4MOST – 4m Multi-Object Spectroscopic Telescope

Developing survey strategy for the 4MOST survey

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www.4MOST.eu

Simulating 4MOST observations: a general flow-chart

Input catalogues: FoM, ETC, survey parameters, requirements

(1)

4MOST Visit Planner: an optimized tiling algorithm

Where to point the telescope?

(2)

4MOST Scheduler: scheduling observations for the 5-year survey

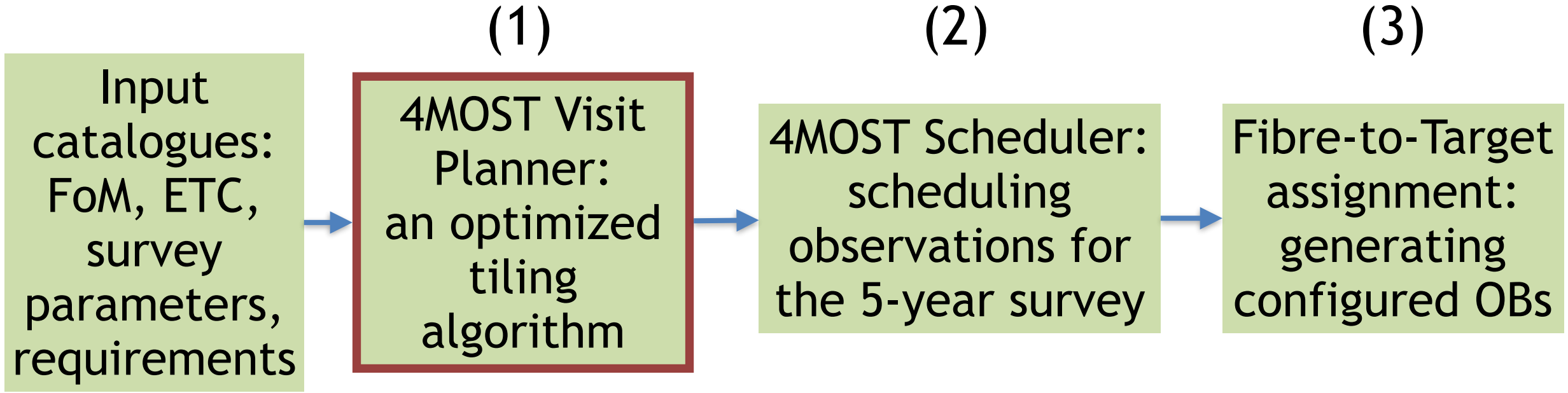
How to schedule the observations?

(3)

Fibre-to-Target assignment: generating configured OBs

Which targets should be selected?

Simulating 4MOST observations: a general flow-chart



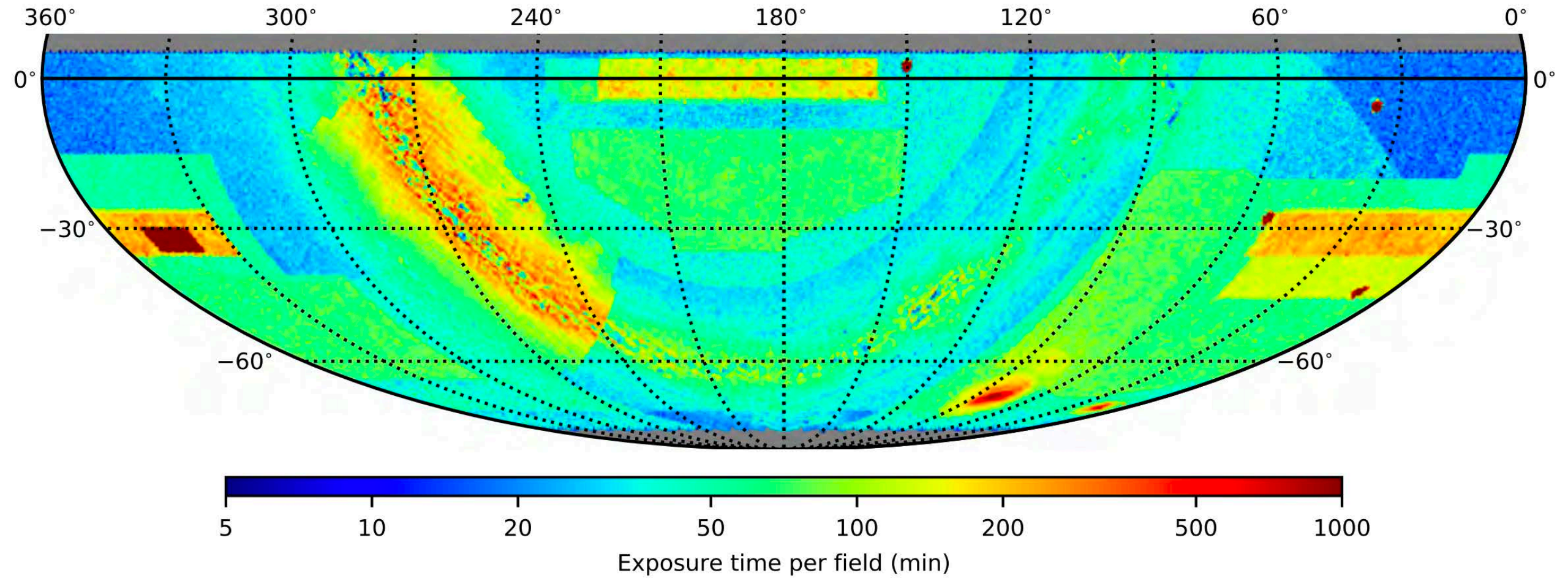
(1) Tempel et al. (2020) “An optimised tiling pattern for multi-object spectroscopic surveys: application to the 4MOST survey”, MNRAS, submitted (arXiv:2007.03307)

(3) Tempel et al. (2020) “Probabilistic fibre-to-target assignment algorithm for multi-object spectroscopic surveys”, A&A, 635, A101 (arXiv:2001.09348)

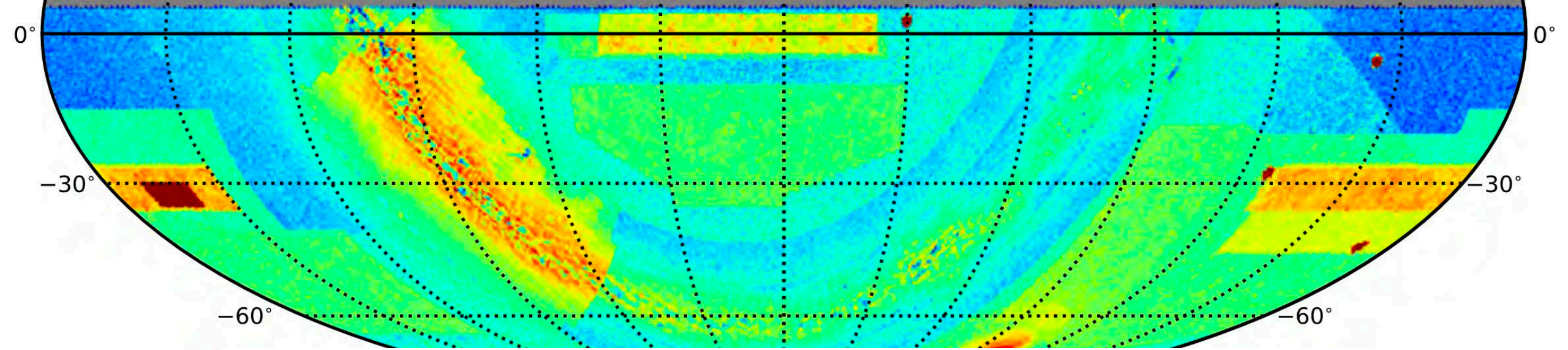
4MOST Visit Planner: a tiling challenge

- **Where to point the telescope?** The list of tile centres and orientation angles that are needed to effectively observe the given list of targets with required completeness.
- **What is the exposure time of each tile?** Attach an exposure time for each tile so that the targets are observed efficiently.
- **How to divide the tiles between predefined** (e.g. Bright, Grey, Dark) **sky conditions.**
- **How to include survey specific requirements**, e.g. contiguous area in the sky.

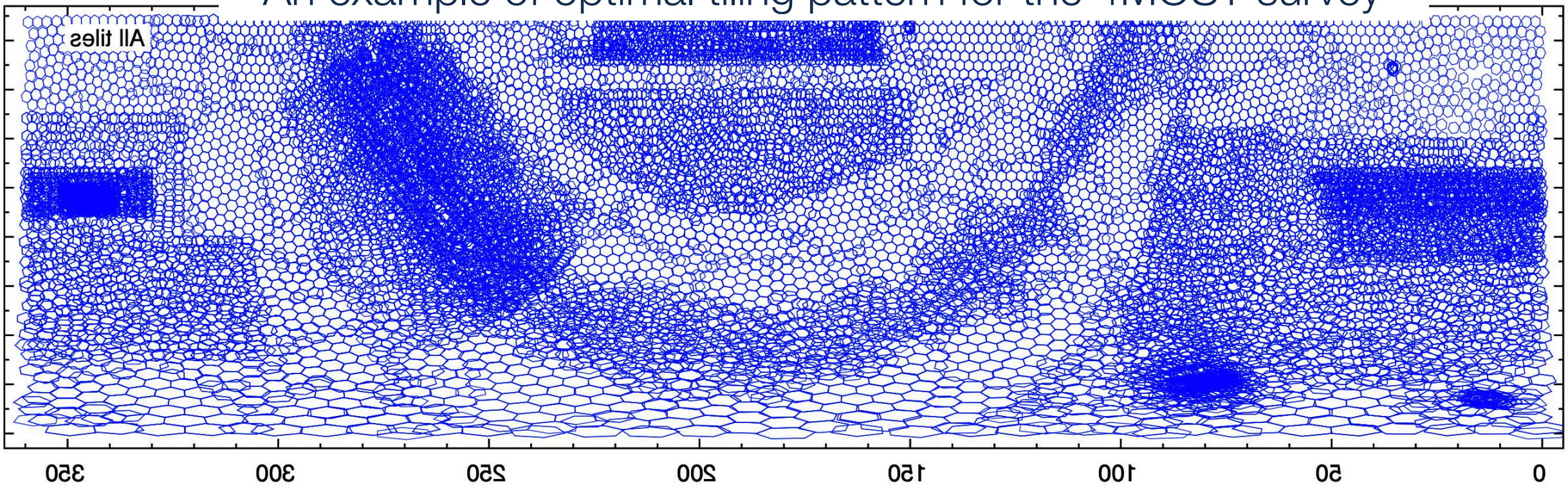
Why do we need a Visit Planner?



- Target density across the sky varies significantly.

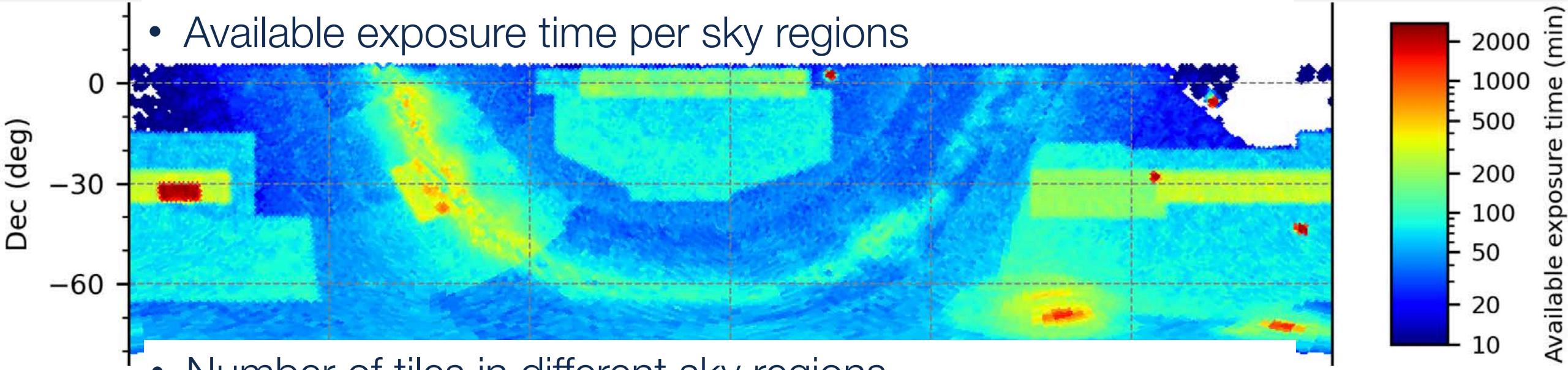


- An example of optimal tiling pattern for the 4MOST survey

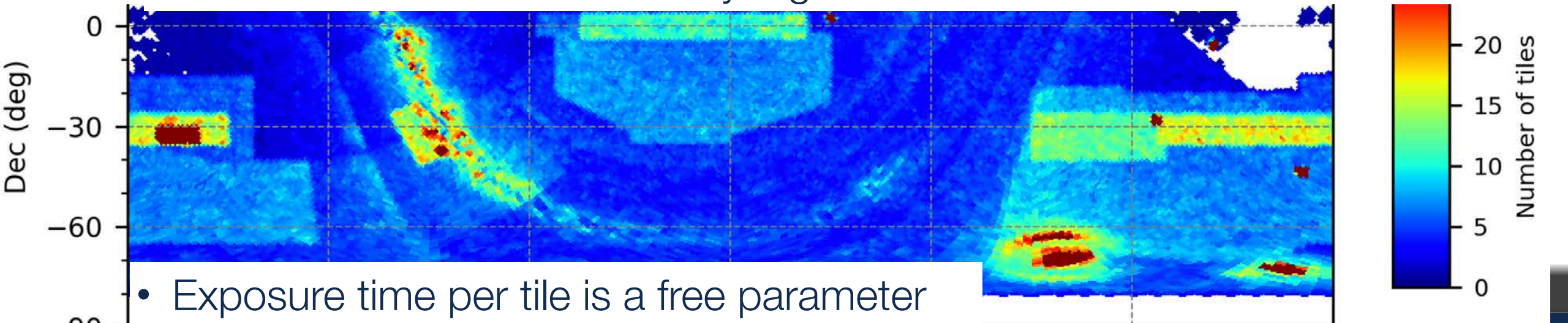


Number of observations and total exposure time

- Available exposure time per sky regions

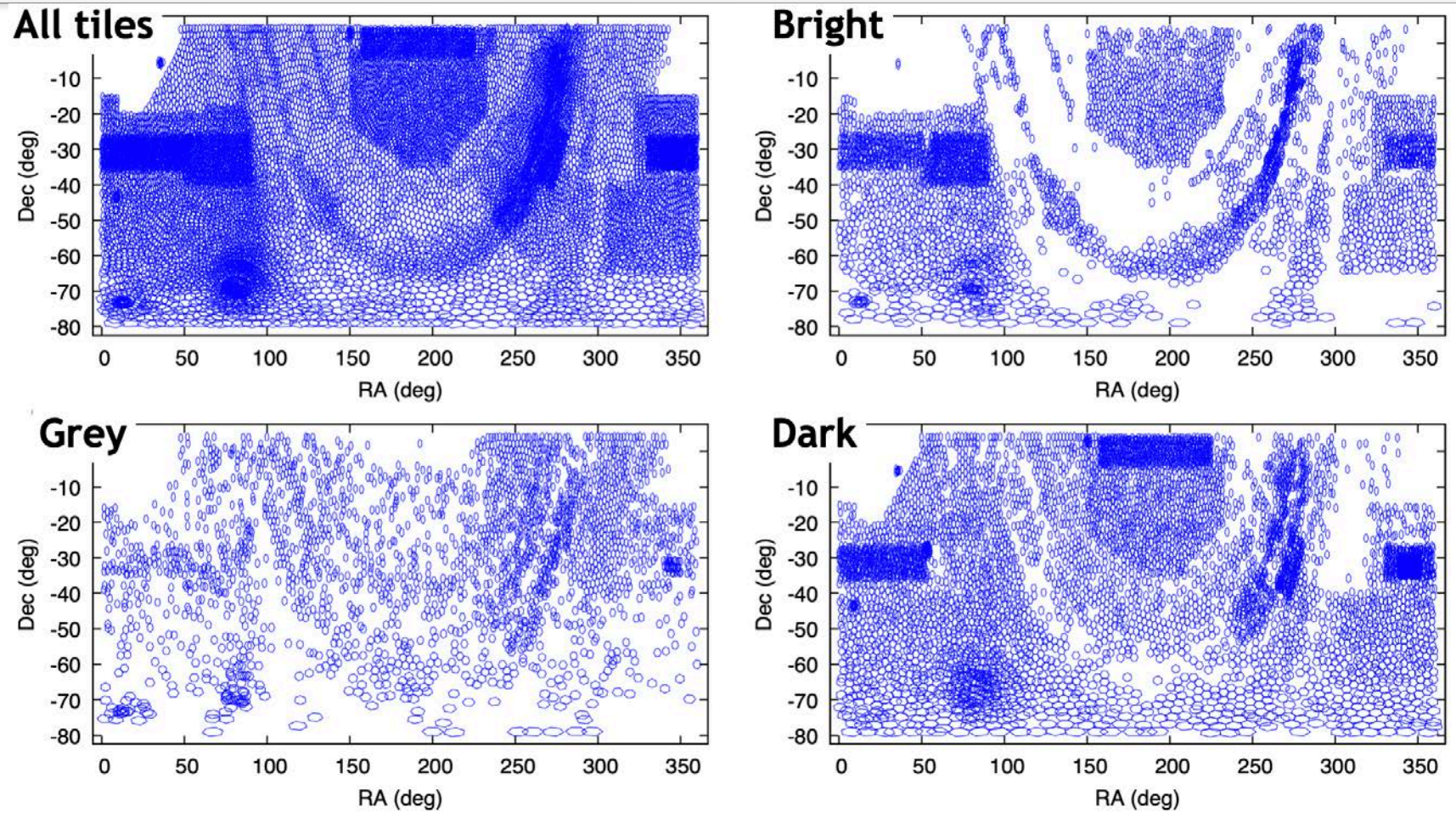


- Number of tiles in different sky regions

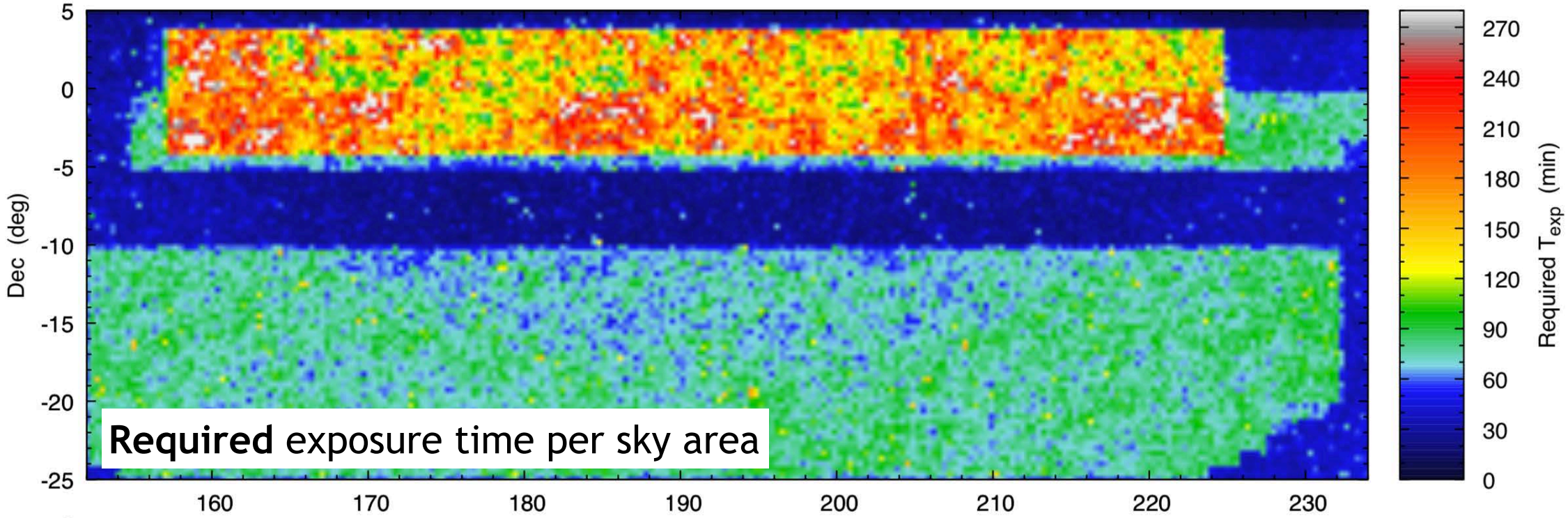


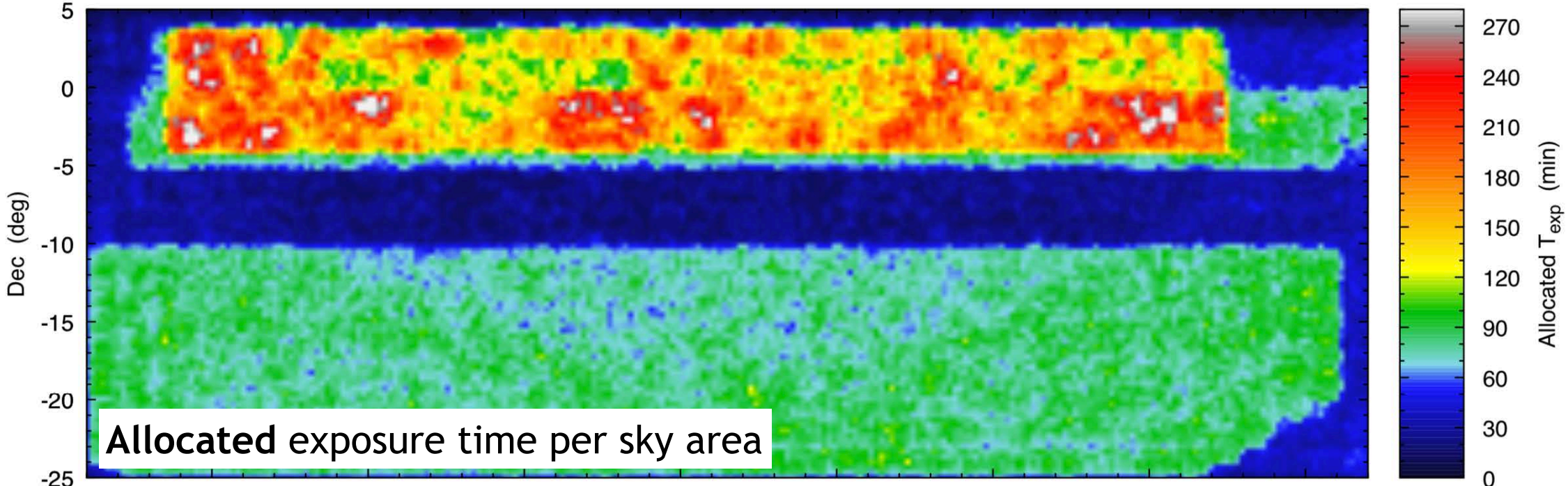
- Exposure time per tile is a free parameter

Dividing tiles between predefined sky conditions



- Tiles are divided between Bright/Grey/Dark based on the target exposure times



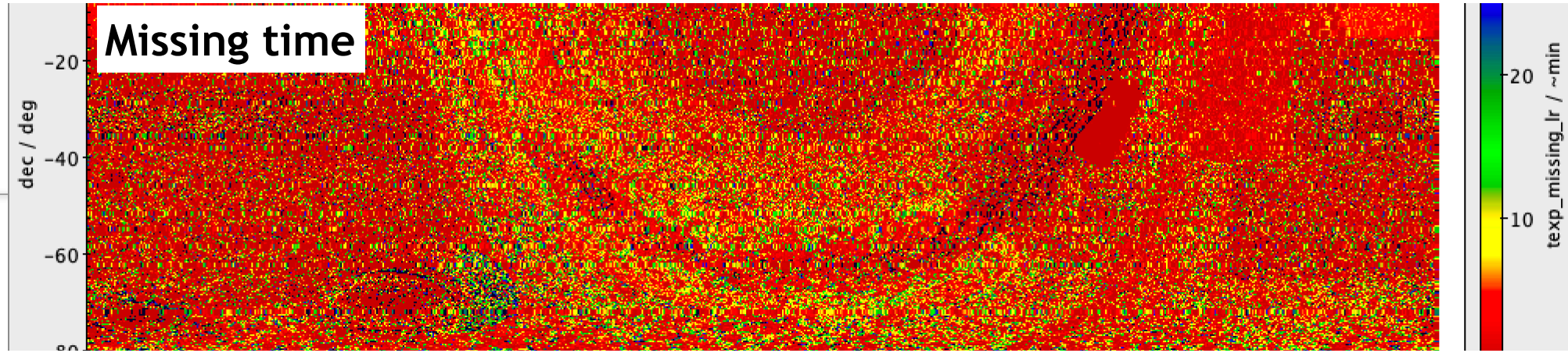


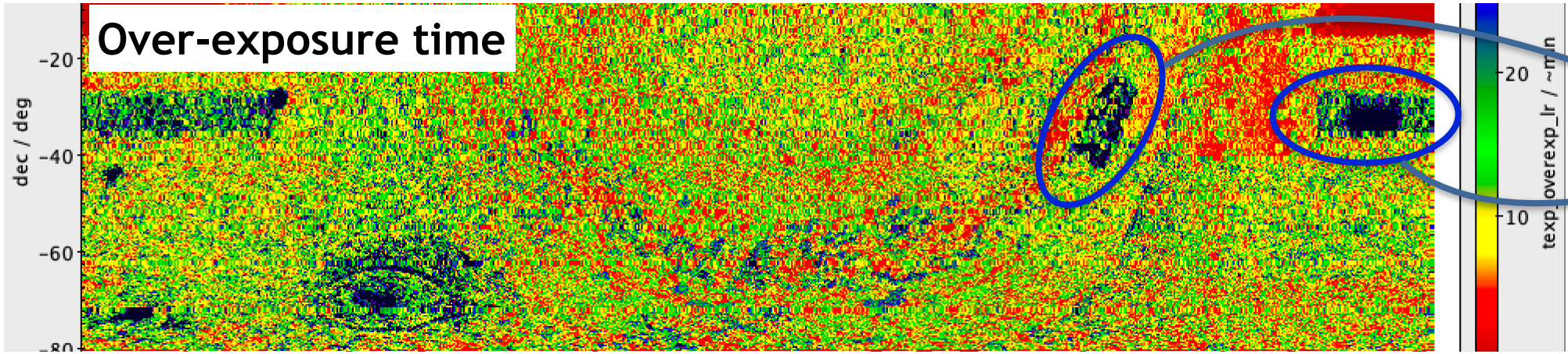
Example: Visit Planner algorithm minimizes the difference between required and allocated time.

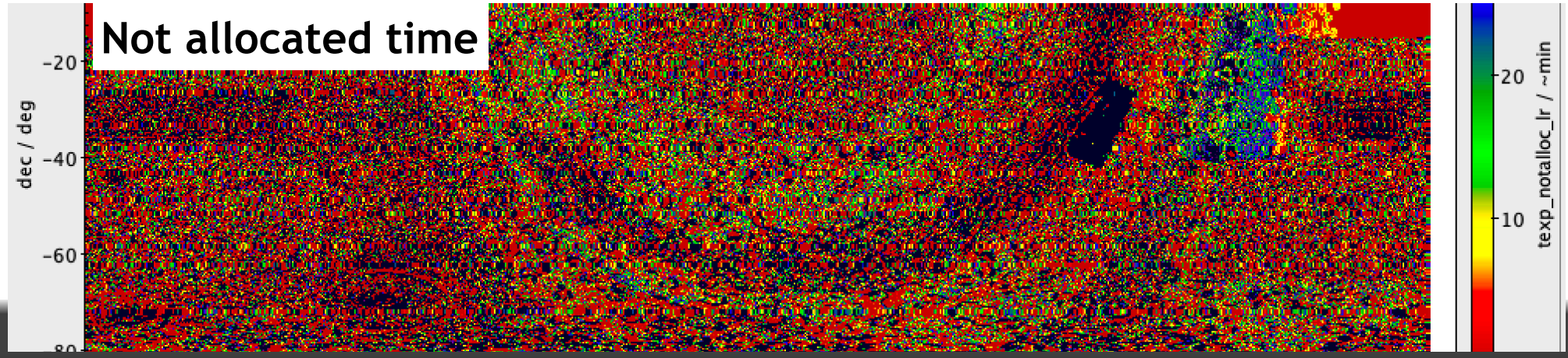
4MOST Visit Planner: defining an optimal tiling

- Minimize time that is **missing** to observe required targets.
- Minimize **over-exposure** time per target.
- Minimize wasted (**not allocated fibres**) time.
- Minimize **overheads** associated with each observation.
- Minimize **total survey time** while dividing tiles into predefined sky conditions.

- (optional) minimize tiling overlap to have more uniform completeness and to mitigate the field pattern in the sky.
- (optional) other potential requirements from surveys.







Example

Mismatch between LR and HR targets

4MOST Visit Planner: summary

- The Visit Planner algorithm allows to generate an optimal tiling pattern based on the input target catalogs.
- The algorithm is flexible and allows to include survey requirements as needed.
- The algorithm has many parameters that allow to influence the final tiling solution. Theoretically, with wisely chosen parameters, any optimal tiling solution can be achieved.

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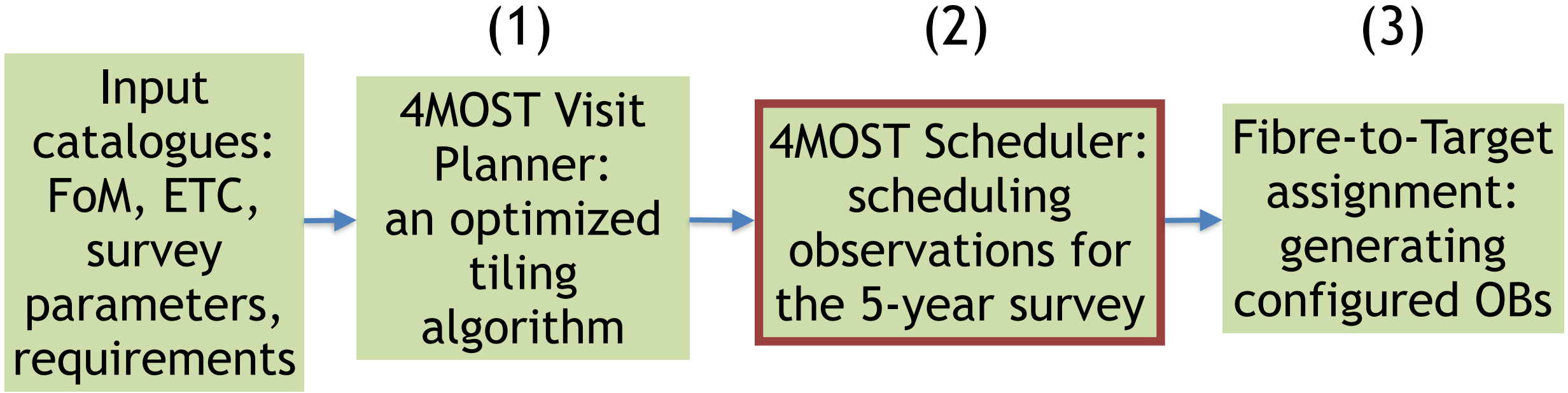
Simulating 4MOST observations: a general flow-chart



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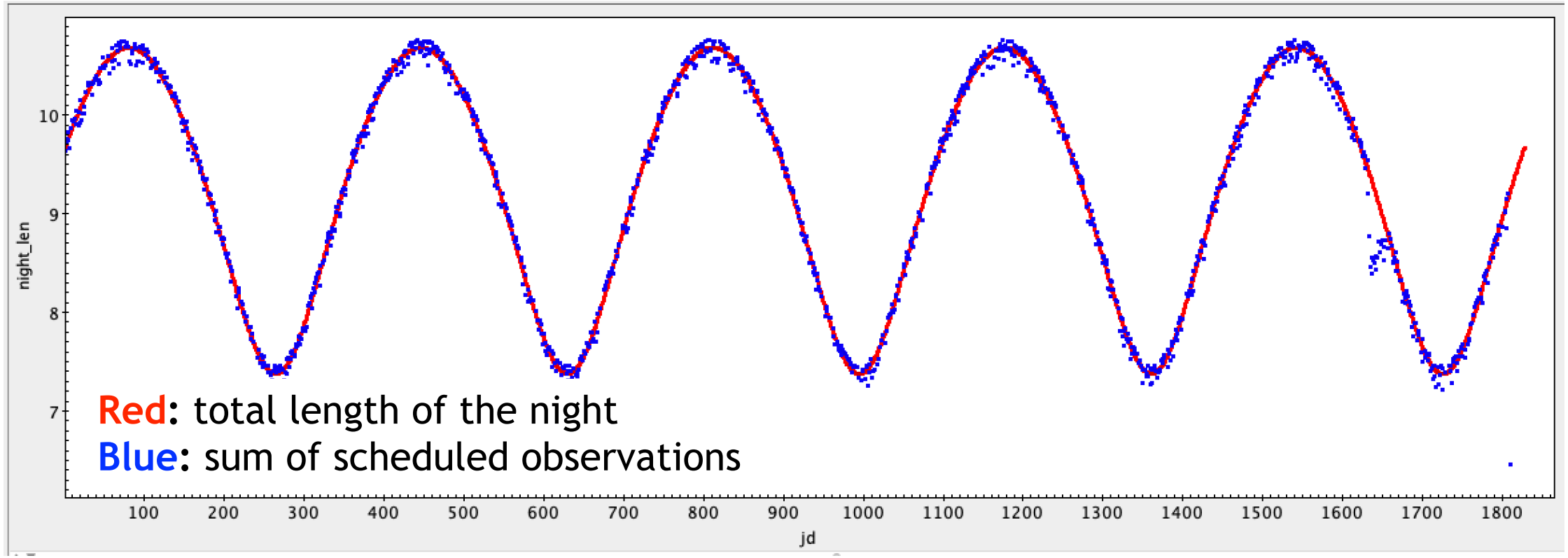
4MOST Scheduling algorithm

- **Long-term scheduler:** plans ahead the observations for the 5-year survey. Includes all predictable aspects.
- Long-term scheduling guarantees that we do not “run out” of the tiles during the survey.
- Long-term scheduling allows to observe all tiles close to their best observing conditions.
- **Short-term scheduler:** takes into account the real weather effects.

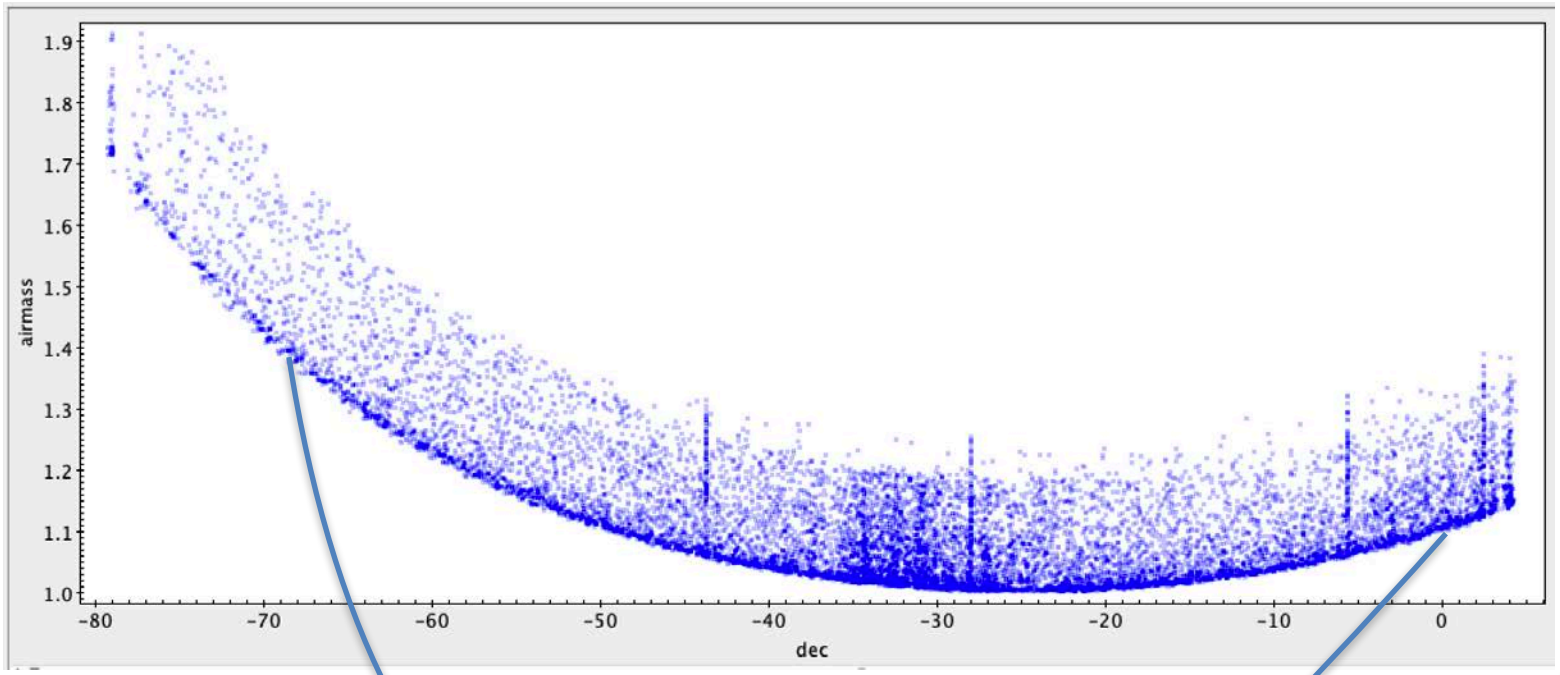
4MOST Scheduling algorithm: an example

Example tiling that requires exactly the total available time: only 1% of tiles are not scheduled



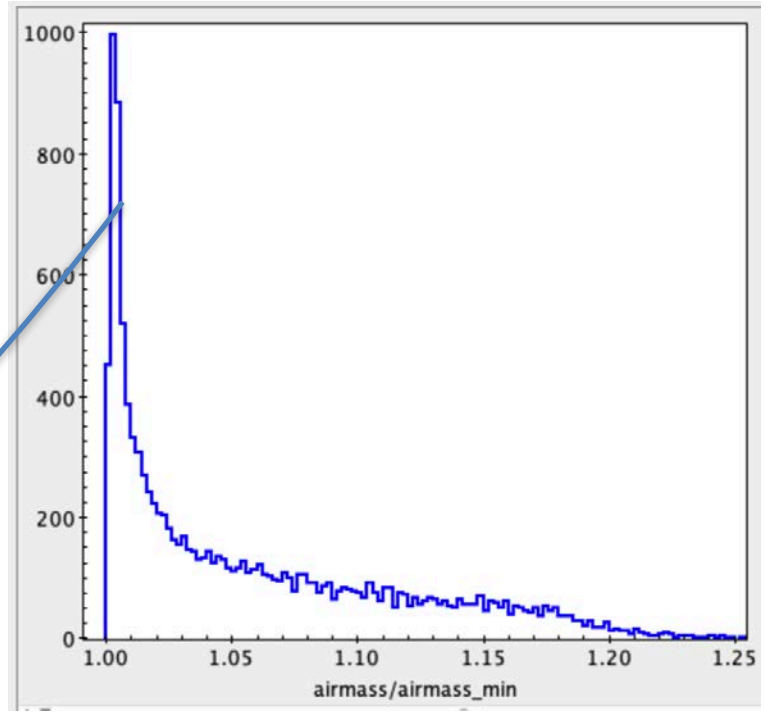
Days since the start of the survey

4MOST Scheduling algorithm: an example



Arimass

Declination



Number of observations

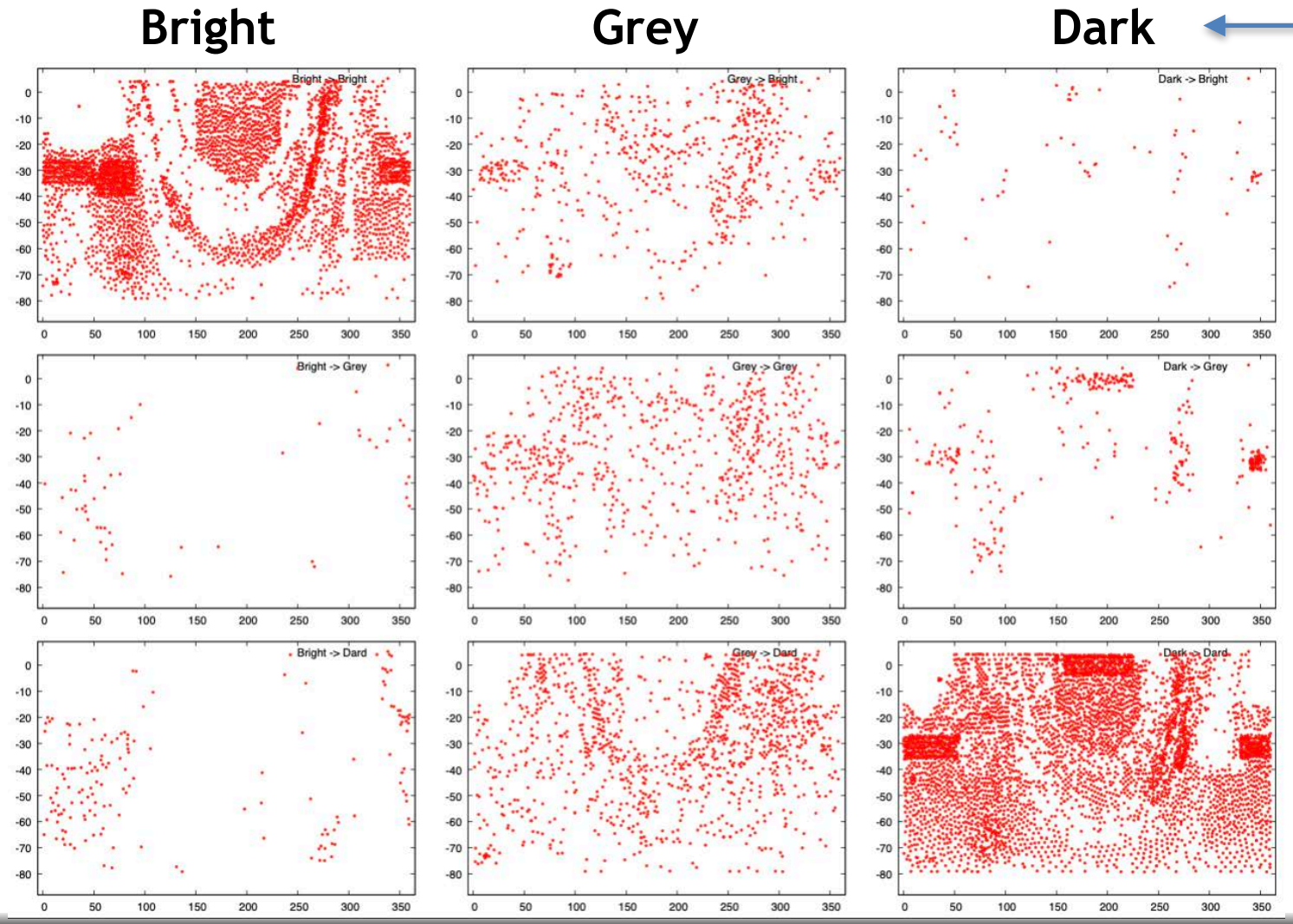
Theoretical limit: best possible airmass

Airmass_OBS / Arimass_MIN

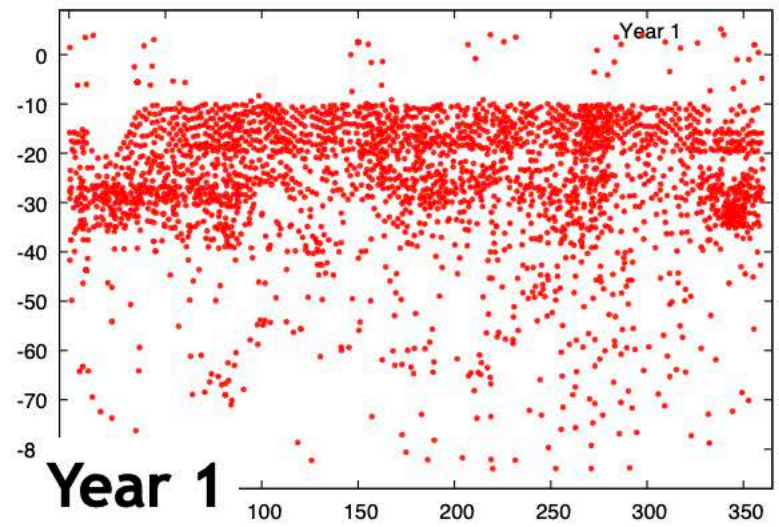
4MOST Scheduling algorithm: an example

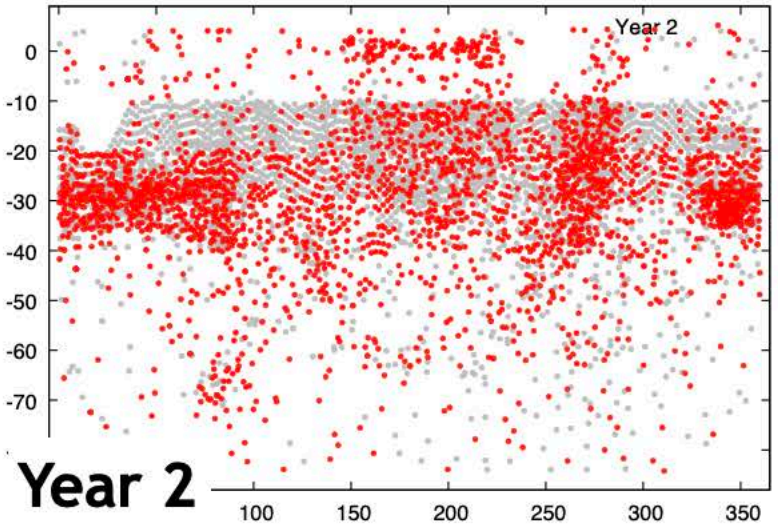
Requested sky condition

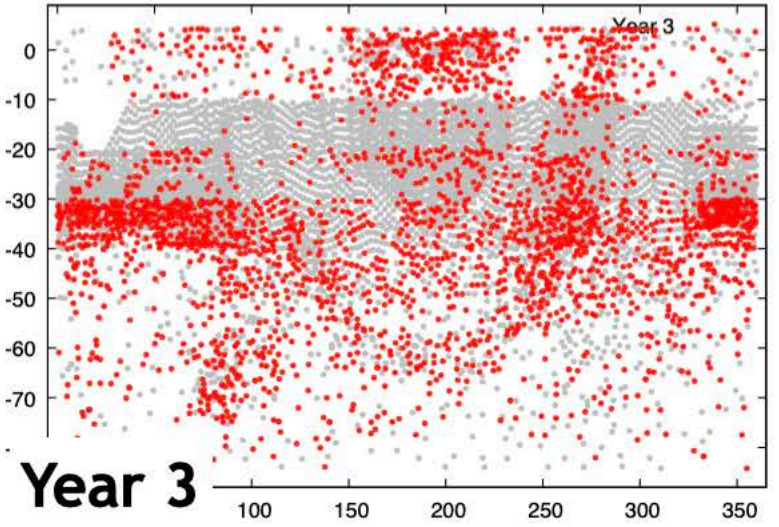
Observed sky condition

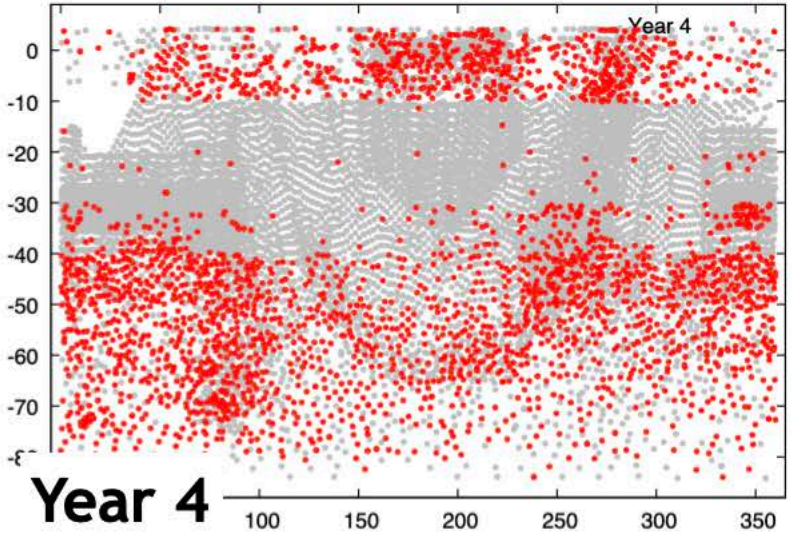


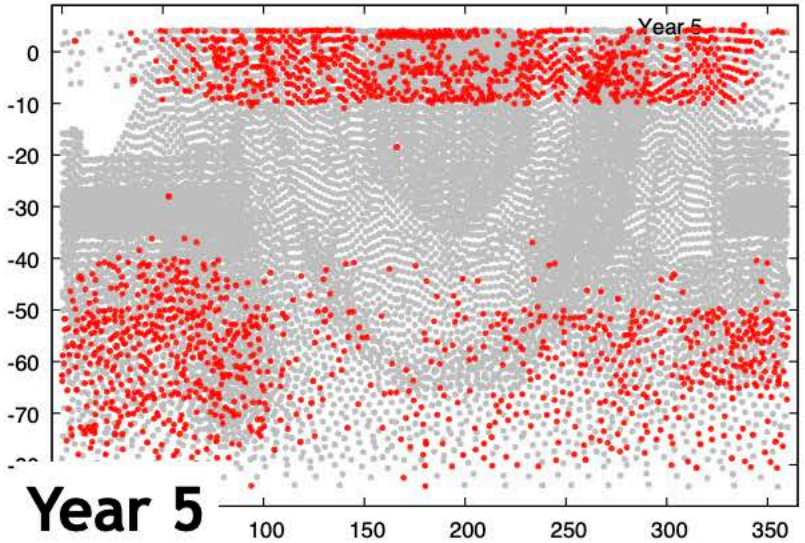
4MOST Scheduling algorithm: forced scheduling







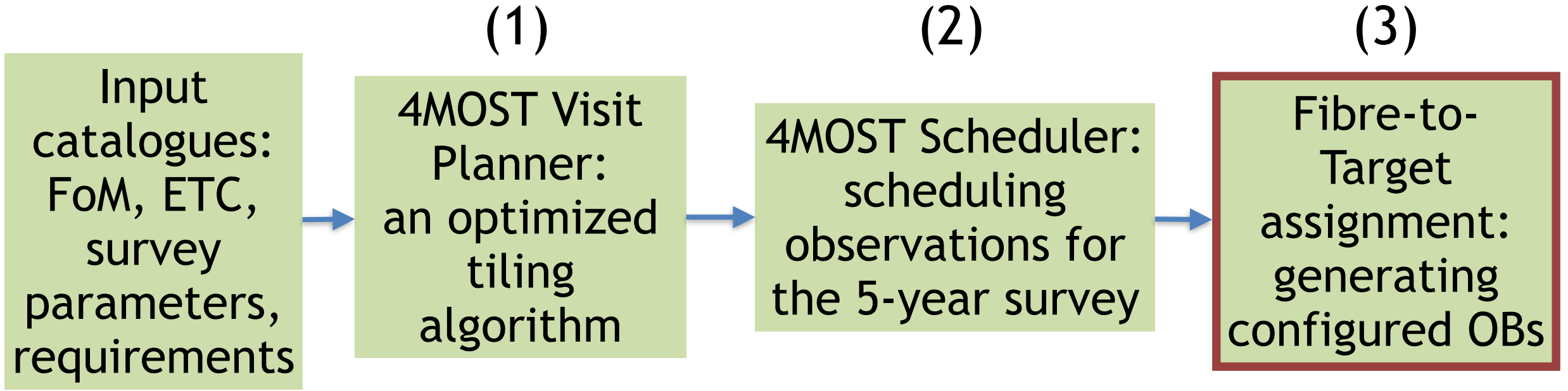




4MOST Scheduling algorithm: summary

- Overall scheduling is done using long-term scheduler, which includes all predictable aspects.
- Short-term scheduler is taking into account unpredictable weather effects.
- All OBs are observed close to their best observing conditions.
- Algorithm allows to define sky regions that should be finished preferentially.
- Algorithm allows to follow the LSST scheduling as much as is reasonable (without loss of efficiency).

Simulating 4MOST observations: a general flow-chart



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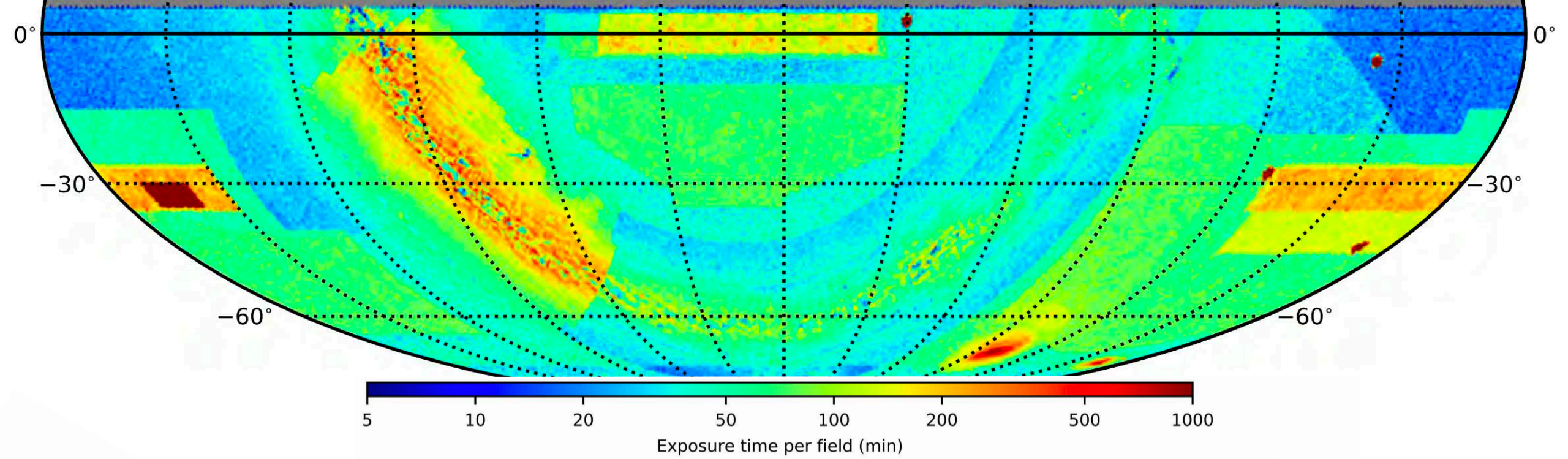
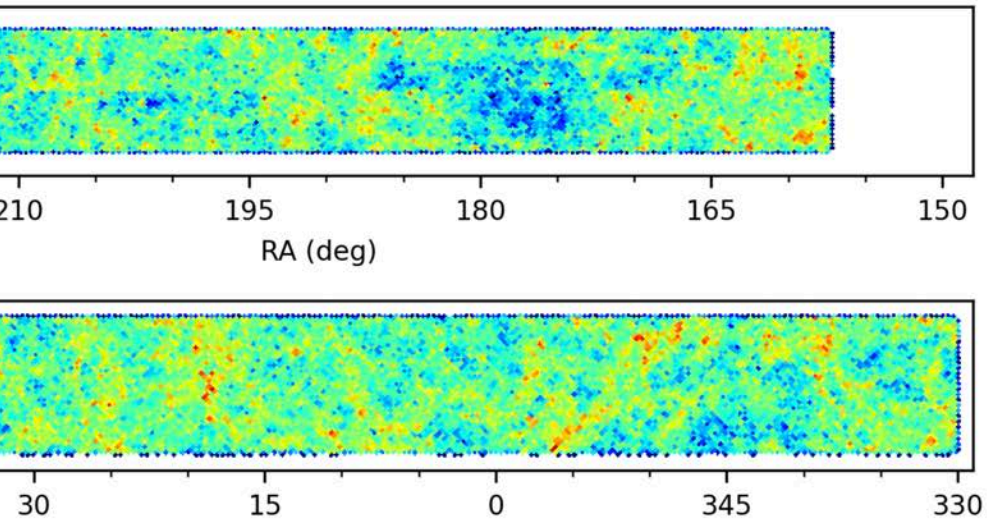
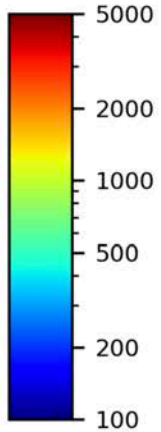
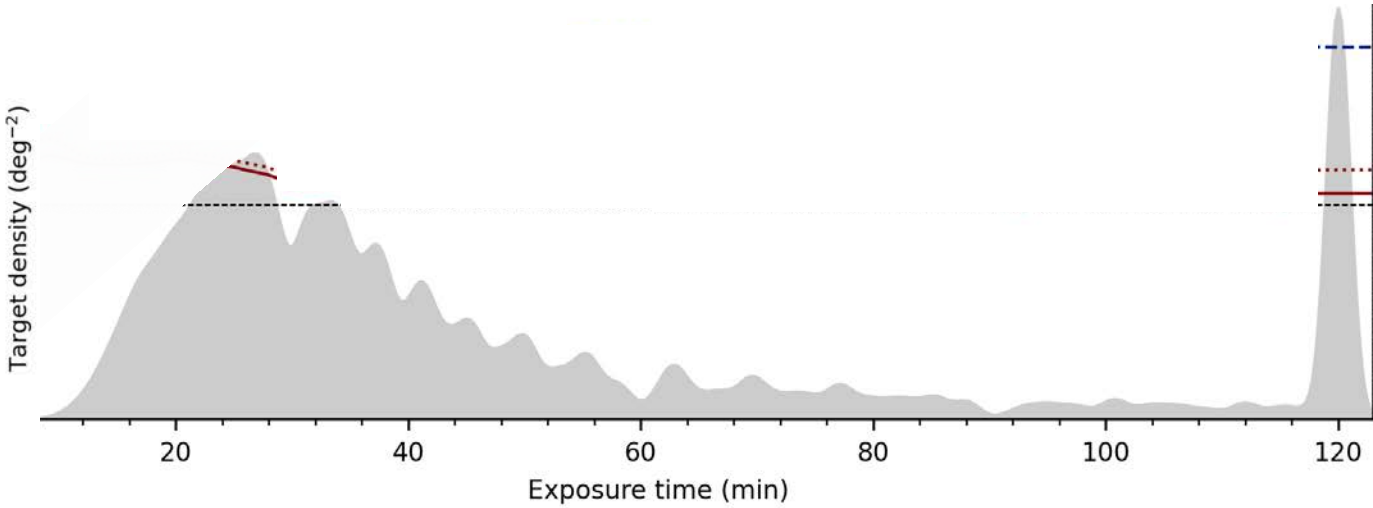
Probabilistic targeting algorithm: a challenge

- Focal plane is shared by several sub-surveys.
- Exposure time requests for different targets vary significantly.
- For many sub-surveys, a predefined fraction of targets is sufficient to fulfil the sub-survey's science goals.
- Fibre positions in the field of view are fixed with limited patrol areas.
- Fibres are divided between low- and high-resolution.

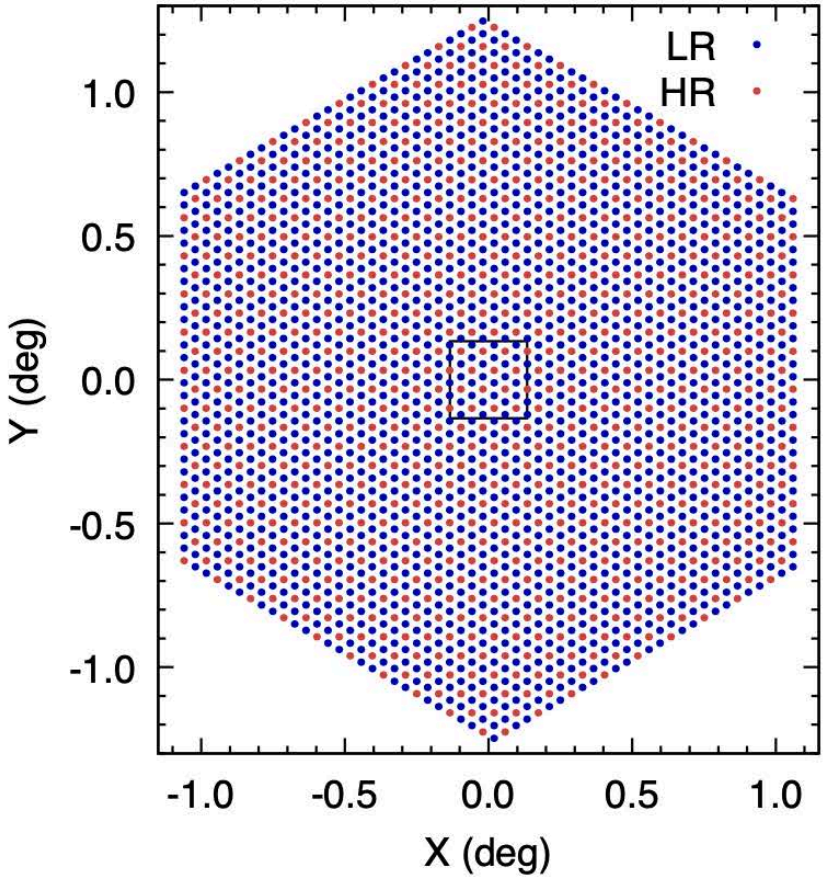

0°
−30°
−60°
0°
−30°
−60°
5
10
20
50
100
200
500
1000
Exposure time per field (min)

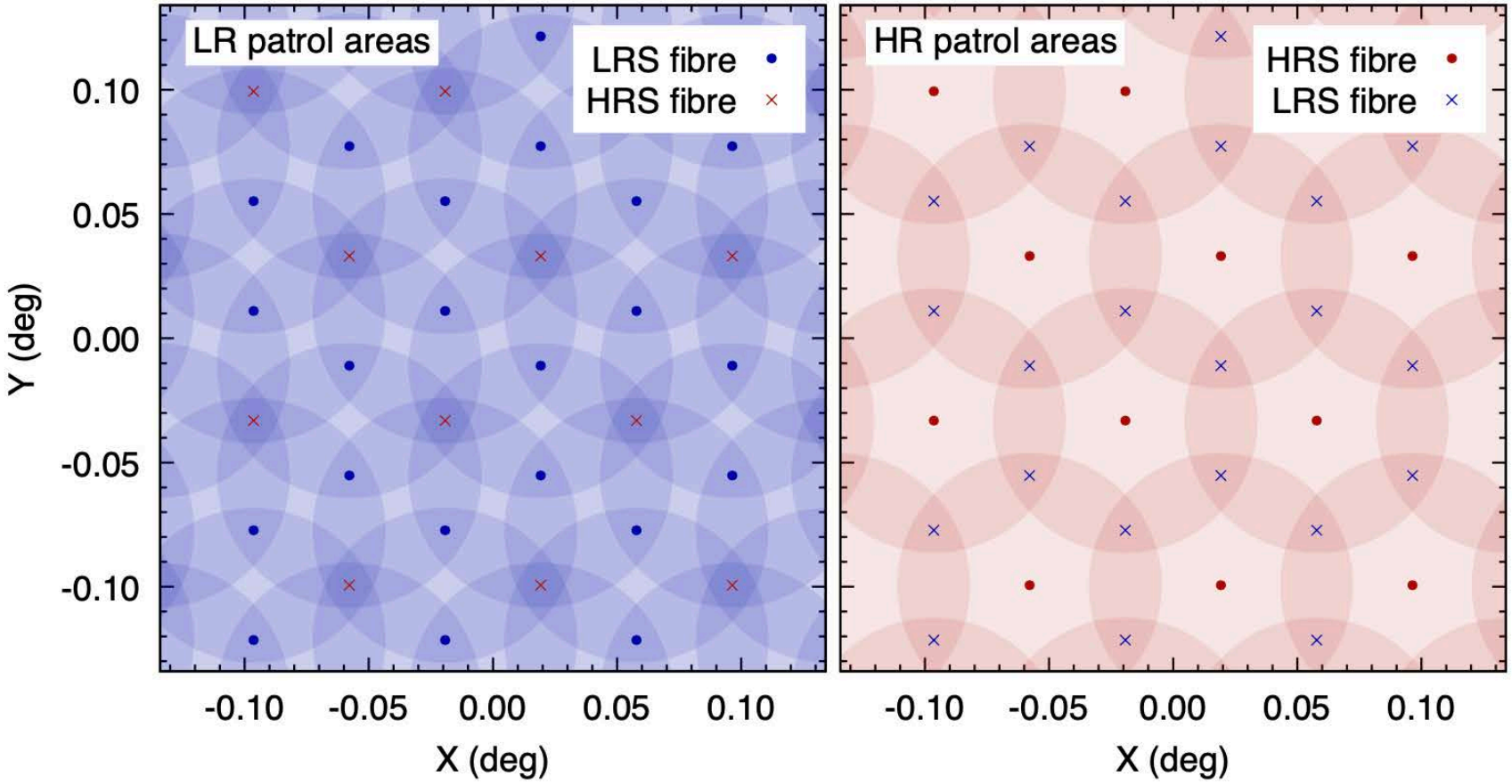

210
195
180
165
150
RA (deg)
30
15
0
345
330


5000
2000
1000
500
200
100

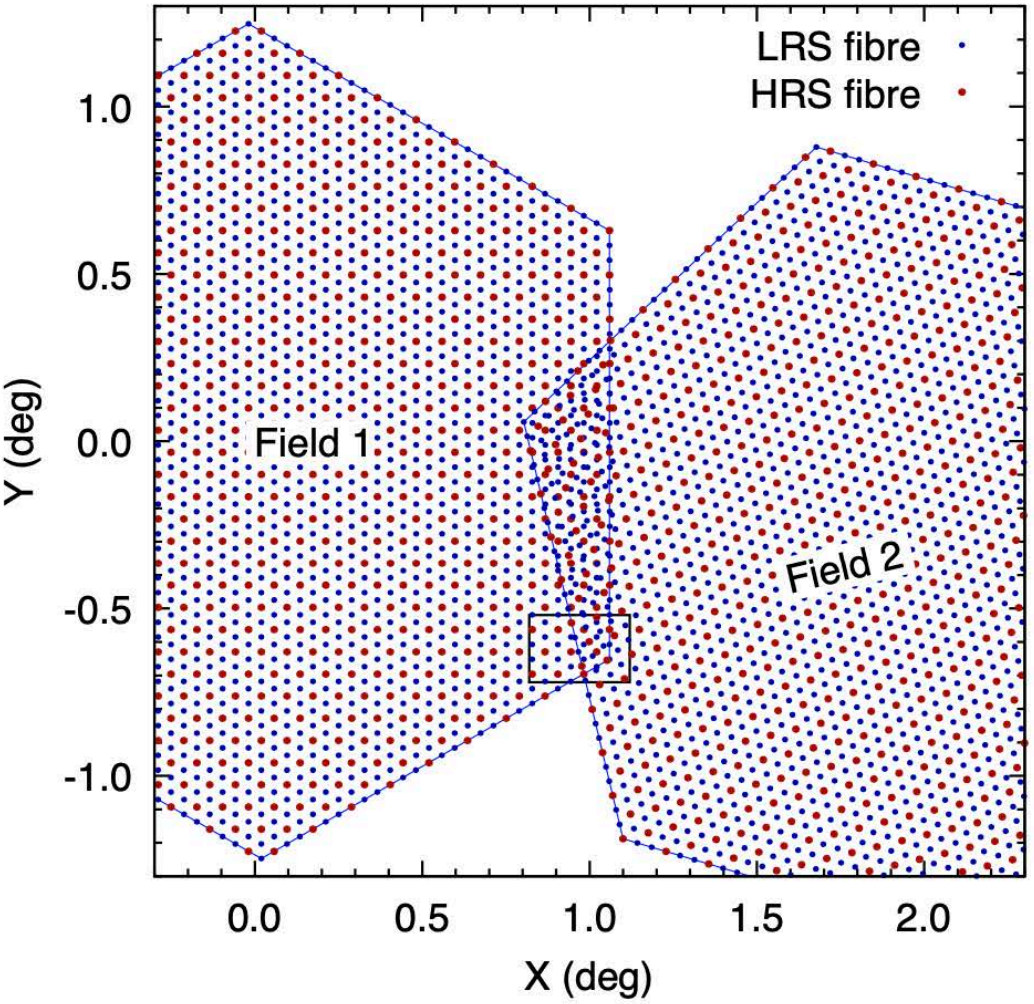

Target density (deg^{-2})
20
40
60
80
100
120
Exposure time (min)

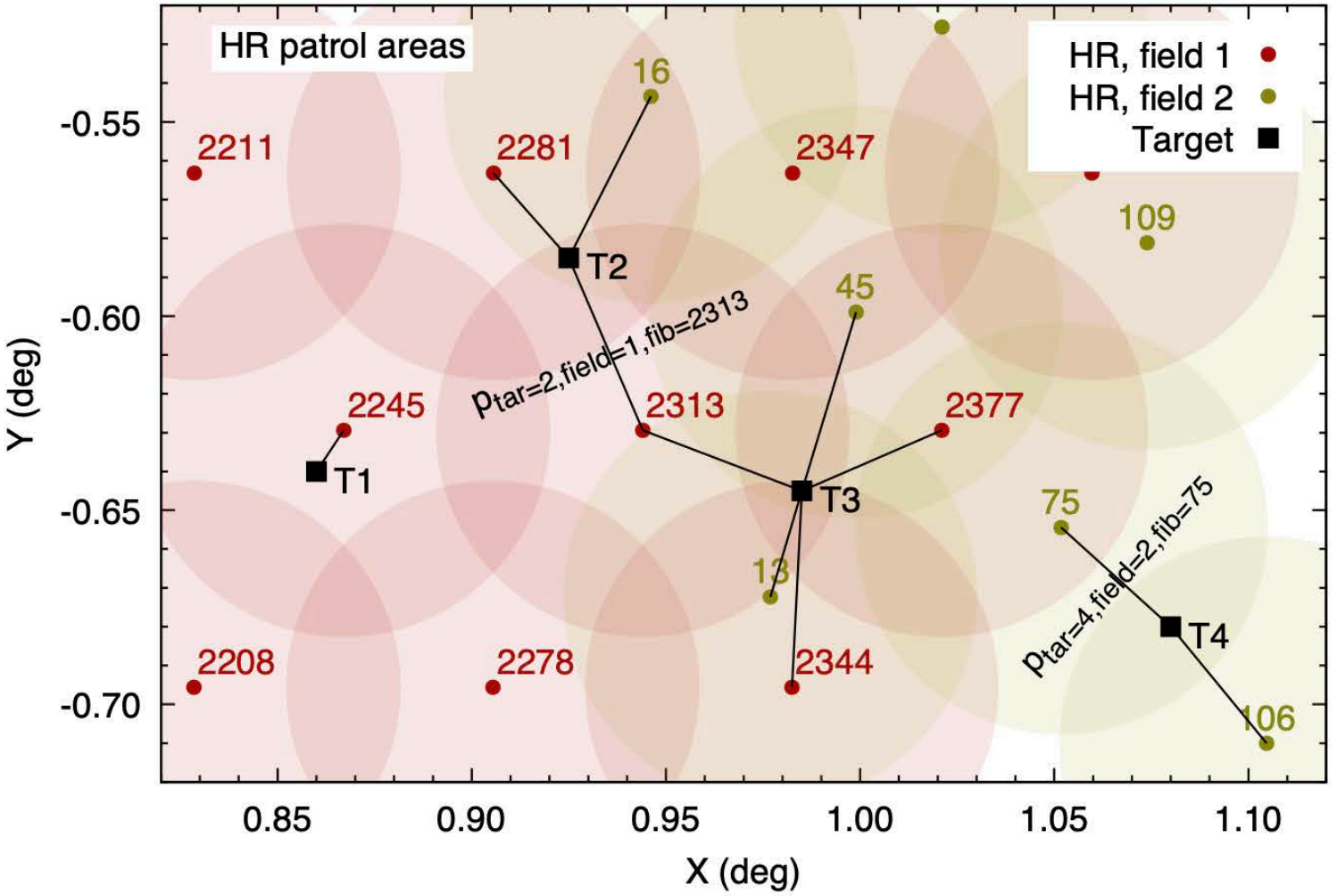
Fibre pattern in one Field of View





Assigning probabilities for fibre-target pairs

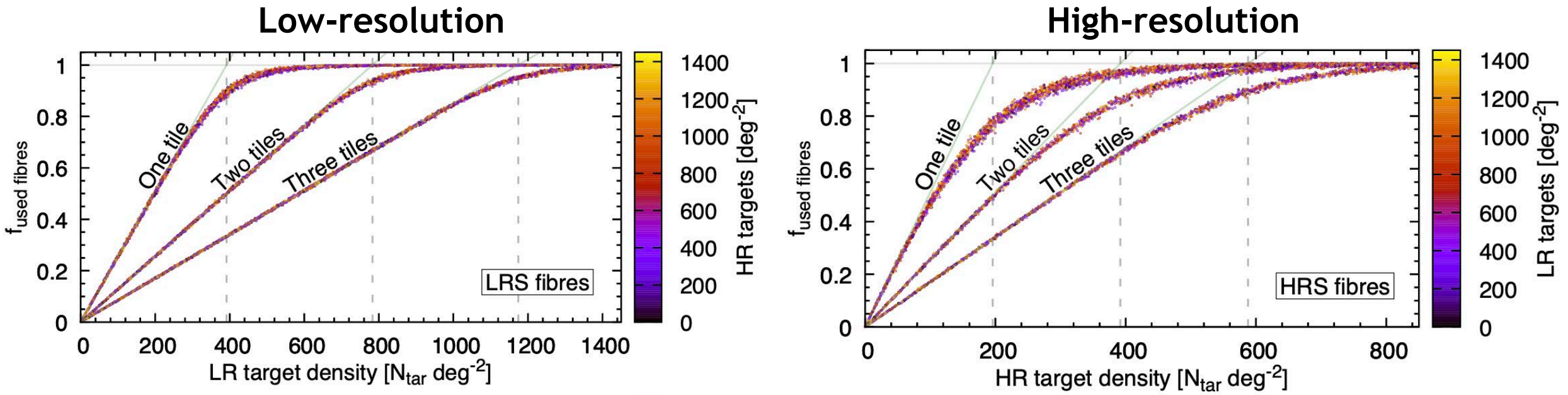




Fibre-target pair probabilities take into account:

- Target density across the field and clustering of targets to achieve uniform completeness as a function of target separation.
- Requested exposure times to achieve nearly uniform completeness as a function of exposure time or magnitude.
- Sub-survey completeness requirements.
- Fixed fibre density of the 4MOST instrument.
- Observing efficiencies (fibre throughput, sky condition, etc)
- Sub-survey specific factors (e.g. high completeness for WAVES)

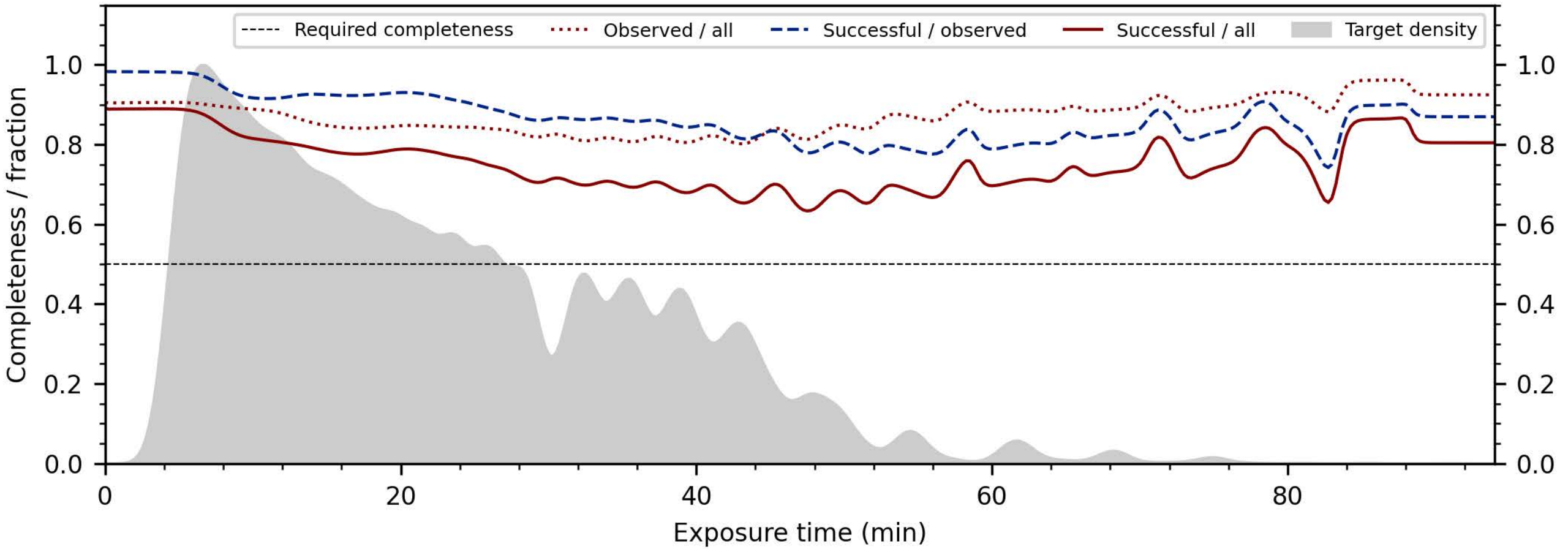
Fibre-density vs target-density



Targeting efficiency for randomly distributed targets

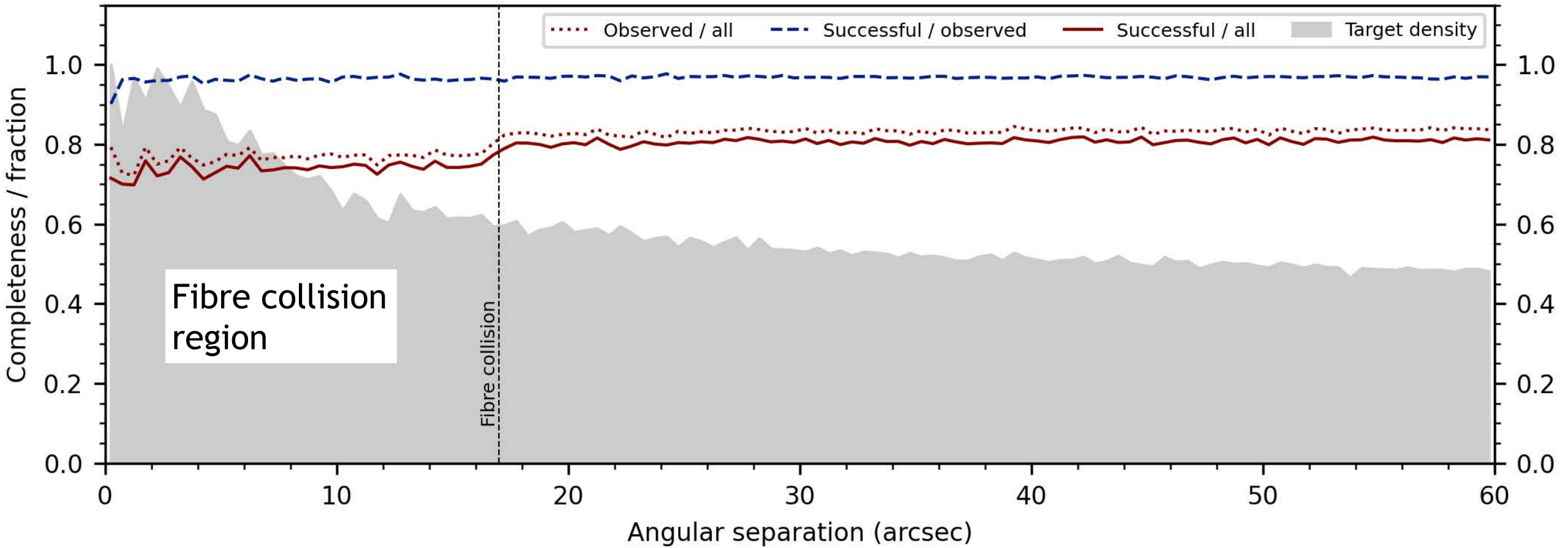
- For efficient survey, it is important to have more targets in the catalog than are required for the science goals.

Survey simulation: an example



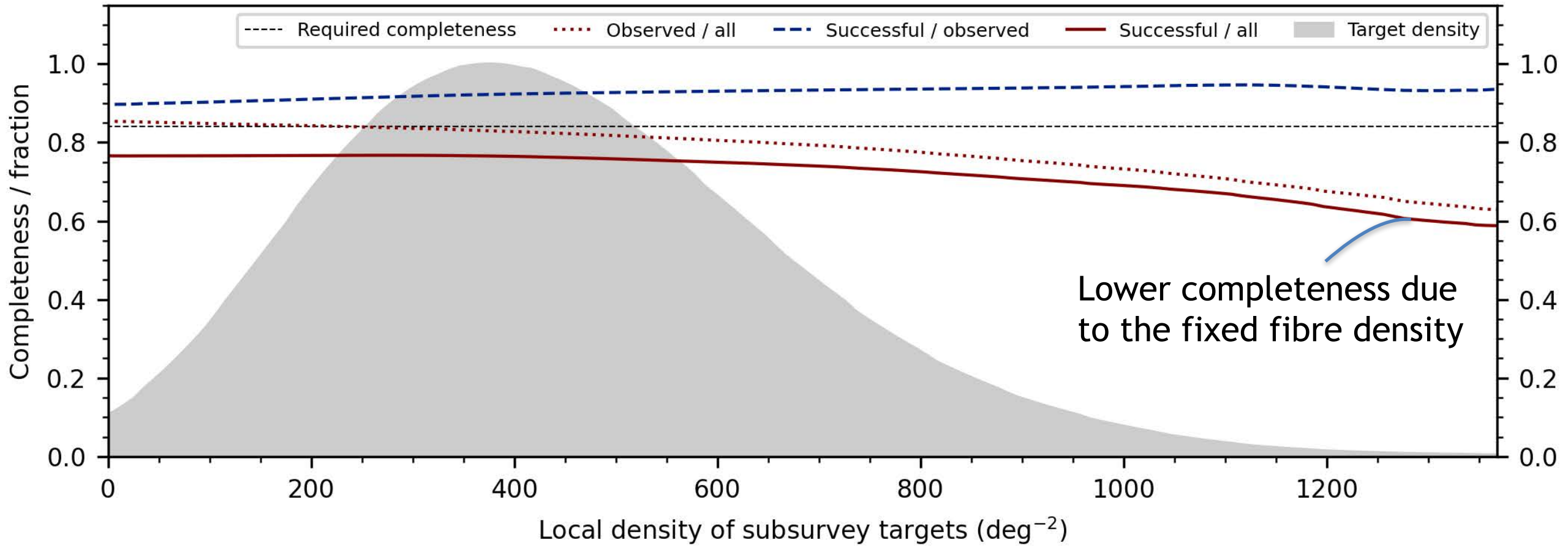
- Completeness as a function of exposure time.

Survey simulation: an example



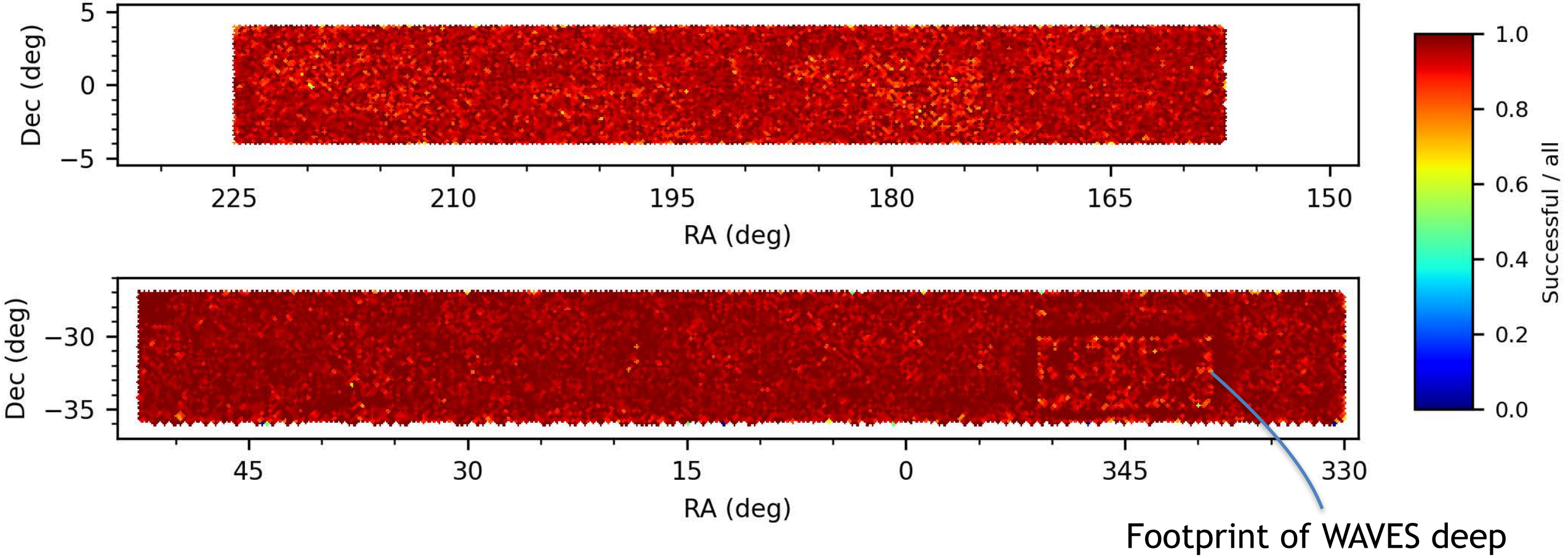
- Completeness as a function of angular separation.

Survey simulation: an example



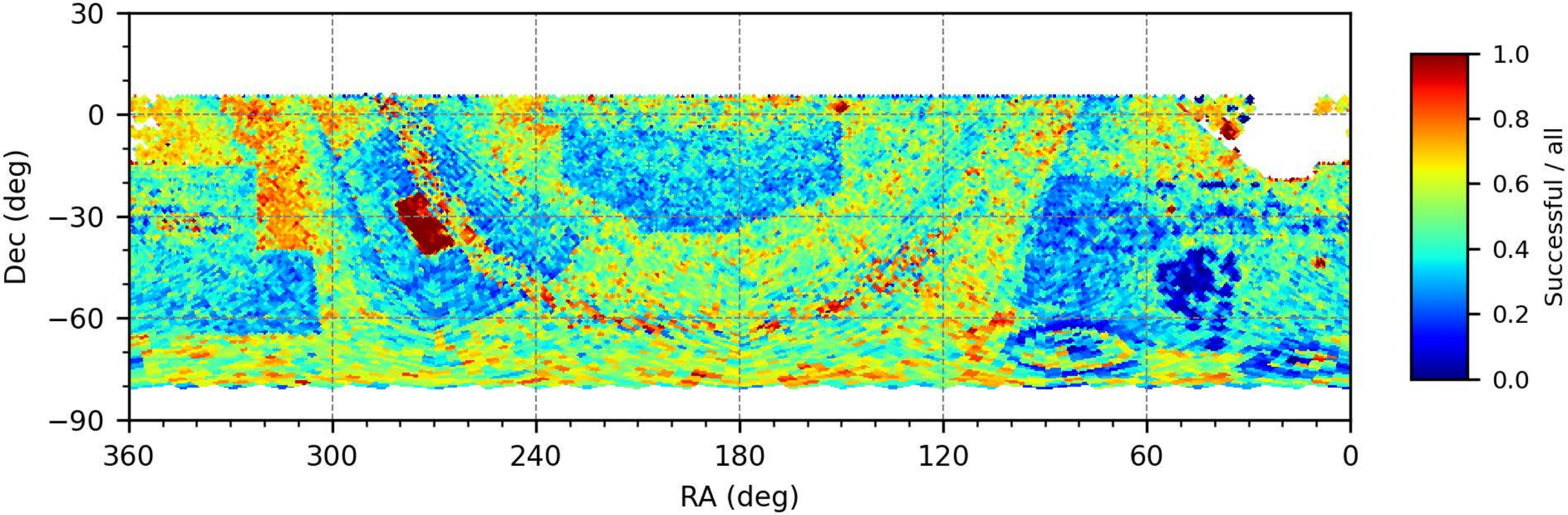
- Completeness as a function of target density.

Survey simulation: an example



- Completeness as a function of sky coordinates.

Survey simulation: an example

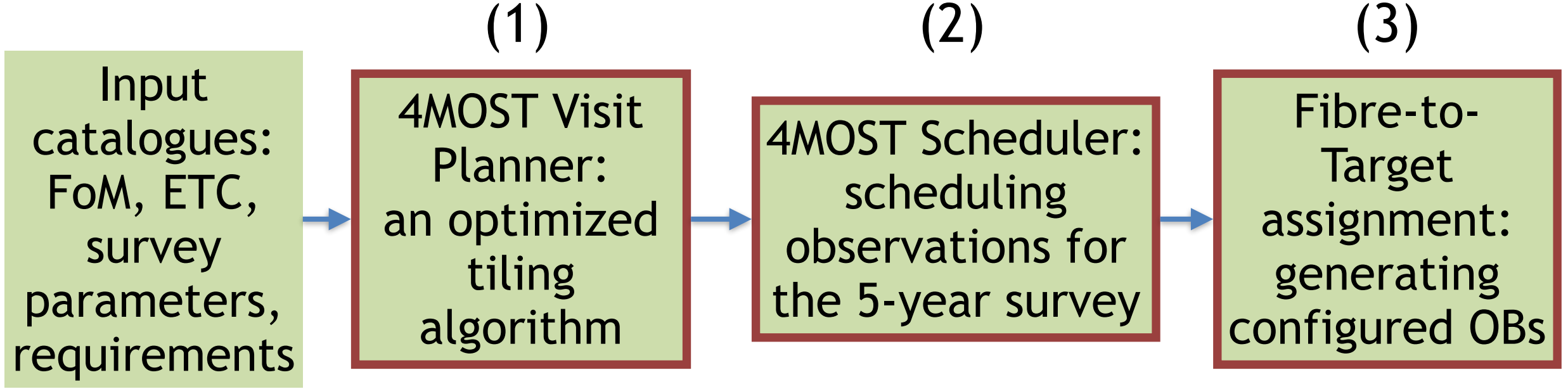


- Completeness as a function of sky coordinates.

Summary: Probabilistic fibre-to-target assignment

- Probabilistic fibre to target assignment allows to have uniform completeness as a function of:
  - sky coordinates
  - exposure times, magnitudes
  - angular separation, target density
- A predefined fraction of targets is observed in every sub-survey.
- Most of the targets that are targeted, are completed, while minimizing the overexposure per target.
- Probabilistic targeting allows to have an accurate Selection Function.

Summary: all algorithms are in development and will improve during the next years



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