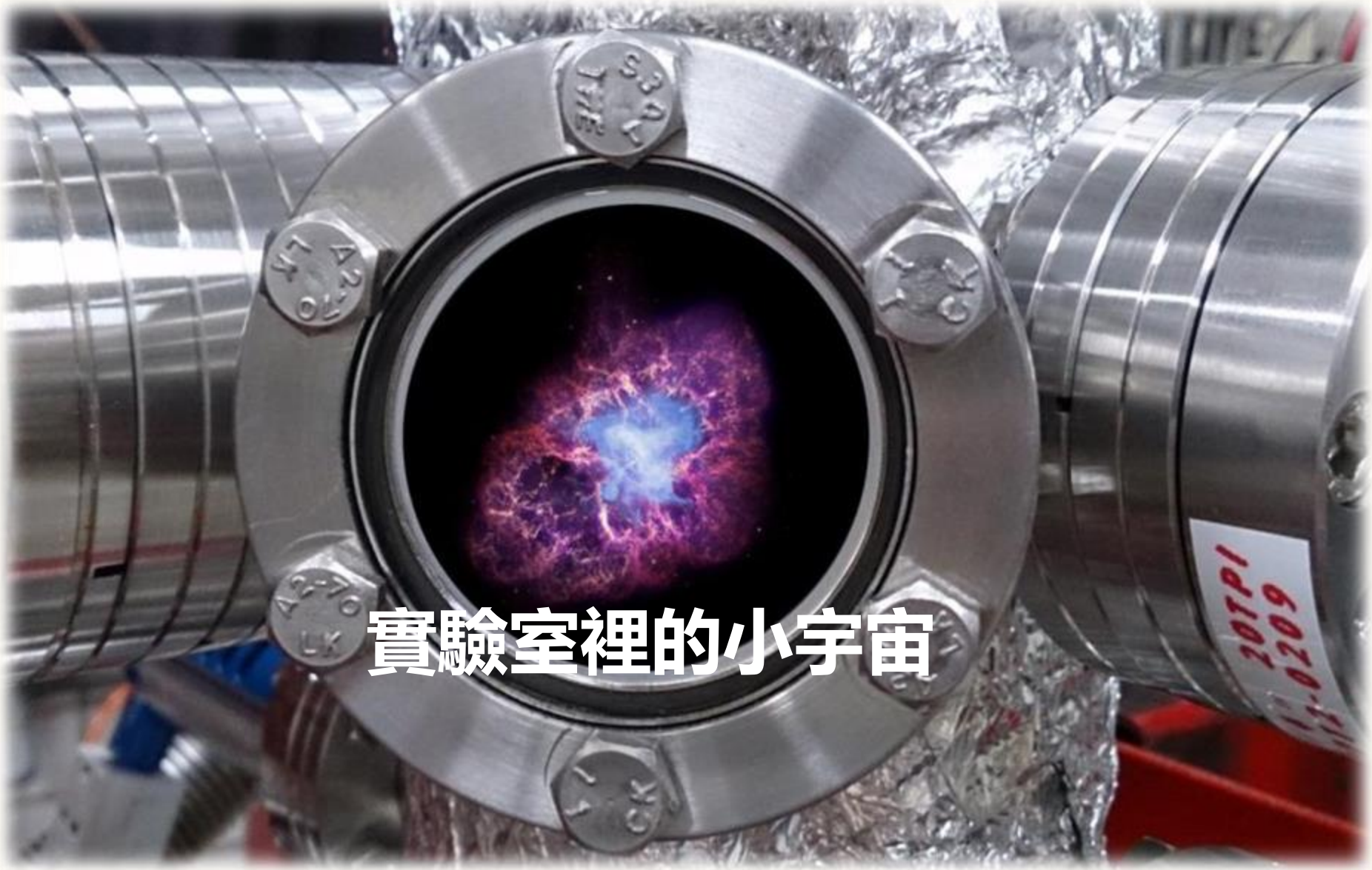


實驗室裡的小宇宙

國立中央大學物理系
光子作用與光譜分析實驗室
陳 俞 融


我是 陳俞融
來自 台東 成功鎮


探索宇宙的渴望
來自於我們認知地球的渺小

$1^\circ = 60' = 3{,}600''$

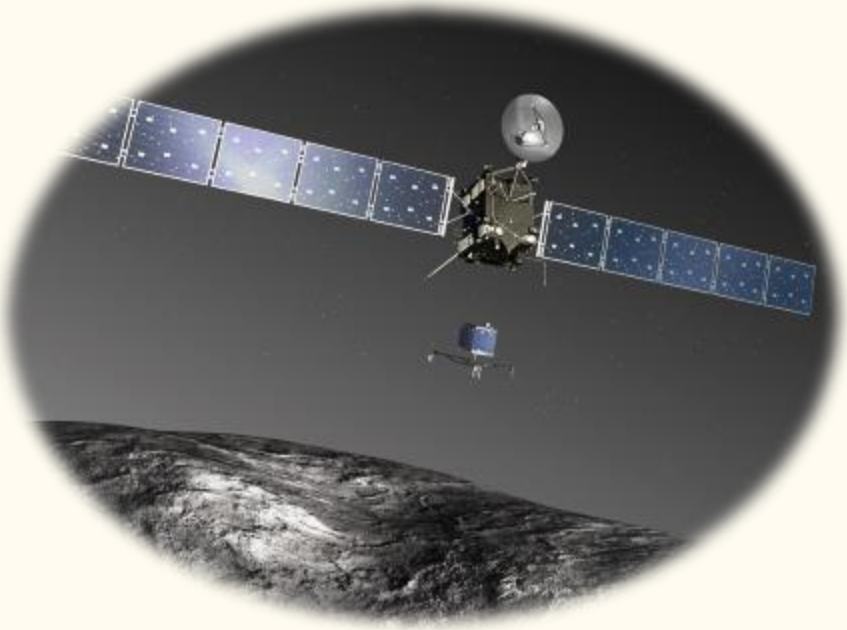
$0.005'' = 0.00000139^\circ$

來源：中研院天文所

2013 / 13億 美金

阿塔卡瑪大型毫米及次毫米波陣列

ALMA (12m*50 + 12m*4 + 7m*12)

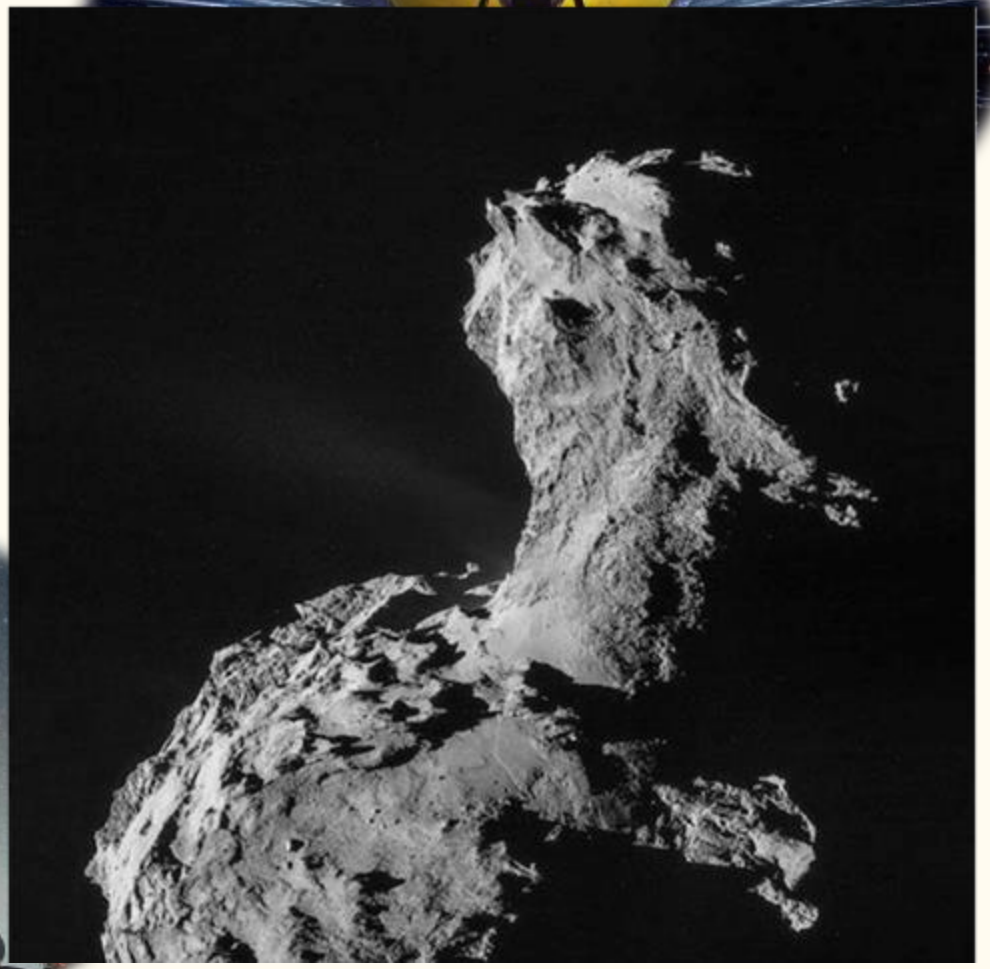


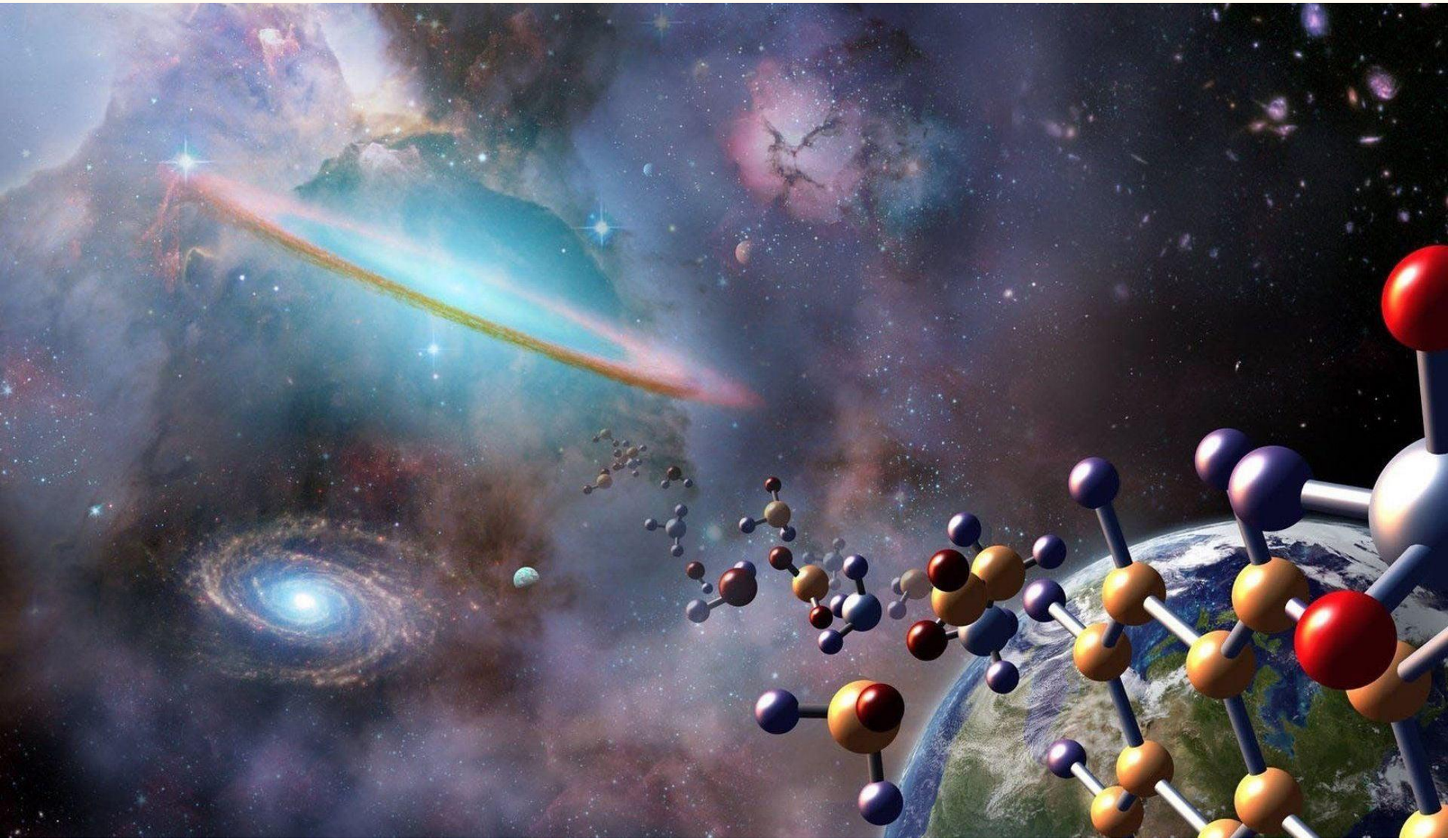
2014 / ESA / 17億 美金
羅塞塔任務/ Churyumov–Gerasimenko
1986 / 喬托號任務

Organic molecules make up half of Comet 67P

The Rosetta spacecraft collected more than 35,000 dust grains from Comet 67P/Churyumov-Gerasimenko to help determine its chemical composition.

By Jake Parks | Published: Friday, December 1, 2017





來源：ESA

2 atoms	3 atoms	4 atoms	5 atoms	6 atoms	7 atoms	8 atoms	9 atoms	10 atoms	11 atoms	12 atoms	>12 atoms
CH^+	C_3^*	c-C_3H	C_5^*	C_5H	C_6H	CH_3C_3N	CH_3C_4H	CH_3C_5N	HC_9N	c-$C_6H_6^*$	C_{60}^*
CH	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	n-C_3H_7CN	C_{70}^*
CN	C_2O	C_3N	C_4Si	$C_2H_4^*$	CH_3C_2H	CH_3COOH	$(CH_3)_2O$	$(CH_2OH)_2$	C_2H_5OCHO	i-C_3H_7CN	C_{60}^{++}
OH	C_2S	C_3O	l-C_3H_2	CH_3CN	HC_5N	C_7H	CH_3CH_2OH	CH_3CH_2CHO	$CH_3OC(O)CH_3$	$C_2H_5OCH_3$	c-C_6H_5CN
CO	CH_2	C_3S	c-C_3H_2	CH_3NC	CH_3CHO	C_6H_2	HC_7N	CH_3CHCH_2O	$CH_3C(O)CH_2OH$	1-c-C_5H_5CN	$HC_{11}N$
H_2	HCN	$C_2H_2^*$	H_2CCN	CH_3OH	CH_3NH_2	CH_2OHCHO	C_8H	CH_3OCH_2OH	c-C_5H_6	2-c-C_5H_5CN	1-$C_{10}H_7CN$
SiO	HCO	NH_3	CH_4^*	CH_3SH	c-C_2H_4O	l-HC_6H^*	$CH_3C(O)NH_2$	c-C_6H_4	$HOCH_2CH_2NH_2$	CH_3C_7N (?)	2-$C_{10}H_7CN$
CS	HCO^+	HCCN	HC_3N	HC_3NH^+	H_2CCHOH	CH_2CHCHO	C_8H^-	H_2CCCHC_3N	H_2CCCHC_4H	n-C_3H_7OH	c-C_9H_8
SO	HCS^+	$HCNH^+$	HCCNC	HCCCHO	C_6H^-	CH_2CCHCN	C_3H_6		$C_{10}H^-$	i-C_3H_7OH	1-c-C_5H_5CCH
SiS	HOC^+	HNCO	HCOOH	NH_2CHO	CH_3NCO	H_2NCH_2CN		?)	$H_2C(CH_3)_3CN$?	$(CH_3)_2C=CH_2$	2-c-C_5H_5CCH
NS	H_2O	HNCS	H_2CNH	C_5N	HC_5O						c-$C_5H_4CCH_2$
C_2^{**}	H_2S	$HOCO^+$	H_2C_2O	l-HC_4H^*				E-$CH_3CHCHCN$			2-C_9H_7CN
NO	HNC	H_2CO	H_2NCN	l-HC_4N			HCCCHCHCN	Z-$CH_3CHCHCN$			C_6H_5CCH
HCl	HNO	H_2CN	HNC_3	c-H_2C_3O		$HCCCH_2CN$	H_2CCHC_3N	$CH_3C(CN)CH_2$			$CH_3OCH_2CH_2OH$ (2024)
NaCl	MgCN	H_2CS	SiH_4^*	H_2CCNH	c-C_3HCCH	HC_5NH^+	$H_2CCCHCCH$	CH_2CHCH_2CN			1-$C_{12}H_7CN$ (2024)
KCl	MgNC	H_3O^+	H_2COH^+	C_5N^-	l-H_2C_5	CH_2CHCCH	HOCHCHCHO (2024)	$HOCH_2C(O)NH_2$			5-$C_{12}H_7CN$ (2024)
AlCl	N_2H^+	c-SiC_3	C_4H^-	HNCHCN	MgC_5N	MgC_6H	HC_7N^+ (2024)	CH_3CH_2CCH (2024)			1-$C_{16}H_9CN$ (2024)
AlF	N_2O	CH_3^*	HC(O)CN	SiH_3CN	CH_2C_3N	$C_2H_3NH_2$	$CH_2(CCH)_2$ (2024				2-$C_{16}H_9CN$ (2025)
PN	NaCN	C_3N^-	HNCNH	C_5S	NC_4NH^+	$(CHOH)_2$	$(CH_3)_2S$ (2025)				4-$C_{16}H_9CN$ (2025)

338種分子

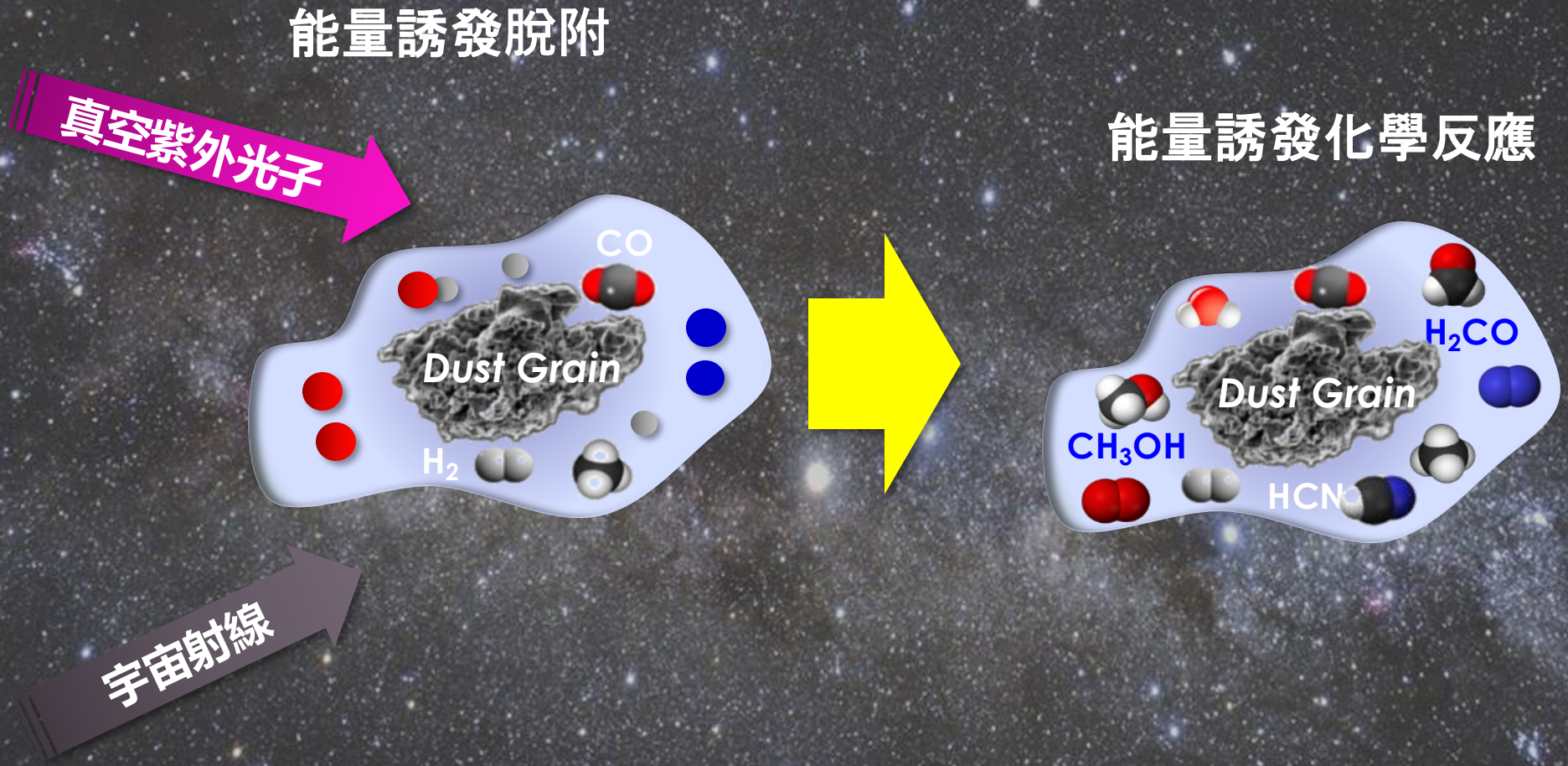
https://cdms.astro.uni-koeln.de/classic/molecules

http://www.astrochymist.org/astrochymist_ism.html

天文小科普

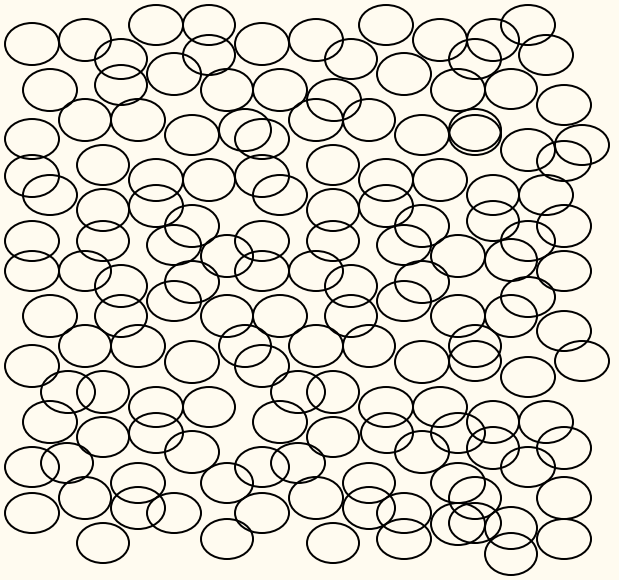
星際介質

99% 氣體分子 + 1% 星際塵埃


能量誘發脫附
真空紫外光子
CO
Dust Grain
H_2
宇宙射線
能量誘發化學反應
H_2CO
Dust Grain
CH_3OH
HCN

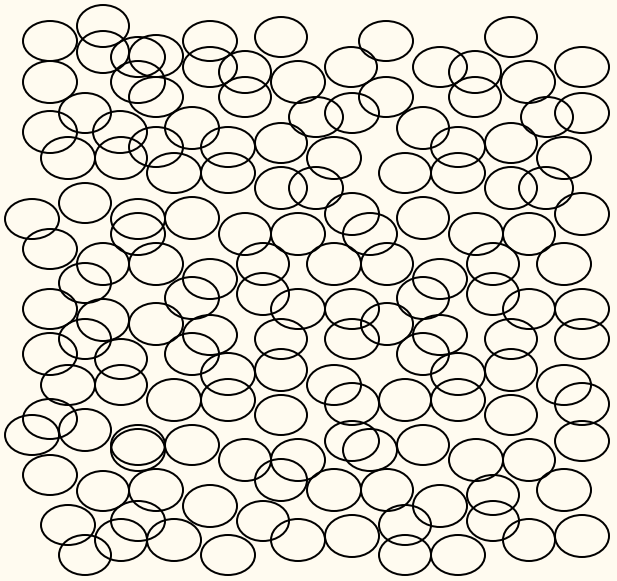
真空紫外光子

- 分子斷鍵
- 分子游離
- 穿透深度受冰晶光學特性限制



宇宙射線

- 分子斷鍵
- 分子游離
- 產生高能量的二次電子
- 穿透深度只受粒子能量與冰晶的阻擋能力



在實驗室裡如何創造一個小宇宙?

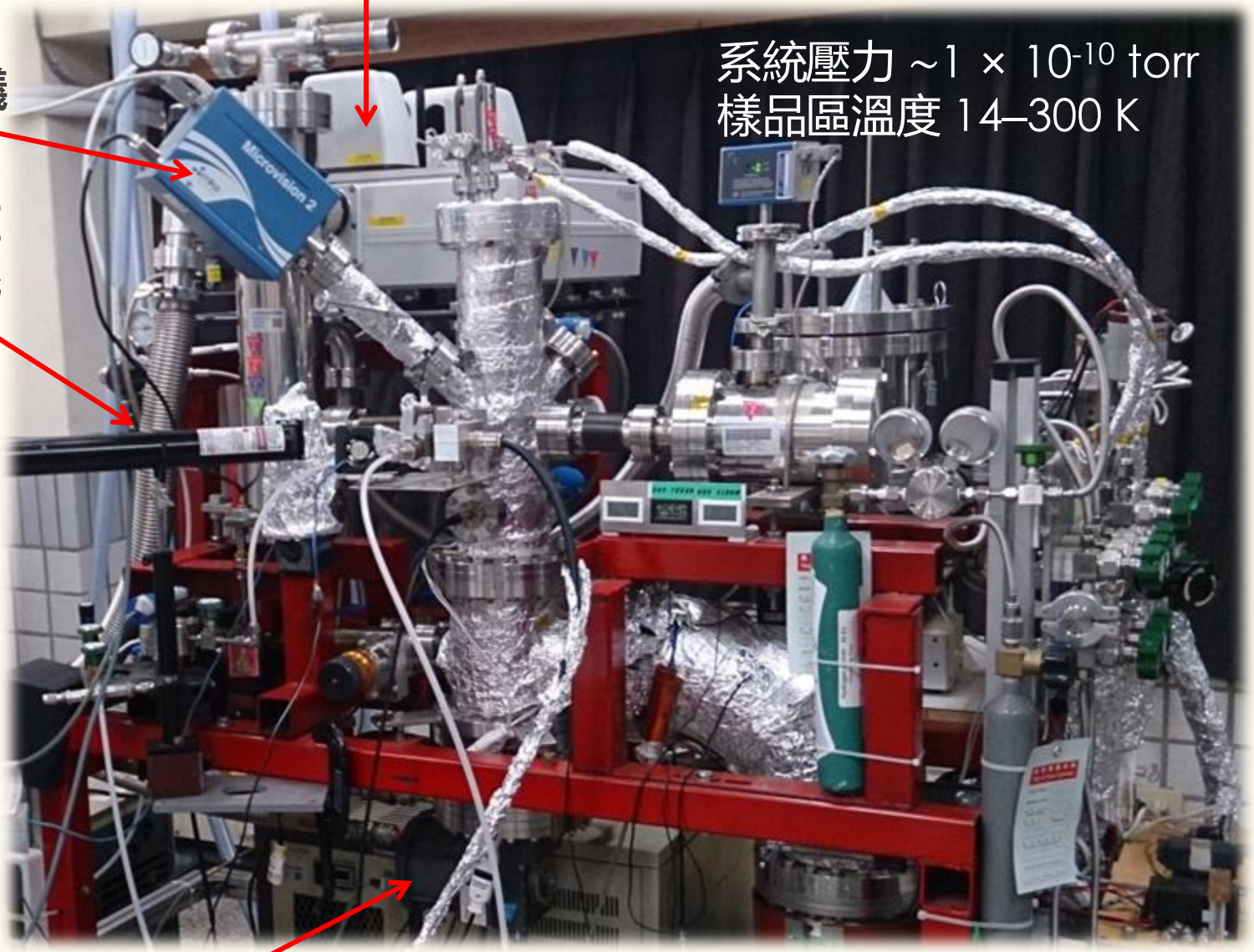
- 超高真空
- 極低溫
- 能量源

穿透式傅立葉轉換紅外光譜儀

~10^6 molecules/cm^3

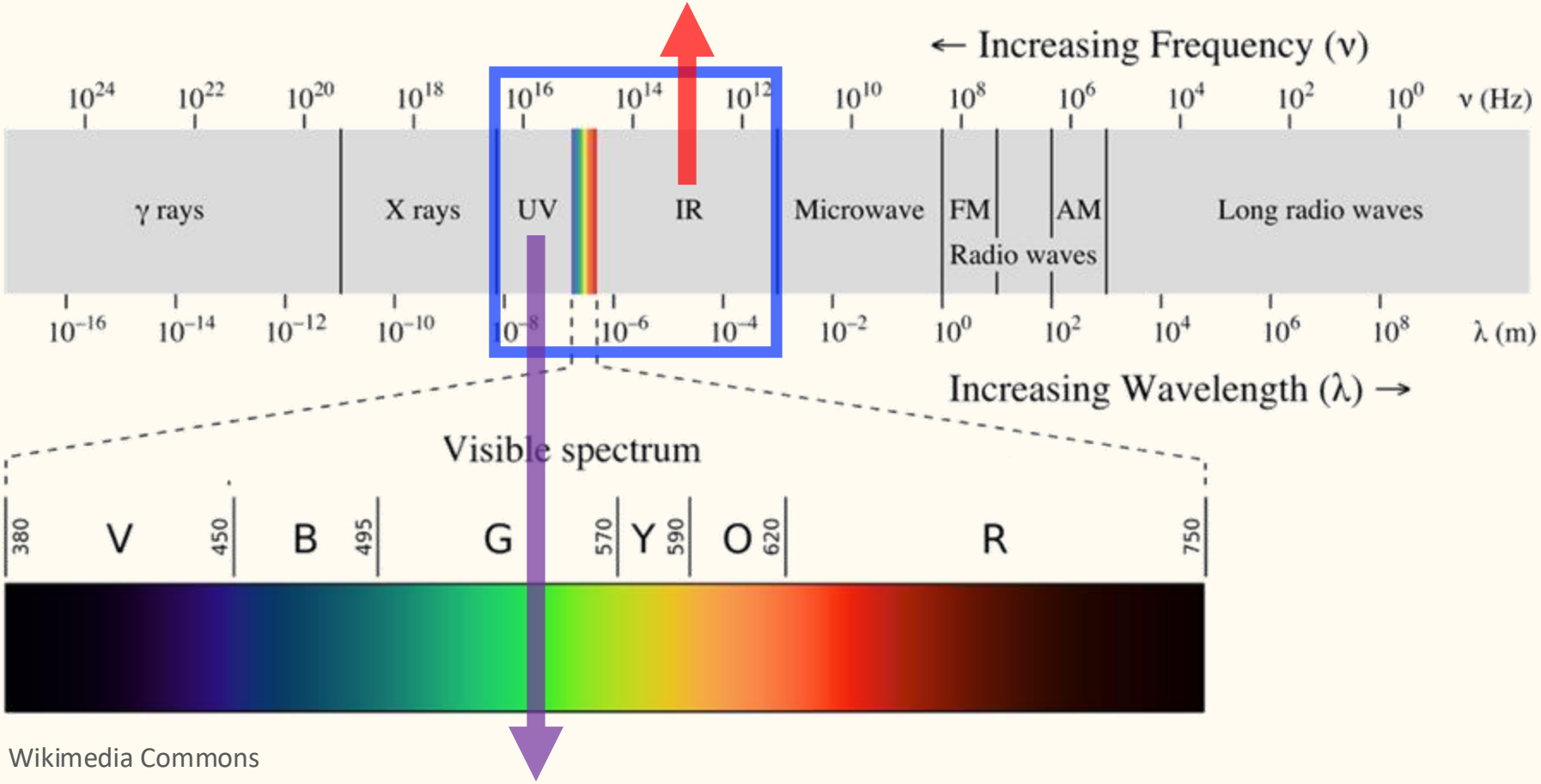
四極質譜儀

雷射干涉厚度量測系統



循環式氦氣冷凍頭

Mid-IR: 4000–500 cm^{-1} (2.5–20 μm)



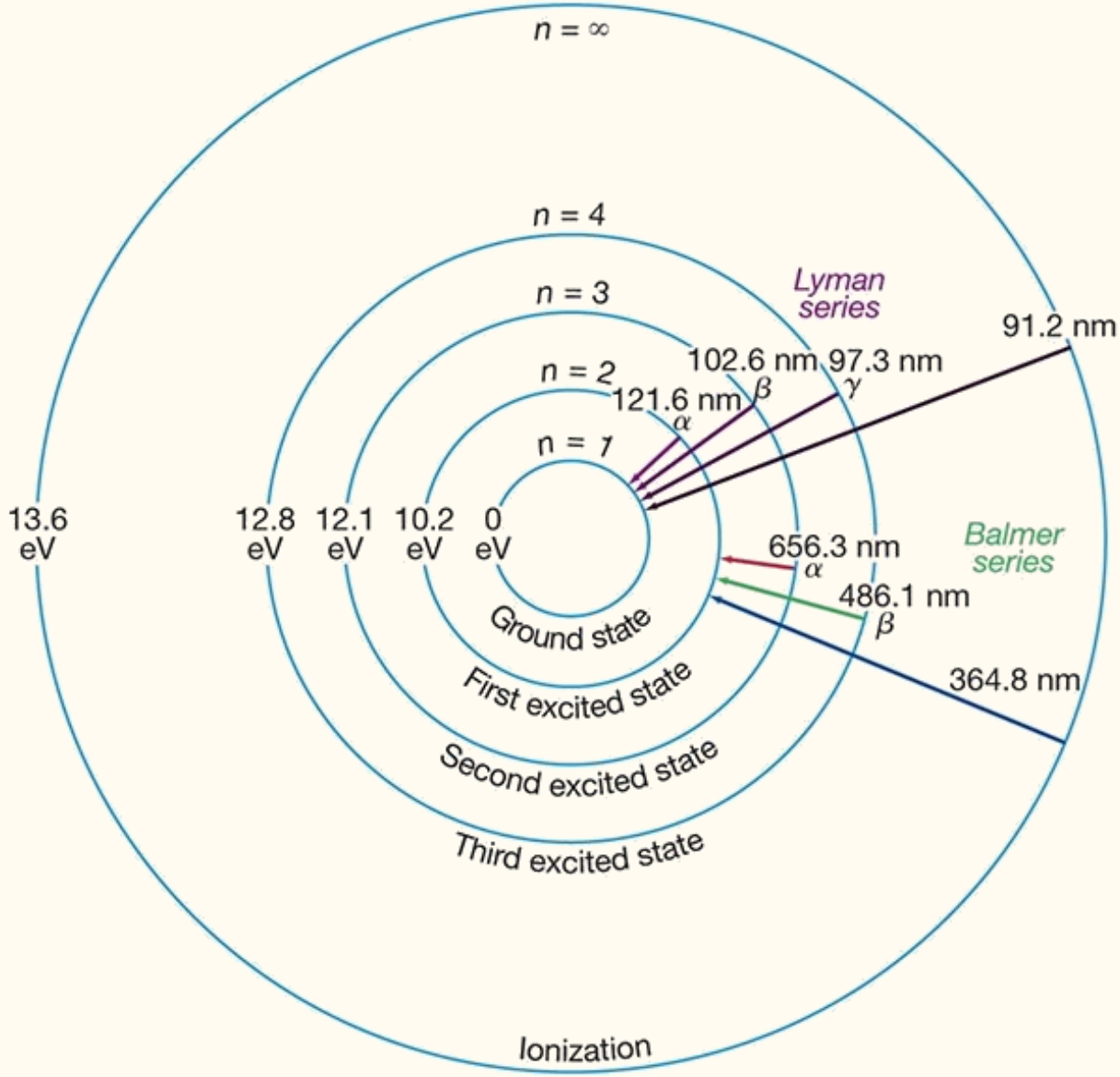
Wikimedia Commons

UV (Ultraviolet): 200–400 nm
[320–400 nm (UVA); 280–320 nm (UVB); 200–280 nm (UVC)]

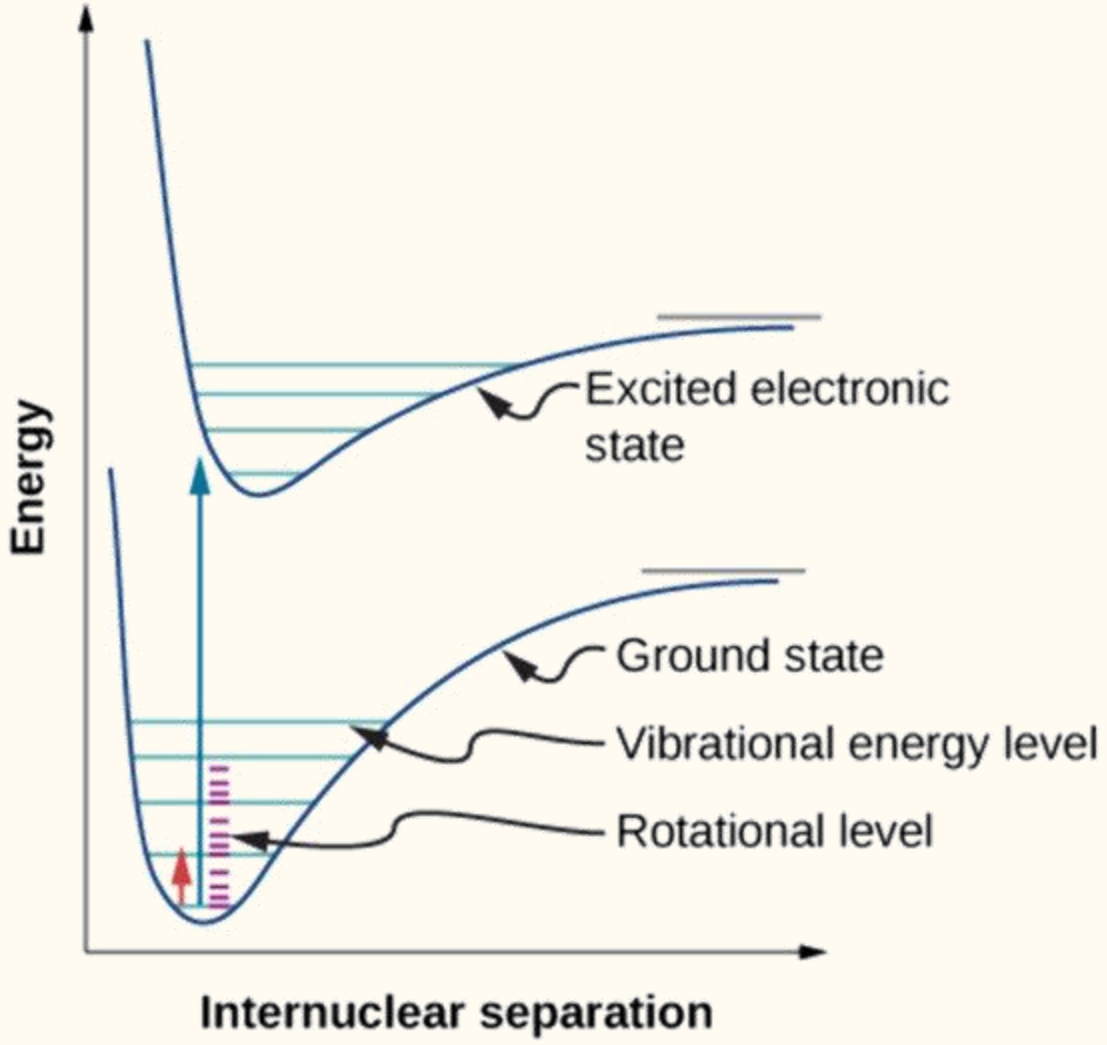
VUV (Vacuum Ultraviolet): 100–200 nm

EUV (Extreme Ultraviolet): 10–124 nm

$$E = \frac{hc}{\lambda} \approx \frac{1240\ \text{eV}}{\lambda\ (\text{nm})}$$


n = ∞
n = 4
n = 3
n = 2
n = 1
Lyman series
91.2 nm
102.6 nm
97.3 nm
121.6 nm
β
γ
α
13.6 eV
12.8 eV
12.1 eV
10.2 eV
0 eV
656.3 nm
α
Balmer series
486.1 nm
β
364.8 nm
Ground state
First excited state
Second excited state
Third excited state
Ionization

除了電子能階躍遷之外
分子還具有振動能階與旋轉能階躍遷



分子的指紋

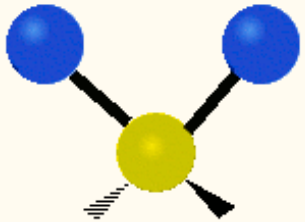
真空紫外光–可見光
- 電子能階

紅外光
- 振動能階

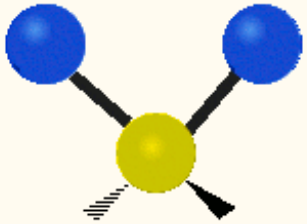
雷達電波
- 轉動能階

分子振動模式

伸縮振動：改變鍵長(需要較多能量)

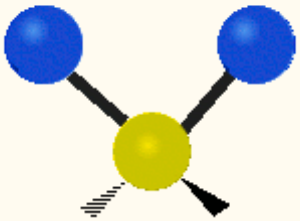


Symmetrical stretching

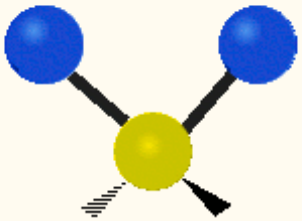


Asymmetrical stretching

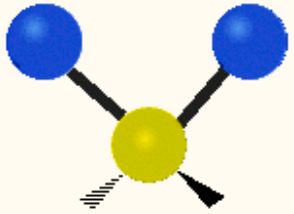
彎曲振動: 改變鍵角(需較少能量)



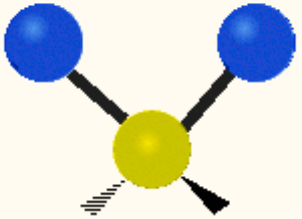
Rocking



Scissoring

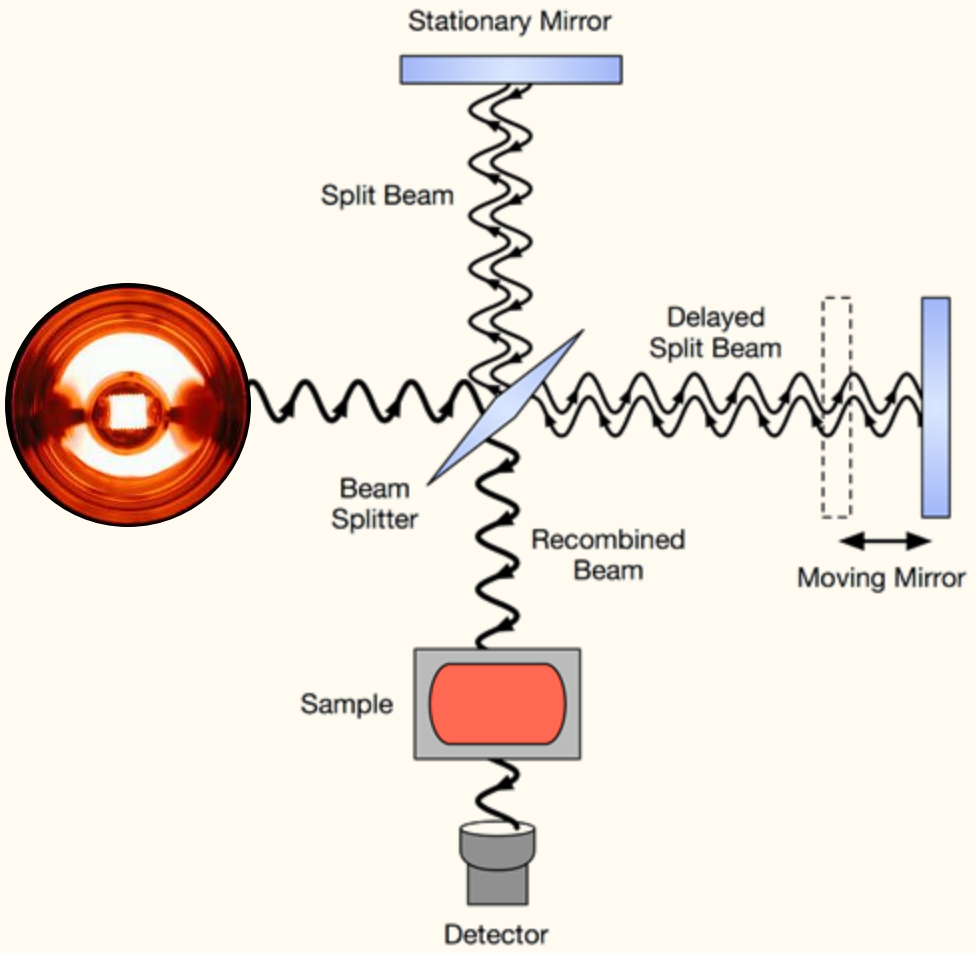


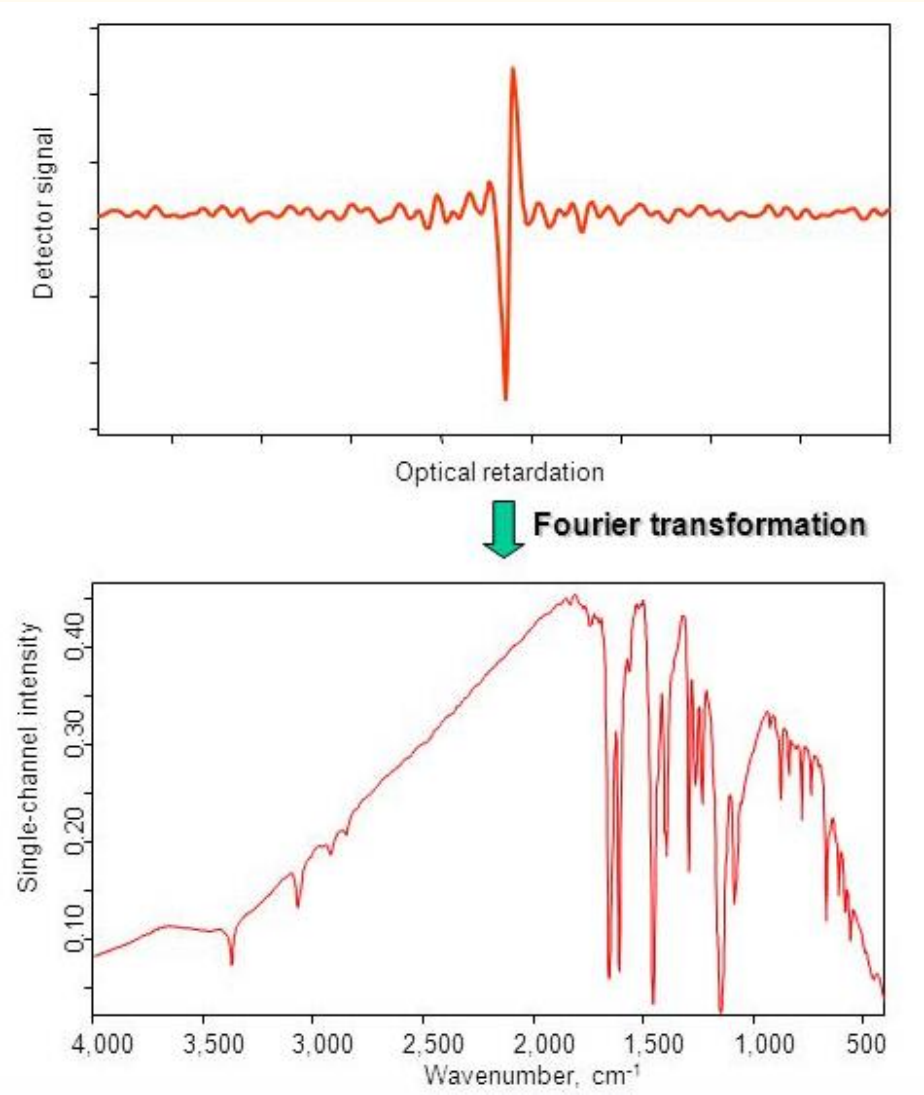
Twisting



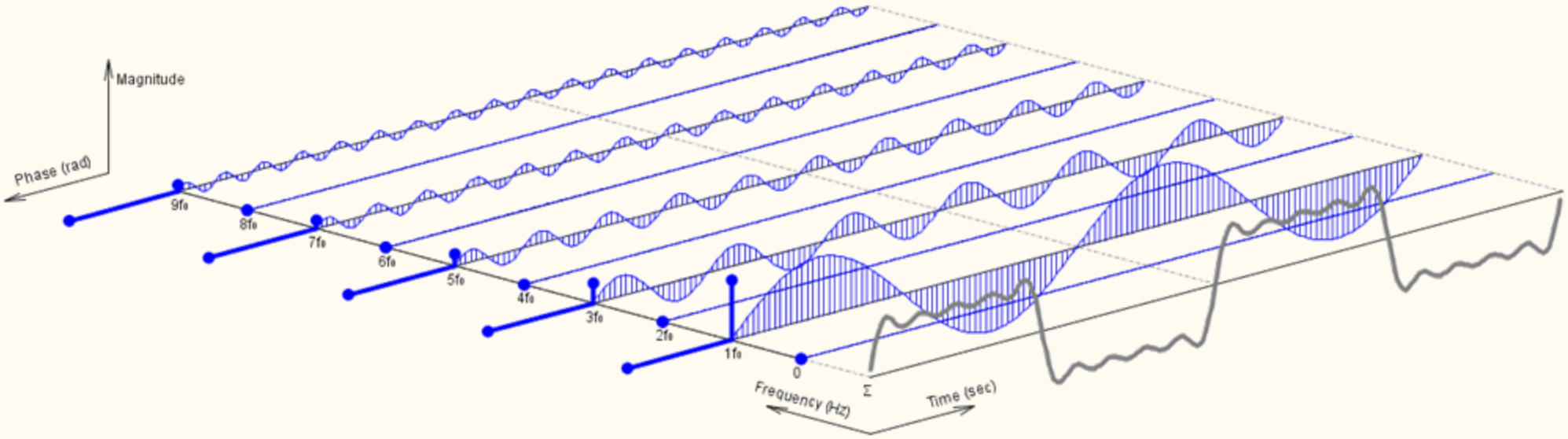
Wagging

傅立葉轉換紅外光譜儀

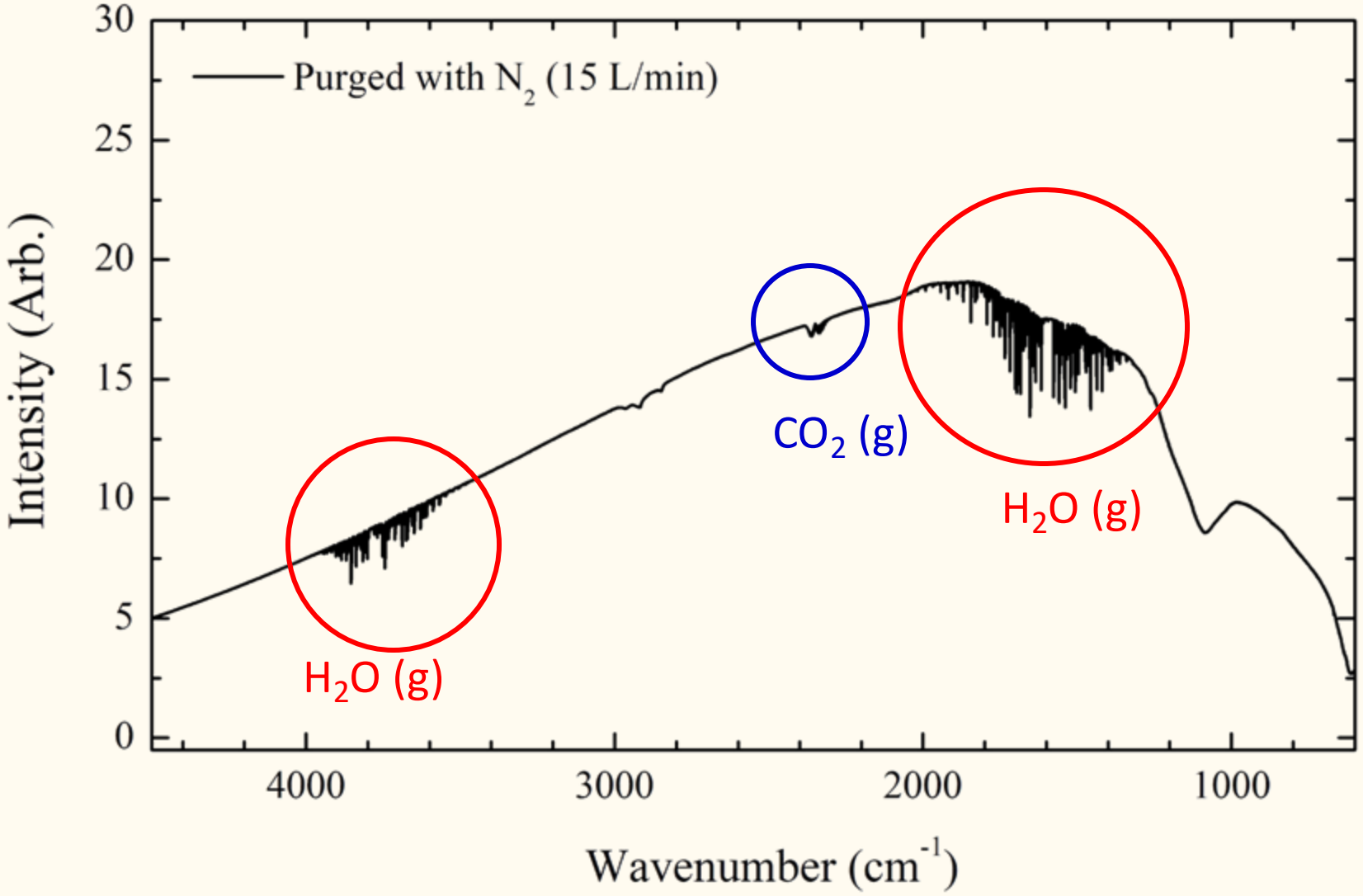

Stationary Mirror
Split Beam
Delayed
Split Beam
Beam
Splitter
Recombined
Beam
Moving Mirror
Sample
Detector

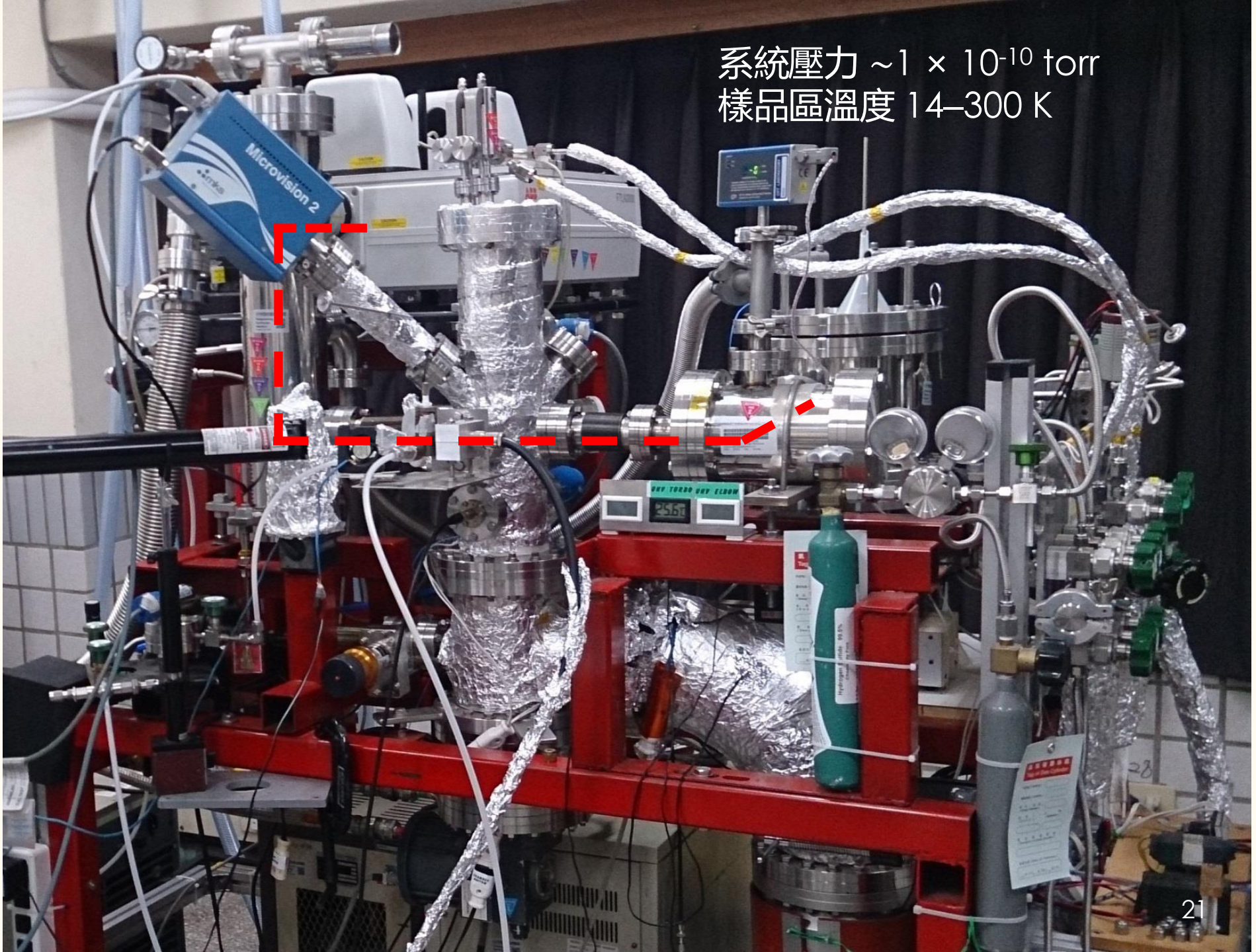

Detector signal
Optical retardation
Fourier transformation
Single-channel intensity
0.10
0.20
0.30
0.40
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Wavenumber, cm-1

傅立葉轉換紅外光譜儀

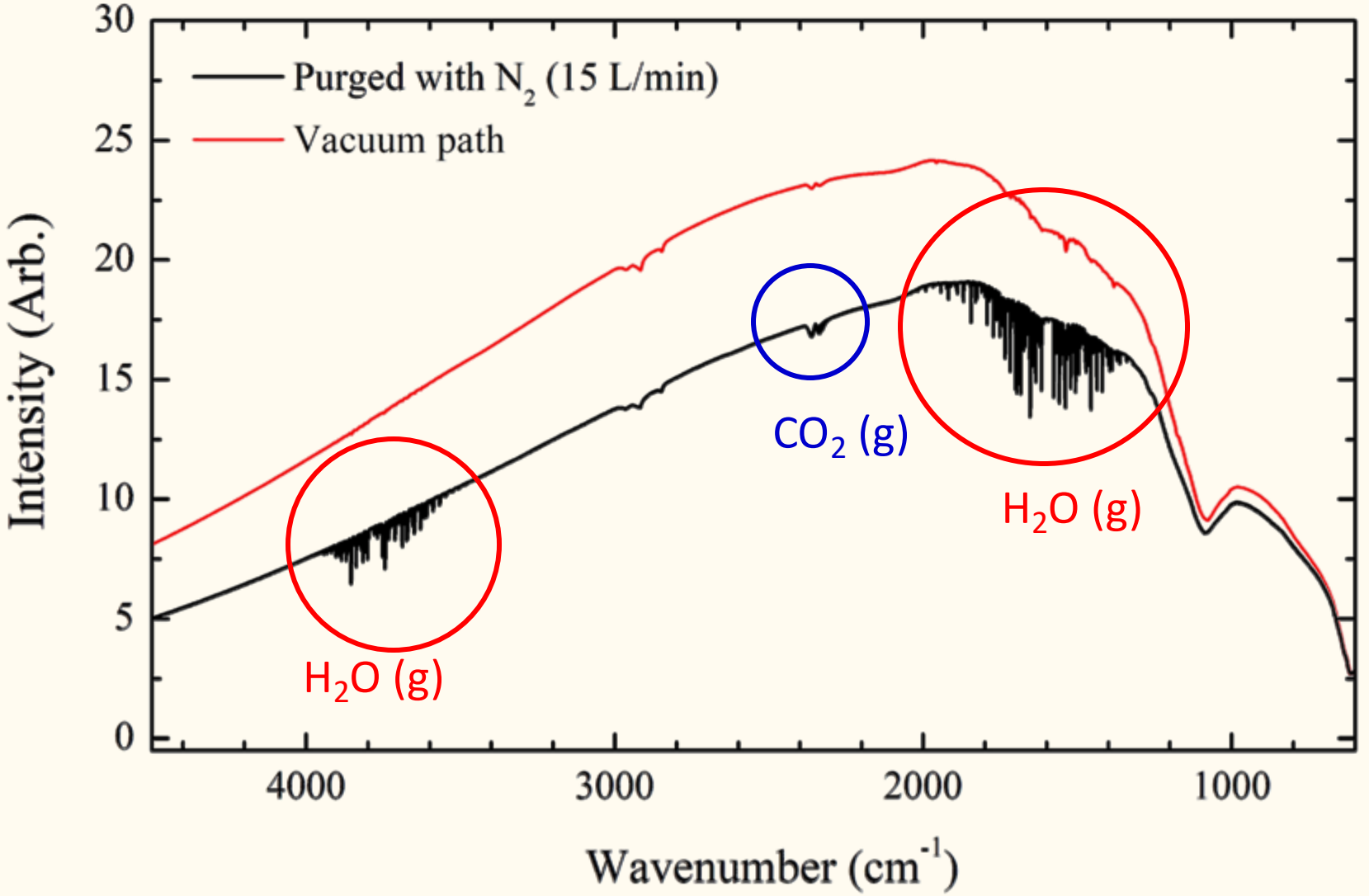

Magnitude
Phase (rad)
9f₀
8f₀
7f₀
6f₀
5f₀
4f₀
3f₀
2f₀
1f₀
0
Frequency (Hz)
Σ
Time (sec)

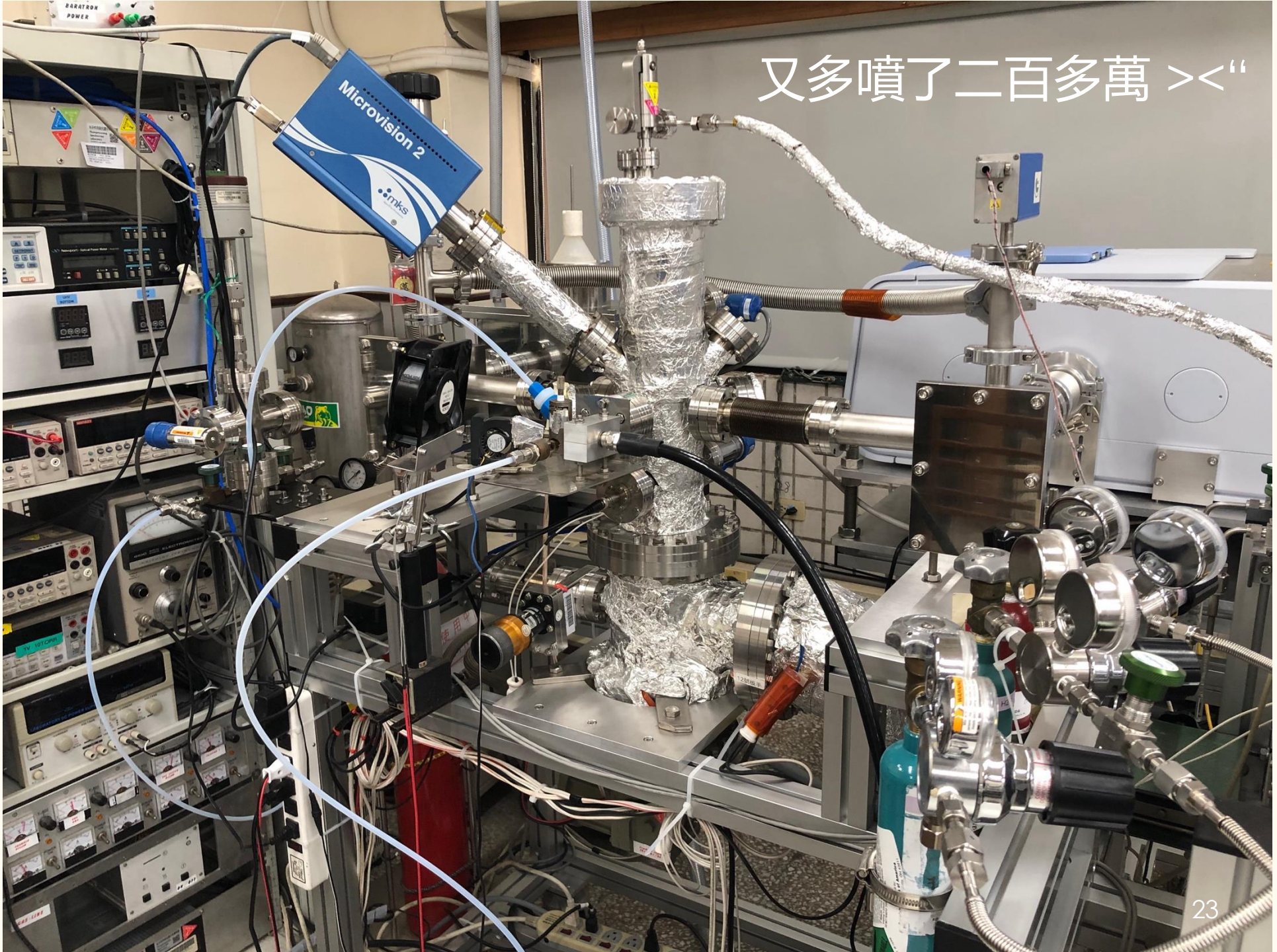
對抗霹靂無敵潮溼的鬼天氣




系統壓力 ~1 × 10^{-10} torr
樣品區溫度 14–300 K
Microvision 2

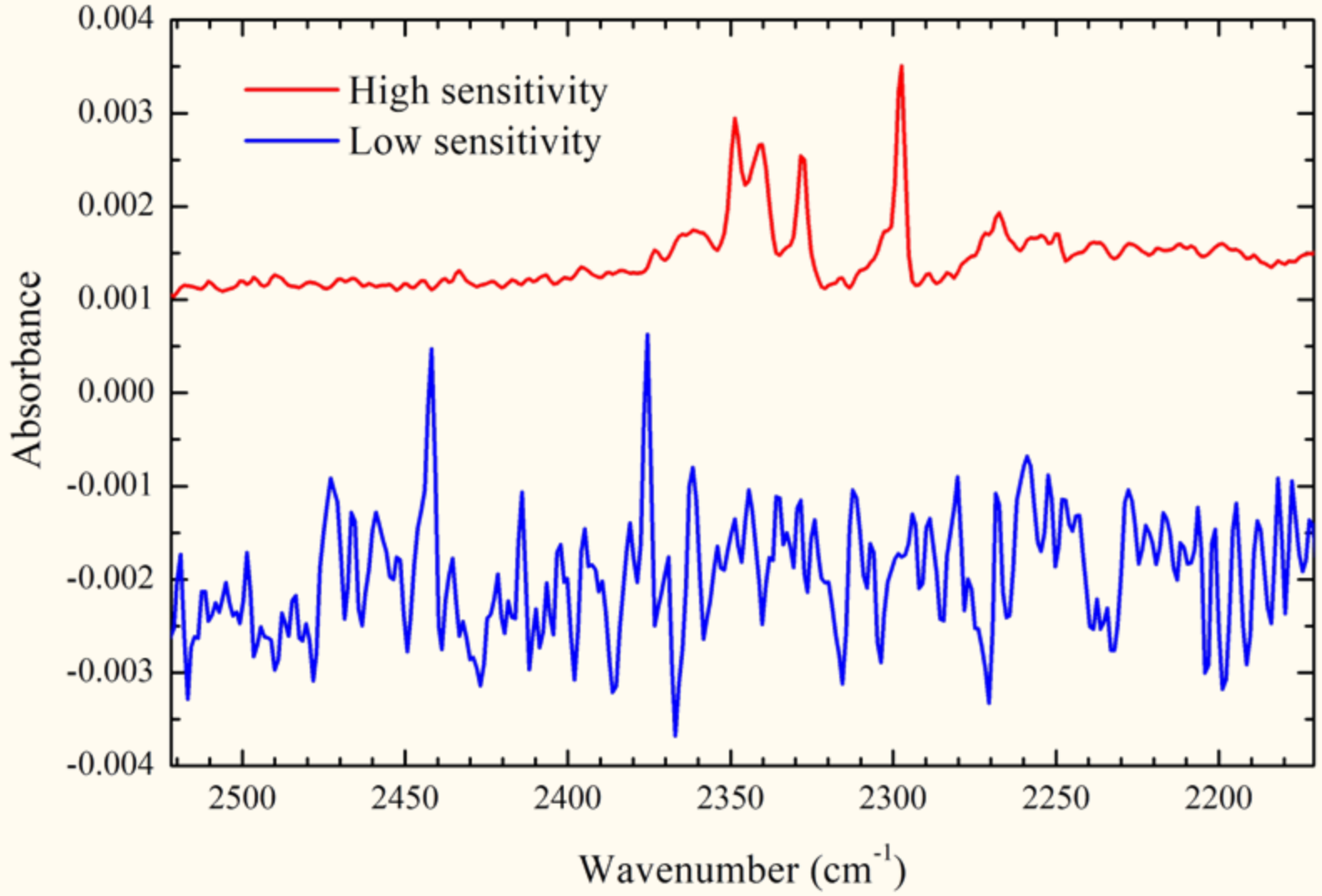
對抗霹靂無敵潮溼的鬼天氣



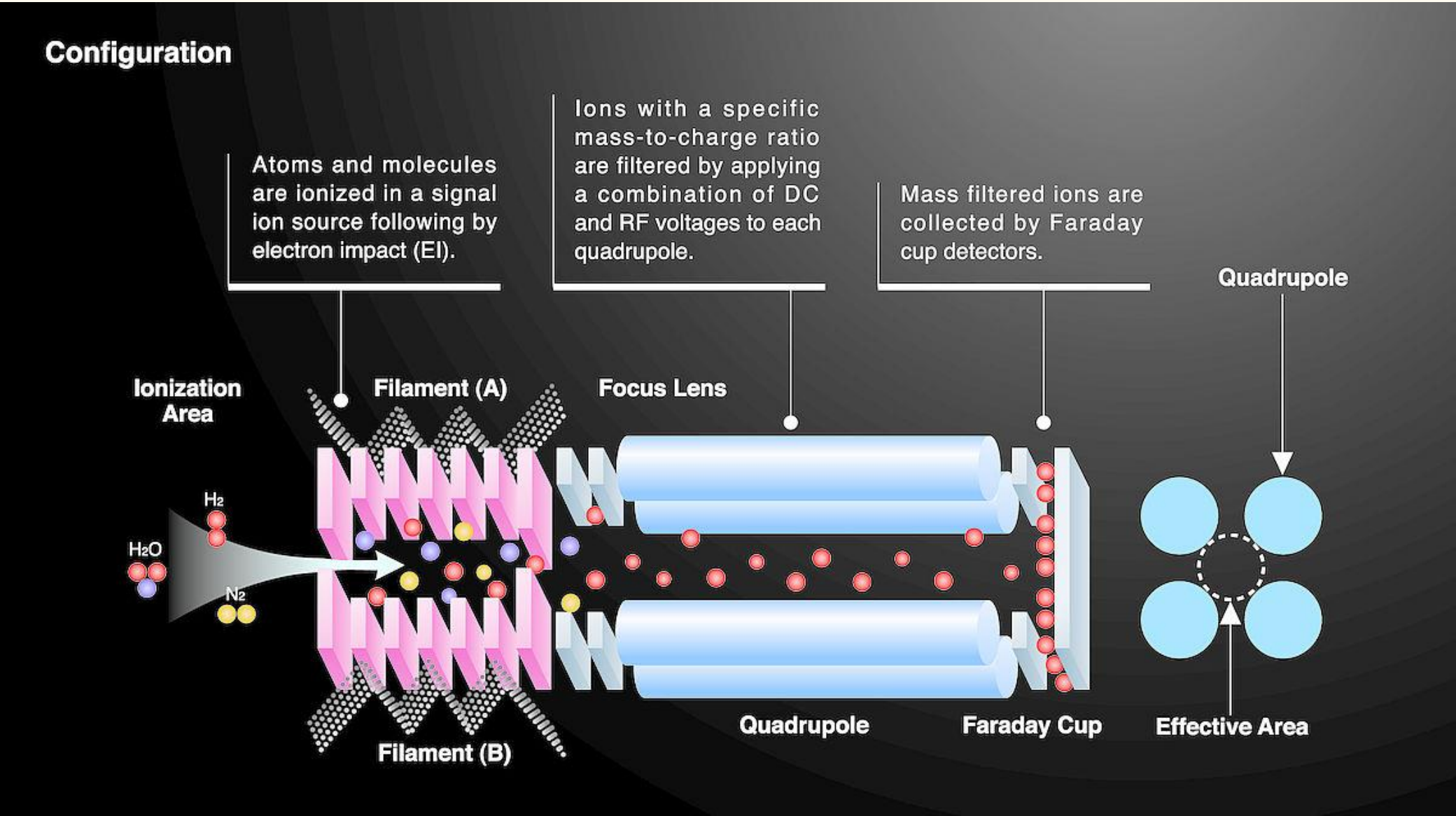


又多噴了二百多萬 ><“

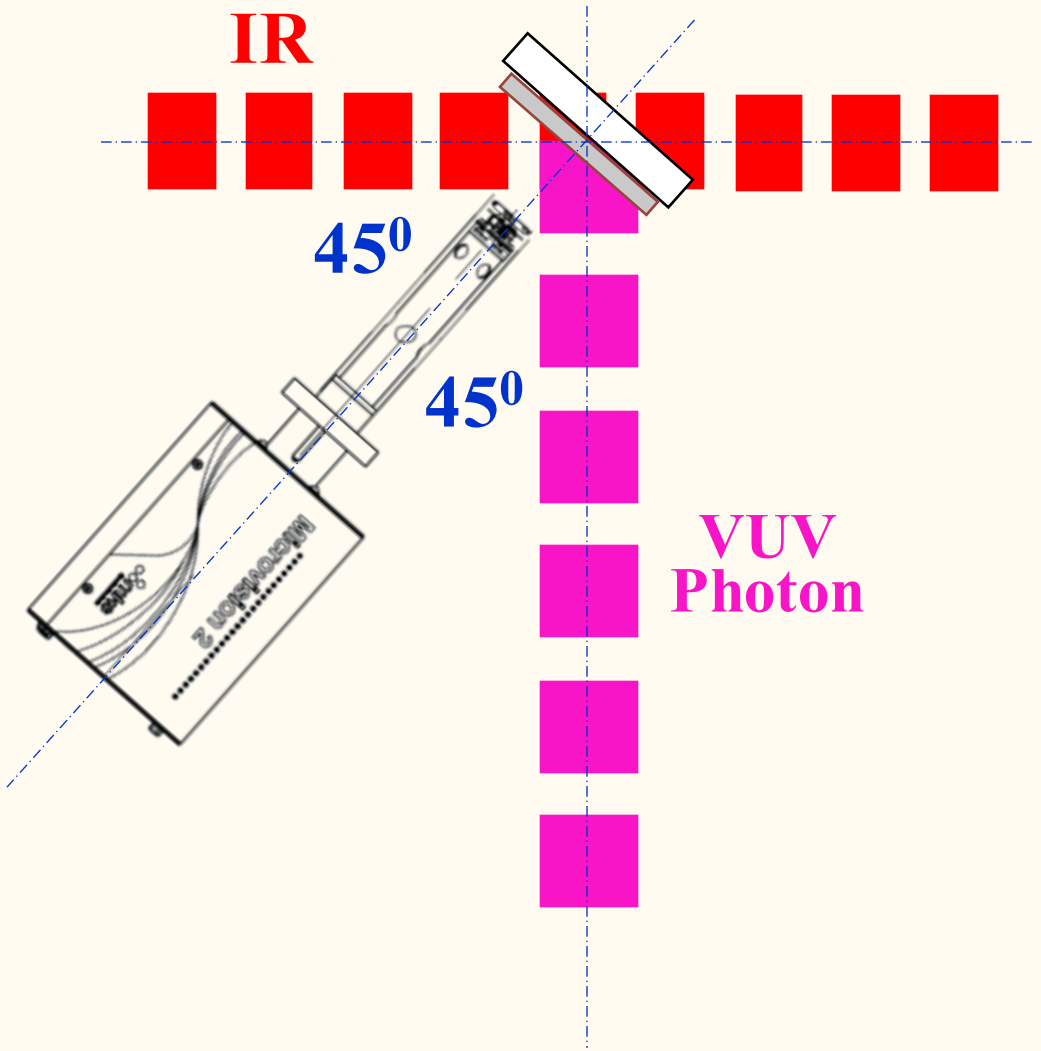
只為看到看不見的訊號!


High sensitivity
Low sensitivity
Absorbance
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
2500
2450
2400
2350
2300
2250
2200
Wavenumber (cm-1)

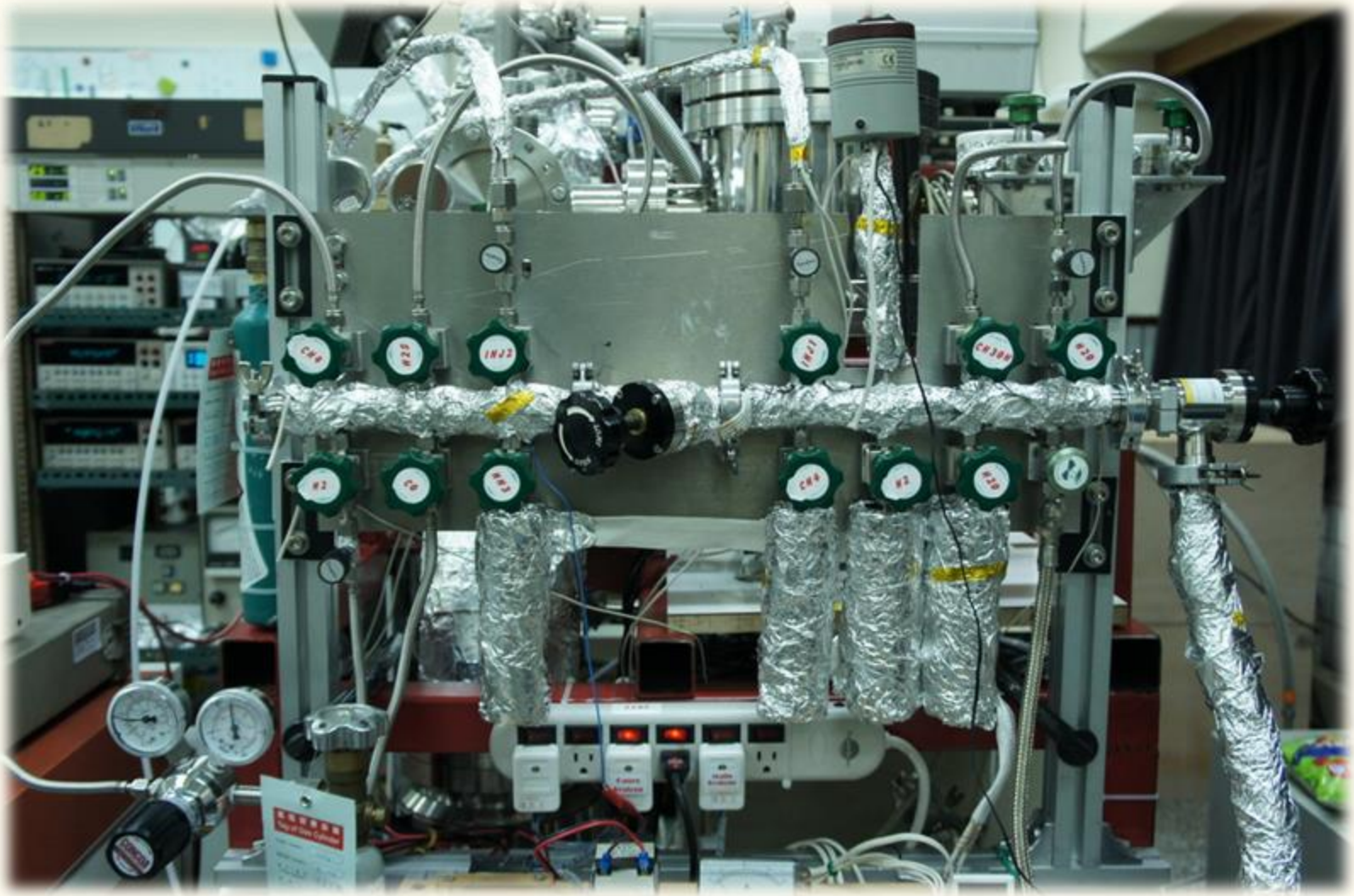
四極柱質譜儀

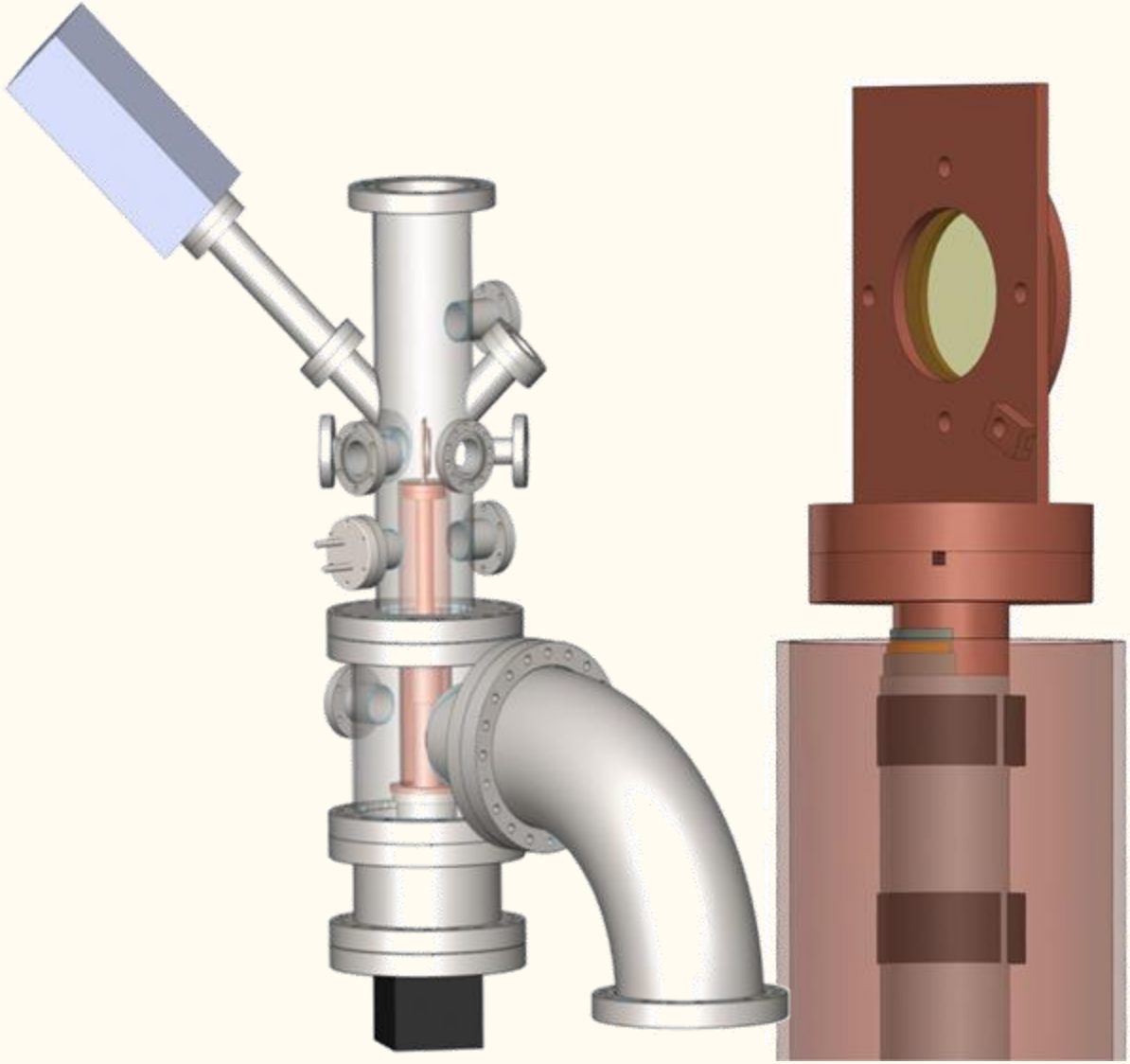

Configuration
Atoms and molecules are ionized in a signal ion source following by electron impact (EI).
Ions with a specific mass-to-charge ratio are filtered by applying a combination of DC and RF voltages to each quadrupole.
Mass filtered ions are collected by Faraday cup detectors.
Quadrupole
Ionization Area
Filament (A)
Focus Lens
H2
H2O
N2
Filament (B)
Quadrupole
Faraday Cup
Effective Area

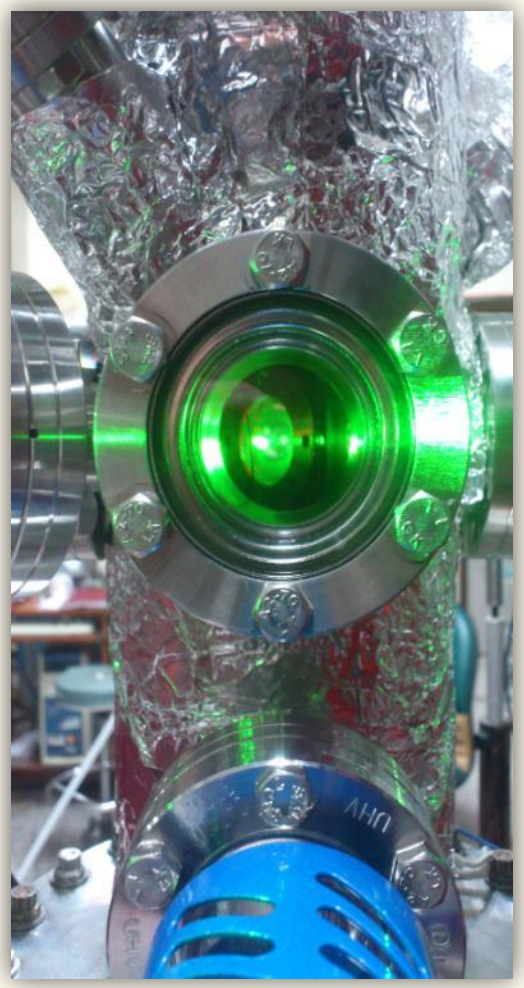
穿透式紅外光譜儀(固態) + 四極柱質譜儀(氣態)

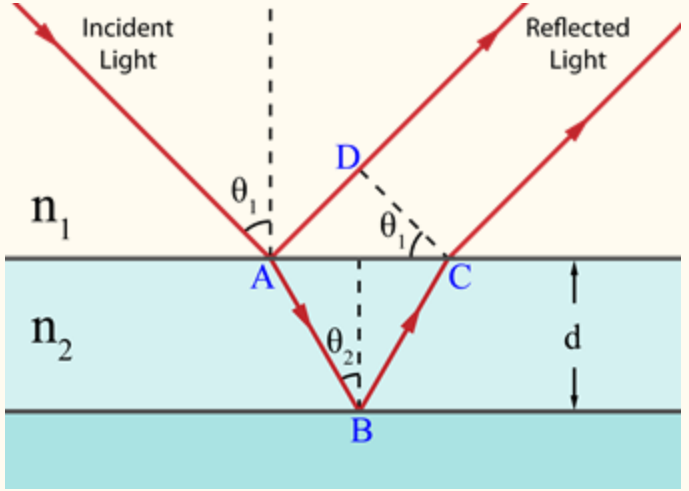


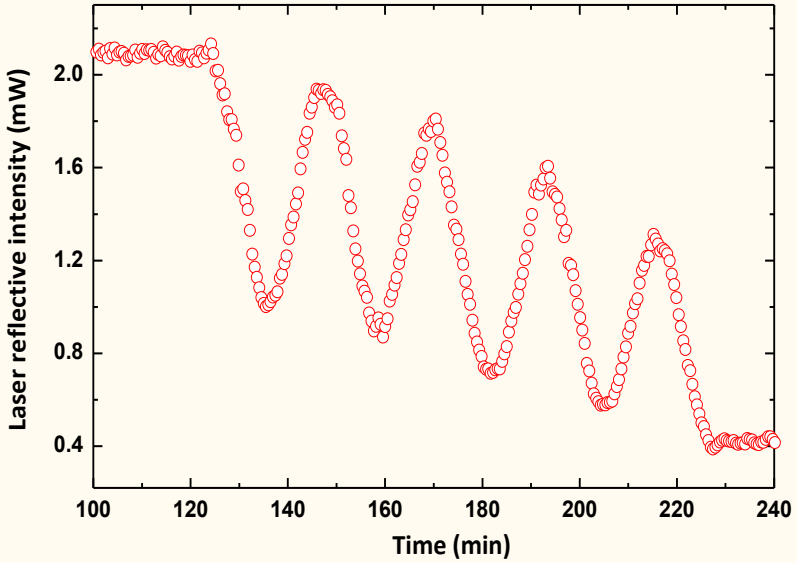
氣體預混系統





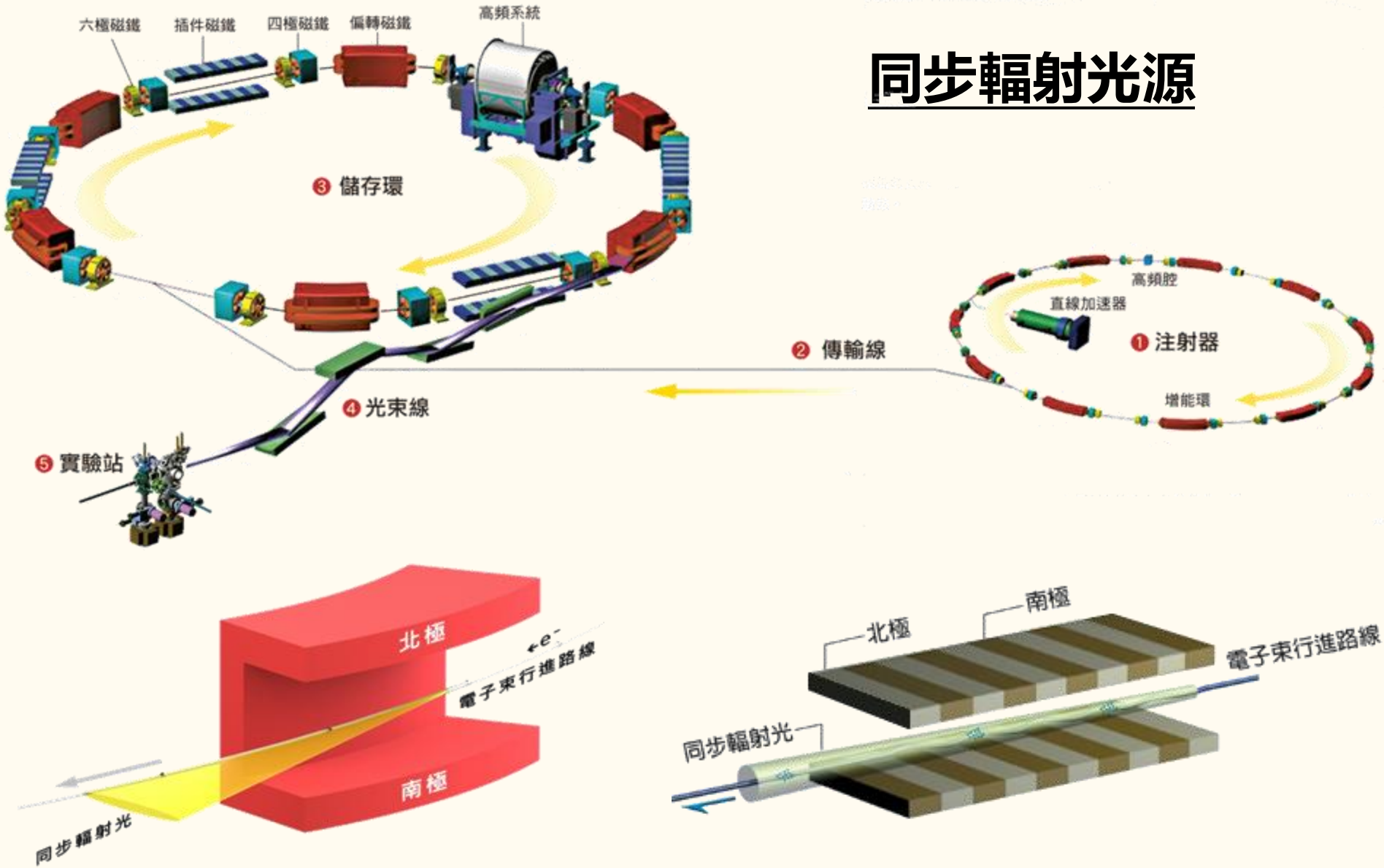



Incident Light
Reflected Light
n_1
n_2
θ_1
θ_1
θ_2
A
B
C
D
d

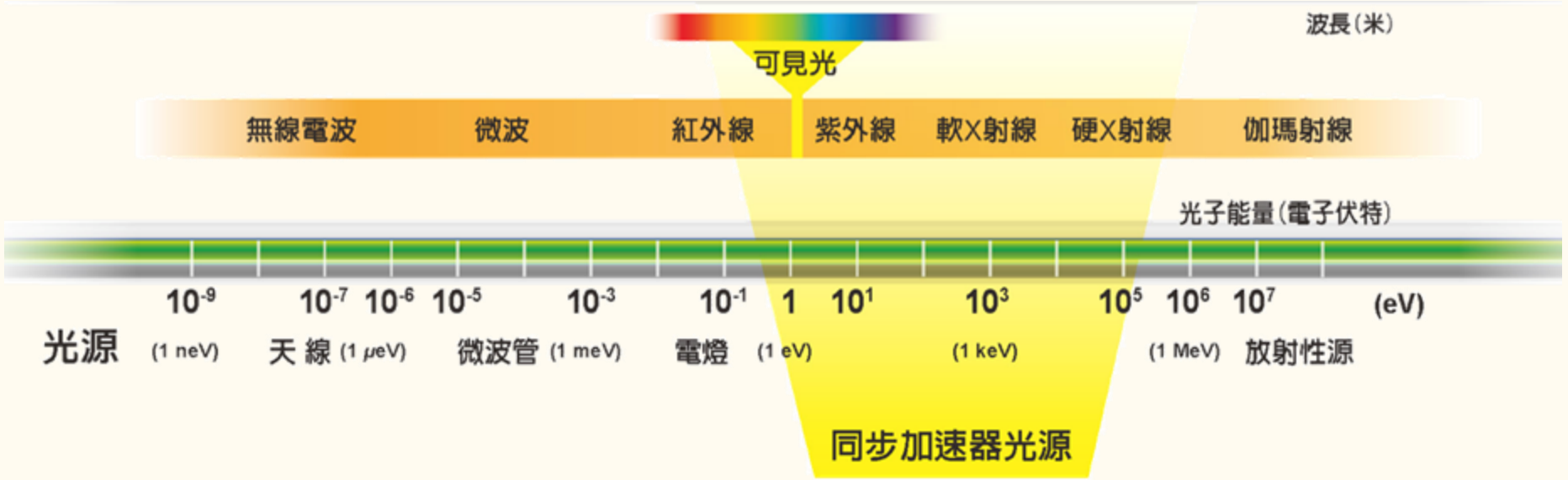

Laser reflective intensity (mW)
2.0
1.6
1.2
0.8
0.4
100
120
140
160
180
200
220
240
Time (min)


國家同步輻射研究中心

同步輻射光源


六極磁鐵
插件磁鐵
四極磁鐵
偏轉磁鐵
高頻系統
❸ 儲存環
❷ 傳輸線
❹ 光束線
❺ 實驗站
高頻腔
直線加速器
❶ 注射器
增能環
北極
南極
電子束行進路線
同步輻射光
北極
南極
電子束行進路線
同步輻射光

同步輻射光源



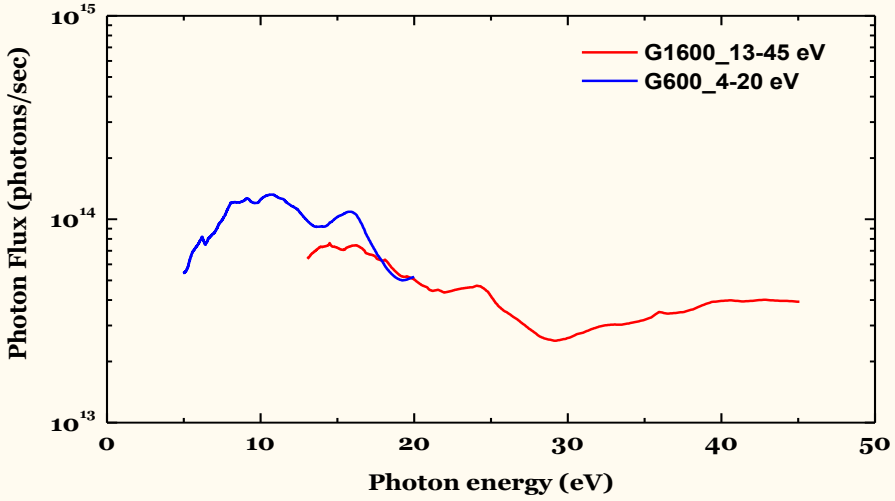
同步加速器光源的特色

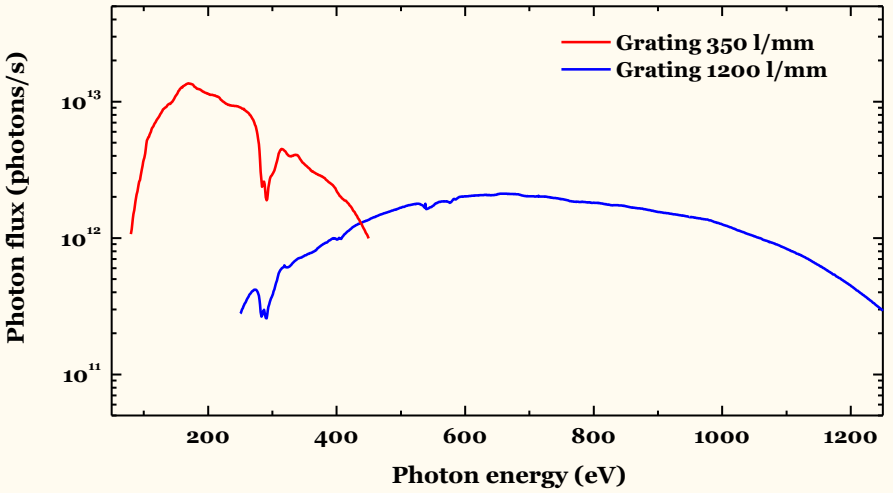
- 強度極高
- 波長連續
- 準直性佳
- 光束截面積小
- 具有時間脈波性與偏振性

同步輻射光

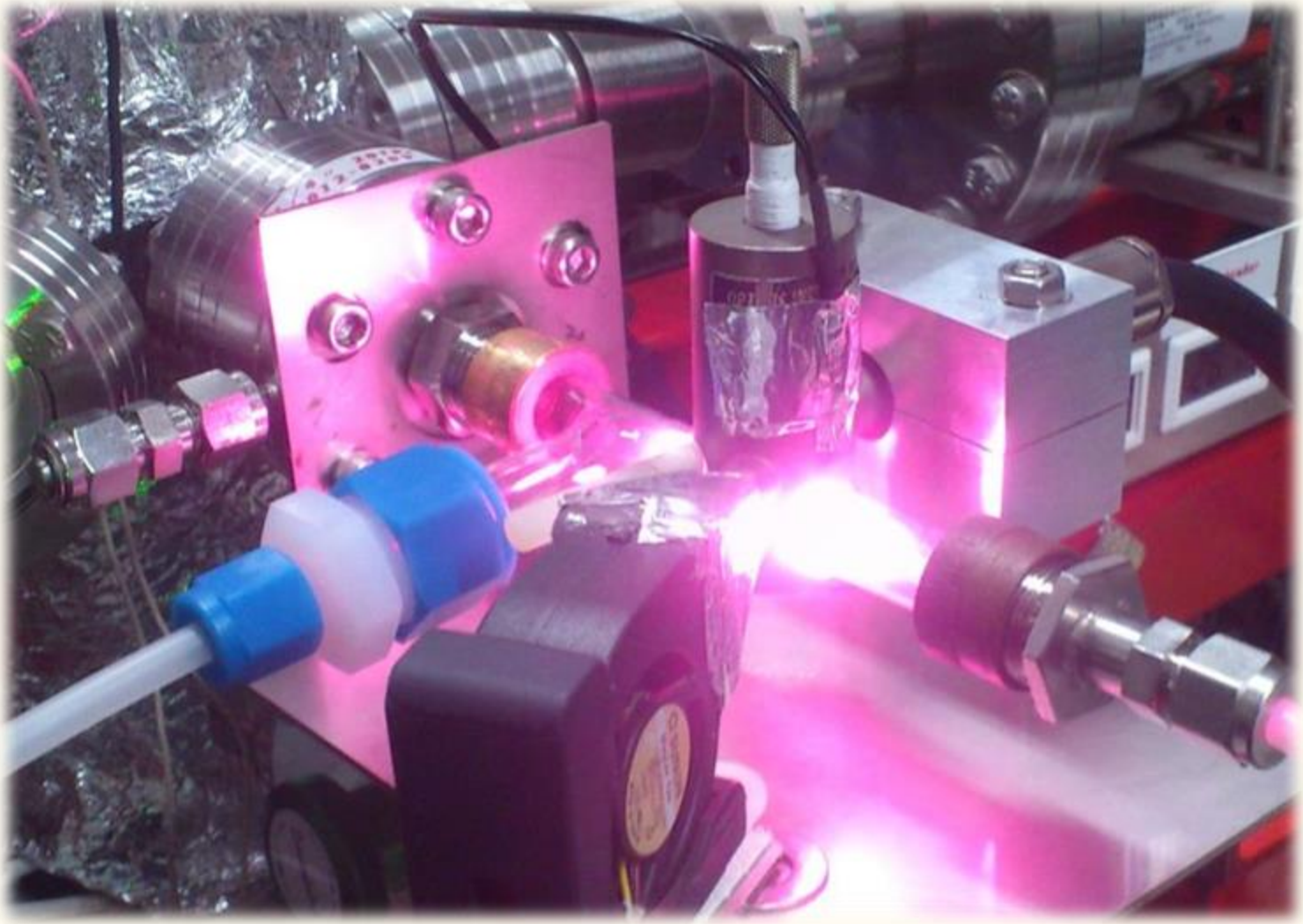
BL03A (4–45 eV)

BL08B (80–1250 eV)

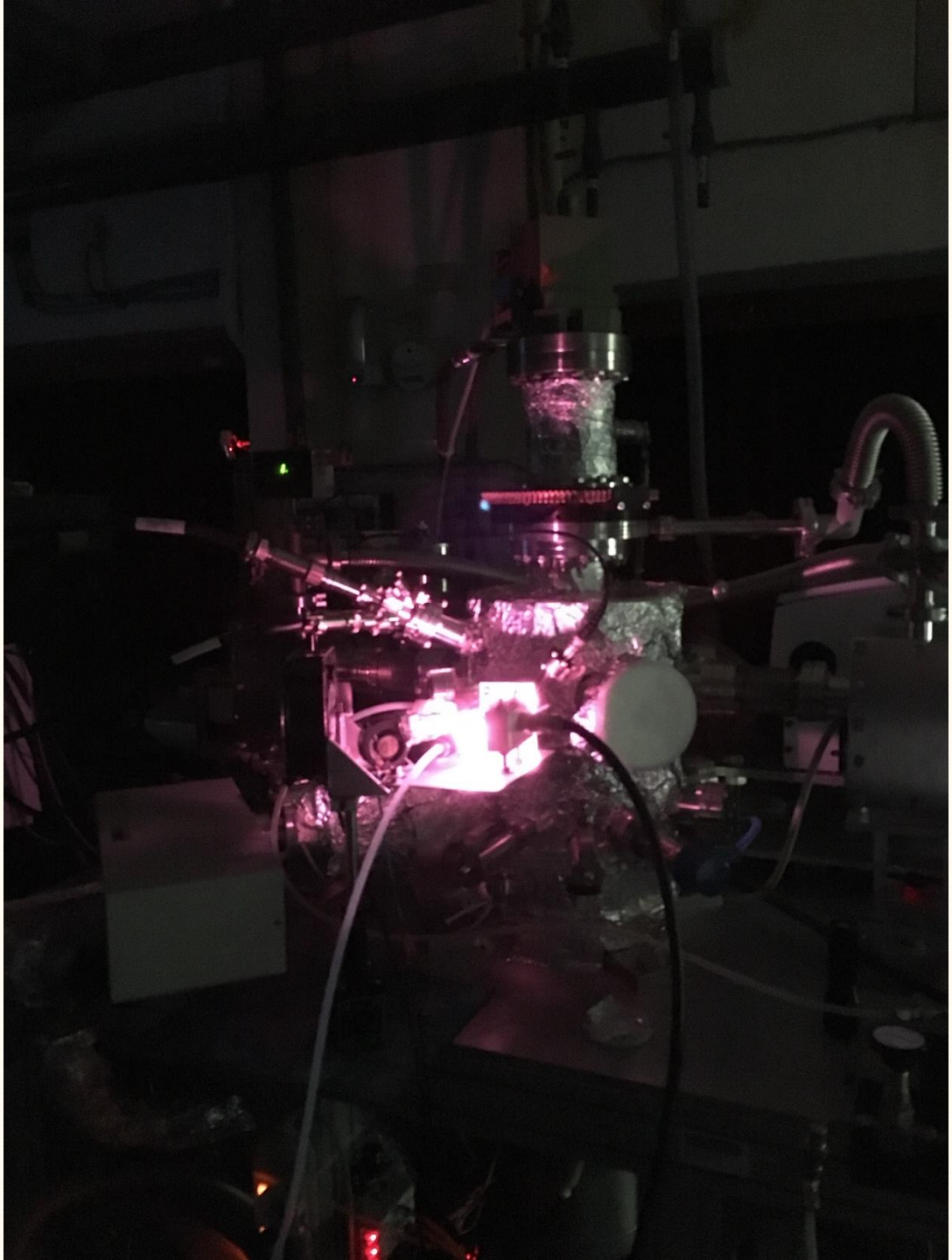




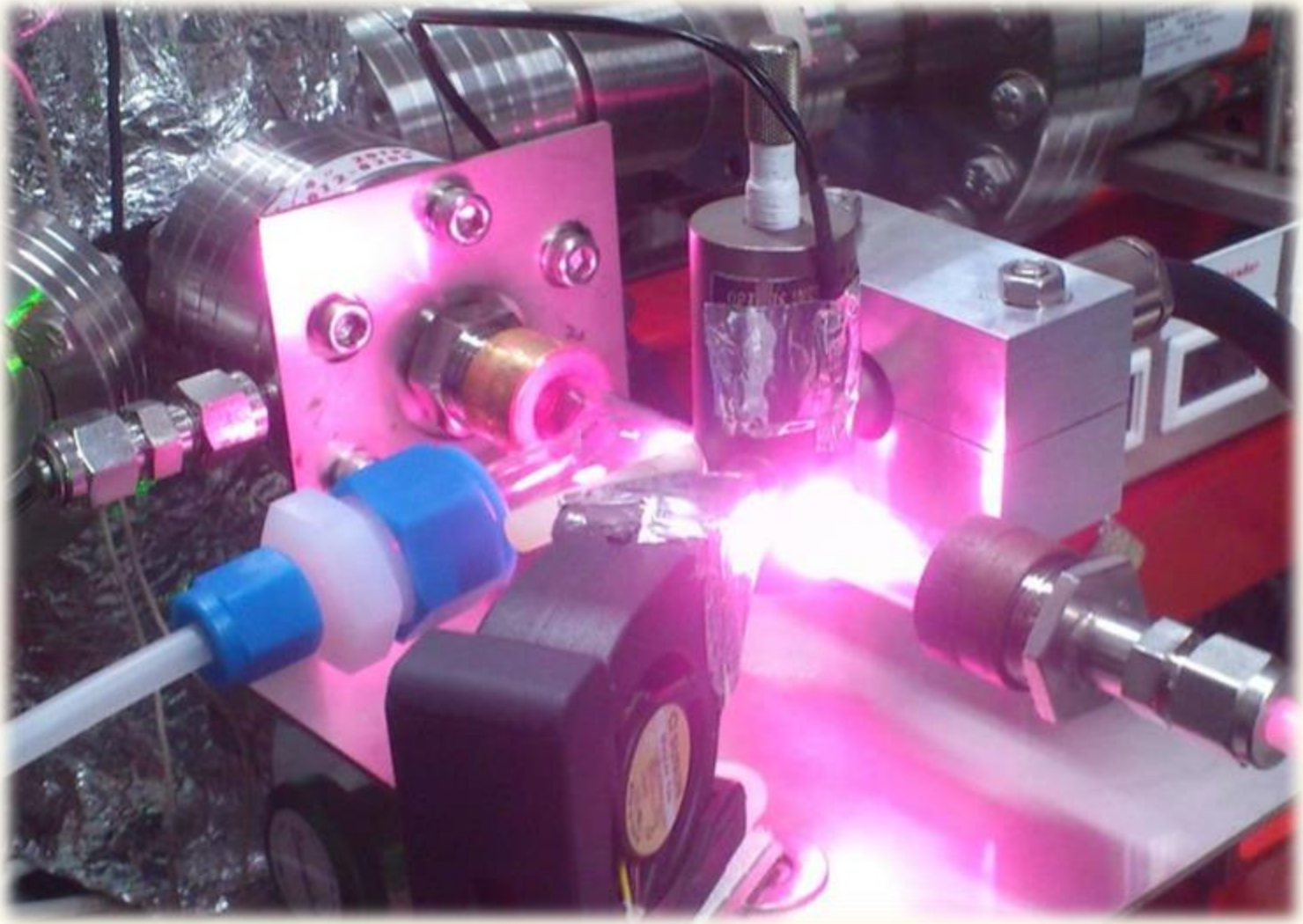
微波氣體放電管



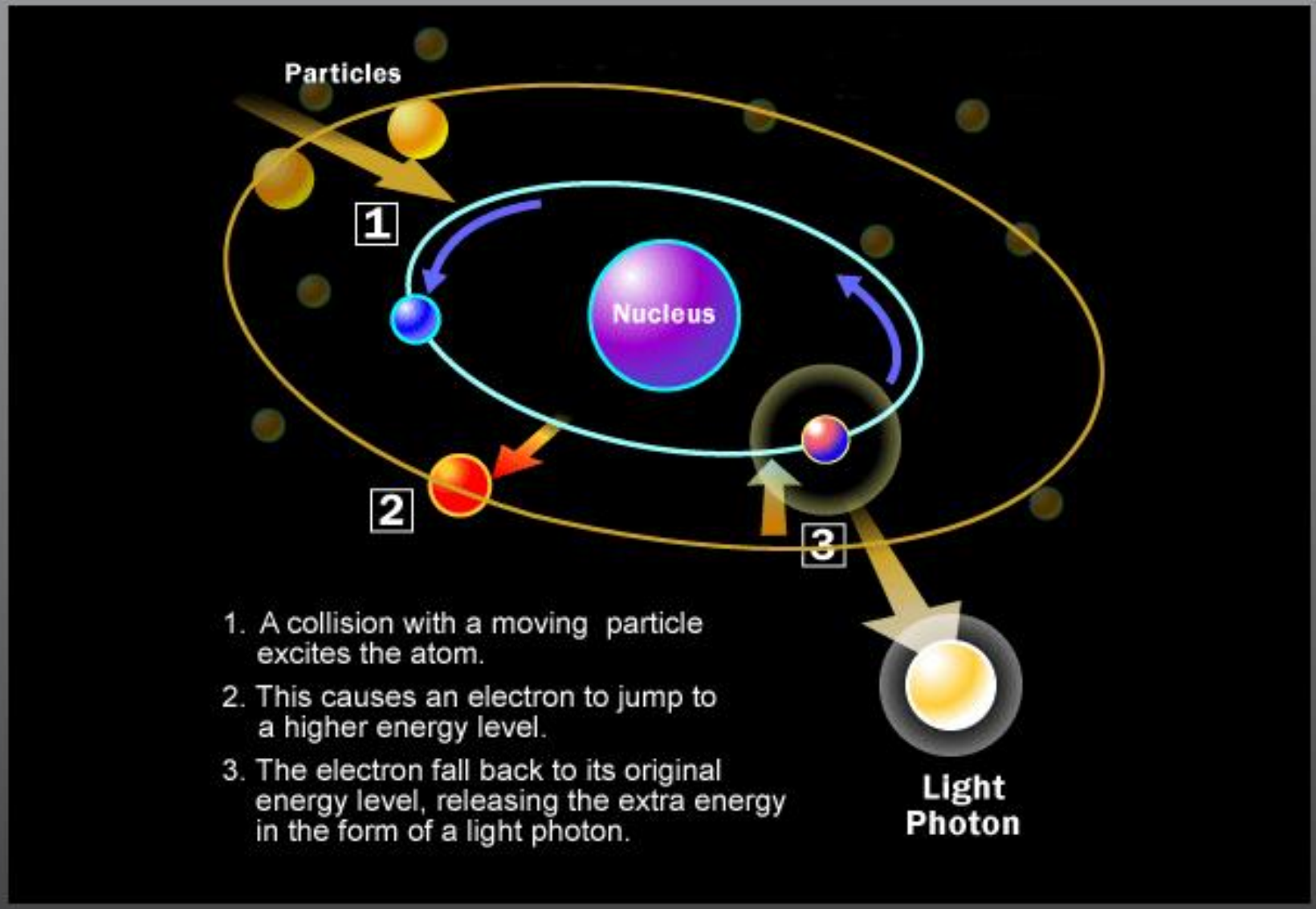

話題
主播 莊雨潔
6月25日 週三
亂吃不運動
3成童水桶腰
只用半個月..大學生自製核反應爐
12:15:13
體壇動態
溫網男單 王宇佐對俄羅斯戰士

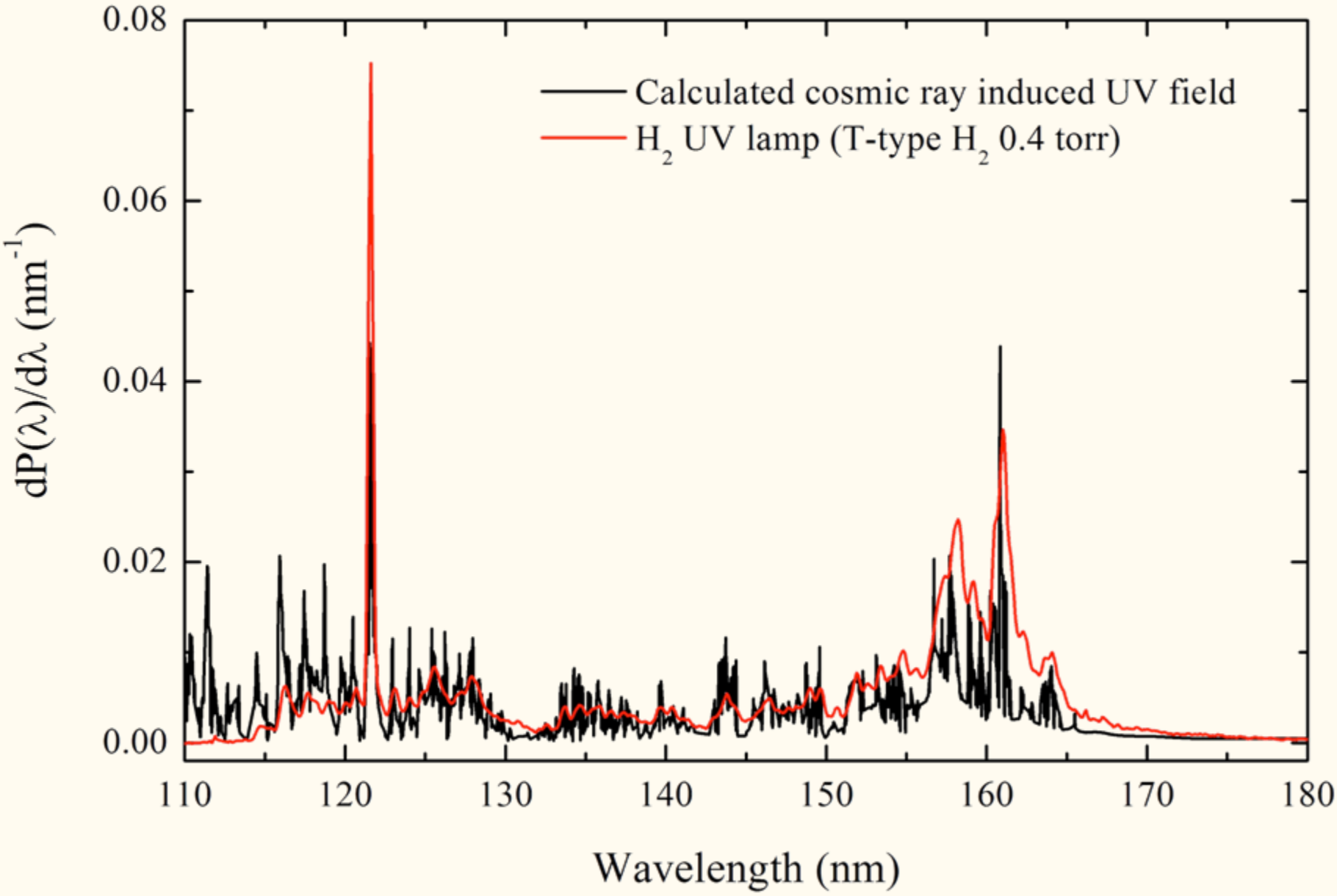


微波氣體放電管



HOW ATOMS EMIT LIGHT

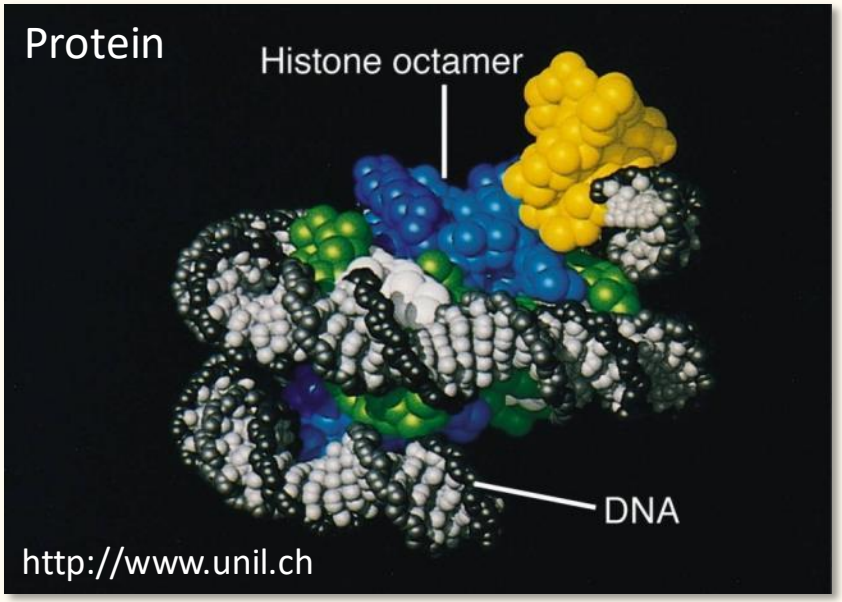


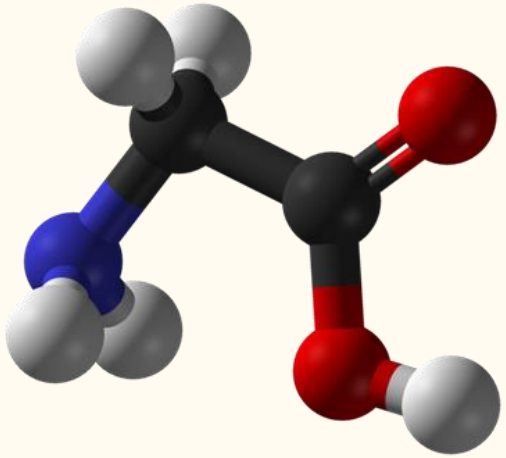

0.08
0.06
0.04
0.02
0.00
dP(λ)/dλ (nm-1)
Calculated cosmic ray induced UV field
H2 UV lamp (T-type H2 0.4 torr)
110
120
130
140
150
160
170
180
Wavelength (nm)

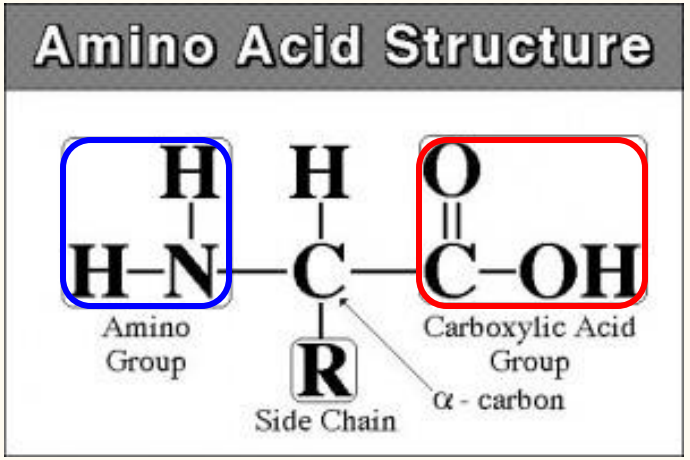
很炫但是很複雜的研究題目..

生命的起源


Cell
http://www.shfuke.com


Protein
Histone octamer
DNA
http://www.unil.ch

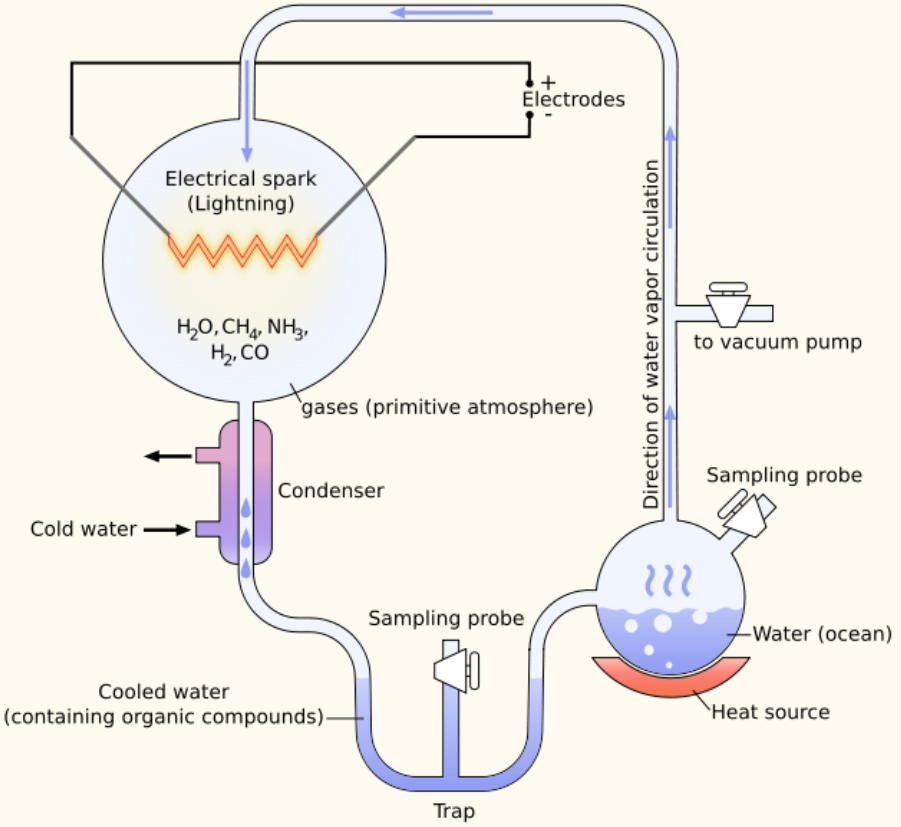



Amino Acid Structure
H
H–N
Amino Group
H
C
R
Side Chain
α - carbon
O
C–OH
Carboxylic Acid Group

米勒-尤里實驗


Miller-Urey exp. (1952)

2％碳 → 胺基酸



米勒-尤里實驗的結果證明生命在最初可能是自然發生的。
可是，他的解釋能否成立，卻基於一個假設，就是地球的原始大氣是「還原性」，而非「氧化性」的。

胺基酸無法在氧化性的環境下存活 (脫氨基)

LETTER

doi:10.1038/nature10655

The oxidation state of Hadean magmas and implications for early Earth's atmosphere

冥古宙岩浆

Dustin Trail[1,2], E. Bruce Watson[1,2] & Nicholas D. Tailby[1,2]

Magmatic outgassing of volatiles from Earth's interior probably played a critical part in determining the composition of the earliest atmosphere, more than 4,000 million years (Myr) ago[1]. Given an elemental inventory of hydrogen, carbon, nitrogen, oxygen and sulphur, the identity of molecular species in gaseous volcanic emanations depends critically on the pressure (fugacity) of oxygen. Reduced melts having oxygen fugacities close to that defined by the iron–wüstite buffer would yield volatile species such as CH_4, H_2, H_2S, NH_3 and CO, whereas melts close to the fayalite–magnetite–quartz buffer would be similar to present-day conditions and would be dominated by H_2O, CO_2, SO_2 and N_2 (refs 1–4). Direct constraints on the oxidation state of terrestrial magmas before 3,850 Myr before present (that is, the Hadean eon) are tenuous because the rock record is sparse or absent. Samples from this earliest period of Earth's history are limited to igneous detrital zircons that pre-date the known rock record, with ages approaching ~4,400 Myr (refs 5–8). Here we report a redox-sensitive calibration to determine the oxidation state of Hadean magmatic melts that is based on the incorporation of cerium into zircon crystals. We find that the melts have average oxygen fugacities that are consistent with an oxidation state defined by the fayalite–magnetite–quartz buffer, similar to present-day conditions. Moreover, selected Hadean zircons (having chemical characteristics consistent with crystallization specifically from mantle-derived melts) suggest oxygen fugacities similar to those of Archaean and present-day mantle-derived lavas[2–4,9,10] as early as ~4,350 Myr before present. These results suggest that outgassing of Earth's interior later than ~200 Myr into the history of Solar System formation would not have resulted in a reducing atmosphere.

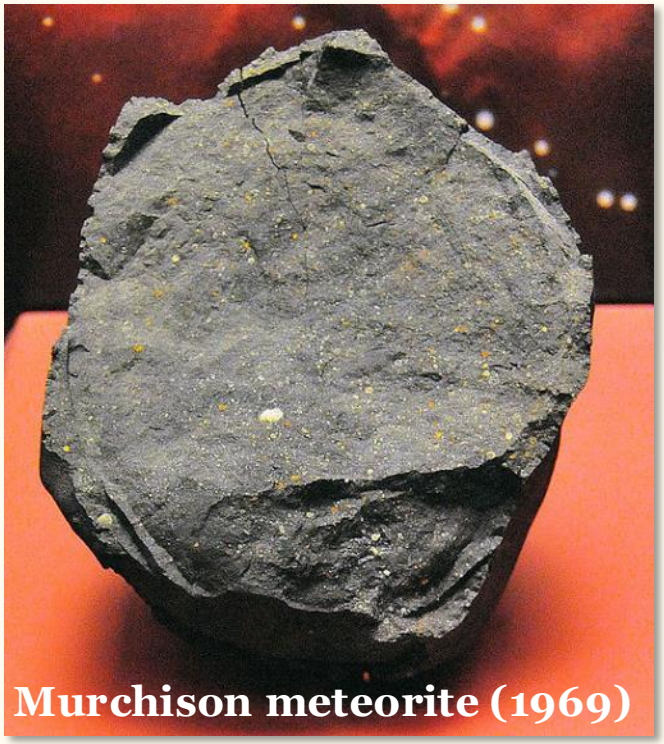
Here we report a calibration to determine the oxidation state of a magmatic melt based on the incorporation of cerium (Ce) into zircon. Cerium is unique among elements that partition into zircon (and among the rare-earth elements, REEs) in that it can exist in melts as either Ce^{4+} or Ce^{3+}. The magnitude of Ce enrichment in zircon depends on the Ce^{4+}/Ce^{3+} ratio of the medium from which it crystallizes. Because Ce^{4+} is vastly more compatible than Ce^{3+} in zircon, more-oxidized melts will yield higher Ce contents in the mineral. To explore the details of Ce uptake, zircons were grown in a piston cylinder apparatus at a pressure of 1 GPa and at temperatures of 900–1,300 °C from hydrous silicate melts (~72 wt% SiO_2) doped with lanthanum (La), Ce and praseodymium (Pr) (with and without phosphorus). Lanthanum and Pr were included as 'bracketing' elements because these exist only as 3+ ions, and partition coefficients for zircon trivalent REEs are known to monotonically increase from La to lutetium (Lu) (ref. 13); by convention, partition coefficients are expressed as the crystal/melt concentration ratio, $D_{REE}^{zrc/melt}$ (here zrc indicates zircon, the crystal concerned). This systematic behaviour provides a convenient reference for natural zircon to characterize the relative enrichment of Ce in zircon, relative to other REEs, with changes in f_{O_2}. This is expressed as a 'Ce anomaly', $(Ce/Ce^*)_D$, and is calculated in the following manner:

$$\left(\frac{Ce}{Ce^*}\right)_D = \frac{D_{Ce}^{zrc/melt}}{\sqrt{D_{La}^{zrc/melt} \times D_{Pr}^{zrc/melt}}} \quad (1)$$

where $D_{Ce}^{zrc/melt}$ is the combined partition coefficient of Ce^{4+} and Ce^{3+} in zircon, and $D_{La}^{zrc/melt}$ and $D_{Pr}^{zrc/melt}$ are respectively the partition coefficients for trivalent La and Pr. The denominator on the right hand

Trail et al. 2011, Nature 480, 79

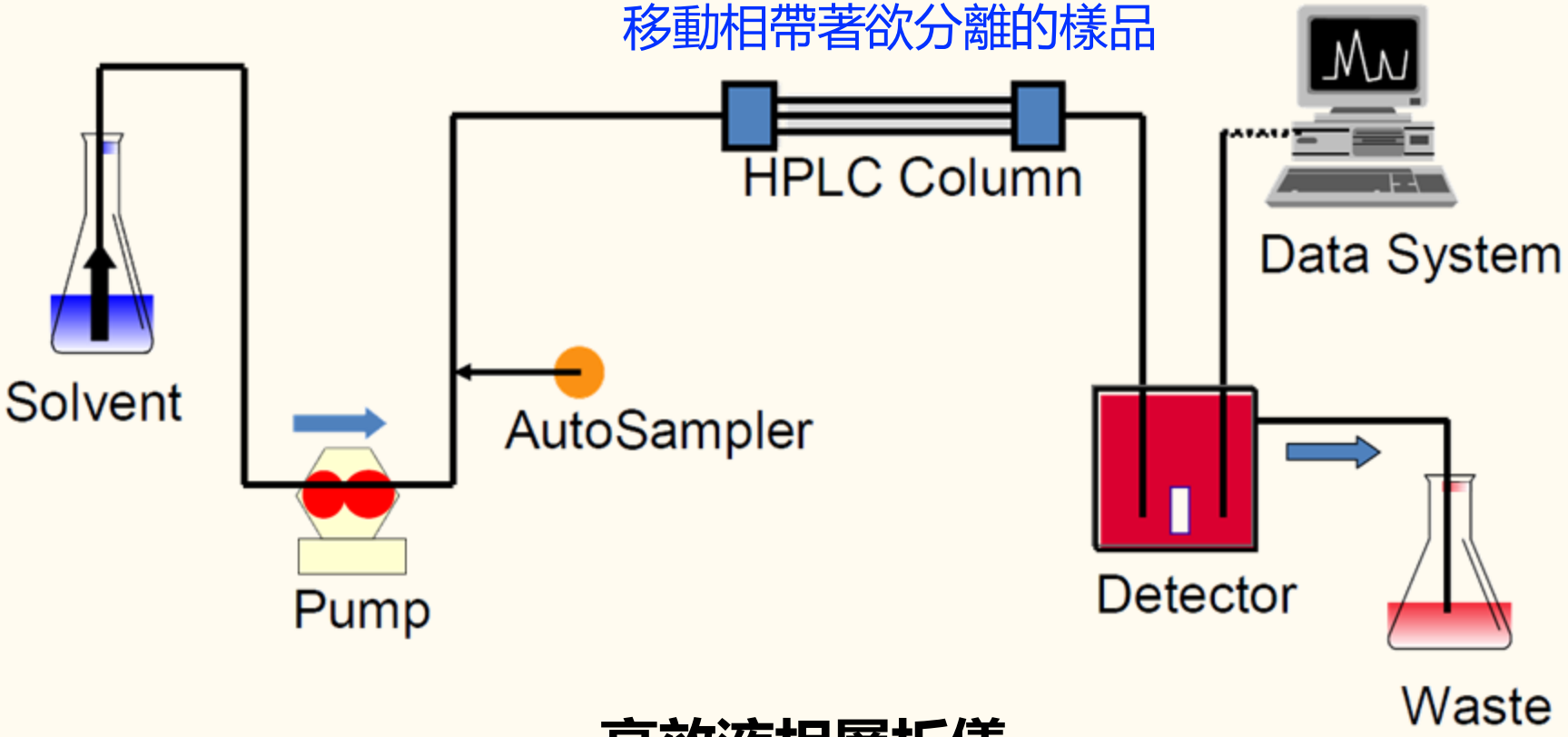

1969/09/28



高效液相層析儀

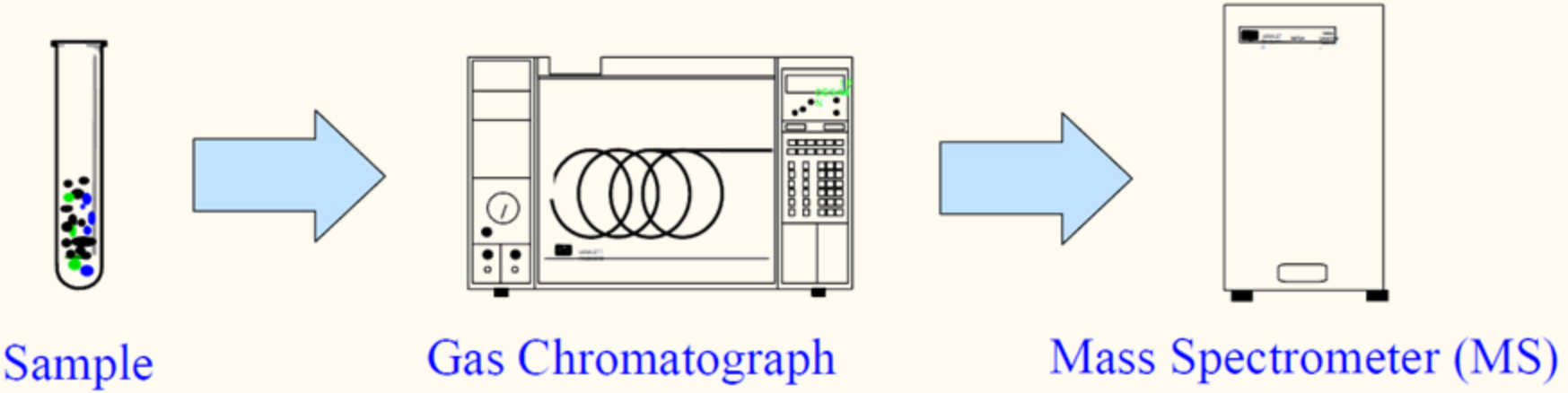
氣相層析儀

移動相帶著欲分離的樣品

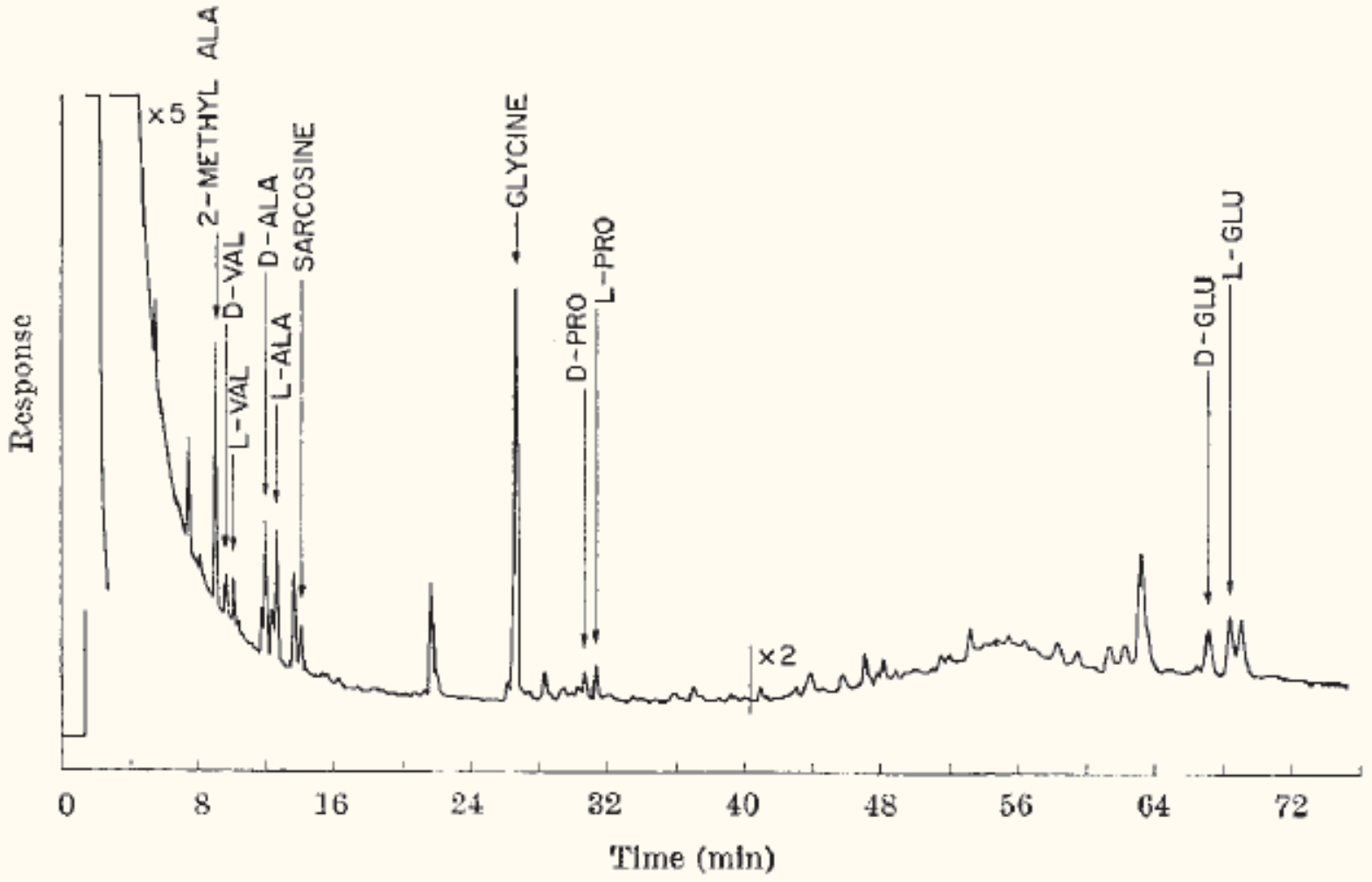


高效液相層析儀

氣相層析儀


Sample
Gas Chromatograph
Mass Spectrometer (MS)
D
C
B
A
Sample
B
A
C
D
Separation
A
B
C
D
Identification

超過15種胺基酸被偵測出



Kvenvolden et al. 1970, Nature, 228, 923

不是污染?!

同位素分餾

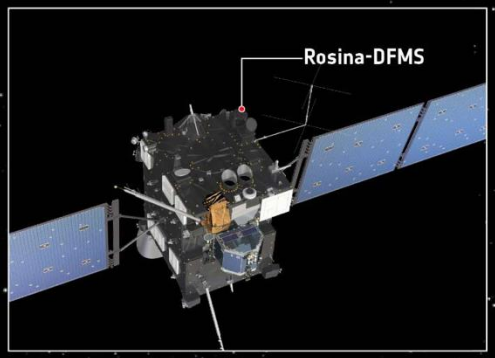
Table 1 Amino-acid abundances and $\delta^{15}N$ values

Amino acid	Concentration ($nmol\,g^{-1}$)	$\delta^{15}N$ (‰)*
α-Aminoisobutyric acid	20.1	+184
Sarcosine	ND†	+129
Isovaline	8.0‡	+66
Glycine	24.5	+37
β-Alanine	12.8	+61
D-Alanine	–§	+60
L-Alanine	10.4‡	+57
L-Leucine	2.5§	+60
D,L-Proline	ND†	+50‖
D,L-Aspartic acid	4.7§	+61‖
D-Glutamic acid	–§	+60
L-Glutamic acid	10.8§	+58

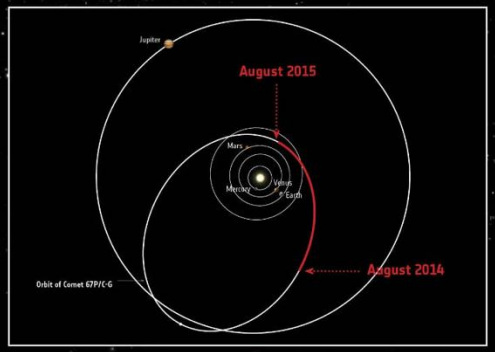
$$\delta^{15}N(‰) = [(^{15}N/^{14}N)_{sample}/(^{15}N/^{14}N)_{standard} - 1] \times 10^3$$

Engel et al. 1997, Nature 389, 265

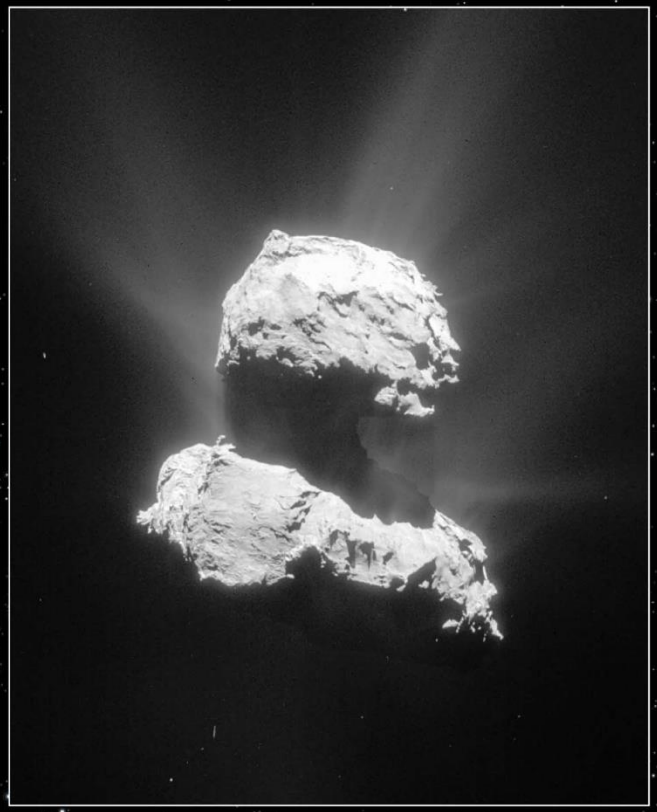
→ ROSETTA'S COMET CONTAINS INGREDIENTS FOR LIFE



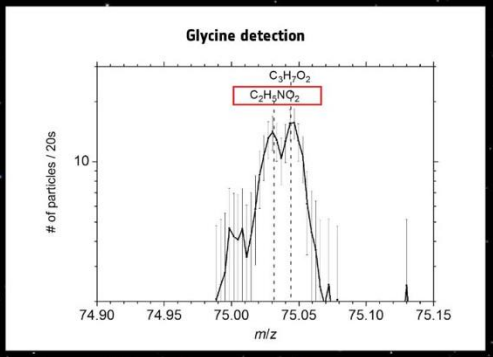
The measurements were made with the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis Double-Focusing Mass Spectrometer (ROSINA-DFMS).



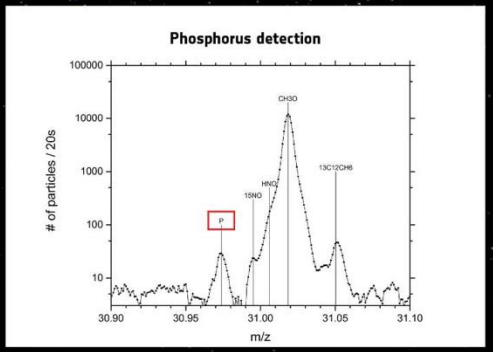
The data were collected between August 2014 and August 2015.



The measurements were made when Rosetta was between 10 and 200 km from the comet.



Spectrum indicating glycine ($C_2H_5NO_2$) detection on 9 July 2015. The simple amino acid glycine is a biologically important organic compound commonly found in proteins.



Spectrum indicating phosphorus (P) detection, along with other gases, on 26 October 2014. Phosphorus is a key element in all living organisms. It is found in DNA, RNA and in cell membranes, and it is used in transporting chemical energy within cells for metabolism.

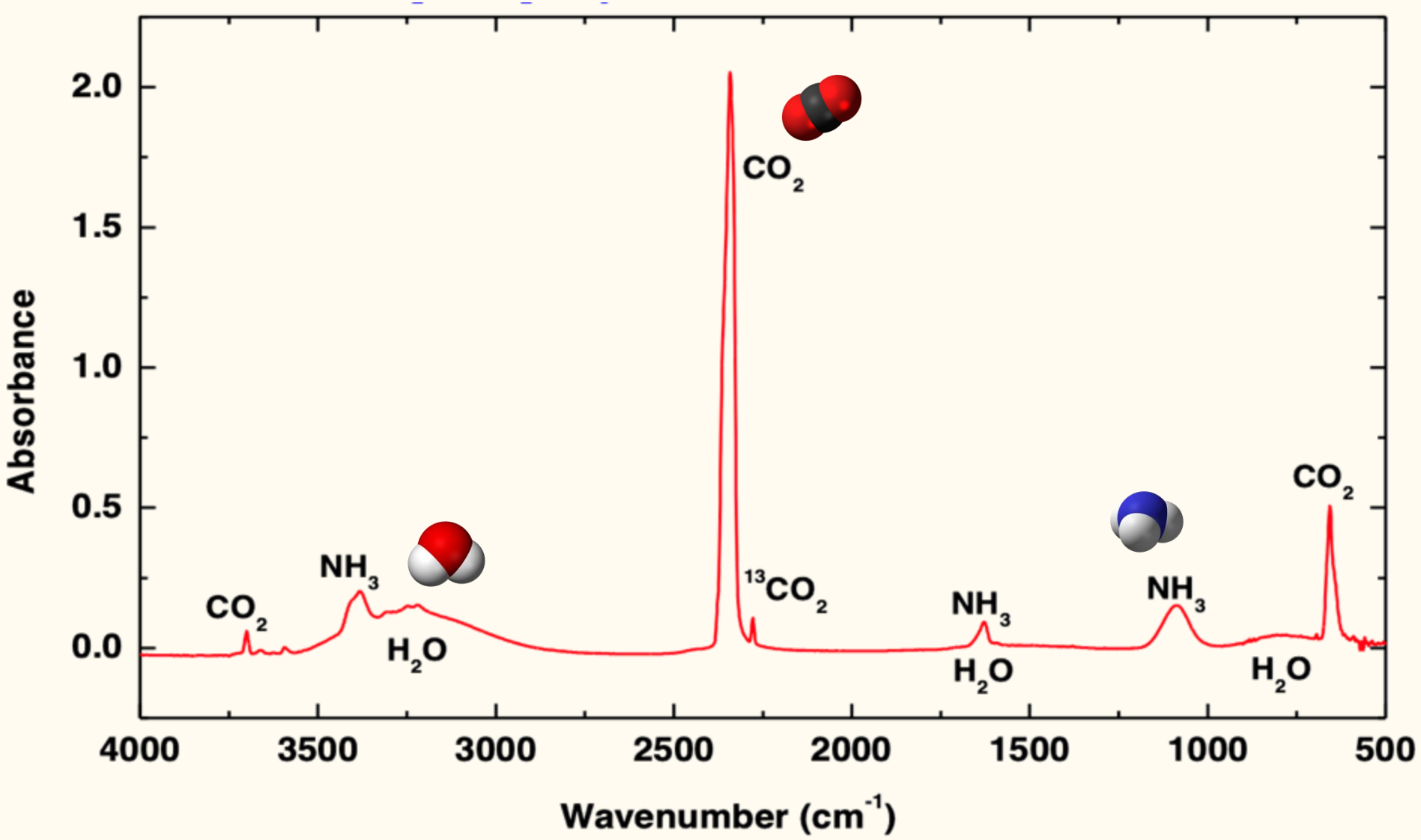
Spacecraft: ESA/ATG medialab; Comet: ESA/Rosetta/NavCam – CC BY-SA IGO 3.0; Data: Altwegg et al. (2016)

生命的起源來自外太空？

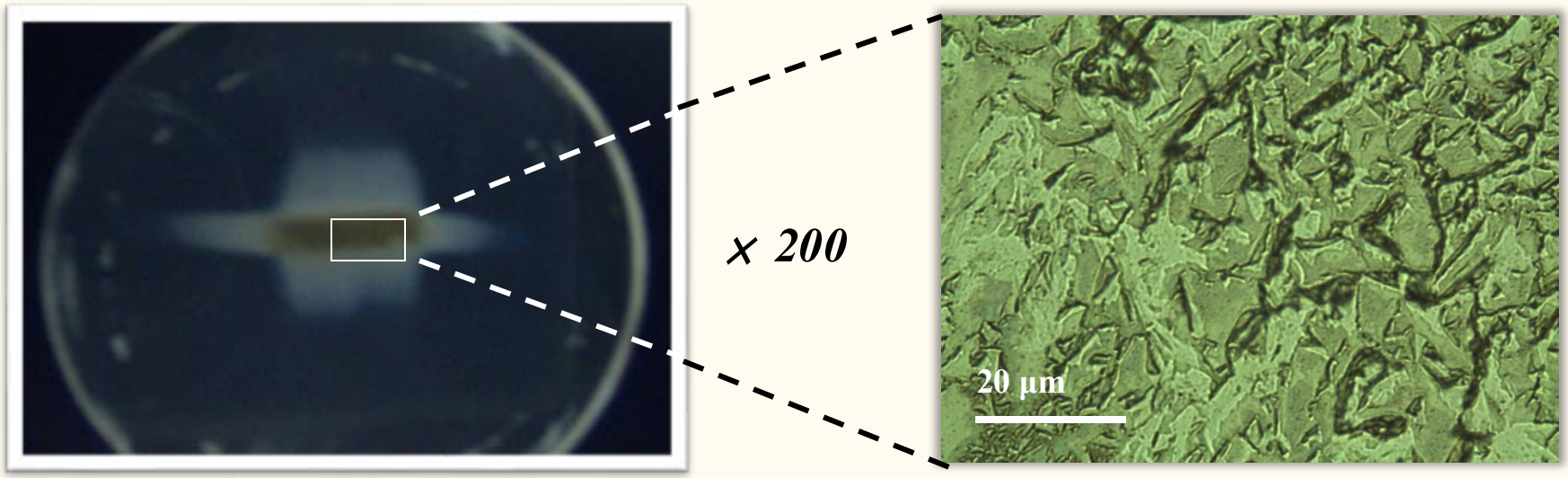
Species	Comet Hale-Bopp [a]	NGC 7538 IRS 9 [b]	W33A [b]
H_2O	100	100	100
CO	20	16	9
CO_2	6	22	14
NH_3	0.6	13	15
CH_3OH	2	5	22
H_2CO	1	4	1.7-7
HCOOH	0.05	3	0.4-2
CH_4	1	2	2
C_2H_2	0.5	...	...
C_2H_6	0.5	...	...
OCN^-	0.37	1	3
OCS,XCS	0.7	...	0.3
SO_2	0.15	...	...

a. Crovisier et al. 1998, Faraday Discussion, 109, 437
b. Gibb et al. 2000, ApJ, 536, 347

$H_2O+CO_2+NH_3$ 混和冰晶紅外光譜圖

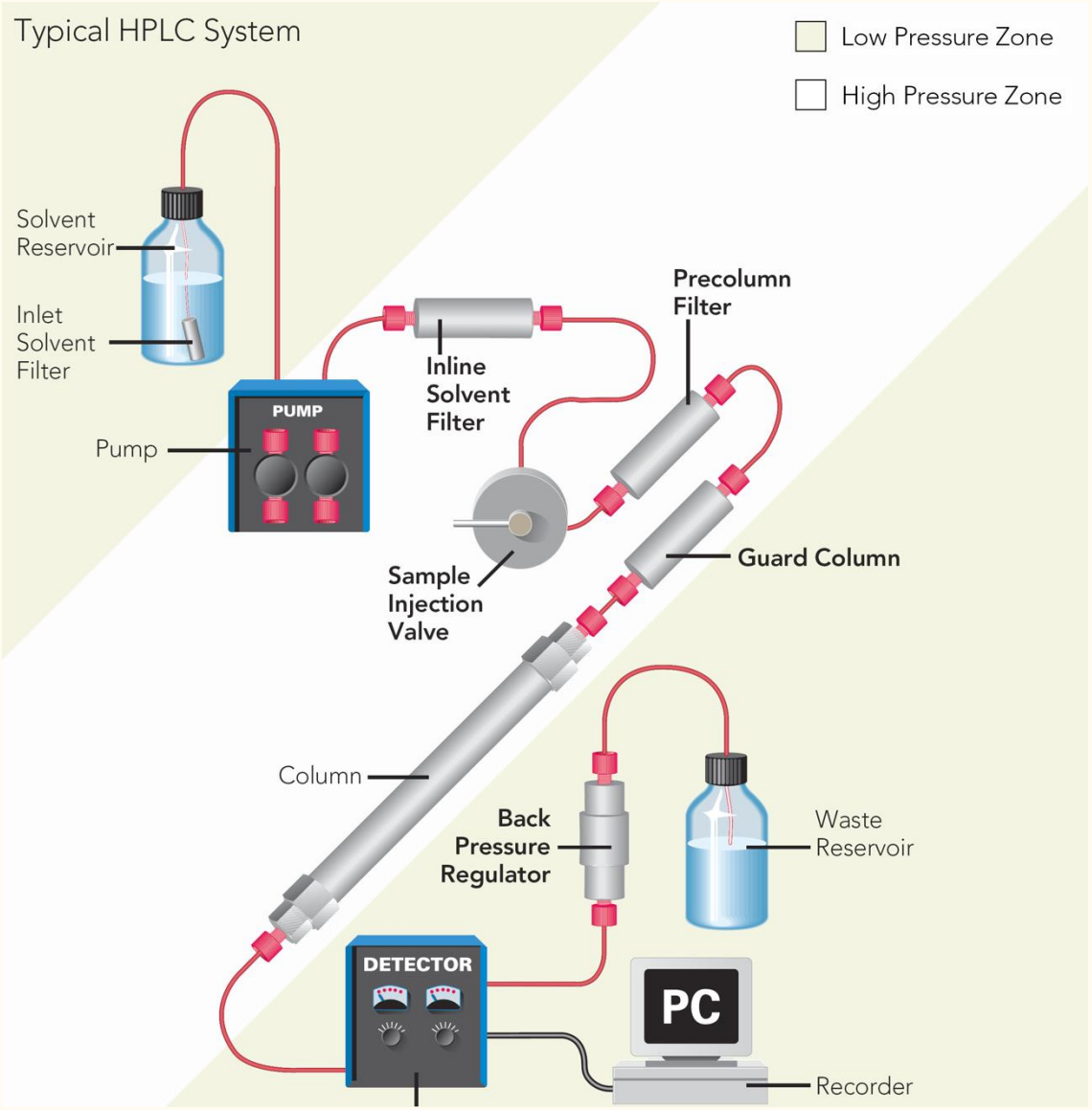


真空紫外光照射後殘存的物質

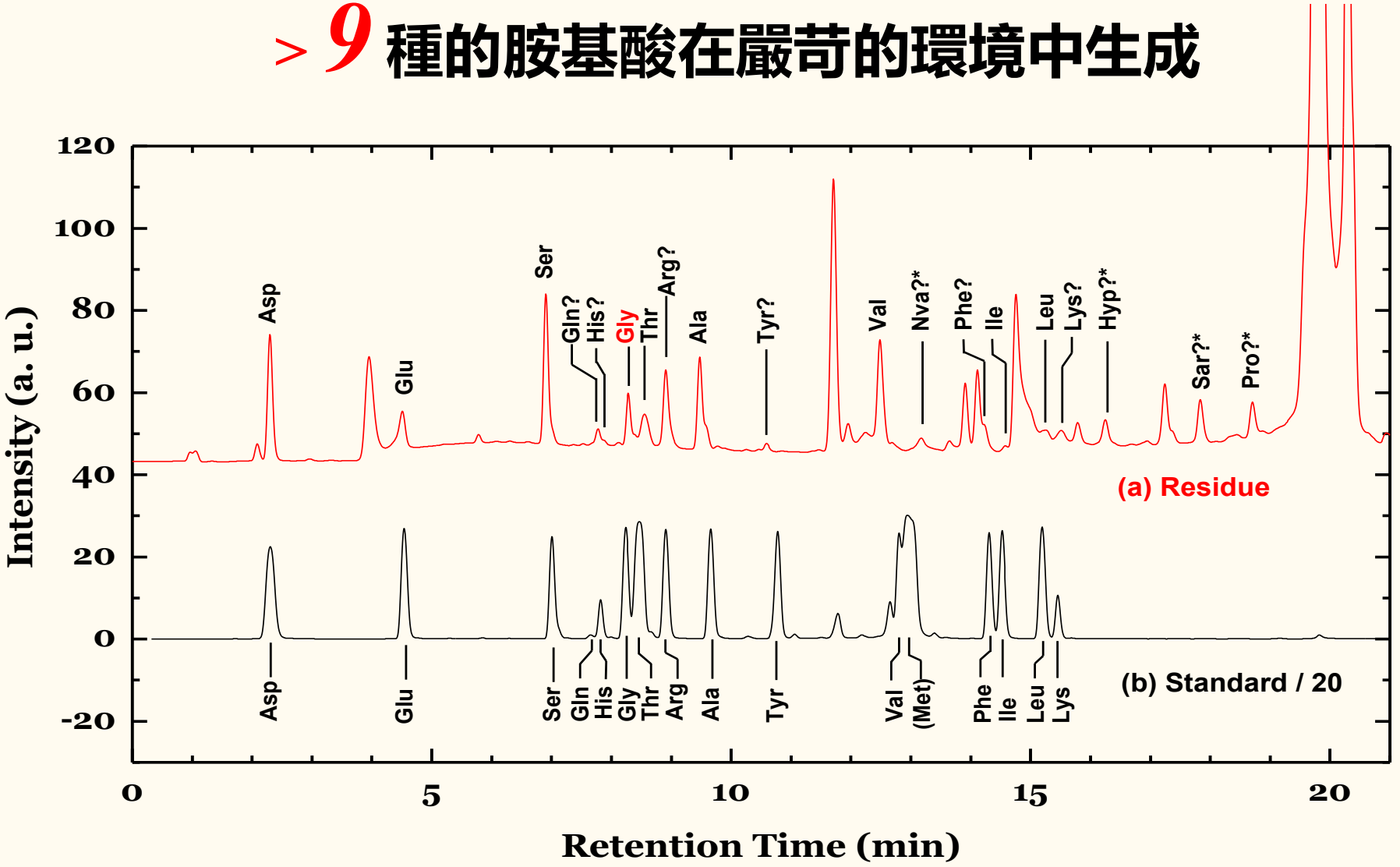


After broad band VUV/EUV irradiation (4-20 eV) and warmed up (15-300 K)

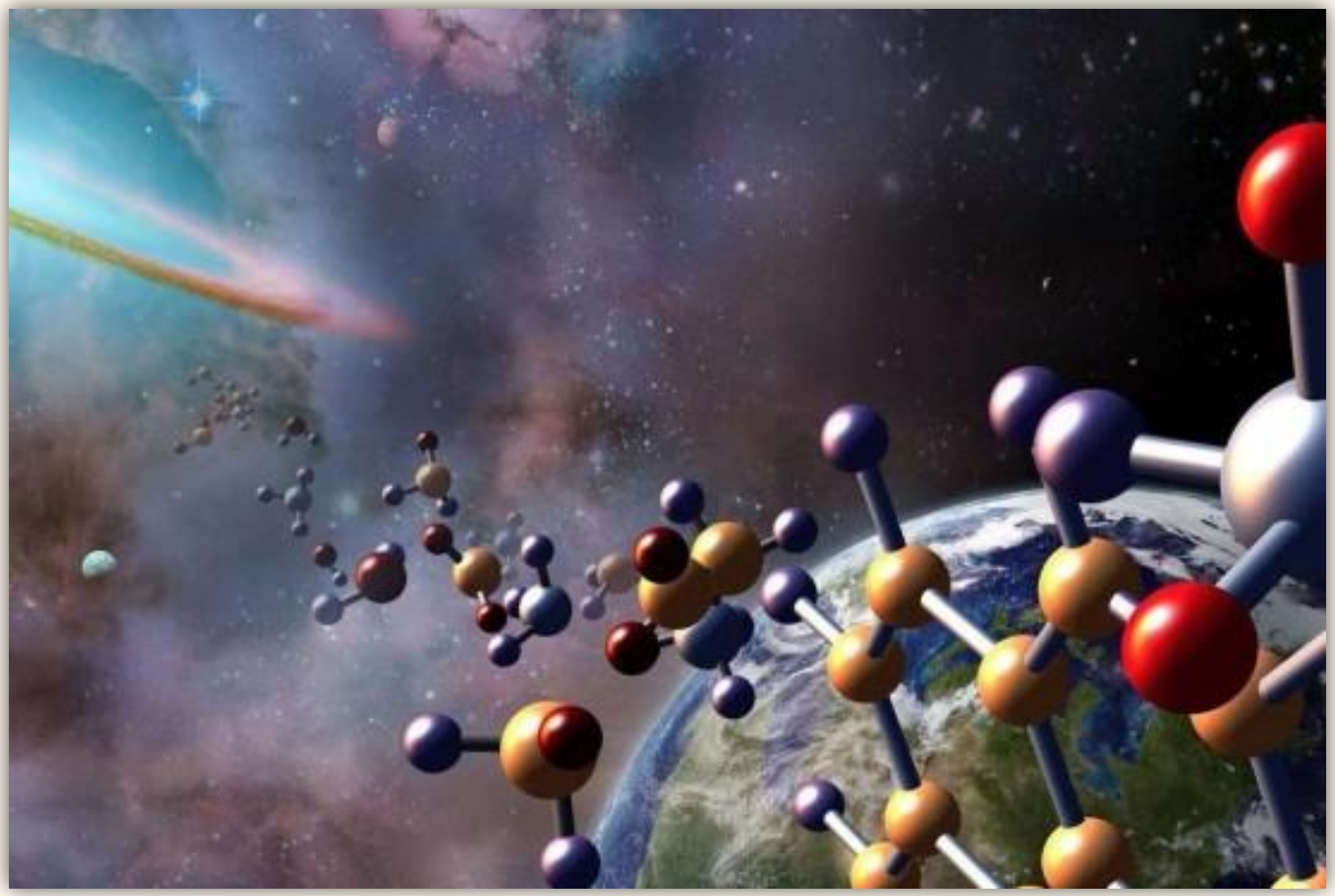
高效液相層析儀


Typical HPLC System
Low Pressure Zone
High Pressure Zone
Solvent Reservoir
Inlet Solvent Filter
Pump
PUMP
Inline Solvent Filter
Precolumn Filter
Sample Injection Valve
Guard Column
Column
Back Pressure Regulator
Waste Reservoir
DETECTOR
PC
Recorder

> 9 種的胺基酸在嚴苛的環境中生成



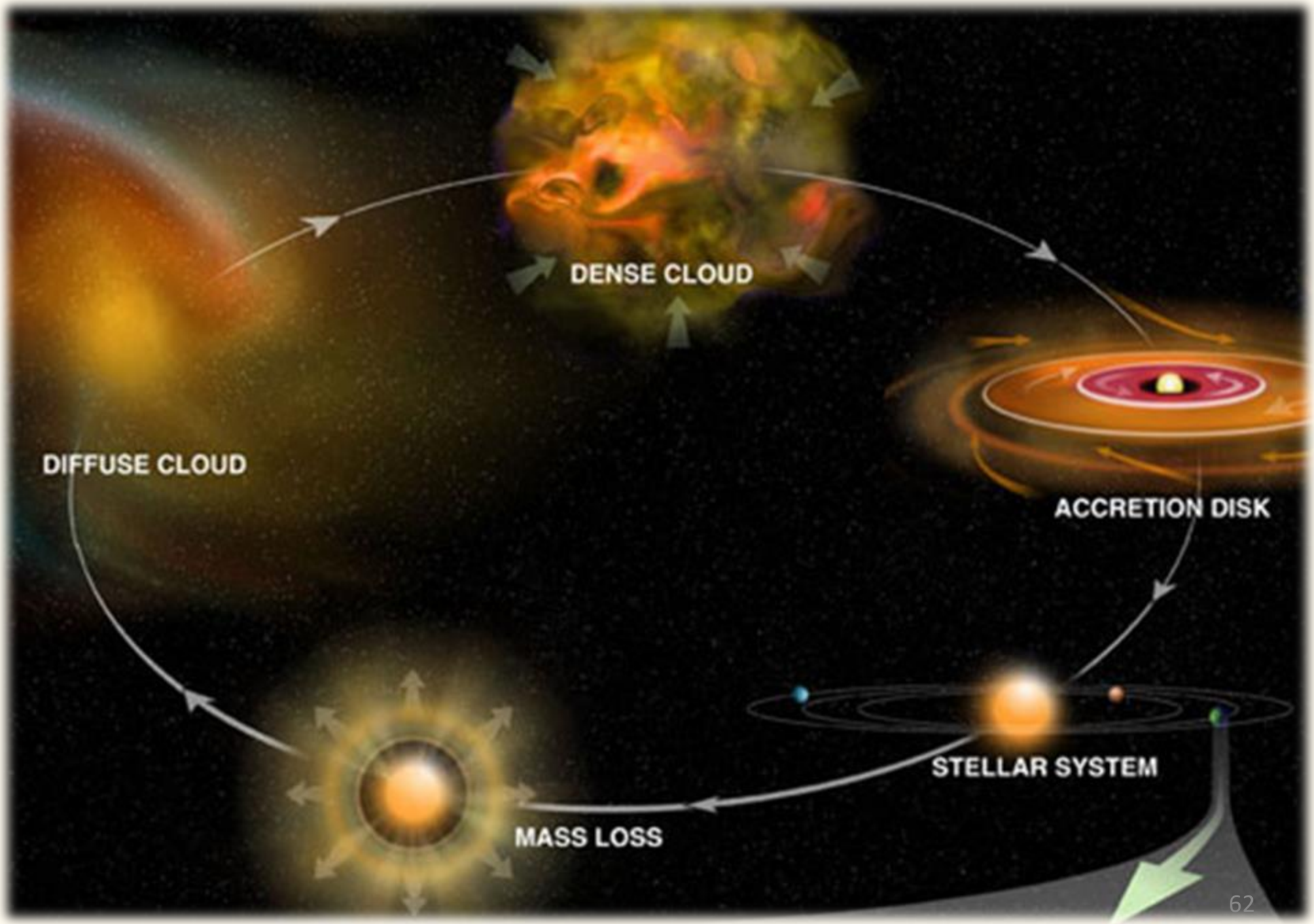
A possible scenario of the origin of life




台視HD
探索科學
宇宙奇航

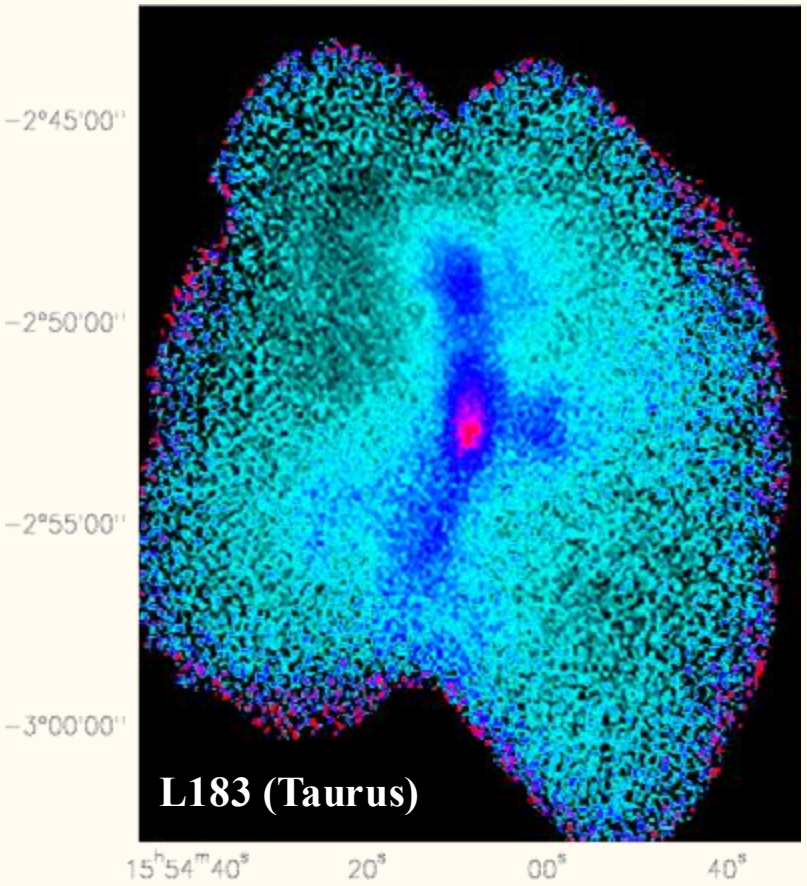
好像太過化學了..

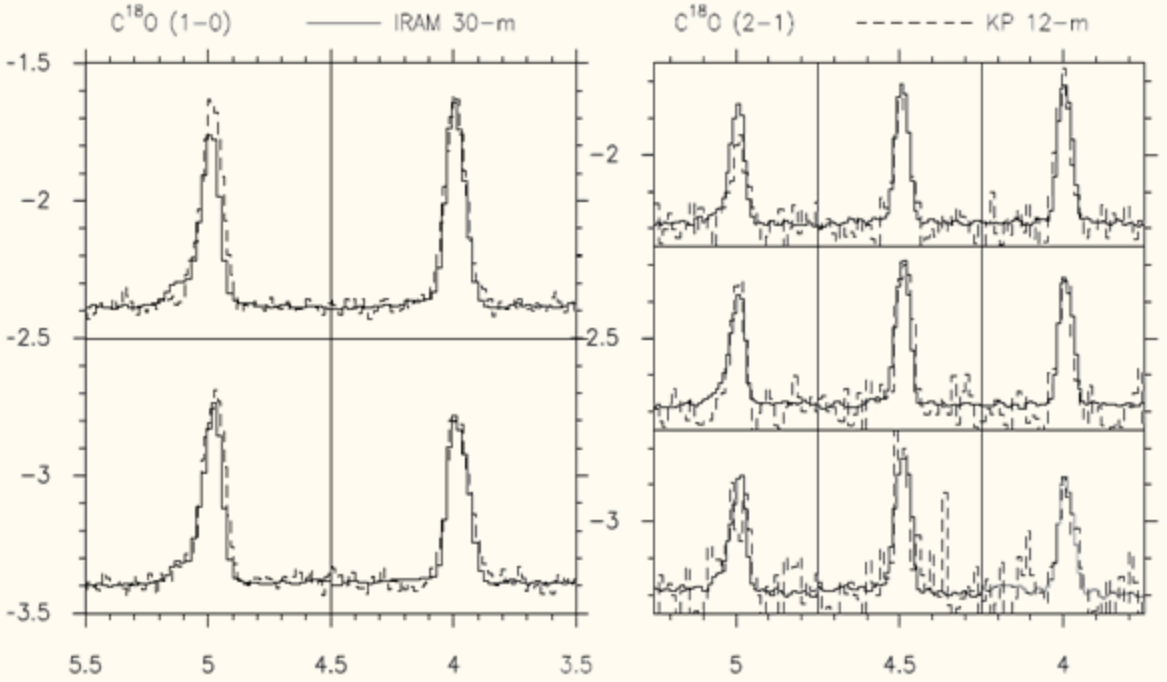
那來點物理好了


DENSE CLOUD
ACCRETION DISK
DIFFUSE CLOUD
STELLAR SYSTEM
MASS LOSS

根據吸積模型在冷星雲環境中除了氫分子外，其餘分子應該在不到百萬年的時間內，都要在塵埃表面固化成冰晶

Willacy & Millar, 1998, MNRAS, 298, 562

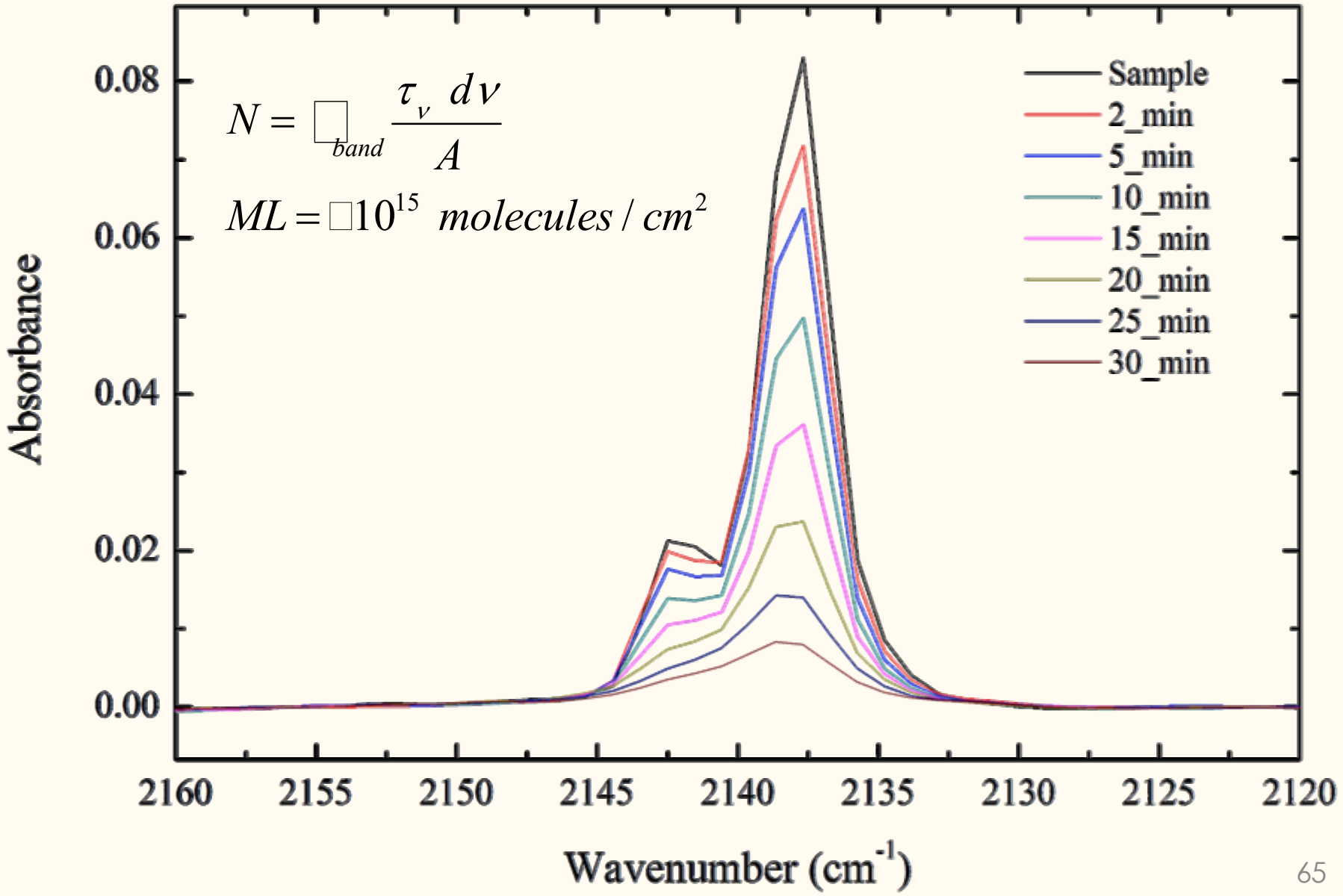




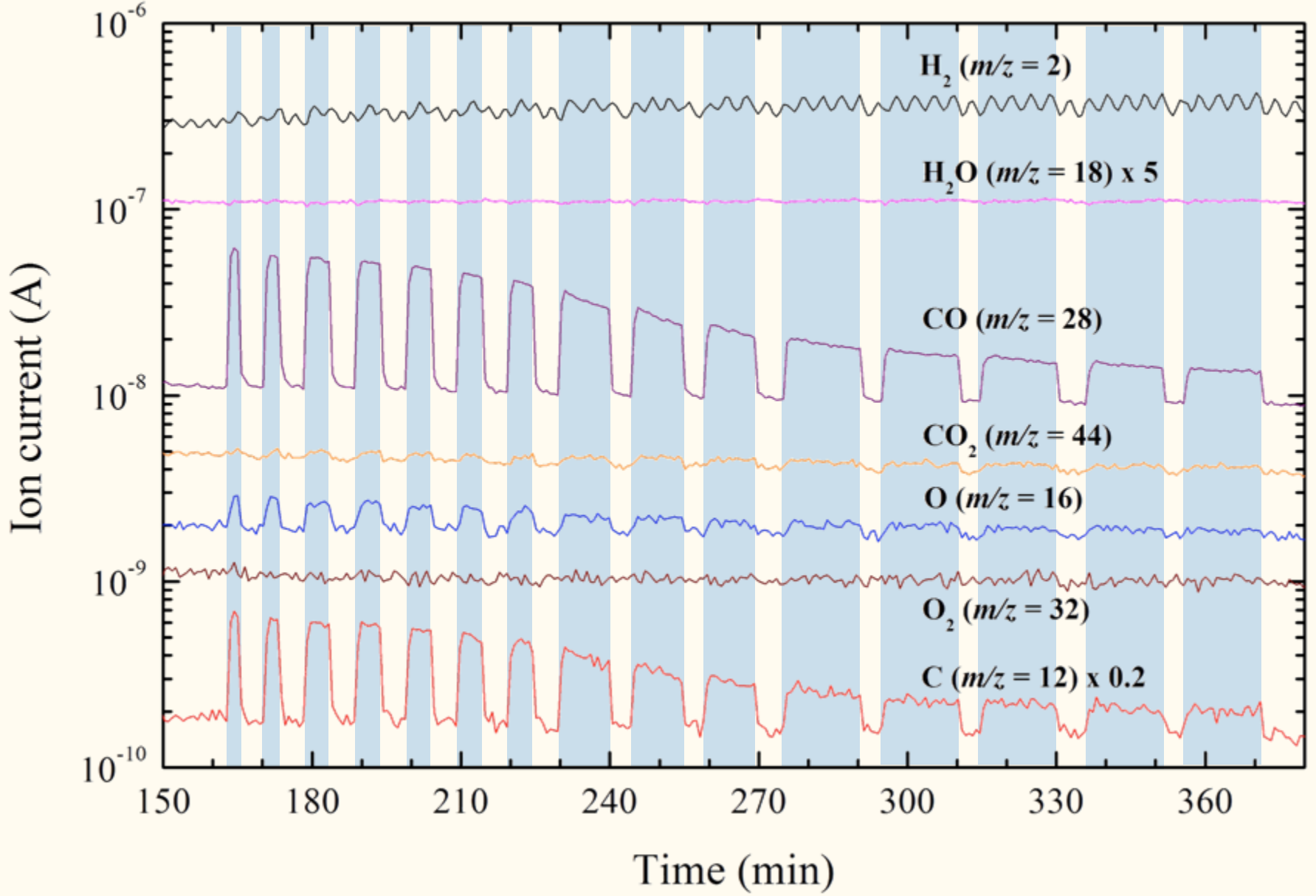
Pagani et al. 2005, A&A, 429, 181

一氧化碳在L183冷星雲被觀測到以氣態形式存在

一氧化碳冰晶的紅外光吸收譜

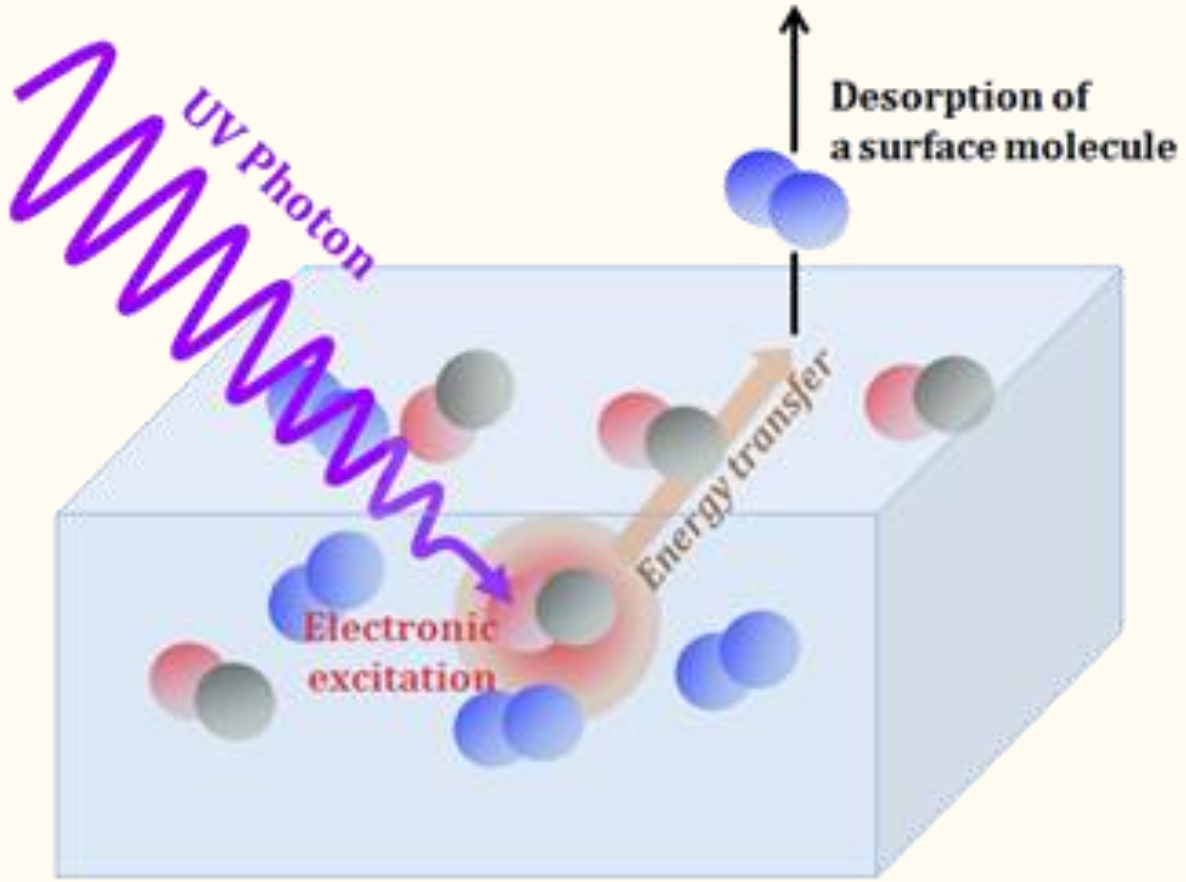


一氧化碳冰晶照射真空紫外光過程的質譜圖

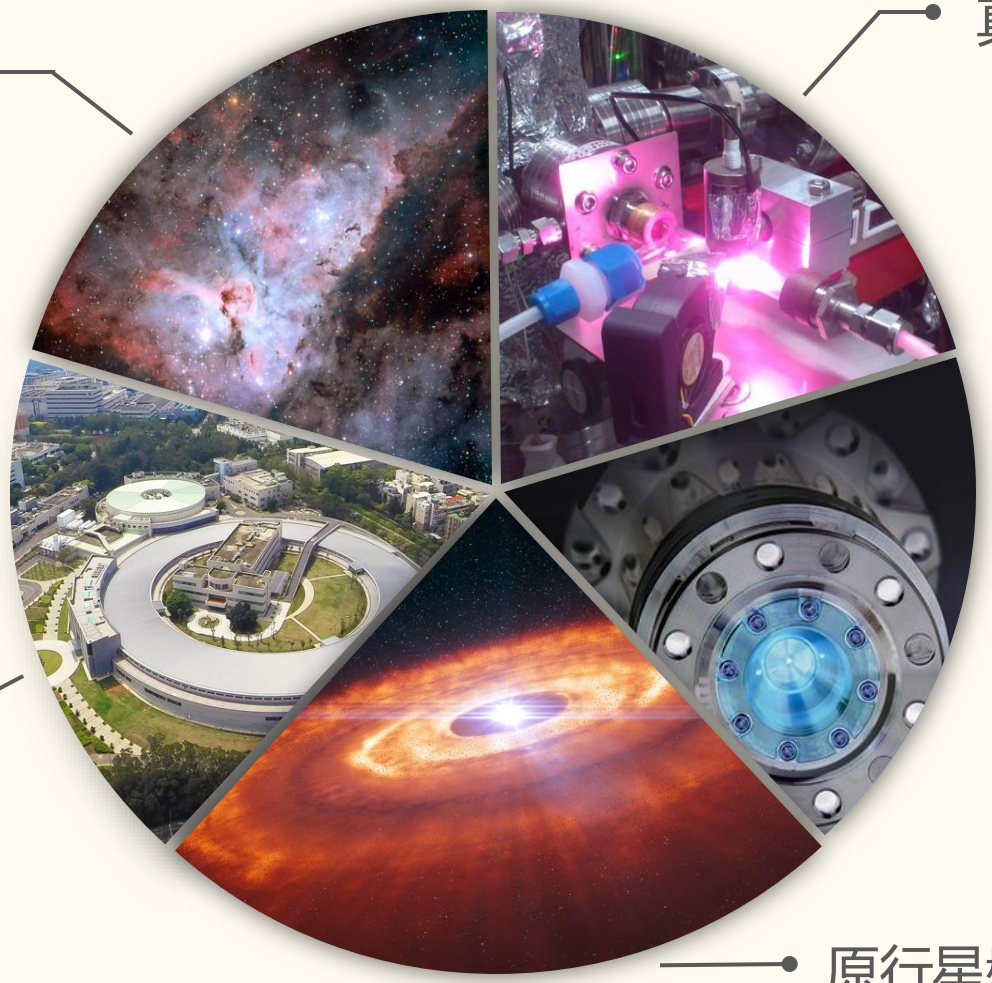


電子能階躍牽誘發脫附

好東西要和好朋友分享



實驗室天文學



冷星雲

真空紫外光
110–170 nm

能量電子
100–5000 eV

同步輻射光源
80–1250 eV

原行星盤

聯合天文學實驗室

Dr. A. Jimenez-Escobar

Dr. M. Nuevo

Dr. A. Ciaravella

Prof. C. Cecchi-Pestellini

NSRRC

Prof. K.-J. Chuang

Dr. G. M. Muñoz Caro

Prof. C. Jäger

Prof. S. Cazaux


Any Questions