Effects of star-disc encounters on protoplanetary discs

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Investigation of coplanar and non-coplanar parabolic encounters.

INTRODUCTION

- Embedded clusters are fundamental units of star formation. [1]
- Young stars are initially surrounded by protoplanetary discs.
- Studies show significant effects of stellar encounters on discs in young dense clusters. [2] [3] [4] [5]
- Star-disc encounters can be generalised to disc-disc encounters. [6]

Typical observed disc sizes:

- Disc size within which $2/3$ of total disc mass is found. [7]
- Radius containing 90% of luminosity.
- Typical disc sizes: 100 - 200 AU.

ENCOUNTER SIMULATIONS

AIM: Studying the importance of inclined encounters.

Disc setup:

- Low-mass thin disc.
- Initial disc sizes: 100 & 200 AU.
- Initial 10^4 particles.
- Initial constant particle distribution ($\Rightarrow$ higher resolution in outer disc).
- Initial r^{-1} mass distribution.

Encounter setup:

- Coplanar and non-coplanar parabolic encounters.
- Prograde ($0° \leq i < 90°$), orthogonal ($i = 90°$) & retrograde ($90° < i \leq 180°$) cases.
- Different orientations. [$\omega = 0°$ (Fig.1), $45°$, $90°$ (Fig.2)]

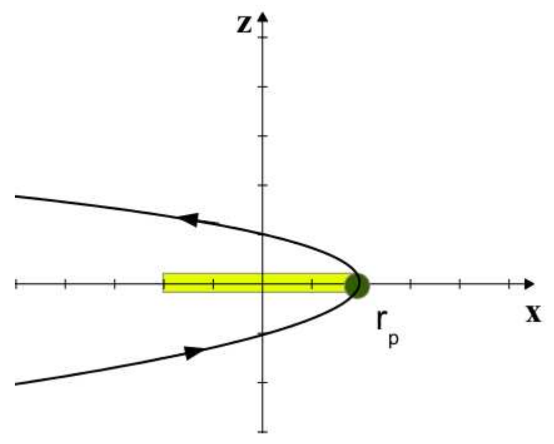

Figure 1: Encounter orbit with periastron in disc plane. [8]

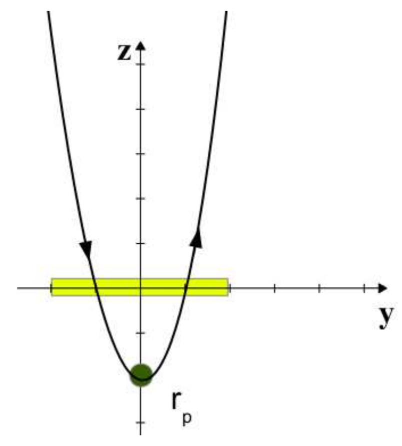

Figure 2: Encounter orbit with periastron below the disc plane. [8]

DISC-SIZE DETERMINATION

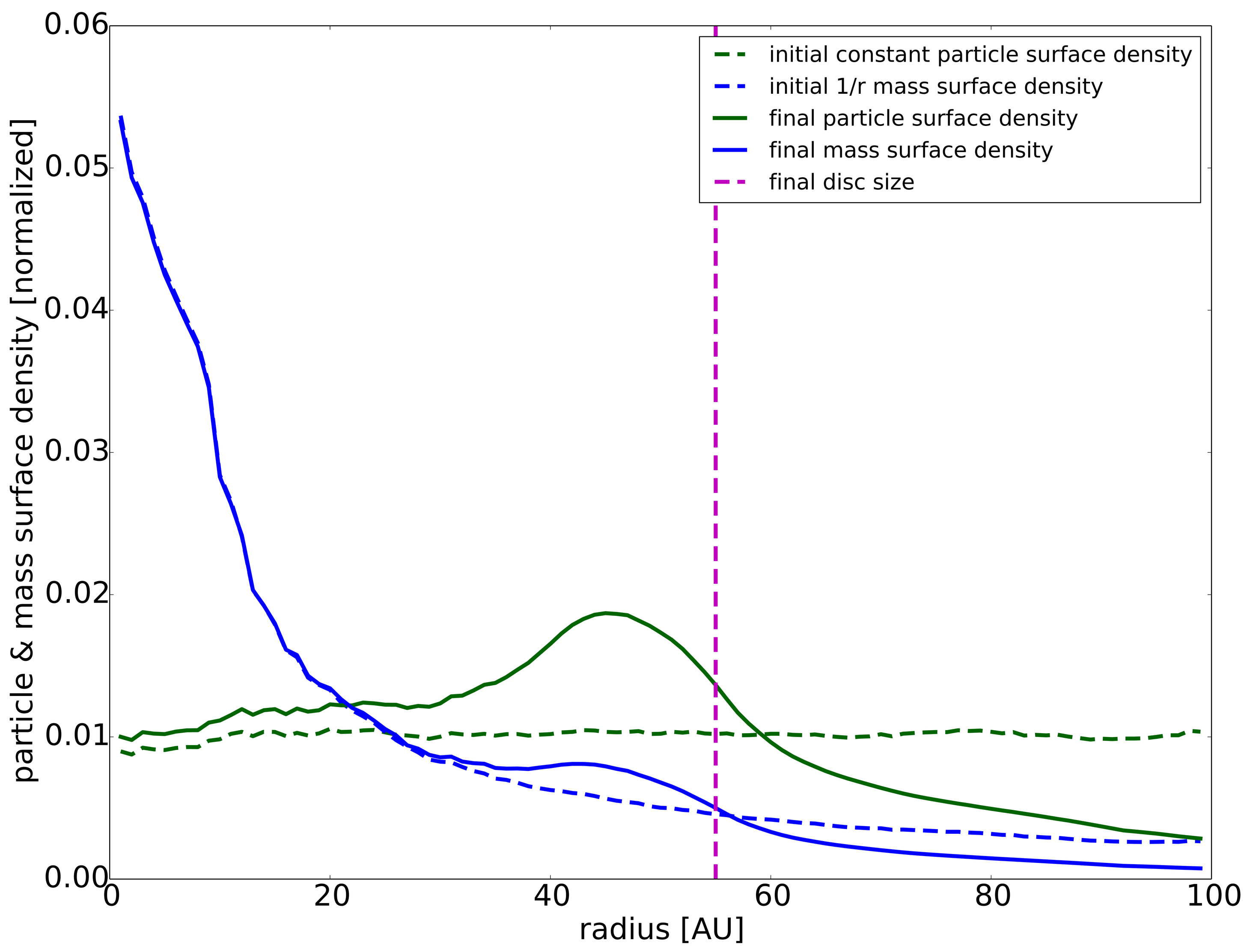

Figure 3: Surface density for a disc with an initial 100 AU radius around a 1 $M_\odot$ star perturbed by a 1 $M_\odot$ star at a periastron distance of 200 AU. The vertical dashed purple line shows the final disc radius estimated from the steepest gradient in the surface density profile.

- **Use steepest gradient in outermost density contrast.** [9]
- Error estimate: distance to inner edge of density contrast.

COPLANAR & NON-COPLANAR ENCOUNTERS

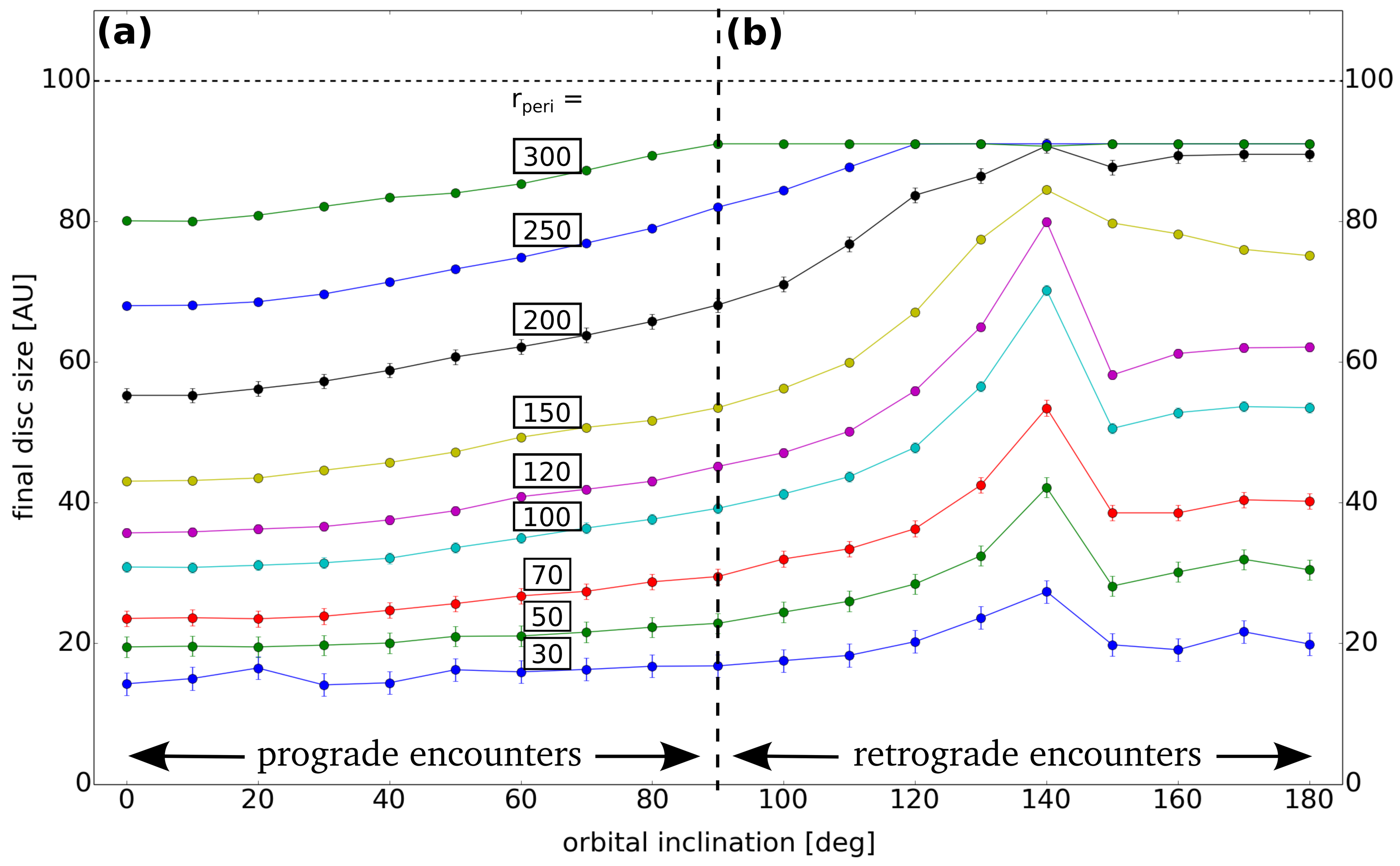

Figure 4: Final disc size from our simulation versus orbital inclination [deg] covering (**a**) prograde encounters, orthogonal (dashed line) and (**b**) retrograde encounters. Here the equal-mass case is shown for different periastron distances ($r_{\rm peri}$) [AU, in boxes].

- Inclined and even orthogonal encounters change the disc size significantly.
- Nearly linear dependence of disc size on orbital inclination for prograde encounters.

DEPENDENCE ON ENCOUNTER PARAMETERS

Fit formula:

$$r_{\rm final} \approx \begin{cases} 1.6 \cdot m_{12}^{-0.2} \cdot r_{\rm peri}^{0.72}, & \text{for } r_{\rm final} \leq r_{\rm init} \\ r_{\rm init}, & \text{otherwise.} \end{cases}$$

$r_{\rm final}$ = final disc size, $r_{\rm init}$ = initial disc size

- Strong dependence of disc size on encounter parameters:
  - periastron distance $r_{\rm peri}$ [30 AU - 1000 AU]
  - mass ratio $m_{12} = M_2/M_1$ [0.3 - 50]
  ($M_2 = \text{perturber mass}, M_1 = \text{host mass}$)

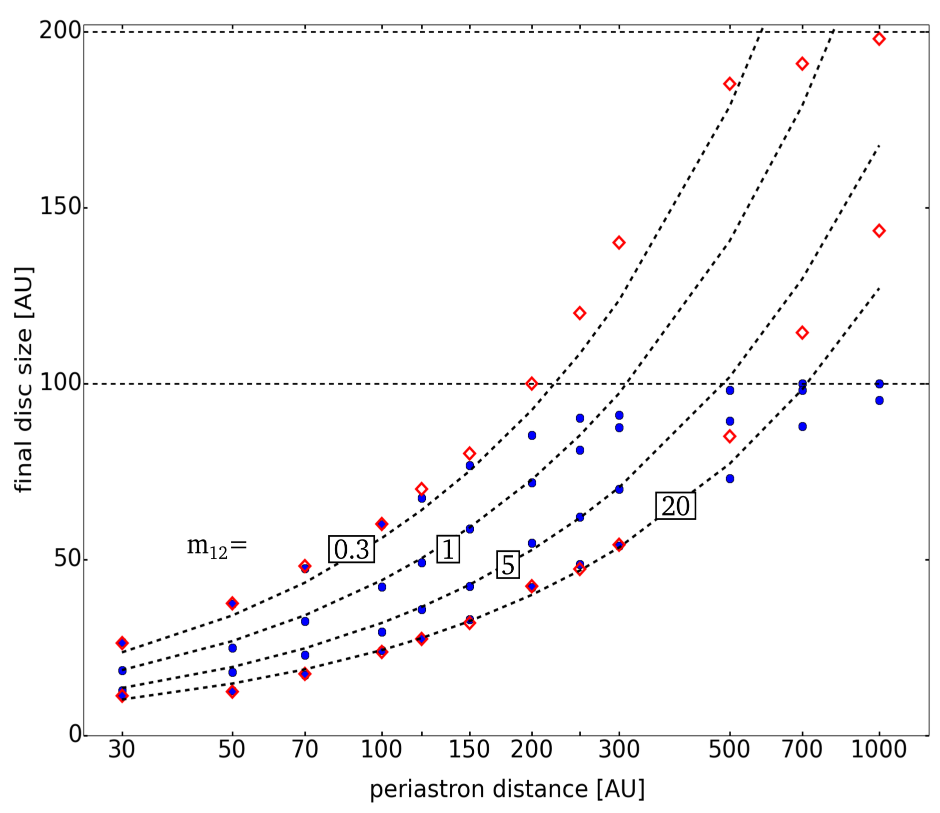

Figure 5: Final disc size versus periastron distance for different mass ratios (m_{12}, in boxes) for a disc with an initial 100 AU radius (blue circles) and 200 AU radius (red diamonds) around a 1 $M_\odot$ star. Dashed lines represent the fit formula.

CONCLUSION

- **Non-coplanar encounters have a strong influence on the final disc size.**
- Prograde encounters have a greater influence on disc sizes than retrograde encounters.
- Significant effect of change in orbital orientations on outer disc particle inclination and eccentricity
  $\Rightarrow$ Implications on Sedna-like objects.
- Applications to the solar system forming encounter.
- Applications to cluster simulations (fit formula).

References: [1] C. J. Lada and E. A. Lada, *ARA&A*, 41:57–115, 2003. [2] A. Scally and C. Clarke, *MNRAS*, 325, 449±456,2001. [3] H. Kobayashi and S. Ida, *Icarus*, 153:416–429, October 2001. [4] C. Olczak, S. Pfalzner, and A. Eckart, *A&A*, 509:A63, January 2010. [5] G. P. Rosotti et.al., *MNRAS*, 441, 2094-2110, 2014. [6] S. Pfalzner, S. Umbreit, and T. Henning, *ApJ*, 629:526-534, August 2005. [7] J. P. Williams and L. A. Cieza, *ARA&A*, 49:67-117, 2011. [8] M. Xiang-Gruess, *MNRAS*, 455, 3086, 2016. [9] A. Breslau et.al., *A&A*, 565, A130, 2014.