Cosmic dust and high energy ions. What? Why? How?

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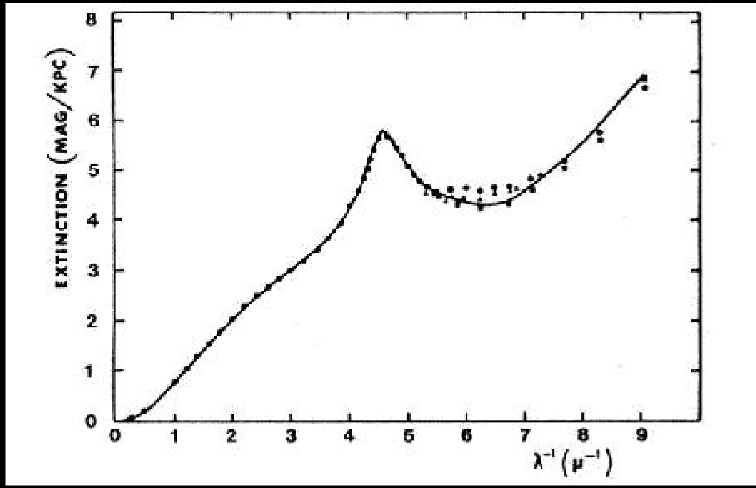
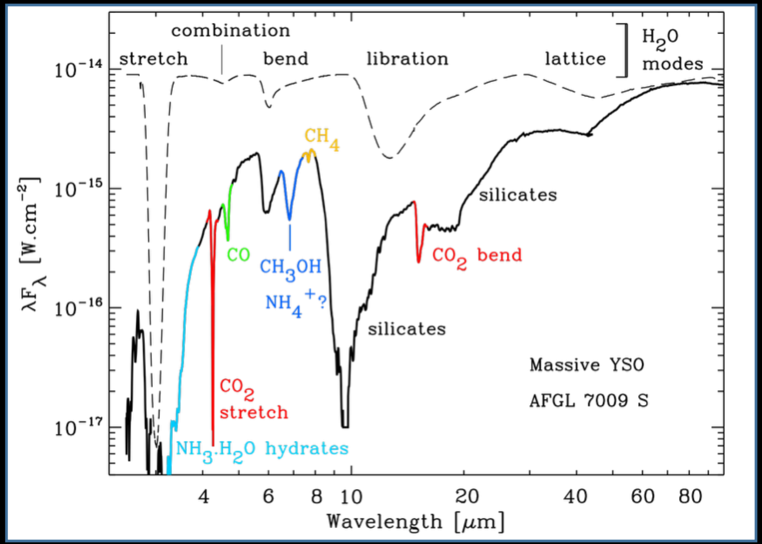
The whole sky (by eyes)

Credit: Lund observatory

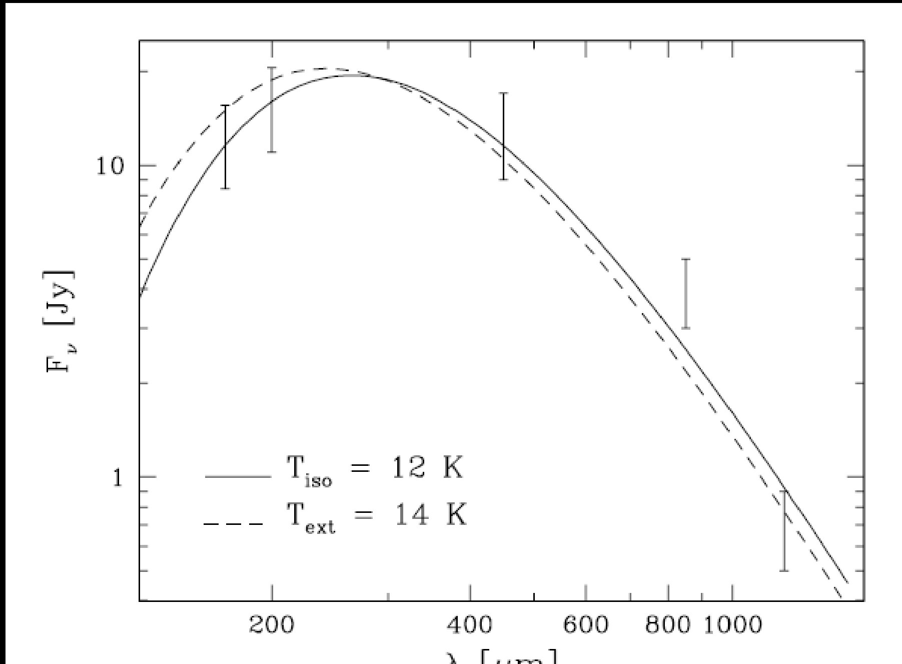
Cosmic dust grains (detection)

Absorption



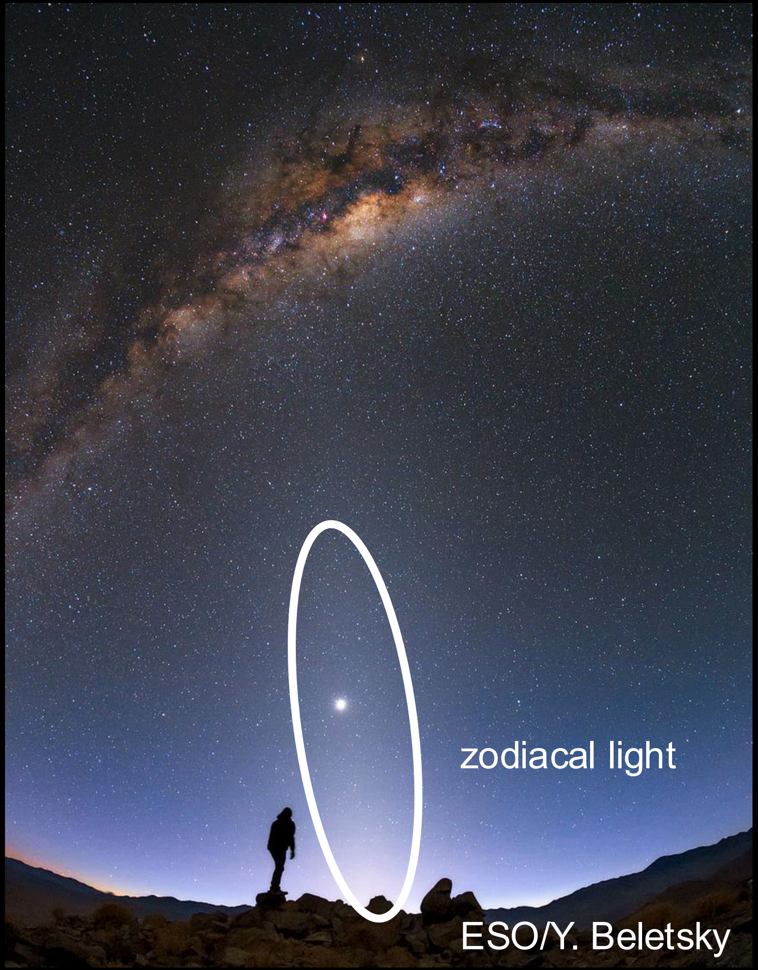


Emission



Bianchi et al. 2003

Scattering



Interplanetary dust particles

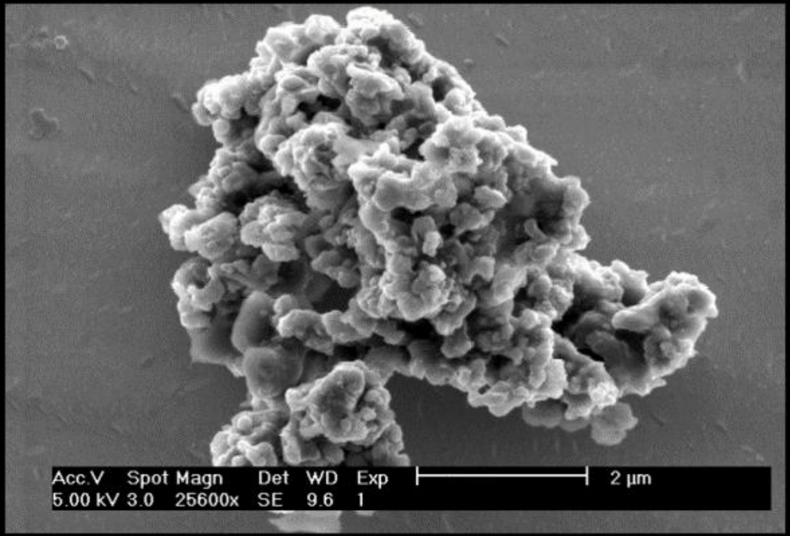
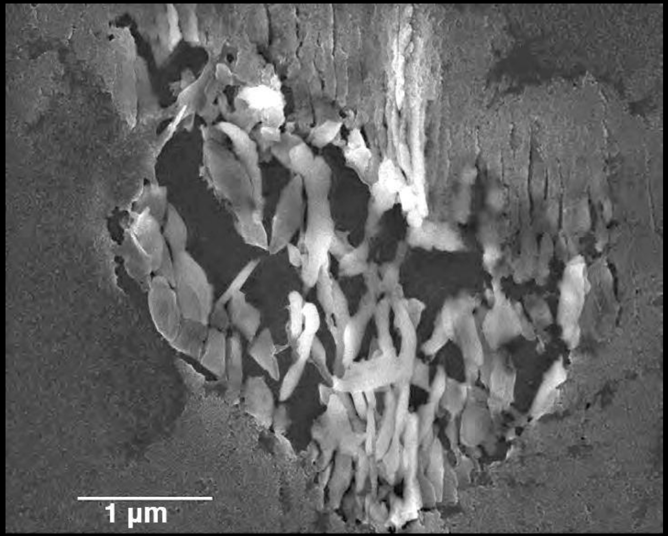
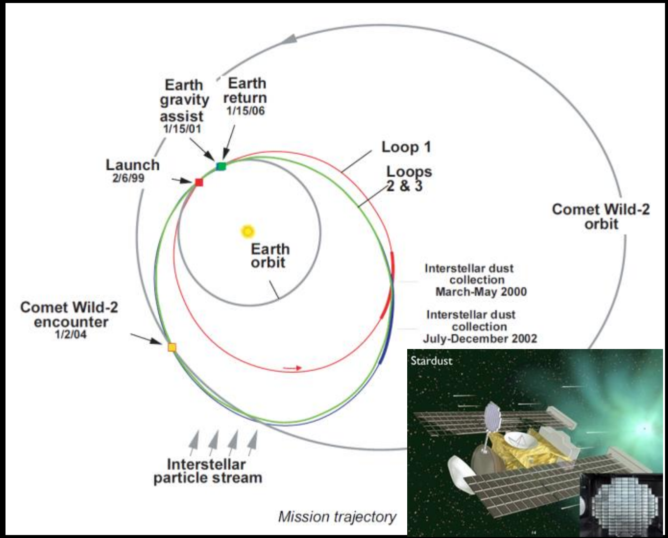


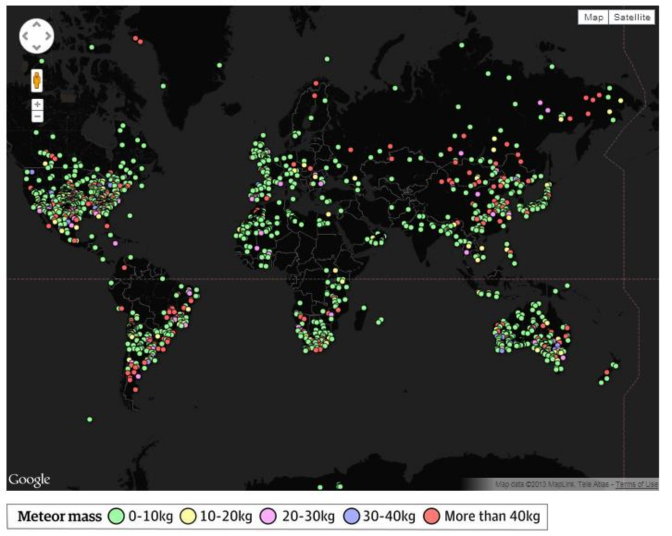
Figure 1 - Two round, large-area cosmic dust collectors deployed beneath the wing of a NASA ER-2 aircraft in flight.

Stardust particles



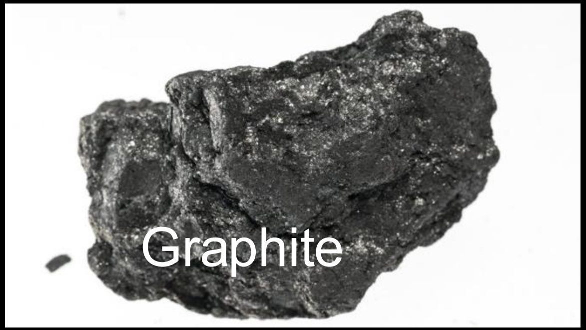


Meteorites

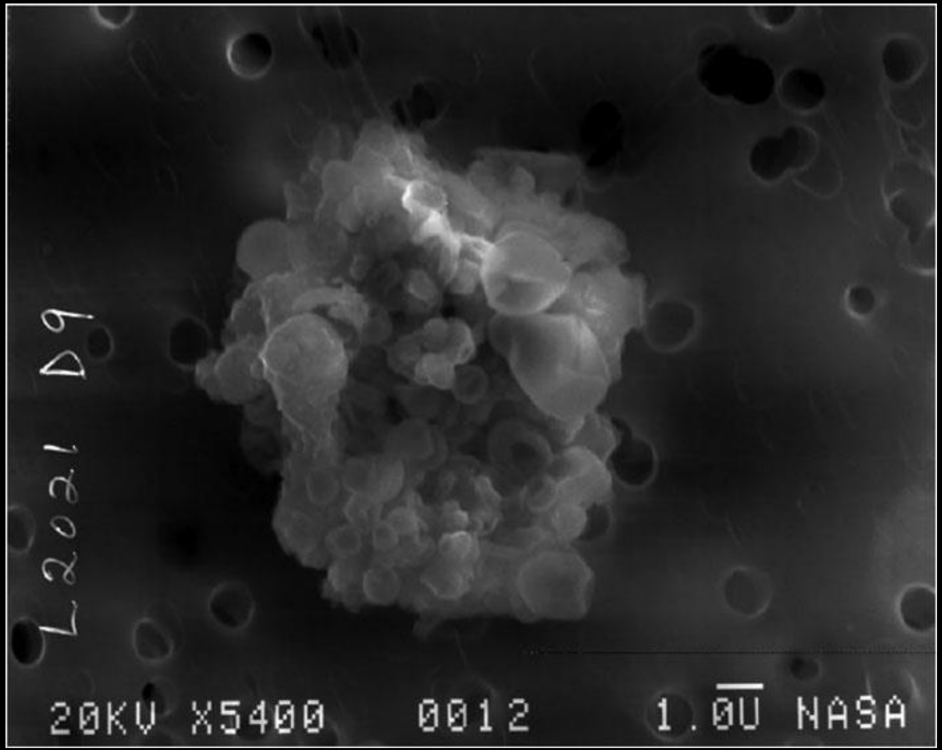


Cosmic dust grains (composition)

Carbonaceous Materials
Amorphous carbon Graphite Diamond PAHs Fullerences
Silicon Derivatives
Silicon Carbide (SiC; carborundum) Silicon Nitride (Si_3N_4)
Oxides
Silicon Dioxide (SiO_2, silica) Aluminium Oxide (Al_2O_3; sapphire) Magnesium Aluminium Oxide ($MgAl_2O_4$, spinel)
Silicates
$(Fe,Mg)_2SiO_4$, Olivine $(Fe,Mg)_2Si_2O_6$, Pyroxene



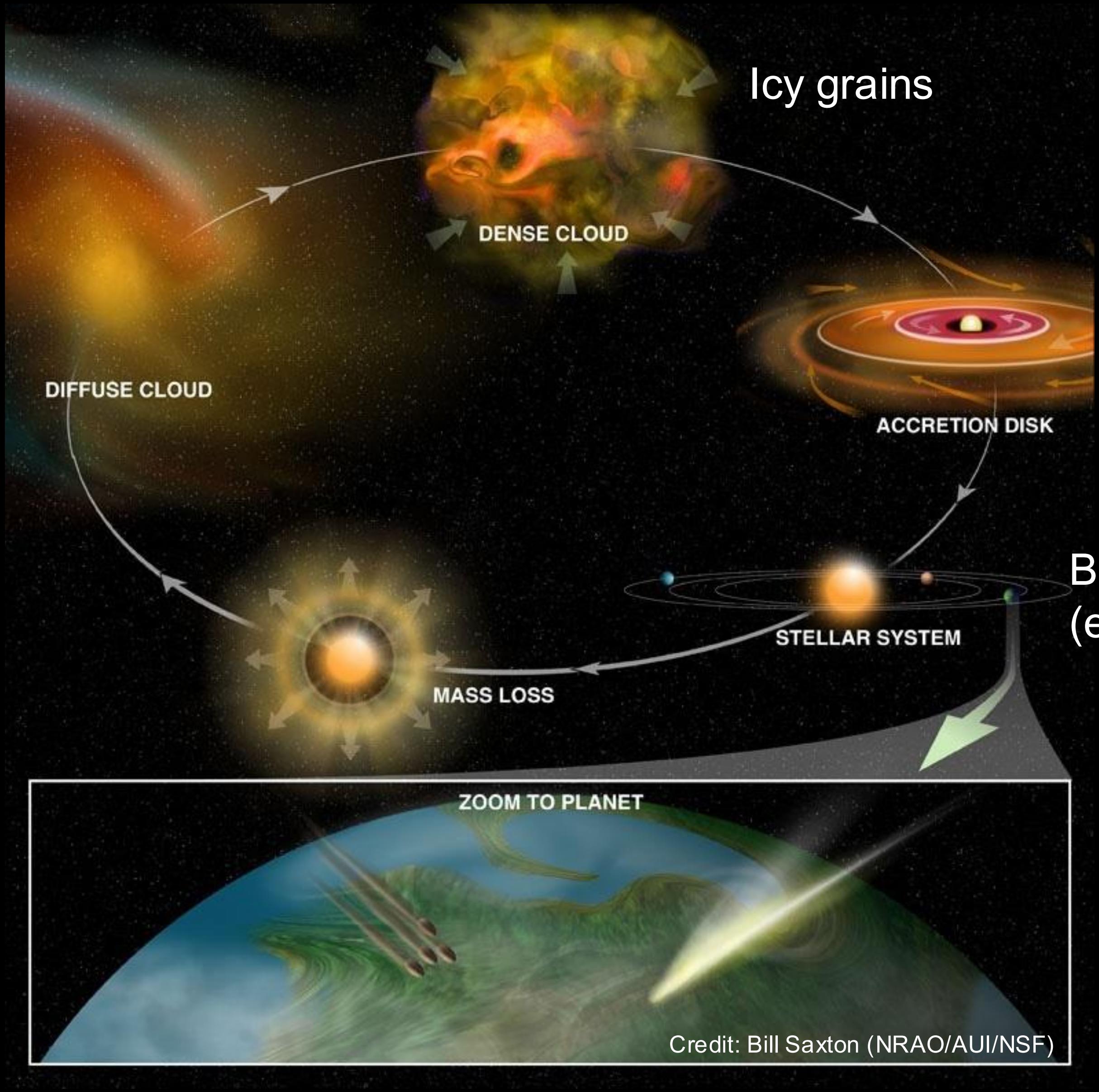
Cosmic dust grains



- Influence the thermodynamic properties of the medium
- Participate in the formation of planets and their atmospheres
- Participate in the delivery of the chemical precursors to life to planets
- Serve as a third body and a catalyst for key chemical reactions

The cosmic life cycle of matter

Bare grains

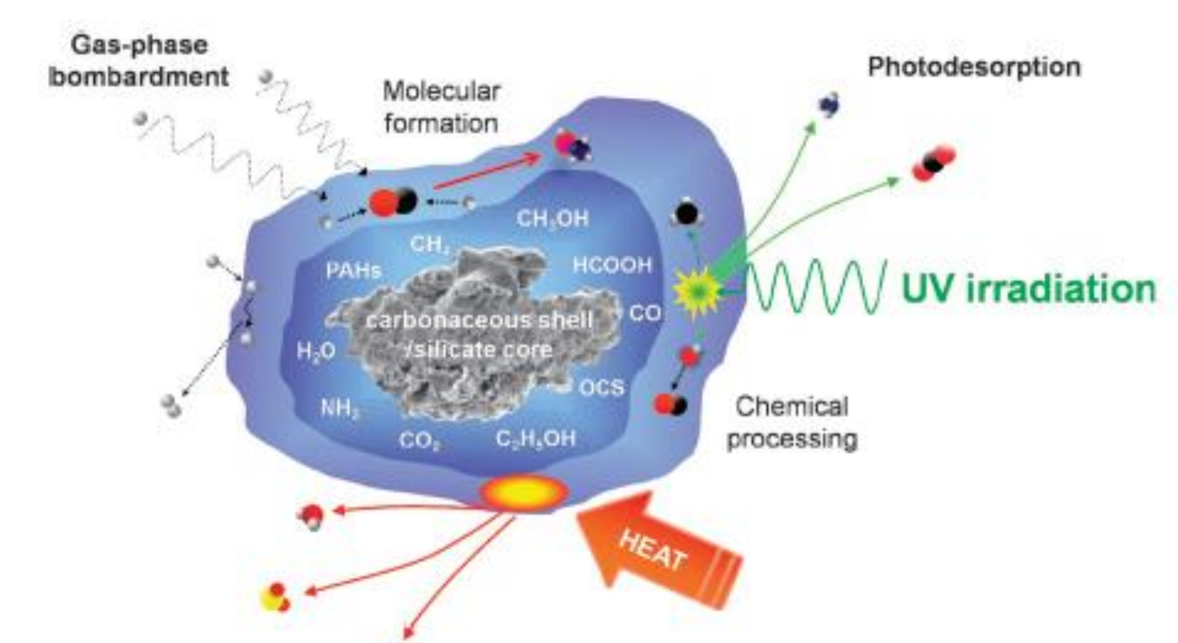


Icy grains

Bare grains
Icy grains

Bare grains
(exoplanet atmospheres)

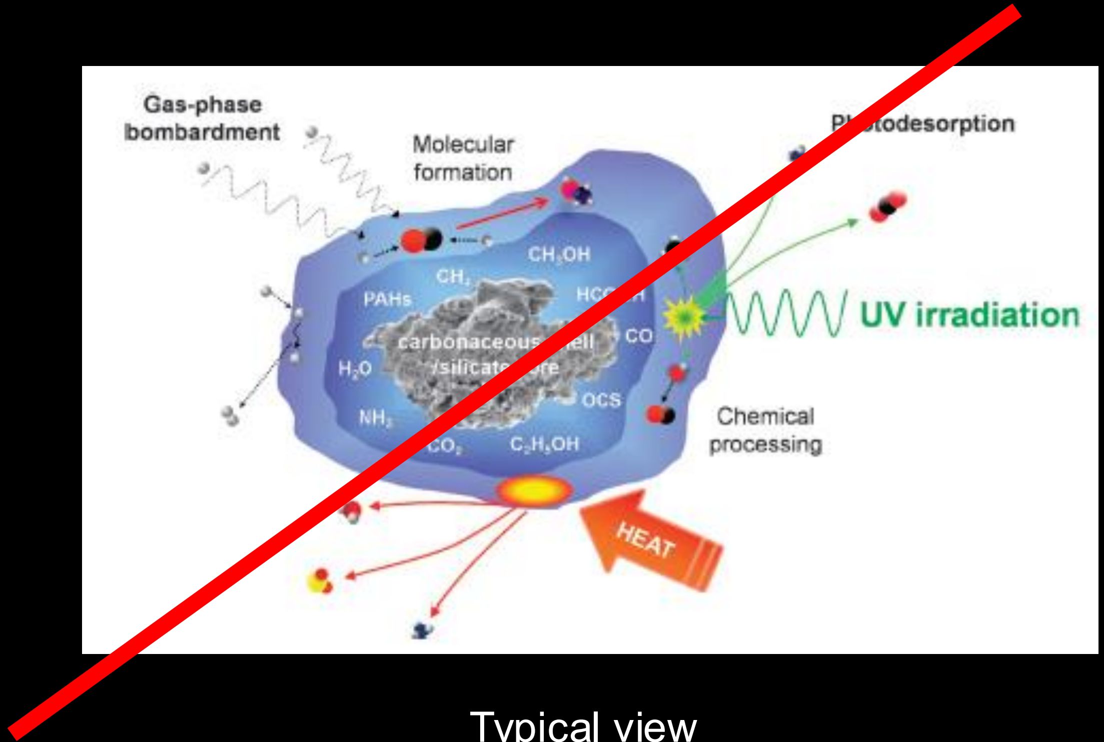
Cosmic dust grains



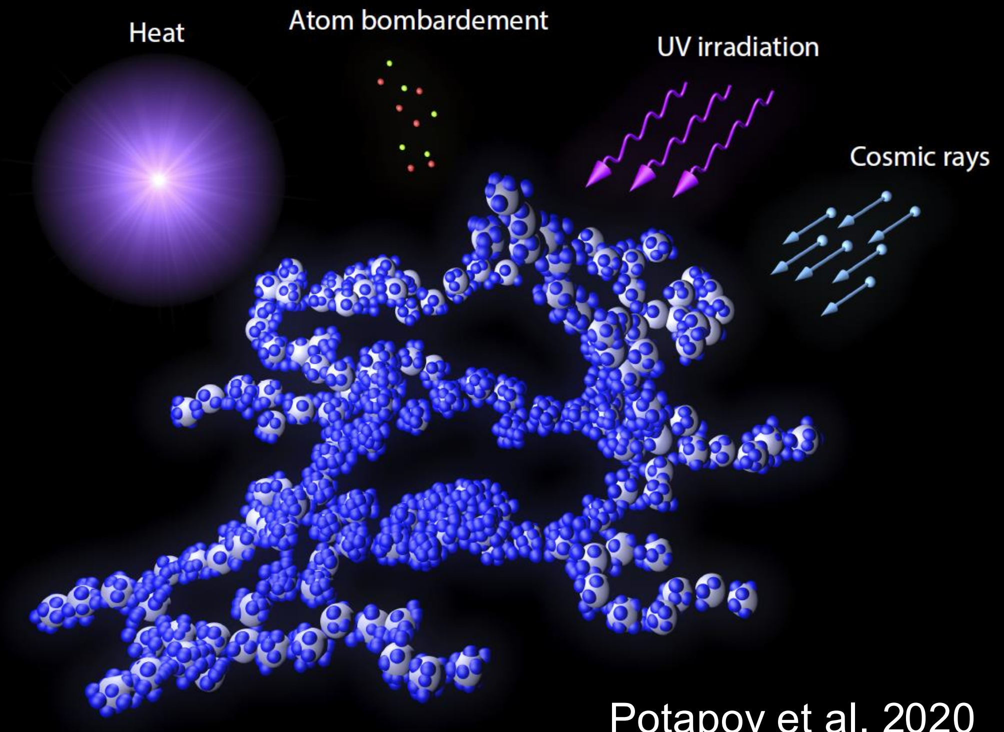
Credit: Burke & Brown 2010

Typical view

Cosmic dust grains

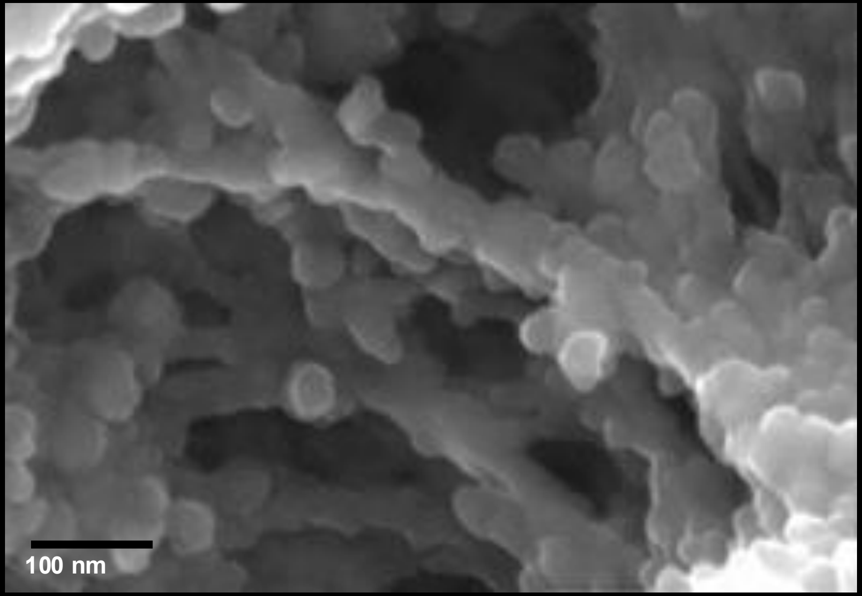


Typical view

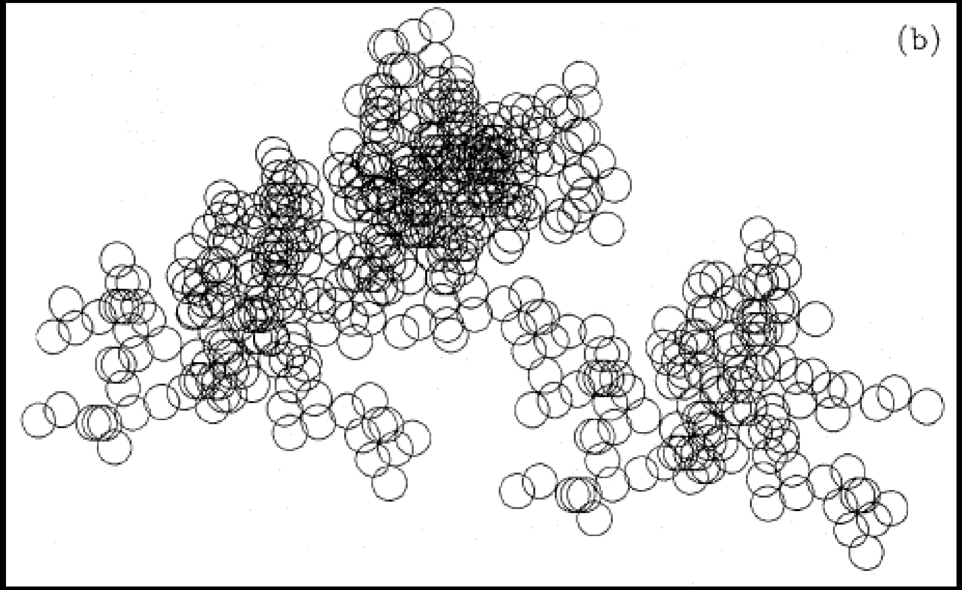


Potapov et al. 2020

Dust growth in the ISM

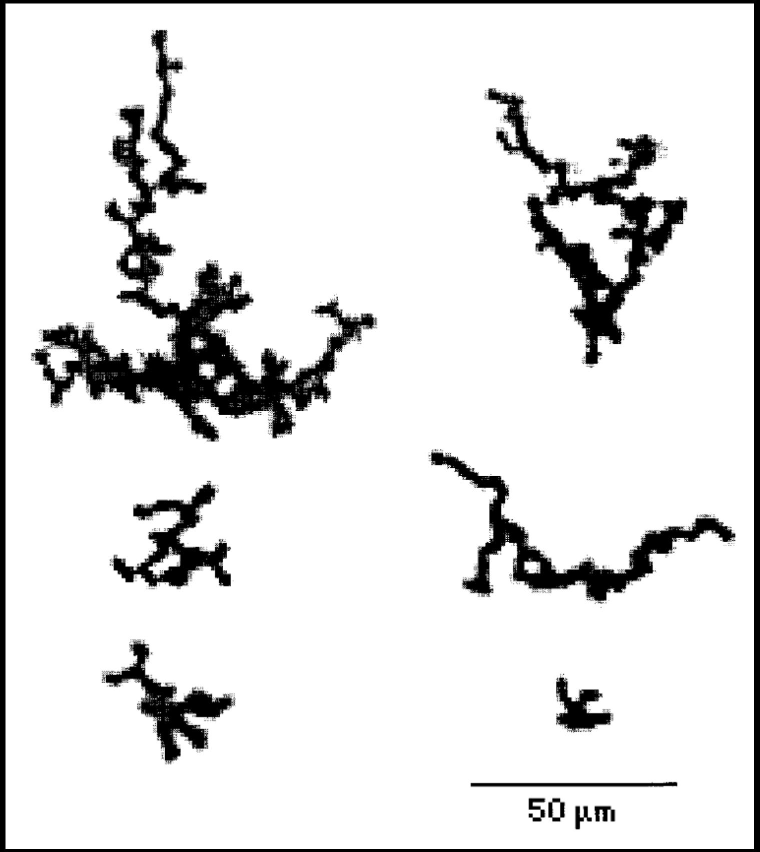


$MgSiO_3$ aggregates, gas-phase condensation + deposition
(Potapov et al. 2019)



Dust aggregate, simulation
(Ossenkopf 1993)

Dust growth in protoplanetary disks



SiO_2 aggregates produced by collisions
(Wurm & Blum 1998)

Dust aggregate, simulation
(Wada et al. 2009)

Dust growth in protoplanetary disks

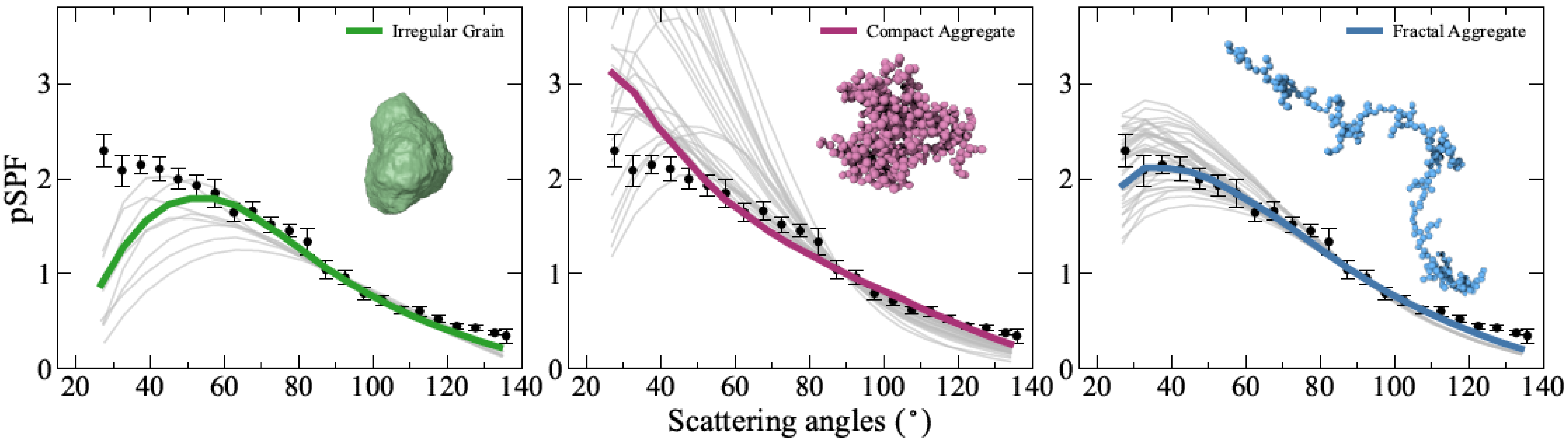
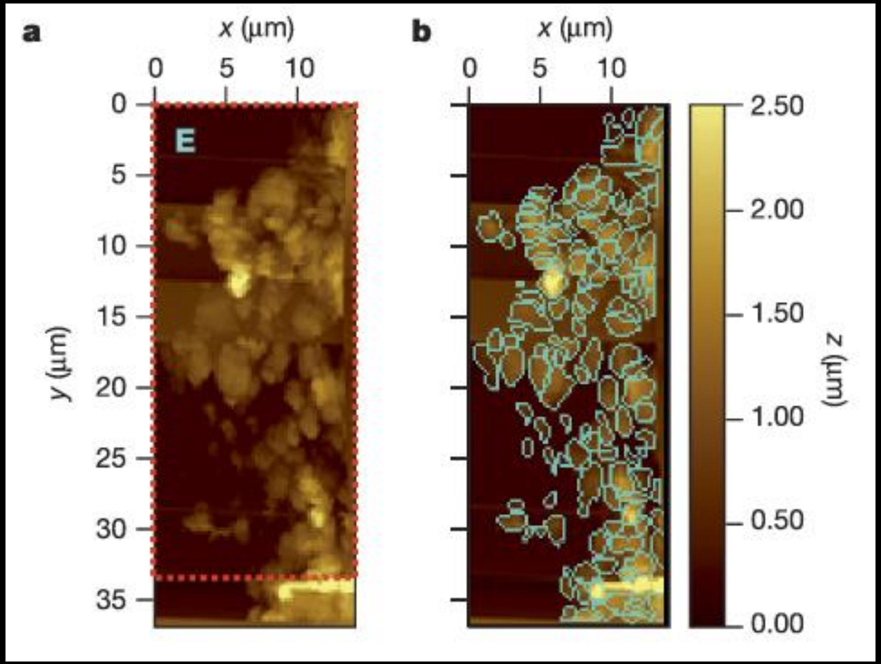
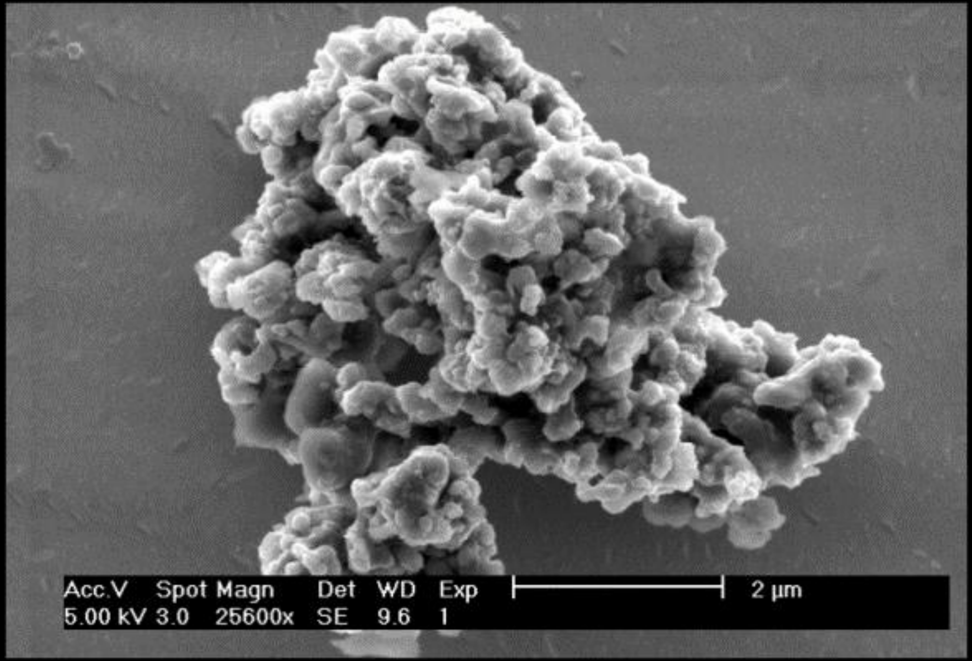


Fig. 10 Polarized scattering phase function (pSPF) extracted for the disk around IM Lup (black points with error bars) and radiative transfer models for irregular grains (left), compact aggregates (middle), and fractal aggregates (right). Thin gray lines in each panel correspond the results obtained for changing aggregate/monomer sizes, porosity, and composition, and the thick solid lines represent the best fit among them for each class of particle morphology. Particle images shown in each panel is the dust model used in the best-fitting model. See Tazaki et al. (2023b) for more detailed information.

Cometary dust particles

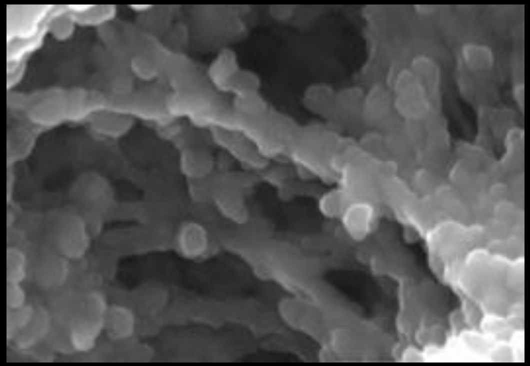


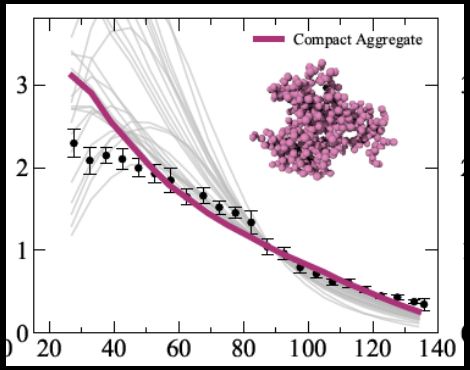
Topographic images of particle E (comet 67P)
(Bentley et al. 2016)

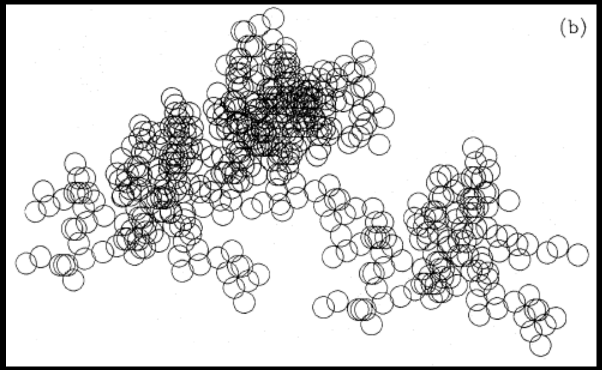


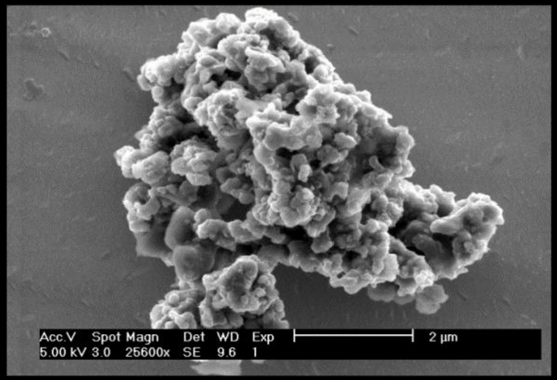
Microscope image of an interplanetary dust particle
(Warren et al. 1997)

Is cosmic dust porous?



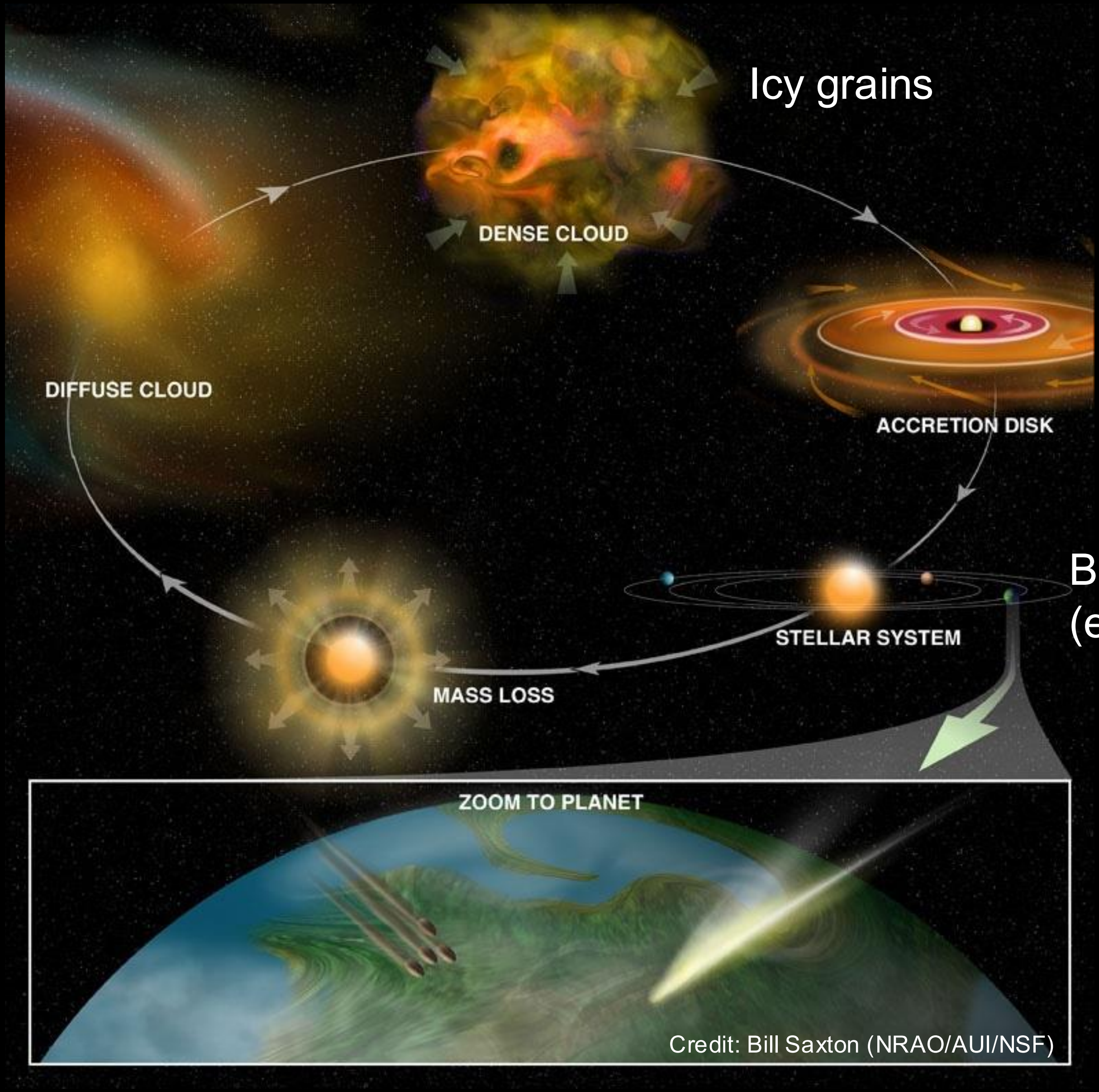






Potapov A., et al., "Is Cosmic Dust Porous?",
The Astronomy and Astrophysics Review, accepted for publication
https://arxiv.org/abs/2509.10292

The cosmic life cycle of matter



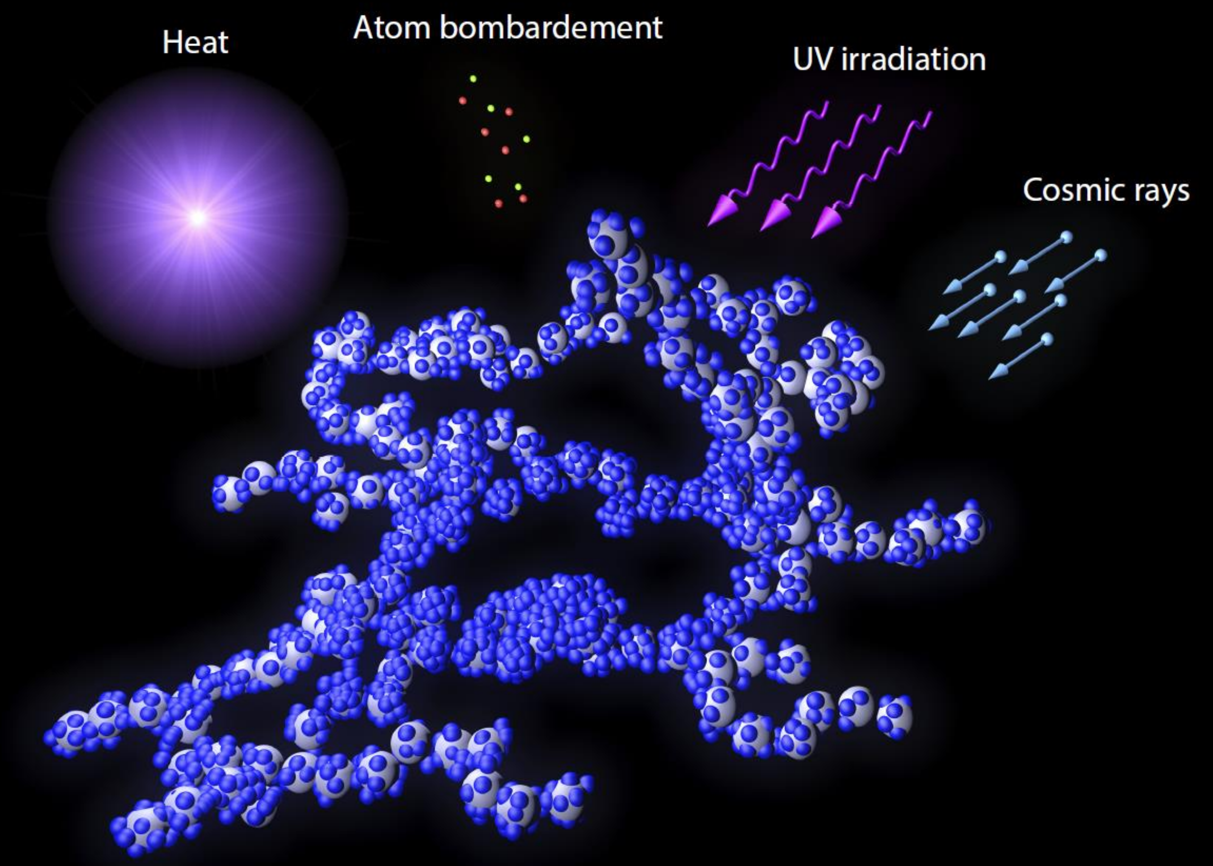
Icy grains

Bare grains

Bare grains
Icy grains

Bare grains
(exoplanet atmospheres)

Ice coverage of dust grains



H_2O ice coverage of dust grains in the ISM:

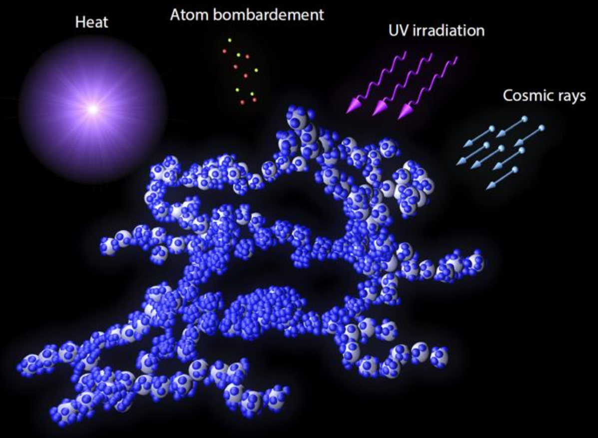
0.3 – 12 x 10^{18} molecule cm^{-2} (observations)

300 – 12 000 ML / 400 = 0.75 – 30 ML

Correction factor due to the dust porosity

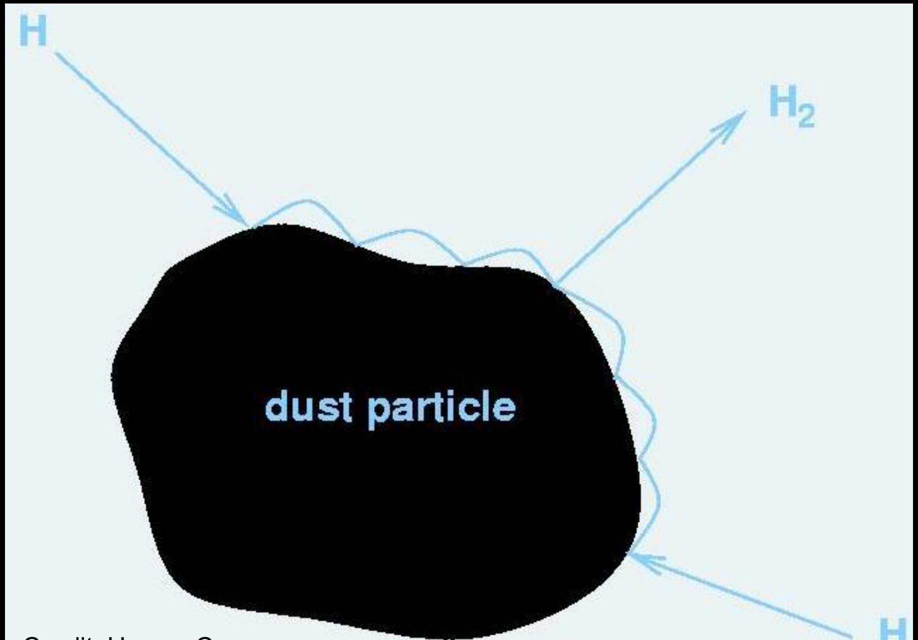
Potapov et al., 2020, Phys. Rev. Lett.

Role of dust grains in the chemistry on their surfaces

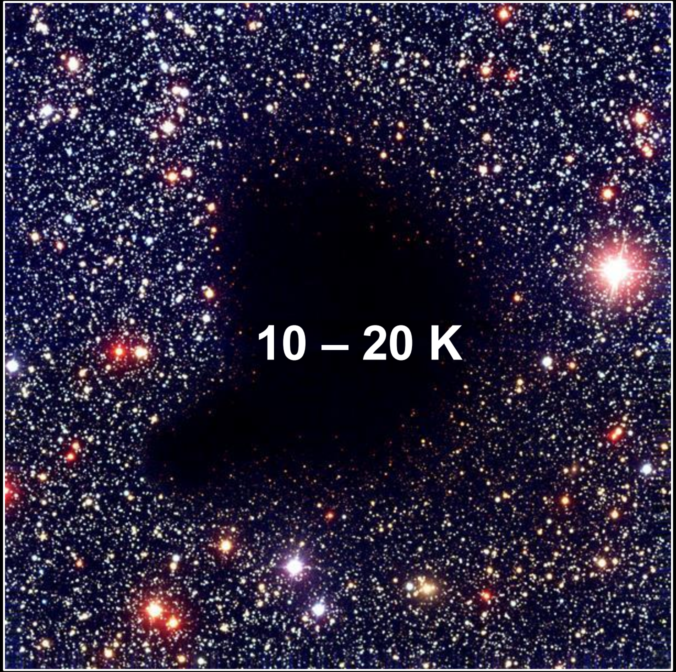


- Meeting place for reactants
- Dissipation of excess energy released in bond formation (third body action)
- <u>Catalytic formation of molecules on dust surfaces</u>

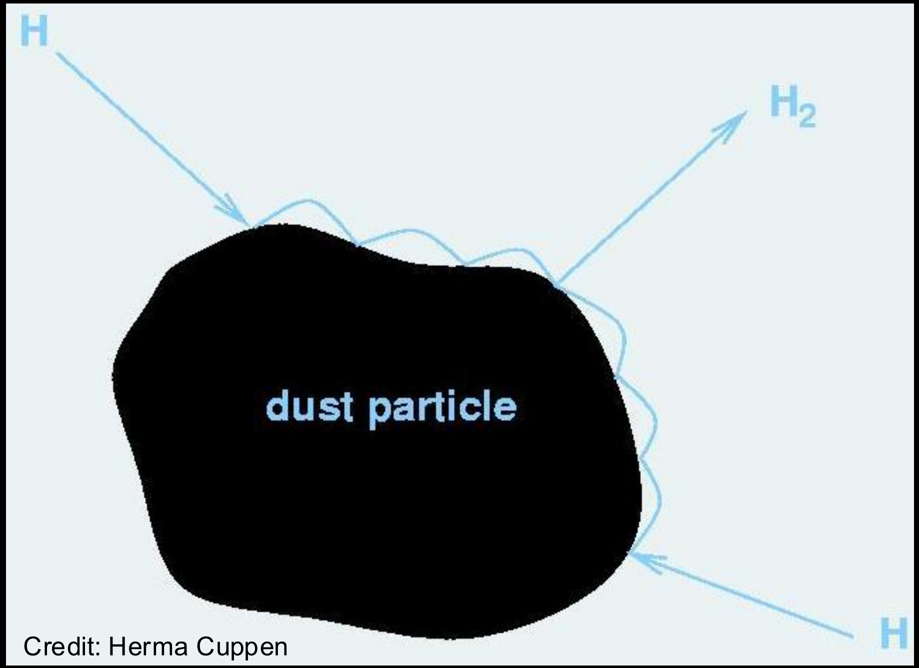
Catalytic formation of molecules

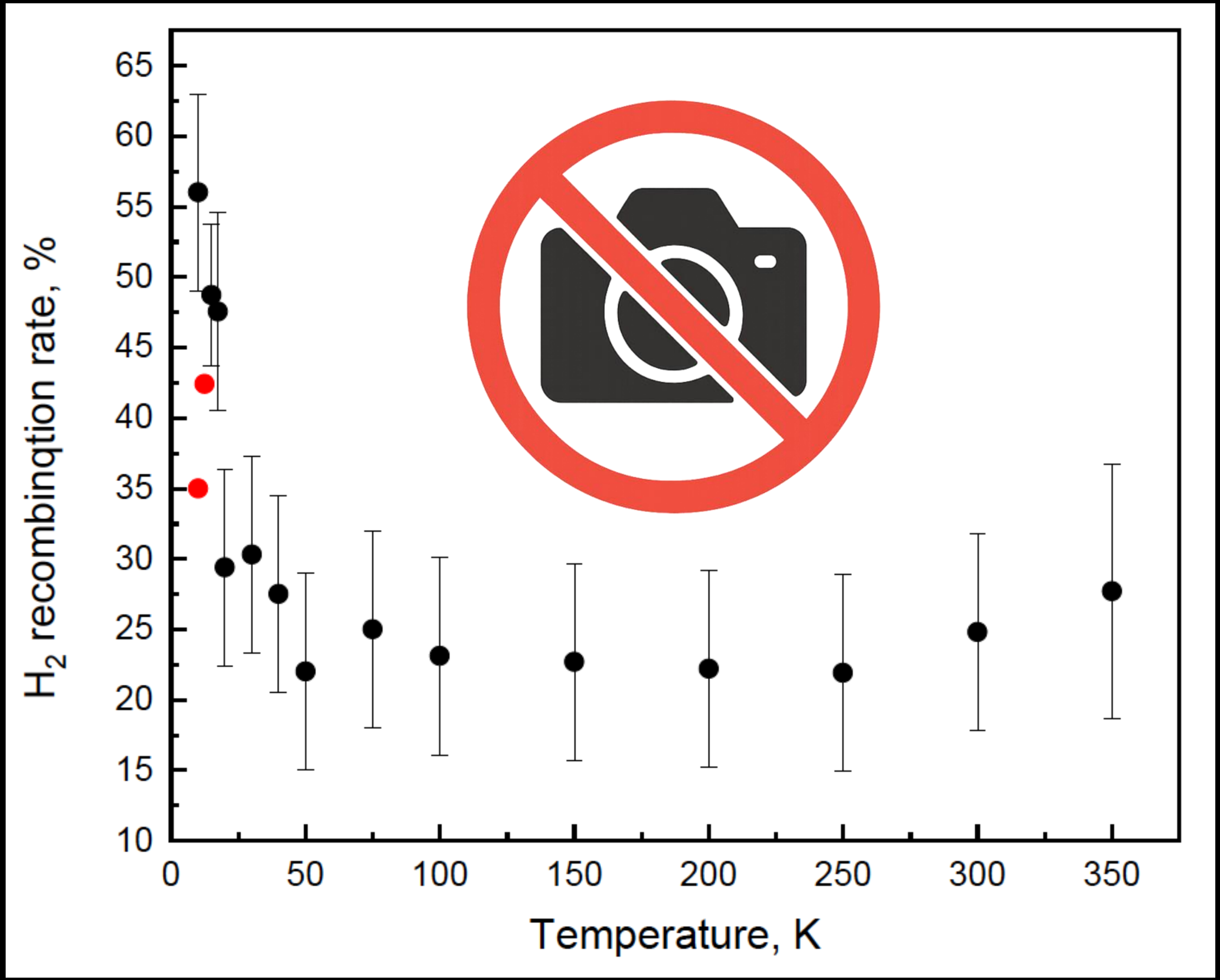


Credit: Herma Cuppen



Catalytic formation of molecules

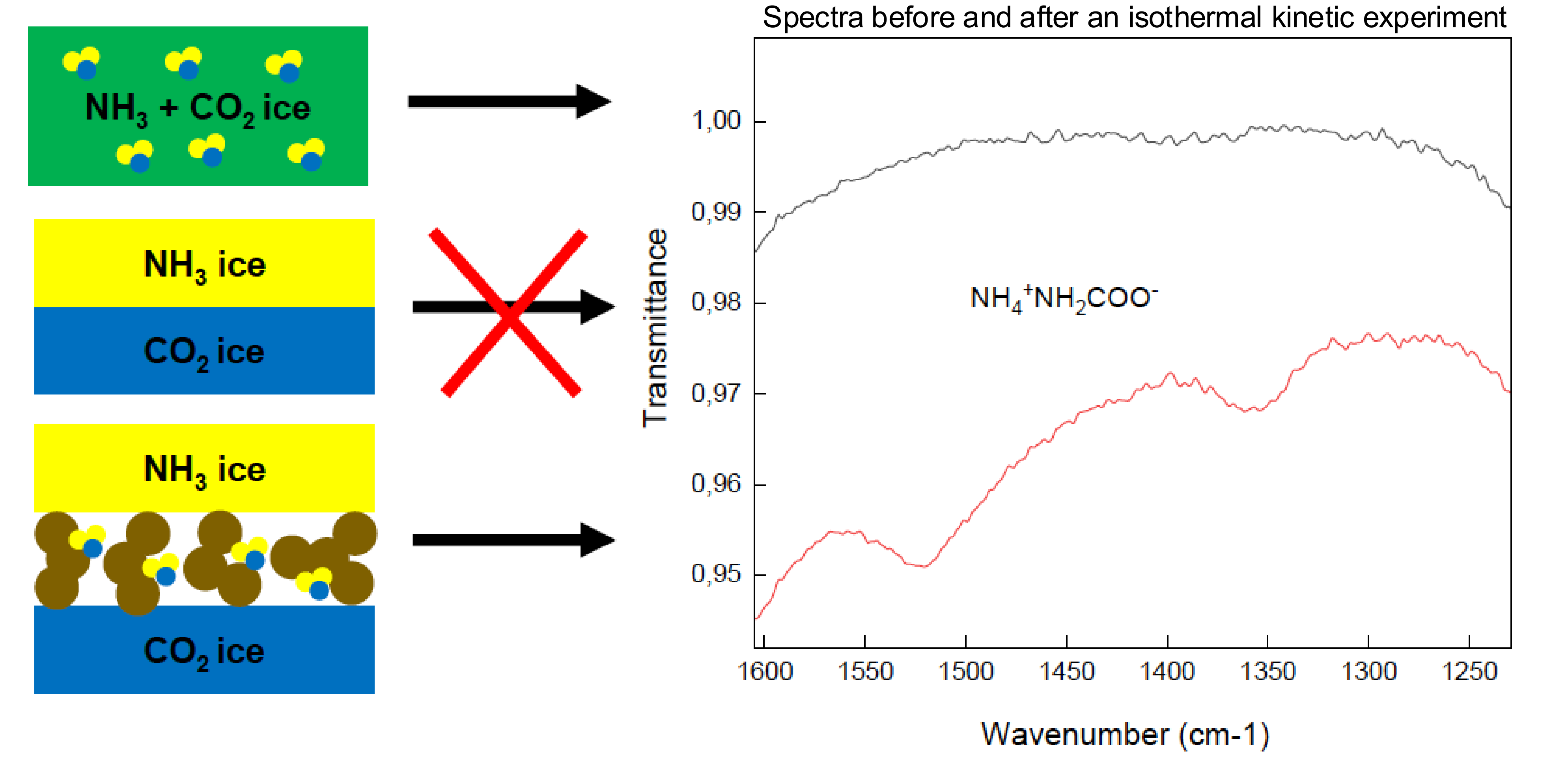




Potapov et al., unpublished

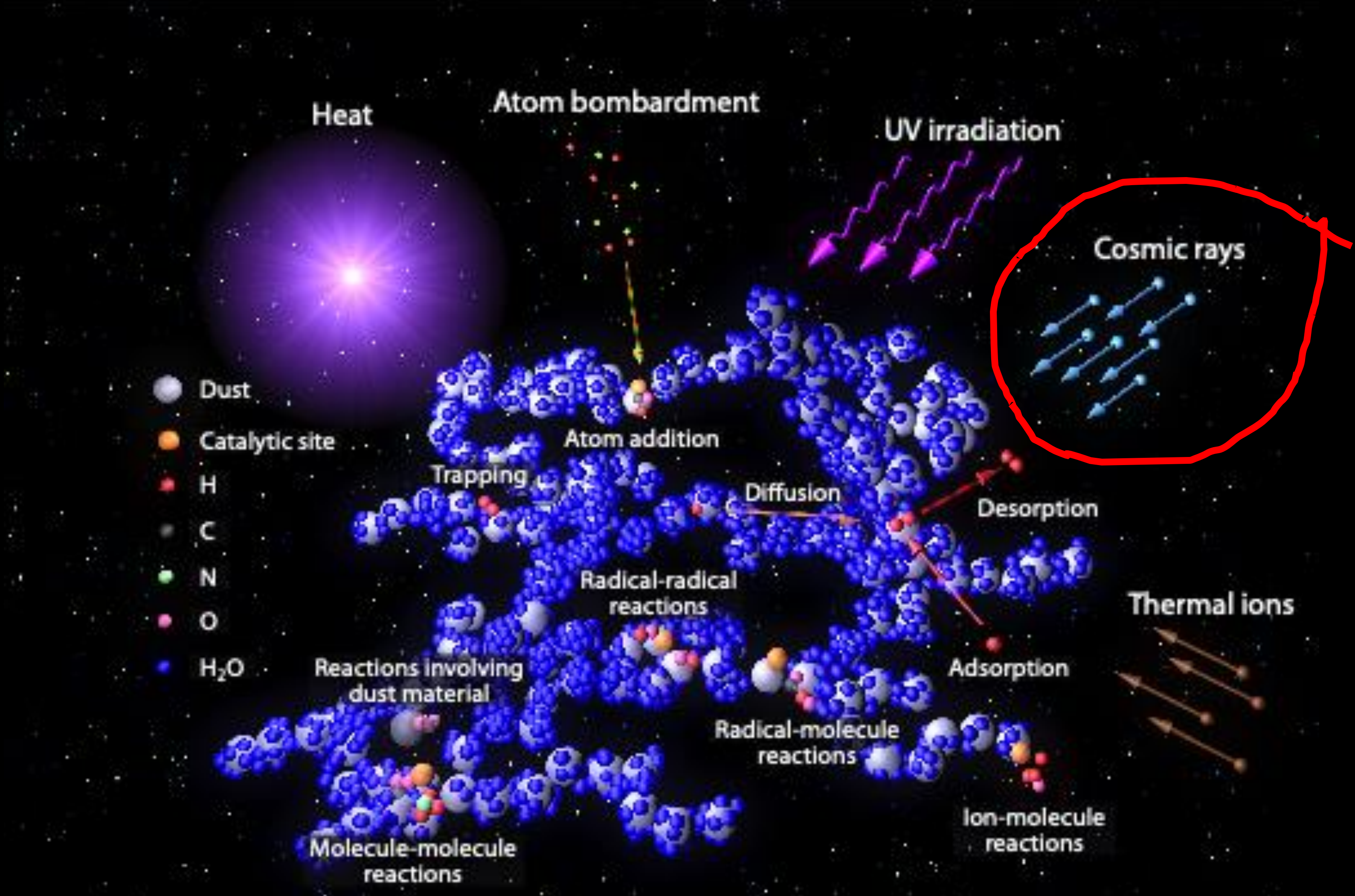
Catalytic formation of molecules

$CO_2 + 2NH_3 \rightarrow NH_4^+NH_2COO^-$



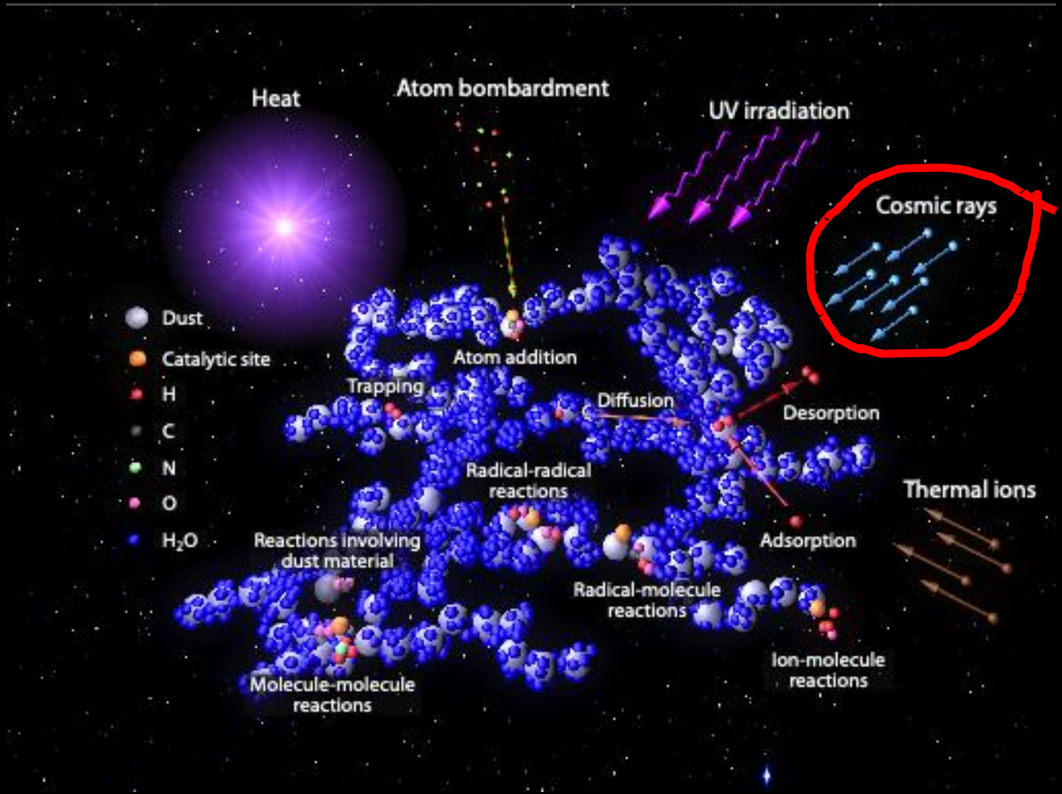
Potapov et al., 2025, The Astrophysical Journal

Physical and chemical processes on dust



Potapov, 2024, Bunsen-Magazin der Deutschen Bunsen-Gesellschaft

Physical and chemical processes on dust



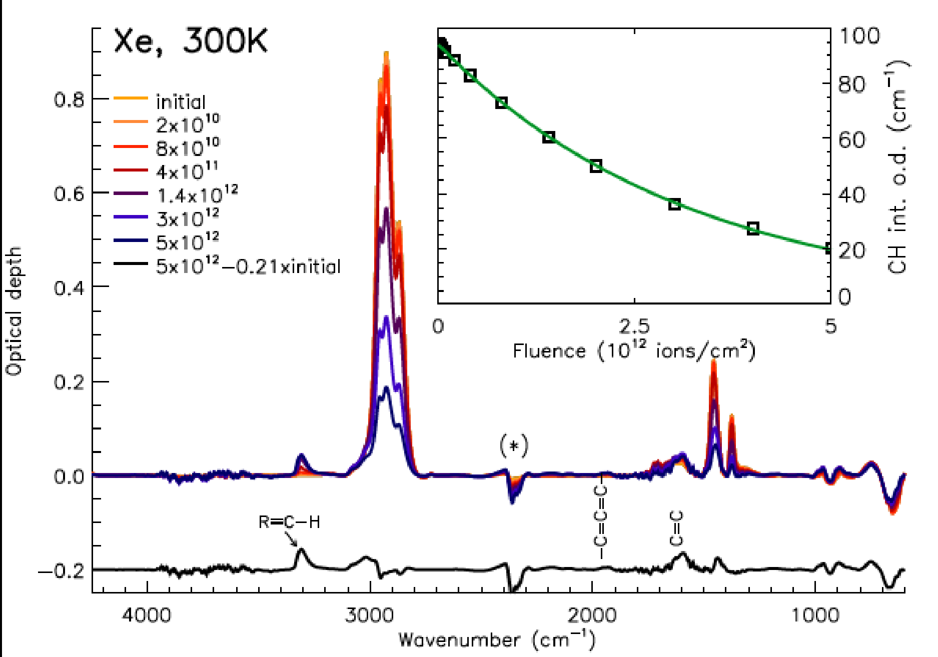
What is the influence of high energy ions on the properties of analogues of cosmic dust grains?

- **Optical (UV, IR spectral)**
- **Compositional (elemental analysis)**
- **Structural (amorphous/crystalline)**
- **Morphological (porosity)**
- **Chemical (catalytic)**

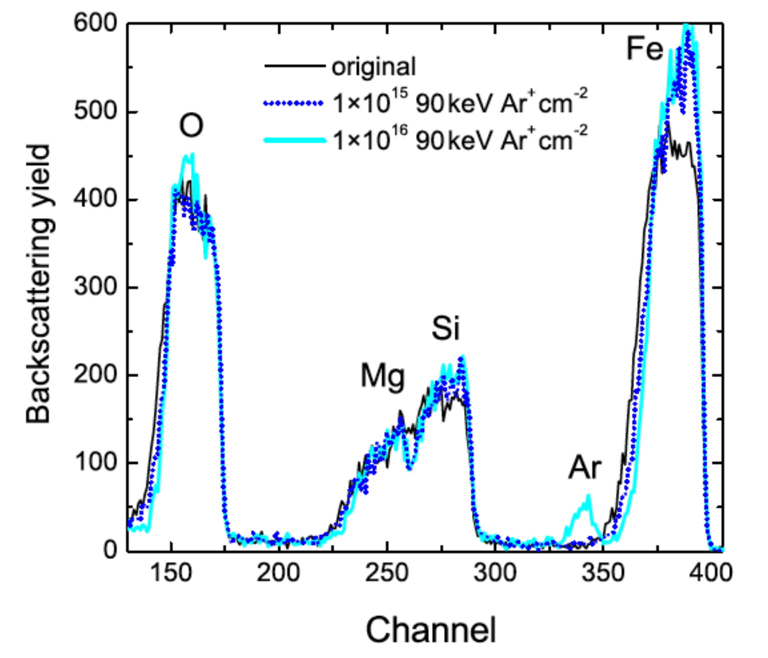
Decoding of astronomical spectra
Reliable cosmic dust models
Understanding of astrochemical processes
Industrial applications

Optical, compositional and structural properties

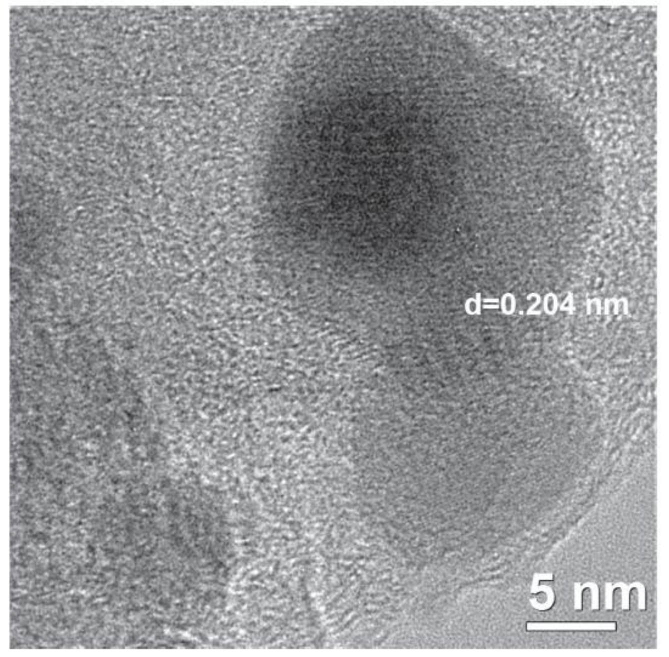
Spectrum



Composition



Structure



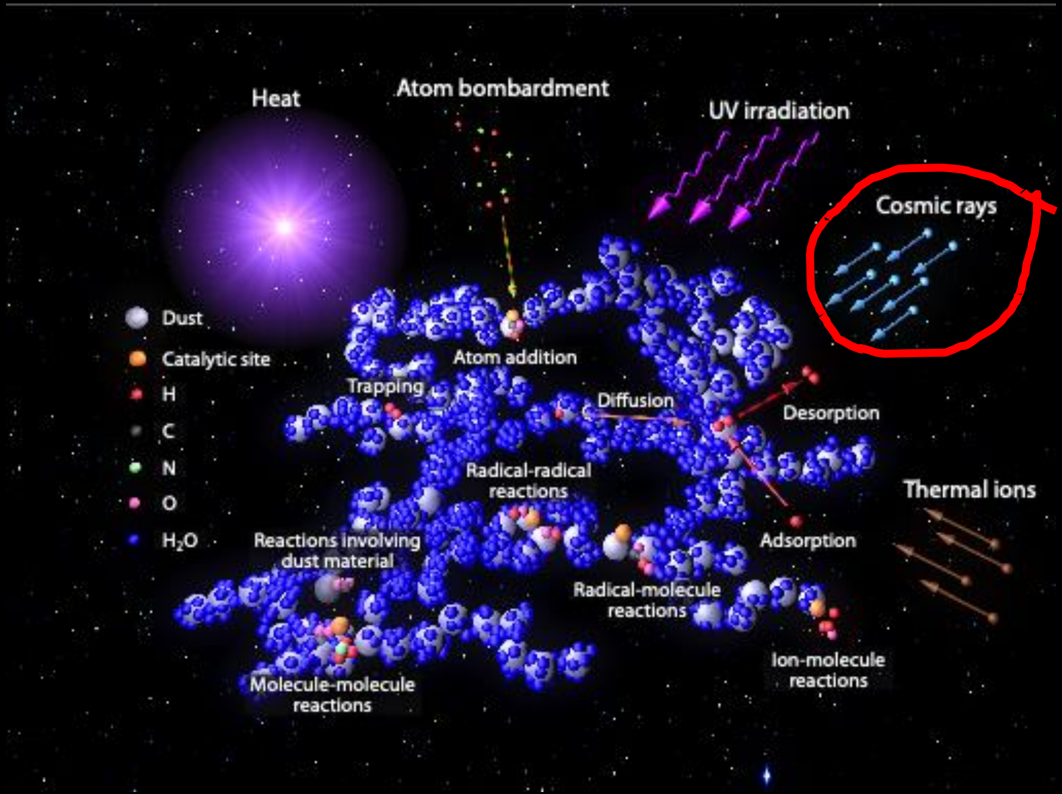
hydrogenated amorphous carbon

$MgFeSiO_4$ grains

Dartois et al., 2017, A&A

Jäger et al., 2016, ApJ

Physical and chemical processes on dust



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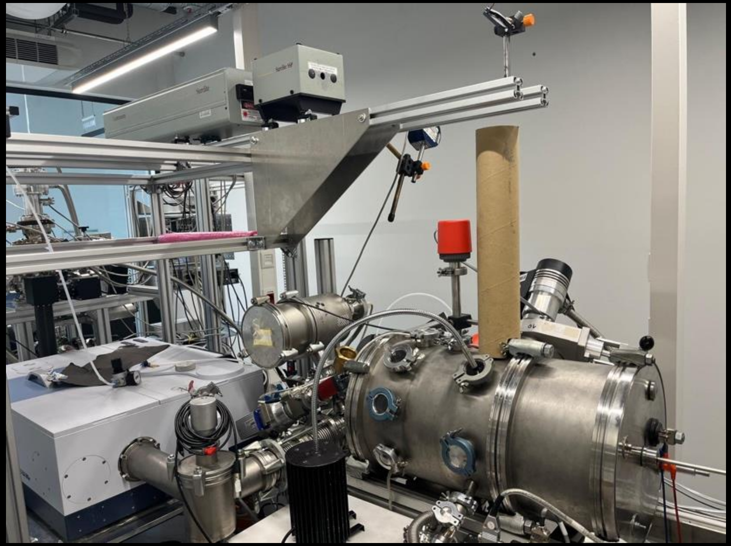
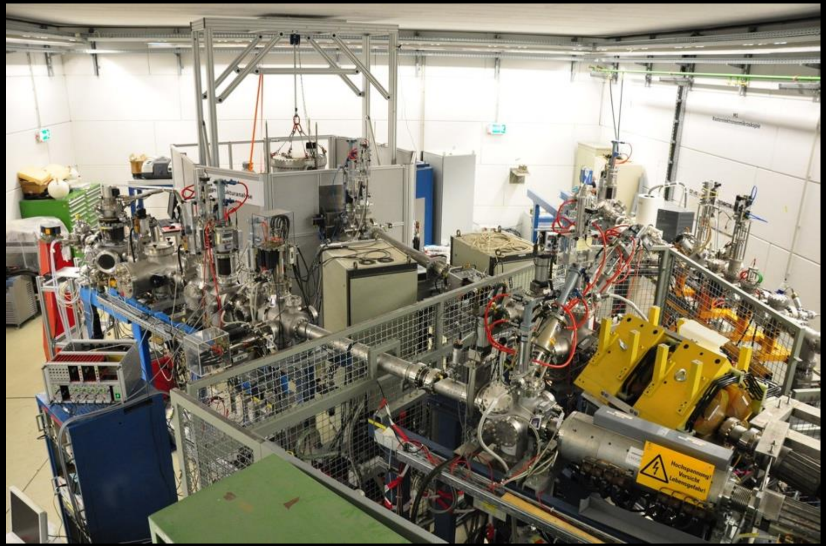
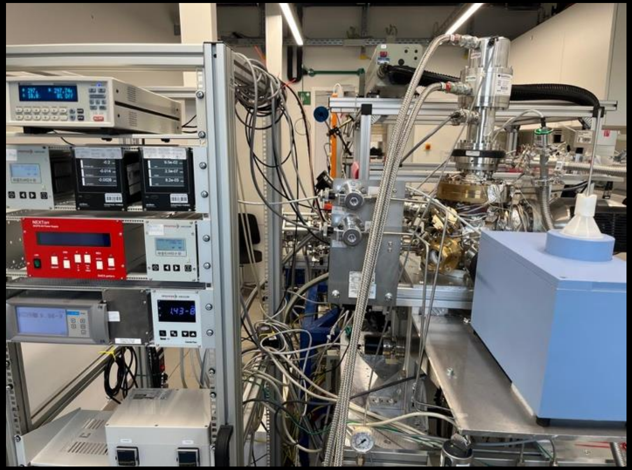
AMG Jena



GSI + IFK Jena



AMG Jena



Sample	Ion current	Implanation time
Fayalit...48	~ 420 nA	51min 34sec
Fayalit...47	~ 460 nA	45min 52sec
MgFeSiO4	~ 470 nA	44min 54sec
MgSiO3 (one sample)	~ 380 nA	55min 39sec
Mg2SiO4	~ 400 nA (3,958E15) ~ 170 nA (8,759E14) ~ 265 nA (5,166E15)	30min 31sec 11min 20sec 40min 35sec
Mg2SiO3 TA=500	~ 310 nA (5E15) ~ 195 nA (5E15)	34min 3sec 1h 7min 7sec
Mg2SiO3 TA=500	~ 330 nA	1h 13min 41sec
C	~ 350 nA	1h 12sec

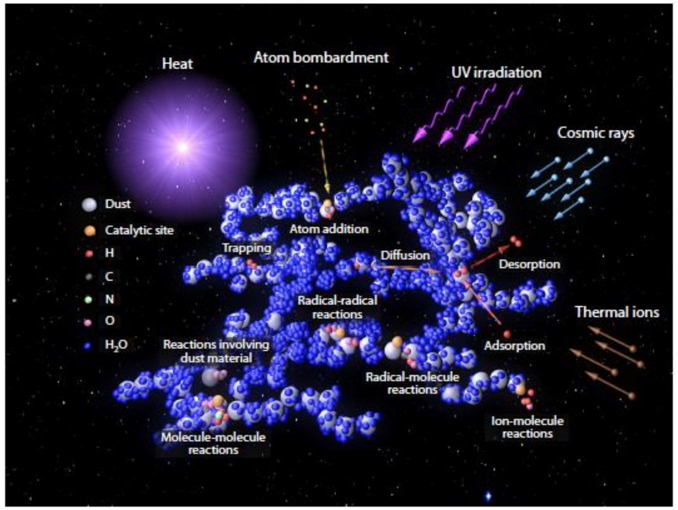
All the best, good luck with the samples, and we will be happy to discuss any results,

Carsten & Sören

Let’s collaborate

Beam Time Proposals to Mat-PAC

Space-weathering of cosmic dust grain analogues triggered by high energy ions



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