UV signal of dust evolution in molecular cloud envelopes

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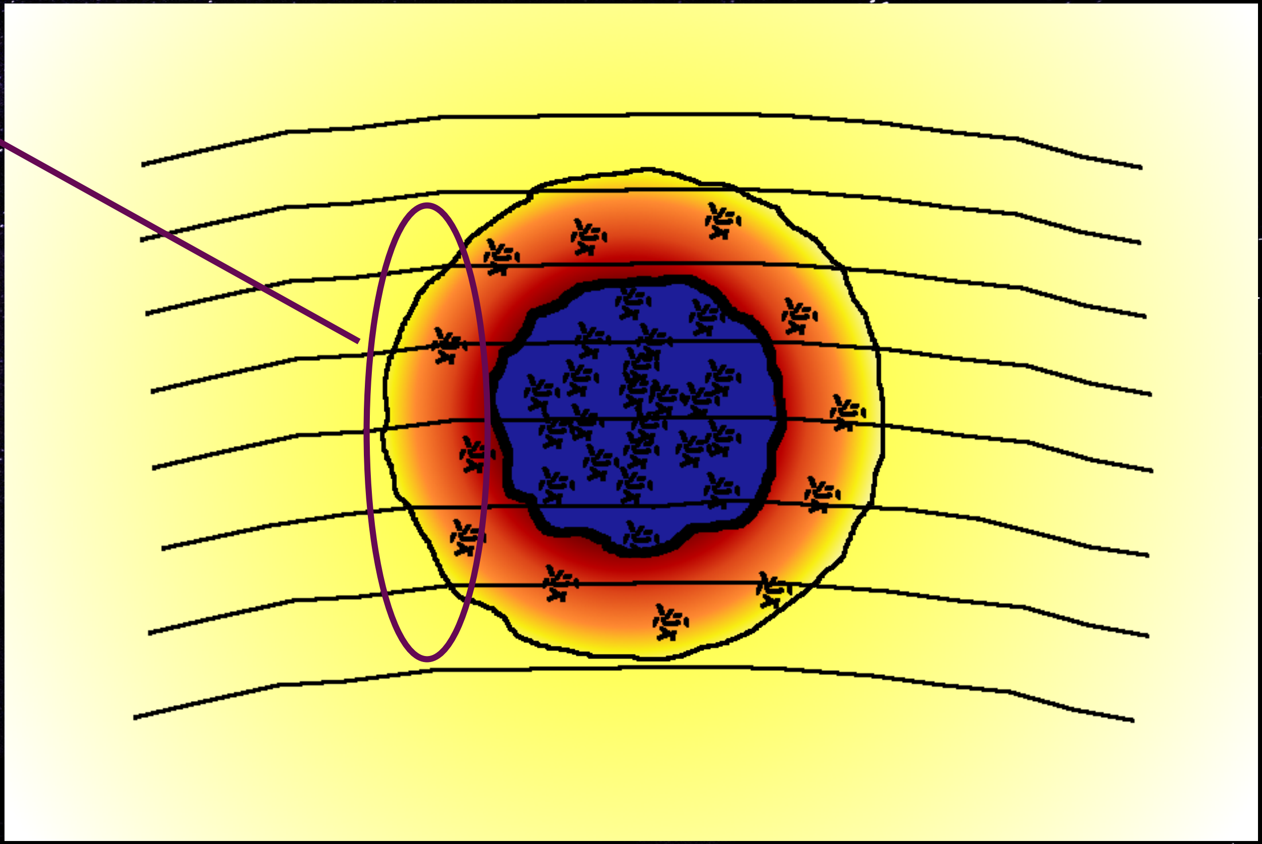
UV Astronomy in the XXIst century

MOLECULAR CLOUD ENVELOPE: WHAT IS IT?

Diffuse gas: 6000 K, $n = 0.1 – 10\ cm^{-3}$
Magnetic field coupling
Partially ionised (gas and dust)
WNM

Can be probed at UV wavelengths



WHY DUST IS IMPORTANT?

Dust grains affect the thermal/chemical evolution of the cloud

Absorption/scattering of UV photons
Photoelectric heating (net charge)
Molecule formation

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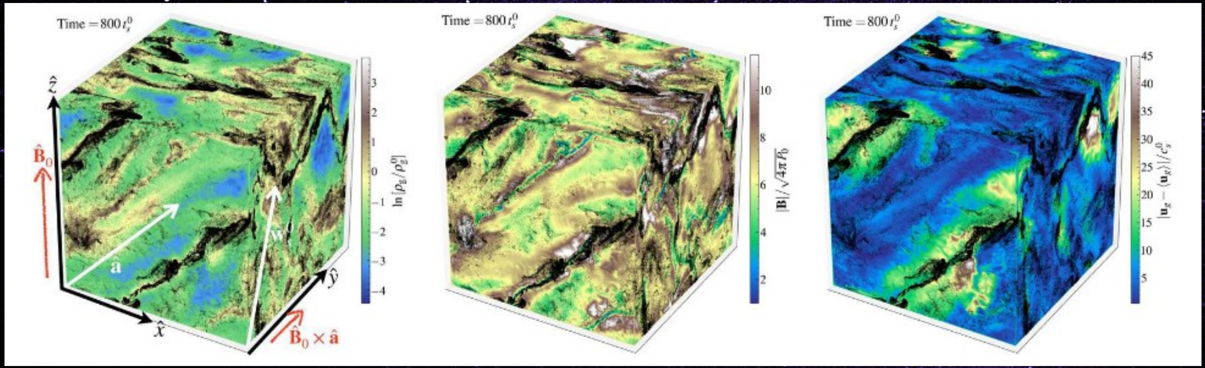
Charged dust grains affect the dynamical evolution of the cloud

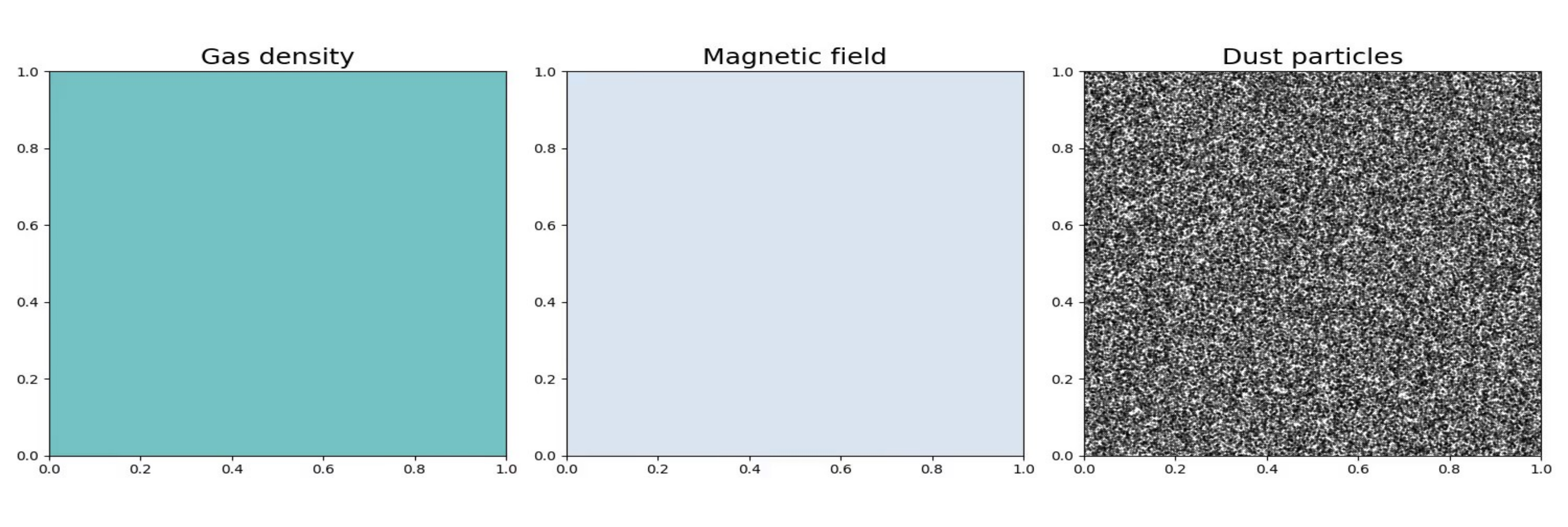


Simulating Diverse Instabilities of Dust in Magnetized Gas, Hopkins et al. (2020)

HOW DOES DUST MOVE INSIDE A MOLECULAR CLOUD ENVELOPE?

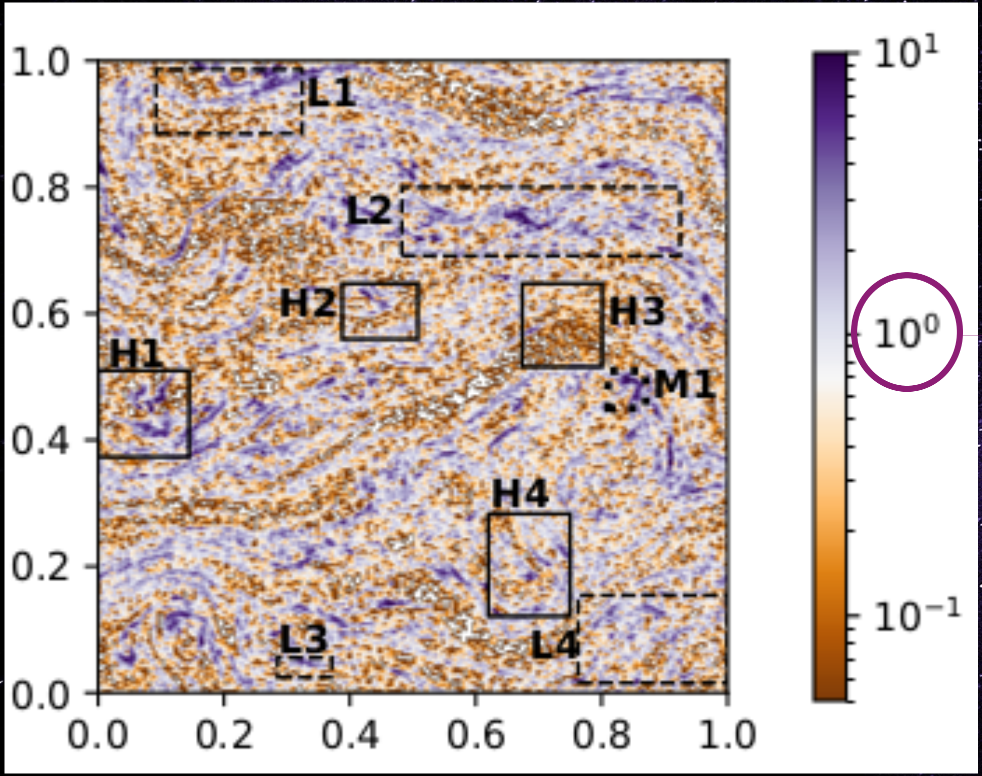
WNM-like conditions
0.05 microns silicate grains (Z = -17)

Beitia-Antero et al. (2021)



DUST FILAMENTS IN MOLECULAR CLOUD ENVELOPES

Dust-to-gas ratio map (normalised)



H1-4: regions of high density gas
L1-4: regions of low density gas

Nominal dust-to-gas ratio value of 0.01

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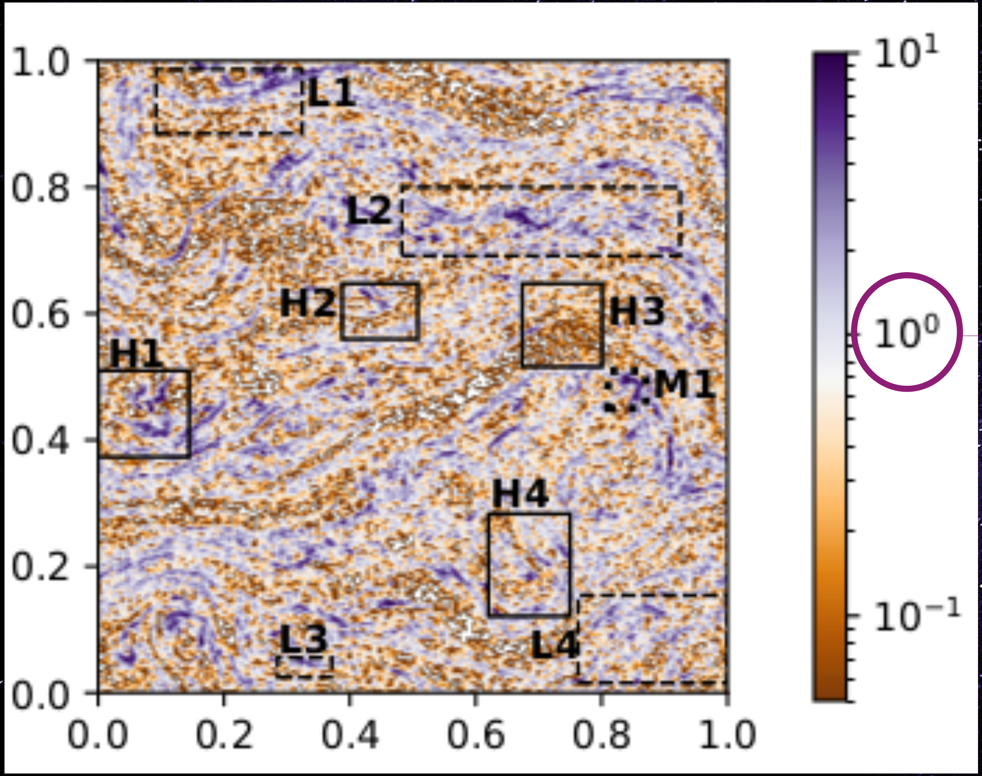

H1-4: regions of high density gas
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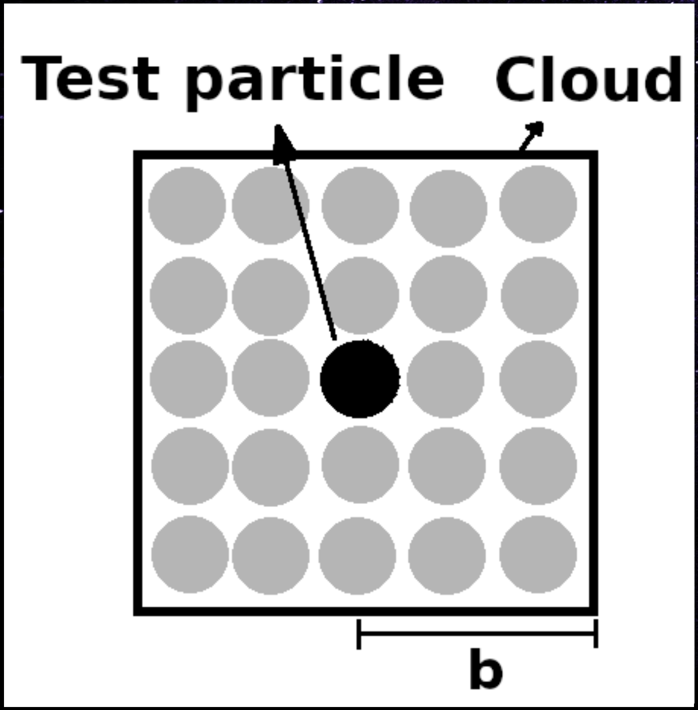
► Nominal dust-to-gas ratio value of 0.01

WHAT HAPPENS INSIDE THOSE FILAMENTS?

A NEW ALGORITHM FOR DUST EVOLUTION IN MHD CODES

Let's assume that computational particles represent a swarm of real particles uniformly distributed around it

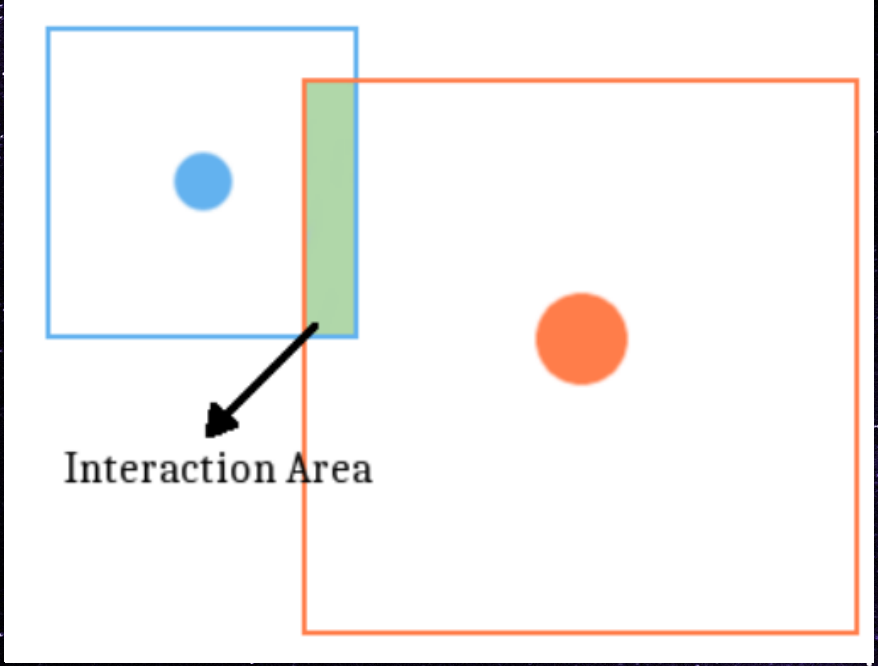


Mass of the computational particle: m
Represented total mass: M

Beitia-Antero & Gómez de Castro (2021)

A NEW ALGORITHM FOR DUST EVOLUTION IN MHD CODES

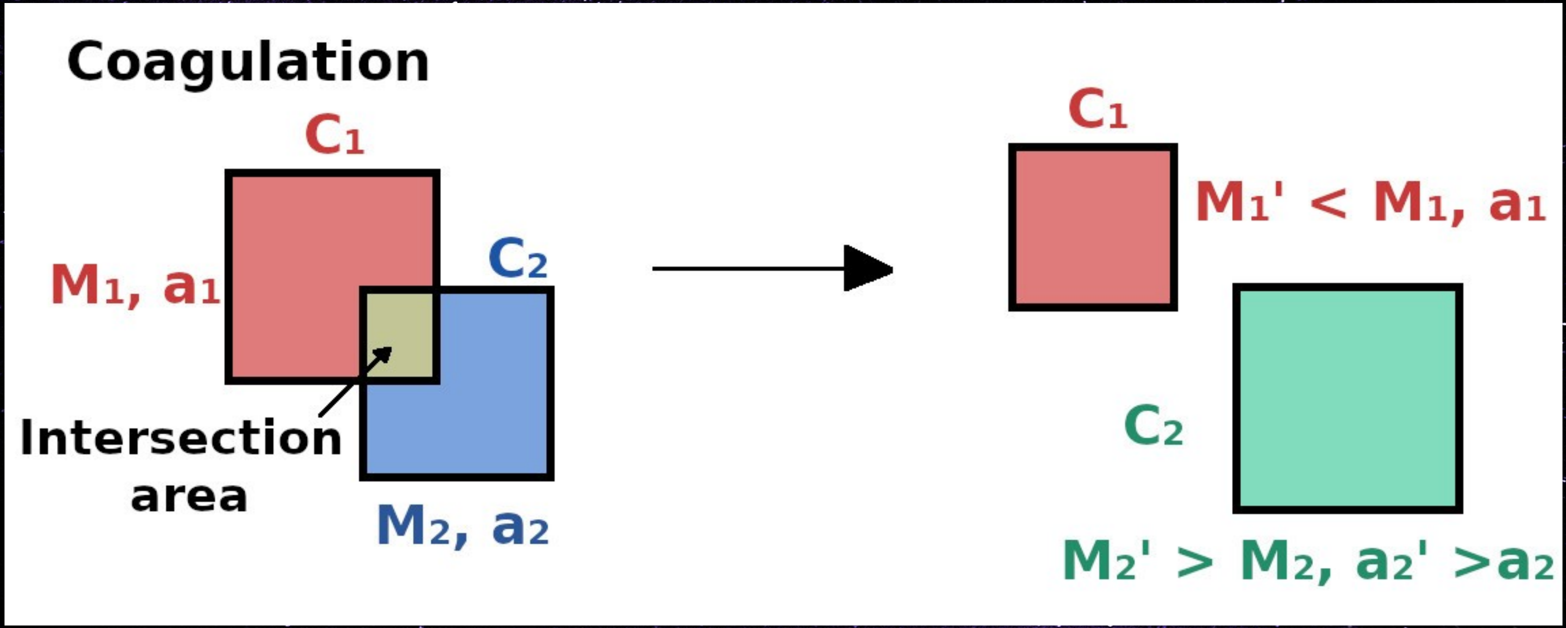
In order to keep constant the total number of computational particles, particle-particle interactions are indirect (mass/momentum exchange)



Beitia-Antero & Gómez de Castro (2021)

A NEW ALGORITHM FOR DUST EVOLUTION IN MHD CODES

Simple dust evolution model – two possible outcomes: coagulation or shattering



Particles exchange mass (M) and momentum

Beitia-Antero & Gómez de Castro (2021)

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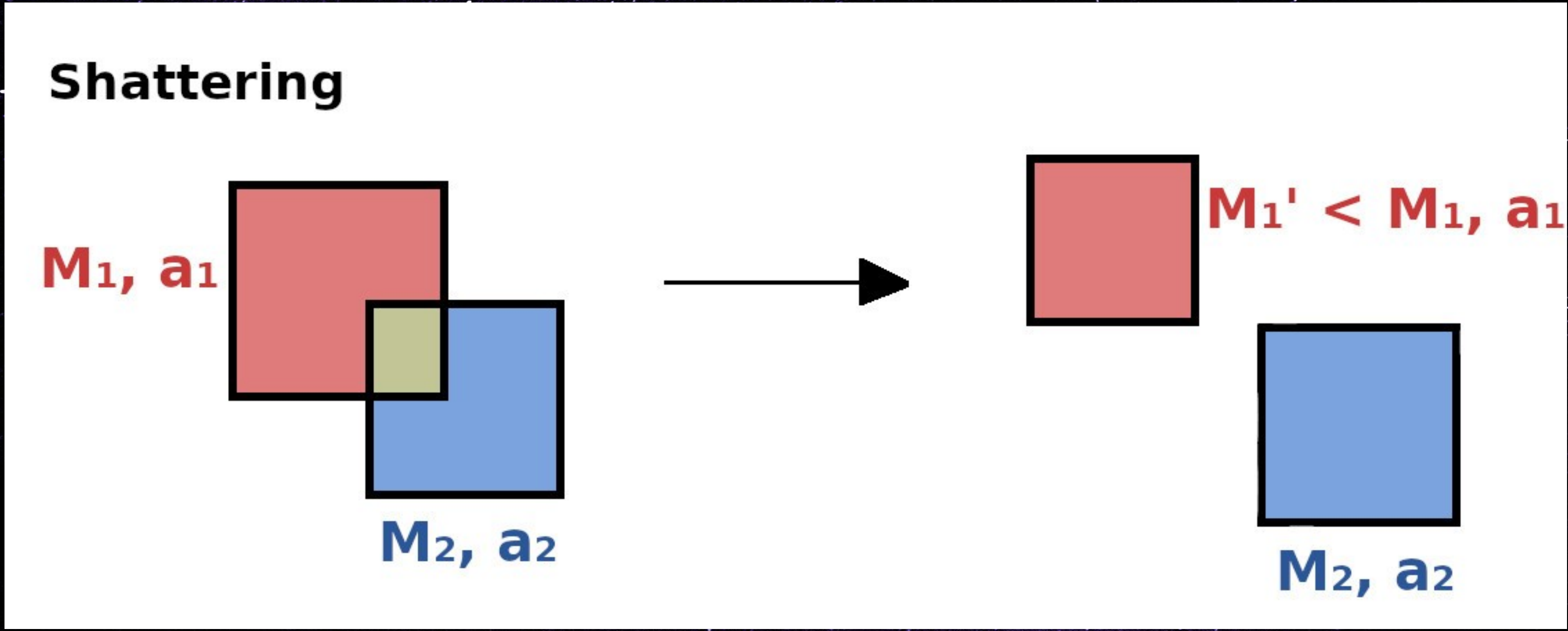

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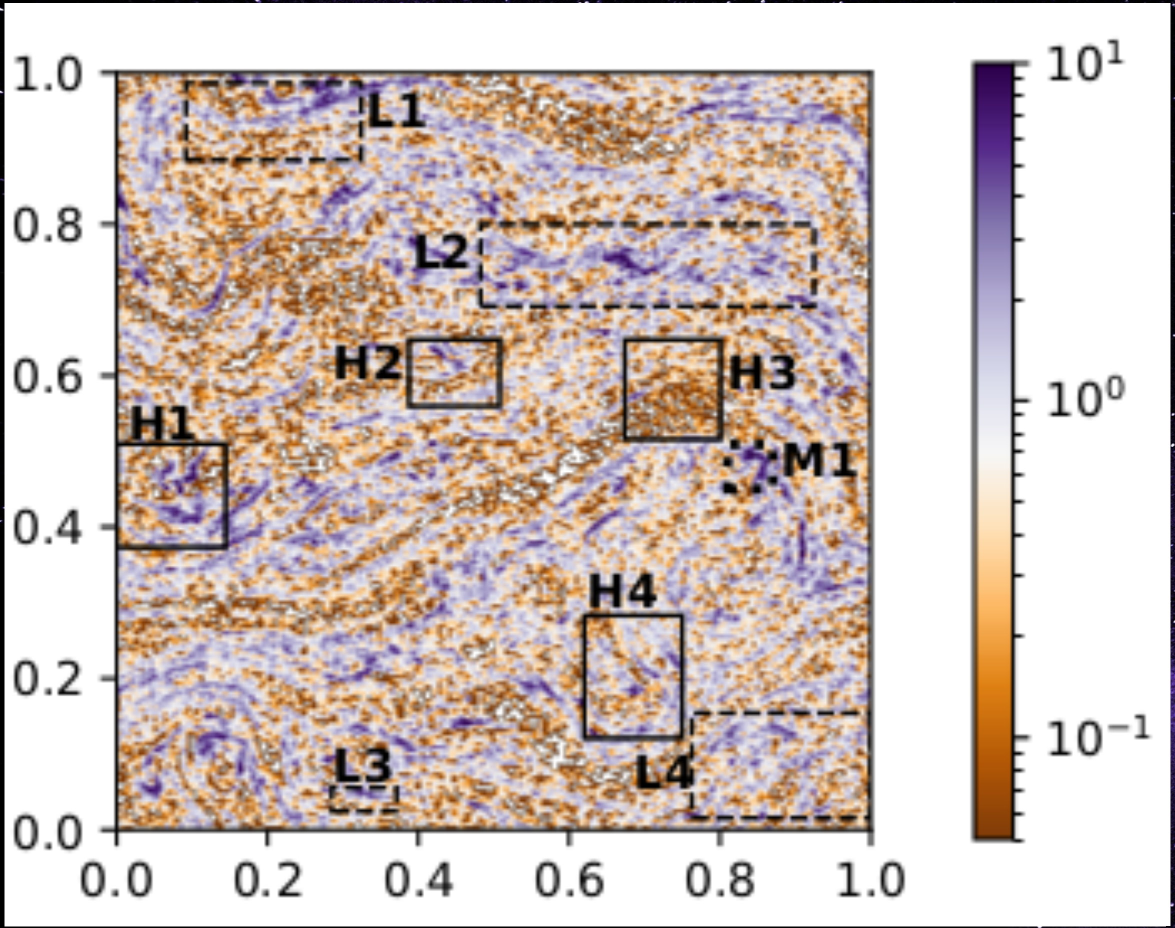
DUST EVOLUTION OF A SINGLE-SIZED DUST POPULATION

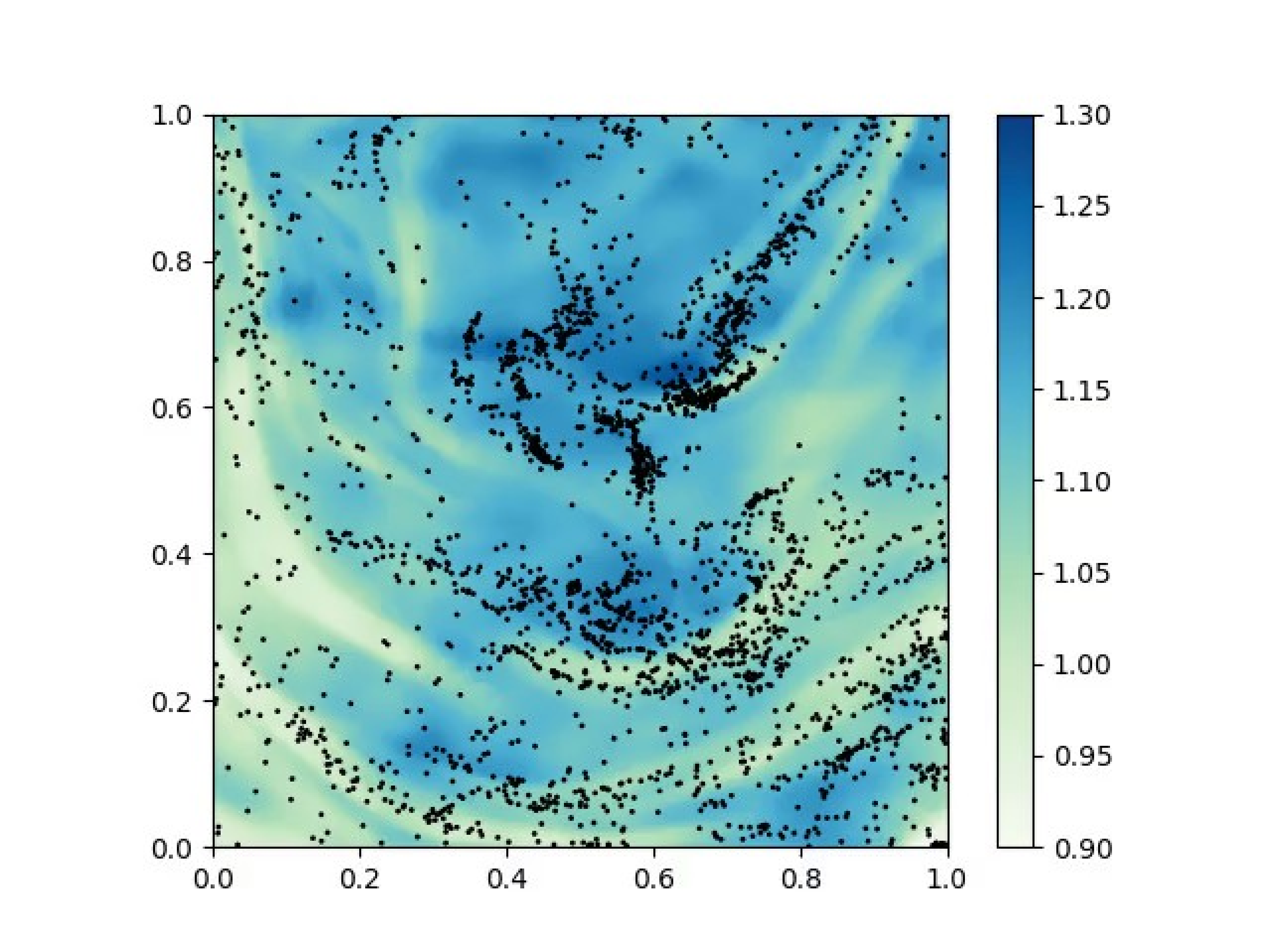


Dust evolution in regions H1, H2, H4, L1, L2, L4, M1 was followed

Particle positions and gas properties from final snapshot of MHD simulation

DUST EVOLUTION OF A SINGLE-SIZED DUST POPULATION

H1



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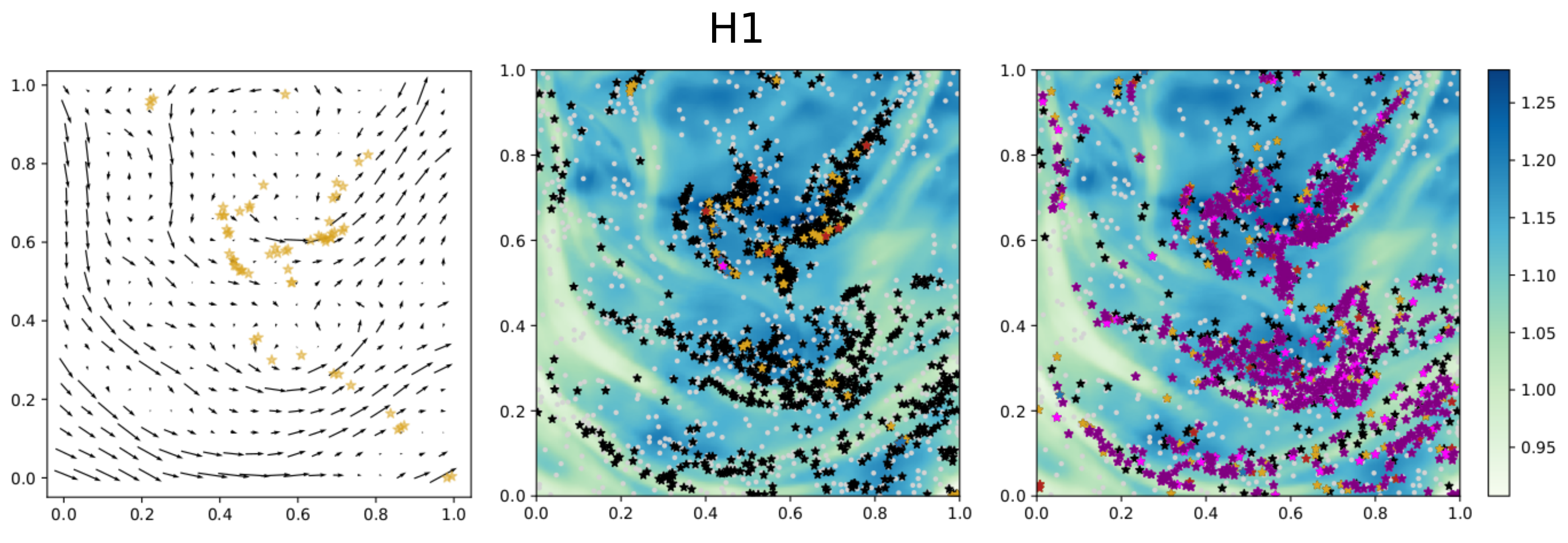
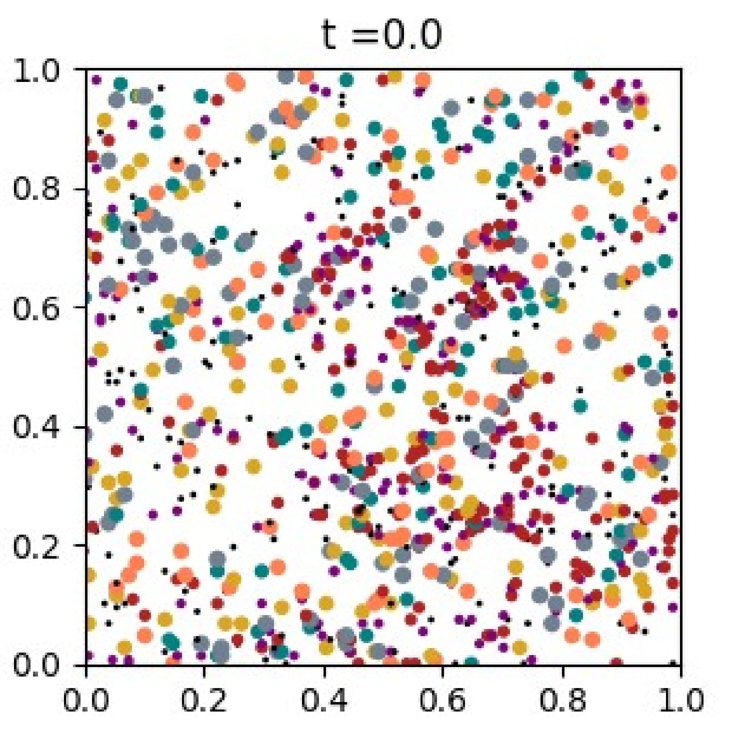


VARIATIONS IN THE DUST SIZE DISTRIBUTION

$n(a) = K\, n_H\, a^q$

We need a real dust size distribution, not a single sized population: **mock sample**



- Two populations: silicate and graphite
- Dust masses equally distributed
- Particle sizes between 50 Å and 0.25 μm (MRN), logarithmically sampled
- 100 test particles of each size
- Random position according to dust size (smaller ones follow the magnetic field, larger ones follow gas)

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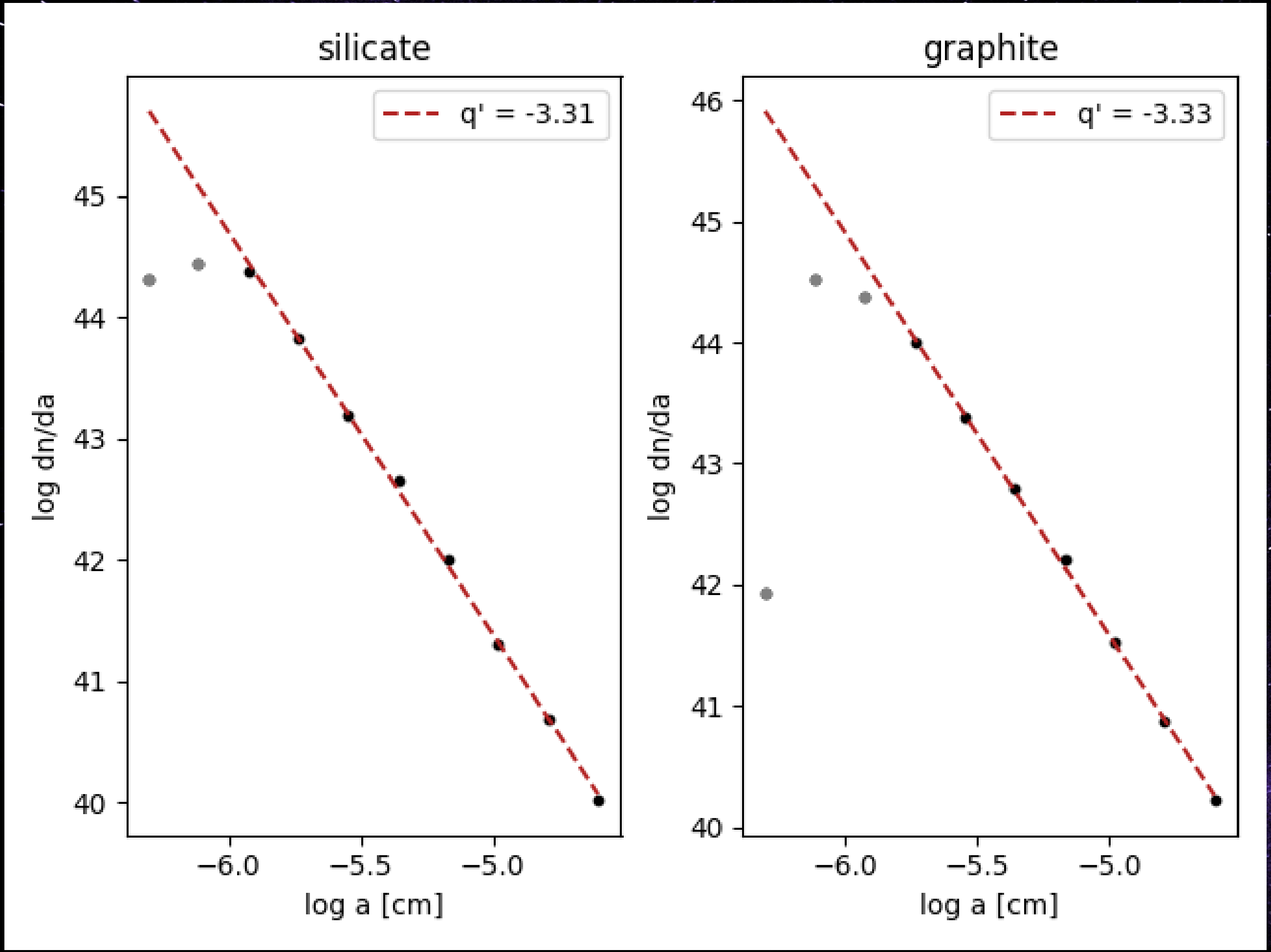

Silicates and graphite evolve independently

Power law index *q* measured for each population and simulation

EFFECTS ON THE UV EXTINCTION CURVE

$$A_\lambda = 1.086\left(\int_{a_{min}}^{a_{max}} \pi a^2 Q^{ext}_{\lambda,sil}(a) n_{sil}(a) da + \int_{a_{min}}^{a_{max}} \pi a^2 Q^{ext}_{\lambda,gra}(a) n_{gra}(a) da\right)$$

Nozawa & Fukugita 2013

$a_{min} = 50$ Å, $a_{max} = 0.25\ \mu$m
$n(a) = K n_H a^q$, $K_{sil} = 10^{-25.11}$, $K_{gra} = 10^{-25.13}$
Q_λ: extinction efficiency (Draine 2003)

q is computed by fitting the final size distributions
values range from -3.4 to -3.07

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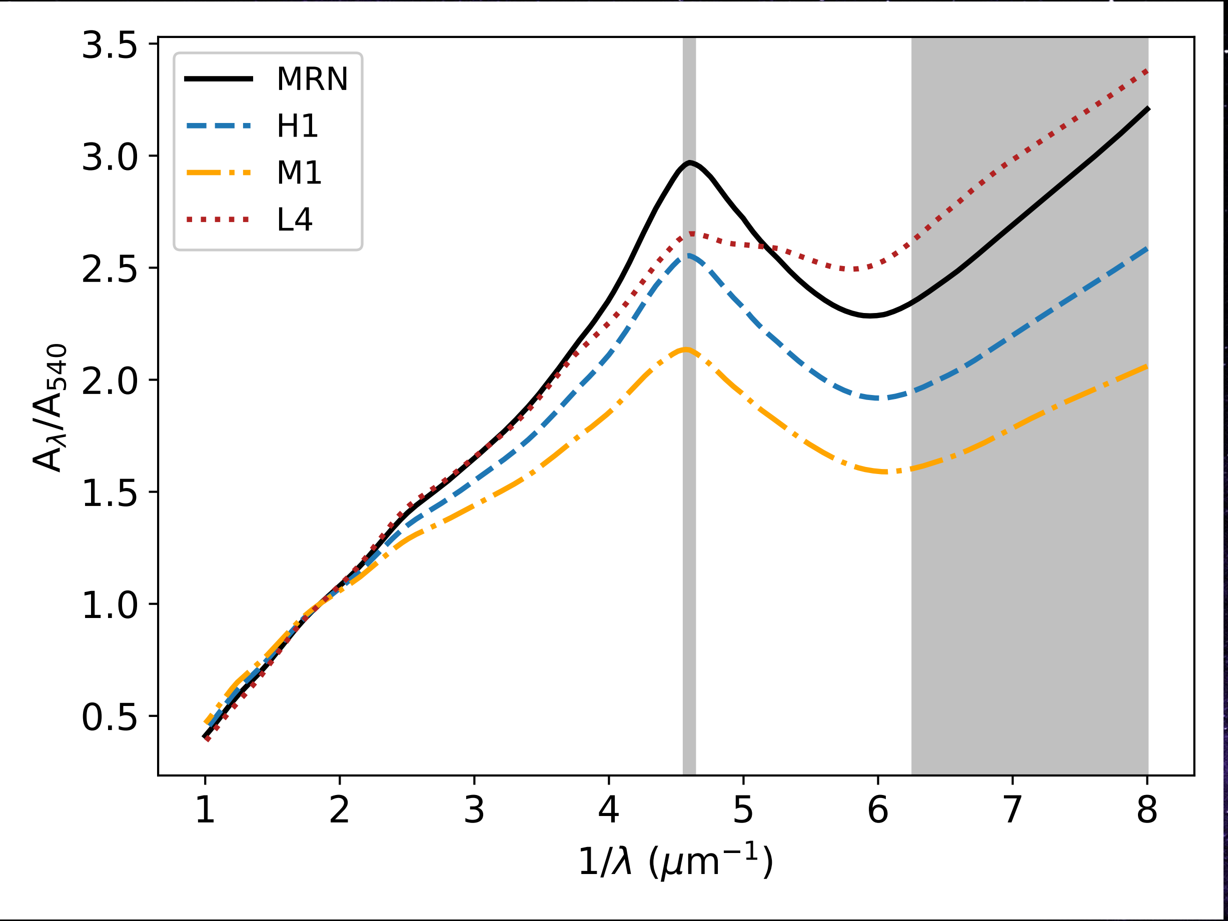

Far-UV slope
b_{FUV}/b^{MRN}

H1 = 0.76
H2 = 0.79
H4 = 0.75
L1 = 0.78
L2 = 0.75
L4 = 0.86
M1 = 0.55

WHICH DUST POPULATION EXERTS A GREATER INFLUENCE?

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L4 = 0.86 → similar depletion of silicates and graphites

M1 = 0.55 → dust destruction very effective

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Fixing q_{gra} and varying q_{sil} do not make a difference

Fixing q_{sil} and varying q_{gra} produce great variations in the slope ratio

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CONCLUSION

Variations in the FUV slope of the UV extinction curve mainly arise from depletion of small graphite grains that return to gas phase