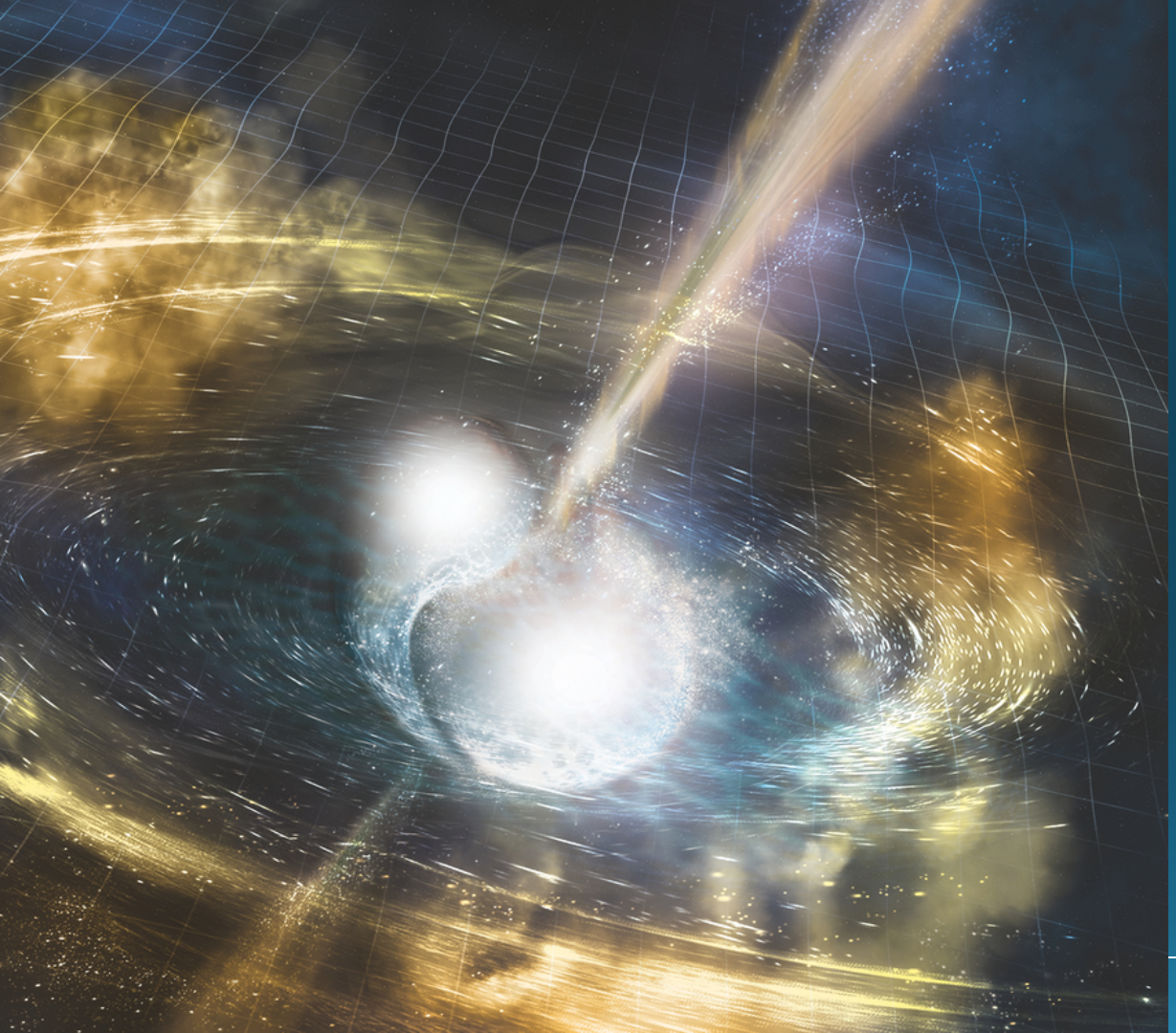

LOFAR triggered observations of gravitational wave merger events and GRBs

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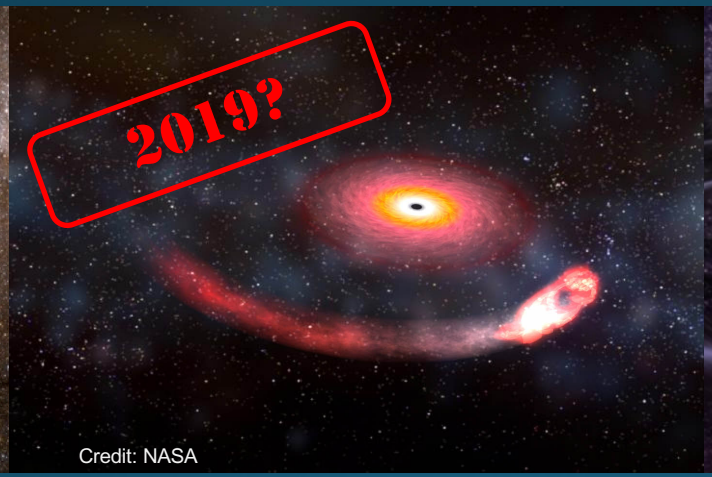
PhD student, University of Amsterdam.

Supervised by
Dr. **Antonia Rowlinson,**
Dr**. Jess Broderick** and
Prof. **Ralph Wijers**

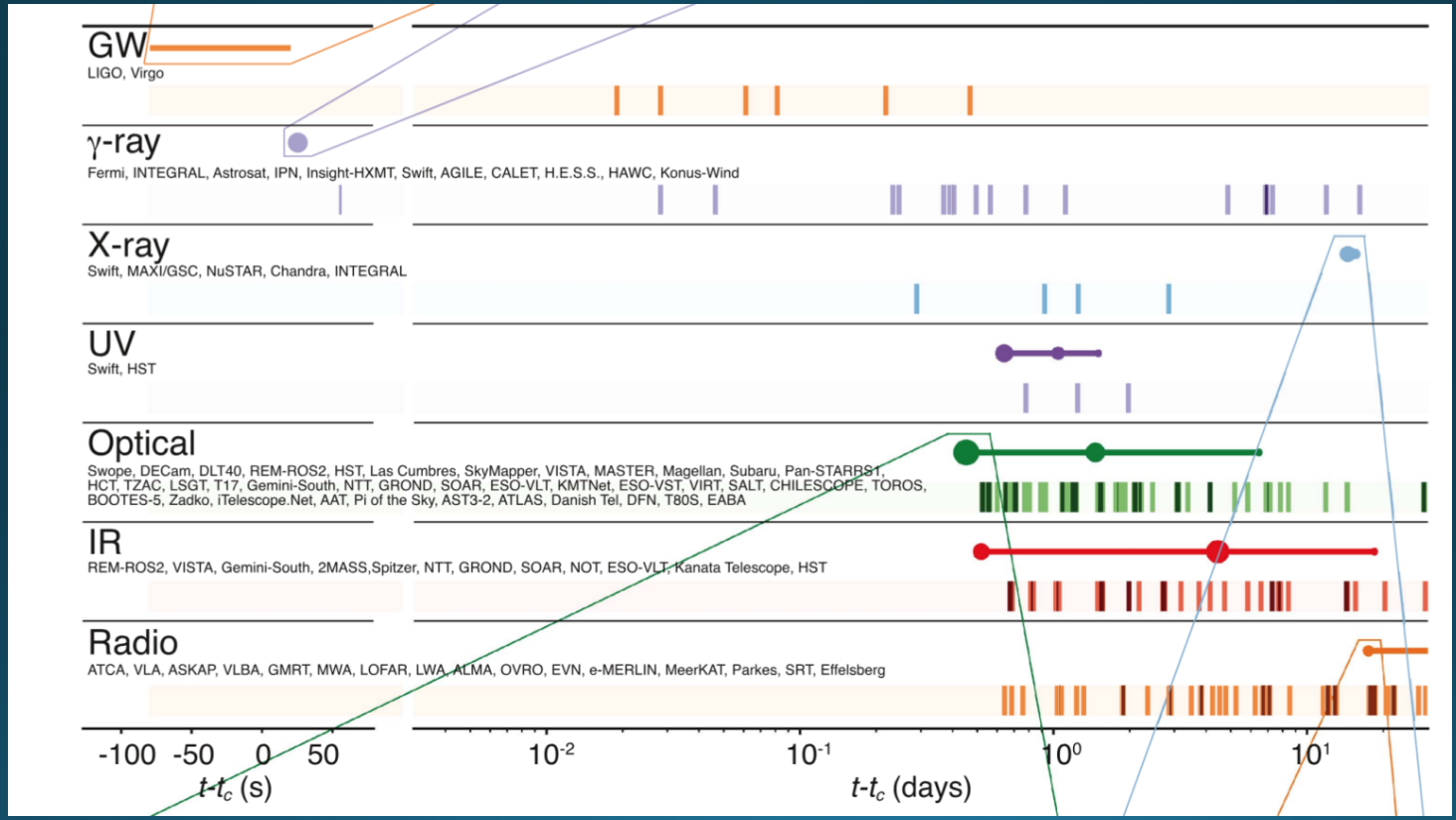
26 March 2019

Gravitational waves (GWs) from compact binary mergers



BH + BH **BH + NS** **NS + NS**

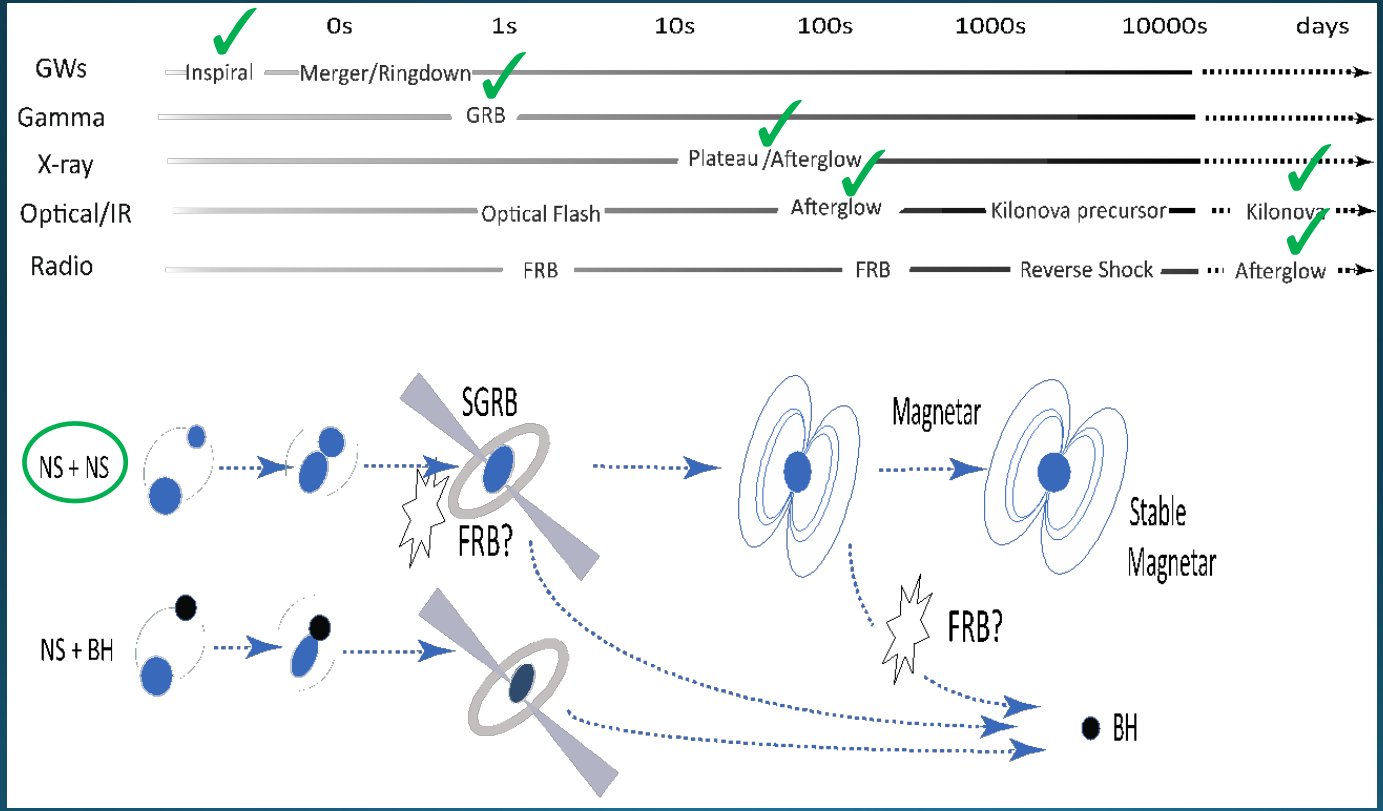
Multimessenger observations of GW170817



Abbott et al. 2017

Possible evolutions and accompanying emission

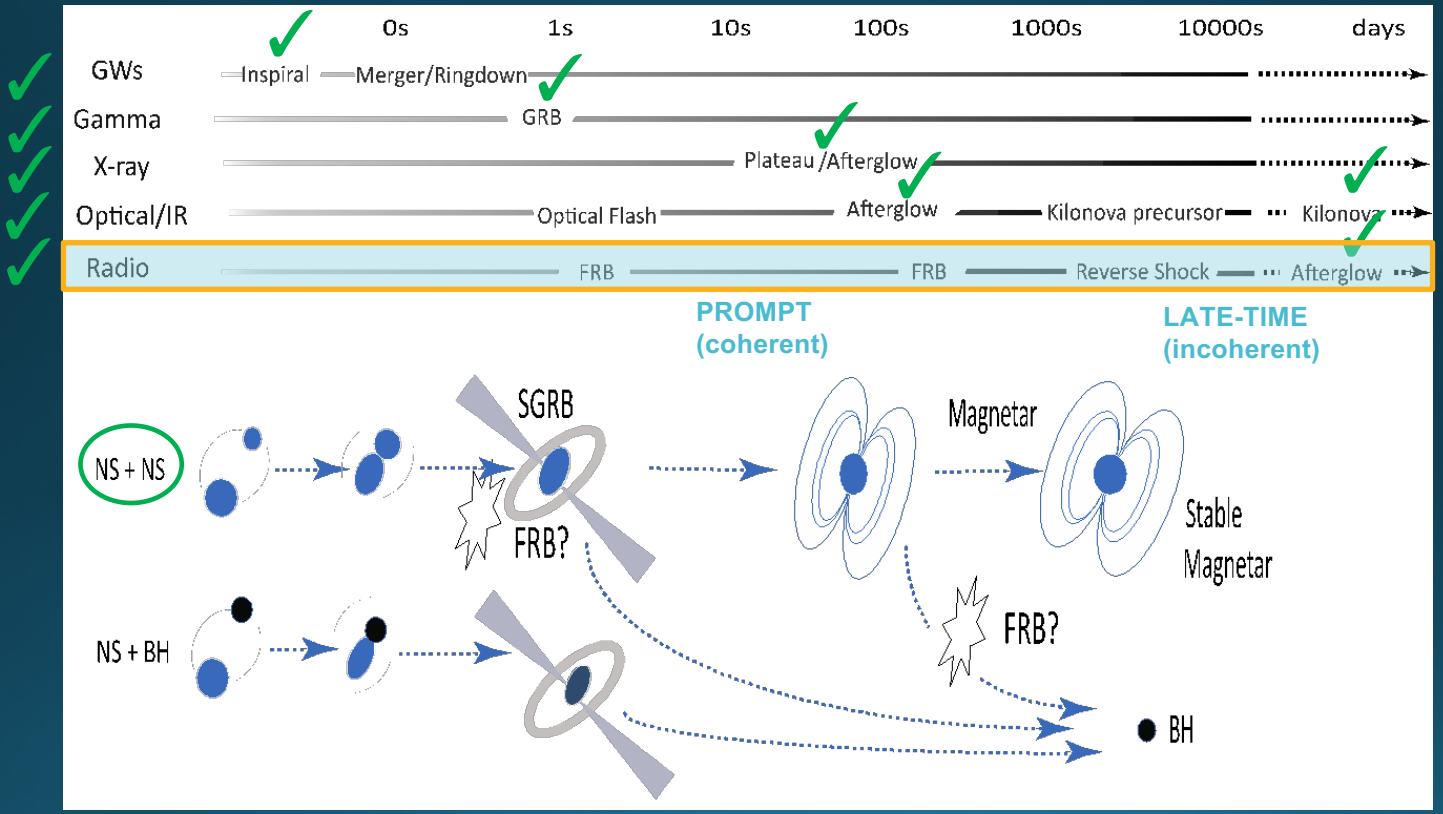
✓observed for GW170817



Chu et al. 2016 (adapted)

Possible evolutions and accompanying emission

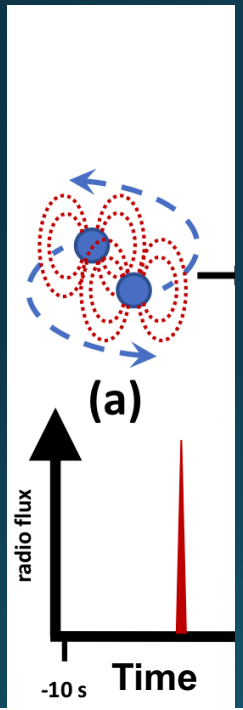
✓observed for GW170817



Chu et al. 2016 (adapted)

Prompt Radio Emission

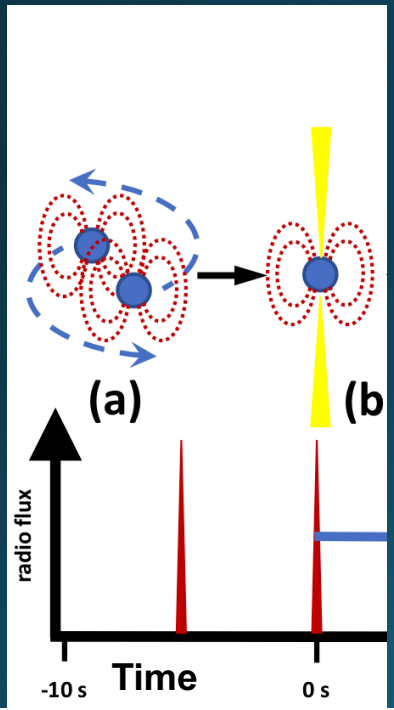
PRE-MERGER



- Interacting NS magnetic fields e.g. Lupunov & Panchenko 1996
- GW + plasma interaction e.g. Moortgat & Kuijpers 2003

Prompt Radio Emission

MERGER

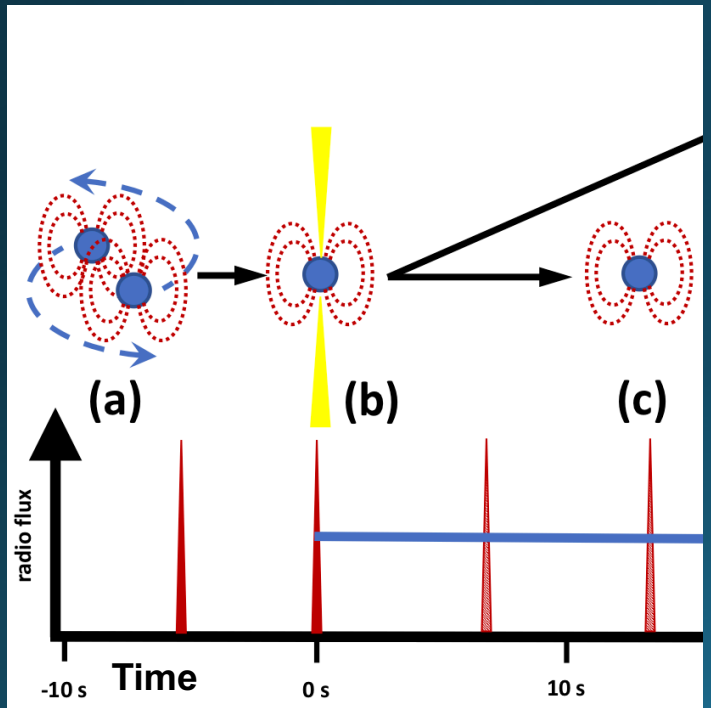


- interactions within the relativistic jet

  e.g. Usov & Katz 2000

Prompt Radio Emission

POST-MERGER



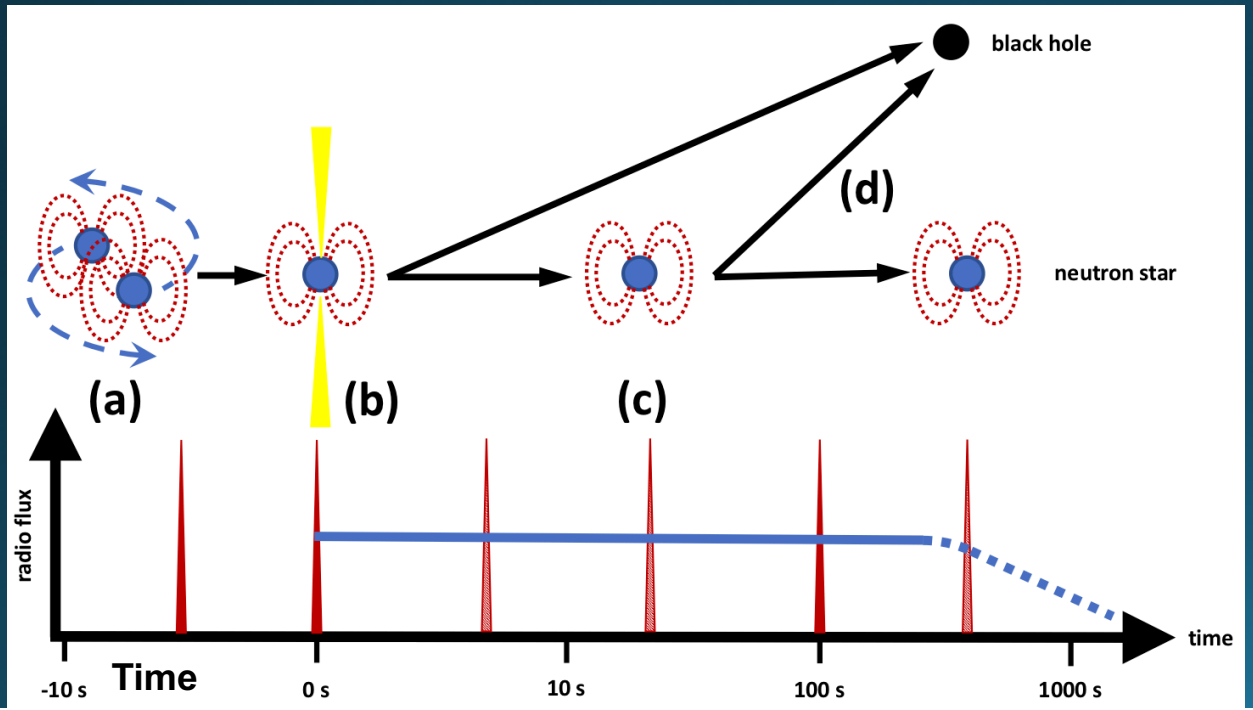
What is the merger remnant?

Key discovery space:

- jet launching mechanism
- NS equation of state (EOS)

Prompt Radio Emission

POST-MERGER



Hypermassive NS

collapse to BH → FRB?

Magnetar

- FRB-like emission
- Pulsar-like emission

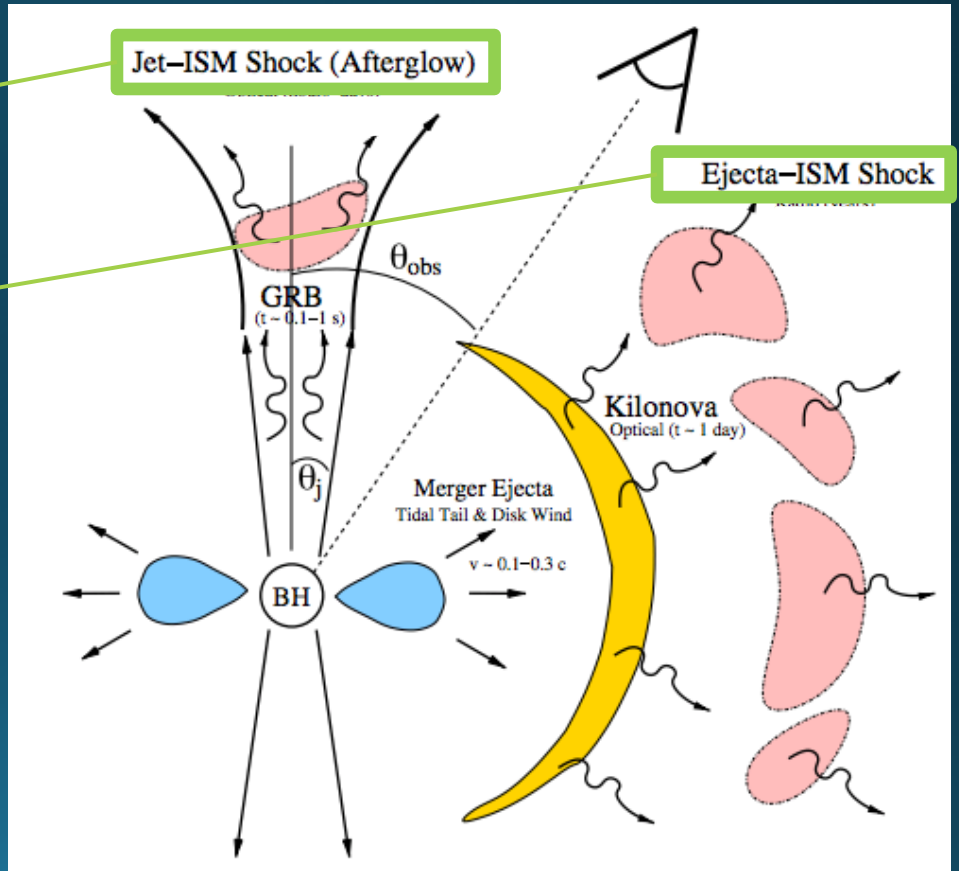
LOW-LATENCY REQUIRED!

Late-time radio emission ✓observed for GW 170817

Jet afterglow: jet structure

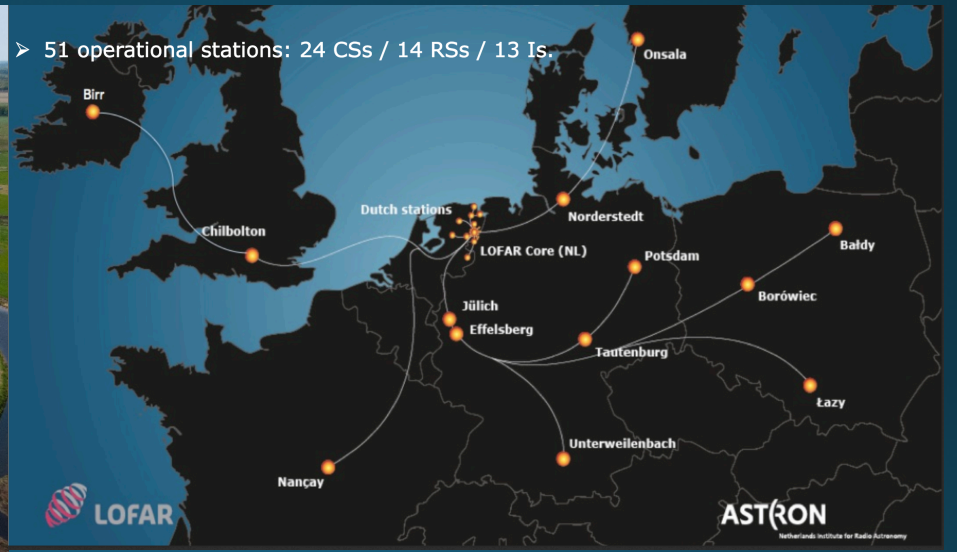
Dynamical ejecta afterglow: EOS

Afterglow brightness
depends on ISM density.



Adapted from Metzger & Berger 2012

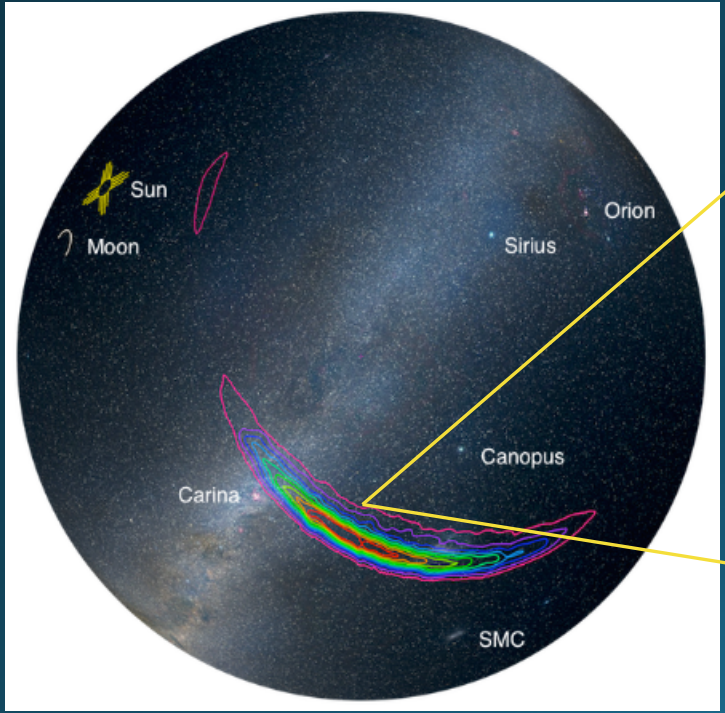
Low-frequency radio follow-up with the LOw Frequency ARray (LOFAR)

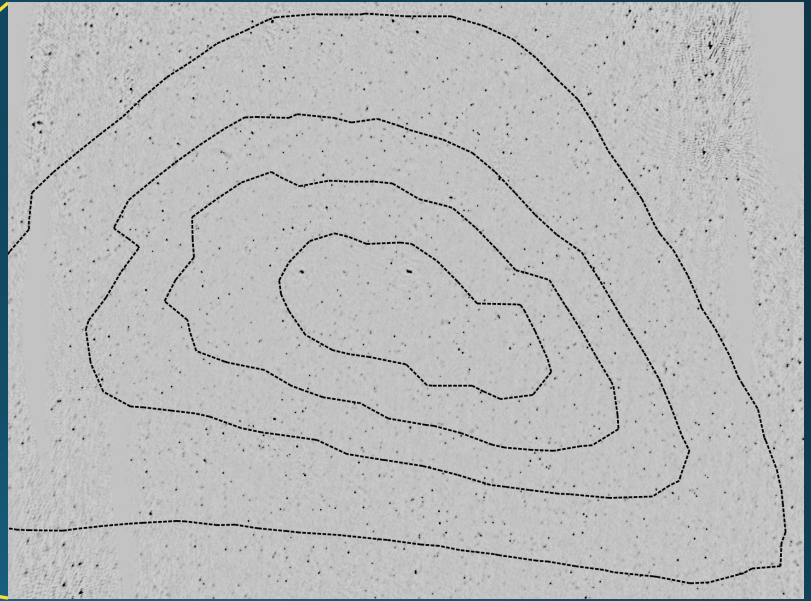


We collect data from 110-190 MHz

Why LOFAR?

Large instantaneous field of view





~60 deg^2

LOFAR follow-up of GW 150914

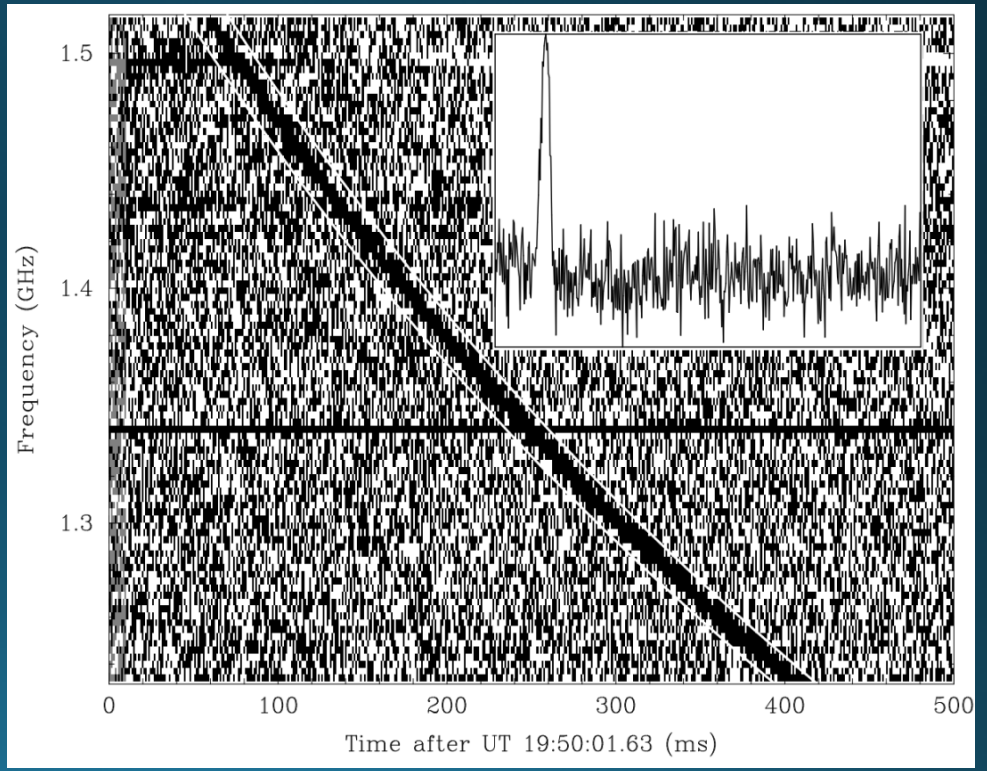
Why LOFAR?

Low frequency

Dispersion delay scales inversely with frequency.

Lower frequencies arrive later.

Gives us a chance to catch coherent emission related to mergers!

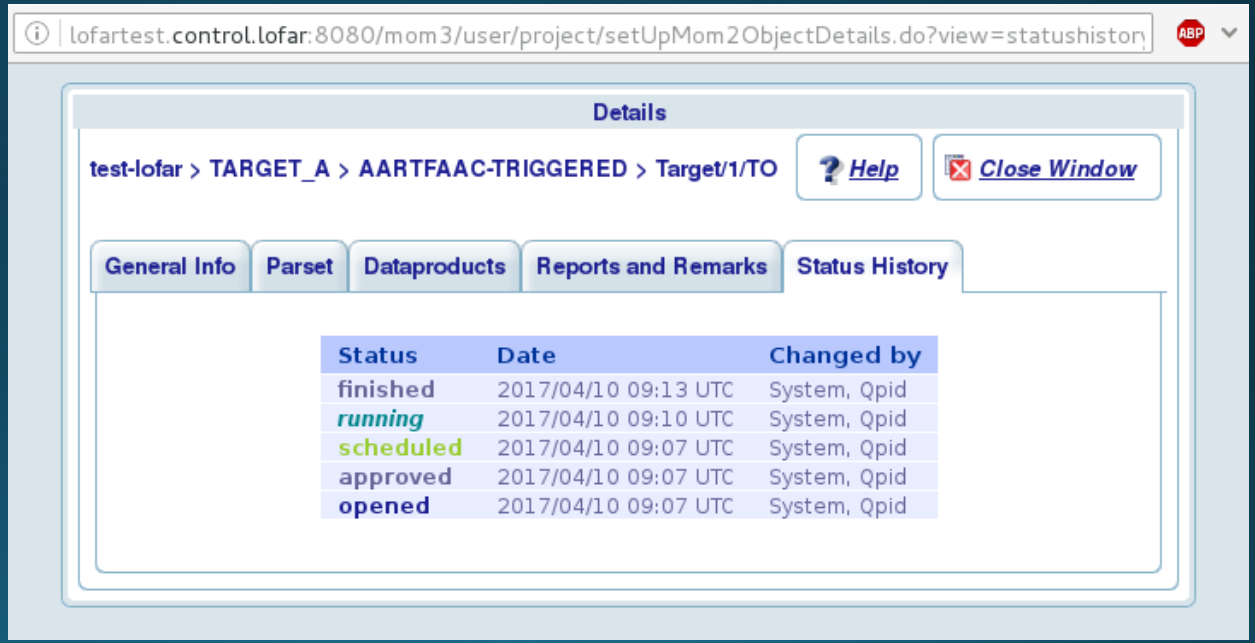


Lorimer et al. 2007

LOFAR rapid response

On source within <5 mins of trigger

Simultaneous beamformed + interferometric observations



See **Sander ter Veen's poster** for more info.

LOFAR GRB triggers

- GW detectors sensitive out to z~0.04
- SGRBs typically $0.1 \leq z \leq 1$
  - higher dispersion delays
- Swift alerts issued in seconds
- Can radio emission escape from LGRBs?

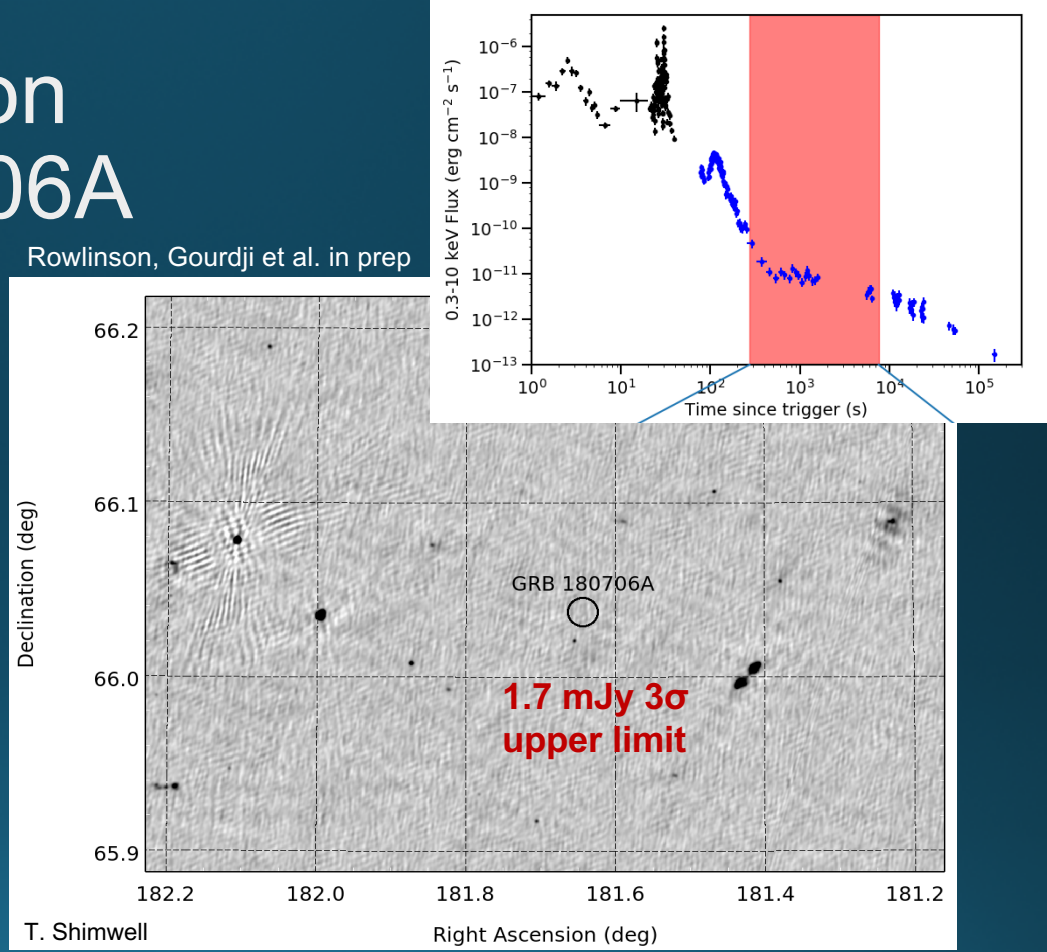
LOFAR Observation of long GRB 180706A

On source 4.5 minutes post-trigger!

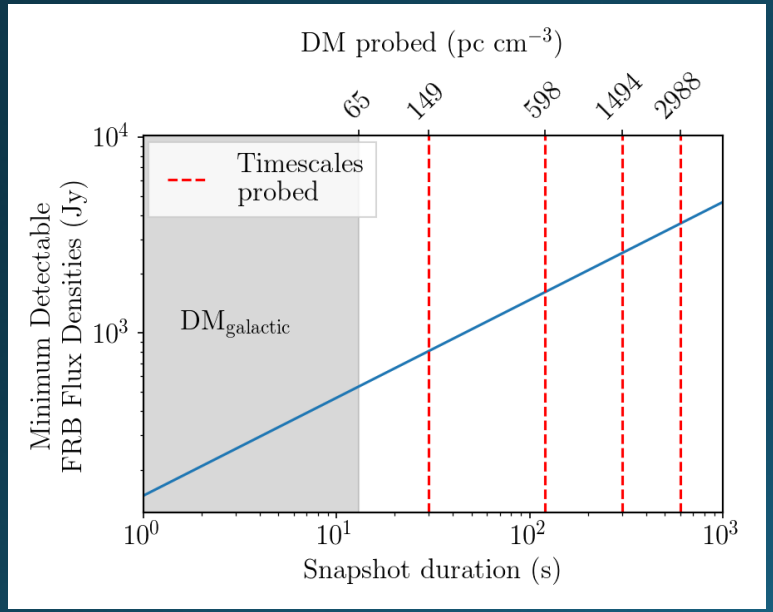
2-hr integration targeting pulsar-like emission

Three orders of magnitude deeper than the best previous study (Kaplan, Rowlinson et al. 2015).

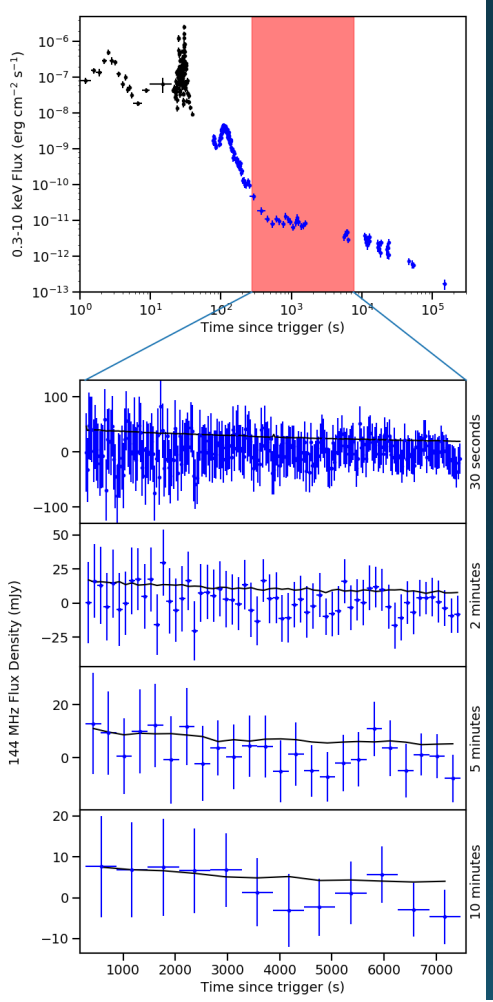
Rowlinson, Gourdji et al. in prep



LOFAR Observation of long GRB 180706A



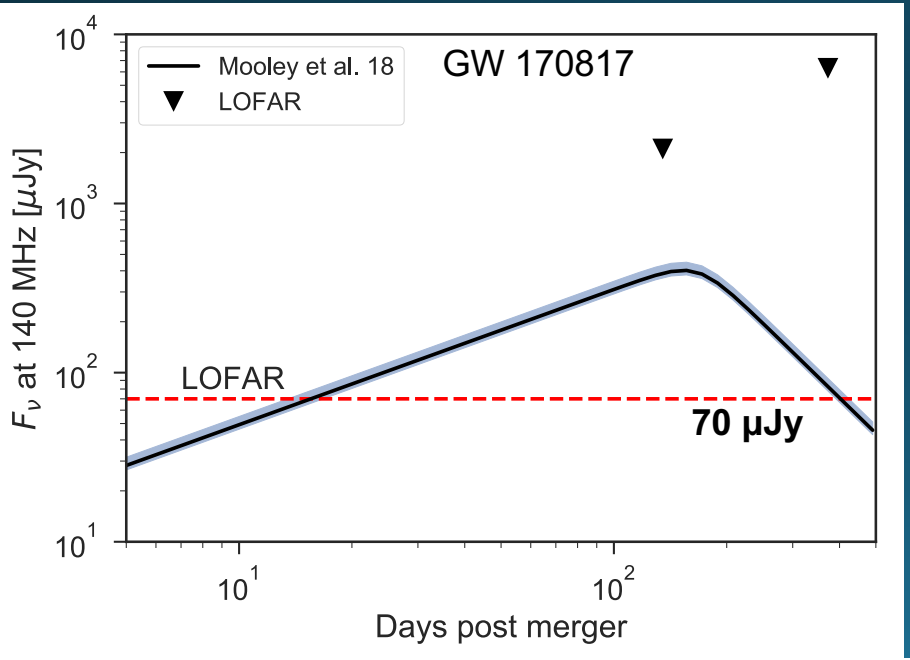
LOFAR Transients Pipeline (TraP)



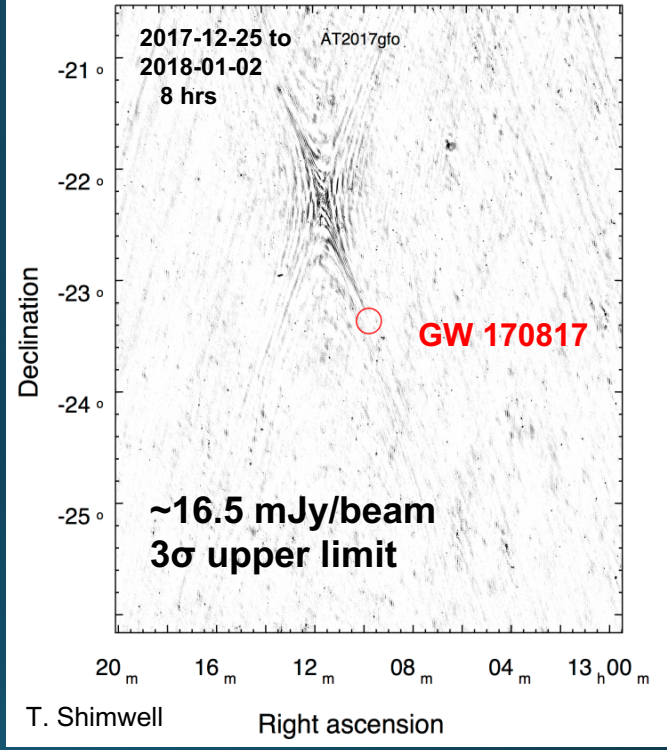
Snapshot images targeting FRB-like emission

Late-time observations of GW 170817

Broderick, Shimwell et al. in prep



Best limit at low frequencies



The deepest image ever made at very southerly declinations with LOFAR!

Max elevation ~13.7 deg

Looking ahead

- 10 triggers for upcoming aLIGO/aVirgo run and ~300 hours of follow-up time
- Larger GW detector network
  - Smaller localization thus deeper images
- Lower latencies for GW alerts and LOFAR triggering
- 2 triggers for GRB follow-up

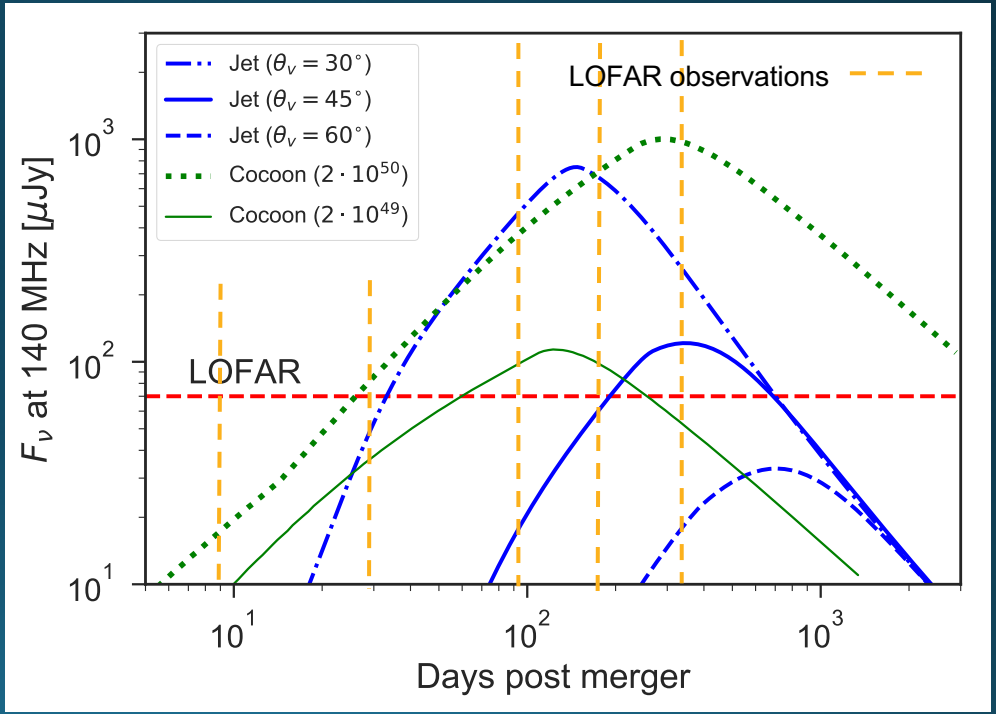
Thank you

ADDITIONAL SLIDES

Late time follow-up

GW170817-like jet, 100 Mpc, 0.01 cm^{-3}

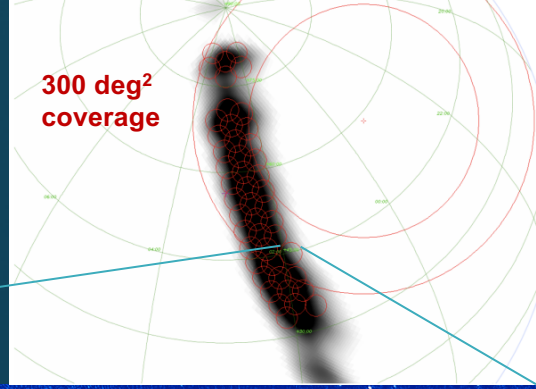
Searching for incoherent emission from e.g. reverse shock and/or afterglow.



Broderick, Shimwell et al. in prep

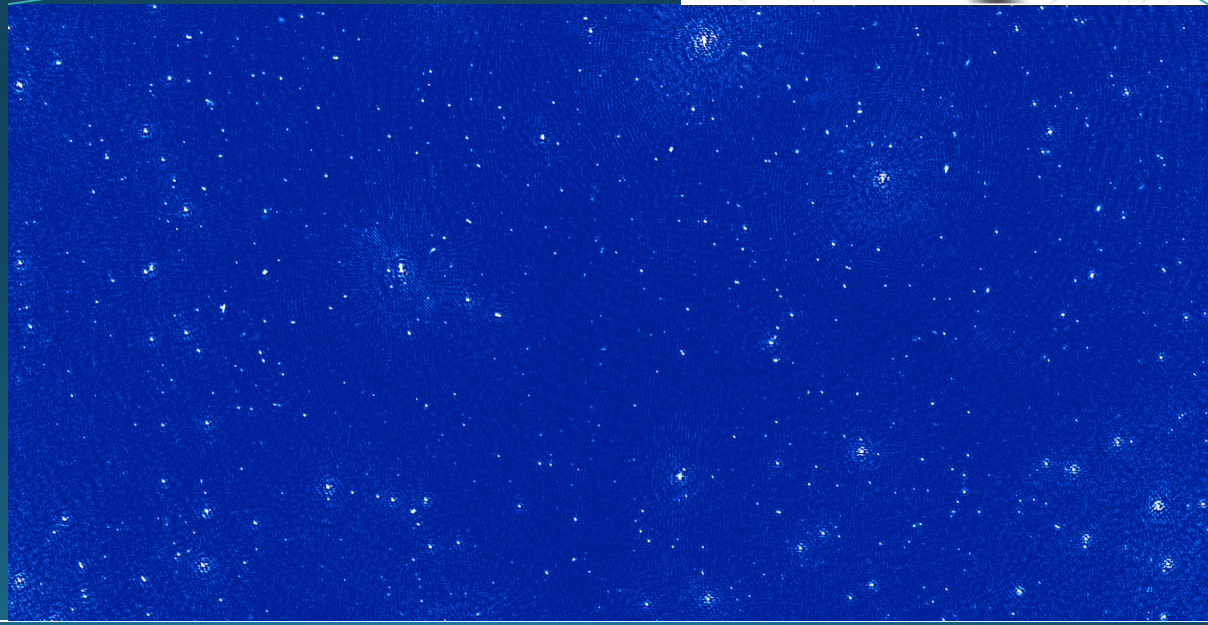
Late time follow-up

1 week, 1 month, 3 months, 6 months, 1 year timescales



Our 225 minute images are reaching 0.5 mJy/beam noise

We will go much deeper for well localized GW sources!



Late time follow-up

Searching for incoherent emission from e.g. reverse shock and/or afterglow.

Example for GW170817