Discs in perturbed binary systems

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Abstract

We perform simulations to follow the evolution of low-mass circum-primary discs in binary star systems where the companion orbit is perturbed by a passing star. Preliminary results from various configurations of the systems show some promise that planet formation and evolution in the disc may be significantly affected.

Introduction

Planet formation is thought to occur in discs around young stars. These young stars are often found in binary systems in dense young clusters. Planet forming circum-primary discs may form in wide binary systems unaffected by the distant companion. But interactions between the companion and other stars in the cluster can alter the companion's orbit and cause the disc to undergo regular perturbations. This could significantly affect the formation of planets in the disc.

Simulations

We firstly prepare a low-mass stable disc with initial configurations and radiation treatment as described in Stamatellos & Whitworth (2007) which is then evolved in isolation. The initial set-up of the isolated disc is summarized as follows.

- Central star: M_{star} = 0.5 M_{sun}, R_{star} = 0.5 AU
- Disc: M_{disc} = 0.06 M_{sun}, R_{disc} = 2-40 AU with initial surface density (Σ) as shown in Fig.1 (black line)
- Number of SPH particles N_{SPH} = 120000

After the disc settles down the companion of mass 0.1 M_{sun} is added at 300 AU with various combinations of orbital eccentricity (e) and inclination angle (i). All simulations are performed by using the SPH code SEREN (Hubber et al. 2010).

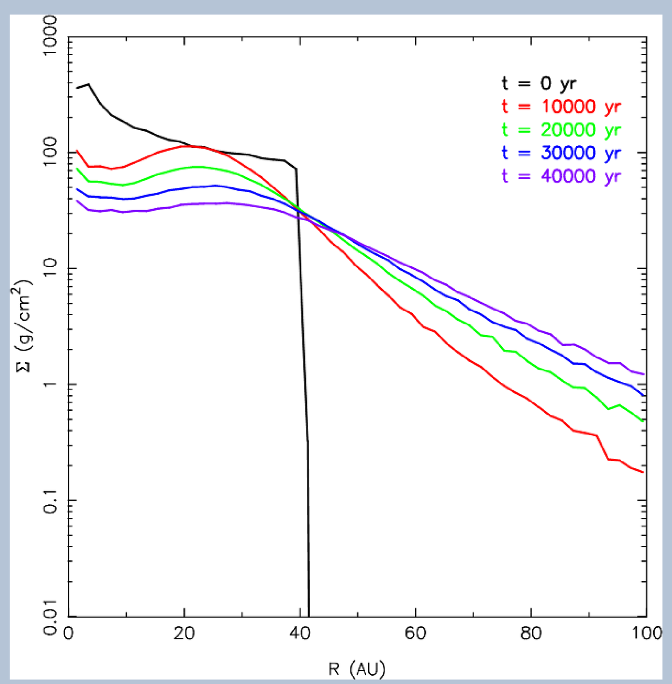

Figure 1. Average surface density of the isolated disc at different times.

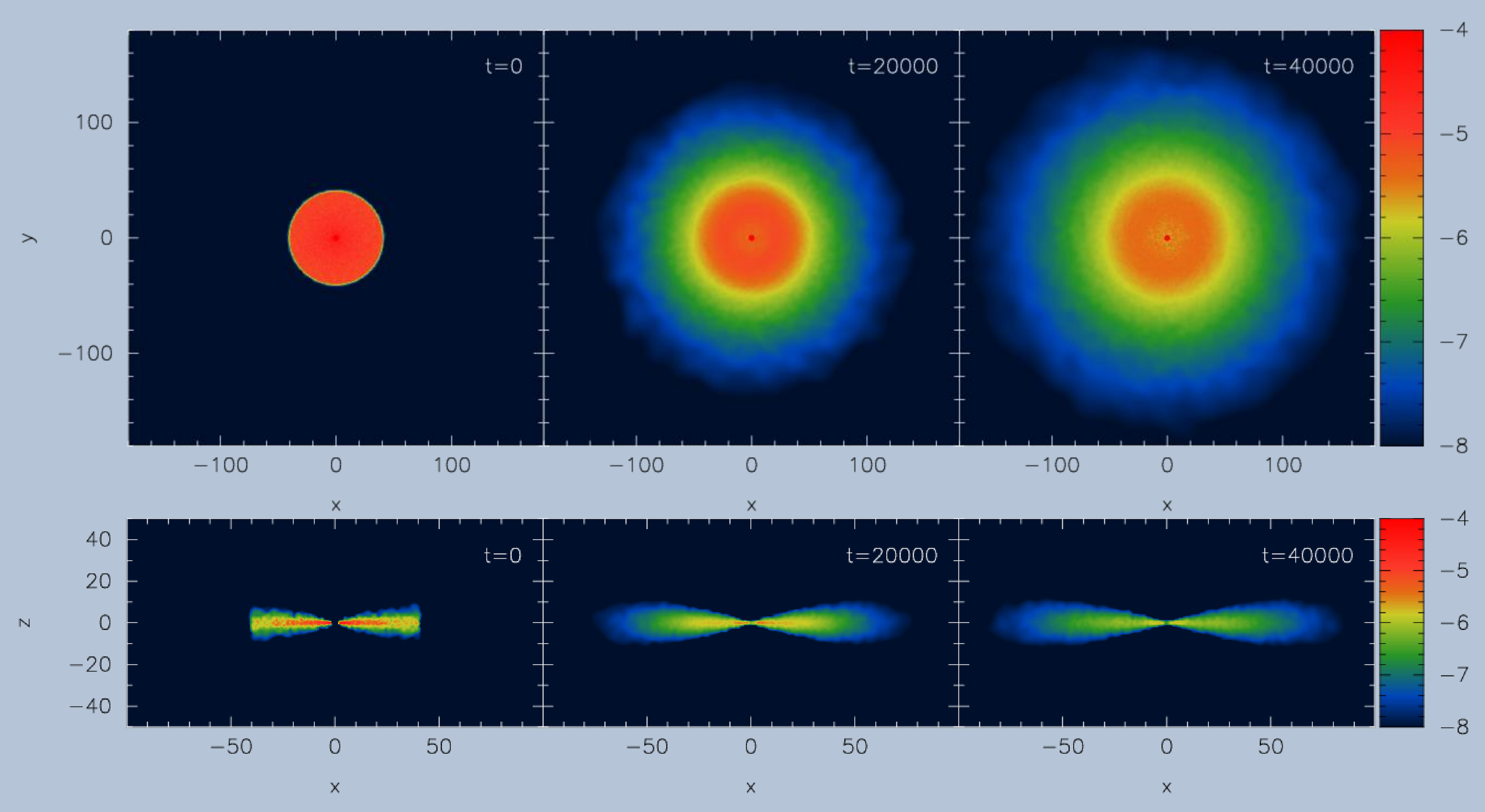

Figure 2. Change in size and density of the isolated disc over time: (a) log column density of face-on view, and (b) log density of edge-on cross section. The unit of time is in yr.

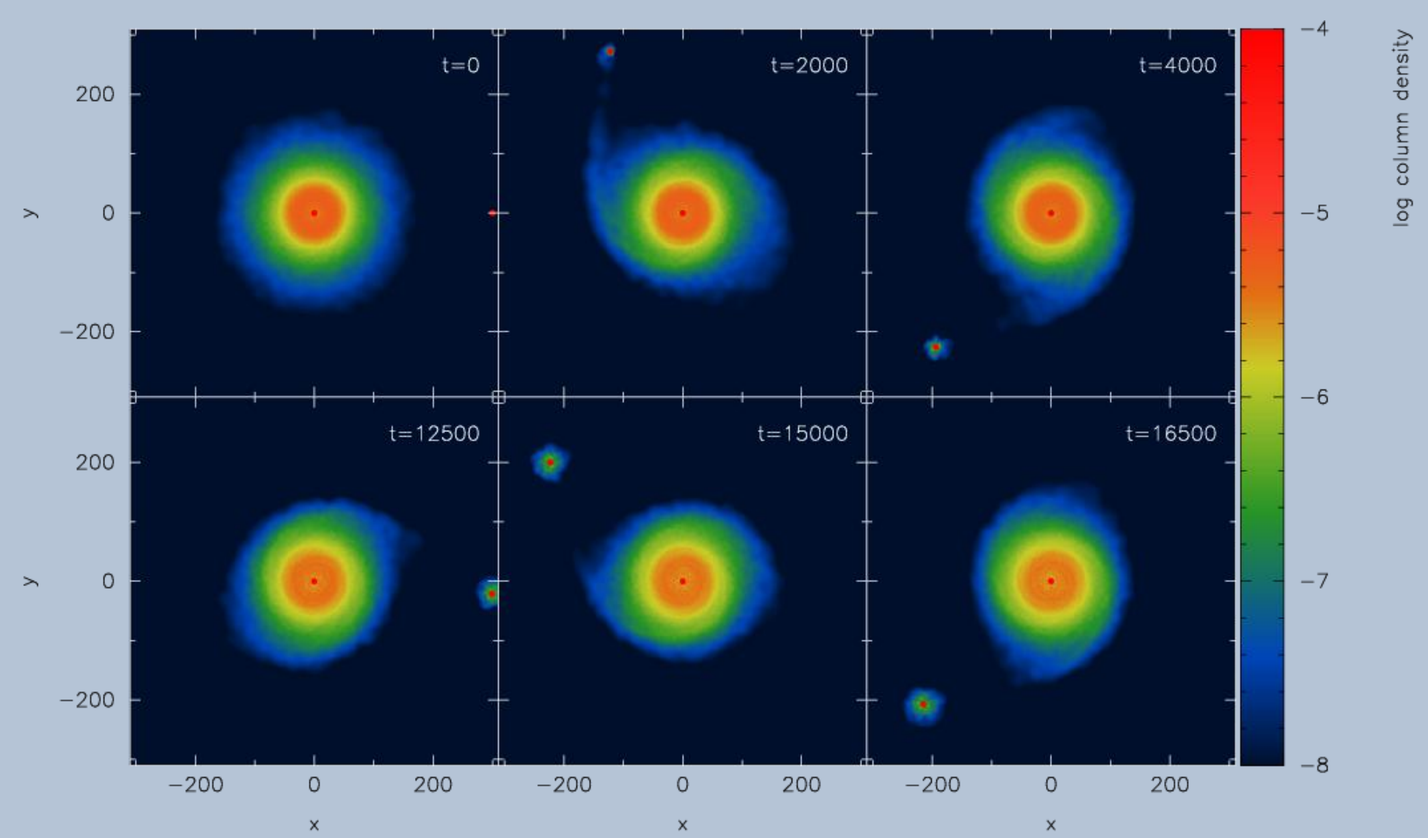

Figure 3. Interaction between disc and companion with e = 0, i = 0°, and orbital period T ~ 6329 yr. There is a mild interaction between the companion and the disc allowing the companion to steal some material.

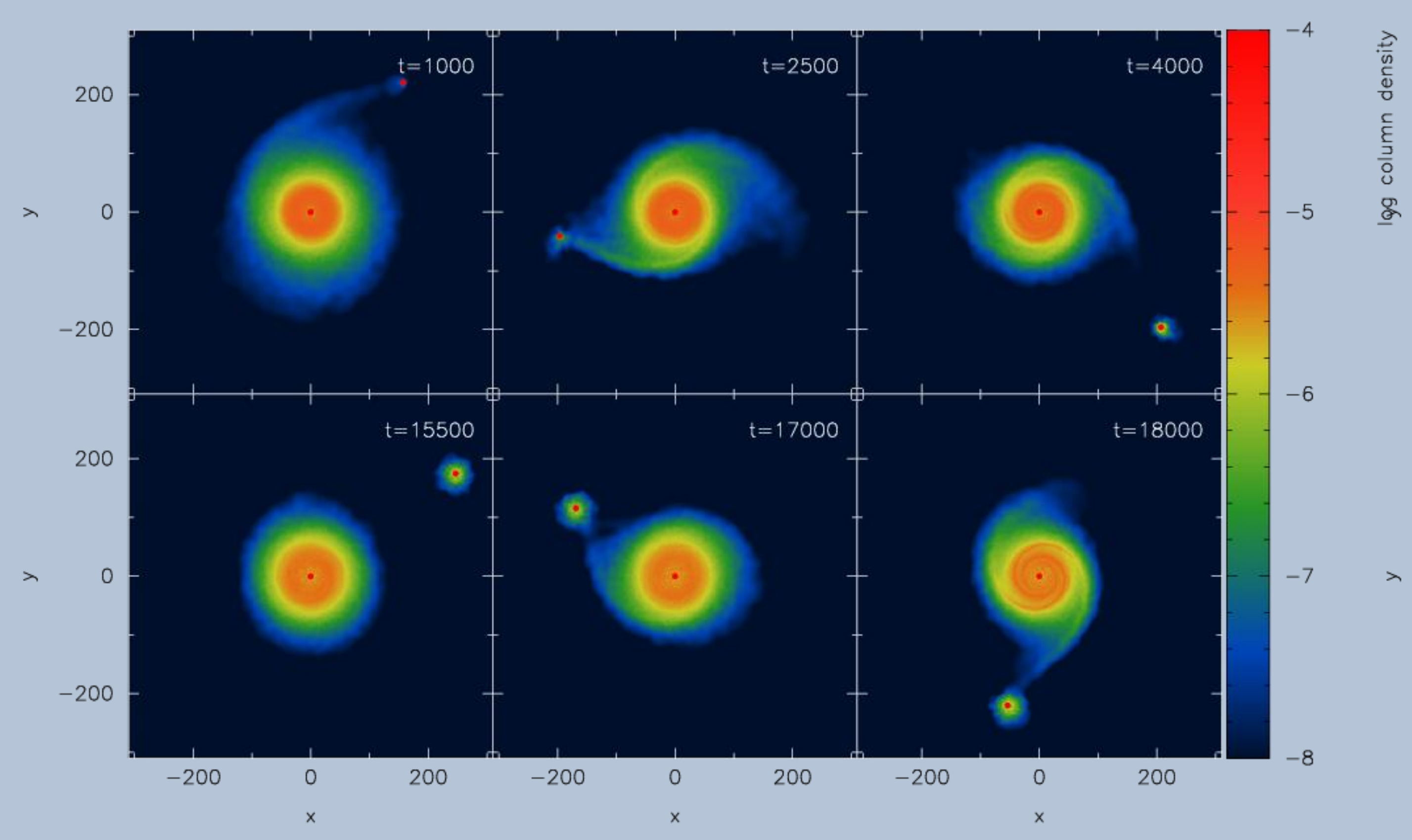

Figure 4. Interaction between disc and companion with e = 0.2, i = 0°, and orbital period T ~ 4815 yr. At a slightly higher eccentricity than Fig.1, the interaction is stronger with obvious tidal tails.

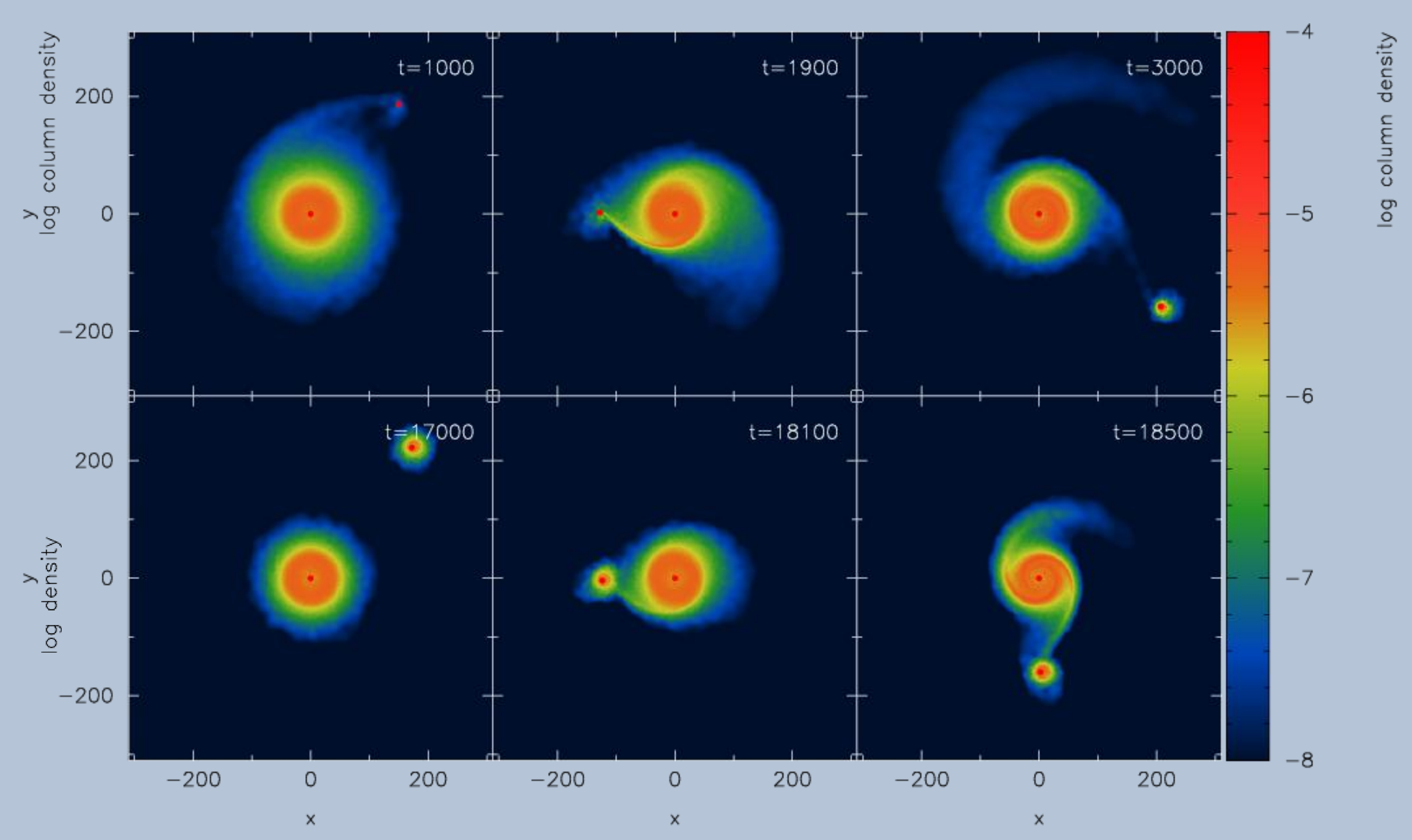

Figure 6. Interaction between disc and companion with e = 0.4, i = 0°, and orbital period T ~ 3821 yr. A moderate change of the companions orbit causes strong interactions and significantly truncates the disc.

Results and conclusion

Isolated disc. The disc quickly readjusts itself in the first few hundred years with an expansion in radial direction and a high accretion rate. The outer radius of the disc expands over time as shown in Fig.1-2. At ~39 kyr the accretion rate falls to ~3×10^{-7} M_{sun}/yr with M_{disc} ~ 0.05 M_{sun} and N_{SPH} ~ 80000. We take the disc at this time for perturbing by a companion.

Perturbed discs. Figures 3, 4, and 6 show that the degree of perturbation of the disc and the amount of disc material transferred to the companion increases with eccentricity. Figure 5 shows smaller effects in a non-coplanar orbit. Periodic perturbations by companions with e > 0 may affect the disc in various ways, e.g. enhancing or inhibiting planet formation and/or disrupting protoplanetary migration in the disc.

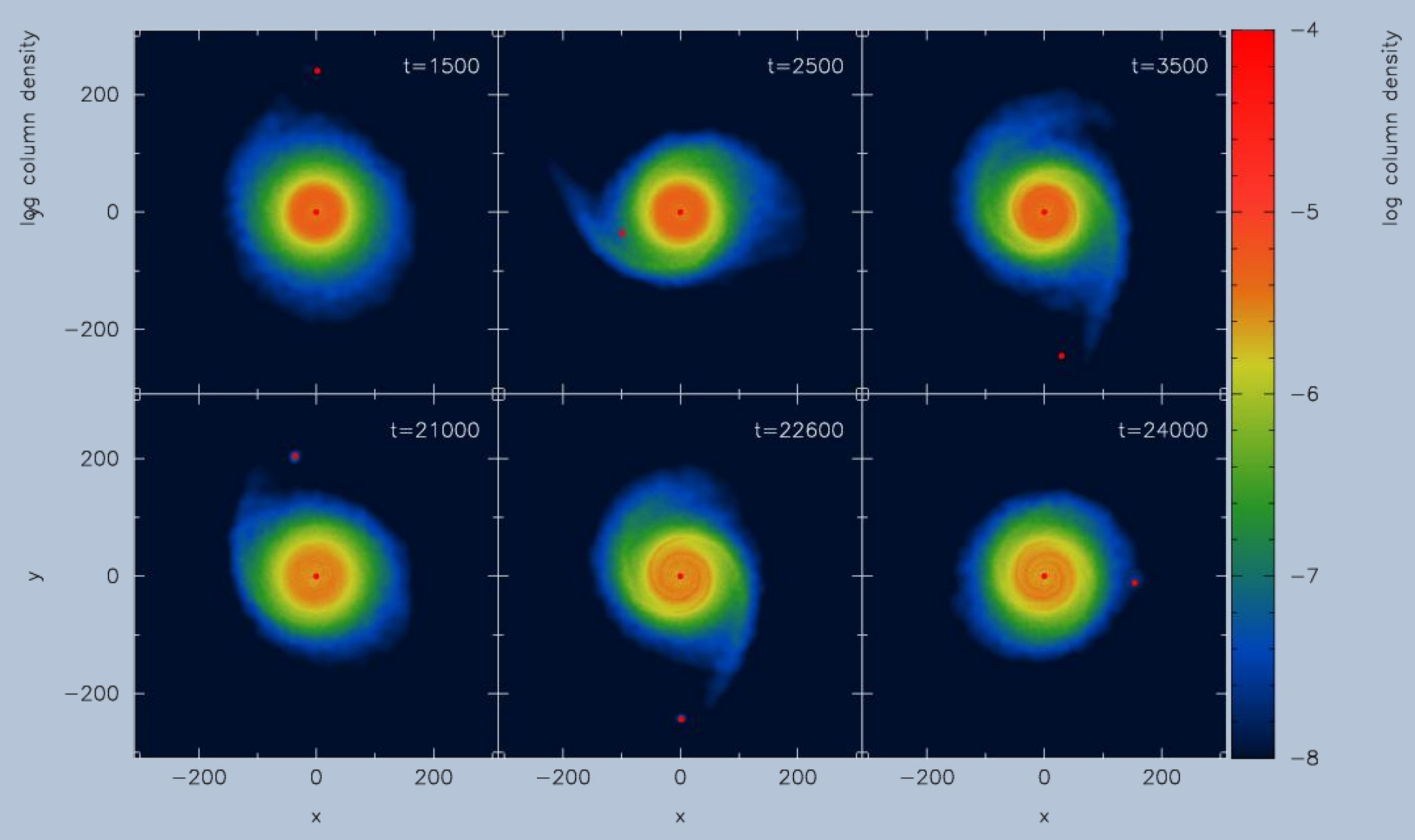

Figure 5. Interaction between disc and companion with e = 0.2, i = 60°, and orbital period T ~ 4815 yr. Note at t = 2500 yr that the companion is behind the disc. When the companion orbit is inclined to the disc the interactions are weaker than in Fig.4, but the disc is still perturbed and we find that its inclination changes with time.

Future work

- Long-term investigation (t > 10^5 yr) of the density and velocity distributions in high-resolution perturbed discs (N_{SPH} > 150000).

- Planetary migration in perturbed discs.

- Improving the initial set-up and relaxation of the isolated discs.

Acknowledgements

Images in Fig.2-6 were produced using SPLASH (Price 2007).

References

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