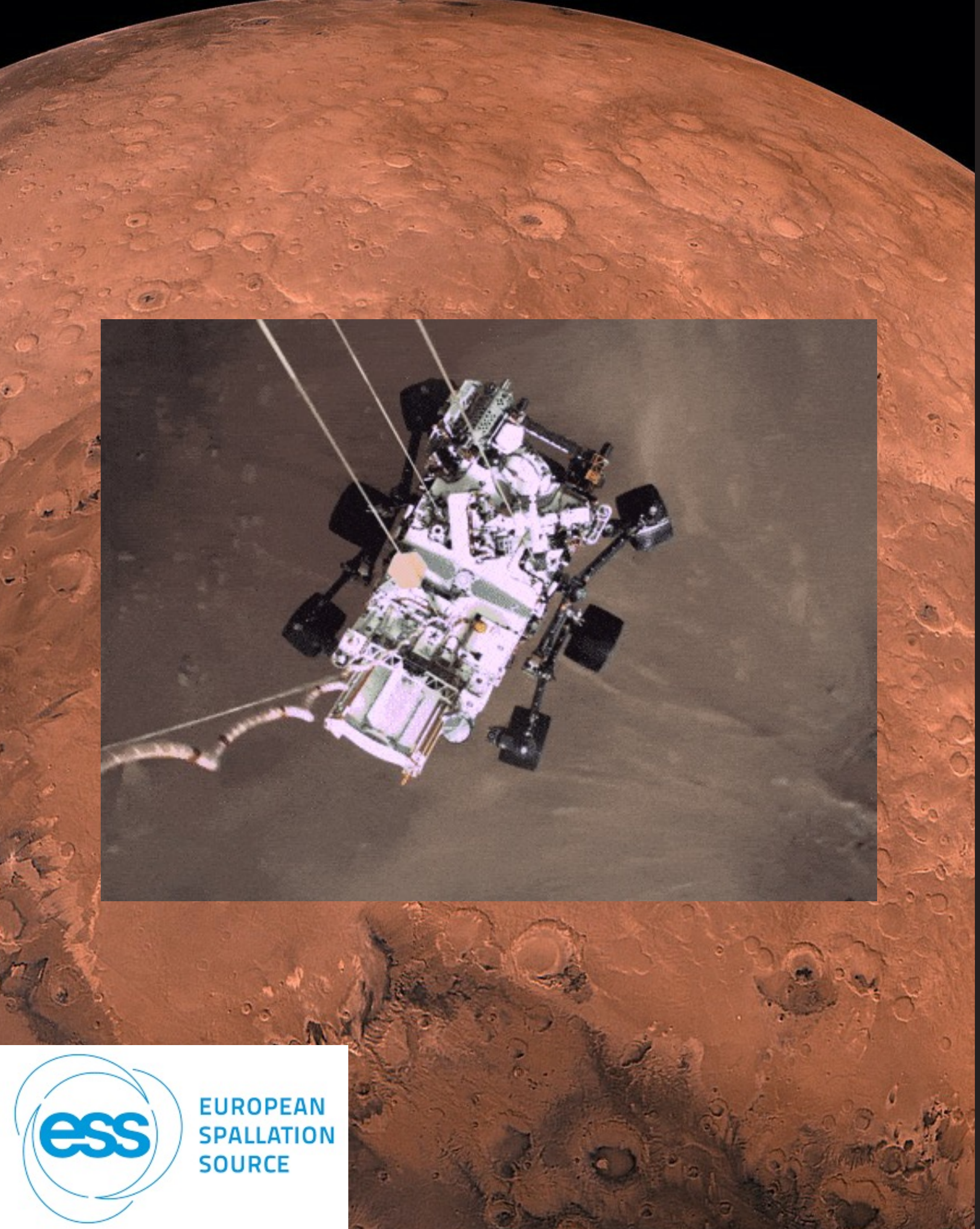
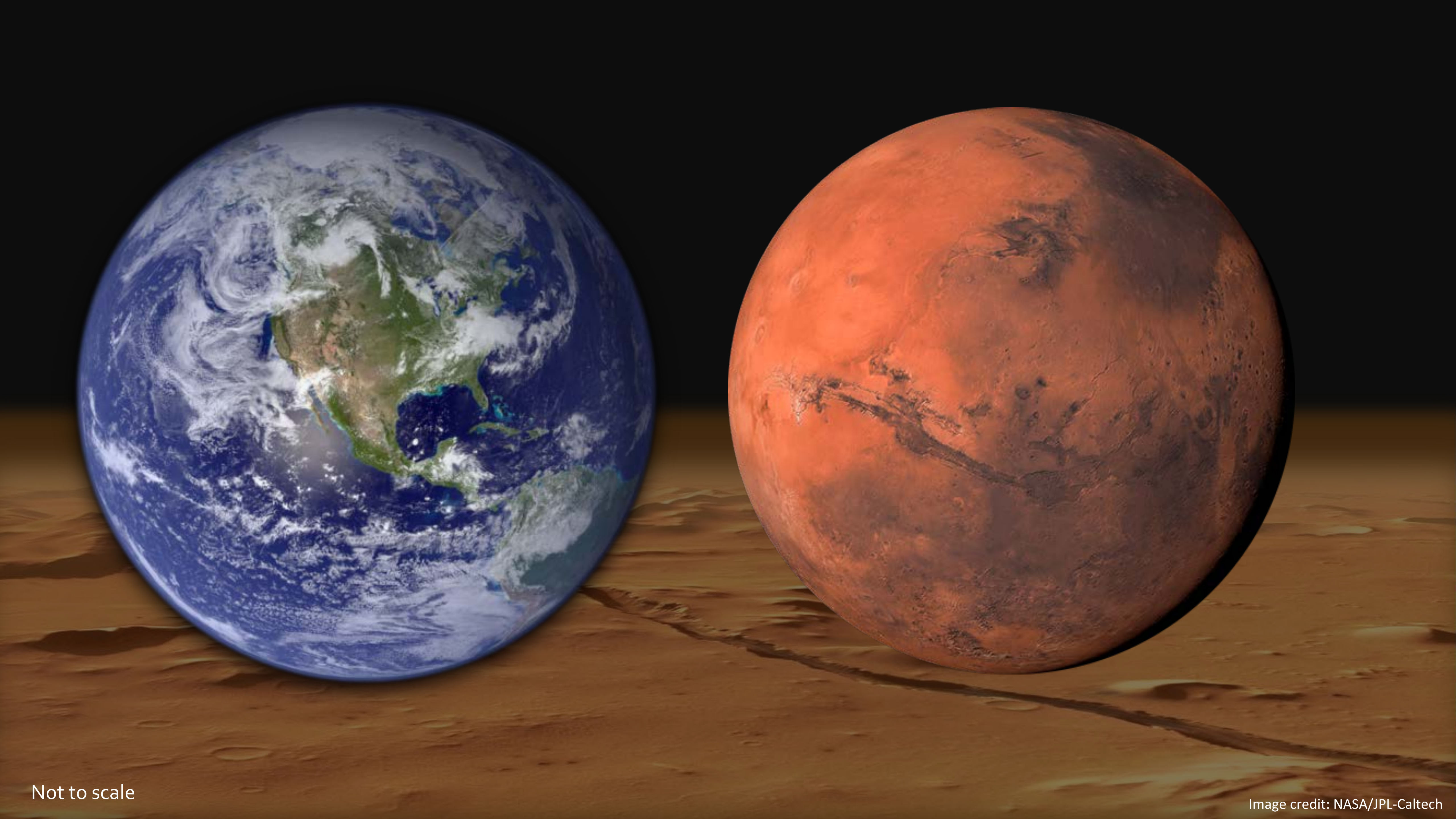


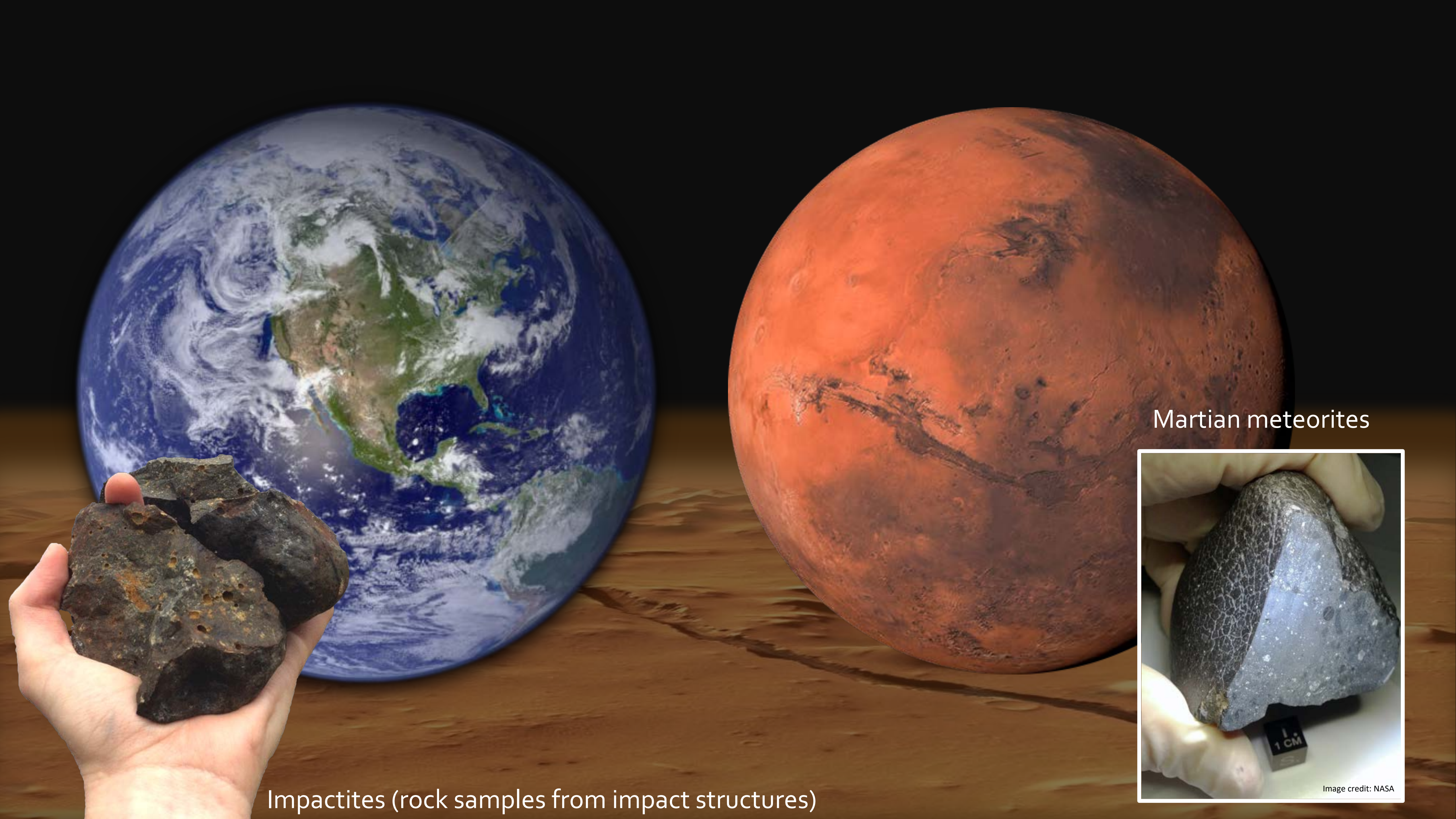
Towards a Better Understanding of Solar System Dynamics and the Impact Cratering Process

ESS SCIENCE DAY 2021

Josefin Martell, PhD student in Planetary geology, Lund University, Sweden

Supervisors: Carl Alwmark (LU), Sanna Alwmark (CU), Robin Woracek (ESS), Luke Daly (Gla)


Not to scale
Image credit: NASA/JPL-Caltech

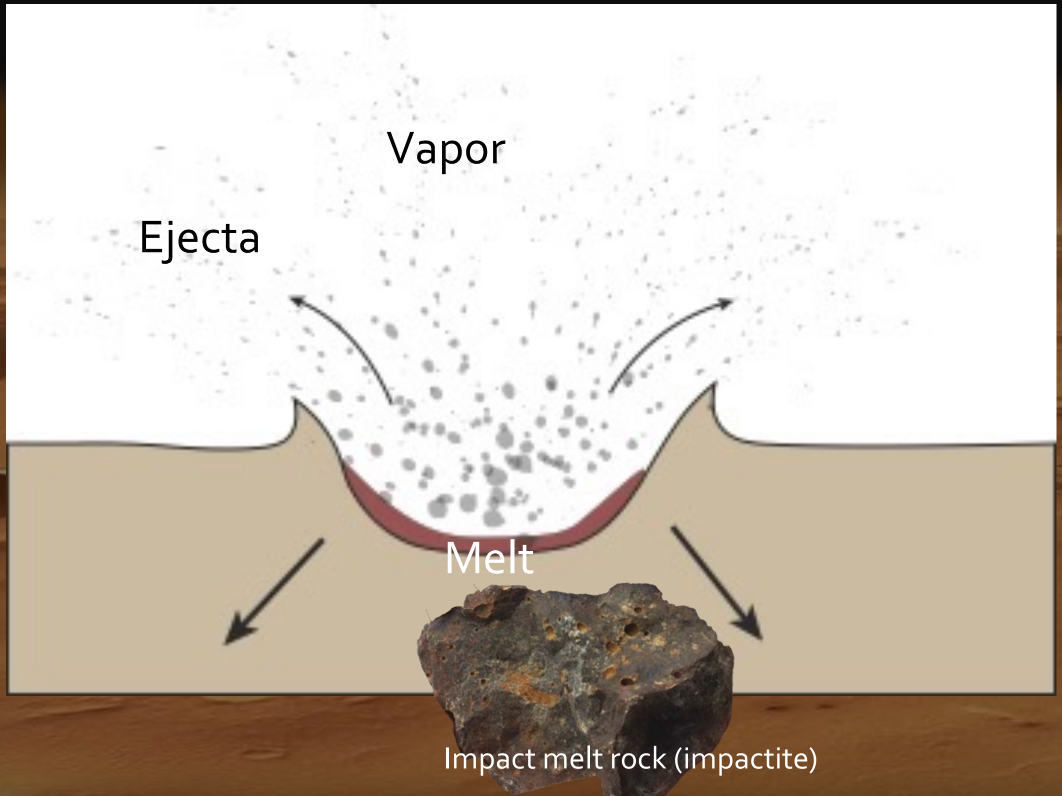

Martian meteorites
Image credit: NASA
Impactites (rock samples from impact structures)

Why use neutrons?

1. Fate of the projectile

Most gets vaporized, but traces of the meteorite can be incorporated in the impactites!

Image credit: solarseven/Shutterstock



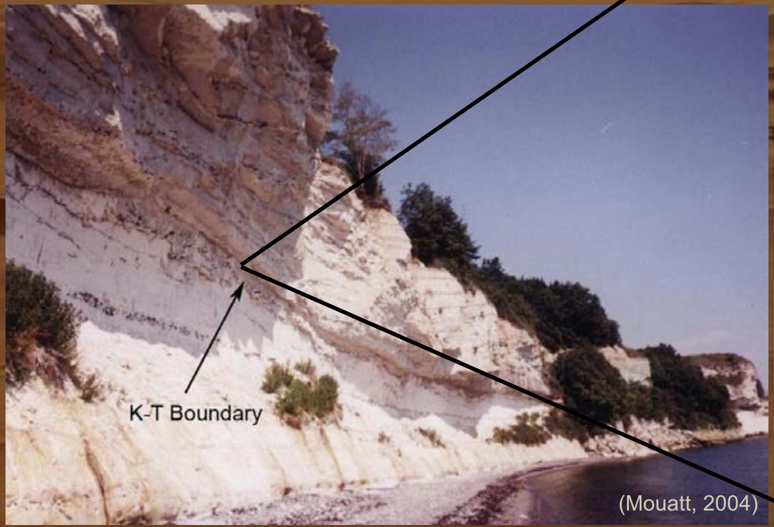
Why use neutrons?

1. Fate of the projectile

Image credit: solarseven/Shutterstock

Stevns Klint in Denmark – layer that marks the transition between the Cretaceous and Paleogene ~66 million years ago!

- Enrichment of Iridium in the layer
- Platinum group elements



(Mouatt, 2004)

https://www.stevnsklint.com/da/viden/historien-om-fiskeleret/

Why use neutrons?

- **Fate of the projectile:**
  Platinum group elements, Iridium!

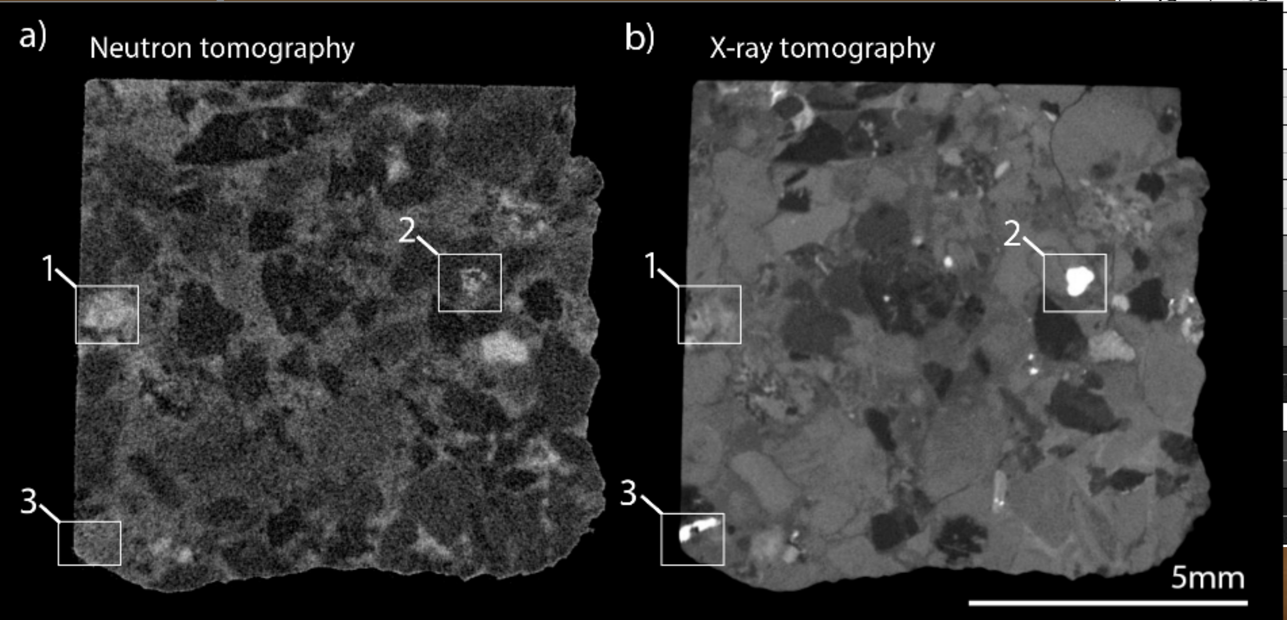
- **Hydrous minerals:**

Attenuation coeffitients for thermal neutrons [cm^{-1}]

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0
H 3.44																	He 0.02
Li 3.30	Be 0.79											B 101.60	C 0.56	N 0.43	O 0.17	F 0.20	Ne 0.10
Na 0.09	Mg 0.15											Al 0.10	Si 0.11	P 0.12	S 0.06	Cl 1.33	Ar 0.03
K 0.06	Ca 0.08	Sc 2.00	Ti 0.60	V 0.72	Cr 0.54	Mn 1.21	Fe 1.19	Co 3.92	Ni 2.05	Cu 1.07	Zn 0.35	Ga 0.49	Ge 0.47	As 0.67	Se 0.73	Br 0.24	Kr 0.61
Rb 0.08	Sr 0.14	Y 0.27	Zr 0.29	Nb 0.40	Mo 0.52	Tc 1.76	Ru 0.58	Rh 10.88	Pd 0.78	Ag 4.04	Cd 115.11	In 7.58	Sn 0.21	Sb 0.30	Te 0.25	I 0.23	Xe 0.43
Cs 0.29	Ba 0.07	La 0.52	Hf 4.99	Ta 1.49	W 1.47	Re 6.85	Os 2.24	Ir 30.46	Pt 1.46	Au 6.23	Hg 16.21	Tl 0.47	Pb 0.38	Bi 0.27	Po	At	Rn
Fr	Ra 0.34	Ac	Rf	Ha													
*Lanthanides	Ce 0.14	Pr 0.41	Nd 1.87	Pm 5.72	Sm 171.47	Eu 94.58	Gd 1479.04	Tb 0.93	Dy 32.42	Ho 2.25	Er 5.48	Tm 3.53	Yb 1.40	Lu 2.75			
**Actinides	Th 0.59	Pa 8.46	U 0.82	Np 9.80	Pu 50.20	Am 2.86	Cm	Bk	Cf	Es	Fm	Md	No	Lr			

Attenuation coeffitients for X-ray [cm^{-1}] (150kV)

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0
																	He 0.02
												B 0.28	C 0.27	N 0.11	O 0.16	F 0.14	Ne 0.17
												Al 0.38	Si 0.33	P 0.25	S 0.30	Cl 0.23	Ar 0.20
		Sc 0.48	Ti 0.73	V 1.04	Cr 1.29	Mn 1.32	Fe 1.57	Co 1.78	Ni 1.96	Cu 1.97	Zn 1.64	Ga 1.42	Ge 1.33	As 1.50	Se 1.23	Br 0.90	Kr 0.73
		Y 1.61	Zr 2.47	Nb 3.43	Mo 4.29	Tc 5.06	Ru 5.71	Rh 6.08	Pd 6.13	Ag 5.67	Cd 4.84	In 4.31	Sn 3.98	Sb 4.28	Te 4.06	I 3.45	Xe 2.53
		La 5.04	Hf 19.70	Ta 25.47	W 30.49	Re 34.47	Os 37.92	Ir 39.01	Pt 38.61	Au 35.94	Hg 25.88	Tl 23.23	Pb 22.81	Bi 20.28	Po 20.22	At	Rn 9.77
		Ac 24.47	Rf	Ha													
		Pr 6.23	Nd 6.46	Pm 7.33	Sm 7.68	Eu 5.66	Gd 8.69	Tb 9.46	Dy 10.17	Ho 10.91	Er 11.70	Tm 12.49	Yb 9.32	Lu 14.07			
		Pa 39.65	U 49.08	Np	Pu	Am	Cm	Bk	Vf	Es	Fm	Md	No	Lr			



https://www.psi.ch/en/niag/comparison-to-x-ray

Why use neutrons?

2. The wet history of the red planet…

Hydrous minerals (water) on Mars – When? How? Life?

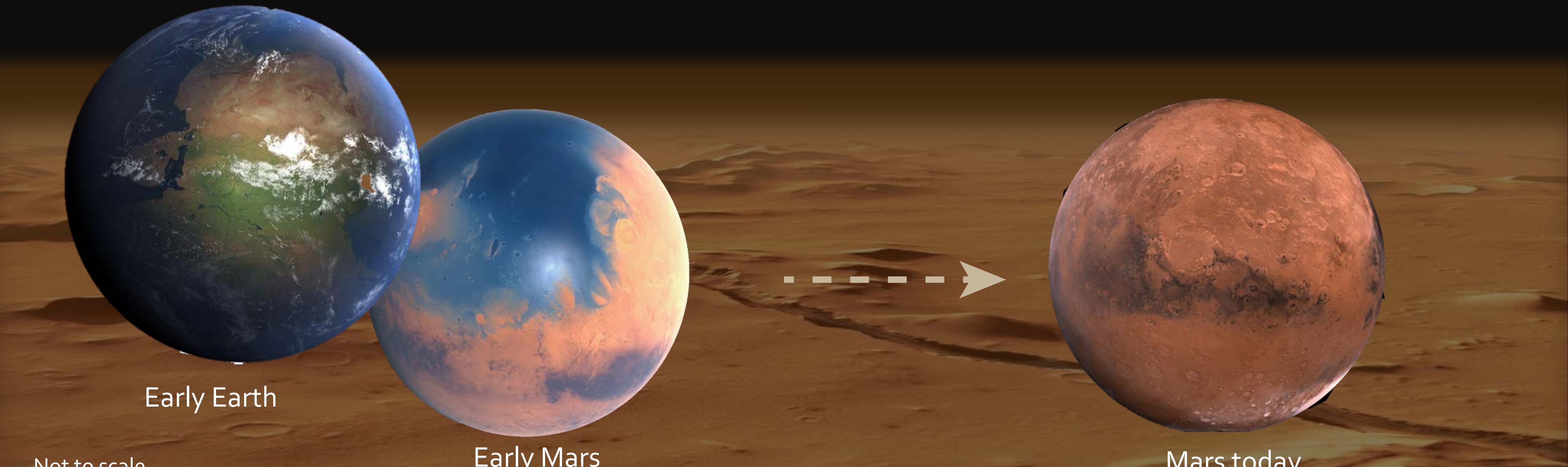


Image credit: M. Kornmesse; NASA

Why use neutrons?

- **Fate of the projectile:** Platinum group elements, Iridium!
- **Hydrous minerals:** Hydrogen…

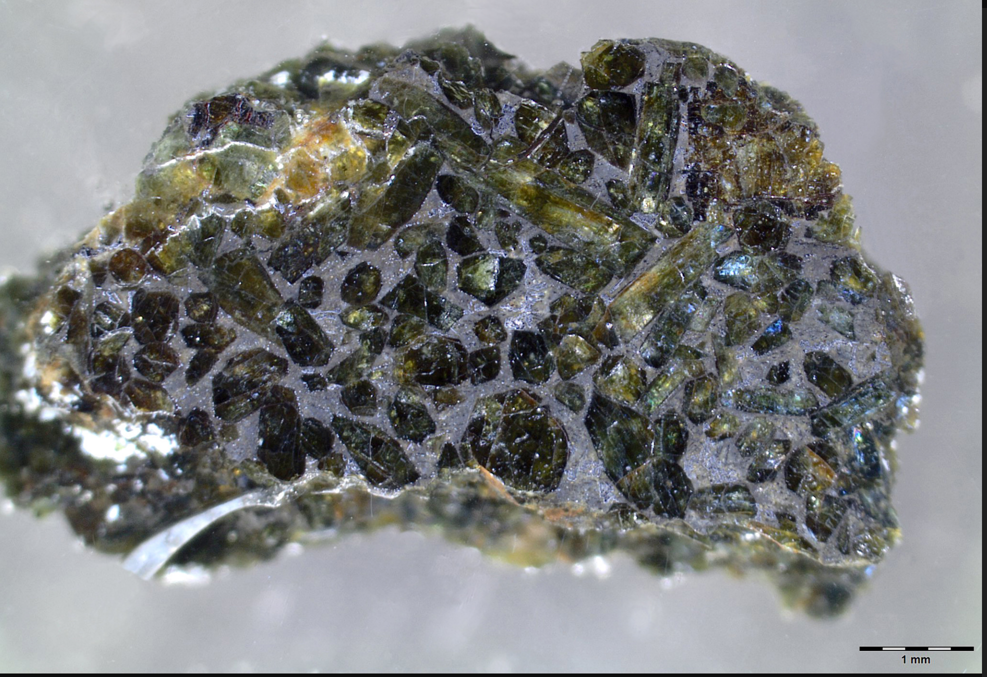
Attenuation coeffitients for thermal neutrons [cm^{-1}]

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0
H																	He
3.44																	0.02
Li	Be											B	C	N	O	F	Ne
3.30	0.79											101.60	0.56	0.43	0.17	0.20	0.10
Na	Mg											Al	Si	P	S	Cl	Ar
0.09	0.15											0.10	0.11	0.12	0.06	1.33	0.03
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
0.06	0.08	2.00	0.60	0.72	0.54	1.21	1.19	3.92	2.05	1.07	0.35	0.49	0.47	0.67	0.73	0.24	0.61
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
0.08	0.14	0.27	0.29	0.40	0.52	1.76	0.58	10.88	0.78	4.04	115.11	7.58	0.21	0.30	0.25	0.23	0.43
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
0.29	0.07	0.52	4.99	1.49	1.47	6.85	2.24	30.46	1.46	6.23	16.21	0.47	0.38	0.27			
Fr	Ra	Ac	Rf	Ha													
	0.34																
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu			
*Lanthanides	0.14	0.41	1.87	5.72	171.47	94.58	1479.04	0.93	32.42	2.25	5.48	3.53	1.40	2.75			
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr			
**Actinides	0.59	8.46	0.82	9.80	50.20	2.86											

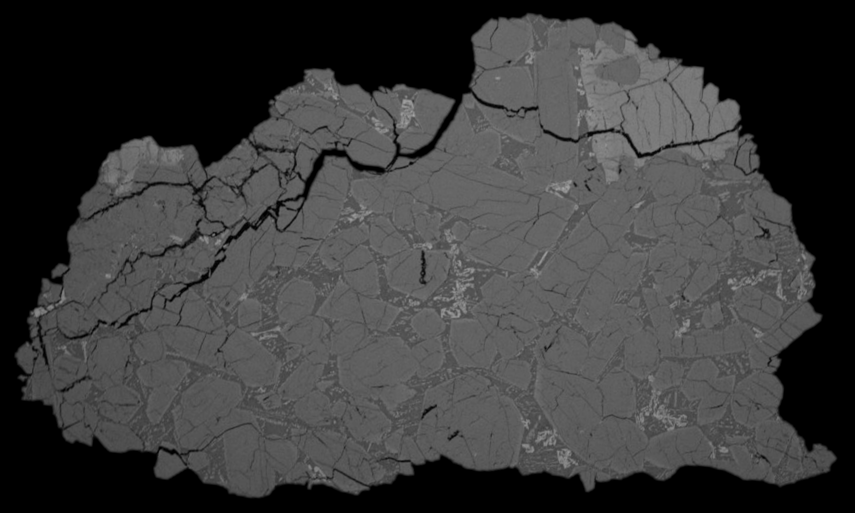
Attenuation coeffitients for X-ray [cm^{-1}] (150kV)

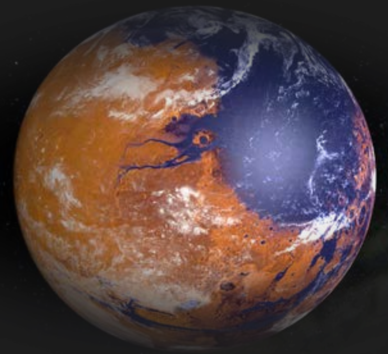
1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0
H																	He
0.02																	0.02
Li	Be											B	C	N	O	F	Ne
0.06	0.22											0.28	0.27	0.11	0.16	0.14	0.17
Na	Mg											Al	Si	P	S	Cl	Ar
0.13	0.24											0.38	0.33	0.25	0.30	0.23	0.20
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
0.14	0.26	0.48	0.73	1.04	1.29	1.32	1.57	1.78	1.96	1.97	1.64	1.42	1.33	1.50	1.23	0.90	0.73
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
0.47	0.86	1.61	2.47	3.43	4.29	5.06	5.71	6.08	6.13	5.67	4.84	4.31	3.98	4.28	4.06	3.45	2.53
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
1.42	2.73	5.04	19.70	25.47	30.49	34.47	37.92	39.01	38.61	35.94	25.88	23.23	22.81	20.28	20.22		9.77
Fr	Ra	Ac	Rf	Ha													
	11.80	24.47															
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu			
*Lanthanides	5.79	6.23	6.46	7.33	7.68	5.66	8.69	9.46	10.17	10.91	11.70	12.49	9.32	14.07			
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Vf	Es	Fm	Md	No	Lr			
**Actinides	28.95	39.65	49.08														

https://www.psi.ch/en/niag/comparison-to-x-ray



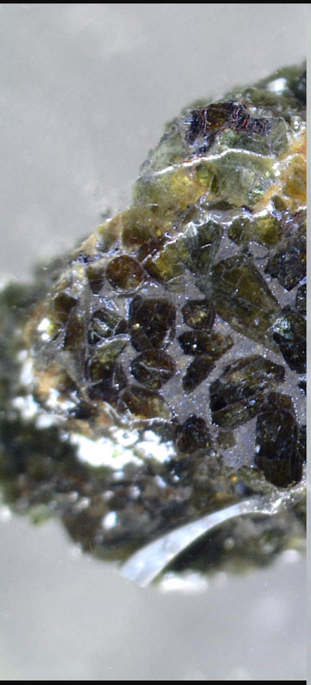
Backscatter electron image



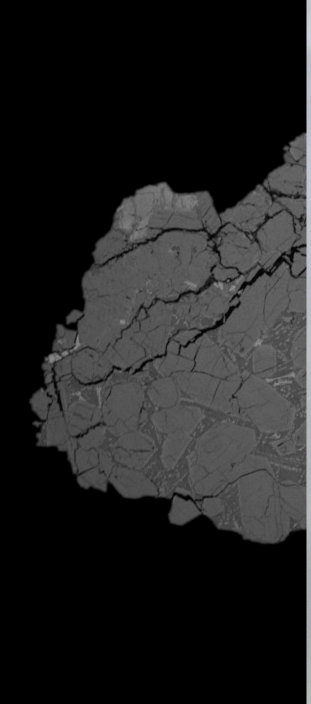


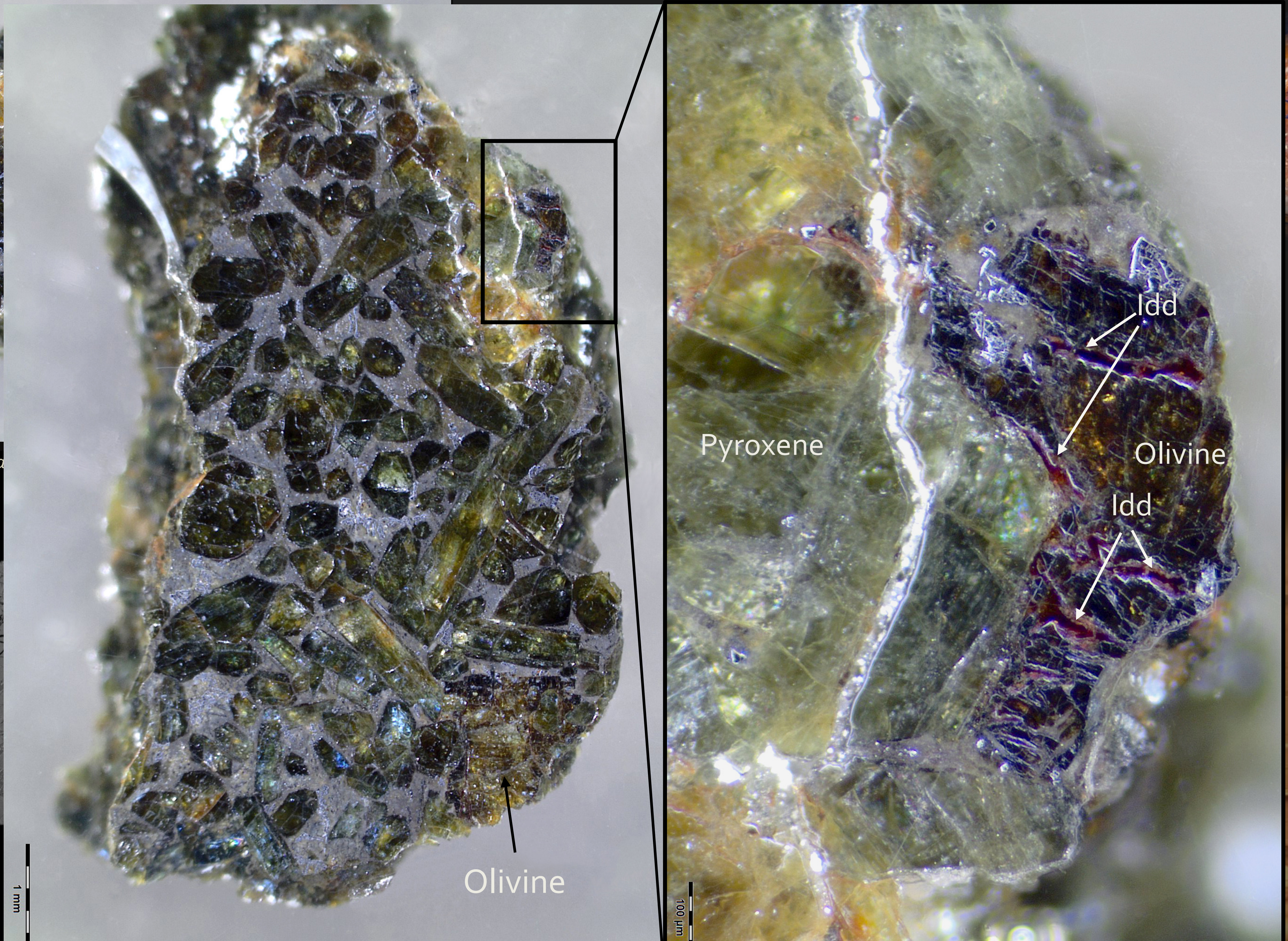
MIL03346

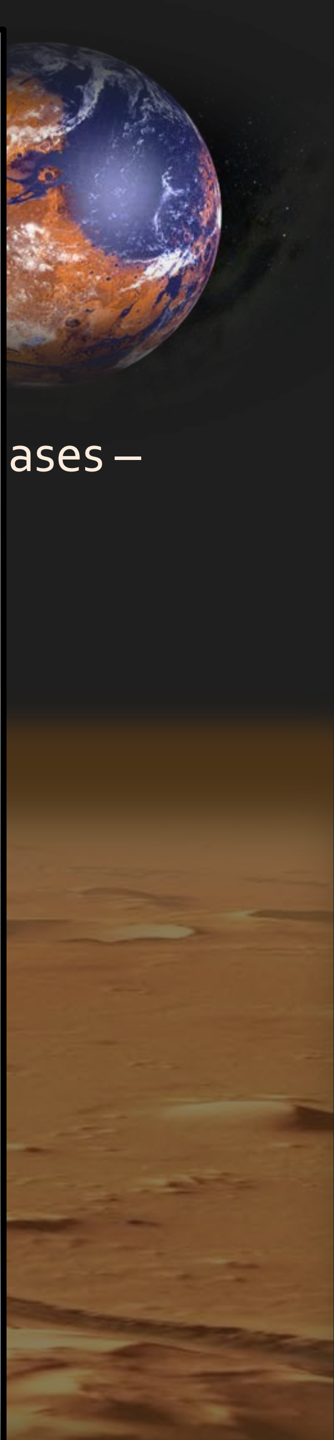
- Martian meteorite, known to contain aqueous phases – clay veins in the mineral olivine.
- Dry period on Mars
- More water during this period then previously thought? Hydrothermal system due to meteorite impact?
- First time visualized in 3D



Backscatter electron ima







ases –

Mars2020

- Future sample return
- Extremely valuable samples… return mission cost estimated $2.5–3 billion (2021)
- Non-destructive analysis – need for sophisticated analysis methods, facilities etc

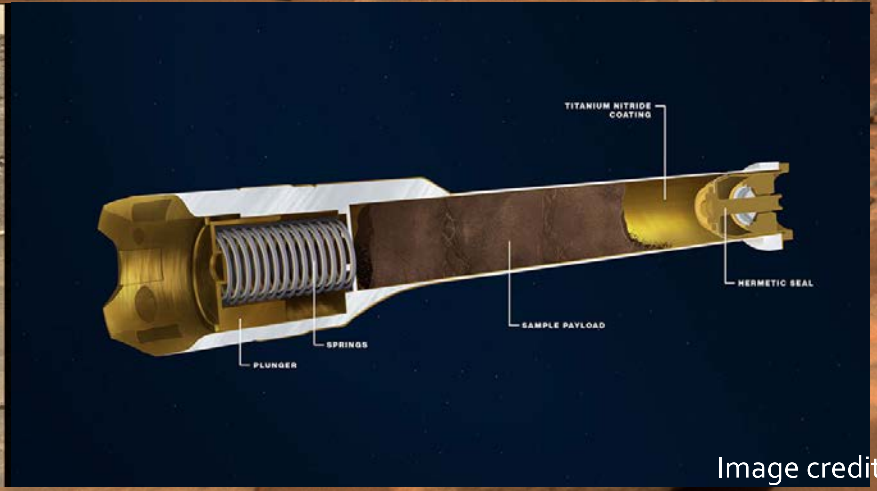


Image credit: NASA