

*Image from Google Themes*

# The NINJA-2 Project

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For the NINJA Collaboration



# What is the NINJA project?

- Numerical INJection Analysis
- Collaboration between the numerical relativity and data analysis communities.
- Project to test search pipelines and parameter estimation against the best available waveforms for binary black hole mergers.



# NINJA-1

- Huge success!
- Contributions from 10 NR groups, 9 DA groups.
- Open policy towards waveform submissions, encouraged wide participation.
- 127 Injections into simulated Gaussian noise.
- Paper published

Benjamin Aylott *et al* 2009 *Class. Quantum Grav.* 26 165008

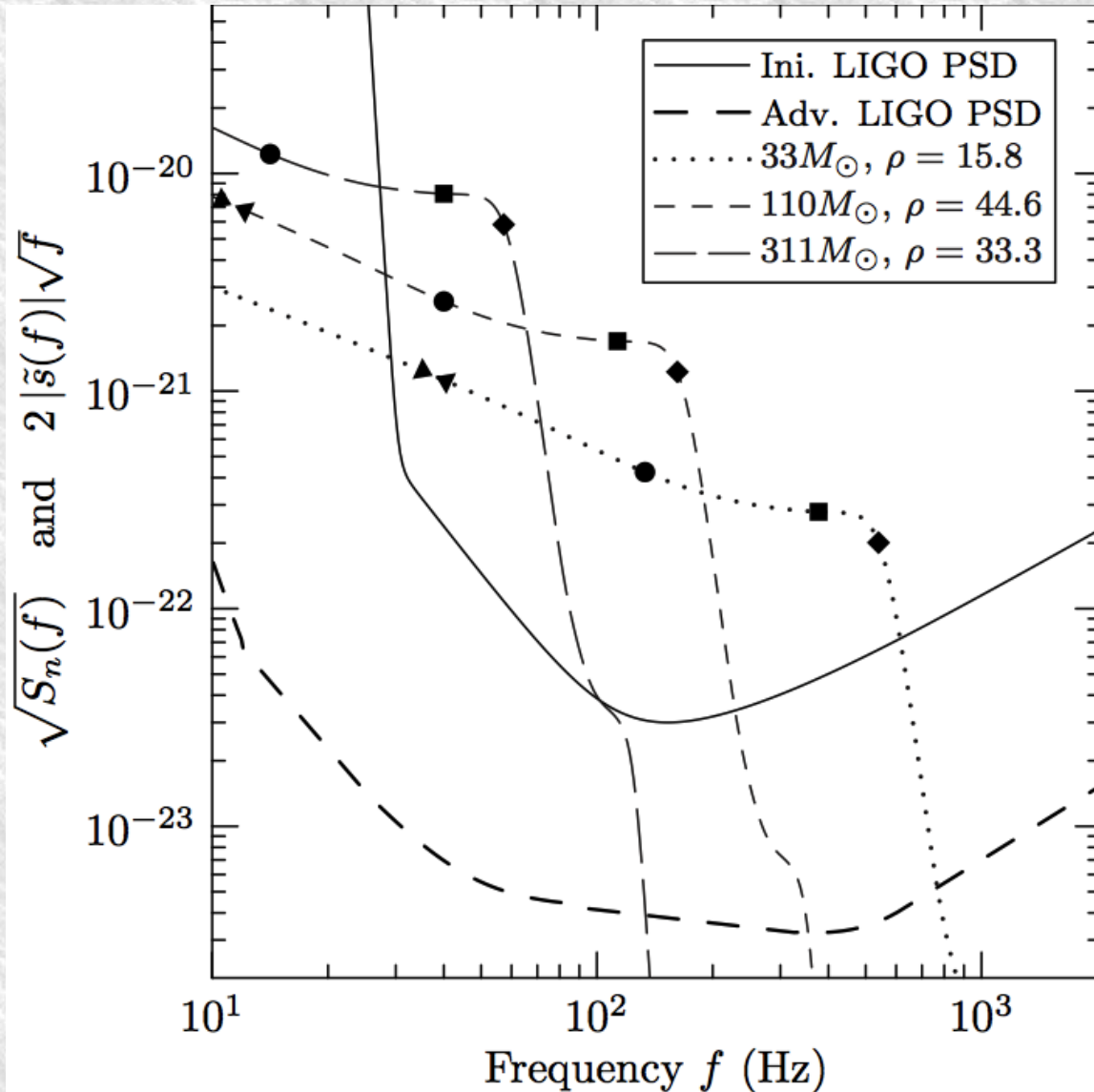


# NINJA-2

- Explore more of the parameter space
- Impose tighter conditions on the waveform submissions
- Use real data (nonstationary, nongaussian, glitches...)
- Contributions from 8 NR groups, 19 data analysis groups have signed up.



# NINJA-2: Waveform Length



- NINJA-1 used pure NR waveforms with no minimum length.
- The lowest mass we could inject was  $36 M_\odot$ .
- NINJA-2 requires  $> 5$  orbits, and robust stitching to PN waveforms to allow injections down to  $10 M_\odot$  starting at 10 Hz.



# NINJA-2: Waveform Parameters

## Mass Ratio ( $q=m_1/m_2$ )

- NINJA-1: One submission with  $q=3$ , two with  $q=4$
- NINJA-2: One submission with  $q=1.25$ , four with  $q=2$ , 2 with  $q=3$ , two with  $q=4$ , one with  $q=10$

## Spin

- NINJA-1: 14 of the 23 waveforms had spin, values up to 0.92, 2 precessing.
- NINJA-2: 24 of 35 waveforms have spin, values up to 0.85
- No precession. Stay tuned for NINJA-3!

## Modes

- NINJA-1: all submissions contained only (2,2).
- NINJA-2: 22 have higher-order modes



# NINJA-2 Data Sets

- 2 One-week test sets in simulated Gaussian noise to shake out bugs in the injection software and procedures and do preliminary pipeline tests.
- 1 Two-month production set in simulated Gaussian noise (first attempt found remaining bugs!)
- 3 mass bins:  $10-40 M_{\odot}$ ,  $25-100 M_{\odot}$ ,  $80-350 M_{\odot}$ .
- Different injection densities over different weeks.
- Uniformly distributed in network SNR between 6-130 for most weeks, in  $1/(\text{network SNR})$  for densest period.
- Raw waveforms will be made available to analysis groups, allowing for tuning runs with thousand of injections.



# Preliminary results

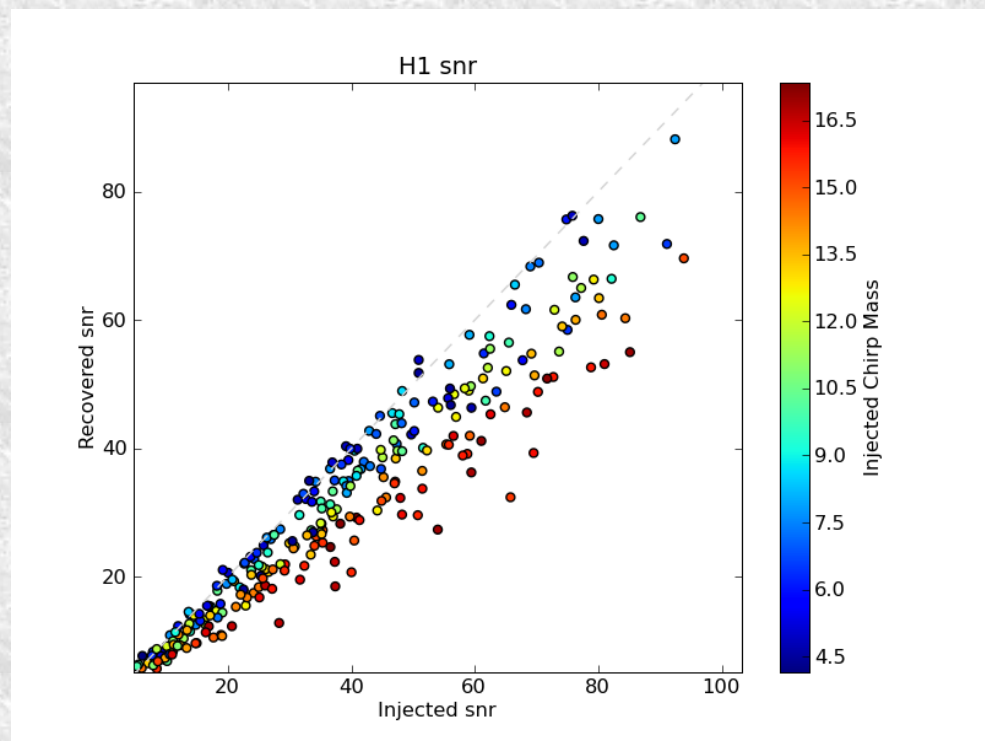
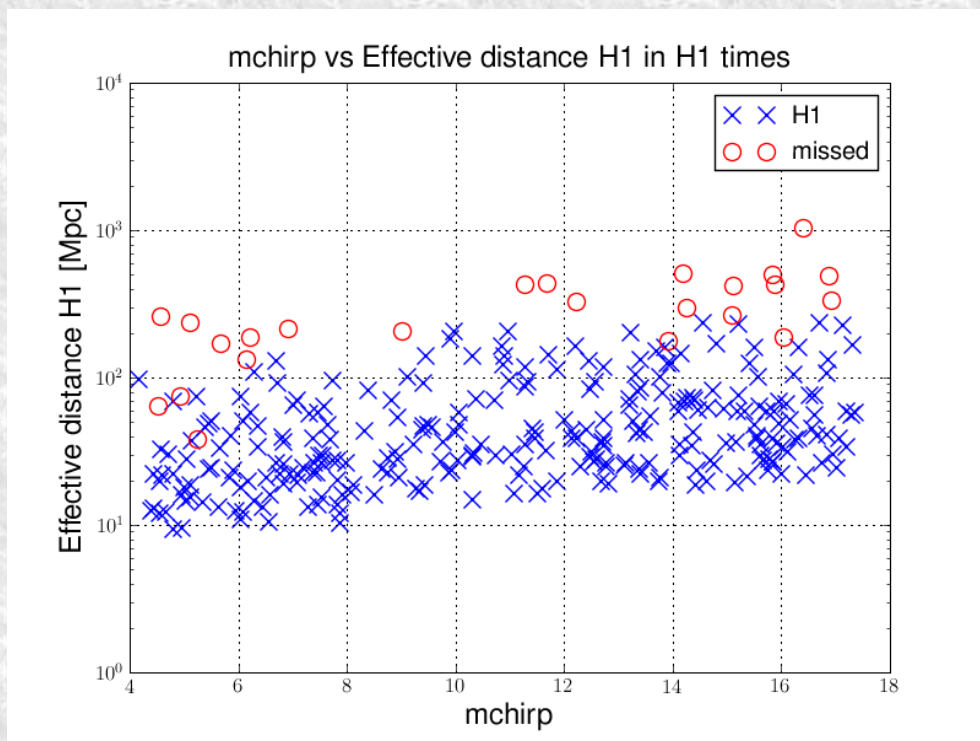
Several analyses have been run on the test weeks

- CBC low mass
- CBC high mass
- Omega, Omega chirplet
- Coherent WaveBurst
- MBTA
- Ringdown
- gstlal/IMRSA
- Bayesian parameter estimation and model selection with lalapps\_inspnest





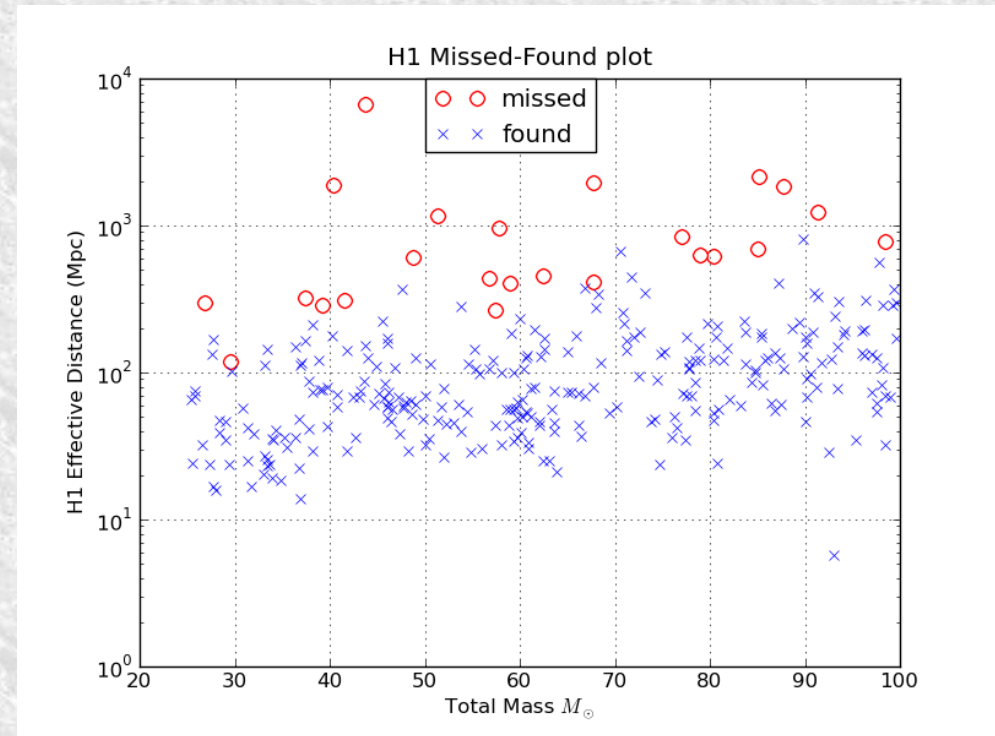
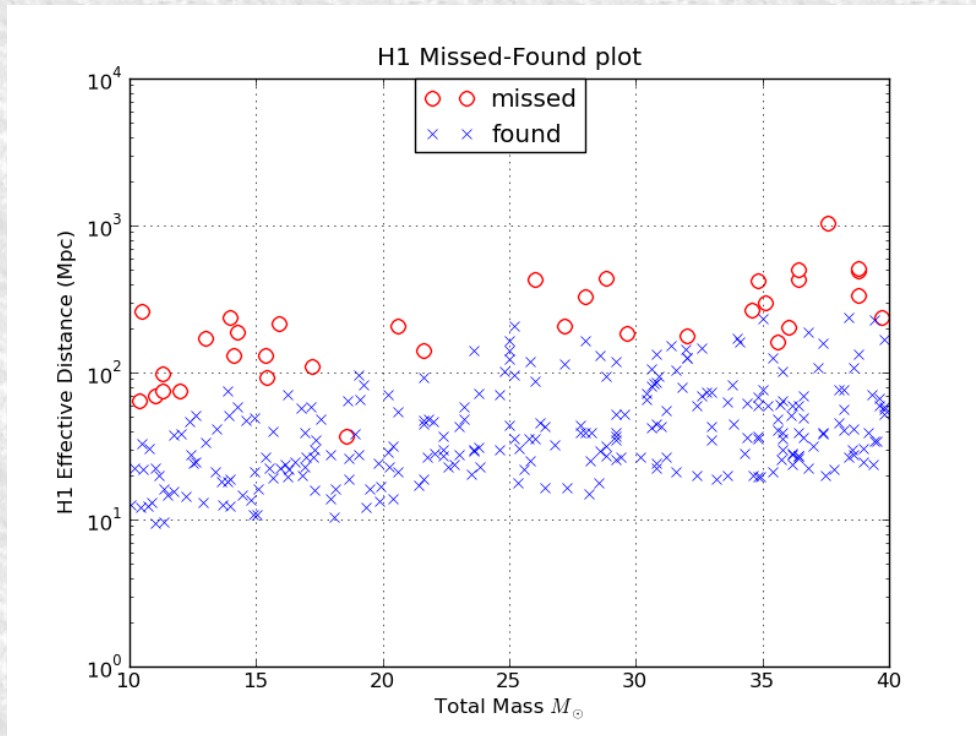
# Preliminary results: CBC low mass



Found/missed and SNR recovery after coincidence  
Low mass data set



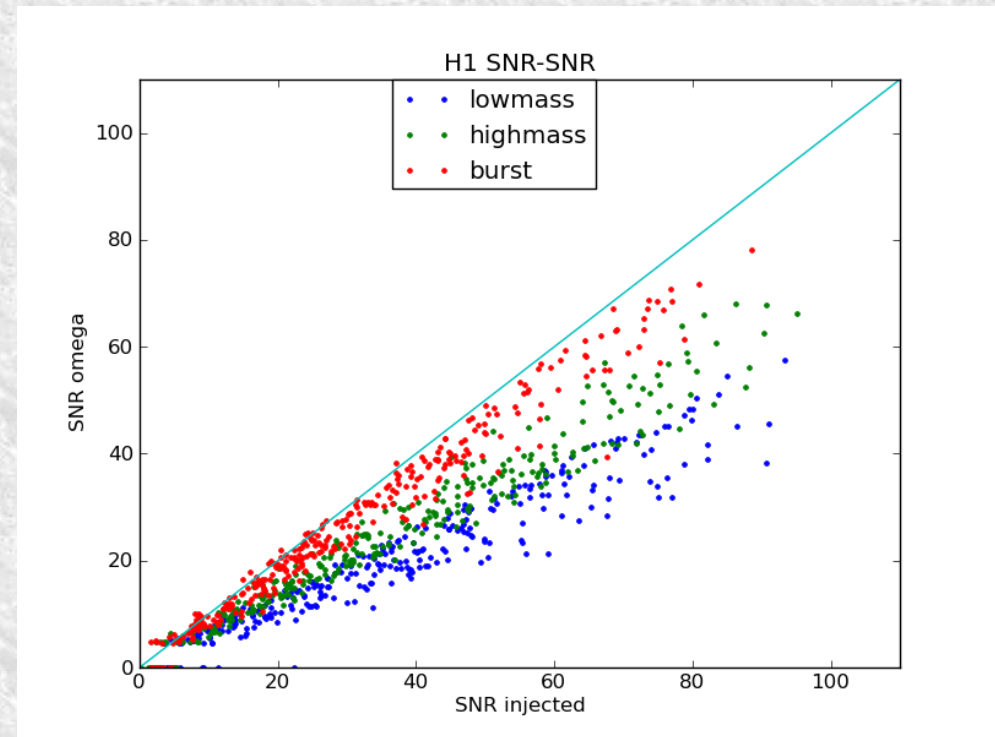
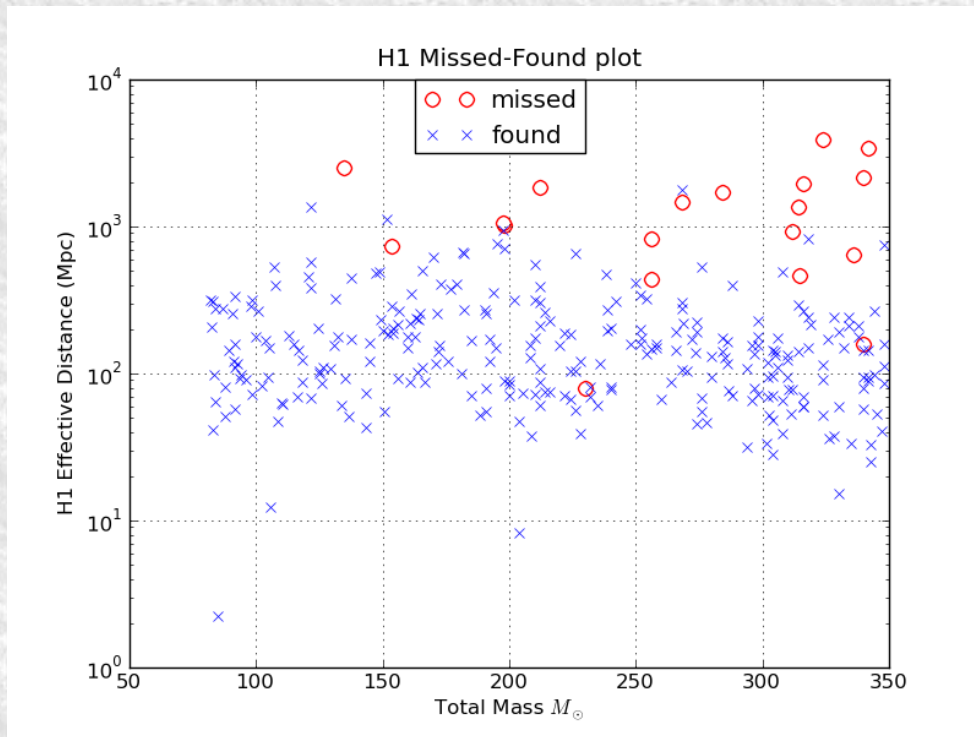
# Preliminary results: Omega (1)



Found/missed before coincidence  
Low mass and high mass data sets



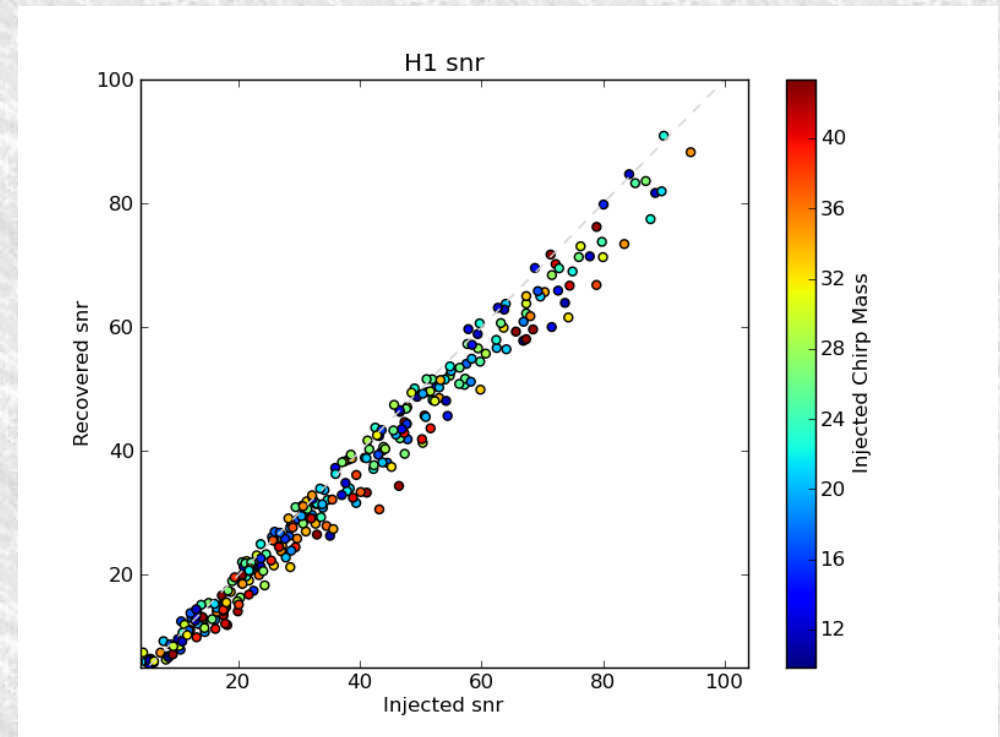
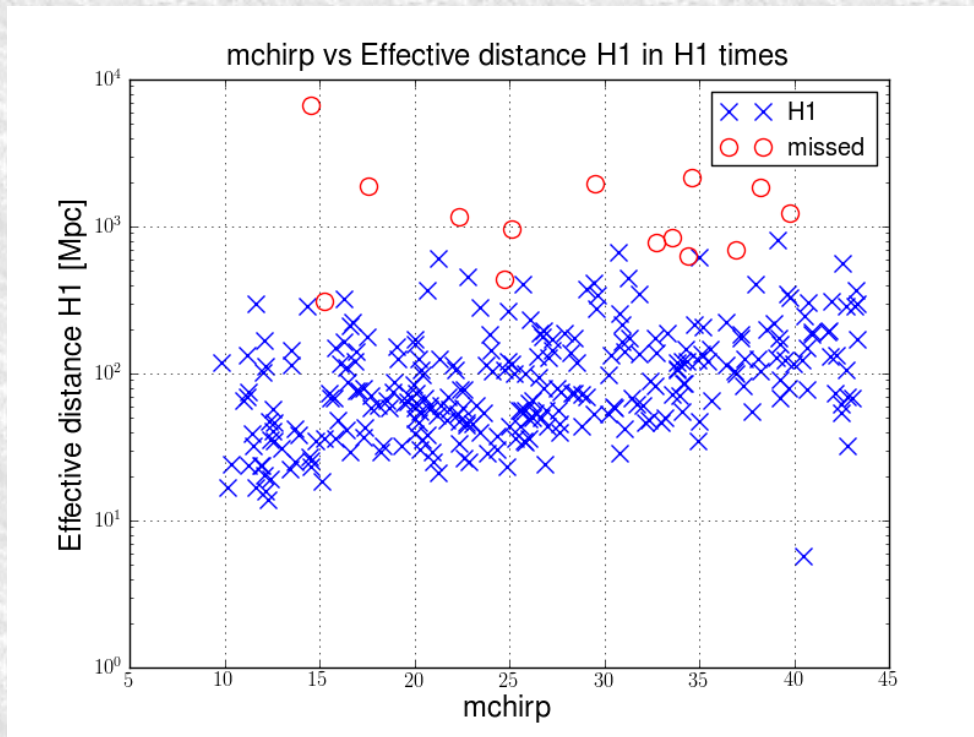
# Preliminary results: Omega (2)



Found/missed before coincidence, burst data set  
SNR Recovery, all sets



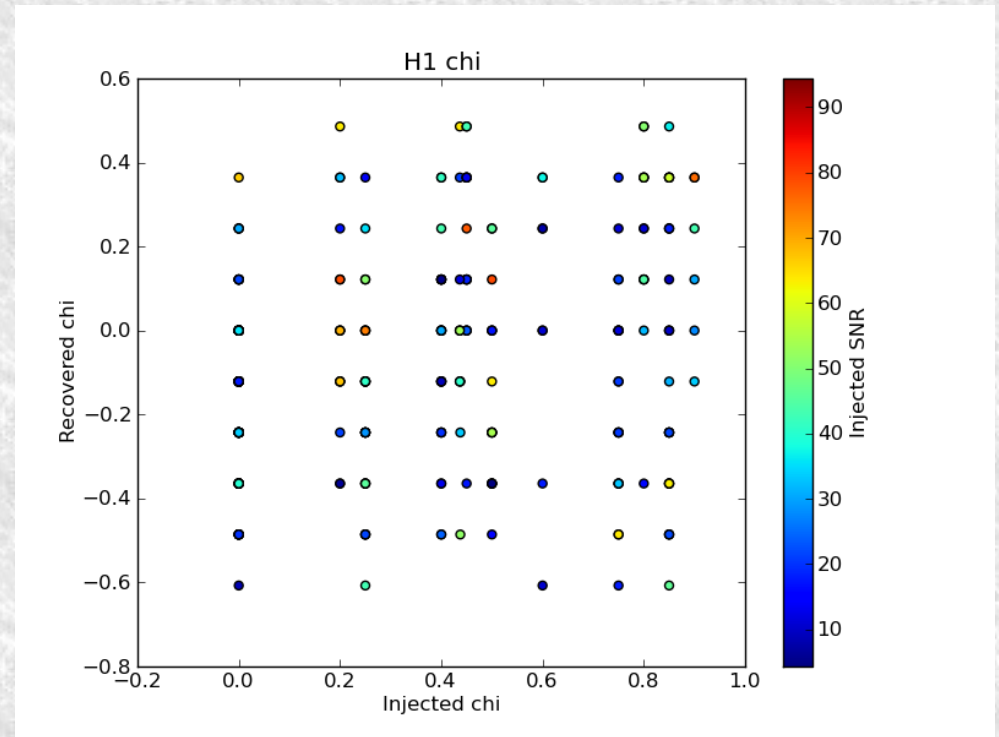
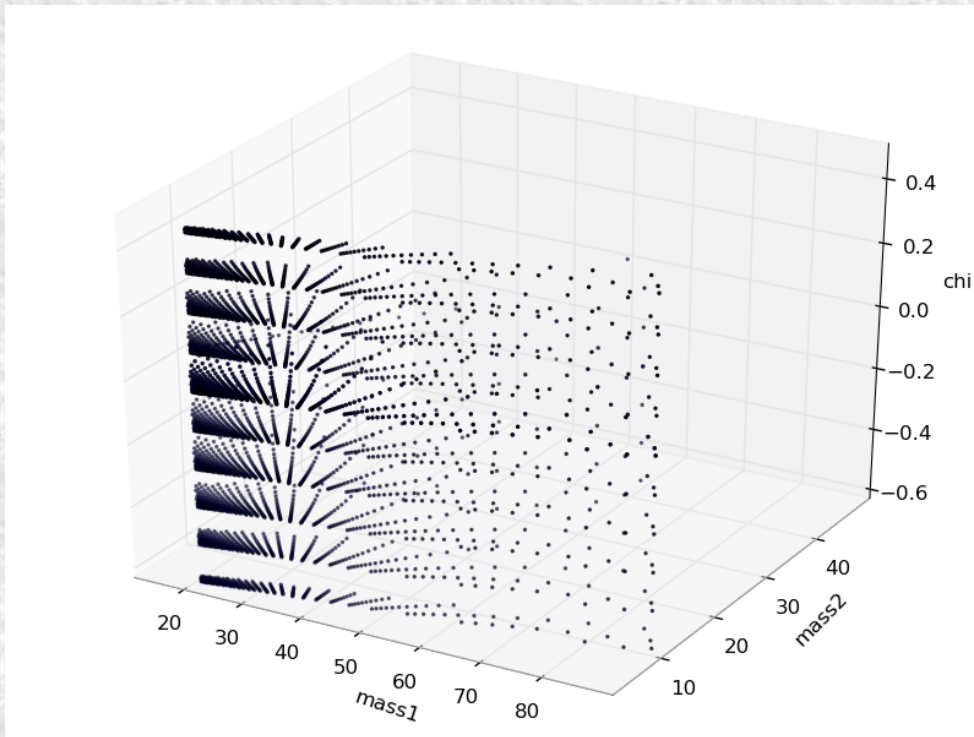
# Preliminary results: gstlal



Found/missed and SNR recovery before coincidence  
High mass data set



# Preliminary results: gstlal spins



3D template bank and spin recovery  
High mass data set



# Status and Next Steps

- All final waveforms have been submitted.
- Extensive cross-checking of the PN coefficients used for hybridization is complete.
- Final validation of stitching procedures are close to complete.
- The full 2-months of Gaussian noise sampled at 16 kHz is ready.
- The bugs have been shaken out of the injection code.
- **Full analysis runs should be able to start in a couple of weeks!**