# Particle fragmentation inside planet-induced spiral waves

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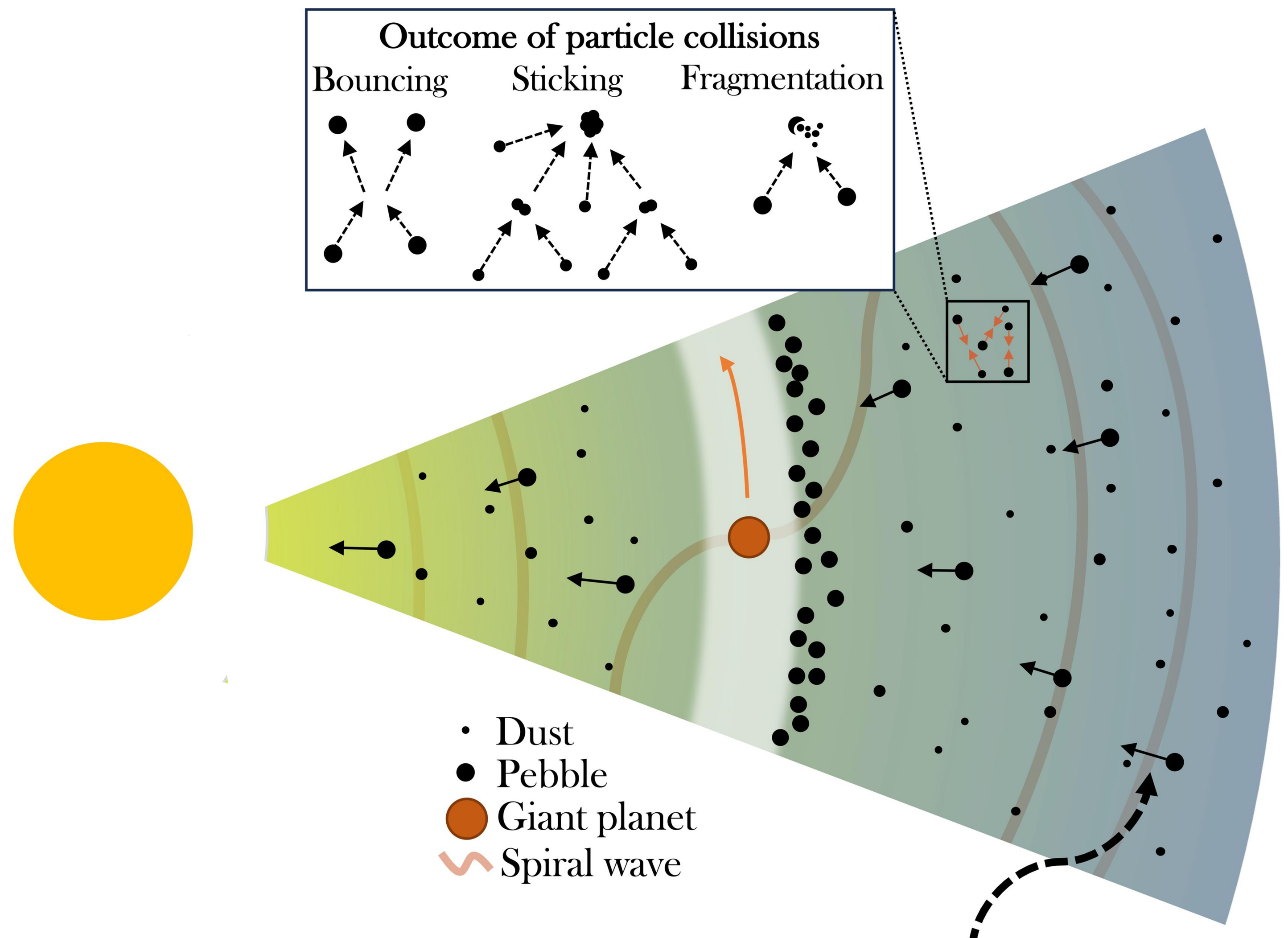
Link to paper


## Abstract

Growing planets interact with their surrounding protoplanetary disk, generating feedback effects that may promote or suppress nearby planet formation.

We study how spiral waves launched by planets affect the motion and collisional evolution of particles in the disk.

To this end, we perform local 2D hydrodynamical simulations that include a gap-opening planet and integrate particle trajectories within the gas field.


What happens when the drifting pebbles pass the spiral wave?

## Conclusions

Particle trajectories bend at the location of the spiral wave, and collisions occurring within the spiral exhibit significantly enhanced collisional velocities compared to elsewhere.

The collisional velocities within the spiral far exceed the typical fragmentation threshold, even for collisions between particles of relatively similar sizes and for planets that do not open deep gaps.

If collisions within the spiral are frequent, this effect could lead to progressively smaller particle sizes as the radial distance from the planet decreases, impacting processes such as gap filtering, pebble accretion, and planetesimal formation.

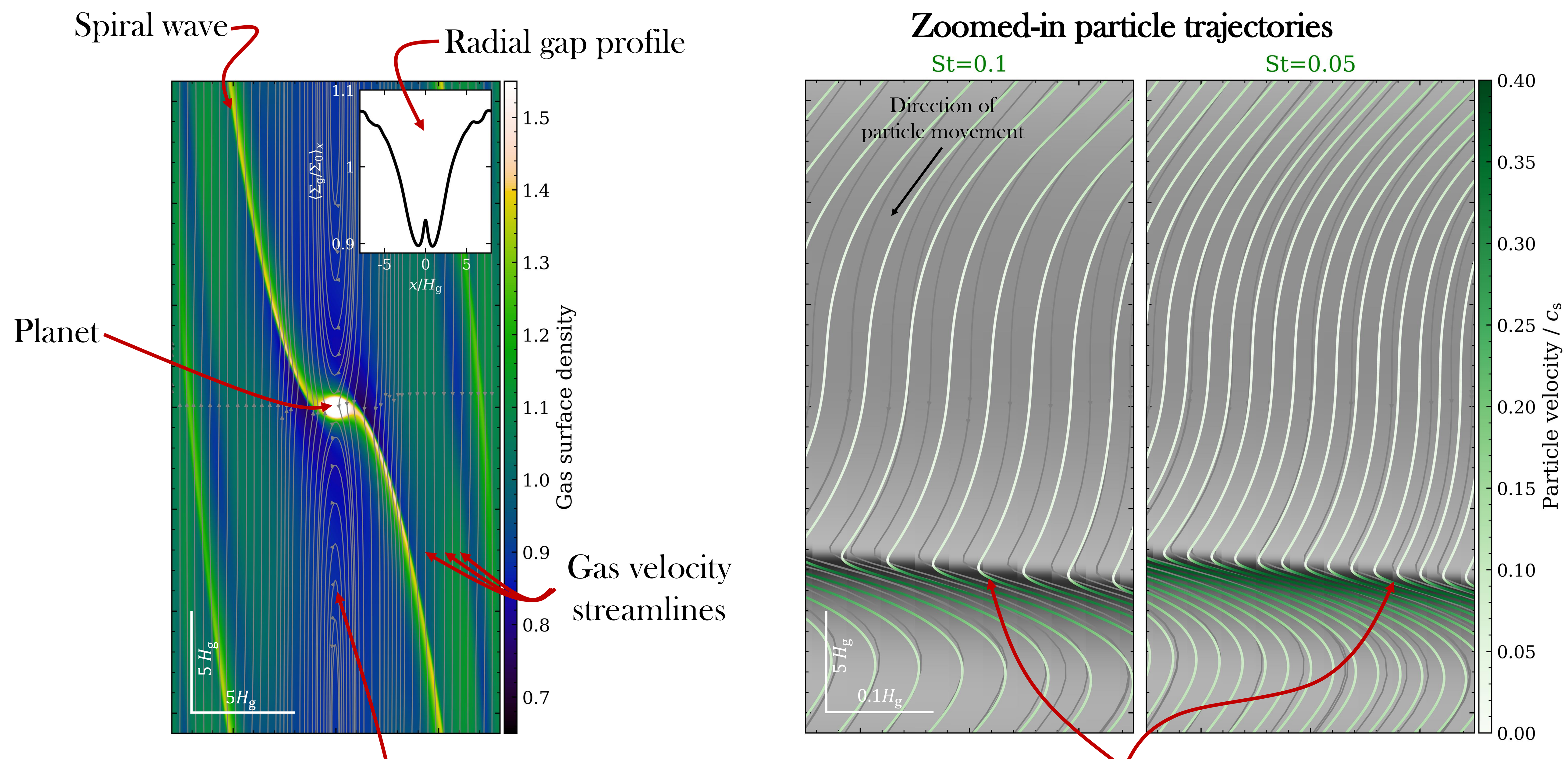
## Numerical method

**Gas**: We adopt the local-shearing-sheet approximation to model a small patch of the disk around the planet. Our simulation domain extends 16 gas scale heights in the radial direction and 32 gas scale heights in the azimuthal direction. The planet is modeled by a gravitational potential, and we consider planetary masses ranging from 0.25 to 1 thermal mass ($0.25M_{\rm th}$: shallow gap, no particle trapping at the gap edge; $1M_{\rm th}$: deep gap, particle trapping at the gap edge).

**Particles**: We use the equilibrium state of the gas disk to post-process the trajectories of particles with varying Stokes numbers (St). We consider St in the range 0.01–0.1.

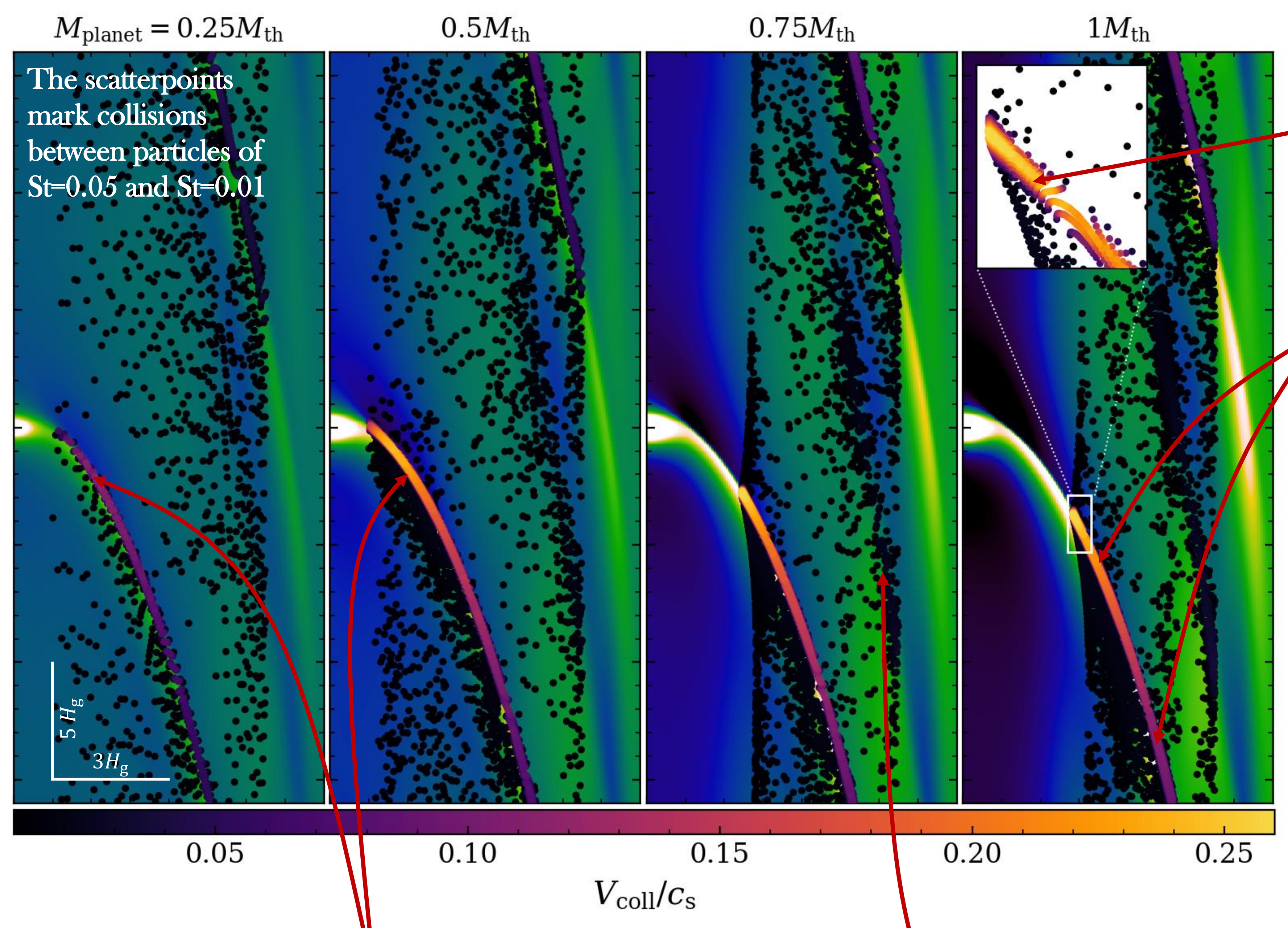
**Collisions**: We identify all intersections between particle trajectories with different St, without accounting for the timing of the collisions. The collisional velocity ($V_{\rm coll}$) is taken to be the relative velocity at these intersection points. Note: our model does not provide information on the frequency of collisions within the spiral wave.

## Effect of spiral on particle trajectories




* Particle trajectories bend sharply at the spiral wave passage
* Particles obtain high velocities at the spiral wave passage

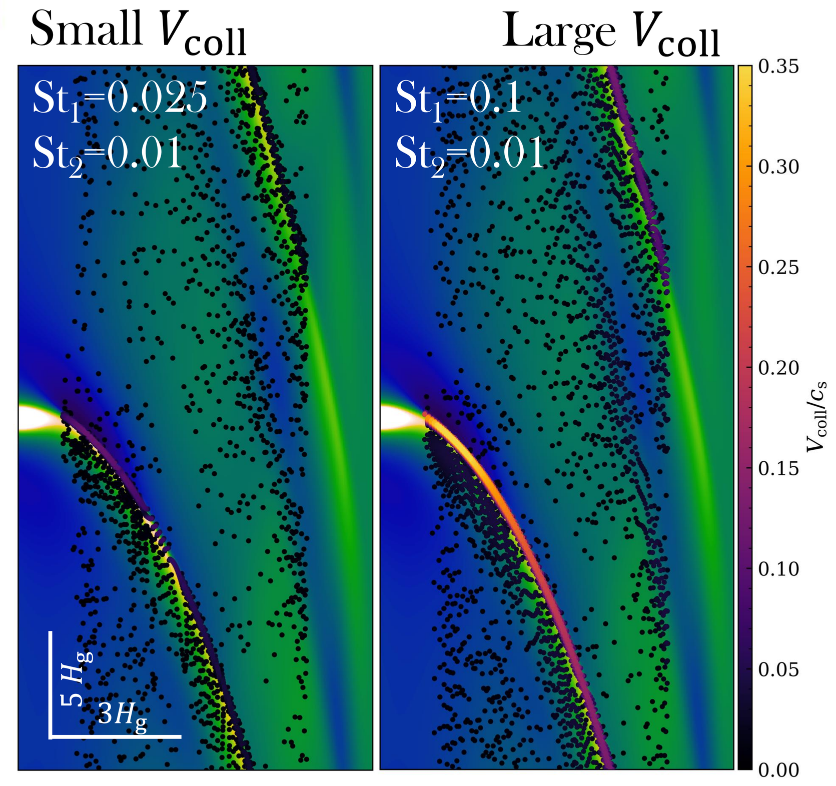
## Effect of spiral on particle collisions




$V_{\rm coll}$ increases with size difference

Small ΔSt → Small $V_{\rm coll}$

Large ΔSt → Large $V_{\rm coll}$




*Collisions inside spirals result in fragmentation*

($V_{\rm frag} = 10{\rm ms}^{-1} \approx 0.02c_s$ at Jupiter's orbit)

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