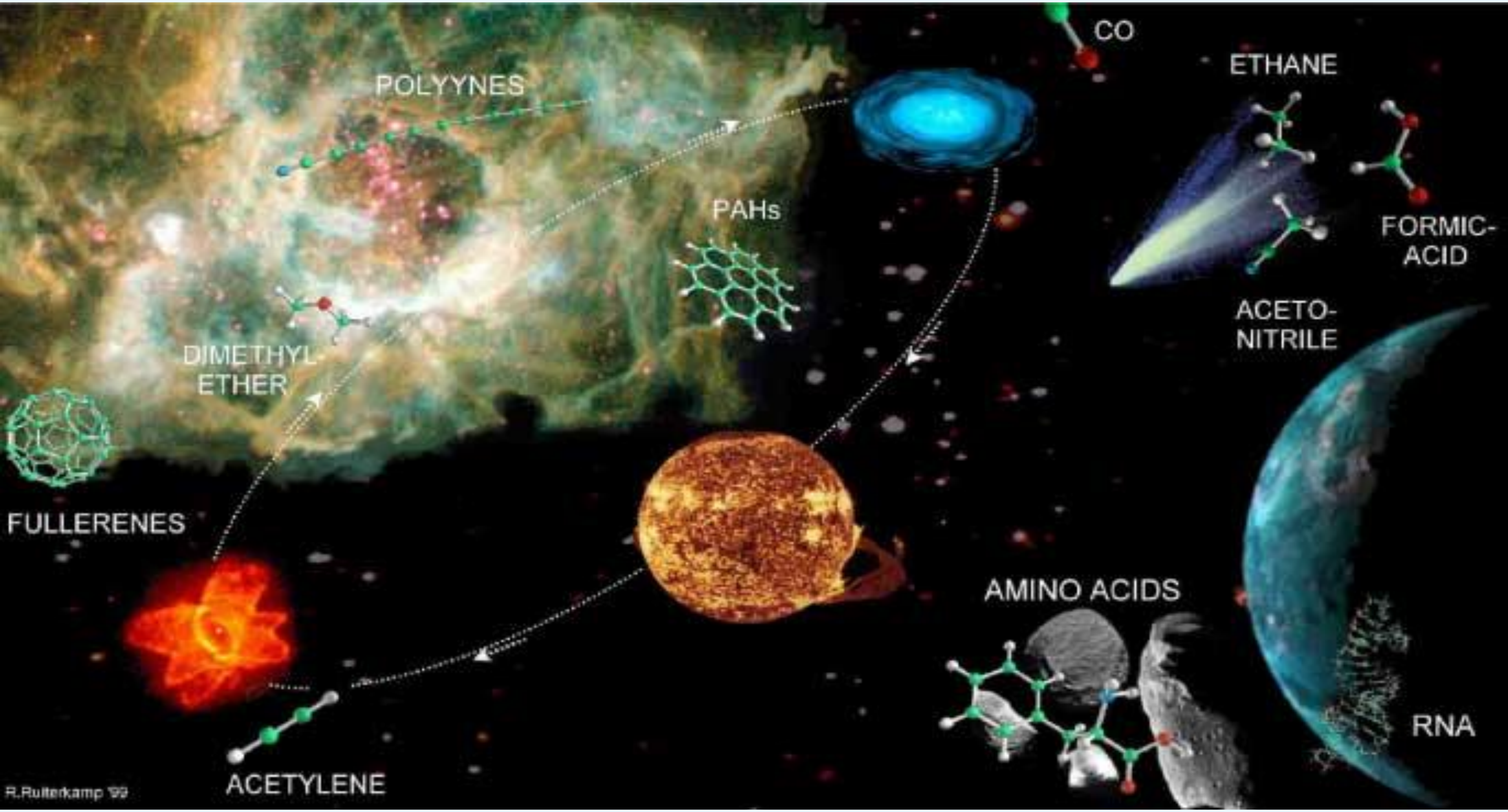
Svatopluk Civiš

PROGRAM CEZHRANIČNEJ SPOLUPRÁCE SLOVENSKÁ REPUBLIKA ČESKÁ REPUBLIKA 2007 2013

EURÓPSKA ÚNIA EURÓPSKY FOND REGIONÁLNEHO ROZVOJA

SPOLOČNE BEZ HRANÍC

FOND MIKROPROJEKTŮ



Záporné ionty, jejich identifikace v laboratoři a v mezihvězdném prostoru

Úvod

- V mezihvězdném prostoru bylo doposud identifikováno přes 150 molekul a iontů
- Ionty mají dominantní úlohu v chemických reakcích
- Celkem identifikováno v mezihvězdném prostoru 17 kationtů:

  (CH^+, CO^+, SO^+, CF^+, HCO^+, HCS^+, HOC^+, N_2H^+, H_3^+, H_2D^+, HD_2^+, CH_2D^+, $HCNH^+$, $HOCO^+$, H_3O^+, H_2COH^+, HC_3NH^+)
- Do roku 2006 nebyly identifikovány záporně nabité ionty
- reakce v interstelární chemii jsou spjaty s reakcemi kationtů $\Rightarrow$ pravděpodobný je i výskyt aniontů

Anionty

- V laboratoři bylo spektroskopicky detegováno

do roku 2006 pouze 11 aniontů:

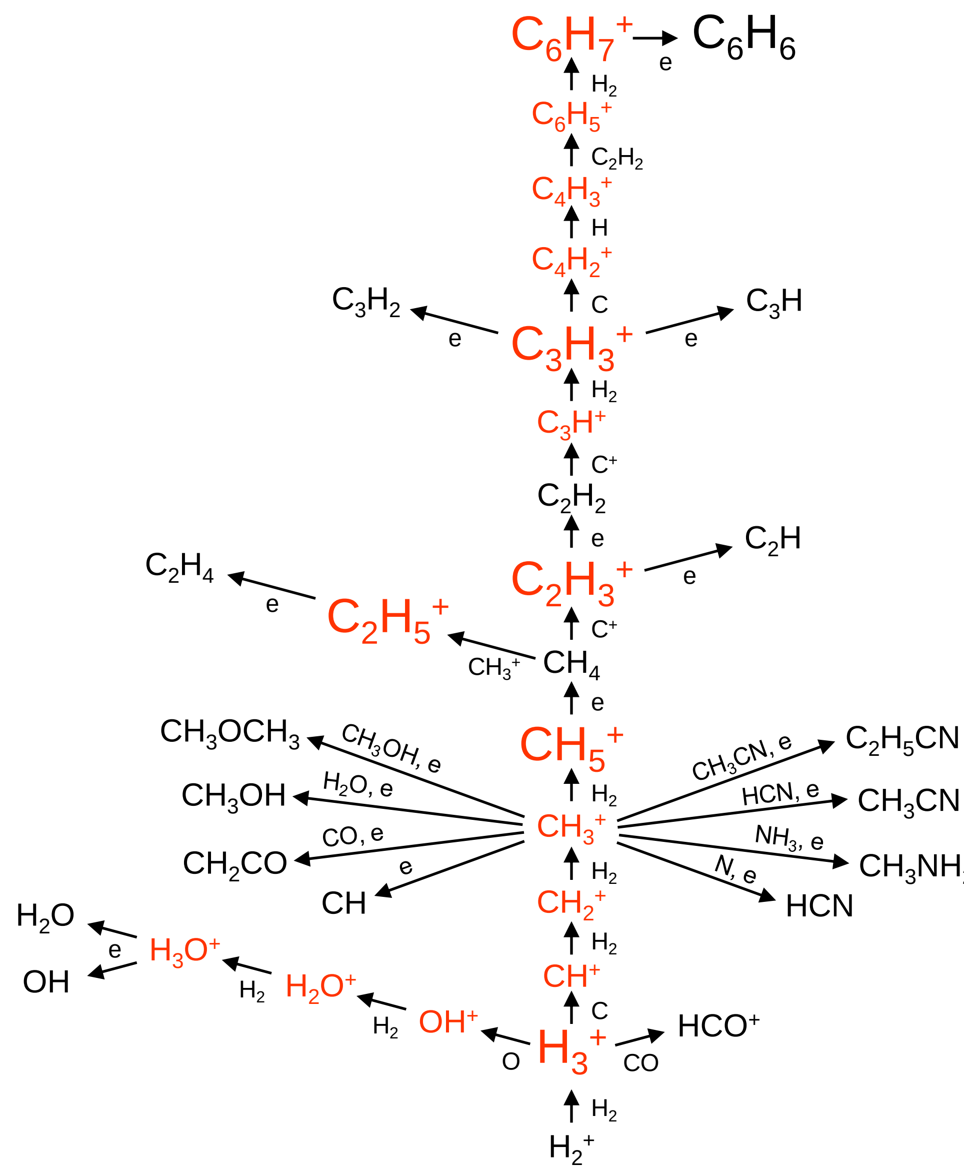
OH^-, SH^-, N_2H^-, N_3^-, NCO^-, NCS^-, NH^-, HNO^-, FHF^-, $ClHCl^-$, C_2^-,

Mezihvězdné molekulární ionty

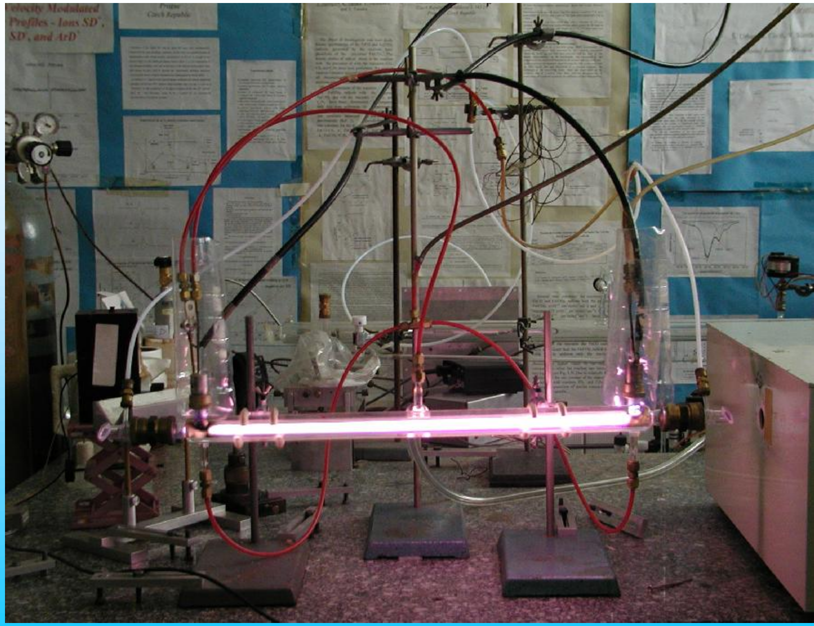
- Reaktivní intermediáty v hustých mezihvězdných oblacích
- nízká n, T

- Důležité z hlediska informace o podmínkách

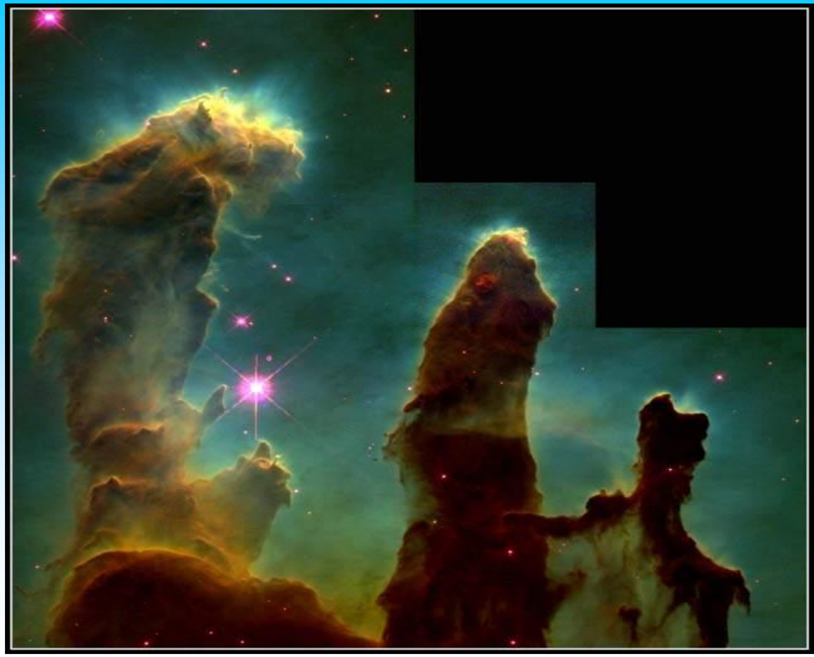
- Astronomická identifikace na základě laboratorních spekter



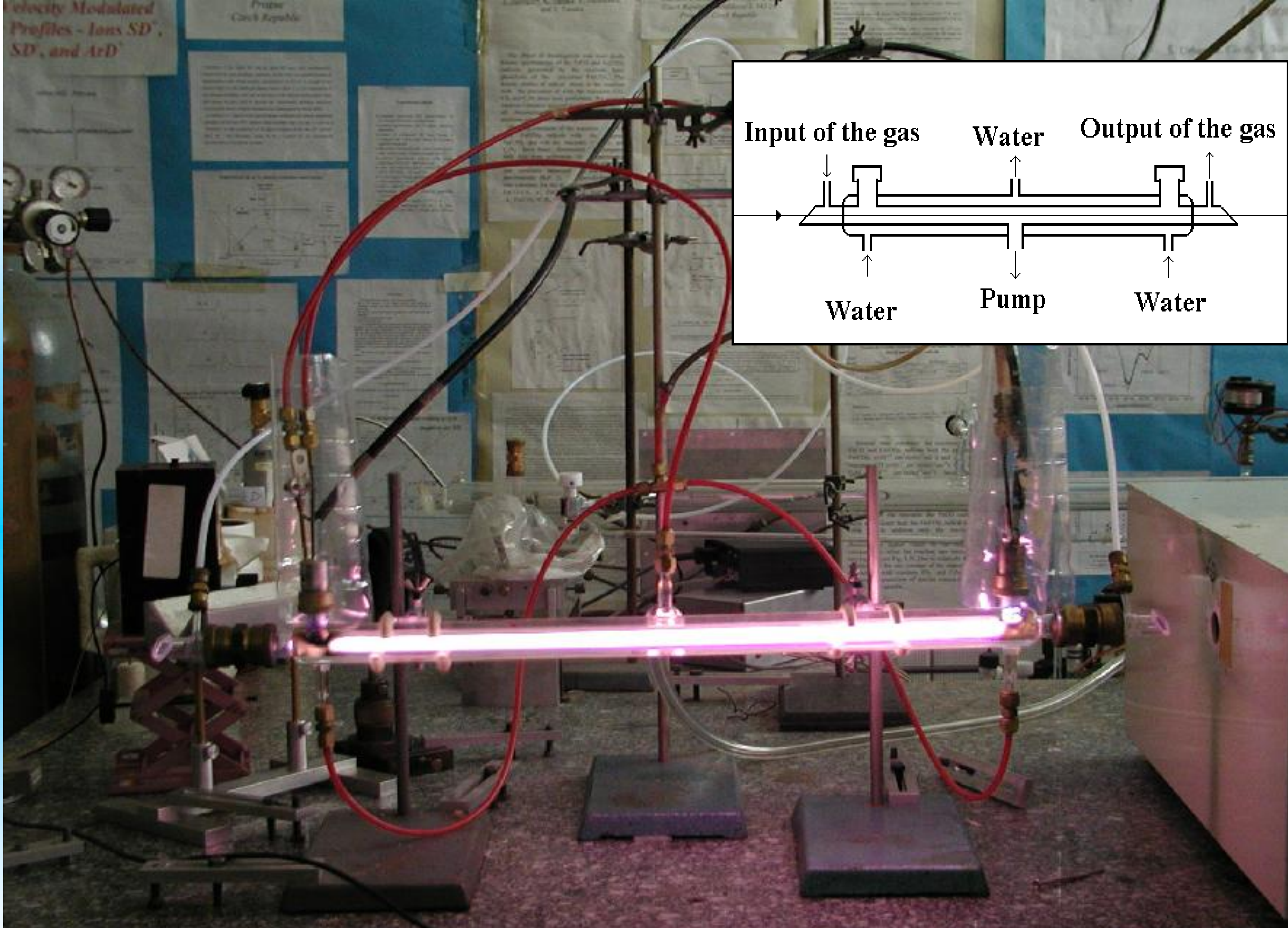
Úvod



Infračervená laser-diodová spektroskopie molekulárních iontů



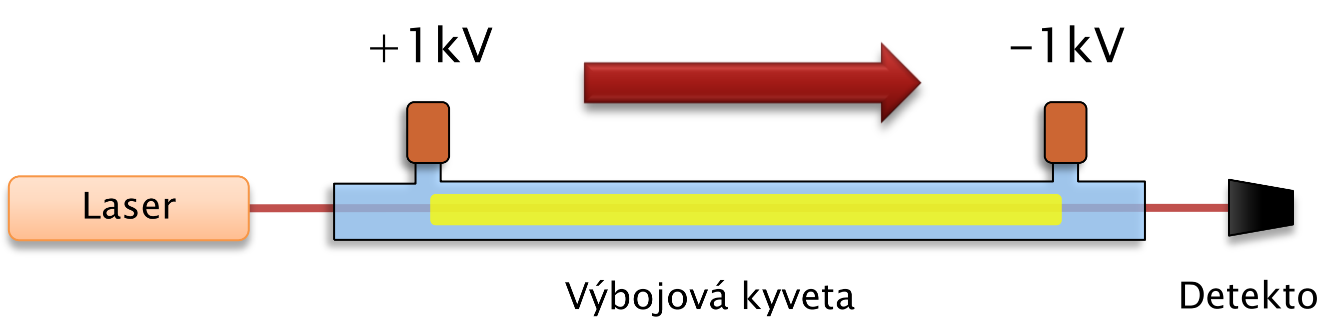
Záporné ionty a jejich identifikace v laboratoři a v mezihvězdném prostoru



Zelinger, Z., Civiš, S., Kubát, P., and Engst, P.: „Diode laser application for research of molecular ions“, *Infrared Phys. Technol.*, 1995, **36,** 537-543

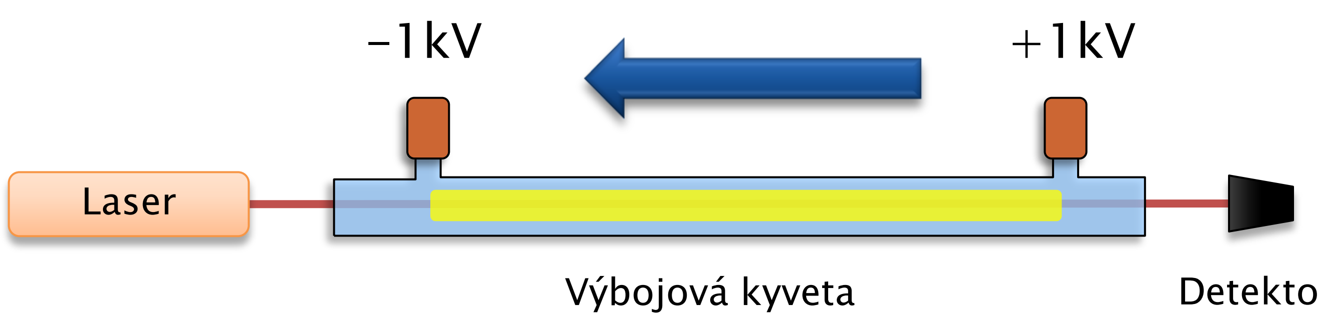
Rychlostně modulační spektroskopie (Dopplerovská modulace)

- Výboj v pozitivním sloupci
  - Vysoká koncentrace iontů, bohatá chemie
  - Kationty driftují ke katodě
  - Anionty opačným směrem
  - Absorpční profily iontů jsou dopplerovsky posunuty



Rychlostně modulační spektroskopie (Dopplerovská modulace)

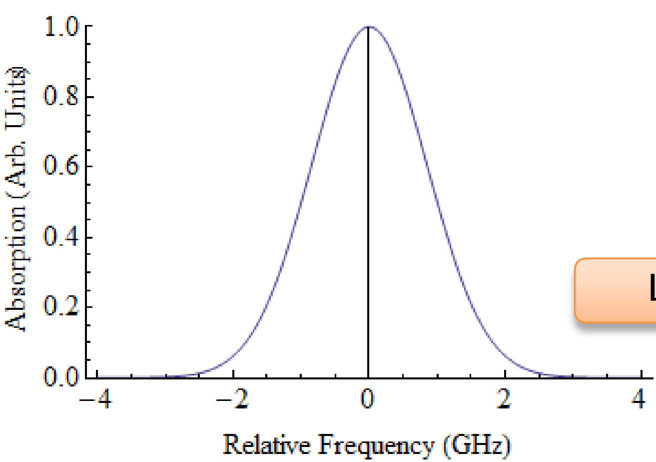
- Výboj v pozitivním sloupci
  - Vysoká koncentrace iontů, bohatá chemie
  - Kationty driftují ke katodě
  - Anionty opačným směrem
  - Absorpční profily iontů jsou dopplerovsky posunuty

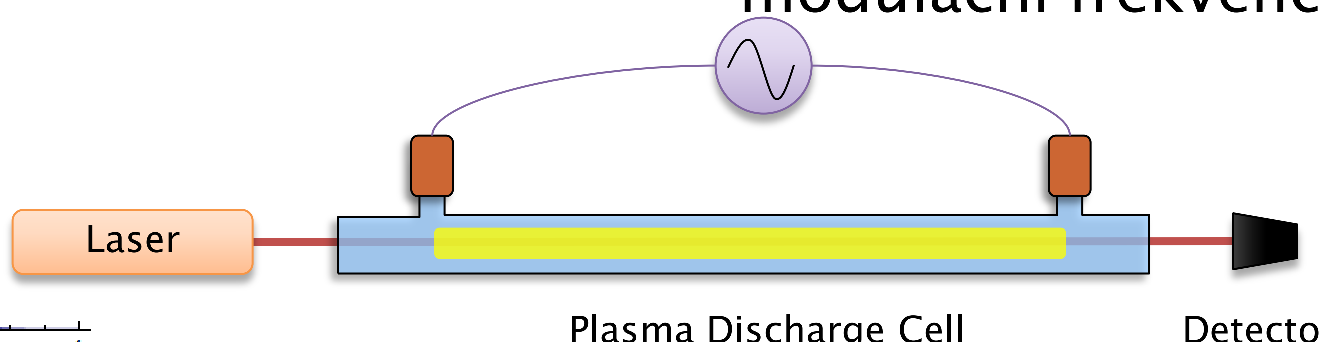


Rychlostně modulační spektroskopie

- Výboj v pozitivním sloupci
  - Vysoká koncentrace iontů, bohatá chemie
  - Kationty driftují ke katodě
  - Anionty opačným směrem
  - Absorpční profily iontů jsou dopplerovsky posunuty
- Střídavé napětí:

Dopplerovský profil iontu: červený/modrý posun vlnočtu, Demodulace signálu detektoru při modulační frekvenci

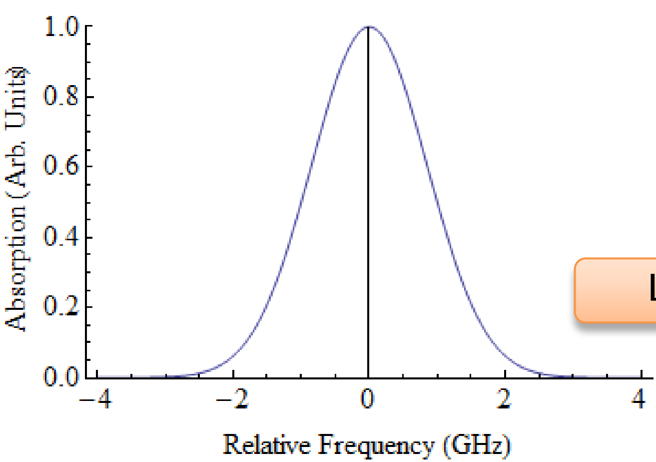


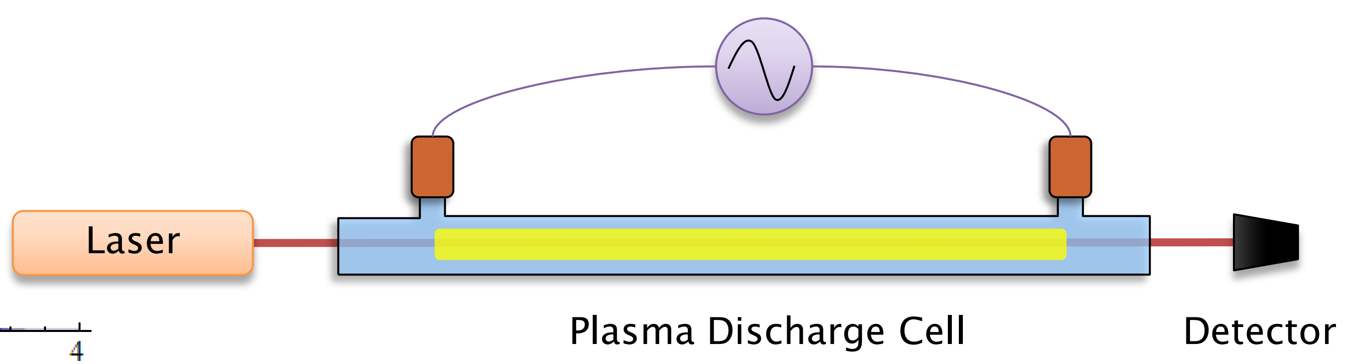


Rychlostní modulace

- Dopplerovský posun je dán vztahem:

$$\Delta\nu = \frac{v(ion)}{c} \times f$$





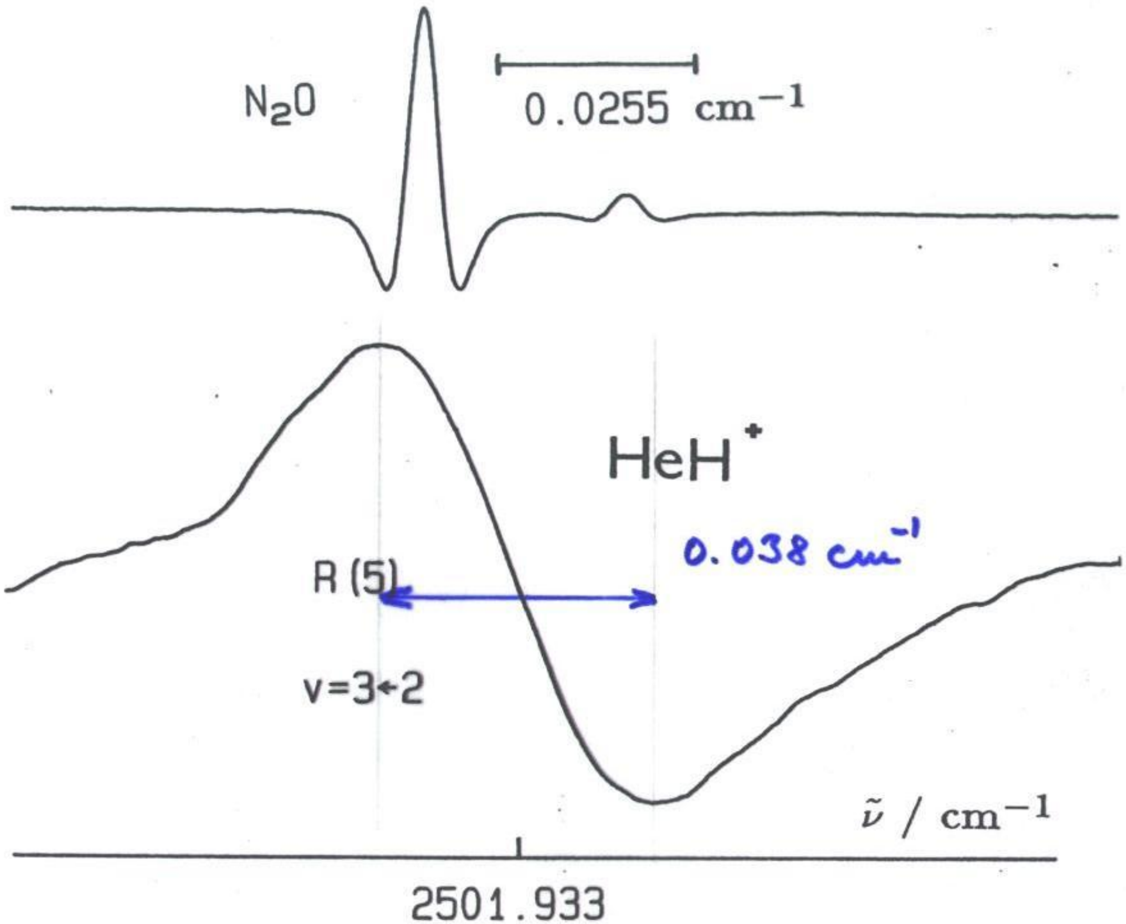
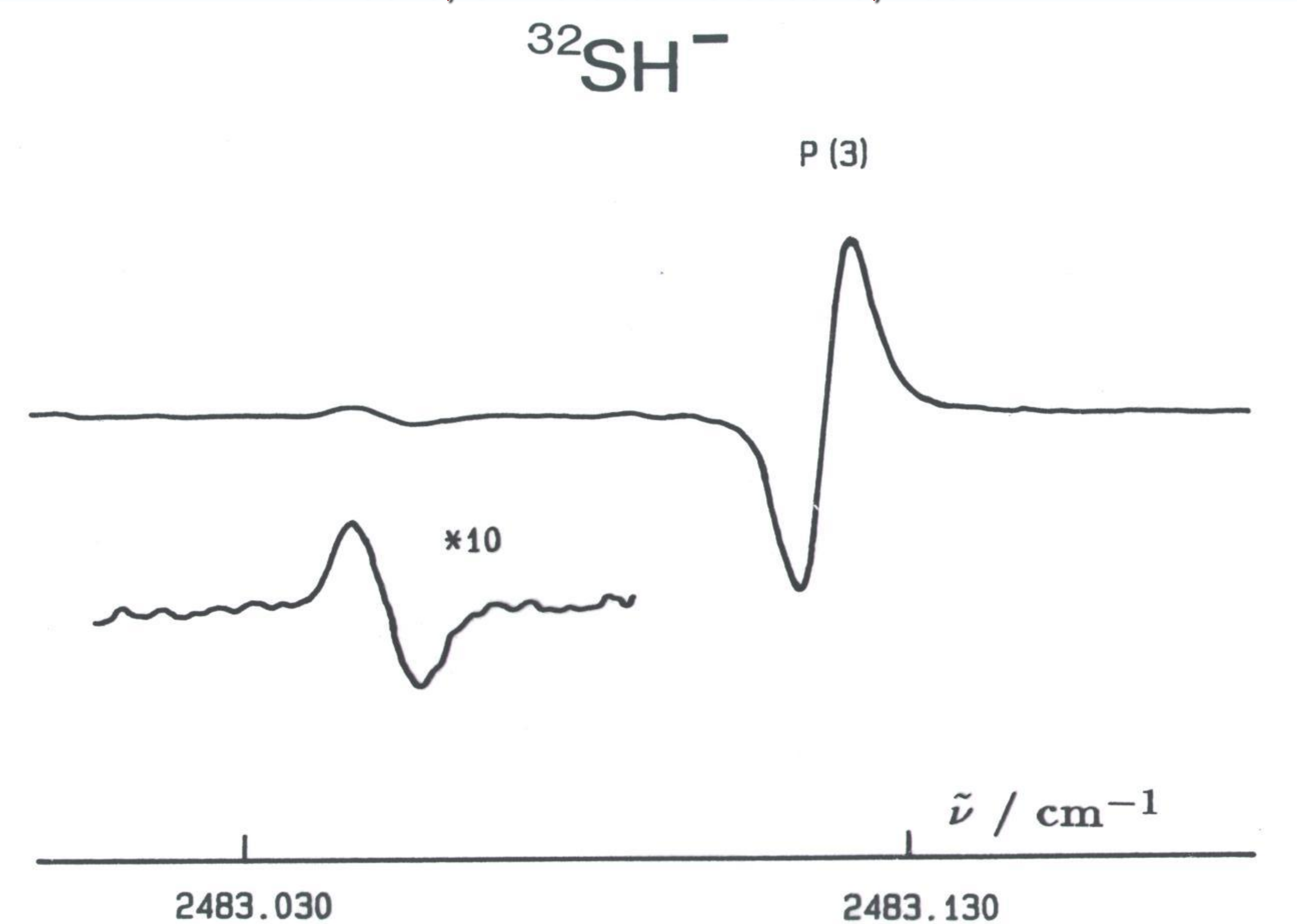


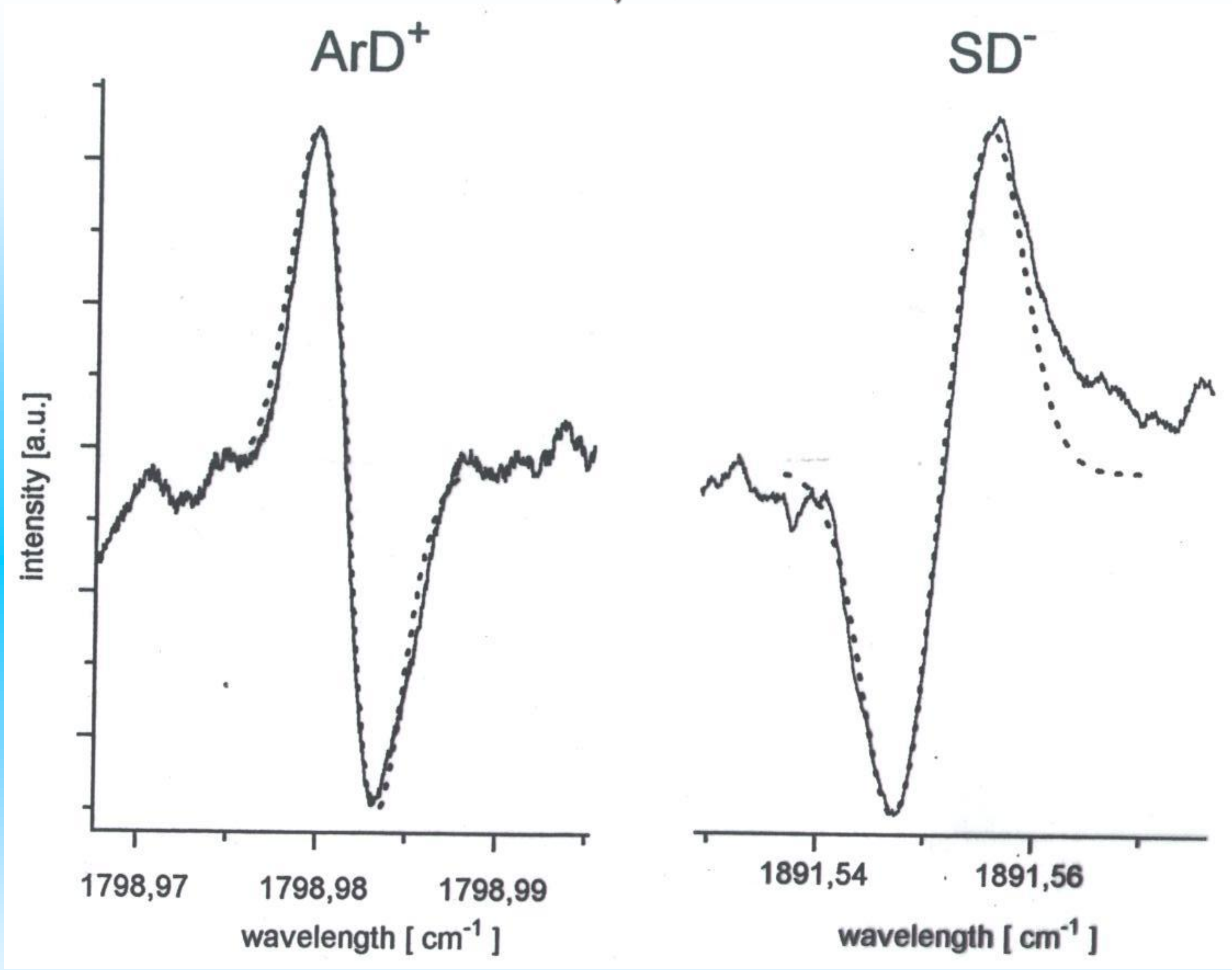
Figure 9. The $v = 3 \leftarrow 2$ R(5) transition of HeH^+

Německo, Universita v Giessenu, 1989

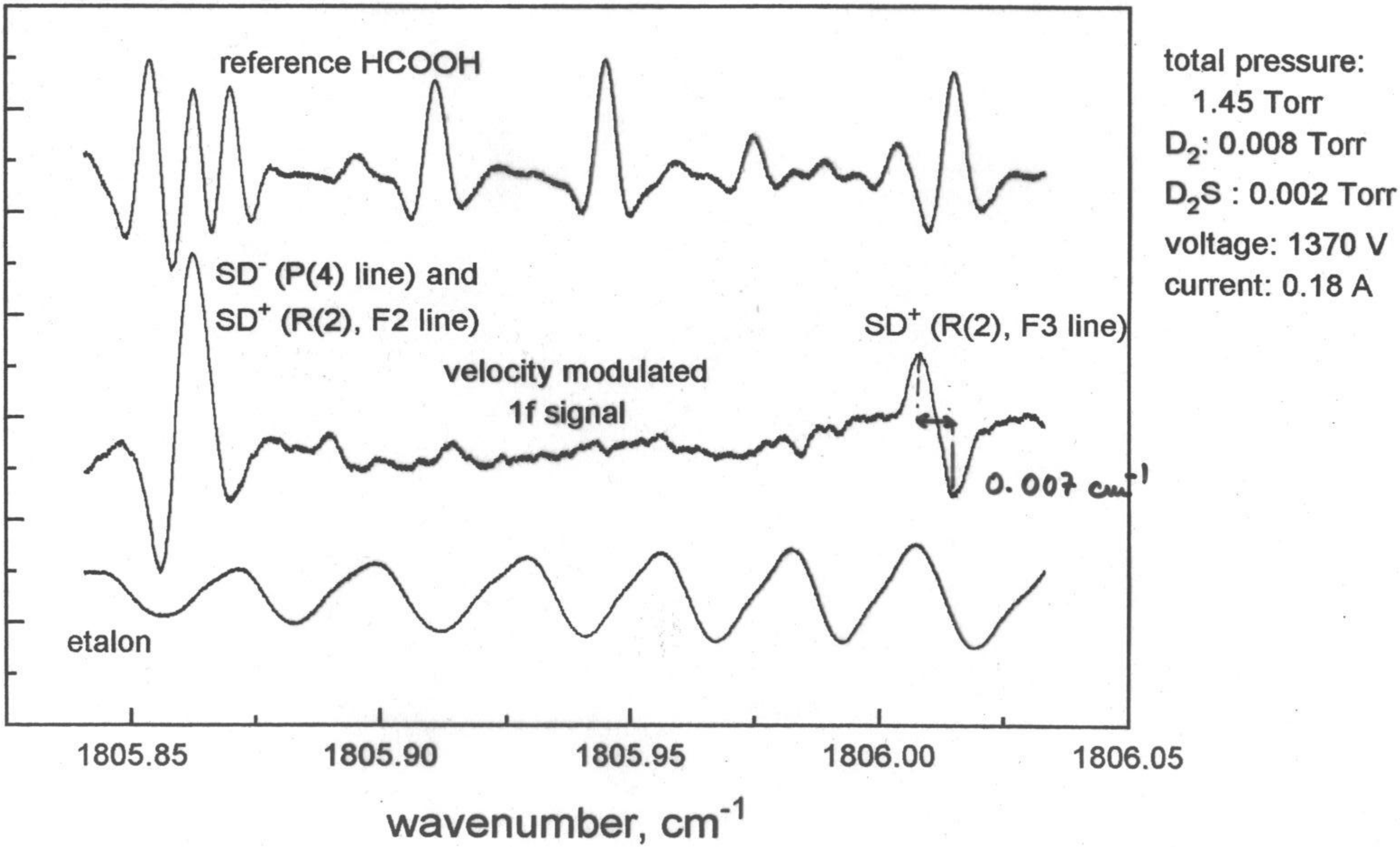


Civiš, S., Blom ,C. E., and Jensen, P.: „Diode Laser Infrared Spectra and Potential Energy Curve for SH^+"
J. Mol. Spectrosc., 1989, **138,** 69-78

Praha, 1994



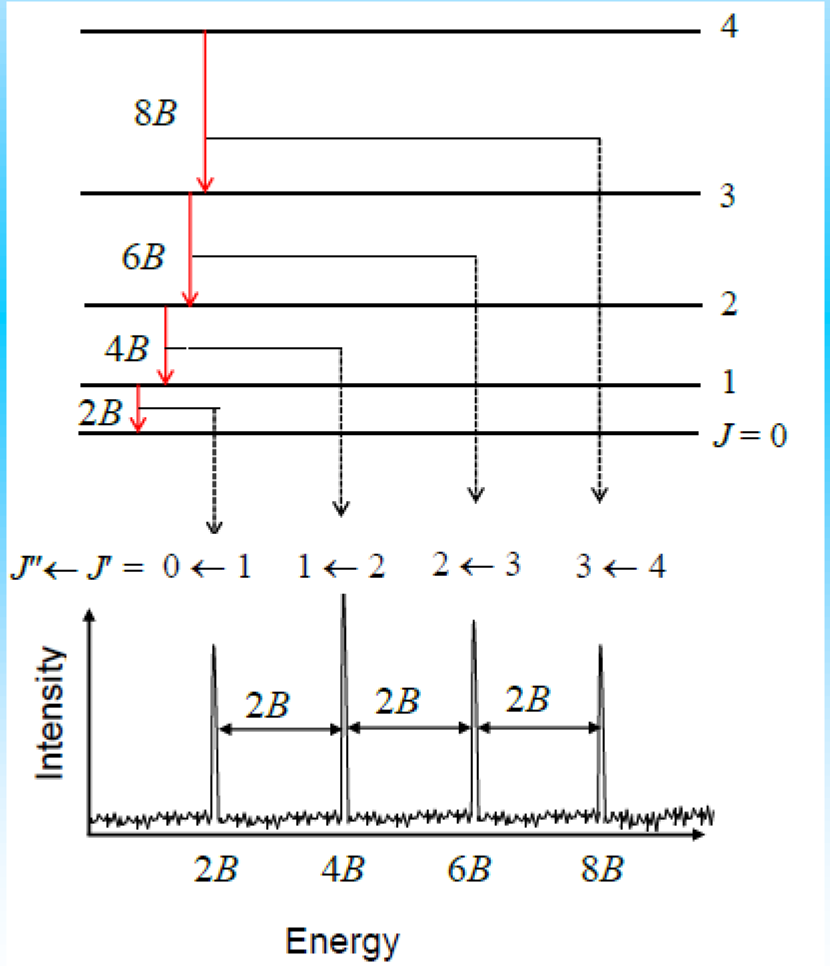
Civiš, S.: „Infrared Diode Laser Study of ArH+ and ArD+ Ions in the Positive Column an ac Glow Discharge“ *Chem. Phys*., 1994, **186,** 63-76



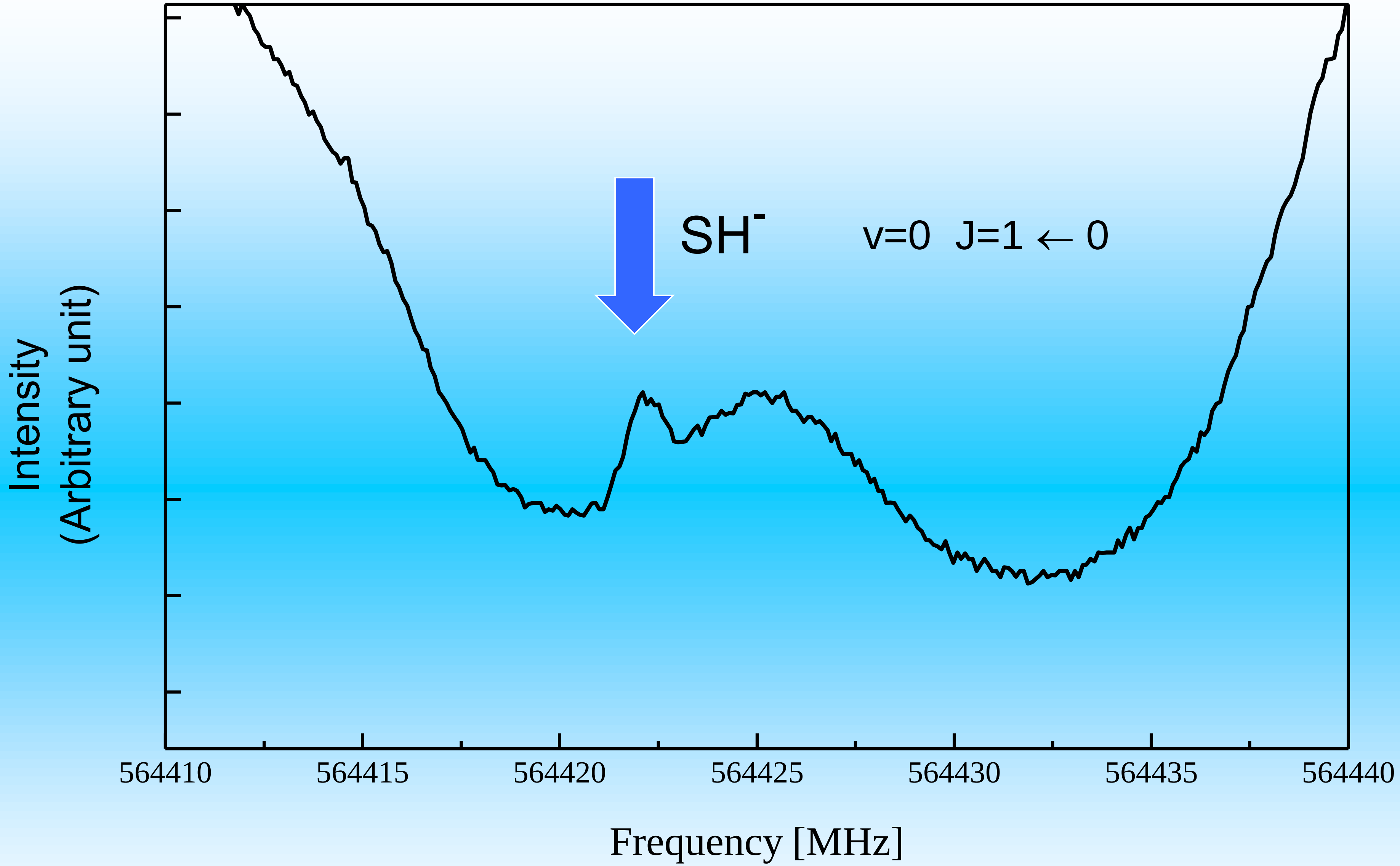
Zelinger, Z., Bersch, A., Petri, M., Urban, W., and Civiš, S.: „Infrared spectrum of SH^- anion“, *J. Mol. Spectrosc*., 1995, **171,** 579-582

Mlhovina M16

SH^- Rotační spektrum-přechody

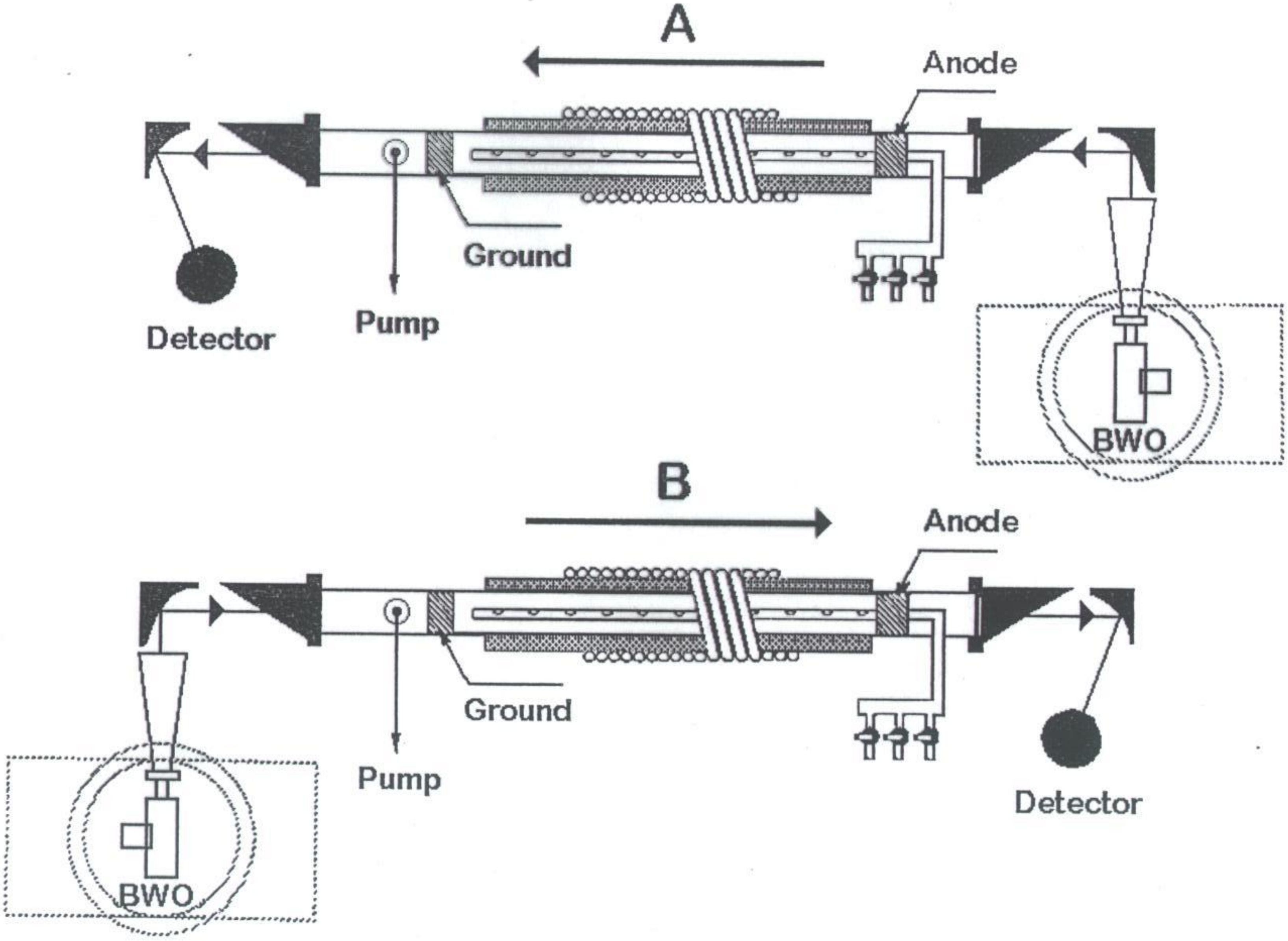


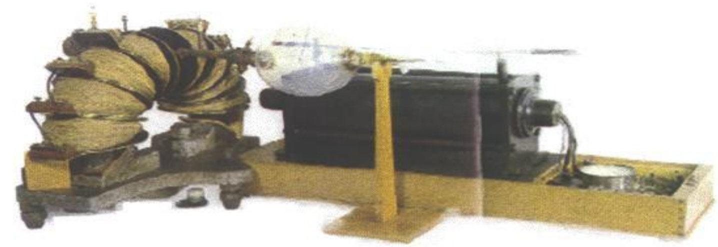
Francie, univerzita v Lille, 1995-1998

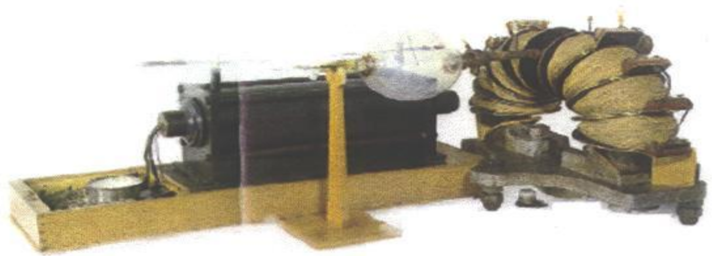


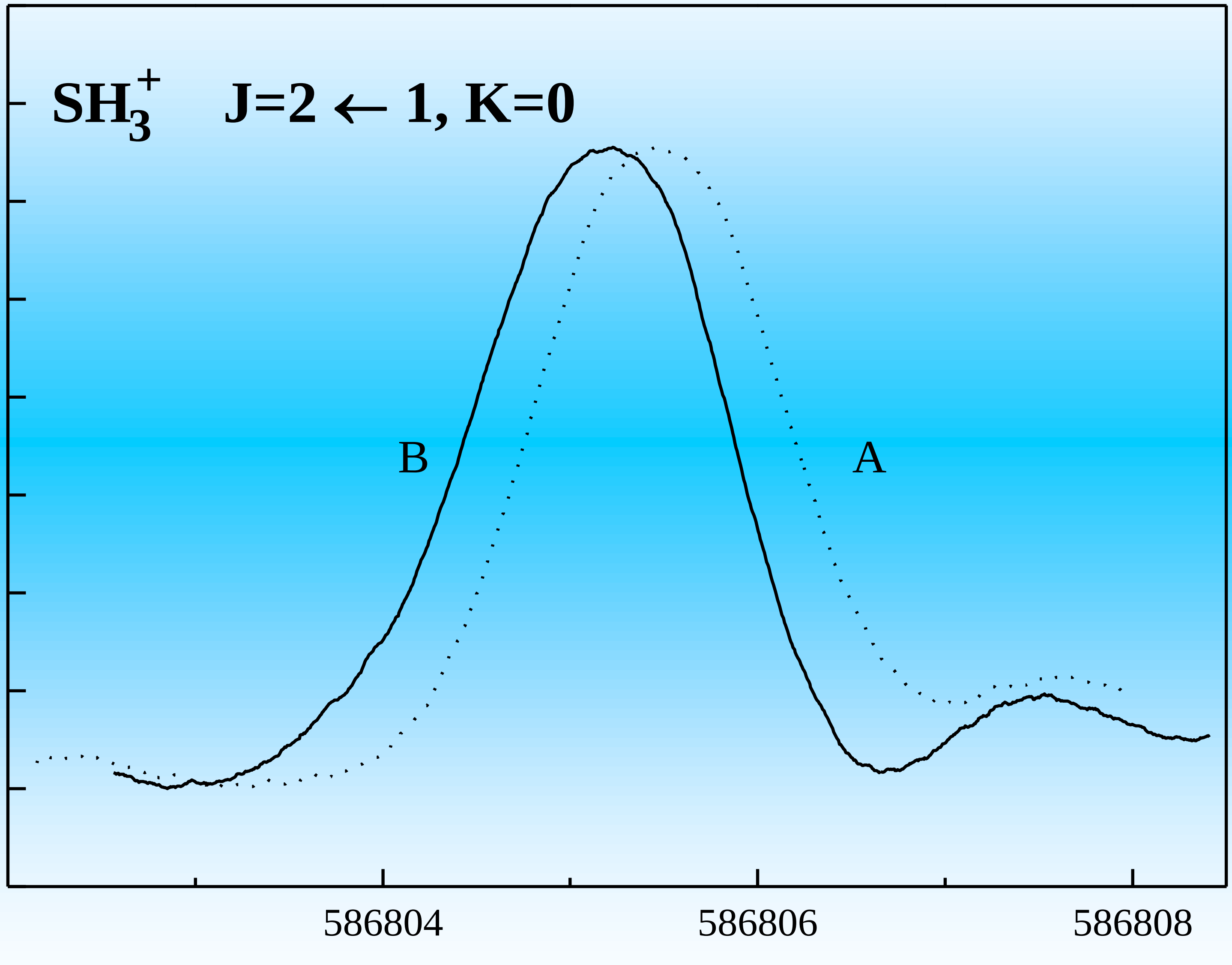
Civiš S., Tretyakov M.Yu., Bailleux S., Bogey M., and Walters A.: „First Identified Submillimeter-wave Spectral Lines of Negative Ions SH- and SD- ", *J. Chem. Phys.*,1998, **108,** 8369-8373

Francie, Universita v Lille

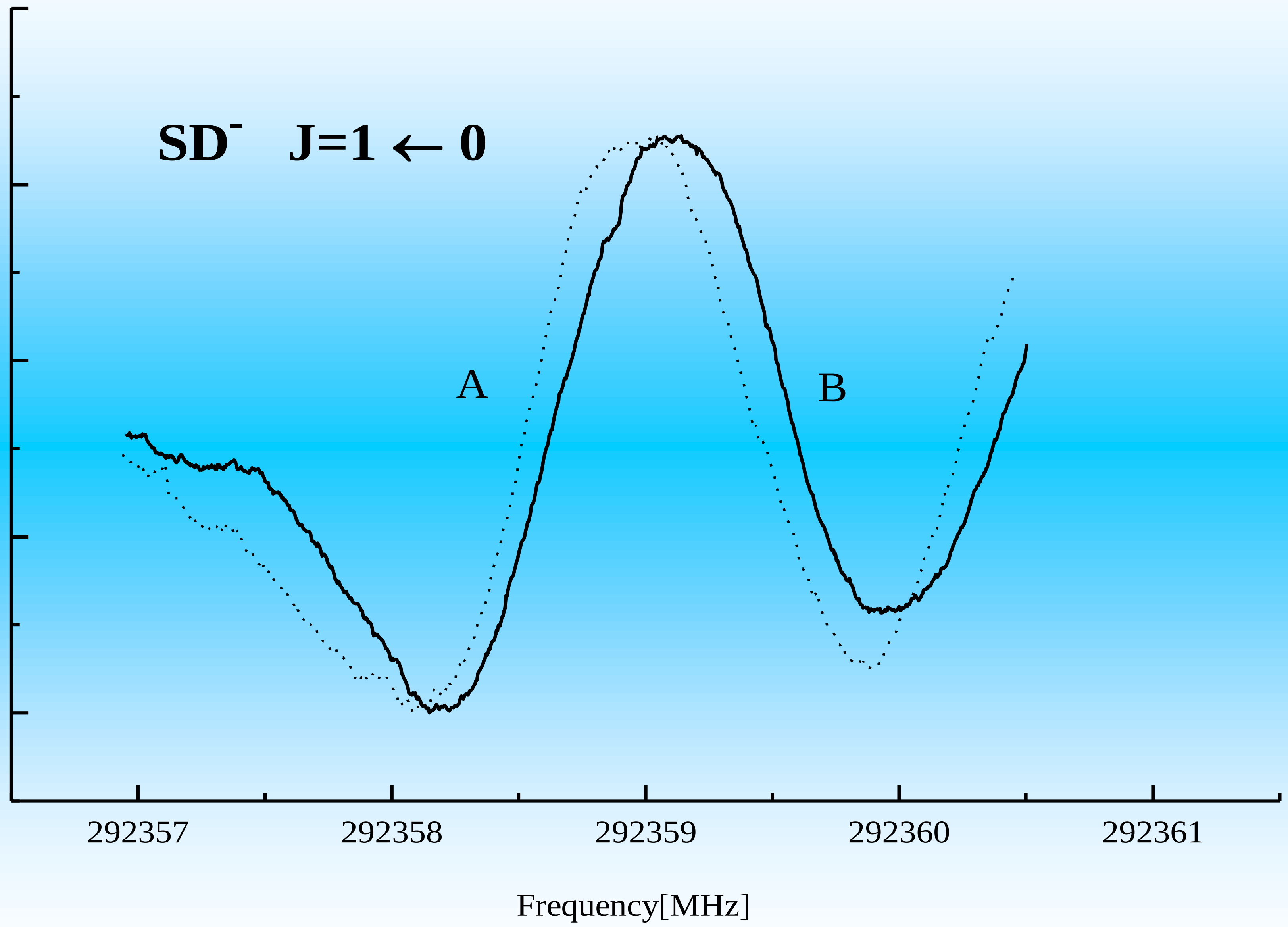




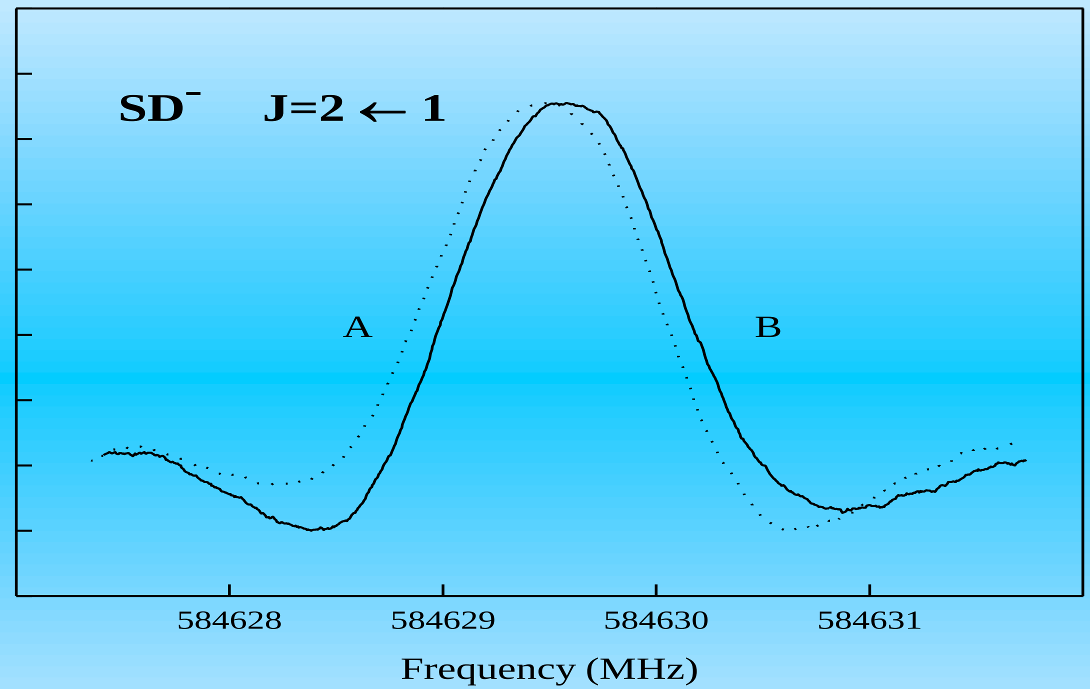




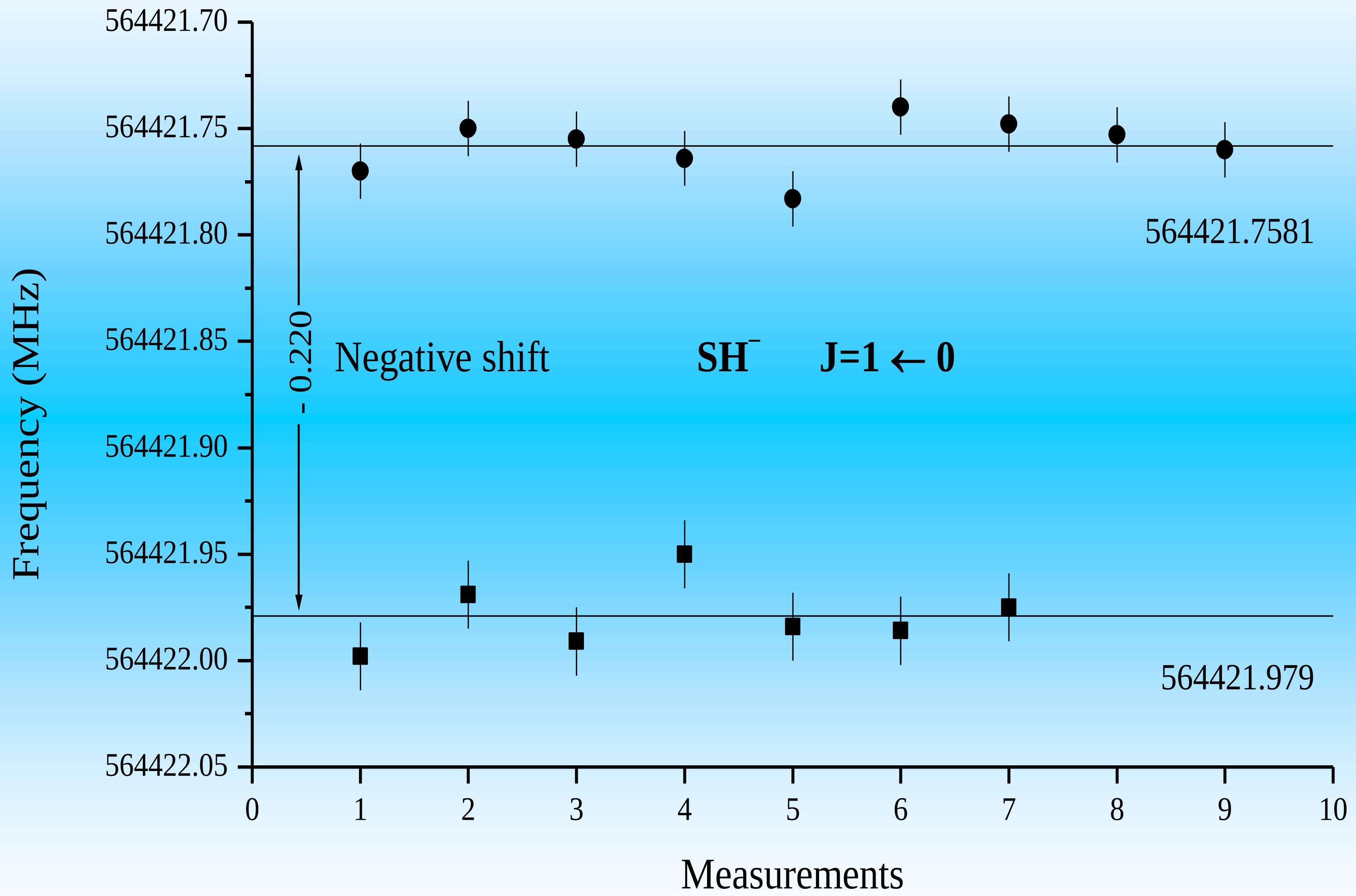
SH_3^+ J=2 ← 1, K=0
B
A
586804
586806
586808



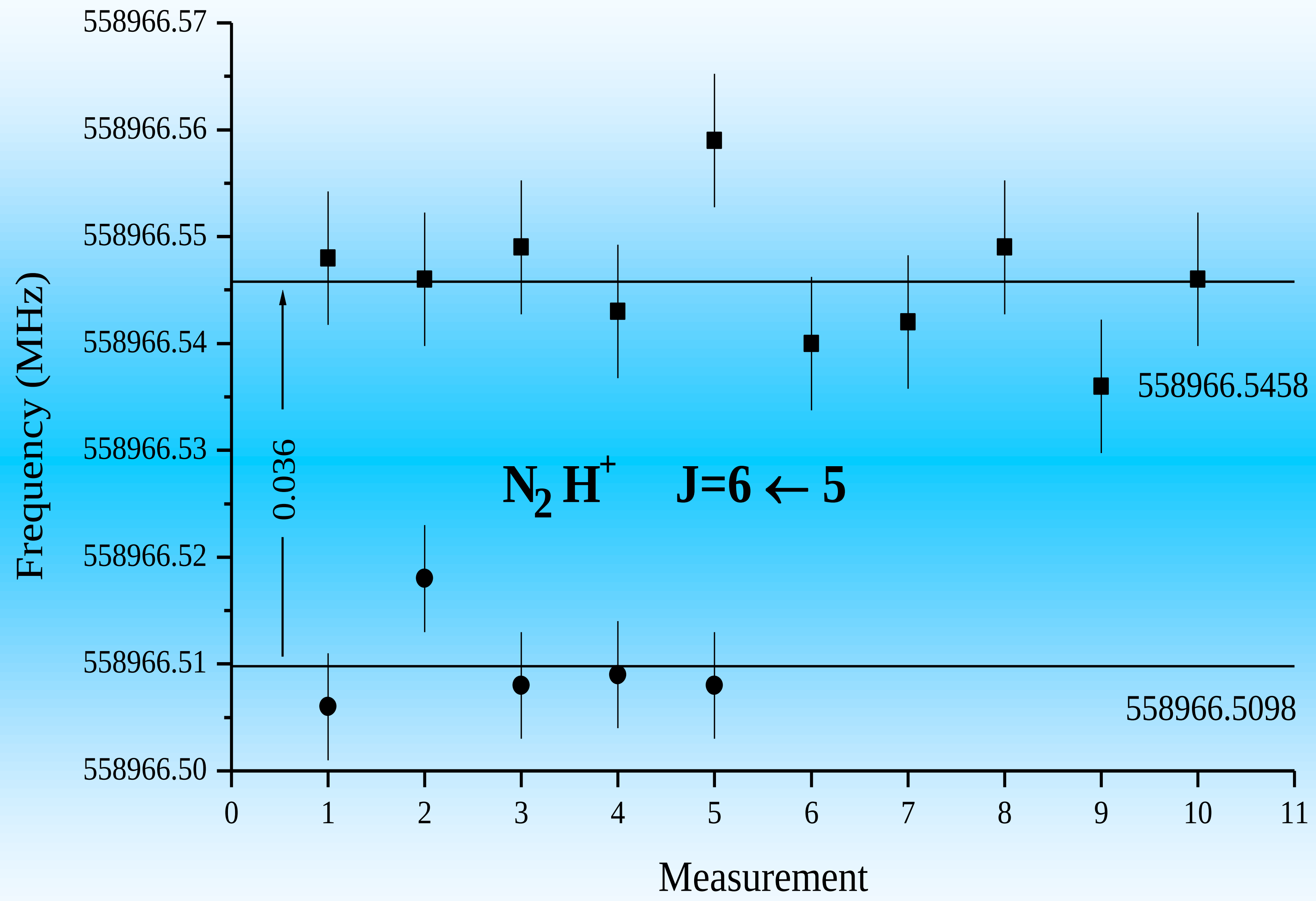
SD$^-$ J=1 ← 0
A
B
292357
292358
292359
292360
292361
Frequency[MHz]



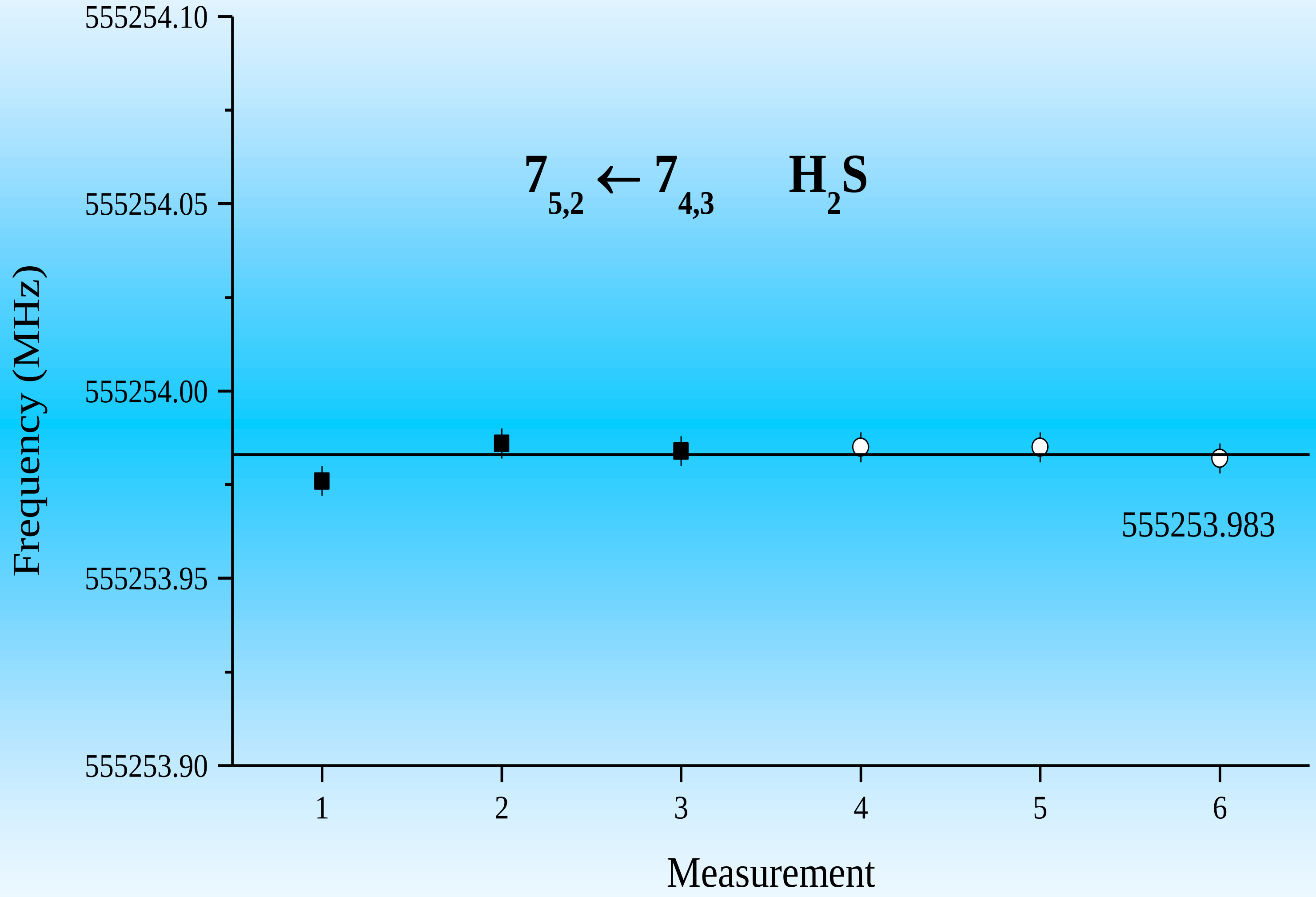
Frequency[MHz]



564421.70
564421.75
564421.80
564421.85
564421.90
564421.95
564422.00
564422.05
Frequency (MHz)
- 0.220
Negative shift
SH⁻
J=1 ← 0
564421.7581
564421.979
0
1
2
3
4
5
6
7
8
9
10
Measurements



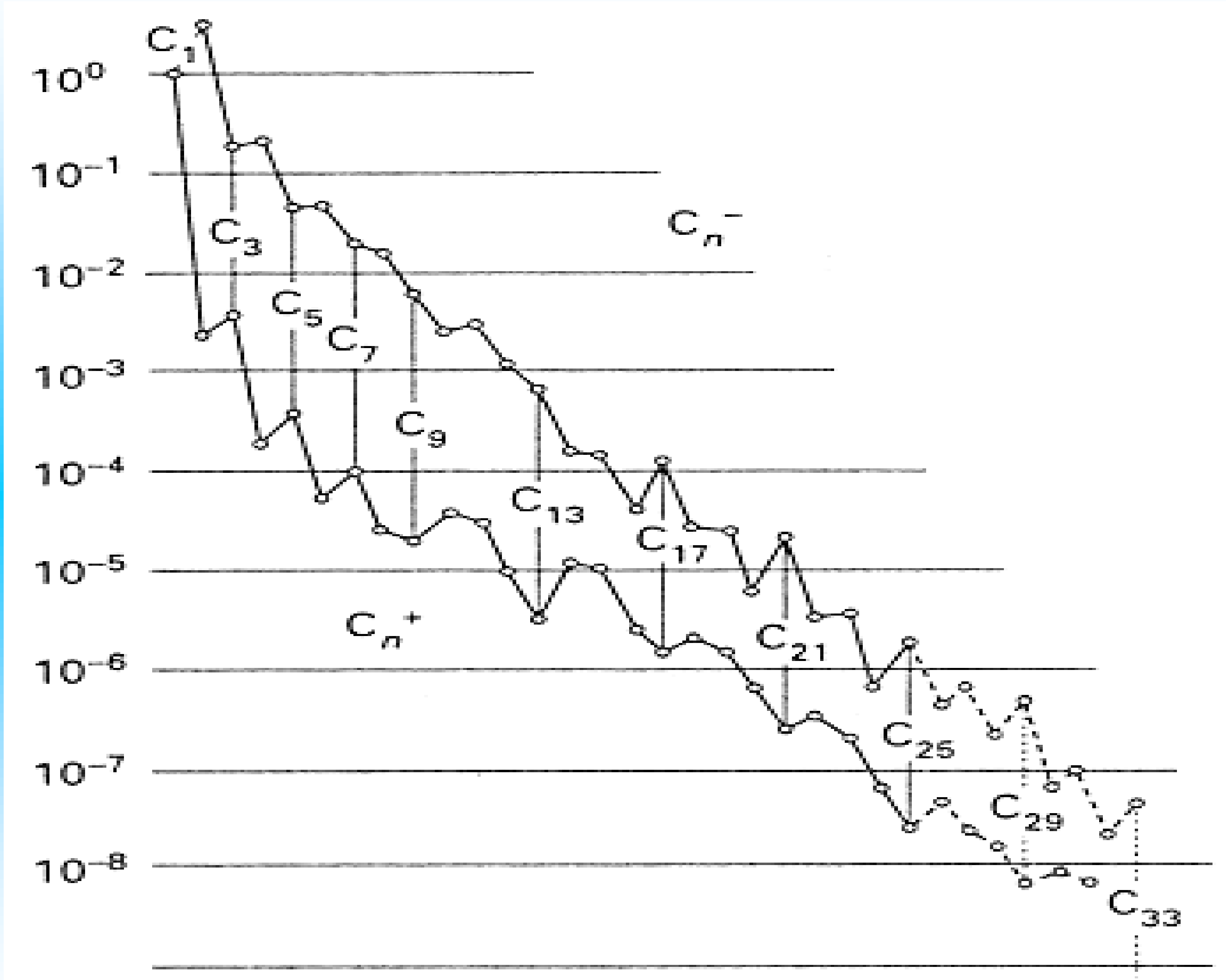
558966.57
558966.56
558966.55
558966.54
558966.53
558966.52
558966.51
558966.50
Frequency (MHz)
0.036
N_2H^+ J=6 ← 5
558966.5458
558966.5098
0
1
2
3
4
5
6
7
8
9
10
11
Measurement



$7_{5,2} \leftarrow 7_{4,3}$ H_2S
555254.10
555254.05
555254.00
555253.95
555253.90
Frequency (MHz)
555253.983
1
2
3
4
5
6
Measurement

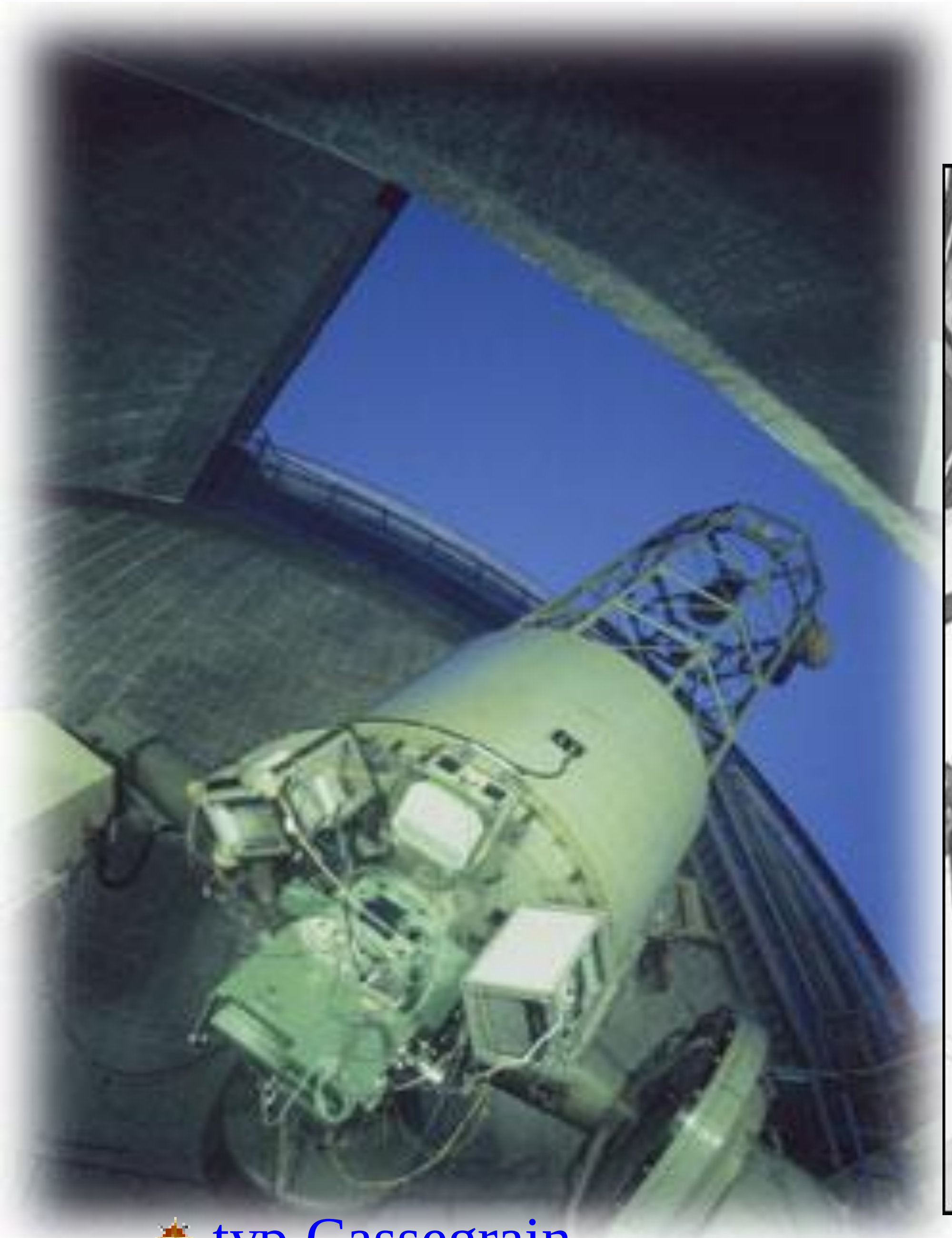
Oka: C_7^- Bands as DIB C**a**rrier, 4I

Civiš, S., Hosaki Y, Kagi E., Kawaguchi K,: Search for C_2^- in Diffuse Clouds and Examination of the C_7^- Bands as DIB Carrier, *Publ. Astron. Soc. Japan*, 2005, **57,** 605-609**.**

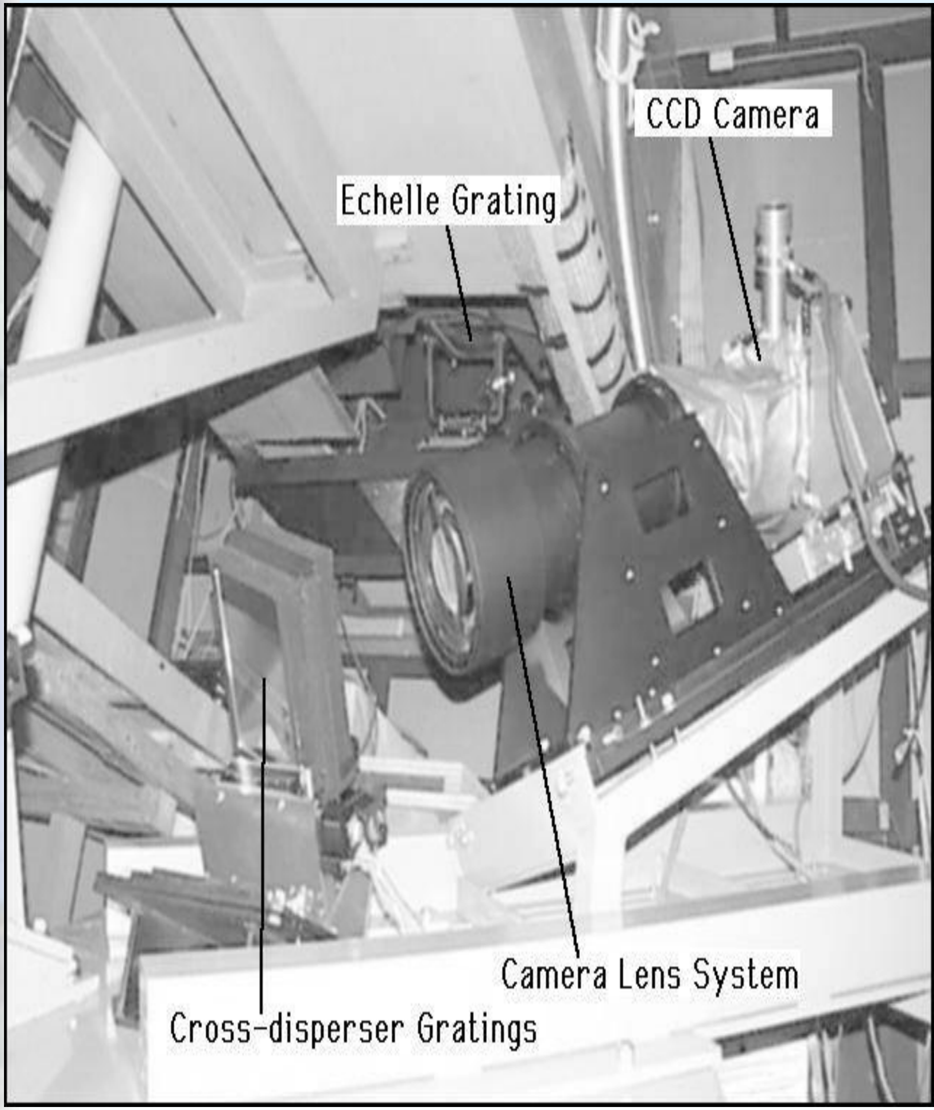


10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
C_1
C_3
C_5
C_7
C_9
C_{13}
C_{17}
C_{21}
C_{25}
C_{29}
C_{33}
C_n^-
C_n^+

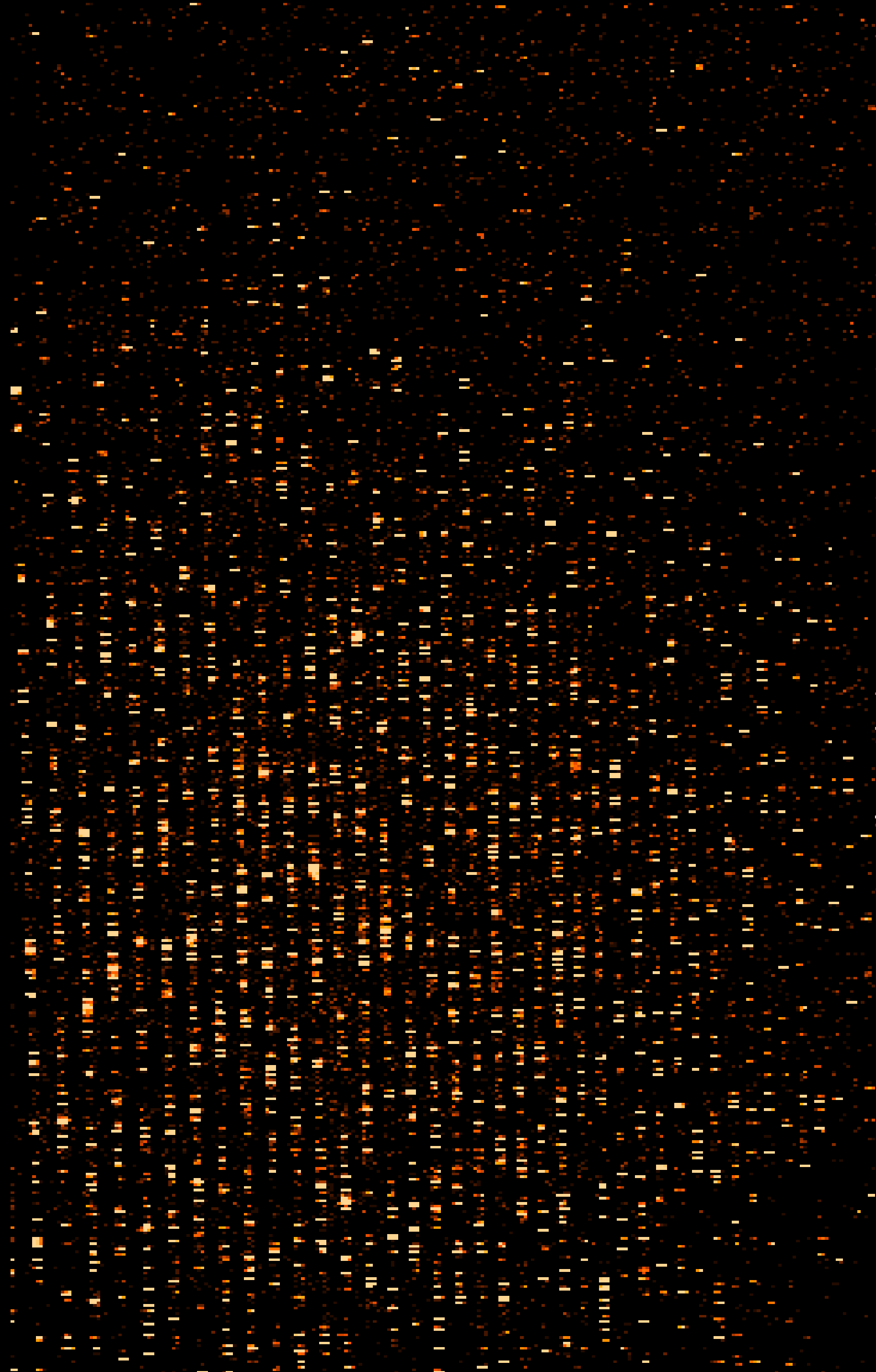
Optický teleskop v Okayamě, Japonsko 2003



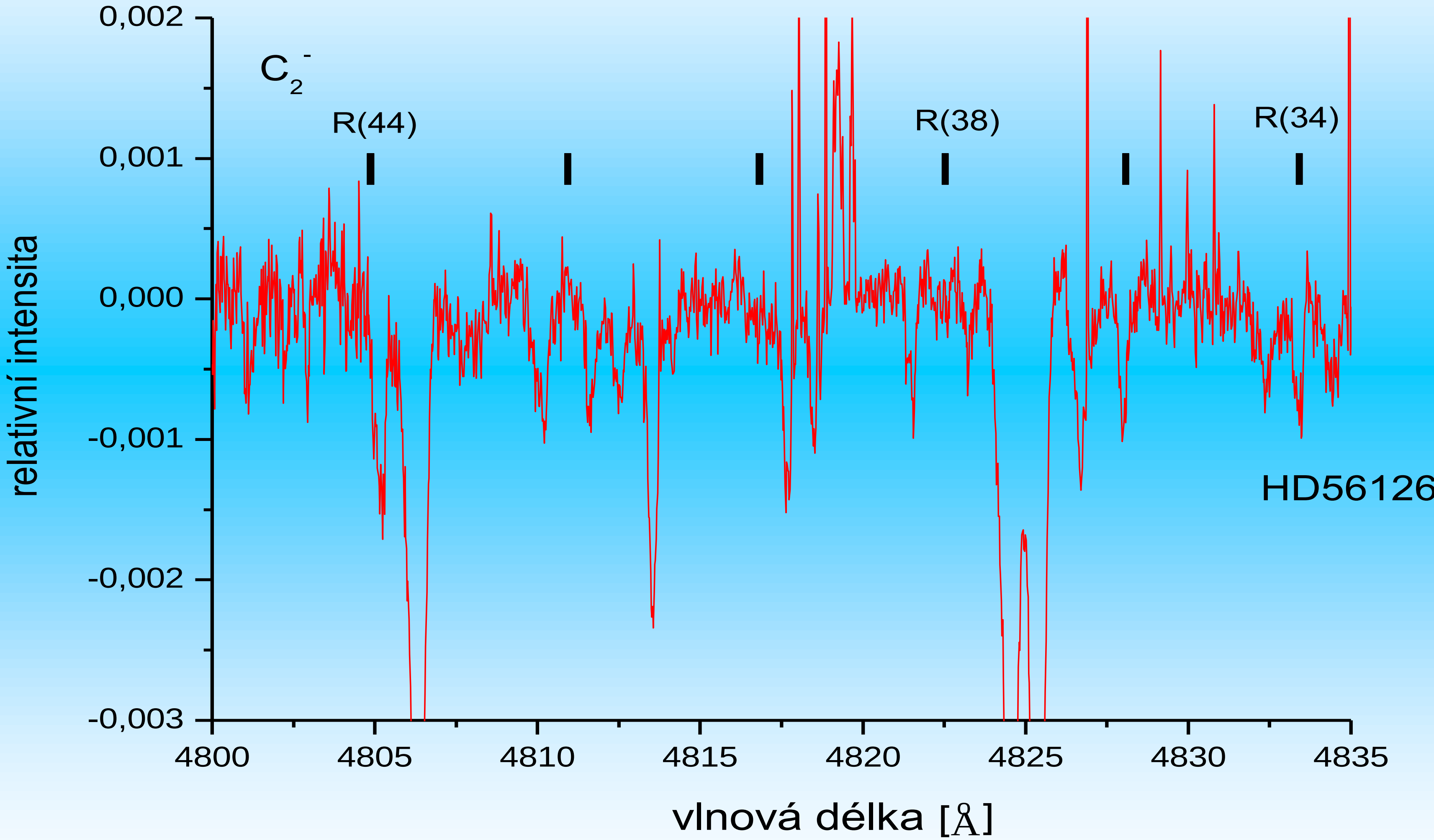
Vysoce disperzní Echellův spektrograf



- typ Cassegrain

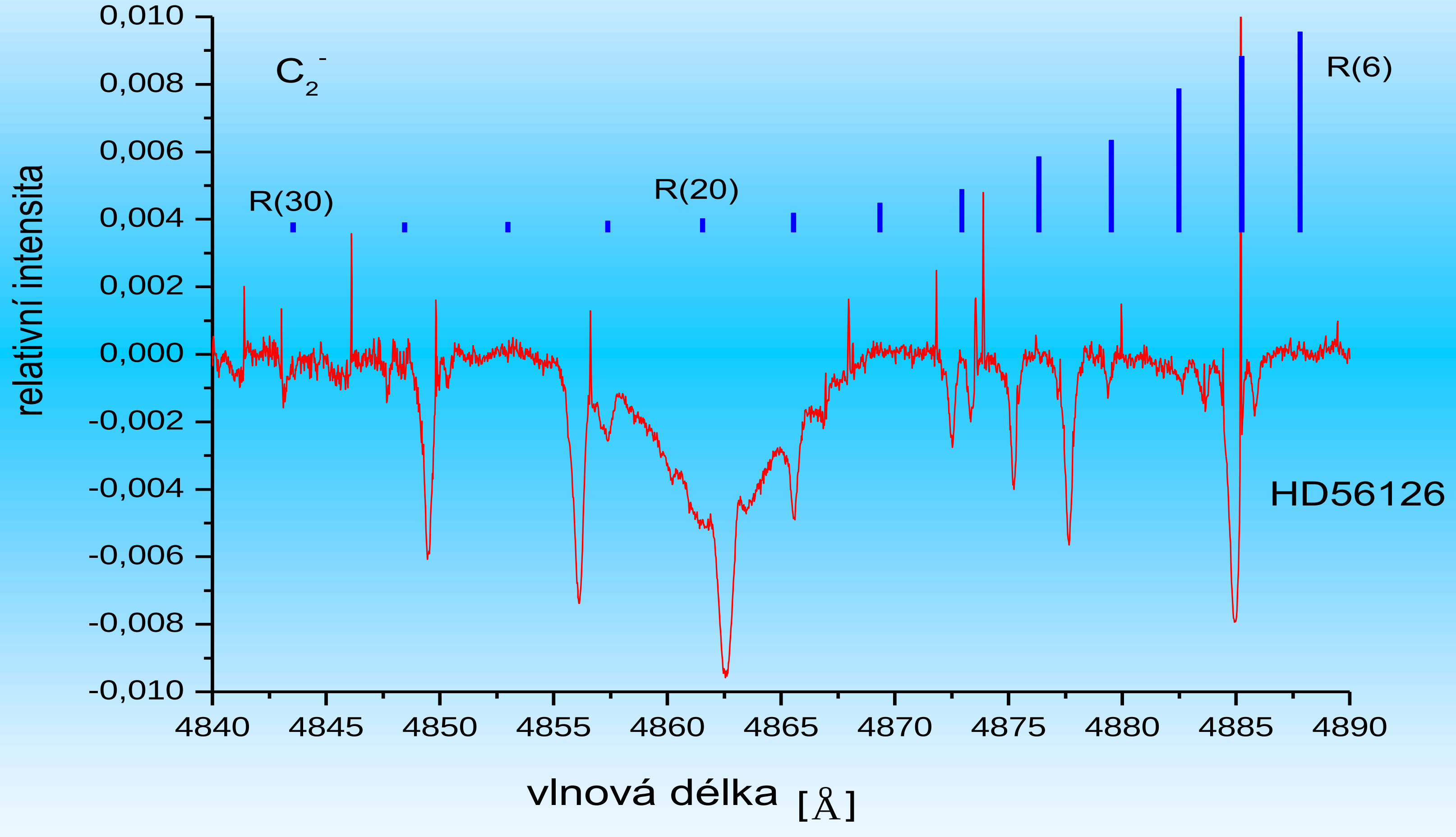


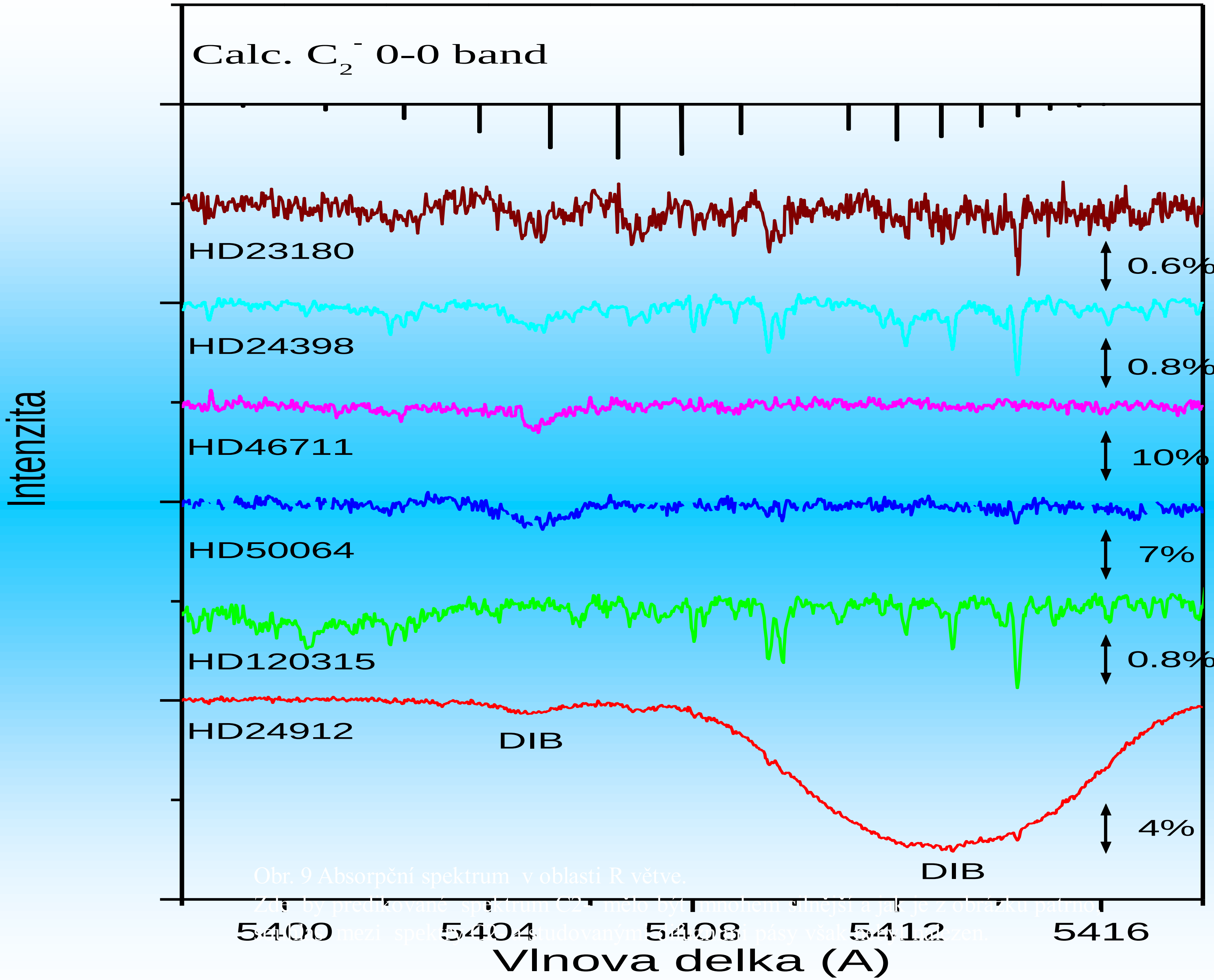
Na observatoři v Nobeyamě, vybavené 2 m optickým teleskopem, jsem měřil spektra objektů studovaných McCallem [47] ve spektrální oblasti absorpce C_2^- aniontu. Výsledky našeho měření shrnují obr., kde je zachyceno absorpční spektrum HD56126 a simulované spektrum C_2^- pro teplotu 240 K. Teplota byla určena na základě intenzit linií C_2 radikálu, přítomných ve spektru HD56126.



Část spektra, ve kterém několik absorpčních linií zdánlivě souhlasí s laboratorním spektrem C_2^-

Srovnání spekter v jiné oblasti vlnových délek





Obr. 9 Absorpční spektrum v oblasti R větve.
Zde by predikované spektrum C2- mělo být mnohem silnější a jak je z obrázku patrno,
… mezi spektry … studovaným … pásy však … nalezen.

Search for C_2^- in Diffuse Clouds and Examination of the C_7^- Bands as DIB Carrier

S. Civiš[1], Y. Hosaki[2], E. Kagi[3], H. Izumiura[4],
K. Yanagisawa[4], T. Šedivcová[1], and K. Kawaguchi[2],

[1] *J. Heyrovský Institute of Physical Chemistry, Academy of Sciences of the Czech Republic, Dolejškova 3, 18223 Prague, Czech Republic*
[2] *Department of Chemistry, Faculty of Science, Okayama University, Tsushima-naka 3-1-1, Okayama 700-8530*
[3] *Department of Chemistry, Faculty of Information Sciences, Hiroshima City University, Ozuka-higashi 3-4-1, Asa-Minami, Hiroshima 731-3194*
[4] *Okayama Astronomical Observatory, National Astronomical Observatory, Kamogata, Asakuchi, Okayama 719-0232*

(Received 2003 October 0; accepted 2003 0)

Abstract

A search has been carried out for the C_2^- ion in diffuse clouds, toward HD 24398, HD 46711, HD 50064, HD 23180, HD 24912, HD 46711 using an Okayama 188-cm telescope HIDES spectrometer. The upper limit for C_2^- of $1.1 \times 10^{10} - 25 \times 10^{11}$ cm^{-2} in column density has been reported, which is smaller than the C_7^- abundance obtained from the assumption that C_7^- is responsible for diffuse interstellar bands (DIBs). To examine the C_7^- assumption, we investigated the wavelength region where many vibrational bands for C_7^- can be expected. The results of all our observations indicate no evidence for the hypothesis that some diffuse bands originate from carbon chain such C_6^-, C_7^- and C_8^-.

Key words: molecular processes - ISM: molecules

Civiš, S., Hosaki Y, Kagi E., Kawaguchi K,: Search for C_2^- in Diffuse Clouds and Examination of the C_7^- Bands as DIB Carrier, *Publ. Astron. Soc. Japan*, 2005, **57,** 605-609**.**

Observational Studies Relating To Diffuse Interstellar Bands

H. Tada[1], K. Kawaguchi[1], H. Izumiura[2], T. Šedivcová[3], and S. Civiš[4]

*[1]Depertment of Chemistry, Faculty of Science, Okayama University,
Tsushimanaka 3-1-1, Okayama 700-8530, Japan*
*[2]Okayama Astrophysical Observatory, National Astronomical Observatory,
Kamogata, Asakuchi, Okayama 719-0232, Japan*
*[3]Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic,
Flemingovo náměstí 2, CZ-166 10 Prague 6, Czech Republic*

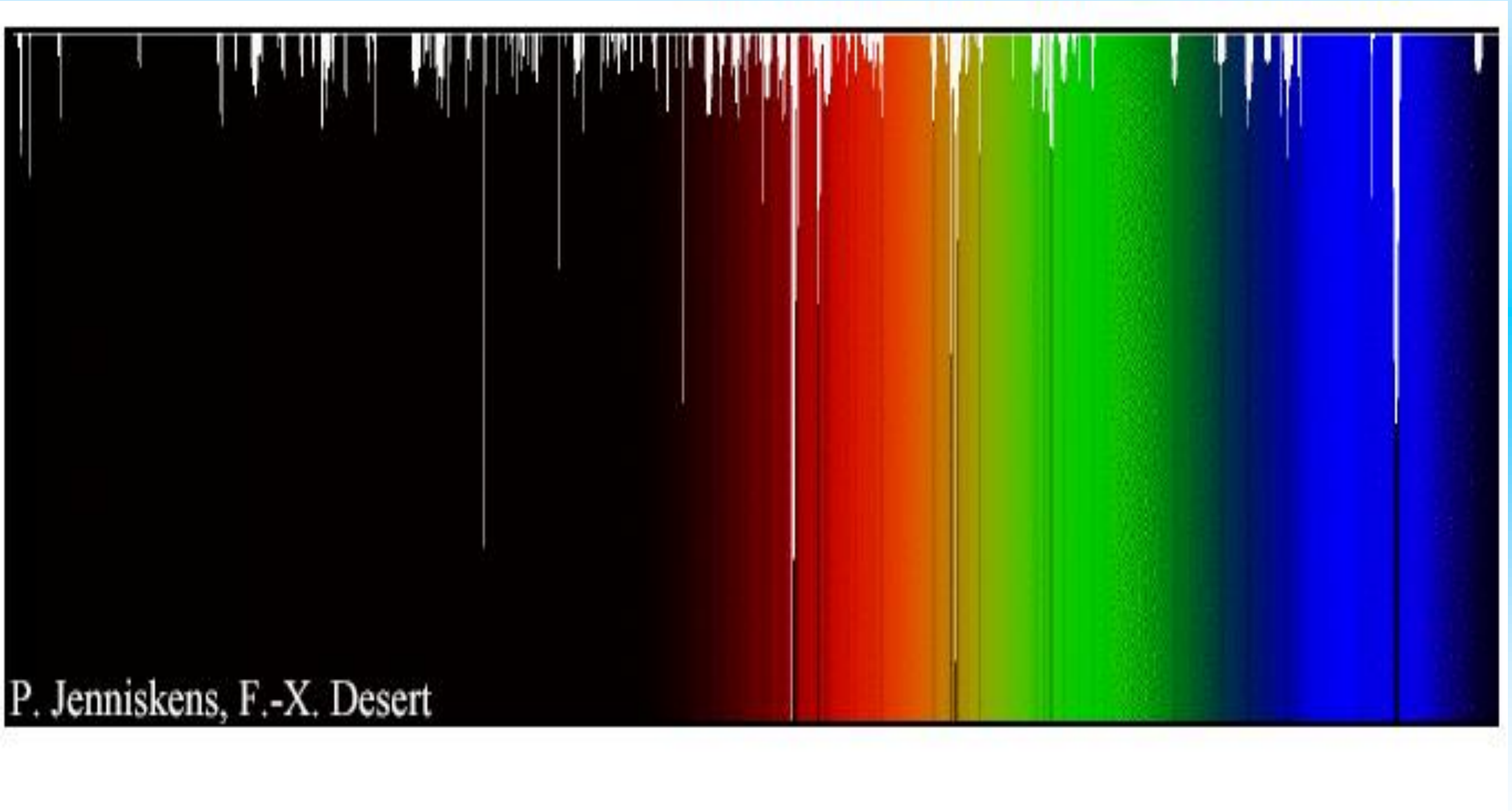
*[4]J. Heyrovský Institute of Physical Chemistry, Academy of Sciences of the Czech Republic,
Dolejškova 3, CZ-18223 Prague 8, Czech Republic*

Abstract. We observed a series of five or six DIBs lines with a nearly constant spacing of about 35 cm^{-1} around 6800 Å by using a spectrometer with a wavelength resolution of $\lambda/\Delta\lambda$=75000. We obtained similar intensities in HD 21389, HD 41117, HD 43384, HD 198478, and HD 206165. As a candidate of these DIBs carrier, a perpendicular vibronic band of CH_2X type molecules has been proposed by Glinski et al., where X is a heavy atom or linear carbon chain. Although the 35 cm^{-1} intervals are interpreted by assuming only ortho lines are detected, we could find none of the spectral lines originating from para levels. For further confirmation we simulated the spectra of the C_7H_2 molecule as a typical CH_2X type molecule, and found that an extraordinarily high temperature is required for explanation of the observed spectra. Thus we concluded that the carrier of series of DIBs appeared near 6800 Å is not explained by the perpendicular vibronic band of CH_2X type molecules. Other candidates are discussed.

Keywords: line: identification – ISM: molecules – ISM: temperatures
PACS: 95.85.Kr

Tada H., Kawaguchi K., Izumiura H., Civiš S., Šedivcová T.: Observational Studies Relating to Diffuse Interstellar Bands, CP855, Astrochemistry, From Laboratory Studies to Astronomical Observations, edited by R.I. Kaiser, P. Bernath, Y. Osamura, S. Petrie, and A.M. Mebel, Astrochemistry, From laboratory studies to atronomical observation, 2006, American Institute of Physics, 219-224, 978-0-7354-0351-2/06

Difůzní interstelární pásy

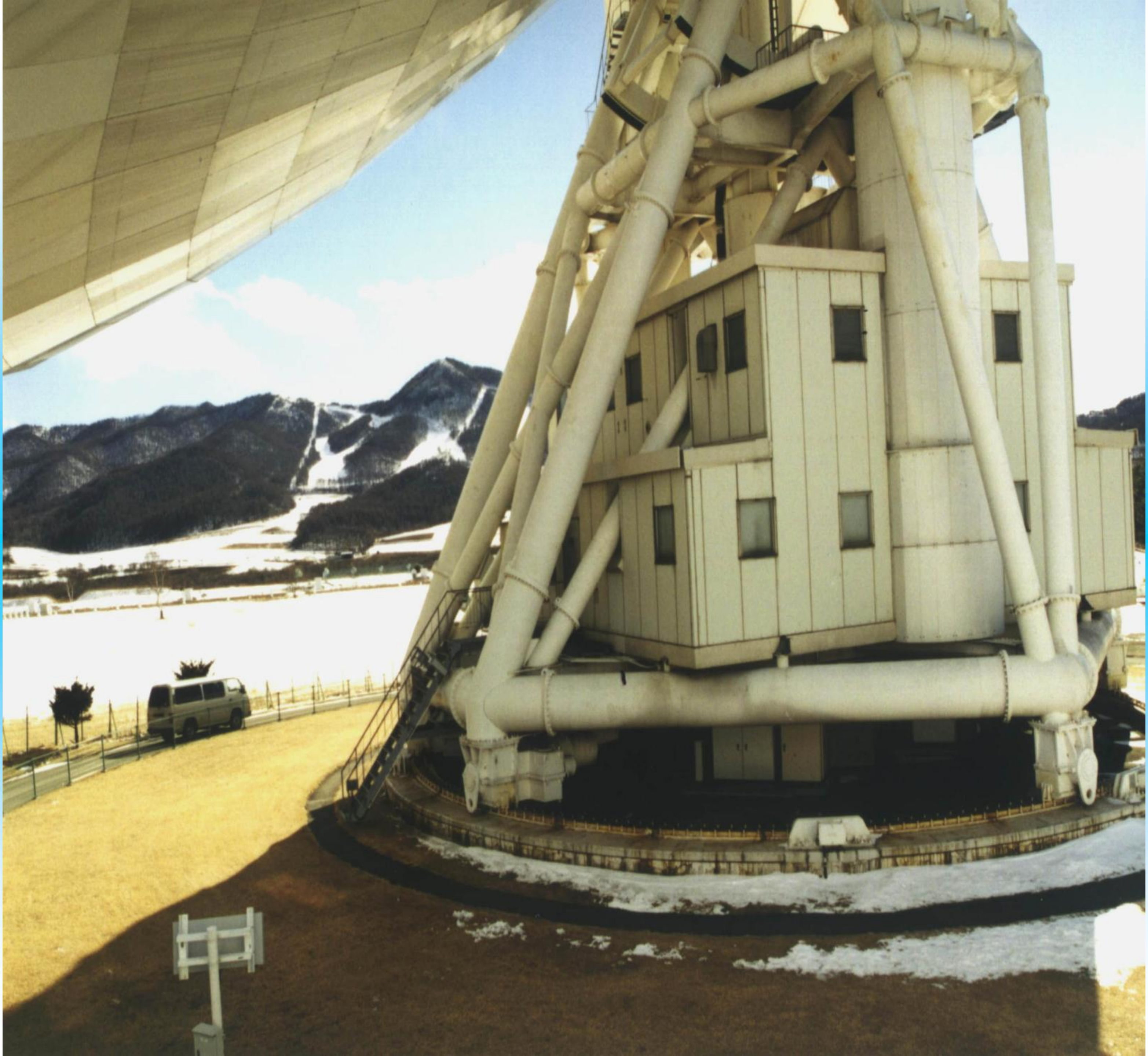


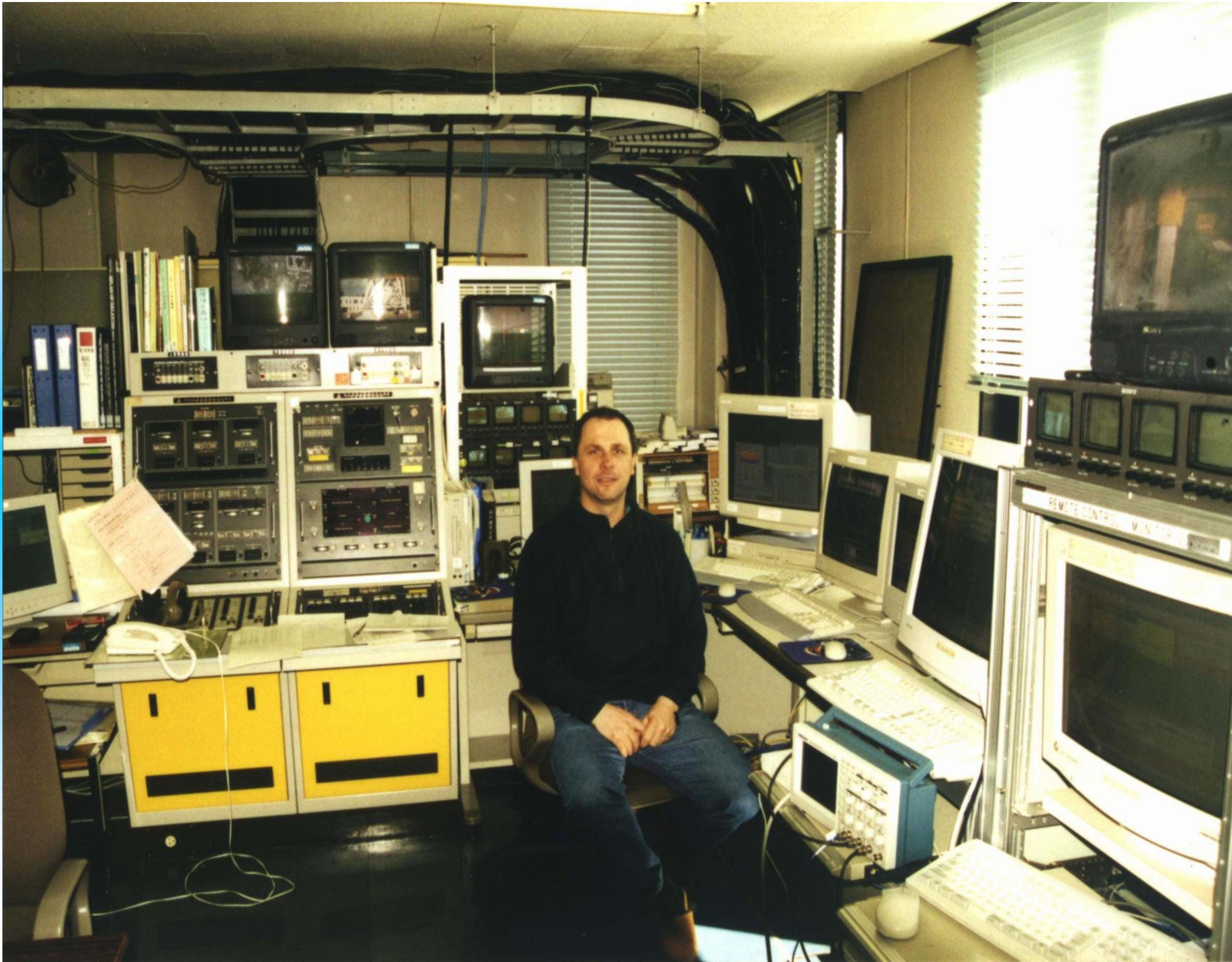
Nobeyama, Japonsko, 2000-2003

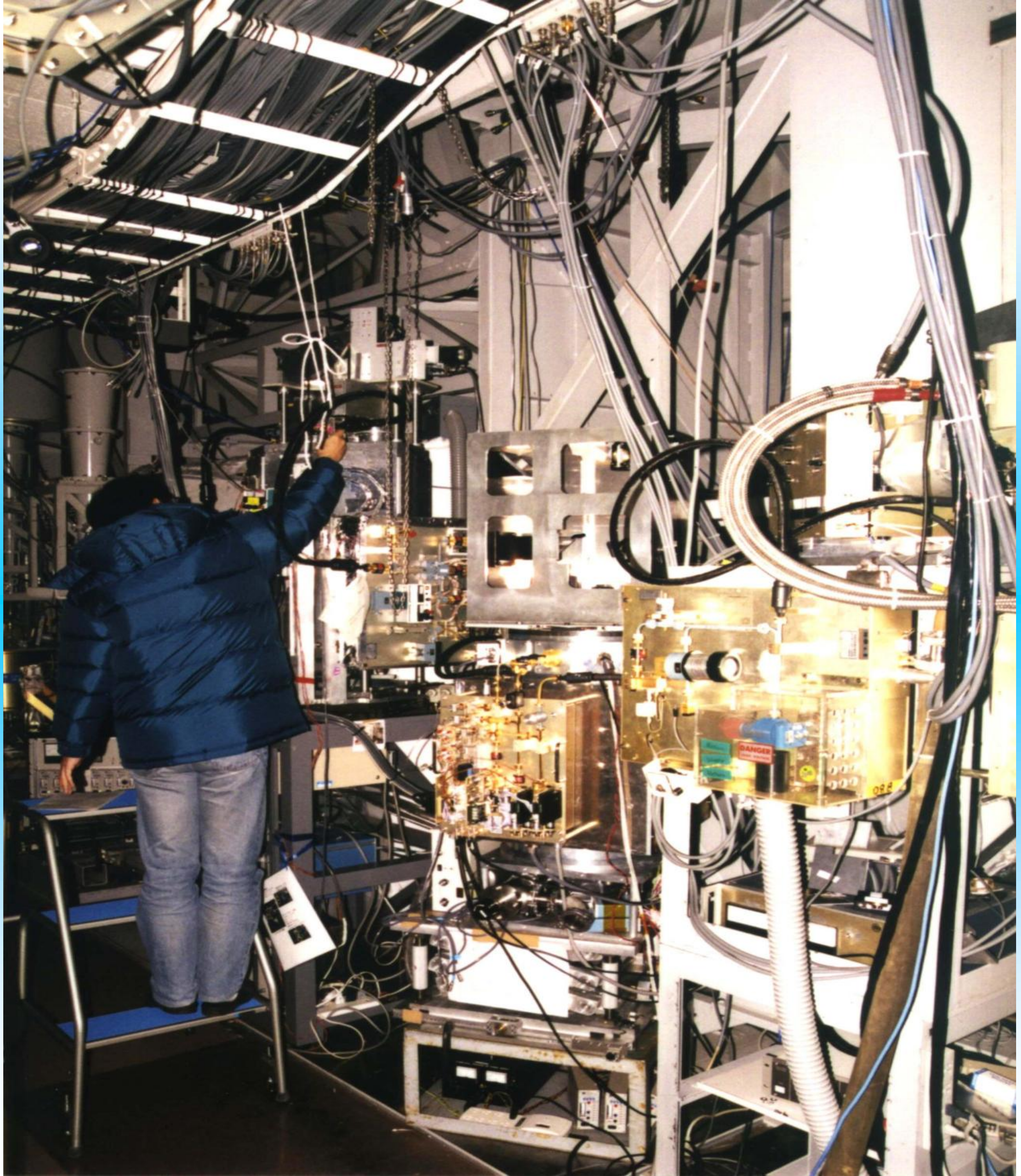
Nobeyama, Japonsko, 2000-2003
45 m radioteleskop

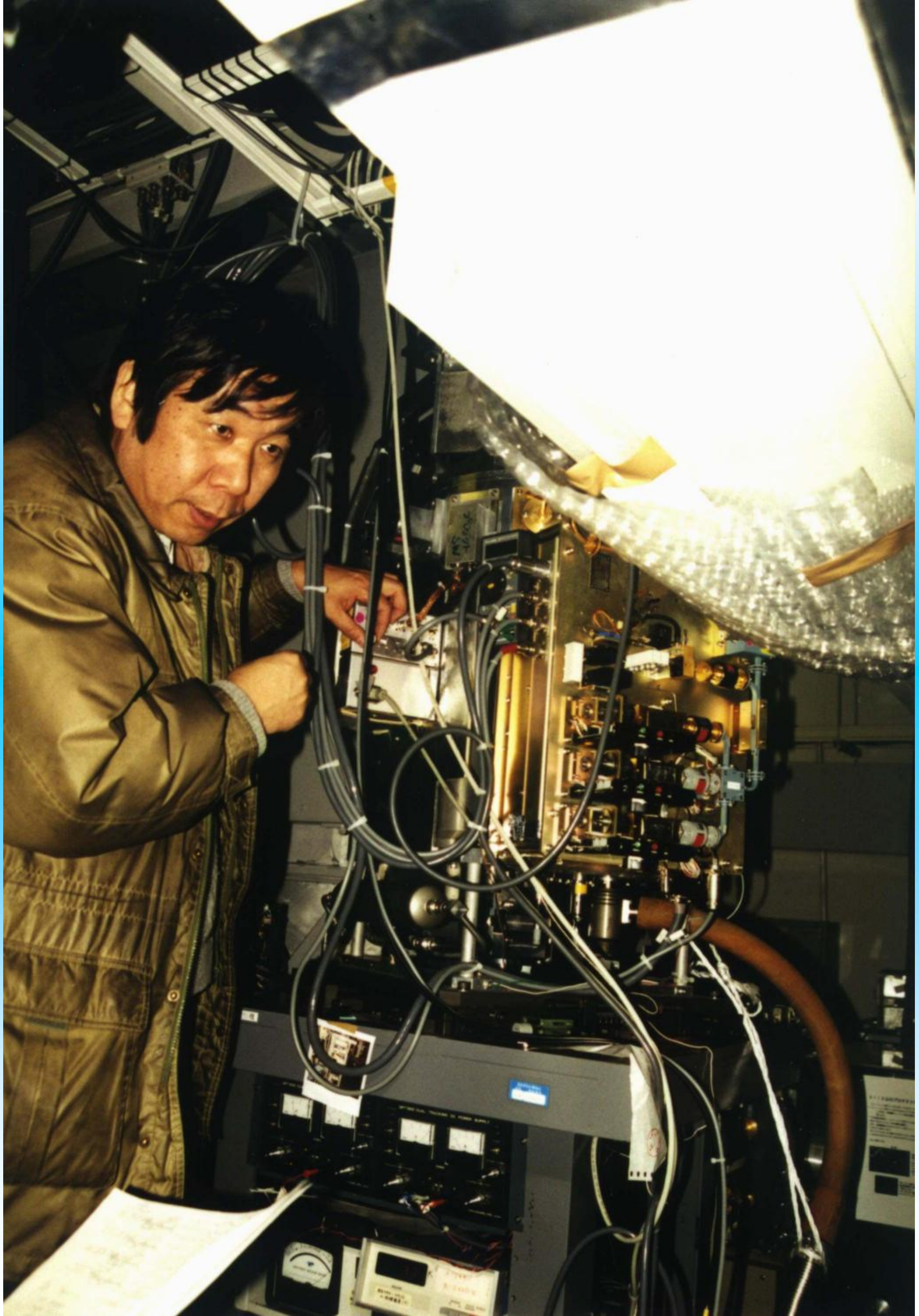
Hledání: NCO^-
NCS^-

Na základě publikovaných infračervených spekter




REMOTE CONTROL



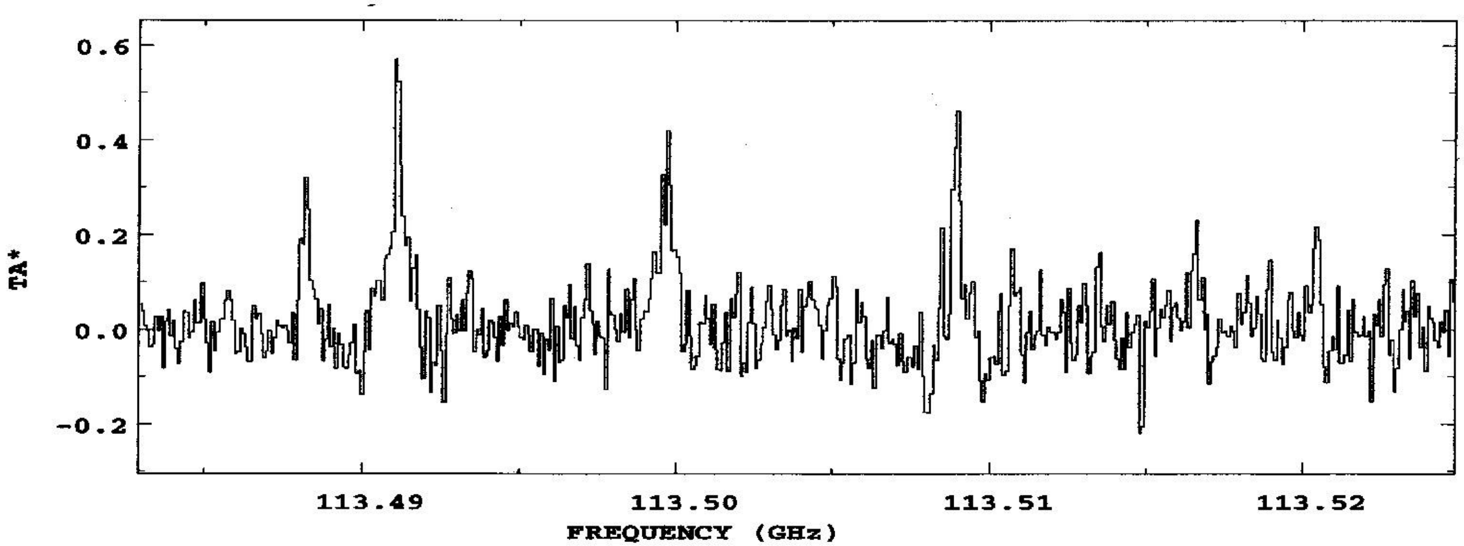


CN RADIKÁL-mikrovlnné spektrum

Taurus molecular clauds

měřeno 40 metrovým teleskopem v Nobeyamě 2000

```
HC3NA          TMC-1(CP)                          #HC3NA_H.SMTHG
Comments
Spectrum-id = 00004 (              )      :  DATE(M D Y) = 02 16 00
Ref. coordinate = RA,DEC                  :  P.A. =    0.000d
X offset = -00d24'34.5"                   :  RA (1950) = +04h36m49.3s      :  l = 173.822D
Y offset = +00d21'36.0"                   :  DEC(1950) = +25d57'21.0"      :  b = -13.525D
Center freq. = 113.504000(GHz)            :  AOS-H6
r.m.s. =    0.1187(K)                     :  Integ time = 00h44m00s
Baseline order = 05                       :  Scaling factor =  1.00
no.   peak T              x of peak                half width                    integ. int.
```



Anion CN^-

CN^- ($^1\Sigma$ základní stav) má disociační energii 10.3 eV [53], vysokou elektronovou afinitu 3,82 eV a dipólový moment 0,62 D. Je izoelektronický s CO, který je přítomen ve vysoké koncentraci v mezihvězdných oblacích. Nejnovější molekulární parametry a spektroskopické konstanty získané pomocí ab-initio výpočtů predikují rotační linii $J=1\leftarrow0$ 113 GHz.

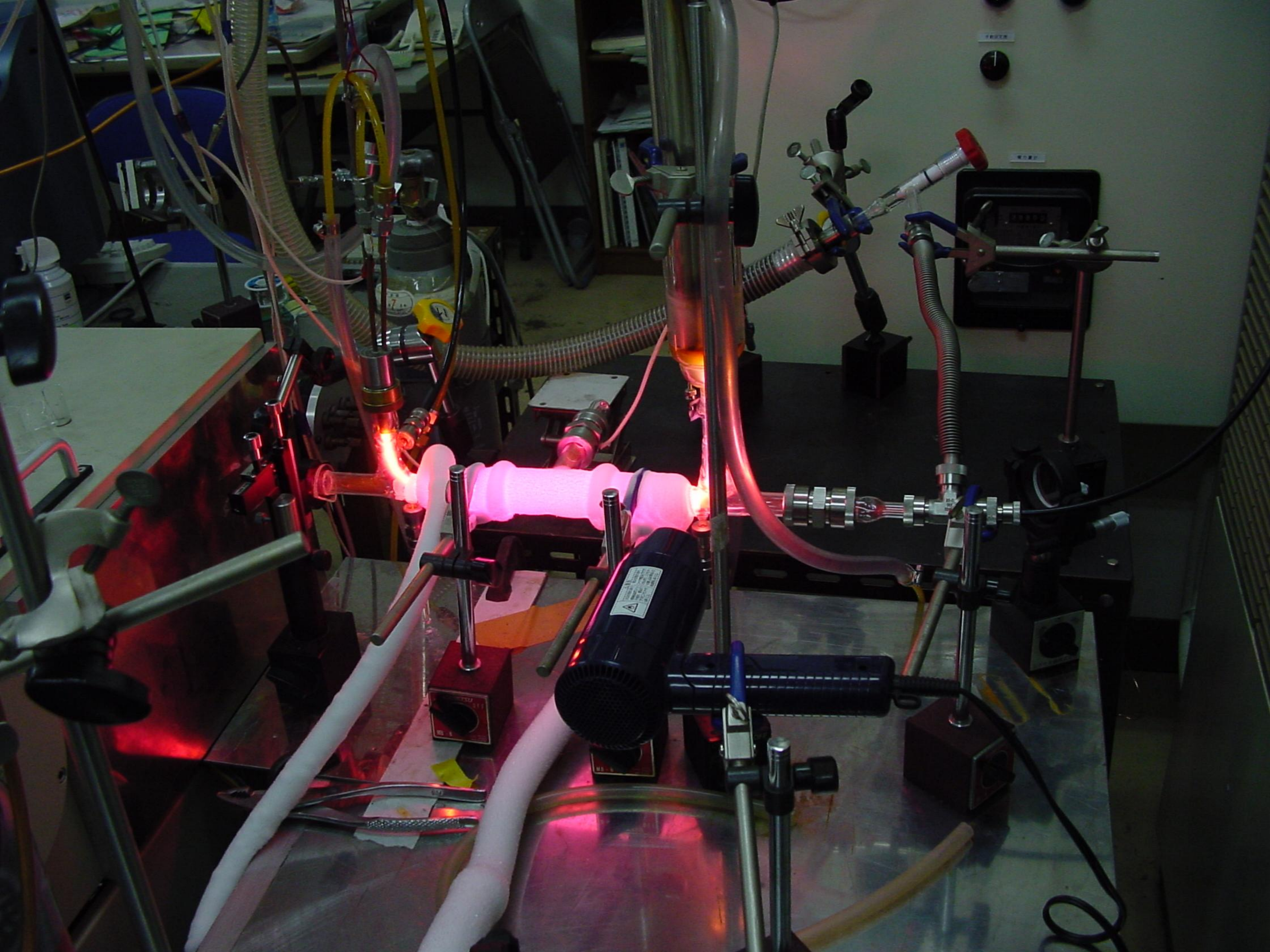
Fundamentální frekvence ν_0 rotačně-vibračního spektra CN^- spadá do oblasti

$\omega e - 2\omega exe = 2044{,}6\ cm{-}1$.

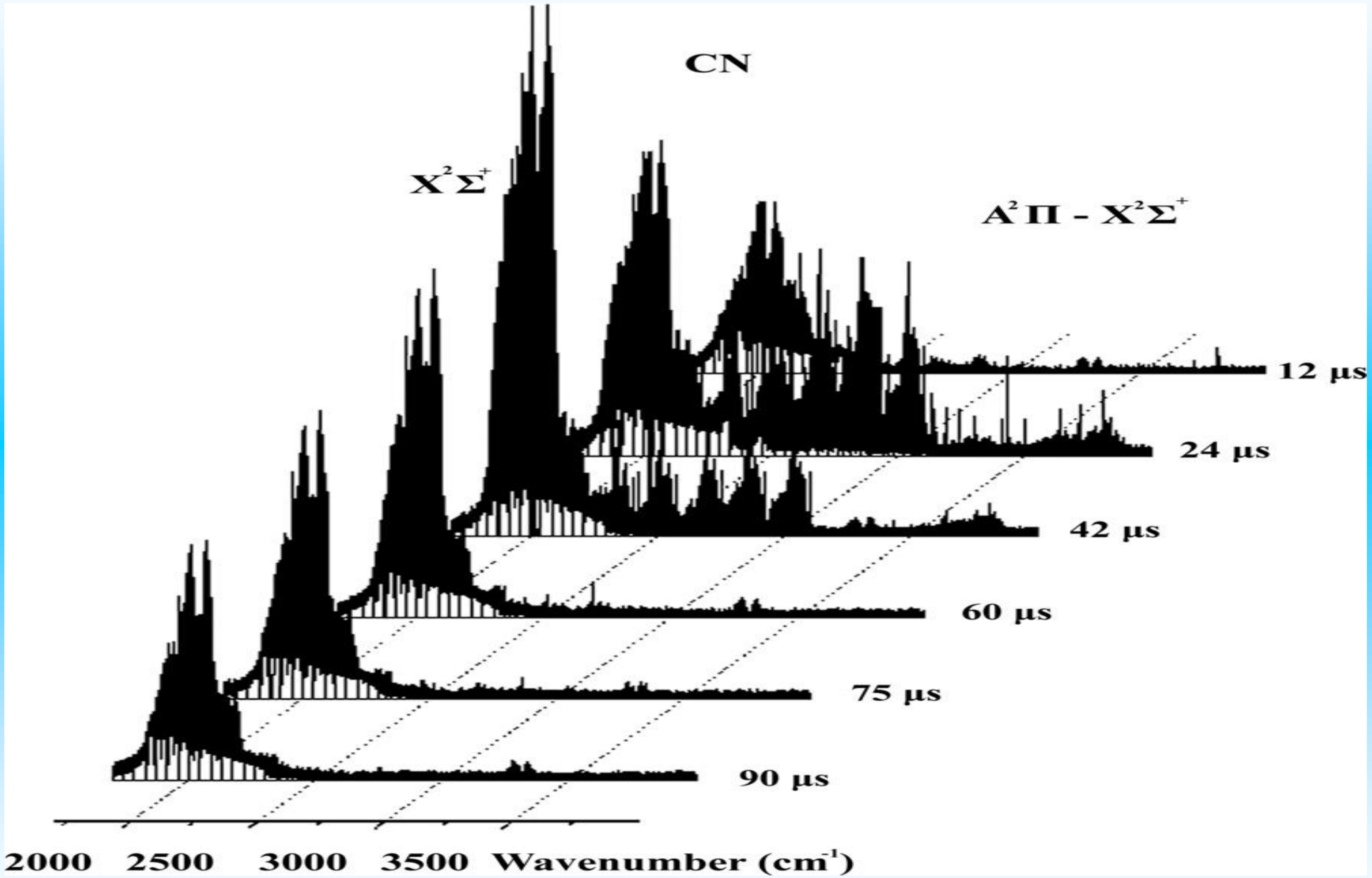
Predikce ab-initio Špirko, Polák

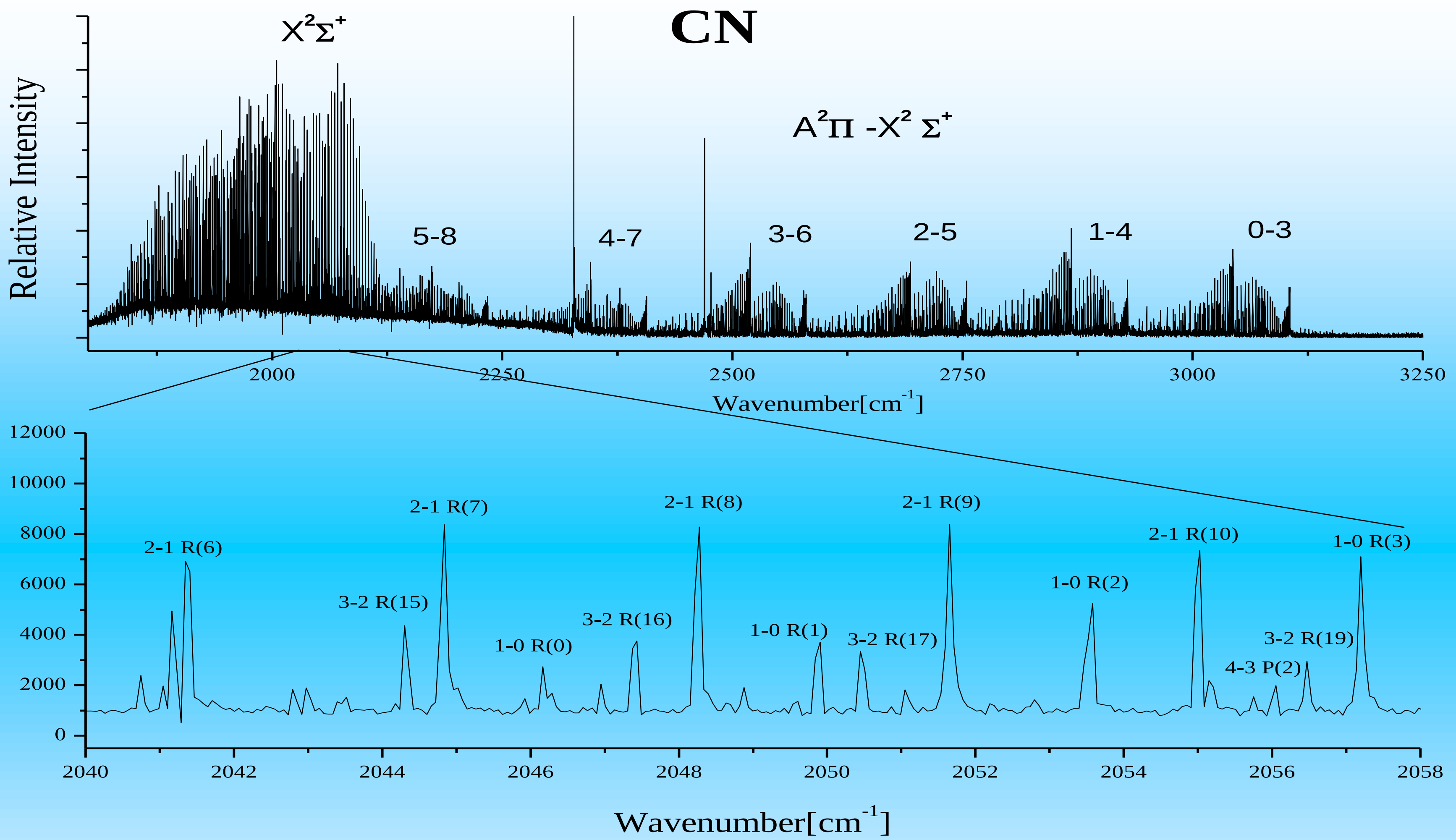
Civiš, S., Šedivcová, T.: „Detekce záporných iontů v mezihvězdném prostoru”, *Čs. čas. fyz.*, 2002, **52,** 152-159.

Praha FT spektrometr



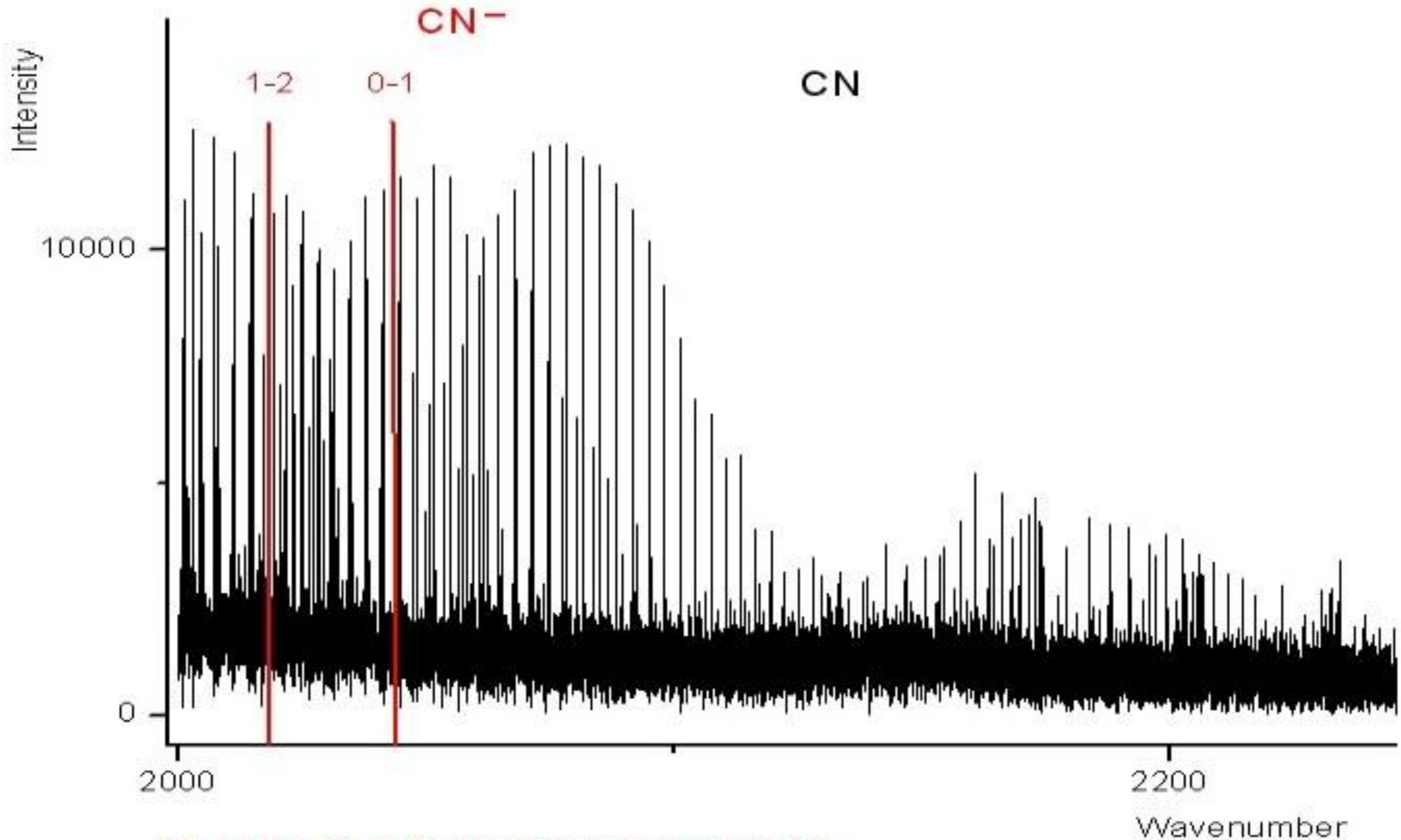
Ar + $(CN)_2$ discharge plasma





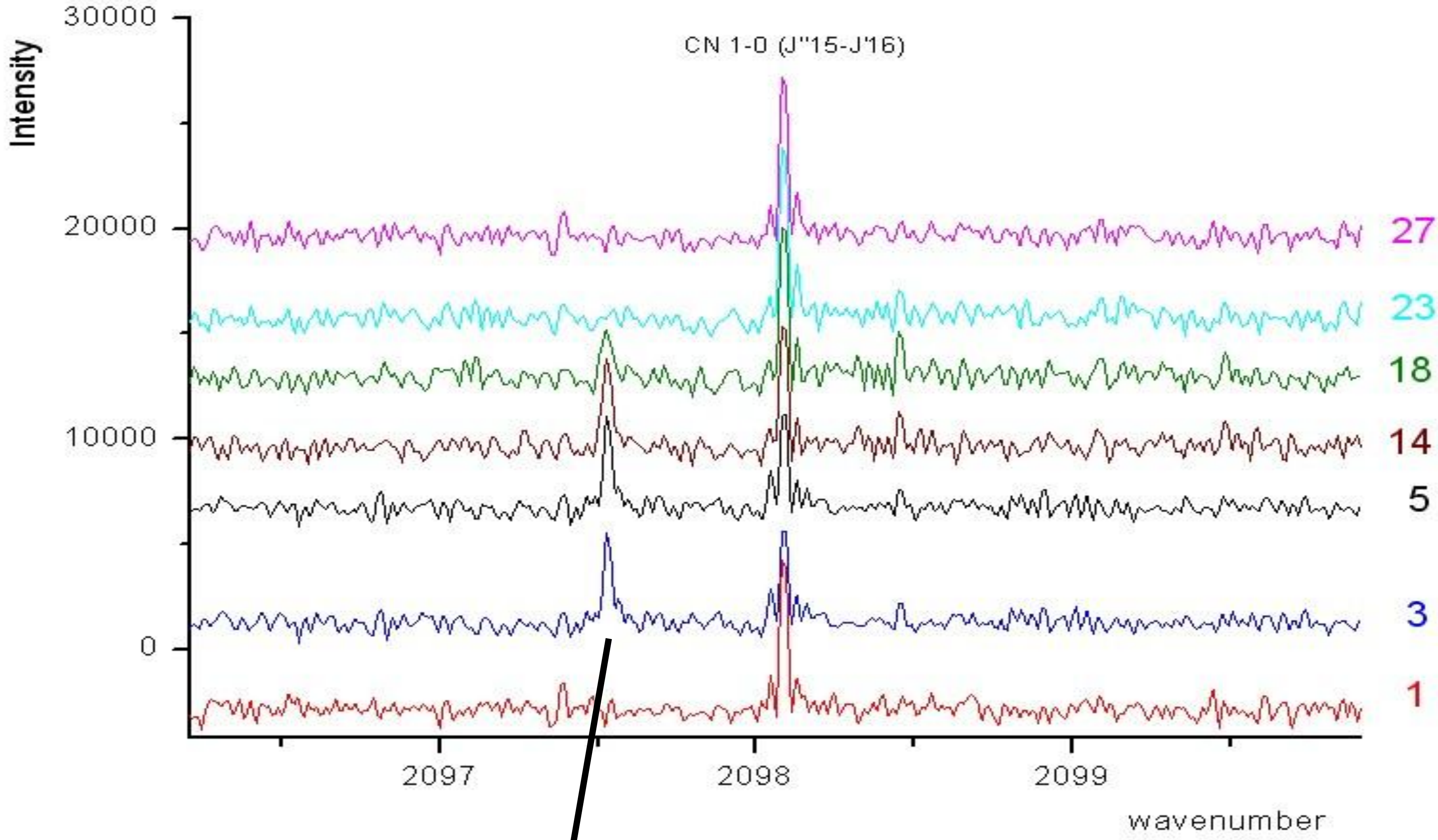
V. Horká, S. Civiš, V. Špirko, K. Kawaguchi: ***Coll. Czech. Chem. Commun.***, 2004, **69**, 73-89

Civiš, S; Šedivcová-Uhliková, T; Kubelik, P. et al.: ***J. Mol. Spectrosc***, 2008, **250,** 20-26



(T. J. Lee, Ch. E. Dateo; Spectrochimica Acta)

(V. Horká, S. Civiš; Collect. Czech. Chem. Commun.)



Nové neznámé linie

Search for rotational spectrum of CN^-

2003, Mito, Japonsko

J= 4-3 transition 449416.6 MHz

Discharge (He buffer gas) and Mg flame, booster pump, He pressure 100 mTorr through electrodes and Mg oven (total 300 mTorrs)

Conditions:

Mg 63 V, 8.5 A

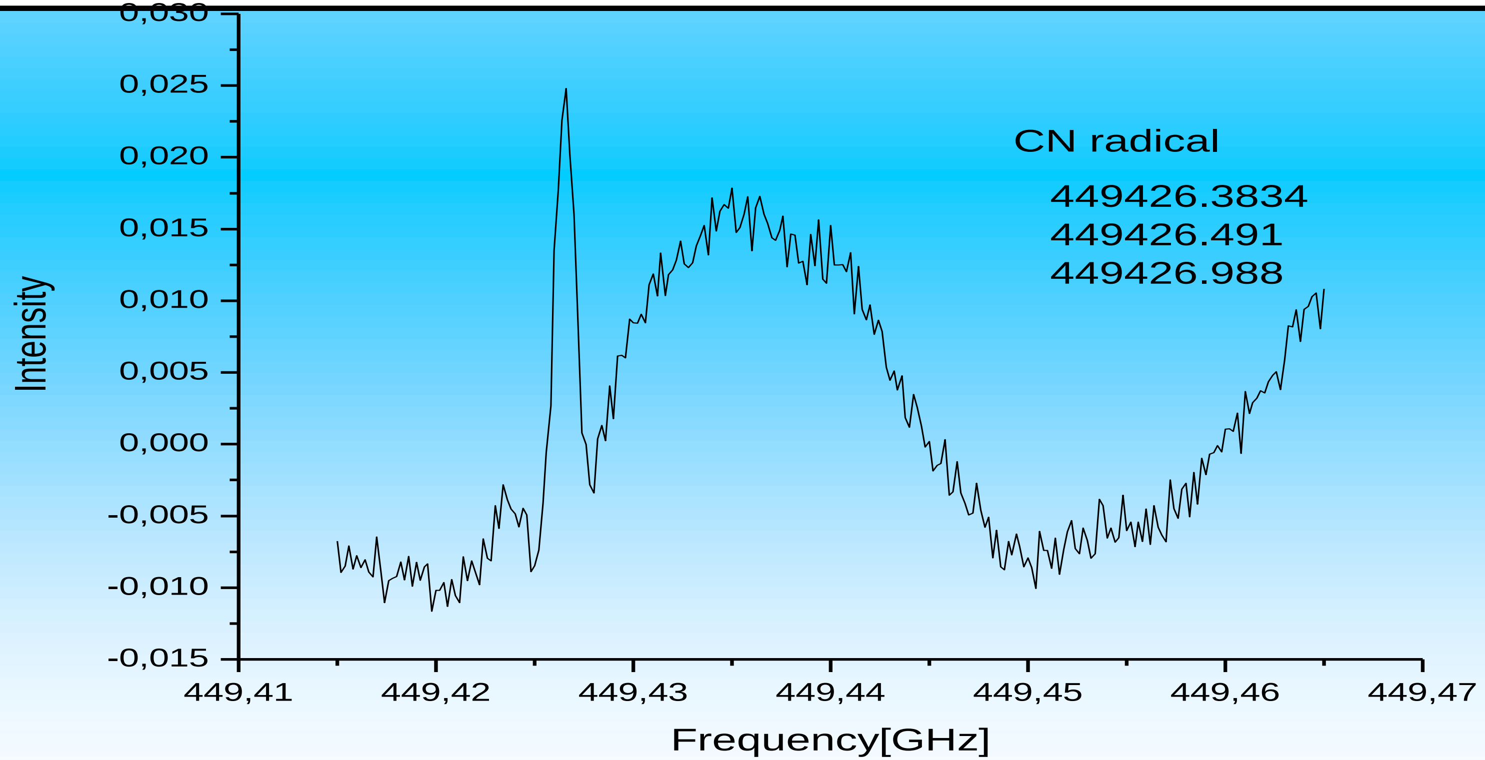
Discharge: 2 kV at the beginning, later 500V, current 10 mA

Blue flame of Mg

After adding $(CN)_2$ change into green

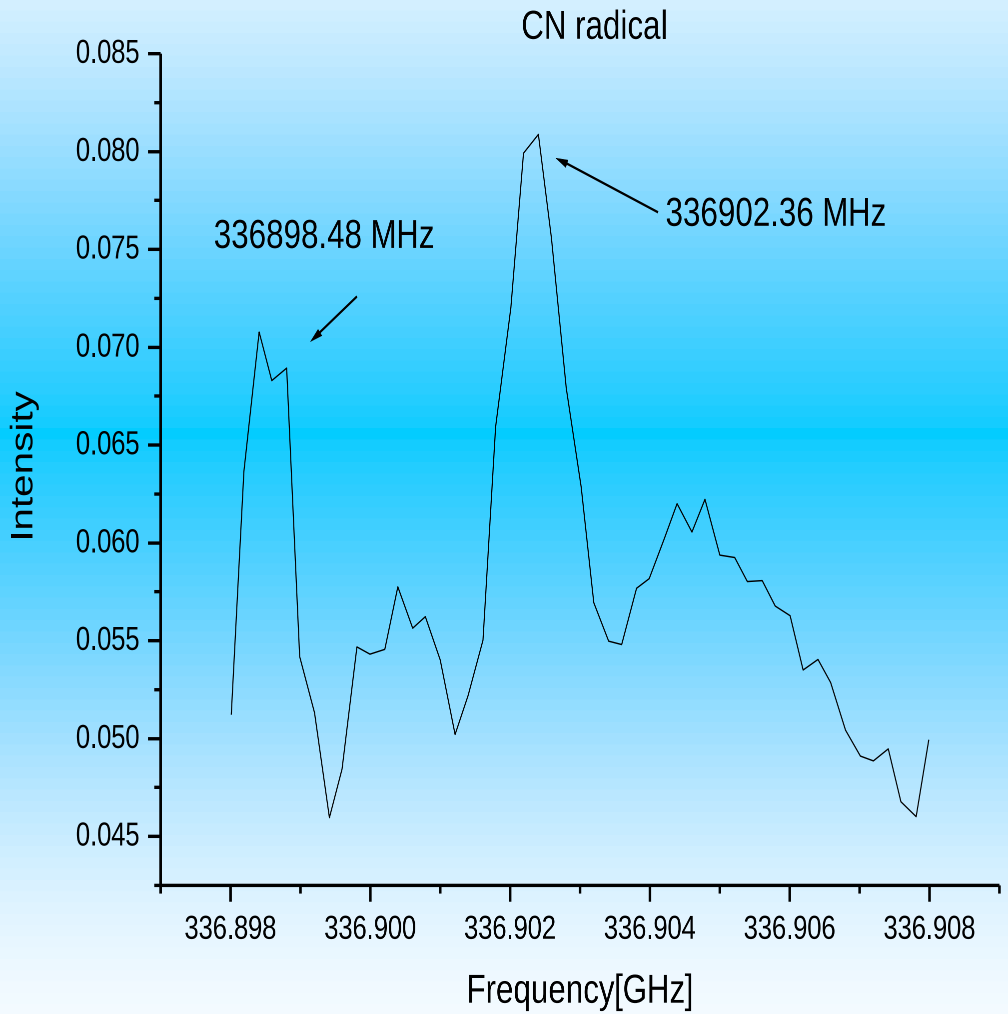
He + Mg +$(CN)_2$

Scan interval : 449100- 449597 MHz ***(J=4←3 449 014.351 MHz)***



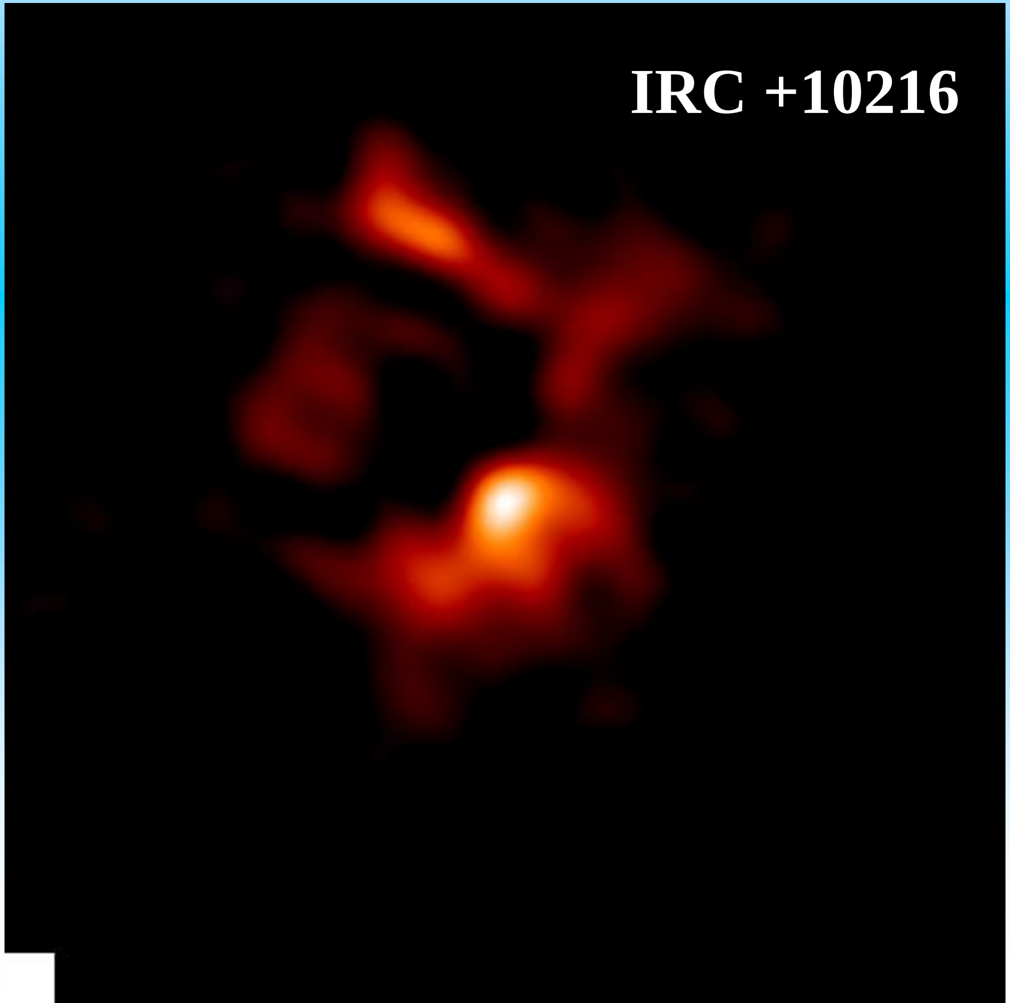
Search for J= 3←2 transition (Predikce 337078 MHz)

From 336900- 337300 MHz



Zlom: rok 2006

Malá exkurze do minulosti (rok 1995)
Nobeyama, Japonsko



K.Kawaguchi

Two well-known astronomical sources: the molecular shell of the **evolved carbon star IRC 10216** and the **rich molecular cloud TMC-1** in the Taurus complex of dark nebulae and in IRC 10216 .
Puzzle of the unidentified harmonic sequence of lines discovered by **Kawaguchi et al. (1995) and designated B1377** because it is apparently from a closed-shell linear molecule
with a rotational constant ***B*** **of 1377 MHz**.

LABORATORY AND ASTRONOMICAL IDENTIFICATION OF THE NEGATIVE MOLECULAR ION C_6H^-

M. C. McCarthy,1 C. A. Gottlieb, H. Gupta, and P. Thaddeus

Received 2006 September 28; accepted 2006 October 17; published 2006 November ABSTRACT

The negative molecular ion C_6H^- has been detected in the radio band in the laboratory and has been identified in the molecular envelope of IRC 10216 and in the dense molecular cloud TMC-1. The spectroscopic constants derived from laboratory measurements of 17 rotational lines between 8 and 187 GHz are identical to those derived from the astronomical data, establishing unambiguously that C_6H^- is the carrier of the series of lines with rotational constant **1377 MHz first observed by K. Kawaguchi et al. in IRC 10216**. The column density of C6H toward both sources is 1%–5% that of neutral C_6H. These surprisingly high abundances for a negative ion imply that if other molecular anions are similarly abundant with respect to their neutral counterparts, they may be detectable both in the laboratory at high resolution and in interstellar molecular clouds.

THE ASTROPHYSICAL JOURNAL, 655: L57–L60, 2007 January 20

ROTATIONAL SPECTRA OF THE CARBON CHAIN NEGATIVE IONS C_4H^- AND C_8H^-

H. GUPTA,[1,2] S. BRÜNKEN,[1] F. TAMASSIA,[3] C. A. GOTTLIEB,[1] M. C. MCCARTHY,[1] AND P. THADDEUS[1]

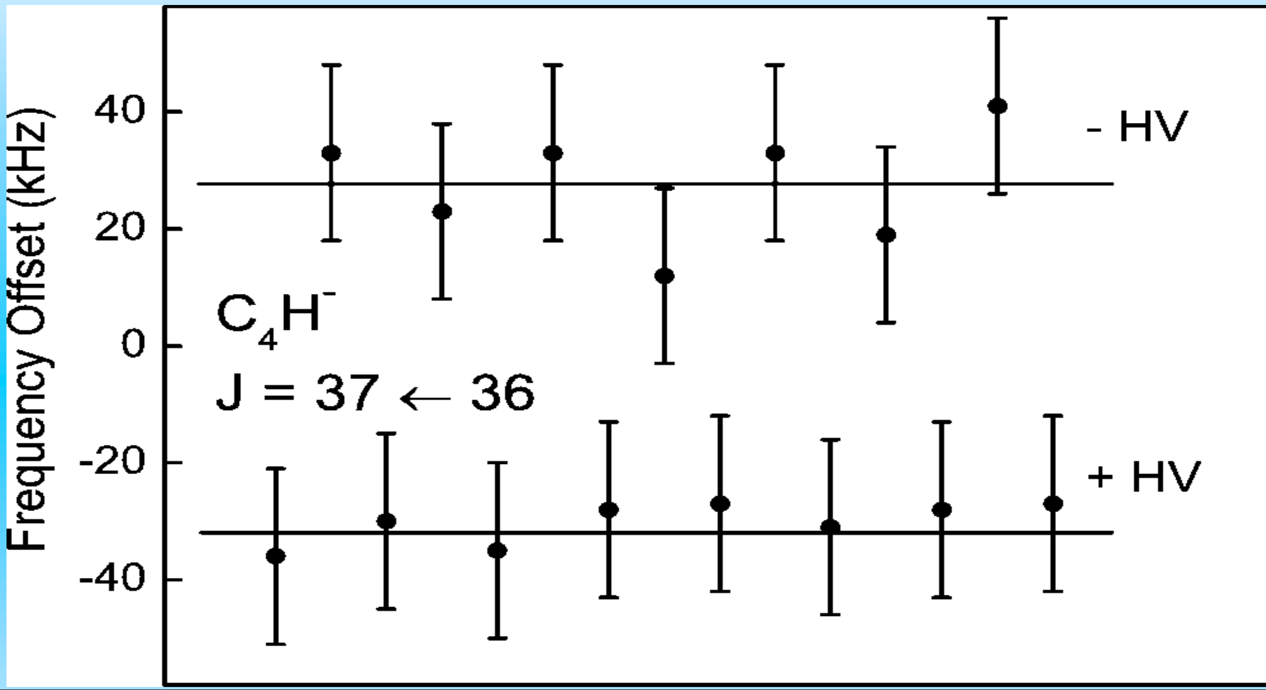


Fig. 3.—Ion drift measurements of C_4H- . Plotted are a series of measurements of the *J* p 37 R 36 line with either positive or negative high voltage (HV) applied to the electrode near the radiation source; the electrode on the detector side was at ground potential in either case. The frequency shift (relative to a center frequency of 344,346.874 MHz) corresponds to a drift velocity of 25 m s^{-1}.

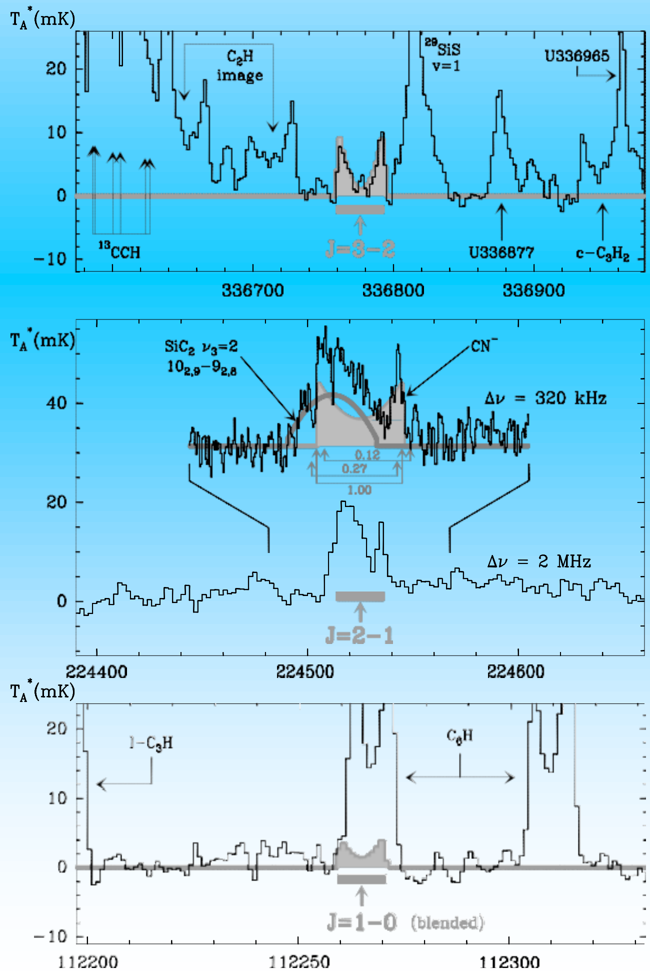
A&A 517, L2 (2010)
DOI: 10.1051/0004-6361/201015186

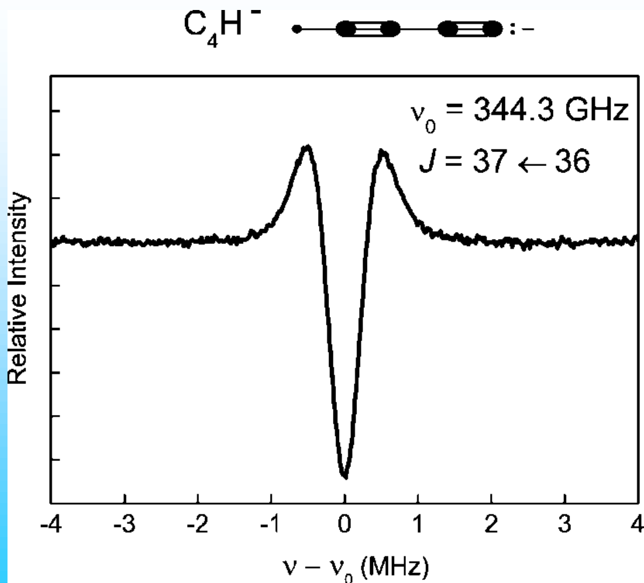
Astronomy & Astrophysics

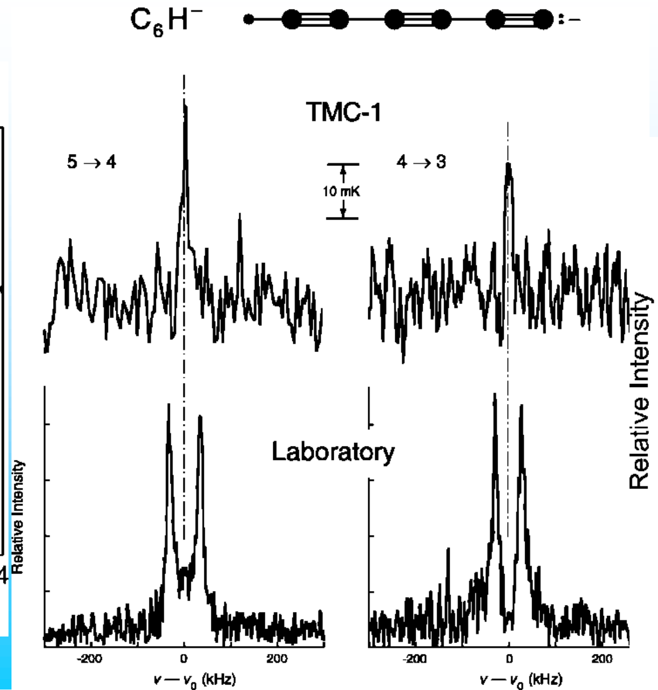
Letter to the Editor

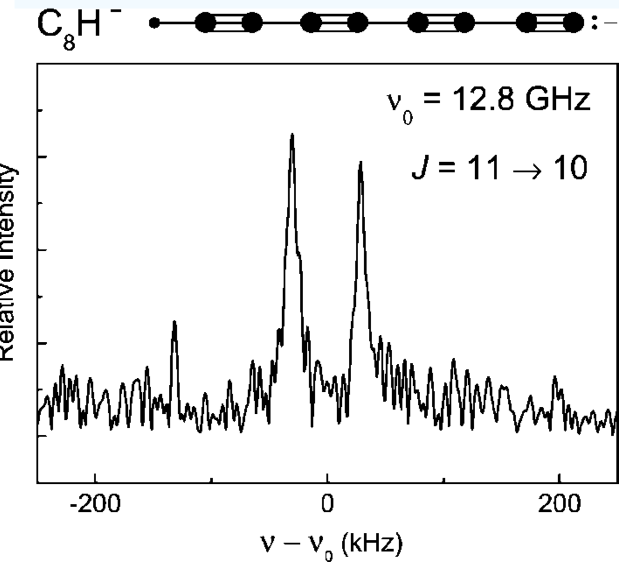
Astronomical identification of CN^-, the smallest observed molecular anion*,**

M. Agúndez[1], J. Cernicharo[2], M. Guélin[3], C. Kahane[4], E. Roueff [1], J. Kłos[5], F. J. Aoiz[6], F. Lique[7], N. Marcelino[2], J. R. Goicoechea[2], M. González García[8], C. A. Gottlieb[9], M. C. McCarthy[9], and P. Thaddeus[9]









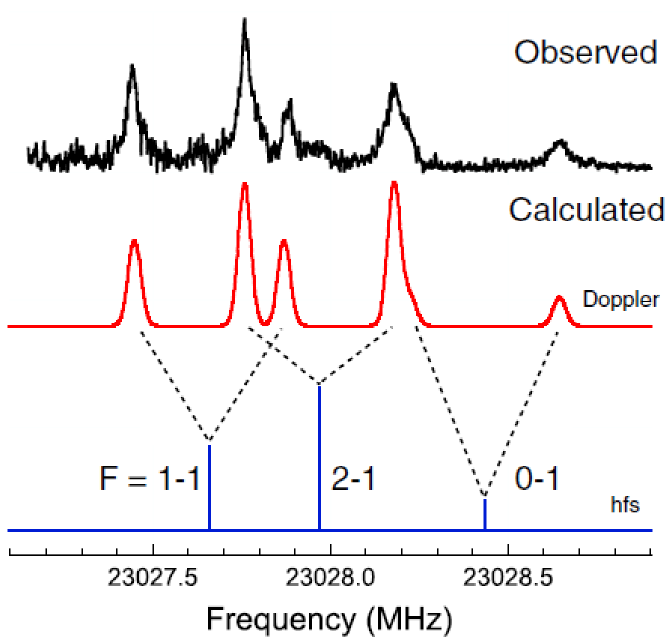
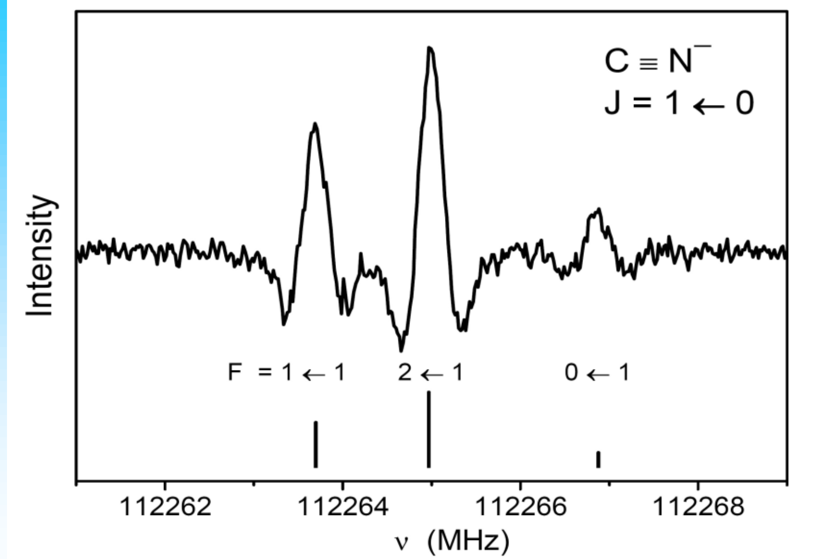
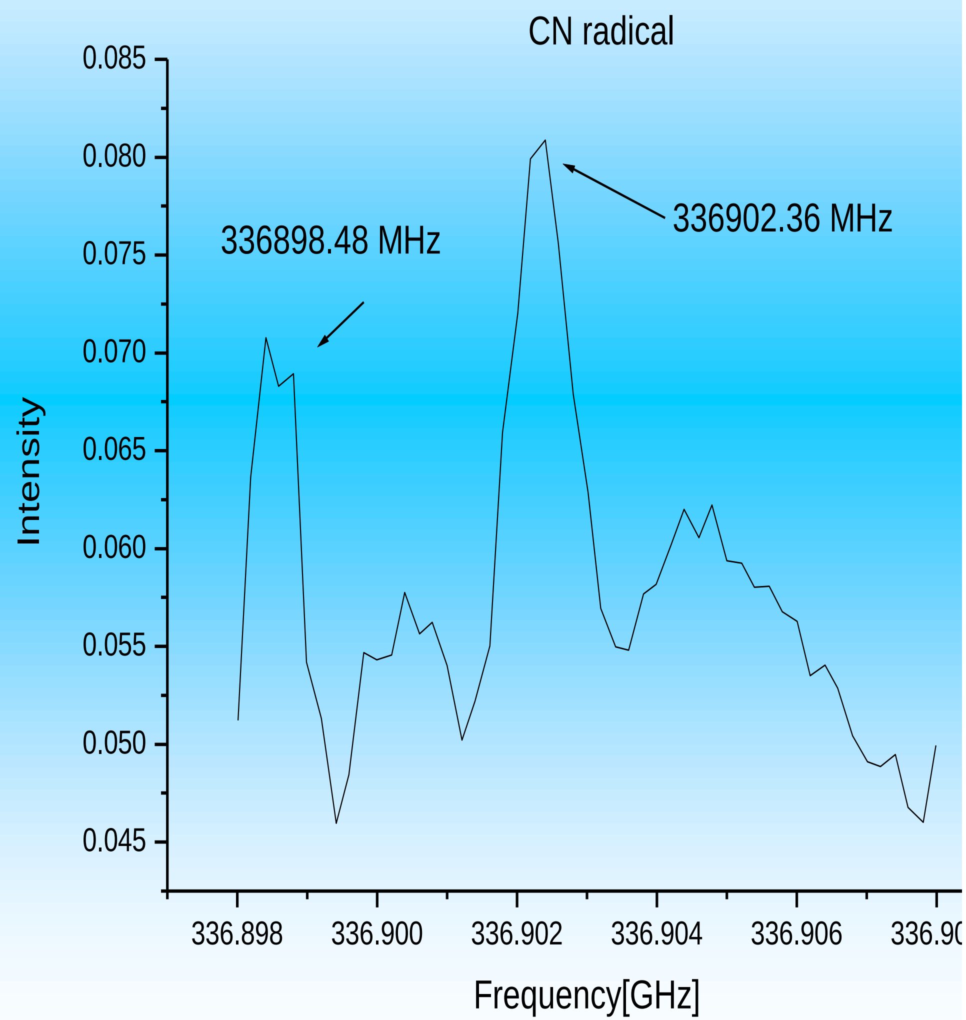


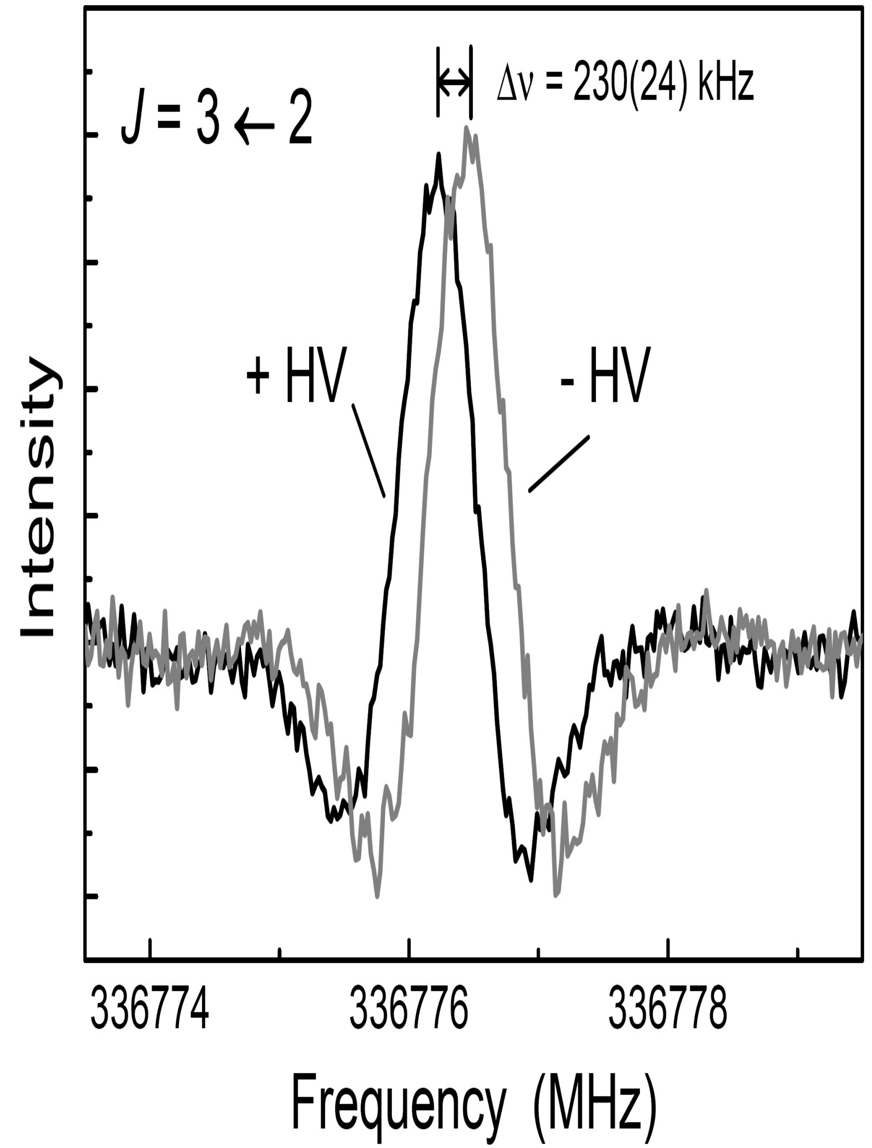
Figure 1. $J = 1 \rightarrow 0$ transition of NCO^- showing the well-resolved triplet



Search for J= 3←2 transition CN⁻ (Predikce 337078 MHz)

From 336900- 337300 MHz





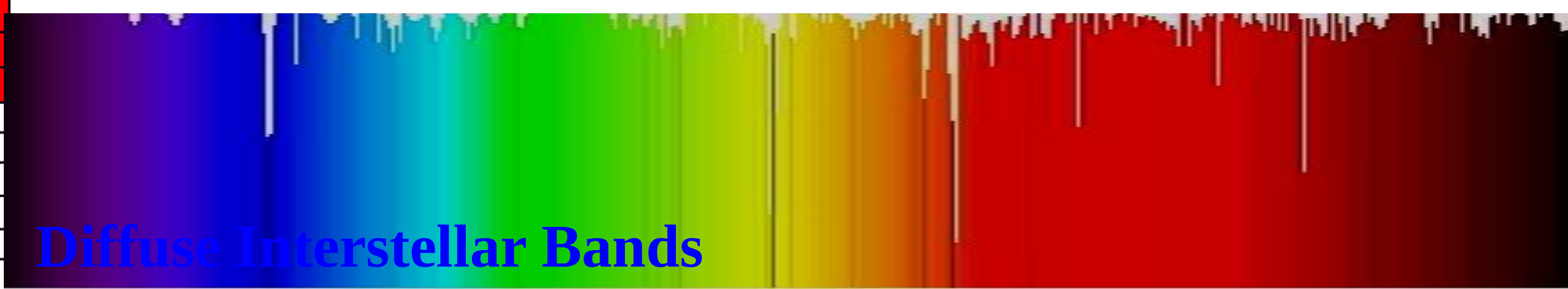
Přehled molekul a iontů detegovaných v mezihvězdném prostoru

2 atoms	3 atoms	4 atoms	5 atoms	6 atoms	7 atoms	8 atoms	9 atoms	10 atoms	11 atoms	12 atoms	13 atoms
H_2	C_3*	c-C_3H	C_5*	C_5H	C_6H	CH_3C_3N	CH_3C_4H	CH_3C_5N	HC_9N	C_6H_6	$HC_{11}N$
AlF	C_2H	l-C_3H	C_4H	l-H_2C_4	CH_2CHCN	$HC(O)OCH_3$	CH_3CH_2CN	$(CH_3)_2CO$	CH_3C_6H	$C_2H_5OCH_3$	
AlCl	C_2O	C_3N	C_4Si	C_2H_4*	CH_3C_2H	CH_3COOH	$(CH_3)_2O$	$(CH2OH)_2$	C_2H_5OCHO	n-C_3H_7CN	
C_2**	C_2S	C_3O	l-C_3H_2	CH_3CN	HC_5N	C_7H	CH_3CH_2OH	CH_3CH_2CHO			
CH	CH_2	C_3S	c-C_3H_2	CH_3NC	CH_3CHO	H_2C_6	HC_7N				
CH^+	HCN	C_2H_2*	H2CCN	CH_3OH	CH_3NH_2	CH_2OHCHO	C_8H				
CN	HCO	NH_3	CH_4*	CH_3SH	c-C_2H_4O	l-HC_6H*	$CH_3C(O)NH_2$				
CO	HCO^+	HCCN	HC_3N	HC_3NH^+	H_2CCHOH	CH_2CHCHO	C_8H^-				
CO^+	HCS^+	$HCNH^+$	HC_2NC	HC_2CHO	C_6H^-	CH_2CCHCN	C_3H_6				
CP	HOC^+	HNCO	HCOOH	NH_2CHO		H_2NCH_2CN					
SiC	H_2O	HNCS	H_2CNH	C_5N							
HCl	H_2S	$HOCO^+$	H_2C_2O	l-HC_4H*							
KCl	HNC	H_2CO	H_2NCN	l-HC_4N							
NH	HNO	H_2CN	HNC_3	c-H_2C_3O							
NO	MgCN	H_2CS	SiH_4*	H_2CCNH							
NS	MgNC	H_3O^+	H_2COH^+	C_5N^-							
NaCl	N_2H^+	c-SiC_3	C_4H^-								
OH	N_2O	CH_3*	HC(O)CN								
PN	NaCN	C_3N^-									
SO	OCS	PH3									
SO^+	SO_2	HCNO									
SiN	c-SiC_2	HOCN									
SiO	CO_2*	HSCN									
SiS	NH_2										
CS	H_3^+*										
HF	H_2D^+										
SH*	HD_2^+										
HD	SiCN										
FeO	AlNC										
O_2	SiNC										
CF^+	HCP										
SiH	CCP										
PO											

Cations

Anions

CN^- NCO^-

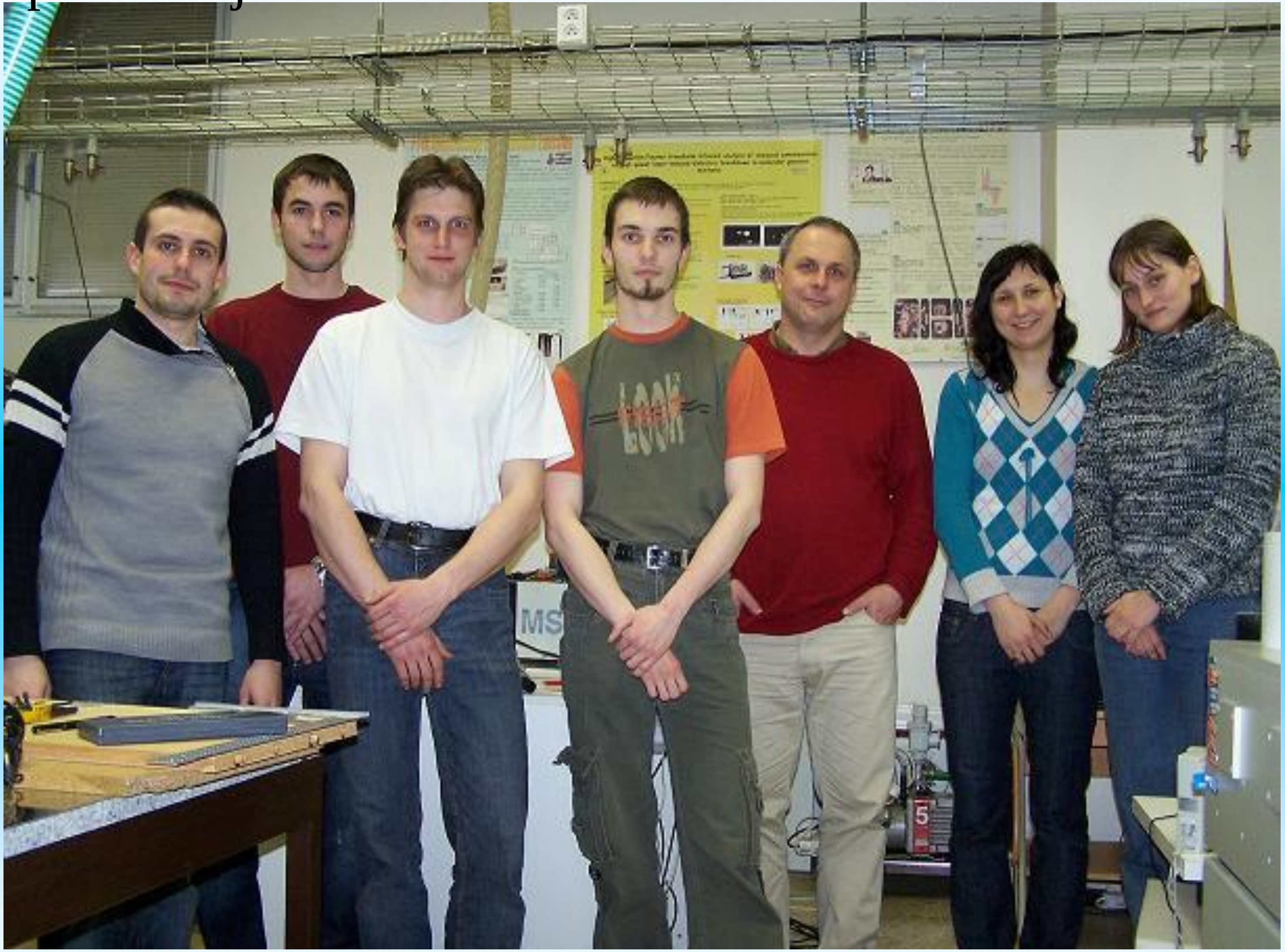


Závěr

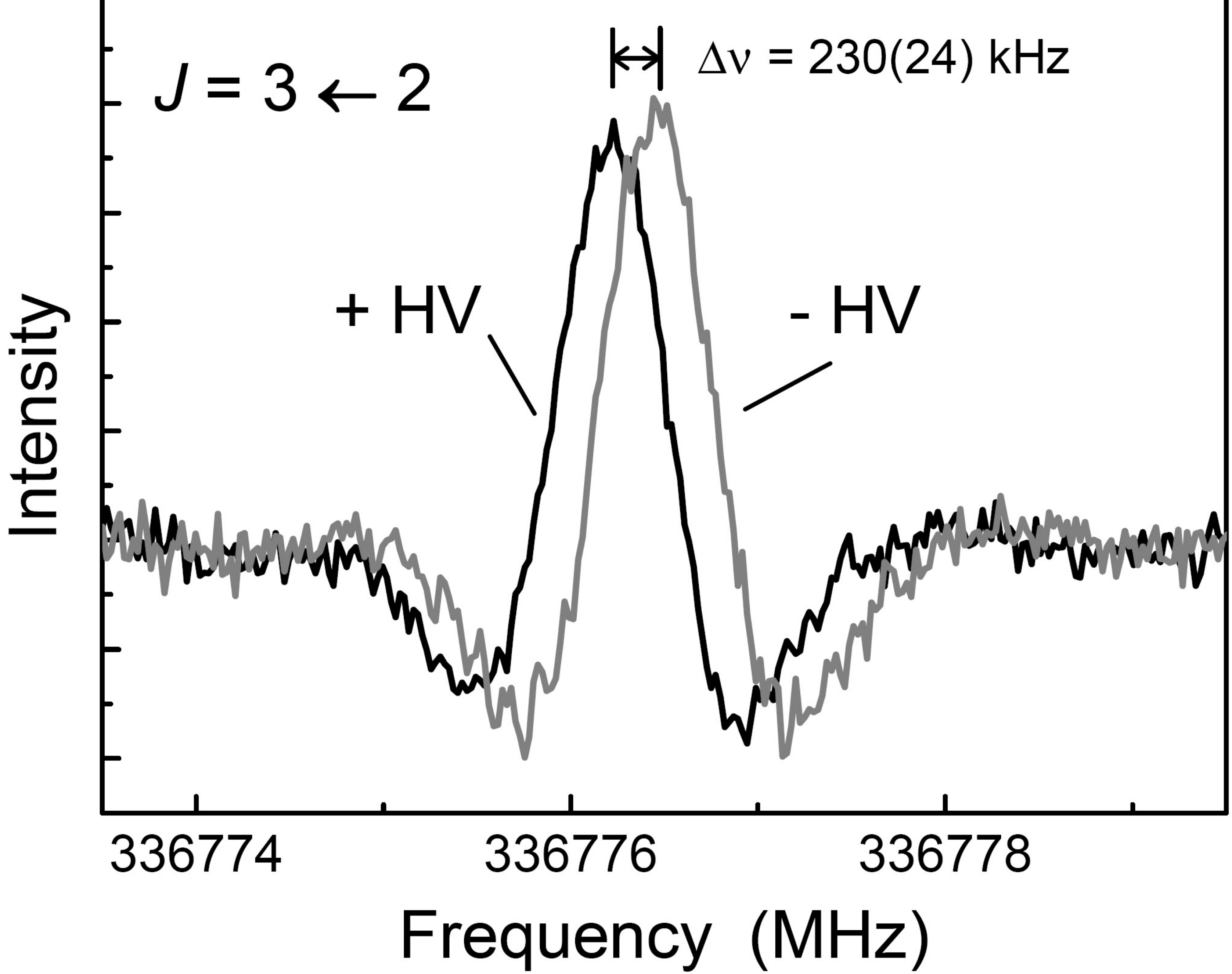
- 20 let studia záporných iontů v laboratoři

Měření rotačně-vibračních, mikrovlnných spekter

- Hledání iontů v mezihvězdných oblacích (45 m teleskop v Nobeyamě, a 2 m optický teleskop v Okayamě, Japonsko) http://www.jh-inst.cas.cz/~ftirlab/



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



Δν = 230(24) kHz
J = 3 ← 2
+ HV
- HV
Intensity
336774
336776
336778
Frequency (MHz)

PASJ: Publ. Astron. Soc. Japan **47**, 853–876 (1995)

A Spectral-Line Survey Observation of IRC +10216 between 28 and 50 GHz

Kentarou KAWAGUCHI,[1] Yasuko KASAI,[2] Shin-ichi ISHIKAWA,[1] and Norio KAIFU[3]

[1] *Nobeyama Radio Observatory, Minamimaki, Minamisaku, Nagano 384-13*
[2] *Tokyo Institute of Technology, Ohokayama, Meguro-ku, Tokyo 152*
[3] *National Astronomical Observatory, Mitaka, Tokyo 181*

(Received 1995 April 4; accepted 1995 June 12)

Abstract

We report on a spectral-line survey of the circumstellar envelope of IRC +10216 between 28 and 50 GHz using the Nobeyama 45-m telescope with a sensitivity of < 10 mK. A total of 188 spectral lines were observed, 150 of which have been assigned to 22 molecules and their isotopic variants. We derived the column densities and excitation temperatures of the observed species by using a local thermodynamic equilibrium approximation. The observed frequency range is characterized by many long carbon chain molecules, up to HC_9N, as well as by 38 unidentified lines.

Key words: Atomic and molecular processes — Circumstellar matter — Interstellar:molecules — Radio sources: lines — Stars: individual (IRC +10216)

1. Introduction

As is well known, the late-type carbon star IRC +10216 is one of the brightest celestial objects in the 10–20 μm region, and has a very rich molecular envelope, as shown by many radio and infrared observations. So far, 47 molecular species have been identified in IRC +10216, 15 of which were only detected in this source. One chemical feature of IRC +10216 is that many carbon chain molecules are synthesized in a mass-loss process from the central carbon star. On the other hand, only two oxygen-bearing molecules, CO and SiO, have been detected. Metal compounds, such as NaCl, AlF, AlCl, NaCN, KCl, MgNC, and MgCN, are also found

The Nobeyama 45-m telescope has been applied for line-survey observations of four typical molecular sources: IRC +10216, TMC-1, Sgr-B2, and Orion-KL. A large acousto-optical spectrometer in our observatory makes it possible to cover a wide frequency range (up to 2 GHz) simultaneously. These observations aim at obtaining molecular-line data in the frequency range of 9–115 GHz in order to determine the molecular abundances and to clarify the chemistry of these objects. Through these unbiased survey observations many un-identified lines have been detected, and eleven new molecular species, namely C_6H, CCS, C_3S, C_4Si, cyclic-C_3H, CH_2CN, CCO, HCCNC, HNCCC, HC_3NH^+, and MgNC, have been identified. In the present paper we report on obser-

The Rotational Spectrum of CN^-

C. A. Gottlieb, S. Brünken, M. C. McCarthy, and P. Thaddeus
Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, and Division of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138
(Dated: April 20, 2007)

The rotational spectrum of the molecular negative ion CN^- has been detected in the laboratory at high resolution. The four lowest transitions were observed in a low pressure glow discharge through C_2N_2 and N_2. Conclusive evidence for the identification was provided by well-resolved nitrogen quadrupole hyperfine in the lowest rotational transition, and a measurable Doppler shift due to the ion drift in the positive column of the discharge. Three spectroscopic constants (B, D, and eQq) reproduce the observed spectrum to within 1 part in 10^7 or better, allowing the entire rotational spectrum to be calculated well into the far IR to within 1 km s^{-1} in radial velocity. CN^- is an excellent candidate for astronomical detection, because the CN radical is observed in many galactic molecular sources, the electron binding energy of CN^- is large, and calculations indicate CN^- should be detectable in IRC+10216 — the carbon star where C_6H^- has recently been observed. The fairly high concentration of CN^- in our discharge implies that other molecular anions containing the nitrile group may be within reach.

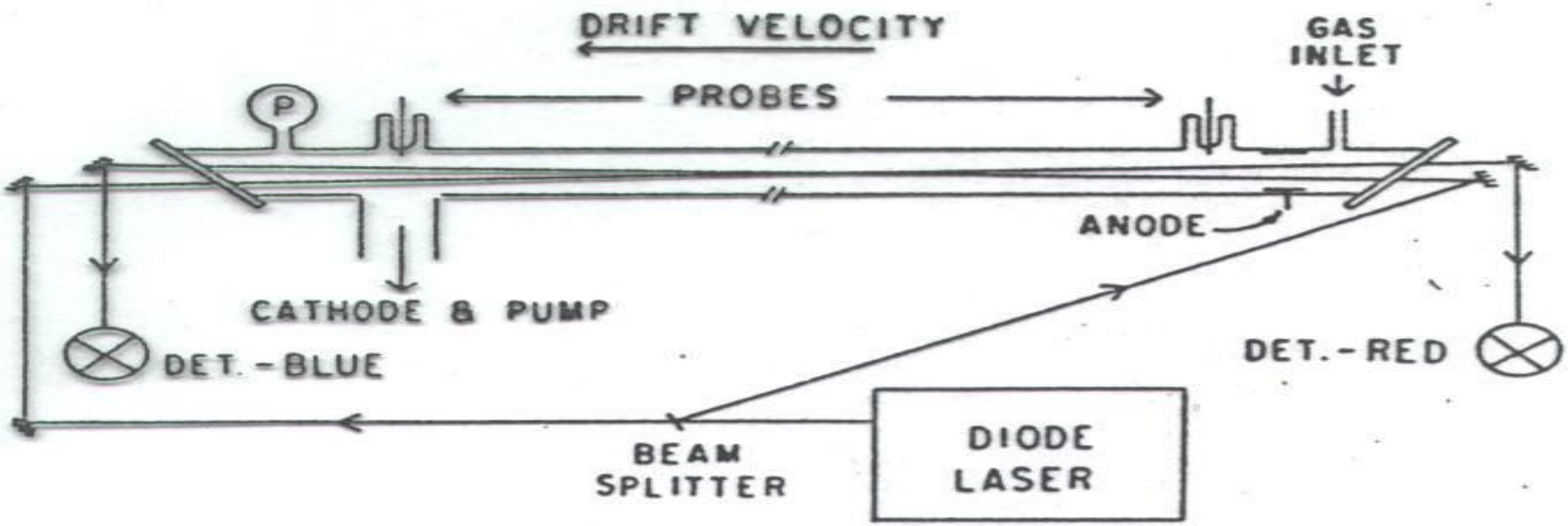


FIG. 1. Doppler–shift discharge cell and optical arrangement.