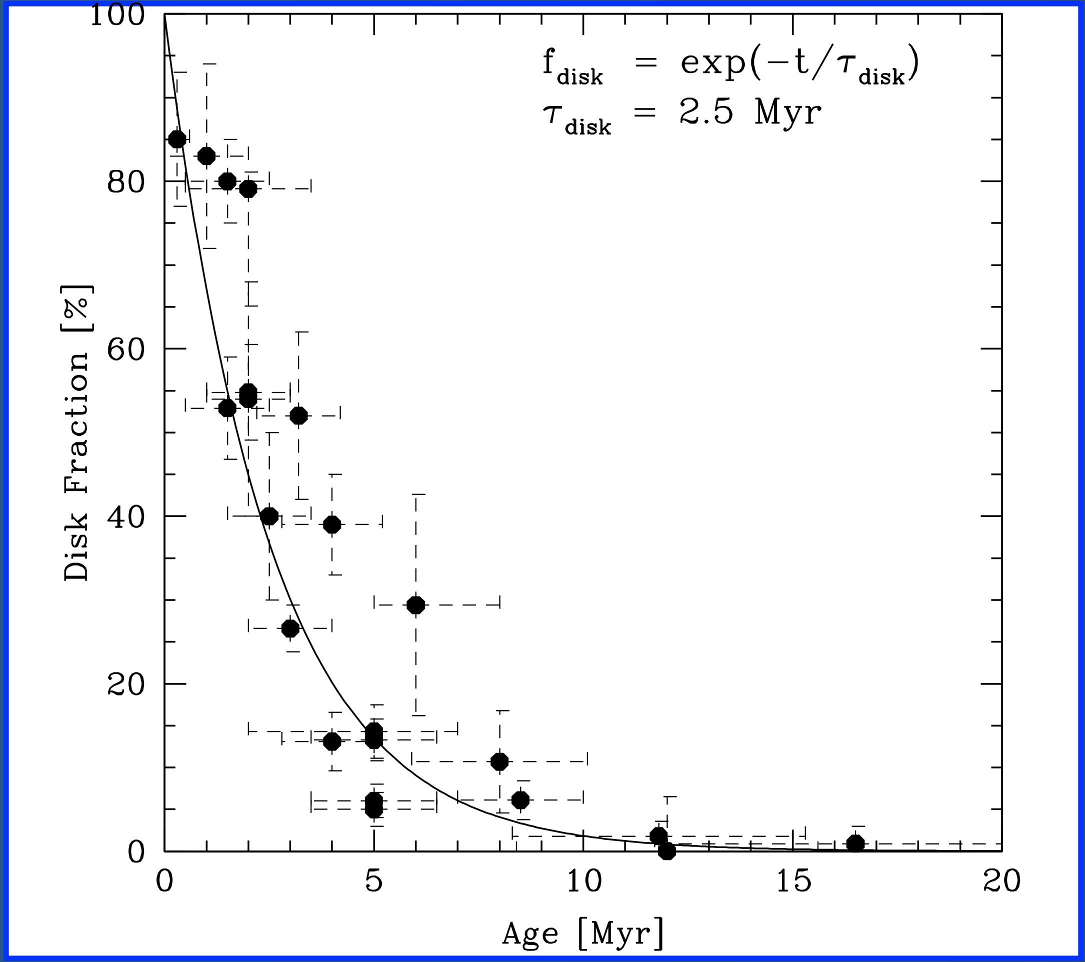
Stellar encounters and protoplanetary disc evolution

Giovanni Rosotti (IoA Cambridge, MPE Munich)
with:
James Dale, Barbara Ercolano, David Hubber (USM, Excellent cluster)
Maria de Juan Ovelar (Leiden, Liverpool)
Diederik Kruijssen (MPA)
Stefanie Walch (Cologne)
Carlo Manara (ESO/ESA)

PROTOPLANETARY DISCS DISPERSAL



Mamajek 09

Dispersal mechanisms

- Viscous evolution (accretion onto the star)

(Lynden-Bell & Pringle 74, Hartmann 98)

- Photoevaporation
  - Internal
  - External

(Clarke 2001; Alexander+ 2004, Adams 2004)

- Planet formation itself

(Armitage & Hansen 1999; Rice 2003+; Zhu 2010+)

- Encounters with stars

(Scally & Clarke 2001, Olczak & Pfalzner 2005, ...)

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

Dispersal mechanisms

- Viscous evolution (accretion onto the star)

(Lynden-Bell & Pringle 74, Hartmann 98)

- Photoevaporation
  - Internal
  - External

(Clarke 2001; Alexander+ 2004, Adams 2004)

- Planet formation itself

(Armitage & Hansen 1999; Rice 2003+; Zhu 2010+)

- Encounters with stars

(Scally & Clarke 2001, Olczak & Pfalzner 2005, ...)

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

ENVIRONMENT DRIVEN

N–body/SPH approach

Previous studies: N-body simulations + post-processing using simulations of single disc-star encounters

(Scally & Clarke 2001, Olczak & Pfalzner 2005, Pfalzner+ 2008, 2009, 2011, Steinhausen+ 2014)

see also poster P7, Vincke

N–body/SPH approach

Previous studies: N-body simulations + post-processing using simulations of single disc-star encounters

(Scally & Clarke 2001, Olczak & Pfalzner 2005, Pfalzner+ 2008, 2009, 2011, Steinhausen+ 2014)

see also poster P7, Vincke

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

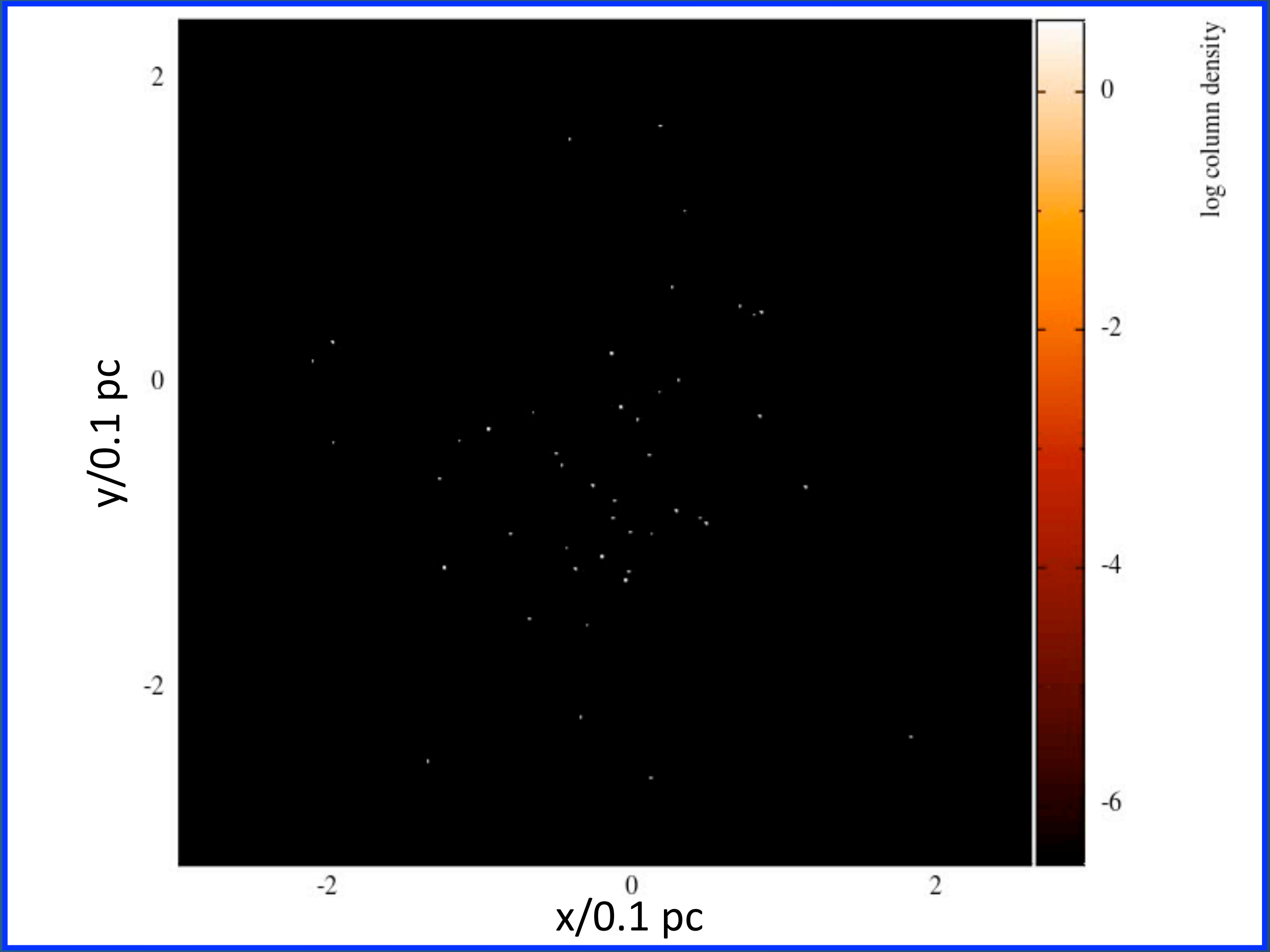
Hybrid SPH/N-body Simulation (Hubber+ 2012)

Combine SPH with N-body collisional dynamics

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

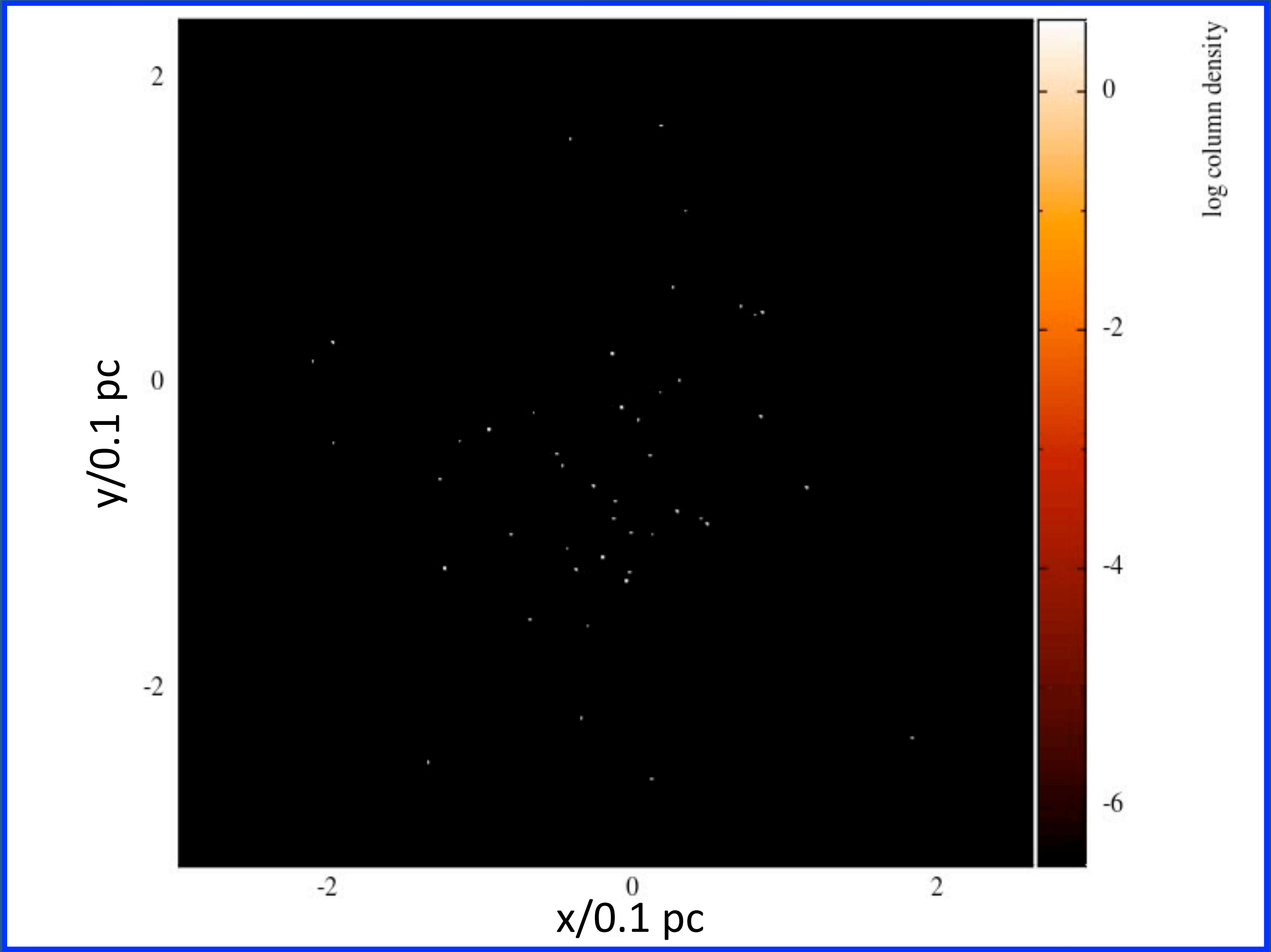
The discs will viscously expand (not included in previous studies) and feel the gravitational interaction of the nearby stars

Evolution



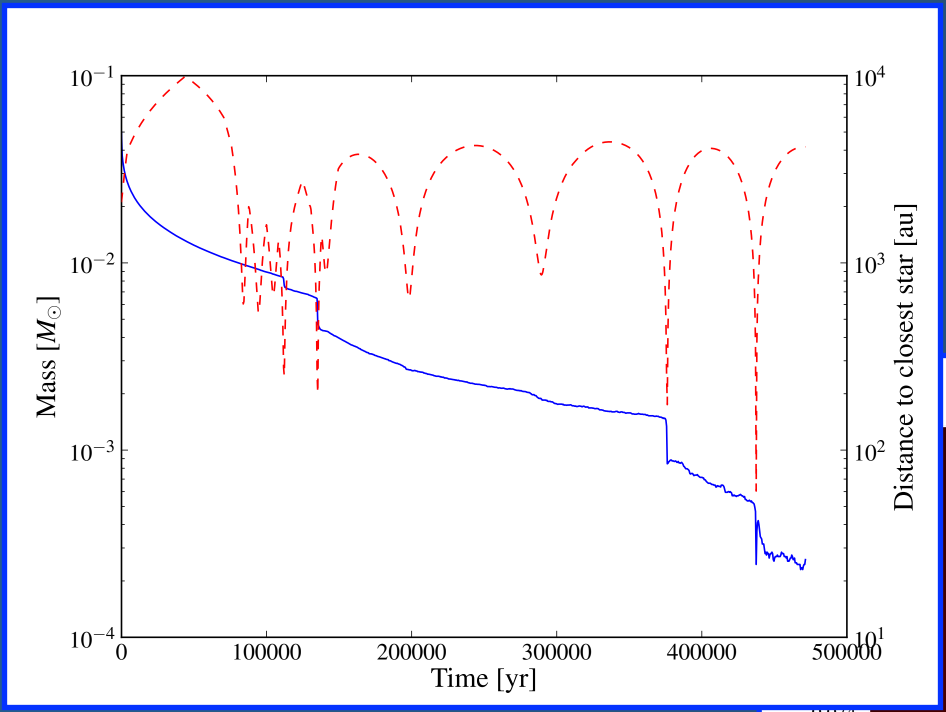
Rosotti+14

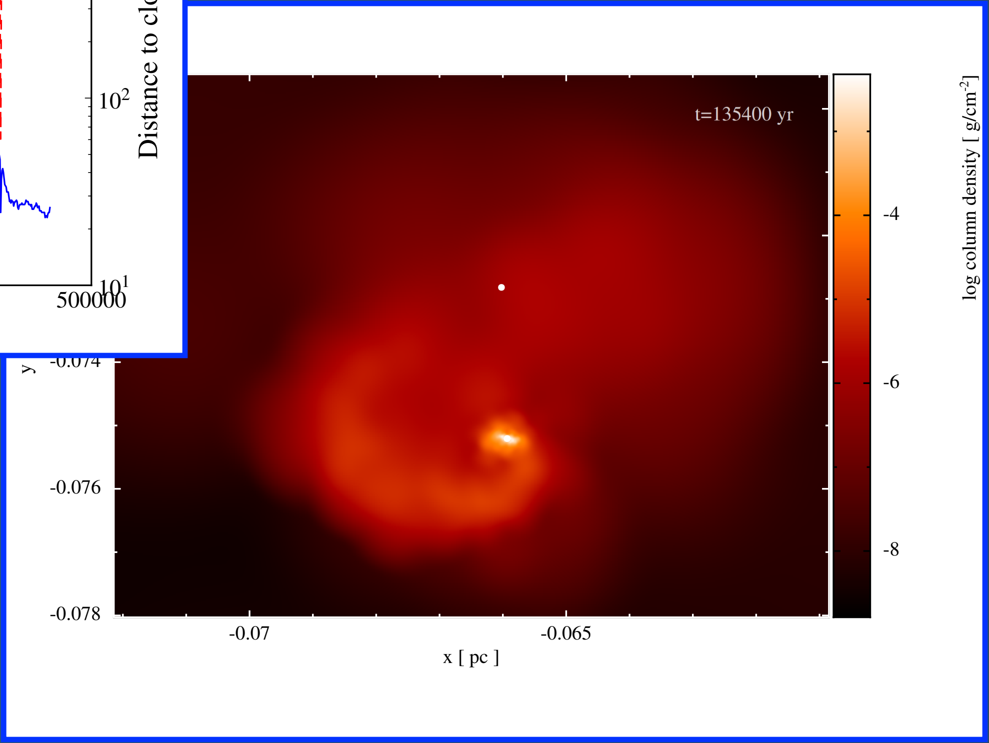
Evolution



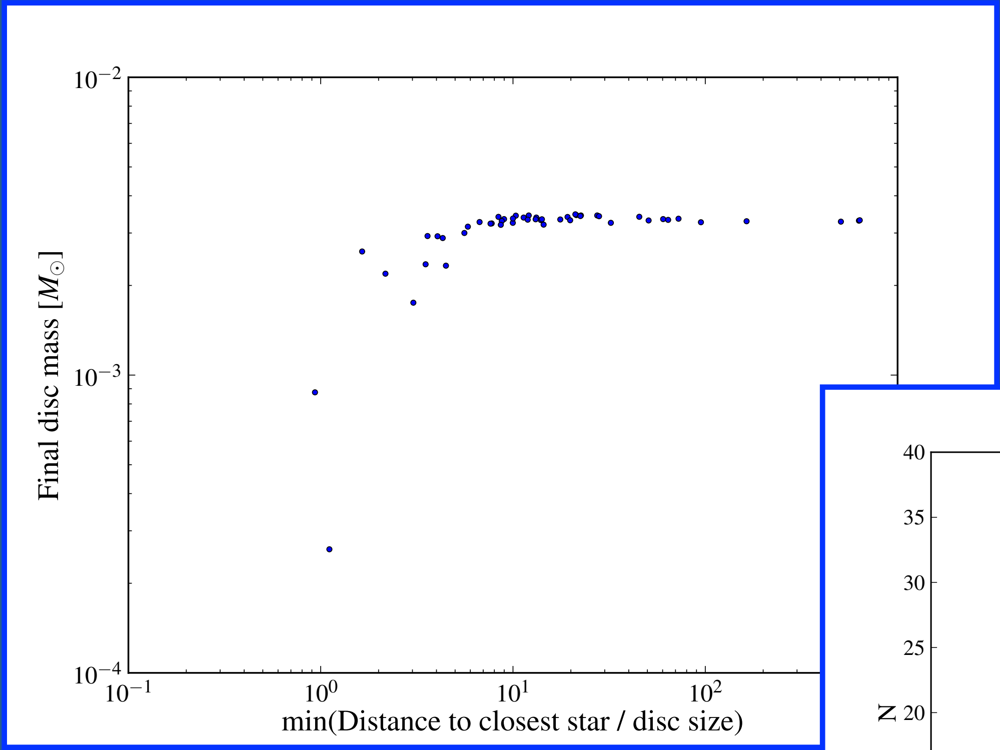
Rosotti+14

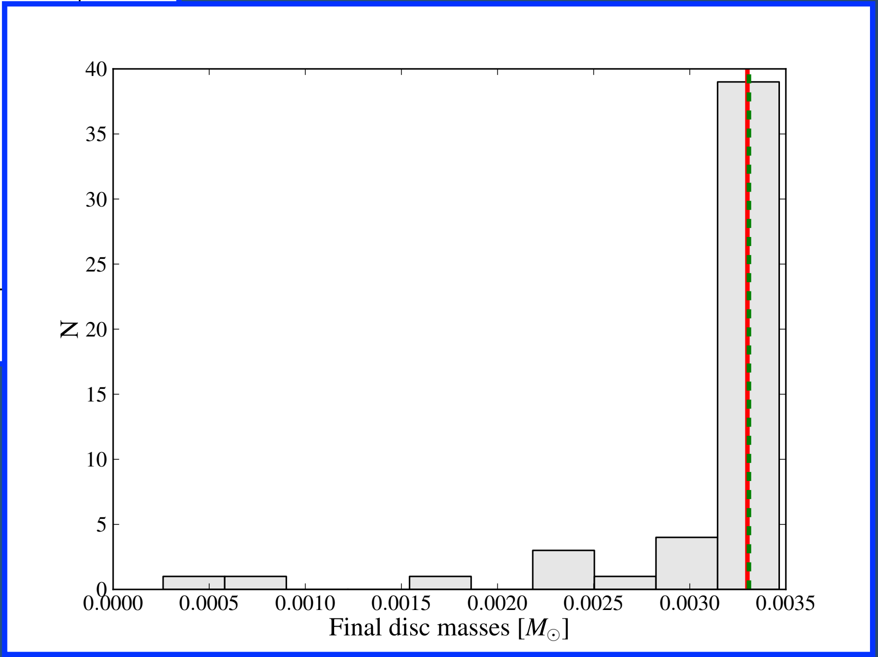
Interaction example





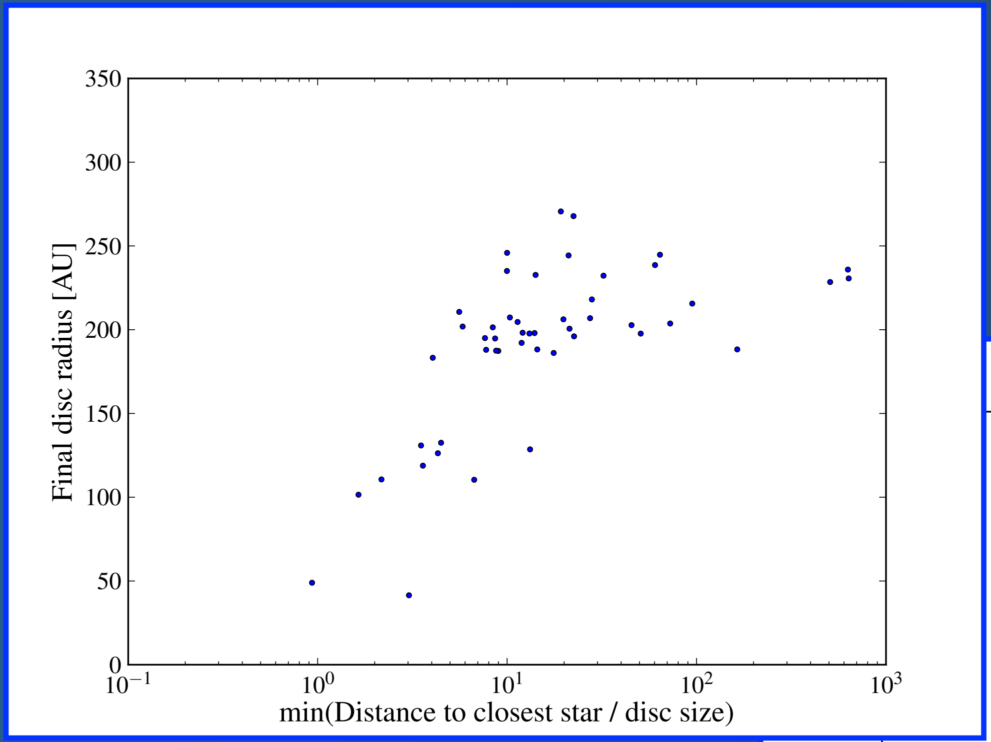
Effects on disc mass…

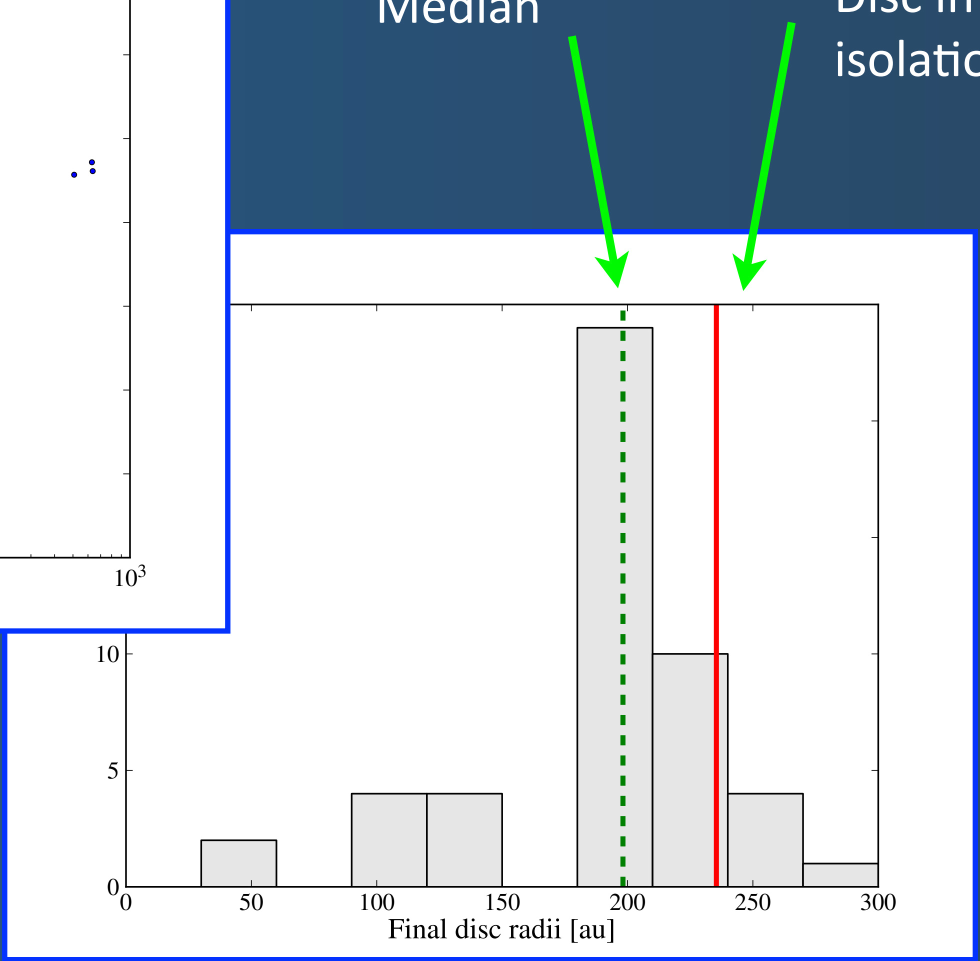




Some disc dramatically affected
but overall little effect

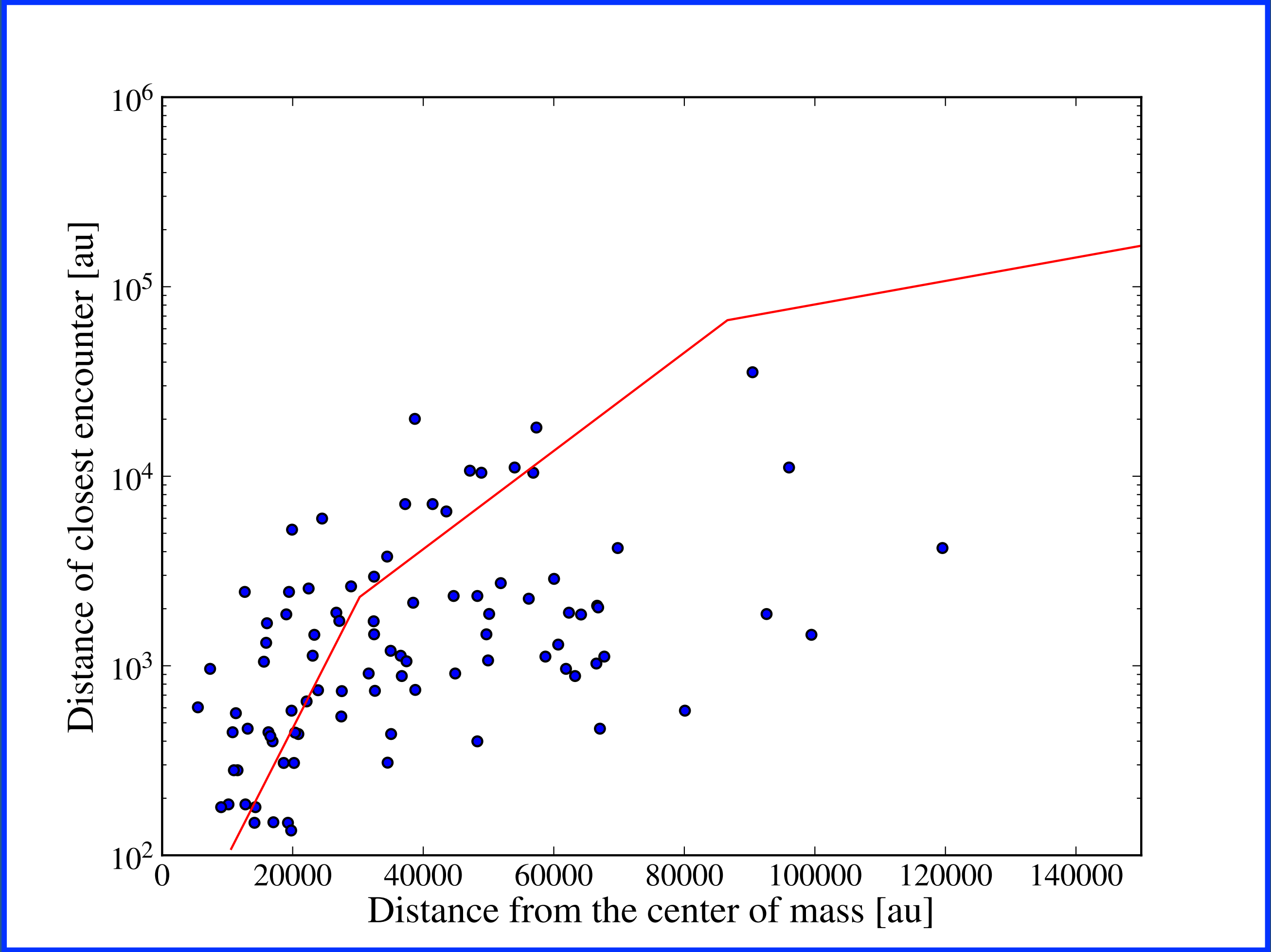
and on disc size





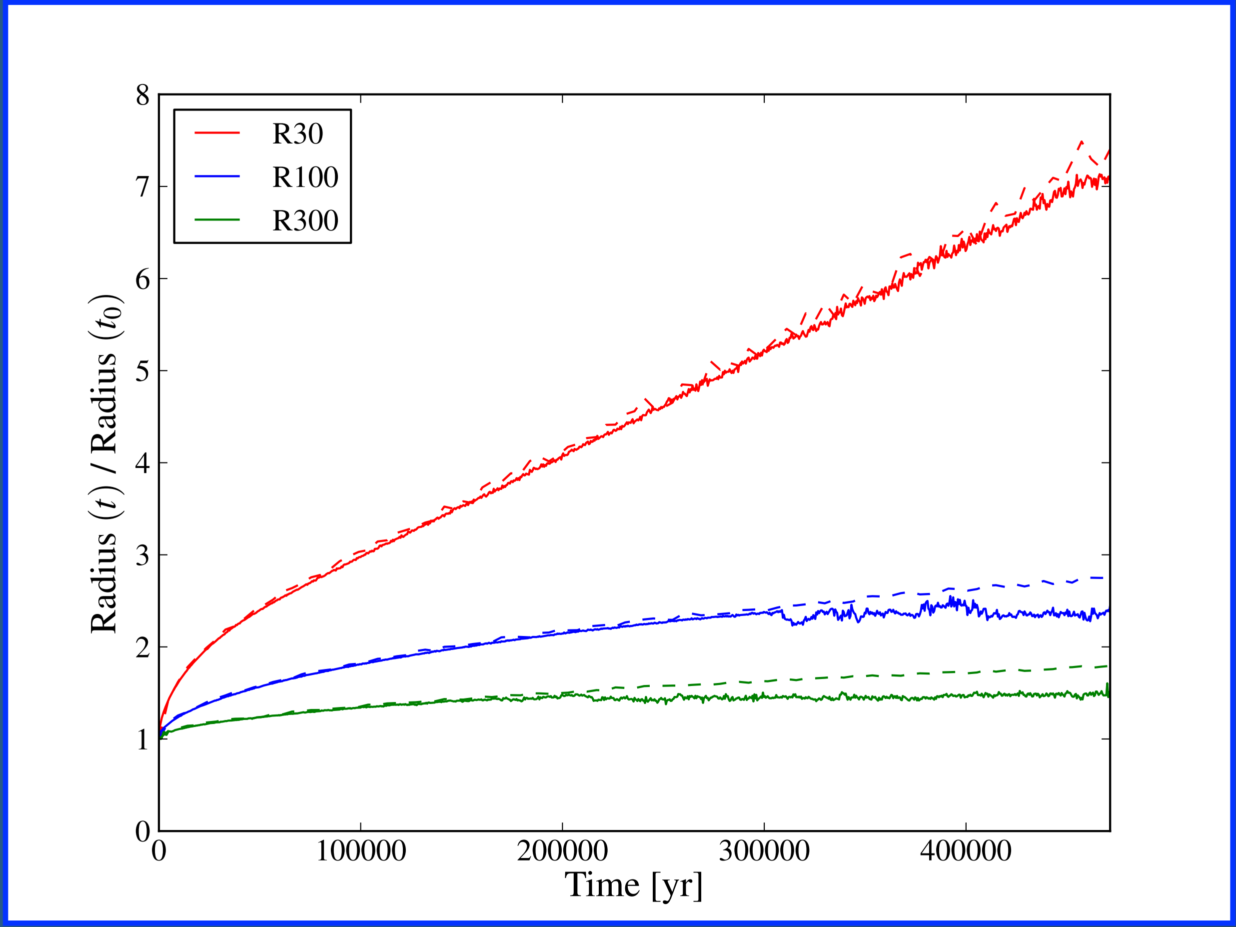
Much more affected

How close do stars get?



Effet of initial disc size

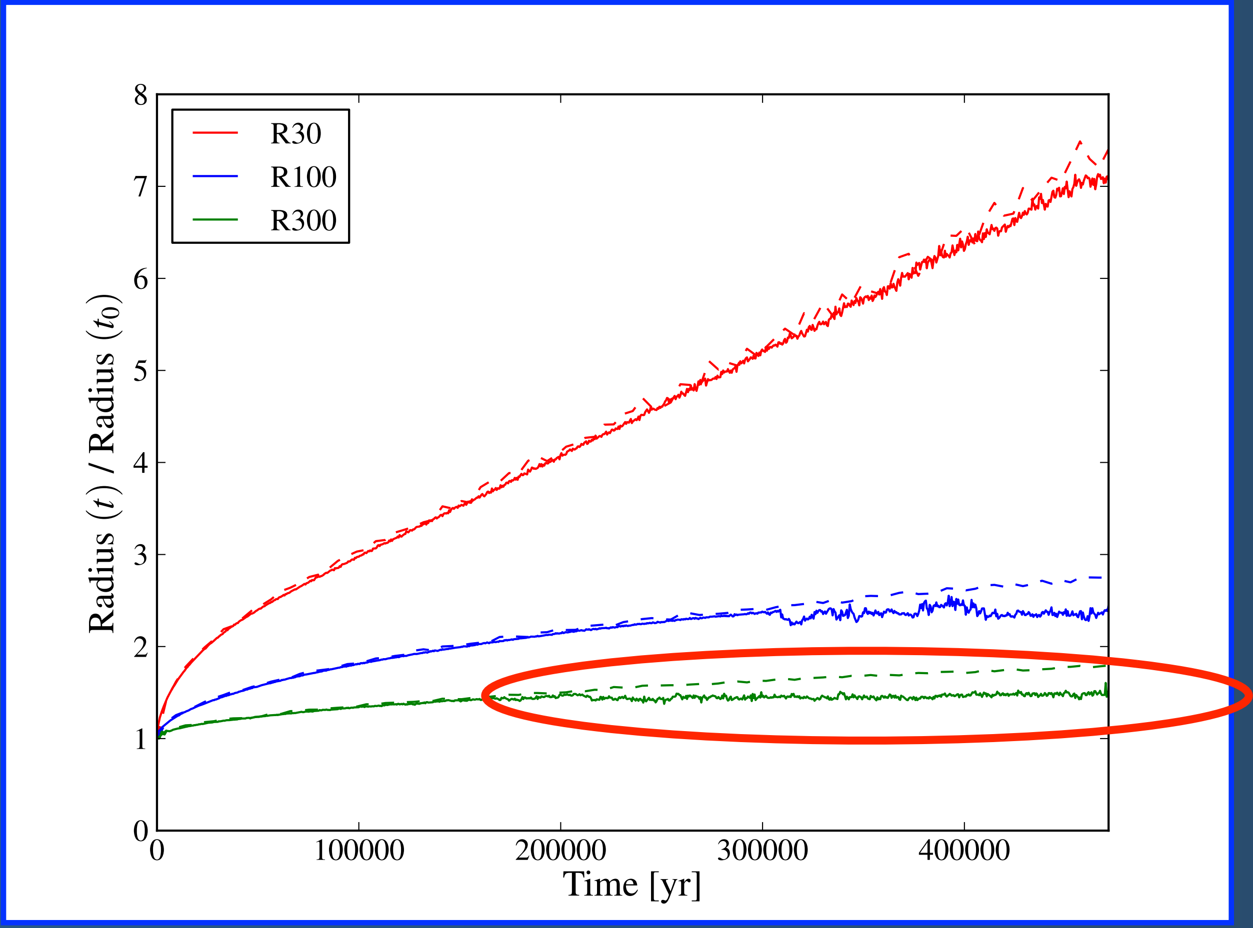
Median vs disc in isolation



Rosotti+14

Effet of initial disc size

Median vs disc in isolation



Equilibrium reached

Rosotti+14

A semi-analytical model

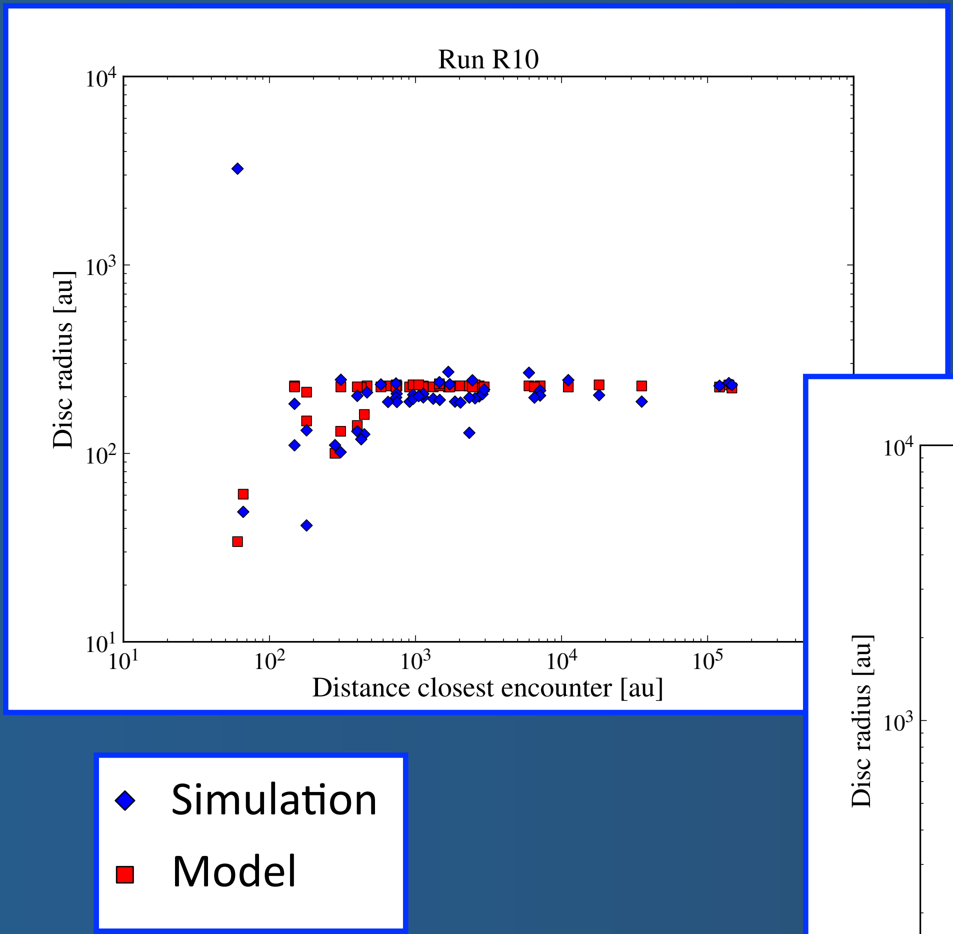
- Fit disc evolution in isolation (evolution described by):

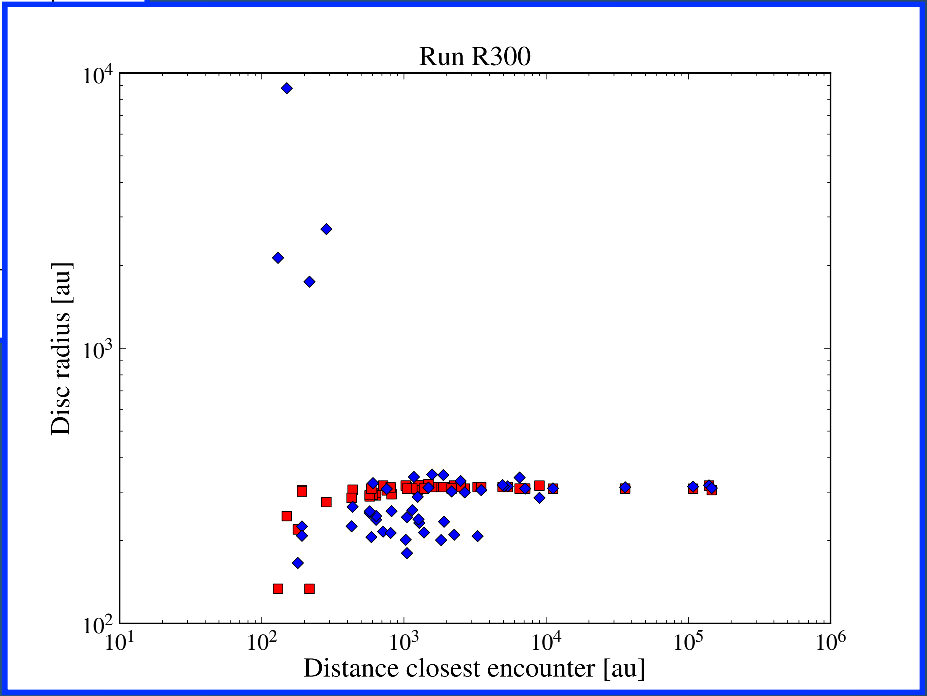
$$R_{\rm disc}(t, R_0, t_{\nu,0}) = \left(1 + \frac{t}{t_{\nu,0}}\right)^{1/(2-\gamma)} R_0$$

Run	$R_{\rm out}$ [au]	γ	t_ν [yr]	$\alpha_{\rm SS}$	$t_{\rm spread}$ [yr]	$\boldsymbol{\alpha}_{\mathbf{SS,local}}$
R10	10	1.11	18891	0.045	16800	0.1
R30	30	0.44	23218	0.062	36220	0.45
R100	100	-1.69	11762	0.133	43400	5.4
R300	300	-3.19	25432	0.161	132000	13

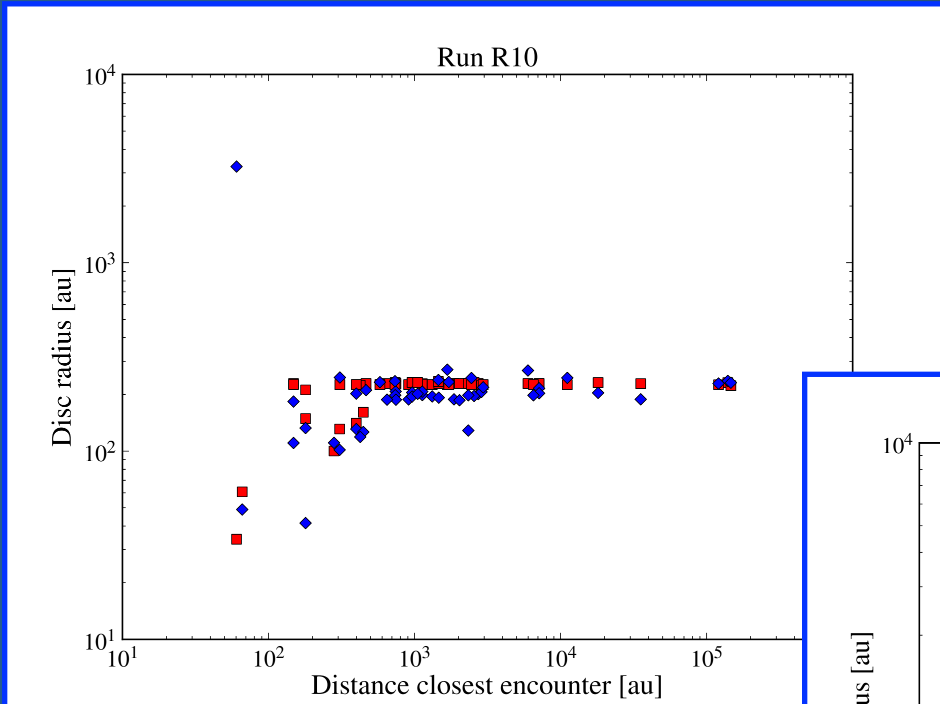
- Look at close encounters
- Assume encounters truncate the disc at r/3 (e.g. Breslau 2014; **remember here stars equal masses**)
- If disc was truncated, reset disc size and grow again

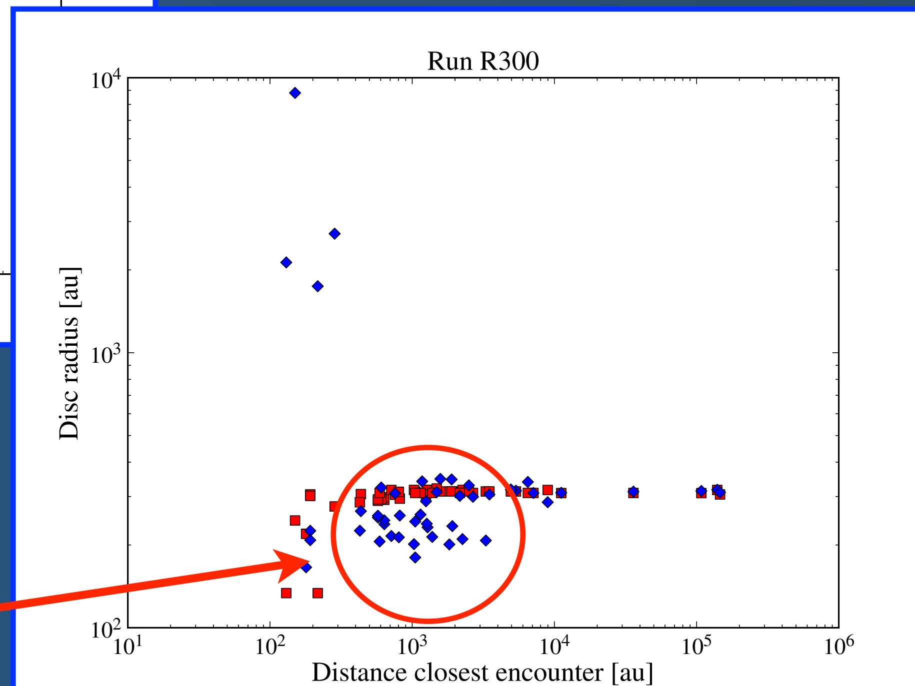
A semi-analytical model (2)





A semi-analytical model (2)



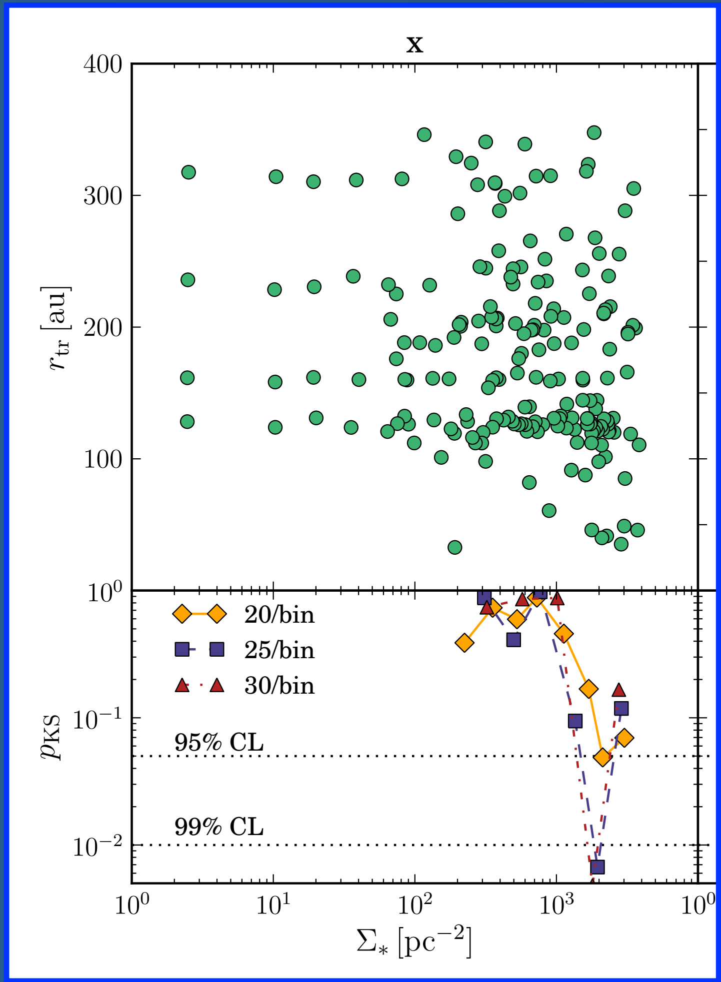


◆ Simulation
■ Model

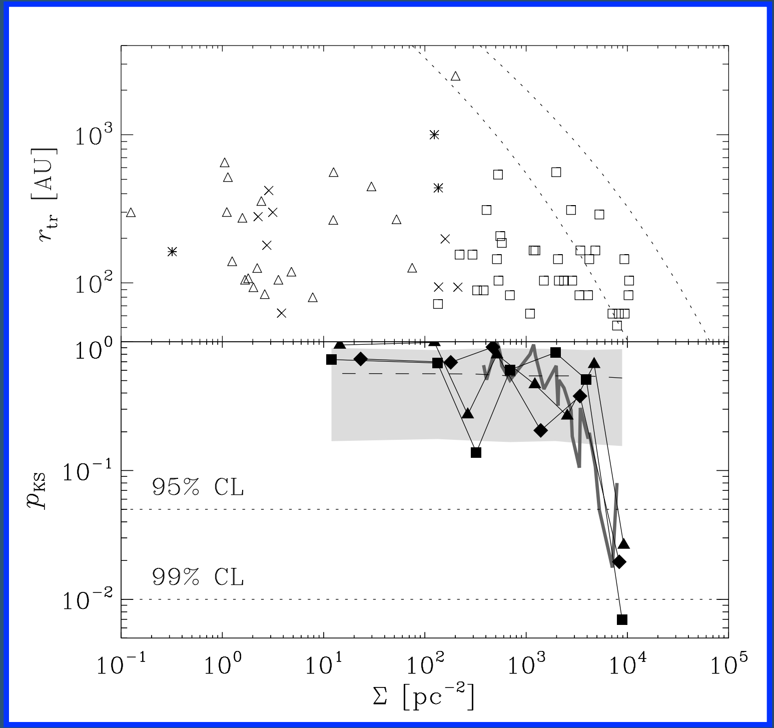
Effect of distant encounters?

Comparison with observations

SIMULATIONS



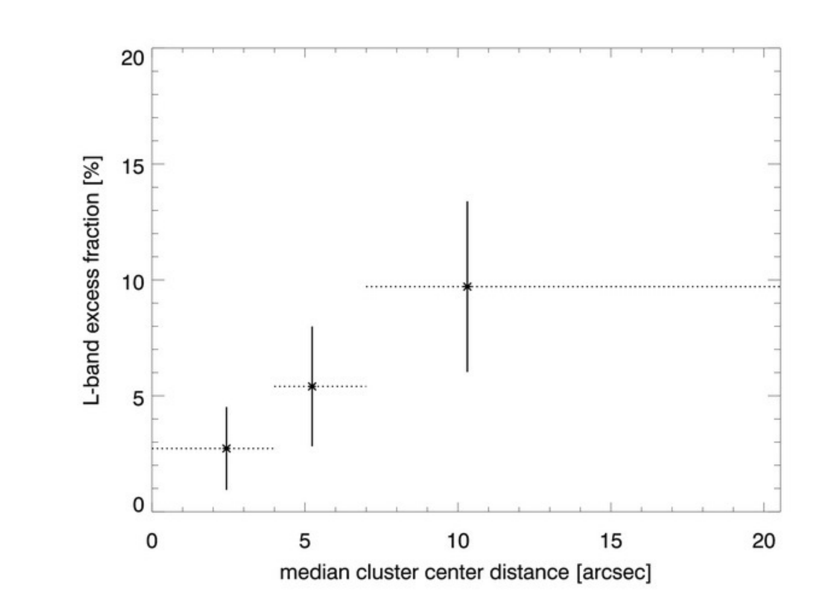
OBSERVATIONS



de Juan Ovelar+, 12

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 (treshold 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