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Sputtering through coronal mass ejections and the fate of nanodust near the Sun

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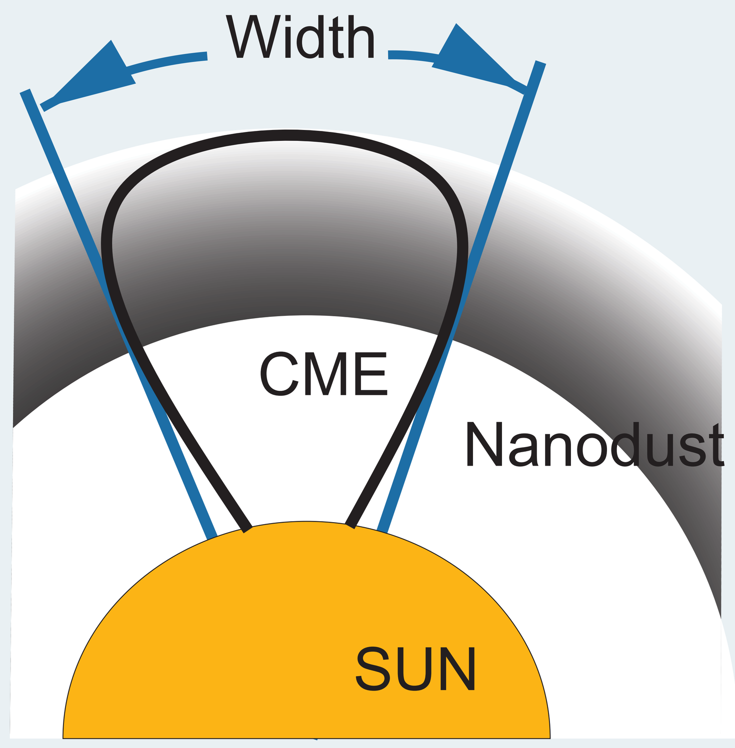
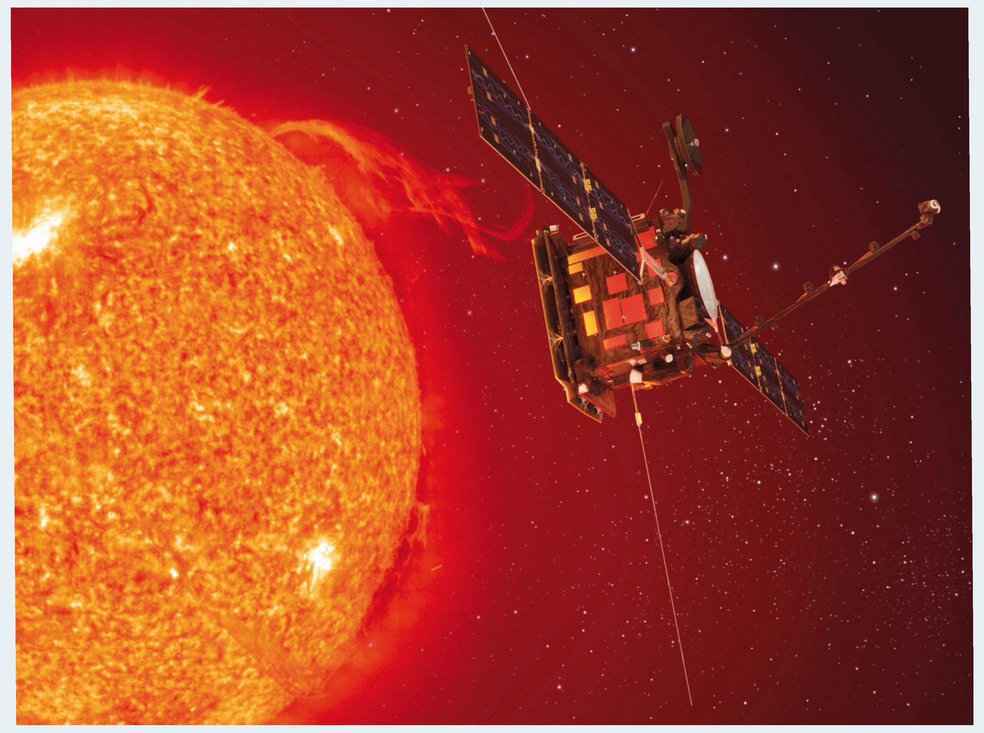
Motivation

The dust environment in the inner Solar system has not been probed so far, but ESA's Solar Orbiter (2020) and NASA's Parker Solar Probe (2018) are about cross the inner solar system.
From [1] we expect a layer of trapped Nanodust around the Sun. [2] investigated the interaction of grains with the Solar wind. But what is the dust's fate when they are struck by a Coronal Mass Ejection (CME). Are they destroyed by sputtering from impacting ions or rather sublimate near the sun. This work investigates whether CME's deplete the Nanodust population locally.



Parker Solar Probe (C) NASA



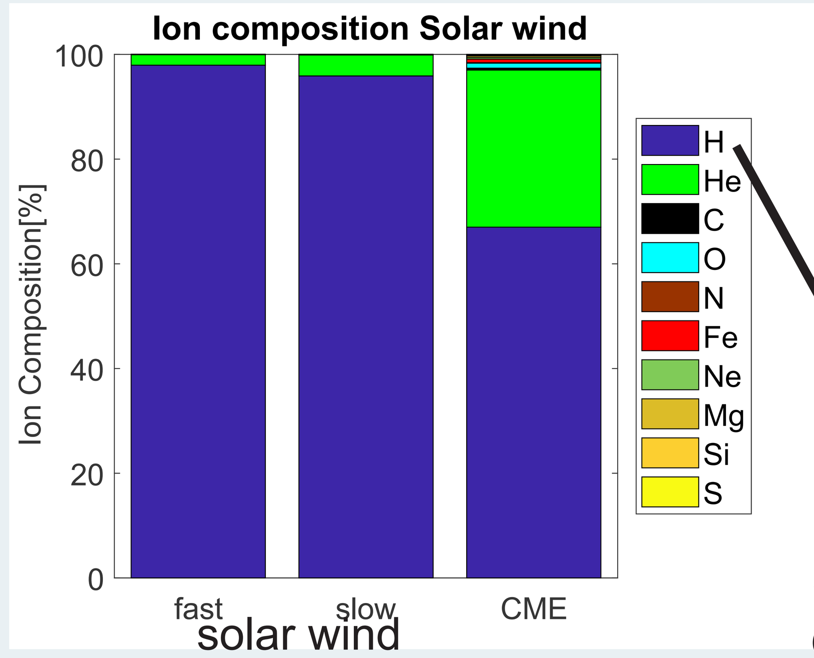
Solar Orbiter (C) ESA

CME properties and sputtering

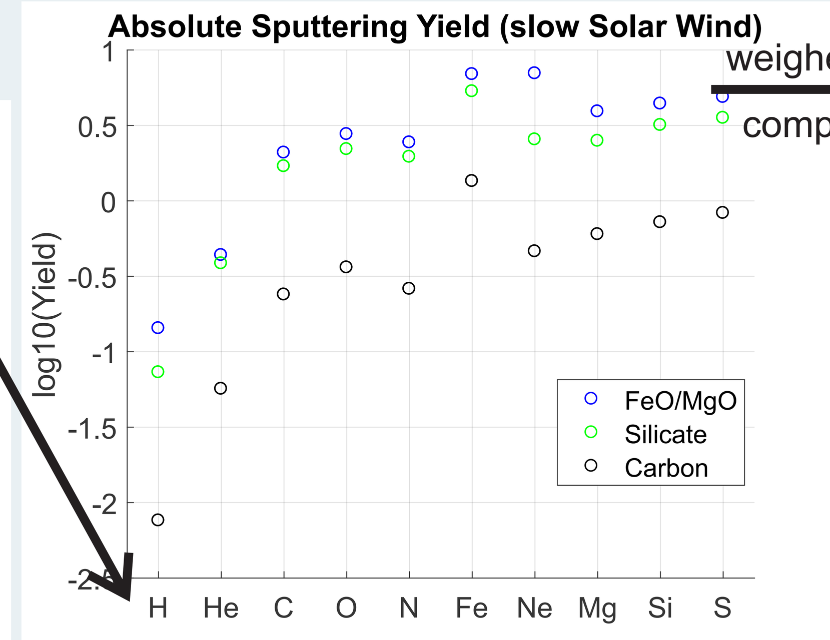
CME contain more heavy ions than solar wind (SW)

during high solar activity ~CMEs/day

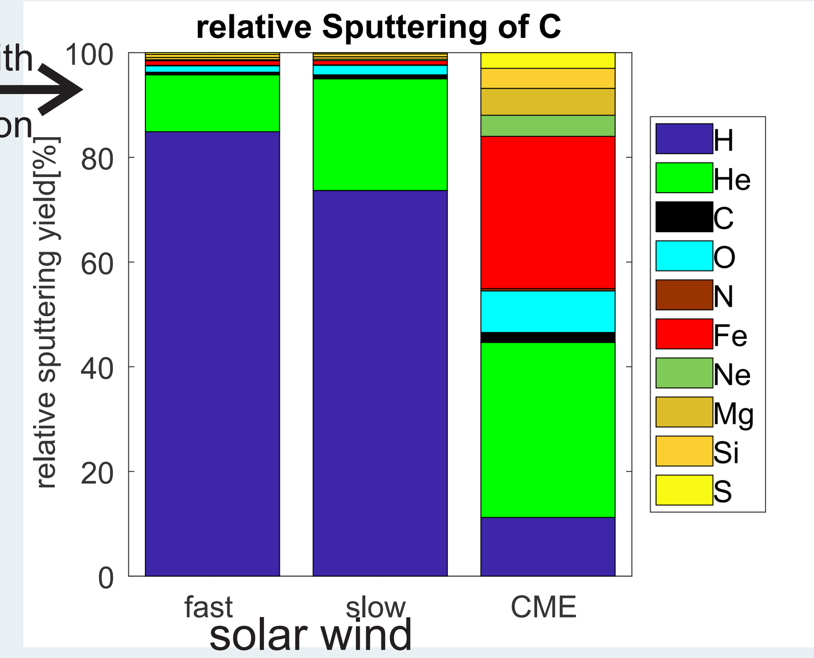
~14% of the space is affected by one CME (from solid angle)



~3 cm^{-3} ~8 cm^{-3} ~70 cm^{-3}
plasma density at 1AU



weighed with composition



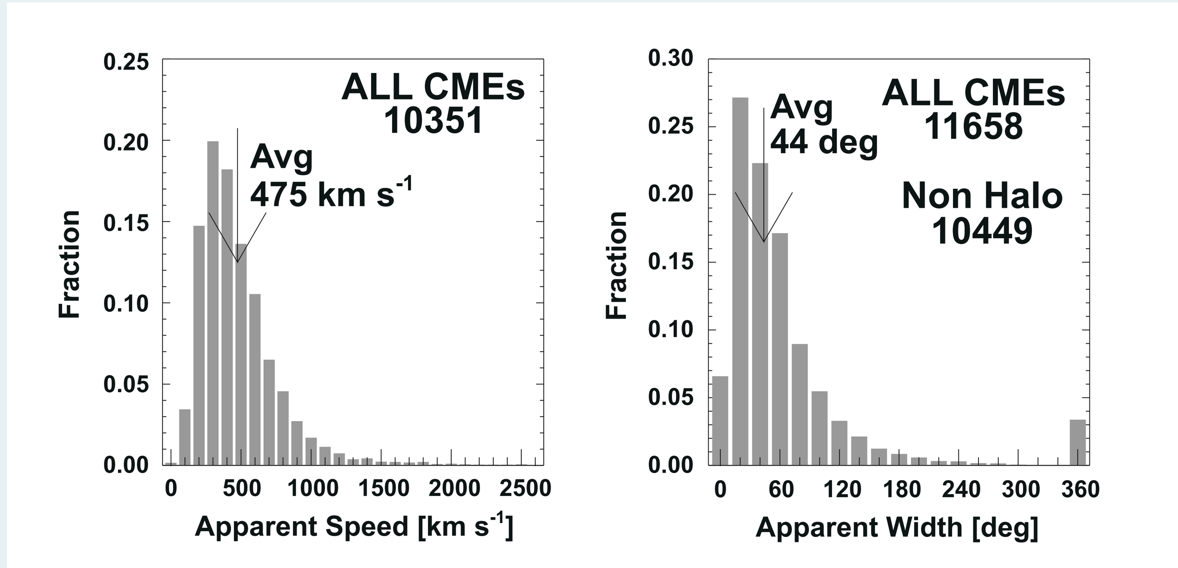
using the TRIM package [4] to derive Yields (sputtered atoms/ incoming SW ion) for different compositions (e.g.FeO/MgO)

$$t_{sput}(d) = \frac{4r_0\rho N_A}{f_{SW}(d)Y_{tot}M}$$

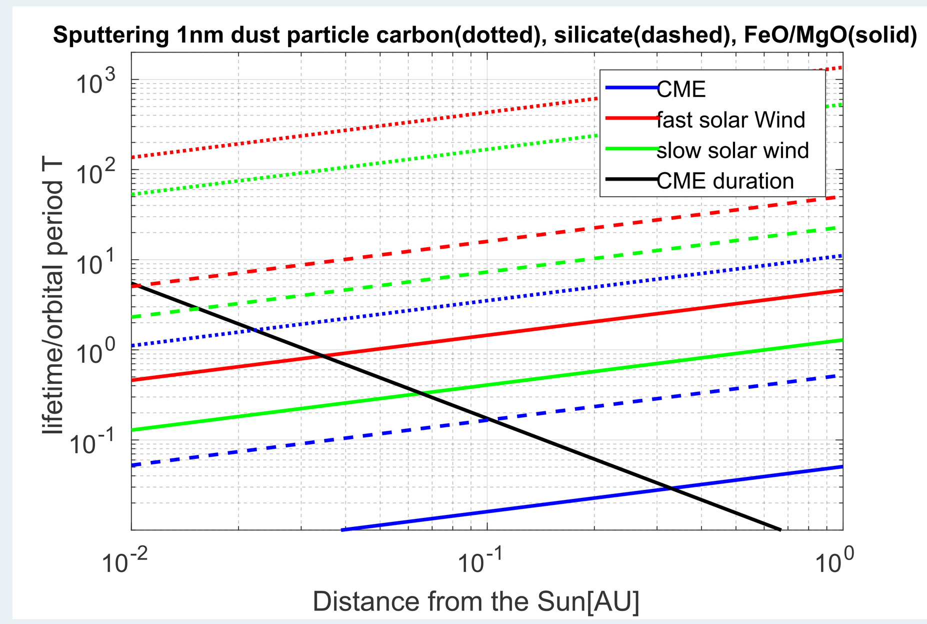
f_{SW} - Solar wind flux
Y_{tot} - total sputtering Yield
d - distance from the Sun

t_{sput} has a strong dependence on dust composition, as well as solar wind properties

Solar wind speed varies
fast SW ~800km/s
slow SW ~300km/s
CME ~500km/s

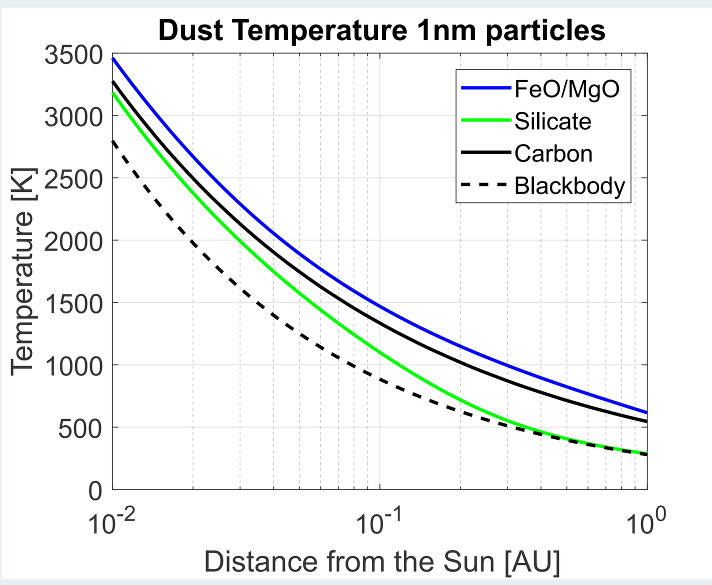


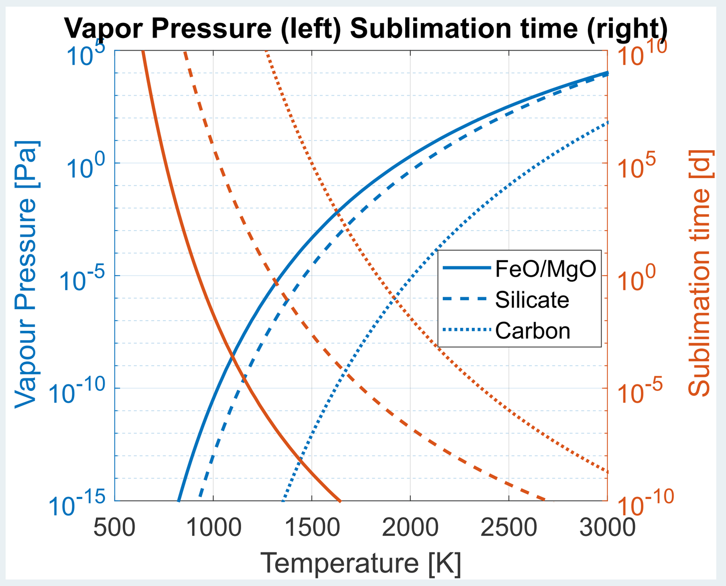
taken from [3]



Sublimation

dust temperature from equilibrium of solar absorption and infrared emission using standard blackbody and Mie calculations for FeO/MgO, Silicate, Carbon grains (see Poster of M. Myrvang)





derive sublimation lifetime from Langmuir equation

$$t_{sub}(d) = \frac{r_0\rho}{p_v(d)}\sqrt{\frac{2\pi RT(d)}{M}}$$

p_v - Vapour Pressure
ρ - particles mass density
d - distance from the Sun

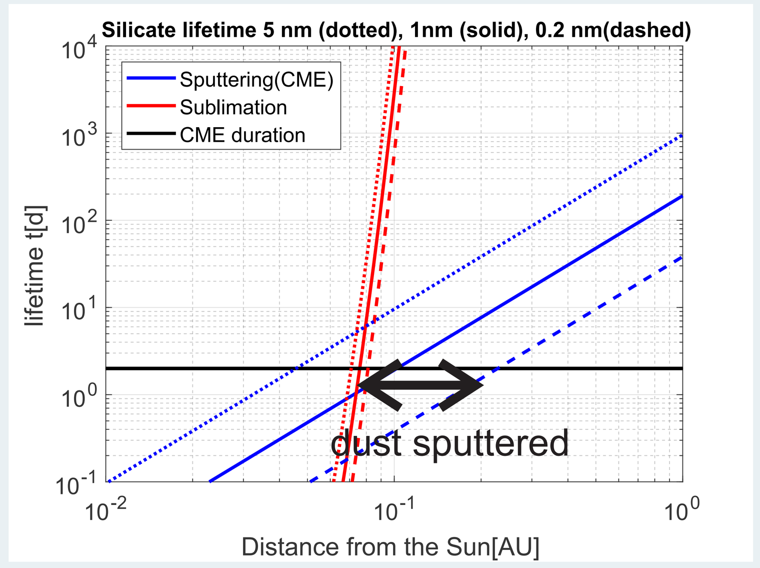
carbon vapour pressure from [6]

usage MAGMA code [5] for FeO/MgO and Silicate grain compositions

Comparison of Lifetimes

Sublimation lifetimes depend strongly on temperature/ vapour pressure

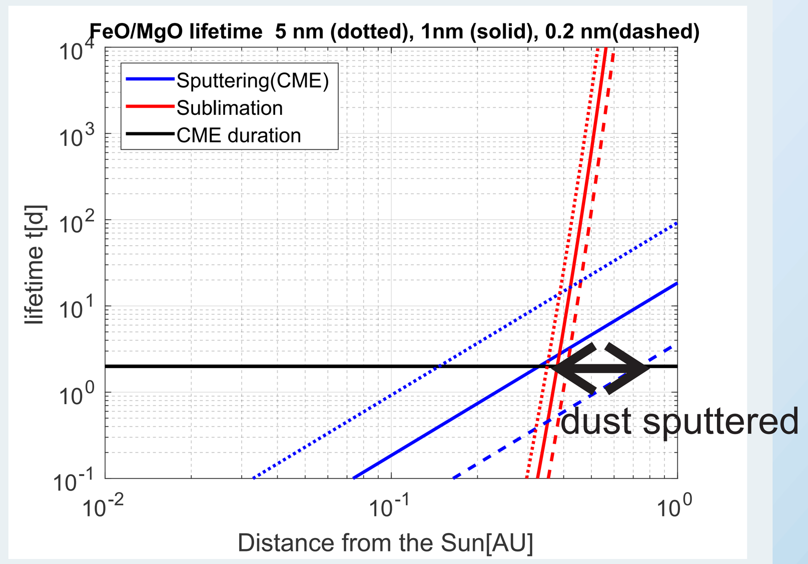
Sputtering lifetimes depend also on the initial grain sizes

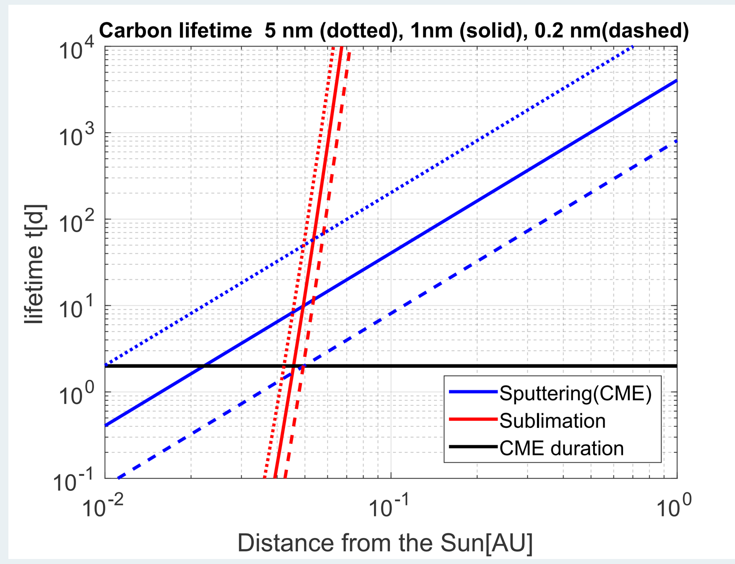


one CME destroys nanodust (silicate, FeO/MgO) near the Sun

Sublimation more important for dust > ~3nm

long lifetimes for carbon dust near the sun, however no destruction due to CME





References

[1] A. Czechowski and I. Mann, Formation and Acceleration of Nano Dust in the Inner Heliosphere, *The Astrophysical Journal* (2010)
[2] T. Mukai and G. Schwehm, Interaction of Grains with the Solar Energetic Particles, *Astron. Astrophys.*, (1981)
[3] N. Gopalswamy et al., The SOHO/LASCO CME catalog , *Earth Moon Planets (2009)*
[4] J Ziegler et al., TRIM/SRIM package (www.srim.org)
[5] B. Fegley and A.G.W. Cameron, A vaporization model for iron/silicate fractionation in the Mercury protoplanet, *Earth and Planetary Science Letters* (1987)
[6] David R. Lide (ed), CRC Handbook of Chemistry and Physics, 84th Edition. CRC Press. Boca Raton, Florida, 2003; Section 6 Fluid Properties; Vapor Pressure

Acknowledgement
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