398

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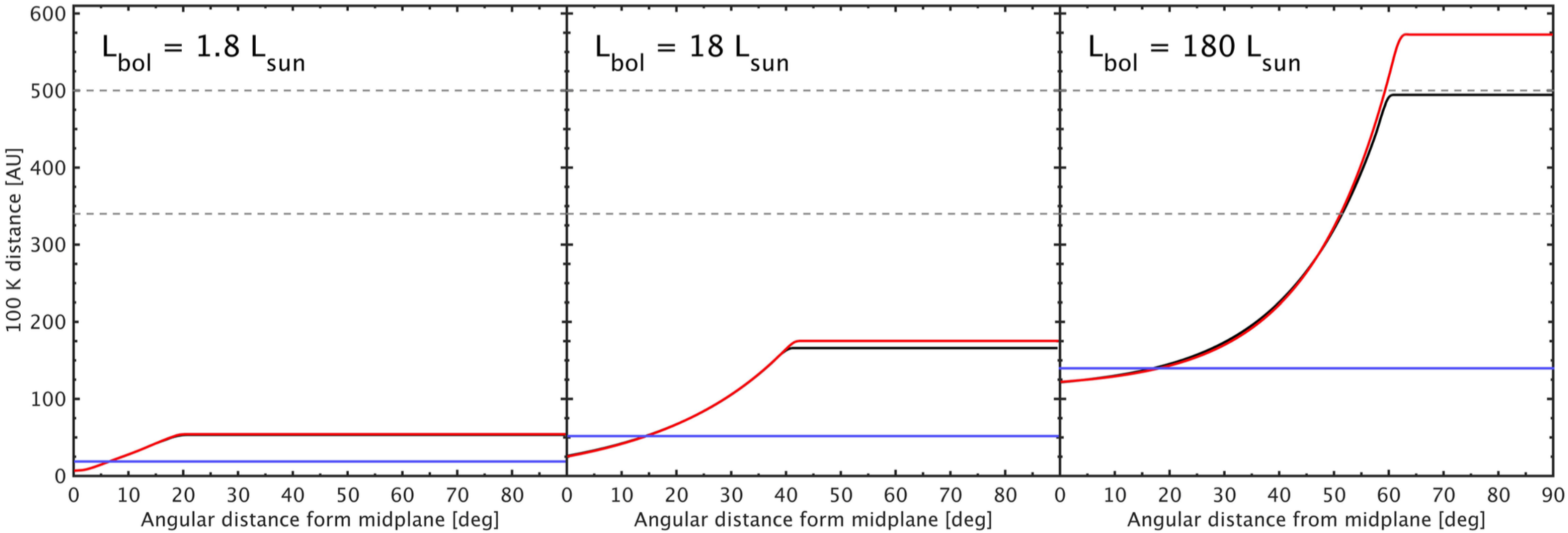

1. **Water sublimation in a spherical envelope?** ✗
   - 100 K radius lower than 200 AU. We see HDO out to 500 AU.
2. **Water sublimation close to protostar and shifted by outflow motions?** ✗
   - Timescale of around 2000 years (too long)
3. **Water sublimation in low-density outflow?** ✔
   - 100 K radius shifted to 500 AU.
   - Consistent with non-detection of $H_2{}^{18}O$

Conclusions

- Presence of HDO consistent with burst scenario
- HDO emission not attributed to shock chemistry
- A lower density outflow can shift the 100 K radius out to 500 AU