Compact Binary Coalescence searches – from past to future

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INSPIRAL
UPPER LIMIT
I-M-R
DETECTION
POPULATION
INFERENCE WITH
MARGINAL EVENTS
"NON-STANDARD"
CBC SIGNALS
imgflip.com

Where we came from

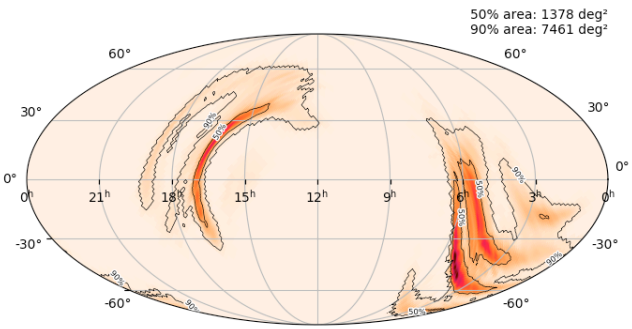
- Initial LIGO/Virgo (up to ~2007)
  'Inspiral Upper Limit' working group
  - no spinning or massive BBH templates ..
  - no capability for high detection confidence ..
  - several months to produce search result ..
- Enhanced LIGO/Virgo (2009-10)
  Blind Injection Challenge
  - detection confidence challenge met 'in principle'
  - unmodelled ('burst') search methods
  - ~weeks to produce batch result

Recent state of the art

- Advanced LIGO/Virgo (2015-16-17)
  - full space bank intended to cover (aligned spin) BNS, NSBH, high mass BBH, IMRI ...
  - searches run online but ‘deep’ results take weeks/ months
  - high detection confidence achieved ‘routinely’
  - ‘simple’ population analysis : Bayesian probability of event being signal vs. noise given (measured) rate of BBH events & simplistic mass model

“O3 is here”

- Searches running online for EM followup
  - detection confidence, sky maps, source identification (NS / BH) ...
- Good multi-ifo coverage (mostly)
- Order 30-50 (?) BBH expected over O3
  many will be ‘marginal’ (low significance)
  ... including the most distant
- So far no clear detection of NSBH/IMBH/IMRI/ eccentric binary/ ...



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Towards 3G

- Heavy BBH visible with high SNR up to very high redshift
  - probe entire star formation history
  - event rate ~1 per 100s of seconds ..
- BNS are quieter
  - will all be detected or only ‘well oriented’ ones?
  - ‘early warning’ (see DAC session)
- search becomes just pre-processing for parameter estimation ?

Open issues in CBC search

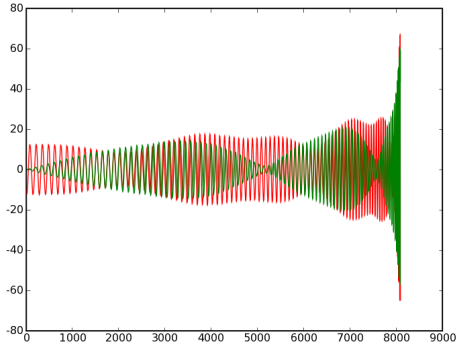
- Highlight a few things with more or less science impact
- Some nontrivial differences between ‘LVC’ and ‘IAS’ searches
- What needs to be done over next N years?

Data ‘cleaning’ and pre-processing

- LVC : data quality vetoes
  - currently only remove bad data if instrumental cause is understood
  - searches ‘deal with’ the rest via ‘gating’ very loud glitches, chi^2 tests, fitting out background tails ..
- IAS :
  - several iterations of data cleaning to remove ‘moderately loud’ things in *h(t)*
  - very stringent signal consistency tests
  - resulting search output closer to Gaussian ...

Set(s) of templates used

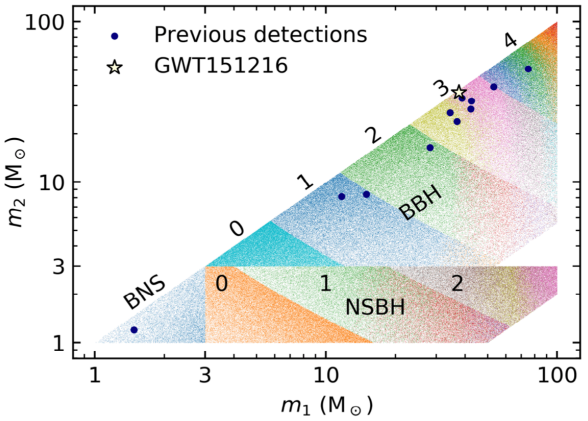
- Precession
  - can detect systems that are ‘weakly’ (invisibly?) precessing
  - what about strong modulation?



- Subdominant modes
  - increasingly important for ‘interesting’ events: IMBH- or IMRI-like
- Eccentric binaries?
- Matter effects? (e.g. disrupting NSBH)

Searches meet GW populations

- Optimal event ranking to maximize detections is the *ratio of signal to noise event densities*
- Depends on mass/spin distribution of signals!
  - LVC ‘assumes’ equal signal rate per template
  - IAS search bins implicitly rank high mass BBH much higher
- Search priors ?
- Joint inference on signal probability plus GW population ?



Invert the problem : DeepLearning

- All CBC searches so far use ‘classical’ methods
- ML / DNN : feed the network many examples of input & desired output, ‘train’ to match output by adjusting millions of parameters
- Typically *very* fast to evaluate once trained
- Scaling to full search space & weeks/months of real data currently unclear

Conclusion

- CBC searches are not finished yet
- First detections only ‘the end of the beginning’
- Systems detected so far are ‘easy’ for existing techniques : suspicious ?