TECHNICAL ENHANCEMENTS OF A SUBMILLIMETER-WAVE SPECTROMETER: LABORATORY DETECTION OF NEW LINES OF METHANOL RADICAL DERIVATIVES

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Methanol radical derivatives: an astrophysical interest

Why should we investigate rotational spectrum of methanol radical derivatives?

- C, O and H containing species
- CH$_2$OH potentially precursor of Complex Organic Molecules
- CH$_3$O already detected in the Interstellar Medium

Experimental set-ups available at ISMO
Experimental set-ups available at ISMO

CH₃OH + HF → CH₃O + HF

Y. Endo et al., J. Chem. Phys. 81, p122, 1984
Experimental set-ups available at ISMO

**Challenges**

- Low SNR for radicals
- Sometimes hidden in precursors lines
- Need to improve our sensitivity \( A=\varepsilon*I*c \)
- Need to improve our discrimination power
Initial experimental set-up

Characteristics:

• Synthetizer (2-20 GHz) + frequency multiplier (VDI)
• Detector: Shottky diode or bolometer
• FM modulation + 2F detection
• 150 cm cell
• Radical produced by fluorine H abstraction
• Typical spectra recorded in 1min40 / 10 MHz
• Roots + primary vacuum pump (250m³/h)

References:
2. Step of 50kHz.
   Time constant of frequency modulation 500ms
Initial experimental set-up

\[
\text{CH}_3\text{OH} + \text{F}^- = \text{CH}_3\text{O}^- + \text{HF}
\]
Initial experimental set-up

**Chemical Reaction:**

\[ \text{CH}_3\text{OH} + \text{F}^- = \text{CH}_3\text{O}^- + \text{HF} \]

**Effect of the magnetic field on an open-shell species\(^1\):**

Zeeman Interaction

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Initial experimental set-up

\[ \text{CH}_3\text{OH} + \text{F}^- = \text{CH}_3\text{O}^- + \text{HF} \]
Initial experimental set-up

Effect of the magnetic field on an open-shell species:\(^1:\)

\[
\text{CH}_3\text{OH} + F^- \rightarrow \cdot\text{CH}_2\text{OH} + \text{HF}
\]

Initial experimental set-up

Effect of the magnetic field on an open-shell species\textsuperscript{1}:

\[
\text{CH}_3\text{OH} + F^- = \cdot\text{CH}_2\text{OH} + \text{HF}
\]

Initial experimental set-up

Effect of the magnetic field on an open-shell species:\footnote{C.K. Jen et al. Physical Review, 74(10), p1396–1406, 1948}

Zeeman Interaction

\[
\begin{align*}
\text{Without magnet} & \quad \text{Intensity (Arbitrary unit)} \\
\text{With magnet} & \quad \text{Intensity (Arbitrary unit)}
\end{align*}
\]
Initial experimental set-up

Effect of the magnetic field on an open-shell species$^1$:

Without magnet

With magnet

Comparison

Initial experimental set-up

Effect of the magnetic field on an open-shell species$^1$:

Without magnet  
With magnet  
Difference spectrum

No signal of CH$_2$OH!

Very short area of radical production!
1°: Increase synthesis yield

$A = \varepsilon \cdot l \cdot c$

Triple areas of radicals production
Shortened injection tube from 1m25 to 40cm

Decrease recombination of atomic fluorine
Increase synthesis yield of radicals
2°: Increase absorption length

\[ A = \varepsilon \cdot l \cdot c \]

Artificially double the length of the cell
3°: Improve discrimination

Intensity of $\overrightarrow{B}$

800 coils for 1m30 cell

AC of 2 A produced by audio amplifier + diode for 16 G magnetic field
3°: Improve discrimination

Modulated magnetic field all along the cell
Larger magnetic field than previously  Larger Zeeman splitting
3°: Improve discrimination

Frequency modulation
(First lock-in)

Modulation of $\vec{B}$
(Second lock-in)

Single demodulation
(FM)

Dual demodulation
(FM and $\vec{B}$)
Results

Initial Set-Up

One area of production
Single passage
Single modulation (FM)

2 Spectra for each lines needed (total of 3min12 in usual conditions)

SNR~2 on weakest lines

Final Set-Up

Triple area of production
Double passage
Double modulation (FM+Magnetic field)

1 Spectrum for each lines needed (3min25 in usual conditions)

SNR~10 for the same line

5 TIMES BETTER !!

in the same condition
for the same time

Initial Set-Up

One area of production
Single passage
Single modulation (FM)

2 Spectra for each lines needed (total of 3min12 in usual cond.

SNR~2 on weakest lines

500 new lines of CH$_2$OH and 476 new lines of CH$_3$O measured up to 900 GHz

See O.Chitarra’s talk (WJ03)
Conclusion and Perspectives

• New study on other interesting radicals: CH$_2$CN

• Apply a larger current

  larger magnetic field means a better modulation

• Fabry-Perot Cavity

  => absorption will be increased by several orders of magnitude
Acknowledgement

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