Zjazd CAMK 2024

Arkadiusz Hypki, 2024

2023.01.31

MOCCA: Global properties of tidally filling and underfilling globular star clusters with multiple stellar populations

Parameter	TF	TuF
N	$N_{SG}/N_{TOT} \approx$, M ↑$_s$, t_{diss} ↑$_s$	$N_{SG}/N_{TOT} \approx$, M ↑, t_{diss} ↑$_s$
r_g	$N_{SG}/N_{TOT} \approx$, M ↑$_s$, t_{diss} ↑	$N_{SG}/N_{TOT} \approx$, M ↑$_s$, $t_{diss} \approx$
fb	N_{SG}/N_{TOT} ↑$_w$, M ↑$_w$, t_{diss} ↓$_s$	$N_{SG}/N_{TOT} \approx$, M ≈, $t_{diss} \approx$
M_{max}	N_{SG}/N_{TOT} ↓, M ≈, t_{diss} ↑	$N_{SG}/N_{TOT} \approx$, M ≈, $t_{diss} \approx$
$conc_{pop}$	N_{SG}/N_{TOT} ↓, M ≈, $t_{diss} \approx$	$N_{SG}/N_{TOT} \approx$, M ↑$_w$, $t_{diss} \approx$
$W_{0,FG}$	N_{SG}/N_{TOT} ↓$_s$, M ↑$_s$, t_{diss} ↑$_s$	$N_{SG}/N_{TOT} \approx$, M ≈, $t_{diss} \approx$
r_{hFG}		N_{SG}/N_{TOT} ↑, M ↓, $t_{diss} \approx$

Parameter	TF	TuF
t_{diss} ↑	N ↑$_s$, r_g ↑, $W_{0,FG}$ ↑$_s$, M_{max} ↑	N ↑$_s$
N_{SG}/N_{TOT} ↑	fb ↑$_w$	r_{hFG} ↑
M ↑	N ↑$_s$, r_g ↑$_s$, fb ↑, $W_{0,FG}$ ↑$_s$	N ↑, r_g ↑$_s$

Figure 1: Summary table showing how one can change t_{diss}, total mass, and N_{SG}/N_{TOT} ratios of GCs.

- MOCCA: Global properties of tidally filling and underfilling globular star clusters with multiple stellar populations, Hypki et al. **sent to A&A**
- we find that in models starting with the FG tidally filling, N_{SG}/N_{TOT} can undergo a significant evolution reaching higher values falling in the range of those observed in Galactic globular clusters
- models with a FG initially tidally underfilling, on the other hand, do not lose a significant number of stars and retain values of N_{SG}/N_{TOT} similar to the initial ones.

New Parameters for Star Cluster Dynamics: the role of clusters' initial conditions

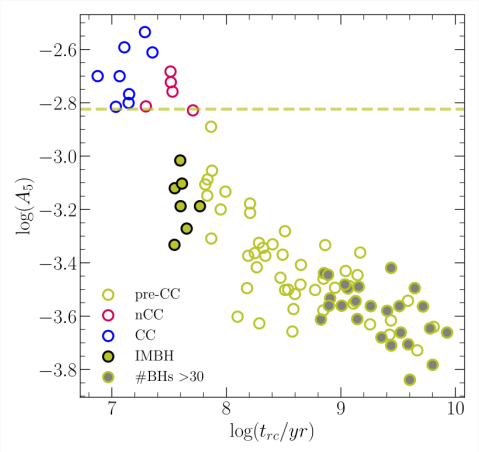

Figure 2: Logarithm of A_5 plotted against the logarithm of t_{rc} which shows division of GCs into different dynamical stages.

- B. Bhat, B. Lanzoni, E. Vesperini, F. R. Ferraro, F. Aros, A. Askar, A. Hypki, **sent to ApJ journal**
- data taken from MOCCA snapshots
- three nCRD parameters A_5 , P_5 and $S_{2.5}$ are powerful diagnostics of the stage of internal dynamical evolution reached by star clusters

Formation of an extremely massive star in realistic million-body simulation

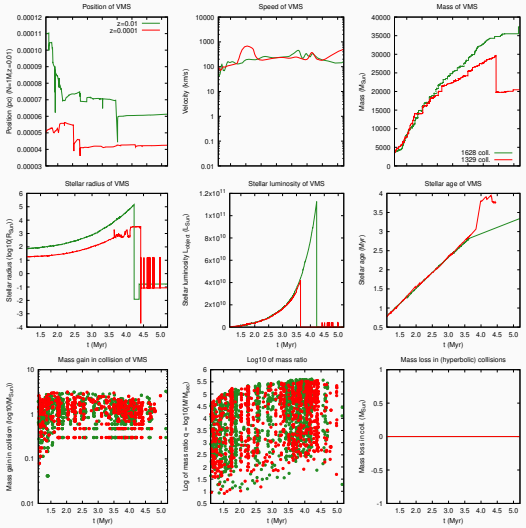

Figure 3: VMS formation done with MOCCA code.

- Kamlah A. et al, **almost finished**
- Rapid formation of a massive black hole of $> 27000\ M_{\odot}$ from the core-collapse of a very massive star (VMS) produced by thousands of stellar mergers in direct N-body simulations of dense star clusters
- seed for IMBH formation
- MOCCA as an independent check for NBODY results

BEANS code

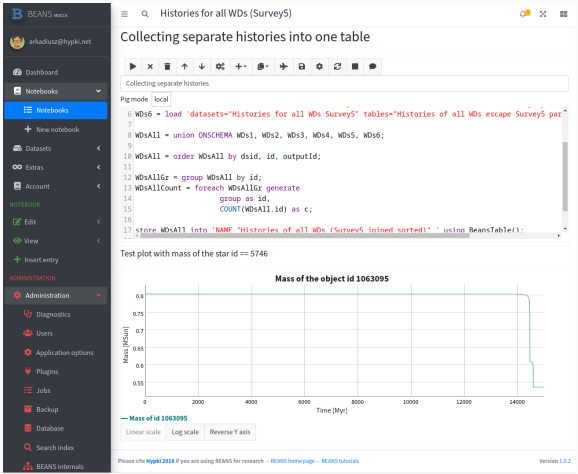

Figure 4: `http://BEANScode.net`

- interactive, distributed data analysis
- web-based
- open source
- data analysis in a form of notebooks (like Jupyter)
- Apache Pig (Apache Hadoop)
- connectors to MOCCA, NBODY codes
- Python, AWK, Gaia plugins
- **access to all simulations from all different mocca-survey from BEANS**

Future plans

Future plans: MOCCA + TSUNAMI

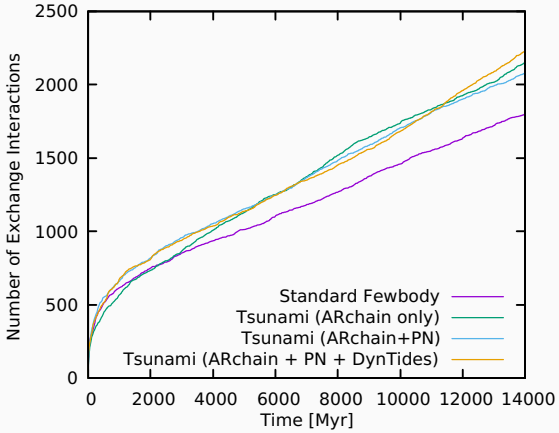

Figure 5: MOCCA+TSUNAMI, n=50k, fb=0.95, rg=20 kpc, rh=1pc, w0=9, GW recoil kicks enabled, plots shows number of exchanges.

MOCCA + TSUNAMI (Trani et al. 2022):

- full integration with Tsunami dynamical interactions between binary-single, binary-binary, or any other hierarchy)
- dynamical tides
- post-Newtonian terms

→ How IMBH formation would be changed?

Future plans: hierarchical systems

- hierarchical system already implemented in MOCCA
- dynamical formation of hierarchical systems
- influence of Zeipel-Lidov-Kozai mechanism on BHs formation and evolution

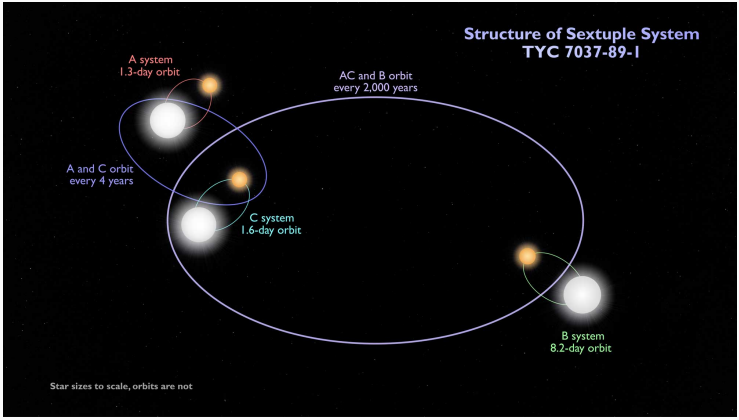

Figure 6: Six-star system TYC 7037-89-1, Credits: NASA

Conclusions

Figure 7: MOCCA, NCAC, NCN

- 2 papers sent
- co-Author in 2 more paper (close to publication) on VMS, and on WD-WD binaries
- Hypki et al. 2024 "MOCCA: Dynamical blue stragglers excess after core collapse" close to submission
- 2 talks on 2 conferences: MODEST, and "Two in a million - The interplay between binaries and star clusters"

http://MOCCAcode.net — **Arkadiusz Hypki** — ahypki@camk.edu.pl