The chemistry of high-mass star formation

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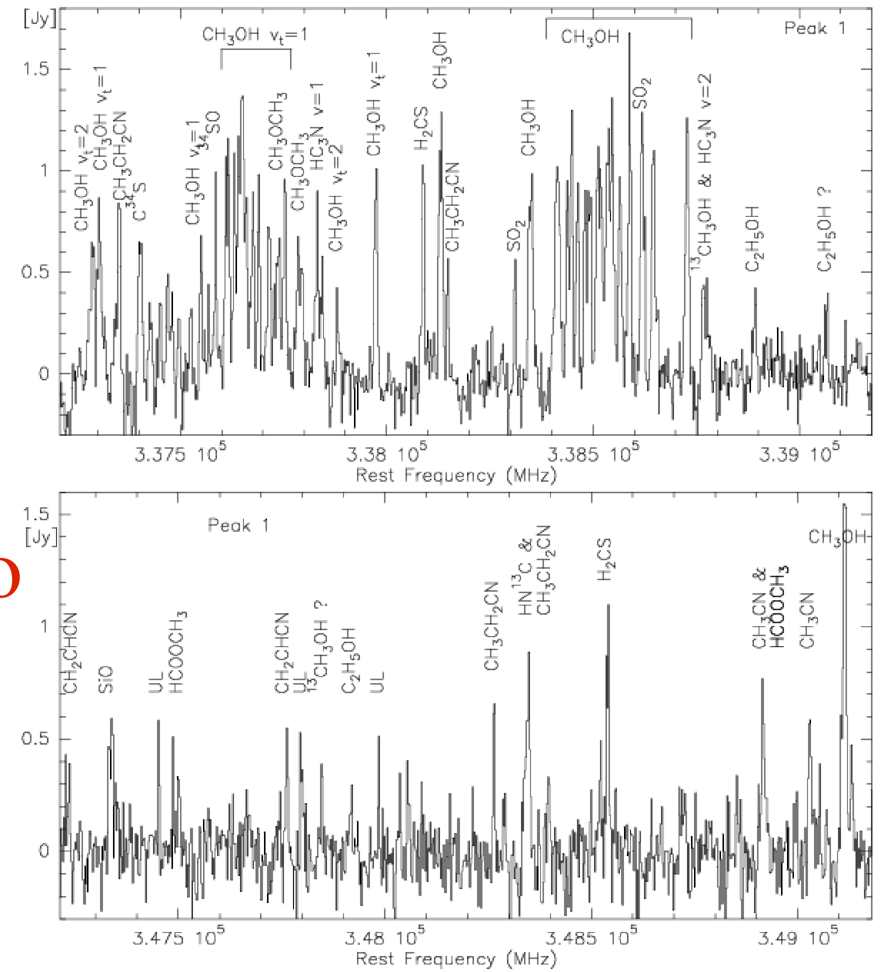
The use of chemistry in astrophysics

Line radiation essential to

- probe kinematics
- diagnose temperatures, densities, ...

Chemical composition sensitive to

- time
- invisible radiation
- history



Beuther et al 2007

Posters Schilke, Leurini

We are all astrochemists!

Basic Astrochemistry

Cold gas: ion-molecule reactions

- no barriers, e.g. $CO + H_3^+ \rightarrow HCO^+ + H_2$
- ions produced by cosmic rays

Warm gas: neutral-neutral reactions

- high barriers, e.g. $O(H_2,H)OH(H_2,H)H_2O$ at $T > 250$ K
- close to young stars / strong interstellar shocks

Cold dust: H & O addition on ice

- produces saturated species (H_2O, NH_3, CH_3OH, ...)

Warm dust: ice rearrangement & evaporation (20 -- 100 K)

- leads to “complex” organic molecules

Chemical Filters

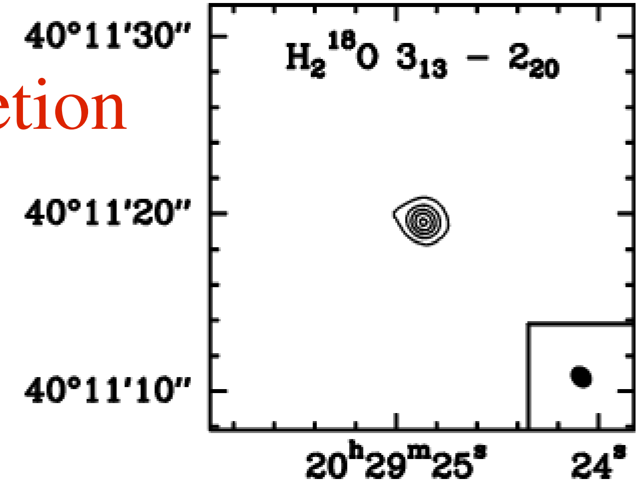
Water: filter for warm gas (> 100 K)

- produced on grains, evaporates at T ~100 K
- extra boost by neutral-neutral channel (T > 250 K)

H_2D^+: filter for cold gas (< 10 K)

- produced by H_3^+ + HD; back reaction slow at low T
- main destroyers CO & O frozen onto dust
- recent highlight: D_2O (Butner et al 2007)
- *See talk Fontani*

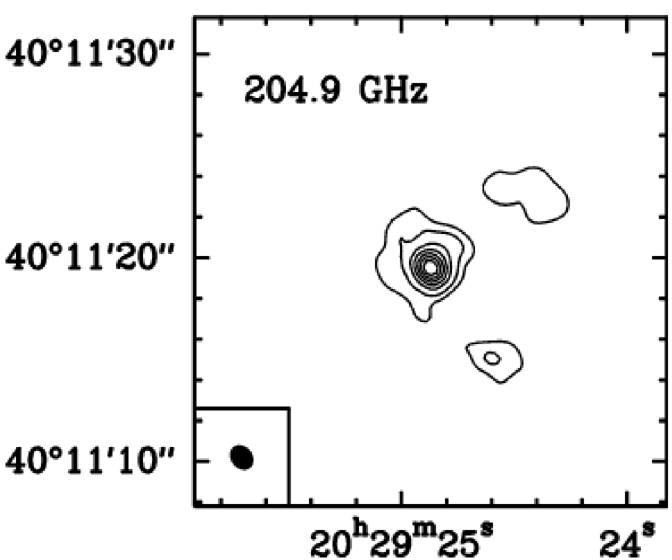
A dust and water disk in AFGL 2591

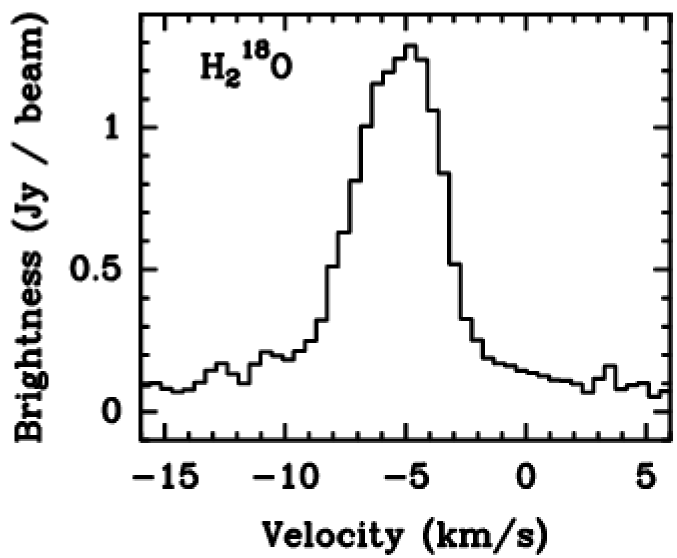


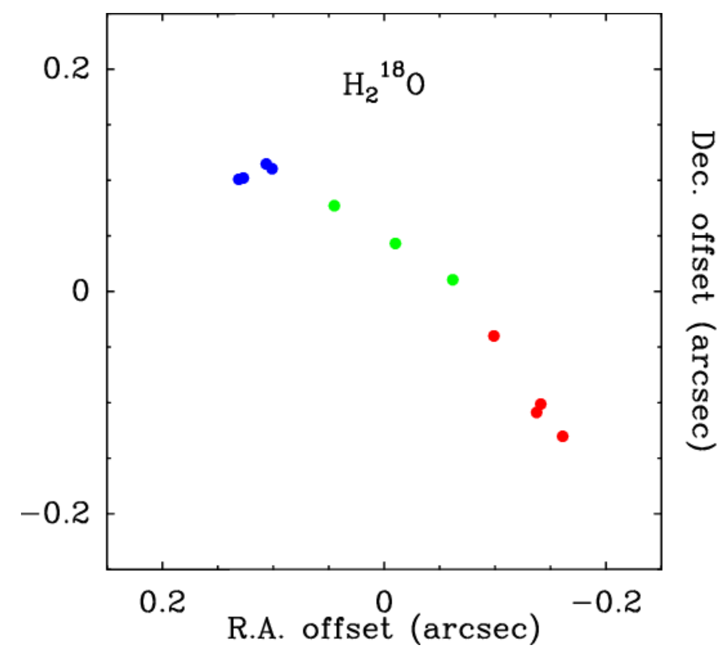
High-mass stars may form through disk accretion

- like low-mass stars
- but massive disks remain elusive

IRAM PdBI: R = 400 AU elongated dust/H_2O source with M = 0.05 M_* and $V = V_K$







Van der Tak et al 2006a

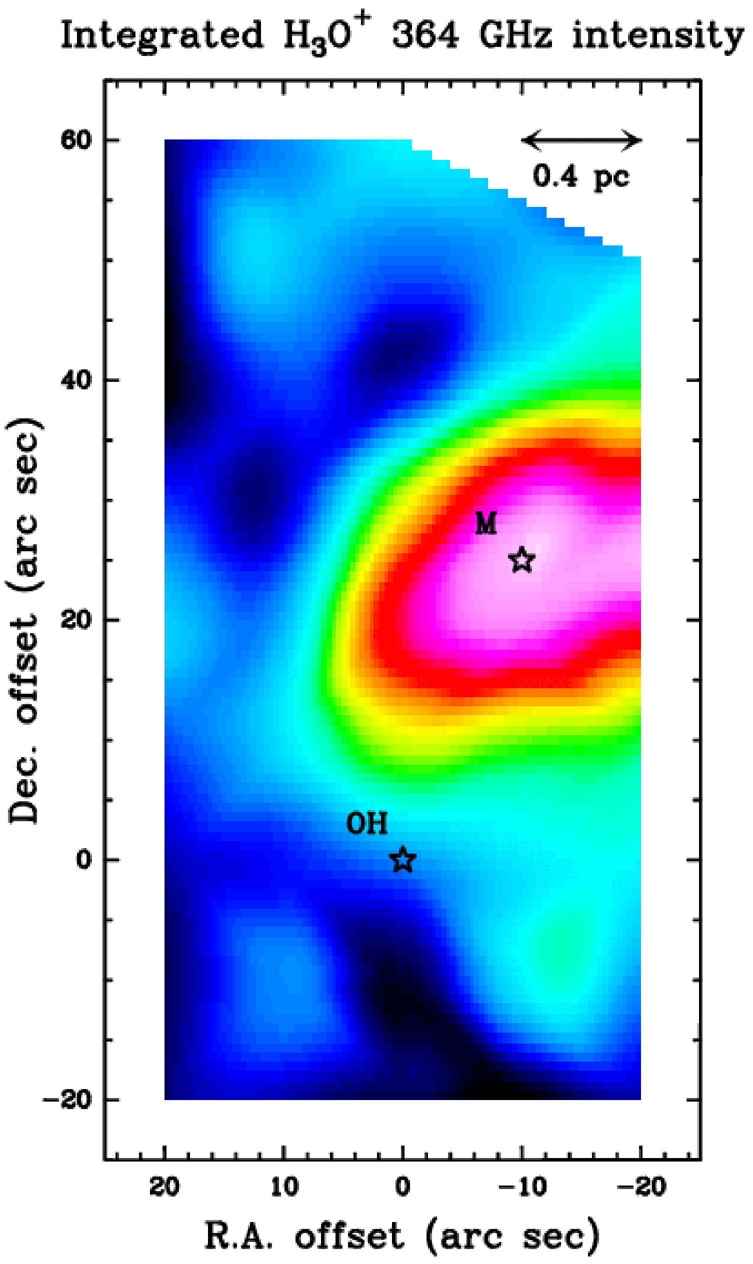
Enhanced cosmic-ray flux in Sgr B2

ζ_{CR} key for cloud dynamics & chemistry

- Locally $\zeta = 3 \times 10^{-17}$ s^{-1}
- variations: column density or location?

Sgr B2: $H_3O^+ / H_2O = 1 / 50$

- ζ is 10x higher than nearby clouds
- even higher ζ in Sgr A: propagation effect (scattering)

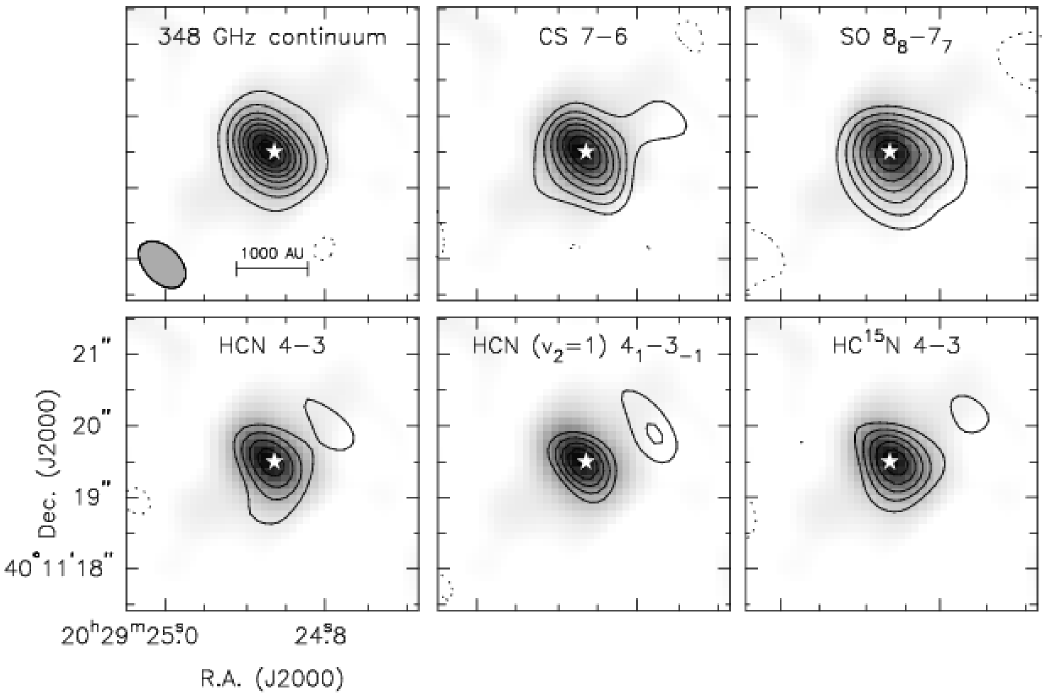


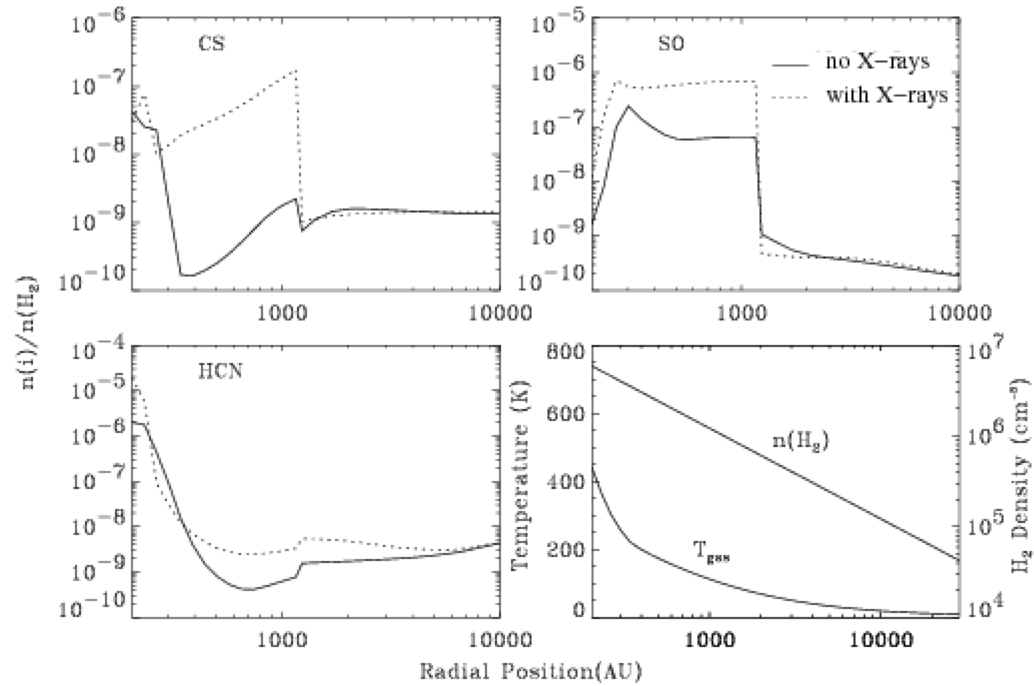
Van der Tak et al 2006b

Irradiation effects on sulphur chemistry

Massive stars emit strong X-rays, but when do they start?

- Protostellar X-rays affect chemistry on <1000 AU scales
- Pronounced peaks in SO and CS seen in SMA data of AFGL 2591: L_X / L_{bol} >~ 10^{-6}





Benz et al 2007

Future opportunities

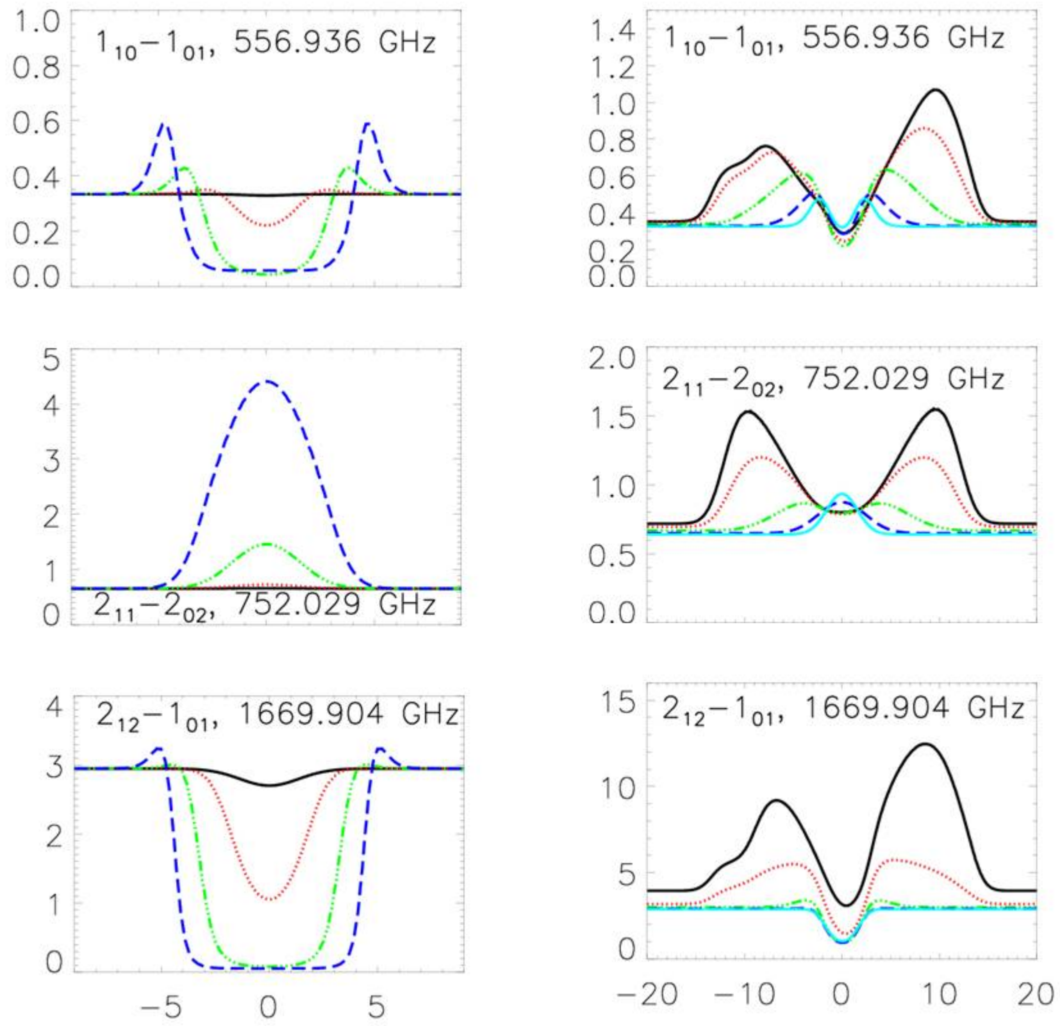
Herschel-HIFI

- WISH
- HS3F *(poster Comito)*

e-SMA

JCMT SLS *(poster Plume)*

ALMA



Poelman & van der Tak 2007