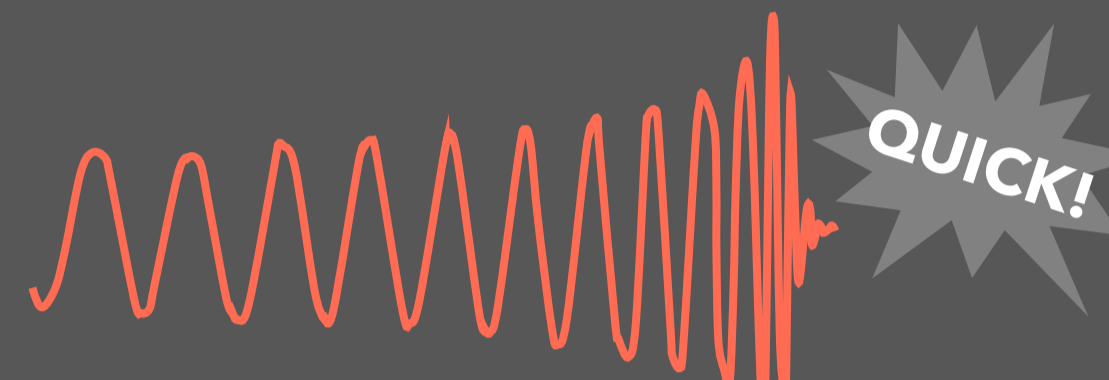# SEARCHING FOR ECCENTRICITY

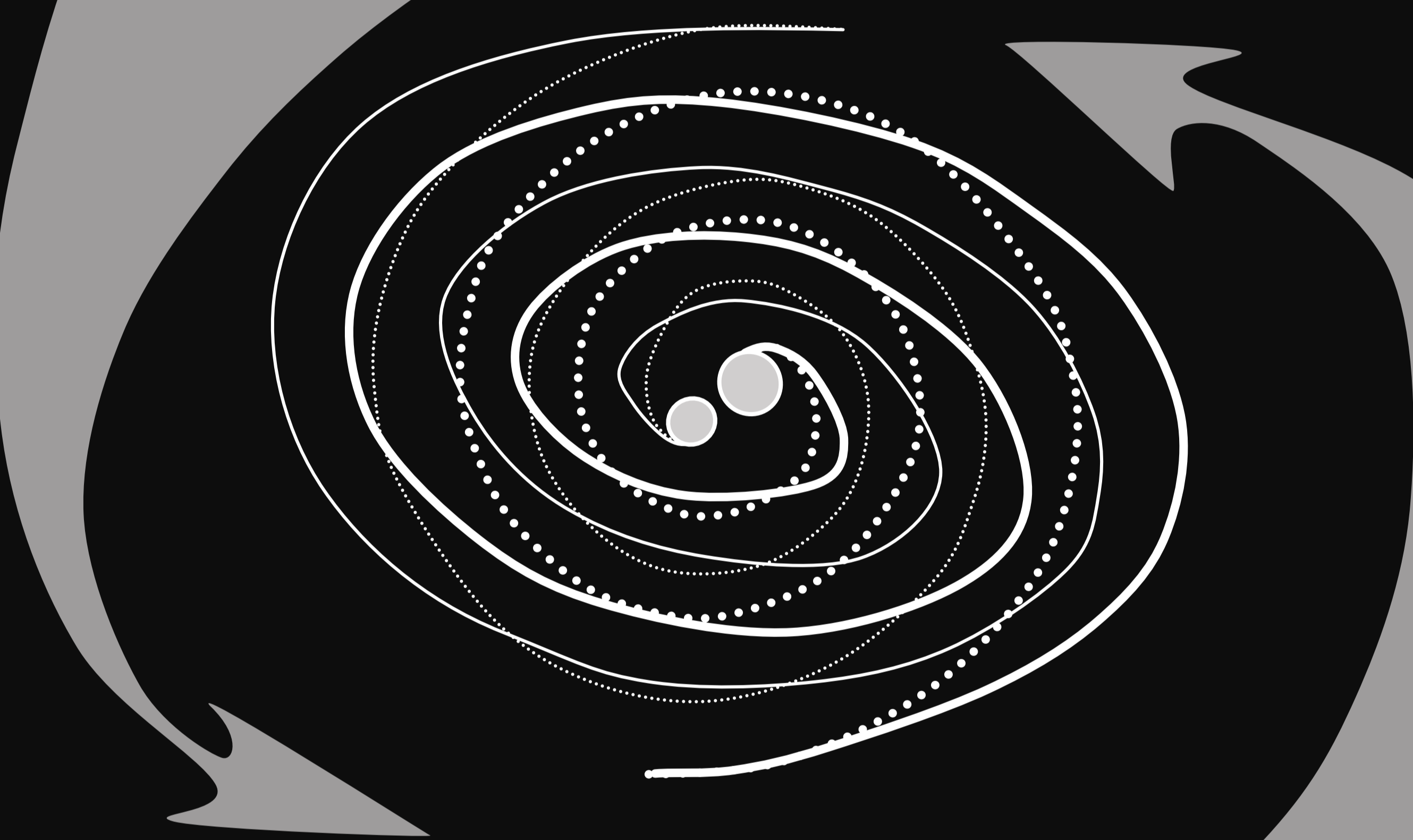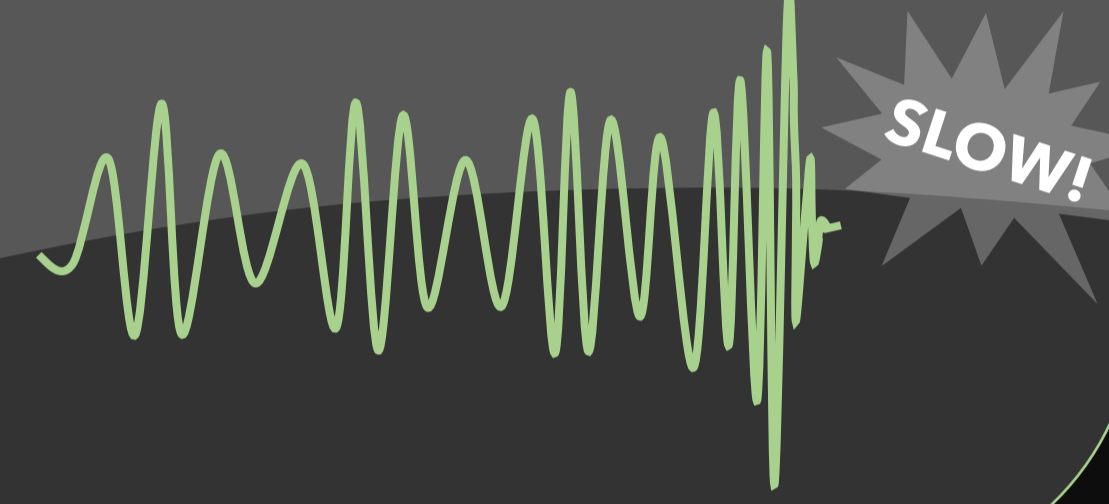ISOBEL ROMERO-SHAW
PAUL LASKY
ERIC THRANE

## BACKGROUND

- ★ **Binary black holes** are thought to form primarily via two channels: **isolated** and **dynamical**.

- ★ The formation channel of a binary can be encoded in its **masses**, **spins**, and **eccentricity**. These properties are imprinted on its gravitational wave signal.

- ★ Binary properties are measured by comparing signals to thousands of templates. **Eccentricity is hard to measure**, because eccentric templates are slow to generate.

- ★ We use **likelihood reweighting** to measure the binary eccentricity of ten events from the first Gravitational Wave Transient Catalogue of LIGO and Virgo.
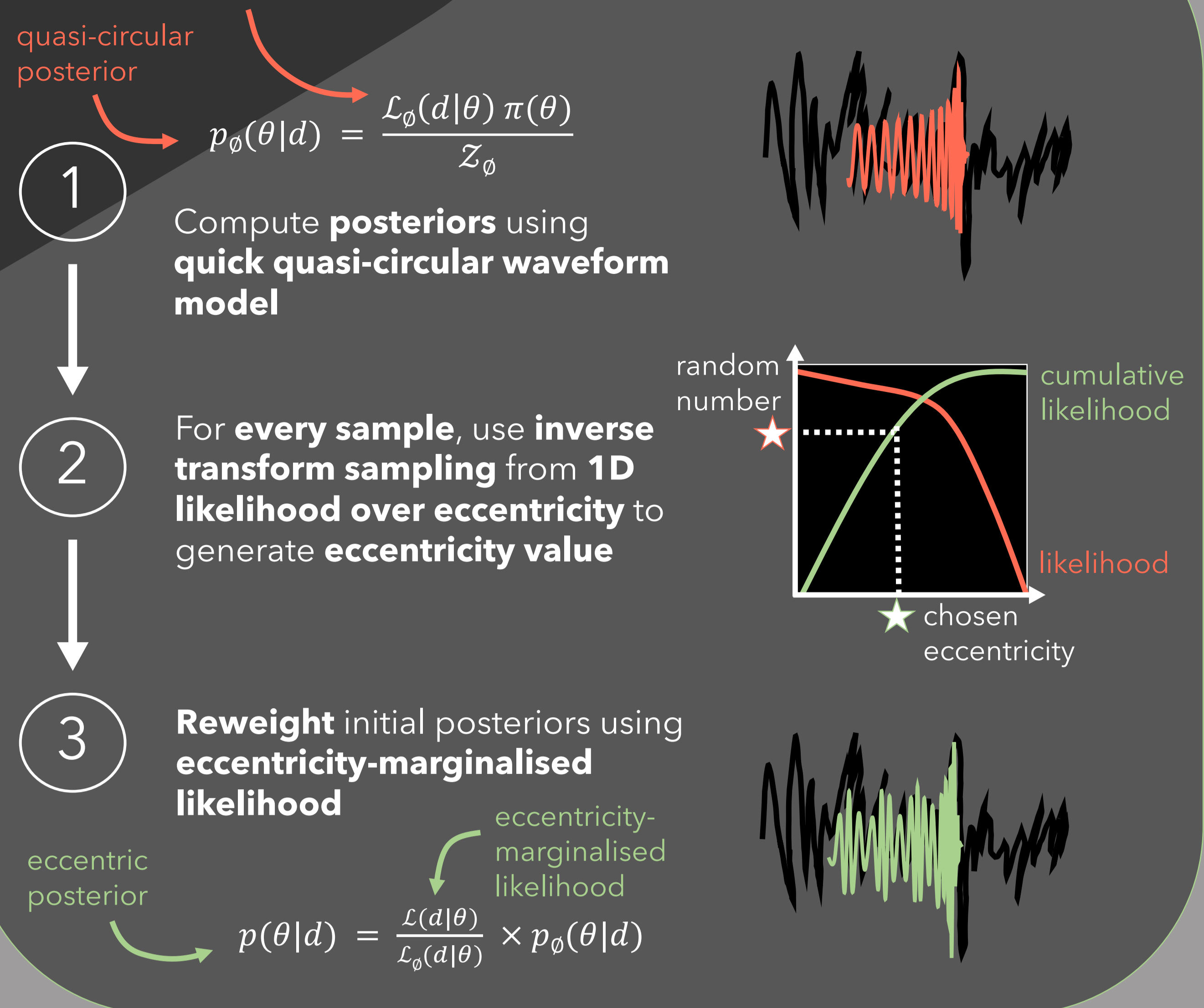
QUASI-CIRCULAR

QUICK!

ECCENTRIC

SLOW!

## METHOD

quasi-circular posterior

quasi-circular likelihood

① $p_\emptyset(\theta|d) = \dfrac{\mathcal{L}_\emptyset(d|\theta)\,\pi(\theta)}{\mathcal{Z}_\emptyset}$

Compute **posteriors** using **quick quasi-circular waveform model**

② For **every sample**, use **inverse transform sampling** from **1D likelihood over eccentricity** to generate **eccentricity value**

random number

cumulative likelihood

likelihood

chosen eccentricity

③ **Reweight** initial posteriors using **eccentricity-marginalised likelihood**

eccentric posterior

eccentricity-marginalised likelihood

$p(\theta|d) = \dfrac{\mathcal{L}(d|\theta)}{\mathcal{L}_\emptyset(d|\theta)} \times p_\emptyset(\theta|d)$

## FORMATION CHANNELS

ISOLATED          DYNAMICAL
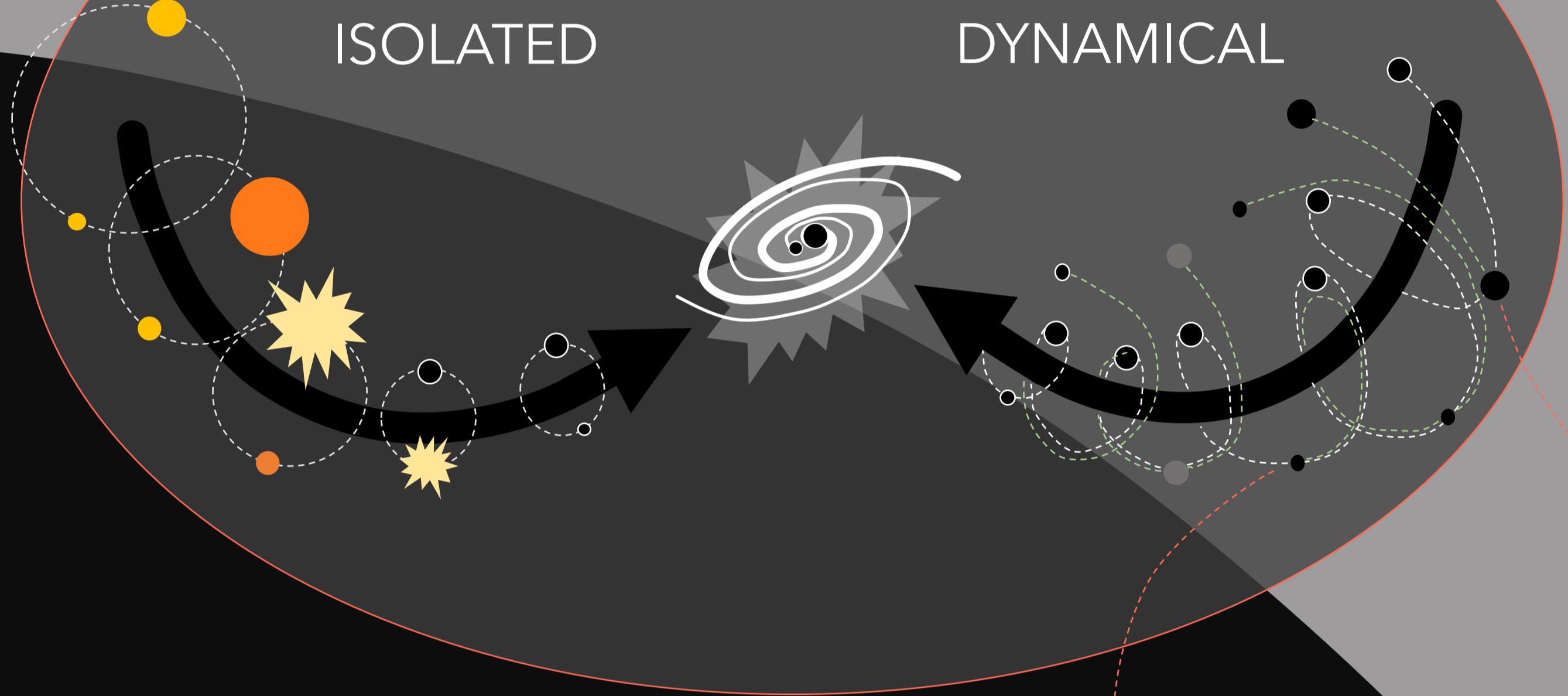
### ISOLATED MERGERS

**FORMATION**
Stellar binaries evolve into black hole binaries.

**MERGE MECHANISM**
Binaries tighten & merge due to the emission of gravitational waves.

**BINARY PROPERTIES**
**Masses** below $\sim 50 M_\odot$
**Spins** aligned with binary angular momentum vector
**Eccentricity** negligible at 10Hz

### DYNAMICAL MERGERS

**FORMATION**
Black holes form bound pairs during interactions in star clusters.
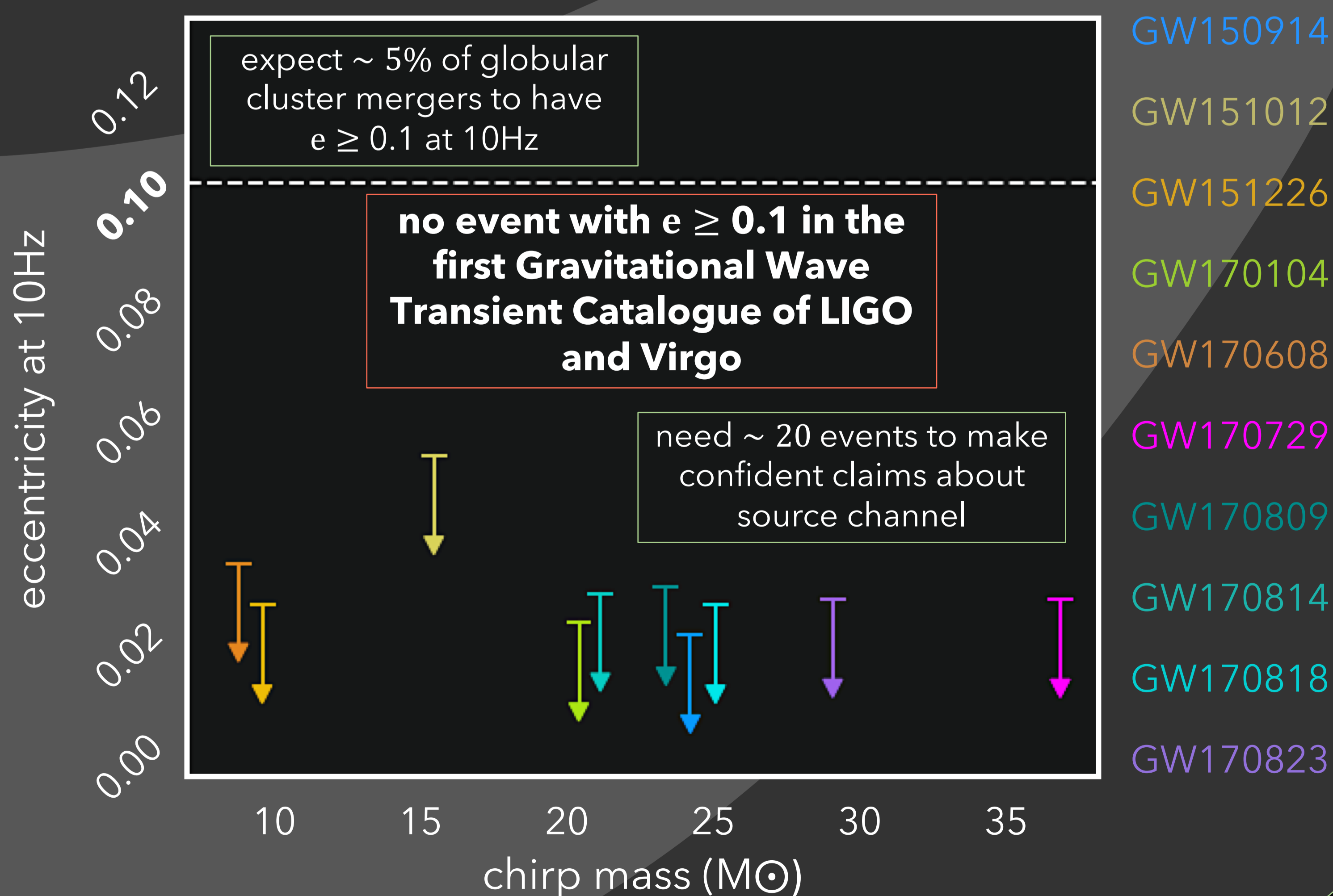
**MERGE MECHANISM**
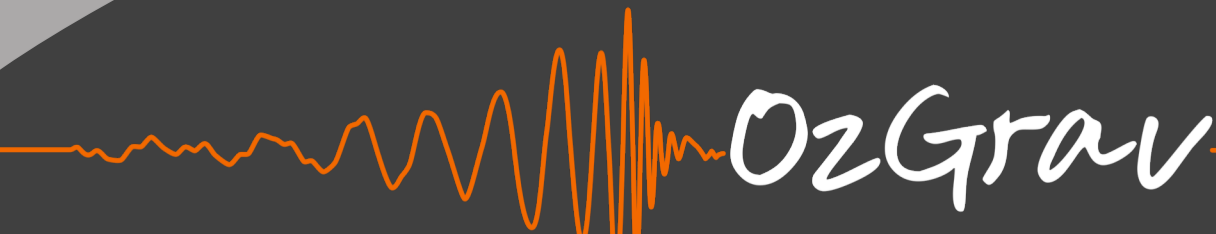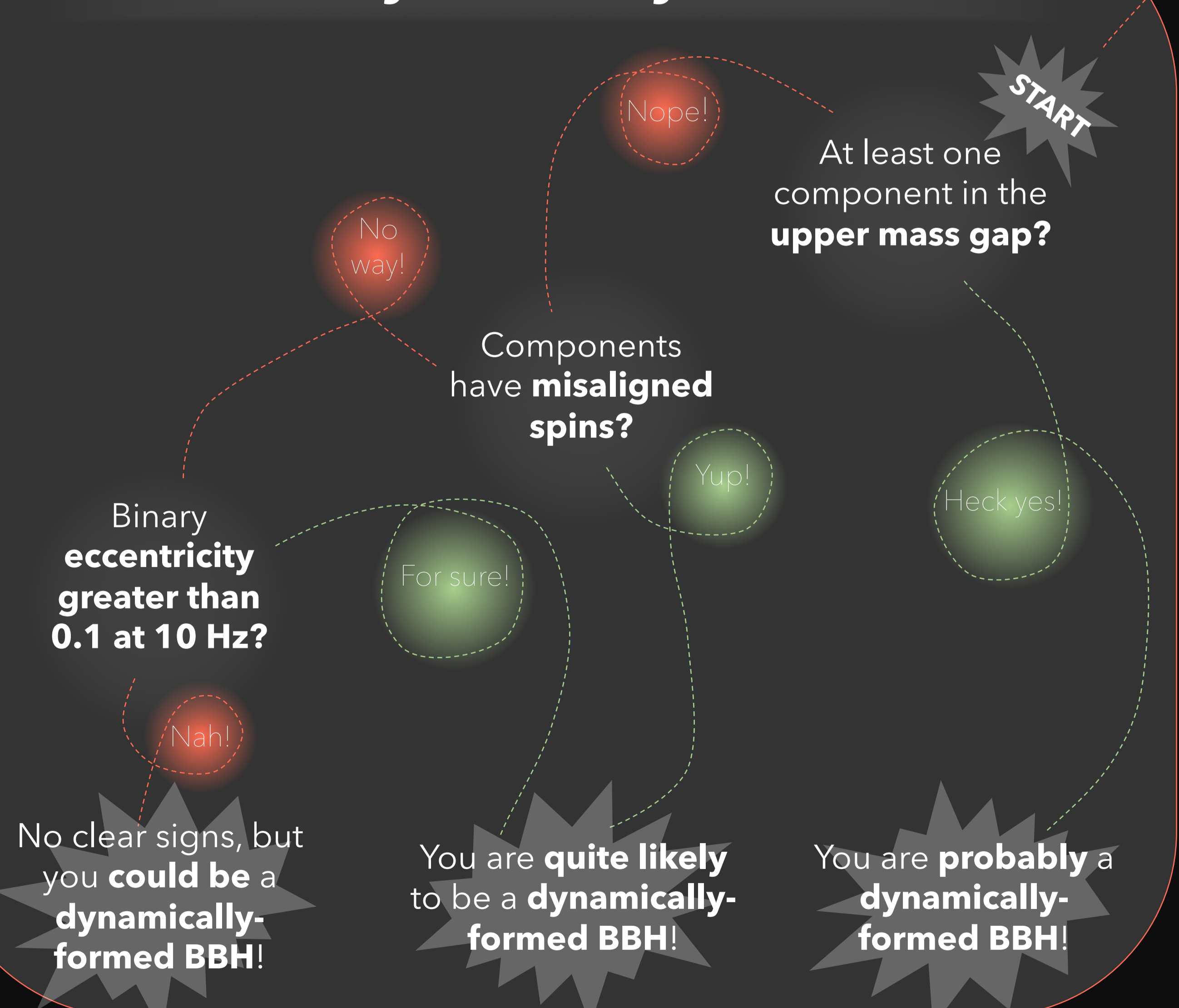Binaries driven to merge through dynamical interactions & gravitational wave emission.

**BINARY PROPERTIES**
**Masses** can be $> 50 M_\odot$
**Spins** isotropically distributed & misaligned
**Eccentricity** can be $\geq 0.1$ at 10Hz

## RESULTS

expect ~ 5% of globular cluster mergers to have e ≥ 0.1 at 10Hz

**no event with e ≥ 0.1 in the first Gravitational Wave Transient Catalogue of LIGO and Virgo**

need ~ 20 events to make confident claims about source channel

eccentricity at 10Hz

chirp mass (M⊙)

GW150914
GW151012
GW151226
GW170104
GW170608
GW170729
GW170809
GW170814
GW170818
GW170823

## Are **YOU** a dynamically-formed BBH?

START

At least one component in the **upper mass gap**?

Nope!

No way!

Components have **misaligned spins**?

Yup!

Heck yes!

For sure!

Binary **eccentricity greater than 0.1 at 10 Hz**?

Nah!

No clear signs, but you **could be** a dynamically-formed BBH!

You are **quite likely** to be a dynamically-formed BBH!

You are **probably** a dynamically-formed BBH!

LIGO          OzGrav          MONASH University

**REFERENCES by e-print ID:**
**This research:** 1909.05466
**Isolated evolution:** 1209.4302 ★ 1603.02291 ★ 1610.04417 ★ 1802.00441 ★ 1807.11489
**Dynamical formation:** 1409.0866 ★ 1711.09989 ★ 1712.04937 ★ 1811.04926 ★ 1906.10260
**Likelihood reweighting:** 1905.05477
**Determining formation modes:** 1503.04307 ★ 1704.07379 ★ 1709.08584 ★ 1712.04937 ★ 1805.06442
**Eccentric globular cluster mergers:** 1308.2964 ★ 1711.07452 ★ 1810.00901 ★ 1903.09659
**Gravitational Wave Transient Catalogue 1:** 1811.12907
**Waveform models used (quasi-circular, eccentric):** 1508.07253 ★ 1708.00166

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