

Remnant Mass, Spin, and Recoil From Spin Aligned Black-hole Binaries II

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Introduction

- 80 new simulations for 5,000,000 SUs
- 51 new aligned-spin runs and 10 precessing
- Targeted runs in parameter space of GW150914
- Reconstructing gravitational wave source parameters via direct comparisons to numerical relativity (U14 Monday afternoon)
- Direct comparison with SXS
- Reassess and recalibrate our Mass/Spin/Kick fits

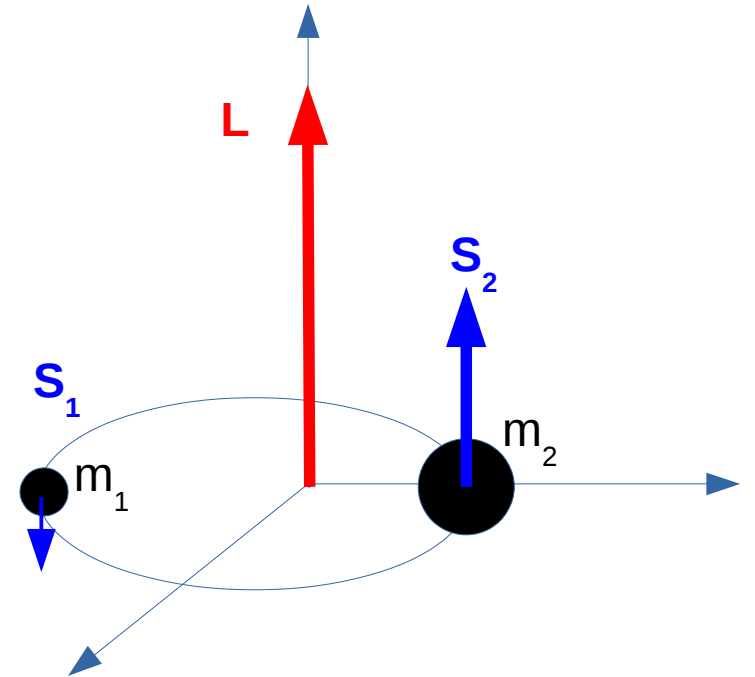
Fitting Model

- PRD 90, 104004 (2014) or arxiv:1406.7295
- PN motivated series expansion in δm , S , and Δ

$$m = m_1 + m_2 \qquad \vec{S} = \vec{S}_1 + \vec{S}_2$$

$$\delta m = \frac{m_1 - m_2}{m} \qquad \vec{\Delta} = m(\vec{S}_2/m_2 - \vec{S}_1/m_1)$$

- Fitting order determined by combinations of δm , S , and Δ
- Which combinations occur in fit determined by symmetry
- Explicit enforcement of particle limit

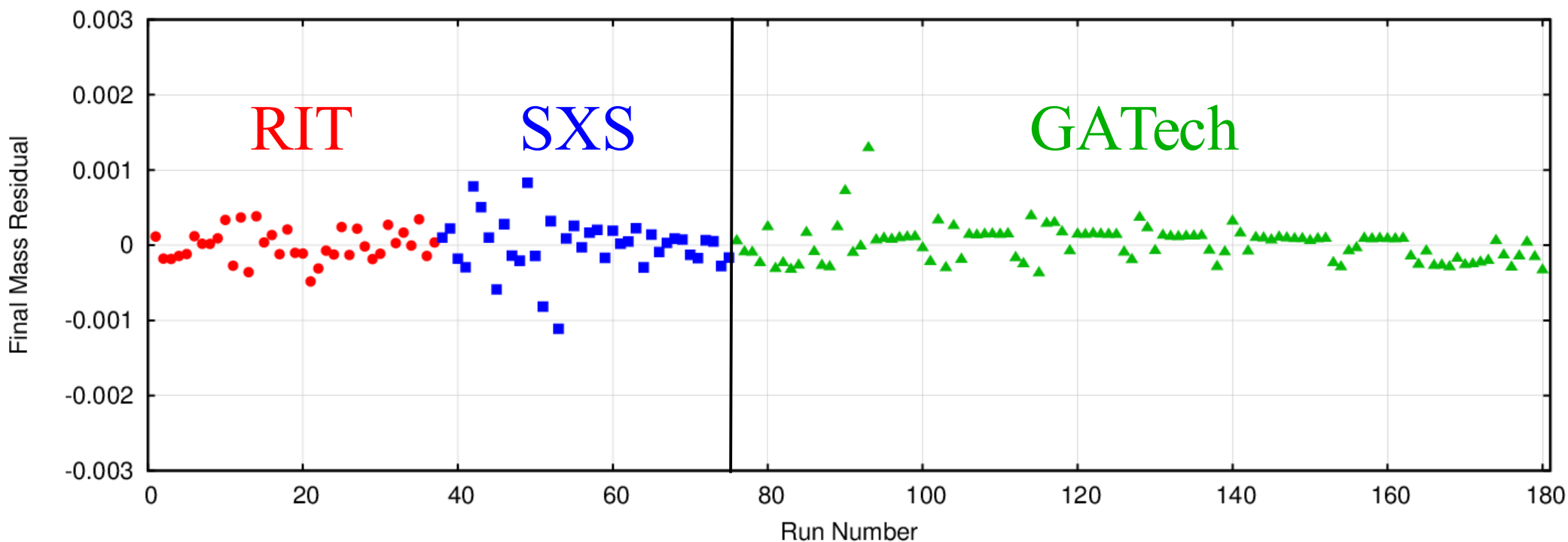


Fit Calibration

- 37 RIT spin-aligned configurations
- 38 additional runs from SXS catalog
<http://www.black-holes.org/waveforms>
- $0.1 \leq q \leq 1.0$
- For $q=1$, χ as high as **0.98** (SXS)
- Others, χ as high as **0.83**

Category	RIT runs	SXS runs
$\delta m = S = \Delta = 0$	1	0
$\delta m = 0$	5	2
$S = 0$	4	0
$\Delta = 0$	4	0
$\delta m = S = 0$	3	15
$\delta m = \Delta = 0$	1	7
$\delta m, S, \Delta \neq 0$	19	14

Mass Residuals



Fit Calibration

RIT RMS $2.07e-4$

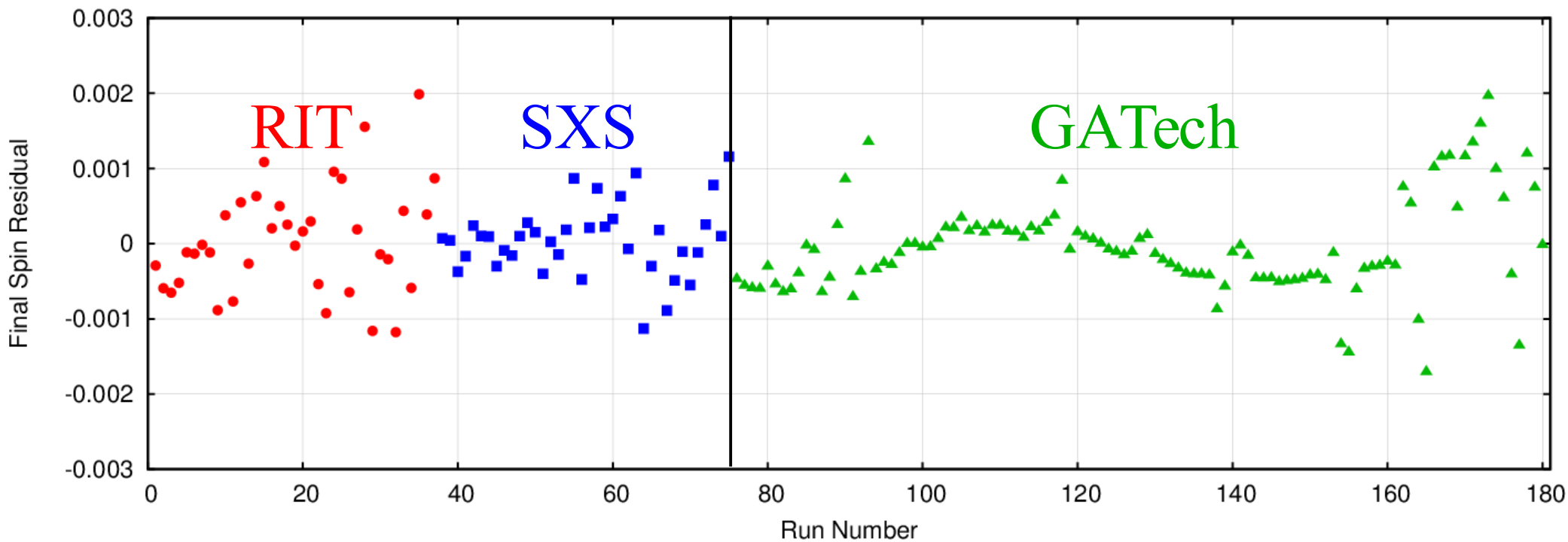
SXS RMS $3.56e-4$

Independent Verification

GATech RMS $2.35e-4$

Overall RMS $2.61e-4$

Spin Residuals



Fit Calibration

RIT RMS $7.16e-4$

SXS RMS $4.73e-4$

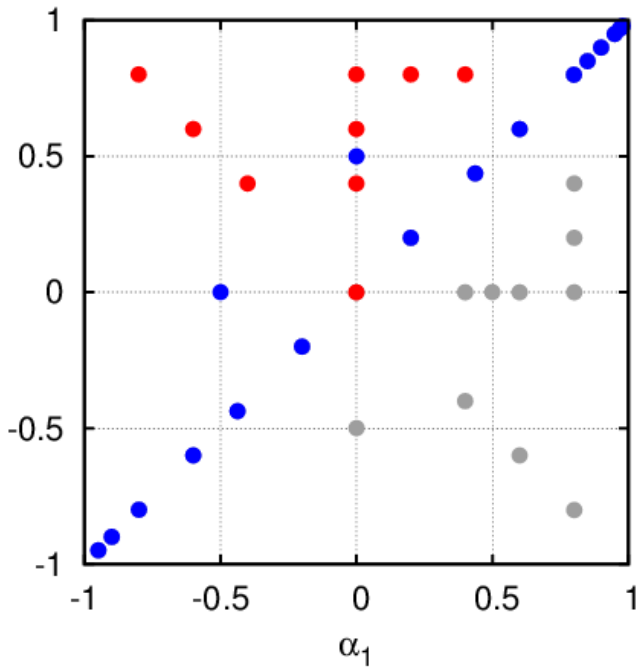
Independent Verification

GATech RMS $6.25e-4$

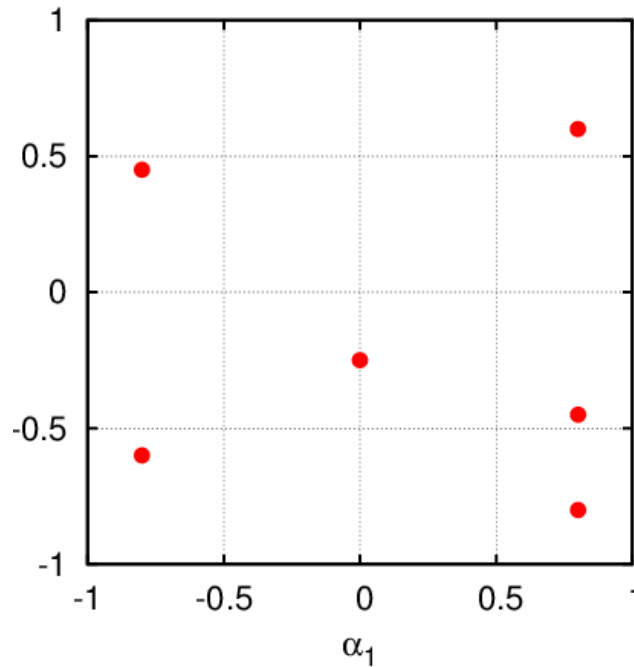
Overall RMS $6.18e-4$

Parameter Space Coverage

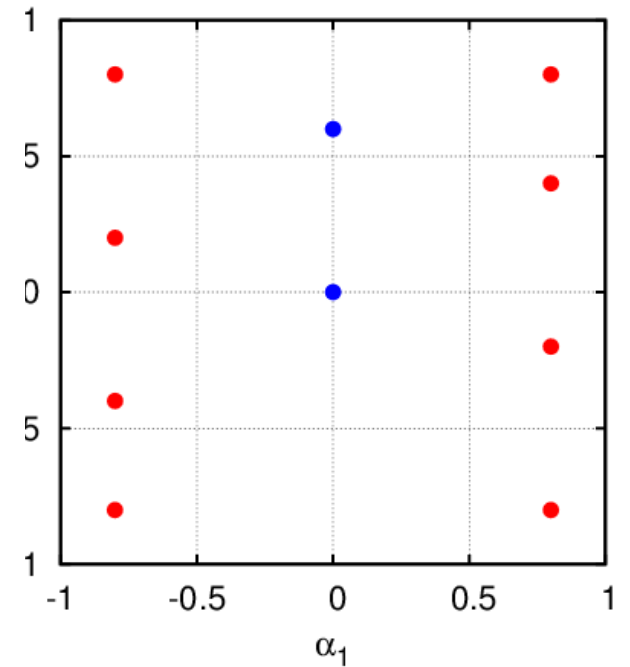
$q=1.00$



$q=0.75$



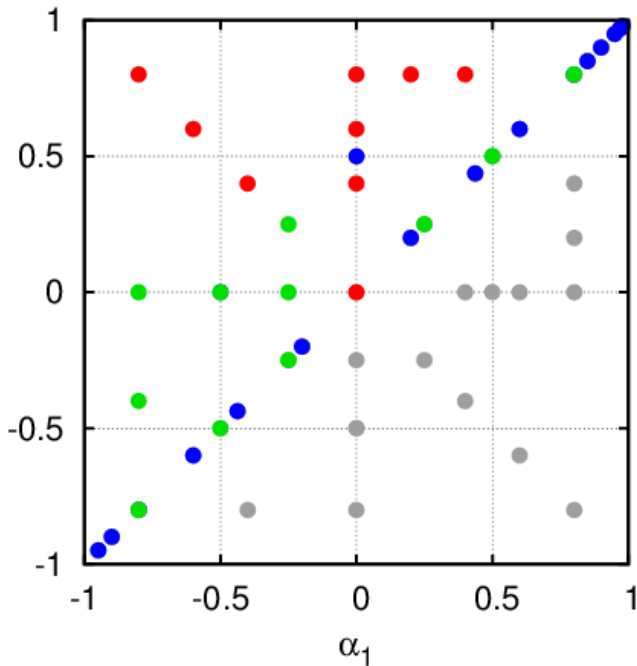
$q=0.50$



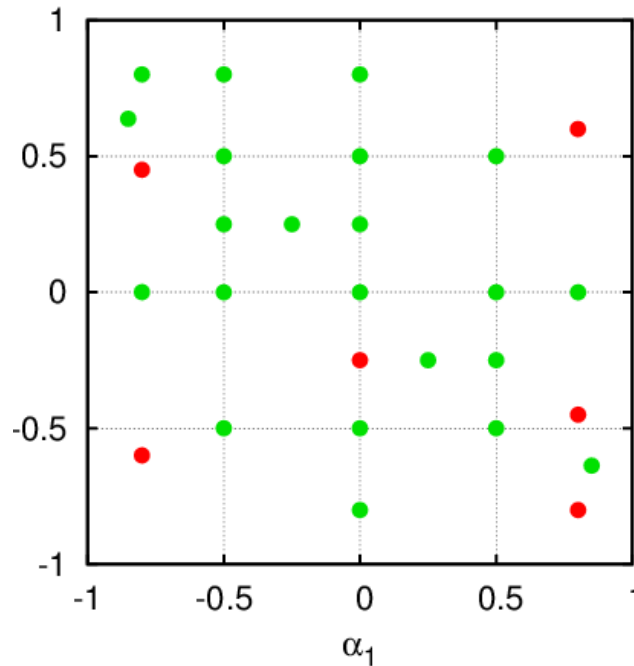
- Additional 5 runs at $q=2/3$ (SXS)
- 28 runs with $q<0.50$ (RIT+SXS)

Parameter Space Coverage

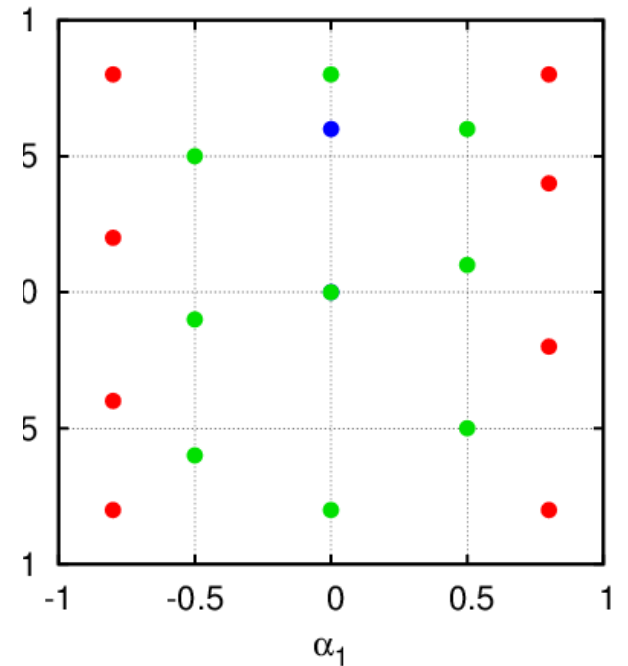
$q=1.00$



$q=0.75$



$q=0.50$



- 10 new non-spinning runs with $0.17 \leq q \leq 0.85$
- GW150914 estimate: $q=0.82$ and $S \sim 0$

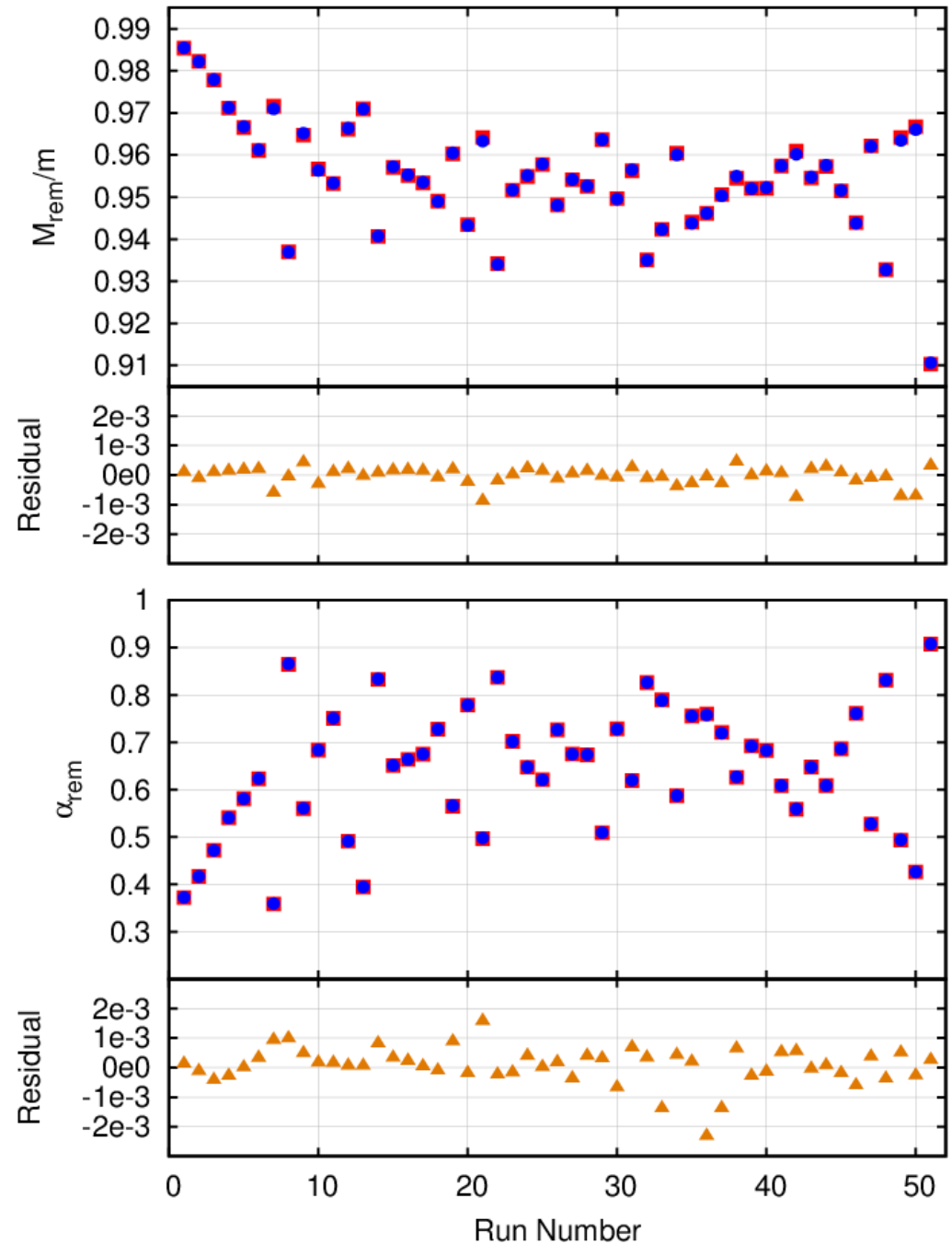
New Runs

Mass

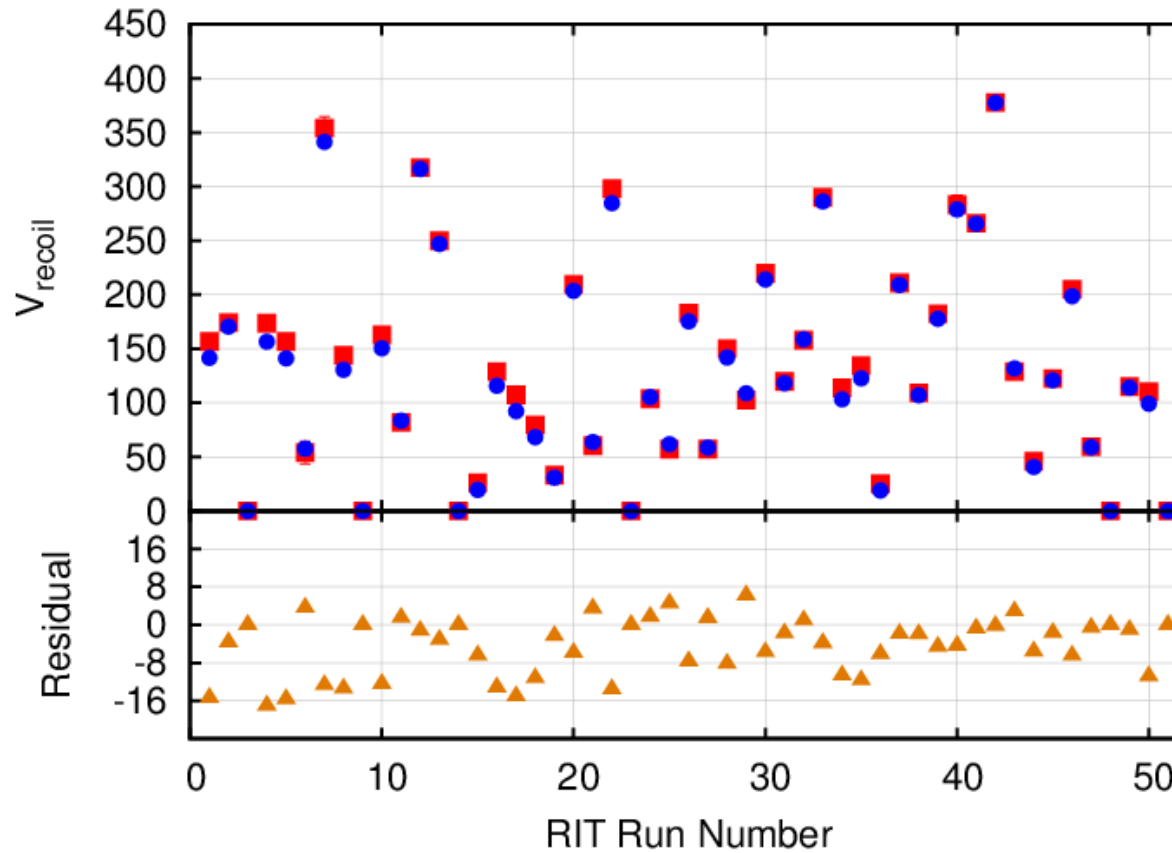
RMS $2.93e-4$
Avg(diff) $-3.57e-5$
Max(|% diff|) 0.09%

Spin

RMS $6.25e-4$
Avg(diff) $7.02e-5$
Max(|% diff|) 0.32%



Recoil Velocity



RMS 7.5 km/s

Future Work

- Approximately 80 simulations for 5MSUs
- Recalibrate all fits with new runs
- Improve kick fit – reduce error bars
- Luminosity fit – same difficulties as kick fit
- Unify the aligned and precessing spin fits into one all encompassing fit

4th order Convergence

GW150914 estimate

$$q = m_1/m_2 = 0.82 \quad \alpha_1 = -0.44 \quad \alpha_2 = 0.33$$

Resolution	Mass	Spin	Recoil
100	0.952015 ± 0.000003	0.691961 ± 0.000003	131.79 ± 1.44 km/s
110	0.952020 ± 0.000003	0.691965 ± 0.000003	133.35 ± 1.01 km/s
120	0.952021 ± 0.000003	0.691969 ± 0.000003	134.38 ± 0.68 km/s
Extr. Inf.	0.952021	0.691979	137.23 km/s
% diff (Inf and 120)	Within rounding	0.001%	2.12%