Status of the NINJA-2 Project

Larne Pekowsky for the NINJA-2 Collaboration

The Numerical INjection Analysis (NINJA) project is a collaboration between numerical relativists and gravitational wave astronomers. The goal is to test search pipelines and parameter estimation against the best available waveforms for binary black hole mergers.

In NINJA 1[1] NR waveforms were injected into simulated Gaussian noise shaped to match the initial LIGO and Virgo noise curves. Data analysis groups then ran detection and parameter estimation codes and compared the results against the injected parameters. NINJA 1 had an open submission policy. NINJA 2 imposes tighter requirements so that we can draw more quantitative conclusions:

- > 5 orbits of NR
- Hybrid NR/Post-Newtonian waveforms long enough to be injectable down to 8 M_O, turning on at 35 Hz
- Non-spinning, aligned or anti-aligned spins (NINJA3 will address precession)
- Higher-order modes encouraged!

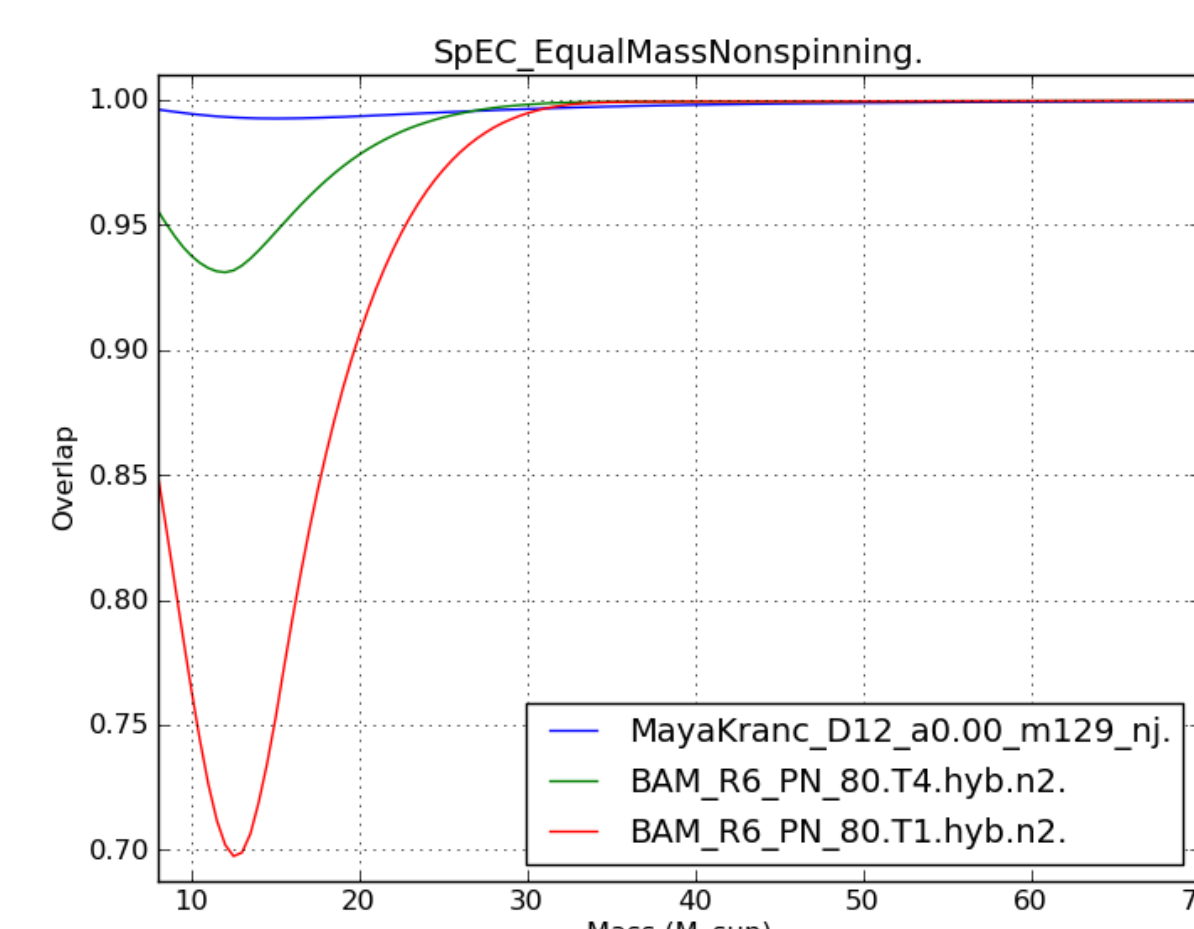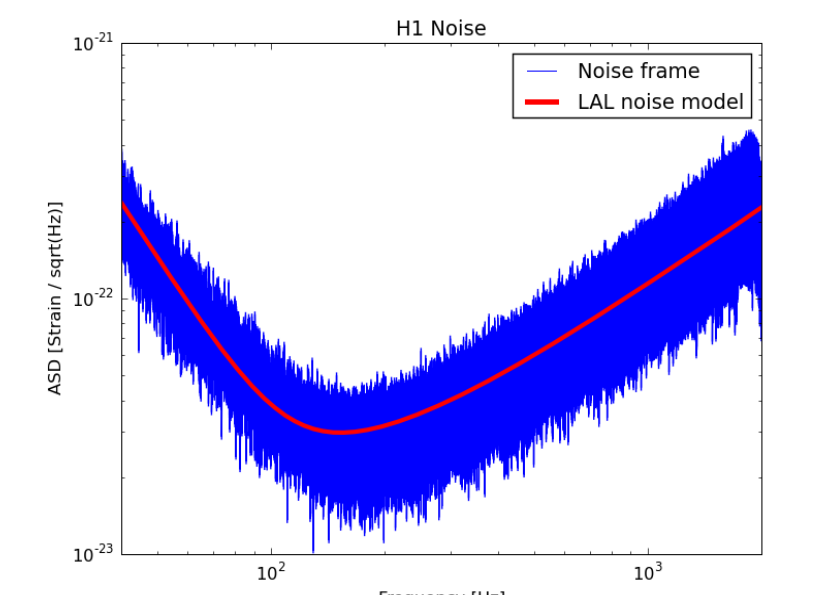[1] Benjamin Aylott *et al* 2009 *Class. Quantum Grav.* 26 165008 arXiv:0901.4399v2

Contributing numerical relativity groups

BAM
Bernd Bruegmann[1], Doreen Mueller[1], Mark Hannam[2], Sascha Husa[3]

Florida Atlantic University
Pedro Marronetti[4], Petr Tsatsin[4], Wolfgang Tichy[4]

University of Illinois at Urbana-Champaign
Zachariah Etienne[11], Yuk Tung Liu[11], Stuart Shapiro[11]

Llama
Philipp Moesta[3], Frank Ohme[3], Denis Pollney[7], Christian Reisswig[6], Lucia Santamaria[3]

Rochester Institute of Technology
Manuela Campanelli[8], Carlos O. Lousto[8], Bruno C. Mundim[8], Hiroyuki Nakano[8], Marcelo Ponce[8], Yosef Zlochower[8]

LEAN
Ulrich Sperhake[6]

Georgia Institute of Technology
James Healy[5], Pablo Laguna[5], Deirdre Shoemaker[5], Lionel London[5], Tanja Bode[5], Roland Haas[5]

SPeC
Nicholas Taylor[6], Bela Szilagyi[6], Mark Scheel[6], Larry Kidder[9], Harald Pfeiffer[10], Tony Chu[6], Mike Boyle[9]

[1]Friedrich-Schiller-Universität Jena, [2]Cardiff University, [3]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), [4]Florida Atlantic University, [5]Georgia Institute of Technology, [6]California Institute of Technology, [7]Universitat de les Illes Balears, [8]Rochester Institute of Technology, [9]Cornell University, [10]Canadian Institute for Theoretical Astrophysics, [11]University of Illinois at Urbana-Champaign

Detector noise and data analysis: The LSC and Virgo Collaborations
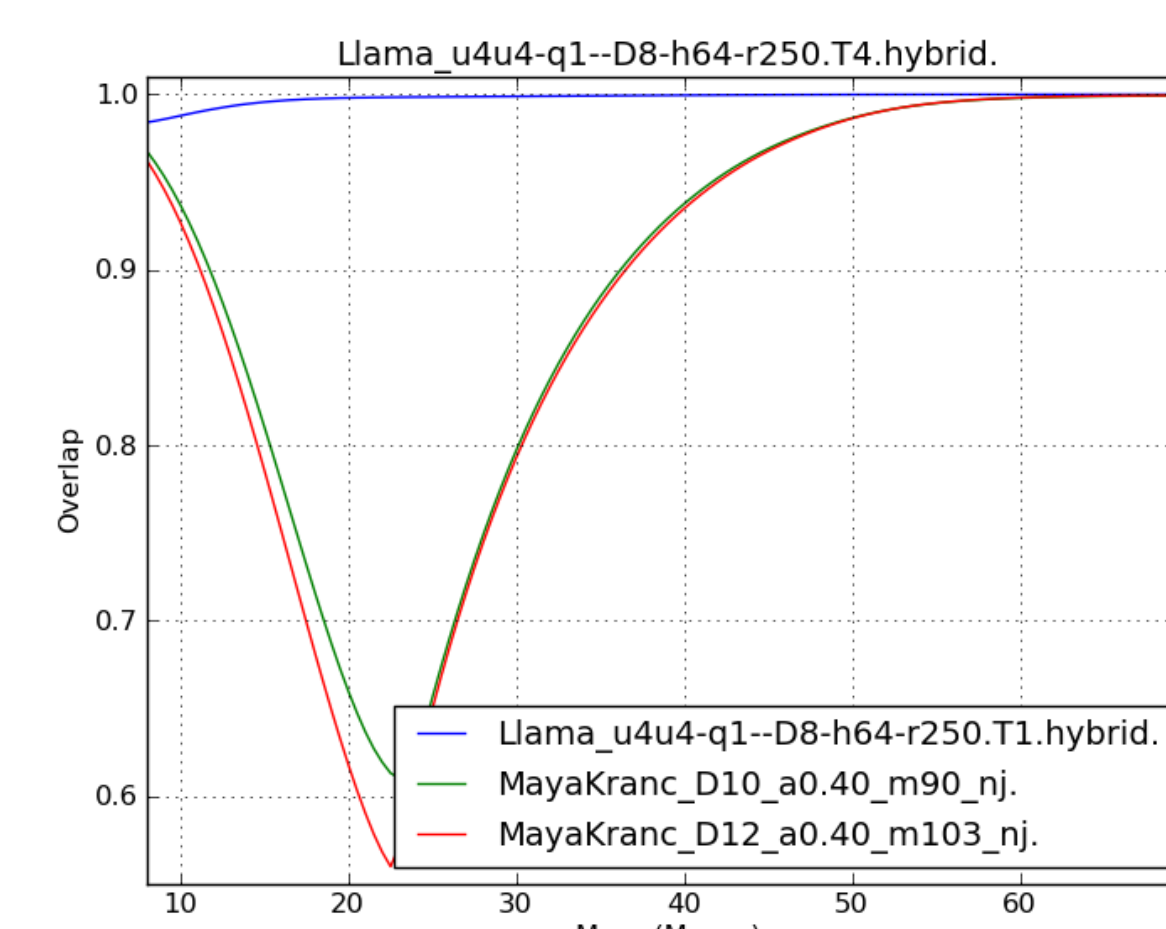
Waveform comparisons

Sets of waveforms with identical parameters have been compared by calculating their overlap using the initial LIGO noise curve. One waveform (title) is selected and the overlap with the others in the same family (Y axis) is calculated as a function of mass (X axis). Initial studies have shown that additional work needs to be done on hybridization.

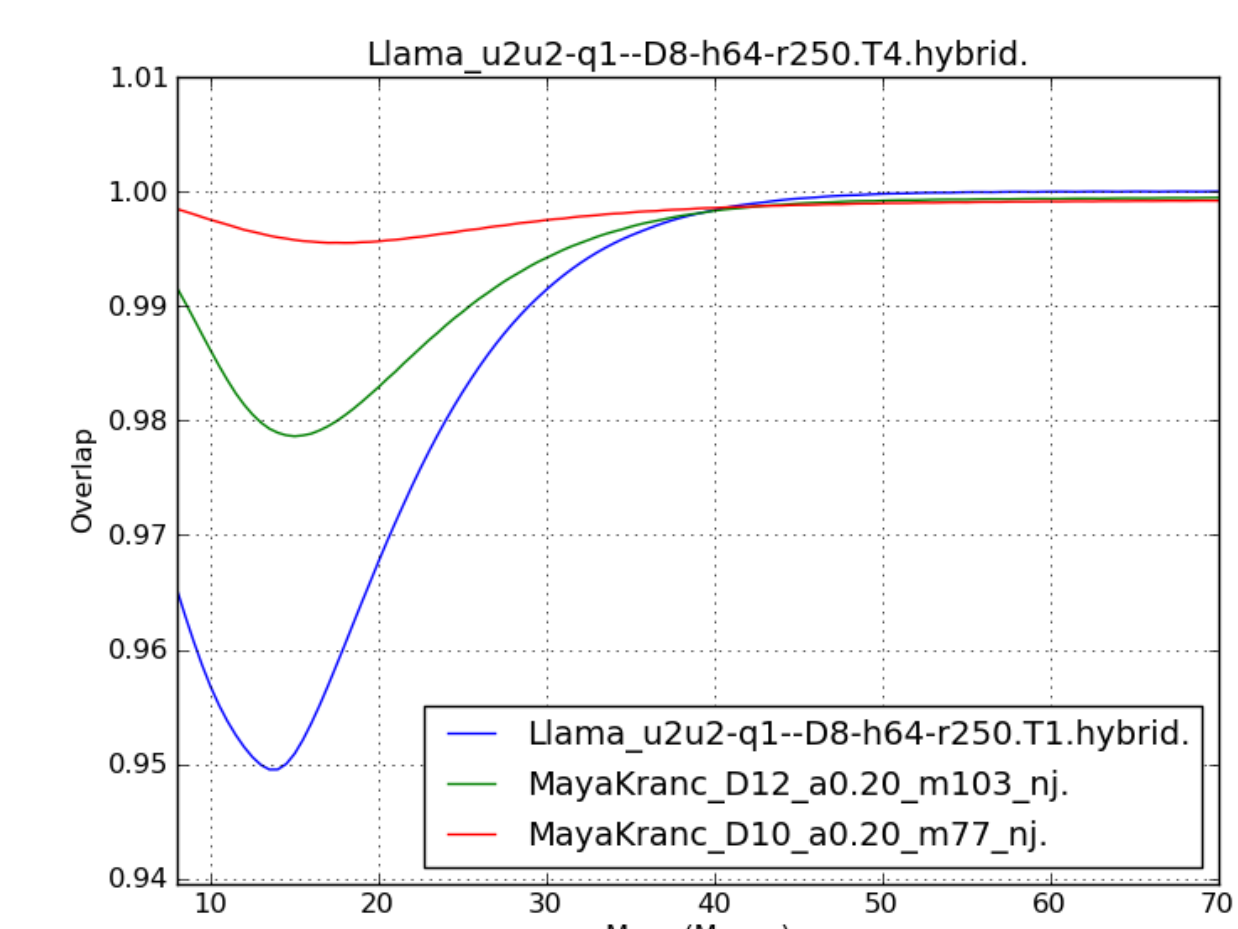$$\mathcal{O}(h,s) = \frac{\langle s|h \rangle}{\sqrt{\langle s|s \rangle \langle h|h \rangle}}$$

$$\langle s|h \rangle = 4\Re \int_0^\infty \frac{h^\star(f)s(f)}{S_n(f)}\, df$$

| Mass ratio	Spin1	Spin2	Submissions
1	-0.85	-0.85	BAM(2)
1	-0.75	-0.75	BAM(2)
1	-0.50	-0.50	BAM(2)
1	-0.44	-0.44	SpEC
1	-0.40	-0.40	Llama(2)
1	-0.25	-0.25	BAM(2), UIUC
1	-0.20	-0.20	Llama(2)
1	0.00	0.00	SpEC, GATech, BAM(2)
1	0.20	0.20	Llama(2), GATech(2)
1	0.25	0.25	BAM(2)
1	0.40	0.40	Llama(2), GATech(2)
1	0.44	0.44	SpEC
1	0.50	0.50	BAM(2)
1	0.60	0.60	GATech(2)
1	0.80	0.00	GATech
1	0.80	0.80	GATech(2)
1	0.85	0.85	BAM(2), UIUC
1	0.90	0.90	GATech
3	0.40	0.60	BAM
4	0.00	0.00	LEAN, BAM(2)
3	0.00	0.00	BAM(2)
2	0.02	0.08	GATech
2	0.00	0.00	GATech, BAM(2)
10	0.00	0.00	RIT

q=1,spin1=spin2=0

q=1,spin1=spin2=0.4

q=1,spin1=spin2=0.2

Initial Data Set

NINJA2 will allow data analysis groups to perform injections on the fly in order to tune and test pipelines. To compare results between search groups we will also produce common data sets. The first of these consists of 2 months of simulated Gaussian noise with 1029 injections, with masses uniformly chosen from 10 to 350 M_O with different densities and SNRs over the course of the run.

Full Run, All masses

SNR, weeks 1-3

SNR, weeks 4-6

SNR, weeks 7-8
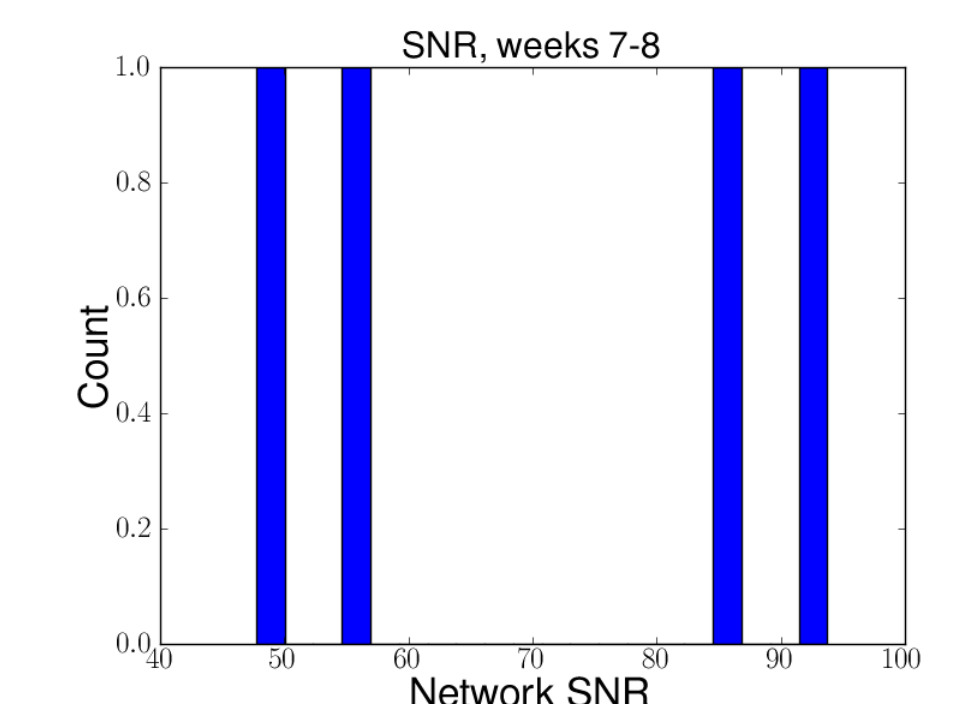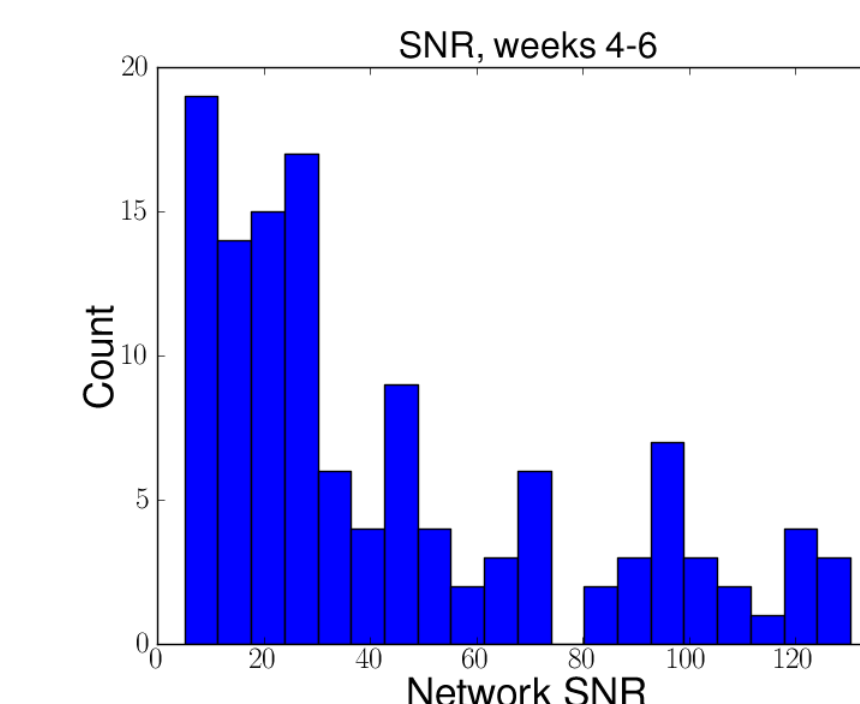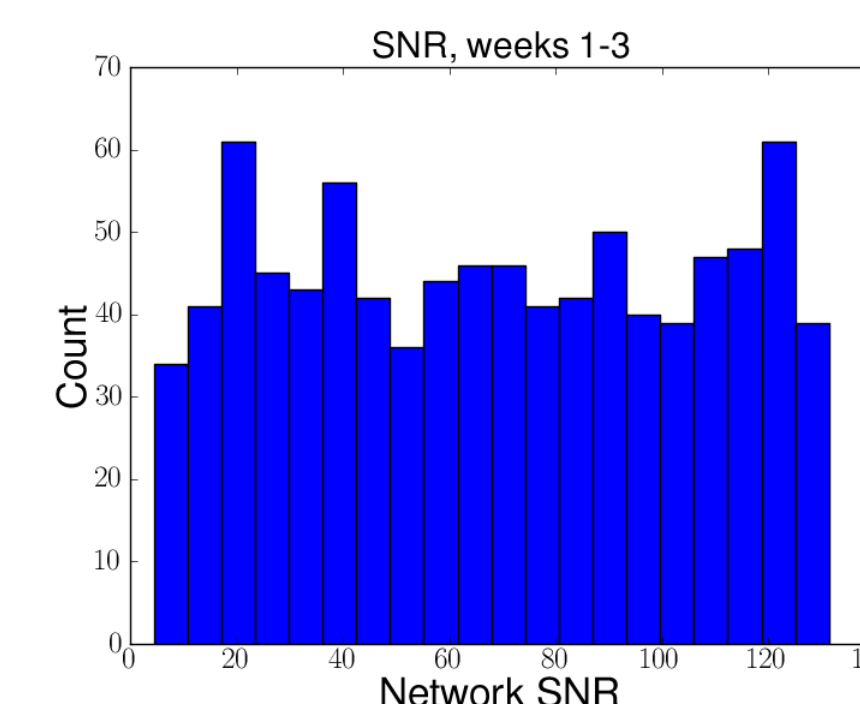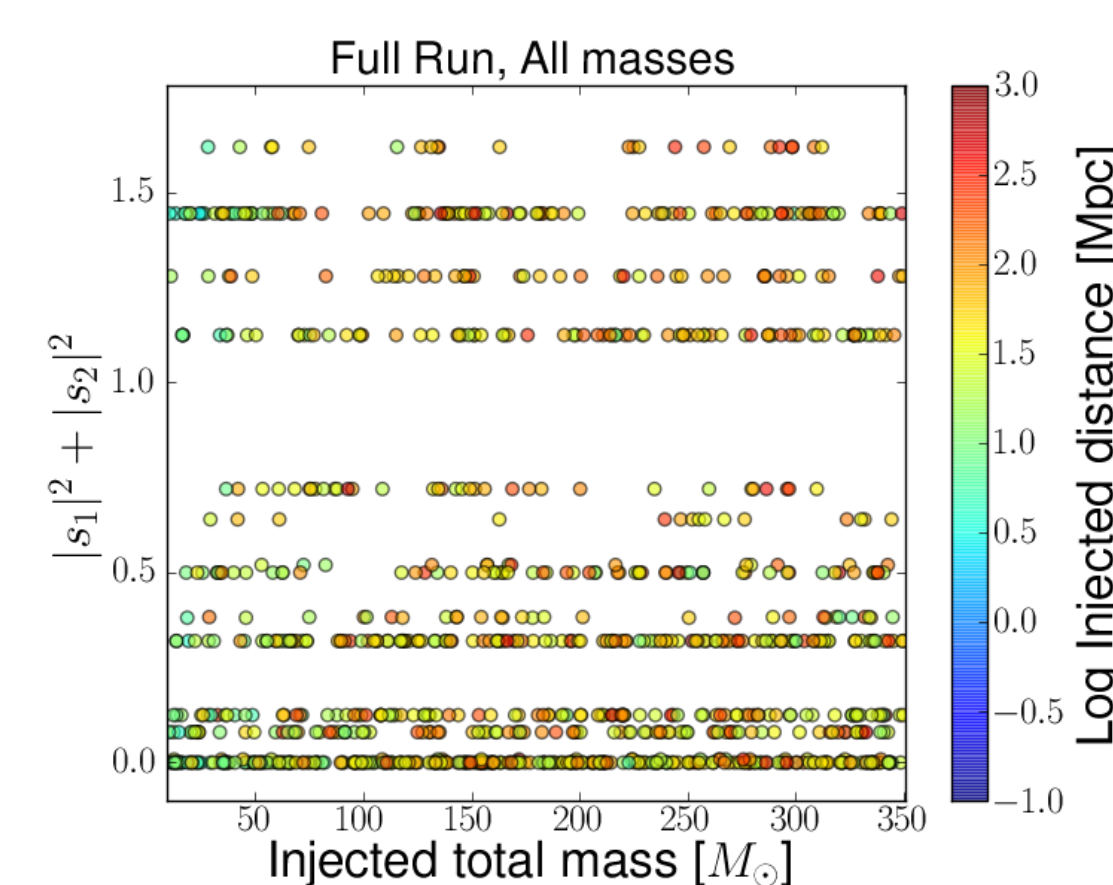
Status

The initial data set has been generated and is being distributed to clusters for analysis. A second round of waveform submissions has been opened to refine current waveforms and accept new ones. An agreement between NINJA and the LIGO and Virgo collaborations has been reached which will allow the use of real detector noise in subsequent data sets. Data analysis will begin shortly, with preliminary results to be discussed at the NRDA conference in July.