Scan strategy requirements table

Jacques Delabrouille

24/10/2017

INTRODUCTION

We assume that the satellite will observe from an orbit around the L2 Lagrange point, and that the scan strategy (at least for the main survey) will combine a yearly rotation of the spacecraft together with the Earth and L2 around the Sun; a rotation with period T_{spin} around a spin axis that precesses around the anti-solar axis with precession angle α and a period T_{prec}. The main optical axis is offset from the spin axis by a boresight angle β. The objective of this note is to define criteria to optimize the scan strategy, which is described here by the angles α and β, and by periods T_{spin} and T_{prec}.

We note ϑ_{FP} the maximum angular extent of the field of view of the useful focal plane in the cross-scan direction.

We assume that the timelines are sampled above the Nyquist frequency. A good rule of thumb is 3-4 samples or more per beam FWHM θ_{beam} for proper co-scan sampling. We note τ_{beam} the time needed to scan a beam FWHM ($\tau_{beam} = \sin\beta \times \theta_{beam}/360 \times T_{spin}$, if θ_{beam} is expressed in degrees).

(The characteristics of the orbit around L2 impact the maximum elongation of the Earth and Moon from the solar direction. However, this is not directly connected to the scan strategy itself. It impacts instead the telecommunications system, and the level of sidelobe pickup of Earth and Moon. The size of the orbit around L2 can be optimized indepenently of the scan strategy itself. The table below hence does neither address orbit nor telecommunication systems requirements).

The table below gives figures of merit for characteristics of the scan strategy. Constraints are not always compatible, and the optimum must make a balance between the various constraints. A criticality number [*C*, from 1 to 4] is assigned to each of the requirements, with the numbers meaning: 1 (nice to have); 2 (important); 3 (essential); 4 (critical).

REQUIREMENTS and FIGURES OF MERIT

Requirement	*C*	FOM or constraint	Comment
Full sky coverage	2	$\alpha+\beta+\vartheta_{FP} > 90°$	This is required for the full sky, including the NEP and SEP, to be seen by all detectors.
Negligible beam smearing	3	$\tau_{det} < \kappa \times \tau_{beam}$	The detector time constant sets a requirement on τ_{beam} and hence β, θ_{beam}, T_{spin}. The value of κ is TBD.
Optimal scan angle distribution	1	for each pixel maximize $\Delta = \langle\cos^2\psi_i\rangle \times \langle\sin^2\psi_i\rangle$	where ψ are the scanning angles in the pixel. This minimizes the volume of the error box on Q and U for single-

			detector measurements [Couchot et al. 1999]. Note: Δ is proportional to the determinant of the inverse of the noise covariance matrix of I, Q, U.
Avoid high excess 1/f noise	4	$\sin\beta\ f_{spin} > \kappa \times f_{knee}$	The value of κ is TBD. κ<6 is demonstrated to be acceptable by [Natoli et al., 2017] when 1/f noise is considered in isolation of other systematics.
Re-observe each pixel on all time scales	2	uniformity of observation-time histogram in 6-month survey periods	To monitor time-variations of instrumental response, and for general redundancy.
Make continuous maps of Q and U on timescales < κ days with fixed detector sets (e.g. 2 or 4 dets)	4	maximize A/P, where A is the observed area (pixels observed) and P the corresponding perimeter (pixels adjacent to an unobserved pixel)	Capability to convert Q, U maps obtained with small number of detectors (ideally 1 detector), or otherwise sets of 2 or 4 associated detectors) to E, B maps on timescales < κ days.
Observe (major) planets every few days	3	maximize sky area covered every few days	For relative photometric calibration and measurement of beams.
Calibrate on CMB dipole	4	$\beta > \beta_0$	β0 is TBD. Large scans see more dipole.
Observe distant points at close times	2	maximize β	Large scans connect distant points faster. Maximizing β is incompatible with optimal scan angle distribution.
Avoid thermal fluctuations	3	keep the spin axis antisolar	Also make the satellite symmetric, for constant absorbed Solar flux
Pointed observation mode	1		After a few surveys it is nice to be able to integrate deeply in clean patches if tensor modes still escape detections.