67P/CG Dust Particles Composition as measured by the COSIMA/Rosetta Mass Spectrometer

Robin Isnard[1,3], Anaïs Bardyn[2], **Christelle Briois[1]**, Nicolas Fray[3], Donia Baklouti[4], Hervé Cottin[3], Cécile Engrand[5], Harald Fischer[6], Esko Gardner[7], Klaus Hornung[8], Yves Langevin[4], Harry Lehto[7], Léna Le Roy[9], Nicolas Ligier[4], Sihane Merouane[6], Paola Modica[1], François-Régis Orthous-Daunay[10], John Paquette[6], Jouny Rynö[11], Rita Schulz[12], Johan Silén[11], Sandra Siljeström[13], Oliver Stenzel[6], Laurent Thirkell[1], Kurt Varmuza[14], Boris Zaprudin[7], Jochen Kissel[6] and Martin Hilchenbach[6].

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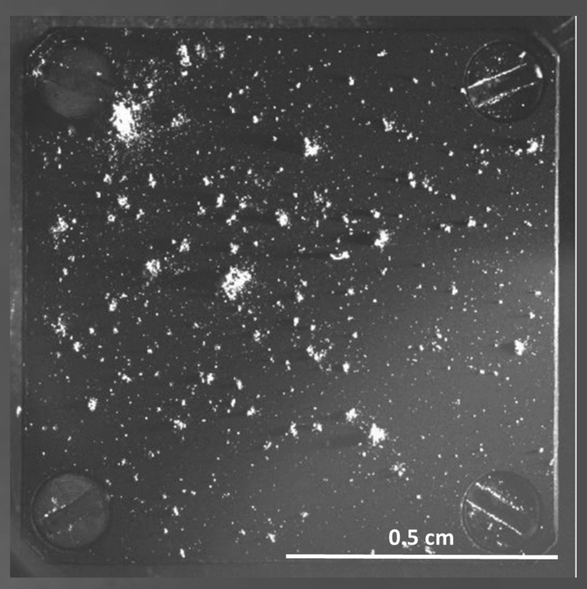
COSIMA - COmetary Secondary Ion Mass Analyser

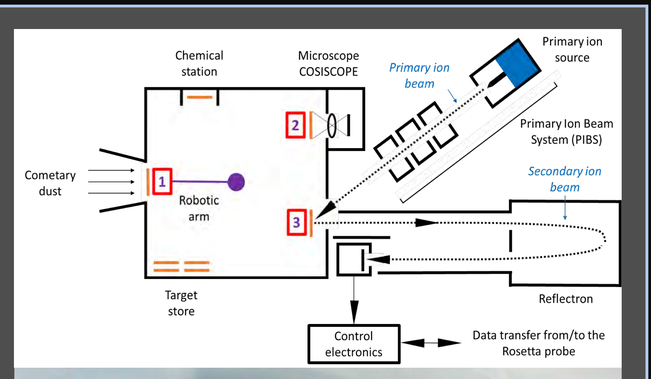
The COSIMA instrument is a Time-Of-Flight Secondary Ion Mass Spectrometer [1] (TOF-SIMS) equipped with dust collectors (72 targets of 1 cm^2 were available), a target manipulator unit, an ion gun, an optical microscope for grain localization and a sample heating station.

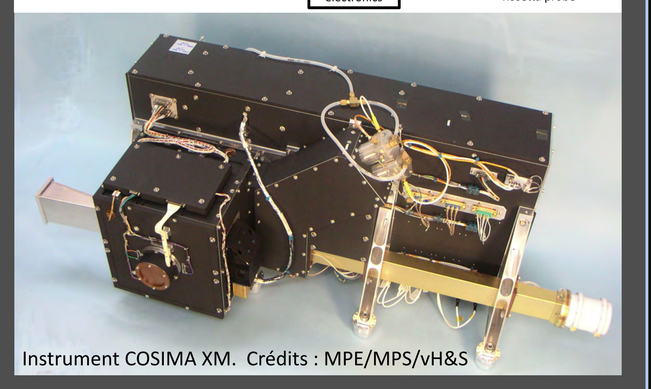
On board the Rosetta orbiter
Collect (1), Image (2) and Analyze (3)

Over the two years of the Rosetta exploration mission (at the comet from aug. 2014 to Sept. 2016), COSIMA realized *In situ* collection of cometary dust grains in the coma of comet 67P/Churyumov-Gerasimenko and the chemical analysis of the chemical composition of 67P's dust.



- 21 targets exposed
- > 35,000 particles [2]
- Size: ~10 to 1000 µm
- ~250 particles analyzed

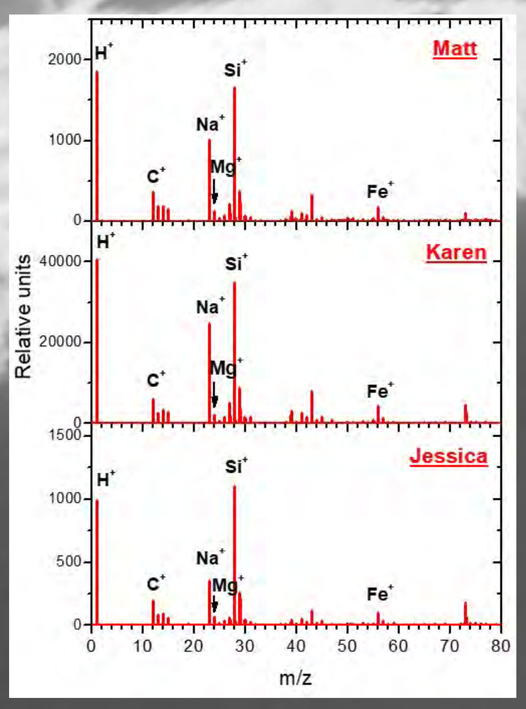




Instrument COSIMA XM. Crédits : MPE/MPS/vH&S

- 986 mm x 356 mm x 362 mm
- 17.5 k g - 21 W max
- Mass resolution of 1400 at 100 u
- Microscope with 14 um resolution

COSIMA analysis

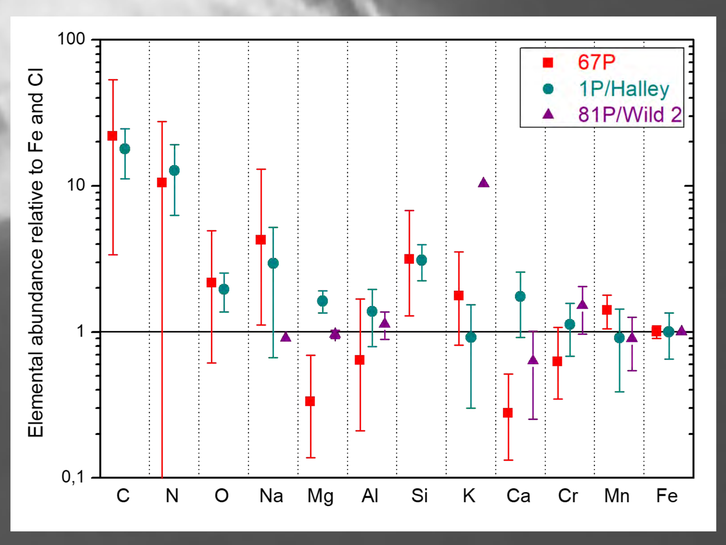


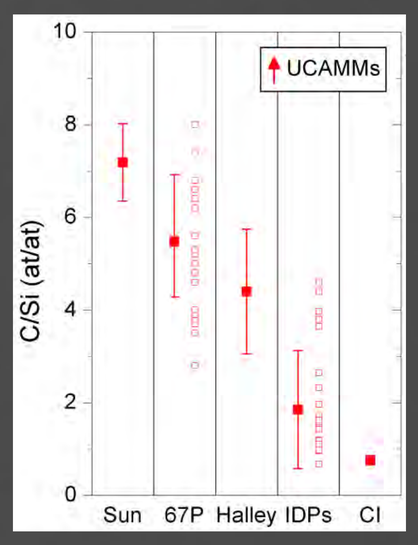
ion beam size: 30 x 50 µm²

Positive ion mass spectra
contribution from background has been removed

- Similar mass spectra signatures [3]
- Always a mixture of carbonaceous matter and mineral phases

67P's dust global composition as measured by COSIMA





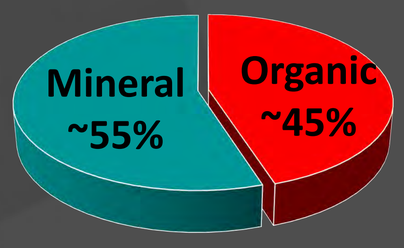
67P's dust compared to comets Halley and Wild 2 *[3]*

- 67P's dust is chondritic within a factor of 3, C excepted
- Consistent with the composition of Halley and Wild 2
- C/Si 6 times higher than in CI chondrites

Mass ratio of organic to mineral matter in 67P's dust

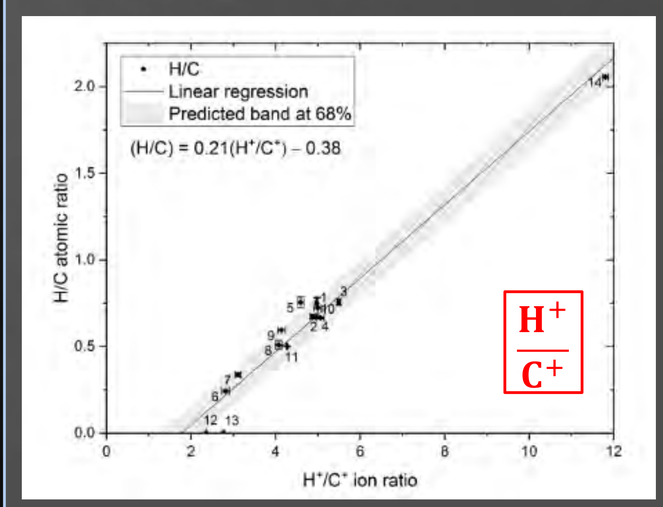
- Based on the elements quantified in [3, 4] and H/C = 1.04 ± 0.16 [5]
- Assumptions:

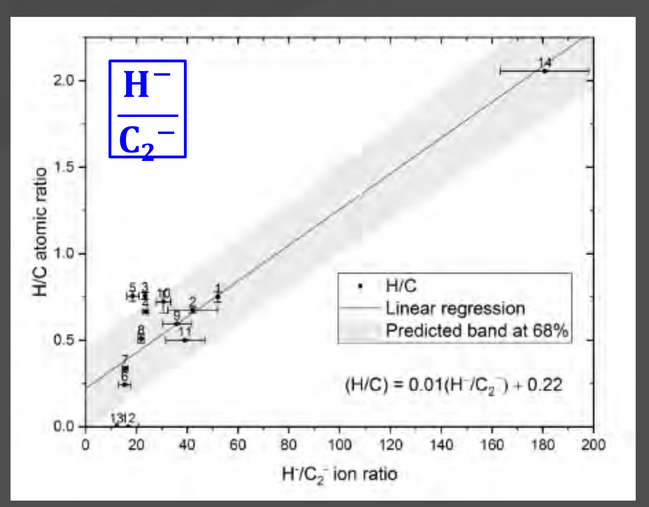
(i) S/Fe = 0.5 (chondritic)
(ii) C, H and N in organic
(iii) O/Si = 4 in mineral (SiO_4) and the remaining O in the organic phase

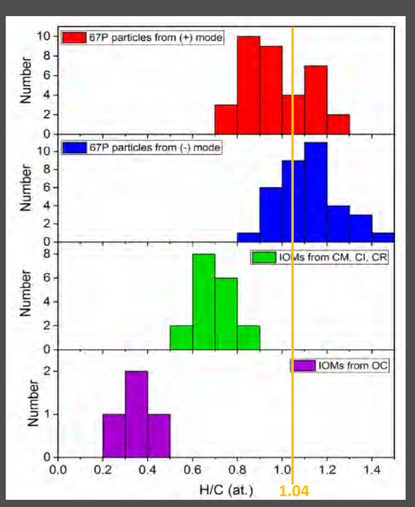


Summary

- Dust particles are carbon-rich: ~45% organic matter in mass
- Macromolecular carbonaceous matter [6] is a major non-volatile component of 67P dust
- High molecular weight refractory organic matter detected in 67P particles is less unsaturated than meteoric IOMs







H/C elemental ratio of the refractory organic matter of 67P's dust *[5]*

- H/C = 1.04 ± 0.16 [5]
- ≥ H/C of IOMs (higher value ≃ 0.9)

References
[1] Kissel *et al.* (2007), [2] Merouane *et al.* (2017), [3] Bardyn *et al.* (2017), [4] Fray *et al.* (2017), [5] Isnard *et al.* (2019), [6] Fray *et al.* (2016). Credit images: ESA

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Over the two years of the Rosetta mission, the COmetary Secondary Ion Mass Analyzer (COSIMA), on board the orbiter, had collected *in situ* more than 35,000 dust particles and particle fragments in the inner coma of the comet 67P/CG (67P/Churyumov-Gerasimenko). These particle agglomerates with size ranging from ~50 to ~1000 µm, were captured at a low impact velocity (< 10 m/s) on metal targets and imaged and identified *in situ* with the COSIMA optical microscope COSISCOPE. Among all the dust particles collected, around 250 were chemically analyzed by the secondary ion mass spectrometry (SIMS) technique.

We have compared the global composition measured for 67P/CG's dust to previous results obtained from the Giotto and Vega missions for comet 1P/Halley and the Stardust mission for comet 81P/Wild 2, to the composition of Chondritic Porous Interplanetary Dust Particles (CP-IDPs) and to the CI chondrite composition. We have demonstrated that the organic matter of 67P/CG was different from all the semi-volatile compounds analyzed during the calibration step. However, similarities with Insoluble Organic Matter (IOM) extracted from carbonaceous chondrites are notable. Moreover, we have demonstrated that cometary particles from 67P are among the most carbon-rich objects in the Solar System, containing about 50% in mass of organic matter. Estimated H/C elemental ratio of the 67P/CG cometary organic matter is also reported.

Acknowledgements
COSIMA was built by a consortium led by the Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany in collaboration with Laboratoire de Physique et Chimie de l'Environnement et de l'Espace, Orléans, France, Institut d'Astrophysique Spatiale, CNRS/ Université Paris Sud, Orsay, France, Finnish Meteorological Institute, Helsinki, Finland, Universität Wuppertal, Wuppertal, Germany, von Hoerner und Sulger GmbH, Schwetzingen, Germany, Universität der Bundeswehr, Neubiberg, Germany, Institut für Physik, Forschungszentrum Seibersdorf, Seibersdorf, Austria, Institut für Weltraumforschung, Österreichische Akademie der Wissenschaften, Graz, Austria and is led by the Max-Planck- Institut für Sonnensystemforschung, Göttingen, Germany with the support of the national funding agencies of Germany (DLR, grant 50 QP 1801), France (CNES), Austria and Finland. Rosetta is an ESA mission with contributions from its Member States and NASA.

European Astrobiology Network Association

19th EANA Astrobiology Conference

3rd-6th September 2019

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Programme

TUESDAY 3rd SEPTEMBER		
8:00am	**Registration opens**	
9:00am	Frances Westall, Frédéric Foucher	Welcome and Opening Remarks
9:30am	André Brack	*Opening Talk*: Opening avenues in astrobiology, a testimony
Social Sciences, Philosophy and Education **Chair: Muriel Gargaud**		
10:00am	Joseph Gale	Will recent advances in AI result in a paradigm shift in Astrobiology and SETI?
10:20am	Jacques Arnould	Is real life somewhere else?
10:40am	Gerhard Haerendel	Extraterrestrial civilizations? Scientific, philosophical and theological consequences
11:10am	**Coffee Break**	
Astrochemistry and Prebiotic Chemistry (I) **Chair: Paola Modica**		
11:40am	Kensei Kobayashi	Formation of amino acid precursors in slightly reducing primitive atmospheres by solar energetic particles
12:00pm	Terence Kee	Exploring proto-cytoplasmic media. Self-assembly and molecular diffusion in salt-hydrogel phases
12:20pm	Tony Jia	Membraneless polyester microdroplets as primordial compartments at the Origins of Life
12:40pm	**Lunchtime**	
Astrochemistry and Prebiotic Chemistry (II) **Chair: Anna Neubeck**		
2:00pm	Kristin Johnson-Finn	Probing organic transformations on mineral surfaces through electrochemical and hydrothermal experiments
2:20pm	Savino Longo	Anomalous fluctuations and selective extinction in populations of primordial replicators

2:40pm	Andrea Greiner	Prebiotic reaction vessels – RNA formation in nanoconfinements of water
3:00pm	Tommaso Fraccia	Liquid crystal ordering of single and oligo nucleotides: from supramolecular assembly to polymeric nucleic acids
3:20pm	Naïla Chaouche	Study of the evolution of nucleobases under Mars-like conditions: impact of UV irradiation and perchlorates on uracil and cytosine
3:40pm	**Coffee Break**	
Astrophysics and Planetary Habitability **Chair: Russell Deitrick**		
4:10pm	Ewa Szuszkiewicz	Early stages of the evolution of planetary systems
4:30pm	Cedric Gillmann	The evolution of Venus and its late accretion
4:50pm	Lena Noack	Evolution of early Earth's atmosphere depending on interior volatile depletion and outgassing
5:10pm	Fabien Bernadou	Experimental constraints on the timing of degassing of nitrogen in the atmosphere
5:30pm-7:45pm	**Poster Session 1 (Group 1):** • Life Sciences, • Astrochemistry, • Prebiotic Chemistry, • Astrophysics and Exoplanets, • Planetary Geology and Habitability	
6:30pm-7:30pm	**Public lecture (in French) – Michel Viso (CNES)**	

WEDNESDAY 4th SEPTEMBER

Space Factor Contest **Chairs: Lena Noack and Marta Cortesão**		
9:00am	Lora Jovanović	Pluto, a distant cousin of the primitive Earth?
9:15am	Antonín Knížek	Formation of (per)chlorates on Mars
9:30am	Lefteris Profitis	Automatic rock identification in macroscopic scale using image processing techniques: An application for planetary exploration
9:45am	Barnabé Cherville	Optimization of the LAb-CosmOrbitrap experiment negative ion mode
10:00am	Kateřina Němečková	Raman analysis of pigments from Messinian gypsum endoliths
10:15am	Sayak Mukhopadhyay	Understanding natural genetic networks and engineering artificial gene circuits in microgravity
10:30am	Corentin Loron	Diversification of complex life on the early Earth: the Proterozoic of Arctic Canada as a case study
10:45am	Stella Koch	Addressing the fungal contamination – testing antifungal materials and radiation-driven decontamination methods
11:00am	**Coffee Break**	
Astrophysics and Planetary Habitability **Chair: Beda Hofmann**		
11:30am	Jacob Heinz	Are perchlorate brines habitable?
11:50pm	Philippe Reekie	Perchlorate glasses on Mars and the search for extraterrestrial life
12:10pm	Dirk Schulze-Makuch	The process of deliquescence might allow methanogenic archaea to metabolize on Mars
12:30pm	**Lunchtime**	
ExoMars 2020 (I) **Chair: Frances Westall**		
2:00pm	Jorge L. Vago	ExoMars 2020

2:30pm	Matt Balme	The ExoFit Rover field trial - simulating ExoMars Rover operations
2:50pm	Lucia Mandon	Investigating the clay-bearing unit of Oxia Planum, the landing site of the ExoMars 2020 mission
3:10pm	Francois Raulin	MOMA: the Mars Organic Molecule Analyzer experiment on ExoMars 2020
3:30pm	Frédéric Foucher	Testing the ExoMars 2020 scientific exploration protocol
3:50pm	**Coffee Break**	
ExoMars 2020 (I) **Chair: André Brack**		
4:20pm	Jean-Luc Josset	CLUPI: Geology and biosignatures on Mars close up
4:40pm	Andrew Coates	The PanCam instrument for the Rosalind Franklin (ExoMars 2020) rover
Space Missions and Instrumentation (I) **Chair: Elias Chatzitheodoridis**		
5:00pm	Michel Viso	Toward a European Mars sample receiving facility
5:20pm	Petra Rettberg	Scientific challenges to prevent the biological contamination of Outer Solar System bodies - what do we need to know for planetary protection?
5:40pm-7:45pm	**Poster Session 2 (Group 2):** • **Space Missions,** • **Instrumentation and Approaches,** • **Biosignatures and Biogeosciences,** • **Social Sciences and Philosophy,** • **Education, Outreach and Networking,** • **Space Factor Contest**	

THURSDAY 5th SEPTEMBER

Space Missions and Instrumentation (II) **Chair: Pauli Laine**		
9:00am	Laura Selliez	High resolution mass spectrometry for future space missions: comparative analysis of Titan's tholins
9:20am	Boris Laurent	UV luminescence characterisation of organics in Mars-analogue substrates
9:40am	Franco Ferrari	Newly developing methodologies to investigate health hazards posed by ionizing radiation to space travel
10:00am	**EANA and EAI Round Table Discussion** with Wolf Geppert (EAI Chair) and EANA members	
11:00am	**Coffee Break**	
Life Sciences (I) **Chair: Oleg Kotsyurbenko**		
11:30am	Hajime Mita	Exposure Experiments in the 2nd Japanese Astrobiology Experiment, Tanpopo2
11:50am	Shin-ichi Yokobori	Survival and DNA damage of Deinococcal species in space: three years of microbe space exposure experiment of Tanpopo Mission at exposure facility of Japanese experiment module of International Space Station
12:10pm	Sara Gómez de Frutos	Improved resistance to UV radiation resistance of Arabidopsis thaliana by expressing genes isolated from hyperhalophilic microorganisms
12:30pm	**Lunchtime**	
Life Sciences (I) **Chair: Claudia Pacelli**		
2:00pm	Jorge Díaz-Rullo	Search for perchlorate resistance genes in microorganisms of a hypersaline lake of Atacama
2:20pm	Macarena Benguigui	Search of mechanisms of adaptation to UV radiation in microorganisms from salterns using a functional metagenomics approach

2:40pm	Rosa de la Torre	Resistance to simulated extraterrestrial conditions (space and Mars) of the first colonizing lichens collected from a Mars analogue volcanic area (Lanzarote)
3:00pm	Yannick Lara	Antarctic cyanobacteria sources of biosignatures
3:20pm	Kai Finster	Effect of saltation and abraded silicates on the survival of bacteria on Mars
3:40pm	**Coffee Break**	
Biosignatures & Biogeosciences (I) **Chair: Barbara Cavalazzi**		
4:10pm	Karin Moelling	Viroids and viruses during evolution of life on Early Earth as model for Exoplanets?
4:30pm	Adrienne Kish	Reasons to get salty
4:50pm	Laura Sánchez-García	Searching for molecular biomarkers in Atacama microbialites (N Chile). Relevance for astrobiological exploration of rocky planets
5:10pm	Laura García-Descalzo	Bacterial presence in cold perchlorates solutions: Implications for Mars
5:30pm	**Space Factor Contest Award Ceremony**	
7:30pm-10:00pm	**Conference Dinner (Jardin des Plantes)**	

FRIDAY 6th SEPTEMBER

Biosignatures & Biogeosciences (I)
Chair: Kai Finster

9:00am	Mickael Baqué	Effect of solar radiation on the distribution of Raman biosignatures in salt nodules from the Atacama Desert
9:20am	Jean-Pierre de Vera	Planetary simulations at DLR Berlin and in space – results and future work
9:40am	Nicasio T. Jiménez-Morillo	Pyrolysis-compound specific isotope analysis (Py-CSIA) of terrestrial analogue samples. Possible applications in astrobiology and geomicrobiology
10:00am	Konstantinos Gkrintzalis	Simple biochemical methods for the detection of life-inhibiting peroxidants and life signatures on Mars-like soils
10:20am	Sean McMahon	The trouble with tubules: iron-mineral chemical gardens mimic numerous purported fossil microbial filaments
10:40am	Keyron Hickman-Lewis	Multi-scalar trace element biosignatures and rare earth element reconstruction of Palaeoarchaean biomes of microbial life: a fossil-calibrated approach
11:00pm	**Coffee Break**	
11:30am	Rocco Mancinelli	*Concluding Talk*: Astrobiology: the future of life and the search for life in the universe
12:00pm	Frances Westall	Concluding Remarks
12:30pm	**Lunchtime**	