

PROSPECTS ON SUPERMASSIVE BLACK HOLE BINARY DETECTIONS WITH LISA

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OUTLINE

1 THE WAVEFORM OF A BINARY SMBH

2 MEASUREMENT ERRORS

- Statistical errors
- Theoretical errors

3 QUESTIONS

GW detection: template-based searches

No exact solution for binary system

⇒

- Inspiral phase: Post-Newtonian waveform
- Merger phase: Numerical relativity, still very time-consuming, not all parameter space explorable

15 (17 or more) parameters needed

⇒ need structure to break degeneracies

STRUCTURE OF THE WAVEFORM

Wave interacting with detector:

$$h_{+,x} = \frac{2G\mu x}{d_L c^2} \left[\sum_{n \geq 0} \left(A_{+,x}^{(n)} \cos n\phi + B_{+,x}^{(n)} \sin n\phi \right) \right]$$

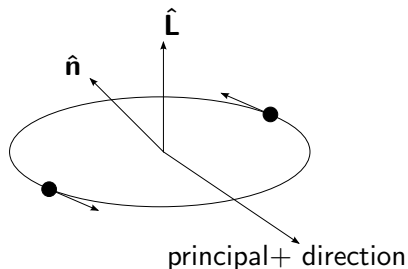
Series in $x \equiv \left(\frac{GM\omega}{c^3} \right)^{2/3}$:

- $\phi = \phi(x)$
- $A, B_{+,x}^{(n)} = A, B_{+,x}^{(n)}(x)$

STRUCTURE OF THE WAVEFORM

Additional effect:

- Spin-orbit precession $\implies \mathbf{S}_i(x), \hat{\mathbf{L}}(x), \delta\phi(x)$

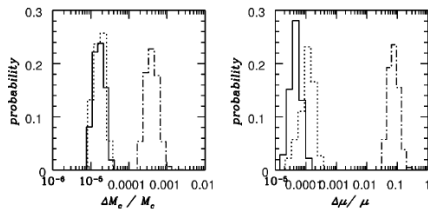


Potential differences between waveforms:

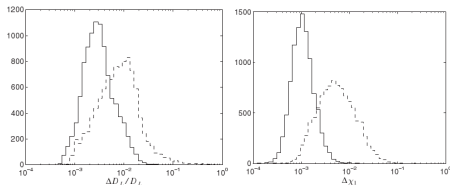
- PN expansion of orbital phase (largest effect [Cutler et al., 1993])
- Presence of different harmonics
- PN expansion of harmonics amplitude
- Spin-orbit precession
- Additional effects (eccentricity, alternative gravity, etc)

- Statistical errors: Originate from unpredictable nature of noise
 - Should tend to non-zero value dependent on detector specs as PN accuracy increases
 - Decrease for lower separations
- Theoretical errors: Originate from approximative nature of templates
 - Should tend to zero as PN accuracy increases
 - Increase for lower separations

SPIN-ORBIT PRECESSION

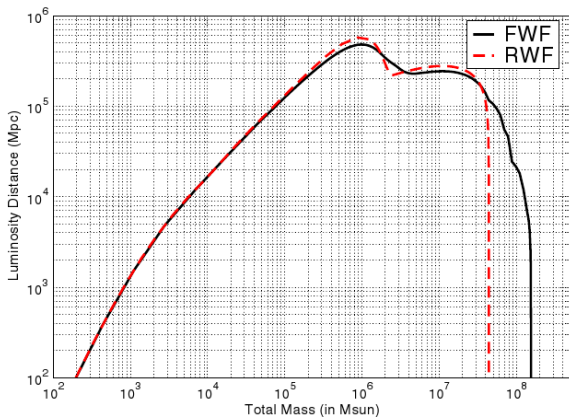


[Vecchio 2004], presence of spin, simple precession



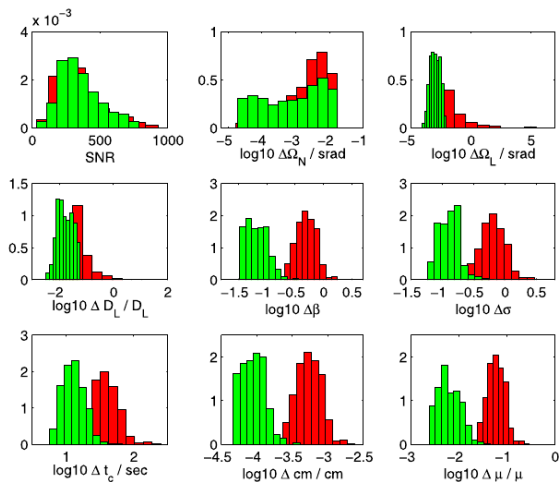
[Lang & Hughes 2006], full precession equations

PRESENCE OF DIFFERENT HARMONICS WITH AMPLITUDE MODULATIONS



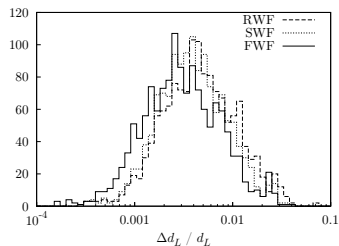
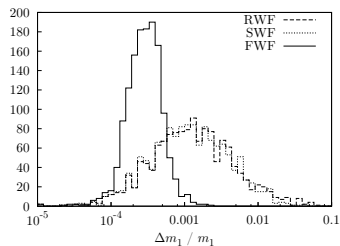
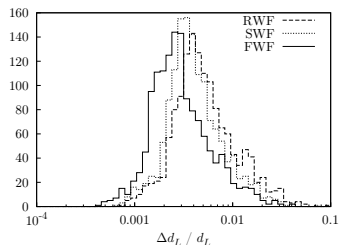
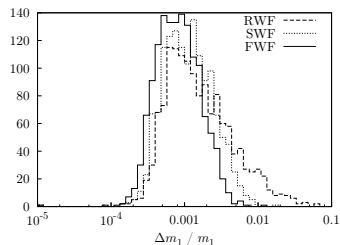
[Arun et al. 2007]

PRESENCE OF DIFFERENT HARMONICS WITH AMPLITUDE MODULATIONS



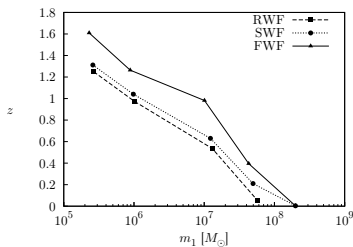
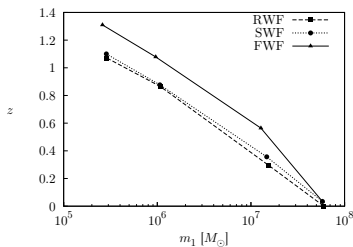
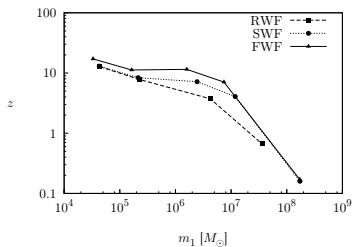
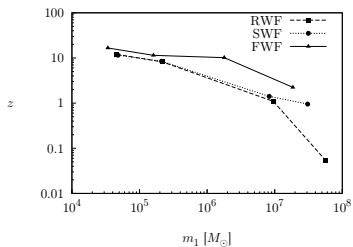
[Trias & Sintes 2008]

SUBDOMINANT HARMONICS AND SPIN-PRECESSION



[AK, Jetzer, Sereno 2009]

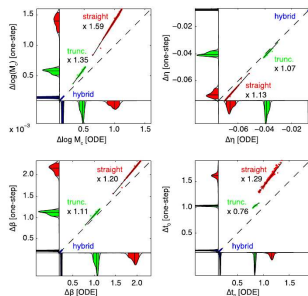
SUBDOMINANT HARMONICS AND SPIN-PRECESSION



[AK, Jetzer, Sereno 2009]

THEORETICAL ERRORS

- Difficult to evaluate, as exact waveform not known
- Increase for lower separation/louder signal
- Best evaluation: Order-by-order comparisons



[Cutler & Vallisneri, 2007]

HYBRID WAVEFORM

Principle: waveform is Series in x and in $\nu = \frac{m_1 m_2}{M^2}$
 \implies BH perturbation theory \longrightarrow first order in ν

Hybrid waveform:

up to 2.5PN spin-dependent

up to 3.5PN spin-independent

up to 5.5PN 1st order in ν .

- Impact of eccentricity/alternative GR - Kerrness params?
- Include merger and ringdown using NR?
- Estimate theoretical errors comparing NR \longleftrightarrow PN?
- Quantify theoretical \longleftrightarrow statistical errors?