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Predicting the rate of fast radio bursts in globular clusters from binary black hole observations

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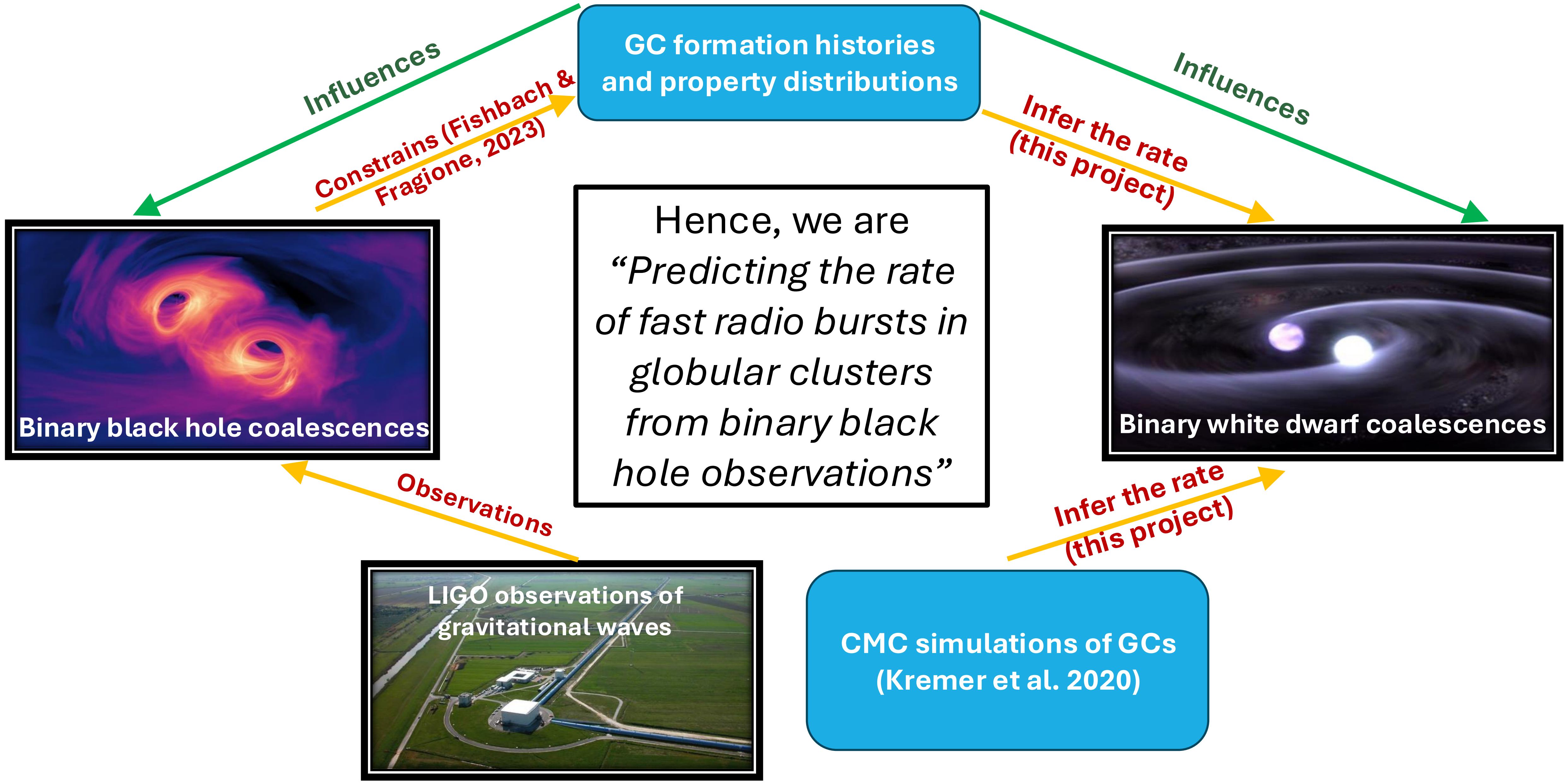
Introduction

- **Background:**
  - Fast radio bursts (FRB) either follow star formation history (SFH) or they don't.
  - Recent studies suggest that FRBs are delayed from the SFH *(Zhang & Zhang, 2022)*.
  - FRB detected in a globular cluster near M81 *(Bhardwaj et al. 2021)*.
- **Aim of the project:**
  - To test whether young NSs formed via BWD coalescences in old GCs can explain FRBs.
- **Our approach:**
  - Compare the predicted rate of BWD coalescences to FRB source rate as a function of redshift.

References: Bhardwaj, M., Gaensler, B. M., Kaspi, V. M., et al. 2021, ApJL, 910, L18, doi: 10.3847/2041-8213/abeaa6726
Zhang, R. C., & Zhang, B. 2022, ApJL, 924, L14, doi: 10.3847/2041-8213/ac46ad850

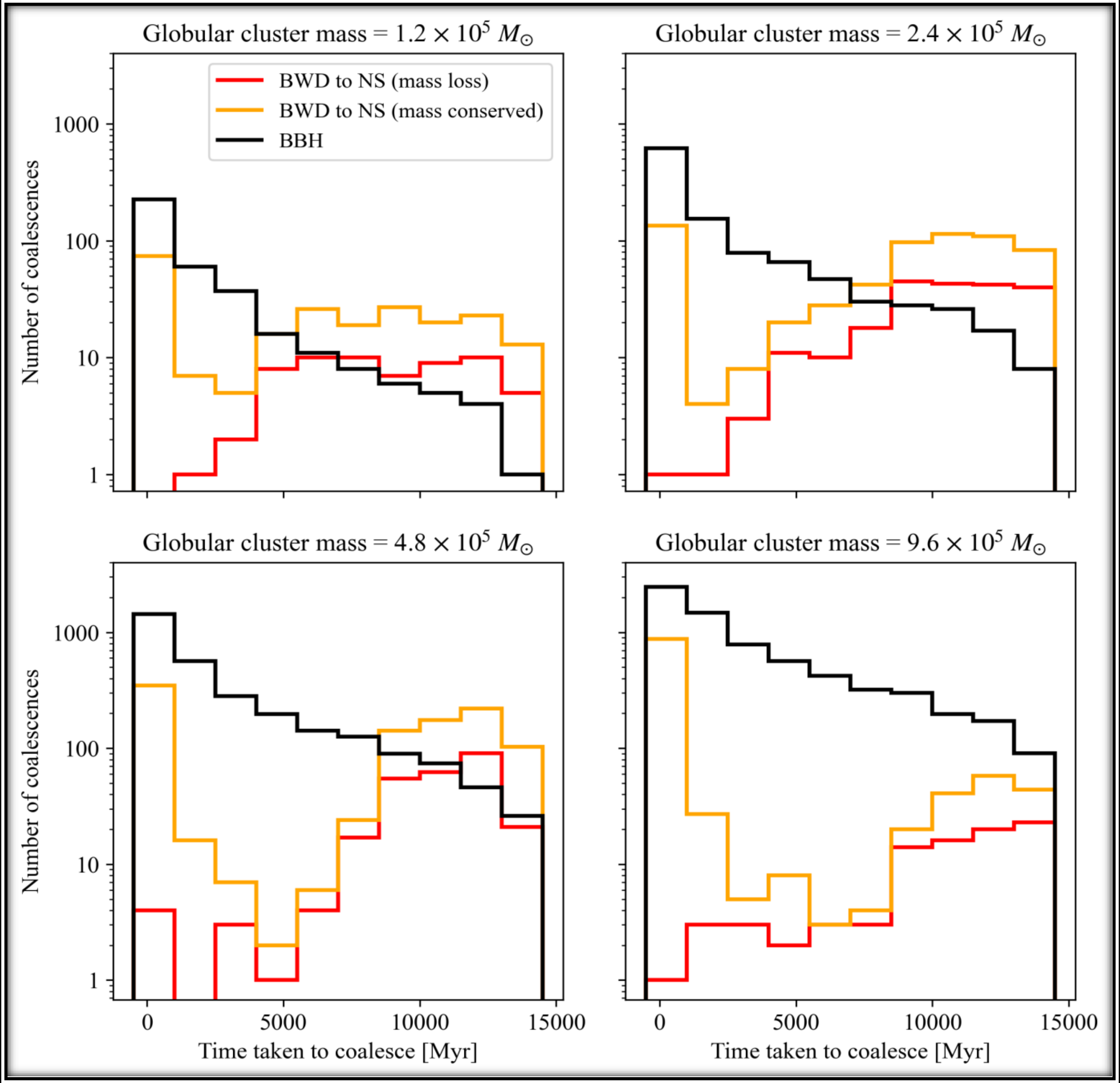


References: Fishbach, M., & Fragione, G. 2023, MNRAS, 522, 5546, doi: 10.1093/mnras/stad1364749
Kremer, K., Ye, C. S., Rui, N. Z., et al. 2020b, ApJS, 247,48, doi: 10.3847/1538-4365/ab7919

Globular clusters and compact object mergers

- ❖ BBH coalescences occur earlier in a GC's life.
- ❖ BWD coalescences occur later in a GC's life.
- ❖ Explained by mass segregation:
  - ➢ Heavier BHs sink to the GC center first.
  - ➢ This kicks many BHs out of the GC.
  - ➢ Less heavy WDs to sink to the center later.
- ❖ Only looking at BWD coalescences forming NS.
- ❖ Which BWD coalescence forms a NS?
  - ➢ Mass-conserved scenario (Ye et al. 2024)
  - ➢ Mass-loss scenario (Breivik et al. 2020)
- ❖ Mass conserved case includes primordial events.

Figure from (Rao et al. 2024)



References: Breivik, K., Coughlin, S., Zevin, M., et al. 2020, ApJ, 898, 71, doi: 10.3847/1538-4357/ab9d85734
Ye, C. S., Kremer, K., Ransom, S. M., & Rasio, F. A. 2024, ApJ, 961, 98, doi: 10.3847/1538-4357/ad089a845
Rao, A., Ye, C. S., & Fishbach, M. 2024, arXiv e-prints, arXiv:2409.20564, doi: 10.48550/arXiv.2409.20564

What do I mean by constrain?

- We are interested in **GC formation histories** and **GC property distributions.**
- **Quantifying this:**
  - Can be mathematically defined using certain functions.
  - The functional form is determined by a group of parameters.

$$\mathcal{R}_{\rm GC}(z) = \mathcal{R}_0 \frac{(1+z)^{a_z}}{1 + \left(\frac{1+z}{1+z_{\rm peak}}\right)^{a_z+b_z}}$$

- **Constraining this:**
  - Involves constraining the values the parameters can take.
  - Done by fitting to GWTC-3 observations (Fishbach & Fragione, 2023).

References: Fishbach, M., & Fragione, G. 2023, MNRAS, 522, 5546, doi: 10.1093/mnras/stad1364749

Fast Radio Burst Rates

- These models are based on observations of FRBs.
- For this project we only consider **FRB source rates.**
- There are two types of FRB rate models:
  - Models that trace the star formation history (SFH)
  - Models that are delayed from the SFH
- BWD coalescences are delayed from the SFH.
- Hence, we only consider the latter group of FRB models.

The CHIME Experiment

SFH Models:

A: Accumulated model (Zhang & Zhang, 2022)

B: SFH model (Zhang & Zhang, 2022)

C: SFH model (Shin et al. 2023)

Time Delayed Models:

D: Model from (Hashimoto et al. 2022)

E: Model from (Chen et al. 2024)

F: Hybrid model (Zhang & Zhang, 2022)

G: Lognormal delay model (Zhang & Zhang, 2022)

H: Model from (Zhang et al. 2024)

Figure from (Rao et al. 2024)

References: Rao, A., Ye, C. S., & Fishbach, M. 2024, arXiv e-prints, arXiv:2409.20564, doi: 10.48550/arXiv.2409.20564

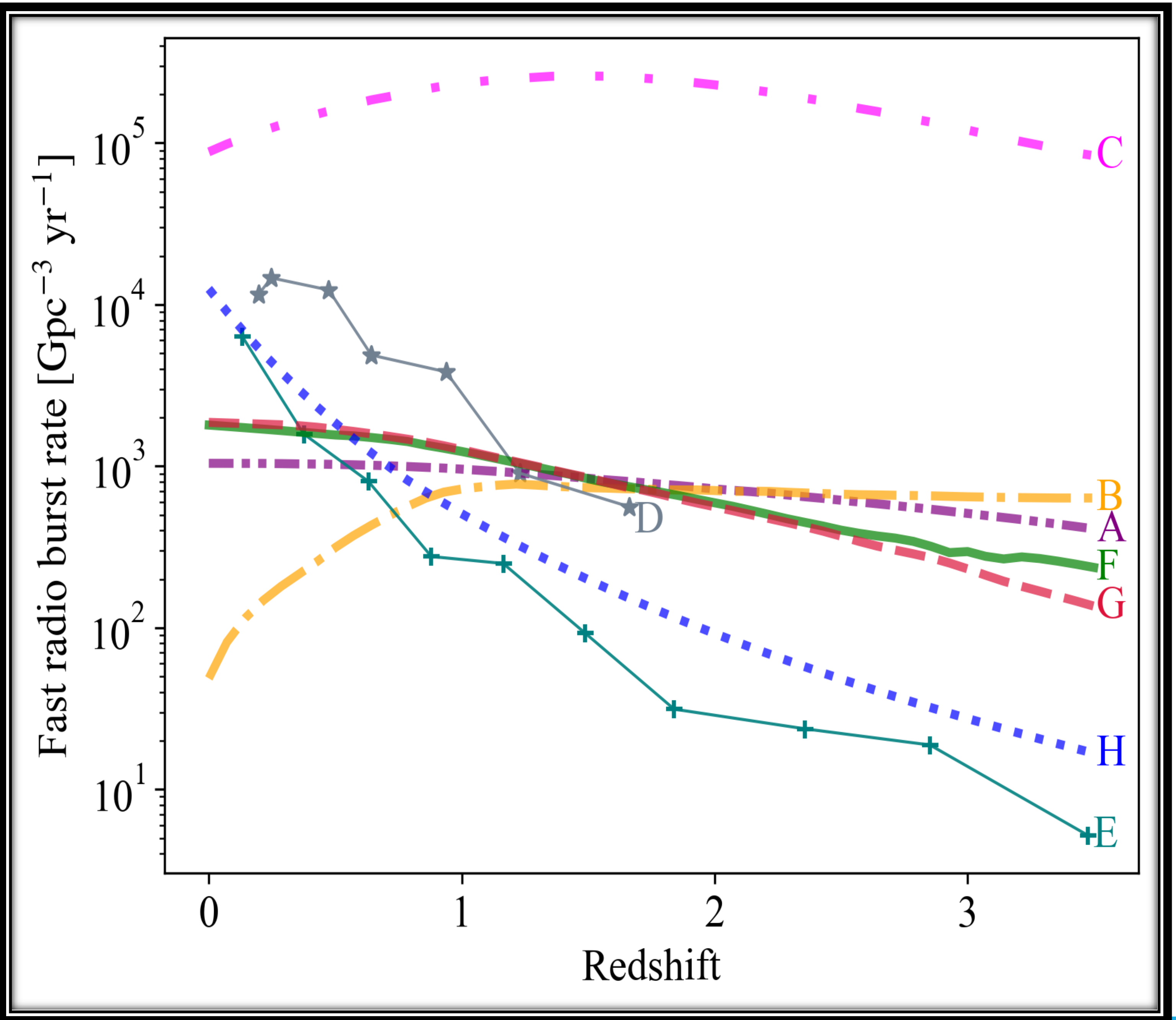
Chen, J. H., Jia, X. D., Dong, X. F., & Wang, F. Y. 2024, arXiv e-prints, arXiv:2406.03672, doi: 10.48550/arXiv.2406.03672741

Hashimoto, T., Goto, T., Chen, B. H., et al. 2022, MNRAS, 511, 1961, doi: 10.1093/mnras/stac065755

Shin, K., Masui, K. W., Bhardwaj, M., et al. 2023, ApJ, 944, 105, doi: 10.3847/1538-4357/acaf06831

Zhang, K. J., Dong, X. F., Rodin, A. E., et al. 2024, arXiv e-prints, arXiv:2406.00476, doi: 10.48550/arXiv.2406.00476848

Zhang, R. C., & Zhang, B. 2022, ApJL, 924, L14, doi: 10.3847/2041-8213/ac46ad850



Results

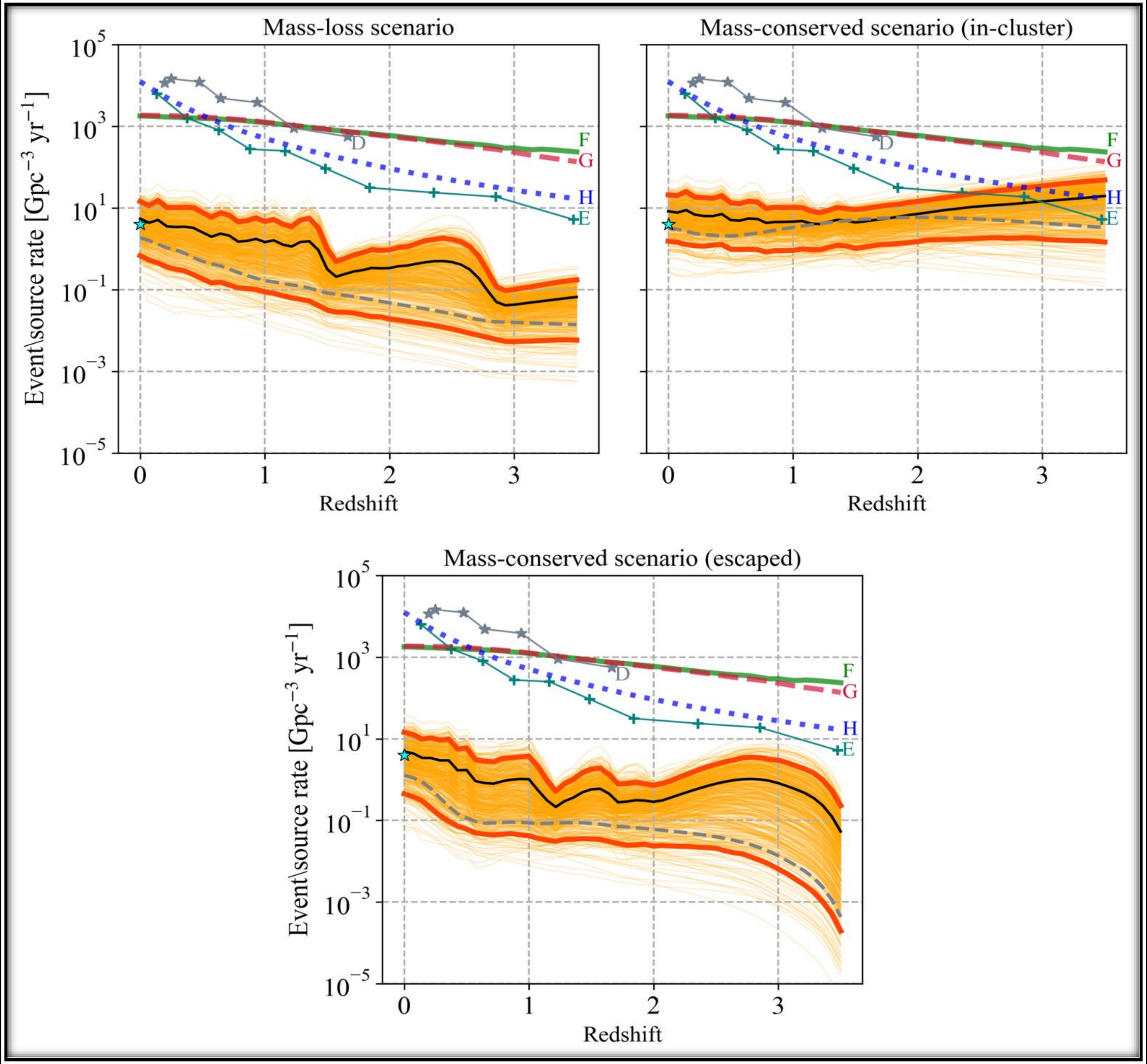
- The inferred BWD coalescence rate is shown in orange.
- Mass conserved scenario includes escaped mergers.
- Observational FRB rate models shown for comparison.
- Star shows BWD rate at $z = 0$ by Kremer et al. (2023).
- The black curve is the mean BWD coalescence rate.

References: Rao, A., Ye, C. S., & Fishbach, M. 2024, arXiv e-prints, arXiv:2409.20564, doi: 10.48550/arXiv.2409.20564

Fishbach, M., & Fragione, G. 2023, MNRAS, 522, 5546, doi: 10.1093/mnras/stad1364749

Kremer, K., Li, D., Lu, W., Piro, A. L., & Zhang, B. 2023, ApJ, 944, 6, doi: 10.3847/1538-4357/acabbf772

Shin, K., Masui, K. W., Bhardwaj, M., et al. 2023, ApJ, 944, 105, doi: 10.3847/1538-4357/acaf06831



Results from (Rao et al. 2024)

Conclusions

- **Main takeaways:**
  - BWD coalescences in GCs cannot account for a large fraction of FRBs in the local Universe.
  - Multi-messenger nature of gravitational wave astronomy.
  - Future GW observations of BWDs can shed light on mechanism of their coalescences.
- **Refining the results:**
  - Better localizations of FRBs to higher redshifts and further refine FRB rate models.
  - Further observations of gravitational waves from LVK will help better constrain GC formation histories.
  - Will allow more accurate inference of BWD coalescence rate.

Full paper available at: