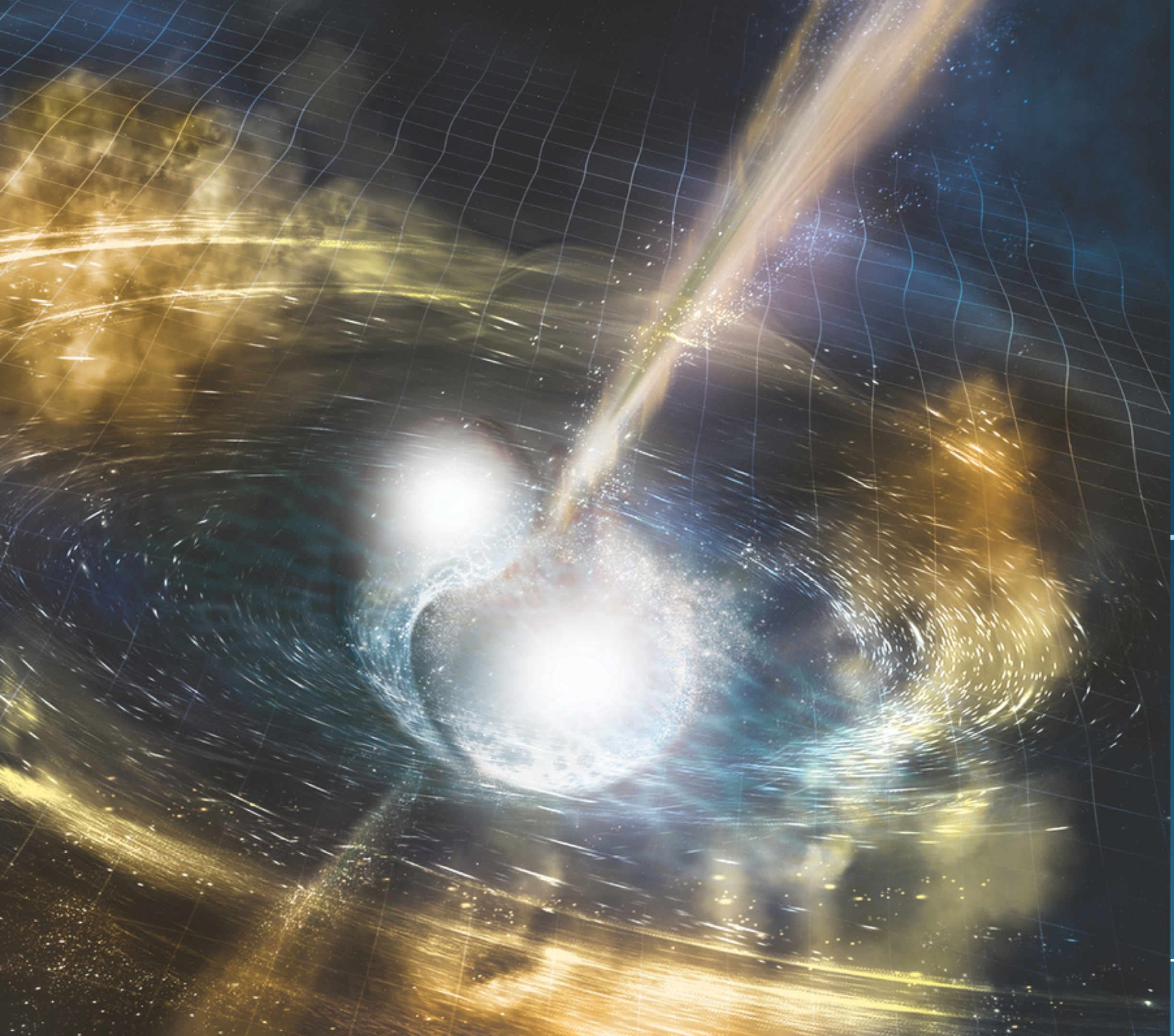

Observing radio signatures of compact binary mergers and GRBs with LOFAR

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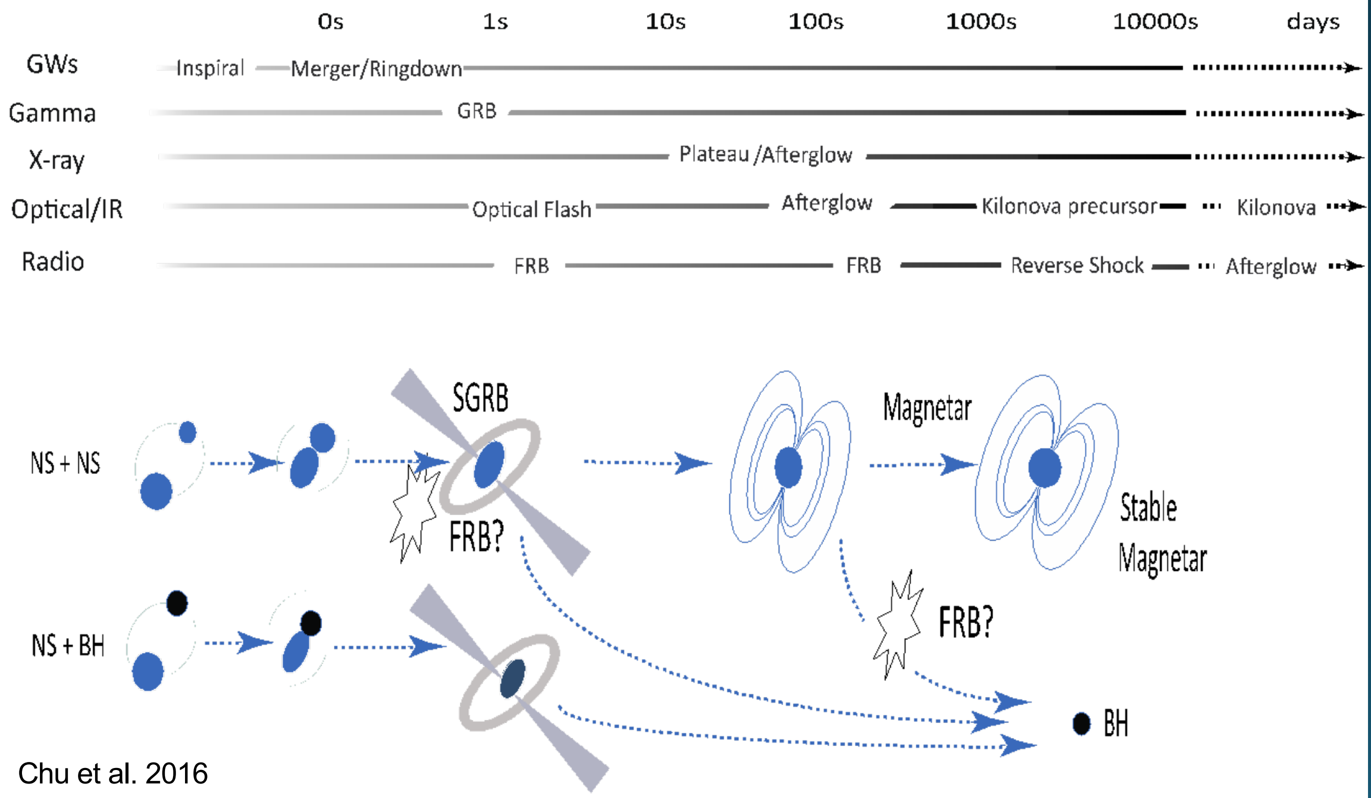
PhD student
University of Amsterdam

Supervised by
Dr. **Antonia Rowlinson,**
Prof. **Ralph Wijers**

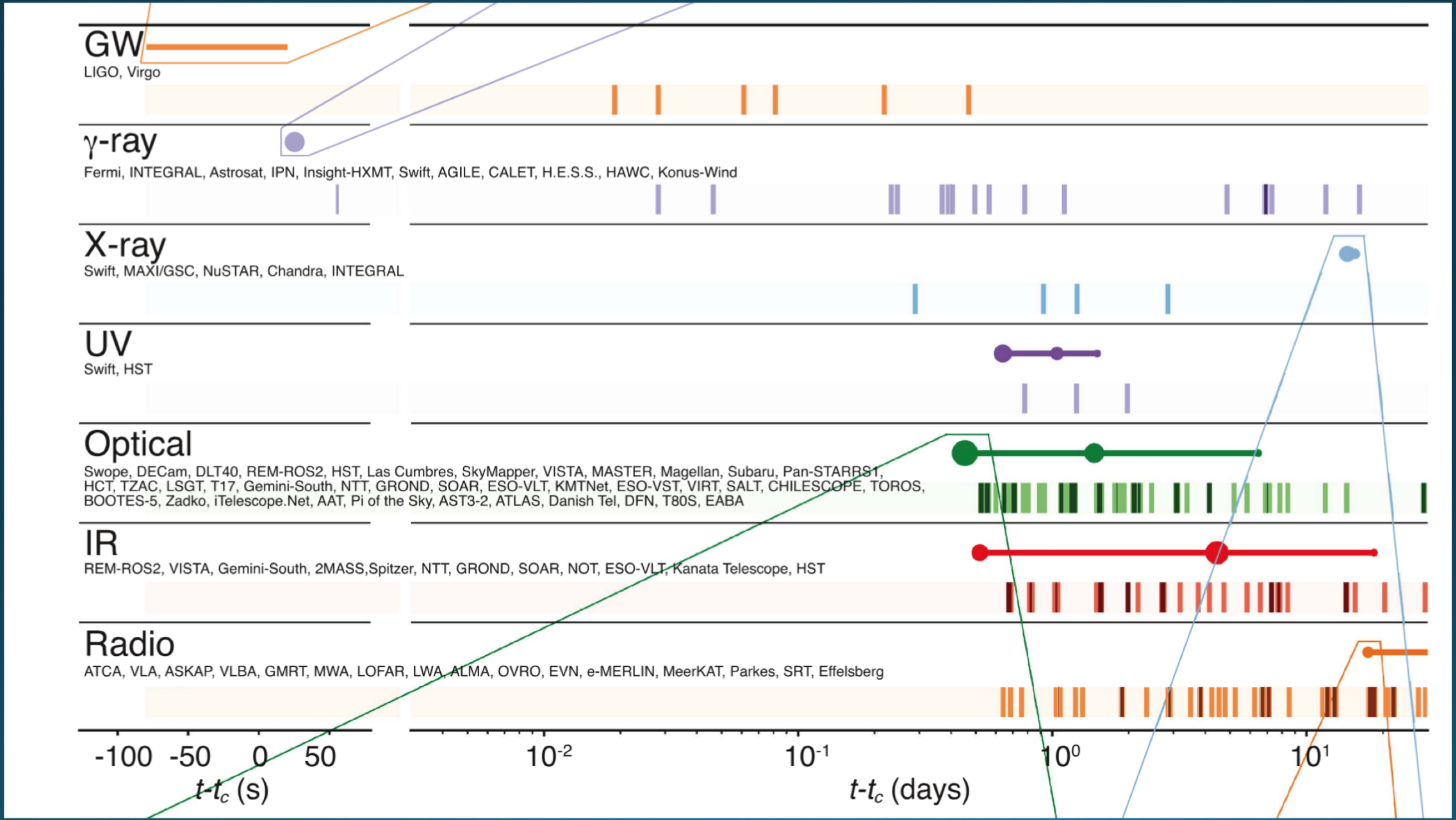
26 September 2019

Possible evolutions and accompanying emission



Chu et al. 2016

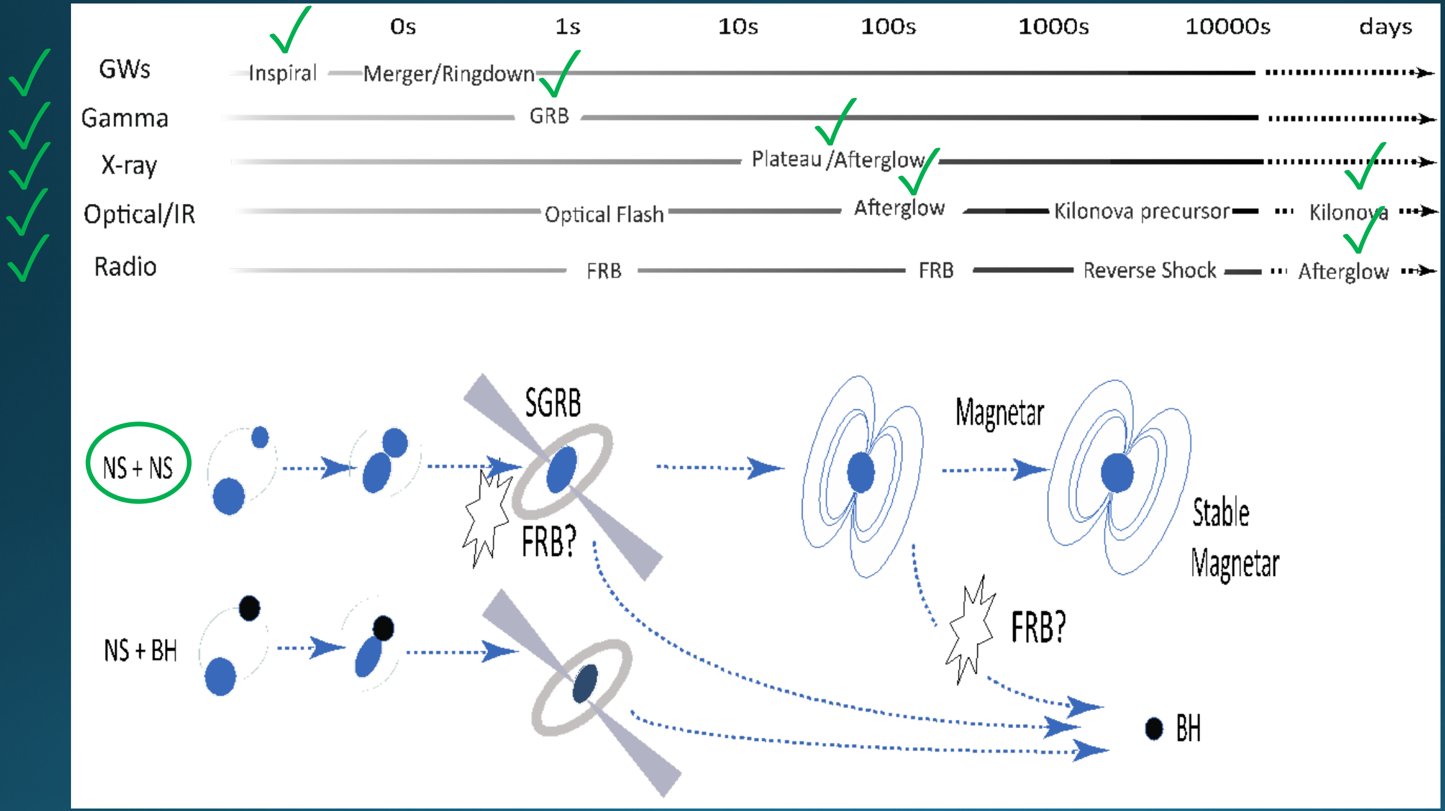
Multimessenger observations of GW170817



Abbott et al. 2017

Possible evolutions and accompanying emission

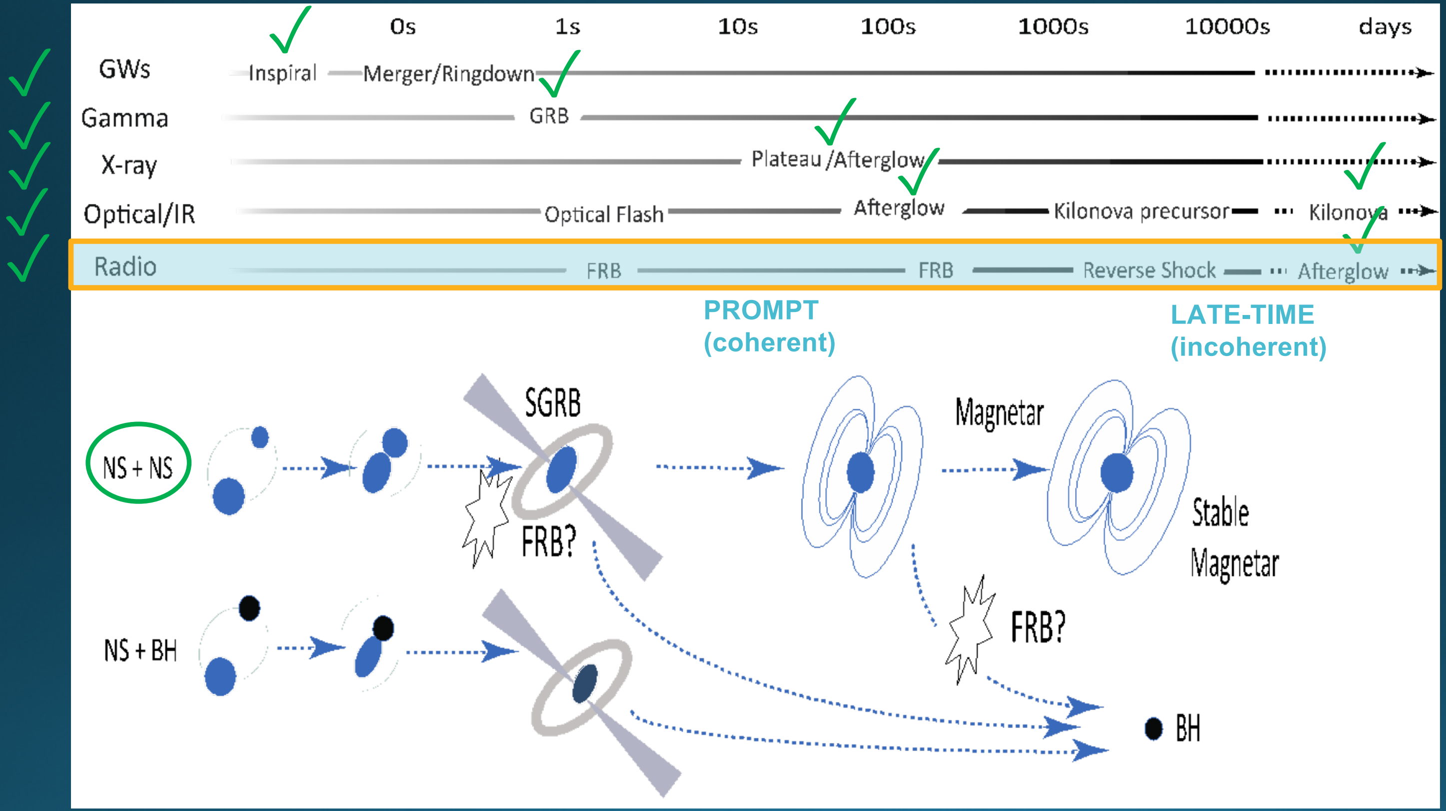
✓observed for GW170817



Chu et al. 2016 (adapted)

Possible evolutions and accompanying emission

✓observed for GW170817

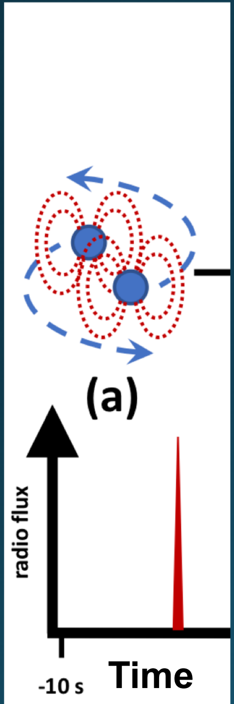


Chu et al. 2016 (adapted)

Prompt Radio Emission

Overview paper: Rowlinson & Anderson 2019

PRE-MERGER

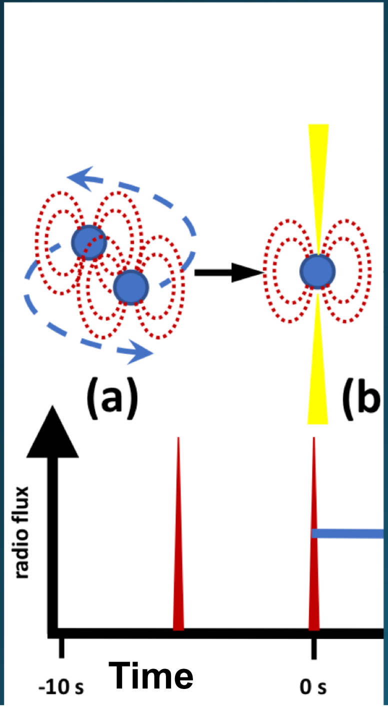


- Interacting NS magnetic fields e.g. Lipunov & Panchenko 1996
  Metzger & Zivancev 2016
- GW + plasma interaction e.g. Moortgat & Kuijpers 2003

Prompt Radio Emission

Overview paper: Rowlinson & Anderson 2019

MERGER



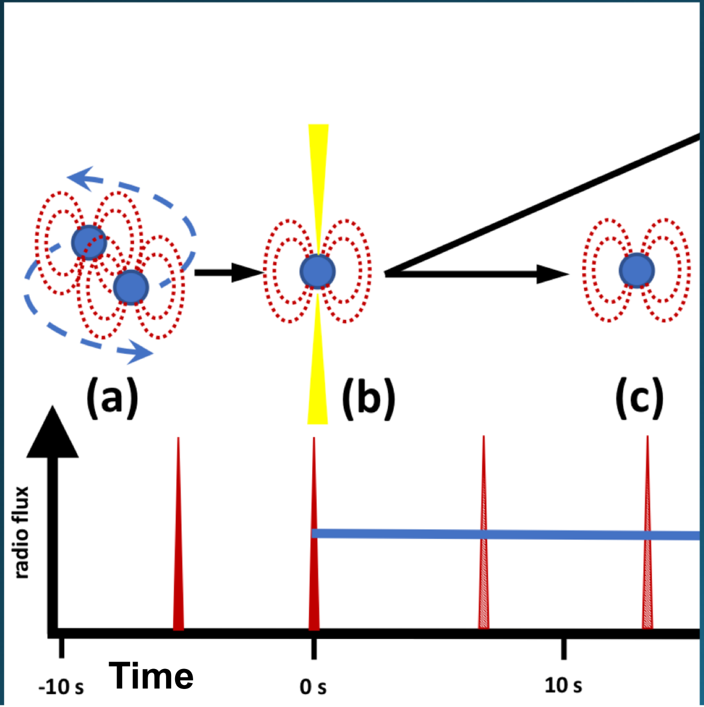
- interactions within the relativistic jet

  e.g. Usov & Katz 2000

Prompt Radio Emission

Overview paper: Rowlinson & Anderson 2019

POST-MERGER



What is the merger remnant?

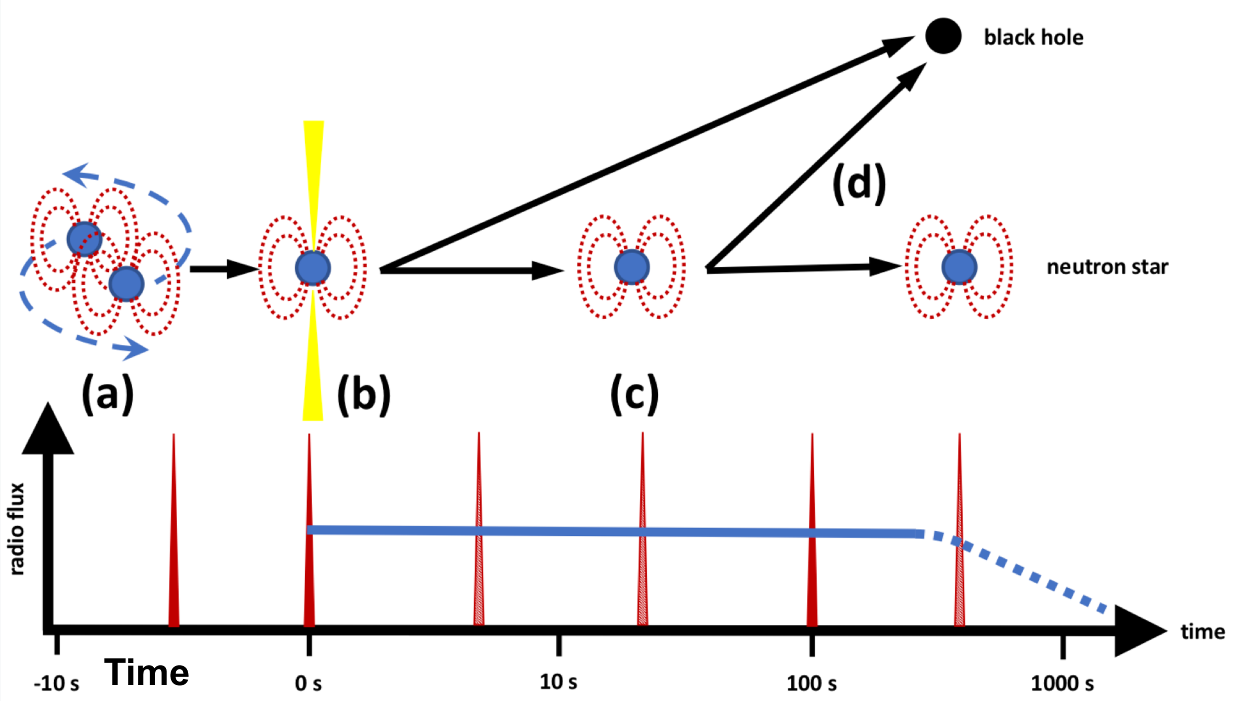
Key discovery space:

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

Prompt Radio Emission

Overview paper: Rowlinson & Anderson 2019

POST-MERGER



Hypermassive NS

collapse to BH → FRB?

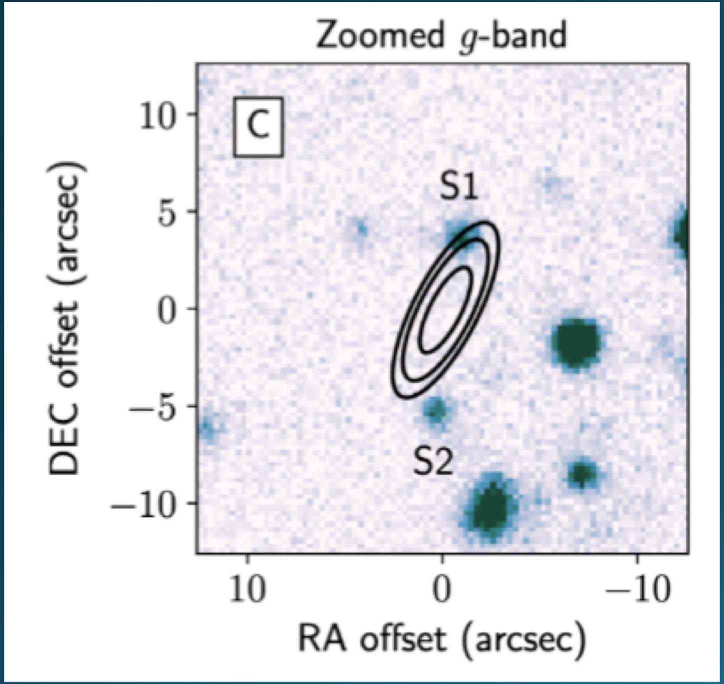
e.g. Falcke & Rezzolla 2014

(un)stable Magnetar

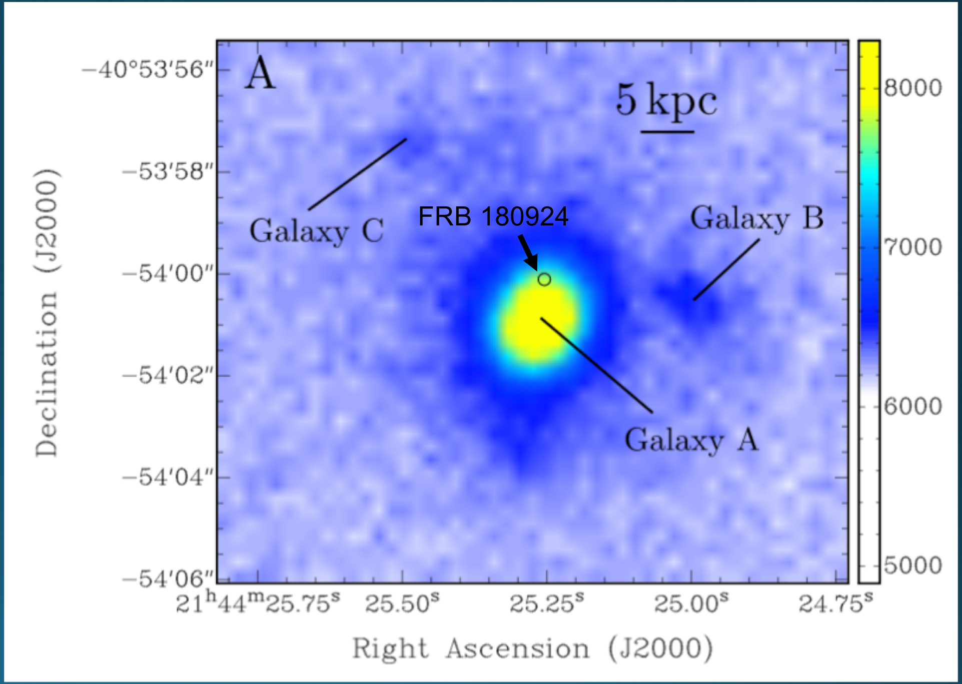
- FRB-like emission
- Pulsar-like emission

LOW-LATENCY REQUIRED!

Tantalizing FRB localizations…



Ravi et al. 2019



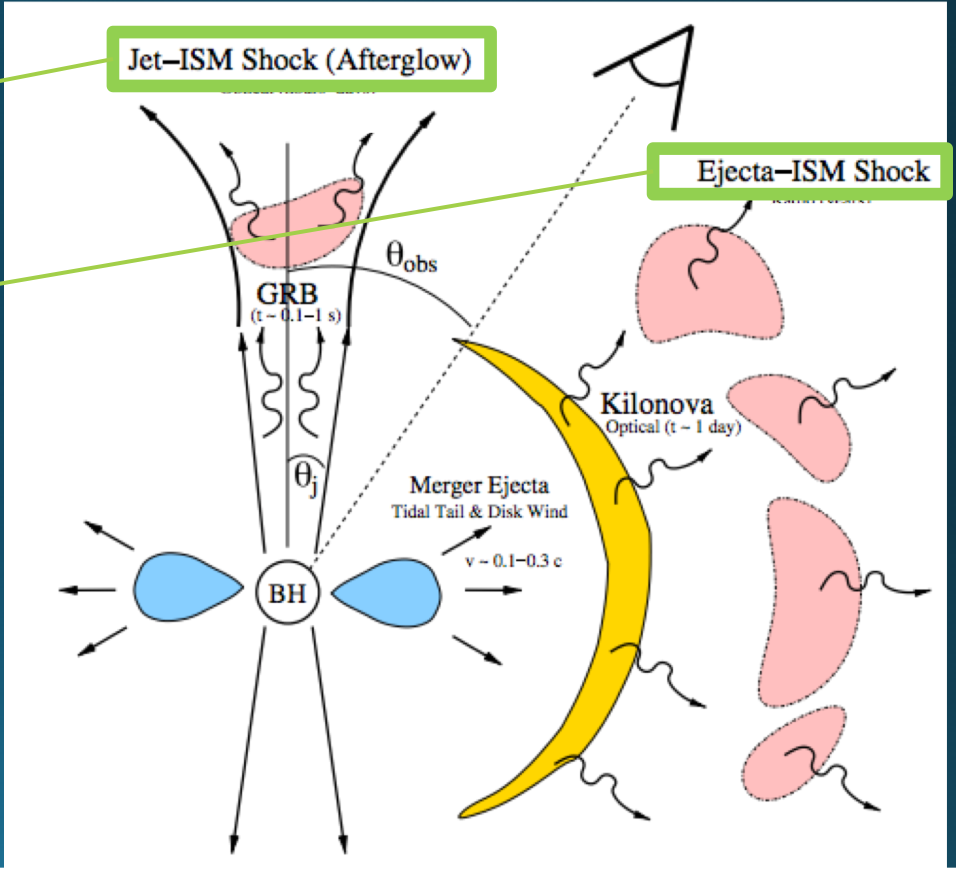
Bannister et al. 2019

Late-time radio emission ✓observed for GW 170817

Jet afterglow: jet structure

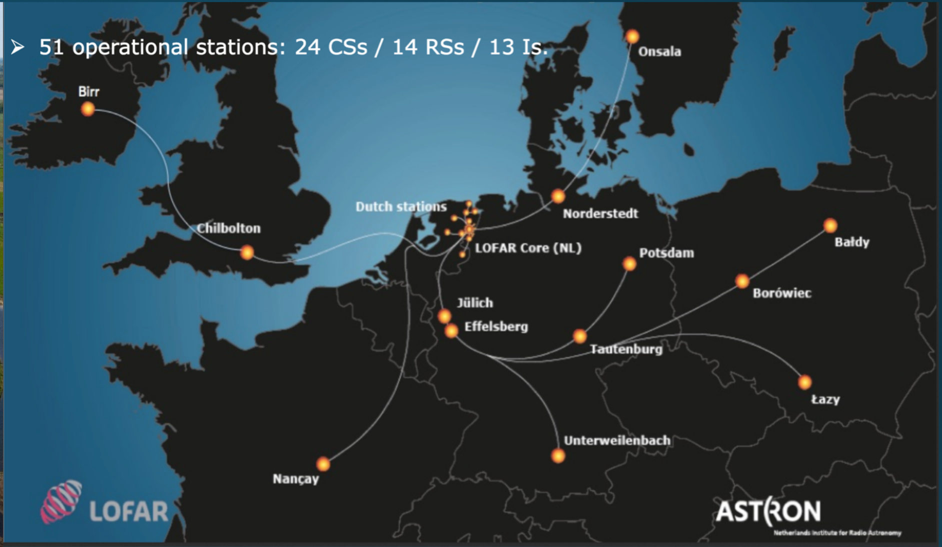
Dynamical ejecta afterglow: EOS

Afterglow brightness depends on ISM density.



Adapted from Metzger & Berger 2012

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



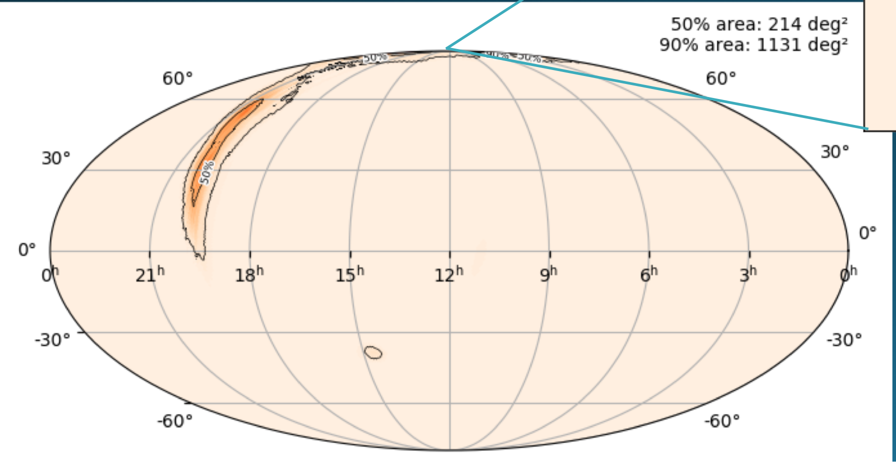
We collect data from 110-190 MHz

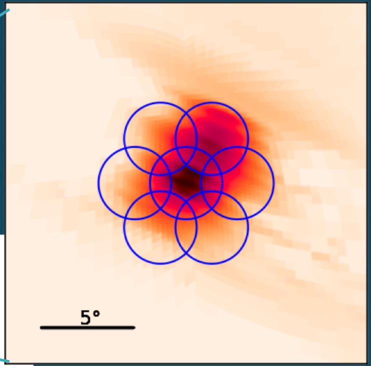
Why LOFAR?

Large instantaneous field of view

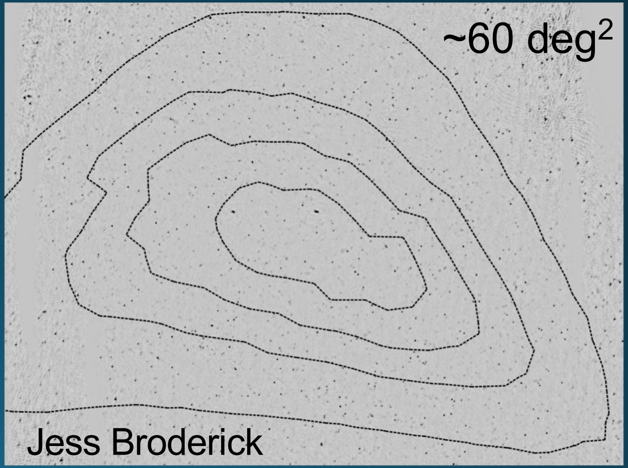
S190426c – BH/NS candidate

LOFAR covers ~22% of GW probability map





LOFAR follow-up of GW 150914



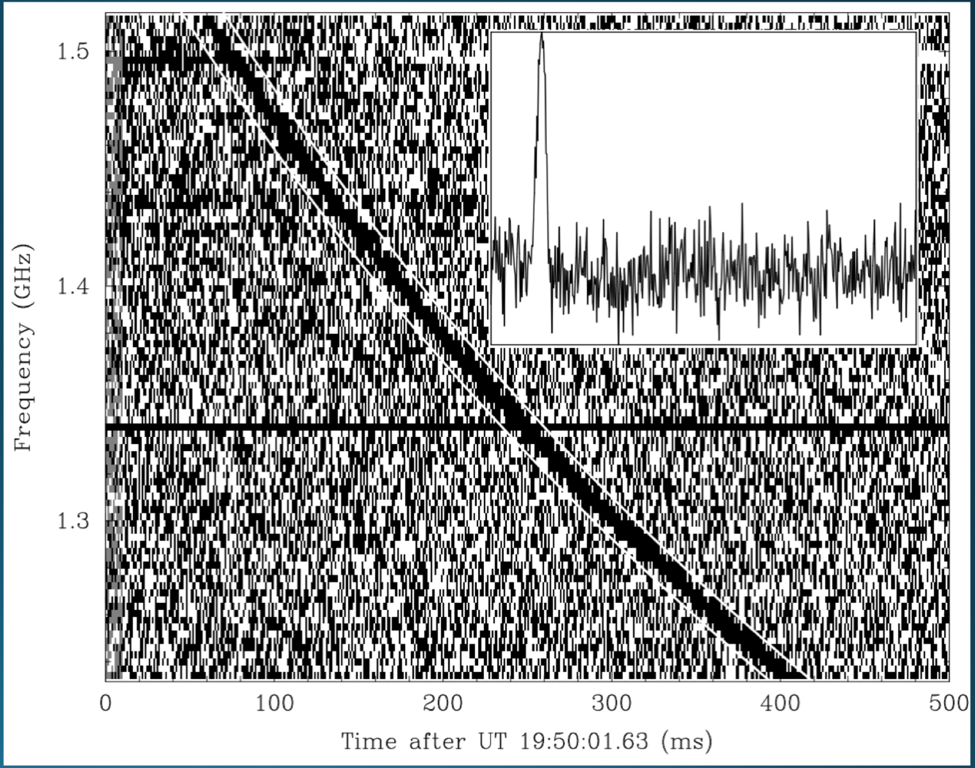
Why LOFAR?

Low frequency

Dispersion delay scales inversely with frequency.

Lower frequencies arrive later.

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

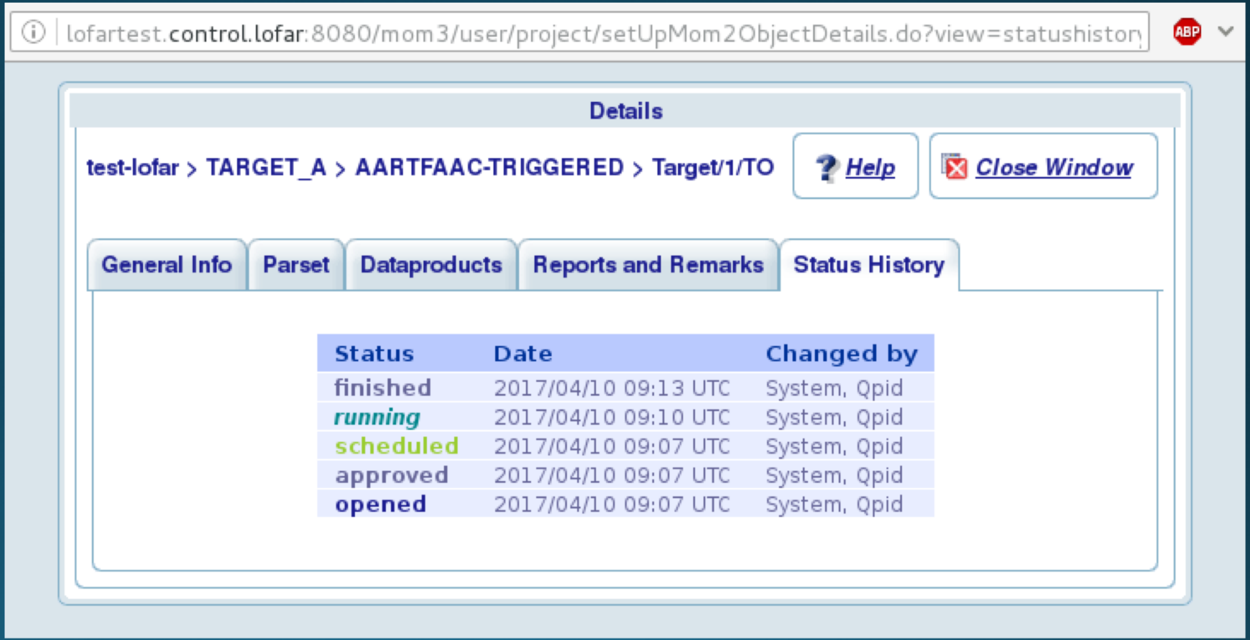


Lorimer et al. 2007

LOFAR rapid response

On source within <5 mins of trigger

Simultaneous beamformed (soon) + interferometric observations



See https://asterics2020.eu for more info.

LOFAR GRB triggers

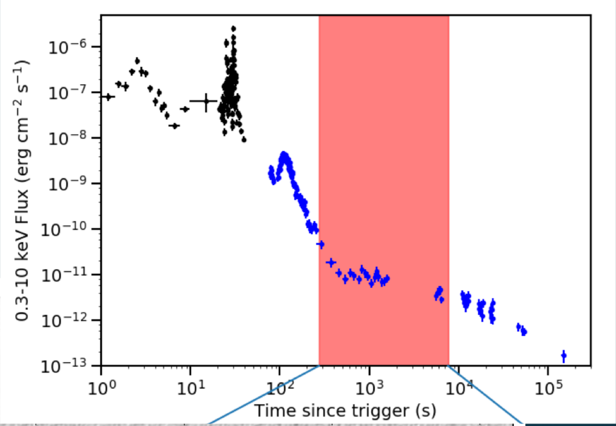
- GW detectors sensitive out to only z~0.04
- SGRBs typically $0.1 \leq z \leq 1$
  - higher dispersion delays
- Swift alerts issued in seconds
- LGRBS (CCSN), unclear if radio emission can escape.

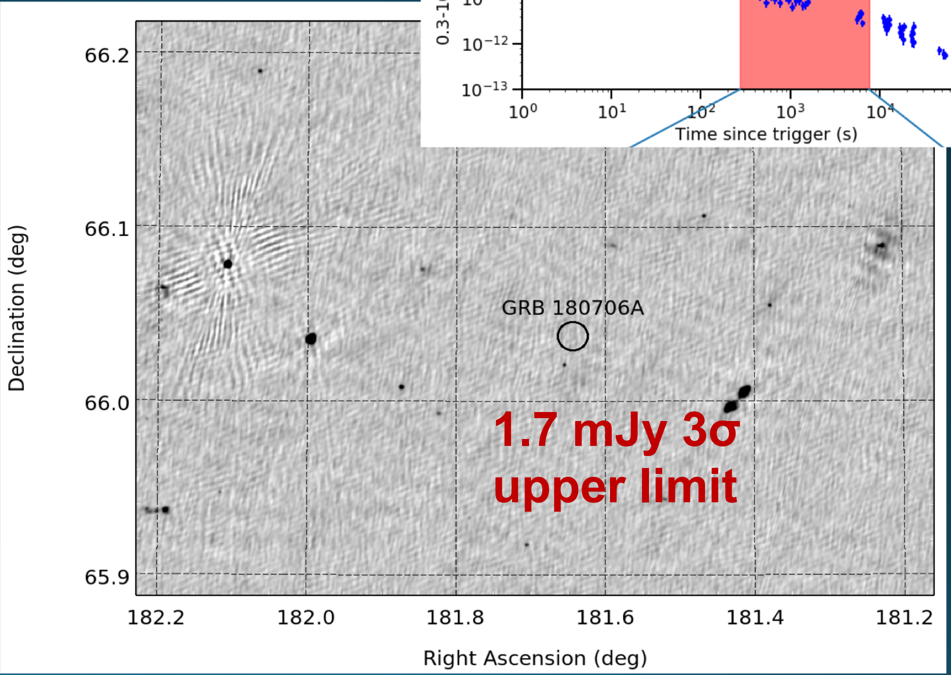
LOFAR Observation of long GRB 180706A

On source 4.5 minutes post-trigger

2-hr integration targeting pulsar-like emission

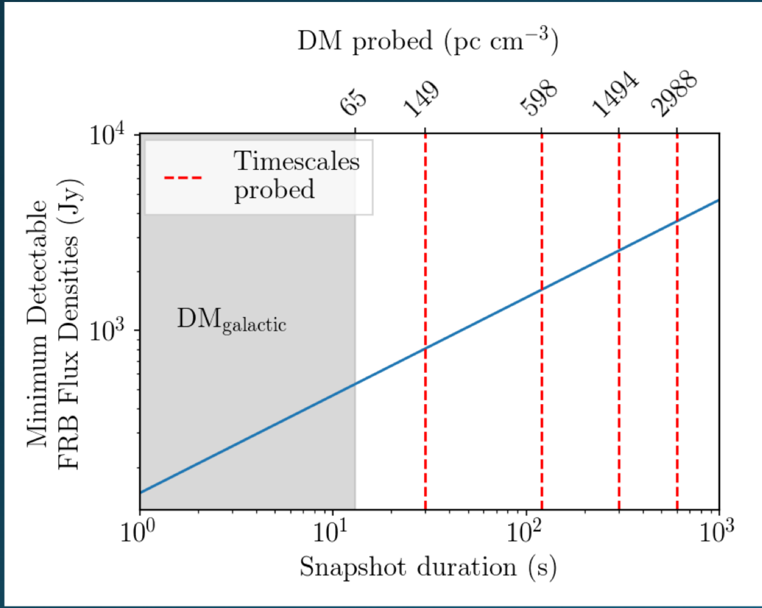
Three orders of magnitude deeper than the best previous study (Kaplan, Rowlinson et al. 2015).





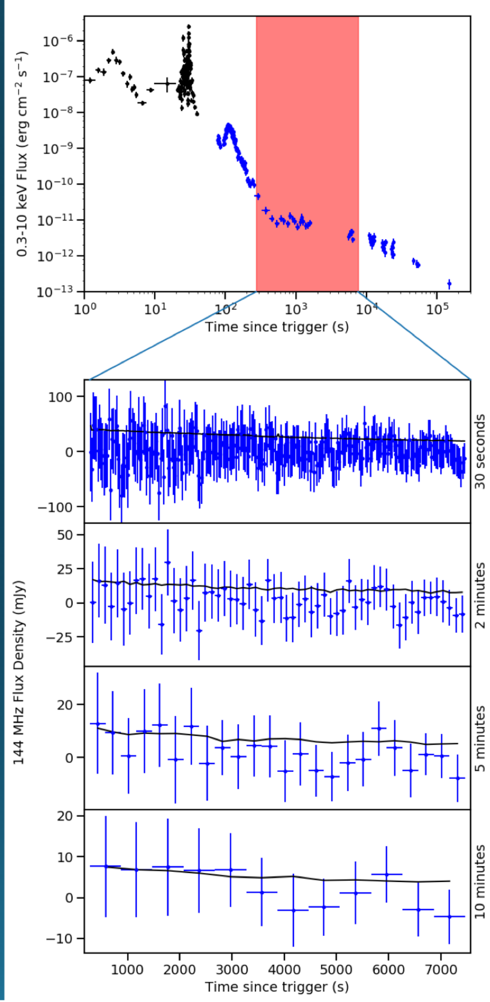
Rowlinson, Gourdji et al. 2019

LOFAR Observation of long GRB 180706A



Rowlinson, Gourdji + 2019

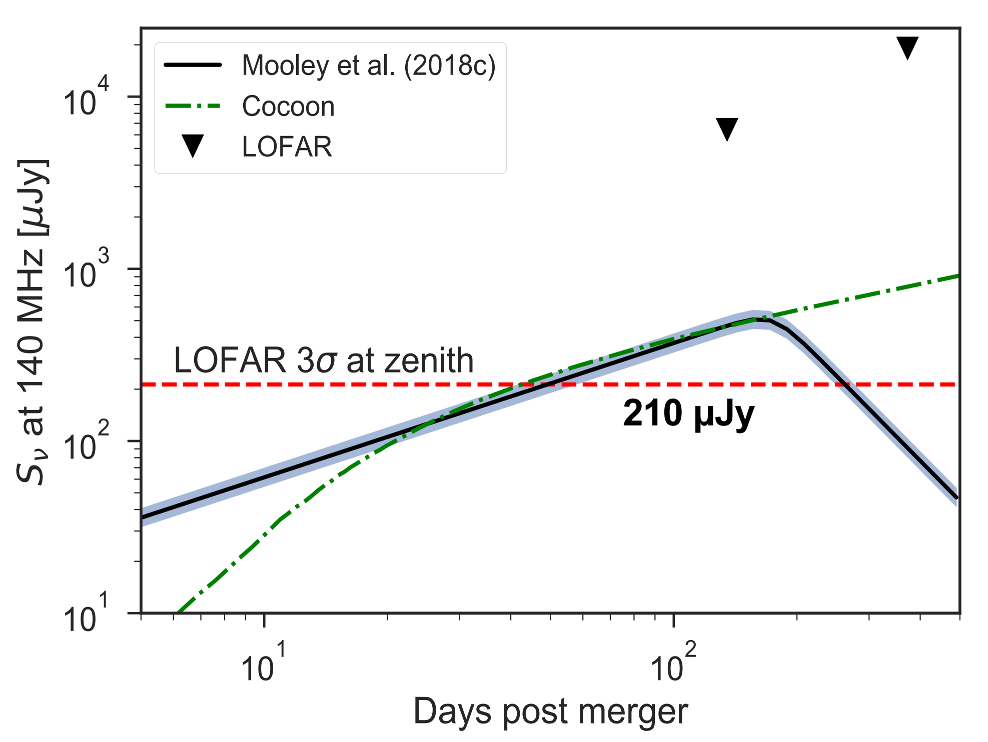
LOFAR Transients Pipeline (TraP)

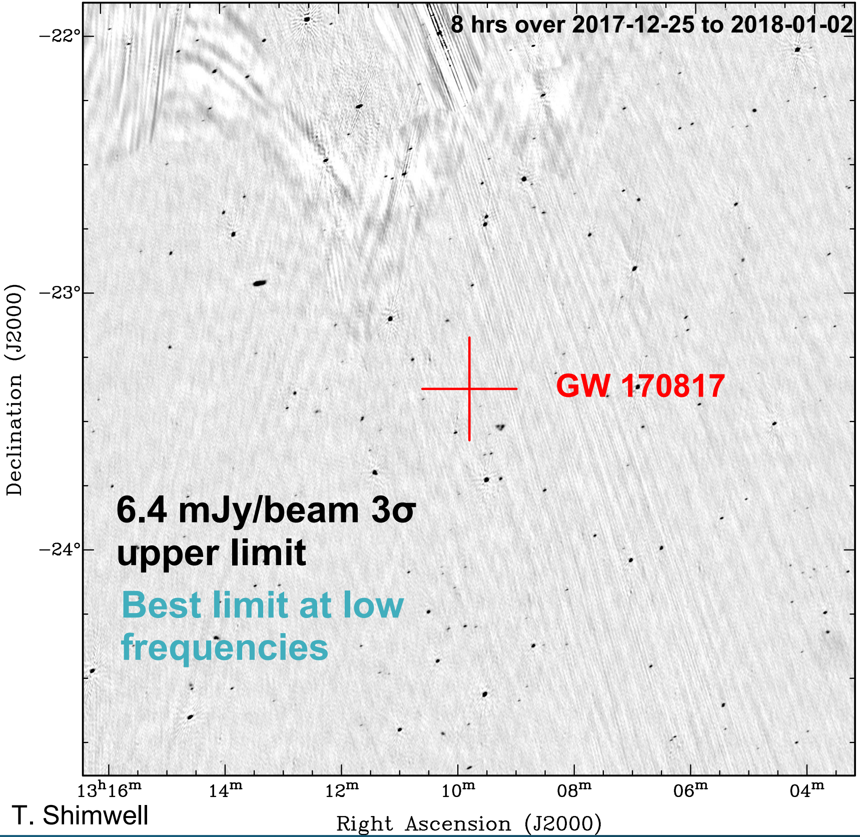


Snapshot images targeting
FRB-like emission

Late-time observations of GW 170817

Broderick, Shimwell, Gourdji + in prep





T. Shimwell

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

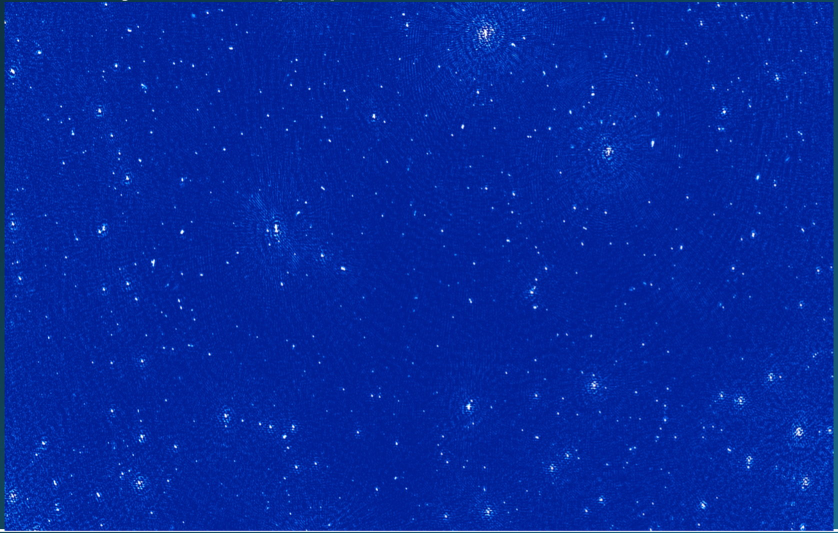
Max elevation ~13.7 deg

Late time follow-up

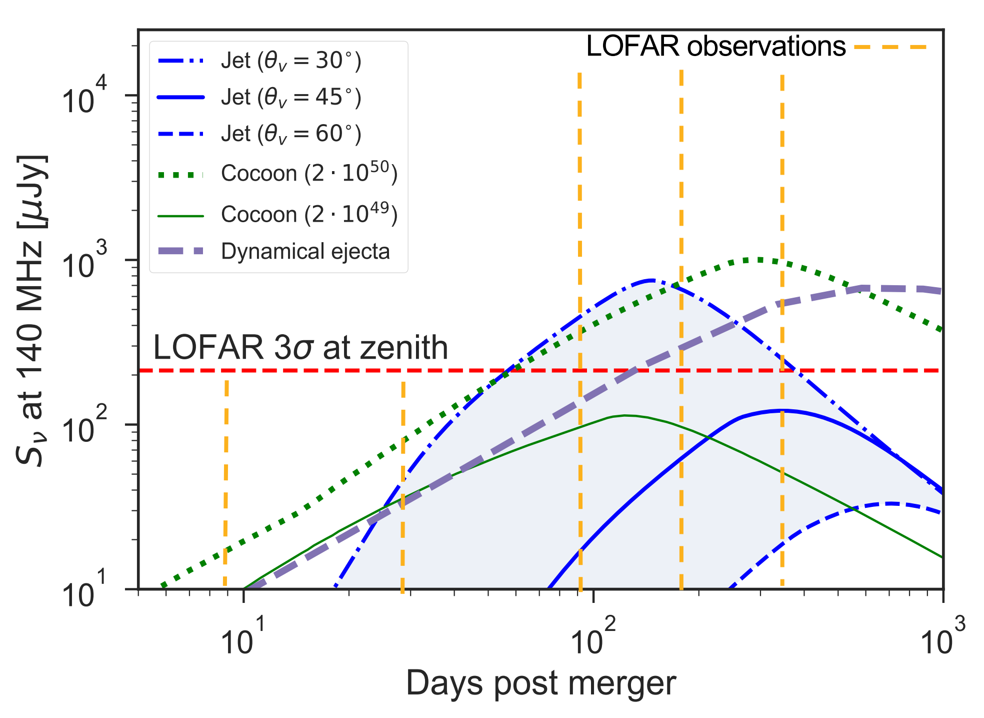
Searching for incoherent emission from afterglow.

Our 225 minute images are reaching 0.5 mJy/beam noise before DDC (sophisticated calibration techniques)

Gourdji et al. in prep



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



Broderick, Shimwell, Gourdji et al. in prep

Summary

Radio observations of BNS mergers can

- constrain the remnant
- tell us about the jet and neutron star(s) via the afterglow

LOFAR telescope triggers (within minutes)

- on GW merger events
  - constrains existence of a magnetar
- on Swift GRBs
  - Allows us to probe earlier timescales of compact mergers (sGRBs) and core-collapse supernovae (lGRBs)