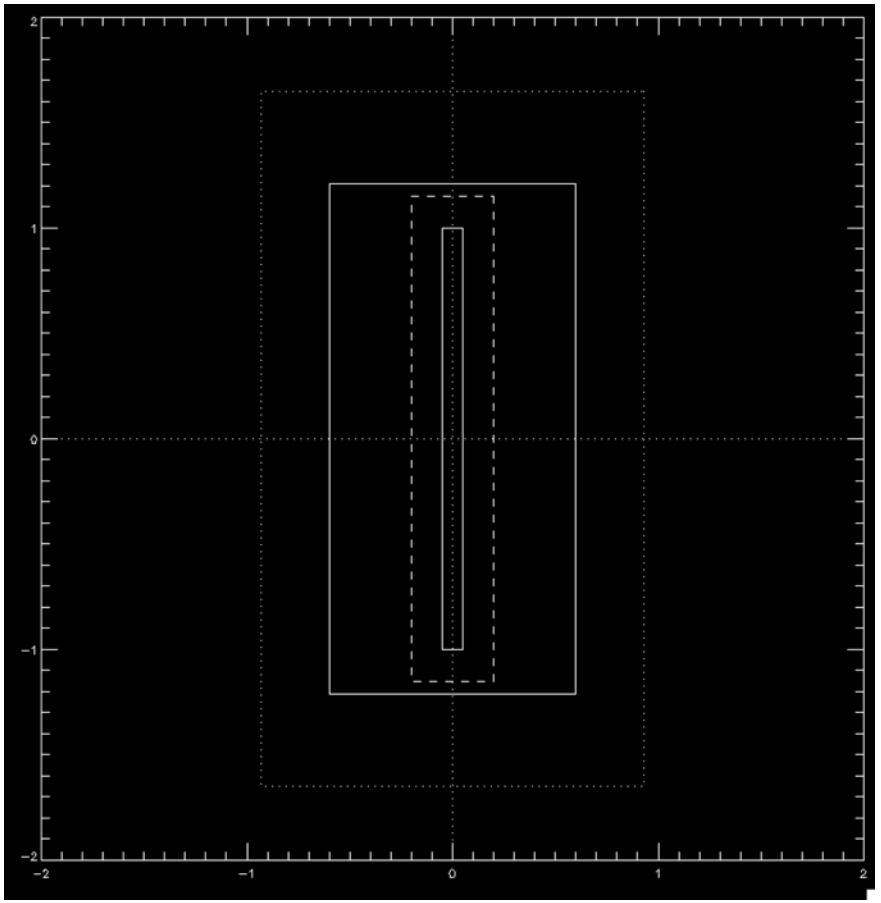
Pointing Performance

E Quémerais & the PHEBUS team

Current Status

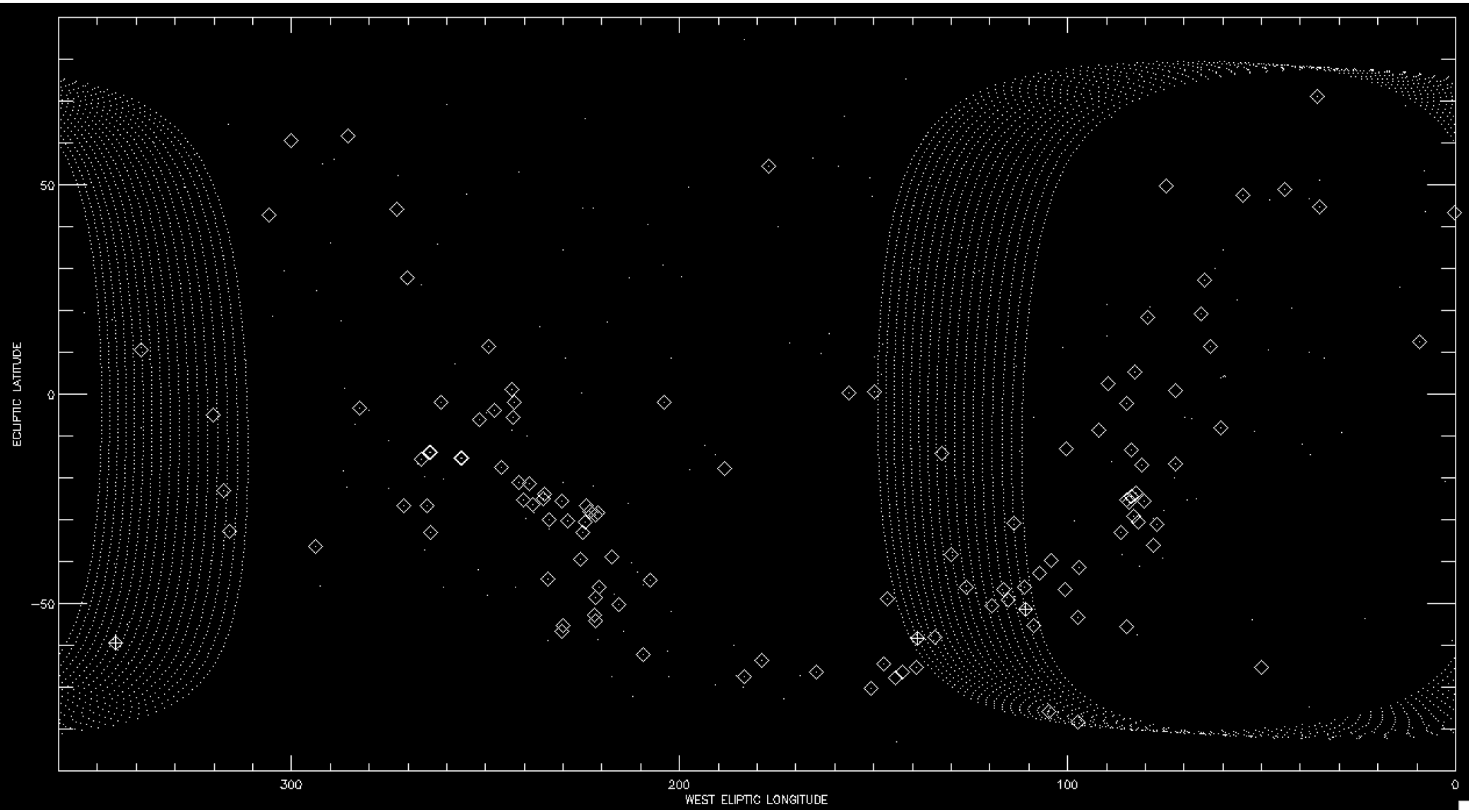
- **Nominal PHEBUS Field of View is defined as**
- **WITH Slit**
  - 75% : $\begin{cases} |x| \leq 0.05\ deg \\ |y| \leq 1.00\ deg \end{cases}$
  - 100% : $\begin{cases} |x| \leq 0.20\ deg \\ |y| \leq 1.15\ deg \end{cases}$
- **WITHOUT Slit**
  - 75% : $\begin{cases} |x| \leq 0.60\ deg \\ |y| \leq 1.21\ deg \end{cases}$
  - 100% : $\begin{cases} |x| \leq 0.93\ deg \\ |y| \leq 1.65\ deg \end{cases}$
  - X – Spectral axis
  - Y – Spatial axis



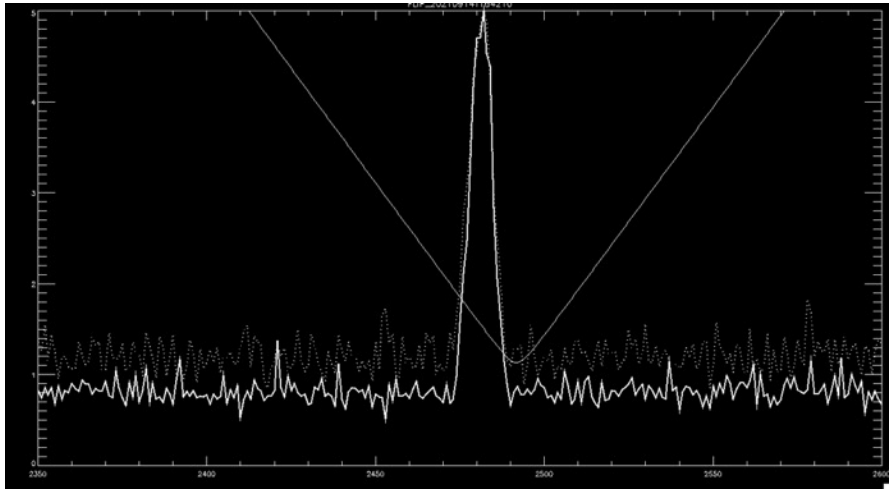
Star and Planet observations

- **In 2019-2020, most observations were successful. However the count rates varied a lot suggesting that the observations were performed close to the edge of the field of view (vignetting).**
- **In 2021, the stars cross the Field of View of PHEBUS faster due to larger orbital velocity around the Sun. The windows to observe stars are shorter -> Many star or planet observations failed.**
- **We used flip maneuver observations to derive a correction of the pointing direction.**
  - The observations were made between February and April 2021 -> 9 useful observations with different scanner angles.

Trace of the PHEBUS FoV during a flip maneuver « quasi circles »

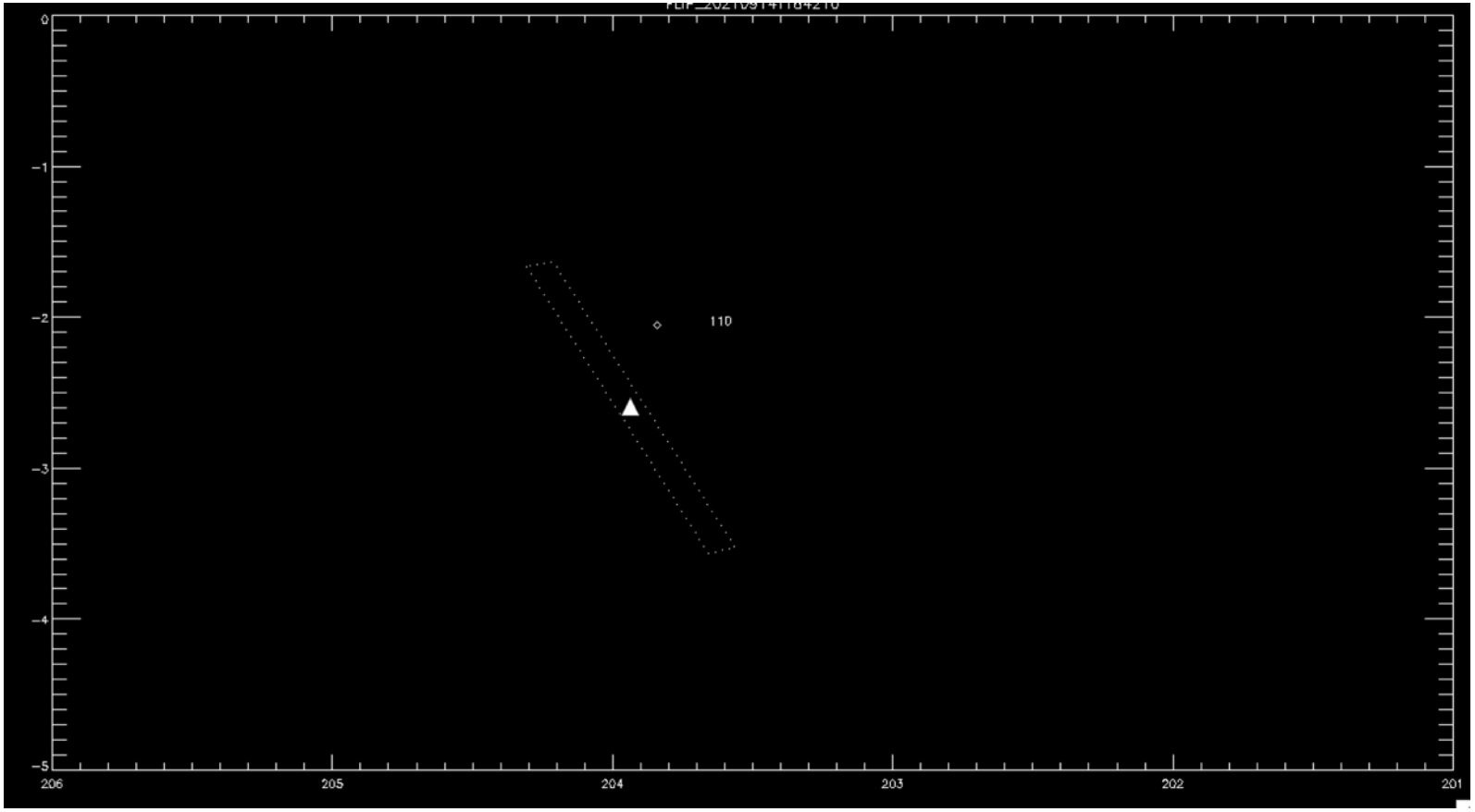


Flip data: Slit ON and NUV only



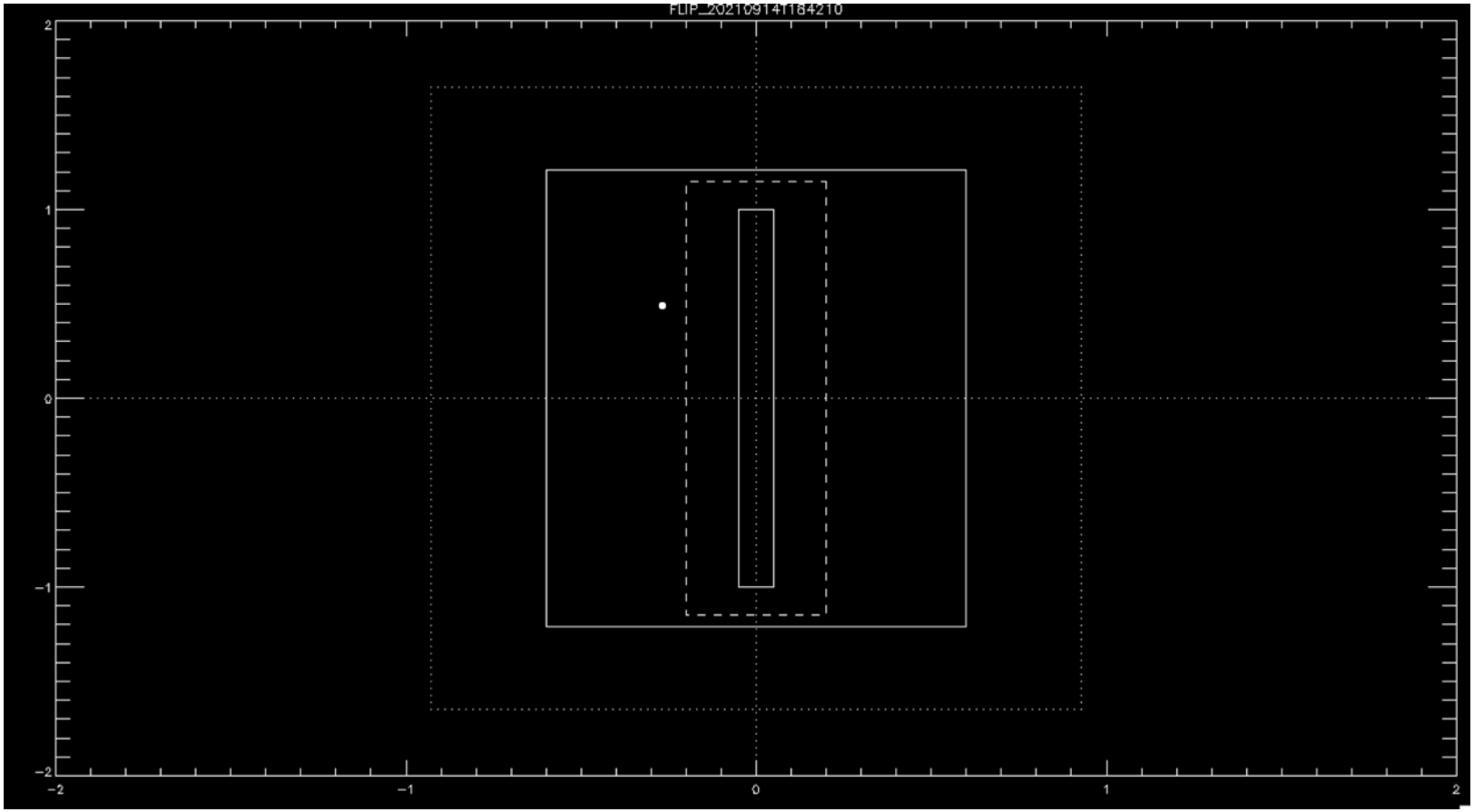
- During the flip the PHEBUS FoV sweeps a circle in the sky. Bright stars cause a spike in the count rate when they cross the slit. By comparison with a catalog we can find which star has been seen and check the count rate with the estimate of the star flux at 400 nm.

Flip data: Slit ON and NUV only



- **Once the star is identified (here #110 in our catalog), we can project the slit on the sky and verify the position of the star wrt to the slit**

Flip data: Slit ON and NUV only



- Here the dot shows the position of the star in the FoV.
- In this case the star is not in the slit. -> Pointing error (0.5 deg)

Deriving the pointing error

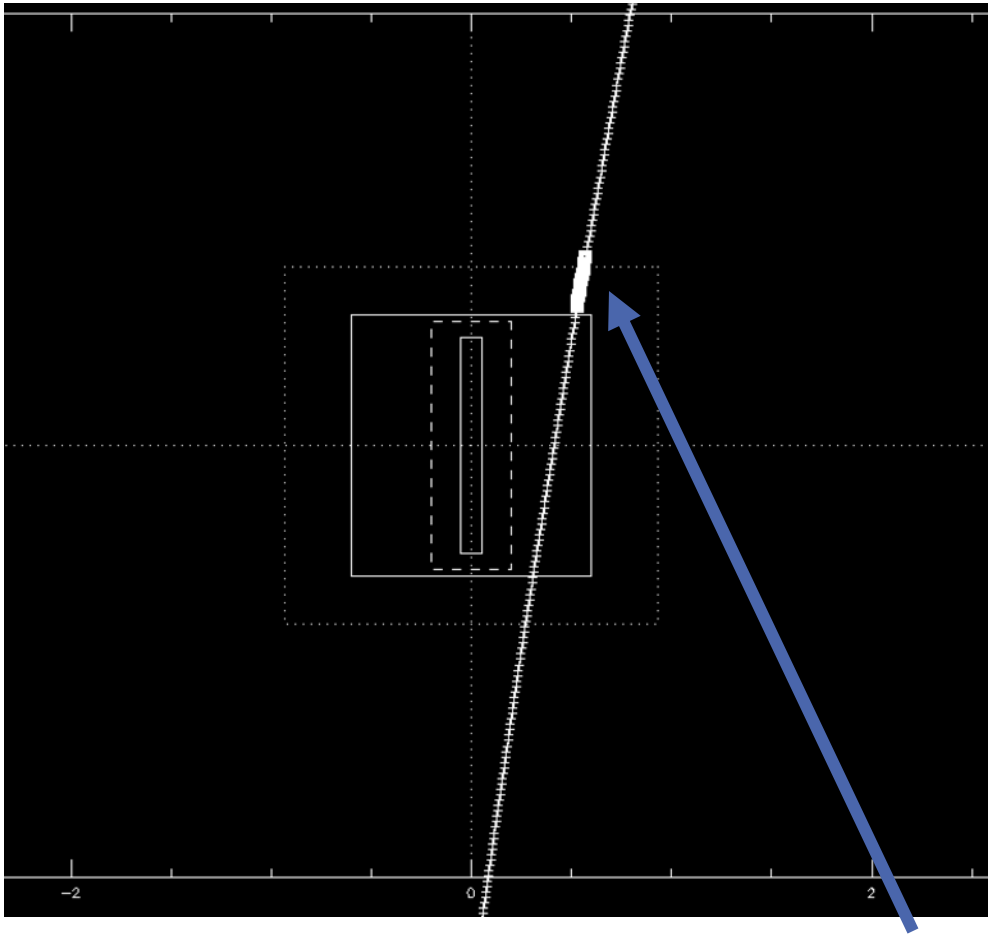
We have assumed that the misalignment is between the PHEBUS reference frame and the spacecraft frame.

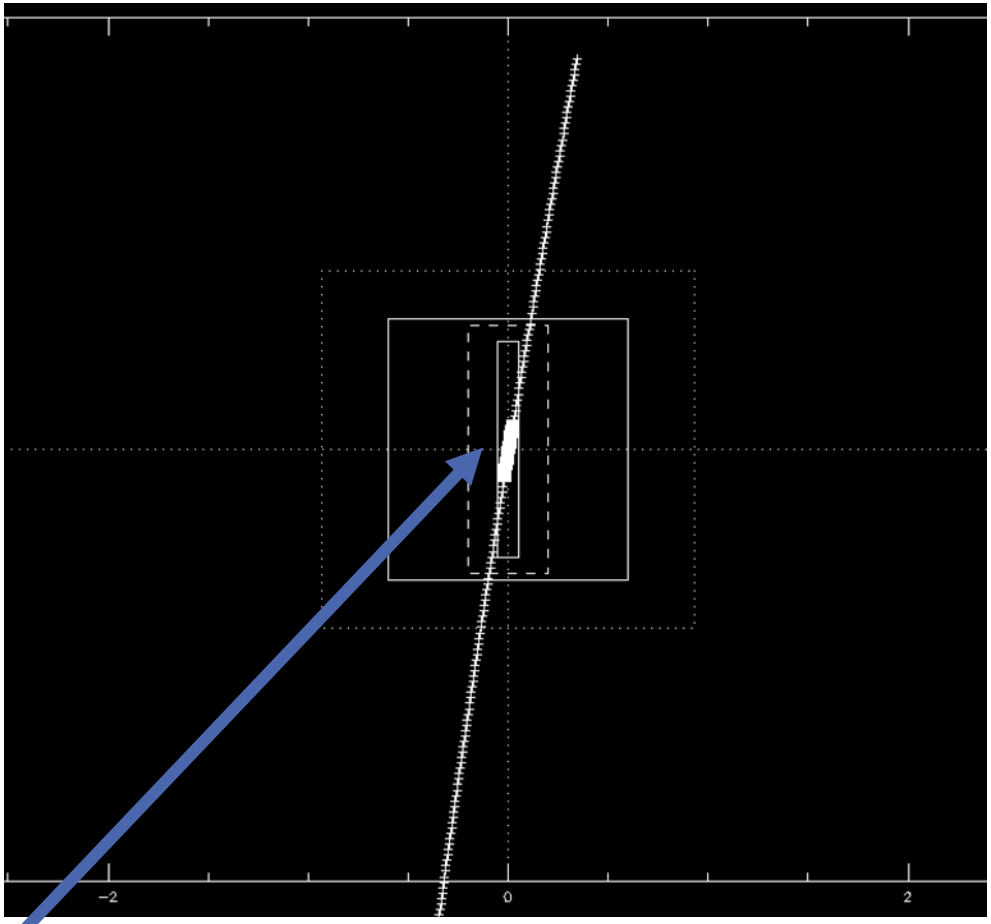
The misalignment is represented by 3 rotations applied on each axis of the spacecraft.

If we combine enough observations with distinct scanner positions, we can find a solution that will be applicable to all scan angles with good accuracy.

A solution was derived in May 2021 and applied in June 2021.

Example of correction





BEFORE

SPIKE IN COUNT RATE = STAR POSITION

AFTER

Failed observations in August and September 2021

- **During the Venus Swing-By 2, we tried to do an occultation of star Alpha Leo -> failure.**
  - Geometry reconstruction with pointing correction predicted that the star was in the FoV
- **On September 14/15 we tried to test the FUV detector while observing Alpha Vir. The detector behaved as expected but there was no stellar spectrum.**
  - Geometry reconstruction with pointing correction predicted that the star was in the FoV
- **4 flip maneuvers were performed end of June 2021 and 4 additional were performed on September 14/15**
- **The pointing correction found in May 2021 does not work with these two sets of additional flips.**

Estimating the difference between the corrections

❑Correction #1 is defined as

- Rot_axeX = 0.49 °
  Rot_axeY = -0.61 °
  Rot_axeZ = -0.26 °

- This correction is based on 9 flips and 6 scan angles

❑Correction #2 is defined as

- Rot_axeX = [-0.15 , 0.15]
  Rot_axeY = -0.15 ± 0.05
  Rot_axeZ = -0.50 ± 0.10

- This correction is based on 3 flips and 2 scan angles

Proposed next steps

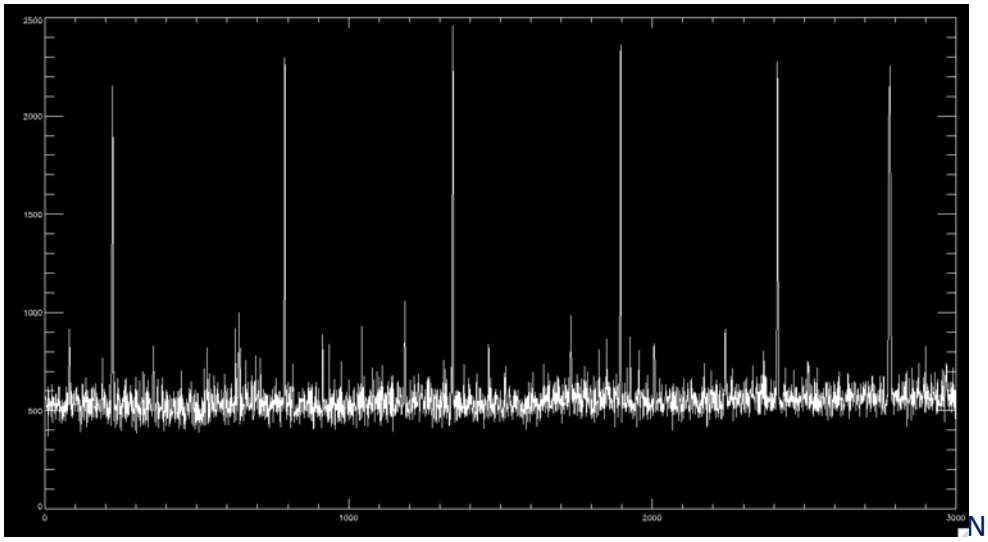
- **We need to modify our model so that a misalignment inside PHEBUS is taken into account, for instance between the slit and the primary mirror.**
  - A LATMOS optical engineer is working on a parametric representation that could be used to fit the data.
- **Recurring flip campaigns.**
  - LATMOS will design flip campaigns that will allow to characterize the pointing error (6 scan angles per flip)
    - We will verify the dates for which a bright star is available.
    - Slit ON, NUV only , data volume = 1 Mbyte per flip
    - This should be repeated on a regular basis (monthly ?) to check for any temporal variations.

❑Added on October 15th

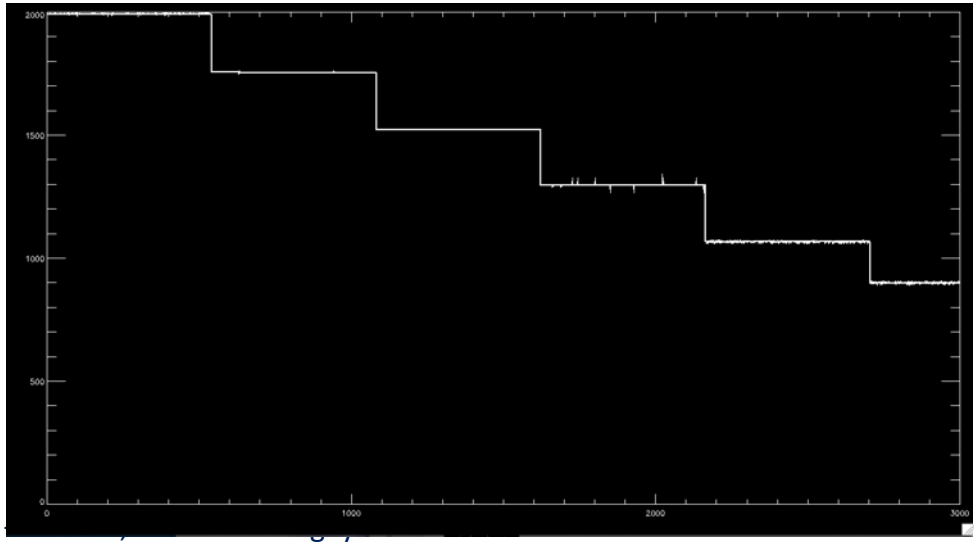
Flip Observation from 11-10-2021

- On October 11 2021, we performed a flip observation with 6 scanner positions. The aim is to look at the same star at 6 different positions.
- Every 20 minutes, the scanner rotates to compensate for the rotation of the platform wrt the star.

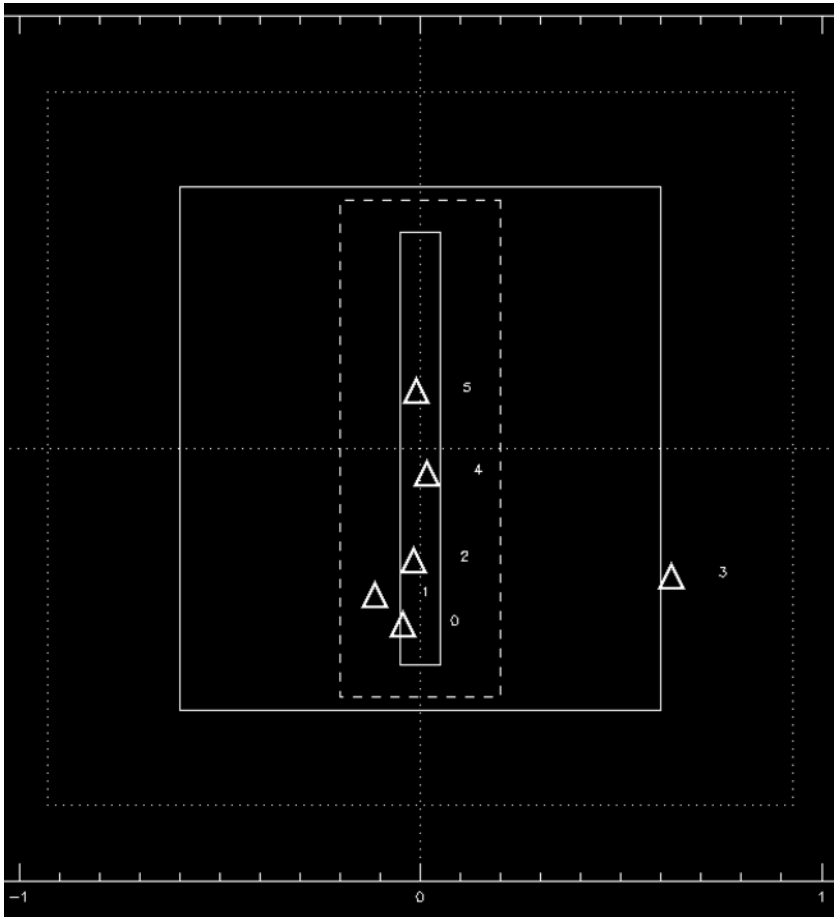
COUNTS DURING THE OBSERVATION



SCAN ANGLE DURING THE OBSERVATION

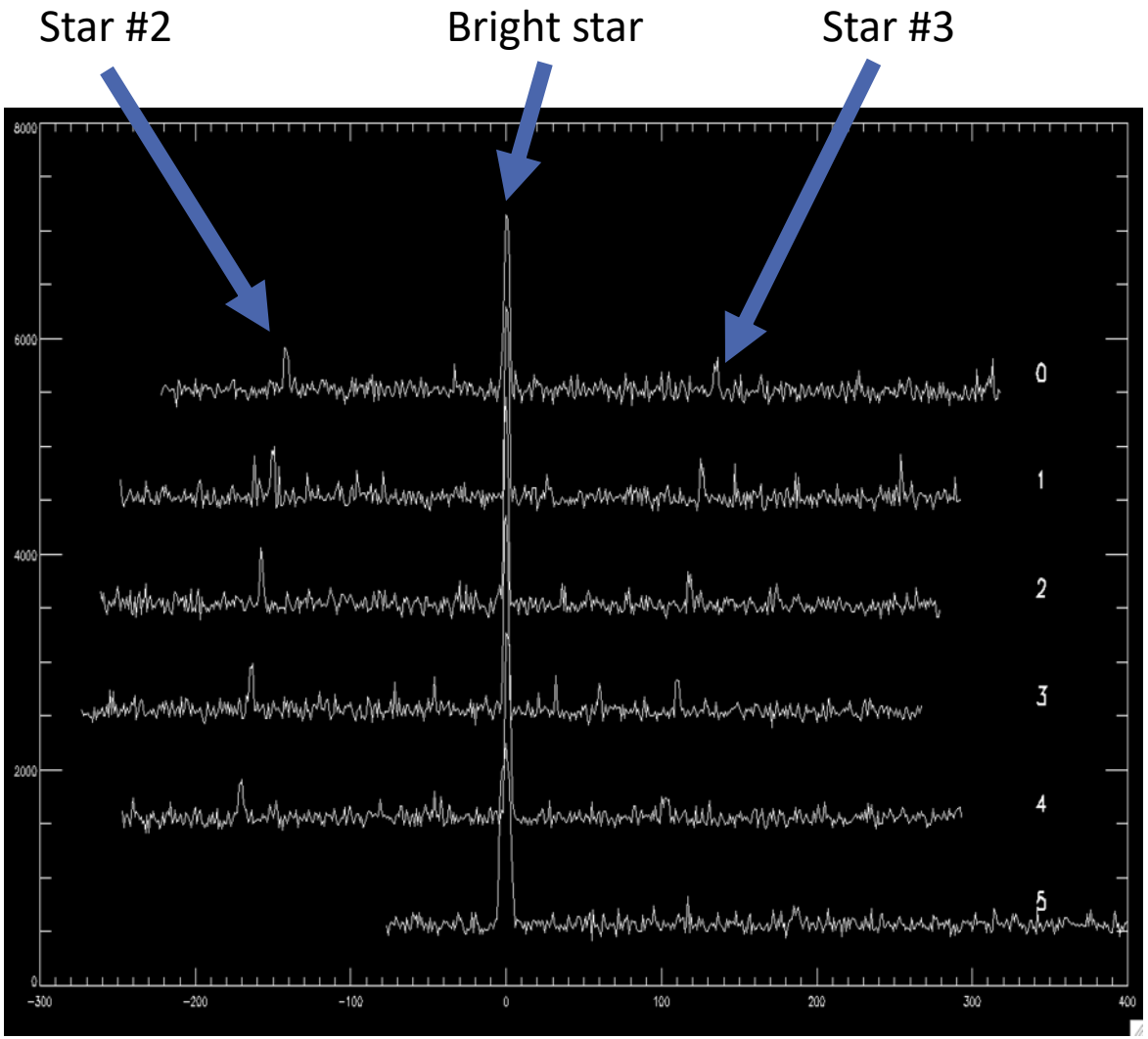


Flip Observation from 11-10-2021



- No solution was found to fit all 6 positions
- However, one solution was found fo fit 5 out of 6, except for the fourth position (position #3, numbering starts at #0)

Flip Observation from 11-10-2021

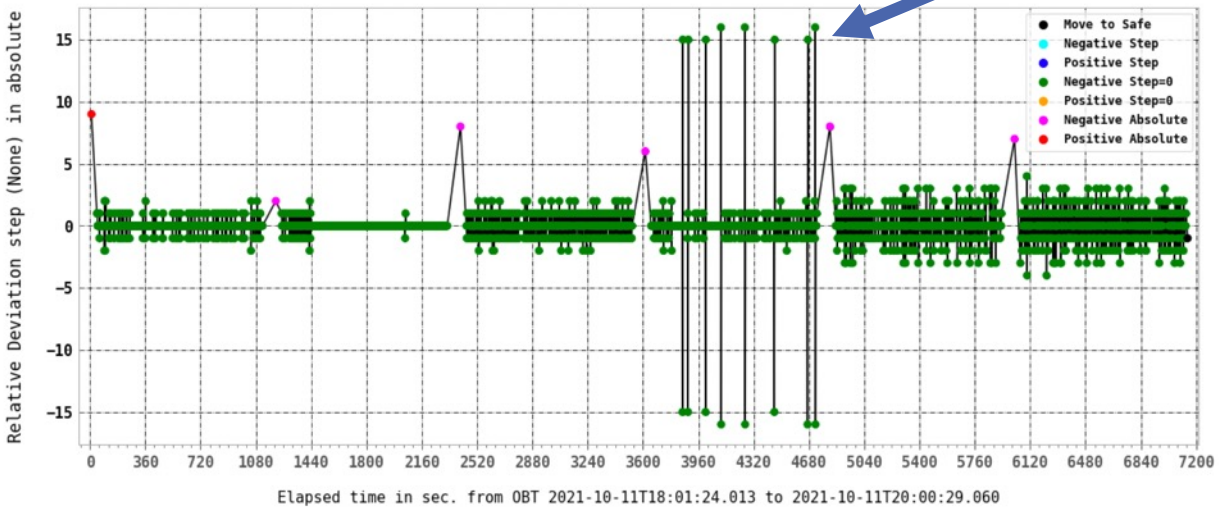


- **What is different for position #3 ?**
- **There are two other stars visible and the delays between the spikes are consistent with the orientation of the slit (changes with scanner angle) -> #3 is delayed, the scan angle is not correct !**

From the HK data report

Scanner HK, Pointing

- 6 fixed positions @ 1985 (P dir.), 1758(N dir.), 1530 (N dir.), 1302 (N dir.), 1075 (N dir.), 904 (N dir.) **(=> scan angles : 175, 155, 135, 115, 98, 80°; each during 18 min)**
- mean absolute positions measured : 1994, 1756, 1528; 1296; 1067, 897
  - Deviation 1st absolute position commanded/measured : +9; -2; -8; -6; -8; -7;
  - Abnormal measurements observed during 4th position



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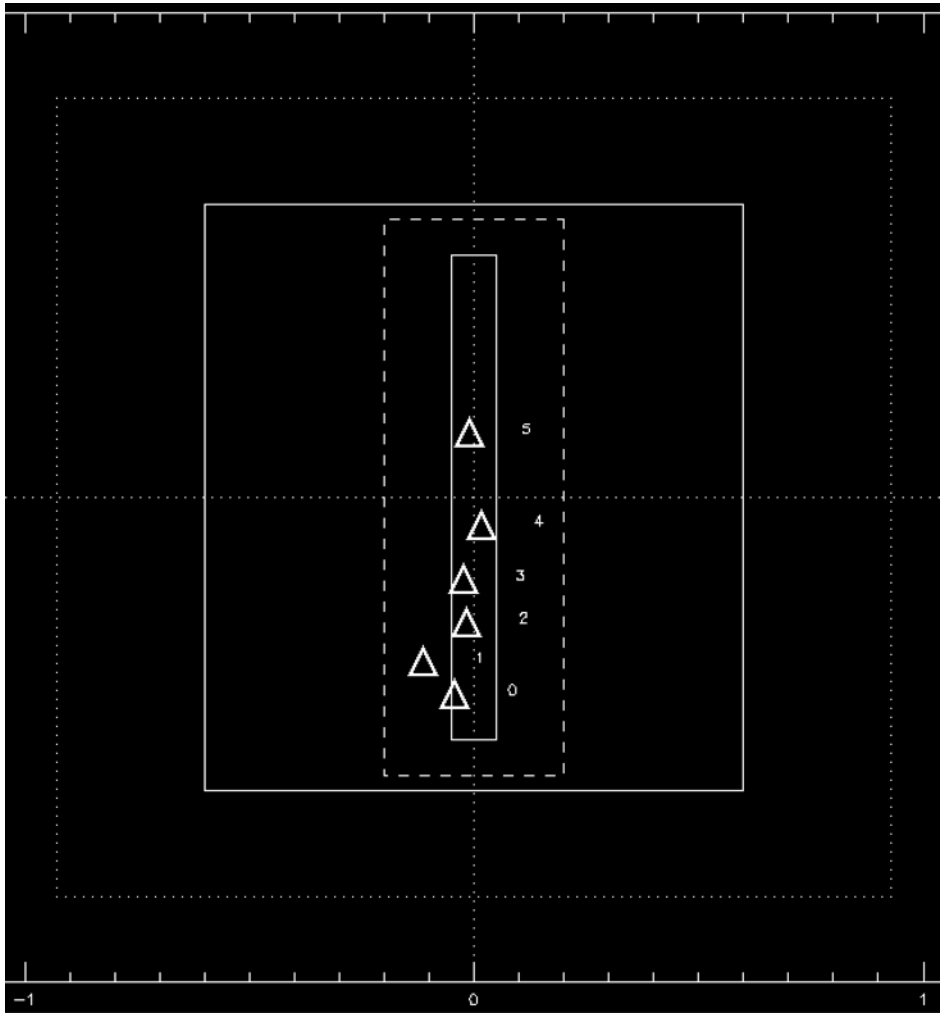
Observation #3 (the fourth one) has larger deviations than normal

Remark:
The noise of the position measurement is not systematic and does not seem to be correlated with the shift of -8 step

Flip Observation from 10-2021



- If we shift the scanner by 8 bits then position #3 agrees with the others !
- The correction found is
  - Rot_ X = 0.01 +/- 0.1
  - Rot_Y = -0.65 +/- 0.1
  - Rot_Z = -0.15 +/- 0.1
- This solution works with the flips on 14/15 september if scanner positions close to 115 are shifted by -8 (in steps)

Is there a change in the correction?

Solution found in April 2021

Rot_axeX = 0.49 °
Rot_axeY = -0.61 °
Rot_axeZ = -0.26 °

Acceptable (marginal) for 09-2021 values

Not acceptable for 10-2021

Solution found for 09-10 2021

Rot_ X = 0.01° +/- 0.1
Rot_Y = -0.65° +/- 0.1
Rot_Z = -0.15° +/- 0.1

Works for February flips.

This is a better solution

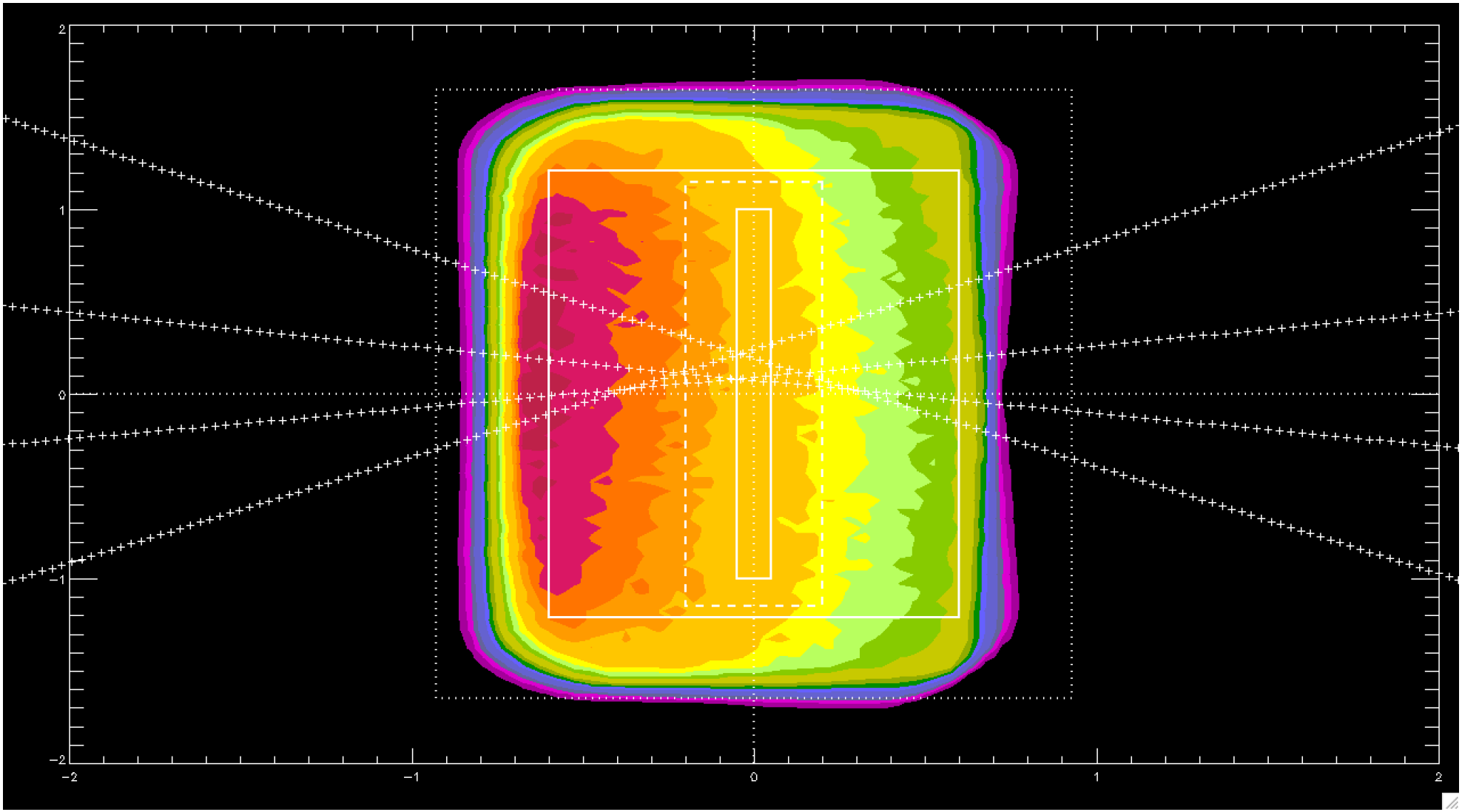
Conclusion

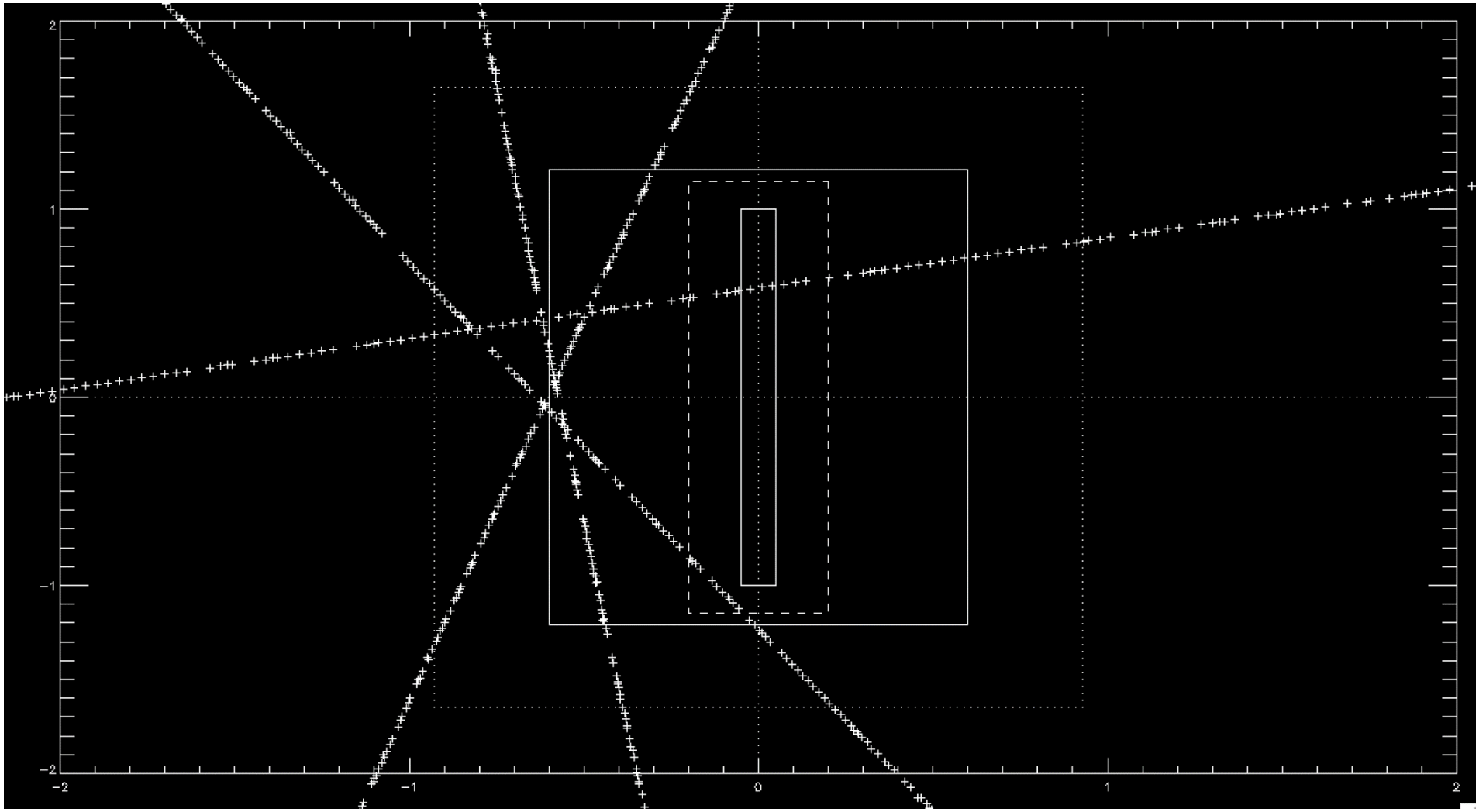
- We have found a solution which is in agreement with the flip observations from 2021. This requires to shift one scanner position by -8 steps in 3 flips.
- We will try to improve the solution by including an internal misalignment between the primary mirror and the slit.
- More data should be acquired to improve accuracy and check for temporal variations.
- Scanner position 115° +/- TBD (1308 steps) seems to correspond to an erroneous encoder value (real value is obtained by a shift of -8 step). Is this the only one ? Is this systematic (at least 4 occurrences, 3 flips 1 missed occultation)?

❑Update 20-01-2022

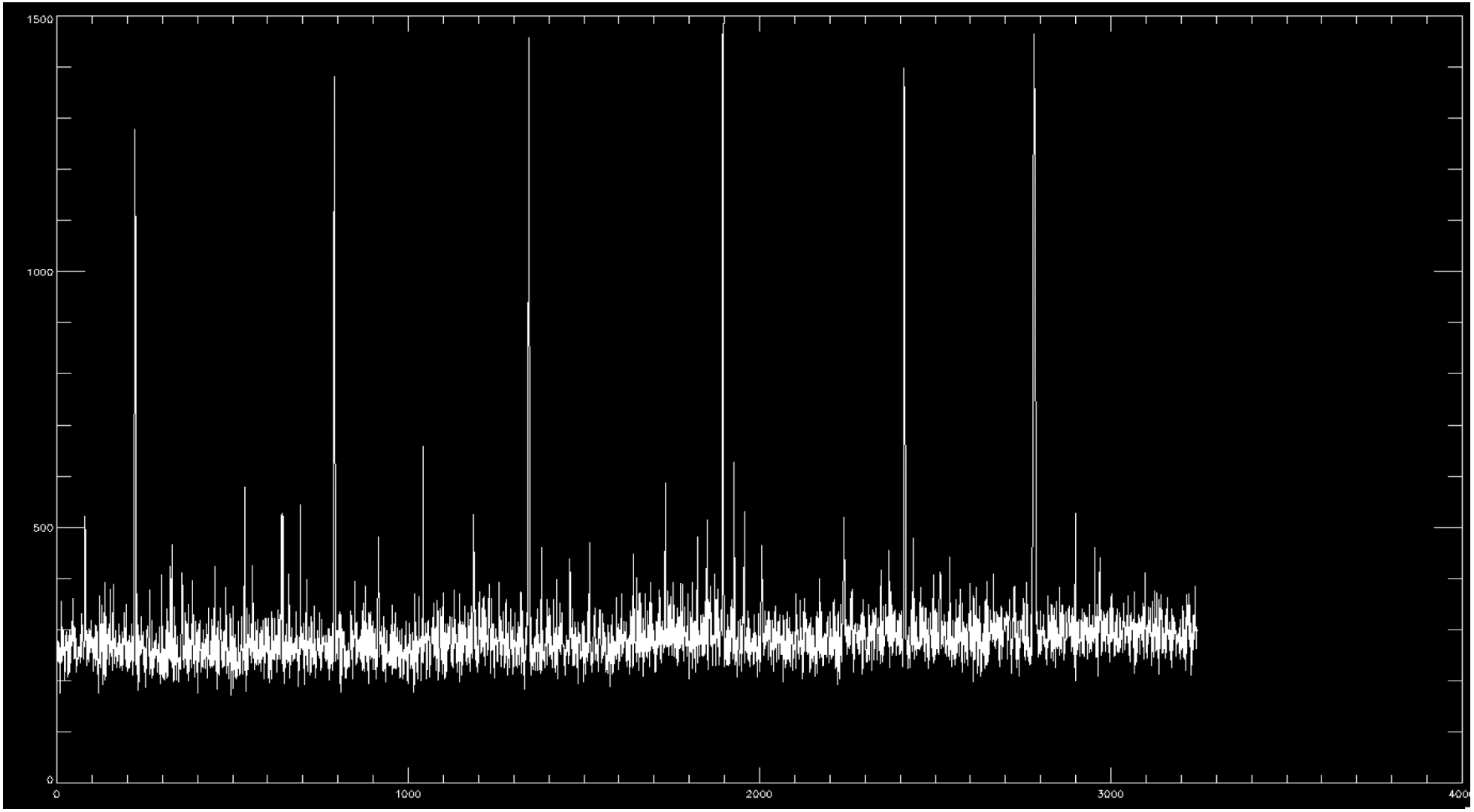
- New data available
- October 11 2021 : 6 « crossings » of Eps CMa
- December 21 2021: 5 « crossings » of Alpha Leonis
- January 2022 observation cancelled (safe mode).

next observations Feb-April 2022 (STP 77, 78 & 79)


2
1
0
−1
−2
−2
−1
0
1
2


2
1
0
−1
−2
−2
−1
0
1
2

6 crossings of Eps C Ma



Eps CMa October 11, 2021

6 scanner positions:

0	540	175.078
541	1081	154.160
1082	1622	133.770
1623	2163	113.906
2164	2704	93.7793
2705	3245	79.0137

Spacecraft axes rotation compared to angle between scanner position

angle pos #0 - 0 = 0.00 (deg) = 0 (step) - delta scanner (step) = 0 - difference = 0 (step) - Old Pos = 1992 - New Pos = 1992

angle pos #0 - 1 = 21.18 (deg) = 240 (step) - delta scanner (step) = 238 - difference = 2 (step) - Old Pos = 1754 - New Pos = 1751

angle pos #0 - 2 = 41.90 (deg) = 476 (step) - delta scanner (step) = 470 - difference = 6 (step) - Old Pos = 1522 - New Pos = 1515

angle pos #0 - 3 = 62.61 (deg) = 712 (step) - delta scanner (step) = 696 - difference = 16 (step) - Old Pos = 1296 - New Pos = 1279

angle pos #0 - 4 = 82.10 (deg) = 934 (step) - delta scanner (step) = 925 - difference = 9 (step) - Old Pos = 1067 - New Pos = 1057

angle pos #0 - 5 = 96.49 (deg) = 1097 (step) - delta scanner (step) = 1093 - difference = 4 (step) - Old Pos = 899 - New Pos = 894

Alpha Leonis

5 scanner positions

Nom = 32Alp Leo

0	240	160.488
241	481	145.635
482	722	129.990
723	963	115.049
964	1204	99.3164

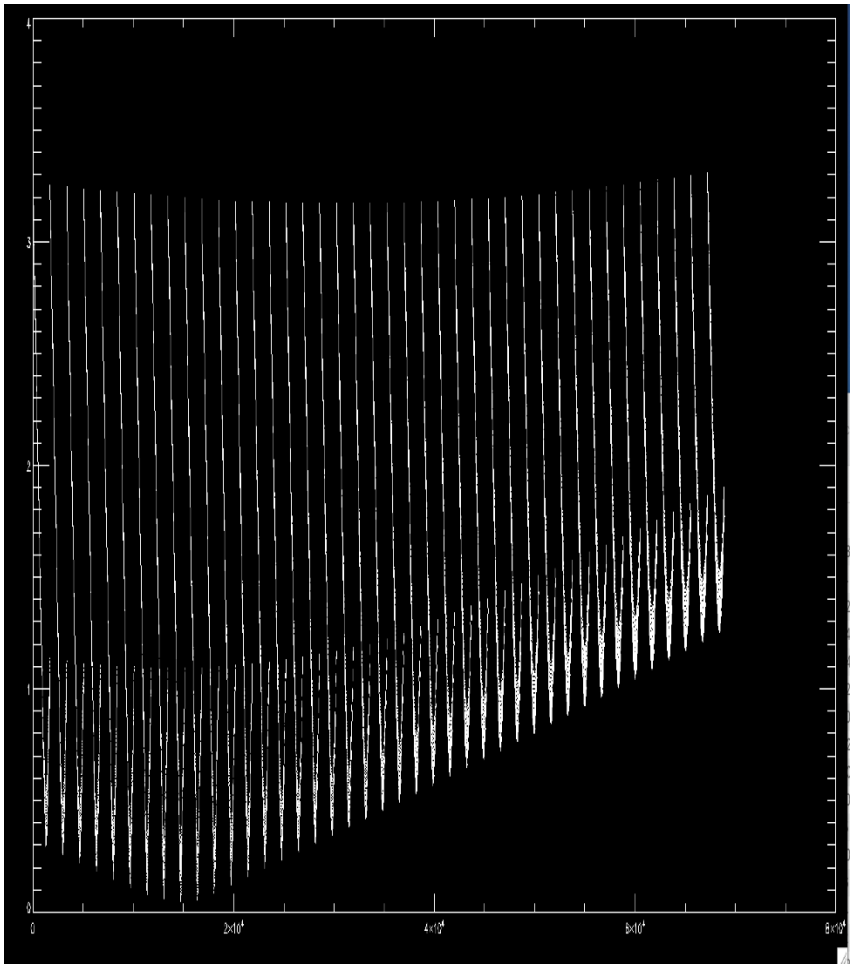
angle pos #0 - 0 = 0.00 (deg) = 0 (step) - delta scanner (step) = 0 - difference = 0 (step) - Old Pos = 1826 - New Pos = 1826

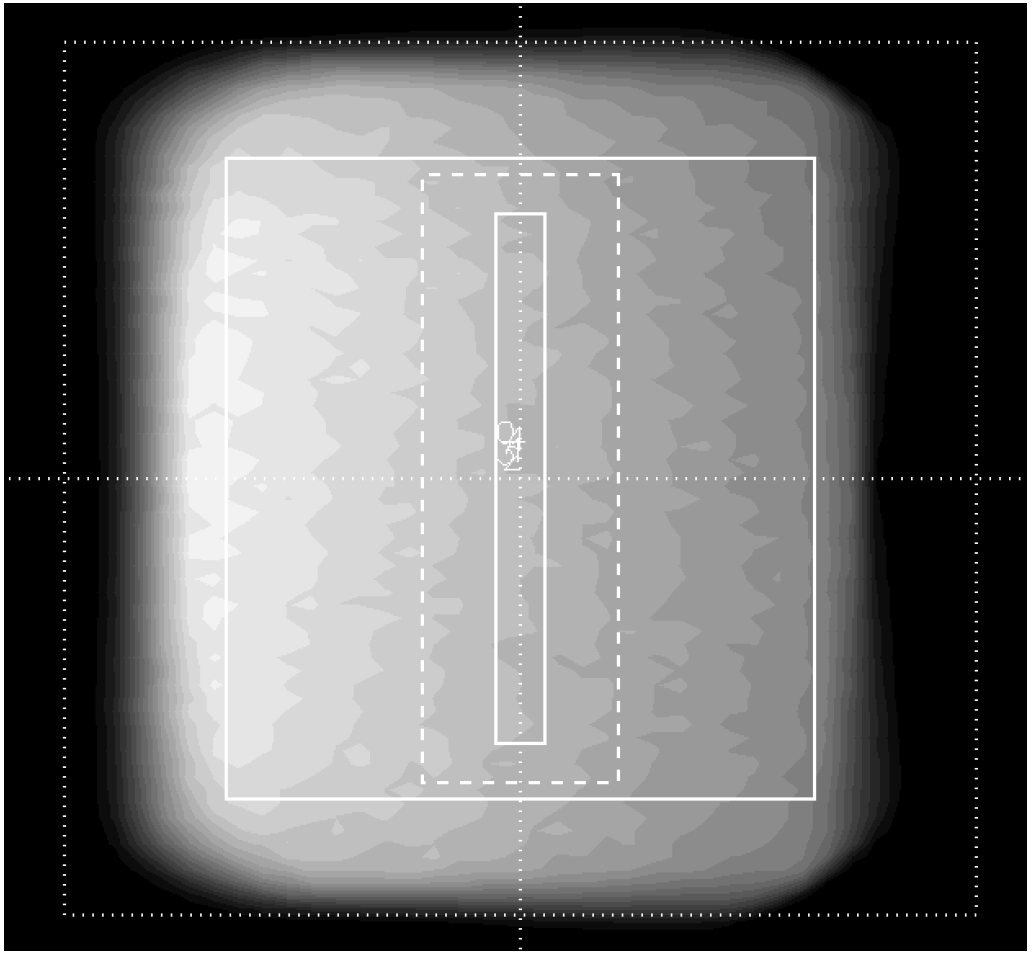
angle pos #0 - 1 = 14.87 (deg) = 169 (step) - delta scanner (step) = 169 - difference = 0 (step) - Old Pos = 1657 - New Pos = 1656

angle pos #0 - 2 = 30.21 (deg) = 343 (step) - delta scanner (step) = 347 - difference = -3 (step) - Old Pos = 1479 - New Pos = 1482

angle pos #0 - 3 = 45.90 (deg) = 522 (step) - delta scanner (step) = 517 - difference = 5 (step) - Old Pos = 1309 - New Pos = 1303

angle pos #0 - 4 = 61.23 (deg) = 696 (step) - delta scanner (step) = 696 - difference = 0 (step) - Old Pos = 1130 - New Pos = 1129





;;;; best result, Eps CMa

RX = 0.447 & RY = 1.153 & RZ = 0.366

X2 = 0.047

;;;; best result, Alp Leo

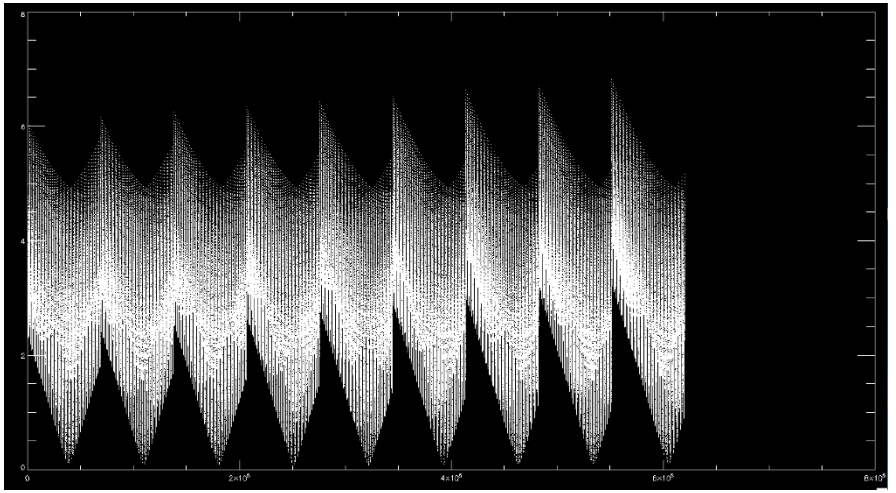
RX = 0.035 & RY = 0.520 & RZ = -0.605

X2 = 0.022

- New parameter to consider: deviation angle (angle between LOS and optical axis)
- D = 100° +/- x °

- Ex Eps CMa

- 0.50 1.20 0.30 99.9 0.12050695
- 0.50 1.20 0.40 100.0 0.10443838
- 0.50 1.20 0.50 100.1 0.096401472
- 0.50 1.20 0.60 100.2 0.098336927
- 0.40 1.20 0.70 100.3 0.091720253
- 0.40 1.20 0.80 100.4 0.093753077
- 0.40 1.20 0.90 100.5 0.10550495
- 0.30 1.20 1.00 100.6 0.11663856



Conclusion on pointing

The position given by the scanner encoders is inaccurate (approx 0.5°, may vary with scanner position). Proved by multiple crossing flip observations.

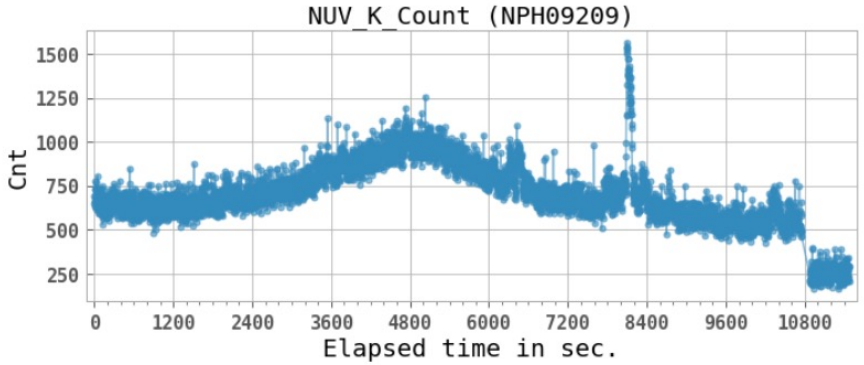
This is linked to the backlash observed on the ground (same amplitude).

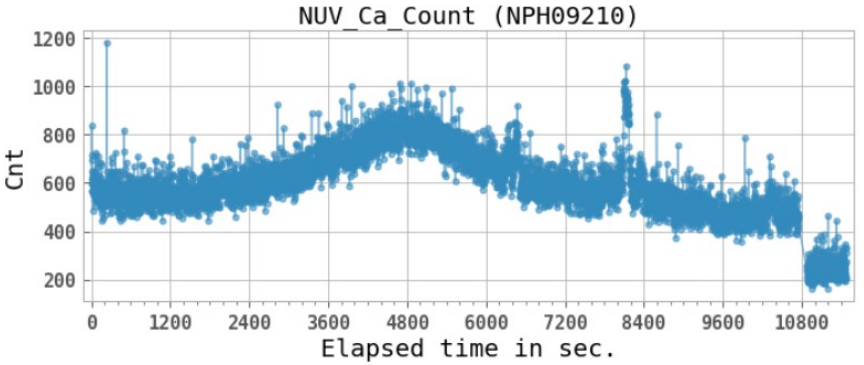
No pattern found yet (need more flip observations with multiple crossings of FoV by the same star).

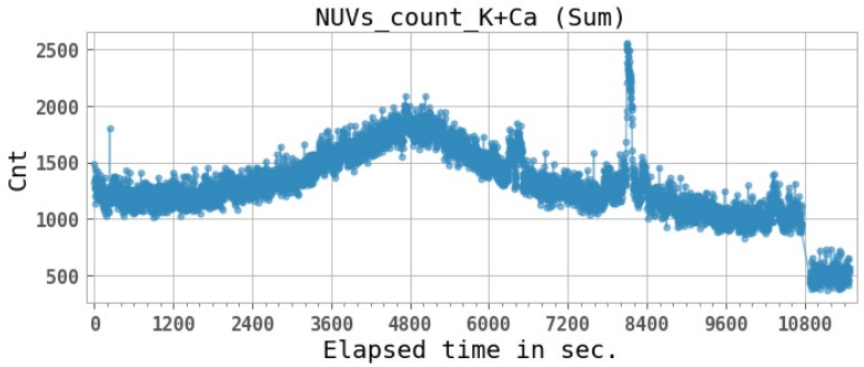
This inaccuracy is likely the reason why we cannot find a single solution for the pointing correction. It is likely that the de-pointing is smaller than the scanner position inaccuracy.

Optical analysis shows that the deviation angle should also be used in the optimization, which increases the number of possible solutions.

Count rate during flip maneuvers

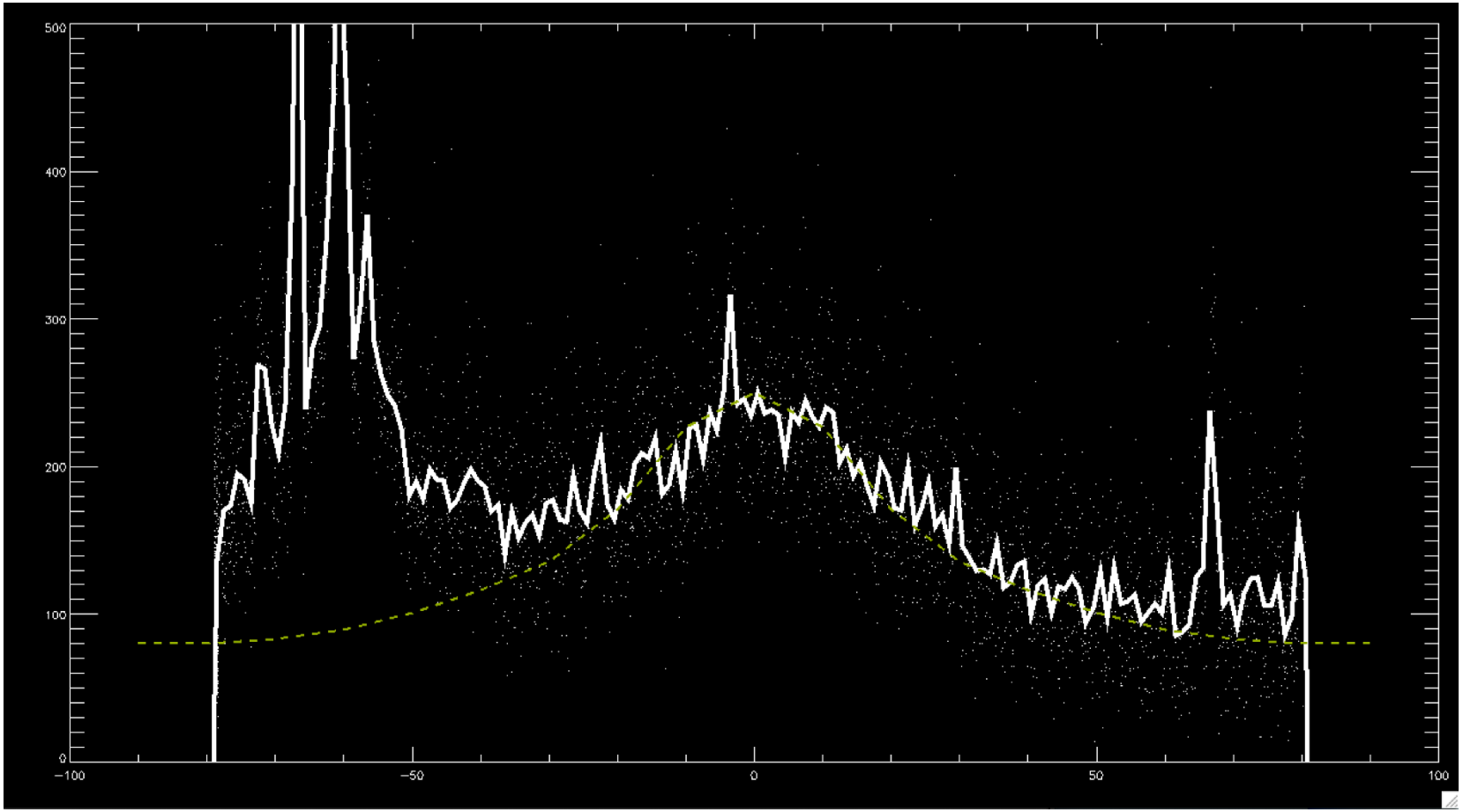






Elapsed time in seconds from OBT 2022-03-09T19:20:02.957 to 2022-03-09T22:31:17.000

Zodiacal Light



Conclusion 16-3-2022

As of March 2022, the main source of pointing error seems to be caused by

- **Inaccuracy of the scanner position given by encoders (backlash).**
- **It seems premature to define a pointing correction. So we propose not to use it for now.**
- **More flip observations with multiple crossings of the FoV must be performed (only 2 successful as of March 2022).**

Zodiacal light and stellar background (galactic plane) have been shown to be contributing to the visible channel counts (equivalent to dark counts). We need to perform more calibration to be able to model these contributions. ZL contribution will be significantly stronger during the orbital phase.

- **We need more observations during flip maneuvers (only one scanner position).**
- **These observations should resume after MSB2 when possible.**