The observational impact of dust trapping in self-gravitating discs

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1. Gravitational instability and the growth of spiral substructure

Young, massive discs may be **self-gravitating (SG) if**

$$\frac{M_{disc}}{M_{star}} \gtrsim 10^{-1} - 10^{-2}$$

The susceptibility of a disc to the growth of a **gravitational instability (GI)** can be determined by considering the **Toomre parameter** (Toomre 1964),

$$Q = \frac{c_s \Omega}{\pi G \Sigma}$$

GI may lead to the growth of grand design **spiral substructure when $Q \lesssim 1$.**

2. Trapping of dust in spirals leads to enhanced millimeter emission

Gas-dust drag due to gas orbiting with sub-Keplerian velocities causes radial migration of solids, and **concentration of dust grains at pressure maxima in spiral regions**.

Dust-to-gas ratios of **millimeter and centimeter grains** may be **enhanced** by up to **an order of magnitude** in spirals.

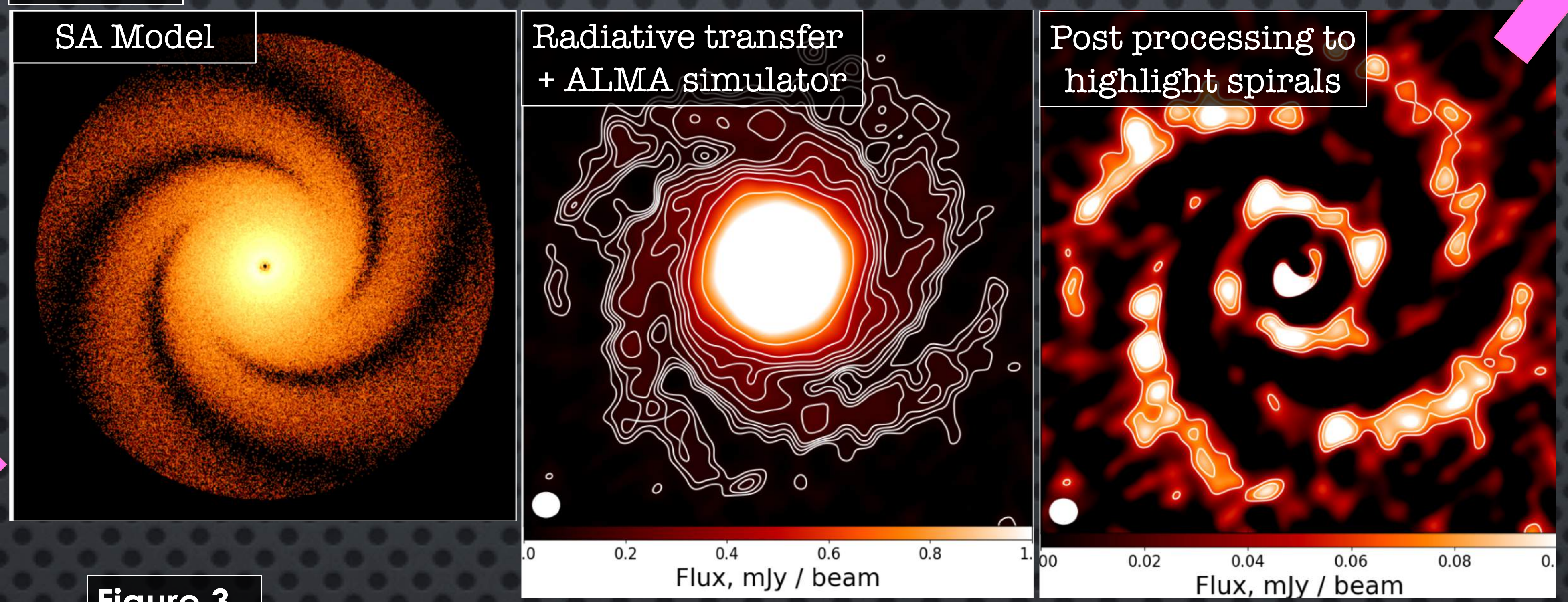
3. Semi-analytic models of GI discs, with dust trapping

Hydrodynamic simulations including gas-dust dynamics is expensive.

We develop an efficient semi-analytic (SA) model of SG discs, with realistic dust distributions informed by hydrodynamic simulations.

Radiative transfer models and the **ALMA simulator** allow us to generate **synthetic observations of these discs**.

Figure 1



4. Dust trapping leads to enhanced emission

Enhanced millimetre emission in **spirals** means they **appear sharper** for the same disc properties, thus **broadening the potential parameter space** within which we may observe SG spirals (see Figure 2.).

This is **most effective** when the dust mass budget is dominated by millimetre and centimetre grains (i.e. **when $a_{max} = 1\text{mm} - 10\text{cm}$** in Fig 3).

When the dust mass budget is dominated by micron or metre sized solids, arm-interarm contrasts are low and **spirals become challenging to resolve** (i.e. **when $a_{max} = 10\mu\text{m} - 100\text{cm}$** in Figure 3).

Figure 2

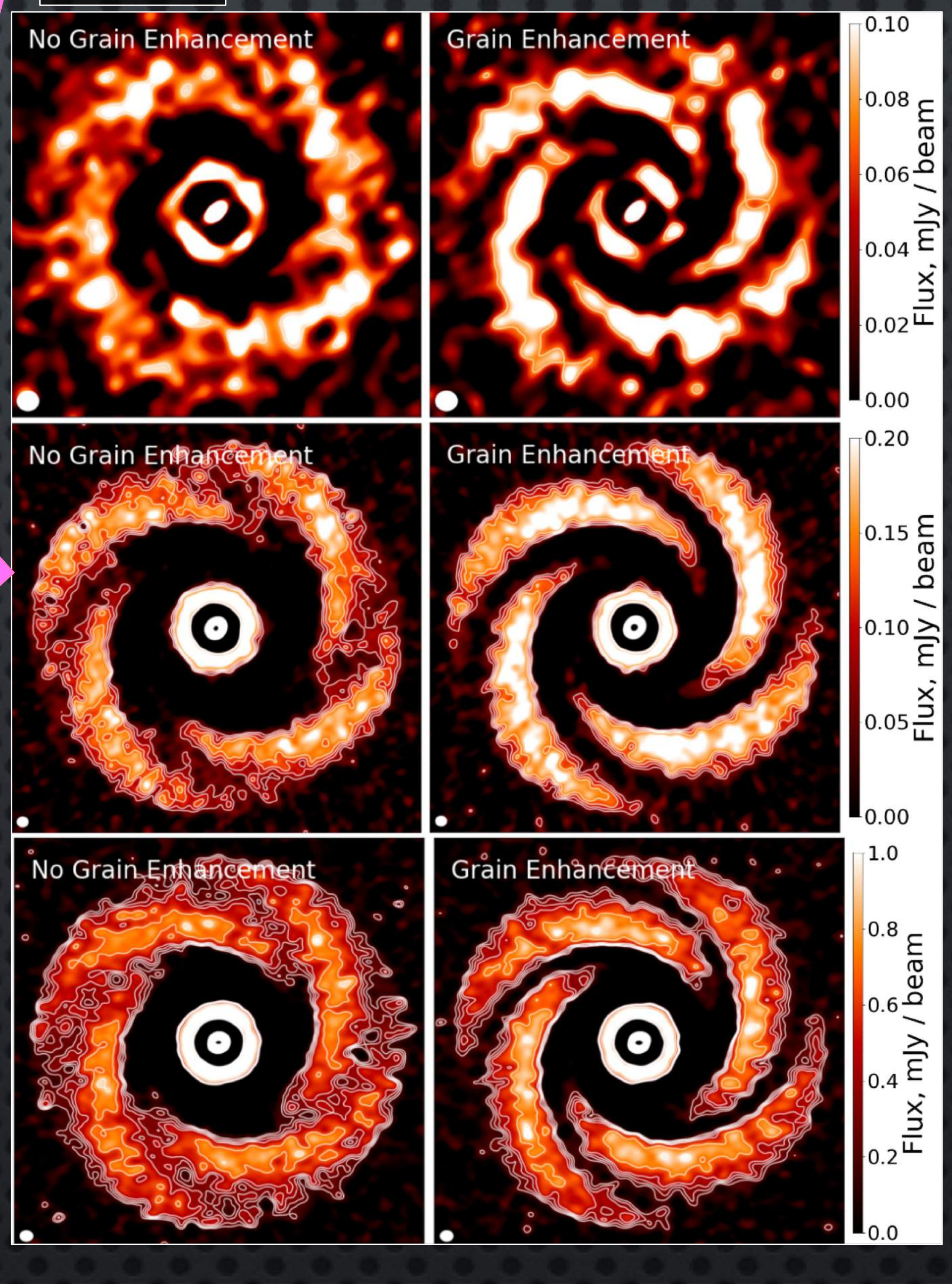
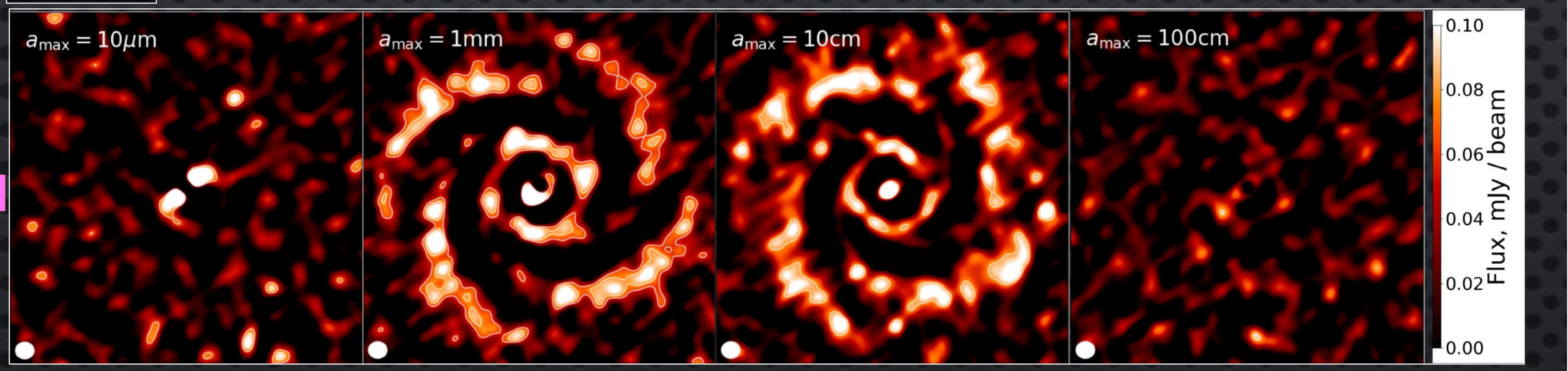


Figure 3



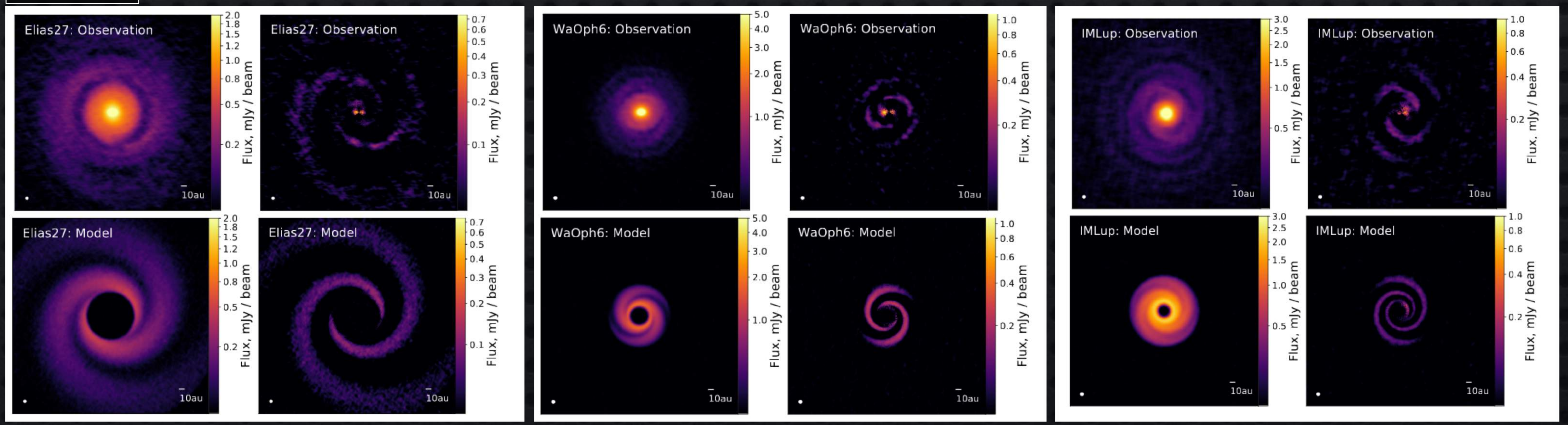
5. Spirals observed in the DSHARP sample are consistent with GI

We can use these models to **analyse the spirals observed in the DSHARP survey.**

We set up discs with mass accretion rates and outer radii equal to those measured from 3 DSHARP systems, with realistic dust distributions and self-consistently calculated spiral amplitudes.

The observed spirals in Elias 27, WaOph 6 and IM Lup are all consistent with being driven by GI (see Figure 4).

Figure 4



6. Conclusions

We develop a **semi-analytic model for generating computationally efficient synthetic observations of SG discs, with a realistic prescription for dust trapping.**

Dust trapping of millimetre-centimetre grains in SG spirals **leads to significantly enhanced millimetre emission.**

We predict that **disc masses as low as $\frac{M_{disc}}{M_{star}} = 0.1$ may drive spirals observable with ALMA** - lower than previously predicted.

The spirals observed in Elias 27, IM Lup and WaOph 6 are all consistent with being driven by GI.

References - Toomre A., 1964, ApJ, 139, 1217