Integral EO

Feasibility of EO pre-perigee

INTEGRAL MOC

Content

- Operational effort for an EO
- Problems with post-perigee EOs in 2012
- The proposal: pre-perigee EOs
  - Risk assessment
  - Results of preliminary analysis of feasibility of pre-perigee EO
- Open issues / way to go ahead (?)

Operational effort for EO

- EOs from operational point of view: highly "non-standard"
  - Earth inside the star tracker's & instruments' FoVs
  - Attitude constraint violated (angular separation between STR & Earth <15°)
  - Duration of operation of an EO post perigee:
    - Before perigee of rev. EO-1: 5 hours
    - After perigee of rev. EO: 20 hours
  - **Operational success ensured by careful planning of EO and lots of effort on all sides (ISOC, FD, FCT):**
    - **Planning starts 7 weeks before the EO & consists of 38 steps**
    - **Preliminary planning, final planning, detailed sequence of events, careful review of sequence, TN with all the relevant information**
    - **Regular meetings, telecons and emails to follow up of status**
    - **Execution of EO: dedicated EO shifts (software support on-call, FD & FCT on site), ISDC on call, ISDC activities**

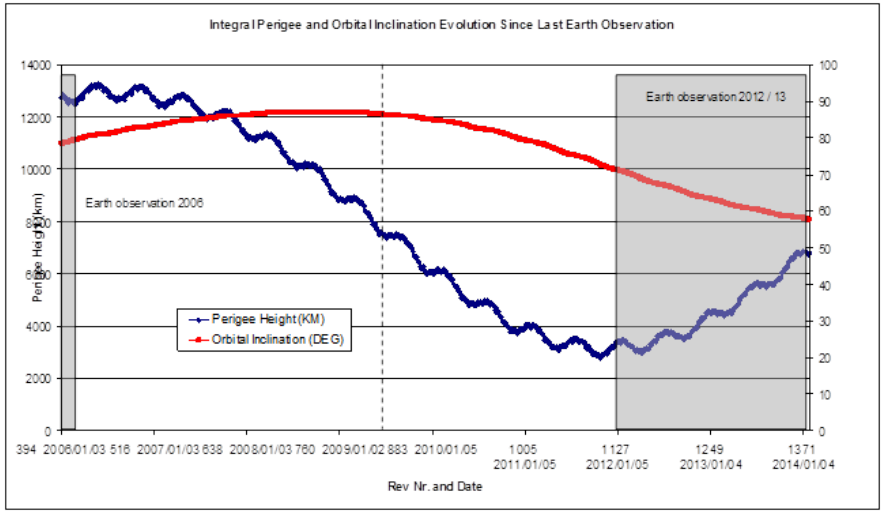
Background

- Earth occultation observations in 2006:
  - In total: 4 EOs executed within 2 weeks
  - EO post perigee
  - Close to sol. minimum
  - More manpower
  - Test the non-standard observation technique

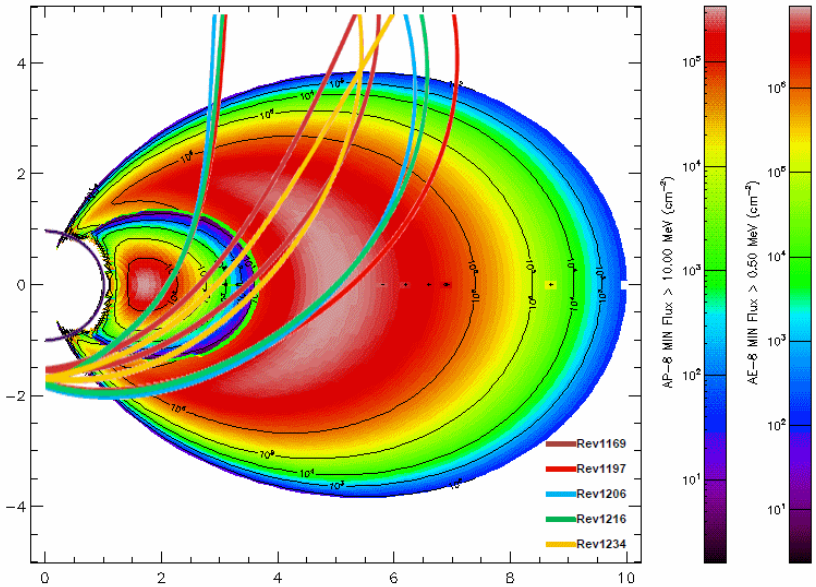
- Earth occultation observations 2012 onwards:
  - Up to now: 5 EOs (EO 2.6 cancelled due to G/S issues)
  - Same strategy as in 2006
  - Benefit from both
    - Reduced contamination by foreground sources
    - Reduced emission of the Earth's atmosphere itself above ~70 keV due to the increase of solar activity
  - But: effects due to orbital evolution

Differences between EOs in 2006 & 2012

- Orbital & belt exit evolution
  - Lower perigee height
- Different
  - Illumination
  - Radiation environment
  - Position in solar cycle
  - Activation of S/C after perigee



	Perigee height [km]	Rad belt exit alt. [km]	Duration of STR blinding (15°) [hours]	STR blinding actual
EO 1.1	12730	40000	08:20	04:15
EO 1.2	12578	40000	08:24	04:15
EO 1.3	12654	40000	08:24	04:07
EO 1.4	12648	40000	08:25	04:08
EO 2.1	3285	53000	16:09	08:02
EO 2.2	3780	50000	15:31	05:50
EO 2.3	3648	50000	16:42	06:14
EO 2.4	3575	50000	15:47	06:43
EO 2.5	4166	56000	15:03	05:33

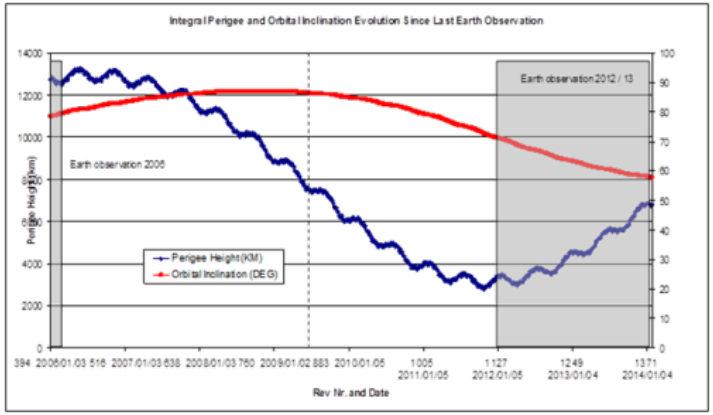


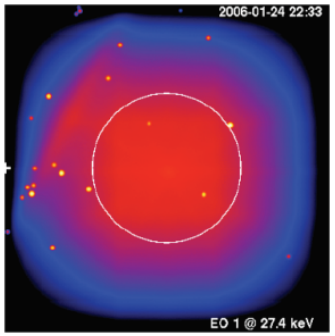
Belts Exit Evolution for EOs in 2012

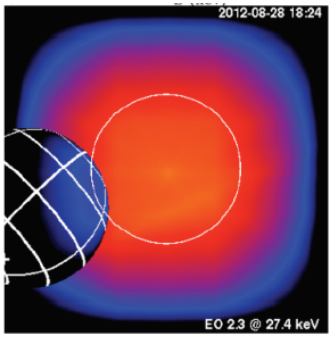
BUT: Problems with post-perigee EOs in 2012

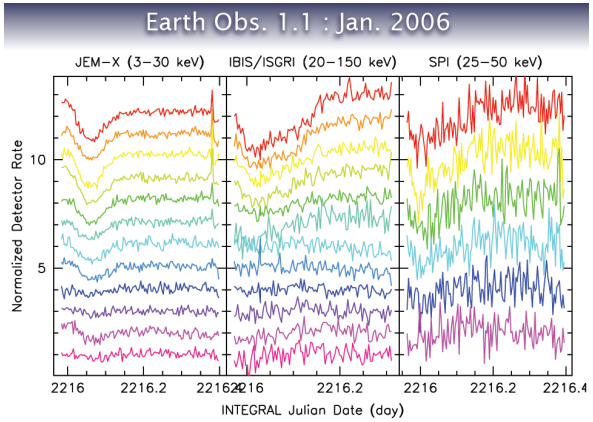
- Analysis performed by Marc Türler
  - Fast change in flux needed & ideally have full detector light curve available
  - Mainly IBIS data, additional JEM-X
- Difference to EOs in 2006 due to INT orbit evolution
  - Late rad. belt exit → Earth already half way within IBIS FoV at observation start (close to max. occultation). This will not change for the next years.
  - Low perigee → satellite is charged/activated from belts passage → count rates decay until half way through EO and overlay EO modulation
  - Observations are ~2x longer than in 2006

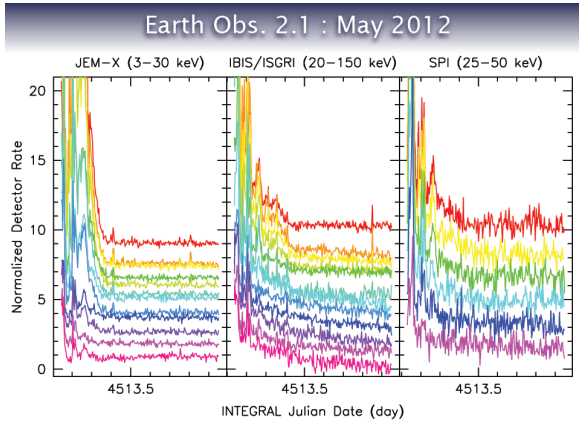
⇨ **not possible to extract the occultation signals**

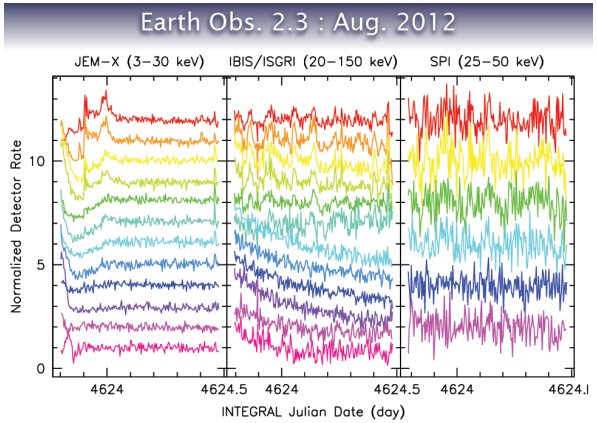






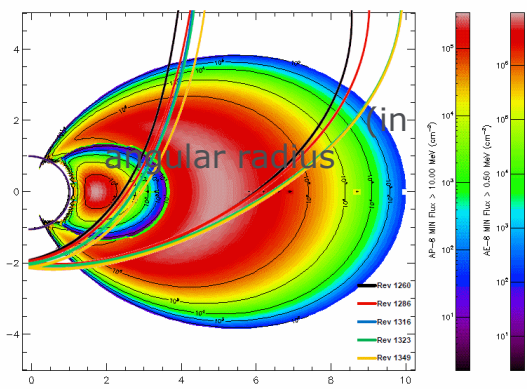






The proposal: EO pre-perigee

- Proposal was already made in the past
  - Considered possibly risky in case of instrument failure pre-perigee → too little reaction time
  - But: non standard observation now tested; lots of experience with EOs → new assessment of original proposal possible
- Advantages of pre-perigee EO
  - Lower instrument's internal background: background not biased following belts passage → better data quality → possible to extract EO modulation
  - Whole light curve / transit of Earth through FoV available within IBIS window possible
  - EO at lower altitude
    - Critical alt. at belts entry is much lower than at belts exit 2006 this was not the case) → larger Earth apparent (4-8°)
    - Earth moves faster → duration of EO is (potentially) shorter
      - Easier to meet the off-on-off pointing requirement
      - Less manpower shifts



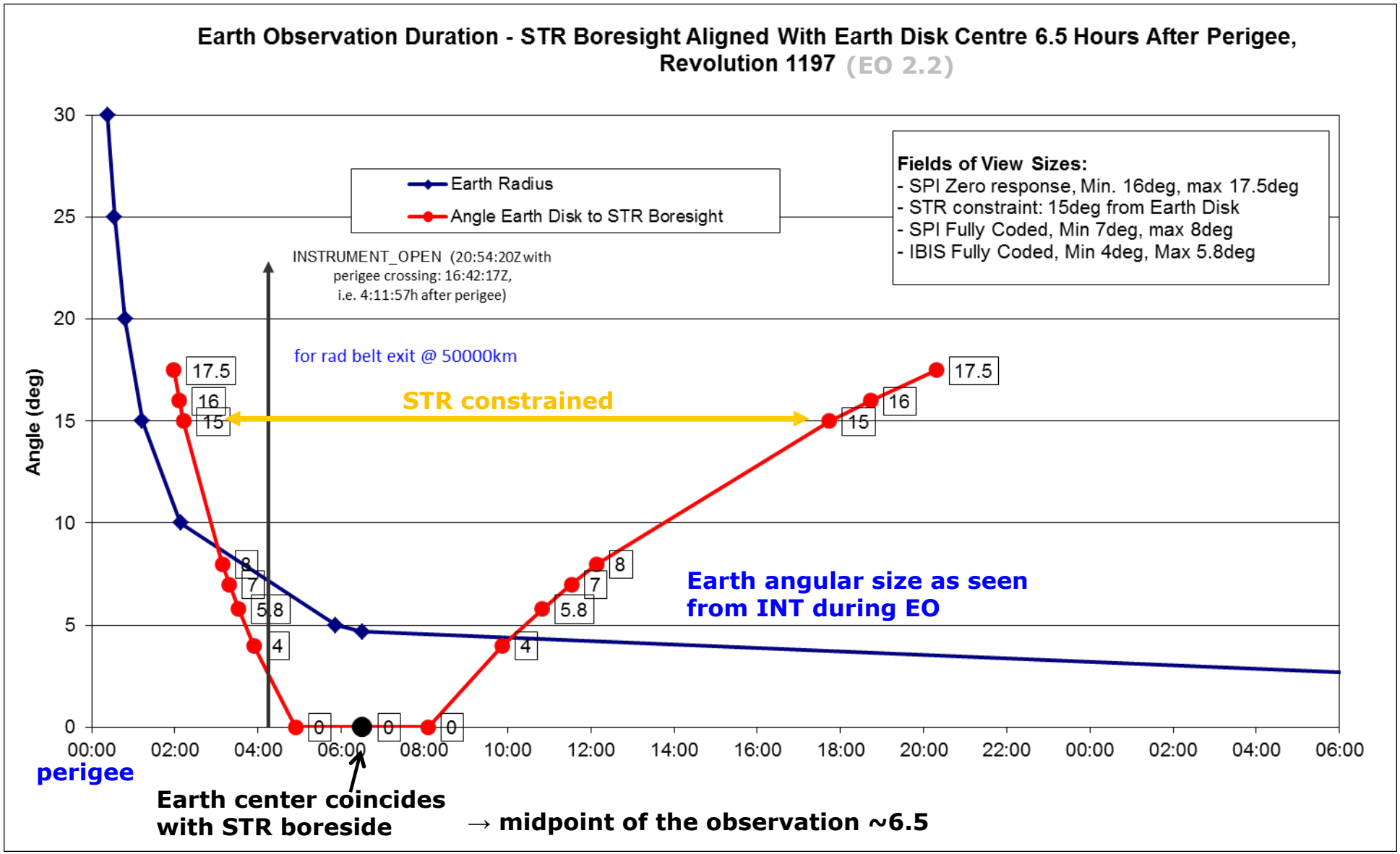
Analysis of pre-perigee EO operations

- SVM operations analysis
  - Only affected subsystem during EO: AOCS → star tracker blinding
  - AOCS designed to cope with STR blinding → no impact in this config. (esp. during rad. belts)
  - Necessary for implementation of pre-perigee EO
    - Before EO: period of stable pointing for IMU calibration before EO
    - **After EO: enough time for attitude reconstruction pre LOS at perigee, potentially CGS (impact of perigee passage without Guide Star, attitude drift of about 1DEG in yaw)**
- PLM operations analysis
  - **Nominal operation from T/L identical to nominal rev. (belts entry & instr. deactivation)**
  - Added protection for PLM
    - Protection against high rad. environment: internal (JEM-X) & IREM O/P (OMC & IBIS)
    - Standard procedures for commanding instruments in a safe configuration if necessary
    - **Leave radiation monitor flag (DRMC) in BCPKT enabled. This might lead to an increased risk of interrupting EO due to IREM crash (OMC, IBIS only).**
    - G/S: Use of Maspalomas gives more flexibility - LOS is ~20min later than KIRUNA
  - Possible further safety measures
    - Create contingency sequences for each instrument to switch PLM safe quickly
    - Double G/S coverage during 1st pre-perigee EO (TBD)
    - Perth G/S to cover period around perigee (TBD)
  - → **no foreseeable additional risks and safety issues**

Analysis of pre-perigee EO

- Analysis for EO-midpoints at 3-8 hrs before perigee
  - Pointing constraints, apparent Earth angular radius, EO duration,…
- Main trade off
  - EO as close as possible to perigee, BUT end of STR blinding at around LOS_CHECK window -30min (time to recover STR Ops.)
  - Use of Maspalomas would give more flexibility since LOS at MSP is about 20min later than at REDU or KIRUNA

EO post-perigee: EO duration
(STR boresight aligned with Earth disc centre)



EO pre-perigee: EO duration
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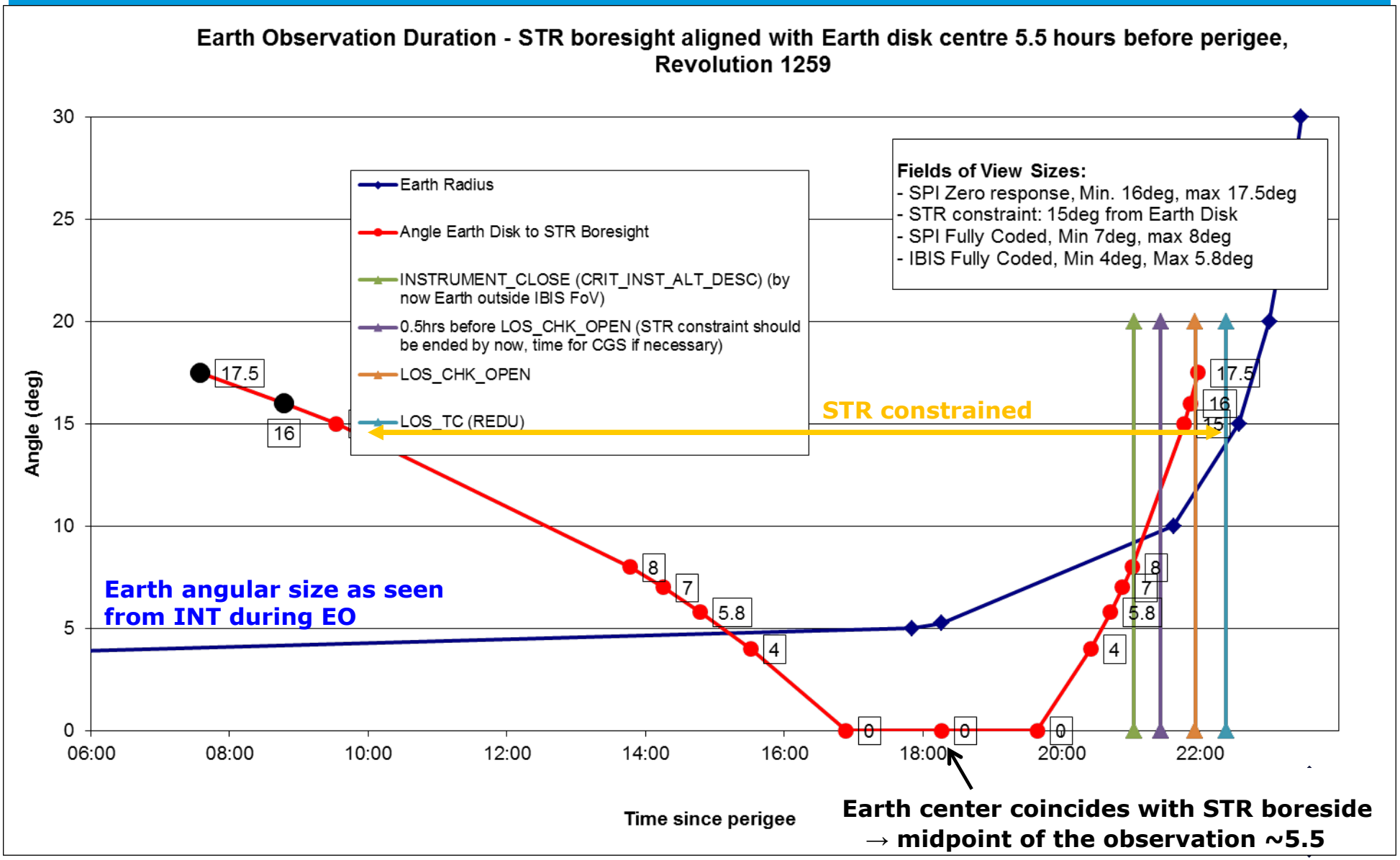
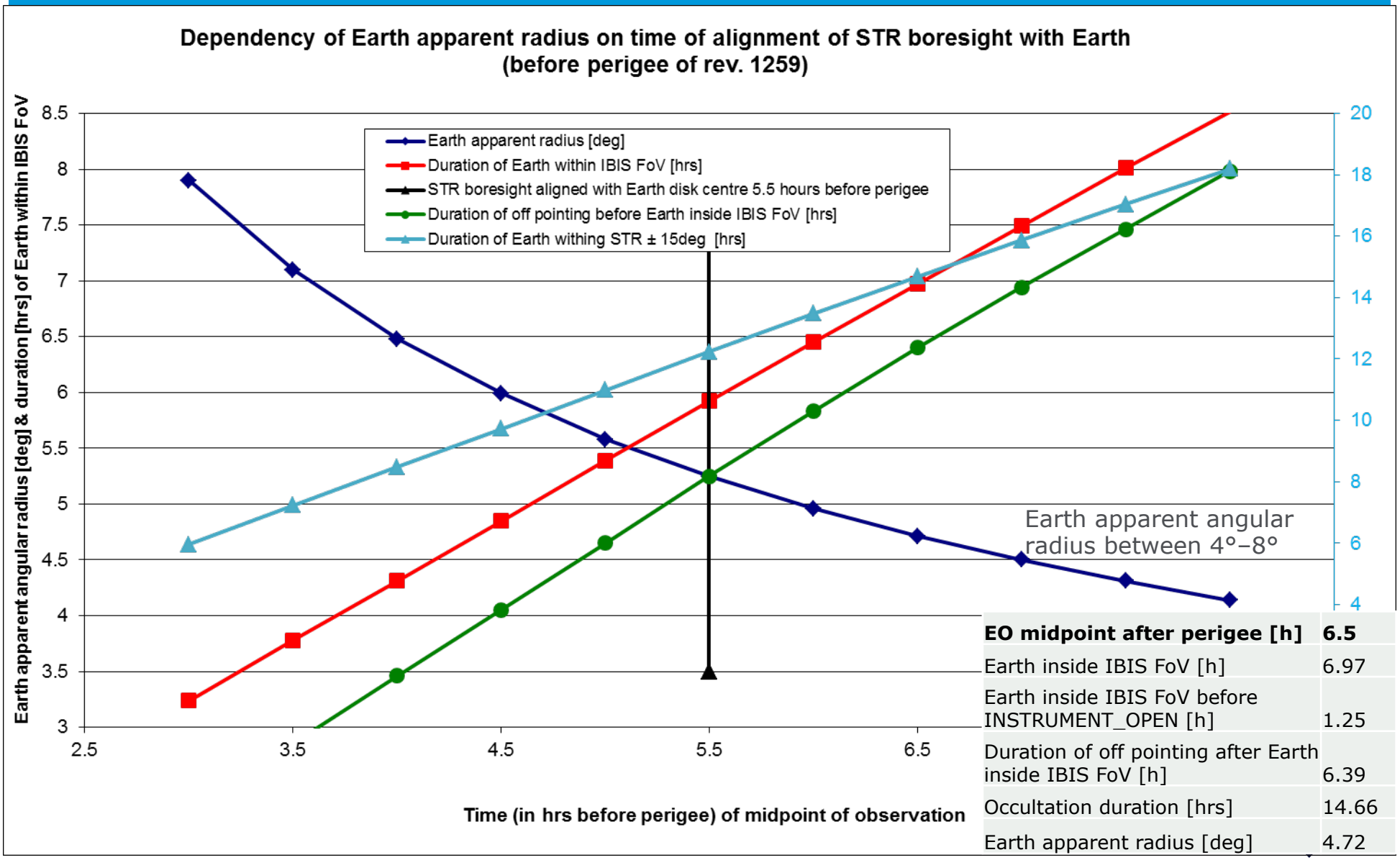


Results: EO pre-perigee

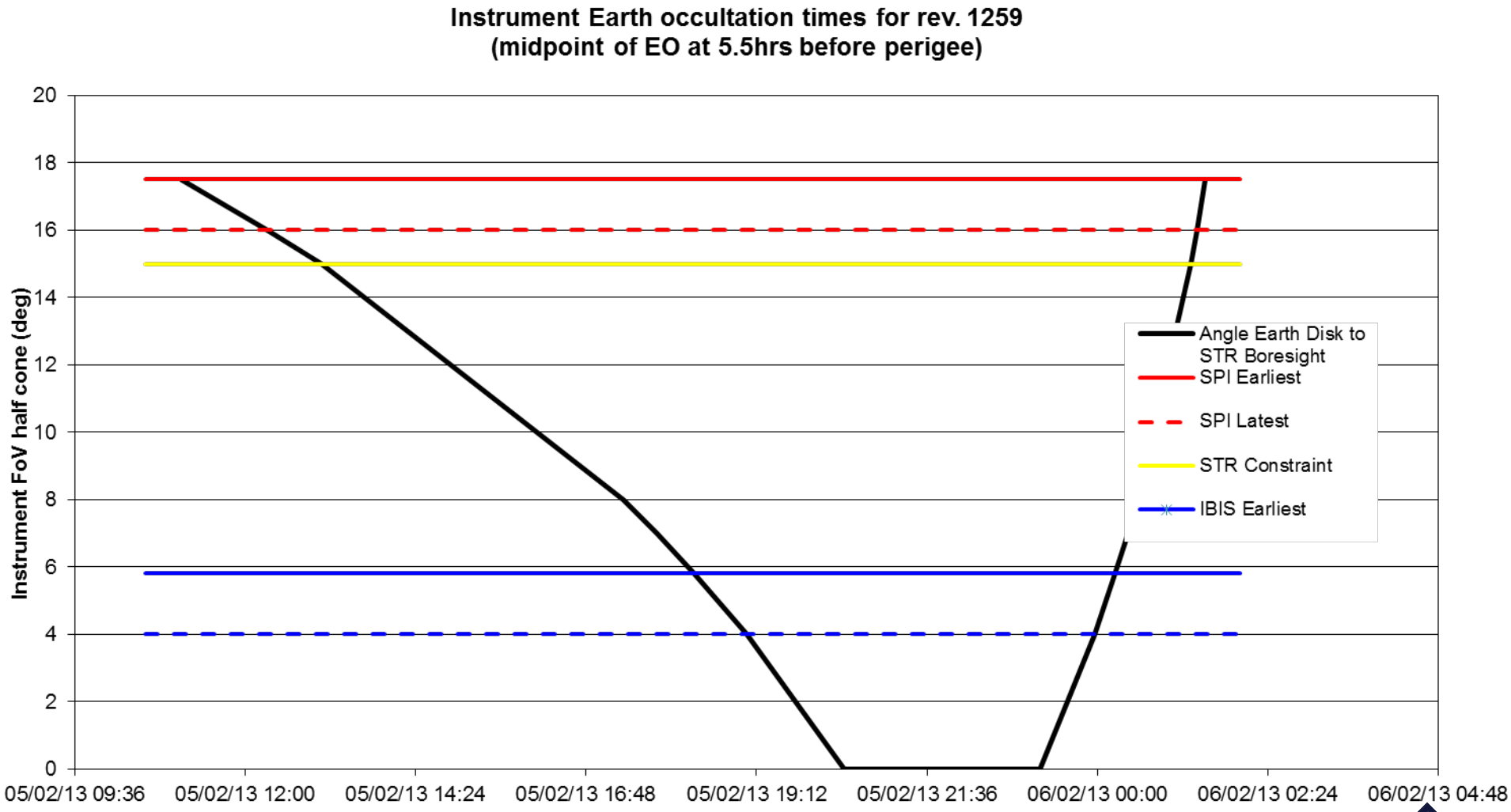


EO midpoint after perigee [h]	6.5
Earth inside IBIS FoV [h]	6.97
Earth inside IBIS FoV before INSTRUMENT_OPEN [h]	1.25
Duration of off pointing after Earth inside IBIS FoV [h]	6.39
Occultation duration [hrs]	14.66
Earth apparent radius [deg]	4.72

EO pre-perigee: Our proposals

- **Results**
  - EO dates have to be re-scheduled
  - The Earth position relative to the galactic plane is different wrt to the post perigee case. The galactic coordinates of the EO pointings are in the range:
    - 302°–330° longitude
    - 2°-18° latitude
- **Our Proposals**
  - Additional requirement: Earth transit fully within IBIS FoV
  - EO executed with midpoint of observation **5.5hrs before perigee** (example EO: rev 1259):
    - Duration of Earth within IBIS FoV ("on-pointing"): 6 hrs
    - Duration of STR constraint: 12.25 hrs
    - Off-pointing before EO with STR being constrained: 5.25 hrs
    - Short off pointing until perigee & shortly after perigee (but S/C activated)

Results: EO pre-perigee
Instrument Earth occultation times



Pre-perigee EO: Proposed sequence of operations

- **Last part of revolution EO**
  - **Adjust PST load for pre-perigee EO before or after slew to EO**
  - PREQ to EO attitude as science slew (OSL + corrective CSL) – TL **(at EOA: off-pointing performed before on-pointing)**
  - Disable timeline commanding to
    - AOCS until after the exit from STR constraint in rev. 1169
    - OBDH until perigee
  - IMU switch on and calibration (>2h thermal stability and 1h calibration) **(not needed in case performed recently)**
  - INSTRUMENT_CLOSE (CRIT_INST_ALT_DESC) – TL

Results of first assessment:

- The current EO strategy works for planning of pre-perigee EOs

Differences wrt EO post-perigee:

- STR blinding is pre-perigee
- EO will extend to a lower altitude
- Operations may be slightly simplified
  - Leave DRMC enabled → no tricks with Broadcast Group 1 parameters needed
  - No group 1 load during EO

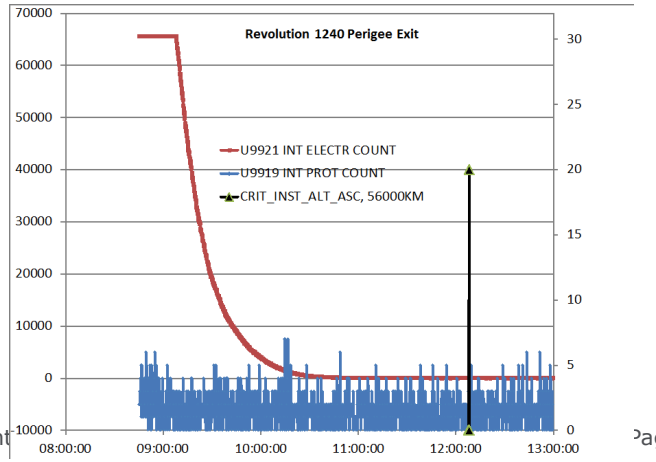
Execution of EO pre-perigee:

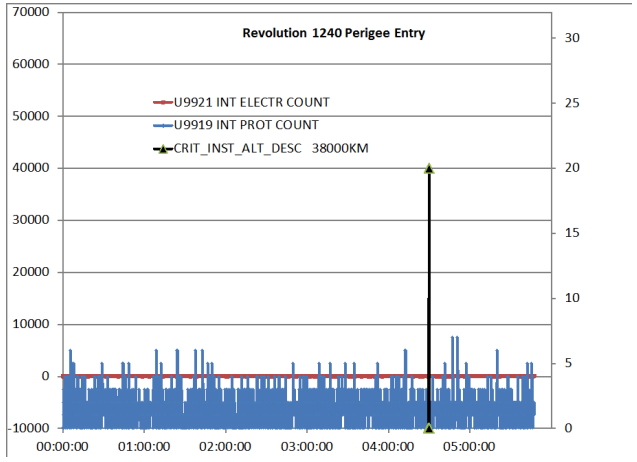
- Slew back to EO attitude post perigee will be executed below the belts → reduced science time for EO

- **Revolution EO+1**
  - AOS TC
  - Return STR to AOCS Control Loop – Manual, reconfiguration of SVM: 1.5h
  - Execute Recover schedule to EO attitude to compensate for drift – Manual
  - PREQ to Earth observation attitude – not to be executed – TL
  - Return BCPKT OTF to automatic control (remove OTF override) – Manual
  - In parallel: start of nominal instruments calibration and activation – TL
  - RWB
  - PREQ to next science attitude

Conclusions & recommendations to IUG

- MOC's recommendations: Perform pre-perigee EO
  - Post-perigee EO strategy works for pre-perigee EOs (needs to be adapted)
  - Science outcome probably better
  - No obvious risks or problems associated with pre-perigee EO
  - Operations possibly slightly less complex
  - Transfer TM allocation from SPI to IBIS? (SPI data used at all?)
  - Lower rad. belt entry altitude (conservative) → later instr. Close → later EO
    - Belts entry altitude is kept artificially high to allow MOC to react in case of failure of instruments to go to safe mode at belts entry. Recommendation: reduced this for individual EOs

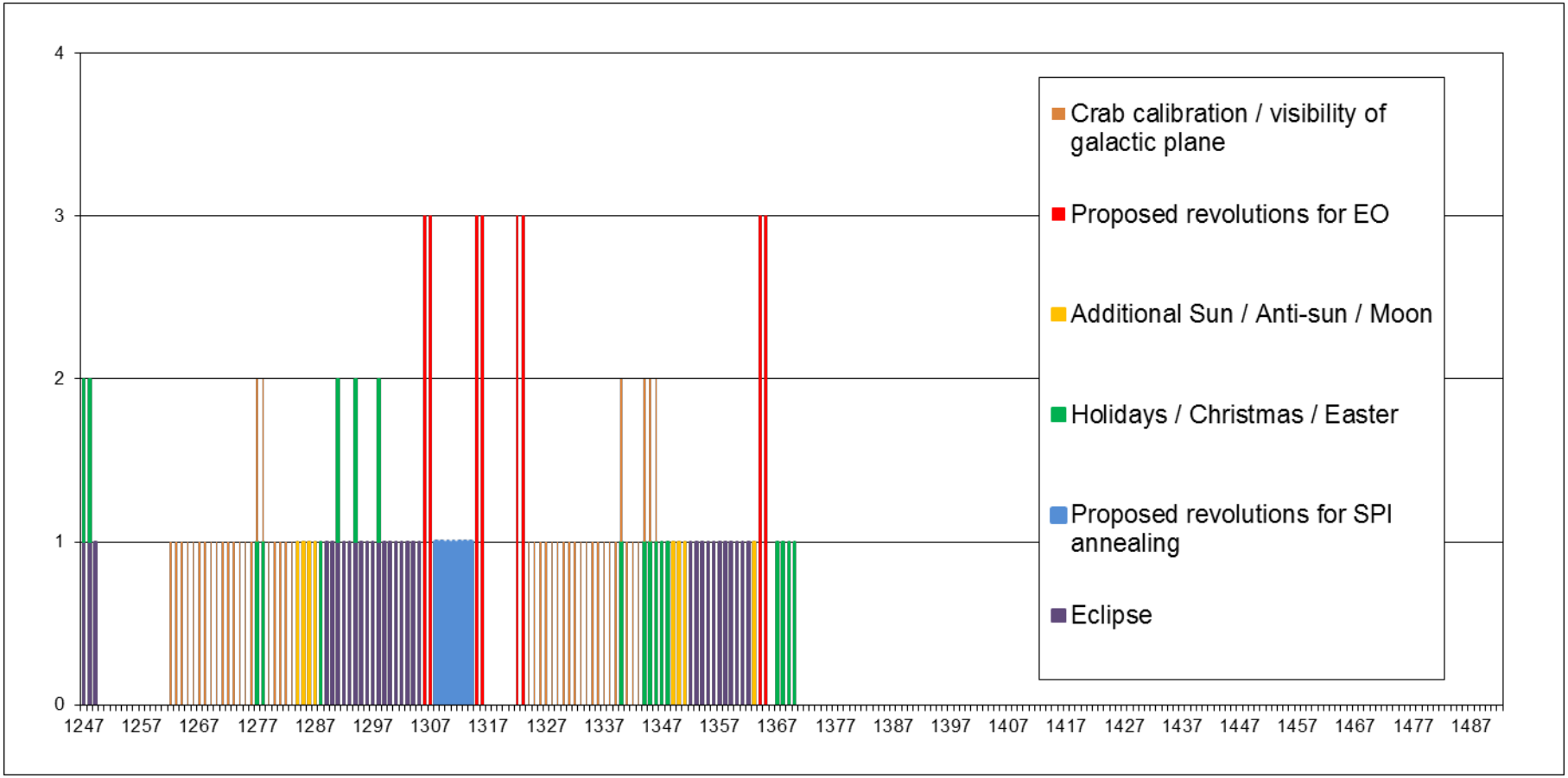




Scheduling of pre-perigee EOs: Proposed revolutions for EOs in 2013

- Old proposed dates
  - EO 2.6: Rev 1260 (starting 06.02.2013) → cancelled
  - EO 2.7: Rev 1286 (starting 24.04.2013) → constrained
  - EO 2.8: Rev 1316 (starting 23.07.2013)
  - EO 2.9: Rev 1323 (starting 13.08.2013) → partly constrained
  - EO 2.10: Rev 1349 (starting 30.10.2013) → constrained
- Possible revolutions selected for the EOs in 2013 (pre-perigee case):
  - EO 3.1: Rev 1306 (EO: 25./26.06.)
  - EO 3.2: Rev 1315 (22./23.07.)
  - EO 3.3: Rev 1322 (12./13.08.)
  - EO 3.4: Rev 1364 (16./17.12.)
- Constraints:
  - SPI annealing

Scheduling of pre-perigee EOs: Constraints



Open issues

Open issues to be decided by IUG/scientists

- Who is analyzing the EO data? → PK to write email to scientists
- Transfer TM allocation from SPI to IBIS? (SPI data used at all?) → No
- Reduction of belts entry to decrease observation duration (but not for 1st pre-perigee EO)
- Use of different mode for PICsIT during EO? → No

Open issues to be analysed by ISOC

- G/S handover during EO: constraints due to ISOC mission planning (OMC)? → check offline with ISOC

Open issues to be resolved by MOC

- Reduce effort of planning of EO necessary
- G/S issues: Planning of KIR > 3 weeks in advance, reliable G/S for long passes
- Double G/S coverage during 1st pre-perigee EO (TBD)
- Perth G/S to cover period around perigee (TBD)

Note

- EO would work with all slews as OSLs

Ground Station Situation

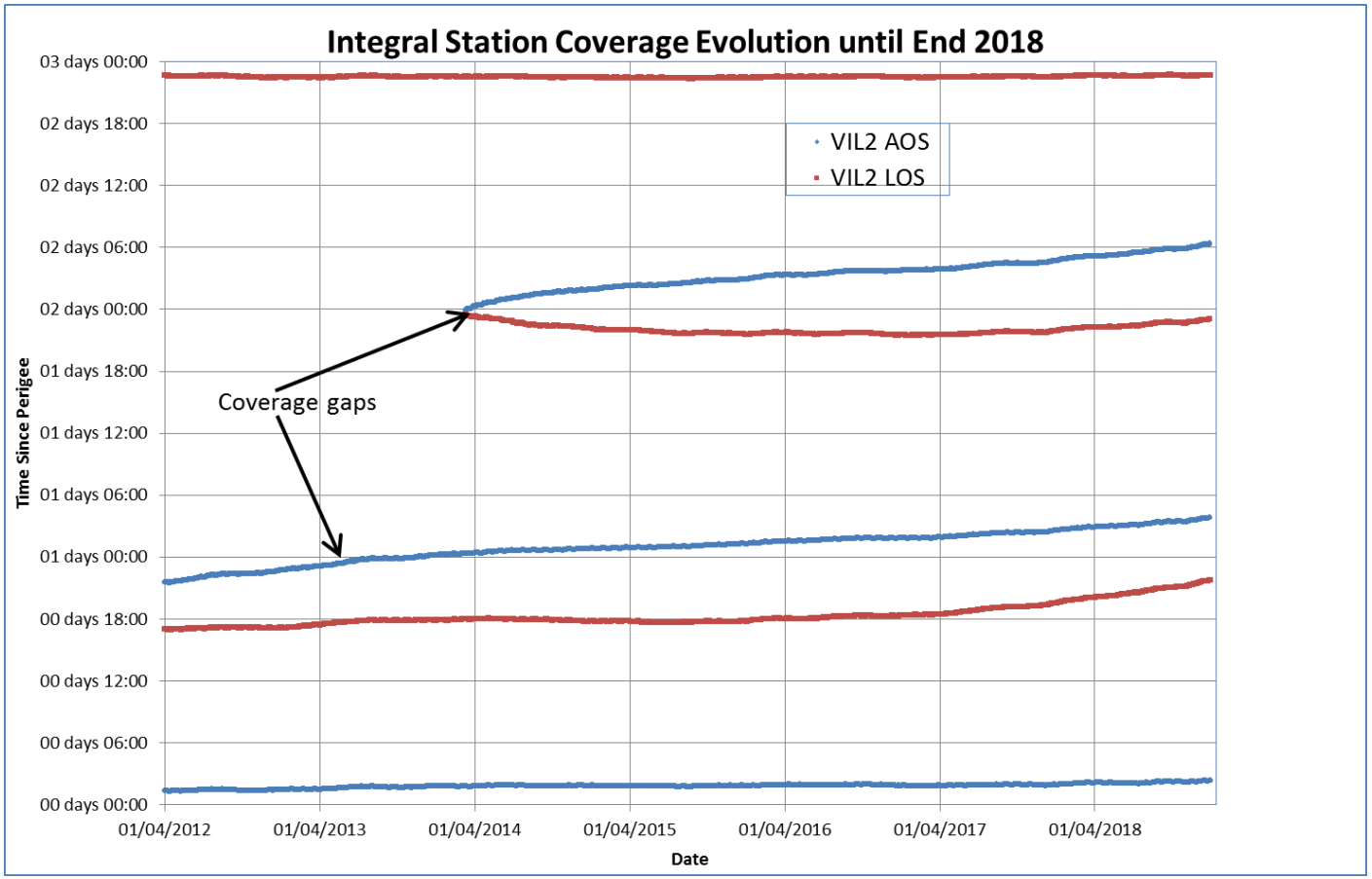
Ground Stations configured to support Integral

- **REDU:** prime station → use of REDU by GALILEO from 22/01/13
- **VIL2:** main prime station in case
- **MSP:** main back-up station in case of unavailability of VIL2
- **Perth:** can provide visibility close to perigee, hardly used
- **Weilheim:** back-up in case of unavailability of European ESA station, use should be avoided / only in emergency/contingency – Non ESA Station
- **Kiruna 1:** back-up station; prime station in the future after GOCE de-orbit

- Gaps from VIL2, MSP, (WHM) are in same part of orbit – no combination of these stations can compensate
- Kiruna 1: prime station of GOCE until ~09/2013; close to full Integral visibility (entire usable part of revolution)

Ground Stations Visibility – VIL2

- Current gap in coverage duration increases, maximum 7 hours
- 2nd gap opens in early 2014, maximum 7 hours



Ground Stations Visibility – MSP

- Current gaps in coverage duration increases, maximum 2 x 10 hours