Title: NINJA-2

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Abstract: TBA

NINJA-2

The revenge

Mike Boyle
With the NINJA-2 collaboration*

Theory meets data analysis
June 24, 2010

* 106 “members” of NINJA-2

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Outline

- The case for NINJA-2
  - NINJA-type projects in general
  - Why NINJA-2?
- Numerical relativity
  - Requirements
  - Contributions
- Data Analysis
  - The data set
  - Analyses
- The road ahead
  - Validate PN and NR input
  - Inject into real LIGO/Virgo data and analyze

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Section 1

The case for NINJA-2

The Experiment

Theory:

General Relativity

- Compact objects
- Interaction
- Emission and propagation of GWs

Test:

Gravitational-wave detectors

- Negative control
- Positive control

The Experiment

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- Negative control
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The case for NINJA-N

Science:

- Powerful positive control
- Allows testing methods objectively
- Allows testing non-LVC methods

Practicality/sociology:

- Get various pipelines working together, and automated
- Gets NR people involved in DA
- Gets DA people involved in NR

The case for NINJA-N

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- Horizontal structure $\Rightarrow$ everyone's input had weight
- Limited scope $\Rightarrow$ the project got done
- Each side learned a lot about the other side

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- Limited to 2—or maybe 5—waveforms per group (23 total)
- Mostly equal-mass systems (3 of 23 were unequal)
- Few interesting spins
- Gaussian colored noise
- Short waveforms; no hybrids

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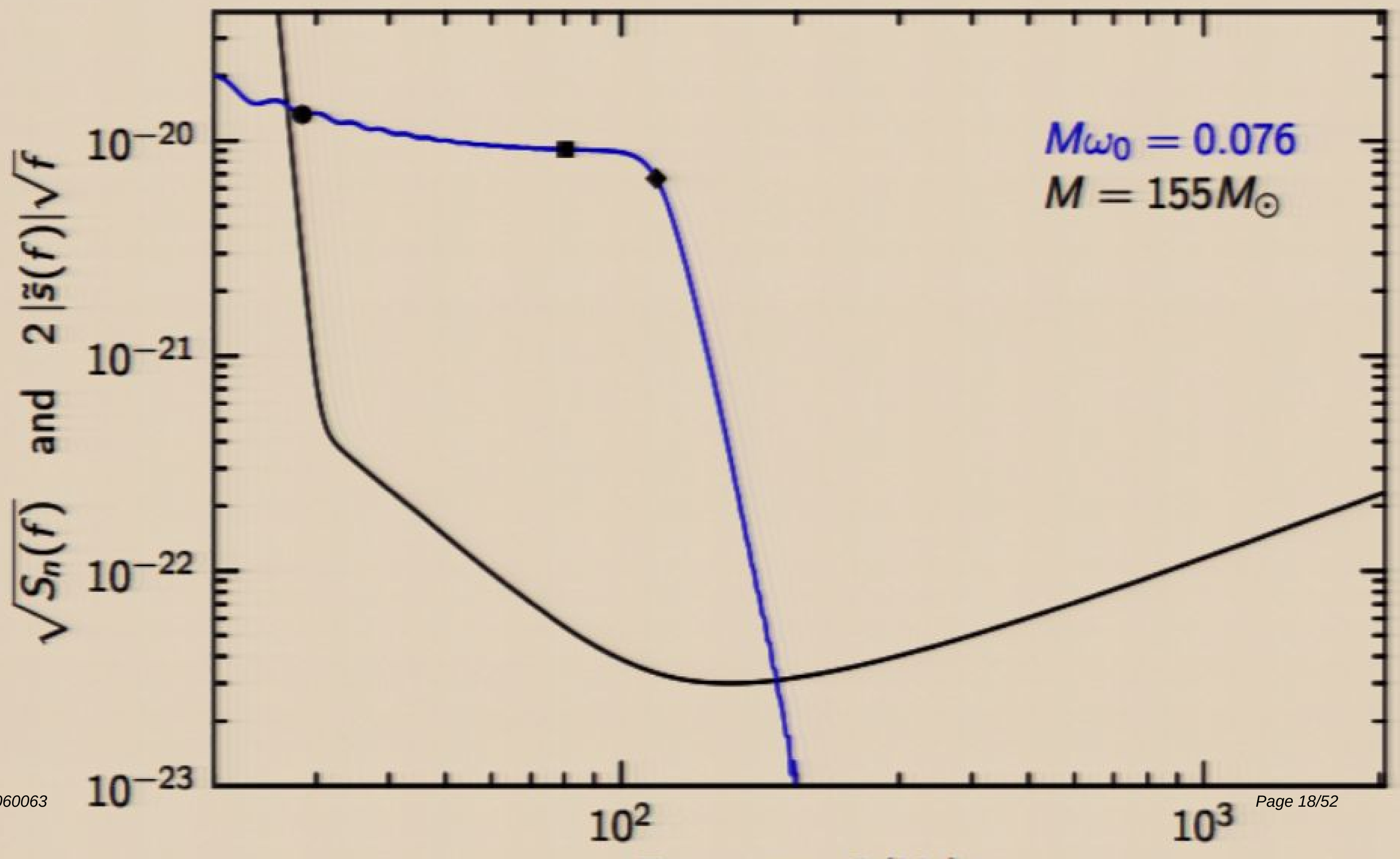

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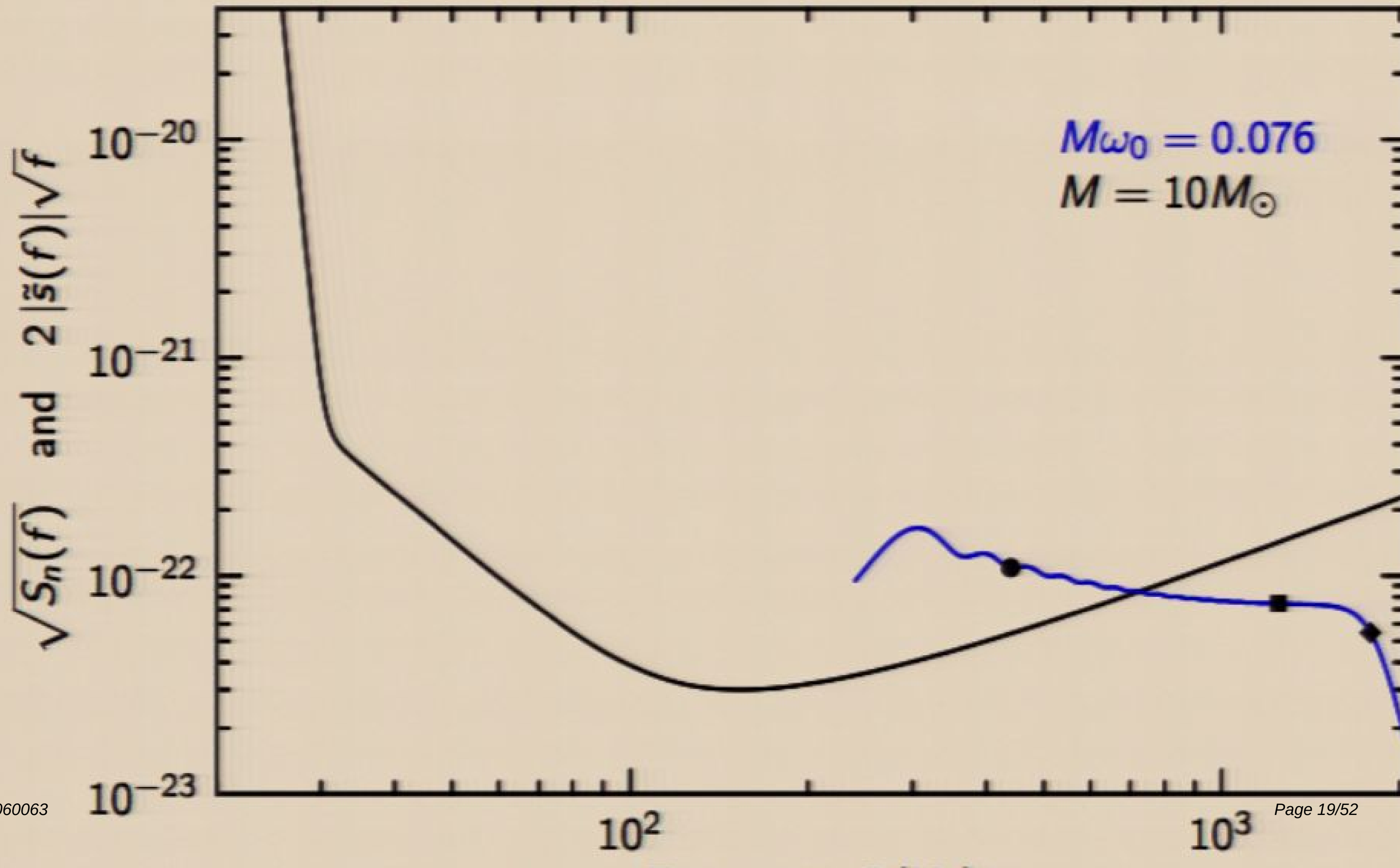

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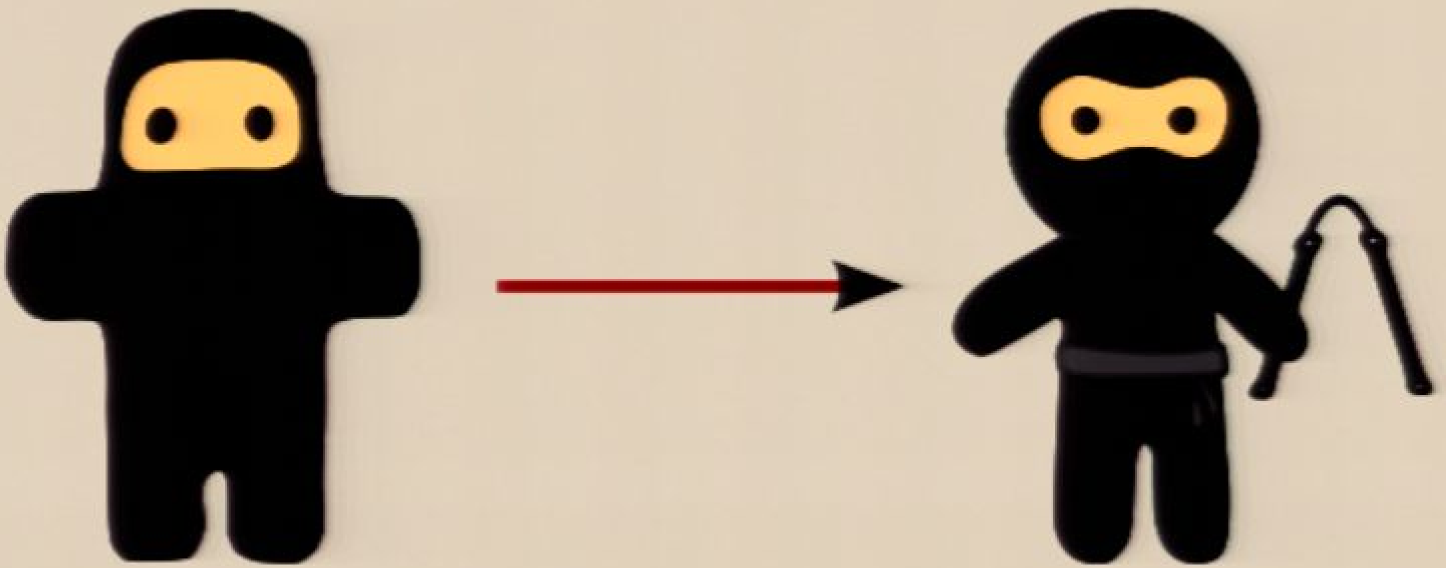

How is NINJA-2 better?

- Higher-quality data
- Basic accuracy requirements
- More interesting physics
- Real LIGO/Virgo data as noise?
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Section 2

Numerical relativity

Requirements

- At least 5 orbits
- Accurate to $\leq 5\%$ in amplitude
- Accurate to ≤ 0.5 radians
- Stitch to PN at $M\omega \leq 0.075$
- Full hybrid should extend to 20Hz at $10 M_\odot$ ($M\omega_0 = 0.006$)

Contributed data

- Over 50 waveforms
- About half are equal-mass; some up to 4:1
- Spins up to 0.9
- Mostly quasi-circular data (no eccentricity removal)
- So far, about half are hybrids

Data format

- Amplitude and phase
- Keep only points needed for accurate linear interpolation
- Storage reductions typically 95%

[redacted]

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What about precession?

Arguments for:

- There will be precessing binaries in LIGO/Virgo data
- The effects of precession on data analysis are not well known

Arguments against:

- Are those *hybrids* really accurate enough?
- We like to keep NINJA simple and conservative

Section 3

Data analysis

The data set: Target

- Real LIGO/Virgo data (S5/VSR1) used as “noise”
- As many waveforms as can comfortably fit in the set
- Injections using astrophysically realistic distributions
- Two sets
  - Training ($\sim$ 1 month)
  - Challenge ($\sim$ 2 months)

The data set: Status

- Gaussian noise colored by detector sensitivities
- Injections of non-hybrid waveforms
- Three sets so far:
  1. 1-week set to work out the bugs
  2. Another 1-week set to work out the bugs
  3. An 8-week set with the bugs worked out

Detection: Low-mass CBC

Template bank:

- Nonspinning TaylorF2 templates terminated at ISCO
- $M_{\mathrm{TOT}} \in [2, 35]\, M_\odot$
- $M_1, M_2 \in [1, 34]\, M_\odot$

Steps in detection:

- Threshold SNR at 5.5
- Look for coincidence in at least two detectors
- Rank by "combined effective SNR"

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- ~ 3000 templates for H1 and L1; ~ 11500 for V1

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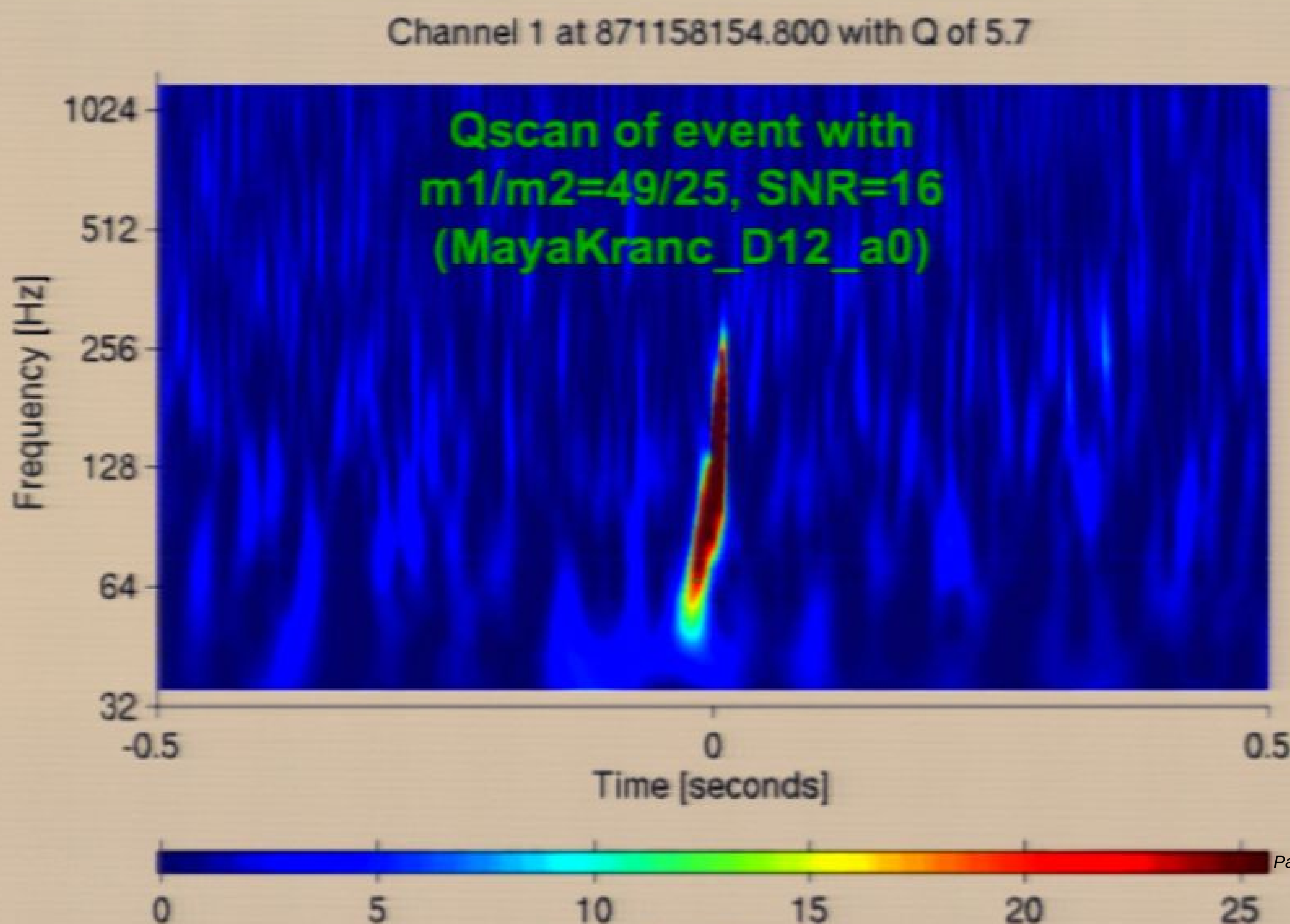

Detection: Burst search

The template bank

- Sine-Gaussian templates
- $M_{\mathrm{TOT}} \in [10, 350]\, M_{\odot}$

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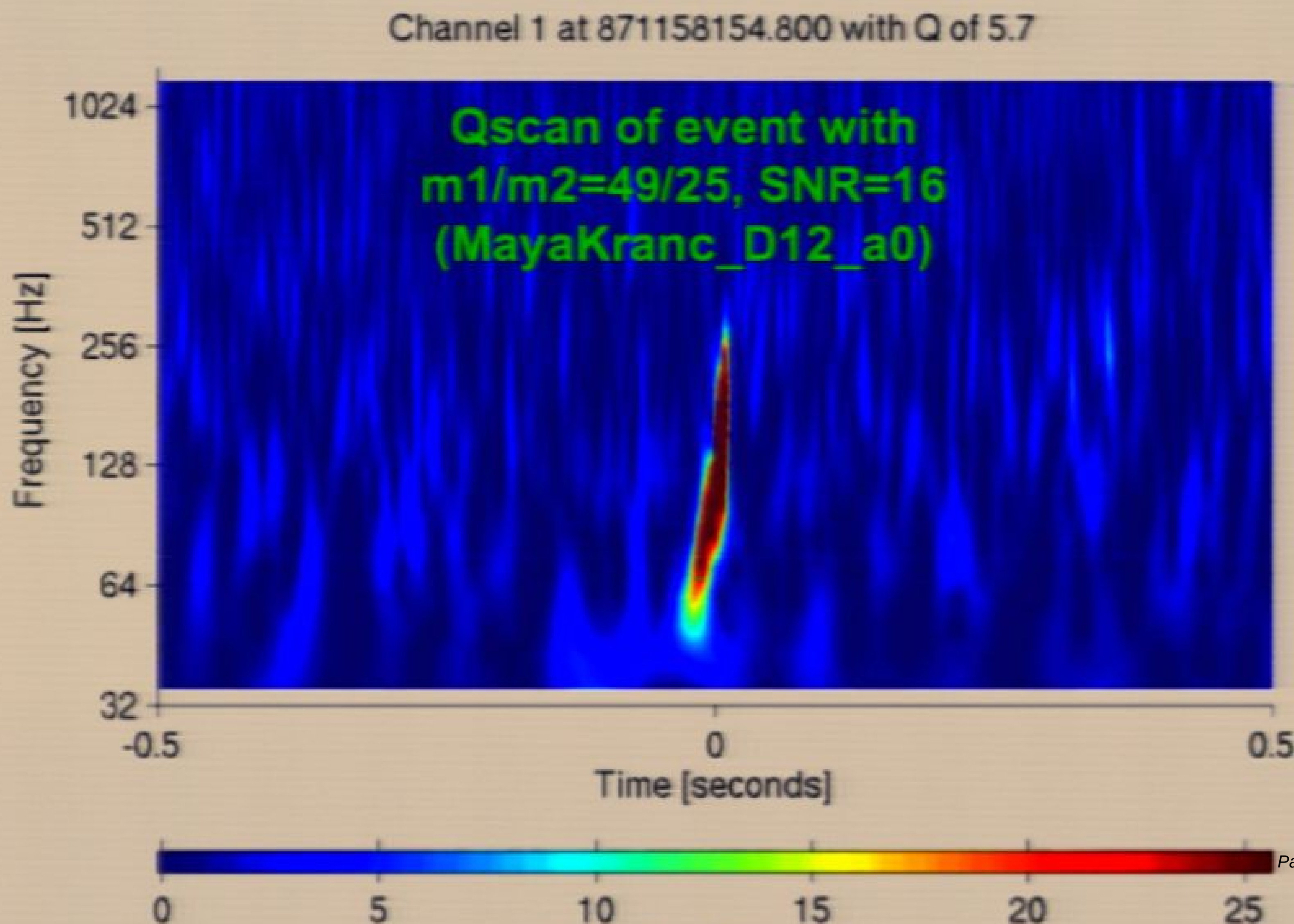

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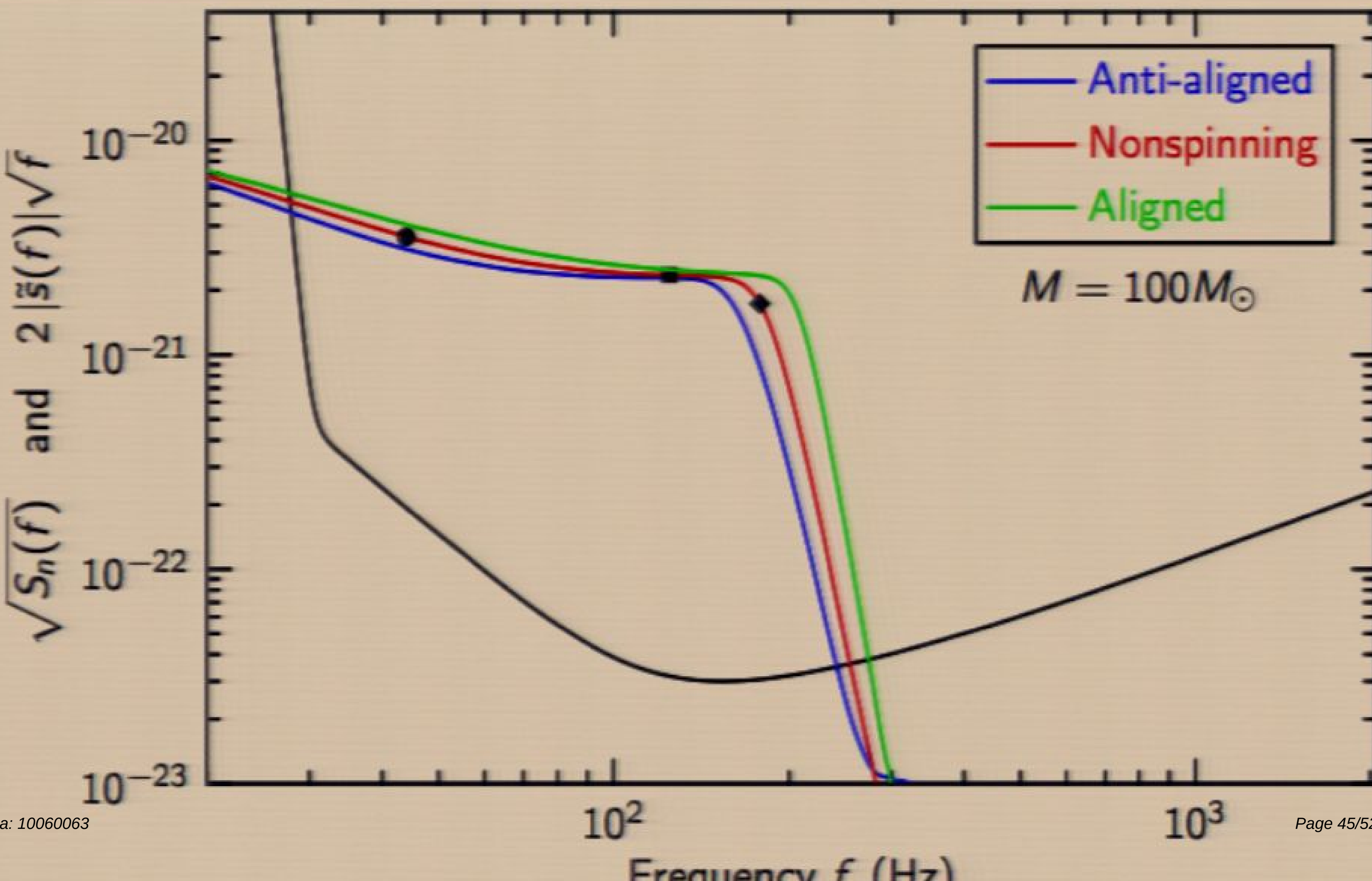
Possible bias in the burst search?



Parameter estimation

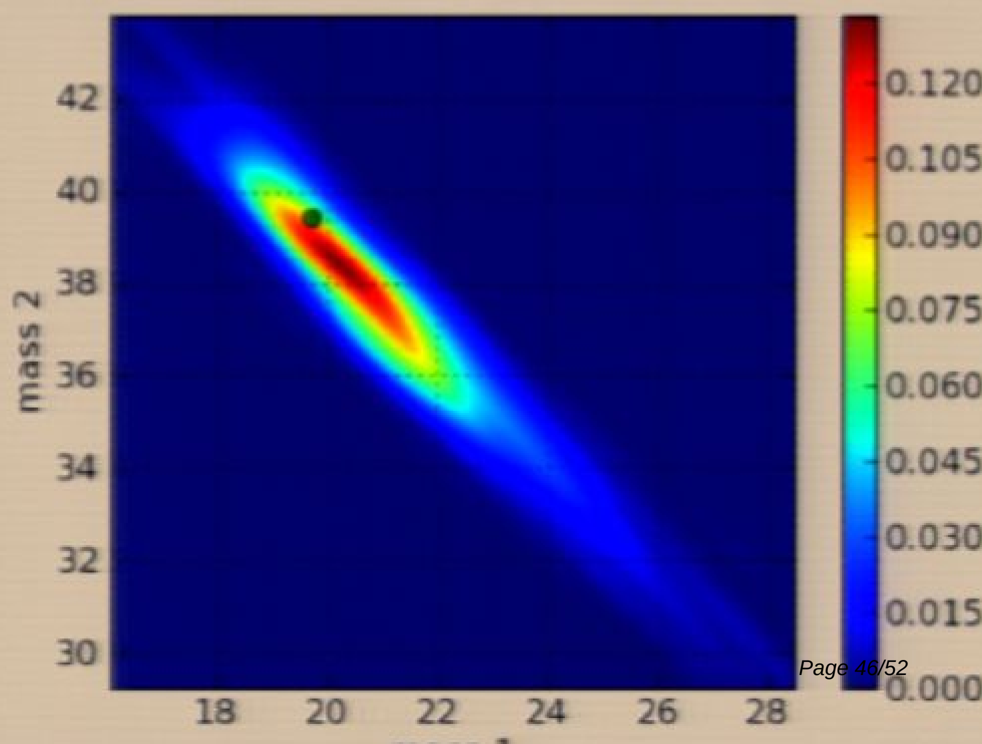
Motivation
Doing science will require accurate source characterization

Challenge
9- to 15-dimensional parameter space with degeneracies

Solution
Bayesian inference; stochastic sampling of high-likelihood regions

Techniques used in NINJA-2:

- MCMC
- Nested Sampling
- MultiNest



Section 4

The road ahead

Next steps for NR

1. Improve data quality (see Reisswig&Pollney arXiv:1006.1632)
2. Validate numerical waveforms
3. Validate post-Newtonian waveforms
4. Hybridize

Next steps for DA

1. Get MOU signed
2. Generate training and challenge data
3. Analyze with all our favorite pipelines

What's wrong with NINJA-2?

- Limited to non-precessing systems
- Mass-ratios $\leq$ 4:1
- Not enough waveforms?
- Not enough higher modes?
- Hybridization frequency too high?
- Why not NINJA-2_{LISA}?

Summary

- NINJA is a vital part of the GW-detection endeavor
- We've got a good start on the waveform catalog, but more work is needed
- Current data set is colored Gaussian noise
- New data set expected in ~two months
- NINJA-2 is off to a strong start

Next NR representative:

Enrique Pazos

Congratulations!