

Spectral Line Study for Measurement of Carbon-14 and H-3

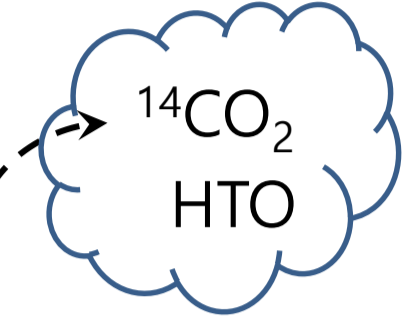
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Introduction

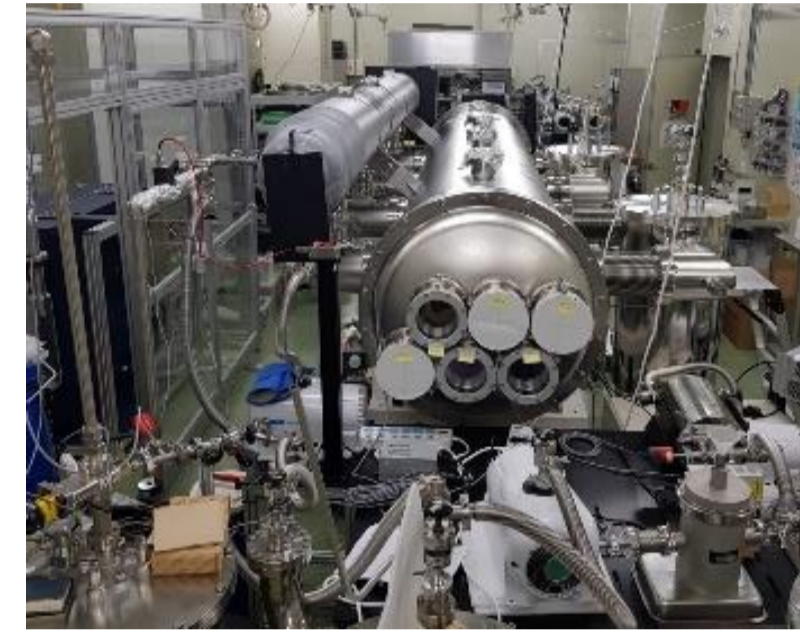
C-14 & H-3 Measurement

Environmental monitoring



방사성물질의 배출관리 기준 (Bq/m³)
- 방사선 방호 등에 관한 기준 [원자력안전위원회 고시 제 2019-10호]

C-14/heavy water recycling

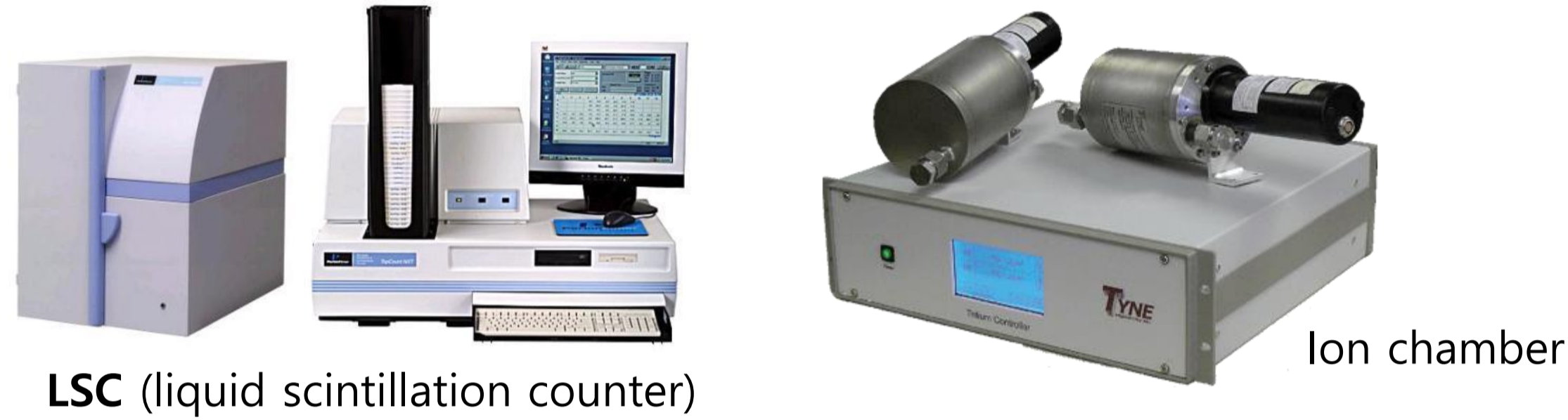


ALSIS Technology in KAERI
(Advanced Laser Stable Isotope Separation)

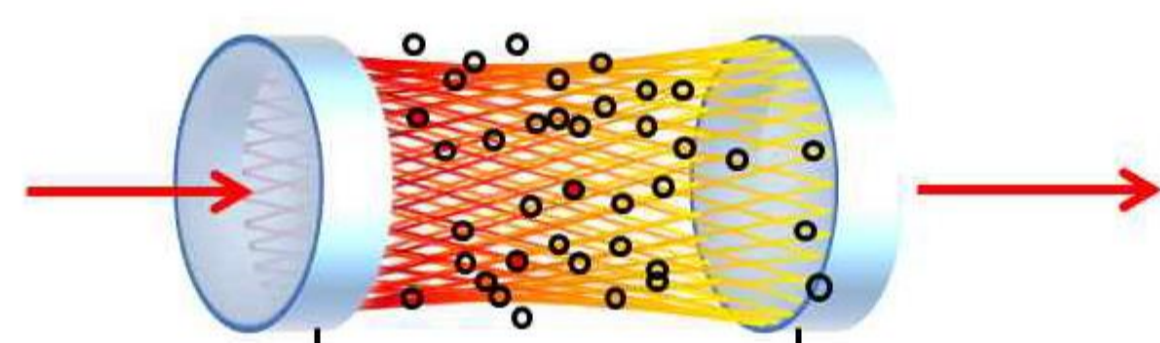
Process monitoring
- Target Isotope concentration ~ 0~90 %

C-14	Gas	1x10 ²	H-3	HTO (피부흡수 포함)	3x10 ³
	CO ₂	1x10 ⁴		Organic H-3	2x10 ³
	CO	9x10 ⁴	Atomic H-3	4x10 ⁷	
			CH ₃ T	4x10 ⁵	

Radiation detection method



- Real-time Measurement
- Simple and easy-to-use
- Comparable measurement sensitivity



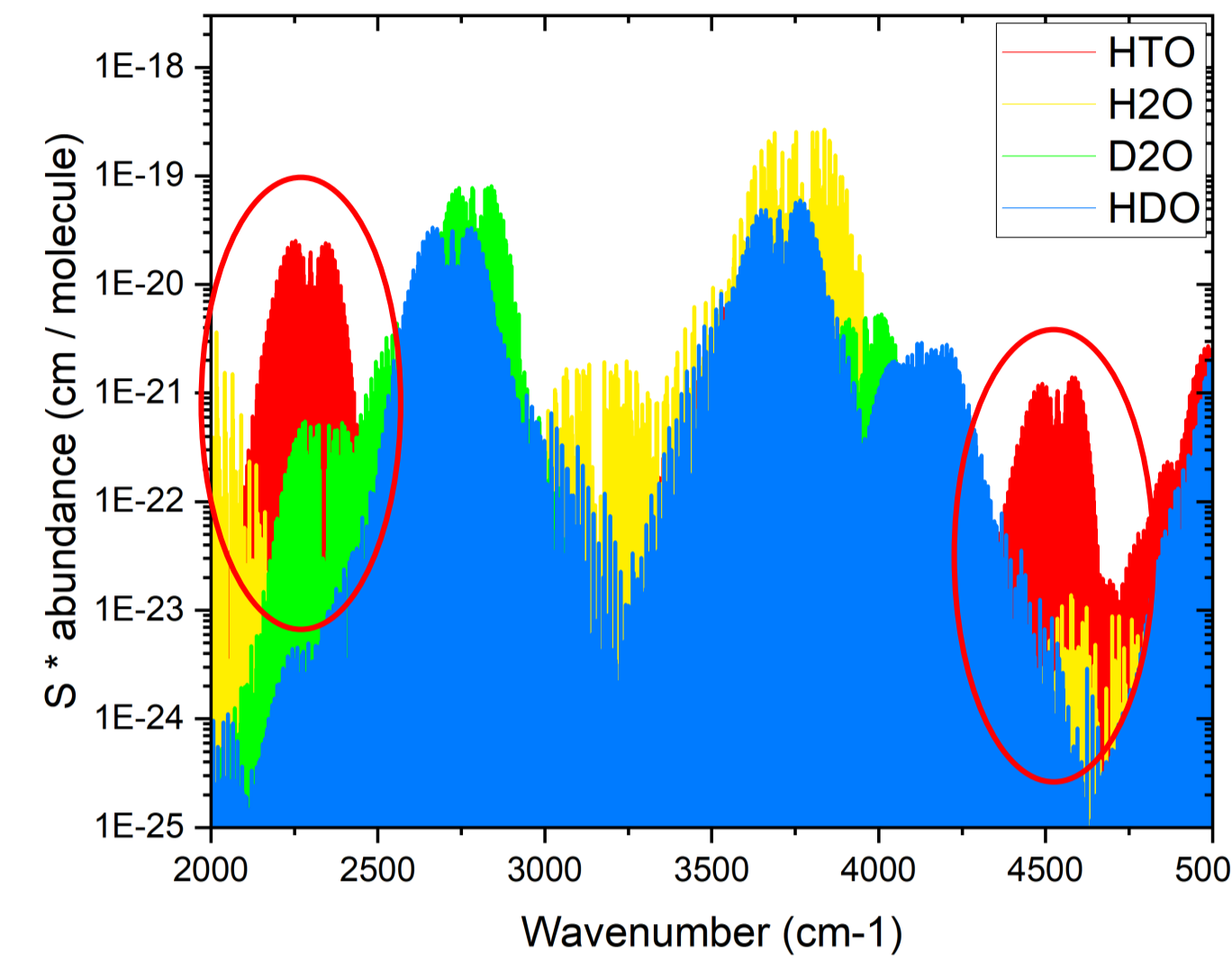
Optimal Method – Cavity enhanced technique

Investigate the spectrum of target molecules – $^{14}\text{CO}_2$ and HTO

Spectrum of HTO

- The HTO shows relatively large absorption band in 2.17 μm and 4.35 μm mid-IR range.

Water isotopologues absorption band



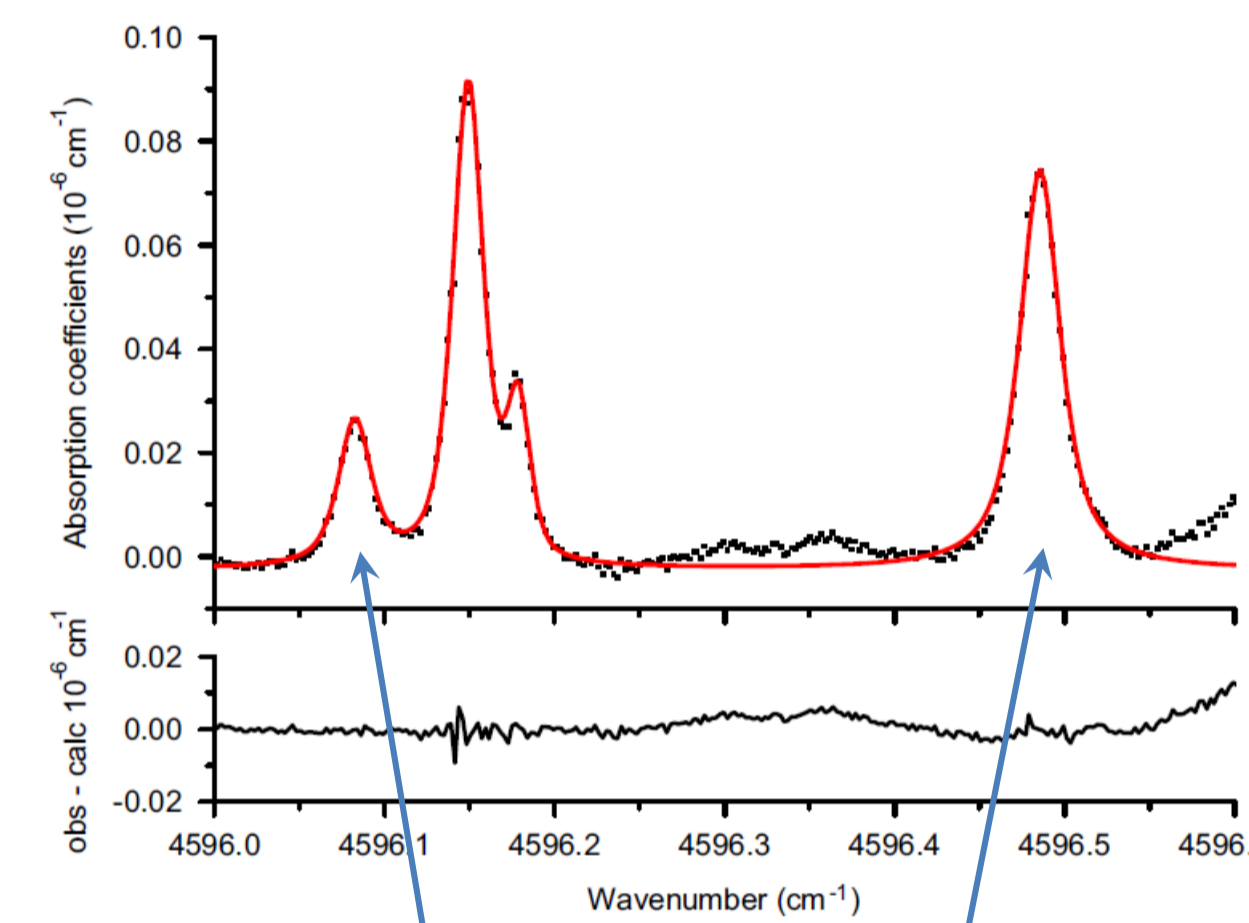
Spectroscopy of Atmospheric Gases (<http://specta.tsu.ru>)
Schwenke-Partridge 296K. Molecule H₂O
T: 296 K, P: 1 atm

Theoretical Calculation Database

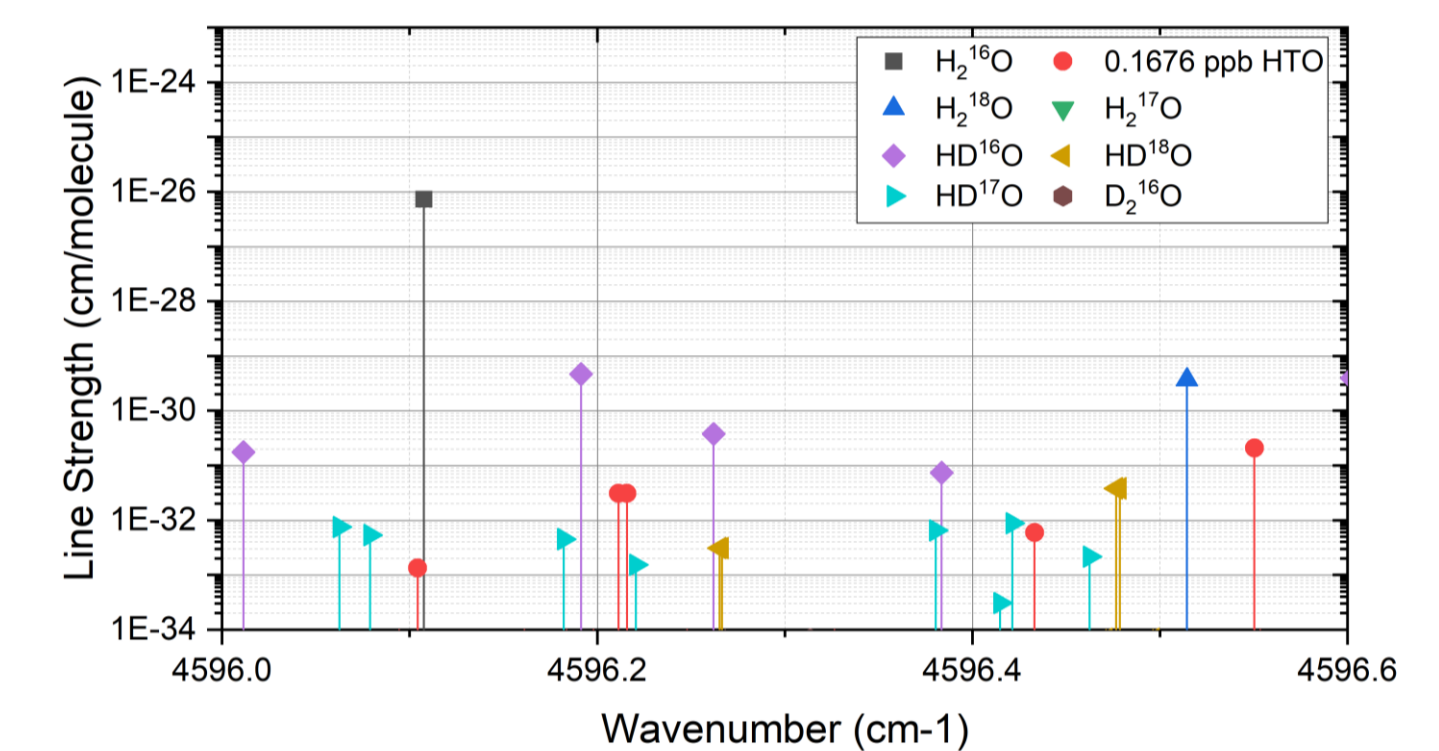
Formula	Natural abundance	
H ¹⁶ OH	0.997317	
H ¹⁶ O	0.00199983	
H ¹⁷ OH	0.000371884	371.88 ppm
H ¹⁶ OD	0.000310693	310.69 ppm
H ¹⁸ OD	0.00000623003	623.00 ppb
H ¹⁷ OD	0.00000115853	115.85 ppb
D ¹⁶ O	0.00000024197	24.197 ppb
D ¹⁷ O	0.000000004852	48.52 ppt
D ¹⁸ O	0.000000000902	9.02 ppt
HT ¹⁶ O	4.987e-17	
DT ¹⁶ O	7.7685e-21	
T ₂ ¹⁶ O	6.235e-34	
T ₂ ¹⁸ O	1.25e-36	

HTO spectral lines in previous studies

Nucl. Instrum. Methods. Phys. Res. A **789**, 43, 2015



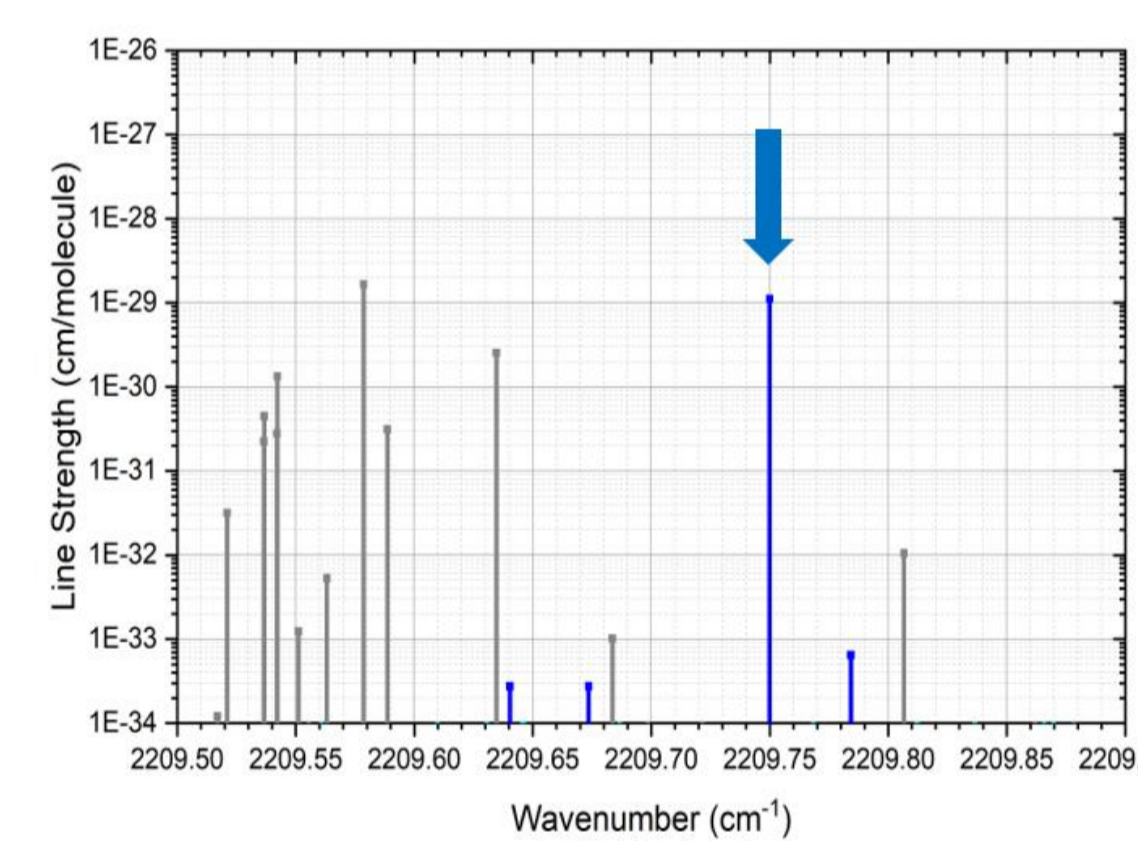
4,596.083 cm⁻¹ & 4,596.485 cm⁻¹



- Measurement sensitivity is not sufficient for sub-ppb level HTO measurement.

Our Suggestion

- We suggest the 4.35 μm wavelength range which absorption cross-sections are 10 times larger than 2.17 μm wavelength range.
- Consider all possible isotopologues of H₂O (9 configuration) with natural abundance



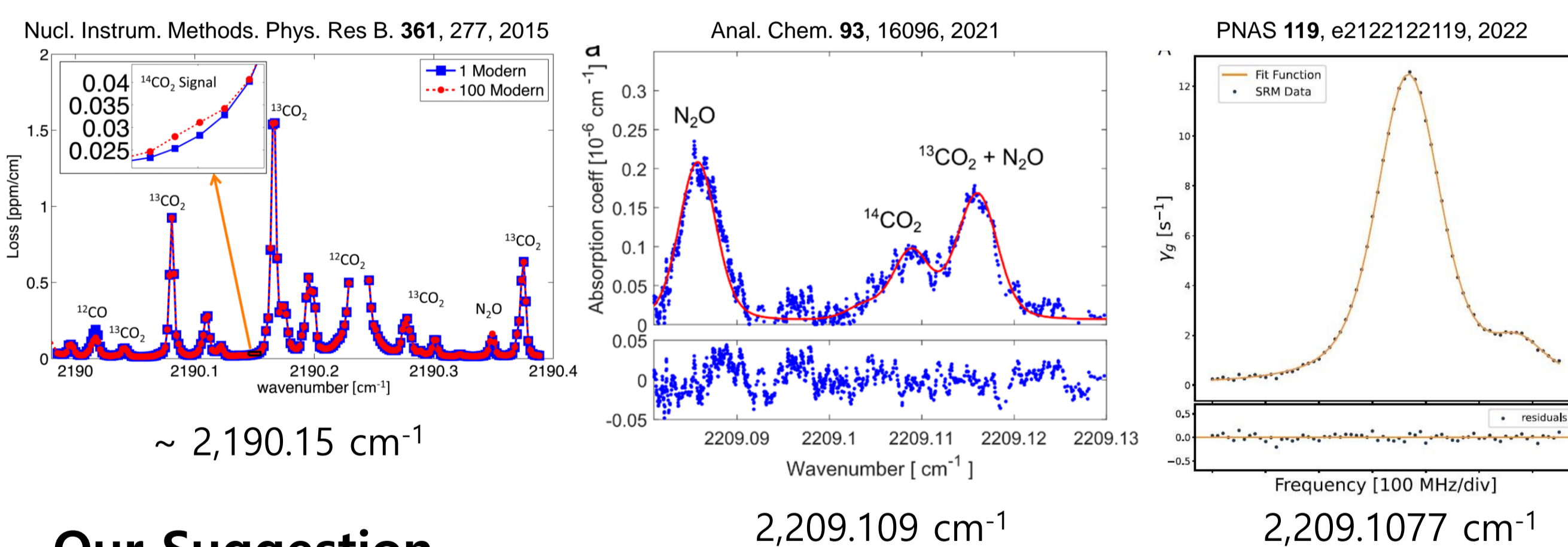
2,209.7500 cm⁻¹

- Target : 10 kBq/g-H₂O
- Near the $^{14}\text{CO}_2$ measurement line
- Experimental verification is needed

Spectrum of $^{14}\text{CO}_2$

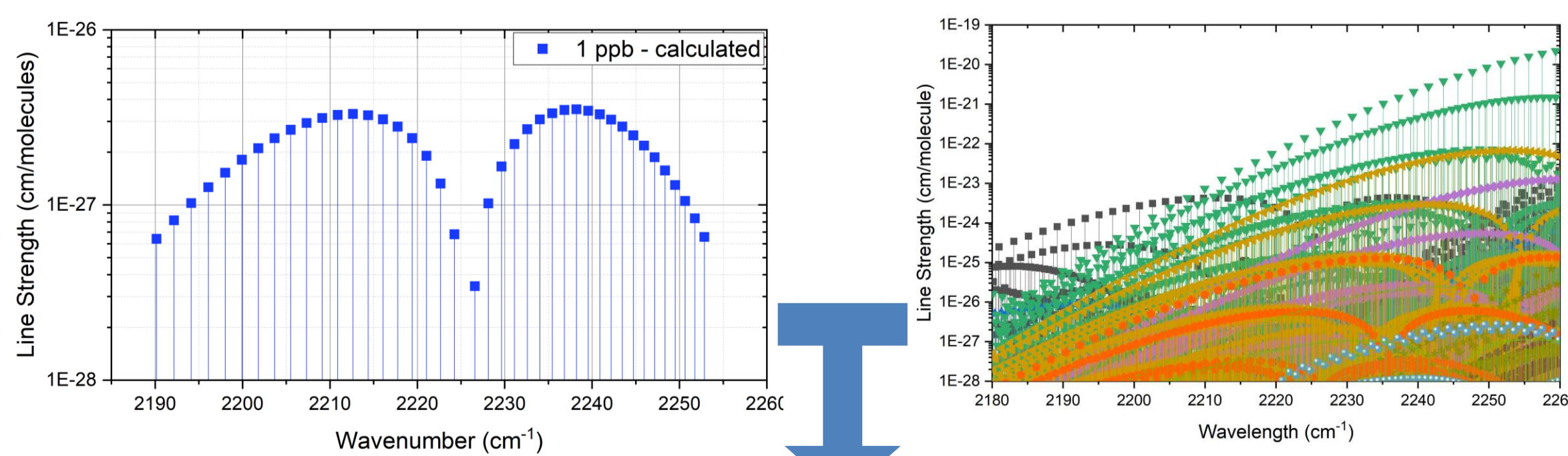
- The largest absorption band of $^{14}\text{CO}_2$ = 4.5 μm mid-IR range
⇒ Good candidate for measurement

$^{14}\text{CO}_2$ spectral lines in previous studies



Our Suggestion

- $^{14}\text{CO}_2$ spectrum : calculation
- Consider all possible isotopologues of CO₂ (12 configuration) with natural abundance
HITRAN on Web (<http://hitran.iao.ru>)

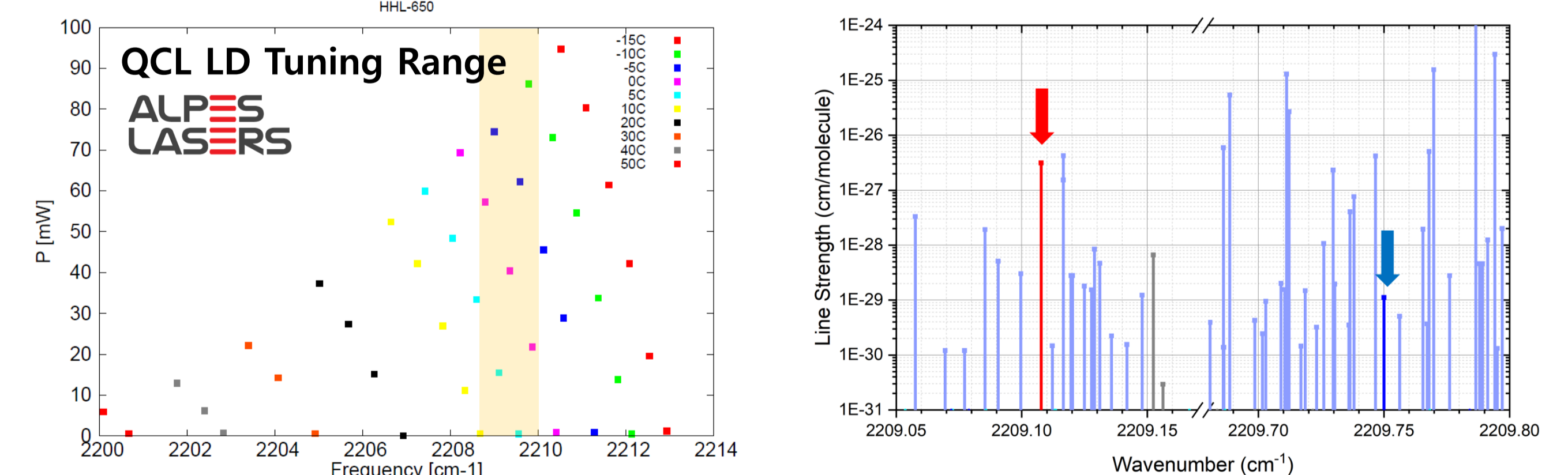


2,209.1077 cm⁻¹

- Similar to previous studies
- The largest absorption line
- Experimental verification is needed

Simultaneous Measurement

- Two proposed lines for $^{14}\text{CO}_2$ and HTO are in close proximity.



- A single equipment capable for $^{14}\text{CO}_2$ and HTO measurement
- Mutual interference between $^{14}\text{CO}_2$ and HTO for mixed sample
 - Depends on concentrations
 - $^{14}\text{CO}_2$ line is still good candidate for same amount of HTO
 - HTO line is influenced by $^{14}\text{CO}_2$

Conclusion and Future Works

- We investigated the $^{14}\text{CO}_2$ and HTO spectral lines
- We suggest the spectral lines for $^{14}\text{CO}_2$ and HTO measurements.
- We already construct the CRDS setup for $^{14}\text{CO}_2$ measurement and will measure the HTO using same setup.