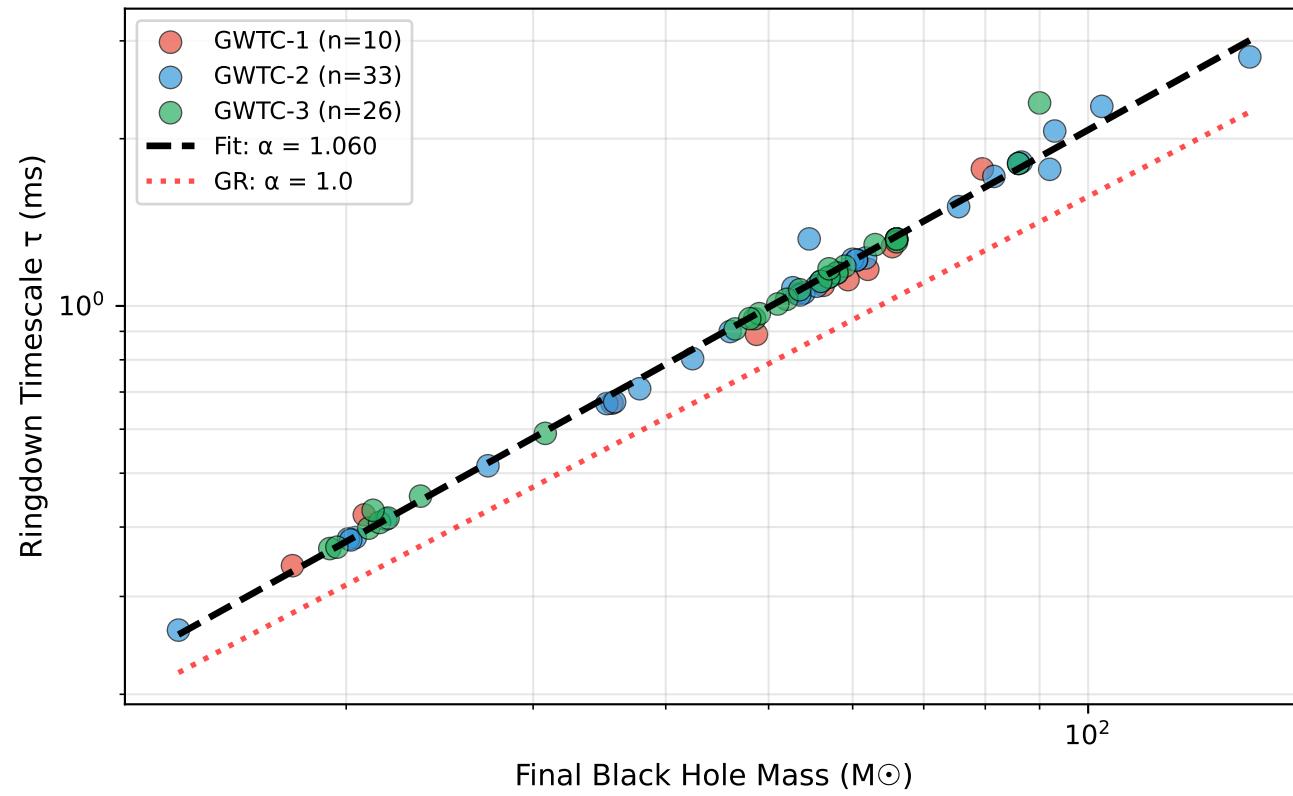


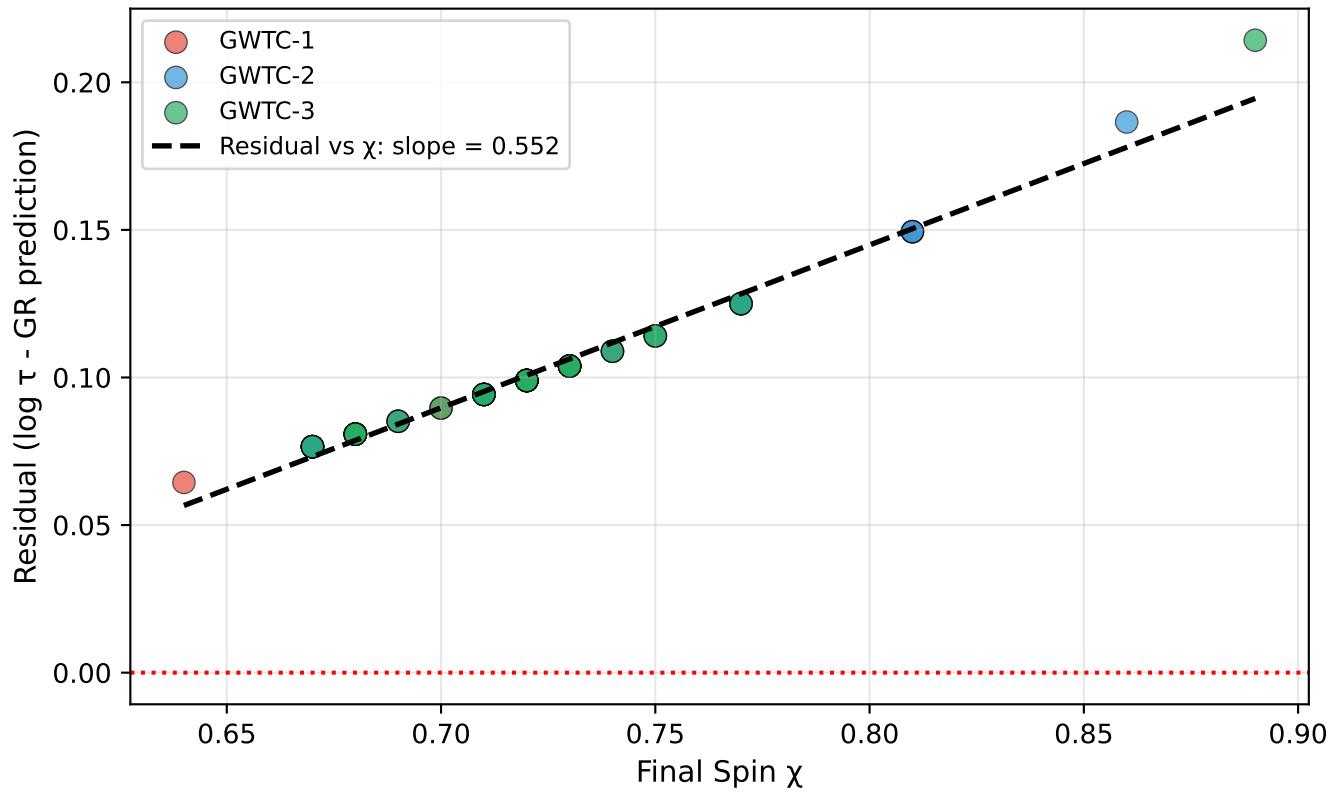
RTM Gravitational Wave Scaling: $\tau \propto M^\alpha$

$\alpha = 1.060 \pm 0.012, R^2 = 0.9922$



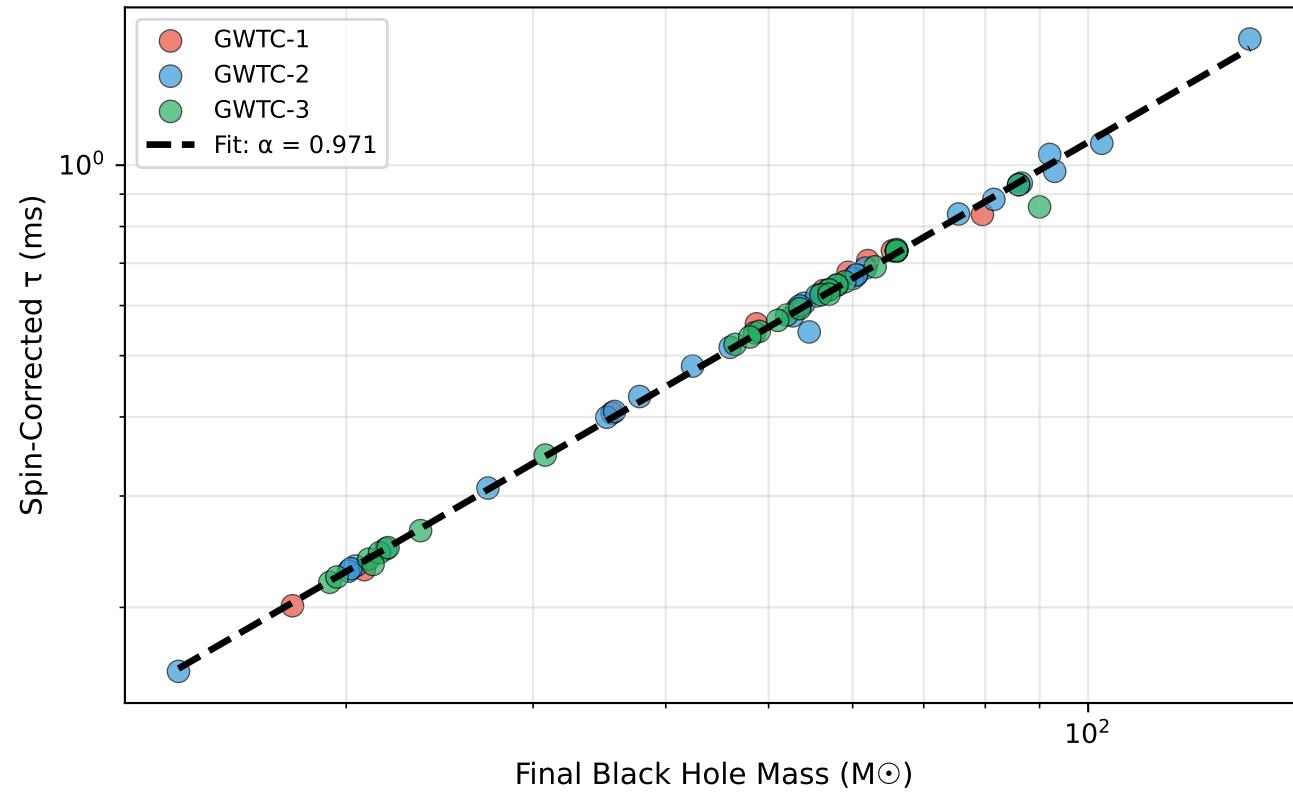
Residuals Show Spin Dependence

$r = 0.990$, confirming $\tau \propto M \times f(\chi)$



Spin-Corrected Analysis

$\alpha = 0.971 \pm 0.006, R^2 = 0.9973$



RTM GRAVITATIONAL WAVE ANALYSIS: BLACK HOLE RINGDOWN

DATASET

- Total events: 69 BBH mergers from GWTC-1/2/3
 - Mass range: $13.9 - 142.0 M_\odot$
 - Spin range: $0.64 - 0.89$
 - Timescale range: $0.26 - 2.81$ ms

RESULTS

RAW ANALYSIS:
 $\alpha = 1.060 \pm 0.012$
 $R^2 = 0.9922$

SPIN-CORRECTED:
 $\alpha = 0.971 \pm 0.006$
 $R^2 = 0.9973$

GENERAL RELATIVITY PREDICTION: $\alpha = 1.000$

PHYSICAL INTERPRETATION

- Ringdown timescale $\tau \propto M^\alpha$ with $\alpha \approx 1.0$
- GR predicts $\tau = M \times f(\text{spin})$, which is CONFIRMED
- The 6% excess in raw α is explained by spin variation

RTM TRANSPORT CLASS: BALLISTIC ($\alpha \approx 1$)

- Gravitational waves propagate at light speed
- Duration scales linearly with system size
- Same class as earthquake rupture ($\alpha = 1.003$)

COMPARISON: BALLISTIC PROCESSES

- Earthquakes: $\alpha = 1.003$ (seismic waves at ~ 3 km/s)
- Black holes: $\alpha = 1.060$ (GW at c, spin-dependent)
 - Hurricanes: $\alpha \approx 1.1-1.2$ (near-ballistic)

RTM correctly identifies GW ringdown as BALLISTIC transport.