

SVOM

General Program

Mission Planning and Programming

Requirements and Simulation Overview

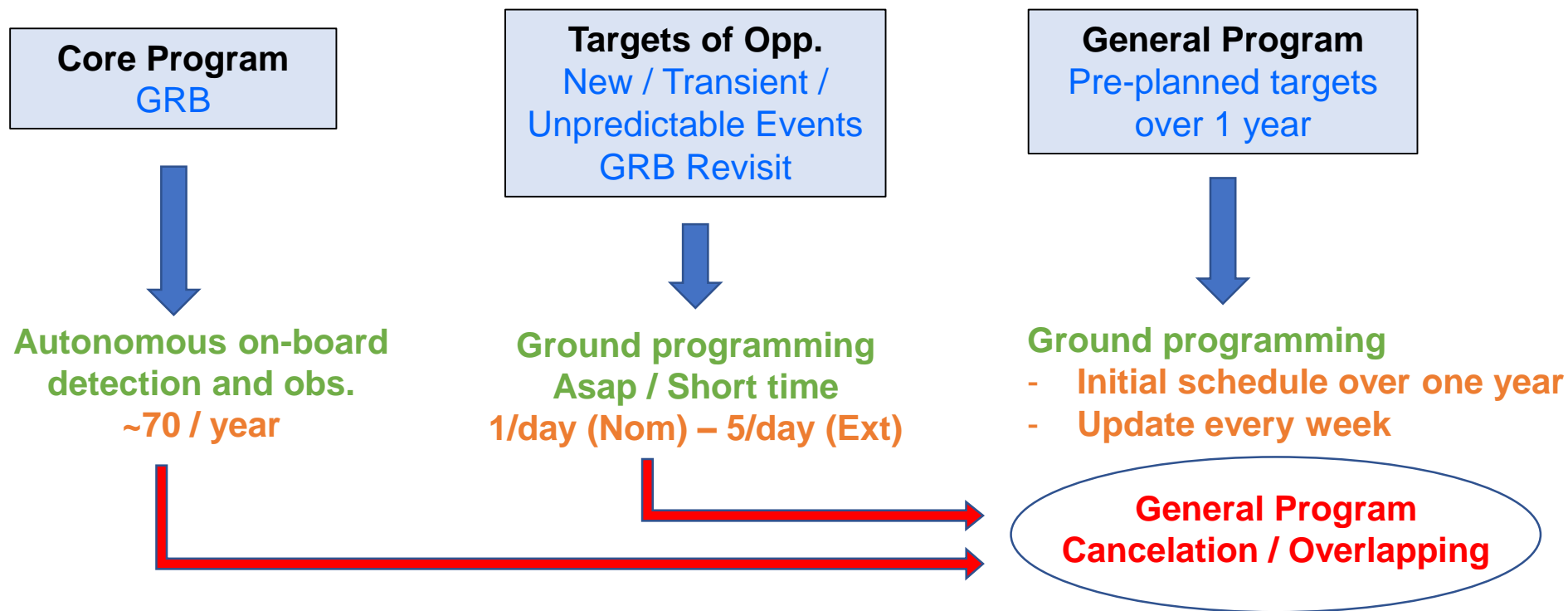
Jean JAUBERT
CNES



- **Scope of Mission Planning and Programming issues for SVOM**
- **GP Mission Planning and Programming requirements and design**
- **GP Mission Planning and Programming Simulations**
 - Inputs
 - Results and Performances overview
- **Findings, Open points and Further Prospects**



Scope of Mission Planning and Programming activities for SVOM



Mission Planning issues for the General Program = How to :

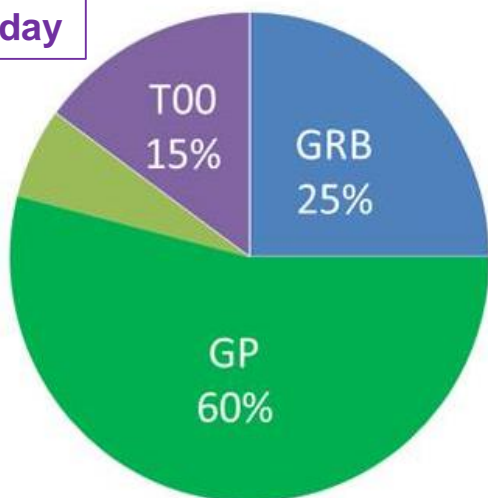
- **Establish an initial one year schedule** (from Call for Obs) **optimized** wrt :
Users requests + MRR and system constraints + Best time occupation
- **Ensure the best possible completion of GP requests** at the end of the year :
Using a possible weekly update

Scope of Mission Planning and Programming activities for SVOM

NOMINAL MISSION

USEFUL MISSION TIME

1 ToO per day



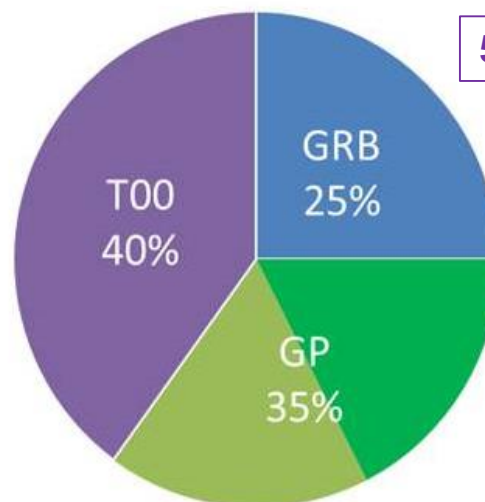
85% of the GP within 10° / B1 pointing
50% UMT for A-targets

60% UMT Chinese users / 40% UMT French users

EXTENDED MISSION

USEFUL MISSION TIME

5 ToO per day

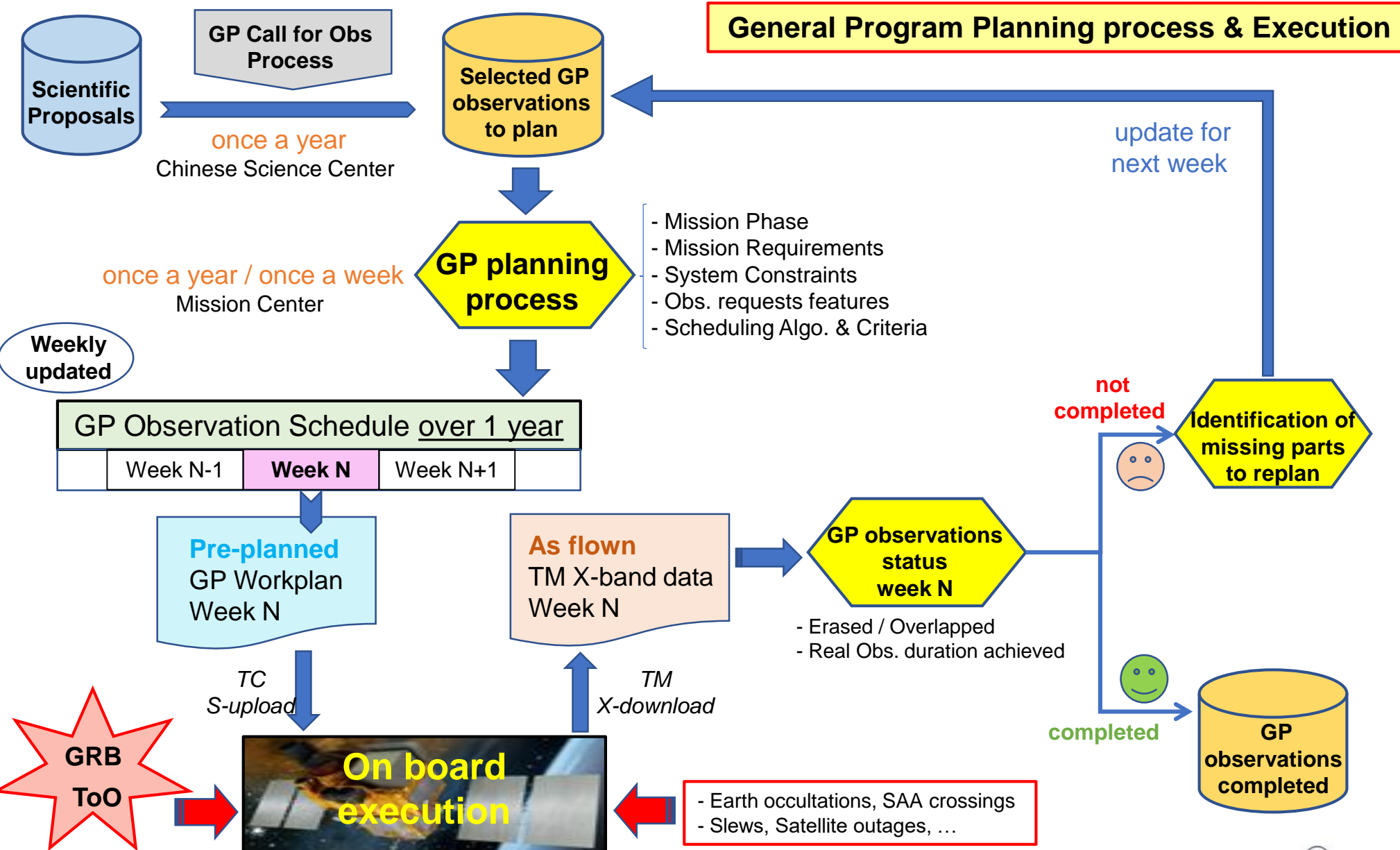


50% of the GP within 10° / B1 pointing
30% UMT for A-targets

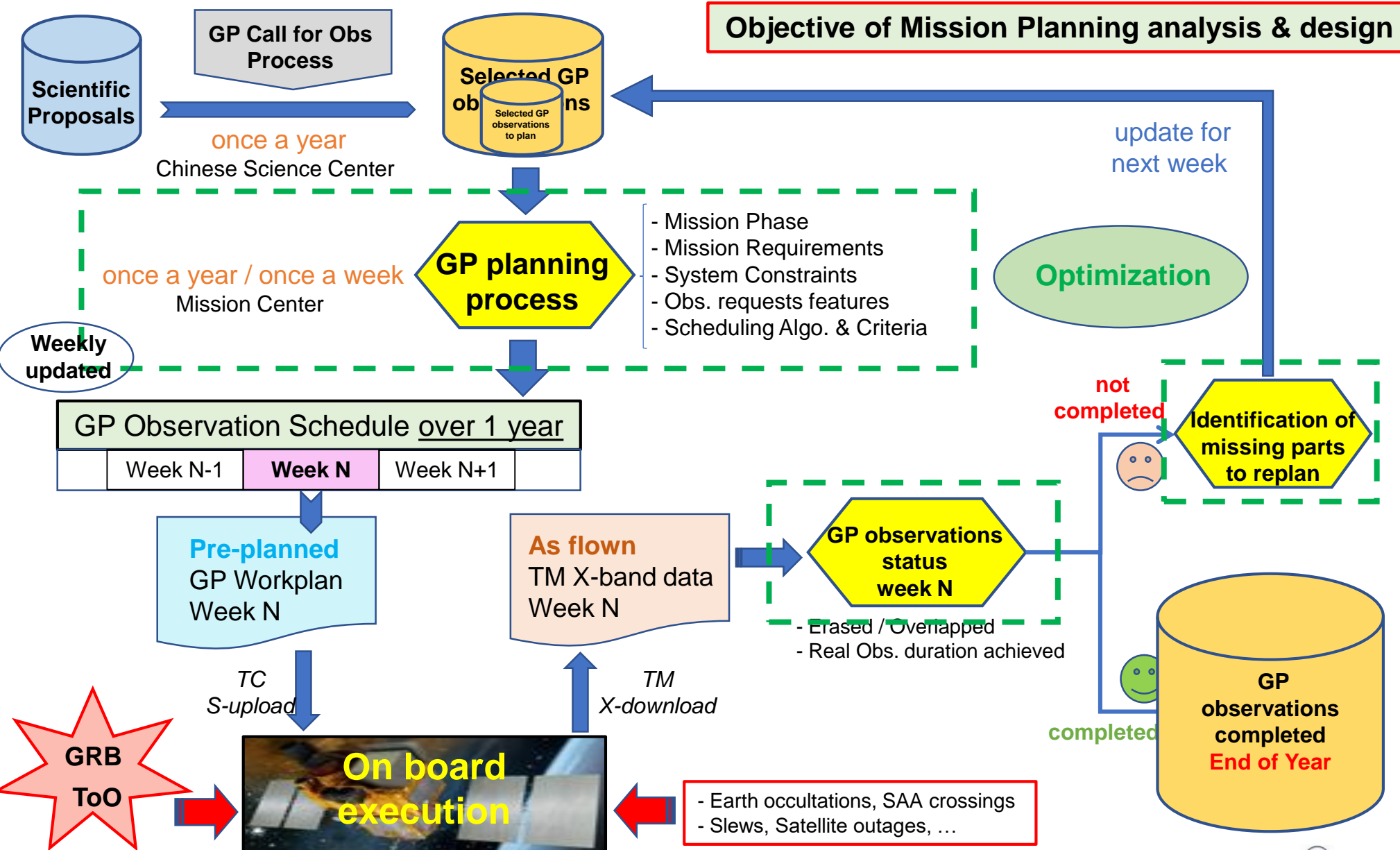
Reminder :

The « B1 pointing law » is a reference inertial pointing defined for each day of the year and designed to favor the GRB detection by instrument ECLAIRs and their follow-up by ground telescopes.

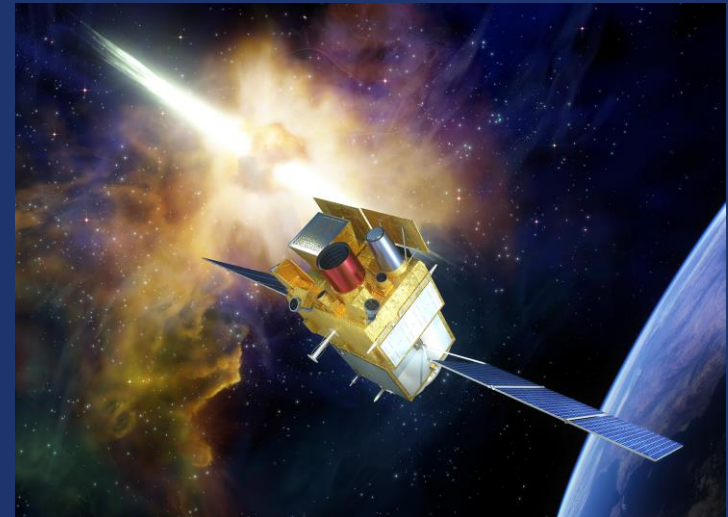
General Program Planning process & Execution



Objective of Mission Planning analysis & design



- Scope of Mission Planning and Programming issues for SVOM
- **GP Mission Planning and Programming requirements and design**
- **GP Mission Planning and Programming Simulations**
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GP Mission Planning requirements and design :

❖ Status of GP Mission Planning requirements :

➤ Documentation : **SV-SY-SP-680-JPO** (2.0)

➤ Main contents and status :

- Requirements for GP Mission Planning process applicable for Mission Center (NSSC). Implementation has started (system in phase C).
- Inherited from Mission Analysis and Simulation results and findings
- Approved at System Interface Review (end 2017)
- Consistent with programming loop workflows and MOCD document (operational proc.)

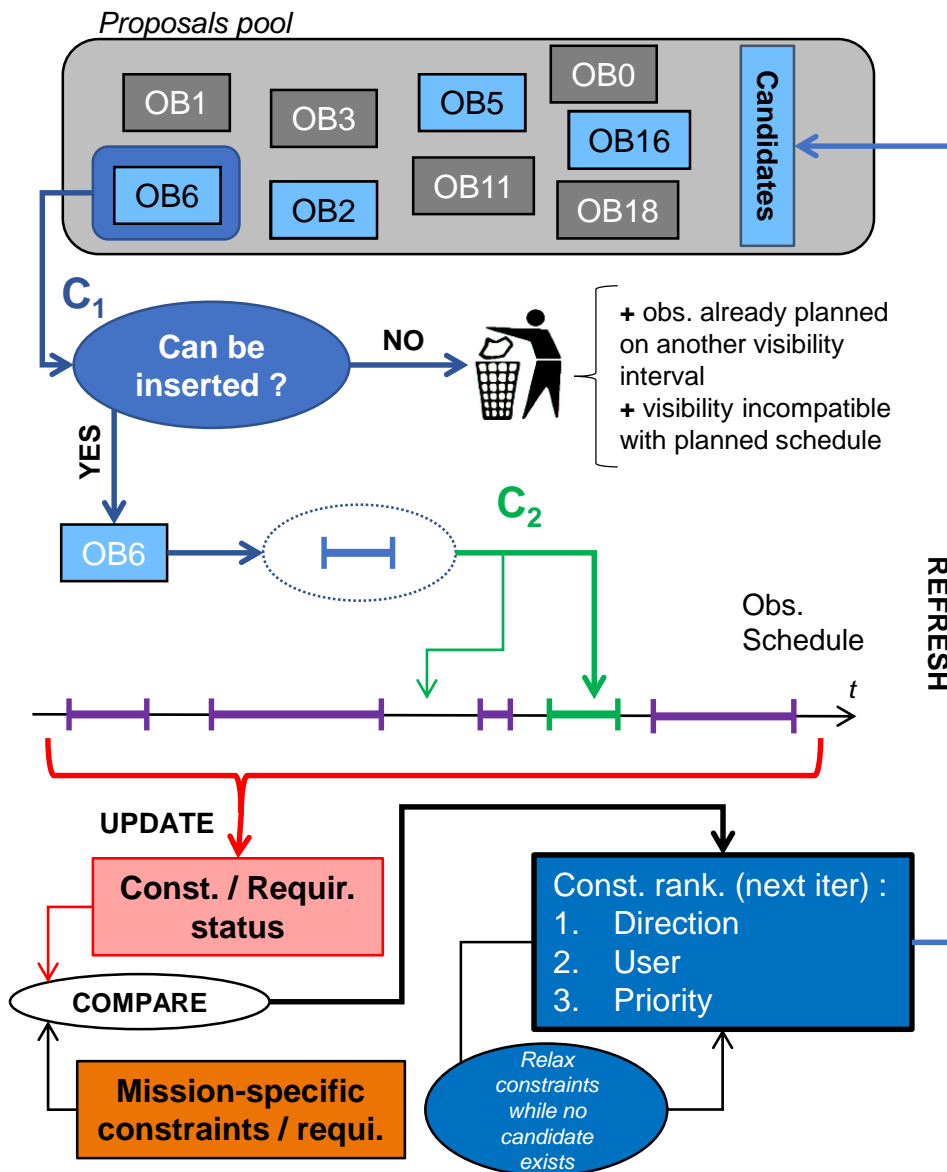
GP scheduling process

Aim
Automatically fill the GP-schedule over 1 year while meeting the mission requirements :

- GP time allocation / pointing dir. : % close to / far from B1
- User entity time allocation : 60% CH, 40% FR
- A-targets allocation : Priority-A proposals prevail

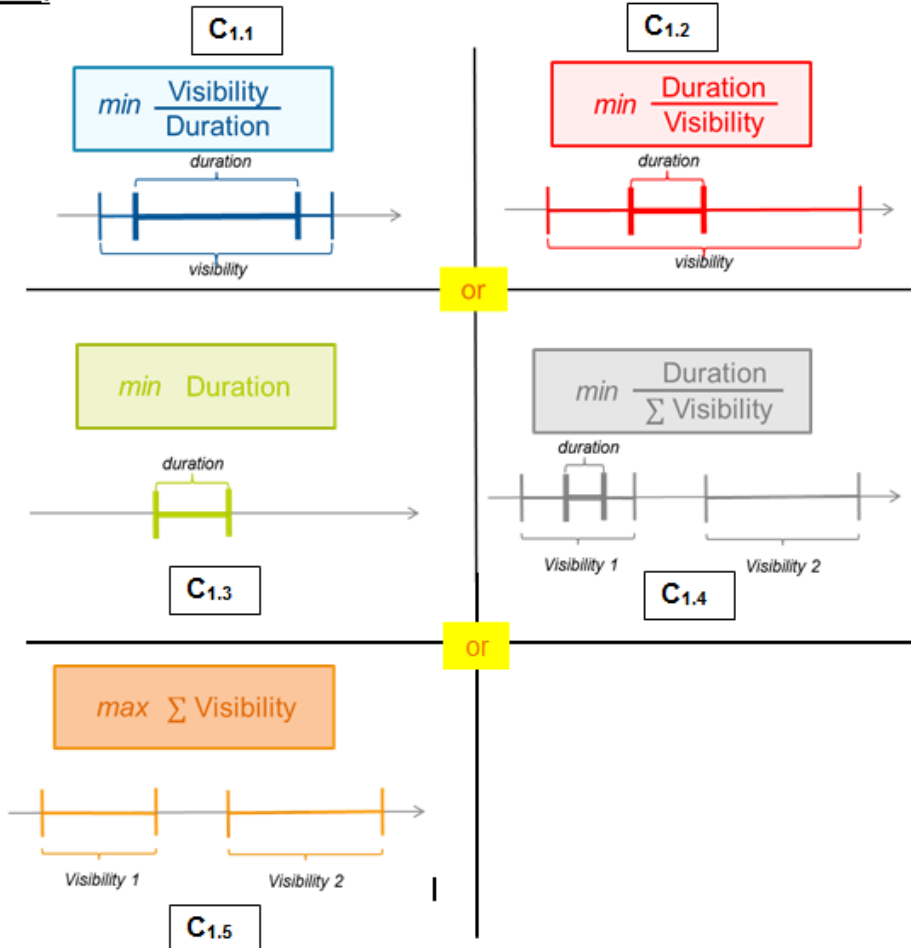
Algorithm
Iterative 3-steps process (greedy algorithm), each step requiring a selection criterion :

1. **Select the candidates** for mission requirements compliance (B1 / ~B1, Ch / Fr, A-targets, Obs. started)
2. **Select an observation** to be scheduled among available candidates → criterion c_1
3. **Insert the observation** in the schedule at the best position for criterion c_2



Selection

Criteria C₁:

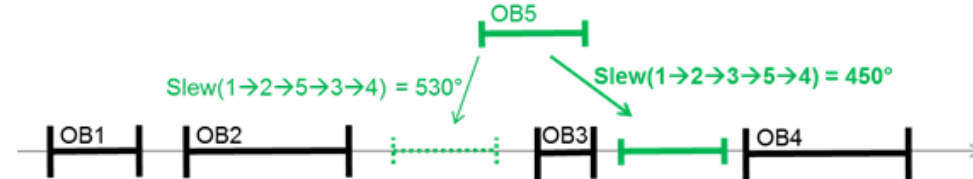


- + Mission Time Allocations Pointing dir - CH/FR user – A-targets
- + Prioritize A-targets and observations already started

Insertion

Criteria C₂:

C_{2.1}: Slew minimization



C_{2.2}: A-targets start dates minimization

$$C_2 = \sum_{i \in \{GP-PA\}} t_i^{start}$$

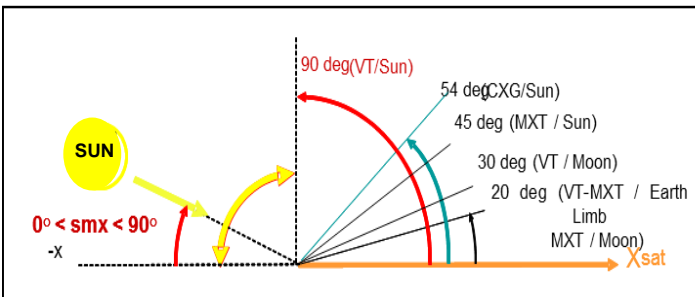
+ Possible local re-arrangement of the schedule

Reminder : Slews are attitude maneuvers to switch from one pointing to the next one.

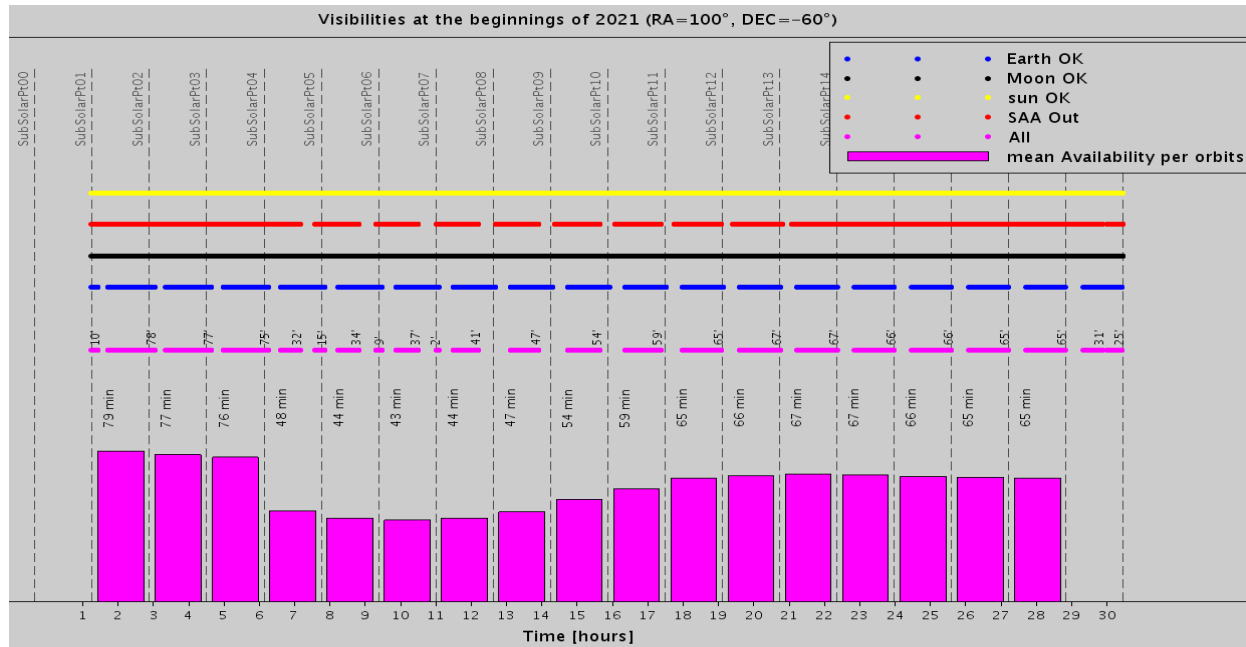
GP Mission Planning design : Available obs. duration / orbit

The useful observation duration per orbit depends on :

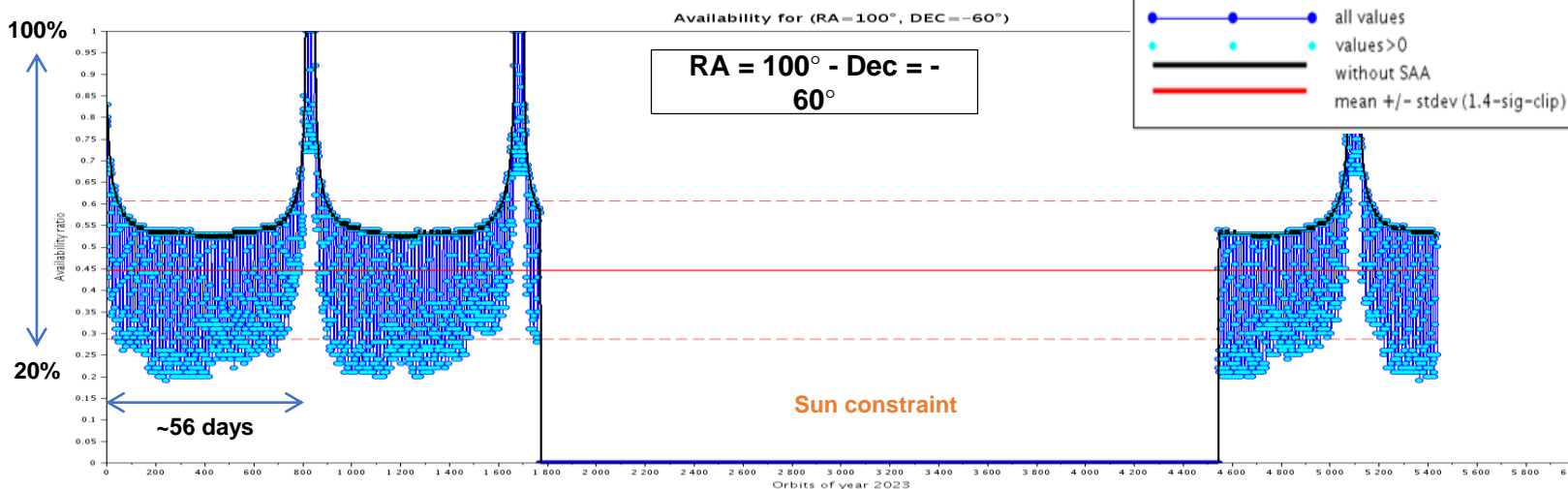
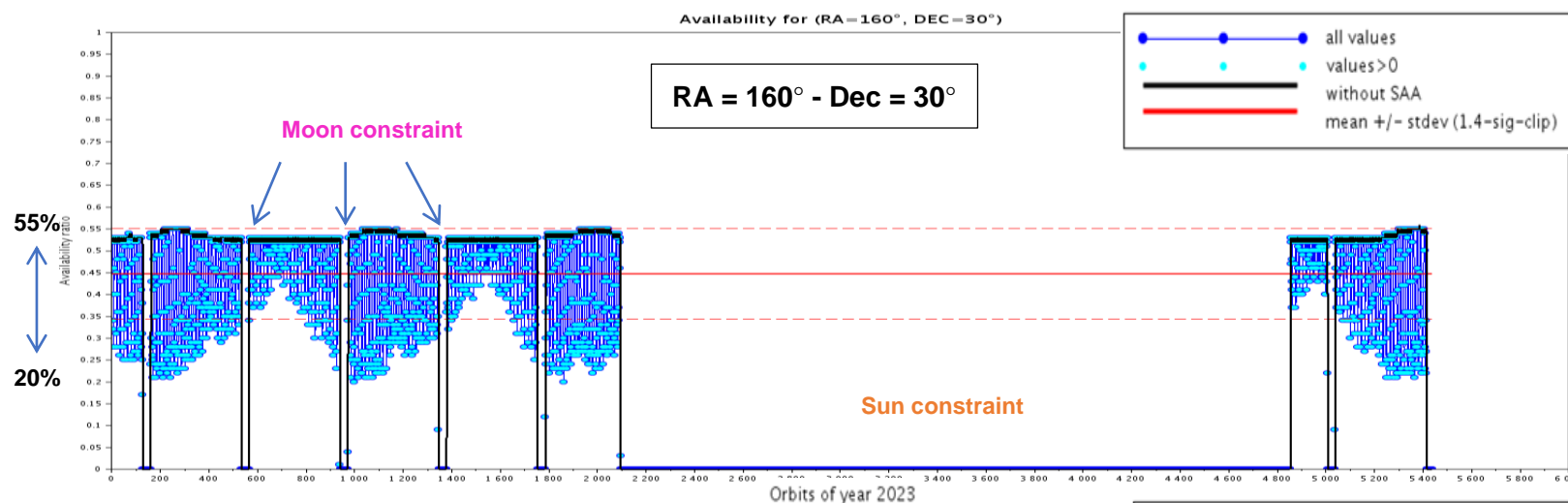
- The Earth occultation, Sun and Moon avoidance
- The SAA crossings
- The date
- The pointing direction
- The instrument



Instruments & Satellite constraints



GP Mission Planning design : Available obs. duration / orbit

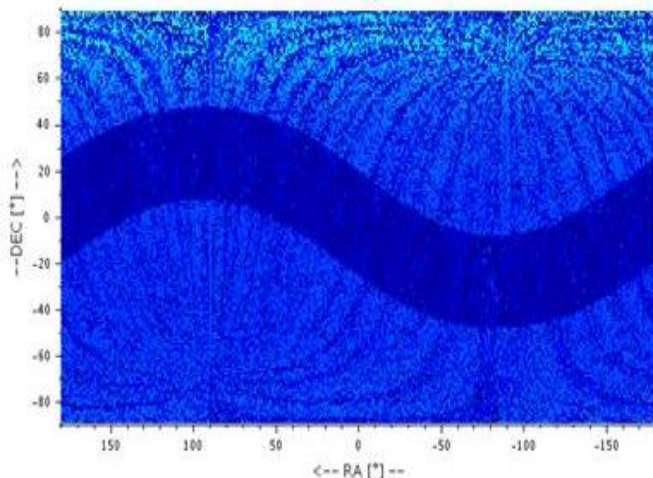


Availability ratio per orbit for one pointing direction over 1 year

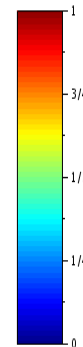
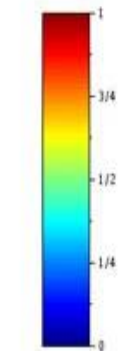
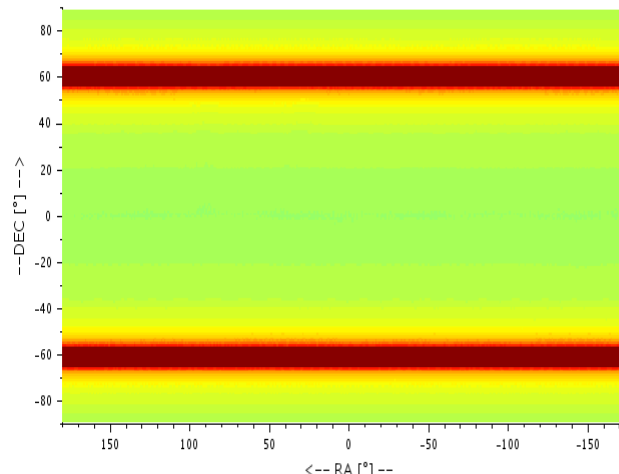
(envelope of constraints over all instruments)

GP Mission Planning design : Available obs. duration / orbit

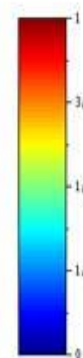
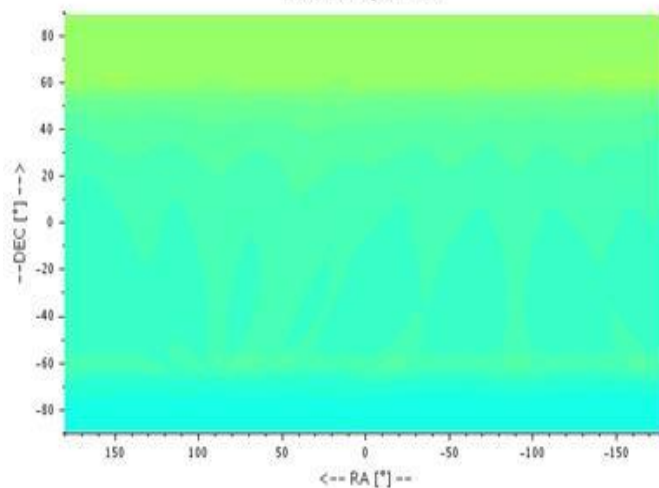
Availability : min



Availability : max



Availability : mean



Average availability
~40% \leftrightarrow ~60%
for any direction

Global availability ratio per orbit for all pointing direction (J2000) over 1 year

(when Sun constraint OK)

GP Mission Planning design : Available obs. duration / orbit

❖ SVOM Mission Planning Process Requirements (GP)

Question : For a given GP request with X ksec to be observed, how can we manage an available duration per orbit varying (when not 0%) from ~20% up to 100% in the one year scheduling process ?

« **Best** » **Solution** : Consider always average available duration / orbit
(depending on each pointing direction) for GP scheduling process

- Number of orbits allocated to the GP requests (calc. with average dur. / orb) not date dependent
- Takes advantage of the weekly re-planning process (existing for ToO, GRB impacts) to determine the global real duration already observed on past orbits (including Earth occ., SAA crossings effective impacts) and to adjust the number of orbits to be planned again during the rest of the year

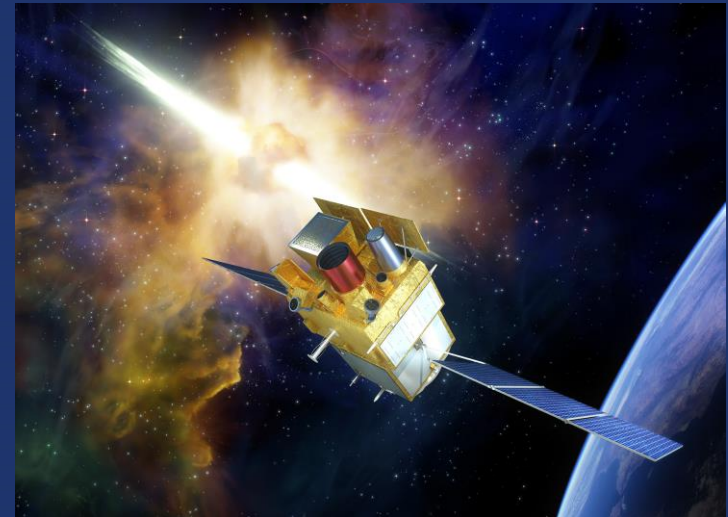


Matches with current scheduling principles
Required observing duration can be well met
Compromise between complexity / performances



Solution currently chosen and specified

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Mission Planning Simulations

Inputs for scenarios of observation requests :

➤ **Former** General Program pools of proposals :

- Pools of users proposals were **fully simulated using random draws** in given ranges for target directions (close / far from B1 law) and observation durations (1 orb-5 days)

➤ **Latest** General Program pools of proposals :

- Pools of proposals consisting of **real targets and near-real observation duration requests**

➤ **Consideration of pools of Fill-In Targets (FITs) to supplement the schedule :**

- Predefined observation requests of the SVOM system (not provided by the yearly Call for Obs process). Close to the B1 pointing law.
- Used to occupy the available observing time while meeting the mission allocations. Lowest priority.

Catalogue of GP proposals :

A catalogue of proposals has been provided by the French scientific team in early 2017 (A. Goldwurm) corresponding to :

- ◆ Real targets of scientific interest close (i.e. 10 deg) or far from the B1 pointing
- ◆ Near realistic observation durations based on fluxes and SNR assumptions (MXT)

GP Catalogue description : **426 sources + 7 survey areas**

Sources :

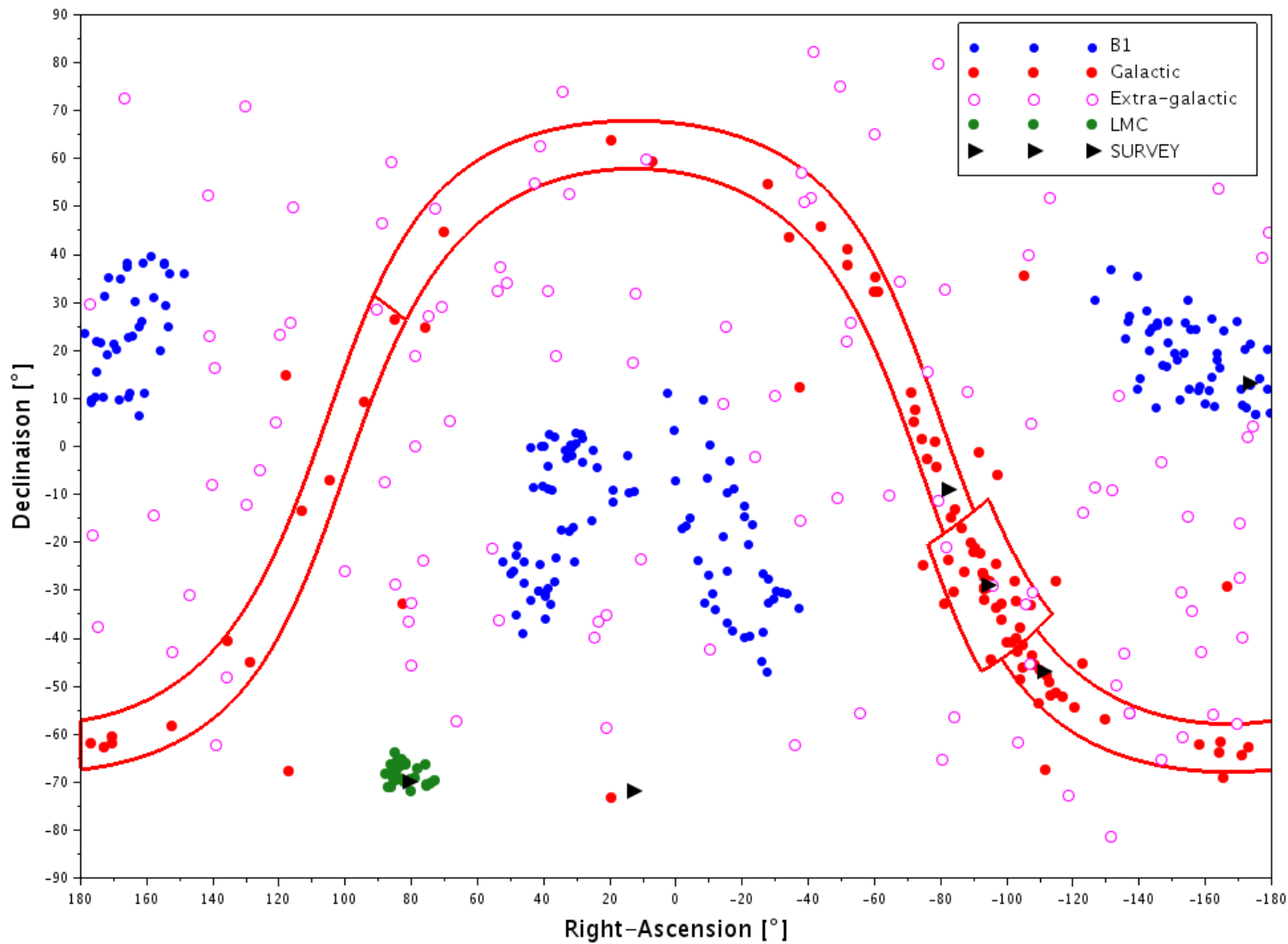
- ◆ Number of sources close to B1 pointing (within 10°) : **175** (78 low fluxes, 97 high fluxes)
- ◆ Number of sources far from B1 pointing : **251** (96 in galactic plane, 155 out of galactic plane including 36 in LMC)

Supplemented with several surveys for narrow FoV instruments :

Areas in the sky which have to be pointed to as many times as possible, with no precise duration required and with the aim of observing several sources or variable events.

- ◆ Number of surveys close to B1 pointing (within 10°) : **1**
- ◆ Number of surveys far from B1 pointing : **6**

GP Catalogue : 426 target sources + 7 survey areas



J2000

Catalogue of GP proposals :

GP Catalogue description :

Priorities, Users groups :

- ◆ ~ 50% A-targets, 50% B-targets, Surveys with C-priority (preliminary assumption)
- ◆ 60% Chinese, 40% French observation requests

Details about Observation durations :

Reminder : For the pre-planned General Program, only one target is observable per orbit at the most

The observation durations that are first expressed by user in seconds depending on the flux of the targets and the SNR assumptions then, are converted for scheduling into whole numbers of orbits using the **average available duration** for the pointing direction that is associated to each request.

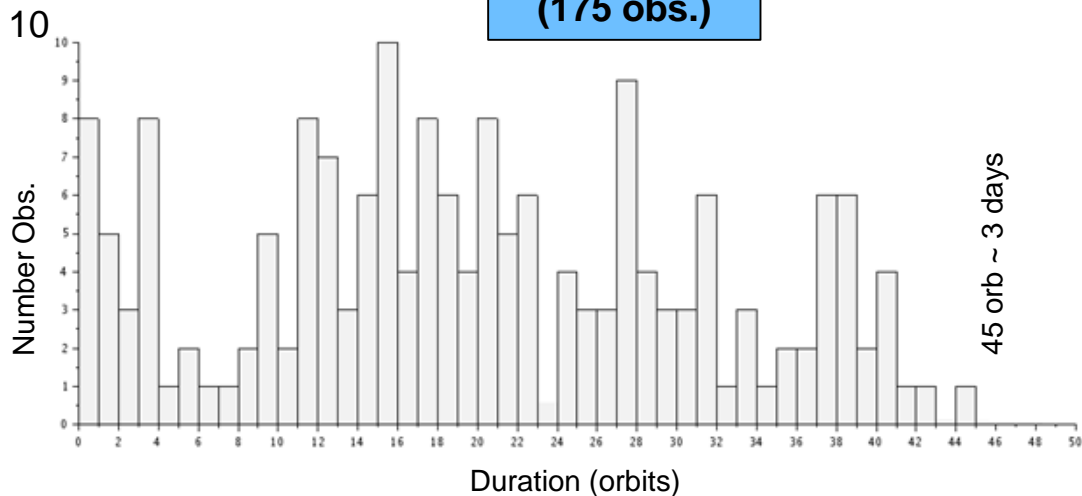
Total observation duration of GP catalogue (without Surveys and FITs) :

~ 13275 ks, 5381 orbits, 360 days

For the survey areas, repeating observation requests with minimum duration of 1 orbit.

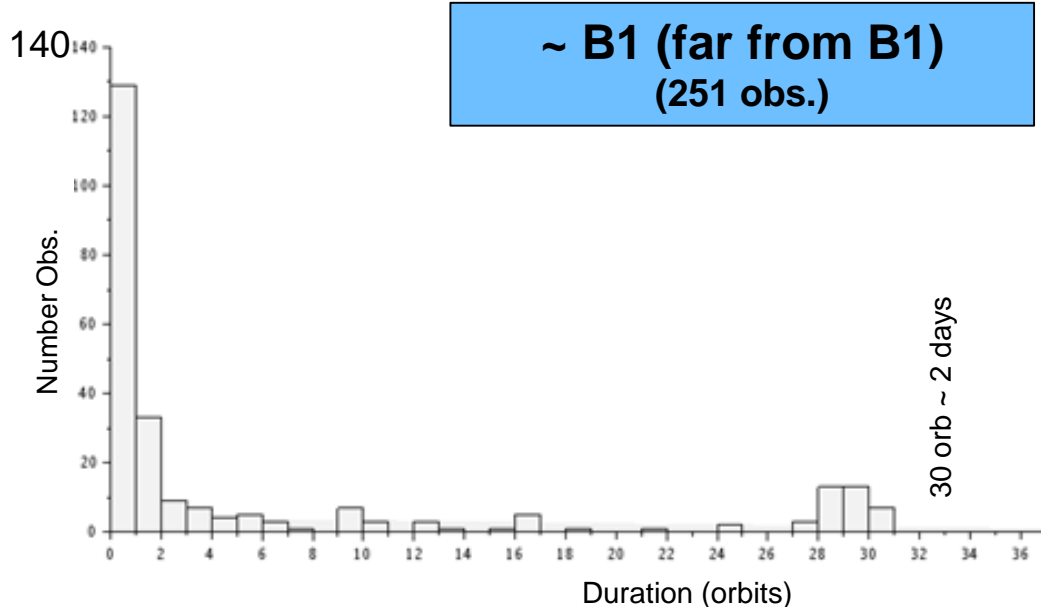
**10° / B1
(175 obs.)**

**Catalogue
Observation durations
distributions
(in orbits)**



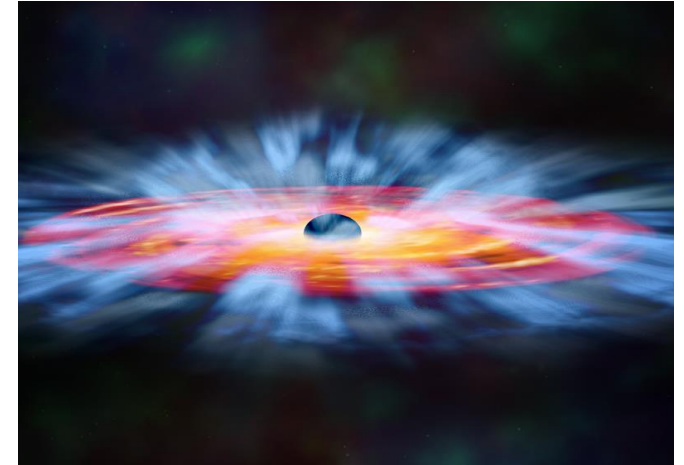
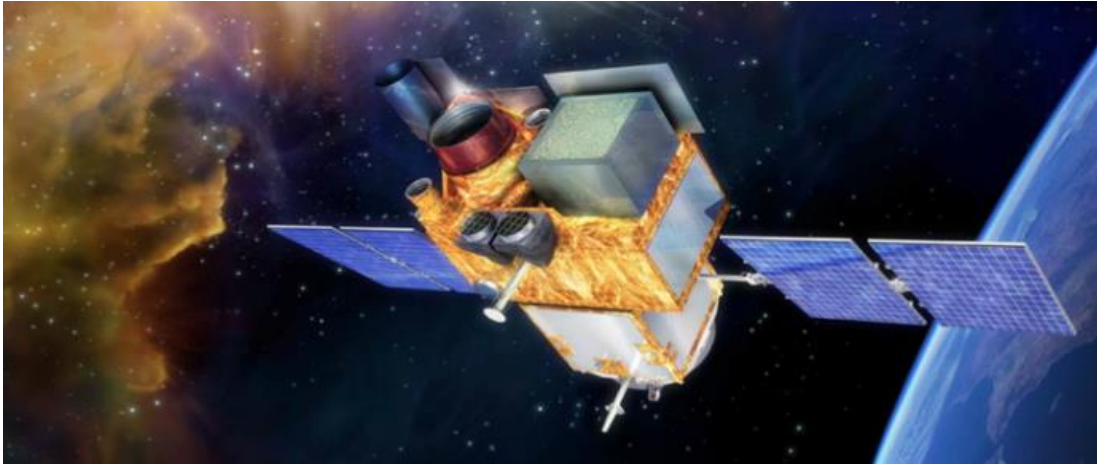
Converted with mean available duration for pointing direction associated to each request

**~ B1 (far from B1)
(251 obs.)**





SVOM MISSION



General Program List of Sources for 1-yr GP

Andrea Goldwurm
(APC – Paris & SAp/CEA – Saclay)
SVOM mission scientist for Observatory Science
with inputs from the **SVOM Observatory Science WG**

GP Source List : close to B1



- List of potential targets for 1 year GP close to B1
- Selection of SWIFT/XRT sources $< 10^\circ$ from B1 (BAT classified s.): 178 source total (mainly AGN)
 - 1 List: s. with 0.3-6 keV Absorbed Flux > 0.2 mCrab: 99
 - 2 List: s. with $F_{0.3-6} > 0.1$ and < 0.2 mC: 79
- Exposure times computed requiring S/N ~ 20 for the 1st and 10 for the 2nd. Total exposure ~ 250 days (1 orbit ~ 40 min eff. exposure).
- Survey program on Virgo Galaxy Cluster to search for TDEs: 9 pointing 1° apart, total Exposure TBD

GP Source List: out of B1



- List of potential targets of 1 year GP out of B1 (15%)
- Selection of SWIFT/BAT sources $> 10^\circ$ away B1 with counterpart in the Swift/XRT catalogue ($F > 1$ mC)
- Exposure times computed from XRT flux requiring $S/N=20$ with MXT (or MaxExp 72hr, $S/N > 10$). Total exposure ~ 55 days (1 orbit 40 min eff. exposure).
- Science Programs :
 - Extragalactic sources (mainly AGN): 119 s , 42 d
 - Galactic sources (mainly X-ray binaries): 96 s, 13 d
 - Surveys of Galactic Center (or Bulge), Norma/Perseus and Scutum/Sagittarius Galaxy Spiral Arm regions, LMC/SMC



Expected Eclairs 1 yr - Exposure

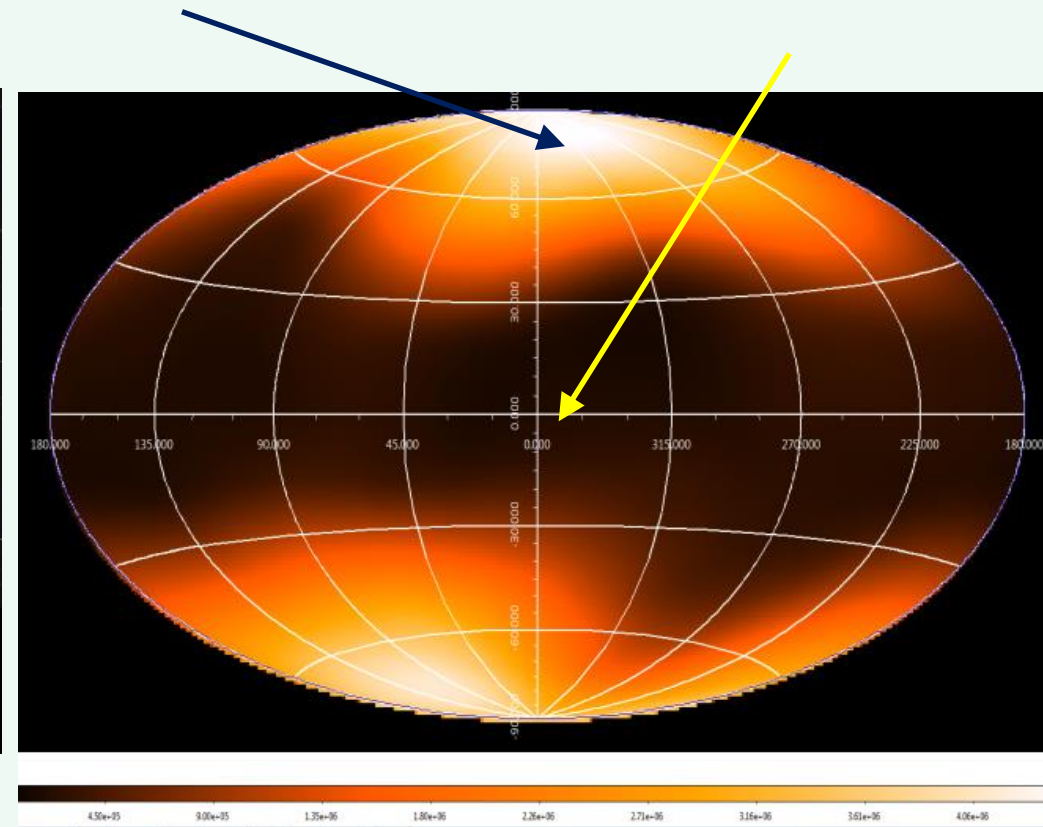
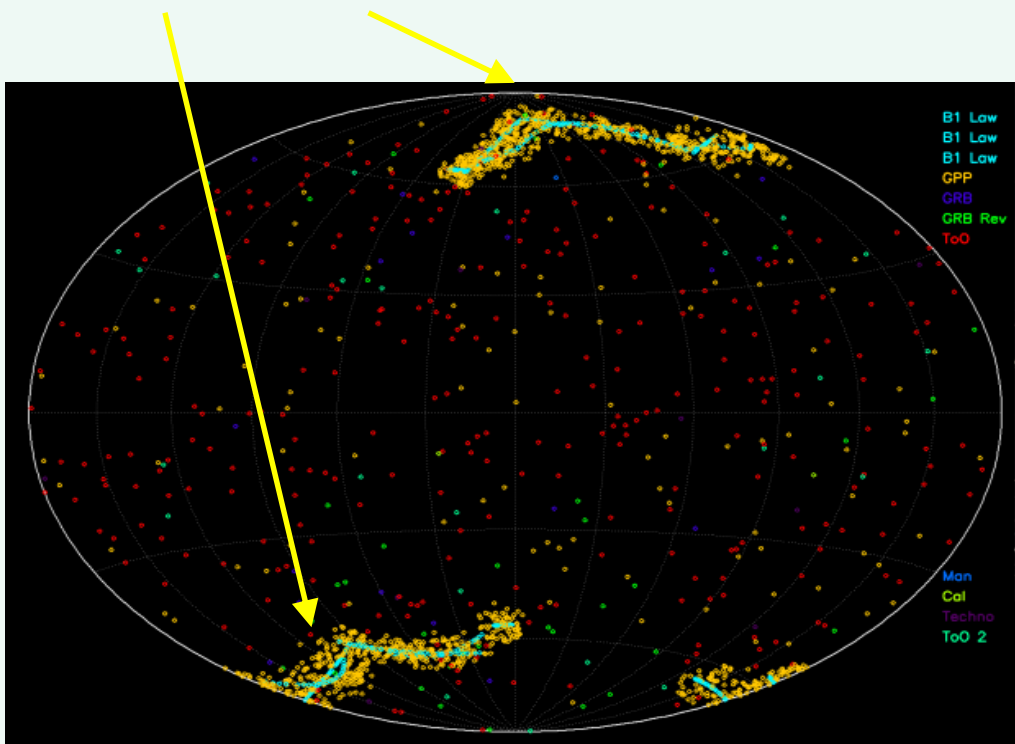


Old (2014) Simulation of 1 yr SVOM Observing Program

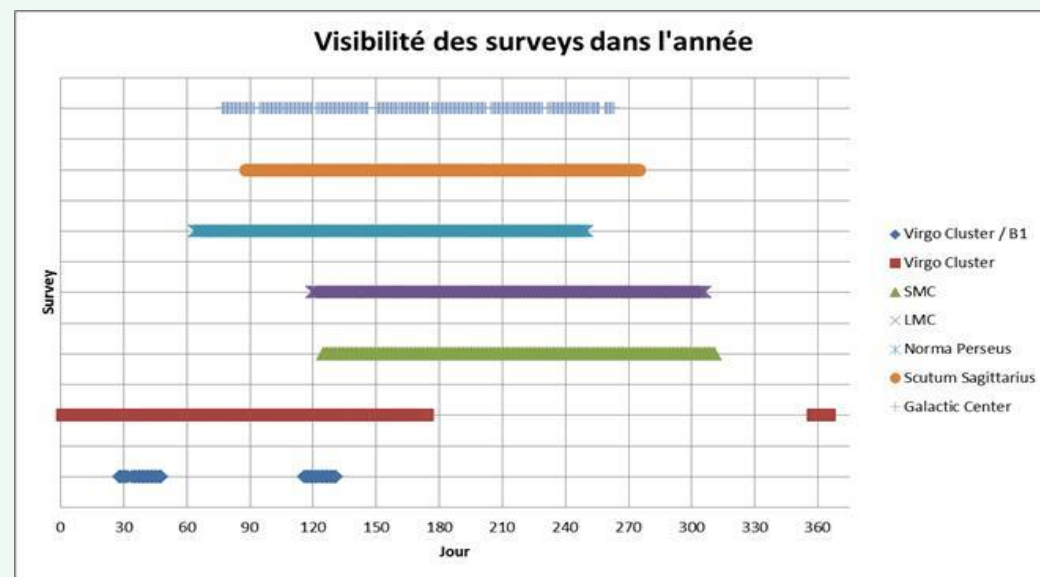
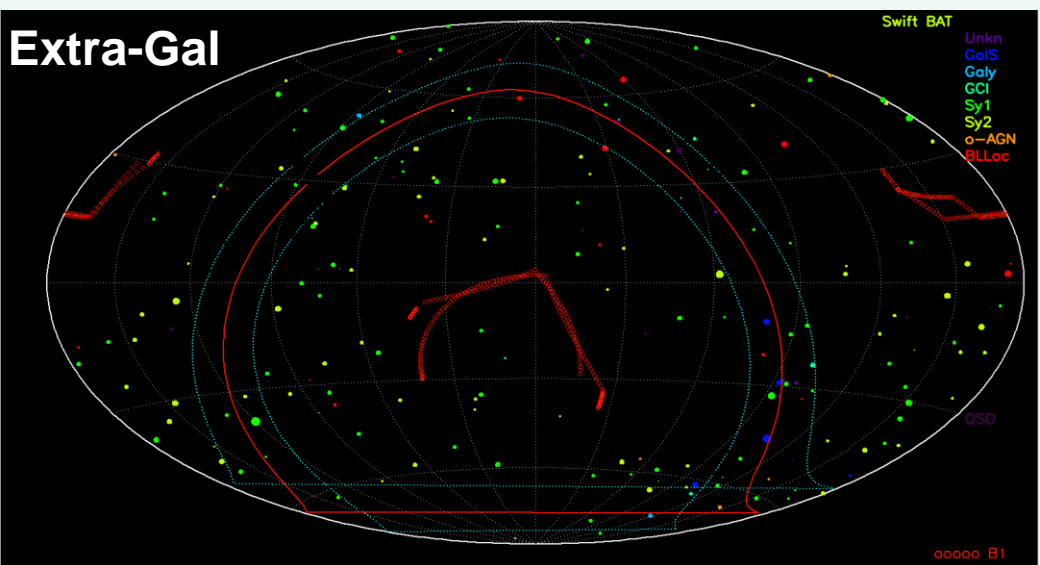
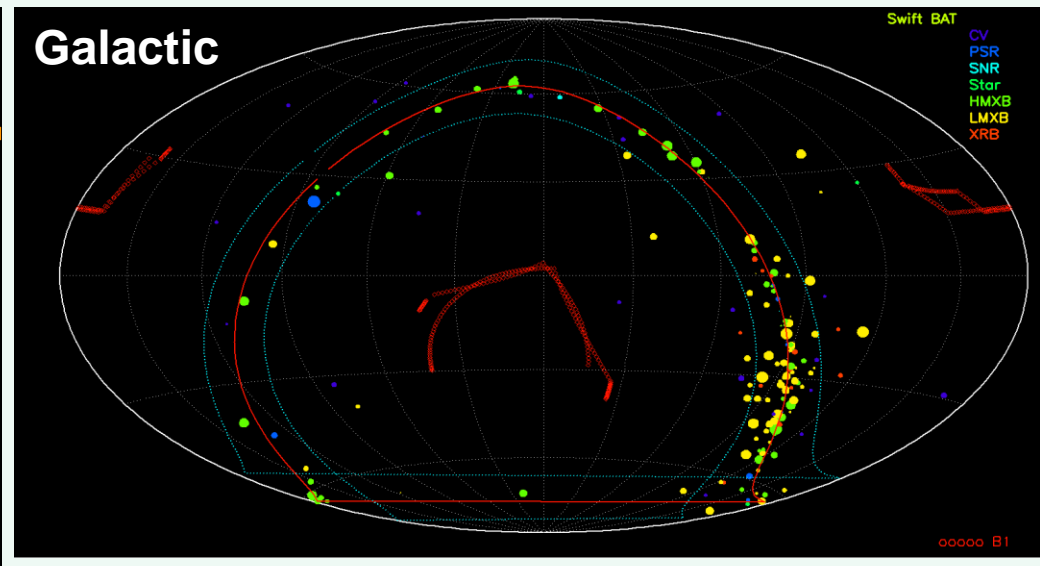
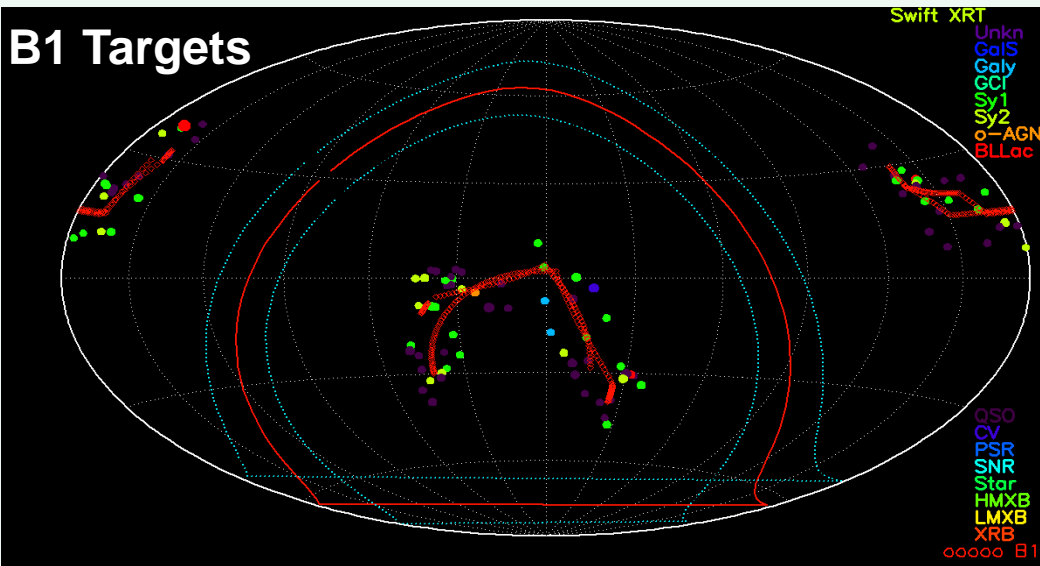
B1 Attitude law

Max Expo: 4.5 Ms

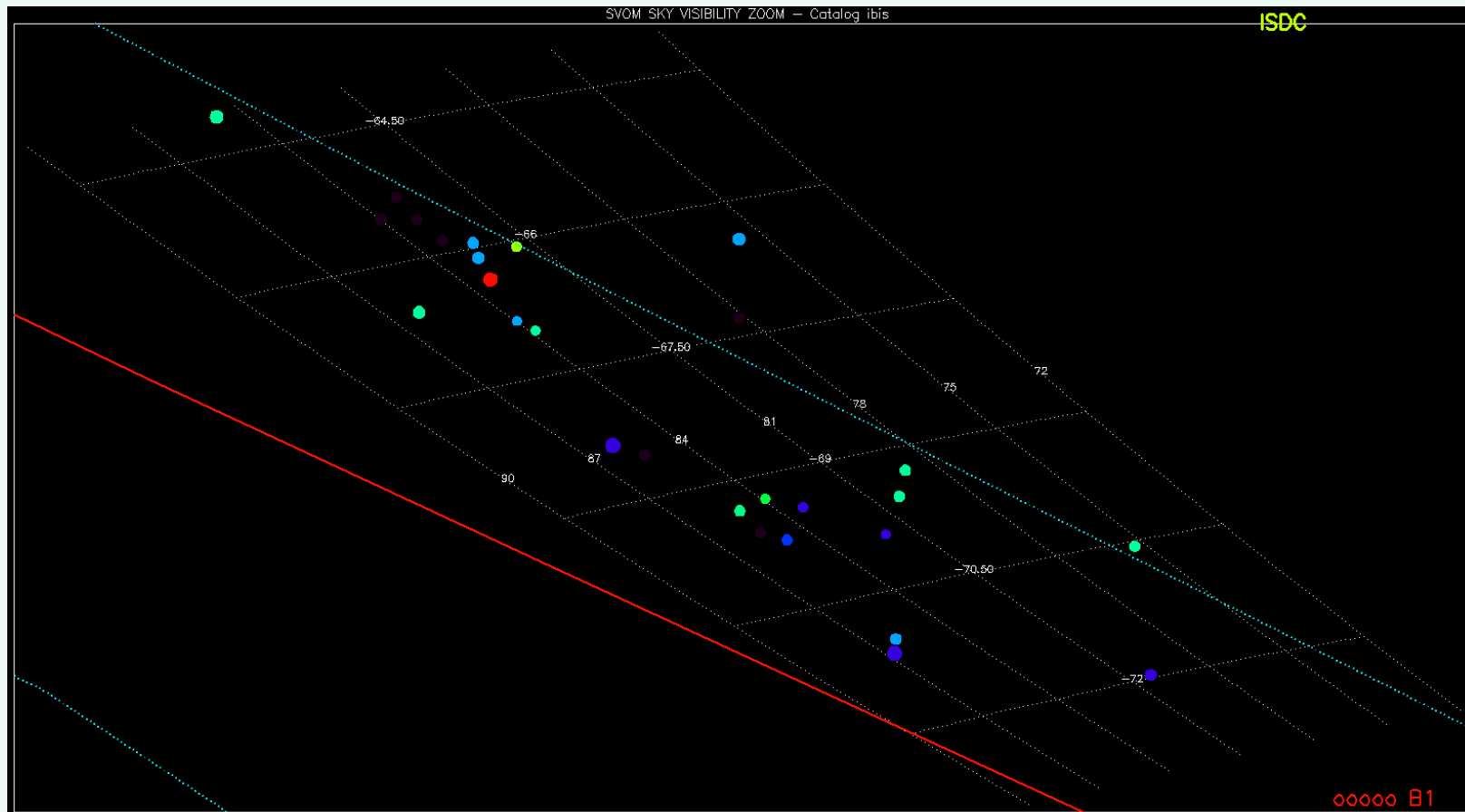
Galac. Cent: 200 Ks



Targets of 1 year General Program

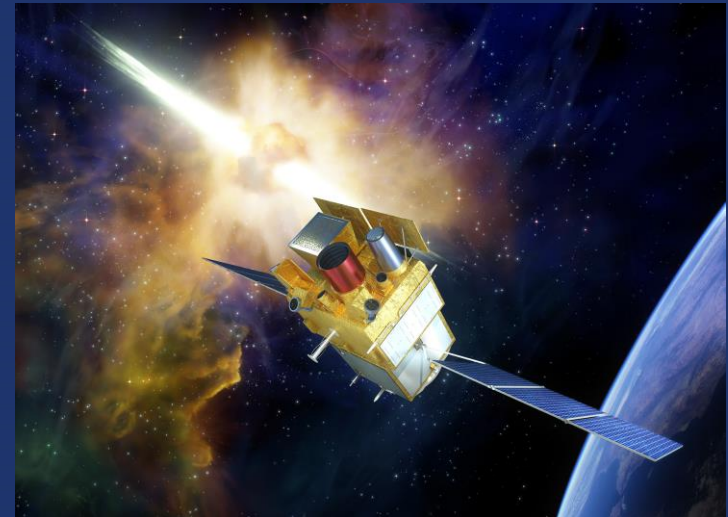


Large Magellanic Cloud Survey



LMC HE sources that will be included in the Survey

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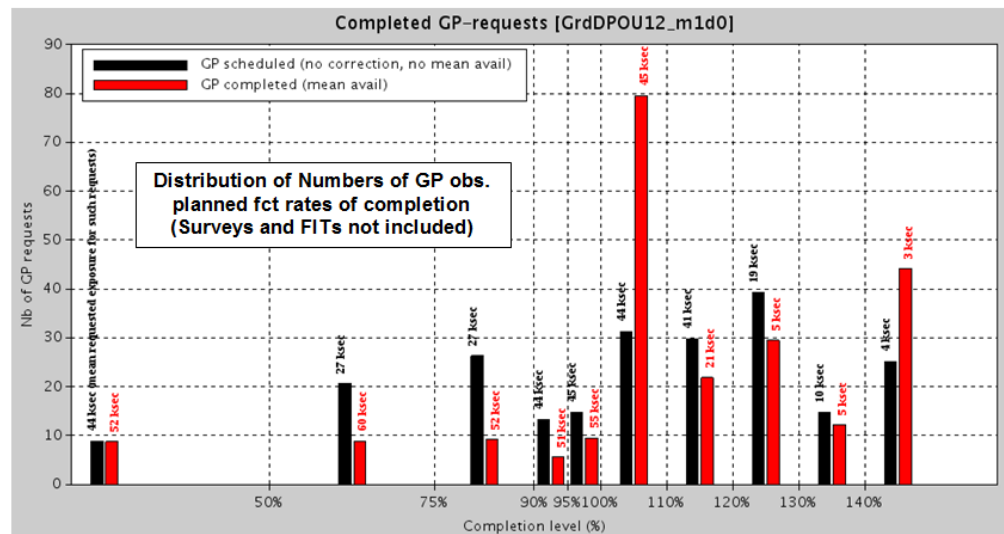
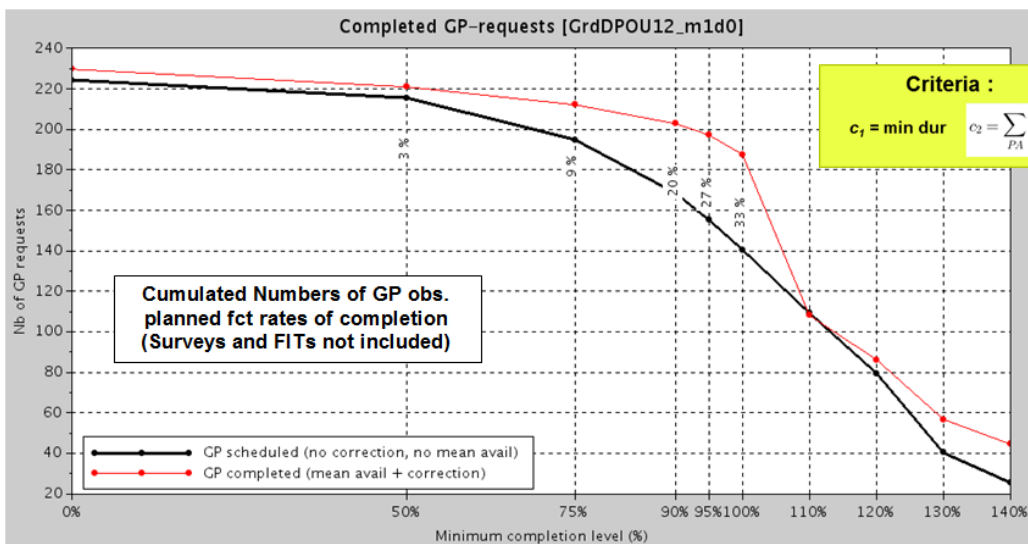


Mission Planning Analysis and Simulations

❖ GP Mission Planning and Execution Simulations :

=> **Assessment of performances** for achievement of General Program at the end of the year from :

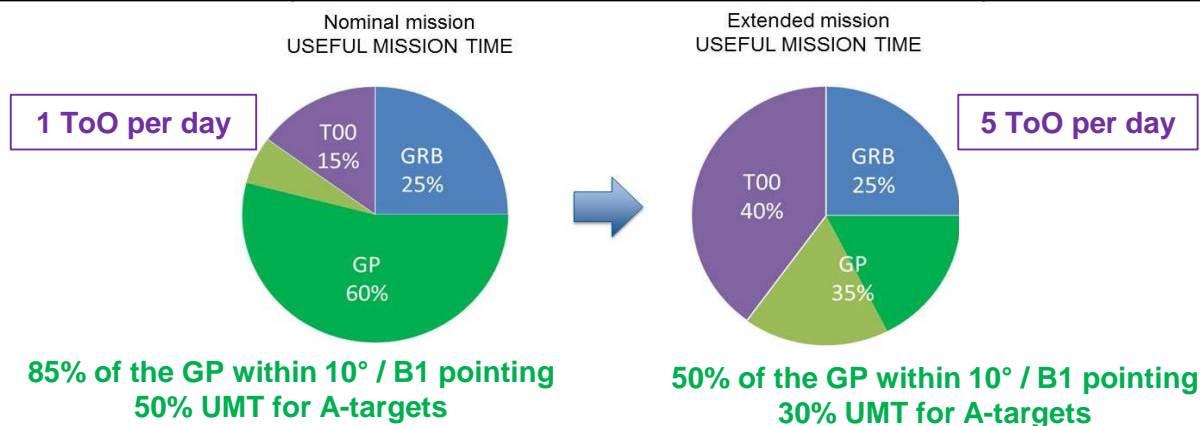
- 1st one year schedule established from input catalogue of requests (after the Call for Obs process)
- Consideration of GRB, ToO occurrences and impacts and simulation of weekly replanning process



Simulated Events	Frequency / Distribution	Duration
GP requests (PA / PB)	85% → 10° / B1 (Nominal Mission) 50% → 10° / B1 (Extended Mission)	1 orbit – 3 days (see input GP catalogue)
CALIBRATIONS	9% of year (Nominal Mission) 3% of year (Extended Mission)	14 orbits
ToO – NOMINAL	1 / day (Nominal Mission) 5 / day (Extended Mission)	1 orbit
ToO – EXCEP (incl. MM)	20 / year	14 orbits
ToO – REVISIT	For 80% of GRB, 28 orbits later	6 orbits
GRB	70 / year	14 orbits

New assumptions for ToO-MM frequency not considered yet

To be updated ?



Ranking : GP < ToO-NOM < ToO-REVIS < CAL < GRB < ToO-EXCEP

Simulation GP planning and execution results

Nominal Mission Context

GP Catalogue of selected proposals			
NB obs tot		Dur obs tot (days)	
426		372	
Nb obs B1	Nb obs ~B1	Dur obs B1	Dur obs ~B1
175	251	252	120
Nb obs PA	Nb obs PB	Dur obs PA	Dur obs PB
224	202	202	171

GP 1st one year schedule			
NB obs tot		Dur obs tot (days)	
268 (63%)		237	
Nb obs B1	Nb obs ~B1	Dur obs B1	Dur obs ~B1
143	125	185	52
Nb obs PA	Nb obs PB	Dur obs PA	Dur obs PB
205	63	163	74

GP Final exec (+ ToO, GRB, Replan, Av. Dur Mngt)			
NB obs tot achieved > 95%		Dur obs tot (days) act. > 95%	
198 (74%)		138 (58%)	
Nb obs B1	Nb obs ~B1	Dur obs B1	Dur obs ~B1
95	103	107	31
Nb obs PA	Nb obs PB	Dur obs PA	Dur obs PB
163 (80%)	35	107	31

FITs and Surveys not detailed

Simulation GP planning and execution results

Extended Mission Context

GP Catalogue of selected proposals			
NB obs tot		Dur obs tot (days)	
426		372	
Nb obs B1	Nb obs ~B1	Dur obs B1	Dur obs ~B1
175	251	252	120
Nb obs PA	Nb obs PB	Dur obs PA	Dur obs PB
192	234	175	198

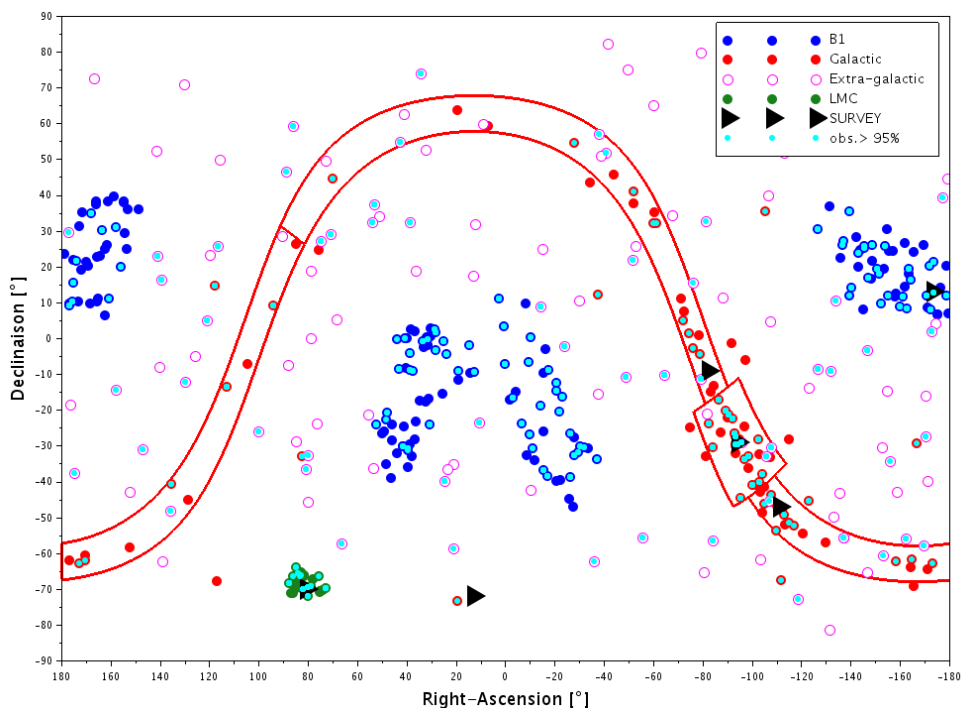
GP 1st one year schedule			
NB obs tot		Dur obs tot (days)	
368 (86%)		269	
Nb obs B1	Nb obs ~B1	Dur obs B1	Dur obs ~B1
125	243	152	117
Nb obs PA	Nb obs PB	Dur obs PA	Dur obs PB
184	184	155	114

GP Final exec (+ ToO, GRB, Replan, Av. Dur Mngt)			
NB obs tot achieved > 95%		Dur obs tot (days) acli. > 95%	
185 (50%)		98 (36%)	
Nb obs B1	Nb obs ~B1	Dur obs B1	Dur obs ~B1
27	158	19	79
Nb obs PA	Nb obs PB	Dur obs PA	Dur obs PB
151 (82%)	34	89	9

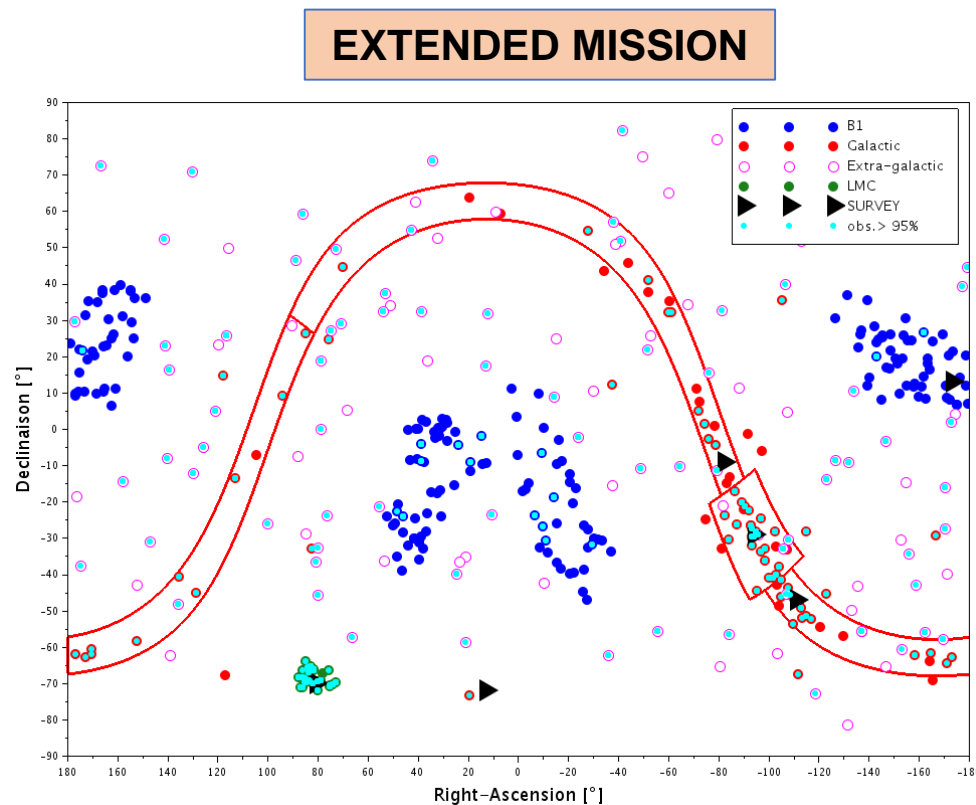
FITs and Surveys not detailed

Mission Planning Analysis and Simulations

GP Mission Planning and Execution Simulations :



NOMINAL MISSION



EXTENDED MISSION

Simulation GP planning and execution results

Time Occupation / Mission allocations

Nominal Mission Context : UMT = 365 days – 9% Calibration = **332** days

Extended Mission Context : UMT = 365 days – 3% Calibration = **354** days

Time GP = Time GP targets + Time GP Surveys + Time FITs

Time GP (no FITs) = Time GP targets + Time GP Surveys

Time B1 = Time GP B1 targets + Time GP B1 Surveys + Time FITs

Objectives

60%

50%

85%

GP Final exec (+ ToO, GRB, Replan) - NM			
Time GP (days)	227	%/UMT	68,4
Time GP (no FITs) (d)	175	%/UMT	52,7
Time A-tg (days)	130	%/UMT	39,1
Time B1 (days)	187	%TimeGP	82,4
Warning : with all obs. cat. achieved > 0 % for A-tg , B1			

GP Final exec (+ ToO, GRB, Replan) - EM

Objectives

35%

30%

50%

GP Final exec (+ ToO, GRB, Replan) - EM			
Time GP (days)	174	%/UMT	49,2
Time GP (no FITs) (d)	153	%/UMT	43,2
Time A-tg (days)	118	%/UMT	33,3
Time B1 (days)	82	%TimeGP	47,1
Warning : with all obs. cat. achieved > 0 % for A-tg , B1			

Time allocations (Mission Requirements) quite well met (except for A-targets in Nominal Mission due to scheduling criteria used promoting short durations)

Simulation GP planning and execution results

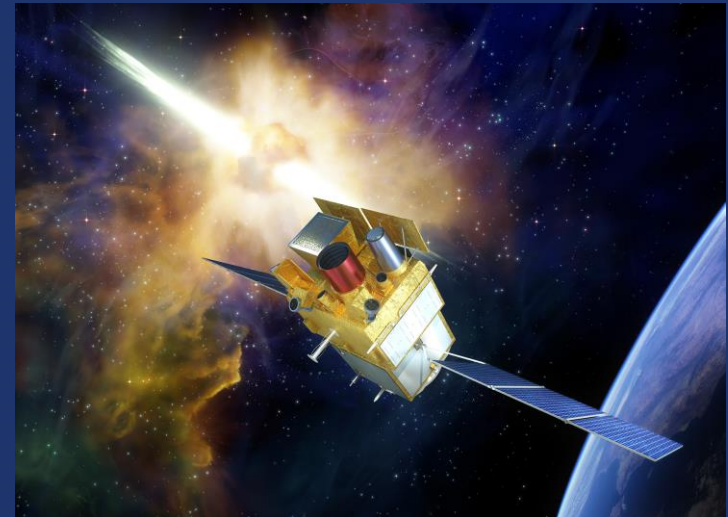
❖ Fill-In targets (FITs) :

- Predefined observation requests of the SVOM system (not provided by the yearly Call for Obs process). Close to the B1 pointing law.
- Used to occupy the available observing time while meeting the mission allocations. No priority.
- **With current input scenario and simulation, can occupy 40 days (NM) / 20 days (EM).**

❖ Surveys (for narrow FoV instruments) :

- Specific observation requests (provided by the yearly Call for Obs process) without precise observing duration required (min/max cumulated duration eventually). Close or far from the B1 pointing law. Can require specific tiling of sky areas.
- With current input scenario and no priority given, very short duration performed for surveys (few days).
 - **Specific priority levels introduced in Mission Planning requirements (to rank surveys wrt GP obs)**

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Important Messages for GP Mission Planning

❖ Lessons learned / findings for GP Mission Planning management :

➤ **All GP observation requests can't be fulfilled → Important to prioritize observations :**

A-targets for completion, B-targets and FITs for best effort (apportionment to be adjusted).
Survey requests to be managed specifically.

➤ **2 main principles for GP observation management :**

- Replan of missing parts every week (promoting the ones already started and A-targets)

- Planning and replanning always with average available duration / orbit (depends on pointing dir.)
+ Adjustment of observing duration (real / required) during weekly replanning process

➤ **One given GP observation request can be performed with several trunks over the whole year.**

➤ **Scheduling criteria can significantly impact the resulting planning and the performances :**

If promote short durations, better requests completion.

If promote long durations, better time occupation.

Important Messages for GP Mission Planning

- ❖ For GP Mission Planning design and simulation continuation & improvement :
 - **New input catalogue of GP requests for simulation runs** with representative features for requests (observing duration and pointing distributions, time constrained, periodic observations, ...) would still be **useful**.
 - **Impacts of new requirements for ToO-MM** (1/week) or GRB follow-up duration to be assessed.
 - **Scheduling criteria** currently proposed are for performances of completion and not driven by scientific or users goals.
New / additional criteria to be expressed and implemented in connection with specific features for requests ?
(e g, allocations between various scientific objectives and observation programs for GP)
 - **Proposal** : Alternative for FITs could be the scheduling of low priority GP requests with reduced duration wrt duration required. Relevant ?

Implementation by Mission Center has started.

→ Urgent to update or supplement requirements and design if needed.

Mission planning documentation

- **SV-SY-NT-644-JPO (2.0)** : Assumptions and Inputs for the SVOM Mission Planning Simulations
- **SV-SY-NT-798-CNES (2.0)** : Study of the useful observation duration per orbit
- **SV-SY-RP-554-CNES (3.0)** : Mission Analysis Part IV Mission Progr. / Simulation results
- **SV-SY-SP-680-JPO (2.0)** : SVOM Mission Planning Process Requirements (General Program)
- **SV-SY-SP-xxx-JPO (x.x)** : SVOM Mission Planning Requirements for ToO (in progress)

谢谢

Thank You

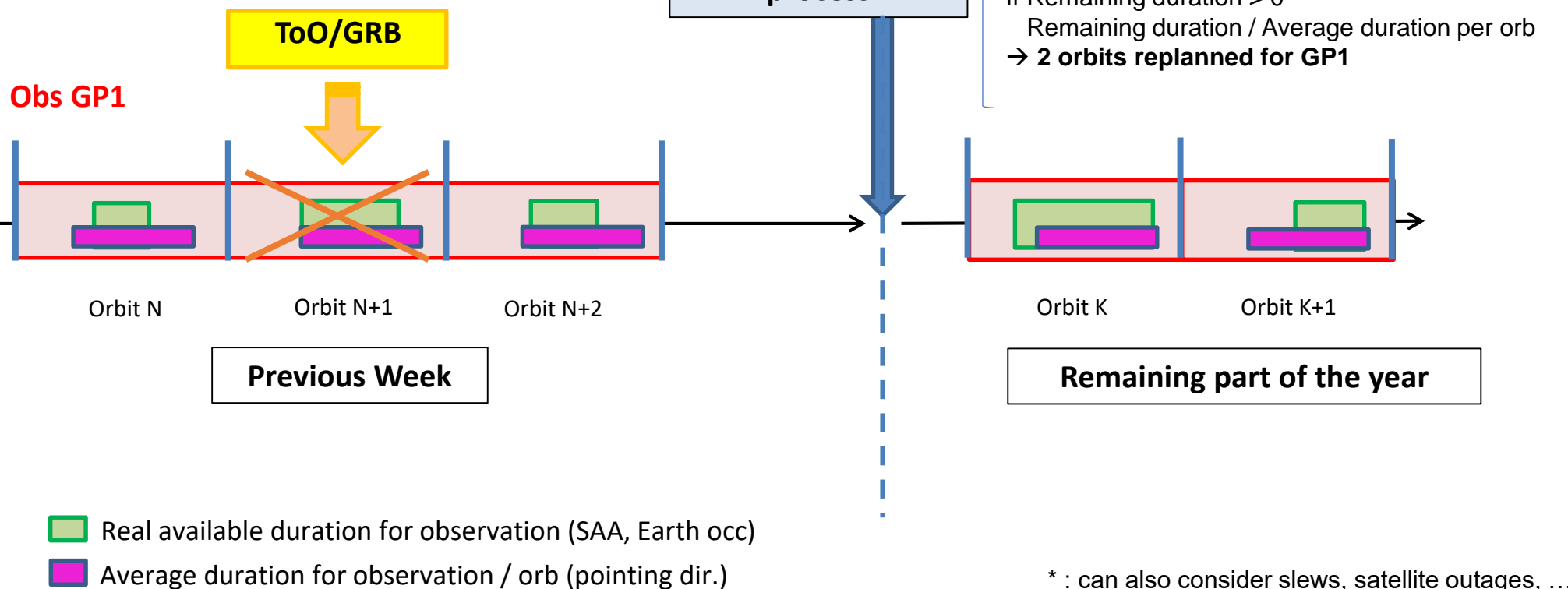
Back-up slides

Available obs. duration / orbit

❖ SVOM Mission Planning Process Requirements (GP)

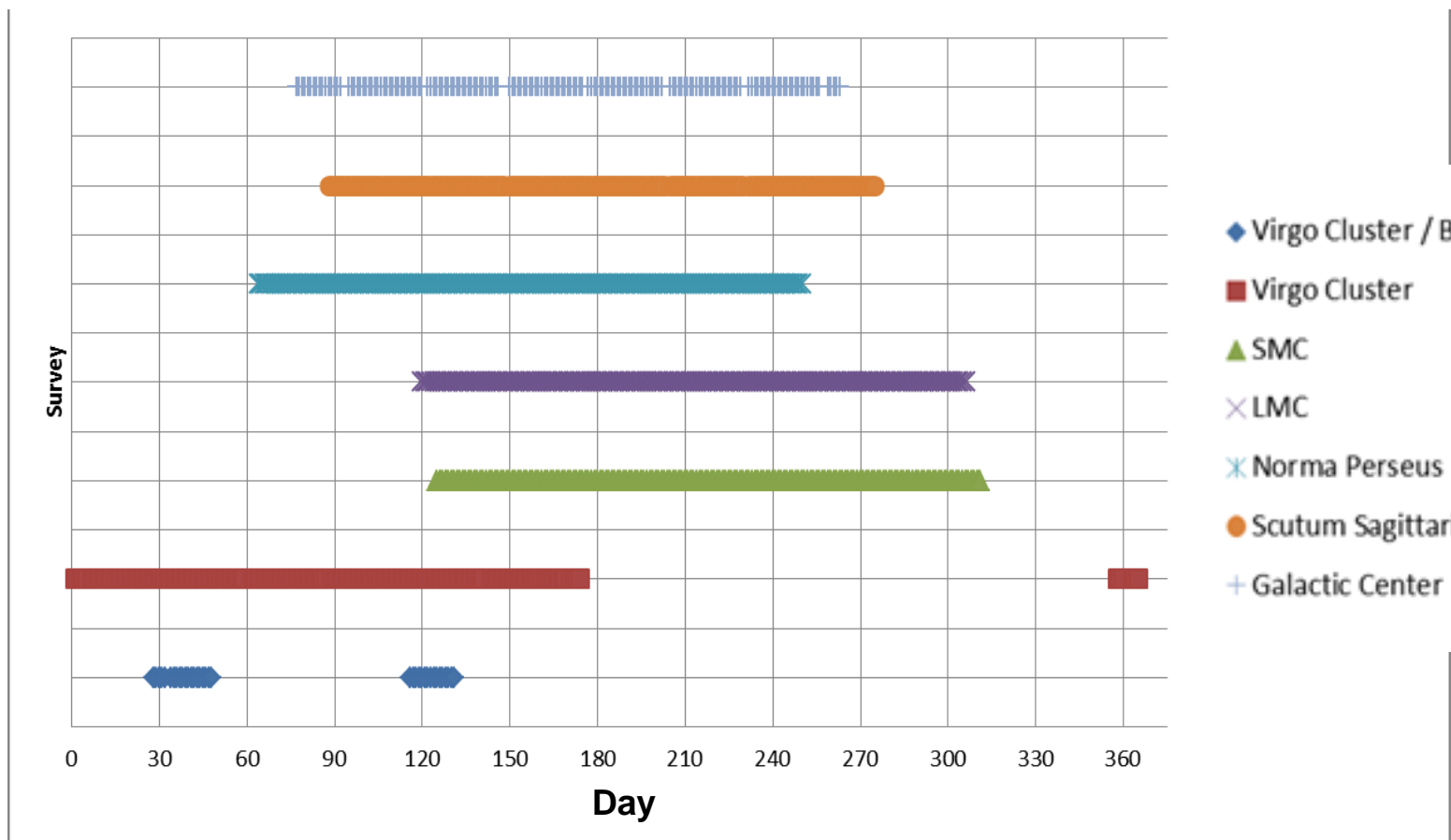
Example of GP request GP1 :

Required duration for GP1 / Average duration per orb
(GP1 pointing)
→ 3 orbits initially allocated to GP1



* : can also consider slews, satellite outages, ...

Survey visibility periods over one year



Pools of users proposals used for simulations Sum up

GP Catalogue (NM)			
NB obs tot		Dur obs tot (days)	
426		372	
Nb obs B1	Nb obs ~B1	Dur obs B1	Dur obs ~B1
175	251	252	120
Nb obs PA	Nb obs PB	Dur obs PA	Dur obs PB
224	202	202	171

GP Catalogue (EM)			
NB obs tot		Dur obs tot (days)	
426		372	
Nb obs B1	Nb obs ~B1	Dur obs B1	Dur obs ~B1
175	251	252	120
Nb obs PA	Nb obs PB	Dur obs PA	Dur obs PB
192	234	175	198

+ 1 Survey B1 + 6 Surveys ~B1 → N obs. of 1 orbit ($N < 80$ B1, $N < 200$ ~B1)

+ Fill-In Targets (FITs) → 1 FIT B1 / day

GP Mission Planning design : Available obs. duration / orbit

❖ SVOM Mission Planning Process Requirements (GP)

Question : For a given GP request with X ksec to be observed, how can we manage an available duration per orbit varying (when not 0%) from ~20% up to 100% in the one year scheduling process ?

1st Solution : Consider real available duration / orb all along the 1 year scheduling process

- Real available durations have to be computed for every orbit all over the scheduling period and for all requests
- Number of orbits allocated to the GP request varies and depends on the date of insertion in the schedule
- Scheduling criteria depend on the numbers of orbits allocated to the requests
- Scheduling process is iterative

➡ Complexity, Computation time ++

2nd Solution : Consider average available dur. / orb for each pointing direction for scheduling

- Number of orbits allocated to the GP requests (calc. with average dur. / orb) not date dependent
- Take advantage of the weekly re-planning process (existing for ToO, GRB impacts) to determine the global real duration already observed on past orbits (with Earth occ., SAA crossings) and to adjust the number of orbits to be planned again during the rest of the year

➡ Match with current scheduling principles
 Required obs. duration well met
 Compromise between complexity / perfo



Simulation GP planning and execution results

Time Occupation / Mission allocations

Nominal Mission Context : UMT = 365 days – 9% Calibration = **332** days

Extended Mission Context : UMT = 365 days – 3% Calibration = **354** days

Time GP = Time GP targets + Time GP Surveys + Time FITs

Time GP (no FITs) = Time GP targets + Time GP Surveys

Time B1 = Time GP B1 targets + Time GP B1 Surveys + Time FITs

GP 1st one year schedule (NM)			
Time GP (days)	332	%/UMT	100
Time GP (no FITs) (d)	237	%/UMT	71,4
Time A-tg (days)	163	%/UMT	49,0
Time B1 (days)	280	%TimeGP	84,3

GP 1st one year schedule (EM)			
Time GP (days)	354	%/UMT	100
Time GP (no FITs) (d)	269	%/UMT	75,9
Time A-tg (days)	155	%/UMT	43,8
Time B1 (days)	237	%TimeGP	66,9

Objectives

60%

50%

85%

GP Final exec (+ ToO, GRB, Replan) - NM			
Time GP (days)	227	%/UMT	68,4
Time GP (no FITs) (d)	175	%/UMT	52,7
Time A-tg (days)	130	%/UMT	39,1
Time B1 (days)	187	%TimeGP	82,4
Warning : with all obs. cat. achieved > 0 % for A-tg , B1			

Objectives

35%

30%

50%

GP Final exec (+ ToO, GRB, Replan) - EM			
Time GP (days)	174	%/UMT	49,2
Time GP (no FITs) (d)	153	%/UMT	43,2
Time A-tg (days)	118	%/UMT	33,3
Time B1 (days)	82	%TimeGP	47,1
Warning : with all obs. cat. achieved > 0% for A-tg , B1			