

# XMM-Newton gravitational wave follow-up program and policies

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# Scientific Assumptions

- Scientific assumptions:
  - GW-event is accompanied by a short Gamma Ray Burst (sGRB)
    - Requires quickest reaction
    - XMM-Newton field of view (FoV) has  $r=15$  arcmin
      - In general XMM-Newton (FoV) is too small to identify GW events by itself
      - Detection of sGRB by other facility

# Policy based on 3 Pillars

- Policy of GW-event follow-up is based on 3 Pillars:
  1. MoU between Science Operations Centre and LIGO/Virgo Consortium
  2. Anticipated Target of Opportunity Observations (TOO)
  3. Unanticipated TOO / Directors Discretionary Time (DDT)

# MoU between Science Operations Centre and LIGO/Virgo Consortium



1. MoU between Science Operations Centre (SOC) and LIGO/Virgo Consortium
  - MoU adapted to comply with ESA and XMM-Newton rules
    - SOC receives the LIGO/Virgo alerts
  - Open to X-ray community (within the MoU)
    - but, anticipated TOO's have higher priority
  - SOC receives the LIGO/Virgo alerts
    - Allows quickest reaction time



# MoU between SOC and LIGO/Virgo Consortium: quickest reaction

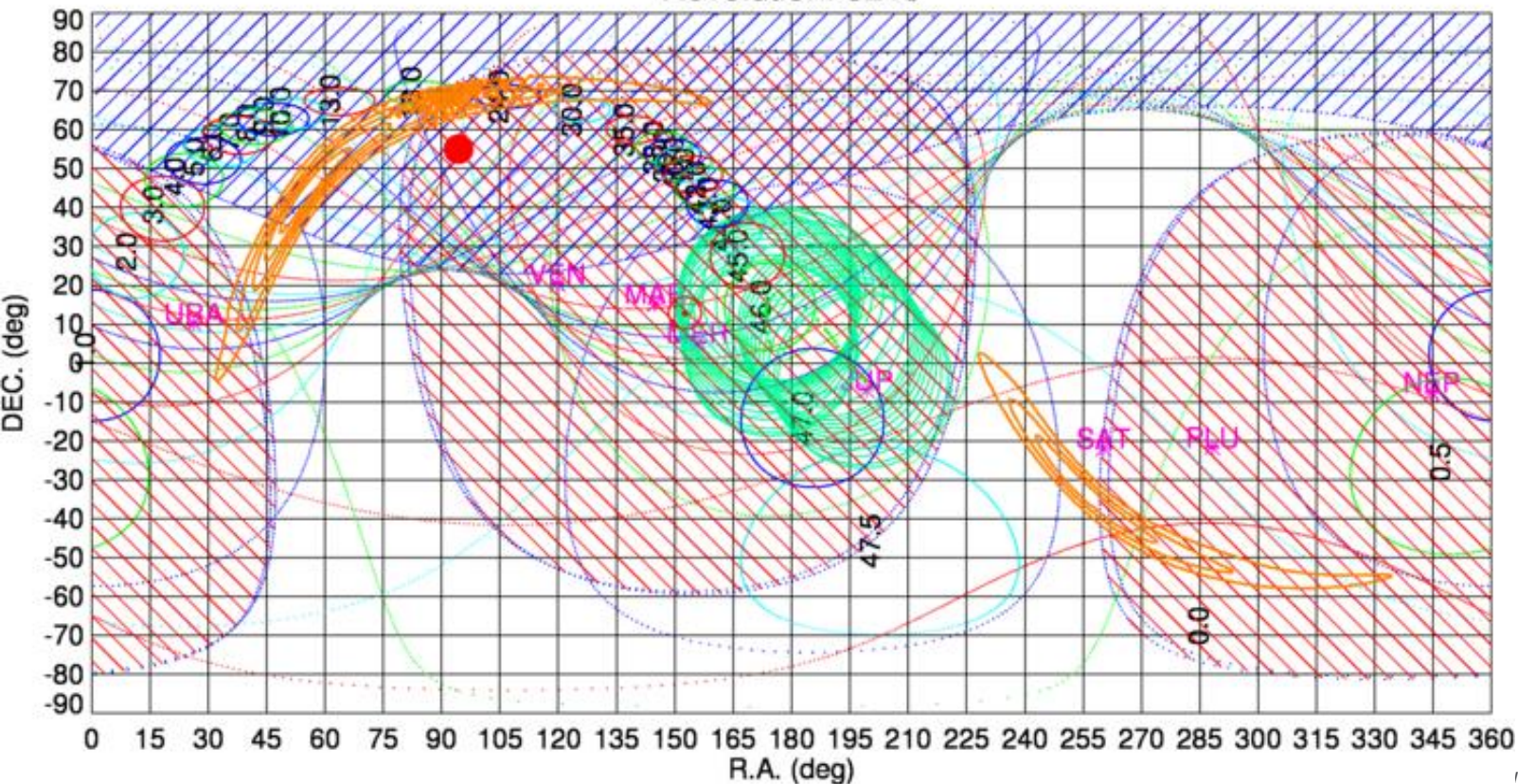


1. LIGO/Virgo alert
2. GW location is checked against:
  - A. XMM-Newton visibility window
  - B. Location of GRB detected during ( $\pm 3$  days of GW-event)
  - C. Production of a XMM-Newton visibility plot with the GW probability region
3. If A and B are fulfilled  $\rightarrow$  PS is instantaneously called

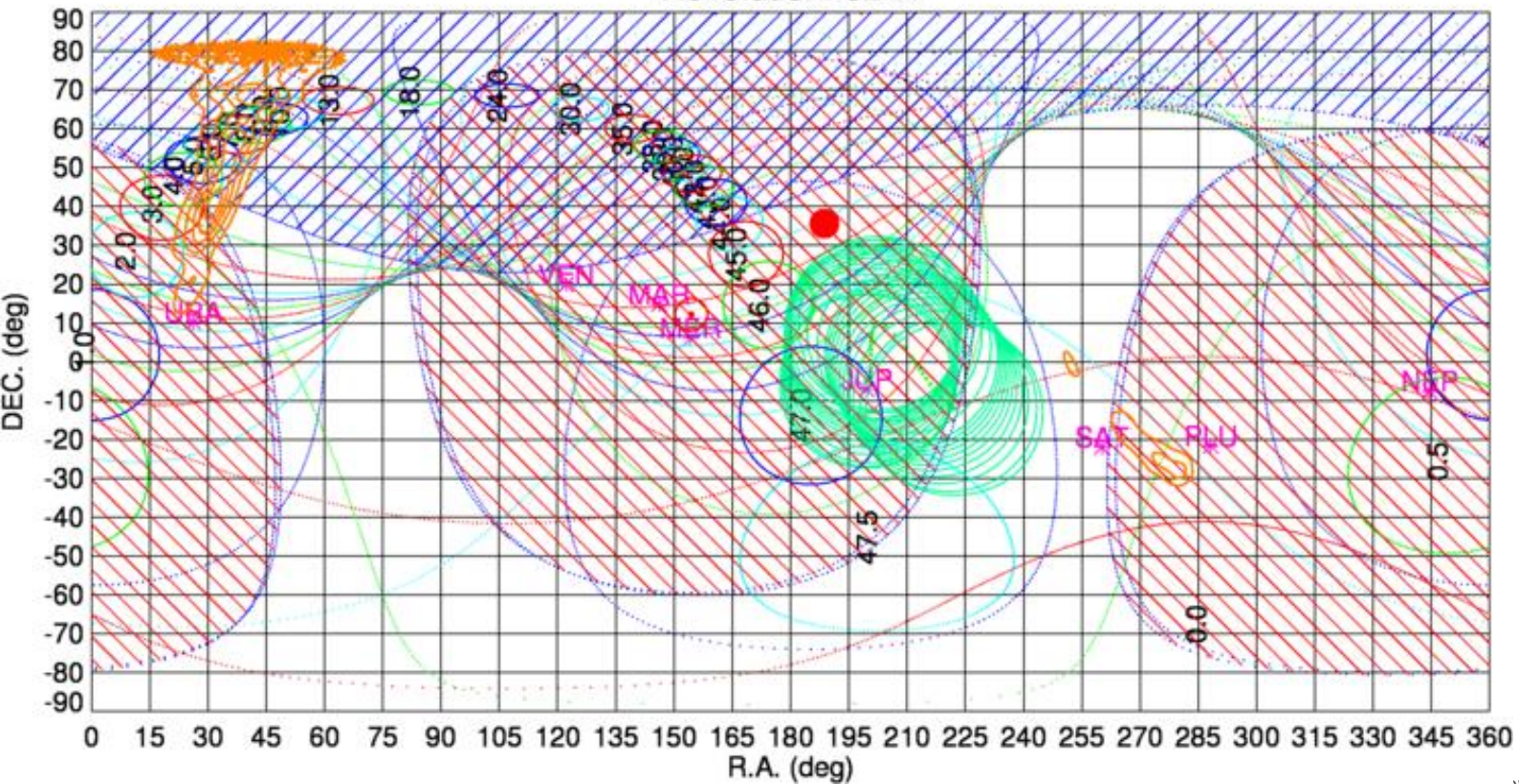
All the required software was developed by Pedro Rodriguez-Pascual (XMM-Newton SOC scientist)

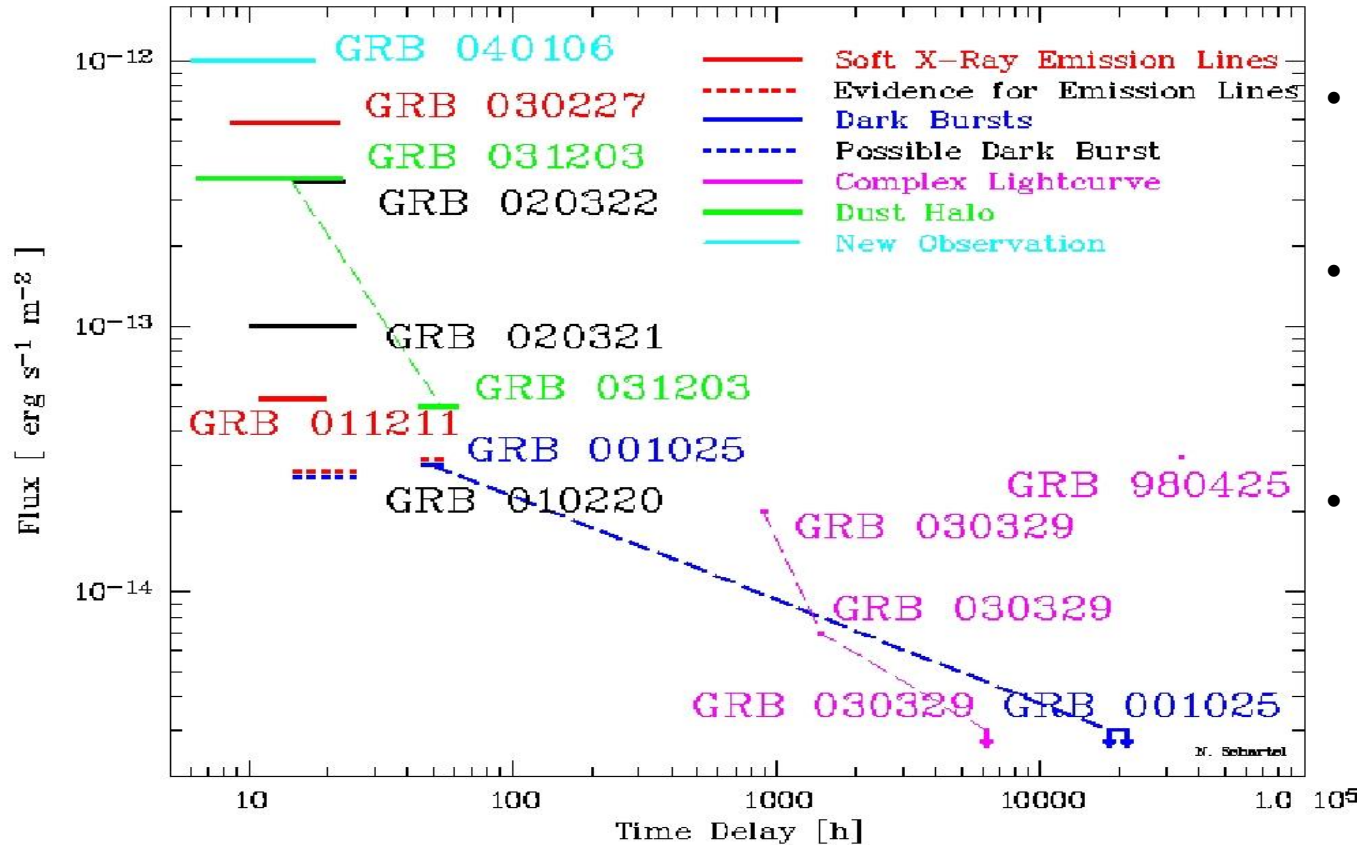


Revolution: 3243



Revolution: 3244





- XMM-Newton was not designed for fast response
- We reached reaction times of ~6 hours (best 4.5 hours)
- Manpower cuts at MOC will decrease the performance significantly from March 2018 onward



# Anticipated Target of Opportunity Observations



- The Observing Time Allocation Committee has accepted several TOO proposals for or including GW-events/sGRBs:
  - Fong: 18ks & 63 ks
  - D'Avanzo: 23ks & 53ks
  - Tanvir: 3 x 18ks
  
- Observing strategies of all anticipated TOOs assume the behaviour typically found for short GRBs



# Unanticipated Target of Opportunity Observations



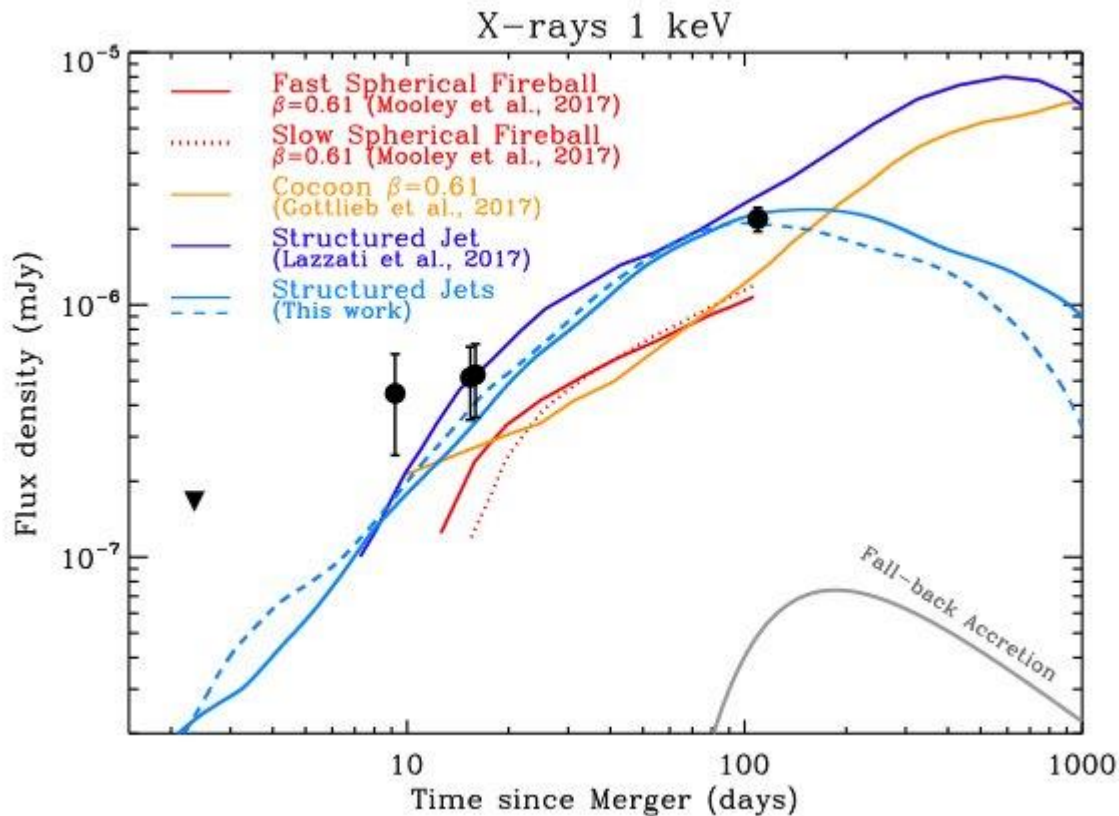
- GW170817-GRB170817A
- First GW-event of NS-NS merger
- X-ray counterpart (re)-detected early December by Chandra
  - Source was coming out of the Sun constraint
- None of the anticipated TOOs was foreseeing that an X-ray counterpart would be visible after several months
- Two unanticipated TOOs:
  - Piro: 1 x 100 ks
  - D'Avanzo: 2 x 40 ks (with distance of about one month)
- Approved two observations: 40ks and 100ks (one month after first one)
- First results see talk by D'Avanzo



- No X-ray detection 2 days after merge (Chandra) and 3 days (Swift) (Haggard et al., 2017, ApJ 848, L25)
- X-ray counterpart first detected on 26 August by Chandra (Troja et al., 2017, Nature 551, 71)
- X-ray counterpart further detected  $> 140$  days after merger (Margutti et al., 2018arXiv180103531M)

# GW170817-GRB170817

Margutti et al.,  
2018 arXiv  
180103531M)



# Future Challenges



- Optical
  - Rapid optical follow-up and GW counterpart identification will be essential, especially as LIGO/Virgo+ will quickly improve sensitivity
  - 24 hours sky-coverage?
  - Standalone Search of NS-NS & NS-BH mergers in optical surveys



- XMM-Newton
  - If X-ray counterparts have a lifetime of  $>140$  days, then **XMM-Newton will be able to observe the large majority of X-ray counterparts of GW-events**
  - The XMM-Newton **TOO policy will be changed** (specifying a probability of an event) **to promote the acceptance of more** anticipated TOO proposals
    - **Next call deadline: 5 October 2018** see at <https://www.cosmos.esa.int/web/xmm-newton/ao18-timeline>
    - **If visible, XMM-Newton will look very early ( $<1$  day)** to see if mergers show an early X-ray signature