Methane retained by carbon dioxide and water ices.

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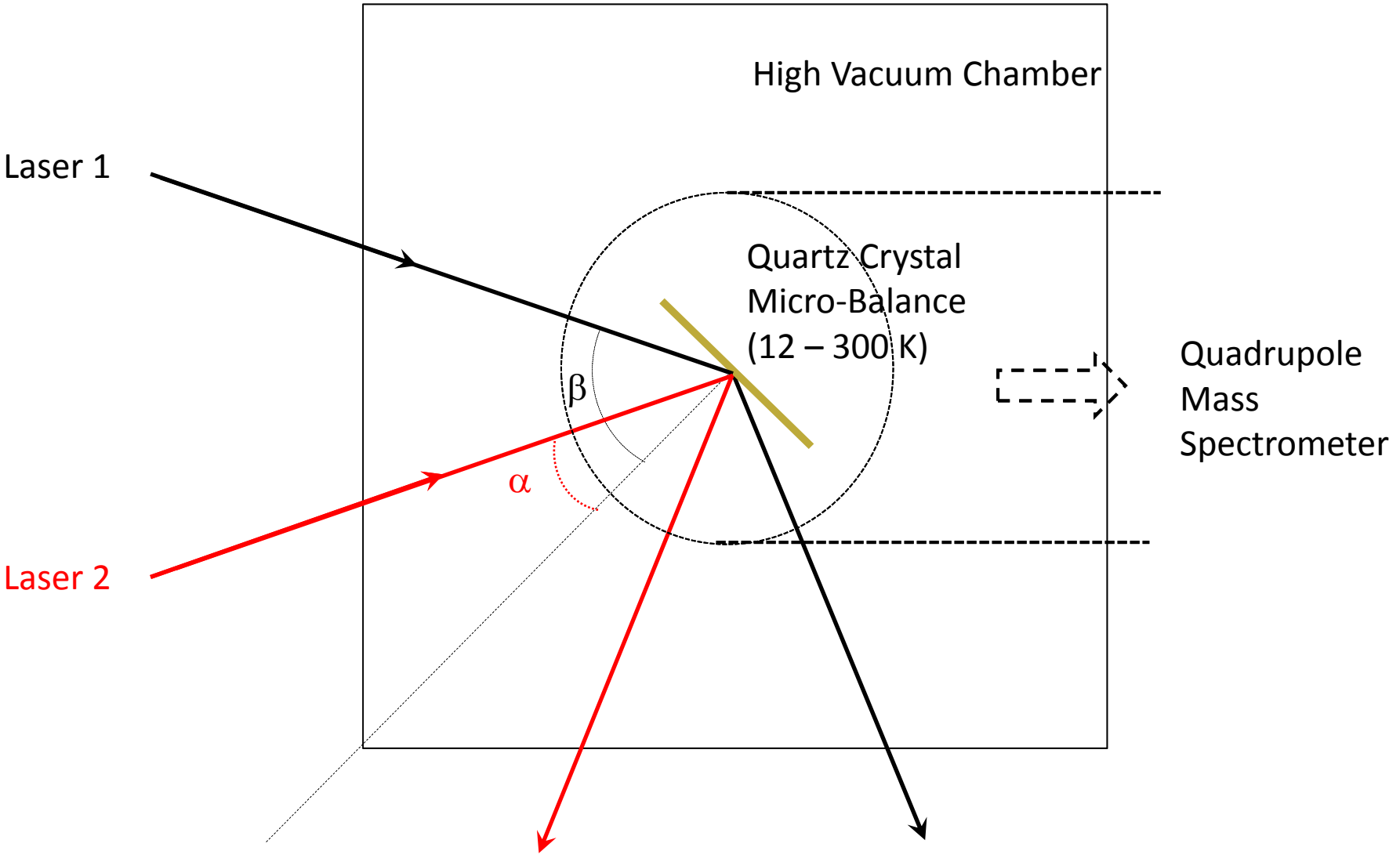
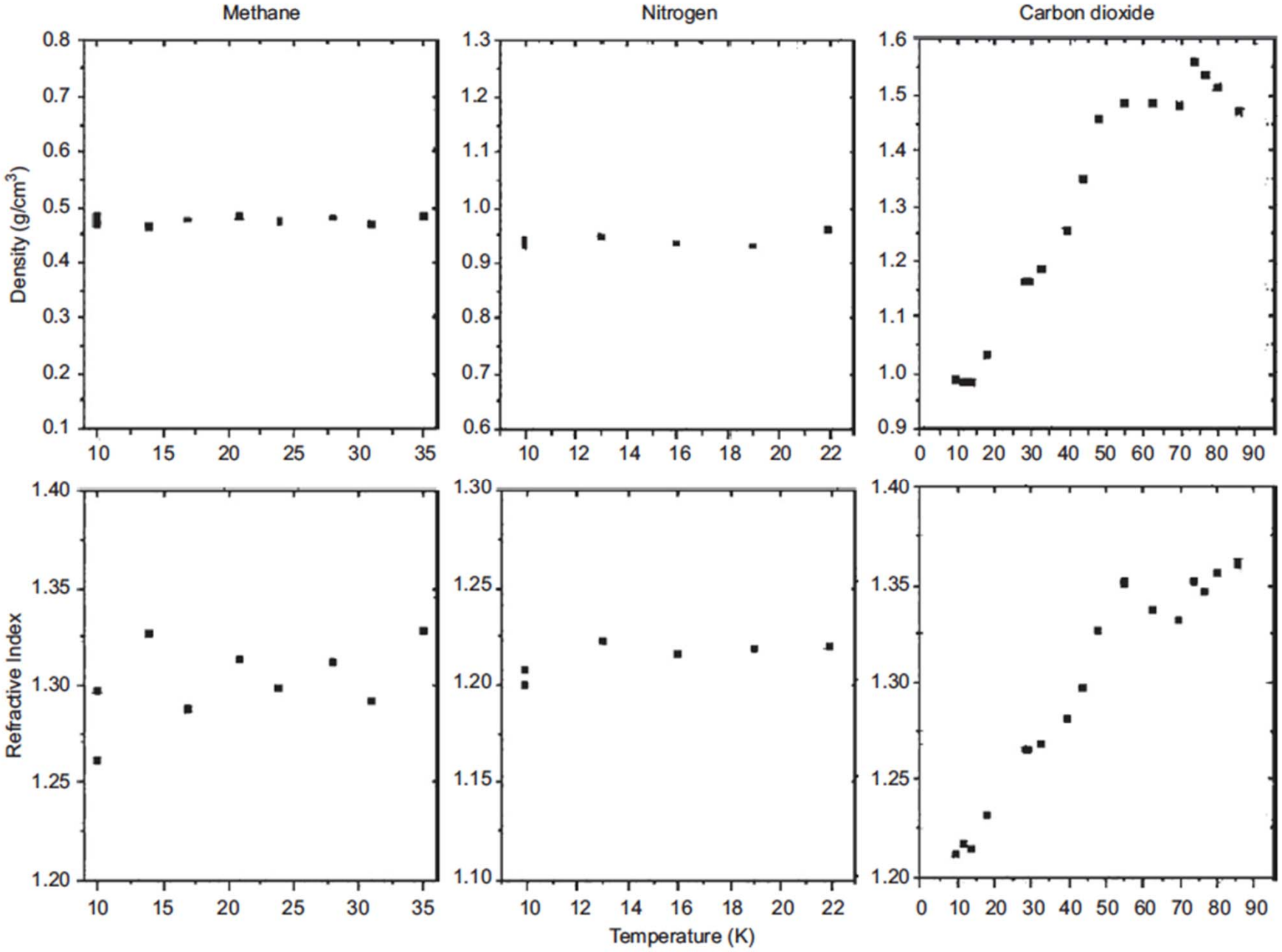
Outline

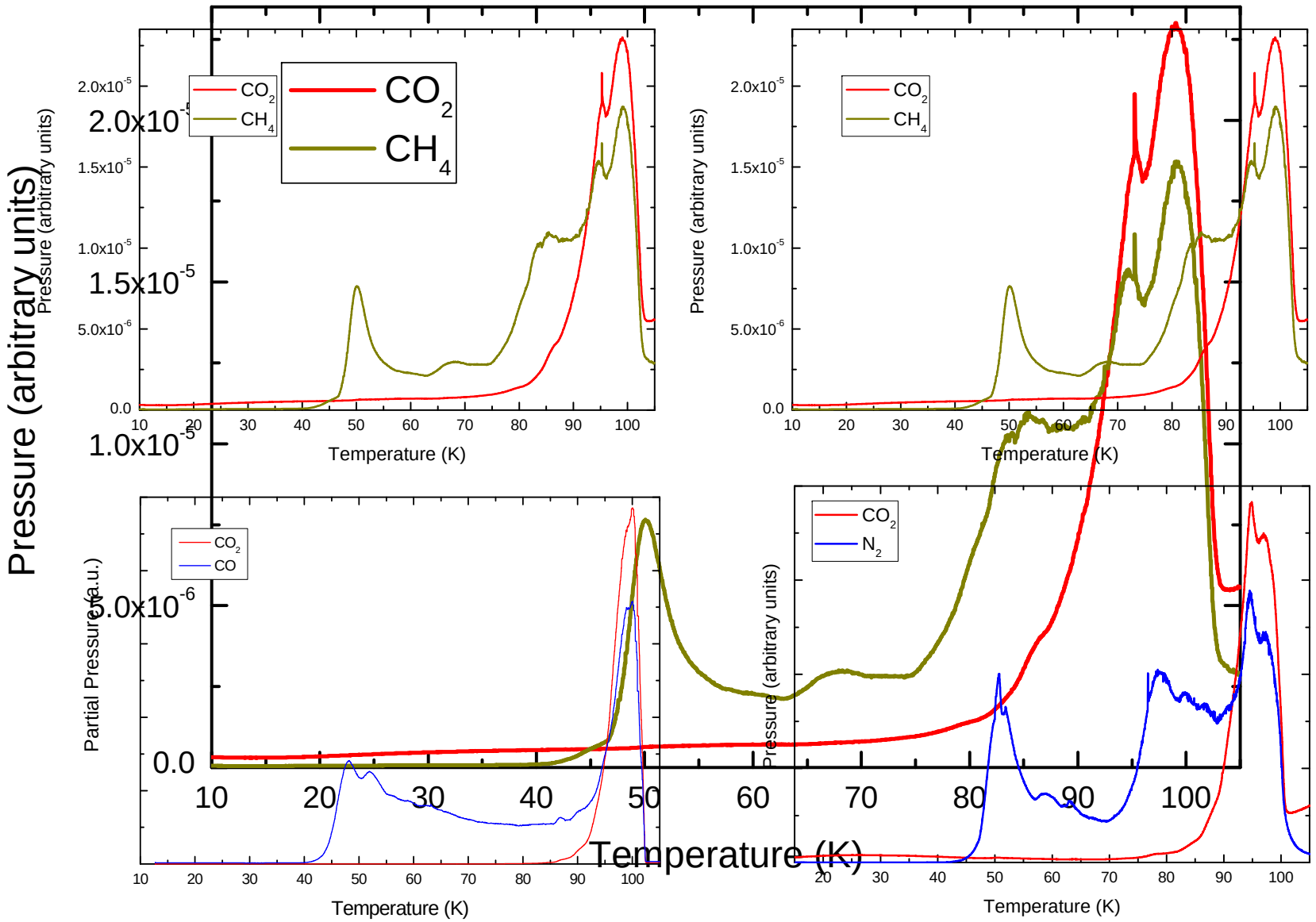
- Introduction
- Experimental setup
- CO_2 and H_2O structure and methane desorption
- Porous structures and adsorption

Double Laser Interferometry and QCMB



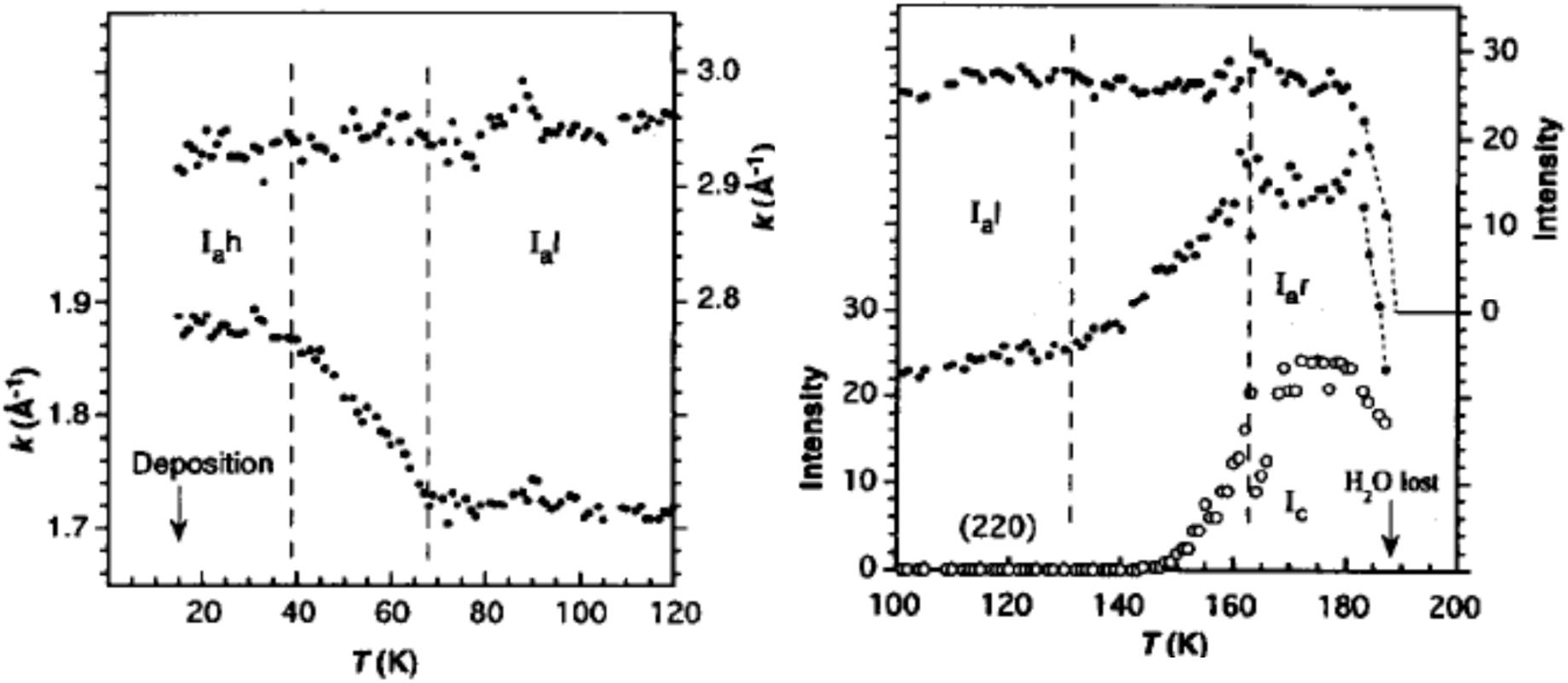


Satorre et al P&SS 2008, 56, 1748-1752

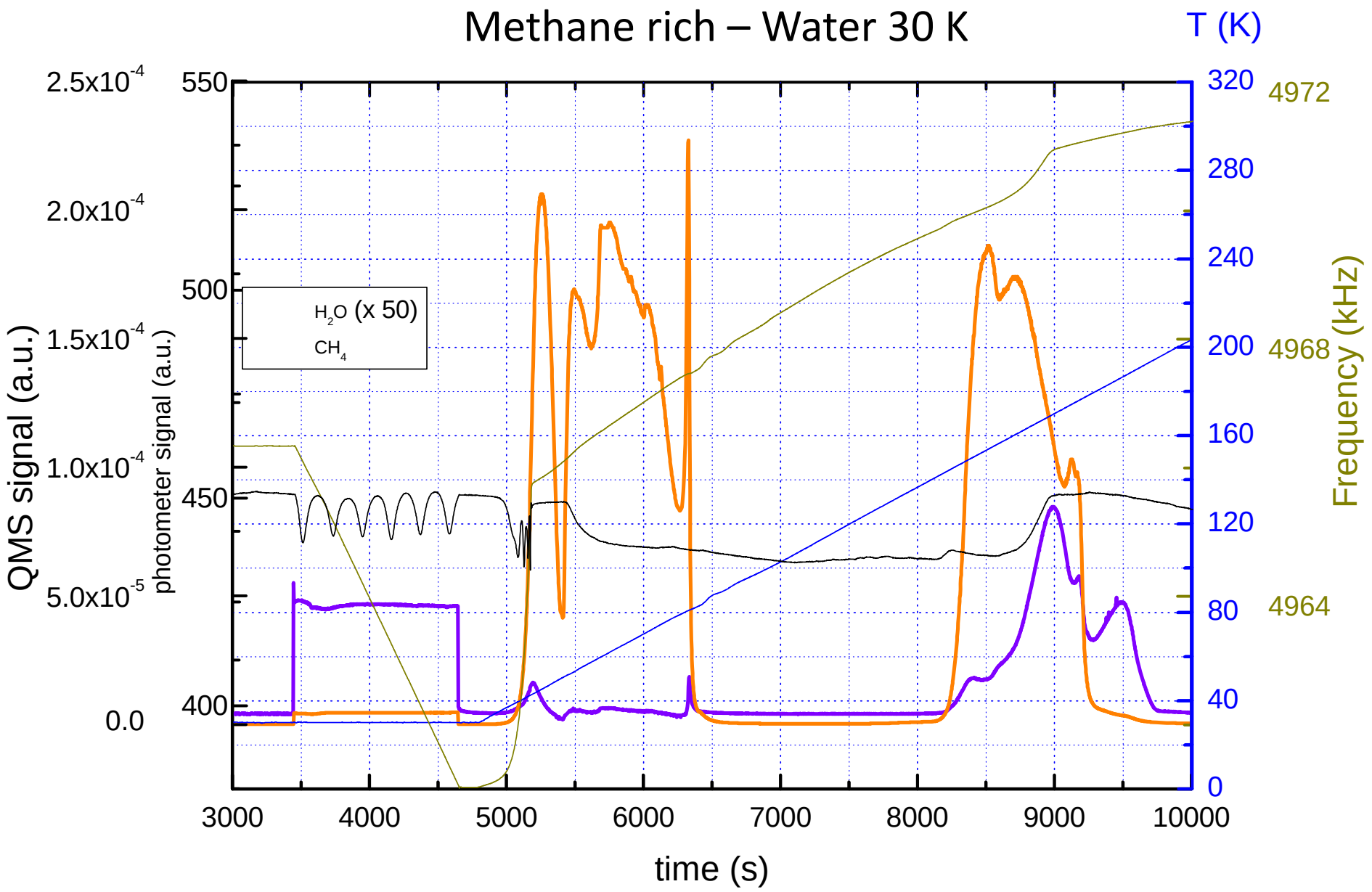


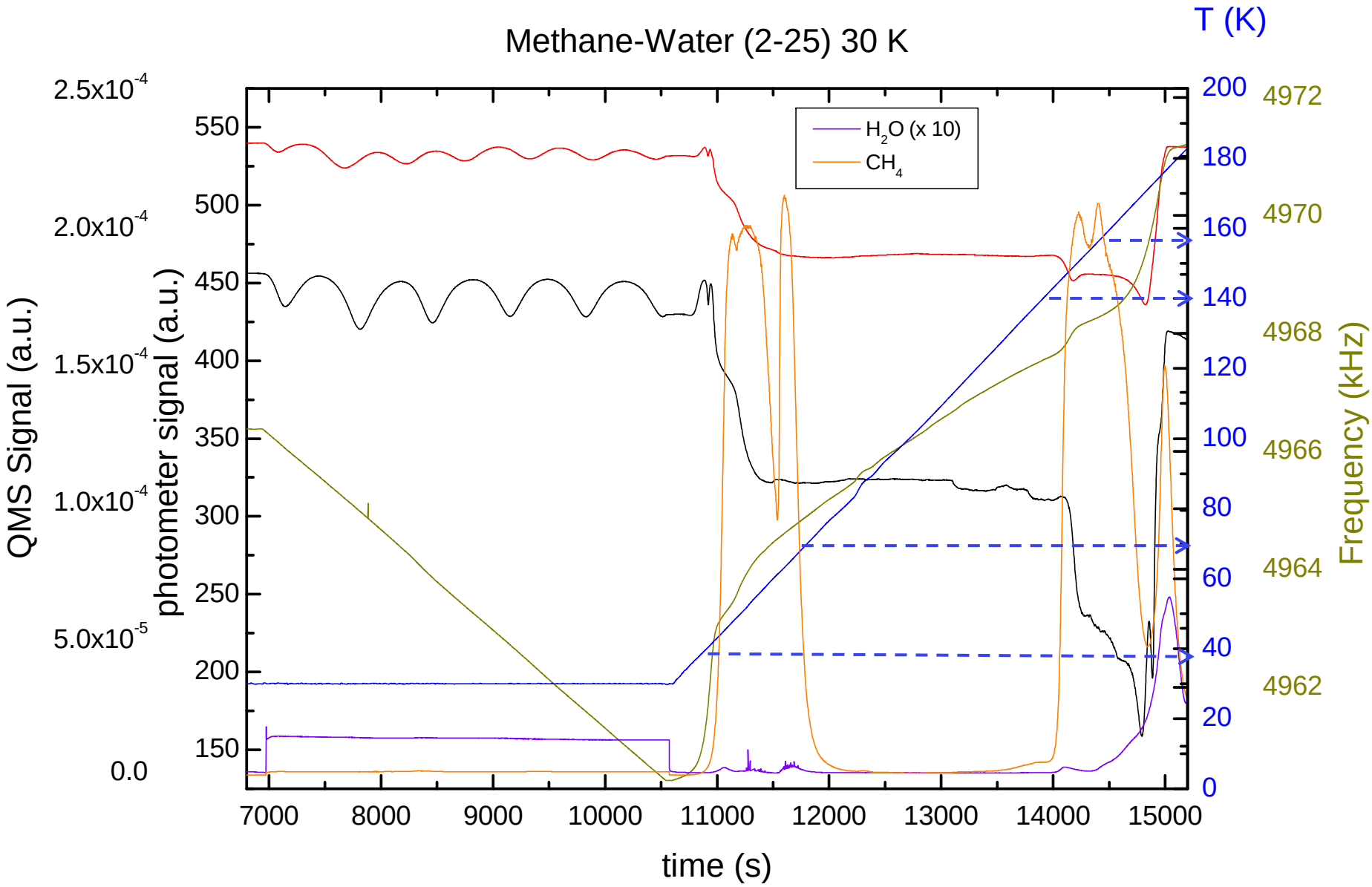
Luna et al Ap&SS 2008, 314, 113-119

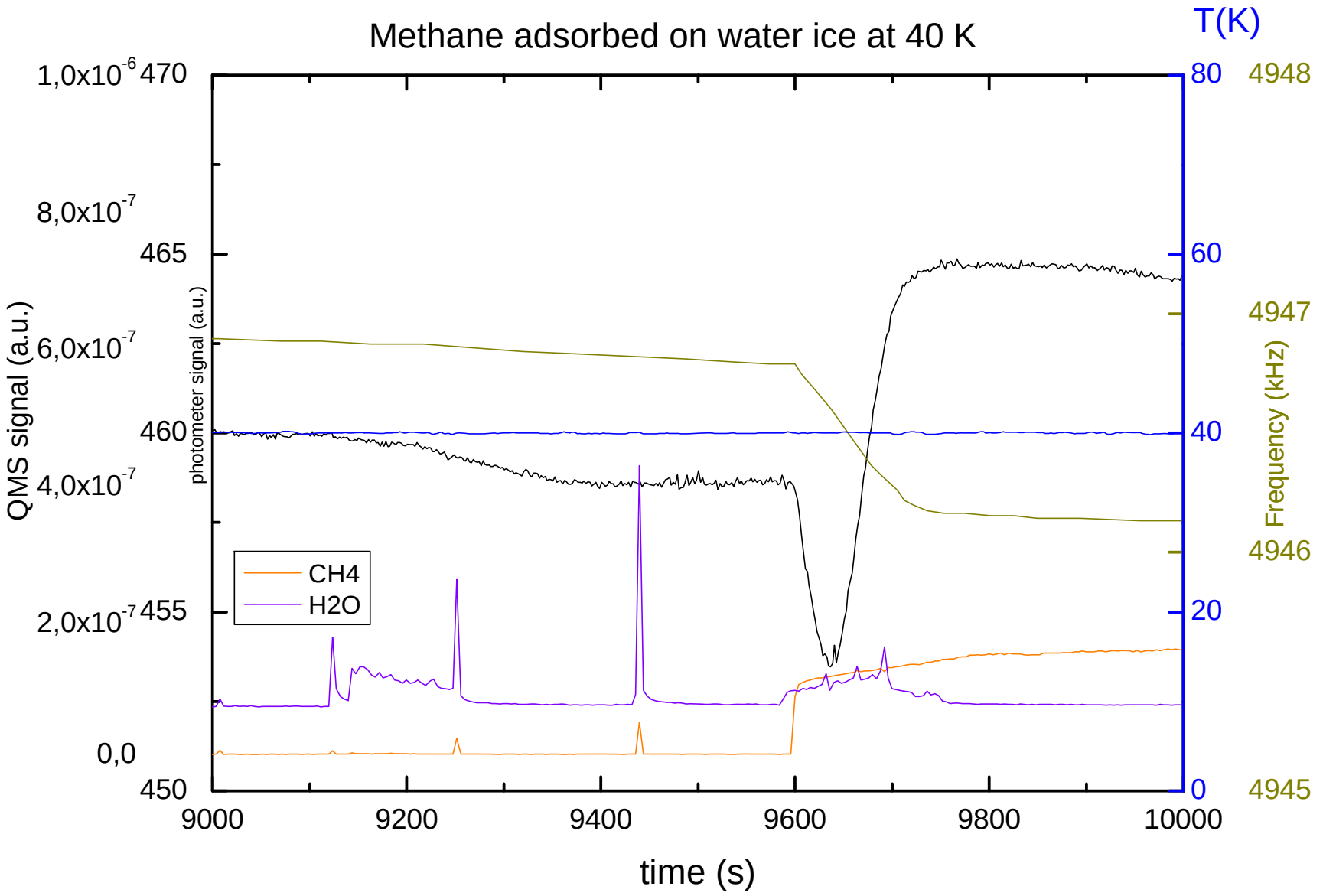
Structural changes in water ice



Jenniskens and Blake, Science, 1994, 265, 753-756


Methane rich – Water 30 K
T (K)
Frequency (kHz)
QMS signal (a.u.)
photometer signal (a.u.)
time (s)
H2O (x 50)
CH4
2.5x10-4
2.0x10-4
1.5x10-4
1.0x10-4
5.0x10-5
0.0
550
500
450
400
320
280
240
200
160
120
80
40
0
4972
4968
4964
3000
4000
5000
6000
7000
8000
9000
10000


Methane-Water (2-25) 30 K
T (K)
QMS Signal (a.u.)
photometer signal (a.u.)
Frequency (kHz)
time (s)
H2O (x 10)
CH4
2.5x10-4
2.0x10-4
1.5x10-4
1.0x10-4
5.0x10-5
0.0
550
500
450
400
350
300
250
200
150
200
180
160
140
120
100
80
60
40
20
0
4972
4970
4968
4966
4964
4962
7000
8000
9000
10000
11000
12000
13000
14000
15000


Methane adsorbed on water ice at 40 K
T(K)
QMS signal (a.u.)
photometer signal (a.u.)
Frequency (kHz)
time (s)
CH4
H2O
1,0x10-6
8,0x10-7
6,0x10-7
4,0x10-7
2,0x10-7
0,0
470
465
460
455
450
80
60
40
20
0
4948
4947
4946
4945
9000
9200
9400
9600
9800
10000

Conclusions

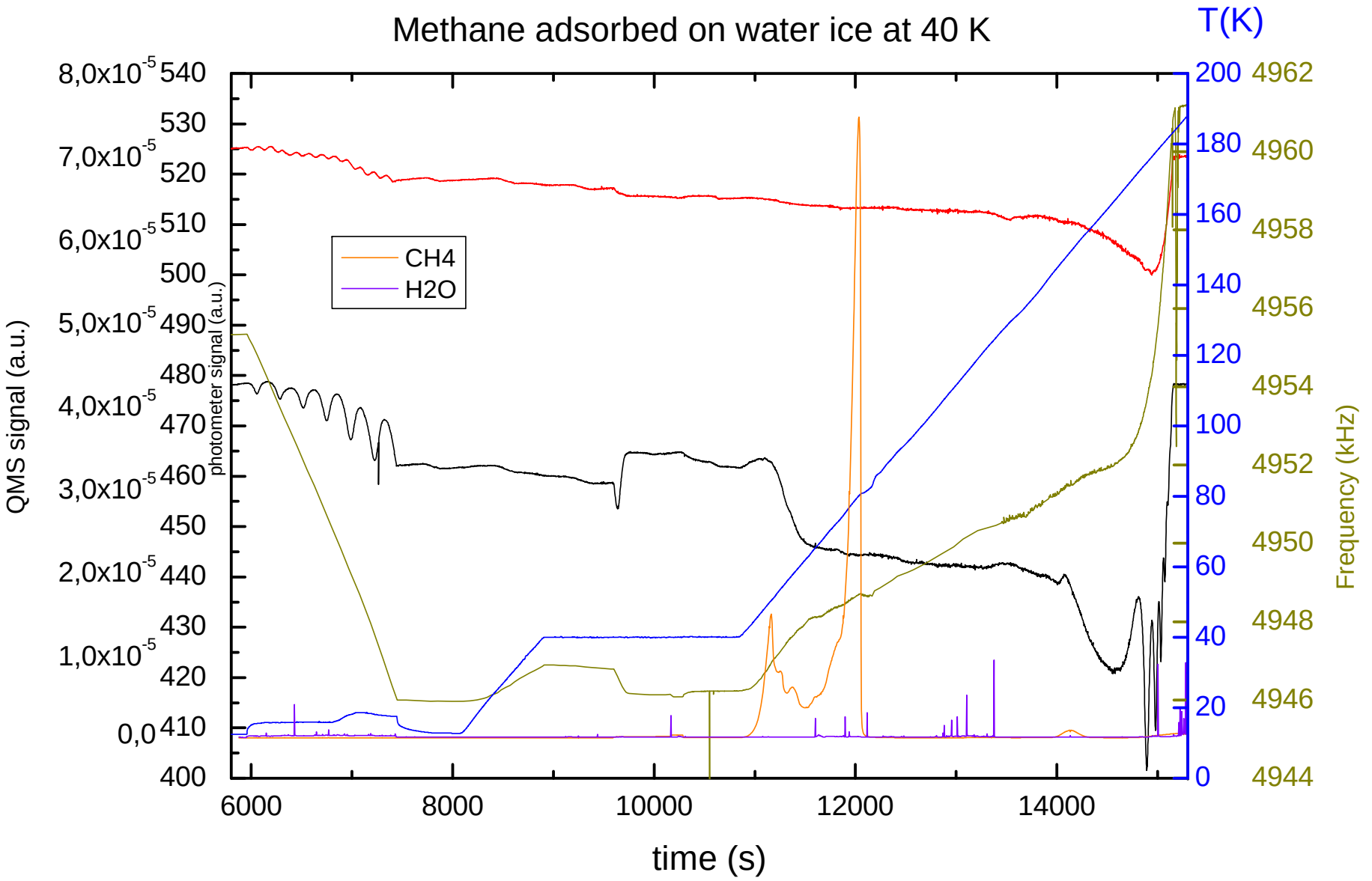
- Carbon dioxide and water retain efficiently methane within their structures
- Structural changes occur during temperature variations causing methane release
- CO_2 and H_2O ices present porous structures that can adsorb atmospheric CH_4. It is not necessary co-deposition

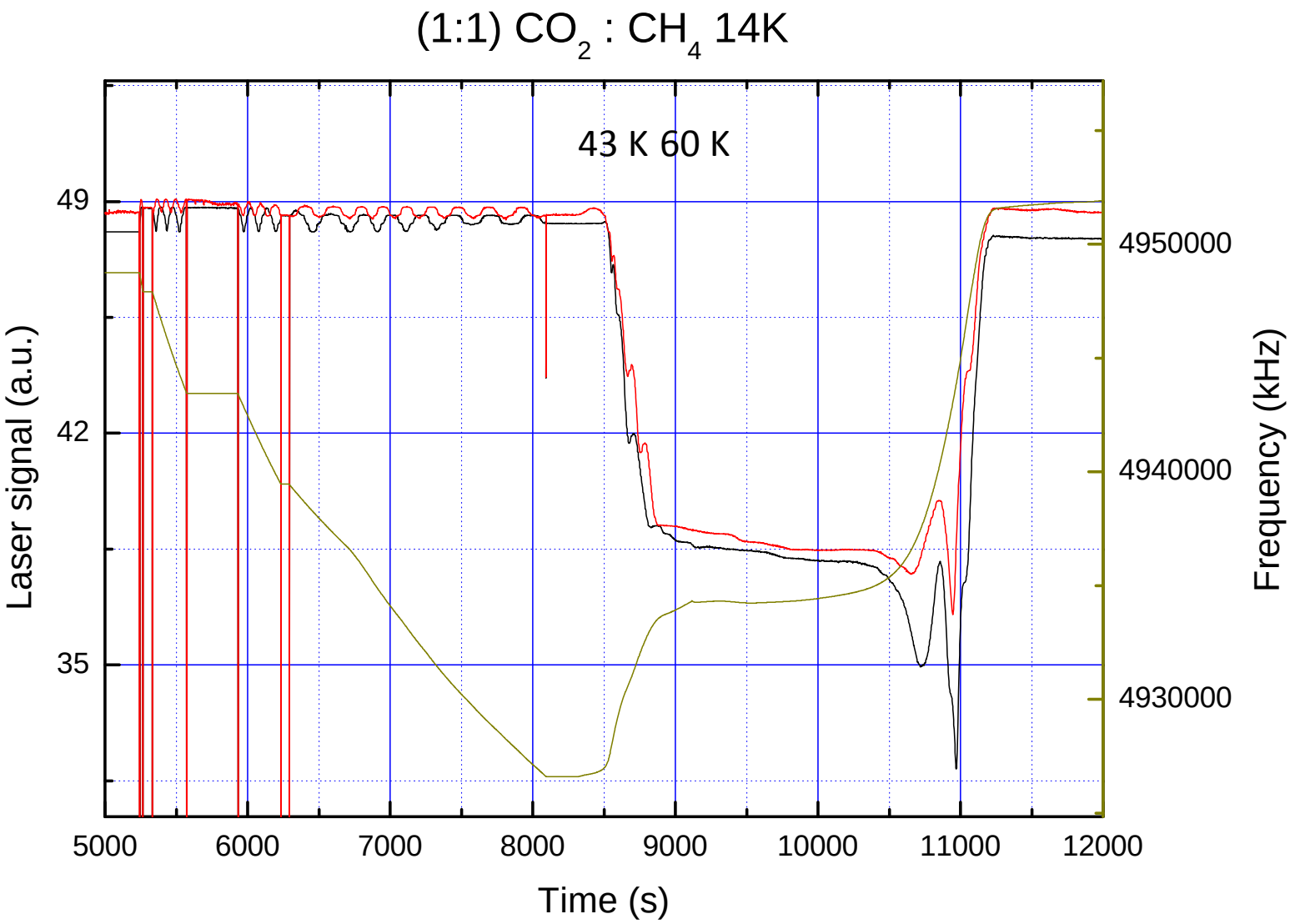
The hope is that if we do understand the ice crystal we shall ultimately understand the glacier. R. P. Feynman (1965).

One intriguing question whose answer I would like to know

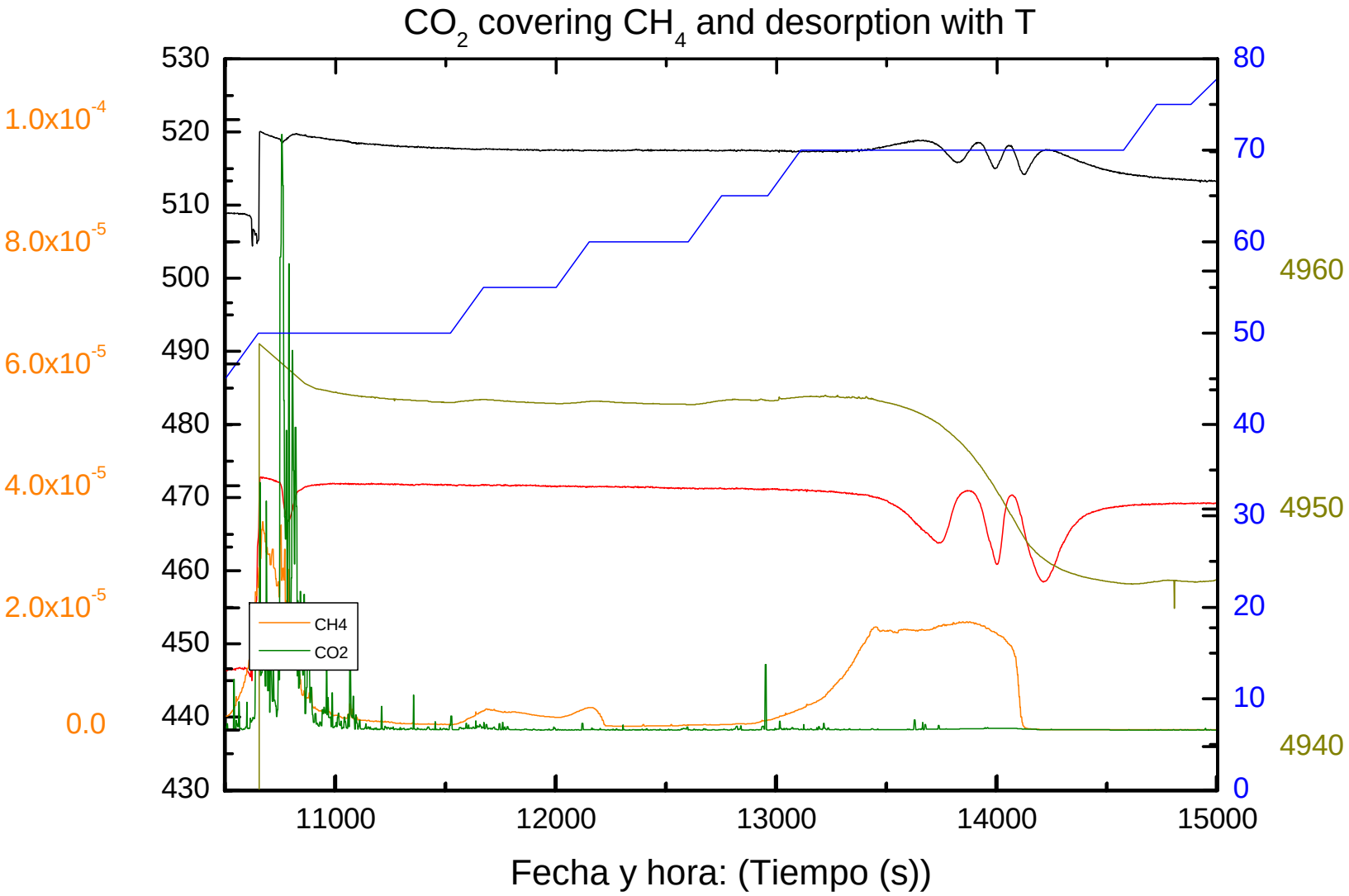
- Are those results useful for you?
- How can we fit our experiments to become relevant for Mars research?

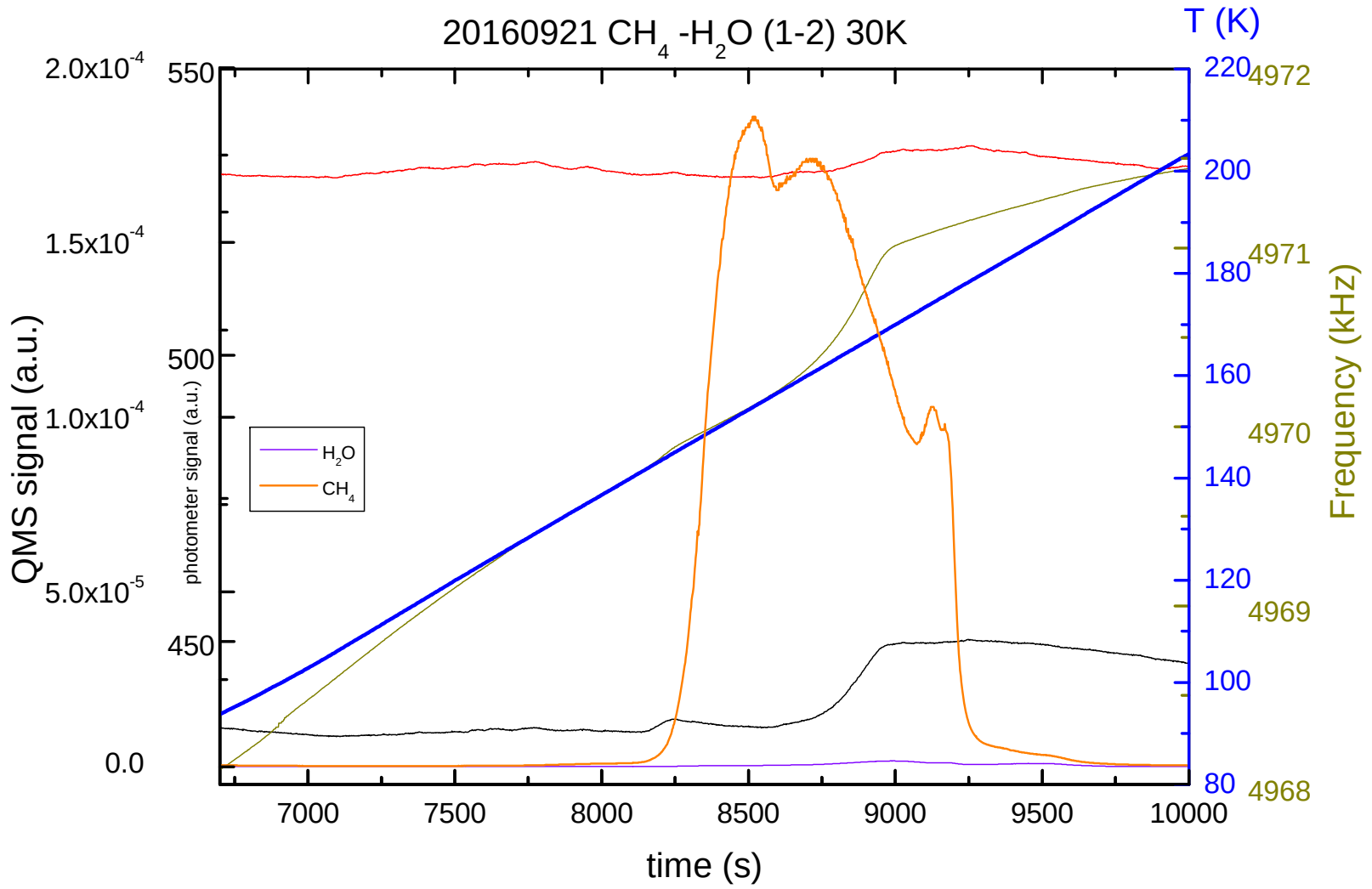
Acknowledgements. MICIN and Feder Funds FIS2016-77726-C3-3-P and FIS2013-48087-C2-2-P

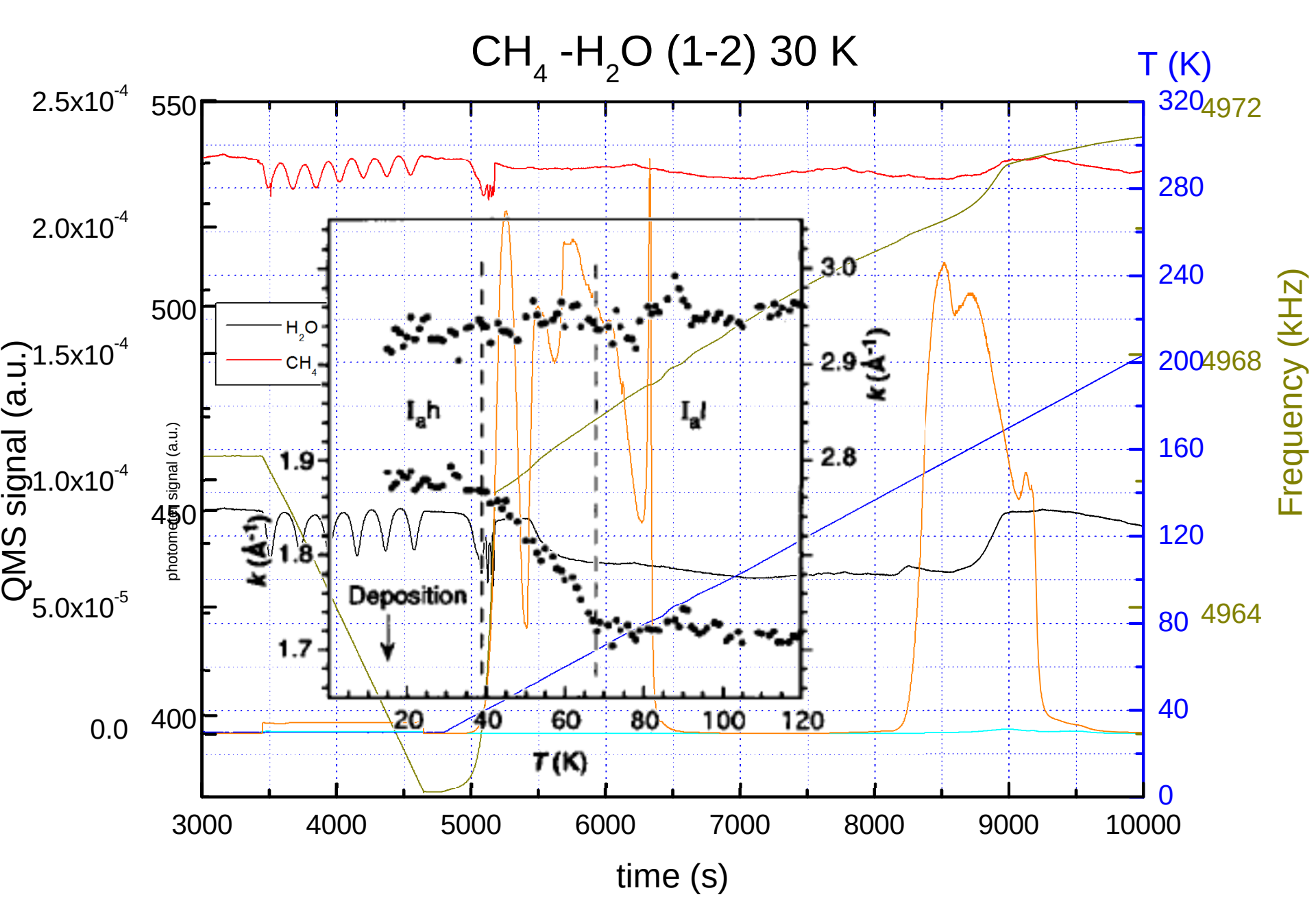

Methane adsorbed on water ice at 40 K
T(K)
QMS signal (a.u.)
photometer signal (a.u.)
Frequency (kHz)
time (s)
CH4
H2O
8,0x10-5
7,0x10-5
6,0x10-5
5,0x10-5
4,0x10-5
3,0x10-5
2,0x10-5
1,0x10-5
0,0
540
530
520
510
500
490
480
470
460
450
440
430
420
410
400
200
180
160
140
120
100
80
60
40
20
0
4962
4960
4958
4956
4954
4952
4950
4948
4946
4944
6000
8000
10000
12000
14000


(1:1) CO2 : CH4 14K
43 K 60 K
Laser signal (a.u.)
49
42
35
Frequency (kHz)
4950000
4940000
4930000
5000
6000
7000
8000
9000
10000
11000
12000
Time (s)

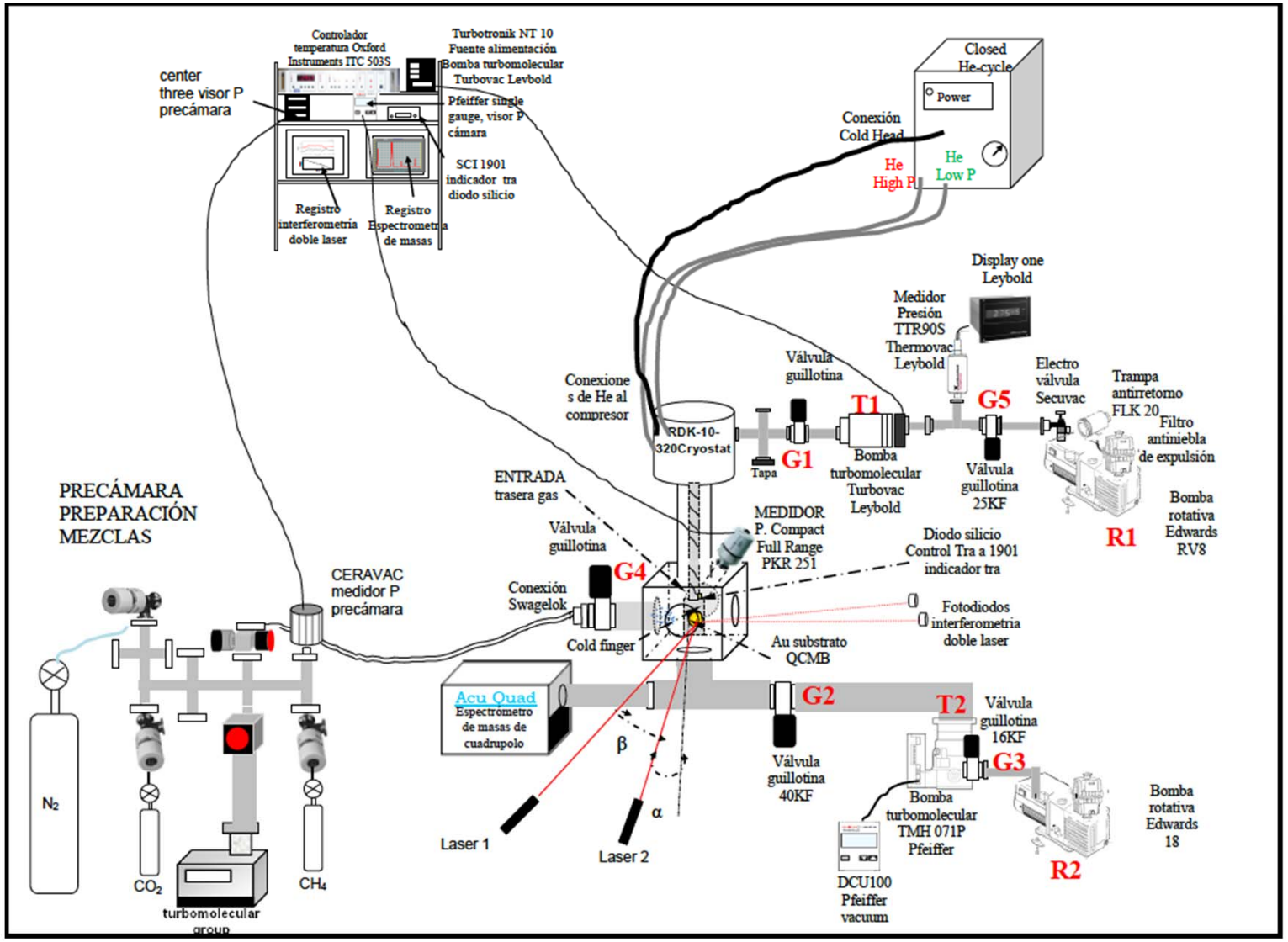
CH_4 beneath CO_2 release at constant T

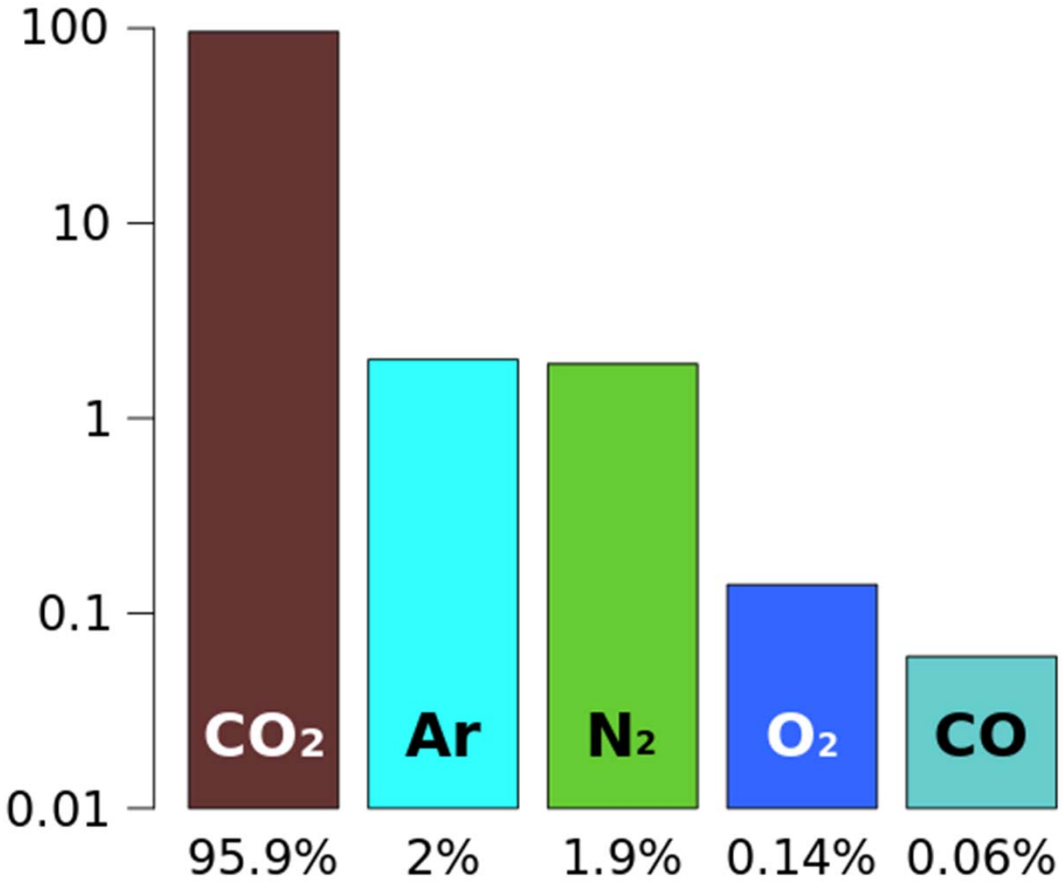



20160921 CH4 -H2O (1-2) 30K
T (K)
QMS signal (a.u.)
photometer signal (a.u.)
Frequency (kHz)
time (s)
H2O
CH4
2.0x10-4
1.5x10-4
1.0x10-4
5.0x10-5
0.0
550
500
450
220
200
180
160
140
120
100
80
4972
4971
4970
4969
4968
7000
7500
8000
8500
9000
9500
10000


CH4 -H2O (1-2) 30 K
T (K)
Frequency (kHz)
QMS signal (a.u.)
photometer signal (a.u.)
time (s)
H2O
CH4
Deposition
Ia h
Ia l
k (Å-1)
T (K)

Experimental set-up





Data credit: NASA/JPL-Caltech, SAM/GSFC

Main Estructural Changes

- Crystallization (50 K)
- Compaction (70 K)
- Desorption (90 K)

- High to low intrinsic density (50-60 K)
- Crystallization and restrained amorphous water (150 K)
- Desorption (175 K)

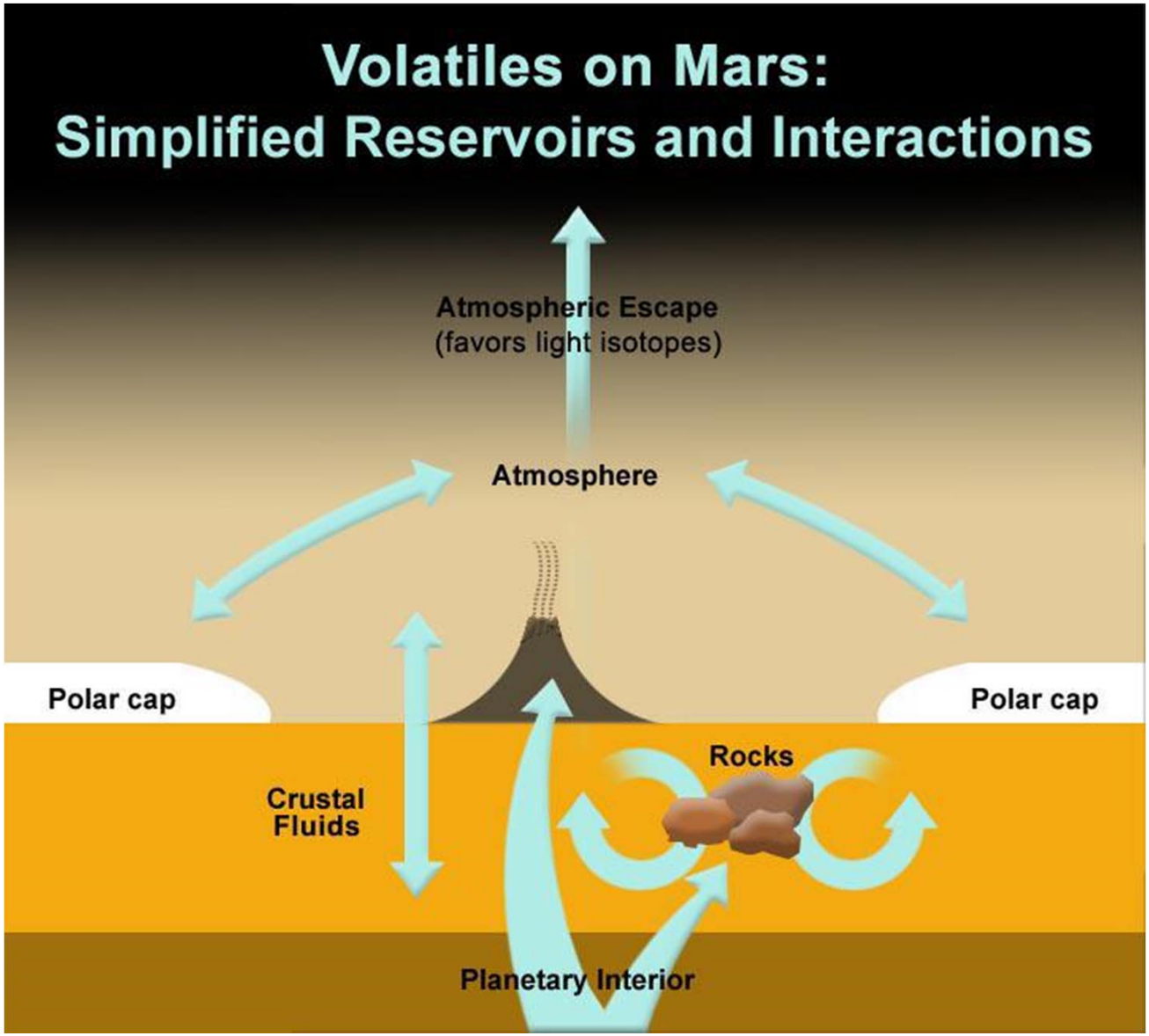
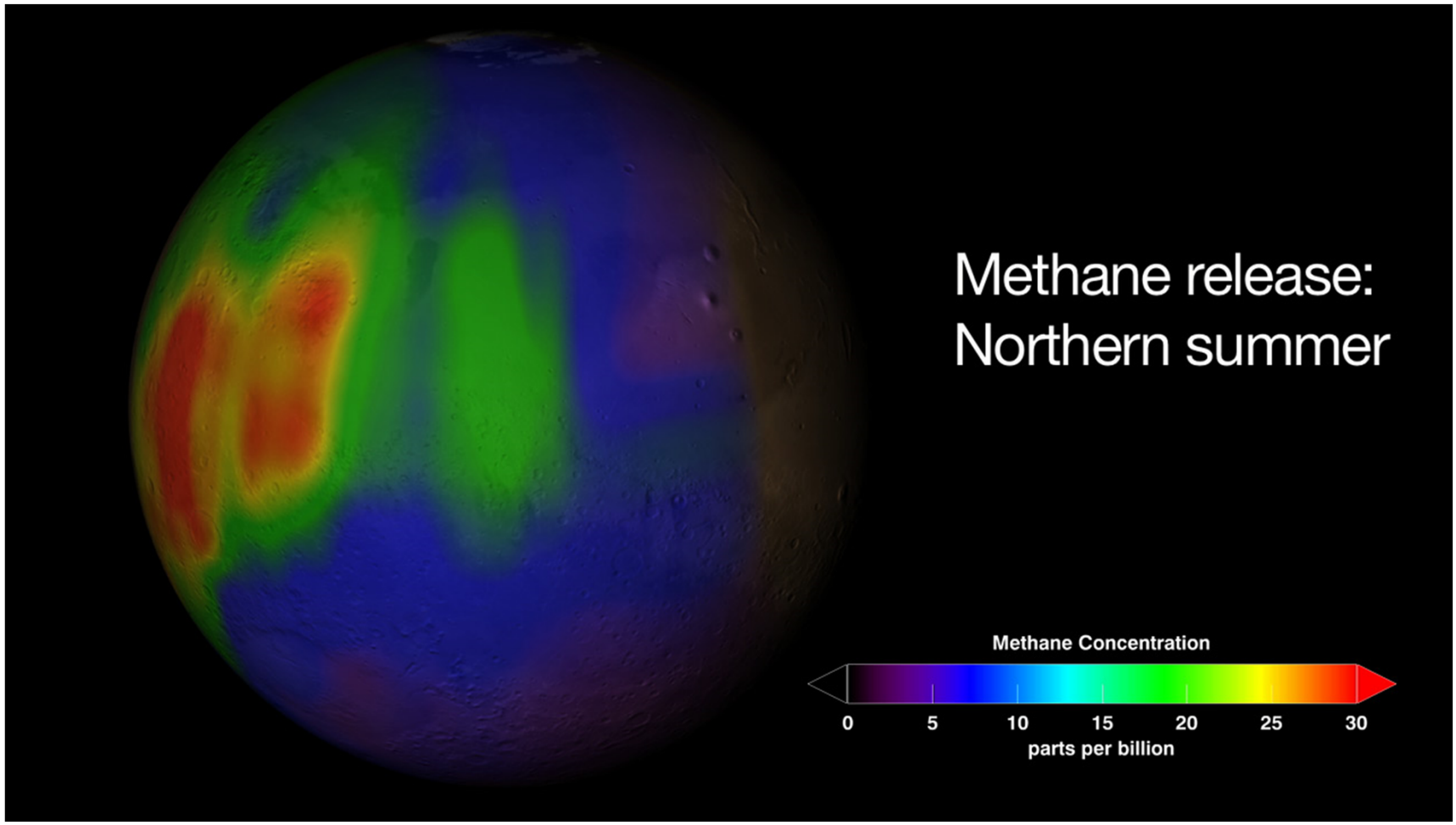
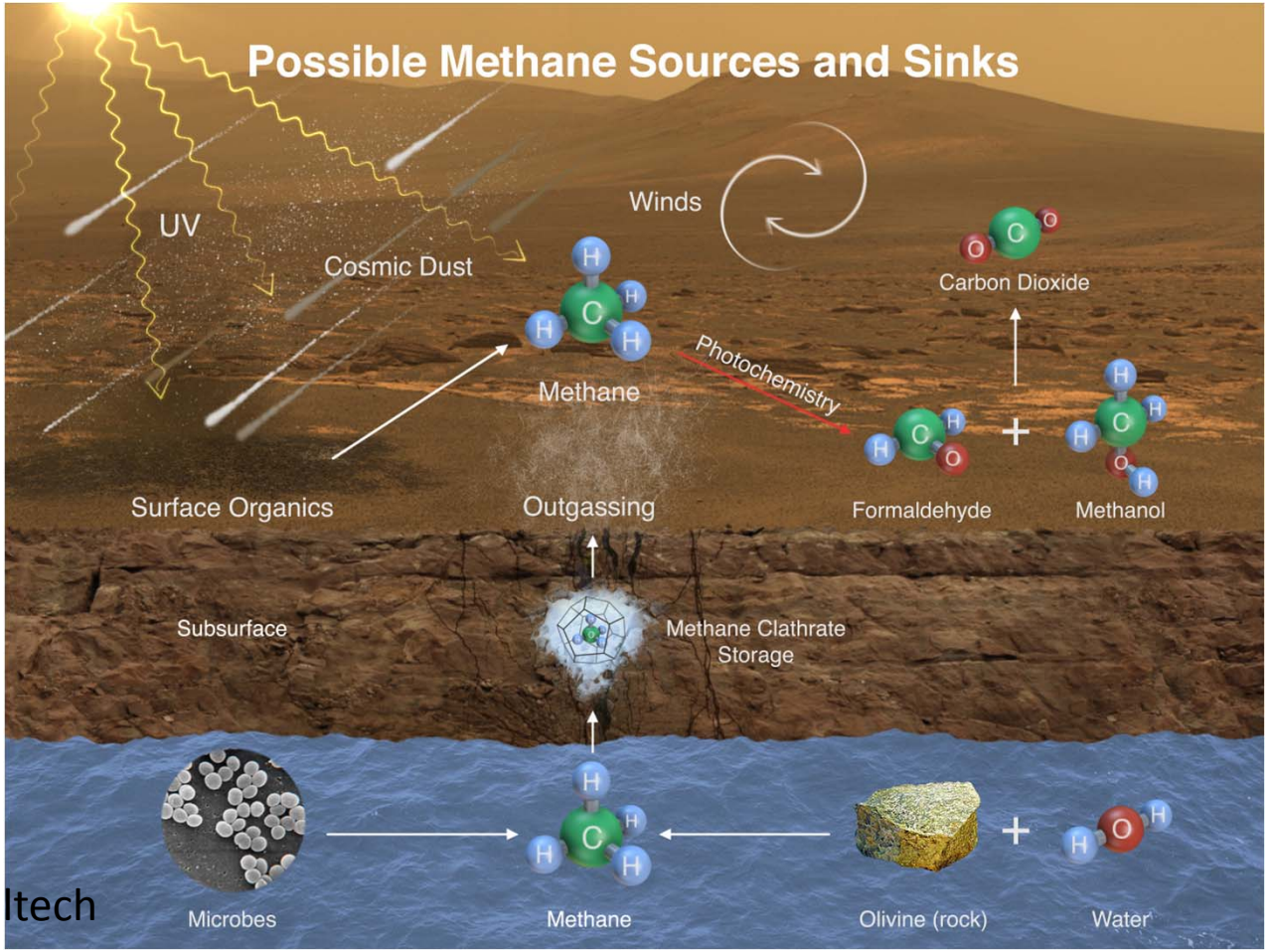


Image Credit: NASA/JPL-Caltech

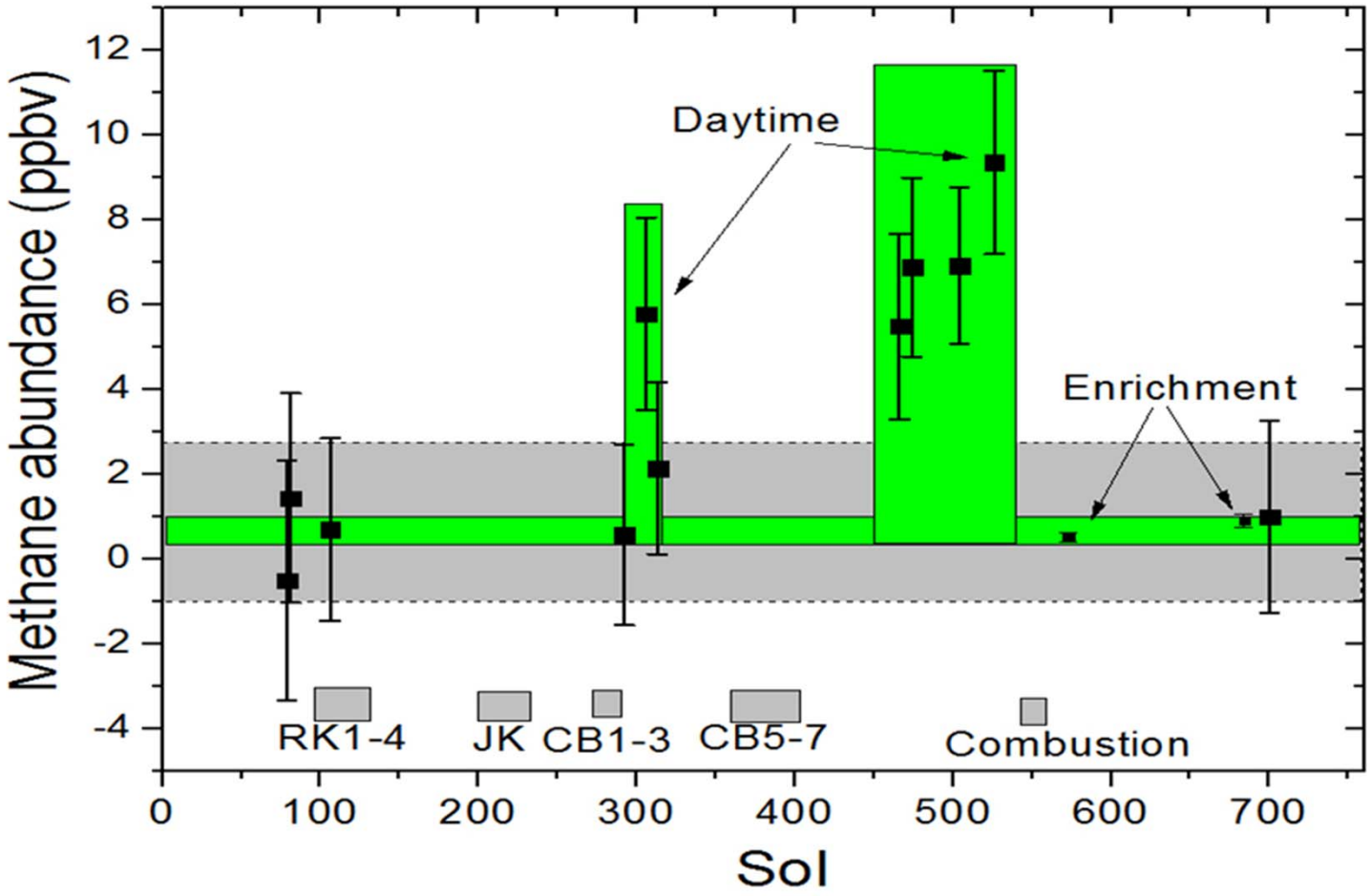
- Average temperatures 218 K; equator at noon 293 K; poles 120 K (even 70 K crater see ref)



NASA/Trent Schindler



NASA/JPL-Caltech


Methane abundance (ppbv)
12
10
8
6
4
2
0
-2
-4
Daytime
Enrichment
RK1-4
JK
CB1-3
CB5-7
Combustion
0
100
200
300
400
500
600
700
Sol

Deposition and sublimation: laser interferometry, QCMB and QMS

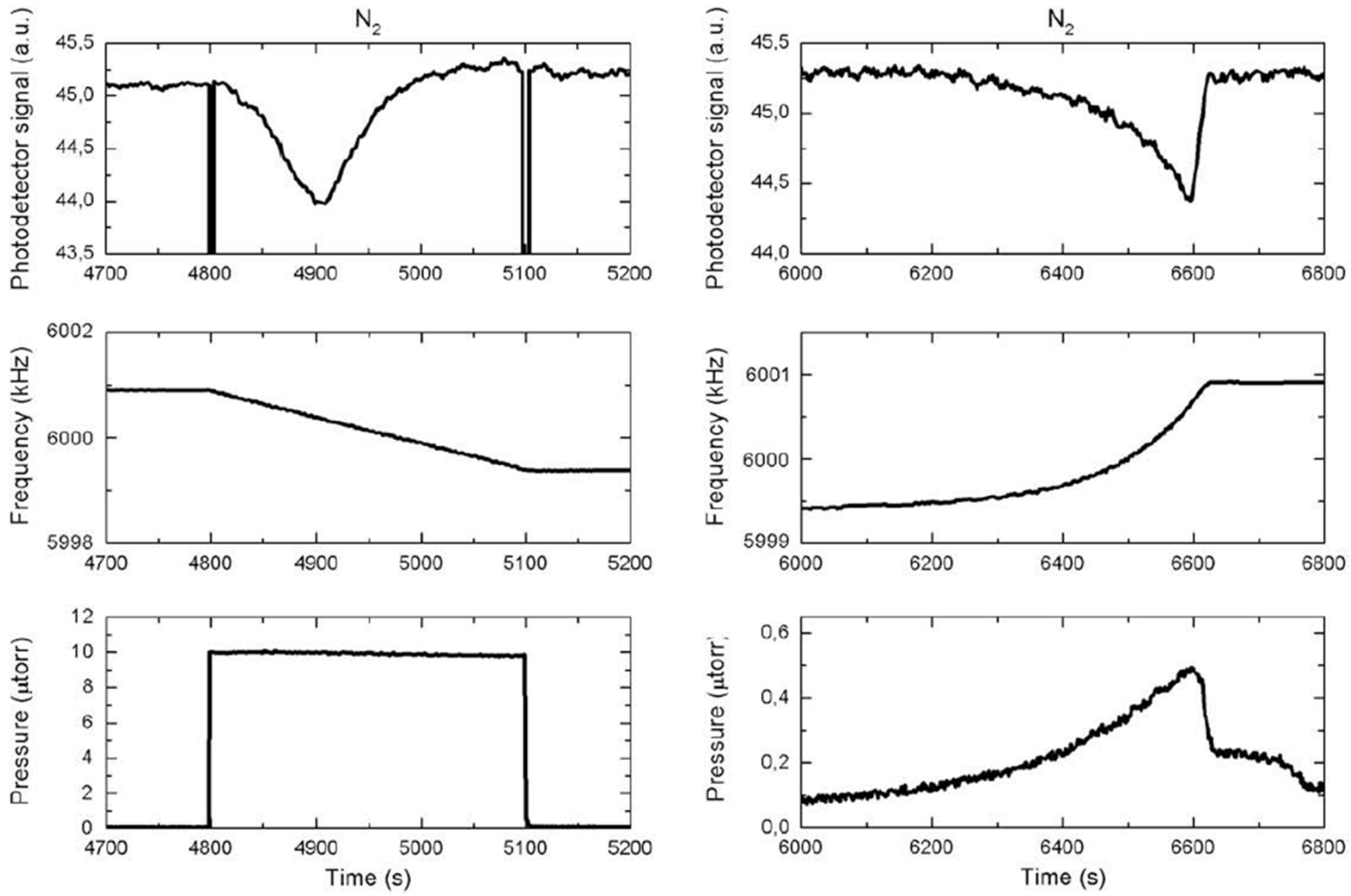


Table 1. Published values of the refractive indices and densities of pure ices at low temperatures.

Molecule	T° (K)	Refractive index at 632.8 nm	Density (g cm^{-3})	Reference
H_2O	82		0.81	Seiber et al. 1970
	30–135		0.94	Ghormley & Hochanad 1971
	10		1.1	Narten 1976
	77		0.94	Narten 1976
	20–50–80	1.32		Wood & Roux 1982
	20–140	1.316		Warren 1986
	82	1.26	0.80 ± 0.01	Berland et al. 1995
	20	1.19	0.6	Brown et al. 1996
	90	1.27	0.8	Brown et al. 1996
	130	1.31	0.93	Brown et al. 1996
	20–140	1.29 ± 0.01	0.82 ± 0.01	Westley, Baratta & Baragiola 1998
	22	1.285 at $< 40^{\circ}$	0.94 at $< 40^{\circ}$	Dohnalek et al. 2003[a]
	22	1.27 at 45°	0.87 at 45°	Dohnalek et al. 2003[a]
	22	1.05 at 86°	0.16 at 86°	Dohnalek et al. 2003[a]
	80	1.29 ± 0.01		Romanescu et al. 2010
CO_2	25	1.3	1.15	Schulze & Abe 1980
	20	1.28	1.08	Wood & Roux 1982
	25	1.25	1.1	Satorre et al. 2008
CO	20	1.22 ± 0.02		Pipes et al. 1978
	20	1.27	0.80	Roux et al. 1980
CH_4	20	1.38 ± 0.02		Pipes et al. 1978
	20	1.35	0.426	Roux et al. 1980
	10–35	1.30 ± 0.02	0.47	Satorre et al. 2008
	16	1.329	0.403	Brunetto et al. 2008
NH_3	20	1.42 ± 0.02		Pipes et al. 1978
	20	1.37	0.76	Wood & Roux 1982
	25	1.44 ± 0.1		Dawes et al. 2007
	20	1.40 ± 0.03	0.72 ± 0.05	Satorre et al. 2013
	15	1.36 ± 0.01		Zanchet et al. 2013
	30	1.38 ± 0.01		