The survival of molecules in MHD disk winds

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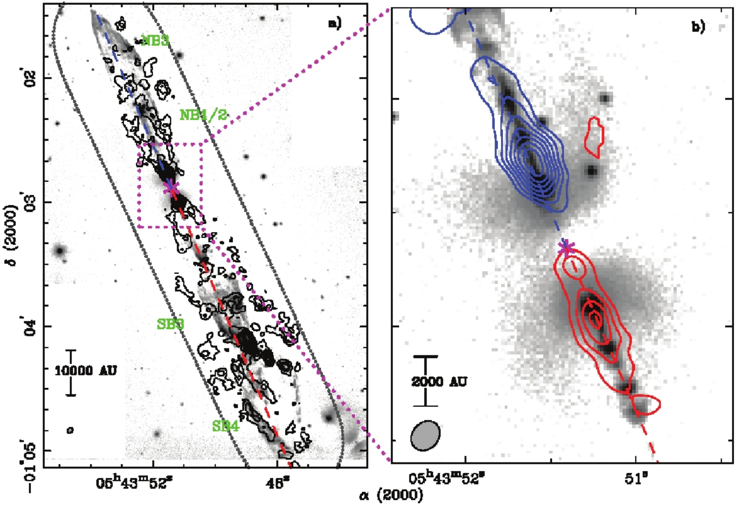
Protostellar jets in context
Rhodes, 7-11 July 2008

Scientific rationale

- **Molecular jets?** From colder **MHD jets** from inner areas of disk **OR** is it **gas from infalling envelope?**

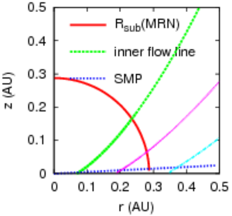


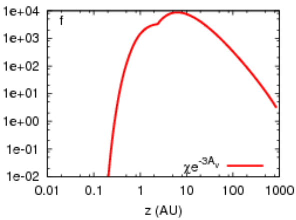
The model

Aim: introduce molecular chemistry in disk winds
and see whether molecules survive and/or be formed

- **Dynamical variables** - flow lines of a self-similar MHD disk wind (Casse and Ferreira, 2000)
  - magnetically driven centrifugal disk wind
  - consistency with underlying accretion disk
- **Atomic disk wind** model (Garcia et al., 2001)
  - ion-neutral momentum exchange rates
  - calculation of ion-neutral drift speed from $\vec{J} \times \vec{B}$
- **1D steady state MHD shock model** for molecular ISM (Flower and Pineau des Forêts, 2003)
  - thermochemical ionization structure along flow line

Radiation field - Class I star

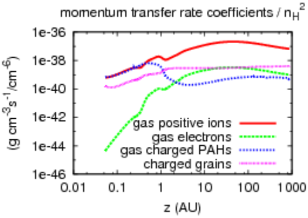




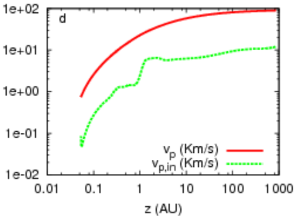
dust composition and grain size distribution constant (Mathis et al., 1977)

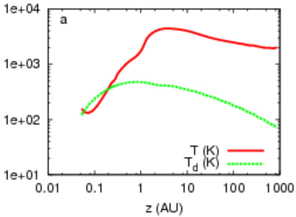
radiation field coming from star (4 000 K) + hot spots (10 000 K); here UV flux normalized by mean interstellar background (Draine, 1978), attenuated by dust

Dust grains



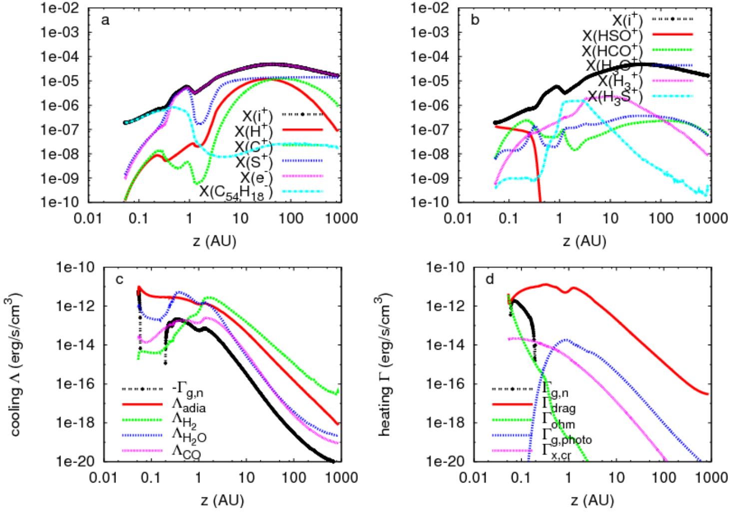
separate calculation of the momentum transfer rate coefficients for gas ions, charged grains, and charged PAHs to the neutrals



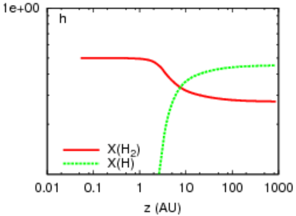


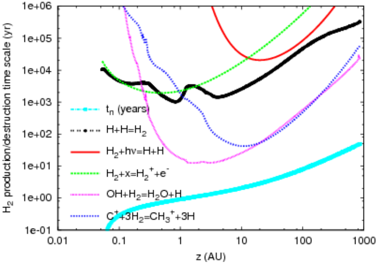
dust temperature from radiation equilibrium

Heating/cooling sources - Ionization contributors



H_2 dissociation





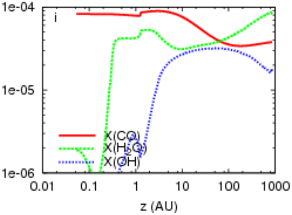
- quite well self-shielded
- close to the star:
  X-rays destruction balances H_2 formation on grains
- along the flow line
  - collisional dissociation too slow
  - chemical dissociation by charged hydrocarbons

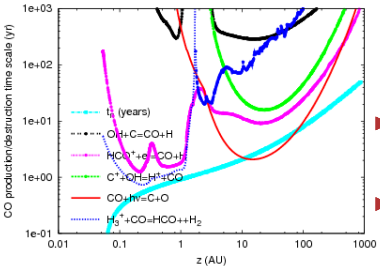
$$
\begin{array}{rcl}
C^+ + H_2 & \longrightarrow & CH^+ + H \\
CH^+ + H_2 & \longrightarrow & CH_2^+ + H \\
CH_2^+ + H_2 & \longrightarrow & CH_3^+ + H
\end{array}
$$

  - endothermic neutral-neutral reactions:

$$OH + H_2 \longrightarrow H_2O + H$$

CO survival



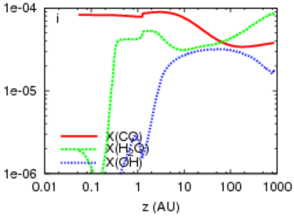


- CO self- and cross-shielding not that good
- close to the star: formation/destruction

$$\mathrm{HCO^+ + e^- \rightarrow CO + H}$$
$$\mathrm{H_3^+ + CO \rightarrow HCO^+ + H_2}$$

- along the flow line: photodissociation
- by end partly reforms from first reaction

H_2O formation

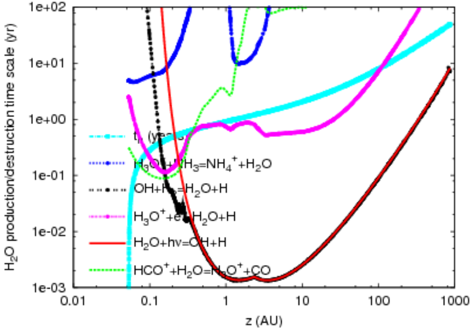


- beyond 1 AU

  $H_3O^+ + e^- \longrightarrow H_2O + H$

  dominates
- H_2O photodissociation balances

  $OH + H_2 \longrightarrow H_2O + H$



Conclusions - Future work

- **Molecules can survive in MHD disk winds**
  - low temperature plateau $\simeq 2,000$ K
  - outer flow lines (e.g. for $\dot{M}_{acc} = 10^{-6} M_{\odot}/\mathrm{yr}$ and warm solution, 60% of H is molecular for $r_0 = 1$ AU)
  - higher accretion rates
- study dust depletion at starting point - depends on launching point, $\dot{M}_{acc}$ ... if inside of sublimation radius
- Prepare full sets of observational predictions

References

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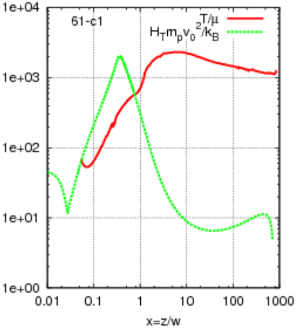
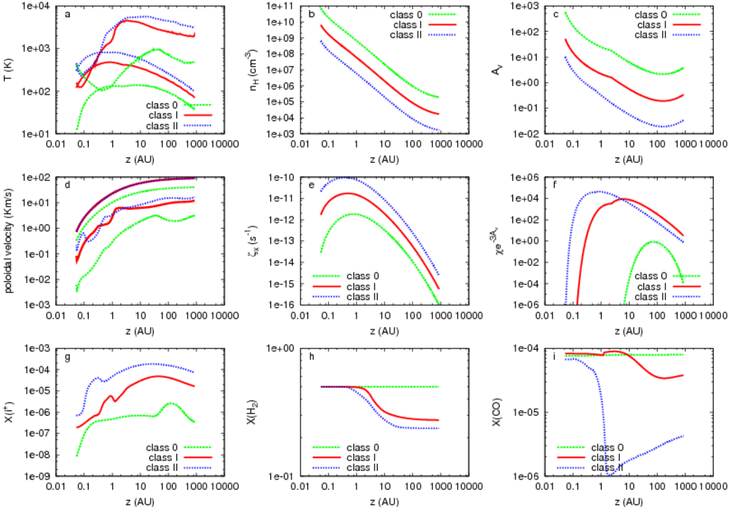
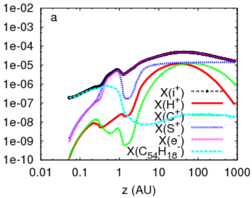
Consistency



Class 0, class I, class II



H^+ formation



1. forms by X-rays, destructed by PAH^-
2. forms by X-rays, destructed by H_2O
3. forms by charge exchange of H and H_2^+, photodissociation of CH^+
4. forms or dissociates by $H^+ + H_2O = H_2O^+ + H$