HYDRODYNAMIC SIMULATIONS OF SUPERNOVA REMNANTS:
DUST DESTRUCTION BY THE REVERSE SHOCK

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Supernova Remnants II

Chania, Greece | June 5, 2019

THE SNDUST PROJECT

Theme 1:

Measuring dust ejecta mass from observations

Theme 2:

Modelling of dust (destruction) in SNRs

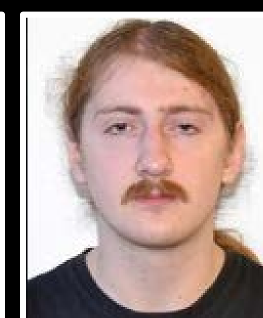
Antonia Bevan

Mike Barlow

Ilse De Looze

Florian Kirchschlager

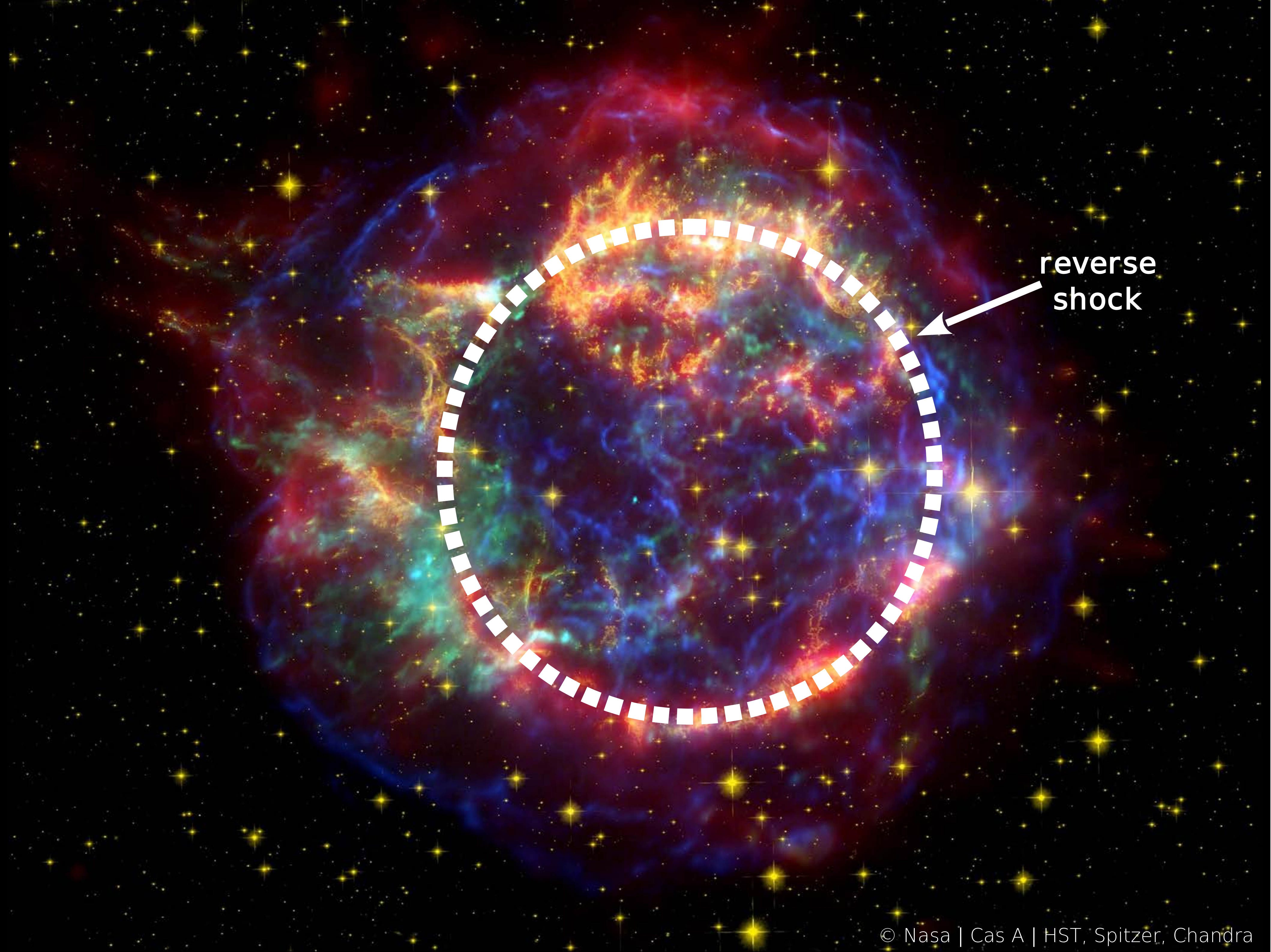
Maria Niculescu-Duvaz



Felix Priestley

Roger Wesson

All group members have brought posters to present their work so please do check those out! :)


reverse
shock
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PREVIOUS DUST DESTRUCTION MODELLING

Typical setups

- Analytical density profiles
- Shock-ejecta (smooth/clumpy) interactions

Numerical studies[1] predict SNR dust survival rates anywhere between

0 and **99%** but:

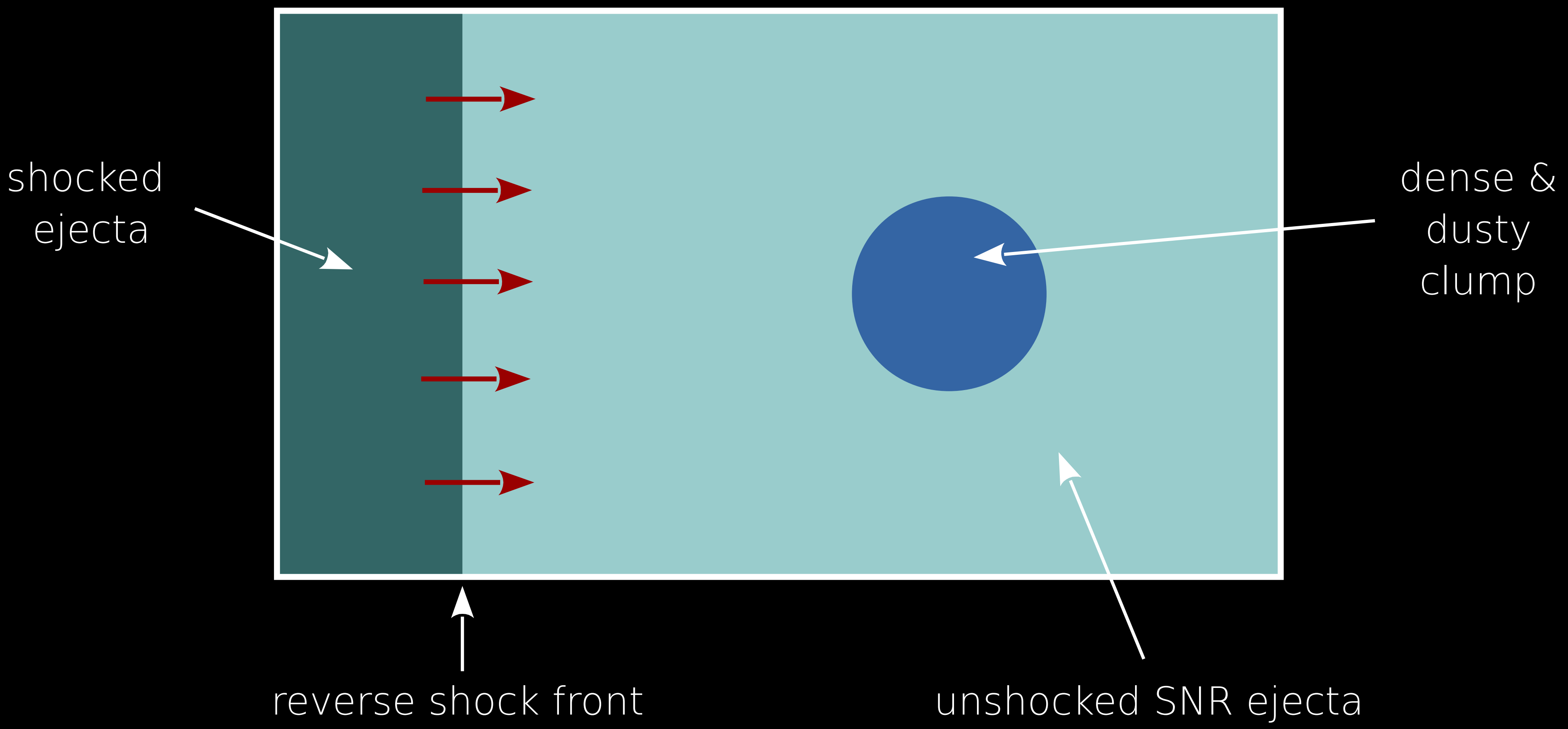
Simplified physics

- Passive non-interacting tracers
- No grain-grain collisions
- Initial conditions

[1]e.g. Nozawa et al., 2007 (0-80%), Bianchi & Schneider, 2007 (2-20%), Nath et al., 2008 (80-99%), Silvia et al., 2010 (0-70%), Biscaro & Cherchneff, 2016 (6-98%), Boccio et al., 2016 (1-8%), and Micelotta et al., 2016 (12-16%)

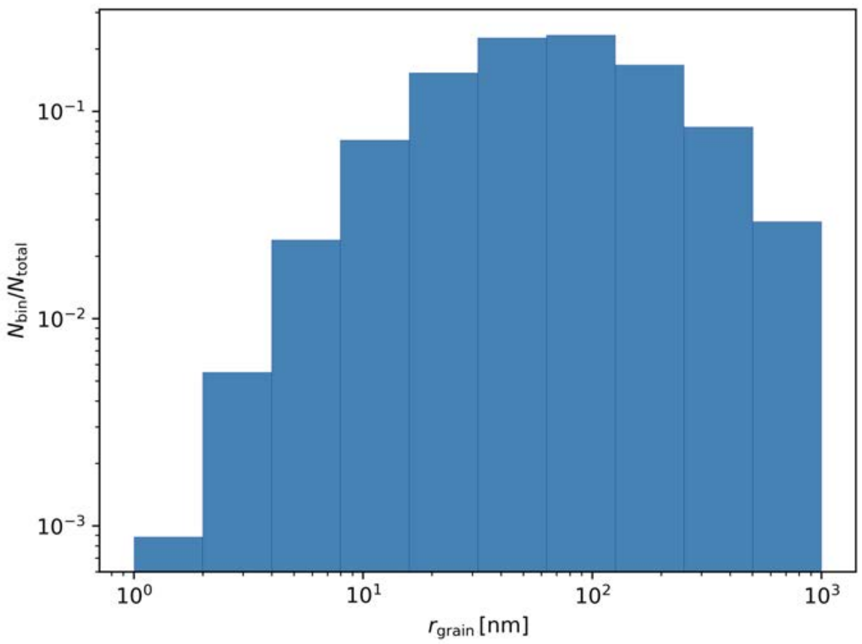
THE 'CLOUD CRUSHING' MODEL

We simulate the conditions in the SNR using the hydrodynamic code AstroBEAR (Carroll-Nellenback et al., 2013) and the 'Cloud Crushing' model (Woodward, 1976).



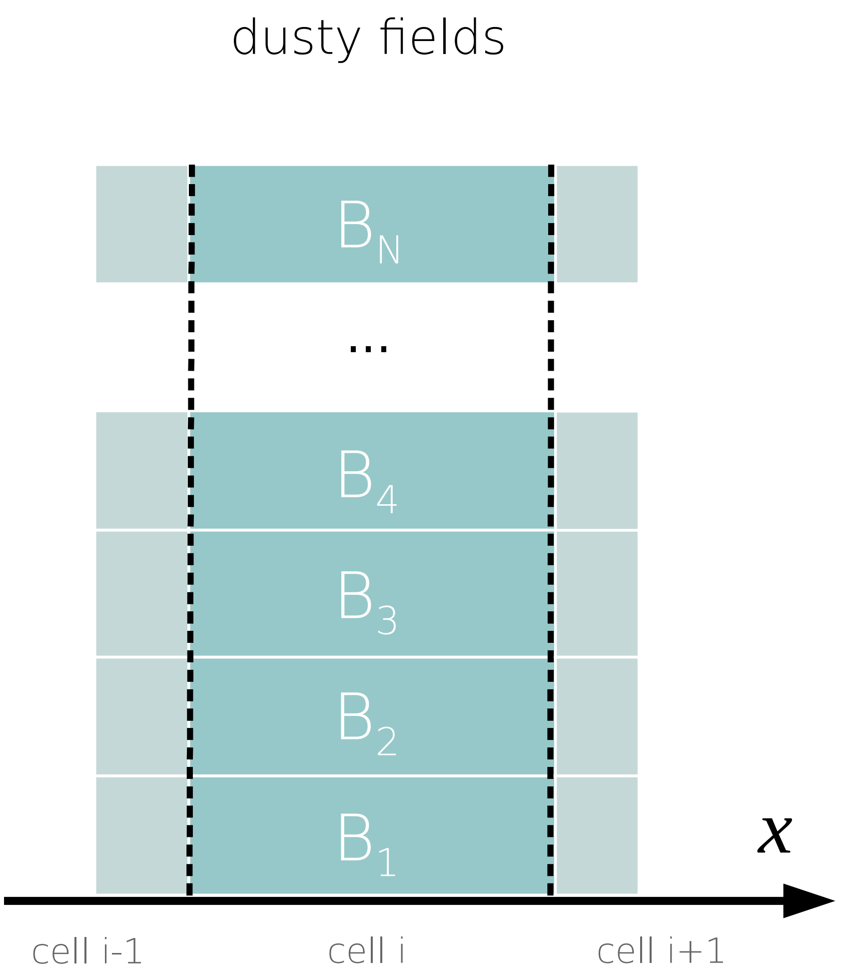
THE 'DUSTY GRID' MODEL

- We sort the dust grains into N grain size bins



THE ‘DUSTY GRID’ MODEL

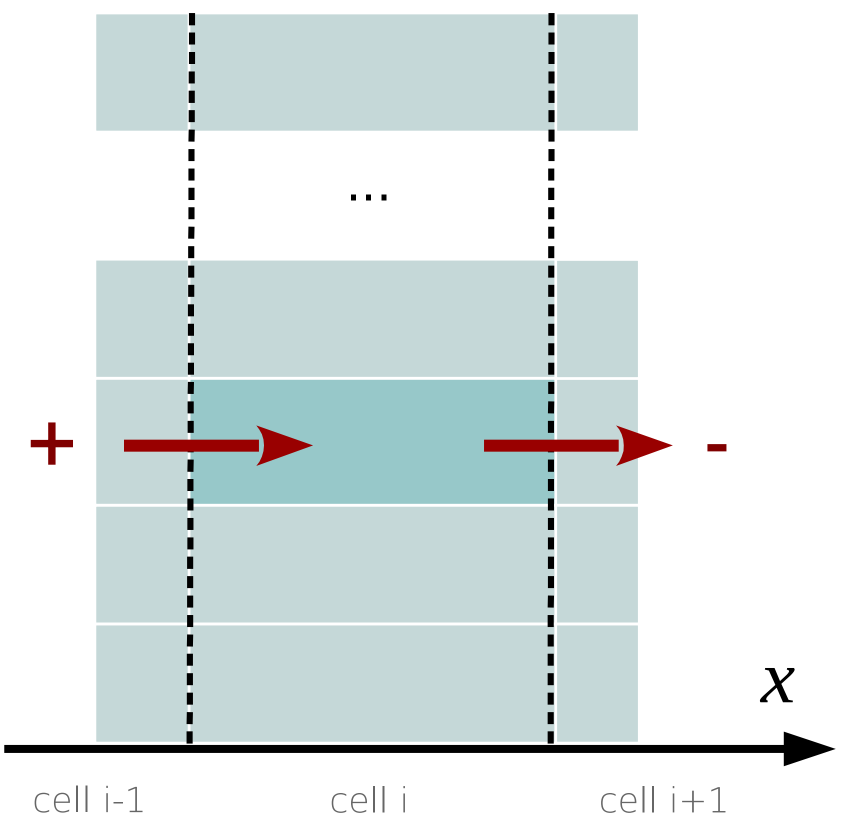
- We sort the dust grains into **N** grain size bins
- Each bin is added as a time-dependent quantity to our HD simulations



THE 'DUSTY GRID' MODEL

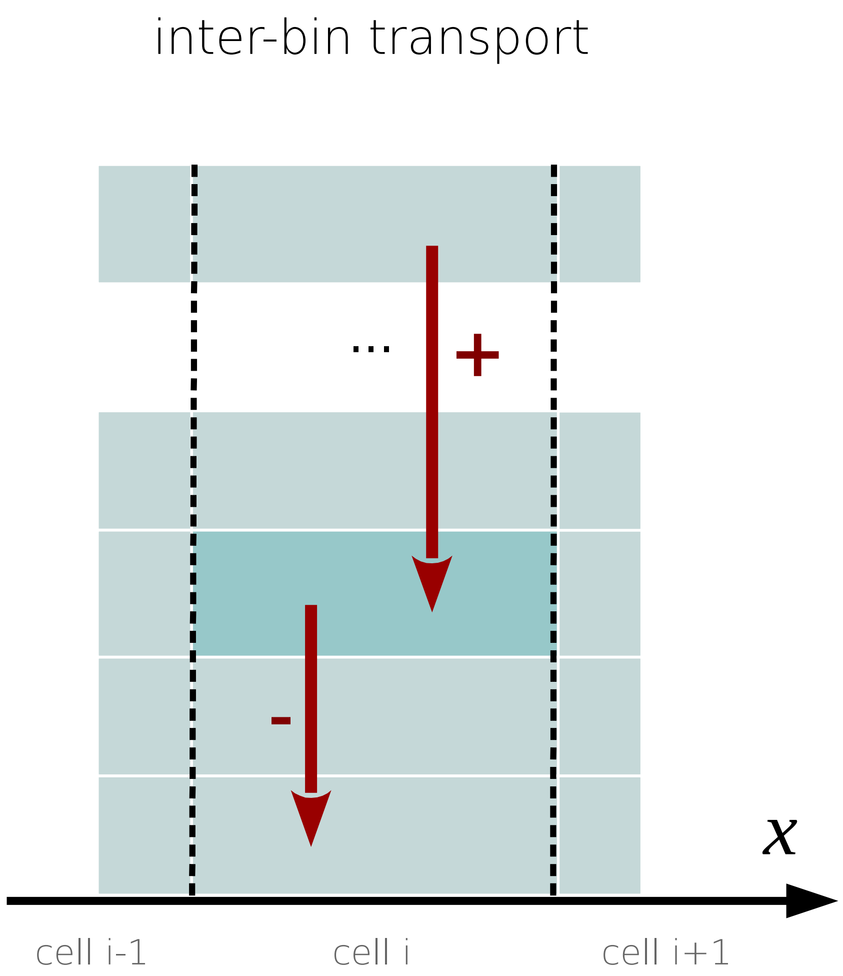
- We sort the dust grains into N grain size bins
- Each bin is added as a time-dependent quantity to our HD simulations
- Modified advection routines move the dust from cell to cell

inter-cell transport



THE 'DUSTY GRID' MODEL

- We sort the dust grains into N grain size bins
- Each bin is added as a time-dependent quantity to our HD simulations
- Modified advection routines move the dust from cell to cell
- Source terms shuffle grains between bins (dust destruction & creation)



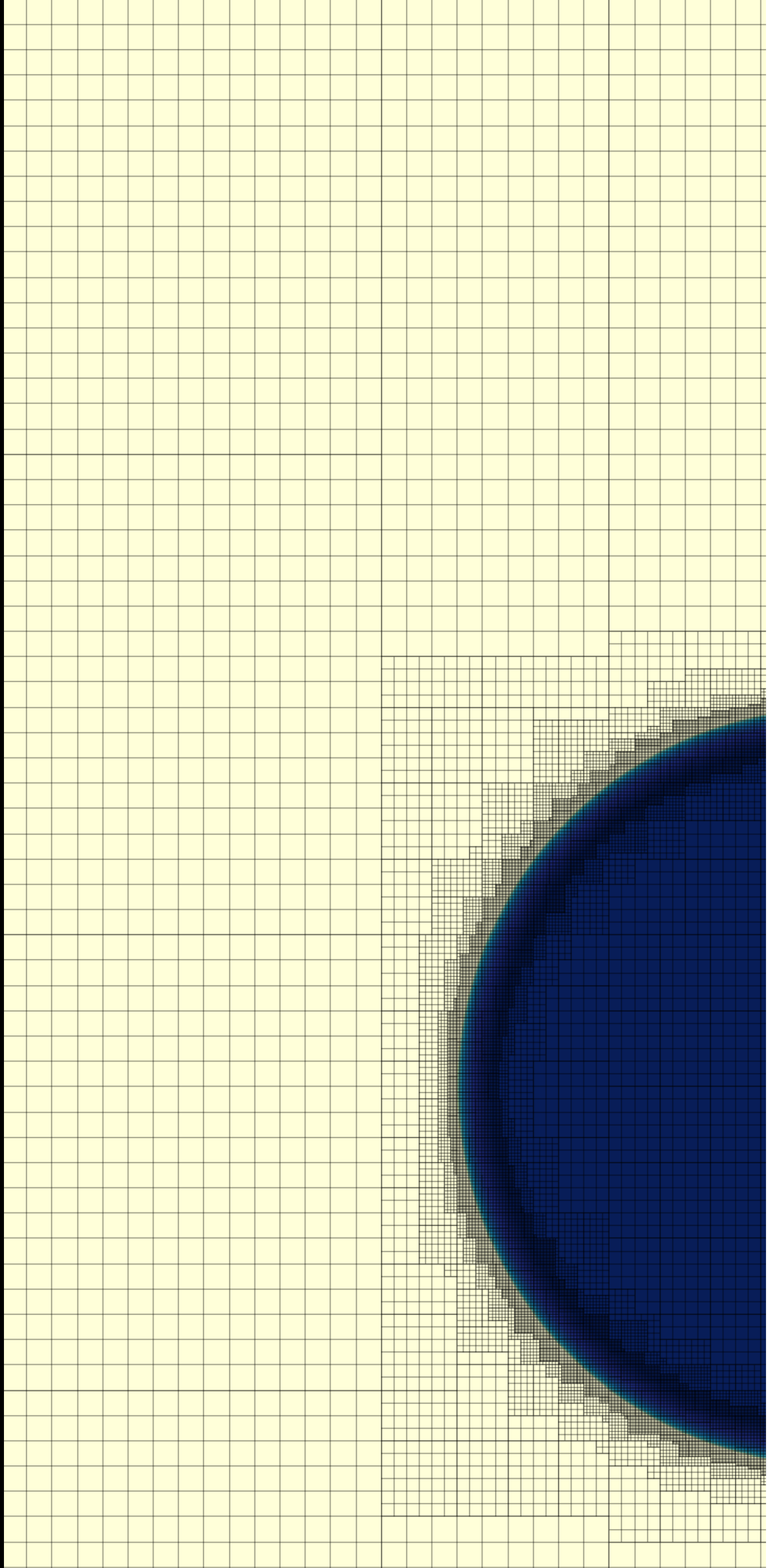
MODEL FEATURES

Hydrodynamic Simulations

- Cooling
- AMR

Dust physics

- Carbon and/or Silicate dust
- Grain charging
- Grain size distribution tracking
- Drag (gas and plasma)
- Sputtering (thermal & kinetic)
- Grain-grain collisions



RESULTS

DUST SURVIVAL RATES IN CAS A

INITIAL CONDITIONS

Ambient Medium

$n_{\mathrm{am}} = 1\,\mathrm{cm}^{3}$ $\qquad$ $T = 10^{4}\,\mathrm{K}$

Gas Cloud

$n_{\mathrm{cl}} = \chi \cdot n_{\mathrm{am}}$ $\qquad$ $\chi \in [100, 1000]$

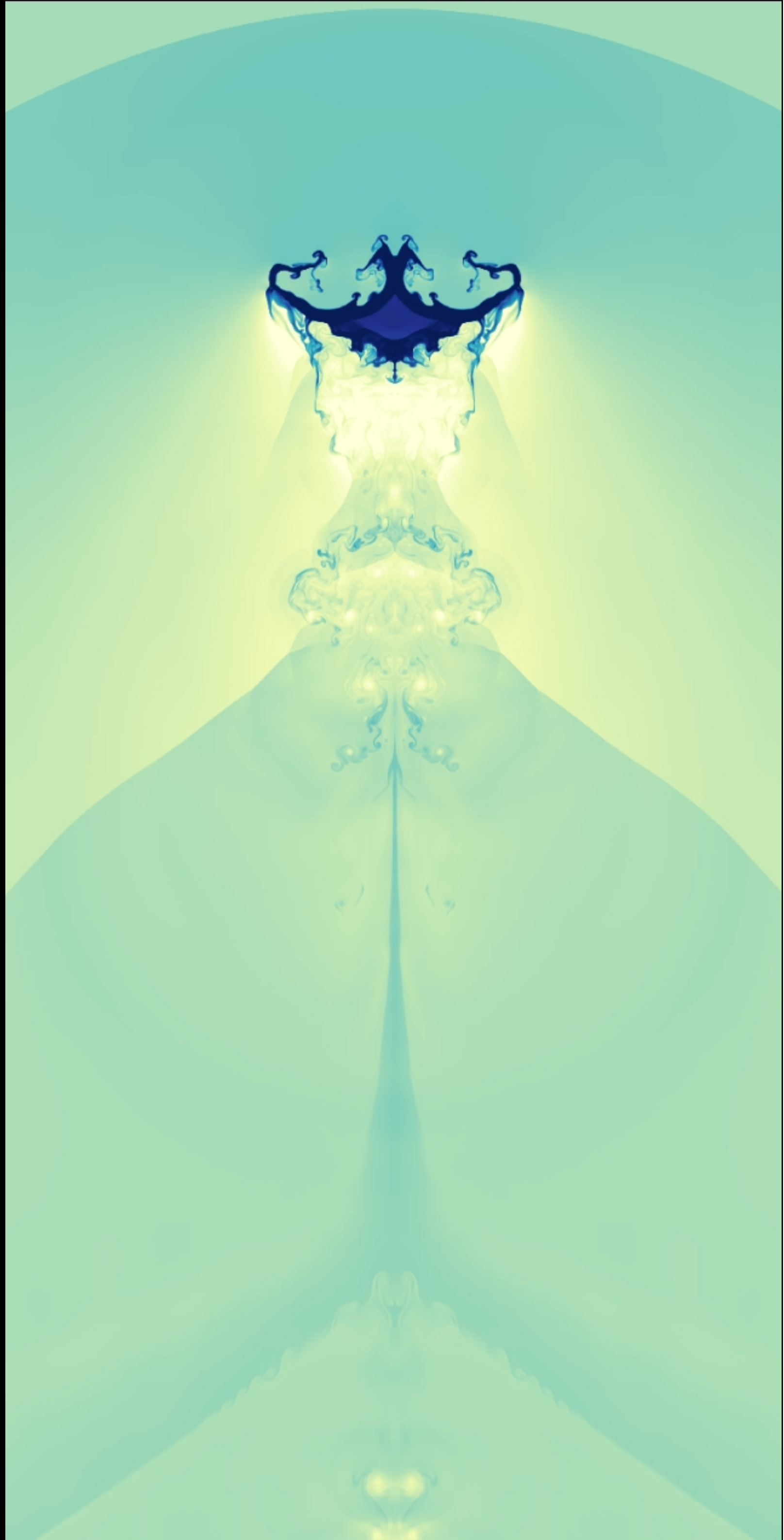
$T = 10^{2}\,\mathrm{K}$ $\qquad$ $R_{\mathrm{cl}} = 10^{16}\,\mathrm{cm}$

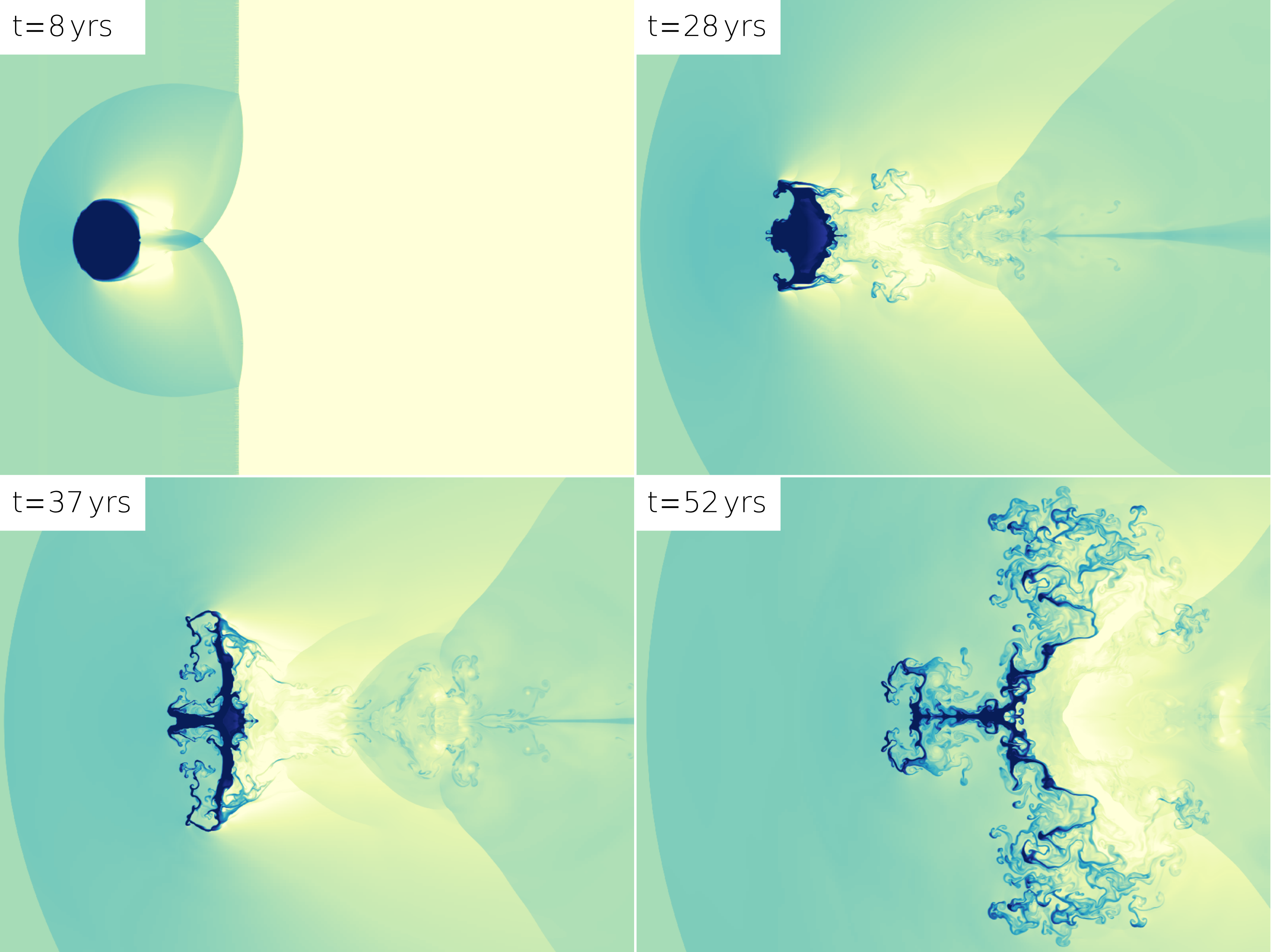
Shock

$v_{\mathrm{sh}} = 1600\,\mathrm{km/s}$

Dust

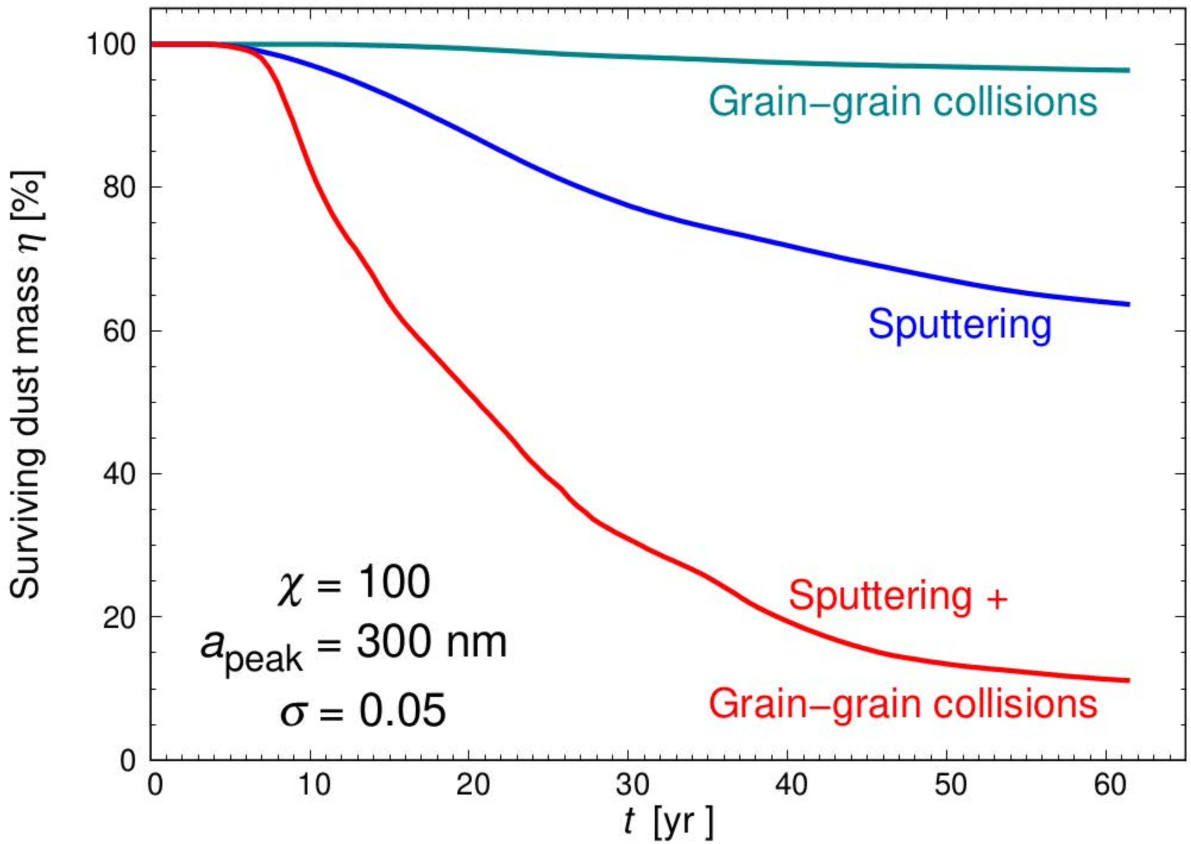
$\Delta_{\mathrm{gd}} = 10$





t=8 yrs
t=28 yrs
t=37 yrs
t=52 yrs

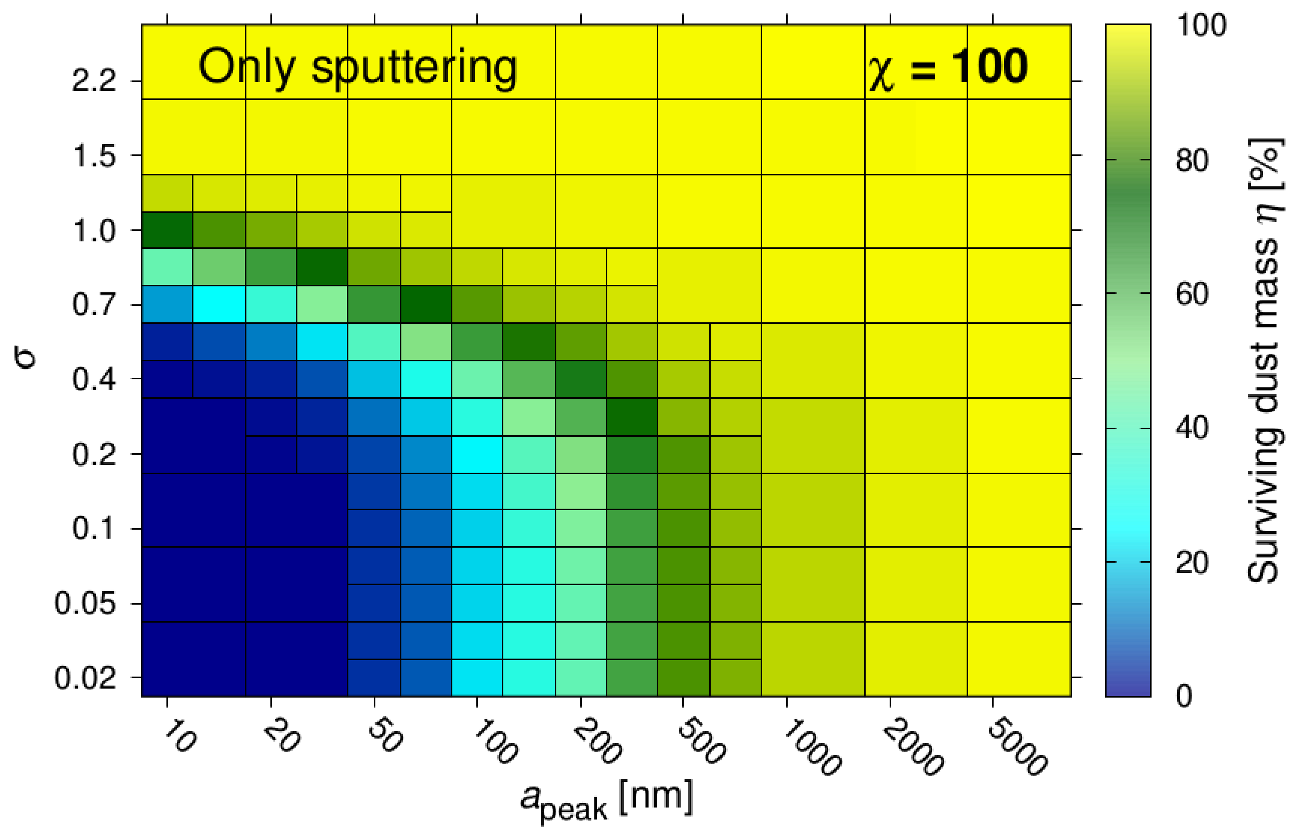
SPUTTERING & GRAIN-GRAIN COLLISIONS



Kirchschlager et al., 2019, submitted

We find that the inclusion of grain-grain collisions facilitates dust destruction by turning large grains into smaller grains which are more easily sputtered.

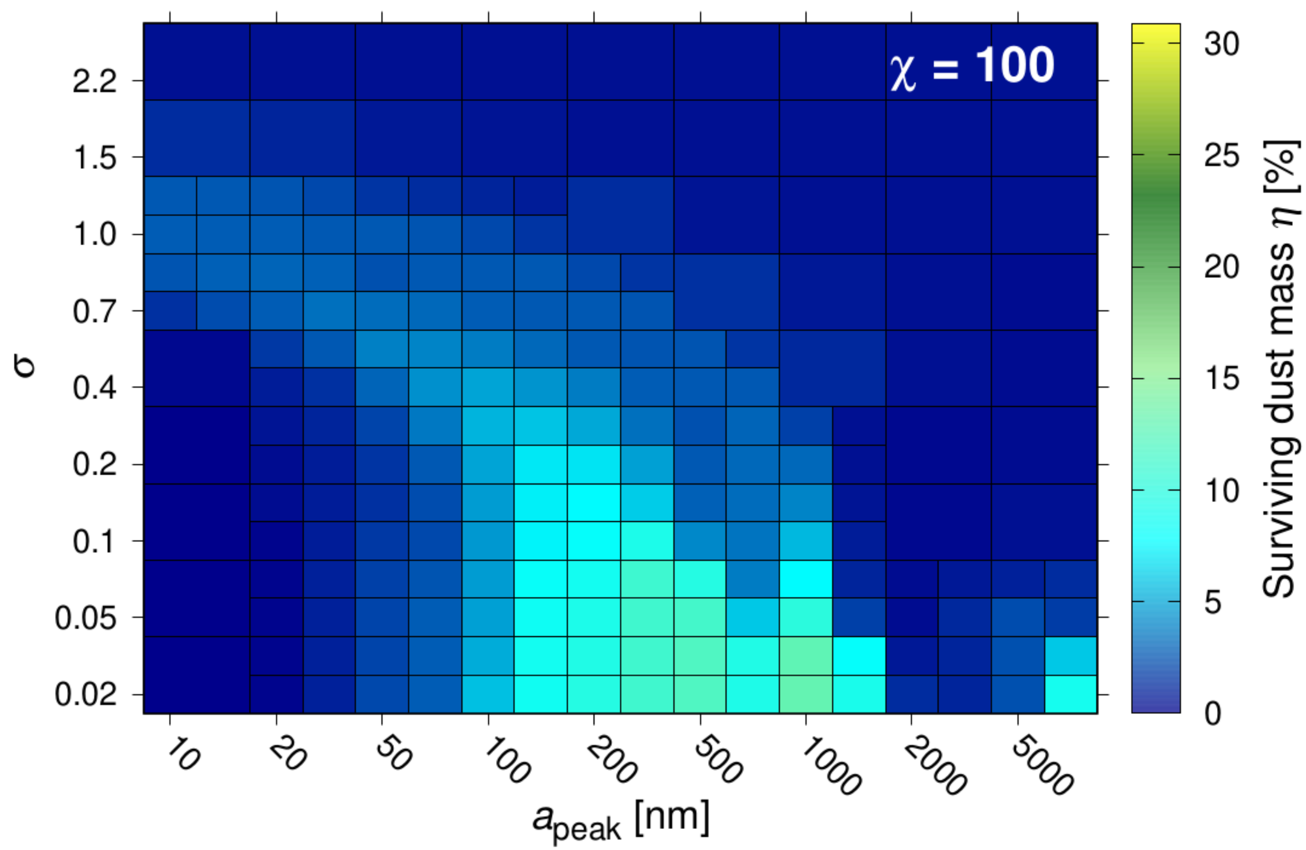
INITIAL DUST GRAIN SIZE DISTRIBUTIONS



Kirchschlager et al., 2019, submitted

Large grains and broad distributions result in the highest survival rates if we consider sputtering only.

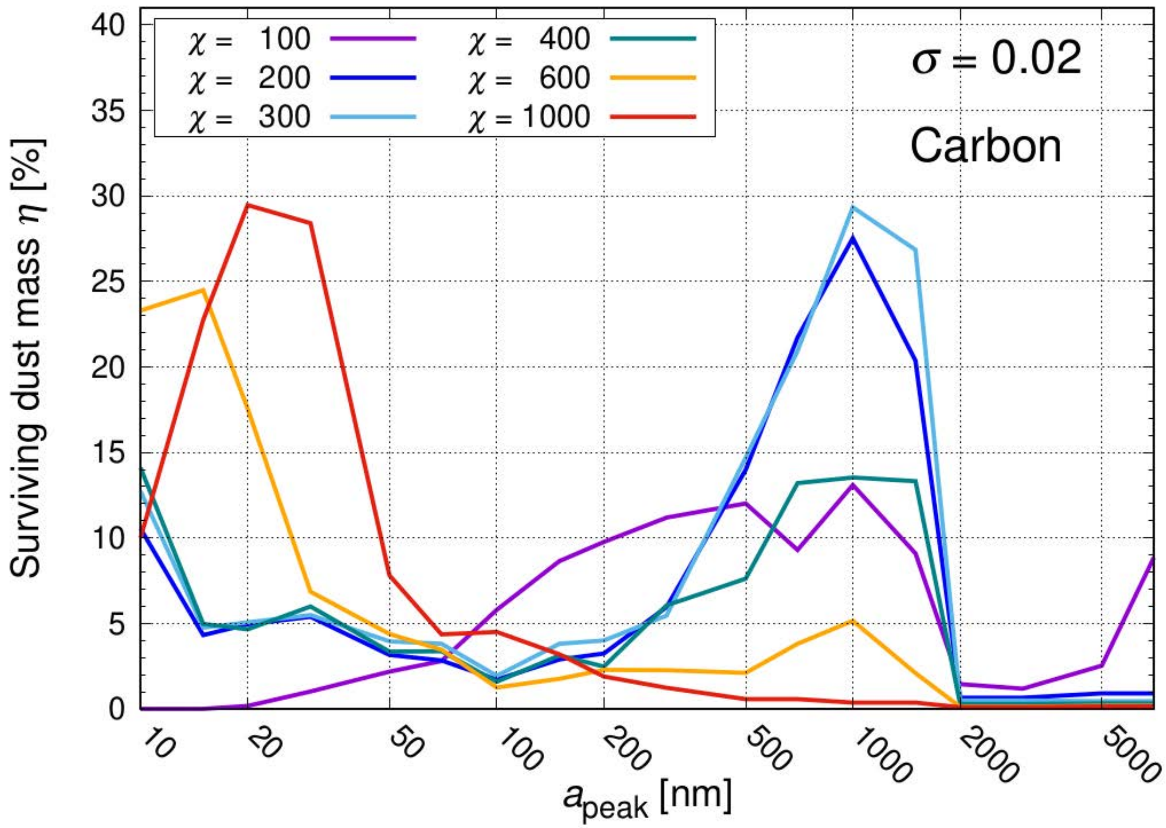
INITIAL DUST GRAIN SIZE DISTRIBUTIONS



Kirchschlager et al., 2019, submitted

Survival rates change significantly if we consider grain-grain collisions due to the interplay between collisions and sputtering.

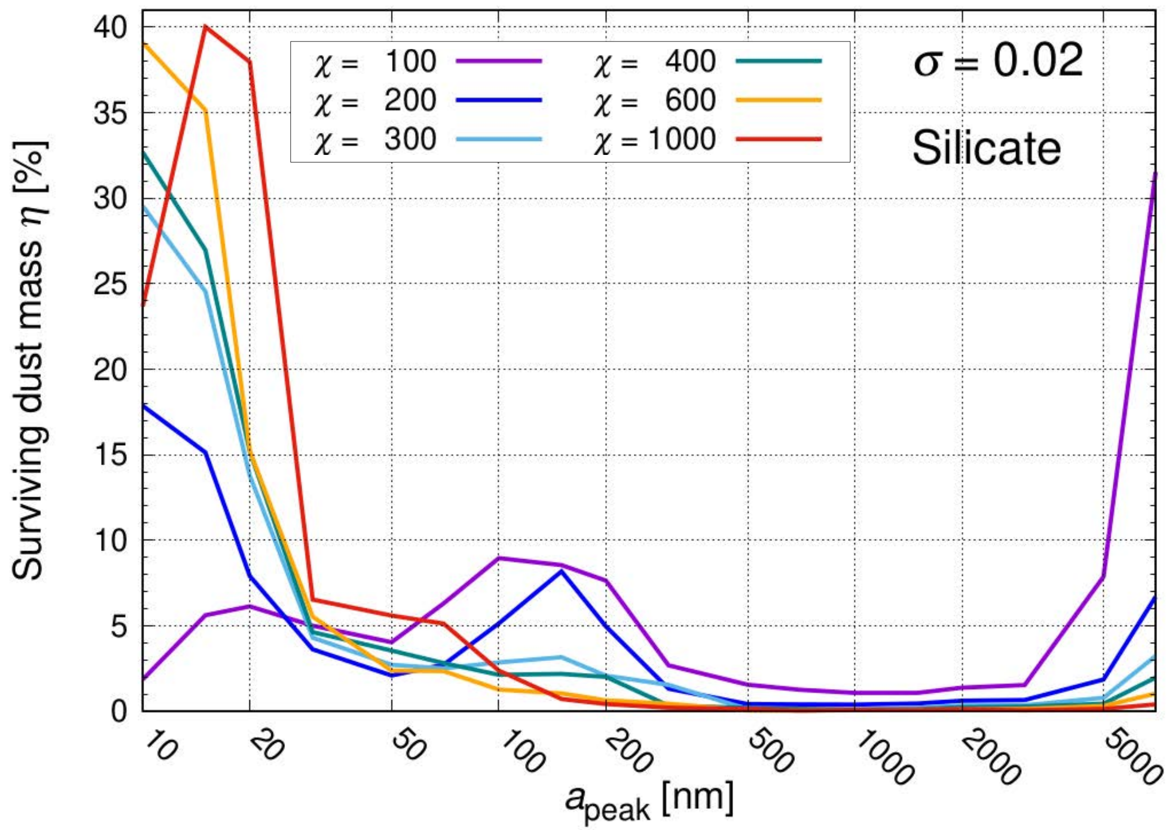
CLUMP-TO-AMBIENT-MEDIUM GAS DENSITY RATIO (C)



Kirchschlager et al., 2019, submitted

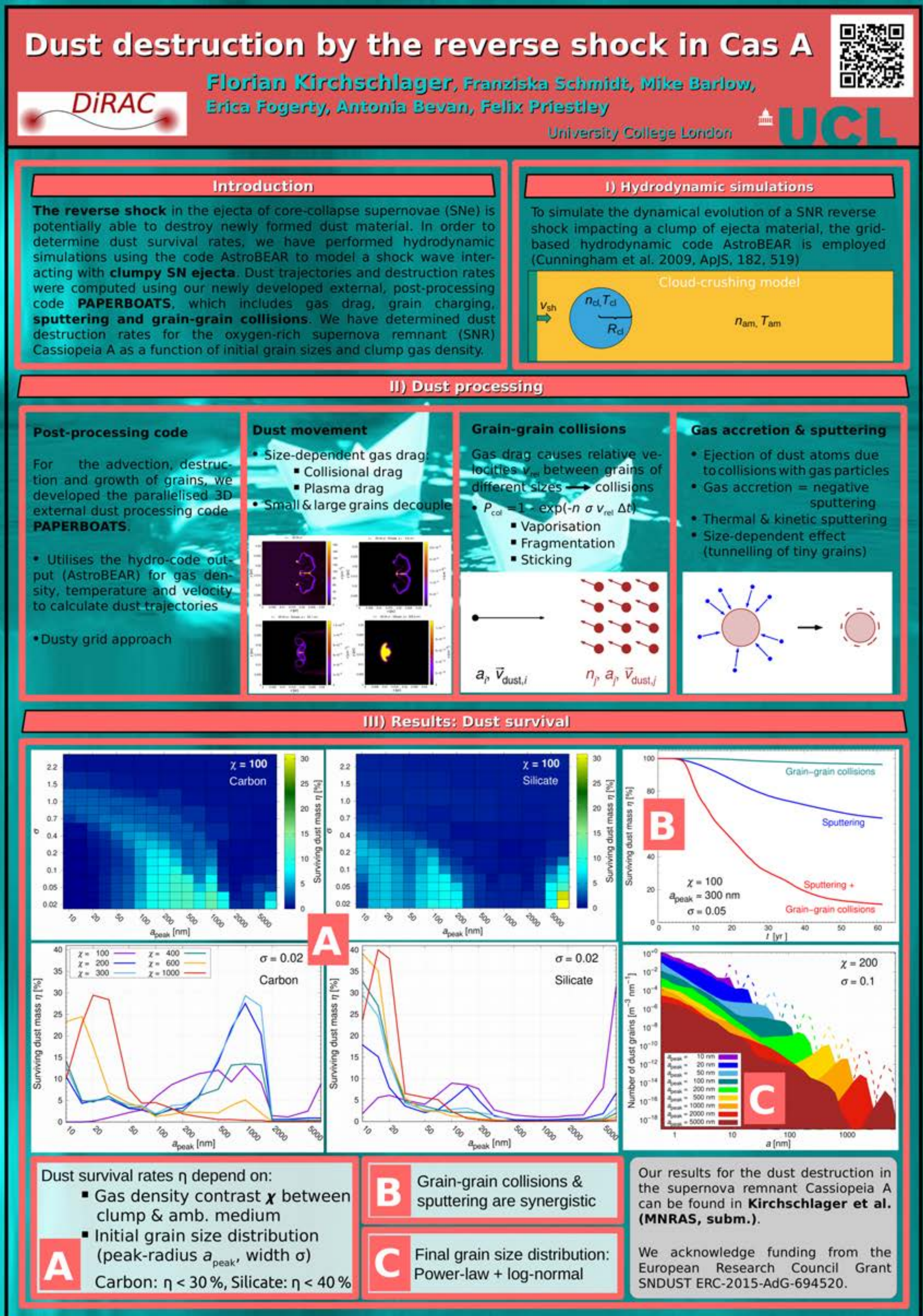
Depending on the initial clump-to-ambient-medium gas density ratio we find survival rates up to 30% for carbon dust.

CLUMP-TO-AMBIENT-MEDIUM GAS DENSITY RATIO ($MgSiO_3$)



Kirchschlager et al., 2019, submitted

Depending on the initial clump-to-ambient-medium gas density ratio we find survival rates up to 40% for silicate dust.



PAPERBOATS

An external dust processing code for HD simulations.

For more information please see the poster & have a chat with Florian and keep an eye out for Kirchschlager et al., 2019 (submitted)!

CONCLUSIONS

Summary

- We use hydrodynamics simulations and dust processing routines to model dust destruction in SNRs
- Grain-grain collisions facilitate dust destruction by sputtering and should not be neglected!
- Depending on grain species, grain size distribution and clump-to-ambient-medium gas density ratio we find survival rates up to 40%.

Future Work

- 3D simulations (DiRAC!)
- MHD simulations