Evaluation of the in-orbit pointing accuracy of XRISM

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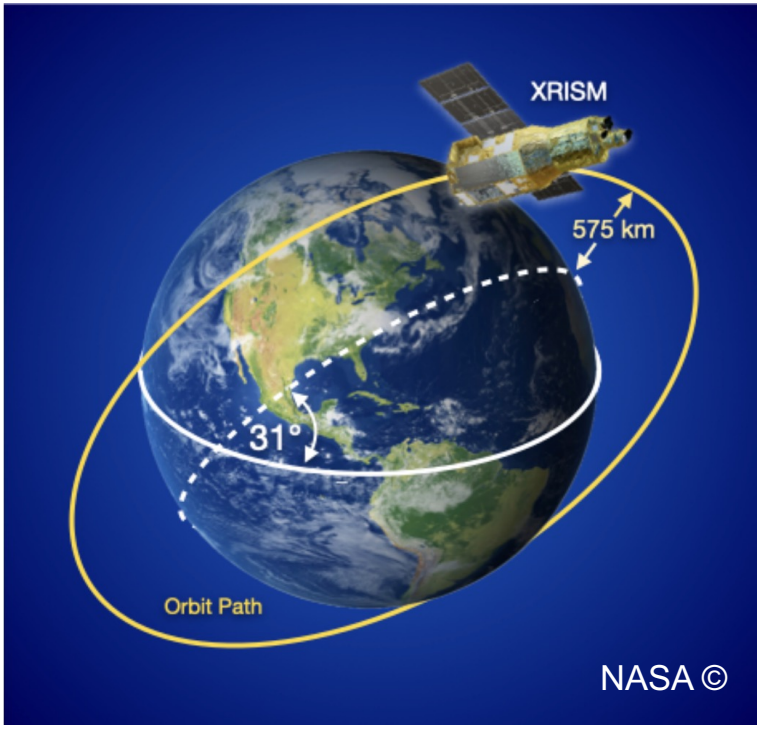
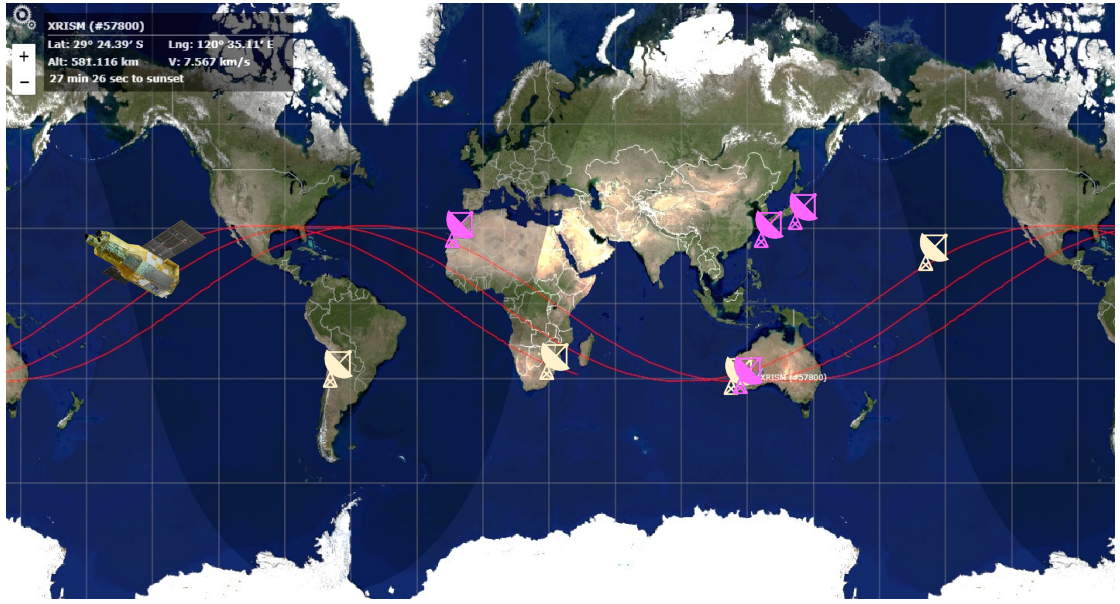
Talk plan

1. Introduction
2. Aimpoint search
3. Comparison of Resolve and Xtend
4. Control and Determination accuracy

Introduction

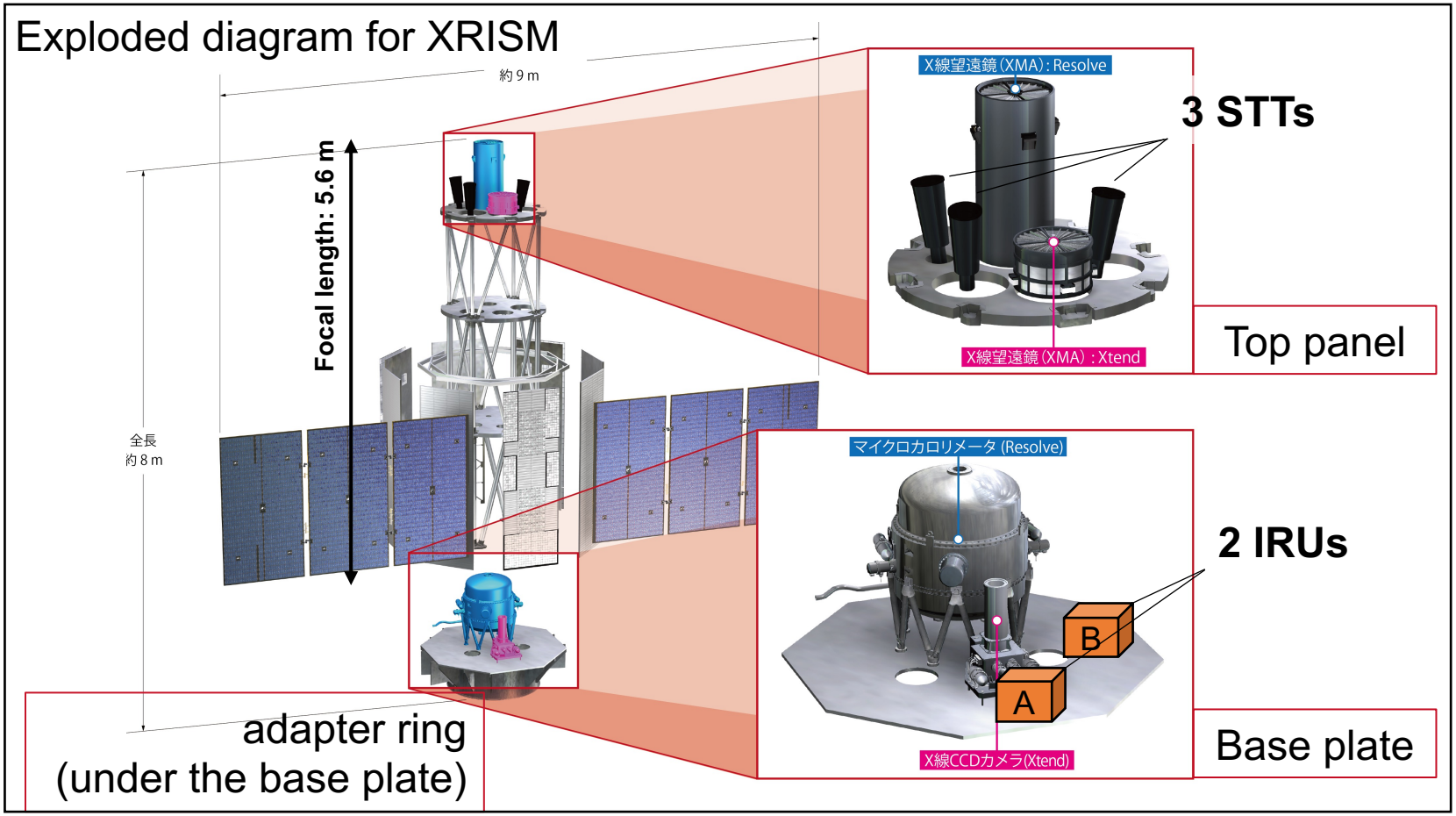
Orbit of XRISM





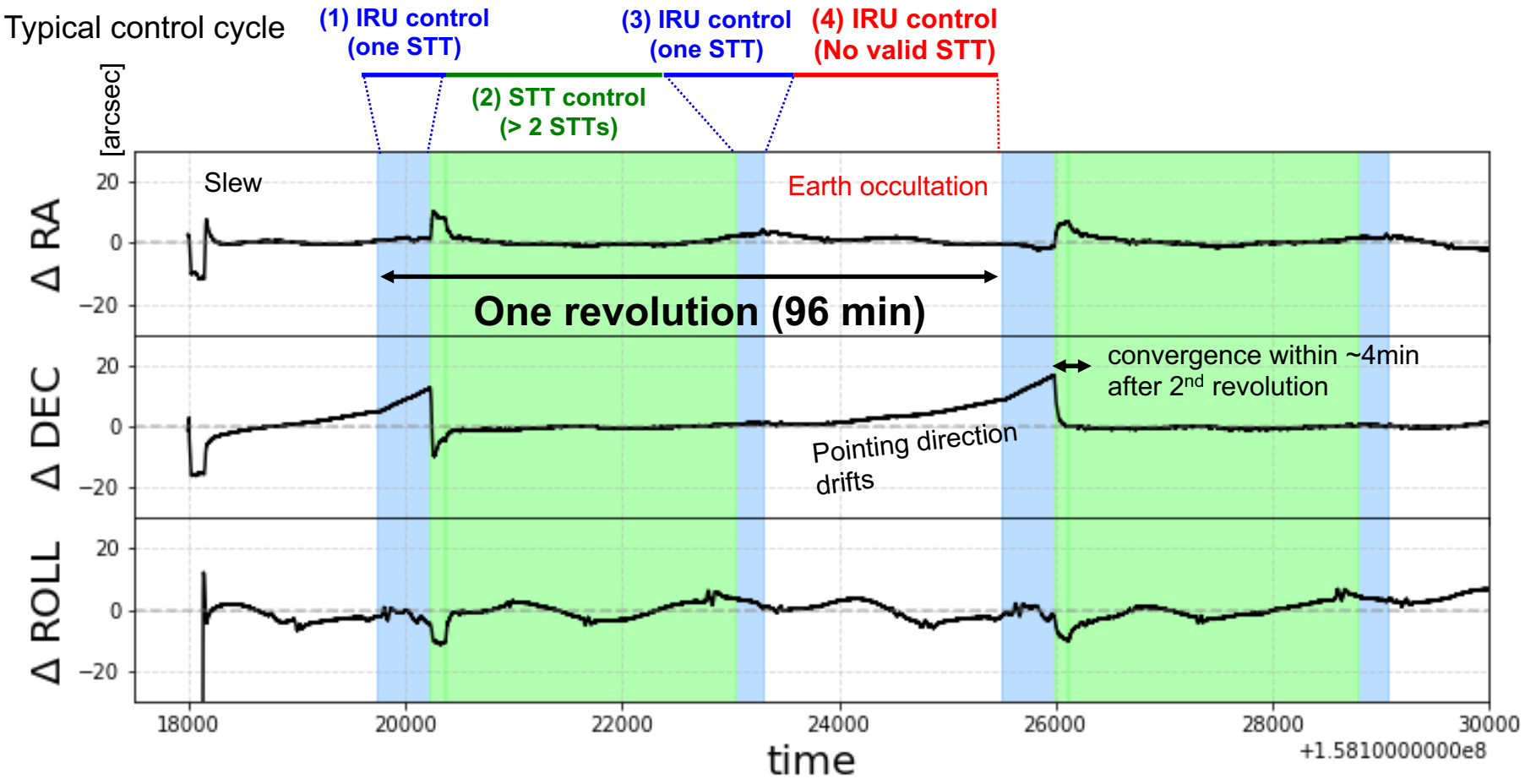
- XRISM was successfully launched on 6 Sep 2023 (UTC).
  - Altitude: 575 km
  - Inclination angle: 31 degree
  - Orbital period: 96 min
- Almost all observations contain the earth occultation.

Main components for pointing determination



- XRISM carries three star trackers (STTs) on the top panel and two inertial reference units (IRUs) on the base plate. These components are mainly used for pointing determination.
- In the normal mode, the attitude is controlled using two STTs as long as there is no earth occultation blocking their FOV. If this condition isn't met, IRUs take over the attitude control.

Typical attitude control cycle



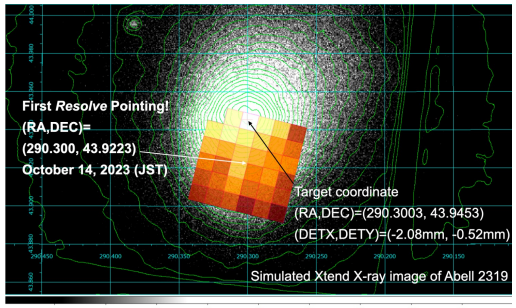
Deviations from nominal RA, Dec, and Roll

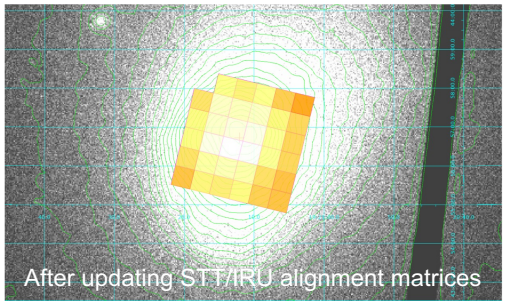
- In the normal mode, the attitude is controlled using two STTs as long as there is no earth occultation blocking their FOV. If this condition isn't met, IRUs take over the attitude control.

Aimpoint search

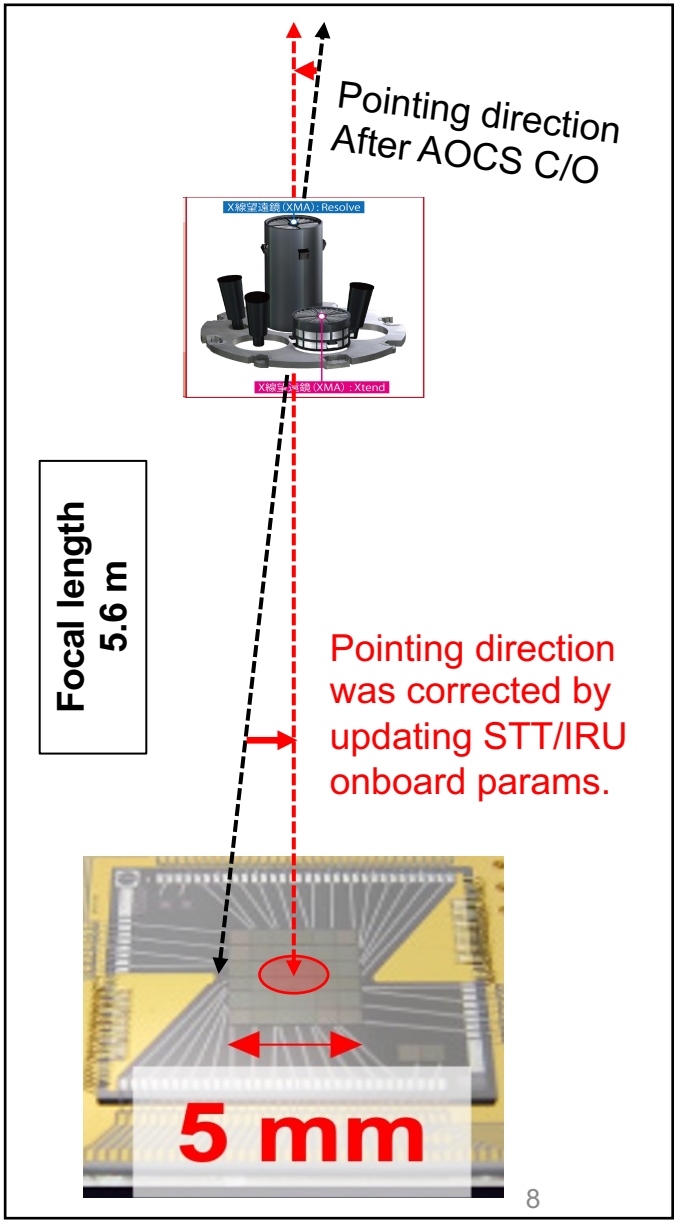
Aimpoint search

- After the AOCS checkout phase, aimpoint search was performed twice.
- The objective is to calibrate and validate the aimpoint within a 1.5 mm (55") radius from the center of the array by updating onboard STT/IRU parameters.
- Aimpoint search 1
  - **rough adjustment** by an extended source

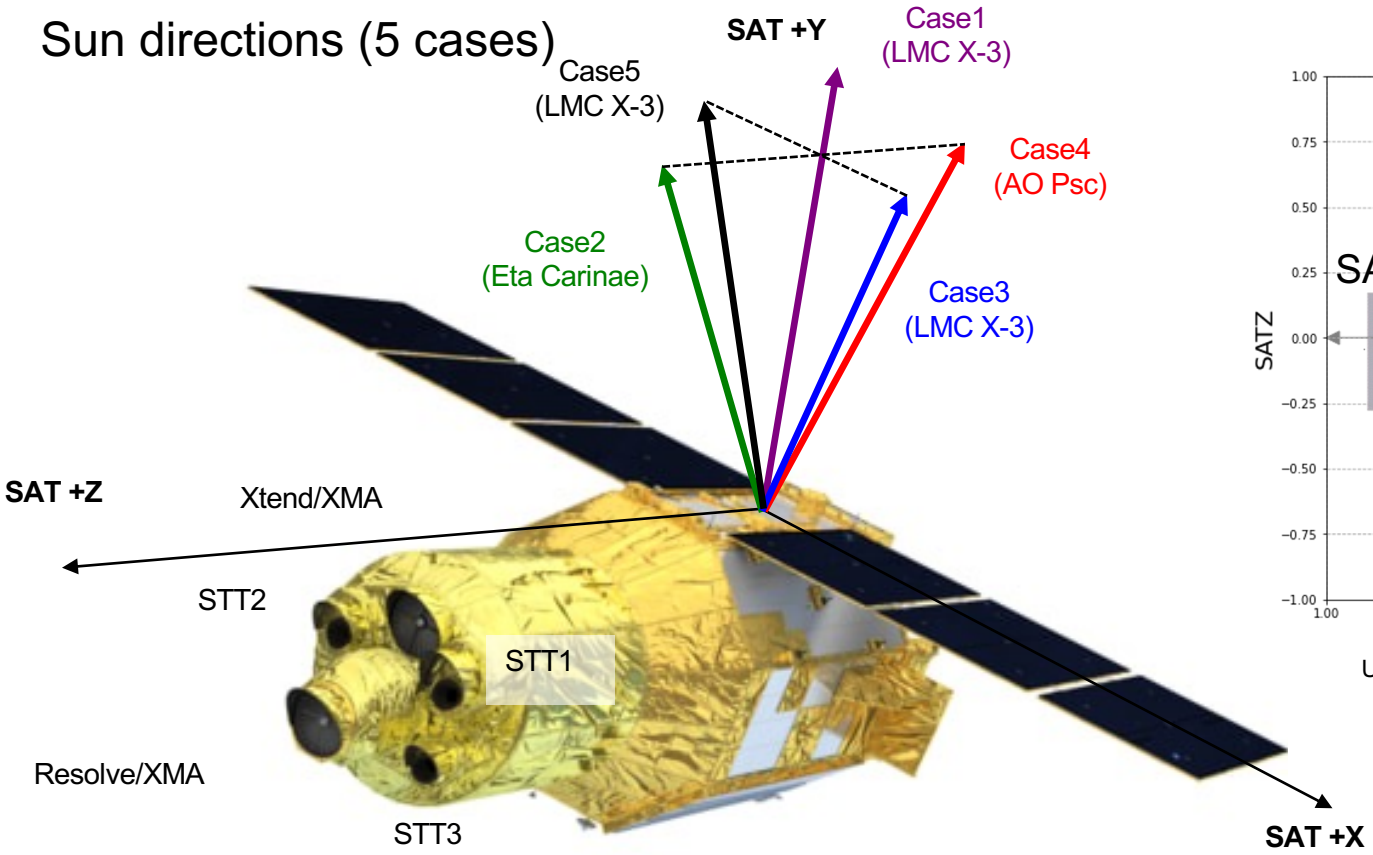


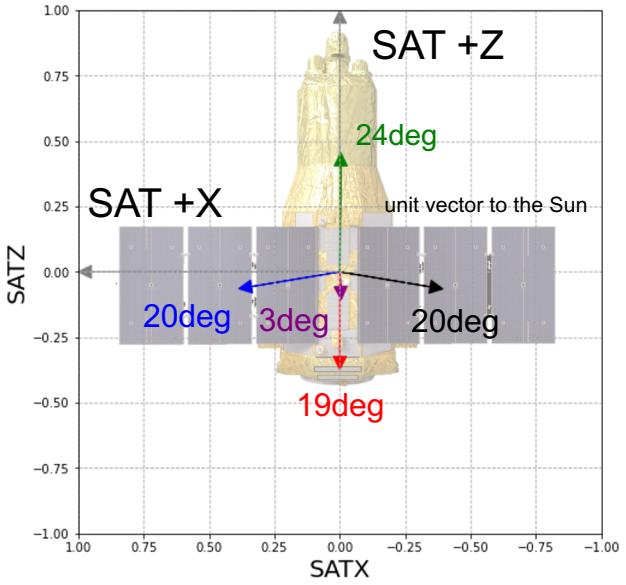


- Aimpoint search 2
  - **precise adjustment** and validation by point sources with different sun direction and STT combinations.



Aimpoint search 2

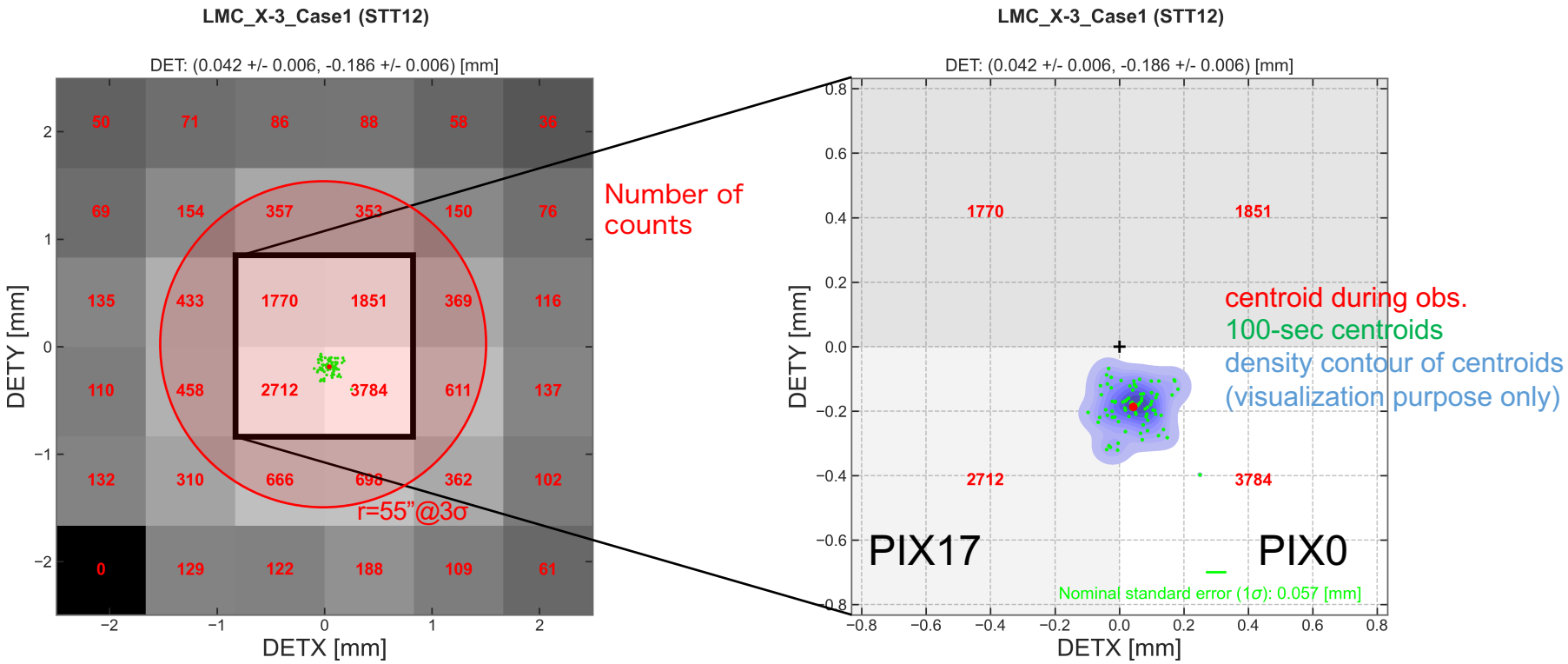




Unit vectors toward the Sun from SAT +Y

- In aimpoint search 2, 15 patterns datasets are obtained to consider **(1) sun direction** (Thermal strains) and **(2) STT combinations** (STT biases)
- 5 sun directions × 3 STT combination = 15 patterns
  - Case 1, 3, 5: rotation about Sat +Z
  - Case 1, 2, 4: rotation about Sat +X

Count map and centroids after screening

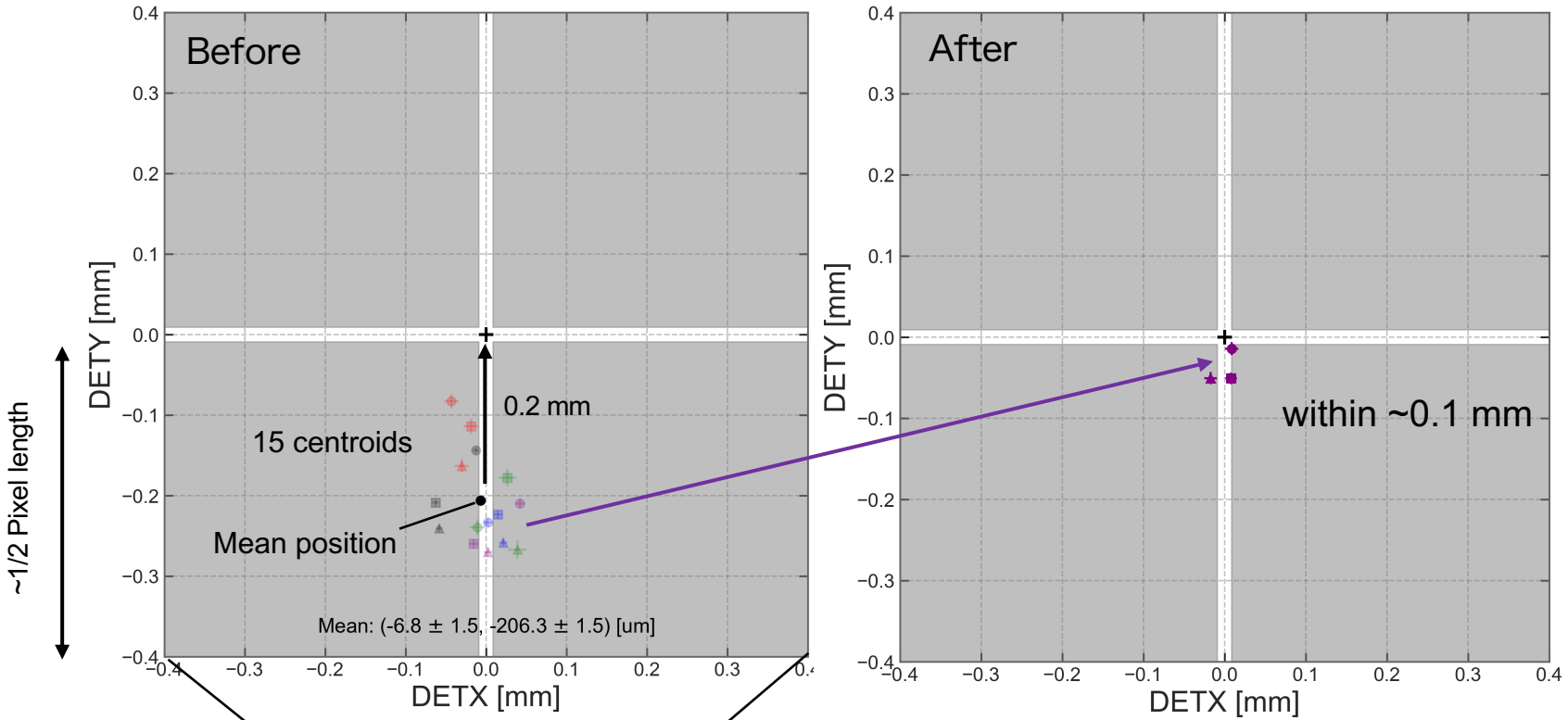


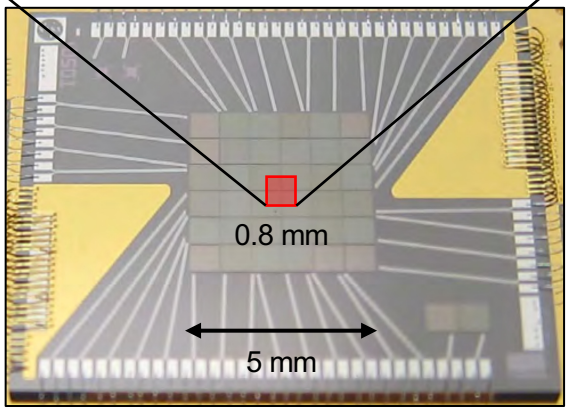
DET count map after screening

zoomed image

- After the event and good-attitude GTI screening, X-ray photon centroids were obtained from 15 patterns.
- In 15 datasets, the brightest pixel is always Pixel 17 or 0. So the aimpoint was located at the lower center.

Result of aimpoint search 2





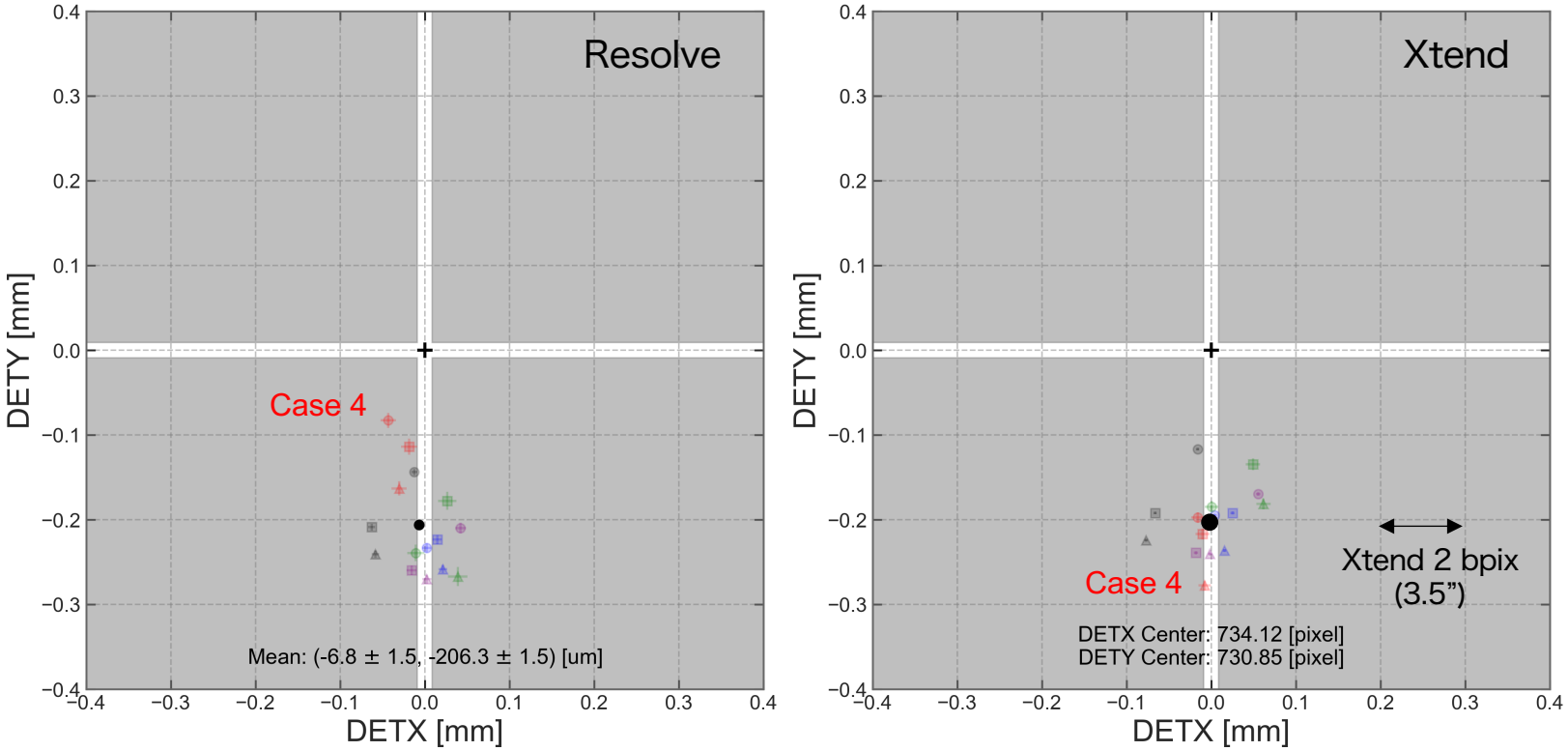
- The observed offset was (DETX, DETY) = (0.0 mm, -0.2 mm), and we updated STT/IRU onboard alignment matrices.
- The centroids of verification observations were located within 0.1 mm from the center. It satisfied the requirement of a 1.5 mm (55") radius.

Result of aimpoint search

1. The centroids of verification observations were located within 0.1 mm from the center of the array. It satisfied the requirement of a 1.5 mm (55") radius.
2. The **sun direction** and the **STT bias** can cause the aimpoint shift by ~0.1 mm in DET coordinates.
   - Although the **STT bias** can be mitigated in SKY coordinate by offline processing, the **sun direction's effect** cannot be corrected in SKY coordinate. The a few arcsec offset remains.

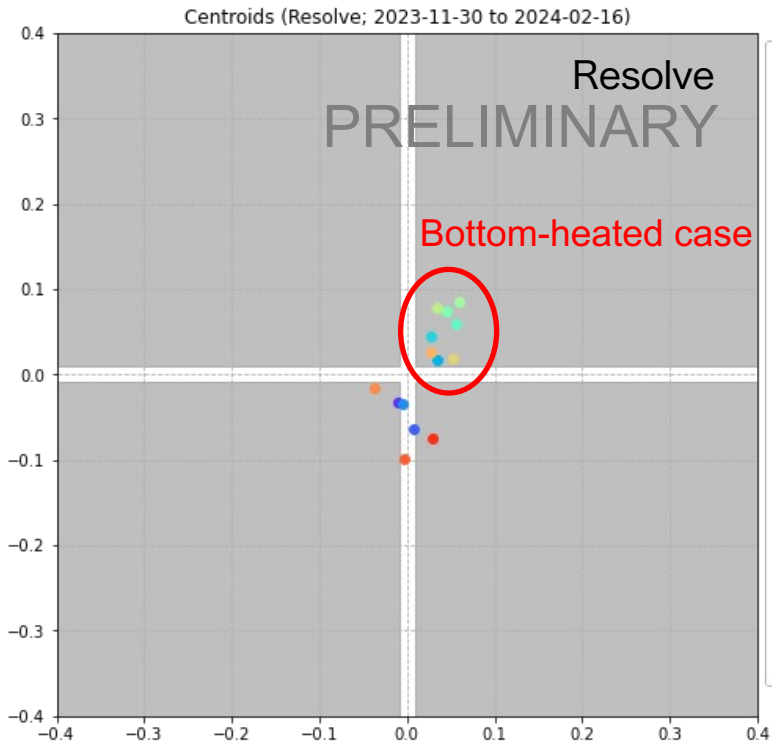
Comparison of Resolve and Xtend

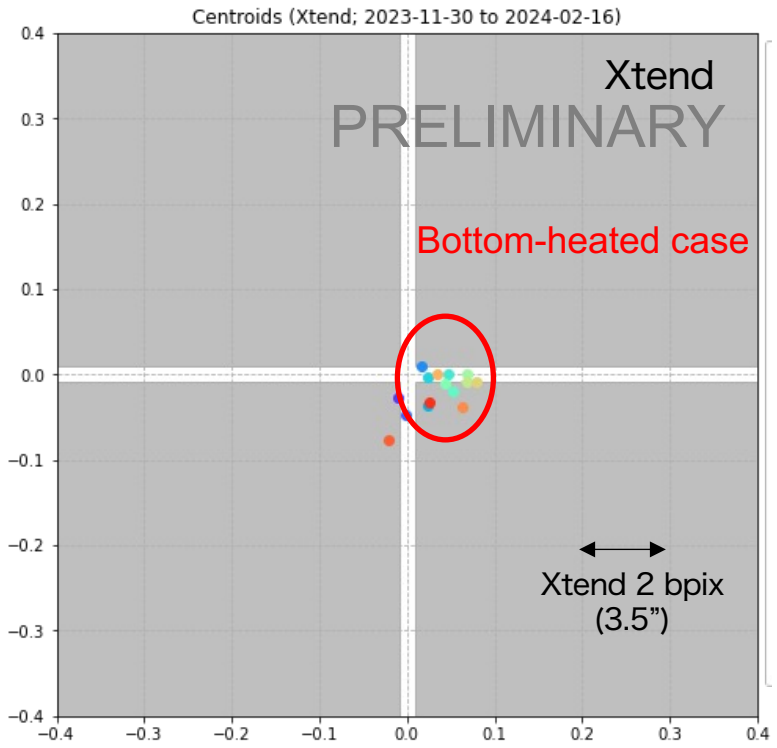
Comparison of Resolve and Xtend



- Comparison of Resolve and Xtend
  - Dataset: Aimpoint search observations
  - The shift amounts and directions of Resolve and Xtend are similar, except for the bottom-heated case (Case 4).

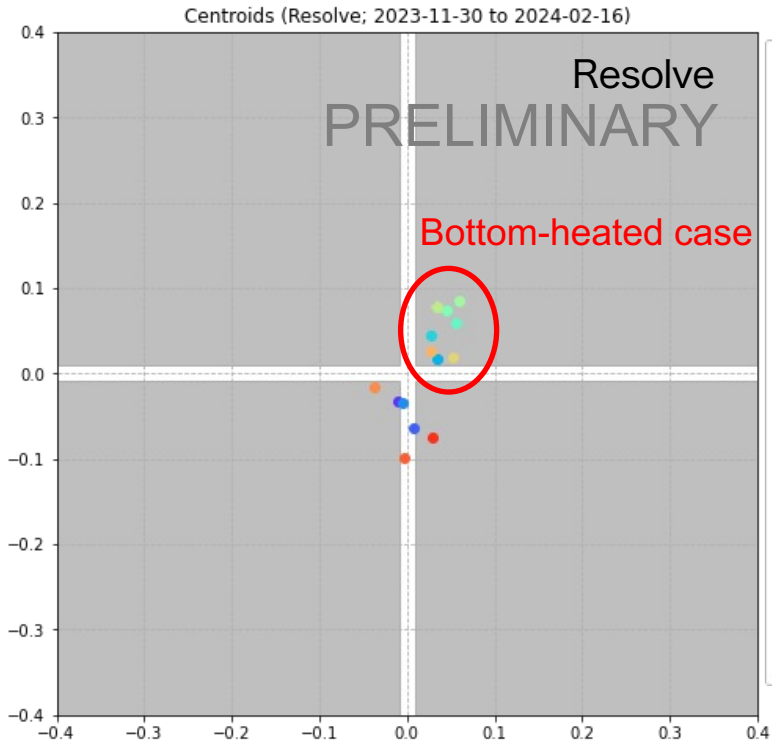
Comparison of Resolve and Xtend

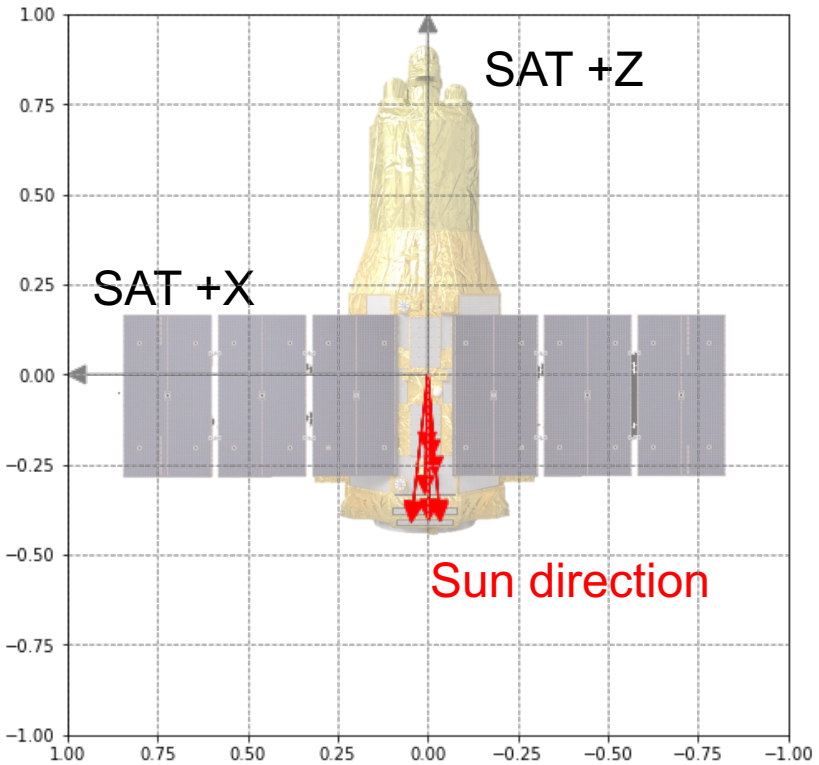




- Comparison of Resolve and Xtend
  - Dataset: observations after aimpoint search
  - Similar results to the aimpoint search observations.
  - Resolve's DETY shift remains in bottom-heated cases.

Sun direction and centroids





Unit vector toward the Sun from SAT +Y

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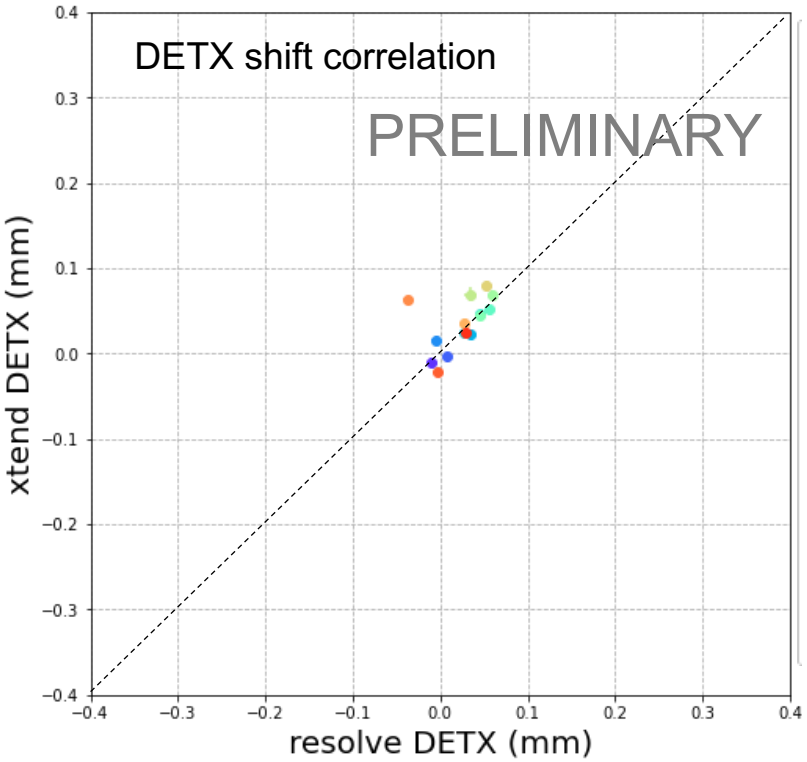
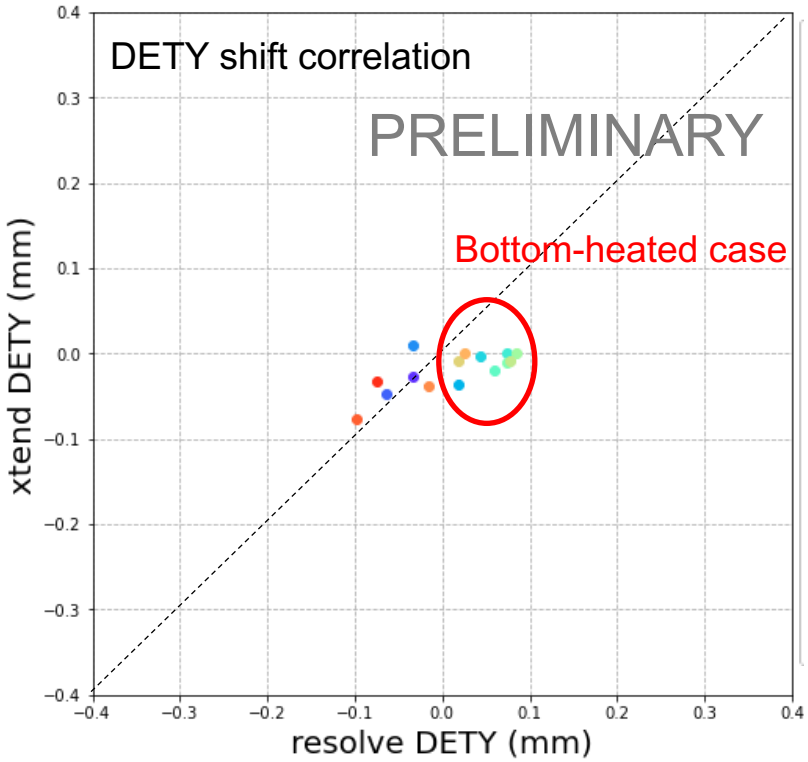
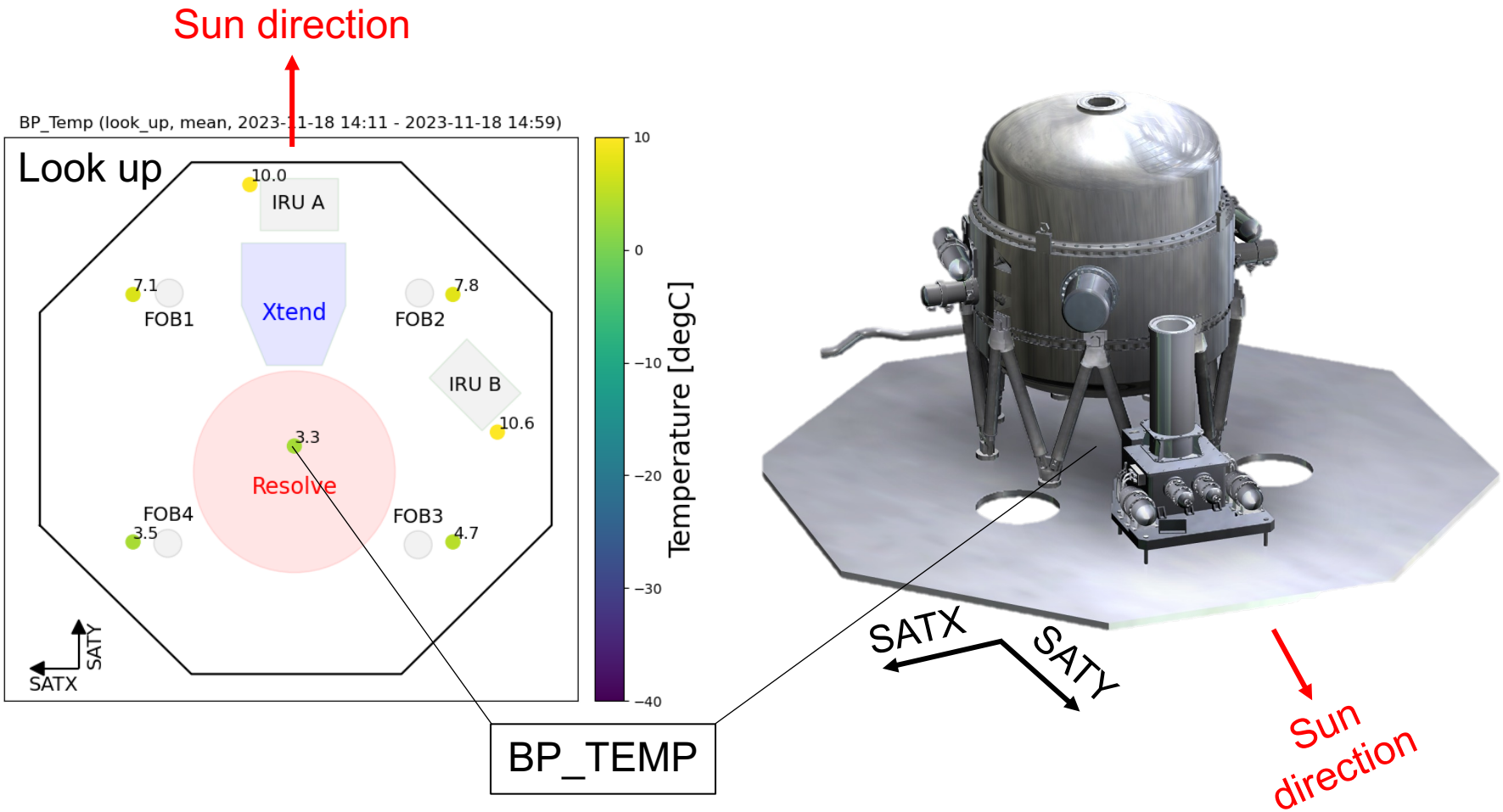
Comparison of Resolve and Xtend





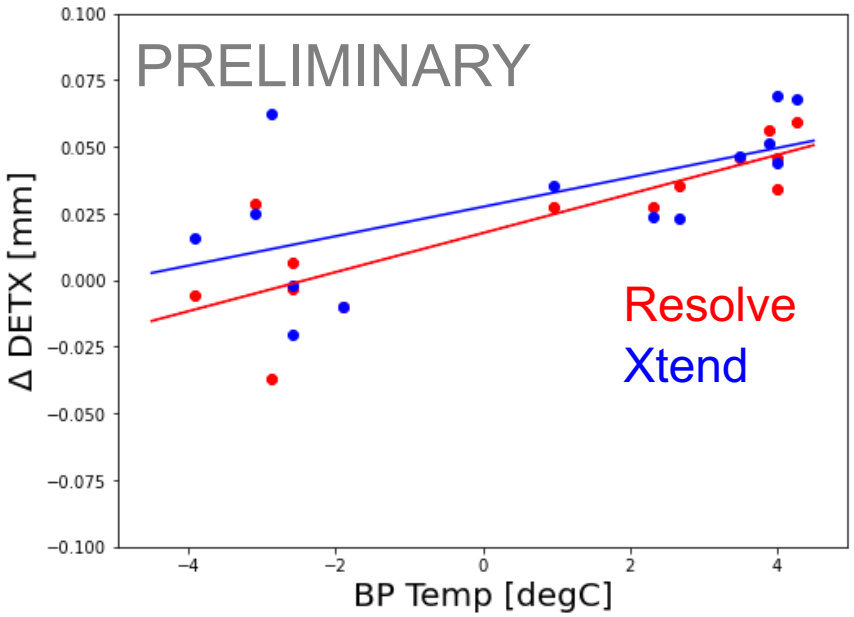
- Comparison of Resolve and Xtend
  - Dataset: observations after aimpoint search
  - DETX shifts of both detectors have a good correlation.
  - DETY shifts have different tendencies.

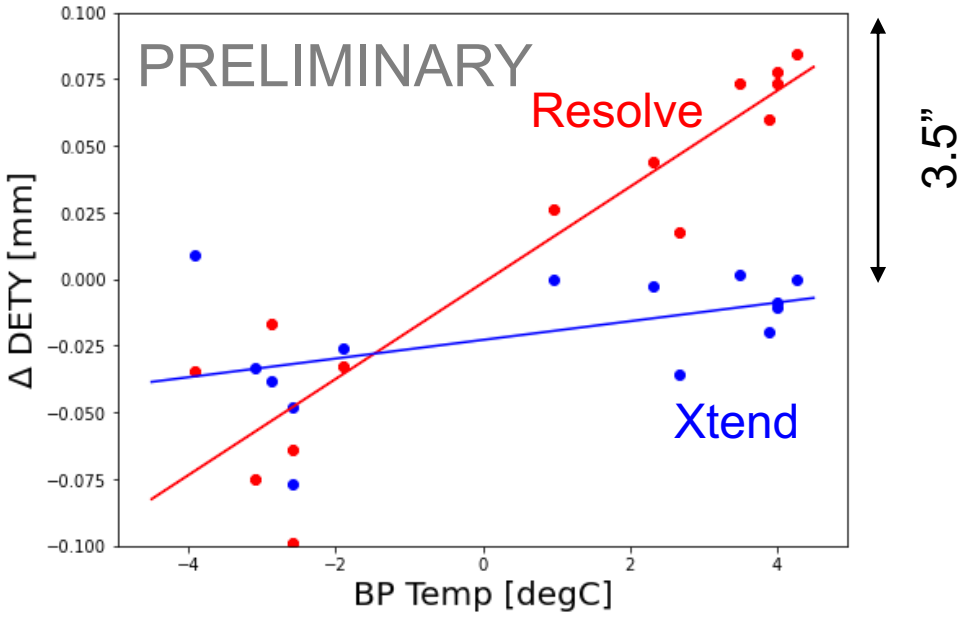
BP temperature



- BP_TEMP can increase up to 5 degrees Celsius in the bottom-heated case.

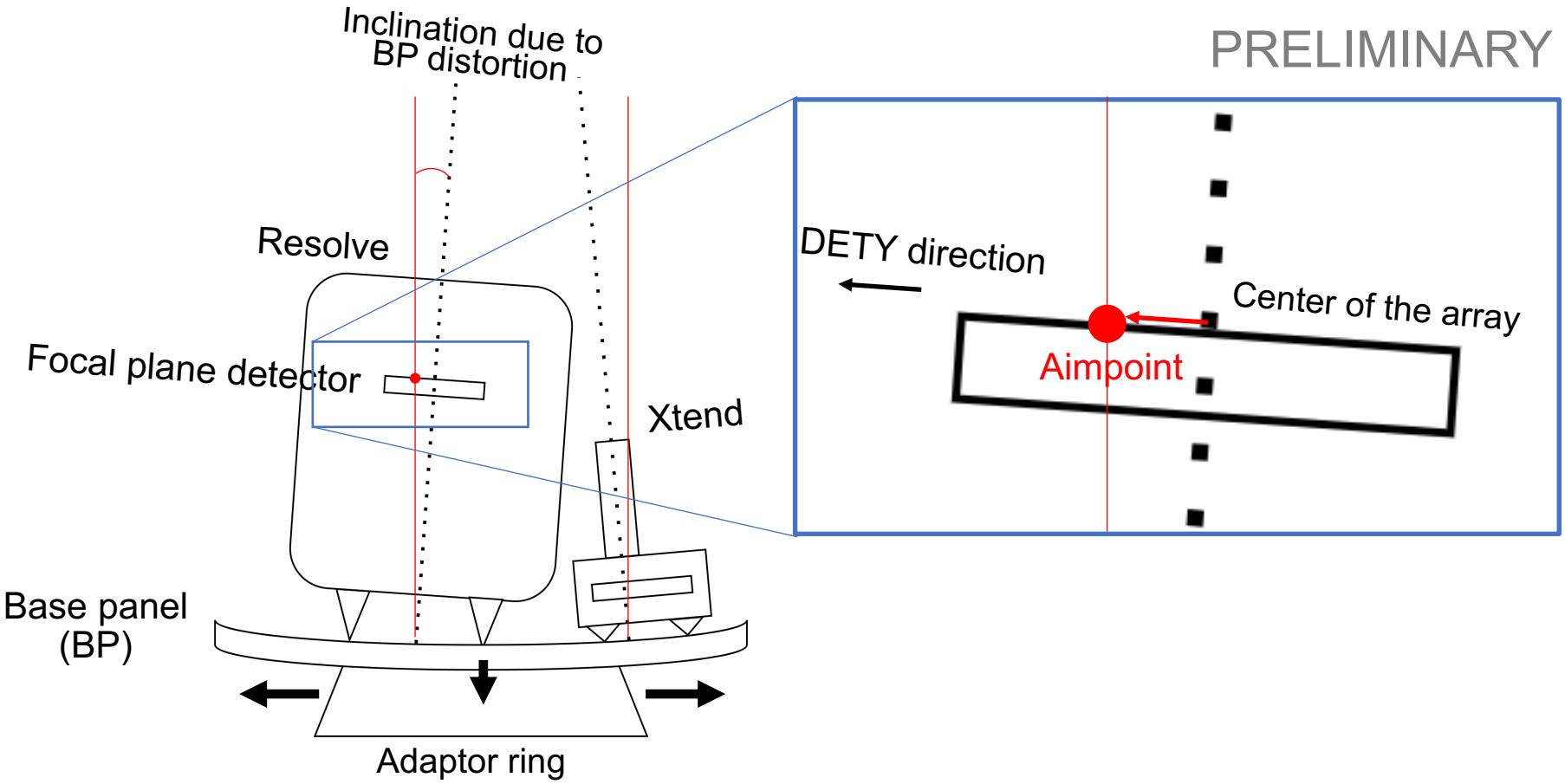
Comparison of Resolve and Xtend





- BP_TEMP can increase up to 5 degrees Celsius in the bottom-heated case.
- DETX shifts of both detectors have similar dependence.
- DETY shift of Resolve depends on BP temp due to the thermal strain.
- The shift amount is a few arcsec, though the shift is not corrected by attitude correction.

Comparison of Resolve and Xtend



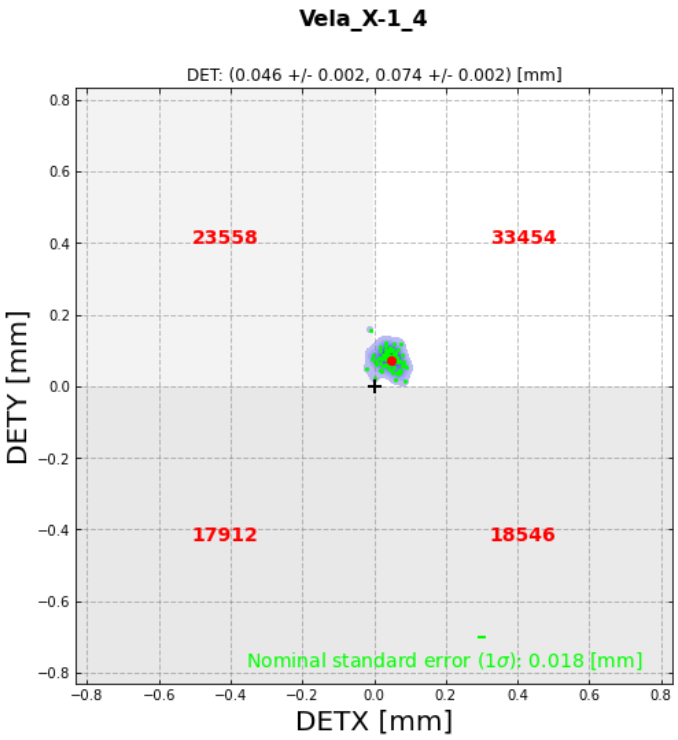
- The heat expansion of the aluminum adaptor ring causes the base panel to distort into a downwardly concave shape.
- The DETY shift is likely to be caused by the inclination of the focal plane detector.
- The effect is greater for Resolve than Xtend, which has a longer distance between the focal plane and the base panel.

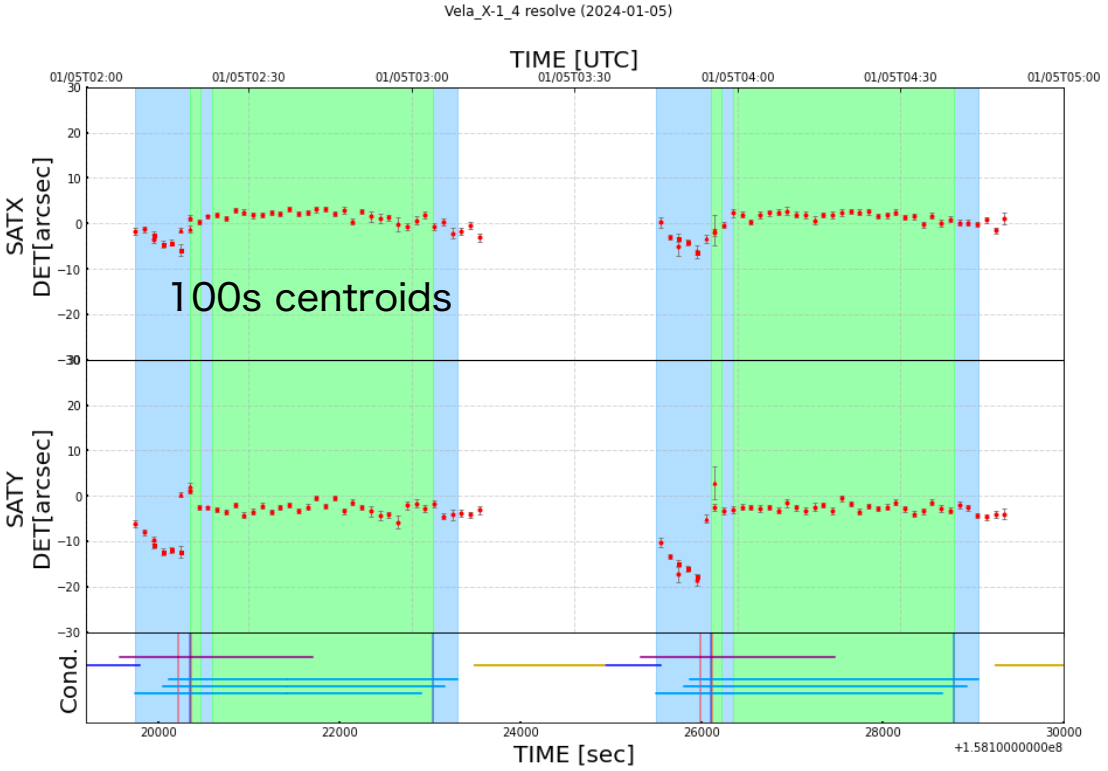
Result of the comparison

1. The shift amounts and directions of Resolve and Xtend are similar, except for the bottom-heated case.
2. DETX shifts of both detectors have a good correlation.
3. DETY shift of Resolve is likely to depend on BP temperature. The typical amount is a few arcsecs in the bottom-heated case.

Control and Determination accuracy

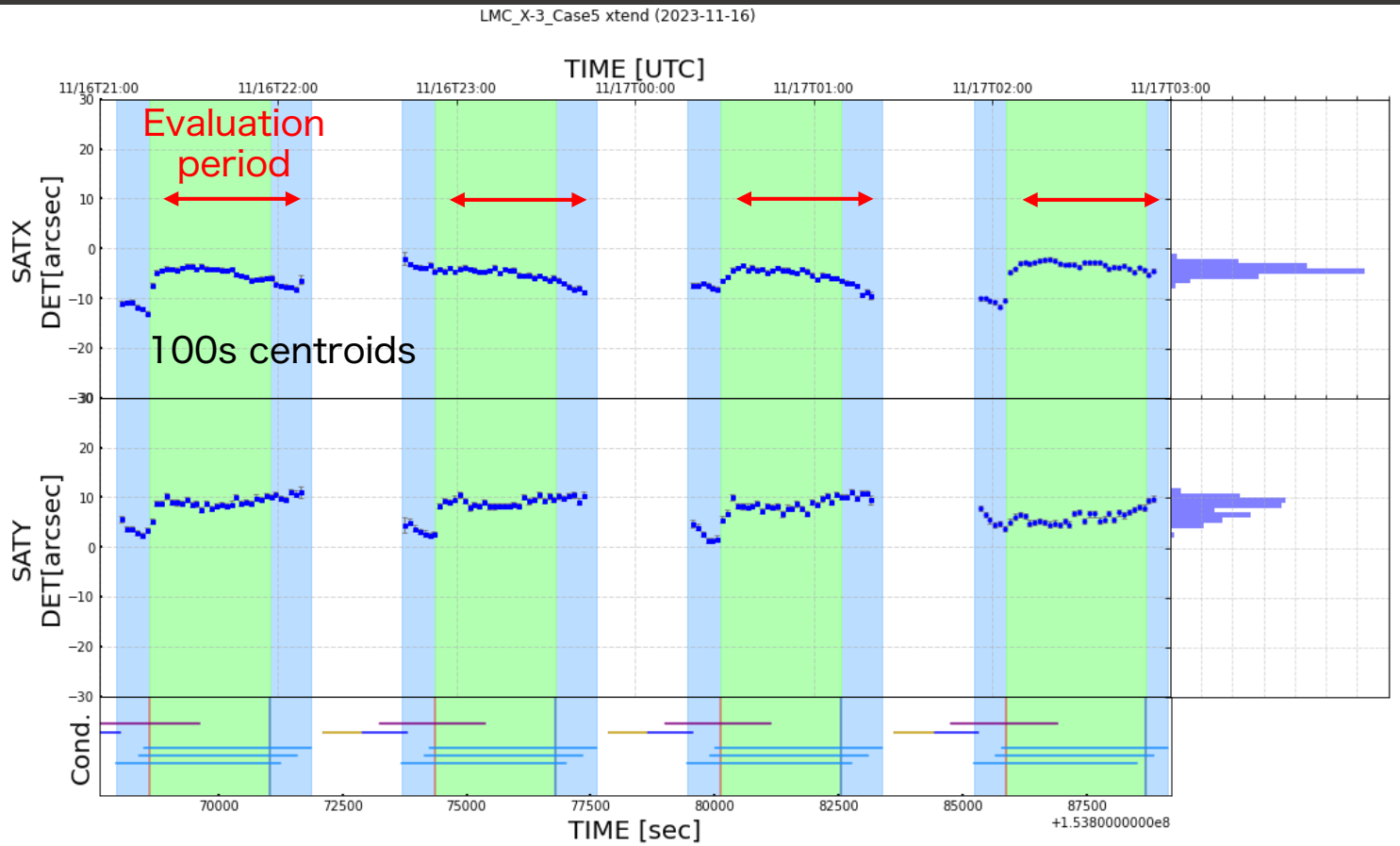
Pointing accuracy





- Control and determination accuracies are analyzed by the trend of 100-sec centroids from Resolve and Xtend data.
  - Control accuracy: AOCS control
  - Determination accuracy: Attitude offline processing

Attitude Control accuracy



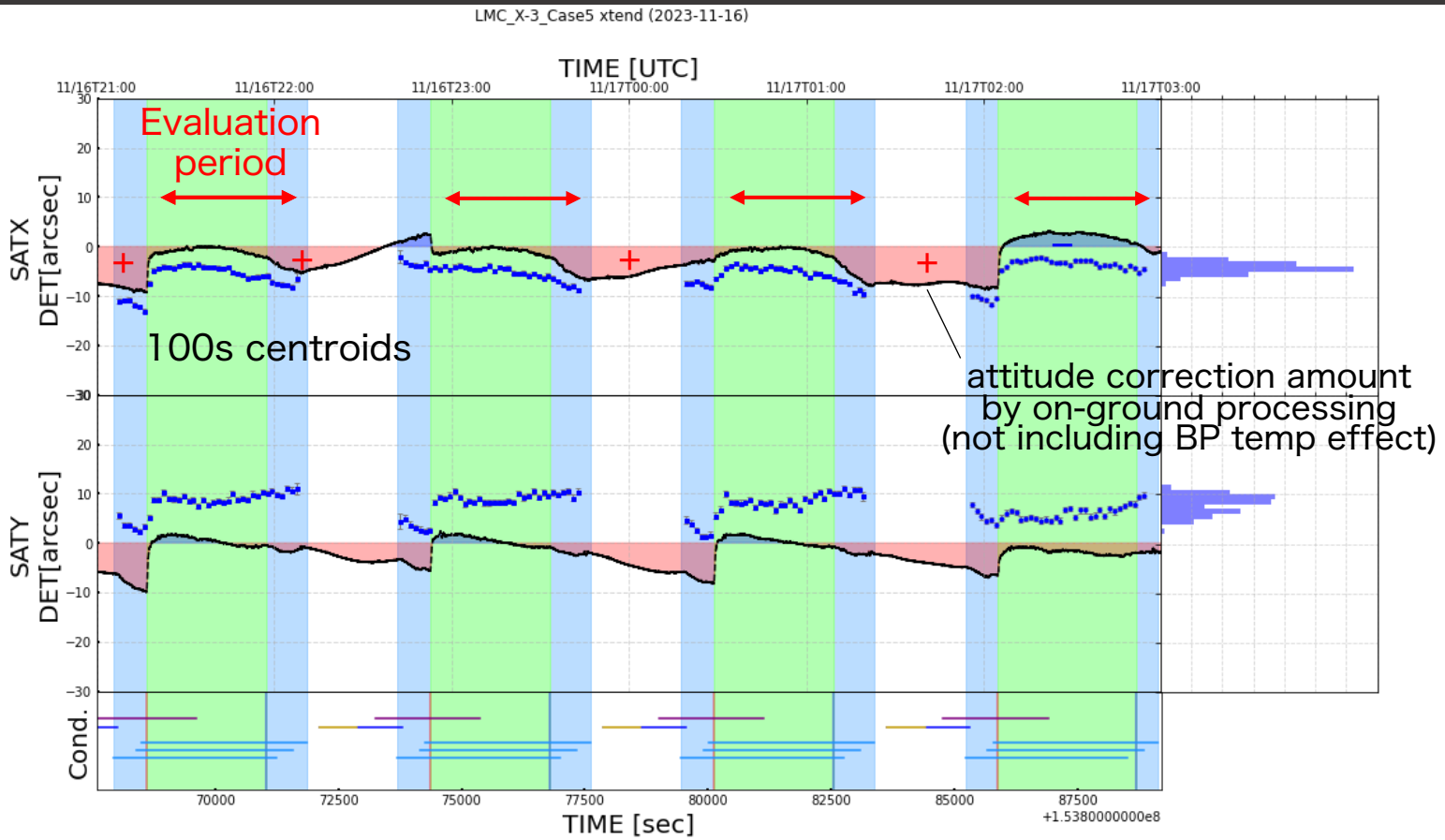
- Control accuracy was evaluated by the X-ray photon centroids in DET coordinates after the convergence of the Kalman filter.

	Measurement (3σ)	Requirement (3σ)
Resolve	15.0 ± 1.2''	55''
Xtend	52.3 ± 0.5'' (*)	184''

Requirements are Satisfied.
- Including aimpoint shift and orbital variation.

- (*) Xtend result includes a deviation of 38.2'' from the ground measurement.

Attitude Control accuracy



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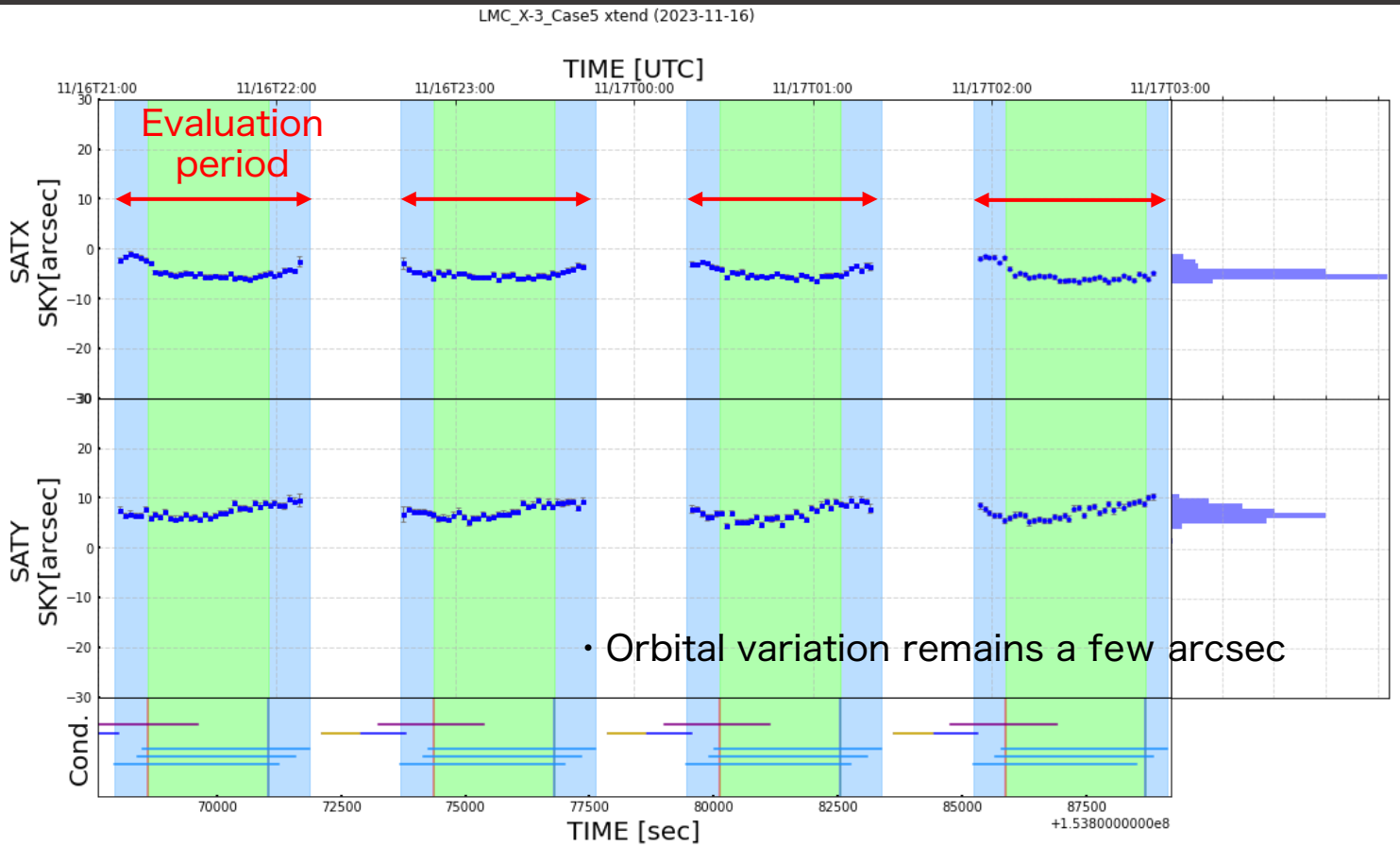
Determination accuracy



・Orbital variation remains a few arcsec

- Determination accuracy was evaluated by the X-ray photon centroids in SKY coordinates during the time at least one STT is activated.

	Measurement (3σ)	Requirement (3σ)
Resolve	17.4 ± 1.5''	20''
Xtend	17.0 ± 1.0''	20''

Requirements are Satisfied.
- Including aimpoint shift and orbital variation.

- Attitude correction methods are almost complete in the commissioning phase, though we are considering the need for a minor update.

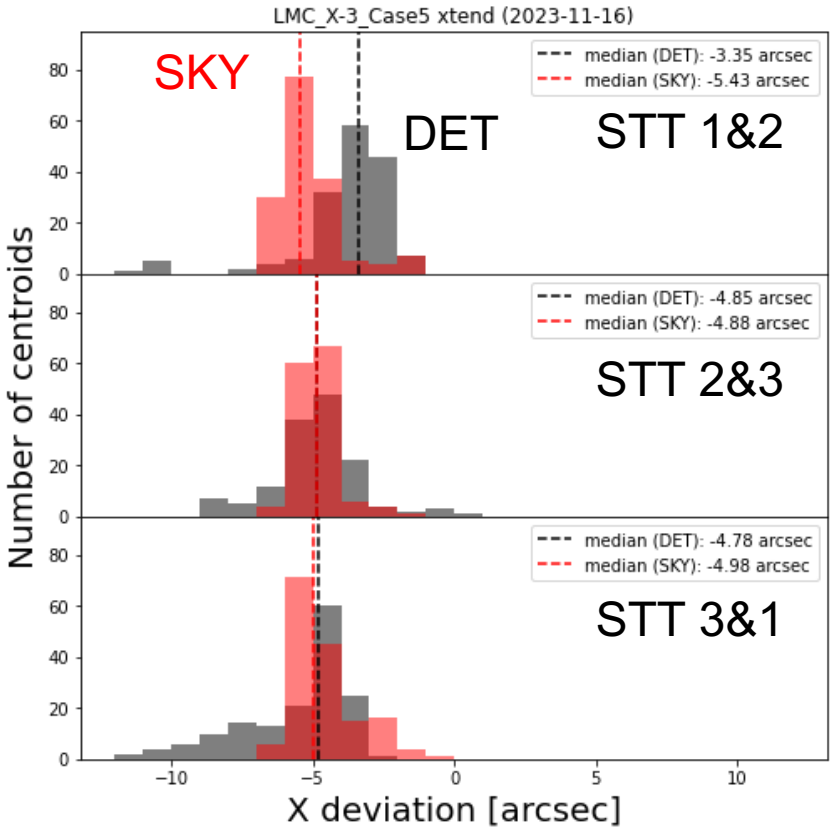
Result of control & determination accuracies

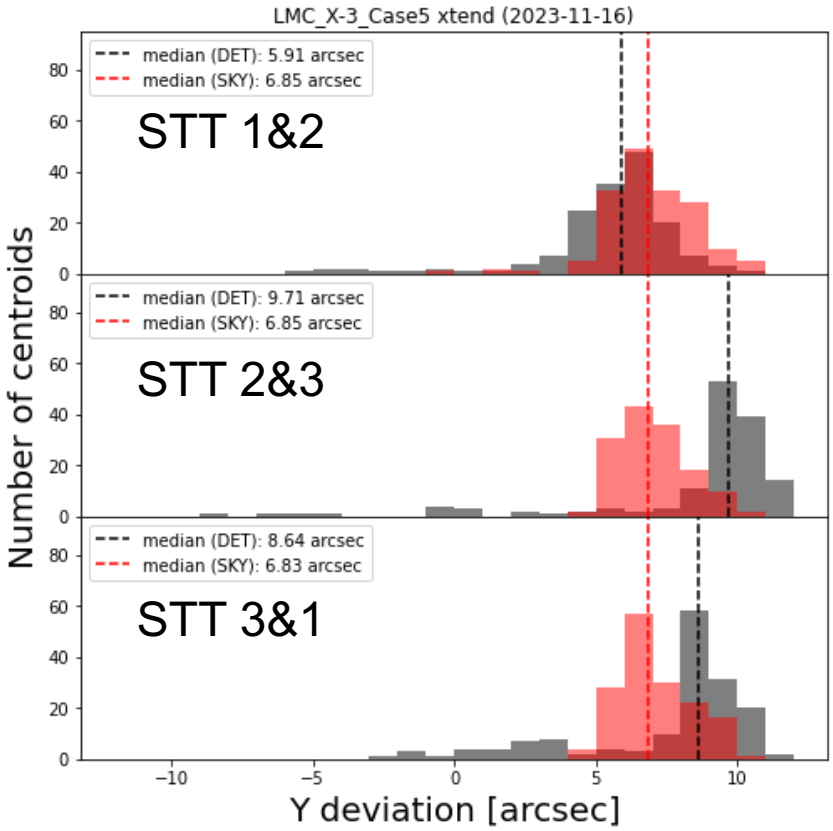
XRISM X-Ray Imaging and Spectroscopy Mission

1. On-axis determination accuracy is generally less than 20”@3σ.
2. X-ray photon centroid trends of Resolve and Xtend are very similar including bottom-heated case. The aimpoint shift can be treated as a fixed bias.
3. A few arcsec orbital variation still exists in some observations after the update. We are still investigating the cause.
4. The commissioning result doesn’t include the annual variation. Pointing accuracy analysis is still ongoing.

Backup

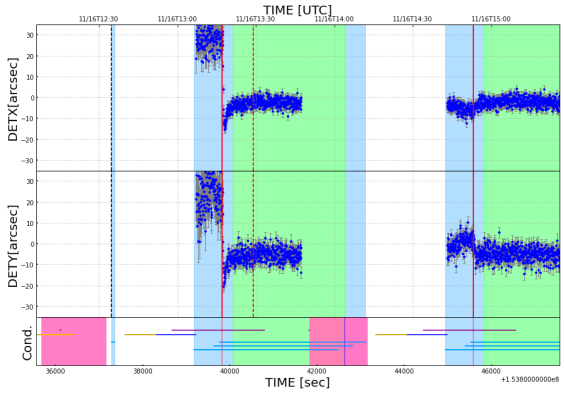
STT bias correction





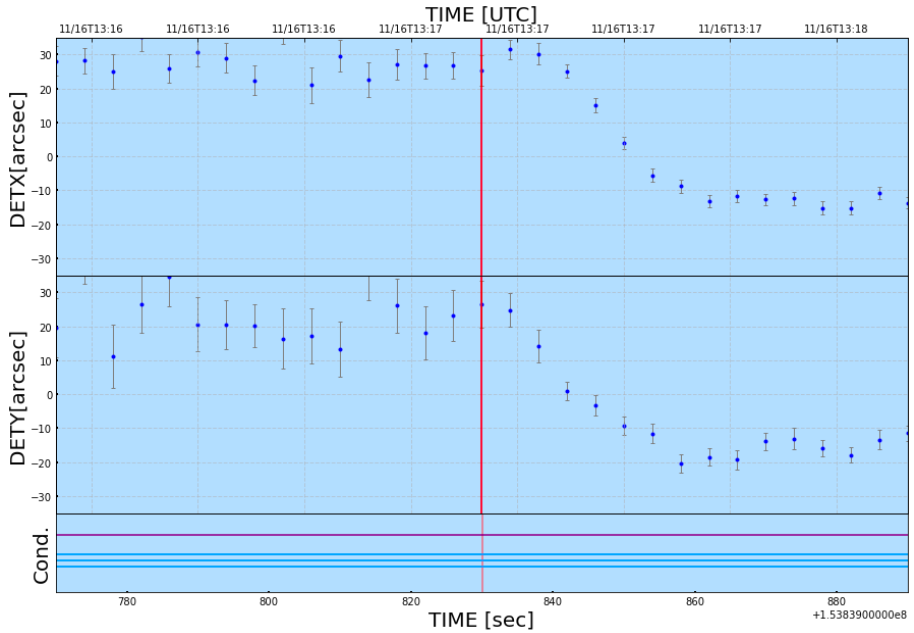
4-sec centroids for 1st & 2nd Revolutions

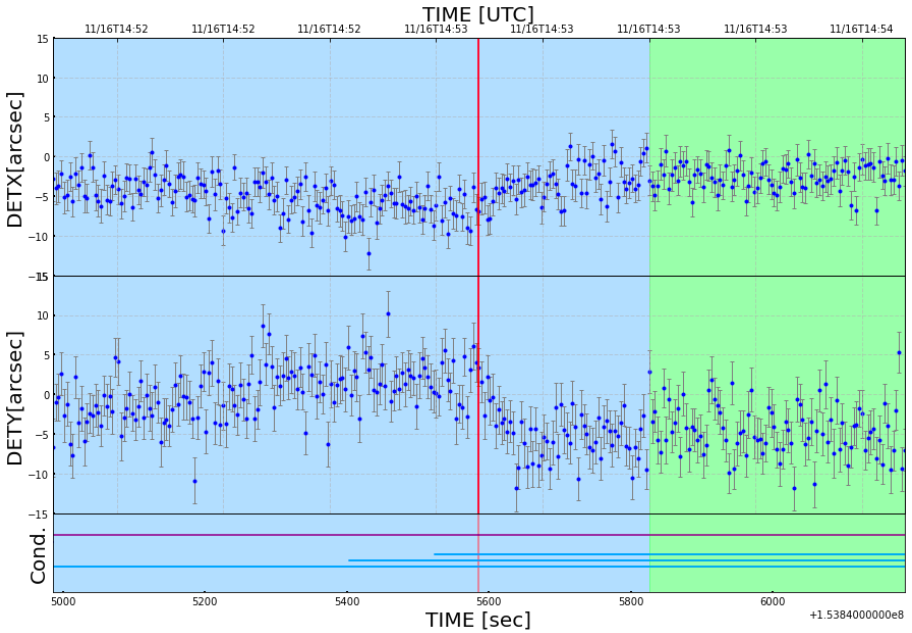
1st Rev. 2nd Rev.



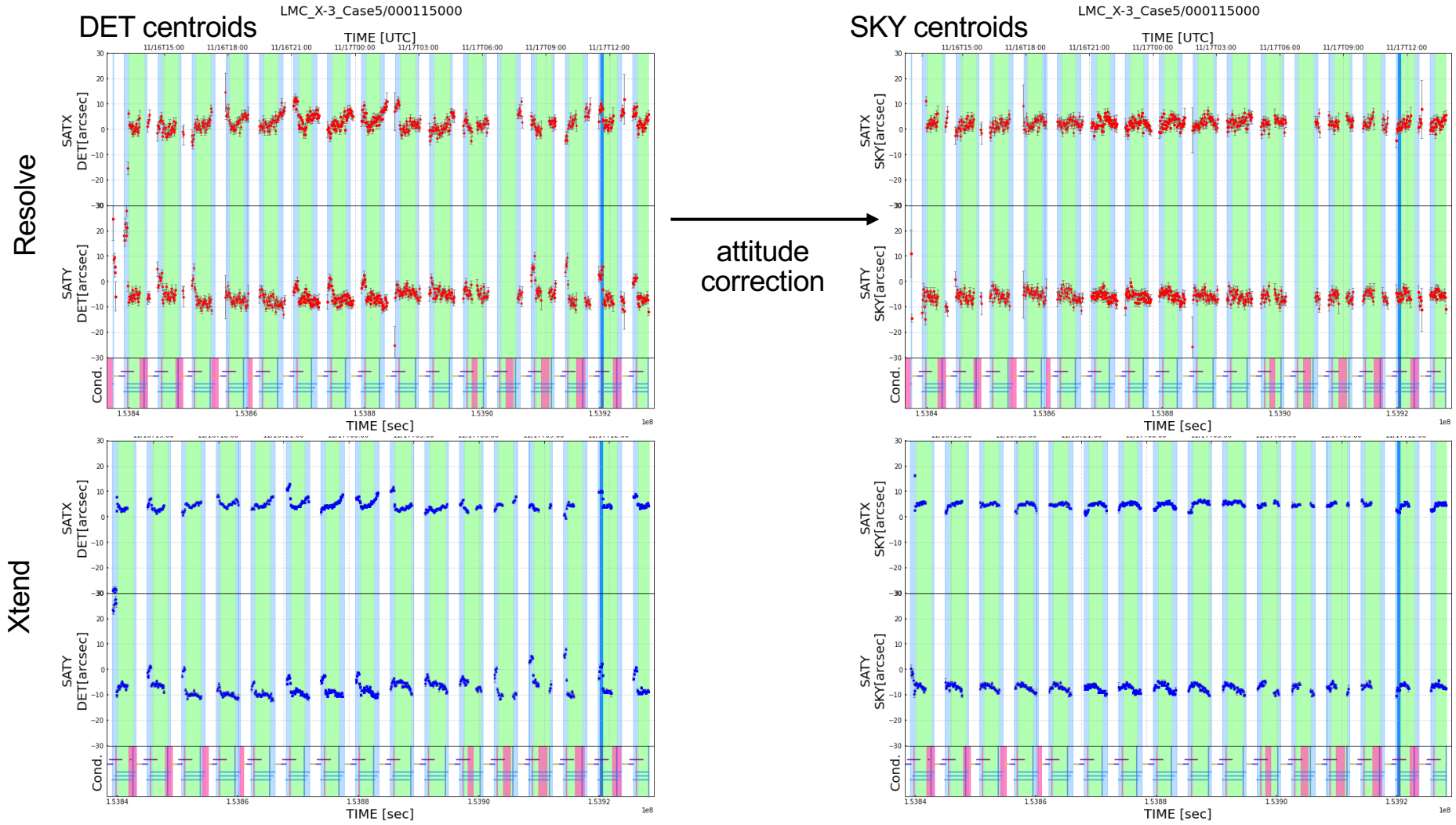
The speed after MNV is a few arcsec/sec.

The attitude converged within 240 seconds





Attitude determination accuracy



- The trends of Resolve and Xtend in DET and SKY coordinates are similar.
- **Attitude correction reduces the deviations <~10"** by offline processing in PPL.
- A few arcsec orbital variation still exists in some observations after updating PPL.