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Can Star-disk Collisions Explain the Missing Red Giants Problem in the GC?

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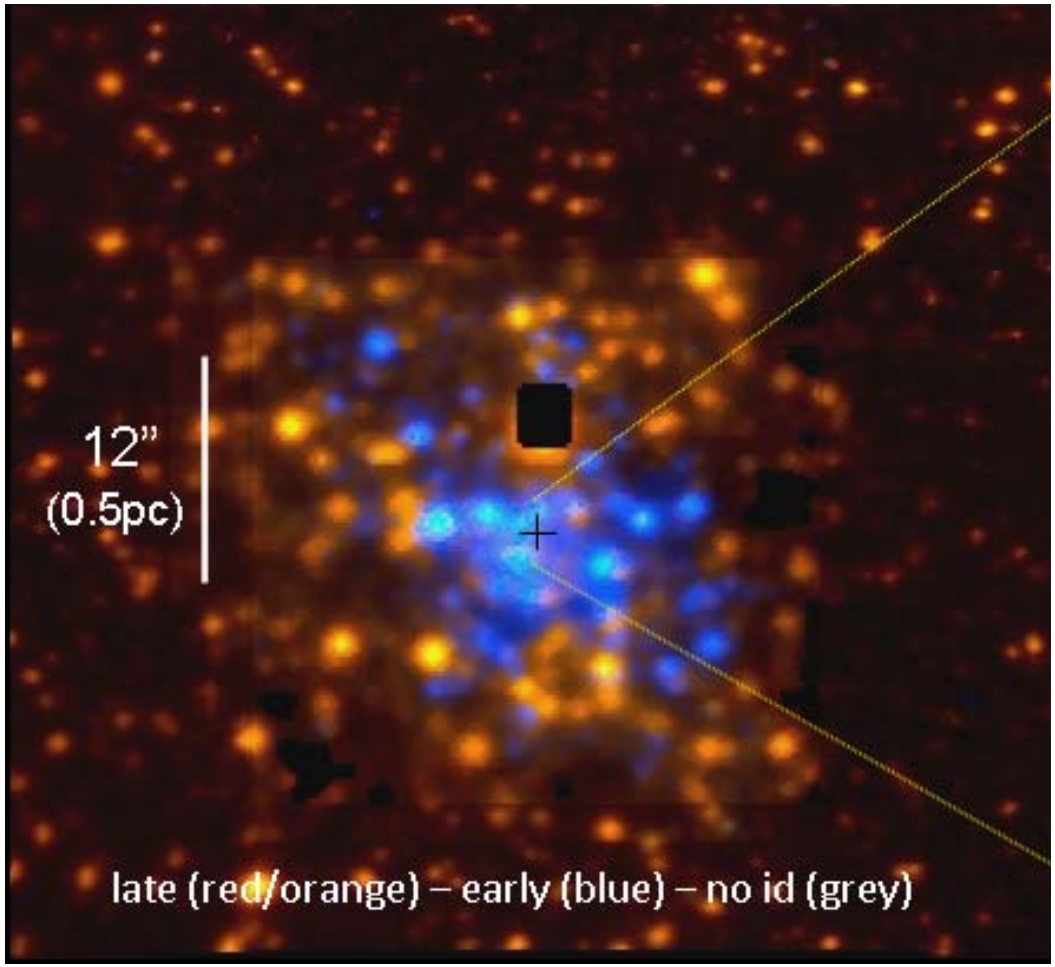
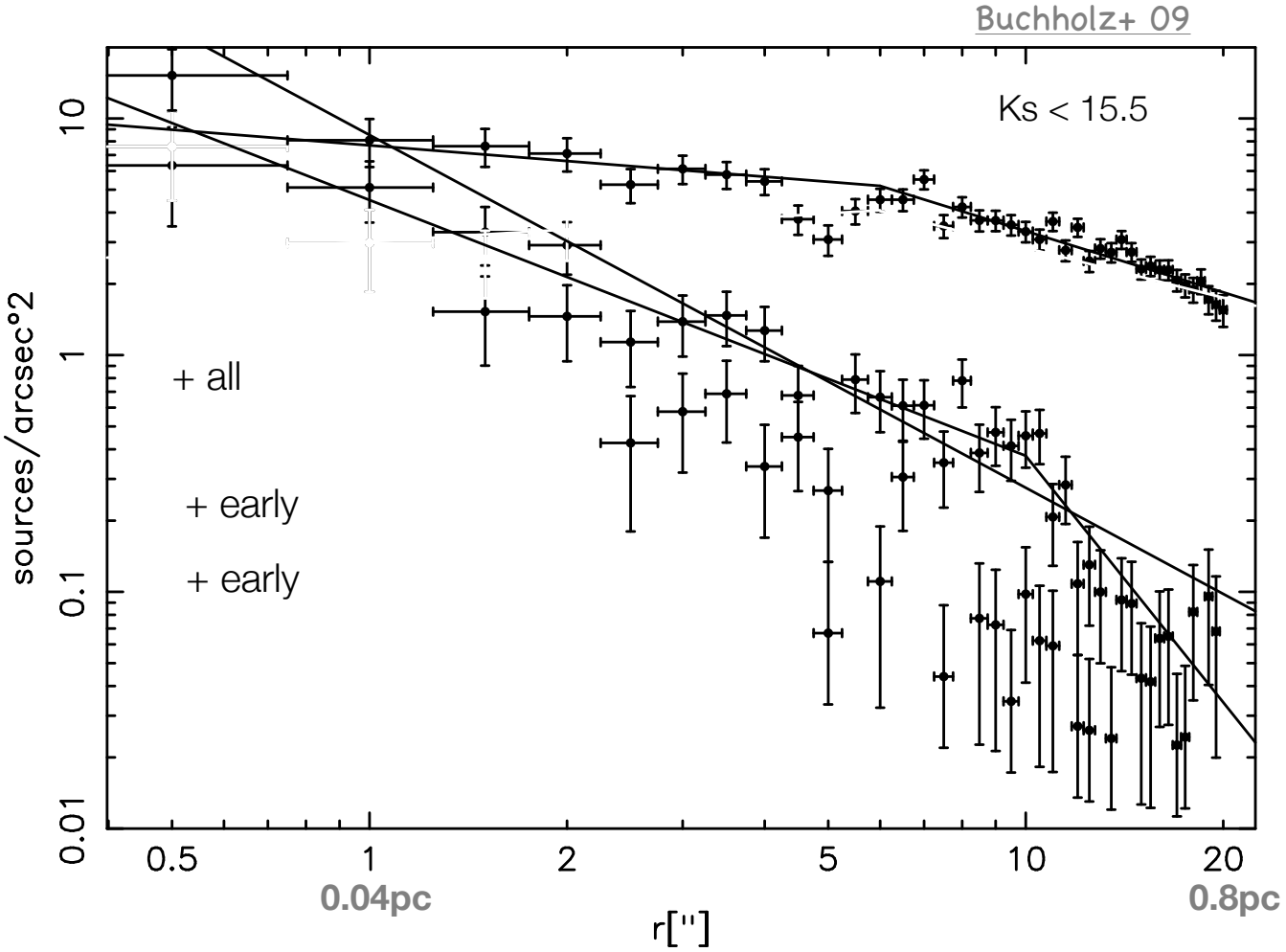
The Central Parsec

- 96% of observed stars are ~1Gyr old RG and HB stars M~0.5-4$M_\odot$
- Young stars at <1 pc appear to be confined to two disks with different inclinations (Genzel+ 03, Tanner+ 06, Paumard+ 06)
- ~100 WR and O-type stars: M~10-60$M_\odot$, ~10^6 yr old



Credit: SINFONI/VLT/Genzel 10 (1.1–2.4 μm)

Deficit of old stars



- Distribution of old stars contrasted by steeply rising population of young stars (Genzel 03, Paumard 06, Buchholz+ 09, Do+ 09, Bartko+ 10)

But why the central deficit of old stars?

- Born this way (Alexander 07; Preto & AS 10; Merritt 10; Lady Gaga 11)
- Ejection of stars by an IMBH - SMBH binary
- Top-heavy IMF close to the SMBH
- Star-star collisions
- Star-disk collisions

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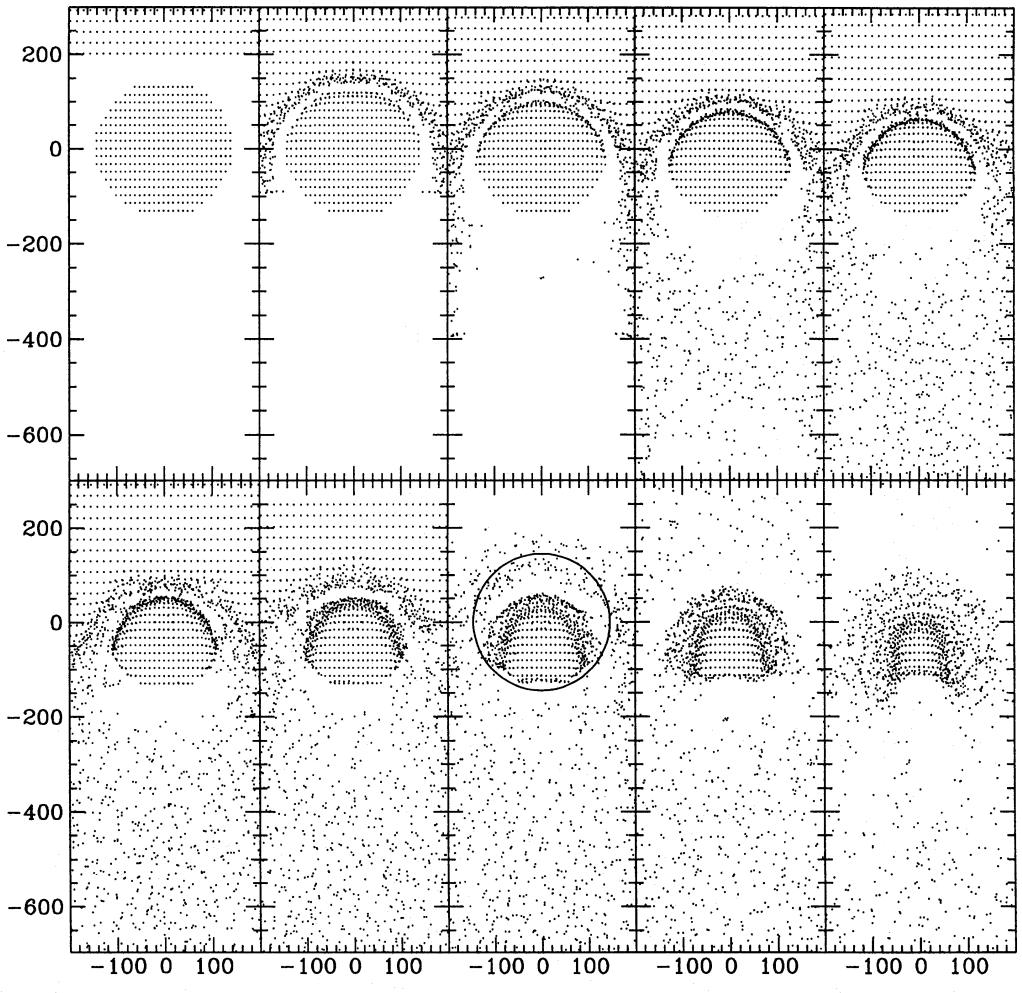
Star-disk collisions

Amaro-Seoane & Chen 14

- RGs' extended, tenuous envelopes removed in collisions with the fragmenting disk.

- RGs with R=150$R_\odot$ lose 50% of mass in ~10 impacts with clumps of surface density 10^4 g/cm^2



Credit: Armitage, Zurek & Davies 96

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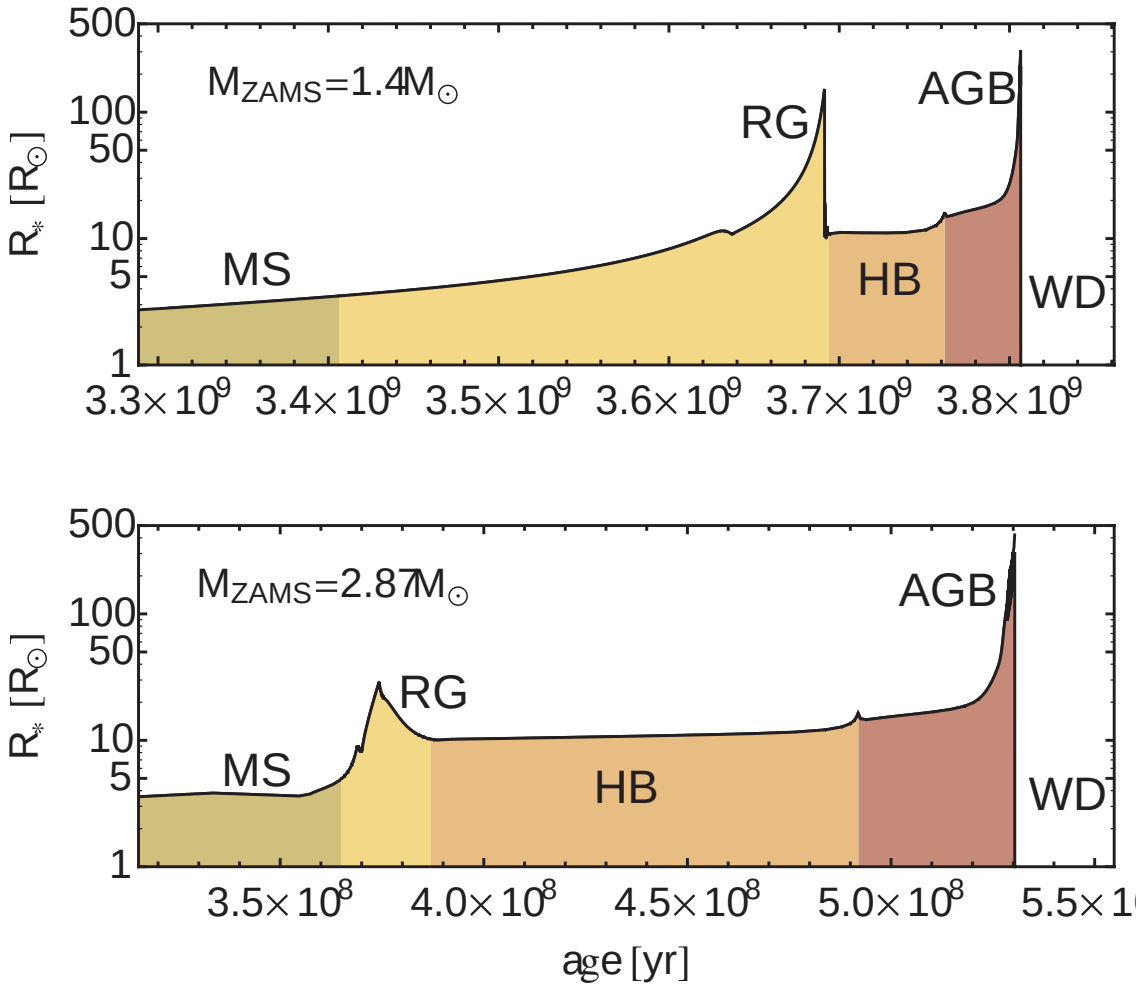
- Smaller RGs and HB stars with $R\sim10R_{\odot}$ require more impacts or denser clumps.

Post-MS stellar evolution calculated with MESA (MacLeod+ 12)



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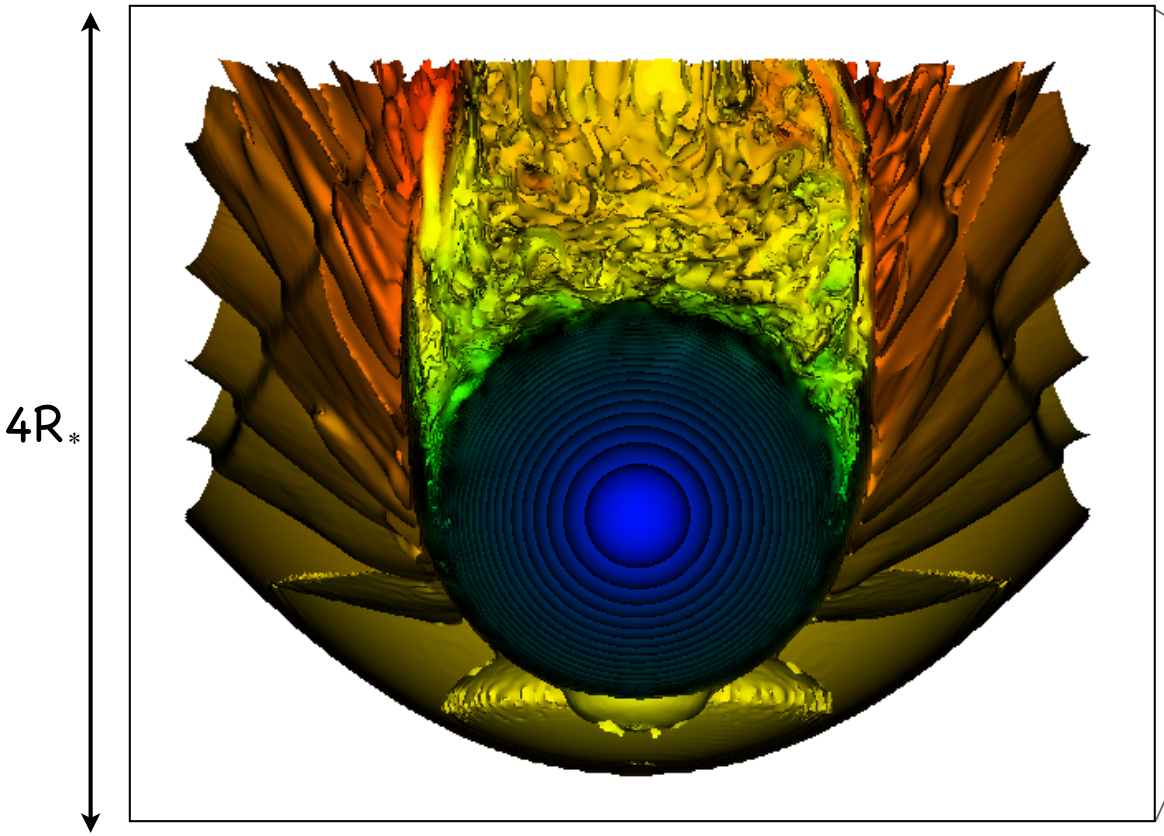
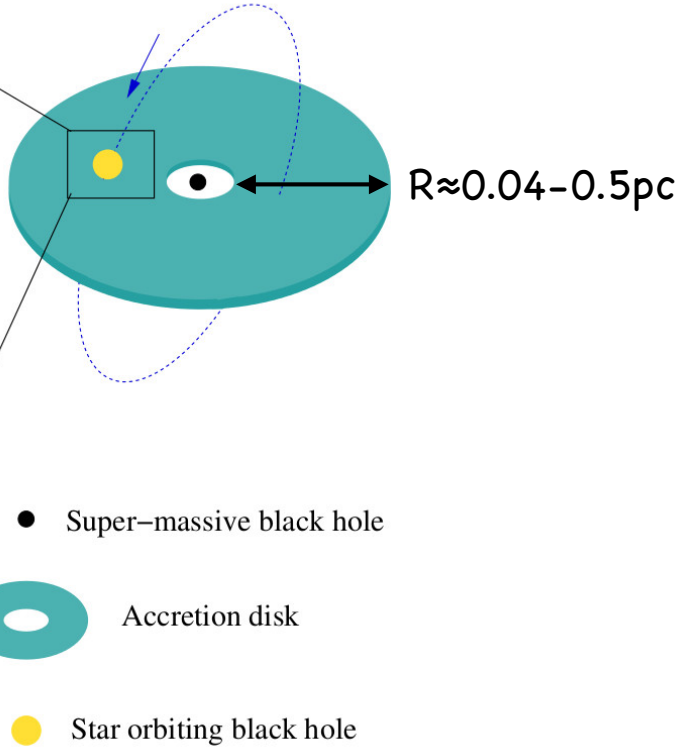
Computational setup: Star in a wind tunnel



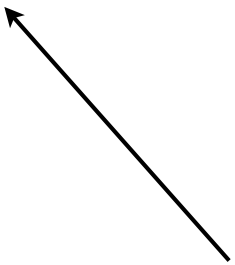
(Illustration from Nayakshin+ 03)



$P_{orb} \approx 10^3 - 10^4$ yr $V_{orb} \approx$ 200 - 1200 km/s

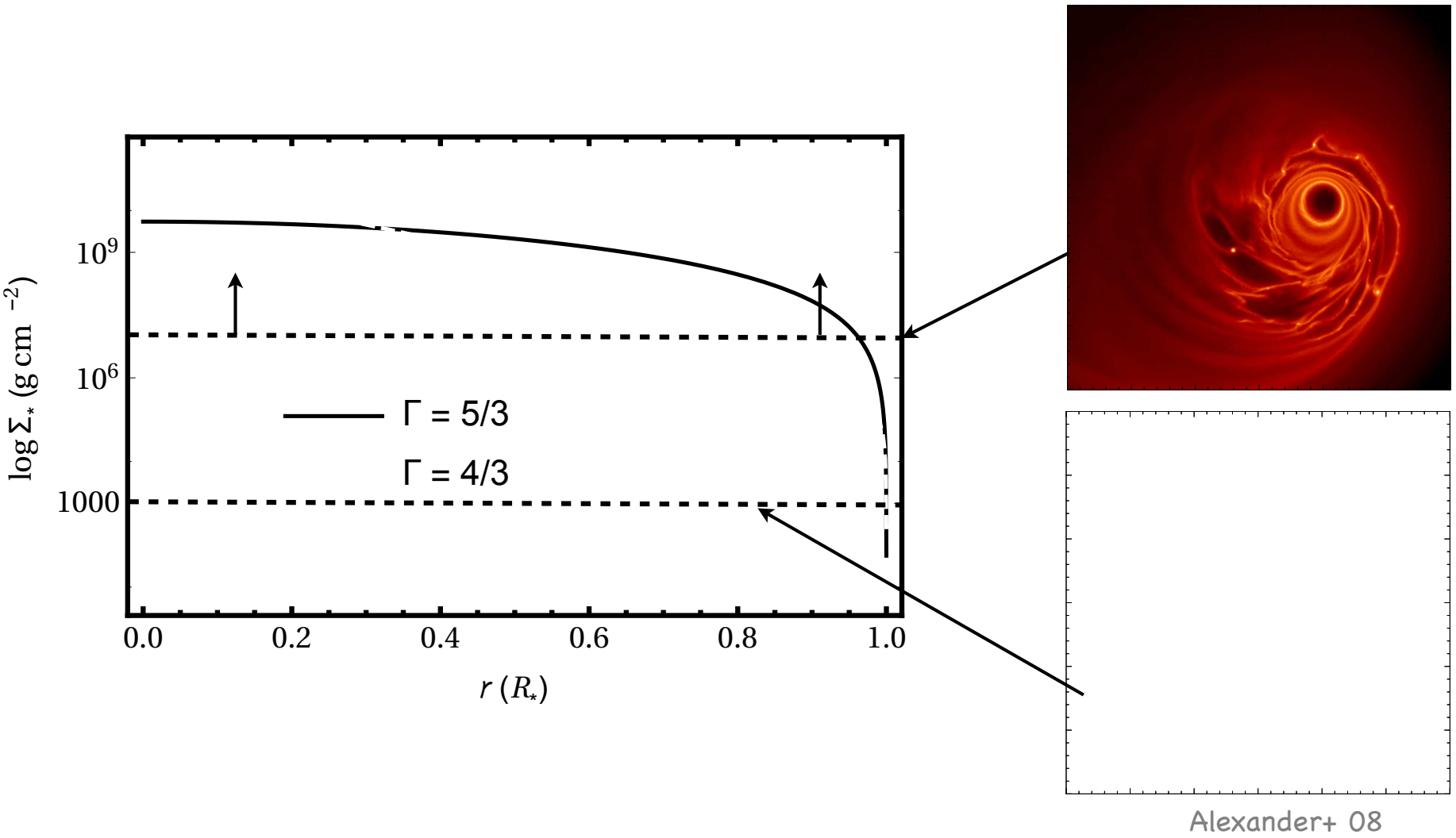
Properties of the modeled RG star

$R_* = 10R_\odot$ $M_* = 1M_\odot$ t_{dyn}~11hr



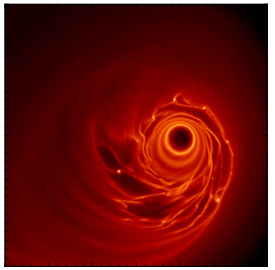
Barely any mass in the envelope beyond 0.5R

RG in encounters a fragmenting disk



Alexander+ 08

Collisions with clumps

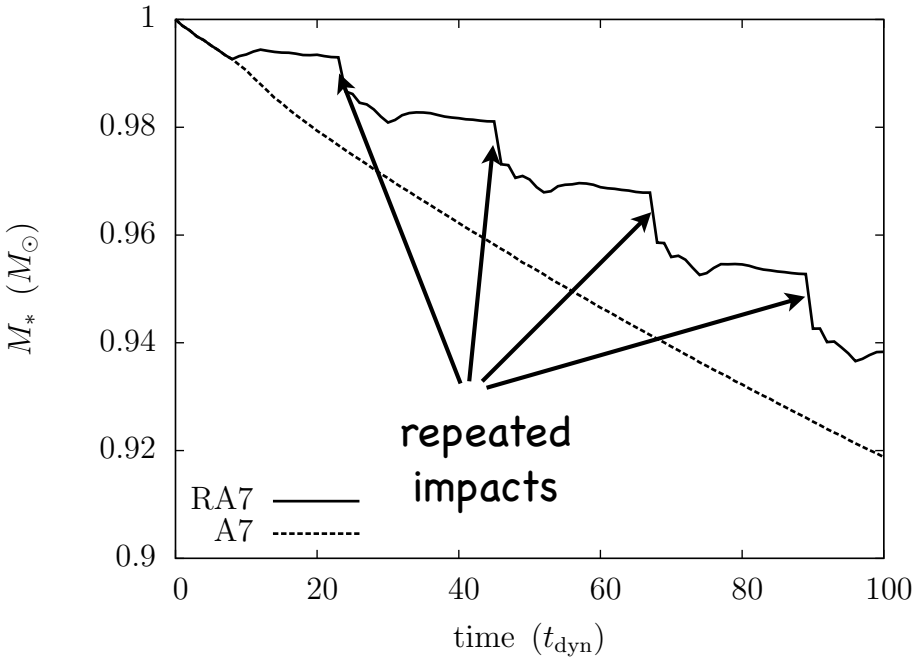


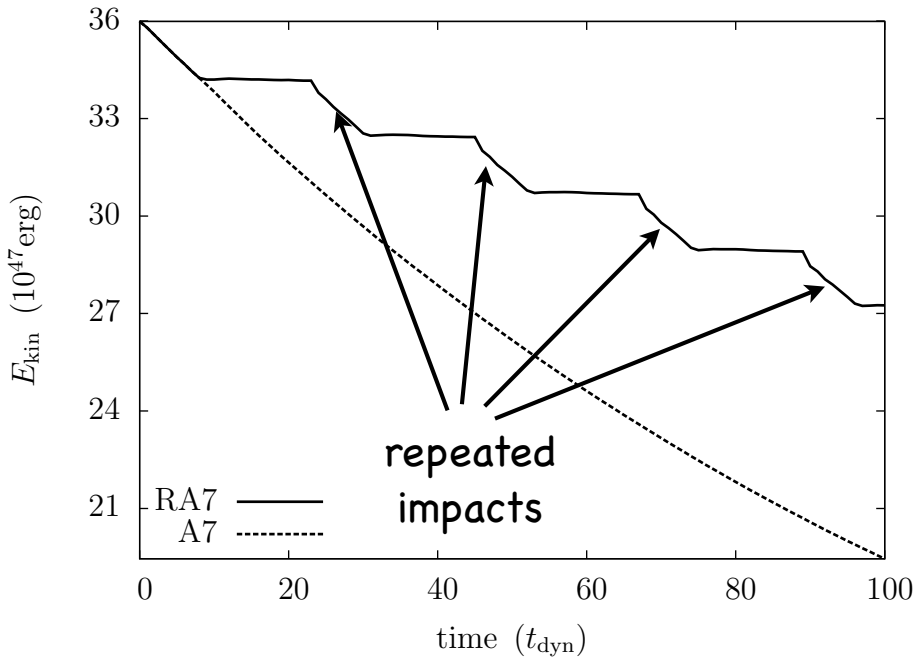
$\Sigma_c = 10^{7-8}\,g/cm^2$ $R_c = 10^{13}\text{-}10^{14}\,cm$ $M_c = 100 M_\odot$ $t_{lc} \sim 1\,Gyr$ $t_{cc} \sim 5\text{-}100\,t_{dyn}$

Setup: "continuous" or "repeated impacts"

Effect of repeated impacts

$\Sigma_c = 10^8$ g/cm^2 , V_{orb} = 600km/s





Repeated impacts are more efficient at removing the RG envelope on account of the linear momentum and kinetic energy of the star.

$$f_n = \frac{\Delta M_{n+1}}{\Delta M_n}$$

repeated impacts	continuum
$\langle f_n \rangle \simeq 1.1$	$\langle f_n \rangle \simeq 1.0$

So, can star-disk collisions explain the missing RGs in the GC?

- RG and HB stars with R~10$R_\odot$ must collide with clumps 10s of times.
- Compact clumps with $\Sigma_c > 10^7$ g/cm^2 needed to strip significant fraction of stellar mass.

Rate of collisions: $$\Gamma_{\rm coll} = \frac{2N_c}{P(a)} \left(\frac{R_c}{R_d}\right)^2$$

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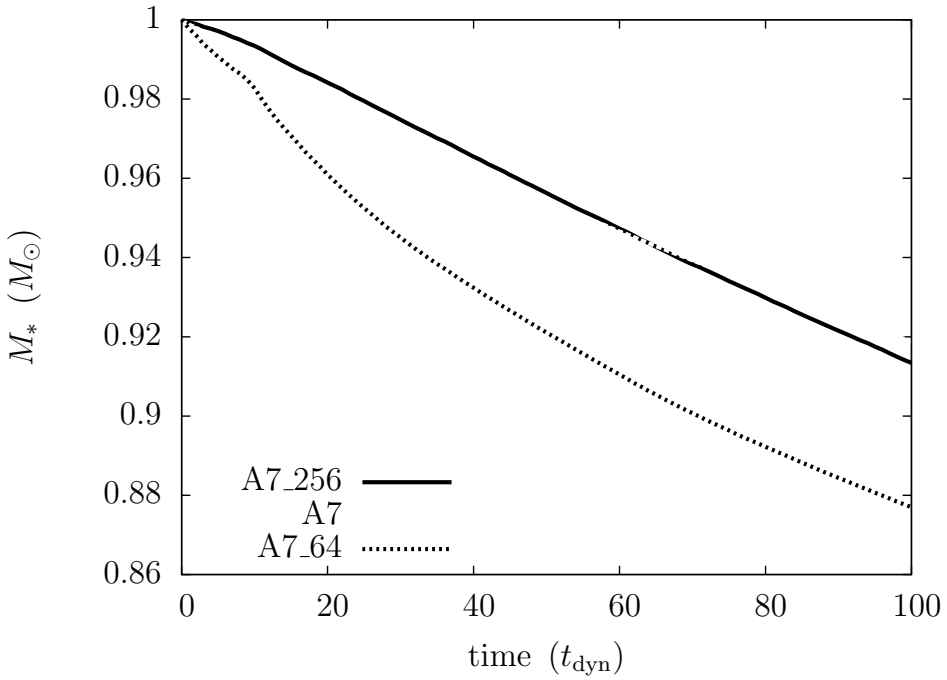
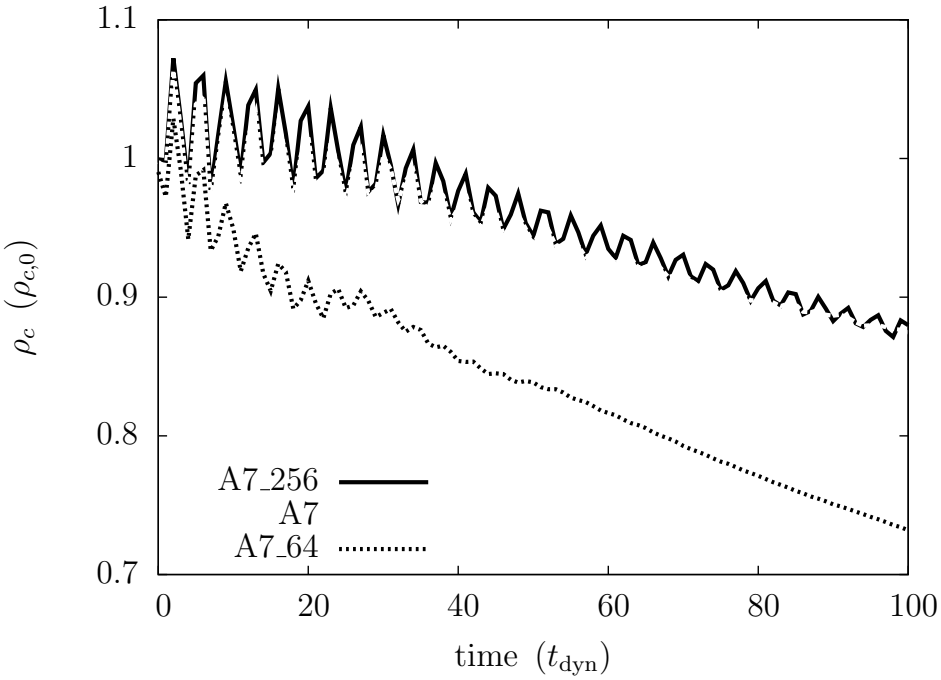
Average time btw collisions:

$$\langle t_{\rm coll} \rangle = \frac{1}{\Gamma_{\rm coll}} \sim 2 \times 10^{10} {\rm yr} \left(\frac{N_c}{100}\right)^{-1} \left(\frac{R_d}{0.5\,{\rm pc}}\right)^2 \left(\frac{R_c}{10^{-5}\,{\rm pc}}\right)^{-2} \left(\frac{a}{0.1\,{\rm pc}}\right)^{3/2}$$

$$t_{\rm RG} \sim t_{\rm lc} \sim 1\,{\rm Gyr}$$

- Larger N_c and and co-planar orbit can shorten the average collision time by a few mags.
- Not impossible!

Numerical convergence tests