Stellar encounters and protoplanetary disc evolution

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PROTOPLANETARY DISCS DISPERAL

\[ f_{\text{disk}} = \exp\left(-\frac{t}{\tau_{\text{disk}}}\right) \]
\[ \tau_{\text{disk}} = 2.5 \ \text{Myr} \]

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Mamajek 09
Dispersal mechanisms

- Viscous evolution (accretion onto the star)
  (Lynden-Bell & Pringle 74, Hartmann 98)

- Photoevaporation
  - Internal
  - External

- Planet formation itself
  (Armitage & Hansen 1999; Rice 2003+; Zhu 2010+)

- Encounters with stars
  (Scally & Clarke 2001, Olczak & Pfalzner 2005, ...)

- (Winds, outflows, supernovae, ...)

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N-body/SPH approach

Previous studies: N-body simulations + post-processing using simulations of single disc-star encounters
see also poster P7, Vincke
N-body/SPH approach

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We simulate the **viscous evolution** and the **encounters**

Hybrid SPH/N-body Simulation (Hubber+ 2012)
Combine SPH with N-body collisional dynamics

- 100 stars, Plummer sphere, r=0.1 pc
- Stars have same mass: 1 M☉
- 50 discs around them, m=5% star mass
- Evolve for t=0.5 Myr

The discs will viscously expand (not included in previous studies) and feel the gravitational interaction of the nearby stars

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Evolution

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Evolution

Rosotti+14

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Interaction example

![Graph and Image]

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Effects on disc mass...

Some disc dramatically affected but overall little effect
and on disc size

Much more affected

Median

Disc in isolation

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How close do stars get?

Distance from the center of mass [au]

Distance of closest encounter [au]

How close do stars get?
Effet of initial disc size

Median vs disc in isolation

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Effet of initial disc size

Median vs disc in isolation

Equilibrium reached

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A semi-analytical model

- Fit disc evolution in isolation (evolution described by):

\[
R_{\text{disc}}(t, R_0, t_\nu, 0) = \left(1 + \frac{t}{t_\nu, 0}\right)^{1/(2-\gamma)} R_0
\]

<table>
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<th>Run</th>
<th>(R_{\text{out}}[\text{au}])</th>
<th>(\gamma)</th>
<th>(t_\nu[\text{yr}])</th>
<th>(\alpha_{\text{SS}})</th>
<th>(t_{\text{spread}}[\text{yr}])</th>
<th>(\alpha_{\text{SS,local}})</th>
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<td>13</td>
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</tbody>
</table>

- Look at close encounters
- Assume encounters truncate the disc at \(r/3\) (e.g. Breslau 2014; remember here stars equal masses)
- If disc was truncated, reset disc size and grow again
A semi-analytical model (2)

Run R10

Run R300

Simulation
Model
A semi-analytical model (2)

Effect of distant encounters?

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Comparison with observations

SIMULATIONS

OBSERVATIONS

de Juan Ovelar+, 12

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Other hints from observations

• Sicilia-Aguilar+ 2013: Coronet cluster (50 stars, 0.15 pc) discs seem much more evolved than clusters of same age (and even of some older ones)
• Stolte+ 2010: disc fraction increases with distance from the center
CONCLUSIONS

- Evolution of discs in a clustered environment
- Encounter-driven mass loss:
  - can be dramatic
  - but do not expect the majority of disks to go through it
- Encounter-driven size reduction:
  - encounters truncate the disc
  - turnover in disc size seems consistent with observations (threshold at ~2-3 x 10^3 pc^-2)

FUTURE WORK

- Simulate more realistic clusters
- Include massive stars and external photo-evaporation
- Compare spatial distribution of discs with observations