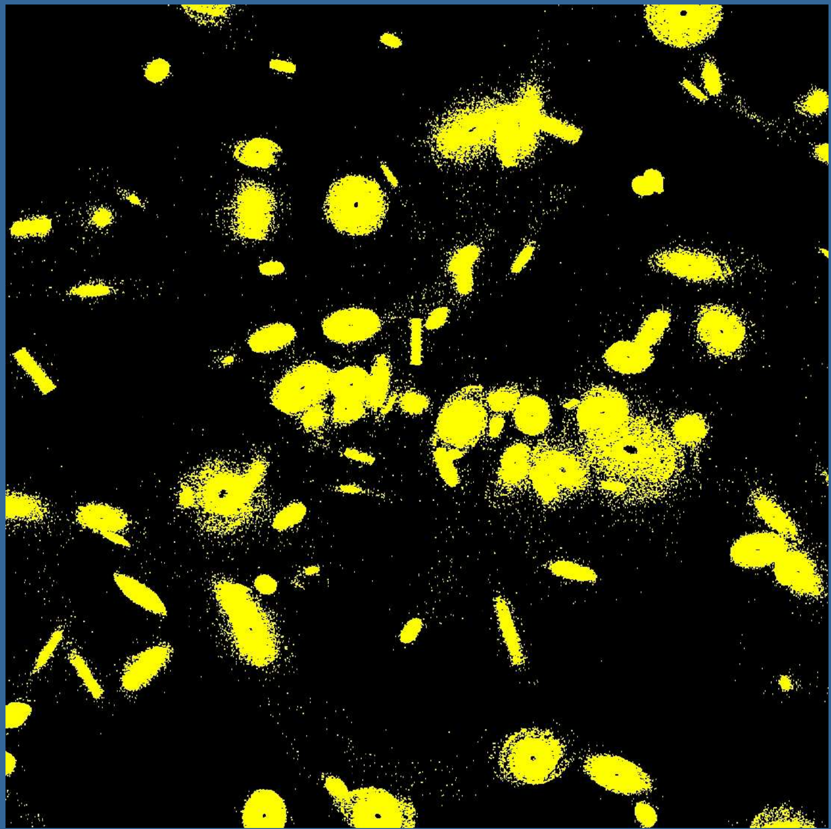
The Effect of the Environment on Protoplanetary Discs -

The example of the ONC



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Motivation

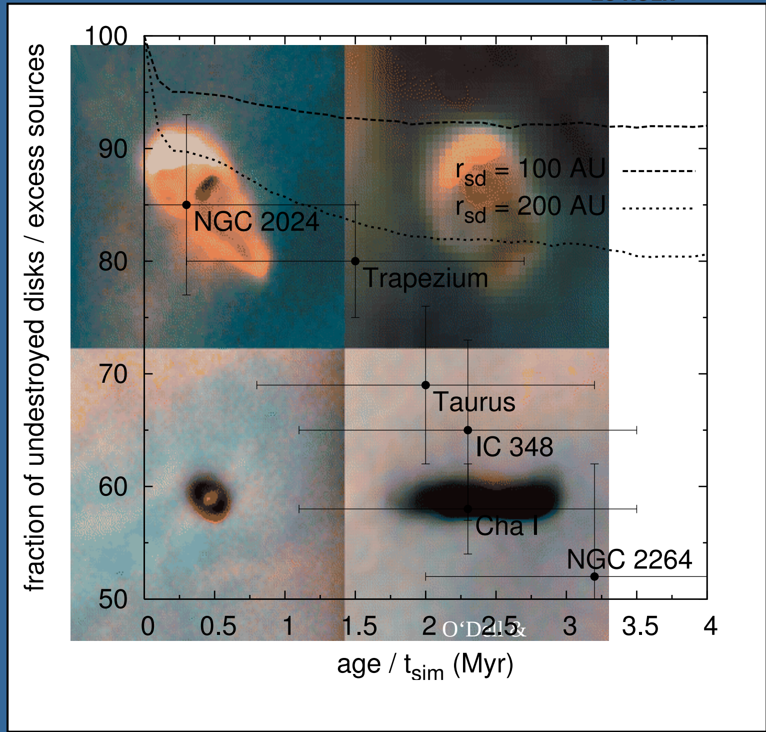
Observations show that most(if not all) young stars are initially surrounded by discs

Such young star-disc systems are mostly not isolated but members of young clusters

Close connection between star formation and development of plantary system

Many open questions in this phase of star-planet formation:

- Importance of disc loss mechanisms
- Angular momentum transport
- Formation of massive stars
- Formation of gas giants planets



However, prevailing view:

Encounters are too rare to matter

The ONC as model cluster

Orion Nebula

Subaru Telescope, National Astronomical Observatory of Japan

CISCO (J, K′ & H_2 (v=1-0 S(1

January 28, 19

The Orion Nebula Cluster (ONC) is

- One of the best observed star forming regions

⇒ many of the physical parameters are well known

- One of the densest star forming regions in the Galaxy

⇒ high probability of encounters

- A typical star forming region

⇒ Results probably applicable to other star forming

Simulating a cluster with star-disc encounters

Method

1. Parameter study of star-disc encounter
Code: hierarchical tree code
Encounter-effect in a disc for different encounter situations

2. Dynamical model of the ONC
Stars only
Code: NBODY6++
List of encounter informations of all stars (Encounter partners, orbits)

Parameter space:

- M_2/M_1 = 0.1…500.0
- r_{peri}/r_{disc} = 0.1…20.0
- e = 1.0…900.0

Only coplanare, prograde encounters

Dimension: $R \approx 2.5$ pc
Number of stars: $N \geq 4000$
Density profile: $\sim r^{-2}$
high central stellar density:
$n^* \geq 4.7 \times 10^4$

Average encounter-effect on protoplanetery discs in ONC

Investigated Properties: Disc Mass and Angular Momentum Loss

- Dynamical model of the ONC

  List of encounter parameters (partners, periastron)

- Each star has initially a disc(size varies as $r_{disc} = 100$ AU $M_1^{0.5}$)

  Loss calculated according to fit formula from parameter.

- Due to the approximations,

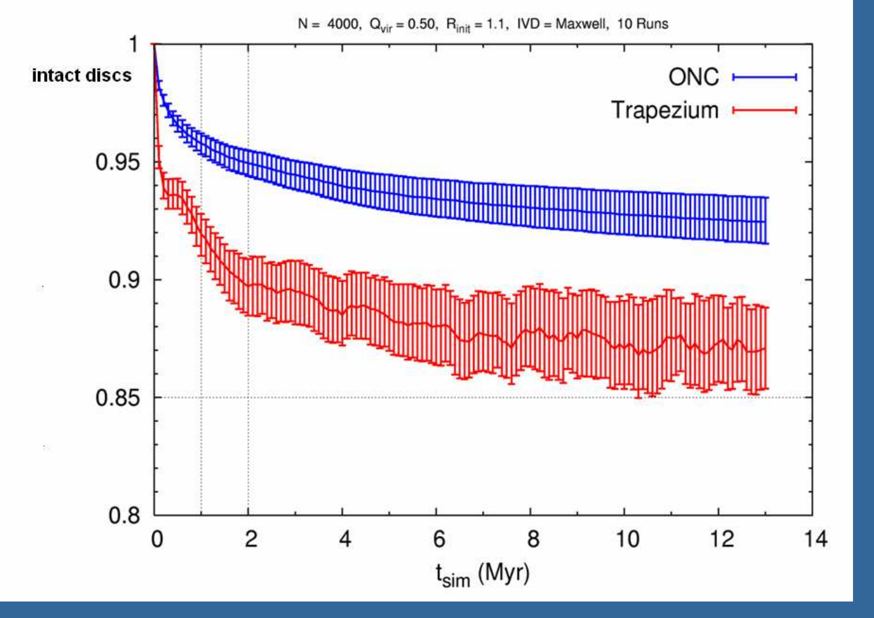
  1. prograde coplanare encounters,
  2. star-disc- instead of disc-disc encounters,

  results represent <u>upper limit of mass and angular momentum loss</u>

Result in Christoph's Diploma thesis: Disc destruction frequency

after 1-2 Myr : ~ 5% in the entire ONC (R = 2.5 pc)

~ 10-15% in Trapezium region (R = 0.3 pc)



Olczak, Pfalzner, Spurzem
ApJ 642, 1140 (2006)

→ In accordance with Lada et. al (2001):
80-85 % of stars in Trapezium Cluster possess discs

Angular momentum loss

Long-standing Problem:

Disc angular momentum far to big to be absorbed in

Gravitational instability scenar

In other words: How do stars accrete matter anyway?

3-5% angular momentum loss

Can encounters reduce angular momentum in disc? f

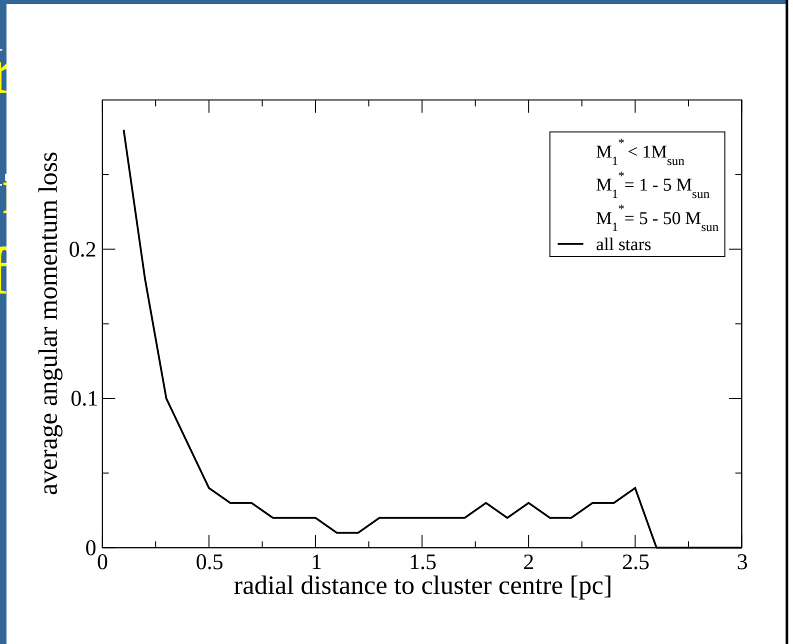
necessary prerequisite for the f

giant planets

My answer: **Yes, but by far not enough!**

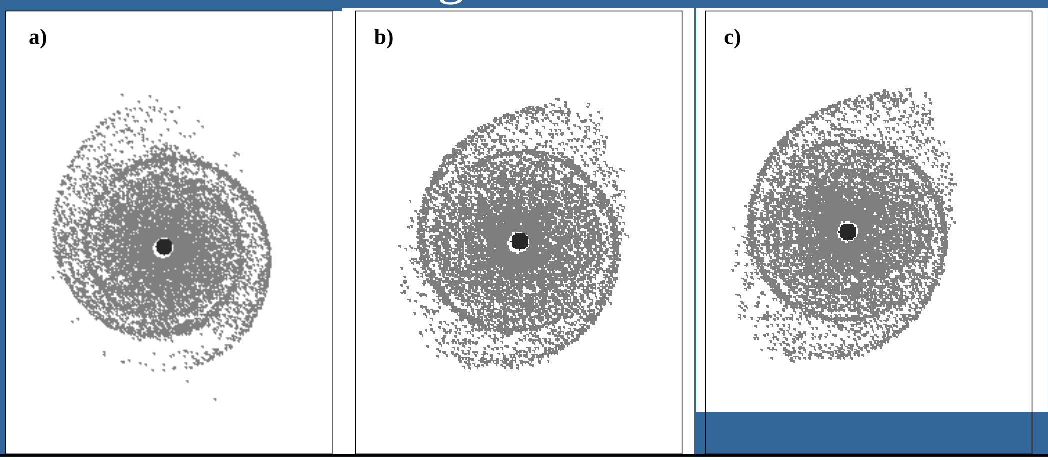
3-5% in entire cluster

15-20% in Trapezium



Pfalzner & Olczak, accepted by A&A

What does a 3-5% angular momentum loss in the disc mean?



Importance of massive stars

Massive stars are mostly (not always) found near cluster center (Mass segregation)

Densest part

In estimates of encounter relevance commonly two mistake are made:

a) Uniform distribution
b) **All stars have the same mass**

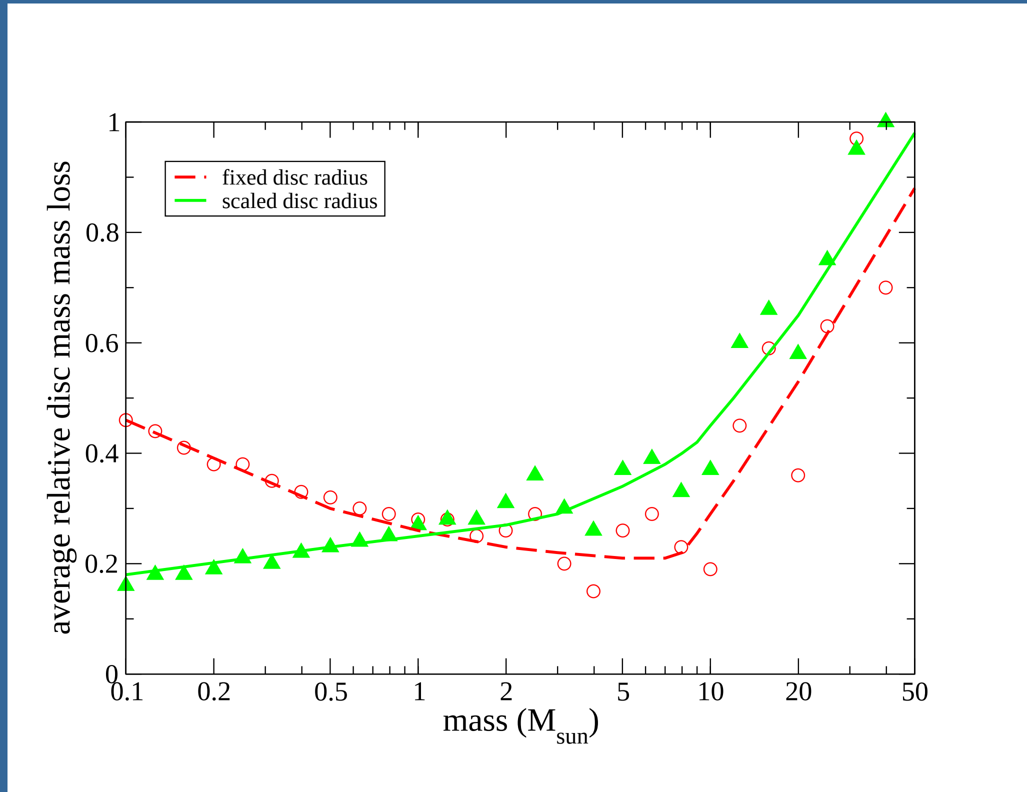
Missed:
Massive stars function as gravitational foci

What does that mean for the massive stars?

They loose their disc

- **much faster and**
- **to a higher degree**

than low-mass stars



Observation of IC348 (Lada 2006)

Disc frequency lower for massive stars

Massive stars :11% ± 8%

Intermediate :47% ± 12%

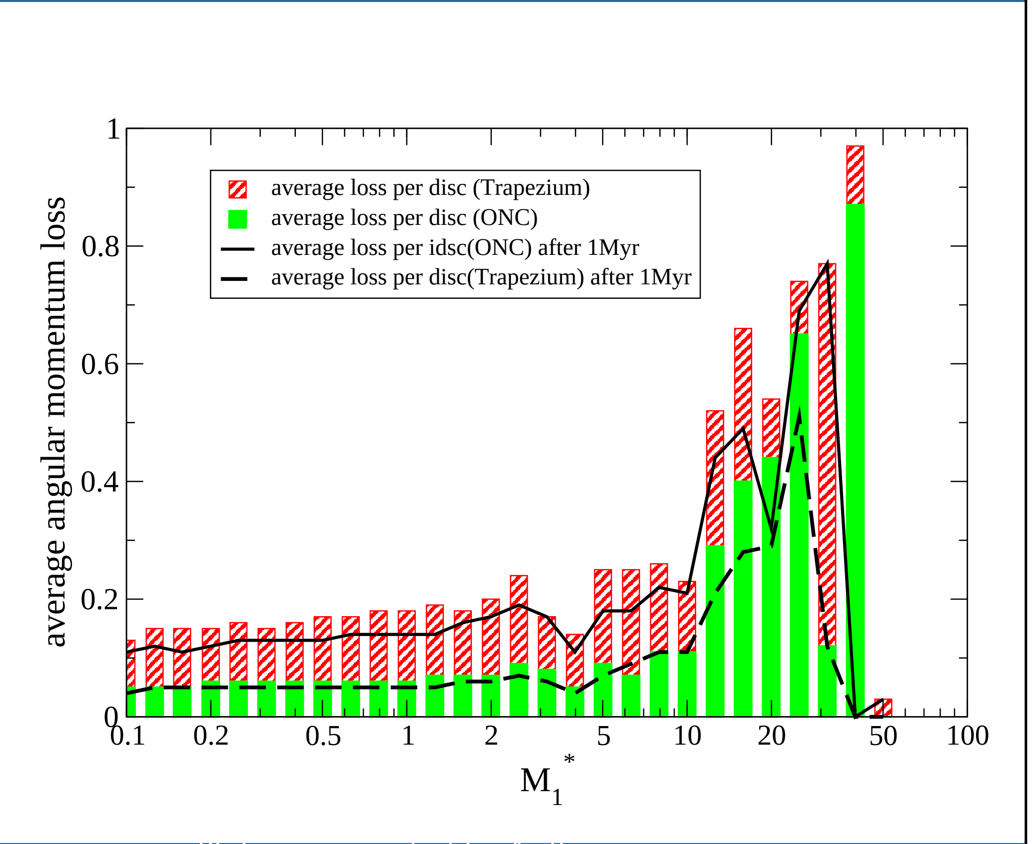
Low-mass stars:28% ± 5%

What about angular momentum loss of discs around the massive stars?

They loose angular momentum faster and to a higher degree than low-mass stars

The specific angular momentum (AM/per particle) is reduced

⇨ higher accretion rate



Pfalzner, accepted by ApJL

Cluster-assisted accretion

Cluster assisted accretion

Massive stars become even more massive

⇨ **Possible mechanism for the formation of massive stars**

Competitive vs cluster-assisted accretion

Similarity: Accretion determined by interplay between cluster stars

Difference: Low-mass stars induce accretion in high-mass stars

Summary

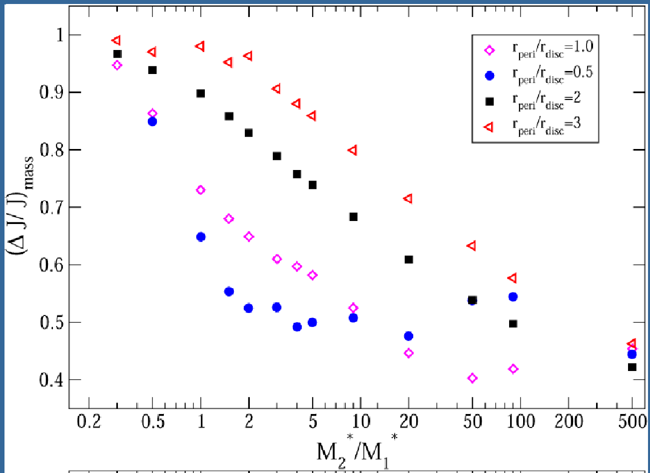
⇒ **Star-disc encounters in dense young stellar clusters have important consequences for the formation of massive stars and planetary systems**

Future plans:

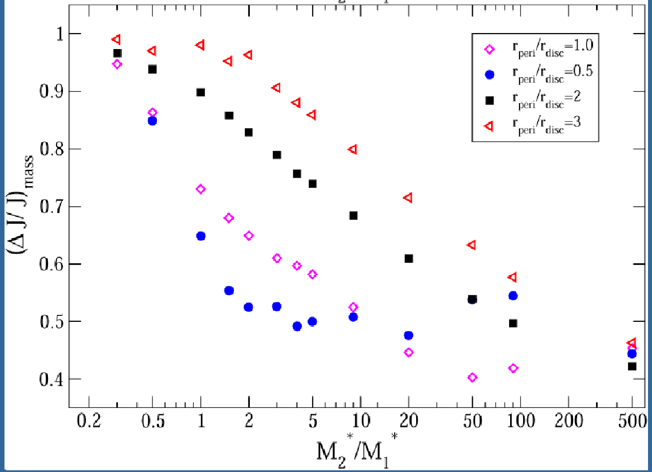
- **Encounter induced accretion**
- **Disc truncation? Change of density distribution in disc?**

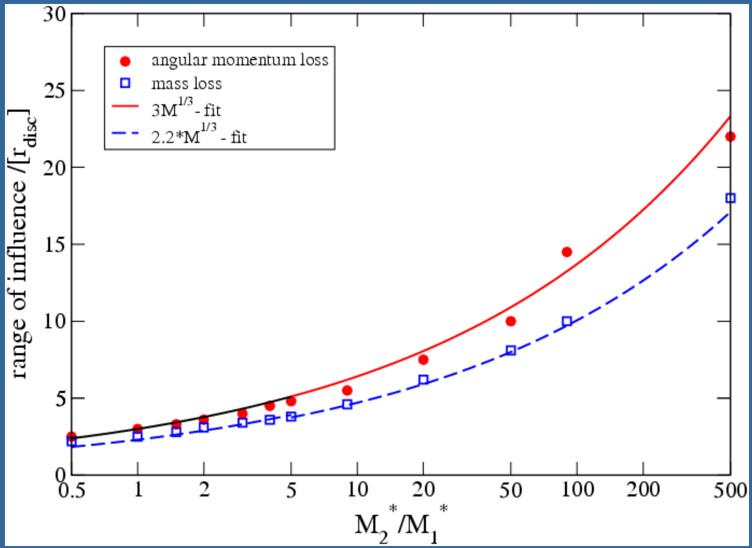
Angular momentum loss in star-disc encounter

a)



b)





Interaction region for angular momentum loss larger than for mass loss

➤ Fit formula for AML ➤ Input in cluster simulations

Further ONC images