BHextractor / PCA Update & Notes

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Things we have going on / I know about

- Continuing BHextractor / Sant-Cugant work
  - 'September paper'
- NR catalogue studies
  - PCAT-style clustering
  - Waveform / parameter Interpolation
- Analytic Catalogue Studies
  - PCA Characterization & Exploration

BHextractor: previous work

- Small (20 waveforms) catalogues (Q, HR, RO3)
- Used all available harmonics, constructed optimally oriented (face-on) waveforms
- PCs computed from truncated, aligned & SNR-scaled waveforms
- Evidence computed in old SMEE matlab script for each catalogue
- No sky-location search, no time-search, no mass-search
- Single IFO
- Reasonable success in distinguishing the more 'distinct' waveforms
- No attempt at parameter estimation; goal was *only* separation of catalogues

BHextractor: Recent / On-going

- N. Mangini (now left): started looking at PCs with complex ($h_+ - ih_\times$) waveforms and handling inclination
- D. Leininger (Glasgow summer): investigated sky-localisation and multi-IFO application
- A. Lombardi (UMass): understand / incorporate search over total mass (amplitude scaling & ∼resampling)
- S. Kimbrell: tentative plan is to repeat & extend Sant-Cugant study using `LALInference` implementation of SMEE. J. Powell working to publish a branch of `LAL` with the SMEE edits.

Note: we also need

1. **careful treatment of orientation & harmonics**
2. a consistent and meaningful way to define catalogues (do we even *want* catalogues?)

Waveform Clustering

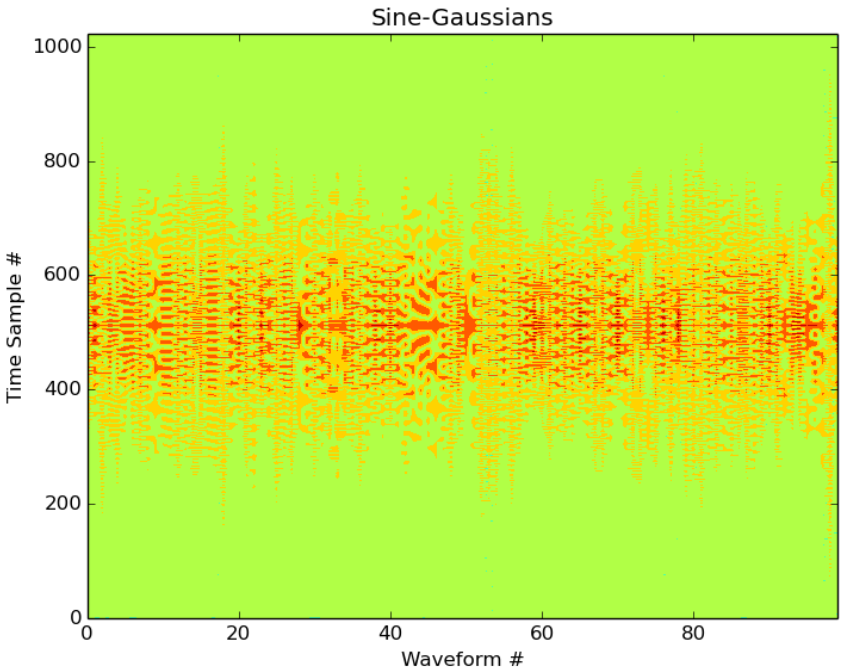
'PCAT': algorithm for glitch classification in detchar:

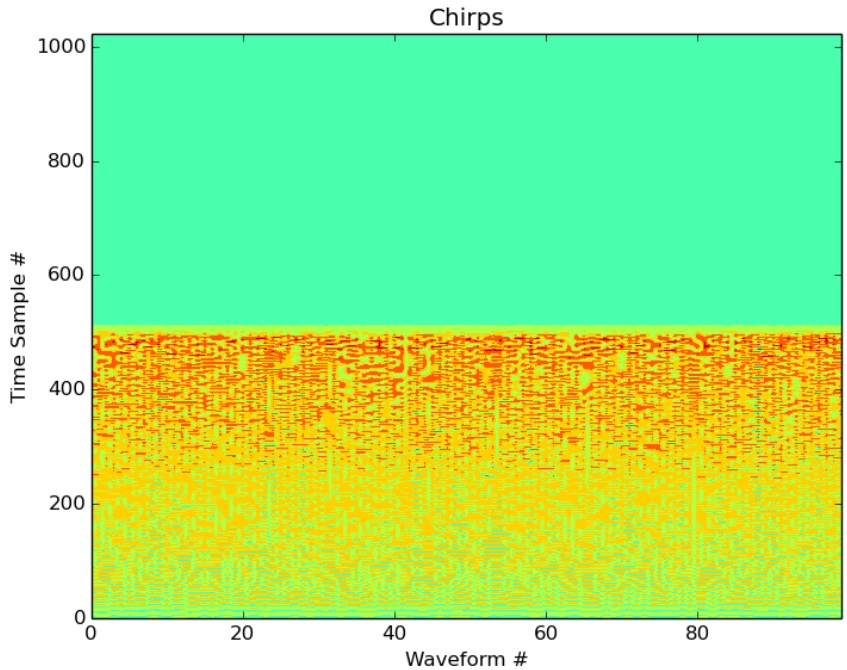
1. Construct a *single* catalogue of all waveforms
2. Perform PCA
3. Use GMM to identify clusters of principle component 'scores'
4. Clusters in PC-score space represent morphologically similar waveforms

So far: prototype script to generate a catalogue comprised of sine-Gaussians & chirps (randomised params), perform PCA / clustering and identify the different families

- *Potential* use in constructing morphologically similar catalogues
- *Potential* use in grouping together similar waveforms for constructing sensible interpolants in PCA-based waveform interpolation ...

Waveform Clustering Demo / Prototype





500 waveforms of each type: algorithm identifies 2 distinct waveform morphologies from clustering the PCA scores with 48/52% membership, using just the first 50 PCs.

PCA & Parameter Estimation / Waveform Interpolation

Finally understand the fundamental idea behind waveform interpolation and connection with parameter estimation!

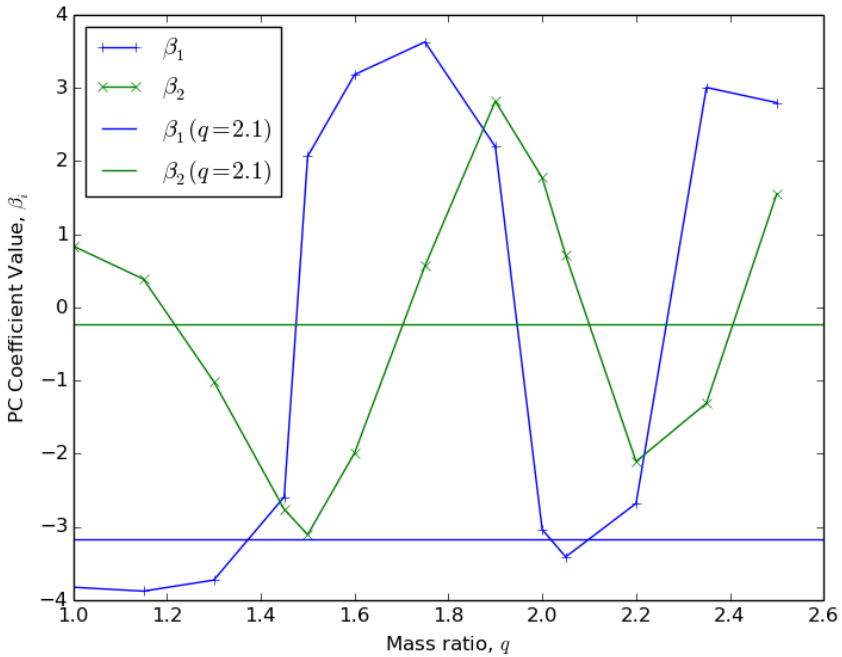
1. Build catalogue of waveforms with varying (say) $q = m_1/m_2$; catalogue: $\{h(t|q_1),\ h(t|q_2),\ \dots\}$
2. Compute PCs U_i and coefficients β_i where waveform is

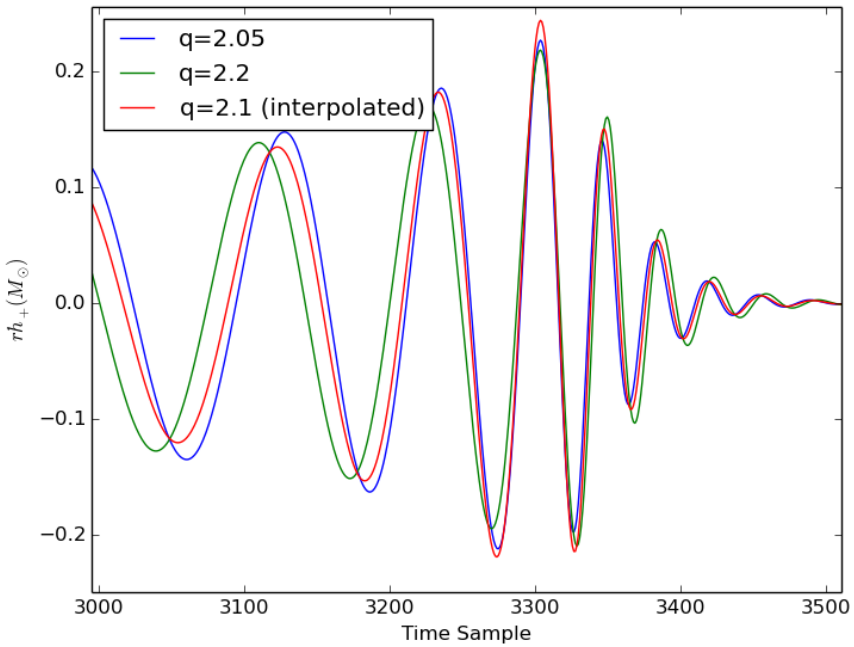
$$h(t|q) = \sum_{i=1} \beta_i U_i \tag{1}$$

3. Realise we can interpolate *each* β_i as a function of q
4. E.g., have discretely sampled $\{\beta_1(q)\} = \{\beta_1(q_1),\ \beta_1(q_2),\ \dots\}$ (and similarly for $\beta_2,\ \dots$)
5. So we can get $h(t|q')$ for arbitrary q' by interpolating $\beta(q)$

PCA & Parameter Estimation / Waveform Interpolation

Example: Q-series has mass ratios
$q = \{1., 1.15, 1.3, 1.45, 1.5, 1.6, 1.75, 1.9, 2., 2.05, 2.2, 2.35, 2.5\}$;
interpolate to find $h(t|q = 2.1)$:





PCA & Parameter Estimation / Waveform Interpolation

- 1-D interpolation between (e.g.) mass ratios ∼trivial
- To be useful, we need multivariate interpolation to handle spins and internal orientation angles
- http://en.wikipedia.org/wiki/Multivariate_interpolation
- See also §8 of arXiv:1402.4146 - seems to be supported in Mathematica, Matlab but still casting around for pythong solutions
- Any local experience / expertise with *tensor product spline interpolation*???
- Note: it may well be useful / necessary to group like-waveforms together, essentially into distinct catalogues, each with their own interpolants; this is the *potential*[1] use of the PCAT-style clustering

[1] no idea if this will be sensitive to different BBH waveforms!

PCA & Parameter Estimation / Waveform Interpolation

Other thoughts / concerns:

- Do we want to be stuck in the time-domain? (The SEOBNR ROMs are F-domain). F-domain is *strongly* preferred for any kind of parameter estimation.
- How can we use PCA & interpolation to identify under-sampled regions of parameter space in NR simulations?
- *What do we do with higher modes & unknown source orientation?*
  - Include orientation in PCA? Seems unfeasible / unnecessary / ugly
  - PCA & interpolants for *each* mode?

Where Next / Plans

- Sant-Cugant study using LALInference implementation of SMEE
  - will get evidence for 'catalogues' and posterior samples for β_i; can we say something useful using these without going as far as waveform interpolation?
- 'September paper': overhaul of Sant-Cugant study
- Clustering: tidy up demo script, understand and charaterise clustering behaviour, apply to BBH waveforms
- Interpolation: understand implementation of tensor spline interpolation
  - Call to be scheduled with J. Veitch next week to talk about what we could do
  - Particularly interested in identifying under-sampled regions of parameter space to guide NR simulations
  - B. Day's studies with EOBNR & PCA could be a good test-bed for interpolation studies

Wavelets?

Maybe something useful to do with wavelet scaleograms (a la 'eigenfaces')?
Left side: Q-series, face-on; Right side: RO3-series, edge-on