SPICAM and SPICAV data level 1A UV
Process description

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1 Introduction

1.1 Purpose

This document provides a description for the different process applied on the raw SPICAM and SPICAV UV data to obtain the level 1A. Concatenated with the geometry, the data in the level 1A raw data is corrected from the missing packets, the erroneous spectra (for SPICAM only), the pixels altered by saturation and cosmic rays, the dark charge and the electronic noise. Each step of the correction is described in a different section.

1.2 Reference documents

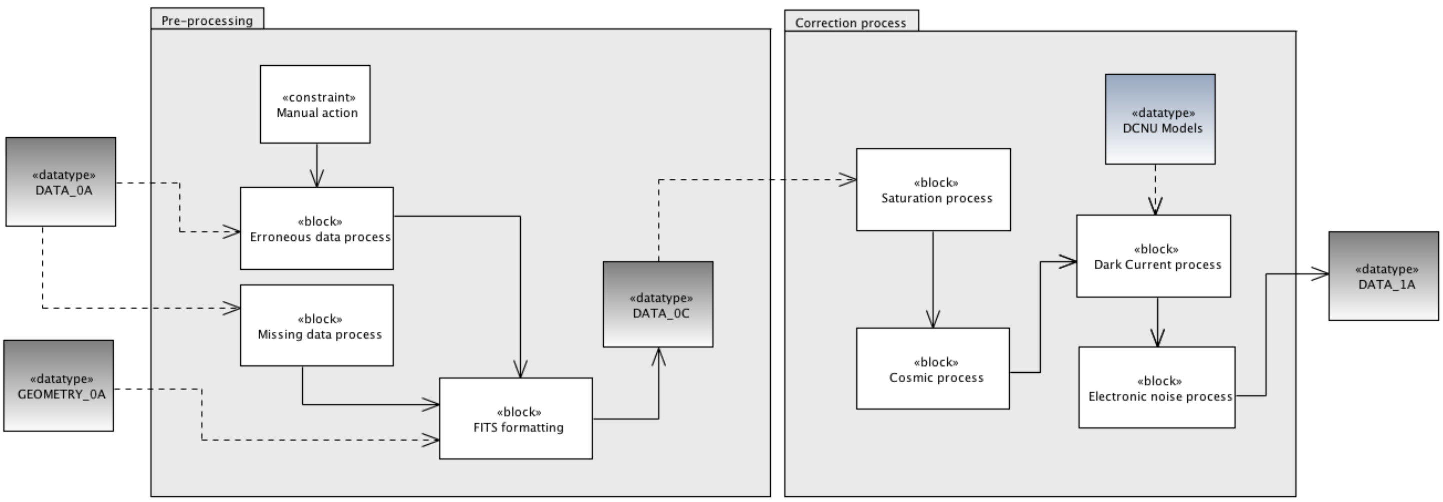
Ref N°	Title	Author	Date
1	Modèles de DCNU – Données SPICAM	Aurélie Reberac	23/01/2012
2	Note technique, Filtrage SPICAM	Aurélie Reberac, Bruno Rougerie	19/12/2011
3			

1.3 Abbreviations

SPICAM	Spectroscopy for Investigation of Characteristics of the Atmosphere of Mars
SPICAV	Spectroscopy for Investigation of Characteristics of the Atmosphere of Venus
DC	Dark Current
DCNU	Dark Charge Non Uniformity
FITS	Flexible Image Transport System
NaN	Not a Number
EN	Electronic Noise
ADU	Analog to Digital Unit

2 Overall overview of the process

The following diagram represents an overall overview of the correction process:



3 Pre-processing

A pre-processing step is done to format the data and detect missing and erroneous data. A mask array, named *Flags* with the same size of the data array, is also inserted during this step. This array contains an integer value (from 0 to 5) for each pixel, corresponding to the process detection or correction done. The pre-processing is necessary in order to perform higher-level process. It results in the construction of an intermediate data level, the level 0C, which is not archived.

3.1 FITS formatting

In the level 0A (raw), the data and geometry are available in two different files. For convenient use, both data and geometry are concatenated in one file under the FITS[1] format. The benefit of this format is the flexibility to add several image extensions.
An image extension is an array with the same size as the main data. In the level 1A, an extension called *Flags* is embedded in the FITS file and contains an integer value (from 0 to 5) defining the process done for each pixel of the data.

3.2 Missing data processing

SPICAM and SPICAV observations can have missing packets due to the communication troubles between the satellite and the earth ground segment. The presence of missing packets in an observation causes a wrong total number of records (or spectra). Two spectra can be consecutive but are in fact separated by a certain gap time corresponding to missing data. This process purpose is to inject empty values to retrieve the correct number of records.

The criterion to look for gaps is the record time. New lines, corresponding to the detected missing records, are injected with:

- Correct record number in the records array (geo.record.number)
- 'N/A' in the time array (geo.record.time)
- NaN[2] values in the data array, for all the pixels of the spectrum
- Flag number 1 in the Flags array (1 is the flag associated to a missing spectrum), all the pixels corresponding to the missing spectrum are flagged.

3.3 Erroneous data processing [SPICAM only]

This section concerns only the SPICAM UV data.

Erroneous data have been witnessed since the MTP 22 of the MARS EXPRESS mission. The SPICAM UV internal intensifier defect causes the appearance of random noise and alter the quality of SPICAM UV spectra.
The process to detect the erroneous data is a manual process.

The flag associated to a missing spectrum is 2. All the pixels corresponding to a given spectrum are flagged.

[1] FITS: Flexible Image Transport System
[2] NaN: Not a Number, data type representing an undefined value, IEEE 754 standard

4 Correction process description

4.1 Saturation detection

The saturation detection process detects and flags the saturated samples to permit to avoid them in further treatment.
The saturated samples are first detected by a simple check on a threshold value, the data array indices of saturated pixels are detected by:

$$ADU_{px} = K_1$$

Where $K_1 = 4095$ ADU

A second check is performed on the masked pixels (pixels number 397 to 406, first pixel is the number 0). If the following condition is fulfilled, the whole spectrum is flagged:

$$mean(ADU_{mpx}) > K_2$$

Where $K_2 = 3000$ ADU
And $ADU_{mpx}$is the masked pixels signal in ADU.
The flag associated to a saturated pixel is 3. The values of the saturated samples are not removed, but only flagged. The user should apply the *Flags* mask on the data.

4.2 Cosmic ray detection

This process has the purpose to identify the pixels affected by high-energy particles, known as cosmic ray, which mostly come from the interplanetary or interstellar medium. The cosmic ray produces a charge alteration on the CCD, resulting a very located signal peak (in time and wavelength). This can affect one pixel or several pixels, if the incidence angle with the CCD is small.

The detection follows two steps:

1. The temporal detection

The chance of a cosmic ray to affect a pixel on one spectrum and the same pixel on the spectrum before or after is very low. The detection of a cosmic ray is done by comparing the spectrum *n* with the spectra *n-1* and *n+1*. The conditions to fulfil the identification is:

$(S_n - S_{n-1}) > K_3$ and
$(S_n / S_{n-1}) > K_4$ and
$(S_n - S_{n+1}) > K_3$ and
$(S_n / S_{n+1}) > K_4$

Where S_n is the spectrum at records number *n*.
Note that for alignment mode, the comparison is done with the spectra *n-2* and *n+2*.

2. The spectral detection

The first step permits to locate in time (or spectrum) a signal peak due to a cosmic ray. The second step permits to simply study the spectral degradation, by the application of a median filter. The pixels damaged by a cosmic ray are identified by:

$\left(S_n(px) - median(S_n)\right) > K_3$ and
$\left(S_n(px) \,/\, median(S_n)\right) > K_4$

The flag associated to a pixel damaged by a cosmic ray is 4. The values of the detected samples are not removed, but only flagged. The user should apply the *Flags* mask on the data.

4.3 Dark Current correction

The process aims to estimate the Dark Current (DC) and remove it from the raw data. The estimation and correction of the DC per observation is based on general models, which are built upstream of the 1A process, and use dedicated SPICAM/SPICAV observations (no intensification, HT:0).
The purpose of these models is to contain the evolution of the variation of the DC signal pixel-by-pixel, during the whole mission. This variation is a characteristic known as the Dark Charge Non Uniformity (DCNU), and depends of the UV detector operating parameters (Binning and Y0). Consequently, there is one model per operating mode. The models are regularly updated with the most recent DCNU observations.

The estimation of the DC for a given pixel is given by the following linear equation:

$$DC_{p/k} = MeanSignal_{p/k}\left(DC_{pm/k} \times A_k + B_k\right)$$

Where:

- p is the pixel number,
- k is the number of band,
- $MeanSignal_{p/k}$ is the signal of the mean normalized spectra at pixel p and band k
- $DC_{p/k}$ is the Dark Current for the pixel p for the band k
- $DC_{pm/k}$ is the mean Dark Current of the masked pixel *pm* (pixels number 397 to 406) for the k band
- A_k and B_k, coefficient for the whole mission and operating parameter (Binning and Y0)

$MeanSignal_{p/k}$, A_k and B_k, are embedded in the general DCNU models. The *MeanSignal* signal parameter contains the information about the DCNU (evolution pixel by pixel). There is one *MeanSignal* per band for every orbits of the mission. For a 5-band acquisition mode, the number of bands is from 1 to 5. For an alignment mode, it can be from 1 to the number corresponding to the duration of the observation. An advantage of this method is the detection and correction of the "hot" and "cold" pixels (pixels with a higher or lower DC intensity than the mean DC intensity).

$DC_{pm/k}$ is a fit of the masked pixels, on the whole duration of the given observation to be corrected from the DC. The fit permits to avoid outliers signal induced by "hot" or "cold" pixels, or non-detected cosmic rays.

The the statistical error on the estimated DC is computed with:

$$E_{p/k}^{DC} = \sqrt{\left(MeanSignal_{p/k}^2 \times \left(\delta DC_{pm/k}^2 \cdot A_k^2 + DC_{pm/k}^2 \cdot \delta A_k^2 + \delta B_k^2\right) + \delta MeanSignal_{p/k}^2 \times \left(DC_{pm/k}^2 \cdot A_k + B_k\right)\right)}$$

Where:

- $\delta DC_{pm/k}$ is the absolute error between $DC_{pm/k}$ and the fit, $\delta DC_{pm/k} = \sqrt{\left(DC_{pm/k} - fit\left(DC_{pm/k}\right)\right)^2}$
- δA_k and δB_k are the errors on coefficients A_k and B_k
- $\delta MeanSignal_{p/k}$ is the error on $MeanSignal_{p/k}$

With the DC signal estimation, the corrected signal is obtained with:

$$S_k^C = S_k^C - DC_k$$

Where:

- S_k^C is the corrected signal for the band k, with all previous corrections applied.
- DC_k is the estimated DC signal for the band k.

And the statistical error is applied as below:

$$E_k = \sqrt{E_k^2 + {E_k^{DC}}^2}$$

Where:

- E_k is the overall error on corrections for the band k
- E_k^{DC} is the statistical error on the estimated DC for the band k

The initial value of E_k is computed with the following formula:

$$E_k = \sqrt{S_k^R / K_5}$$

Where:

- S_k^R is the measured raw signal
- K_5 = 125 for SPICAM, and K_5 = 153 for SPICAV

[Note for SPICAM only]

The SPICAM clean data (erroneous spectra deleted) are corrected using the DC model constructed with only clean data. The erroneous spectra are also corrected from the DC, but using the DC model constructed with the clean and erroneous data.

4.4 Electronic noise correction

The SPICAM and SPICAV raw signal shows along the wavelength axis a wave-like small (a few ADU) component induced by electronics. For further analysis this signal fraction, called electronic noise (EN), must be subtracted from the raw data. The point of this process is to model the EN and store it in a structure to retrieve it from the main signal.

The EN correction and its error associated are applied as below:

$$S_k^C = S_k^C - EN_k$$

$$E_k = \sqrt{E_k^2 + {E_k^{EN}}^2}$$

Where:

- EN_k is the Electronic Noise model for the band k
- E_k^{EN} is the associated statistical error

The process to model the EN is based on a sinusoidal signal prototype, whose parameters are determined by a fit of the fluctuant part of the raw signal along the wavelength axis. This fluky part is obtained by subtracting a boxcar median of the signal to the signal itself.
This process is applied band/image by band/image, and the fit is based on pixels that are thought to have as less signal as possible for better results.
For star occultations, given the fact that outer bands have a faint signal and the central band a strong one, the process is only applied to the outer bands. Bands 2 and 4 EN is then modelled as a dephased of model of the outer bands. Finally the central band also has the same parameters and the phase is a combination of band 1 and 3 phases.