# Impact of eccentricity on the gravitational wave searches for binary black holes

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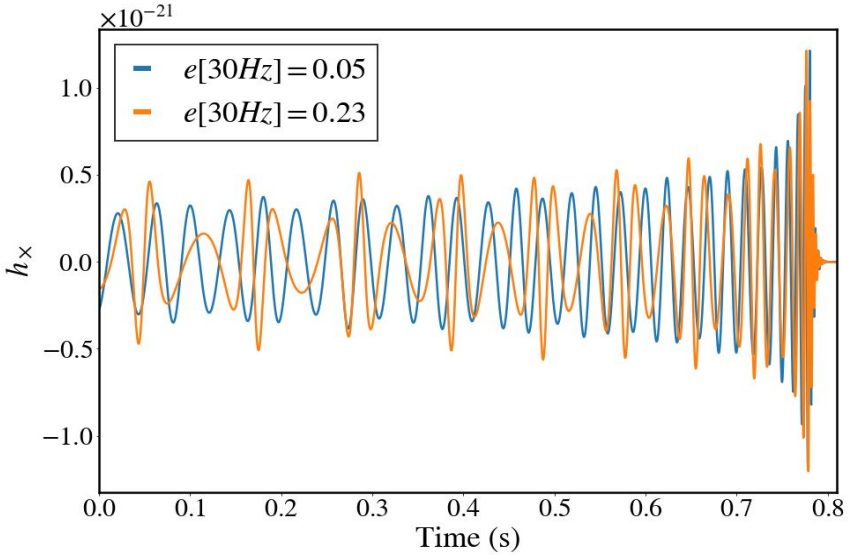
**Abstract:** The possible formation of stellar-mass binary black holes through dynamical interactions in dense stellar environments predicts the existence of binaries with non-negligible eccentricity in the frequency band of ground-based gravitational wave detectors; the detection of binary black hole mergers with measurable orbital eccentricity would validate the existence of this formation channel. Waveform templates currently used in the matched-filter gravitational-wave searches of LIGO-Virgo data neglect effects of eccentricity which is expected to reduce their efficiency to detect eccentric binary black holes. Meanwhile, the sensitivity of coherent unmodeled gravitational-wave searches (with minimal assumptions about the signal model) have been shown to be largely unaffected by the presence of even sizable orbital eccentricity. I will briefly discuss the results of my paper arXiv:2005.14016 [gr-qc] regarding the sensitivity of two different LIGO gravitational wave search algorithm to the full signal of eccentric binary black holes.

# Context of research

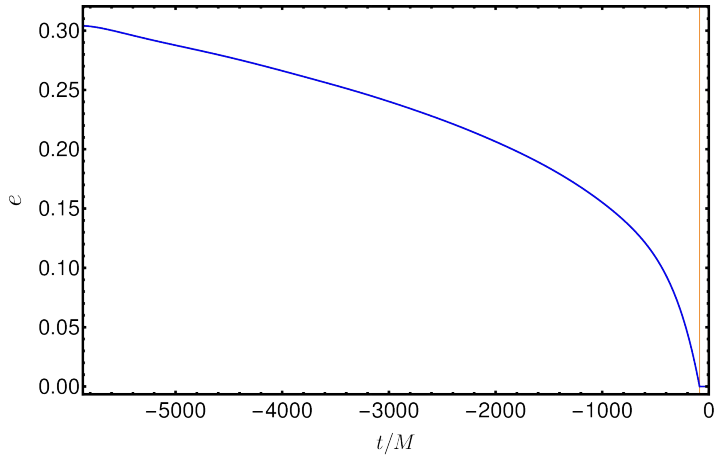
- In the literature several Inspiral-Merger-Ringdown (IMR) eccentric gravitational waveform models exist [Huerta+, Hinder+, Hinderer+, Chiaramello+].
- However, none of those implemented in LIGO Algorithm Libraries. Only inspiral models.

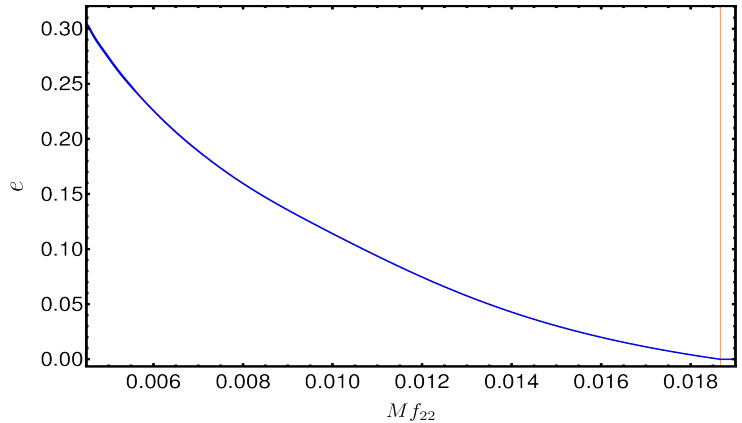
- So far, sensitivity of matched filtered search pipelines only tested with inspiral waveforms so far [Brown+].
- Sensitivity of unmodeled searches has been investigated with a particular IMR eccentric waveform model [Abbot+].
- Impact of eccentricity on the morphology of the gravitational wave (GW) signal. Increase of amplitude and phase modulations due to asymmetric emission of gravitational radiation.



# Description of the work: Sensitivity of GW searches

- For the first time estimation of the sensitivity of PyCBC [Biwer+] and coherent Wave Burst (cWB) [Klimenko+] to full inspiral-merger-ringdown (IMR) eccentric numerical relativity (NR) waveforms.
- Data from chunk 8 of O2. (Both pipelines in O2 configuration settings).
- Eccentricity definition at 30 Hz due to the limited length of the NR waveforms.
- Eccentricity measurement from NR as monotonically decaying function [Ramos-Buades+] :

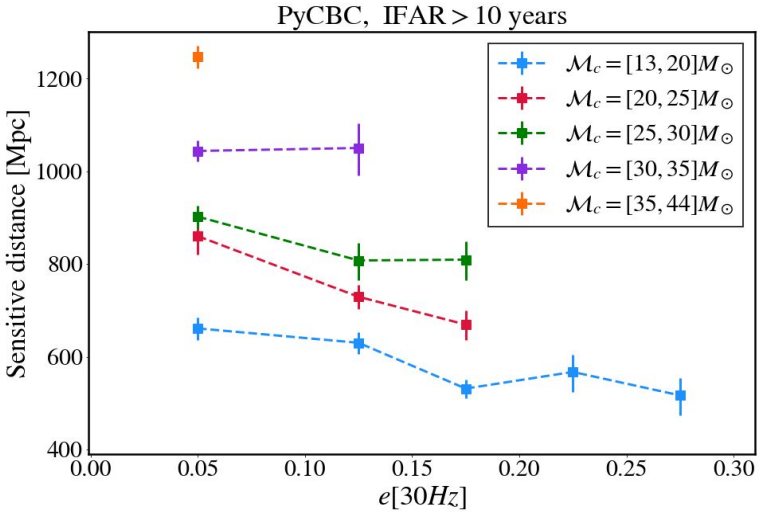


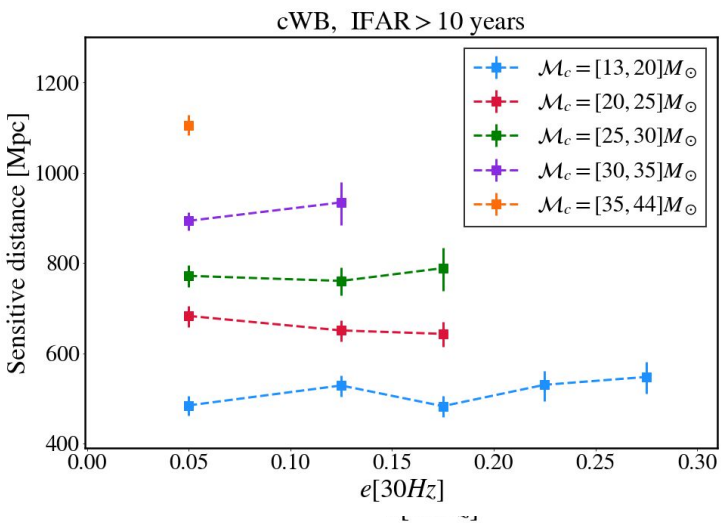




- Injection set includes spinning eccentric simulations with spins aligned with the orbital angular of the system.

# Results: Sensitive distance

- Sensitive distance computed injecting eccentric GW signals.
- Binned in chirp mass and eccentricity. Results at (inverse False Alarm Rate) IFAR > 10 years.

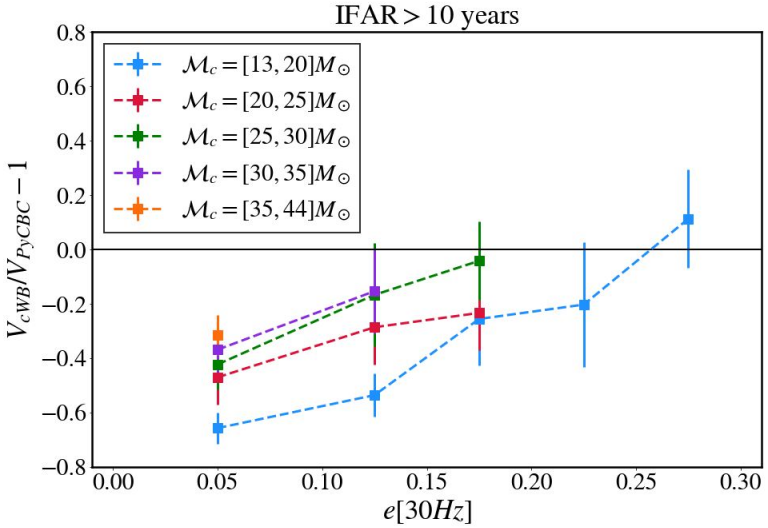


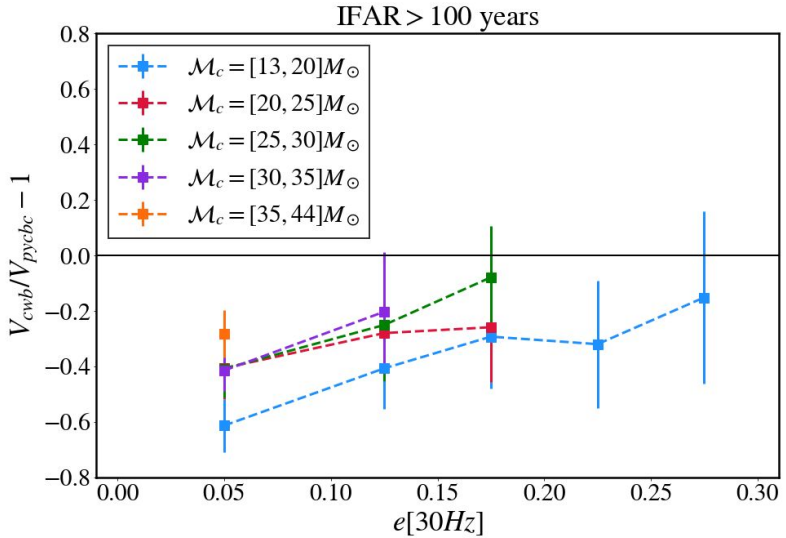




- As expected PyCBC degrades in the low chirp mass bin (more eccentric inspiral).
- Similar behavior at other values of IFAR (see extra slides).

# Results: Comparison in sensitive volume

- Sensitive volume: $V(\xi) = \int_0^\infty f(z|\xi)\frac{dV_c}{dz}\frac{1}{1+z}dz,$ $f(z|\xi)$ prob. of a binary with params. $\xi$ at redshift $z$, averaged over extrinsic parameters.




- cWB improves performance with increasing eccentricity. Major improvement at low chirp mass bin.
- PyCBC recovers accurately at high chirp mass bins.
- At IFAR>100 years similar trend. Overall decrease in sensitivity makes larger error bars.

# Impact and prospects for the future

- Estimated sensitivity of two search pipelines to IMR NR eccentric waveforms.
- Show complementarity of both pipelines to detect eccentric signals for a small part of the parameter space. Low mass parameter space more interesting for searches of eccentric BBHs.

- Caveats:
  - Short length of NR waveforms restricted to relatively high total masses.
  - Small values of eccentricity for spinning cases do not allow to disentangle spin and eccentricity effects.

- Future work:
  - Use eccentric hybrids/IMR waveform models to analyze low total mass systems.
  - Study inclusion of higher order modes for high mass ratio eccentric waveforms.
  - Inject higher eccentricity spinning waveforms, including also spin-precessing waveforms.