Massive collisions in debris discs: possible application to the β Pic disc

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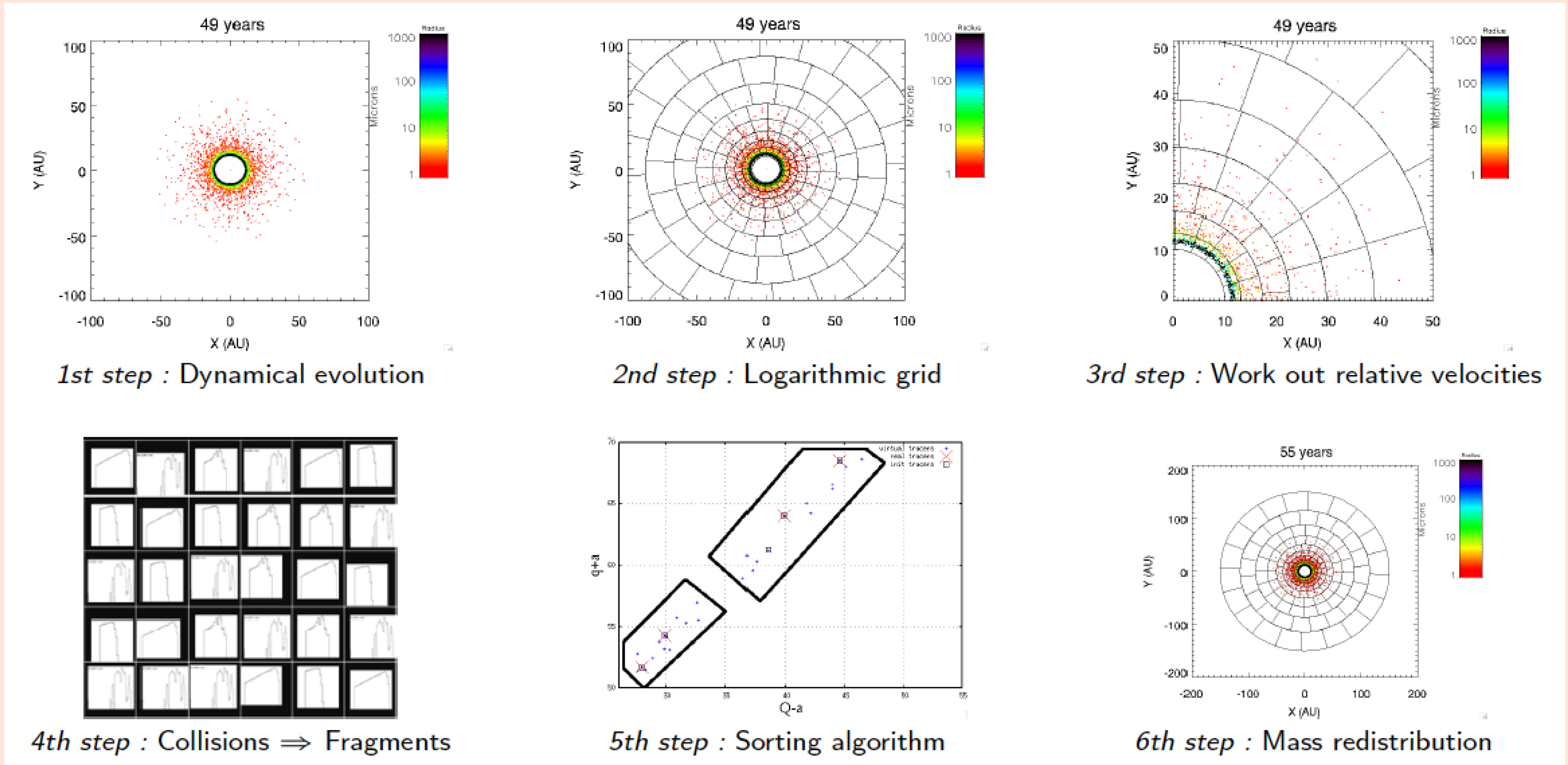
Context & Aim

We use **the new LIDT-DD code** to study **massive collisions in debris disc**. This hybrid model is the first to self-consistently couple the dynamical and collisional evolution in debris discs (Kral et al. 2013). It can be used to study numerous astrophysical cases : disc/planet interactions, exozodis, disc in binaries, etc.
Here we consider the case of the collisional break-up of massive planetesimals in young or mature debris discs. We investigate the signature left in the aftermath of such an event. We quantify the lifetime and luminosity of the post-breakup debris cloud and assess its observability, in photometry and imagery, with present and future observing facilities.

The LIDT-DD code

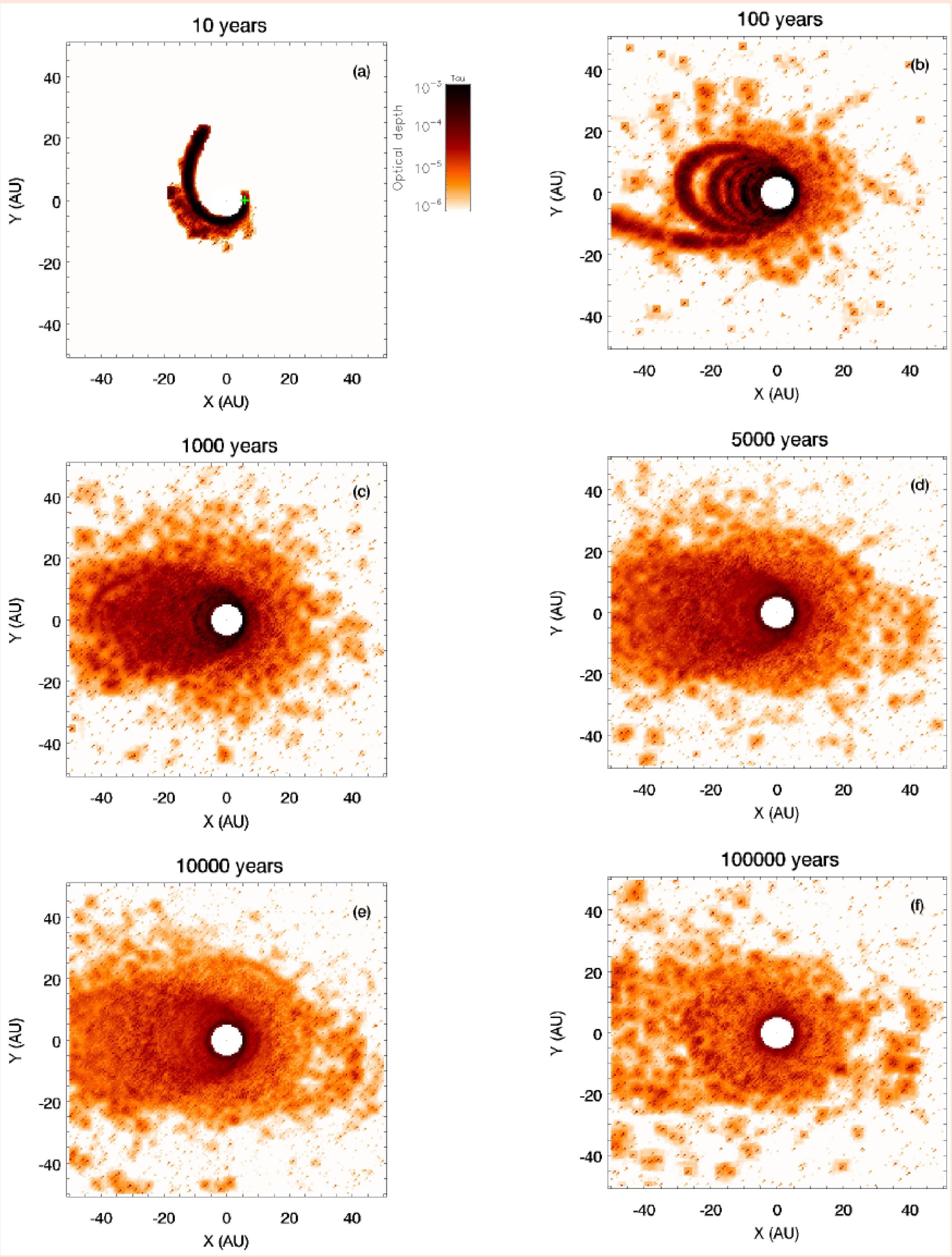
LIDT-DD is an **hybrid 3-D code that couples dynamical and collisional evolution**. It follows the evolution of dust grains with great details accounting for radiation pressure. It is able to provide images or SEDs thanks to a coupling with the radiative transfer code GRaTer.
Grains of given sizes at a given location in a disc are grouped into "super-particles" (called tracers), whose orbits are tracked with an N-body code and whose mutual collisions are treated using a particle-in-a-box scheme. The process step by step is explain here below :



Schematic description of the different procedures within a typical time step in LIDT-DD.

Massive collisions in debris discs : collisional simulation

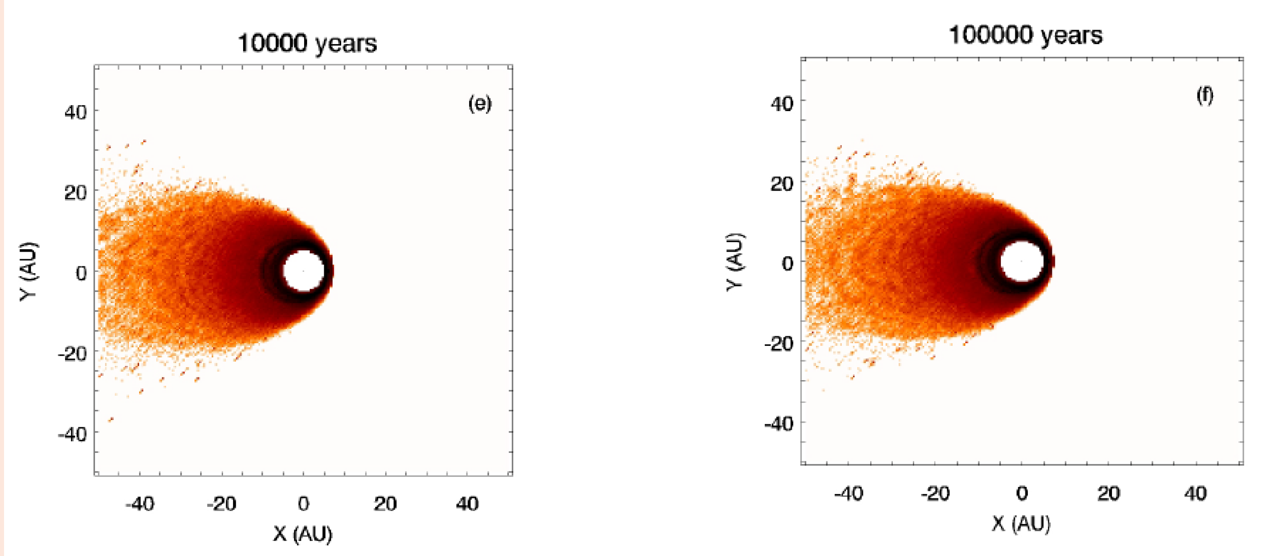
▶ Collisional simulation with LIDT-DD of the aftermath of a massive collision :



Evolution of the system after the release of 10^{21}kg of material at 6 AU from the central A7V star. 2-D map of the optical depth at different epochs after the initial breakup. The green cross on plot (a) is the location of the initial breakup. The color index goes from 10^{-3} (black) to 10^{-6} (light orange). Kral et al. 2014, subm

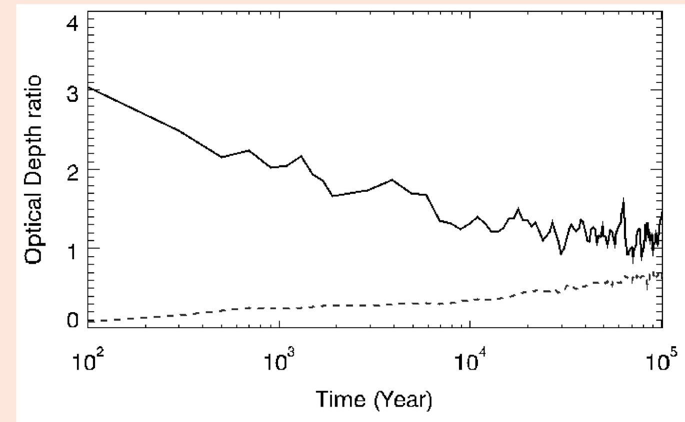
Comparison with Dynamical simulations without collisions

▶ Purely dynamical evolution of the same violent breakup (no collisions) :

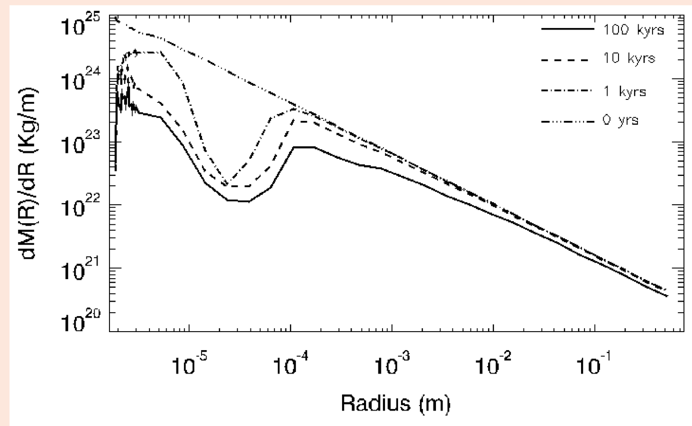


Same as the previous figure, without collisions.

Disc asymmetry and PSD evolution with collisions



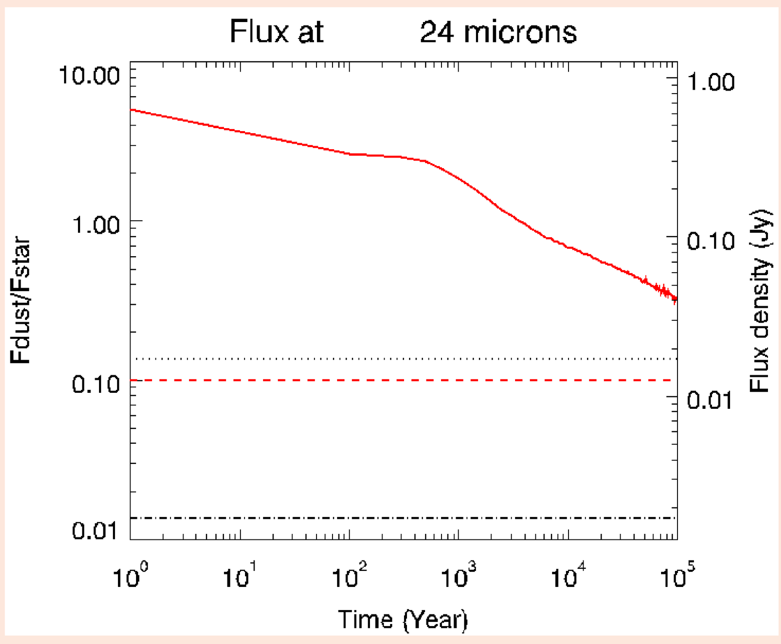
Evolution of the system's left-right asymmetry, as quantified by the right-to-left flux ratio within the inner bright ring at $\simeq 6$ AU (top) and in the region beyond it (bottom).



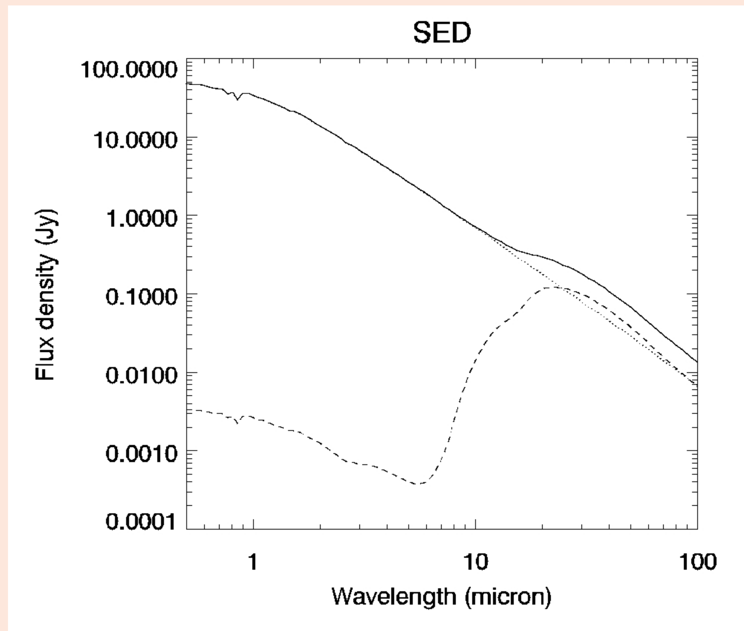
Evolution of the differential mass distribution $\mathbf{dM/dR}$ within the inner bright ring (at $\simeq 6$ AU) at 4 different epochs after the initial breakup.

Observability of such massive impacts

▶ Detectability by photometry :

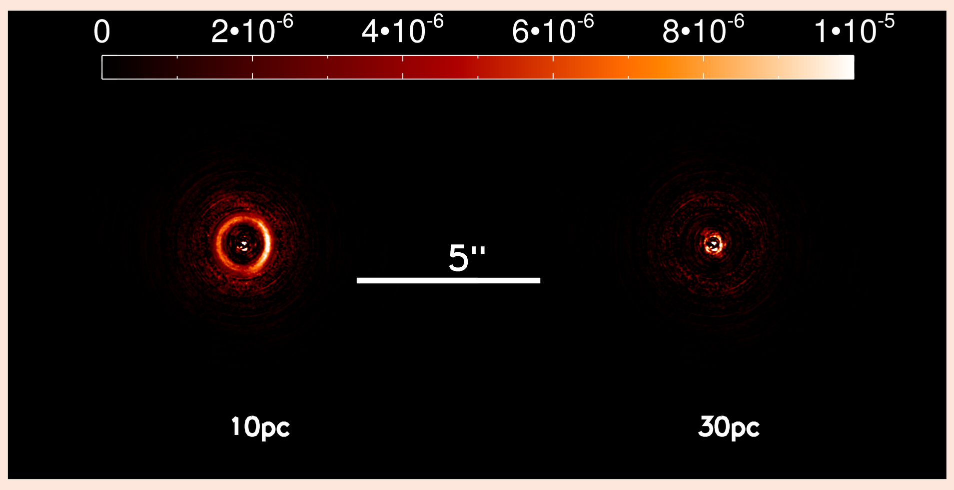


Evolution of the disc-integrated flux at 24 μm, as computed with GRaTer (red solid line). The dotted and dash-dotted black lines give the maximum possible luminosity, at 1Myrs and 10Myrs, for a hypothetical collisional cascade at steady-state.

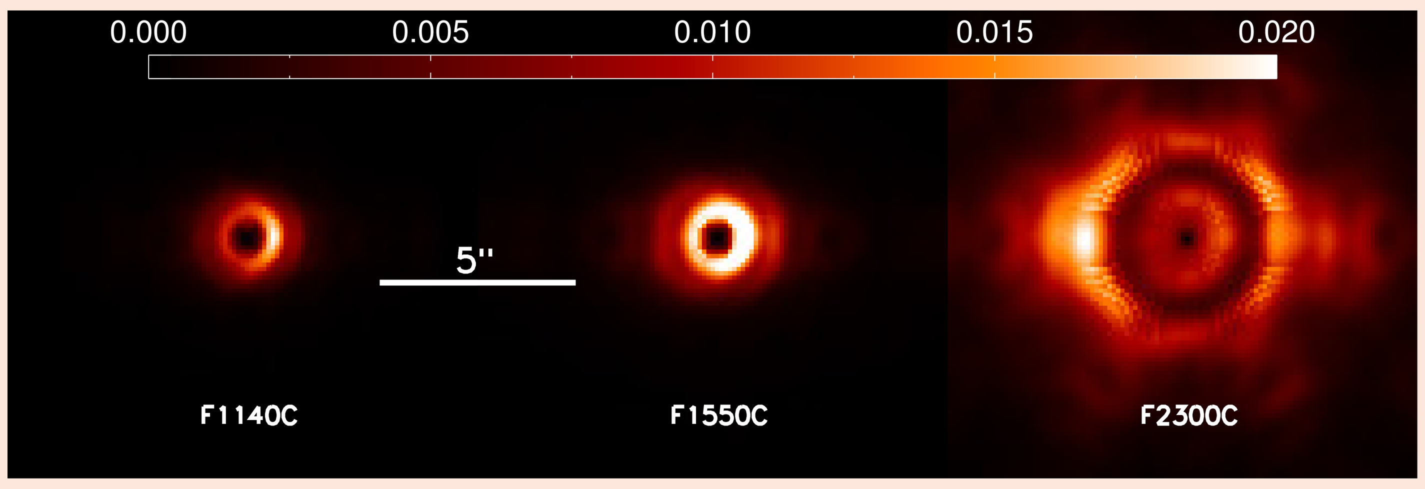


SED of the integrated system, as estimated with the GRaTer package at 10 kyrs after the breakup. The full line is for the total emission, the dashed line for the sole dust disc and the dotted one for the photosphere.

▶ Observability in imagery with SPHERE/VLT and MIRI/JWST :



Synthetic images at 1.6μm for the SPHERE/VLT instrument, for the system in its "asymmetric disc" phase at $\mathbf{10^4}$ years after breakup, at 10 (left) and 30 pc (right) obtained with the reference star subtraction method. The color scale gives the flux ratio with respect to the brightest pixel in the PSF.



Same as previous image with the MIRI/JWST instrument at 10 pc with different filters at 11.4, 15.5 and 23μm (from left to right).

Perspectives

- **Full modeling of the β Pic** system with LIDT-DD
- Study of disc(s)/planet(s) interactions with this global model
- Test transient effects (avalanches, comet evaporation, passage of a pertuber)
- Model exozodiacal clouds
- Possible **refinement** of LIDT-DD to include sublimation, accretion, gas

Summary and Conclusion

We investigate the aftermath of a massive-collision in a debris disc using the new-generation LIDT-DD code. We find that the breakup of a Ceres-sized body at 6 AU creates an asymmetric dust disc that is homogenized, by the coupled action of collisions and dynamics, on a timescale of a few $\mathbf{10^5}$ years. The particle size distribution in the system, after a transient period where it is very steep, relaxes to a collisional steady-state law after $\sim \mathbf{10^4}$ years. The luminosity excess in the breakup's aftermath should be detectable by mid-IR photometry, from a 30 pc distance, over a period of $\sim \mathbf{10^6}$ years that exceeds the duration of the asymmetric phase of the disc (a few $\mathbf{10^5}$ years). We derive synthetic images for the SPHERE/VLT and MIRI/JWST instruments, showing that such collisions should be clearly resolved from a 10 pc distance. Images at 1.6μm (marginally), 11.4 and 15.5μm would show the inner disc structures while 23μm images would display the outer disc asymmetries. LIDT-DD can be used to **fully model the Beta-Pic system** accounting for the planet, disc, collisions, asymmetries and reproduce the observations such as SED, brightness profiles, etc.

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