Probing the diffuse interstellar gas with Herschel observations of OH^+ and H_2O^+

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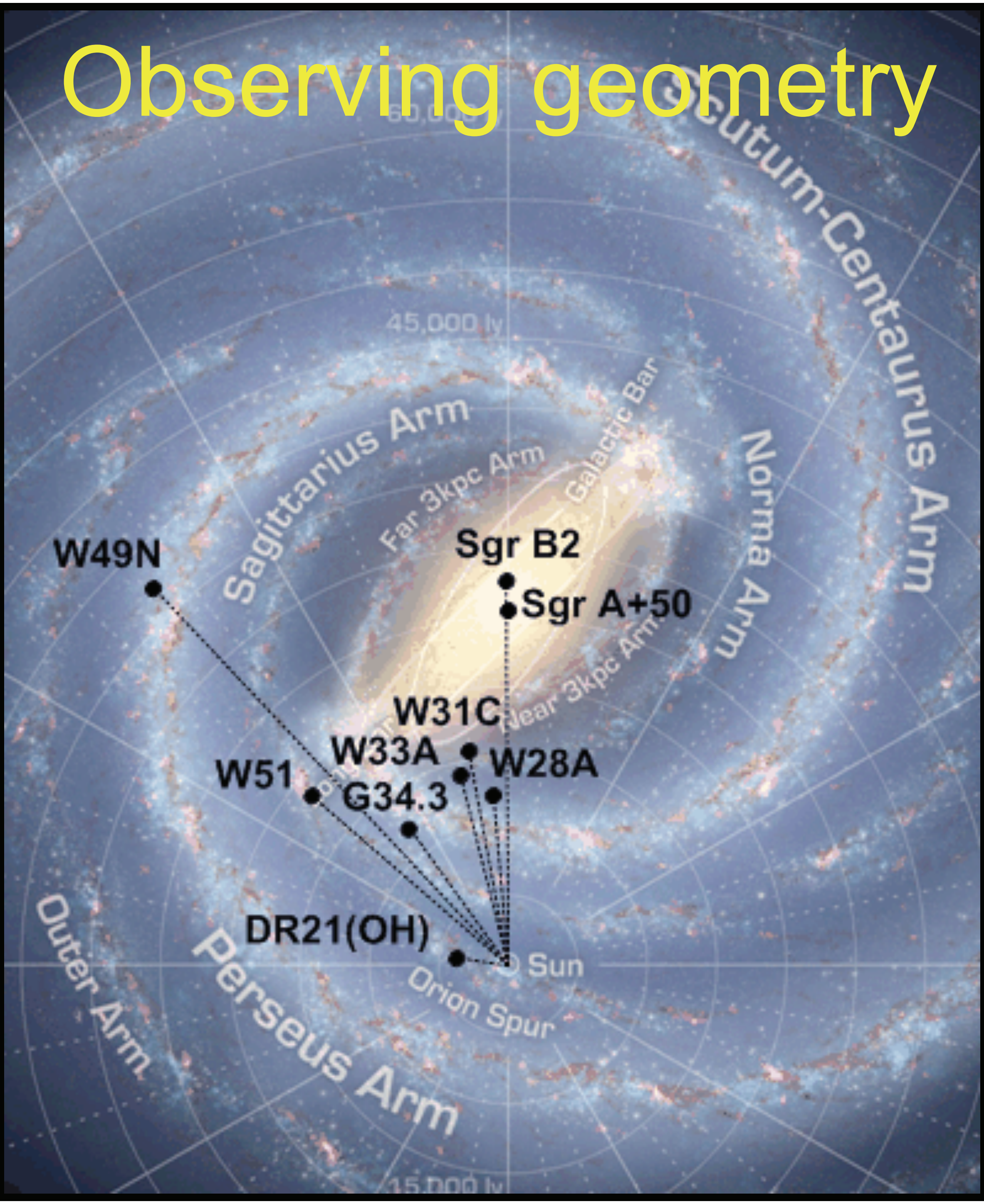
Interstellar hydrides

- Given the elemental abundances in our Universe, it is natural to expect that hydrides will be abundant constituents of the ISM
- Herschel/HIFI provides a unique opportunity to study interstellar hydrides with large rotational constants
- The PRISMAS key program (PI, M. Gerin) has carried out absorption line studies of foreground clouds along the sight-lines to bright Galactic continuum sources

Observing geometry



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Interstellar hydrides

- Herschel/HIFI observations, of very short duration, quickly provided spectacular spectra that reveal the presence in diffuse clouds of:

CH, CH^+ (Gerin et al., Falgarone et al.)

NH, NH_2, NH_3 (Persson et al. – also **Poster 2.76**)

OH^+, H_2O^+, H_3O^+, H_2O (Gerin et al., Neufeld et al.)

HF (Neufeld et al., Sonnentrucker et al.,, Monje et al. – also **Poster 2.65**)

SH^+ (Falgarone et al. in preparation)

H_2Cl^+ (Lis et al.)

HCl (Monje et al. in preparation)

HCl^+ ? (de Luca et al. – **Poster 3.24**)

Note also APEX observations of OH^+ (Wyrowski et al. 2010 – also **Poster 2.103)** **and SH^+ (Menten et al. 2010), Paranal observations of** OH^+ (Krelowski et al 2010)

Interstellar hydrides

Absorption line observations of foreground clouds provide *extremely robust* estimates of the column densities that are almost independent of

gas temperature

density

collisional excitation rates

the details of radiative transfer

This is a particularly “clean” experiment

Interstellar OH^+ and H_2O^+:

probing the cosmic ray ionization rate in clouds of low molecular fraction

Dissociation energy of the diatomic hydrides (eV)

H_2 4.48							
LiH 2.41	BeH 2.24	BH 3.44	CH 3.49	NH 3.22	OH 4.39	HF 5.87	
NaH 2.04	MgH 1.99	AlH 2.95	SiH 2.98	PH 2.87	SH 3.65	HCl 4.43	
KH 1.87	CaH 1.77	GaH 2.78	GeH 2.73	AsH 2.66	SeH 3.11	HBr 3.76	

ScH 2.09	TiH 2.08	VH 1.67	CrH 2.27	MnH 1.27	FeH 1.59	CoH 1.97	NiH 2.57	CuH 2.64	ZnH 0.83

Neufeld and Wolfire 2009, ApJ

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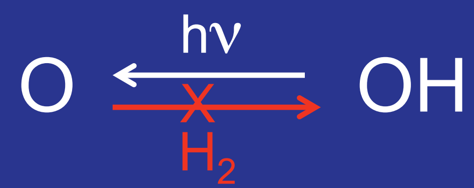
Chemistry of interstellar oxygen

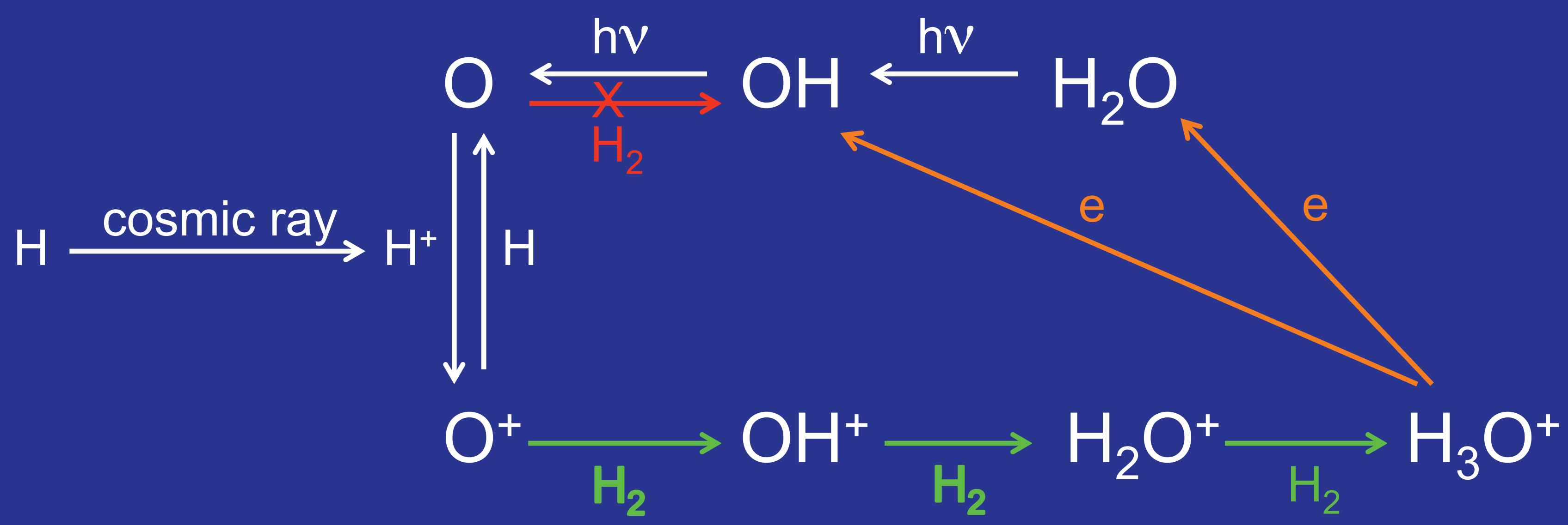
- Oxygen differs from fluorine



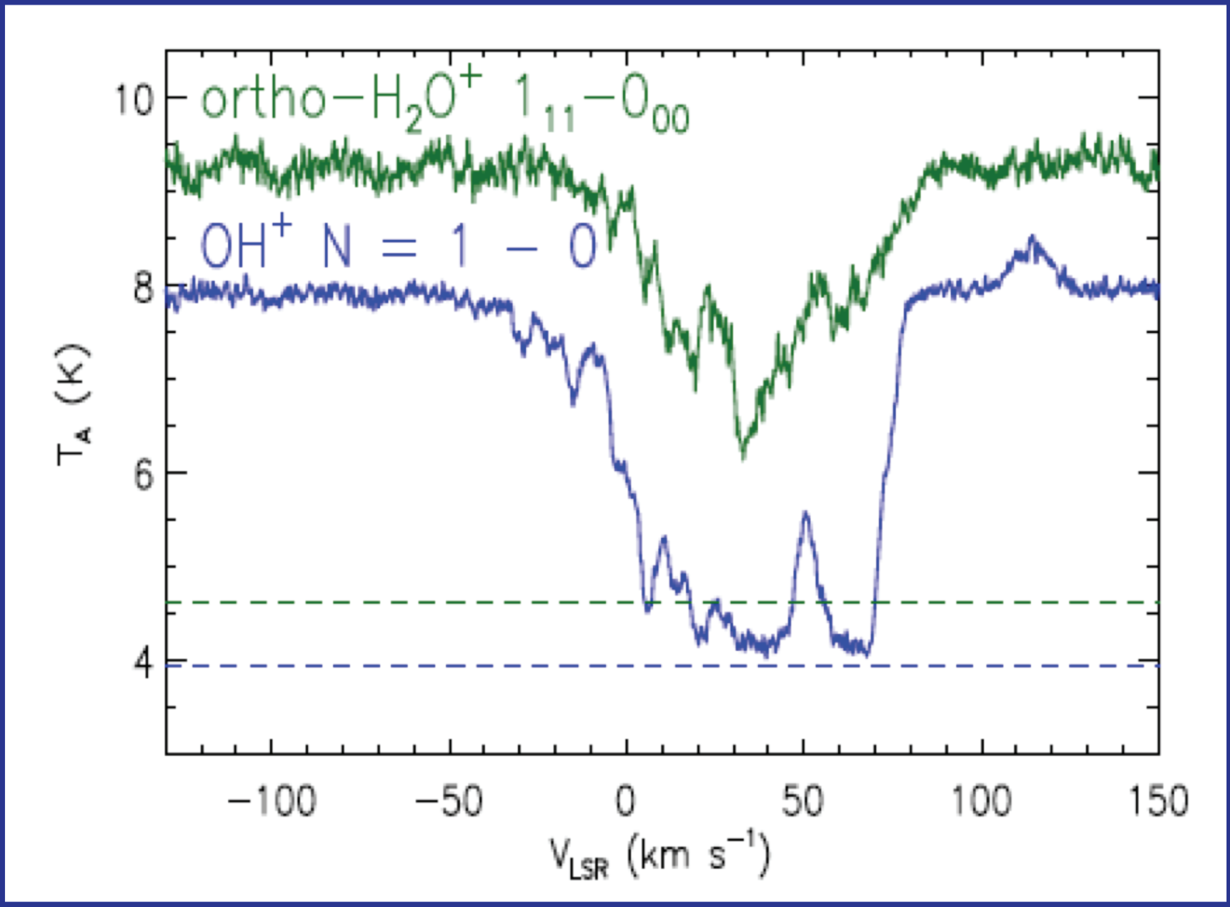
O cannot react with H_2 except at high temperature (> 300 K)

Chemistry of interstellar oxygen

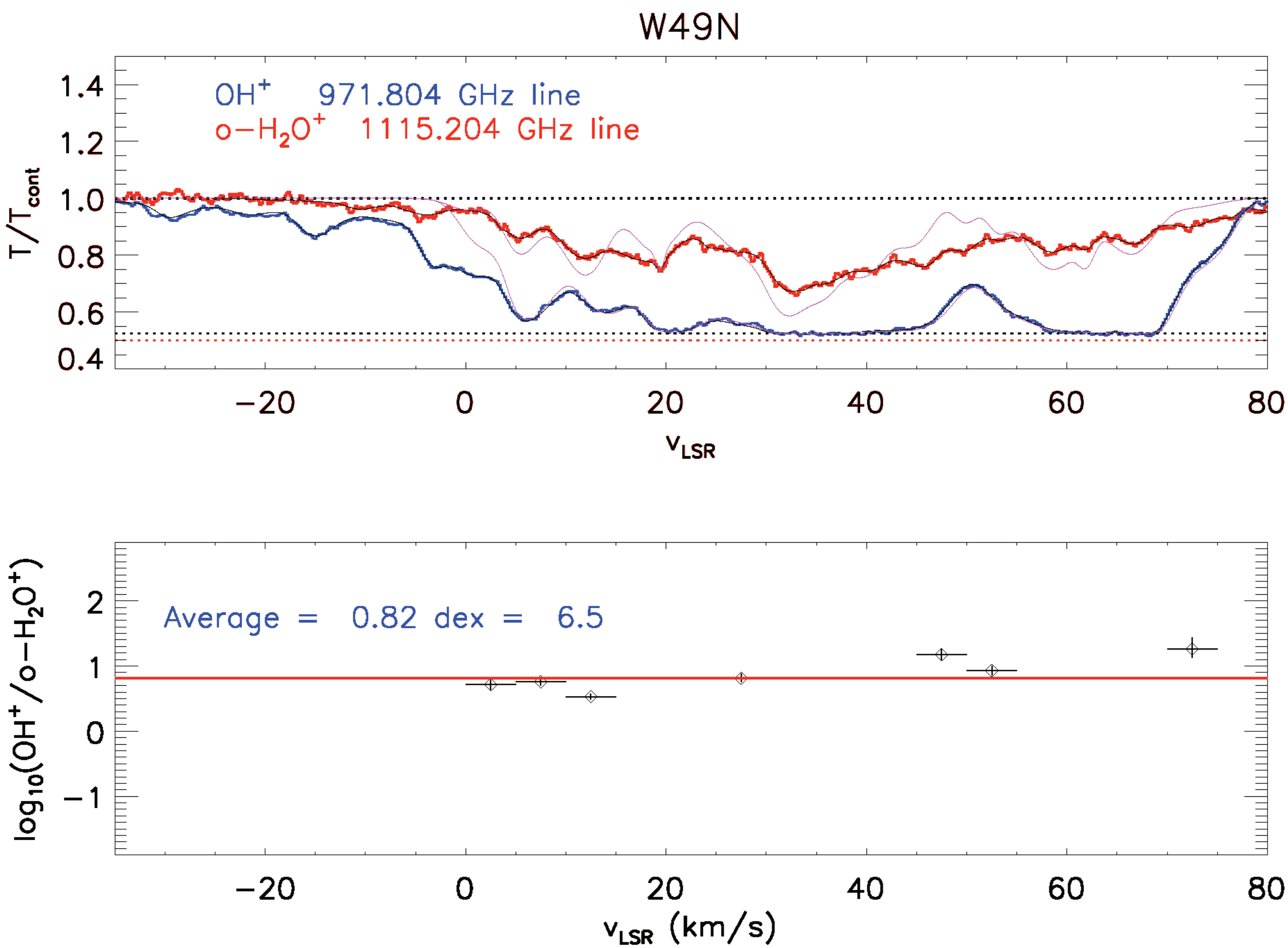
- Chemistry is initiated by cosmic rays



OH^+ and H_2O^+ along the sight-line to W49N



Neufeld, Goicoechea, Sonnentrucker et al. 2010, A&A



W49N
OH^+ 971.804 GHz line
$o-H_2O^+$ 1115.204 GHz line
T/T_{cont}
v_{LSR}
Average = 0.82 dex = 6.5
$\log_{10}(OH^+/o-H_2O^+)$
v_{LSR} (km/s)

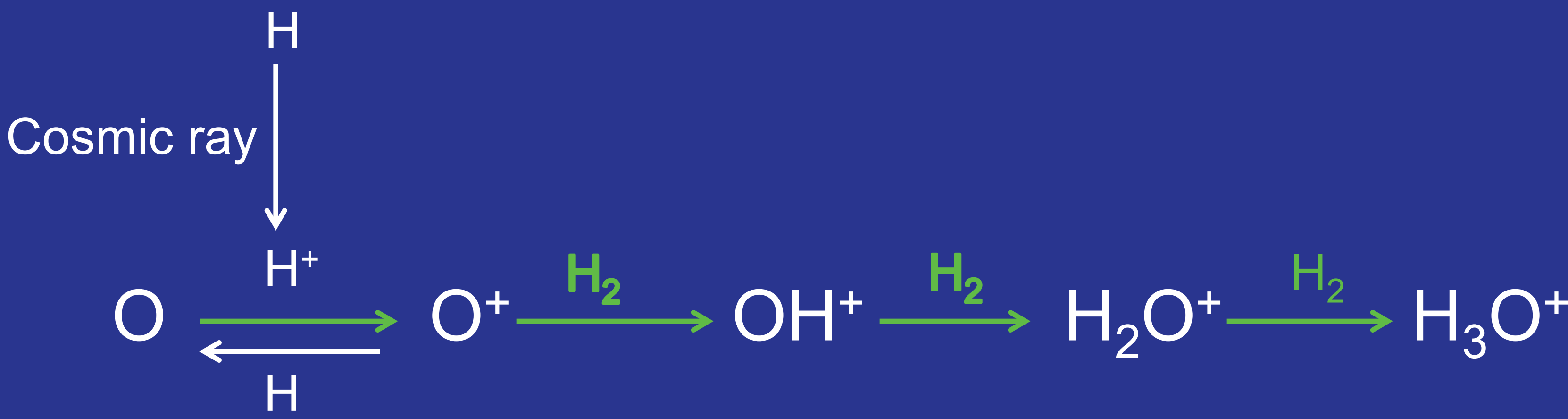
OH^+ and H_2O^+ along the sight-line to W49N

Rather surprising result:

$OH^+/H_2O^+ = 3 – 15$

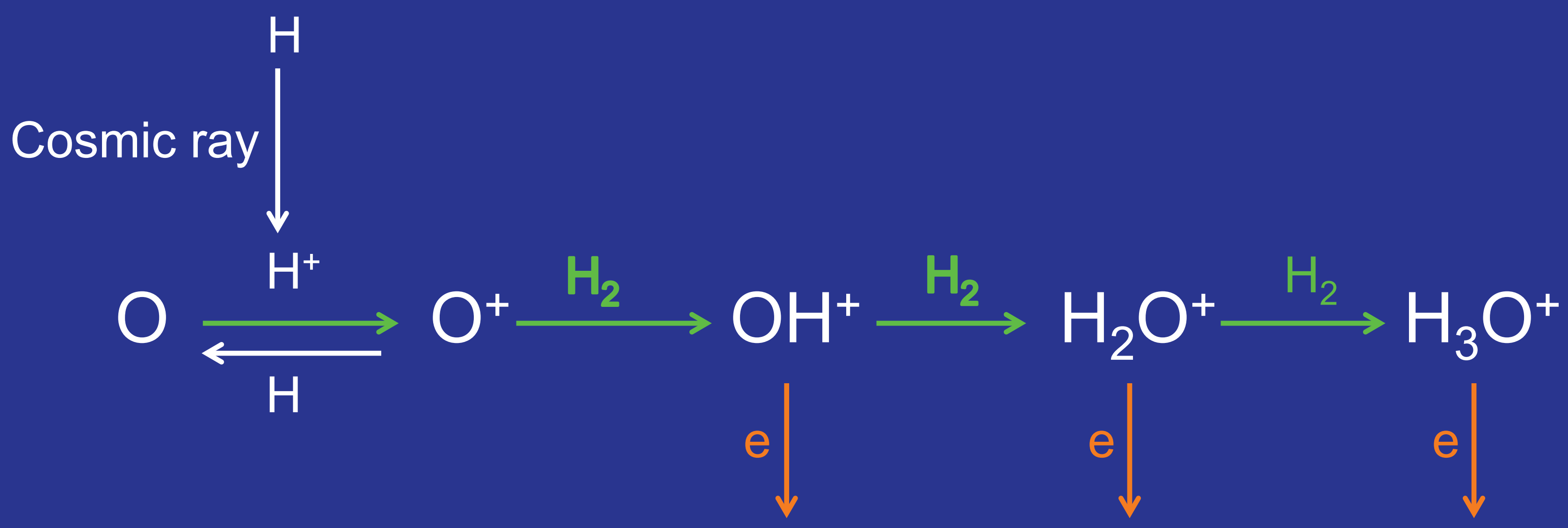
We would have expected a ratio ~ 1 if reaction with H_2 dominated the destruction of H_2O^+

The oxygen pipeline



The large OH^+/H_2O^+ ratio implies that the pipeline is leaky

The oxygen pipeline



The large OH^+/H_2O^+ ratio implies that the pipeline is leaky – electrons are competing with H_2 in destroying molecular ions

Implication: the molecular fraction is only 2 – 8 %

OH^+ and H_2O^+ along the sight-line to W49N

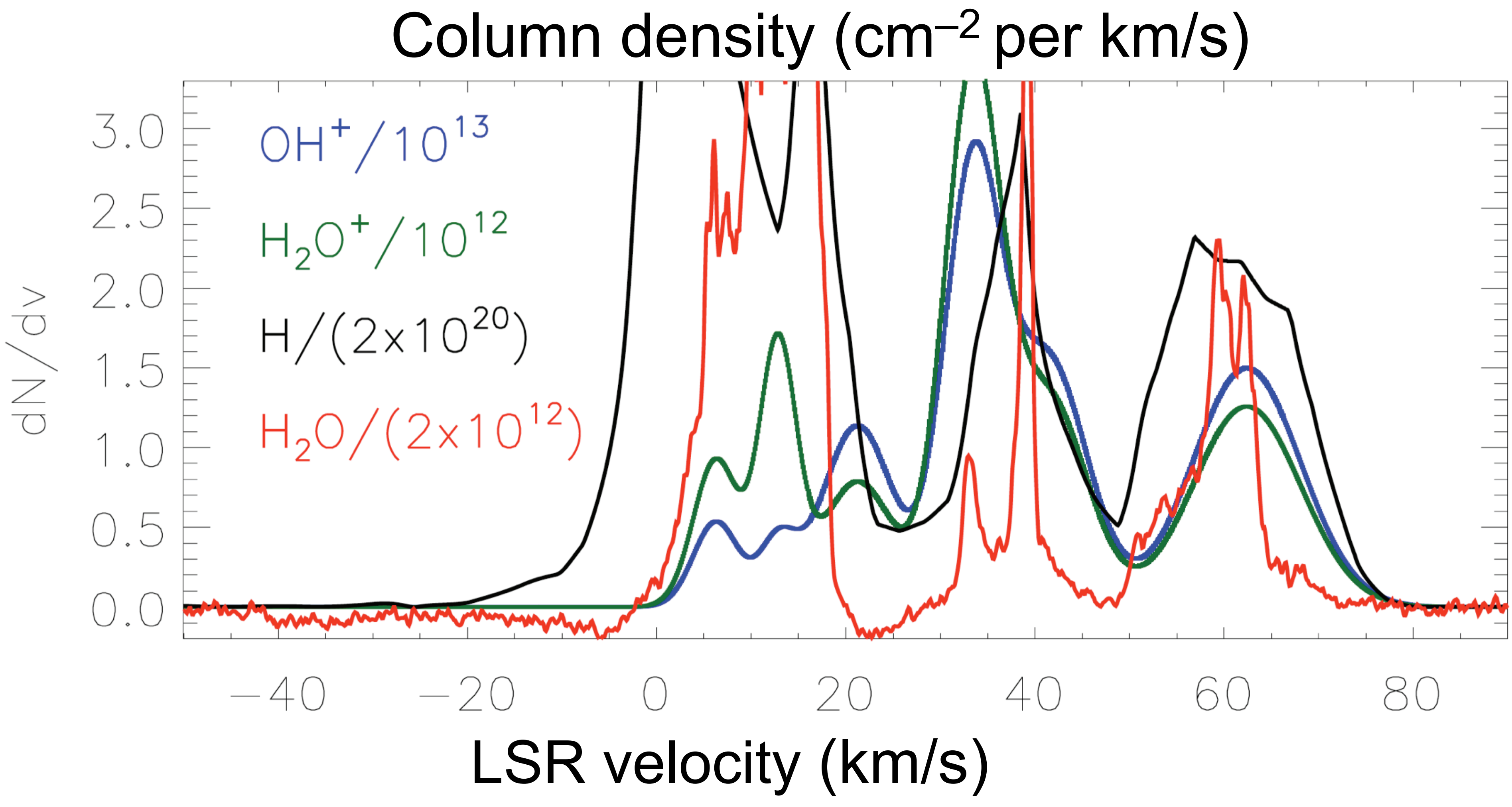
Two important implications:

(1) OH^+/H_2O^+ ratio → low molecular fraction

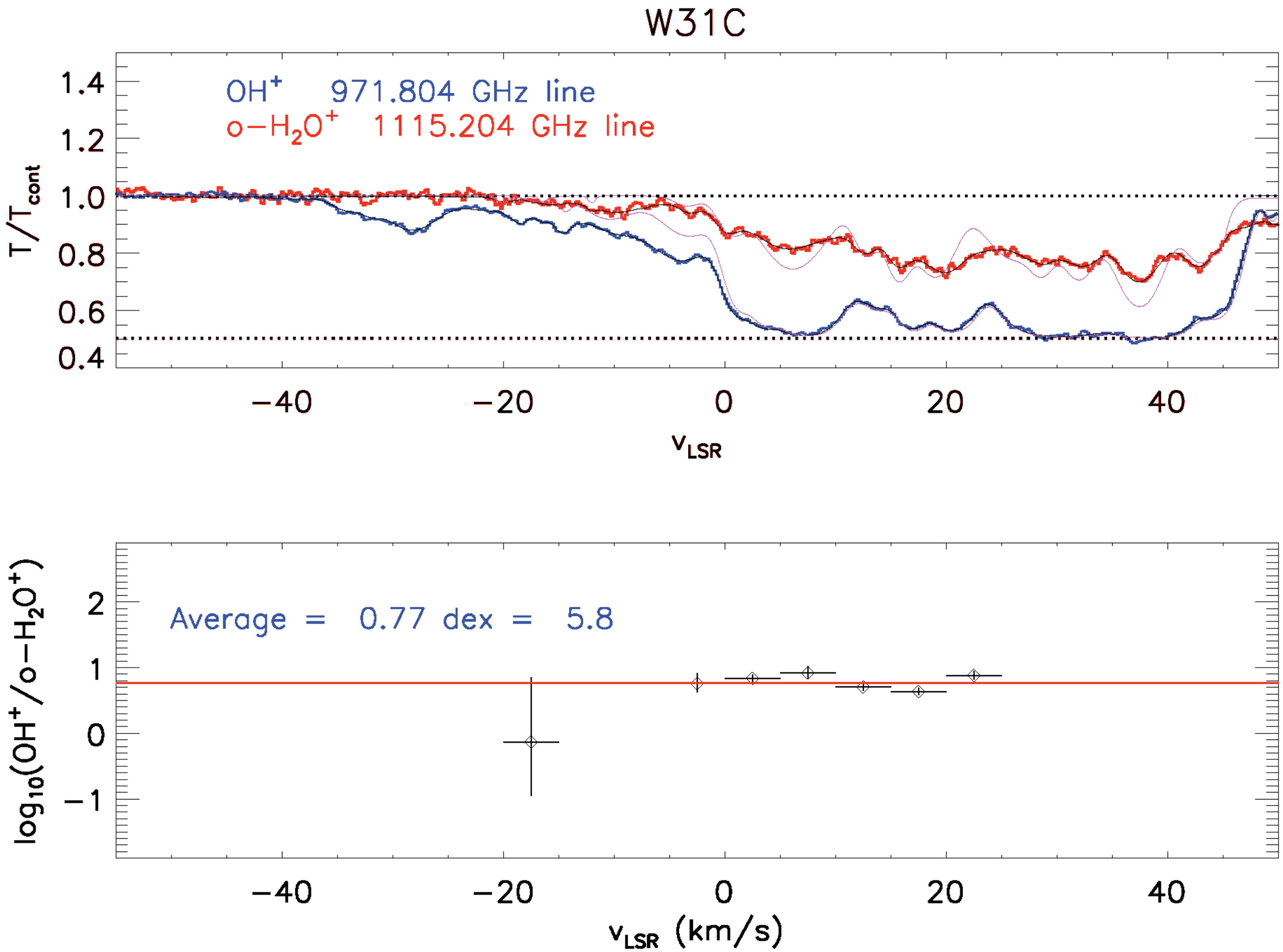
Many small clouds along the sight-line (weakly shielded), or could represent departure from steady state

We may be witnessing the transition from atomic to molecular clouds

The OH^+ and H_2O^+ distributions follow that of HI (Fish et al. 2003) rather than H_2O



Similar results for OH^+/H_2O^+ are obtained toward other sources



Gerin et al. 2010

OH^+ and H_2O^+ along the sight-line to W49N

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OH^+ and H_2O^+ along the sight-line to W49N

Two important implications:

(2) OH^+ column density → cosmic ray ionization rate

Preliminary estimate: $\zeta_H = 0.5 – 3 \times 10^{-16}\ s^{-1}$ in W49N

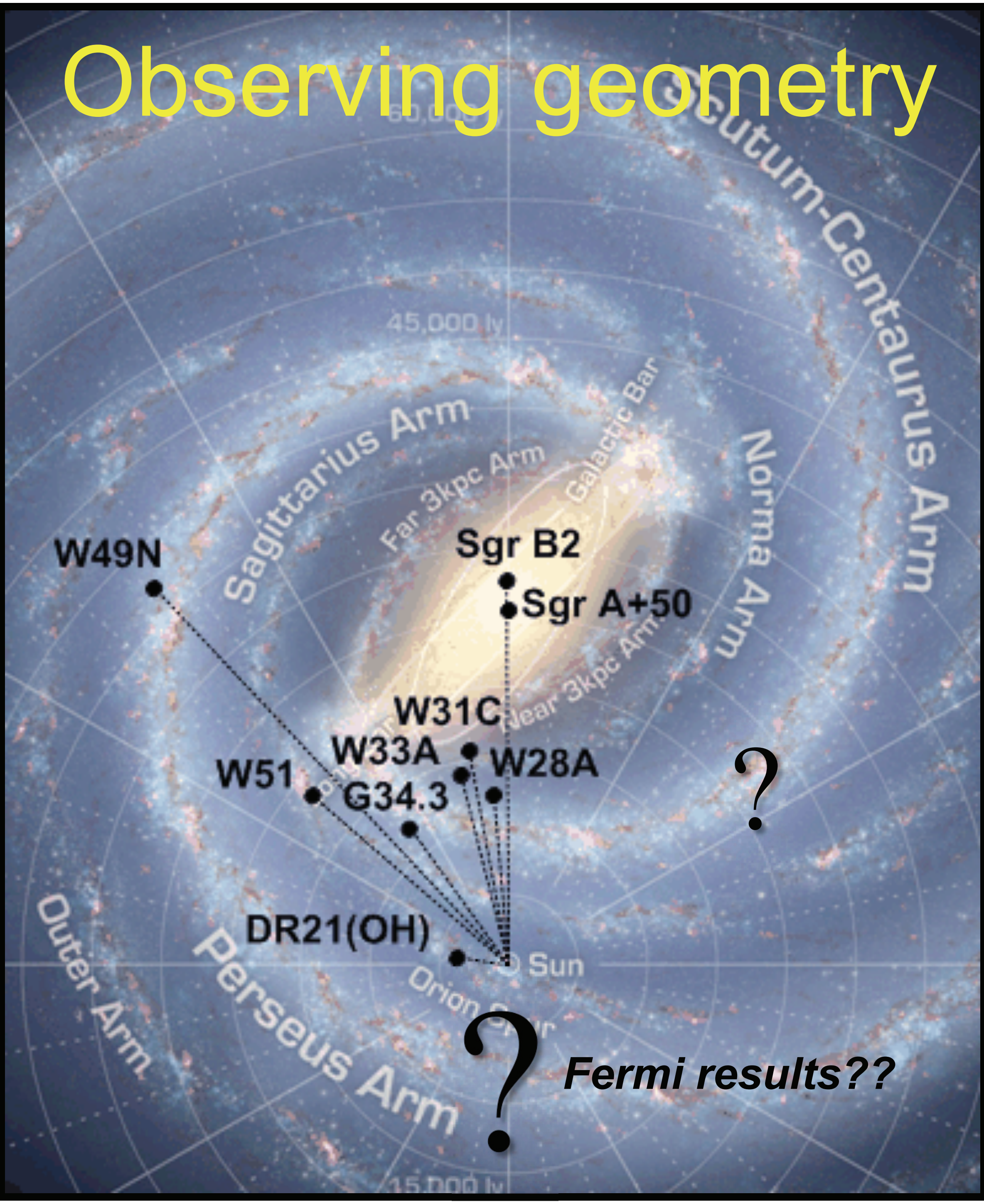
Confirmation of new larger values inferred by Indriolo, Geballe, Oka, & McCall from observations of H_3^+

Next steps:

more detailed analysis of chemistry

investigate variation with position in the Galaxy

Observing geometry



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The future of absorption line spectroscopy, after Herschel

The future of absorption line spectroscopy, after Herschel

SOFIA can push high resolution spectroscopy to higher frequencies

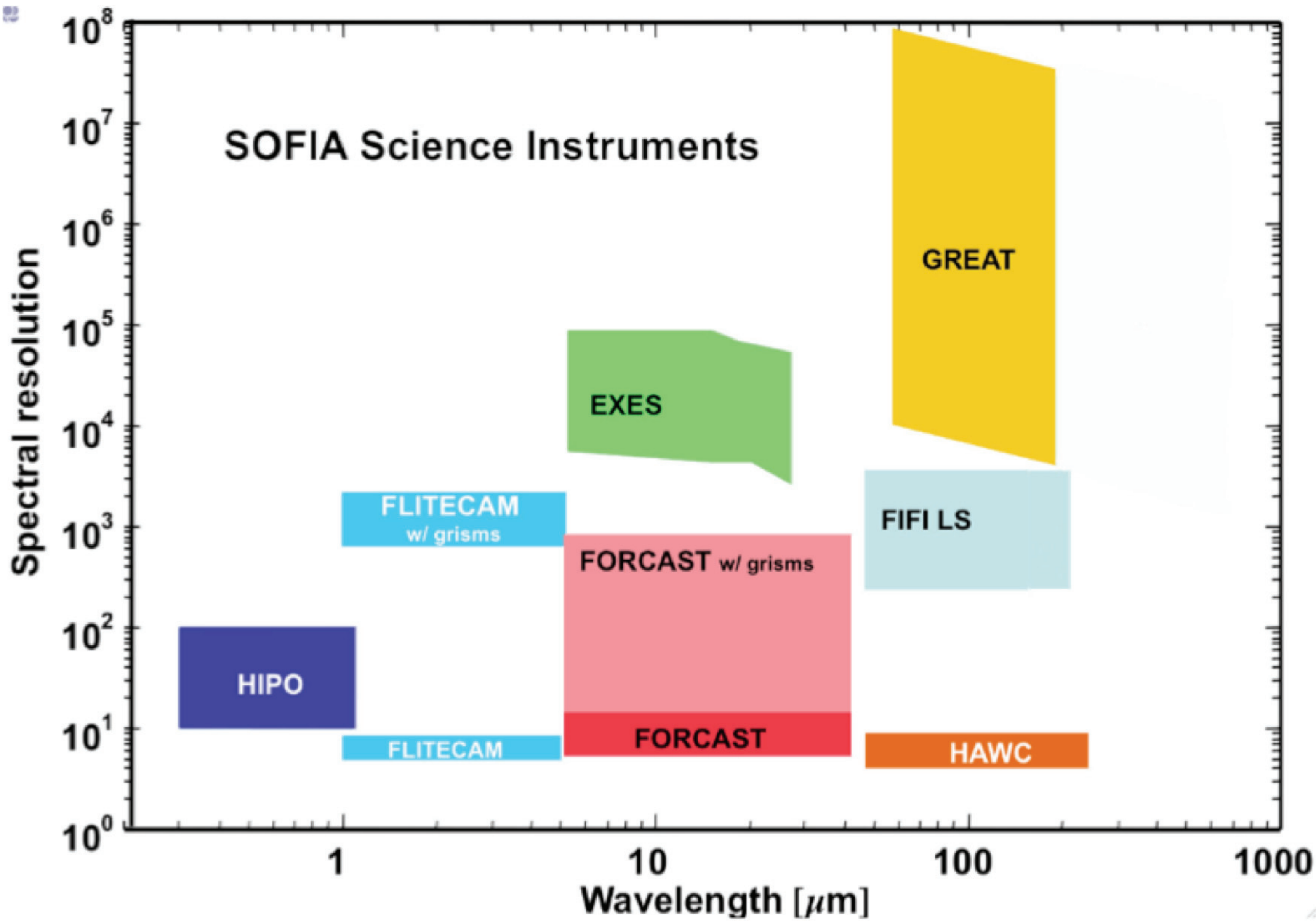
GREAT: access to

HD $J = 1 – 0$

OH $^2\Pi_{3/2}$ $J = 5/2 – 3/2$

SH $^2\Pi_{3/2}$ $J = 5/2 – 3/2$

Excellent Spectroscopy Capabilities: $R=10^2$ to 10^8



Anticipated Schedule

- FORCAST Basic Science Flights: May to June 2011
- GREAT Basic Science Flights: July and September 2011

Draft AO for 2nd Generation Instruments

- Draft AO: http://soma.larc.nasa.gov/SOFIA/sofiapbtelecon_agenda.html
- Anticipated proposal announcement: Mid- 2011
- Asilomar meeting proceeding

http://www.sofia.usra.edu/Science/workshops/asilomar.html

Next Science Proposal Call

- Fall to Winter 2011, 300 hours observing time
- FORCAST grism, FLITECAM and HIPO are likely to be included.
- Data Analysis funding is available for US Investigators