Experiences concerning the com-position of a spacecraft generated atmosphere from Rosetta/ROSINA

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Experiences concerning the composition of a spacecraft generated atmosphere from Rosetta/ROSINA

1. How?

2. What?

3. Measures to reduce contamination hazards

Focus on outgassing of condensable and non-volatile compounds from spacecraft

ROSINA provides an excellent diagnostics to identify and study such compounds

JOURNAL OF SPACECRAFT AND ROCKETS
Vol. 45, No. 1, January–February 2008

Thruster Plumes: Sources for High Pressure and Contamination at the Payload Location

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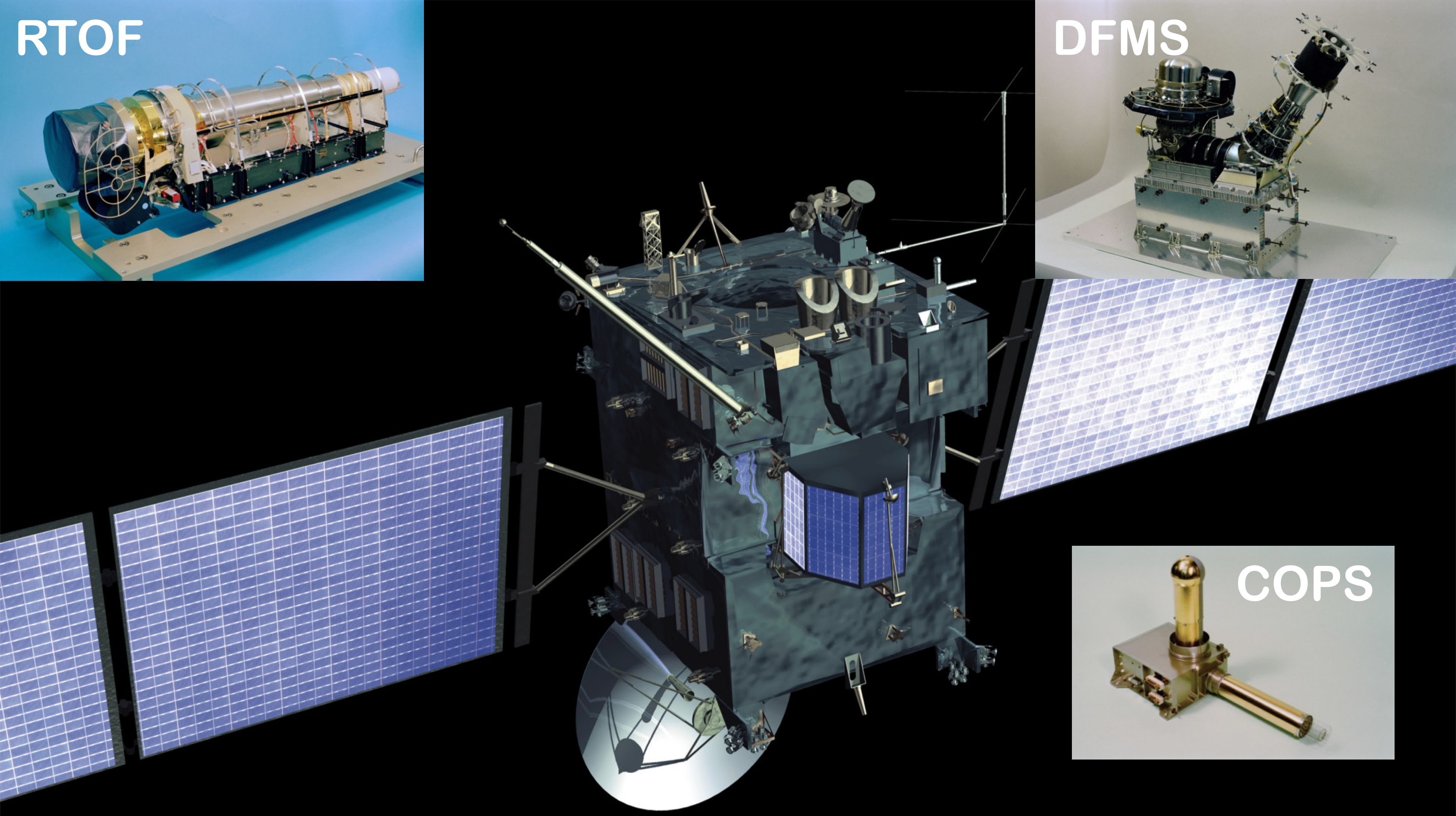
DOI: 10.2514/1.30600

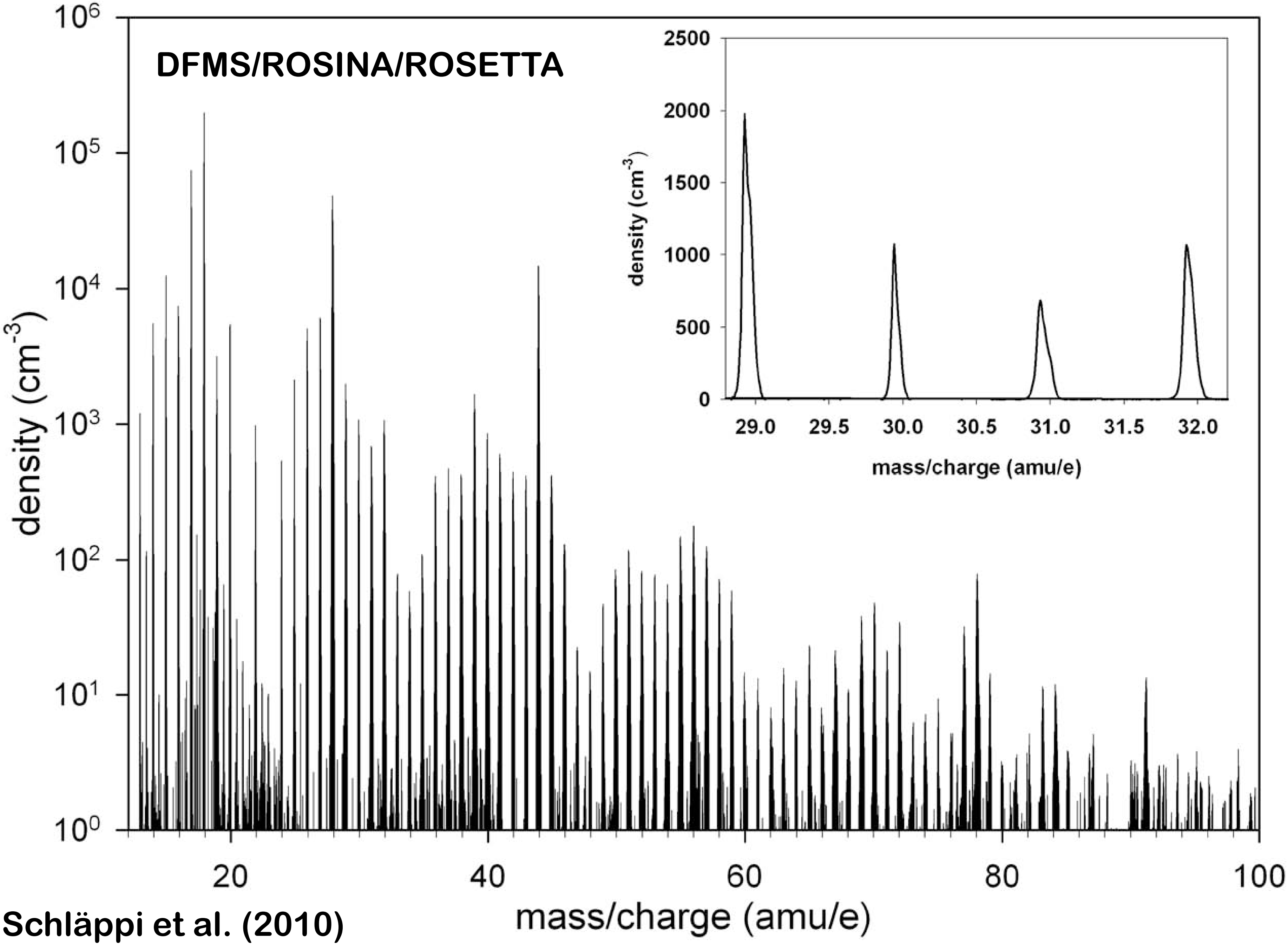
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, A12313, doi:10.1029/2010JA015734, 2010

Influence of spacecraft outgassing on the exploration of tenuous atmospheres with in situ mass spectrometry

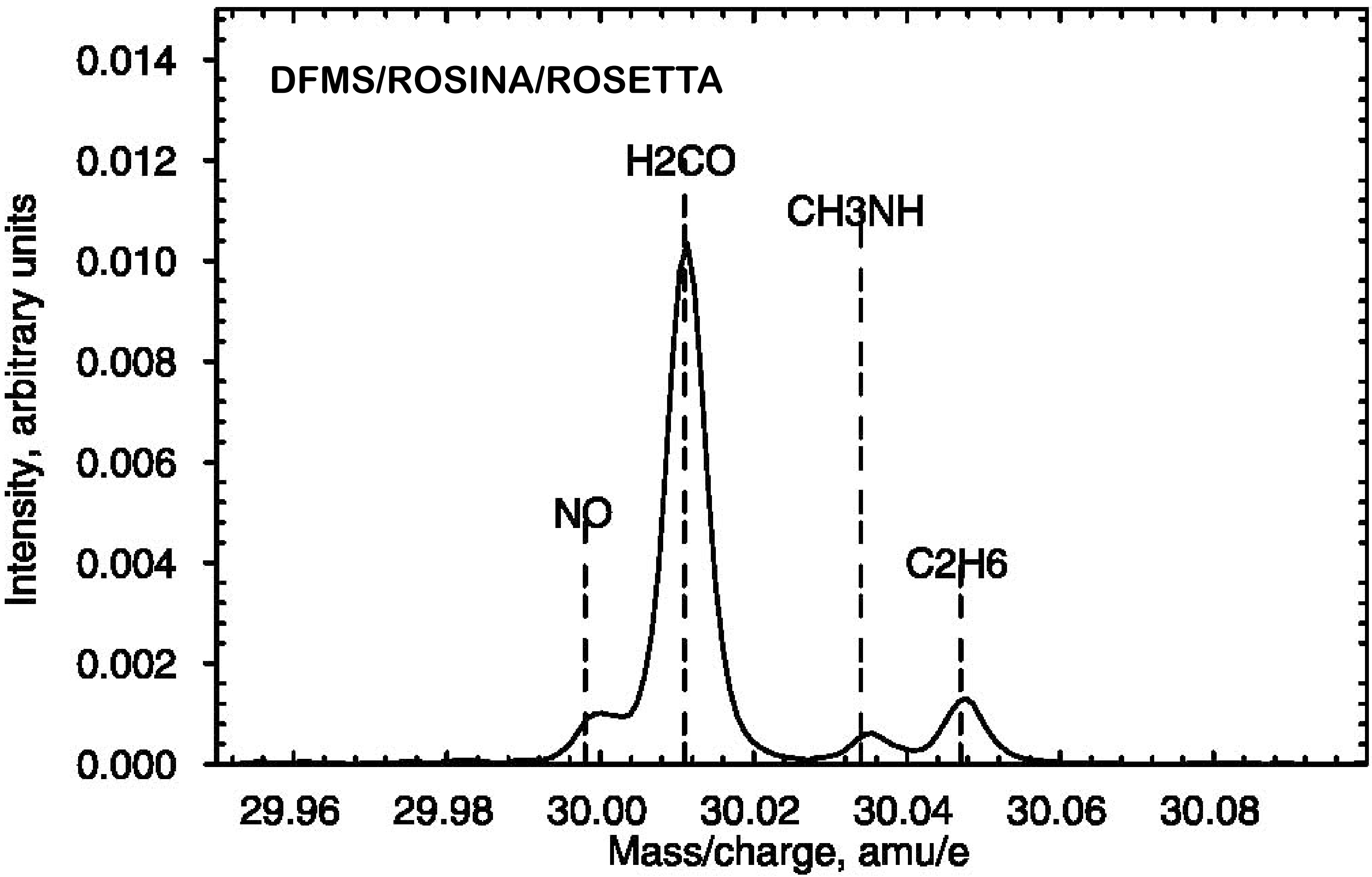
B. Schläppi,[1] K. Altwegg,[1] H. Balsiger,[1] M. Hässig,[1] A. Jäckel,[1] P. Wurz,[1] B. Fiethe,[2] M. Rubin,[3] S. A. Fuselier,[4] J. J. Berthelier,[5] J. De Keyser,[6] H. Rème,[7,8] and U. Mall[9]



ROSINA package on the Rosetta Cometary Explorer

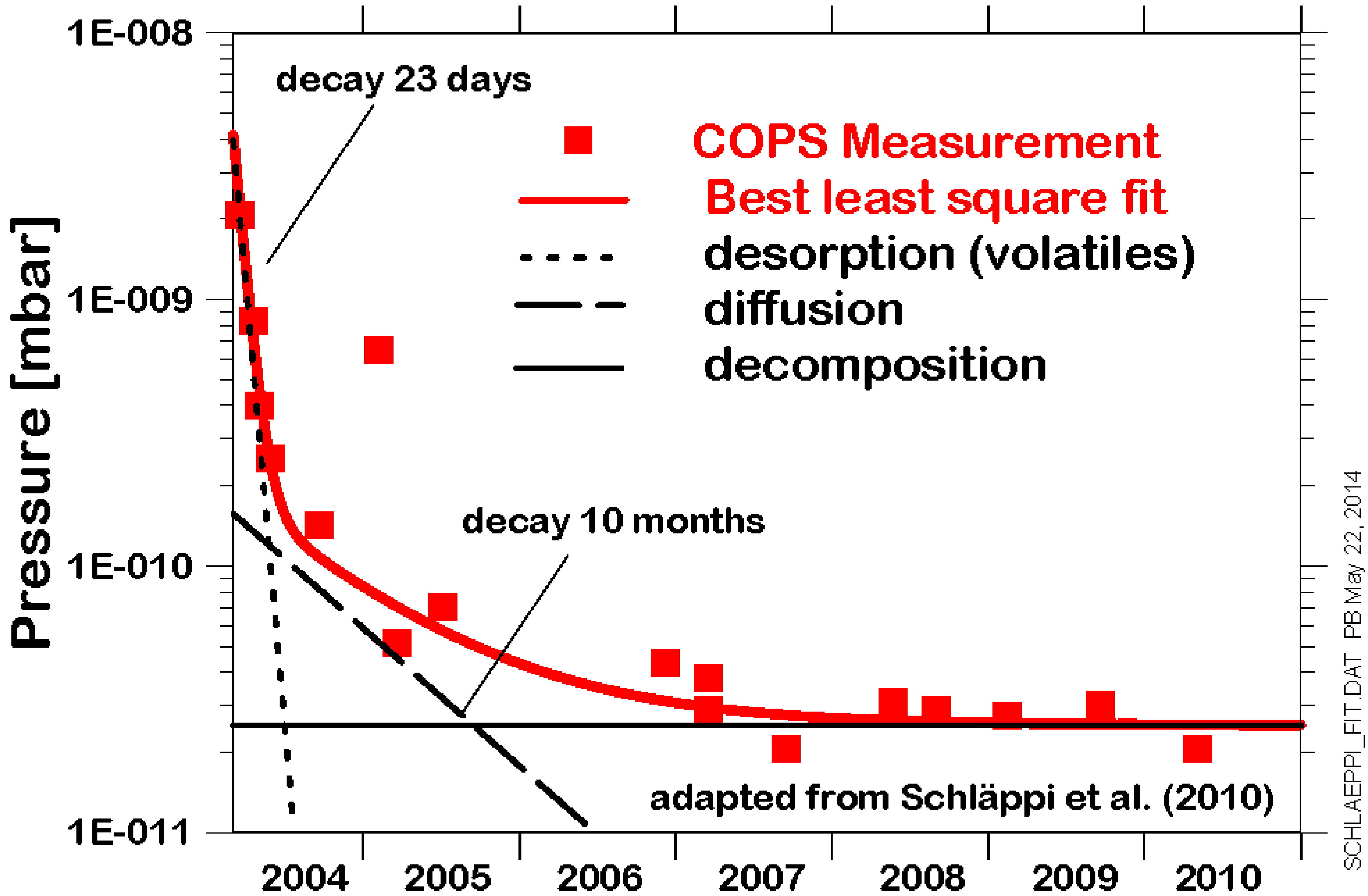


Schläppi et al. (2010)

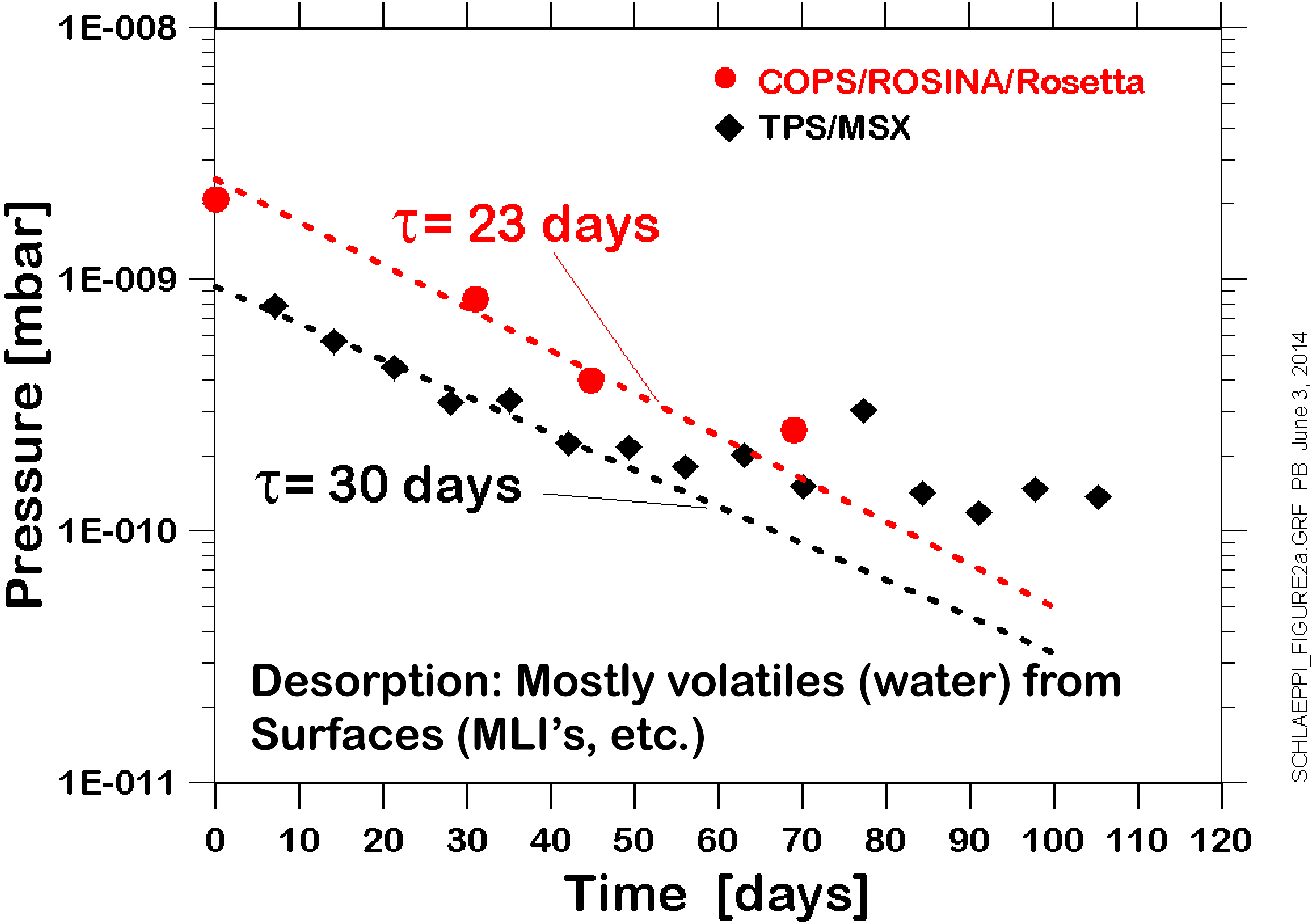


Schläppi et al. (2010)

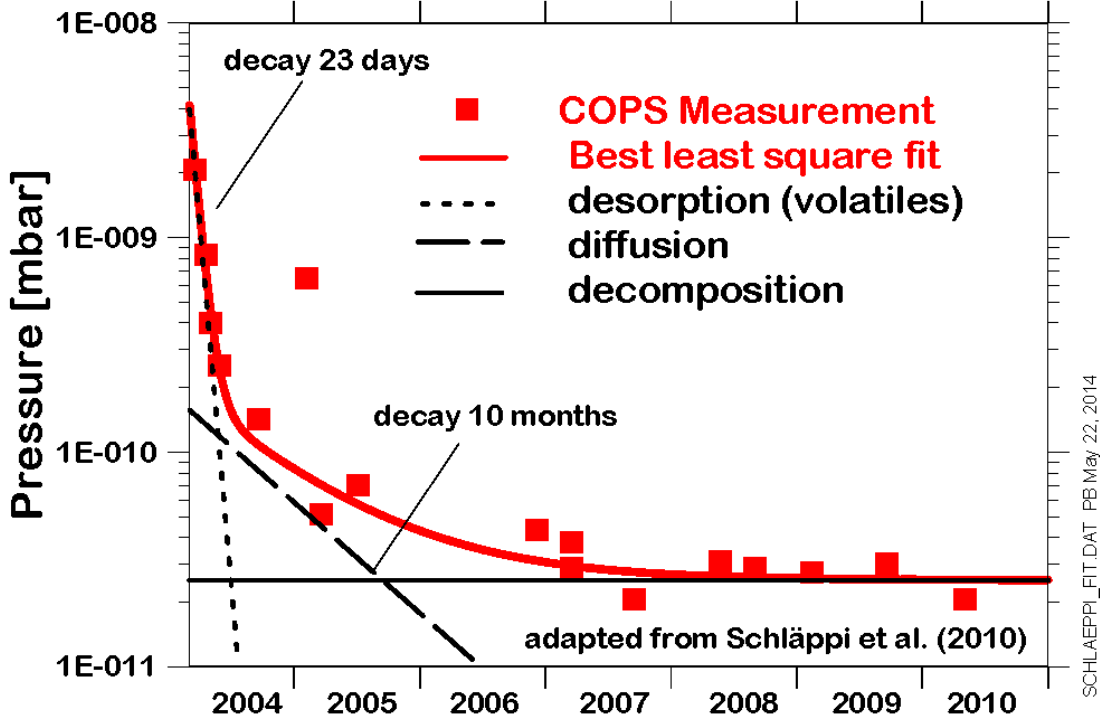
How?



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



COPS/ROSINA/Rosetta
TPS/MSX
τ= 23 days
τ= 30 days
Desorption: Mostly volatiles (water) from Surfaces (MLI's, etc.)
Pressure [mbar]
1E-008
1E-009
1E-010
1E-011
0
10
20
30
40
50
60
70
80
90
100
110
120
Time [days]
SCHLAEPPI_FIGURE2a.GRF PB June 3, 2014



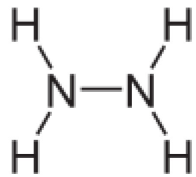
Diffusion: From interior of spacecraft,
Timescale: 10 months

Decomposition: From UV-irradiation of plastics
Timescale: Duration of mission

Thruster Firings

Hydrazine properties:

$3N_2H_4 \rightarrow 4NH_3 + N_2$



$N_2H_4 \rightarrow N_2 + 2\ H_2$

Rosetta: Monomethylhydrazine + Oxidizers

CH_6N_2

Boiling point (at 1 atm) 91 ^oC

Heat of vaporization 40.4 kJ/mole
(Water 40.7 kJ/mole)

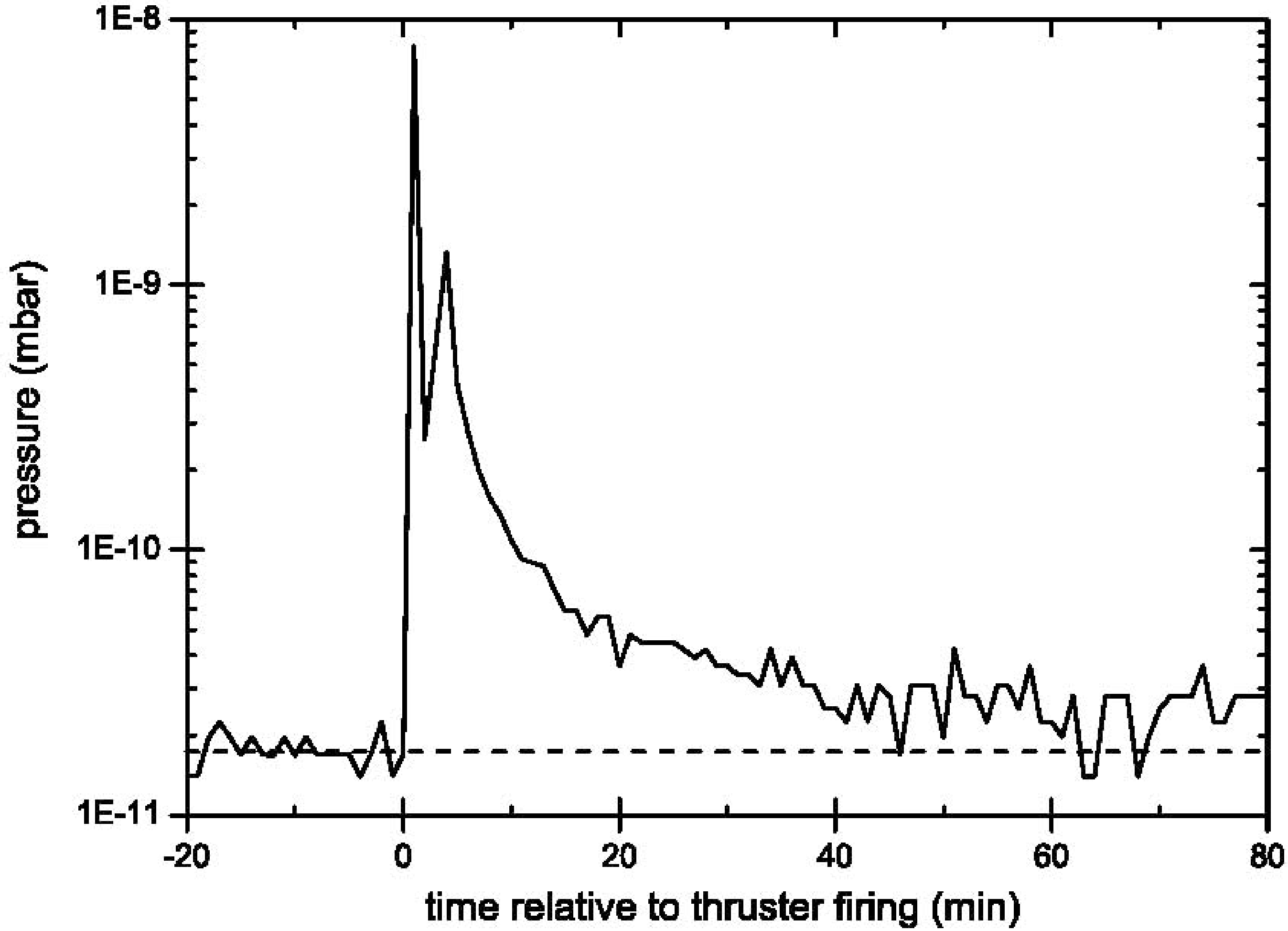
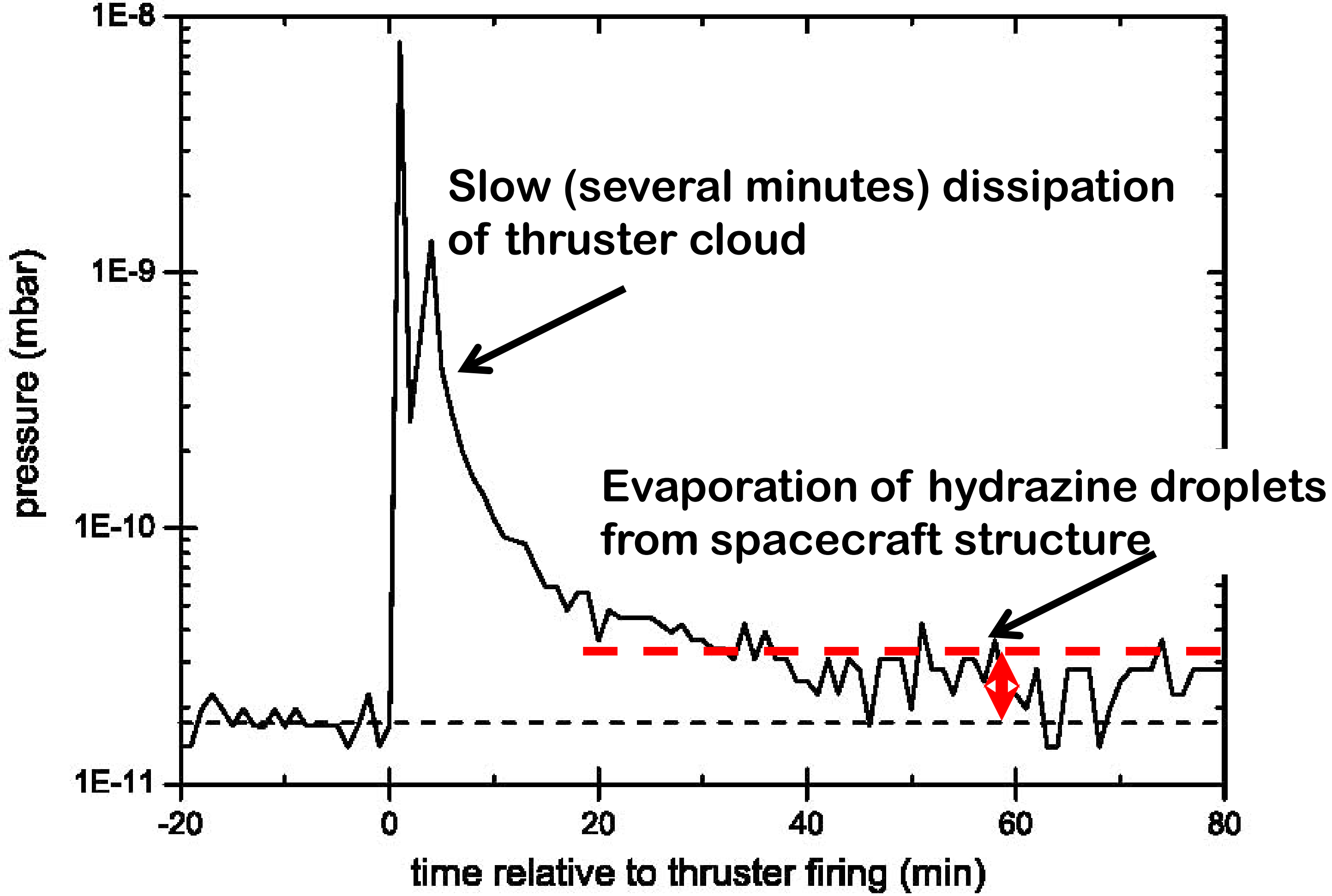


Figure 13. Pressure during and after thruster firing. Multiple thrusters have been activated in this case, which yields pressure peaks of almost three orders of magnitude above the background level. The pressure decreases at the end of the firing within minutes to the 10^{-11} mbar range but stays above the background level (dashed line) for more than 1 h.



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Diffusion of hard spheres in a cloud:

$$D \cong \lambda \cdot <v> = \frac{<v>}{n\sigma}$$

D: Diffusion "coefficient", depends on density !

λ: Mean free path

$<v>$: Average thermal speed

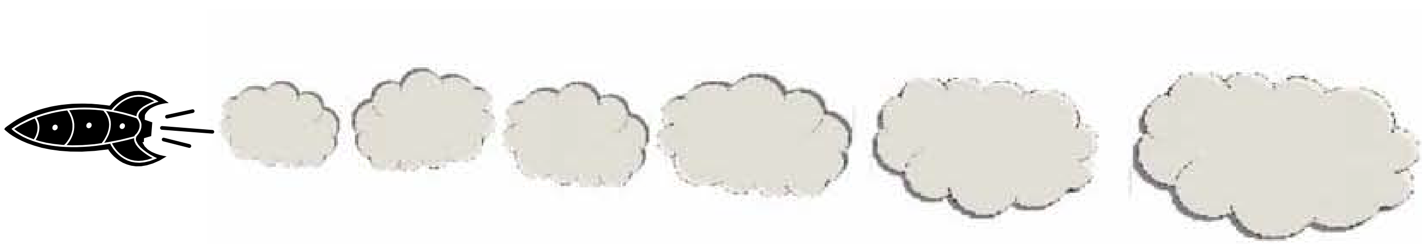
n: Particle density

σ: Collision cross section of hard spheres

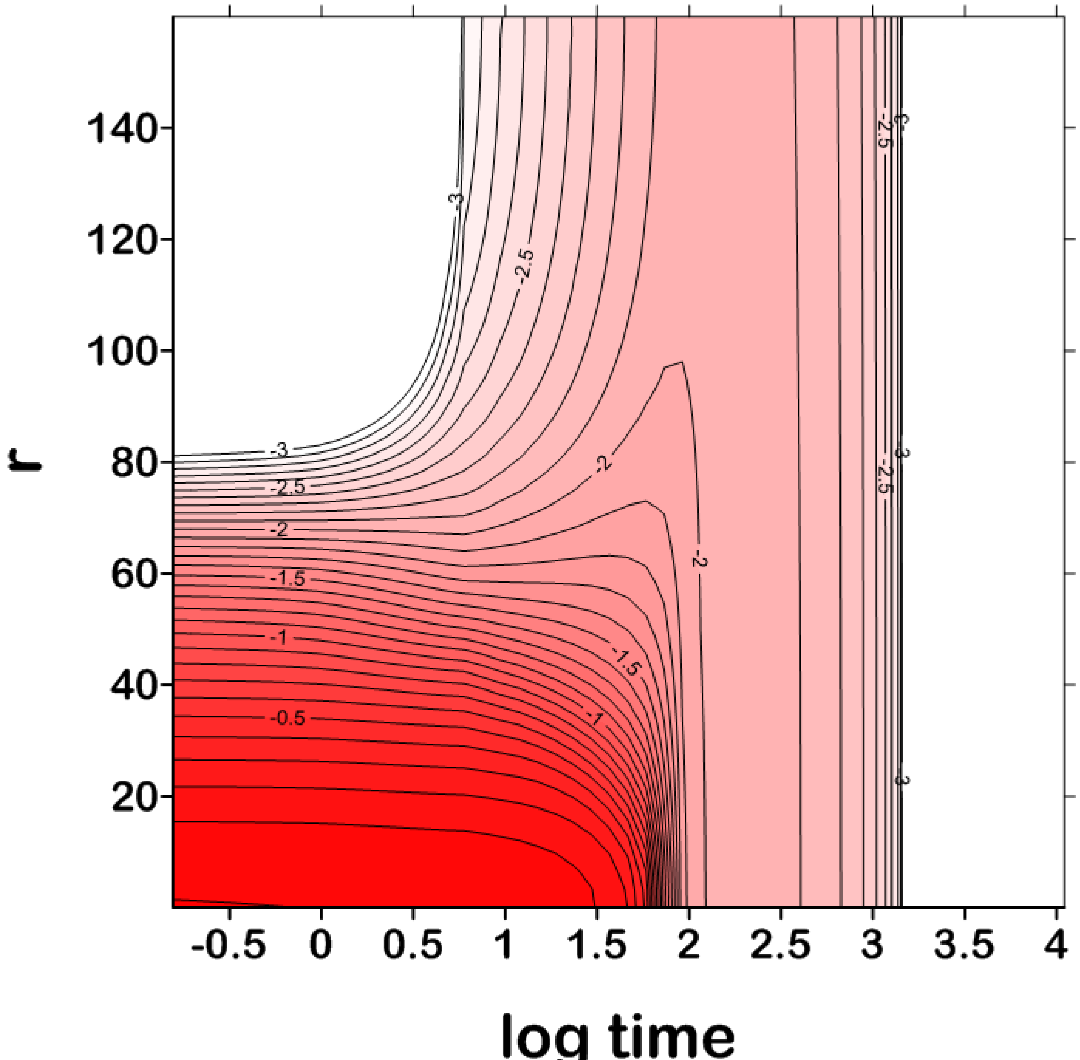
Spherical cloud:

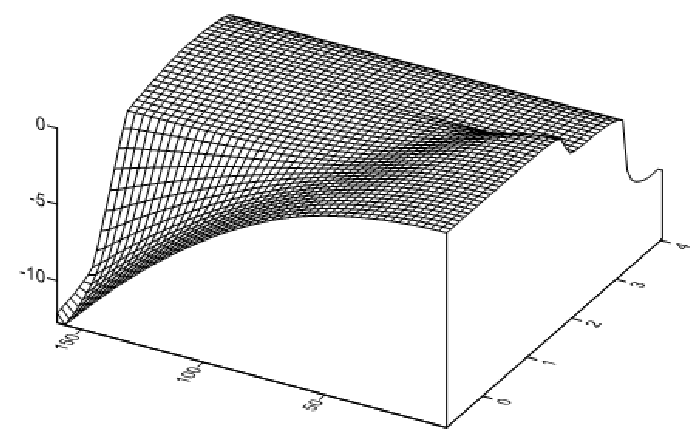
$$\frac{\partial n(r,t)}{\partial t} = \frac{D_o}{r^2} \frac{\partial}{\partial r} r^2 \frac{\partial n(r,t)}{n(r,t)\partial r}$$

Spherical cloud, expanding and moving away



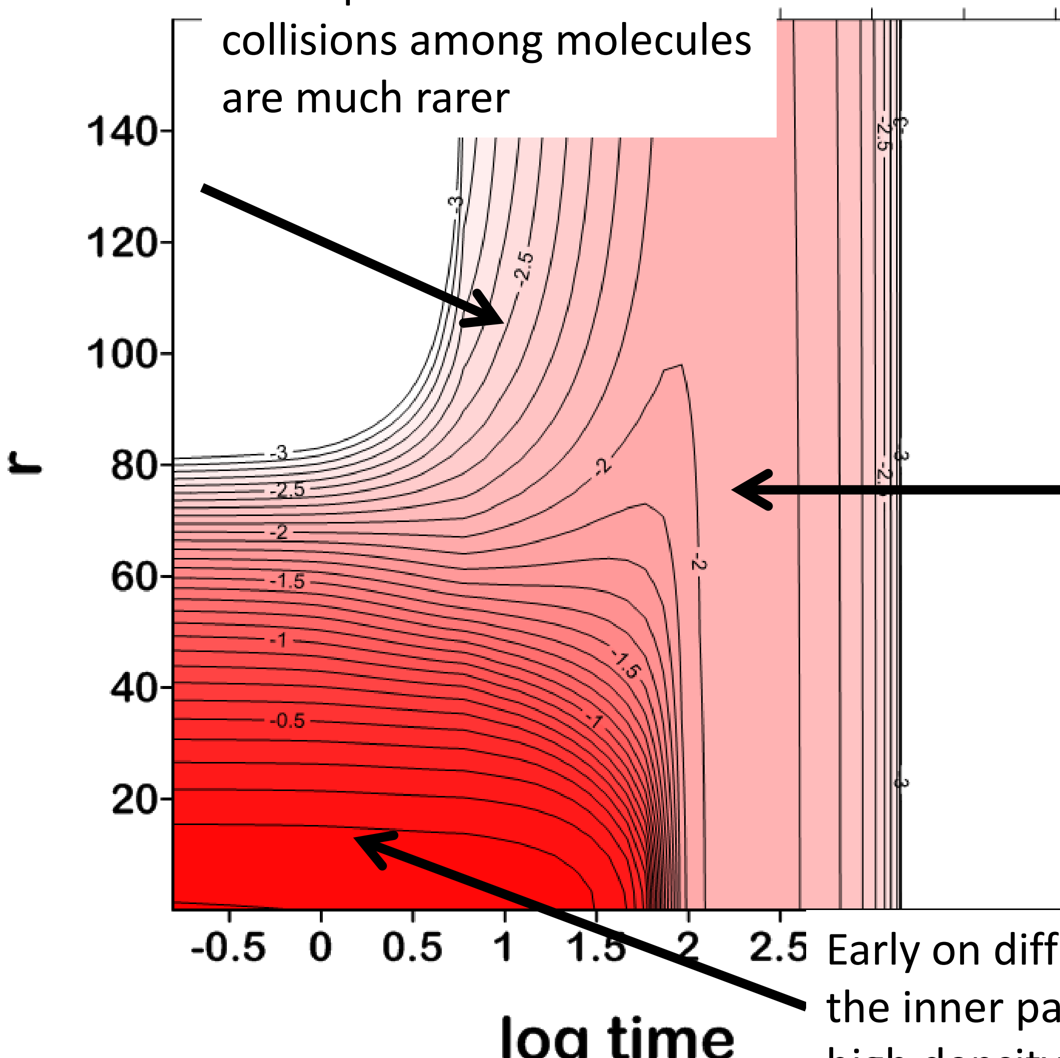
Modeling Thruster Firings



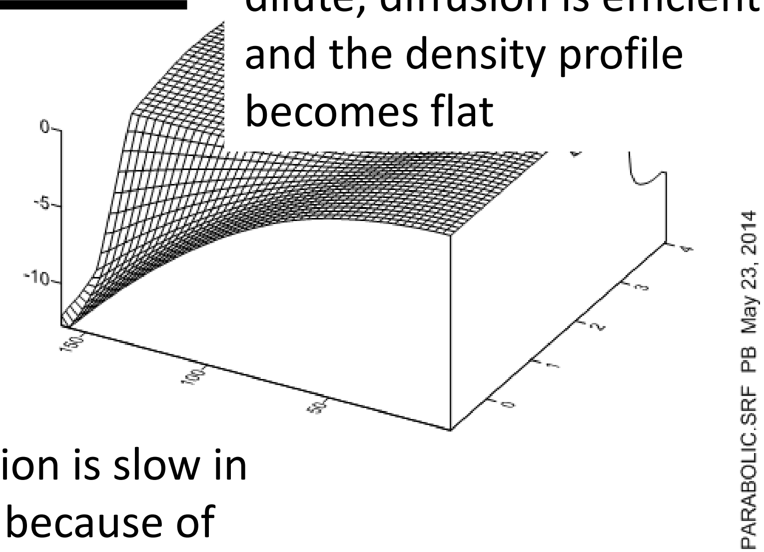


PARABOLIC.SRF PB May 23, 2014

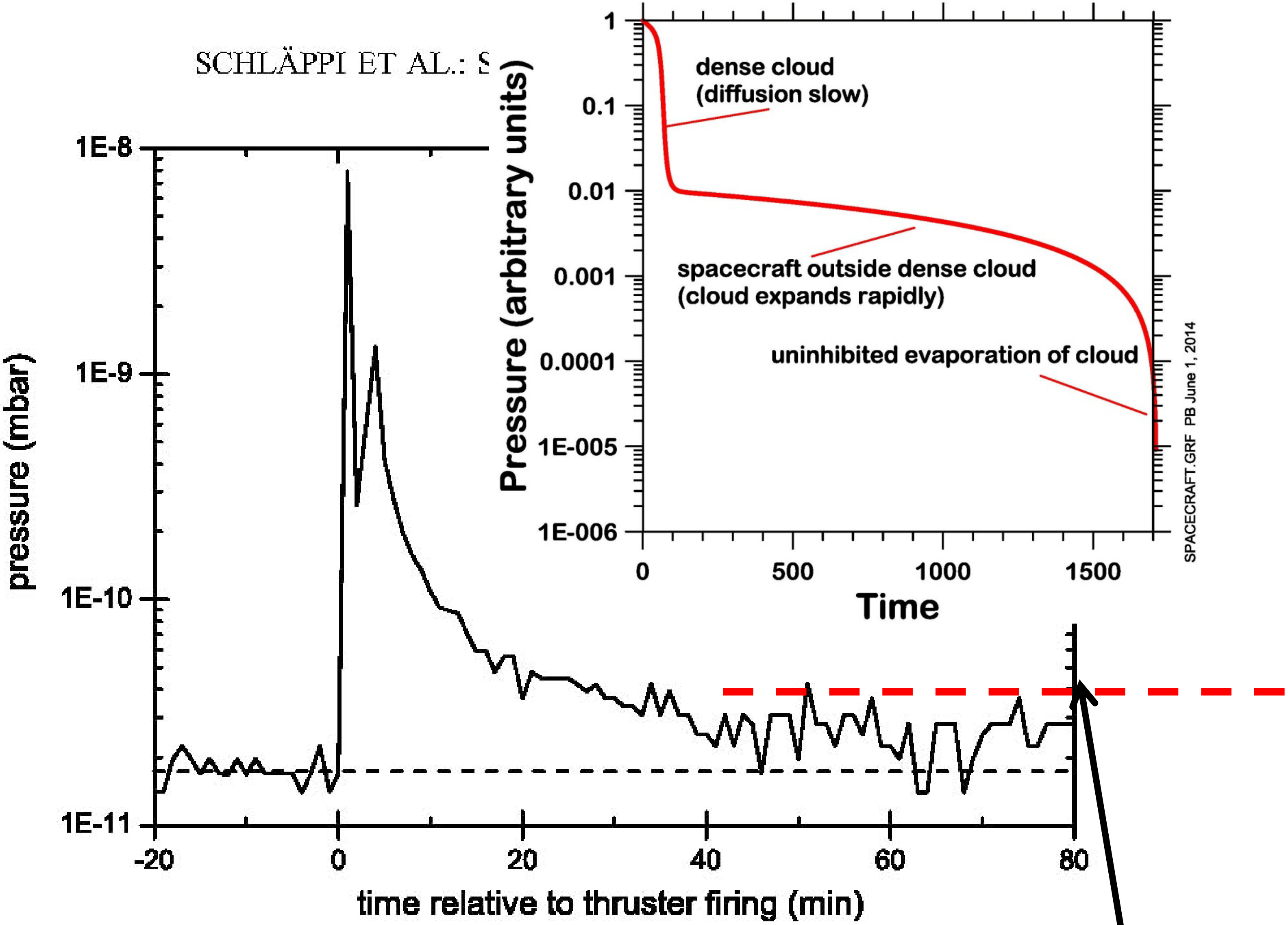
"Evaporation" of outer atmosphere where collisions among molecules are much rarer



Atmosphere has become dilute, diffusion is efficient and the density profile becomes flat

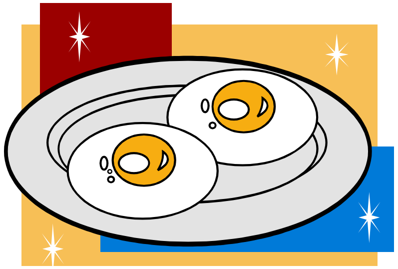


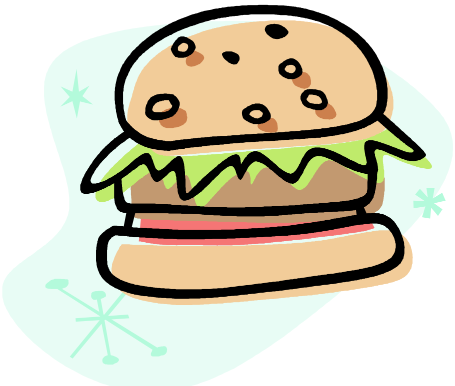
Early on diffusion is slow in the inner part because of high density



Evaporation of hydrazine droplets from spacecraft structure

What?

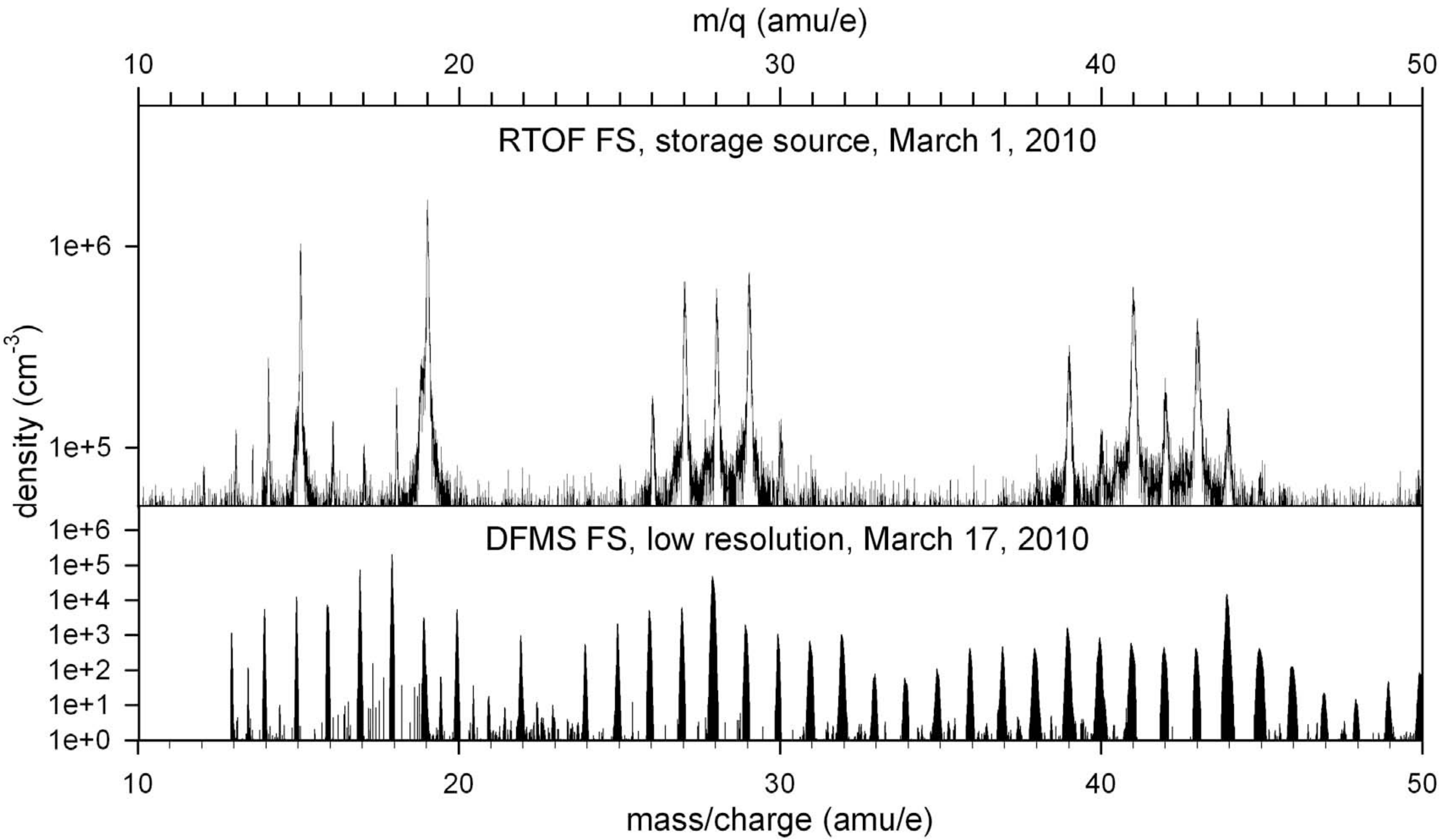




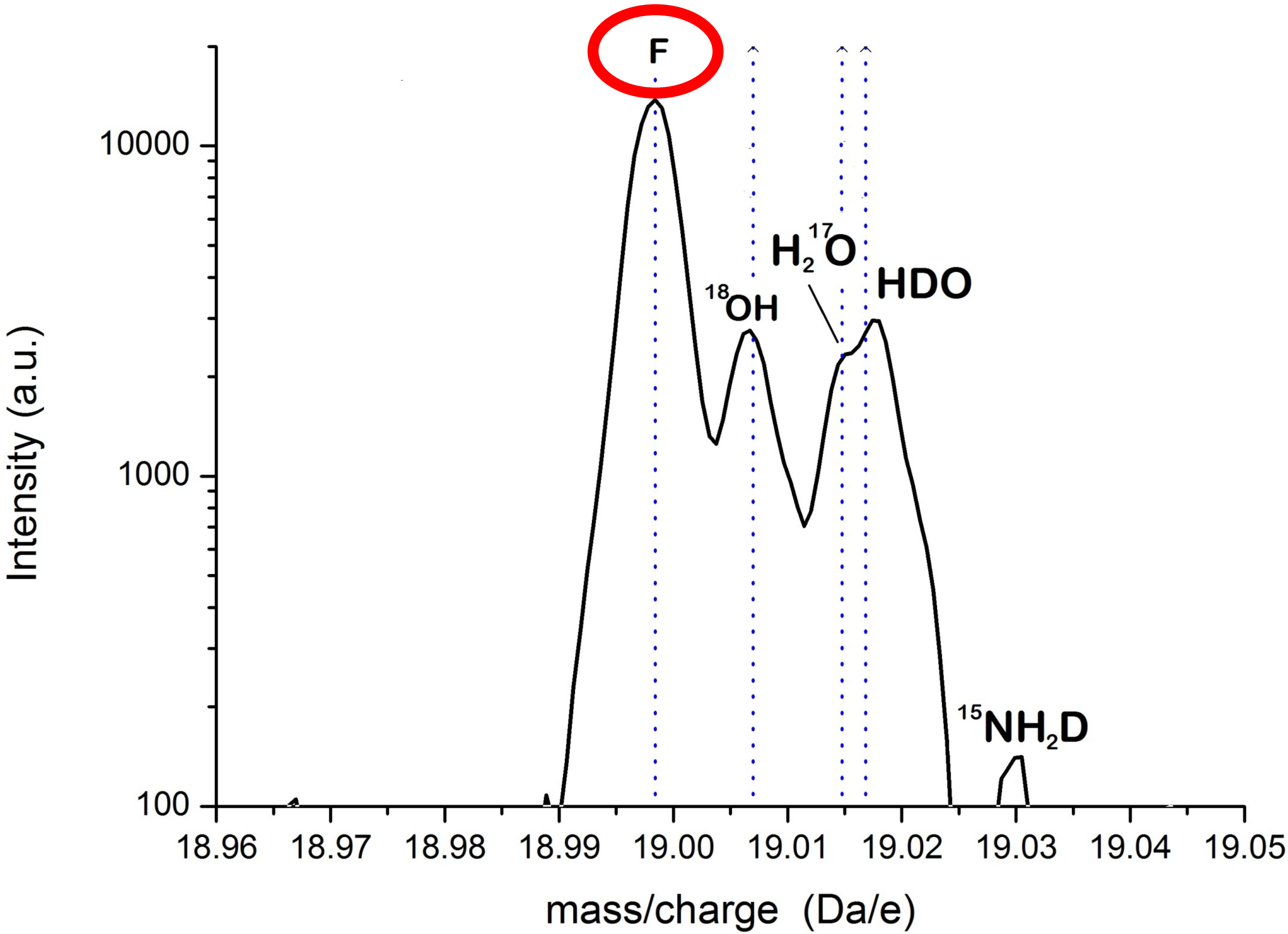
List of (toxic) chemicals detected by ROSINA

Hydrocarbons			**PAH**	**C-O**		**C-N**	**N-O**	**N-H**	**Fluorine**
CH	C_4	C_5H_{10}	C_6H	CO	$C_2H_2O_2$	CN	NO	N	F
CH_2	C_4H	C_5H_{11}	C_6H_2	CO_2	$C_2H_3O_2$	CHN	CNO	NH	HF
CH_3	C_4H_2	C_5H_{12}	C_6H_3	HCO	$C_2H_4O_2$	CH_2N	$HCNO$	NH_2	CF
CH_4	C_4H_3		C_6H_4	CH_2O		CH_3N	H_6CNO	NH_3	
	C_4H_4		C_6H_5	CH_3O	C_4H_4O	CH_3NH	NO_2	N_2	**Sulfur**
C_2	C_4H_5		C_6H_6	CH_4O	C_4H_5O	CH_3NH_2	HNO_2		S
C_2H	C_4H_6			CH_5O	C_4H_6O	CH_3N_2H	H_4NO_2	**Oxygen**	N_2S
C_2H_2	C_4H_7		C_7H_3		C_4H_7O	$CH_3N_2H_2$	H_2N_2O	O	SO_2
C_2H_3	C_4H_8		C_7H_4	C_2O	C_4H_8O	$CH_3N_2H_3$		OH	
C_2H_4	C_4H_9		C_7H_5	C_2HO			$CHNO_2$	H_2O	**Chlorine**
C_2H_5	C_4H_{10}		C_7H_6	C_2H_2O		C_2H_2N	CH_3NO_2	DHO	^{35}Cl
C_2H_6			C_7H_7	C_2H_3O		C_2H_3N	CH_4NO_2	$H_2{}^{18}O$	^{37}Cl
	C_5		C_7H_8	C_2H_4O		C_2H_4N	C_2H_6NO	O_2	$H^{35}Cl$
C_3	C_5H			C_2H_5O			C_2N_2O		$H^{37}Cl$
C_3H	C_5H_2		C_8H_{10}			C_5H_4N	C_2HN_2O		CCl
C_3H_2	C_5H_3			C_3H_2O		C_5H_5N	$C_2H_2N_2O$		CCl_2
C_3H_3	C_5H_4		C_9H_{12}	C_3H_3O		C_5H_6N	$C_2H_3N_2O$		
C_3H_4	C_5H_5			C_3H_4O		C_5H_7N	$C_2H_5N_2O$		
C_3H_5	C_5H_6			C_3H_5O		C_5H_8N	$C_2H_6N_2O$		
C_3H_6	C_5H_7			C_3H_6O			$C_2H_7N_2O$		
C_3H_7	C_5H_8			C_3H_7O		$C_4H_4N_2$	$C_2H_8N_2O$		
C_3H_8	C_5H_9								

Figure 6. Detected species and fragments in the vicinity of Rosetta.


m/q (amu/e)
10
20
30
40
50
RTOF FS, storage source, March 1, 2010
1e+6
1e+5
density (cm^{-3})
DFMS FS, low resolution, March 17, 2010
1e+6
1e+5
1e+4
1e+3
1e+2
1e+1
1e+0
10
20
30
40
50
mass/charge (amu/e)

Vacuum Grease



F
^{18}OH
$H_2{}^{17}O$
HDO
$^{15}NH_2D$
10000
1000
100
Intensity (a.u.)
18.96
18.97
18.98
18.99
19.00
19.01
19.02
19.03
19.04
19.05
mass/charge (Da/e)

Measures to reduce contamination hazards (lessons learned so far)

Thruster firings produce atmospheres of condensable organic contaminants, which can last for hours in the vicinity of the spacecraft!

Spacecraft design might require new (expensive) standards

Careful choice of location of instrument apertures on spacecraft, venting of all instruments at appropriate places!

Modeling of contamination risks might help to mitigate the problem

Keep surfaces near instrument apertures warm – also when shaded, to avoid condensation of contaminants.

Duplicate instrument with spare instrument for calibration purposes