Synthetic catalog of black holes in the Milky Way

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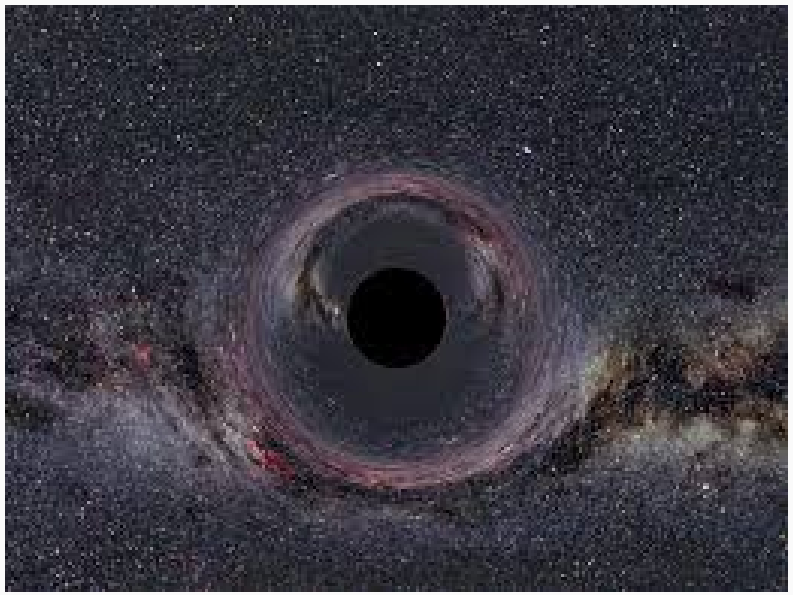
Project motivation

- Most of Galactic black holes are so far not detected.
- Open access database for observers which contain basic statistical properties of Galactic BHs. (**https://bhc.syntheticuniverse.org/**)
- Prediction of origins and binary black boles configurations.
- Microlensing (number of events), BH binaries (parameters), GW (Galactic merger rates)



An artist's portrayal of a BH in the Milky Way. Corvin Zahn

Method

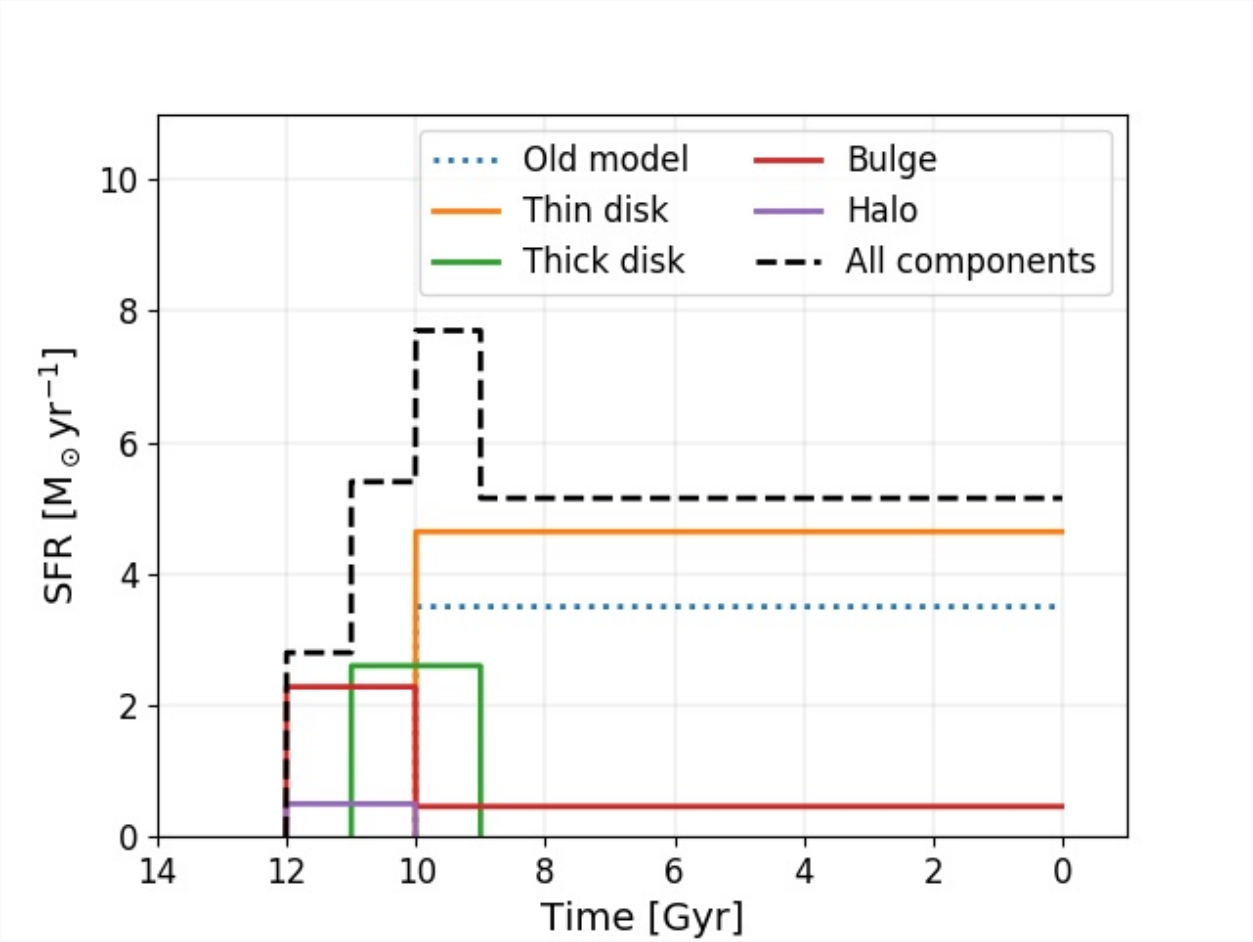
Method

- Updated synthesis population (StarTrack code)
- Binary and single star systems evolution with standard physical model including:
  - natal kicks from Maxwellian velocity distribution with fallback, v $\propto \frac{1}{M}$ (Hobbs et al. 2006)
  - rapid SN engine reproducing first mass gap (Fryer et al. 2012).
  - PPN/PPSN limit reproducing second mass gap (Woosley 2017, Leung et al. 2019)
  - $Z_{\odot}$=0.014 (Asplund et al. 2009)
  - two scenarios of HG star in common envelope (model A and B)

New SFR and chemical evolution model

Old model: one Galactic component (disk), const. SFR, const. metallicity

New model:



Disk

Disk mass:

$5.2 \times 10^{10}\ M_{\odot}$

Thin Disk:

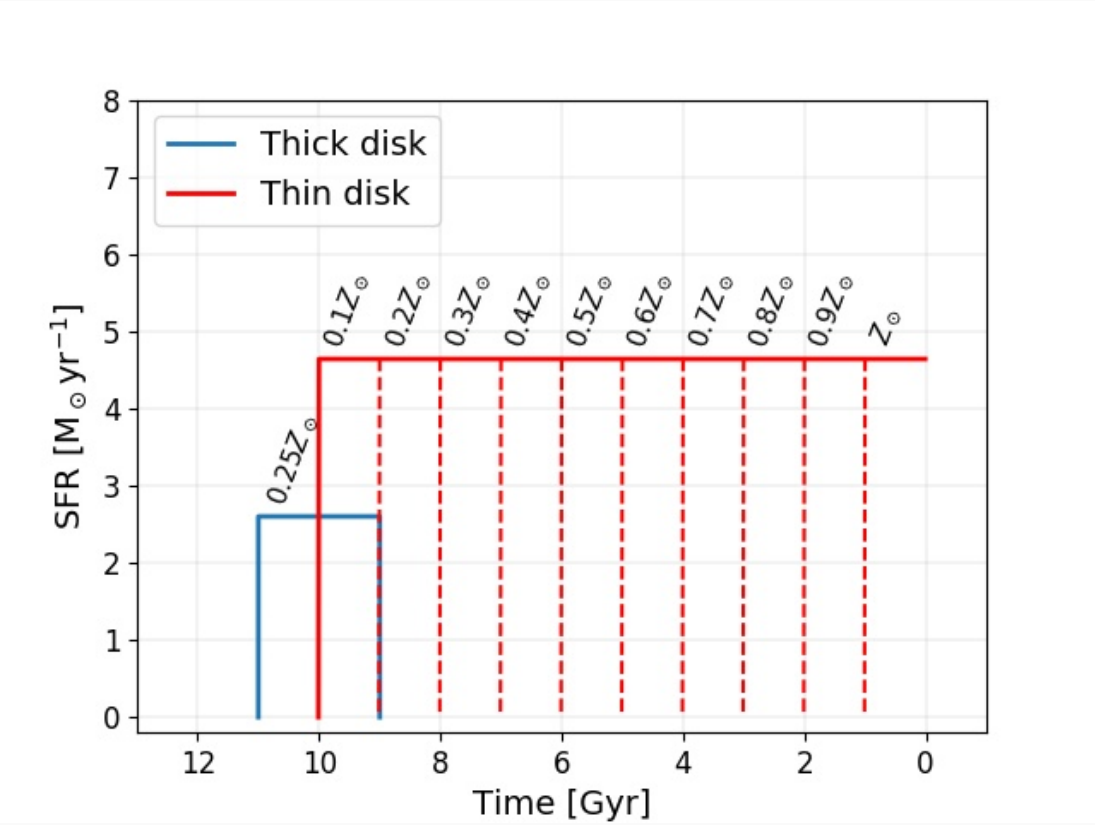
age: 0-10 Gyr

Z: 0.1-1.0 $Z_{\odot}$

Thick Disk:

age: 9-11 Gyr

Z: 0.25 $Z_{\odot}$



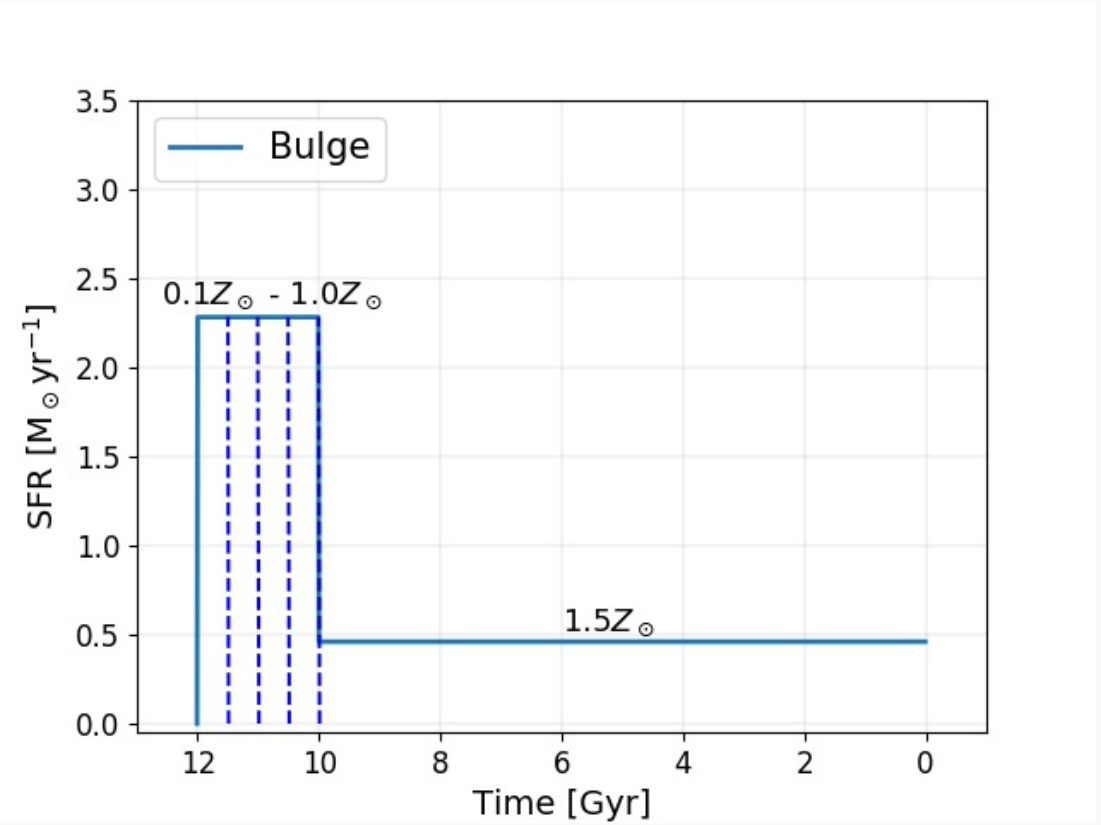
Bulge

Bulge mass:

0.9×10^{10} $M_\odot$

age: 0-10 Gyr

Z: 0.1-1.5 $Z_\odot$



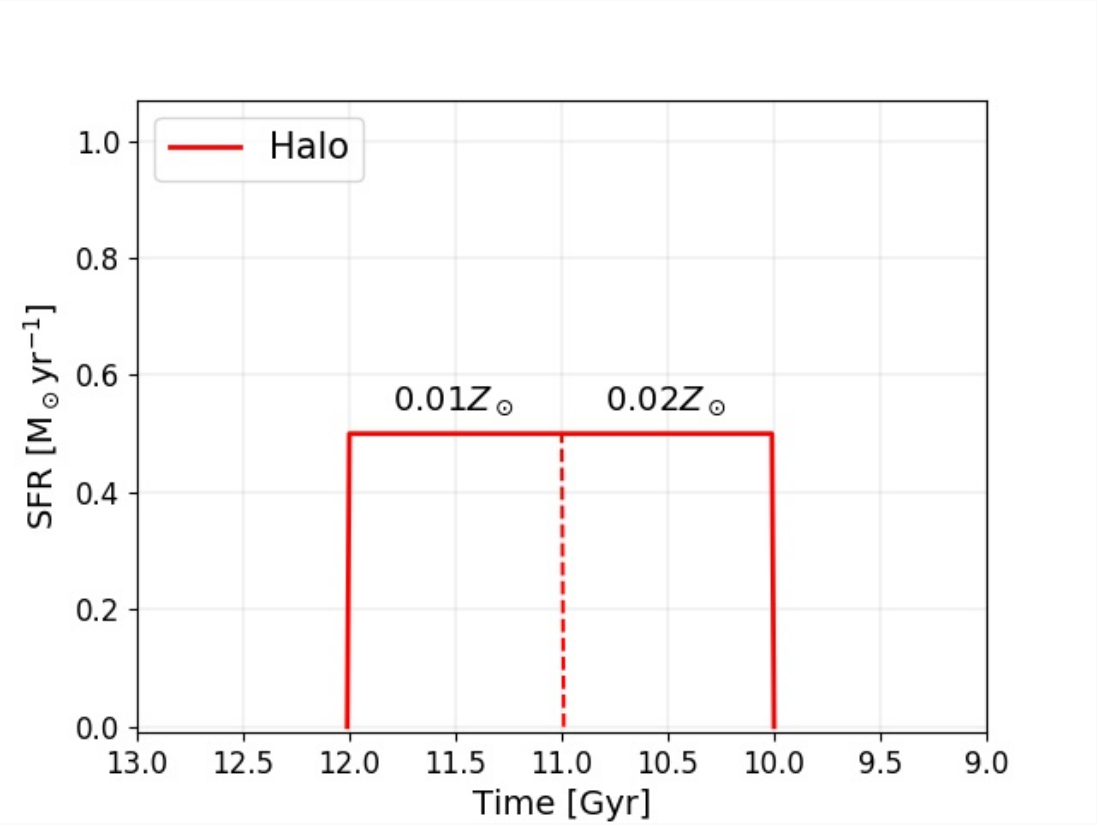
Halo

Halo mass:

2.0×10^9 $M_\odot$

age: 10-12 Gyr

Z: 0.01-0.02 $Z_\odot$



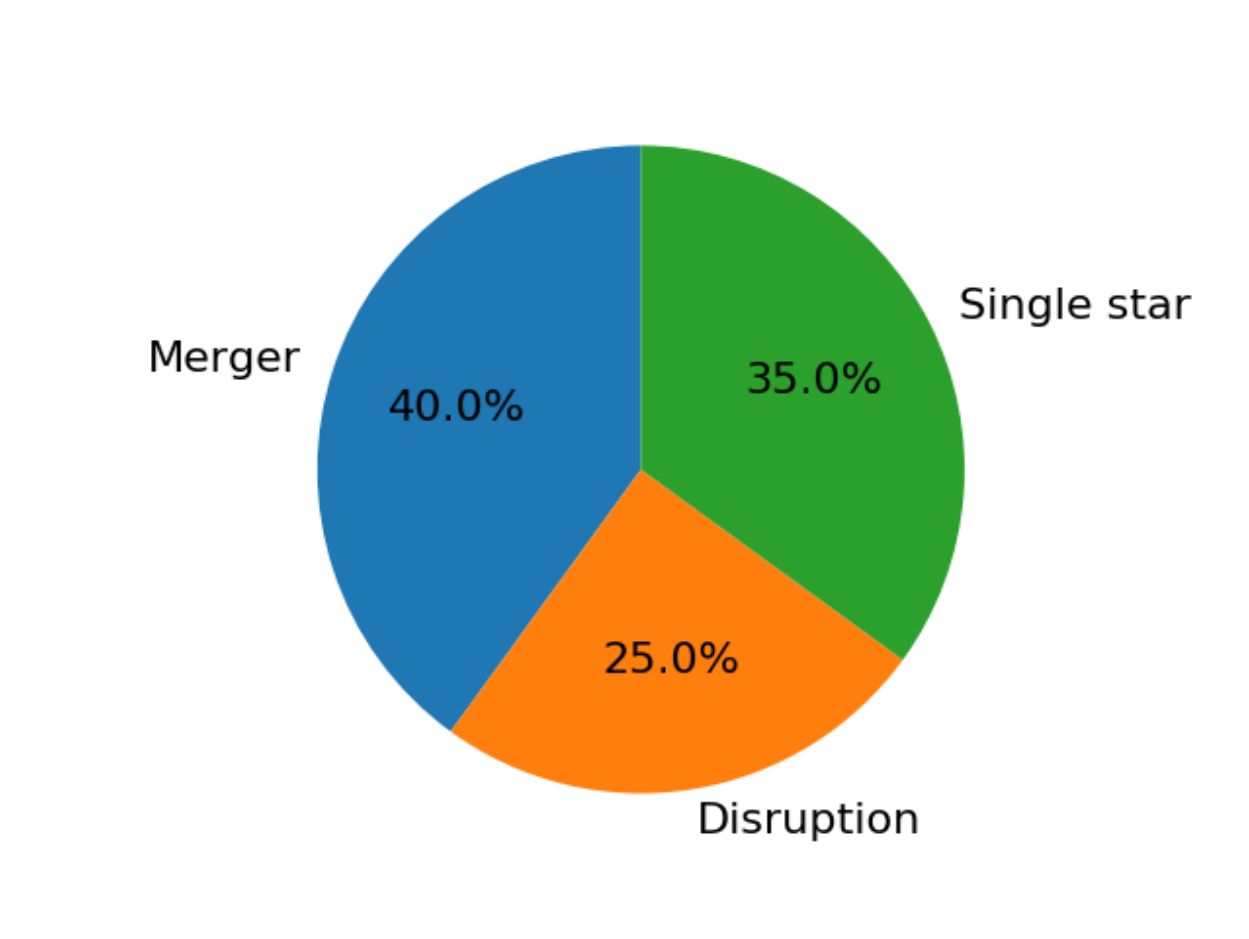
Results

Single black holes

1.6 $\times 10^8$ single black holes

Initially: 2/3 of stars in binary systems...finally: 95 % of black holes are single.

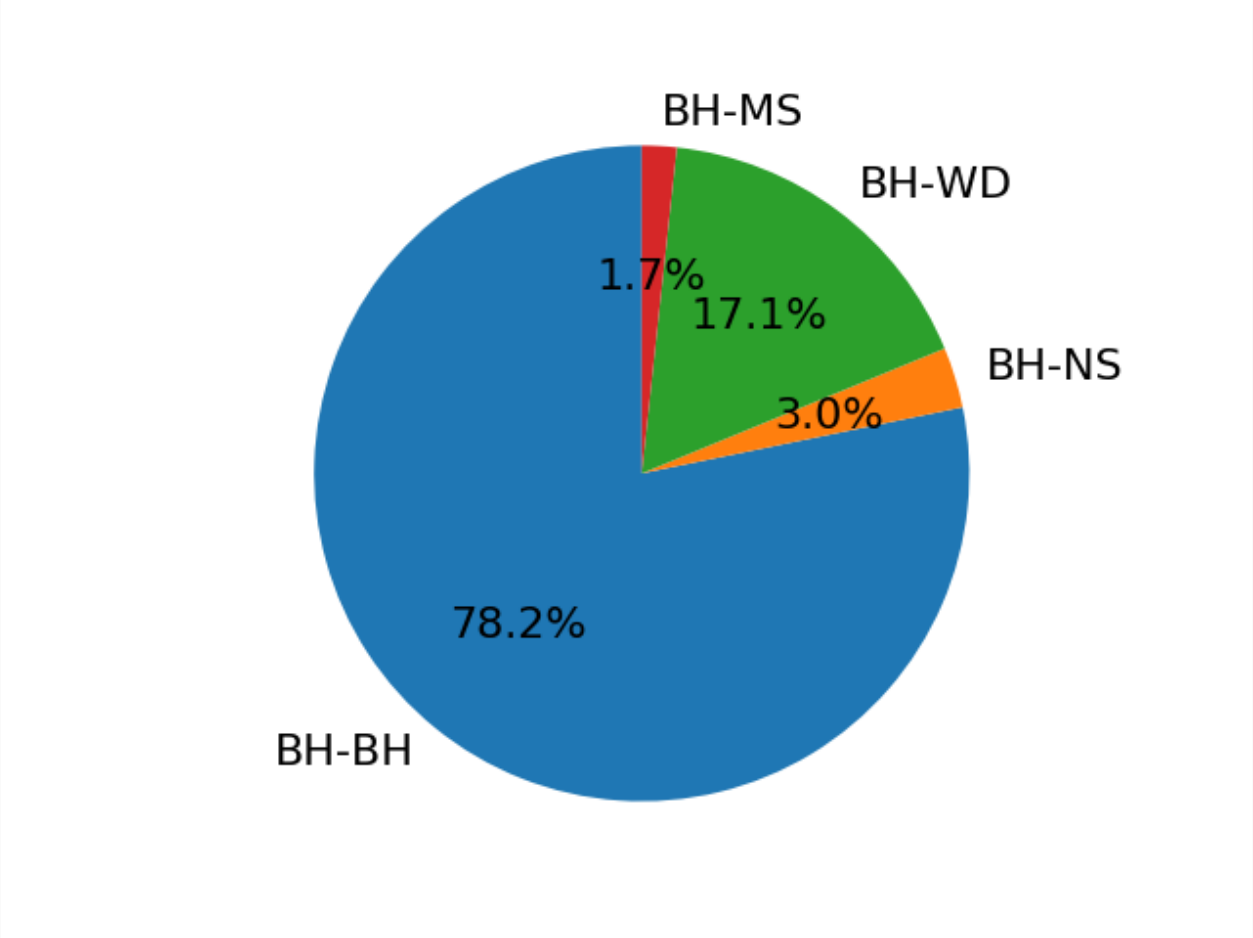
Single BHs origins:



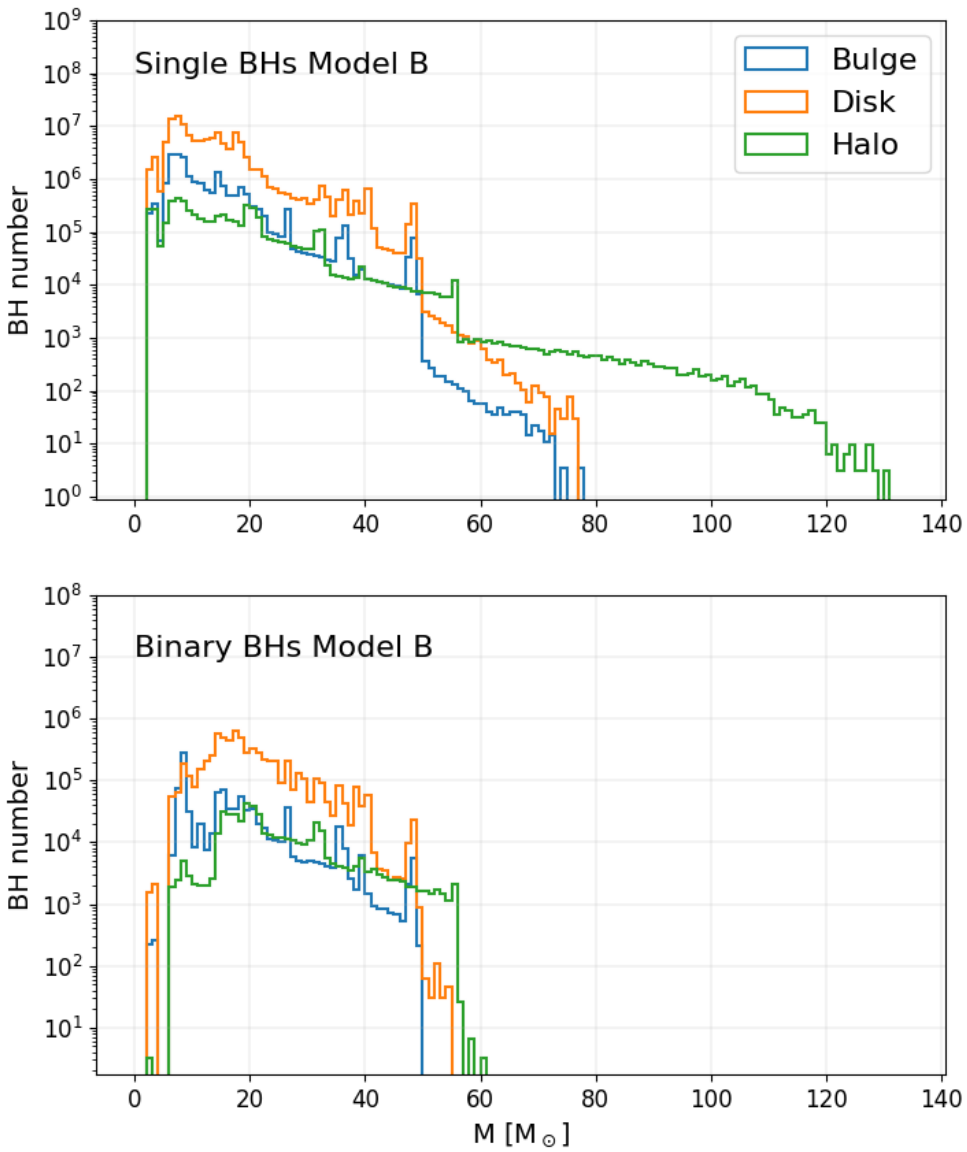
Binary black holes

9.3 $\times 10^6$ black holes in binary system

Majority BH-BH systems (natal kicks)



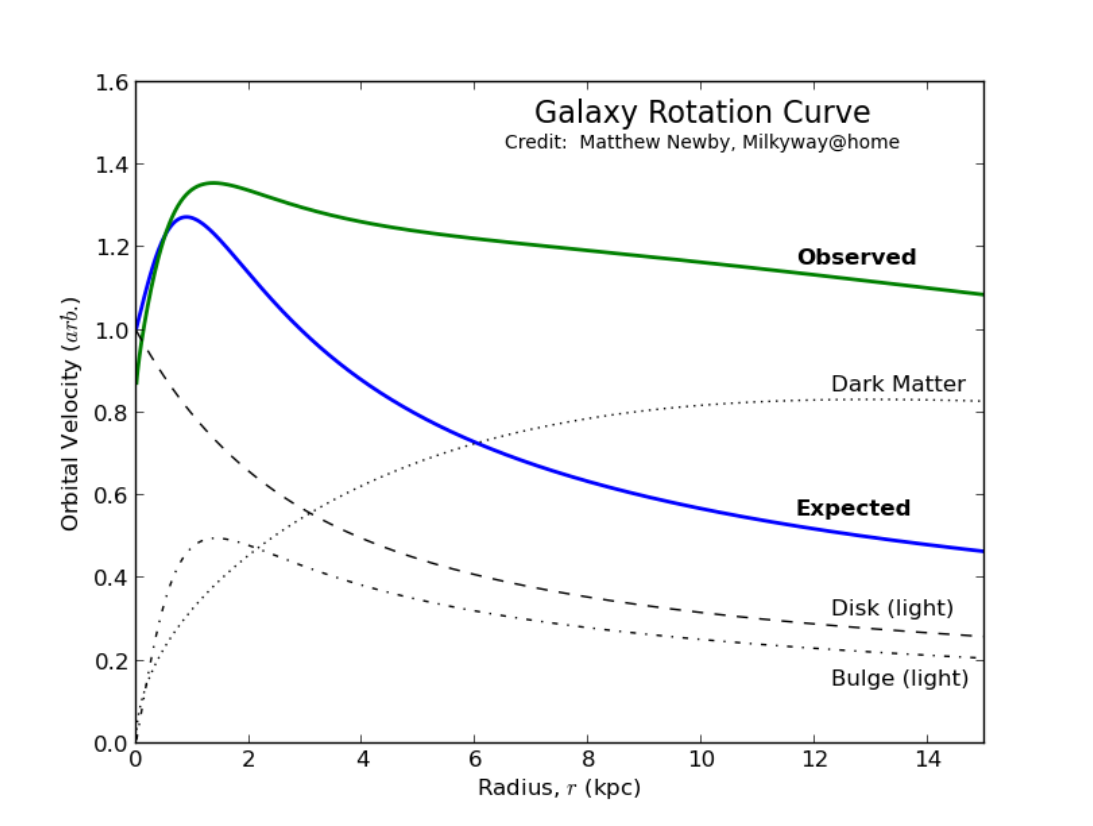
Mass distributions of Galactic black holes



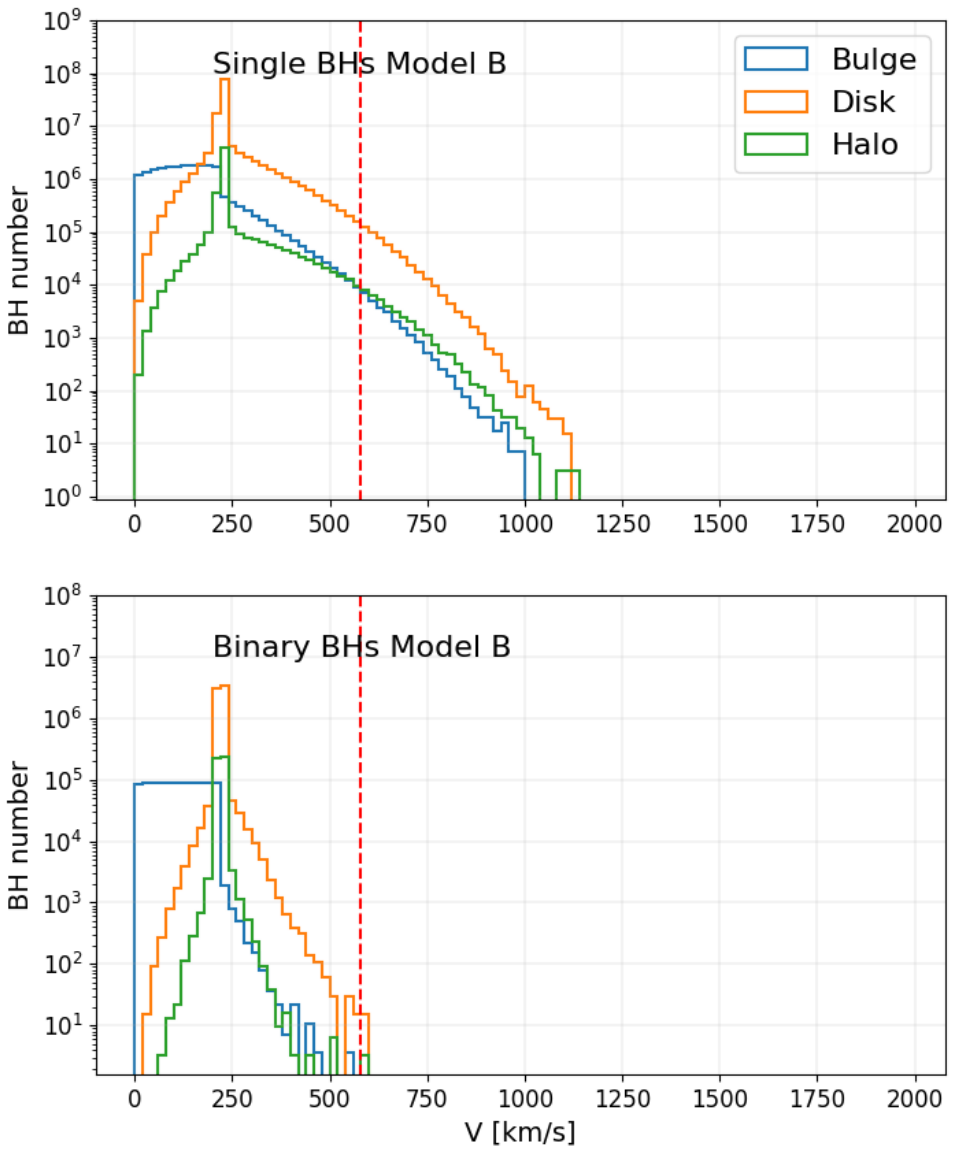
- Average mass of single BH $\sim 13M_{\odot}$, average mass of BH in binaries $\sim 19M_{\odot}$
- No first and second mass gap in single BHs distribution (mergers)
- Narrow, isolated peak near a 2.5 $M_{\odot}$ (binaries).

Velocity distribution

Total velocity: sum of Galactic potential and stellar evolution.
Approximated form of Galactic rotational curve (V_r):
$V_r = 220$ km/s for disk and halo and
$V_r = 220 \text{ km/s} \times r/R_b$ for bulge

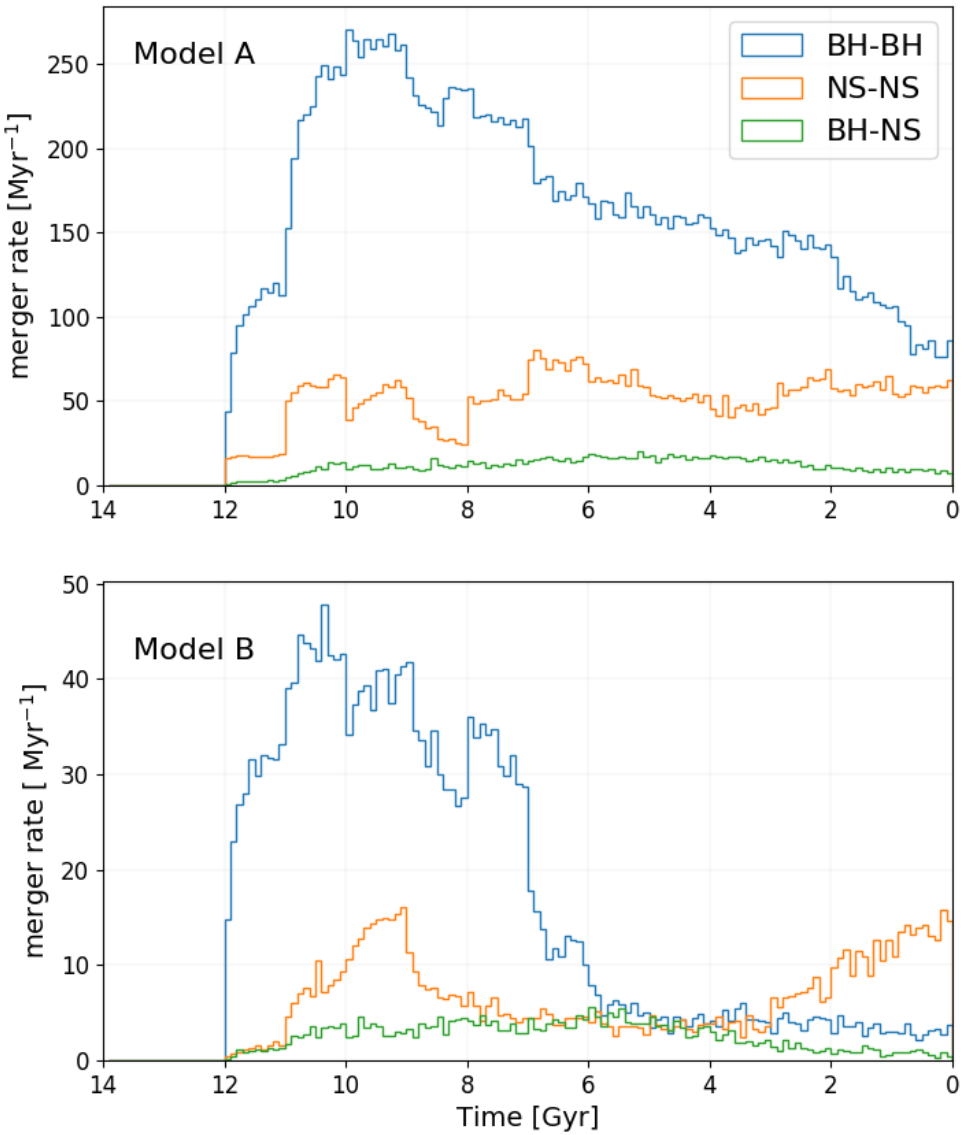


Velocity distribution



About 5% of single BHs ($\sim 8 \times 10^6$) and less than 0.001 % of binary BHs (~ 100) have velocities greater than 550 km/s, the lowest escape velocity from Milky Way .

Galactic merger rates



- The higher SFR in the given time, the higher merger rates.
- Metallicity strongly influences DCO merger rates, especially for BH-BH systems
-NS-NS, BH-NS rates quite constant.

Galactic merger rates

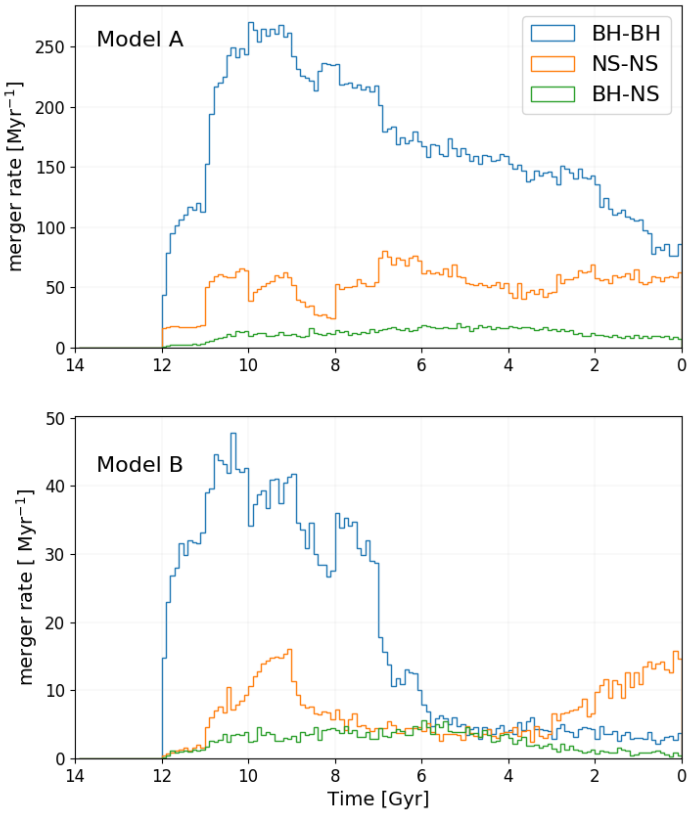


Table 1: Current Galactic merger rates.

System	[Myr^{-1}]
BH-BH	81.1/(3.1)
BH-NS	8.5/(0.7)
NS-NS	59.0/(14.1)

Summary

Galactc BH population:

- 1.6×10^8 single BHs with average mass ~ 13.0 $M_\odot$ and 9.3×10^6 BHs in binaries with average mass ~ 19.0 $M_\odot$
- Most of Galactic black holes (95%) are single. Main formation channels: 35% single star evolution, 40% binary systems merger, 25% disrupted binary systems
- Black holes in binary systems are 5% of Galactic BH population. Binary BHs are mostly (80%) BH-BH systems
- Max. single BH mass in Galactic halo - 130 $M_\odot$ (merger)
- Current Galactic merger rates estimated at: 81/3 Myr1, for BH-BH, 9/1 Myr1, for BH-NS and 59/14 Myr1 for NS-NS systems.

Halo BH mass

Aim: Amount of halo mass in stellar origin BHs outside the observation range.
Method: Lower limit: microlensing timescales $\sim 20 M_\odot$, upper limit: wide binaries in halo $\sim 100 M_\odot$.
Result: Total $M_{BH} = 5.2 \times 10^7 M_\odot$, only $\sim 0.005\%$ of total Galactic halo mass ($10^{12} M_\odot$)