Hydro- and Thermodynamic Effects on the Circumbinary Disc Shape

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Half of all stars are in binary or multiple systems. Binary carve large asymmetric cavities into their discs threaded by streams between the binary and inner disc edge and force spiral patterns.[1]
Therefore, circumbinary discs are common paths of star and planet formation that can help us constrain the underlying physics for general protoplanetary discs.

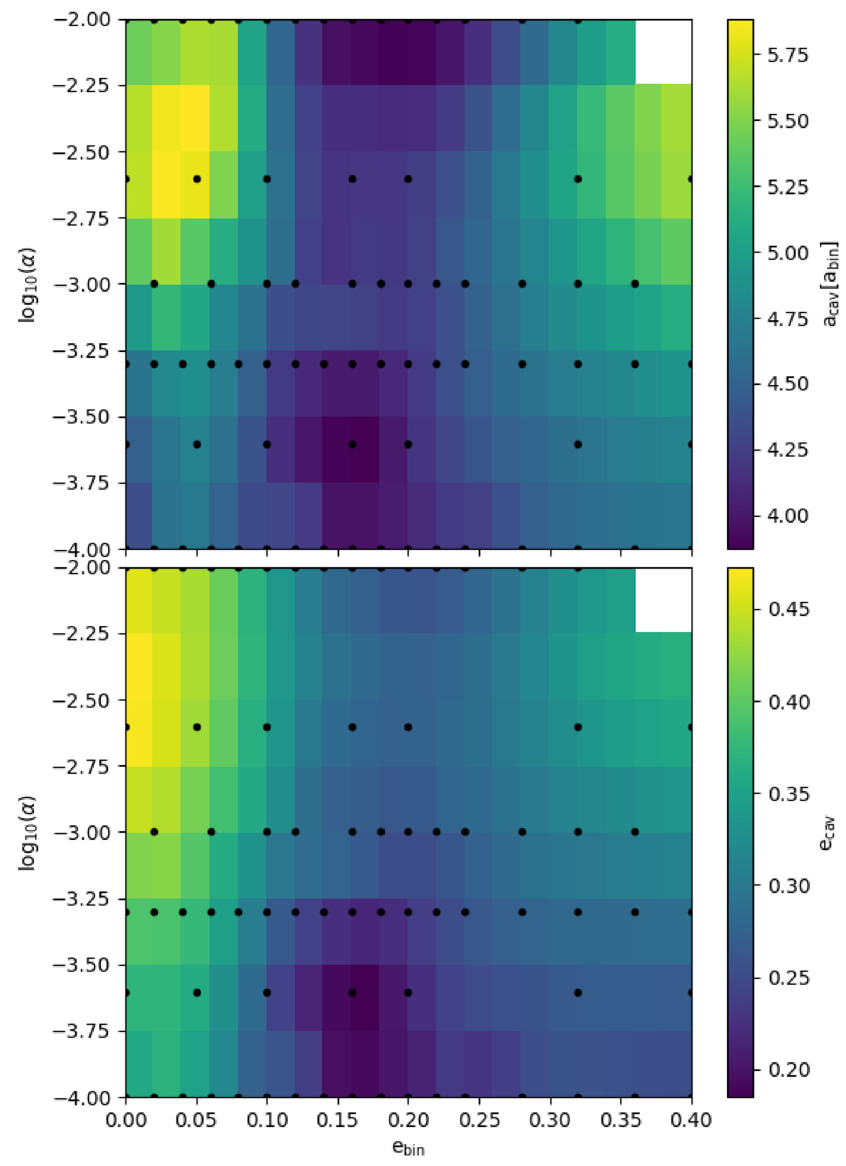
The question to investigate becomes:

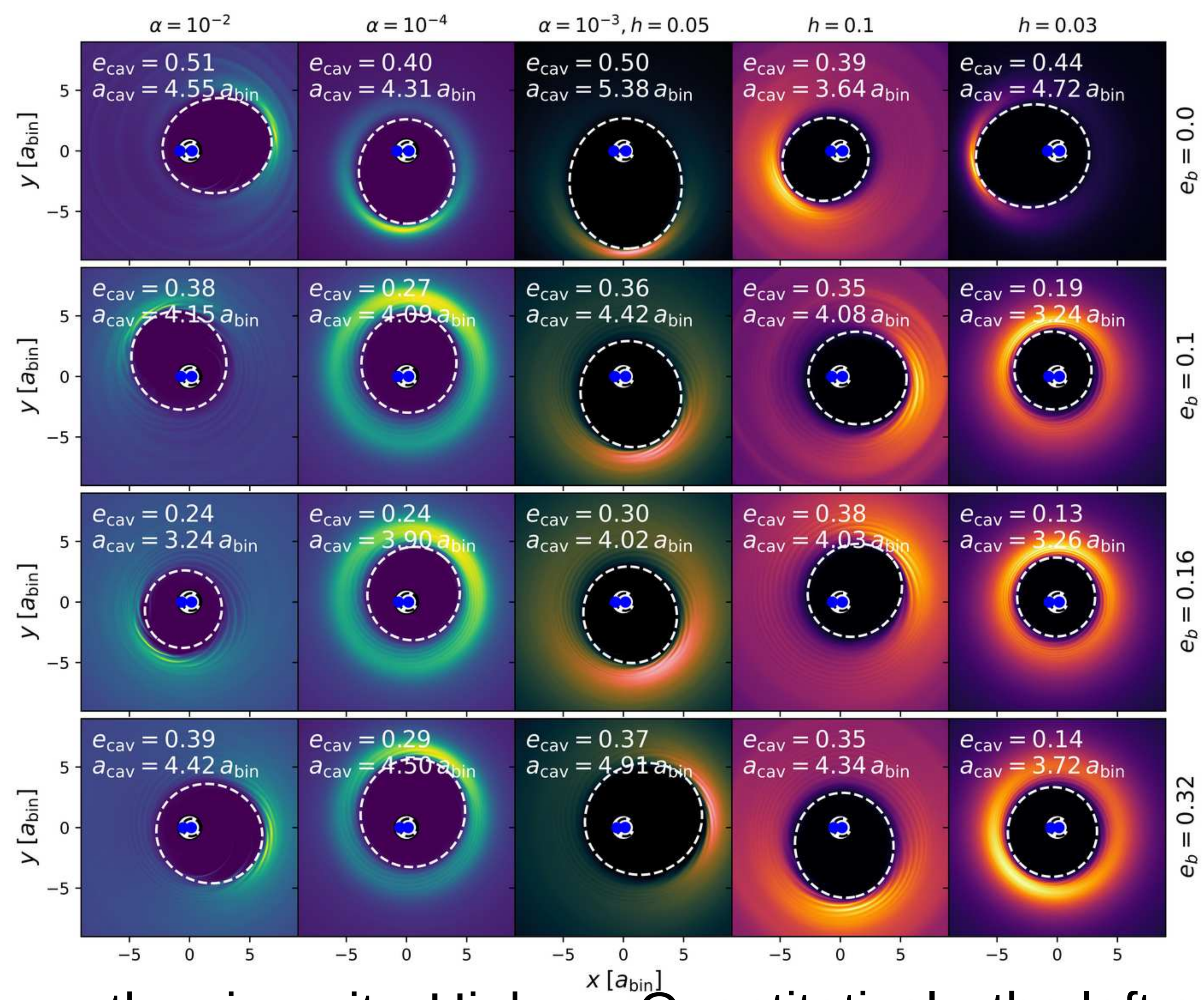
- **Can the disc shape constrain physical parameters?**
- **Are there limiting case that relate to one specific setup?**
- **How do the effect interact?**

To investigate circumbinary disc we perform 2D hydrodynamic simulations using a GPU-version[2] of the PLUTO[3] code. We assume an Shakura-Sunvaey viscosity model. ($\nu=\alpha c_s H$)

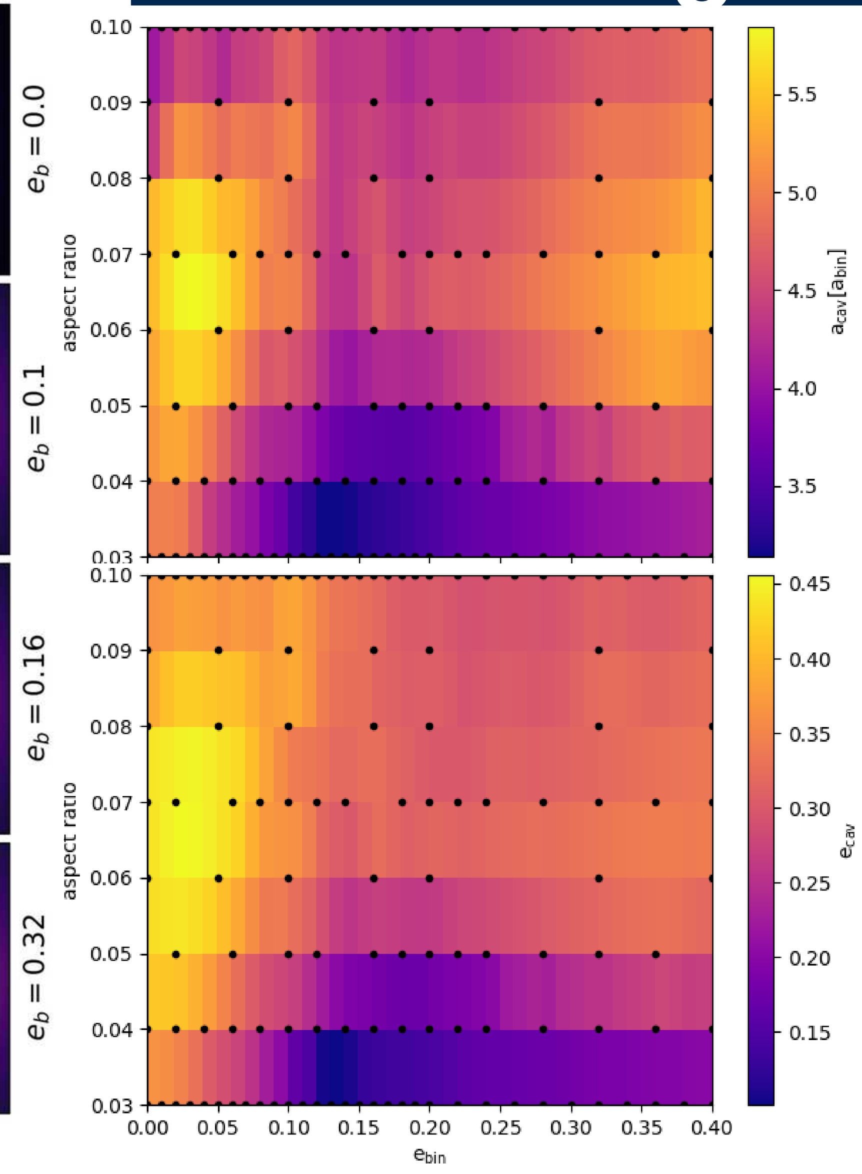
Locally isothermal models

Viscous α





Scale height

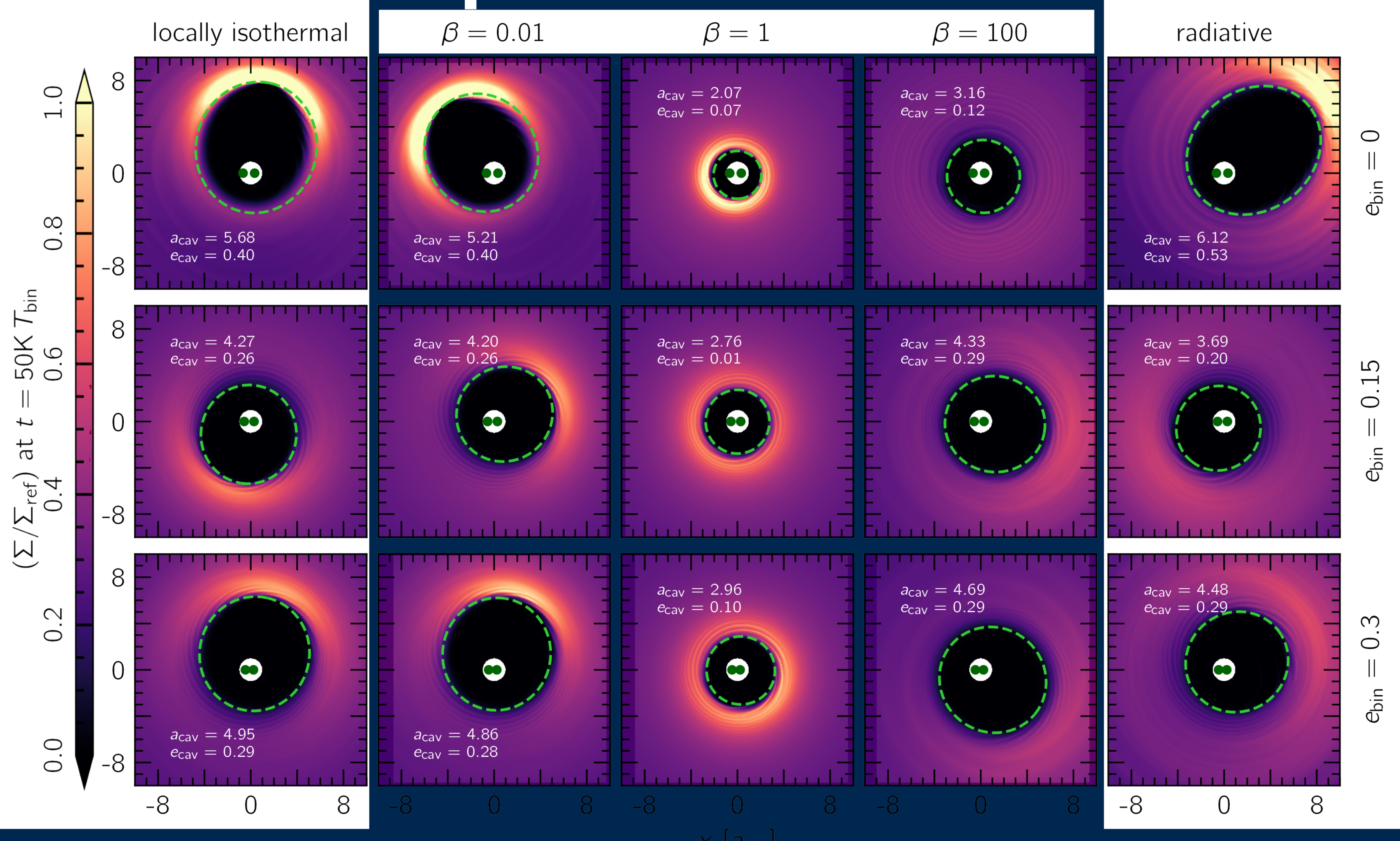


The eccentricity of the cavity depends on the viscosity. High viscosities lead to more eccentric cavities. In the mid figure **(left panels) the viscous α** was varied from 10^{-2} to 10^{-4}. The inner disc becomes more circular and the density maximum wider. For lowering **H/R (right panels)** the disc become more circular as well and the density at the edge of the disc is more evenly distributed, but the width of the density features is smaller as for varying α.

Quantitatively, the left and right figures map the full parameter space of viscosities and binary eccentricities with the correlated inner cavity size and eccentricity for α at H/R=0.05 and H/R at $\alpha=10^{-3}$. The highest eccentricity is reached around $\alpha=10^{-2.4}$ and H/R=6%.
More viscous disc are more circular and smaller, as the size is balanced by the infalling disc against the motion of flung-out streamer material.

Effects of cooling

iso parametrized radiative

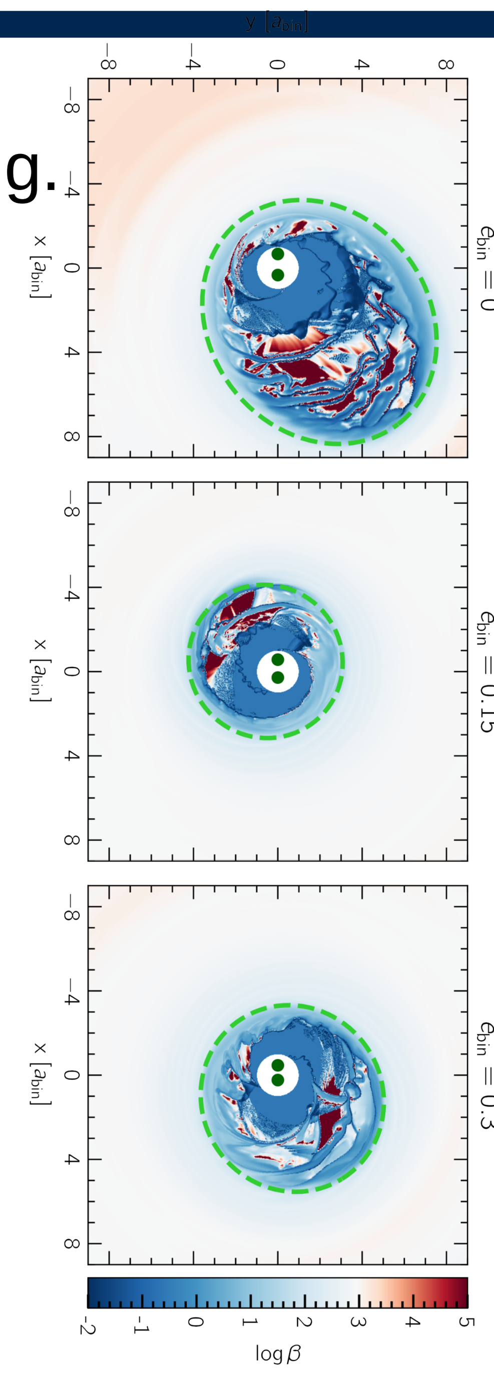


In the models we assume a_{bin}=0.2au and $\alpha=10^{-3}$. The heating due to viscous heating.

The disc emits blackbody radiation, that depends on the disc opacity $\tau_{eff}(T, \Sigma)$

$$Q_{cool} = -2\,\sigma_{sb}\frac{T^4}{\tau_{eff}}$$

In radiative models the cavities are large and eccentric and the pressure maximum in the inner disc is more diffuse.



Looking at the temperature relaxation times β (right Fig.), the cavity cools very quickly comparable to loc. Iso.
The disc has a long cooling time leading to stronger pressure that diffuses the maximum.

The temperature relaxation is scaled by β in units of the local orbit velocity.[4]

$$\frac{\partial T}{\partial t} = \frac{T - T_0}{\beta}\Omega_K$$

- Small β reproduce loc. Isothermal models
- Large β overpressure the disc and can lead to circular cavities for small e_{bin}
- β ≈ 1 leads to wave damping.[5] Cavities are not excited and are set by the unstable region[6].

Limiting the cooling to 1 parameter can not represent the cavity better than iso models.

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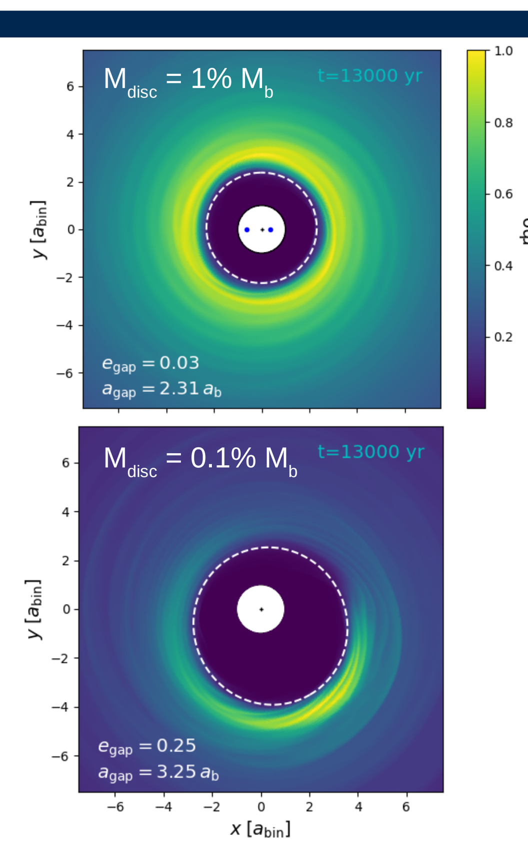
Take home & next steps

- **Cavity is smallest for e_{bin}=0.18**
- **Cavity is biggest for $\alpha=10^{-2.4}$ & H/R=6%**
- **β ≈ 1 collapses cavity to unstable region.**
- **Disc and cavity cool differently.**



Stellar irradiation could change temperature/ opacity for different disc sizes and evolution times (see right Fig.)