Operability vs optimization in automated telescopes

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Abstract

It is a frequent temptation in the scientific world to plan for highly optimized observations that would provide the theoretical best possible data quality. However, this implies having to carefully plan each observation individually, plus the need to re-plan the observation if the conditions change. This scenario also applies to ground-based telescopes, but is particularly salient in space-borne instruments, where the available resources are particularly limited and observation conditions hard to predict.
A second problem of over-optimized observations is the assimilation of data acquired with wildly different settings, which strongly increases the dependency on the accuracy of the calibration, in particular on an accurate determination of the observation conditions.
Based on the lessons learnt during the operation of the Dawn Framing Cameras[1] in the asteroid belt and the Rosetta Osiris Telescopes[2] around comet 67/P Churyumov-Gerashimenko, we present a set of guidelines for finding a balance between operability and optimality of the observations, and a few scenarios where a seemingly suboptimal set of observations proved to be better as a set than the optimal ones.

Objectives

1. Establish the importance of operability in the quality of the final data sets
2. Identify aspects of the observation sequences with an impact on operability
3. Define strategies for trading-off scientific vs. operational constraints

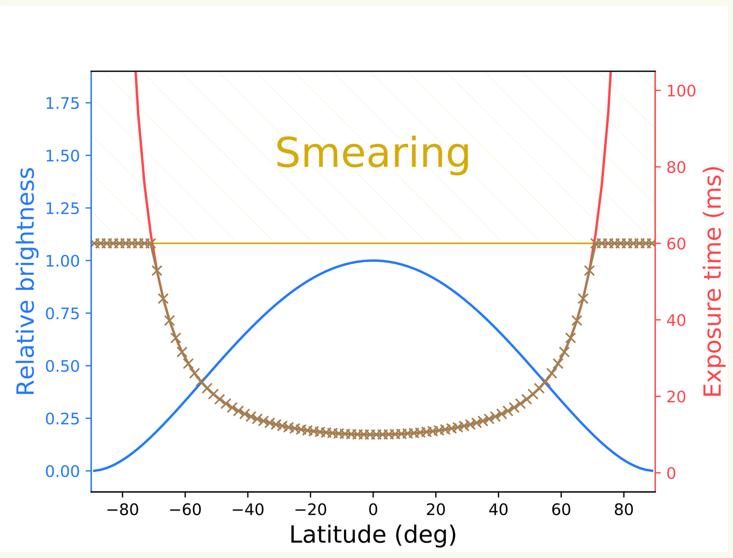
Operability affects data quality

The definition of a telescope observation sequence[3] implies the exploration of a multi-dimensional parameter space over time:

- Pointing(s)
- Filter/wavelength
- Exposure time
- Cadence or repetition pattern

However, observations can become very complex, and human and environmental factors can render the obtained data set unusable for the purpose that it was intended.

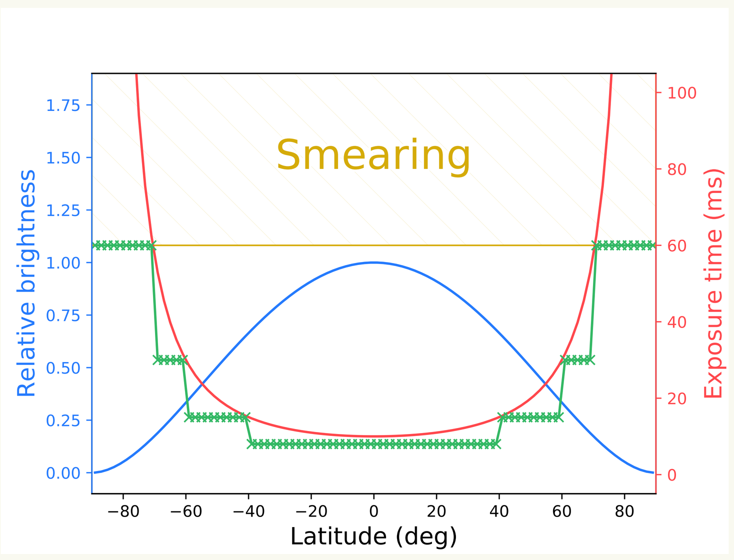
A (counter) example from Vesta



- 90 observations
- 36 different values
- $\Delta_{max} = 15\%$
- $\Delta_{min} = 0.18\%$

Figure 1: "Optimal" exposure time over a half orbit

- Is the complexity of the sequence manageable by the operator?
- Is the generation/update effort reasonable within the schedule?
- Is the sequence resilient against changes in the observation conditions?



- 90 observations
- 4 different values
- $\Delta_{max} = 66.6\%$
- $\Delta_{min} = 60.9\%$

Figure 2: "Operable" exposure time over a half orbit

Rules of operability

Observation sequences have to include some margins to accommodate uncertainties in several parameters. As a general rule, if the uncertainty in the parameter is bigger than the variation predicted by the model, use a **common and easy value** to ease the operations:

1. If possible, use a common value:
   Instead of 15.3, 15.4 and 15.5 ms of exposure, use 15.3 ms in all three.
2. If possible, use a simple value:
   Use 15.0 ms instead of 15.3 ms (easier number).
3. If possible, use an existing block:
   If a previous run uses 14.0 ms, reuse it instead of defining a new one.
4. If needed, clone and change existing blocks:
   To create a shorter run, clone the 14.0 ms block and change only the number of repeats.

These three rules have several positive effects[**?**] in the quality of the generated data that normally offset the deviation from the models:

- Sequences are faster to create (few, easy values)
- Sequences are easier to verify (few macro-commands)
- Sequences need less updates (small changes get absorbed)
- Observations are more robust during execution (bigger built-in margin)
- Data sets are simpler to use (few different observation conditions)

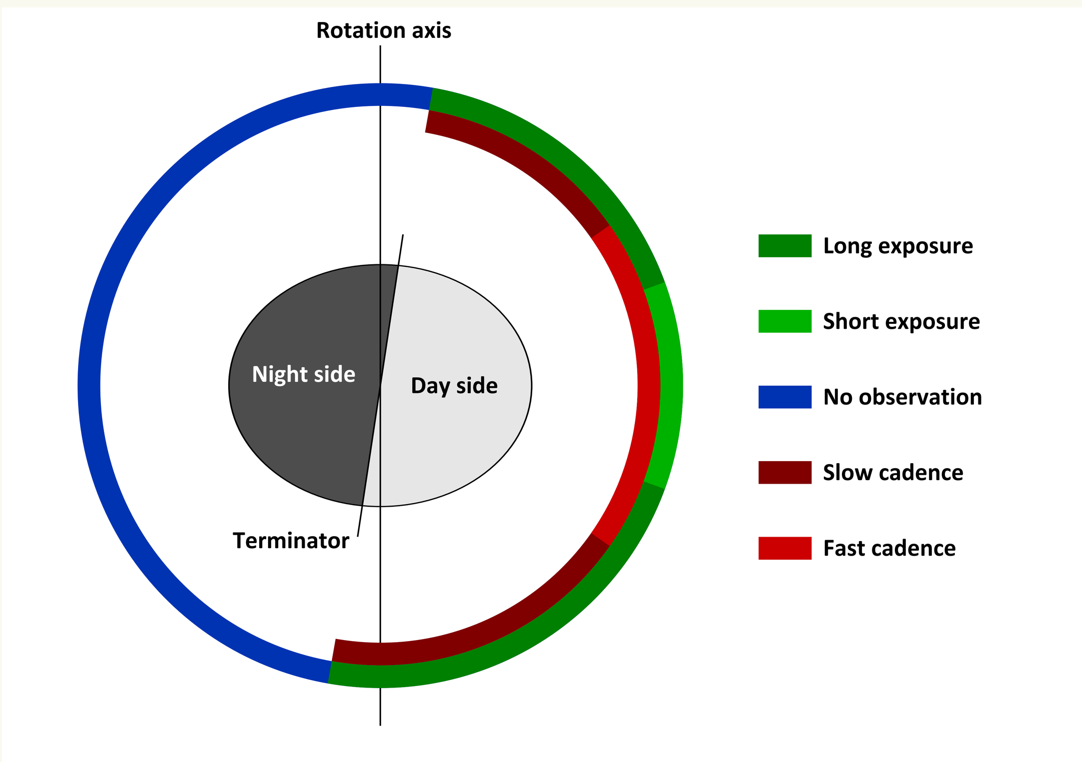


Figure 3: Combination of two parameters

Conclusions

- The complexity of the observation sequences is another factor in the trade-off of telescope operations.
- Reasonable compromises have proven helpful at obtaining useful data sets[**?**][4].
- Commonalities with ground-based telescopes can be leveraged to improve their operation.

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