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Sorting a multicomponent dust in discs: new clues on the aggregation of chondritic material

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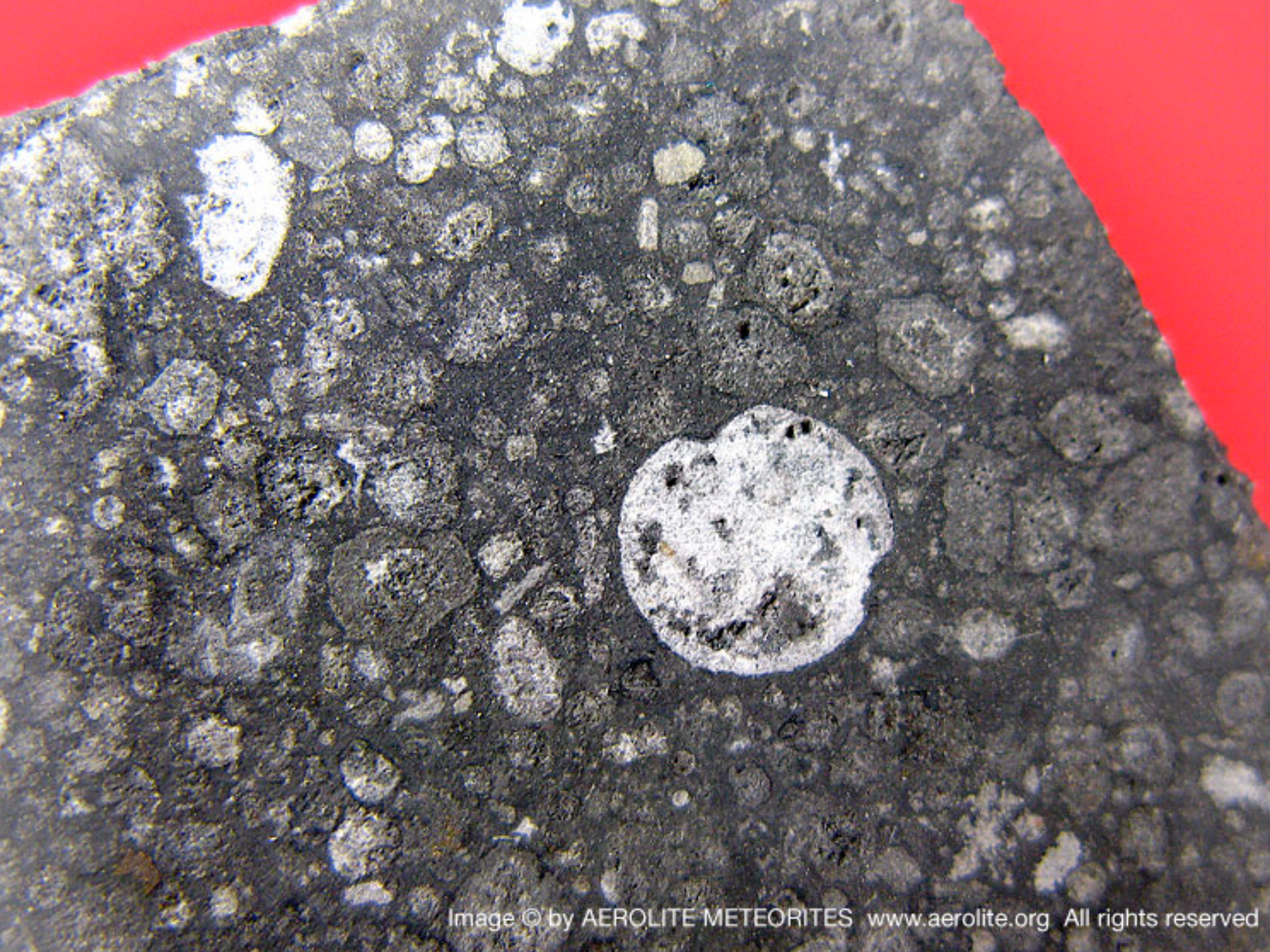
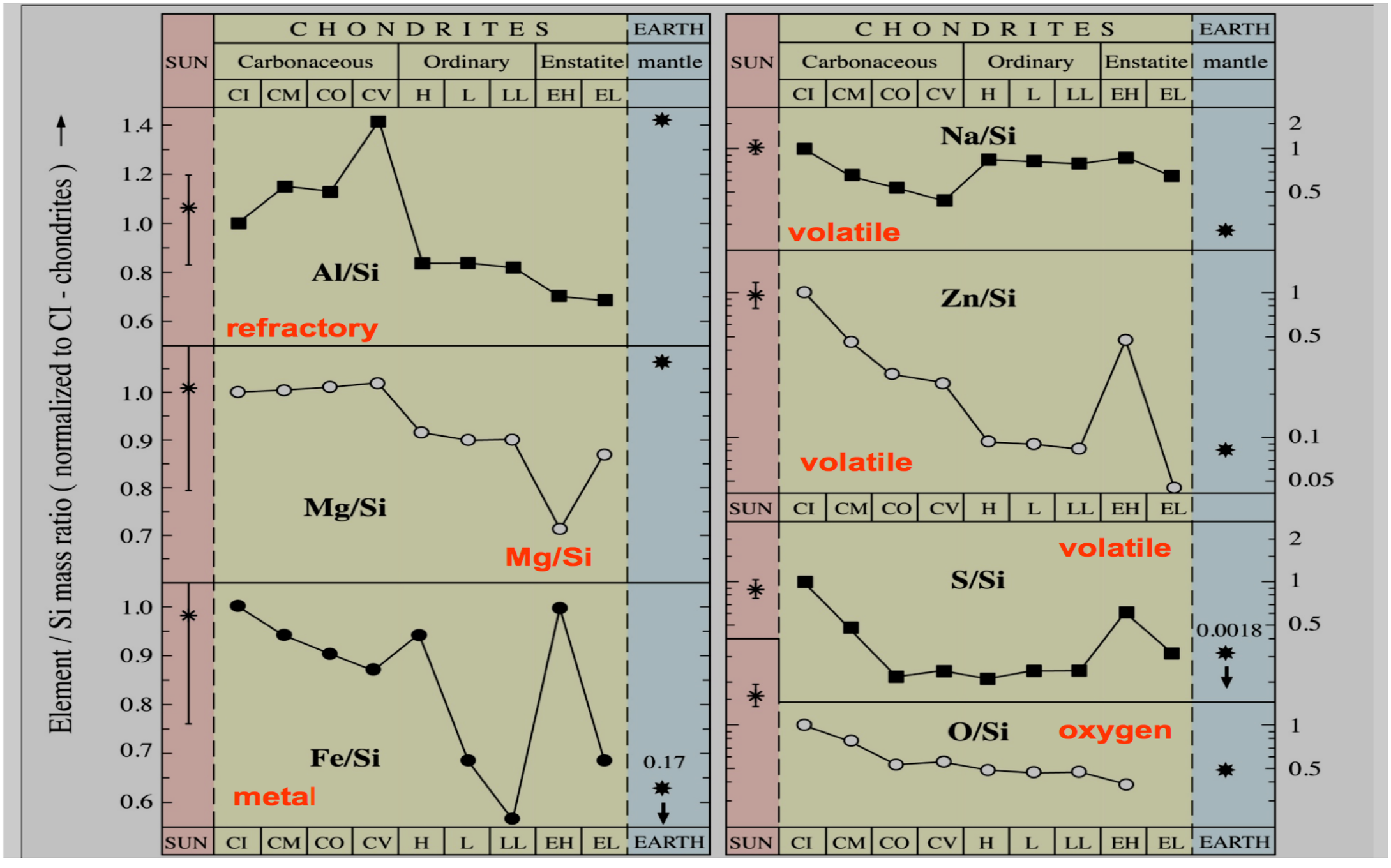
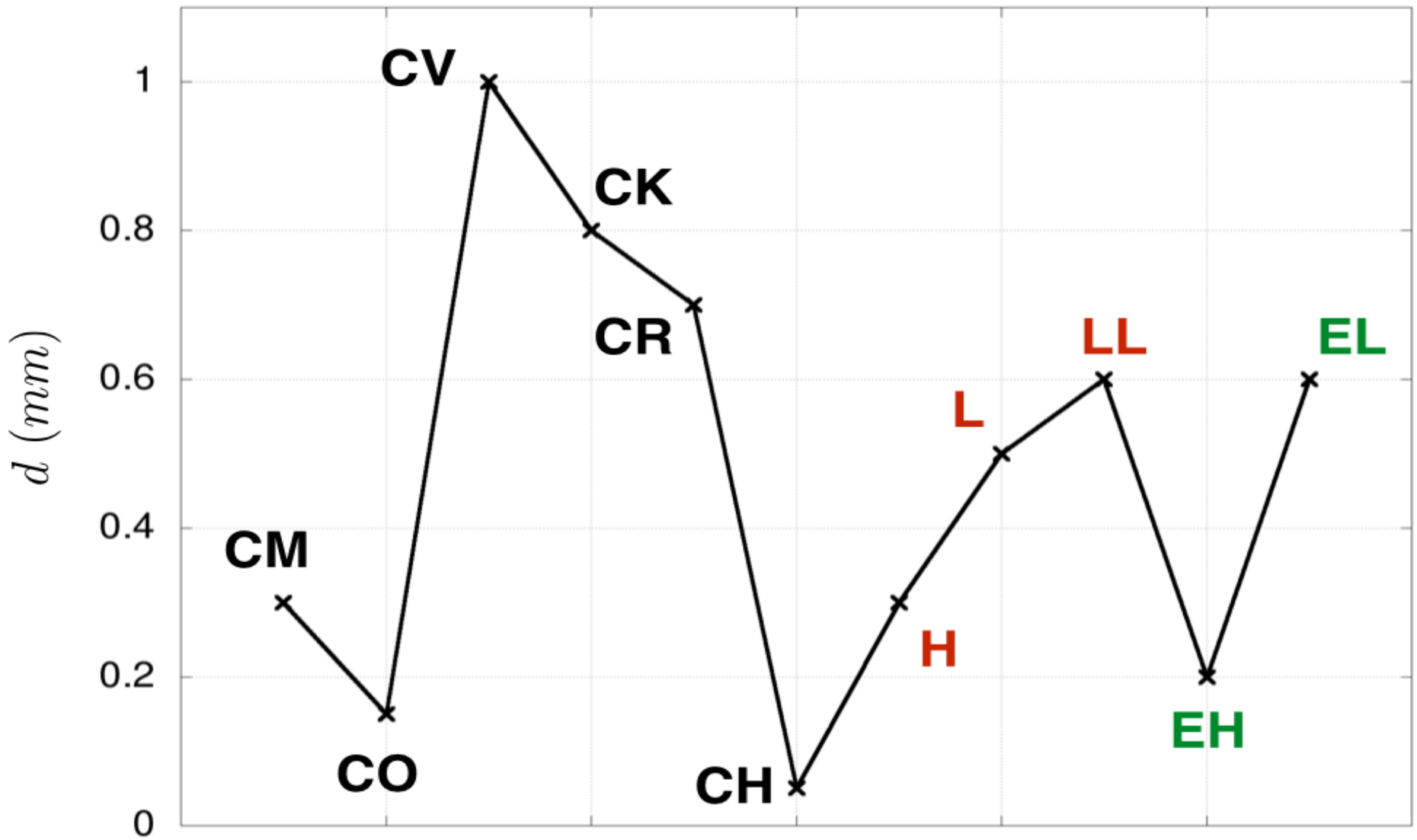


chondrites exhibit different degrees of fractionation



Larimer & Anders (1970) Palme & Jones (2003)

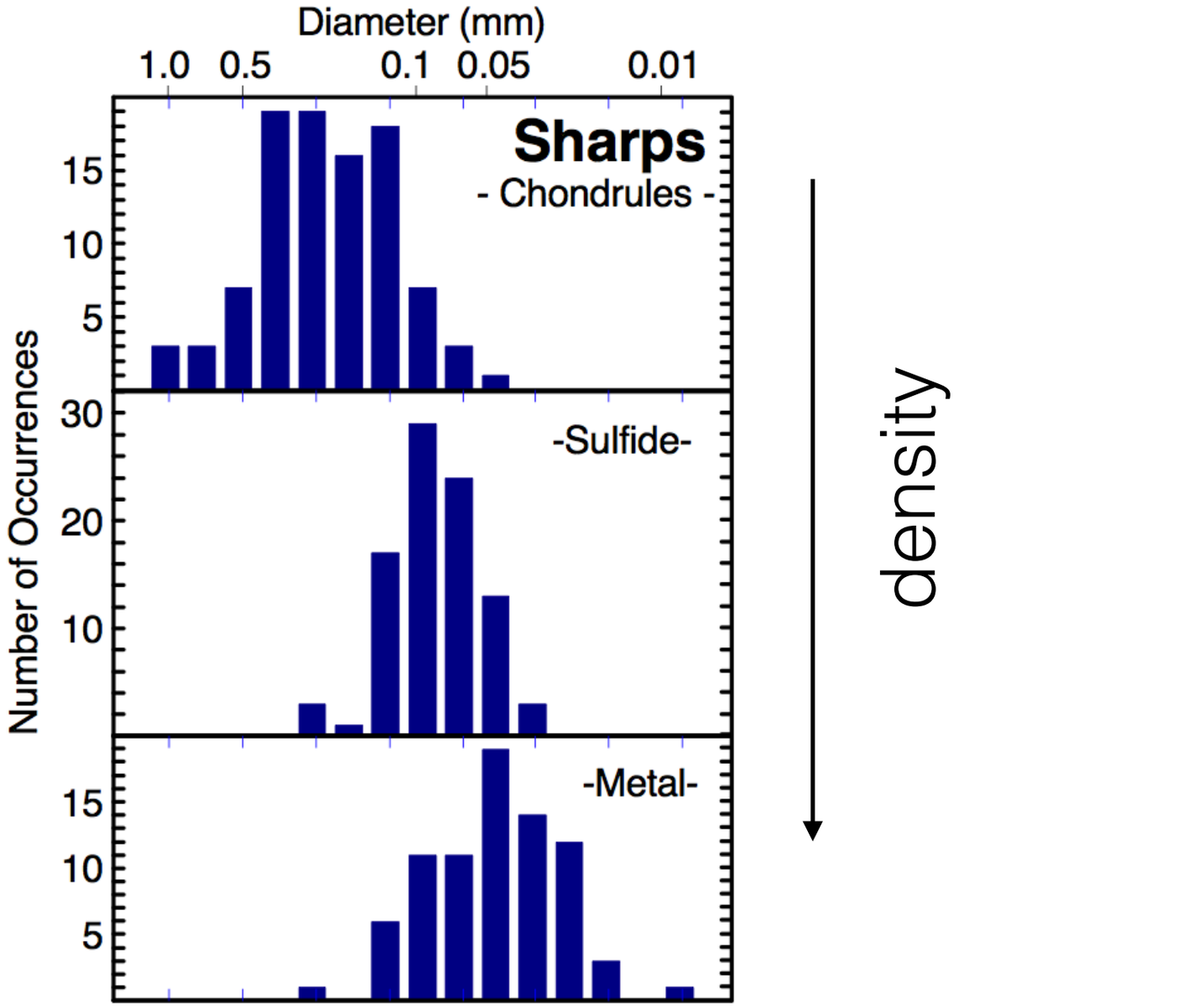
chondrules size varies in chondrites groups



adapted from Palme & Jones (2003) Scott & Krot (2005)

Rubin et al. (2010) Weisberg et al. (2006) Friedrich et al. (2014)

chondrules and metallic grains are size-density $(s\rho)$ sorted



Benoit et al. (1998)

Kuebler et al. (1999)

where?

- collapsing nebula
- post shock in parent body collision
- local turbulence
- mid scale turbulence (vortex)
- large scale sorting (disc)
- external sources (jet flow)

large literature available

Clayton (1980) Cuzzi (2001) Akridge & Sears (1999) Larimer & Wasson (1988a,b) Liffman (2005)

Cuzzi & Weidenschilling (2006) Dullemond & Dominik (2004) Jacquet et al (2012)

Ciesla (2009) Charnoz et al. (2015) Testi et al (2014) Goldberg et al (2014)

DYNAMICS: SPH SMOOTHED PARTICLES HYDRODYNAMICS

simultaneous analysis of the effects of size, growth, density in a 3D evolving disk

SPH 3D two phases (gas+dust)

Fouchet et al. (2005) Fouchet et al. (2010)

Gas Pressure, Gas Drag, Dust Back Reaction, Stellar Gravity

Grain growth

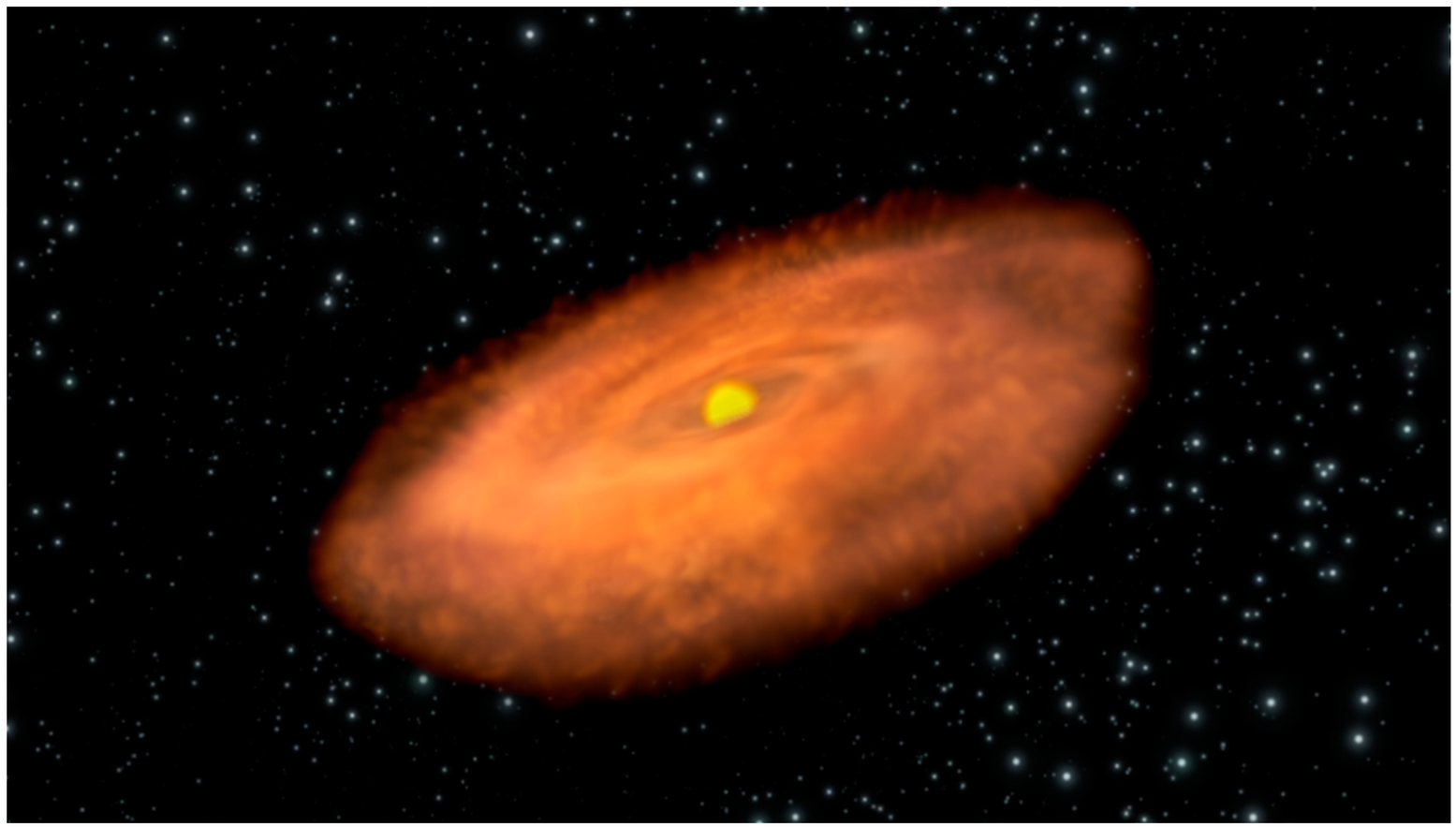
$$\frac{ds}{dt} = f(\rho_d, \rho_g, c_s, s)$$ Stepinski & Valageas (1997)

Laibe et al. (2008)

Multicomponent dust

Pignatale et al. (under review)

3D SPH SIMULATION: DISK MODEL



http://sci.esa.int/science-e-media/img/7e/Herschel_protoplanetary-disc.jpg

SPH simulation

400000 particles

$s_0 = 10\ \mu\mathrm{m}$

$$M_\star = 1 M_\odot$$

$$M_{disk} = 0.02 M_\star$$

$$20 \leq R(\mathrm{AU}) \leq 400$$

$$M_{gas} = 100 M_{dust}$$

$$H/R_0 = 0.05$$

$$R_0 = 100\ AU$$

$$H = c_s/\Omega_K$$

$$c_s \propto R^{-3/8}$$

$$T \propto R^{-3/4}$$

$$\Sigma \propto R^{-3/2}$$

$$\alpha = 0.01$$

3D SPH SIMULATION: MULTICOMPONENT DUST

Group	dust species	wt%	density gcm^{-3}
Fe	metallic iron	1	7.87
	troilite	6	4.83
Si	olivine & pyroxene	25	3.46
org	refractory organics	25	1.5
	volatile organics	4	1
H_2O	ice	39	0.92
		ratios	
H_2O/Si		1.56	
Fe/Si		0.28	

Pollack et al. (1994)

homogeneously distributed in the disc

no mixed growth no fragmentation compact grains

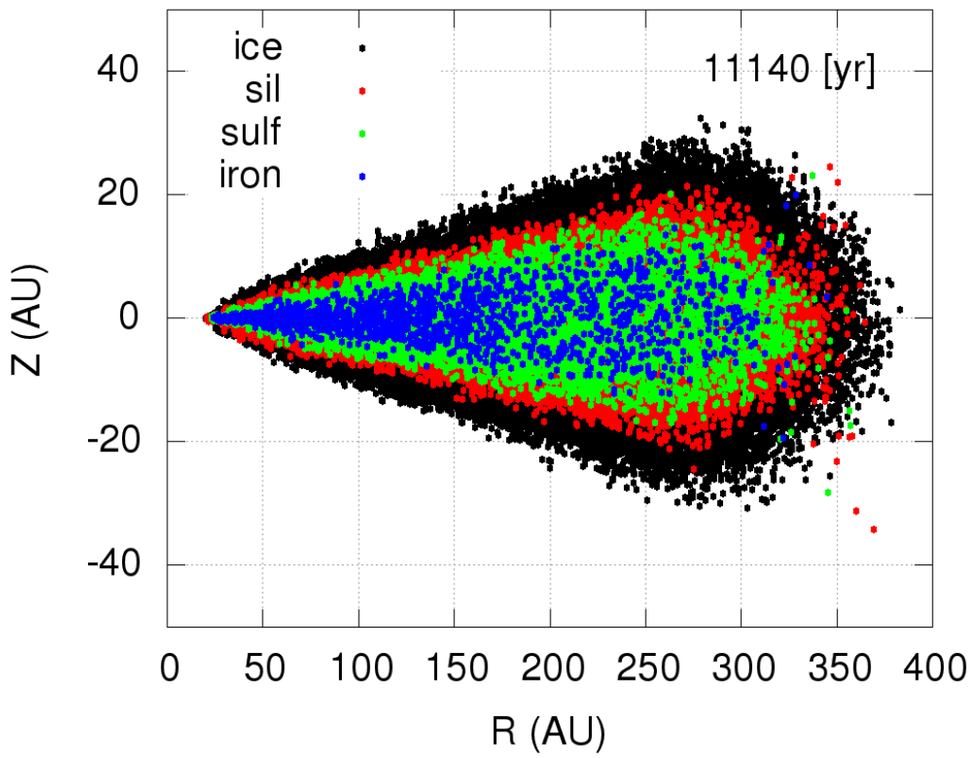
3D SPH SIMULATION: DUST EVOLUTION

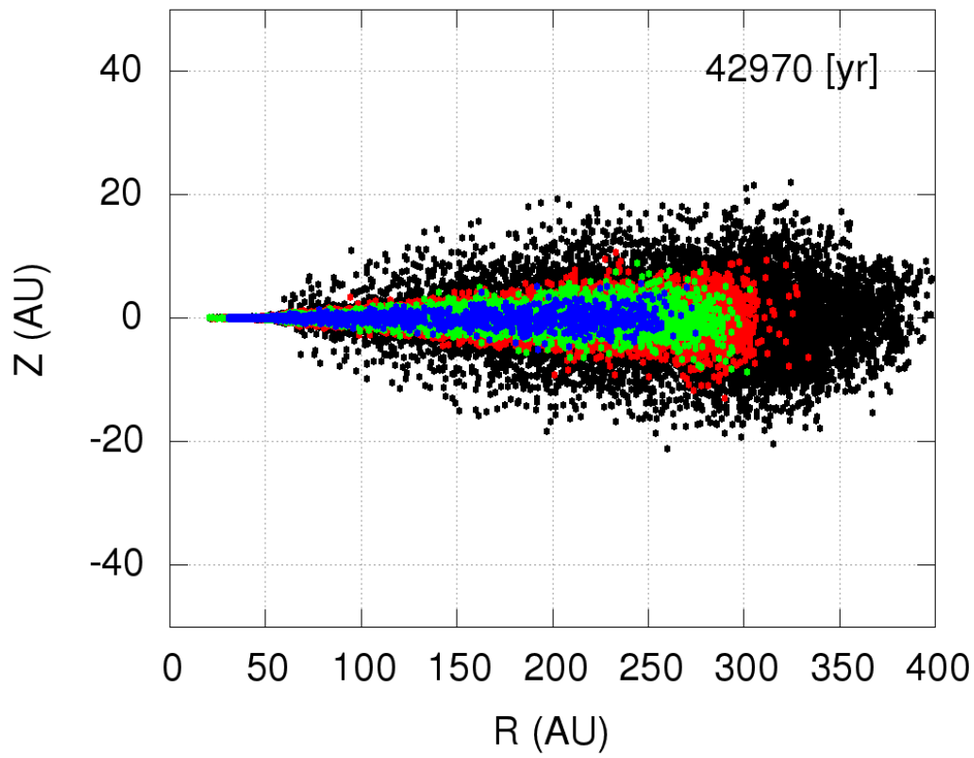
ice

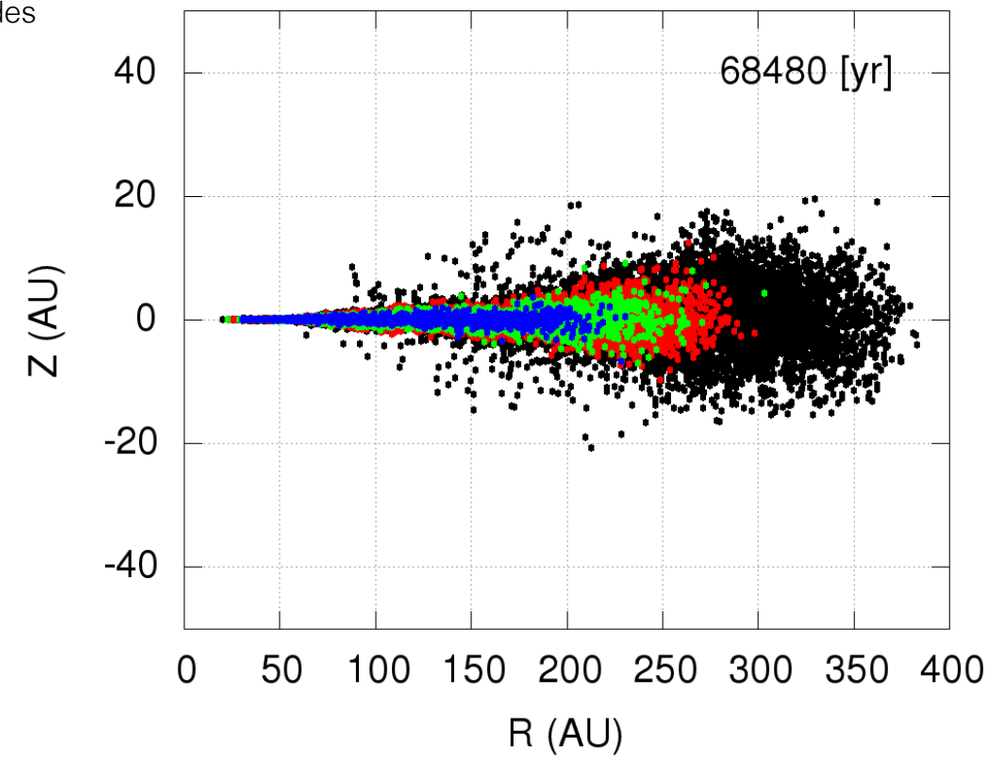
silicates

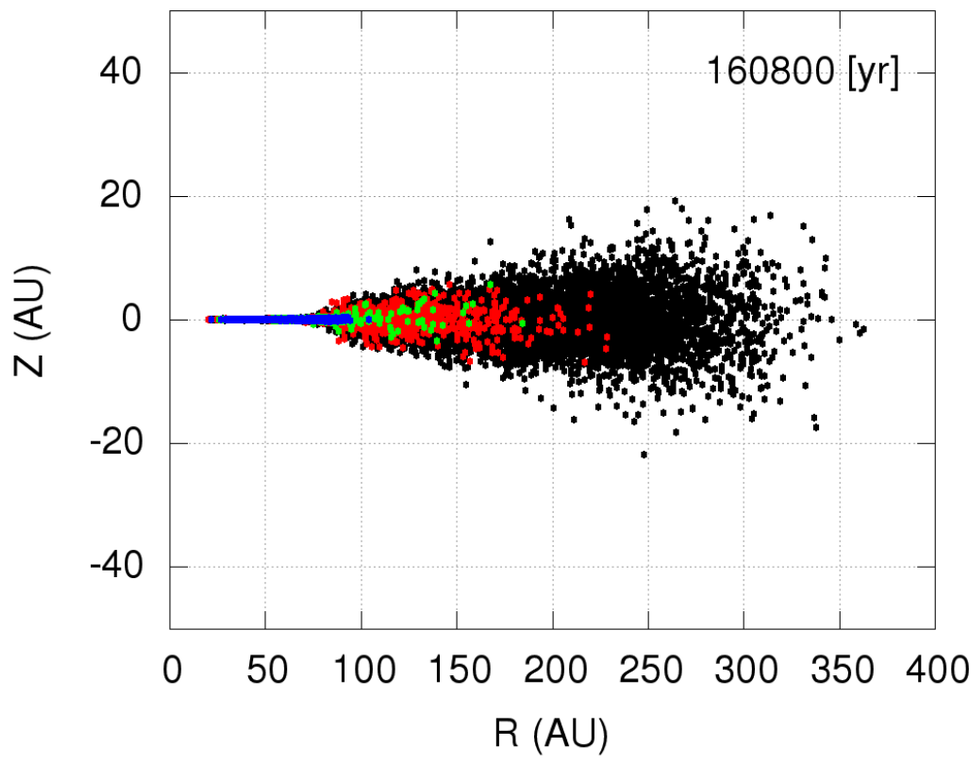
sulphides

iron

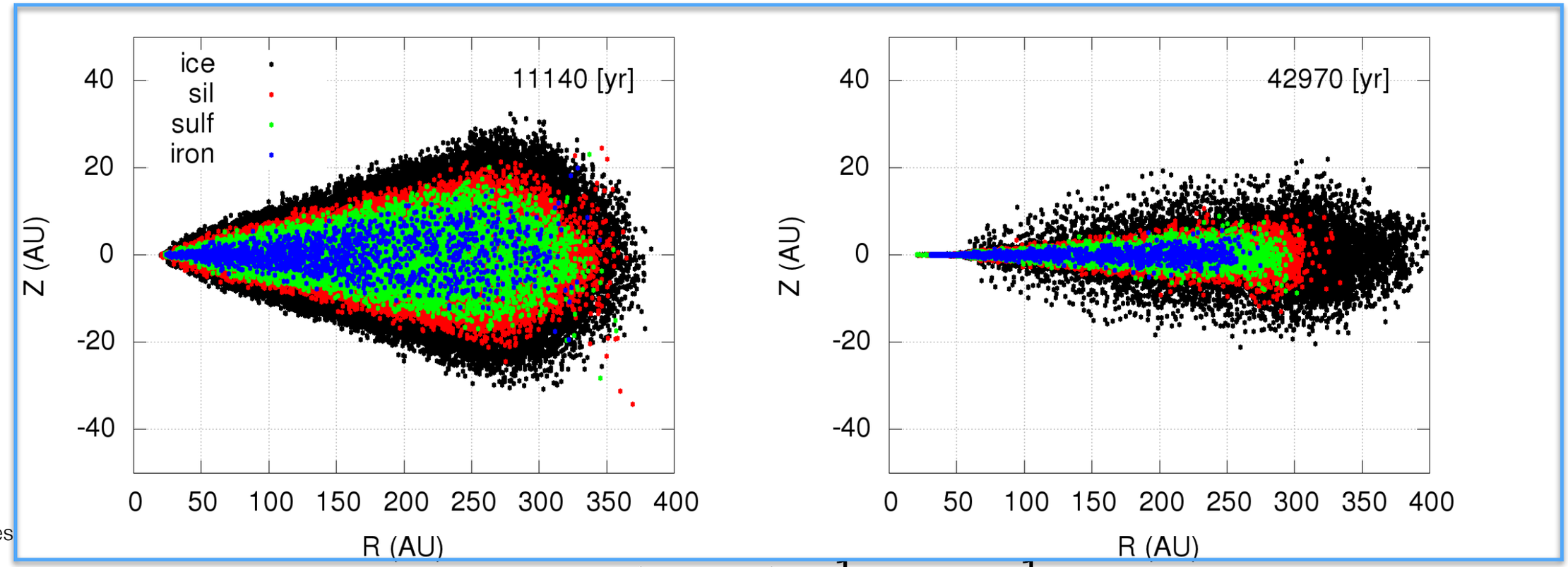








3D SPH SIMULATION: VERTICAL SETTLING



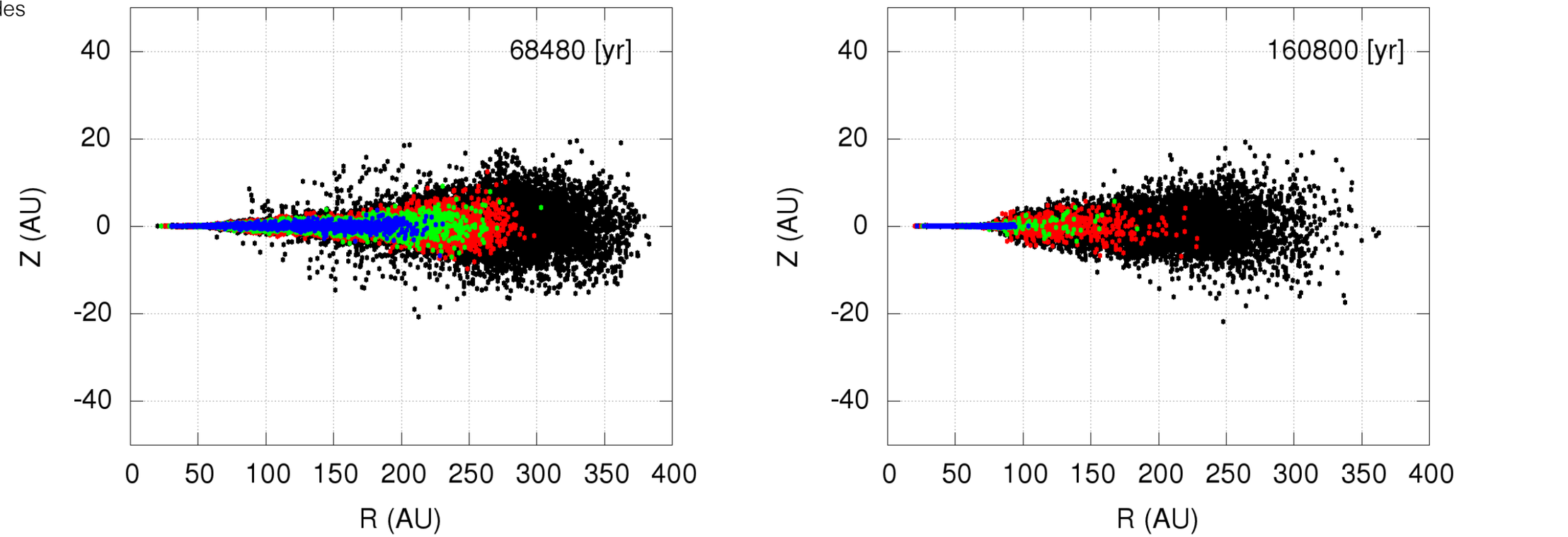
ice

silicates

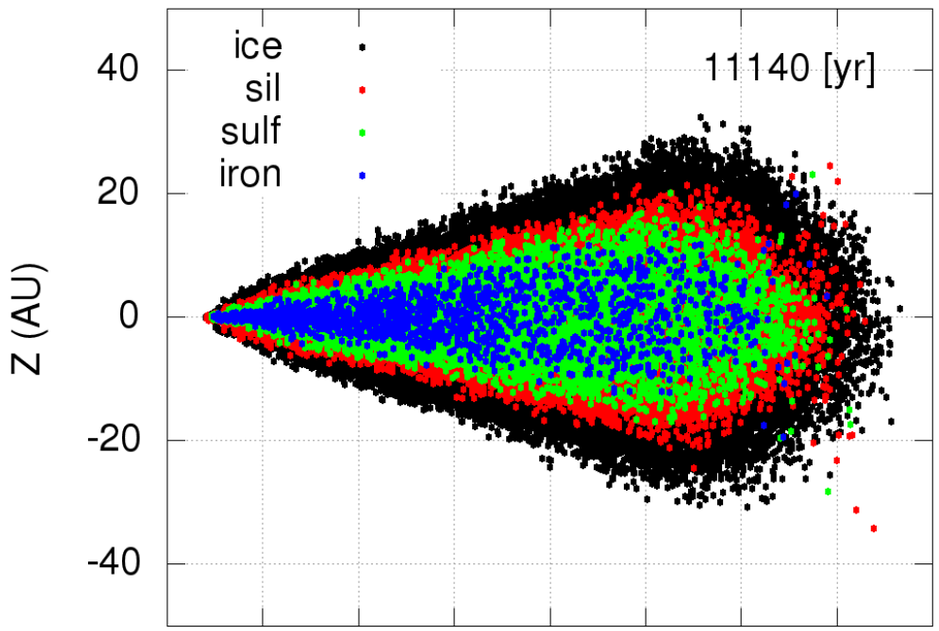
sulphides

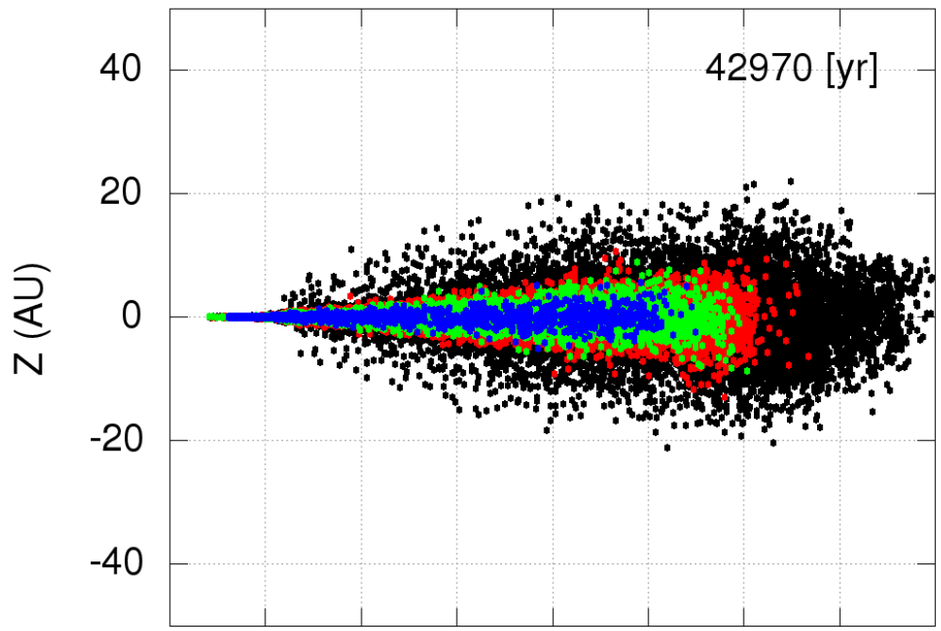
iron

$$t_{sett} = (\rho_d s_d)^{-1} = \zeta^{-1}$$



3D SPH SIMULATION: RADIAL DRIFT





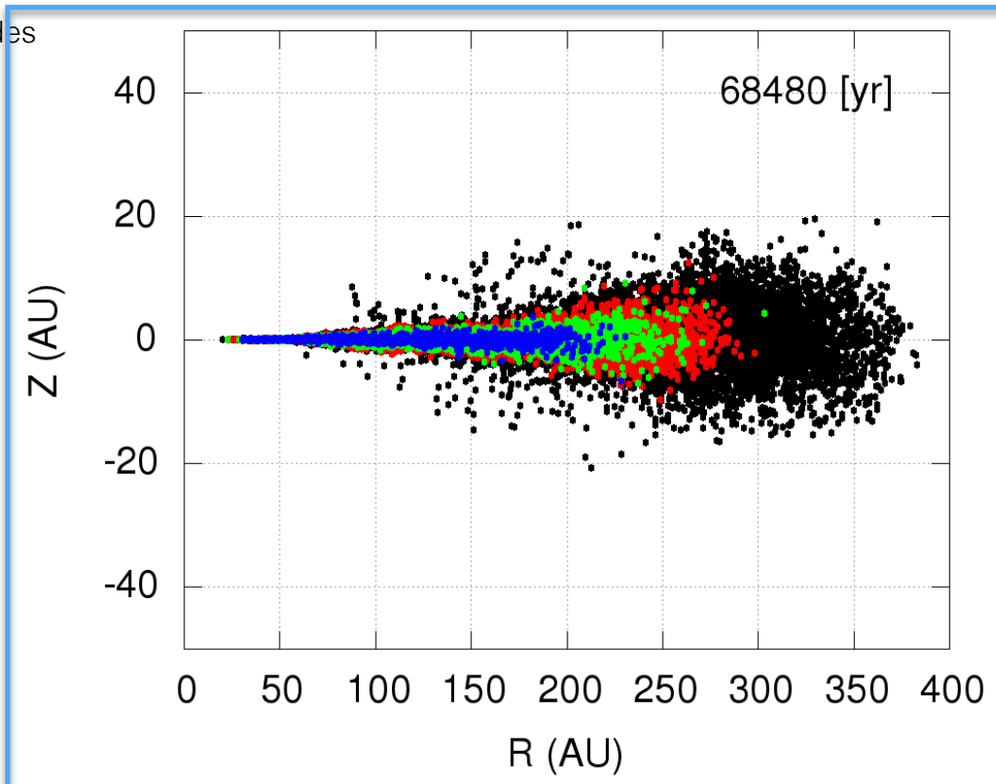
ice

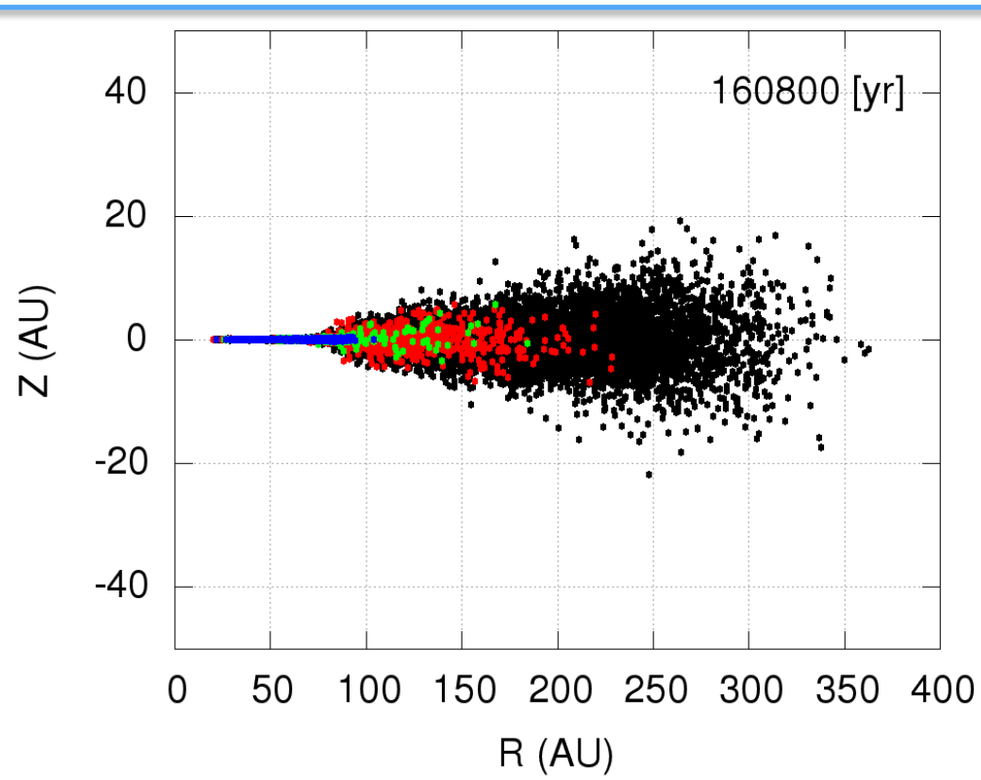
silicates

sulphides

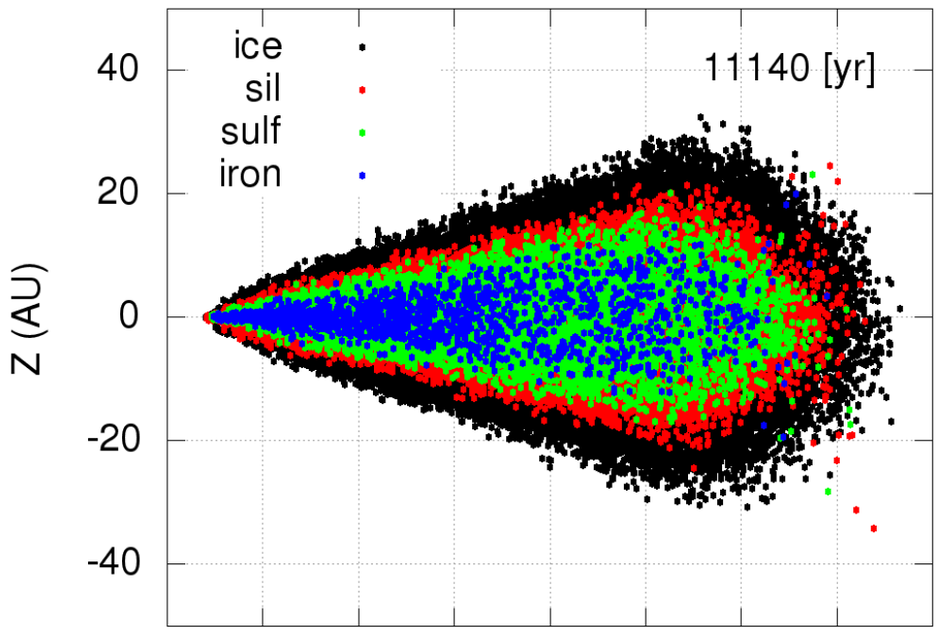
iron

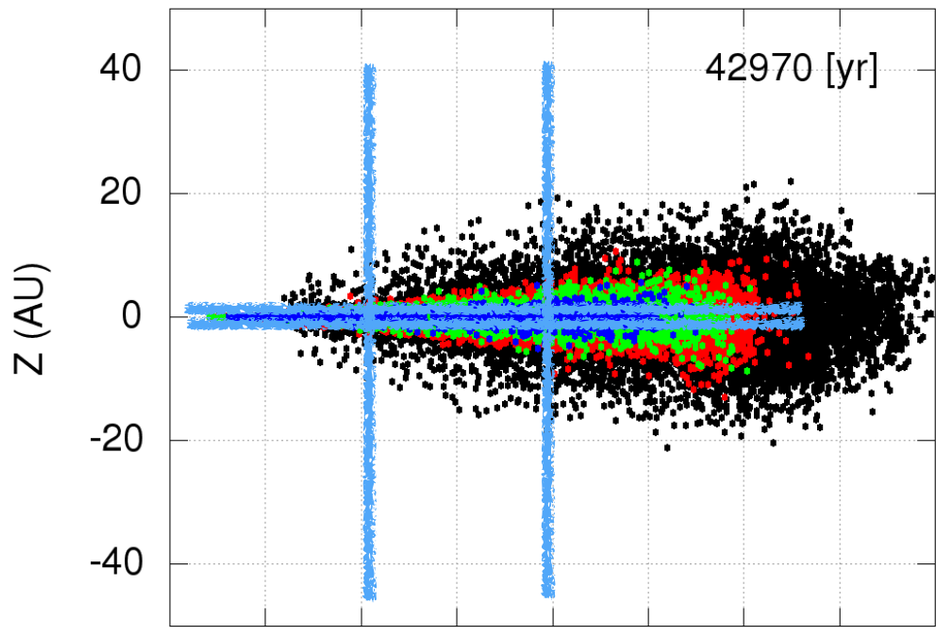
$$s_{opt} = \frac{c_s \rho_g}{\Omega_k \rho_d}$$





3D SPH SIMULATION: CHEMICAL EVOLUTION





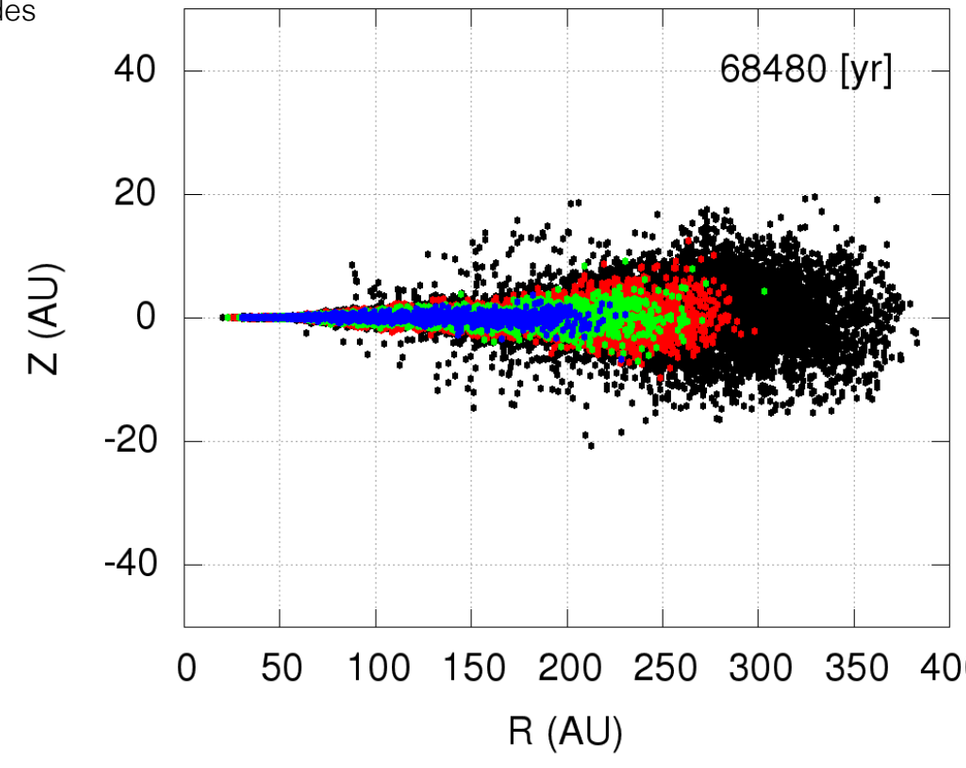
ice

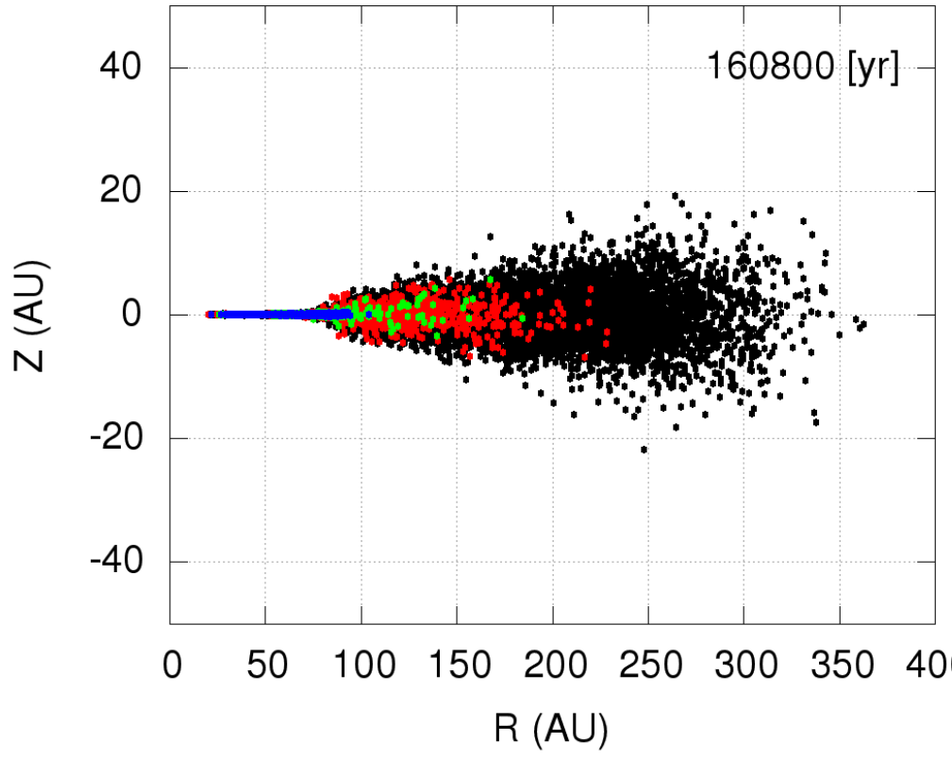
silicates

sulphides

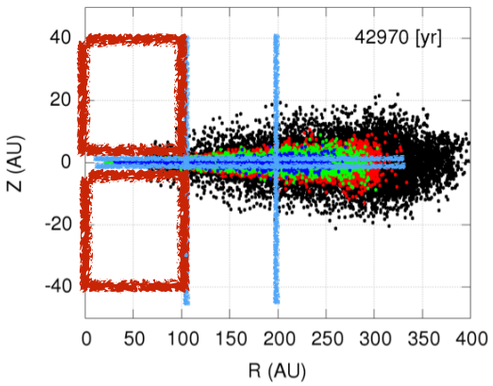
iron

where aggregates mimic chondrites?

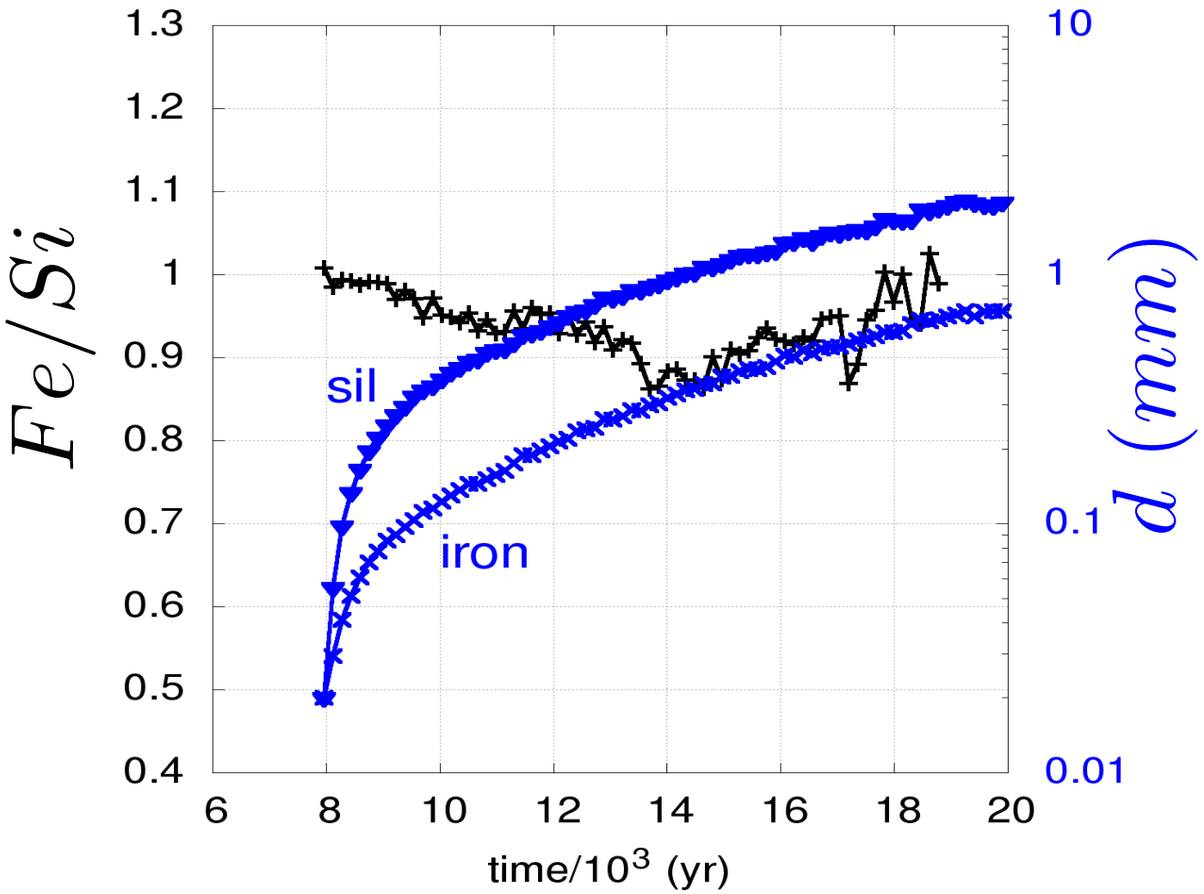




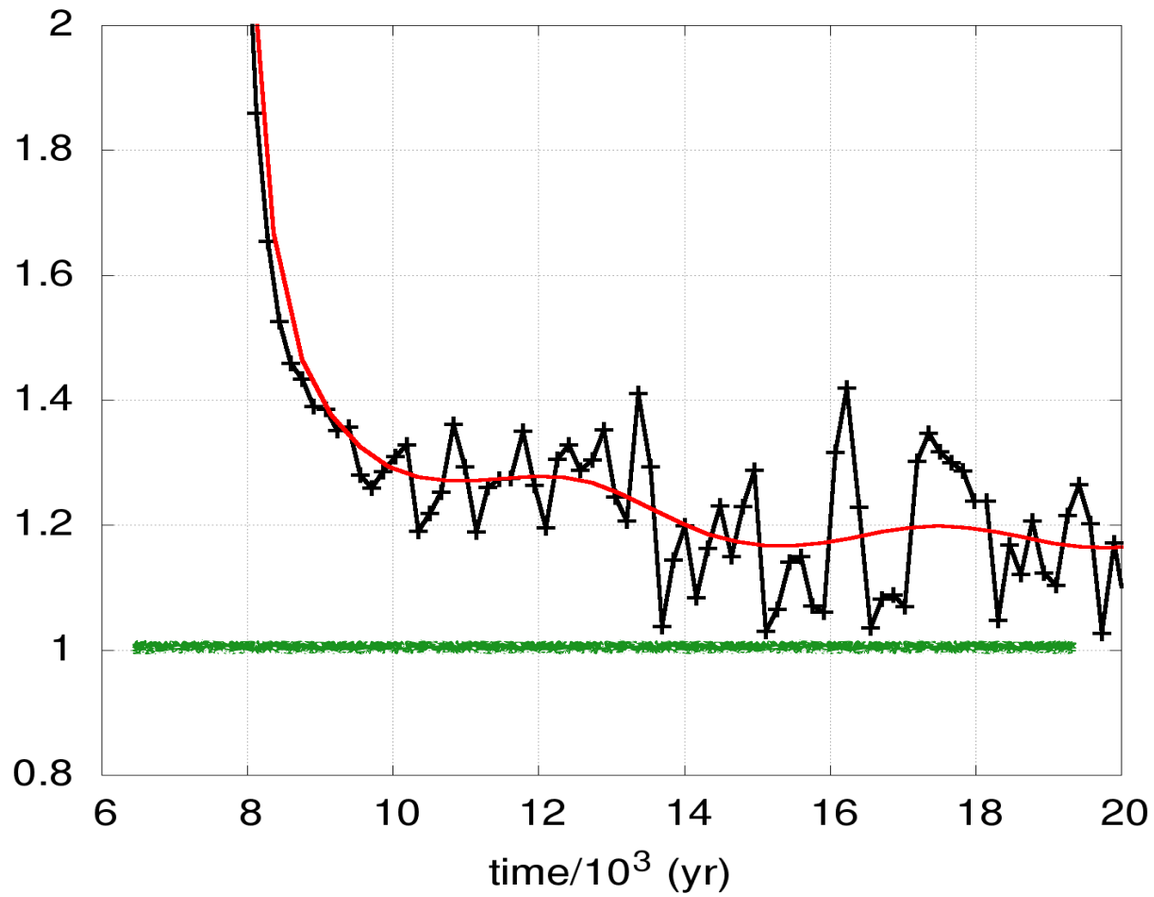
3D SPH SIMULATION: CHEMICAL EVOLUTION



surface
R<100 |Z|>1



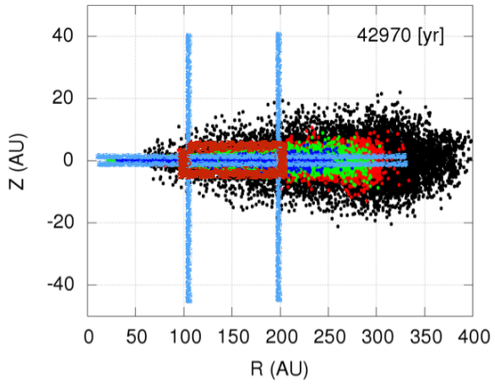
ζ_{iron}/ζ_{sil}



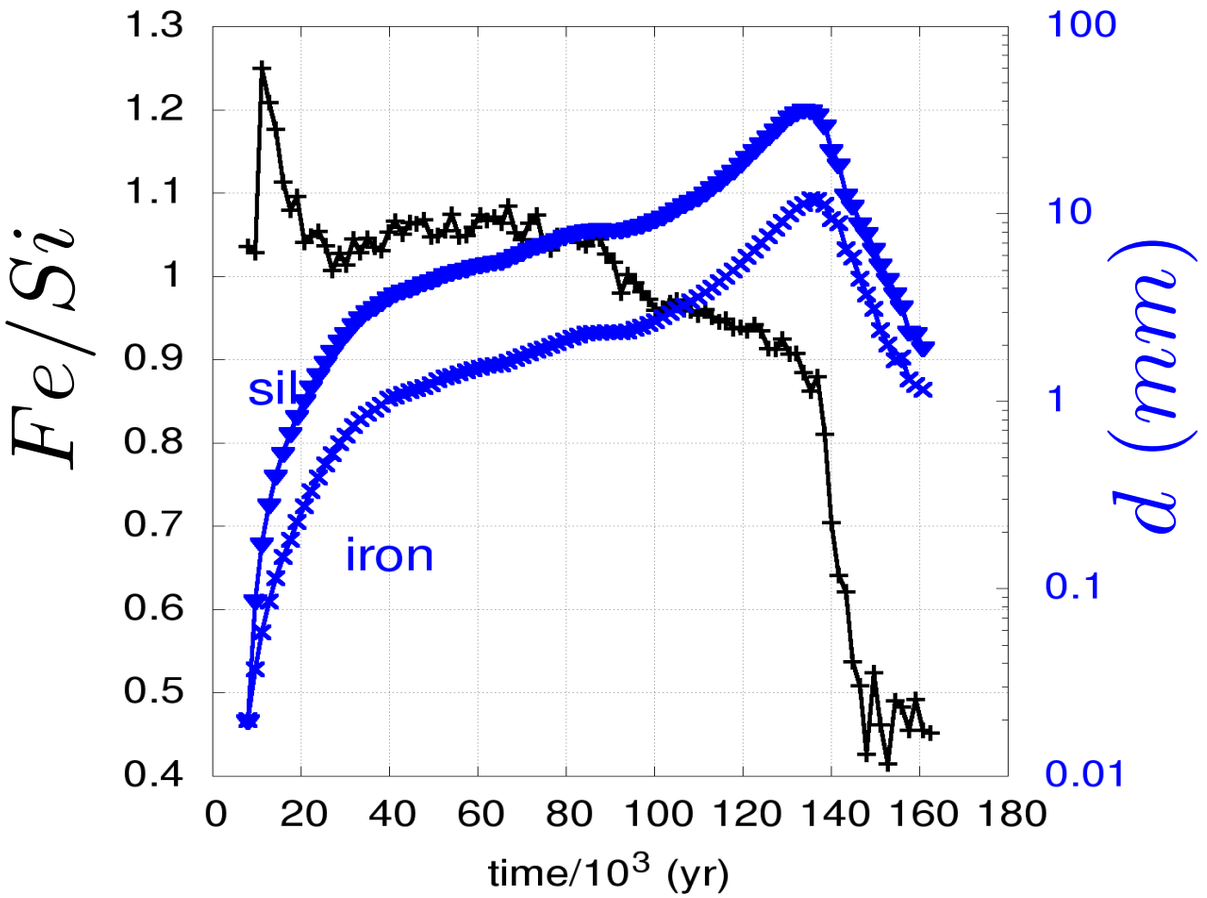
similar trend all over the disc surface

aggregates mimic the global properties of chondrites

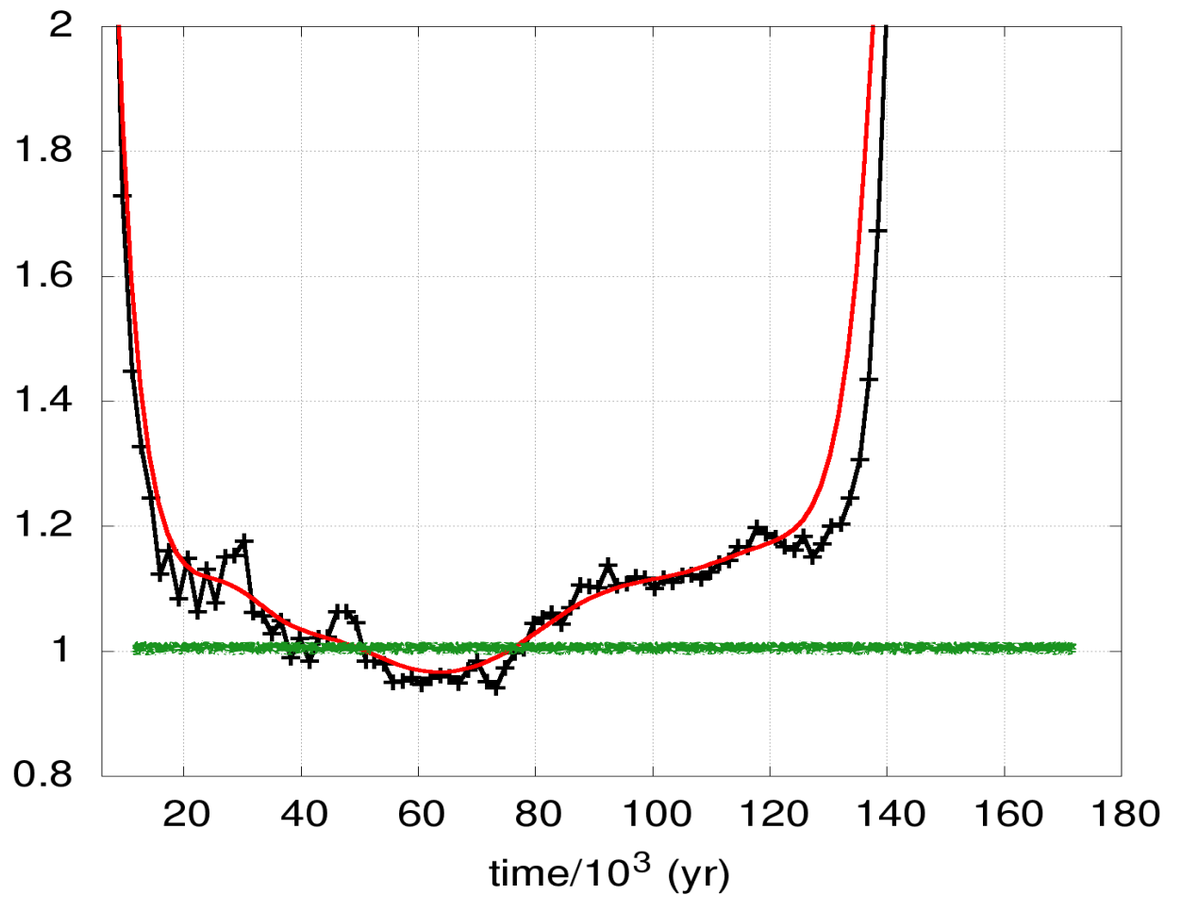
3D SPH SIMULATION: CHEMICAL EVOLUTION



midplane
100<R<200 -1<Z<1



ζ_{iron}/ζ_{sil}



3D SPH SIMULATION: CONCLUSIONS

Vertical settling

1st phase: (density driven) vertical chemical sorting

fractionation occurs at early stages

2nd phase: (size driven) re- mixing chemical sorting is lost

Radial drift

chemical radial sorting (persist) (!)

fractionation occurs at late stages, but larger grains

Size and density sorting

aggregates in disk are generally size-density sorted

Dynamics of multicomponent dust

aggregates mimic chondrites bulk properties

Pignatale et al. (under review)