

Spectroscopy of Highly Excited HCNH⁺
Using
Infrared Heterodyne Velocity Modulation

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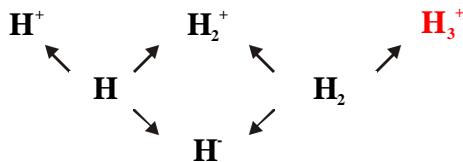
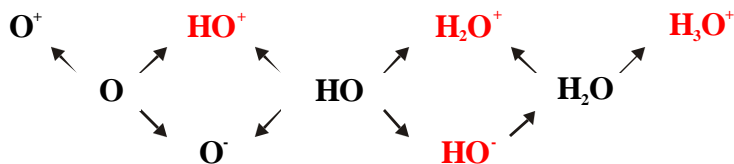
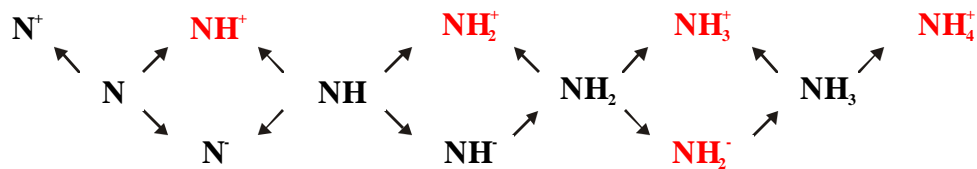
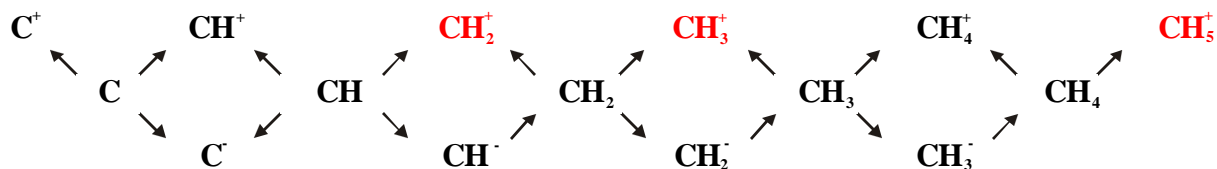
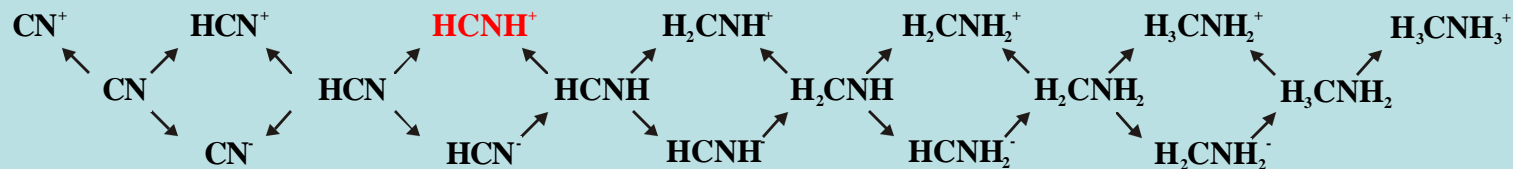
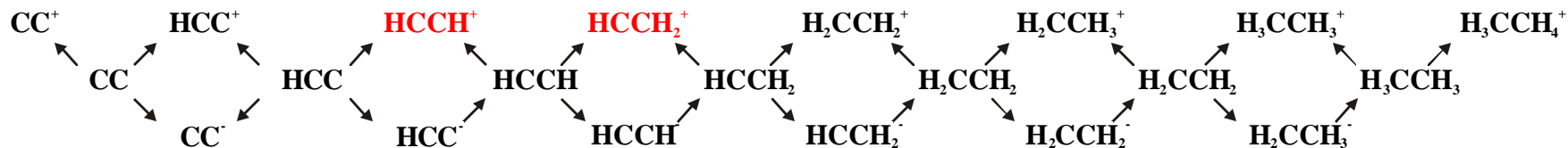
Astronomically observed molecules

2-atom	3-atom	4-atom	5-atom	6-atom	7-atom	8-atom	9-atom	10-atom	11-atom	12-atom
H ₂	H ₂ O	NH ₃	CH ₄	C ₂ H ₄	C ₆ H	CH ₃ C ₃ N	CH ₃ C ₄ H	CH ₃ C ₅ N	HC ₉ N	HC ₁₁ N
CO	CO ₂	C ₂ H ₂	SiH ₄	CH ₃ CN	CH ₂ CHCN	HCOOCH ₃	CH ₃ CH ₂ CN	(CH ₃) ₂ CO		
CH	HCO	H ₂ CO	c-C ₃ H ₂	C ₅ H	CH ₃ C ₂ H	CH ₃ COOH	(CH ₃) ₂ O	NH ₂ CH ₂ COOH		
CH ⁺	HCO ⁺	H ₃ O ⁺	l-C ₃ H ₂	C ₅ O	HC ₅ N	C ₇ H	CH ₃ CH ₂ OH			
OH	HOC ⁺	c-C ₃ H	C ₅	CH ₃ NC	HCOCH ₃	H ₂ C ₆	HC ₇ N			
C ₂	HCN	l-C ₃ H	C ₄ H	CH ₃ OH	NH ₂ CH ₃	CH ₂ OHCHO	C ₈ H			
CN	C ₃	C ₃ N	C ₄ Si	CH ₃ SH	c-C ₂ H ₄ O					
CO ⁺	C ₂ O	C ₃ O	CH ₂ CN	HC ₃ NH ⁺	CH ₂ CHOH					
NO	C ₂ S	C ₃ S	HC ₃ N	HC ₂ CHO						
AlF	CH ₂	HCCN	HC ₂ NC	HCONH ₂						
AlCl	HCS ⁺	HCNH ⁺	HCOOH	l-H ₂ C ₄						
CP	H ₂ S	HNCO	H ₂ CHN	C ₅ N						
CS	HNC	HNCS	H ₂ C ₂ O							
CSi	HNO	HOCO ⁺	H ₂ NCN							
HCl	MgCN	H ₂ CN	HNC ₃							
KCl	MgNC	H ₂ CS	H ₂ COH ⁺							
NH	N ₂ H ⁺	SiC ₃								
NS	N ₂ O									
NaCl	NaCN									
PN	OCS									
SO	SO ₂									
SO ⁺	c-SiC ₂									
SiN	C ₂ H									
SiO	NH ₂									
SiS	H ₃ ⁺									
HF	SiCN									
SH	AINC									
FeO										

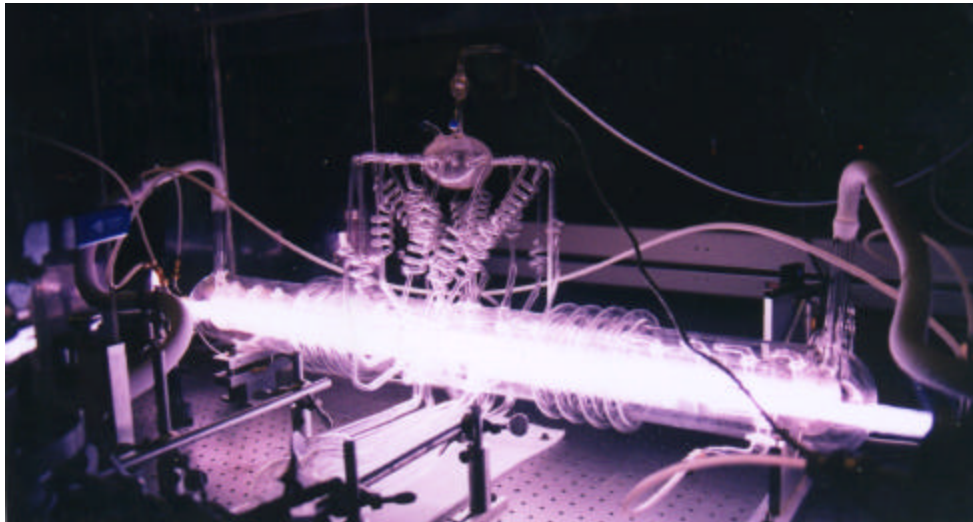
123 observed molecules as of 6/10/2002

From National Radio Astronomy Observatory Web Site:
<http://www.cv.nrao.edu/~awootten/allmols.html>

Ion-neutral Families

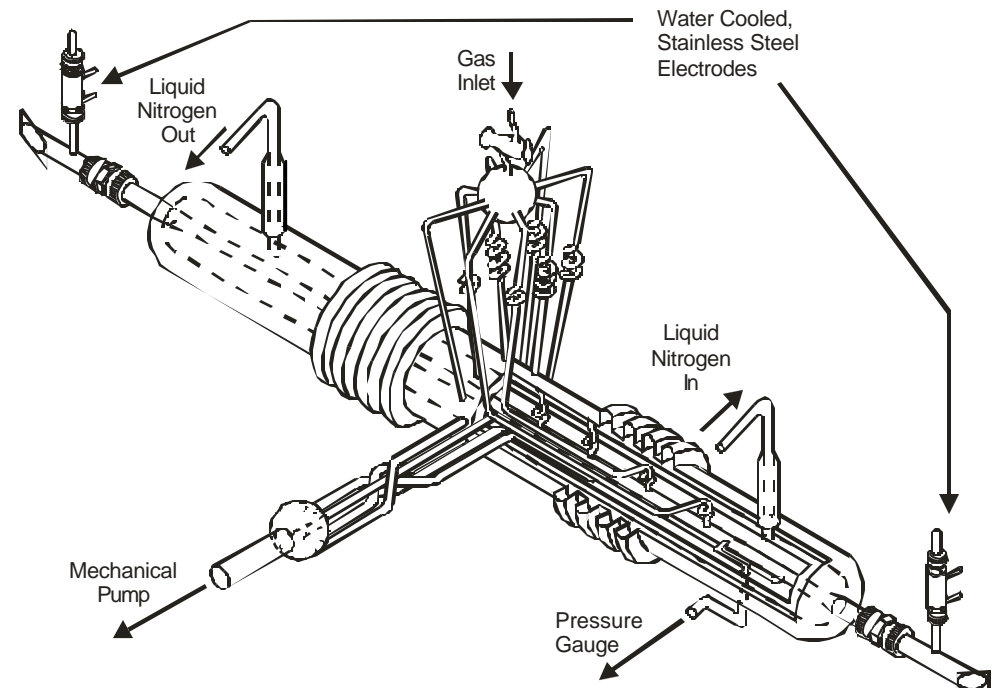


The Oka Ion Factory Positive Column Tube

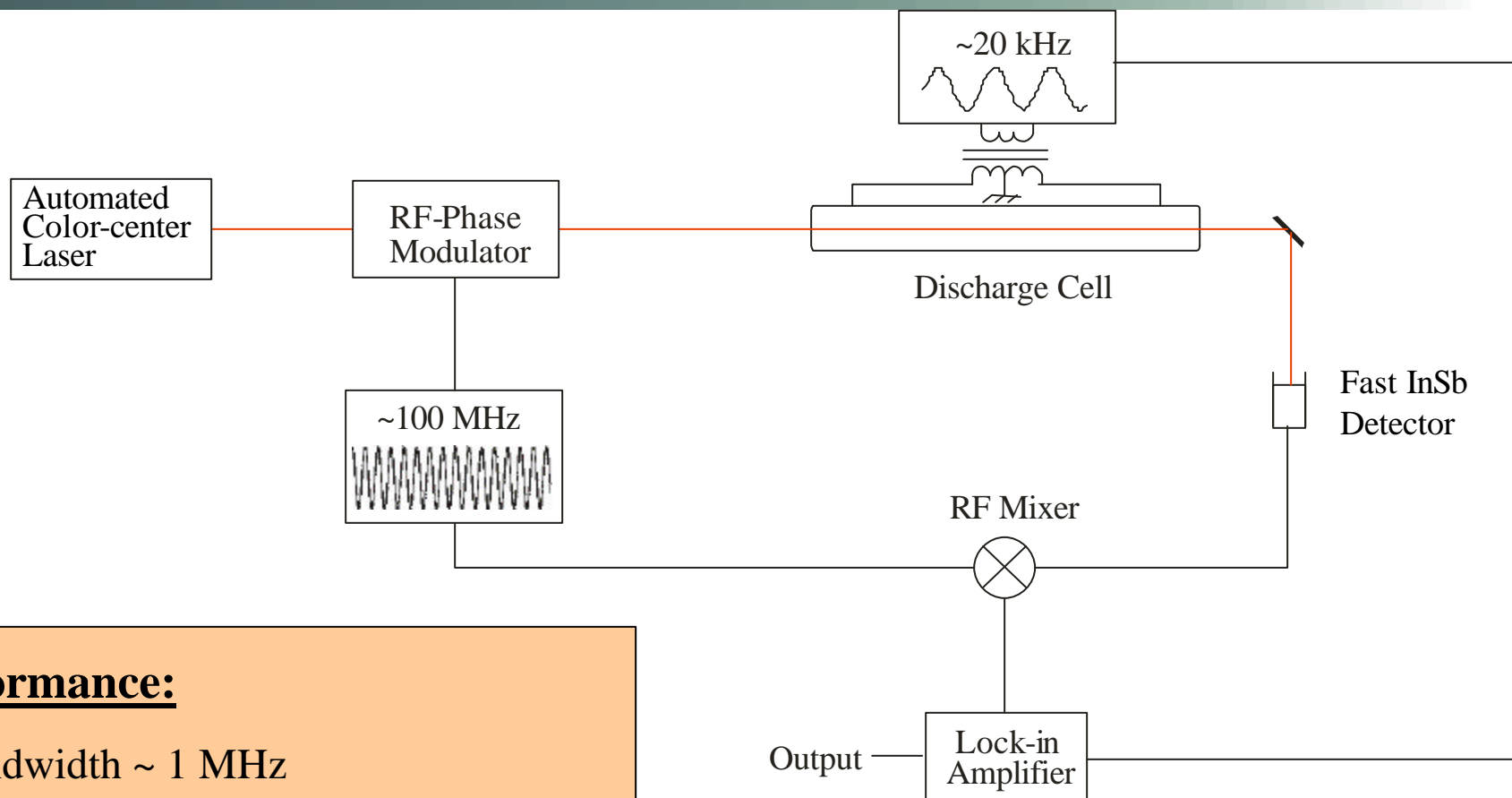


- Pressure: 0.5 - 8 Torr
- Electrode voltage: 1-10 kV
- Current: 50-1000 mA
- ~ 1 ppm ionization
- Ion density: ~ 10^8 - 10^{11} cm⁻³

- Water cooled
- 12 mm diameter inner bore
- Discharge column length ~1 m
- Gas flow rate ~ 200 L/Min
- $T_{\text{Rot}} \sim 500$ K, $T_{\text{Vib}} \sim 1500$ K



Infrared heterodyne detection + velocity modulation

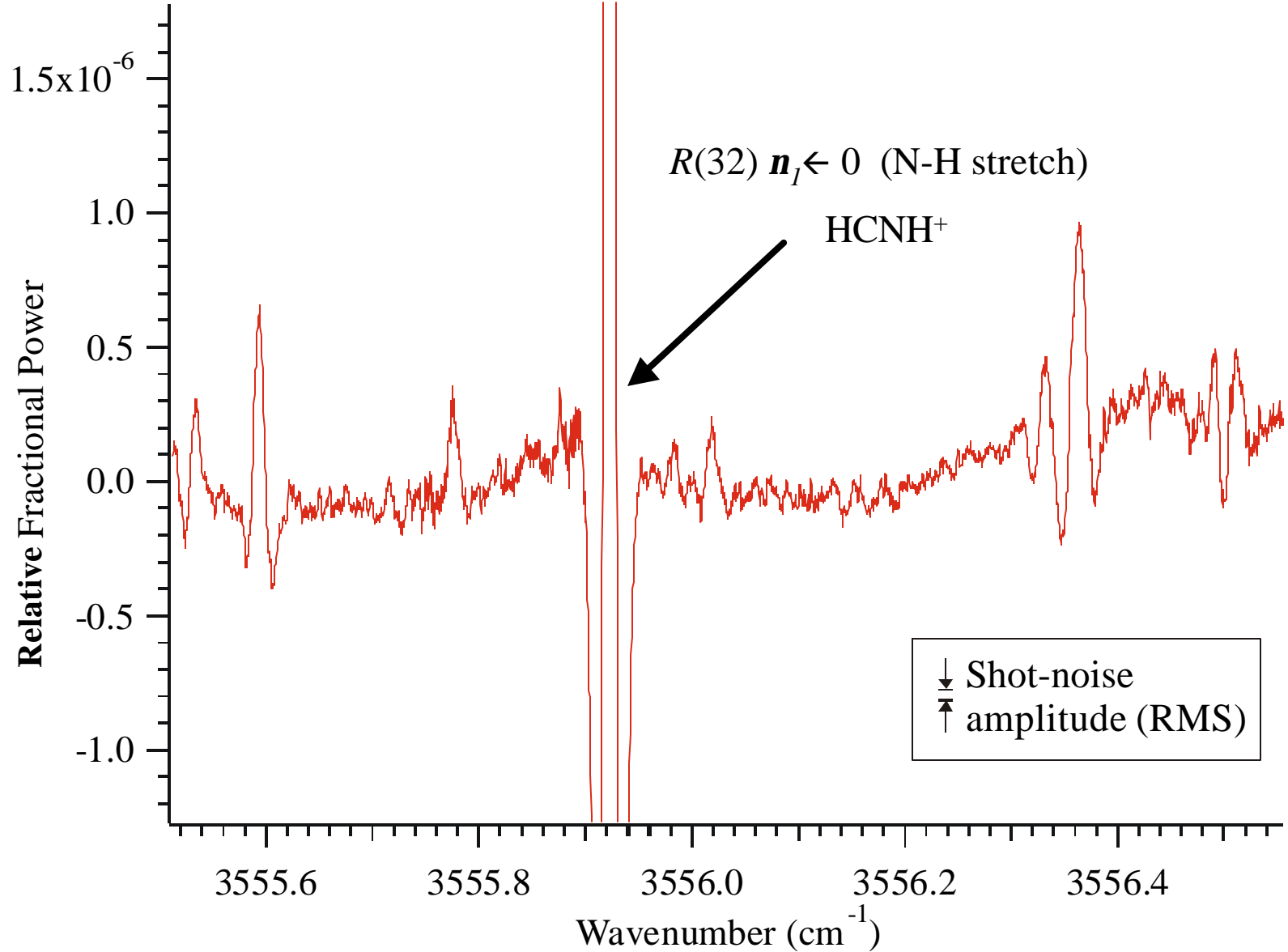


Performance:

- Bandwidth ~ 1 MHz
- $3000\text{--}4200\text{ cm}^{-1} > 1\text{ mW}$
- Scan rates $> 10\text{ cm}^{-1}/\text{hr}$
- Pathlength $\sim 10\text{ m}$
- Detection limit: $\sim 5 \times 10^{-10}\text{ cm}^{-1}\text{Hz}^{-1/2}$

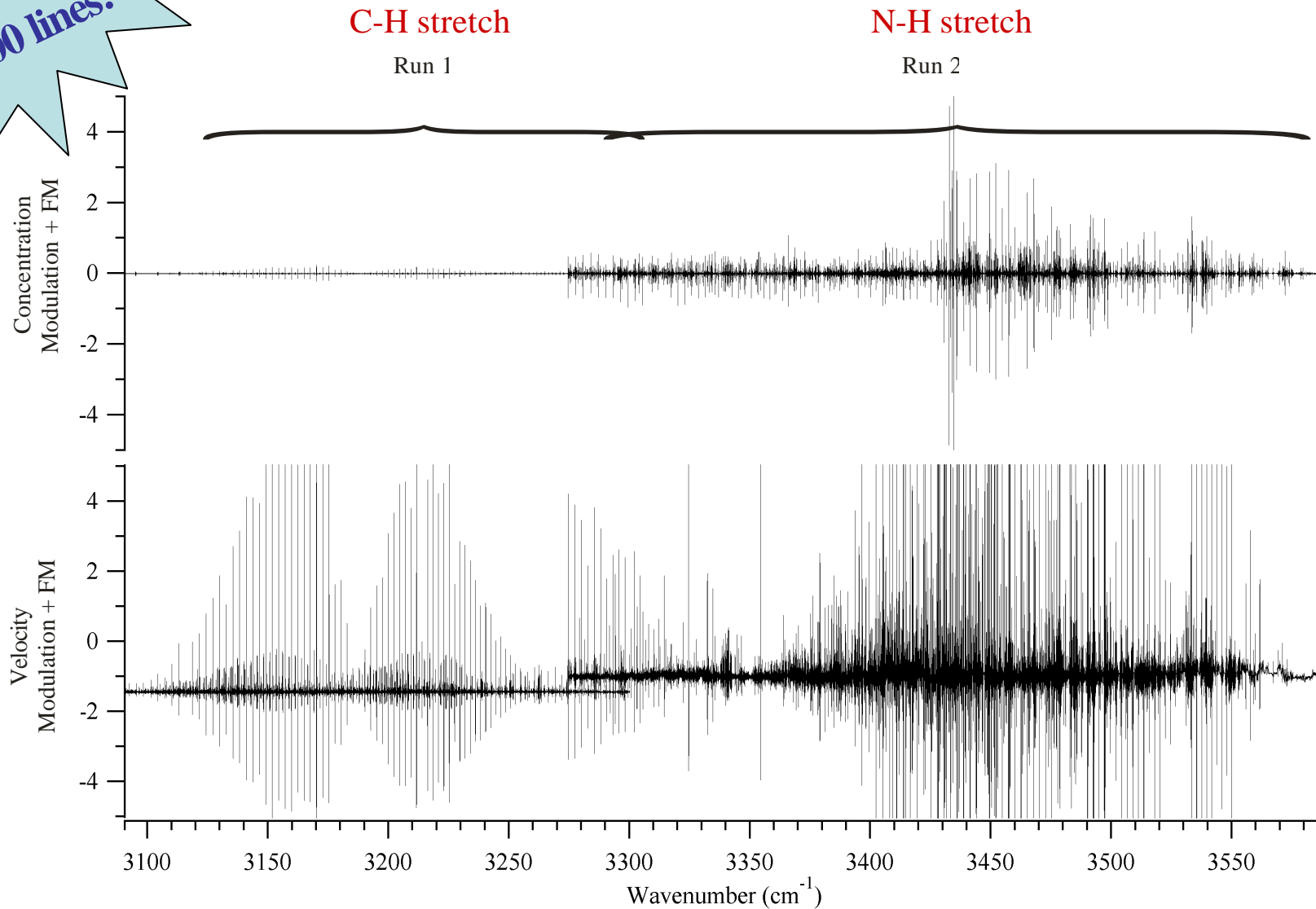
For more details, see WJ10

Performance of Frequency + Velocity Double Modulation

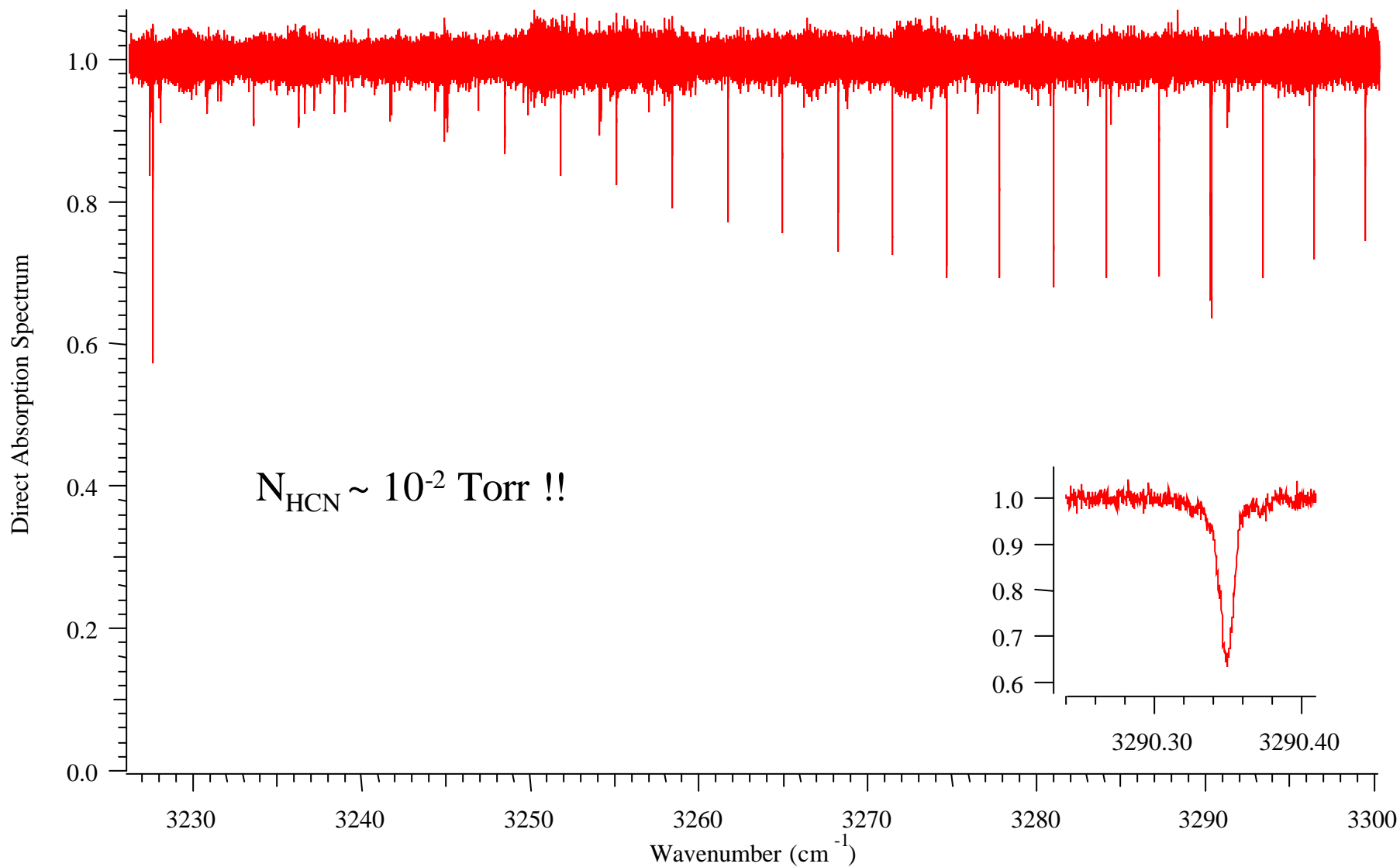


CH₄/N₂/H₂/He Discharge (10:30:45:8000 mTorr)

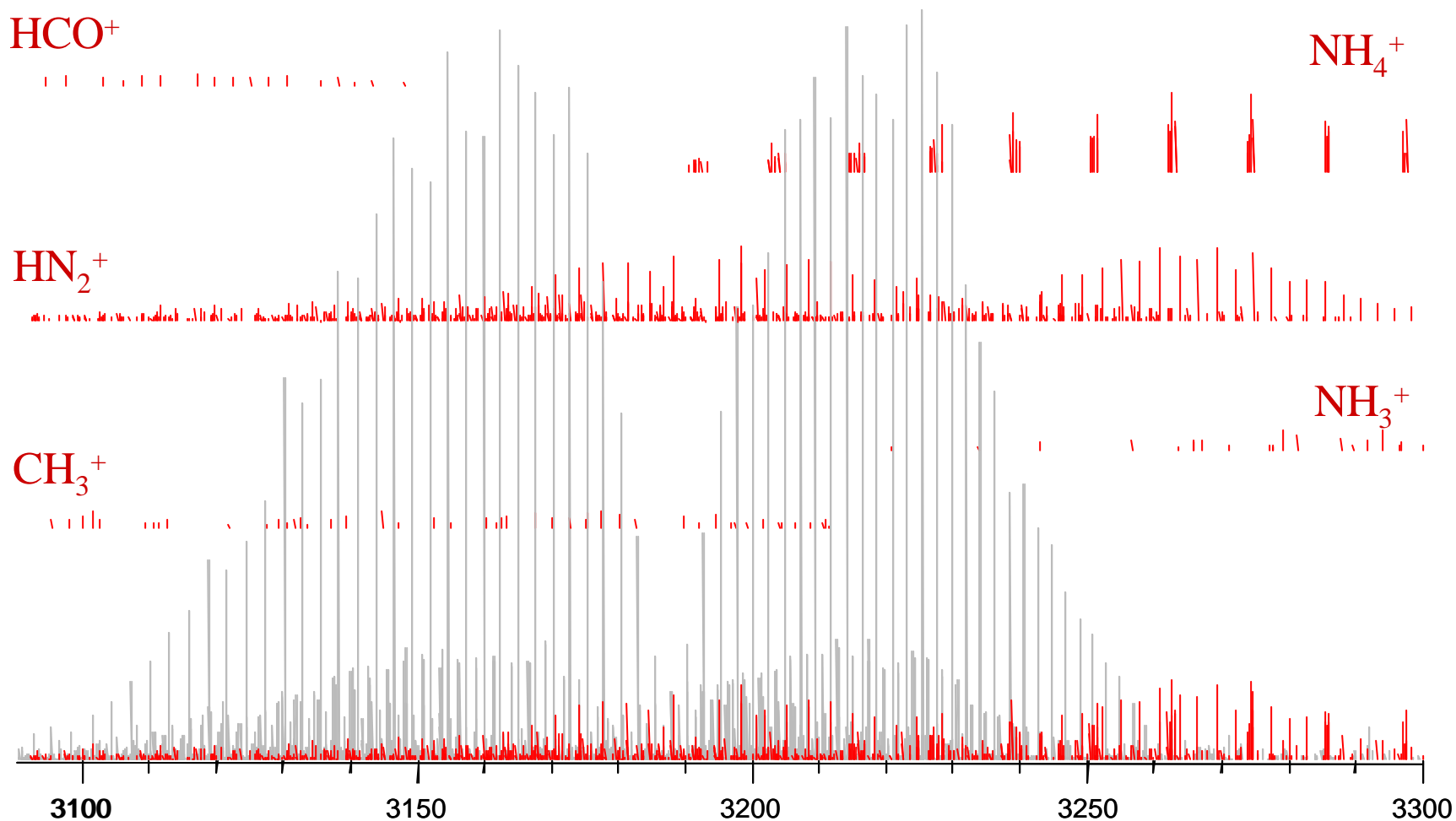
~15,000 lines!



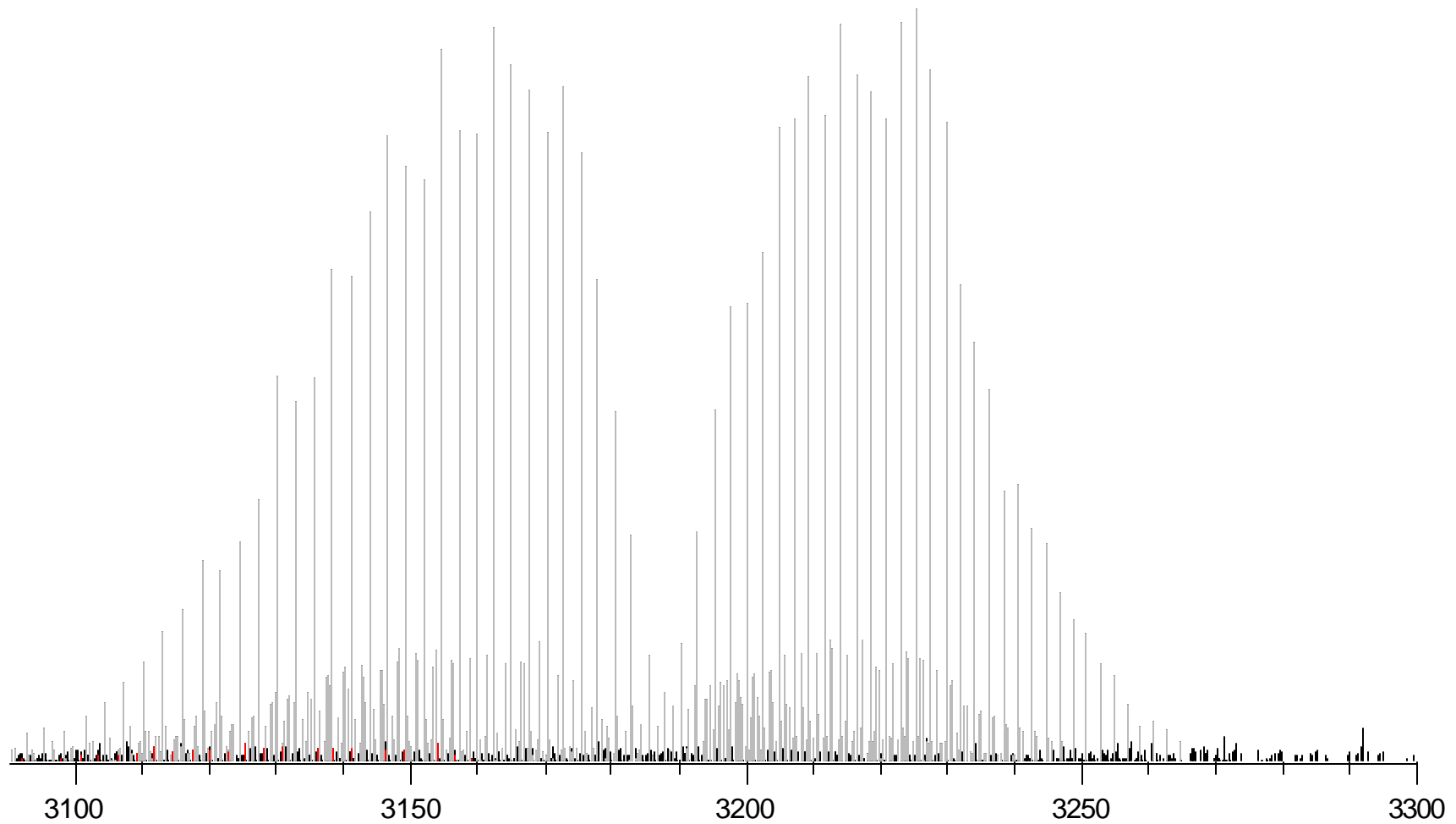
Strong HCN absorption in power spectrum



Infrared Laser Absorption Spectroscopy



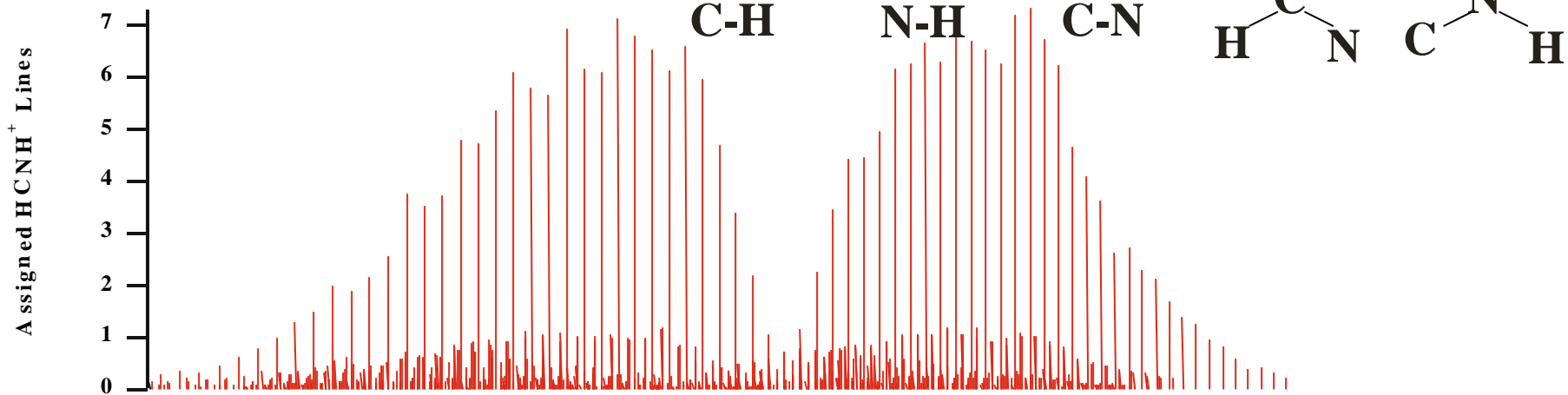
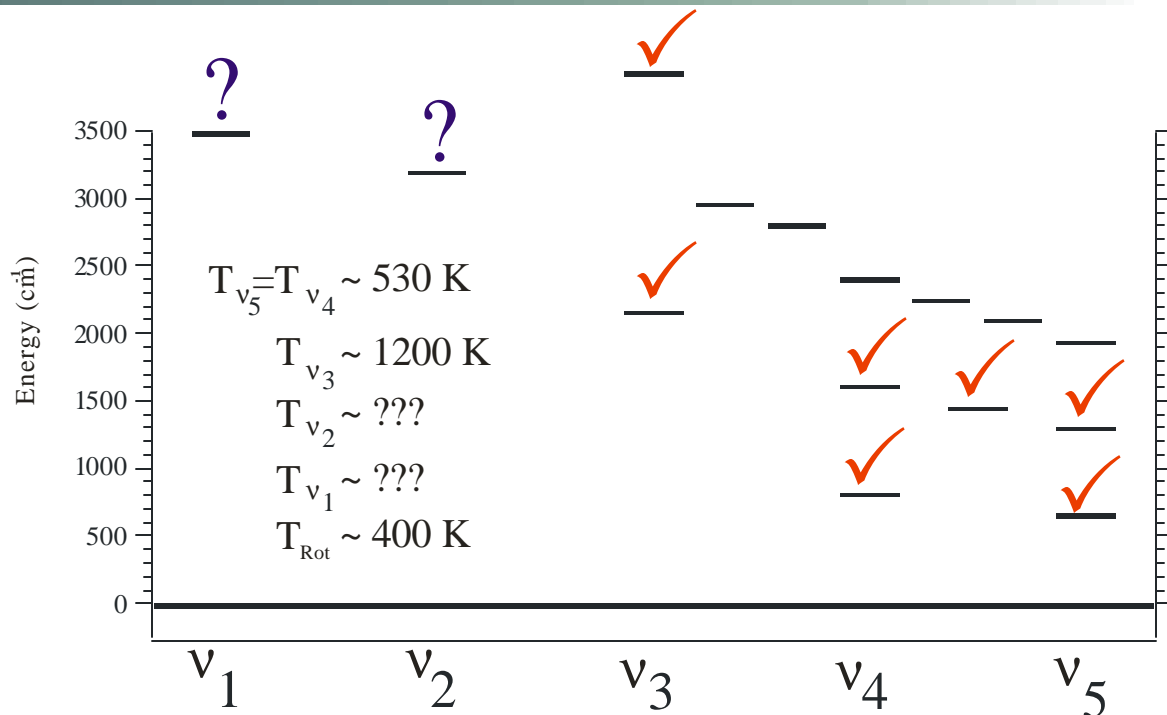
Assignment of the n_2 (C-H) stretch region of HCNH^+



Analysis of the C-H stretch region

~ 650 Lines of HCNH⁺

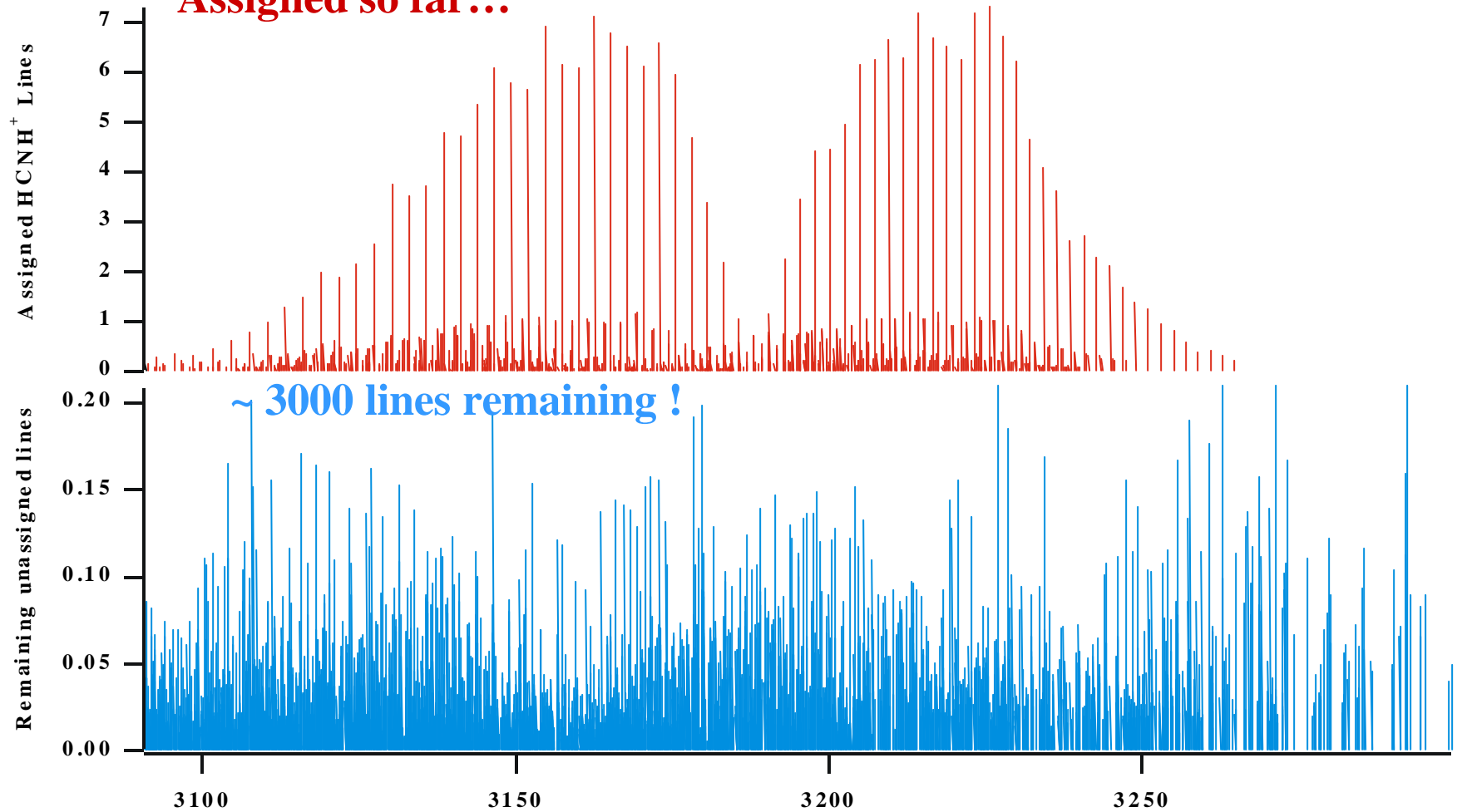
Assigned so far...



Analysis of the C-H stretch region

~ 650 Lines of HCNH⁺

Assigned so far...



Summary of Experiments

- Demonstrated the sensitivity of the new FM+VM technique ($\sim 5 \times 10^{-10} \text{ cm}^{-1} \text{ Hz}^{-1/2}$)
- Recorded $\sim 15,000$ spectral lines observed ($>10,000$ new!)
- Assigned ~ 650 lines (8 bands) to the C-H (ν_2) stretch of HCNH+... more to come
- >10 bands will be assignable in N-H (ν_1) stretch region
- HCN, HN_2^+ , and HCNH^+ strongest species, very highly excited
- Also present HCO^+ , HeH^+ , NH_3^+ , CH_3^+ , NH_4^+
- Not observed: CH_2^+ , C_2H_3^+ , C_2H_2^+ , H_2O^+ , H_3O^+ , H_3^+
- Other unknown species **must** be present
- Analysis of this data will likely take several years