ISOCAM Glitch Library

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1 Introduction

A limitation of the sensitivity of the LW array is due to the responsivity variations and glitches caused by impacts of charged particles. There are two separate problems: i) the response variation after the perigee passage due to the very high radiation dose coming from trapped particles in the van Allen belts, and ii) the glitches due to the impact of single particle from galactic cosmic rays all along the good part of the orbit, i.e. outside the van Allen belts.

A review of algorithms used for glitch removal was already presented at the *ISO detector workshop* (Vilspa, Jan-1998), together with calculation of predicted glitch rate[1, 2]. The purpose of this document is to outline the main ideas about the glitch knowledge right at the end of the ISO mission. The philosophy of this document is more illustrative than quantitative. The reader is referred to [1, 2] for more details about glitch effects, removal algorithms or prediction of glitch rate.

Glitch rate predictions are given in Section 2 and compared with measurements in Section 3. In order to give an easy access to glitch data, a glitch library has been built and is described in this document (see Section 4). Some informations about the ISO glitch web page are given in Section 5. Since the *ISO detector workshop*, a glitch working group (GWG) has been created. The four instruments on board ISO are represented in GWG. Ongoing work relative to GWG/ISOCAM is presented in Section 6. Note that only glitches of the LW detector are addressed here.

2 Predicted Glitch Rate

Along the orbit, the perturbations will come from cosmic rays and trapped particles in the van Allen belts. Their fluxes are defined within a factor of 2, depending on the solar activity. In this paper, The number of direct impacts given below is based on new measurements by the KET[1] on board of the Ulysses spacecraft (Oct-1997 and Feb-1998, when it was close to the ecliptic plane). Primary particles passing through the surrounding material also produce about 50% of additional events either by nuclear reactions or δ-ray emissions[2]. Latest predictions[3] can be summarized as following:

- $\boxed{\text{0.36 sec}^{-1}\text{ of direct impacts}}$ from cosmological particles
- $\boxed{\text{0.18 sec}^{-1}\text{ of secondary particles and }\delta\text{-rays}}$ from materials near the detector and activated by cosmological particles (contribution is ≈50% of direct impacts)
- Still unknown contribution from activated materials in the body of spacecraft

[1] Kinetic Electron Telescope

[2] δ-rays are electrons emitted along the track of particles with sub-relativistic velocity. δ-ray emission is proportional to Z^2 of the incoming particle.

[3] Computed with the help of Jacques Engelmann from CEA-Saclay.

The previous estimation[4, 5, 6] of direct impacts was a bit less than this one (0.28 $\sec^{-1}$ instead of 0.36 $\sec^{-1}$).

In addition to these external particles, the anti-reflection coating of the lens contains Thorium, which generates a flux of low energy particles. This flux depends on the solid angle of the lens viewed from the array, and is maximum for the 12 arcsec/pixel lens:

- 0.35 $\sec^{-1}$ of α-particles from the 12 arcsec/pixel lens
- $\boxed{0.16 \sec^{-1}\ \alpha\text{-particles from the 6 arcsec/pixel lens}}$
- 0.02 $\sec^{-1}$ of α-particles from the 3 arcsec/pixel lens
- 0.002 $\sec^{-1}$ of α-particles from the 1.5 arcsec/pixel lens

Neither the electro-magnetic showers, nor the secondary particles and δ-ray emissions from the body of spacecraft have been taken into account here. These last contributions are more difficult to derive and requires Monte-Carlo simulations. It is very likely that a few tenths of glitch/sec might be added.

Based on the above numbers, the latest estimation of glitch rate is given in **Table 1**. Since uncertainties about the contributions of secondary particles and δ-rays still remain, these results should be taken only as orders of magnitude, and at least as lower limits.

3 Comparison With Measurements

Some key numbers about ISOCAM glitches, as observed in flight, are:

- Average glitch rate = $\boxed{\text{1 glitch/sec}}$
- Average number of hit pixels = $\boxed{\text{8 pixels/glitch}}$

These numbers are mean values and correspond to what should be observed during a standard ISOCAM observation. The glitch occurrence follows Poisson statistics but depends also of the space weather. The glitch rate and/or number of hit pixels are of course orbital position and solar activity dependent (see **Figures 5** and **6**).

These numbers have been derived from algorithms which are used to remove glitch effect in ISOCAM data[3]. These algorithms detect a glitch as a different temporal profile or/and spatial pattern than the expected signal (astronomical background + source + dark current + memory effect). This implies that they do not detect glitches separately (2 or more glitches can be considered as a single one, and also several high value pixels can be considered as many different glitches whereas they belong to the same one). Thus, these algorithms can not be used to derive properties of individual glitches, such as the actual duration, number of hit pixels, rising time, and so on. Nevertheless, some effects can compensate each other and the above numbers can be considered as representative.

Table 1: Predicted glitch rates (unit sec^{-1}). The contribution of secondary particles and δ-rays has been taken equal to 50% of direct contribution. It could be more, up to 60-70%. Furthermore, neither the electro-magnetic showers, nor the secondary particles and δ-ray emissions from the body of spacecraft have been taken into account here (see text).

Contribution	1.5 '' lens[1]	3 '' lens	6 '' lens	12 '' lens[2]
Only direct impacts	0.36	0.36	0.36	0.36
Secondary particles and δ-rays	0.18	0.18	0.18	0.18
α-particles from Thorium	0.002	0.02	0.16	0.35
TOTAL	**0.54**	**0.56**	**0.70**	**0.89**

[1] Contribution of 1.5 arcsec/pixel is completely negligible (≈ 0.002 sec^{-1}).

[2] 12 arcsec/pixel lens was used for very few observations.

4 Different Types Of Glitches

A library containing the most common glitches, as well as other interesting glitches for illustration purpose, was built. Glitches can be divided into 3 families based on their temporal profile. Some other families could be considered taking into account the origin of the glitch impact (proton, electron, heavy ion, ...). Some glitches indeed display some extensions or a curved shape (see **Figure 1**) depending of the nature and energy of incident particle. Note also that there are probably low level glitches, much more difficult to detect, but nevertheless affecting the detector noise.

Temporal families are given below:

- Type-A, common glitches (see **Figure 2**)
- Type-B, faders (see **Figure 3**)
- Type-C, dippers (see **Figure 4**)

Different types of glitches are saved in the IDL file named $\boxed{\text{GLITCH\_LIB.XDR}}$ available in DKB0:[ACLARET.GLITCH.LIB] and in CIA_DIR:[CONTRIB.DATA.BINARY] directories :

- PROFILE_A: 1-D array containing a type-A glitch (common)
- PROFILE_B: 1-D array containing a type-B glitch (fader)
- PROFILE_C: 1-D array containing a type-C glitch (dipper)
- GLITCH_B: structured variable relative to type-B glitch (fader)
- GLITCH_C: structured variable relative to type-C glitch (dipper)
- GLITCH_EOSW: structured variable relative to glitch rate just before the end of scientific window (more electron-glitches, see **Figure 5**)

- GLITCH_REV722: structured variable relative to glitch rate during the solar flare of revolution 722 (see **Figure 6** and [7] for more details)

Structured variables contain a cube, mask and header fields (see below). The header contains some informations about the origin of data, the instrument configuration, and also IDL commands to display the interesting part of data. The header is a 256-string array which can be updated. Note that wheel positions are given in absolute values, integration time in CAMTU, gain in physical value (gain=2 means that the gain was actually 2 and not 2^2).

As an example, some IDL commands to display type-B glitch are given below.

CIA> restore,'DKB0:[ACLARET.GLITCH.LIB]GLITCH_LIB.XDR',/verb

```
% RESTORE: Portable (XDR) SAVE/RESTORE file.
% RESTORE: Save file written by STATION@ISOW40, Wed Apr  8 17:37:53 1998.
% RESTORE: Restored variable: PROFILE_A.
% RESTORE: Restored variable: PROFILE_B.
% RESTORE: Restored variable: PROFILE_C.
% RESTORE: Restored variable: GLITCH_B.
% RESTORE: Restored variable: GLITCH_C.
% RESTORE: Restored variable: GLITCH_EOSW.
% RESTORE: Restored variable: GLITCH_REV722.
```

CIA> help,/struct,glitch_b

```
** Structure <9181d0>, 3 tags, length=993308, refs=1:
   CUBE     FLOAT     Array[32, 32, 121]
   MASK     FLOAT     Array[32, 32, 121]
   HDR   STRUCT    -> <Anonymous> Array[1]
```

CIA> help,/struct,glitch_b.hdr

```
** Structure <918030>, 6 tags, length=2076, refs=2:
   REV   INT  721
   CHANNEL   STRING    'LW'
   GAIN     INT    2
   TINT     INT   36
   WHEELS   INT     Array[6]
   INFO     STRING    Array[256]
```

CIA> print,glitch_b.hdr.wheels

```
308      88     448     125     208     328
```

CIA> print,glitch_b.hdr.info

```
data provided by BA: ... / dedarked with interpolated dark /
type B glitch is visible from frame 19 till end of cube /
CIA> show_frame, glitch_b / CIA> tviso, glitch_b.cube(*,*,19) /
```

5 Miscellaneous

An interesting web page related to ISO glitches has been built by Petteri Nieminen. It is available at (ftp://ftp.estec.esa.nl/pub/wm/wma/ISO/isoradiation.html).

Its purpose is to provide information on the radiation environment of the ISO orbit during the mission (1995-1998) for the analysis of the effects in the four ISO instruments (ISOCAM, ISOPHOT, ISOLWS, and ISOSWS). This page is a good starting point to get some data about the space weather, as measured by several flying spacecrafts.

6 Status Of Ongoing Work

There are two main objectives for the on going work about glitches. First objective is to improve the glitch removal methods. At longer term, second objective is to get as much as possible informations on glitches in order to prepare next space experiments such as FIRST, PLANCK, INTEGRAL, ...

Improvement of glitch removal methods should be possible by deriving proper statistics on individual glitches, in order to determine to which family they belong, and then predict their temporal and spatial behavior. Proton and heavy ions glitches can be easily removed from the observation by a filtering technique. The worst problem is the responsivity variation after the glitch, especially for heavy ions. A model of these effects is under investigation. This seems mandatory for improving removal of type-B and type-C glitches. The difficulty comes from the necessity of detecting glitches individually, in order to build these statistics first, then model their temporal behavior, and finally apply it to individually detected glitches. We can reasonably hope that this will be fulfilled at least for strongest glitches, even if the model concerns only a subset of all glitches.

Around 1.5 hour of ISOCAM calibration time has been dedicated to the glitch study (revolution 832 of Feb-24, 1998). The observing configuration was a bit unusual, with an integration time of 1.12 sec (8 CAMTU), but observations were carried out successfully[4]. This configuration was suited for minimizing the number of glitches in ISOCAM images, in order to derive proper statistics on individual glitches. With 1.12 sec integration time, a bit more than 1 glitch/sec can be found in images. This minimizes the number of glitch overheads. The key numbers given above (1 glitch/sec and 8 pixels/glitch) were easily confirmed. The next step is much more complicated and requires a 3-D analysis for glitch detection and statistics. Glitches are often removed using the multi-resolution method which is based on a temporal criteria only. In spite of being very powerful to remove glitch from ISOCAM data, this method is not good enough to isolate glitches in a 3-D data cube. Thus, proper statistics on individual glitch can not be derived yet, but this should be done in next couple of months. New detection methods, probably very CPU-intensive, remain to be developed.

Message for the whole community: any glitch which seems to be interesting from a physical point of view or simply for an illustrating purpose should be mentioned to our team (claret@discovery.saclay.cea.fr) in order that the glitch library is updated.

[4]Special thanks to the CIDT team in Vilspa for accepting such unusual configuration.

References

[1] A. Claret, et al., 1998, *ISO detector workshop proceedings*, to be published in Experimental Astronomy.

[2] H. Dzitko, et al., 1998, *ISO detector workshop proceedings*, to be published in Experimental Astronomy.

[3] J.-L. Starck, et al., http://isowww.estec.esa.nl/instr/CAM/, *Data analysis with ISOCAM interactive analysis system.*

[4] L. Vigroux, et al., 1992, Internal Report saplv_mc57, *ISOCAM glitches.*

[5] ISOCAM team, http://isowww.estec.esa.nl/manuals/iso_cam/node22.html, *ISOCAM observer's manual.*

[6] C.J. Cesarsky, et al., http://isowww.estec.esa.nl/ISO/AandA/I0110.html, *ISOCAM in flight.*

[7] M. Sauvage, http://isowww.estec.esa.nl/instr/CAM/doc/rev722/rev722.html, *A short assessment of the impact of Rev. 722 solar flare on ISOCAM.*

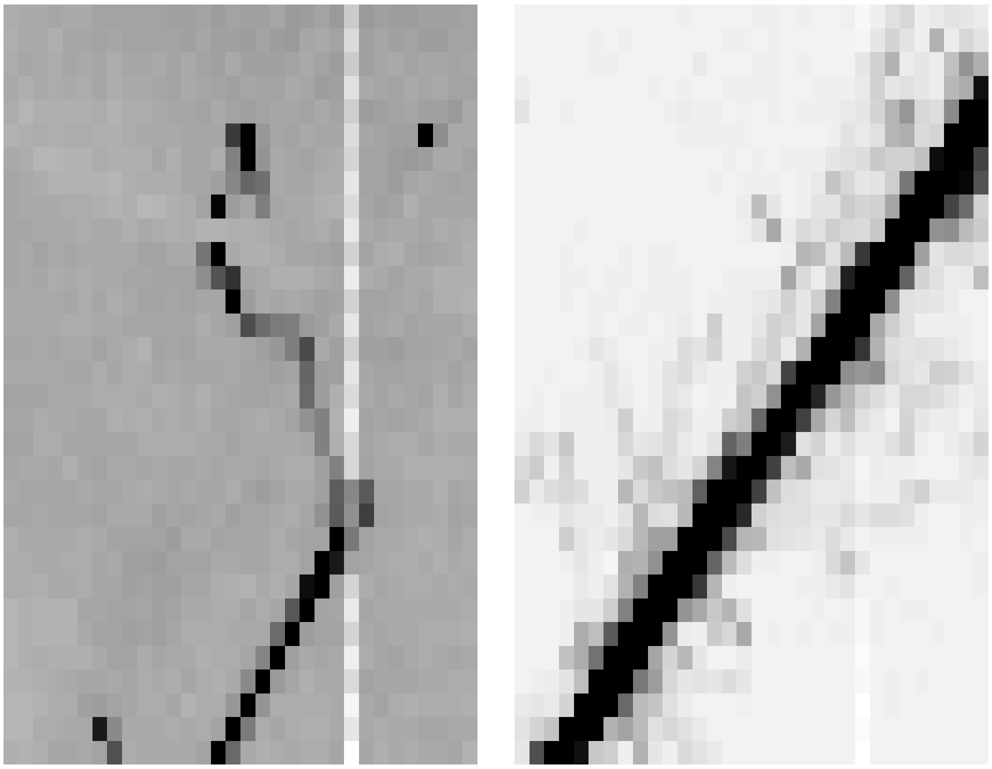

Figure 1: On the left panel, a low energy particle has probably stopped inside the detector. Apparently the incoming particle has collided a nucleus of the detector and the faint track might result of this recoil nucleus. Typical high energy heavy ion passing through the detector is visible on right panel. δ-rays are likely emitted along the track and could be responsible of various pixels hitted along the heavy ion track.

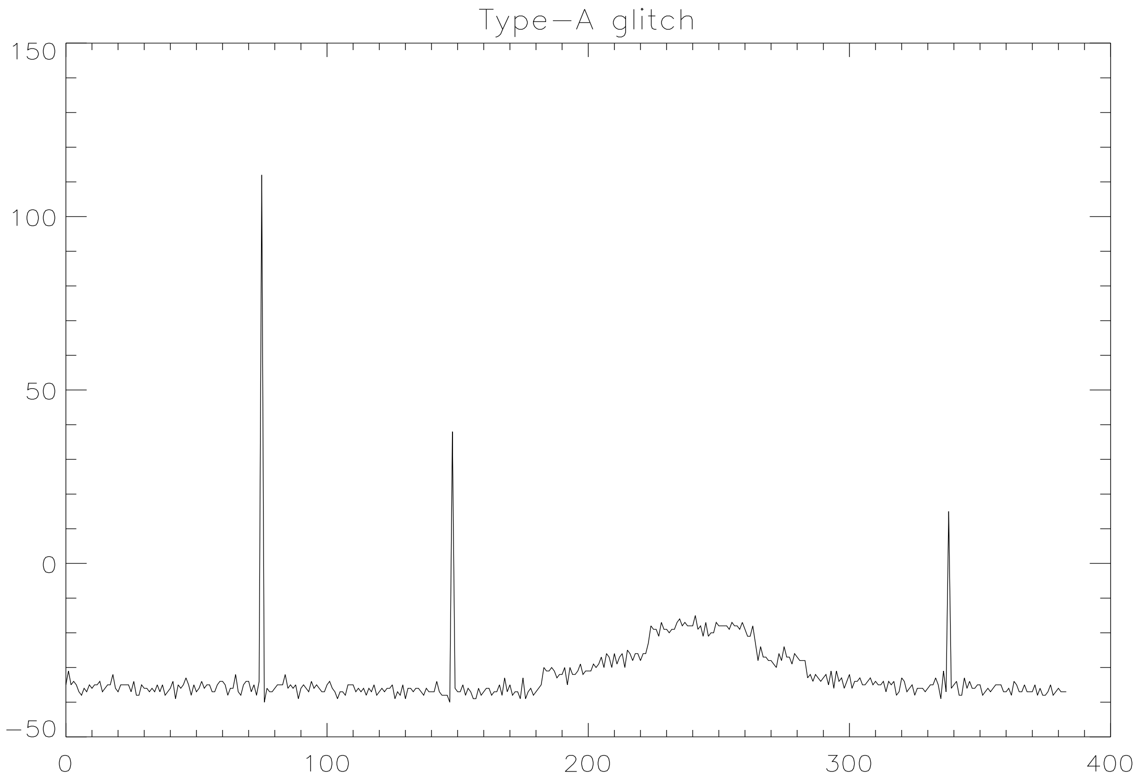

Figure 2: The decay time is roughly as short as the rise time for common glitches (Type-A).

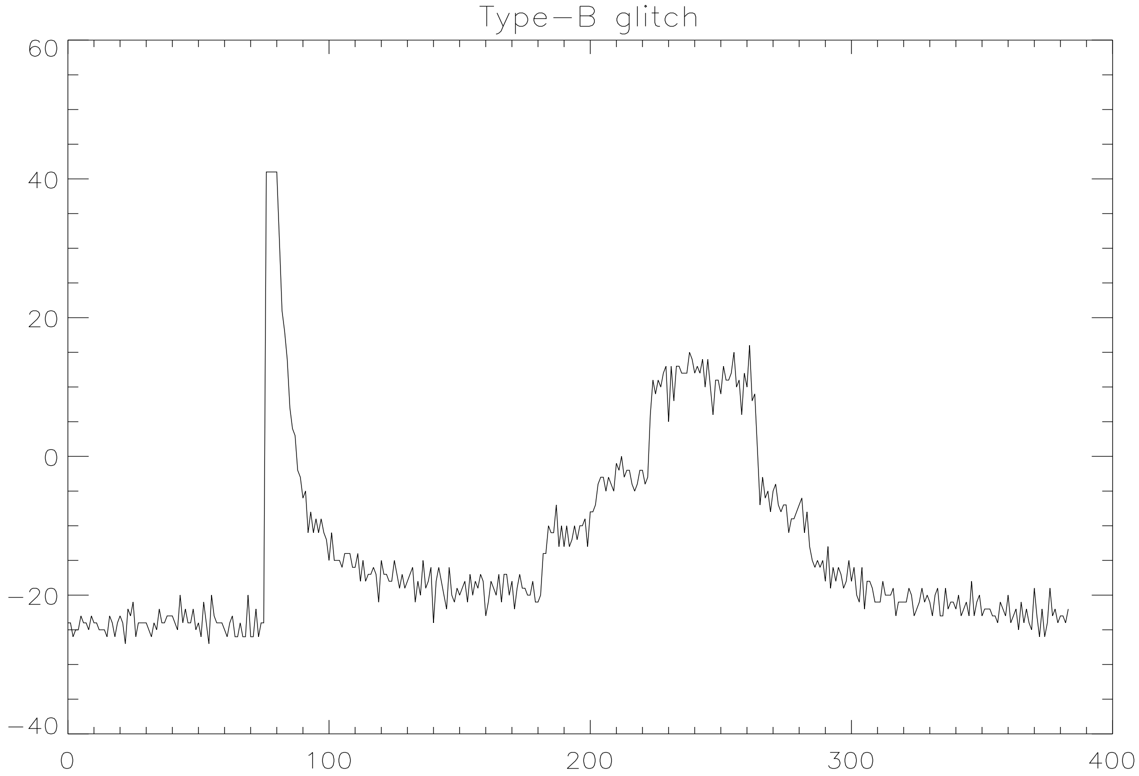

Figure 3: The decay time is much longer than the rise time and has a exponential profile for fader glitches (Type-B).

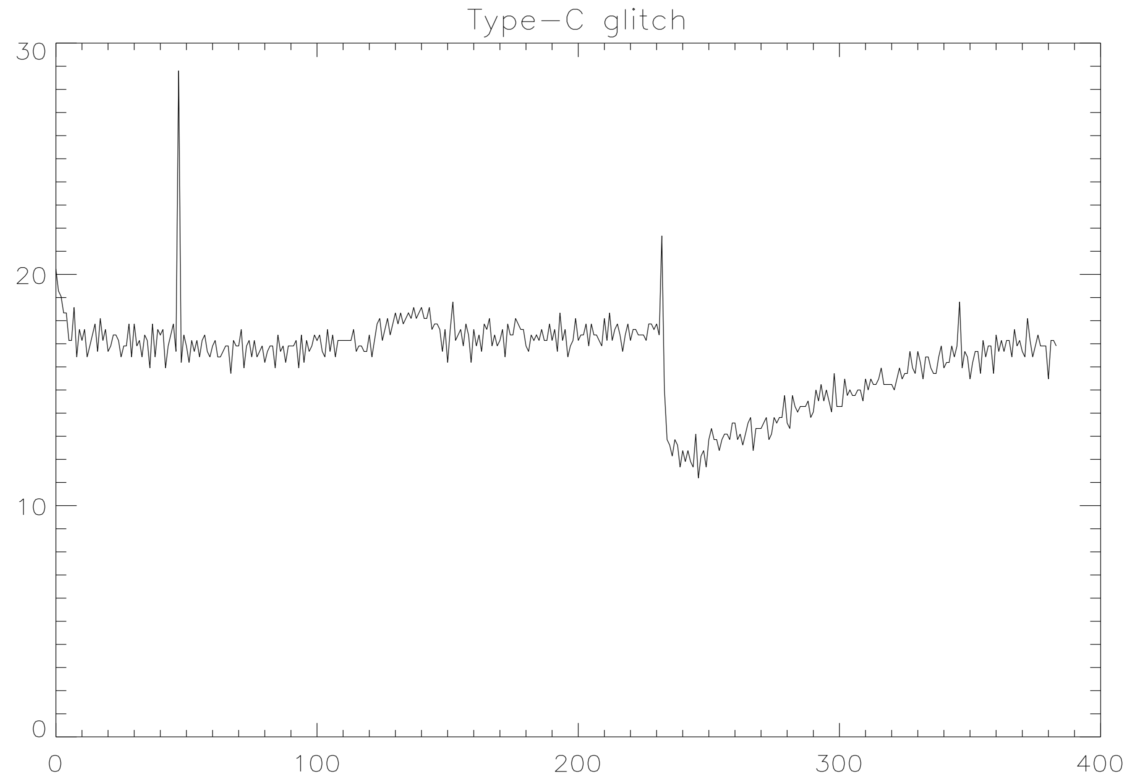

Figure 4: The detector gain is affected and the nominal sensitivity is recovered only after several readouts for dipper glitches (Type-C). This gain variation can be interpreted as a transient behavior by transient correction algorithms and thus lead to false source detection. Note also that type-C glitches are not necessarily the strongest ones in amplitude.

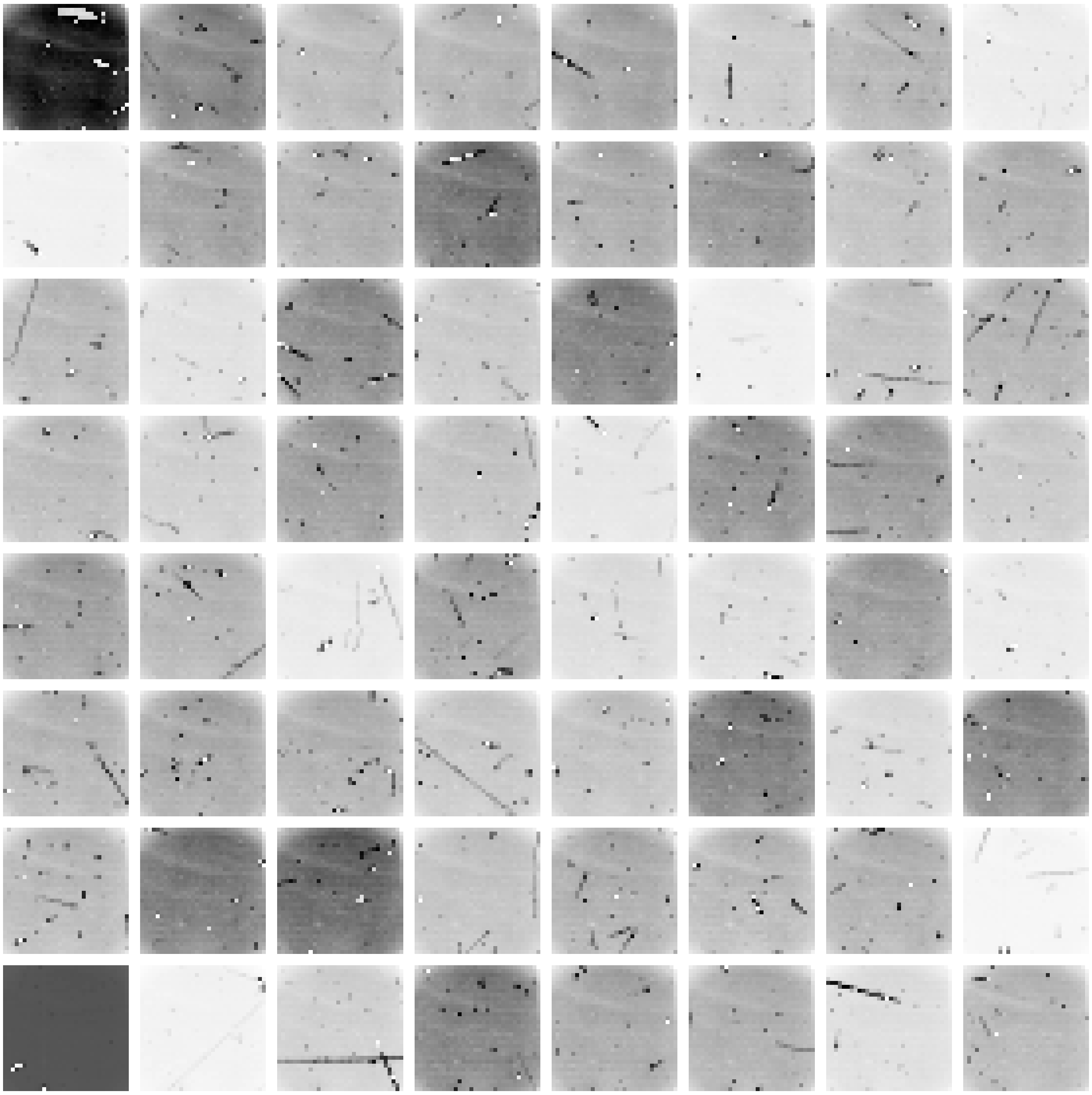

Figure 5: Some glitches just before the end of scientific window: an increase of point-like glitches can be noted. These glitches are likely produced by electrons in the van Allen belts.

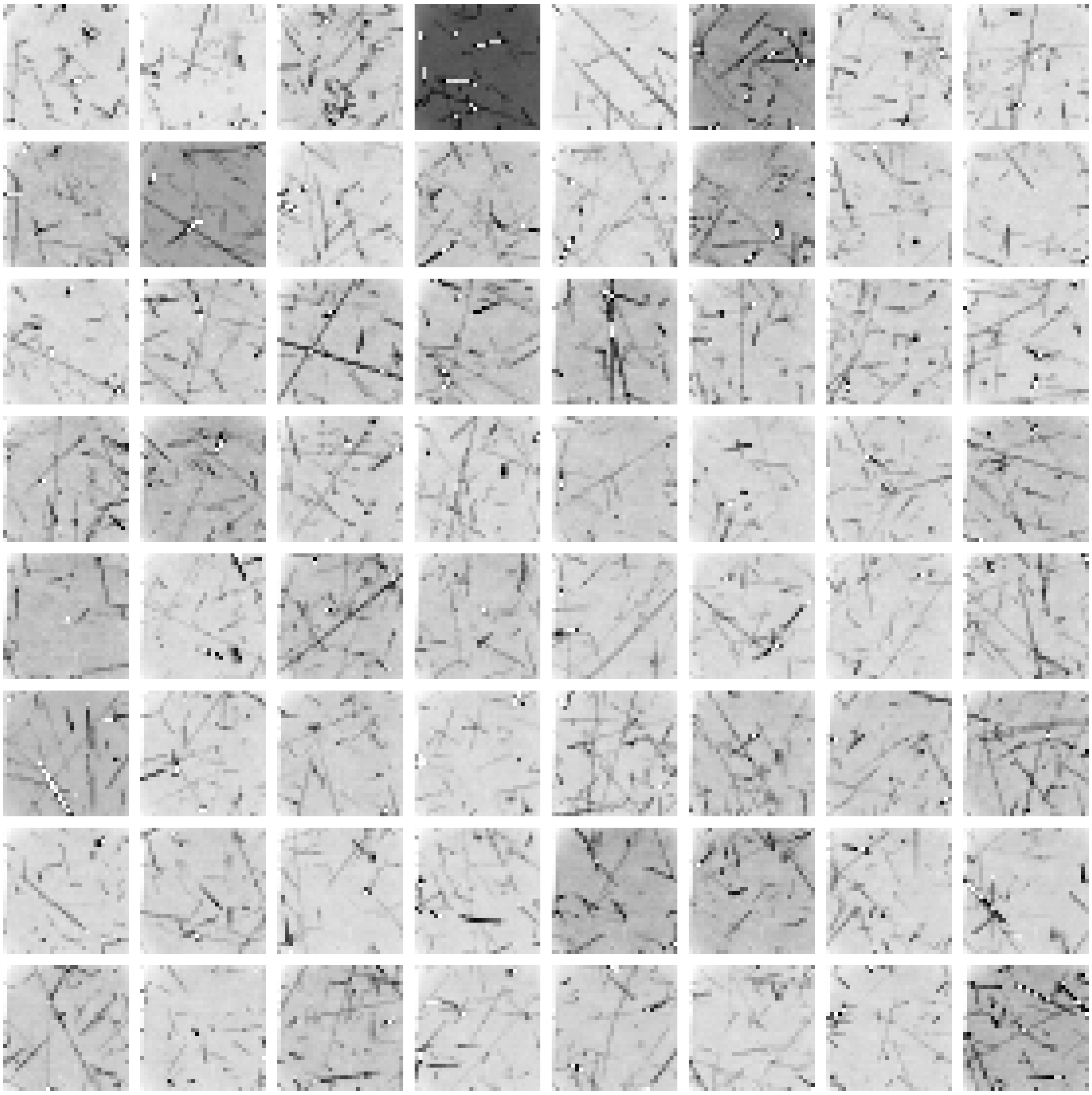

Figure 6: Some glitches during the solar flare of revolution 722. The glitch rate has increased by a factor of at least 7, and probably around 10.