Merging binary black holes formed through isolated binary stars with all the metallicities

GR23, July 5 2022 Ataru Tanikawa

- Tanikawa, Yoshida, Kinugawa, Trani, Hosokawa, Susa, Omukai (2022, ApJ, 926, 83)
- Tanikawa, Moriya, Tominaga, Yoshida (2022, arXiv:2204.09402)

Binary black holes



LIGO-Virgo-KAGRA | Aaron Geller | Northwesterr

2021

Typically massive, wider mass range than BHXBs

- Isolated binary stars with wider metallicity range
- Dense star clusters
- Primordial BHs

Metallicity

- Initial stellar mass function (IMF)
 - $Z/Z_{\odot} \gtrsim 10^{-5}$: top-light IMF
 - $Z/Z_{\odot} \lesssim 10^{-5}$: top-heavy IMF
- Strength of stellar winds
 - Lower metallicity → weaker stellar winds → more massive BHs





Pair instability supernovae



GW190521





Pop III stars



Binary population synthesis

- Evolution track
 - Hurley's model for $> 0.1Z_{\odot}$
 - Tanikawa's model for $\leq 0.1 Z_{\odot}$
- Belczynski's stellar winds
- Fryer's rapid supernova model with Leung's PISN/PPISN model
- Fallback BH natal kick (265km/s for NS)
- Wind accretion, mass transfer, tidal interaction, common envelope, etc.
- Top-light IMF for high Z and top-heavy IMF for low Z, and Sana's binary ICs
- Madau & Fragos's cosmic star formation



BH mass distribution



- All metallicities are important.
- Pop III + EMP stars dominate pair instability mass-gap events.



Tanikawa et al. (2022, ApJ, 926, 83)

Caveats - Initial conditions

 10^{2}

 10^{1}

 10^{0}

Top-light IMF even for Pop III stars

GWTC-3

Pop III+EMP

All Z

Pop I Pop II

- Top-heavy IMF is *not* confirmed observationally.
- No close binary may be formed • under Pop III environment.



Caveats - Overshoot





Another solution



Different PISN detectability



Summary

- Isolated binary stars can form binary BHs consistently with GW observations.
- Pop III + EMP stars dominate pair instability mass-gap events.
 - Top-heavy IMF, short-period binary stars, and small overshoot are mandatory.
 - Nevertheless, these uncertainties are relaxed if we consider Pop III star clusters like simulations by Kamlah et al.
- Our scenario will be partly checked by Euclid's PISN detection number.