Exploration of Spacecraft Environments with Mass Spectrometers

Experiences with ROSETTA, SOHO and others

Peter Bochsler
Physikalisches Institut
University of Bern
Bern /Switzerland
Bochsler@space.unibe.ch

EIT/SOHO October 15, 2019

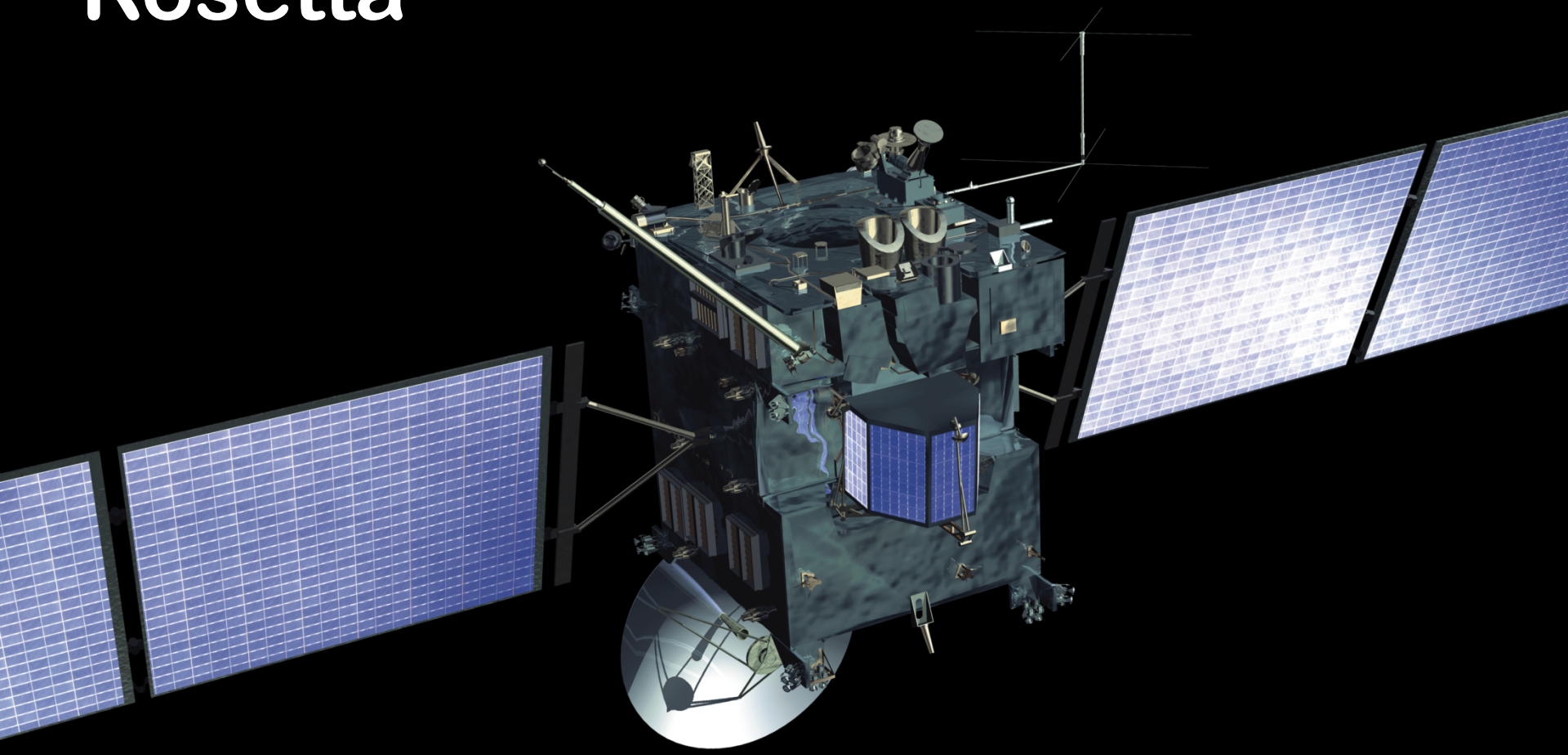
Experiences…

Degradation…

Experiences…

Rosetta/ROSINA

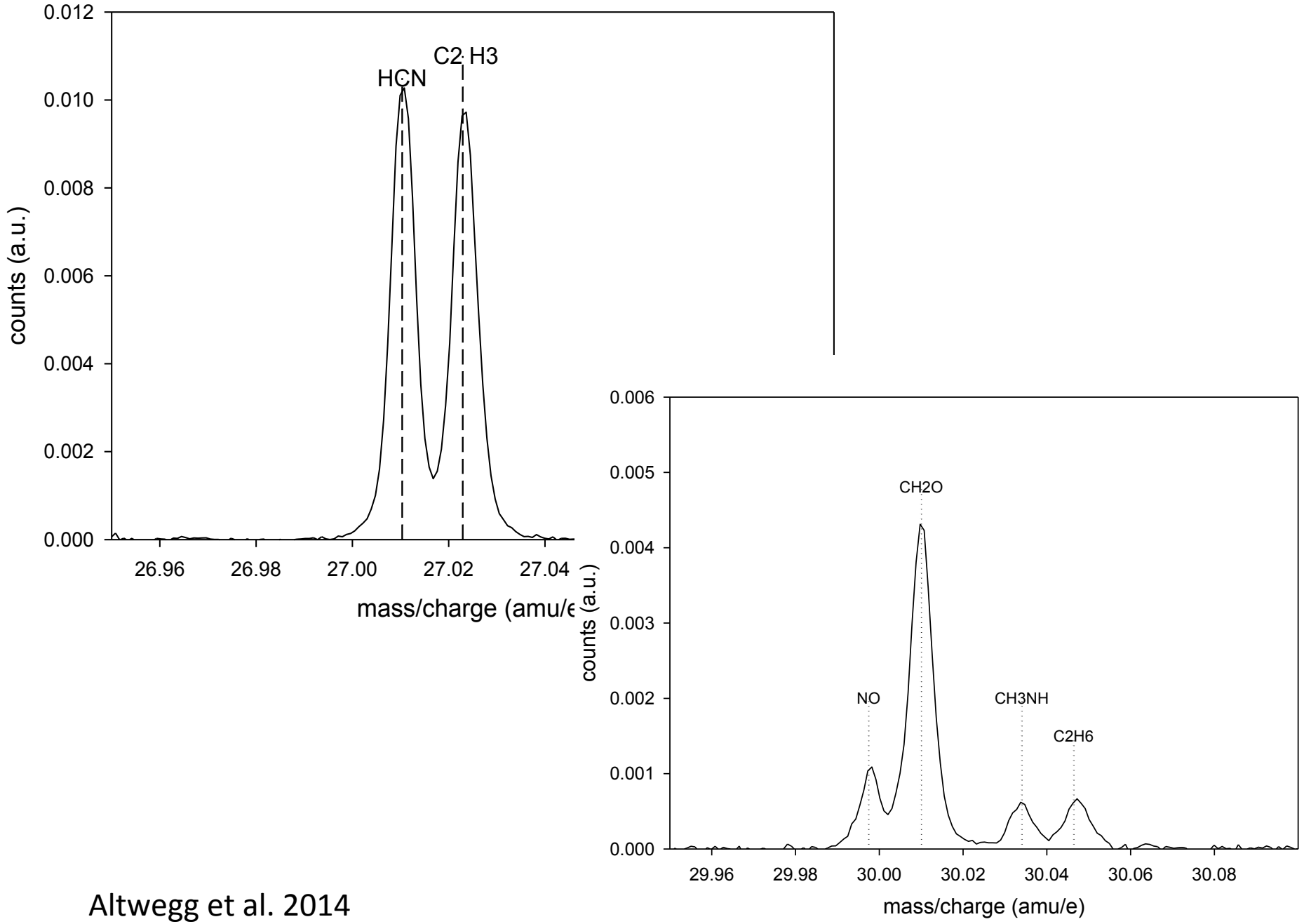
Rosetta



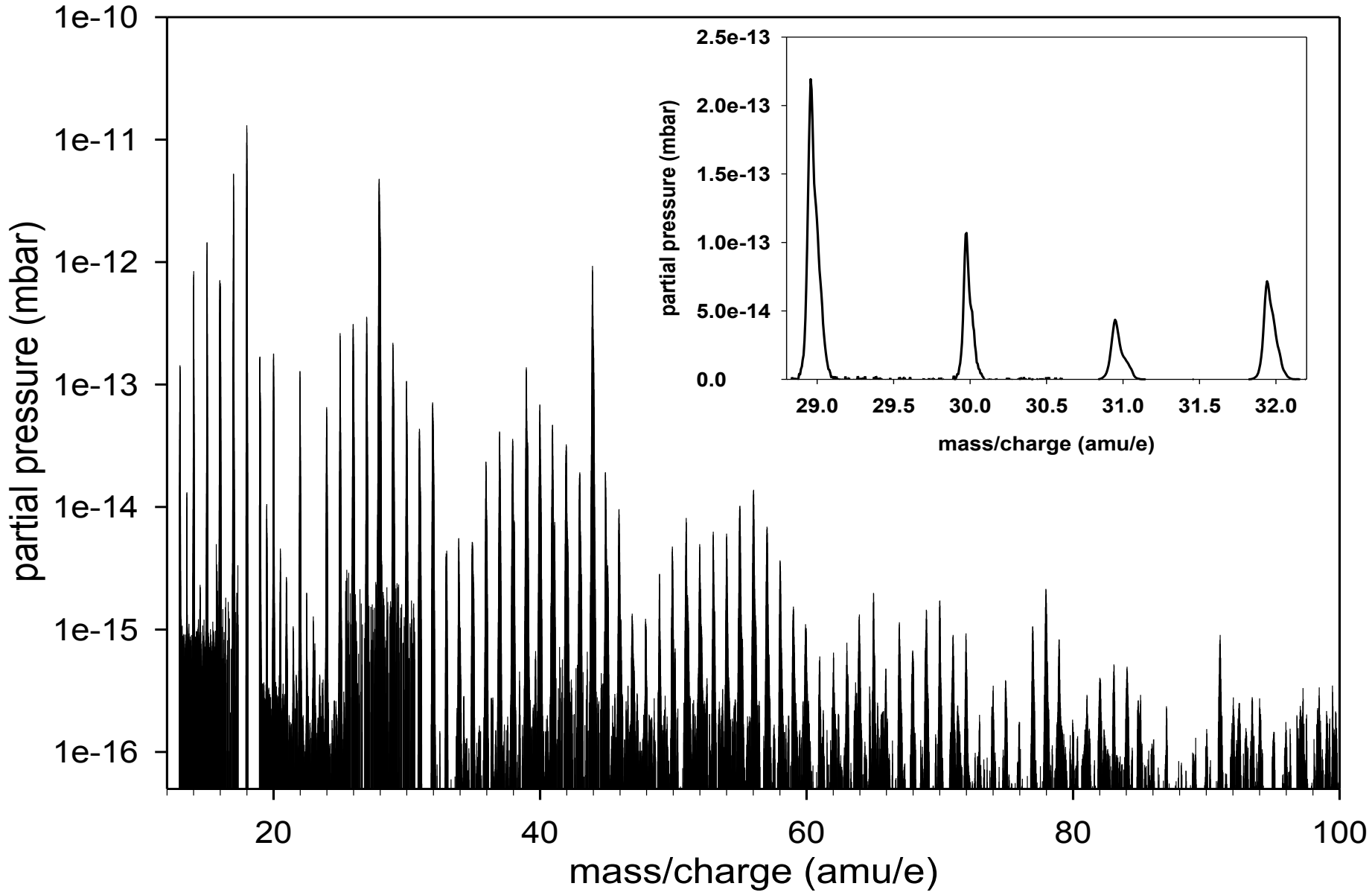
esa

DFMS

COPS



Altwegg et al. 2014



Altwegg et al. 2014

Environment of the Rosetta Spacecraft

Carbohydrates				
	C2	C_3	C_4	C_5
CH	C_2H	C_3H	C_4H	C_5H
CH_2	C_2H_2	C_3H_2	C_4H_2	C_5H_2
CH_3	C_2H	C_3H_3	C_4H_3	C_5H_3
CH_4	C_2H_4	C_3H_4	C_4H_4	C_5H_4
	C_2H_5	C_3H_5	C_4H_5	C_4H_5
	C_2H_6	C_3H_6	C_4H_6	C_5H_6
		C_3H_7	C_4H_7	C_5H_7
		C_3H_8	C_4H_8	C_5H_8
			C_4H_9	C_5H_9
			C_4H_{10}	C_5H_{10}
				C_5H_{11}
				C_5H_{12}

PAH		
C_6H		
C_6H_2		
C_6H_3	C_7H_3	
C_6H_4	C_7H_4	
C_6H_5	C_7H_5	
	C_7H_6	
	C_7H_7	
	C_7H_8, Toluene	
	C_8H_{10}	
	C_9H_{12}	

N-H
N
NH
NH_2
NH_3
N_2

Hydrazine
CN
CHN
CH_2N
CH_3N
CH_3NH
CH_3NH_2
CH_3N_2H
$CH_3N_2H_2$
$CH_3N_2H_3$

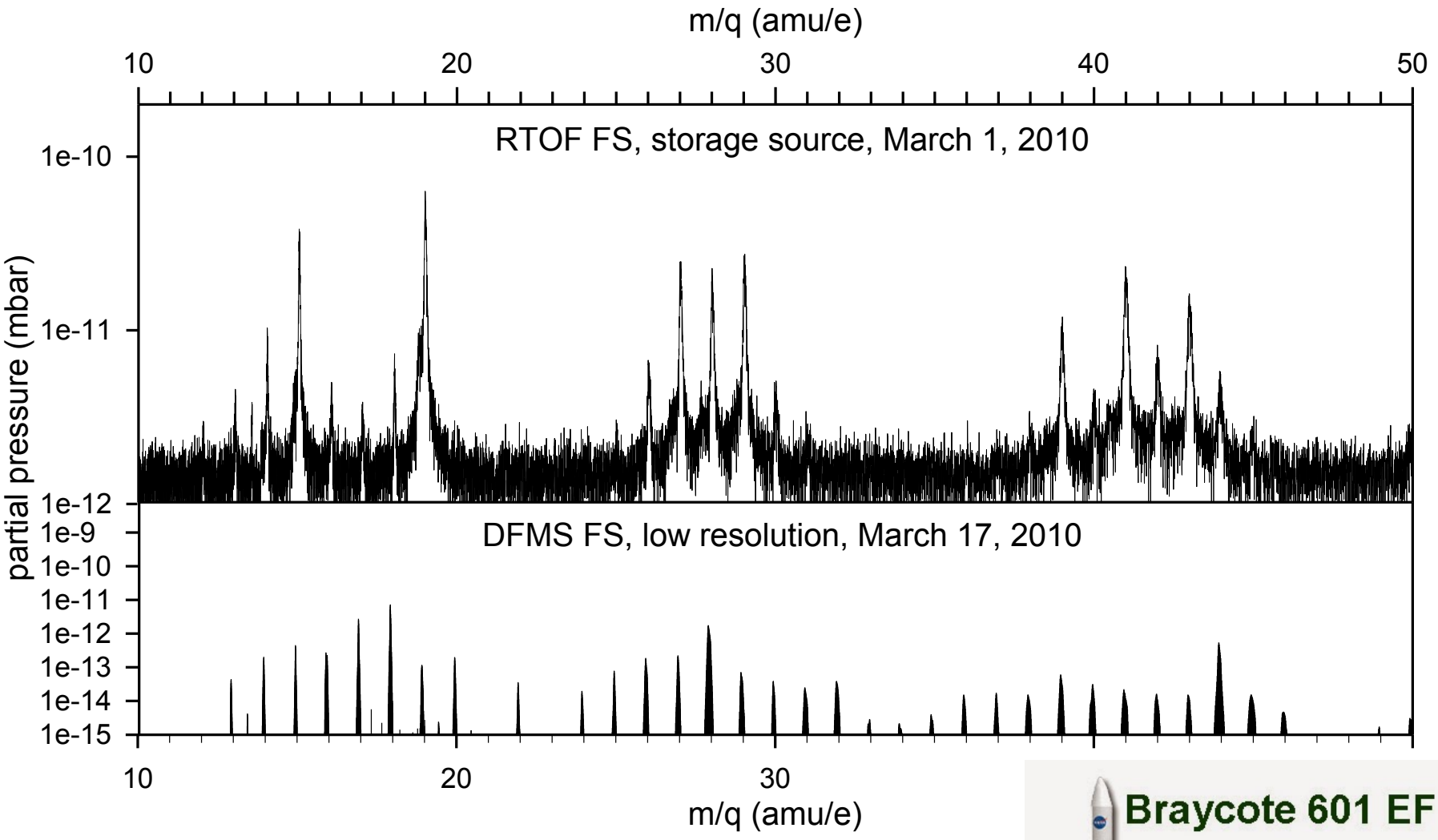
C-N	
C_2H_2N	
C_2H_3N	
C_2H_4N	
C_5H_4N	
C_5H_5N	
C_5H_6N	
C_5H_7N	
C_5H_8N	
$C_4H_4N_2$	

Oxygen	
O	
OH	
OH2	
ODH	
$^{18}OH_2$	
O2	

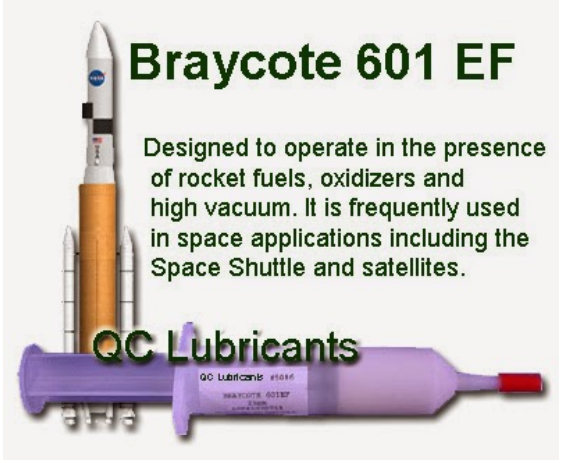
N-O
NO
CNO
HCNO
H_6CNO
NO_2
HNO_2
H_4NO_2
$CHNO_2$
CH_3NO_2
CH_4NO_2
C_2H_6NO
H_2N_2O
C_2N_2O
C_2HN_2O
$C_2H_2N_2O$
$C_2H_3N_2O$
$C_2H_5N_2O$
$C_2H_6N_2O$
$C_2H_7N_2O$
$C_2H_8N_2O$

Halogens & Sulfur	
F	Cl
FH	HCl
CF	CCl
S	CCl_2
N_2S	
SO_2	

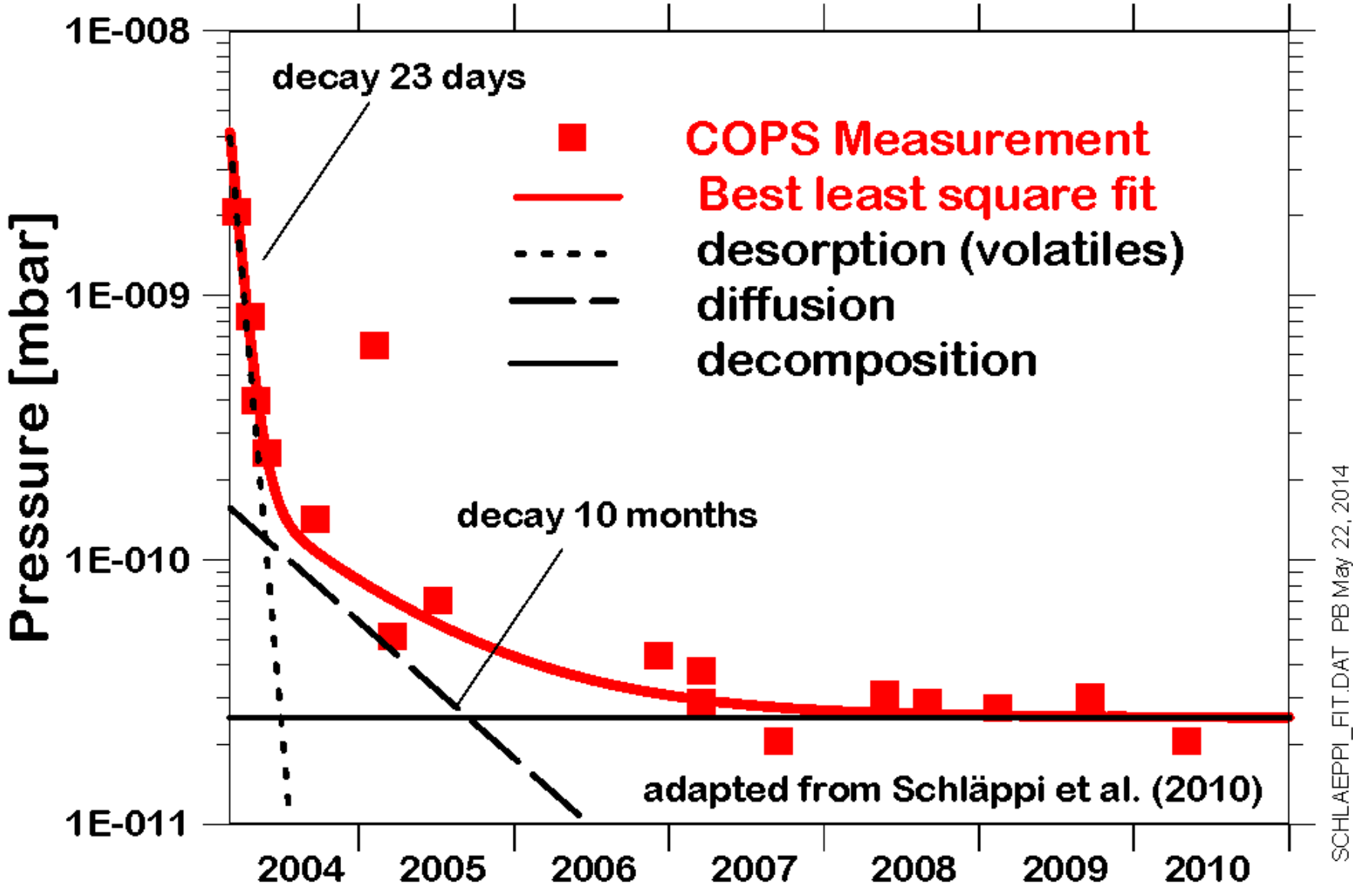
Altwegg et al. (2014)



The Braycote Problem



Altwegg et al. 2014

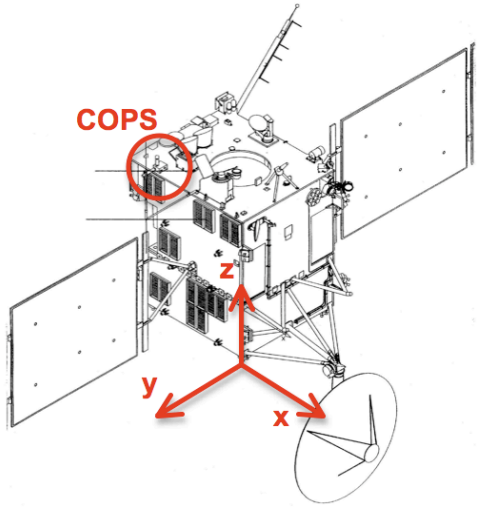

1E-008
1E-009
1E-010
1E-011
Pressure [mbar]
2004
2005
2006
2007
2008
2009
2010
decay 23 days
decay 10 months
COPS Measurement
Best least square fit
desorption (volatiles)
diffusion
decomposition
adapted from Schläppi et al. (2010)
SCHLAEPPI_FIT.DAT PB May 22, 2014

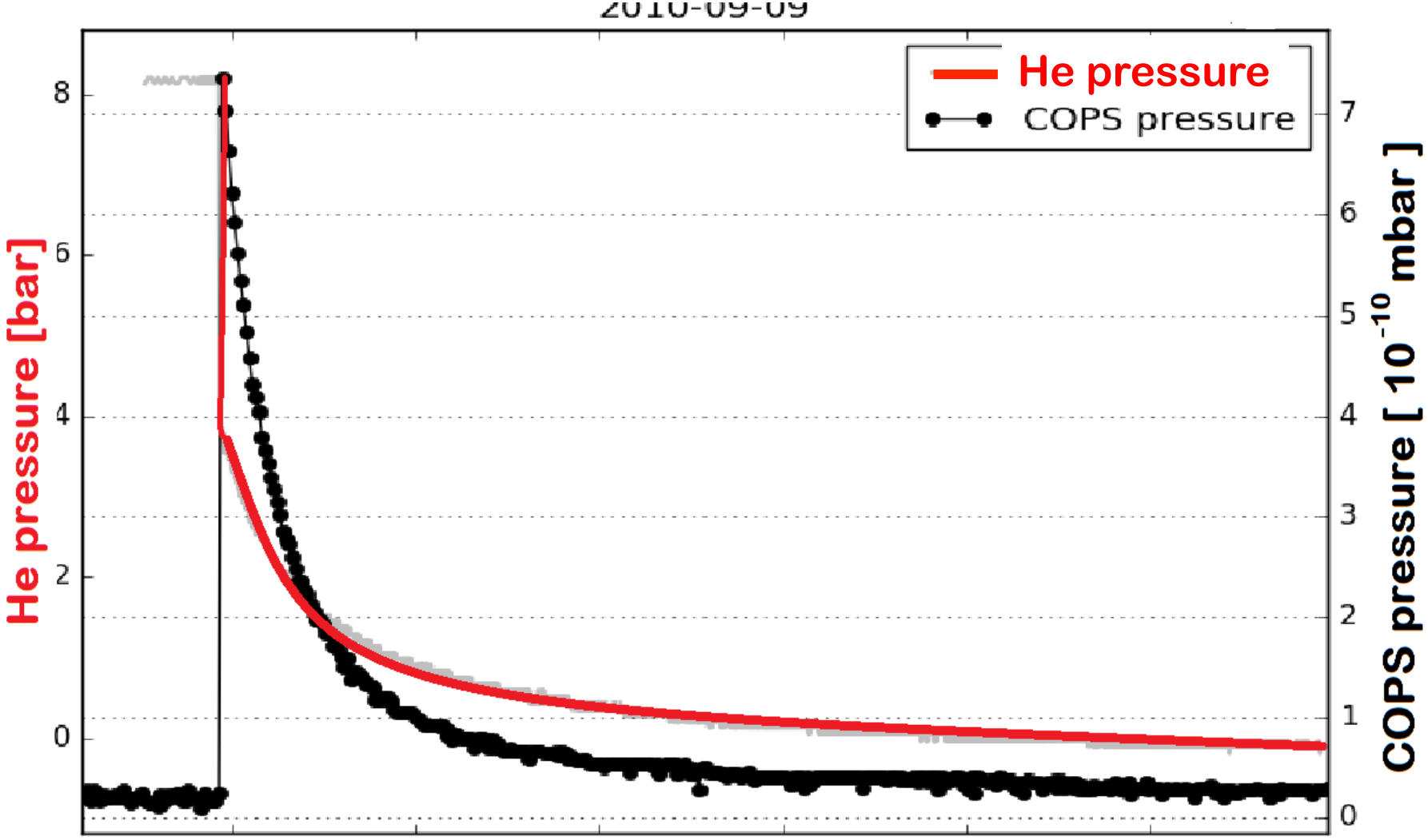
Helium measured by COPS during the thruster pressurization test on September 9, 2010

Martin Rubin, Valeriy M. Tenishev, Kenneth C. Hansen, Michael R. Combi, Tamas I. Gombosi
University of Michigan

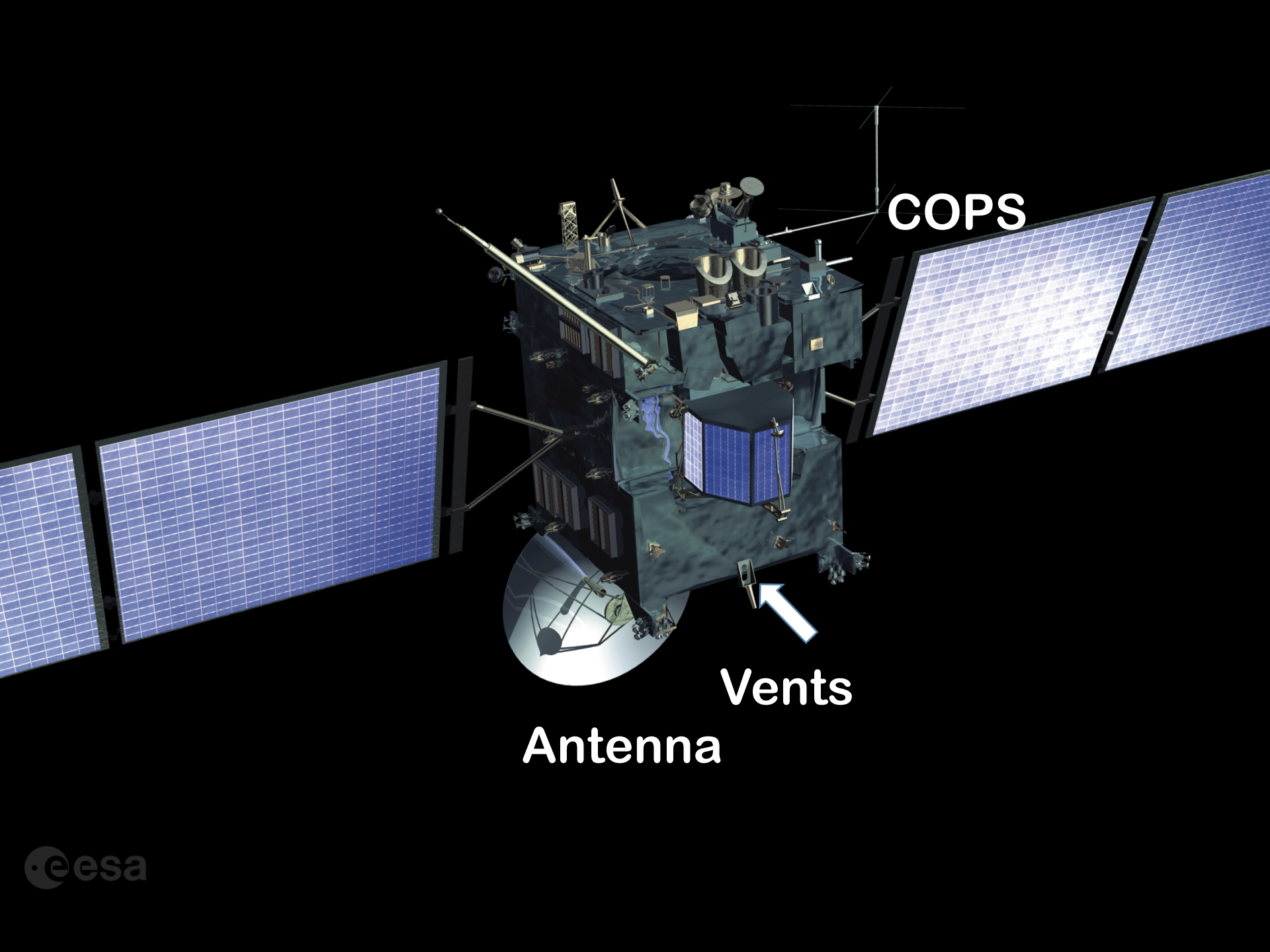
Kathrin Altwegg
University of Bern

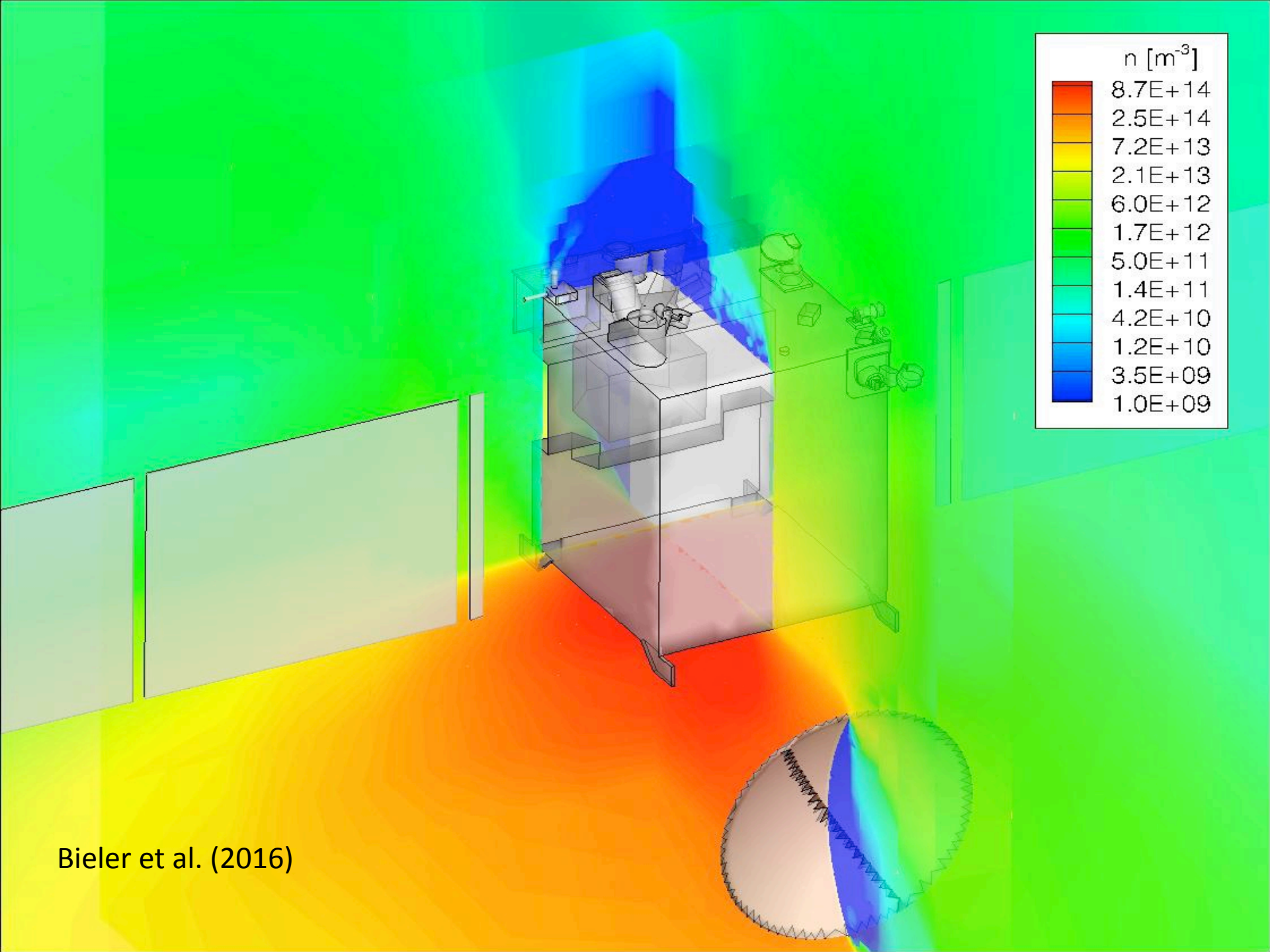
thanks to:
Andrea Accomazzo and ESA



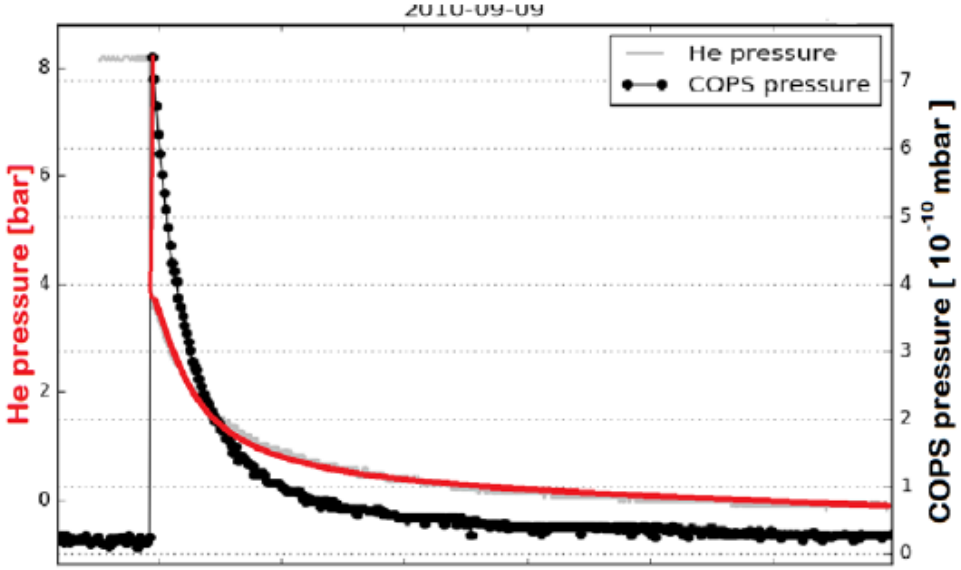


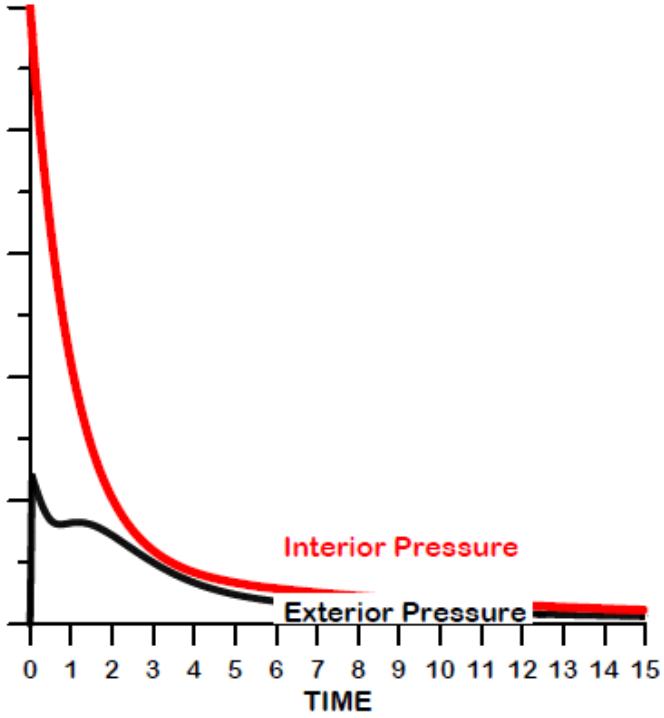
Bieler et al. (2016) SPIE 9952


COPS
Vents
Antenna
esa



Bieler et al. (2016)


2010-09-09
He pressure
COPS pressure
He pressure [bar]
COPS pressure [10^-10 mbar]
0
2
4
6
8
0
1
2
3
4
5
6
7


Interior Pressure
Exterior Pressure
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
TIME

Advances in Astronautics Science and Technology (2018) 1:183–190
https://doi.org/10.1007/s42423-018-0026-0

ORIGINAL PAPER

Influence of Ultraviolet Irradiation on the Deposition of Spacecraft Molecular Contamination

Wei Dai[1] · Jiawen Qiu[2] · Zicai Shen[3] · Yanbin Yang[3]

Received: 27 March 2018 / Revised: 3 July 2018 / Accepted: 20 August 2018 / Published online: 7 January 2019

$\dot{m}_d$ rate of deposition [g/cm^{2}s]

$\dot{m}_i$ mass flux of contaminant [g/cm^{2}s]

$$\dot{m}_d = \alpha \dot{m}_i - \frac{m_d}{\tau}$$

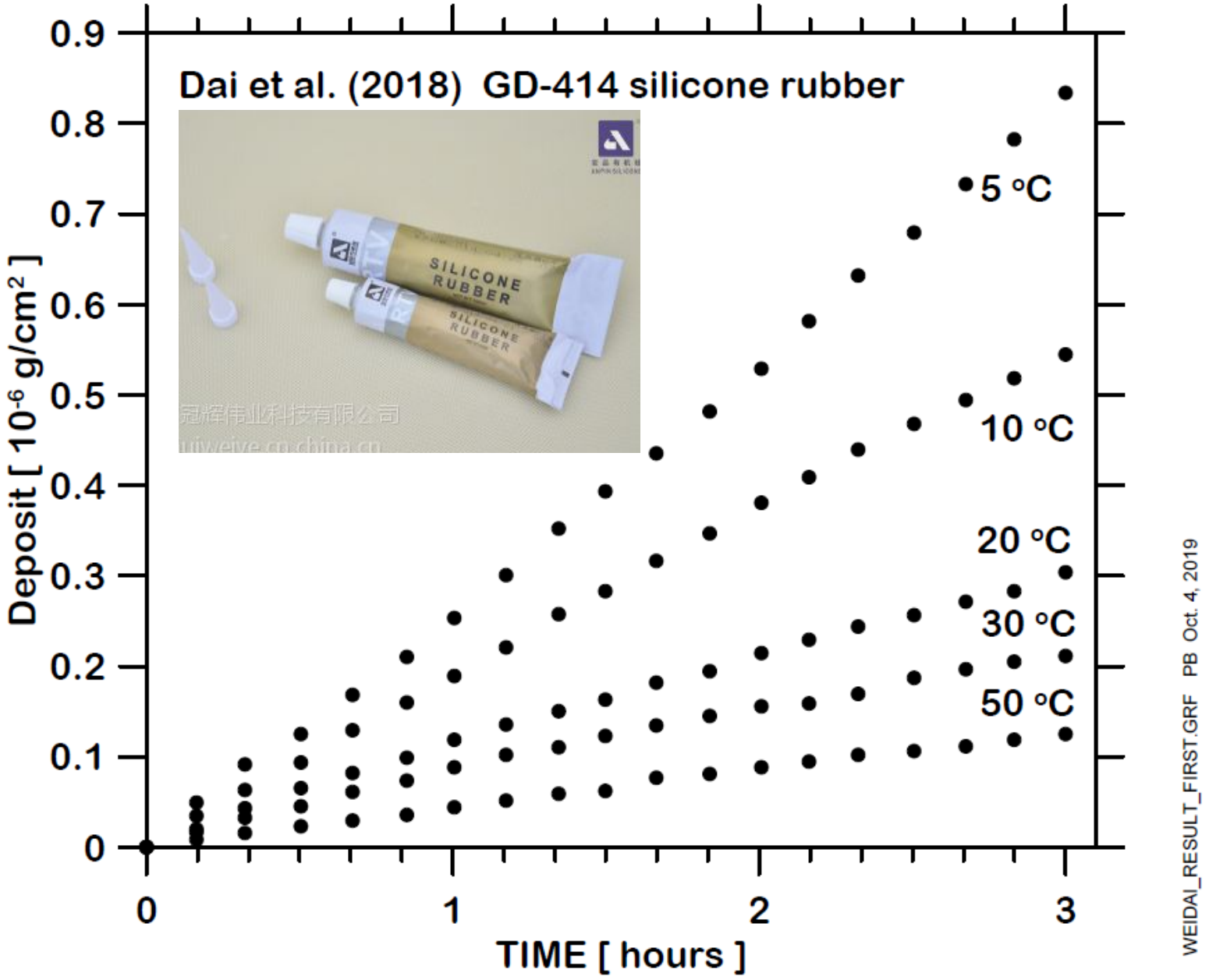
α sticking probability

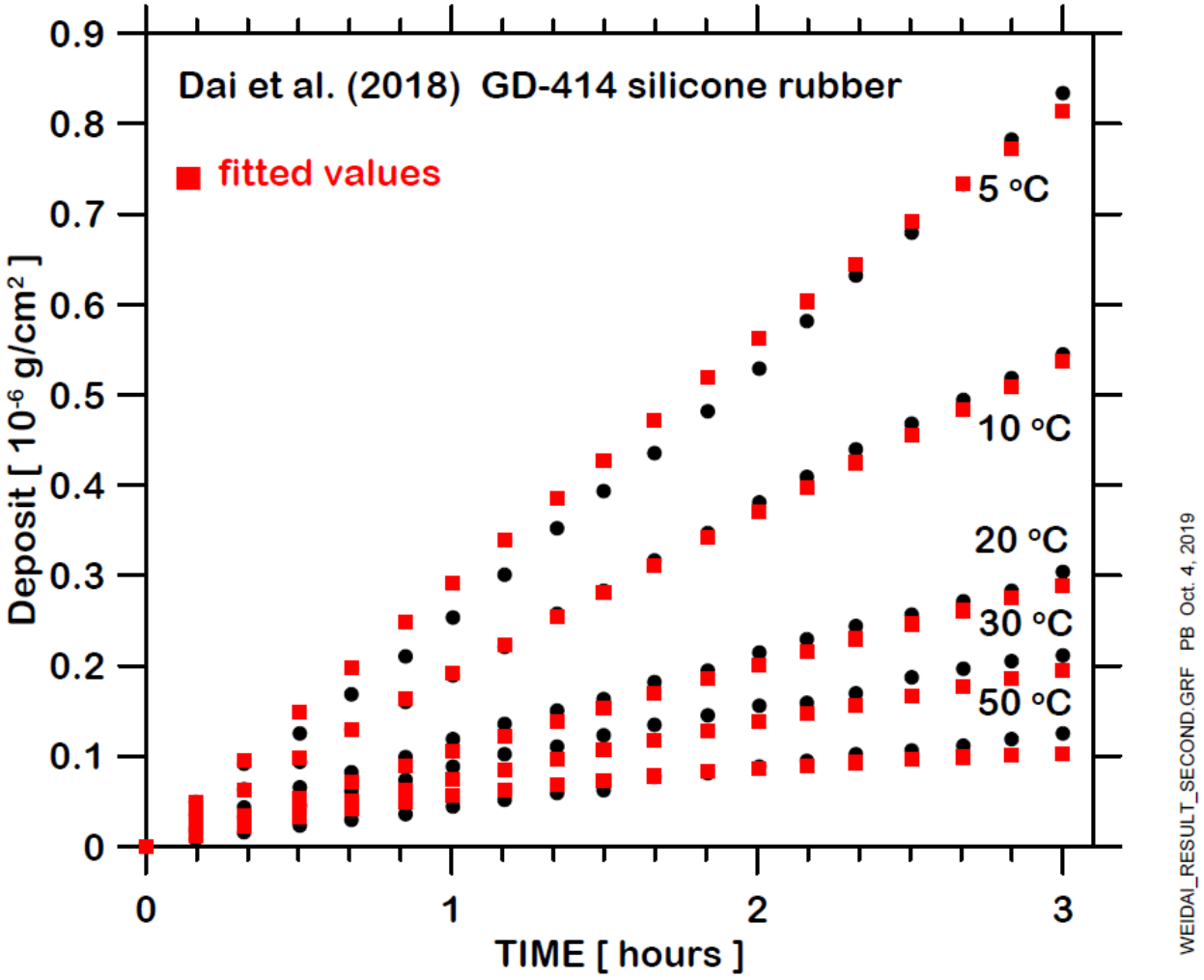
τ residence time [s]

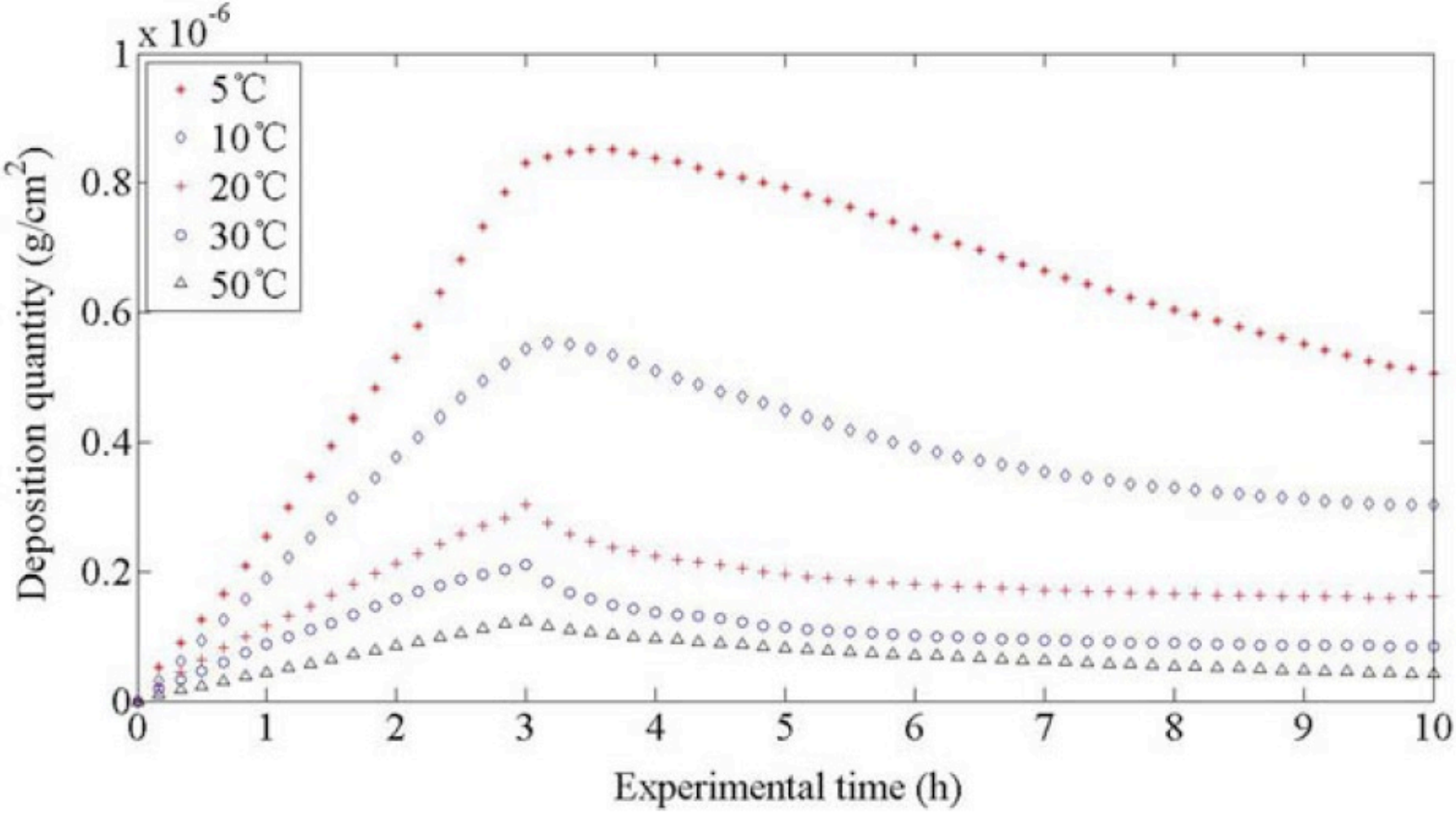
$$\alpha = \frac{1}{1 + \exp\left(\frac{T - T_C}{\Delta T_C}\right)}$$

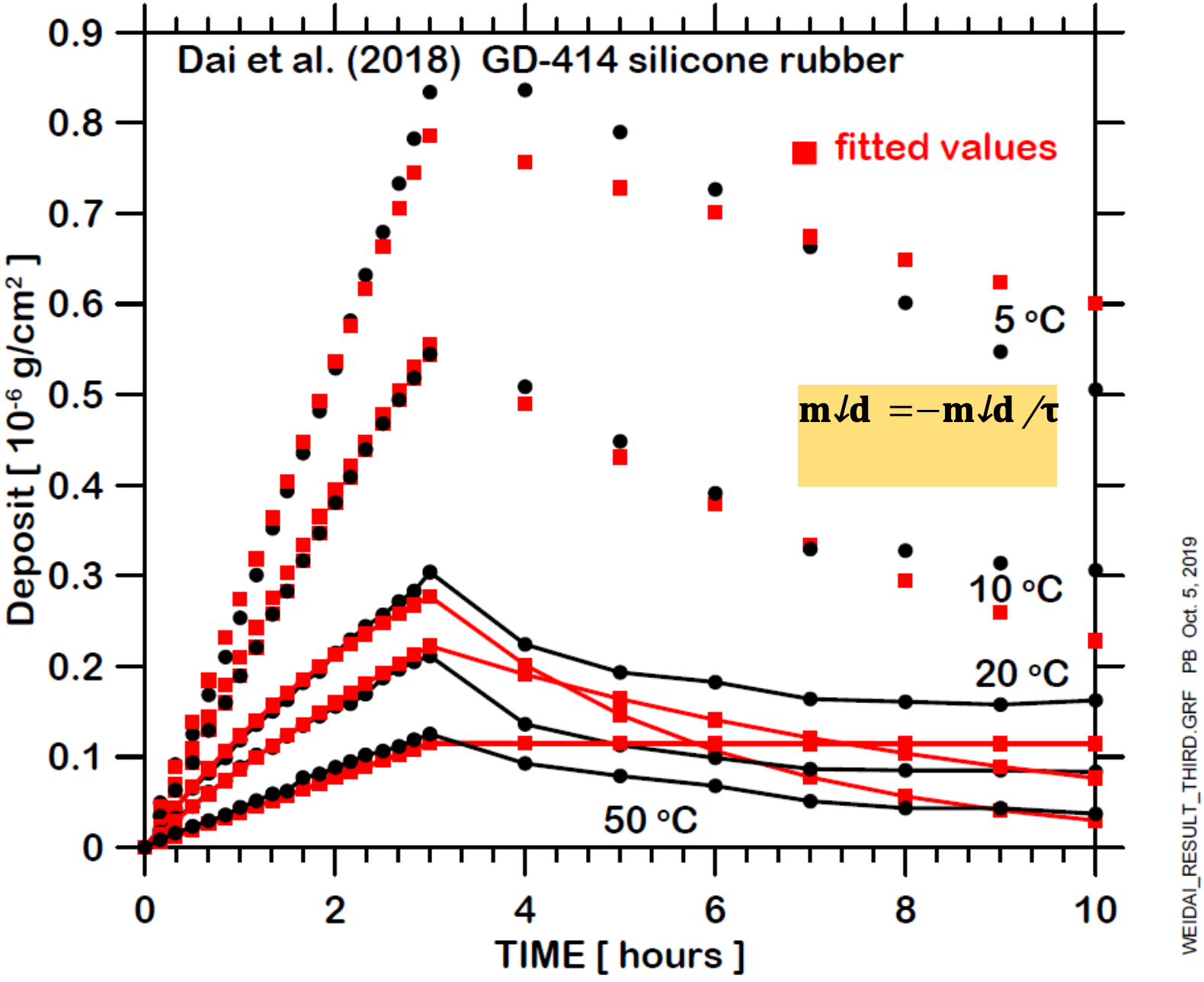
E_d desorption energy [J]

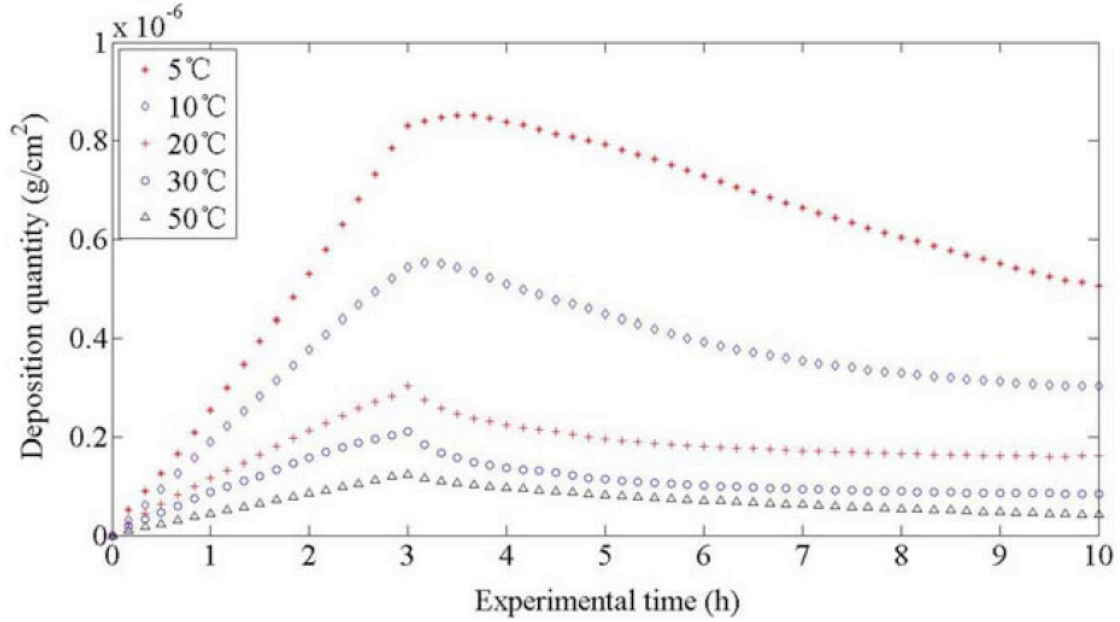
$$\tau = \tau_0 \exp\left(\frac{E_d}{RT}\right)$$


Dai et al. (2018) GD-414 silicone rubber
SILICONE RUBBER
SILICONE RUBBER
5 °C
10 °C
20 °C
30 °C
50 °C
Deposit [10-6 g/cm2]
TIME [hours]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
1
2
3
WEIDAI_RESULT_FIRST.GRF PB Oct. 4, 2019

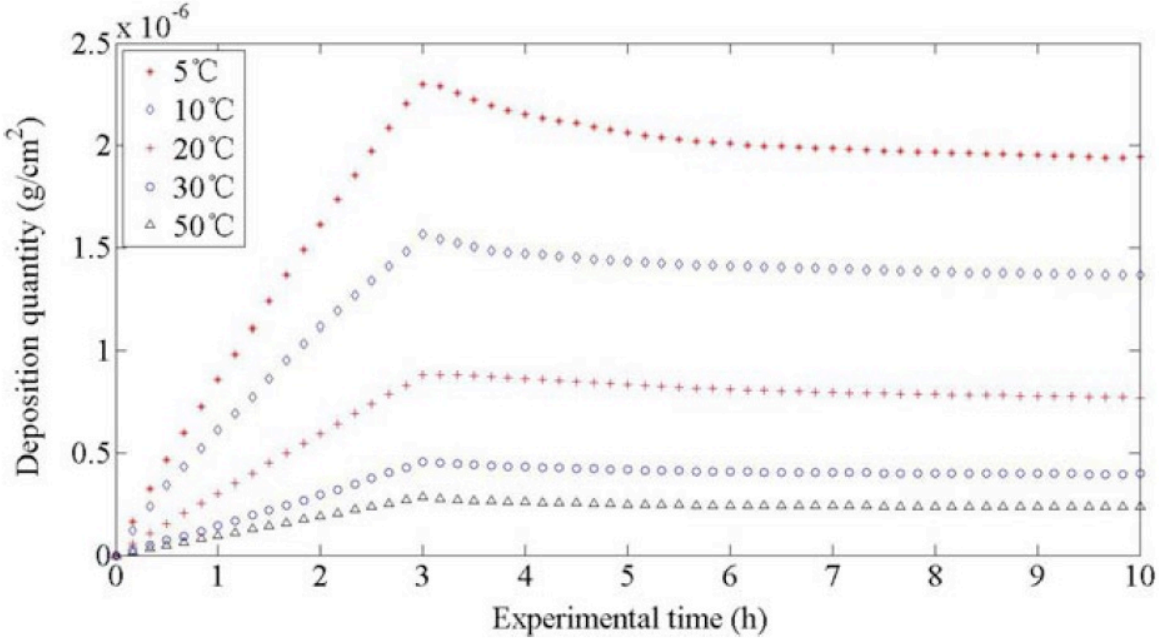

Dai et al. (2018) GD-414 silicone rubber
fitted values
5 °C
10 °C
20 °C
30 °C
50 °C
Deposit [10-6 g/cm2]
TIME [hours]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
1
2
3
WEIDAI_RESULT_SECOND.GRF PB Oct. 4, 2019


x 10^-6
1
0.8
0.6
0.4
0.2
0
Deposition quantity (g/cm^2)
5℃
10℃
20℃
30℃
50℃
0
1
2
3
4
5
6
7
8
9
10
Experimental time (h)


Dai et al. (2018) GD-414 silicone rubber
fitted values
5 °C
10 °C
20 °C
50 °C
m↓d = −m↓d / τ
Deposit [10-6 g/cm2]
TIME [hours]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
2
4
6
8
10
WEIDAI_RESULT_THIRD.GRF PB Oct. 5, 2019



Unirradiated



Irradiated

Dai et al. (2018)

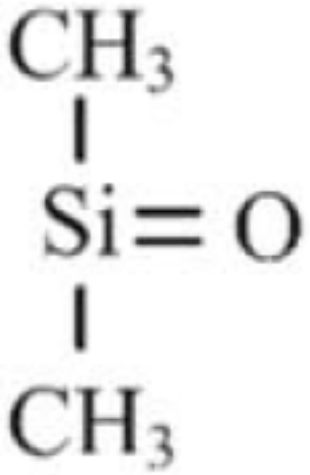


Fig. 8 Polymerization of $CH_3Si(O)CH_3$

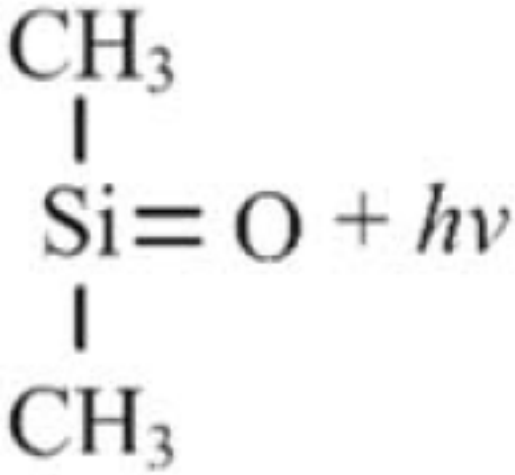


Fig. 8 Polymerization of $CH_3Si(O)CH_3$

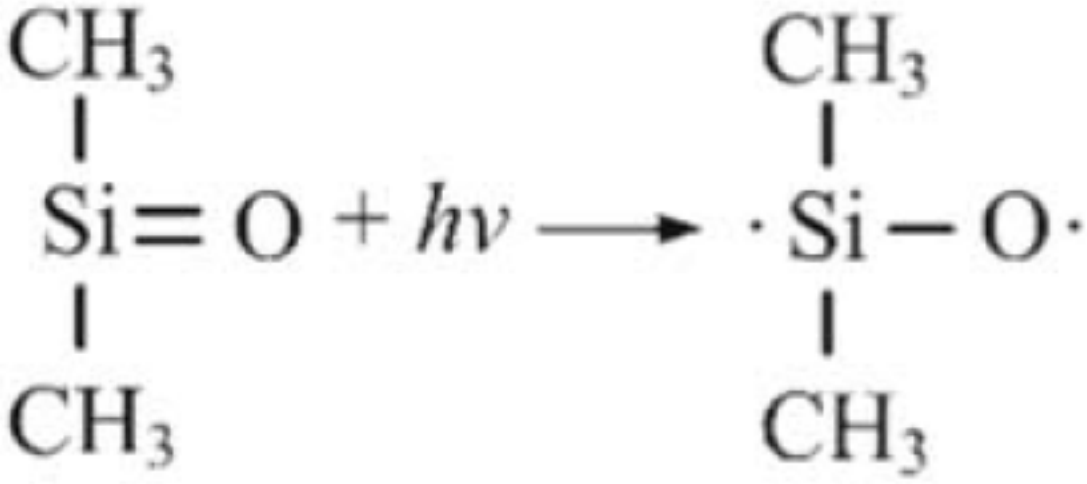


Fig. 8 Polymerization of $CH_3Si(O)CH_3$

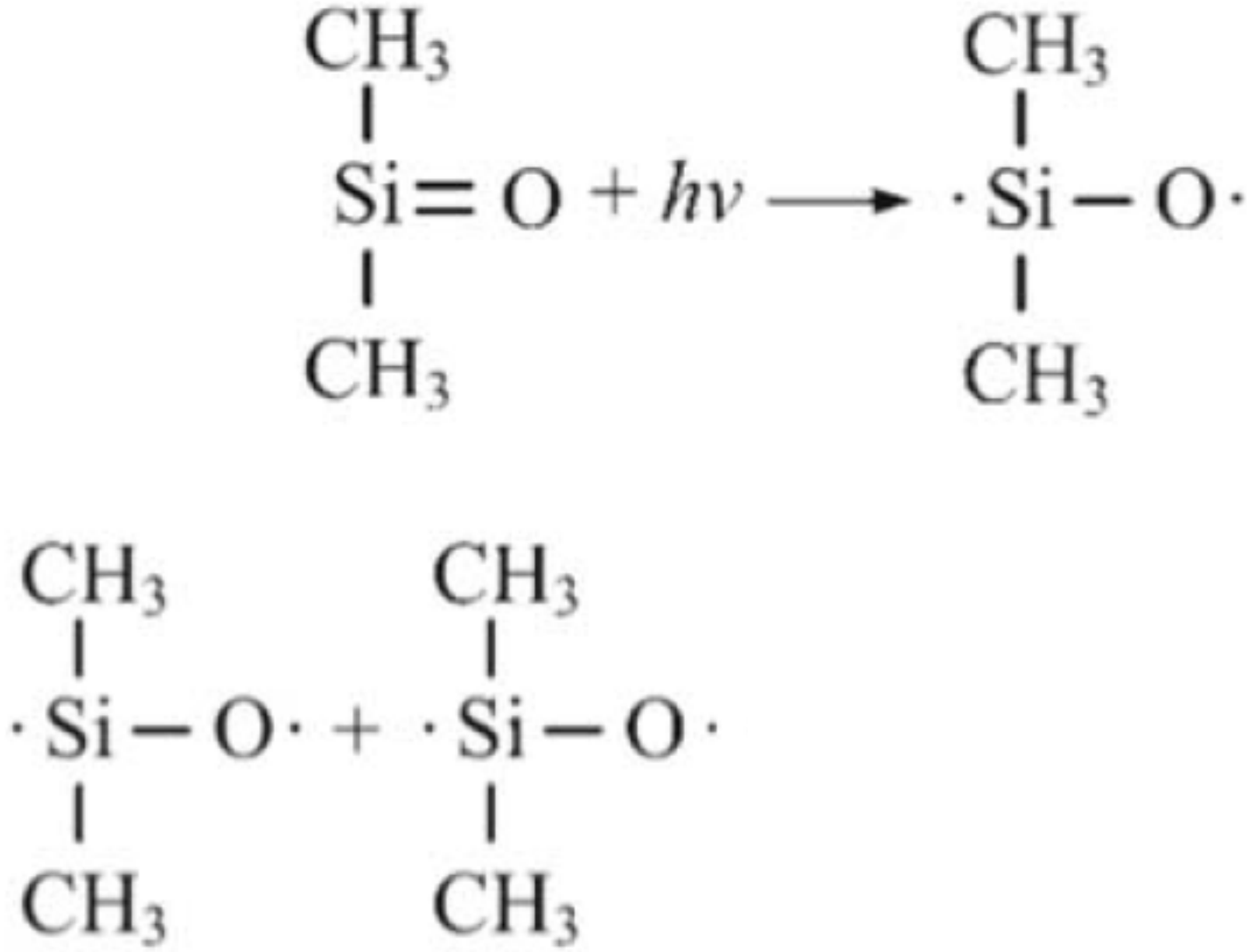


Fig. 8 Polymerization of $CH_3Si(O)CH_3$

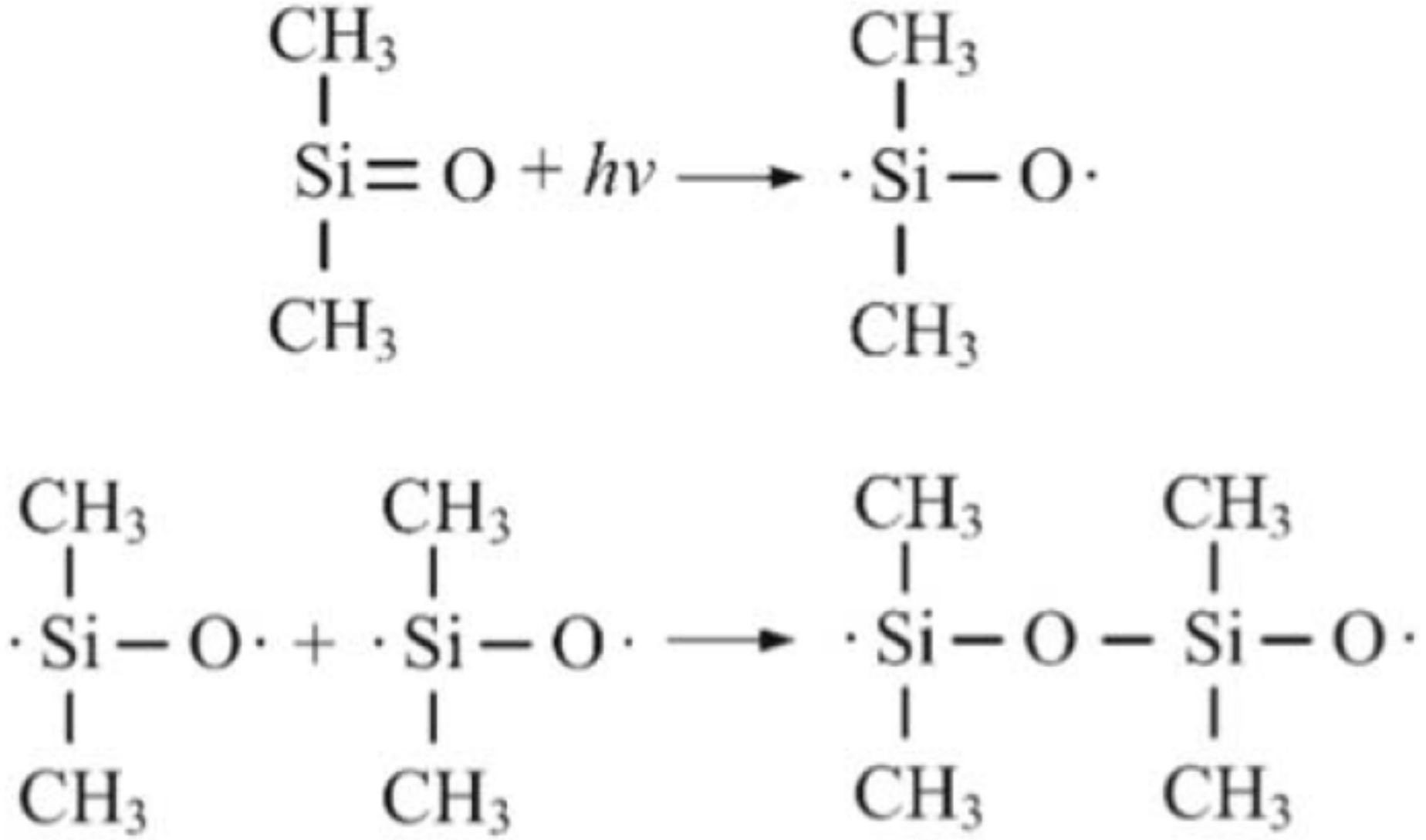
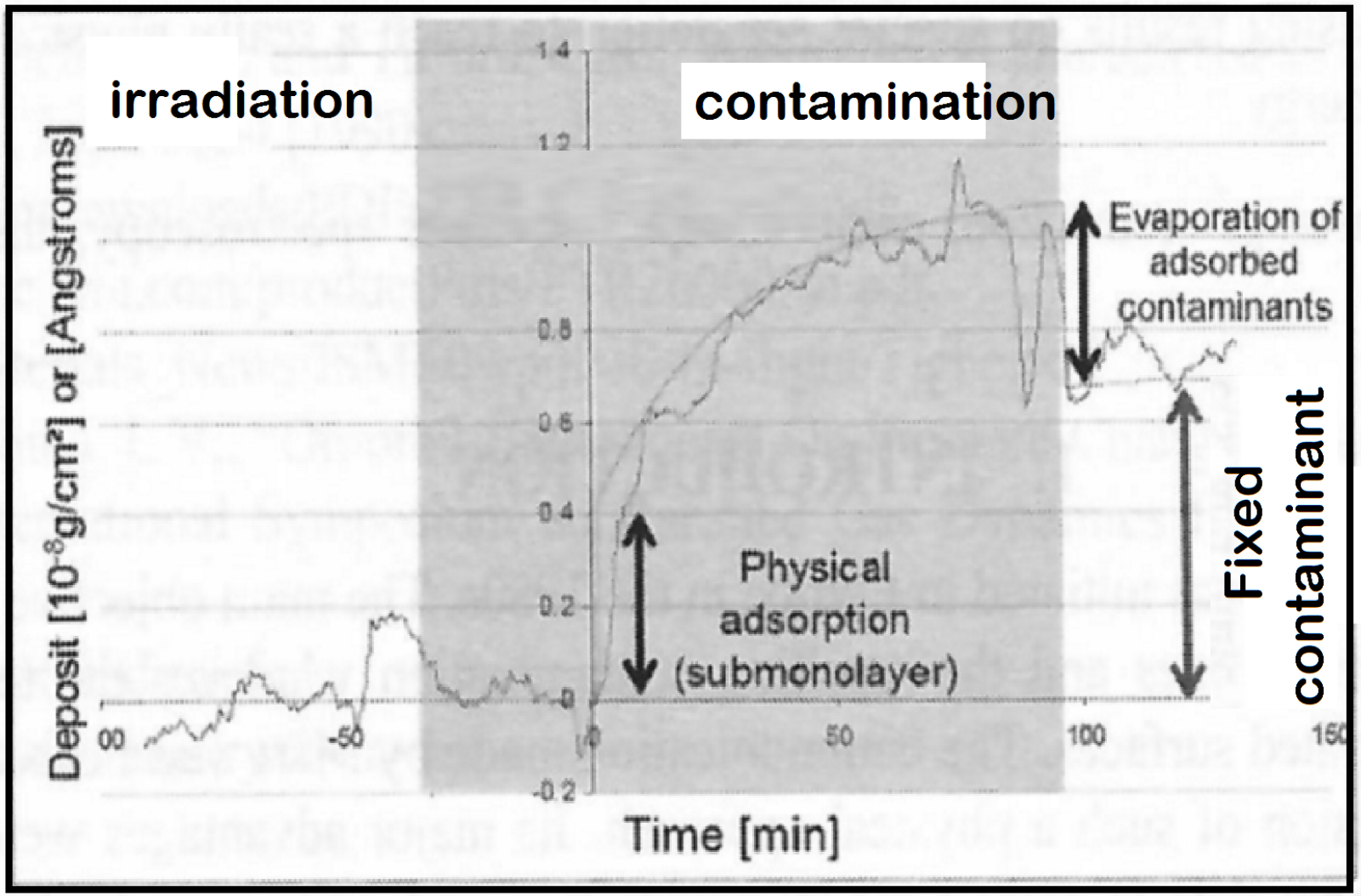


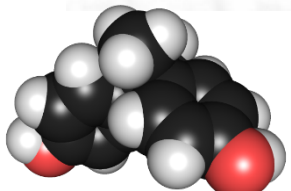
Fig. 8 Polymerization of $CH_3Si(O)CH_3$

Comments:

- Simple evaporation from surface vs. diffusion of contaminant through polymer?
- Break-up and volatilization of contaminants?
- Mono- vs. multilayer adsorption?

Roussel et al. (2016) J. Spacecraft and Rockets 53





Bisphenol A

esa

Software information | Contact | Site informations

ONERA

COMOVA

COntamination Modelling Outgassing & Vent Analysis

The new ESA contamination modelling software

Examples

- ISS
- Test Spacecraft
- Ground experiment

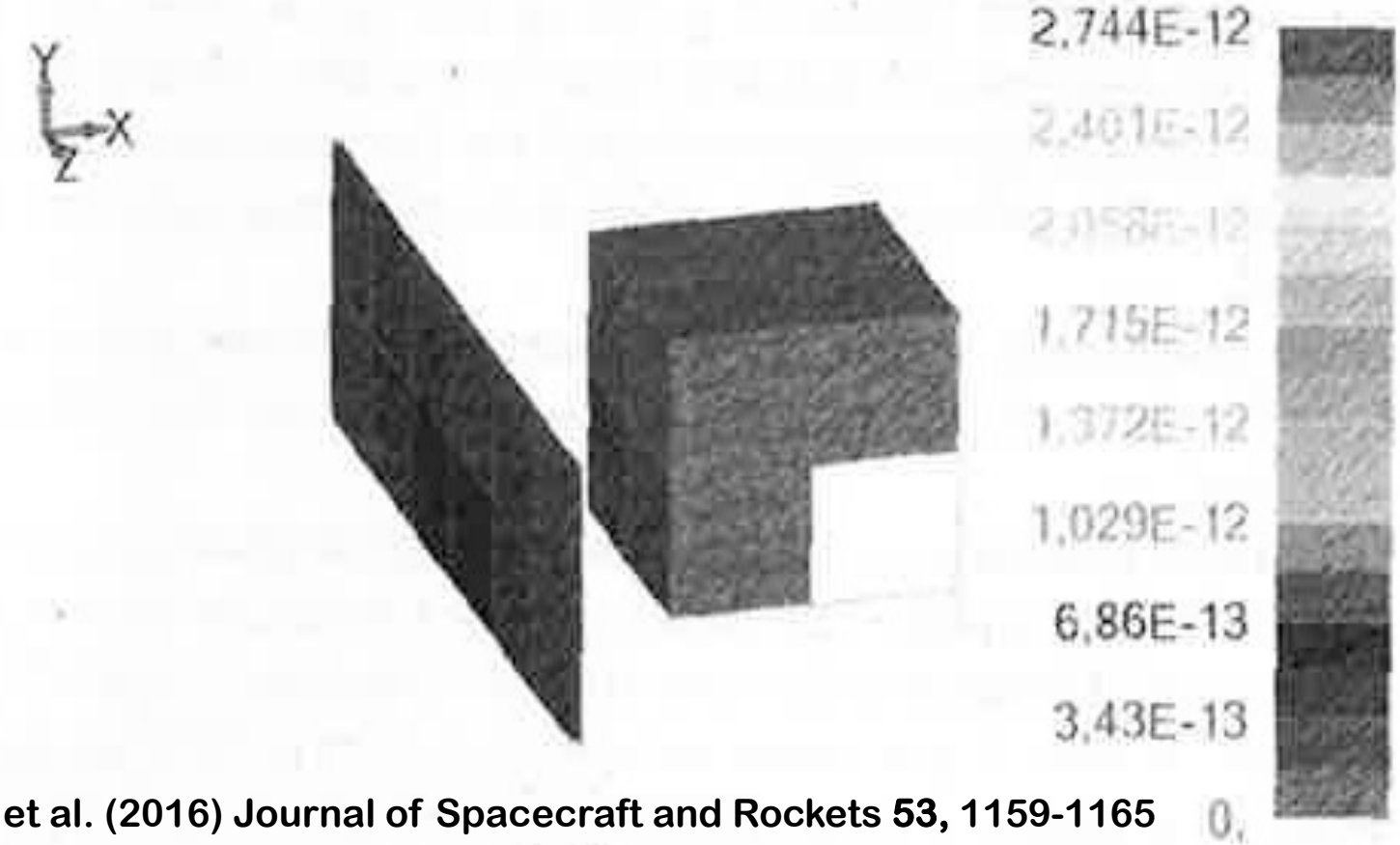
The Physics

- Contaminant sources
- Contaminant transport
- Surface contaminant interactions
- Time integration

How to use COMOVA

- General organisation
- Input parameters
- Pre/post-processing (external tools)

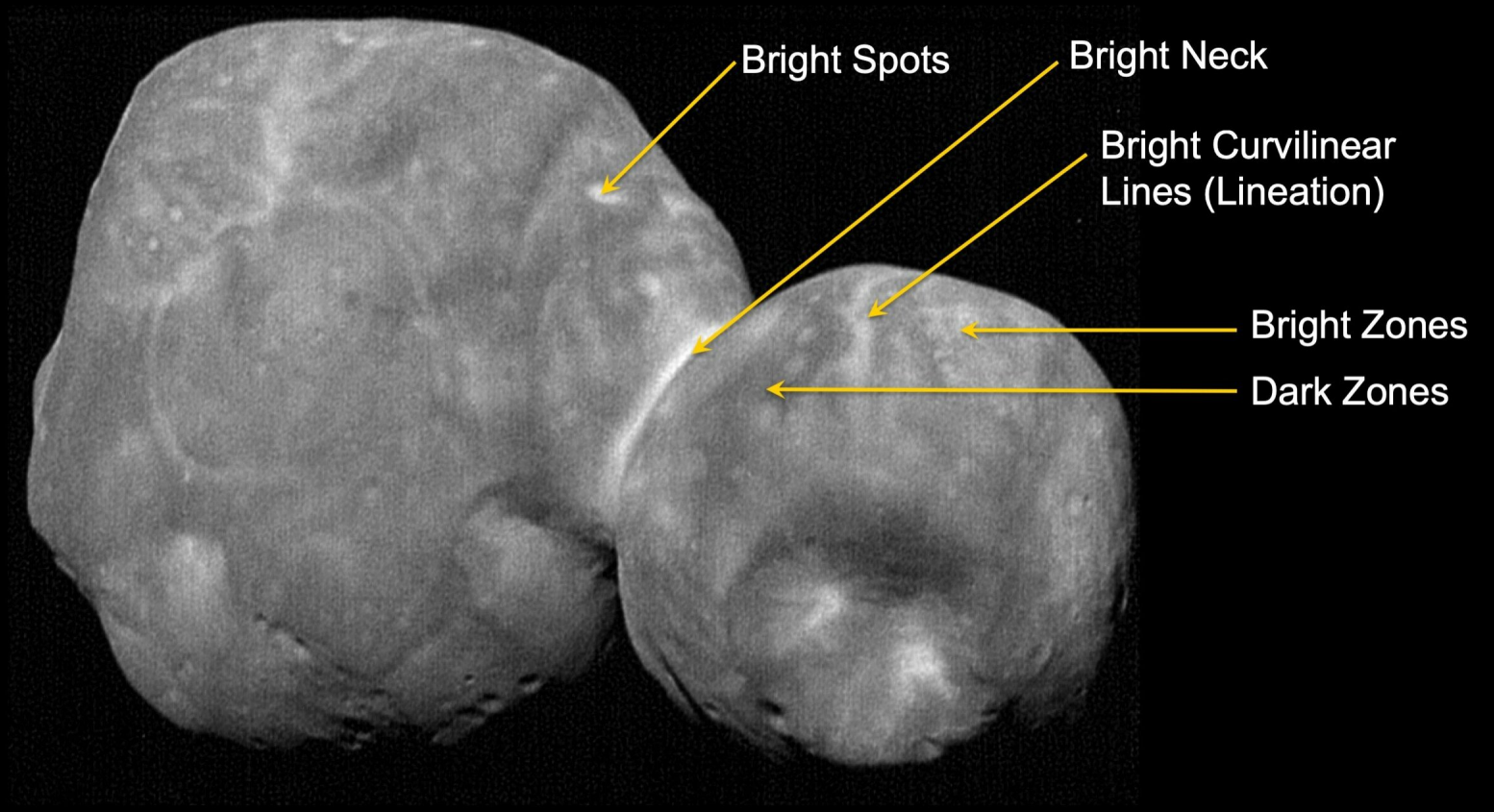
COMOVA: COntamination Modelling Outgassing & Vent Analysis



Roussel et al. (2016) Journal of Spacecraft and Rockets **53**, 1159-1165

Ultima Thule (New Horizons)

Enigmatic Albedo Markings



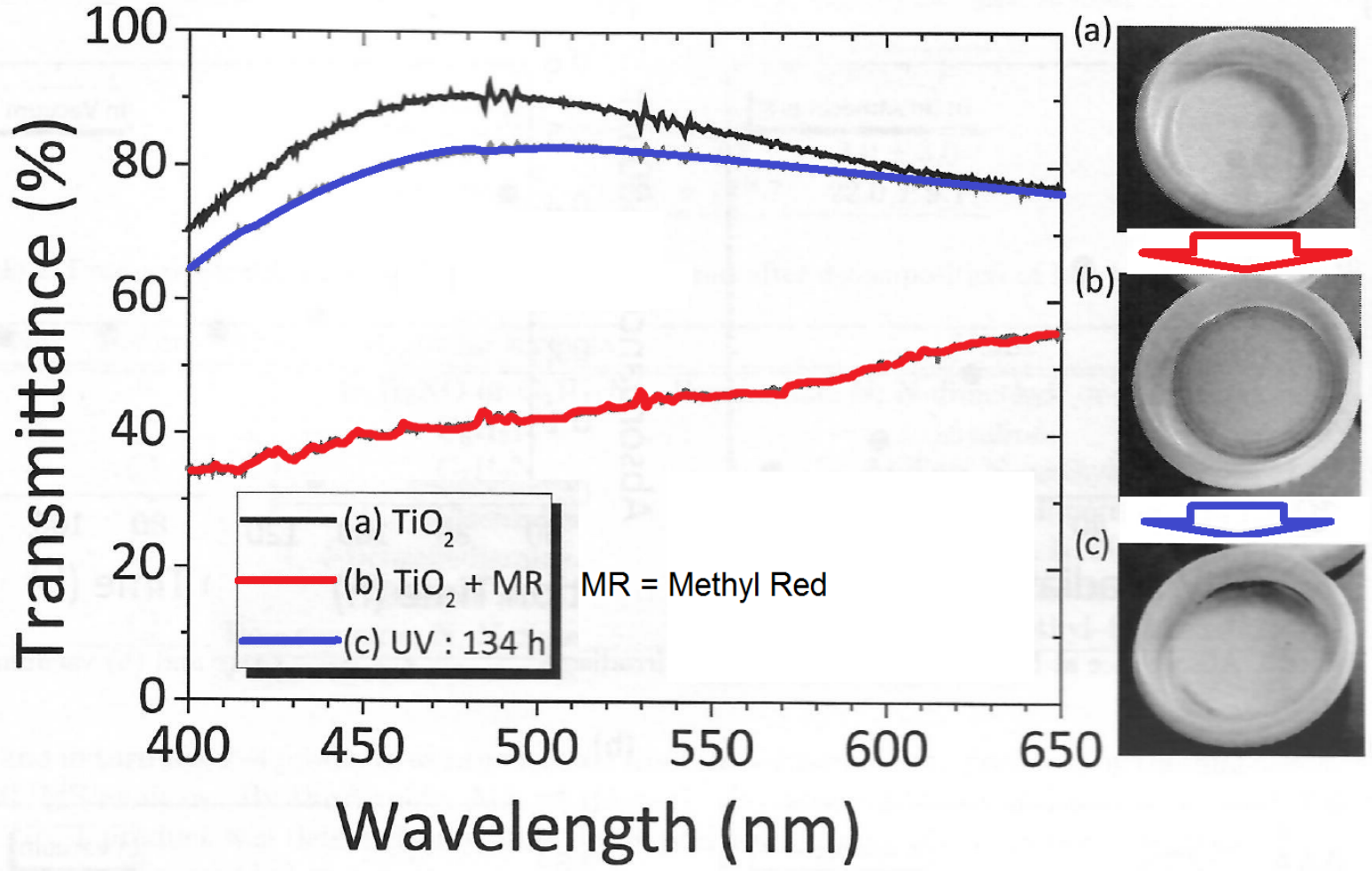
Planetologists are interested in modeling adsorption and re-evaporation of volatiles on complicated bodies under variable conditions of illumination

Crazy Ideas:

J.R (2018):

Replace cables by wave guides

- **Clean Rooms: Manipulating experiments by robots**
- **Propulsion: Use inert gases**
- **Assembling complete missions by robots in space**

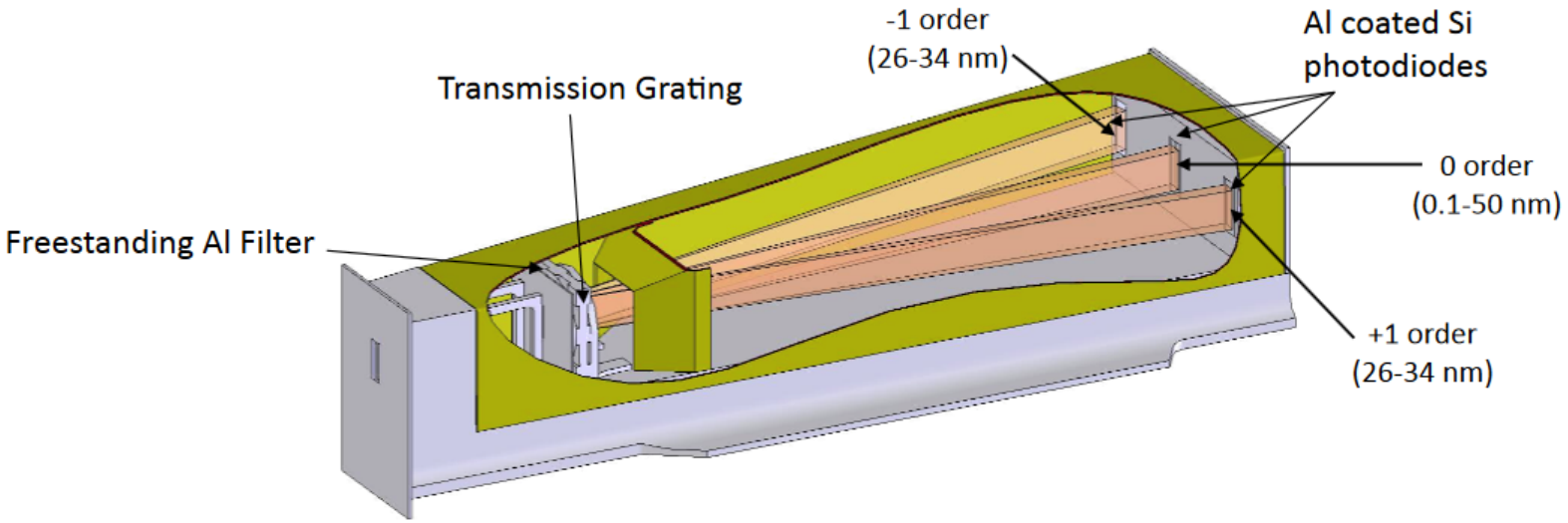


N. Shimosako et al. (Proc. of SPIE Vol 10748)
Effects of Vacuum on Photocatalytic Activity of TiO_2

UV Transmittance ???

Healthy Ideas: The foolproof solution

SEM on SOHO



Seth Wieman et al. (2013)

Monitoring Solar EUV-Output:

Including Frequent Calibration with Rocket Flights

Application:

EUV Output is important for understanding
Sun- Interstellar Medium Interaction
(Time constants of the order of months)

Comment:

Cross talk with other experiments and intercalibration are important and useful

Monitoring Solar EUV-Output:

Including Frequent Calibration with Rocket Flights

Monitoring Solar EUV

EUV Output is important for understanding Sun - Interstellar Medium Interaction (Time constants of the order of months to decades)
Long range time series of

Comment:

intercalibration

are important and useful

those rely with other experiments and

Comment:

But make sure that community of users is informed!