Sizes of Protoplanetary Discs after Star-Disc Encounters

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Simulations to determine sizes of perturbed discs for encounters common in star clusters

Introduction

- Most young stars initially surrounded by protoplanetary discs
- Discs: precursors of planetary systems

Observed disc sizes

- Radius containing 90% of luminosity
- Typical disc sizes: $100 - 200$ AU

- Most stars form in clusters [1]
- In dense clusters, encounters with other stars are common [2]

Star-Disc Encounters

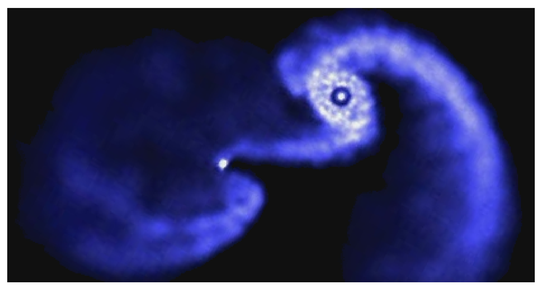

Figure 1: Star with protoplanetary disc during an encounter.

- Encounter: disc material removed or redistributed
- **Disc size changed by encounter**
- **Disc truncated at $\approx 1/3$ periastron?** [3]

Encounter simulations

- Low-mass disc
- Prograde, coplanar, parabolic encounter
- Star-disc encounters can be generalised to disc-disc encounters [4]
- Parameter range like in ONC [2]
- **Task: Find new "edge" of disc**

Size definition for simulations

Sizes for extensive parameter space

Disc-Size Determination

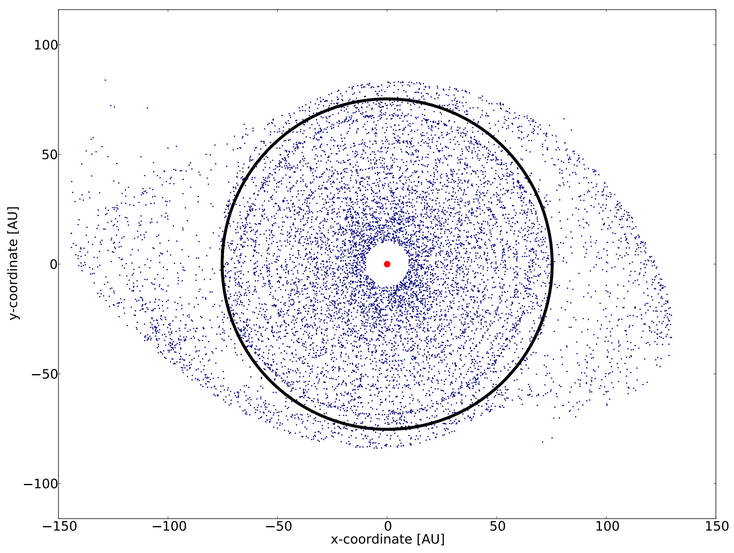

Figure 2: Disc with initially 100 AU radius around a 1 $M_\odot$ star perturbed by a 20 $M_\odot$ perturber with 700 AU periastron distance. The black circle shows the final disc size obtained with the criterion described on the right.

- Depending on encounter type: many particles on eccentric orbits
- No straightforward definition of size
- Time average of surface density distribution over 1000 yr after encounter
- Mimic observational size determination
- **Use steepest gradient in outermost density contrast** (Fig. 3)
- Error estimate: distance to inner edge of density contrast

Have a look at a encounter visualisation on
http://tiny.cc/encounter_movie

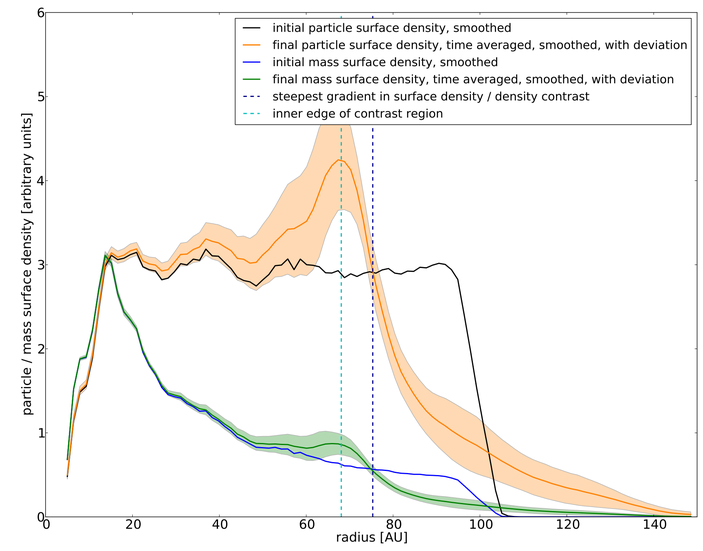

Figure 3: Surface density for a disc with initially 100 AU radius around a 1 $M_\odot$ star perturbed by a 20 $M_\odot$ perturber with 700 AU periastron distance. The dashed red line shows the size obtained with the criterion described on the left.

Dependence on Encounter Parameters

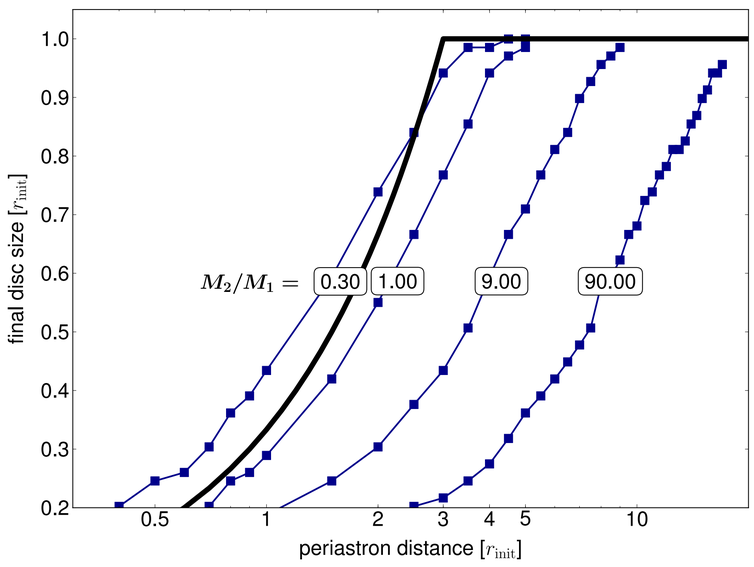

Figure 4: Disc sizes from simulation data for several mass ratios (blue lines). For comparison the size obtained with a truncation at 1/3 of periastron distance is shown in black.

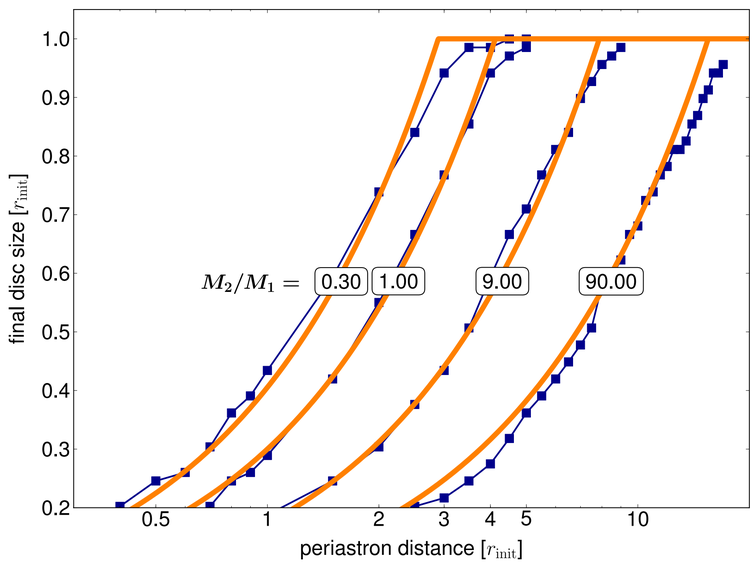

Figure 5: Disc sizes from simulation data for several mass ratios (blue lines). The red lines show the sizes obtained with our fit formula (see below).

- Strong dependence of disc size on encounter parameters:
  - periastron distance p [$r_{\rm init}$]
  - mass ratio $m = M_2/M_1$
- Disc truncated at $1/3$ of periastron distance only valid for small parameter range

- Function fitting the obtained sizes well within errors ($\lesssim 10\%$):

$$\frac{r}{r_{\rm init}} = \frac{0.3 \cdot p^{0.85}}{\sqrt[4]{m}}$$

r = final disc radius, $r_{\rm init}$ = initial disc radius, m = mass ratio, p = periastron [$r_{\rm init}$]

Conclusion

- **Disc size definition**:
  Steepest gradient in surface density
- **Fit function** for sizes over parameter range in clusters:
  $m = M_2/M_1 = [0.3 - 90]$
  $p \gtrsim [0.1 - 2]$ (depending on m)
- Applicable to all types of clusters

References

[1] C. J. Lada and E. A. Lada. Embedded Clusters in Molecular Clouds. *ARA&A*, 41:57–115, 2003.

[2] C. Olczak, S. Pfalzner, and A. Eckart. Stellar interactions in dense and sparse star clusters. *A&A*, 509:A63, January 2010.

[3] R. Brasser, M. J. Duncan, and H. F. Levison. Embedded star clusters and the formation of the Oort Cloud. *Icarus*, 184:59–82, September 2006.

[4] S. Pfalzner, S. Umbreit, and T. Henning. Disk-Disk Encounters between Low-Mass Protoplanetary Accretion Disks. *ApJ*, 629:526-534, August 2005.

For further information, please ask me or visit

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