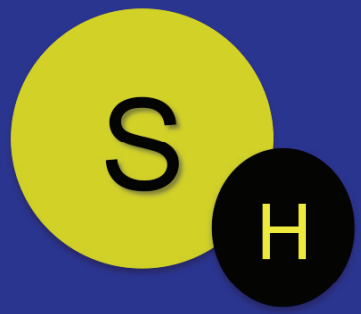
Search for interstellar mercapto radicals (SH) with SOFIA/GREAT

David Neufeld

Johns Hopkins University



and

M. Gerin, E. Falgarone, B. Godard, E. Herbst,

G. Pineau des Forêts, R. Güsten, H. Wiesemeyer

and the GREAT team

Discovery of interstellar mercapto radicals (SH) with SOFIA/GREAT

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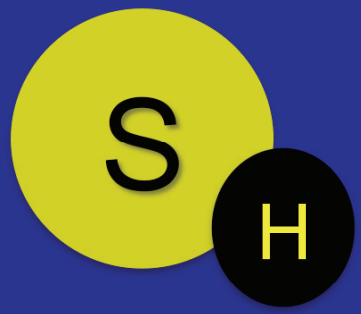

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Interstellar molecules

- More than 150 interstellar molecules have now been detected, most of them polyatomic, and many organic and quite complex

- Arguably, the simplest interstellar molecules – the diatomic hydrides – show the greatest promise for advancing our understanding of astrochemistry

Interstellar hydrides

- Prior to SOFIA, 6 or 7 neutral diatomic hydrides had been detected

H_2 (Carruthers 1970)				**CH** (Swings & Rosenfeld 1937)	**NH** (Meyer & Roth 1991)	**OH** (Weinreb 1963)	**HF** (Neufeld et al. 1995)	
				SiH ? (Schilke et al. 2001)			**HCl** (Blake et al. 1985)	

Interstellar hydrides

…along with four diatomic hydride cations

				CH^+ (Douglas & Herzberg 1941)		**OH^+** (Gerin et al. & Wyrowski et al. 2010)		
						SH^+ (Benz et al. 2010)	**HCl^+** (DeLuca et al. 2012)	

Interstellar hydrides

Individual hydrides trace distinctive aspects of the interstellar environment

For example:

- OH^+ probes the cosmic ray ionization rate
- HF is a proxy for molecular hydrogen
- CH^+ and SH^+ probe warm regions – heated by shocks, or the dissipation of turbulence – where endothermic reactions (e.g. $C^+ + H_2 \rightarrow CH^+ + H$) are enhanced

The mercapto radical

- SH was conspicuously absent from the list of known interstellar hydrides

H_2 (Carruthers 1970)				**CH** (Swings & Rosenfeld 1937)	**NH** (Meyer & Roth 1991)	**OH** (Weinreb 1963)	**HF** (Neufeld et al. 1995)	
				SiH ? (Schilke et al. 2001)		What about **SH** ...?	**HCl** (Blake et al. 1985)	

The mercapto radical

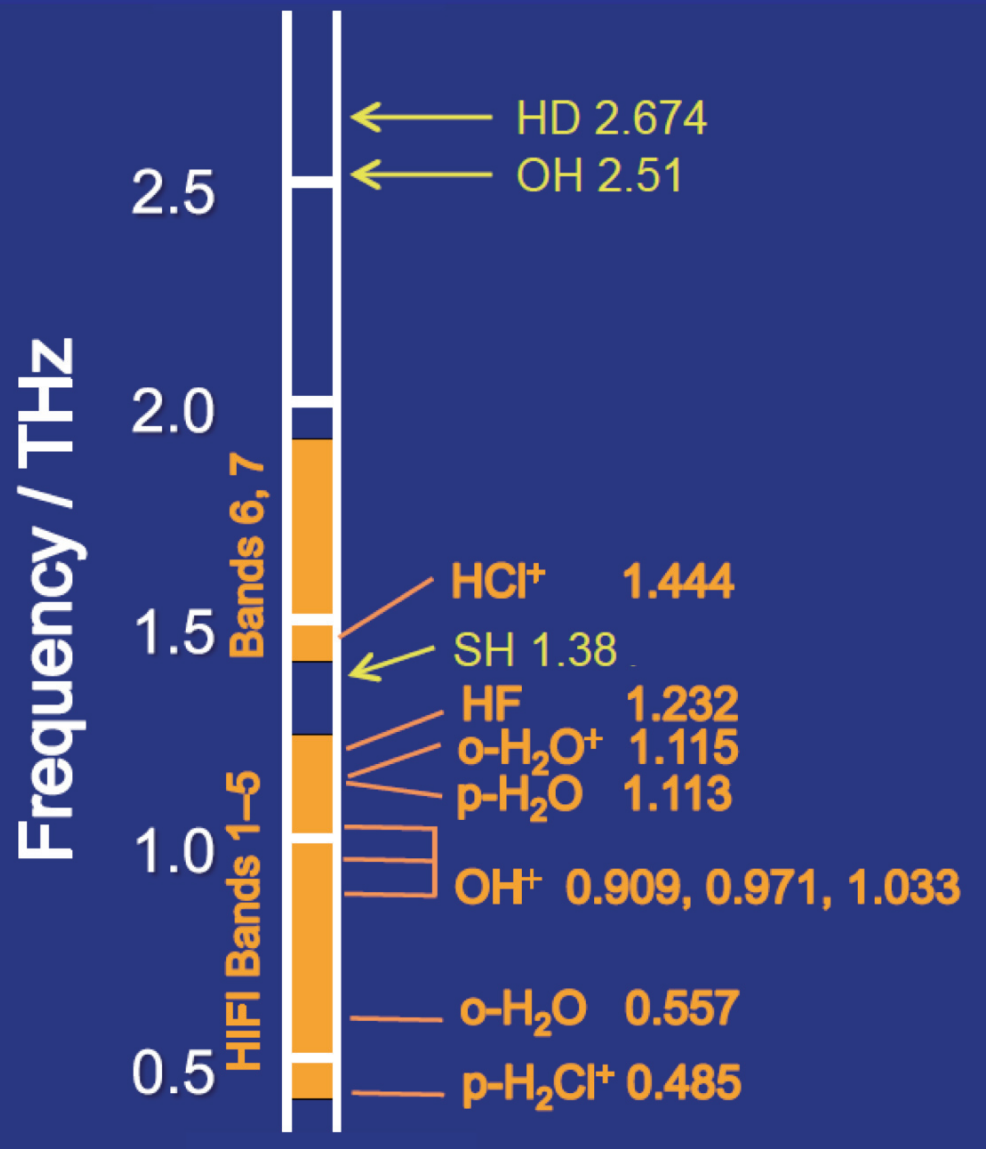
- Cold SH is unobservable from the ground
- The “ground state” rotational transition of SH

$^2\Pi_{3/2}$ J= 5/2 → 3/2 at 1.383 THz

falls right in the gap between Bands 5 and 6 of *Herschel*’s HIFI spectrometer

The mercapto radical

- The GREAT spectrometer on SOFIA has a receiver designed to cover this gap in *Herschel*/HIFI coverage (1250 – 1410 GHz)



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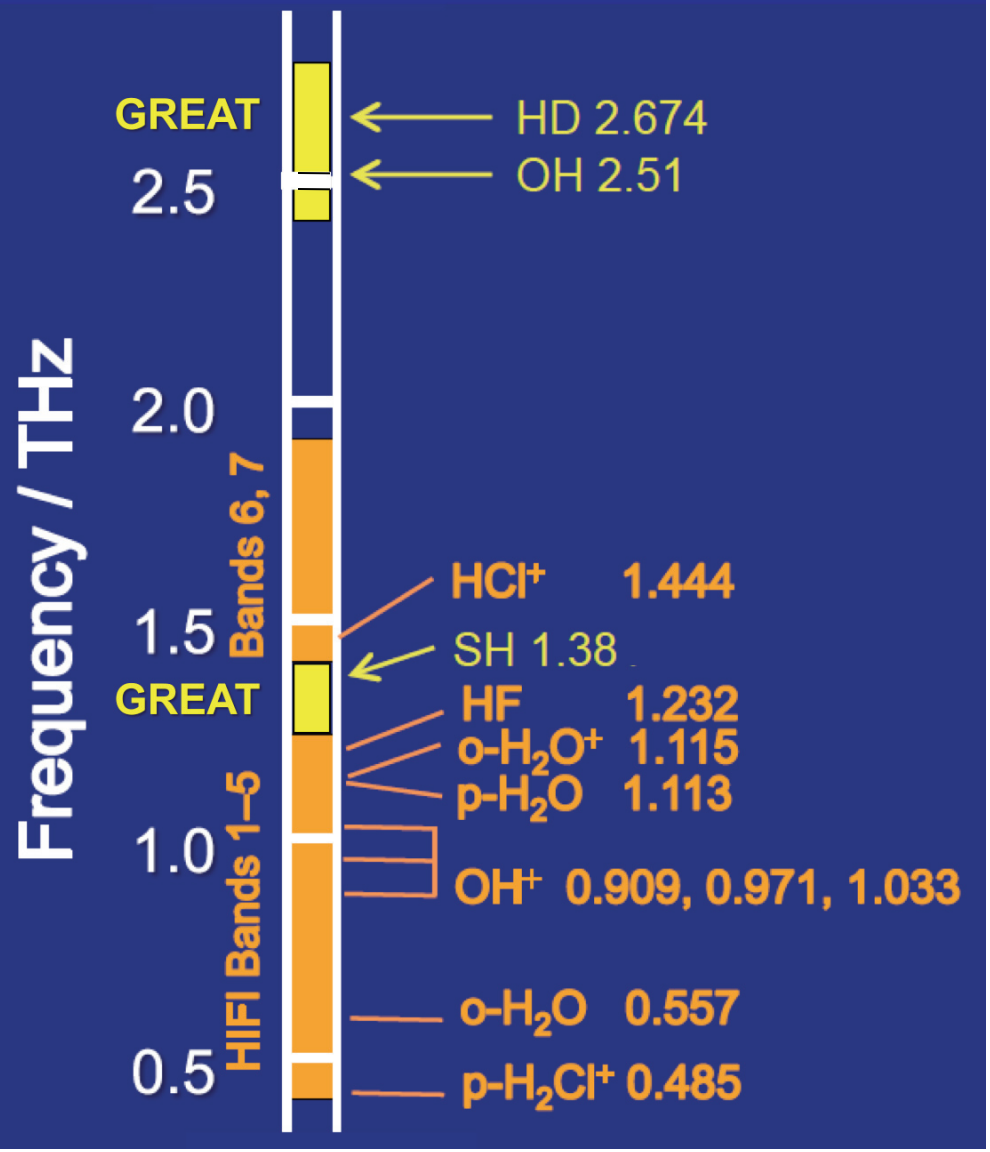
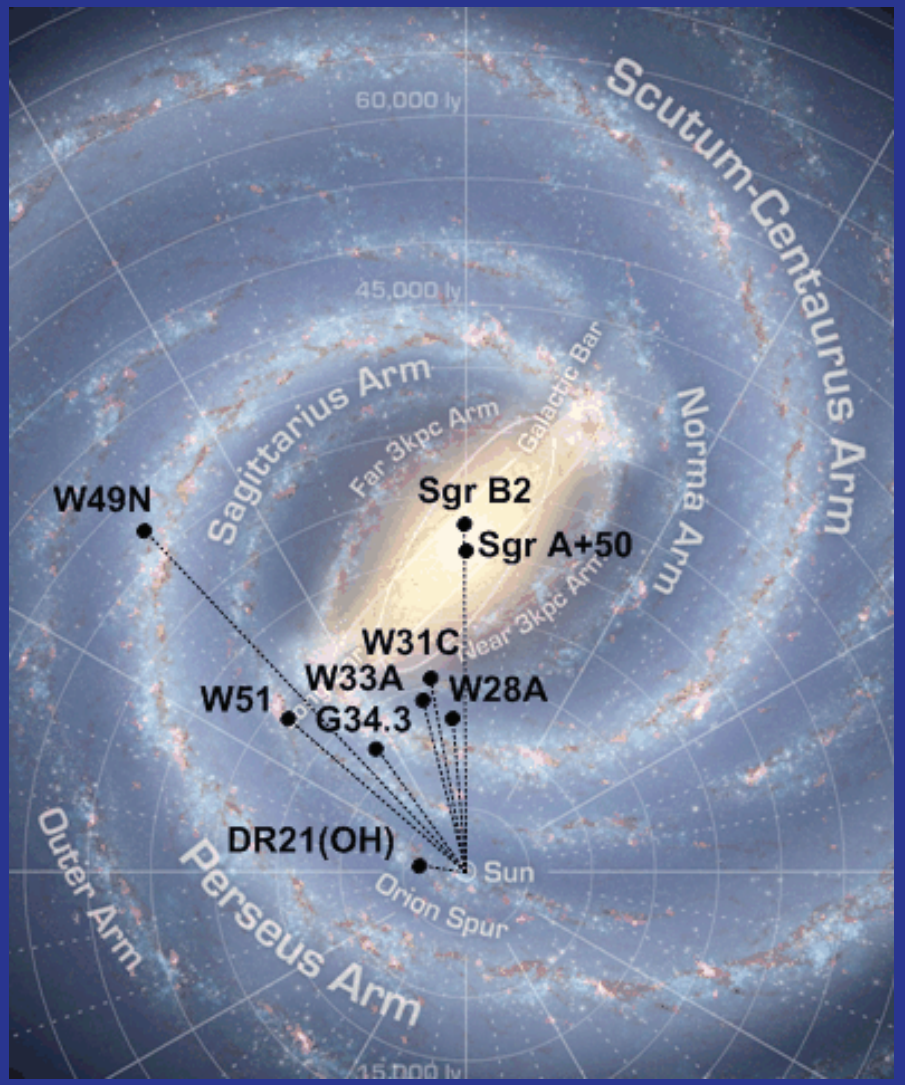
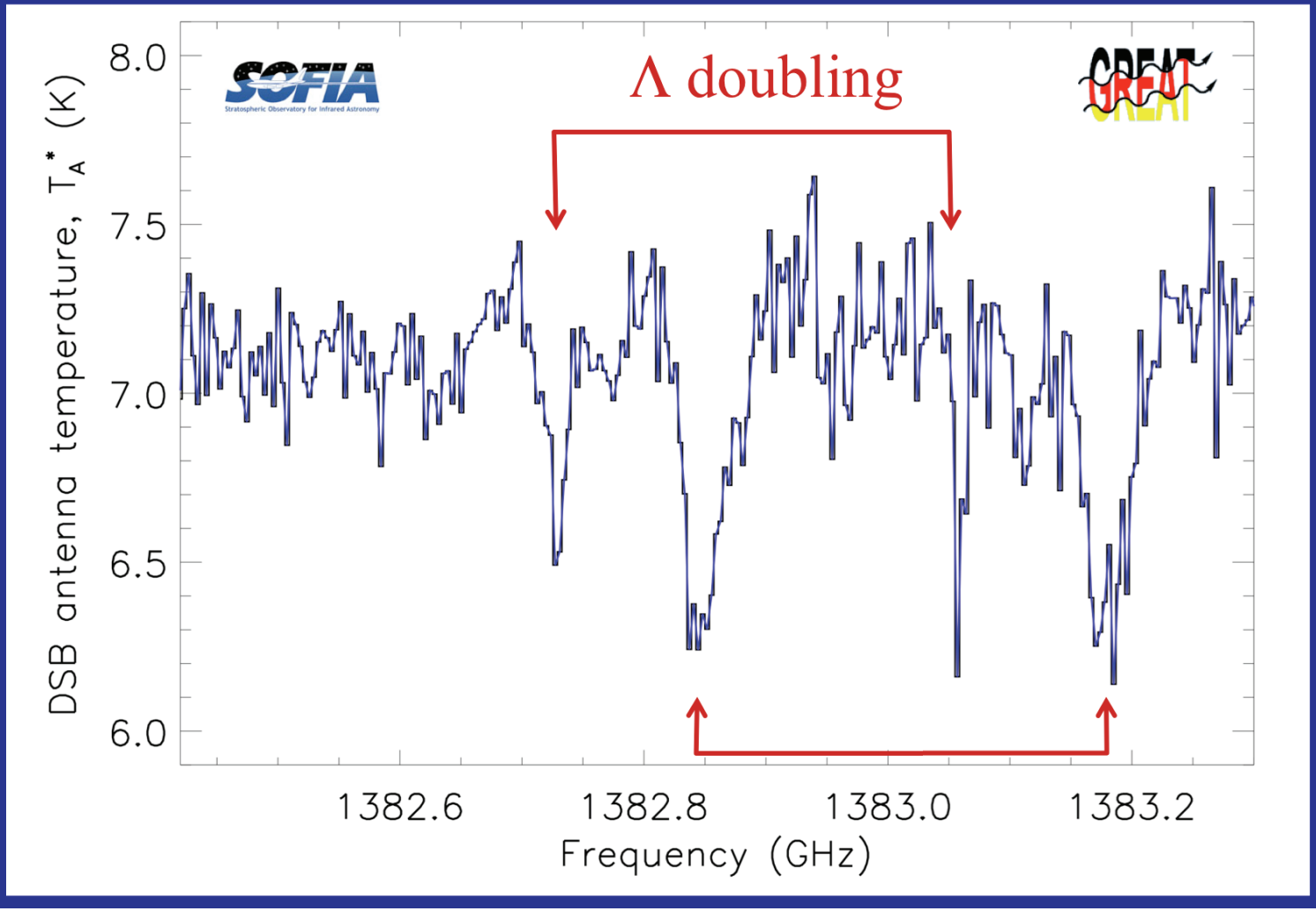


Search for SH in absorption toward W49N

- We used a very luminous region of massive star formation (W49N) as a background THz continuum source
- We searched for absorption by SH in foreground material
- This experiment was performed in a Basic Science (“General Investigator”) program

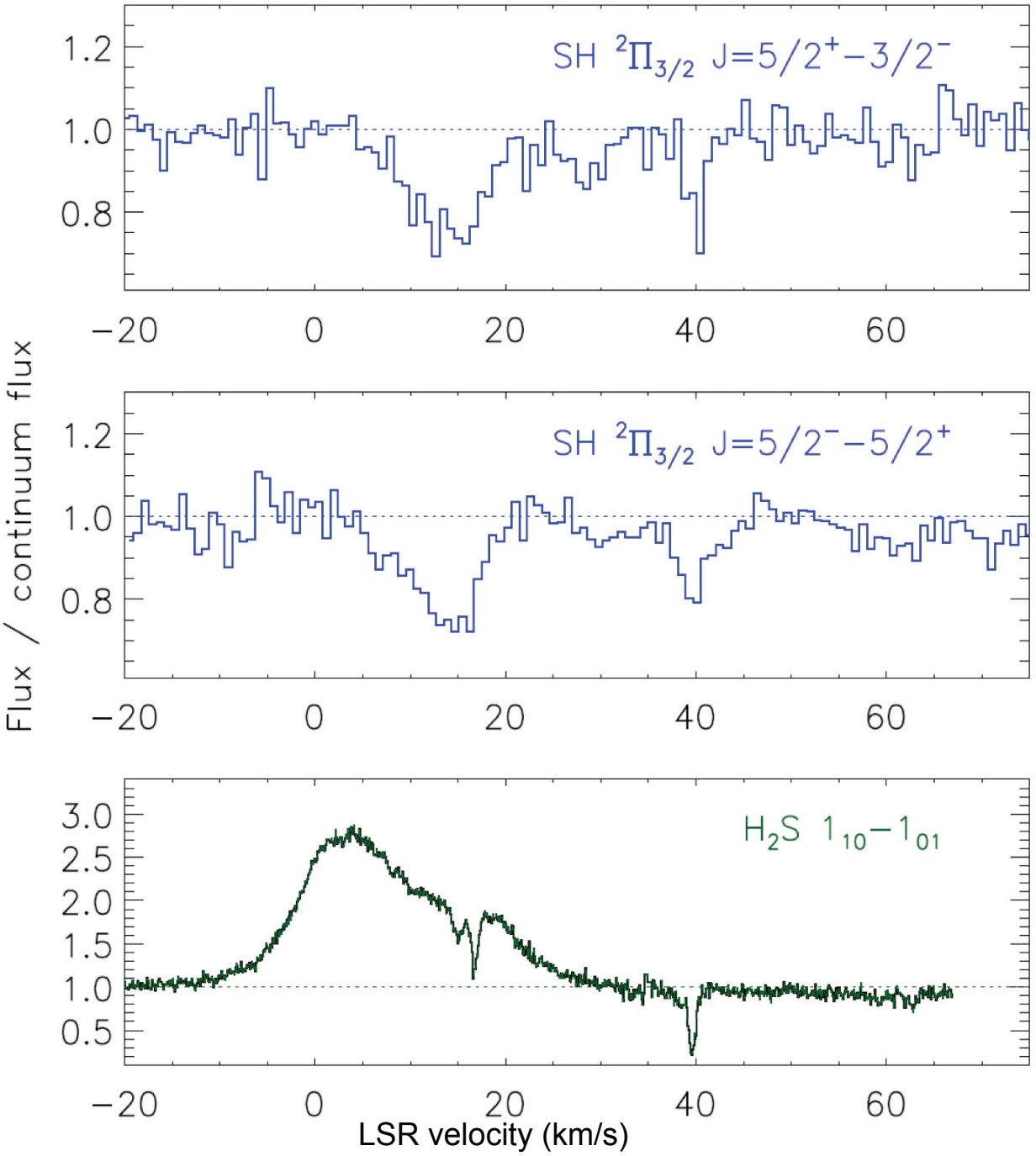


Mercapto radicals were clearly detected in absorption toward W49N



SH

with H_2S from the IRAM 30m



Molecular abundances

- This narrow feature at v_{LSR} ~ 39 km/s is observed in the spectra of many molecules
- It arises in a diffuse molecular cloud at roughly 6.7 kpc from the Galactic Center

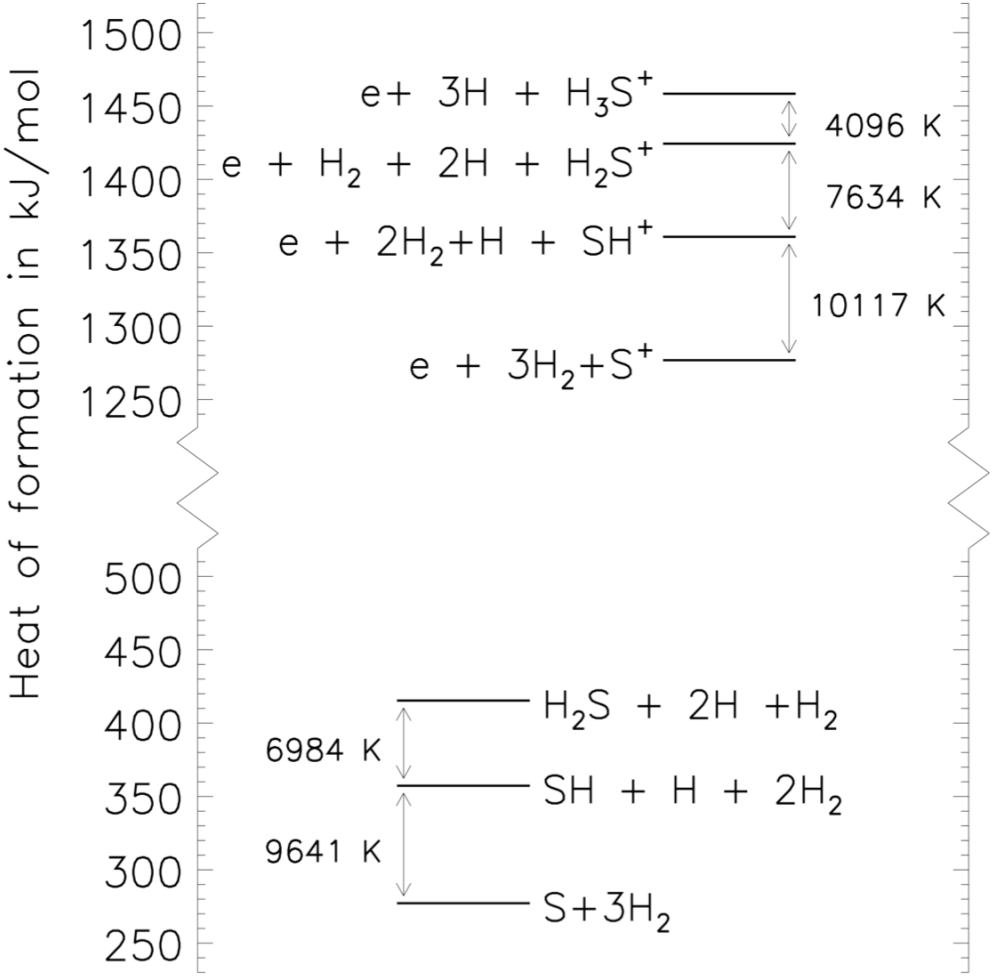
Molecule	Column density (10^{12} cm^{-2})	Abundance relative to H_2	Fraction of solar	
SH	4.6	6.9×10^{-9}	0.026%	Neufeld et al. 2012
H_2S	35	5.2×10^{-8}	0.20%	Gerin et al. 2012
SH^+	2.6	3.9×10^{-9}	0.015%	Godard et al. 2012
CS	12	1.8×10^{-8}	0.070%	Miyawaki et al. 1988
H_2O	60	9.6×10^{-8}	0.010%	Sonnentrucker et al. 2010
CH	58	9.0×10^{-8}	0.017%	Gerin et al. 2011

Implications

- The hydrides SH, H_2S and SH^+ collectively account for only ¼% of interstellar sulfur
- However, this is much more than expected in cold (100 K) interstellar clouds
- Further evidence for a "warm" chemistry in which endothermic reactions are enhanced, requiring
  - elevated temperatures

    OR
  - ion-neutral drift

Thermochemistry of sulfur hydrides



Implications

- The relatively low SH/H_2S ratio ~ 0.13 suggests that

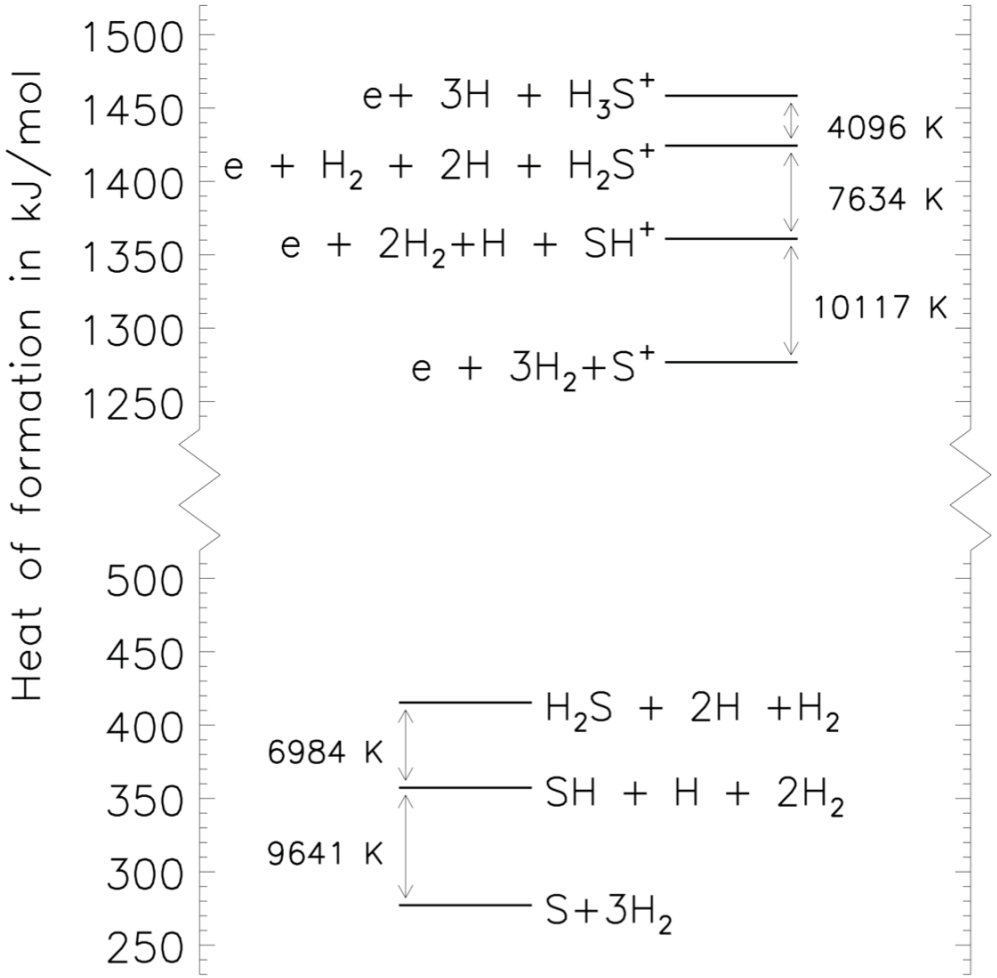
  $SH + H_2 \rightarrow H_2S + H$

  must be rapid

- This suggests that neutral-neutral reactions are enhanced along with ion-neutral reactions

- This requires gas temperatures ~ 1000 K (and not just ion-neutral drift)

Thermochemistry of sulfur hydrides



Summary

- We have obtained the first detection of interstellar mercapto radicals, using GREAT instrument on SOFIA
- The ground state $^2\Pi_{3/2}$ J= 5/2 → 3/2 transition at 1.383 THz was detected in absorption toward W49N
- Both components of this lambda doublet were unequivocally detected in material associated with W49N and in a foreground diffuse cloud
- The implied diffuse clouds abundance, $SH/H_2 \sim 10^{-8}$, suggests the presence of elevated gas temperatures (~ 1000 K)