SODISM DATA

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PICARD WORKSHOP April, 10 2012

SUMMARY

- ✓ 0 – SODISM DATA
- ✓ 1 – DATA PROCESSING ORGANIGRAMS
- ✓ 2 – L1 PRODUCTS
- ✓ 3 – FLAT FIELD
- ✓ 4 – DARK CURRENT
- ✓ 5 – N1 PRODUCT EXAMPLES

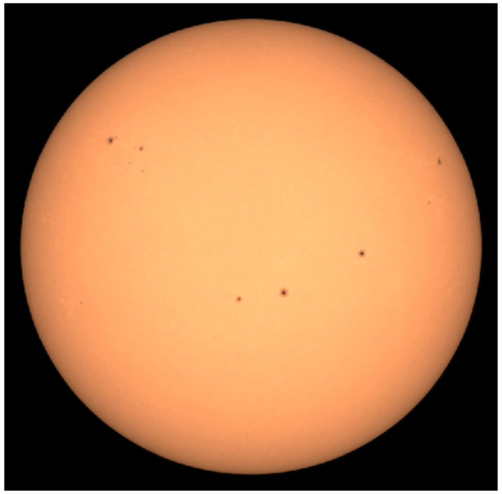
SODISM DATA (1/4)

Solar images

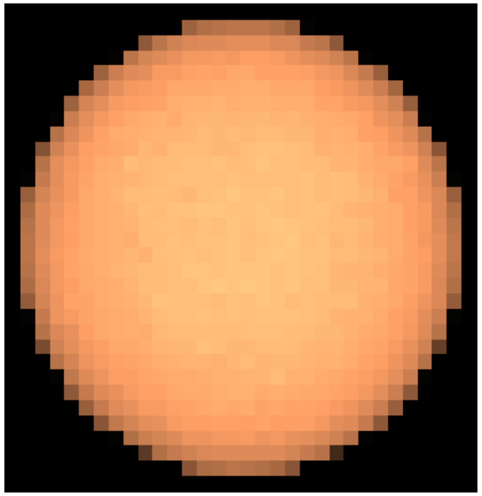
Full images of size 2048x2048 pixels recorded at wavelengths 215, 393, 535, 607 and 782 nm (2 images / orbit : 393 nm and another one)

Macropixel images of size 256x256 pixels at 535 nm with a cadence of 60 seconds (helioseismology)

Full Image



***Macropixel* Image**



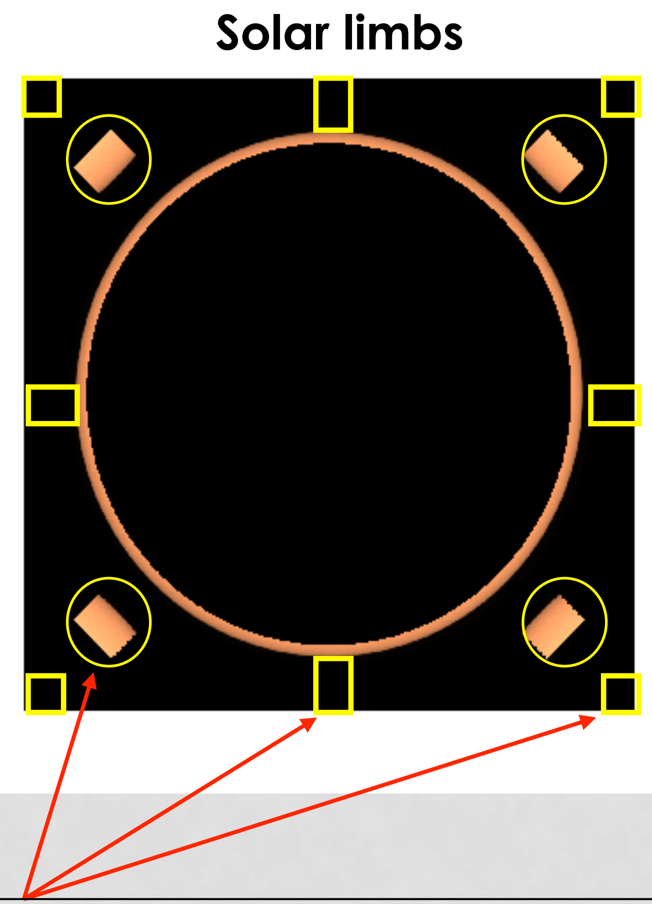
(size : 64x64 *macropixels*)

SODISM DATA (2/4)

Solar limbs

- <u>22 pixels wide limbs</u> recorded at 535 nm with a cadence of 120 s (helioseismology)

- <u>40 pixels wide limbs</u> recorded at 215, 393, 535, 607 and 782 nm at a rate of 2 / orbit / wavelength



Parts of the whole SODISM image are extracted and present with the limbs
These **markers** are used to follow instrument behavior on orbit

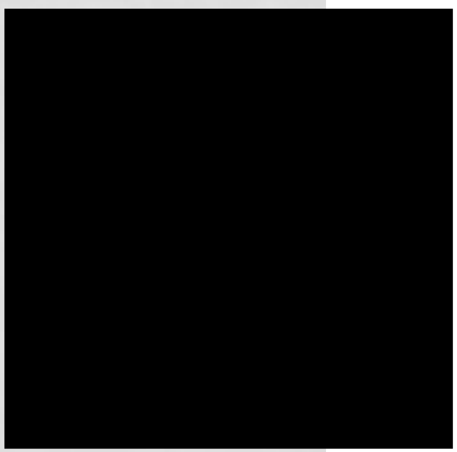
SODISM DATA (3/4)

- **Flat field** (with a divergent lens 1/ day) and **Dark Signal images** (size 2048x2048 pixels 3 / day)

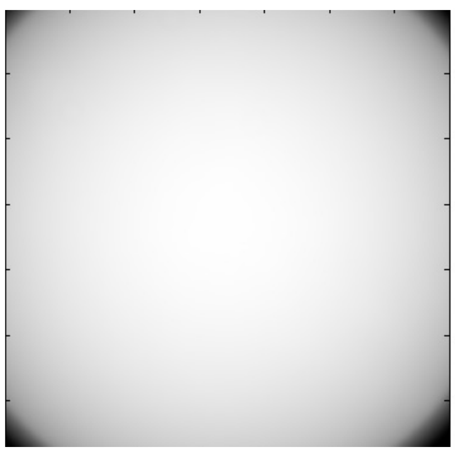
- **Dark Signal limbs** (40 pixels wide limbs) : 4/orbit

- **Doublet stars images** (2 windows image of size 768x768 pixels) : 1/few months

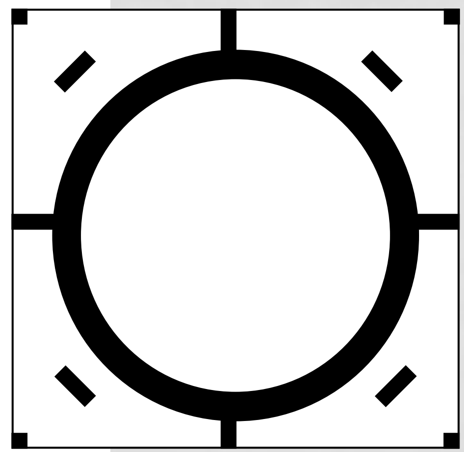
Dark signal image



Flat Field image



Dark signal limb



Double stars image

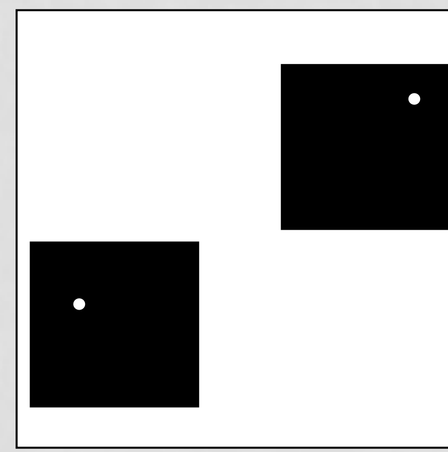
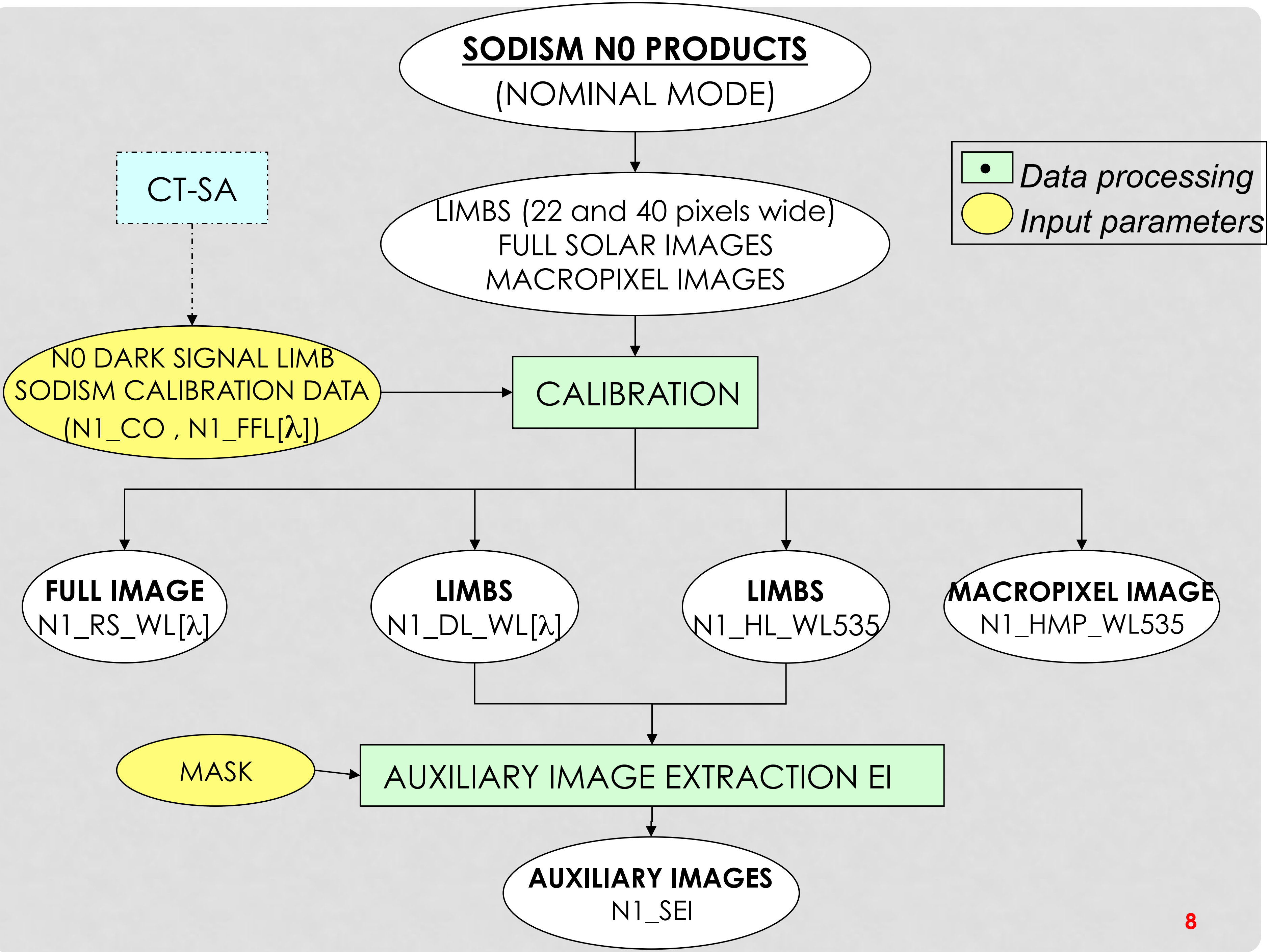


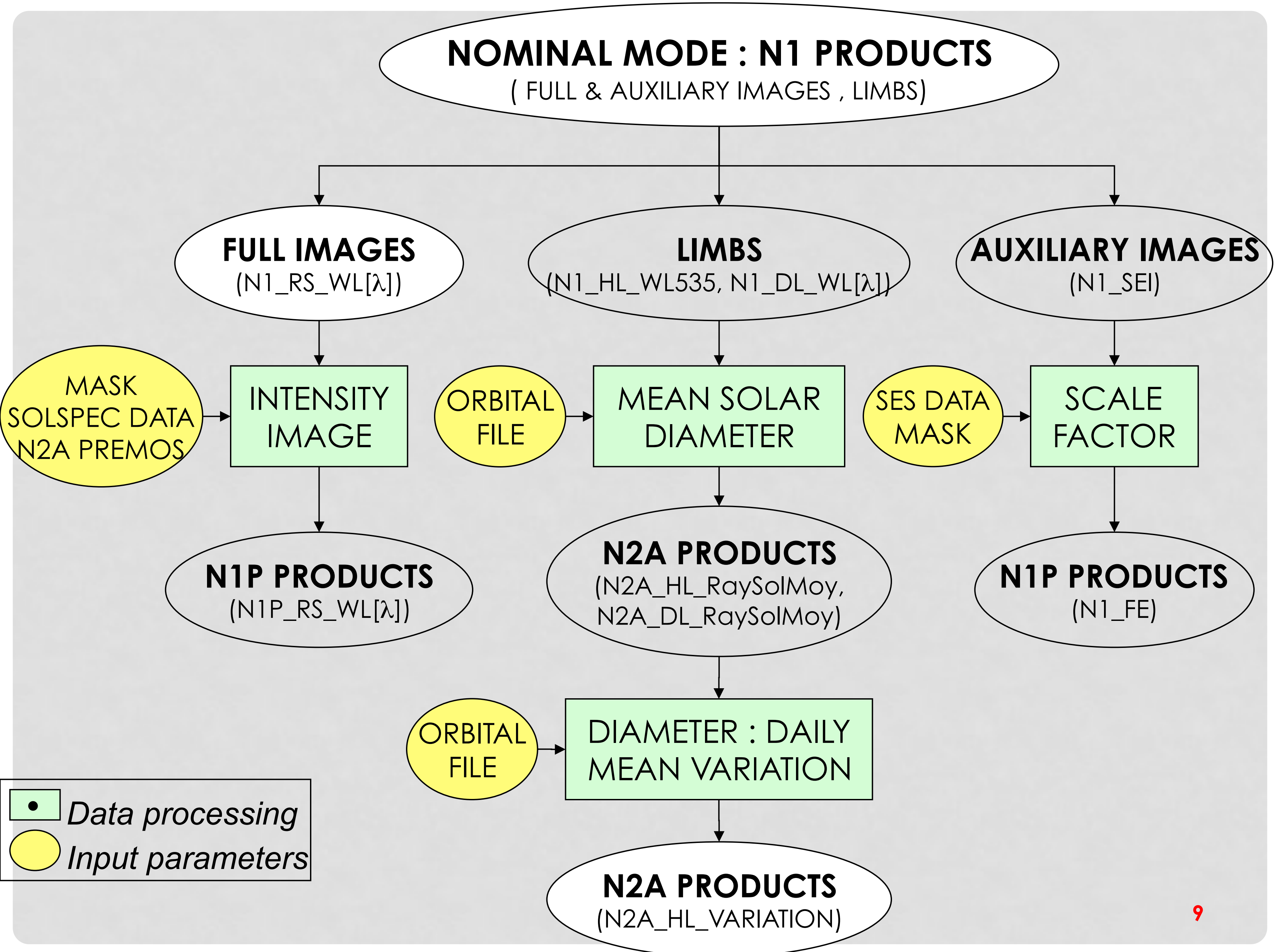
Image size are all 2048x2048 pixels

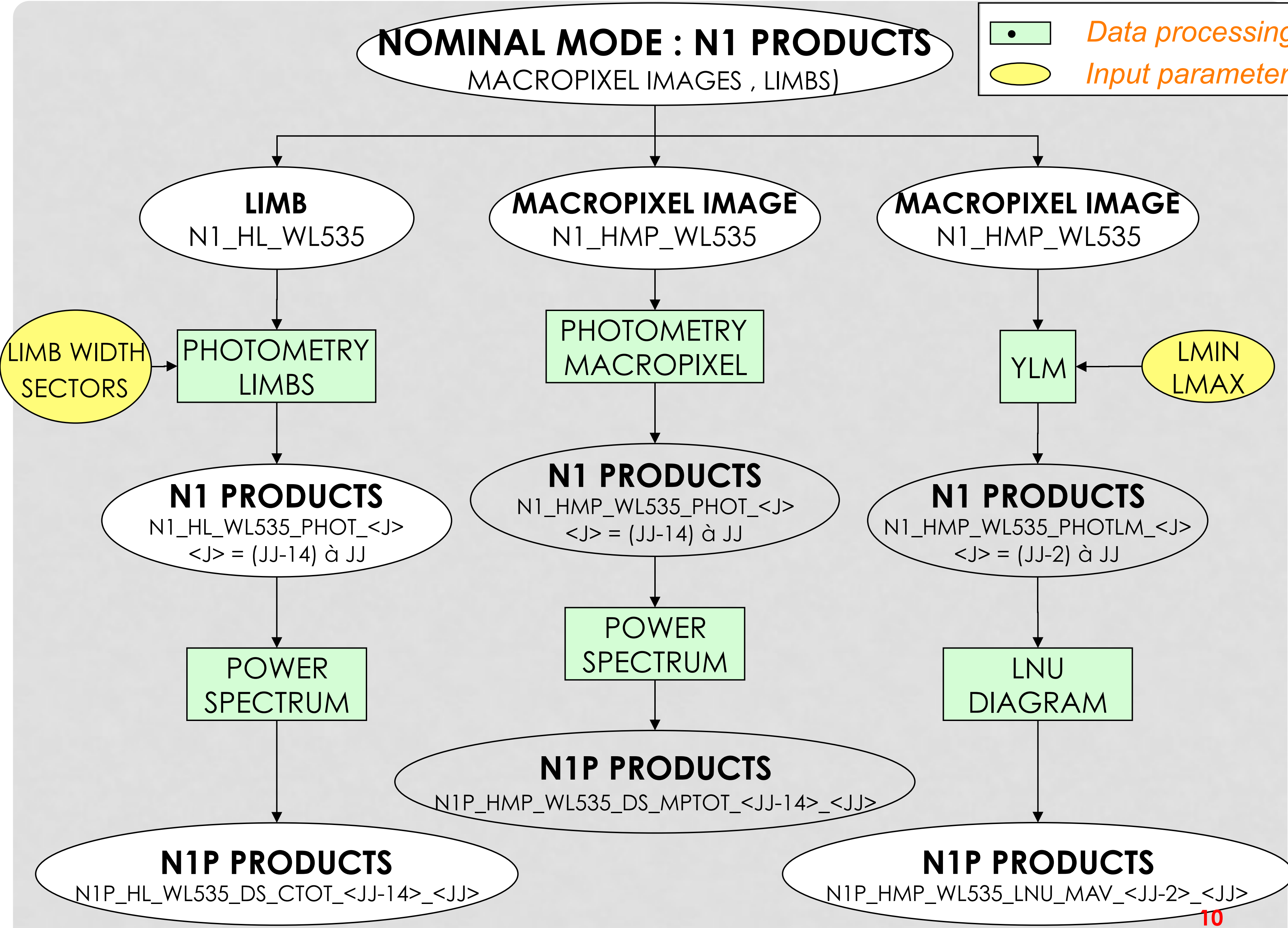
SODISM DATA (4/4)

Wavelength λ in nm	**Daily data rate** (nominal mode at the beginning of the mission)
215	**3 - 4**
393.37	**11**
535.7	**3 - 4**
535.7 H	**3 - 4**
607.1	**3 - 4**
782.2	**3 - 4**

I – DATA PROCESSING ORGANIGRAMS


SODISM N0 PRODUCTS
(NOMINAL MODE)
LIMBS (22 and 40 pixels wide)
FULL SOLAR IMAGES
MACROPIXEL IMAGES
Data processing
Input parameters
CT-SA
N0 DARK SIGNAL LIMB
SODISM CALIBRATION DATA
(N1_CO , N1_FFL[λ])
CALIBRATION
FULL IMAGE
N1_RS_WL[λ]
LIMBS
N1_DL_WL[λ]
LIMBS
N1_HL_WL535
MACROPIXEL IMAGE
N1_HMP_WL535
MASK
AUXILIARY IMAGE EXTRACTION EI
AUXILIARY IMAGES
N1_SEI


NOMINAL MODE : N1 PRODUCTS
(FULL & AUXILIARY IMAGES , LIMBS)
FULL IMAGES
(N1_RS_WL[λ])
LIMBS
(N1_HL_WL535, N1_DL_WL[λ])
AUXILIARY IMAGES
(N1_SEI)
MASK
SOLSPEC DATA
N2A PREMOS
INTENSITY IMAGE
ORBITAL FILE
MEAN SOLAR DIAMETER
SES DATA MASK
SCALE FACTOR
N1P PRODUCTS
(N1P_RS_WL[λ])
N2A PRODUCTS
(N2A_HL_RaySolMoy,
N2A_DL_RaySolMoy)
N1P PRODUCTS
(N1_FE)
ORBITAL FILE
DIAMETER : DAILY MEAN VARIATION
Data processing
Input parameters
N2A PRODUCTS
(N2A_HL_VARIATION)


NOMINAL MODE : N1 PRODUCTS
MACROPIXEL IMAGES , LIMBS)
Data processing
Input parameters
LIMB
N1_HL_WL535
MACROPIXEL IMAGE
N1_HMP_WL535
MACROPIXEL IMAGE
N1_HMP_WL535
LIMB WIDTH
SECTORS
PHOTOMETRY
LIMBS
PHOTOMETRY
MACROPIXEL
YLM
LMIN
LMAX
N1 PRODUCTS
N1_HL_WL535_PHOT_<J>
<J> = (JJ-14) à JJ
N1 PRODUCTS
N1_HMP_WL535_PHOT_<J>
<J> = (JJ-14) à JJ
N1 PRODUCTS
N1_HMP_WL535_PHOTLM_<J>
<J> = (JJ-2) à JJ
POWER
SPECTRUM
POWER
SPECTRUM
LNU
DIAGRAM
N1P PRODUCTS
N1P_HMP_WL535_DS_MPTOT_<JJ-14>_<JJ>
N1P PRODUCTS
N1P_HL_WL535_DS_CTOT_<JJ-14>_<JJ>
N1P PRODUCTS
N1P_HMP_WL535_LNU_MAV_<JJ-2>_<JJ>

ALGORITHM NEEDS

Presented L1 algorithms need software developments

They consist in :

- ***calibration data***
- ***scale factor estimation***
- ***analysis of helioseismology limbs and macropixel images***

II - L1 DATA PROCESSING

L1 DATA PROCESSING (1/5)

LIMB and FULL IMAGE (both high and low resolution) CALIBRATION

$$Ic(M) = \alpha(\lambda)\, G(\lambda, M)\, [I(M) - N(M)] \quad \text{where } M = M(x,y)$$

$I(M)$ is the high and low resolution solar or the limb image and $Ic(M)$ the calibrated one

$N(M)$ is the CCD mean dark signal image

$\alpha(\lambda)$ is the calibration factor at wavelength λ to transform ADU in $mW/m^2/nm$

$G(\lambda, M)$ is the CCD gain matrix obtained from flat field images : $< G(\lambda, M) >= 1$

The gain matrix $G(\lambda, M)$ and dark signal image $N(M)$ for low resolution images are computed in the same way as they are built onboard using full resolution ones

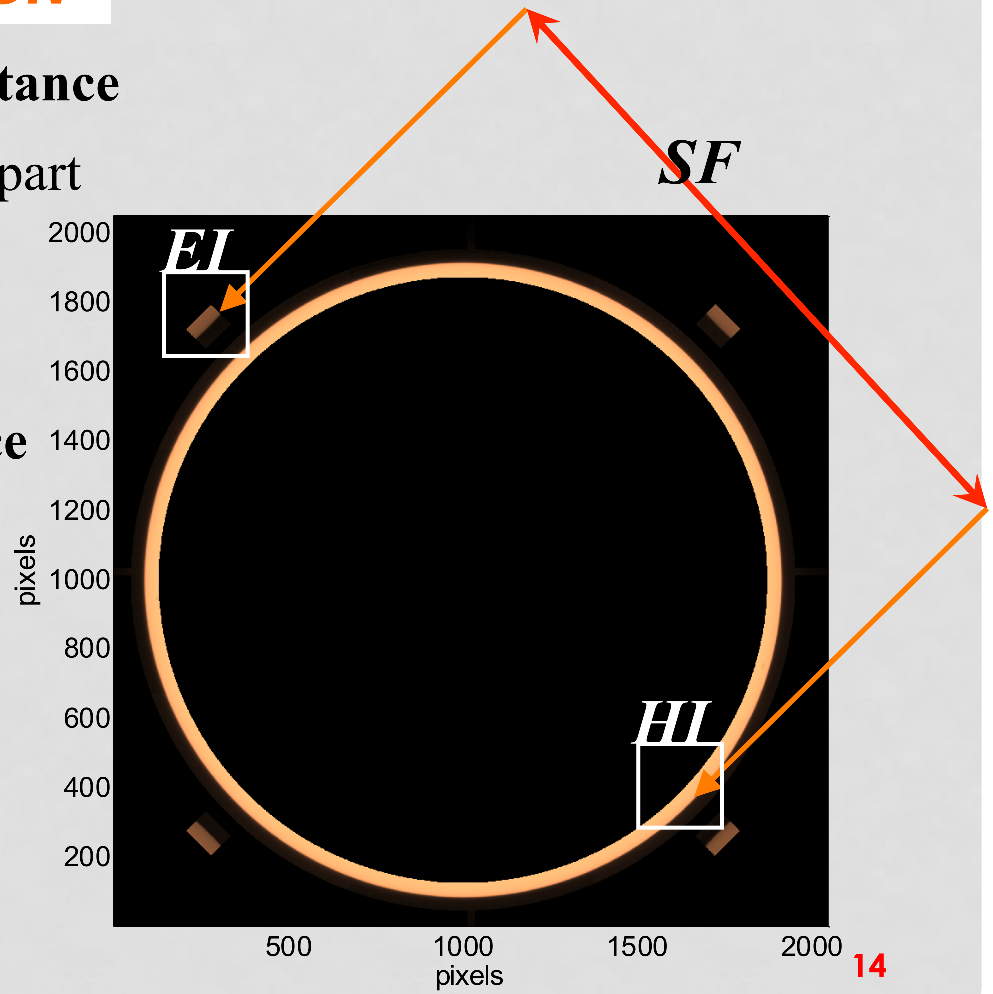
L1 DATA PROCESSING (2/5)

❑ *SCALE FACTOR : ILLUSTRATION*

The internal Scale Factor **SF** is **the distance** between the corner image and the same part in the main one.

It is obtained by computing **the distance** between :

- the maximum of the intercorrelation function of EI and HI images and
- the maximum of the autocorrelation function of the image EI.



L1 DATA PROCESSING (3/5)

❑ ***SCALE FACTOR : ESTIMATION***

The Scale Factor is determined from intercorrelation of images :

$$C(\Delta M) = EI(M) * HI(M) \text{ where } M = M(x,y) \text{ and } \Delta M = (\Delta x, \Delta y)$$

$*$ denotes the convolution opération

C is the intercorrelation function of EI and HI

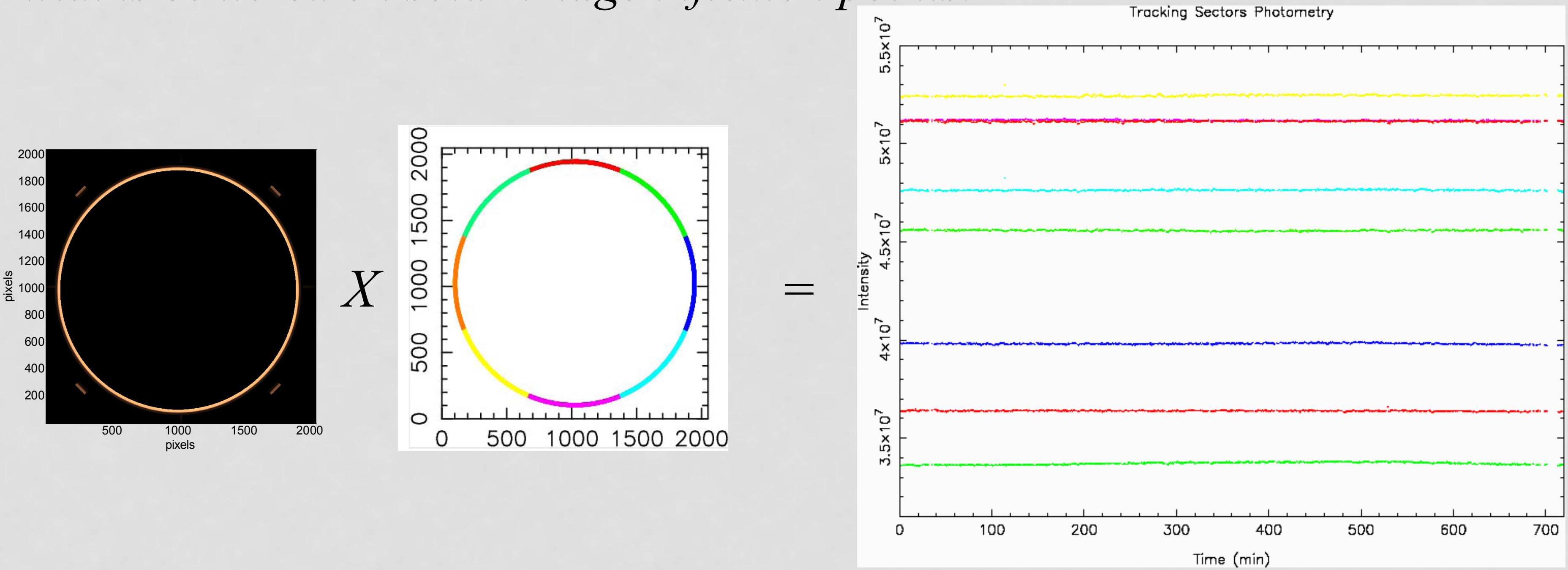
$EI(M)$ is an auxiliary solar image used for calibration and

$HI(M)$ is its corresponding part in the limb

L1 DATA PROCESSING (4/5)

❑ *HELIOSEISMOLOGY : MONITORING OF LIMB INTENSITY*

Limb photometry is computed over several sectors and rings of different widths centered on solar image inflexion points.



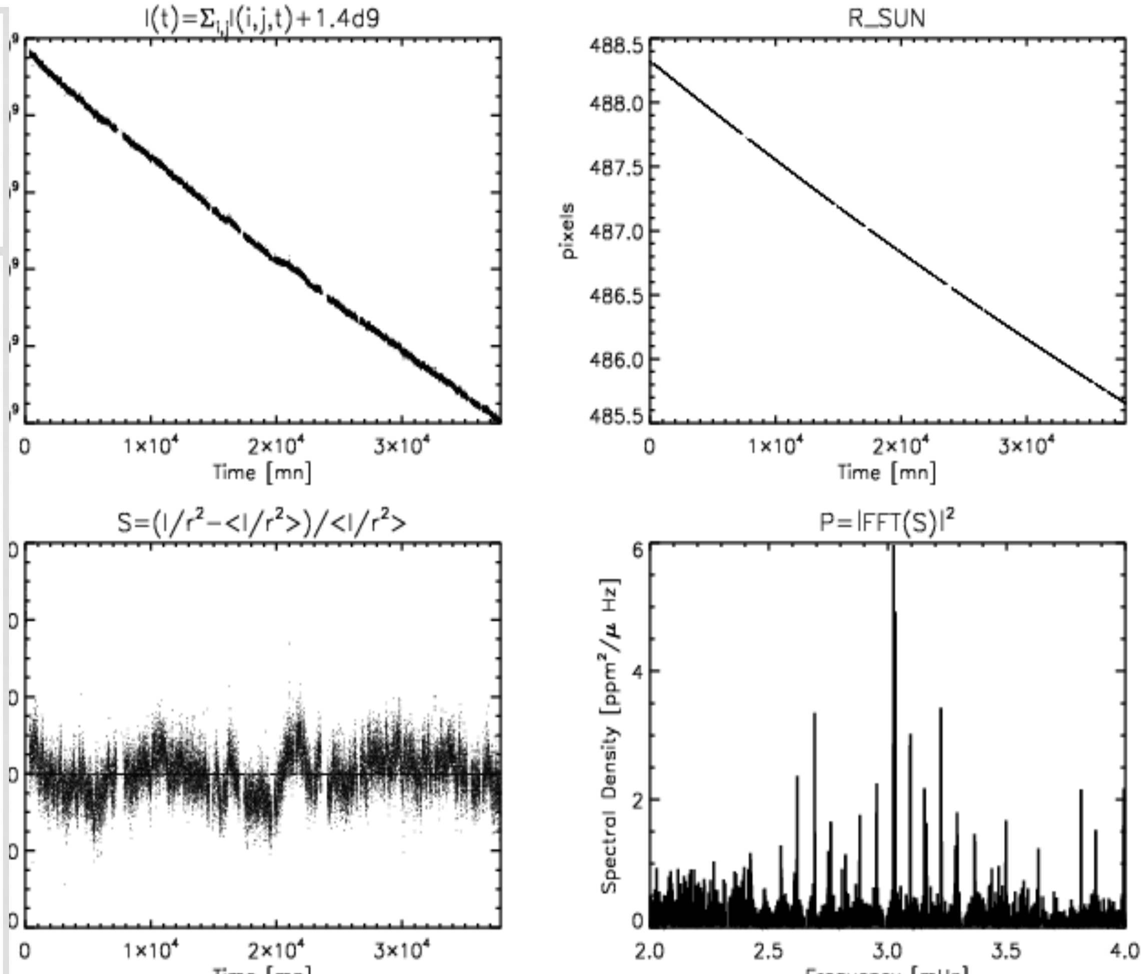
Case of limb photometry computed over 8 sectors

L1 DATA PROCESSING (5/5)

❑ *HELIOSEISMOLOGY : MONITORING OF MACROPIXEL PHOTOMETRY*

Intensity of all macropixel images is computed.

***Power spectrum of temporal fluctuations of macropixel image intensity** corrected from Satellite-Sun distance is calculated every **15 days over a period of 15 days**.*
(also for 22 pixels wide limb Intensity)



Temporal fluctuations of image intensity and its Power spectrum

III - FLAT FIELD

KUHN-LIN-LORANZ (KLL) METHOD

(Kuhn et al., Astronomical Society of the Pacific, 103: 1097-1108, October 1991)

THE FLAT FIELD IS ESIMATED FROM IMAGES RECORDED AT DIFFERENT POSITIONS ON THE CCD ASSUMING THAT THE SOURCE REMAINS CONSTANT

The CCD pixel response : $d_i(x) = g(x)s_i(x)$

where d_i, s_i *and* g *are the recorded data, incident signal and the gain of the* ***x*** *pixel.*

We deduce the following equation considering a couple of recorded images (in log) and assuming the source constant :

$$D_i(x+a_i) - D_j(x+a_j) - G(x+a_i) + G(x+a_j) = 0$$

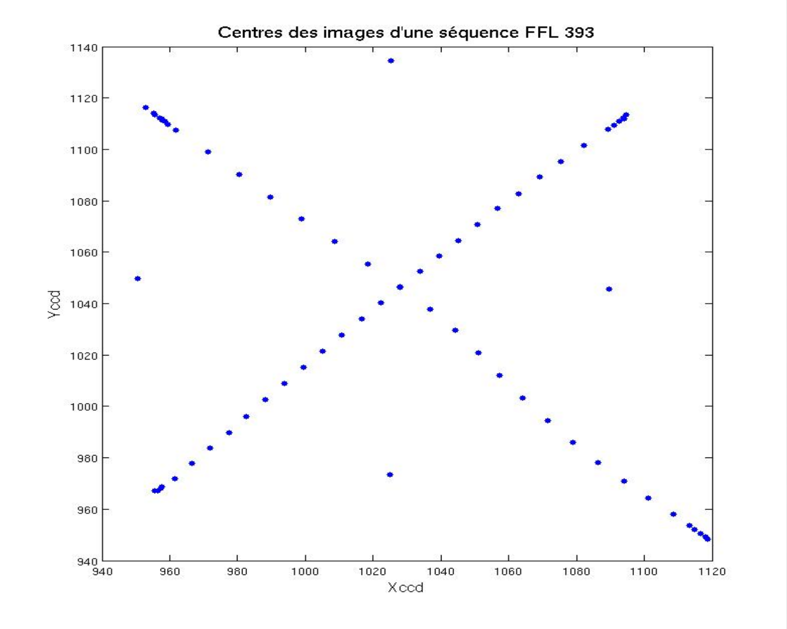
The solution is built with an iteratif process using a least square method. It is given by:

$$G^{r+1}(x) = K(x) + \frac{1}{n(x)} \sum_{i<j} \left[G^r(x-\delta_{ij}) + G^r(x+\delta_{ij}) \right] \quad \text{with} \quad G^0(x) = K(x)$$

$$K(x) = \frac{1}{n(x)} \left\{ \sum_{i<j} \left[D_i(x) - D_j(x-\delta_{ij}) \right] + \sum_{i<j} \left[D_j(x) - D_i(x+\delta_{ij}) \right] \right\}$$

where $\delta_{ij} = a_i - a_j$, $n(x)$, number of terms to calculate $K(x)$

IMAGE SERIE FOR FLAT FIELD ESTIMATION



SODIMS IMAGE POSITIONS ON THE CCD

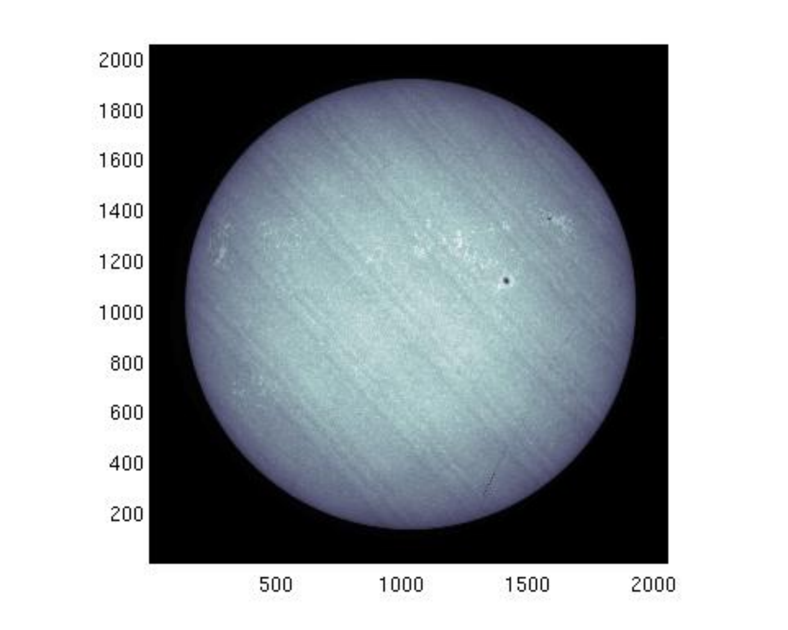


IMAGE RECORDED SEPTEMBER,1 2010 AT 393 nm

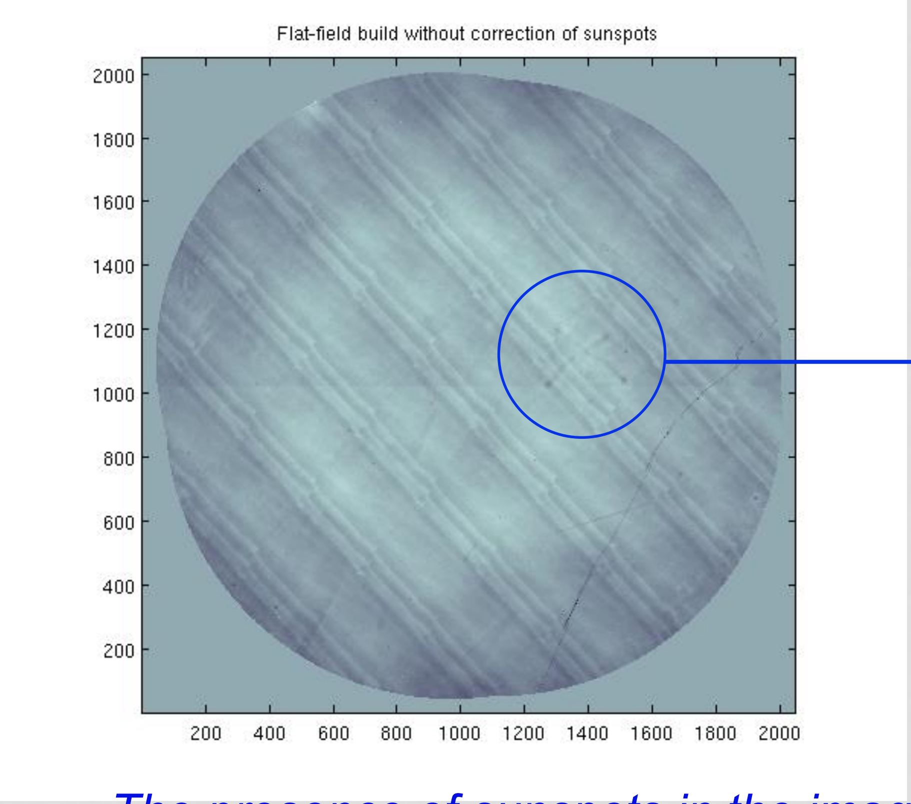
- ***280 IMAGES ARE RECORDED FOR EACH SODISM WAVELENGTH***

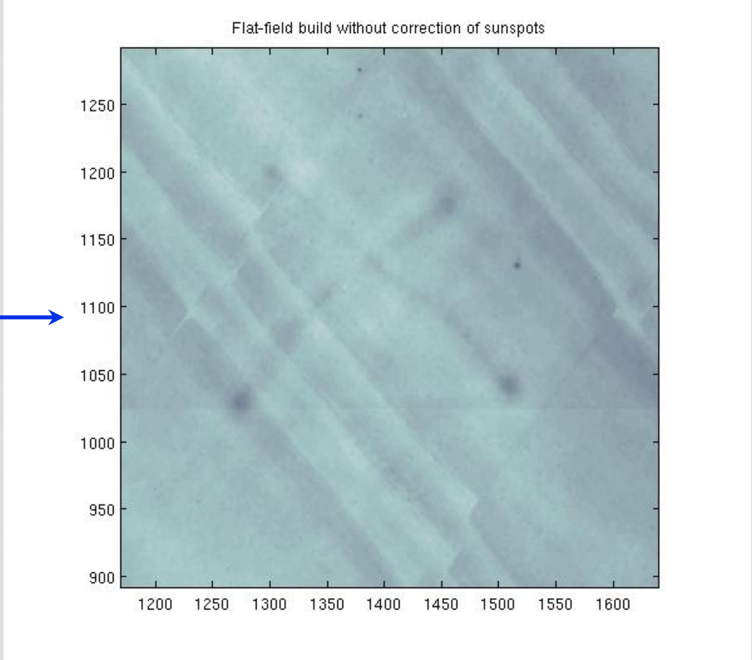
- ***EACH DATA SET TAKES MORE THAN 14 HOURS***

- ***THE SOURCE MAY OFTEN NOT BE CONSIDERED AS CONSTANT DUE TO THE PRESENCE OF SUNSPOTS AND OTHERS FEATURES IN IMAGES***

SUNSPOTS IN IMAGES

FLAT FIELD ESTIMATION WITH IMAGES RECORDED AT 393 nm WHERE SUNSPOTS ARE PRESENTS





The presence of sunspots in the image serie become a cross in the flat field estimation since they relatively move on the CCD when recording them

We need to mask sunspots in images before computing the flat field

<u>First step:</u> - calculation of radius and center coordinate

- correction from bright points and sunspot

  - *Avoid to have wrong pixel when using the KLL method*
  - *Avoid some marks caused by sunspots*

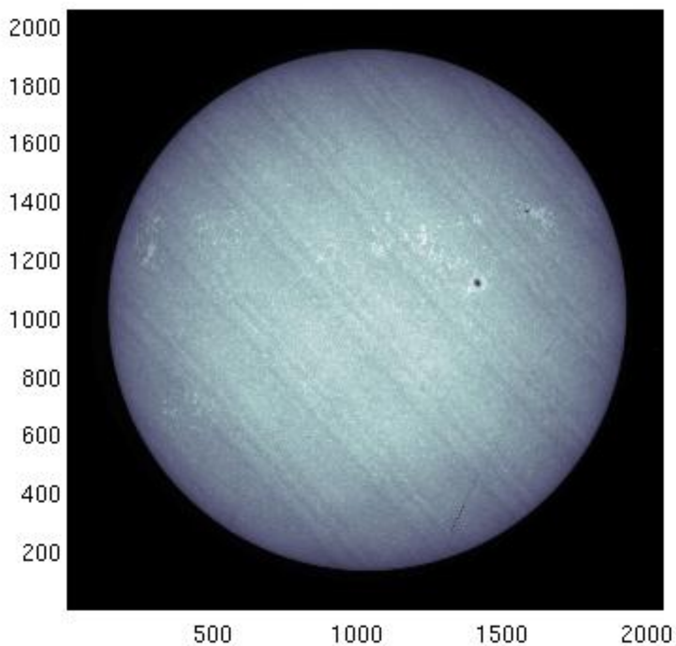
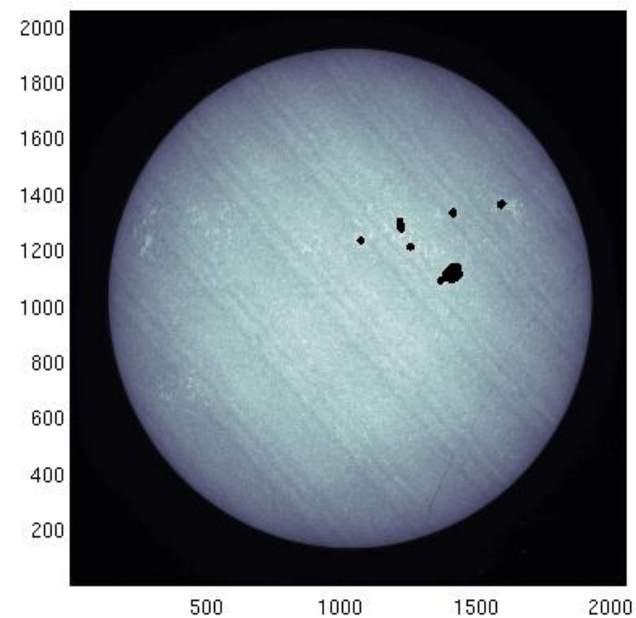


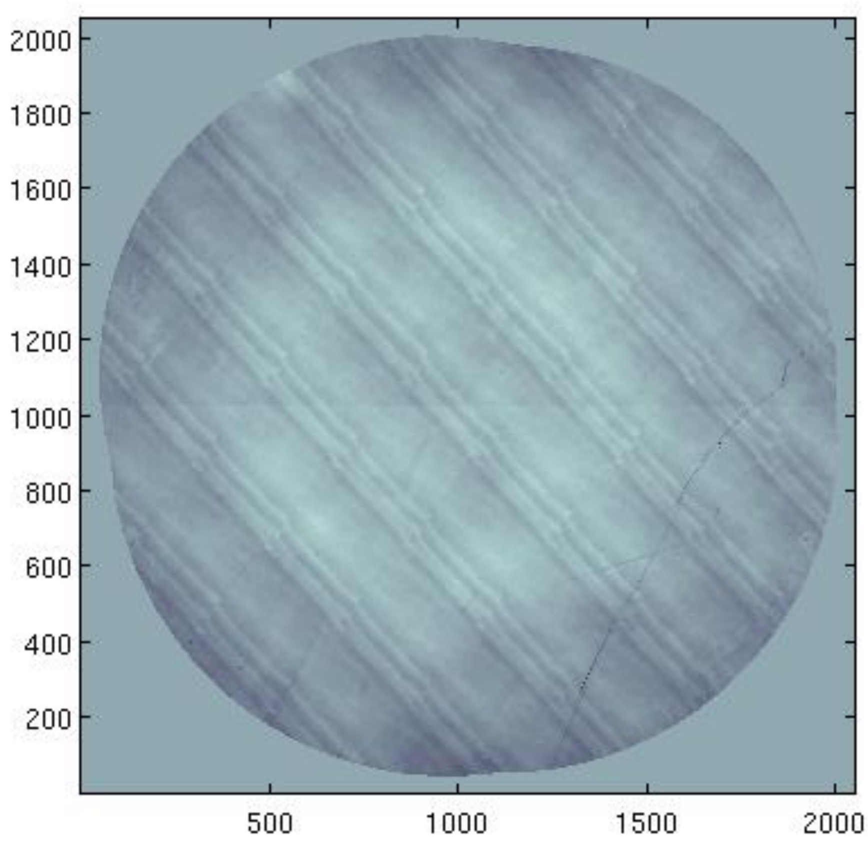
Image at 393 nm with all its features



Images at 393 nm where some features have been located and put to 0

Second step:

*Calculation of the Flat-Field using the KLL method and 280 solar images of 2048*2048 pixels recorded in different positions on the CCD*



- Results

L0 image at 393 nm before correction with the flat-field

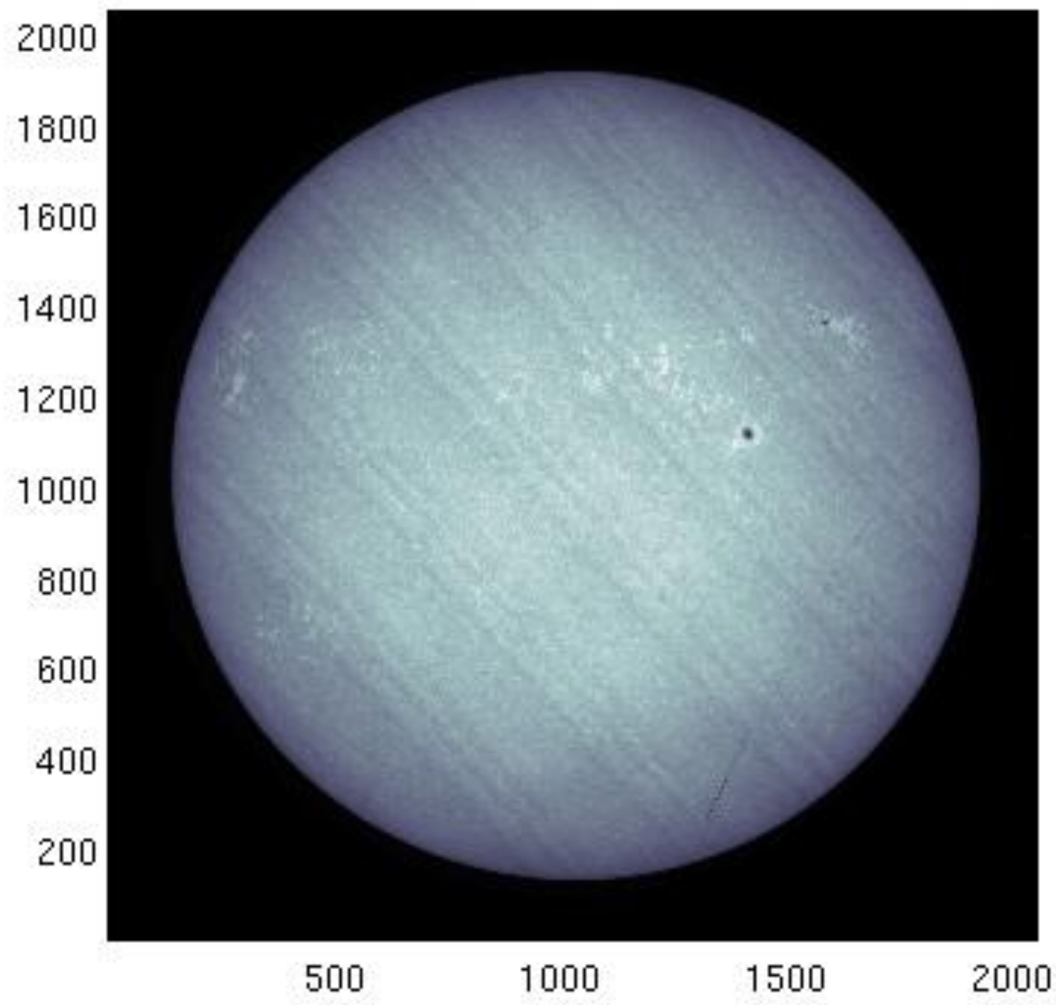
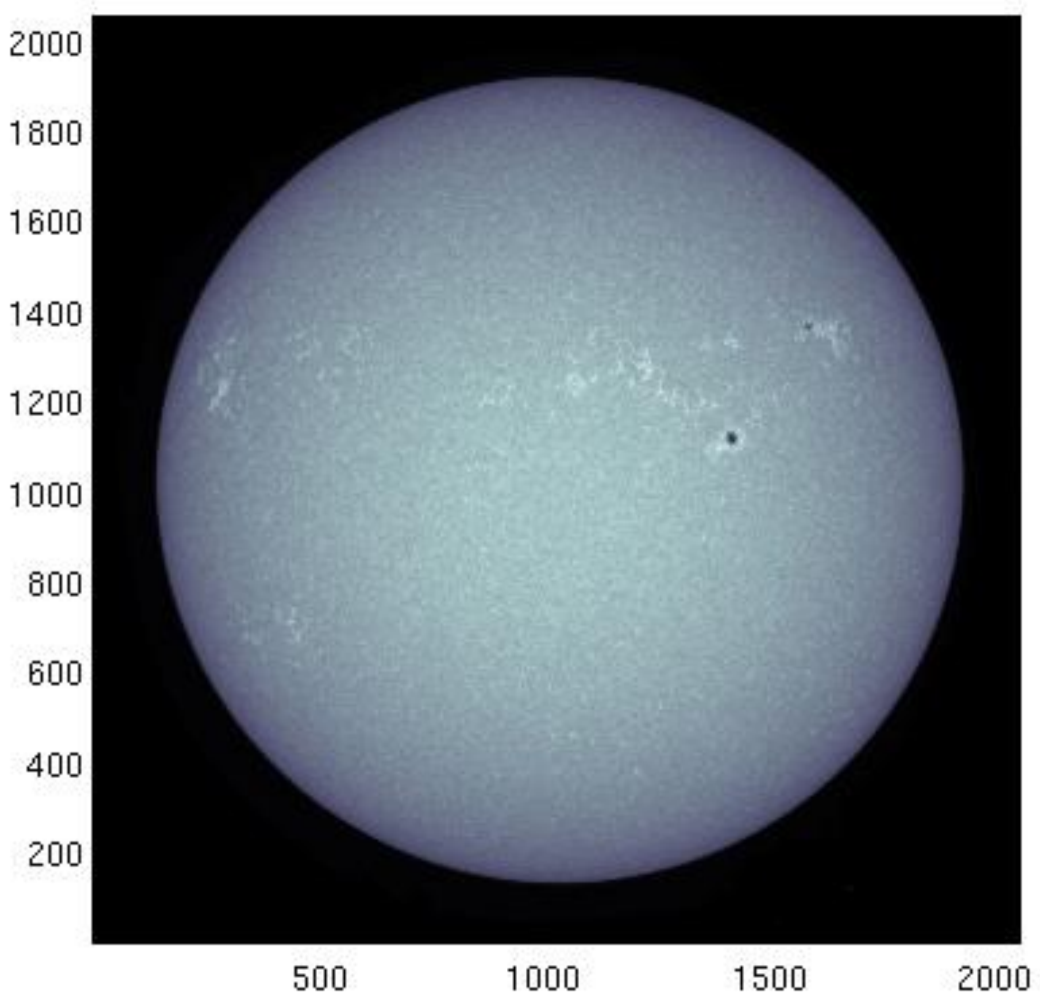
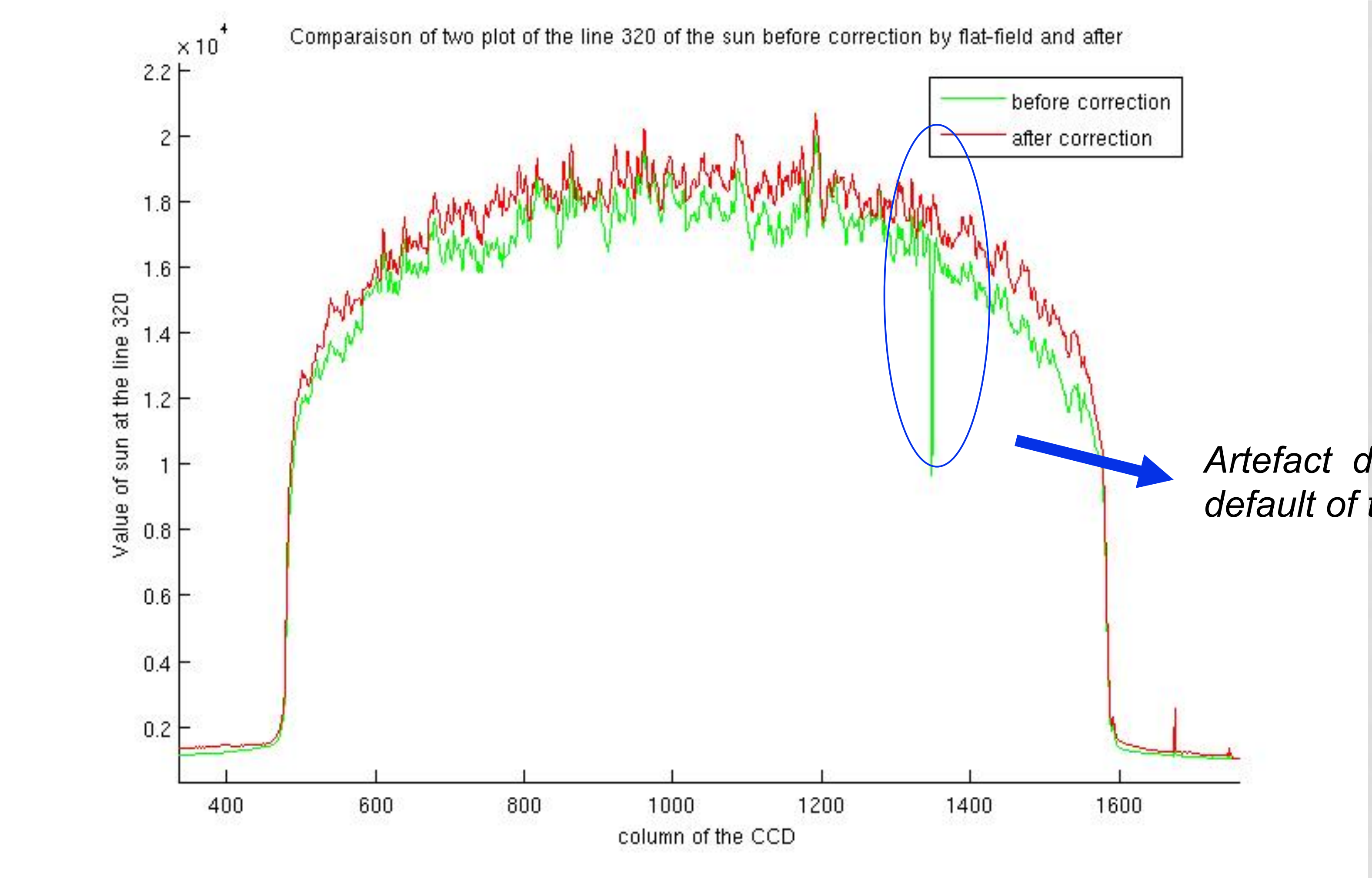


Image at 393 nm after correction with the flat-field

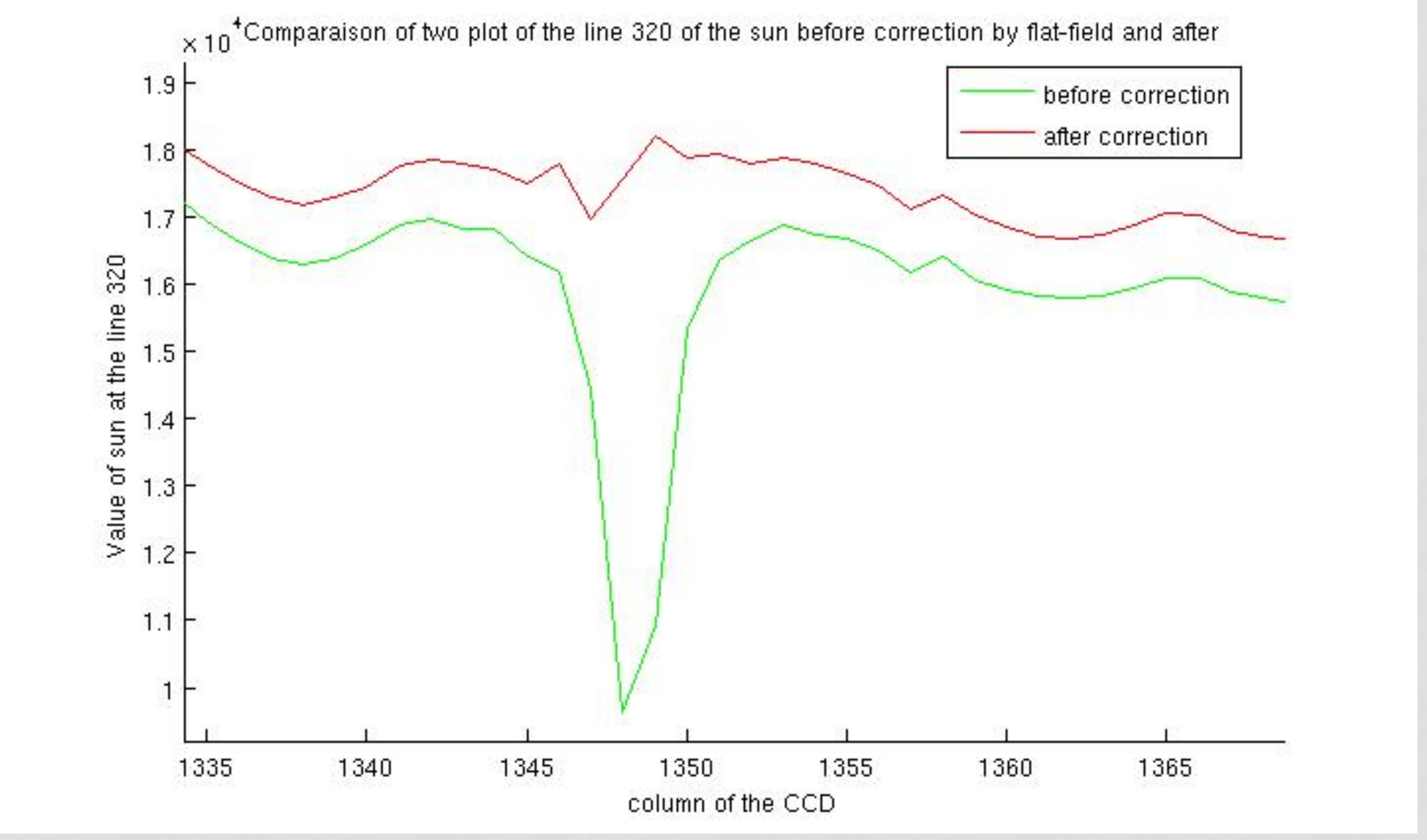


We better see the correction on this following graphic which is an image cut



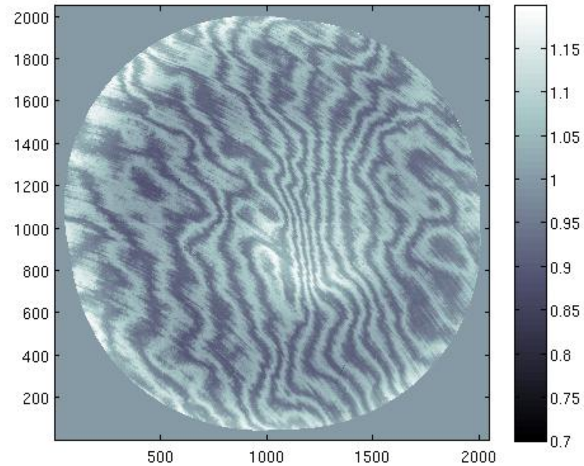
Artefact due to a default of the CCD

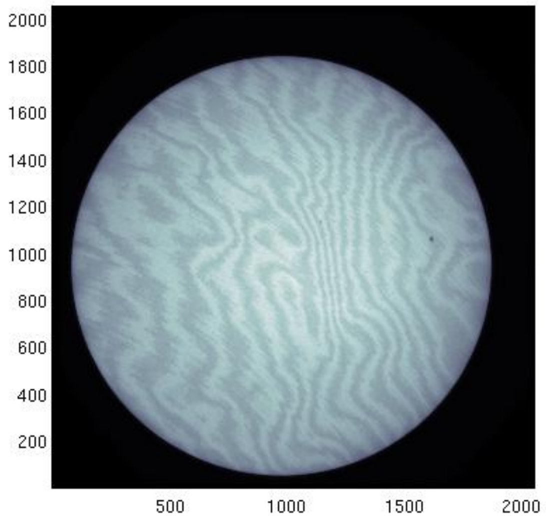
Artefact due to the CCD default : we obtain a good result after correction with the flat-field



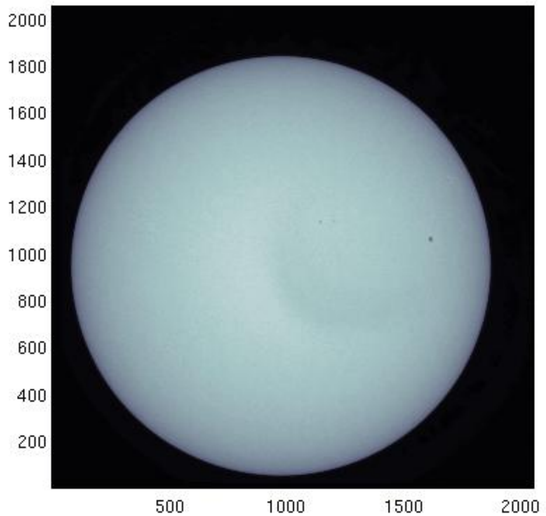
We can see also the result on an image recorede at 782 nm

Flat field at 782 nm



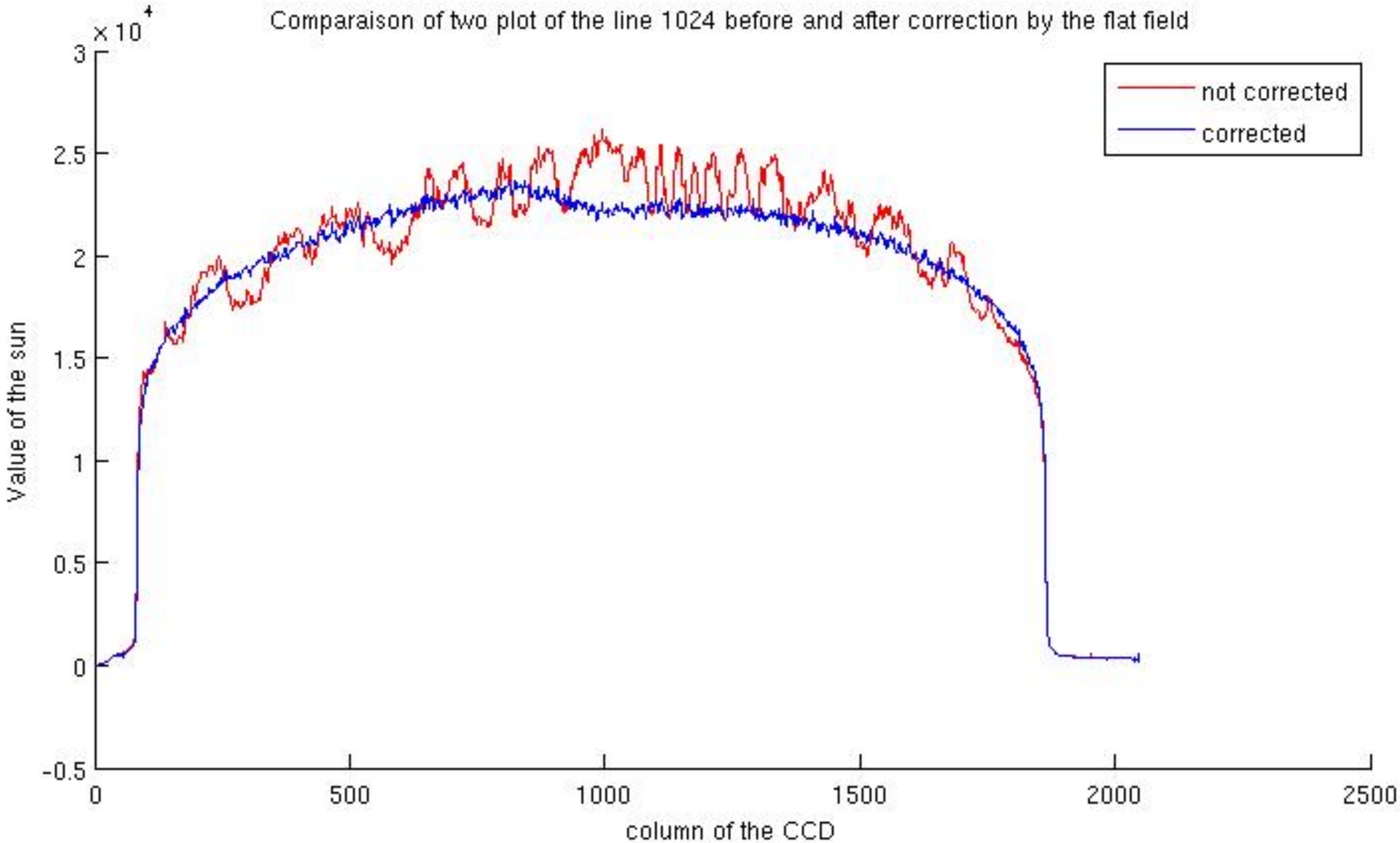


L0 image recorded at 782 nm



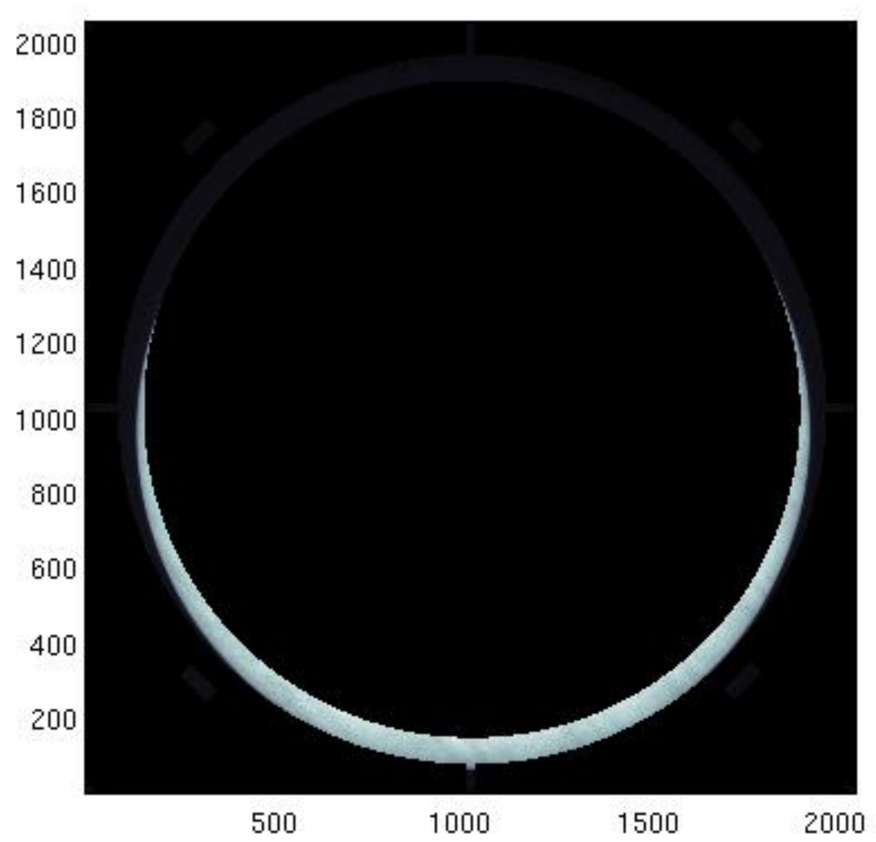
The same image corrected with the flat field

We can see the correction on this following image cut



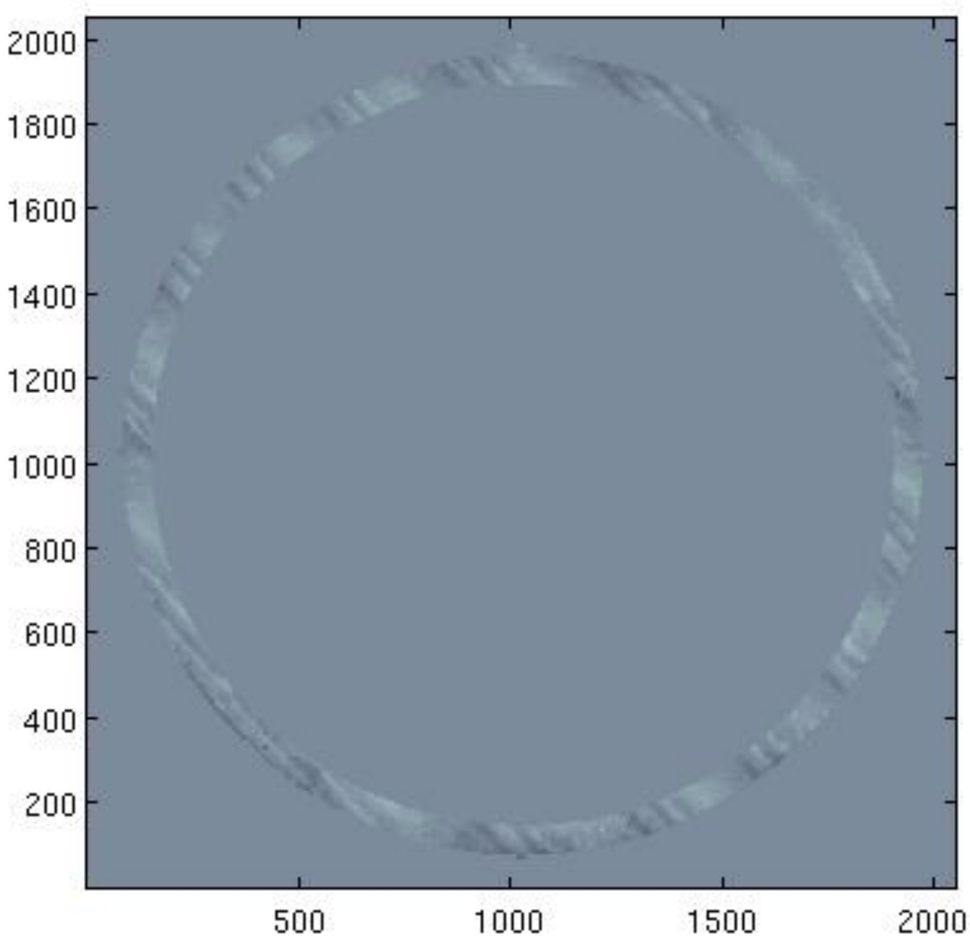
FLAT FIELD ESTIMATION FROM SOLAR LIMB

SOLAR LIMB IMAGES HAVE TO BEEN RECOREDE AT EACH WAVELENGTH TO ESTIMATE THE FLAT FIELD



THE PROBLEM WE ENCOUNTERED IS THAT LIMB IMAGE ARE NOT COMPLETES : SOLAR LIMBE POSITIONS HAVE TO BE ESTIMATED TO USE THE KLL ALGORITHM

WE WERE ABLE TO ESTIMATE THE FLAT FIELD FROM LIMBE (DL) IMAGES



FLAT FIELD ESTIMATION CONSIDERING SOLAR LIMB SERIE AT 393 nm

V - DARK CURRENT

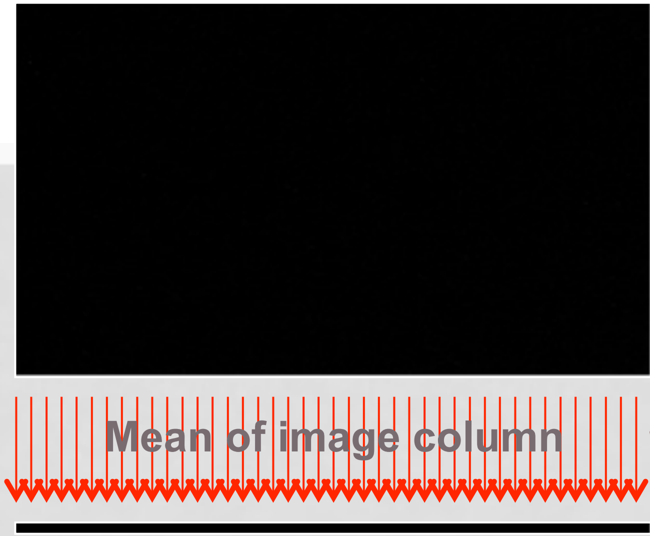
ESTIMATION OF THE DARK CURRENT IMAGE (1/2)

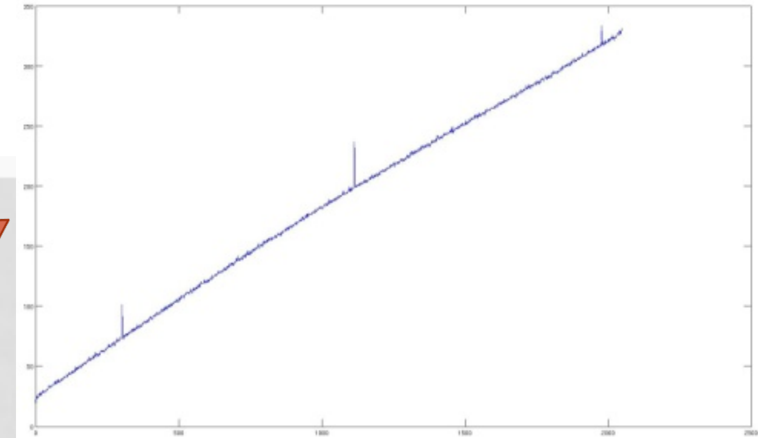
First method

- Hypothesis : **DC (i) = DC(1)*EXPOSURE + RN**
  - DC(i) : Dark Current of the ith image
  - DC(1) : Dark Current at 1 second exposure time
  - RN : CCD reading noise (ramp)

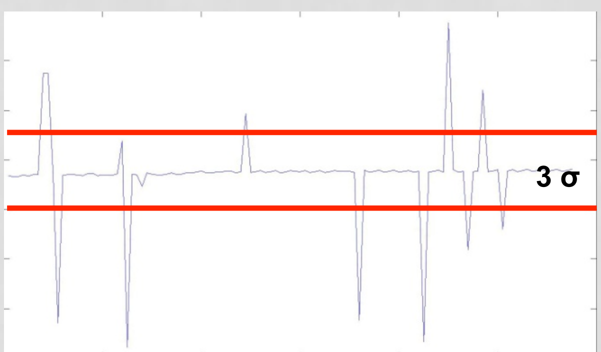
- Estimation of the CCD reading noise RN and DC(1) in 2 steps
  - **RN estimation**
    - **N** images of DC corrected from their offsets
    - Mean of the CCD columns for each image and linear fit
    - Removal of fit bad values obtained from the **N** images
    - Construction of the mean ramp image (2048*2048)

DC Image corrected from offsets



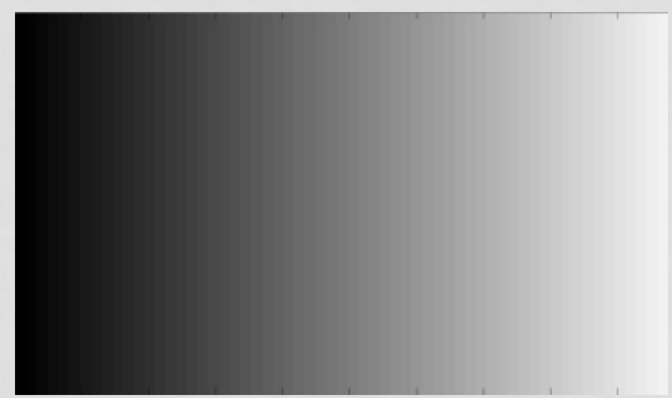


Estmation of the linear fit coefficients (ramp)



Mean ramp coeficients obtained from the N images and 3σ filtering

Constructon of the mean ramp image with the fit coefficients



Reading noise image (ramp)

- **CO(1) estimation**

CO(1) is the average of the **N** CO(i) without the reading noise divided by the exposure time to have an image of **1s integration time**

CO of 1 second integration time (exposure)

- The DC used at the CMS-P is computed using this method
- Limit of the method : reading noise assumed to be linear

ESTIMATION OF THE DARK CURRENT IMAGE (2/2)

Second method

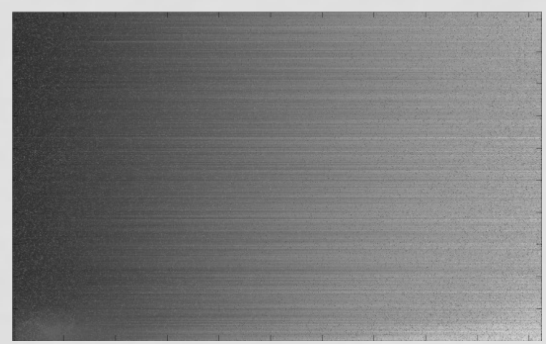
- **N** DC images corrected from offsets
- DC estimation with 1 second integration time **per pixel**
- For each image pixel, resolution of the system of N equations with 2 unknowns :

$$y = DC(1) * EXPOSURE + RN$$

- DC(1) : mean DC with 1s integration time
- RN : reading noise image
- y : pixel response

- This method may be used since october 2011beacause we have now several DC images of different integration times
- We do not need to suppose a linear behavior for the CCD reading noise

CO à 1s



Bruit de lecture (rampe)

THE CCD DARK CURRENT IMAGE FOR IMAGE CALIBRATION

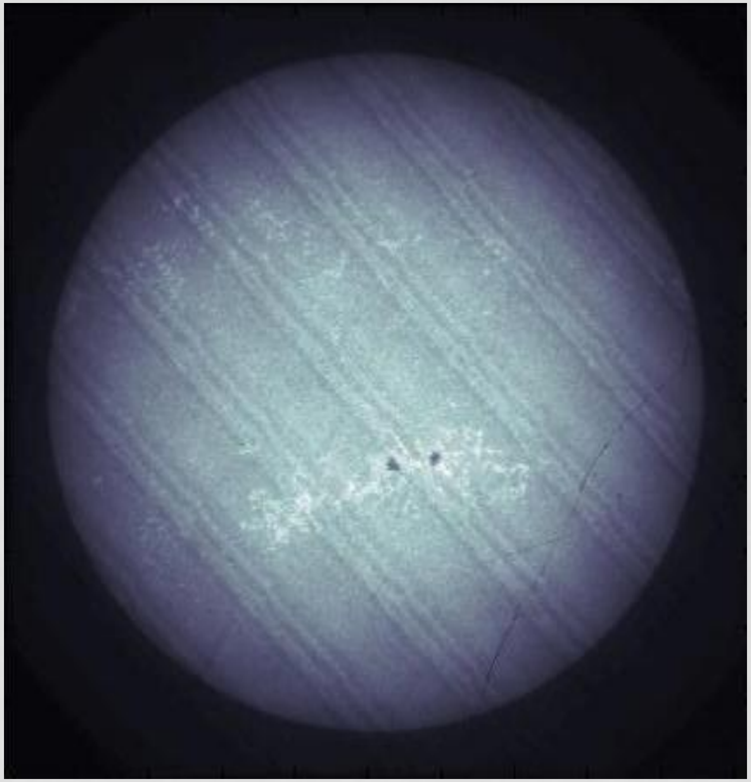
$$CO = (RNoise) + EXPOSURE * CO(1s)$$

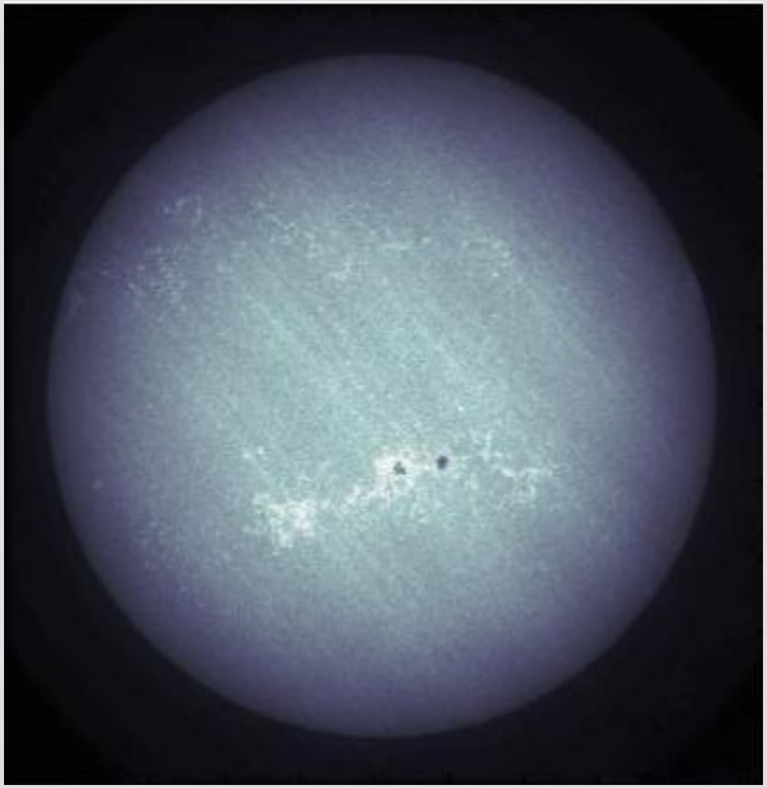
The Dark Current image is built by multiplying the mean dark current of 1 second integration time with the image exposure and adding after the reading noise image.

Image offsets to remove are in the header images

VI - L1 PRODUCT EXAMPLES

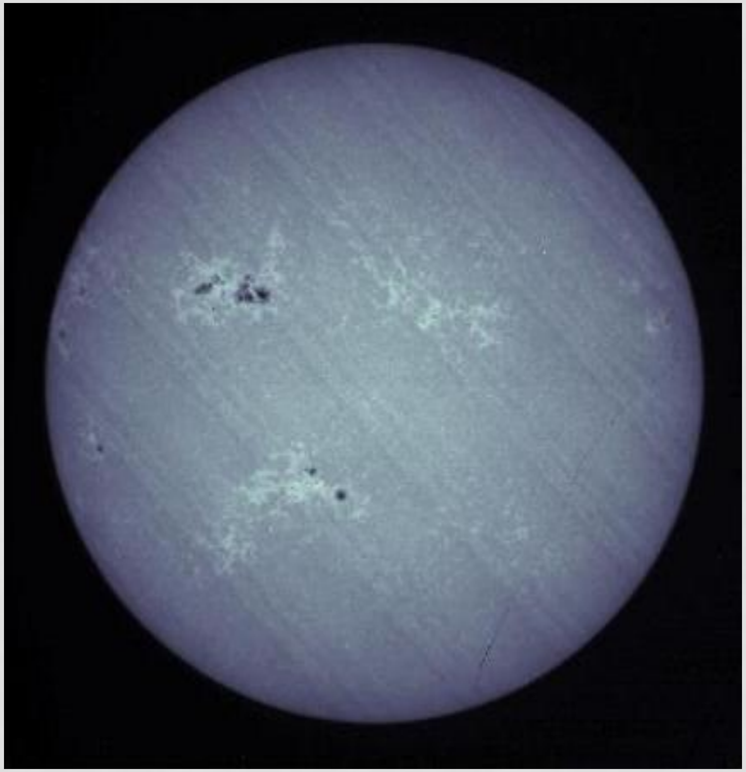
Examples of L0 and L1 images (1/5)

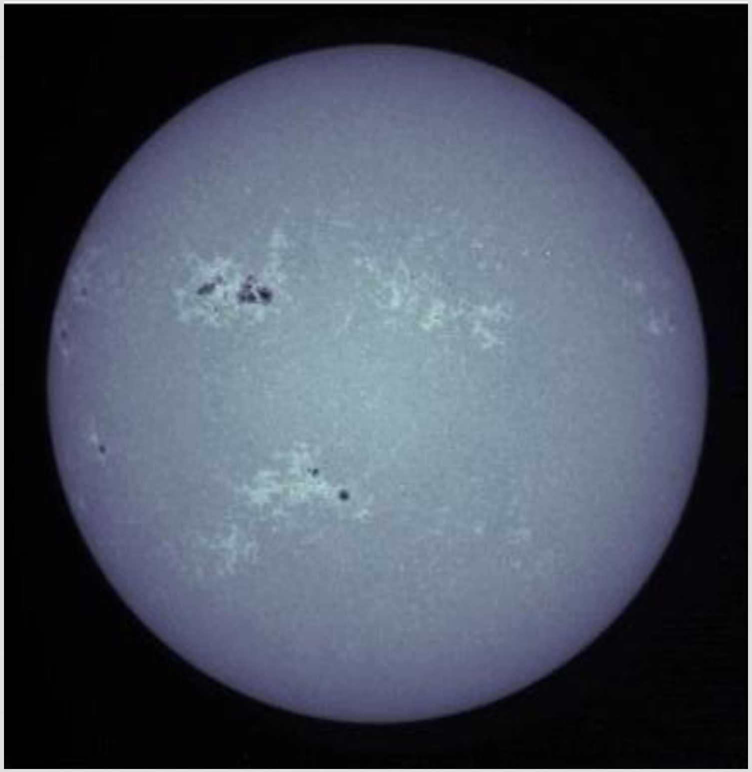




Images @ 215 nm recorded 25 04 2011 before and after correction

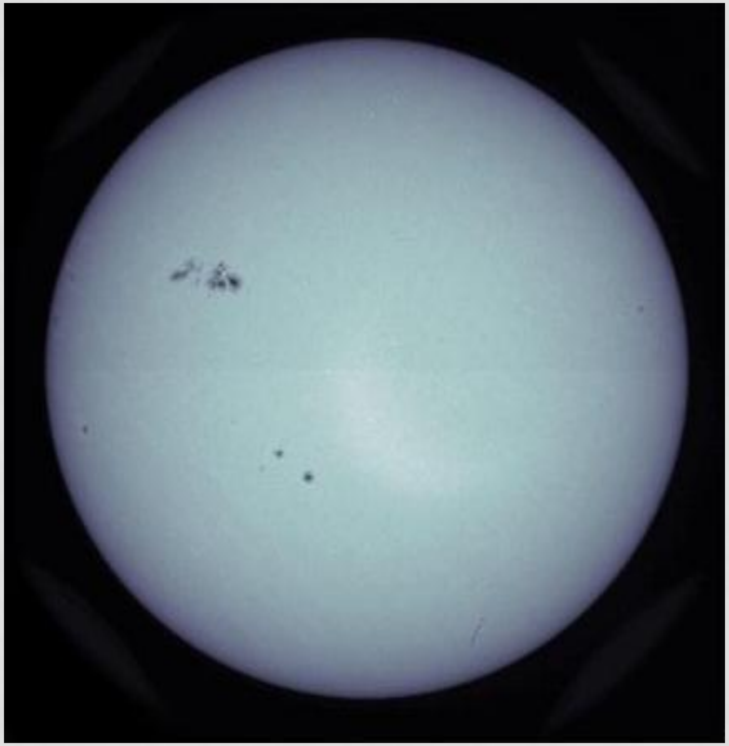
Examples of L0 and L1 images (2/5)





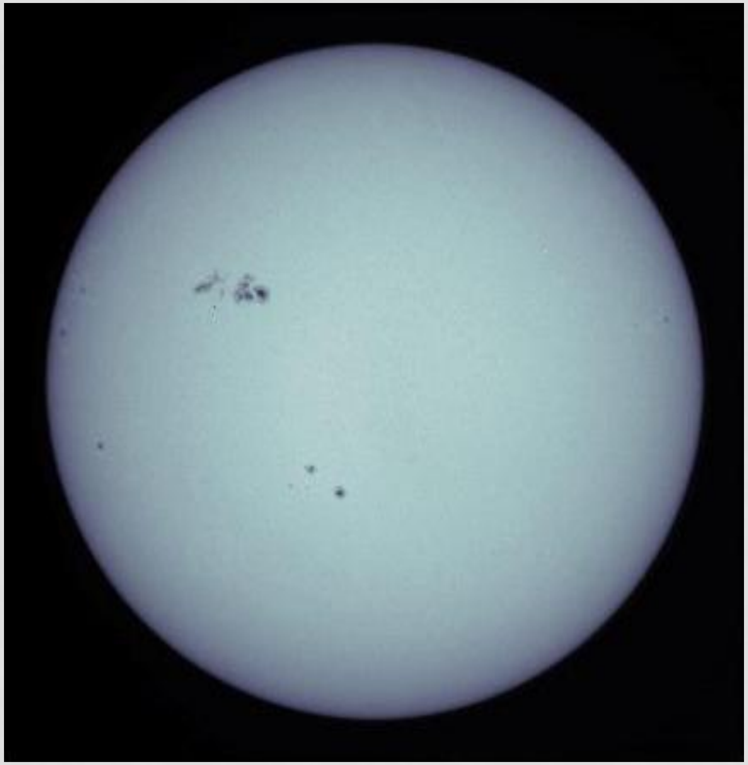
Images @ 393 nm recorded 6 11 2011 before and after correction

Examples of L0 and L1 images (3/5)



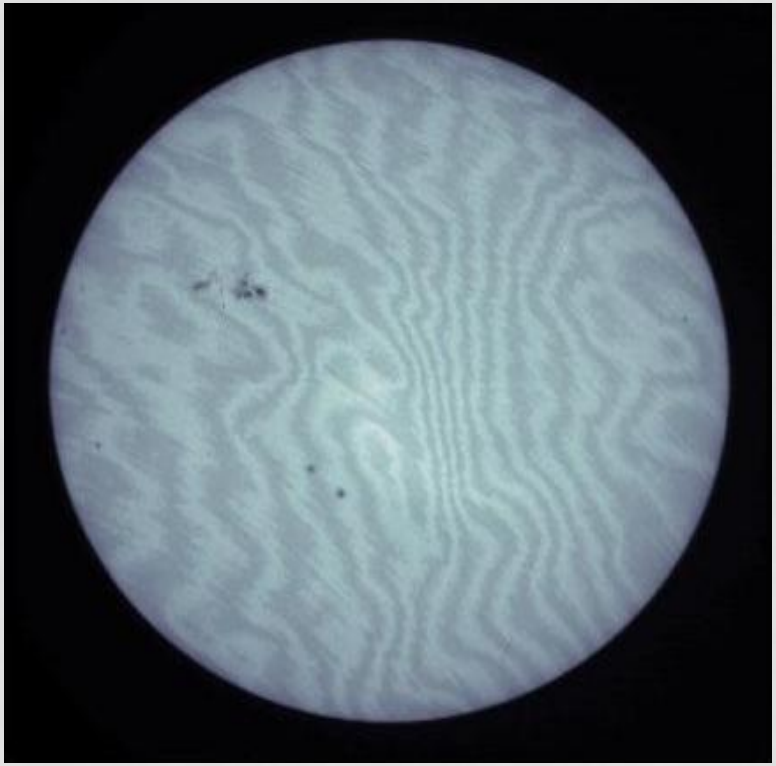
Images @ 535 nm recorded 6 11 2011 before and after correction

Examples of L0 and L1 images (4/5)



Images @ 607 nm recorded 6 11 2011 before and after correction

Examples of L0 and L1 images (5/5)



Images @ 782 nm recorded 6 11 2011 before and after correction

SODISM DATA FORMAT

File format : **FITS** (Flexible Image Transport System)

A FITS file is composed by 1 or several HDU (Header + Data) units.

Kind of Data :

- Simple images (**Header** + **data image**)
  - Full CCD images ⇨ 2048x2048 pixels (or 2060x2053 with overscans)
  - Solar limbs ⇨ 2048x2048 pixels
  - Dark signal windows ⇨ 256x256 pixels
  - Images of Macropixels ⇨ 256x256 pixels
- Multi-FITS images
  - Each HDU is extracted from a limb
- Data tables
  - Follow-up of some values during the mission

FITS HEADER

- Static SODISM header
  - General information on the mission like :
    - Instrument = PICARD
    - Telescope = SODISM
    - Origin = CMS-P
- The File description
  - Few information on the file not the data
    - Filename
    - Date of creation of the file
    - Last release of the file
- Observation Date
  - Date of the image acquisition
- Several keywords
  - Keywords linked to the acquisition image
    (housekeepings, satellite position ...)

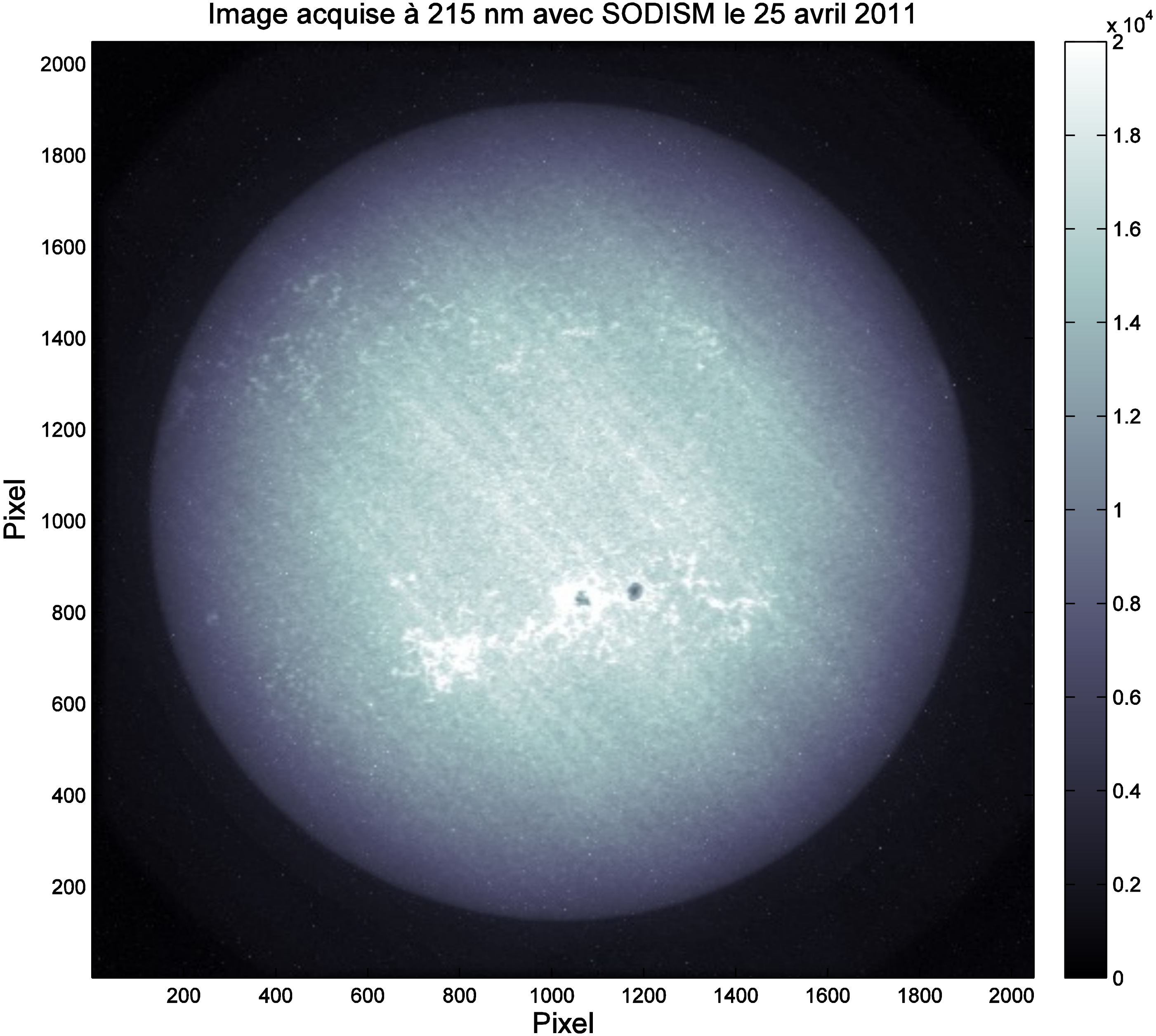
FITS FILE NAMES

File : **PIC_SOD_N0_MTE_RS_WL535_20071121_1400_v01.fits**

Kind of data : Simple image (Header + Image DATA)

Mission : **PIC**ARD
Instrument : **SOD**ISM
Level processing : **N0**
Observation mode : MNM, DCO, MAB, MNT, MDO, MES, **MTE**
Data type : **RS** (Full image)
Image identifier : **WL535** (535nm wavelength)
Date of acquisition (YYYYMMDD_HHMM) : **20071121_1400**
File release : **v01**
Extension : **.fits** (or fits.gz)

Image acquise à 215 nm avec SODISM le 25 avril 2011



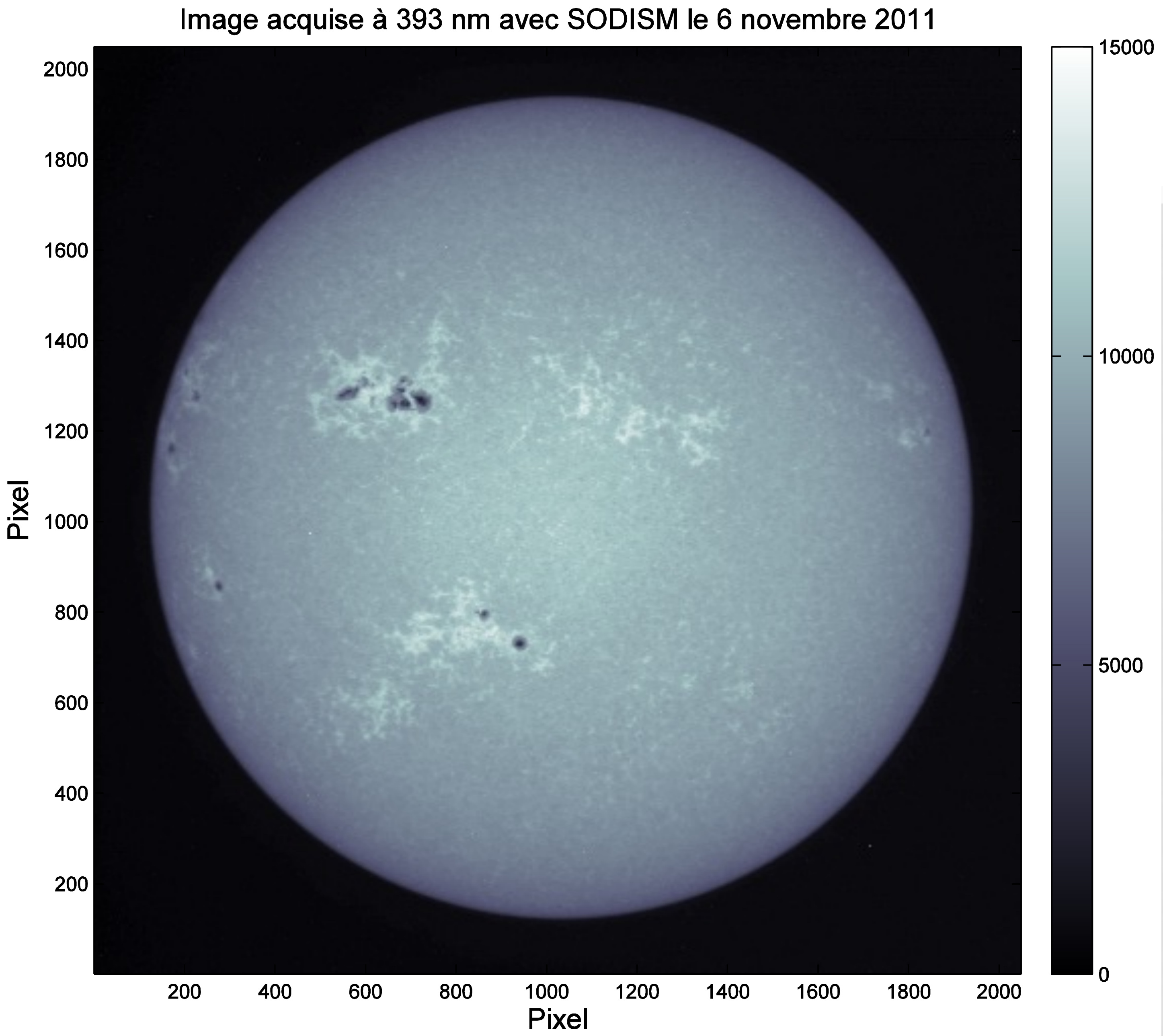


Image acquise à 393 nm avec SODISM le 6 novembre 2011
Pixel
2000
1800
1600
1400
1200
1000
800
600
400
200
200
400
600
800
1000
1200
1400
1600
1800
2000
Pixel
15000
10000
5000
0

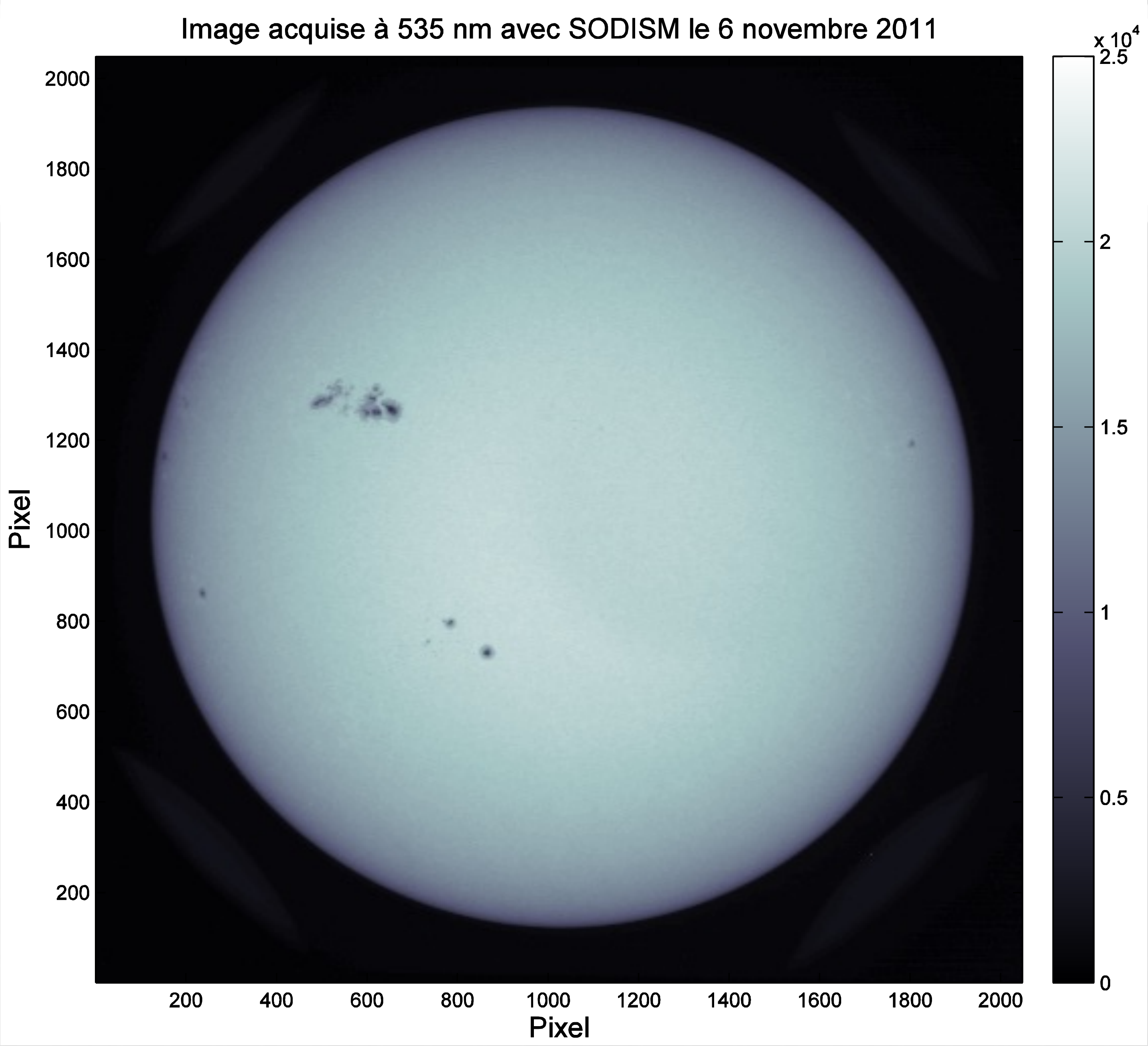


Image acquise à 535 nm avec SODISM le 6 novembre 2011
Pixel
Pixel
2000
1800
1600
1400
1200
1000
800
600
400
200
200
400
600
800
1000
1200
1400
1600
1800
2000
x 10^4
2.5
2
1.5
1
0.5
0

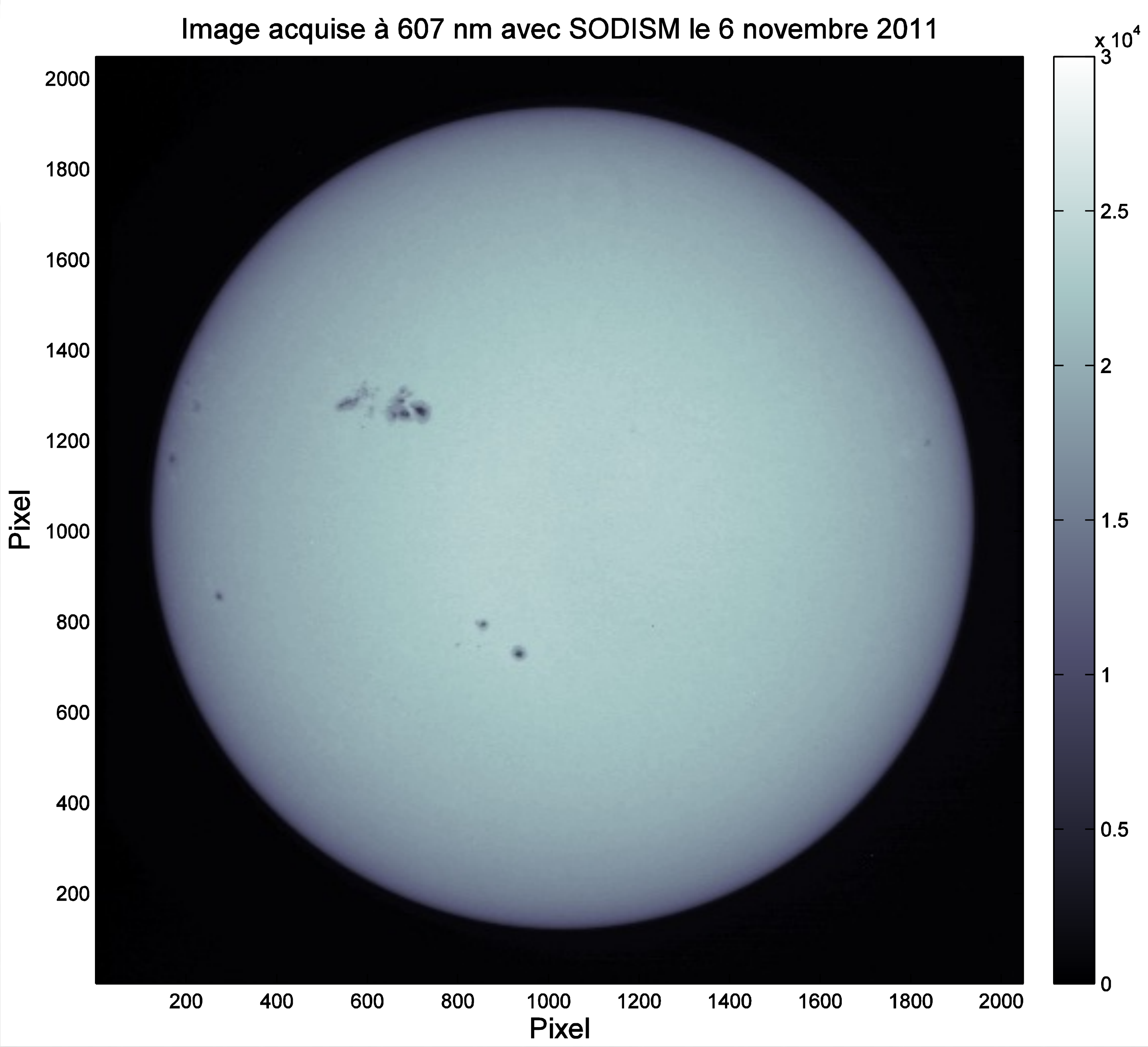


Image acquise à 607 nm avec SODISM le 6 novembre 2011
Pixel
Pixel
200
400
600
800
1000
1200
1400
1600
1800
2000
x 10^4
3
2.5
2
1.5
1
0.5
0

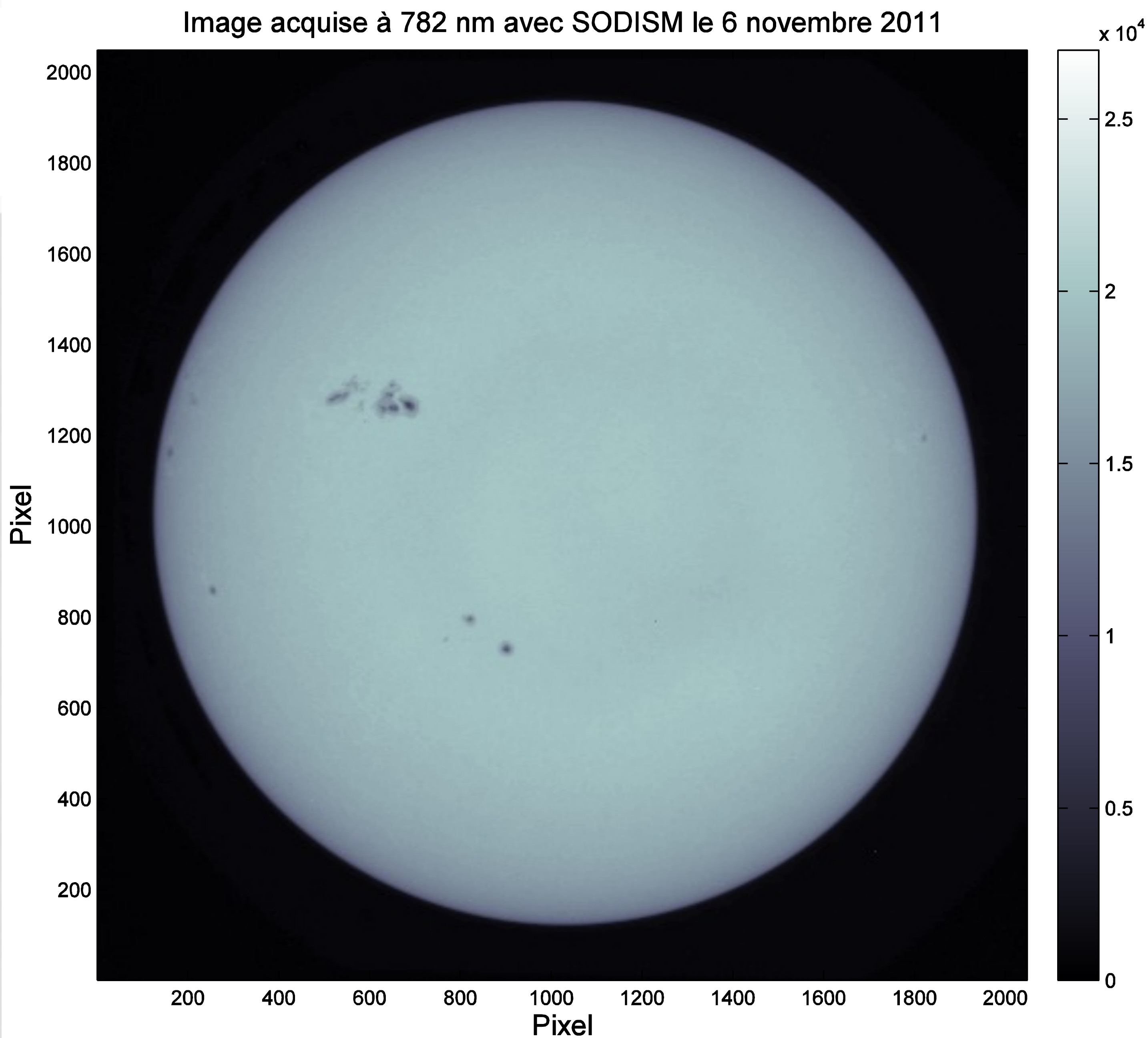


Image acquise à 782 nm avec SODISM le 6 novembre 2011
Pixel
2000
1800
1600
1400
1200
1000
800
600
400
200
200
400
600
800
1000
1200
1400
1600
1800
2000
Pixel
x 10^4
2.5
2
1.5
1
0.5
0