Planet Formation in Stellar clusters

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Background –1–

- Stars form in clusters
- Around young stars there exist circumstellar discs which are remainder of the star formation process.
- Planet forms in the circumstellar disscs. At least of recent few growing planets are observed in discs.
- Why are few planets observed even in open stellar clusters?
  - Observation difficulty?
  - Do planet start forming in the discs after escaping the stellar clusters?
  - Maybe in stellar clusters conditions are never favourable for planet formation

Background –2–

Observation difficulty

1. False positive (Delgado Mena, E., Lovis, C., Santos, N. C., et al. 2018, AA, 619, A2)
2. Shallow dips in the light curves (Pepper, J., Stanek, K. Z., Pogge, R. W., et al. 2008, AJ, 135, 907)
3. Incompleteness of surveys, i.e pleaides (Fujii, M. S.; Hori, Y., et al. 2019,AA,624,A110)

What are the conditions in stellar clusters and what do they mean to planet formation

1. Fly-bys: Truncates the disc (Vincke, Kirsten; Breslau, Andreas; Pfalzner, Susanne,577,A115), eject planets at the discs outskirts (Fragner, M. M.; Nelson, R. P.,2009,AA,505,873-889)
2. Photoevaporation: disc lifetime, planet atmosphere (e.g. Armitage P.J.2000,AA362, 968)
3. Background heating (e.g Ndugu N., Jurua E., Bitsch B., 2018, MNRAS, 474, 886)

Background –3–

What is then missing?

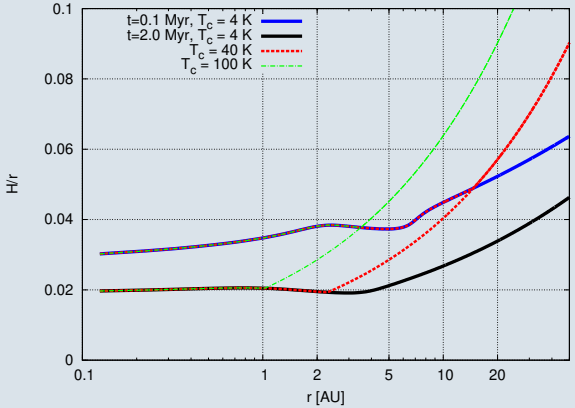
- In sciences it is sometimes good to separate the object of interest from its surroundings and look at it in isolation if clear clarity is needed. sometimes is not always.
- If indeed planets starts forming while their host stars are still in clusters, then it is not good to model planet formation as if they all start forming around field stars.

Planet formation

The most widely accepted planet formation models are the **core accretion** and the gravitational instability models.

- In the core accretion, a bottom top approach is followed.
- Solid materials (cm-sized or km-sized) are accreted from the disc onto the planets-embedded in the disc.
- Aerodynamically coupled pebble (cm-sized) accretion, planetesimal (km-sized) accretion.
- Solid accretion occurs until isolation mass.
- As long as isolation mass is reached when there still gas in the disc, gas accretion proceeds.
- The protoplanet also perturb the natal discs and changes orbit (migration)

Disc structure in stellar clusters: Incorporating background heating (Ndugu et al.2018)

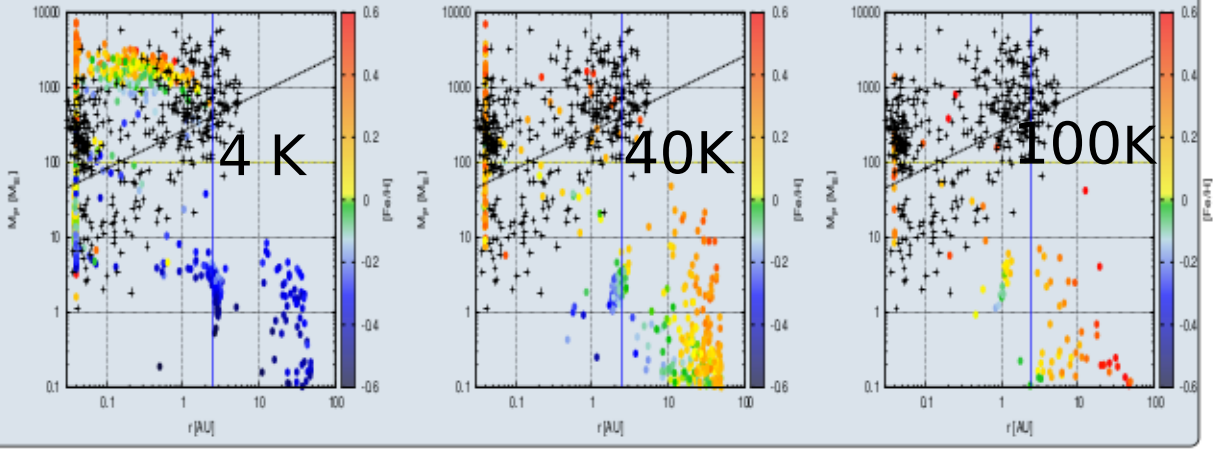


- We expanded the disc model of Bitsch et al. 2015 to account for background heating.
- Cluster environments cause flaring H/r profile of the disc.
- Since, $M_{\rm iso} \propto \left(\frac{H}{r}\right)^3$, high H/r implies higher $M_{\rm iso}$
- Cores therefore takes longer time accreting times. By the time gas accretion starts disc might be dispersed.

Planet population synthesis

- **How does it work?**
  1. Randomize the initial conditions of planet formation.
  2. Generate population of planets.
  3. Compare the population of the synthesized planets to observation.
  4. Evaluate the suitability of the planet formation models in matching the observation.

Mass-distance distribution



SE: Super Earth

NP:Neptunian

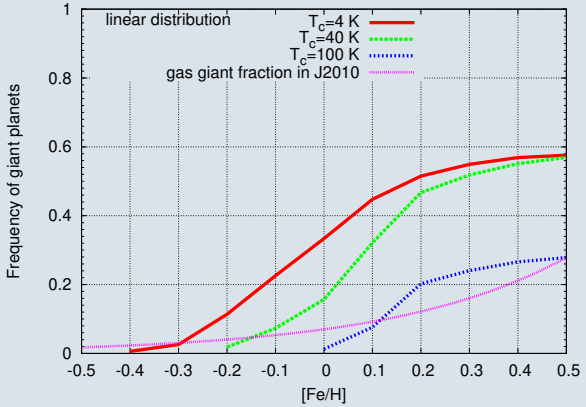
HJ: Hot Jupiter

$T_c[K]$	SE	NP	HJ	WJ	CJ	Others
4	32.2	8.9	32.4	16.1	1.2	9.2
40	5.3	3.3	10.7	0.7	0.7	79.3
100	1.9	0.6	1.2	0.0	0.0	96.3

WJ:Warm Jupiter

CJ: Cold Jupiter

Comparison to giant exoplanets



- Overfits at low cluster environment.
- Relatively better fit at high cluster environment.
- Saturation of the simulation curve at high metallicity.
- Maybe for efficient solid accretion (pebble accretion), hotter background heating like in clusters is needed for matching the gas giant planets.

Remarks

- We modelled only the background heating from stellar clusters, but did not incorporate the impact of clusters on disc truncation and thus on a decrease in pebble flux.
- Our approach is the simplistic, one-embryo per disc, multiplicity will even slower down pebble accretion more due to enhanced eccentricity.
- We did not account for ejection of gas giant planet at the disc's outskirts due to parabolic encounters.
- Our approach immediately stopped when the disc is disc is dispersed, the important long time evolution even after disc evolution not incorporated