

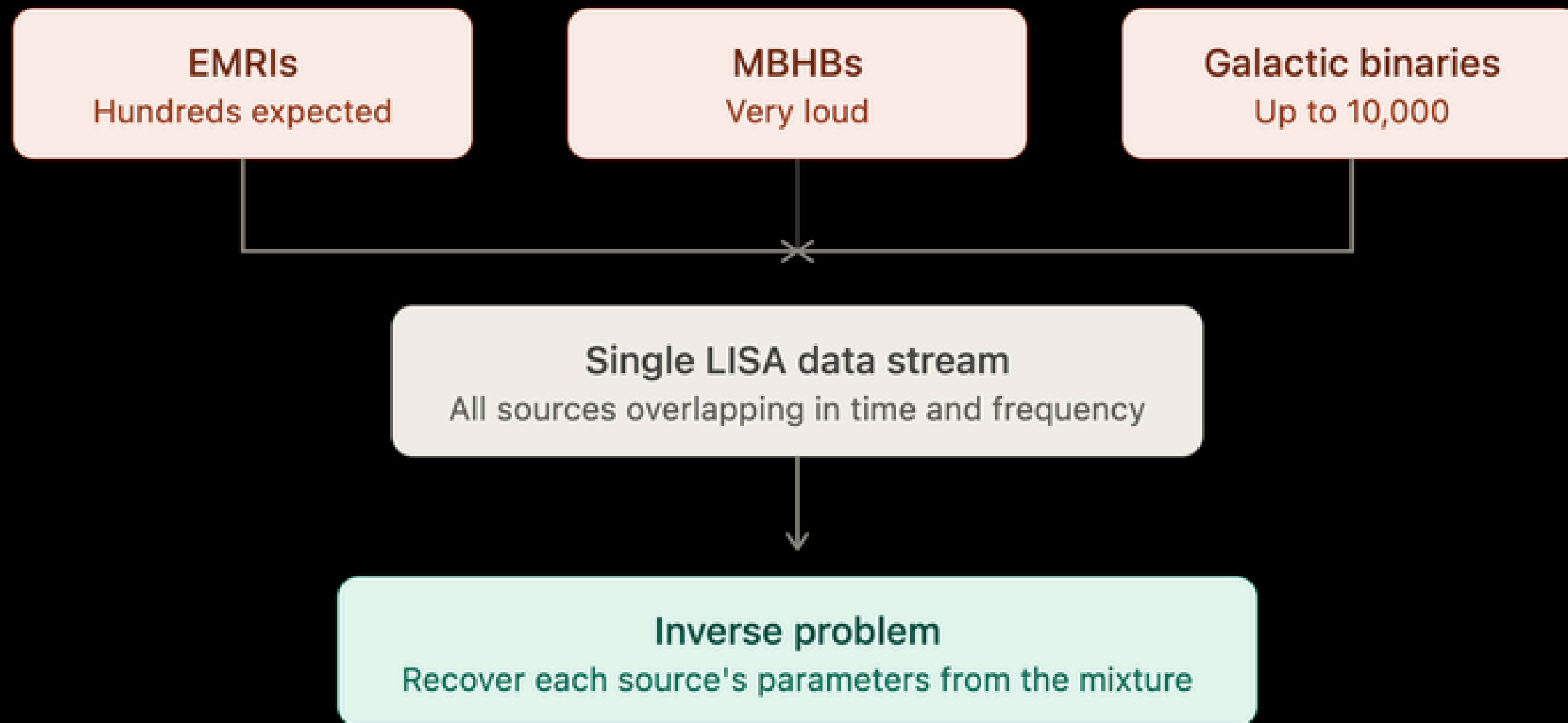
CHARACTERIZING BIAS IN MULTI-SOURCE GRAVITATIONAL WAVE INFERENCE WITH LISA



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in collaboration with

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SOURCE INFERENCE PIPELINE



— GLOBAL FIT

- **Simultaneous inference of all source parameters**
- **Uses joint-likelihood function to infer in a very high dimensional-space.**
- **Extremely Expensive**
 - **Especially For EMRIs**

SOURCE INFERENCE PIPELINE



— LOCAL FIT

- Infer source parameters sequentially and subtract it from the data stream
- Unequal subtraction and presence of other sources can cause bias
- Less Expensive compared to global fit.

SOURCE INFERENCE PIPELINE



— LOCAL FIT

- Especially motivated by

Low overlap among EMRIs →

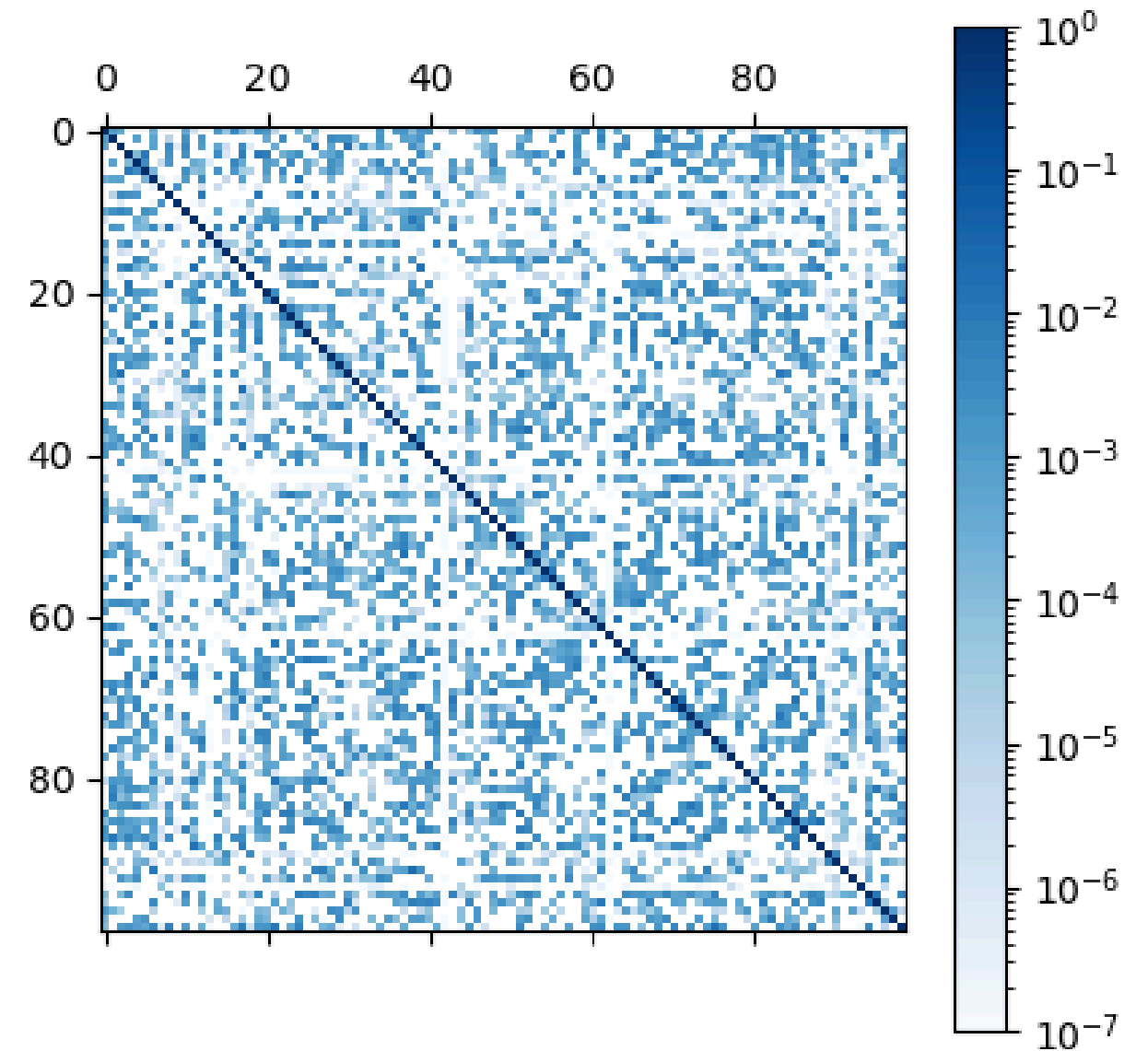


FIG. Overlap matrix of 100 random EMRIs

• SETUP

Waveform Model

- **EMRI: KERR ECCENTRIC EQUATORIAL (ZEROTH ORDER POST-ADIABATIC)**

$$\theta_{\text{EMRI}} = \{ M, \mu, a, p_0, e_0, D_L, \theta_S, \phi_S, \theta_K, \phi_K, \Phi_{\varphi 0}, \Phi_{r 0} \} \quad (12)$$

- **MBHB: PhenomHM**

$$\theta_{\text{MBHB}} = \{ M, q, a_1, a_2, \iota, D_L, \phi_{\text{ref}}, \lambda, \beta, \psi, t_{\text{ref}} \} \quad (11)$$

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DATA MODEL

Response Channel (2nd generation TDIs) : A, E, T

$$x_{\text{signal}} = \sum_{i=1}^n x_{\text{EMRI},i} + \sum_{j=1}^m x_{\text{MBHB},j} + \hat{n}$$



No. of Parameter (np) scales as $12n + 11m$

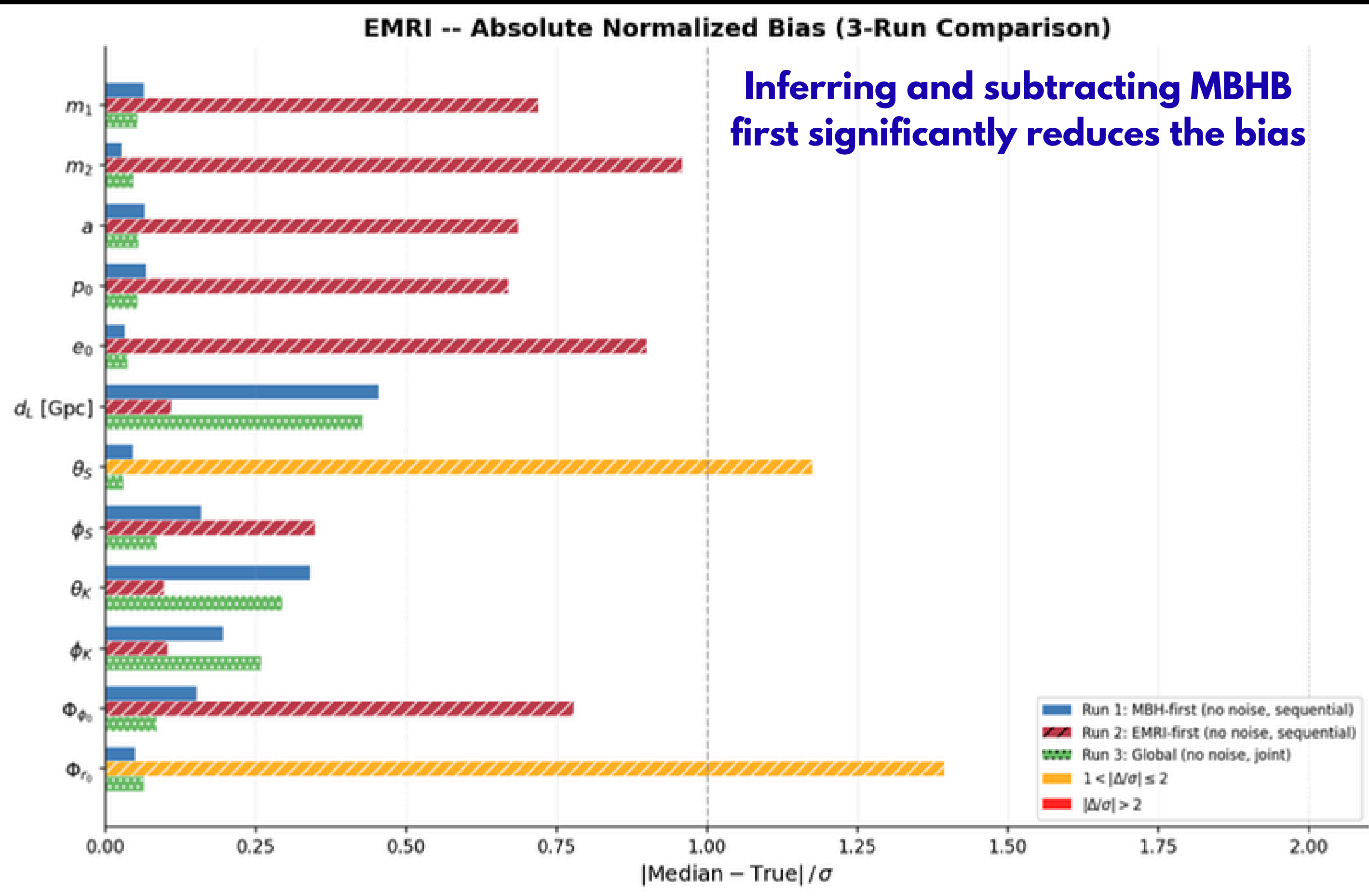
- SIGNAL COMPOSED OF 1 MBHB AND 1 EMRI**

$$x_{\text{signal}} = x_{\text{EMRI}} + x_{\text{MBHB}}$$

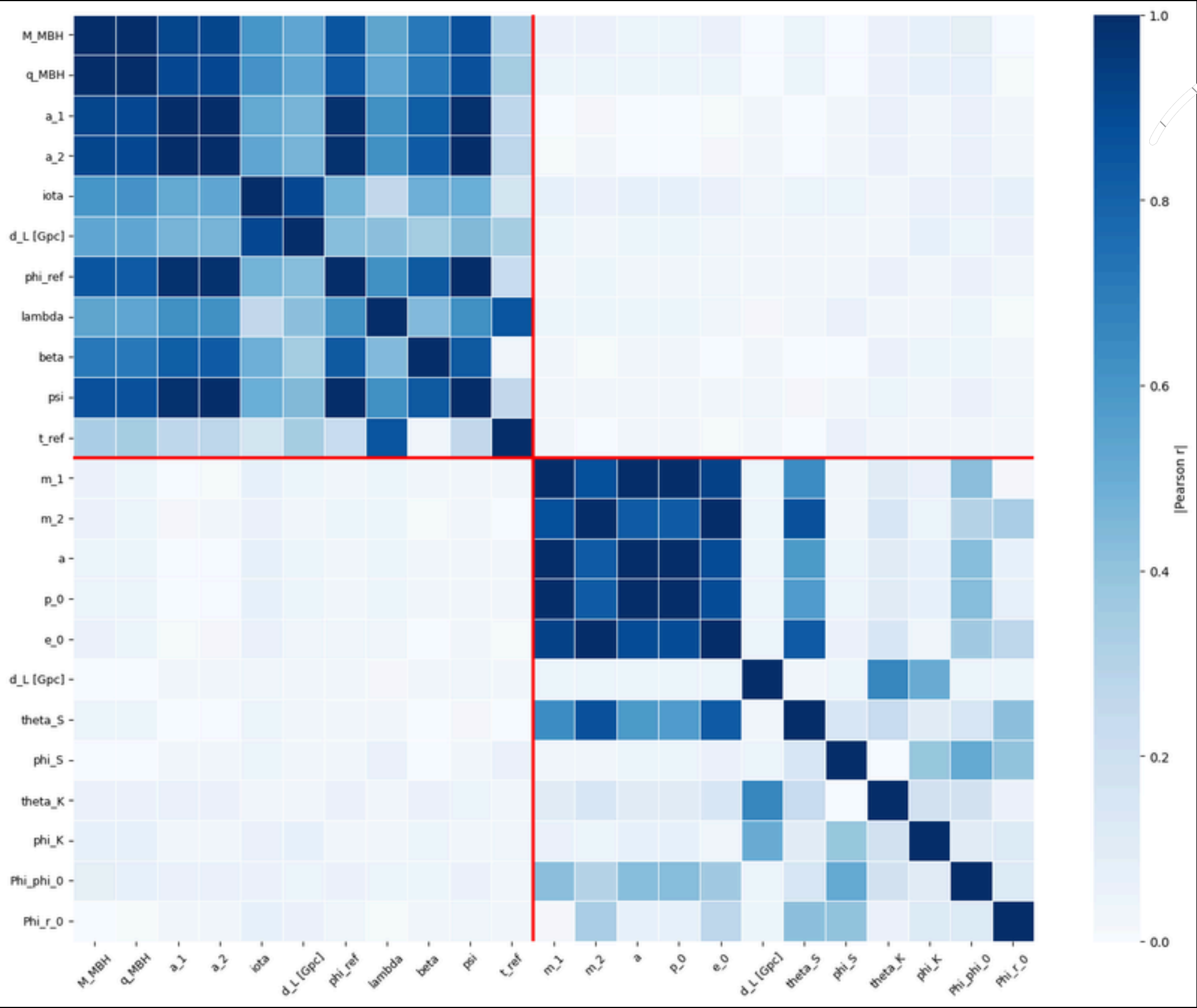


Signal to Noise Ratio (SNR)

• SIGNAL COMPOSED OF 1 MBHB AND 1 EMRI



• **SIGNAL COMPOSED OF 1 MBHB AND 1 EMRI**



NO INTER-PARAMETERIC CORRELATION

Correlation matrix - Simultaneous characterization of an EMRI and a MBHB

• **MULTIPLE EMRI SYSTEMS**

3 EMRI SYSTEM

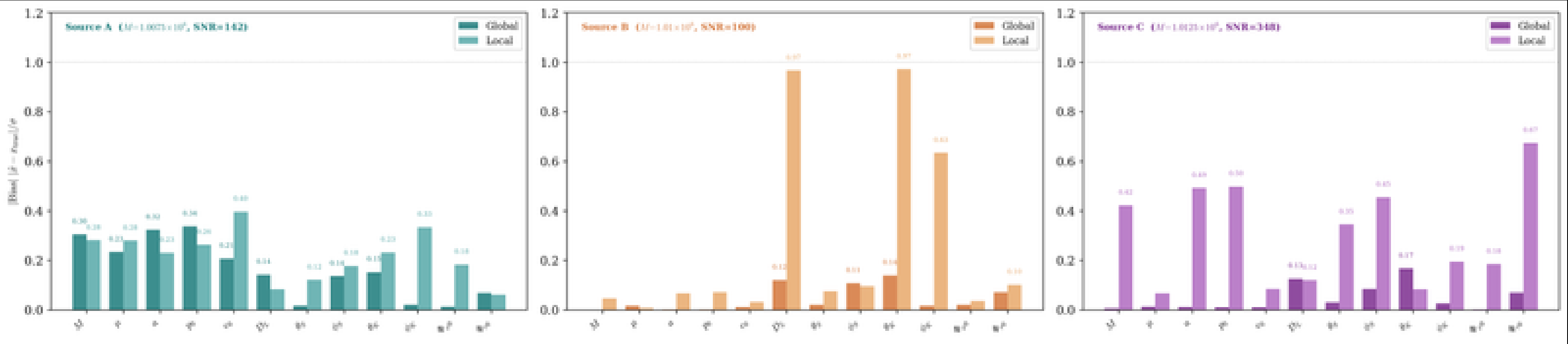


FIG. Bias Comparison for Local Fit vs Global Fit for signal comprising 3 distinct EMRIs,

• MULTIPLE EMRI SYSTEMS

3 EMRI SYSTEM

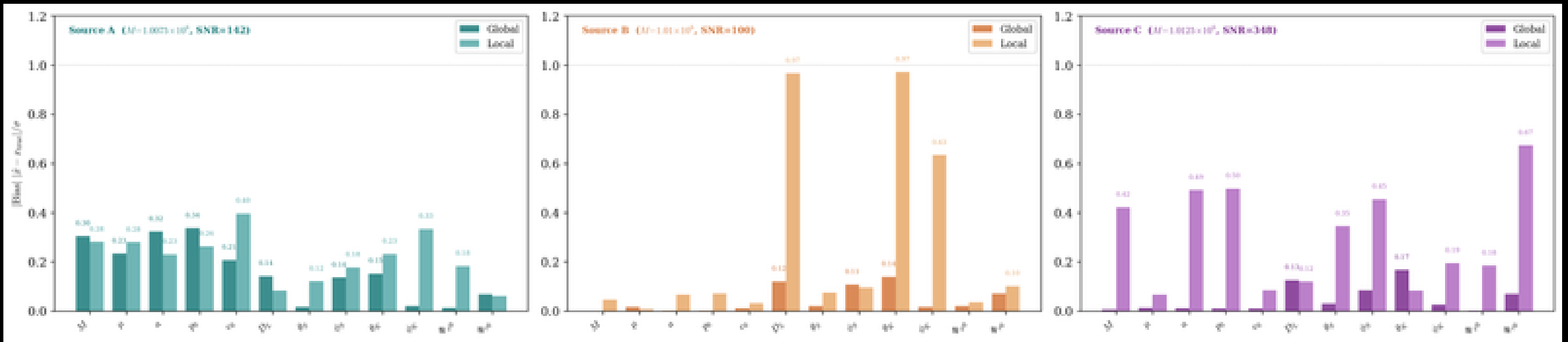


FIG. Bias Comparison for Local Fit vs Global Fit for signal comprising 3 distinct EMRIs,

~ **EVEN FOR LOCAL FIT APPROACH, THE BIAS IS LESS THAN $1 \sigma_{std}$**

TIME FOR CONVERGENCE USING LOCAL FIT APPROACH ON A100

~ 24 HRS

3 EMRI SYSTEM

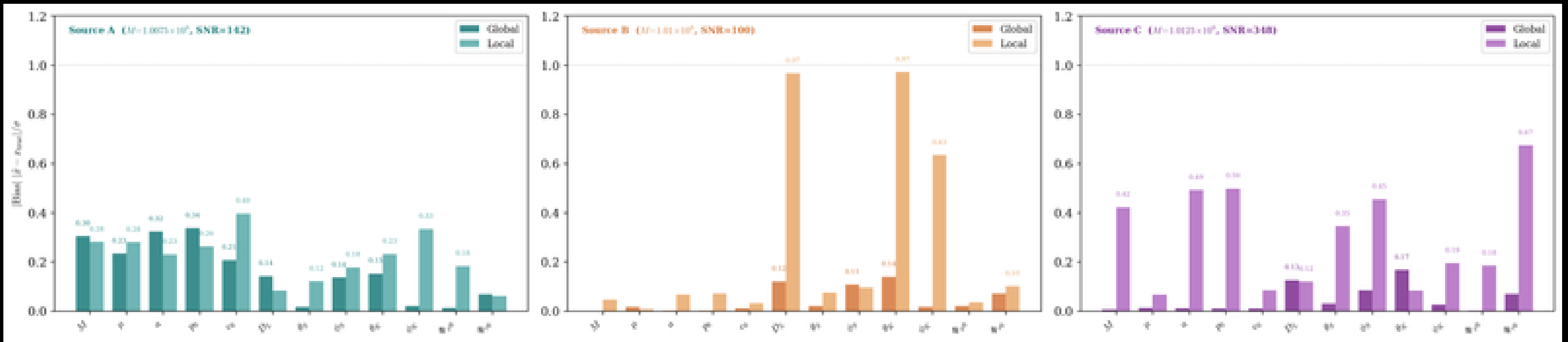


FIG. Bias Comparison for Local Fit vs Global Fit for signal comprising 3 distinct EMRIs,

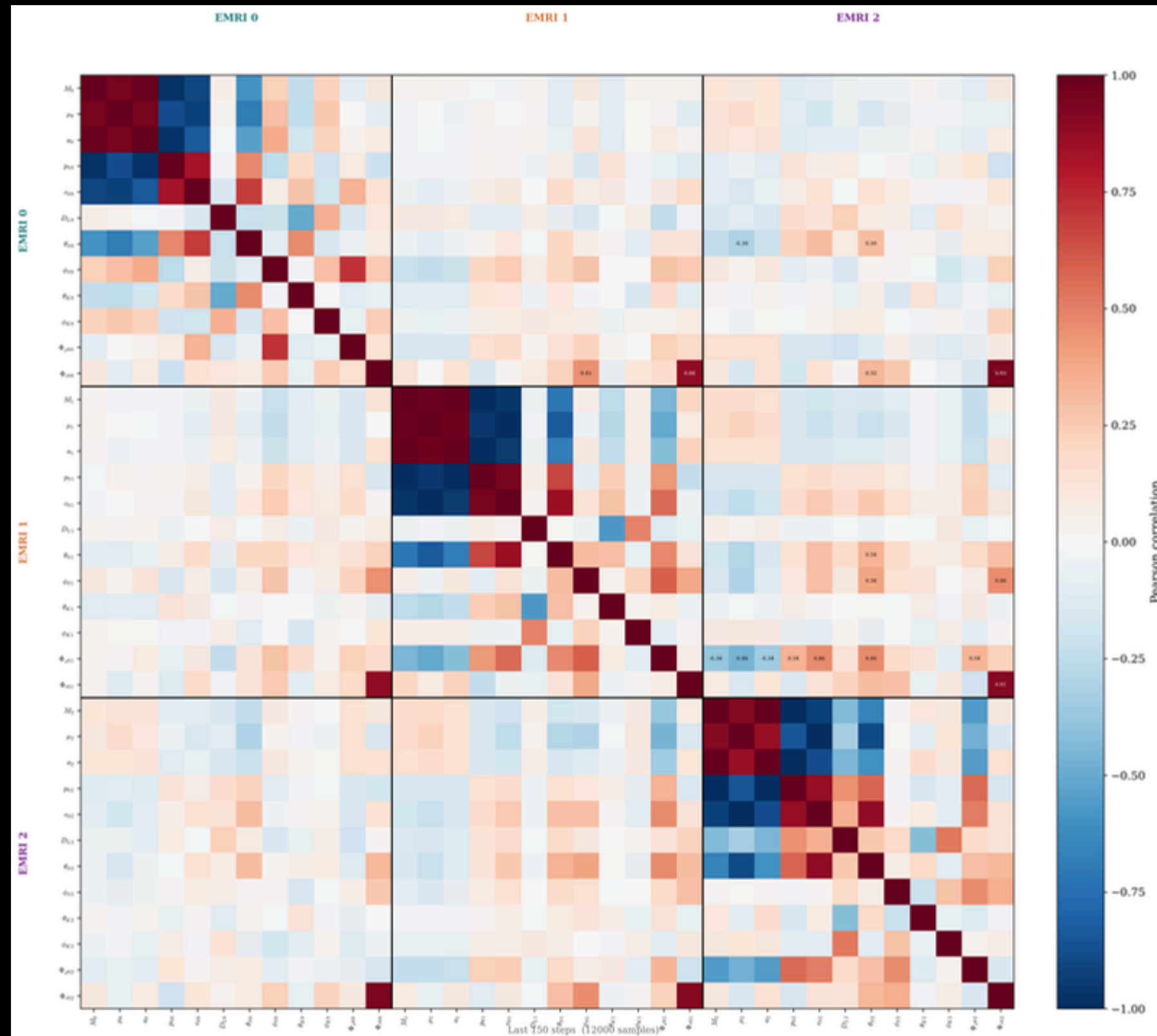
~ GLOBAL FIT APPROACH HAS LOWER BIAS, BUT

TIME FOR CONVERGENCE USING GLOBAL FIT APPROACH ON A100

> 240 HRS

- **MULTIPLE EMRI SYSTEMS**

3 EMRI SYSTEM

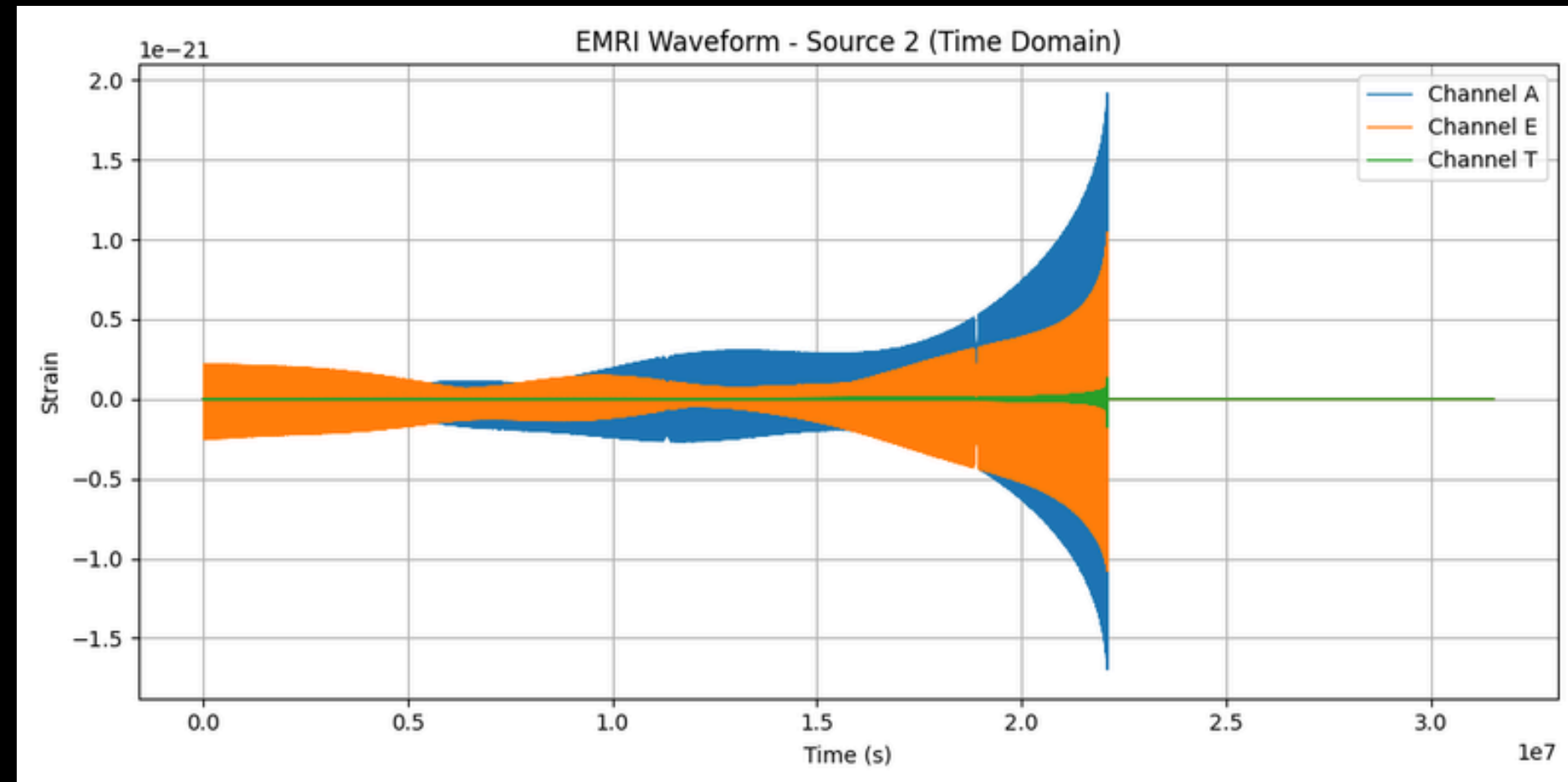
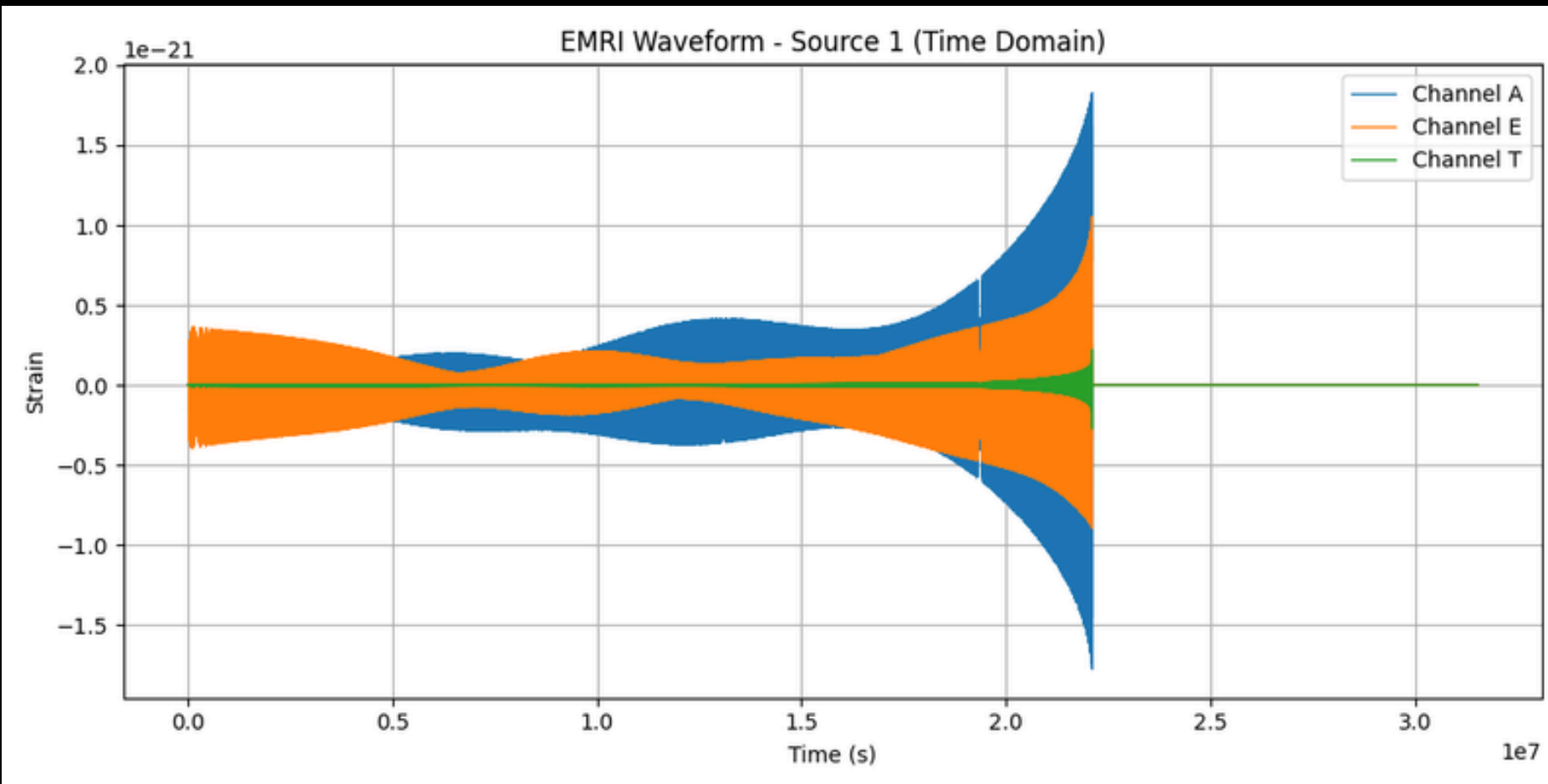


**NO INTER-
PARAMETRIC
CORRELATION
AMONG
DIFFERENT
EMRI_s**

Fig. Correlation Matrix - Simultaneous Characterization of 3 EMRIs

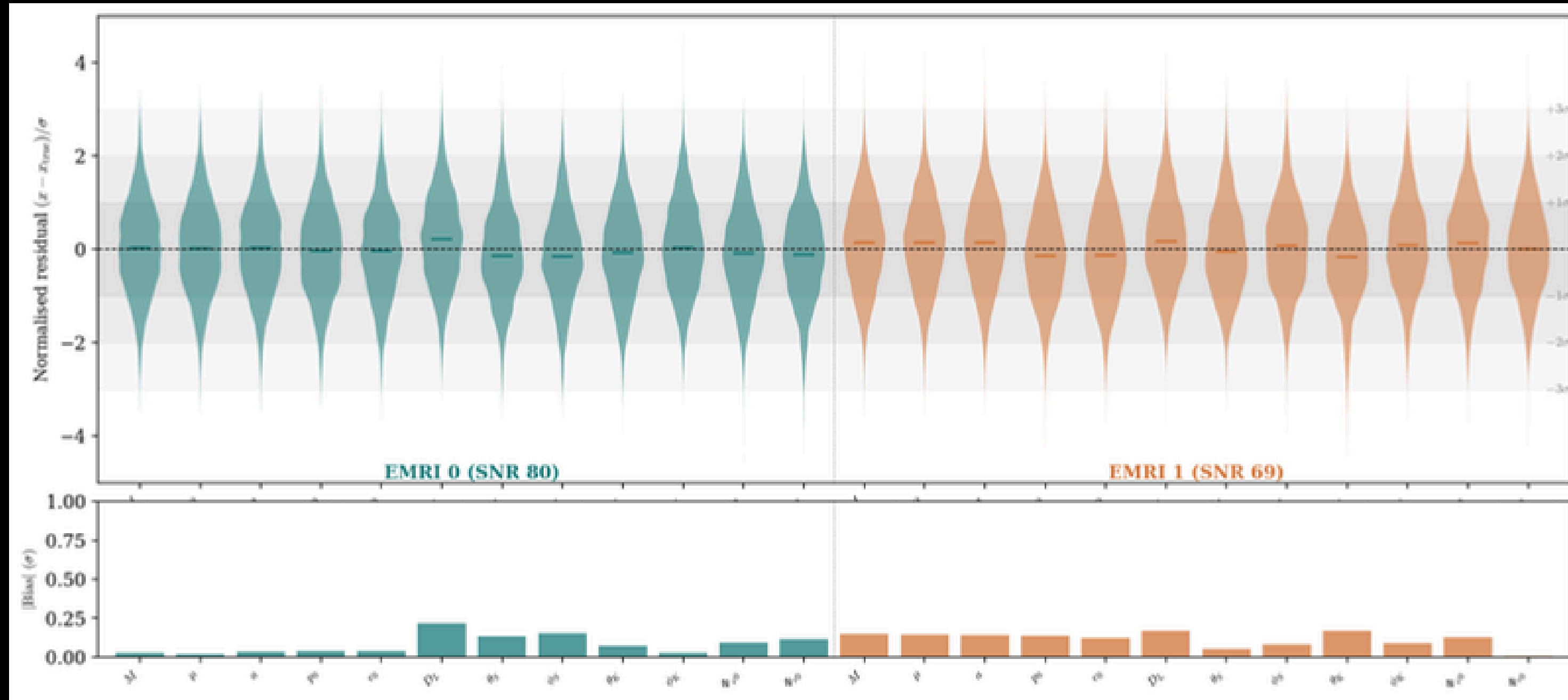
- MULTIPLE EMRI SYSTEMS**

2 EMRI SYSTEM WITH OVERLAPPING NEAR PLUNGE



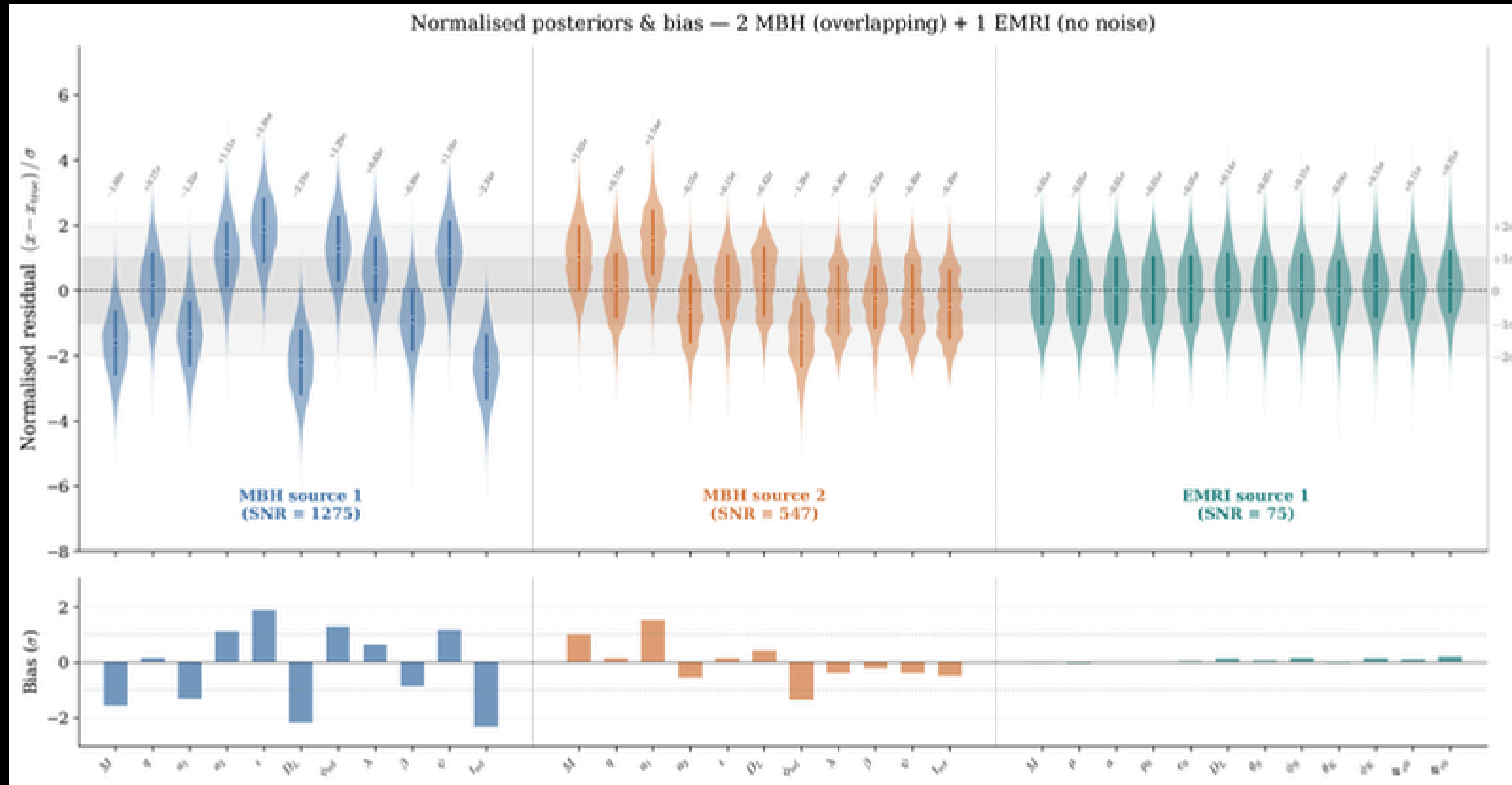
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2 EMRI SYSTEM WITH OVERLAPPING NEAR PLUNGE



• MULTIPLE EMRI + MBHB SYSTEMS

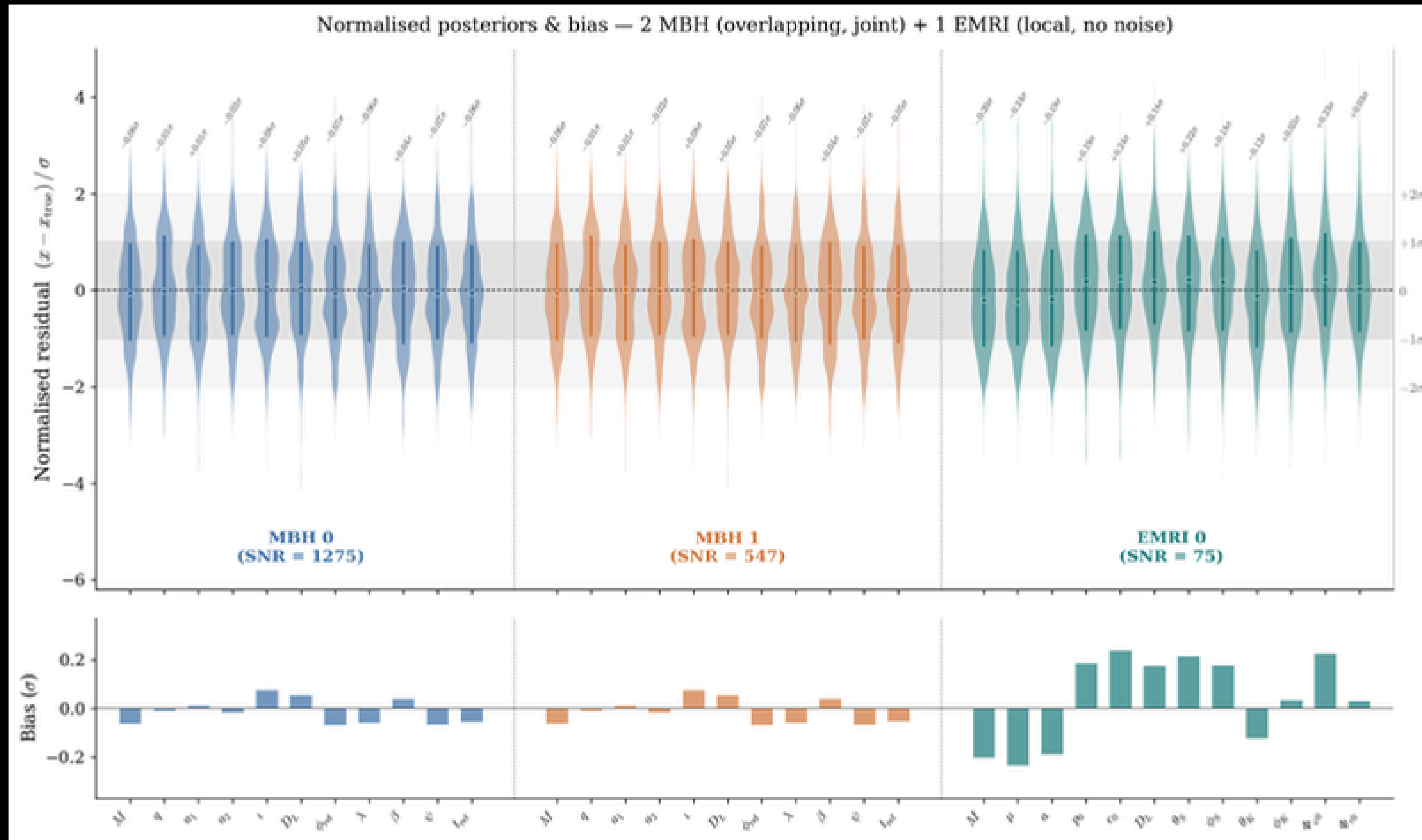
2 MBHB (Overlapping Coalescence Time)+ 1 EMRI



LOCAL FIT

• MULTIPLE EMRI + MBHB SYSTEMS

2 MBHB (Overlapping Coalescence Time)+ 1 EMRI

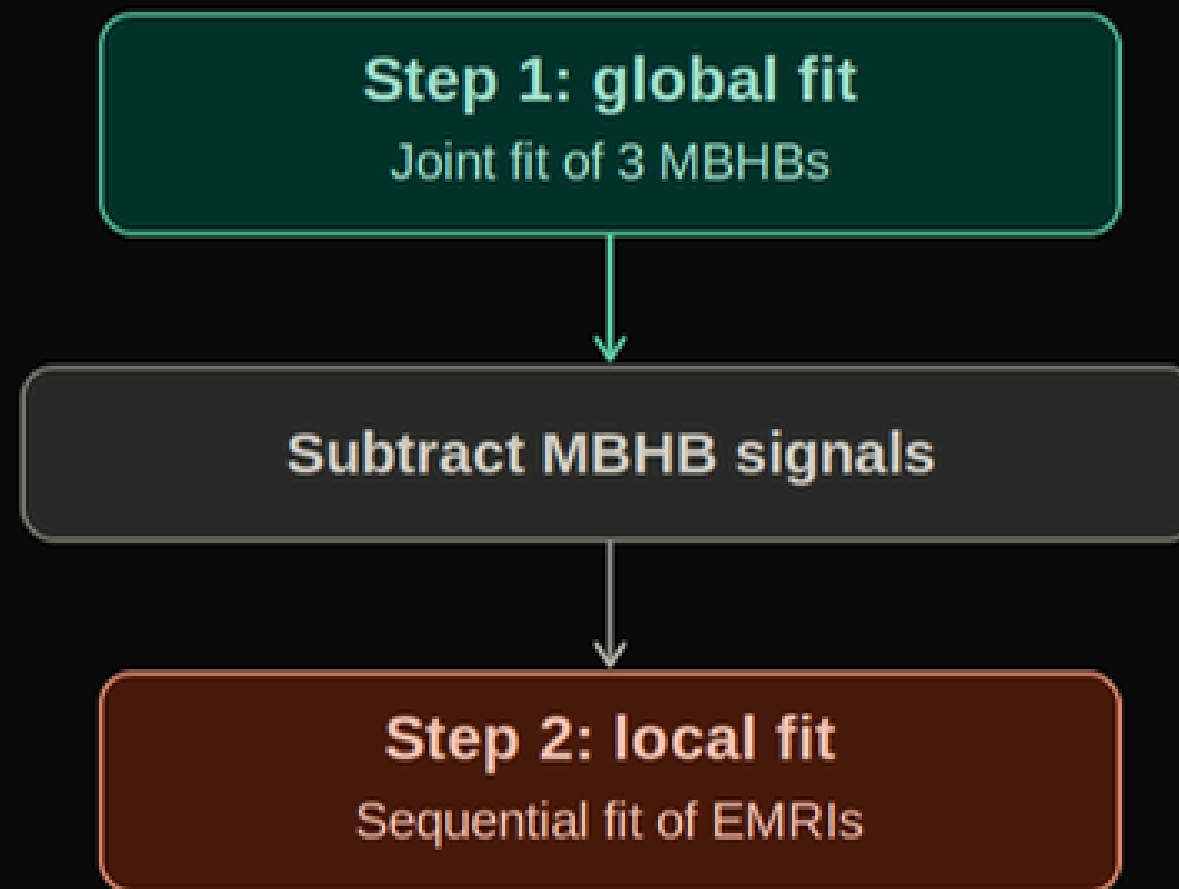


**Global Fit on
MBHB and
Local Fit on
EMRIs**

- **MULTIPLE EMRI + MBHB SYSTEMS**

3 EMRI + 3 MBHB + NOISE (WEAKLY STATIONARY)

*UNRESOLVED GALACTIC BINARIES CONFUSION
NOISE BAKED INTO IT*



Global fit on MBHBs first, then subtract and locally fit each EMRI

• MULTIPLE EMRI + MBHB SYSTEMS

3 EMRI + 3 MBHB + NOISE (WEAKLY STATIONARY)

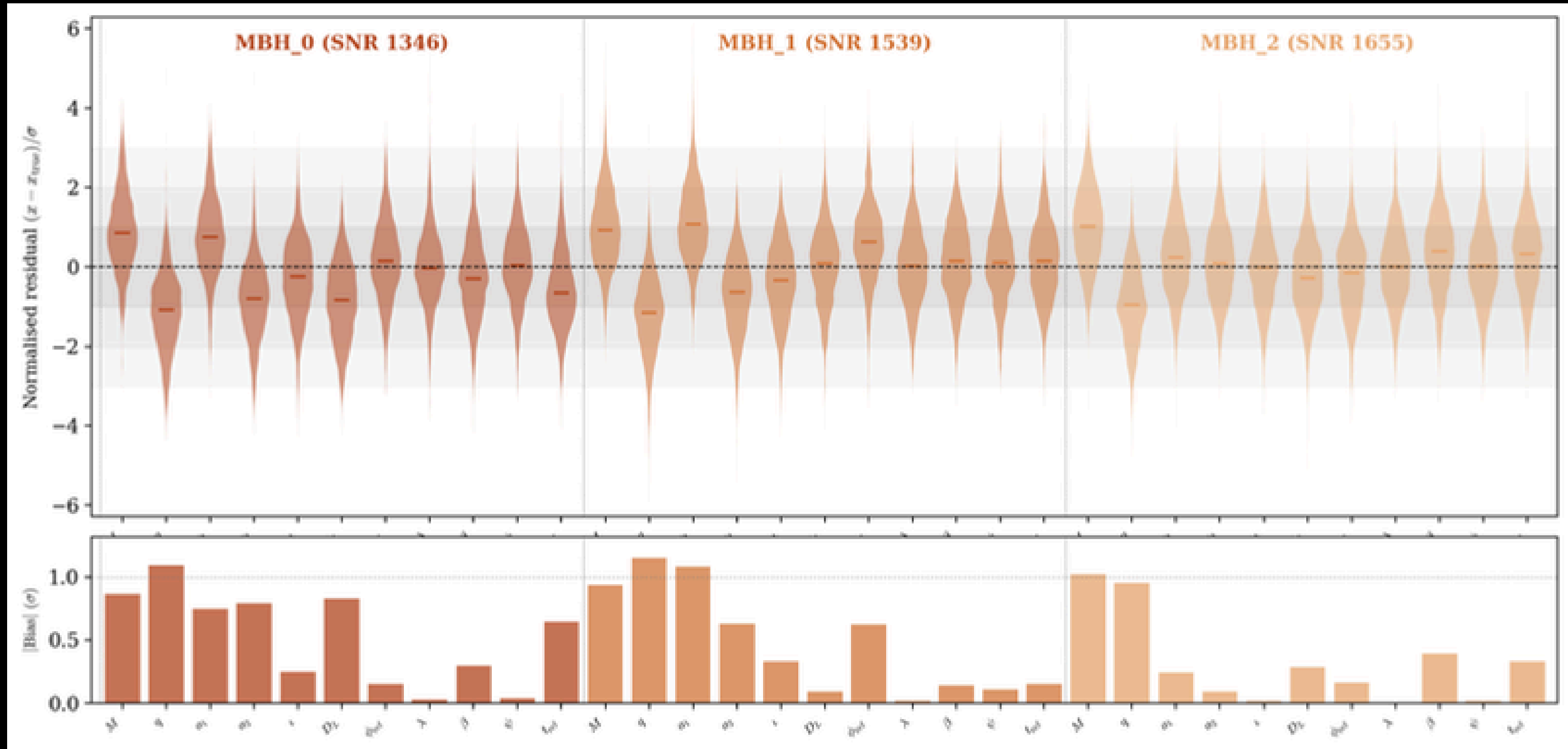


Fig. 3 MBHB Merger Global Fit Inference

CONCLUSION

- **Limited overlap among sources**
 - **MBHB vs EMRIs**
 - **EMRIs vs EMRIs**

CONCLUSION

—

- **Limited overlap between sources**
- **Low inter-parametric, but high intra-parametric correlation**

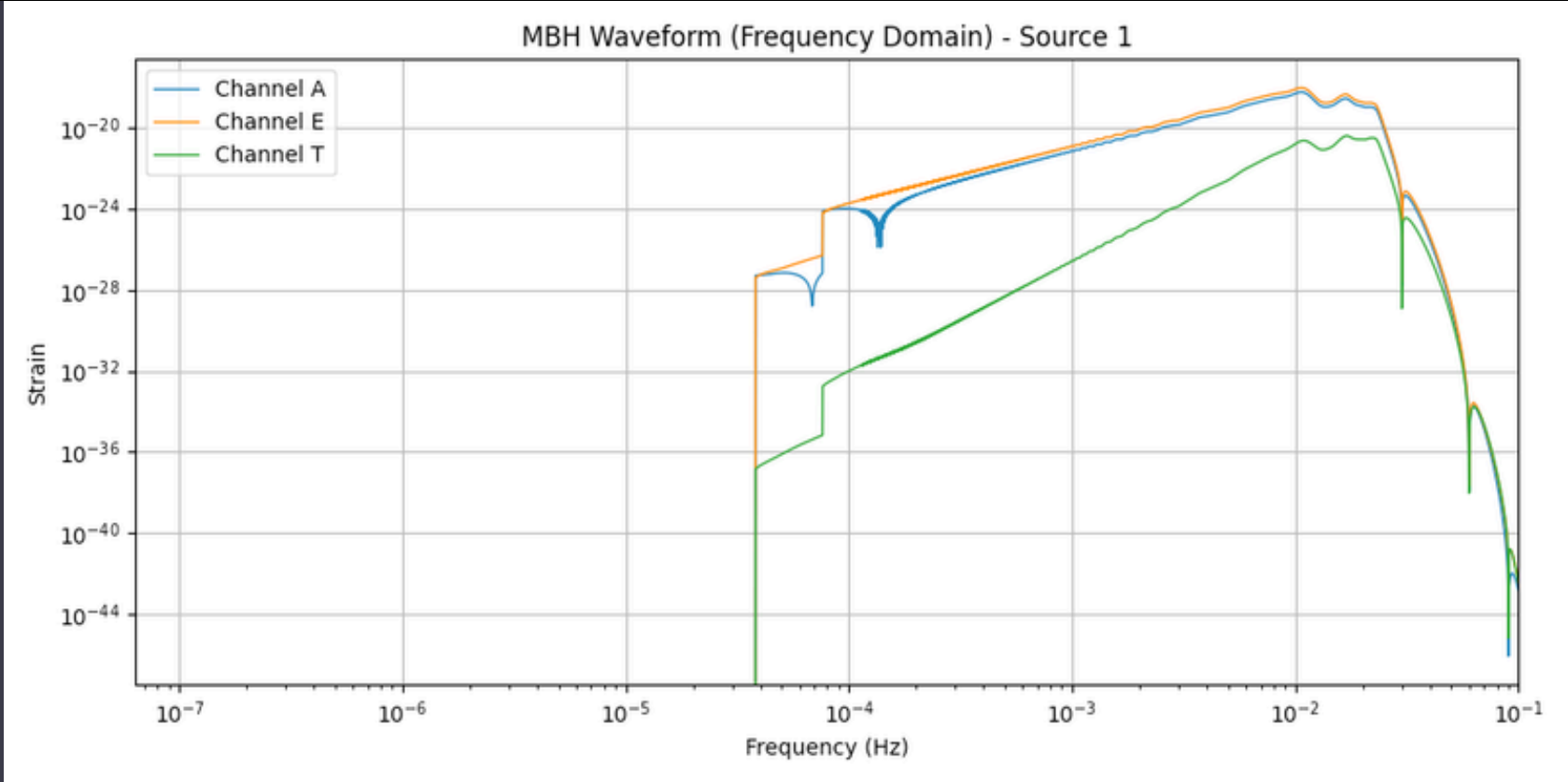
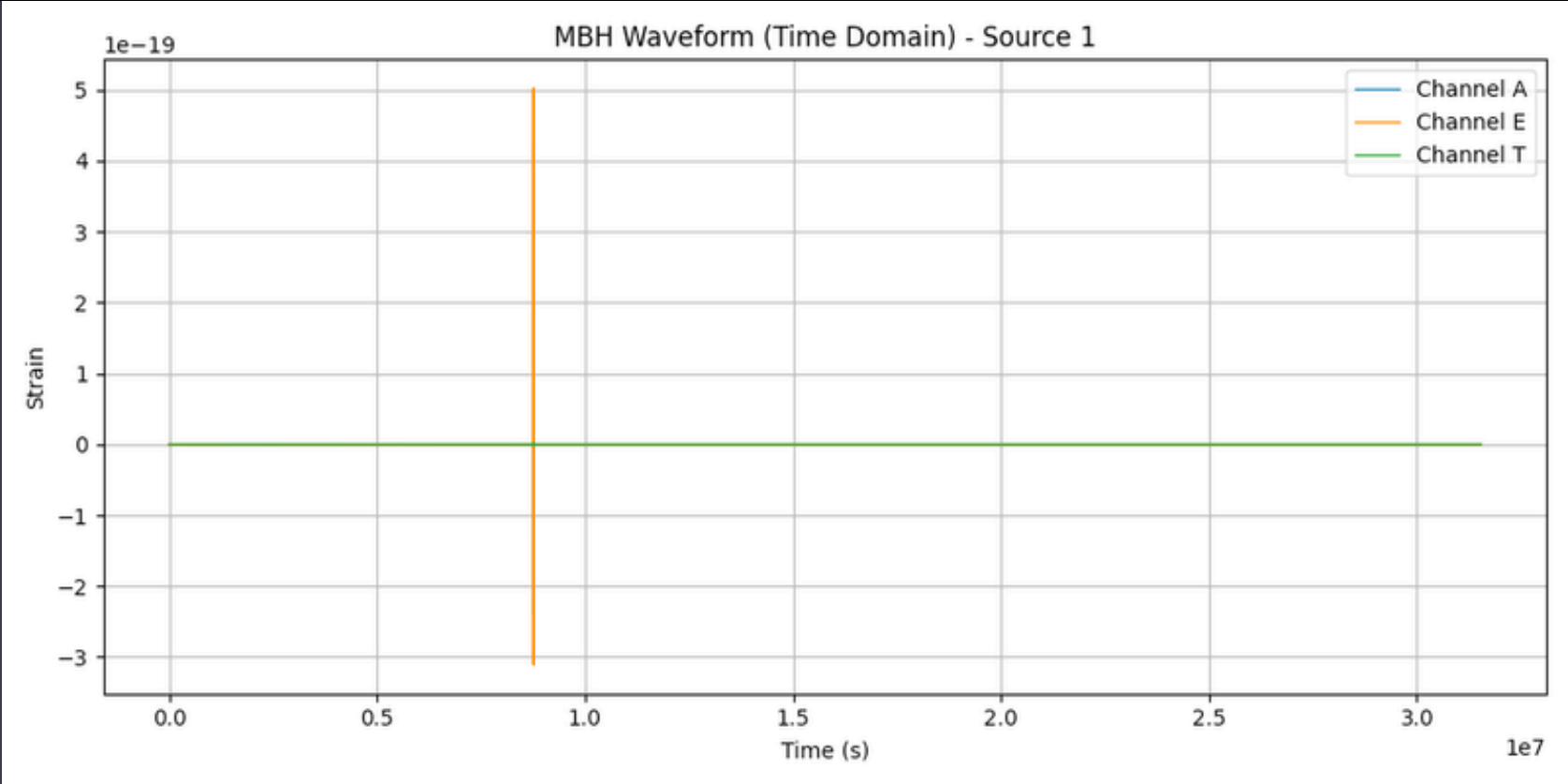
CONCLUSION

- **Limited overlap between sources**
- **Low inter-parametric, but high intra-parametric correlation**
- **Local fit → better for EMRI as less expensive**
 - **increase in bias, not significant**

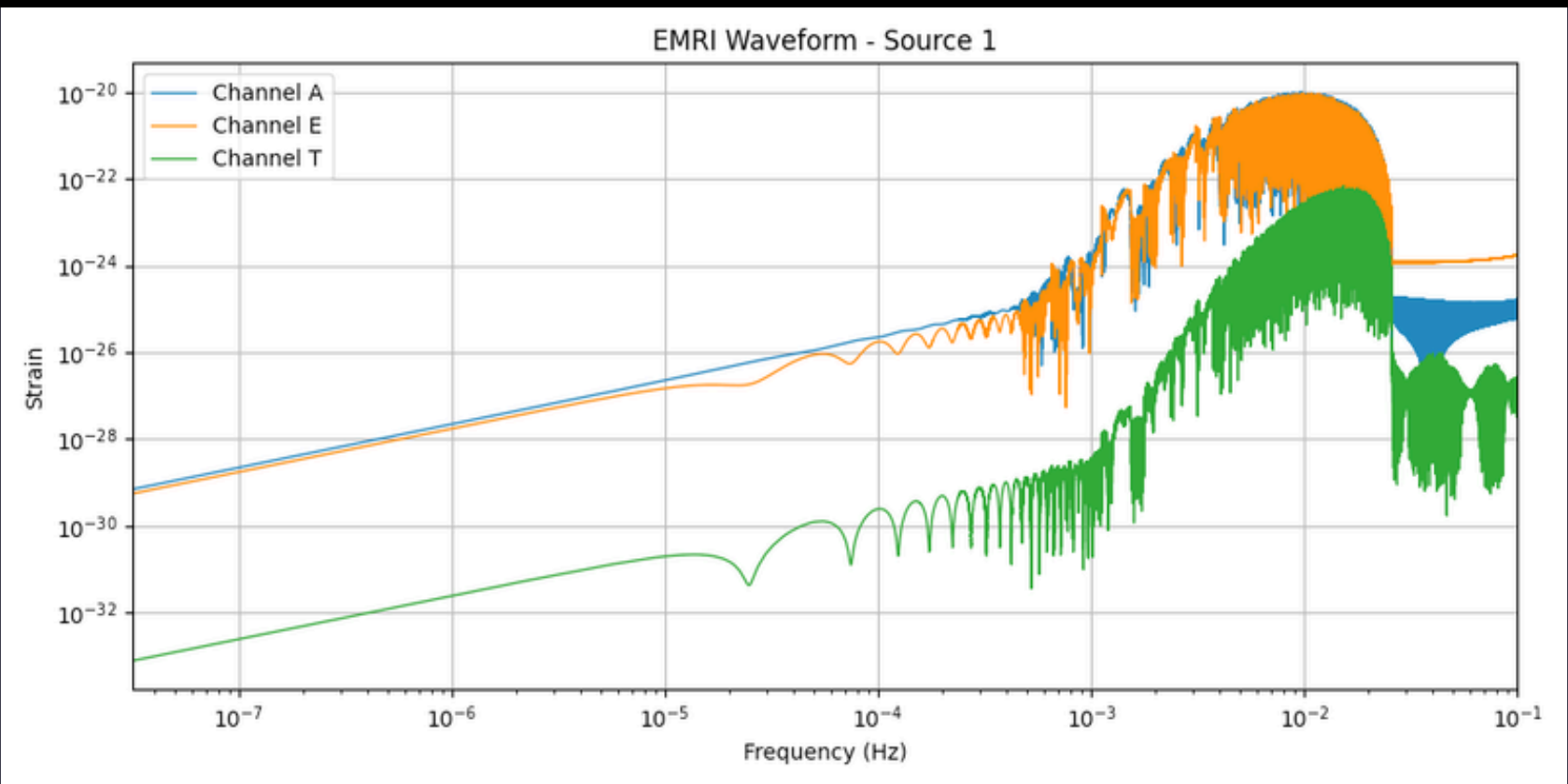
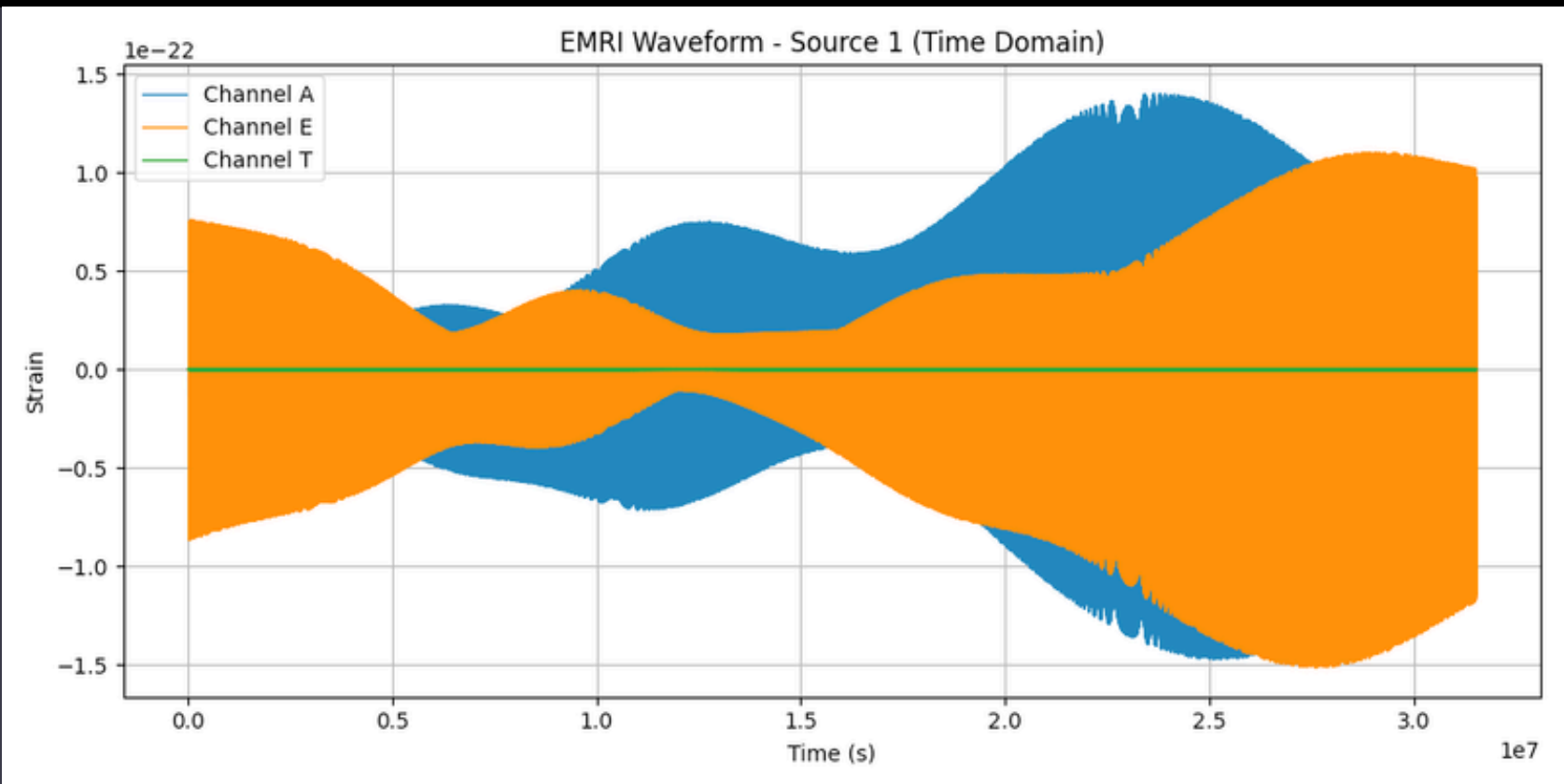
THANKYOU

QUESTIONS?

MBHB Waveform

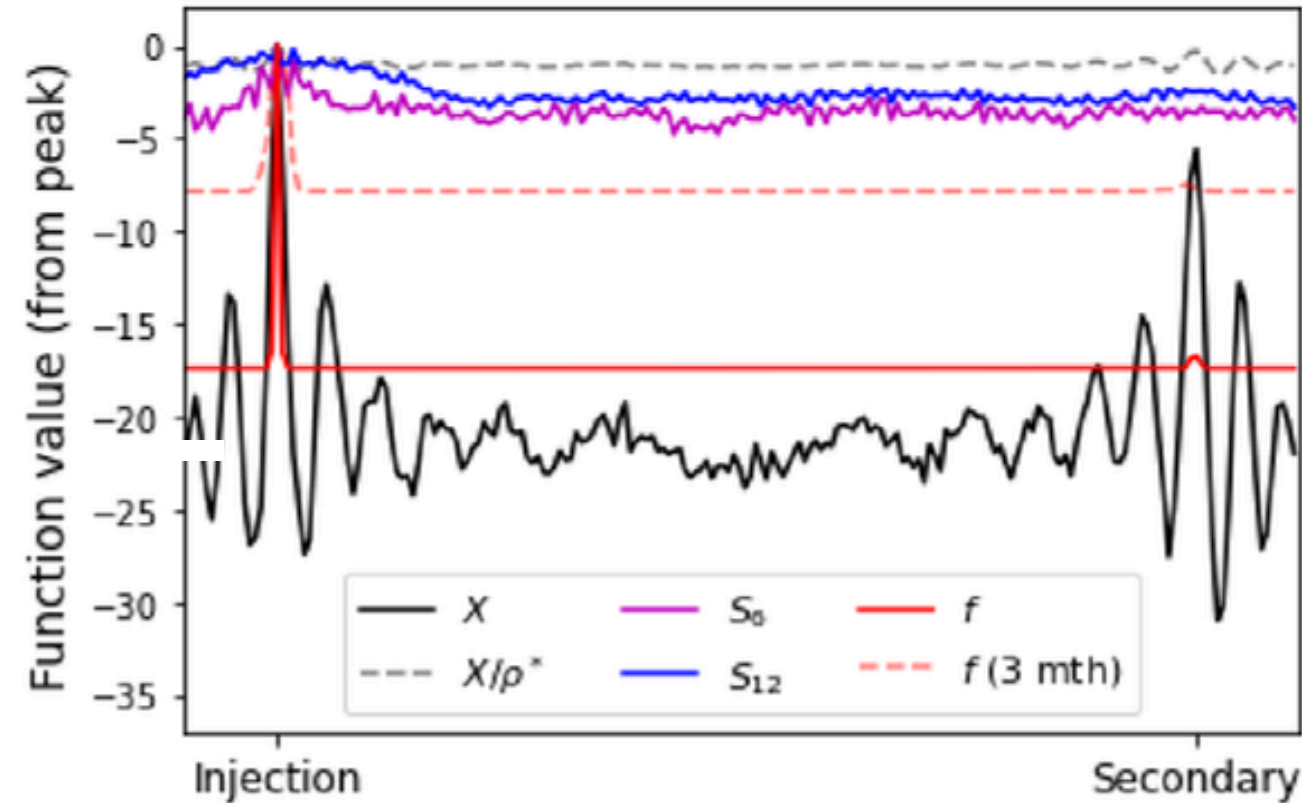
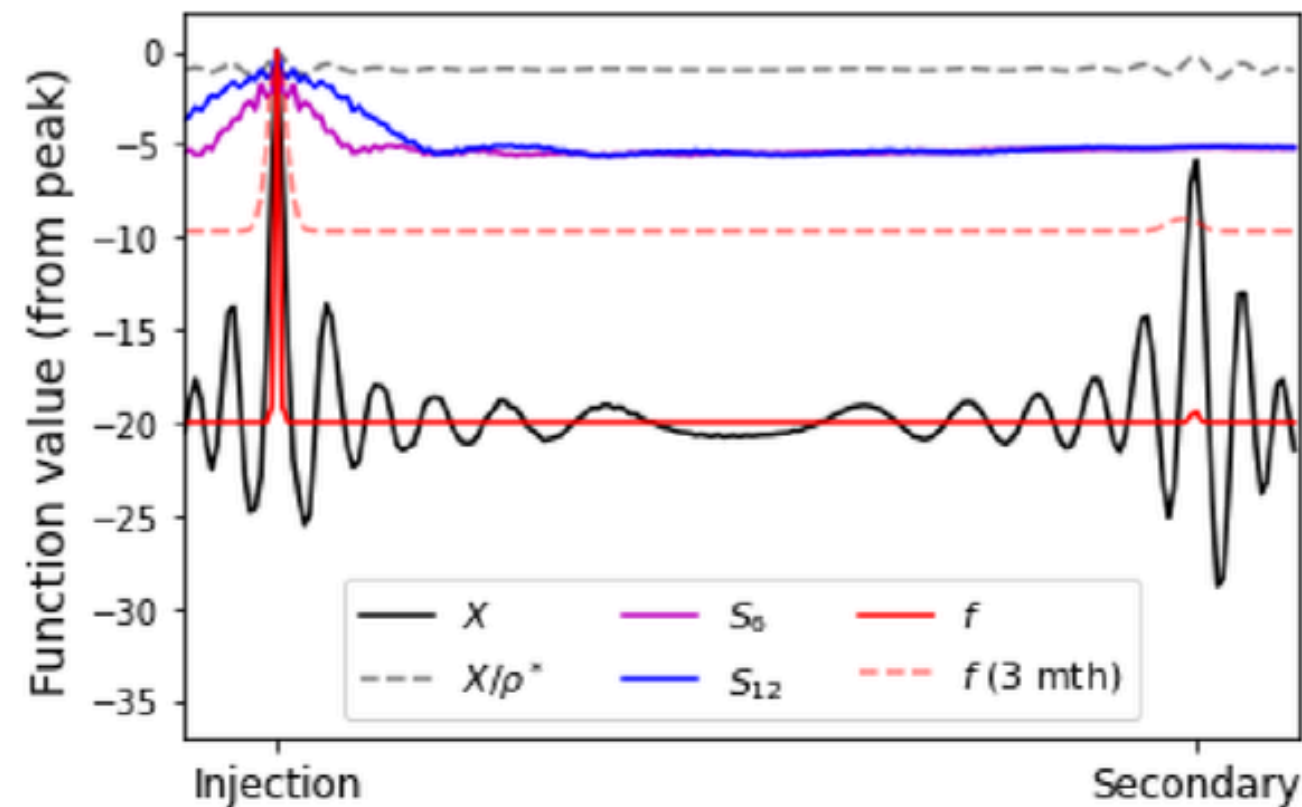


EMRI Waveform



PROBLEMS WITH EMRI ANALYSIS

1. Non-local secondaries
2. High Dimensionality of Parameter Space
3. Unknown Error in Waveform Modelling
4. Long Time Required For Waveform Evaluation



MOTIVATION

- **Orthogonality of GWs Sources**
- **Quantifying Bias in EMRI and MBHB Parameters Using Local fit and Global fit**
- **Intra-correlation Among the Parameters of Same Source**
- **Inter-correlation of Parameters Among Different Sources**

