Metallicity dependence of BH+MS binaries detectable with Gaia

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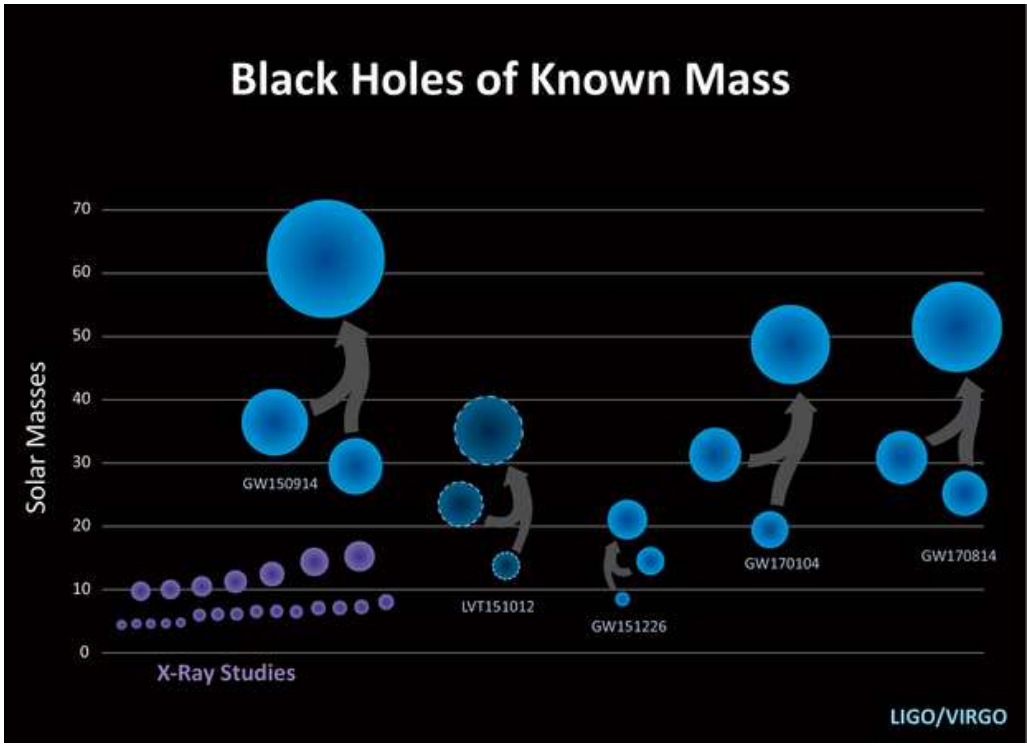
arXiv:1810.09721

Massive BHs observed by LIGO

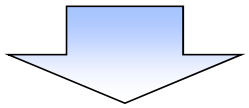
- Extremely metal poor stars or first stars are the candidate of the origin of these massive BHs

- But, BH do not have the information of metal.



Our target : BH+MS binaries (Z=Zsun, 0.1Zsun)

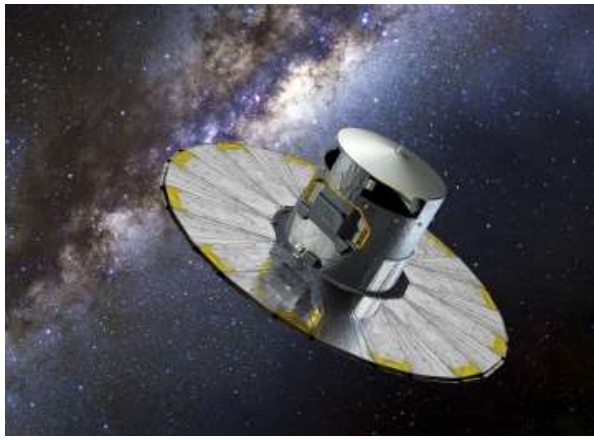
- GAIA possibly detects BH+MS binaries.
  Dmax: ~1.4 kpc (~1Msun), ~10kpc (~10Msun)
- The MS companion has the information of metallicity.
- Using the spectroscopic observation with 4-m class telescopes such as Anglo-Australian Telescope, Mayall telescope, and Kyoto university 3.8m telescope, we can check the metallicity of BH-MSs



We can get the BH mass distribution for each metallicity.

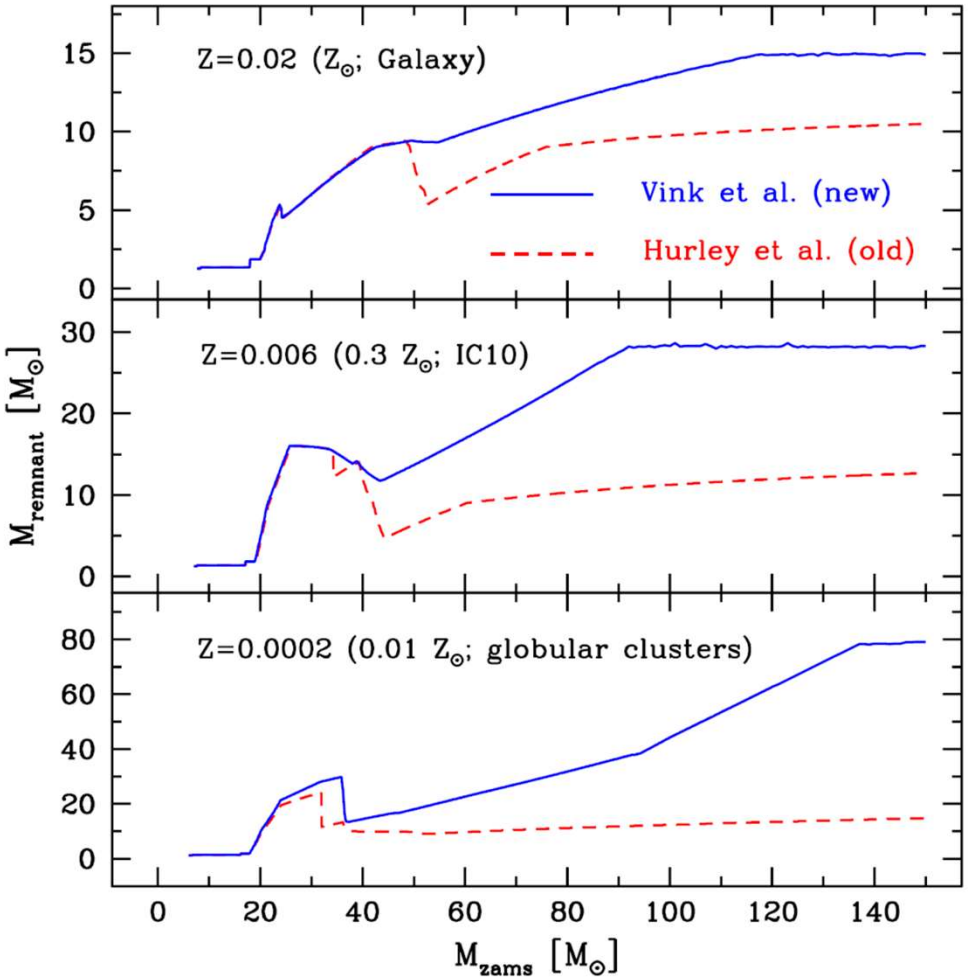
Gaia(Global Astrometric Interferometer for Astrophysics)

- Astrometry space observatory
- observation started at 25th/July/2014
- Mission lifetime: 5 yrs
- Gaia is expected to transform the field of astrometry by measuring the three dimensional spatial and velocity distribution of nearly ~1 billion stars brighter than magnitude G ~ 20 (Lindegren et al. 2016).



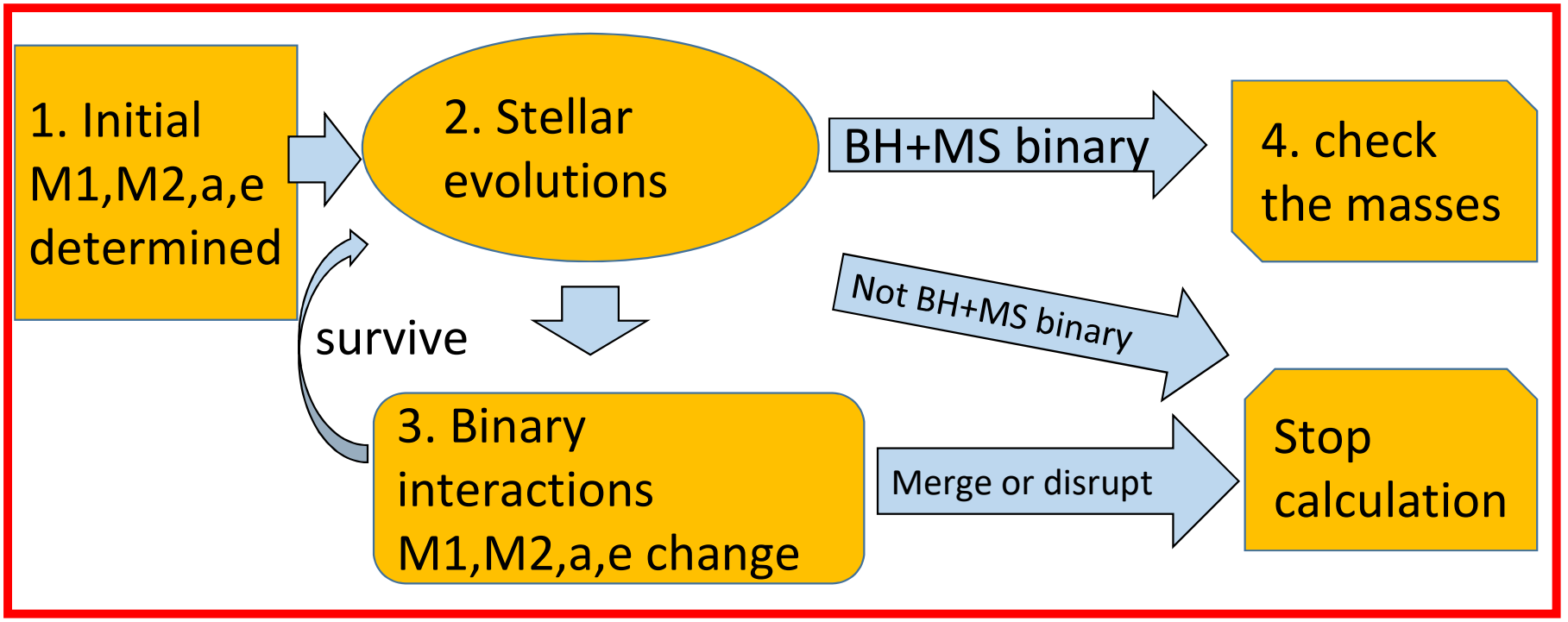
The BH mass of Pop I+II star

- The stellar wind mass loss depends on the metallicity.
- Low metallicity star possibly become a massive compact remnant.
- The BH mass distribution possibly depends on the metallicity.



Belczynski et al. 2010

The binary population synthesis

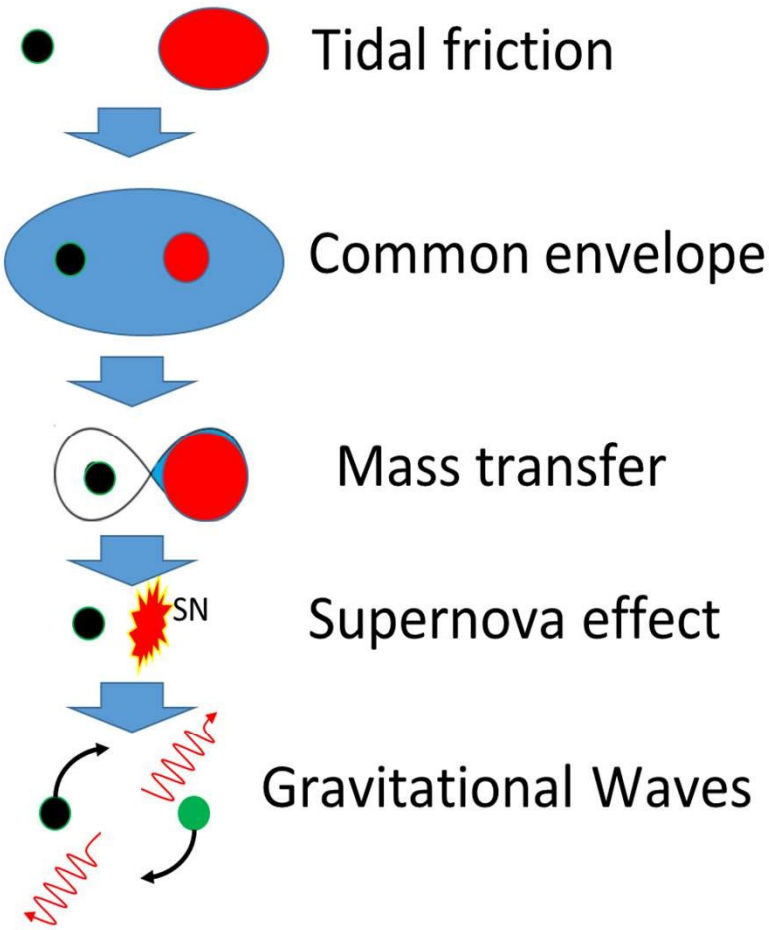


$\times 10^5$

Binary interactions

- Tidal friction
- Common envelope (CE)
- Mass transfer (MT)
- Supernova (SN) effect
- Gravitational radiation

Change
M1,M2,a, e



We need to specify some parameters to calculate these effects.

e.g. CE parameter αλ=1

Conservative MT

SN kick 0 km/s

Pop I+II binary population synthesis

- We simulate 10^5 binary evolutions for each metallicity and estimate how many binaries become a BH+MS binary whose period is 50 days<P< 5 yrs.
- We use Hurley code which is modified on the wind and some binary interaction parts.
- Initial parameter (M1,M2,a,e) distribution function P(x)

  M1 : Salpeter (5 Msun<M<100 Msun)

  q=M2/M1 : P(q)=const. (0<q<1)

  a : $P(a) \propto 1/a$ (amin<a<106Rsun)

  e : $P(e) \propto e$ (0<e<1)
- $\alpha\ \lambda = 1$
- SFR=2.5 Msun/yr
- Zsun:0.1Zsun=1:1

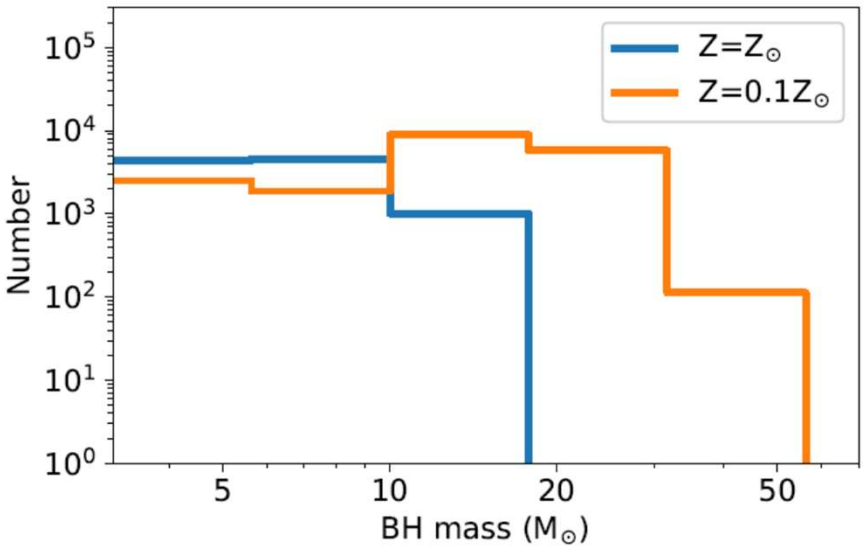
Result

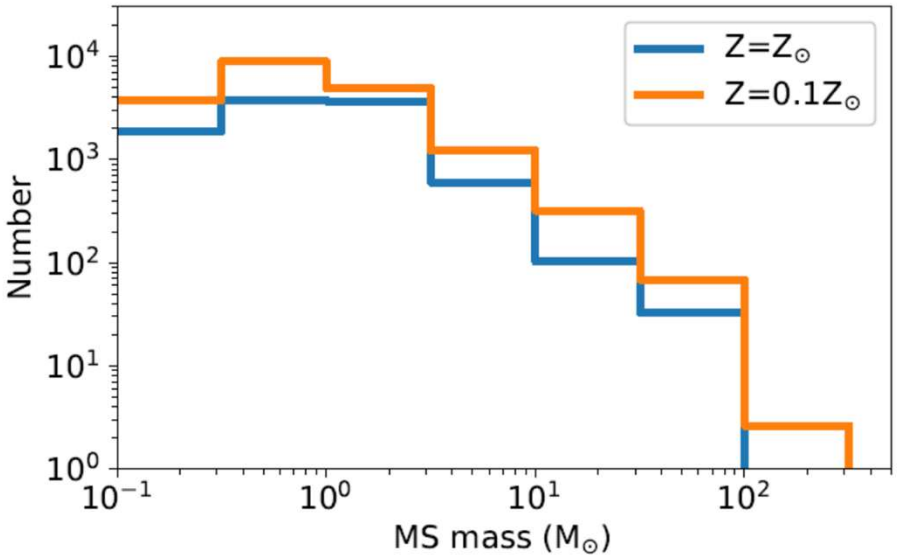
- The numbers of BH-MSs N_{BHMS} whose periods are 50 days $< P <$ 5 yrs for 10^5 binaries, the numbers of such BH-MSs in the entire galaxy N_G, and the number of BH-MSs detected by Gaia N_D for each metallicity case.

metallicity	$Z_\odot$	$10\%Z_\odot$
$N_{\rm BHMS}$	1322	2841
$N_{\rm G}$	4985	9586
$N_{\rm D}$	234	412

BH+MS binaries in our galaxy

- We calculate BH+MS binaries whose period is 50 days<P< 5 yrs in our galaxy

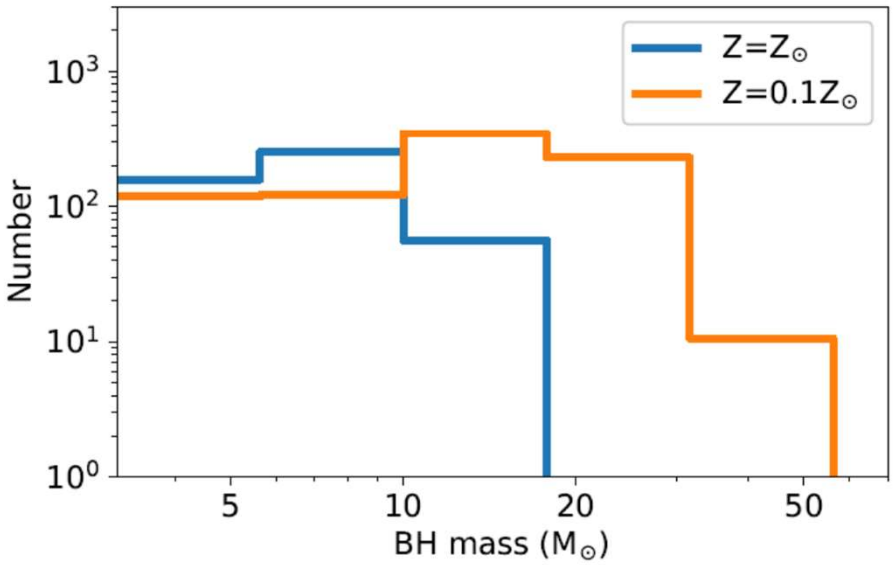


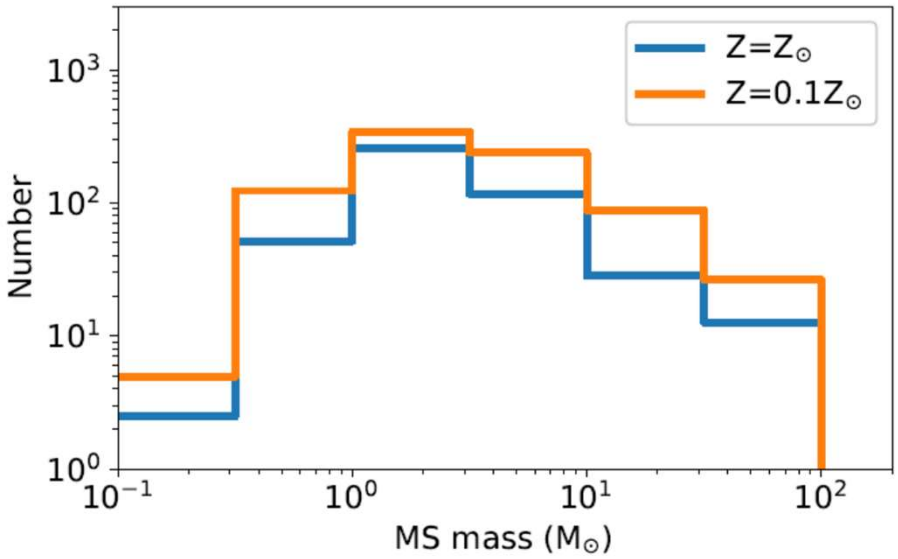


BH+MS binaries detectable with GAIA

- We consider the BH+MS which can be detected by GAIA with S/N>10.
- We use the constraint Eqs from Yamaguchi et al. 2018.

  e.g. Dmax (1Msun) = 1.4 kpc





Summary

- GAIA possibly detects BH+MS binaries.
- Using the spectroscopic observation with 4-m class telescopes, we can check the metallicity of BH+MSs
- We calculate the detection number of BH+MSs
- GAIA can detect ~200, and ~400 BH+MSs for Z=Zsun, and 0.1Zsun
- **We can get the BH mass distribution for each metallicity**