FIS Slow Scan Tool, advanced
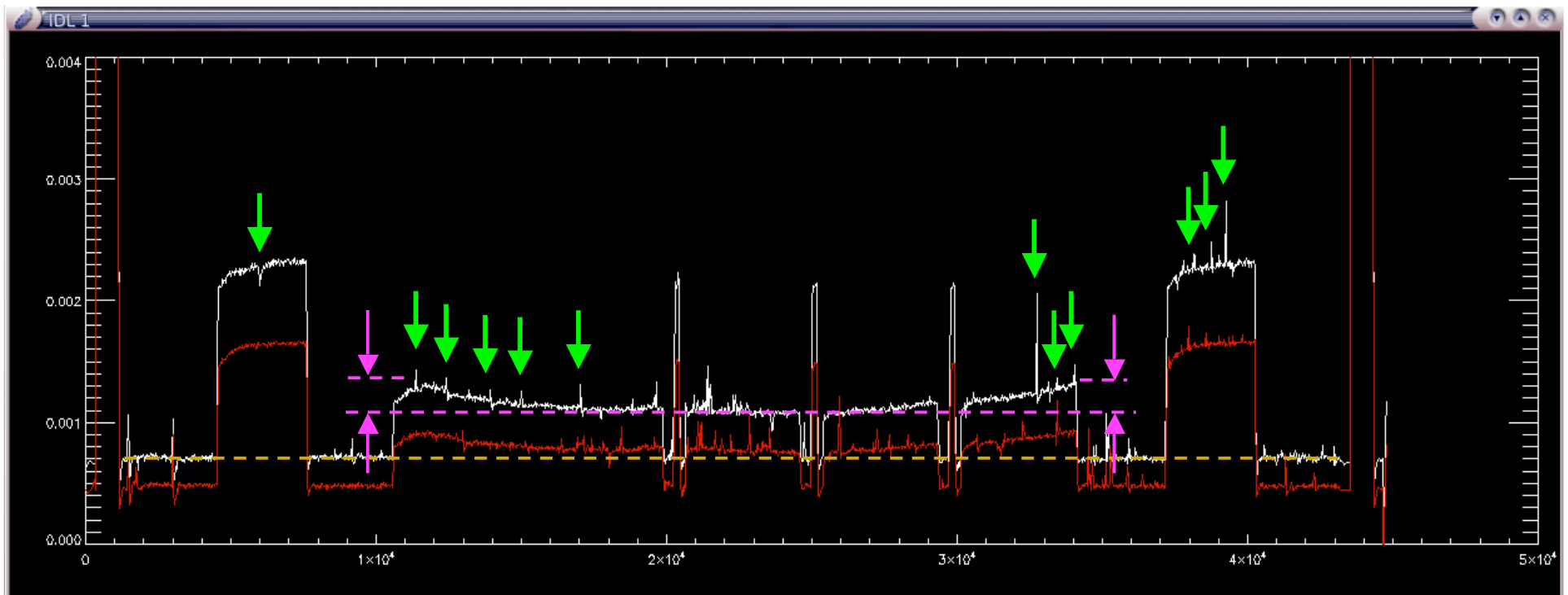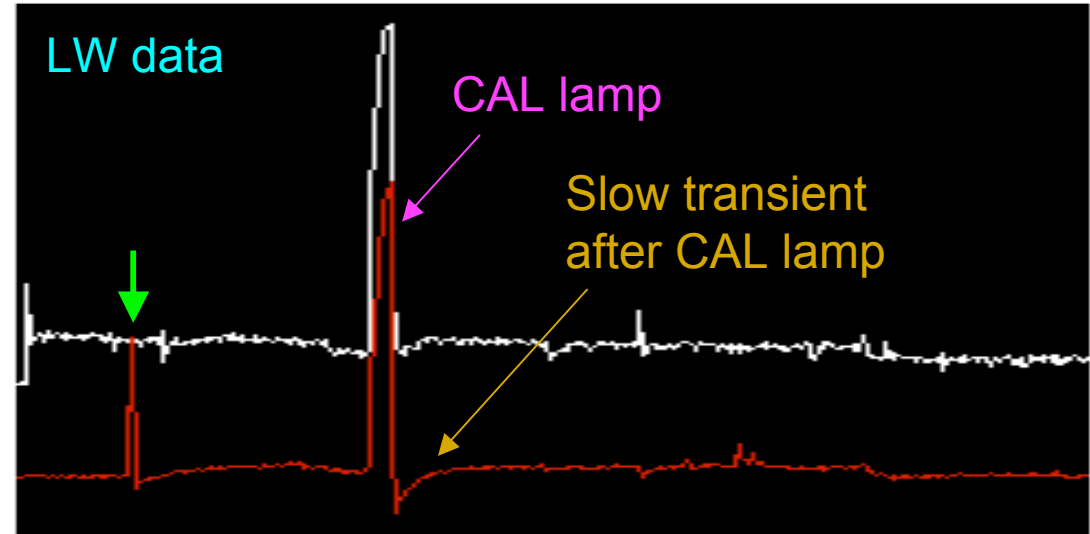
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I. Need for correction of various detector effects

Time domain:
1. Dark subtraction
2. Responsivity correction
3. Flat fielding
4. Correction of slow transients
5. Stray light removal
6. Glitches

LW data

CAL lamp

Slow transient after CAL lamp

II. Optional functions of "ss_run_ss.pro"

1. /LOCAL_FLAT (,T_FLAT_START=value, T_FLAT_END=value)

   Produce a flat field by integrating the data for a given time range.

2. /TRANS_COR

   Correction of the drift after shutter close/open.

3. /SL_RMV

   Stray light removal with a very slow filter.

4. /SMOOTH_FILTER or /MEDIAN_FILTER (,WIDTH_FILTER=value)

   High-pass filter with smooth or median function for a given time width.

5. BAD_THRSHLD=value

   Threshold for the bad-pixel rejection by checking the responsivity.

6. SIGMA=value

   Threshold for the bad-pixel rejection in the co-add process.

7. N_RAMP_DIV=value

   Each ramp is divided into this number.

8. GRID_SW=value, GRID_LW=value

   Grid size specified for making co-added image.

9. /PIX_MAPPING

   To produce a smooth image with finer pixel by the pixel convolution.

10. /SCUT

   To produce individual co-added images for all 4(2) scans of FIS01(02).

II-1. Flat field:
Pre-measured flat (default)

- Zodi / Cirrus observations in PV
- Dark
- Cal - Dark
- Flat_sky - Dark

- CTOF
  = (Cal - Dark) / (Flat_sky - Dark)

- Flat = (Cal - Dark) / CTOF,
  by default
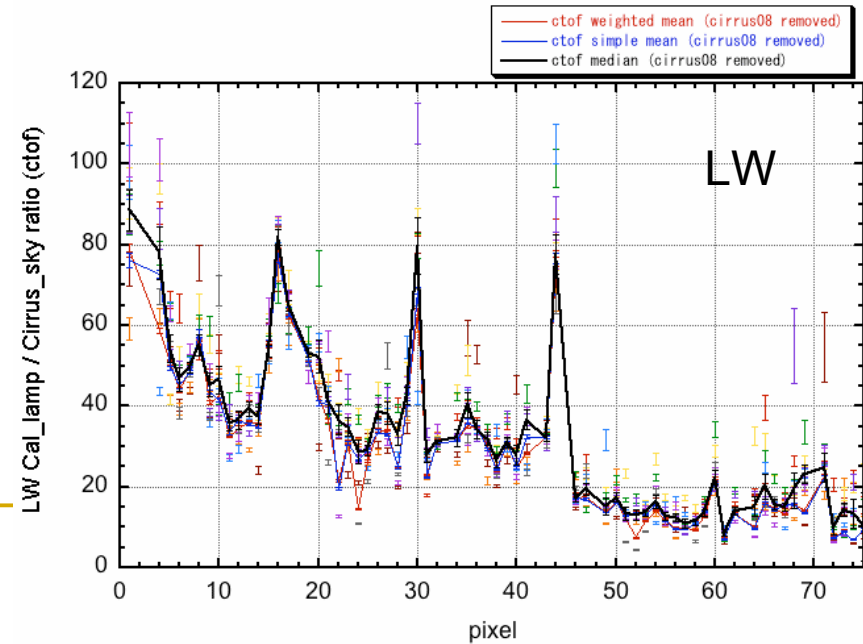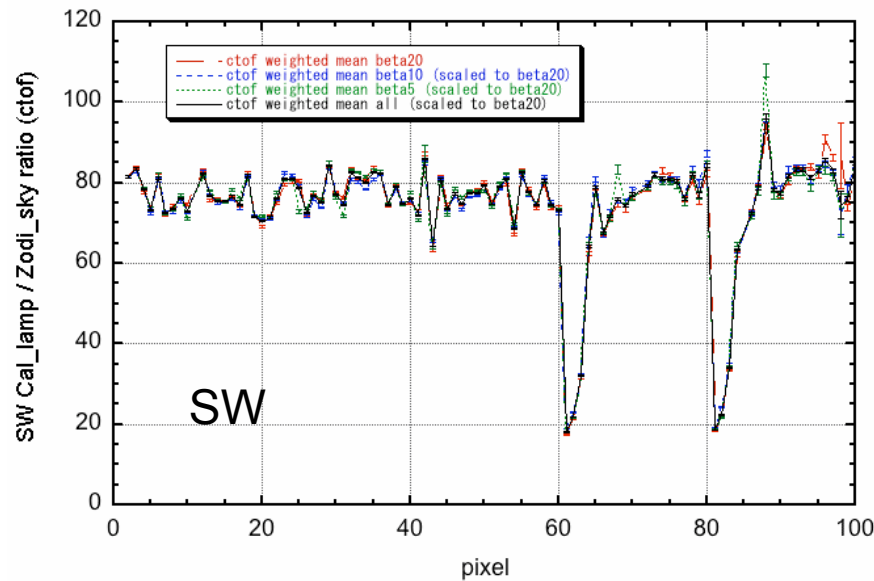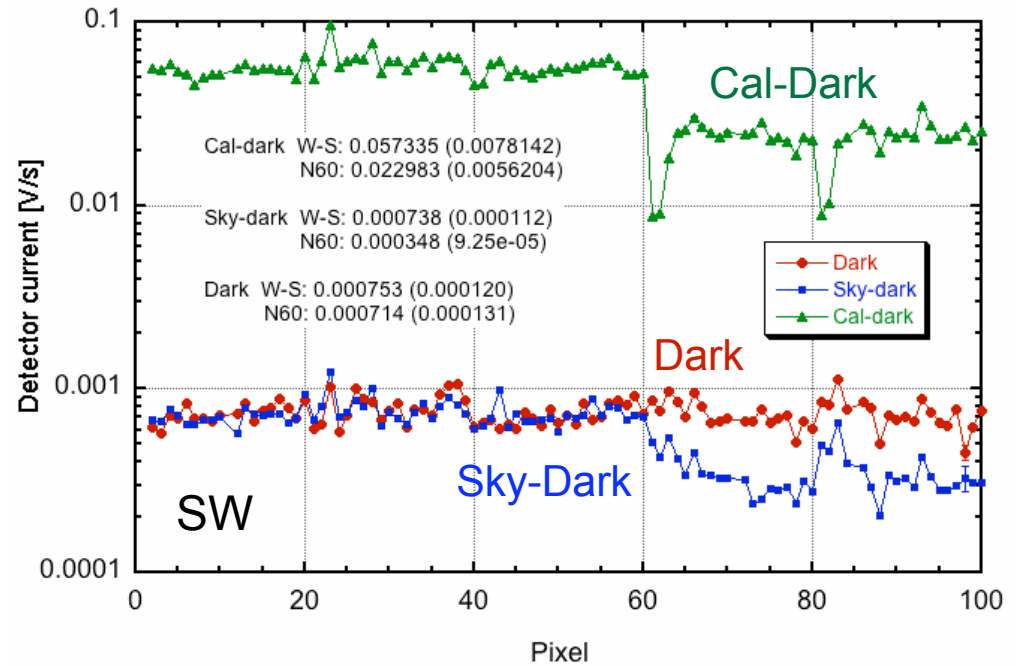
II-1. Absolute calibration

- **Responsivity**
  Conversion factor
  from: detector current
  to: absolute sky brightness

- Absolute scale for pix-averaged responsvity was scaled to DIRBE/COBE data.

- Responsivity for diffuse source in orbit was consistent with pre-flight measurement in lab.

- Calibration for point sources was separately done.
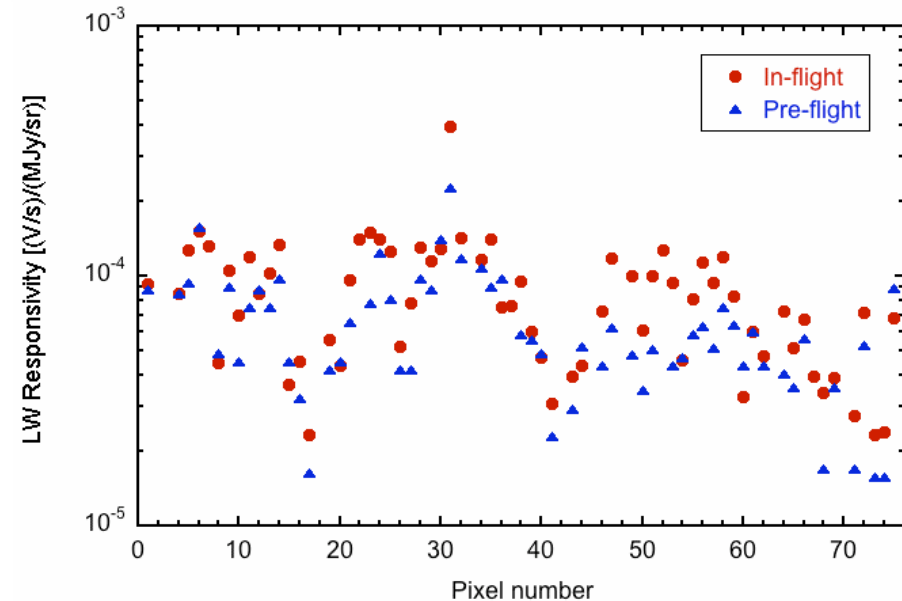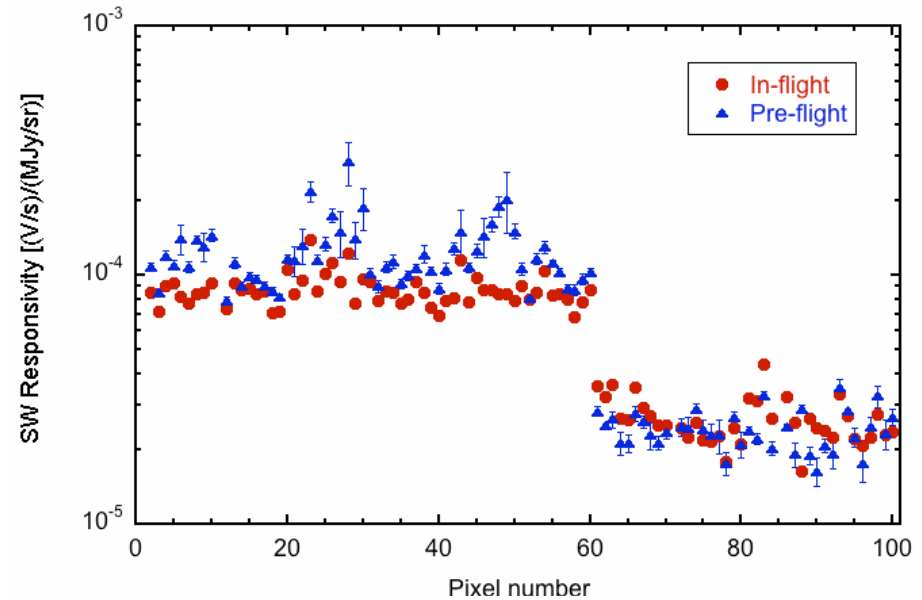
II-1. Flat field option: /LOCAL_FLAT

- A flat field is produced by integrating the data during the attitude settling time (after CAL sequence and before starting the scan), instead of the pre-measured flat.
- Time range used for the flat field can be specified as :
  T_FLAT_START = value and T_FLAT_END = value.
- If a smooth sky is chosen, better result than default is obtained.
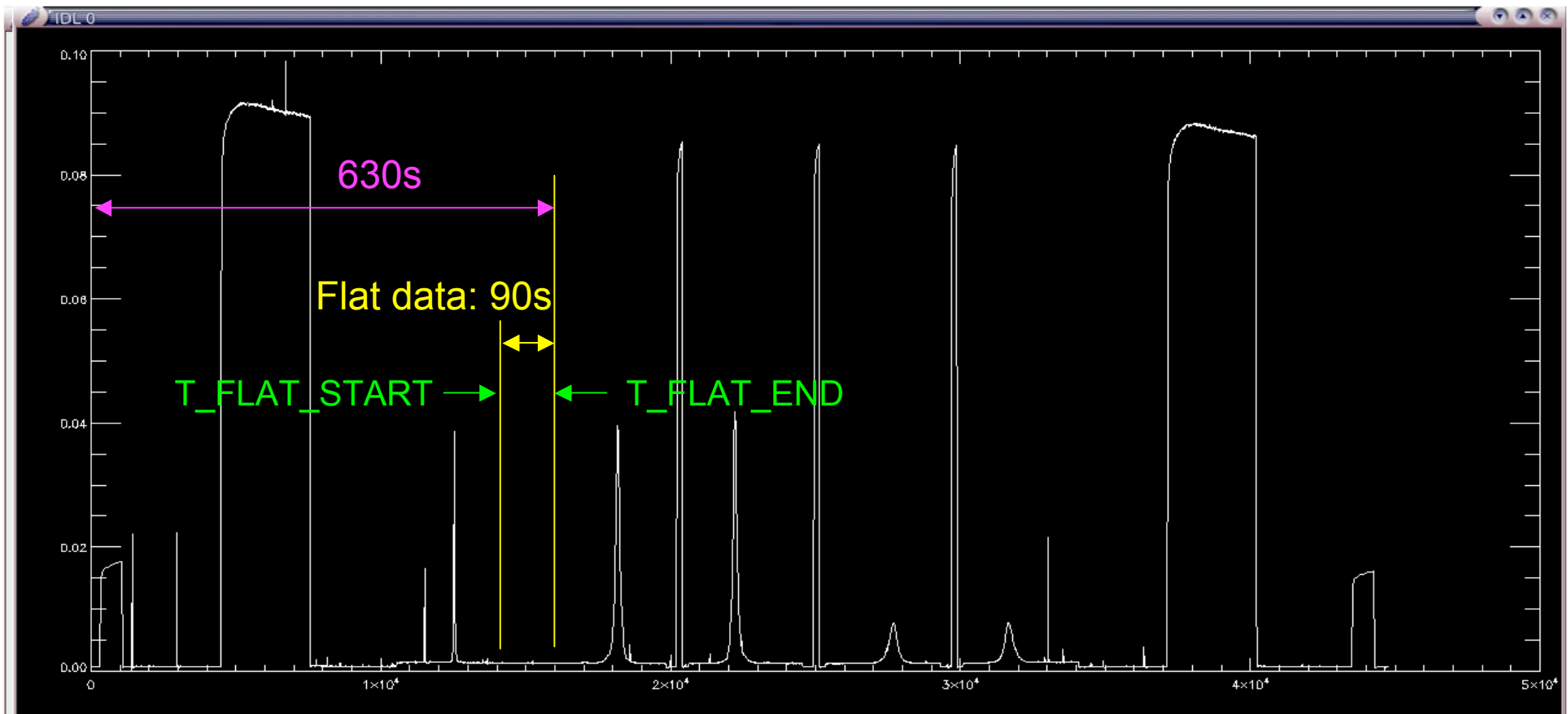
II-1. /LOCAL_FLAT

- /LOCAL option is effective to clean up stripes.
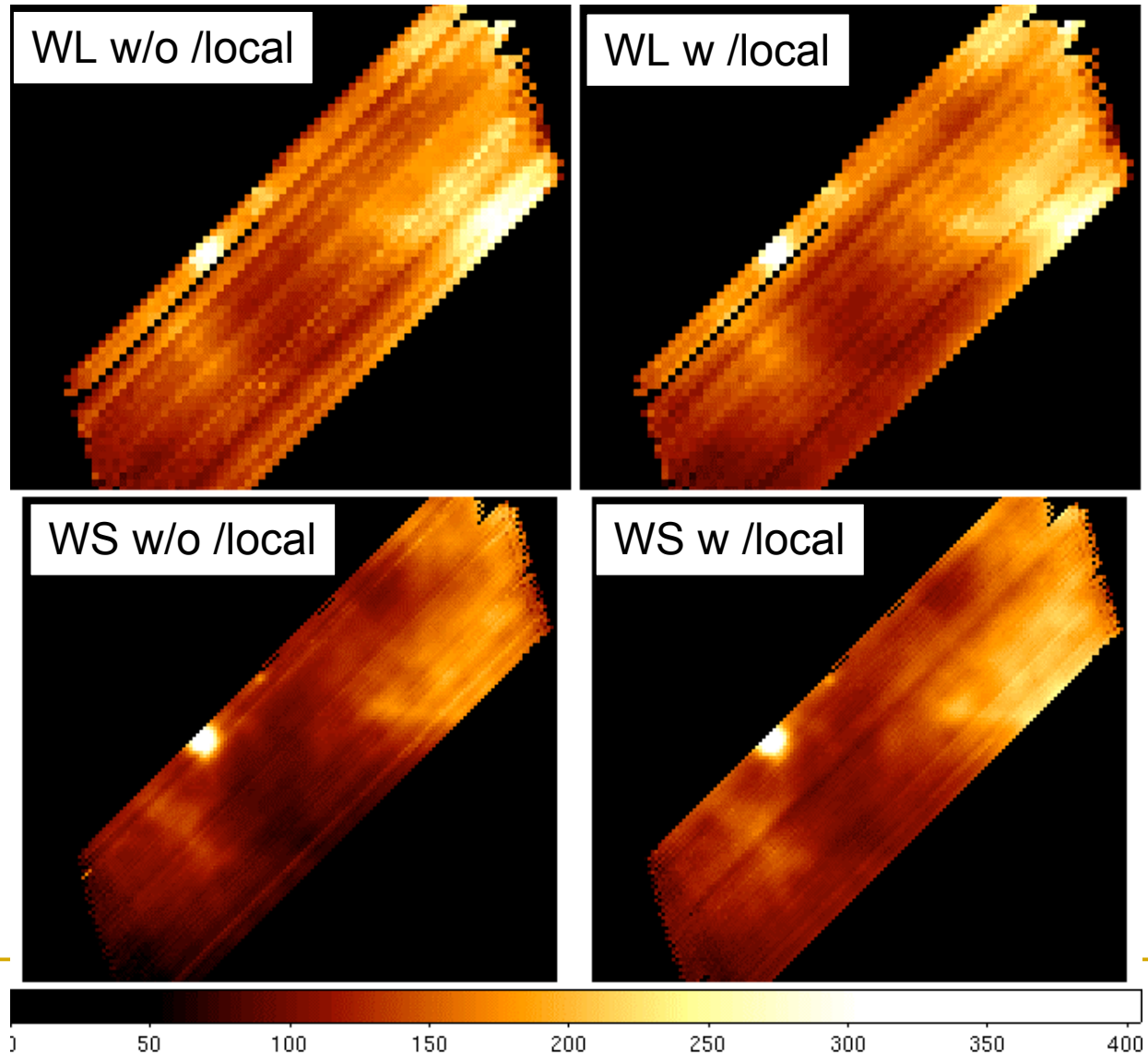
II-2. Treatment for transient effects

- **After effect induced by cosmic-ray events**
  - Current version removes the glitches in the linear fitting process.
  - Tails due to responsivity drift are partly rejected in the co-addition process by the redundancy.
  - – correction for the tails, to be implemented soon

- **After effect induced by CAL & Dark measurements**
  - – correction process is implemented as /TRAS_COR option

- **Slow response to astronomical signals**
  - – future work
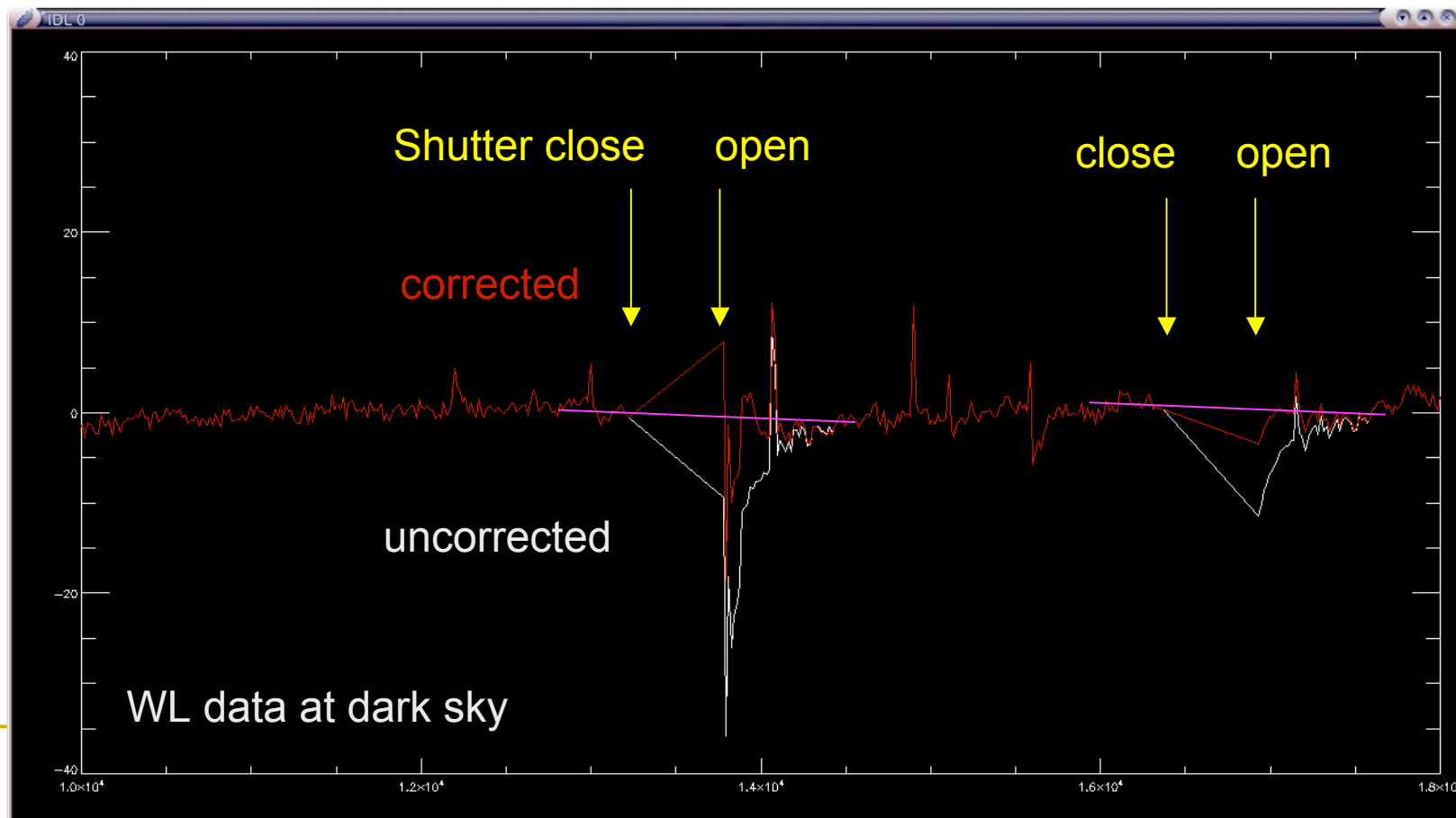
II-2. Rejection of glitches

- For slow-scan observation, glitch signal is much faster than the source signal.
- Data affected by glitch can be easily flagged out. (set to zero)
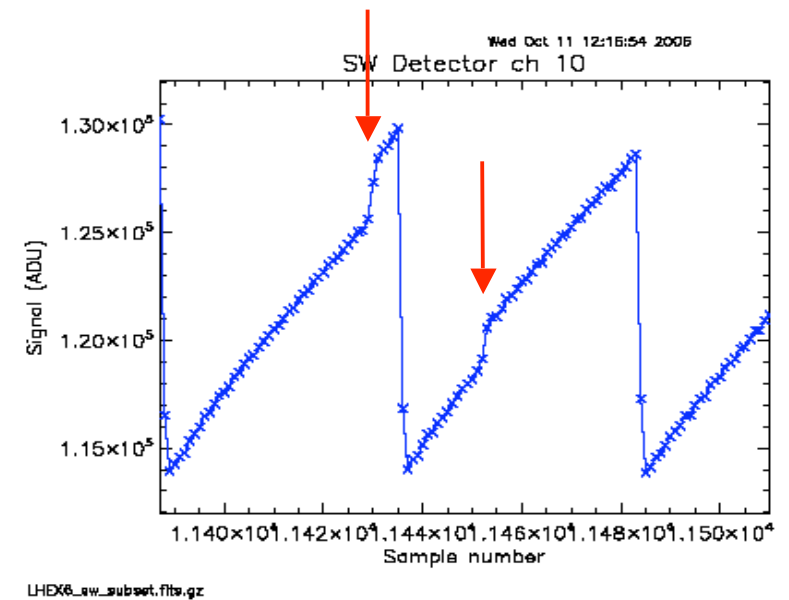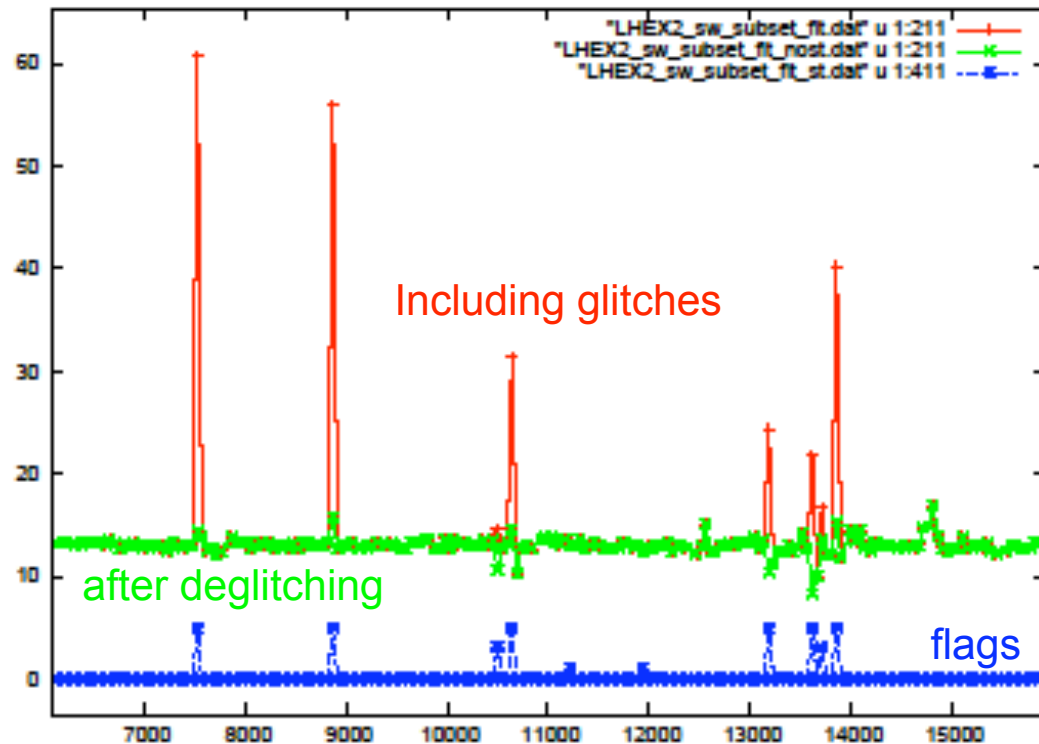
II-2. /TRANS_COR

- Slow transient correction for the data after shutter close/open.
- Applicable in any observations, but over/under correction may happen in some rare cases.

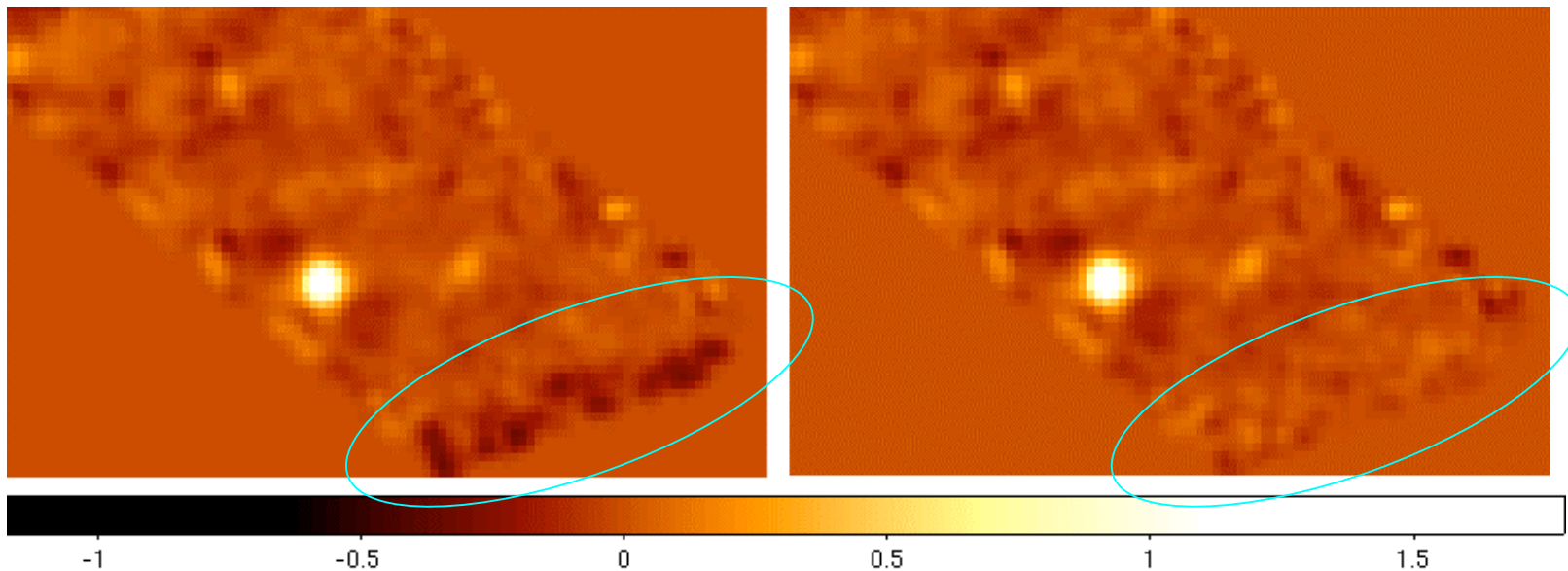" FIS_[SW|LW]_*_ar.sav "

II-2. /TRANS_COR

- Useful for mosaic imaging which requires smooth connection between different observations at the edge.
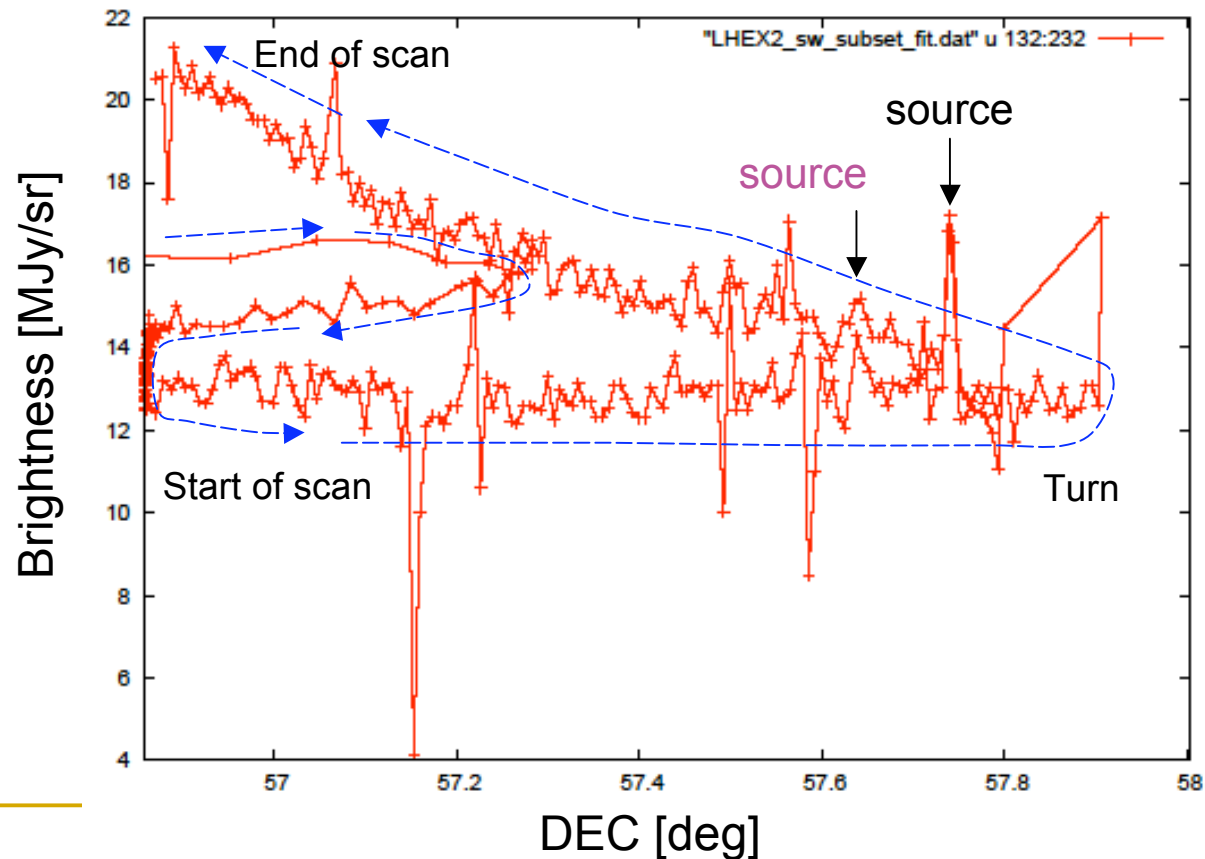
w/o /TRANS   w /TRANS

II-3. Need for stray light removal

- Time series data plotted as a function of ecliptic coordinate.
- Co-addition of the data including the stray light may smear out faint sources.
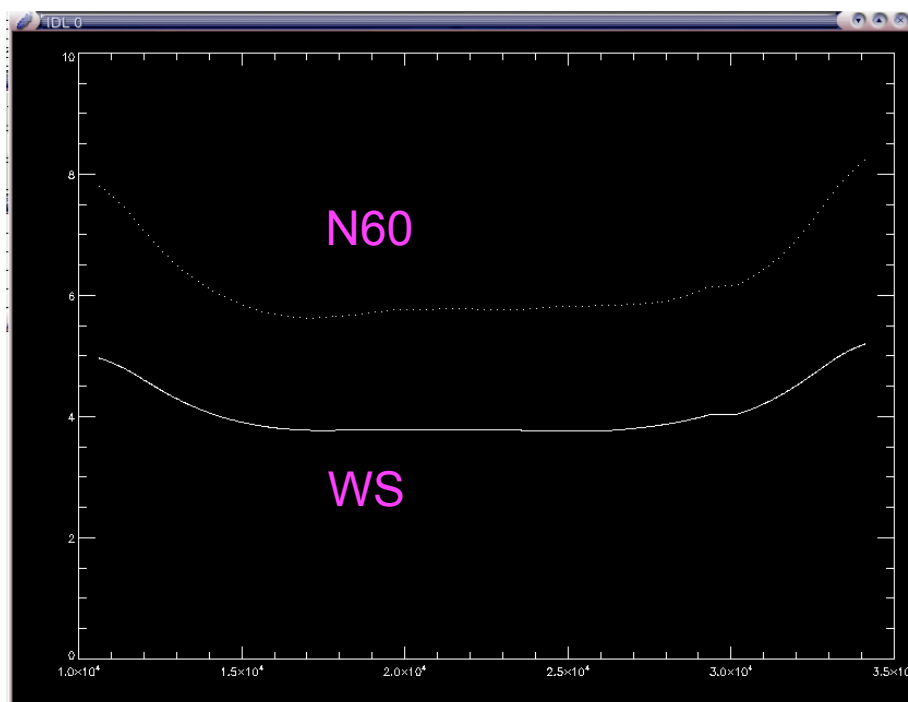
II-3. /SL_RMV

- Stray light intensity depends on the earth avoidance angle (EAA).
- High-pass filtering with a very long time constant (fixed to 90s).
- Minimum brightness during the observation at the maximum EAA is assumed to be "real" sky brightness.
  - If monotonic increase/decrease of signal exists, mean brightness around the maximum EAA is used as "real" sky brightness.
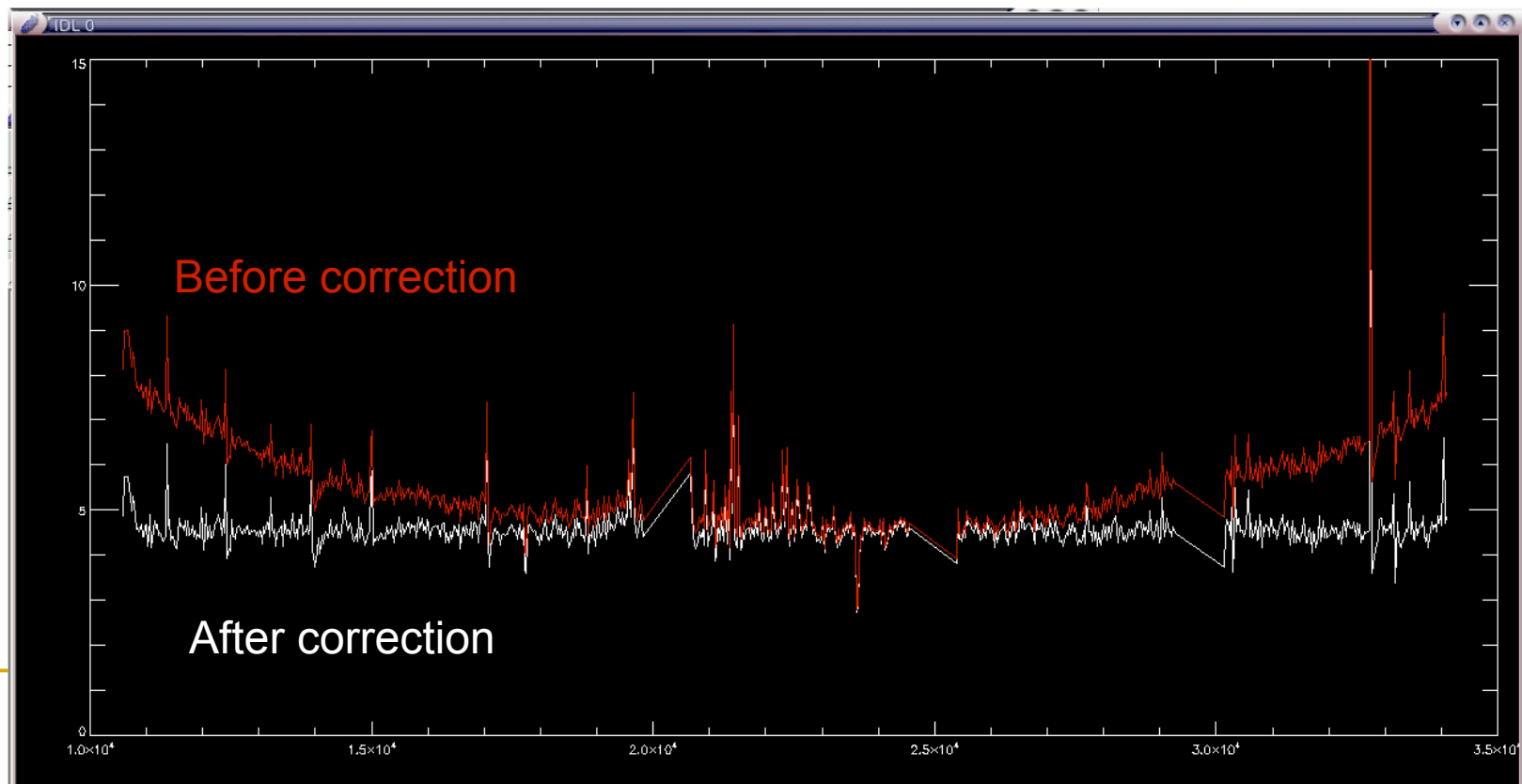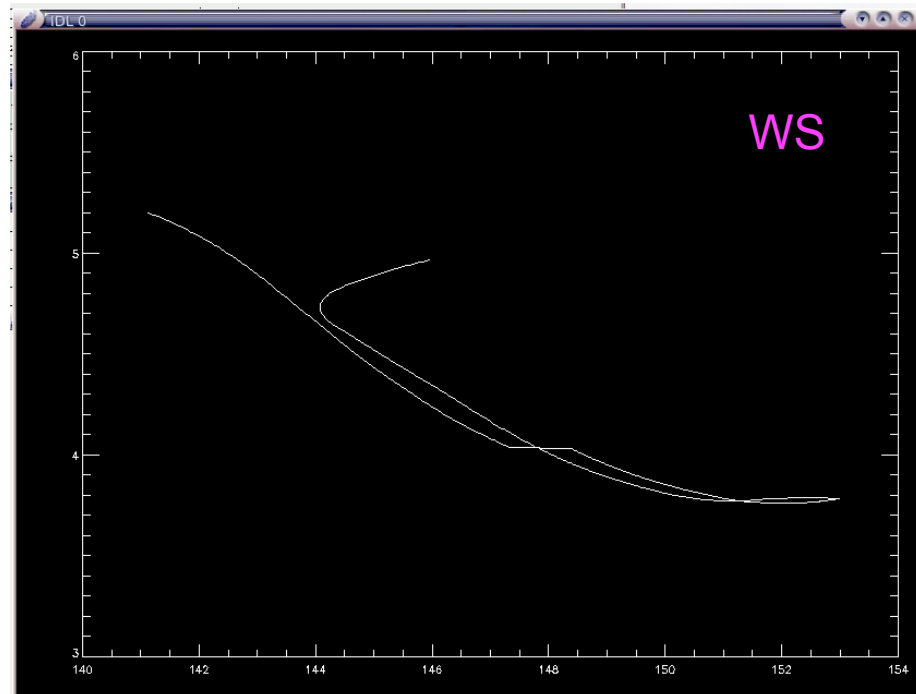
II-3. /SL_RMV

- Average intensity of the stray light as functions of time and EAA.
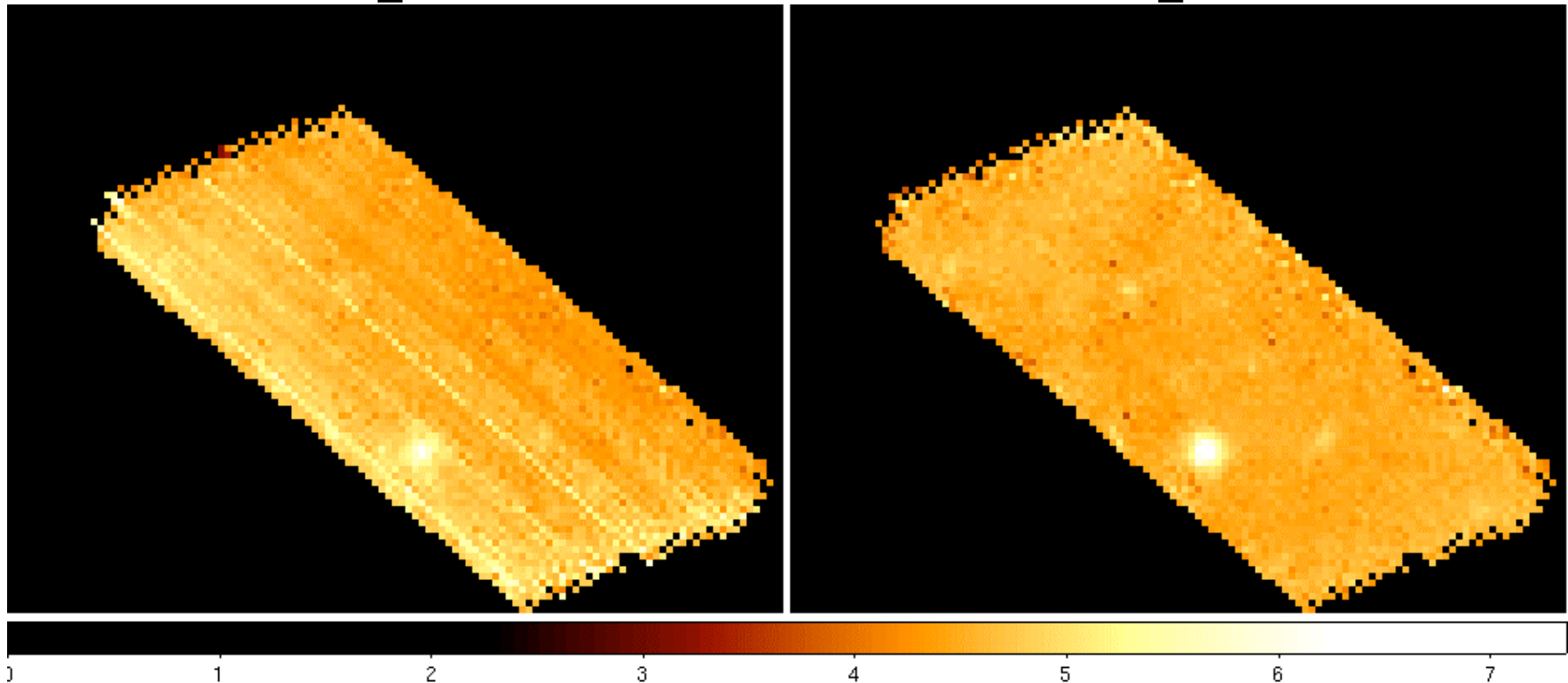- This information is saved as " FIS_[SW|LW]_*_sl.sav ".

time

Earth Avoidance Angle

II-3. /SL_RMV

- WS data at dark sky (~5 MJy/sr)
- Stray light (max~3 MJy/sr) has non-negligible contribution.
- Co-addition of data including the stray light is awful.
- Applicable only for dark sky (<10 MJy) in general, or for compact source with a size smaller than (90s x scan-speed).

w/o /SL_RMV   w /SL_RMV

II-3. Another method of stray light removal

- Note that the use of /SL_RMV option is one of practical methods.
  - Development of more advanced method, modeling the stray light profiles as functions of EAA and satellite orbit, is in progress.

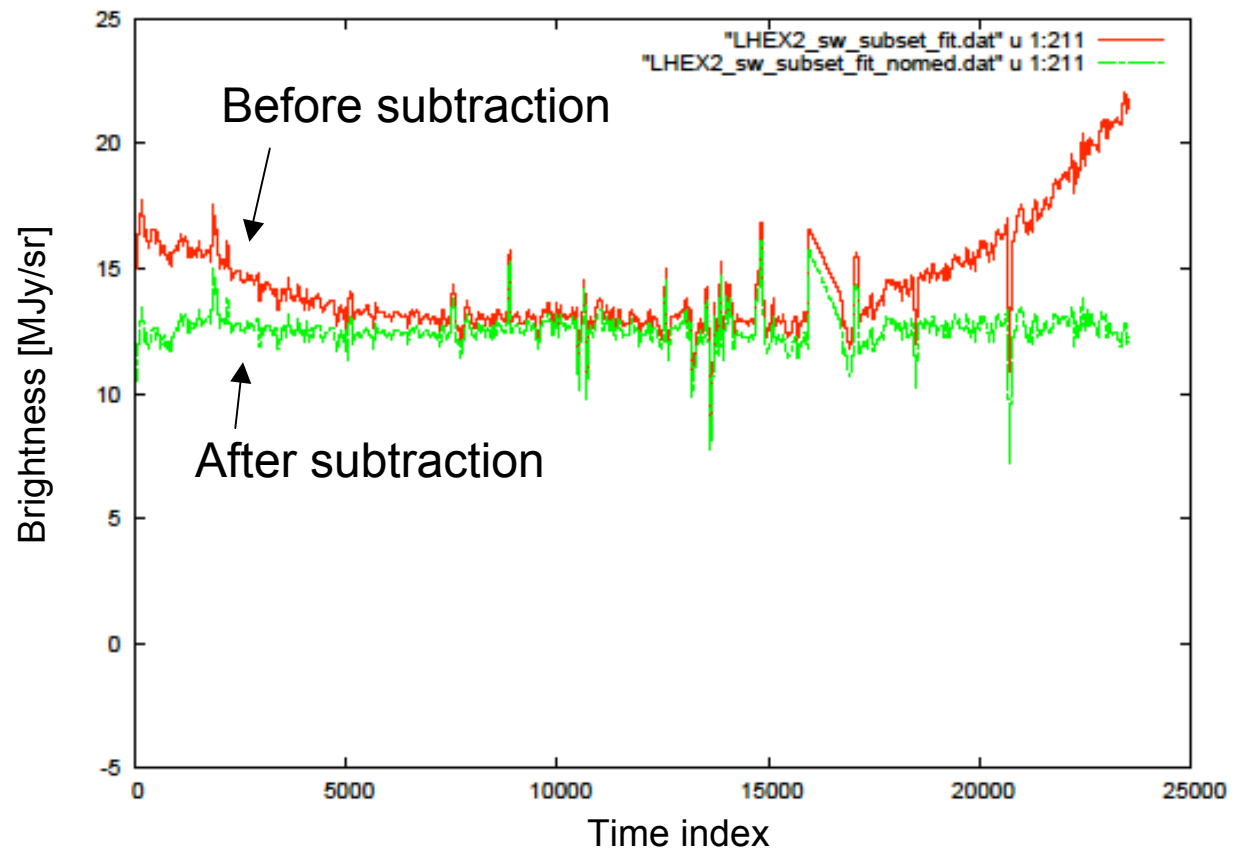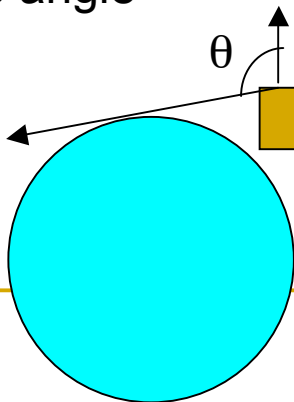Baffle function is assumed to follow exp-law

$I = B + A*exp[-(\theta/C)^2]$

I: total signal
B: sky background
A: fitting constant
θ: earth avoidance angle
C: scale angle

Before subtraction

After subtraction

II-4. /SMOOTH_FILTER or /MEDIAN_FILTER

- High-pass filtering with a default/user-specified time constant as WIDTH_FILTER = value in [s].

- WIDTH_FLITER = 40 by default.

- Sky background is subtracted and its mean is set to zero.

- (WIDTH x scan-speed) has to be larger than size of the source of interest.

- The filtered data and related information, " FIS_[SW|LW]_*_sl.sav ".

Width=20   Width=40 (default)   Width=90 (same as SL_RMV)
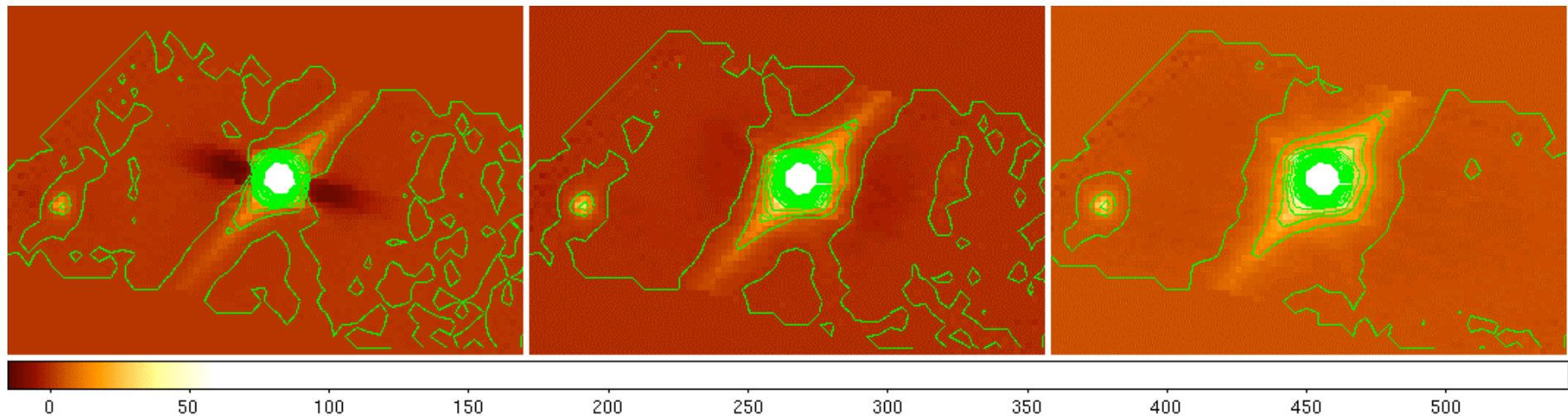
Contour: 0-100 (every 5), peak ~550

II-5. BAD_THRSHLD

- Threshold for the bad-pixel rejection in a process of responsivity correction, as BAD_THRSHLD=value.
- After strong radiation events, the detector responsivity changes with a very long decaying time.
- Detector responsivity is checked by the CAL light measurements in the sequence.
- If the CAL signal of a certain pixel is stronger/weaker than the pixel-averaged CAL signal by a factor of BAD_THRSHLD, this pixel is removed from the as a bad pixel.
- BAD_THRSHLD may take any positive value.
- Default setting is a large value of 10, and this function is not effective.

# II-6. SIGMA

- Threshold for the sigma clipping in the co-addition process, as SIGMA=value in [sigma].
- Default setting is SIGMA=2.
- User can specify smaller value, e.g. SIGMA=1.5, as far as number of non-rejected data points is sufficiently large.

II-7. N_RAMP_DIV=value

- A ramp is divided into the specified number.
- Linear fitting is done for each sub-ramp.
- Useful to obtain finer grid sampled image.

- Some artifacts
  may appear due
  to incompleteness
  of non-linear ramp
  correction.

Please check
 " FIS_[SW|LW]_*_ar.sav "
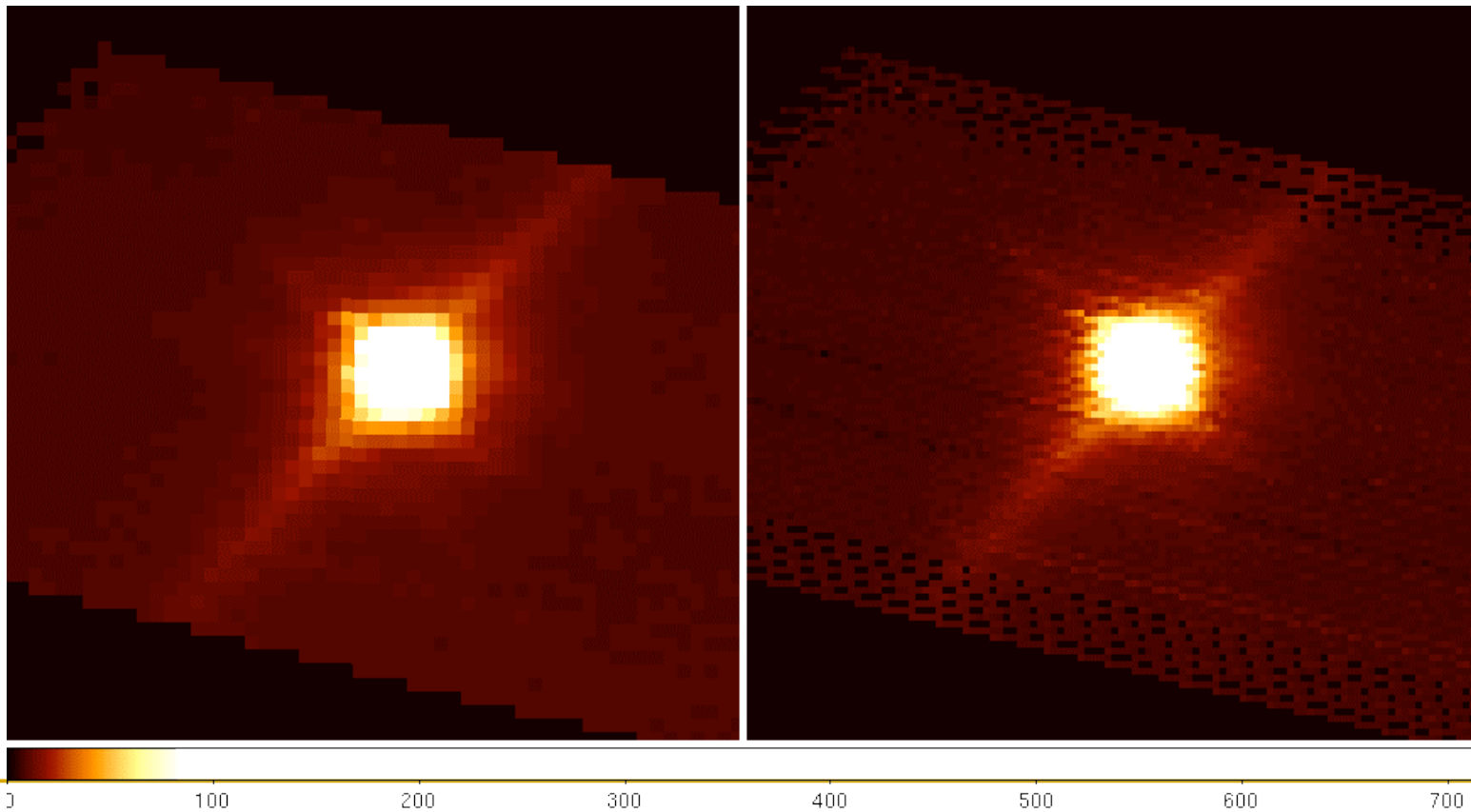 (processed time series data)
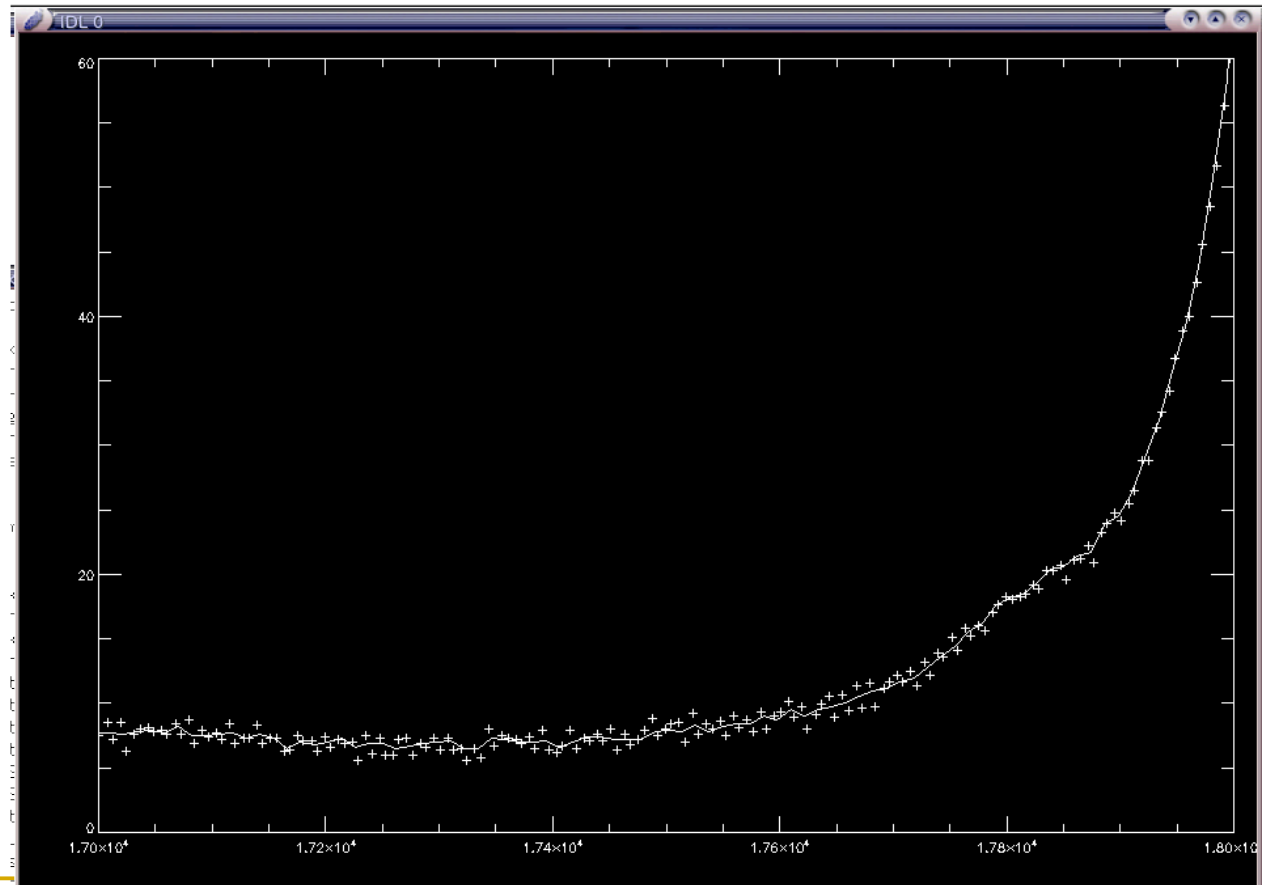
II-8. GRID_SW=value, GRID_LW=value

- Finer image is obtained by taking smaller GRID_SW/LW.
- The grid size has to be large enough to keep the redundancy, corresponding to N_RAMP_DIV.
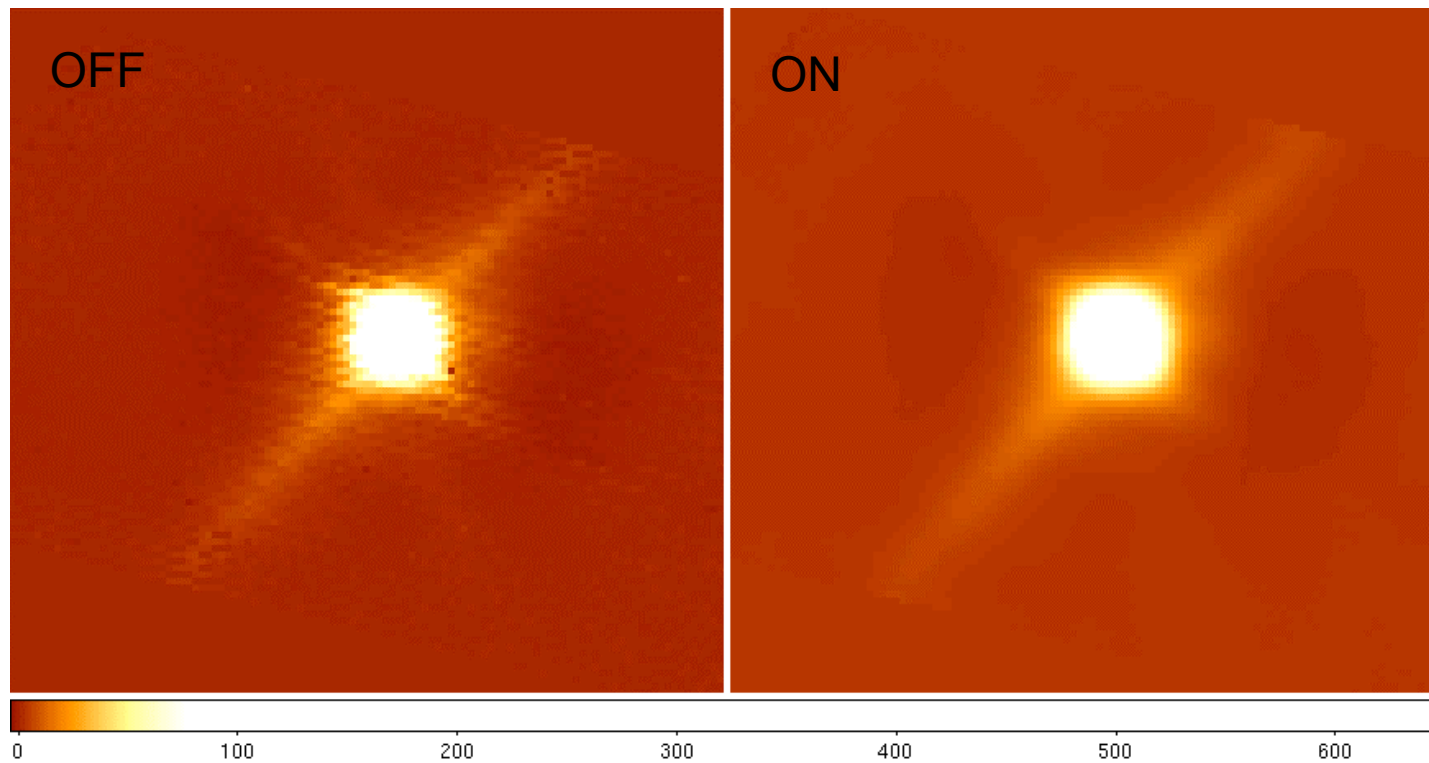
Default: N_RAMP=1, GRID_SW=15   N_RAMP=2, GRID_SW=7.5

II-9. /PIX_MAPPING

- To produce a smooth image with finer grid by the pixel convolution.
- Be careful that co-added image with too small grid size is not reliable because of low redundancy.

II-10. /SCUT

- It produces individual co-added images for all 4(2) scans of FIS01(02).
- Useful to check the multiple viewing of a source.
- Outputs "FIS_*_[1-4].sav" and "FIS_*_[1-4]_[w|n].fits"
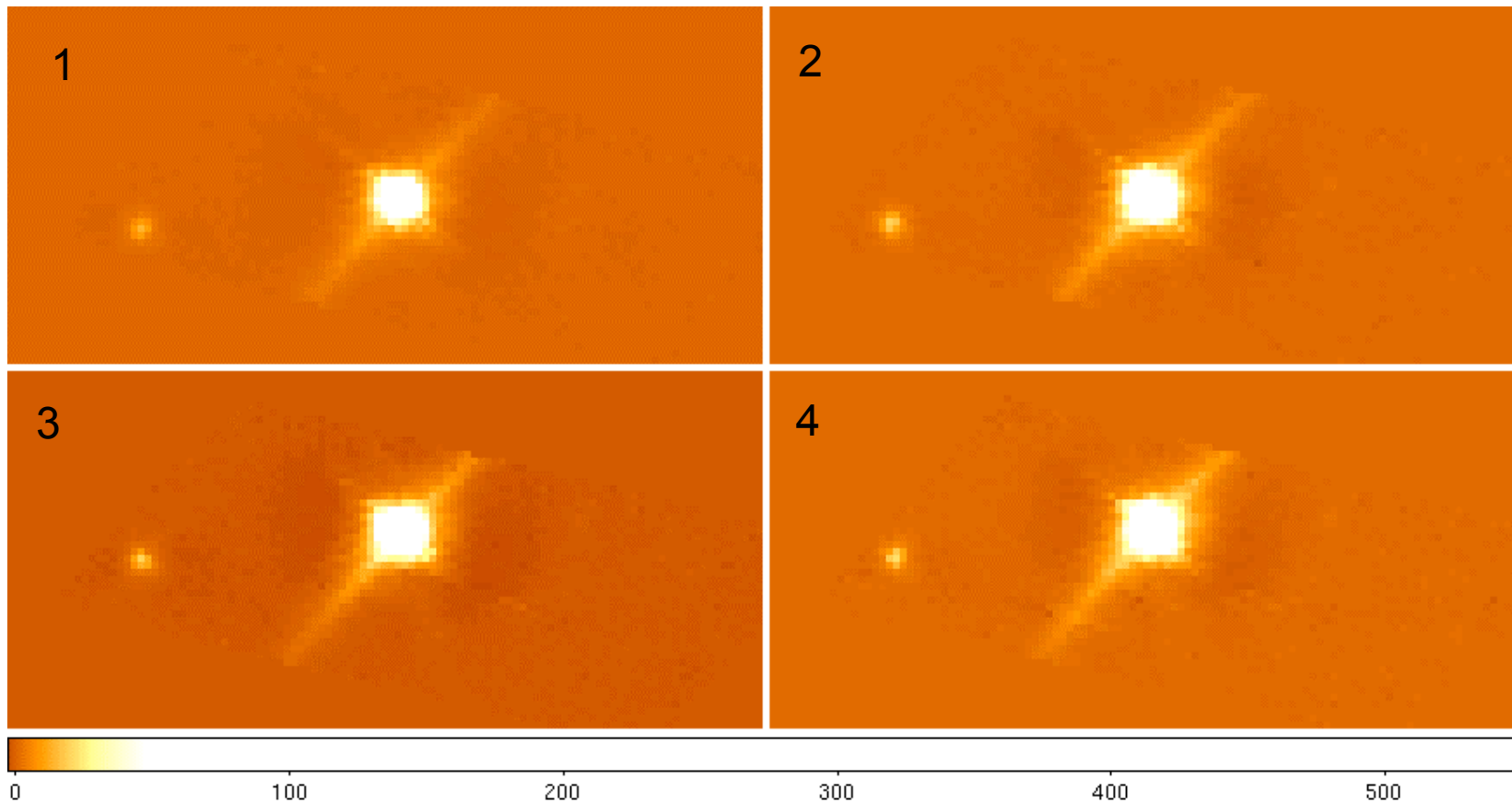
III. Recommended combination of options

Point source:
Bright (>10 Jy)
    ss_run_ss, 'dir' (, /local, /smooth, width_filter = 90)

Isolated, medium (0.2 ~ 10 Jy)
    ss_run_ss, 'dir', /local, /smooth, width_filter = 60 ~ 90

Faint source(s) (<0.2 Jy)
    ss_run_ss, 'dir', /local, /trans, /sl_rmv, /smooth

Diffuse source:
Bright (>10 MJy/sr)
    ss_run_ss, 'dir', /local, /trans
    * T_flat_start/end should be specified for better flat

Faint (<10 MJy/sr)
    ss_run_ss, 'dir', /local, /trans, /sl_rmv

IV. Future plan for the revision of SS-Tools

- Calibration
  - Consistency between diffuse and point sources

- Correction of after effects
  - Correction for the tails after cosmic-ray events
  - Slow response to astronomical signals

- Stray light removal
  - Physical modeling using many observation samples