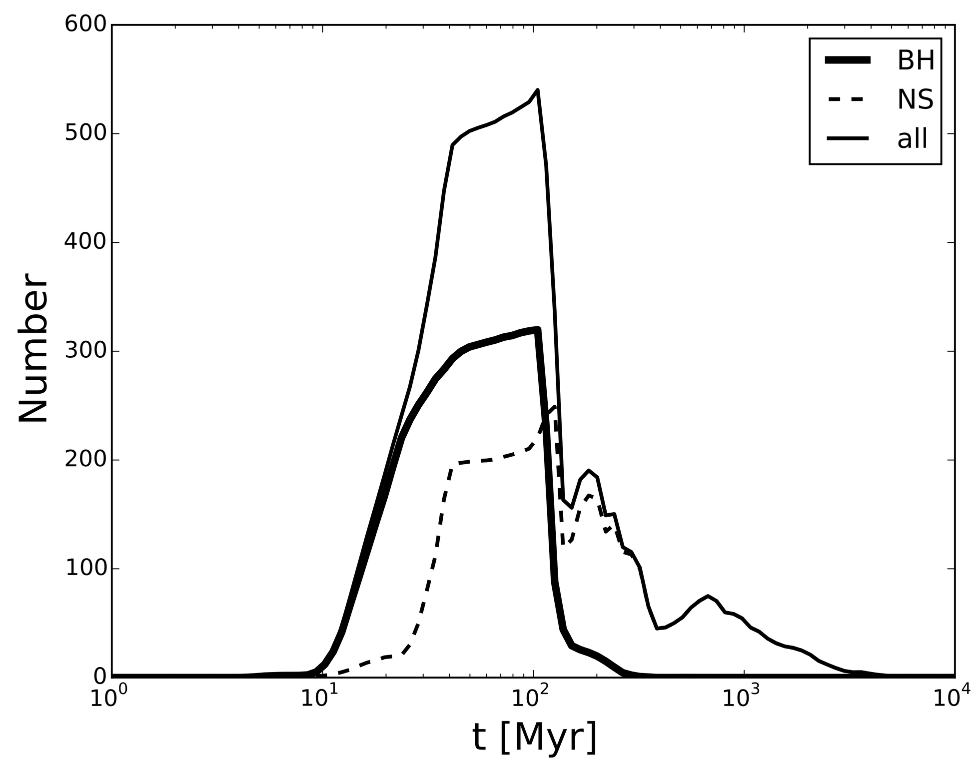
The nature of Ultraluminous X-ray Sources

Grzegorz Wiktorowicz, M. Sobolewska, Jean-Pierre Lasota, K. Belczynski
University of Warsaw, Astronomical Observatory, Poland
gwiktoro@astrouw.edu.pl

Results

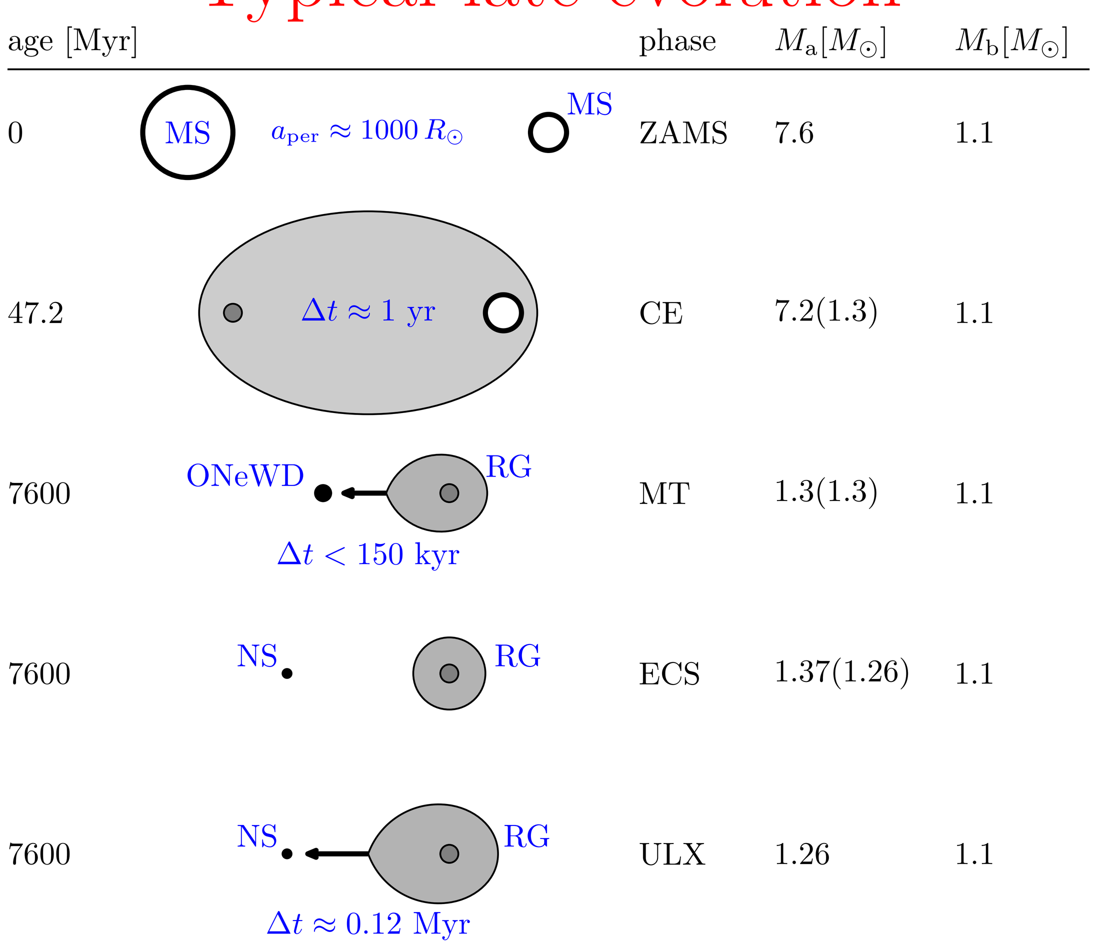
1. Populations older than $\sim 100\,\mathrm{Myr}$ and luminosities between $10^{39}-\sim 10^{40}\,\mathrm{erg\,s^{-1}}$ are dominated by NSs. BHs in ULXs are present in significant numbers only in the first $\sim 100\,\mathrm{Myr}$ after the star-formation start and dominate among the most luminous ULXs.

Number of ULXs



The dependence of the #ULX on the time for burst star-formation. The BHULXs appear earlier, but due to their short lifespan NSULX become dominant shortly after the burst ends at $\sim 100\,\mathrm{Myr}$. The local maxima are related to different evolutionary routes.

Typical late evolution



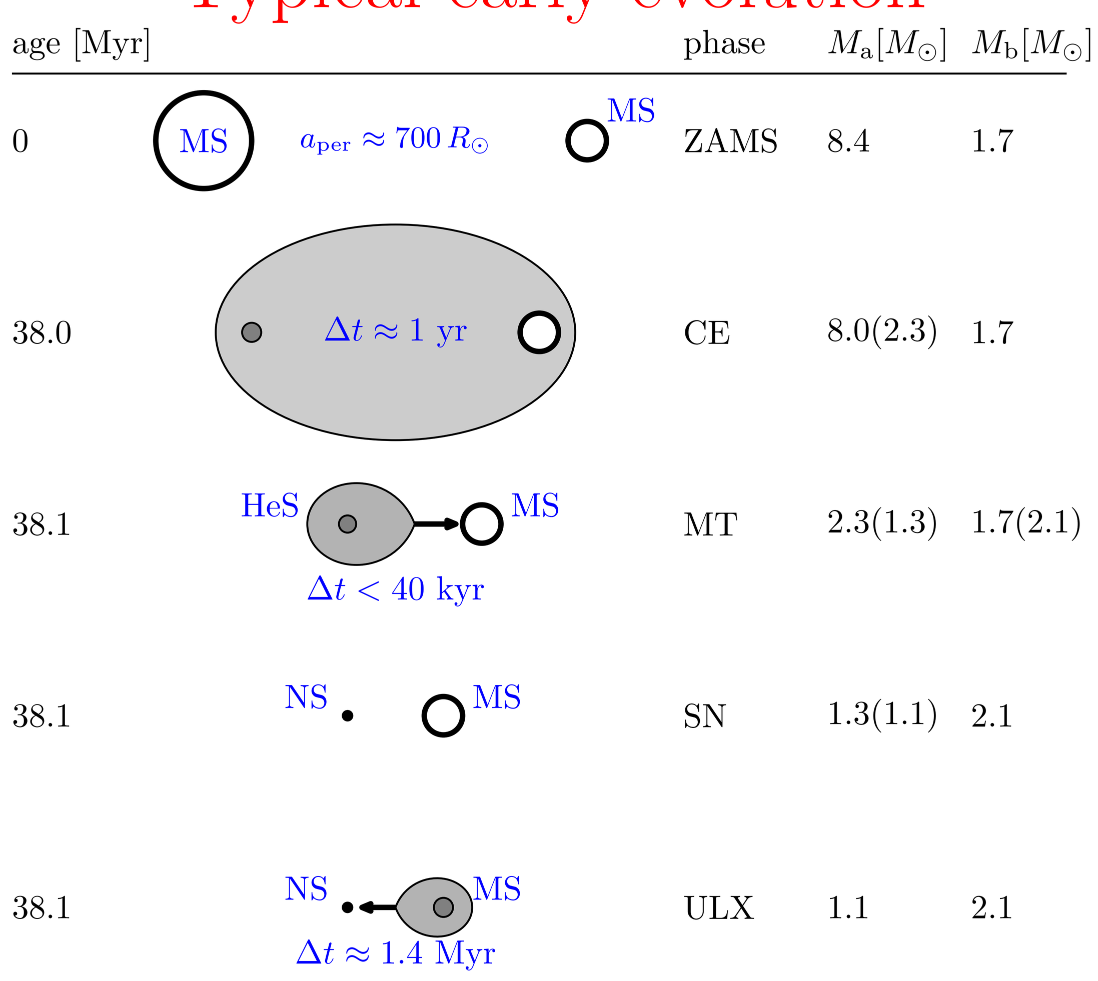
The schematic representation of the evolution of a typical NSULX in old stellar populations. We predicted that systems formed in this route will dominate the ULX population late (*a few* × Gyr) after the end of star-formation.

2. ULXs appear in a very specific sequence after the burst of SF:

Formation sequence

t[Myr]	Accretor	Donor
8 – 30	BH	Main-Sequence
9 – 50	NS	Main-Sequence
140 – 500	NS	Hybrid WD
300 – 1100	NS	Hertzsprung Gap
800 – 1800	NS	Helium WD
900 – 2000	NS	Red Giant

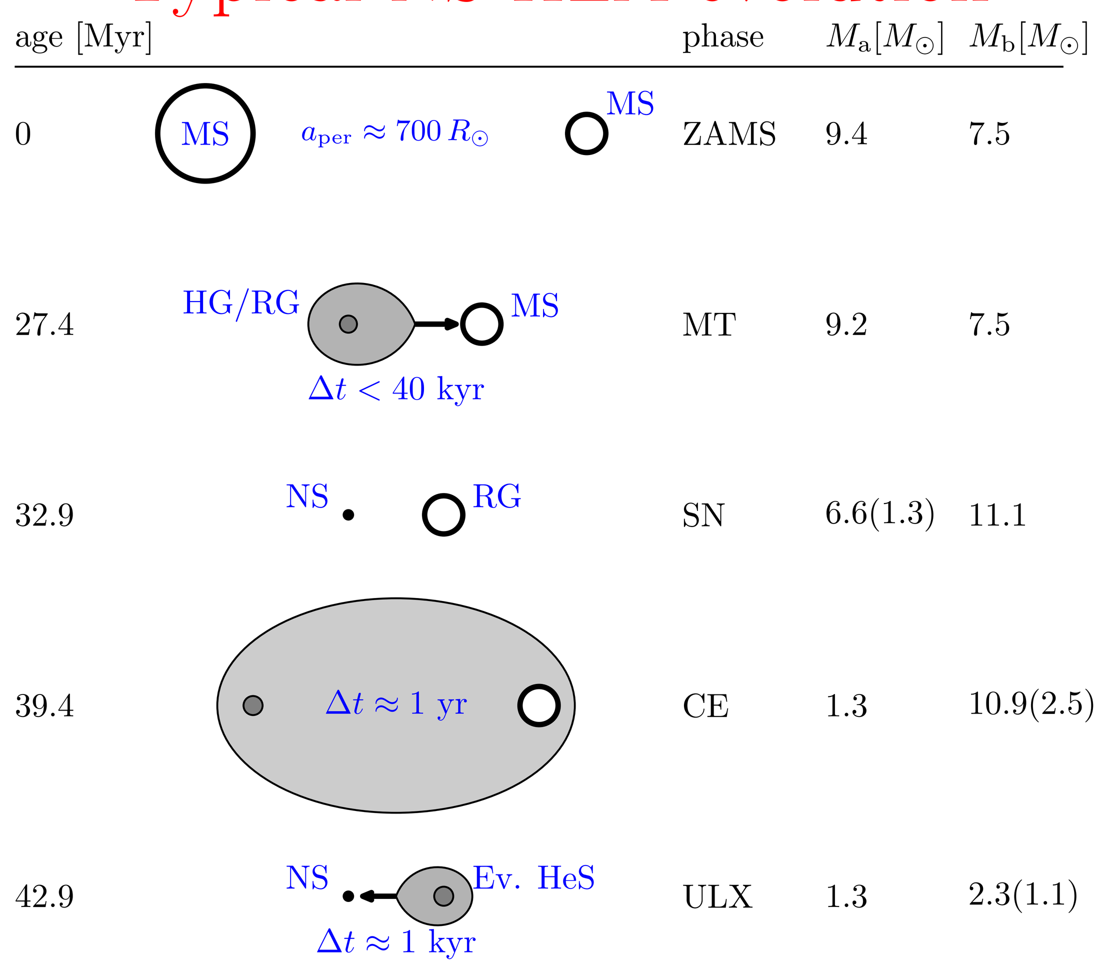
Typical early evolution



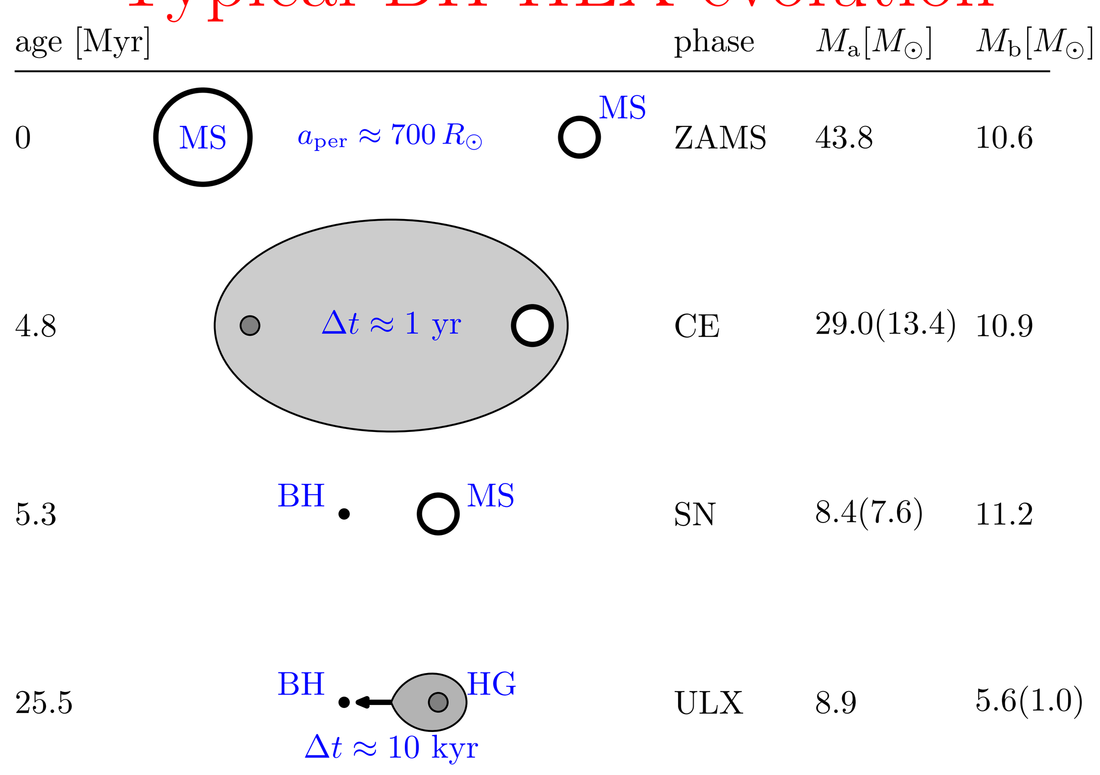
The formation of the most typical NSULX for star-forming regions. Although the ULX population during a star-formation burst is dominated by BHULXs, a fraction ($\sim 10\%$) of NSULXs is present.

3. The most luminous ULXs (HLX; $L_X \gtrsim 10^{40}\,\mathrm{erg\,s^{-1}}$) contain HG donors (BHULXs) or evolved HeS (NSULXs). They form typically within *a few* $\times\,10\,\mathrm{Myr}$ after ZAMS for BH accretors and *a few* $\times\,100\,\mathrm{Myr}$ for NS accretors.

Typical NS HLX evolution



Typical BH HLX evolution



ULX

Ultraluminous X-ray source

Two observational properties:

1. a **point-like** (i.e. not extended), **off-nuclear** X-ray source with a peak emission localized in the **X-ray band**;
2. isotropic equivalent X-ray luminosity in excess of $10^{39}\,\mathrm{erg\,s^{-1}}$ (Eddington limit (EL) for $\sim 10\,M_\odot$ BH).

ULXs were observed to harbor NS:

- ULX X-2 in M82 (Bachetti et al. 2014)
- P13 in NGC 7793 (Furst et al. 2016)
- ULX-1 in NGC5907 (Israel et al. 2016)

Methodology

Simulations

- Population synthesis code `StarTrack`
- 2×10^7 simulated binaries for each model ($\sim$ 5% of the Milky-Way equivalent galaxy)
- burst and constant star-formation
- 3 metallicities: $Z_\odot$, $Z_\odot/10$, $Z_\odot/100$
- 2 accretion models
- 4 beaming models
- only RLOF

Accretion

1. The upper limit model

$$\dot{M}_{\rm acc} = \dot{M}_{\rm RLOF}$$

2. The logarithmic model

$$\dot{M}_{\rm acc} = \min(\dot{M}_{\rm RLOF}, \dot{M}_{\rm Edd})$$

$$L_X = L_{\rm Edd}(1 + \ln \dot{m})$$

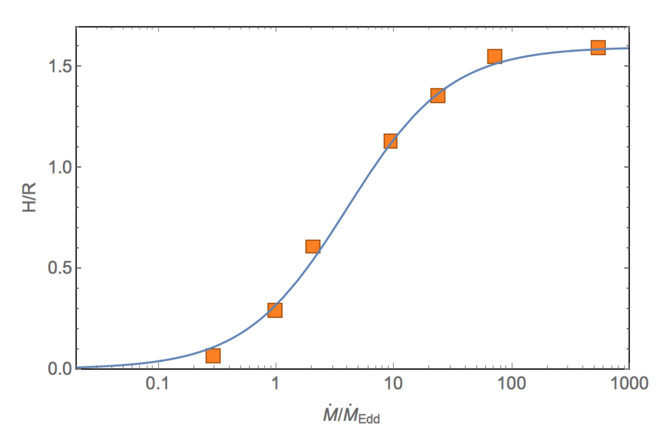
Beaming

Beaming factor: $b = \frac{\Omega}{4\pi}$
Apparent luminosity: $L_{X,\rm iso} = \frac{L_X}{b}$

1. $b = 1$
2. $b = 0.1$
3.

$$b \sim \frac{73}{\dot{m}^2} \quad \dot{m} \gtrsim 8.5$$
$$b = 1 \quad \dot{m} < 8.5$$

4.



based on `Koral` *code*