PyGRB: A Targeted, Coherent CBC Search in PyCBC

Andrew Williamson

Postdoctoral Fellow
Institute of Cosmology and Gravitation
University of Portsmouth

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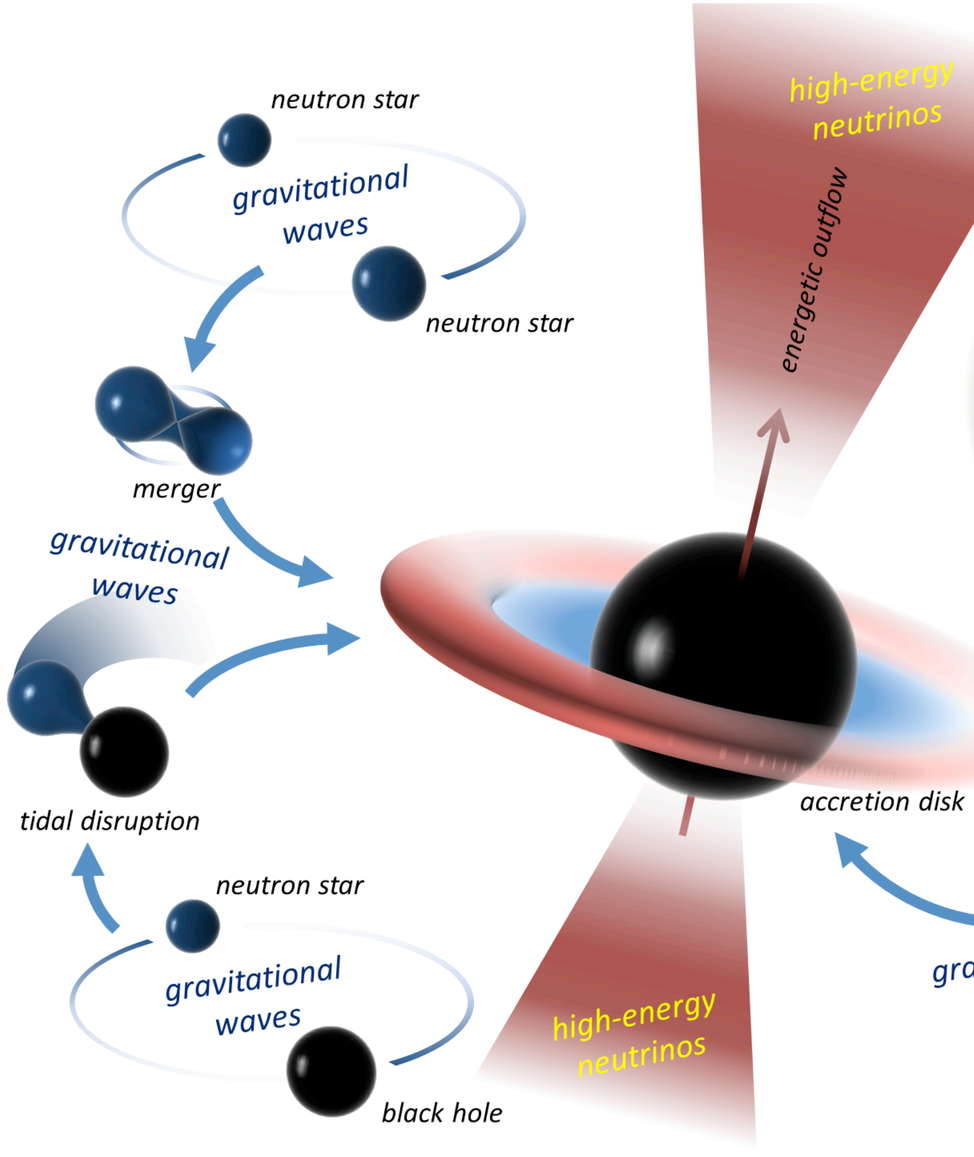
Why ‘PyGRB’?

- Short GRBs are believed to be generated by binary mergers involving at least one neutron star (NS) with perhaps a black hole (BH) companion
- Seeing a short GRB might tell us a GW could be hiding in our data!
- BUT in principle this method could be used for whatever you want to follow up.

Credit: I. Bartos



Why Targeted?

- ‘Standard’ matched filter searches will analyse all available data from GW detectors and look for ‘coincident events’ — times where there are significant events above some threshold in multiple detectors

- They consider the whole sky; they allow for any physically allowed time offset between data streams (e.g. ≤±10 ms for the LIGO sites)

- There may be occasions when we want to target a particular time and/or point(s) on the sky — e.g. if a gamma-ray burst (GRB) or fast radio burst (FRB) has been observed

- This reduces the period of data analysed and reduces the combinations of data streams that contribute to the background

Why ‘Coherent’?

- ‘Coincident’:

  1. Filter each detector’s data separately

  2. Compile lists of above threshold triggers

  3. Look for coincidences across detectors then perform chi-squared tests, etc.

- ‘Coherent’:

  1. Take each template and project it onto the network of detectors and filter them together

  2. Perform signal consistency checks on above threshold triggers that make use of the requirement that any candidate signal looks coherent over the network

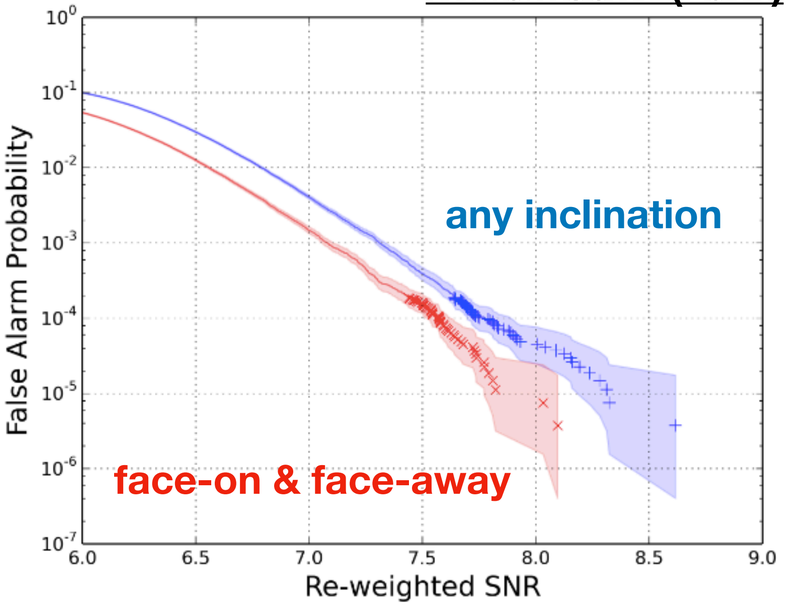
Other Constraints

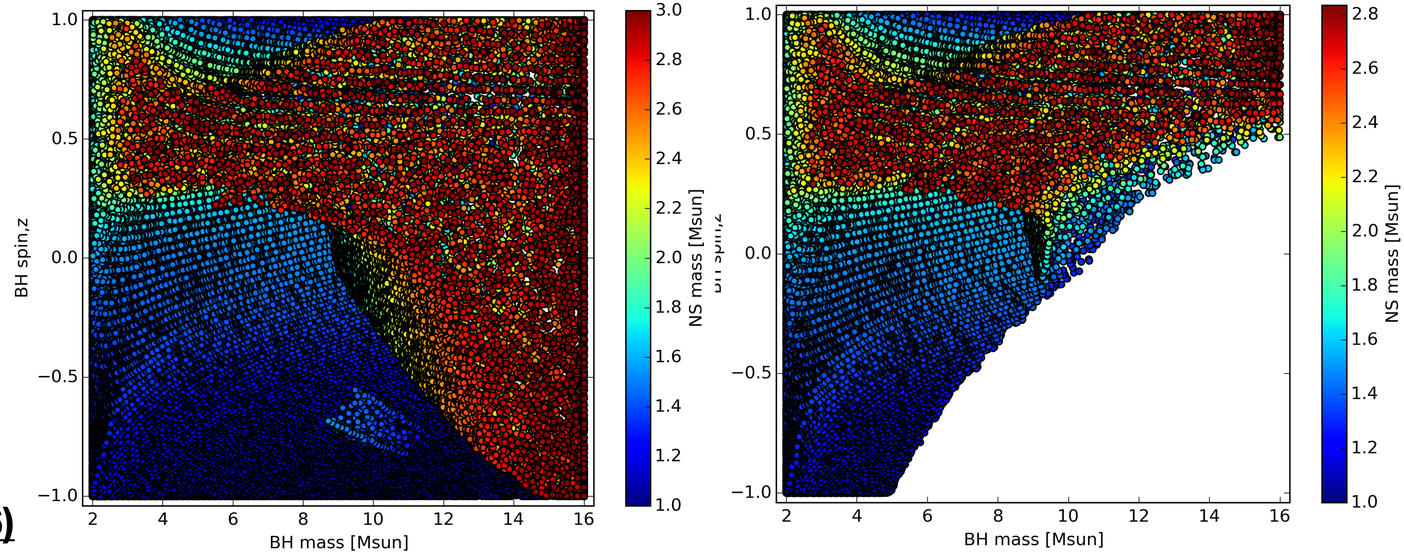
- GRBs are beamed; we can reduce the inclination degree of freedom and filter with only face-on and face-away templates

- We don't care about BH-BH mergers, nor NS-BH mergers without NS disruption = reduced template bank wrt standard pycbc analysis

- **All these elements result in greater sensitivity!**

Williamson+ (2014)

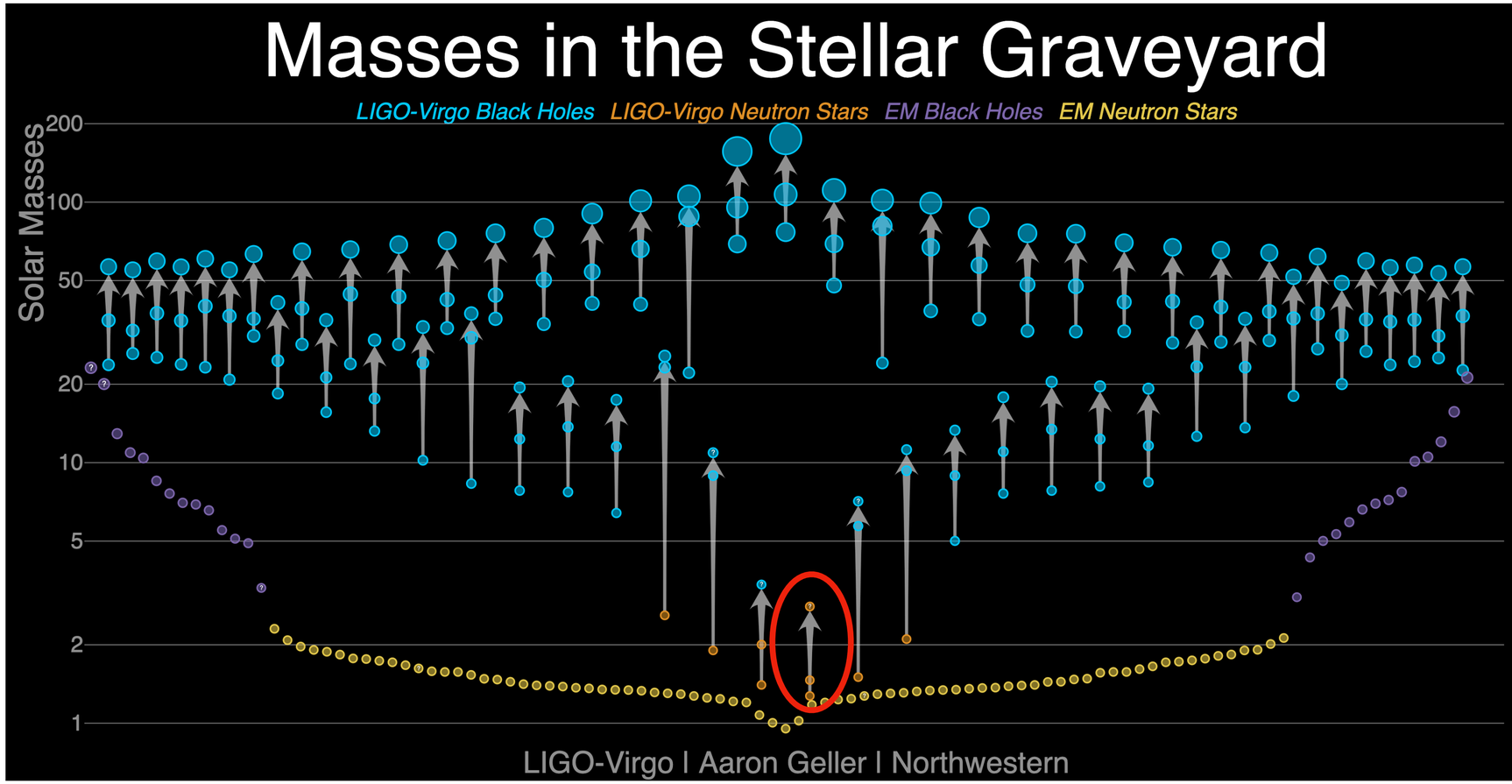




Williamson (2016)

Why ‘Coherent’?

- A coherent search can be more sensitive but this comes at computational cost
  - 10% boost in sensitivity = detection rate increased by 1/3
  - 25% boost in sensitivity = detection rate doubles



GWTC-2.1: Only a few NS binaries, only 1 with EM counterpart

PyGRB at t ≤ O3

- For every external trigger (i.e. GRB) we search a window of time for a candidate, and get a p-value

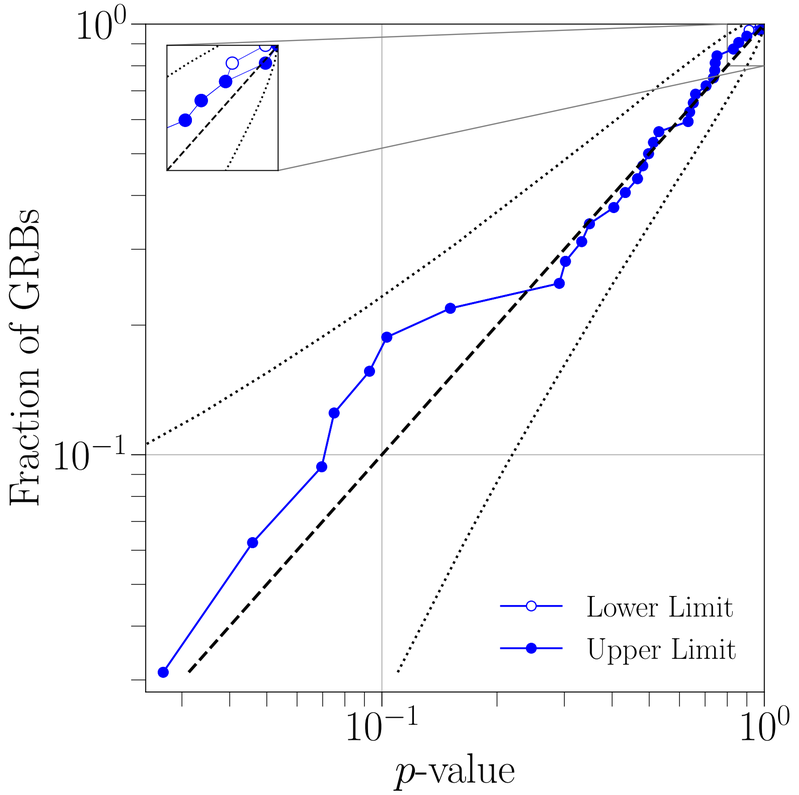
- In the absence of a signal we can place lower limits on distance to the progenitor (assuming a signal model)

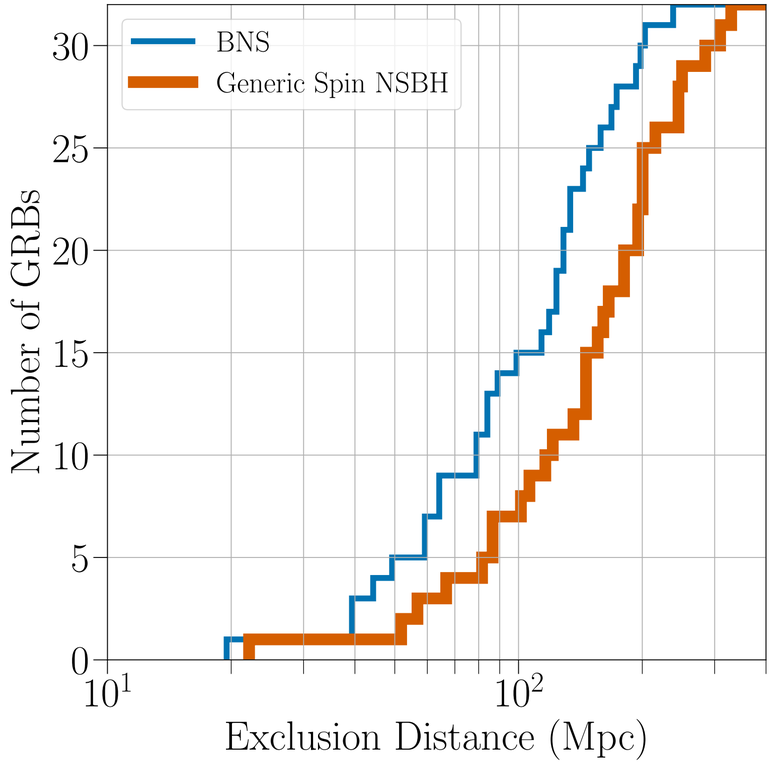
OPEN ACCESS

The Astrophysical Journal, 915:86 (16pp), 2021 July 10

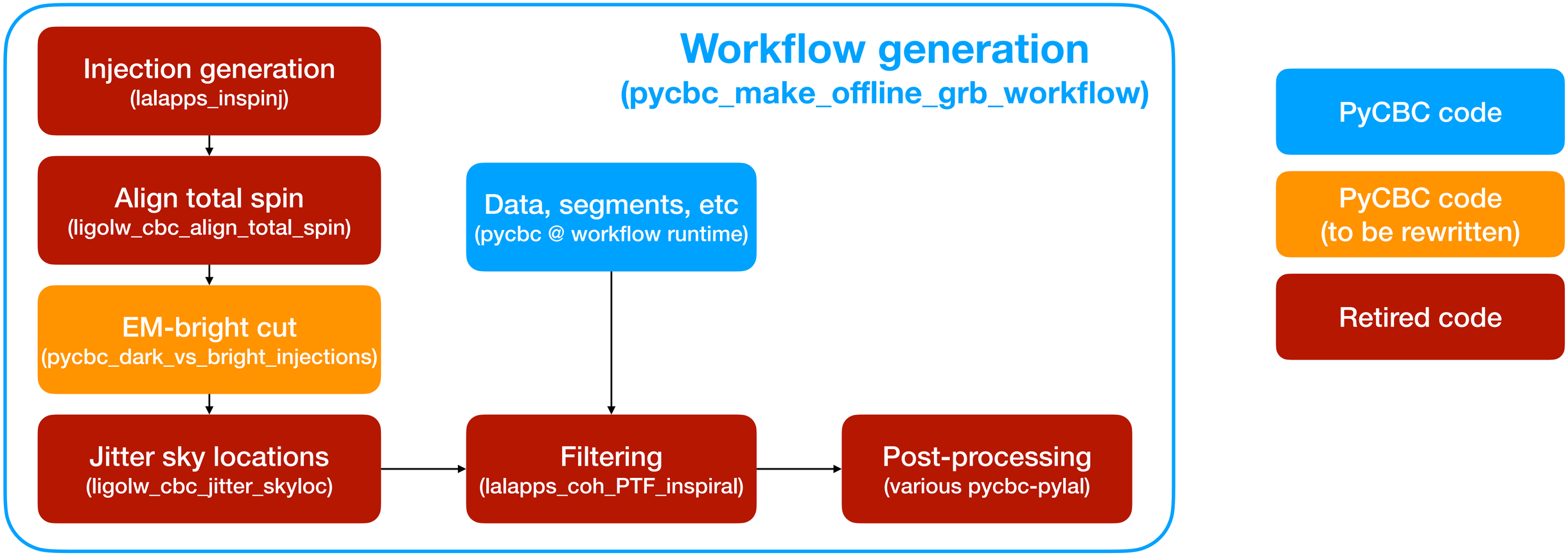
https://doi.org/10.3847/1538-4357/abee15

Search for Gravitational Waves Associated with Gamma-Ray Bursts Detected by Fermi and Swift during the LIGO–Virgo Run O3a

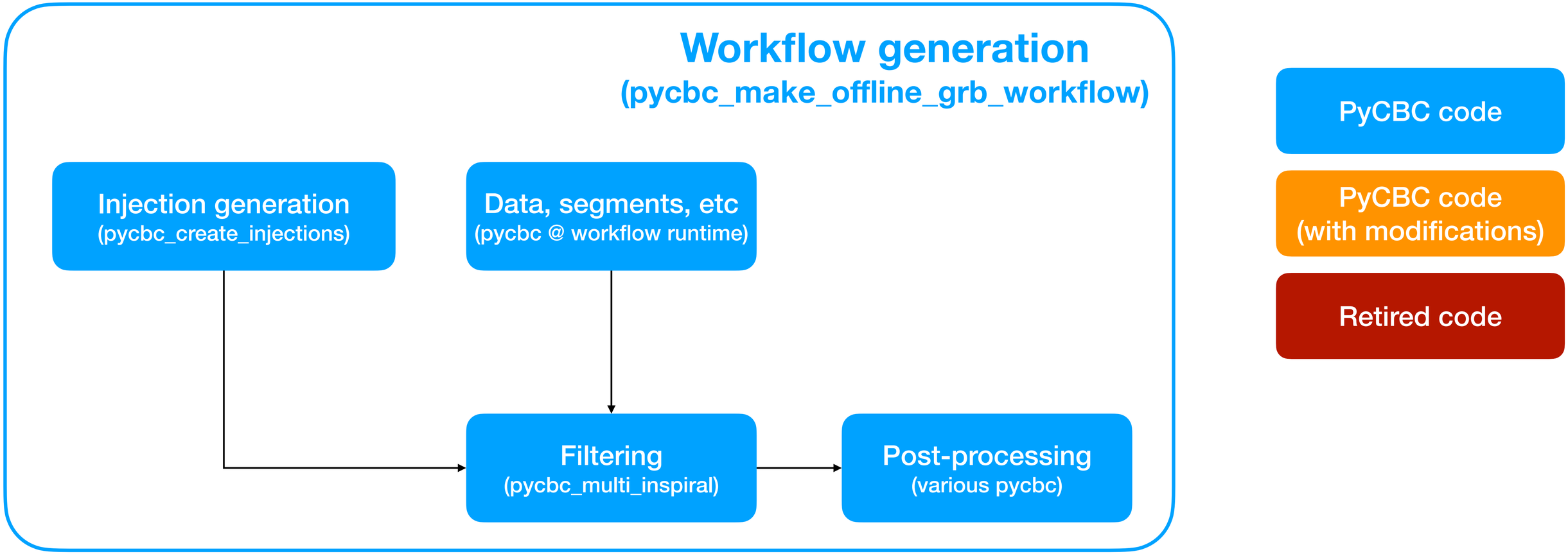




O3 PyGRB Pipeline



O4+ PyGRB Pipeline



O4 Development Tasks

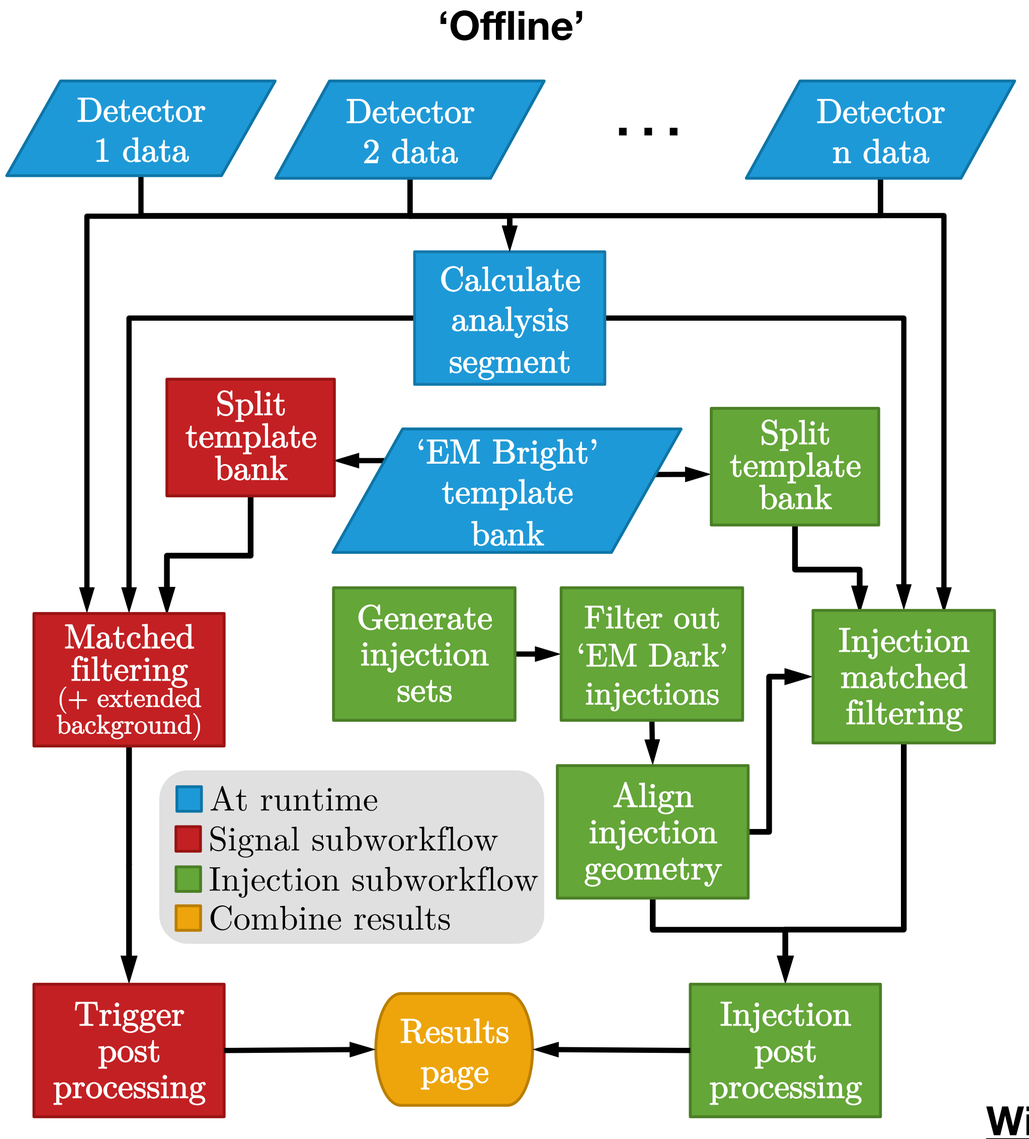
Development wiki page:
https://github.com/gwastro/pycbc/wiki/PyGRB

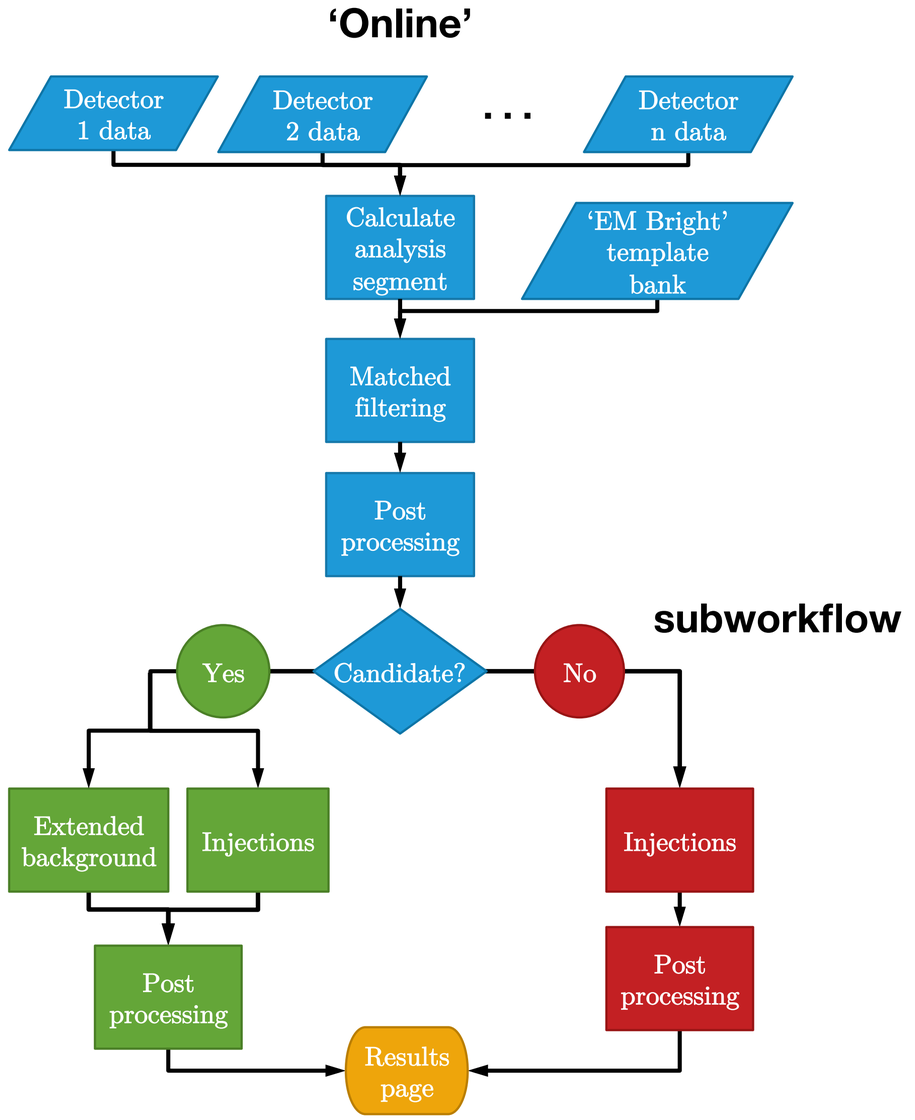
Development task	Assignee
Filtering face-on/-away projections	Jam Sadiq
Chi-sq test implementation	Jacob Buchanan
Detection statistic tuning	Jam Sadiq
Injection Code	Sam Higginbotham, Andrew Williamson
Post-processing	Francesco Pannarale, Cameron Mills
Time slides for background	
Sky tiling / clustering	

- **We need volunteers for tasks (small or large)**
- **Please let us know if you are interested in contributing!**

andrew.williamson@port.ac.uk

A low-latency PyGRB workflow





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