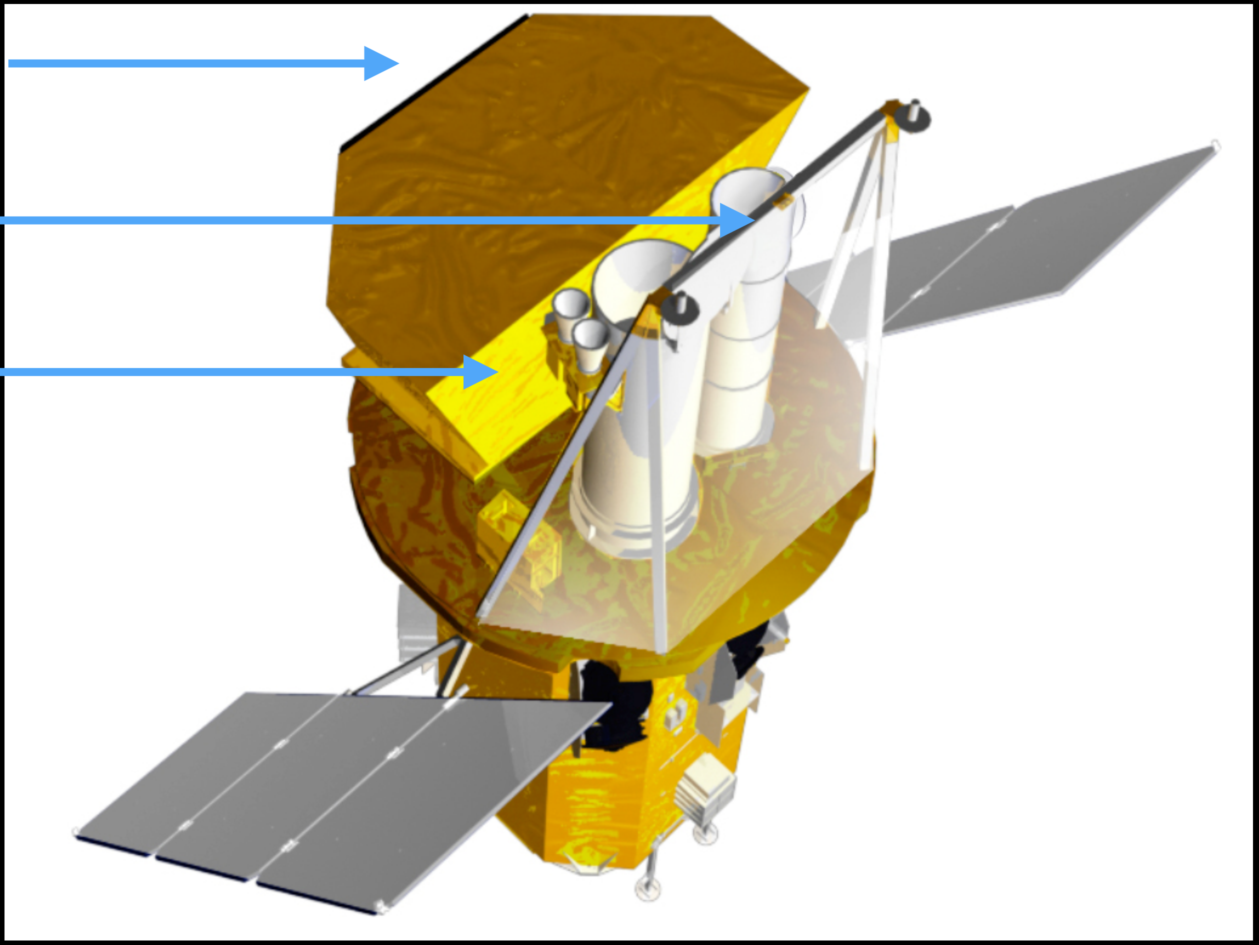
Multimessenger astronomy with Swift: results and prospects

Phil Evans, Jamie Kennea, et al.



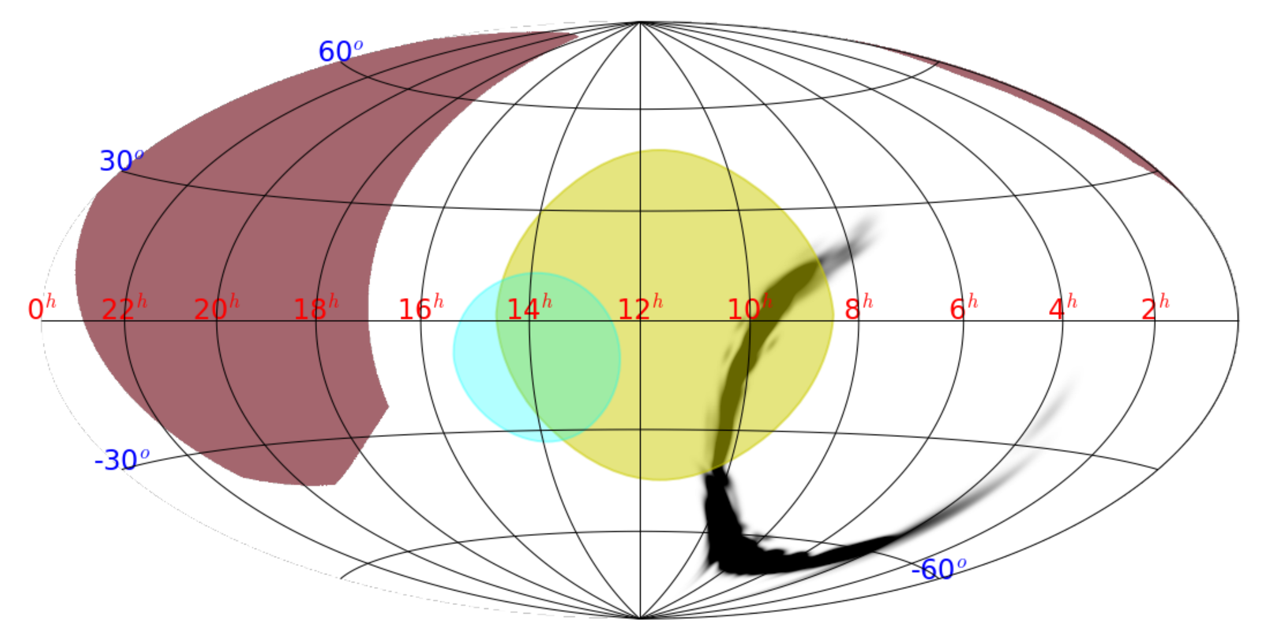
BAT (hard X-ray, trigger instrument)

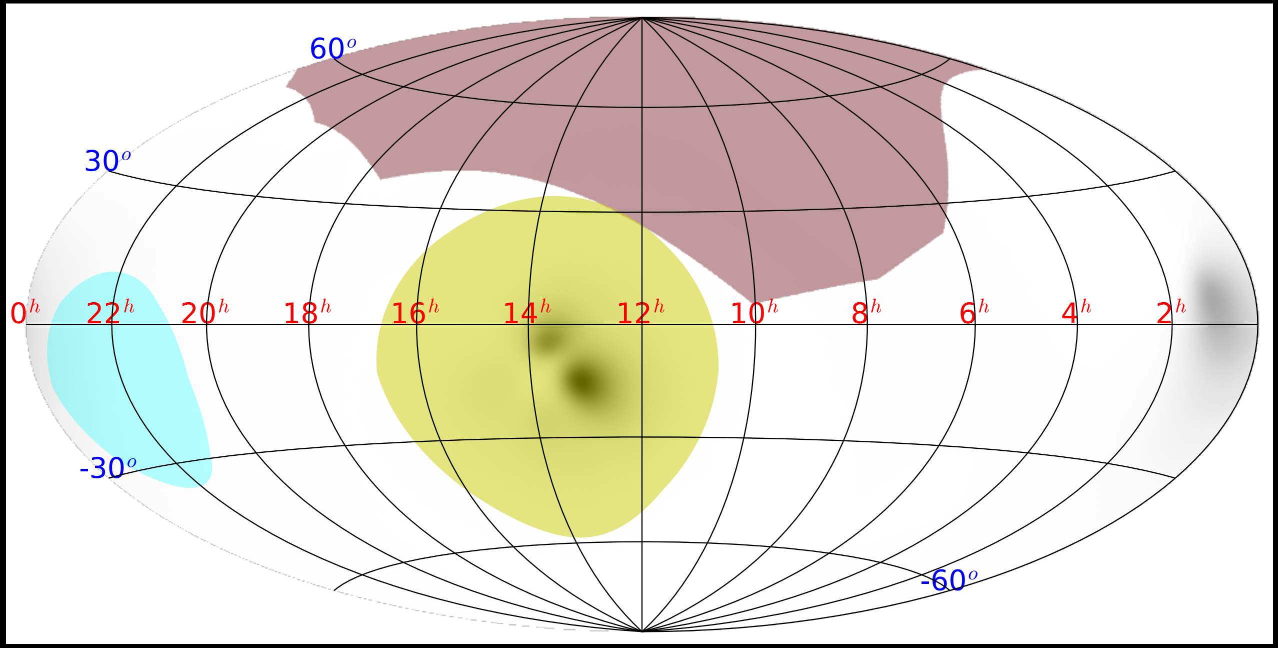
UVOT (~1900-7000 Å)

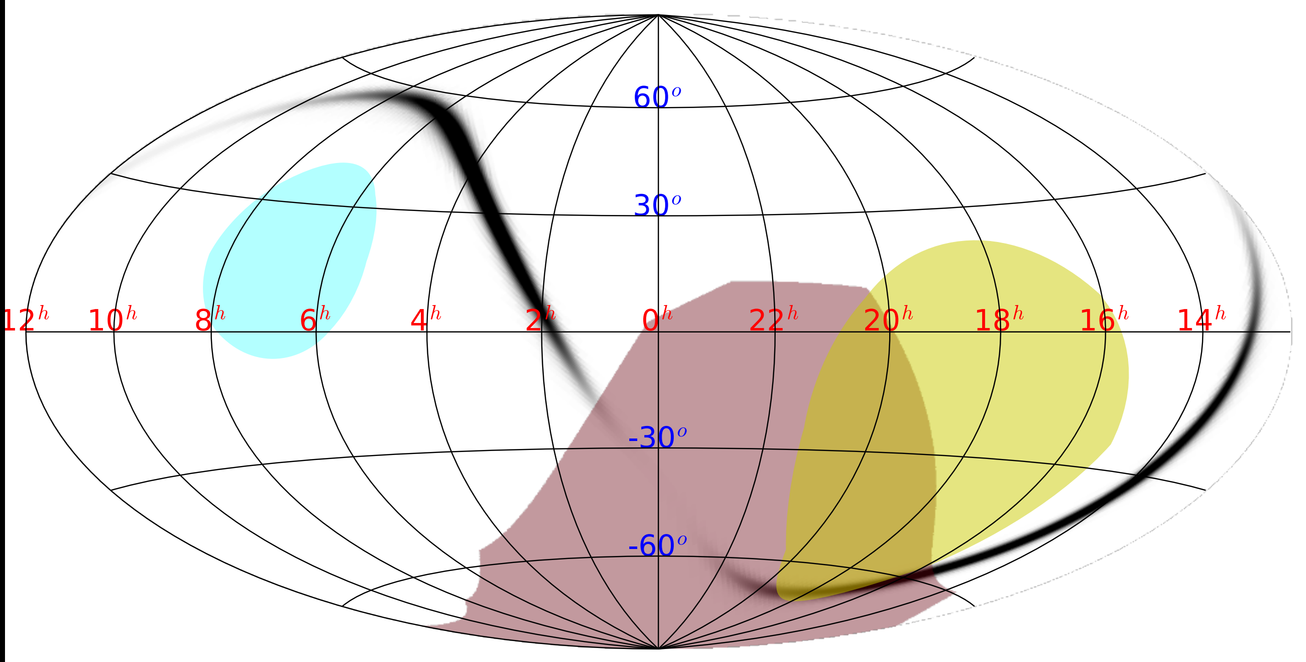
XRT (0.3-10 keV)

Evans et al., 2016, MNRAS, 455, 1522
MNRAS, 460, L40
MNRAS, 462, 1591

BAT + LVC trigger unlikely







Evans+ 2016c, MNRAS, 2016, 462, 1591

Follow up with XRT

Rate of serendipitous X-ray transient probably low (e.g. 1 per 1.6 Ms per Swift fov, Evans+ 2016a).

Many expected GW transients should have some X-ray emission.

- ‘CBC’ pipeline:
  - Short GRBs (prompt and afterglow)
  - Off-axis GRBs (afterglow)
- ‘Burst’ pipeline:
  - SN shock breakout (e.g. SN2008D)
  - SGR flares
  - Isolated NS collapse.

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When and how bright?

Follow up with XRT

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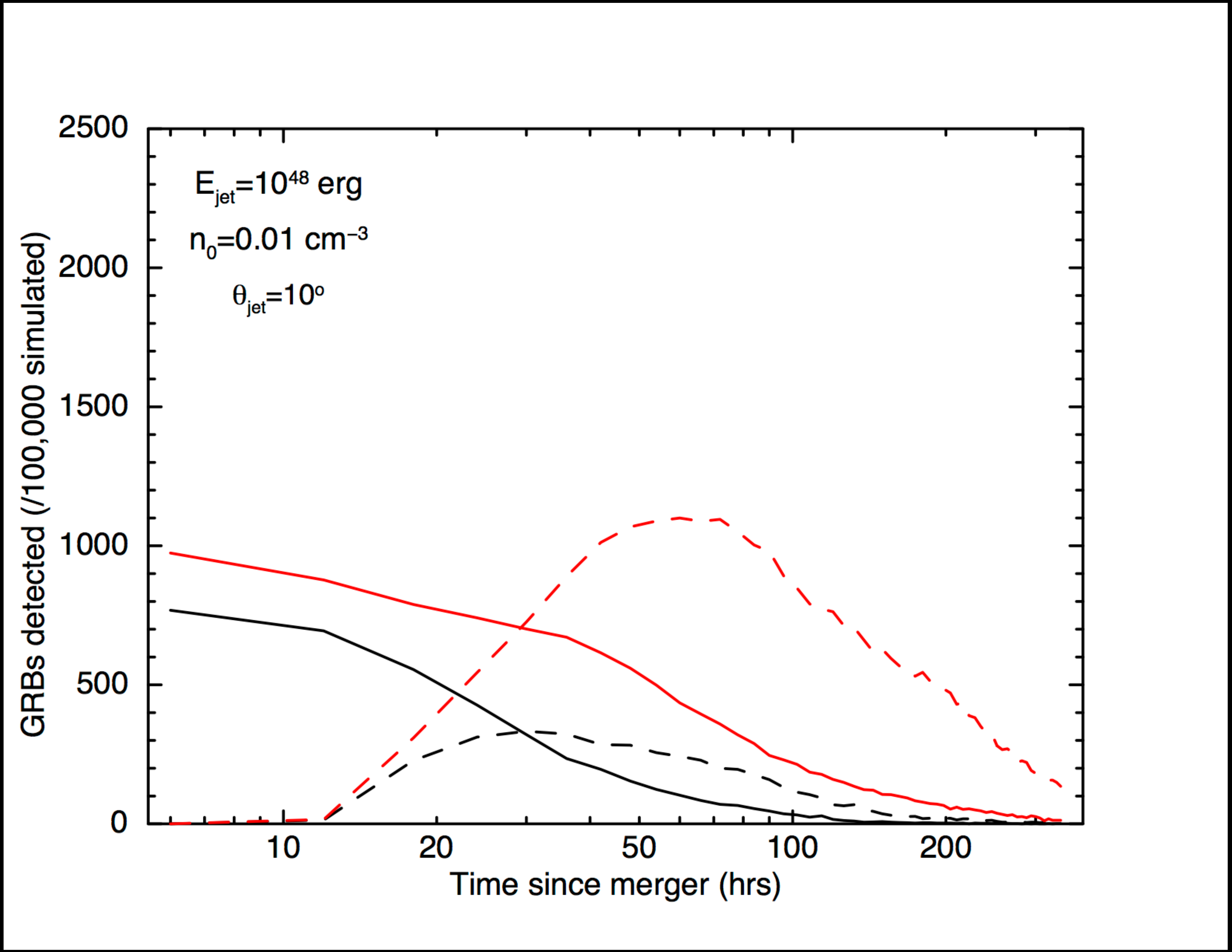

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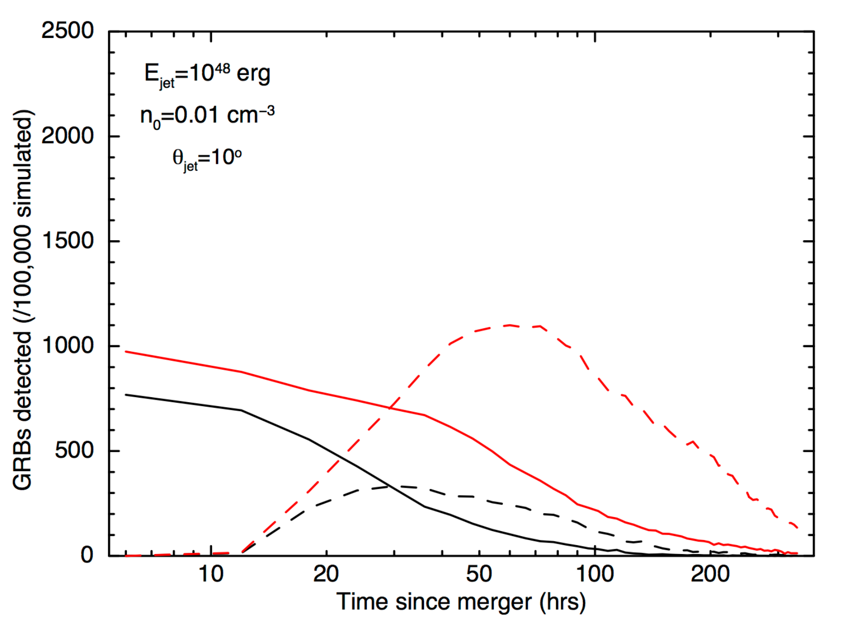
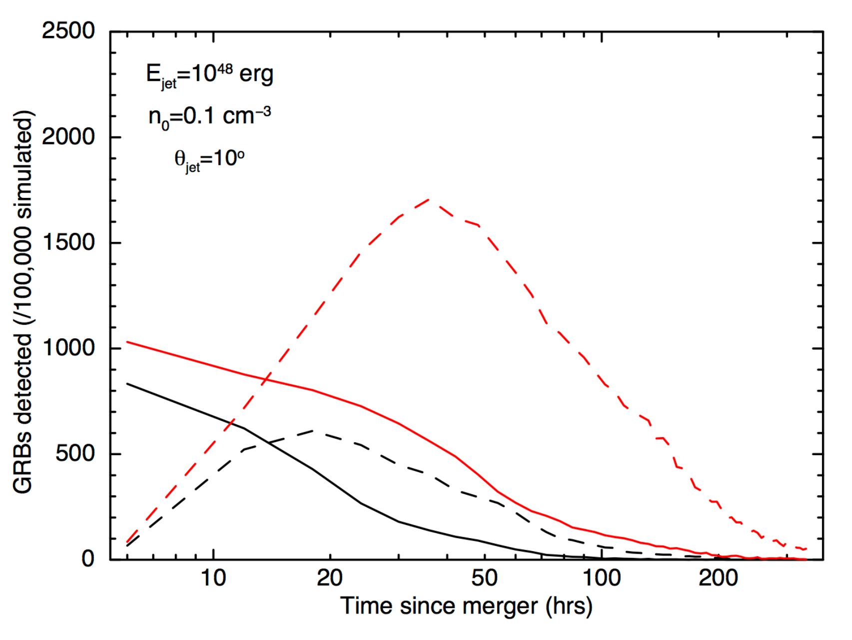
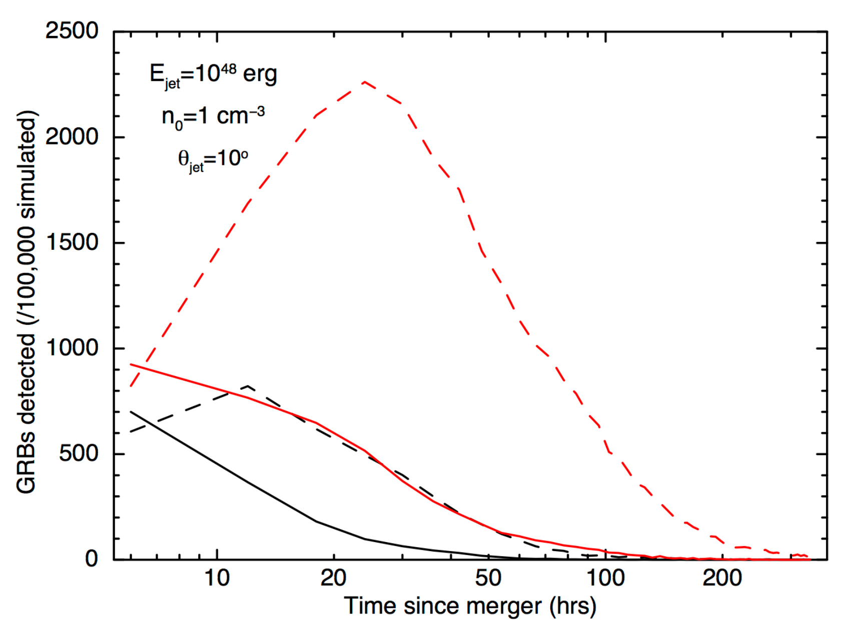
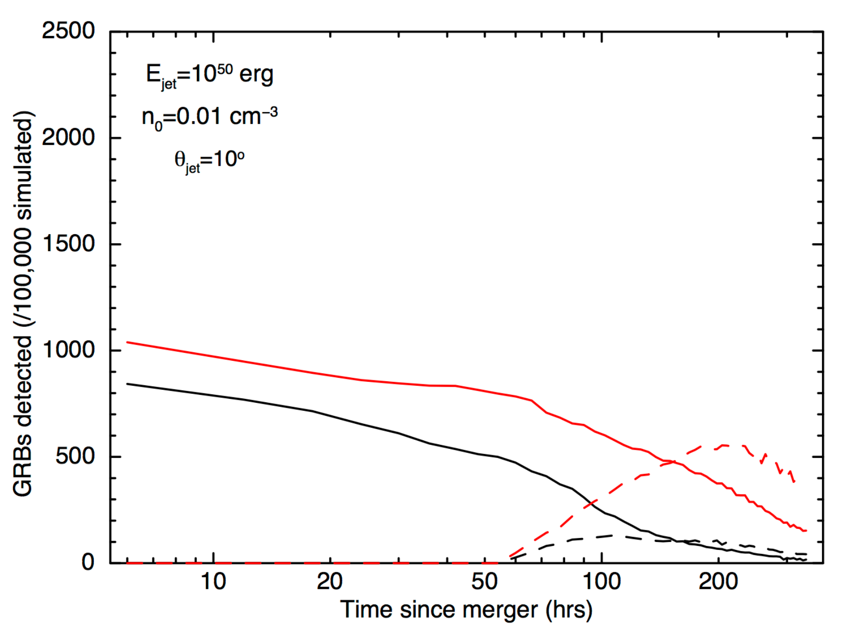
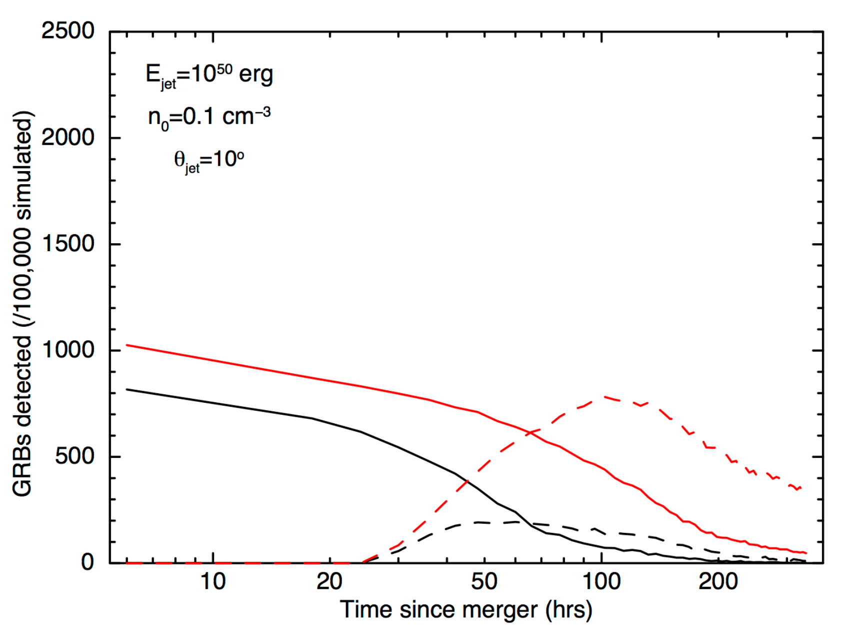
10° jet





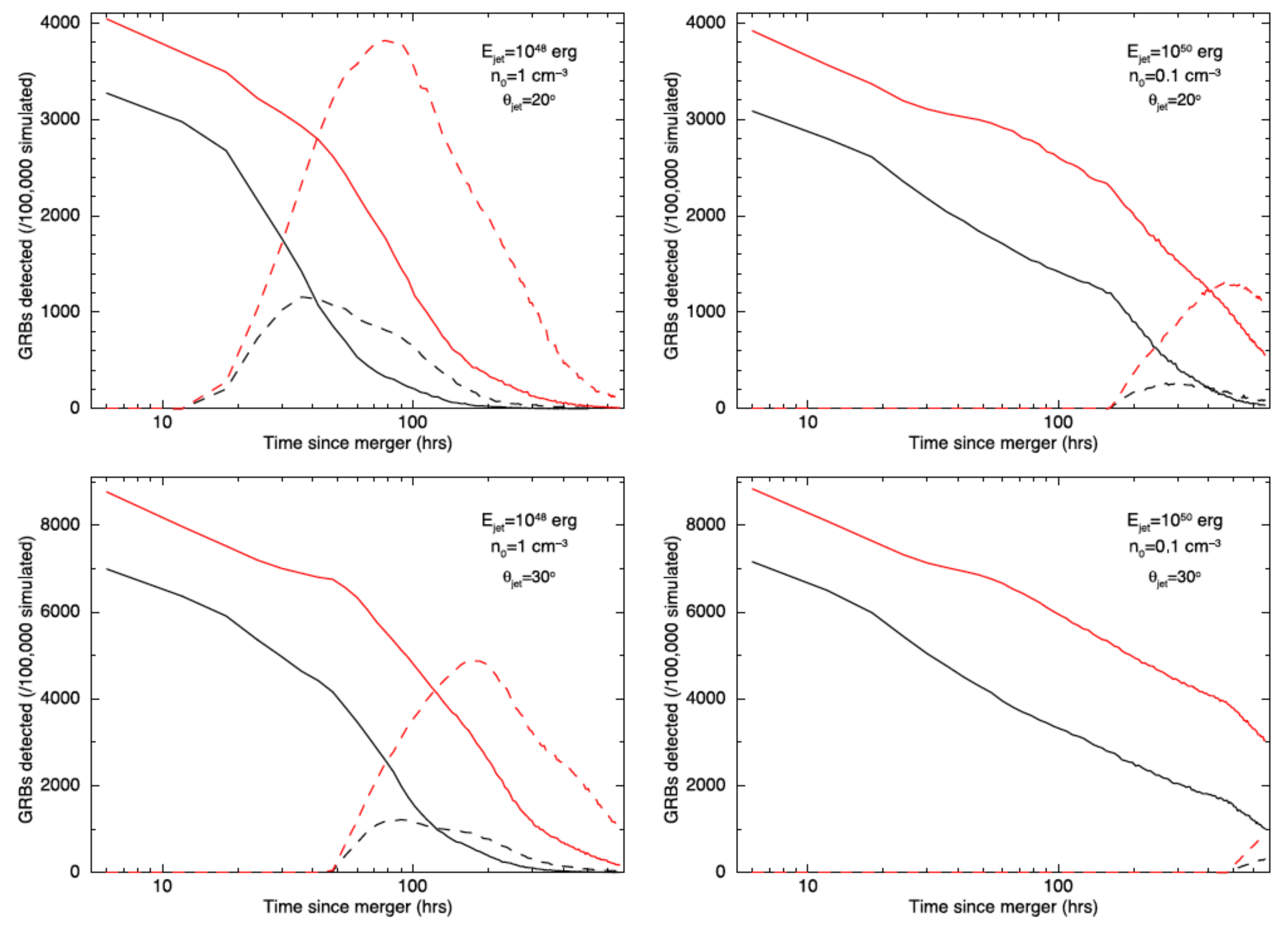






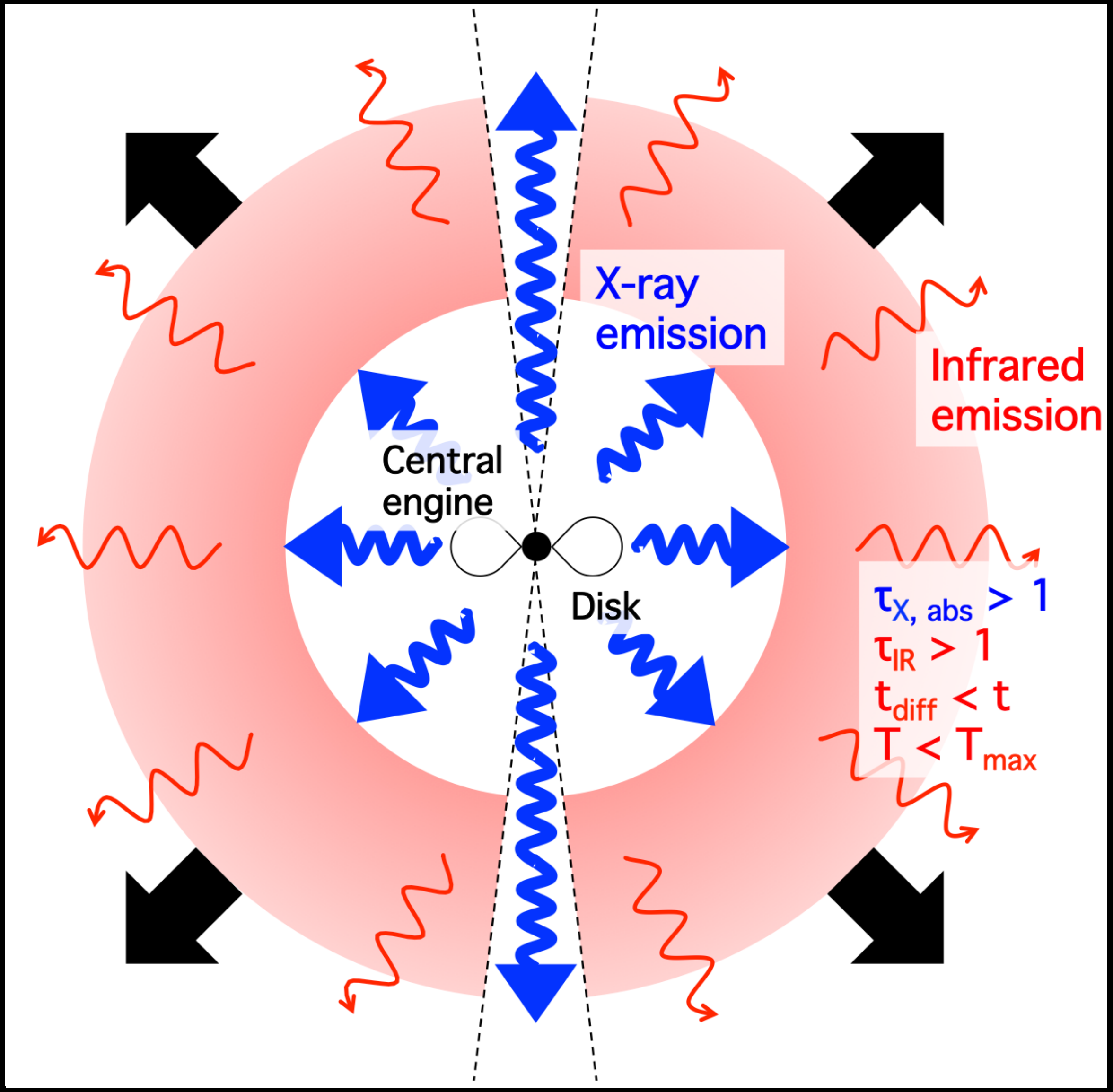
Evans+ 2016a

30° jet



Evans+ 2016a

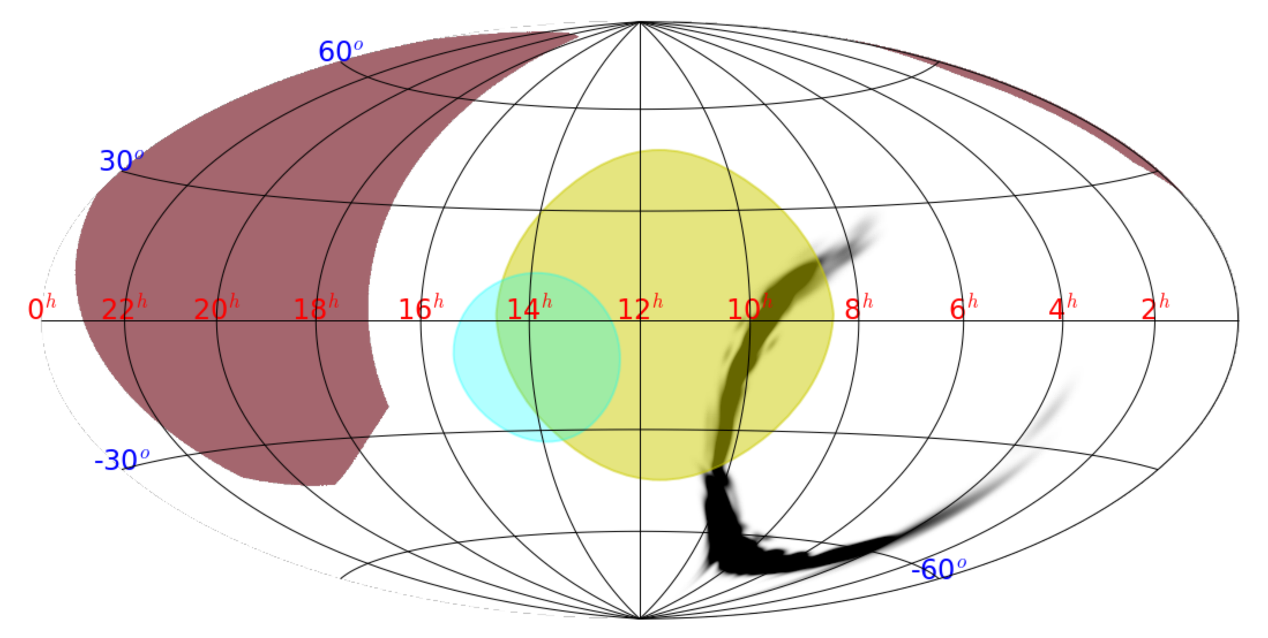
Isotropic X-rays from sGRBs?

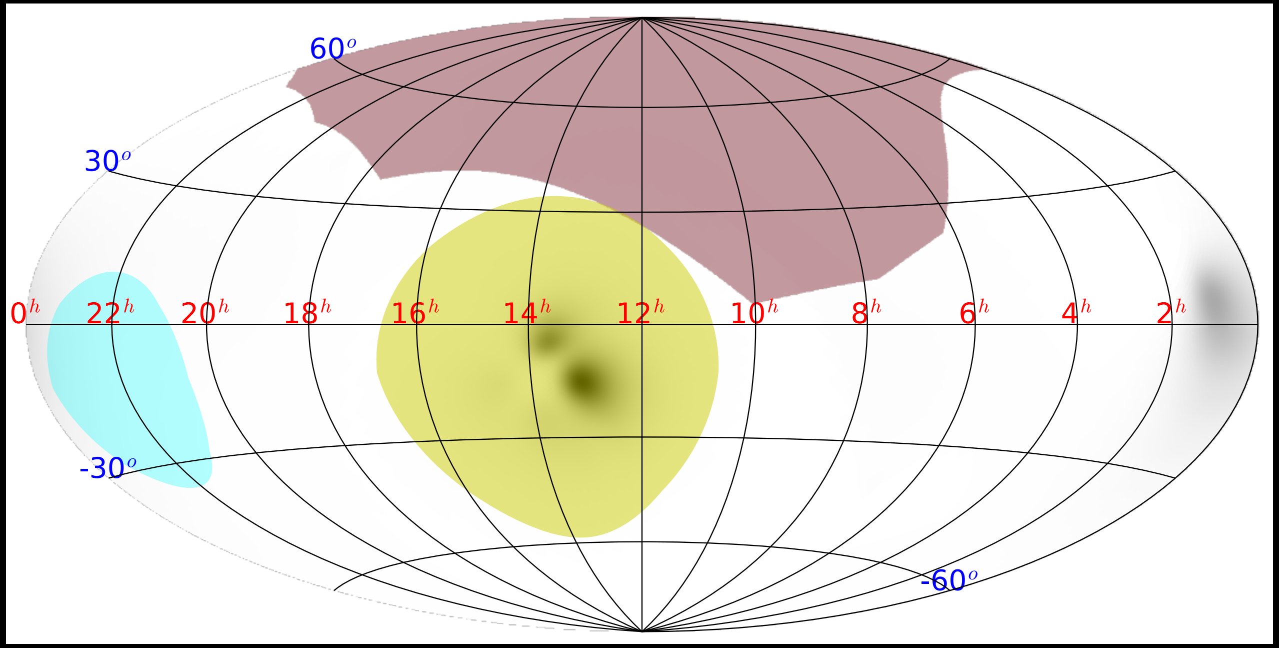


The ‘kilonova’ GRB 130603B, had an X-ray bump coincident with the IR bump (Fong et al., 2014).

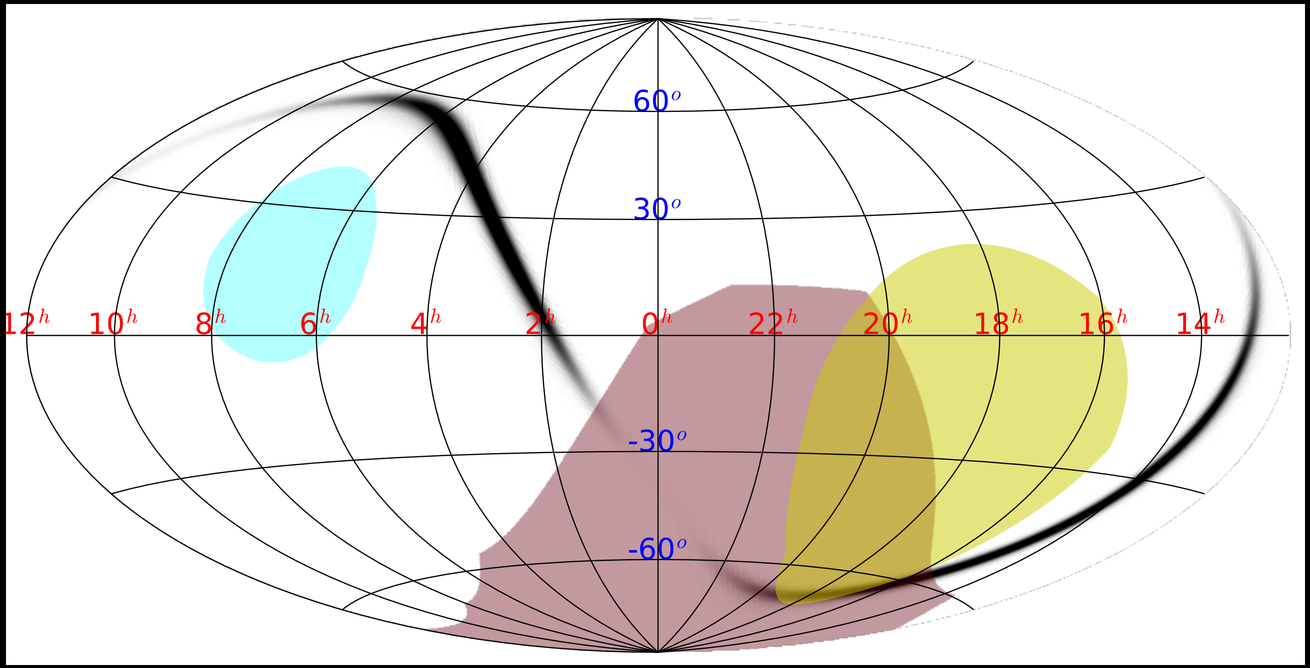
Kisaka, Ioka & Nakar (2015) suggested that the KN is powered by isotropic X-ray emission: a boon for GW follow up!

But it’s hard…

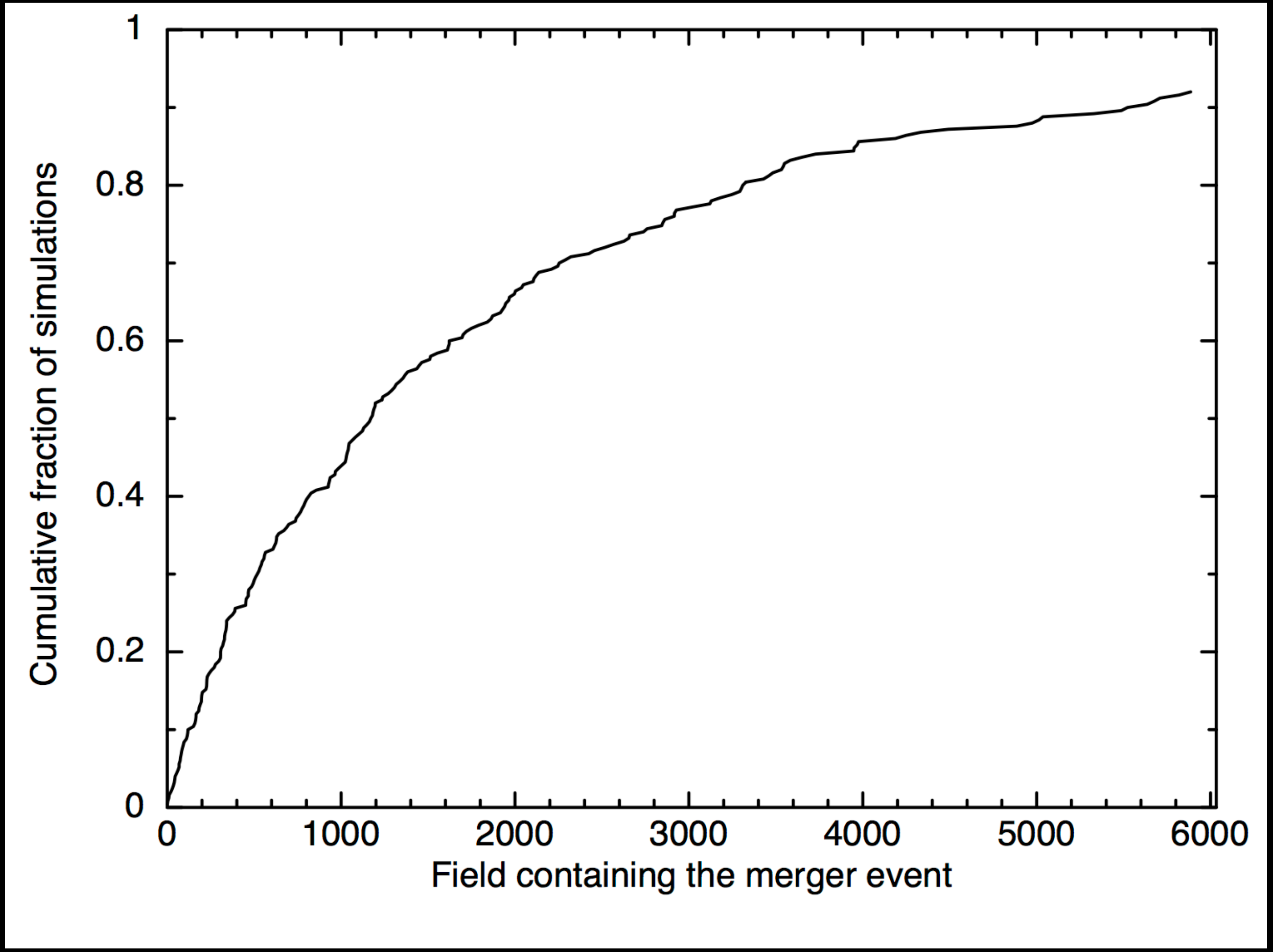




XRT field of view:
- 12’ radius.
- 0.12 square degrees.



Quantifying the issue

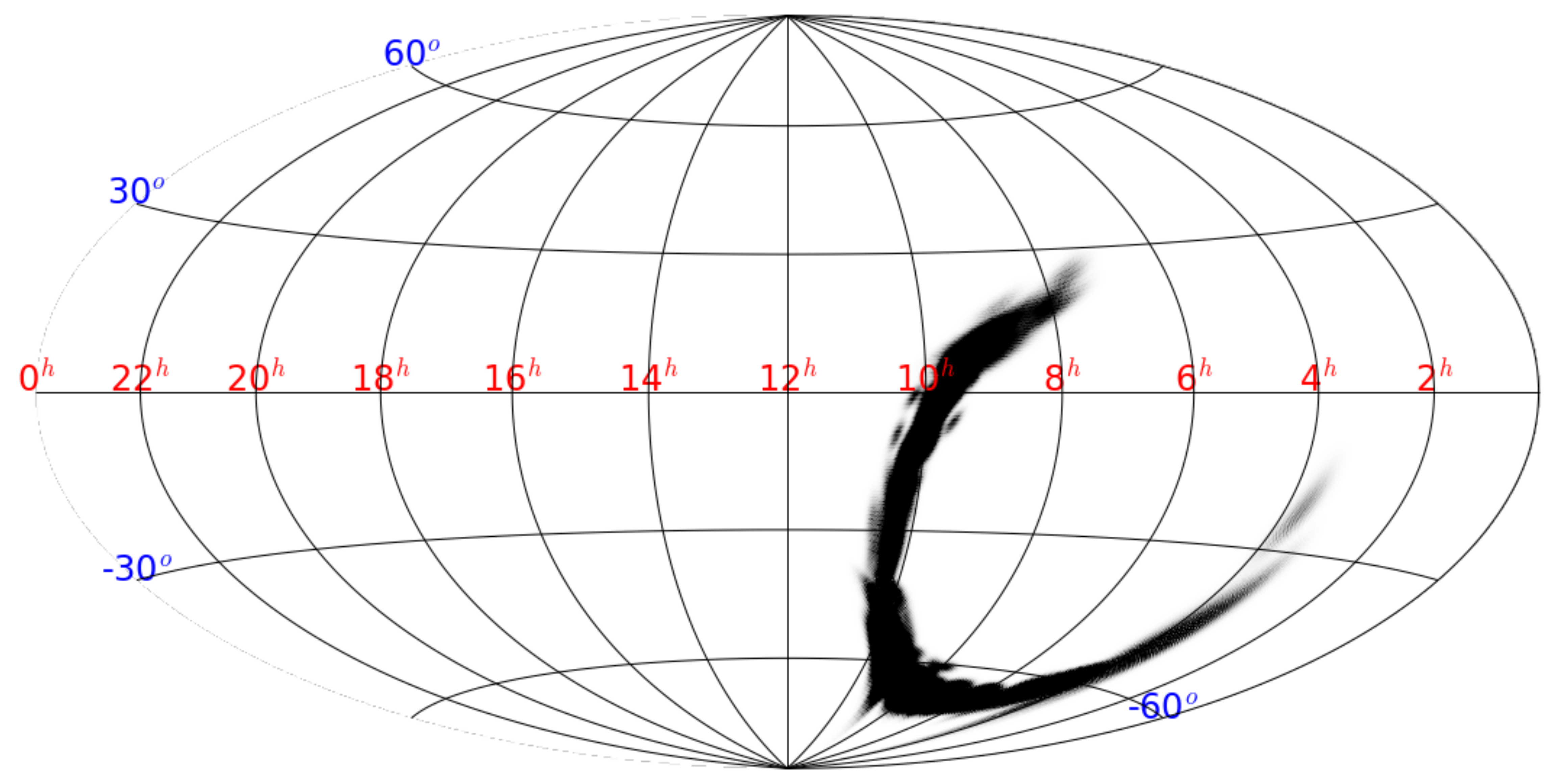


Evans+ 2016c, based on GW simulations by Singer et al. (2014, ApJ, 795, 105).

In the ‘median’ case we would have to observe nearly 1,200 fields with XRT before we get to the correct location.

Typical Swift day has <100 observations.

O1 solution: GWGC catalogue



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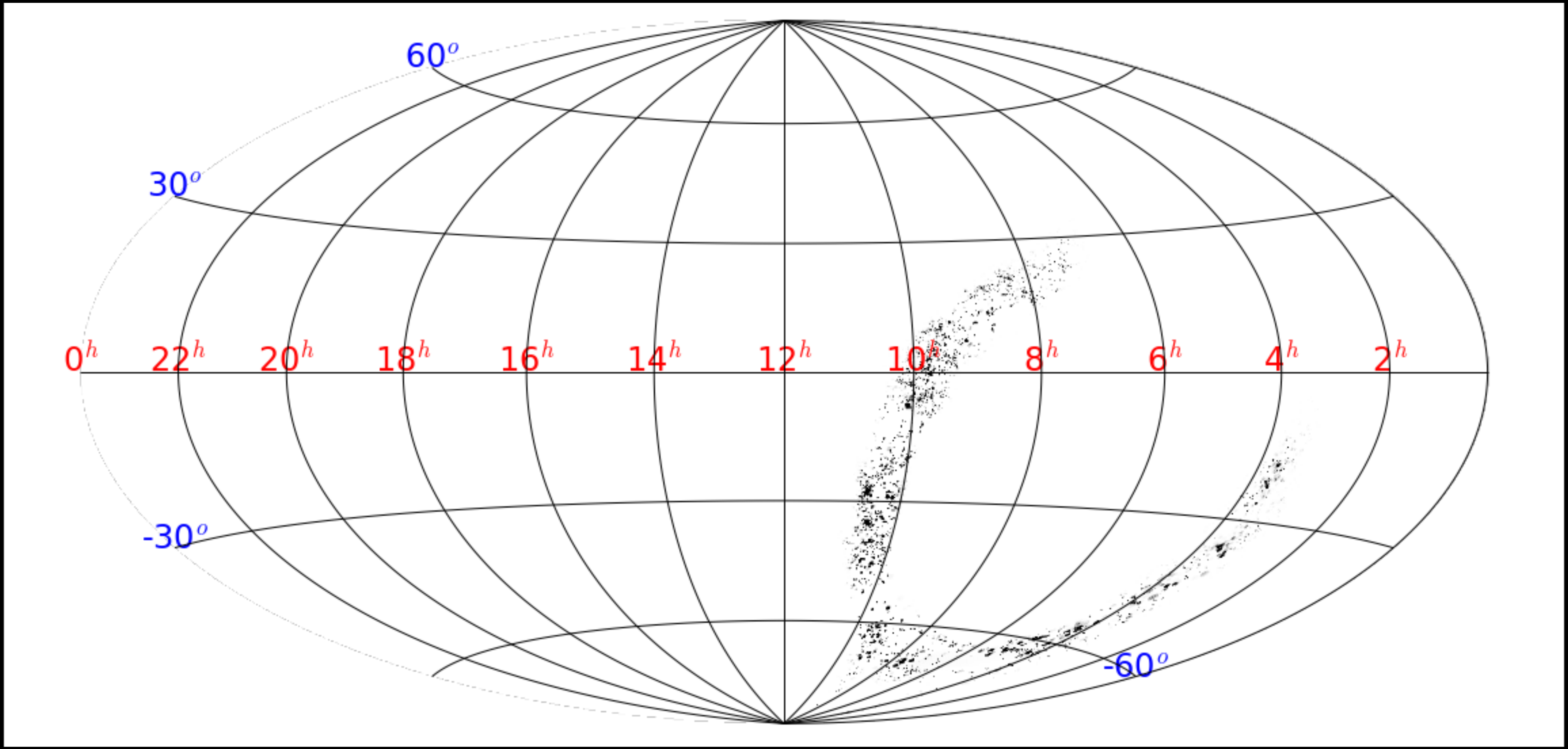

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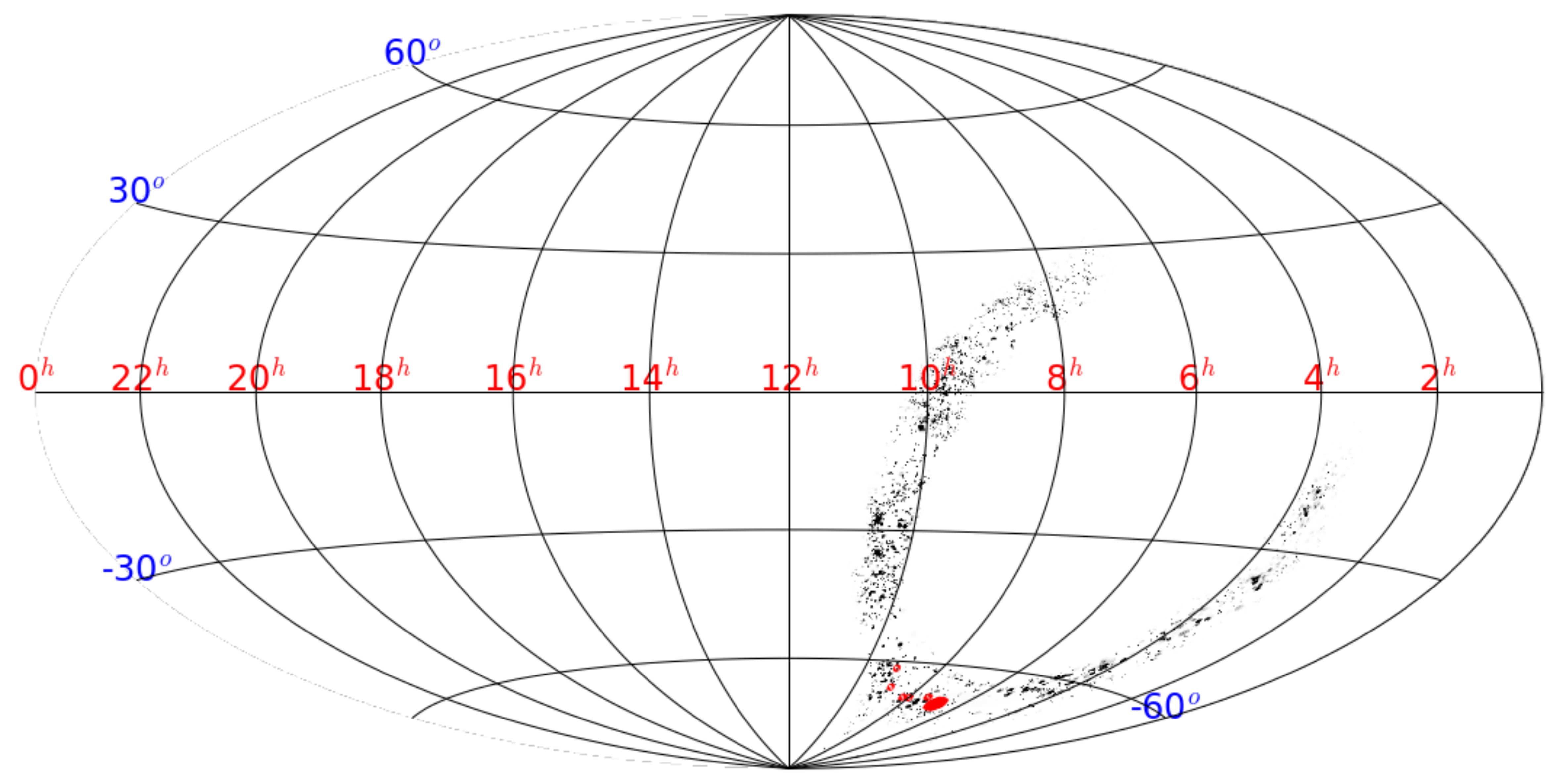
O1 observations: GW 150914



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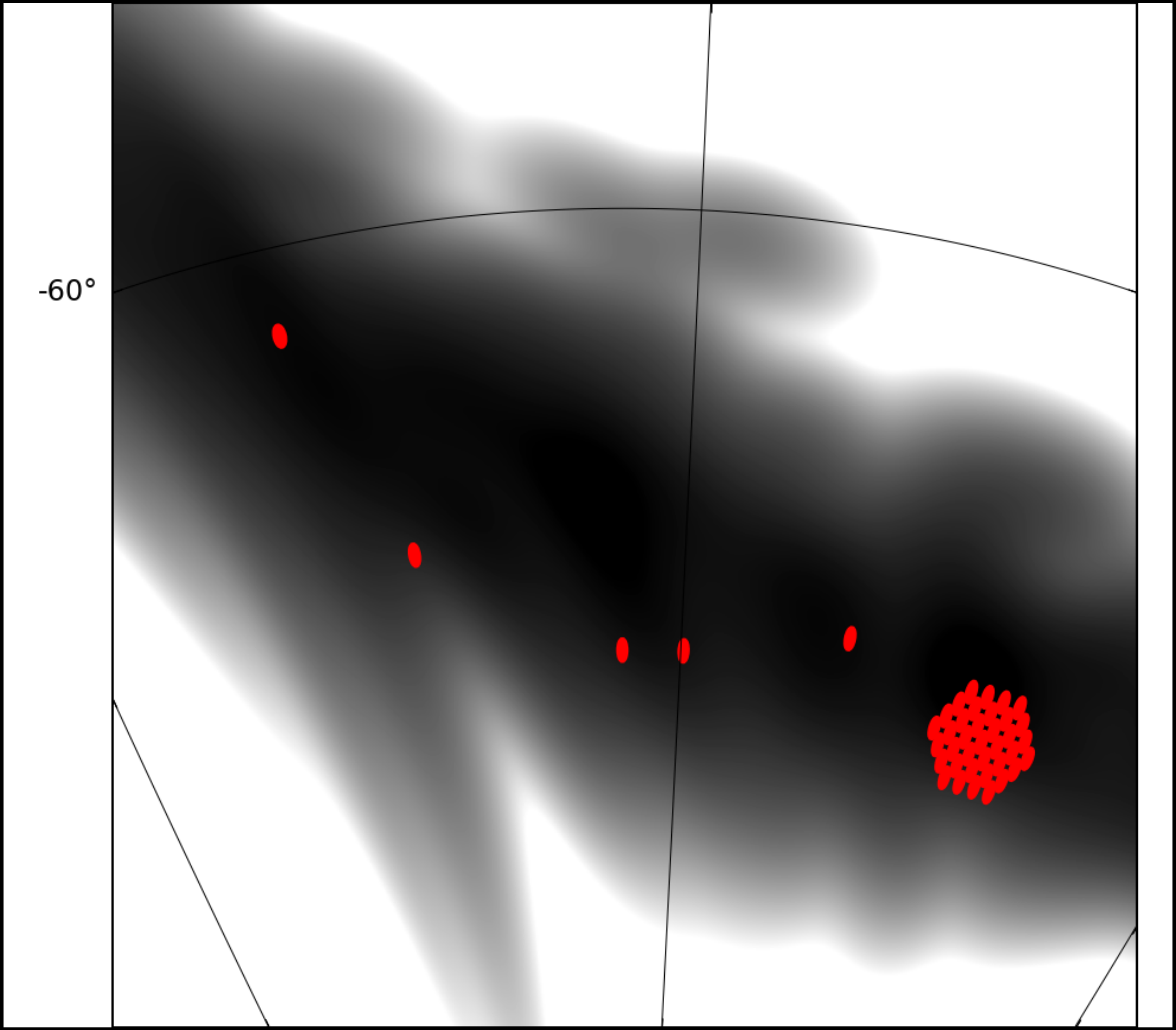

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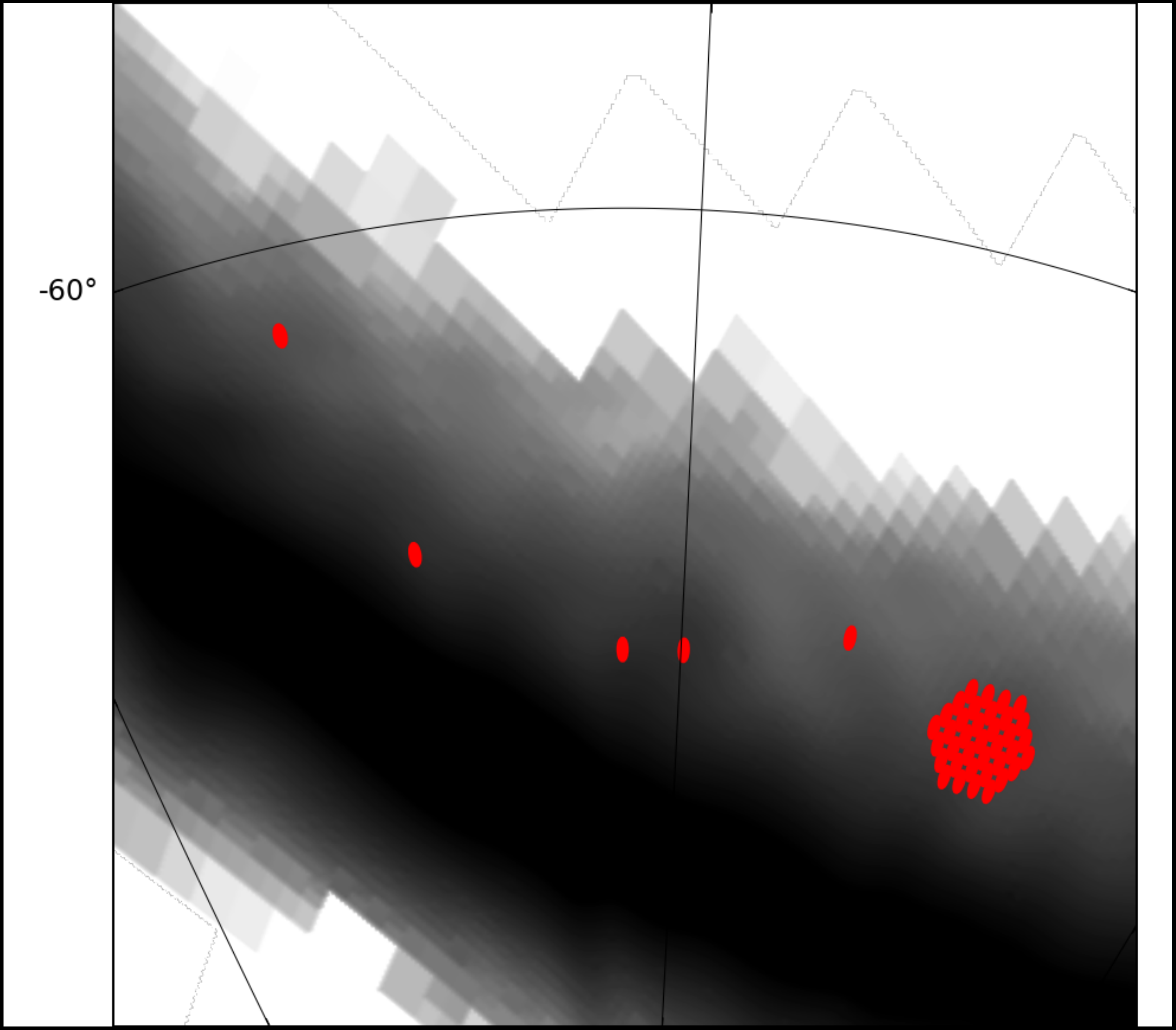


O1 observations: GW 150914

Fields were selected from the ‘LIB’ skymap - the best rapidly available map.

We selected 5 galaxies and tiled the LMC, total: 43 fields.

This enclosed 2% of the LIB probability; or 8% of our galaxy-weighted map.

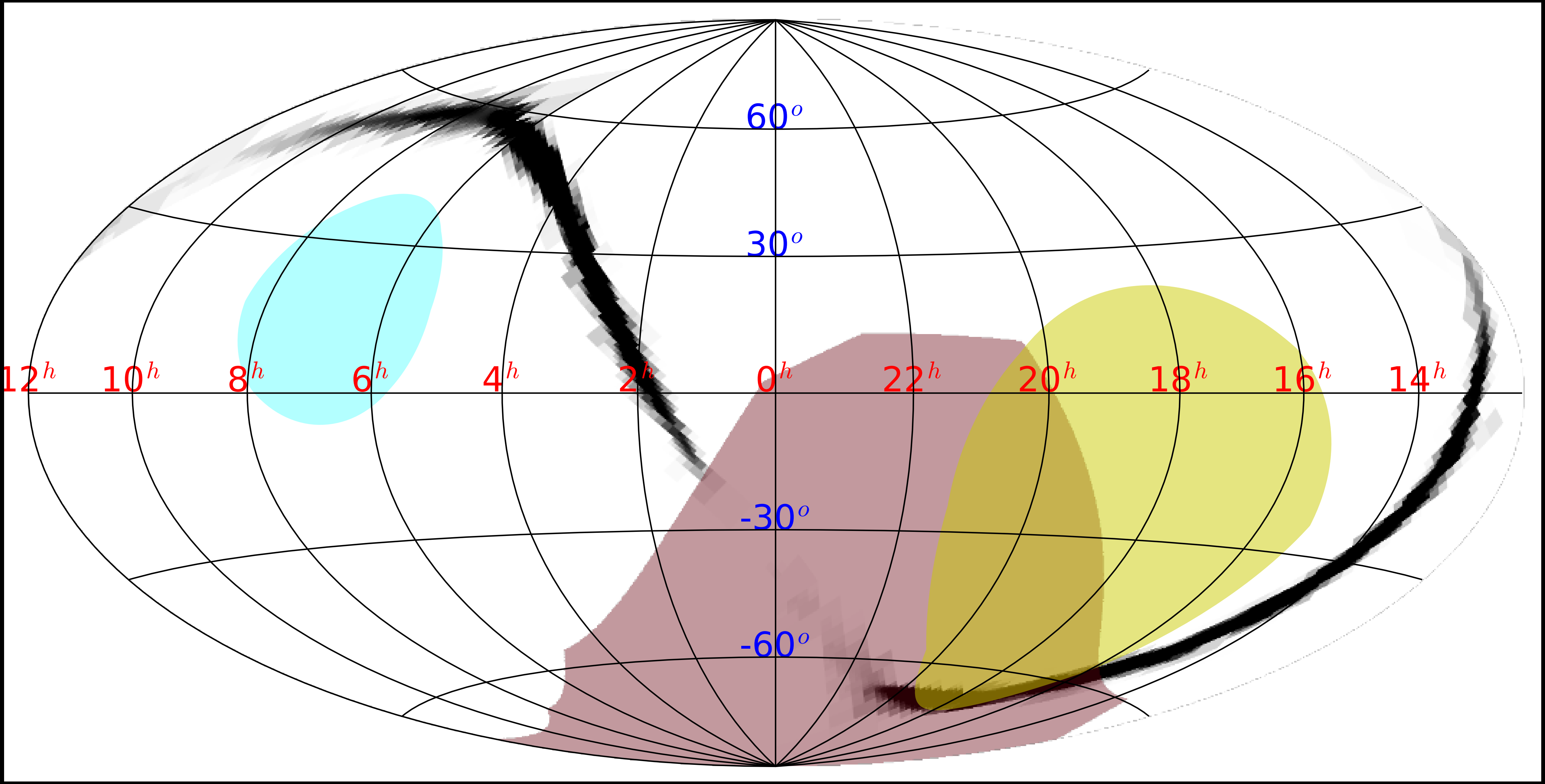
(Of course, much later we learned that the galaxy weighting was not appropriate for this object!)

But… then the LAL_Inference final skymap was produced…

From this map, we enclosed 0.03% (2% with galaxies).

We found 3 X-ray sources: all already known.

O1 observations: GW 151226



O1 observations: GW 151226

Fields were selected from the ‘bayestar’ skymap - the best rapidly available map.

We selected a series of areas using ‘19-tile’ mode.

Covered 8.5 square degrees, which is 0.9% of the probability, or 12% after galaxy-weighting.

16 X-ray sources found. 8 known, 8 faint.

No counterpart to the GW event.

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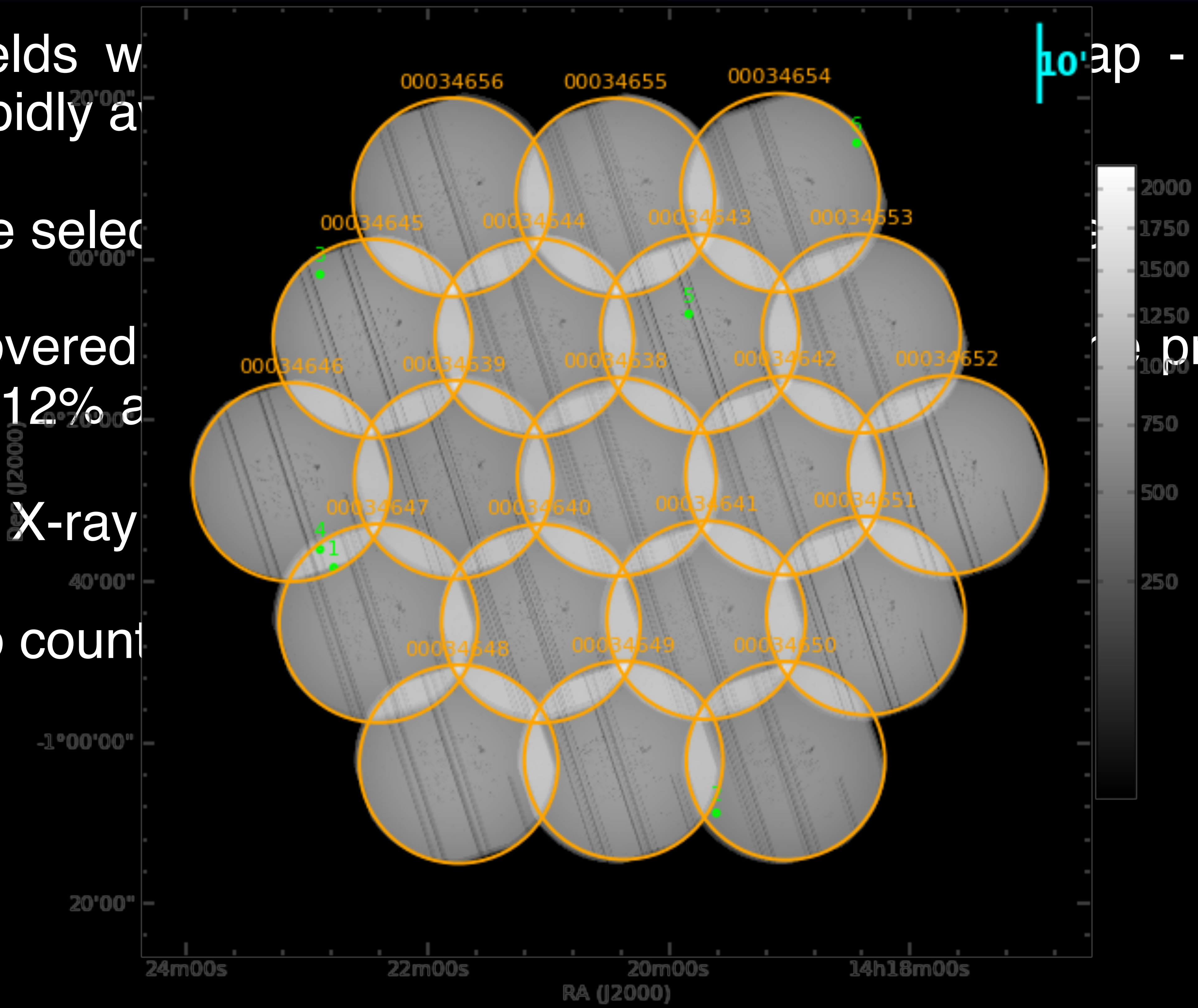

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Prospects for O2

1. 3D LVC skymaps (Singer et al., 2016, ApJ, 829, L15)

Prospects for O2 - 3D skymaps

Horizon distance is higher, so we will use 2MPZ, not GWGC in O2. The completeness towards the horizon distance falls off, so we need to account for this.

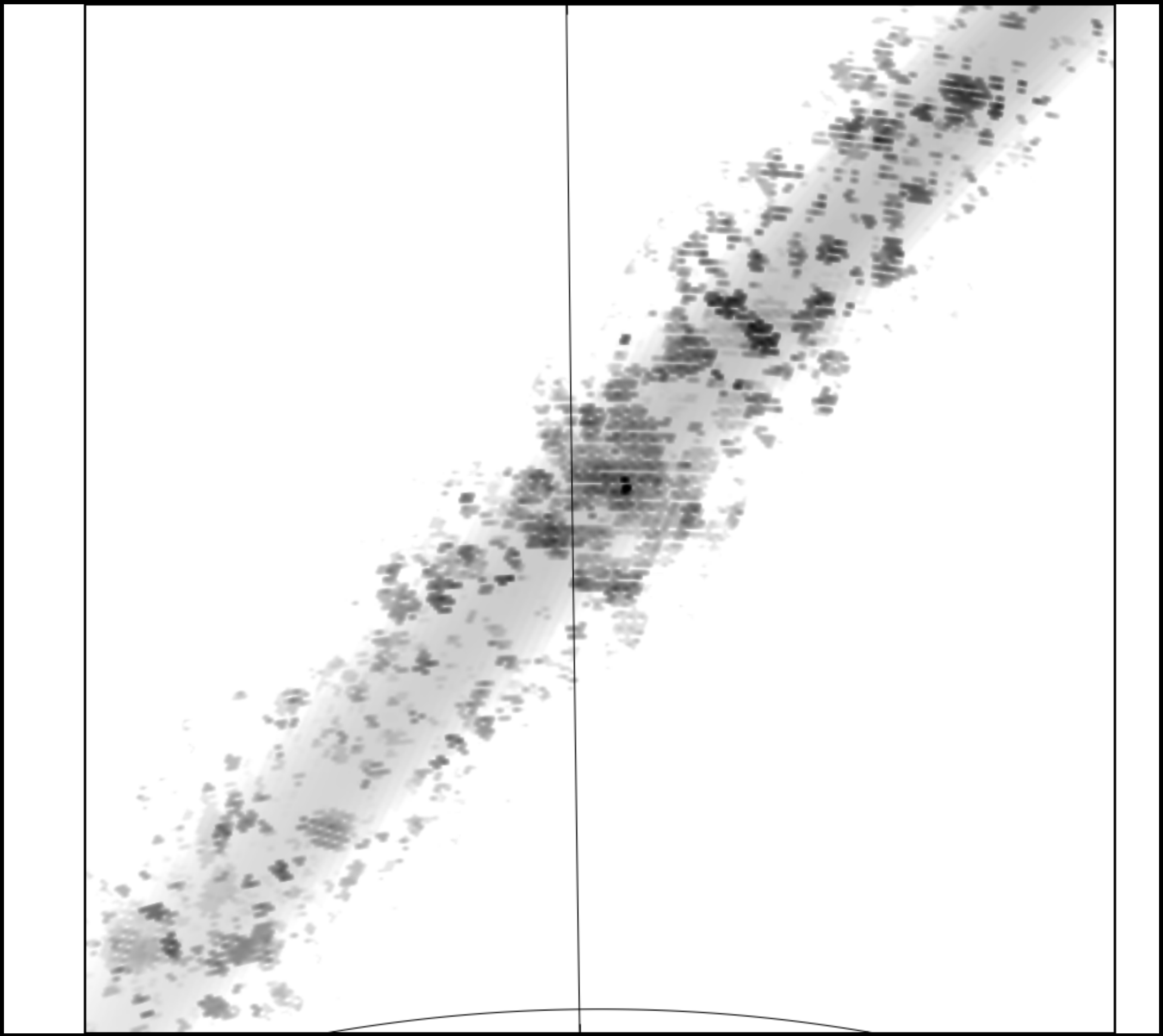
For a given line of sight, we can say:

$$\mathcal{P} = P_{GW}\,(1-C) + P_{GW}\,(C\,\mathcal{P}_G)$$

C is the completeness of the galaxy catalogue.
P_{GW} is the GW probability.
$\mathcal{P}_G$ is the probability that the GW event is in a galaxy on this line of sight.

$$\mathcal{P}_G \propto L\, P_{GW}(D)\, P_G(D)$$

Prospects for O2 - 3D skymaps



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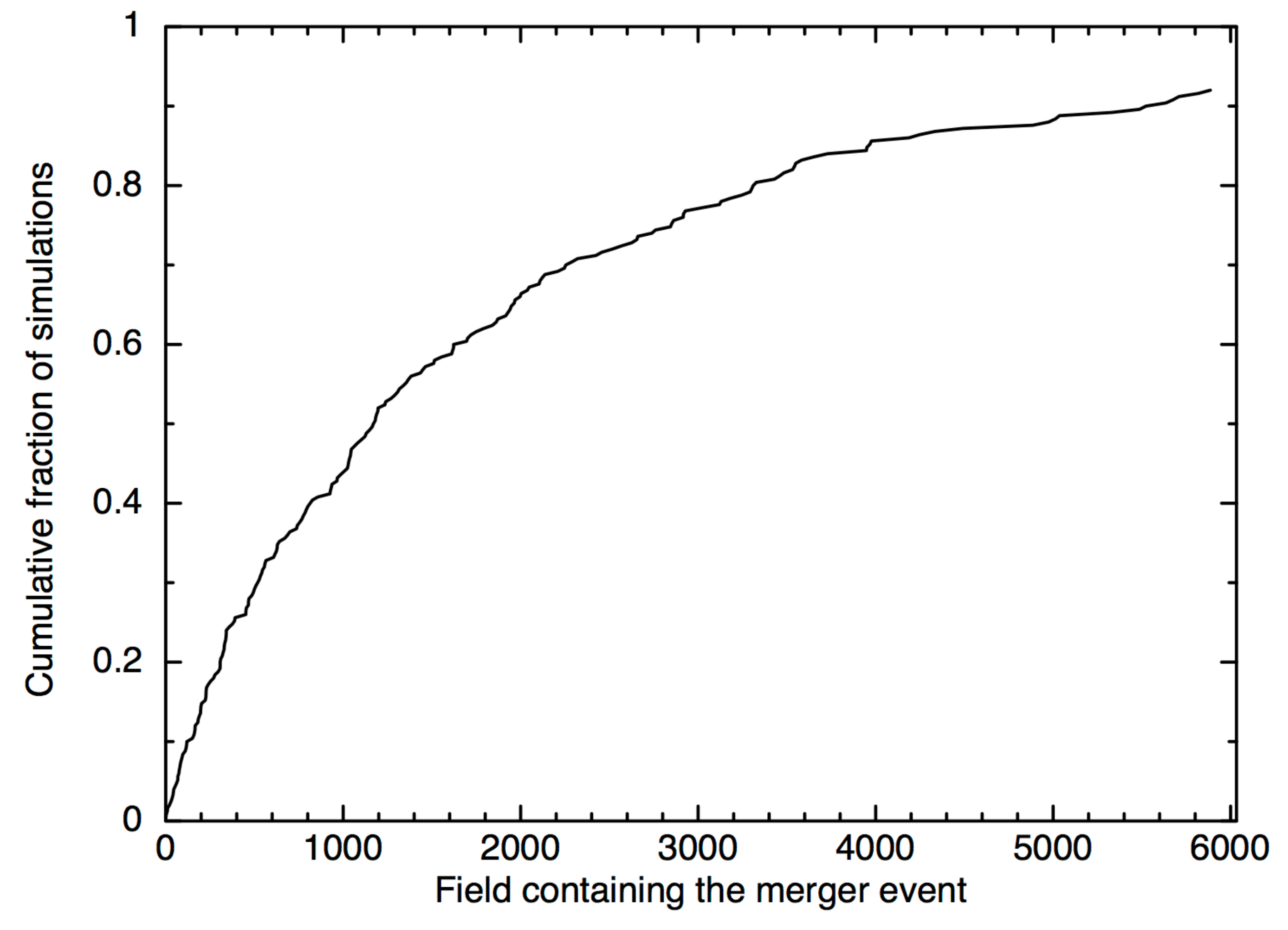

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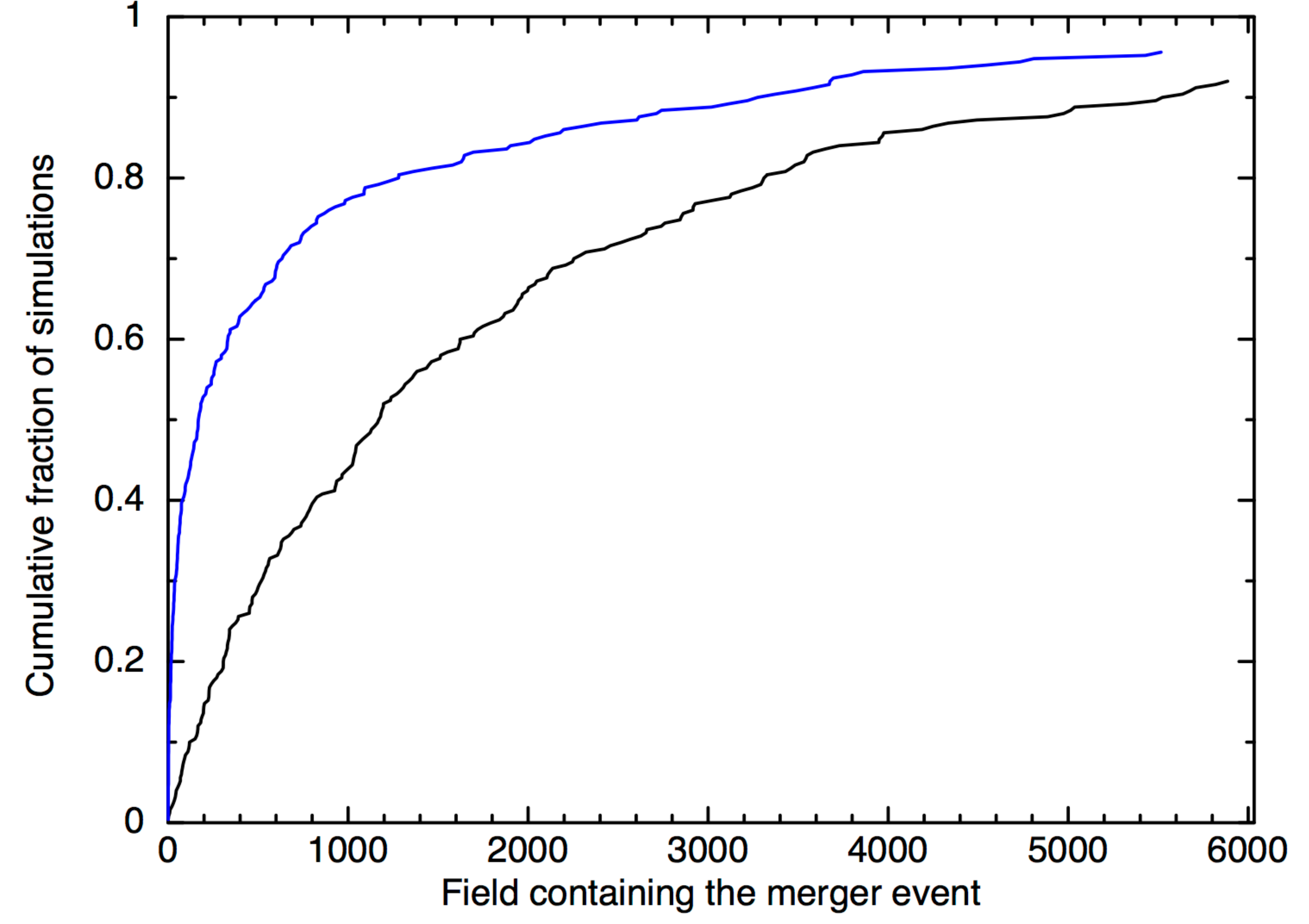

In the ‘median’ case we would have to observe about 170 fields with XRT before we get to the correct location.

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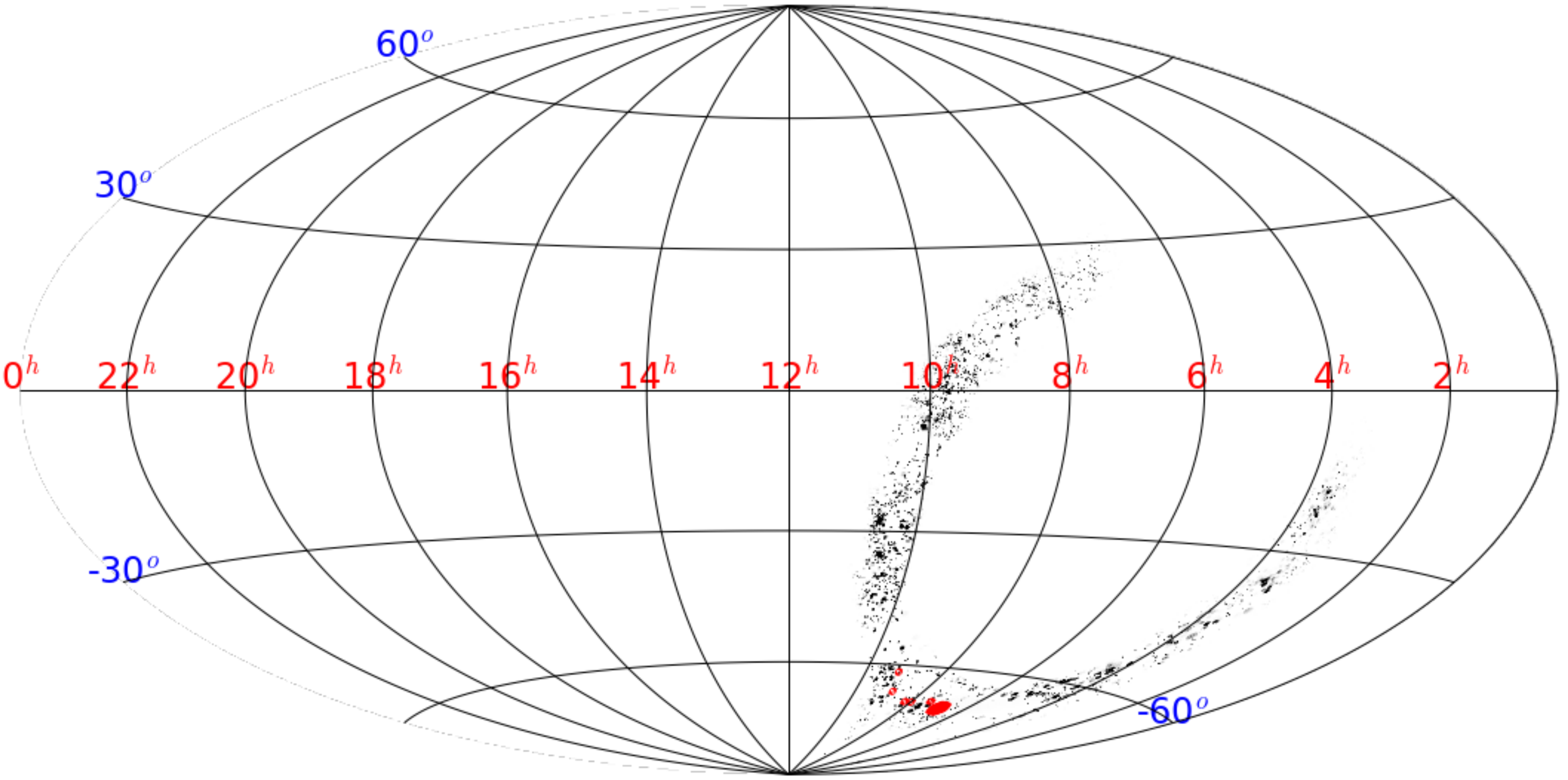
3. Developments in *Swift*’s capabilites.

Prospects for O2 - Swift developments



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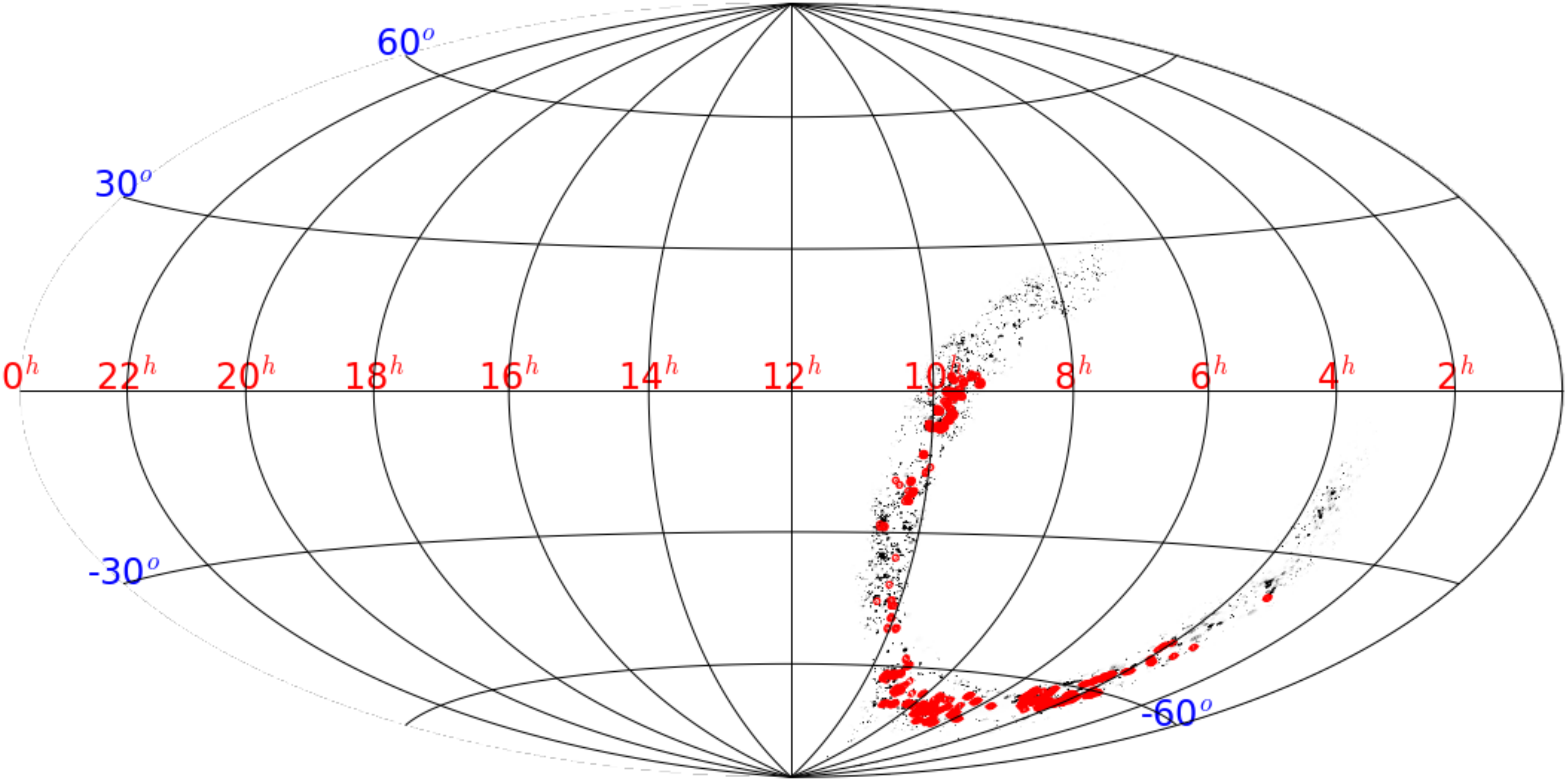

In a recent test, *Swift* observed 426 fields from the GW 150914 error region in 24 hours. This covered 9% of the skymap used (50% after galaxy weighting).

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3. Developments in *Swift*’s capabilites.

   Can now observe hundreds of fields in a day.

   New onboard software for scheduling these is imminent, which will cut down response time.

Plan for O2

We still have the issue of *when* to look, and for how long.

Current plan is based on *Swift* on-axis GRBs, with extrapolations in z, and to expected off-axis behaviour.

- From T_0 to T_0+48 hours
  - Rapid (60-s) observations covering the (convolved) error.
- From T_0+48 to T_0+144 hours
  - Longer (500-s) observations
  - Will prioritise any tantalising sources found in the early run.

ToOs will not be done, but we will consider sources detected elsewhere, and decide if and when to observe them.

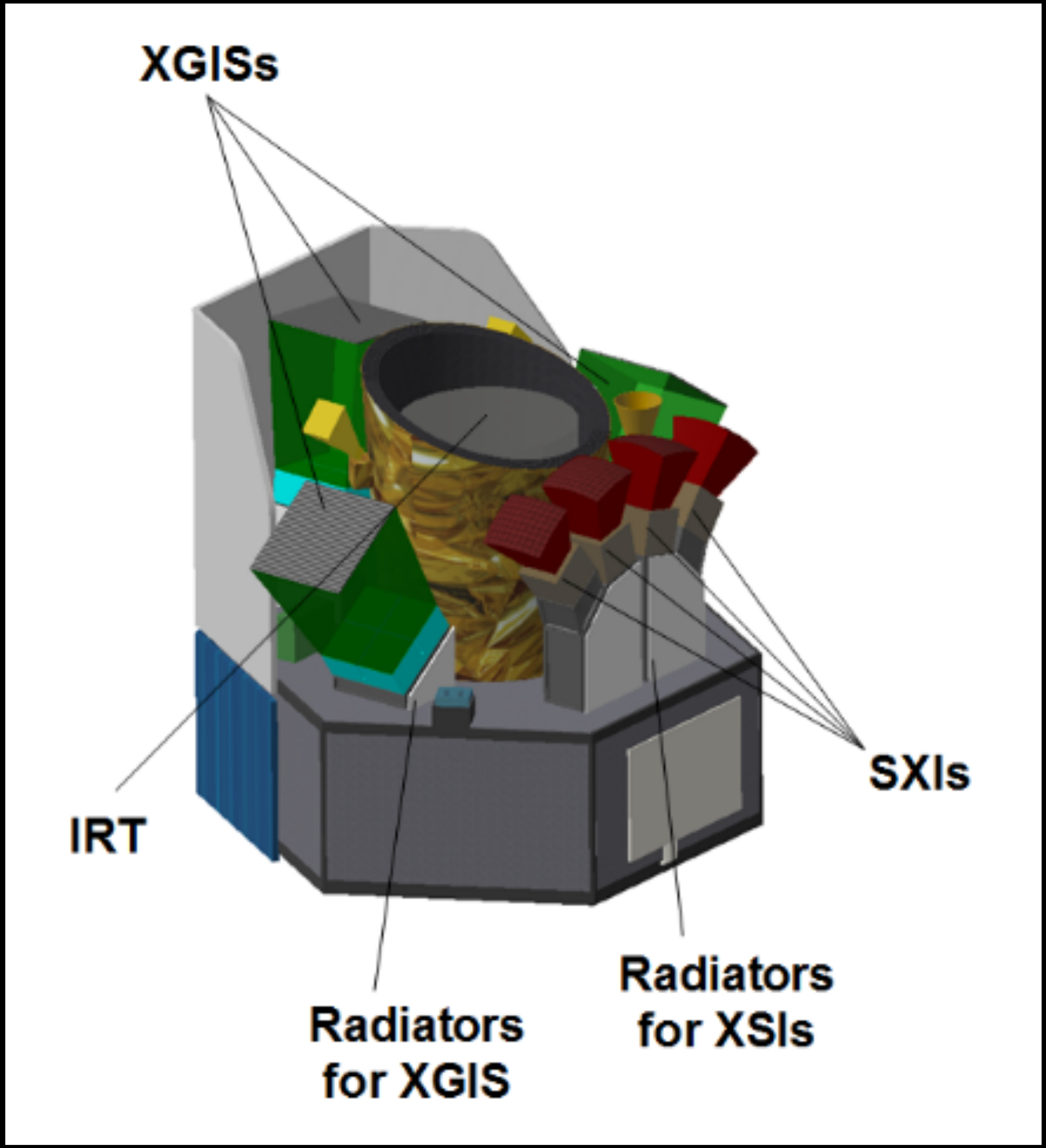
Summary

- Many GW-emitting objects will also emit X-rays.
- *Swift* is going to follow LVC triggers to look for these.
- In O1 we followed 3 triggers, in a limited way.
- In O2 we will have:
  - Better localisations
  - 3D localisations
  - New galaxy-convolution techniques
  - Larger-scale *Swift* response
  - Faster *Swift* response.

GW + EM science is out there, waiting to happen.

Looking ahead

- Swift can do a great job, but it's not what it was designed for. We ***really need*** something built for the job.



For example, THESEUS.
PI: Lorenzo Amati.

See talk on Thursday.

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