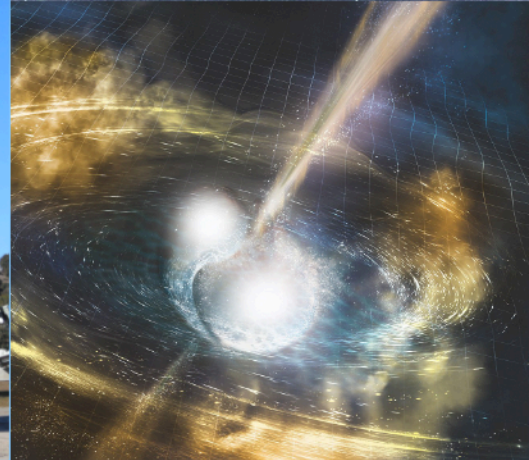
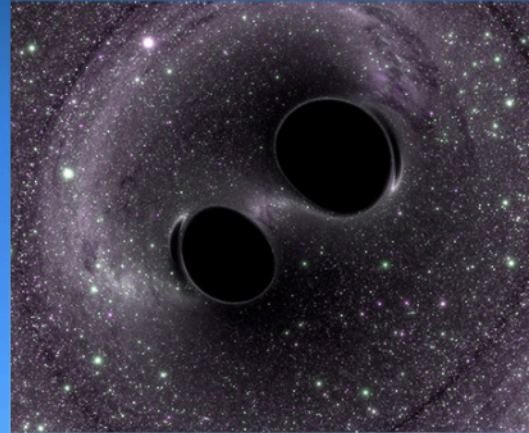
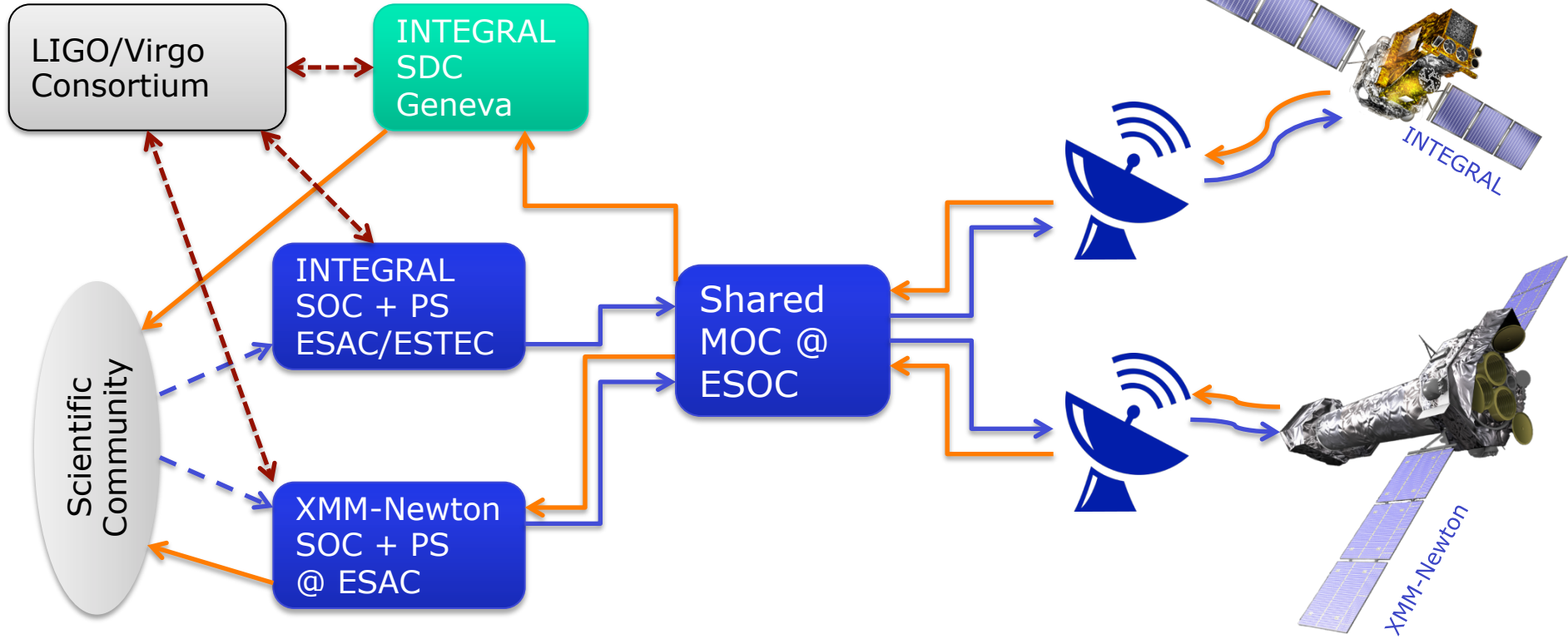


GW Observations with INTEGRAL and XMM-Newton – the Operational Perspective

Peter Kretschmar
on behalf of the teams

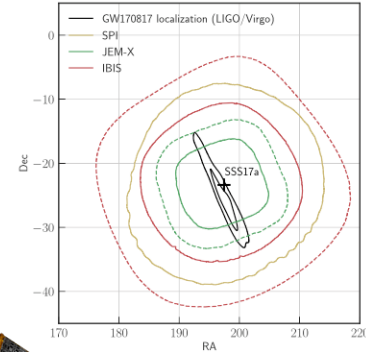
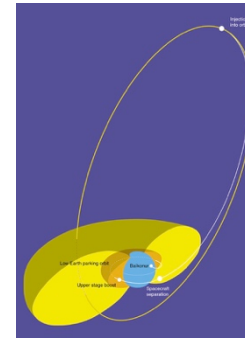


Introducing the players

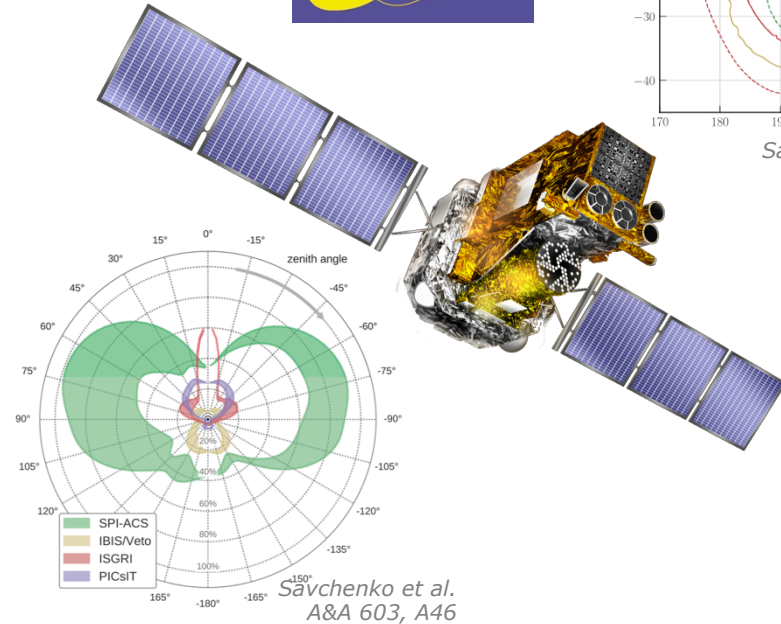


INTEGRAL

- Four instruments (optical, X-ray, gamma-ray imaging, gamma-ray spectroscopy) – all aligned and working in parallel.
- Very wide FOV of main instruments (diameter $>30^\circ$ for SPI) \Rightarrow can cover GW event uncertainty region, but low spatial resolution (12' for IBIS).
- Anti-coincidence shields plus instruments give “all-sky” detection ability for GRB-like events.
- Highly elliptical orbit of now 2 2/3 days, with $\sim 85\%$ of time active outside radiation belts.

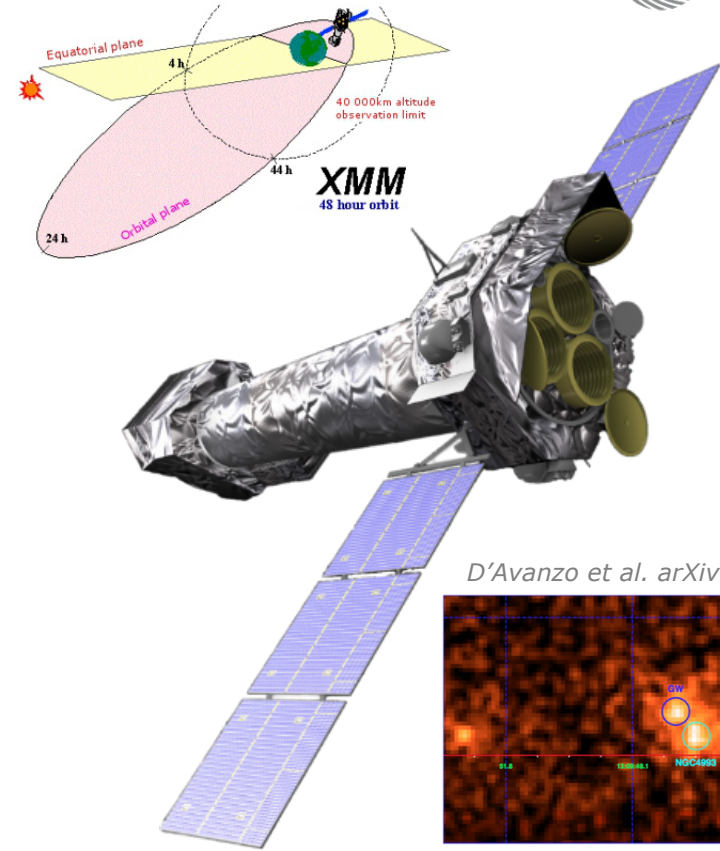


Savchenko et al.
ApJL 848, L15



XMM-Newton

- Three aligned X-ray telescopes in classical X-ray range, plus grating spectrometer & optical monitor.
- 30' diameter FOV for X-ray telescopes → needs to know plausible counterpart position, then few arcsec resolution.
- Highly elliptical orbit of ~ 2 days with $\sim 81\%$ of time active outside radiation belts.



Mission Operations Centre (ESOC, Darmstadt)



- Control of satellites, safety & health monitoring, reception of satellite telemetry via ground stations worldwide, distribution to ground segment.
- Since 2008 both XMM-Newton and INTEGRAL by **shared** team of Spacecraft Controllers.
- Also Instrument Engineers (INTEGRAL) and Flight Dynamics support. On-call 24/7/365.
- From April 2018, **further merge** with Gaia control team
→ more automation and less guaranteed immediate reaction.



XMM-Newton Science Operations Centre (ESAC)



- Handles all aspects of Science Operations, proposals, observation planning, ..., data processing from telemetry to high-level archive products.
- Strong role in instrument operations & calibration.
- For transient events: visibility and feasibility checks, interaction with PS for implementation.
- Recently added: automated checking of confidential GW alerts vs GRBs and visibility.
- Full coverage during normal working hours. 24/7/365 support on-call for re-planning.



Slide 6



INTEGRAL Science Data Centre (Versoix, CH)



- Receives telemetry (usually) within seconds of data taking. Processing up to high-level archive products.
- Immediate check for GRBs in FOV and alerts since 2002 (IBAS).
- Recently added ability to analyse shield & detectors for all sky positions within seconds by script.
- Weekend/holiday coverage by volunteer 'shifts'.



INTEGRAL Science Operations Centre (ESAC)

- Proposal handling, observation planning, coordination,...
- For transient events: visibility and feasibility checks, interaction with PS for implementation.
- Since 2014, normal coverage **only for working days**. Weekend/holiday support on best effort basis (goodwill).
- GW follow-up TOO are **hidden**, not shown in planning data.

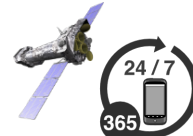


Slide 7



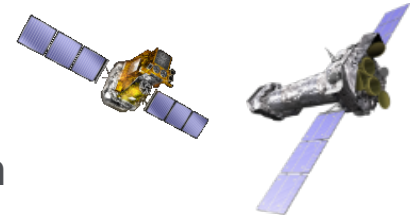
In case of a GW alert ... (status 2017)

- Script at XMM-Newton SOC automatically checks visibility and any GRB positions close in time (3d) to merger. Visible GRB within GW contour
→ alert to (on-call) planning team, possibly ToO response
☞ see talk by Norbert Schartel.
- At ISDC shield and detector data are analysed, also outside office hours in case of especially interesting events.
- INTEGRAL and XMM-Newton Project Scientists decide on possible ToO observations.
- SOC implement approved observations, interact with MOC for implementation.
- MOCs implement changed observing plan, the **earliest a few hours after trigger.**



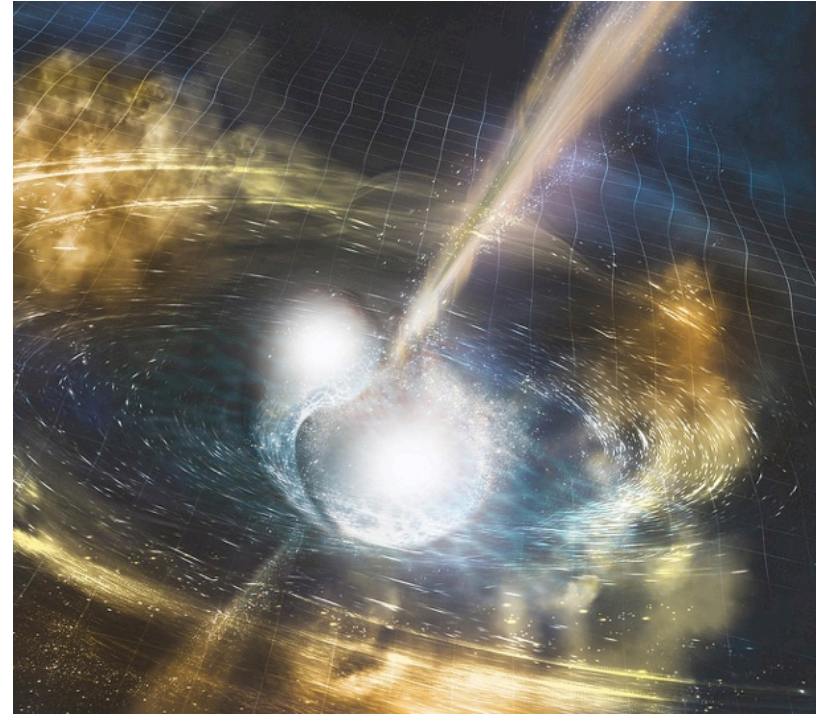
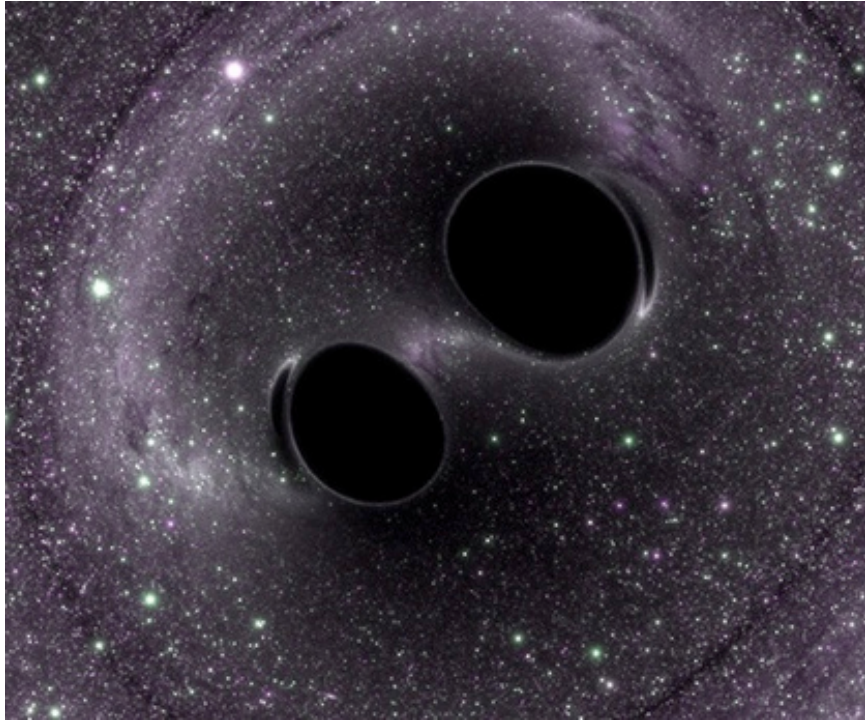
Complications for rapid follow-up of transients

- Visibility constraints and other technical limits.
- Long orbital periods allow long uninterrupted observations, but also lead to long ($\sim 8\text{h}$ or $\sim 10\text{h}$) periods passing through radiation belts with instruments off.
 - ☛ see talk by Jan-Uwe Ness.
- Limited slew speeds ($\lesssim 90$ deg / h). No autonomous slewing.
- Spacecraft attitude mainly controlled via reaction wheels, which need to remain within safe margins \rightarrow reaction wheel profile for each observing sequence.
- Satellite operations driven by pre-defined “timeline” of commands. Any change in observation requires regeneration of timeline, including validation and safety checks, regeneration of reaction wheel sequence, etc.



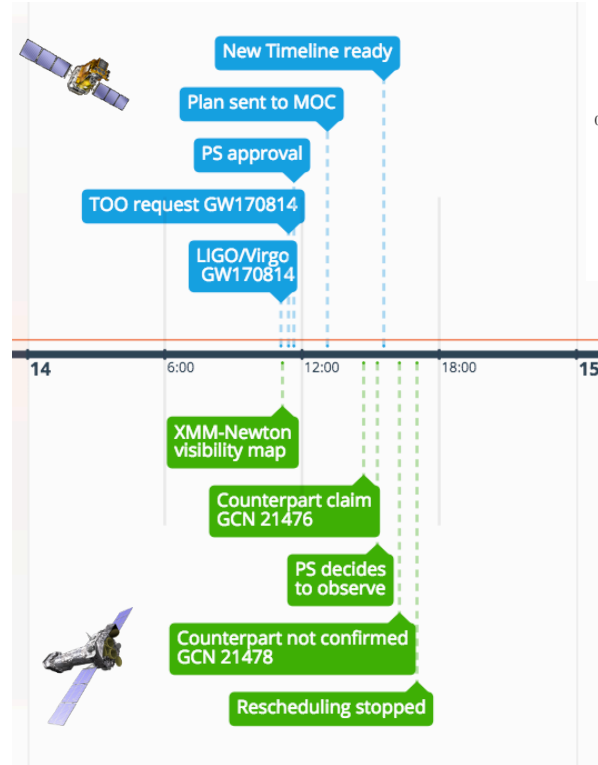
Gravitational Wave Double Whammy

14 and 17 August 2017

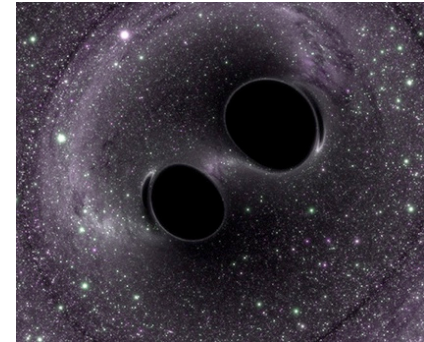
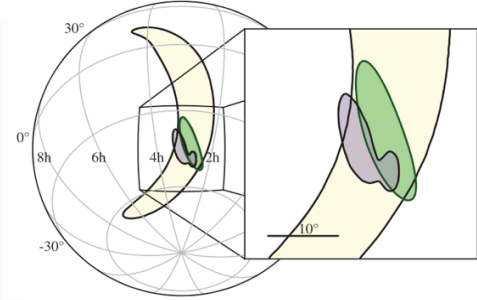


14 August 2017: starting an exciting week

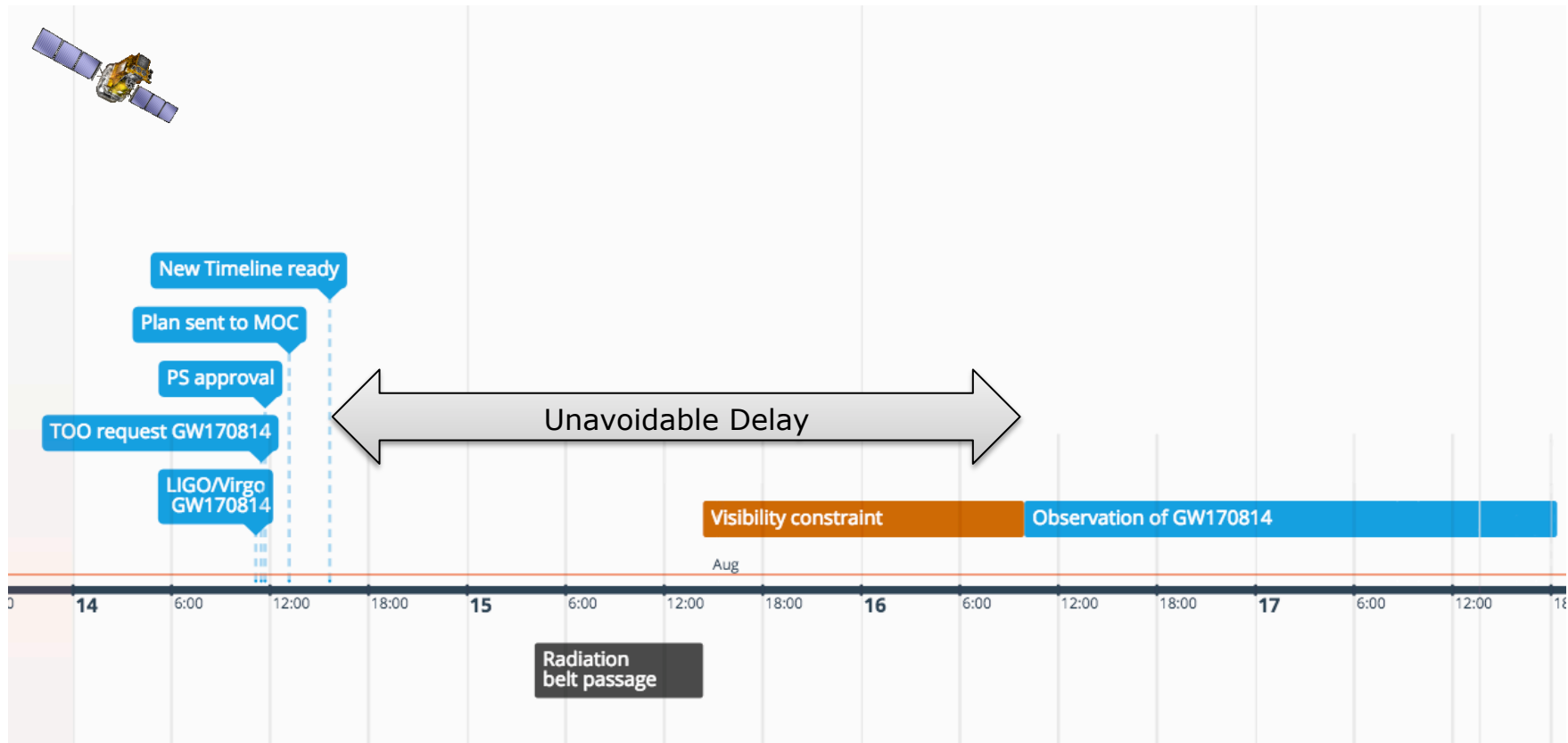
- **20170814 11:01:49UT** the LIGO & Virgo consortia report the brightest BH-BH merger yet, well localized by all 3 detectors \rightarrow ISDC and XMM-Newton SOC spring into action.
- $\sim 1/2$ h after trigger an INTEGRAL follow-up is approved and ~ 4 h later the new timeline is set – but needs to wait to start.
- XMM-Newton PS discusses with SOC from ~ 1 h after trigger. On report of a counterpart an observation is approved, but later cancelled again as counterpart is not confirmed.



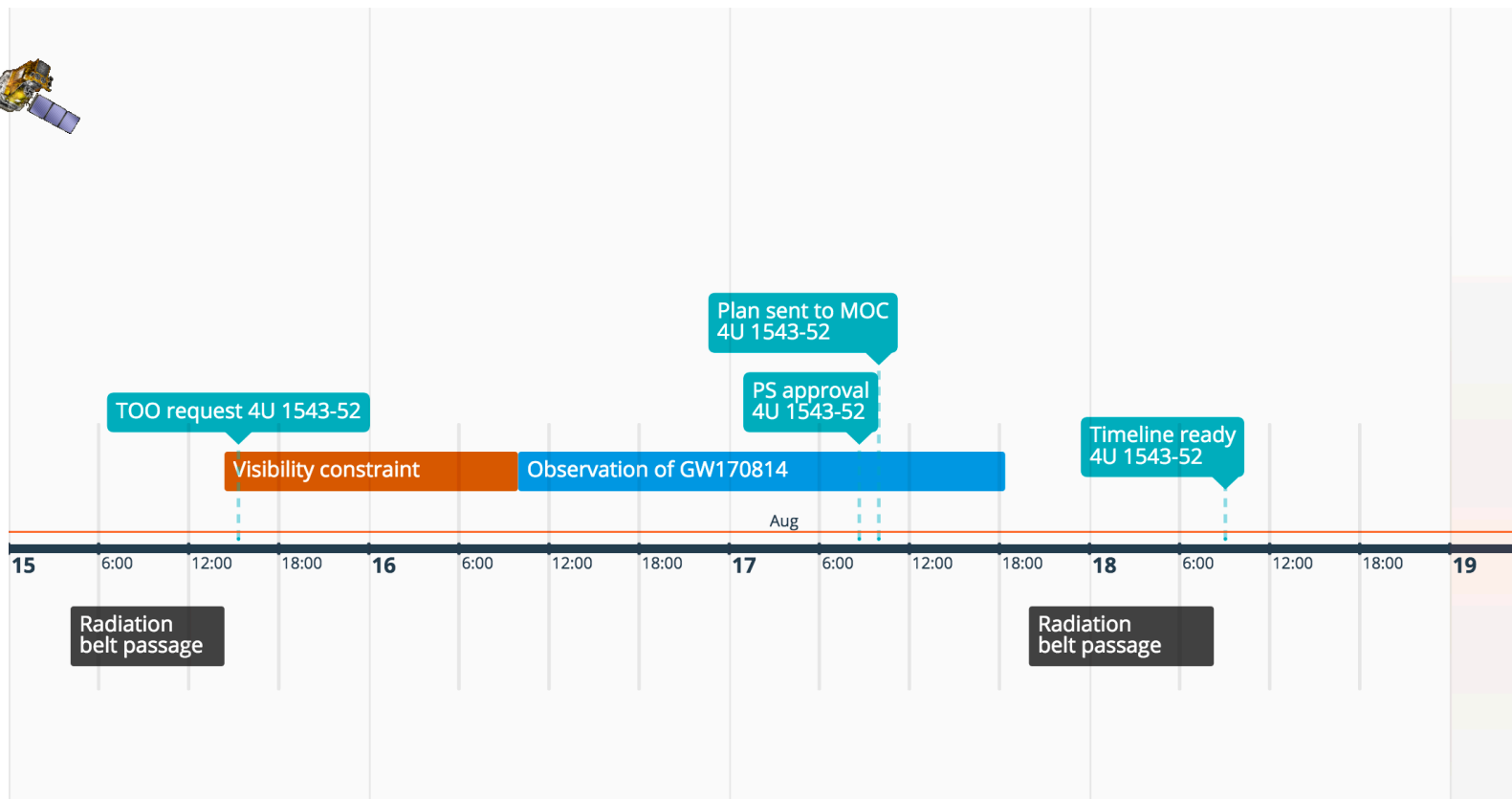
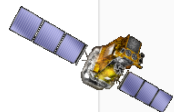
Abbot et al. PRL 119.141101



At first almost a normal INTEGRAL ToO ...

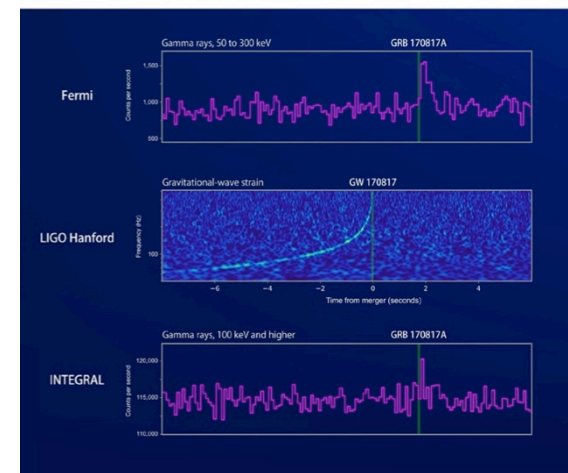
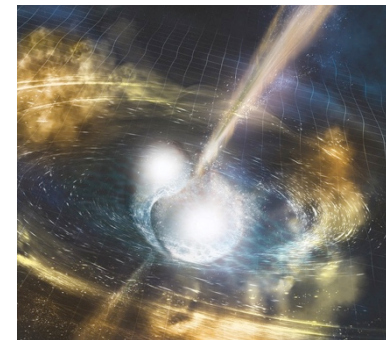


... then another, unrelated ToO is added ...

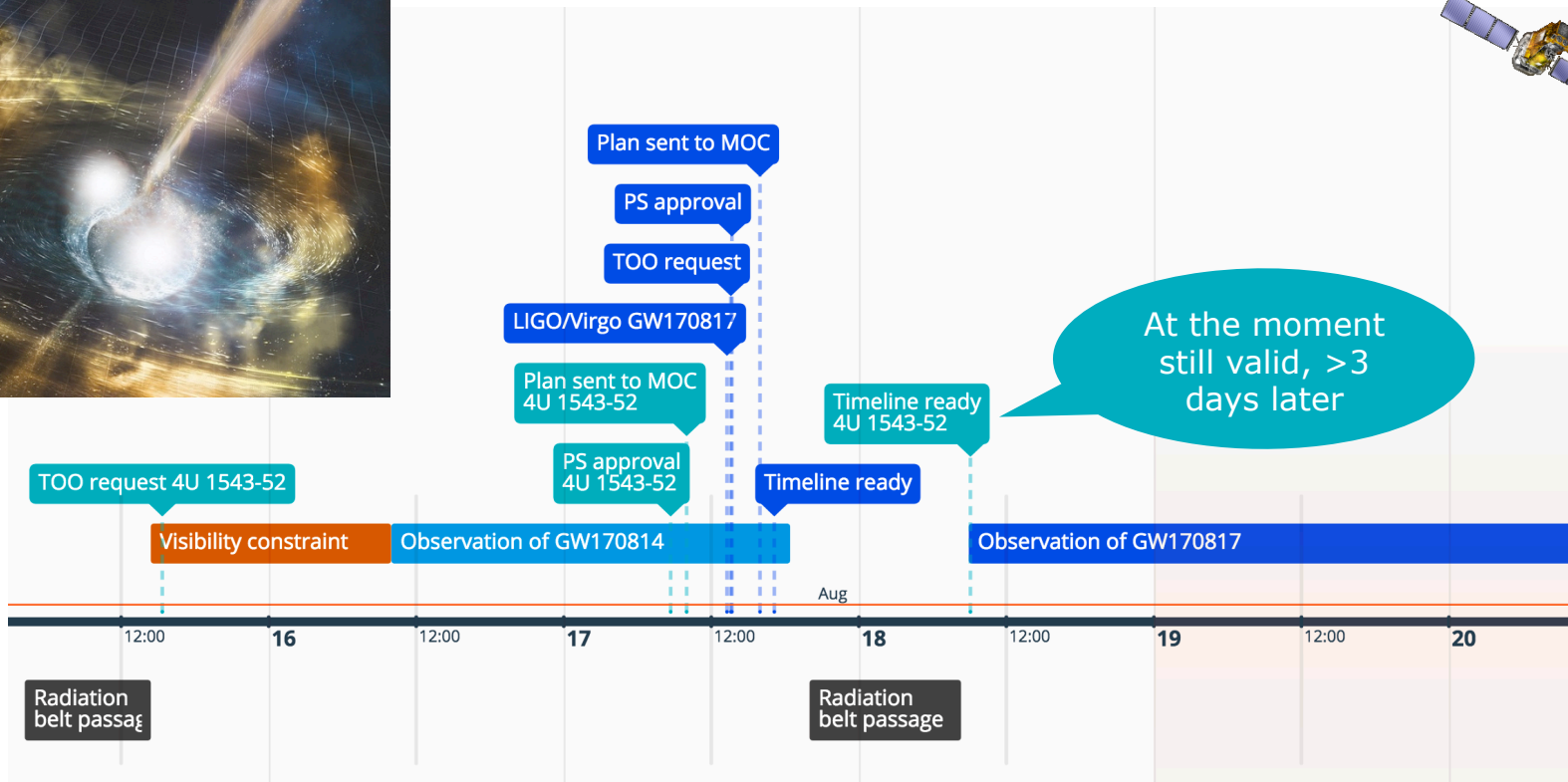
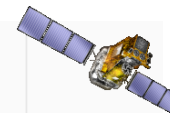
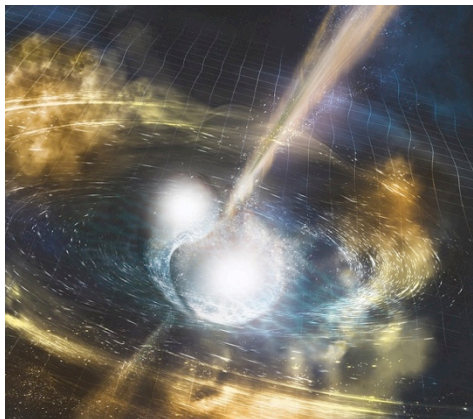


... but then everything changes – GW170817!

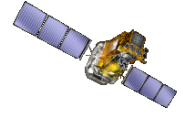
- **20170817 13:08UT** the LIGO & Virgo consortia report an “EM bright” GW event – a plausible Binary NS merger.
- **13:16UT** ISDC informs the PS, Fermi/GBM has a trigger, **but there is a gap in INTEGRAL real-time telemetry!**
- **13:28UT** Fermi GBM counterpart reported (GCN 21505)
- **13:28UT ISDC: gap ended 3 minutes before trigger!**
SPI-ACS data shows excess!
- **13:58UT** INTEGRAL also reports detection of a prompt gamma-ray counterpart (GCN 21507).
- **Meanwhile for XMM-Newton:** the visibility shows that the target region is constrained by the Sun → no further immediate activity.



Rapid planning of INTEGRAL TOO on GW170817

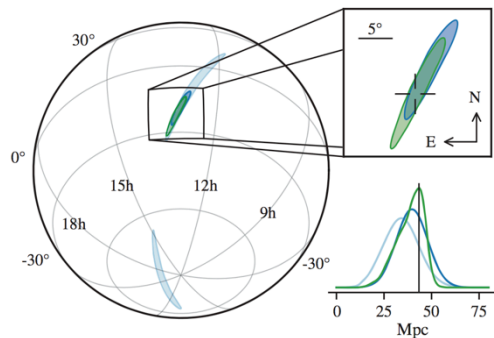
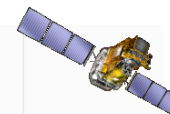


A bit of extra excitement at the MOC

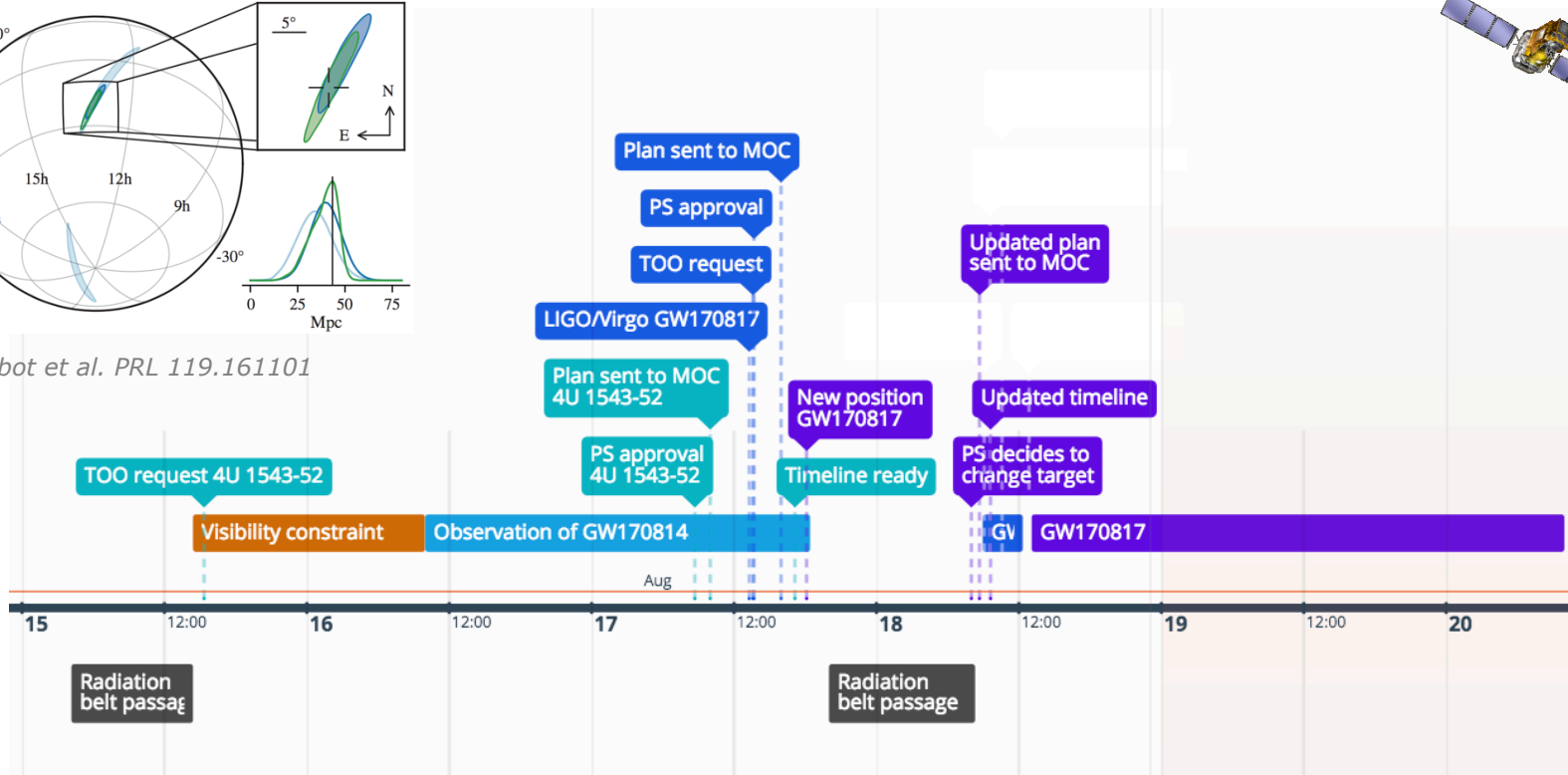


- Holiday season: the two best trained mission planning engineers on leave. Working hard on re-plan for ToO on 4U 1543-52.
- Around midday a network failure affected one of the 2 branches of the ESOC operations local area network for all missions → re-planning from back-up system for INTEGRAL.
- At 13:59UT (15.59 CEST) urgent call from Project Scientist, new 'special' target of highest priority.
- *In addition:* extra work to obtain telemetry from Kiruna ground station quickly, which was stuck due to network problem.

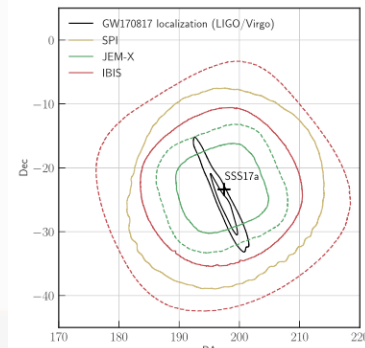
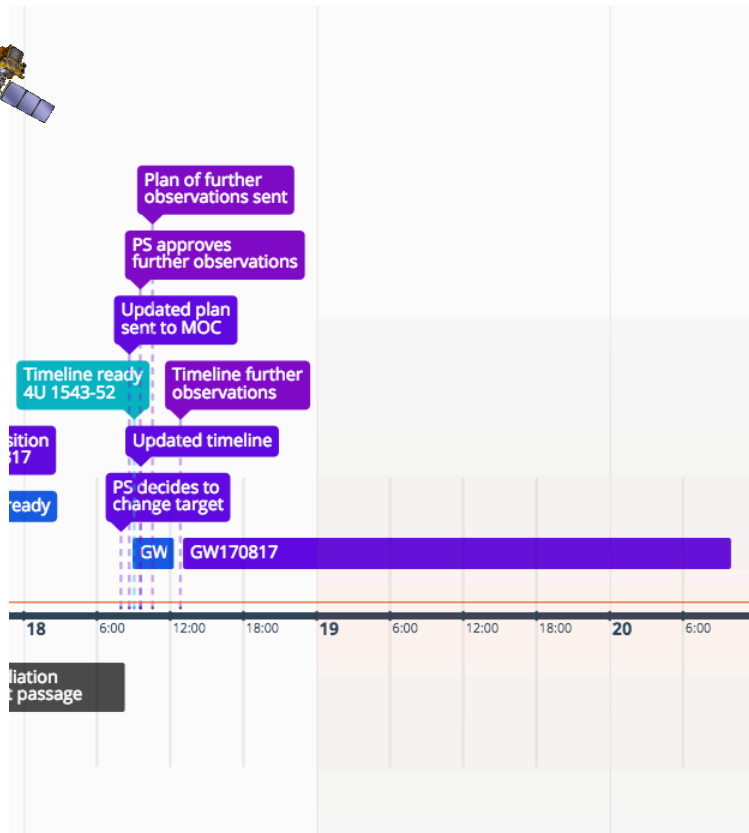
... re-targeting as information evolves ...



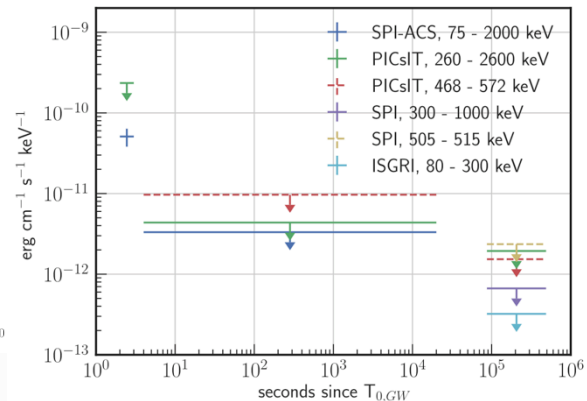
Abbot et al. PRL 119.161101



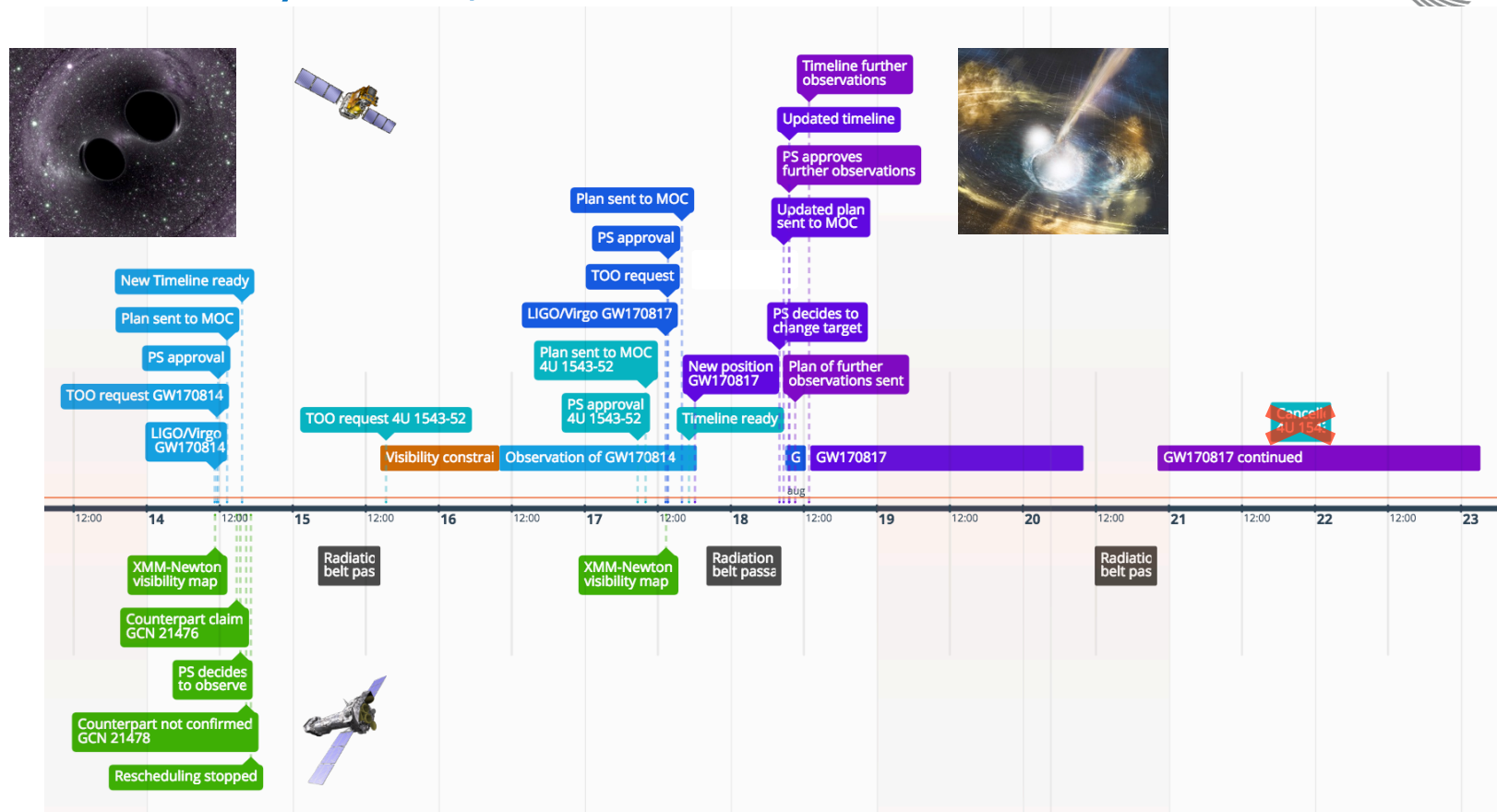
... and adding more observations of GW 170817



Savchenko et al. *ApJL* 848, L15

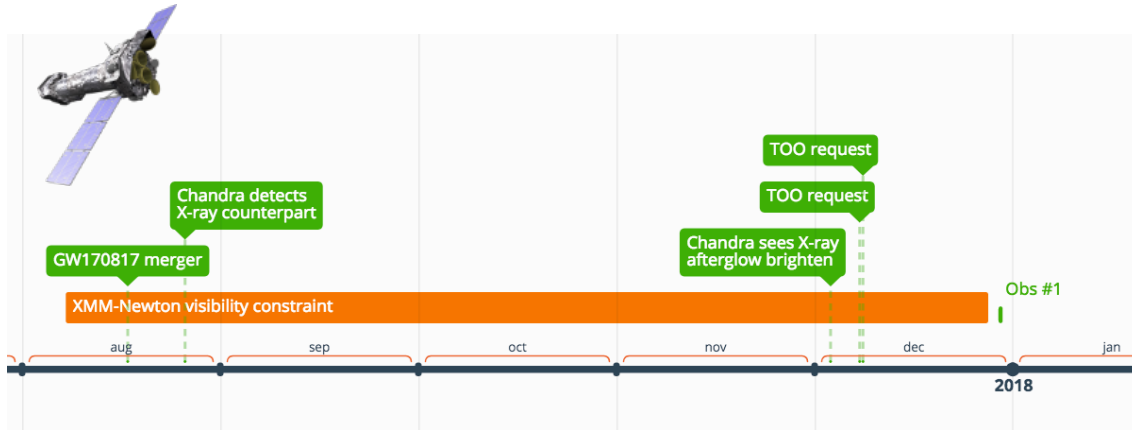


A rather busy week, all in all – but worth it!

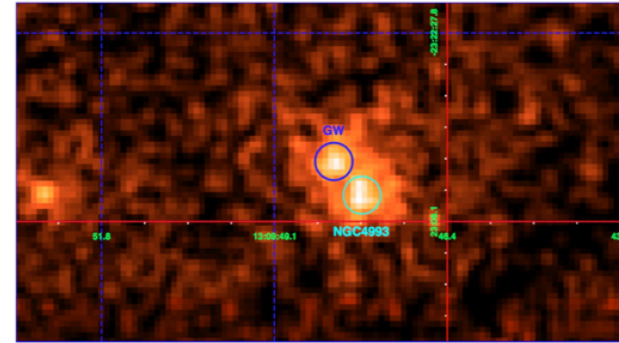


Several months later: the story continues ...

- **20171208**, following Chandra re-detection (ATel 11037) the XMM-Newton SOC receives **two** TOO requests outside the TAC process within the same day
☞ see talk by Norbert Schartel.
- Target position not immediately visible → scheduling done as normal planning.
- First observations 29–30 December 2017, second set 26–27 January.



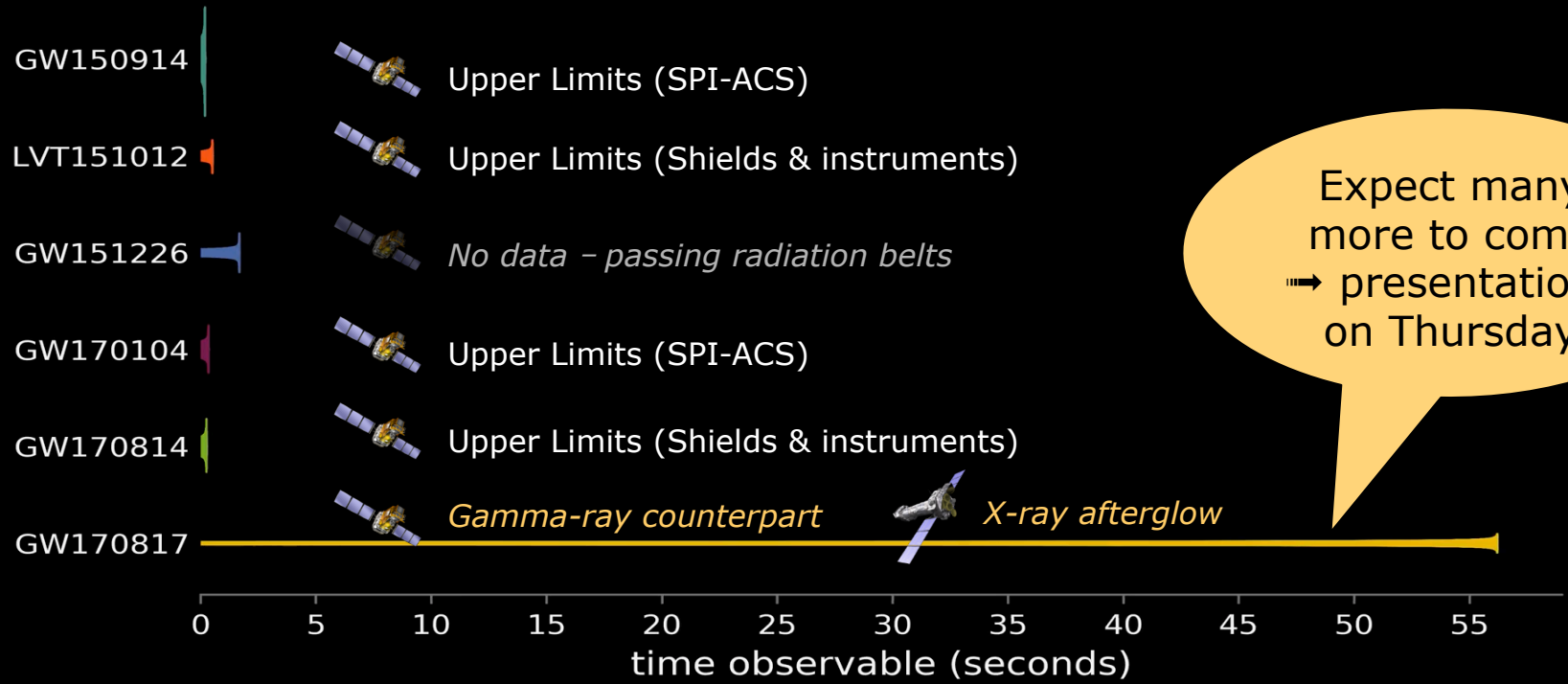
D'Avanzo et al. arXiv 1801.06164



Slide 20

GW results with INTEGRAL and XMM-Newton

Variety of Gravitational Waves and a Chirp



Expect many more to come
→ presentations on Thursday