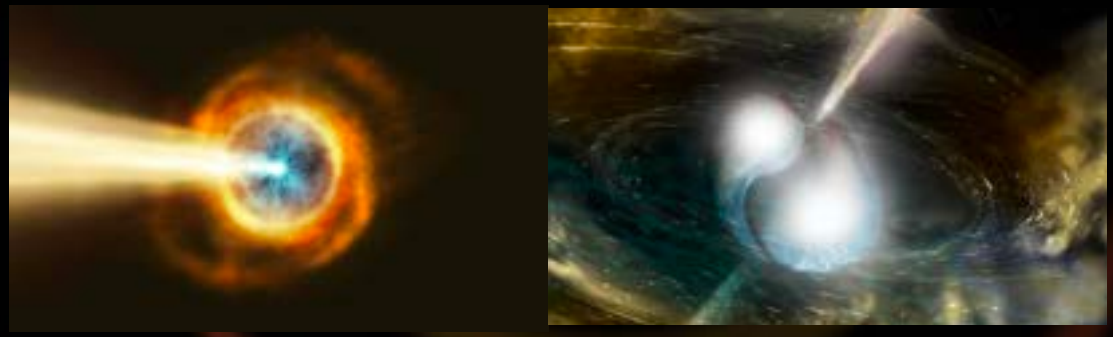
Transient science with the ATCA rapid-response mode



Gemma Anderson

ICRAR-Curtin University

ATUC Science Day – 8 Nov 2022

gemma.anderson@curtin.edu.au

International Centre for Radio Astronomy Research

Curtin University

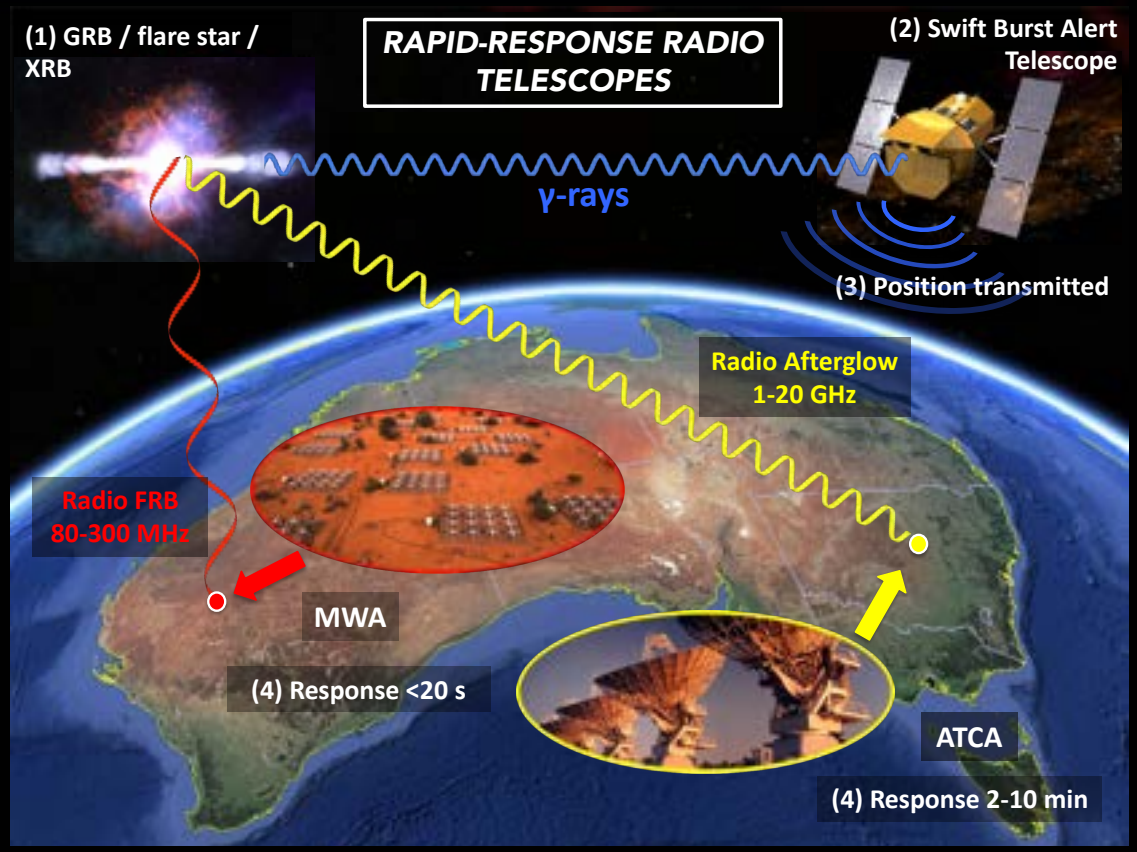
The University of Western Australia

Government of Western Australia
Department of the Premier and Cabinet
Office of Science

ATCA rapid-response mode

Rapid radio follow-up of transient events

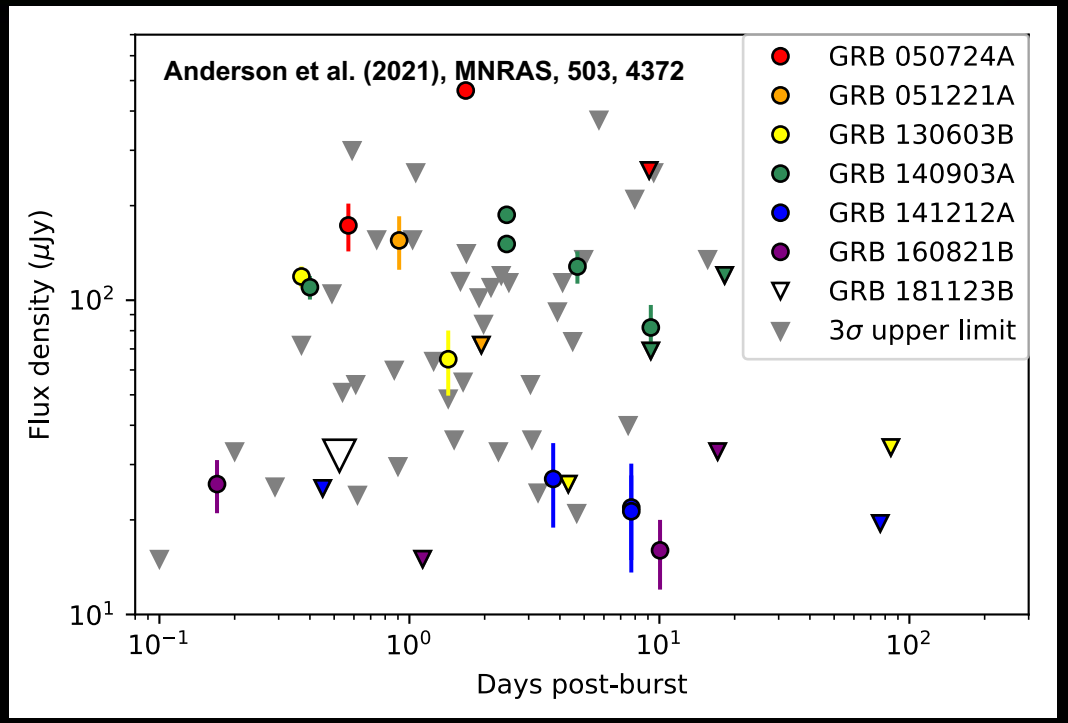
- Running since 2018
- ATCA Front-end (ADACS) triggers on VOEvents
  - VOEvents XML packets
  - Filter VOEvents to minimise contaminating events
    - 18 false alarms in 2019APR (majority canceled before override)
    - Down to ~2/semester, which are cancelled <1hr
  - Complete trigger automation and/or
  - Human-in-the loop decisions
- Hit EVERY edge case imaginable!
  - Also – back-end fails, front-end fails, maintenance, VLBL, calibrator database down
- Now have a reasonably robust system!



Science case: short gamma-ray bursts (GRBs)

Motivation: Gravitational wave links

- BNS merger GW 170817/GRB 170817A
- Only ~10 radio-detected SGRBs
  - Switch on <1 day post-burst, >50% fade <2 days
- MUST observe <24 hrs post-burst
- Short GRBs are RARE!
  - First GRB 181123B
  - ~3/6 short GRBs with rapid-response obs
  - but…. still no detections of short GRBs

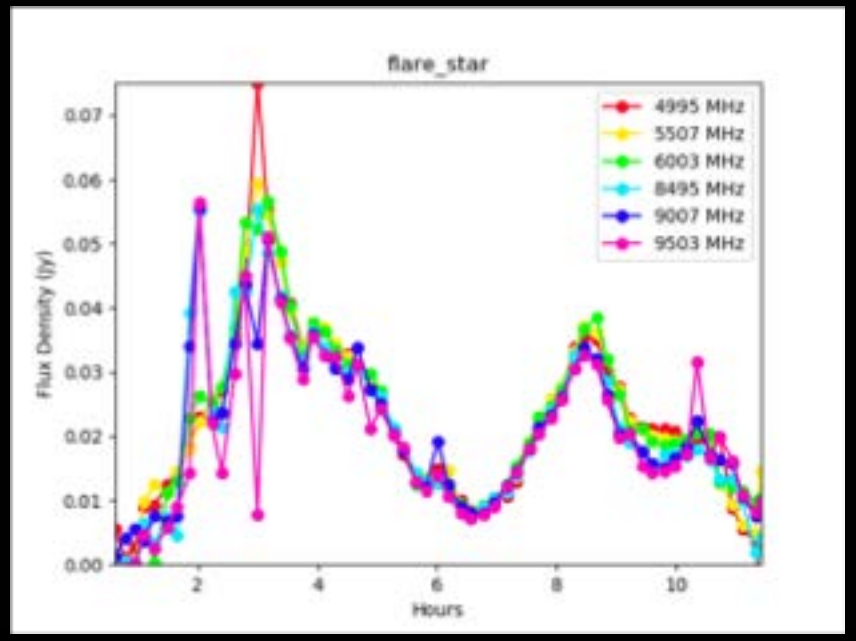


Event	Response (min)	Delay (min)	Data (hr)
LGRB 191004A	3.7	10	2.6
LGRB 191024A	6.8	7	0.3
LGRB 191031C	3.7	NA	2.6
SGRB 181123B	12.6 (hr)	Horizon limit	8.3
SGRB 200411A	1.33 (hr)	Calibrator database	2
SGRB 200907B	<1		6

Science cases: Flare Stars

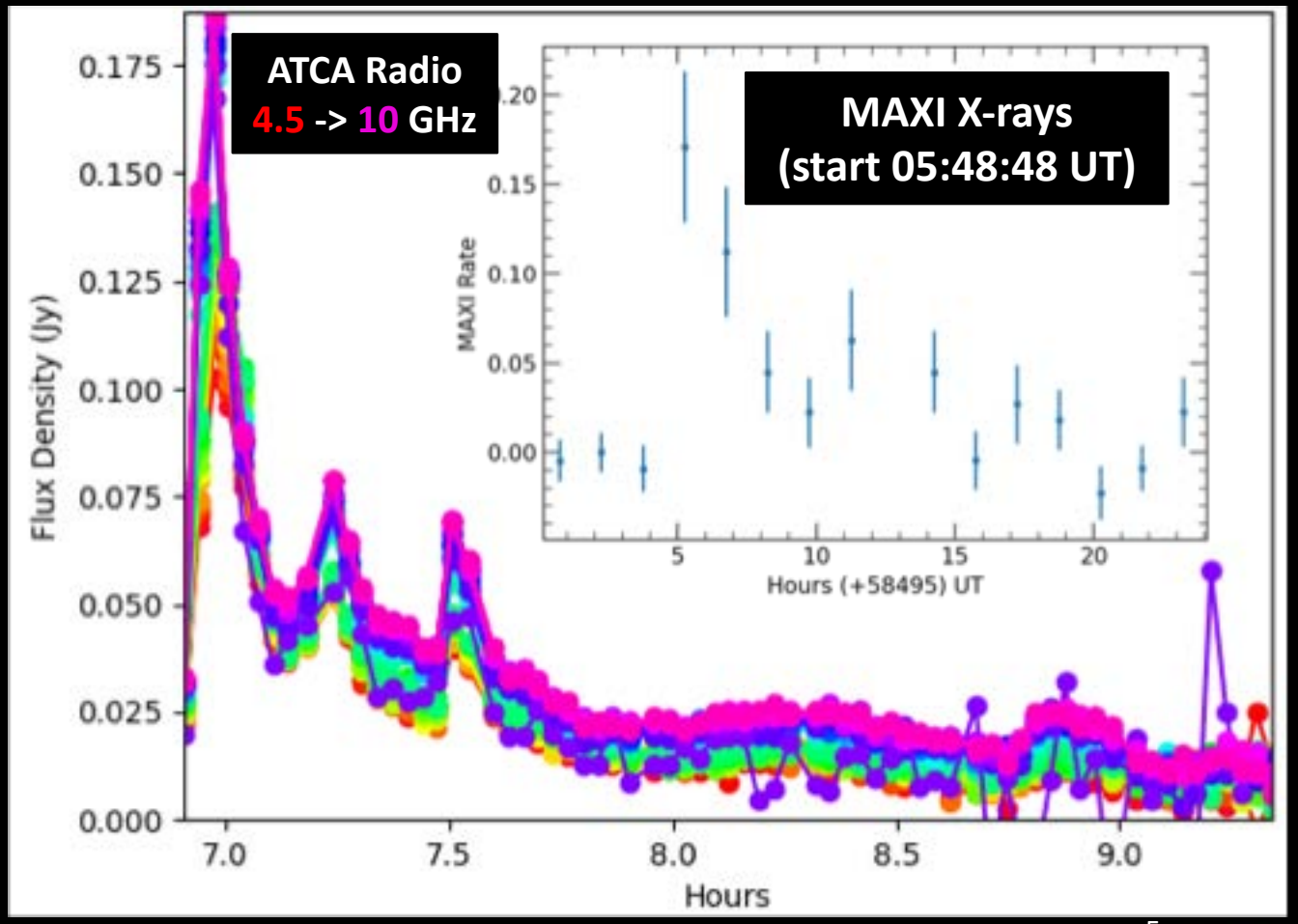
ATCA flare star triggers

X-ray/gamma-ray superflares (synchrotron) from M-dwarfs and RS CVn (gyrosynchrotron)



Credit: Daniele d'Antonio

UV Ceti (left) and AT Mic (right):
ATCA trigger on MAXI-detected flare

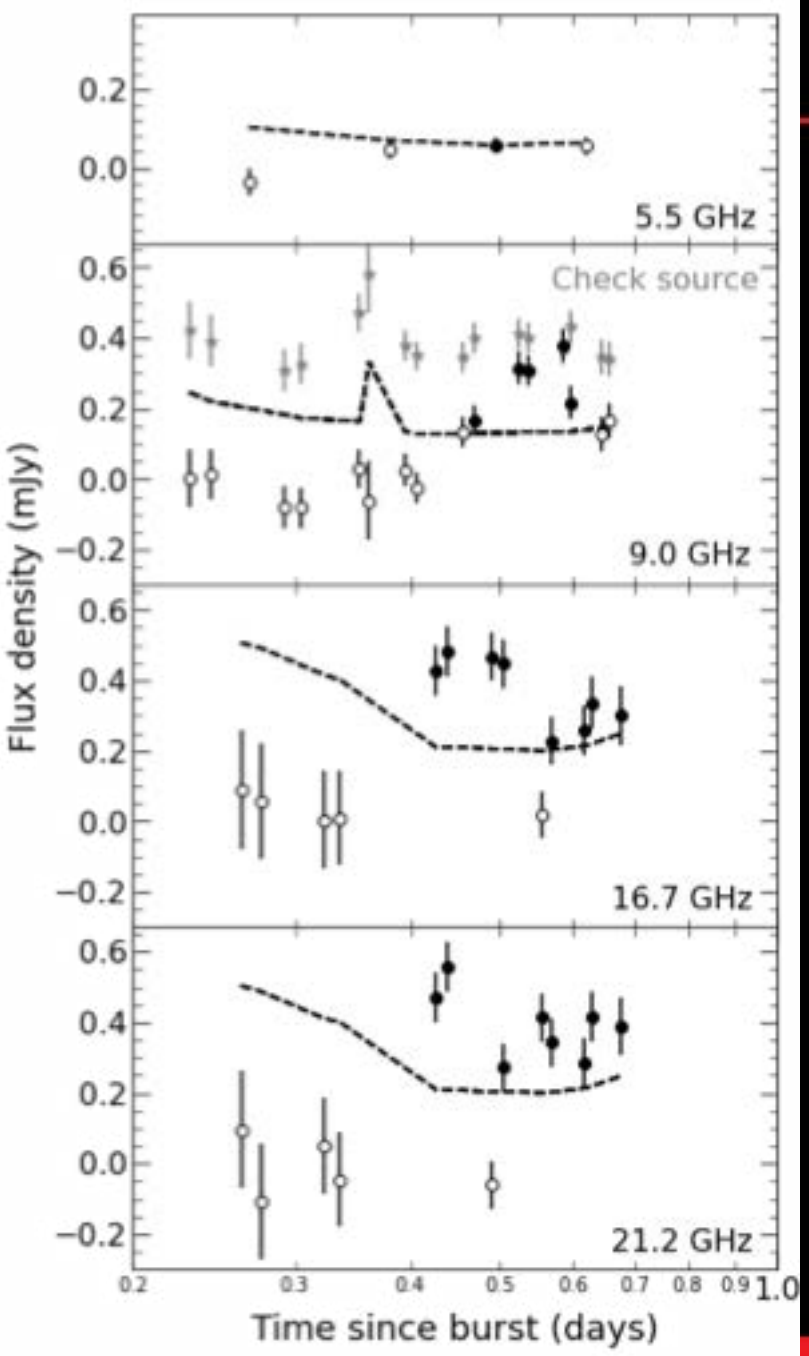


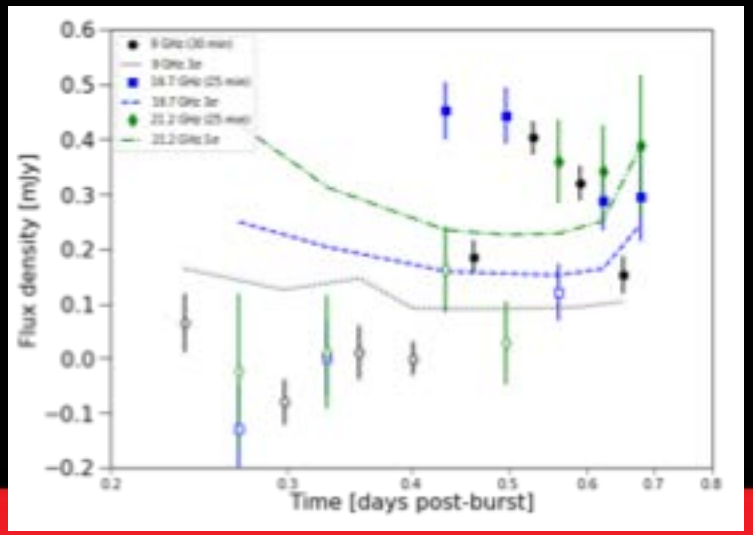
Credit: Jamie Stevens

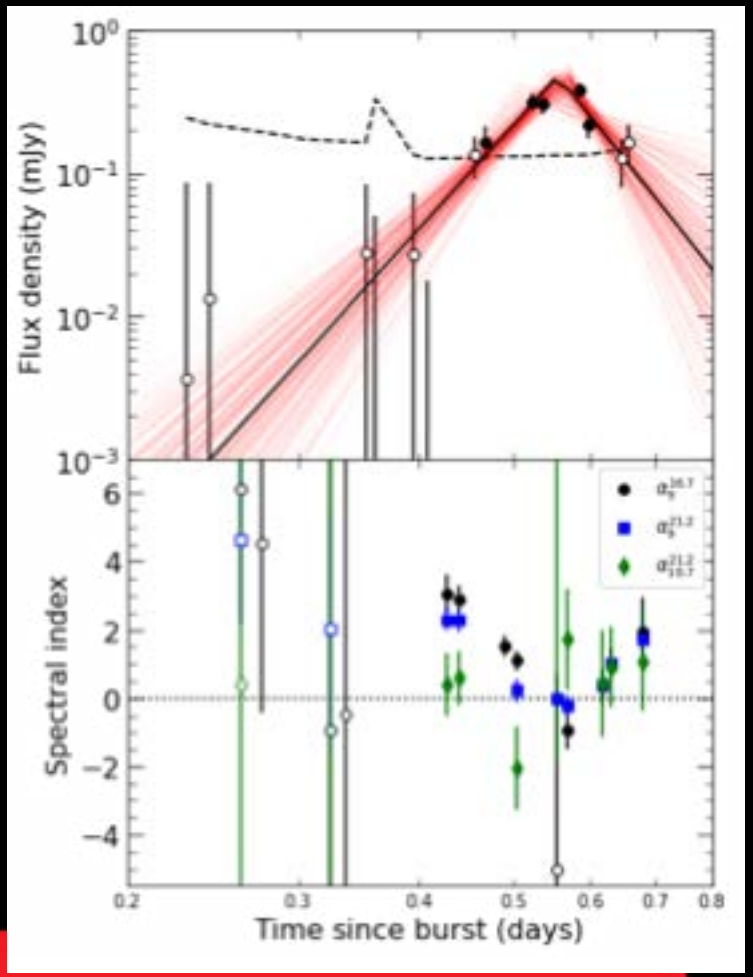
GRB 210702A

ATCA trigger from HESS (HESS/TeV GRB ATCA triggering program)

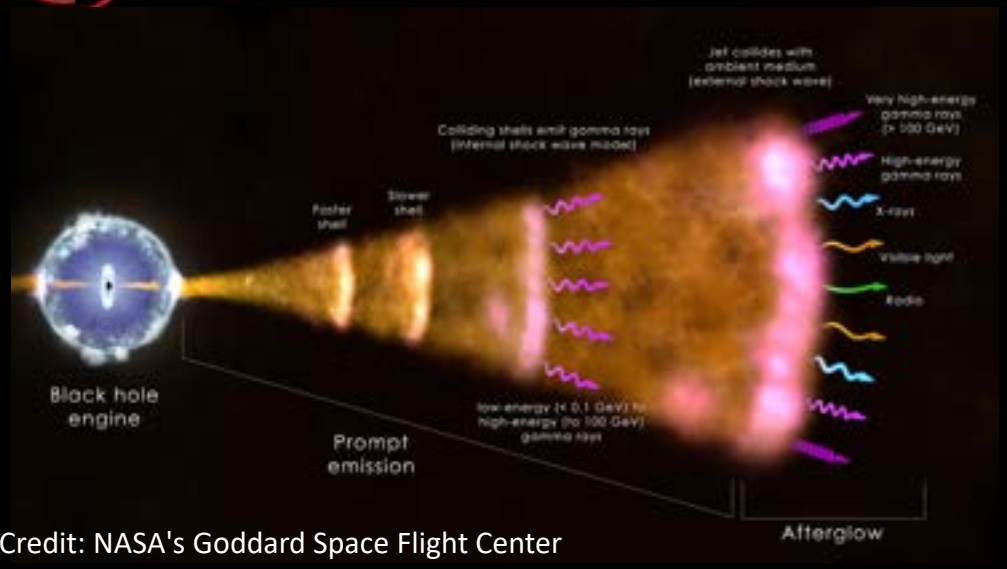
- On target 5.4 to 16.4 hrs post-burst (11 hrs)
- uvmultifit – no imaging, fitting for a point source in *uv*-plane
- 5.5 (60 min), 9 GHz (15 min), 16.7/21.2 GHz (12.5 min)
- 9 GHz flare 9-14 hrs
- Polarisation limits <30%
- Earliest detection of ~min timescale GRB radio variability?
- Cause? Likely Weak ISS
- Earliest GRB source size 8 x 10^{16} cm
- Source of radio emission boosted?







ATCA Large Program APR2023: Long GRBs



Credit: NASA's Goddard Space Flight Center

ATCA triggering experiment:

- Rapid triggering: Track reverse shock rise over 12 hrs (start 4-16 hrs post-burst)
- 5.5, 9, 16.7, 21.1 GHz trigger
- 5.5, 9, 16.7, 21.1, 33, 35, 45, 47 GHz monitoring
- BIGCAT will provide unprecedented quasi-simultaneous monitoring of fast evolving transients!

Science Cases for rapid follow-up

- Source of early-time radio variability (motivated by GRB 210702A)
- Disentangle early-time reverse shock (RS) radio emission from forward shock (FS)
  - RS: baryonic content, initial Lorentz factor, jet magnetization
  - FS: burst energetics, outflow geometry, density structure of circumburst environment
- Polarisation studies of radio RS – jet magnetic field structure
- Late-time radio follow-up is key to understanding early-time radio emission

Conclusions

- Rapid-response mode: GRB and flare star sciences cases are strong
- A lot of science can be extracted from a single rapid-response observation
  - But late time follow-up necessary for complete understanding.
- GRB 210702A: Rapid - response + scintillation can boost the signal
  - Early warning of radio bright GRB?
  - Measure GRB source sizes at early times and compare to afterglow theory
- Require long observations of ~12 hours to track variability in early-time emission.
  - Fit point source in the visibility plane
- **What other phenomena are waiting to be revealed at early times through rapid-respose radio follow-up observations of transients?**