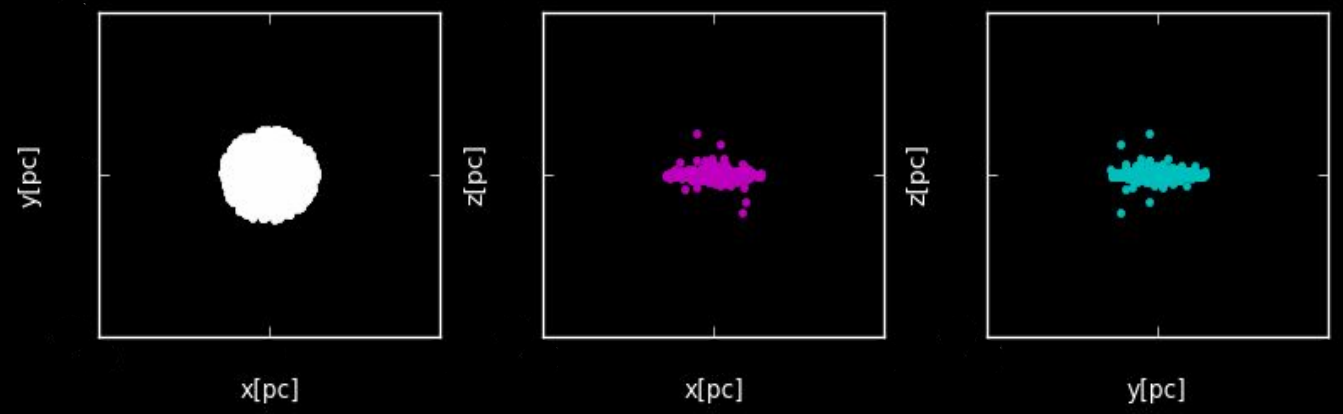
Stellar collisions in flattened and rotating Pop. III systems



Marcelo C. Vergara, D. R. G. Schleicher, T. C. N. Boekholt, B. Reinoso, M. Fellhauer, R. S. Klessen, & N. W. C. Leigh (2021)

Observational evidence of SMBH

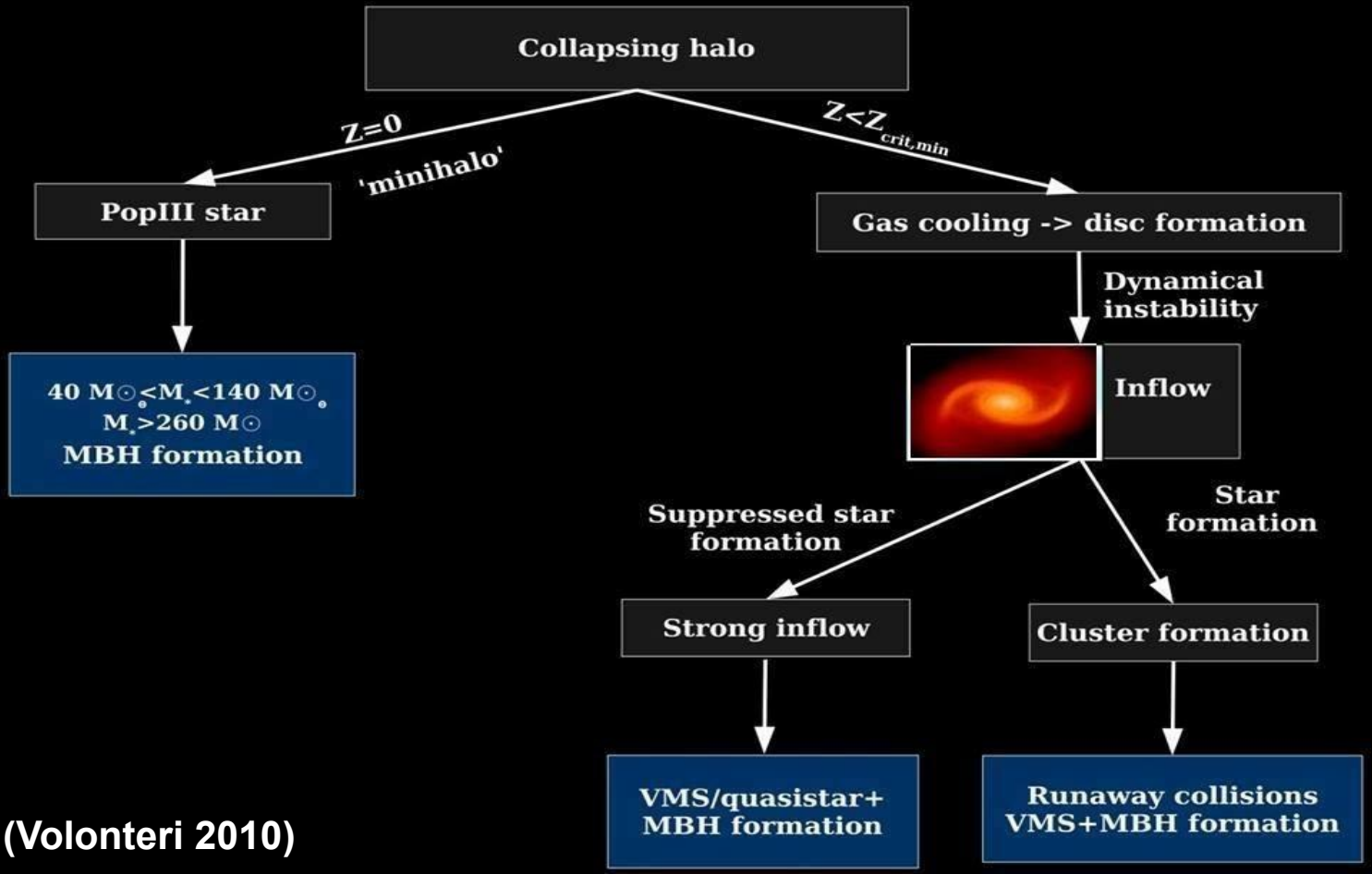
- **The SMBH ULAS J112'+0641 at redshift $z = 7.085$ with mass of $2 \times 10^9 M_\odot$ (Mortlock 2011)**

- **Studies of the properties of more than 100 quasars at $5.6 \leq z \leq 6.7$ (Bañados 2016)**

- **The AGN at $z = 7.5$ with mass of $8 \times 10^8 M_\odot$ when the Universe was only 600~Myr old (Bañados 2018)**

- **The first image confirming the existence of a SMBH with mass of $6.5 \times 10^9 M_\odot$ with the EHT (Event Horizon Telescope Collaboration 2019)**

Pathways to BH formation



(Volonteri 2010)

Miyamoto-Nagai Disk

They defined the density and potential:

$$\rho(r,z) = \left(\frac{Mb^2}{4\pi}\right) \frac{ar^2 + (a+3\xi)(a+\xi)^2}{\xi^3 \left(r^2 + (a+\xi)^2\right)^{5/2}}$$

$$\Phi(r,z) = \frac{GM}{\sqrt{\left(r^2 + (a+\xi)^2\right)}}$$

Where M is total mass of cluster, r and z the radial and z coordinate respectively, the parameters a & b characterizing the shape of the disk and $\xi^2 = z^2 + b^2$

Miyamoto-Nagai Disk

The mean rotational velocity is obtained by assuming an isotropic velocity dispersion around v_{rot}, a natural choice is the k-decomposition introduced by Satoh (1980):

$$v_{rot}^2 = k^2 v_{iso}^2 + (1 - k^2) v_{disp}^2$$

For k=0 all stellar motions are random, while k=1 corresponds to an ordered motion, dominated by rotation.

Nbody6

- We use NBODY6 (Aarseth 2000) to treat collisions.
- It is a fourth order Hermite integrator which includes a spatial hierarchy to speed up the calculations
- The Ahmad-Cohen scheme (1973), to calculate regular and irregular forces.
- Another routine included is the Kustaanheimo-Stiefel regularization (1965), an algorithm to treat close encounters.

Initial conditions

$$M_{cluster} = 10^5 [M_\odot]$$

$$k = 0, 0.4, 0.8, 1$$

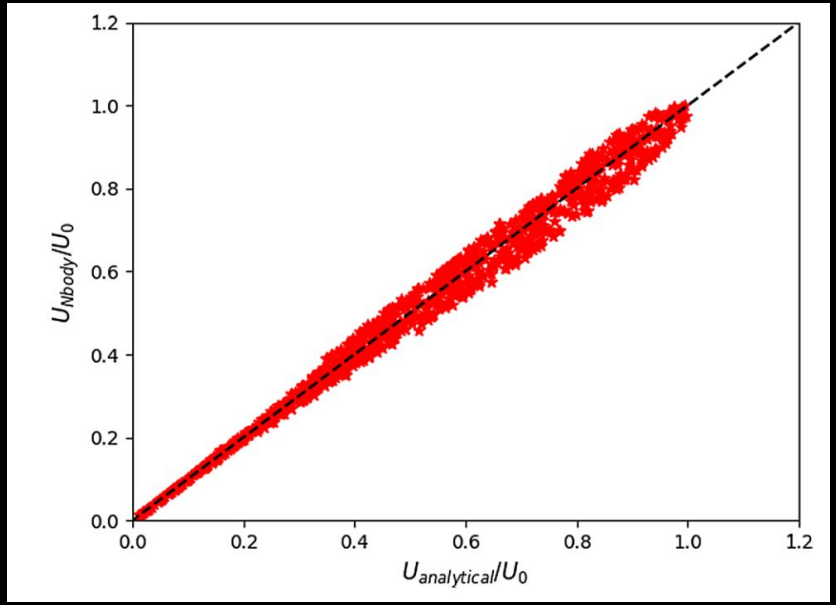
High rotation

$$N_* = 1000, 5000, 10000$$

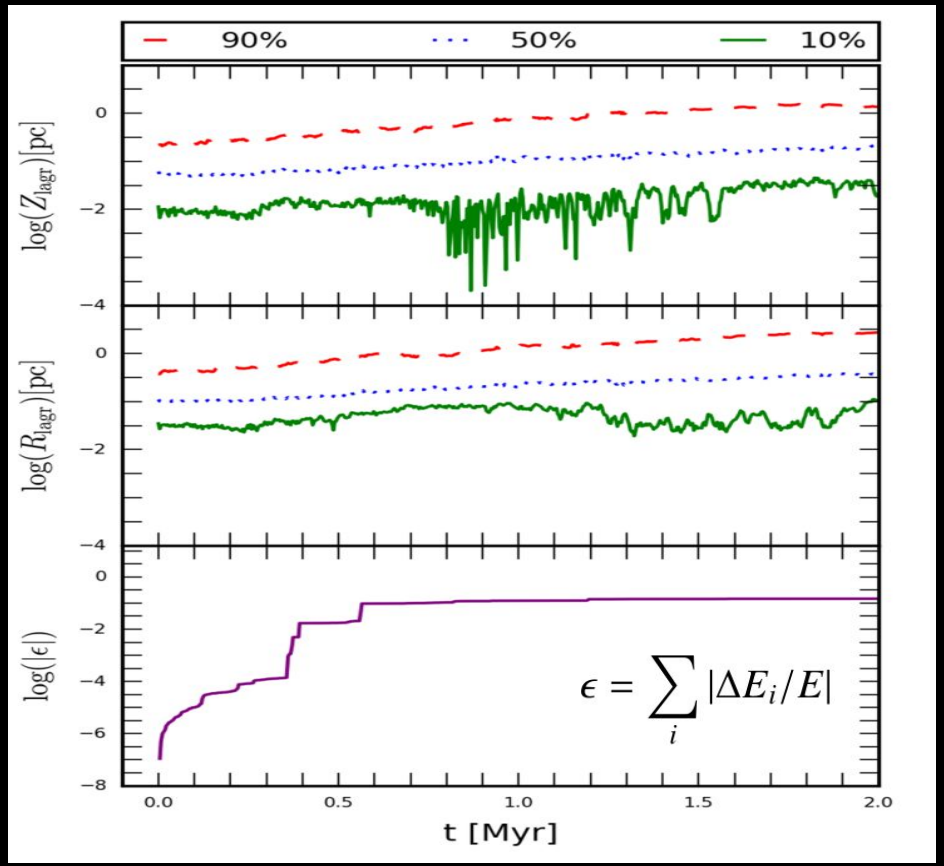
$$R_* = 50, 100, 500, 1000 [R_\odot]$$

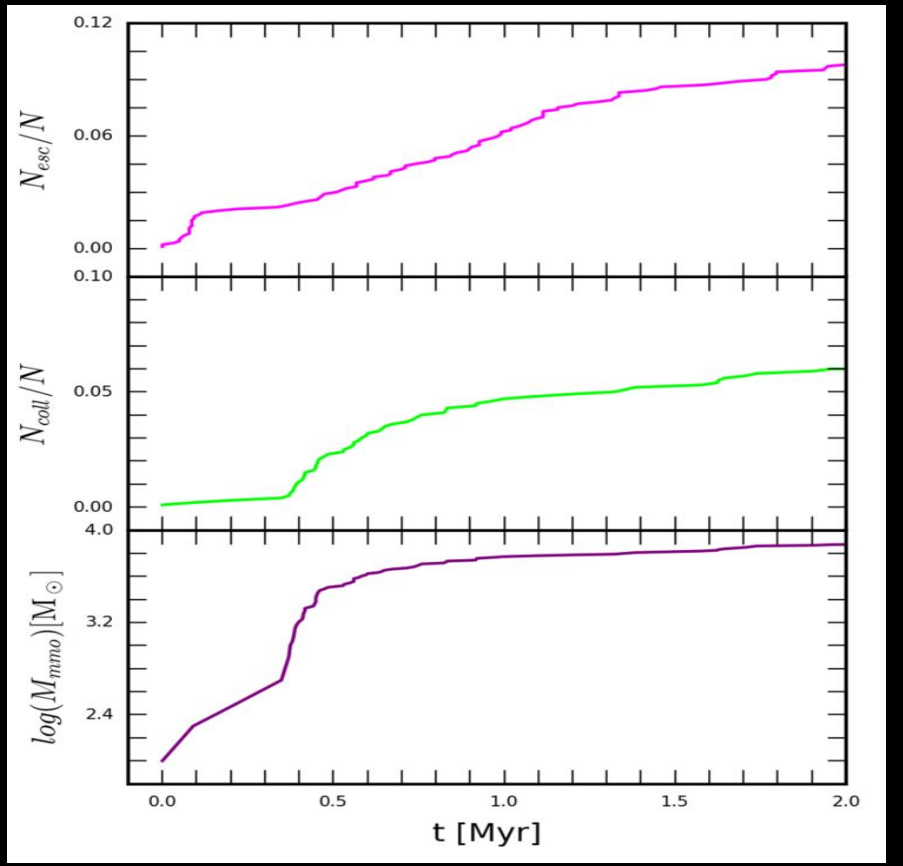
$$M_* = M_{cluster} / N_*$$

cluster name		a [pc]	b [pc]
A	(Flatter)	0.06	0.04
B		0.04	0.06
C	(Rounder)	0.01	0.09



Results

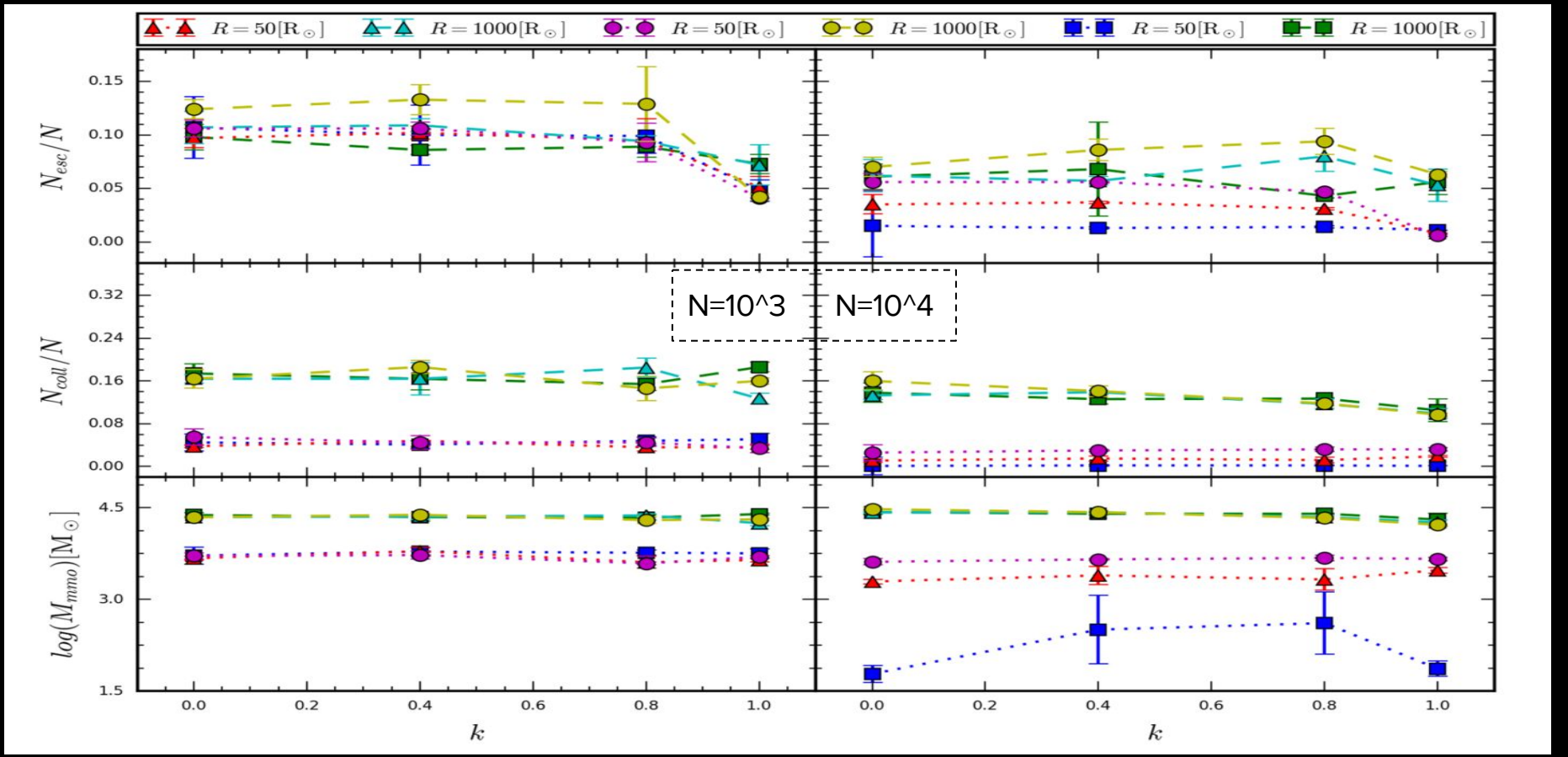




Vergara (2021)

Results

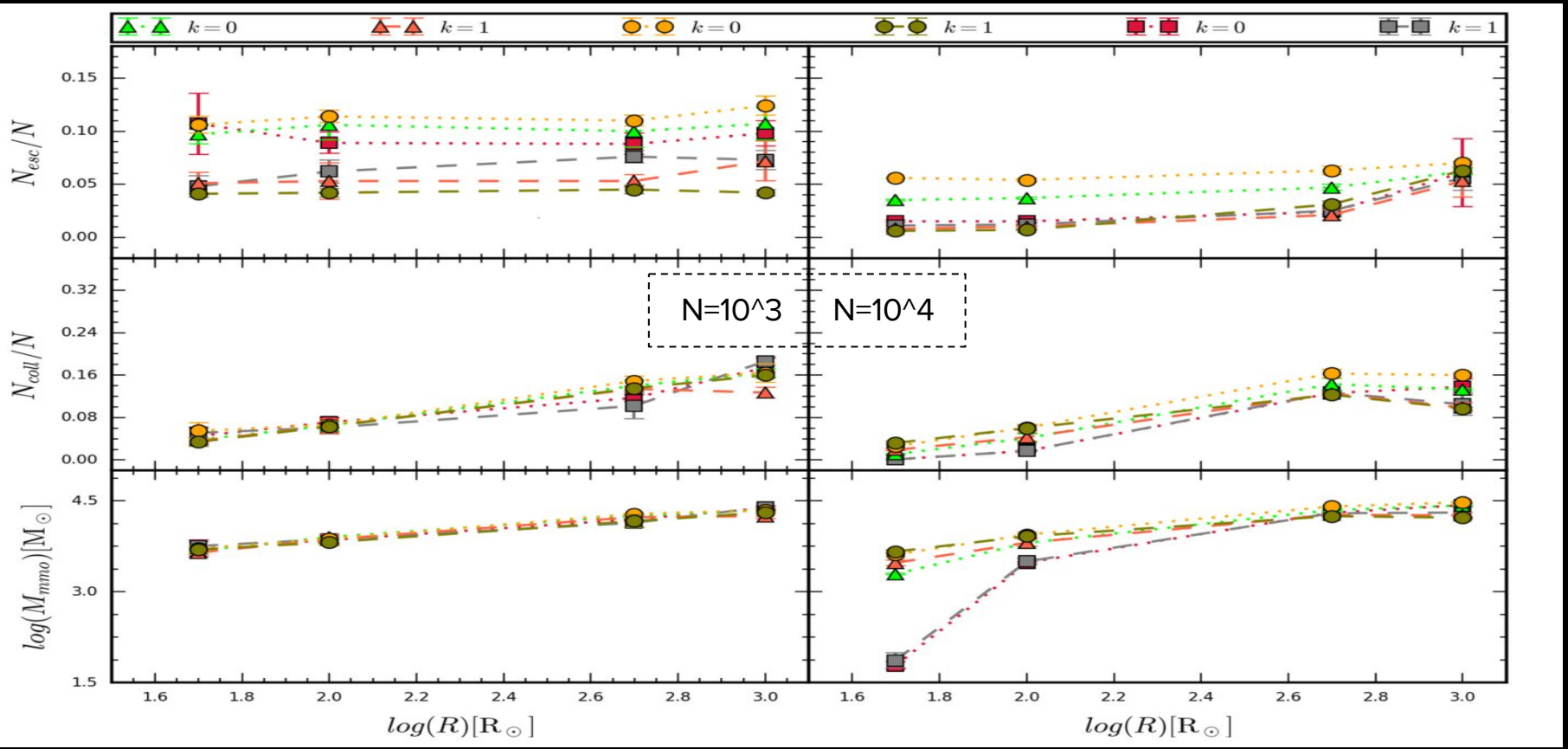
△ A (Flatter) ○ B □ C (Rounder)



Vergara (2021)

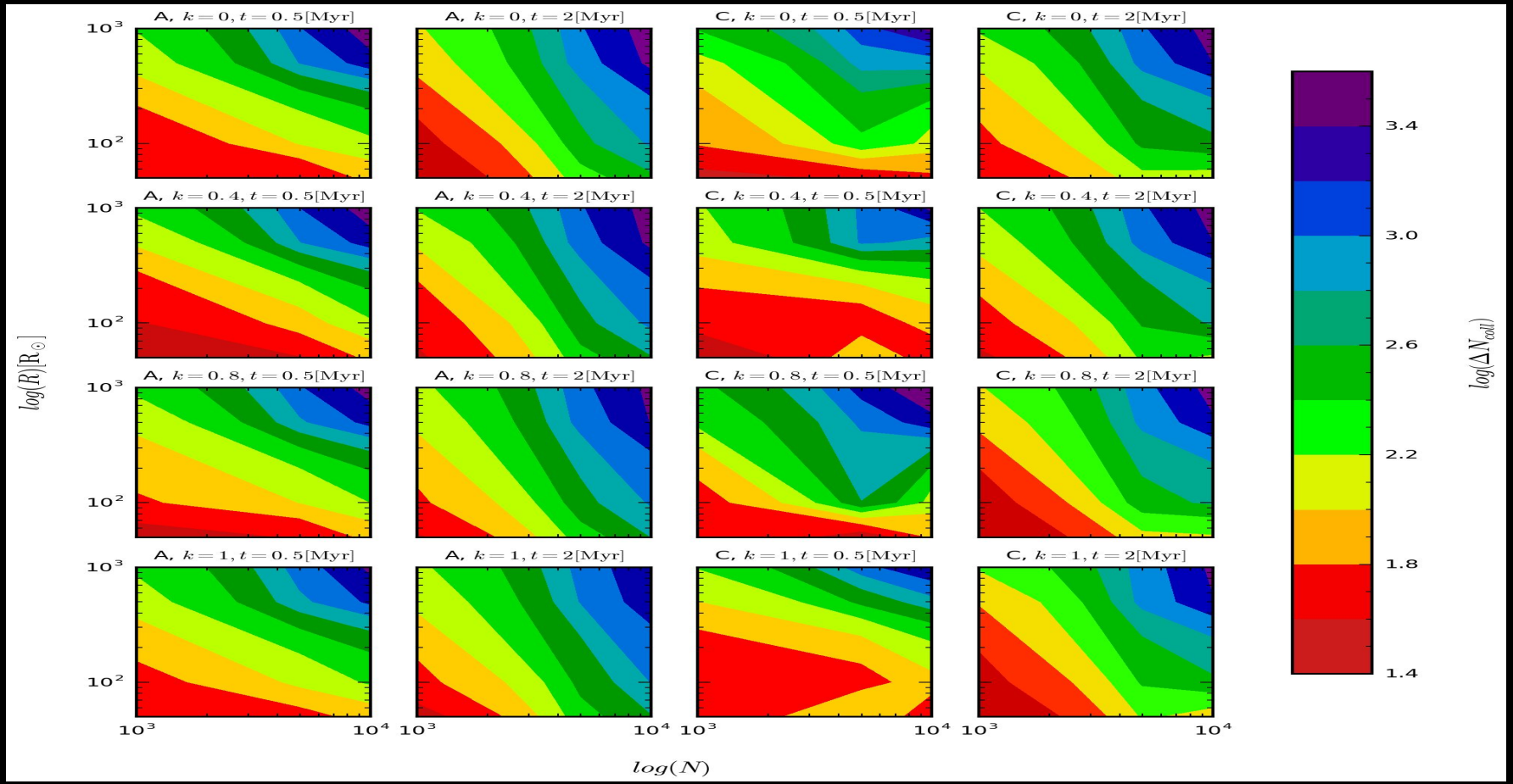
Results

△ A (Flatter) ○ B □ C (Rounder)



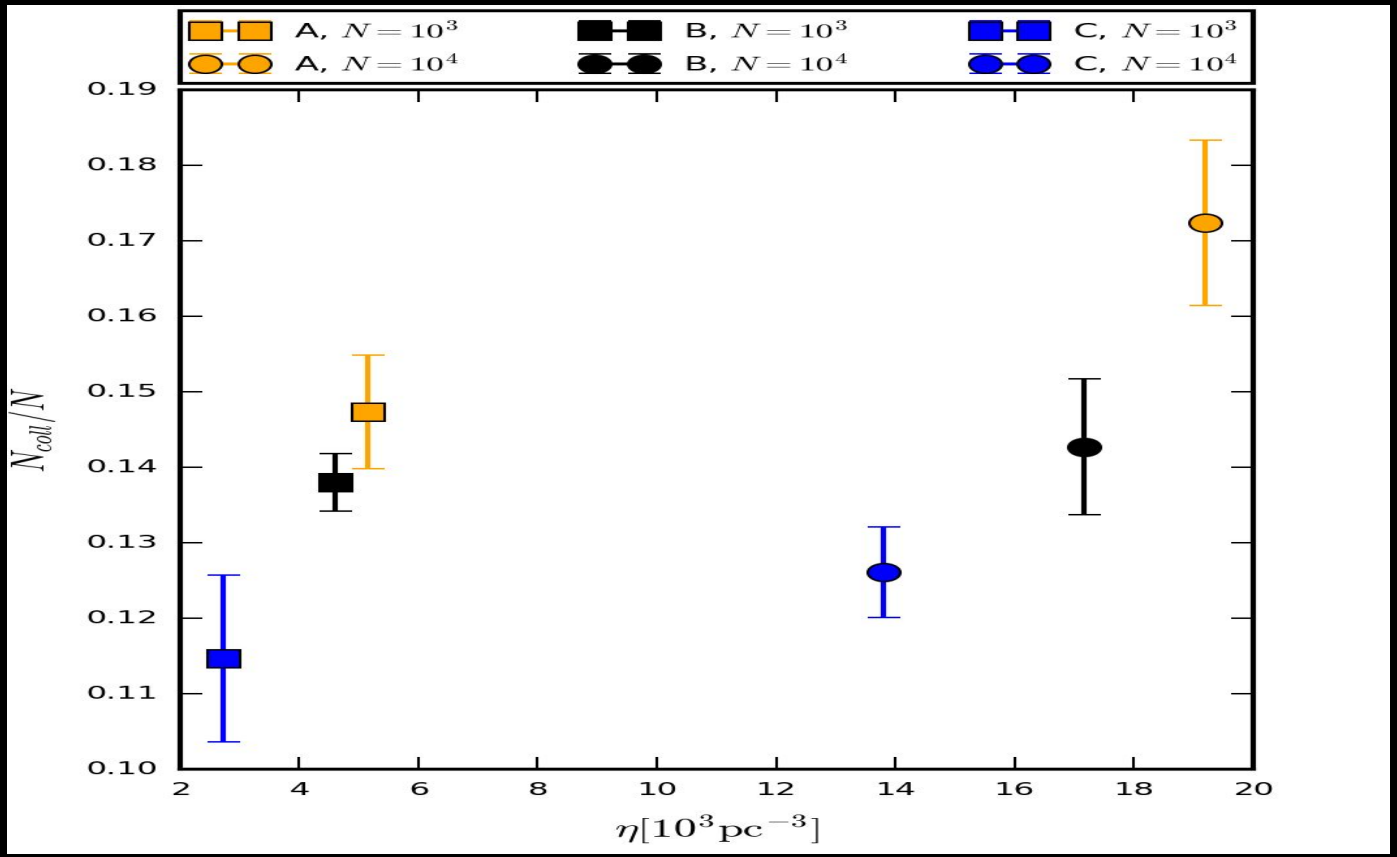
Vergara (2021)

Rotation & Runaway collisions



Vergara (2021)

Flattening & Runaway collisions



Vergara (2021)

Conclusion

- The number of collision is higher in systems with more stars and larger stellar radius.
- The rotation slightly decreases the number of collisions.
- The flattening increase the number of collisions.