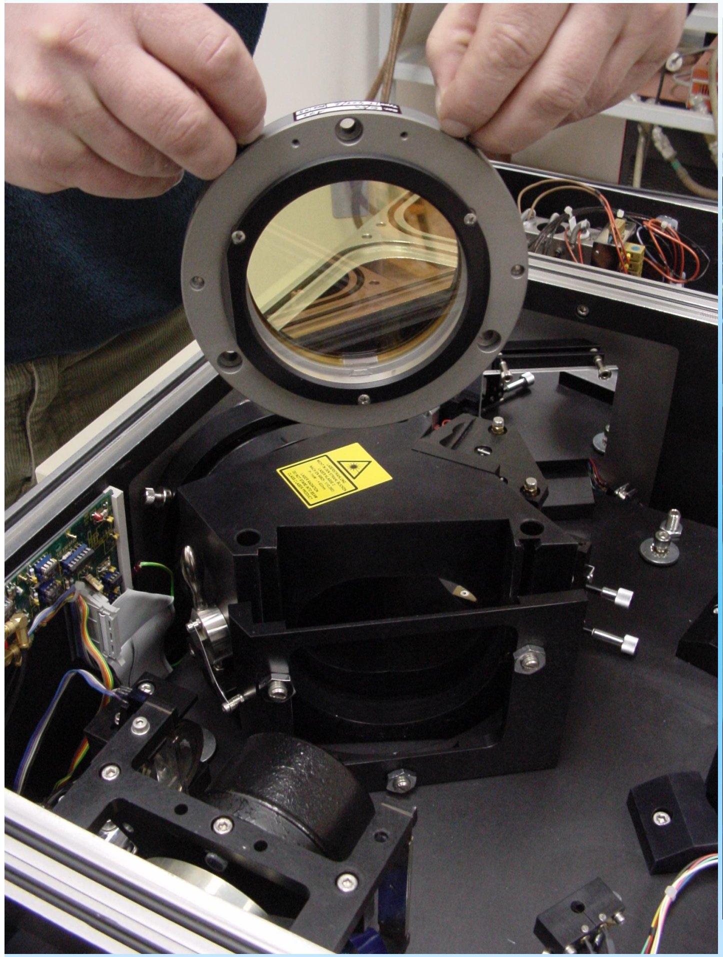
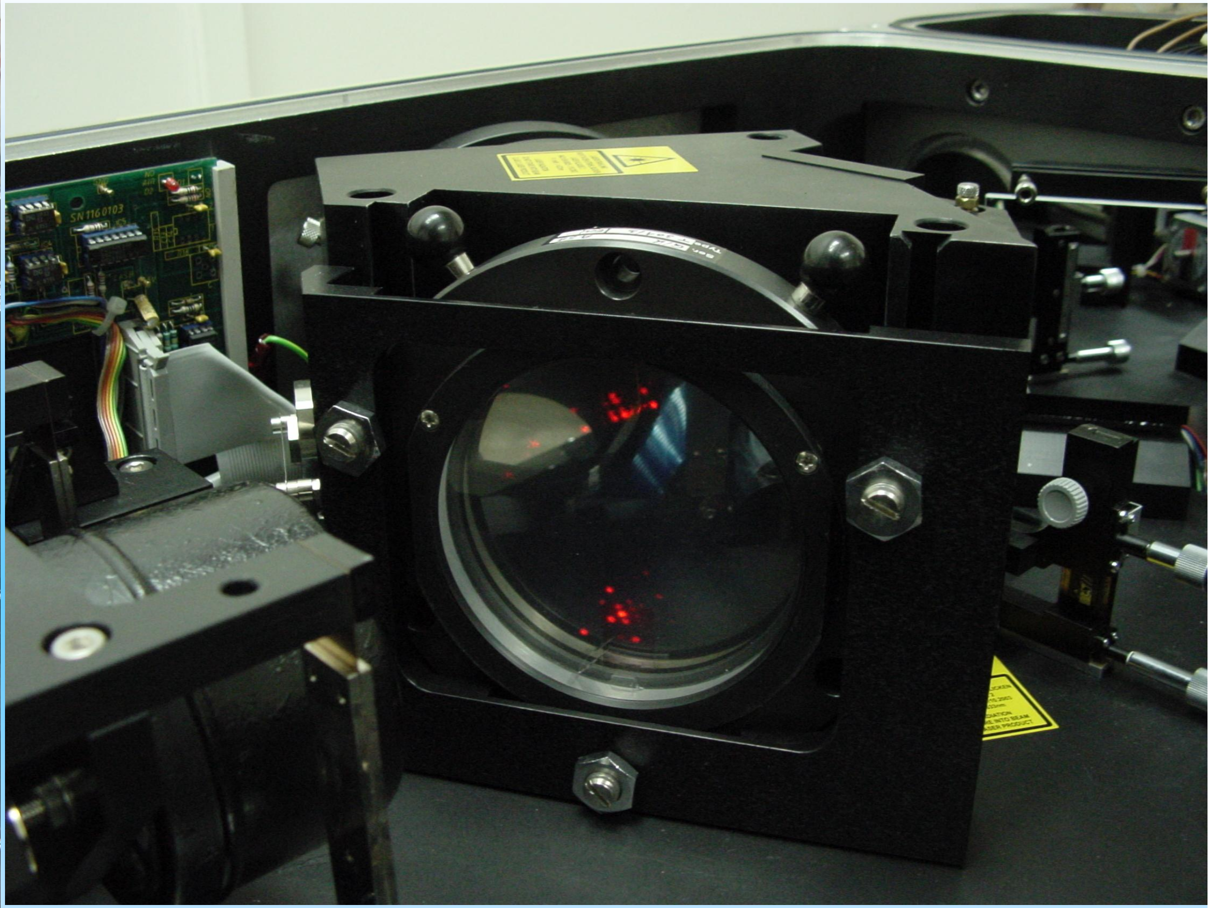
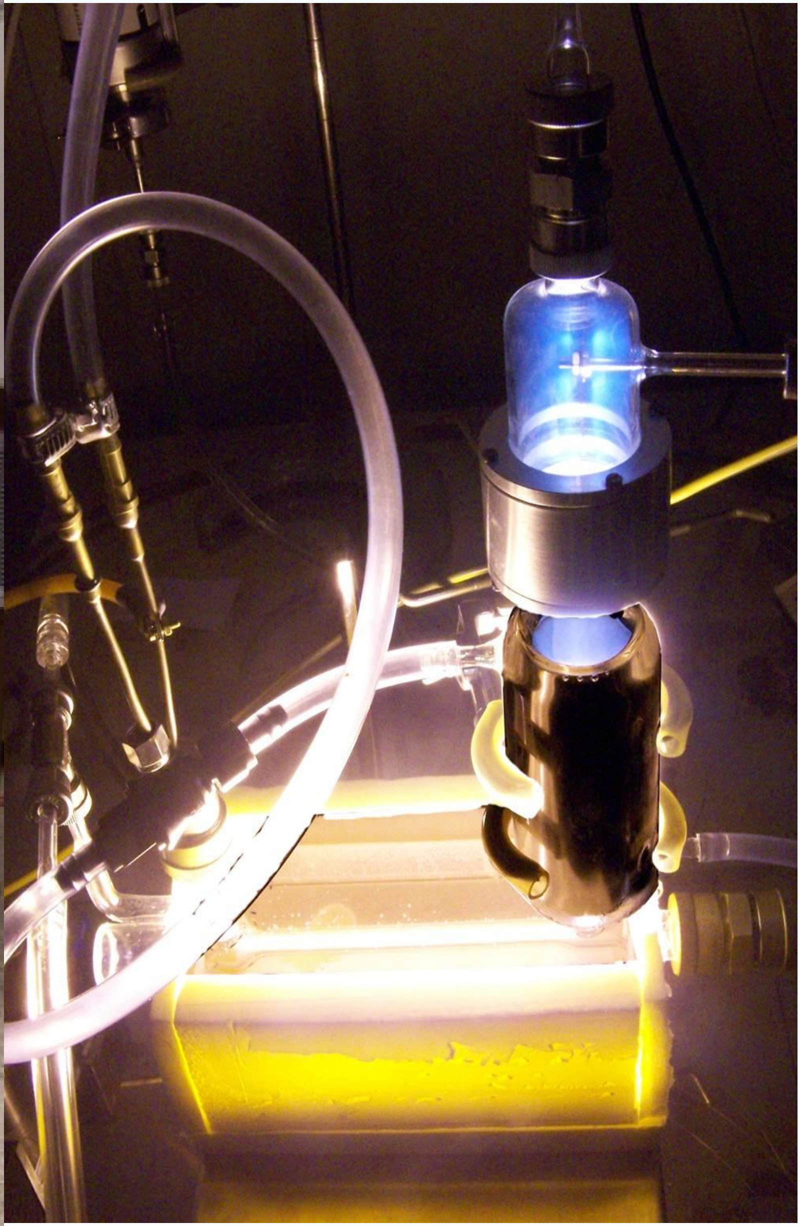
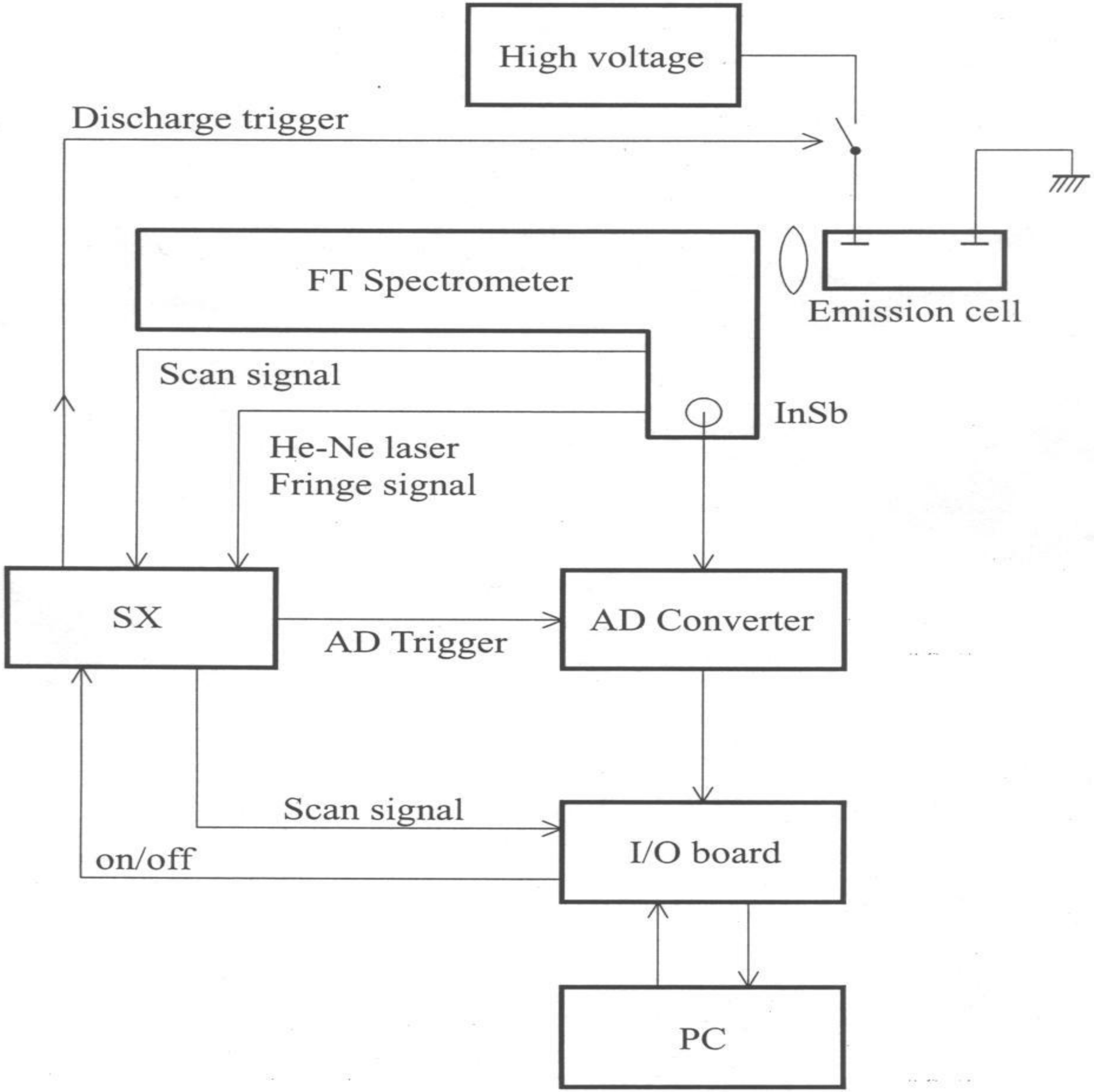
Svatopluk Civiġ

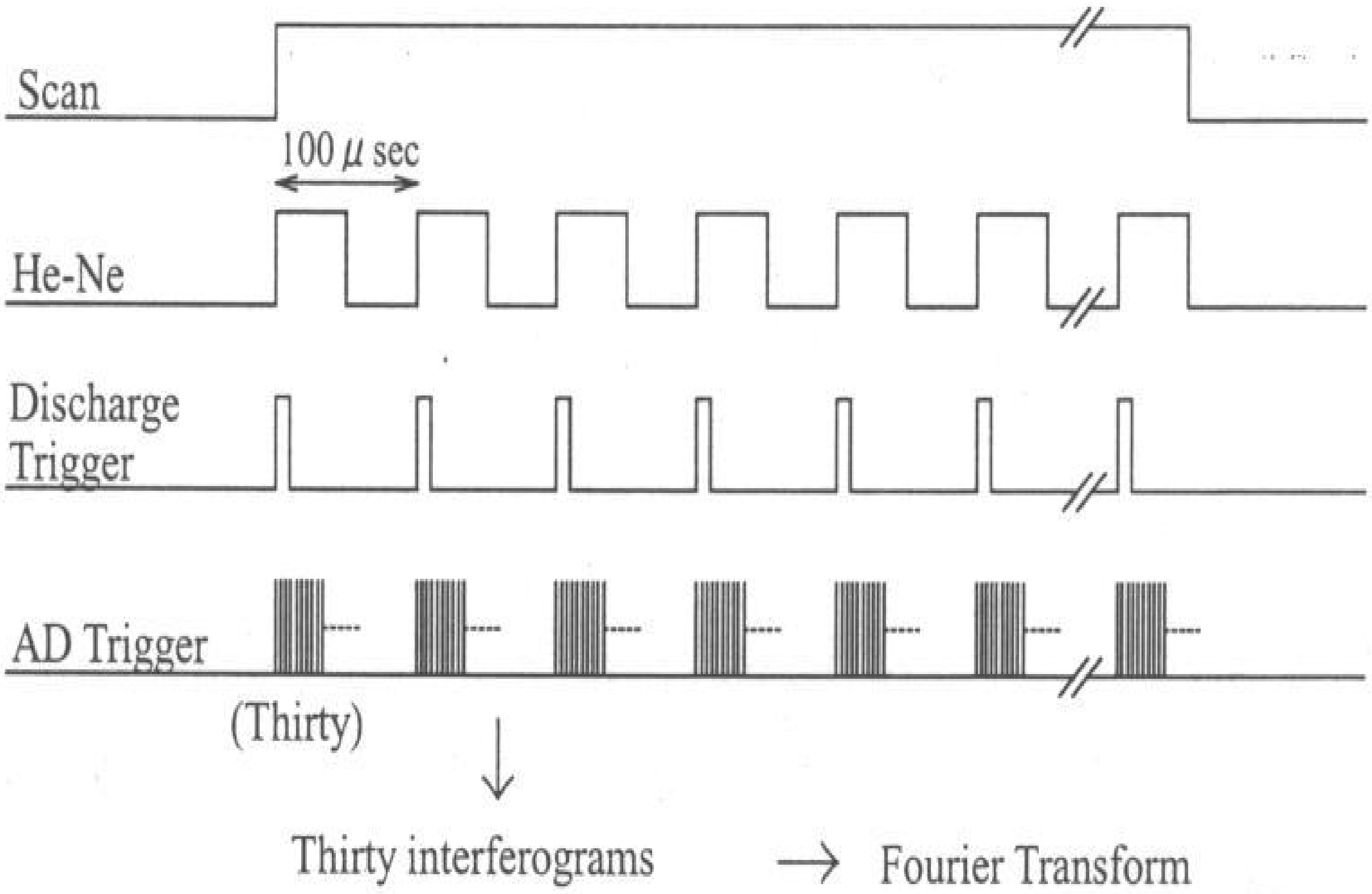
ĂĻasovĐrozliġená infraļervená emisní spektroskopie s Fourierovou transformací a její aplikace v pulzních výbojích a laserové ablaci kovŢñ.



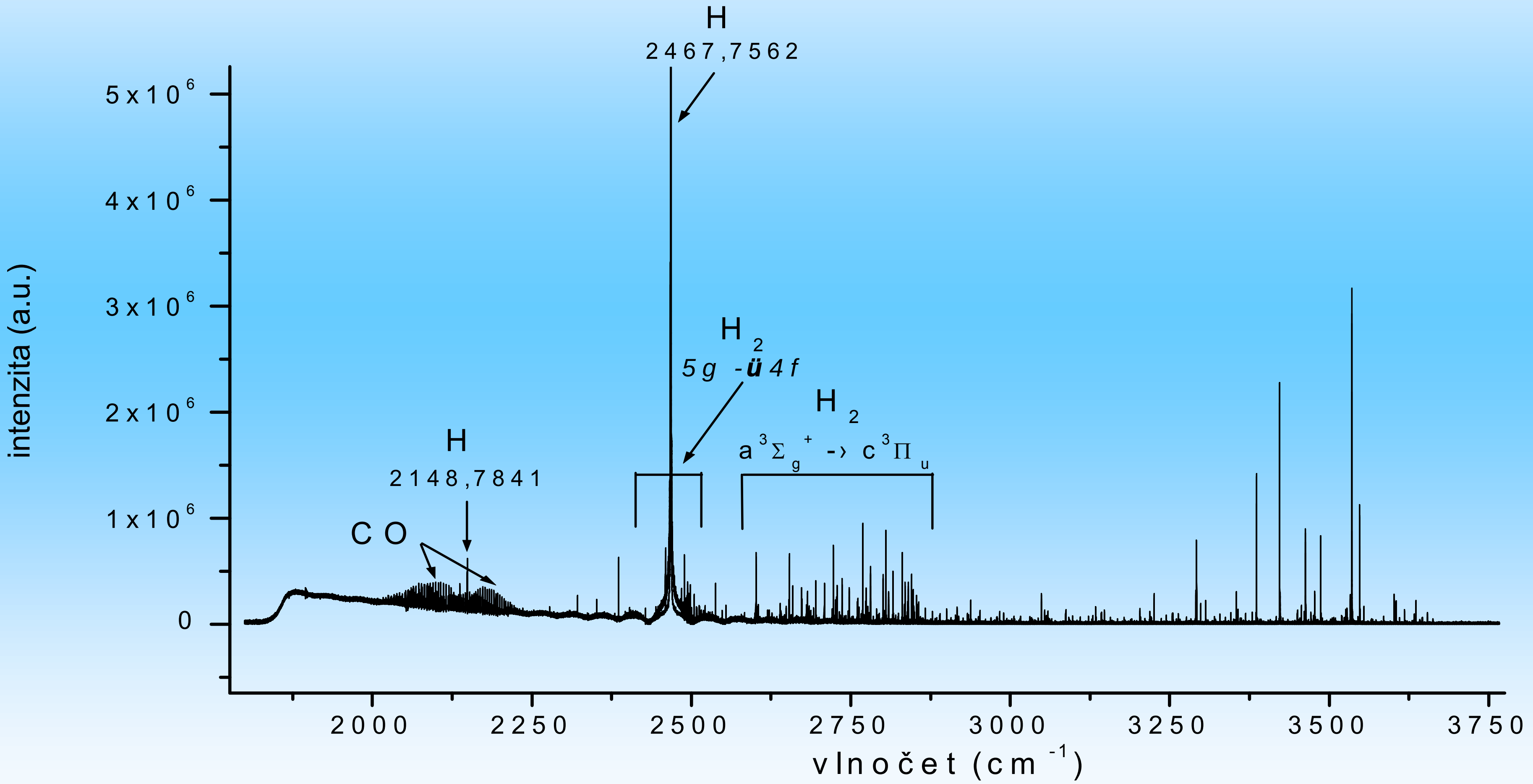

SN 1160103



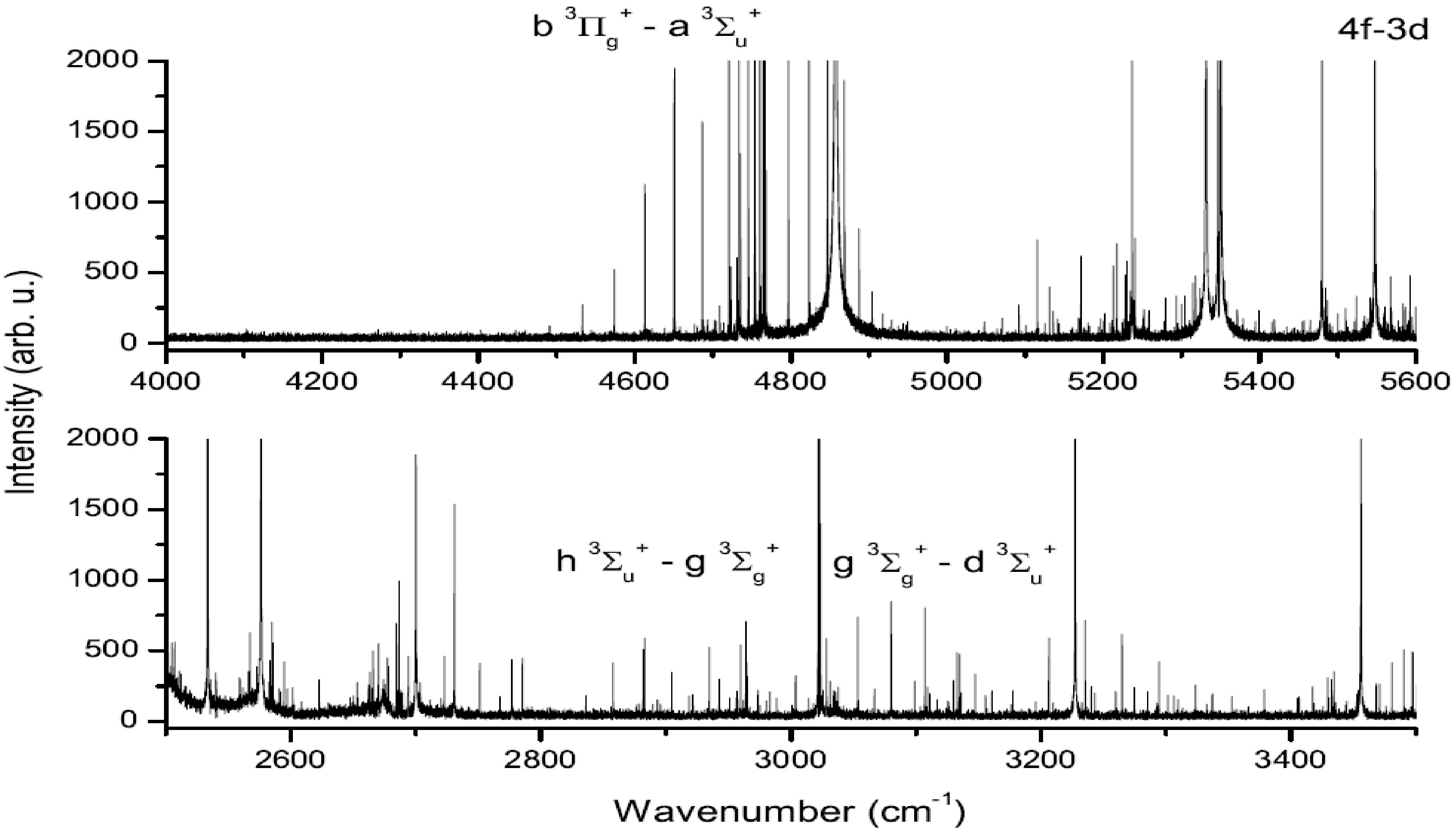

High voltage
Discharge trigger
FT Spectrometer
Emission cell
Scan signal
InSb
He-Ne laser
Fringe signal
SX
AD Trigger
AD Converter
Scan signal
on/off
I/O board
PC


Scan
100 μ sec
He-Ne
Discharge
Trigger
AD Trigger
(Thirty)
Thirty interferograms
→ Fourier Transform

Výboj v čistém vodíku



Helium discharge



Chemical Physics Letters **383** (2004) 256–260

He discharge plasma

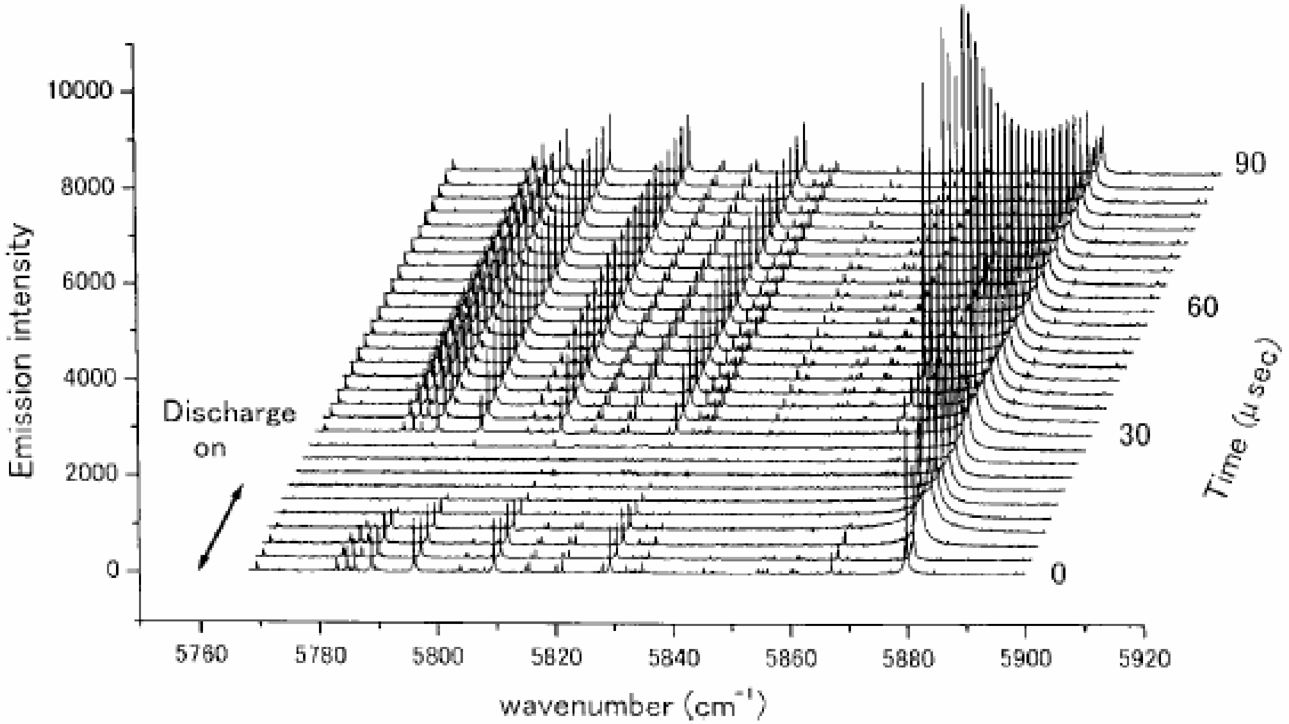


Fig. 1. A portion of the time-resolved spectrum observed by a pulsed discharge in He with a pressure of 1.33 kPa (10 Torr). The discharge was applied in the interval of 0–20 μs with a peak current of 0.5 A. The strongest peak belongs to the atomic He line (4d–3p). Other lines pertain to 4f–3d transitions of He_2.

He_2

$$He^m + He^m \rightarrow He^+ + He + e \qquad (1)$$

$$He^+ + He + M \rightarrow He_2^+ + M \qquad (2)$$

$$He_2^+ + e \rightarrow He_2^* + h\nu, \qquad (3)$$

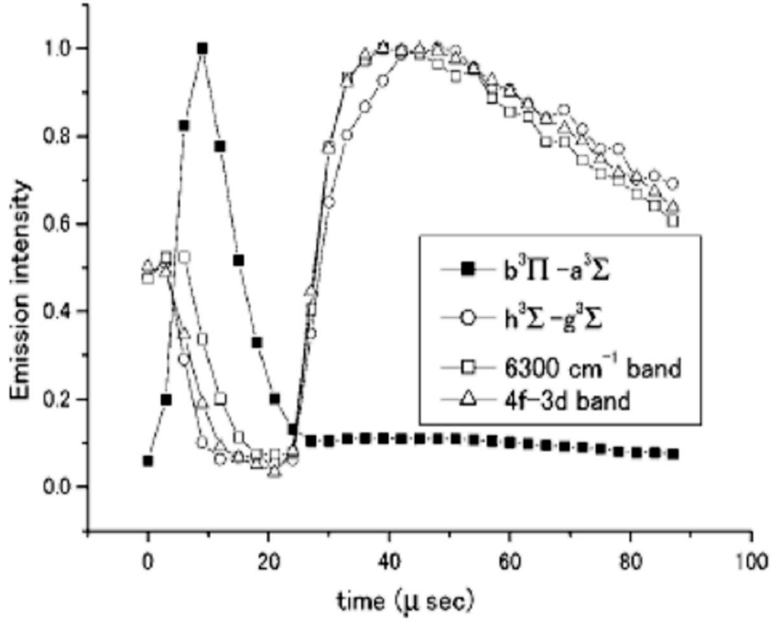


Fig. 3. Observed time profiles of emission intensities of He_2. Abscissa values show normalized intensities of the emission lines. The discharge conditions are as given in the caption of Fig. 1.

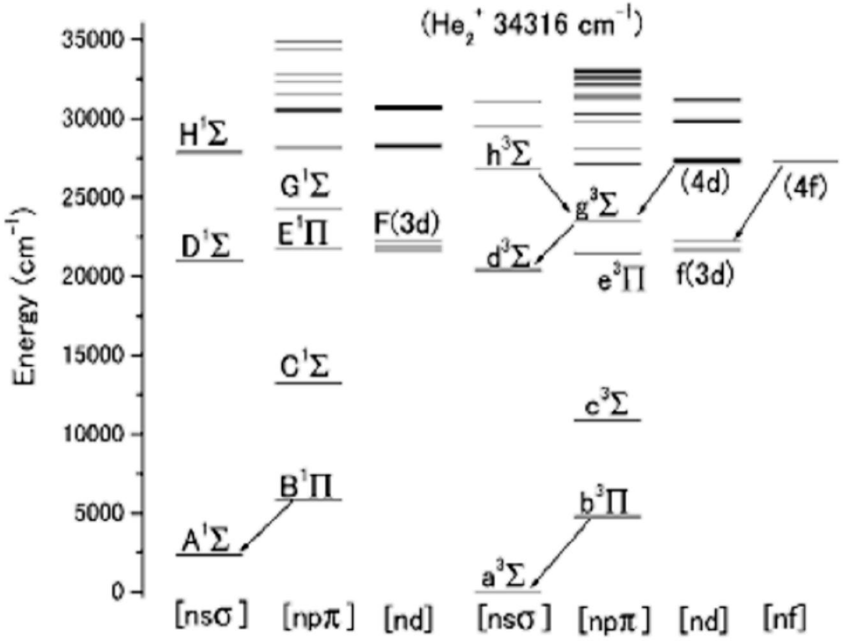
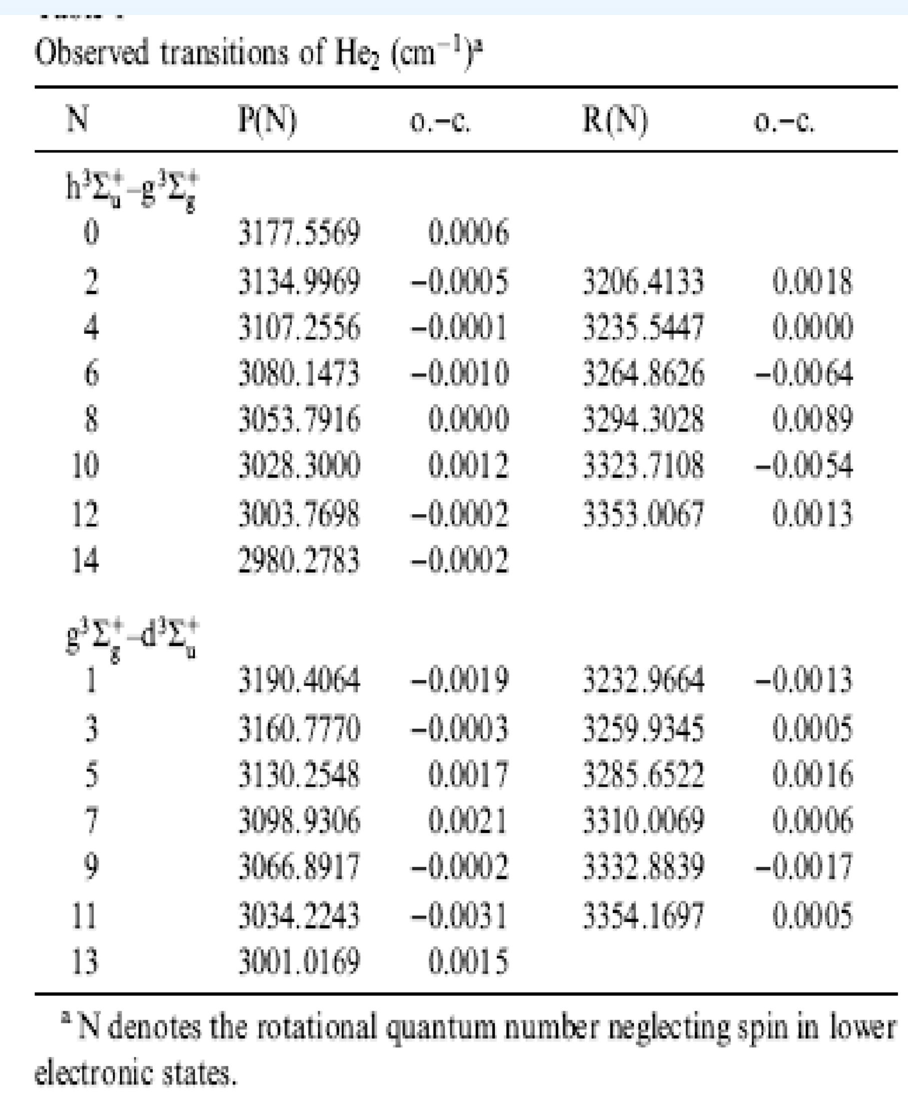


Fig. 4. Energy level diagram of He_2. The transitions observed in the present study are shown by arrows. The energy values are represented relative to the $a^3\Sigma_u^+ v = 0$ state. $n(>1)$ is the principal quantum number in a united atom molecular orbital designation. The ionization limit to He_2^+ is 34 316 cm^{-1}.

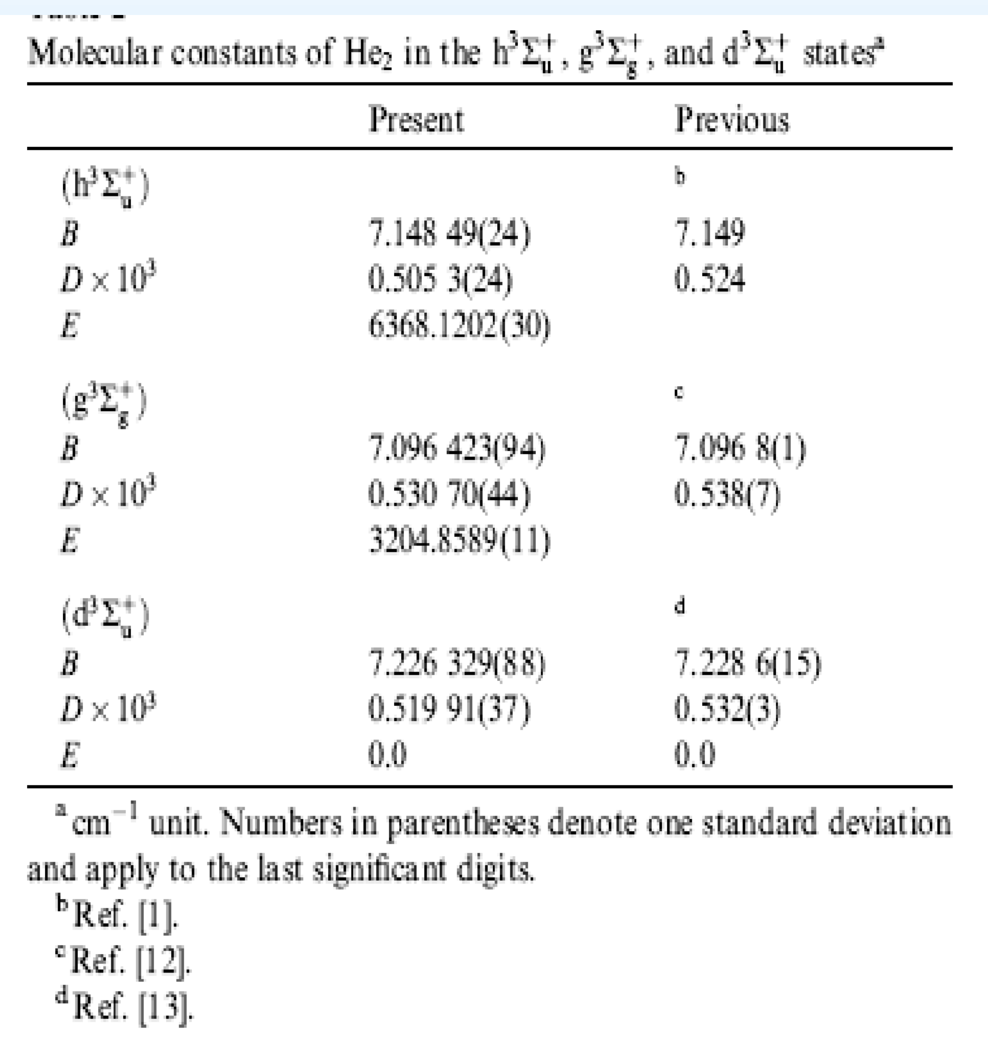
He_2



Observed transitions of He_2 (cm^{-1})[a]

N	P(N)	o.−c.	R(N)	o.−c.
$h^3\Sigma_u^+-g^3\Sigma_g^+$				
0	3177.5569	0.0006		
2	3134.9969	−0.0005	3206.4133	0.0018
4	3107.2556	−0.0001	3235.5447	0.0000
6	3080.1473	−0.0010	3264.8626	−0.0064
8	3053.7916	0.0000	3294.3028	0.0089
10	3028.3000	0.0012	3323.7108	−0.0054
12	3003.7698	−0.0002	3353.0067	0.0013
14	2980.2783	−0.0002		
$g^3\Sigma_g^+-d^3\Sigma_u^+$				
1	3190.4064	−0.0019	3232.9664	−0.0013
3	3160.7770	−0.0003	3259.9345	0.0005
5	3130.2548	0.0017	3285.6522	0.0016
7	3098.9306	0.0021	3310.0069	0.0006
9	3066.8917	−0.0002	3332.8839	−0.0017
11	3034.2243	−0.0031	3354.1697	0.0005
13	3001.0169	0.0015		

[a] N denotes the rotational quantum number neglecting spin in lower electronic states.



Molecular constants of He_2 in the $h^3\Sigma_u^+$, $g^3\Sigma_g^+$, and $d^3\Sigma_u^+$ states[a]

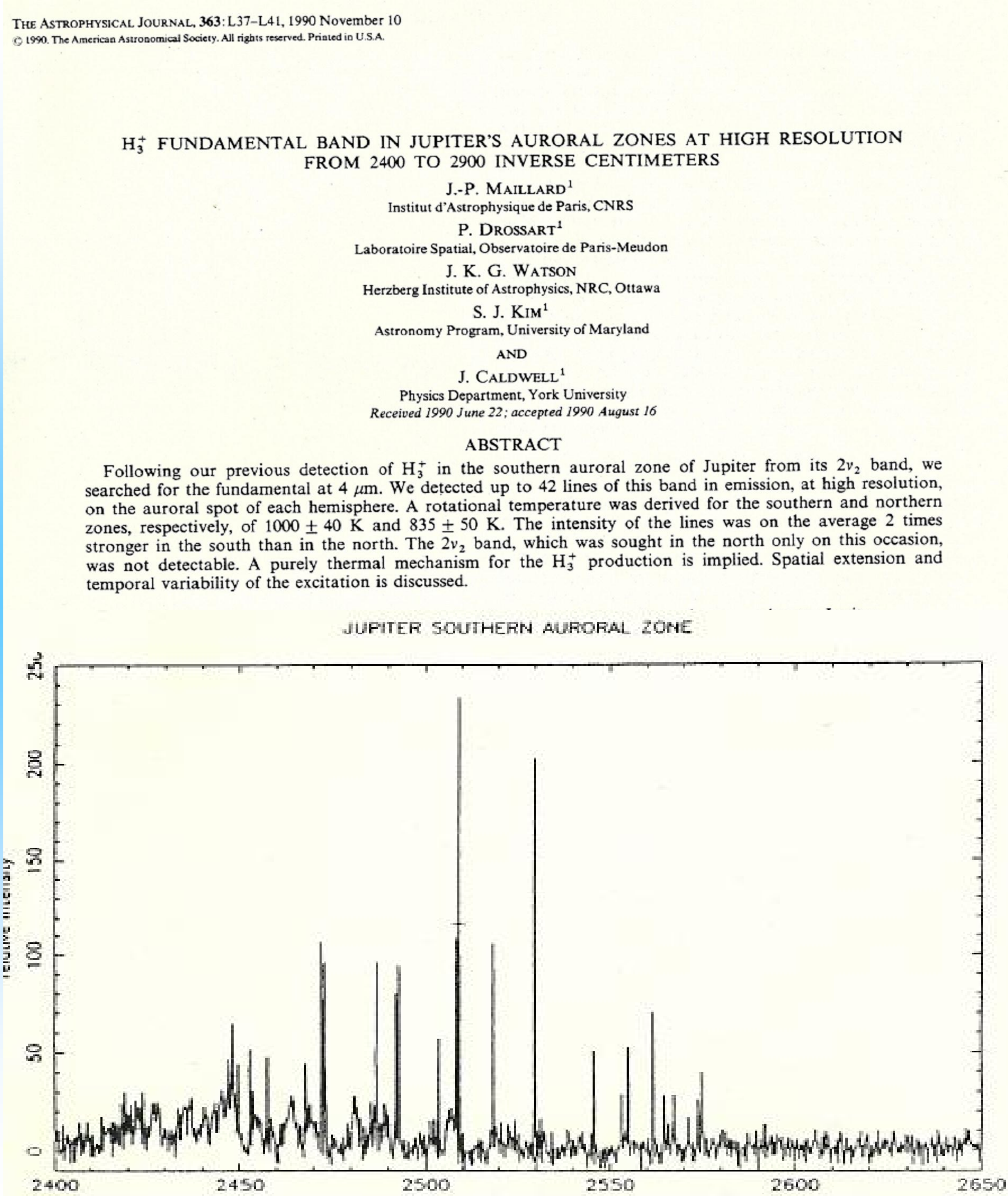
	Present	Previous
($h^3\Sigma_u^+$)		[b]
B	7.148 49(24)	7.149
$D \times 10^3$	0.505 3(24)	0.524
E	6368.1202(30)	
($g^3\Sigma_g^+$)		[c]
B	7.096 423(94)	7.096 8(1)
$D \times 10^3$	0.530 70(44)	0.538(7)
E	3204.8589(11)	
($d^3\Sigma_u^+$)		[d]
B	7.226 329(88)	7.228 6(15)
$D \times 10^3$	0.519 91(37)	0.532(3)
E	0.0	0.0

[a] cm^{-1} unit. Numbers in parentheses denote one standard deviation and apply to the last significant digits.

[b] Ref. [1].

[c] Ref. [12].

[d] Ref. [13].



THE ASTROPHYSICAL JOURNAL, **363**: L37–L41, 1990 November 10

H_3^+ FUNDAMENTAL BAND IN JUPITER'S AURORAL ZONES AT HIGH RESOLUTION FROM 2400 TO 2900 INVERSE CENTIMETERS

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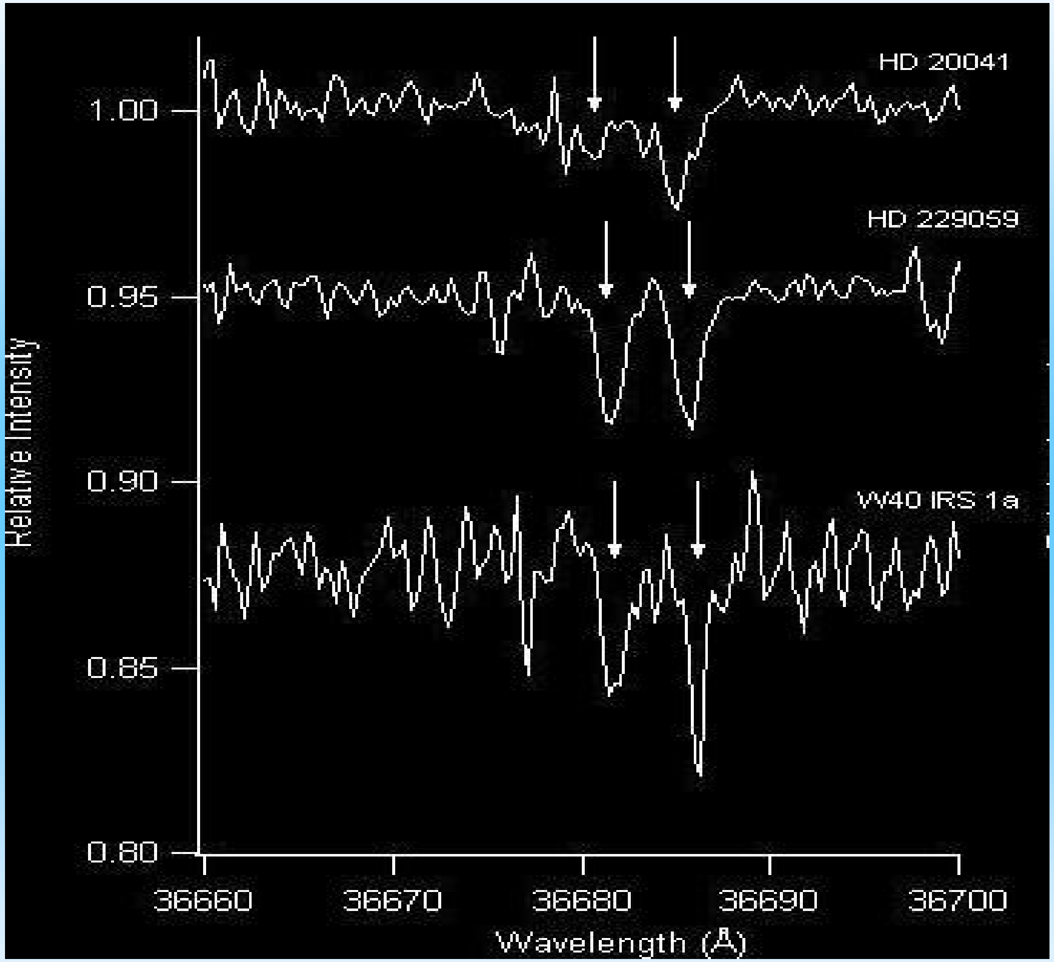
Received 1990 June 22; accepted 1990 August 16

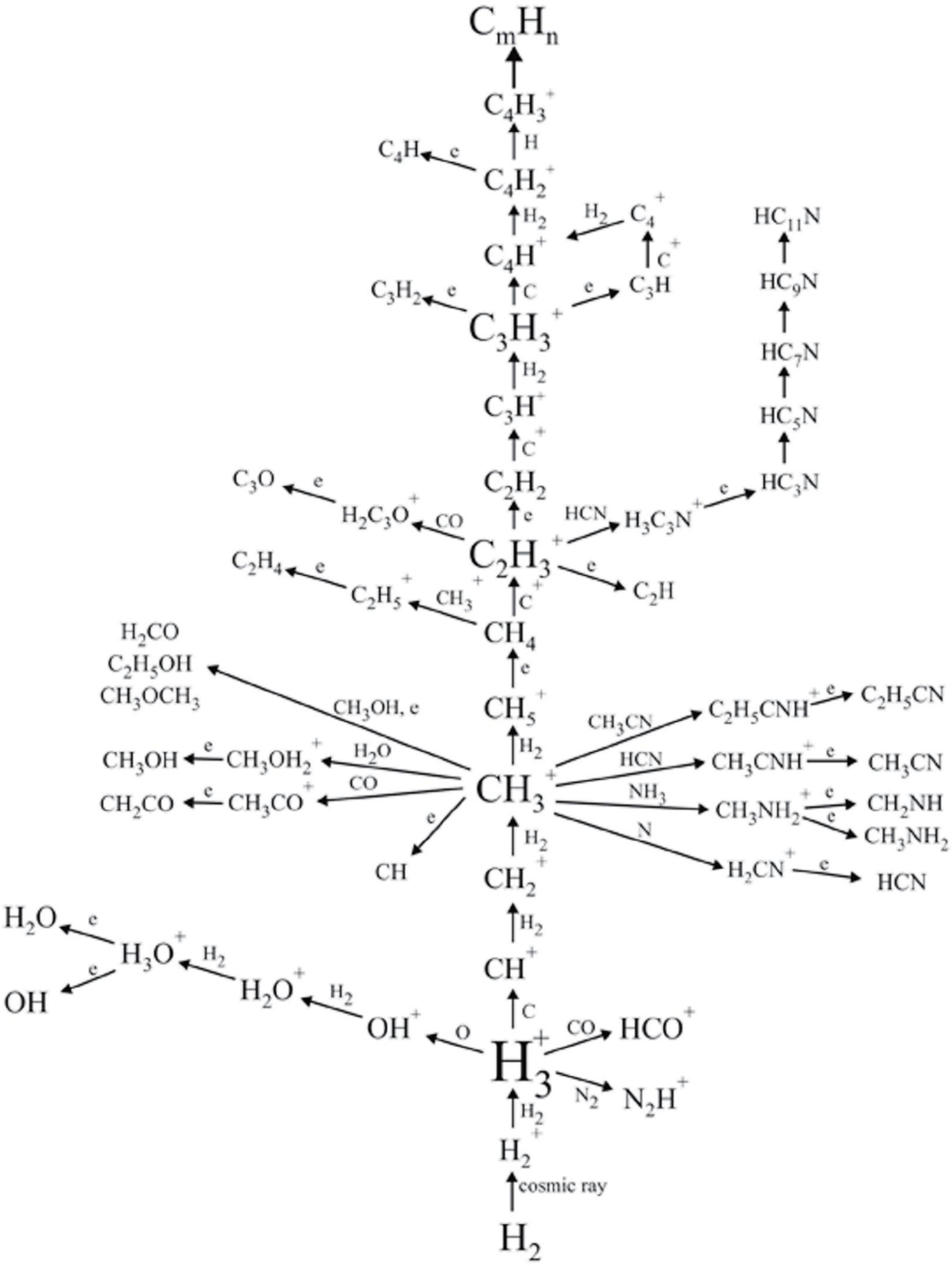
ABSTRACT

Following our previous detection of H_3^+ in the southern auroral zone of Jupiter from its $2\nu_2$ band, we searched for the fundamental at 4 μm. We detected up to 42 lines of this band in emission, at high resolution, on the auroral spot of each hemisphere. A rotational temperature was derived for the southern and northern zones, respectively, of 1000 ± 40 K and 835 ± 50 K. The intensity of the lines was on the average 2 times stronger in the south than in the north. The $2\nu_2$ band, which was sought in the north only on this occasion, was not detectable. A purely thermal mechanism for the H_3^+ production is implied. Spatial extension and temporal variability of the excitation is discussed.

H_3^+ is extremely important to the chemistry of interstellar clouds. This is because H_3^+ willingly donates its extra proton to a variety of collision partners, thus laying the foundation for a large network of ion-molecule reactions.



Spectra of three interstellar clouds showing absorption lines due to the R(1,1)u and R(1,0) transitions of H_3^+. Arrows indicate the expected positions of the absorption features from previous measurements of the interstellar gas velocity.



Why Molecular Ions?

As illustrated in the reaction chart to the left, molecular ions are responsible for driving the chemistry resulting in the formation of complex organic/prebiotic molecules. Detecting these ions in the ISM will lead to a better understanding of chemical evolution in space.

Why High-Resolution Spectroscopy?

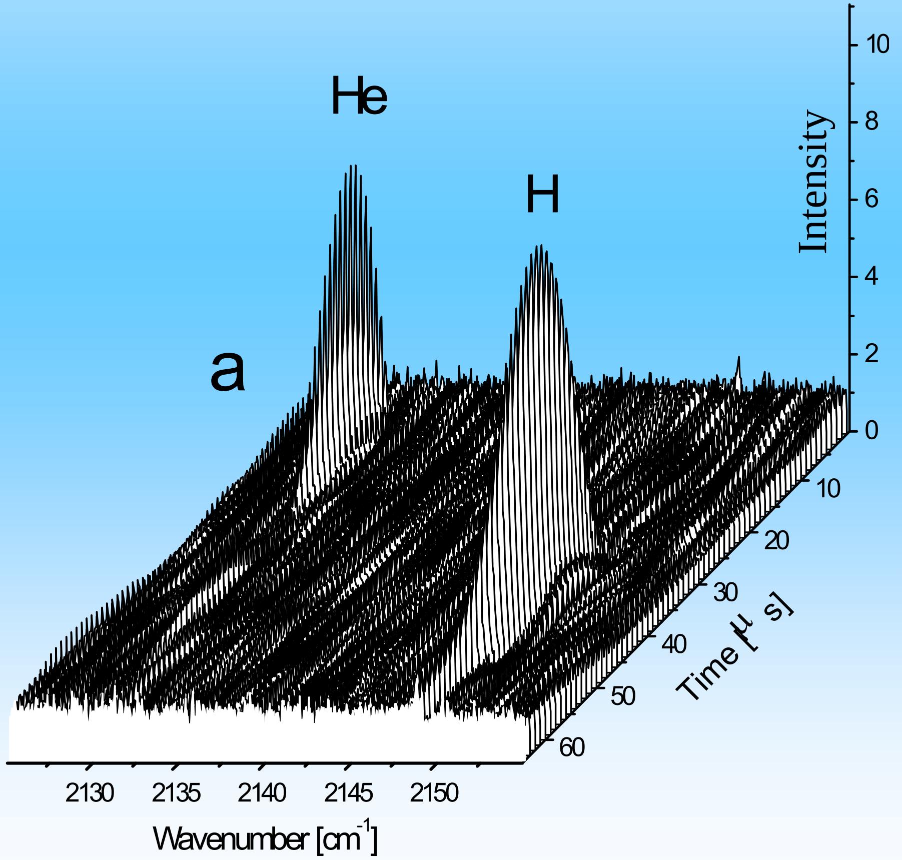
High-resolution spectra serve as molecular fingerprints, enabling astronomical searches for these species in the ISM, planetary atmospheres, and circumstellar environments.

Why Infrared Spectroscopy?

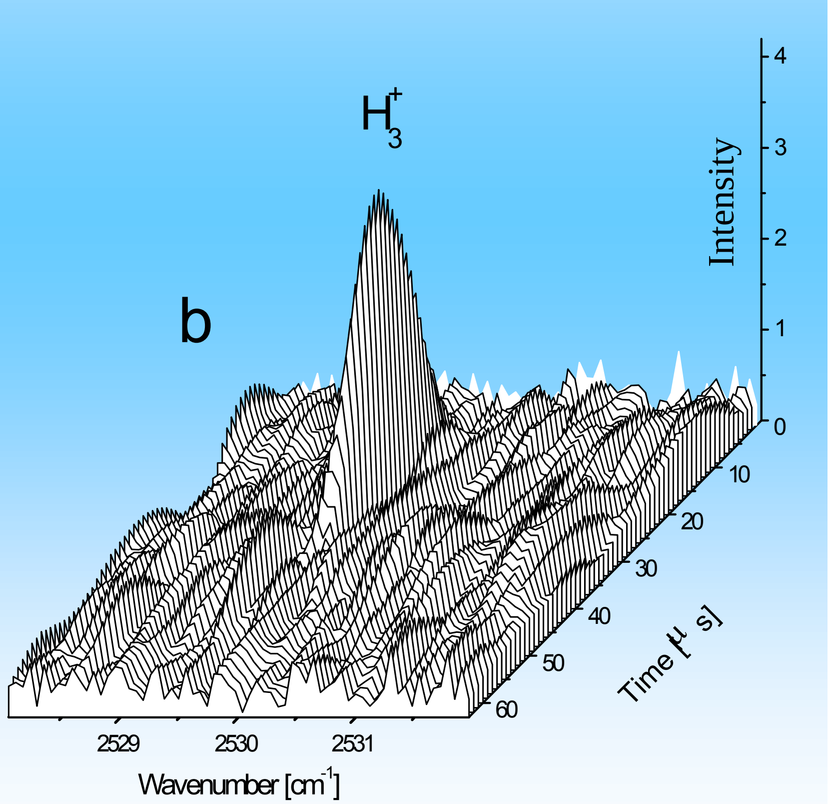
Infrared frequencies can be used to search for molecules without a permanent dipole (precluding microwave spectroscopy/radio astronomy), and can also be used to derive pure rotational transition frequencies of species which do contain a permanent dipole.

He + H_2 discharge plasma

He + H



H_3^+



$He \longrightarrow \ldots \longrightarrow He^*$ Excitation in a discharge

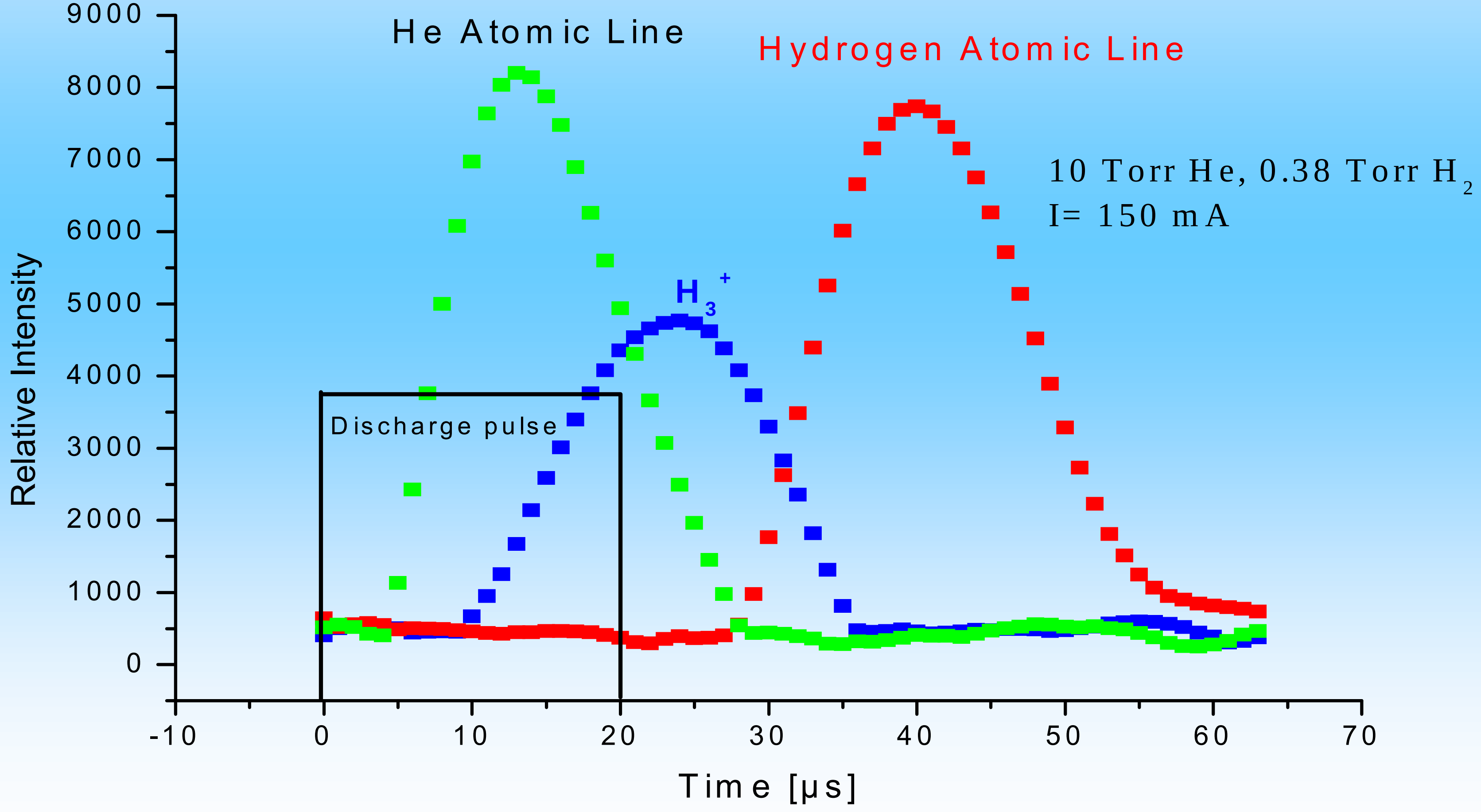
$He^* + H_2 \longrightarrow H_2^+ + e^-$ Penning ionization

$H_2^+ + H_2 \longrightarrow H_3^+ + H$ Formation of H_3^+

Electron recombination

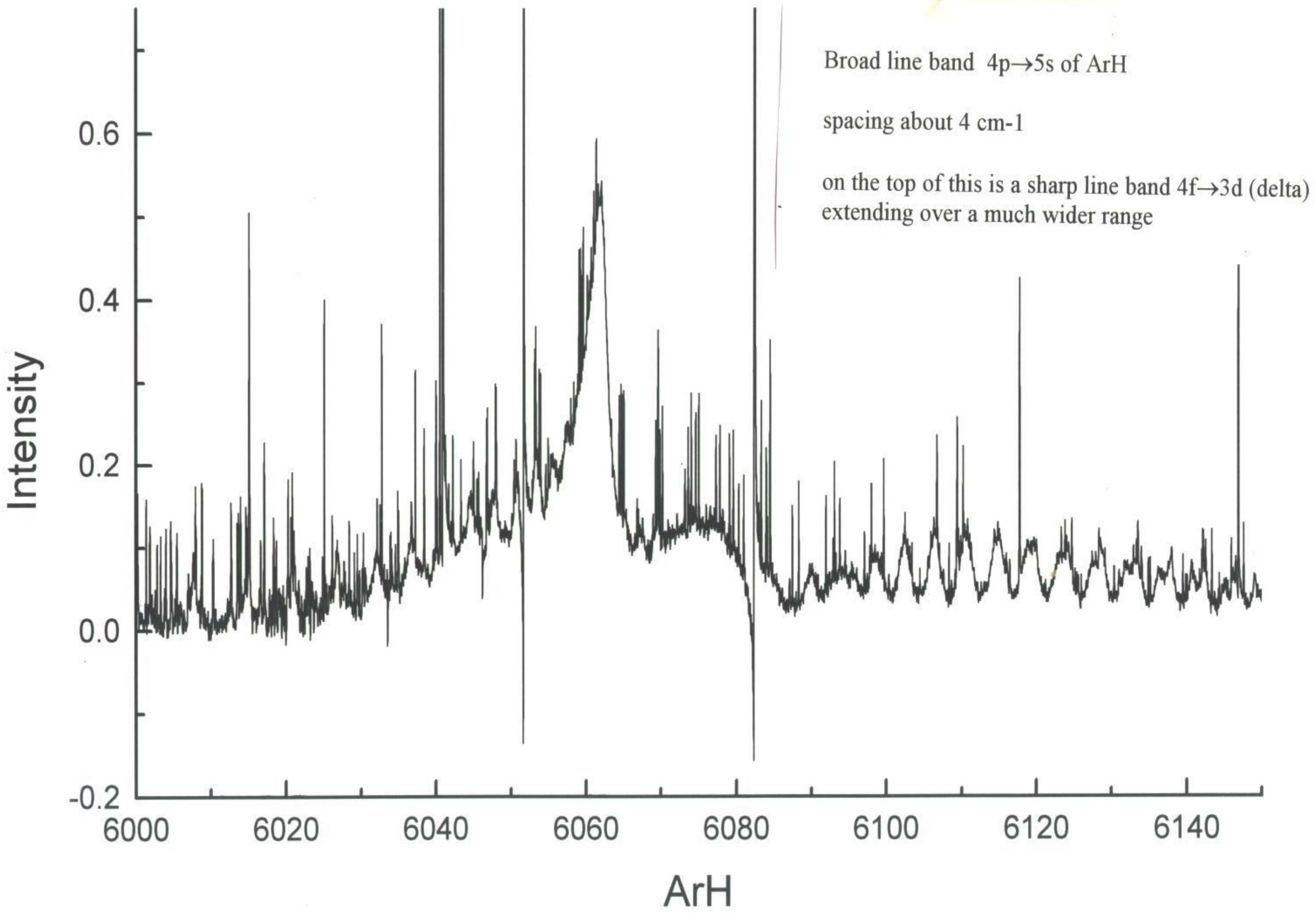
$H_3^+ + e^- \longrightarrow H_2(X^1\Sigma_g^+, vJ) + H(1s),$ $\Delta E = 9.2$ eV electron recombination

$\longrightarrow H(1s) + H(1s)' + H(1s).$ $\Delta E = 4.8$ eV



S. Civis, P. Kubat, S. Nishida, K. Kawaguchi, ***Chemical Physics Letters***, 418 (2006) 448–453

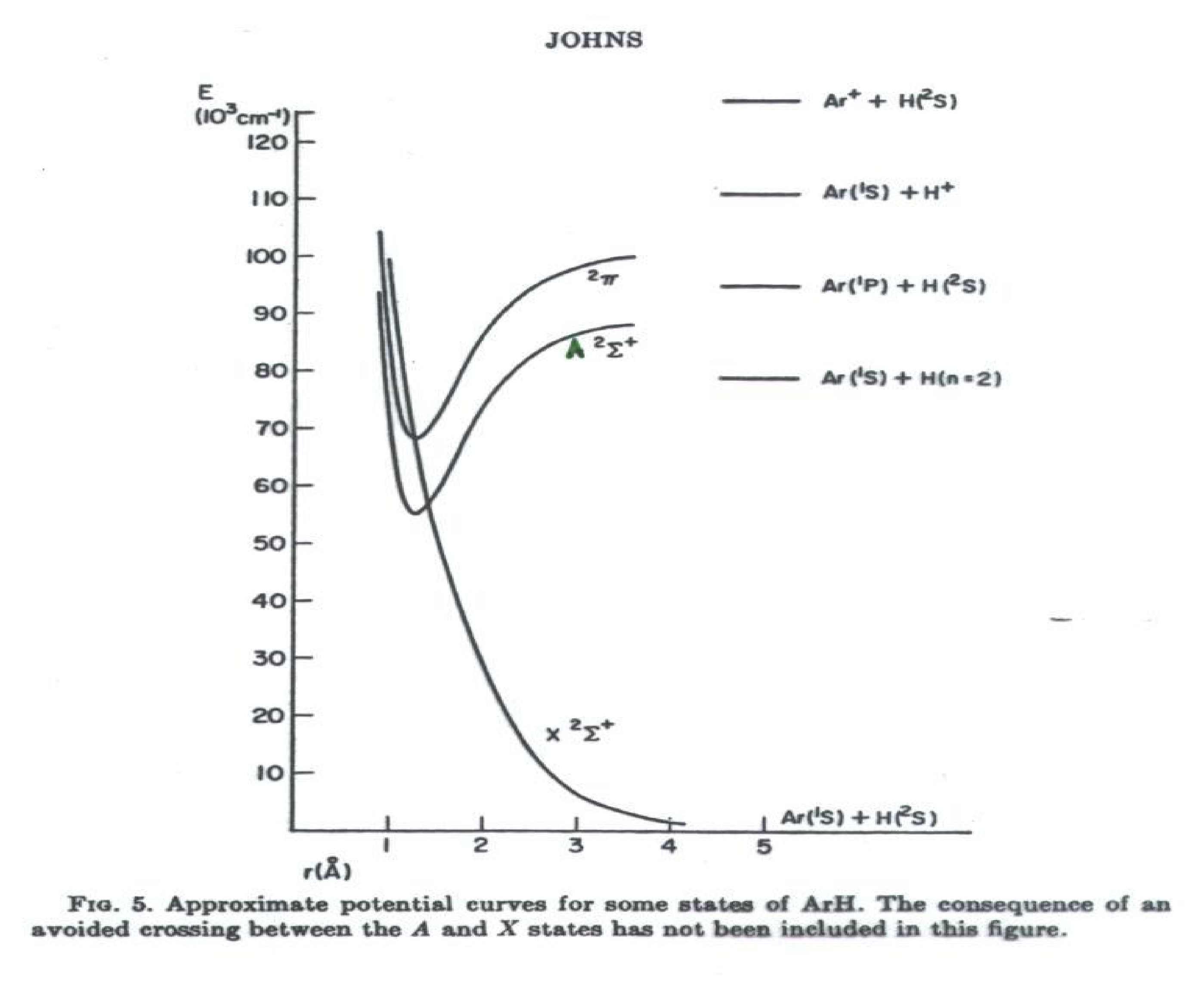
Ar + H_2 discharge plasma


Broad line band 4p→5s of ArH

spacing about 4 cm-1

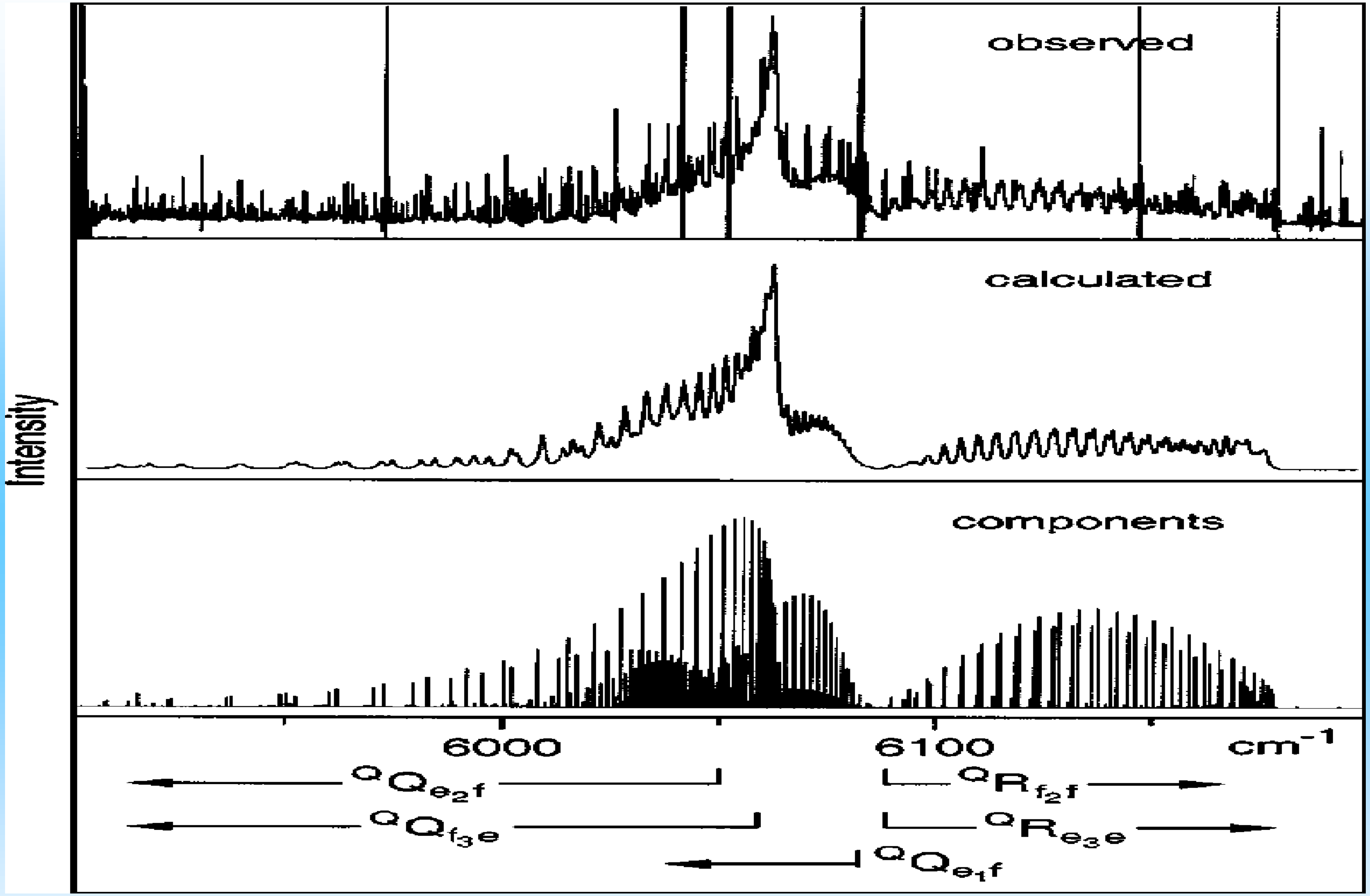
on the top of this is a sharp line band 4f→3d (delta) extending over a much wider range

ArH radical



JOHNS

FIG. 5. Approximate potential curves for some states of ArH. The consequence of an avoided crossing between the *A* and *X* states has not been included in this figure.



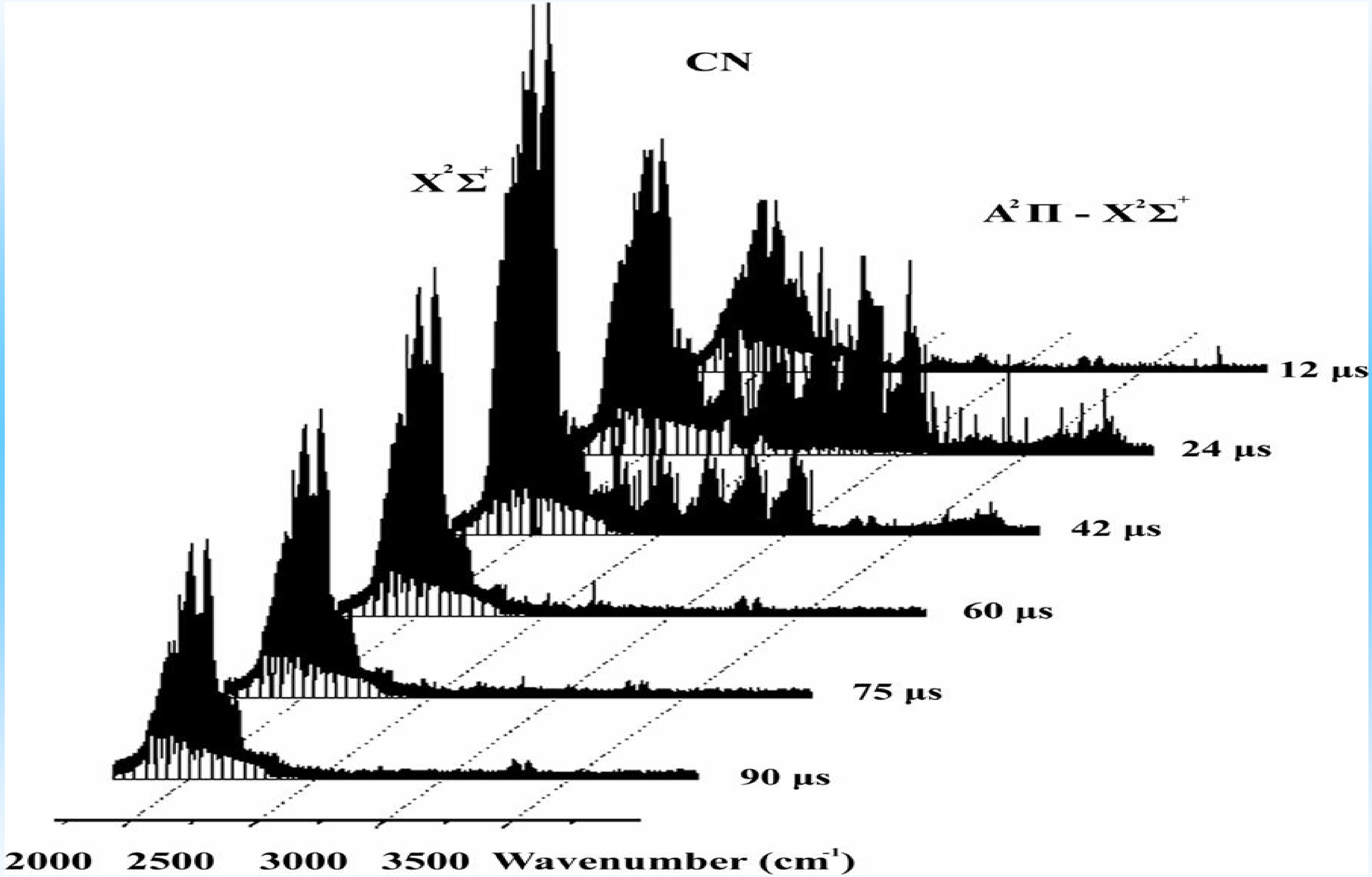
Emission spectrum of the 4*p*-5*s* band ofArH. Sharp lines belong to the 4*f*-3*d* band and probably to other unnassigned bands of ArH. To calculate the spectrum a *T*=2500 K,and a halfwidth of 0.7 cm^{-1} were assumed.

Investigated bands of ArH and ArD

	ArH	ArD		
Transition	Band Origin cm^{-1}		Resolution cm^{-1}	Reference
$3d\pi \rightarrow 5s$	13024	13040	0.1	2
$4d\pi \rightarrow 5s$	19520	19570		3
$\pi \rightarrow 5s$?	-	22575		3
$5p \rightarrow 5s$	-	17487	0.13	5
$5p \rightarrow 6s$	-	3681	0.20	5
$6p \rightarrow 5s$	-	21676	0.20	5
$4p \rightarrow 5s$	-	6120	0.05; 0.2	4
$3d\sigma \rightarrow 4p$	-	10200	0.05; 0.2	4
$3d\pi \rightarrow 4p$	6934	6900	0.05; 0.2	4,6
$3d\delta \rightarrow 4p$	8534	8524	0.05	6
$4d\sigma \rightarrow 4p$	15097	15075	0.3	6
$6s \rightarrow 4p$	7703	7685	0.02	6
$8s \rightarrow 4p$	-	16749	0.20	6
$4f \rightarrow 5s$	20641	20682	0.20	7
$4f \rightarrow 3d\pi$	7627	7649	0.05	7
$4f \rightarrow 3d\delta$	6027	6038	0.05	7
$4f \rightarrow 3d\sigma$	$\sim$4400	4351	0.10; 0.20	7,8

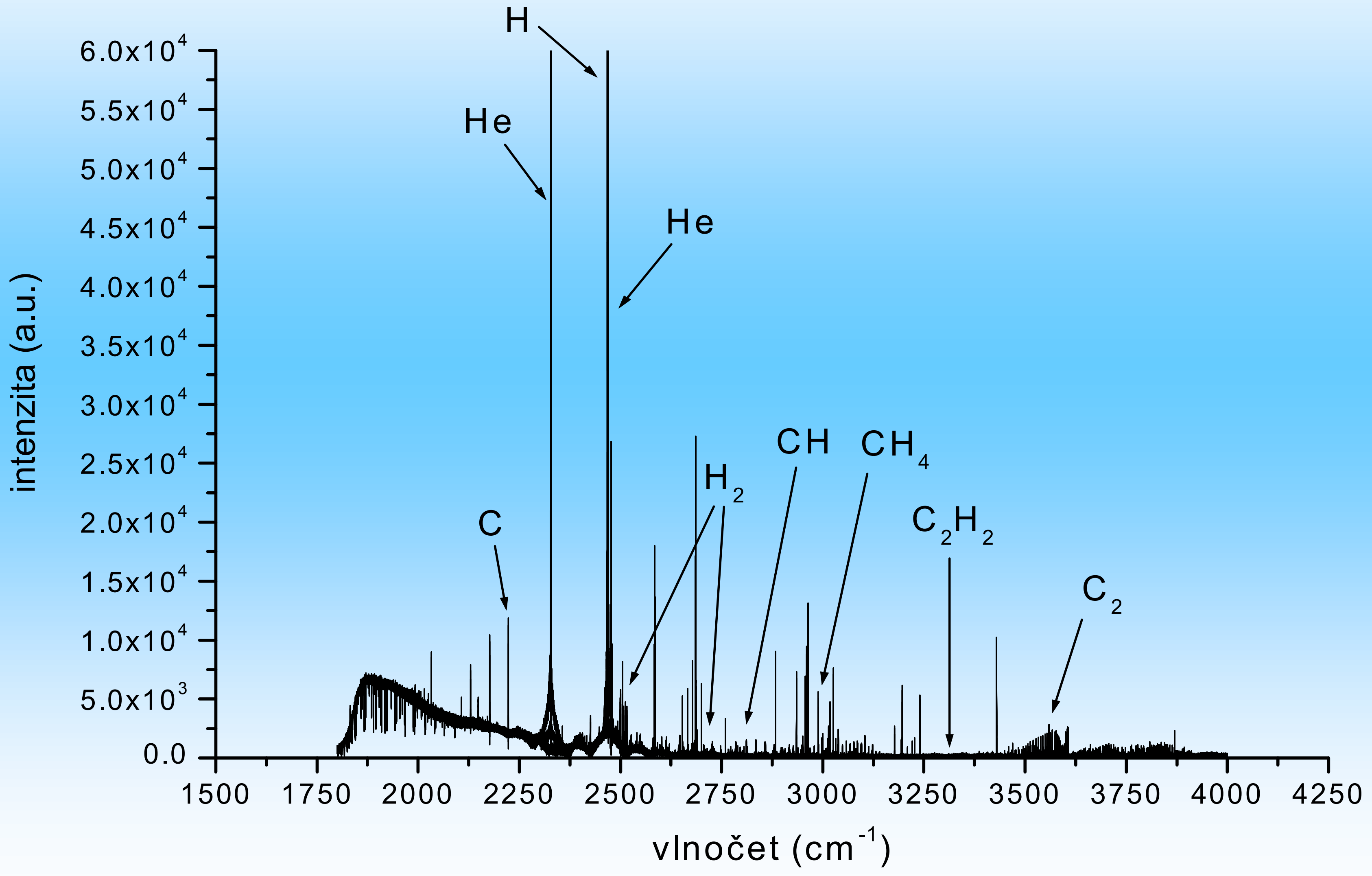
Baskakov O.I., Civiš S., and Kawaguchi K, ***J. Chem. Phys.***, 2005 ,**122** (11) 114302

Ar + $(CN)_2$ discharge plasma



The time-resolved emission FT spectrum from a pulsed discharge in a $(CN)_2$ and He mixture. The discharge pulse duration was 20ε s. The 30 time-resolved spectra were collected from t = 0–90 µs with a step of 3 µs. The spectra of C_2H_2 and C_2 were observed at 3300 and 3600 cm^{-1}.

He + CH_4 discharge plasma



CH

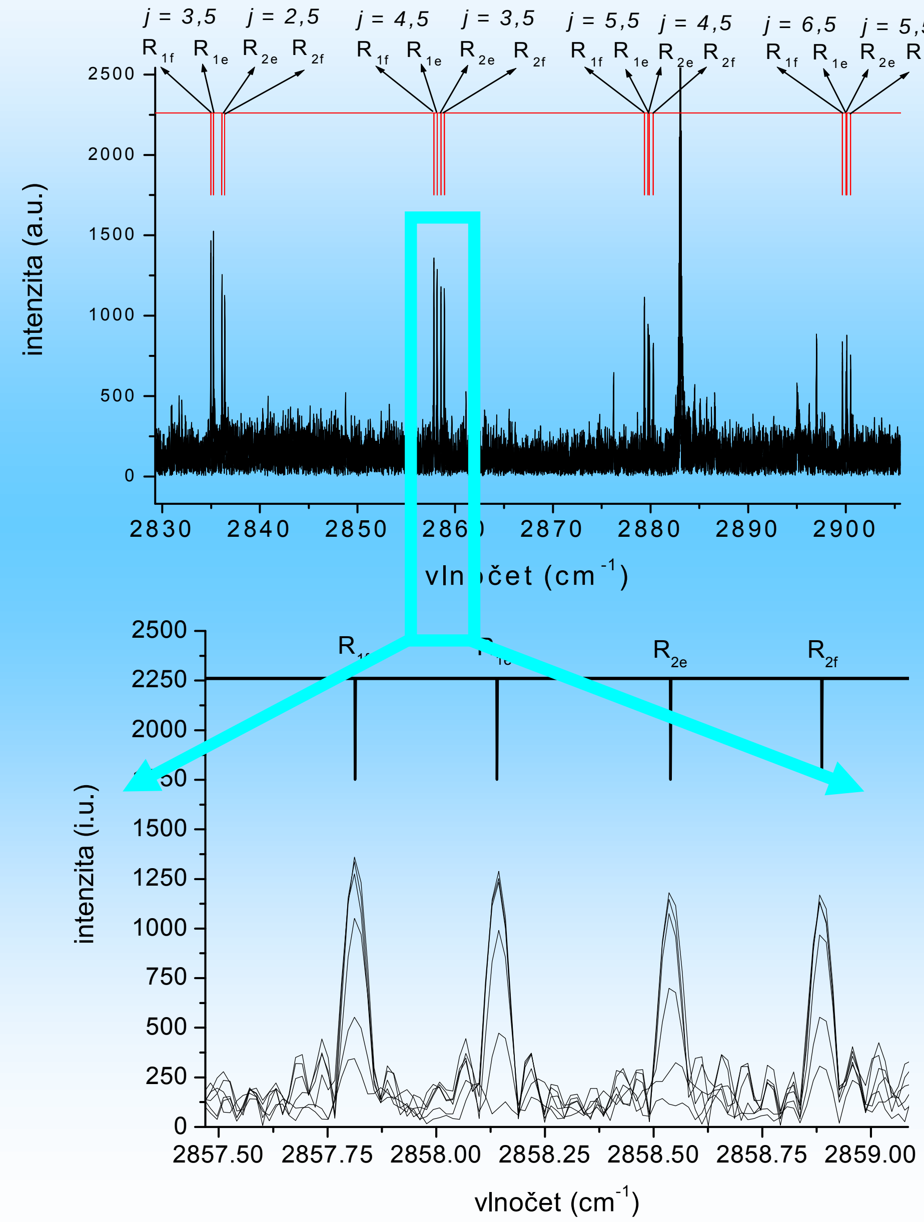
Large Magellanic Cloud

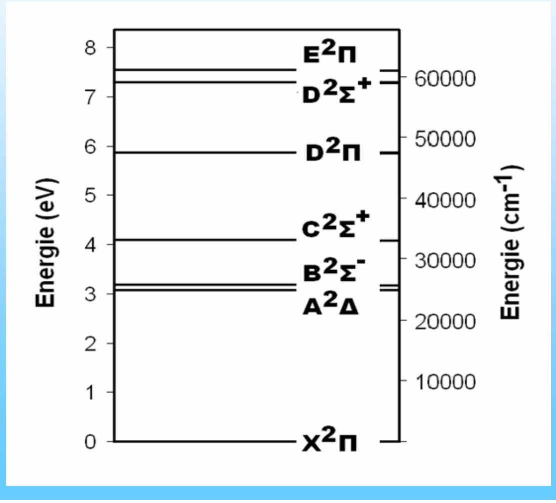
Vis lines at 3878.8, 3886.4, 3890.2, 4300.3, UV lines near 1271, 1368, 1369, 1370, 1549, & 1694 Ù

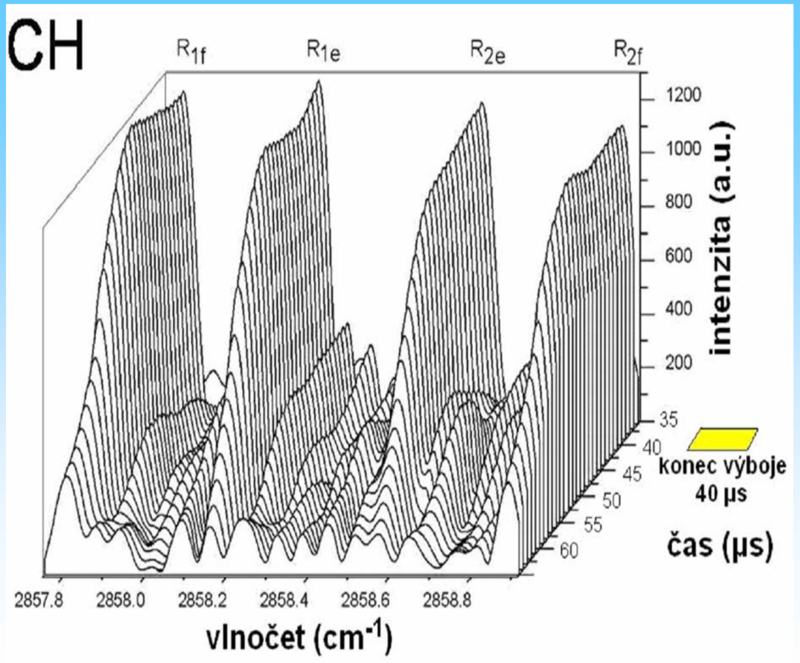
J = 1/2, v_{01} (3263.794 MHz)
J = 1/2, v_{11} (3335.481 MHz)
J = 1/2, v_{10} (3349.193 MHz)

Considerations Regarding Interstellar Molecules
P. Swings and L. Rosenfeld, ApJ 86:483-486 (1937)
Evidence for the Molecular Origin of Some Hitherto Unidentified Interstellar Lines
A. McKellar, Publ Astron Soc Pac 52:187-192 (1940)
Some Results with the COUDÉ Spectrograph of the Mount Wilson Observatory
W. S. Adams, ApJ 93:11-23 (1941)
Radio Detection of Interstellar CH
O. E. H. Rydbeck, J. Elldér, and W. M. Irvine, Nature 246:246-248 (1973)
Hubble Space Telescope Measurements of Vacuum Ultraviolet Lines of Interstellar CH
Y. Sheffer and S. R. Federman, ApJ 659:1353-1359 (2007)

CH radical

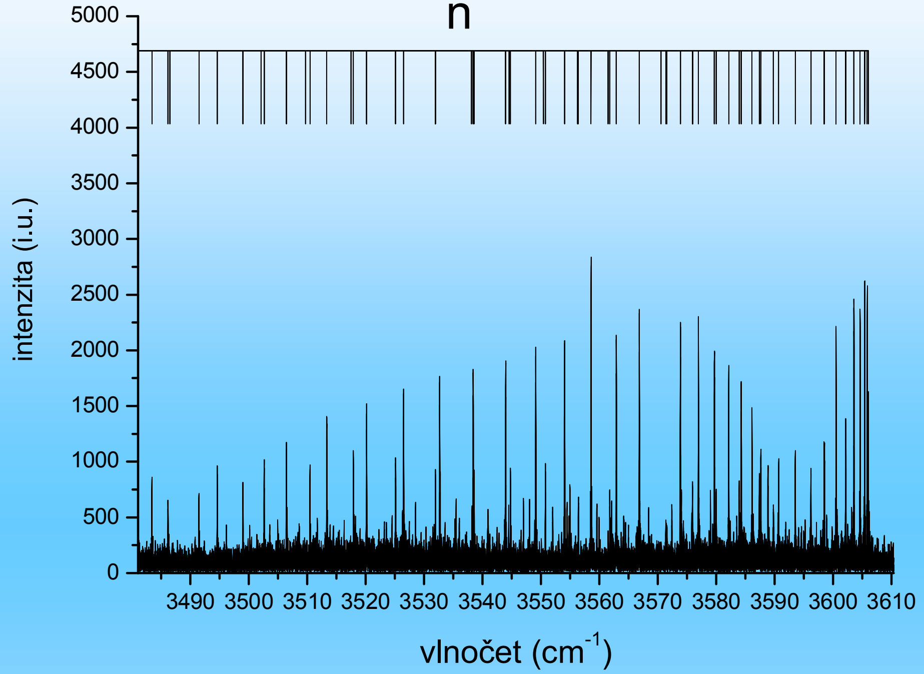

j = 3,5
j = 2,5
j = 4,5
j = 3,5
j = 5,5
j = 4,5
j = 6,5
j = 5,5
R_{1f} R_{1e} R_{2e} R_{2f}
intenzita (a.u.)
2500
2000
1500
1000
500
0
2830 2840 2850 2860 2870 2880 2890 2900
vlnočet (cm^{-1})
R_{1f}
R_{1e}
R_{2e}
R_{2f}
intenzita (i.u.)
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
2857.50 2857.75 2858.00 2858.25 2858.50 2858.75 2859.00
vlnočet (cm^{-1})

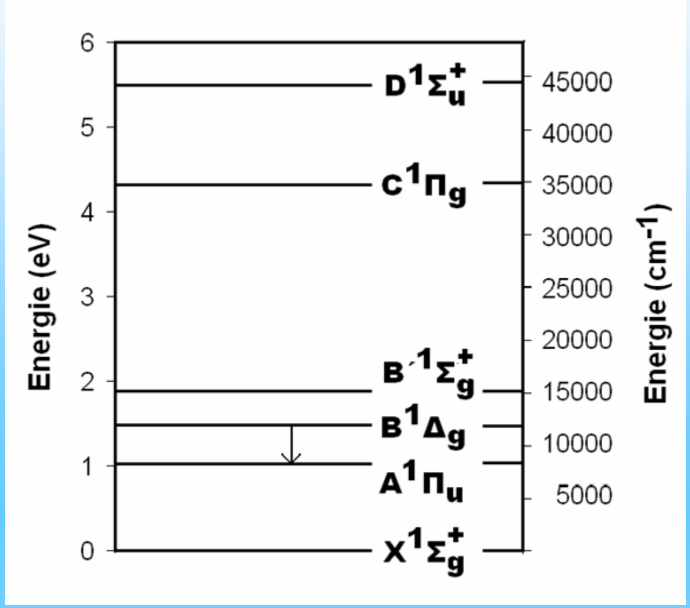

Energie (eV)
Energie (cm^{-1})
0 1 2 3 4 5 6 7 8
10000 20000 30000 40000 50000 60000
$E^2\Pi$
$D^2\Sigma^+$
$D^2\Pi$
$C^2\Sigma^+$
$B^2\Sigma^-$
$A^2\Delta$
$X^2\Pi$

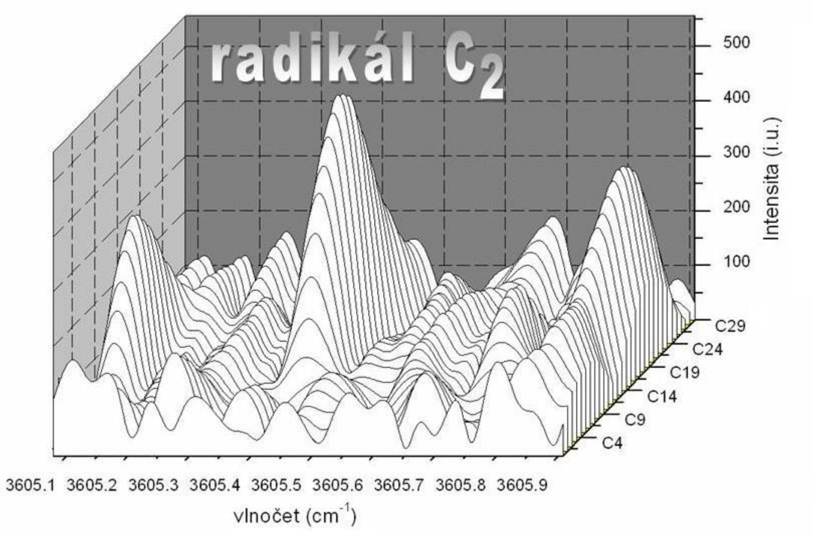

CH
R_{1f}
R_{1e}
R_{2e}
R_{2f}
intenzita (a.u.)
200 400 600 800 1000 1200
35 40 45 50 55 60
konec výboje
40 μs
čas (μs)
2857.8 2858.0 2858.2 2858.4 2858.6 2858.8
vlnočet (cm^{-1})

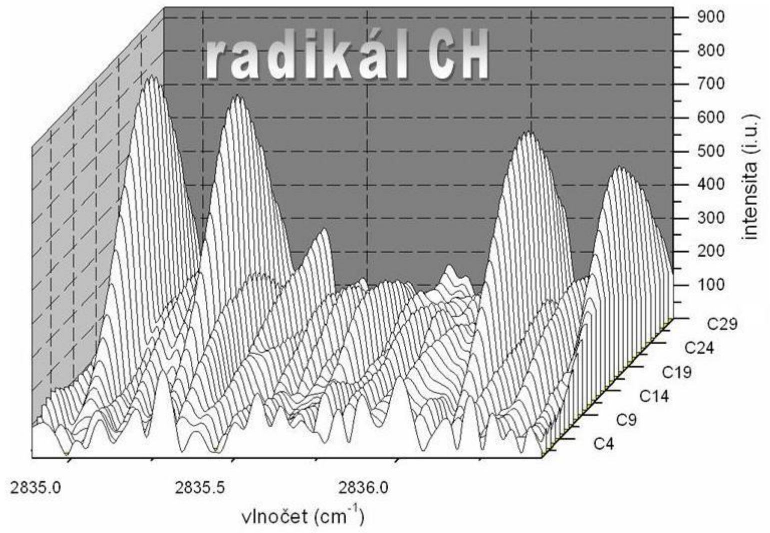
C_2 radical

n

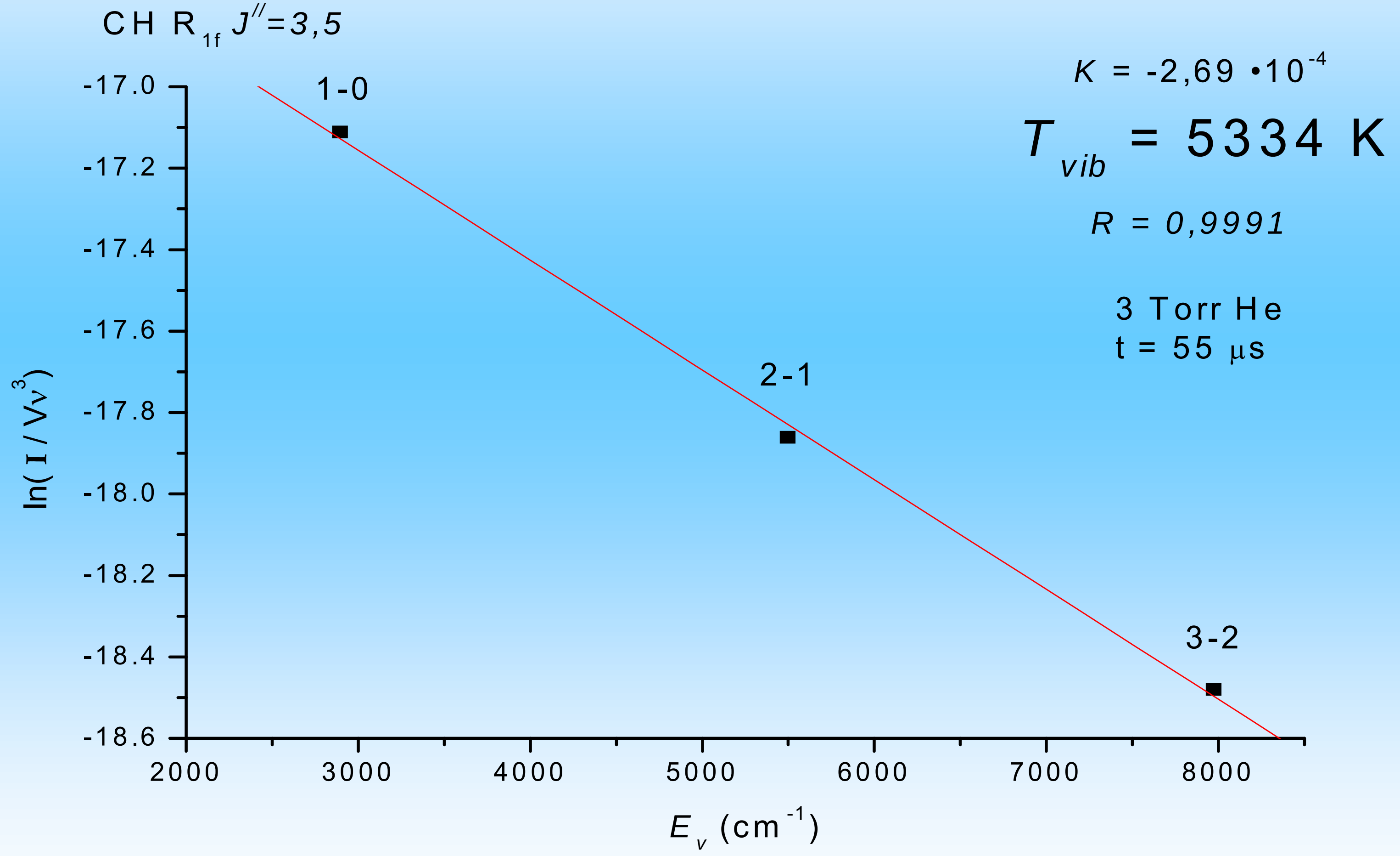

intenzita (i.u.)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
3490
3500
3510
3520
3530
3540
3550
3560
3570
3580
3590
3600
3610
vlnočet (cm^{-1})


Energie (eV)
6
5
4
3
2
1
0
$D^1\Sigma_u^+$
$C^1\Pi_g$
$B'^1\Sigma_g^+$
$B^1\Delta_g$
$A^1\Pi_u$
$X^1\Sigma_g^+$
45000
40000
35000
30000
25000
20000
15000
10000
5000
Energie (cm^{-1})


radikál C_2
500
400
300
200
100
Intensita (i.u.)
C29
C24
C19
C14
C9
C4
3605.1
3605.2
3605.3
3605.4
3605.5
3605.6
3605.7
3605.8
3605.9
vlnočet (cm^{-1})


radikál CH
900
800
700
600
500
400
300
200
100
intensita (i.u.)
C29
C24
C19
C14
C9
C4
2835.0
2835.5
2836.0
vlnočet (cm^{-1})

CH vibrational temperature

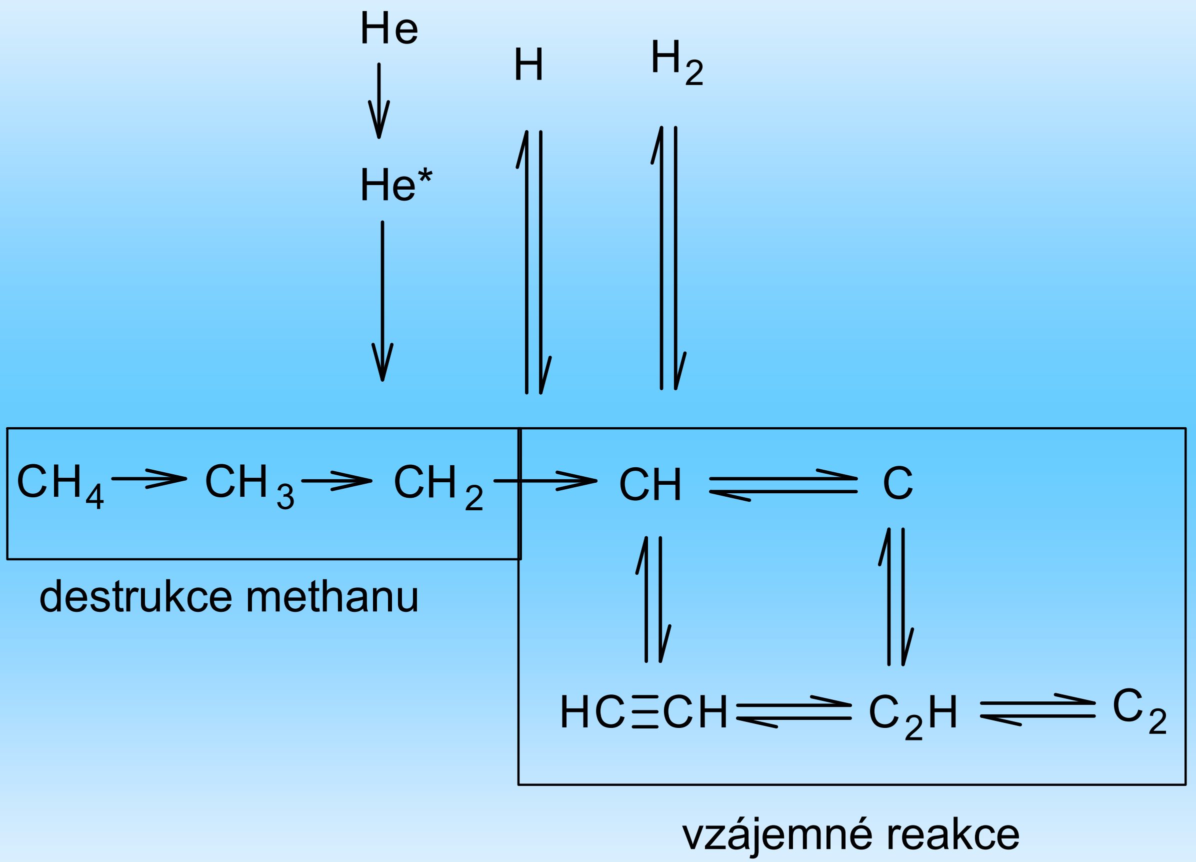


$K = -2{,}69 \cdot 10^{-4}$

$T_{vib} = 5334$ K

$R = 0{,}9991$

3 Torr He
t = 55 µs



He

He*

H

H_2

$CH_4 \rightarrow CH_3 \rightarrow CH_2 \rightarrow CH \rightleftharpoons C$

destrukce methanu

$HC{\equiv}CH \rightleftharpoons C_2H \rightleftharpoons C_2$

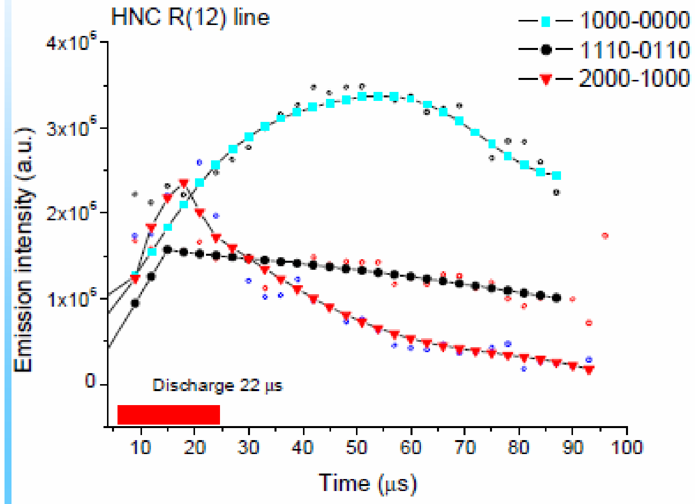
vzájemné reakce

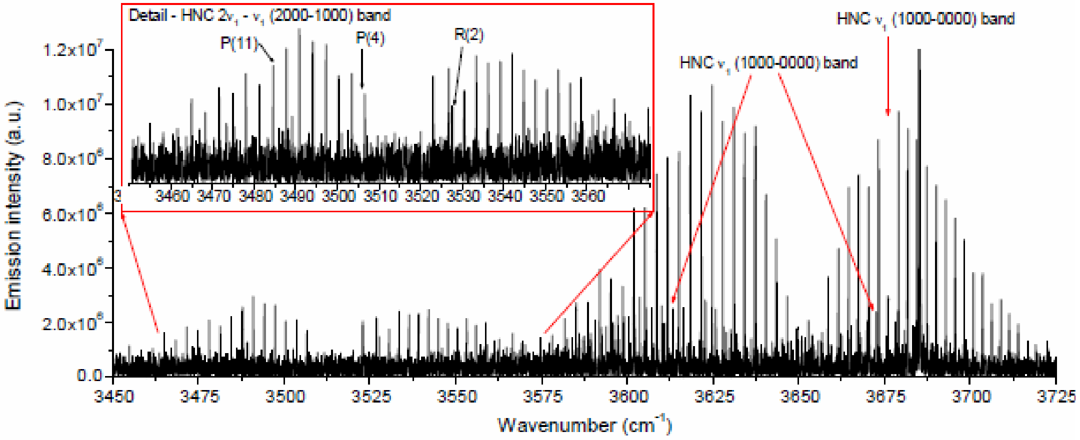
Vibrational temperature 5000 ï 6000 K

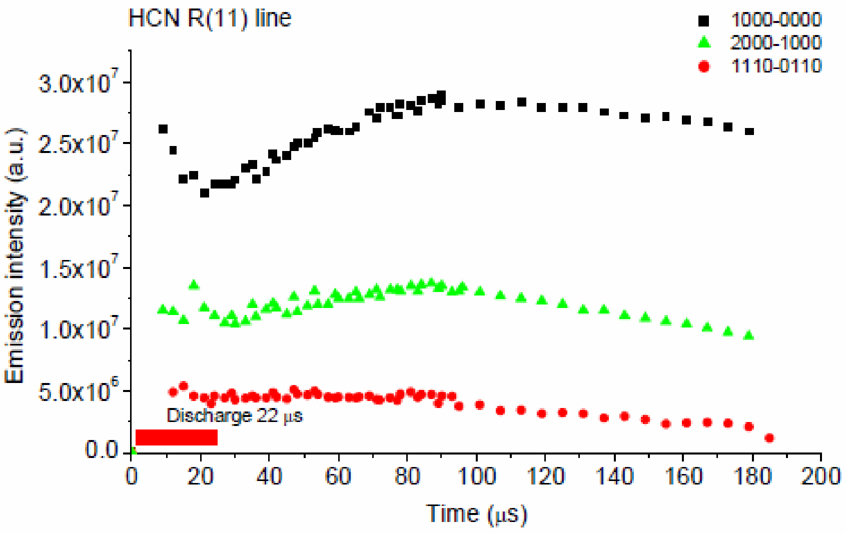
Rotational temperature   550 ï 700 K

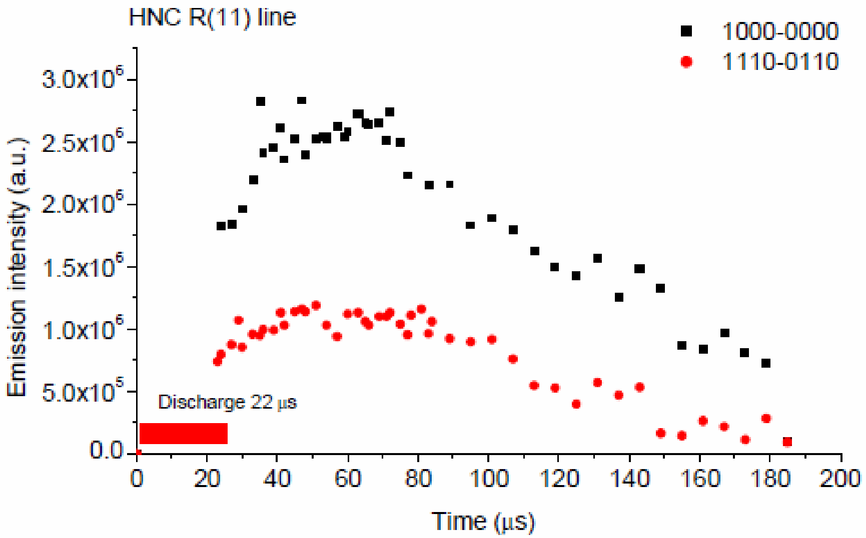
Excitation temperature   2500 ï 3000 K

HNC/HCN emission

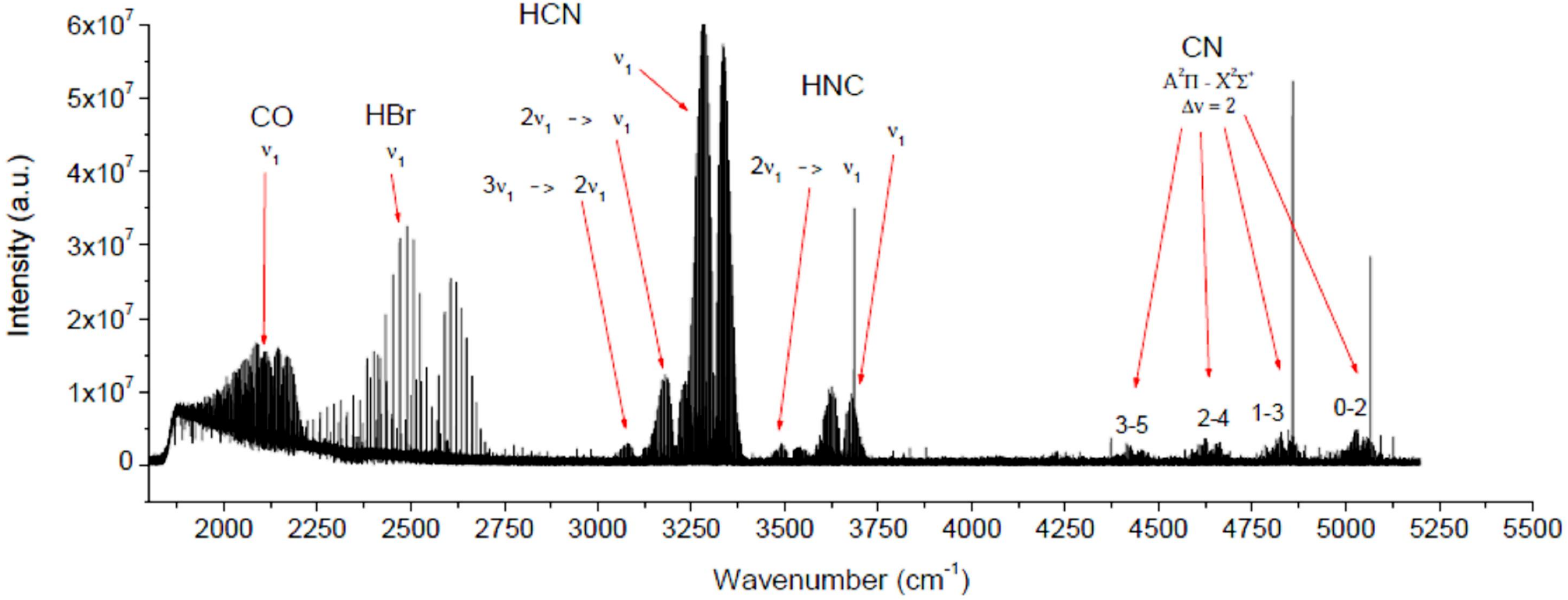




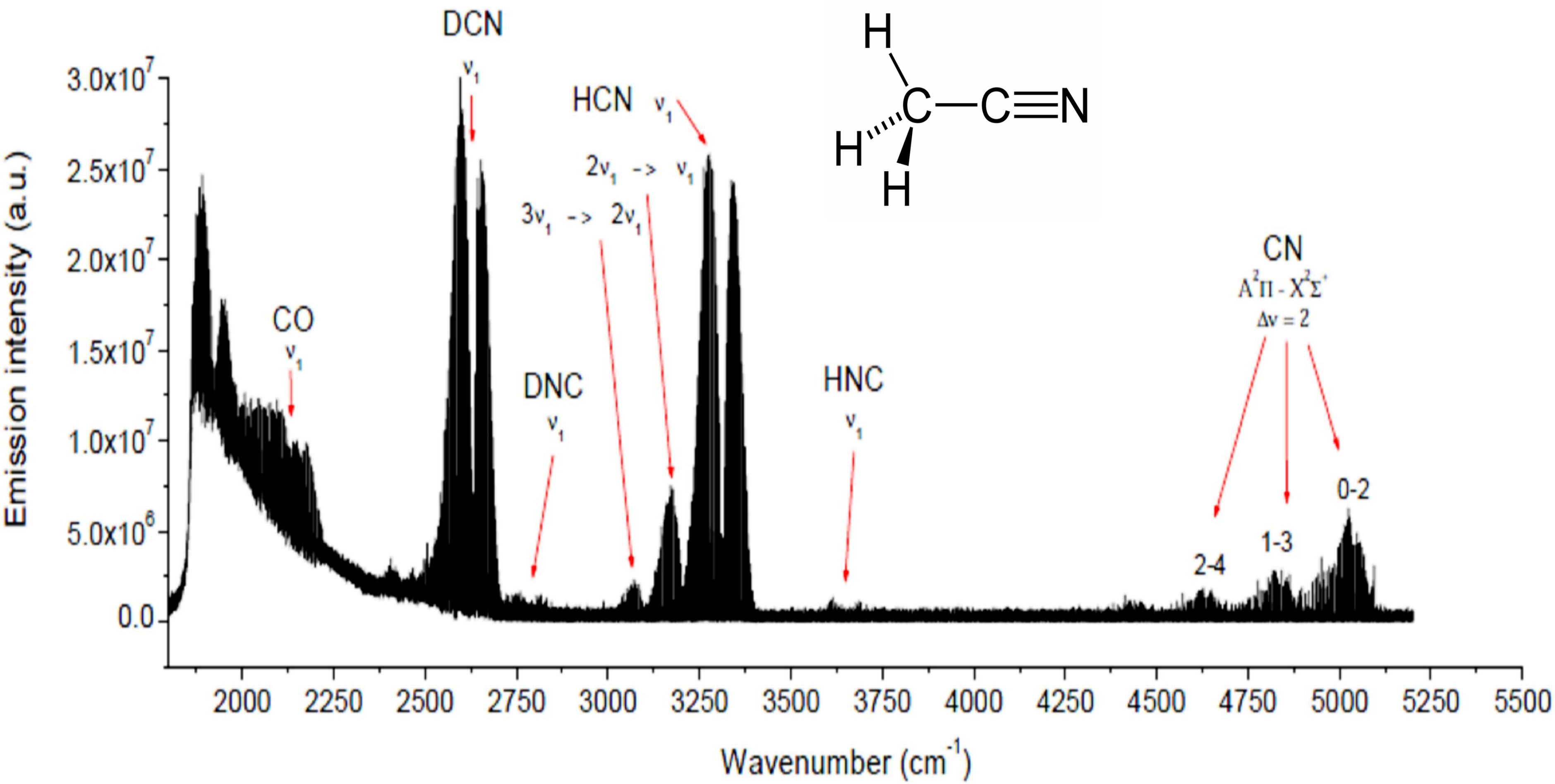




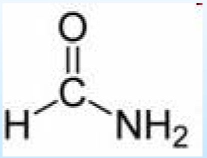
BrCN discharge

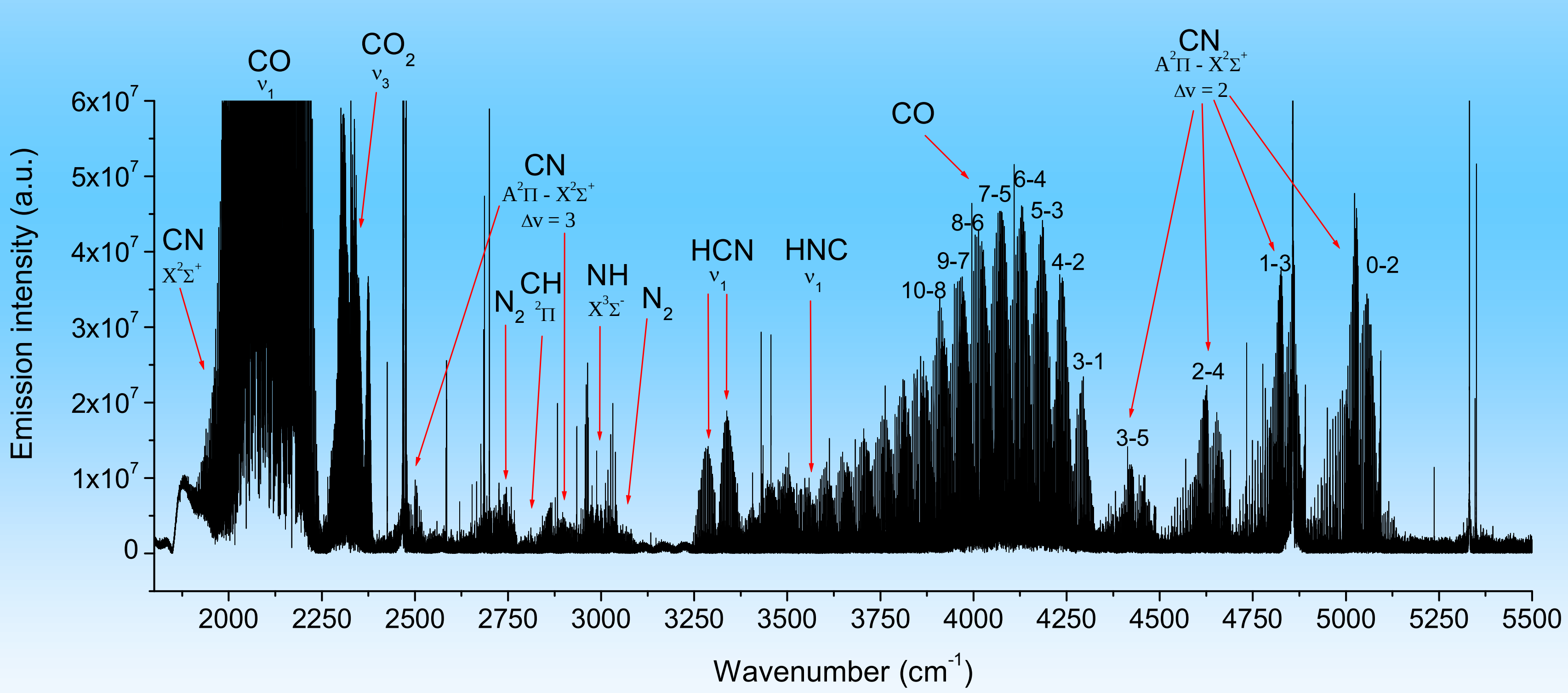


Acetonitrile discharge

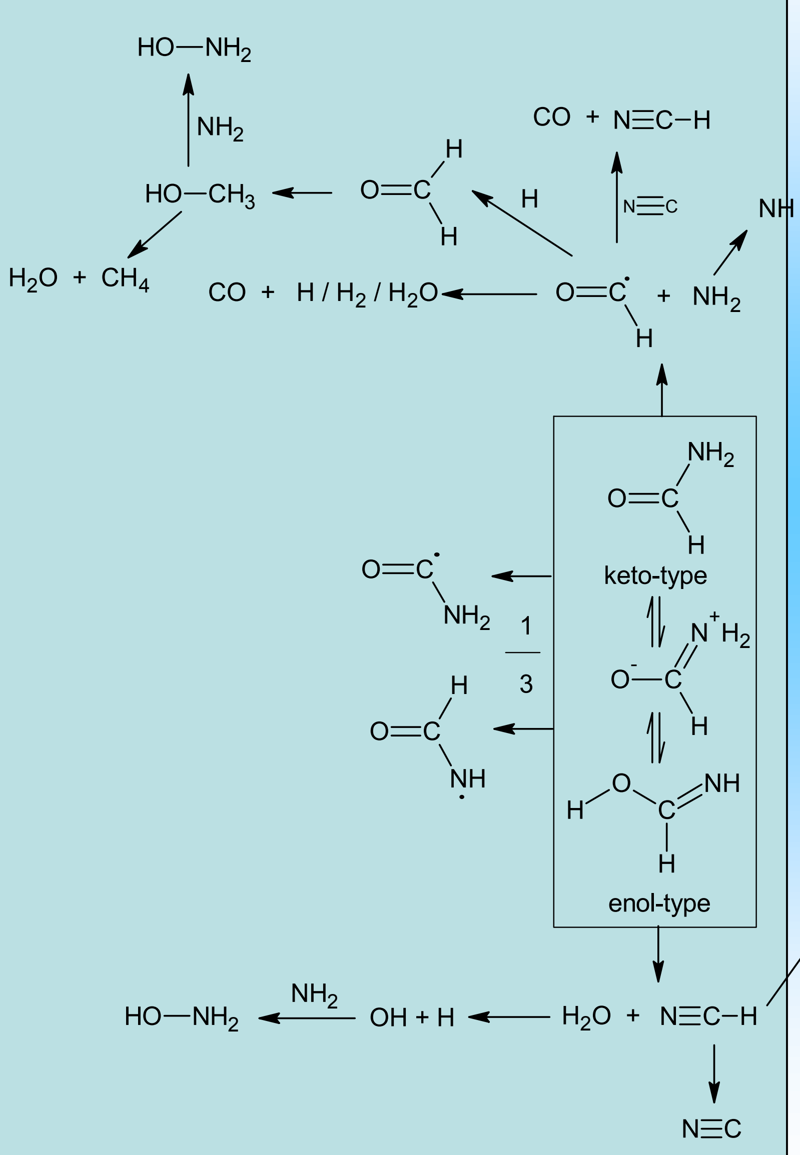


Formamide discharge

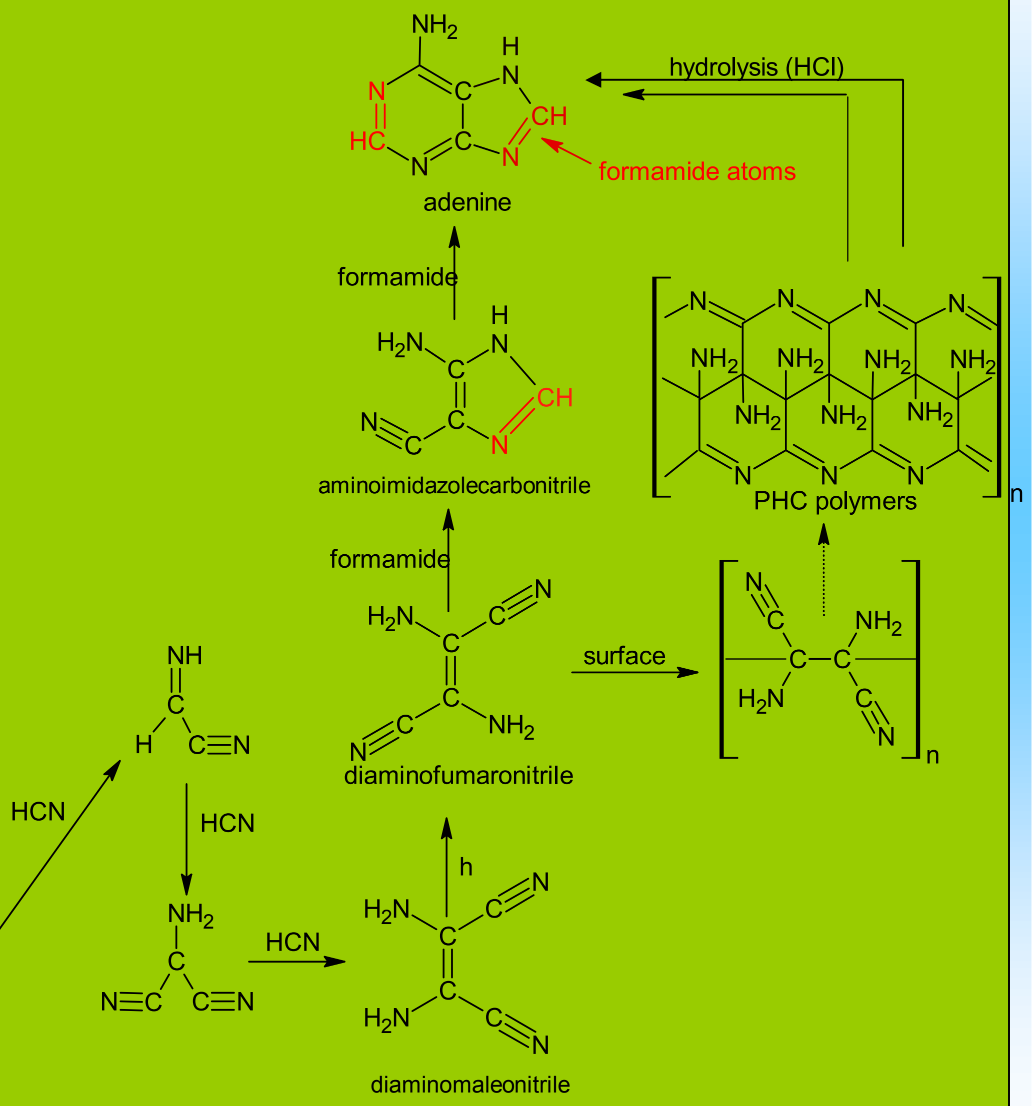




Výboj + laser Asterix



Formování basí (literatura)

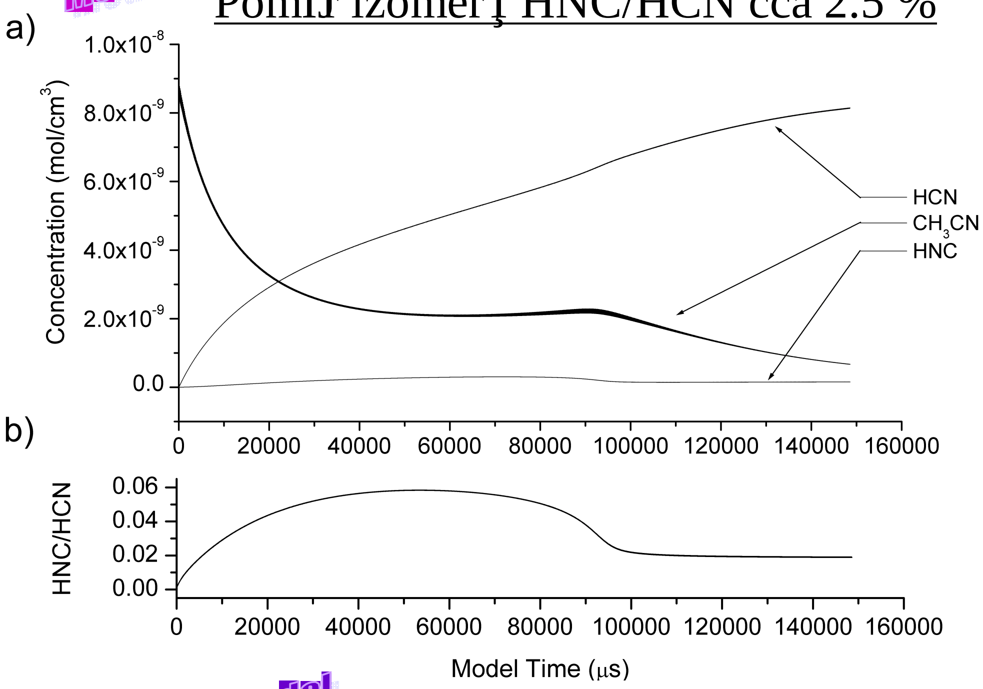


Kinetický model výboje

Model

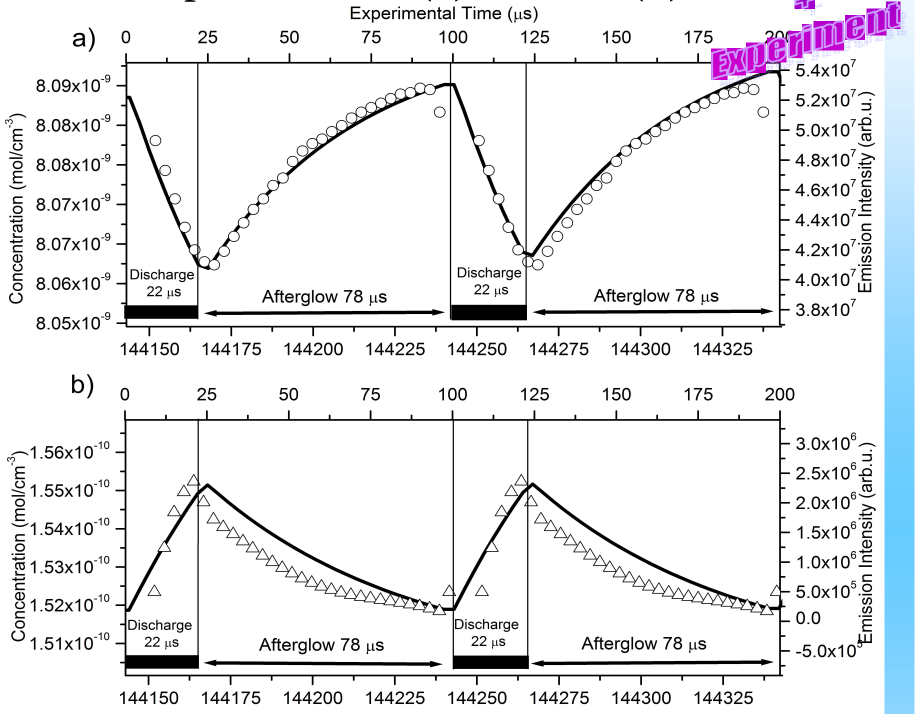
Kumulace produktŢ v cele

PomĦr izomerŢ HNC/HCN cca 2.5 %



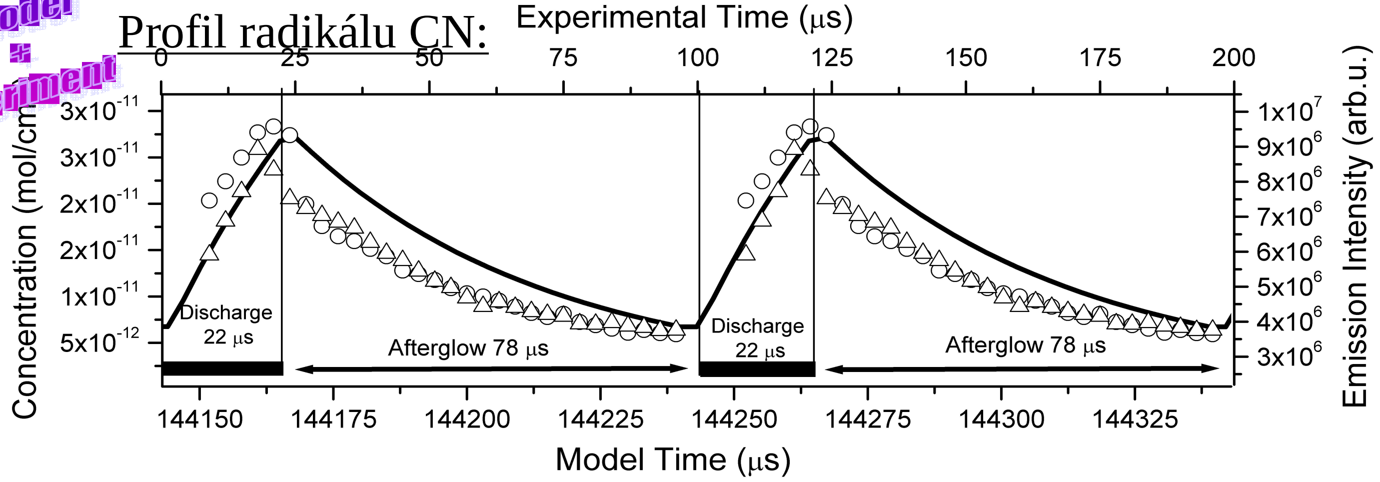
Emisní profil HCN (a) a HNC (b)

Model + Experiment



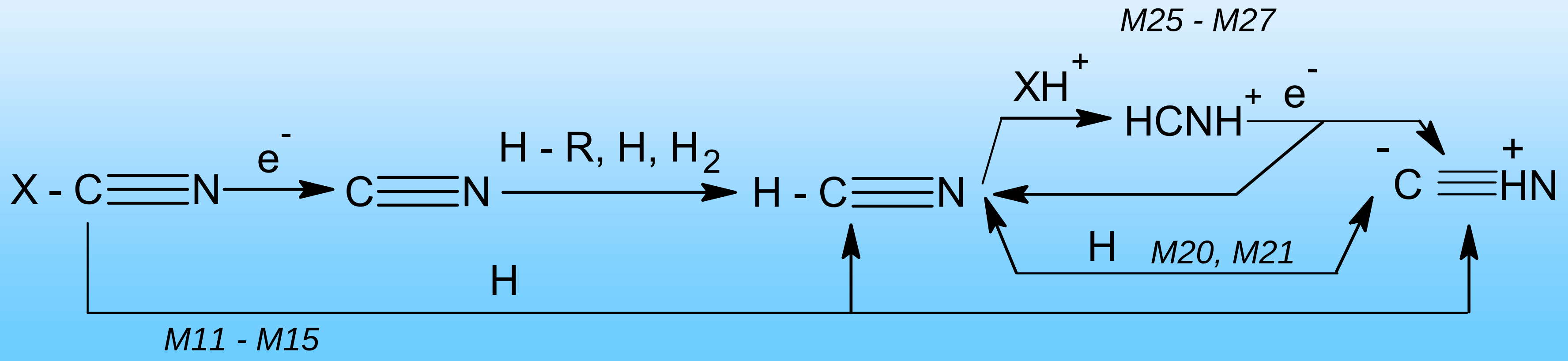
Model + Experiment

Profil radikálu CN:



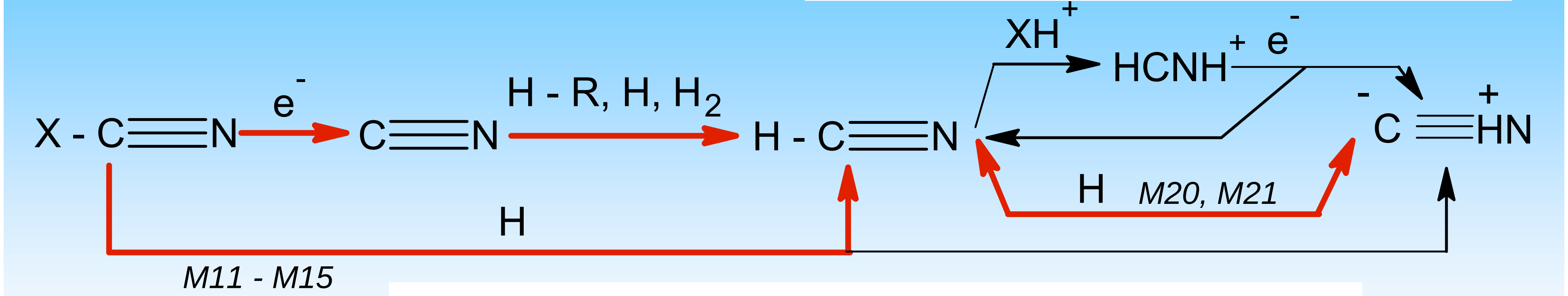
Kinetický model výboje

Možné cesty vzniku HNC ve výboji:



Výsledek modelu vzniku HNC ve výboji:

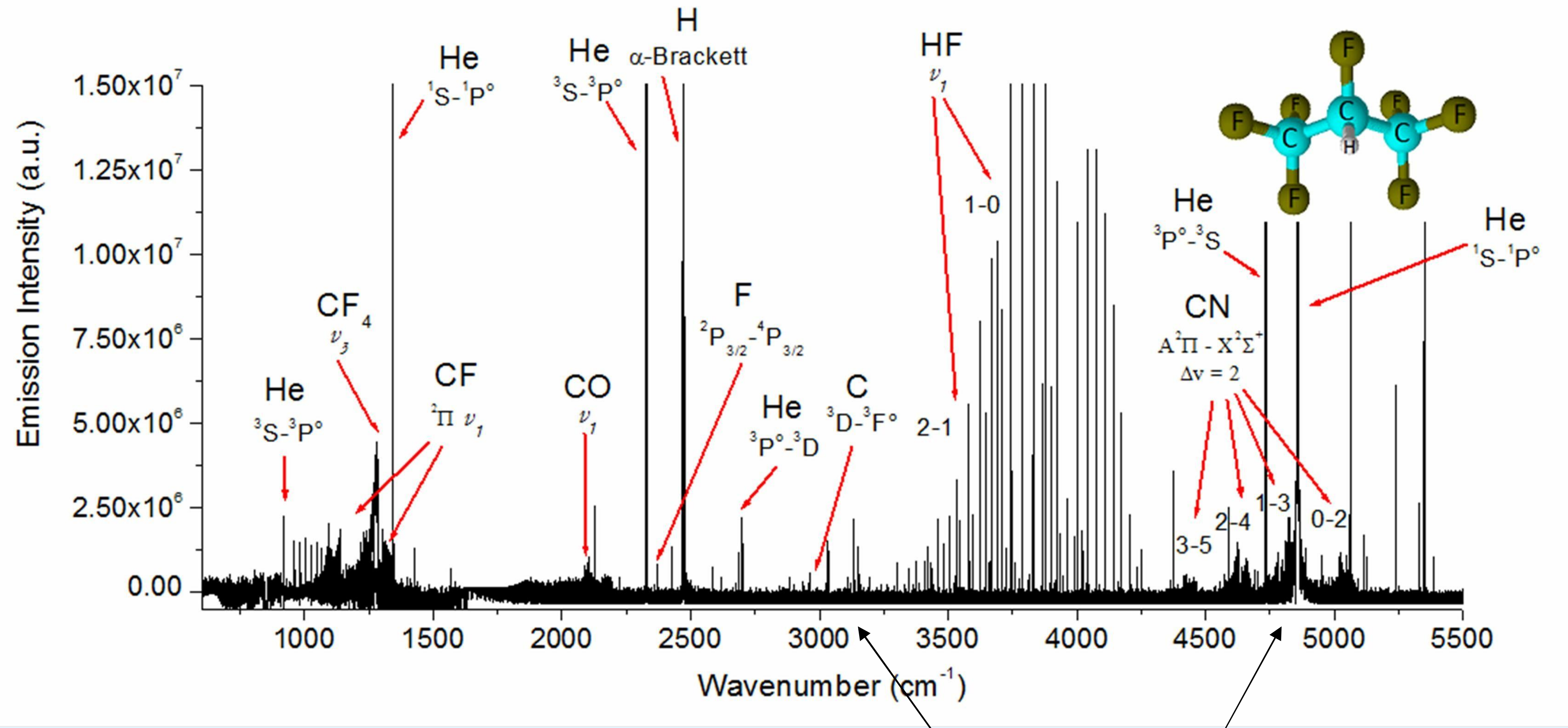
Ionty - rychlé reakce, ale malé koncentrace



Radikály - kumulace HCN ve výbojové cele
během milisekund dáno rovnováhou HNC + H ↔ HCN + H

Potlačením radikálových reakcí vzroste poměr HNC/HCN.

Výboj - hasivo FM 200

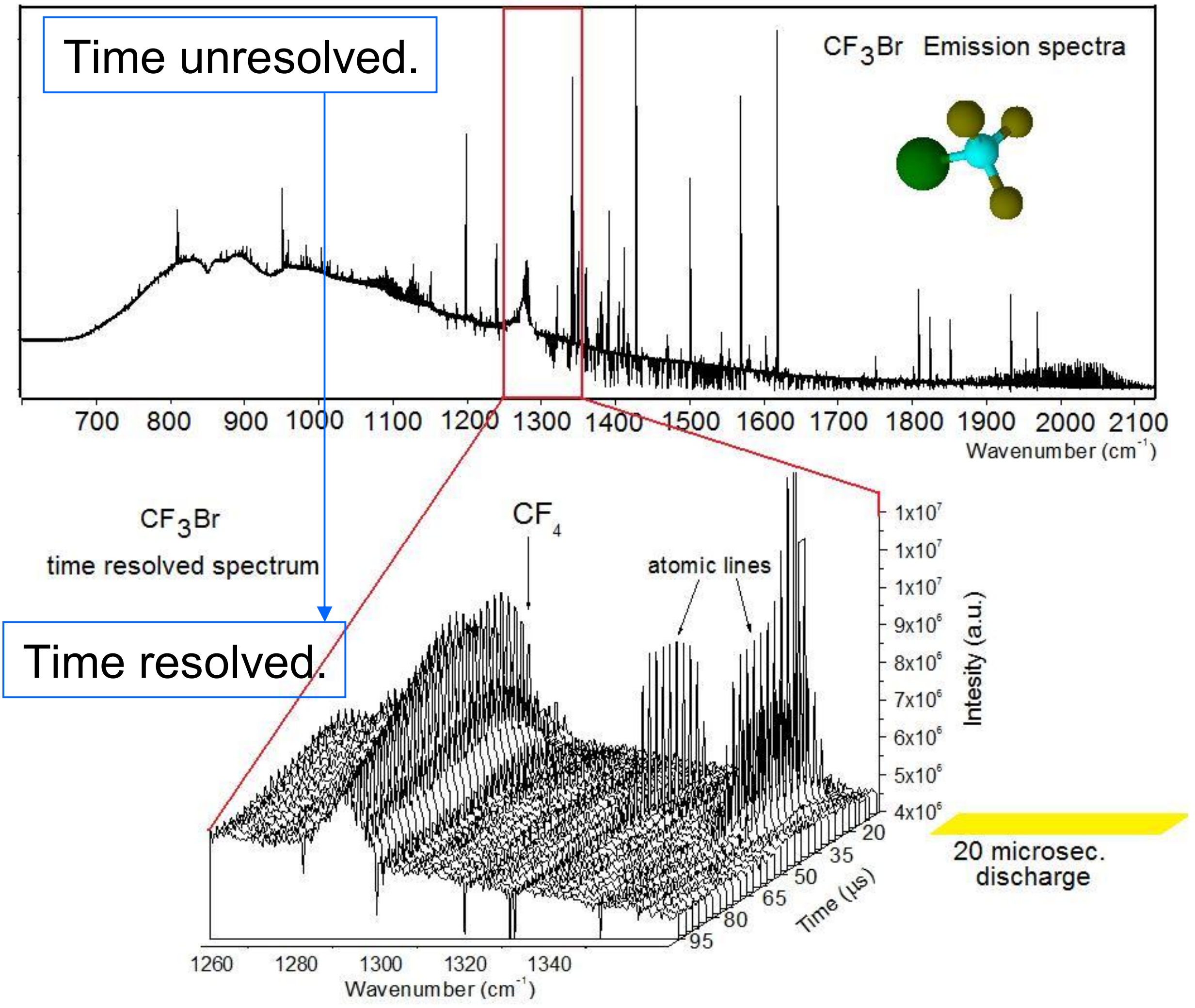


Ve výboji CN
Přídavek vody - HCN (slabý pás).

Result - information about reaction dynamics

Decomposition of extinguish agents CF_3Br and $(CF_3)_2CH$

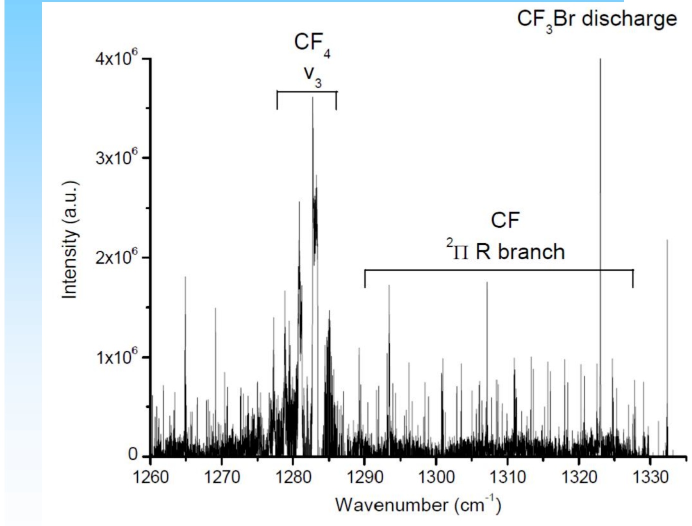
- Emission intensity time profile.
- Brodad spectral range.
- High resolution
  (rovibrational structure)

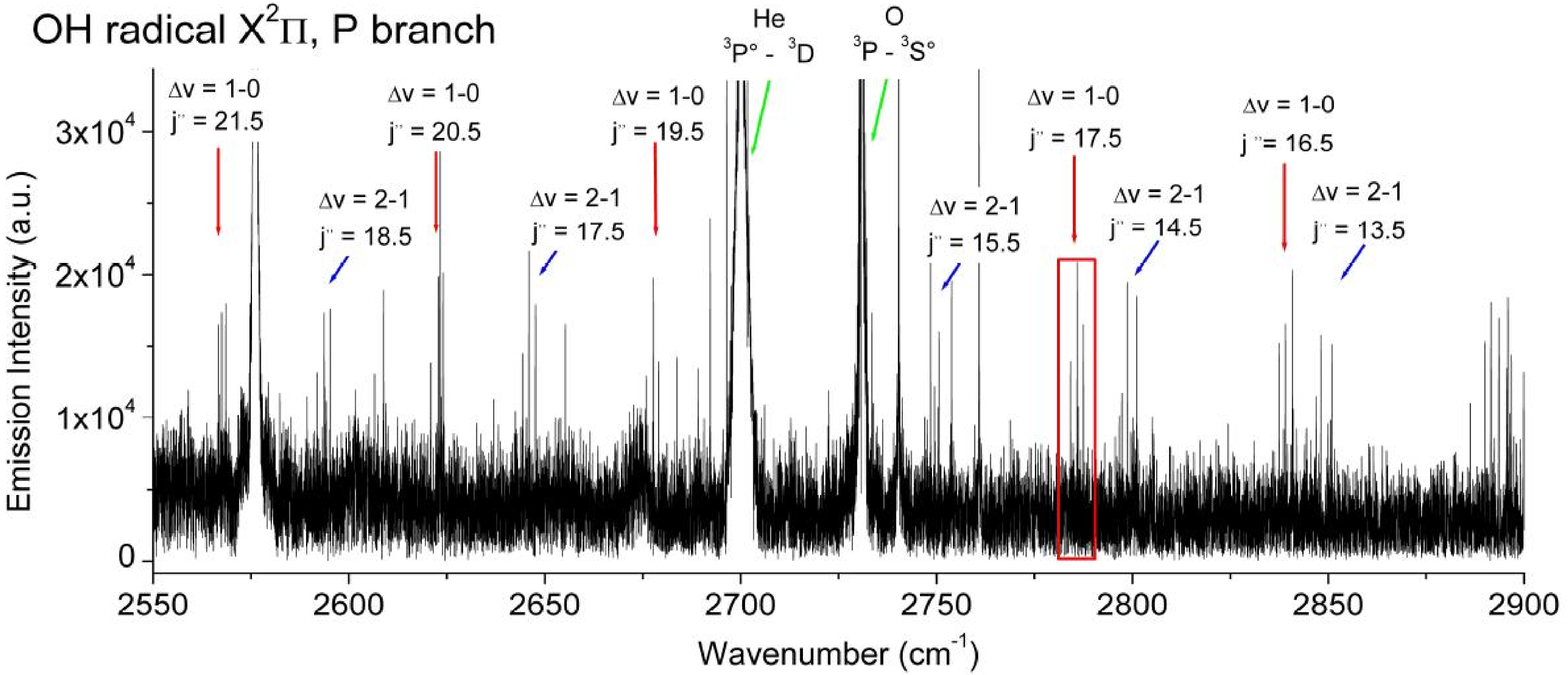


Time unresolved.

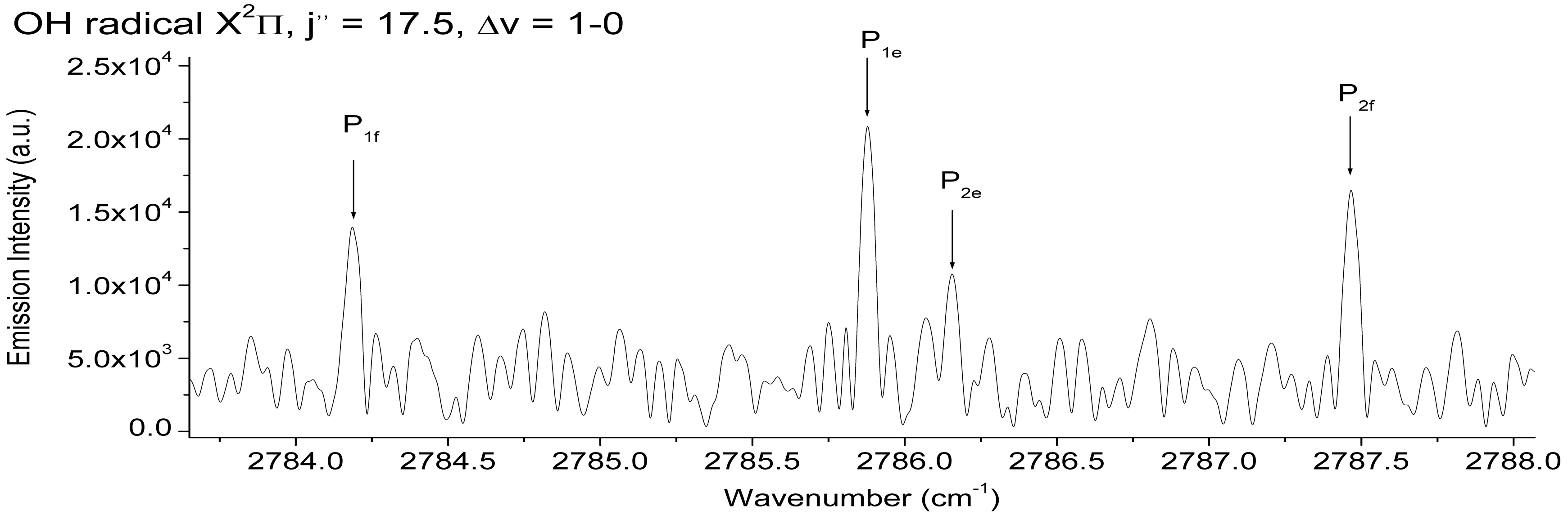
Time resolved.

20 microsec. discharge

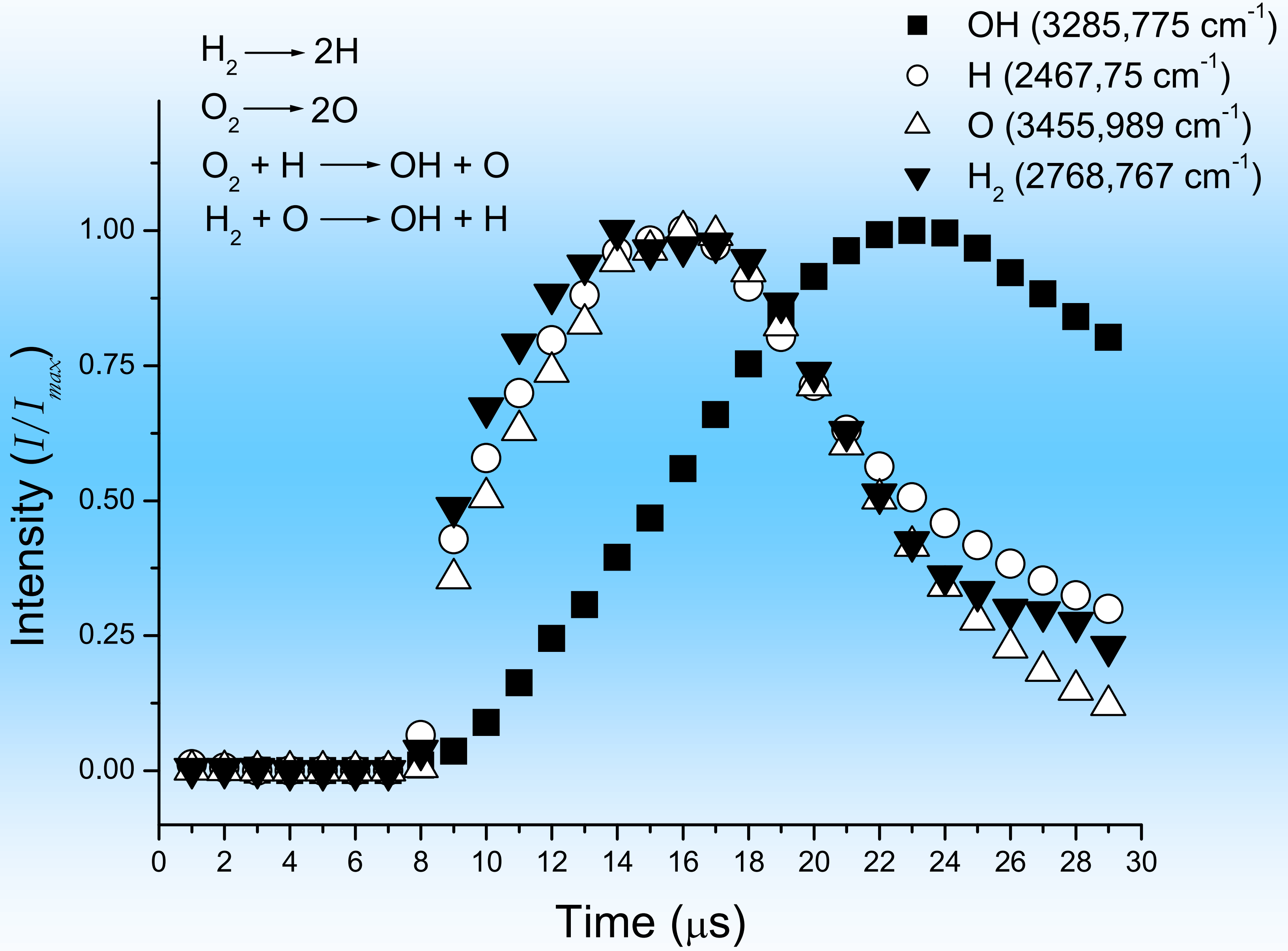




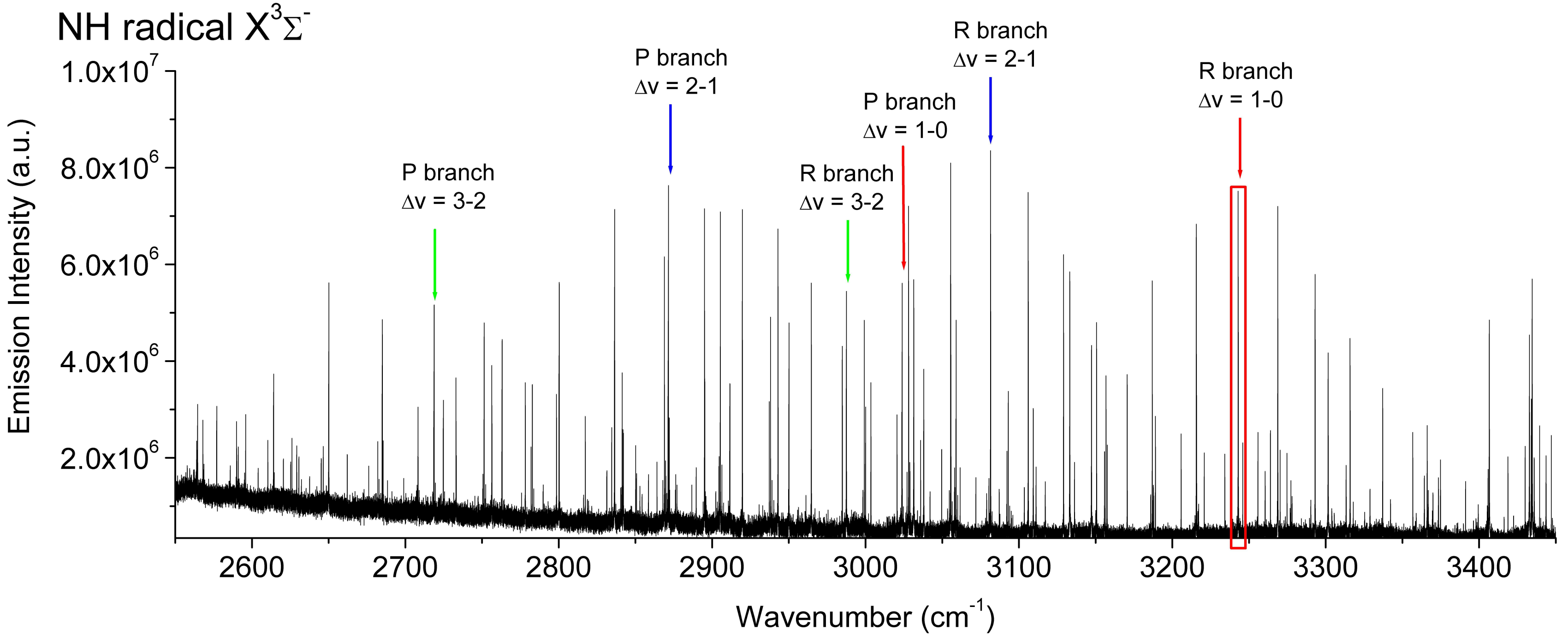
OH radical $X^2\Pi$, P branch

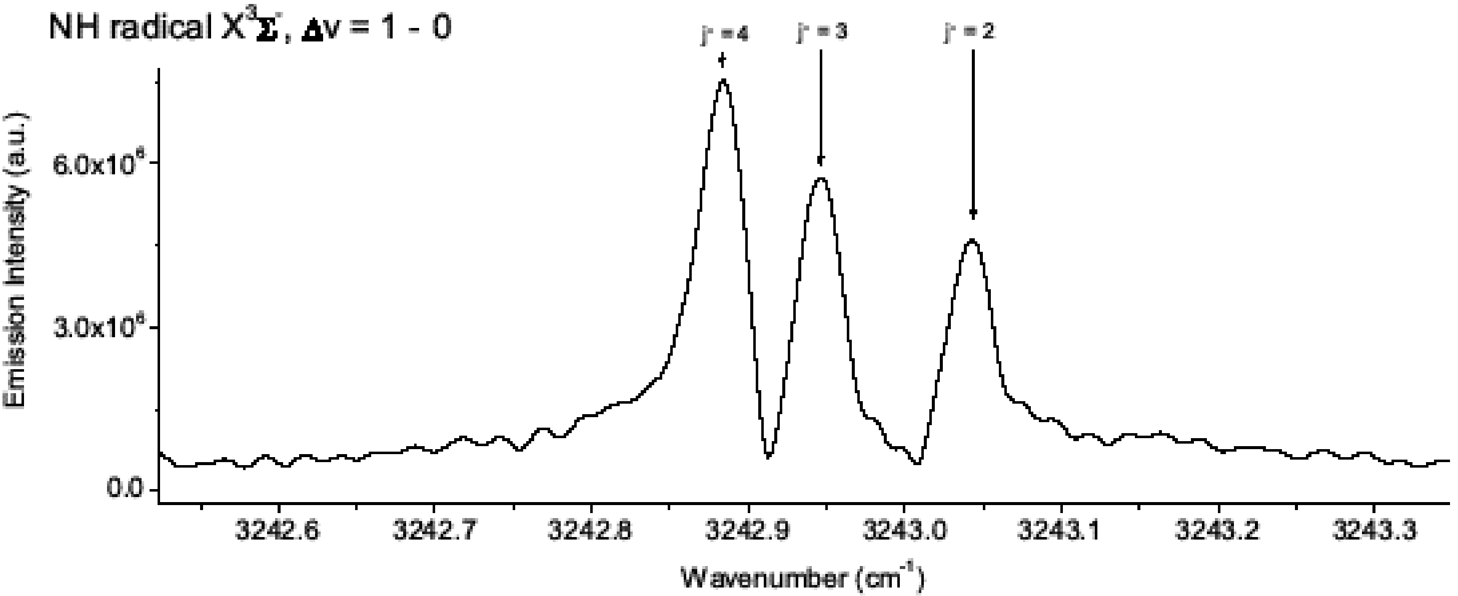


OH radical $X^2\Pi$, j'' = 17.5, Δv = 1-0

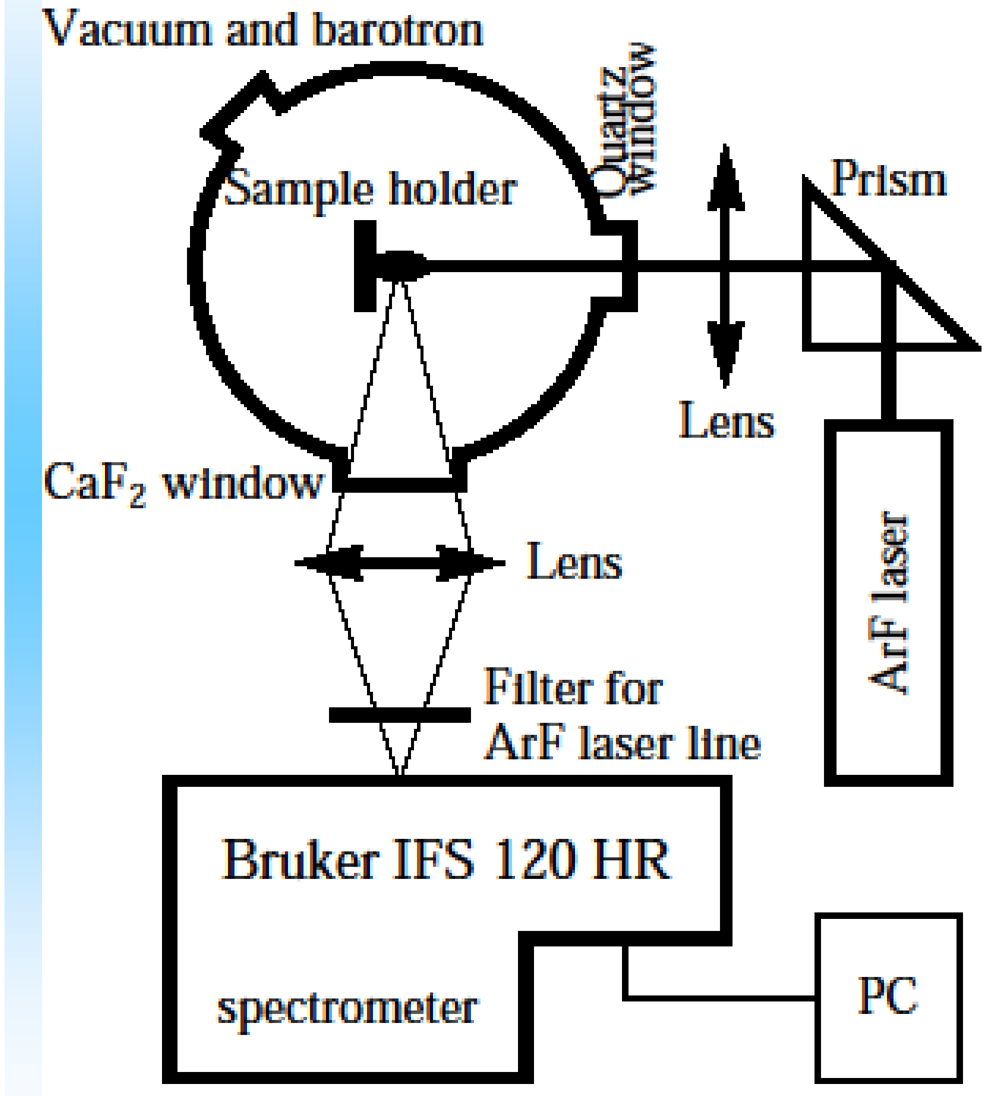


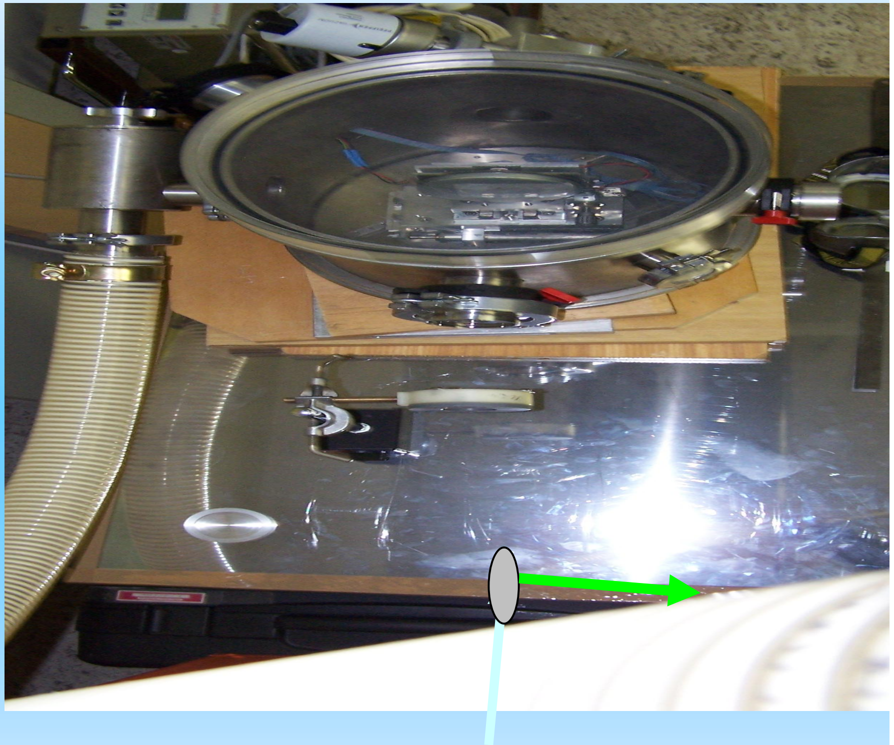
$H_2 \longrightarrow 2H$
$O_2 \longrightarrow 2O$
$O_2 + H \longrightarrow OH + O$
$H_2 + O \longrightarrow OH + H$
■ OH (3285,775 cm^{-1})
○ H (2467,75 cm^{-1})
△ O (3455,989 cm^{-1})
▼ H_2 (2768,767 cm^{-1})
Intensity (I/I_{max})
0.00
0.25
0.50
0.75
1.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Time (μs)


NH radical X$^3\Sigma^-$
P branch Δv = 3-2
P branch Δv = 2-1
R branch Δv = 3-2
P branch Δv = 1-0
R branch Δv = 2-1
R branch Δv = 1-0
Emission Intensity (a.u.)
1.0x10^7
8.0x10^6
6.0x10^6
4.0x10^6
2.0x10^6
2600
2700
2800
2900
3000
3100
3200
3300
3400
Wavenumber (cm^{-1})


NH radical X$^3\Sigma^-$, Δv = 1 - 0
j" = 4
j" = 3
j" = 2
Emission Intensity (a.u.)
6.0x10^6
3.0x10^6
0.0
3242.6
3242.7
3242.8
3242.9
3243.0
3243.1
3243.2
3243.3
Wavenumber (cm^{-1})

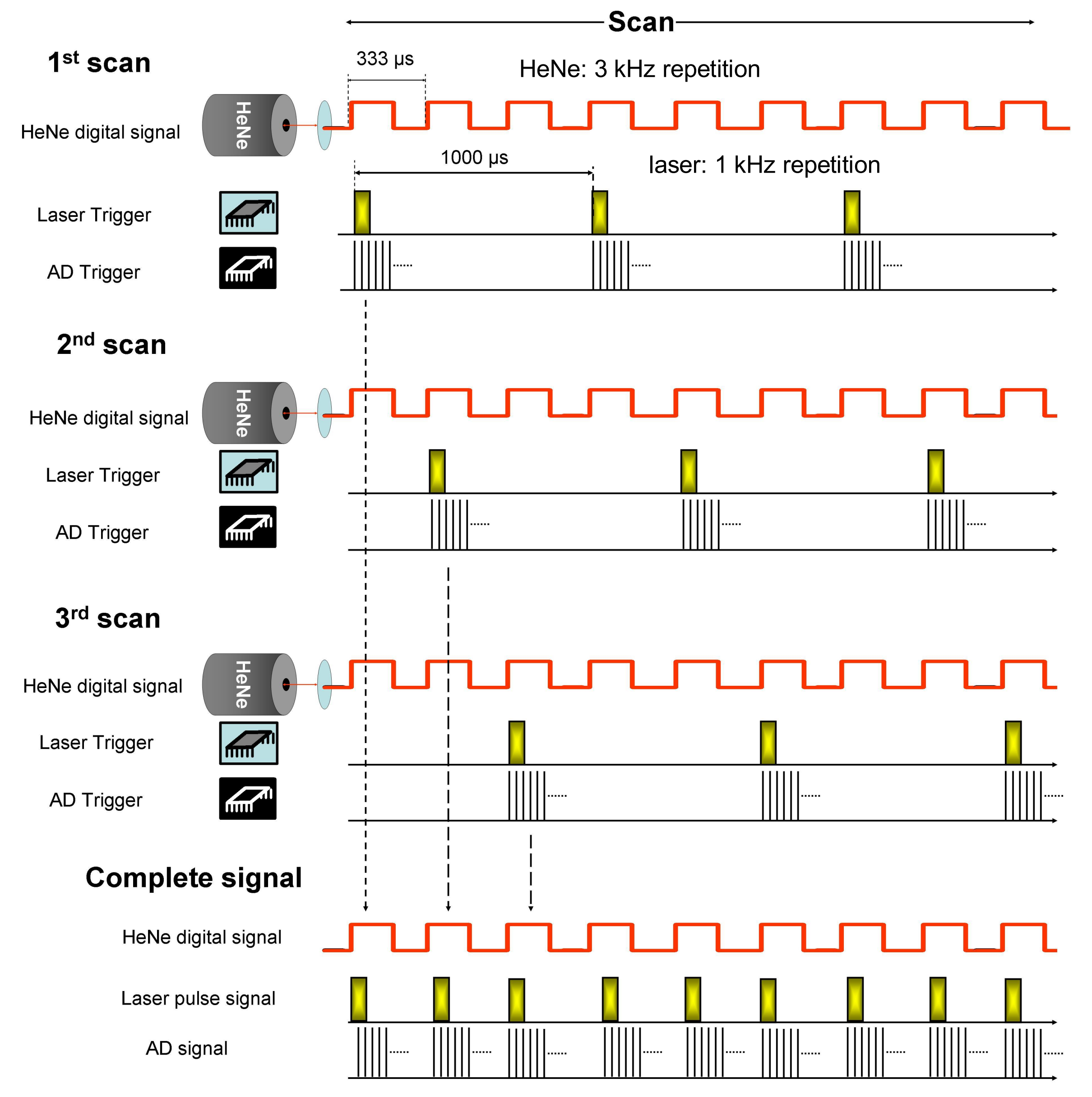
Time resolved FTIR measurement in the laser spark

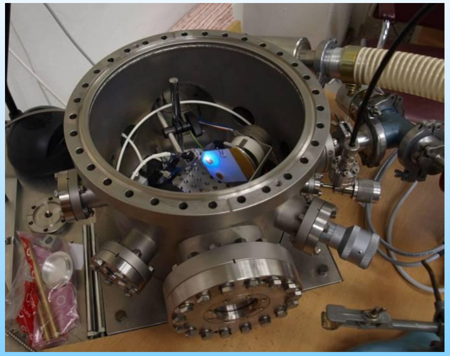




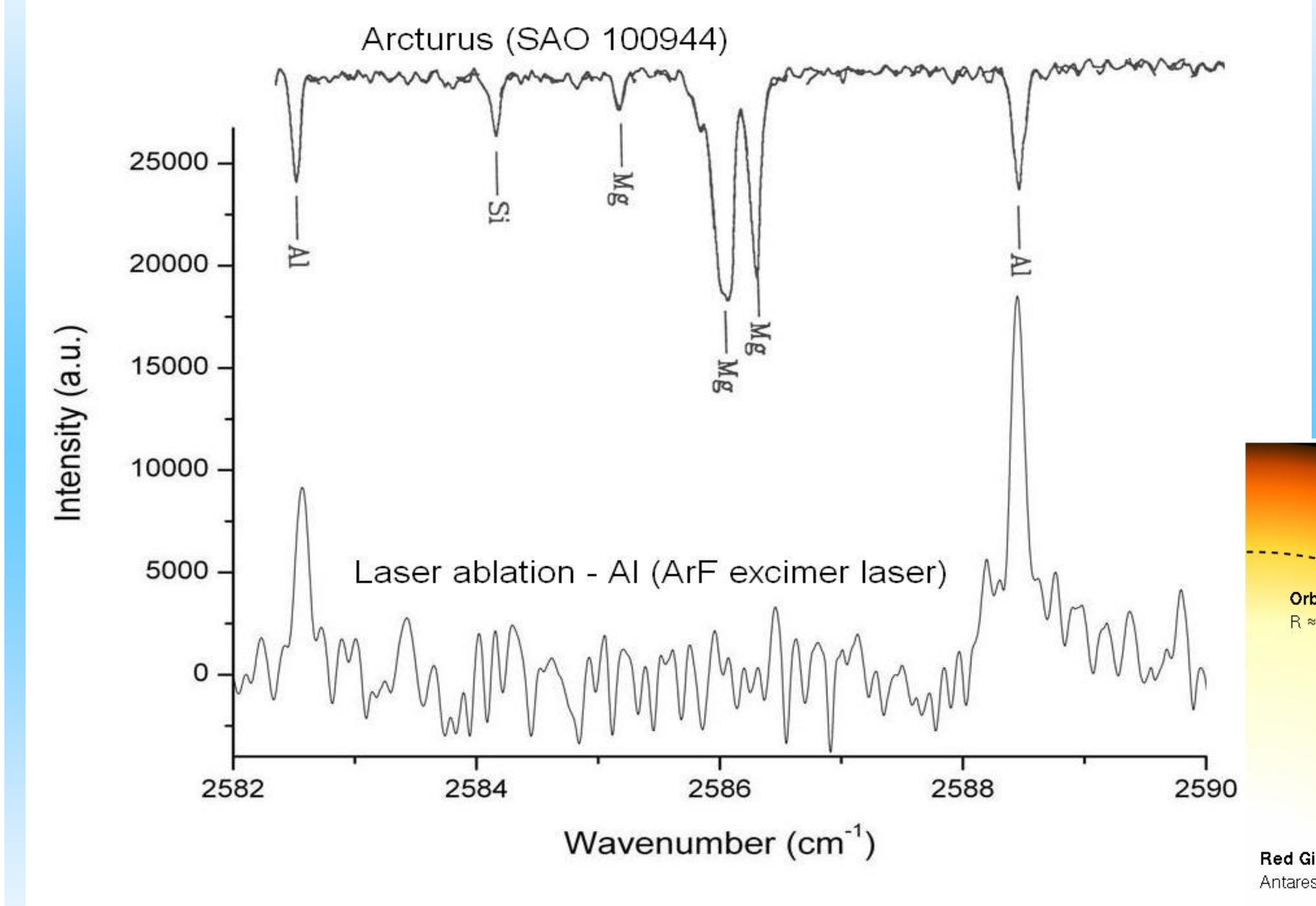
The emission arises in ablation of metal target by laser radiation of a pulsed nanosecond ArF (λ = 193 nm) laser 1 kHz repetition, at fluences around 15 mJ

1/n system

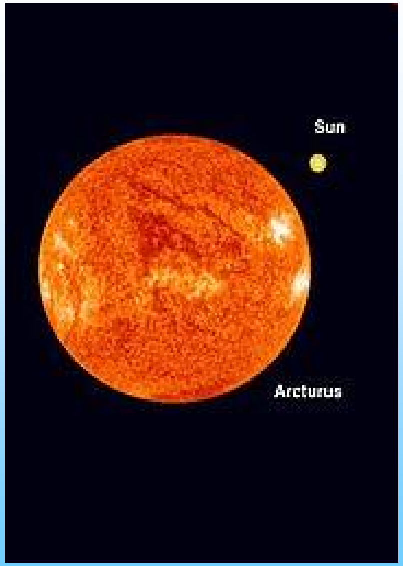

Scan
1st scan
333 µs
HeNe: 3 kHz repetition
HeNe digital signal
HeNe
1000 µs
laser: 1 kHz repetition
Laser Trigger
AD Trigger
2nd scan
HeNe digital signal
HeNe
Laser Trigger
AD Trigger
3rd scan
HeNe digital signal
HeNe
Laser Trigger
AD Trigger
Complete signal
HeNe digital signal
Laser pulse signal
AD signal

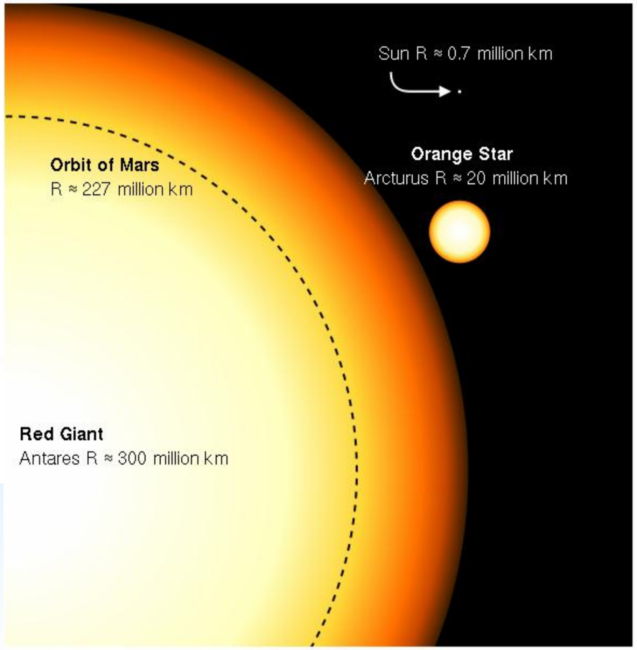


Comparison of Arcturus spectrum with FTIR emission spectrum

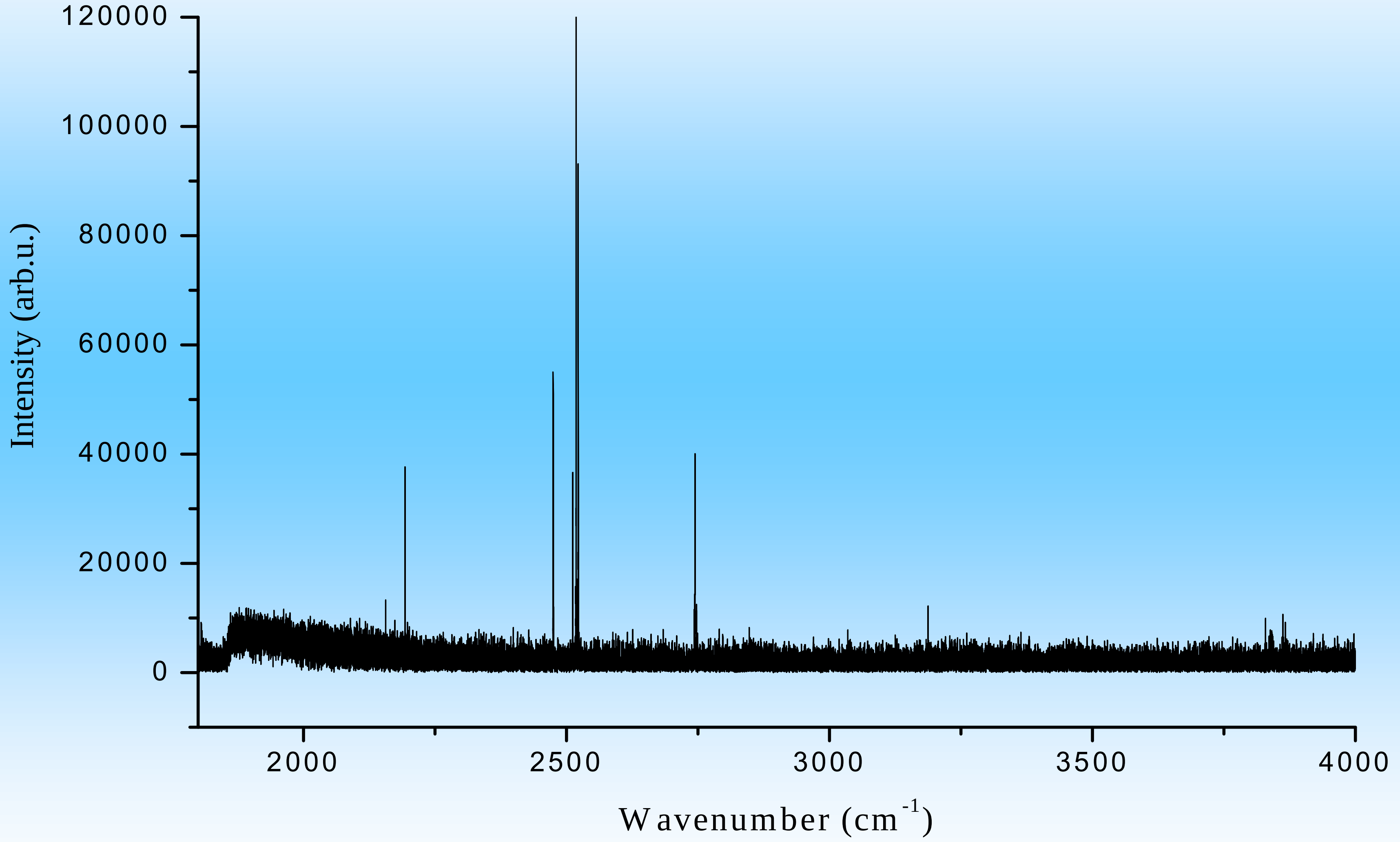


Arcturus' size relative to the Sun

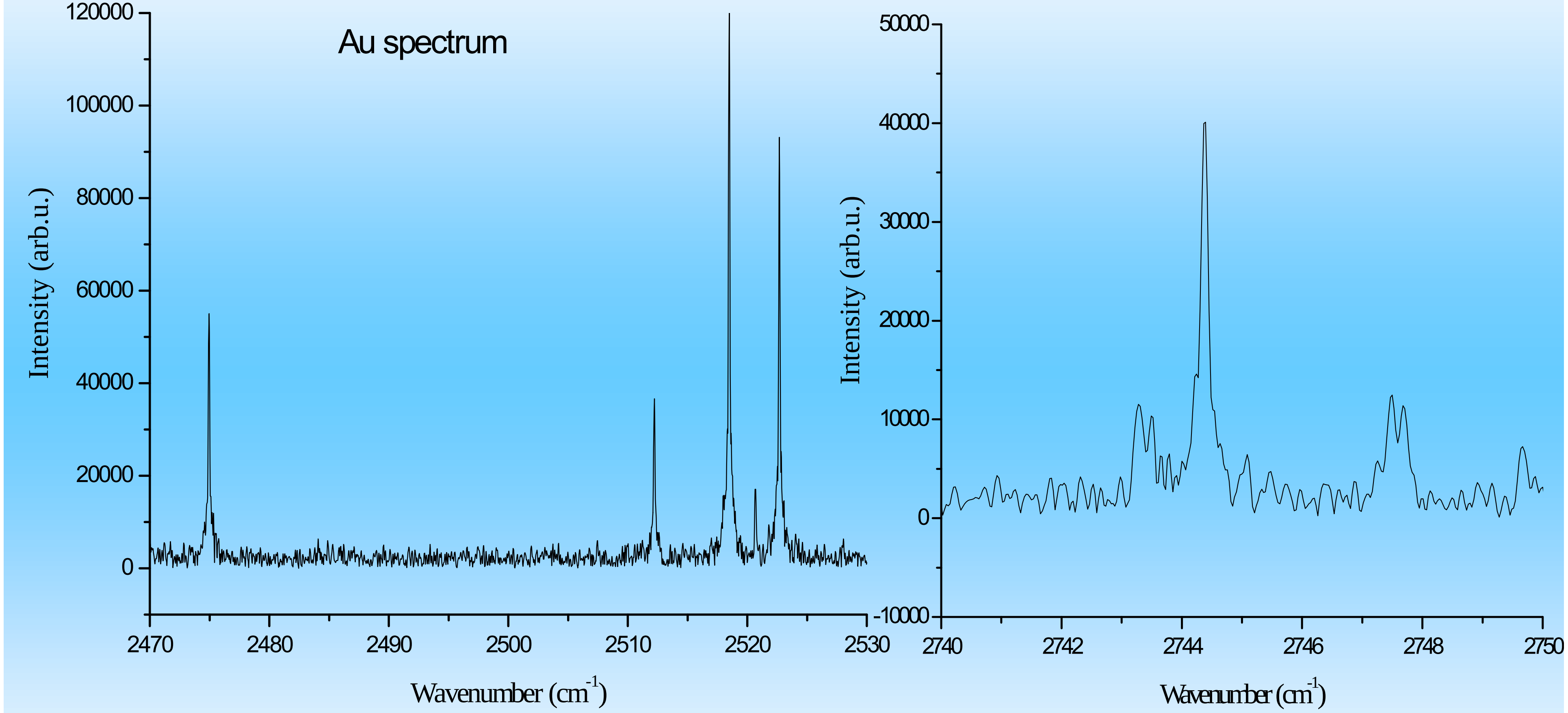




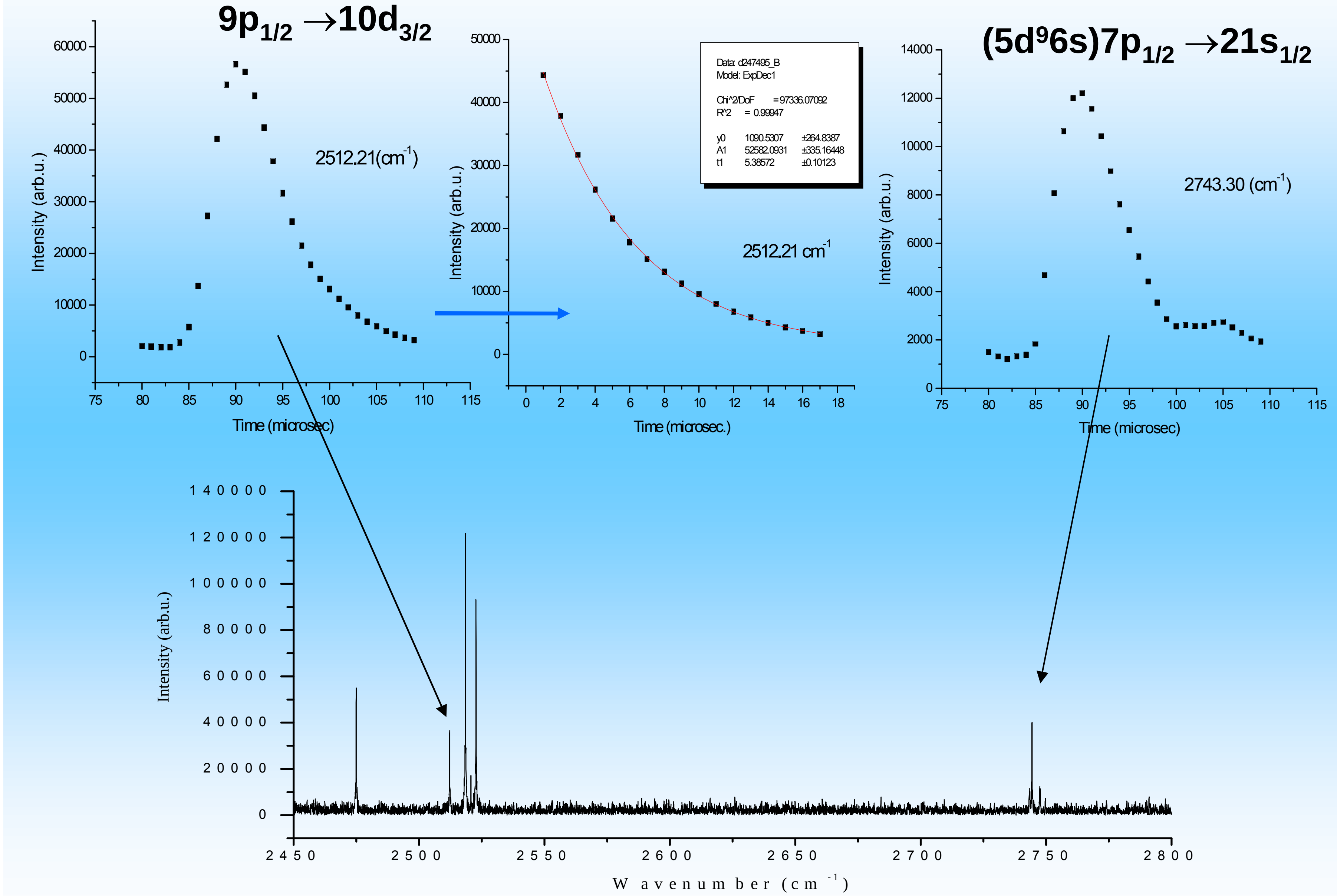
The observed IR emission spectrum of Au



Some parts of the observed IR emission spectra of Au



Spectral resolution 0.05 cm^{-1}



$9p_{1/2} \rightarrow 10d_{3/2}$

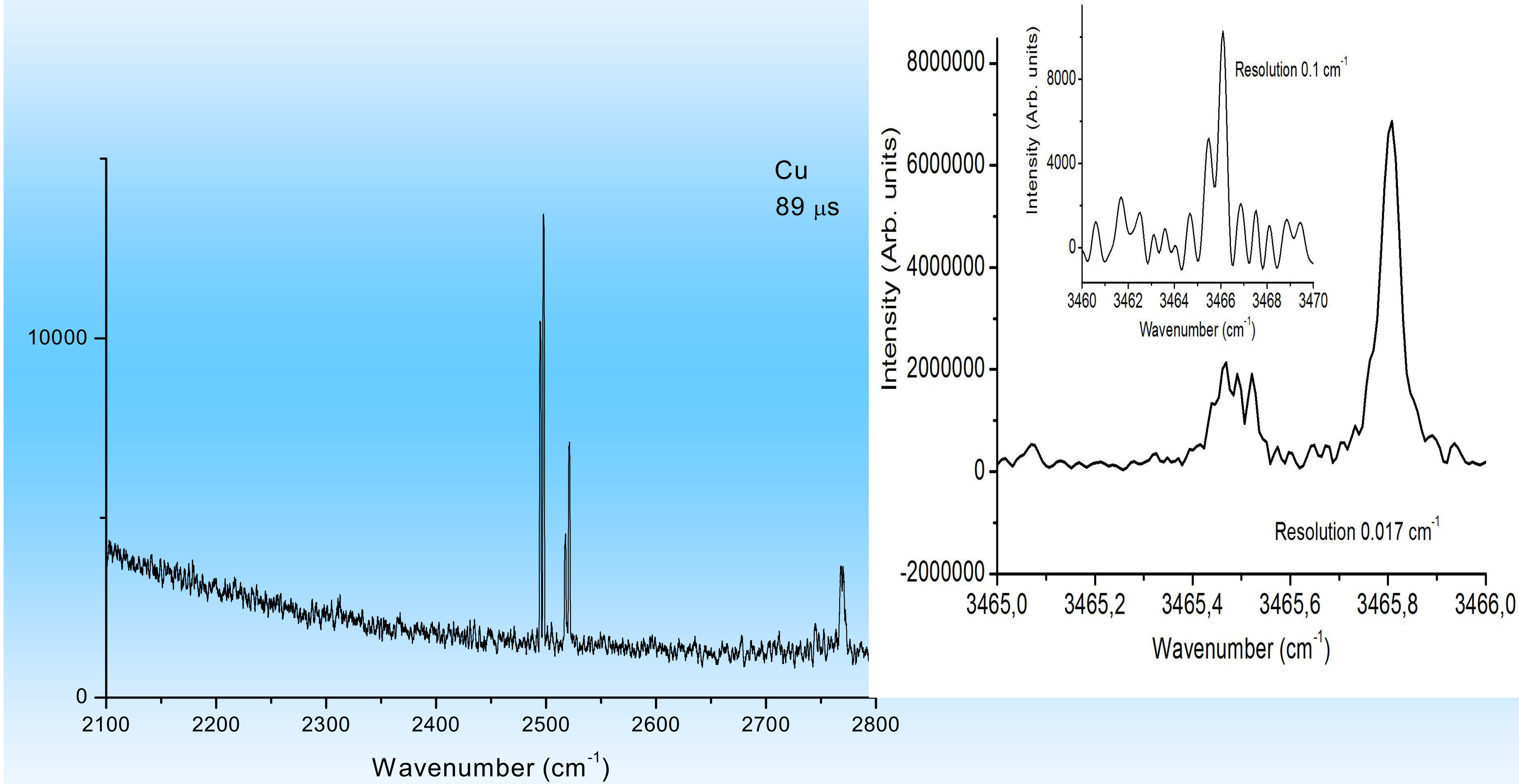
$(5d^96s)7p_{1/2} \rightarrow 21s_{1/2}$

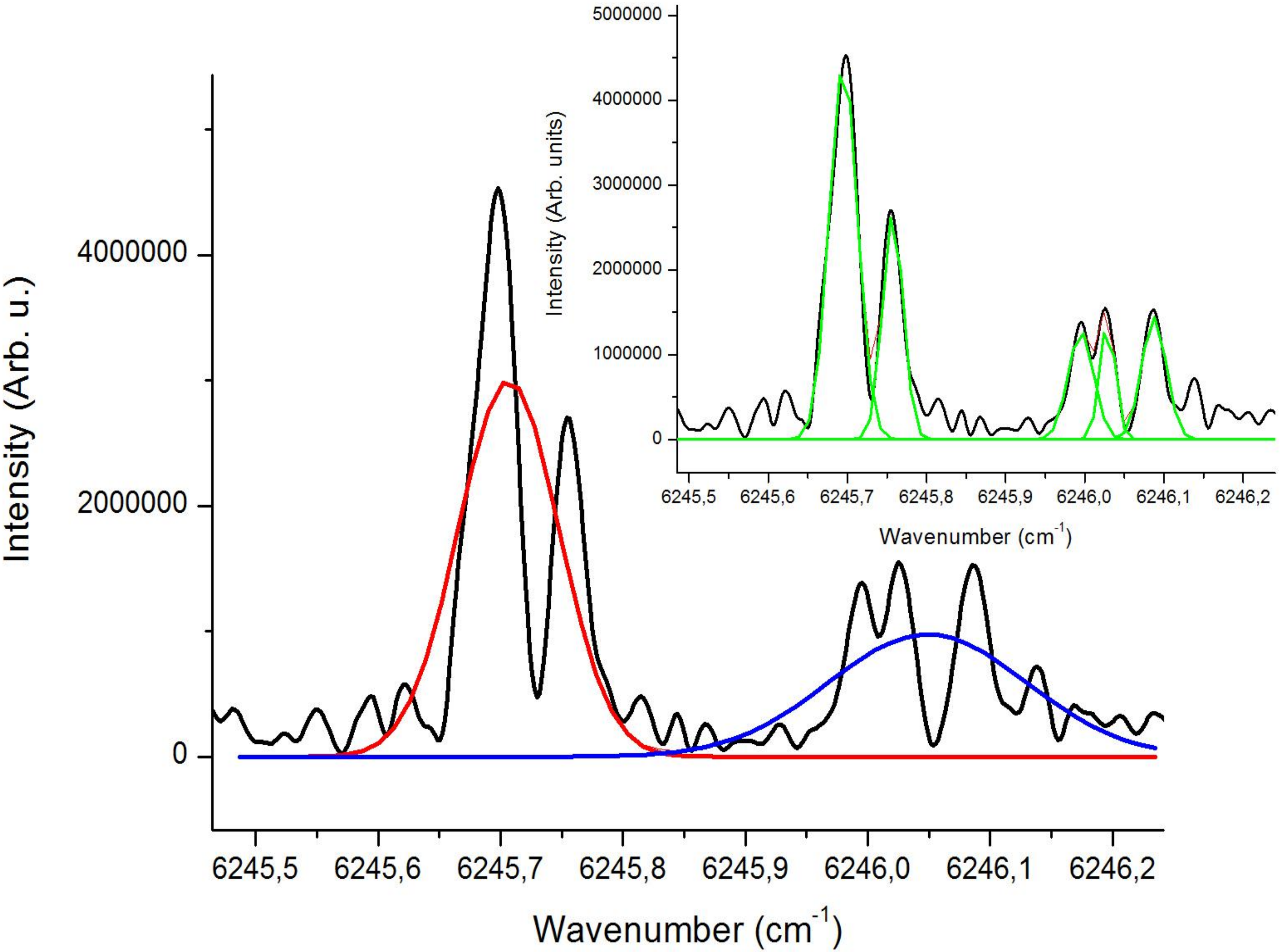
```
Data: d247495_B
Model: ExpDec1

Chi^2/DoF      = 97336.07092
R^2     =  0.99947

y0      1090.5307      ±264.8387
A1      52582.0931     ±335.16448
t1      5.38572        ±0.10123
```

Part of the FTIR spectrum of the emission from Cu target




Intensity (Arb. u.)
4000000
2000000
0
6245,5
6245,6
6245,7
6245,8
6245,9
6246,0
6246,1
6246,2
Wavenumber (cm^{-1})
Intensity (Arb. units)
5000000
4000000
3000000
2000000
1000000
0
6245,5
6245,6
6245,7
6245,8
6245,9
6246,0
6246,1
6246,2
Wavenumber (cm^{-1})

Conclusions

- Several systems inside of discharge plasma has been studied by High resolution FT spectroscopy

- New systems such extinguishing agents will be studied (C

- Laboratory chemistry of HCN and HNC isomerisation

- Many High resolution atomic spectra has been measured by High resolution FT spectroscopy (better understanding of the stellar spectra)

- New detection technique was developed which can be applied for a study of the relaxation profiles of the individual atomic or molecular levels

THANKS:

This work is the part of the research programs of Ministry of Finance, Swiss contribution: **Spolupráce a pŚenos know-how v oblasti výzkumu laserové technologie, project PF 049/4V**

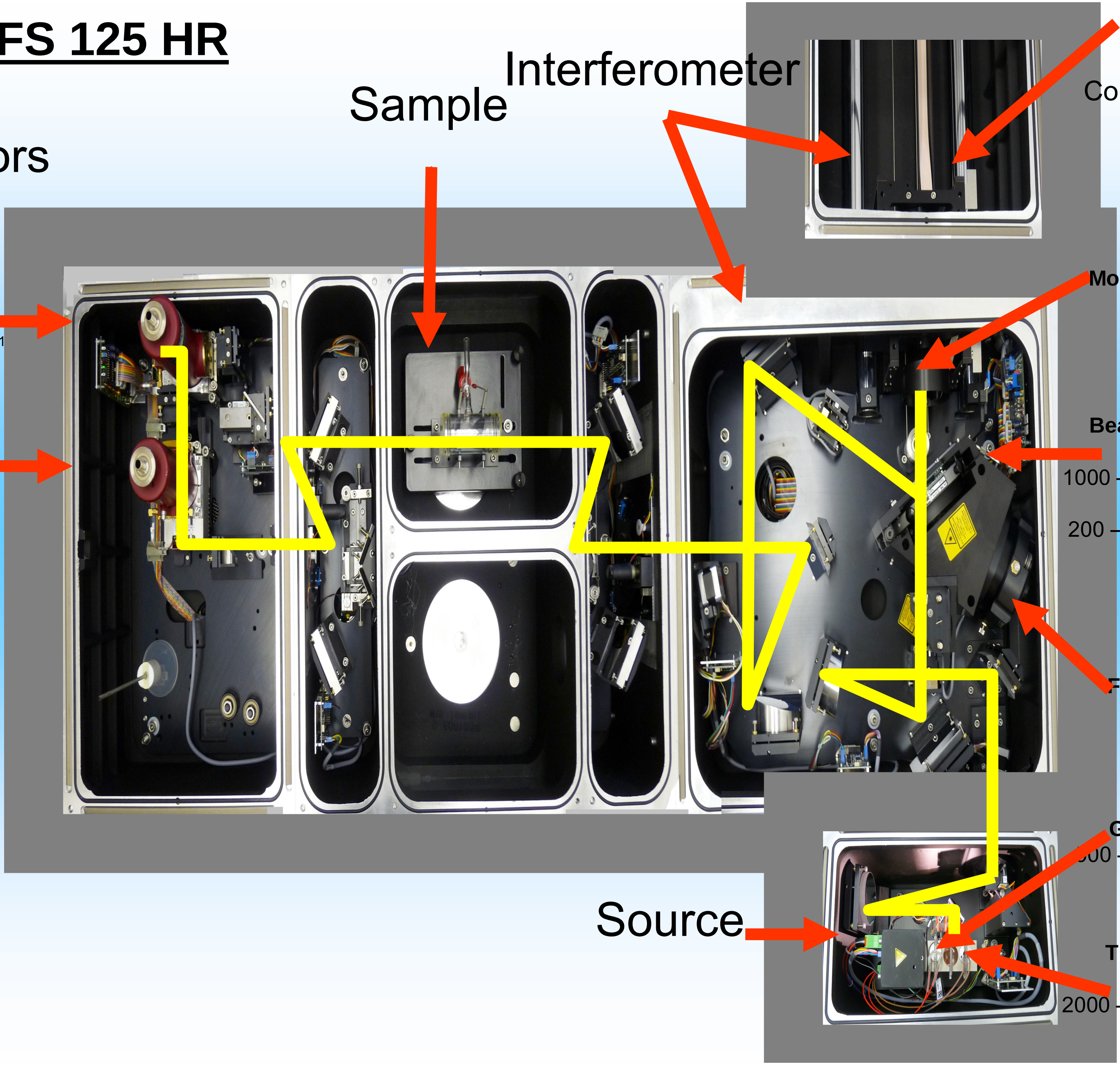
Thanks

http://www.jh-inst.cas.cz/~ftirlab/ (Spectral library)

From the left: M. Ferus, M. Kamas, J. Cihelka, P. Kubelík, S. Civiš, K. Sovová, I. Matulková.


BRUKER
IFS 125HR

Bruker IFS 125 HR



Detectors

InSb
1800 – 8 000 cm^{-1}

MCT
450 – 6 000 cm^{-1}

Sample

Interferometer

Moving
Mirror
Compartment

Moving Mirror

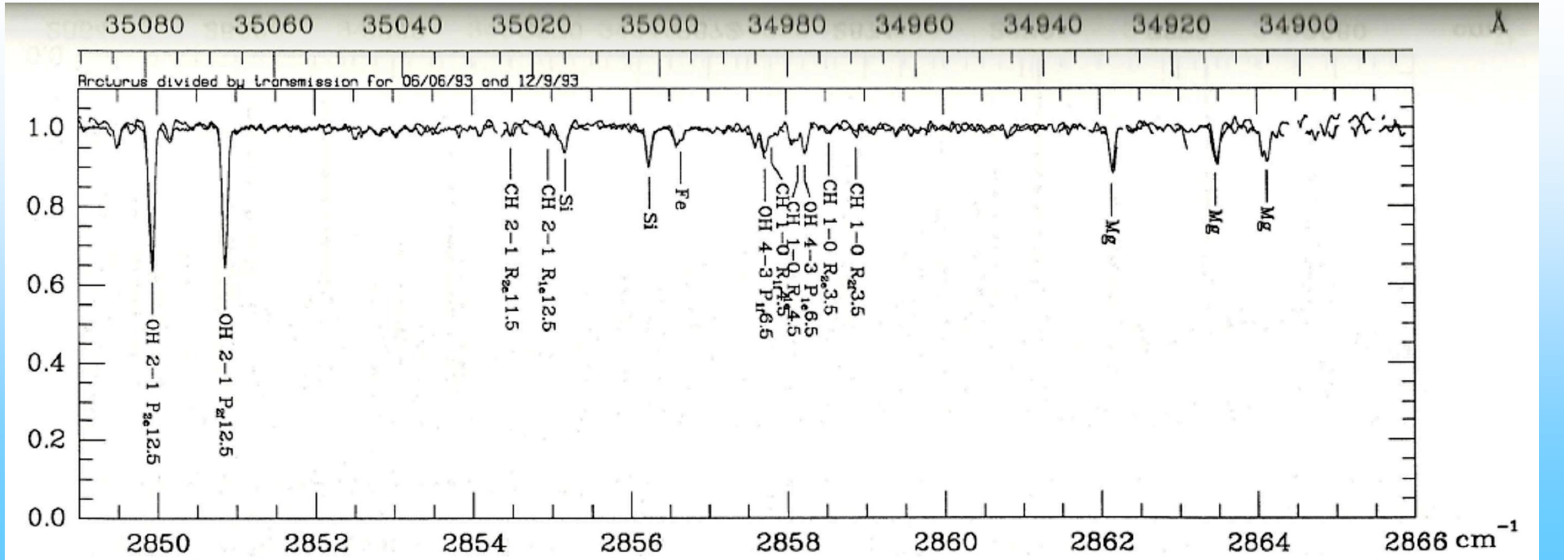
Beamsplitter
CaF_2
1000 – 25 000 cm^{-1}
KBr
200 – 13 000 cm^{-1}

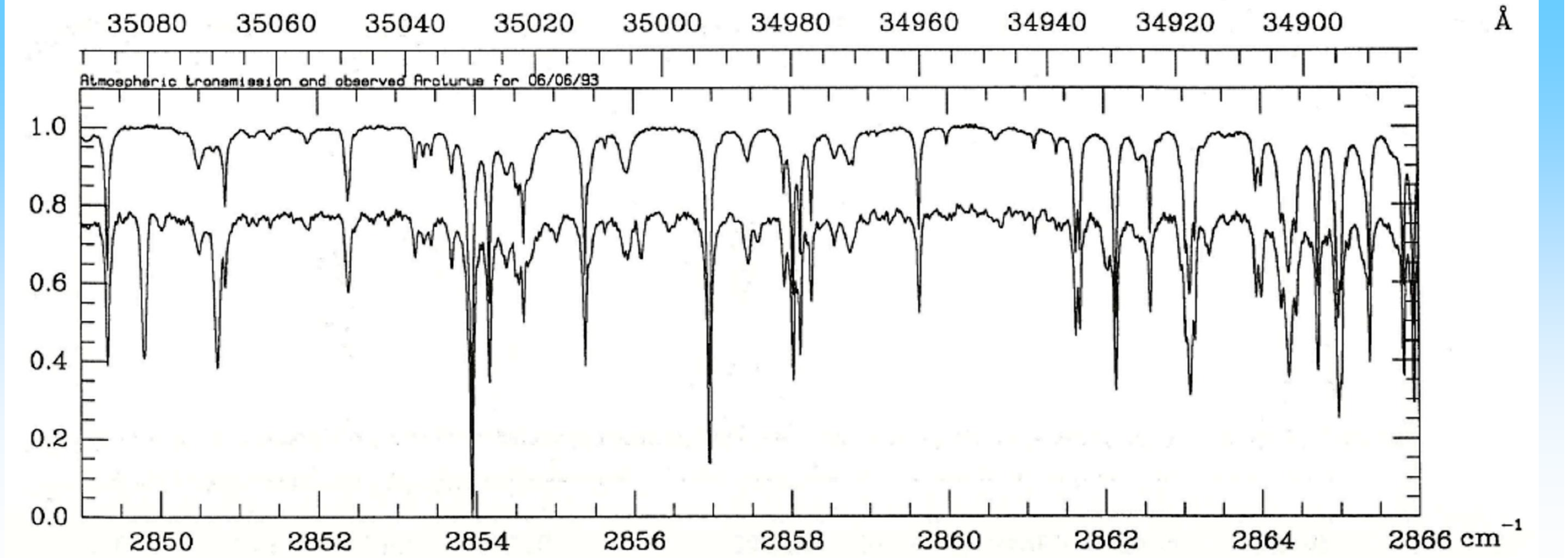
Fixed Mirror

Glowbar
[illegible]00 – 4000 cm^{-1}

Source

Tungsten
Bulb
2000 – 25 000 cm^{-1}


Arcturus divided by transmission for 06/06/93 and 12/9/93
35080
35060
35040
35020
35000
34980
34960
34940
34920
34900
Å
1.0
0.8
0.6
0.4
0.2
0.0
OH 2-1 P_{2e}12.5
OH 2-1 P_{2f}12.5
CH 2-1 R_{2e}11.5
CH 2-1 R_{1e}12.5
Si
Si
Fe
OH 4-3 P_{1f}6.5
CH 1-0 R_{1f}4.5
CH 1-0 R_{1e}4.5
OH 4-3 P_{1e}6.5
CH 1-0 R_{2e}3.5
CH 1-0 R_{2f}3.5
Mg
Mg
Mg
2850
2852
2854
2856
2858
2860
2862
2864
2866 cm^{-1}


Atmospheric transmission and observed Arcturus for 06/06/93
35080
35060
35040
35020
35000
34980
34960
34940
34920
34900
Å
1.0
0.8
0.6
0.4
0.2
0.0
2850
2852
2854
2856
2858
2860
2862
2864
2866 cm^{-1}

Astron. & Astrophys. 34, 479–482 (1974)

Letter to the Editor

Radio Astronomical Determination of Ground State Transition Frequencies of CH

O. E. H. Rydbeck, J. Elldér, W. M. Irvine*, A. Sume and Å. Hjalmarson
Onsala Space Observatory

Received June 26, revised July 9, 1974

Summary. From a comparison of the spectra of CH and other molecules towards Cas A and dark clouds, we have determined the rest frequencies of the three allowed transitions of the $^2\Pi_{1/2}$, $J=1/2$, ground state Λ-doublet of CH to be $\nu_{01}=3263.794\pm0.003$, $\nu_{11}=3335.481\pm0.002$ and $\nu_{10}=3349.193\pm0.003$ MHz. These frequencies cannot be checked by the sum rule, $\nu_{11}+\nu_{00}=\nu_{10}+\nu_{01}$, since the ν_{00}-transition is forbidden in this particular case. The relative errors in these frequencies are about twice as small as those obtained earlier by radio astronomical methods for the two main lines of ground state OH. Further refinements in the determination of the CH frequencies are desirable, since these transitions have not yet been directly measured in the laboratory.

Key words: CH — Cas A — dark clouds — transition frequencies — interstellar molecules

Radio astronomical detection of the ground state $^2\Pi_{1/2}$, $J=1/2$, Λ-doublet of CH has recently been announced by Rydbeck *et al.* (1973). The upper satellite line was detected independently by Turner and Zuckerman (1974). The CH-lines were observed in southern galactic sources by Robinson *et al.* (1974). Measurements of satellite and main line intensity ratios of CH have recently been reported by Rydbeck *et al.* (1974a). The subject of the present Letter is a more accurate determination of the CH frequencies.

The equipment and observing procedure were the same as described by Rydbeck *et al.* (1974a), except that filters of bandwidth and spacing 1 kHz were also used for the present observations. Most of the integrations were done with left circular polarization, there being no evidence for polarization in any of the sources observed.

The CH transition frequencies were determined by Rydbeck *et al.* (1973) to be $\nu_{10}(F=1\rightarrow0)=3349.185\pm0.010$ MHz, $\nu_{11}(F=1\rightarrow1)=3335.475\pm0.010$ MHz, $\nu_{01}(F=0\rightarrow1)=3263.788\pm0.010$ MHz. Those values have now been refined, with the following assumptions: (1) in the sources observed, CH, OH, H_2CO and NH_3 are well mixed, and have the same radial velocity; (2) the correct frequencies for the main lines of OH at 18 cm are those given by ter Meulen and Dymanus (1972); (3) the frequency for the $F=2\rightarrow2$ component of H_2CO at 6 cm is that given by Tucker *et al.* (1971).

For the comparison of OH and CH spectra, we observed towards Cas A and four dark clouds which, according to Turner (1973), have either a single velocity component or at least one narrow, well-defined component.

The profile for the main $F=1\rightarrow1$ line of CH, in the direction of Cas A, was compared with the OH profiles taken by Davies and Matthews (1972) and with unpublished OH data taken at Onsala. The presence of two components in the Orion arm feature at $v\approx-1$ km s^{-1} (Fig. 1) and the characteristic structure of the Perseus arm feature allows the CH and OH spectra to be compared with an accuracy of about ±1 kHz. We estimate a correction, $\delta\nu_{11}$, of 6 ± 1 kHz to our previously published value of ν_{11} (Rydbeck *et al.*, 1973).

Another estimate of $\delta\nu_{11}=5.5\pm2$ kHz was obtained by comparing the main line spectrum of CH with that of H_2CO (Davies, 1973; Davies, 1974; Zuckerman *et al.*, 1970) in the direction of Cas A.

A third, independent, estimate of $\delta\nu_{11}$ was obtained from a comparison of our CH spectra with those of other molecules towards four dark clouds. Table 1 gives a compilation of the radial velocities for CH and other molecules observed at approximately the same positions. The OH values are averages of the data of

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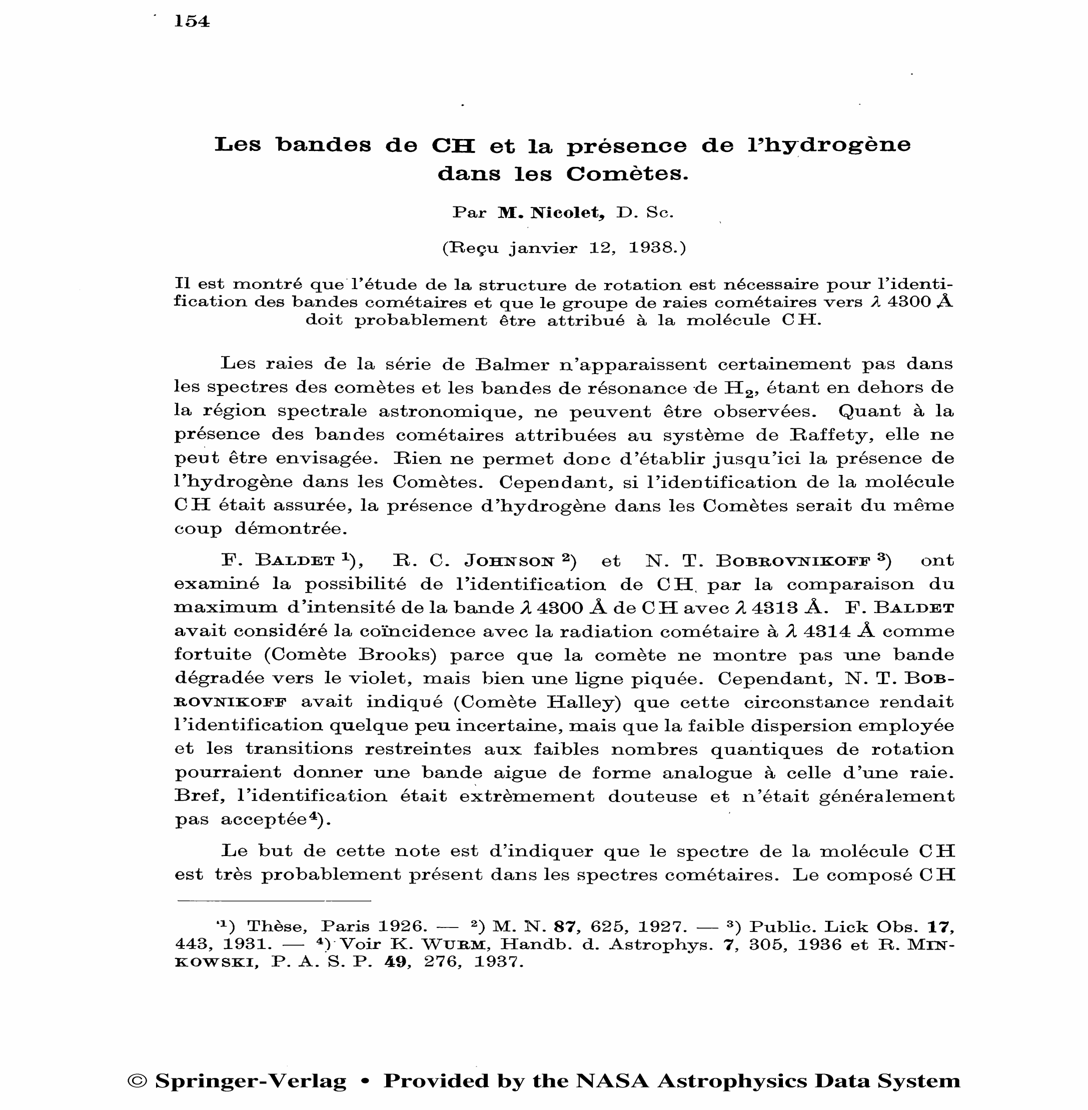
* On leave from the Department of Physics and Astronomy, University of Massachusetts, Amherst.

Title: Les bandes de CH et la présence de l'hydrogène dans les Comètes.
Authors: Nicolet, M.
Journal: Zeitschrift für Astrophysik, Vol. 15, p.154



Les bandes de CH et la présence de l'hydrogène dans les Comètes.

Par **M. Nicolet,** D. Sc.

(Reçu janvier 12, 1938.)

Il est montré que l'étude de la structure de rotation est nécessaire pour l'identification des bandes cométaires et que le groupe de raies cométaires vers λ 4300 Å doit probablement être attribué à la molécule CH.

Les raies de la série de Balmer n'apparaissent certainement pas dans les spectres des comètes et les bandes de résonance de H_2, étant en dehors de la région spectrale astronomique, ne peuvent être observées. Quant à la présence des bandes cométaires attribuées au système de Raffety, elle ne peut être envisagée. Rien ne permet donc d'établir jusqu'ici la présence de l'hydrogène dans les Comètes. Cependant, si l'identification de la molécule CH était assurée, la présence d'hydrogène dans les Comètes serait du même coup démontrée.

F. BALDET 1), R. C. JOHNSON 2) et N. T. BOBROVNIKOFF 3) ont examiné la possibilité de l'identification de CH par la comparaison du maximum d'intensité de la bande λ 4300 Å de CH avec λ 4313 Å. F. BALDET avait considéré la coïncidence avec la radiation cométaire à λ 4314 Å comme fortuite (Comète Brooks) parce que la comète ne montre pas une bande dégradée vers le violet, mais bien une ligne piquée. Cependant, N. T. BOBROVNIKOFF avait indiqué (Comète Halley) que cette circonstance rendait l'identification quelque peu incertaine, mais que la faible dispersion employée et les transitions restreintes aux faibles nombres quantiques de rotation pourraient donner une bande aigue de forme analogue à celle d'une raie. Bref, l'identification était extrèmement douteuse et n'était généralement pas acceptée 4).

Le but de cette note est d'indiquer que le spectre de la molécule CH est très probablement présent dans les spectres cométaires. Le composé CH

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1) Thèse, Paris 1926. — 2) M. N. **87**, 625, 1927. — 3) Public. Lick Obs. **17**, 443, 1931. — 4) Voir K. WURM, Handb. d. Astrophys. **7**, 305, 1936 et R. MINKOWSKI, P. A. S. P. **49**, 276, 1937.