rosetta

esa

Dust particles from comet 67P/Churyumov-Gerasimenko analyzed by COSIMA

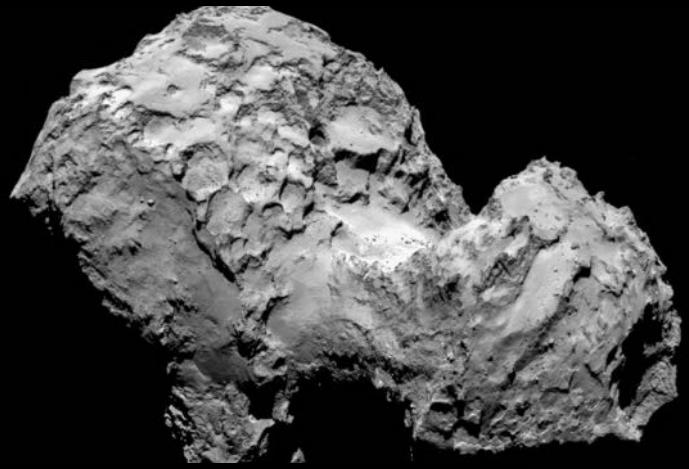
Cécile Engrand
for the COSIMA Team

IAS MPE FMI MPS vH&S esa LPC2E LCM lisa CSNSM Universität der Bundeswehr München

rosetta

esa

67P/Churyumov-Gerasimenko

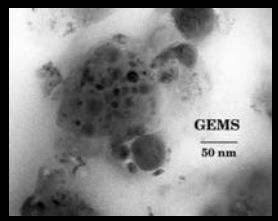


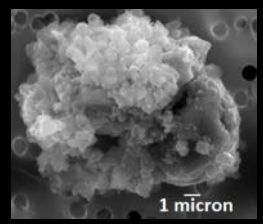
OSIRIS NAC Image Aug. 03, 2014

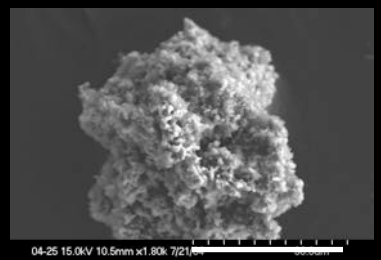
- Composition volatiles/dust/nucleus : *ROSINA, COSIMA, VIRTIS*
- 3 dust instruments on Rosetta
- Composition : COSIMA

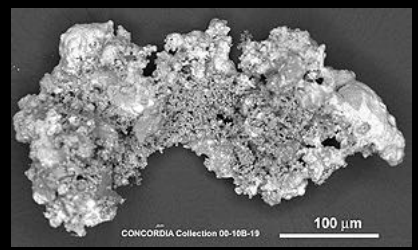
GIADA

MIDAS **COSIMA**



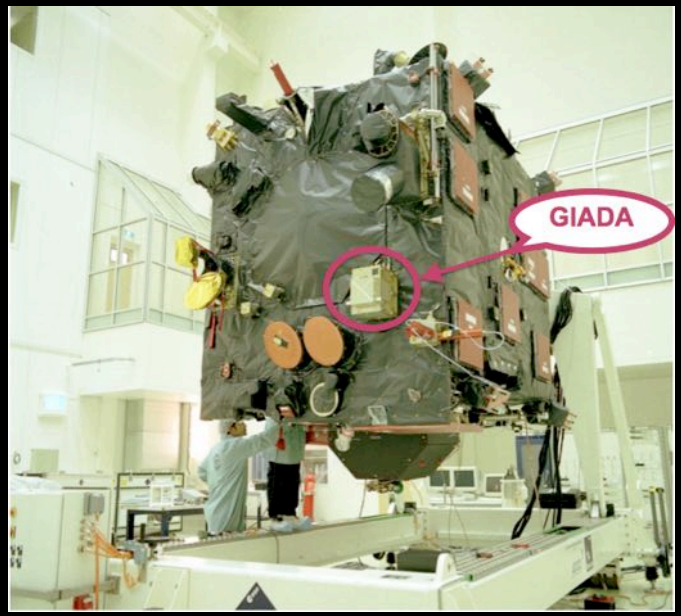


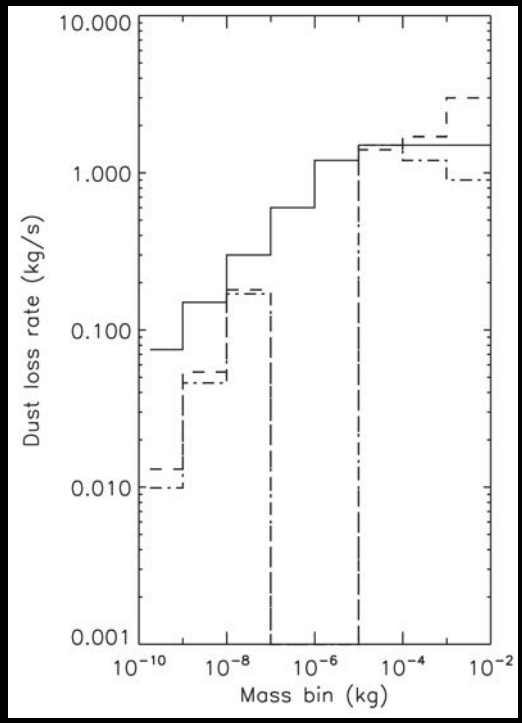




Merouane et al., 2015 (SWT Rosetta)

Dust flux (GIADA)

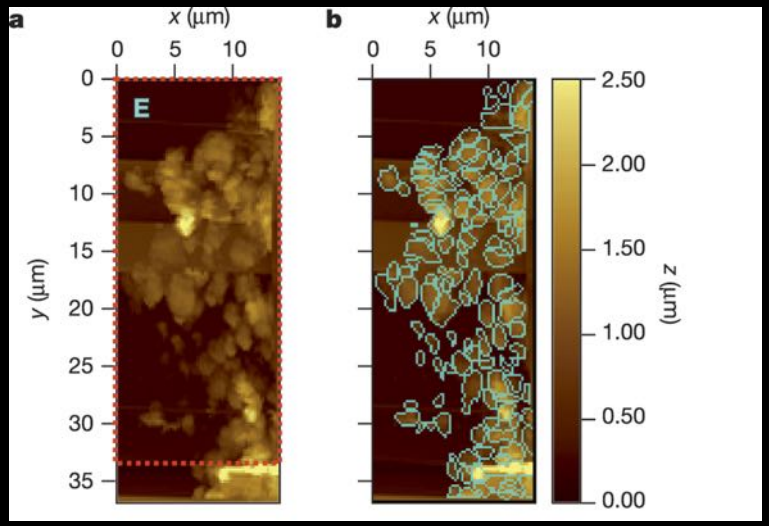


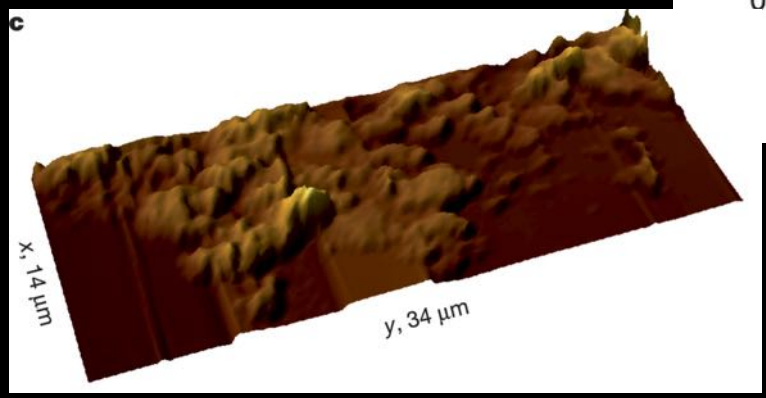


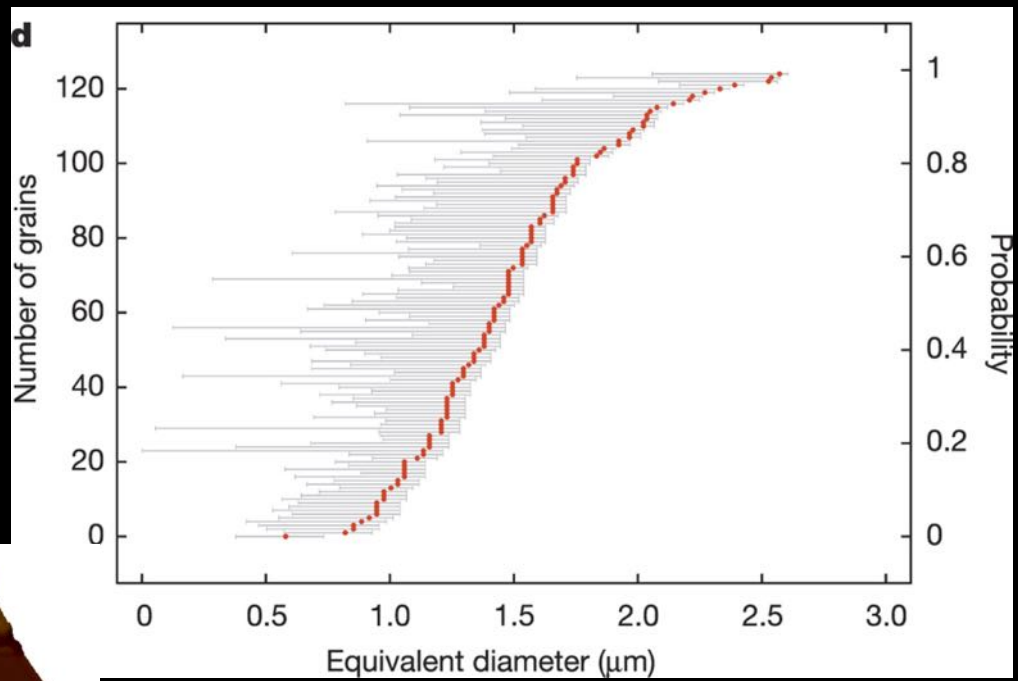
- Low speed (a few m/s)
- Showers of particles
- Detection of 2 types of particles :
  - Compact (0.03 – 1 mm), density: 800–3000 kg/m^3, consistent with a variety of minerals or mixtures of minerals.
  - 'fluffy aggregates' (0.2 - 2.5 mm), density < 1kg/m^3 - sub-micron sized grains with void spaces in between.

(Rotundi et al. 2015)

Sub-um image of comet dust (MIDAS)



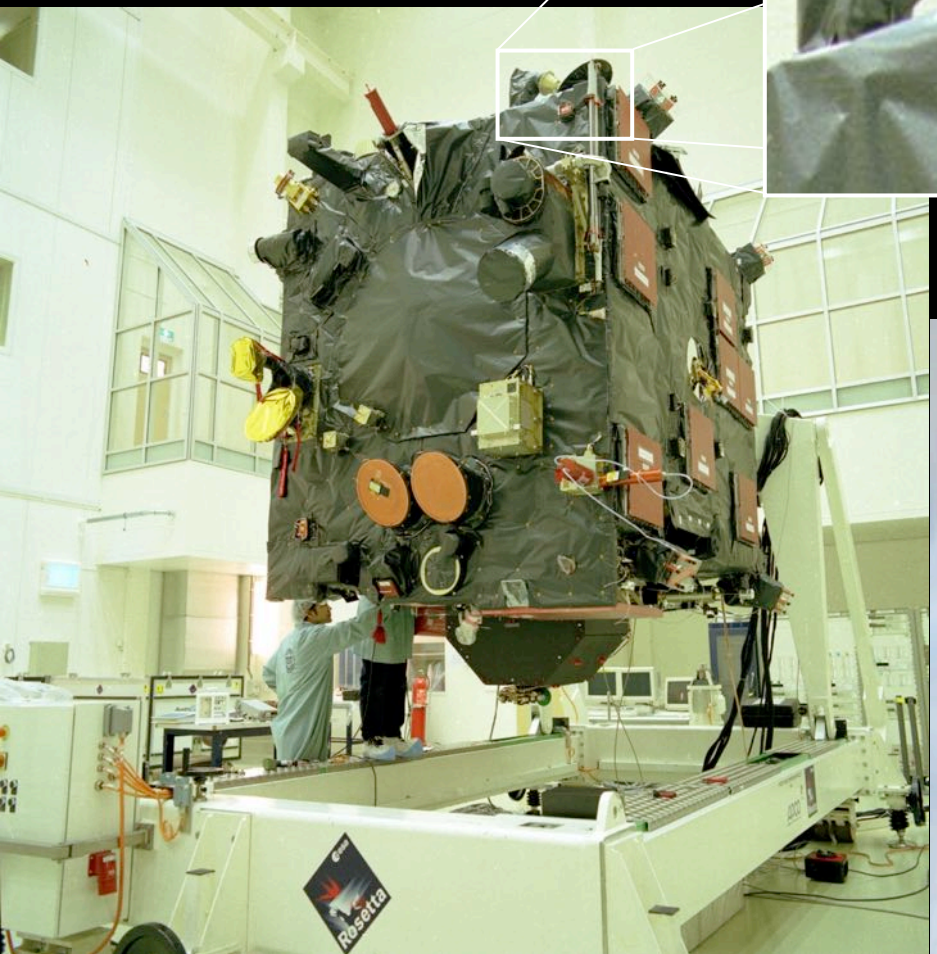




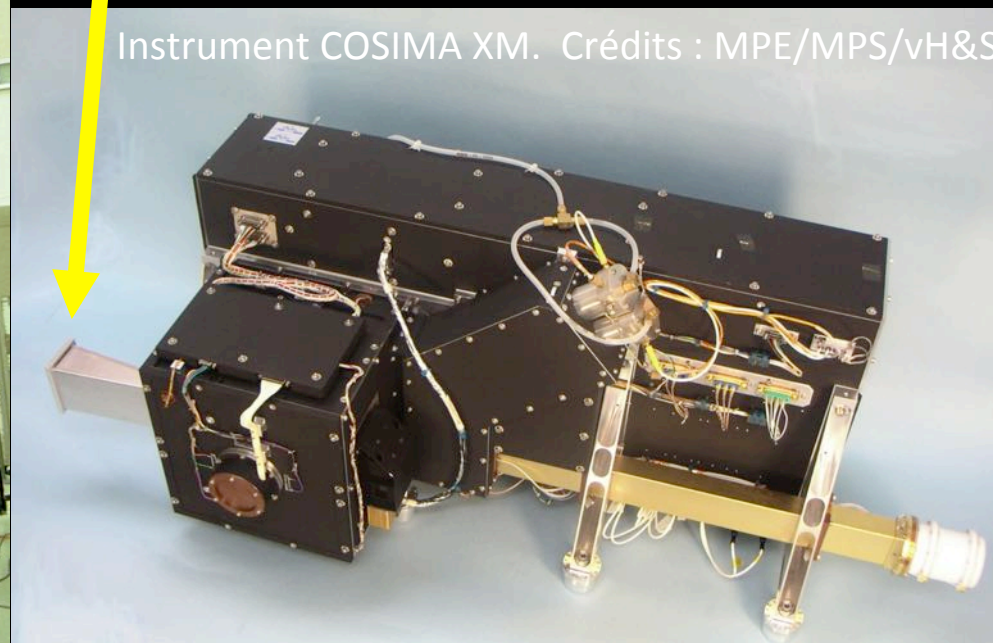
(Bentley et al. 2016)

- Atomic force microscope
- Very fluffy textures reminiscent of IDPs/MMs

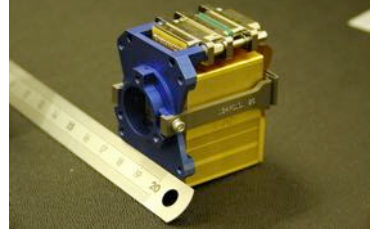
Composition of comet dust (COSIMA - COmetary Secondary Ion Mass Analyzer)



Instrument COSIMA XM. Crédits : MPE/MPS/vH&S

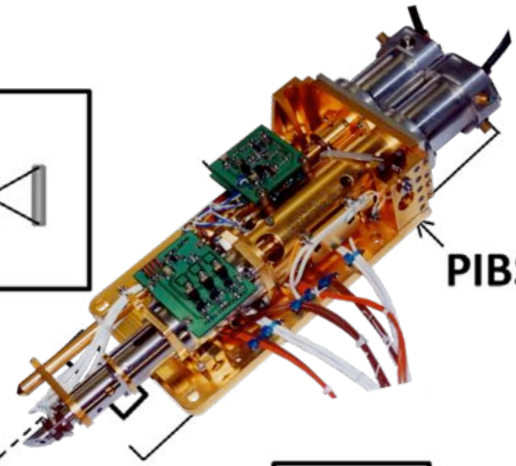


COSIMA



Chemical station
Up to T= 403 K

Microscope (COSISCOPE)



PIBS

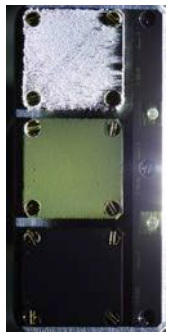
Cometary Grains

Dust collection position
(253 K < T < 303 K)

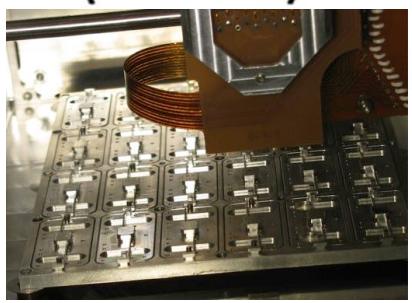
RTOF

vH&S

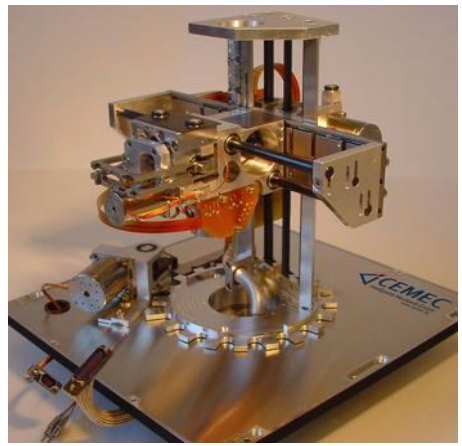
3 x 1 cm²



Target store (24 sets)
(T < 303 K)



Robotic arm



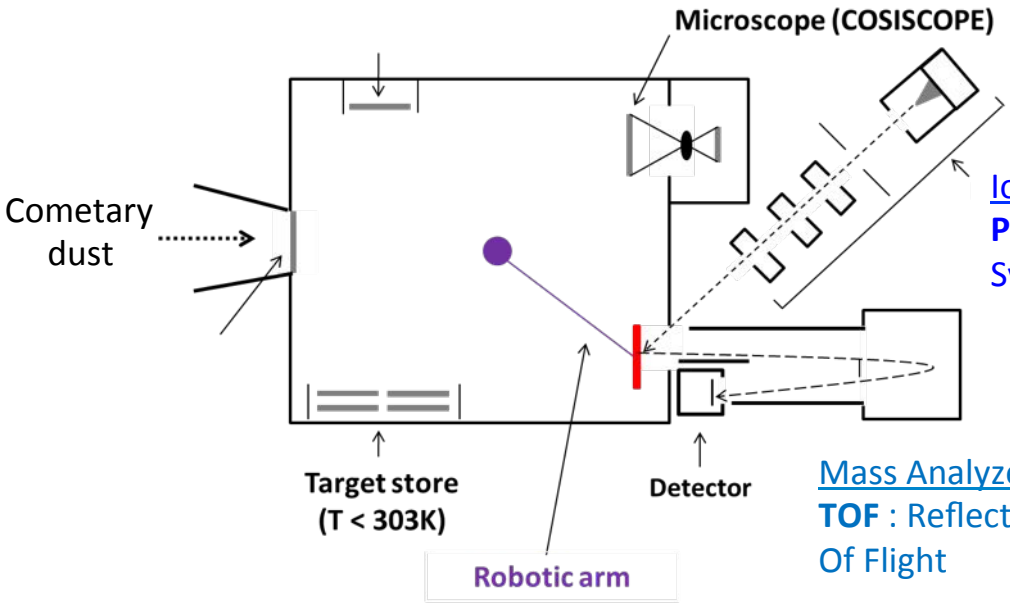
FMI

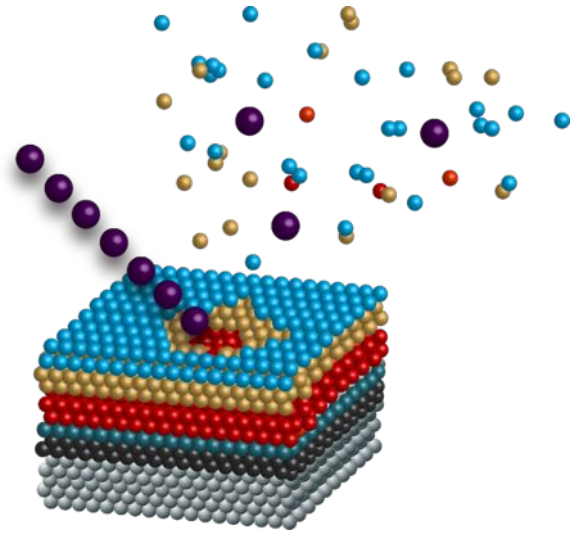
der Bundeswehr Universität München

MPE

COSIMA : COmetary Secondary Ion Mass Analyzer

TOF – SIMS : Time of Flight – Secondary Ion Mass Spectrometry
Surface analysis

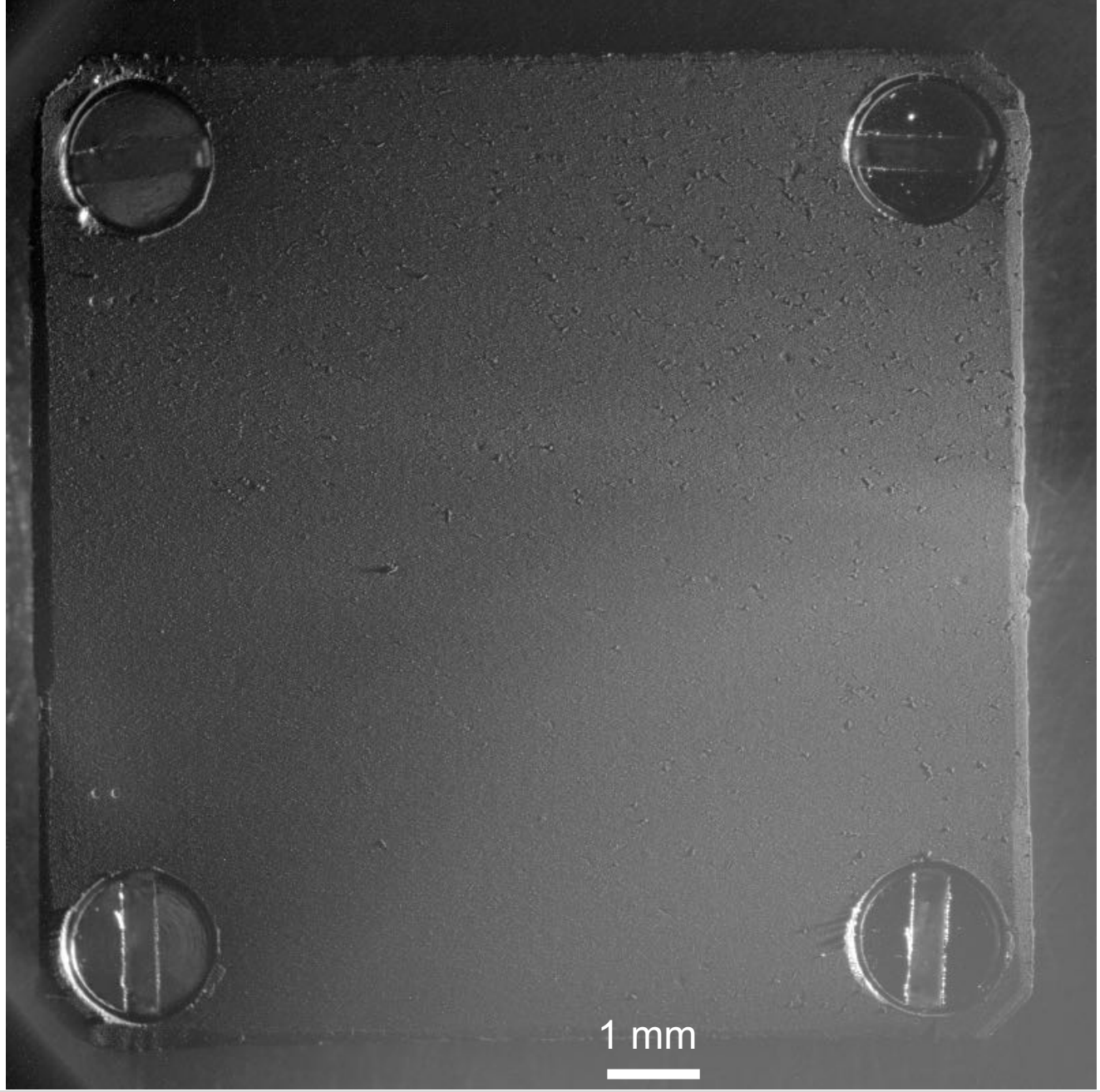




- **Both positive and negative mode:** target at ground & extractor at +/- 3 kV
- **Footprint of the pulsed ion beam:** 35 × 50 µm²
- **Spectral resolution** : m/Δm ≈ 1400
- **Mass range** : from 1 to 1000 amu

Aug 17, 2014
target 1D0

grazing incidence illumination (right)



target 1 x 1 cm^2

Y. Langevin
K. Hornung

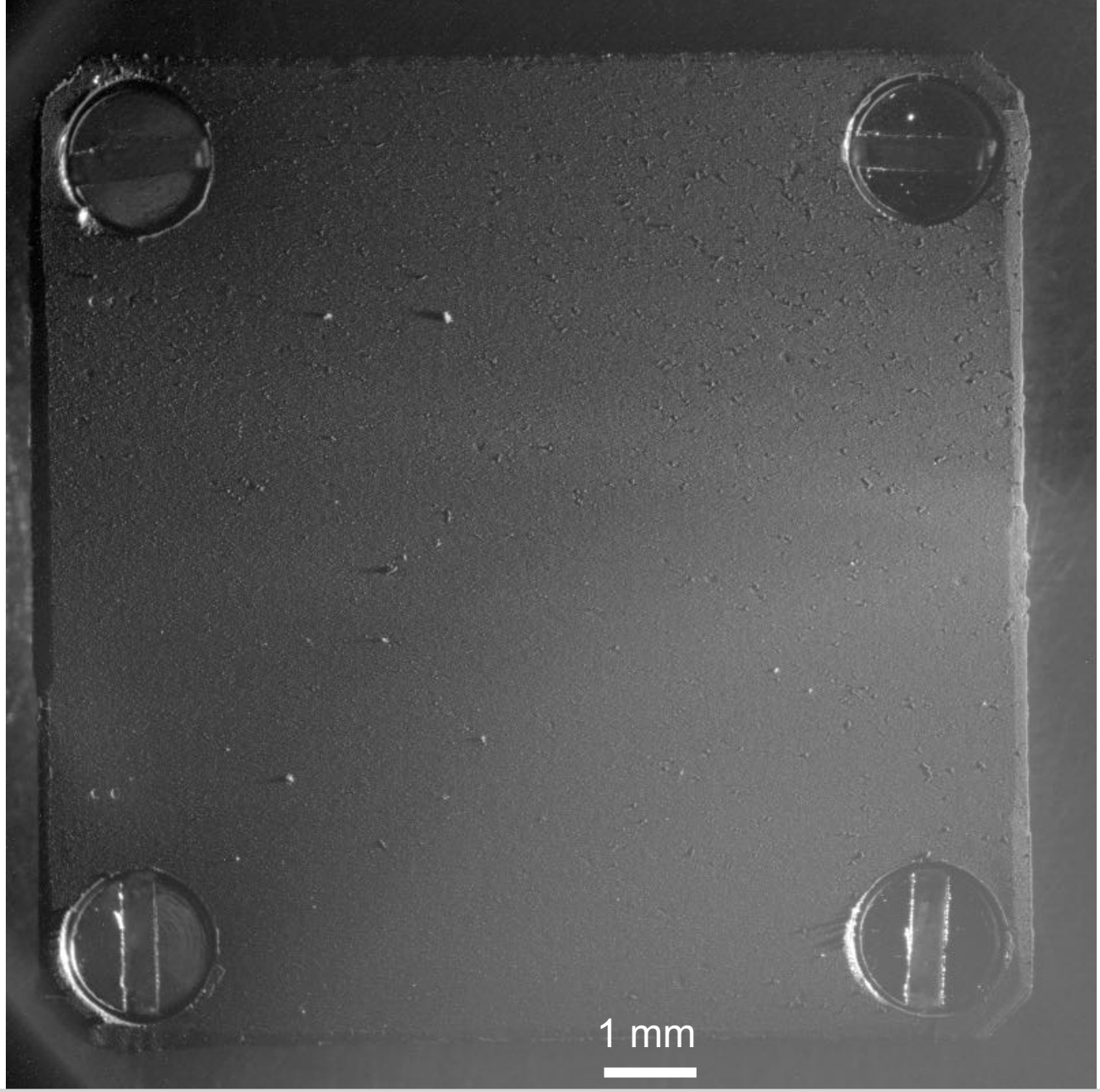
Aug 24, 2014
target 1D0

grazing incidence illumination (right)

cometary dust

target 1 x 1 cm^2

Y. Langevin
K. Hornung



3D0 Target
Exposed 11 Aug 12 Dec 2014

COSISCOPE image 21 Nov. 2014

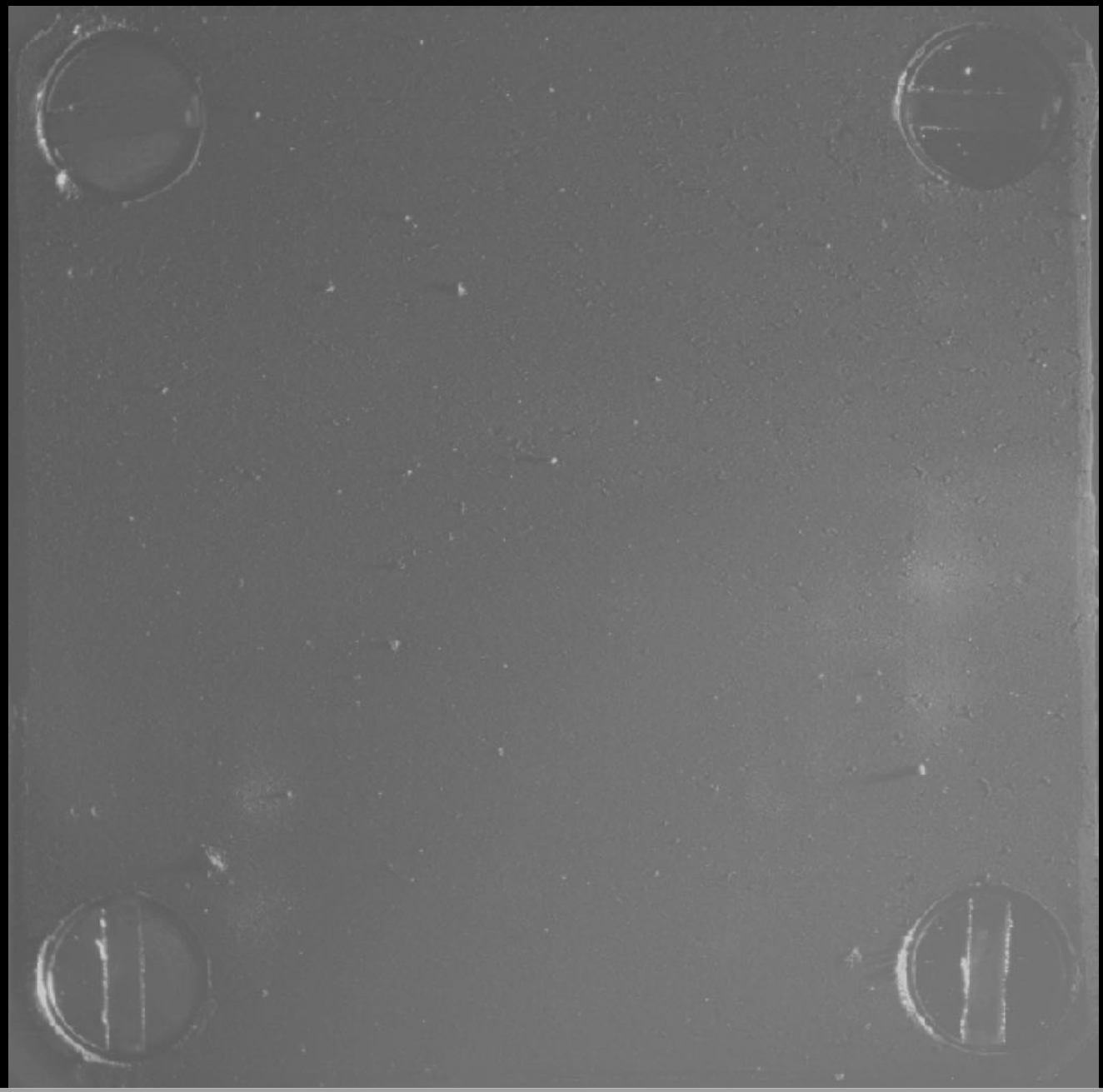
After 15 weeks exposure in the coma of 67P/C-G.

log scale

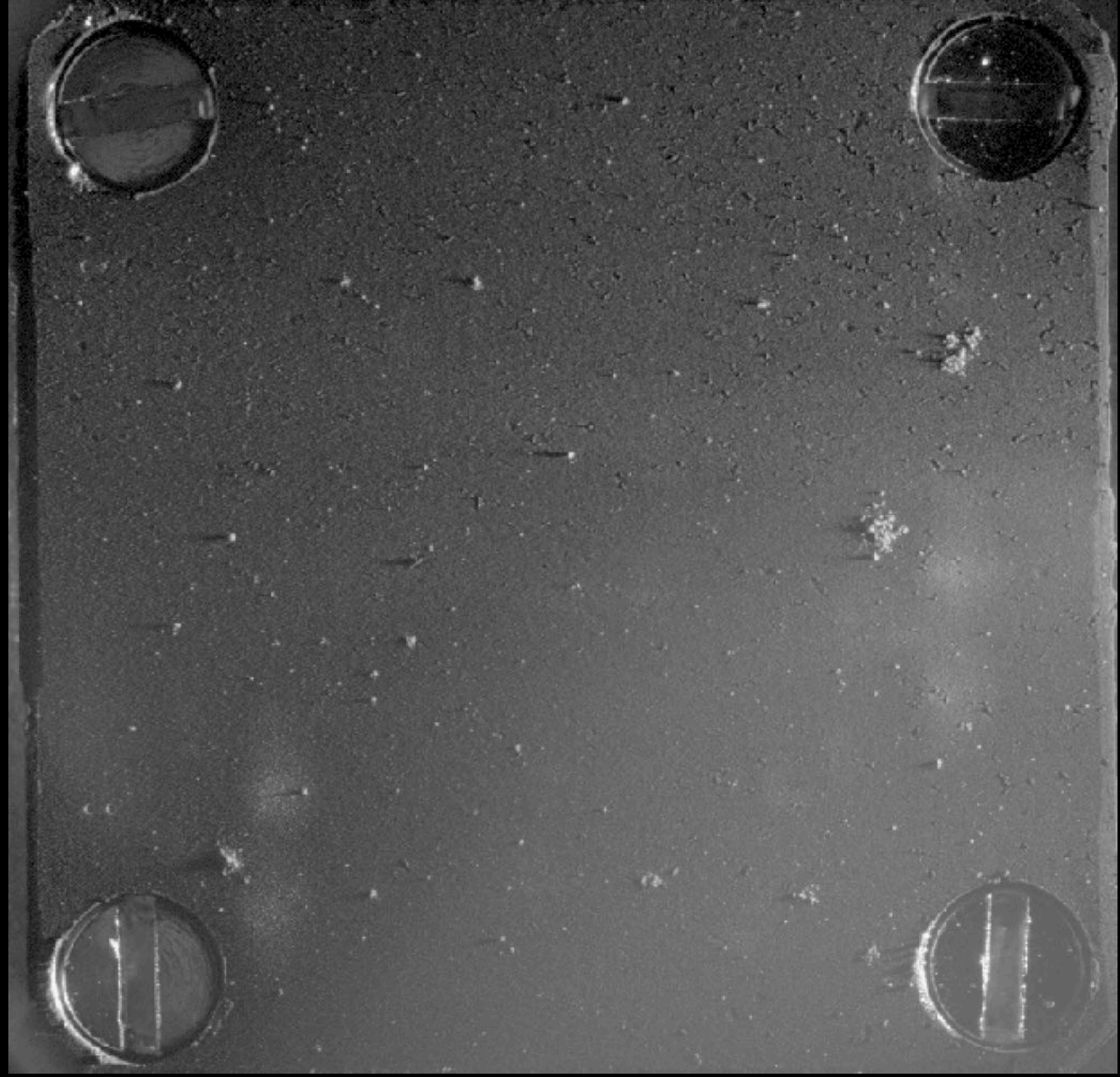
Oleg
Kamil
Kati
Massimiliano
Deborah
Galya
Nick
Robby
Cora
Alessandra
Friedemann
Vincenzo
Britta
Dagny
Walfrid
Jennifer
Tino
Vivica
Regula
Rauni
Hiroshi
Cody
Bob
Ake
Alice
Tia
Berenice
Calliste
Marco
Janet
Sid
Ali
Rosario
Arvid
Joseph
Eloi
Marie-Paule
Ammeris

http://blogs.esa.int/rosetta/2015/04/16/cosima-meet-the-family/

1D0
Nov. 7, 2014

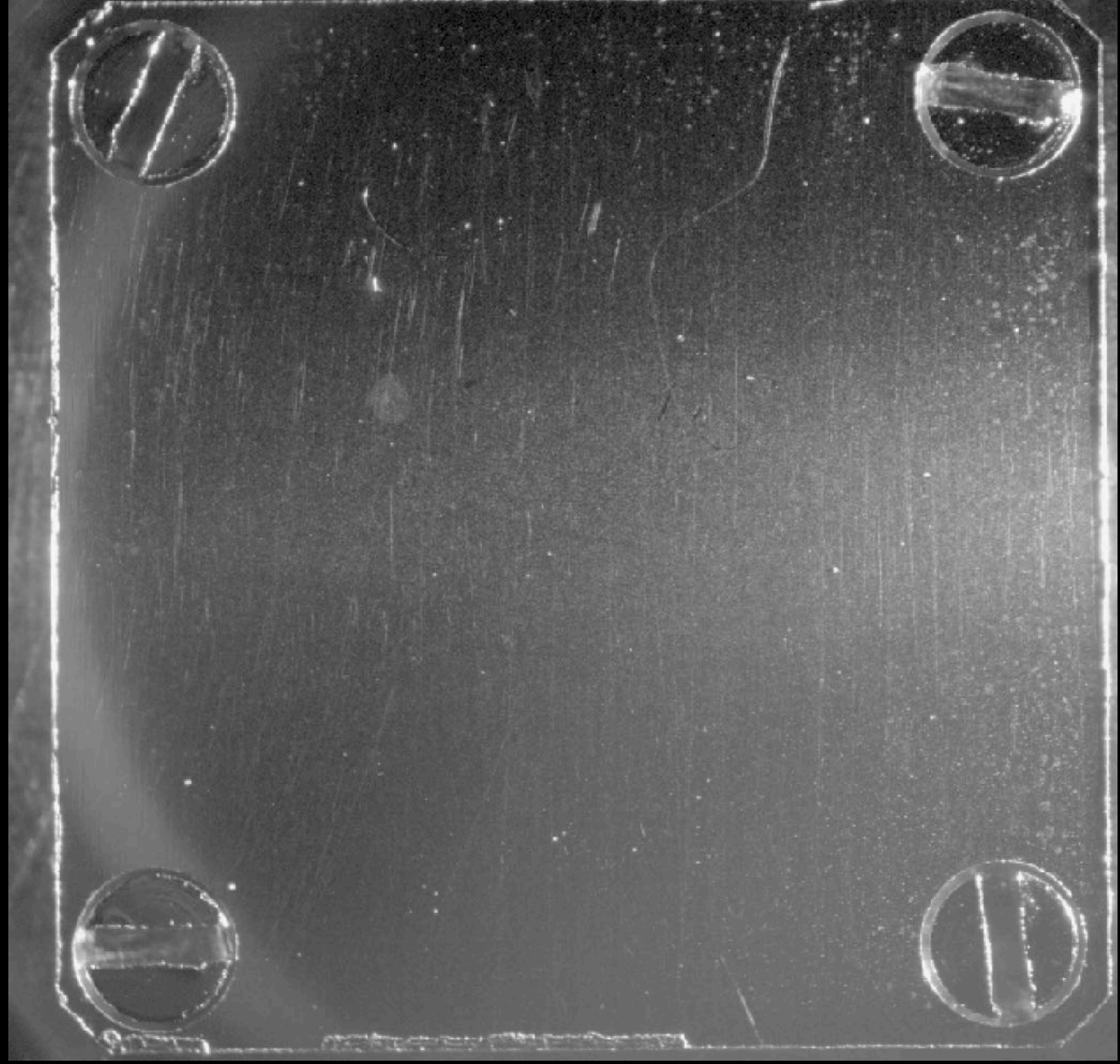


1D0
Sep., 2016



1C7

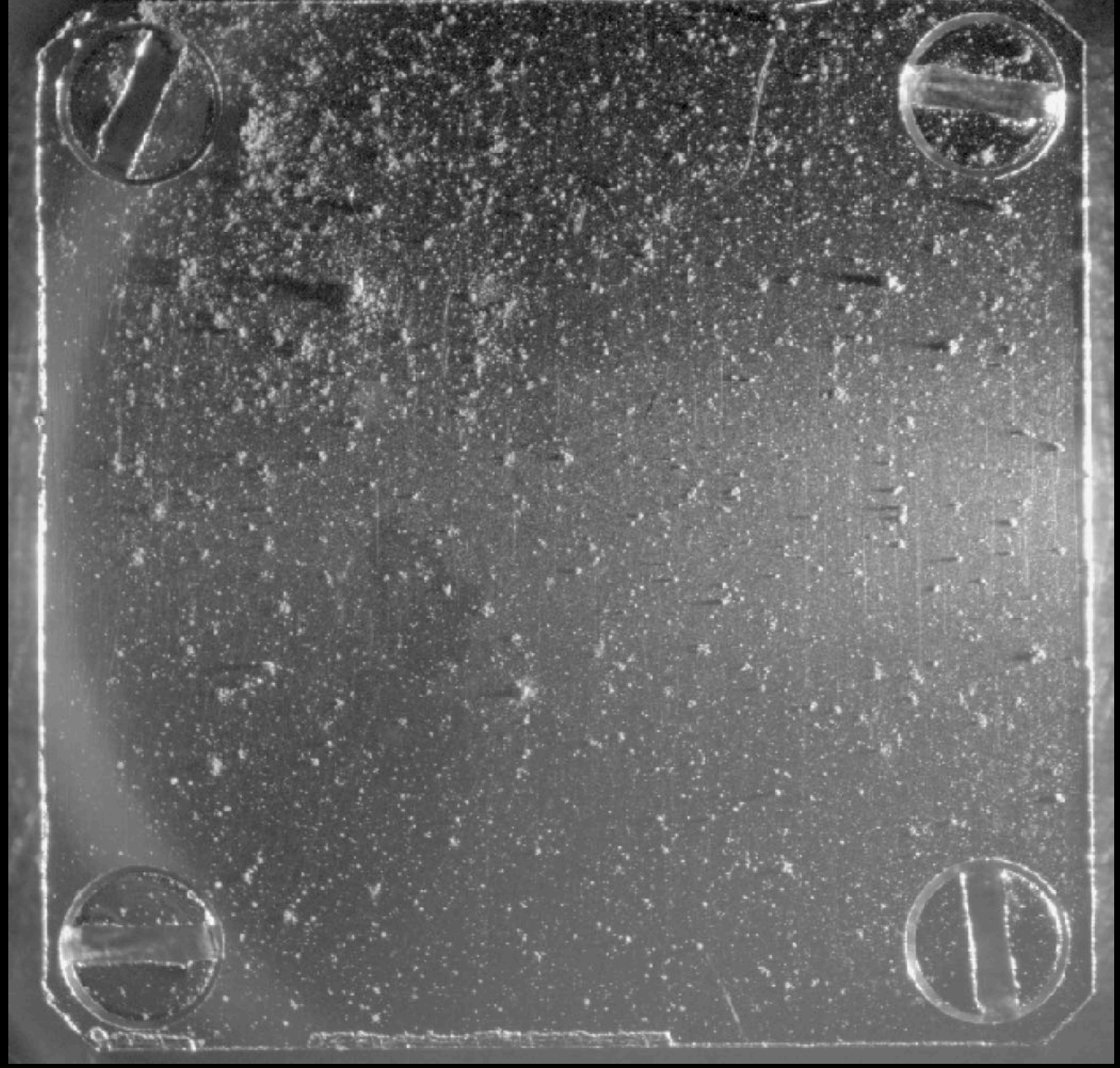
Feb. 12, 2015



IAS MPE FMI MPS vH&S esa LPC2E LCM lisa IWF CSNSM Universität der Bundeswehr München BERGISCHE UNIVERSITÄT WUPPERTAL

1C7

Nov. 11, 2015

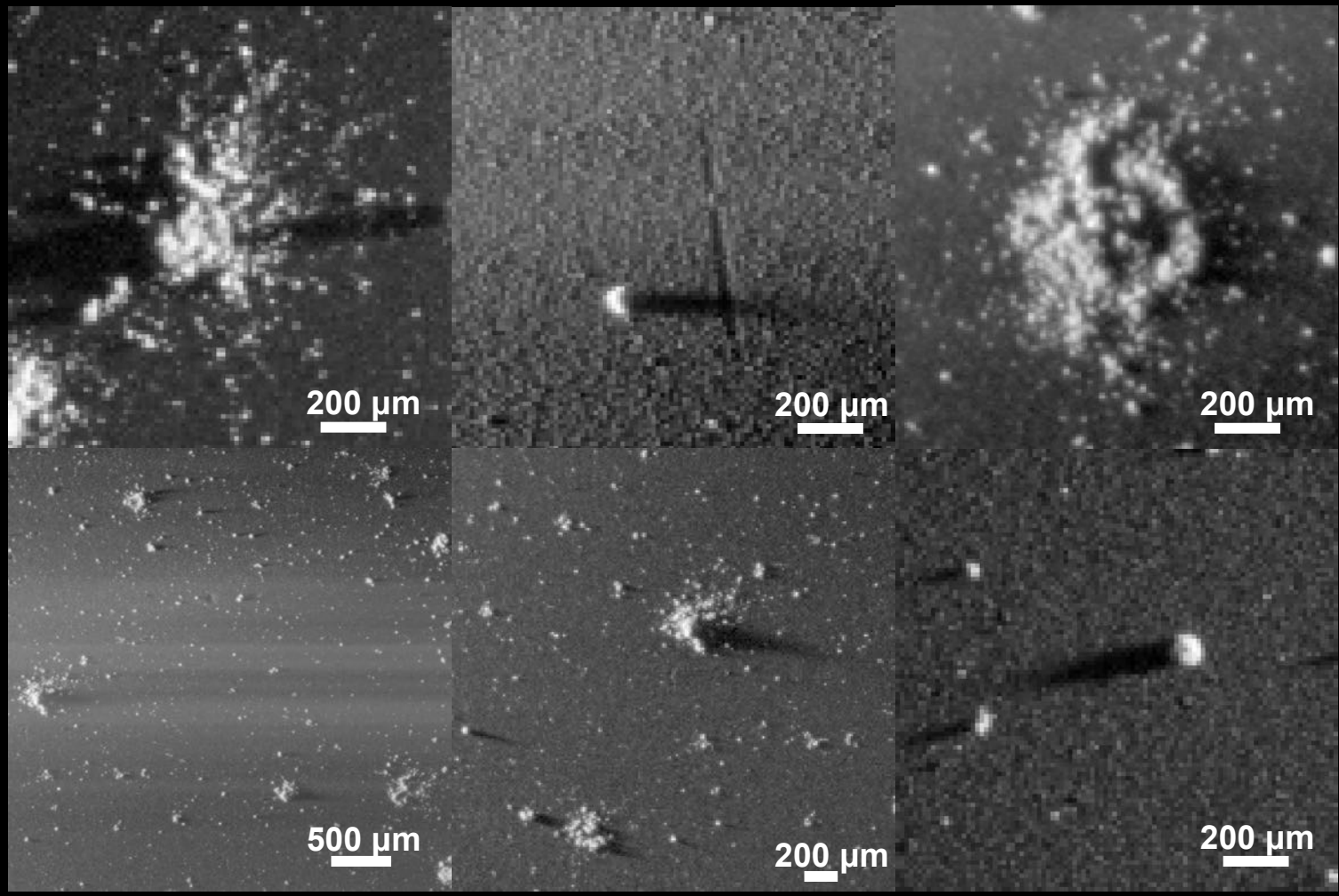


Grains lists (S. Merouane MPS)

X	Y	ID	Rank	area (px²)	area (um²)	First Name	Last Name	Running number	Target	Lost	STP SIMS pos	STP SIMS neg
2732	7255	6	5	16	3136	Francois	Enonvesi	2	1D0	(Orivesi)	16,21	16,21
3952	7227	7	5	35	6860	Boris	Enonvesi	2	1D0	(Orivesi)	16,21,105	16,21,105
3286	3943	8	4	13	2548	Gerhard	Enonvesi	2	1D0	(Saimaa)	16	16
3494	4788	9	0	6	1176	Sandra	Enonvesi	2	1D0	0	0	0
3841	4913	10.1	0	8	1568	Oliver	Enonvesi	2	1D0	0	0	0
3841	4913	10.2	0	2	392	Hugo	Enonvesi	2	1D0	0	0	0
2801	5357	11	0	4	784	Marie	Enonvesi	2	1D0	0	0	0
2496	3957	12	0	6	1176	Thomas	Enonvesi	2	1D0	0	16	16
2053	3915	13	0	6	1176	Wolfgang	Enonvesi	2	1D0	0	23	23
570	4373	14	0	1	196	Alphonse	Enonvesi	2	1D0	0	0	0
5338	4511	15	0	2	392	Ida	Enonvesi	2	1D0	0	0	0
8041	4678	16	0	5	980	Francois-Regis	Enonvesi	2	1D0	0	0	0
6696	7574	17	0	1	196	Berthe	Enonvesi	2	1D0	0	0	0
7874	6493	18	0	4	784	Nigel	Enonvesi	2	1D0	0	0	0
7001	5662	19	0	2	392	Jacques	Enonvesi	2	1D0	0	0	0
7417	5773	20	0	1	196	Claude	Enonvesi	2	1D0	0	0	0
5338	5440	21	0	4	784	Roger	Enonvesi	2	1D0	0	0	0
2122	6438	22	0	1	196	Fernand	Enonvesi	2	1D0	0	0	0
8886	5689	23	0	2	392	Manville	Enonvesi	2	1D0	0	0	0

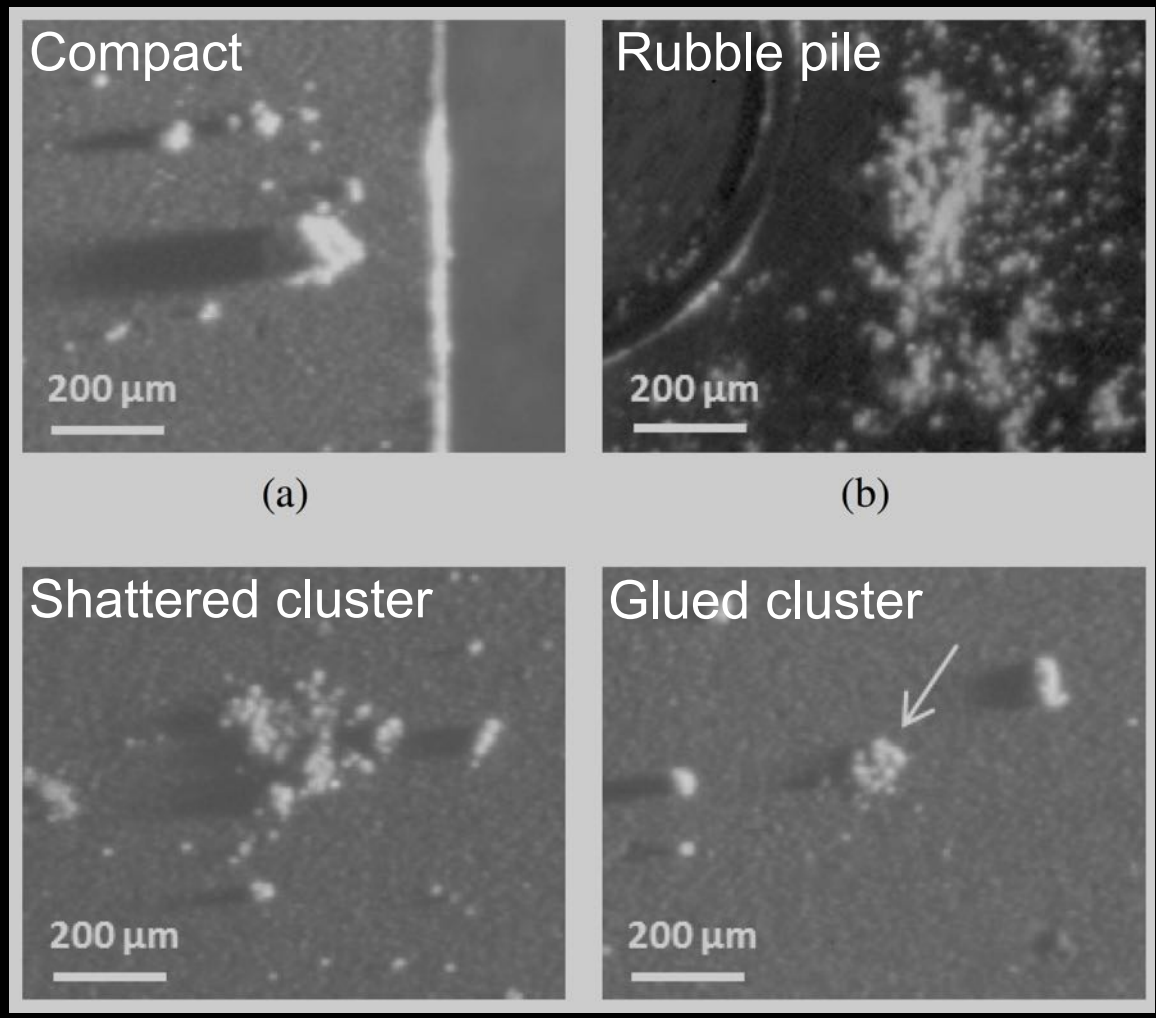
- identification by image blinking (manual)
- > 31,000 particles collected (~ 270 analyzed)
- Sep. 30, 2016 : dust returned to the comet ☺

Different grain typologies



(Langevin et al. 2016)

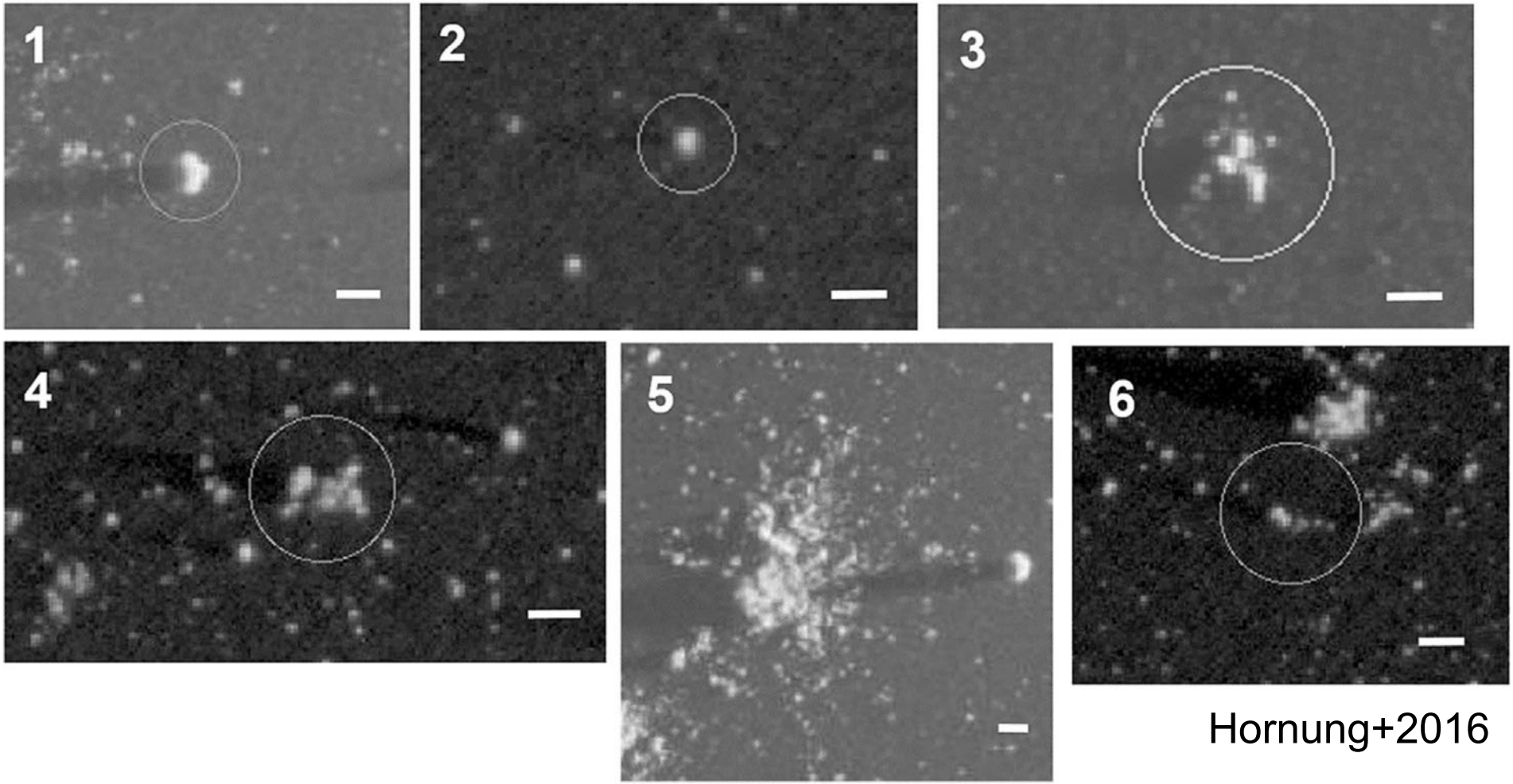
Grain typology



Langevin+2016
Merouane+2016

Compact grains of COSIMA ≡ fluffy grains for GIADA…

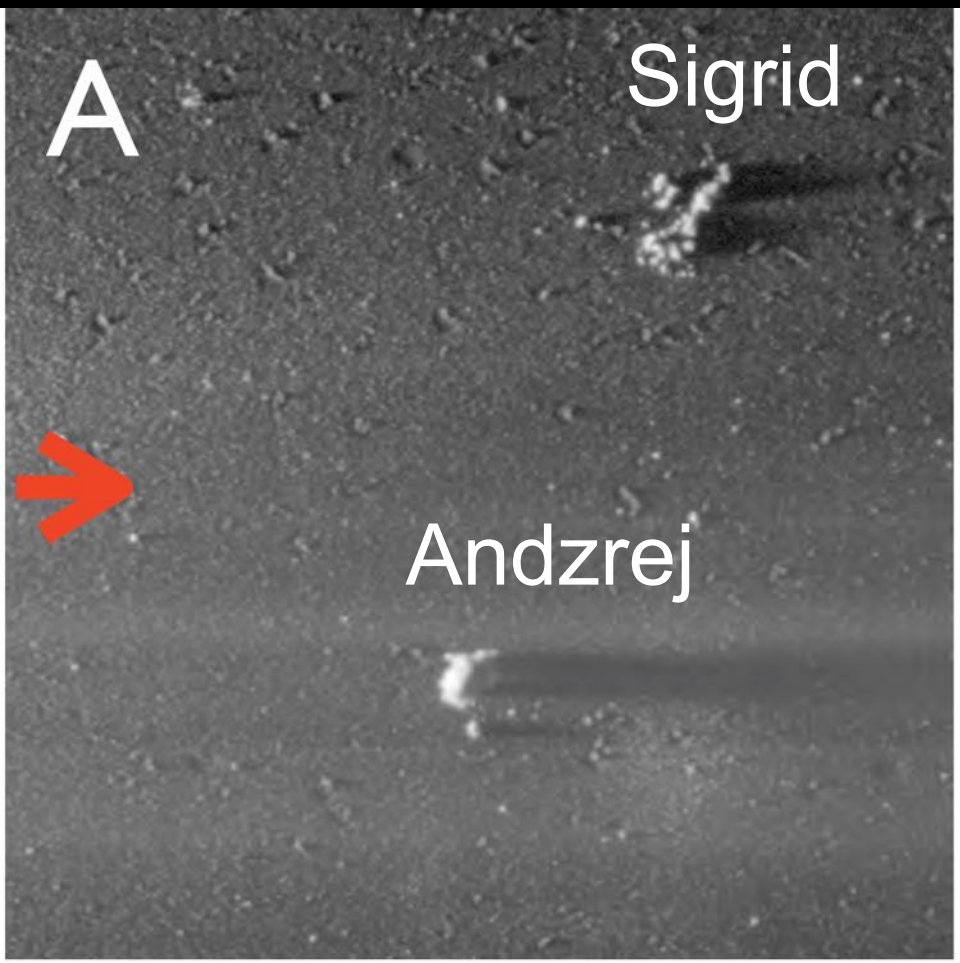
Tensile strength

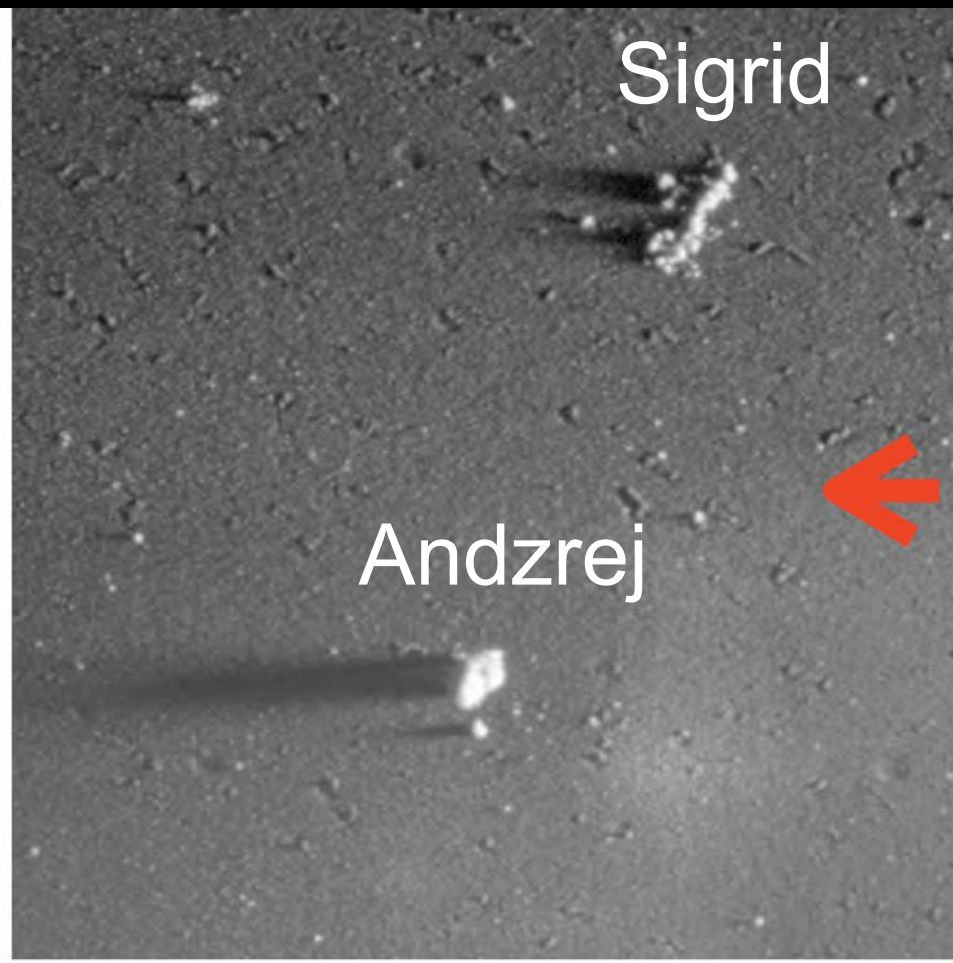


Hornung+2016

- Most particles fragmented upon impact
- low tensile strength ~ 1000 to 2000 Pa

Modification of dust by COSIMA analyses





Before

Hilchenbach+2017

Modification of dust by COSIMA analyses

After pressing Andrzej

Hilchenbach+2017

Modification of dust by COSIMA analyses

After neg. spectra on Andrzej

Hilchenbach+2017

Modification of dust by COSIMA analyses

After pos. spectra on Andrzej

Hilchenbach+2017

Modification of dust by COSIMA analyses

After neg. spectra on Sigrid

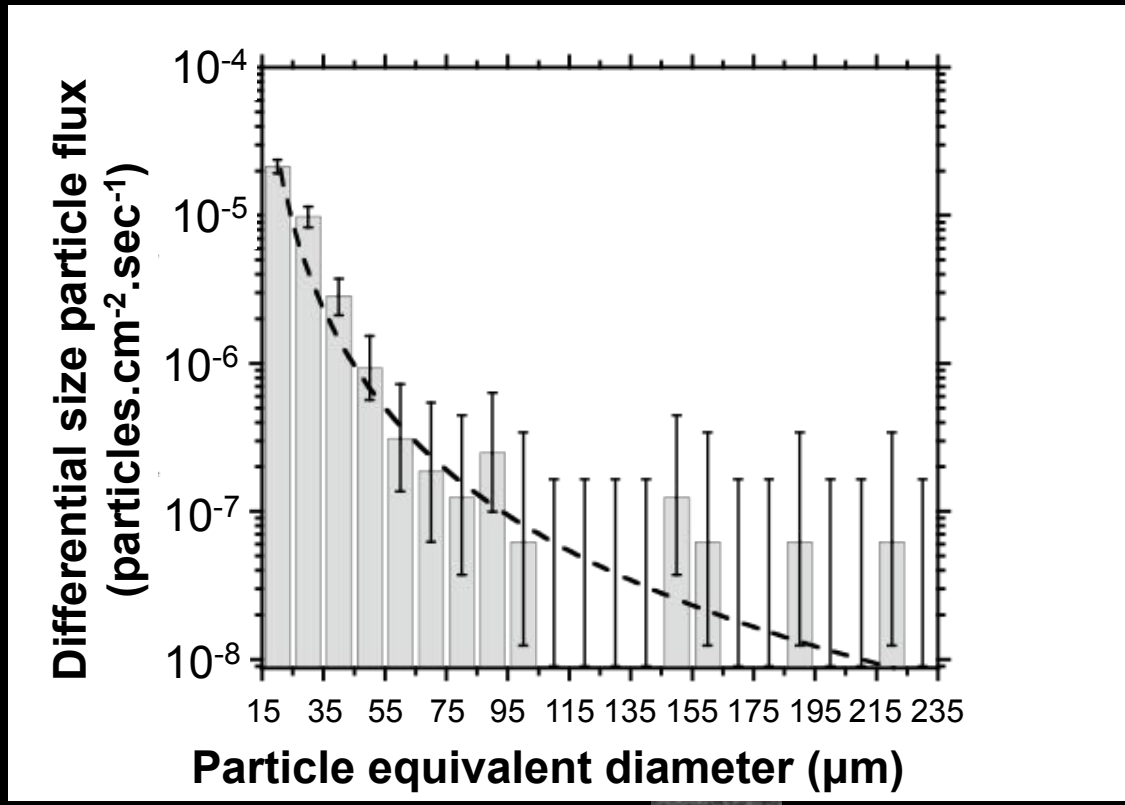
Hilchenbach+2017

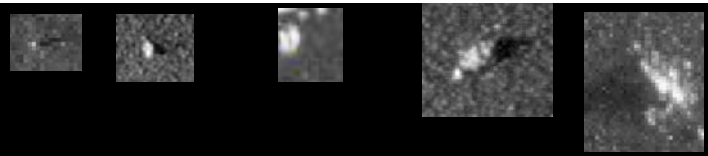
Modification of dust by COSIMA analyses

After pos. spectra on Sigrid

Hilchenbach+2017

Average grain size distribution*

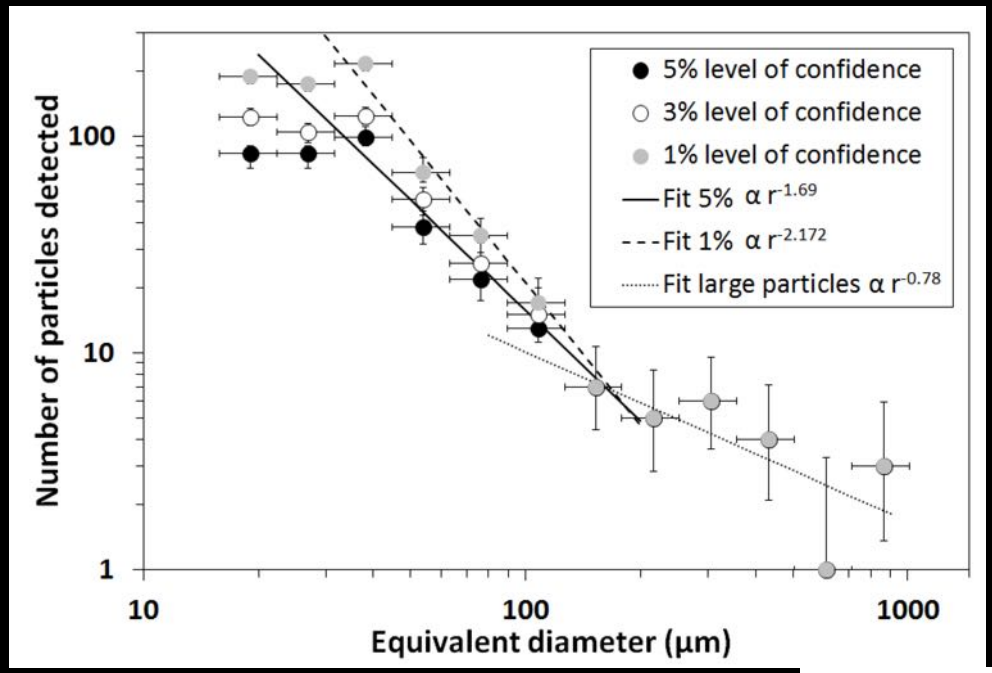




(Merouane et al. 2016)

* time interval : Aug. 11 to Oct. 24 2014

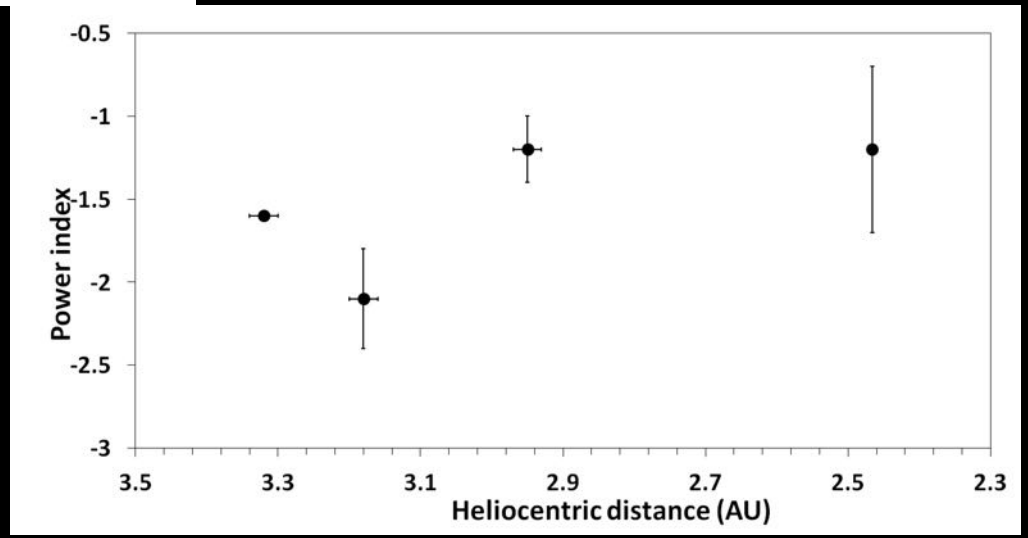
COSIMA size distribution



30-150 µm $r^{-1.9 \pm 0.3}$

> 150 µm power index ~ 0.8

Merouane+2016

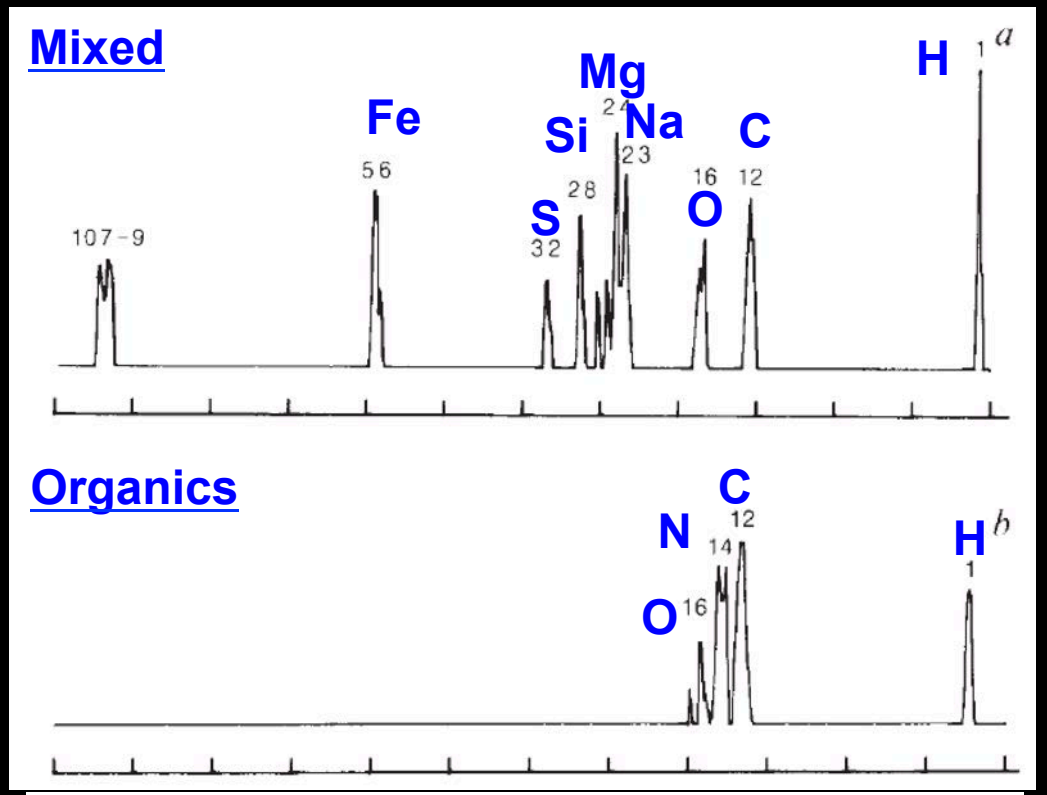


(PIA data)

1986

Comet Halley

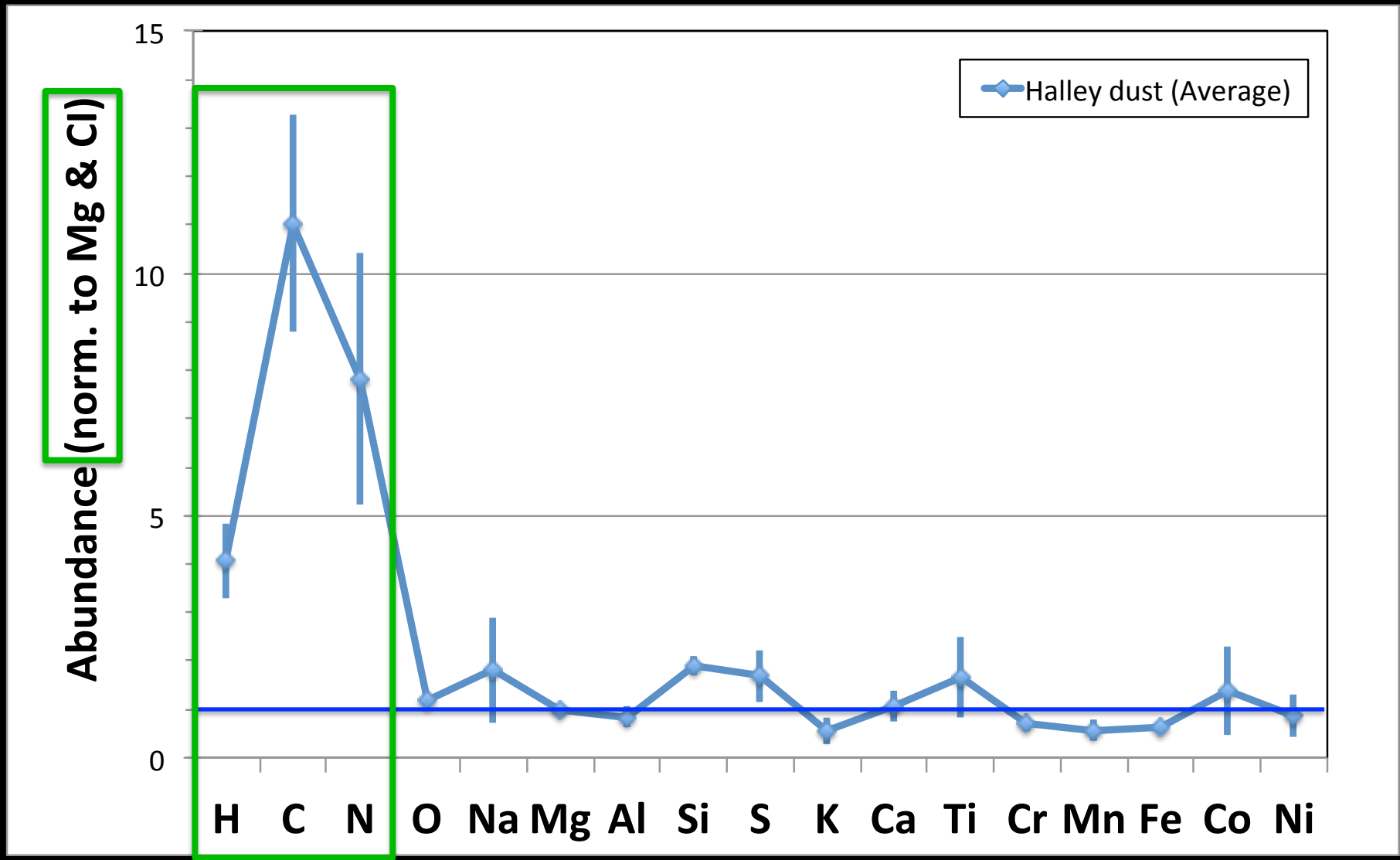
80% of the spectra



- « CHON particles » (or CHNOPS)
- Role of comet in input of prebiotic compounds?

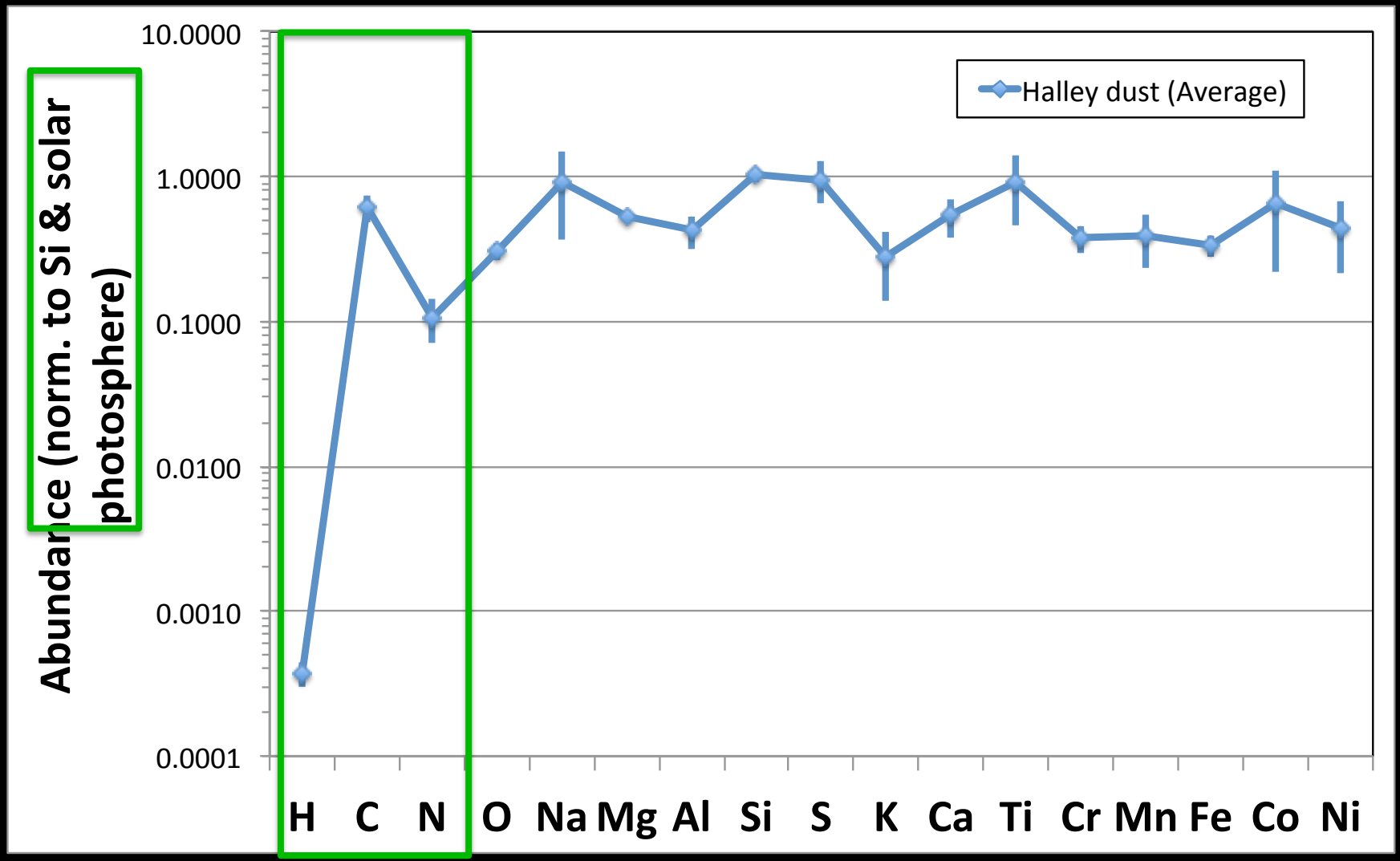
(Kissel et al. 1986)

Halley (VEGA) PUMA experiment



(Jessberger et al. 1988
Lodders et al. 2010)

Halley (VEGA) PUMA experiment



(Jessberger et al. 1988
Lodders et al., 2009)

Dust Composition by COSIMA

- T inside COSIMA ~ 10˚C -> no icy grains
- Mass spectrometer = TOF-SIMS
  - Mass resolution of ~ 1400 @ 100u
  - Detection of position or negative SI
  - Only surface analysis (contamination problem! ☹)
- Organics and inorganics :
  - Calibration for organics (Le Roy+2015) – mostly chemical compounds
  - Calibration for inorganics (Krueger+2015) – only for positive SI

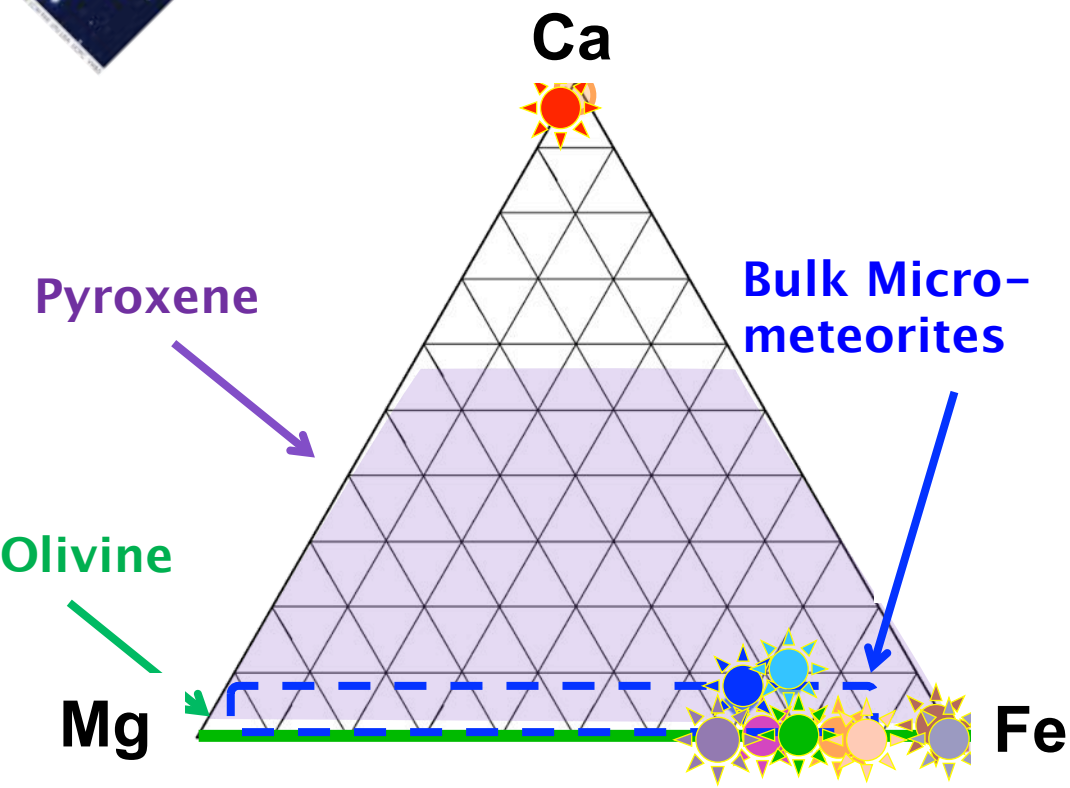
Composition of Dust w/ COSIMA – PhD A. Bardyn

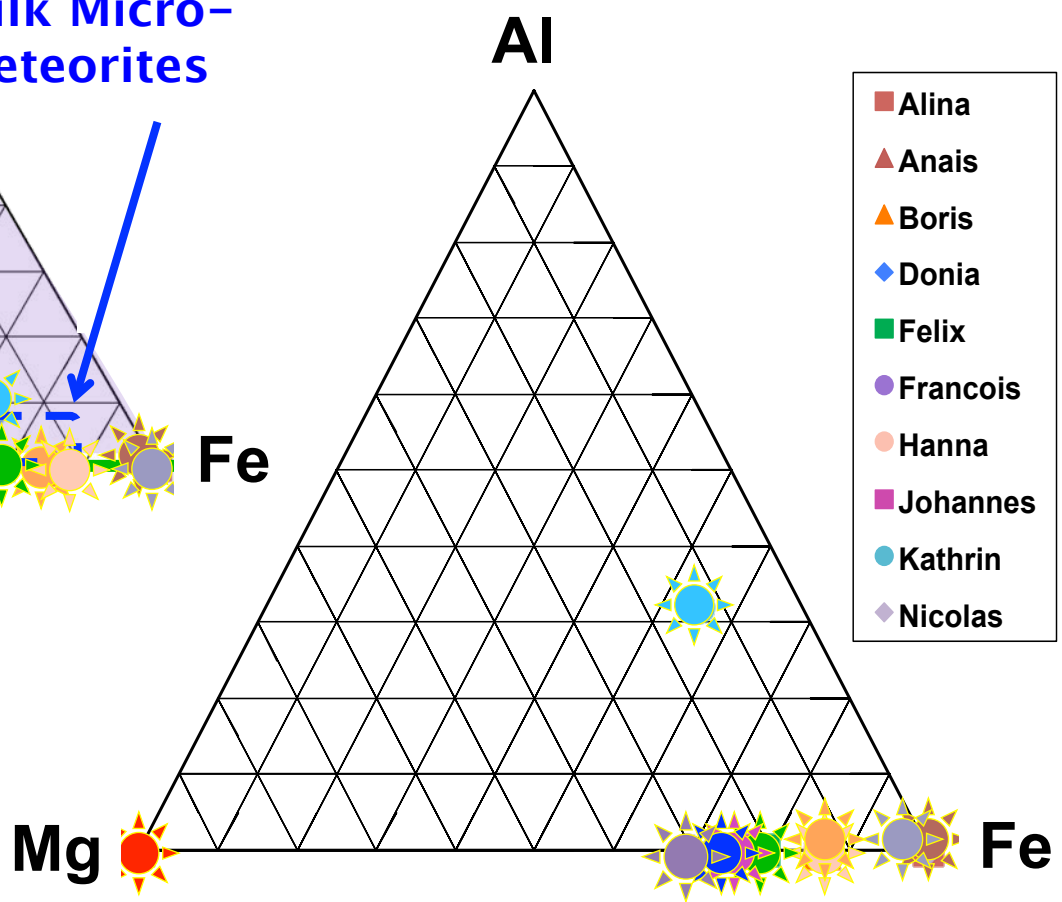
https://cnes.fr/sites/default/files/drupal/201702/default/cnesmag_71_fr_web-simple.pdf

- She was 5 at the time of selection of Rosetta!

Slides on compositions removed (not published)

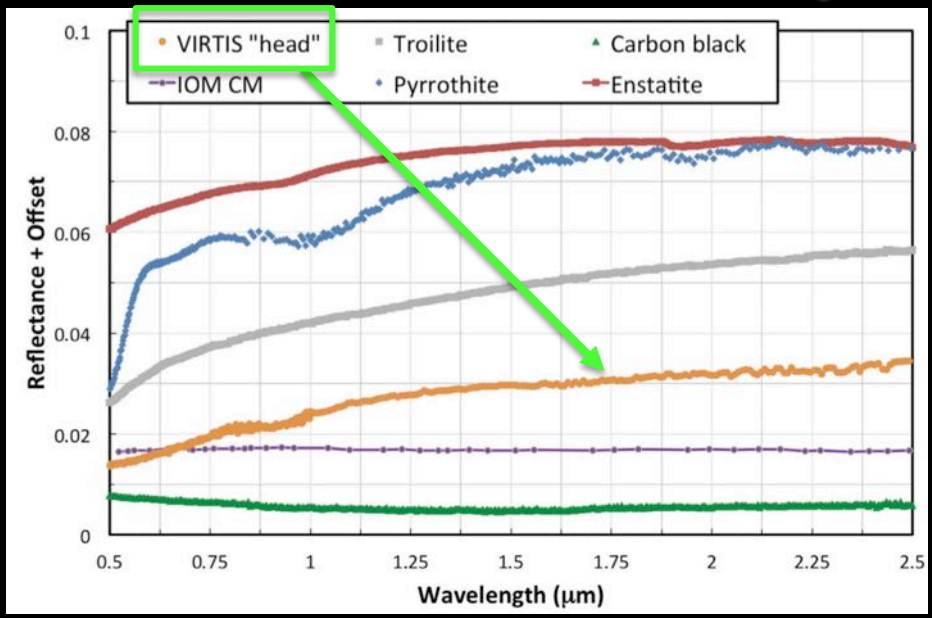
An attempt at mineralogy with COSIMA





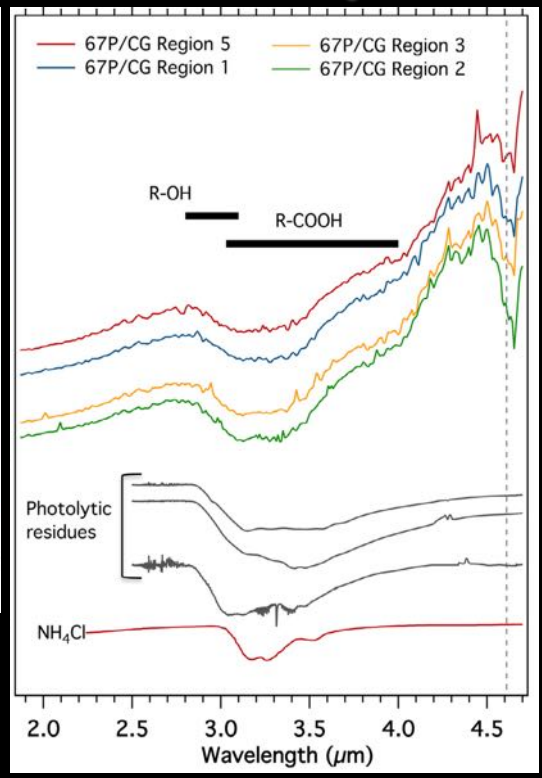
- Compatible with Ol + Px + Fe sulfides
- refractory minerals

Surface composition (VIRTIS)



(En, Pyrrhotite, troilite spectra scaled down by 100 75 and 50% resp.

(Capaccioni et al. 2015)



(Quirico et al. 2016)

- Very low albedo (0.060 ± 0.003 at 0.55 um), Red slope in NIR then flat spectrum , Broad absorption ~ 3.2 um

⇒ Surface (a few 100s um) : T nucleus ~ 180-230K

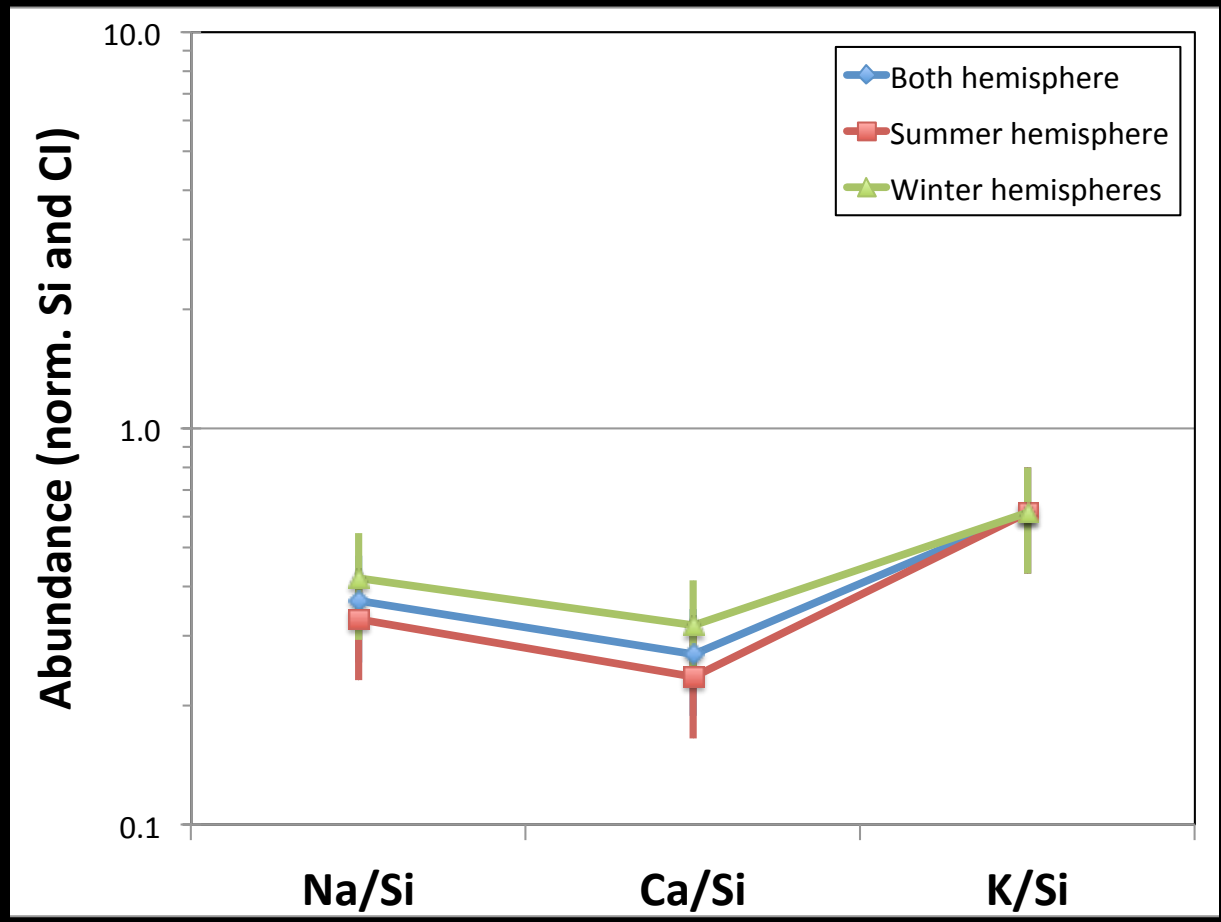
⇒ No water ice signature (1.5, 2, 3 um bands) (10m scale) – upper limit 1%

⇒ Darkening : sulfides and Fe-Ni alloys ? (also red visible slope)

⇒ Polyaromatic organic solids

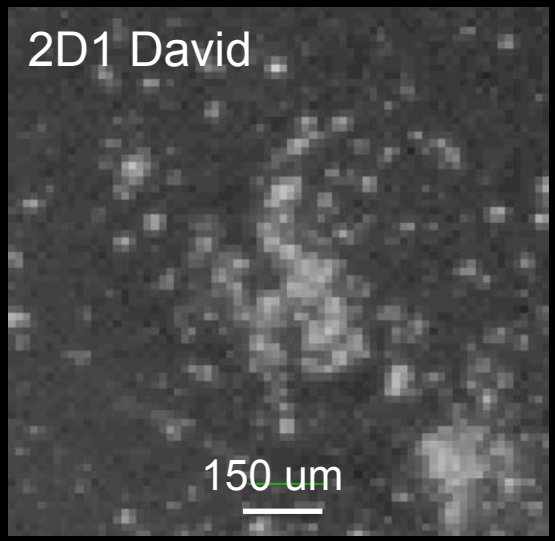
⇒ 3.2 um : OH in COOH group? NH_4^+?

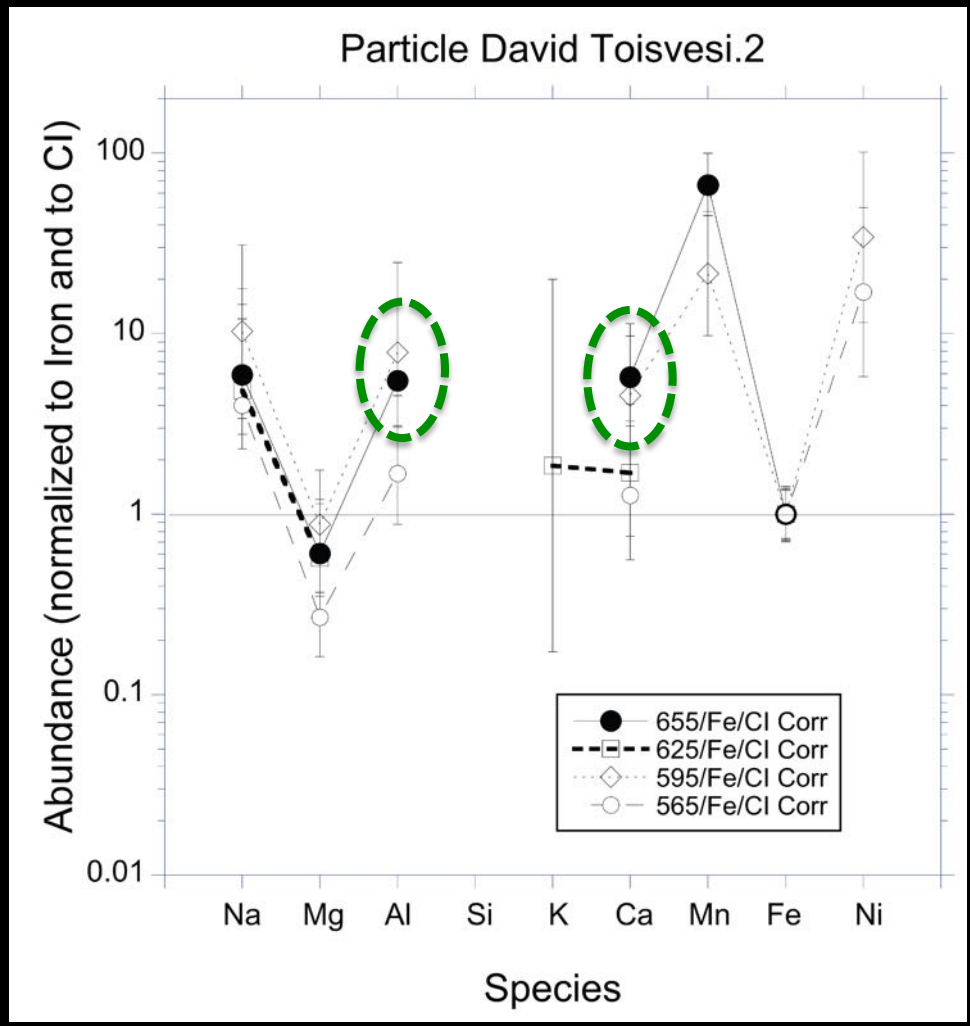
Comp. dust (*ROSINA*)



(Wurz et al. 2015)

Hint for a CAI in 67P/C-G (COSIMA)





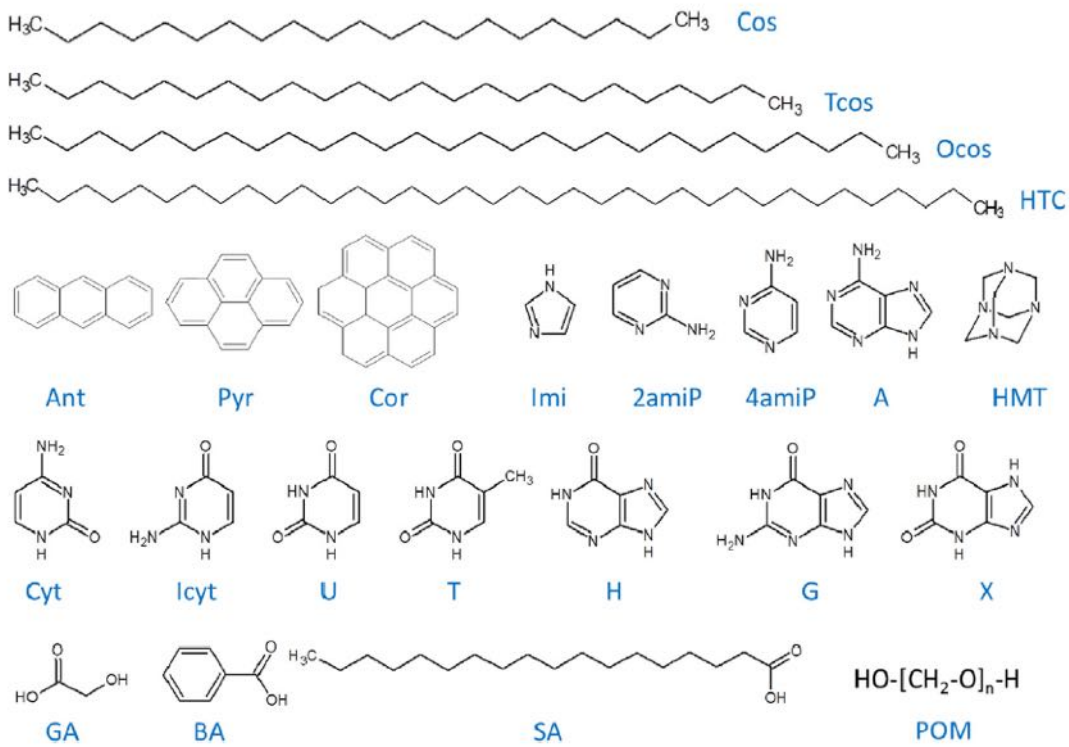
(Paquette et al. 2016)

Organics : Instrument calibration

- **<u>Before the comet:</u> building a reference library for this specific instrument**

- Rationale :
  - Previous observations
  - Lab analogs
  - Astrophysical analogs
  - Quantification

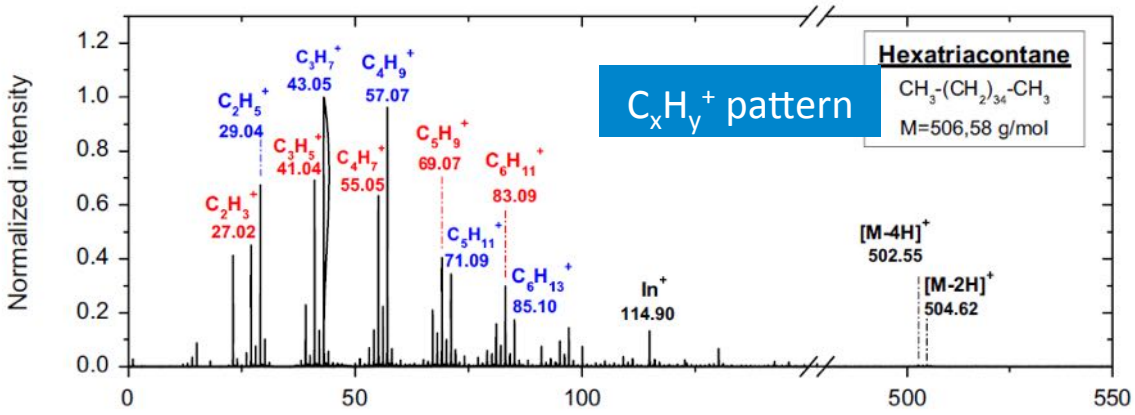
- **23 different "semi-volatile" molecules**
  - **Different chemical familles**
    - **Different structures**



Le Roy et al. (2012) PSS, 65, 83-92
and
Le Roy et al. (2015) PSS, 105, 1-25

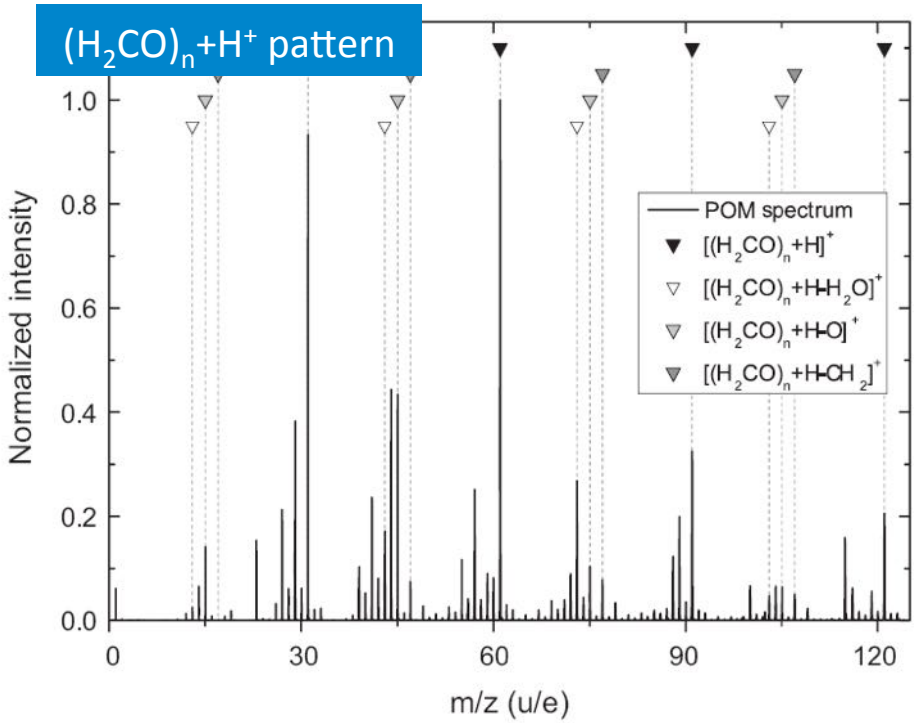
(N. Fray Comets2016 conf.)

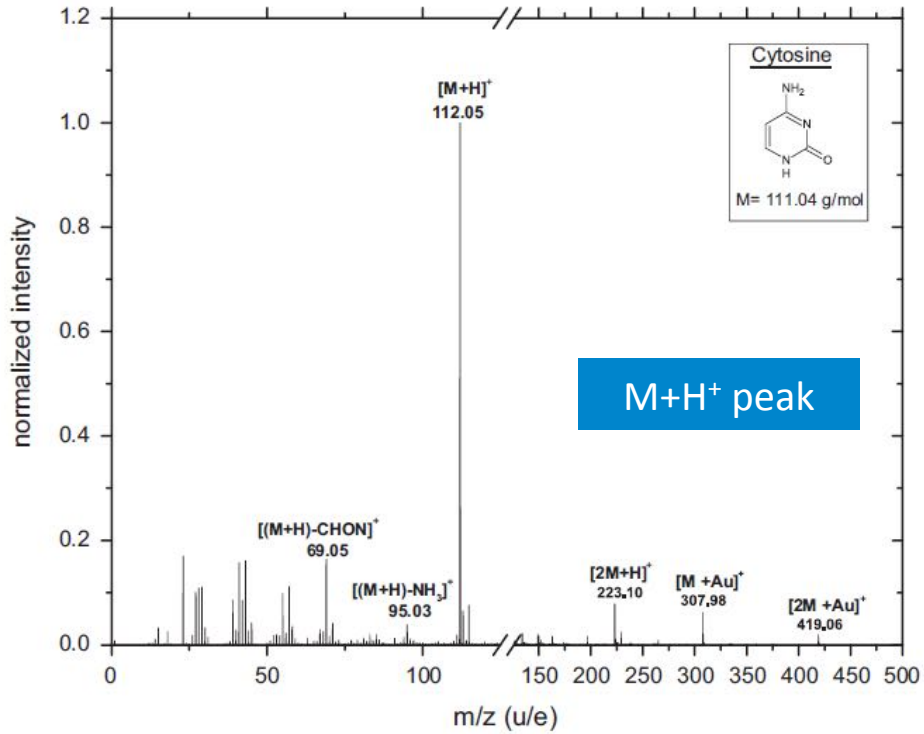
Instrument calibration : some positive ion mass spectra



Positive spectra dominated by

- $C_xH_y^+$ pattern
- $M+H^+$ peak
- …
- **Numerous ionic fragments**
- the **most intense peaks are located at "high" masses.**

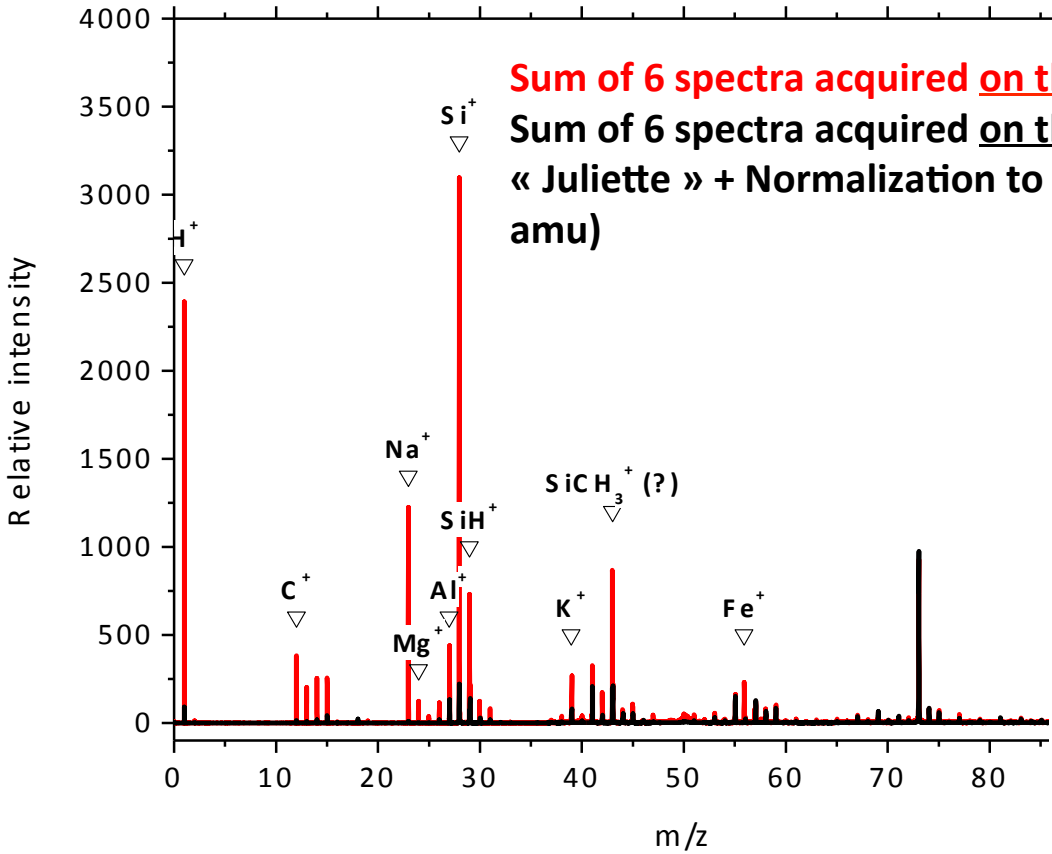




(N. Fray Comets2016 conf.)

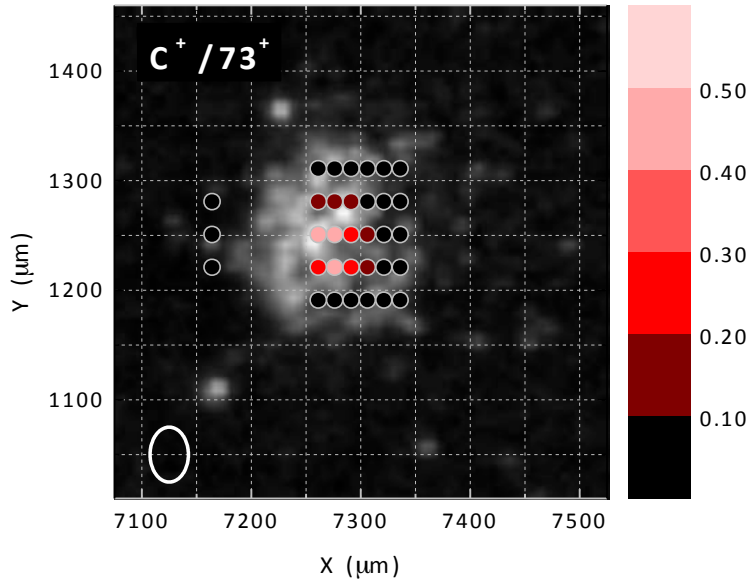
Le Roy et al. (2012) & Le Roy et al. (2015)

Positive ion mass spectra of cometary particles



Sum of 6 spectra acquired on the « Juliette » particles

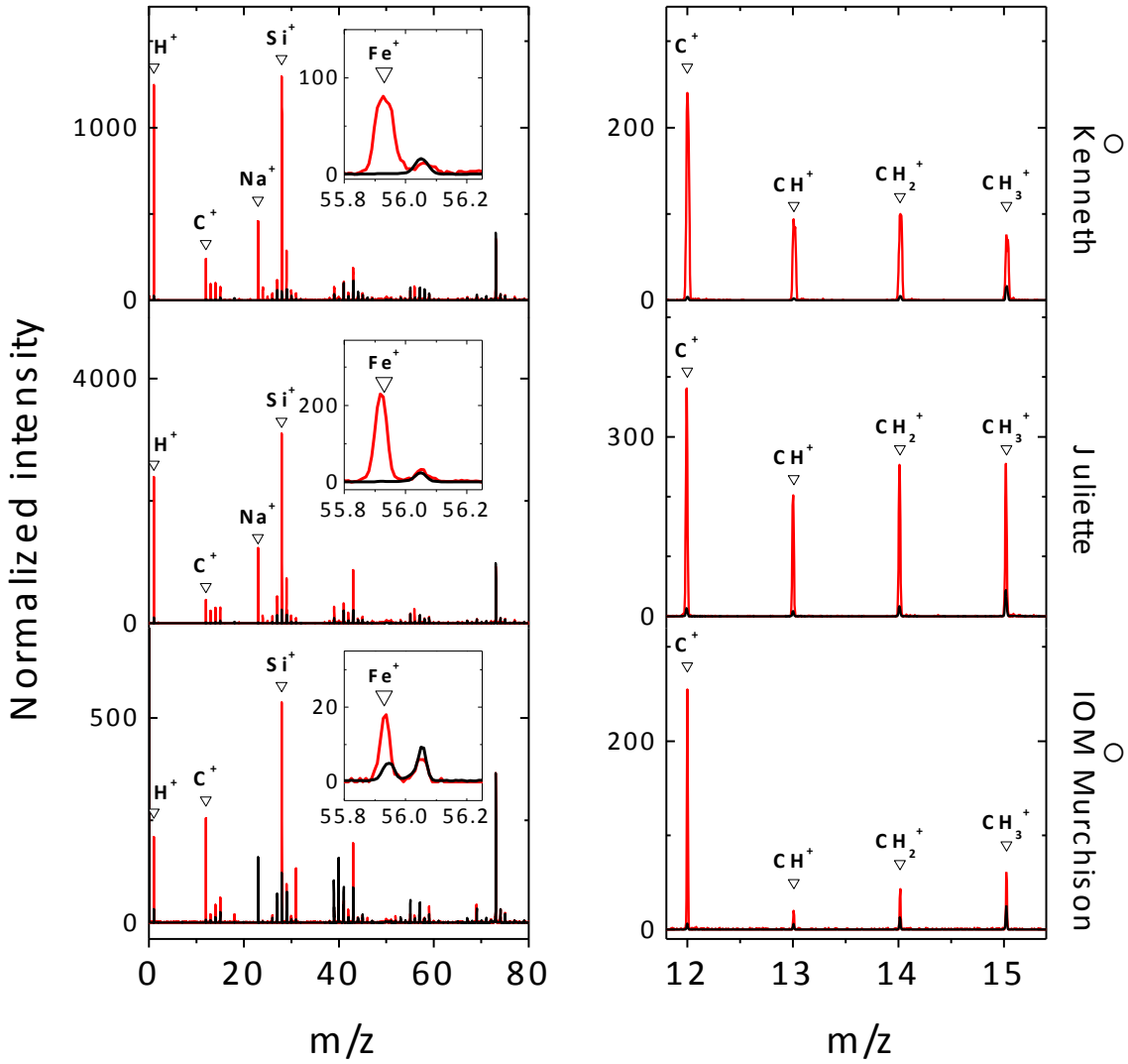
Sum of 6 spectra acquired on the substrate at the vicinity of « Juliette » + Normalization to the most intense peak of PDMS (m/z=73 amu)



- **Detection** of numerous elements and **of organic ions (C⁺, CH⁺, CH_2^+, CH_3^+,…)**
- **Detection of ions containing carbon** and originating from the comet, only at **low masses** (m/z < 50). The mass spectra of cometary particles are different from the calibration mass spectra presented before !
- **No detection of "semi-volatiles" organic molecules, so far…**

(N. Fray Comets2016 conf.)

Positive ion mass spectra of cometary particles



The best analogues found so far to the organic signatures of the 67P particles are the insoluble organic matter (IOM) samples extracted from carbonaceous chondrites (such as the Orgueil and Murchison meteorites)

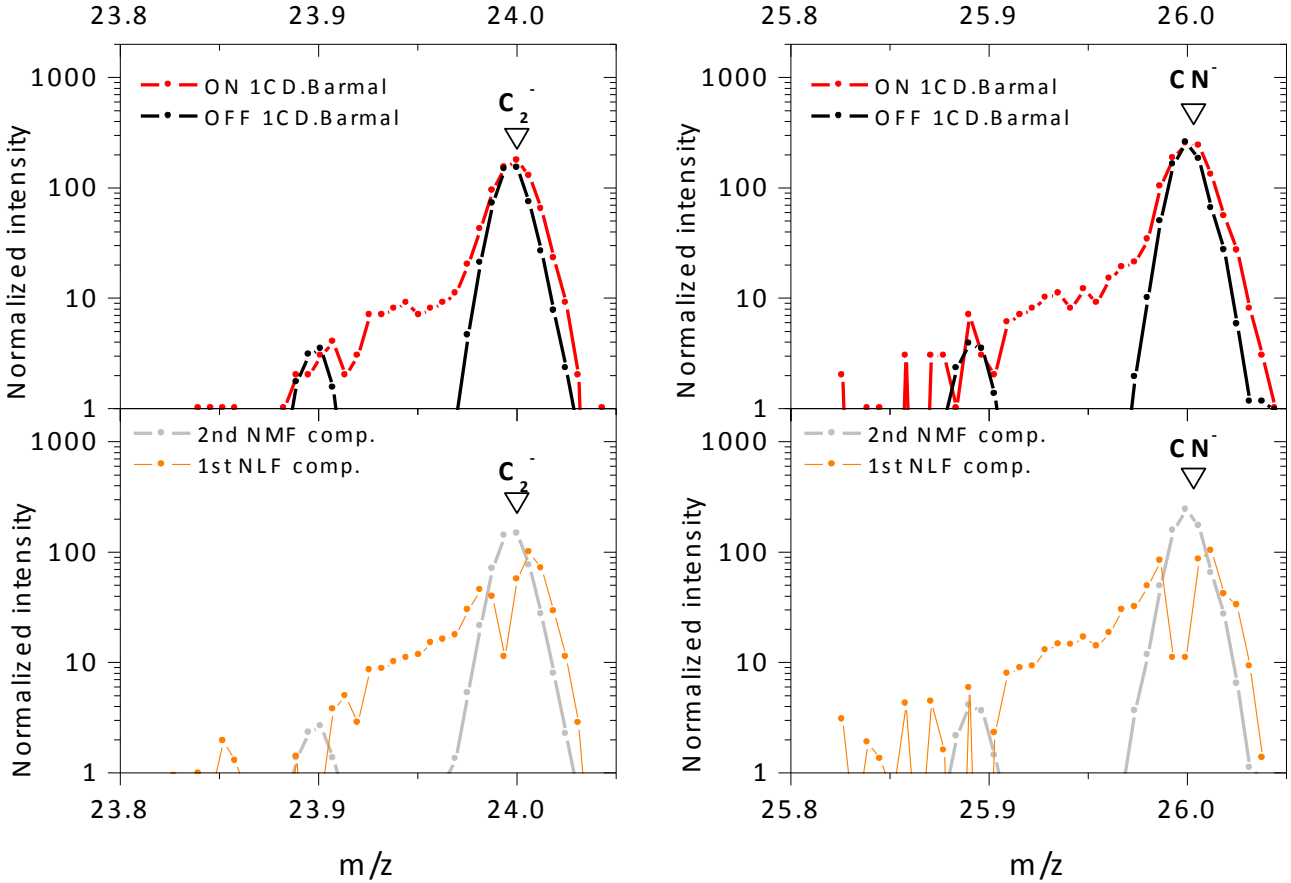
⇨ **Detection of refractory high-molecular-weight organic matter in the particles of 67P !**

The (CH_x^+ / C^+) ionic ratio are higher on the cometary particles than on the IOM sample

⇨ **H/C elemental ratio can be higher in the cometary refractory organic matter than in meteoritical IOM.**

(Fray et al. 2016)

C/N? Negative ion mass spectra of cometary particle



(N. Fray Comets2016 conf.)

(Fray et al. 2017 in prep)

- C_2^- and CN^- are detected in the negative spectra of cometary particles (as well as C^-, CH^-, CH_2^-, C_2H^-,…).
- CN^- and C_2^- ions enables the measurements of the N/C elemental ratio in cometary particles.

Slides on N/C removed (not published)

Summary

- Dust instruments : more than 30,000 particles collected/detected from <1 µm (MIDAS) to > 500 µm (COSIMA, GIADA)
- COSIMA : Flocculent particles (for all sizes), inorganic composition compatible with presence of anhydrous minerals (Ol, Px, Fe-sulfides)
  - similarity with IDPs/MMs collected on Earth
- Composition for inorganic elements ~ chondritic
- Hint for the presence of CAI minerals
- COSIMA analyses of organics not obvious :
  - Organic matter ~ meteoritic IOM?
  - atomic C/Si (Bardyn et al. 2017 sub)
  - atomic N/C (Fray et al. 2017 in prep)
  - Composition compatible with low surface albedo : refractory organics with minerals (silicates, Fe-sulfides)
- COSIMA: a lot more data to analyze…