SVOM
ToO-Multi_Messenger Programming Principles and Simulation Overview

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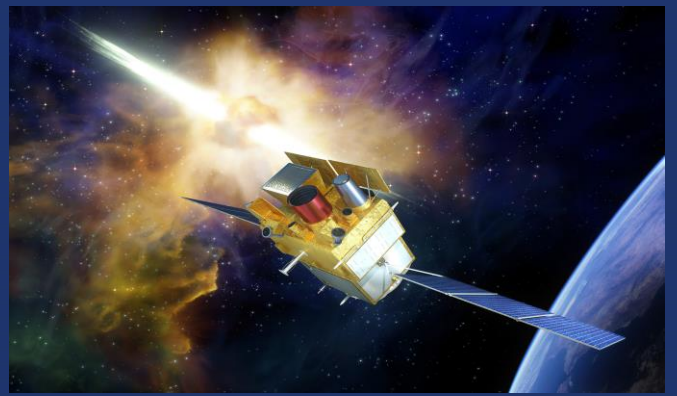
3rd SVOM Scientific Workshop – May 13th-18th 2018 – Les Houches

AGENDA

- Reminders of ToO-MM scope and programming principles
- Prototype for tiles sequencing
- Examples of scenarios and results
- Conclusion and Further Prospects



ToO-Multi Messengers scope

- Definition for the system :
  - Like all Target of Opportunity, unplanned observation requests decided from ground
  - Supplement ToO-Exceptional subset
  - To be performed within short delays / as soon as possible
  - Need a tiling of a sky area (e g, error box linked to GW detection), with for each tile :
    - ✓ Pointing direction
    - ✓ Effective observing duration
    - ✓ Priority

ToO-MM main requirements for tiles programming

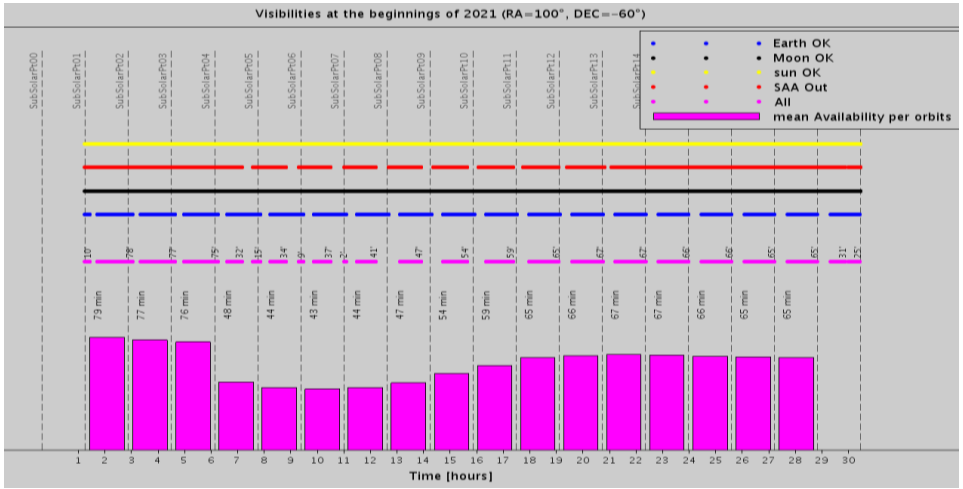
- Current requirements from MRR + SRD documents :
  - 1 ToO-MM / month (→ goal : 1 ToO-MM / week)
  - Observation start (1rst tile) < 12h from ToO-MM alert acceptance
  - ToO-MM : from 4 up to 25 tiles with effective observation duration ~ 10mn / tile
  - Max 14 orbits (~1 day)
  - Max 3 tiles / orbit (→ goal : 5 tiles / orbit)
  - Tiles $\subset$ (5°x5°) in each orbit
  - Implicit : Tiles observed out of Earth occultation and South-Atlantic Anomaly (SAA) crossings, Sun and Moon constraints for MXT & VT applicable
  - MXT photons and VT attitude charts sent to ground via VHF network (for each tile)

ToO-MM main requirements for tiles programming

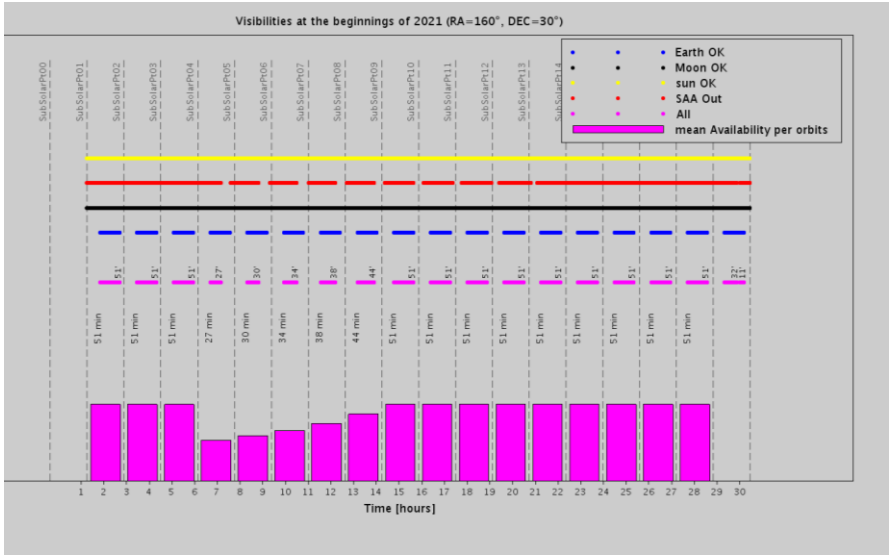
- Additional requirements for tiles programming process :
  - Tiles have priority levels assigned by scientific users (tiling definition process)
  - Slews (i.e. attitude maneuvers) > 5° performed during Earth occultations or SAA crossings (not mandatory, as much as possible)
  - Tiles possible sequencing criteria :
    - ✓ Priority levels (Nominal)
    - ✓ Minimization of whole sequence duration (Alternative TBC)
    - ✓ Minimization of sum of slews amplitudes or amplitude of largest slew (Alternative TBC)

Main Constraint : Available observing duration per orbit

For specific target directions, accessibility periods can vary a lot from one orbit to the next one due to Earth occultations and South-Atlantic Anomaly (SAA) crossings combining together :



Min = 27 mn – Max = 79 mn



Tiles Programming and Duration of whole ToO-MM sequence can vary a lot depending on the start date

MM Alert

Alert Validation
at Science Center
Verification of accessibility
vs Sun/Moon and ToO MM
constraints (error box, etc…)

ToO-MM Tiling Process
providing scenarios
updated along time

Science Center

Tiling Scenario

ToO MM Alert trigger

S-band pass selection process
(e.g. Pass N+3 selected)
at Chinese Control Center

CCC

S-band pass selected

Tiling scenario implementation
picked up at the date for WP elaboration **at the latest**

Mission Center

Work Plan
elaboration

O C G

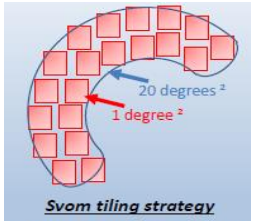
TC plan
generation process

TC plan Upload

CCC

TC

S-band station



Iterative update

Mission Center computes the absolute times of observing slots for each tile of the sequence from scenario available at Science Center **at the date at the latest** for workplan elaboration depending on S-band pass selected by CCC (CLTC) and considering :

- Orbit, Earth occultations & SAA crossings prediction
- Tiles sequencing criterion (e g, priorities assigned)

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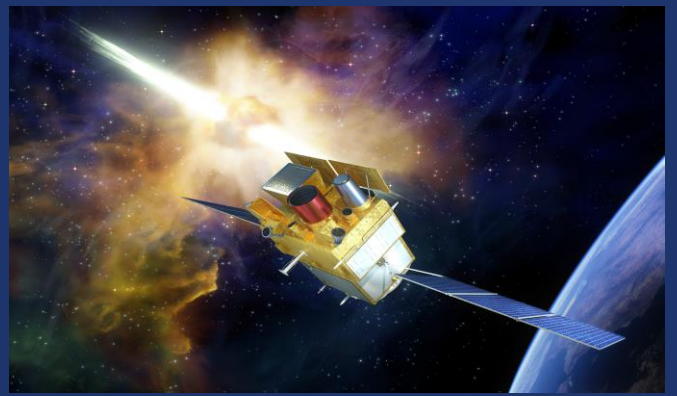
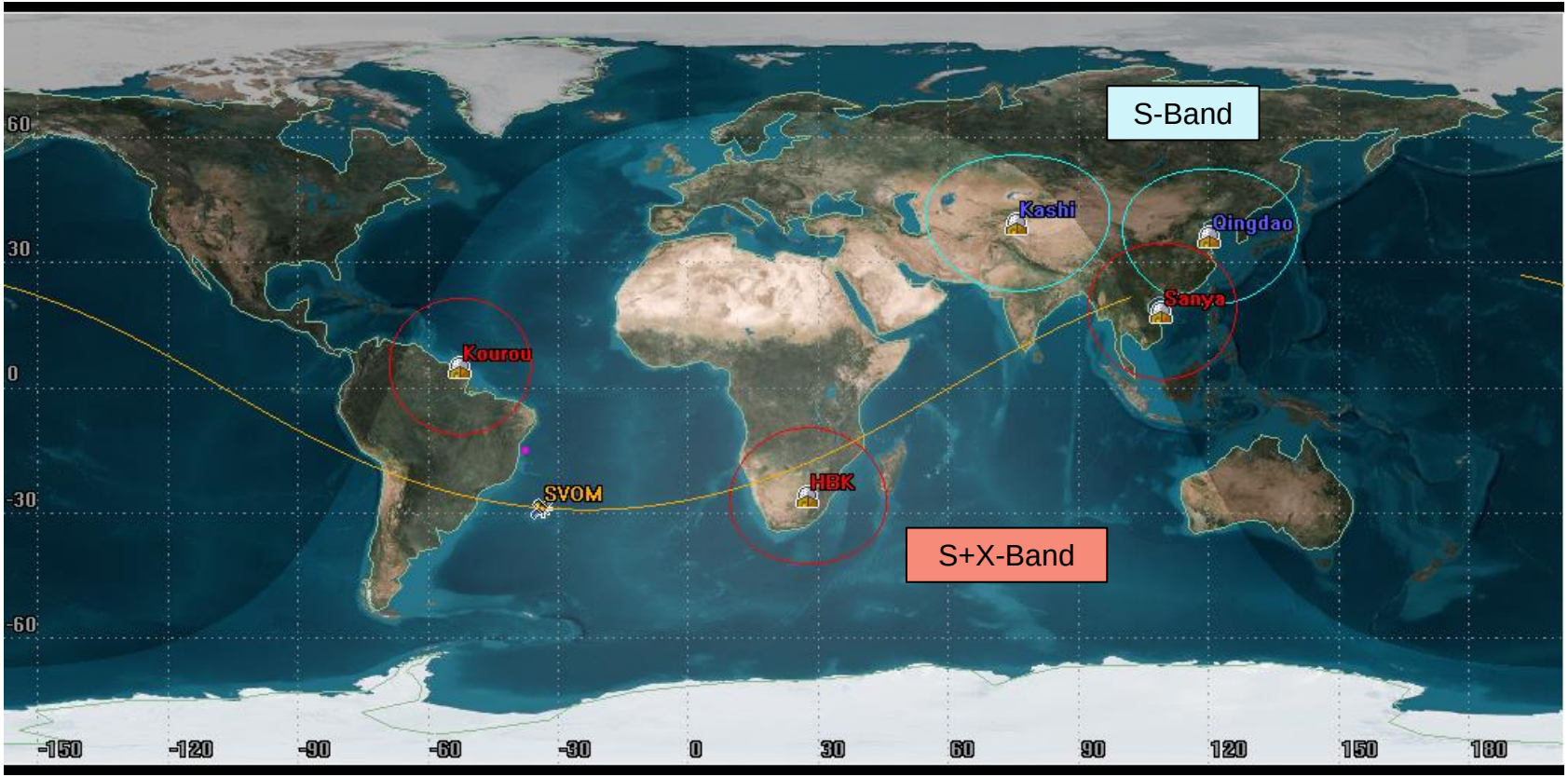


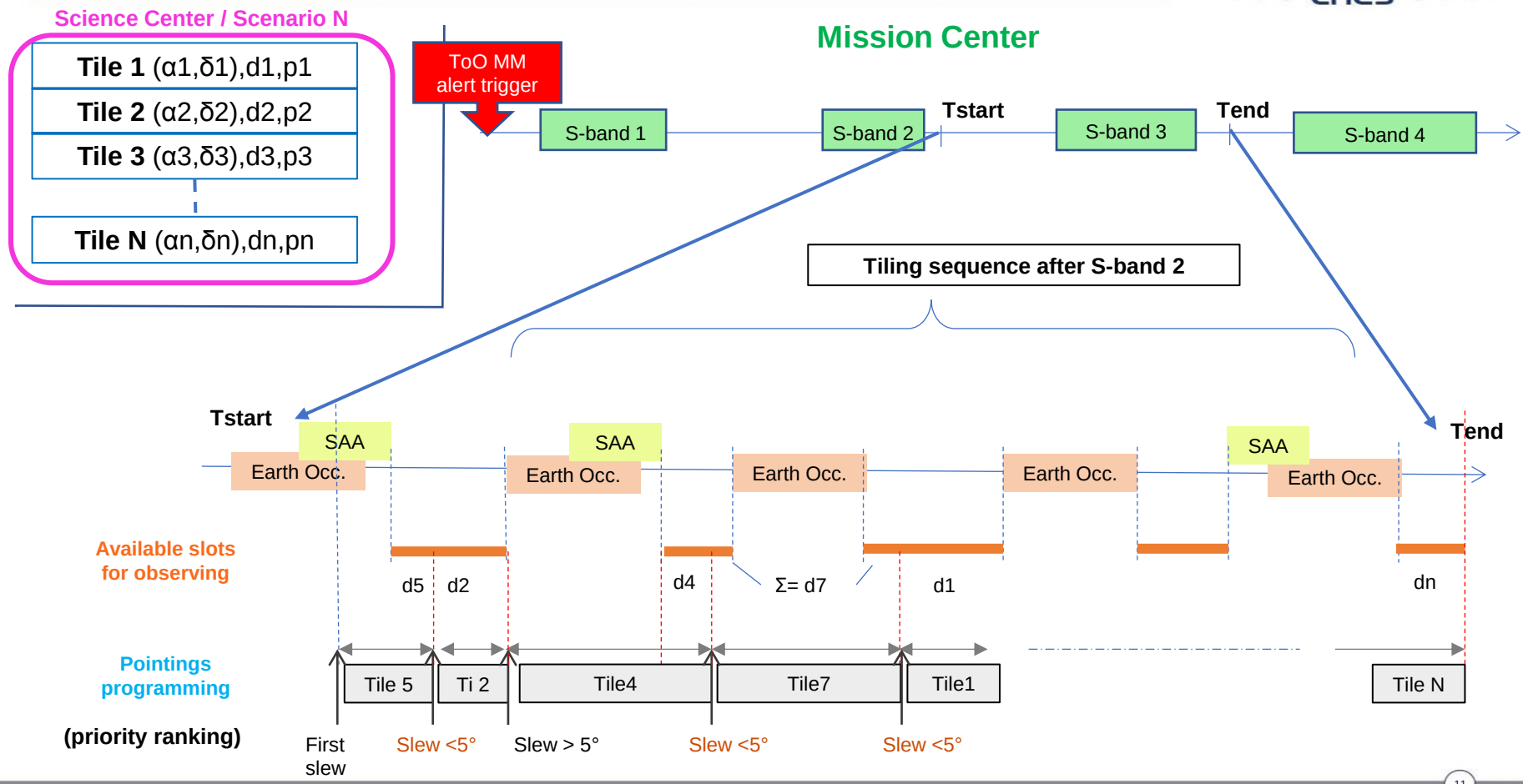
ToO-Multi-Messenger Prototype

- **A first version of a prototype is implemented to program all the tiles of a ToO-MM request considering :**
  - ✓ The definition of the tiles (number, pointing directions, observing duration, priorities)
  - ✓ The S-band pass selected for TC upload (→ earliest start date)
  - ✓ The available observing duration on following orbits (Earth occultations, SAA crossings)
  - ✓ The instruments constraints (MXT, VT) wrt Sun & Moon
  - ✓ The slew speed (4 deg / mn) with random draw for the current pointing preceding ToO-MM start date
  - ✓ The system constraints with some possible relaxation to assess results and impacts :
    - Total number of tiles (can be more than 25),
    - Sequence duration (can be longer than 14 orbits),
    - Number of tiles / orbit (can be more than 3 tiles / orbit),
    - Slews > 5° during occultation or not, tiles of one given orbit in (5°x5°) or not
    - Criteria for sequencing (tiles priority is the nominal, alternatives for sequence duration or slews minimization)
- **Consideration of all S-band passes over a time span (part of year when Sun constraint is ok)**

  → Statistics on tiling sequences (sequence duration, tiles distribution, slews, …)

ToO-Multi-Messenger Prototype




Science Center / Scenario N
Tile 1 (α1,δ1),d1,p1
Tile 2 (α2,δ2),d2,p2
Tile 3 (α3,δ3),d3,p3
Tile N (αn,δn),dn,pn
ToO MM alert trigger
Mission Center
S-band 1
S-band 2
Tstart
S-band 3
Tend
S-band 4
Tiling sequence after S-band 2
Tstart
Tend
SAA
Earth Occ.
Available slots for observing
d5
d2
d4
Σ= d7
d1
dn
Pointings programming
(priority ranking)
Tile 5
Ti 2
Tile4
Tile7
Tile1
Tile N
First slew
Slew <5°
Slew > 5°
Slew <5°
Slew <5°

AGENDA

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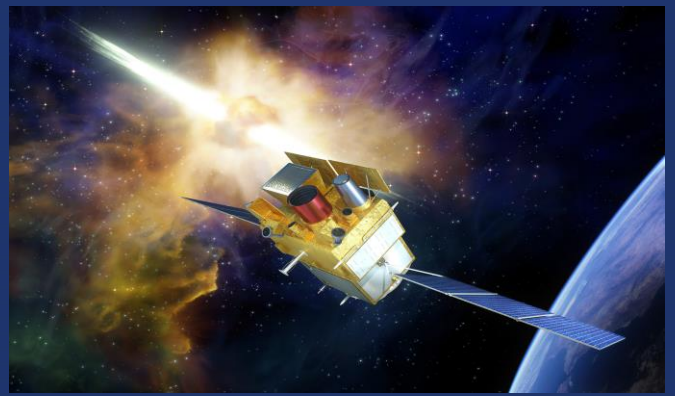
  - Tiles definition process
  - Tiles programming
- **Conclusion and Further Prospects**



ToO-Multi-Messenger Prototype

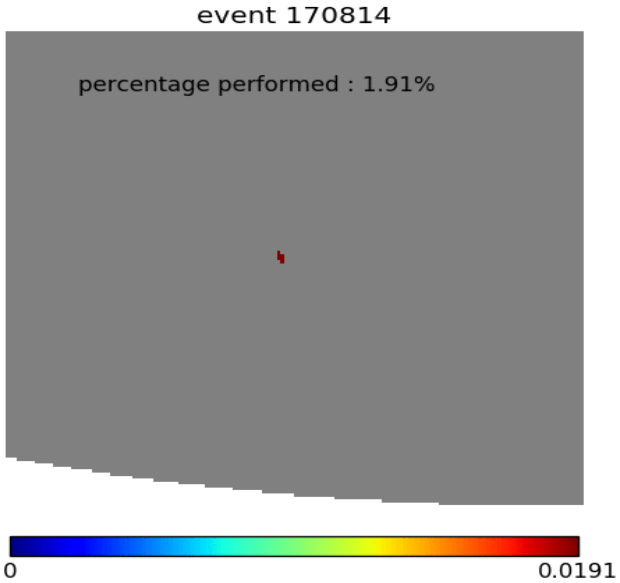
- **Representative scenarios of ToO-MM requests delivered by LAL (N. Leroy / JG Ducoin) :**
  - ✓ 2 scenarios :
    - GW170814 : 42 tiles / 10 mn obs per tile
    - GW170817 : 36 tiles / 10 mn obs per tile
  - ✓ ~ 3500 useful passes over 1 year (when Sun constraint ok)

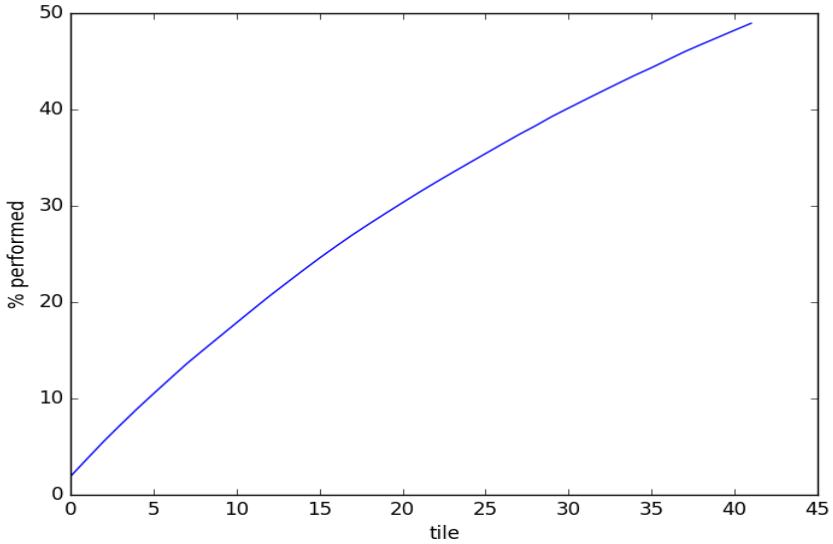
Scheduling by probability

Prioritizing tiles by probability inside each tile - Improve search with 3 tiles per orbit

BBH Exemple : 170814

Probability performed for 42 tiles : 48,96 %



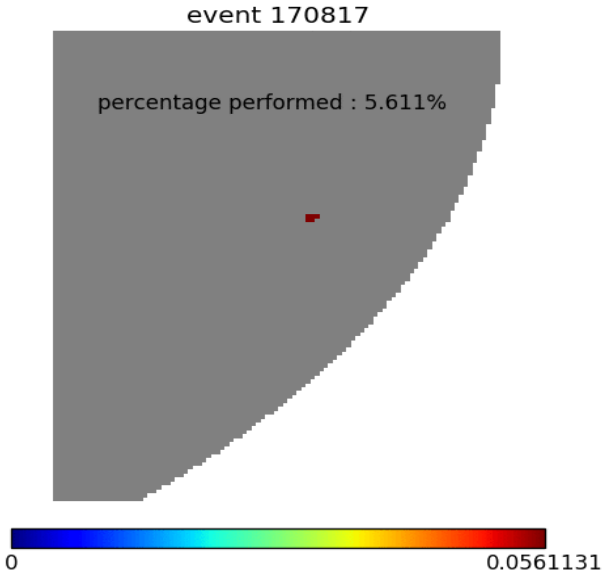


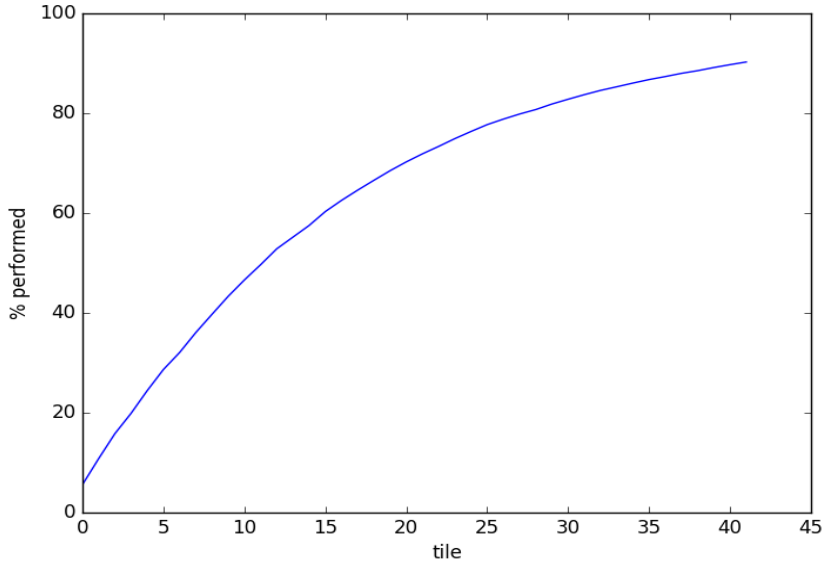
Scheduling by probability

Prioritizing tiles by probability inside each tile

BNS Exemple : 170817

Probability performed for 42 tiles : 90,27 %





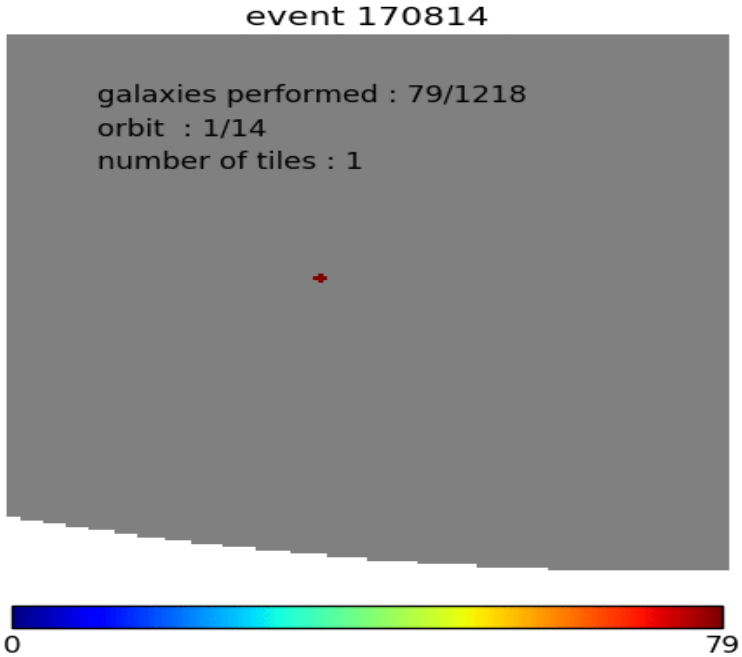
Galaxies targeting

Hypothesis
Researched events happened in a galaxy

- Catalog selection → First example with GLADE
  - ✓ constructed from four existing galaxies catalogs : GWGC, 2MPZ, 2MASS XSC and HyperLEDA.
  - ✓ GLADE contains 3,262,883 objects. (http://aquarius.elte.hu/glade/)
- Selection of galaxies inside the 3D volume RA, Dec, distance (using 3 sigma error for the latest)
- Priorisation of tiles using the number of galaxies inside each of them

Galaxies targeting

BBH CASE : GW 170814

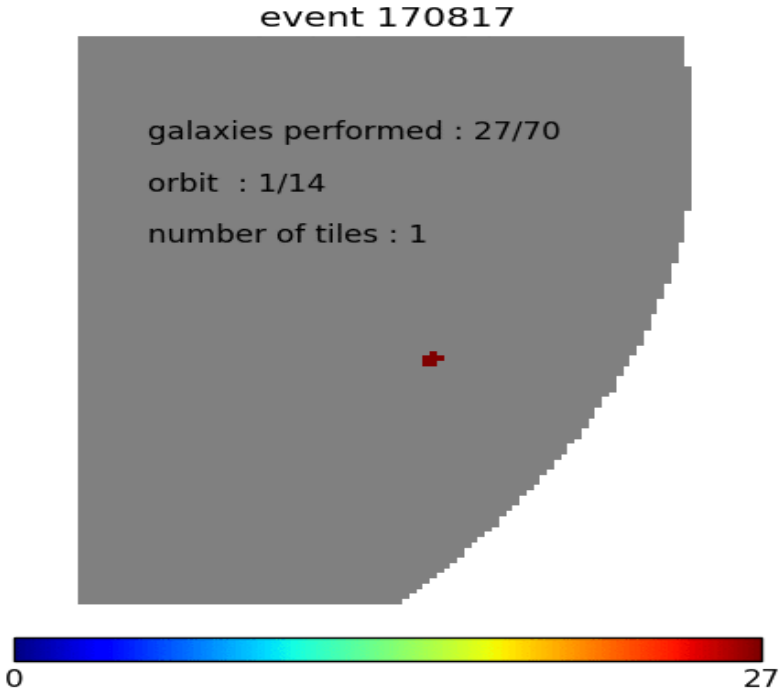


Limitation of 14 orbits and 3 tiles per orbit

	Galaxies performed	Orbit (max 14)	Number of tile (max 42)
50 %	1197/1218	14	42
90 %	4493/9914	14	42

Galaxies targeting

BNS CASE : GW 170817



Limitation of 14 orbits and 3 tiles per orbit

	Galaxies performed	Orbit (max 14)	Number of tile (max 42)
50 %	70/70	4	11
90 %	185/185	13	36

Galaxies targeting

Ongoing :

- Study different catalogs : completness issue, distance computation, …

- Include type of galaxy ?

- More tests are performed with :

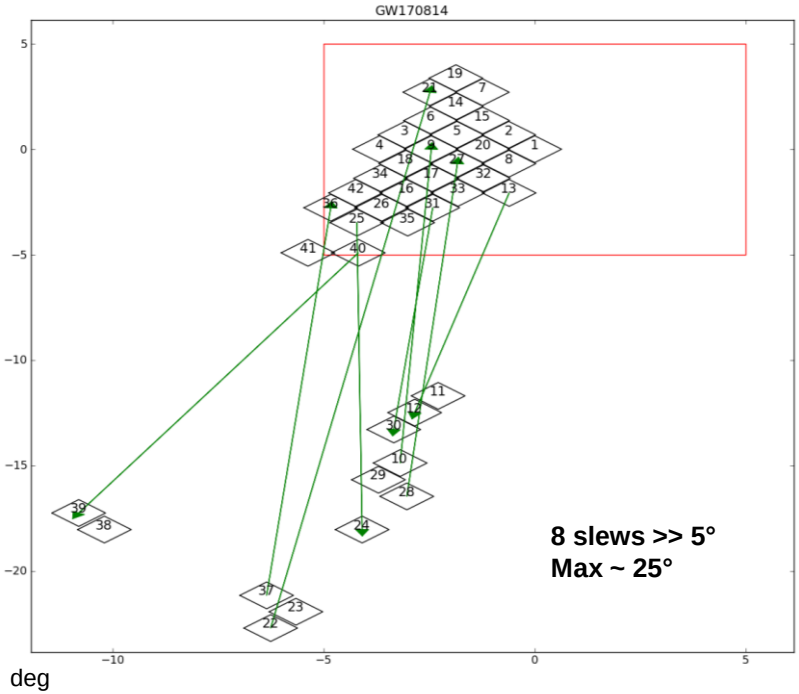
    ~200 simulated 02 skymaps triple coincidence

    Distance between 5 and 270 Mpc

    Error region spanning from 1.2 and 3000 deg2

ToO-Multi-Messenger Prototype

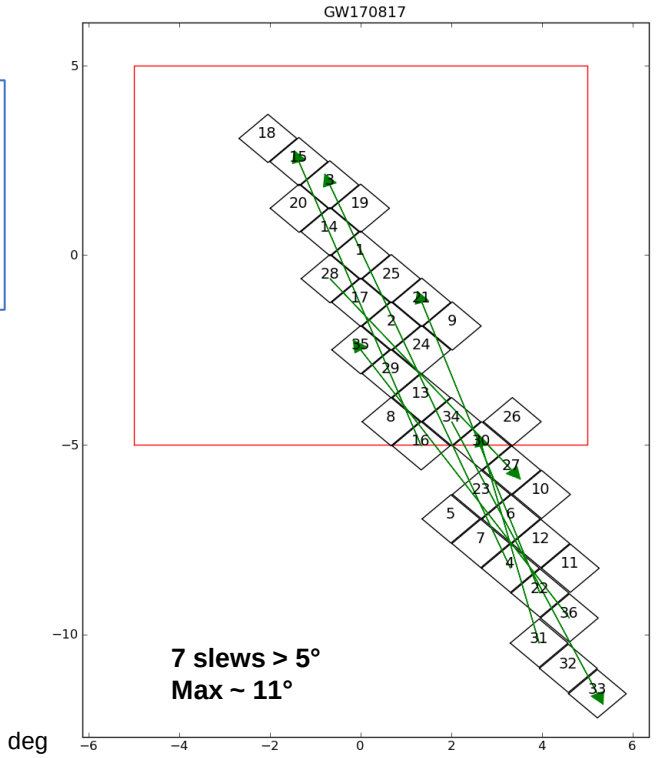
GW170814 : 42 tiles



Simplified representation of tiles centered on tiles n°1

→ Slews > 5°

GW170817 : 36 tiles

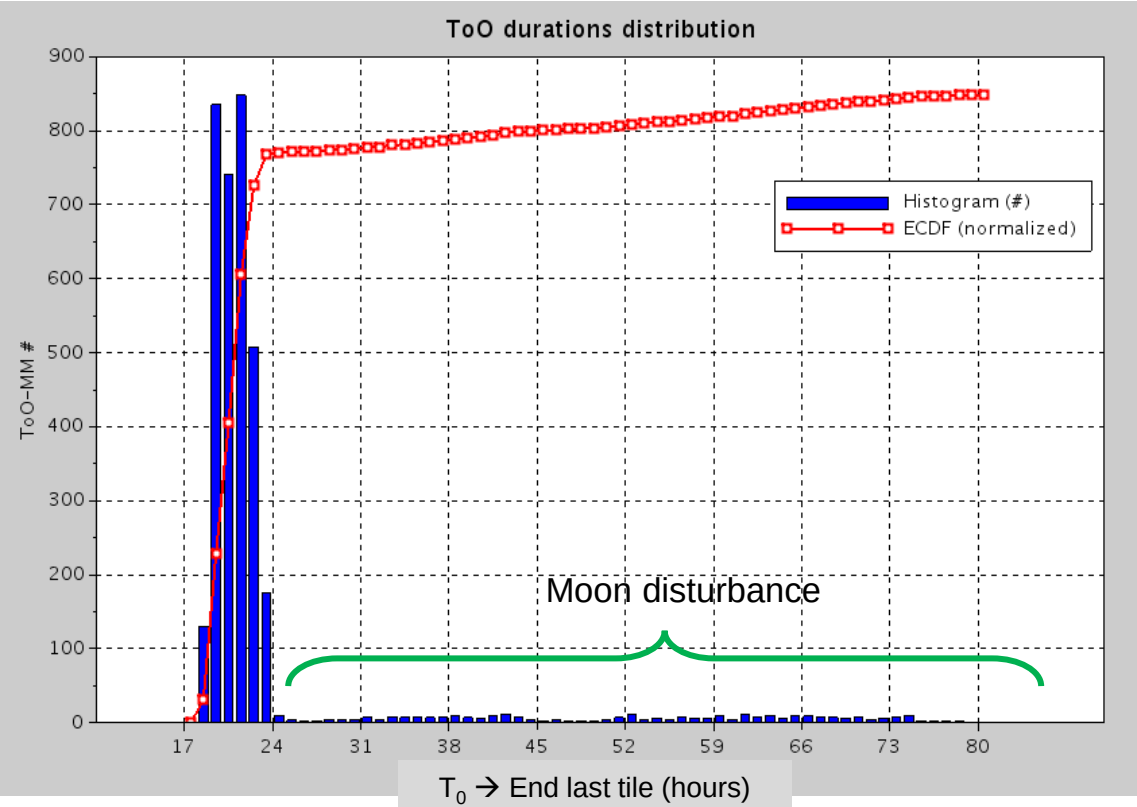


Note : Tiling built to insert slews > 5° every 3 tiles

ToO-Multi-Messenger Prototype

GW170817 : 36 tiles, 10 mn / tile, limited 3 tiles / orb

Slews > 5° not constrained



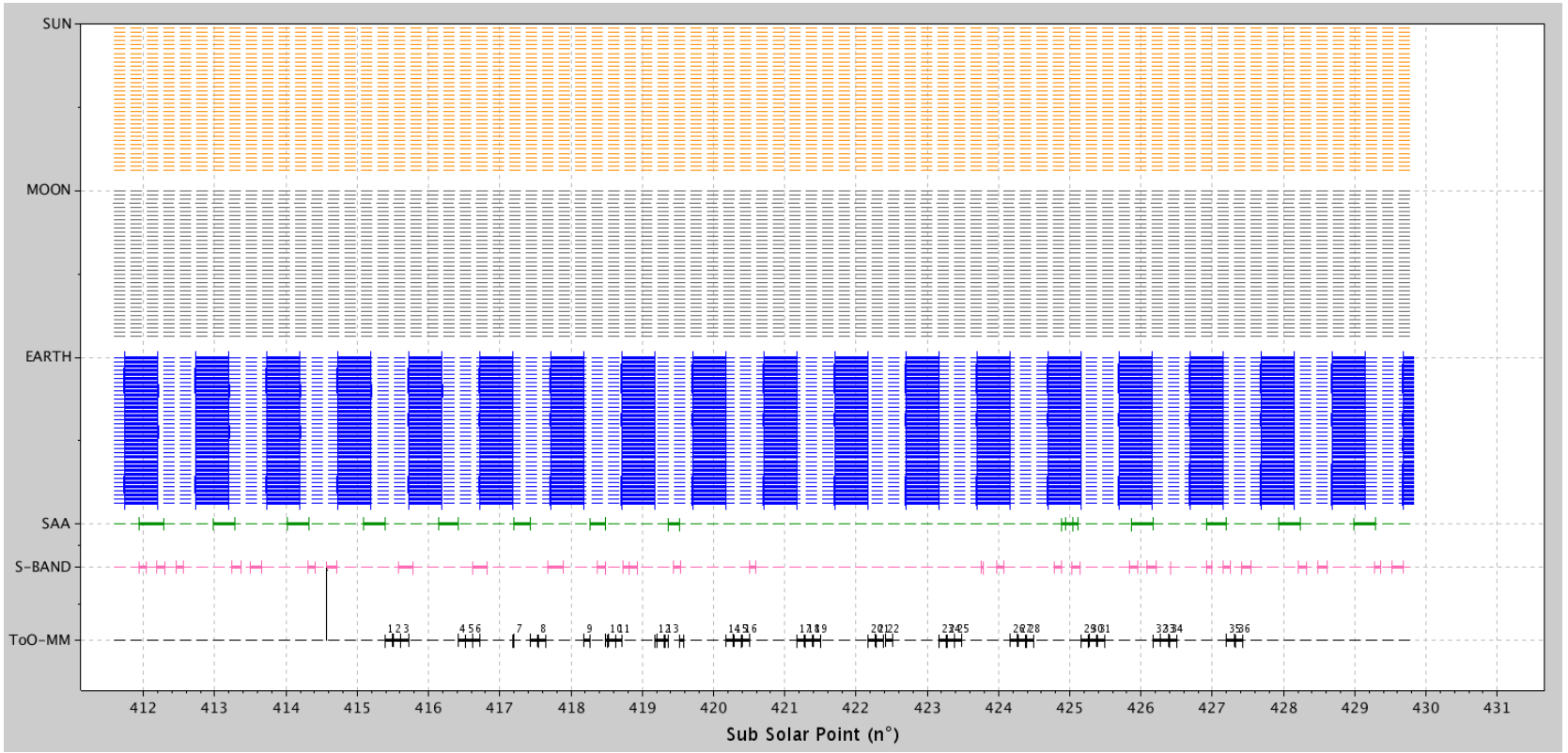
Histogram and cumulative distribution of whole sequence duration for all S-band passes over 1 year (sequencing with tiles priorities)

☞ **T_0 = Start S-band slot**

Min = 18 h
Max = 25 h / 79 h (Moon)
Aver. = 22 h

ToO-Multi-Messenger Prototype

GW170817 : 36 tiles, 10 mn / tile, limited 3 tiles / orb



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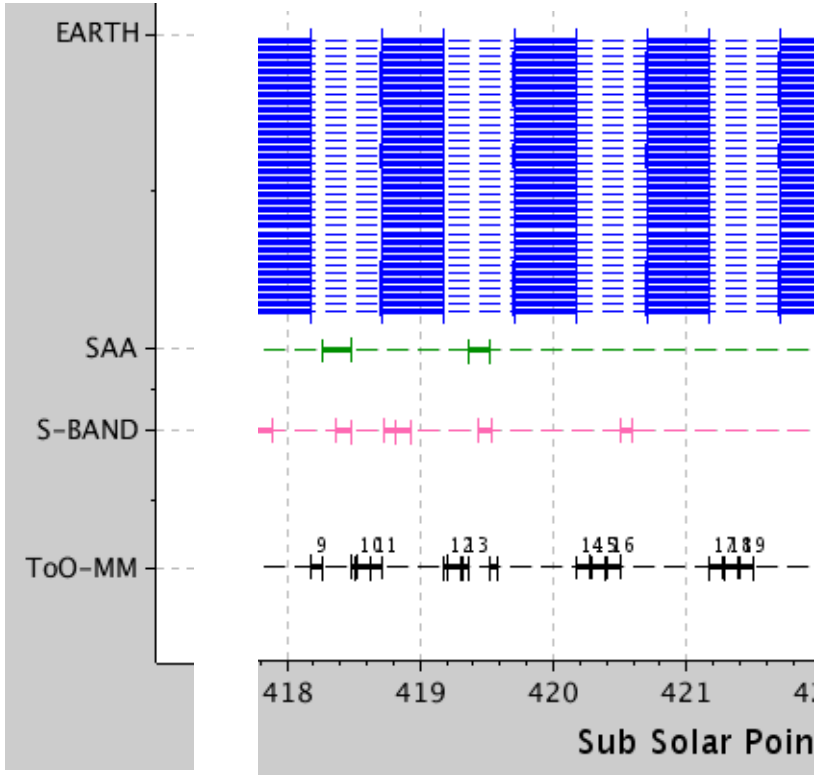

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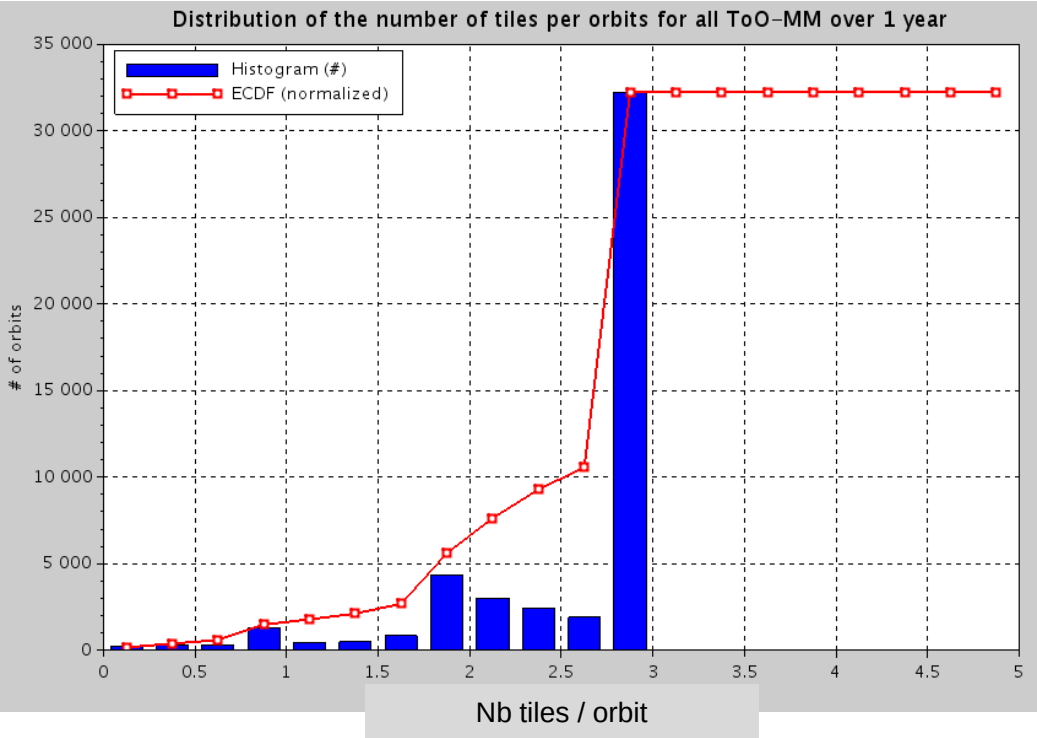


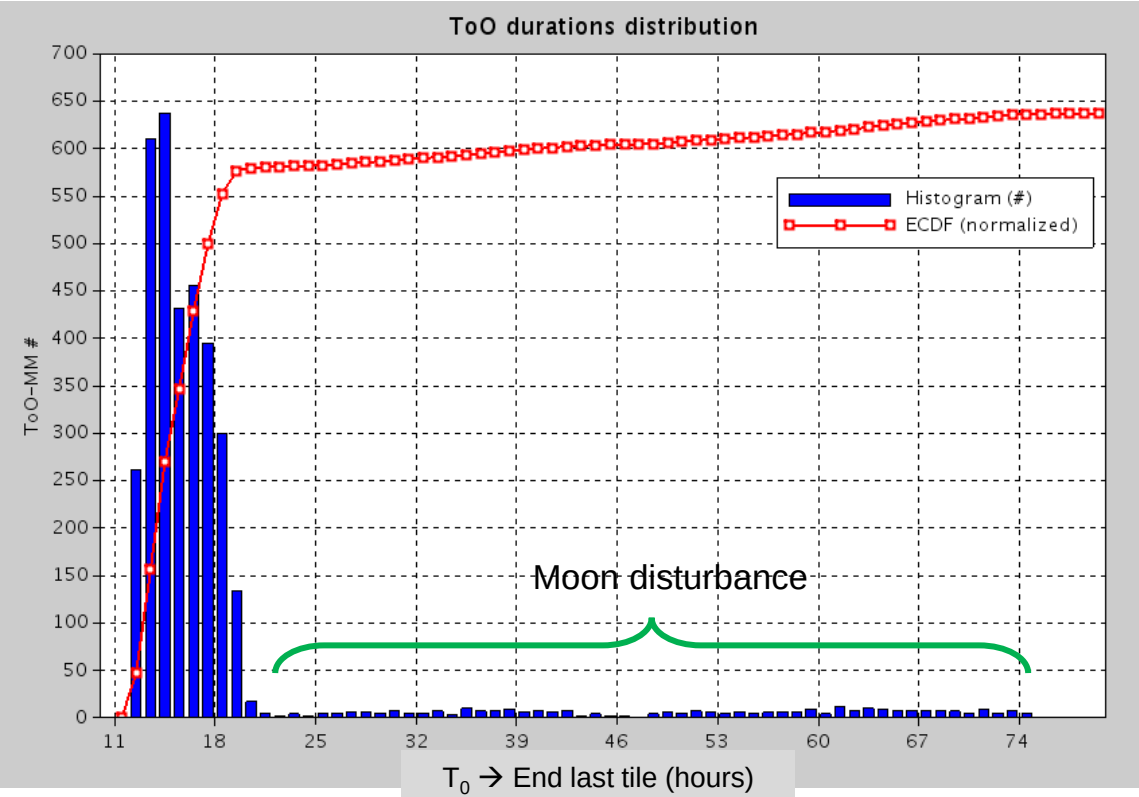
Histogram and cumulative distribution of numbers of tiles per orbit over all sequences for all S-band passes over 1 year (sequencing with tiles priorities)

Most of orbits with 3 tiles

Orbits begin/end at subsolar point

ToO-Multi-Messenger Prototype

GW170817 : 36 tiles, 10 mn / tile, tiles / orb not limited



Slews > 5° not constrained

Histogram and cumulative distribution of whole sequence duration for all S-band passes over 1 year (sequencing with tiles priorities)

☞ **T_0 = Start S-band slot**

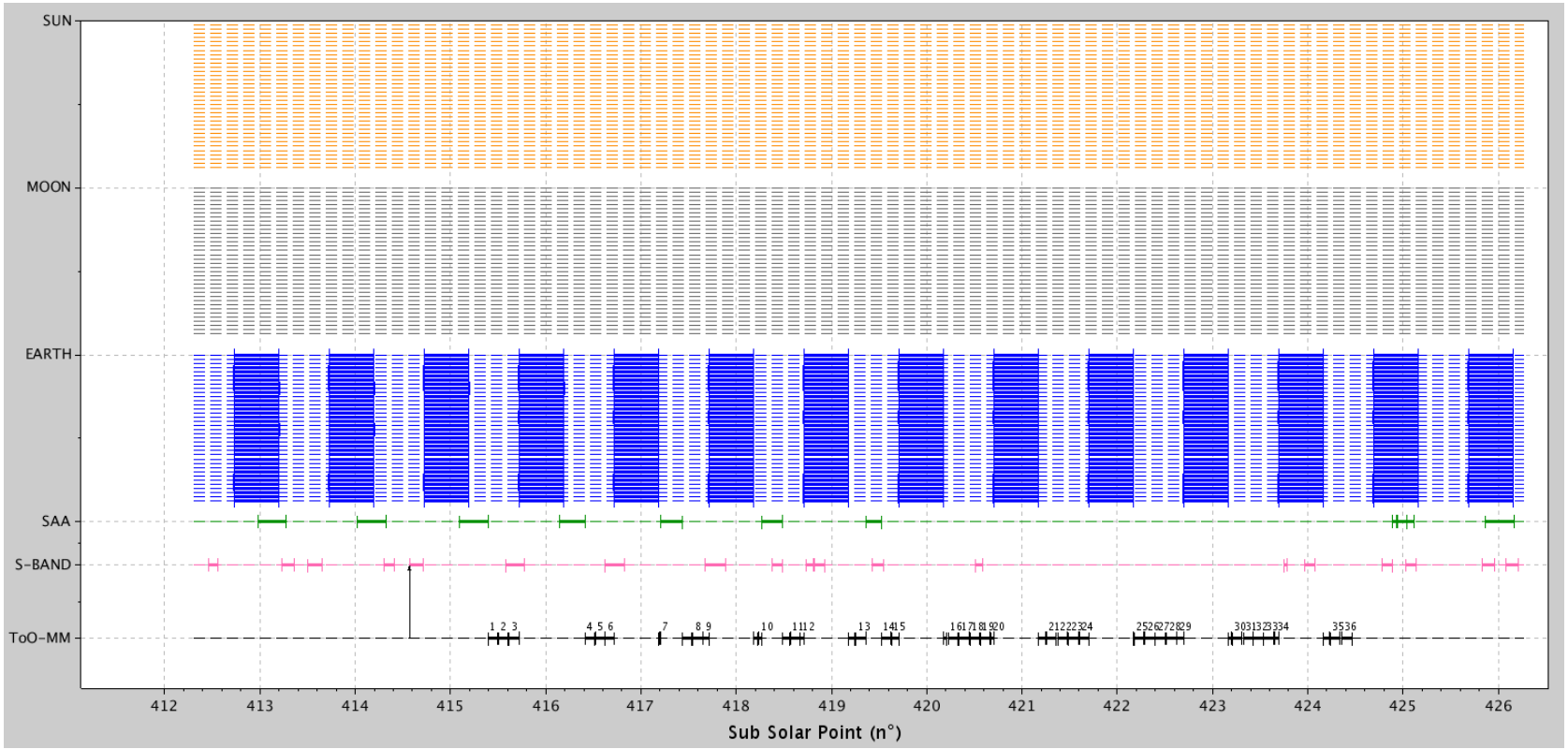
Min = 12 h
Max = 21 h / 75 h (Moon)
Aver. = 15 h

Min = 18 h
Max = 25 h / 79 h (Moon)
Aver. = 22 h

Limited 3 tiles / orb

ToO-Multi-Messenger Prototype

GW170817 : 36 tiles, 10 mn / tile, tiles / orb not limited



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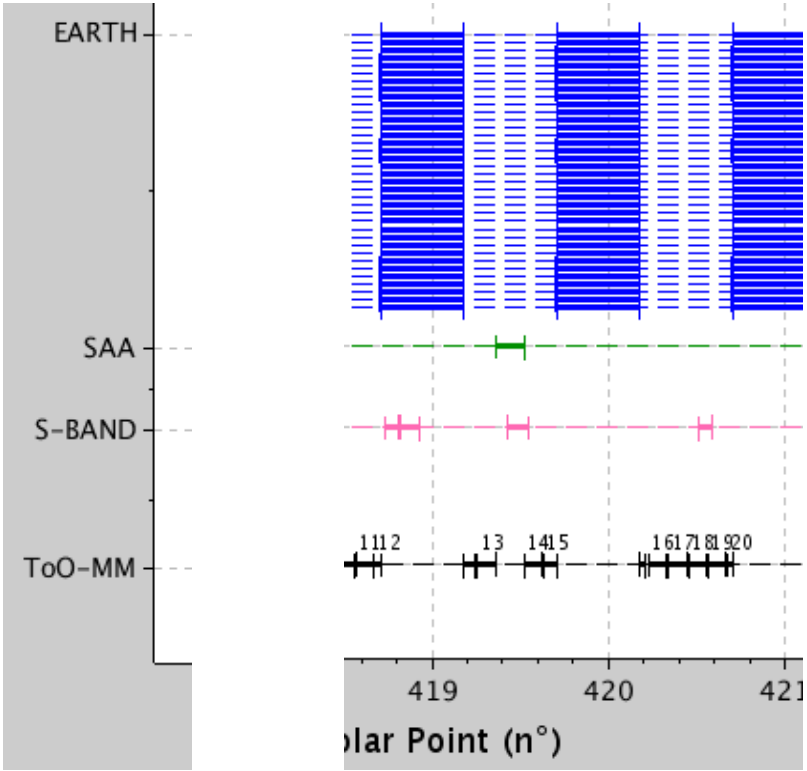

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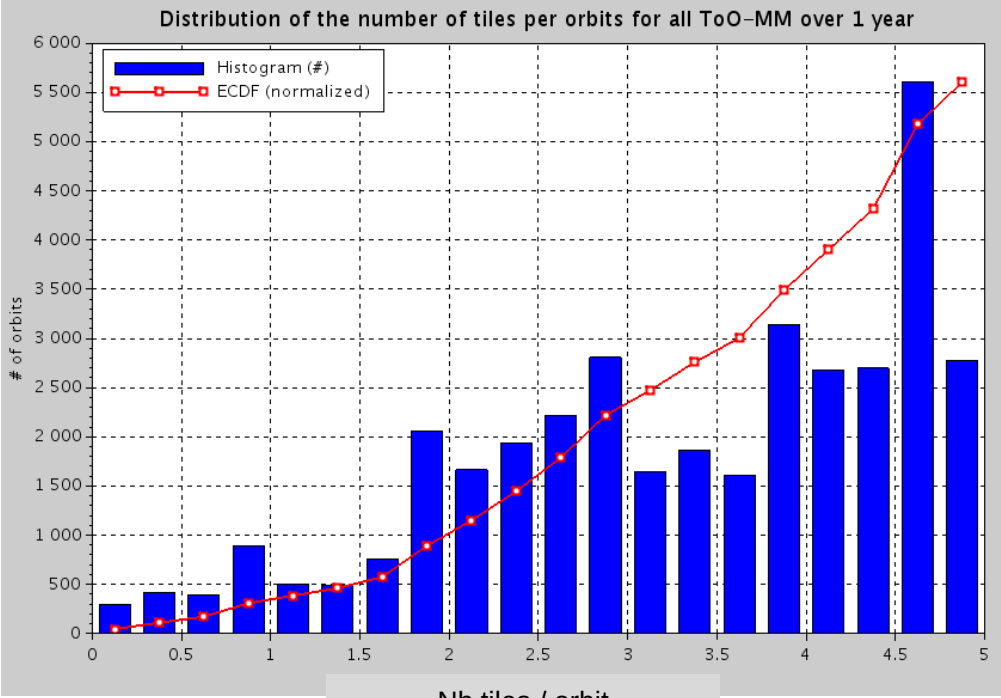


Histogram and cumulative distribution of numbers of tiles per orbit over all sequences for all S-band passes over 1 year (sequencing with tiles priorities)

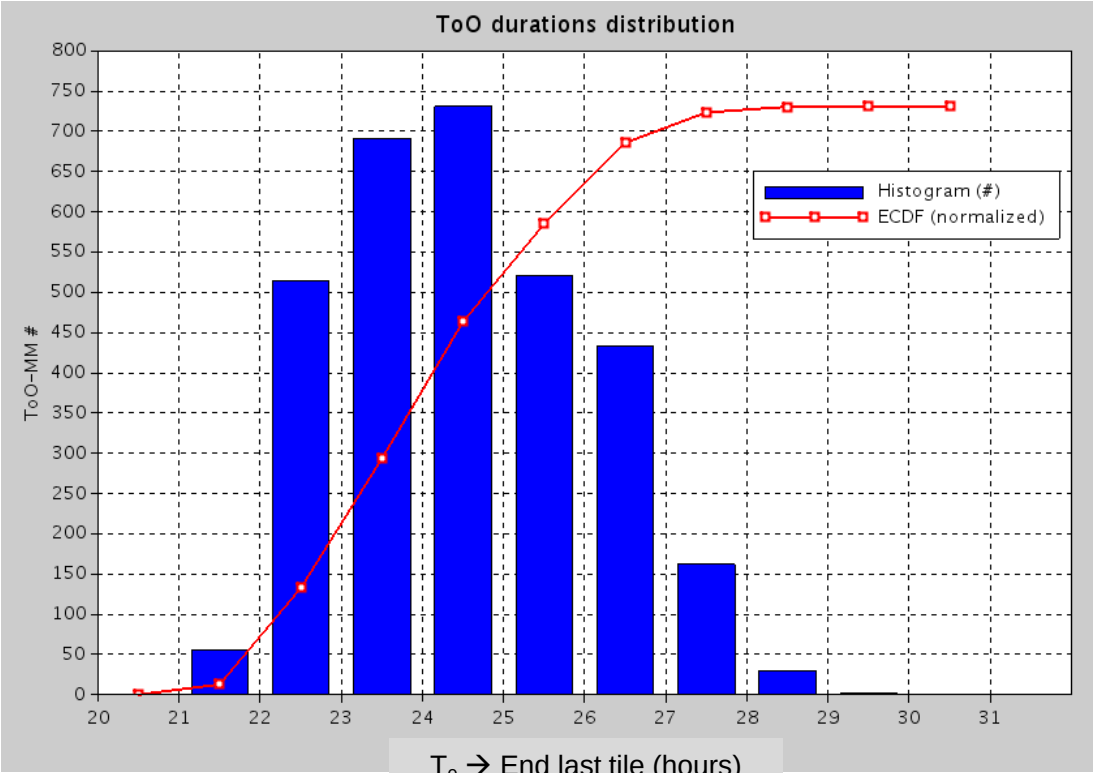
Up to 5 tiles / orbit useful if feasible

Orbits begin/end at subsolar point

ToO-Multi-Messenger Prototype

GW170814 : 42 tiles, 10 mn / tile, limited 3 tiles / orb

Slews > 5° not constrained



Histogram and cumulative distribution of whole sequence duration for all S-band passes over 1 year (sequencing with tiles priorities)

☞ T_0 = Start S-band slot

Min = 22 h
Max = 29 h
Aver. = 25 h

ToO-Multi-Messenger Prototype

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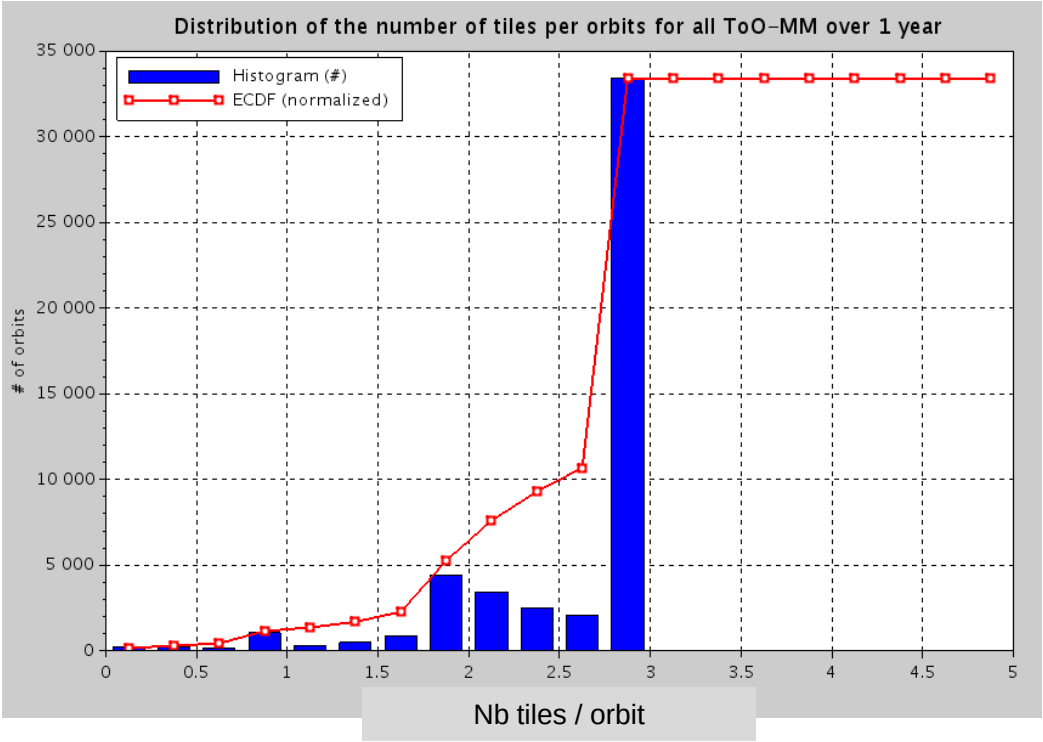
Slews > 5° not constrained



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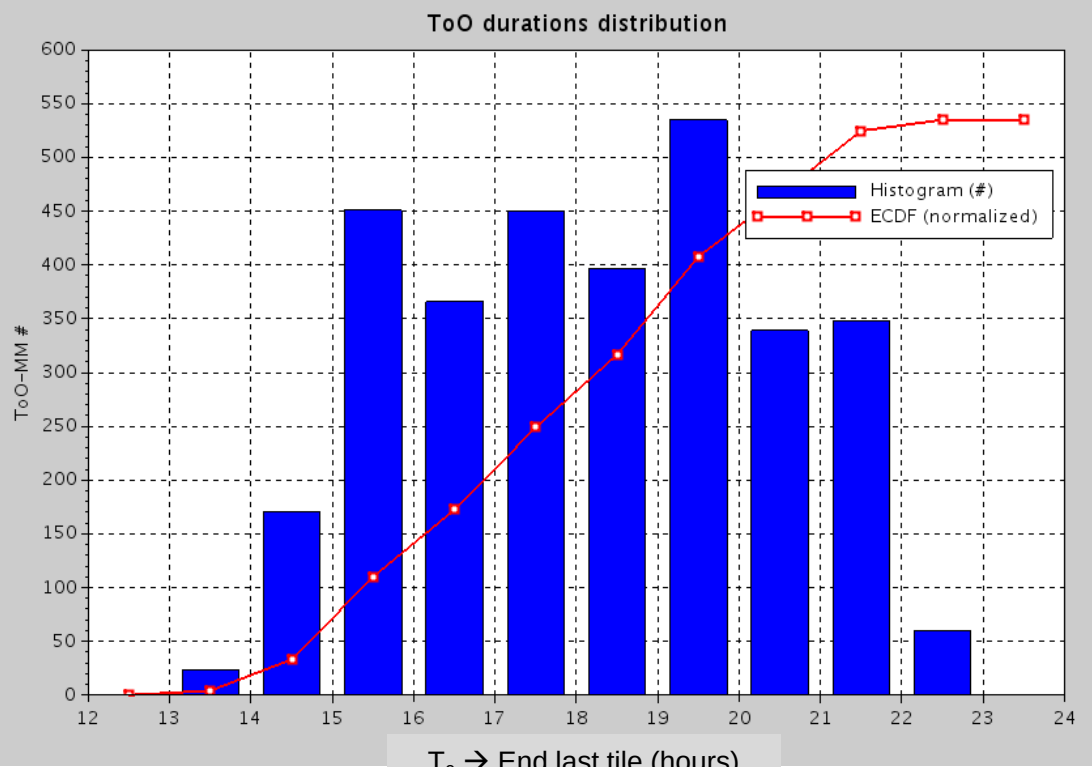

T_0 → End last tile (hours)

Histogram and cumulative distribution of whole sequence duration for all S-band passes over 1 year (sequencing with tiles priorities)

☞ T_0 = Start S-band slot

Min = 14 h
Max = 23 h
Aver. = 19 h

Min = 22 h
Max = 29 h
Aver. = 25 h

Limited 3 tiles / orb

ToO-Multi-Messenger Prototype

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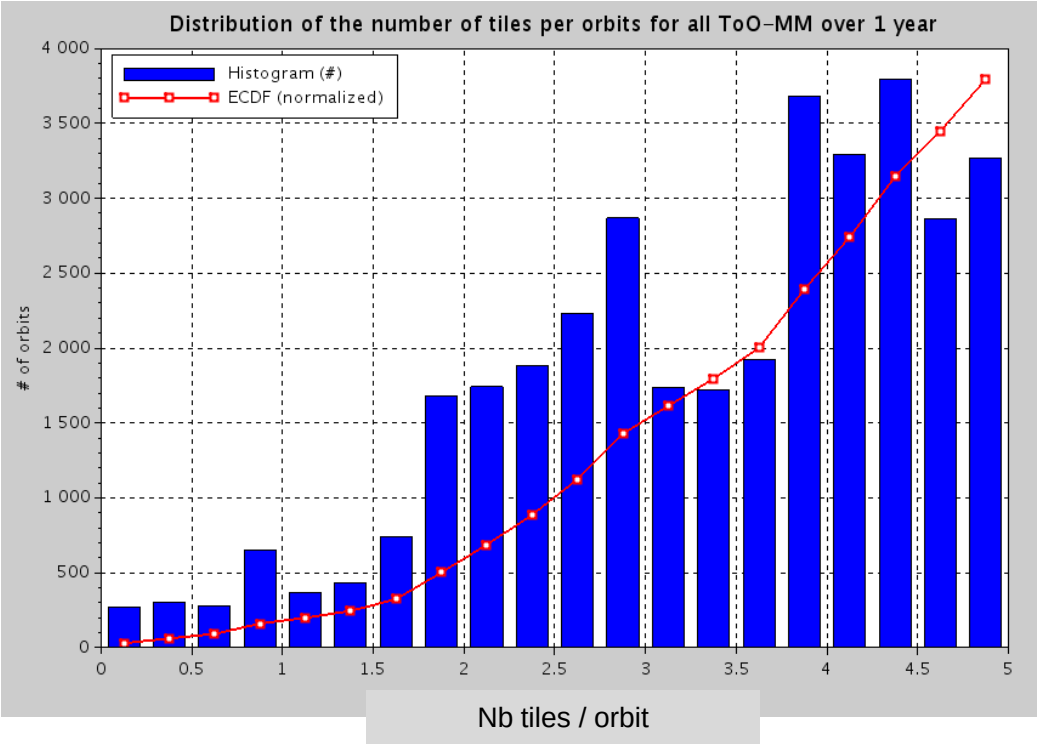
Slews > 5° not constrained



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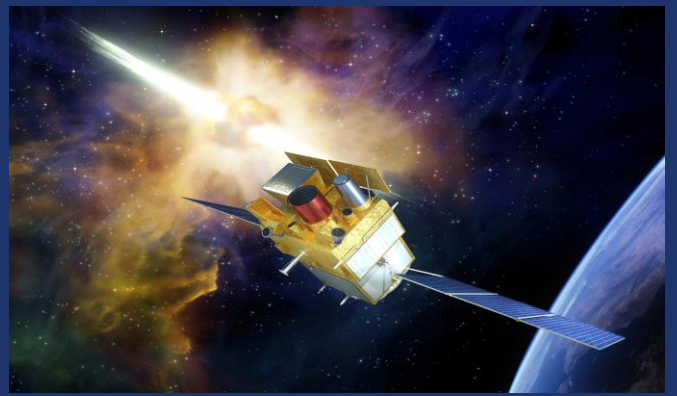

Conclusions and further prospects

- **The prototype implemented currently allows for statistically assessing the duration of whole sequences of tiling relating to ToO-MM scenarios with possible variations for constraints**
- **Refine consideration of constraints (slew constraints / occultation periods if needed)**
- **Implement model for ground delays from MM alert up to S-band TC upload**
  → Total response time for ToO-MM requests
- **Simulations to be performed with additional scenarios of ToO-MM requests delivered by LAL :**
  - ✓ ~200 new scenarios simulated from skymaps

谢谢

Thank You