Synthetic Populations of Ultra-Luminous X-ray Sources in Globular Clusters

Grzegorz Wiktorowicz
&
MOCCA group

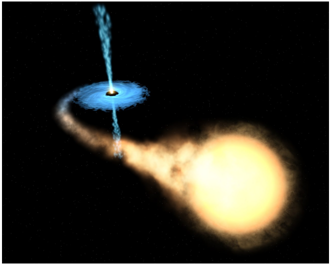
Nicolaus Copernicus Astronomical Center, PAS

MODEST 24
August 22, 2024

Brief introduction

Ultra-luminous X-ray source (ULX)

- point-like
- off-nuclear
- $L_X > 10^{39}$ erg/s (the Eddington limit for a $\sim 10\ M_\odot$ black hole)



Crediti: NASA

The nature of these objects is still unknown!

Two possible explanations:

1. extreme case of an X-ray binary (aka the ULX state)
2. separate group of objects (e.g. an IMBH)

Why to bother?

- scarcely omnipresent (Wang+16)
- population-sensitive

(e.g. age, metallicity, see Wiktorowicz+17)

common objects (e.g XRBs) can be insensitive to evolutionary models (e.g. the common envelope model),

see Wiktorowicz+14

Goals

- Understanding the importance of dynamics in the formation of ULXs
- exotic in exotics -> new formation scenarios
- escapers vs field formation
- fine-tune the models with observations

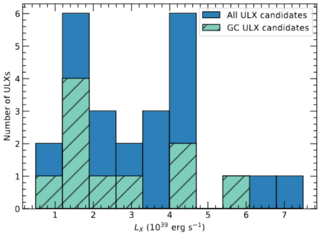
ULX populations

- present in all stellar environments (metalicity, age, size, etc.)
- none present locally

- $\gtrsim 1800$ objects detected (Walton+22)
- a few harbor pulsar accretors

GC population

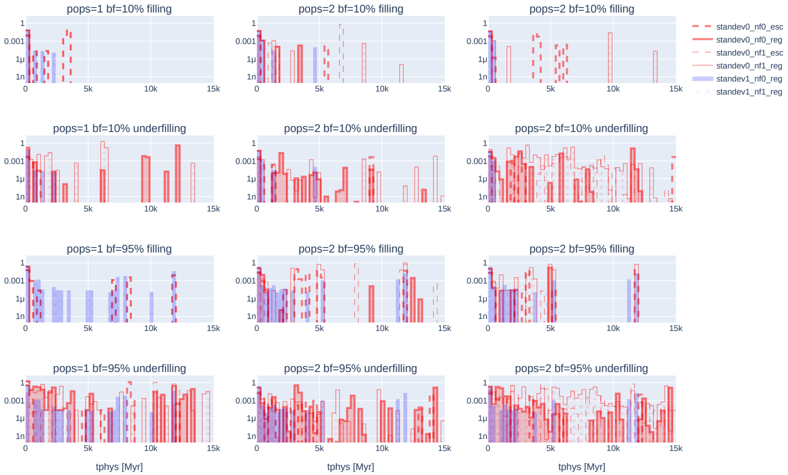
- ~ 30 GC ULX **candidates** (Dage+21, Thygesen+22)



Thygesen+23

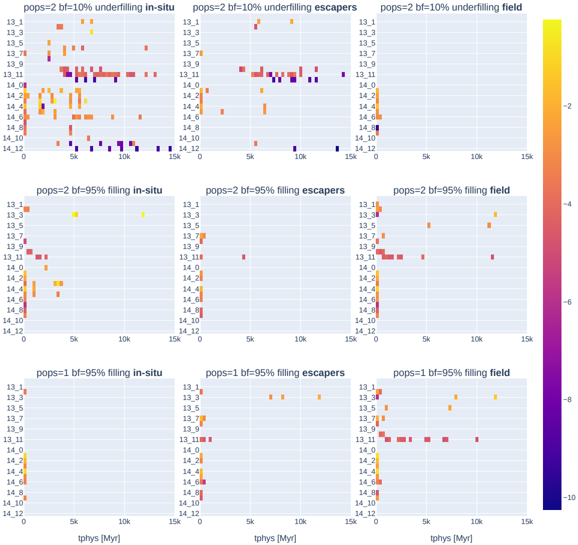
Results (using MOCCA code)

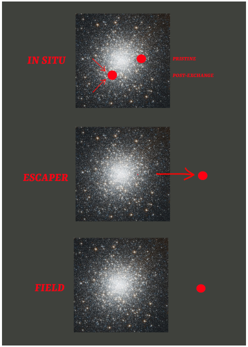
number evolution



Results (using MOCCA code)

STELLAR TYPES **[log10 of expected number]**

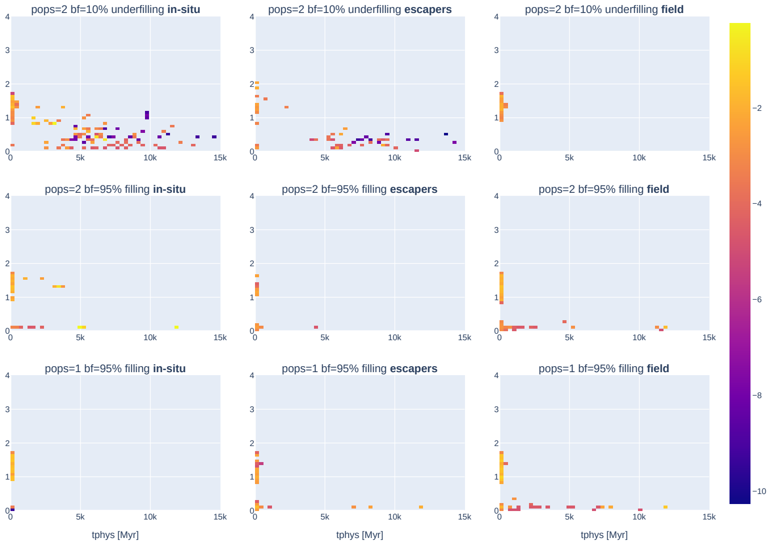




0 = MS star $M \lesssim 0.7$ deeply or fully convective
1 = MS star $M \gtrsim 0.7$
2 = Hertzsprung Gap (HG)
3 = First Giant Branch (GB)
4 = Core Helium Burning (CHeB)
5 = Early Asymptotic Giant Branch (EAGB)
6 = Thermally Pulsing AGB (TPAGB)
7 = Naked Helium Star MS (HeMS)
8 = Naked Helium Star Hertzsprung Gap (HeHG)
9 = Naked Helium Star Giant Branch (HeGB)
10 = Helium White Dwarf (HeWD)
11 = Carbon/Oxygen White Dwarf (COWD)
12 = Oxygen/Neon White Dwarf (ONeWD)
13 = Neutron Star (NS)
14 = Black Hole (BH)
15 = massless remnant.

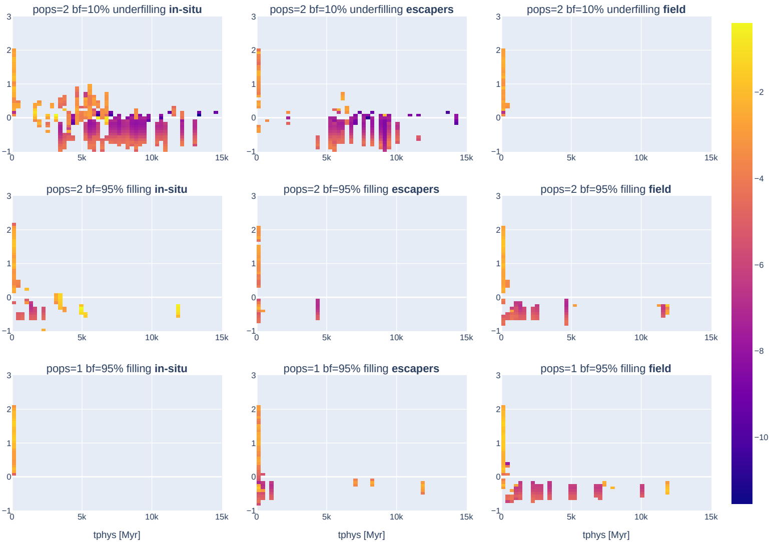
Results (using MOCCA code)

ACCRETOR MASS [log10 of expected number]

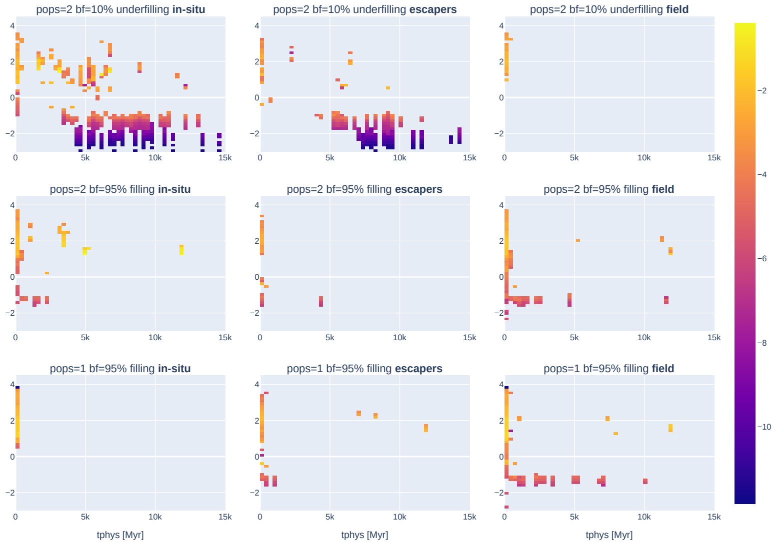


Results (using MOCCA code)

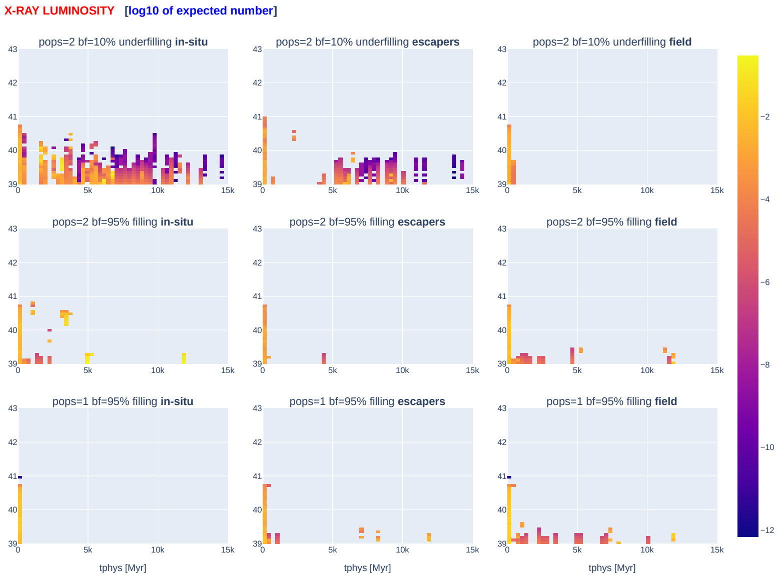
DONOR MASS [log10 of expected number]



SEPARATION [log10 of expected number]



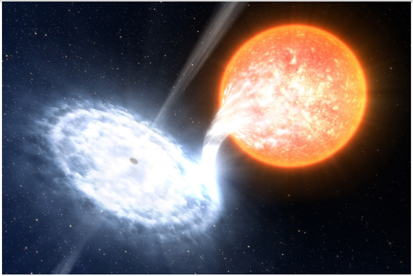
Results (using MOCCA code)



Conclusion and Future Directions

The bottomline

1. generally **dynamics enhances** the formation of ULXs in later evolutionary phases
2. tidal field of the galaxy may **efficiently eject** ULX progenitors from the cluster



Credit: L. Calçada / ESO

- population of ULX formed from escapers is generally similar to field population
- many ULXs form in post-exchange binaries

Future plans

> extrapolate to the entire MOCCA survey

> importance of evolutionary parameters

> beamed radiation