Reactive ions in Orion

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HEXOS — Herschel HIFI Observations of Extraordinary Objects — The Orion and Sagittarius B2 Star-Forming Regions

SRON

ph1 Universität zu Köln

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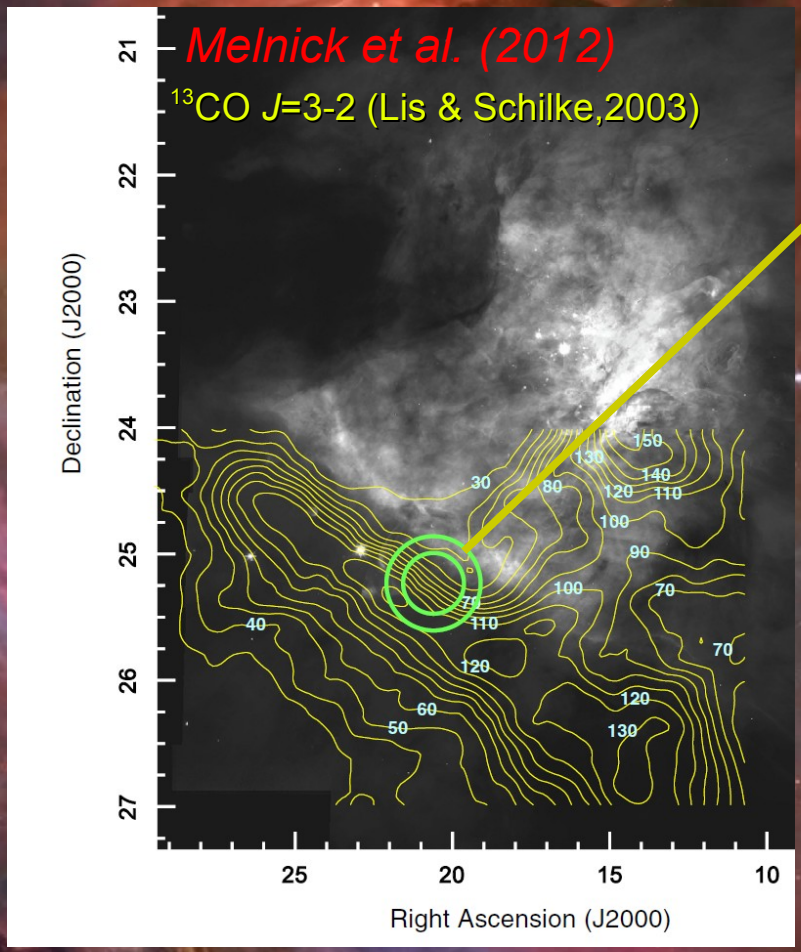
Javier Goicoechea (Centro de Astrobiologia)
Christine Joblin (Universite de Toulouse)
Franck Le Petit, Jacques Le Bourlot (Observatoire de Paris, LUTH)

Reactive ions

- Fast reactions with H, H_2, and electrons
- Rates for collisional excitation and chemical reactions are similar
- Examples: CH^+, SH^+, OH^+, H_2O^+, H_3O^+
- Talks by Godard and Falgarone: diffuse ISM
- This talk: dense ISM with strong UV radiation field

Orion – the Photon Dominated Region



CO^+ peak

-χ=1-4×10^4 χ_0

-Nearly edge-on

P61 – Choi et al.
P67 – Goicoechea et al.
P79 – Morris et al.
P85 – Parikka et al.

Reactive ions with high activation barrier

$$C^+ + H_2 \rightarrow CH^+ + H\ (-4640\ K)$$

$$S^+ + H_2 \rightarrow SH^+ + H\ (-9860\ K),$$

Overcoming the activation barrier?

Turbulent dissipation models

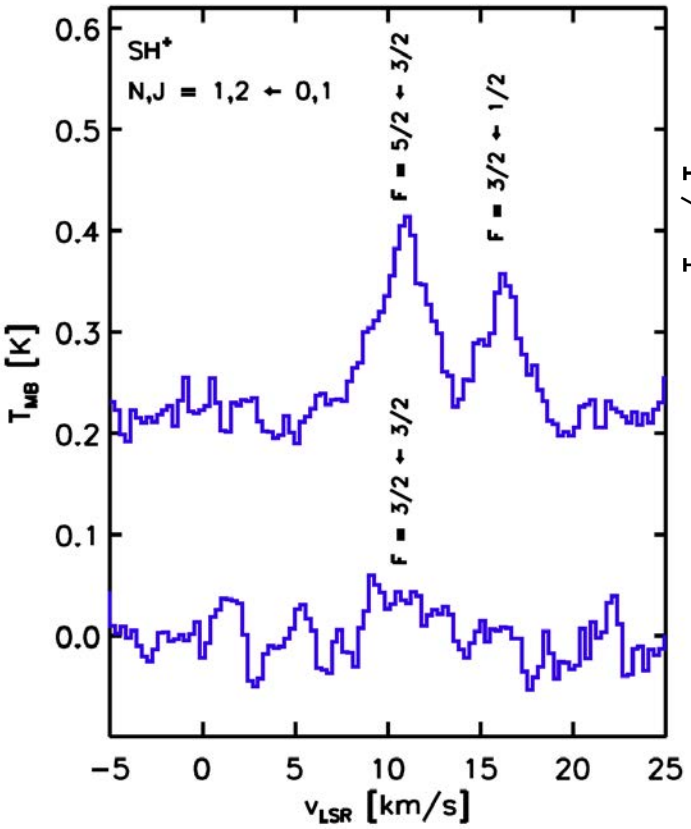
Talks by Falgarone and Godard

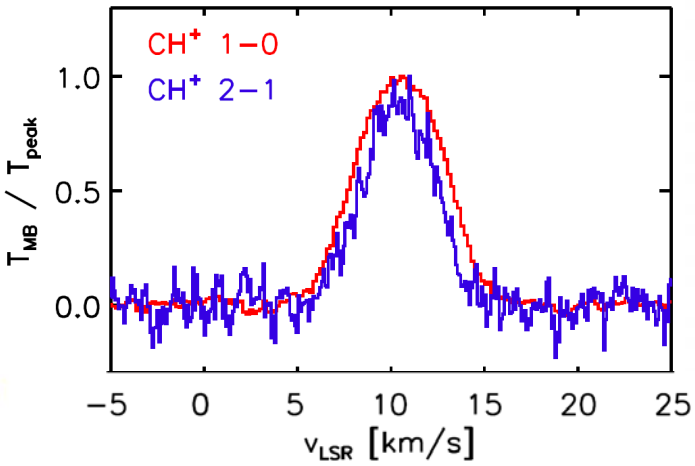
C-shock models

Reactions with vibrationally excited H_2

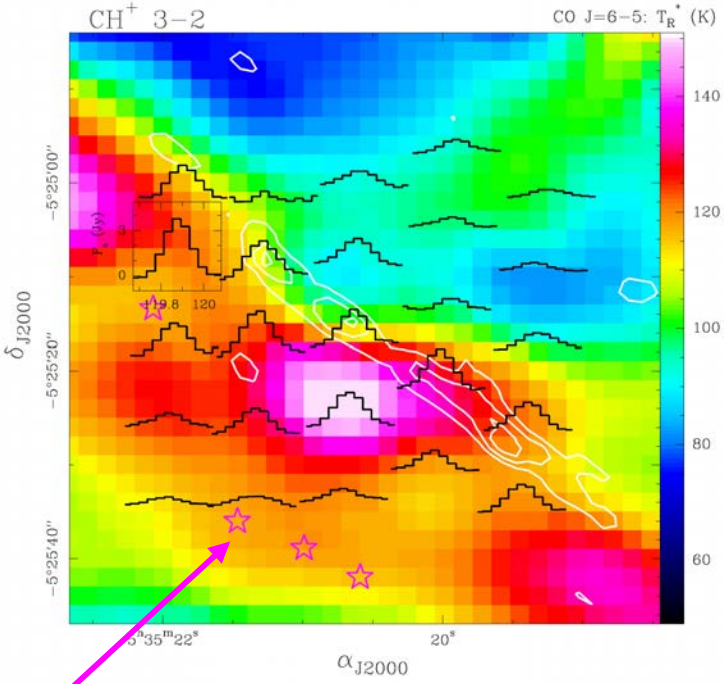
CH^+ and SH^+ in the Orion Bar

Nagy et al. (2013)





Spectrally resolved line profiles (*Herschel*/HIFI)



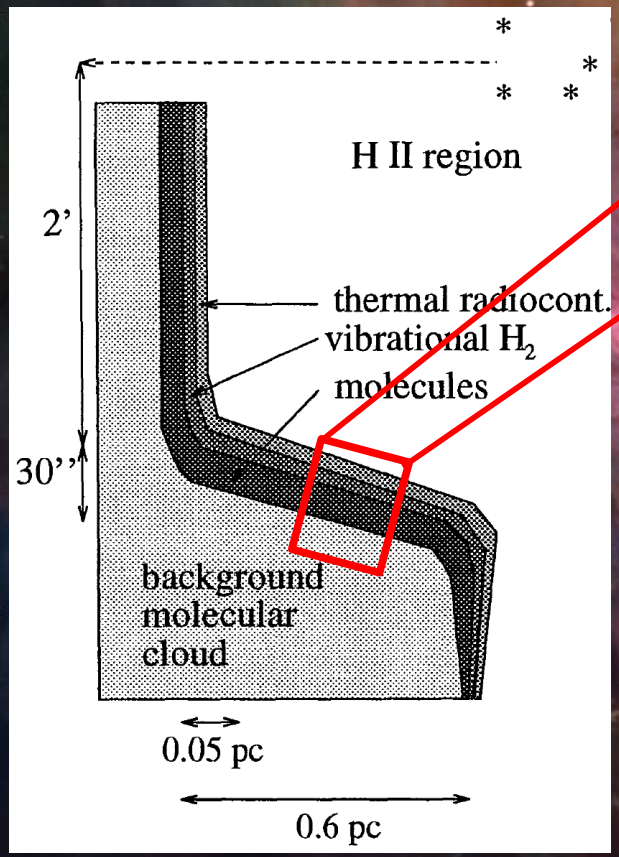
Spectrally unresolved data (*Herschel*/PACS)

$H^{13}CN$ clumps (*Lis & Schilke, 2003*)

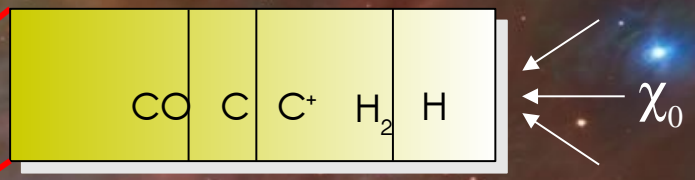
Interpretation – PDR models

-**Isobaric** models

P=5×10^{7}- 2×10^{8} cm^{-3} K



Molecular region



Meudon code (e.g. Le Petit et al. 2006)

-**Radiation field**:

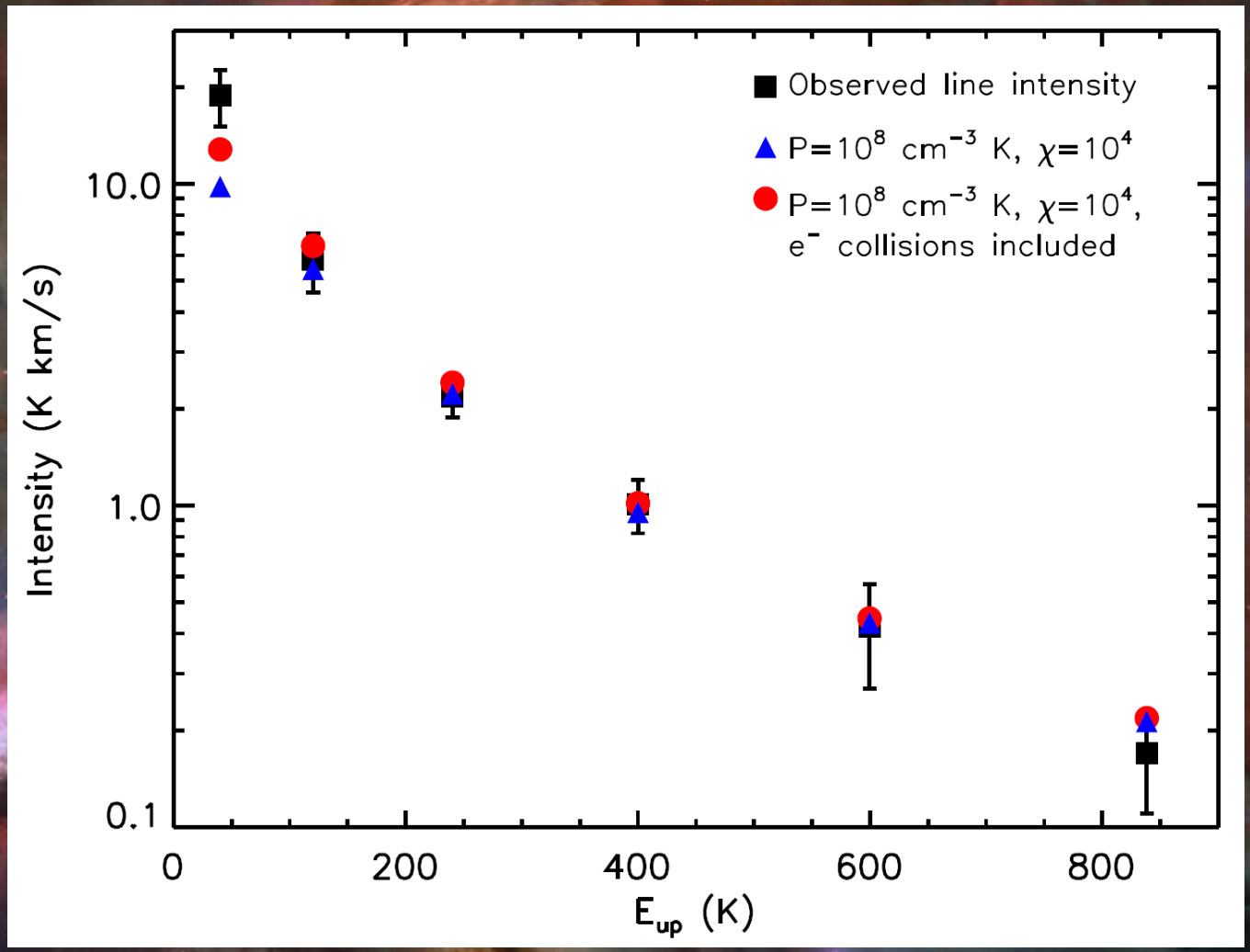
χ_0 ~ 1-3×10^{4}

-Cosmic ray ionization rate

ζ=2×10^{-16} / H_2 molecule

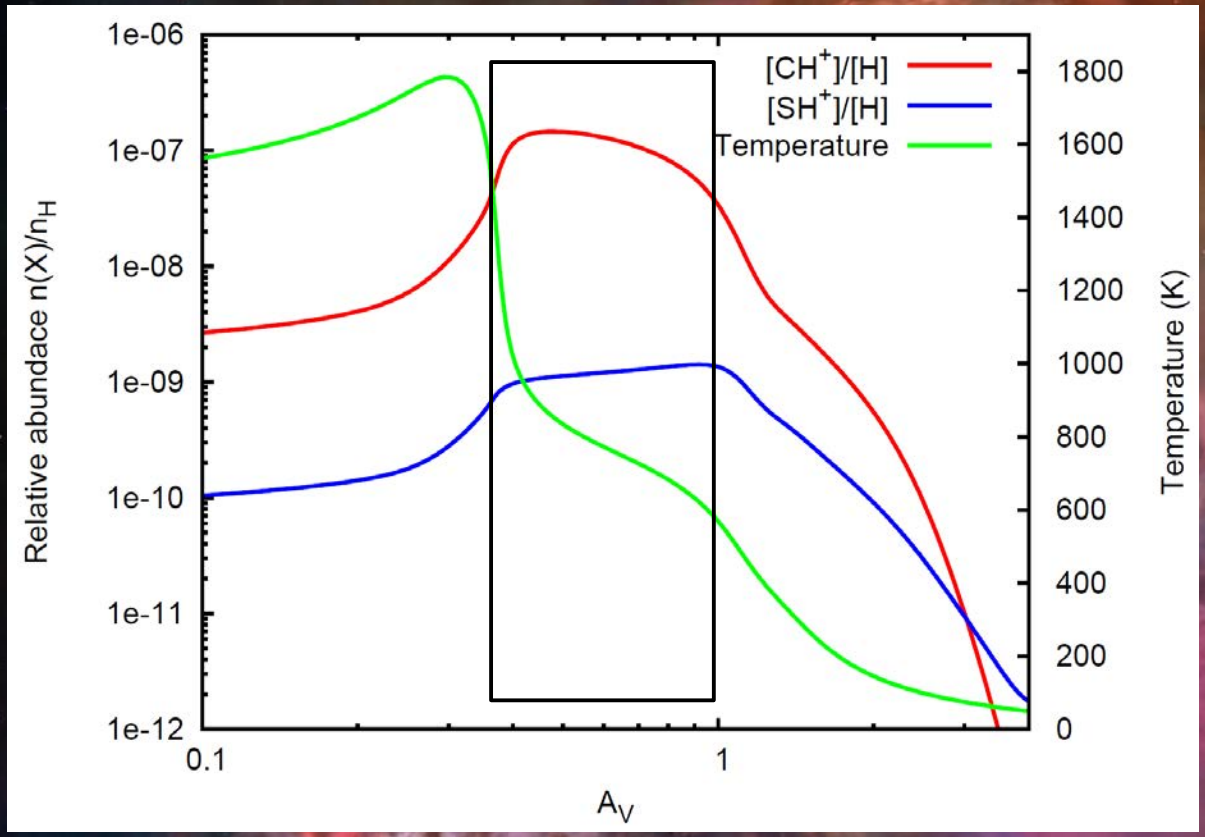
-State-to-state formation for CH^+ and SH^+

Results – PDR models



Nagy et al. (2013)

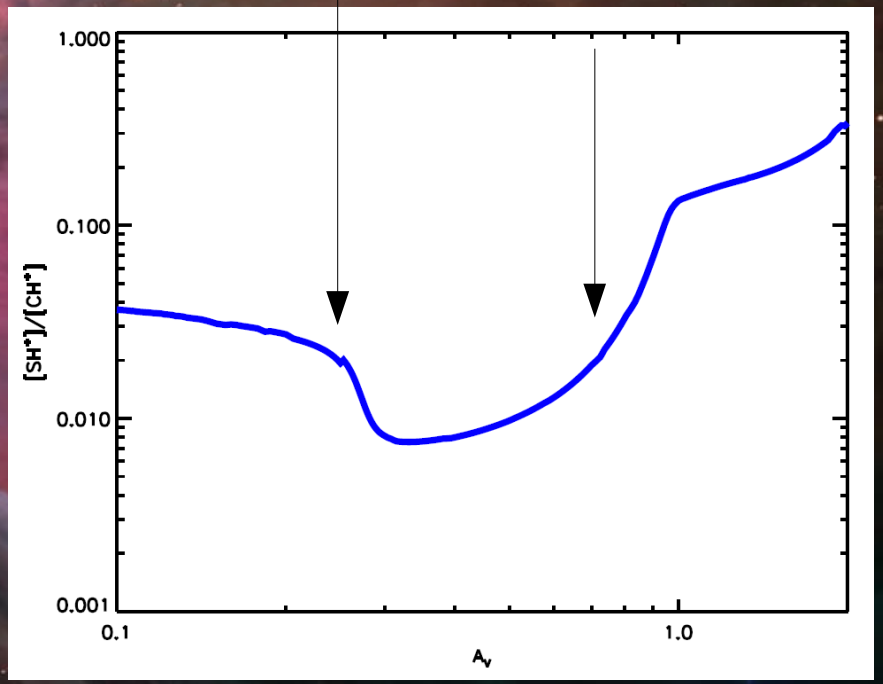
Results – PDR models



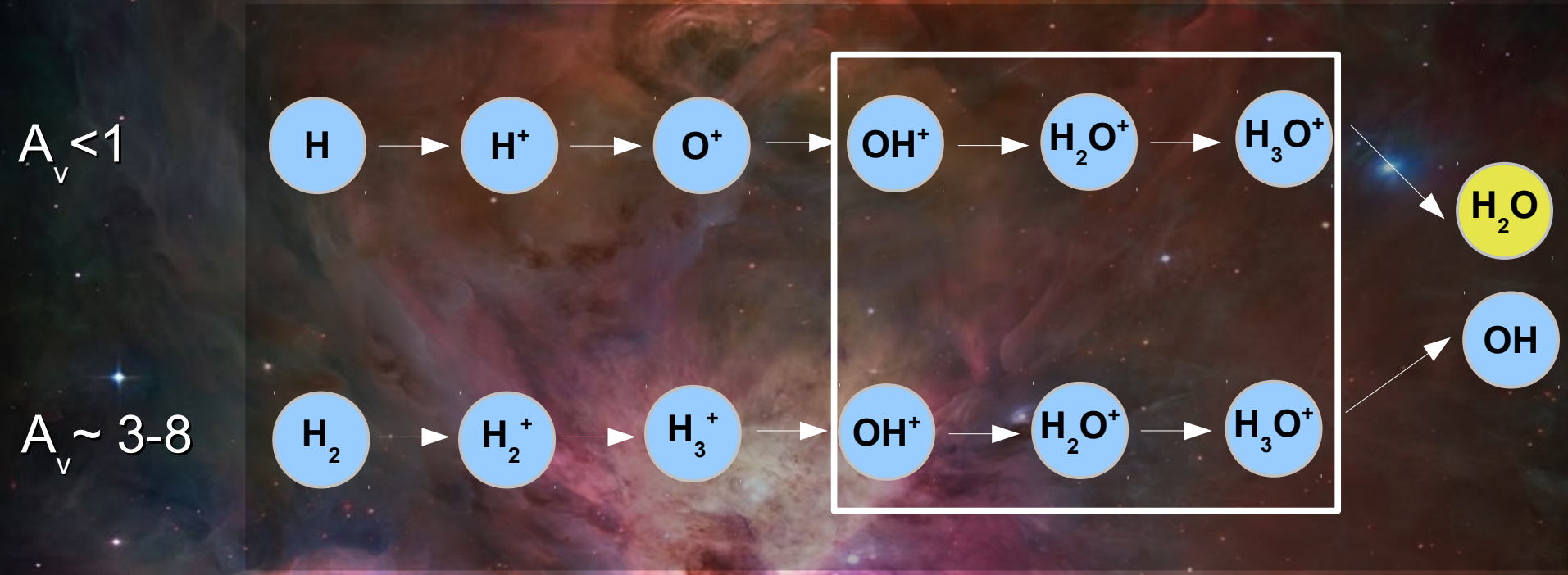
-Abundances peak near the surface
-*T* ~ 500-1000 K

-Main destruction partners:

H H_2 e^-

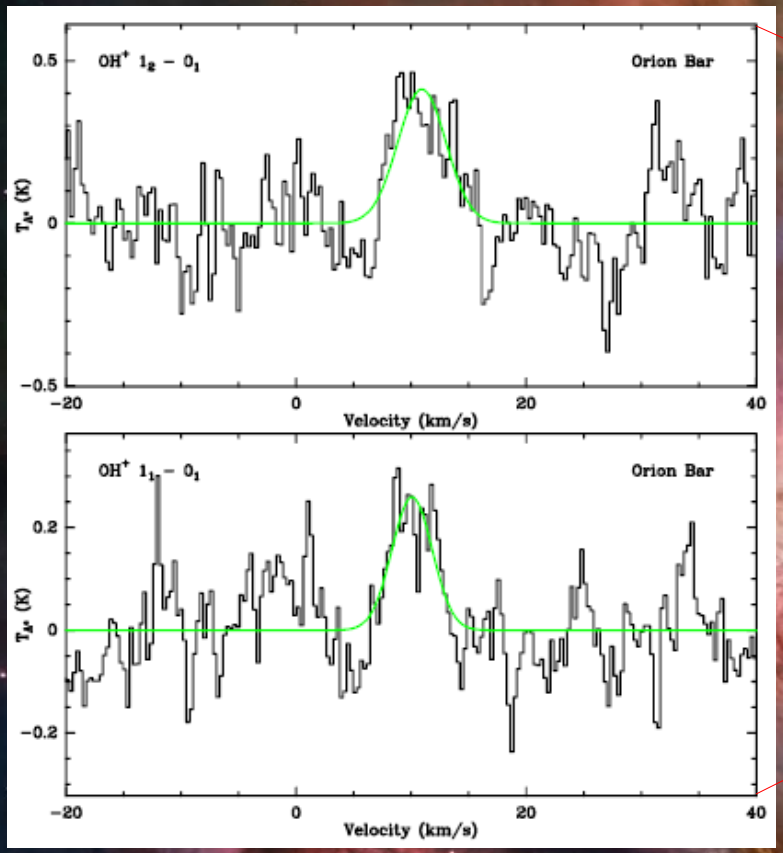


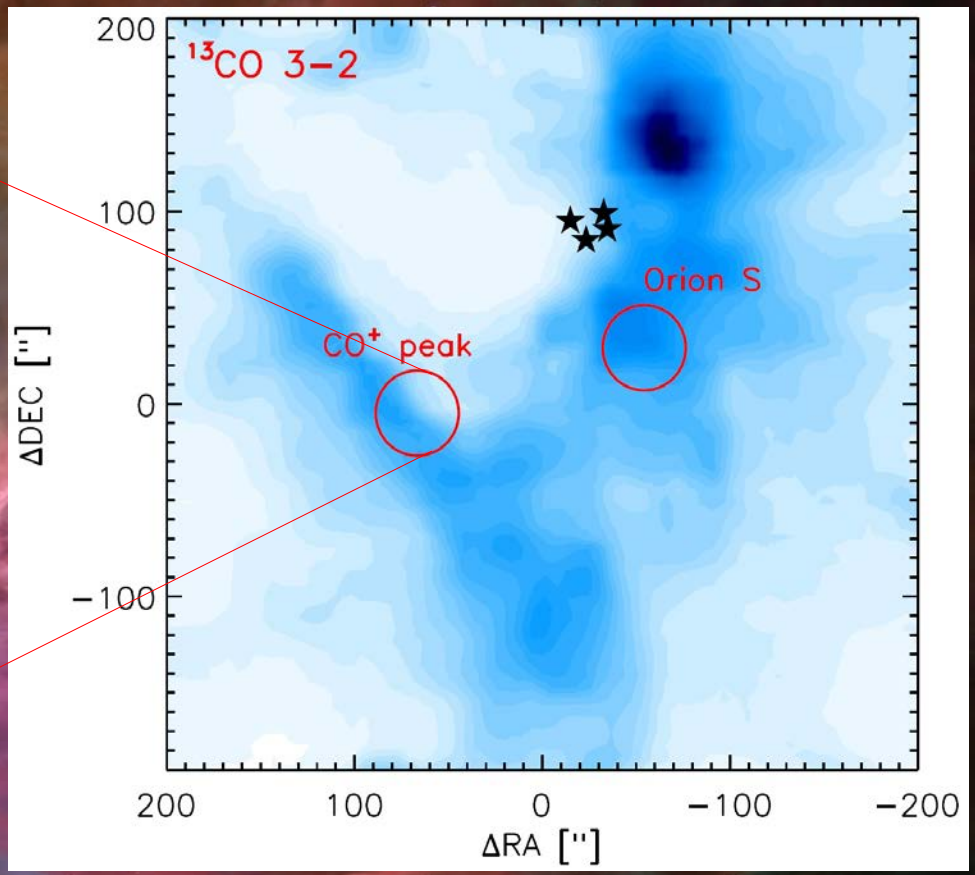
Reactive ions with no activation barrier



- Initiated by (cosmic ray) ionization of H/H_2
- Tracers of cosmic ray ionization rate

OH^+ emission in Orion



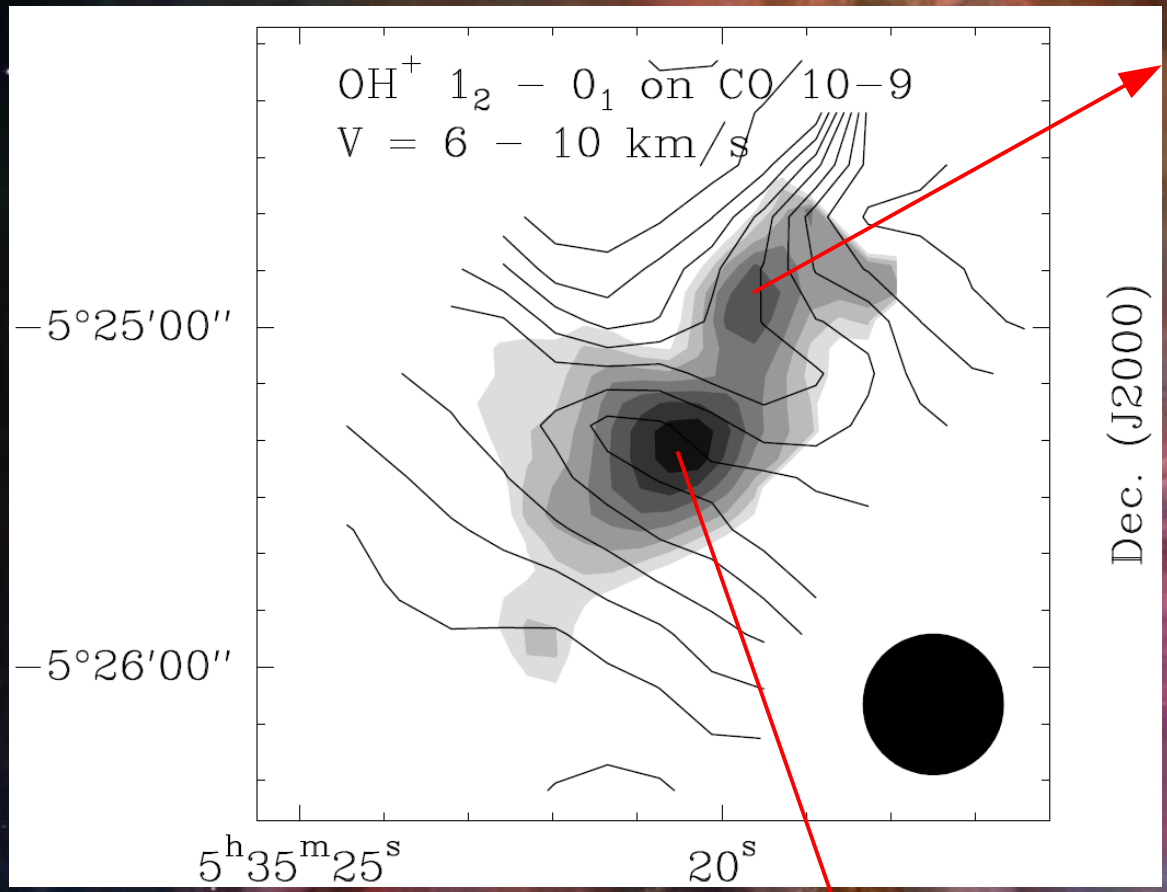


-non-detection of H_2O^+ and H_3O^+

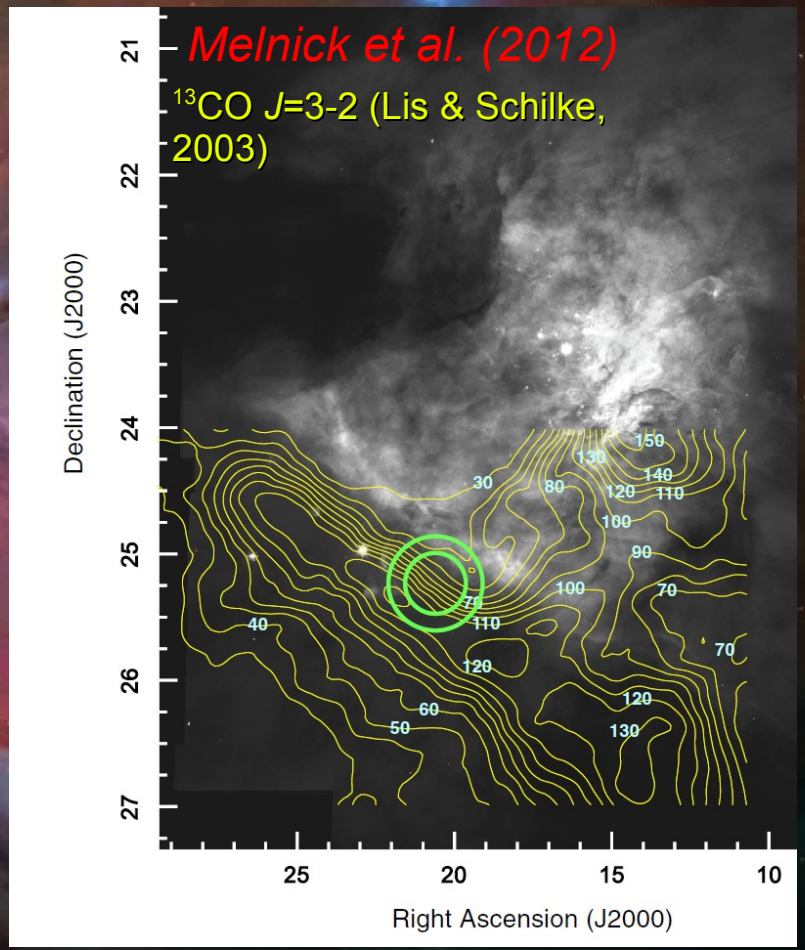
Van der Tak & Nagy et al. (2013)

Detection of several OH^+ transitions in emission

Spatially extended OH^+ emission



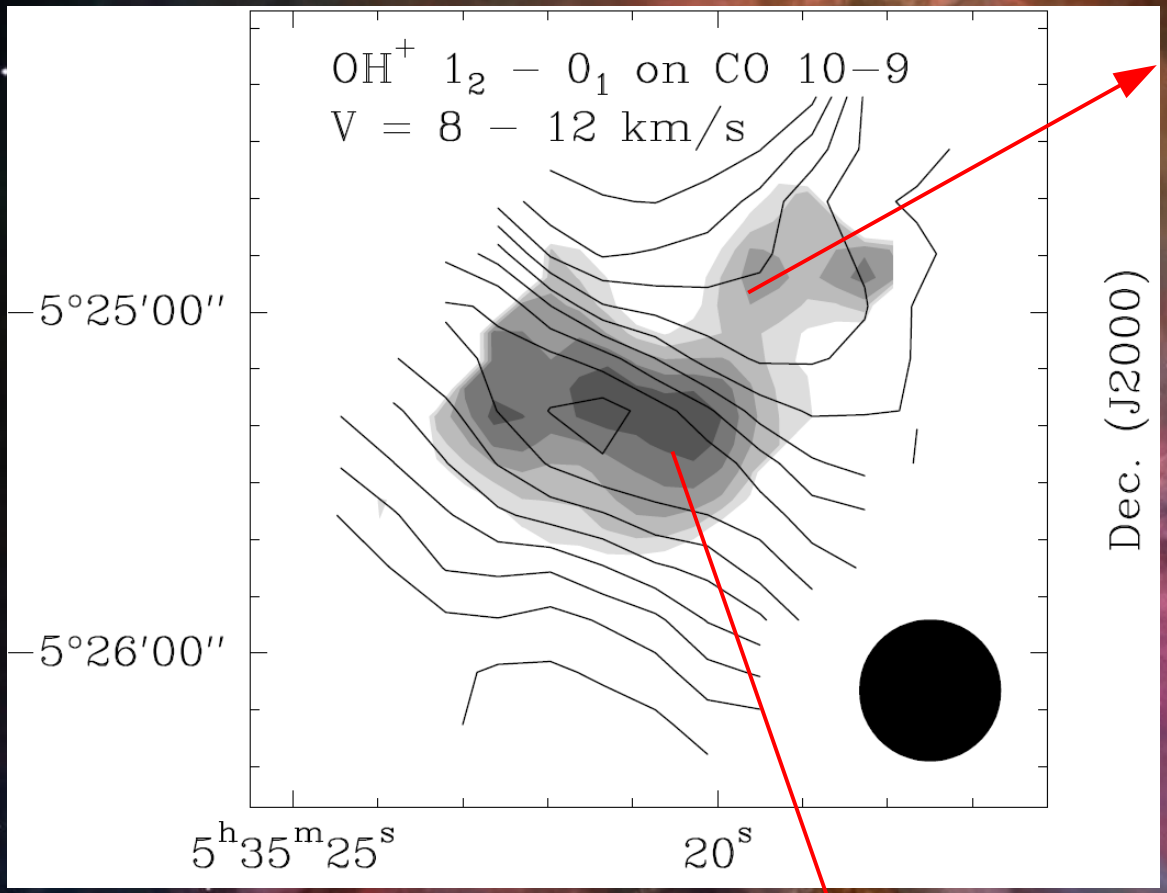
Part of the Orion Ridge



CO^+ peak

Van der Tak & Nagy et al. (2013)

Spatially extended OH^+ emission



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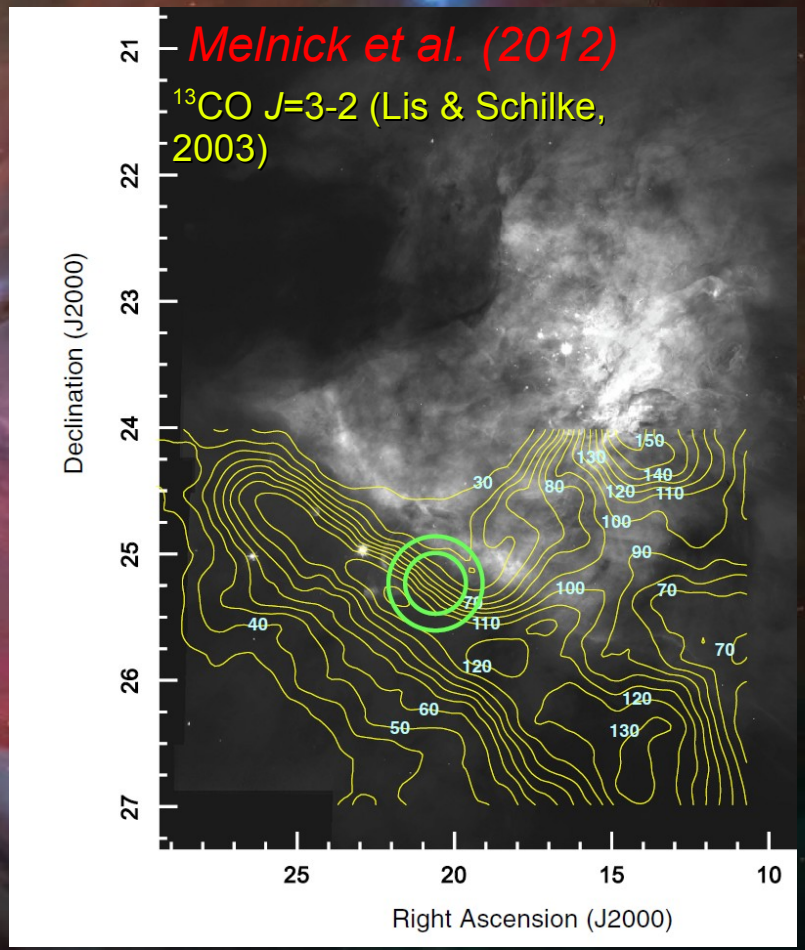

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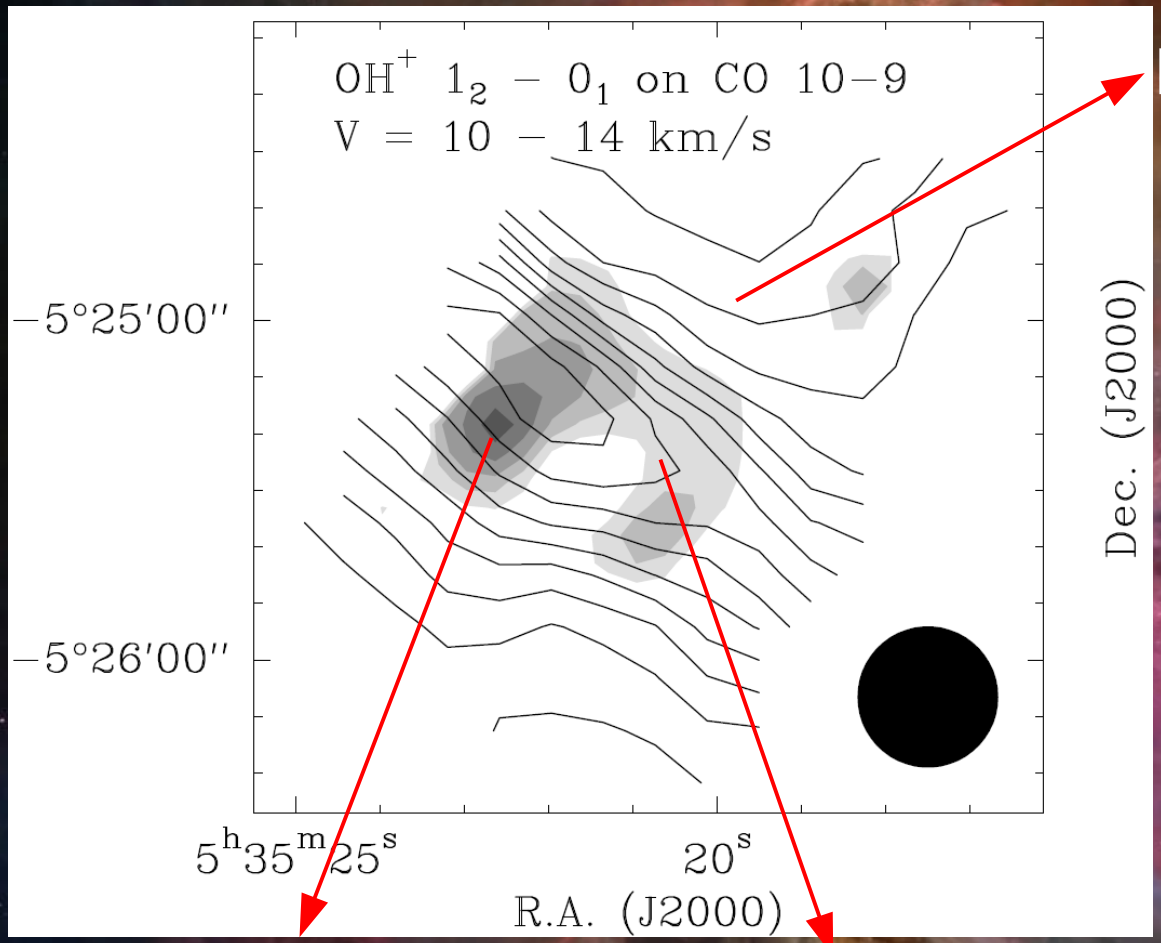
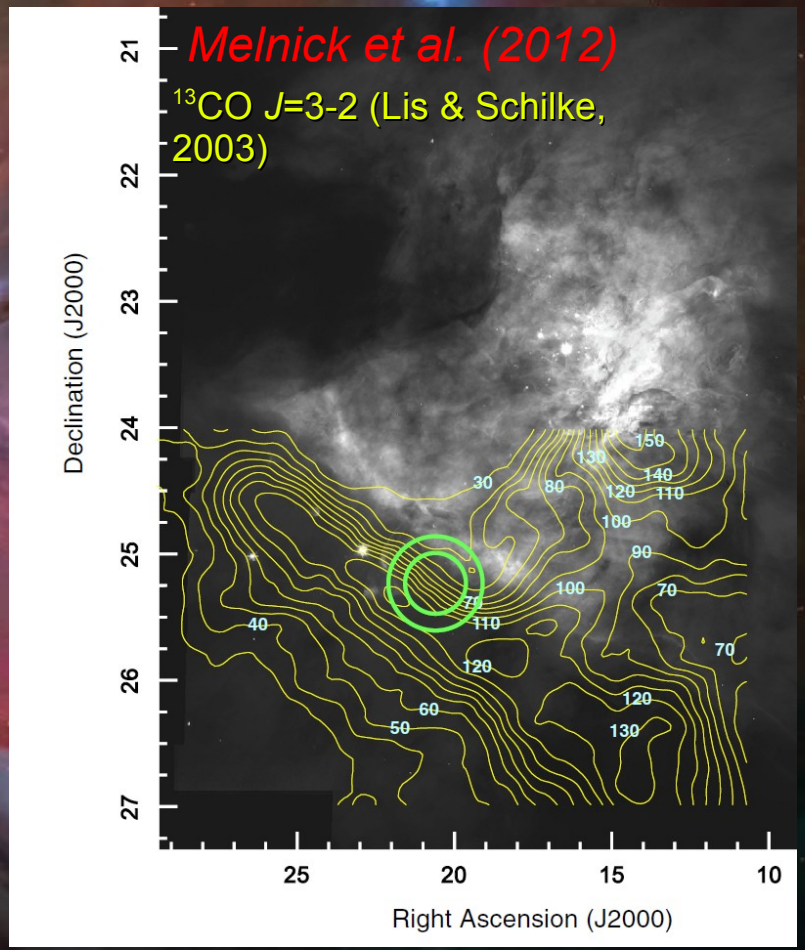


2nd peak

CO^+ peak

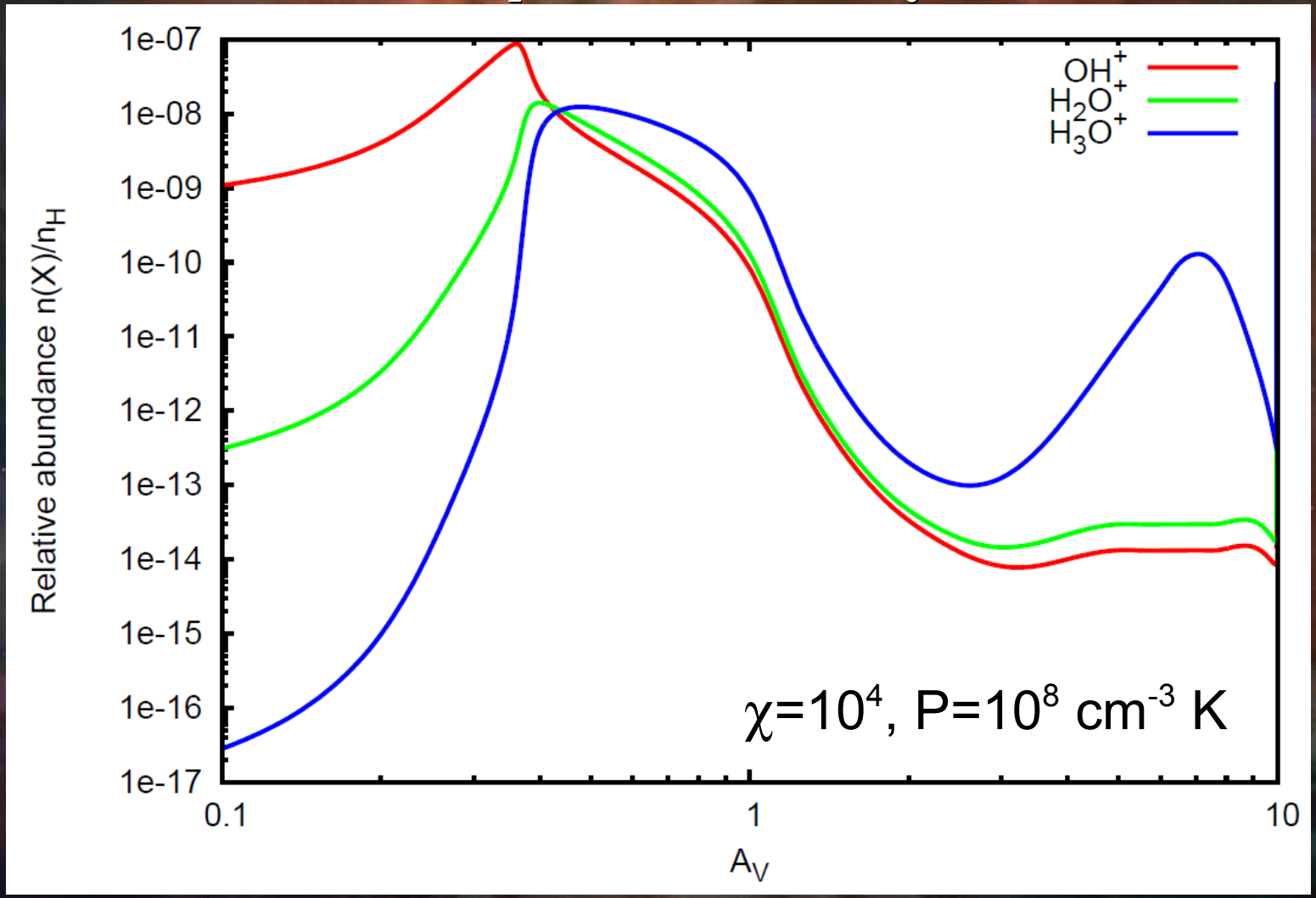
Van der Tak & Nagy et al. (2013)

Part of the Orion Ridge



$OH^+ \rightarrow H_2O^+ \rightarrow H_3O^+$

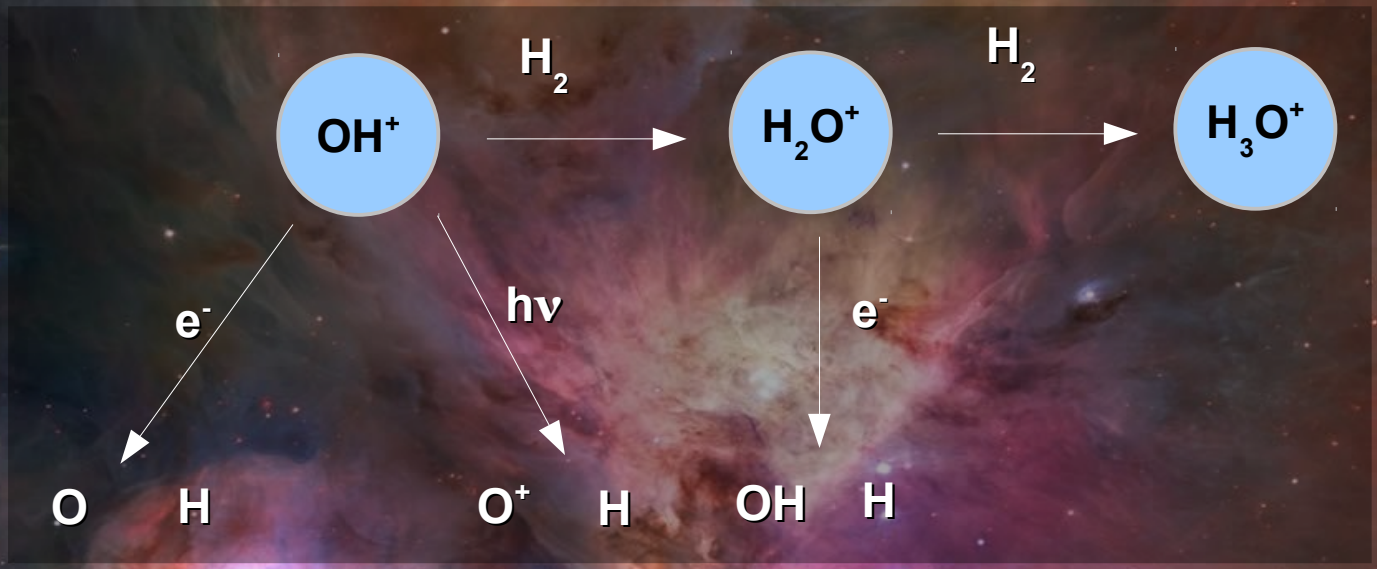
$OH^+/H_2O^+ > 2$ and $OH^+/H_3O^+ > 0.5$



Van der Tak & Nagy et al. (2013)

Reactive ions in Orion

1) **High radiation field** → Recombination + photodissociation



2) **Low molecular fraction**

$$n(\mathrm{OH^+})/n(\mathrm{H_2O^+}) = 0.64 + 430 \times (T/300)^{-0.5} \times [n(\mathrm{e^-})/n(\mathrm{H_2})]$$

Gerin et al. (2010)

Reactive ions in Orion

Detailed excitation model

1) Inelastic collisions

2) Reactive collisions

-Important for H_2, not for e^-

3) Background radiation field

greybody distribution with T_d~50 K and β=1.6 (Arab et al., 2012)

$$N(OH^+)=1.5\times10^{14}\ cm^{-2}$$

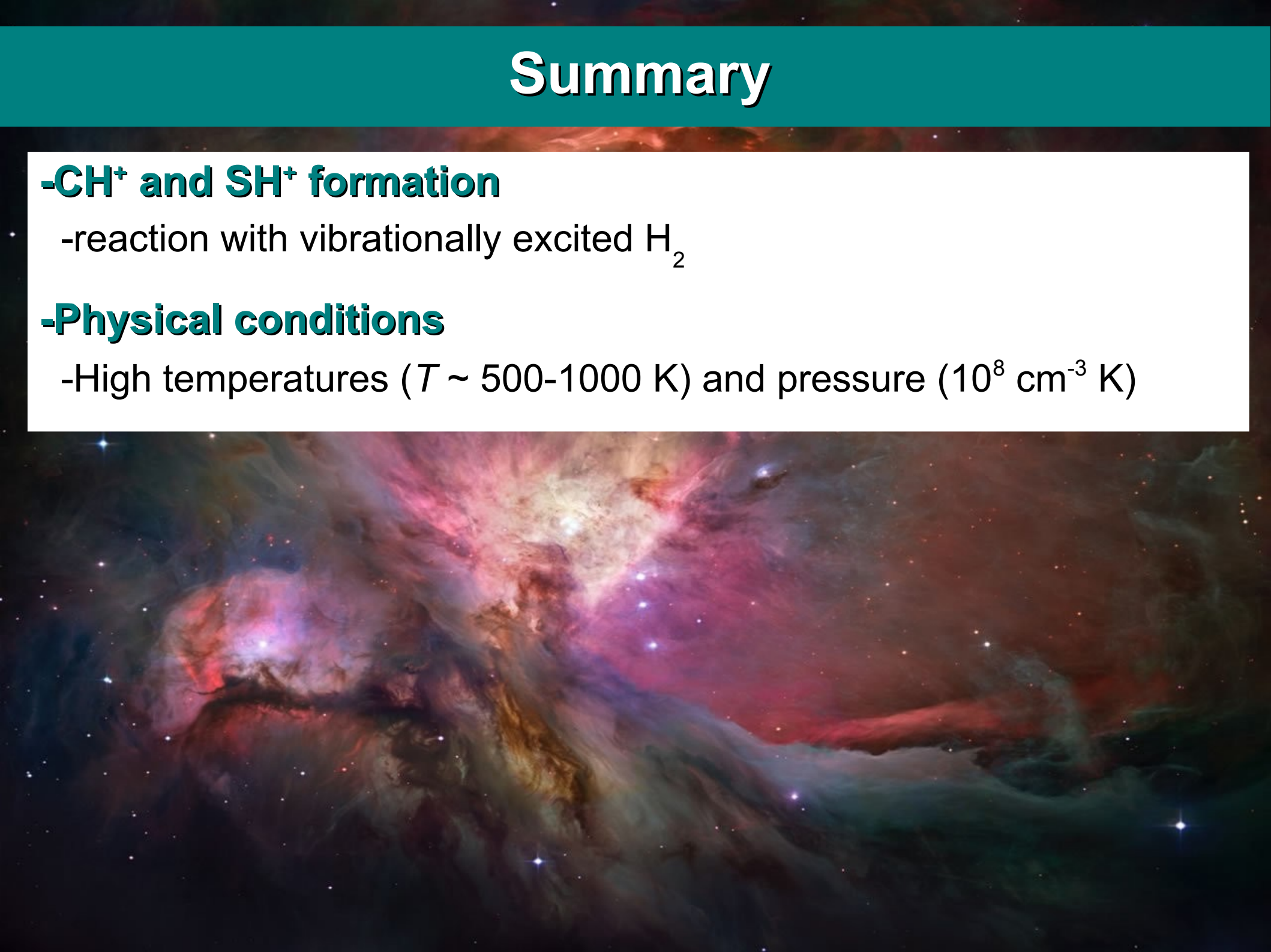
Summary

-CH^+ and SH^+ formation

-reaction with vibrationally excited H_2

-Physical conditions

-High temperatures (T ~ 500-1000 K) and pressure (10^8 cm^{-3} K)



Summary

-CH^+ and SH^+ formation

-reaction with vibrationally excited H_2

-Physical conditions

-High temperatures (T ~ 500-1000 K) and pressure (10^8 cm^{-3} K)

-Spatially extended OH^+ emission

-H_2O^+ and H_3O^+ non-detection

-Recombination, photodissociation & low molecular fraction

-OH^+ excitation

-Inelastic collisions by electrons
-Reactive collisions – formation pumping

-Importance of this work

-Excitation model may apply to AGNs e.g. Mrk 231