A Search for Kilonova Radio Flares in a Sample of Swift/BAT Short GRBs

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Overview

- GW170817 and its ejecta
- Why late-time kilonova emission is important
- Our search
- The ngVLA and the future of neutron star merger searches

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GW170817 and its Ejecta

- Two main components: structured jet and merger ejecta
- Structured jet:
  - Fast core + cocoon
  - Synchrotron radiation from shocked ISM
  - Delayed afterglow for off-axis observers as casual cones widen
- **Our focus:** The optical kilonova (produced via r-process nucleosynthesis by the merger ejecta)

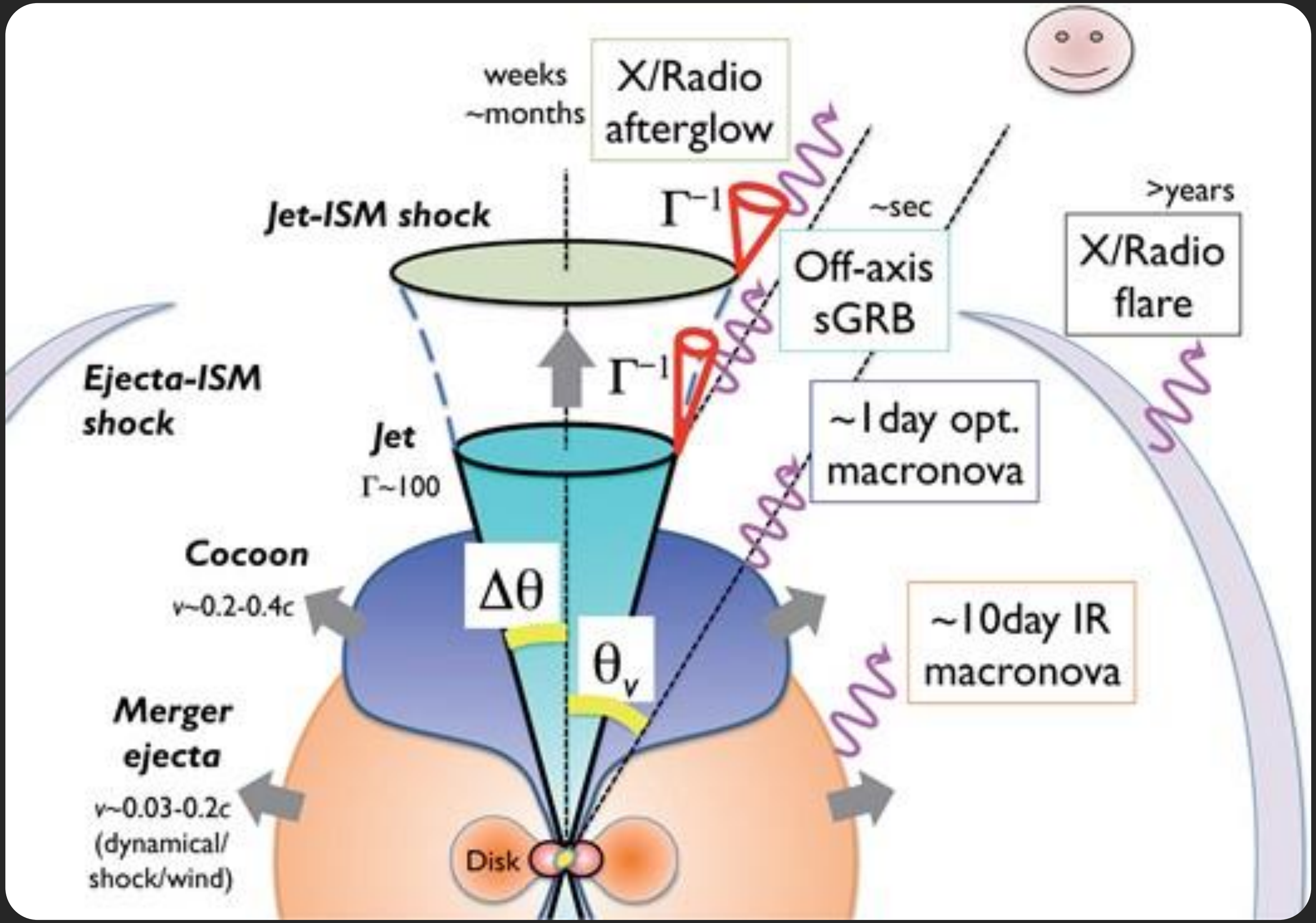
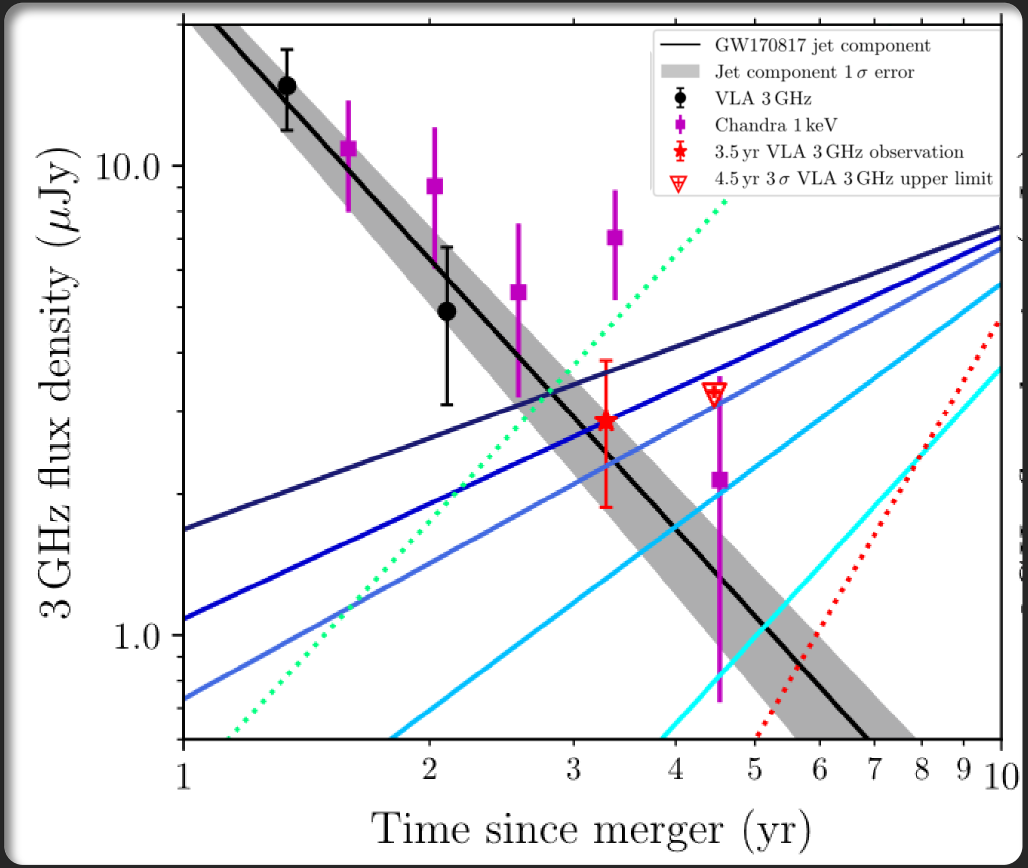


Diagram of GW170817's emission (Ioka & Nakamura 2018)

(Metzger 2017a), (Metzger 2017b)

Why Late-Time Kilonova Emission is Important

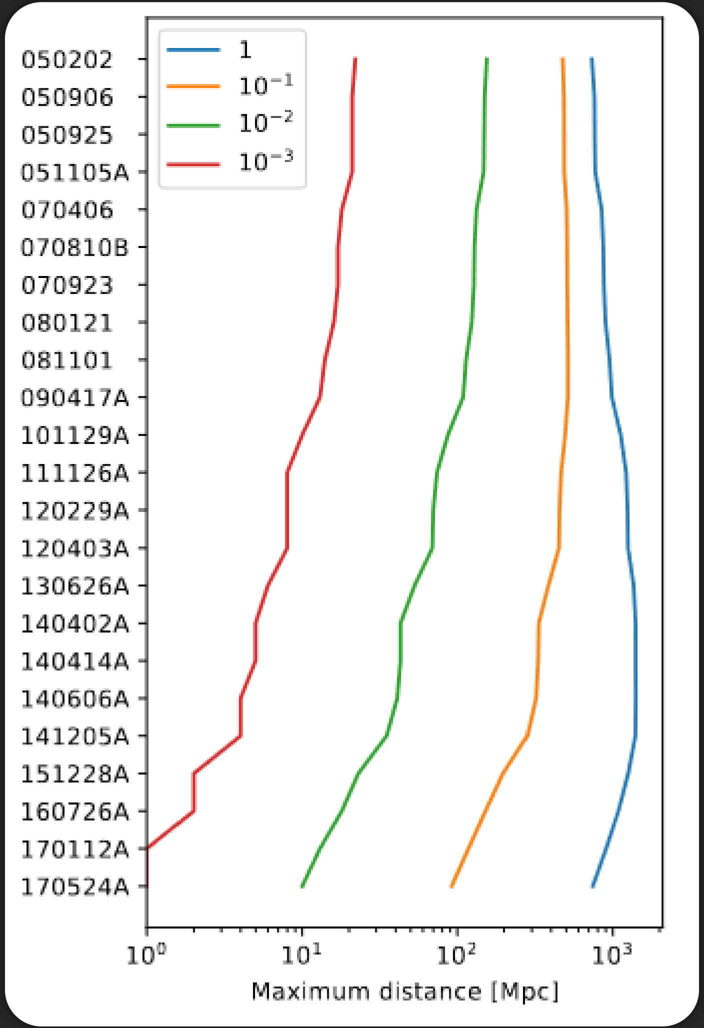


GW170817 3 GHz light curve with predictions of a kilonova afterglow light curve (Balasubramanian et al. 2022)

- GW170817 proved that merger ejecta give rise to optical kilonovae in association with short GRBs.
- Models predict that the merger ejecta can have a fast tail powering late-time radio flares visible once the structured jet afterglow fades.
- Several short GRBs localized to arcmin regions by Swift/BAT did not enjoy extensive follow-up and their distance remains unknown.
- **How many nearby BNS mergers missed? We can search for the late-time radio flares to find out!**

(Nakar & Piran 2011), (Bartos et al. 2019)

Our Search: Sample Selection



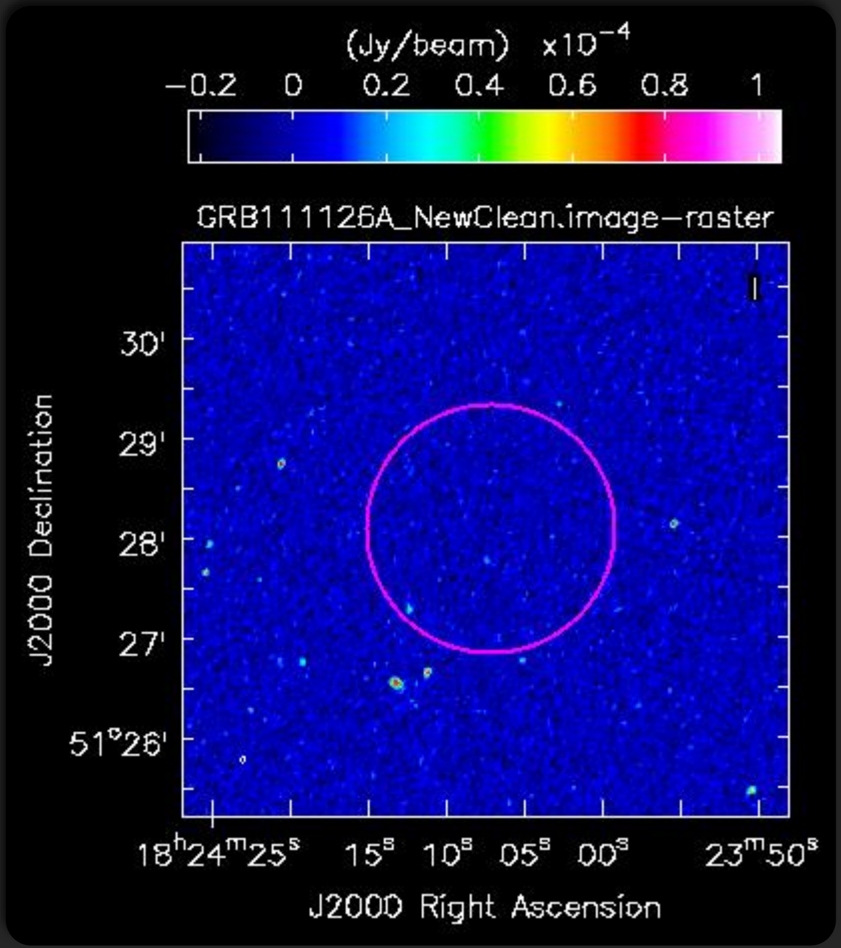
- *Swift* GRBs with BAT arcmin localization, no XRT arcsec localization
- Error region contained within one VLA pointing at 6 GHz
- No optical follow-up that could've found a kilonova already

Maximum distance the VLA can see each candidate GRB per circum-merger density

(Bartos et al. 2019)

Our Search: Observations

- Seven GRB fields observed
- C band (6 GHz) and S band (3 GHz)
- VLA C configuration
- C priority (VLA filler time)
- About 30 minutes on source
- Average RMS of ≈ 11 μJy/beam (neglecting dynamically limited images)
- Blobcat + visual inspection

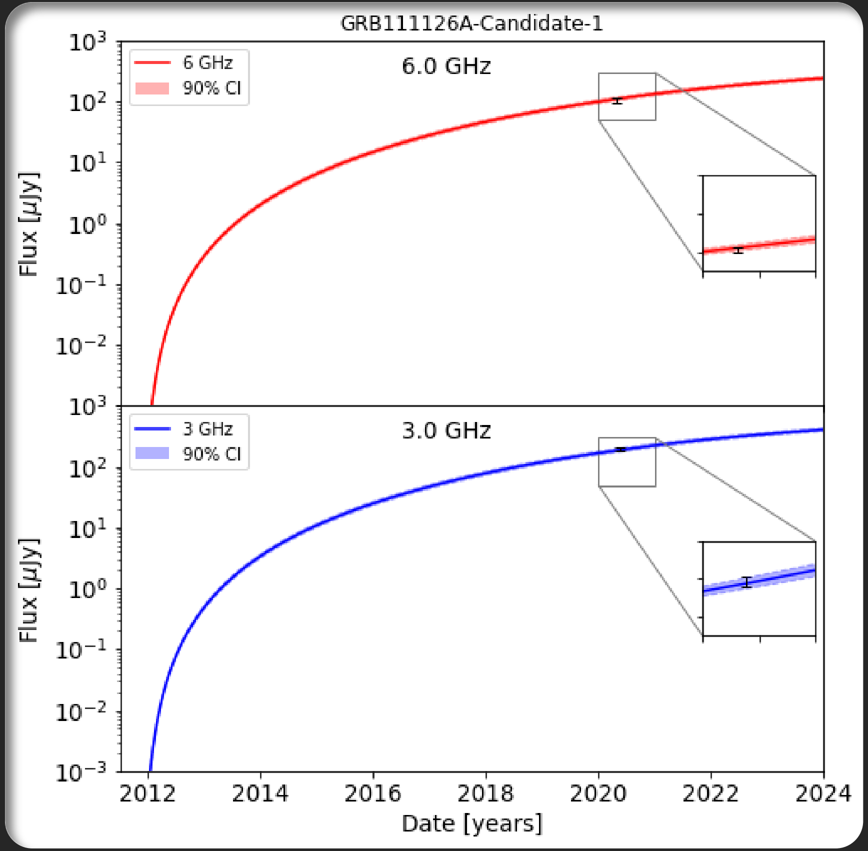


Sample C band image from our data set. Pink circle is the BAT error region.

(Eddins et al. 2022), (Grandorf et al. 2021), (Hales et al. 2012)

Our Search: Data Analysis

- Methods to determine origin of the radio sources found in each GRB field:
  - Point or extended morphology?
  - Sidelobe emission?
  - Spectral information
  - Potential host galaxies or known sources via catalogs:
    - Searched within 1 arcmin of the source location
    - Take closest cataloged source as either known radio source (if in NVSS or FIRST) or host galaxy of a putative radio flare
  - Fit light curves to observations

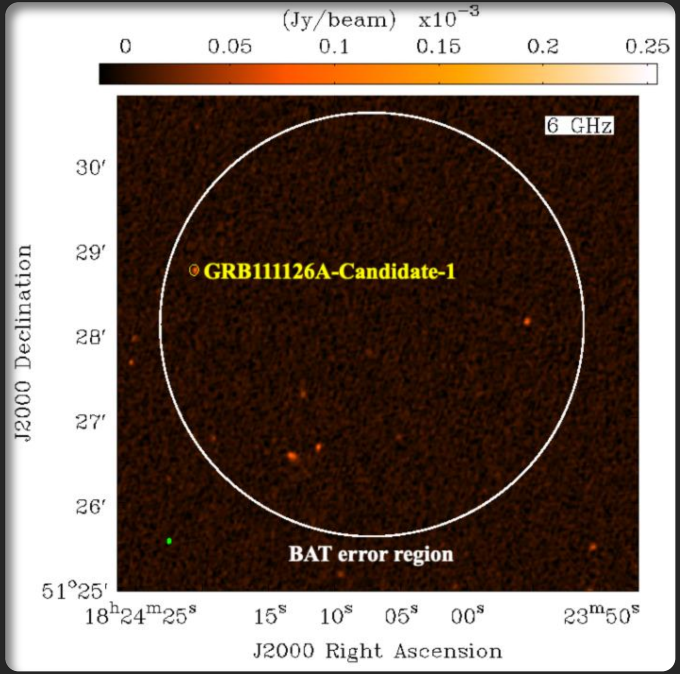


Light curves fit to observations by assuming GW170817-like ejecta and a distance to the source of 40 Mpc

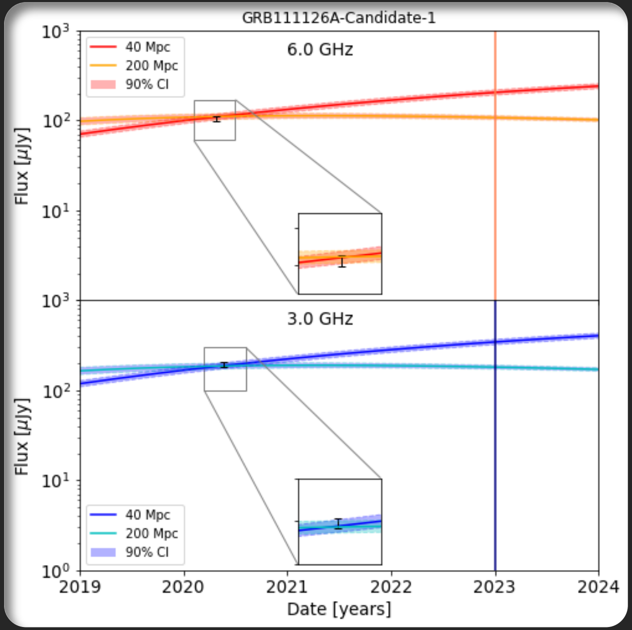
(Eddins et al. 2022), (Grandorf et al. 2021), (Mooley et al. 2013)

Our Search: Results

- This study found a source of interest!
  - Associated with GRB111126A
- To confirm: more radio observations of GRB111126A and GRB130626A
  - Confirm time variability matches predictions
  - Determine type of source and distance to source



Discovery image of our radio candidate

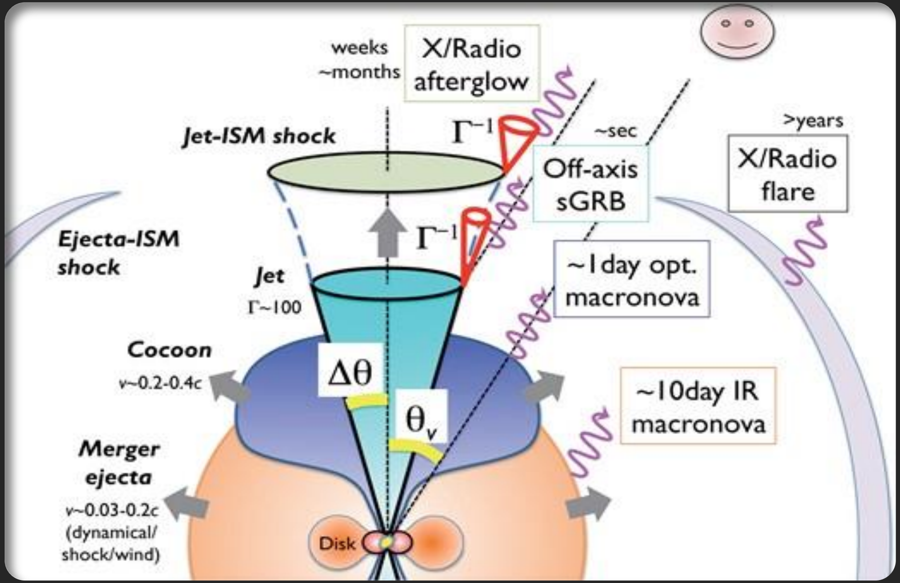


Light curves calculated for this candidate with predicted behavior

(Eddins et al. 2022), (Grandorf et al. 2021)

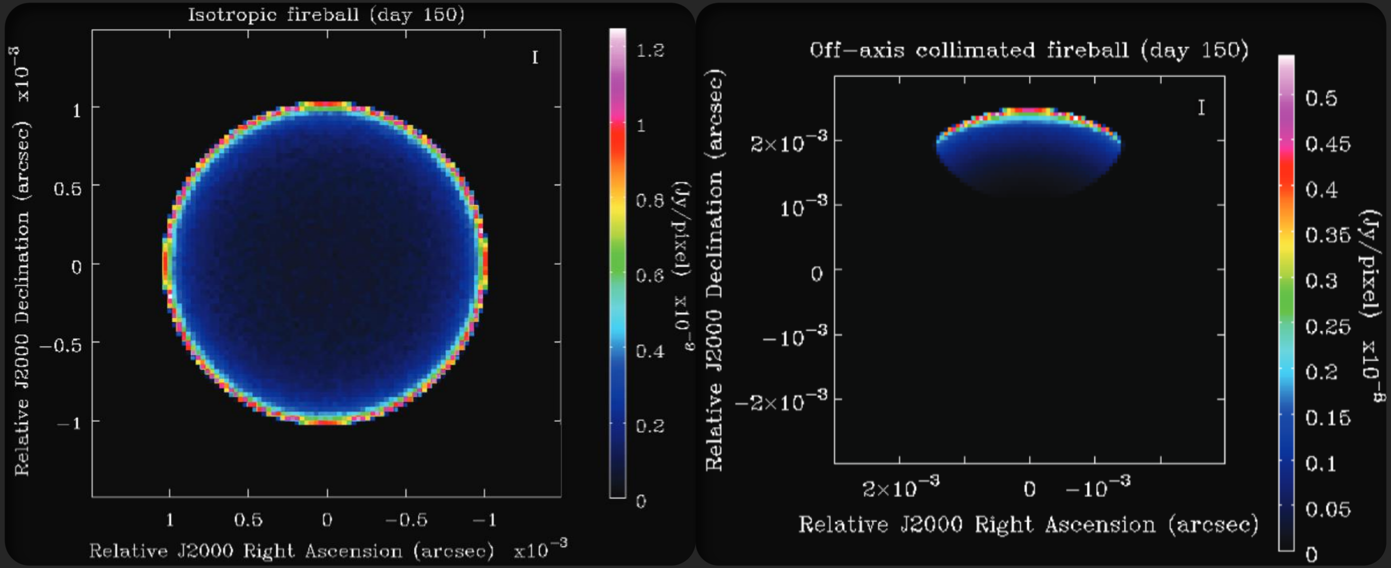
ngVLA and the Future of BNS Detections

- Not easy to distinguish between different scenarios for late-time radio emission:
  - Off-axis jet afterglow
  - Kilonova afterglow
  - Unrelated radio source
- Direct high-resolution imaging with the ngVLA (LBA) can remove degeneracy.
- Current project: work on more detailed simulated ngVLA images.



← Diagram of GW170817's emission (Ioka et al. 2018)

↓ Simulated ngVLA images of isotropic and collimated BNS emission using the LBA configuration (Corsi et al. 2018)



Summary

- GW170817 had a delayed afterglow
- Selected sample of GRBs without x-ray localization (Bartos et al. 2019)
- Searched for theorized late-time kilonova radio flares
- Found a candidate that displays GW170817-like behavior
- Further observation is needed
- Paper in review with AAS and available on arXiv! (arXiv:2210.10675)
- Be on the lookout for ngVLA project

References

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