XMM-Newton

Routine Calibration Plan

Version 2.29

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Revision history

Revision number	Date	Revision author	Comments
Version 2.29	28/01/2021	M. J. S. Smith	Added BPM 16274 observation at the depletion patch centre
Version 2.28	19/03/2020	M. J. S. Smith	Added BPM 16274 offset pointing observation
Version 2.27	01/10/2019	M. J. S. Smith	Change in Vela SNR pointing coordinates
Version 2.26	06/09/2017	M. J. S. Smith	3C 273 EPIC filter changed to Thick in order to mitigate pile-up
Version 2.25	09/06/2016	M. J. S. Smith	AD Dor and HR 1099 replace Capella due to reduced visibility
			Mkn 421 multi-pointing reduced from 5 × 20 ks to 5 × 12 ks
Version 2.24	01/07/2015	M. J. S. Smith	RGS Mkn 421 (5 × 20 ks) has replaced PKS 2155-304
			ζ Puppis off-axis PA angle defined
Version 2.23	23/05/2014	M. Guainazzi	1ES 0102-72 observed twice per year
			ζ Puppis observed once every two years
			RGS Mkn 421 replaces PKS 2155-304 as of 2015
			3C 273 as multi-mission cross-calibration target
Version 2.22	10/05/2013	M. Guainazzi	EPIC ζ Puppis observation modes updated
Version 2.21	19/04/2013	M. Guainazzi	B0102-72.3 in the 2^{nd} semester 2013 (§ 3.3)
			N132D replaces ζ Orionis (§ 3.3)
			HD13499 removed ($ 2.1.3.2)
Version 2.20		M. Guainazzi	RX J1856.6-3754 1^{st} semester 2013 (§ 3.4)
			B0102-72.3 2^{nd} semester 2013 (§ 3.3)
Version 2.19	10/10/2012	M. Guainazzi	ζ Puppis off-axis observations
			Two Crab observations
			Temporary replacement of 1ES 1553+113 (§ 3.5)
			Filter cycling on 1ES 0102-72 (§ 3.5)
Version 2.18	13/02/2012	M. Guainazzi	Mkn 421 replacement (§ 2.1.2.3)
			3C 273 replacement (§ 2.1.4)
			Deviations from RCP in 1^{st} semester 2012 (§ 3.6)
Version 2.17	22/09/2011	M. Guainazzi	Deviations from RCP in 2^{nd} semester 2011 (§ 3.7)
Version 2.16	28/05/2010	M. Guainazzi	Update: Vela SNR filter change
			ζ Orionis introduced
			B0102-72.3 (on-axis), N132D, Tycho removed
Version 2.15	01/12/2009	M. Guainazzi	Update: RXJ1856.6-3754 MOS configuration change
			MOS1 CCD6 health check
Version 2.14	06/08/2009	M. Guainazzi	Update: POS manipulation tool for Mkn 421,
			EPIC exposure times in multi-exposure observations
			(wrong overhead estimates corrected)

Contents

1 Purpose and Scope

This document describes the global planning strategy for *XMM-Newton* calibration observations in the routine phase of the project.

2 XMM-Newton Routine Calibration Program

It has been agreed with the calibration scientists and instrument teams of *XMM-Newton* that the targets listed in Section 2.1 will be used for regular routine calibration observations. These targets are flagged as sources reserved for calibration observations and included in the *XMM-Newton* Observation Lokator (http://xmm.esac.esa.int/external/xmm_sched/obs_lokator/index.php).

2.1 List of Targets and Calibration Budget

Table 1 lists possible calibration targets that should be monitored on a regular time scale and the required calibration time budget for their respective purposes. Note that some targets that were originally part of the routine calibration monitoring have since been dropped and replaced by others. Some of the former targets (for example OMC2/3, MS 1229.2+6430, H 1426+428 or Sco X-1) might be re-visited on request and as non-routine calibration observations. As several routine calibration observations in the plan are marked as 'to be scheduled on request' and might be necessary as non-routine calibration observations, the time actually spent on calibration might be higher. The routine calibration planning skeletons (see Section 4.1) always aim at keeping the time for routine calibrations below the 5% margin (cf *XMM-Newton* Policies and Procedures document) so as to allow for additional NRCOs.

2.1.1 EPIC Routine Calibration Monitoring

It is assumed, unless otherwise stated, that both RGS instruments will operate in the standard spectroscopy mode with all CCDs read during the EPIC calibration observations.

2.1.1.1 CTI, Gain, Noise and Bright Pixel Monitoring

Routine CLOSED/CAL-CLOSED observations of short duration (from 1 to 3 hours) are scheduled for MOS and pn at the start[1] of some revolutions depending on the time between the first observation of the revolution and the time when the radiation model predicts a radiation level below threshold, plus a half hour margin. If this available time is above an intstrument dependent threshold, currently set at 3 ks for MOS and 6 ks for PN[2], a CAL-CLOSED exposure for that instrument should be added. The pointing direction is irrelevant, but it is advantageous to schedule the CLOSED/CAL-CLOSED exposures at the start or end of a revolution with the same position as an adjacent science observation in order to avoid one extra slew.
In the past, longer (at least 15 ks) CLOSED/CAL-CLOSED observations for MOS and pn were performed every two weeks to one month. Such exposures were scheduled as far as possible parasitically with RGS and OM routine calibration observations. If gaps between such calibration observations were too large, dedicated CLOSED/CAL-CLOSED observations had to be requested.

[1] Since the introduction of the auto-commanding functionality in Rev.#1621 (November 2008), CAL-CLOSED exposures are no longer routinely scheduled at the end of a revolution.

[2] These thresholds are updated every several years to take into account the natural decay of the on-board calibration sources.

Table 1: List of Targets for Routine Calibration Monitoring

Source	Time (ks)[a]	N° Visits (yr^{-1})	PA[b] deg.	EPIC Configuration MOS 1	MOS 2	pn	Purpose
EPIC Calibration Targets							
1ES 0102-72[c]	35	2	205 ± 15	LW/THIN	LW/THIN	SW/MEDIUM	A_{eff} (§ 2.1.1.2)
N132D	45	1	248.5	LW/THIN	LW/THIN	SW/THIN	A_{eff}, Redistrib. (§ 2.1.1.2, 2.1.1.5)
ζ Puppis[d]	45	0.5	112	LW/THICK	LW/THICK	SW/THICK	Redistrib. (§ 2.1.1.5)
Crab[e]	10	2		TI/THICK	TI/THICK	BU/THICK TI/THICK	Timing (§ 2.1.1.6)
RX J1856.6-3754[f]	70	2		SW-LW/THIN[g]	SW-LW/THIN[g]	SW/THIN	Redistrib., Contam. (§ 2.1.1.5, 2.1.2.3)
Vela SNR	60	1	102 ± 15	FF/CAL-MEDIUM	FF/CAL-MEDIUM	FF/CAL-THIN	Spec. resolution, Contam. (§ 2.1.1.2, 2.1.1.4)
CLOSED	10	2		FF/CLOSED	FF/CLOSED	FF/CLOSED	Background (§ 2.1.1.1)
RGS Calibration Targets							
AB Dor	100	1		SW/THICK[h] FF/CAL-CLOSED[i] FF/CLOSED[k]	SW/THICK[h] FF/CAL-CLOSED[i] FF/CLOSED[k]	SW/THICK[h] FF/CLOSED[j] LW/CLOSED[j] EFF/CAL-CLOSED[l]	λ scale (§ 2.1.2.1)
HR 1099[m]	50	0.5		SW/THICK[n] FF/CAL-CLOSED[o]	SW/THICK[n] FF/CAL-CLOSED[o]	SW/THICK[n] FF/CAL-CLOSED[o]	CTI (§ 2.1.2.4)
PSR B0833-45	100	1	294 ± 15	LW/MEDIUM[p] FF/CAL-CLOSED[q]	LW/MEDIUM[p] FF/CAL-CLOSED[q]	LW/MEDIUM[p] EFF/CAL-CLOSED[r] EFF/CLOSED[r]	Long-λ (§ 2.1.2.2)
Mkn 421[s]	60	2		FF/CAL-CLOSED	FF/CAL-CLOSED	FF/CAL-CLOSED	A_{eff} (§ 2.1.2.3)
Mkn 421[t]	18	0.5		FF/CLOSED	FF/CLOSED	EFF/CLOSED	Gain & CTI (§ 2.1.2.4)
OM Calibration Targets							
BPM 16274[u]	15	2		SW/CLOSED DIAGN[v] LW/CLOSED DIAGN[v] FW/CLOSED DIAGN[w]		FF/NOISE	Photom. (§ 2.1.3.3)
BPM 16274[x]	7	1		FF/CAL-CLOSED	FF/CAL-CLOSED	LW/CAL-CLOSED	Photom. (§ 2.1.3.3)
BPM 16274[y]	7	1		FF/CAL-CLOSED	FF/CAL-CLOSED	FF/CAL-CLOSED	Photom. (§ 2.1.3.3)
GD 153	15	1		FF/CAL-CLOSED	FF/CAL-CLOSED	EFF/CAL-CLOSED	Grisms & Photom. (§ 2.1.3.1, 2.1.3.3)
HZ 2	15	1		FF/CAL-CLOSED	FF/CAL-CLOSED	FF/CAL-CLOSED	Grisms & Photom. (§ 2.1.3.1, 2.1.3.2, 2.1.3.3)
SA 95-42	35	1		FF/CAL-CLOSED	FF/CAL-CLOSED	FF/CAL-CLOSED	Photom. (§ 2.1.3.3)
Cross-Calibration Targets							
1ES 1553+113	30	1		SW/MEDIUM	SW/MEDIUM	SW/MEDIUM	A_{eff} (§ 2.1.4)
3C 273	60	1		SW/THICK	SW/THICK	SW/THICK	A_{eff} (§ 2.1.4)
ζ Puppis	60	1		SW/THICK	SW/THICK	SW/THICK	Long-λ (§ 2.1.5)

[a]for each observation; [b]PA constraint, where applicable; [c]alternatively twice per year on- and 50" off MOS patch pointings; [d]50" off MOS patch pointings; [e]two observations for each passage; [f]shared with RGS; [g]alternatively every half year on (SW) and 50" off (LW) MOS patch pointing; [h]12 ks; [i]40 ks; [j]22 ks; [k]48 ks; [l]44 ks; [m]to be performed close to t; [n]10 ks; [o]40 ks; [p]10 ks; [q]89.5 ks; [r]37.5 ks; [s]five observations of 12 ks each (four of which off-axis); [t]off-axis pointing (cross dispersion), to be performed close to m (HR 1099); [u]on-axis, twice yearly, 1^{st} semester to be performed close to x and y; [v]once per year (1^{st} semester), in the same observation; [w]once per year (2^{nd} semester); [x]off-depletion-patch; to be performed close to u and y (1^{st} semester). [y]depletion-patch centre; to be performed close to u and x (1^{st} semester).

Due to the decreasing flux of the EPIC internal calibration source longer CAL-CLOSED exposures are needed to obtain high enough statistics for the energy scale monitoring, and especially the CTI derivation.
In April 2005 it was confirmed that MOS Full Frame CAL-CLOSED data collected during slews between adjacent targets can be used for CTI and gain monitoring. For pn, the new request is that instead of several rather frequent 15 ks observations, only long observations should be scheduled parasitically to RGS and OM prime calibration observations. No additional dedicated CLOSED/CAL-CLOSED routine calibration observations are requested with the exception of CLOSED exposure for background monitoring (see below). The frequency of CAL-CLOSED observations hence has been reduced to one observation approximately every 2 - 3 months.
The distribution of specific EPIC CAL-CLOSED exposure times between different readout modes and filter combinations should roughly be:

- for pn:
  CAL-CLOSED Full Frame : CAL-CLOSED Extended Full Frame = 3 : 1
- for MOS:
  always CAL-CLOSED Full Frame

Additionally, CLOSED exposures of 10 ks are needed to track the state of variations in the quiescent particle background. As of the first semester of 2009 they are performed twice yearly, preferentially between orbital phases 0.3 and 0.7. They will be complemented by taking MOS CLOSED exposures during slews (instead of CAL-CLOSED) every four revolutions (as a baseline). The readout modes should be:

- for pn:
  CLOSED Full Frame
- for MOS:
  CLOSED Full Frame

Diagnostics and Noise mode exposures:
MOS diagnostic images should be taken twice per year parasitically to OM routine calibration observations for 10 - 15 ks. The filter and readout modes are:

- scheme 1 ($\approx$ 15 ks): all CCDs Full Frame, 3 exposures per CCD
- scheme 2 ($\approx$ 7+7 ks):
  10 exposures Small Window CCD1 + 1 exposure Full Frame all peripheral CCDs
  5 exposures Large Window CCD1 + 1 exposure Full Frame all peripheral CCDs

EPIC-pn should be scheduled twice per year in Full Frame Noise mode, possibly in parallel with the MOS Diagnostic mode observations **(details are defined in the yearly skeleton plans)**. *Time budget: 20 ks + overheads for the CLOSED for quiescent particle background monitoring. The rest of the observations are performed during slews and calibration observations where EPIC is not prime, so there is no impact on the time available for science.*

2.1.1.2 Effective Area, Gain/Offset Monitoring

The target for the EPIC effective area and gain/offset monitoring is the SNR 1ES 0102-72. As of the second semester of 2010 the SNRs Tycho and N132D were removed from the Routine Calibration Plan to allow the observation of ζ Orionis. However, in 2013 N132D was reintroduced in the Routine Calibration Plan, replacing ζ Orionis to provide a longer baseline for the monitoring of changes in the MOS effective area (see § 2.1.1.5).
1ES 0102-72 should be scheduled twice per year for 35 ks alternately on-axis and at a position 50" offset from the MOS patch. MOS cameras will be in Large Window mode with the THIN filter in place, pn in Small Window mode with THIN filter. For this SNR the pointing coordinates might need to be adjusted (depending on the position angle) to re-centre the slightly extended sources in the pn Small Window field of view. The observations of 1ES 0102-72 are also of importance to RGS for monitoring purposes provided the pointing direction is properly constrained. The PA should be constrained in the interval $205° \pm 15°$.
For the Vela SNR observation (cf. also § 2.1.1.4 below), the same spacecraft position angle (PA) should be kept for repeated observations (i.e. they should always be observed at roughly the same time of the year). The PA should be constrained in the range $102° \pm 15°$.

2.1.1.3 Stability of the Boresight

In the past a test to check the stability of the boresight was scheduled once after every eclipse seasons and once per year after two years of *XMM-Newton* operations with targets NGC 2516 or OMC2/3. This has been dropped from the routine calibration plan and should be requested (if needed) as a non routine calibration observation (NRCO).

2.1.1.4 Monitoring of Spectral Capabilities and Contamination

The best suited target in the past for the check of spectral capabilities seemed originally to be MS 1229.2+6430 which was planned to be scheduled on request. The pn team proposed as replacement target Vela SNR to routinely monitor the low energy part across the face of the detector. This target should be scheduled once per year for 60 ks with EPIC cameras in Full Frame mode. The calibration source + scientific filters CAL-MEDIUM (MOS) and CAL-THIN (pn) should be used.
In order to allow investigation of any spatial dependency of the spectral response (especially at low energies), as of 2019, the pointing will be offset by 8' with respect to the previous years' coordinates. As before, the new pointing coordinates will be maintained for several years in order to build up sufficient statistics.

2.1.1.5 Detector Energy Response and Redistribution Monitoring

To monitor the EPIC energy redistribution, the isolated neutron star RX J1856.6-3754 should be observed twice per year with Small Window THIN filter exposures. MOS calibration needs impose the observation to be performed once at a position 50" offset from the MOS patch, once on the patch position. As also RGS is using this target for monitoring purposes, the observing time was increased to 70 ks and will be counted half and half for EPIC and RGS, respectively. This target is additionally used to monitor the response stability (*i.e.* contamination).
As of the second semester of 2010, the star ζ Orionis was included in the RCP to monitor the energy redistribution, thanks to the prominent and well separated Carbon and Oxygen lines. This target was replaced by N132D in 2013, in order to provide a longer time baseline to study

the evolution of the MOS effective area. This source is also used for monitoring the stability of the pn. It should be observed once per year for 45 ks in Large Window (MOS) and Small Window (pn) mode with the THIN filter. The PA of the observation should be fixed to 248.5°. An annual observation of the the routine calibration target ζ Puppis (§ 2.1.5) will also be used for this monitoring task. In addition, ζ Puppis will be observed once every two years at $50''$ offset for the MOS off-patch response monitoring. The PA of this observation should be 112°.

2.1.1.6 Monitoring of Relative and Absolute Timing Capabilities

The Crab pulsar should be scheduled twice per year for 10 ks each to monitor the EPIC timing capabilities. Both of the 10 ks total time visits should be split into two[3] 5 ks pointings: pn in Burst and Timing Mode with the THICK filter in place. Ideally, these two pointings should be scheduled at different phases of a single orbit to cover different time delays and ground station data links.
For RGS the following setting is used:

- RGS 1: 1 exposure CCDs: - - 3 4 5 - - - -
- RGS 2: 1 exposure CCDs: - - 3 - 5 6 - - -

2.1.1.7 Periodic MOS 1 CCD 6 health check

A test will be periodically done to check variations in the damaged status of MOS1 CCD3 and CCD6. The test shall be performed once per year, nominally about 2 months before the yearly EPIC Operations and Calibration meeting. It will be performed through an Observation Change Request (OCR) issued by the Instrument Engineer and implemented by the Spacecraft Controllers. The test can be done during slews, periods of high radiation or outside the observation window but it cannot be done during operations which require a change in the BRAT. The tests consists in sending a specific Super ED (EE7960, "CCD6 HEALTH CHECK"; total duration 1226 seconds) after verification that the filter wheel is in the CLOSED position. This test does not use science time.

2.1.2 RGS Routine Calibration Monitoring

It is assumed, unless otherwise stated, that during the RGS calibration observations all EPICs will operate the first 10 ks with filters followed or preceded by CAL-CLOSED observations (details are defined in the yearly skeleton plans). The 10 ks exposures with filters different than CAL-CLOSED will be scheduled in the part of the observation closest to apogee, *e.g.* at the beginning of the observation if it is scheduled at the end of the revolution.

2.1.2.1 Confirmation of the Wavelength Scale

Up to the first semester of 2012, the confirmation of the RGS wavelength scale was accomplished with routine observations of AB Dor with one 12.5 ks Thick Filter and one long EPIC CLOSED/CAL-CLOSED exposure (see § 2.1.1.1) performed in parallel. AB Dor is always visible and was scheduled once per year for 50 ks. Subsequently, AB Dor was removed from the RCP to increase the time allocation to PKS 2155-304 and replaced by Capella. The latter was

[3] Three pointings (total exposure time 15 ks) up to the first semester of 2012. The number of exposures has been reduced due to shrinking visibility.

used for *XMM-Newton* RGS gain and CTI monitoring calibration, and occasionally as cross-calibration target until 2015. Due to its drop in visibility it was replaced in 2016 by AB Dor and HR 1099 for the RGS wavelength scale and CTI monitoring, respectively (see also § 2.1.2.4).

2.1.2.2 Long-wavelength Calibration

A single annual 100 ks observation of PSR B0833-45 should be executed to monitor the RGS long-wavelength calibration. The PA should be constrained in the range $294° \pm 15°$ to ensure that the same region of this extended source is encompassed by the RGS aperture.

2.1.2.3 Monitoring of Effective Area

The effective area should be monitored by two observations per year of Mkn 421 (replacing PKS 2155-304 as of 2015). These observations should be executed through varying the pointing direction in five steps along the dispersion axis in order to mitigate the effects of bad pixels and other instrumental features. The exposure time for each step should be 12 ks. The respective pointing offsets are: $-30''$, $-15''$, $0''$, $+15''$, $+30''$[4]. The parallel EPIC exposures with filters other than CAL-CLOSED should correspond to the $0''$ offset.
The *XMM-Newton* cross-calibration target 1ES 1553+113 (see § 2.1.4) can also help in this monitoring task. Up to the 2^{nd} semester of 2011, Mkn 421 was used for this purpose (two 60 ks observations per year). It needed to be replaced due to decreasing visibility.
The soft isolated neutron star RX J1856.6-3754 is a shared target between EPIC and RGS to calibrate the long wavelength effective area. This is the primary target for the measurement of the contamination time evolution (see § 2.1.1.5 for details of the boresight and instrumental configuration).

2.1.2.4 Gain and CTI Monitoring

Mkn 421 should be observed once every two years for 20 ks at large cross-dispersion offsets for CTI monitoring. This observation should be split in two observations of 10 ks each at opposite cross-dispersion offset of $\pm 2'$. In addition, one observation per year (60 ks) of Capella used to be performed for this purpose. However, due to its drop in visibility after 2015, Capella was replaced by HR 1099. The latter should be observed for 50 ks every other year, close in time to the Mkn 421 cross-dispersion offset observations.
Sco X-1 (one CCD at a time to cope with high telemetry rate) should be observed only if required (on-axis, 2 ks per CCD) e.g. after major solar flares. When necessary, specific observations on Sco X-1 with off-axis pointing positions in the cross-dispersion will be requested.

2.1.3 OM Routine Calibration Monitoring

Quoted times for OM include operational overheads. It is assumed, unless otherwise stated, that all EPICs will operate in CLOSED/CAL-CLOSED (details are defined in the yearly skeleton plans) and both RGS will operate in the standard spectroscopy mode with all CCDs read during the OM calibration observations.

[4]This "symmetric pattern" was introduced in the first semester of 2008. Previously, the following "asymmetric pattern" was being used: $-30''$, $-15''$, $0''$, $+10''$, $+20''$

2.1.3.1 Monitoring the Grisms Absolute Flux Calibration

Once per year the two spectro-photometric standard targets GD 153 and HZ 2 should be scheduled for 15 ks each. The observation of HZ 2 is also used to monitor the wavelength scale of the visible grism (see § 2.1.3.2). Since the observations are performed with all filters and grisms, they are also used for photometric performance monitoring of the filters.

2.1.3.2 Monitoring of the Visual and UV Grisms Wavelength Calibration

As mentioned above, HZ 2 is used for wavelength scale monitoring of the Visible grism (an additional 15 ks observation of HD13499 was removed in the 2^{nd} semester 2013).

2.1.3.3 Monitoring the Photometric Calibration

The previously mentioned targets HZ 2 and GD 153 are also used for monitoring the photometric calibration. An additional pair of targets is also used for this purpose:

- BPM 16274: in total, four observations per year, as follows:
  1. two observations per year of 15 ks each, at the nominal aim point;
  2. one off-depletion patch pointing per year, 7 ks;
     PN boresight coordinates: 00 50 15.10, -52 05 46.0, PA $\sim$ 27 deg;
     OM set-up: Filters V, U, B, UVW1, UVM2, UVW2 and WHITE,
     1000 s User defined mode: Image window:
     X0,Y0=[528,528] Xsize,Ysize=[976,960] bin=1 (2x2);
  3. one pointing per year centred on the depletion patch, 7 ks;
     PN boresight coordinates: 00 50 07.06, -52 08 35.8, PA $\sim$ 27 deg;
     OM set-up: Filters V, U, B, UVW1, UVM2, UVW2 and WHITE,
     1000 s User defined mode: Image window:
     X0,Y0=[528,528] Xsize,Ysize=[976,960] bin=1 (2x2).

  Observations 2 and 3 should be performed close in time (ideally within 1-2 weeks) to the 1st semester nominal pointing observation.
- SA 95-42: a single 35 ks observation per year.

2.1.3.4 Engineering Mode Observations

These type of exposures should be performed whenever the OM does not allow any filter observations but needs to be *blocked* because of bright optical sources. A recipe on how to chose engineering mode sequences based on the time available was provided by the OM calibration scientist. Currently the following version applies:

```
Obs.     OM       Sequence of Engineering Modes
Length   Length
[ks]     [s]
-------------------------------------------------------------------------------
 5 - 10   3675    Flat low
10 - 15   8908    E6, Flat low, Dark low
15 - 20  13736    E6, Flat high
20 - 25  17411    E6, Dark low, Flat high
```

25 - 30	24360	Flat high, Full Frame High Res.
30 - 35	29593	E6, Flat high, Full Frame High Res., Flat low
35 - 40	33268	E6, Flat low, Dark low, Full Frame High Res., Flat high
40 - 45	38096	E6, Flat high, Flat high, Full Frame High Res.
45 - 50	41771	E6, Flat high, Flat high, Full Frame High Res., Flat low
50 - 55	48720	Flat high, Flat high, Full Frame High Res., Full Frame High Res.
55 - 60	53953	E6, Flat high, Flat high, Full Frame High Res., Full Frame High Res., Flat low
60 - 65	57628	E6, Flat high, Flat high, Full Frame High Res., Full Frame High Res., Flat low, Dark low
65 - 70	64014	E6, Flat high, Flat high, Flat high, Full Frame High Res., Full Frame High Res., E6

these observations do not reduce the time available for science.

2.1.3.5 Flat fields and dark frames

Independently of the Engineering observations described in Section 2.1.3.4, flat fields and dark frames should be obtained more or less periodically at time intervals around 10 days. The ODB activities "FLAT LOW" and "DARK LOW" shall be used respectively. These observations should be scheduled during slews. The default duration of DARK LOW is 4109 s (1500 s exposure time + 2609 s overhead), and of FLAT LOW 4140 s (1500 s exposure time + 2640 s overhead). The distribution between flat fields and dark frame exposures is established by the following rule: every four revolutions, a Rule & Constraints File (RCF) is uploaded, which yields flat field exposures during slews (when sufficient observing time is available to accommodate them); otherwise a RCF is uploaded, which yields dark frame exposures during slews.

2.1.4 *XMM-Newton* Cross Calibration

In 2003, a major cross-calibration campaign started at the *XMM-Newton* SOC in collaboration with the Instrument Principle Investigator teams. After reaching a good status for the calibration of the individual instruments, the project decided to put significant efforts both into the internal agreement of the *XMM-Newton* detectors and the cross-calibration with other observatories, especially with the *Chandra* X-ray satellite.
The main cross-calibration target with *Chandra*/*Suzaku*/*Swift* was PKS 2155-304, which was used until 2014. In 2015 it was replaced by 3C 273, as the PKS 2155-304 spectrum is too steep, and therefore too weak for NuSTAR, which joined the campaign soon after its launch. In 2017 it was decided to change the EPIC filters to Thick (from the original Medium and Thin for the MOSs and PN, respectively) in order to reduce the count rate, which for 3C 273 in general varies around the pile-up limit.
The multi-mission cross-calibration target is observed once per year in spring for 60 ks exposure time, simultaneously with the above missions still in operation.
For internal cross-calibration, 3C 273 was used together with PKS 2155-304. As of 2013, 3C 273 has been replaced by the blazar 1ES 1553+113 (Perlman et al., 2005, ApJ, 625, 727). This target was selected from an *XMM-Newton*-based study of a large sample of blazar (de la Calle-Pèrez et al., in prep.) complemented with the CAIXA sample of radio-quiet AGN (Bianchi et al., 2009, A&A, 495, 421). According to the results of this study, 1ES 1553+113 is the X-ray brightest AGN in the 2–10 keV energy band, whose X-ray spectrum is only negligibly

affected by intervening obscuration, and not (or only marginally) affected by pile-up even in Small Window Mode. The last conditions ensures that one does not need to excise the PSF core when extracting scientific spectra. The cross-calibration results would be therefore not affected by any additional systematic uncertainties due to the Encircled Energy Fraction correction. This blazar may occasionally be replaced by Capella on request.
The setup for these cross-calibration targets is:

3C 273:

- EPIC-pn: Small Window, THICK filter
- EPIC-MOS: Small Window, THICK filter
- RGS: spectroscopy

1ES 1553+113:

- EPIC-pn: Small Window, MEDIUM filter
- EPIC-MOS: Small Window, MEDIUM filter
- RGS: spectroscopy

2.1.5 *XMM-Newton* Long-Wavelength Response

This routine calibration task will be addressed by one annual 60 ks observation of ζ Puppis. EPIC will normally be scheduled with Small Window THICK filter exposures, see § 2.1.1.5.

3 Deviations from the RCP

On a few occasions, the RCP has been temporarily modified to accommodate specific experiments within the RCP budget. These changes have implied modifications of the allocated time for specific targets, and/or changes of the instrumental configuration. These changes are listed in this Section.

3.1 1^{st} semester 2016

- In order to accumulate instrumental background data for PN Large Window Mode (a mode currently under-represented in the filter-wheel closed data repository), an additional 10 ks LW/CLOSED exposure was performed during the observation of the RGS calibration target PSR B0833-45 (Rev.#3008). Due to the time available for this observation the additional exposure could be fit in without affecting the nominal times for the other PN exposures.
- For the same reason as above, the PN set-up was changed in the cross-dispersion observations of the RGS calibration target Mkn 421: the nominal PN EFF/CLOSED exposures were replaced by LW/CLOSED (2 $\times$ 7 ks, Rev.#3015).

3.2 2^{nd} semester 2014

- The MOS1 is operated with the MEDIUM Filter while observing 1ES 0102-72, to allow evaluating any damages to the optical filter which might have occurred during the MOS1-CCD3 event (possible micrometeorite impact) in Rev.#2382.

3.3 2nd semester 2013

- The observation of 1ES 0102-72 shall be performed with the same instrumental configuration, detector coordinate position, and position angle as in Rev.#1443, to ensure that the comparison of the measured count rates provides a direct measurement of the MOS effective area degradation. The same applies to the observation of N132D, which shall be performed with the same instrumental configuration, detector coordinate position, and position angle as in Rev.#1311 (due to positional angle constraints, this observation must be scheduled in the *first semester 2014*).

3.4 1nd semester 2013

- The observation of RX J1856.6-3754 is performed at the same position in detector coordinates as in Rev.#1335, to allow a direct comparison of the observed flux well-off patch and at the same vignetting positions.

3.5 2nd semester 2012

- The observation of 1ES 1553+113 is replaced by an observation of 3C 273 coordinated with NuSTAR, in the framework of the *Chandra-NuSTAR-XMM-Newton* cross-calibration program.

- The observation of 1ES 0102-72 is performed on-axis, and split in 3 exposures of 15 ks each (*i.e.*, 45 ks net exposure time are planned in 2012-2013 rather then the allocated 30 ks). In each exposure a different EPIC optical blocking filter is used: THIN, MEDIUM, THICK. The main goal of this experiment is to disentangle the dependency on time and filter in the long-term evolution of the Oxygen and Neon line complex normalisations in the MOS spectra (Plucinsky et al., in preparation). This observation aims also at checking the quality of the relative filter calibration.

3.6 1st semester 2012

One of the two EPIC-pn Burst Mode exposures on the *Crab Nebula* is performed with the offset map calculated with the **CLOSED filter**. The primary aim of this experiment is testing the effect of X-ray loading on spectra in Timing Mode. The operational requirement of this experiment are laid down in EOR-10

3.7 2nd semester 2011

- the *B0102-72.3* EPIC-pn exposure is performed in **Timing Mode**, in the framework of its overall recalibration exercise. An observation of the same target at a position close to the readout node is requested in the same semester as NRCO

- the time allocated to *RX J1856.6-3754* is increased to a total of **100 ks** net exposure, split in four observations of **25 ks** net exposure time each. This has been decided to accommodate a raster experiment along the EPIC-pn `RAWX` coordinate, aiming at verifying the positional dependence of the EPIC-pn soft energy response. The time increment does not impact the overall calibration time budget because the net exposure time on ζ Orionis is reduced to **45 ks**

- one of the two EPIC-pn Burst Mode exposures on the *Crab Nebula* is performed in **Timing Mode**, with the offset map calculated with the **CLOSED filter**. The primary aim of this experiment is testing the effect of X-ray loading on spectra in Timing Mode. This requires manual intervention via an OCR (see EOR-9).

- the RGS exposure of *Capella* is performed in **multi-pointing mode**, using a **2×faster readout sequence** for those CCDs where the brightest lines (*e.g.*, FeXVII, OVII) are located in order to mitigate pile-up in the line core. The following non-standard sequences have been implemented:

  - RGS1: 125634568956
  - RGS2: 125637568956

4 Annexes

4.1 Term Planning Skeleton

Routine calibration monitoring formally has started after the revolutions affected by the Cluster launch (i.e. after Rev.#113).
Every year a planning skeleton of the upcoming routine calibration observations is defined in agreement with the calibration scientists and instrument teams. This plan may be included in the general long-term plan for all *XMM-Newton* observations that is available from the WWW at `http://xmm.esac.esa.int/external/xmm_sched/advance_plan.shtml`.
As mission planning constraints can cause a scheduling different from that in the routine calibration planning skeleton, the *XMM-Newton* Observation Log Browser should be checked for info on the actual scheduling and success of a specific routine calibration observation (see URL `http://xmm.esac.esa.int/external/xmm_obs_info/obs_view_frame.shtml`). The "XMM-Newton Observation Lokator" (`http://xmm2.esac.esa.int/external/xmm_sched/obs_lokator/index.php`) can be used to look for targets included in the Routine Calibration Plan but not scheduled yet.
All detailed routine calibration observation implementation plans from 2003 onwards can be found in the EPIC internal calibration web pages:
`http://xmm2.esac.esa.int/x̃mmdoc/internal/int_cal_instr_supp/epic/idt.php`. Older plans are listed in the subsection below.

4.1.1 Planning skeleton for part of year 2000

Planning of *XMM-Newton* routine calibration monitoring after Rev.#113 for the year 2000.

```
Revolutions 122 - 125: affected by Cluster launch
Revolution 121: OY Car, OM fast mode test
Revolution 122 or 123 (if possible): pn CTI check (20 h)
prior to Rev. 125: PG0136+251, EPIC contamination
October, after eclipses: NGC 2516, EPIC metrology
```

4.1.2 Routine calibration plan for Jan - Mar 2001

Planning for the routine calibration observations in Jan-Mar 2001 (i.e. revolutions from 196 to 239).

```
Rev.    Target   Visib.    Time  Objectives
-----------------------------------------------------------------------------
>= 196  AB Dor   196-239   50ks  RGS wavelength
>= 196  N132D    196-236   25ks  EPIC eff area, gain, offset
>= 208  HR1099   208-223   40ks  RGS wavelength
>= 219  Sco X-1  219-230  ~20ks  RGS CTI, EPIC burst, RFS, ff-> PSF wings
~= 220  EXO0748  196-239  ~50ks  OM contam & calib (replaces LBB227)
>= 225  Capella  225-239   30ks  RGS wavelength
>= 238  RXJ0720  238-239   55ks  EPIC contamination
~= 239  AB Dor   196-239   50ks  RGS wavelength
------------------------------------------------------------------------------

 Assuming an average of 2ks for instrument set-up overheads and 6ks for slews
(CLOSED+OPEN), the total amount of time to be spent for routine calibrations
in these three months is ~380 ks.
```

Comments: *N132D analysis of previous failure still pending - was replaced by an observation of NGC 2516. RXJ0720 probably needs major updates of SAS and DB to allow correct analysis of earlier observation - on hold. The last AB Dor observation was dropped as Capella was late and as the next AB Dor observation is planned for rev 250 already.*

4.1.3 Routine calibration plan for Apr - Jun 2001

Planning for the routine calibration observations in Apr-Jun 2001 (i.e. revolutions from 240 to 286).

```
Rev.    Target   Visib.    Time   Objectives
------------------------------------------------------------------------------
=> 240  1ES0102  240-276    30ks  EPIC gain/offset & eff. area
~= 250  AB Dor   240-286    50ks  RGS wavelength
=> 256  Mkn421   256-271    50ks  RGS eff. area
~= 260  EXO0748  240-286    35ks  OM photomometry (last done in 212 TBC)
~= 265  AB Dor   240-286    50ks  RGS wavelength
=> 277  3C273    277-286   100ks  RGS eff. area (not visib. 284, should be
                                  coordinated with SAX(?)/Chandra) &
                                  OM contamination
~= 280  AB Dor   240-286    50ks  RGS wavelength
------------------------------------------------------------------------------

Assuming an average of 2ks for instrument set-up overheads and 6ks for slews
(CLOSED+OPEN), the total amount of time to be spent for routine calibrations
in these three months is ~440 ks (~ 7% of available time).
```

4.1.4 Routine calibration plan for Jul - Dec 2001

Planning for the routine calibration observations in Jul-Dec 2001 (i.e. revolutions from 287 to 378).

```
Rev.    Target   Visib.    Time   Objectives
------------------------------------------------------------------------------
=>291   G153     291-312    30ks  OM photometry
~=310   HR1099   301-316    40ks  RGS wavelength scale
```

~=325	N132D	287-378	25ks	EPIC gain/offset & eff. area
~=340	AB Dor	287-378	50ks	RGS wavelength scale
>344?	NGC2516	287-378	20ks	EPIC stability of boresight (after eclipse)
~=351	EXO0748	287-378	40ks	OM photometry (raster)
~=370	N132D	287-378	25ks	EPIC gain/offset & eff. area
~=370	AB Dor	287-378	50ks	RGS wavelength scale
<=380	3C273	368-381	100ks	RGS eff area (coord), OM photometry, EPIC (parasitically) spectr. capab. & contam.

Note: 3C273 might be replaced by PKS2155.
Assuming an average of 2ks for instrument set-up overheads and 6ks for slews (CLOSED+OPEN), the total amount of time to be spent for routine calibrations in these six months is ~452 ks. If one assumes 10432ks available time the percentage of time for routine calibration will be ~4.3%.

As the OM team suggested, there might be some more time needed for OM NRCOs.

4.1.5 Routine calibration plan for Feb - Jun 2002

Planning for the routine calibration observations in Feb-Jun 2002 (i.e. revolutions from 394 to 468). Note that in Jan 2002 no routine calibrations were performed due to mission planning constraints.

Rev.	Target	Visib.	Time	Objectives
>=396	LBB227	396-409	15ks	OM photometry
~=402	N132D	always	25ks	EPIC gain/offset & eff. area
~=410	GD71	410-425	35ks	OM spectrophotometric Grism
~=415	Capella	408-423	30ks	RGS wavelength scale
~=432	1ES0102	423-459	25ks	EPIC gain/offset & eff. area
>=436	NGC2516	always	20ks	EPIC stability of boresight (after eclipse)
~=439	EXO0748	always	50ks	OM photometry
>=444	BPM16274	444-464	15ks	OM photometry
~=450	PKS2155	438-451	100ks	RGS eff area (coord), OM, EPIC (parasitically) spectr. capab. & contam.
~=460	AB Dor	always	50ks	RGS wavelength scale
~=460	GD153	460-468	35ks	OM spectrophotometric Grism
~=462	N132D	always	25ks	EPIC gain/offset & eff. area

Assuming an average of 2ks for instrument set-up overheads and 6ks for slews (CLOSED+OPEN), the total amount of time to be spent for routine calibrations in these five months is ~425+(12*8)=521ks. If one assumes 140ks available time per revolution, the period covered here (75 revolutions) is 10500ks and hence the percentage of time for routine calibration will be ~5%.

Comments: *LBB227 has been replaced by a NRCO: OM photometric zeropoints (target Feig 16 offset, 25 ks). GD71 was finally removed from the plan and replaced by target SA 95. NGC2516 was dropped in this term.*

4.1.6 Routine calibration plan for Jul - Dec 2002

Rev.	Target	Visib.	Time	Objectives

```
469   N132D      always    25ks  EPIC gain/offset & eff. area
470   GD 153     460-474,  15ks  OM spectrophotometry, EPIC (CAL)CLOSED
                 552-566
480   HD8867     465-480   28ks  OM grism wavelength (5x4ks raster)
480   HD13499    470-487   16ks  OM grism wavelength (3x4ks raster)
480   ?          n.a.      23ks  EPIC (CAL)CLOSED (dedicated)
489   Hz 4       486-501    4ks  OM UV flux (not 499)
489   GD50       484-499    4ks  OM UV flux
489   BD+33 2642 478-499    4ks  OM UV flux
490   HR1099     484-499   40ks  RGS wavelength scale, EPIC (CAL)CLOSED
501   Hz 2       492-496,  15ks  OM grism flux, EPIC (CAL)CLOSED
                 501-506
515   Capella    501-517   30ks  RGS wavelength scale, EPIC (CAL)CLOSED
                                 (after eclipse, coord. with Chandra!)
517   1ES0102    517-551   30ks  EPIC gain/offset & eff. area
525   ?          n.a.      23ks  EPIC (CAL)CLOSED (dedicated)
535   PKS2155    531-544  100ks  RGS eff area, OM & EPIC parasitically
                                 (coord. with Chandra!),EPIC (CAL)CLOSED
541   NGC7293    534,535,  15ks  OM grism flux (ONLY IF NO AO-2 TARGET!)
                 538-546         EPIC (CAL)CLOSED
542   G93-48     533-535,   4ks  OM UV flux
                 538-546
542   BD+284211  541-557    4ks  OM UV flux
547   1ES0102    517-551   30ks  EPIC gain/offset & eff. area
550   AB Dor     always    50ks  RGS wavelength scale, EPIC (CAL)CLOSED
552   BPM 16274  537-556   15ks  OM spectrophotometry, EPIC (CAL)CLOSED
-----------------------------------------------------------------------------

Assuming an average of 2ks for instrument set-up overheads and 6ks for slews
(closed+open), the total amount of time to be spent for routine calibrations
in these six months is ~124ks+{11 targets*(2ks(overhead)+6ks(slew)}=212ks.
If one assumes 135ks available time per revolution, the period covered here
(93 revolutions) is 12555ks and hence the percentage of time for routine
calibration will be ~5%.
```

Comments: *HD8867 was finally removed from the plan. For HD13499 a* 3×8 *ks raster was performed. Dedicated EPIC (CAL-)CLOSED observations in revs. 480 and 525 were dropped as several such observations could be performed parasitically to non EPIC routine cal. and non-routine cal. observations.*