

Radiation Diagnostics in the Protostar-Disk-Outflow System

(**W**ater **I**n **S**tar-forming regions with **H**erschel)

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Goals

1. Probe chemical network of water in YSOs (low-mass, high-mass) under far UV and X-ray irradiation
2. Explore most abundant other hydrides enhanced under irradiation in YSO

Hydrides in YSOs

~~OH~~

Other project in WISH (poster by S. Wampfler)

CH

NH

SH

OH⁺

~~CH⁺~~

Not yet observed
Hydrides have a high activation energy (up to several 1000K)
Formed at high temperature and by reactions with atomic ions → Strong FUV or X-ray fields

NH⁺

SH⁺

~~H₂O~~

Other projects in WISH (van der Tak, Kristensen)

H₂O⁺

H₃O⁺

Hydrides in YSOs

	GHz		E_{up} [K]
CH	536	$1_{122} - 1_{111}$	25.8
SH	1447	$1_{22} - 0_{11}$	640.6
NH	1000	$1_1 - 0_1$	48.0
OH ⁺	1033	$1_{12} - 0_{12}$	49.6
SH ⁺	526*	$1_{22} - 0_{11}$	25.2
NH ⁺	1019	$1_{22} - 0_{33}$	48.7
H ₂ O ⁺	1115*	$1_{11213} - 0_{00112}$	53.5
H ₃ O ⁺	1031	$4_{30} - 3_{31}$	232.2
	1070	$4_{20} - 3_{21}$	364.4

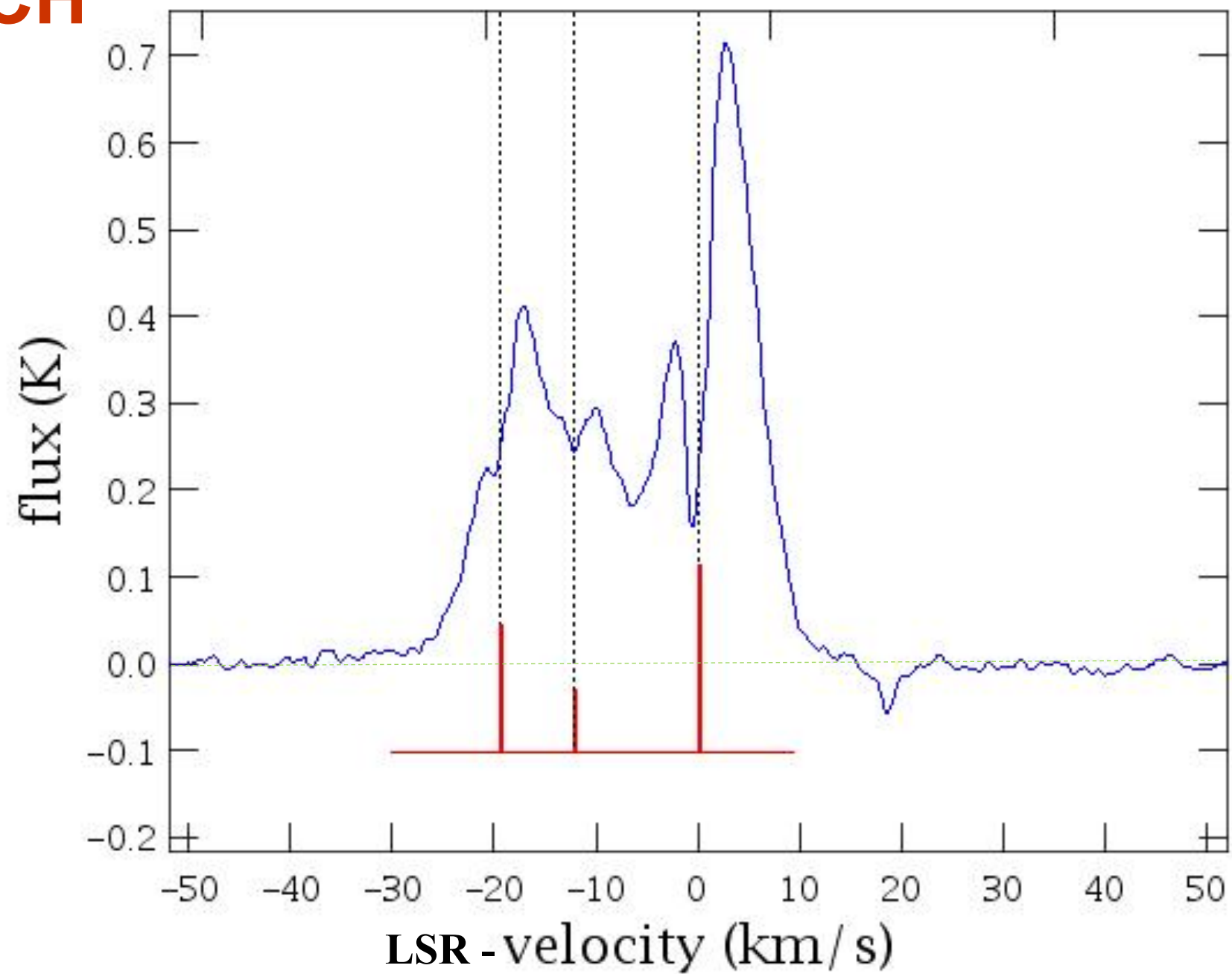
* Bruderer 2006

HIFI Observations of W3 IRS5

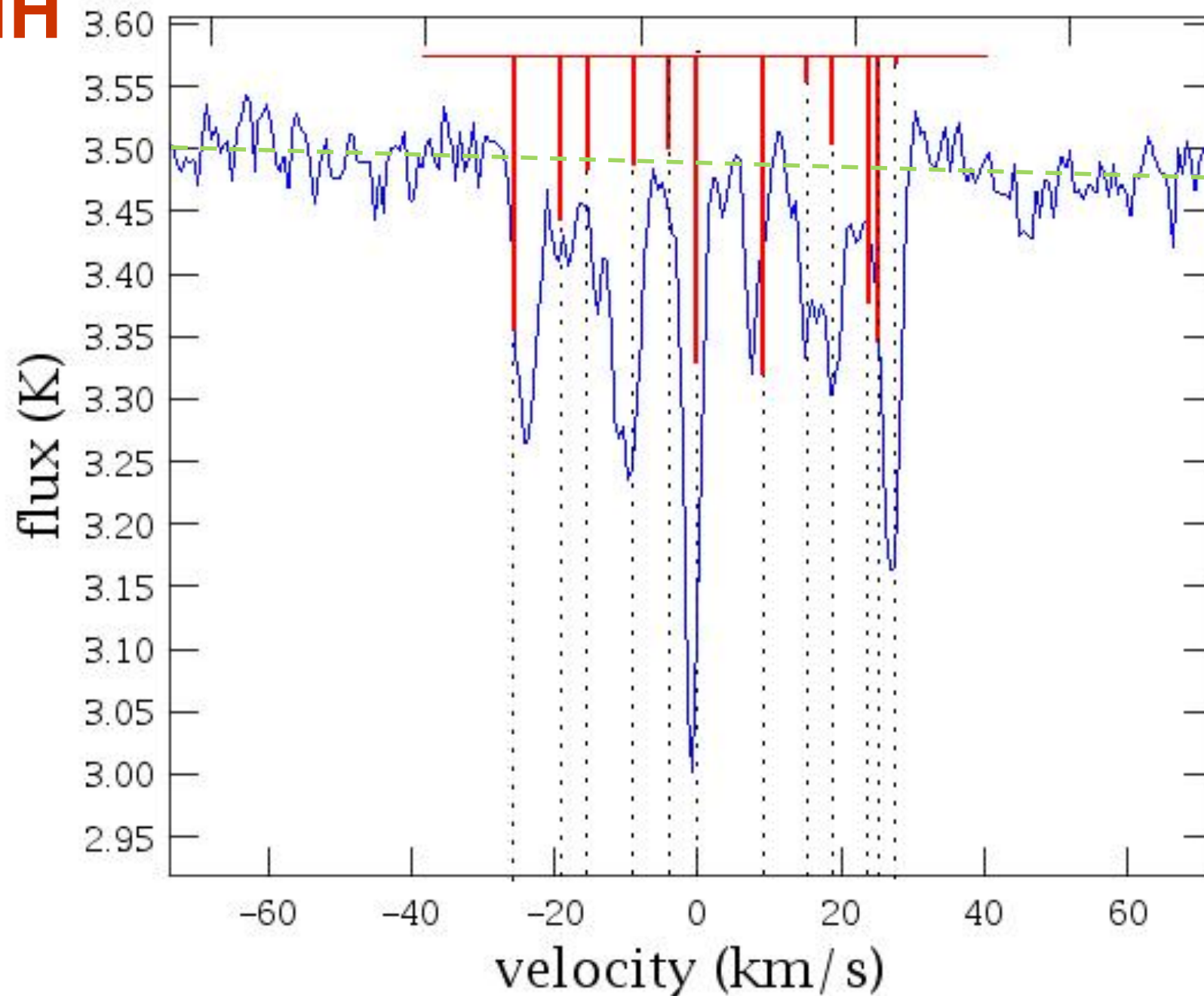
	GHz	E_{up} [K]	$\int T_{\text{mb}} dV$
CH	536	25.8	14.62
SH	1000	640.6	not detected
NH	1447	48.0	- 6.0
OH ⁺	1033	49.6	- 22.8
SH ⁺	526*	25.2	0.624
NH ⁺	1019	48.7	not detected
H ₂ O ⁺	1115*	53.5	- 4.43
H ₃ O ⁺	1031	232.2	3.0
	1070	364.4	11.02



CH

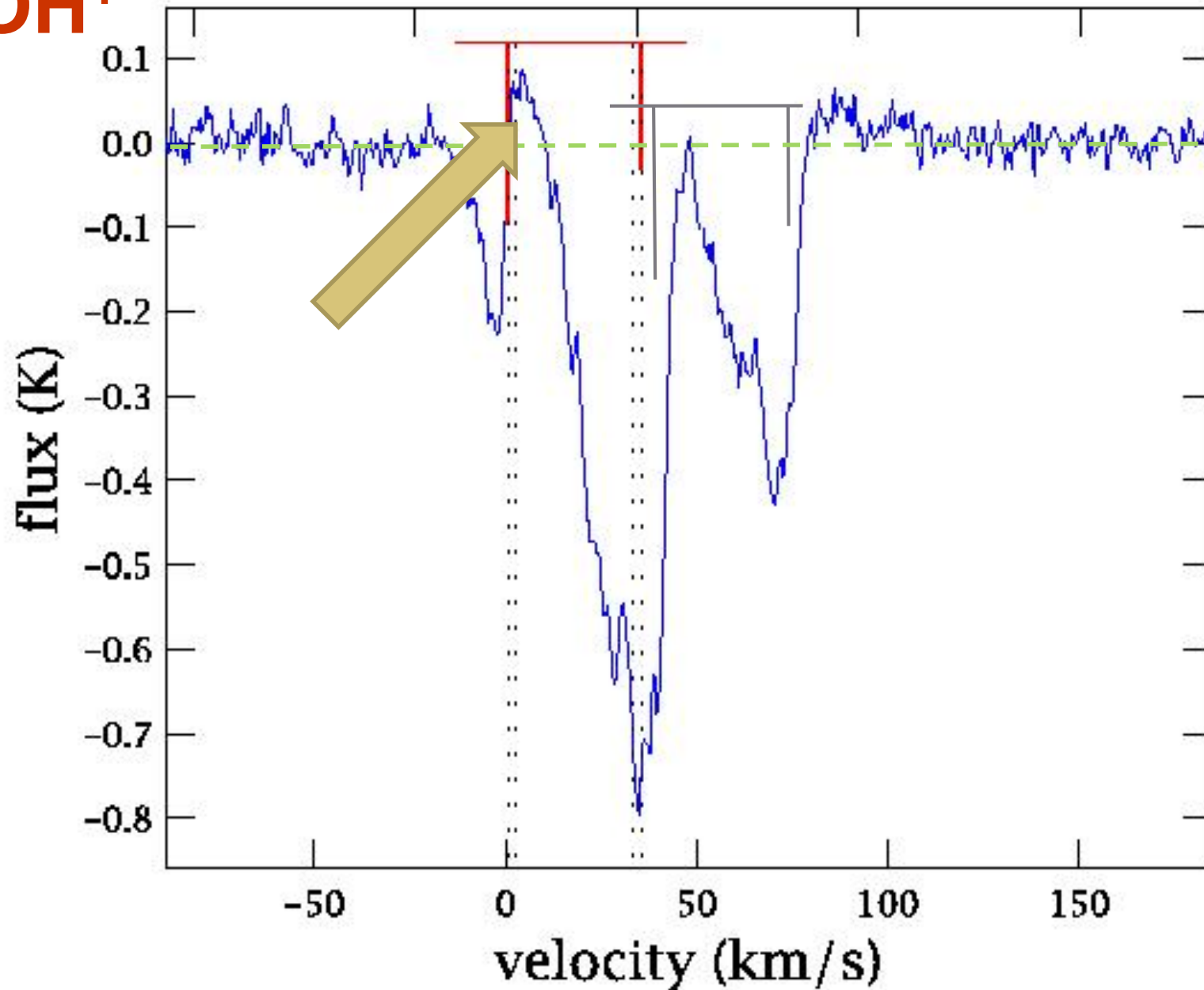


NH



NEW!

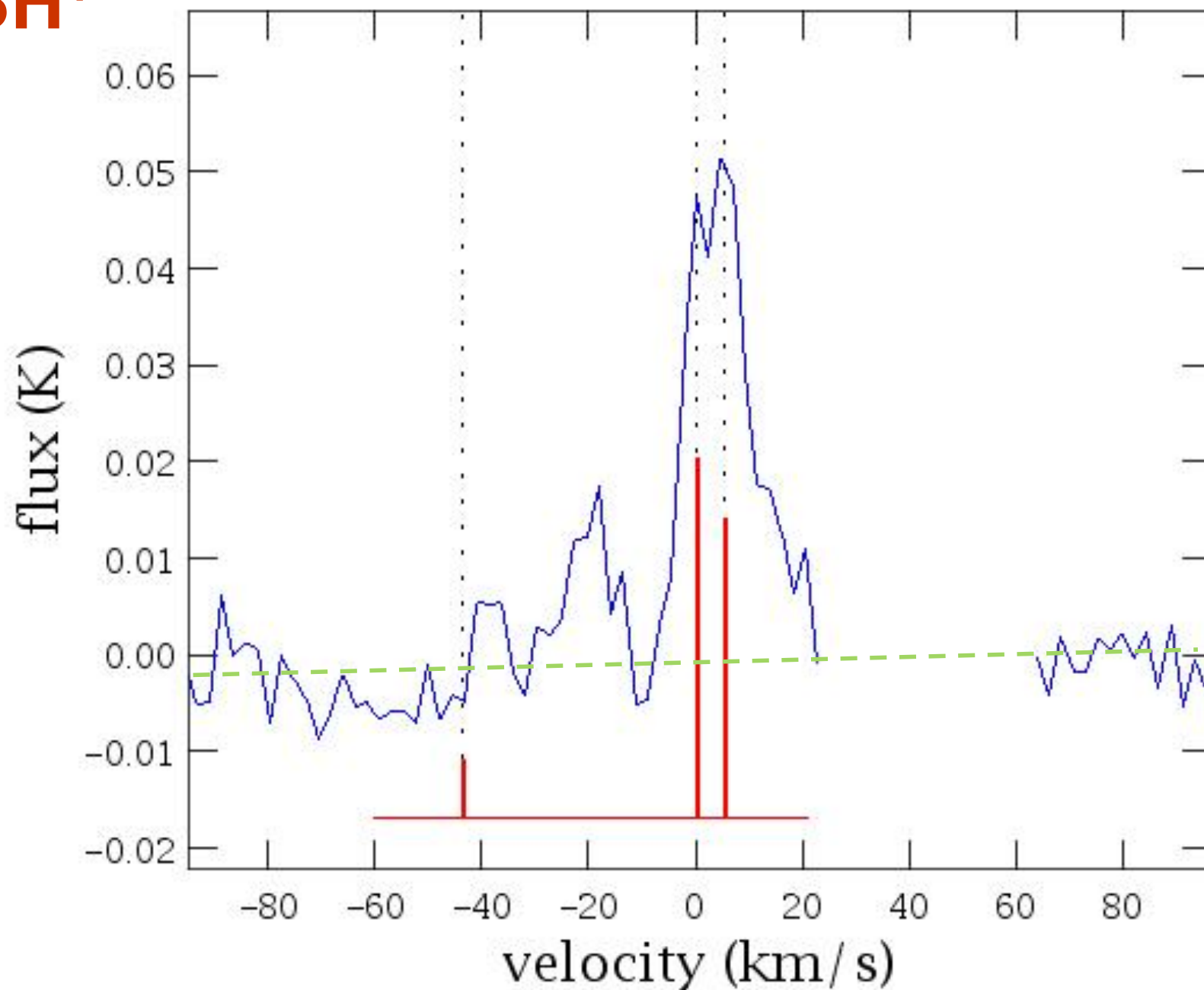
OH⁺



Second and stronger component with velocity shift of +32 km s⁻¹ ?

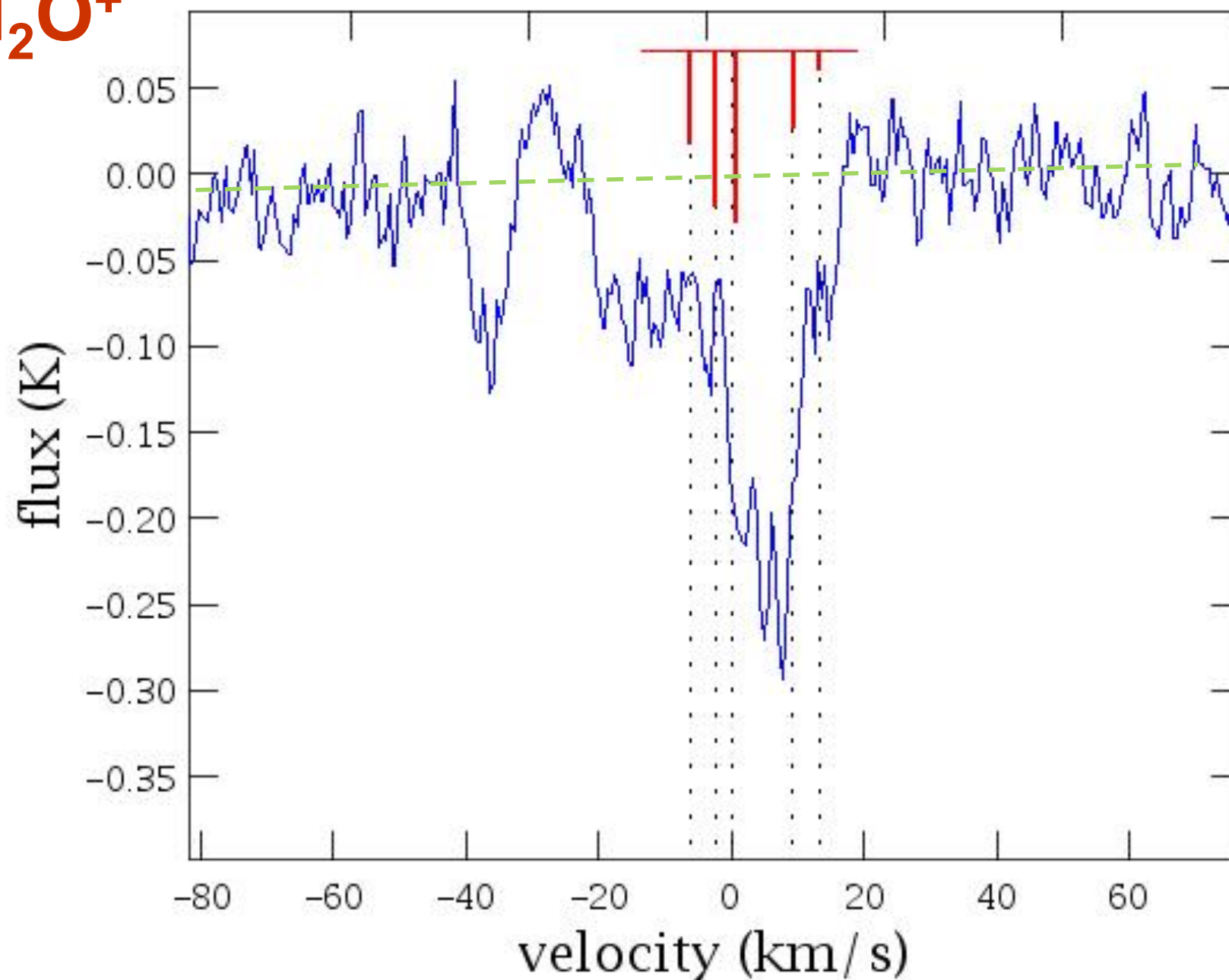
NEW!

SH⁺



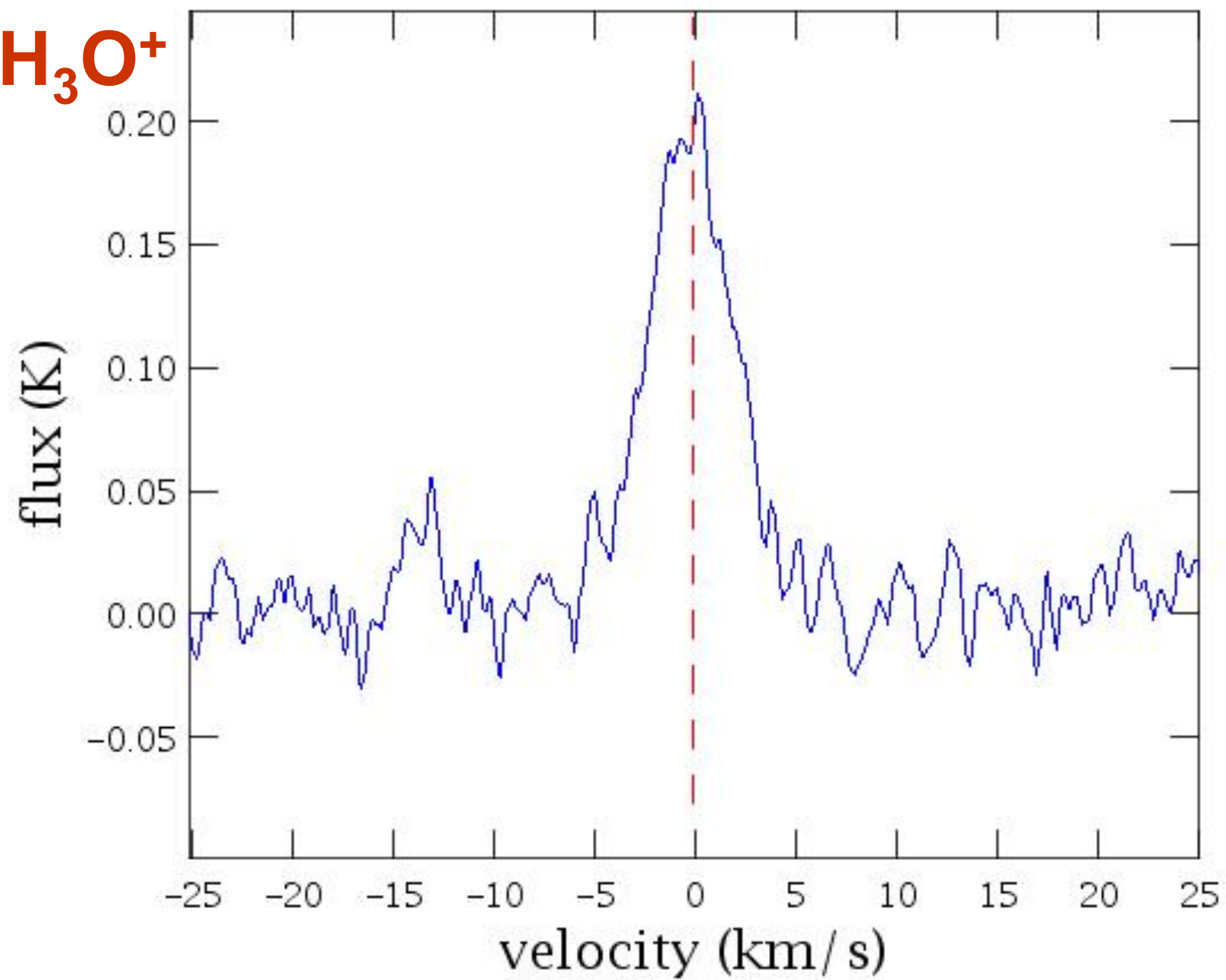
NEW!

H_2O^+

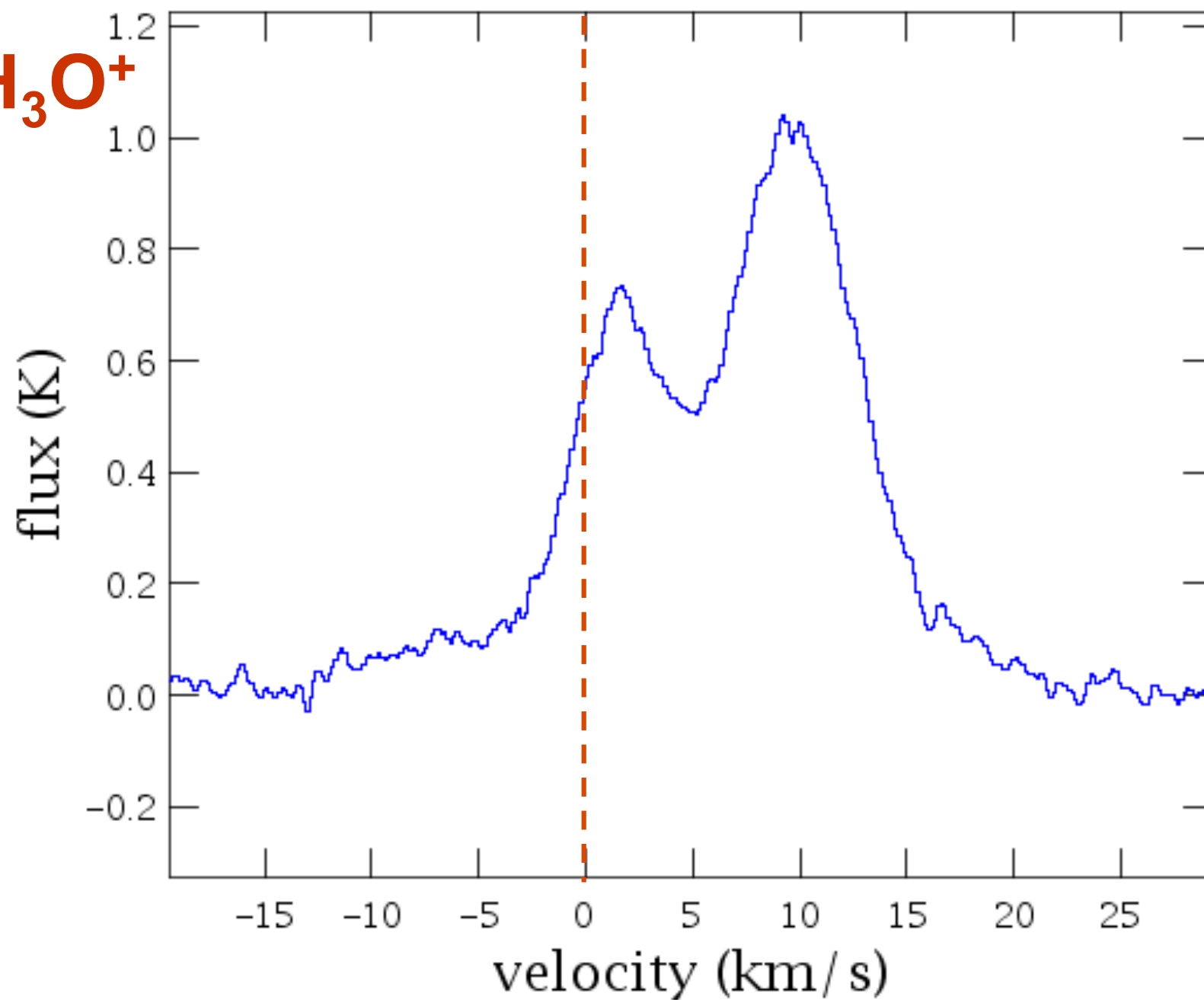


Second component with velocity shift of -42 km s^{-1} ?

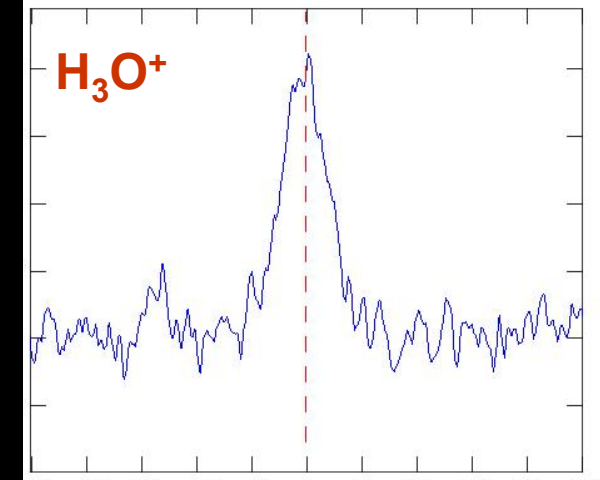
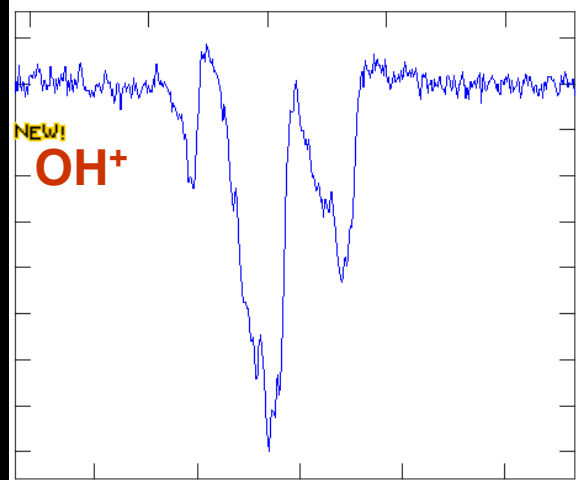
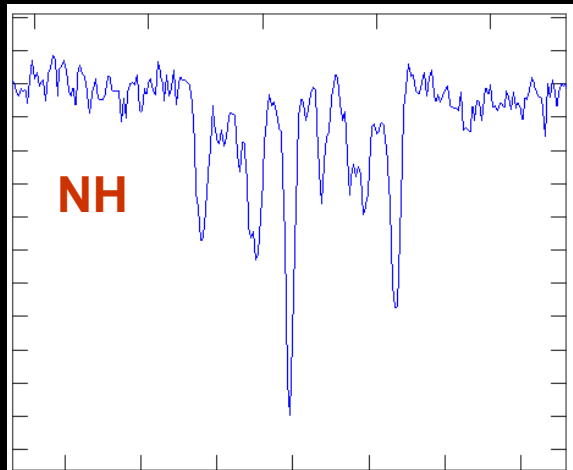
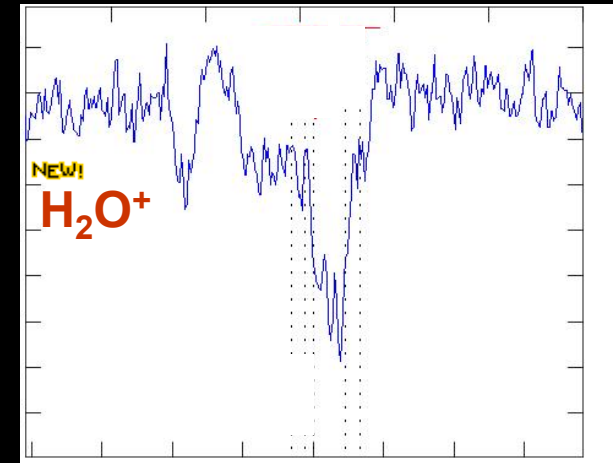
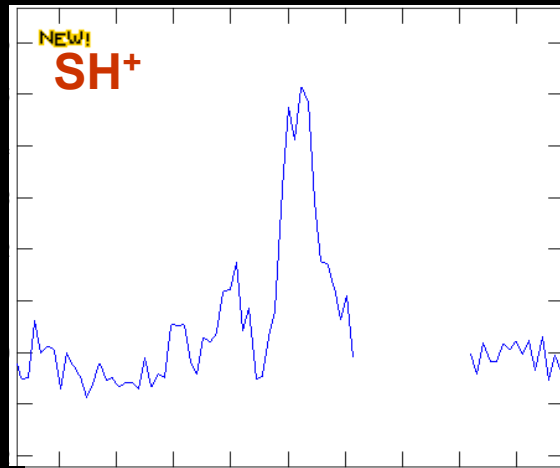
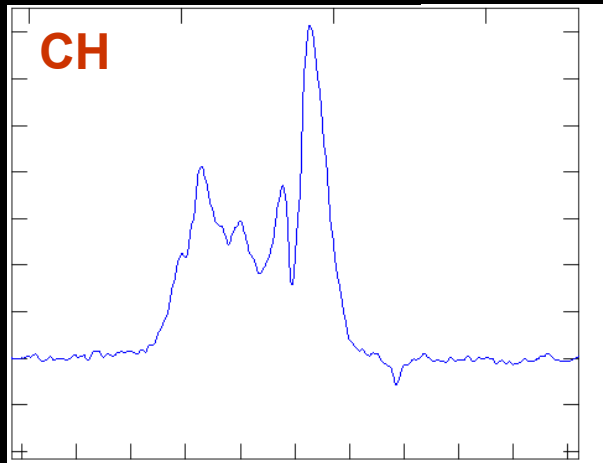
H_3O^+



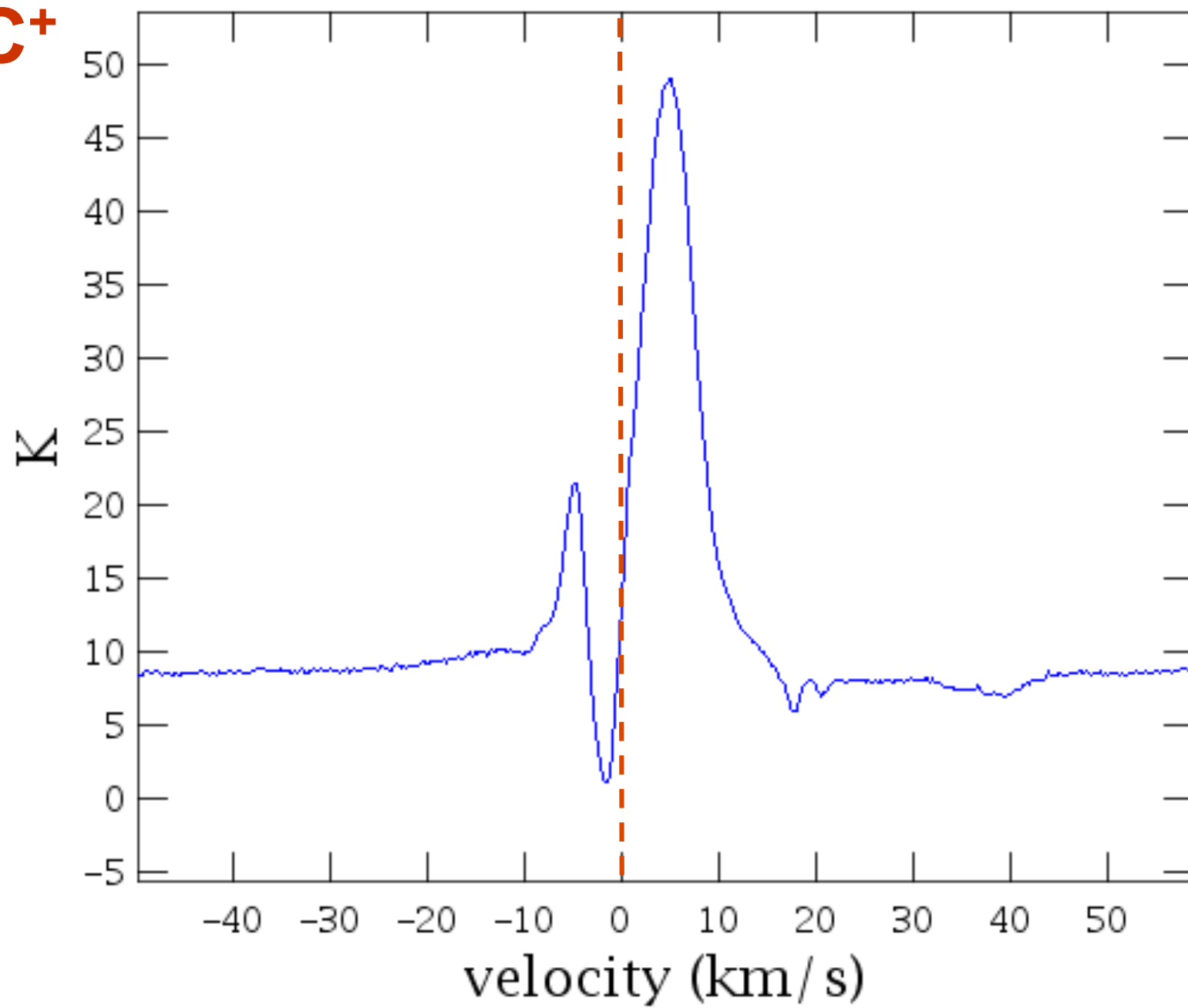
H_3O^+

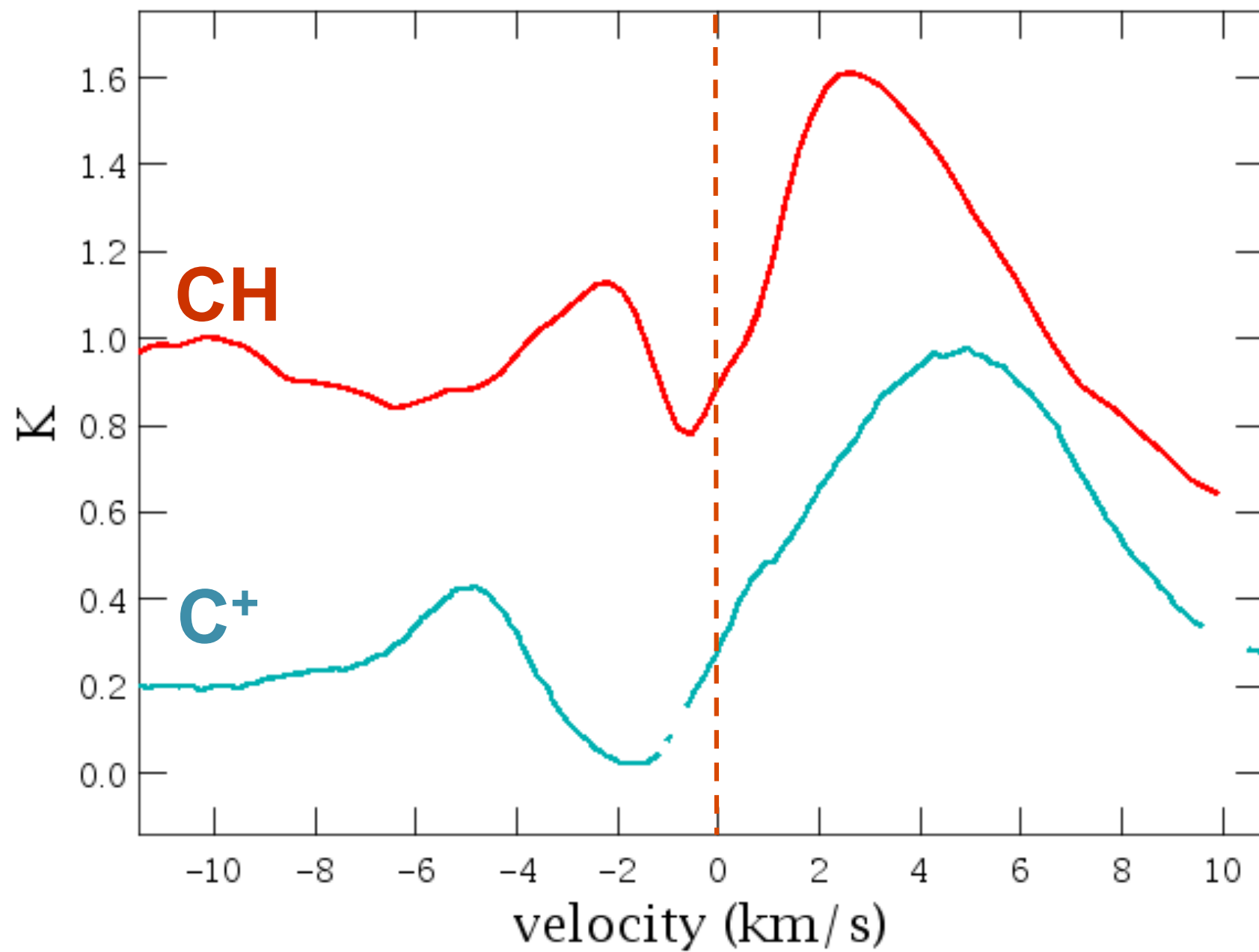


Hydrides in Star Forming Region W3 IRS5



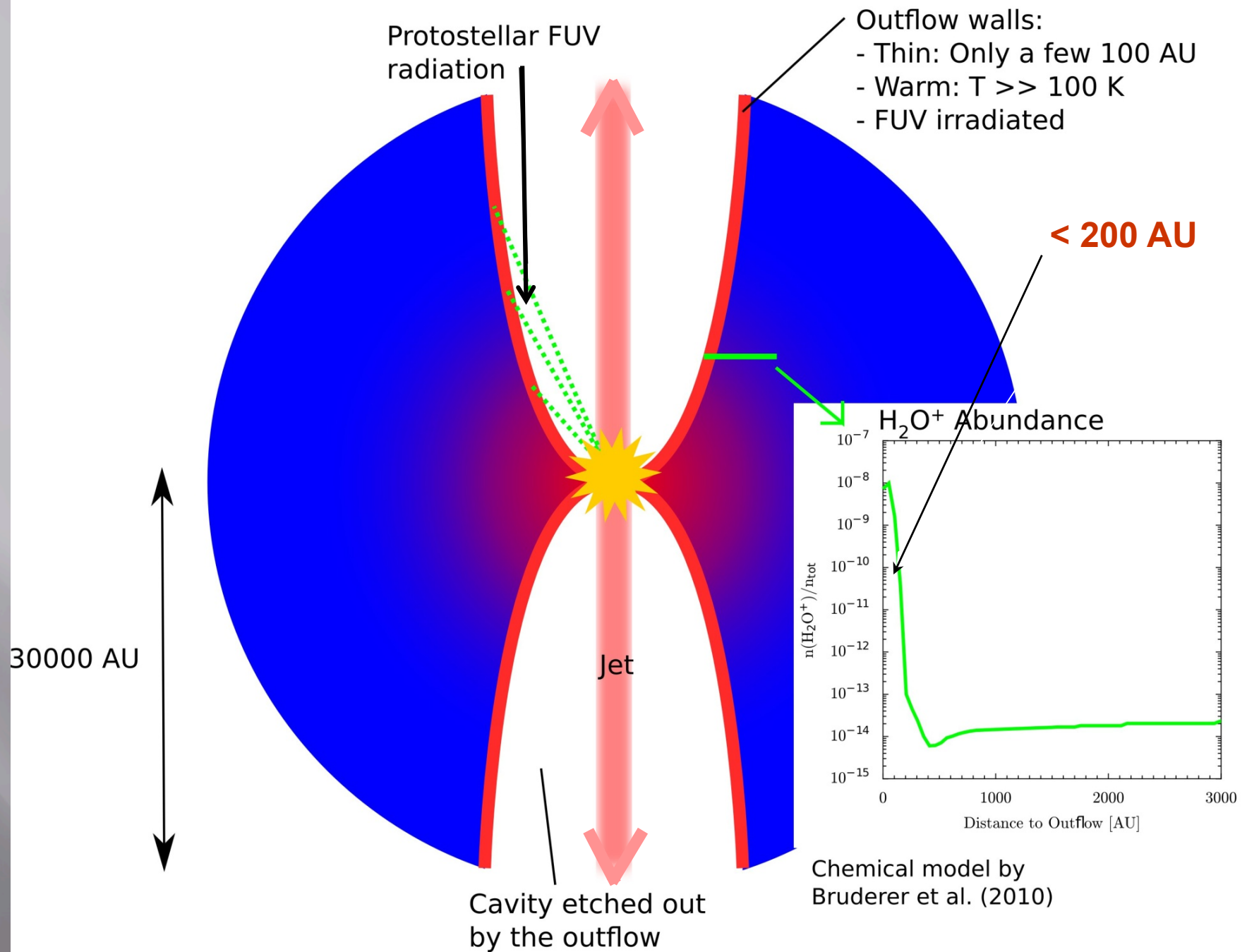
C⁺





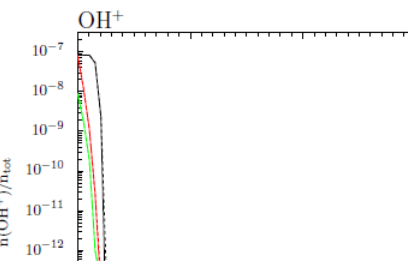
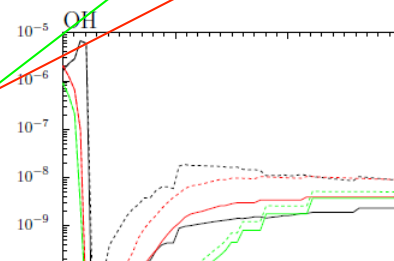
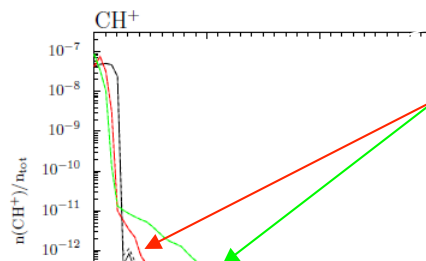
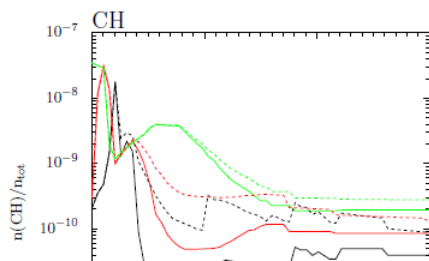
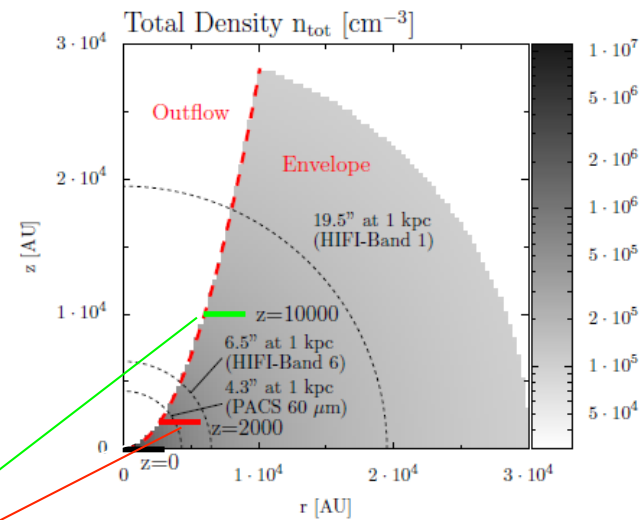
Hydrides in W3 IRS5

	GHz	E_{up} [K]	$\int T_{\text{mb}} dV$	Properties
CH	536	25.8	14.62	P Cyg
SH	1000	640.6	not detected	
NH	1447	48.0	- 6.0	on spot
OH ⁺	1033	49.6	- 22.8	P Cyg + shift 32 km/s
SH ⁺	526*	25.2	0.624	on spot
NH ⁺	1019*	48.7	not detected	
H ₂ O ⁺	1115*	53.5	- 4.43	P Cyg? + shifted ??
H ₃ O ⁺	1031	232.2	3.0	on spot
	1070	364.4	11.02	on spot



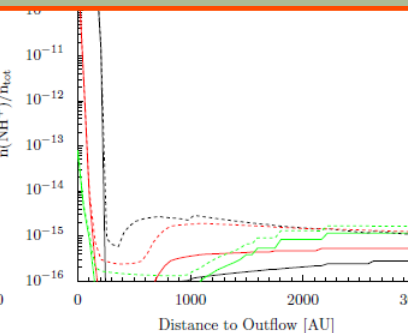
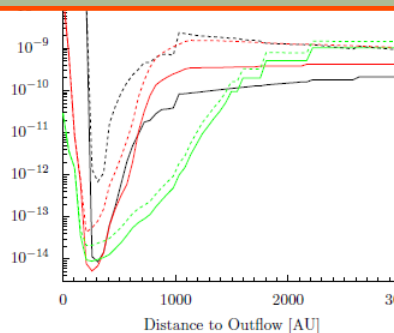
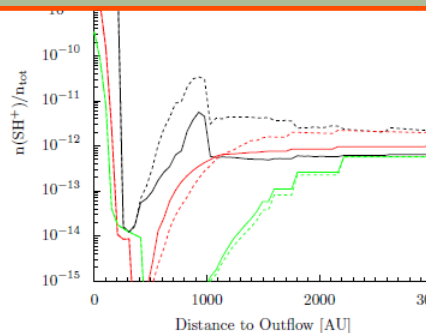
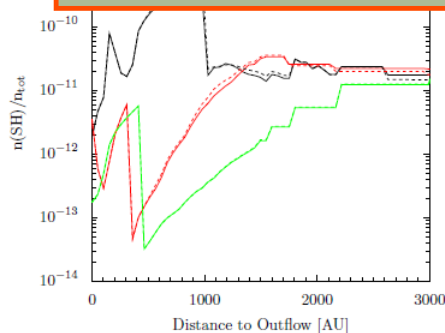
H₂O⁺, OH⁺, CH⁺, and SH⁺ are the paint on the outflow wall

Abundance of hydrides

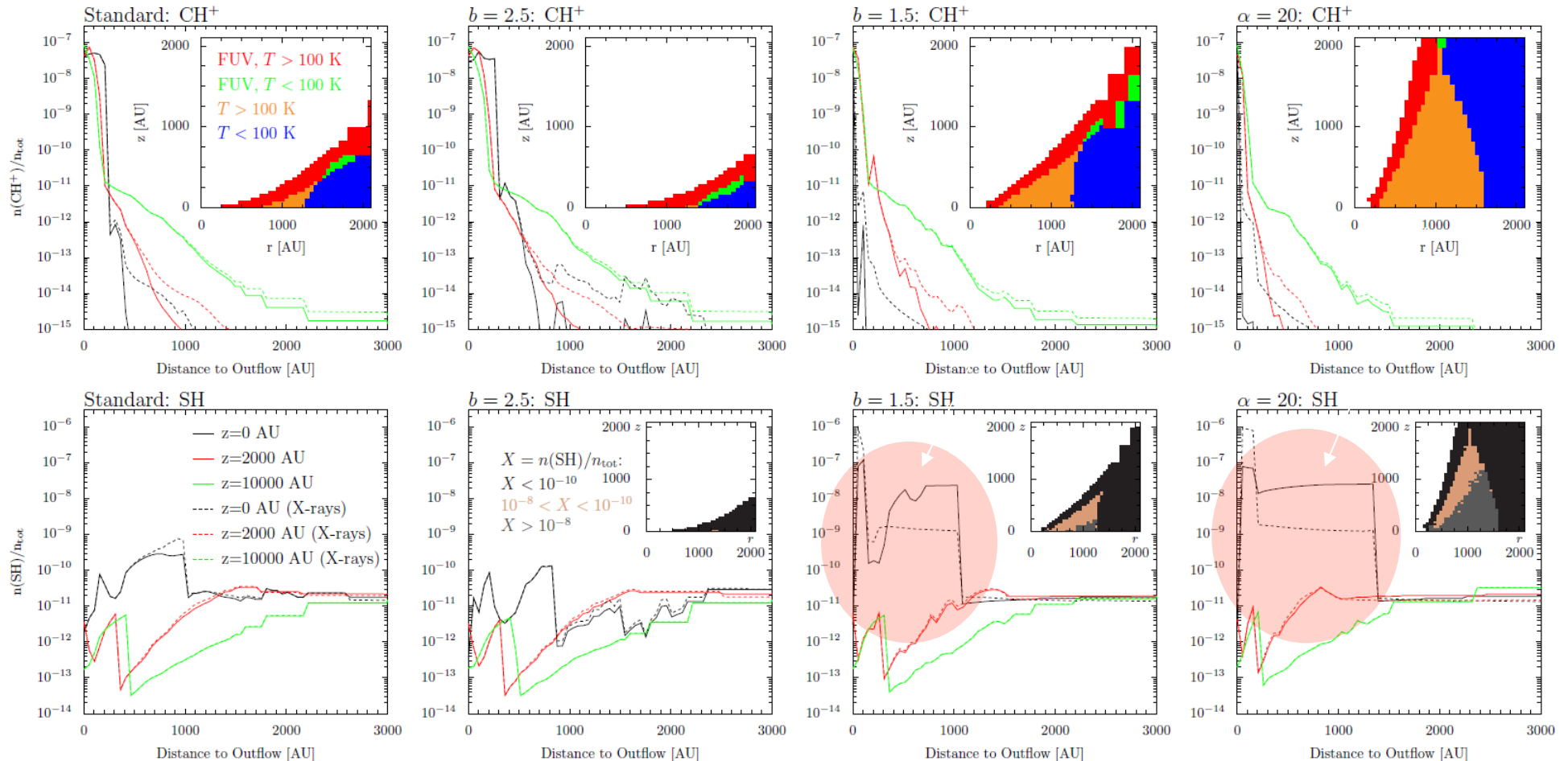


→ CH^+ , OH^+ , NH^+ are enhanced by several orders of magnitude in a thin layer

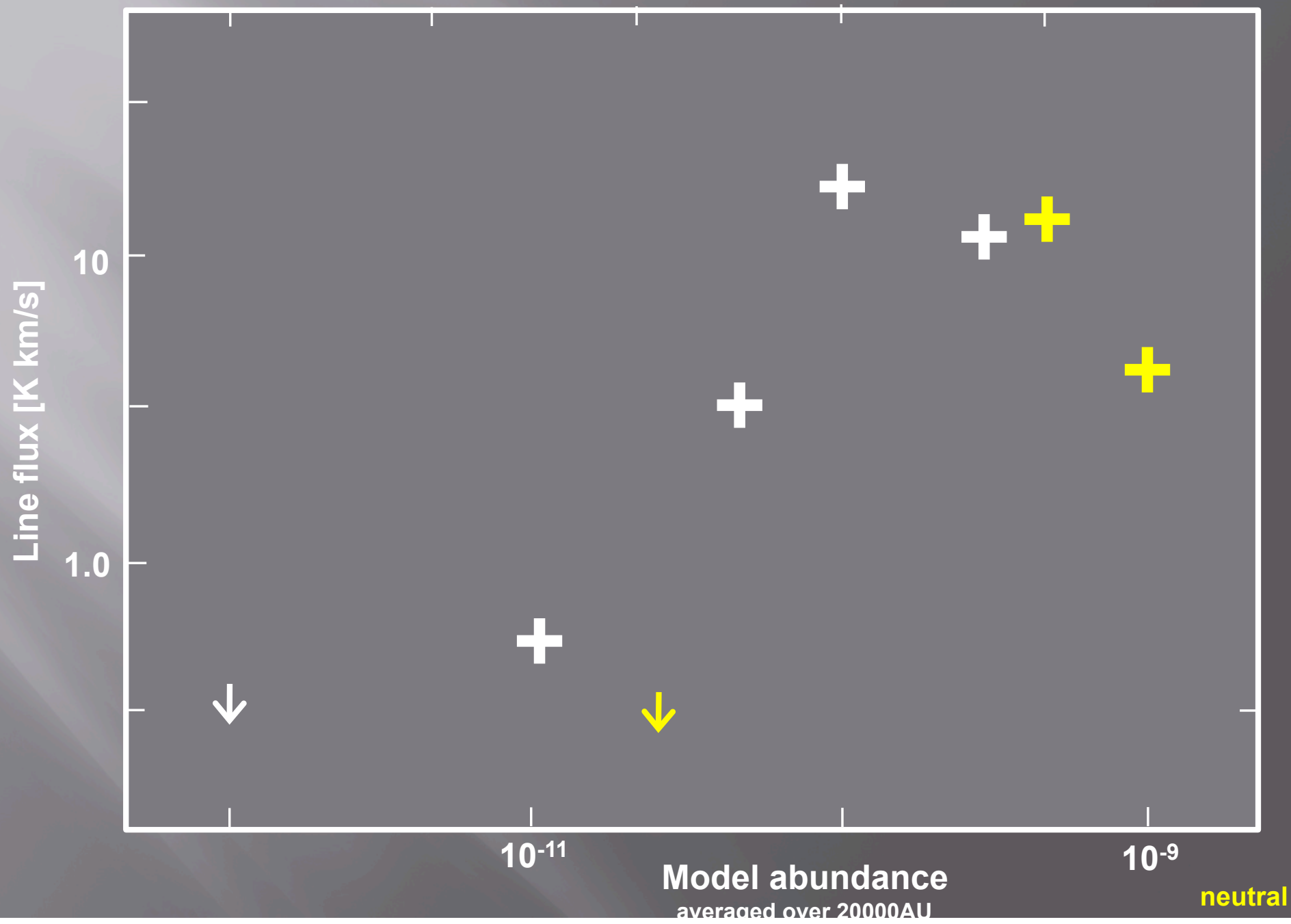
→ Influence of X-rays small in high-mass objects



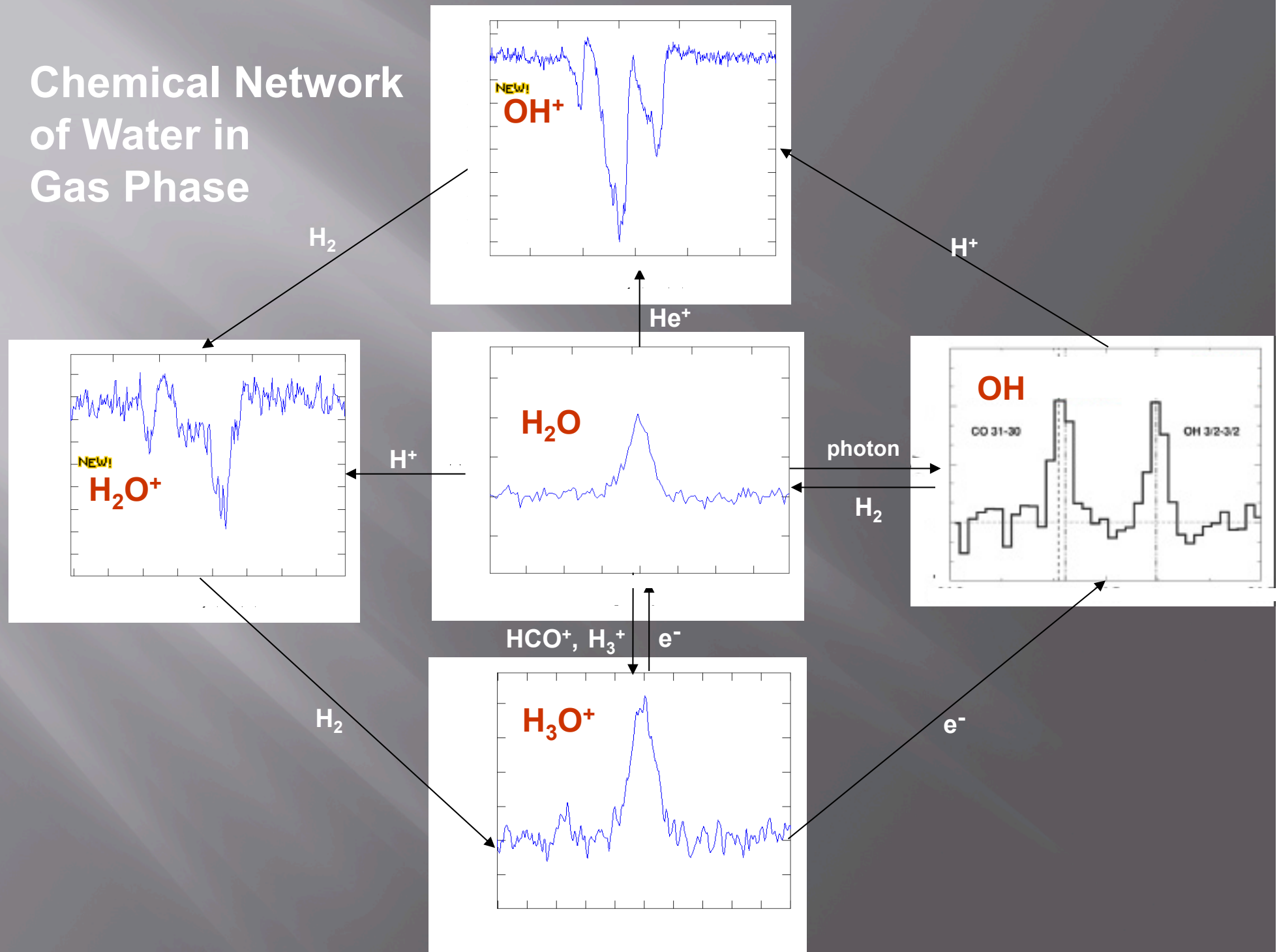
Influence of geometry



→ FUV enhanced species little affected, but FUV destroyed species evaporating in the hot-core depend strongly on geometry: Water!



Chemical Network of Water in Gas Phase



Radiation Diagnostics Summary

1. Ionized molecules detected in young stellar object with HIFI (FUV irradiation, shocks, X-rays?)

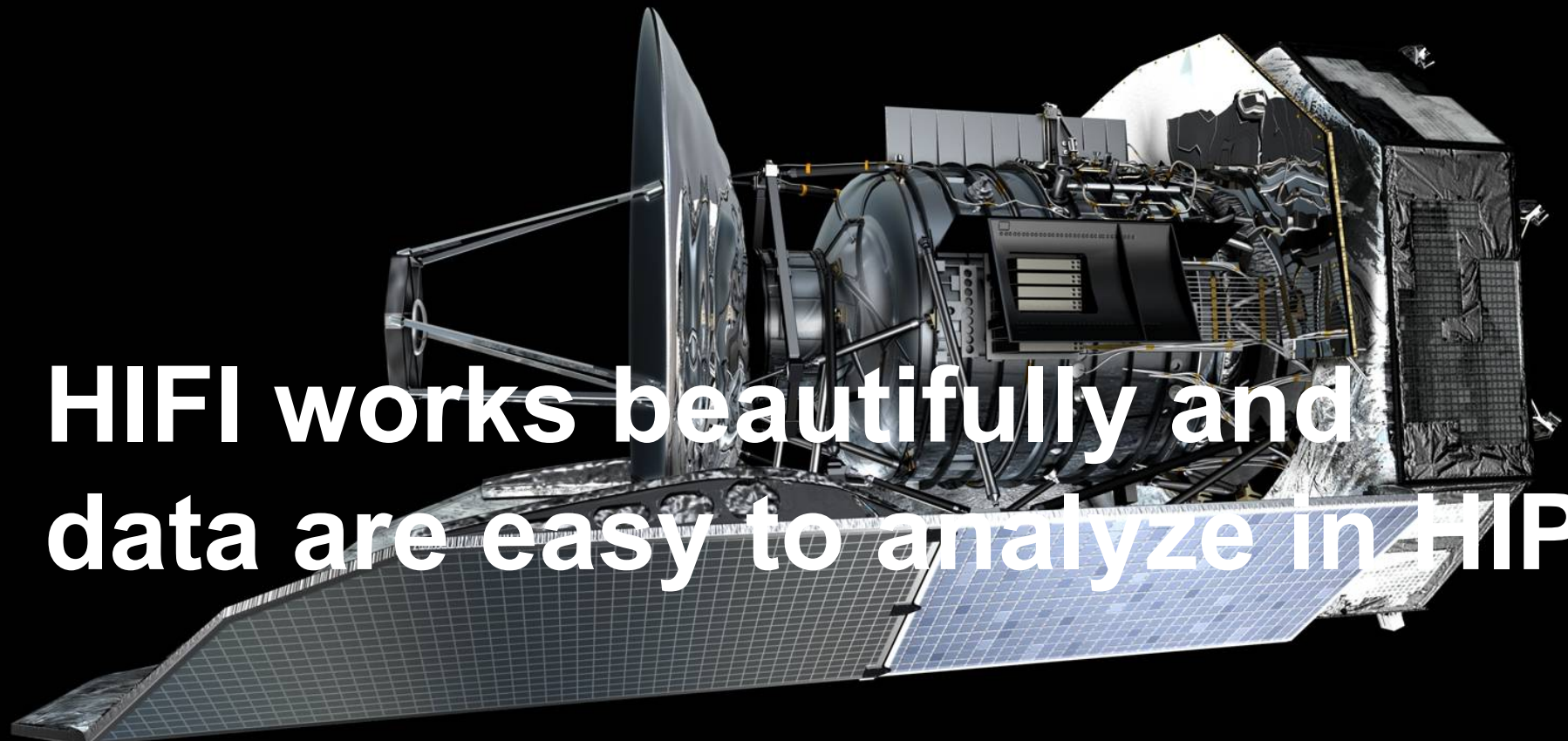
Some shifted lines also seen (ISM ?).

2. New molecules were predicted and observed:
 H_2O^+ , OH^+ , SH^+ in star-forming regions

4. Most ionized molecules intense beyond expectations, indicating high-energy processes in early phase of star-formation.

Radiation Diagnostics Summary

4. Chemical network of water in gas phase and under irradiation observed in W3 IRS5.
5. Higher E_{up} in absorption
6. Up for surprises in low-mass objects



**HIFI works beautifully and
data are easy to analyze in HIPE.**

Thank you all very much!