## Molecules in massive star formation observed at high spatial resolution

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- Introduction
- The template region Orion-KL
- Examples of recent interferometric molecular line studies
- Searching molecular line tracers for massive disk studies
- One interferometric multi-wavelength continuum study
- Conclusions

## Single-dish line surveys of UCHII regions/Hot Cores



Hatchell et al. 1998

### Orion-KL 1: SMA spectra at 338 and 348GHz



- Approximately 150 spectral lines from 26 species
- 90% of them could be identified
- Additional low-level emission which needs further work
- 15% of the lines were not detected by previous single-dish studies (plus low-level emission)



#### **Orion-KL 2: Spectral line emission in the 870µm band**



-10 5 Δ R.A. ["]

- Toward source I mainly SiO
- Sulphur-bearing species toward Hot Core and Compact Ridge
- Sulphur- and oxygen-bearing species toward IRc6



-10





- Oxygen-bearing molecules weaker toward Hot Core and strong toward Compact Ridge
- Nitrogen-bearing molecules strong toward Hot Core

#### **Orion-KL 2: Spectral line emission in the 870µm band** - Toward source I mainly SiO IRe6 d - Sulphur-bearing species toward 0 Hereit SMA1 An compact \$ & Hot Core and Compact Ridge ĥ Δ Dec. ["] 5 -10 - Sulphur- and oxygen-bearing species toward IRc6 0 \$ ~ 10 5 Amplitud ٥ -5 -105 5 - Imaging helps to ider 337.5 338 338.5 339 347.5 348 348.5 349 Frequency [GHz] Southern peak 3 10 Amplitude [Jy] 2 5 1 -10 0 earing molecules -1 337.5 338.5 347.5 348.5 349 339 338 348 ward Hot Core and Frequency [GHz] strong toward Compact Ridge - Nitrogen-bearing molecules 'n strong toward Hot Core -10 -5 -10 Δ R.A. ["]

## **Orion-KL 3: Rotation temperatures from CH<sub>3</sub>OH**





## **Orion-KL 4: SMA line images at 440µm**





## Chemistry in W3OH/(H<sub>2</sub>O)





PdBI, Wyrowski et al. 1999



#### The Hot Core G29.96

















### Potentially disk-tracing molecules



IRAS 18089-1732: HCOOCH<sub>3</sub> Beuther et al. 2004, 2005 IRAS 23151+5912:  $CH_3OH v_t=1$ Beuther et al., in prep.









## Multi-wavelength observations of the HMPO IRAS 05358



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#### Conclusions

- High-spatial-resolution molecular line studies are a powerful tool to: derive molecular abundances
  - detect and identify new molecules
  - estimate physical parameters like temperatures and densities
  - study kinematic and dynamic processes like disk-rotation, outflows ...
- Often multiple sub-sources are identified, and multi-wavelength continuum studies give information about the dust properties and temperatures

However: many questions are still largely unexplored:

- Chemical clocks and chemical evolution of massive cores not well understood
- Gas phase chemistry versus grain surface chemistry, dependence on temperature, density, shocks ...
- What are the right tracers for the various physical processes?

# Lots of work remains!