The impact of metallicity on the dynamics of young star clusters

Alessandro A. Trani (SISSA), Michela Mapelli (INAF-OAPd), Alessandro Bressan (SISSA)

AIM:
We investigate the impact of stellar evolution and dynamics onto core collapse and post-core collapse phase in young massive (M~3×10^4 $M_\odot$) star clusters (SCs) with different metallicities.

CODE:
STARLAB software environment (Portegies Zwart et al. 2001), with upgraded stellar evolution recipes, including metallicity dependence of black hole mass (Mapelli & Bressan 2013)

SIMULATIONS:
100 direct N-body simulations (N=50000) of SCs with metallicity Z = 1, 0.1, 0.01 $Z_\odot$

King model with W_0=5

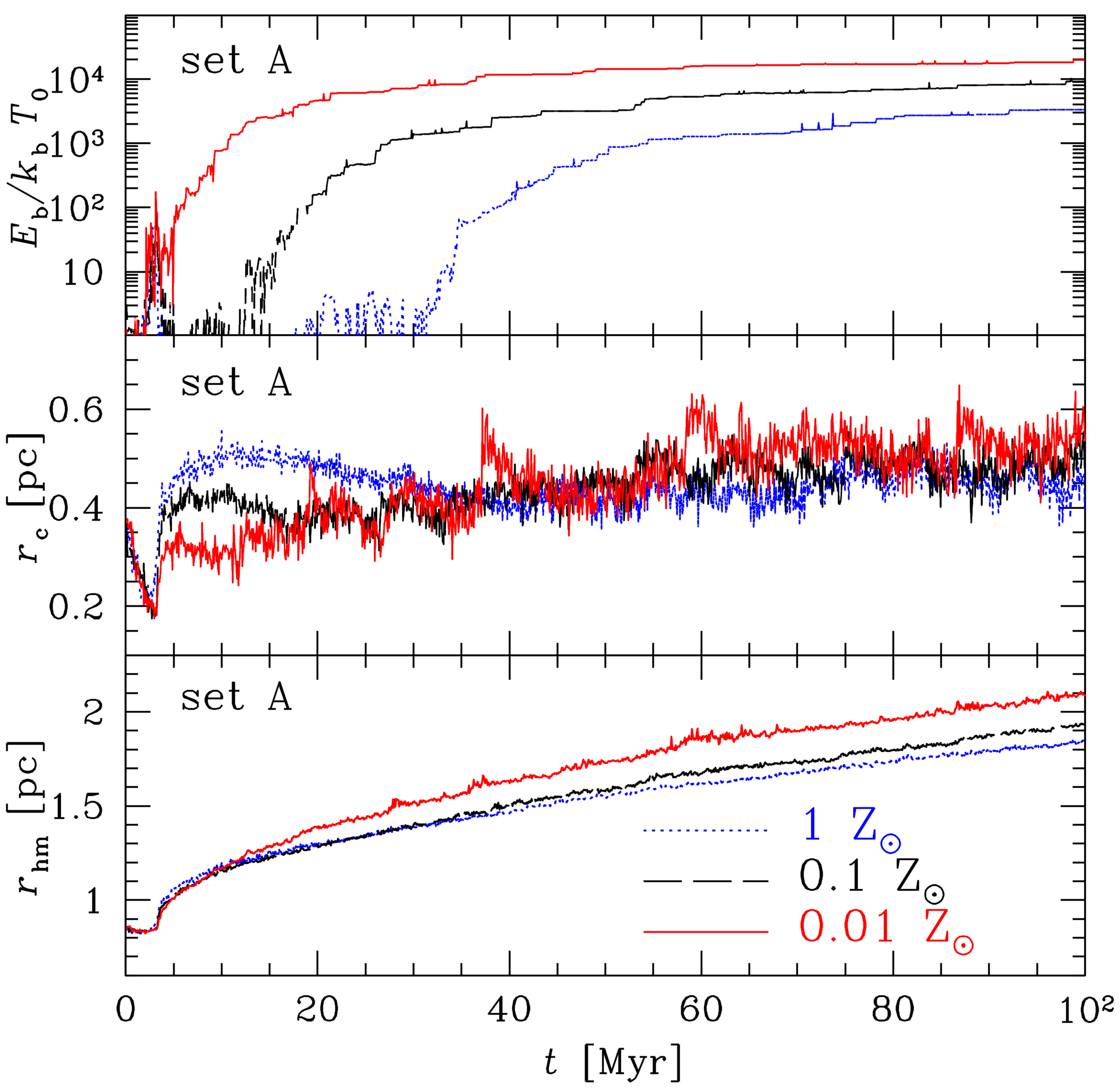
SET A: dense SCs (r_{vir}= 1 pc), SET B: loose SCs (r_{vir}= 5 pc)

Two heating processes:

Stellar mass loss
- makes potential well shallower
- stronger in metal-rich SCs
- relevant in the early life of the SC

Binary hardening
- increases the kinetic energy
- enhanced in metal-poor SCs
- relevant only after core collapse

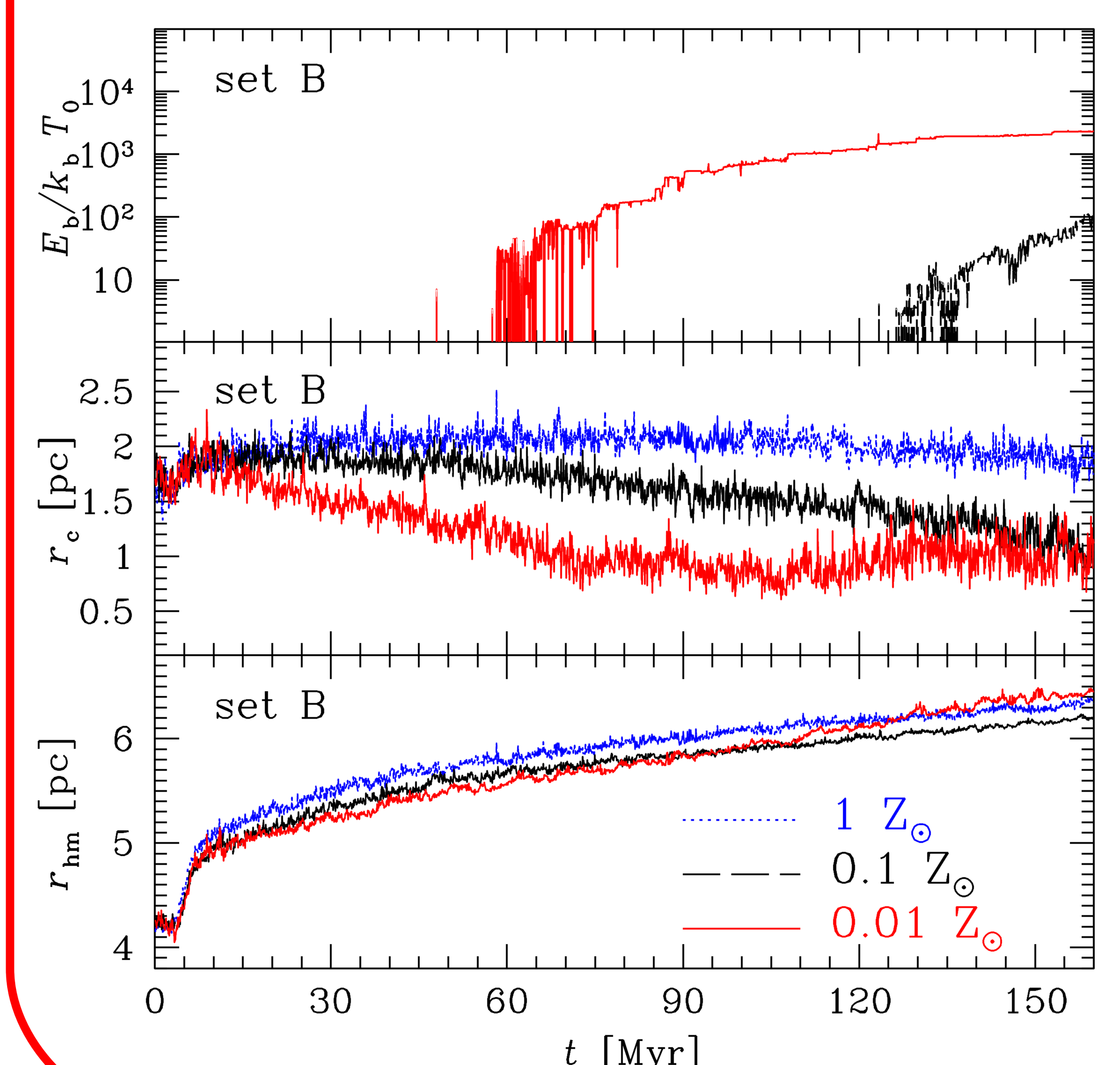
RESULTS: The evolution of the half-mass radius depends on how the core collapse timescale (t_{cc}) and the stellar evolution timescale (t_{se}) compare



SET A: t_{cc} ~ t_{se}

Fig. 1: Total binary binding energy E_b (top panel), core radius r_c (middle panel) and half-mass radius r_{hm} (bottom panel) as a function of time for SCs of different metallicities. Solid red line: Z=0.01 $Z_\odot$; dashed black line: Z=0.1 $Z_\odot$; dotted blue line Z=1 $Z_\odot$. E_b is normalised to the initial average kinetic energy of a star in the SC ($k_b T_0$). Each line is the median value of 10 runs. Dense SCs with initial r_{vir}= 1 pc, N=5×10⁴, W_0= 5. With these initial conditions, t_{cc} ~ 3 Myr is comparable to t_{se}~ 6 Myr.

- **Binary hardening is delayed in metal-rich SCs, because of stronger stellar winds,**
- **core collapse occurs at the same time, independently of metallicity,**
- **core radius expansion occurs earlier in metal-rich SCs, because of stellar winds,**
- **half-mass radius expands more in metal-poor SCs, because of heating by binary hardening (~15% larger r_{hm} than that of metal-poor SCs)**

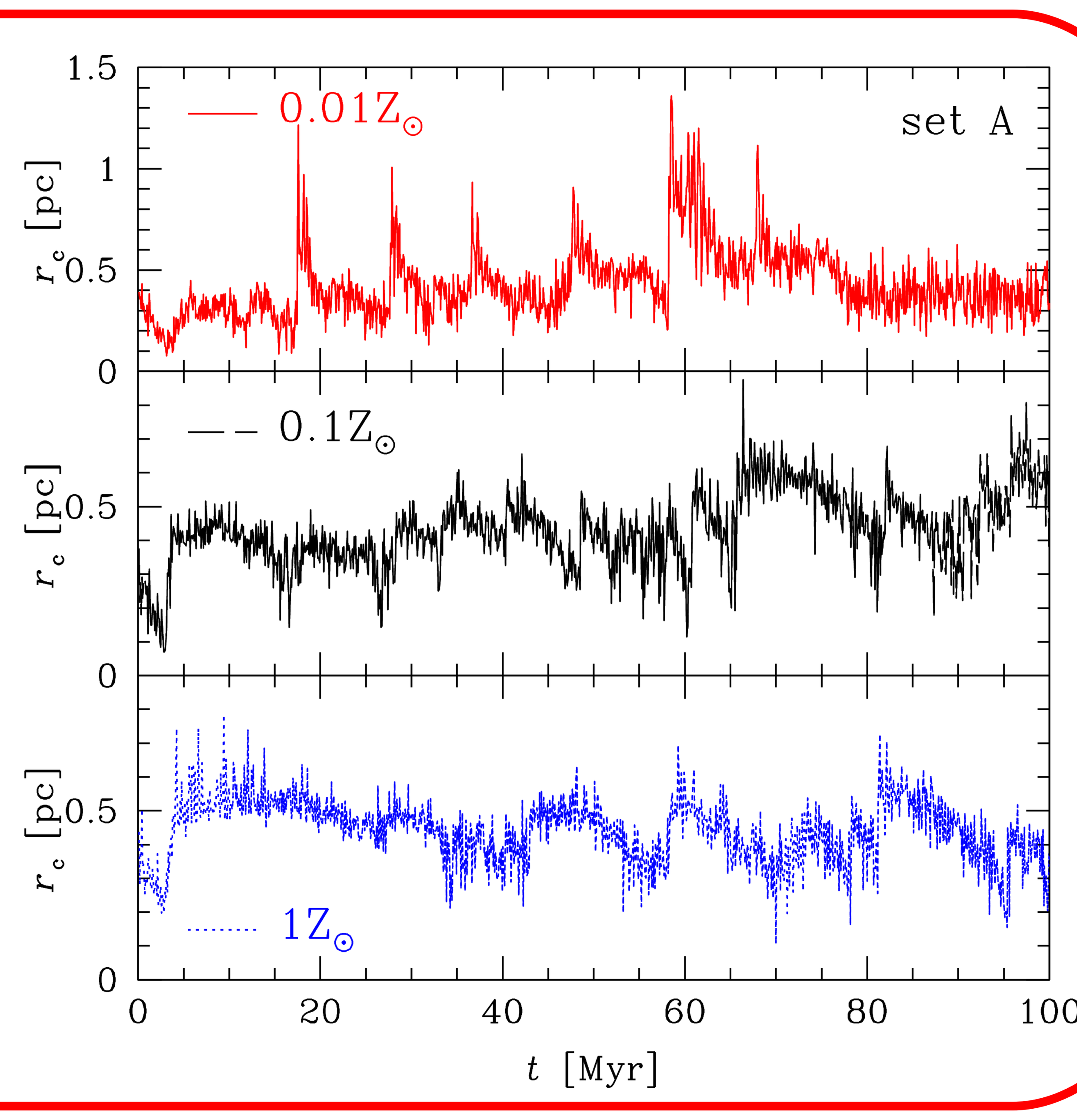


SET B: t_{cc} » t_{se}

Fig. 2: Same as Fig. 1, but for looser SCs (r_{vir}= 5 pc, N=5×10⁴, W_0= 5). Because of the longer two-body relaxation timescale, these SCs have a core collapse timescale much longer than the timescale of mass loss by stellar evolution. (t_{cc} » 6 Myr ~ t_{se}).

- **Evolution dominated by the stellar mass loss, which is a source of heating and causes the SCs to expand,**
- **core collapse delayed in metal-rich SCs (only Z=0.01$Z_\odot$ SCs undergo core collapse before 100 Myr),**
- **binary hardening starts in post-collapse phase, ONLY in metal-poor SCs**
- **half-mass radius begins to expand more than that of metal-rich SCs (differences in half-mass radius <10% throughout the simulations)**

Fig. 3: Core radius as a function of time for three individual dense SCs of set A (r_{vir} = 1 pc, N=5×10⁴, W_0 = 5). Top panel, solid red line: Z=0.01 $Z_\odot$; middle panel, dashed black line: Z=0.1 $Z_\odot$; bottom panel, dotted blue line Z=1 $Z_\odot$.



- **Core radius oscillations in dense SCs are driven by strong three-body encounters,**
- **the oscillation strength increases for the decreasing metallicity of the SC,**
- **the higher maximum remnant mass in low-metallicity SCs explains the stronger and more frequent three-body encounters**

References: Trani et al., in prep.
Mapelli & Bressan, 2013, MNRAS, 430, 3120
Portegies Zwart et al., 2001, MNRAS, 321, 199