LUFTBLICK
EARTH OBSERVATION TECHNOLOGIES

esa

2015-12-8, PMOD-WRC

IDEAS+ WP TD3370 Status
Pandonia updates
Some EPIC info

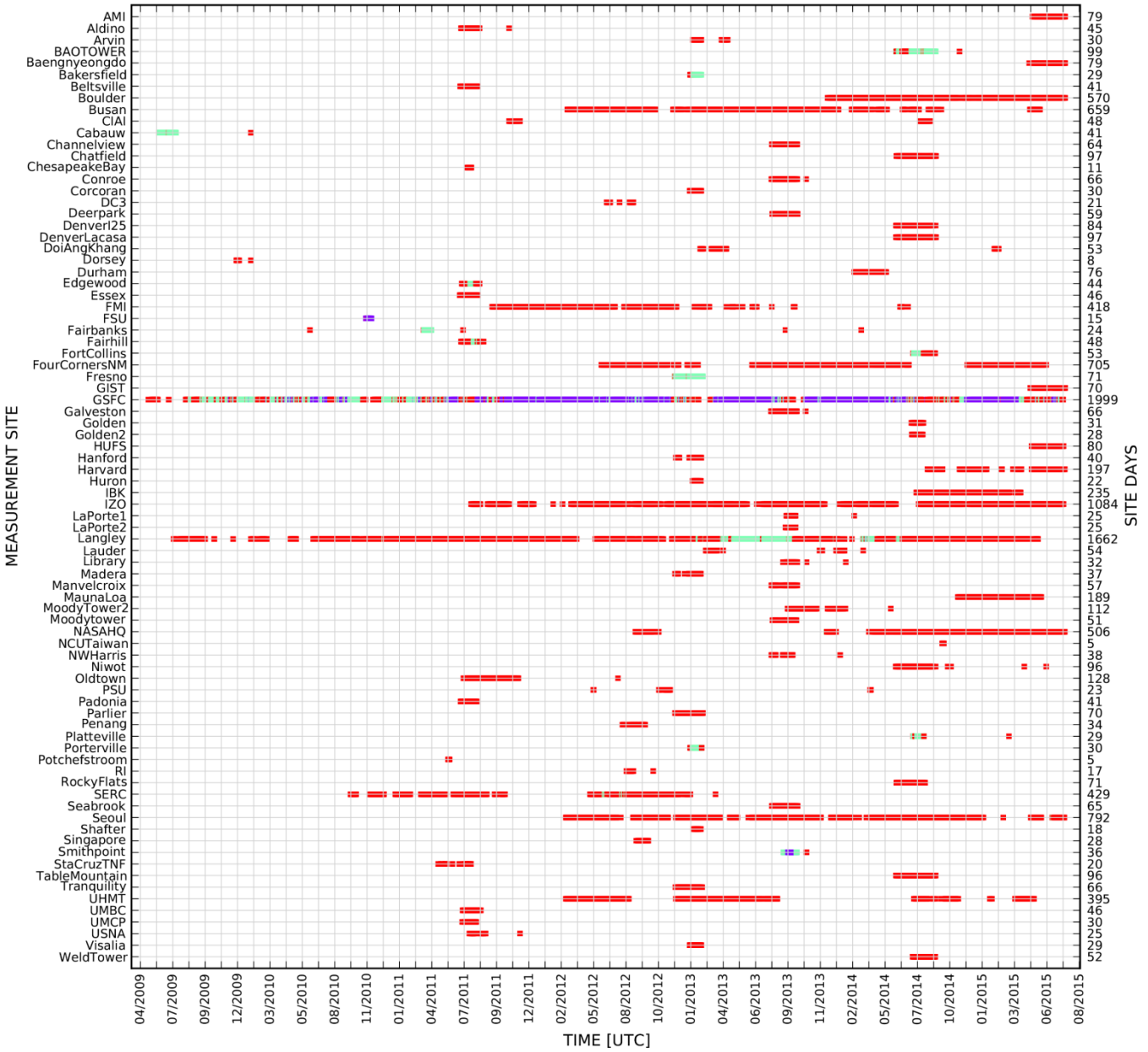
Alexander Cede

IDEAS+ WP TD3370 Status

TD3370.1

Pandora versus OMI

- All available Pandora data have been collected (see figure)
- The historic calibration data for all Pandoras have been re-evaluated
- The data have been re-processed and report TD3370-1.2 is being written.



TD3370.2 Brewer versus OMI

See presentation Alberto Redondas

TD3370.4 Pandora-2S units (2+1)

Status: The are expect to arrive at Innsbruck on 16 Dec 2015. We expect the calibration to be done before the end of the year.

TD3370.3 Pandonia webpage developments

http://www.pandonia.net/

Adapted to match format of SPPA Projects (template 2015-9-15)

pandonia.net

Home | About | Data Ressources | Project Documents | Meetings and Workshops | Login

Background

Welcome to the web-portal of the Pandonia project, powered by LuftBlick and funded by the European Space Agency (ESA).

Pandonia is a ground-based remote sensing network. The main instrument of Pandonia will be Pandora-2S, which is currently being developed under this project as an evolution of the existing Pandora spectrometer system.

Pandora-2S at Innsbruck and Pandora at Tenerife

The Pandonia network emphasizes:

- Homogeneous calibration of instrumentation
- Low instrument manufacturing and operation costs
- Central data processing and formatting
- Quick delivery of final dataproducts

The planned data products of Pandonia are:

- Total and tropospheric ozone (O_3) column
- Total and tropospheric nitrogen dioxide (NO_2) column
- Spectral aerosol optical depth (AOD) in the ultraviolet (>300nm) and visible range
- The possibility of adding other data products such as sulfur dioxide (SO_2), formaldehyde (CH_2O), and water vapor (H_2O) columns is also explored

The reference instruments of Pandonia will be at the Izaña Atmospheric Observatory, Tenerife, Spain, which will also be an instrument test site together with the observation platform of the Biomedical Physics, Medical University Innsbruck, Innsbruck, Austria. All network instruments will be traceable to reference instruments, through intercomparison with a mobile reference unit visiting network locations.

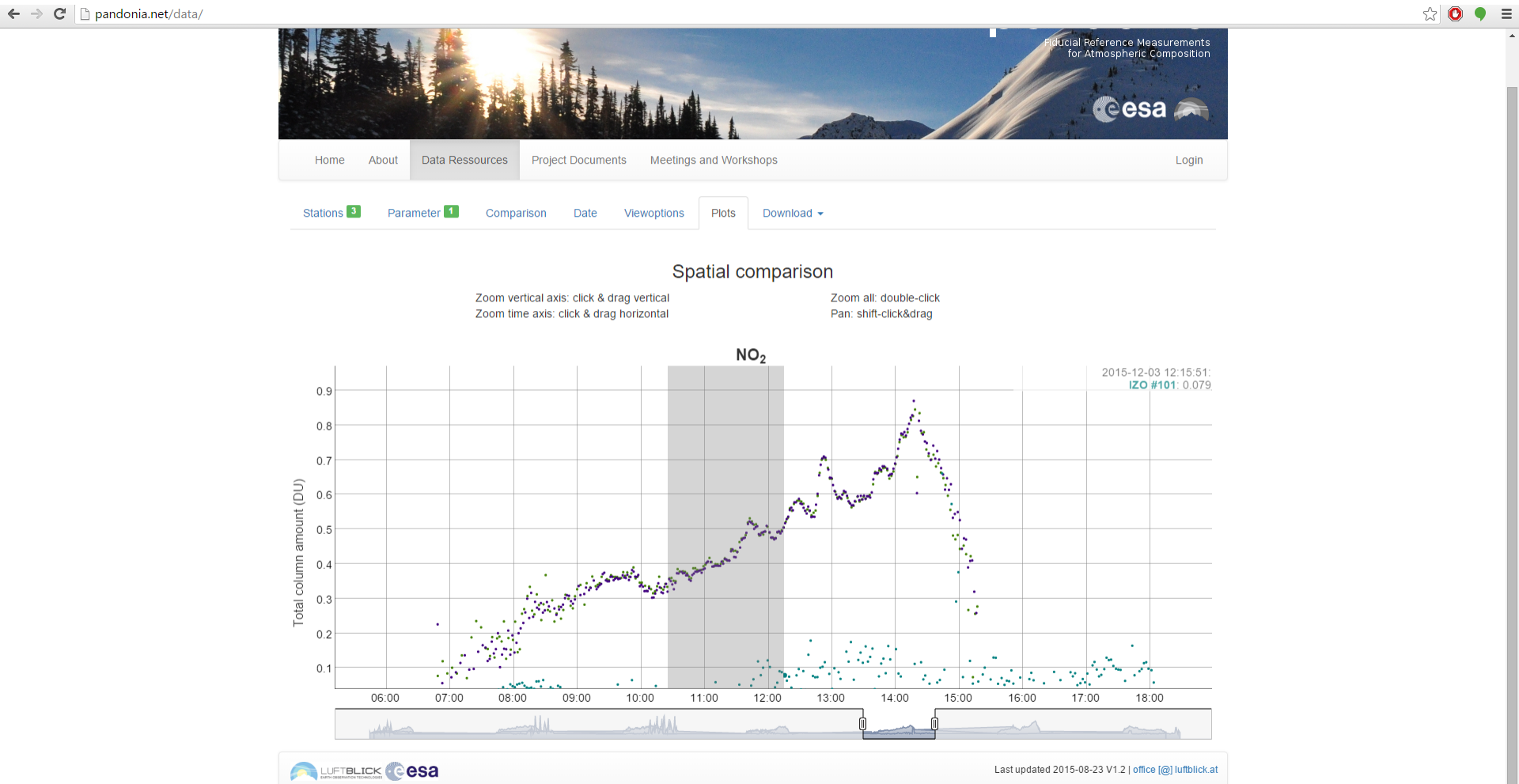
A limited number of instruments will be financed directly by the project. Institutions owning a Pandora or Pandora-2S will have the possibility to join Pandonia, if they agree to provide local support and submit/share their data. As part of Pandonia they will receive:

- Operation and maintenance support by the project
- Central data processing
- Calibration support by the project through regular visits by a mobile reference instrument

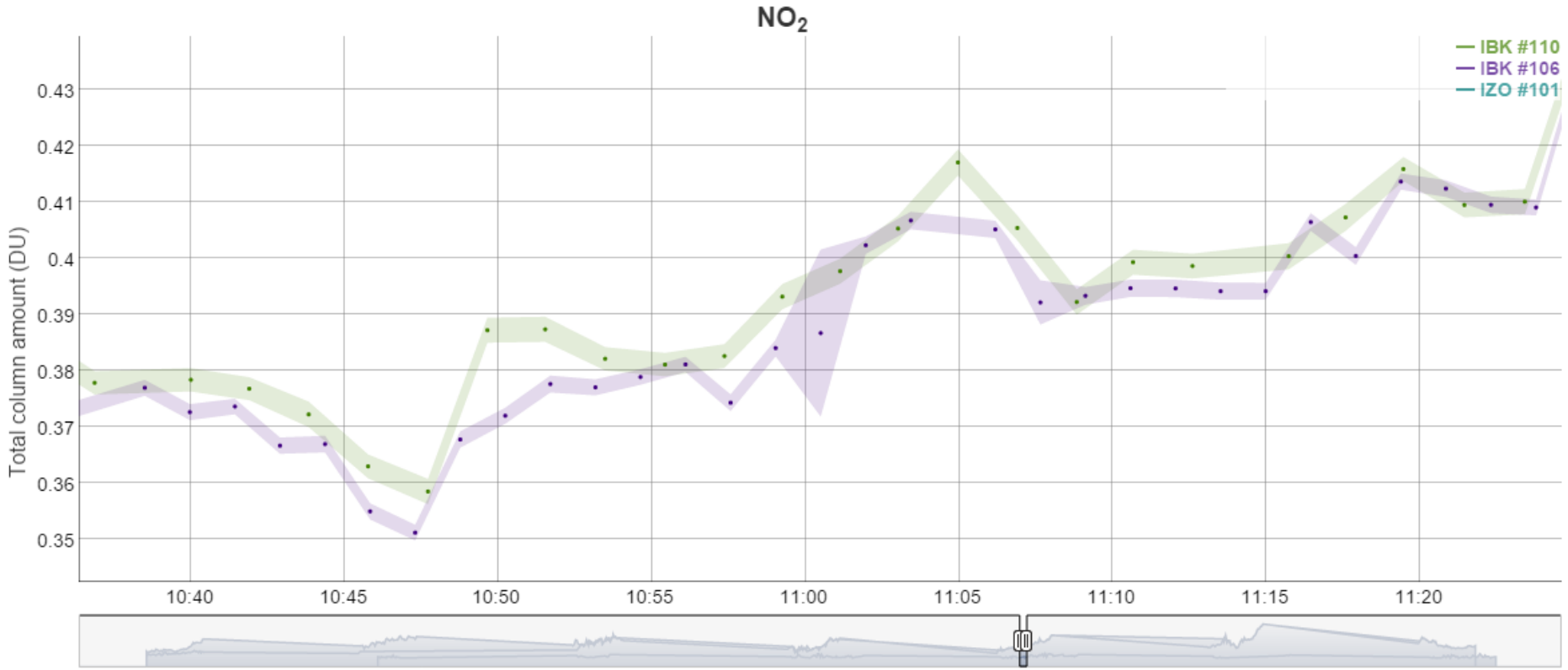
Web service architecture

- Ubuntu 14.04 based operational and development platform
- Webserver: nginx 1.9.x (operational), apache 2.4.x (development)
- Web-framework: django (based on python); some PHP scripts
- Database server: PostgreSQL 9.4
- Fully automated data delivery, processing, registration, QA, validation, ... (python, bash scripts)
- Primary server online since Jan 2013; no outages
- Data display and download tool functional with advanced features (e.g. zoom), but not intuitive to use yet
- Data volume ~4 TB (includes all L1 - L3b and all NASA data)
- Daily average data volume per station/instrument/spectrometer: 100 MB
- Data processing time including QA: 1 h
- Daily backlog processing check (for late delivery data): 5 days
- Daily match with overpass data (sync from AVDC)
- Generation/delivery/analysis of monitoring data every 3 min.
- Thread safe parallel processing sessions

- NO2 data from the 2 Innsbruck Pandoras, 3 Dec 2015 (clear sky)
- “Flat plane” sunrise and sunset at 6:50 and 15:20 UT respectively
- Real sunrise and sunset at 9:20 and 14:20 UT respectively (mountains)
- Extremely good overlap of the two instruments

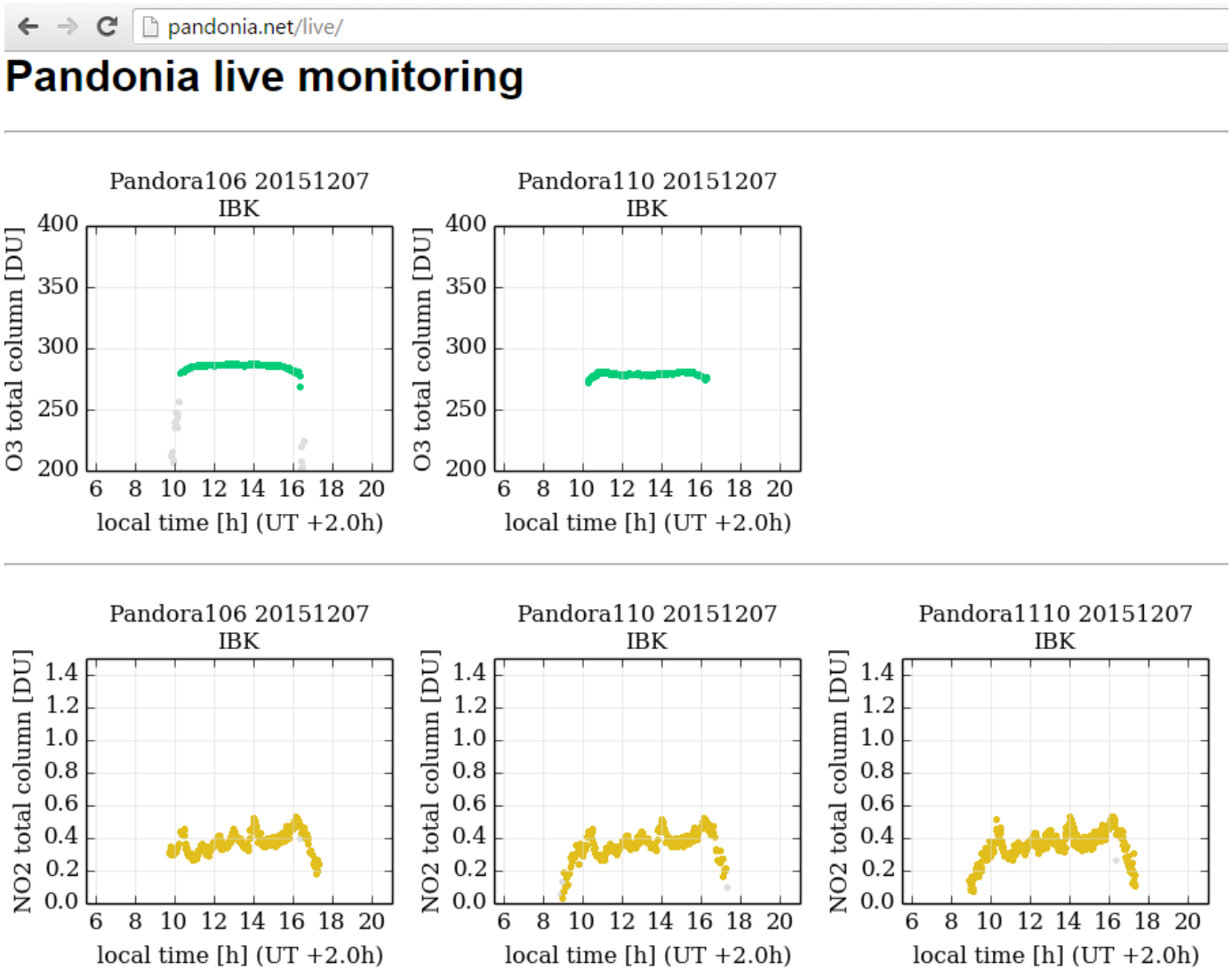


- Shaded areas are the noise in the data
- “Homogeneity” for NO2 about 0.01DU (excellent!)



http://live.pandonia.net/

- 2min data upload tested using Innsbruck units
- This still has to be optimized to handle more instruments (currently we do "too much processing")



http://live.pandonia.net/?avg=1

Near real time data averaging and comparison with OMI

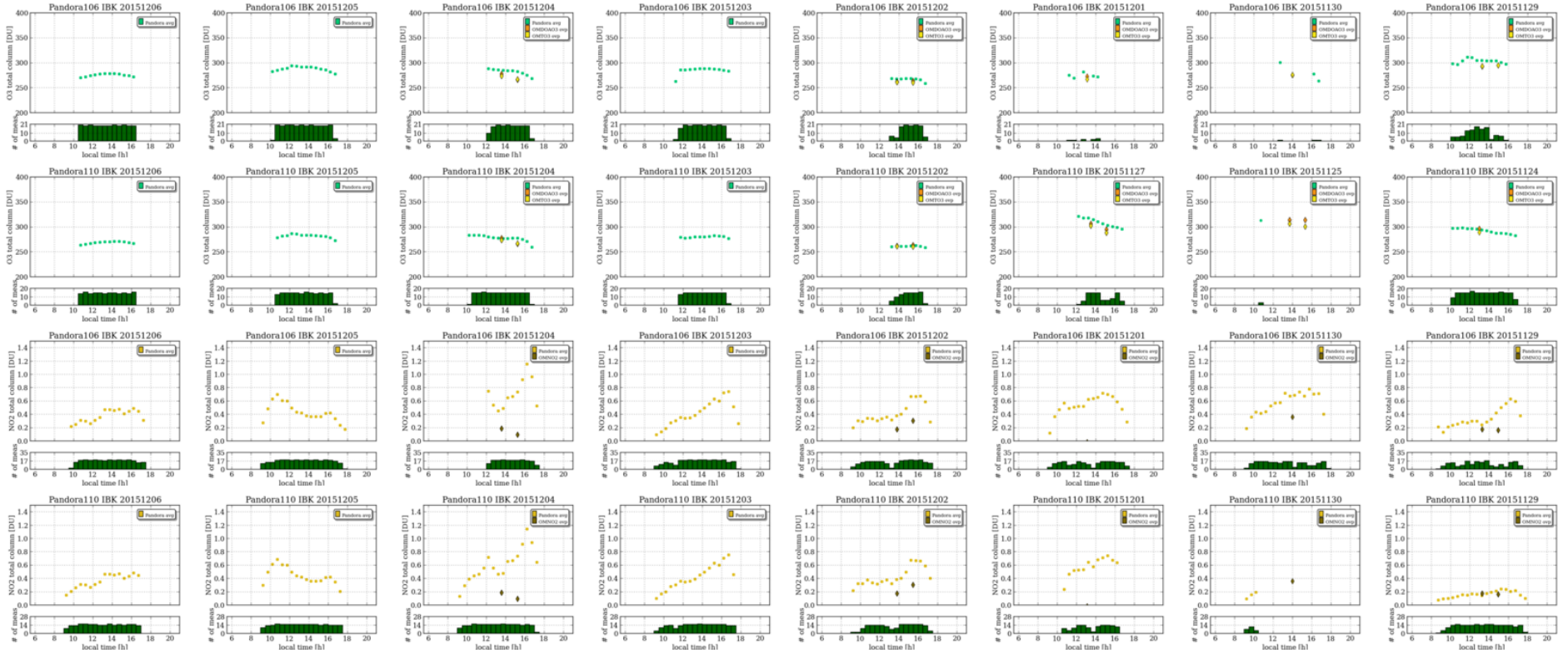
pandonia.net/live/?avg=1

Pandonia live monitoring

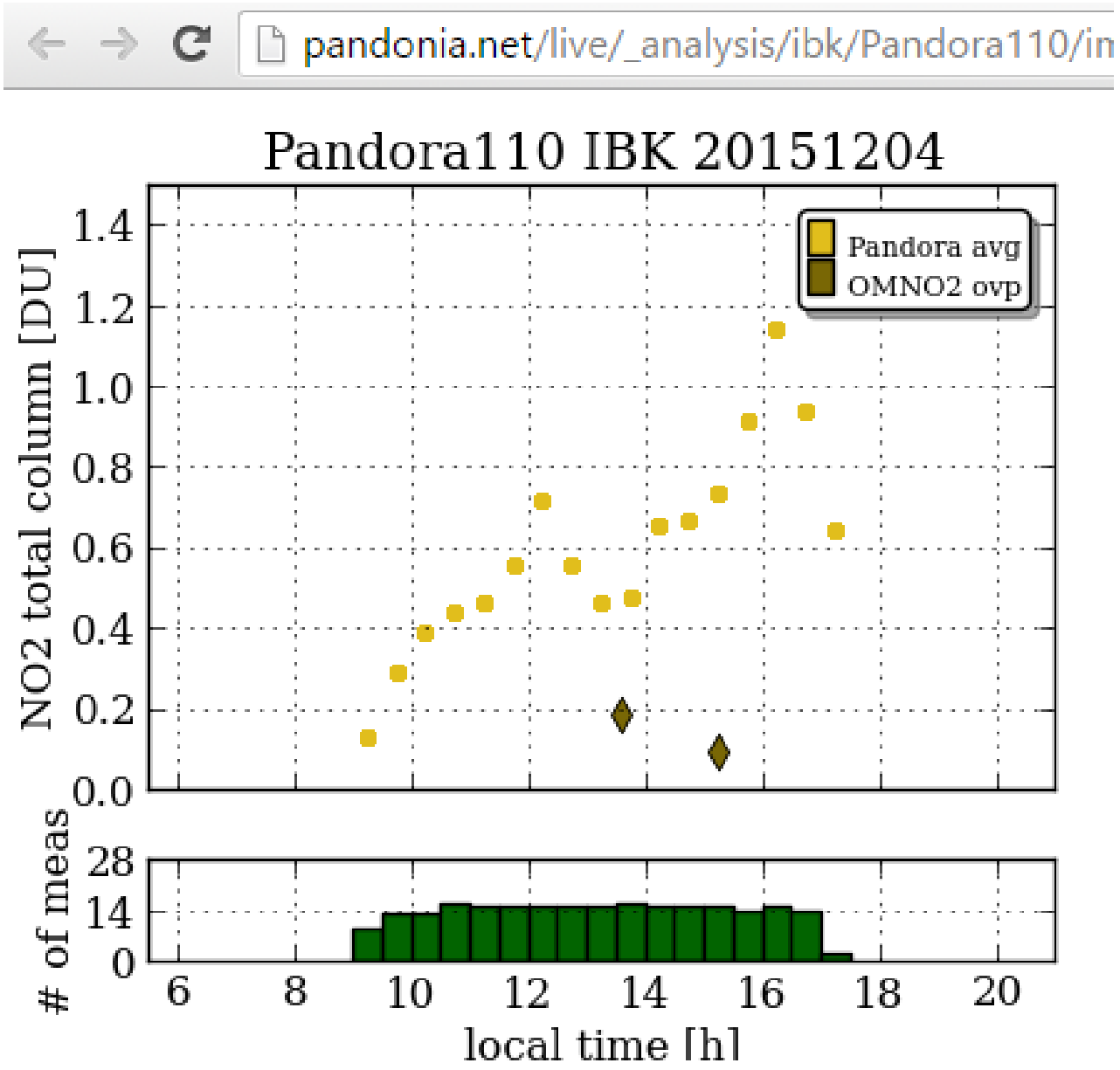
Status

- INFO: Last page update: 2015-12-07 13:53:51 UTC, Next page update: 2015-12-07 19:53:51 UTC

Average data including overpass



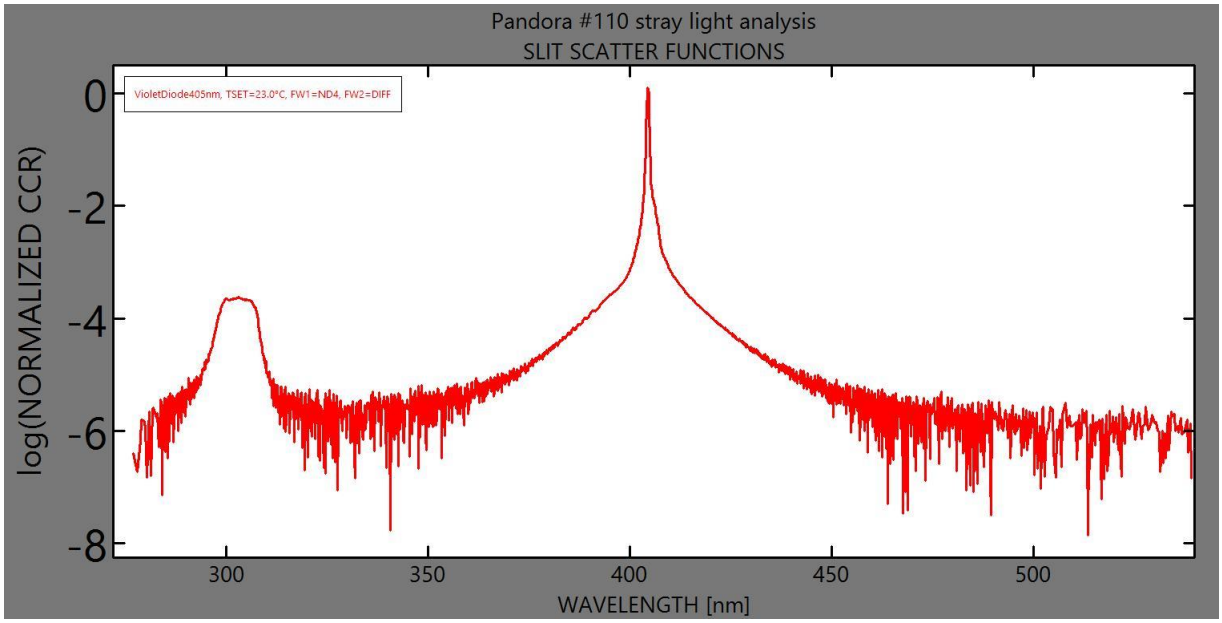
- Figures can be picked out of the overview panel
- Currently cloud filter “too simple”; e.g does not recognize the data before sunrise or after sunset as being bad

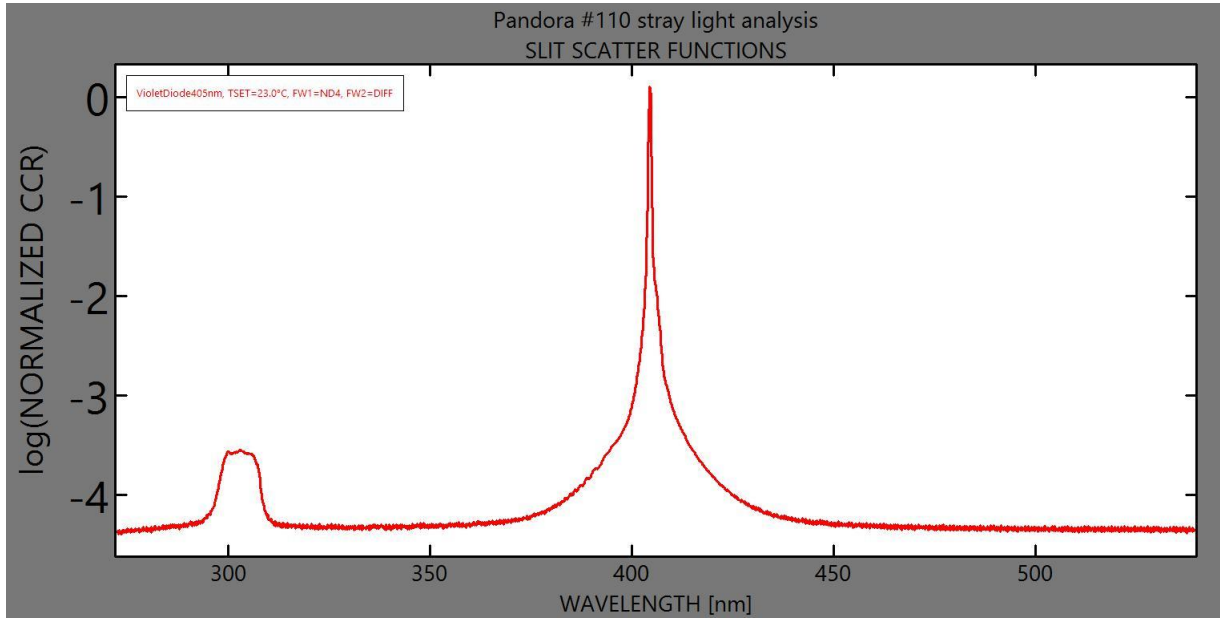


Pandonia updates

Stray light – blind pixels

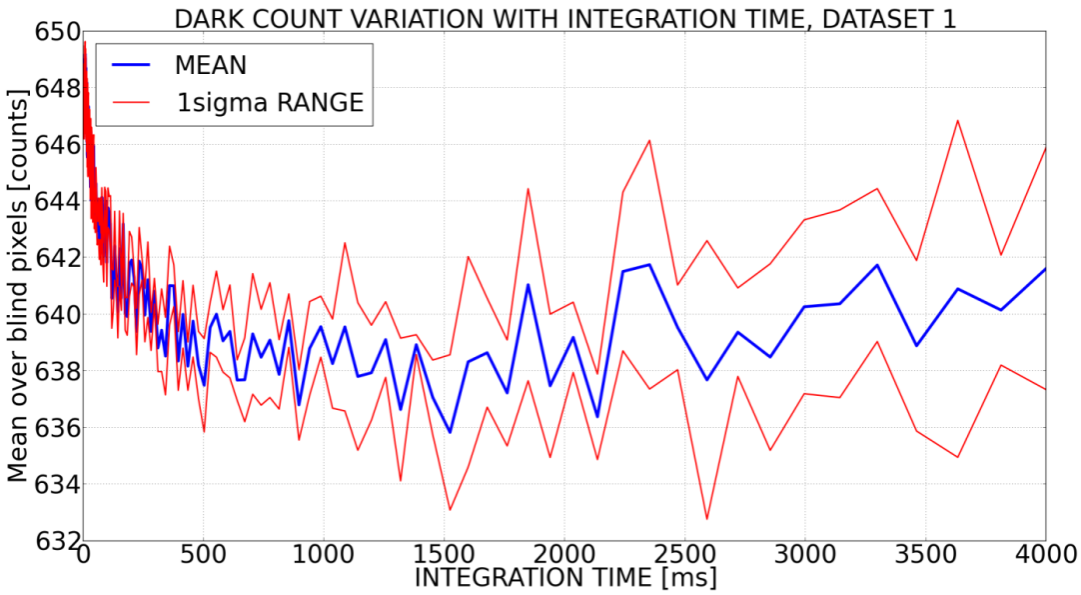
Pandora has a significant dark offset bias from measurement to measurement (mentioned in previous reports). Therefore the stray light characterization had significant problems to determine the stray light level. By using the blind pixels plus merging unsaturated and saturated data we now get excellent line spread functions.

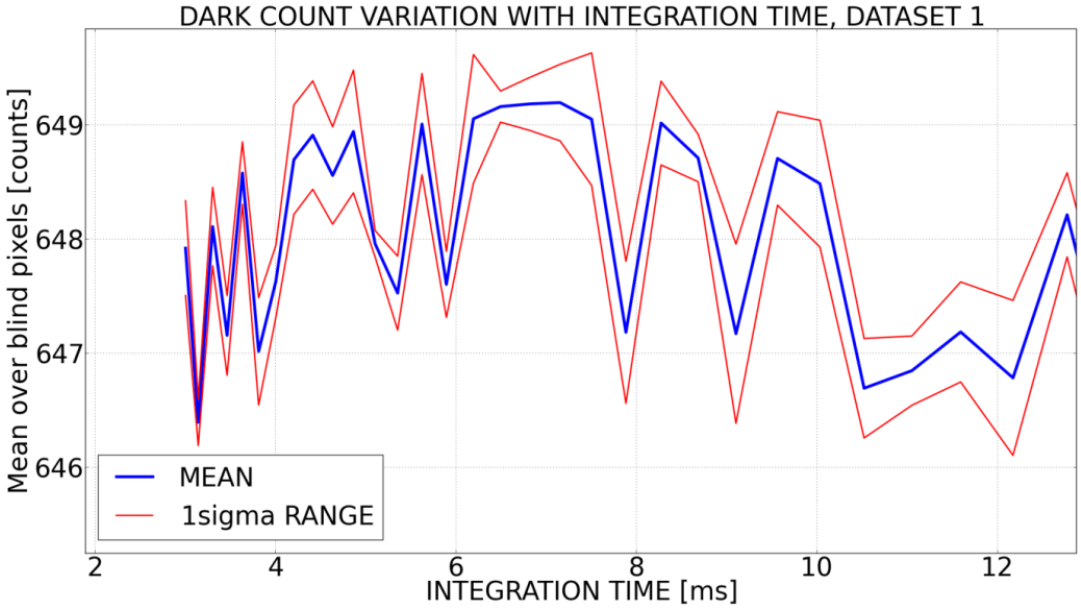




Dark map

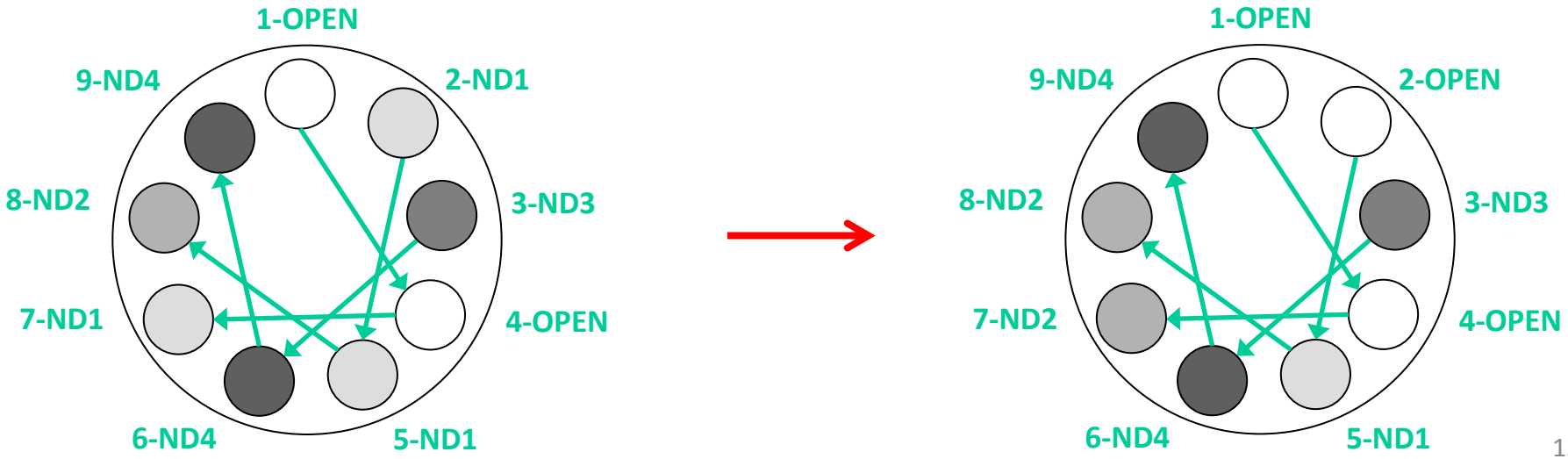
- We try to create a dark map for each Pandora in order to reduce the time Pandora is “wasting” on dark measurements.
- This has shown to be much more difficult than expected. So far we were no able to explain the Pandora dark current as a function of temperature and integration time in a mathematical way.
- At this point we do not know whether the use of a dark map will be successful for Pandora.
- As an example the average over the blind pixels is shown as a function of integration time for constant temperature.





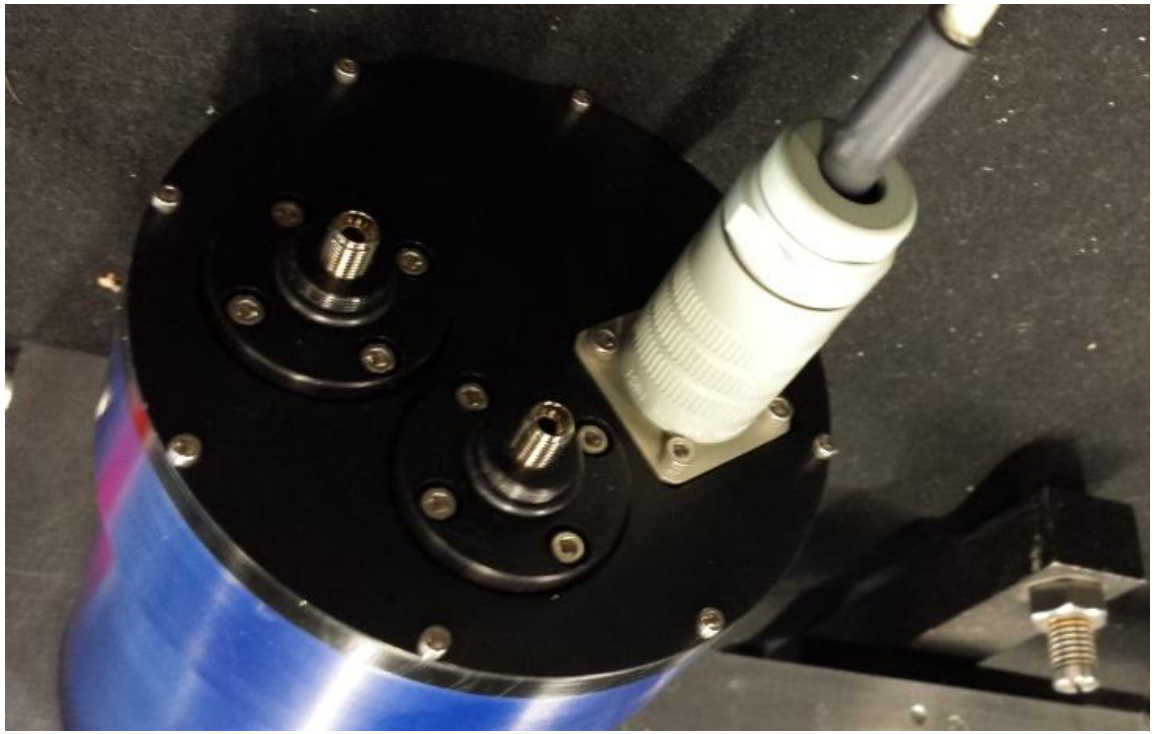
Filterwheel 1 configuration

- We noticed that a OPEN-ND2 combination is more important than a ND1-ND1 combination.
- We changed this in Pandora 110 and for all future ones.
- Pandora 111 (Romania) still has the old combination. We will change this at the next opportunity.



Tracker development

The plan is to start the IDEAS+ CCN in January.
Status of the paperwork?

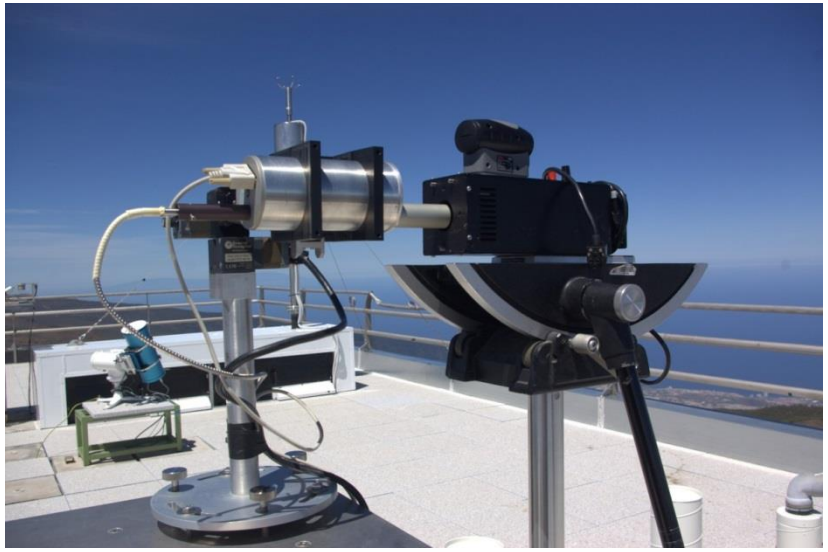


FCT (Field calibration tool)

2 developments:

System without fiber

- Tested at Izaña
- To be used at Izaña

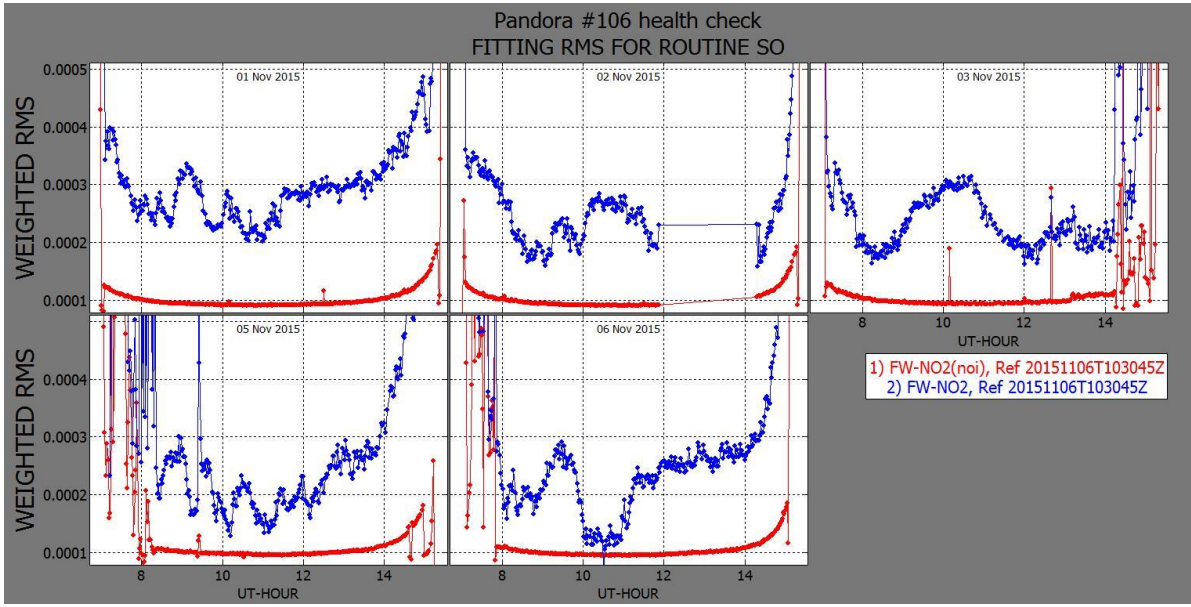


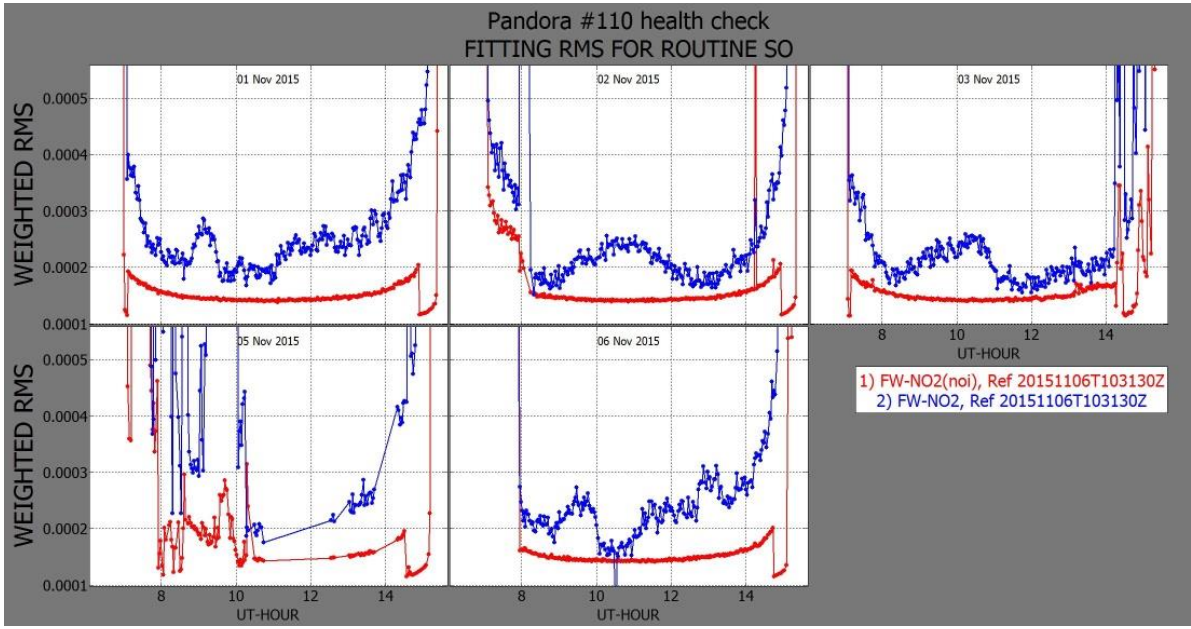
System with fiber

- Tested at Innsbruck
- To be used for mobile reference units

D14: Feasibility to retrieve other trace gases

- We were able to reduce the USS (Unwanted spectral signal) by a factor of 10 with the hardware changes.
- The rms of the residuals is now very small (a few times 1e-4).
- This reduces by about a factor of ten the “temporary systematic errors” (for O3 from 5DU to 0.5DU and for NO2 from 0.07DU to 0.01DU).
- Is this good enough for weaker trace gases, e.g. HCHO?

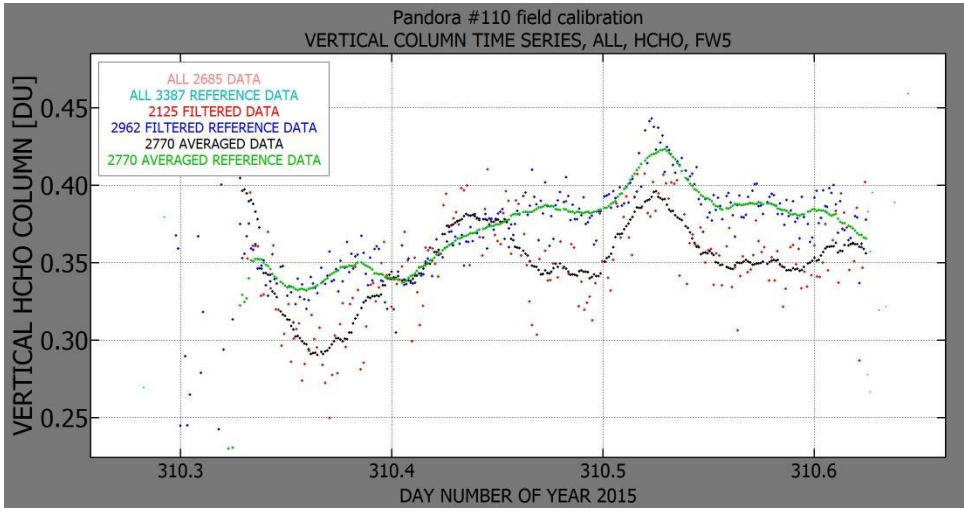


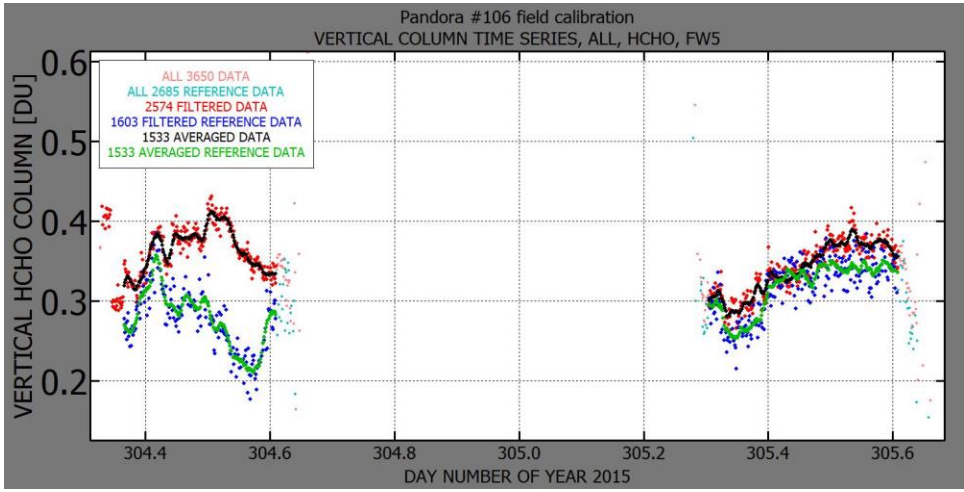


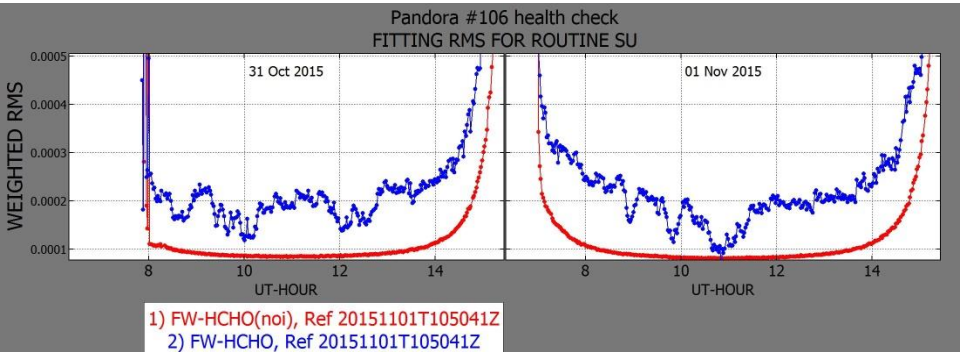
LUFTBLICK

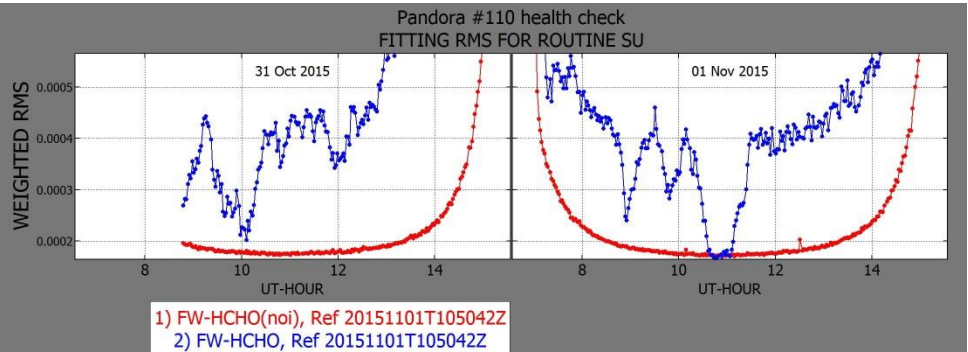
D14: Feasibility to retrieve other trace gases

- Goal: apply same algorithm on two collocated instruments and check “homogeneity”
- Example HCHO: despite very small residuals, the differences can still be rather large
- Unclear, whether this is the USS or another effect
- rms is similar for the two days 31 Oct and 1 Nov 2015, but data agree on one day and not the other

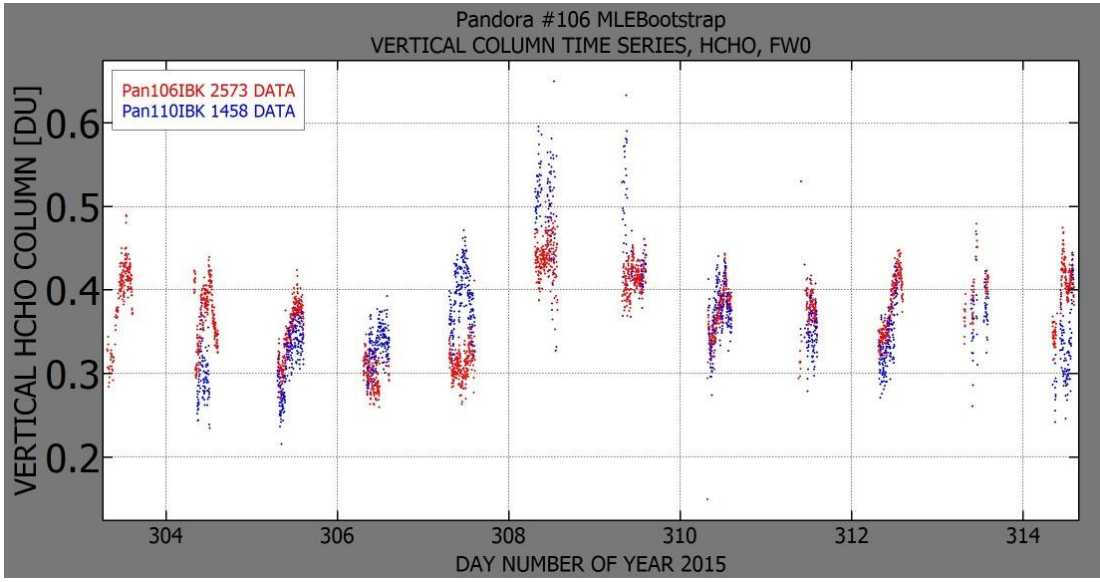


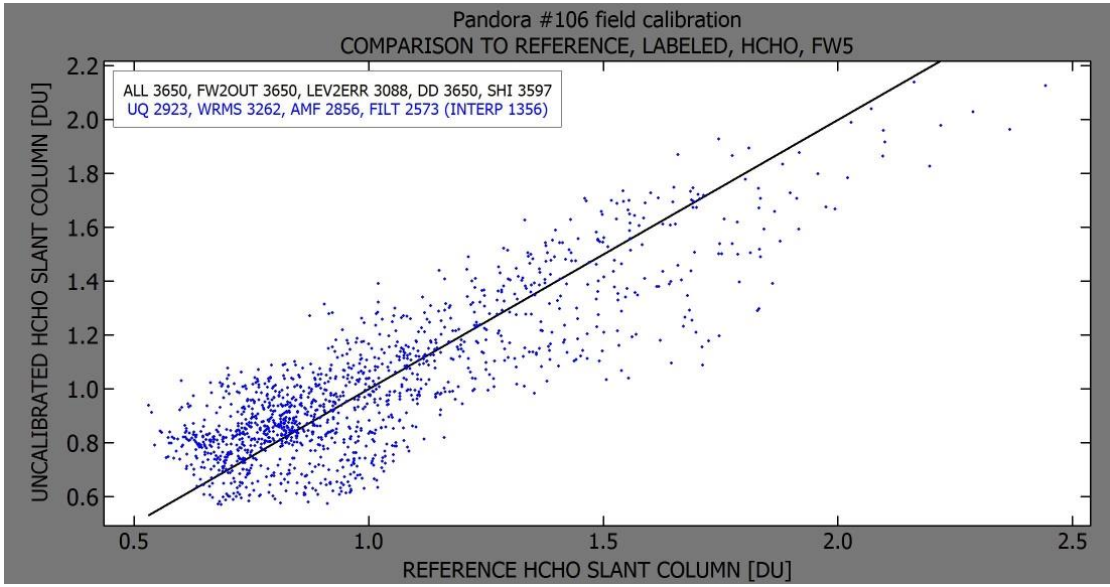






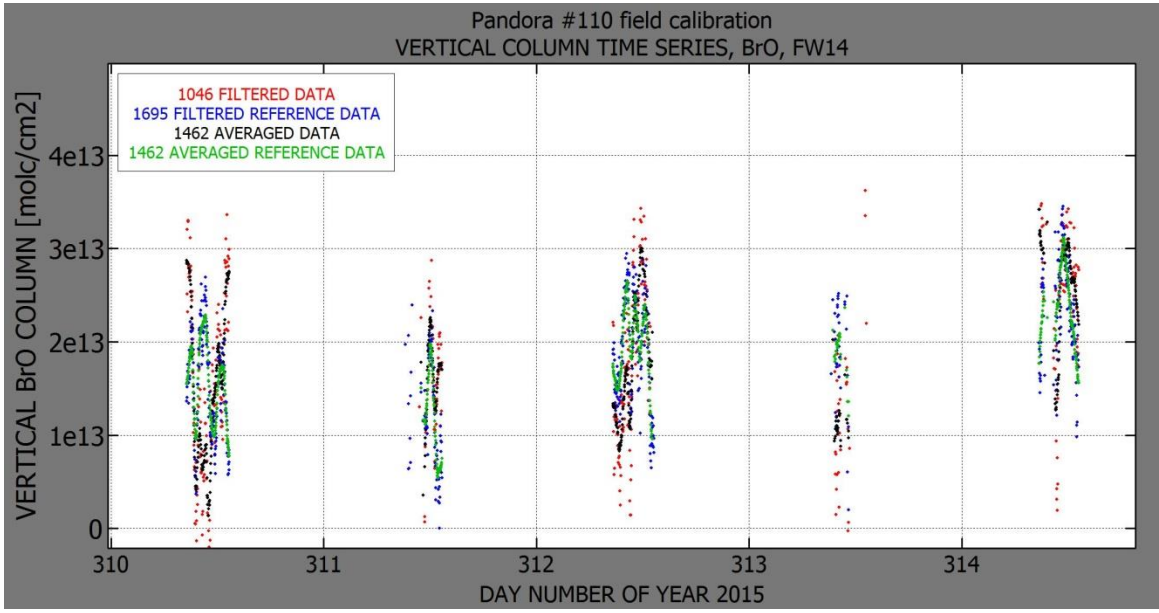
- We are definitely sensitive to HCHO, but there are error sources
- Noise ~0.02DU
- Temporary systematic errors: ~0.1DU (drives the total uncertainty)

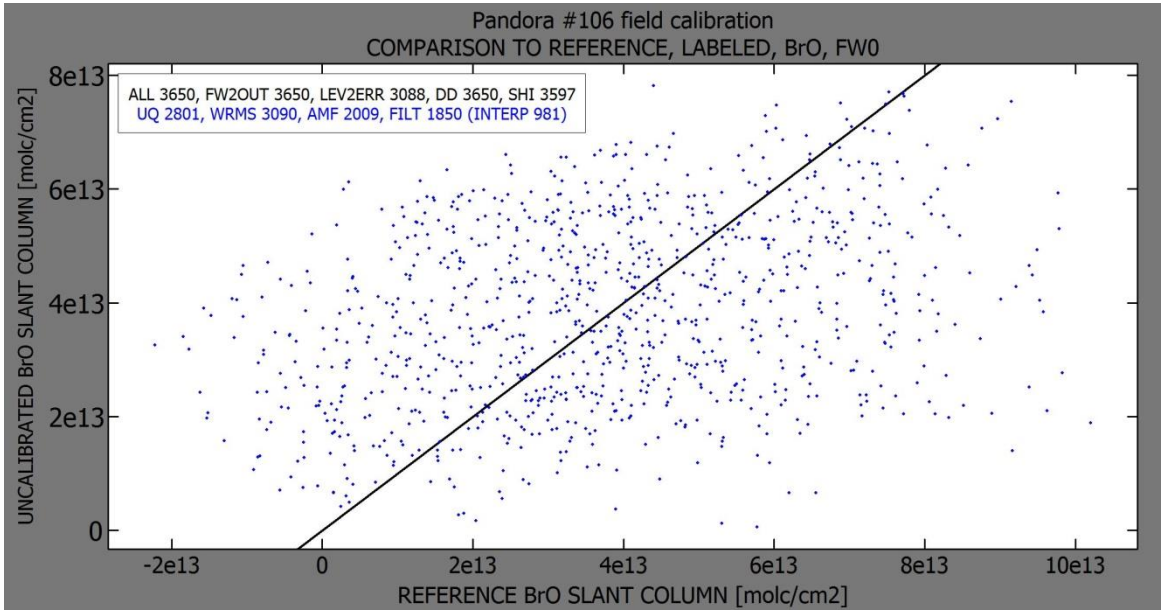




- BrO?

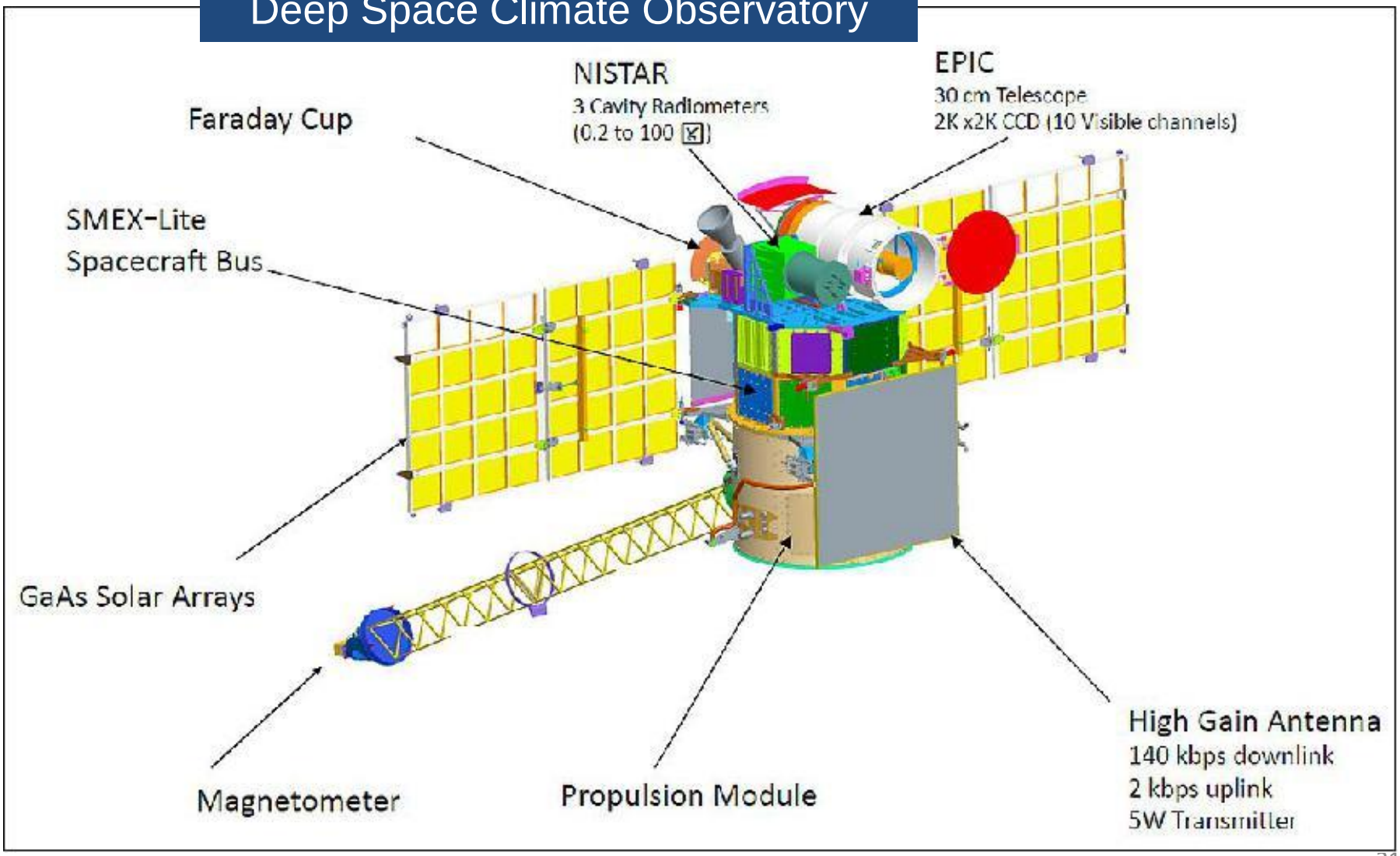
- Feasibility report will be submitted in January 2016.
- It will include homogeneity estimations for HCHO, SO2, O3 + O3-temperature, NO2 + NO2-temperature; possibly BrO



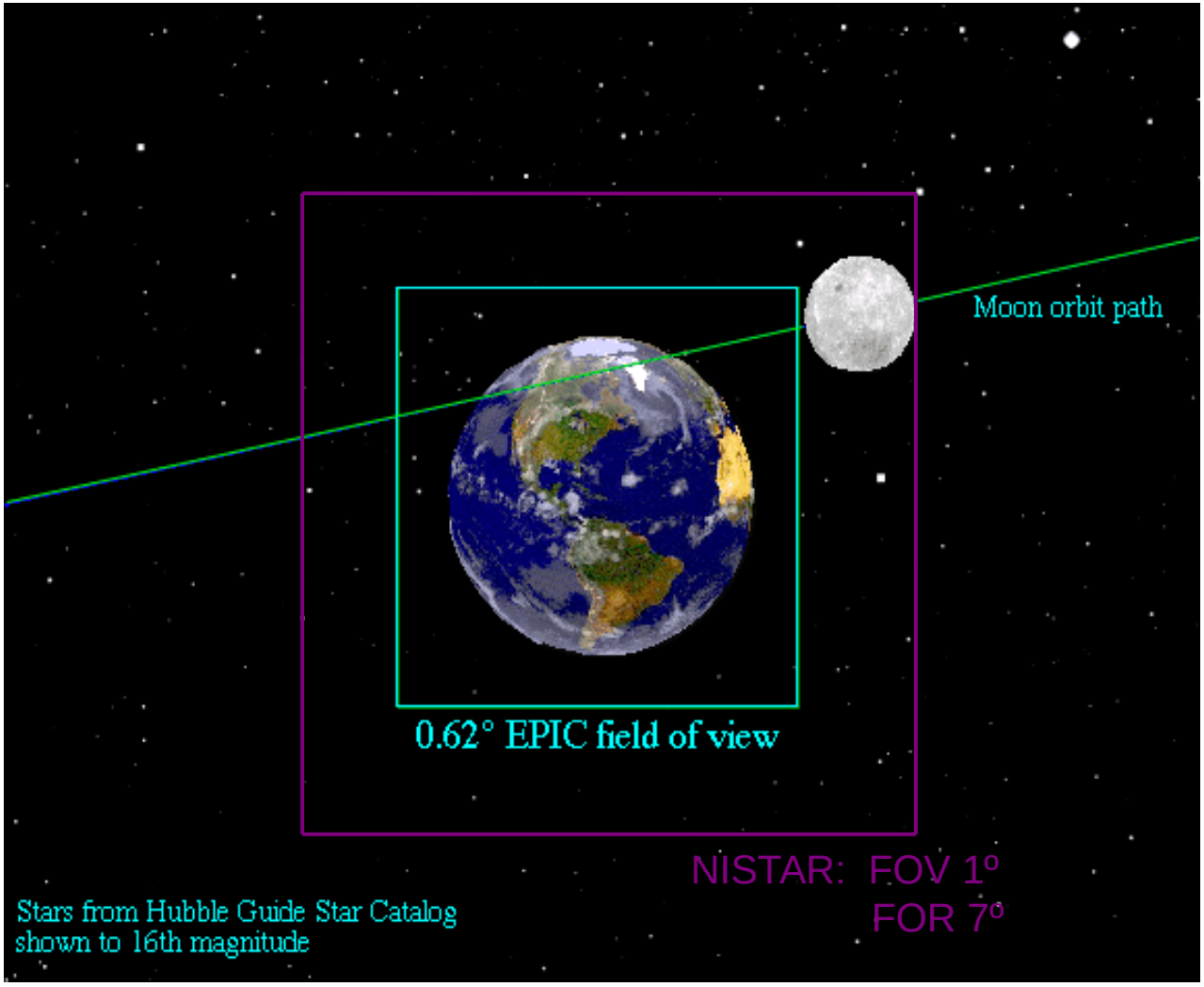


Some EPIC info

DSCOVR
Deep Space Climate Observatory



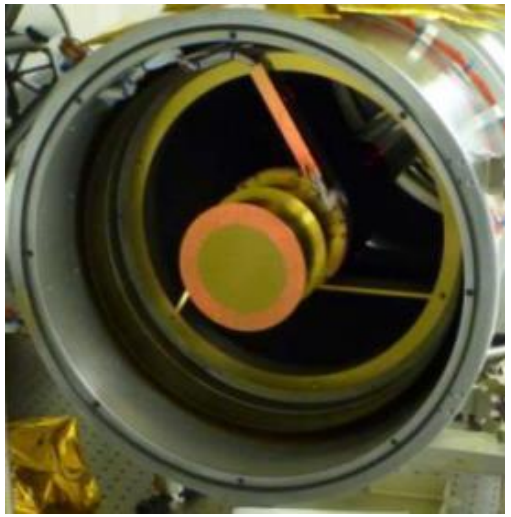
Field of view of EPIC and NISTAR

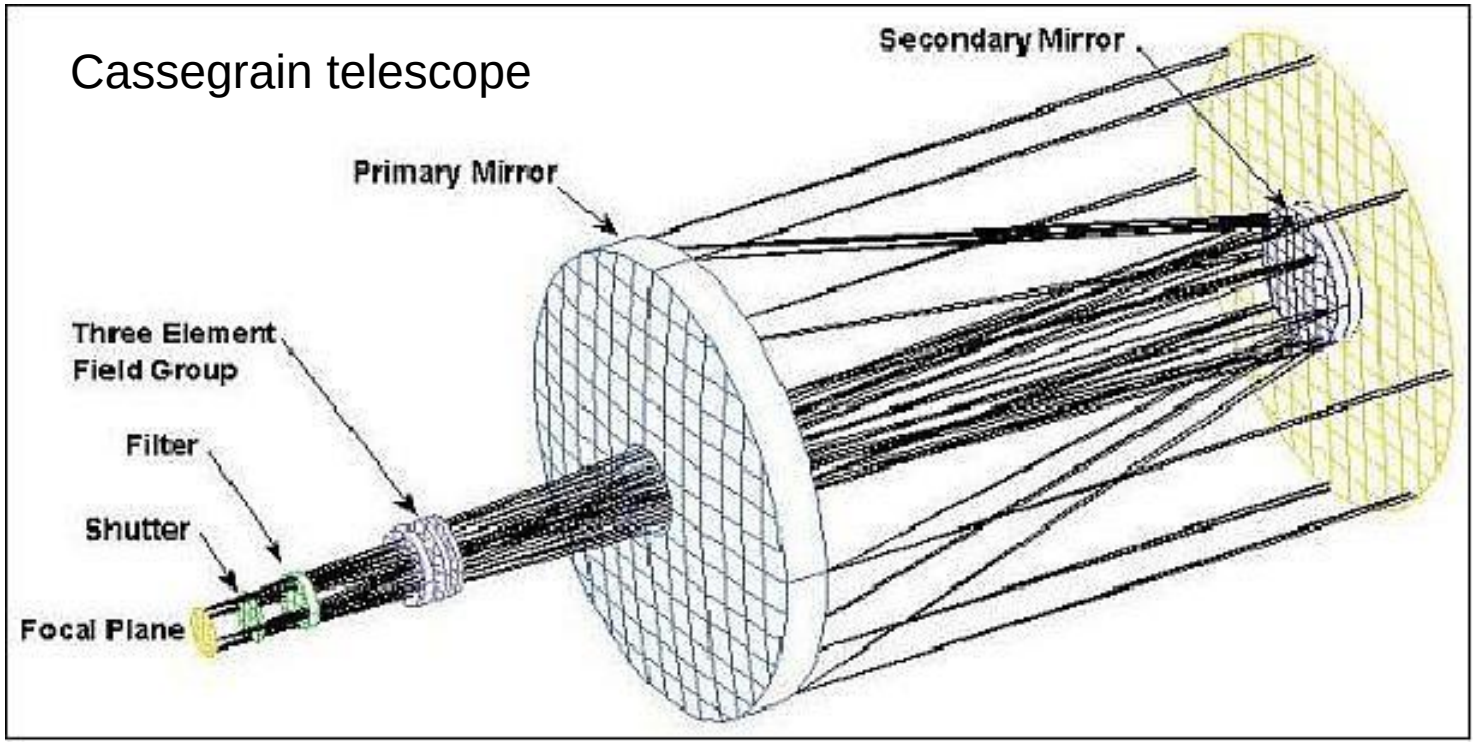


LUFTBLICK

EPIC optical path

2 filterwheels with 6 positions each (open hole plus 5 spectral filters) → 10 channels





Data correction steps

- Several correction steps are applied to the raw data
- The biggest challenges are “Flat fielding” and “Stray light”

Processing step	Average impact	Affected pixels impact
Dark correction	Moderate	Extreme
Enhanced pixel detection	Small	Large
Read wave correction	Small	Small
Latency correction	Moderate	Significant
Non-linearity correction	Small	Small
Temperature correction	Small	Small
Conversion to count rates	Small	Small
Flat fielding	Significant	Large
Stray light correction	Significant	Large
Conversion to radiances	Significant	Significant

Small: $\varepsilon<0.4\%$

Moderate: $0.4\%<\varepsilon<2\%$

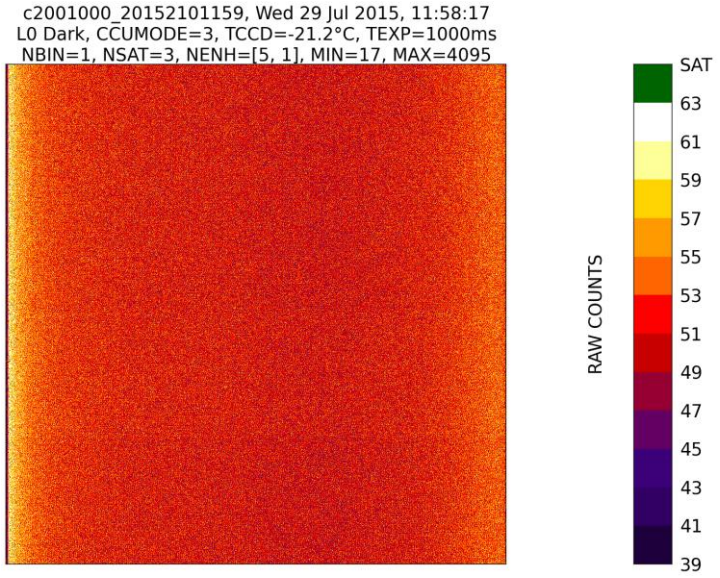
Significant: $2\%<\varepsilon<10\%$

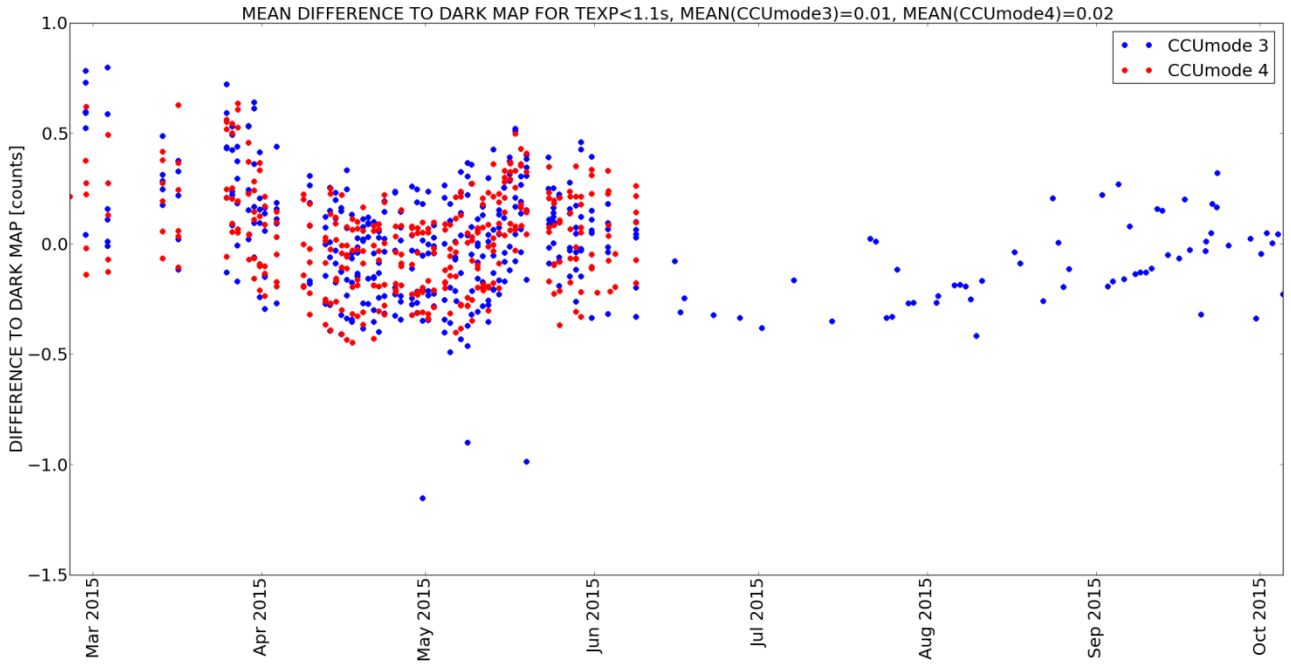
Large: $10\%<\varepsilon<50\%$

Extreme: $\varepsilon>50\%$

Dark correction

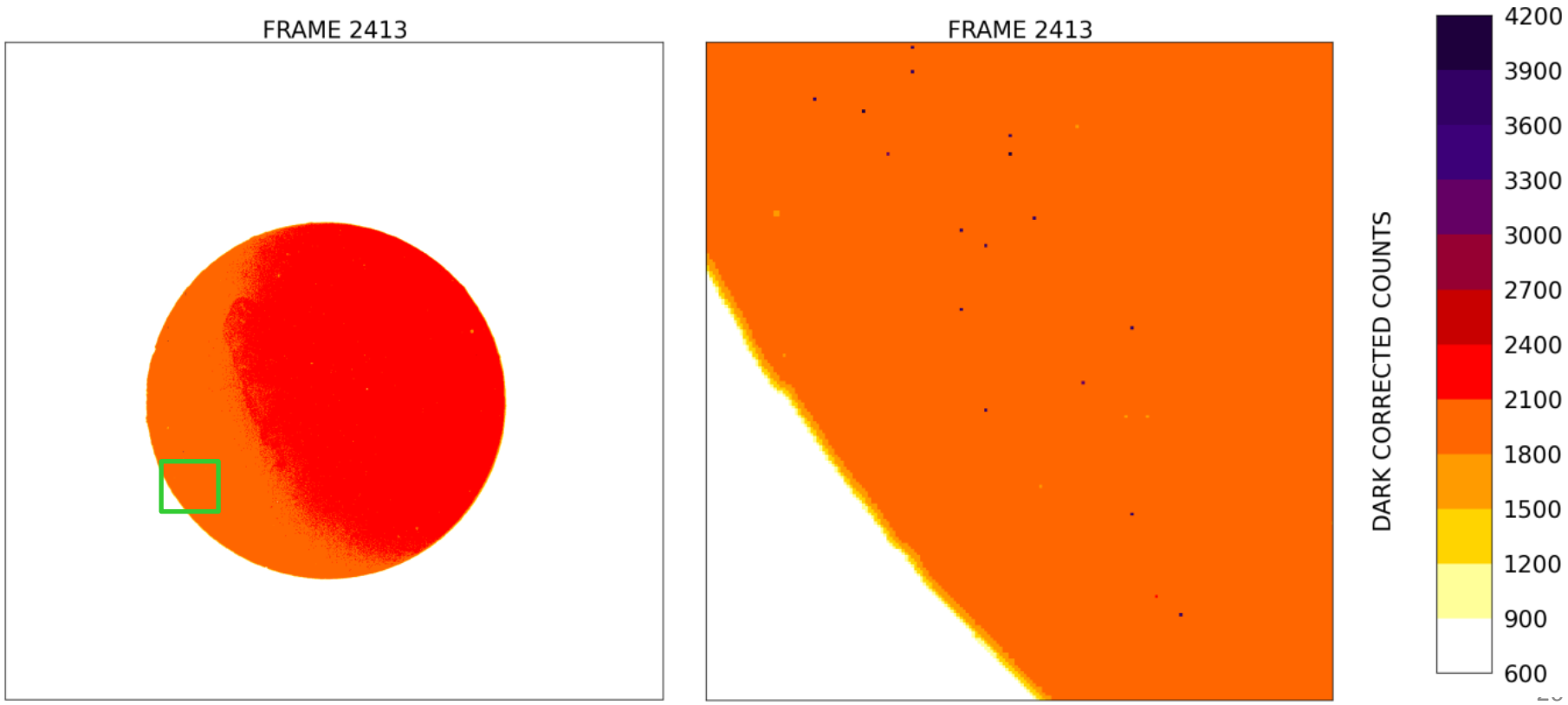
- Dark count (signal at no light input) is caused by thermal electrons and electronic offset.
- It depends on the exposure time and the CCD-temperature.
- It varies over the CCD.
- It is only measured occasionally. Therefore a dark count model is used in the data correction.





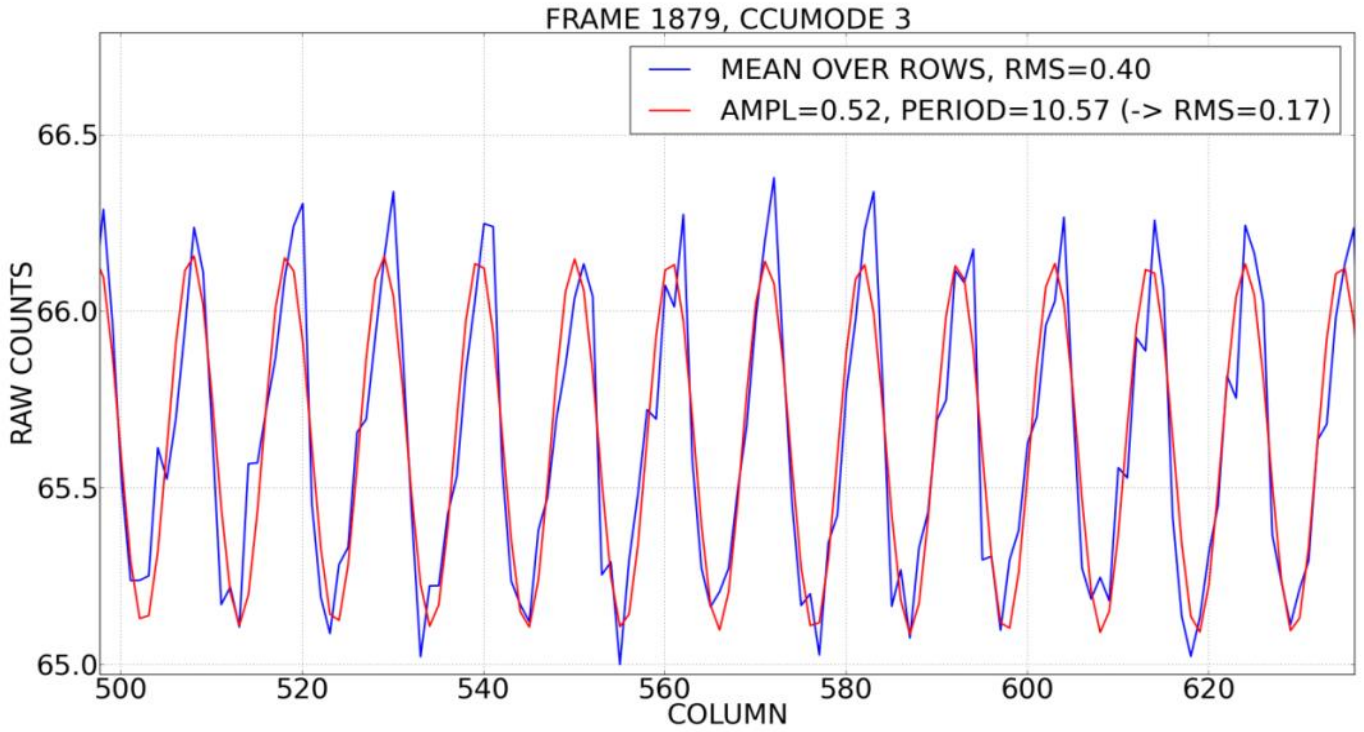
Enhanced pixel detection

- Pixels with physically impossible enhanced values are detected and flagged.
- The reason for such pixels can be effects in the readout electronics or cosmic rays events.



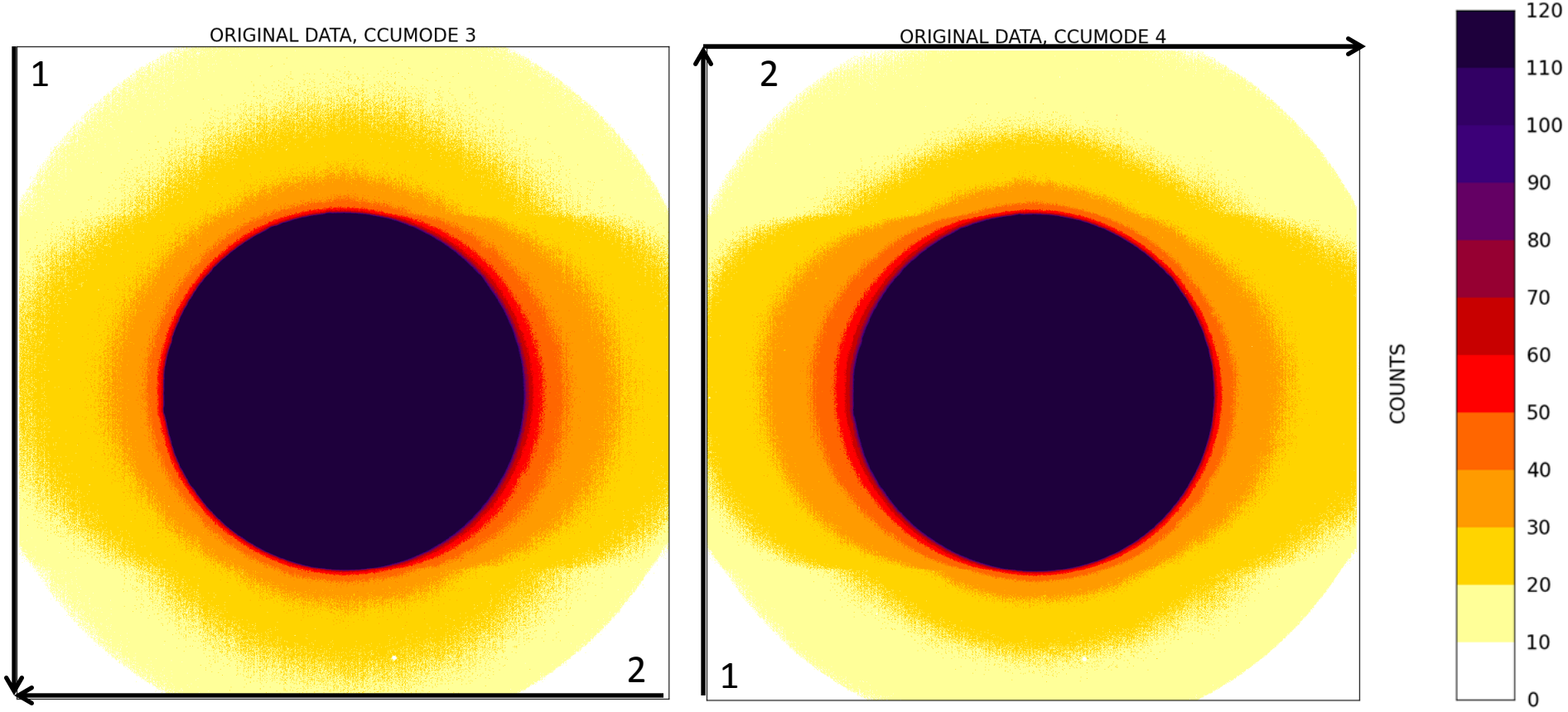
Read wave correction

- EPIC's readout electronics add a small sinusoidal wave to the image, which varies in amplitude and phase from image to image.
- The read wave correction removed this feature from the data.



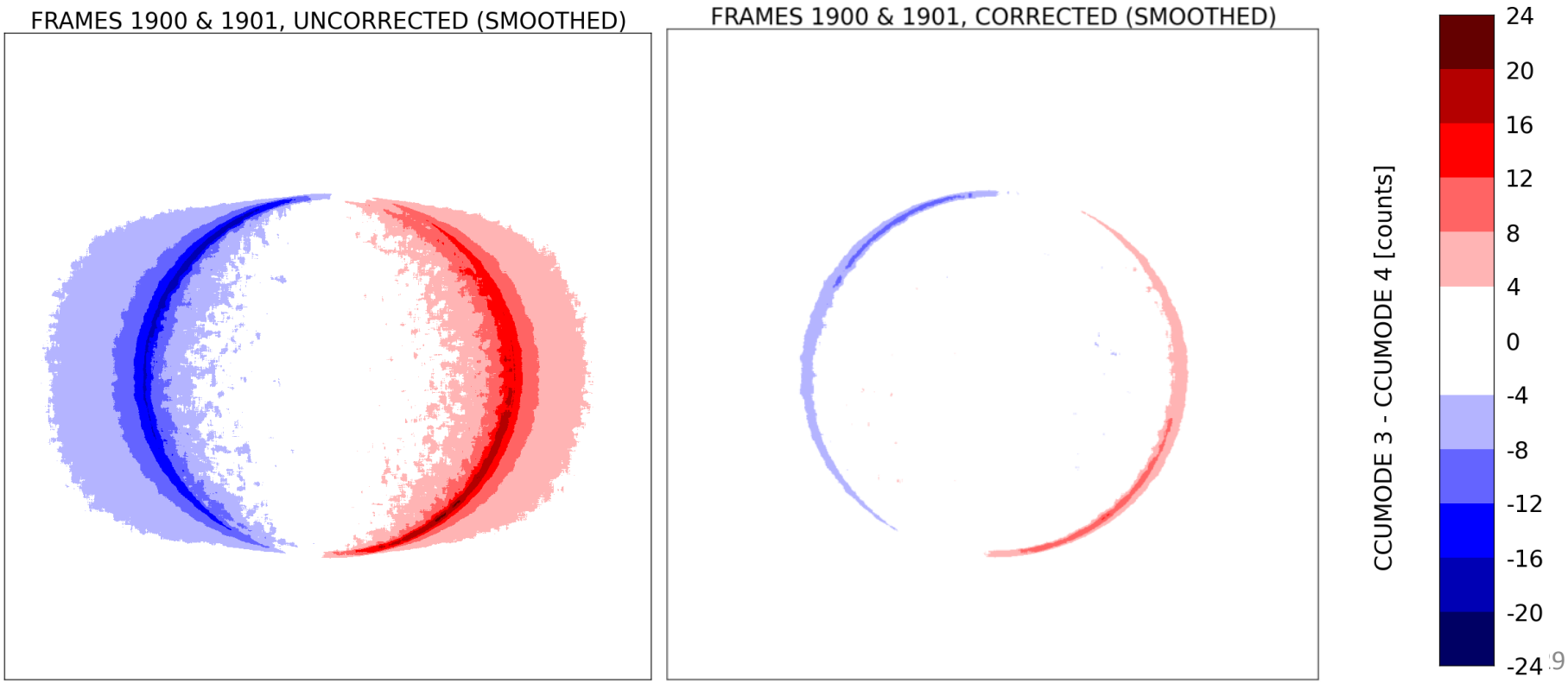
Latency effect

- *"Low signals being read after high signals are biased high!"*
- The same input read from the bottom left corner (left panel) or the top right corner (right panel).



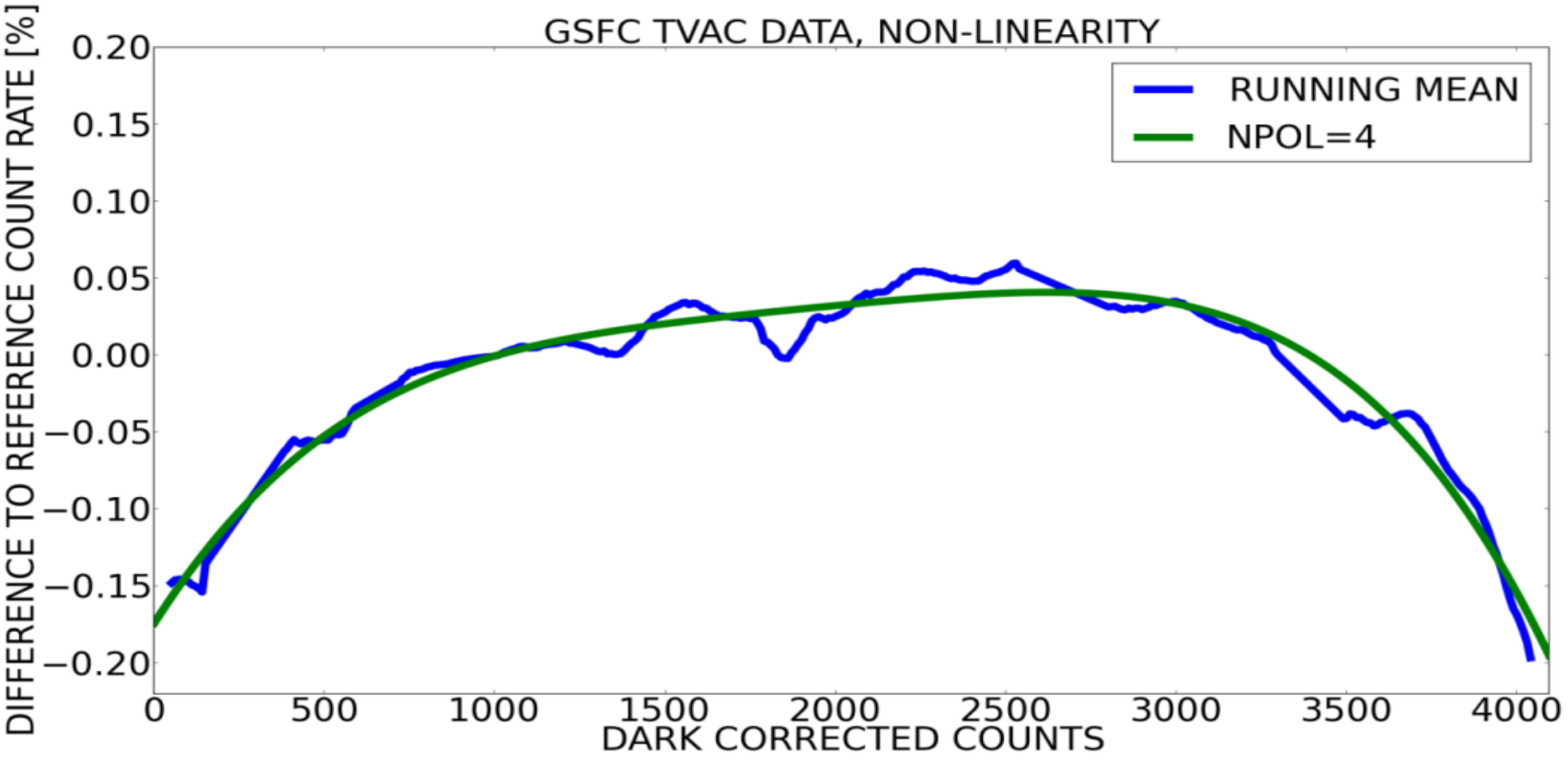
Latency correction

- Latency error before the correction (left panel) and after the correction (right panel).



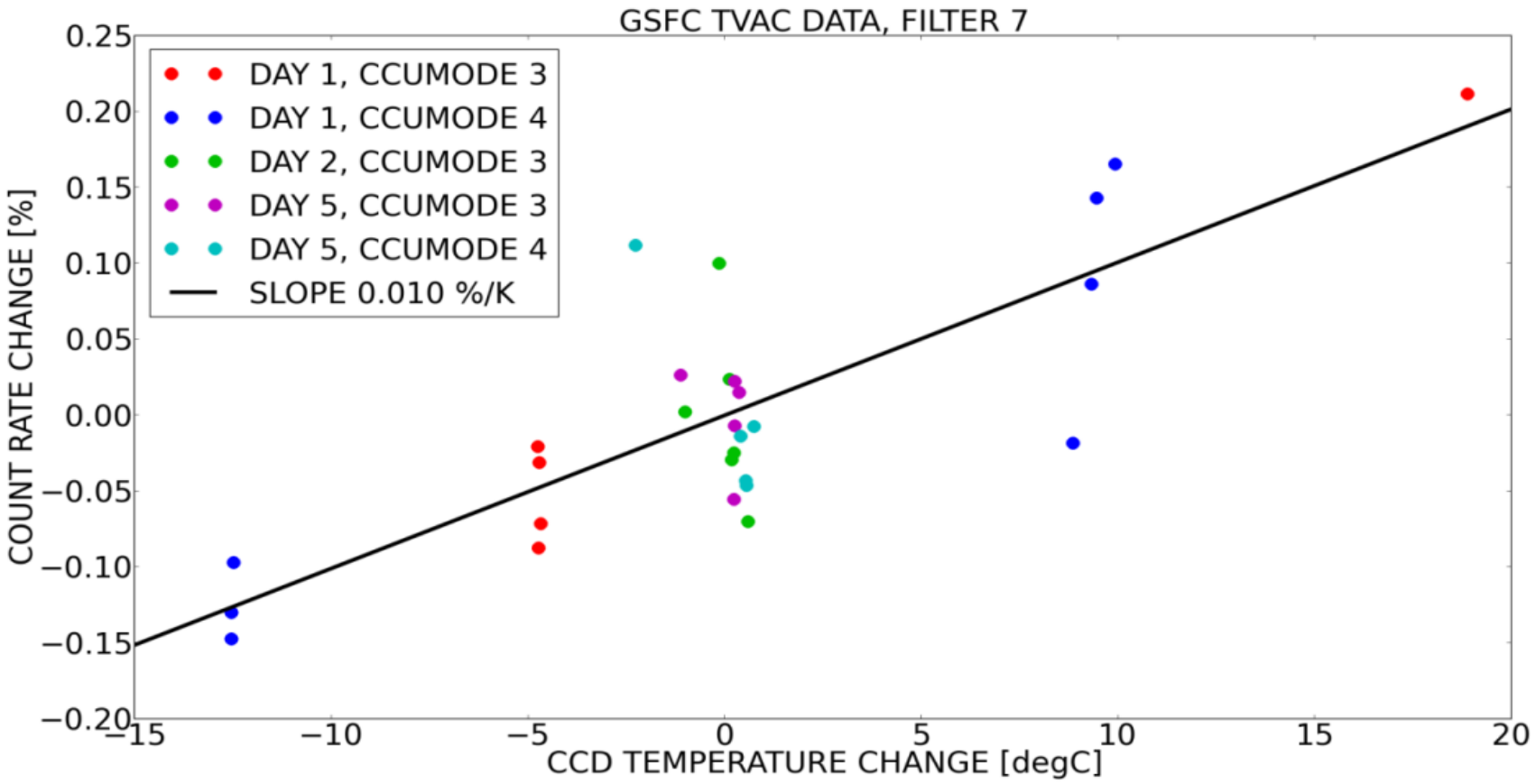
Non-linearity correction

- *"Double input does not produce double signal"*
- EPIC is very linear! The non-linearity correction is below 0.2% over the whole range of counts.



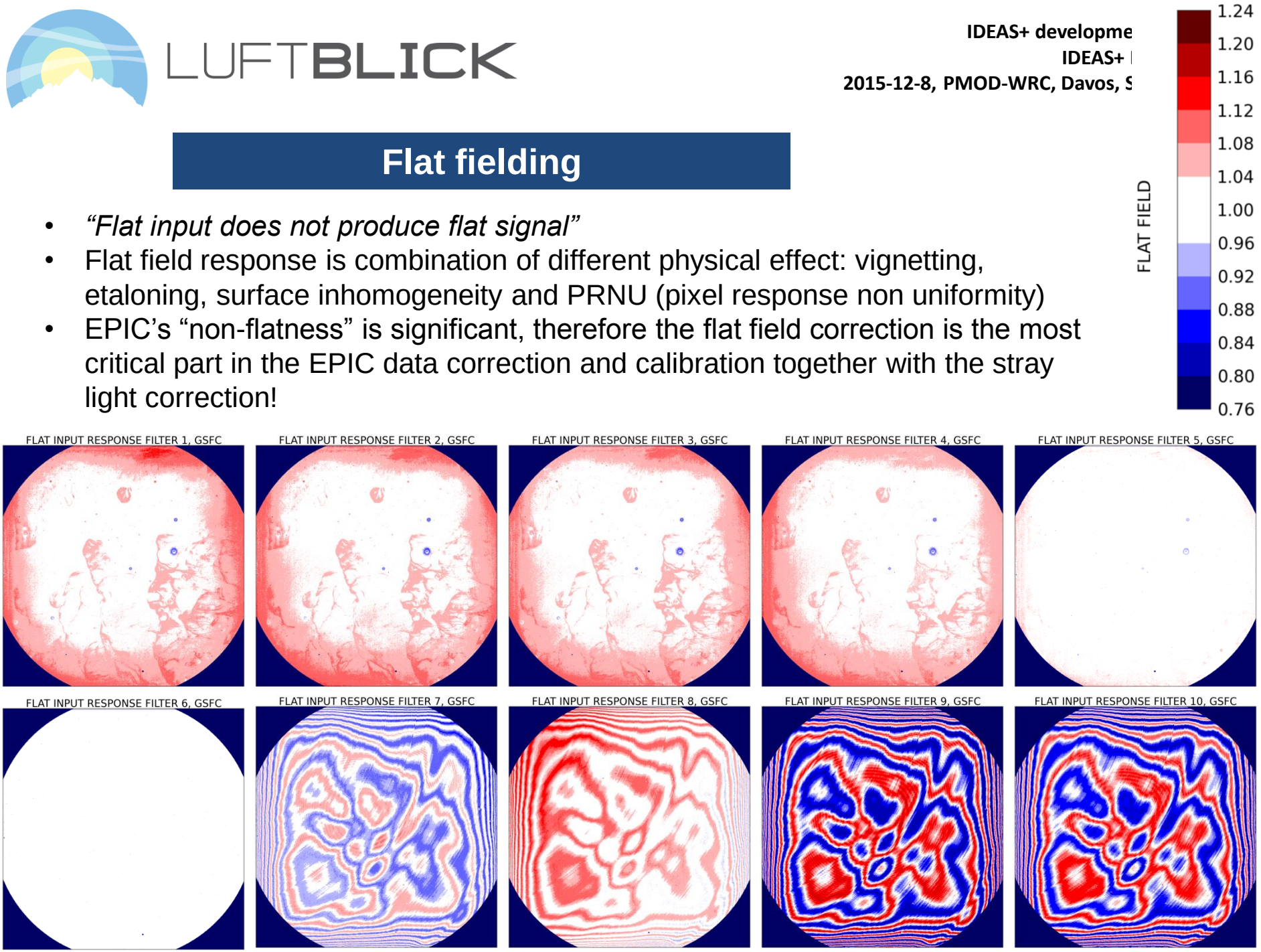
Temperature correction

- *"EPIC is slightly more sensitive, when it is warmer."*
- EPIC temperature dependence is very small.



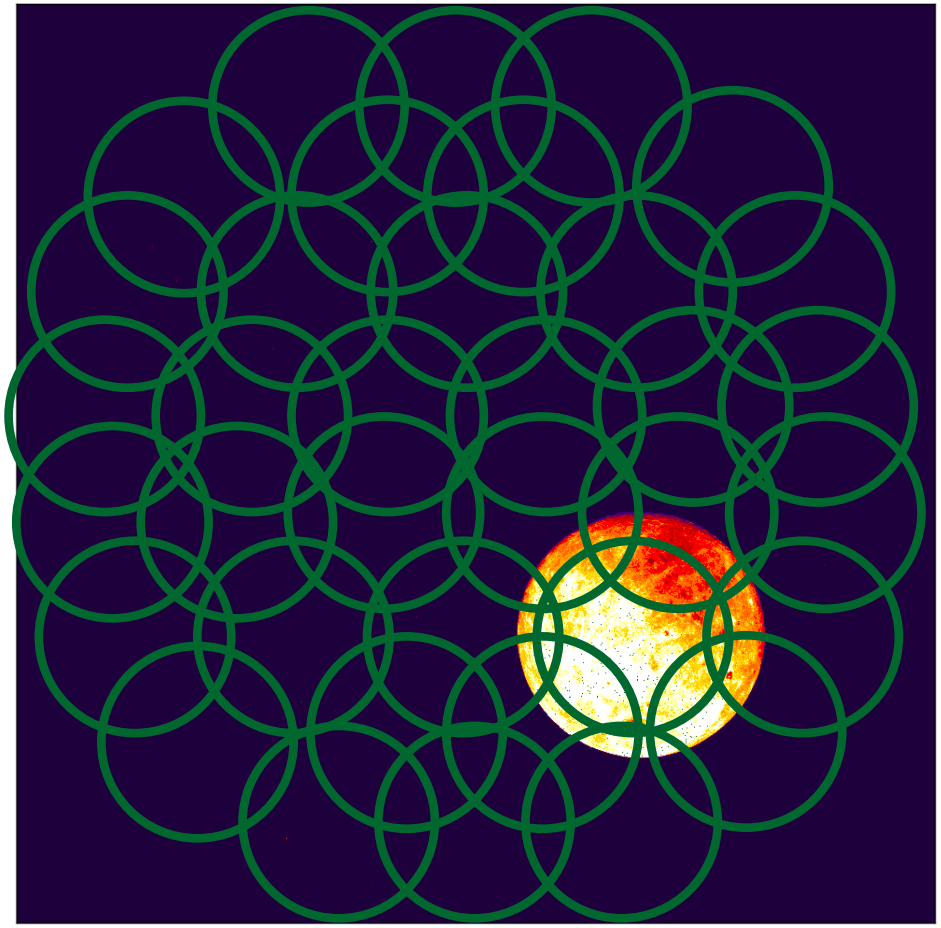
Flat fielding

- *"Flat input does not produce flat signal"*
- Flat field response is combination of different physical effect: vignetting, etaloning, surface inhomogeneity and PRNU (pixel response non uniformity)
- EPIC's "non-flatness" is significant, therefore the flat field correction is the most critical part in the EPIC data correction and calibration together with the stray light correction!



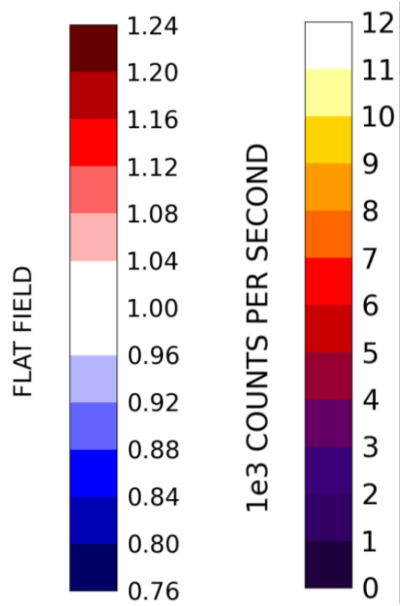
Flat field calibration on orbit

- To improve the flat field correction determined from pre-launch data, images of the moon at different positions on the CCD were made.
- The moon is much “smoother” than the Earth.

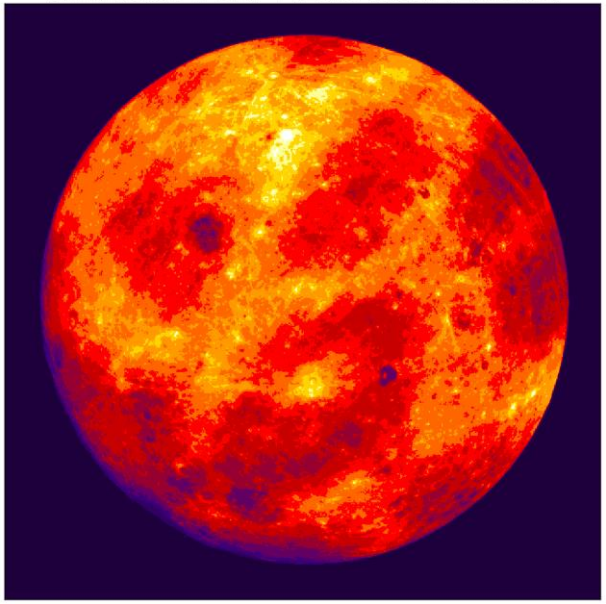


Dark side of the moon

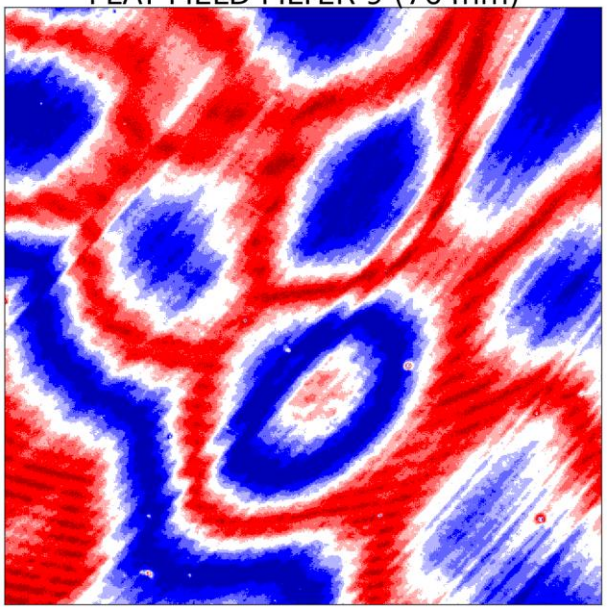
- During new moon, EPIC can see the “Dark side of the moon” in full illumination.
- This side of the moon is “smoother” than the side pointing to the Earth.
- Some features you observe on the left panel do not “belong” to the moon and are caused by the flat field.



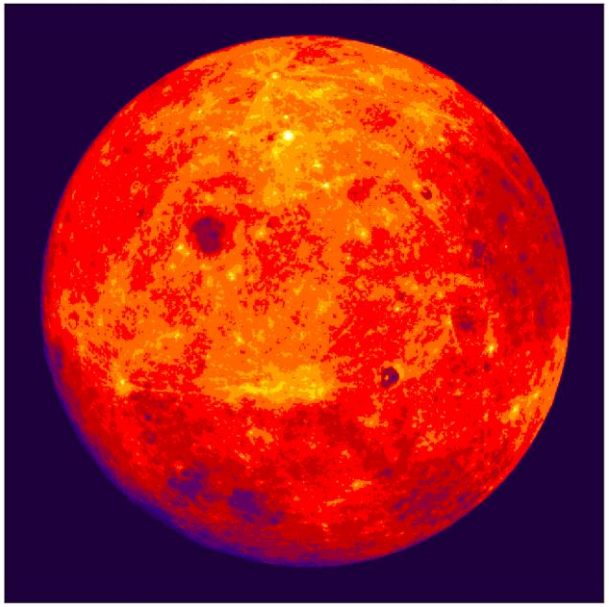
WITHOUT FLAT FIELD CORRECTION



FLAT FIELD FILTER 9 (764nm)



WITH FLAT FIELD CORRECTION

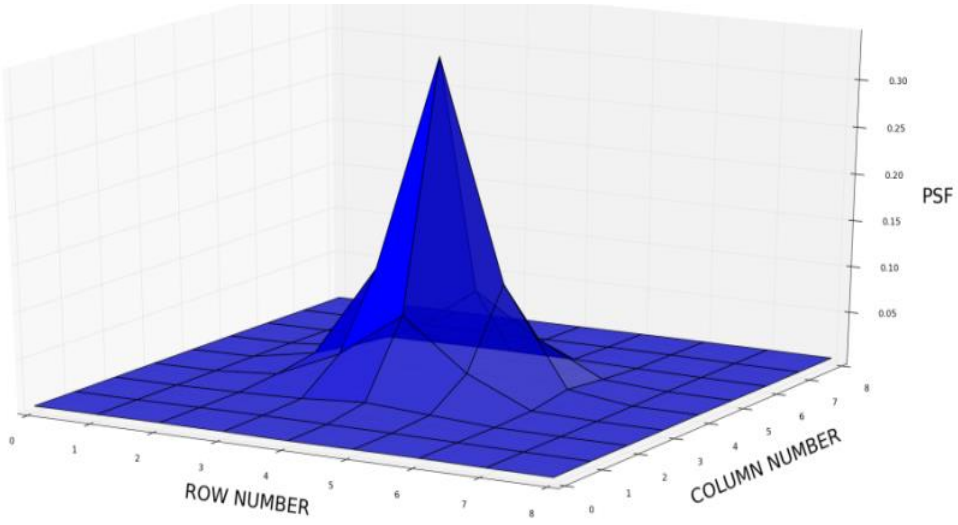


Stray light effect

- *"Not all the light ends up where we want it to end up."*
- We want the light from a point source to end up in the corresponding pixel and the neighbor pixels, however a very significant portion of the light spreads over the entire CCD (stray light).This is described by the point spread function (PSF).
- Lab-measurements were taken with different "targets" .
- The sub-pixel target gives us the core of the PSF but the stray light disappears in the noise.

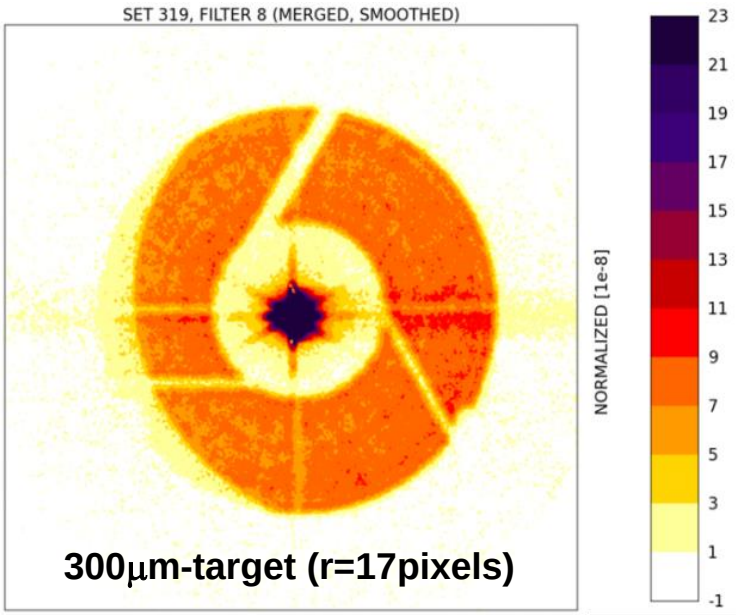
	Straight-diagonal <1%	Second neighbor ~1%	Straight-diagonal <1%	
Straight-diagonal <1%	Diagonal neighbor ~3%	Direct neighbor ~10%	Diagonal neighbor ~3%	Straight-diagonal <1%
Second neighbor ~1%	Direct neighbor ~10%	Target pixel ~30%	Direct neighbor ~10.0%	Second neighbor ~1%
Straight-diagonal <1%	Diagonal neighbor ~3%	Direct neighbor ~10%	Diagonal neighbor ~3%	Straight-diagonal <1%
	Straight-diagonal <1%	Second neighbor ~1%	Straight-diagonal <1%	

5μm-target (sub-pixel)



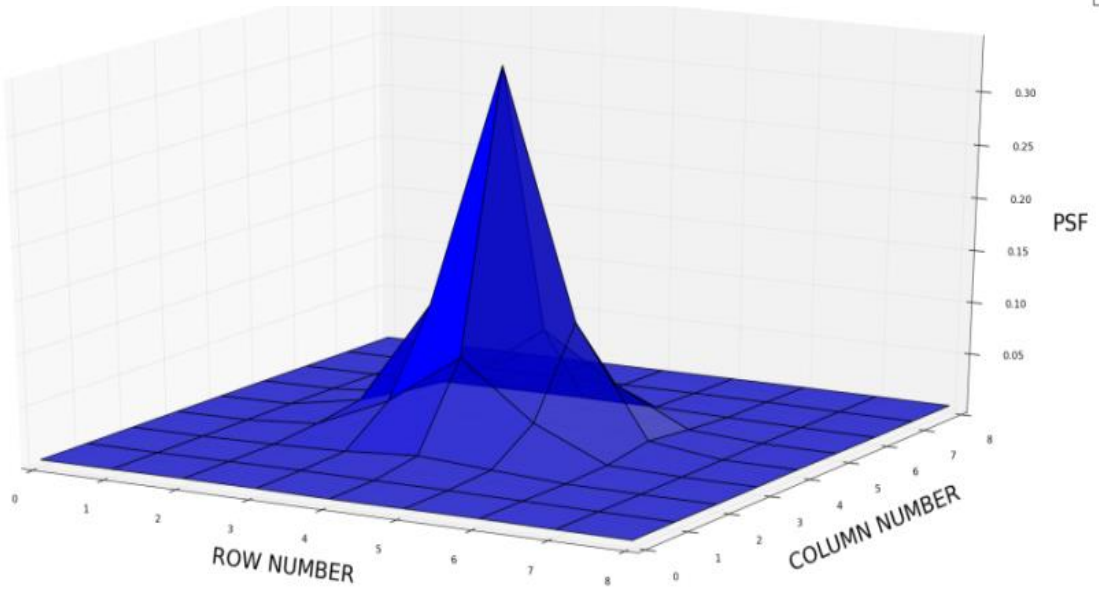
Stray light measurements

- A circular target with radius of 17 pixels shows the stray light.
- We noticed that there is a stray light level of 10-20%!



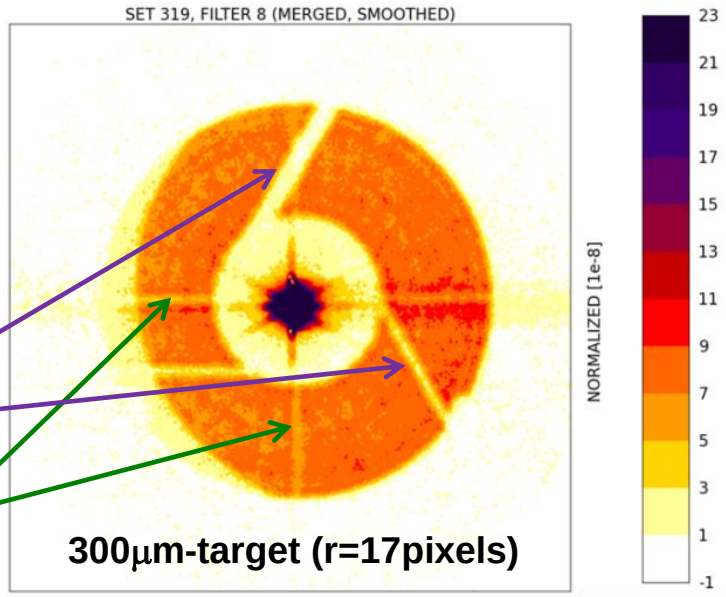
300μm-target (r=17pixels)

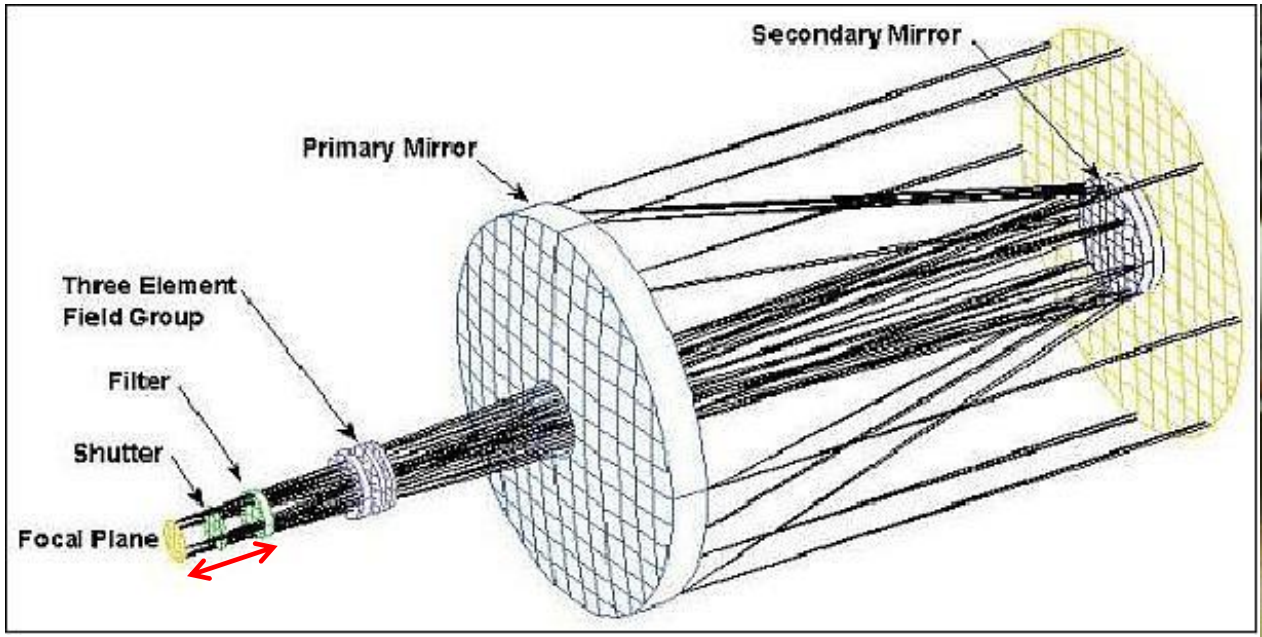
5μm-target (sub-pixel)

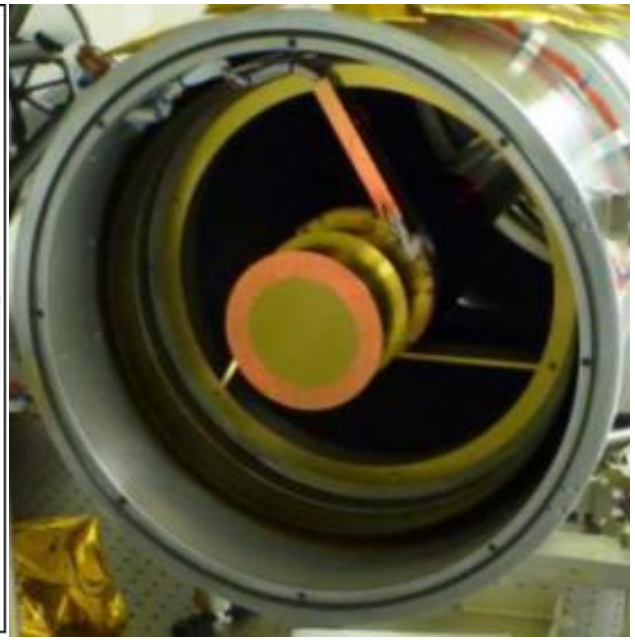


Ghost image

- A significant part of EPIC's stray light comes from reflections between the CCD and the filters producing a "ghost image".
- A major problem in the calibration was to distinguish between features that "belong" to the illumination beam and features from EPIC.

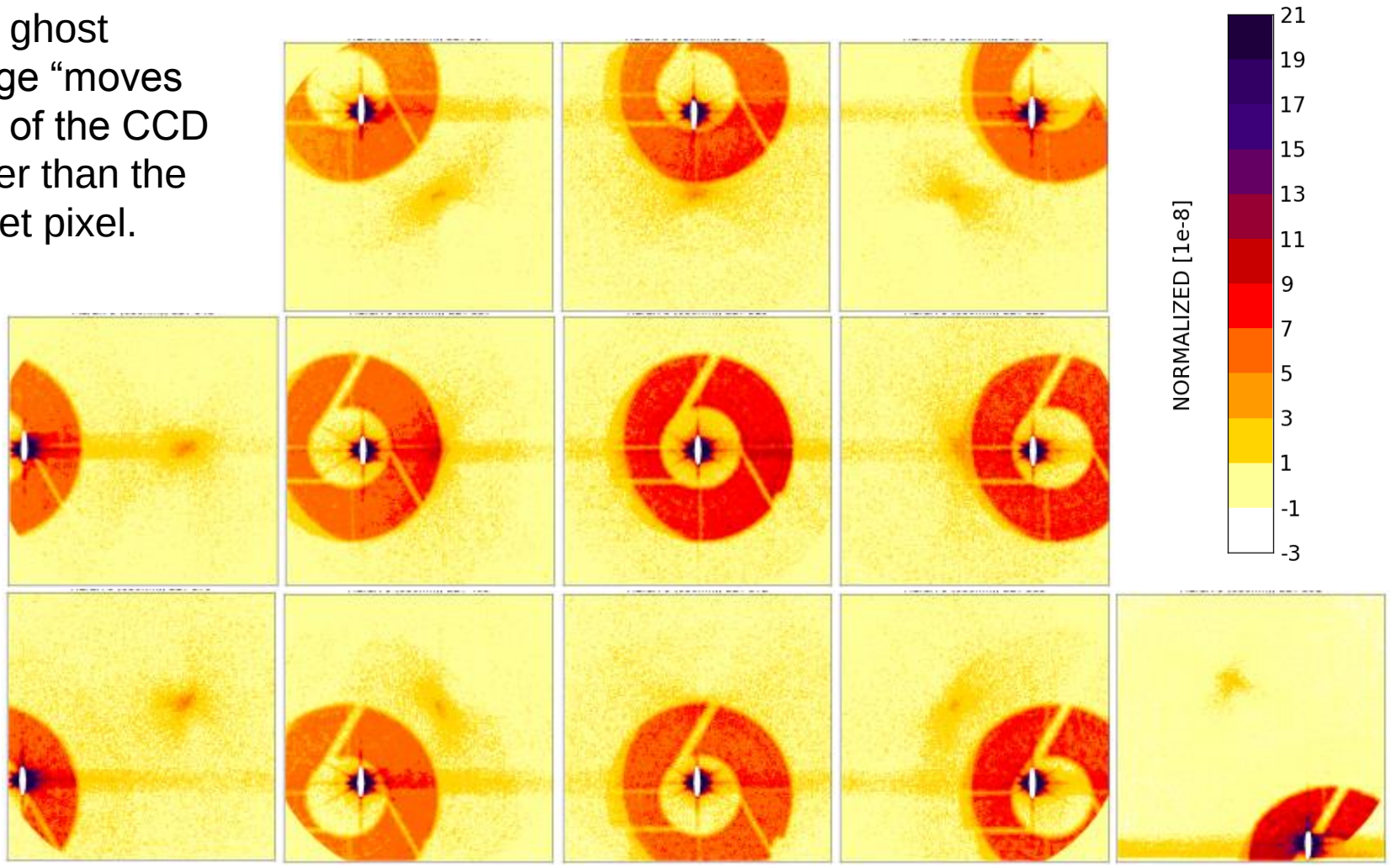






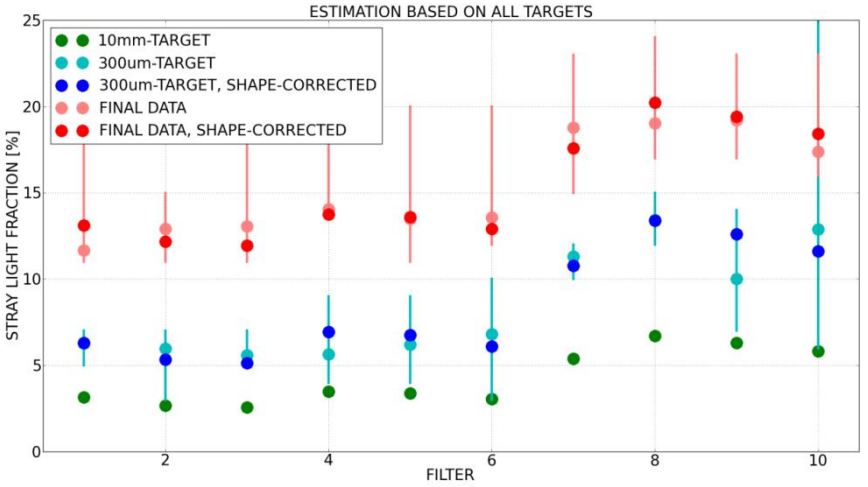
Point spread function

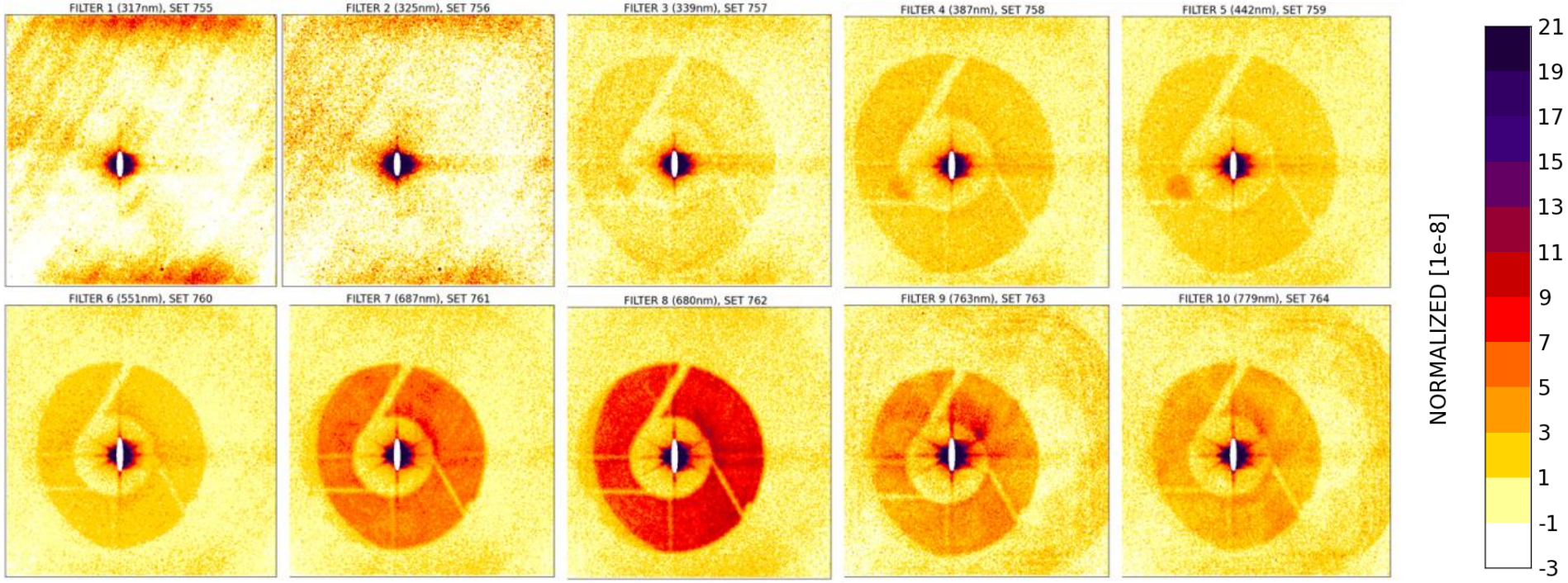
- The ghost image “moves out” of the CCD faster than the target pixel.



Stray light level

- The amount of stray light varies from filter to filter with 11-14% stray light level for filters 1 to 6 (between 317 and 551nm) and a maximum of 20% for filter 8 (680nm).
- There are large uncertainty bars!





Stray light correction

EPIC has a significant amount of stray light, therefore the stray light correction is the most critical part in the EPIC data correction and calibration together with the flat field correction!

The effect of stray light on the EPIC data is that small signals (from clear scenes) are biased high, while large signals (from cloudy scenes) are bias low. Hence the image contrast is reduced. This is not seen “by eye” in the images, but has significant impact on the derived data products.

The stray light effect is stronger for the visible filters than for the UV filter, since…
- …the dynamic range in the visible is stronger (see next slide).
- …the stray light level for filters 7 to 10 is higher.

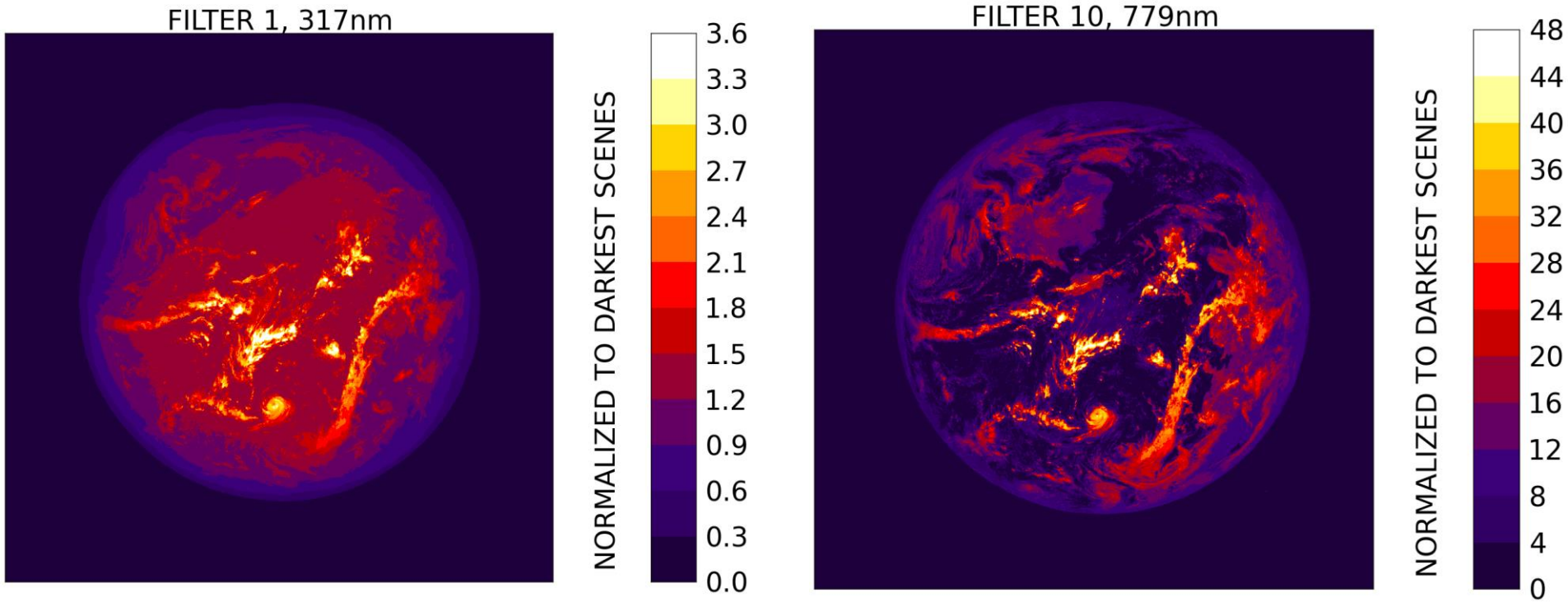
Once the PSF is determined for each of the 4 million pixels, a numerically sophisticated stray light correction algorithm is applied, which e.g. includes the inversion of a huge 4e6 x 4e6 elements diagonally dominant matrix.

The EPIC stray light correction is not implemented yet, i.e. affects the EPIC data products as of now.

Dynamic range

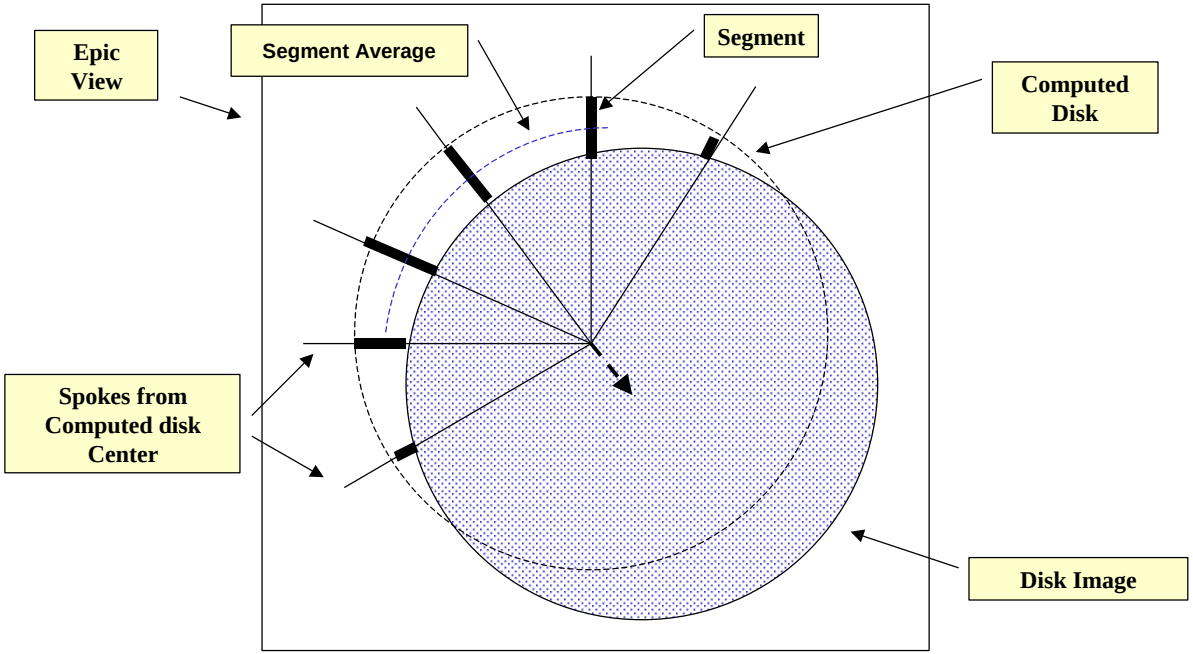
- Images for 317 and 779nm, normalized to the darkest scenes in the center of the CCD.
- Ratio bright scenes (thick clouds) over dark scenes (clear sky over non-reflective ground) is up to 4 at 317nm and up to 50 at 779nm.
- Therefore the stray light has more effect in the visible!

7 Sept 2015, 106 seconds apart



Geolocation and regridding

- Telemetry pointing information accuracy is ~2arcsec (~16km)
- To achieve better accuracy, 'Geolocation' is applied to the data in each filter
- First the centroid ellipse is found (see figure) and then a longitude-latitude grid is created
- Finally data from different channels are shifted to a common grid
- Measurements from 2 filters are 27s apart (Earth rotates 0.5km/s on equator!)



Channels

Ozone and SO2: total column
Aerosol properties: aerosol index, aerosol optical thickness, aerosol height
Cloud & surface properties: cloud fraction, cloud height, surface albedo
Vegetation properties: vegetation index and Leaf Area Index (LAI)
RGB: colored image of the Earth's sunlit face

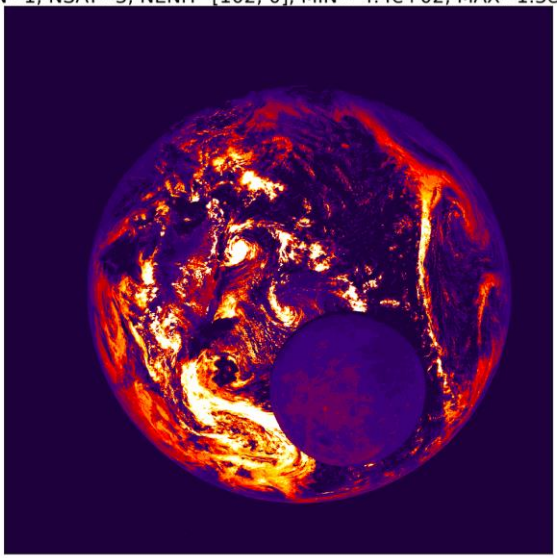
Center [nm]	FWHM [nm]	Primary purpose
317	1	Ozone + SO2
325	1	Ozone + SO2
340	3	Ozone + SO2, Aerosols, Reflectivity
388	3	Aerosols, Reflectivity
443	3	Aerosols, Reflectivity, Vegetation, RGB
552	3	Aerosols, Reflectivity, Vegetation, RGB
680	2	Aerosols, Reflectivity, Vegetation, LAI, O_2B-Band Reference, RGB
688	0.8	O_2B-Band Cloud Height
764	1	O_2A-Band Cloud Height, Aerosol Height
779	2	Aerosols, Reflectivity, Vegetation, LAI, O_2A-Band Reference

RGB

- RGB images are a combination of the images from filter 8 (680nm, red), filter 6 (551nm, green) and filter 5 (442nm, blue).
- Below images taken on 16-July-2015 (new moon).
- About 1min time between green and blue filter.

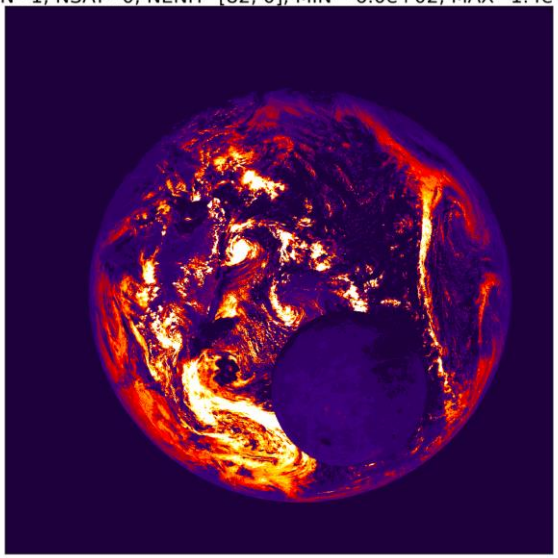
RED

r1972135_20151972140, Thu 16 Jul 2015, 21:36:04
L1a 680nm, CCUMODE=3, TCCD=-21.2°C, TEXP=32ms
NBIN=1, NSAT=3, NENH=[102, 0], MIN=-4.4e+02, MAX=1.3e+05



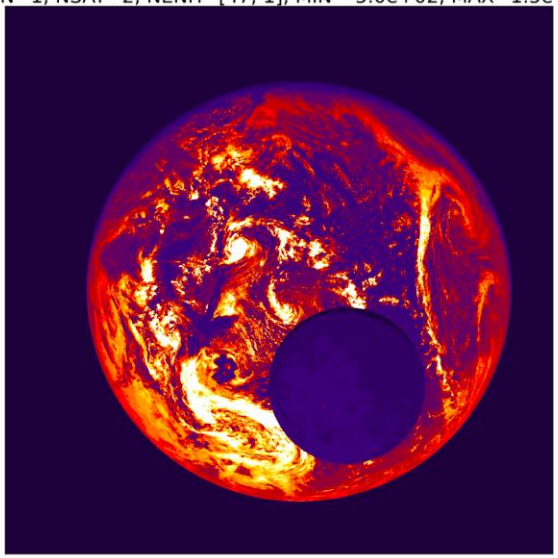
GREEN

b1972135_20151972138, Thu 16 Jul 2015, 21:35:37
L1a 551nm, CCUMODE=3, TCCD=-21.2°C, TEXP=22ms
NBIN=1, NSAT=0, NENH=[82, 0], MIN=-6.0e+02, MAX=1.4e+05



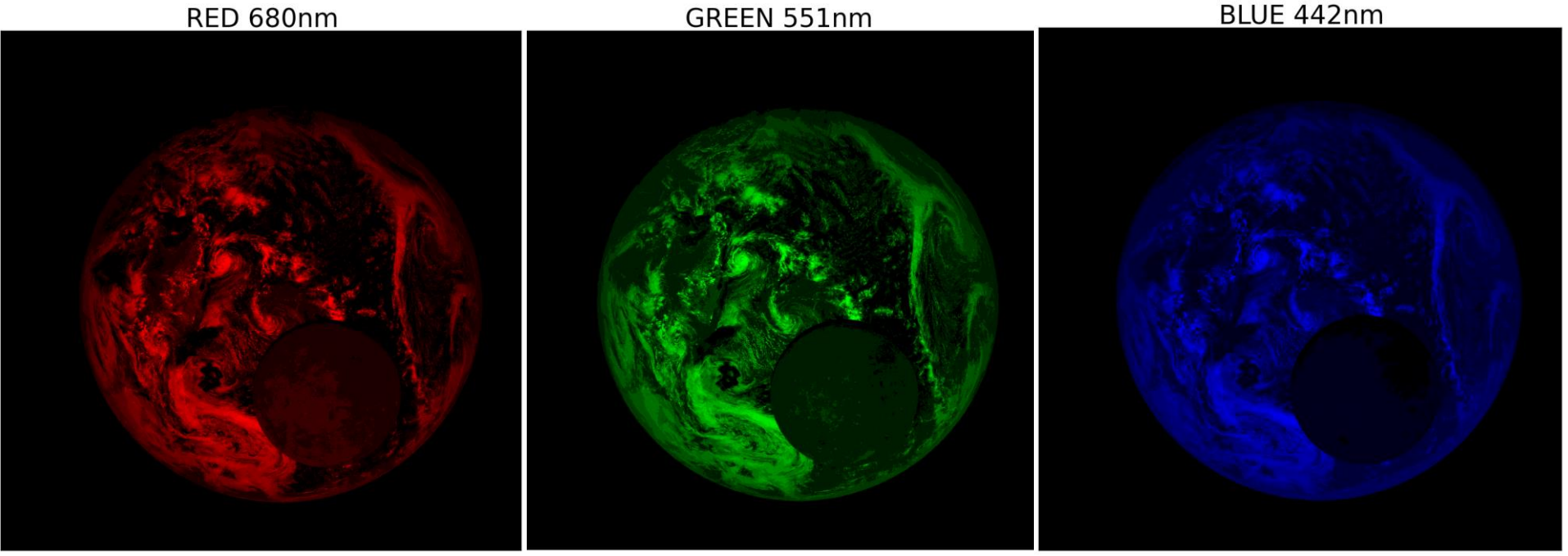
BLUE

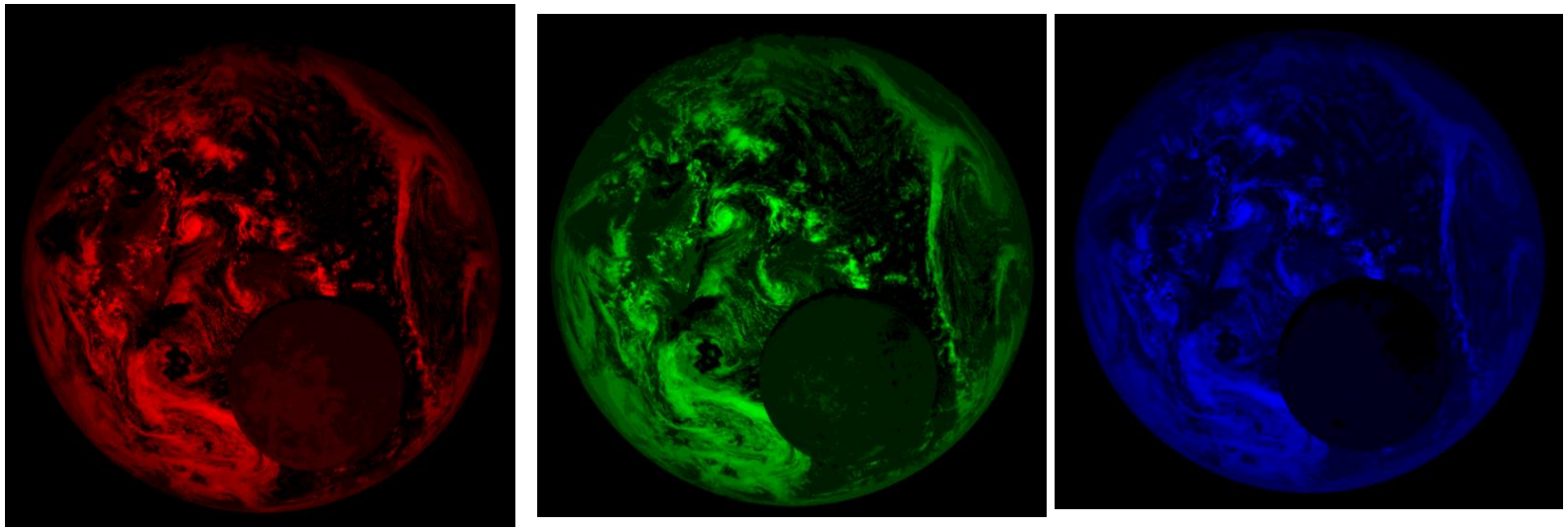
v1972135_20151972142, Thu 16 Jul 2015, 21:36:31
L1a 443nm, CCUMODE=3, TCCD=-22.2°C, TEXP=28ms
NBIN=1, NSAT=2, NENH=[47, 1], MIN=-5.0e+02, MAX=1.5e+05



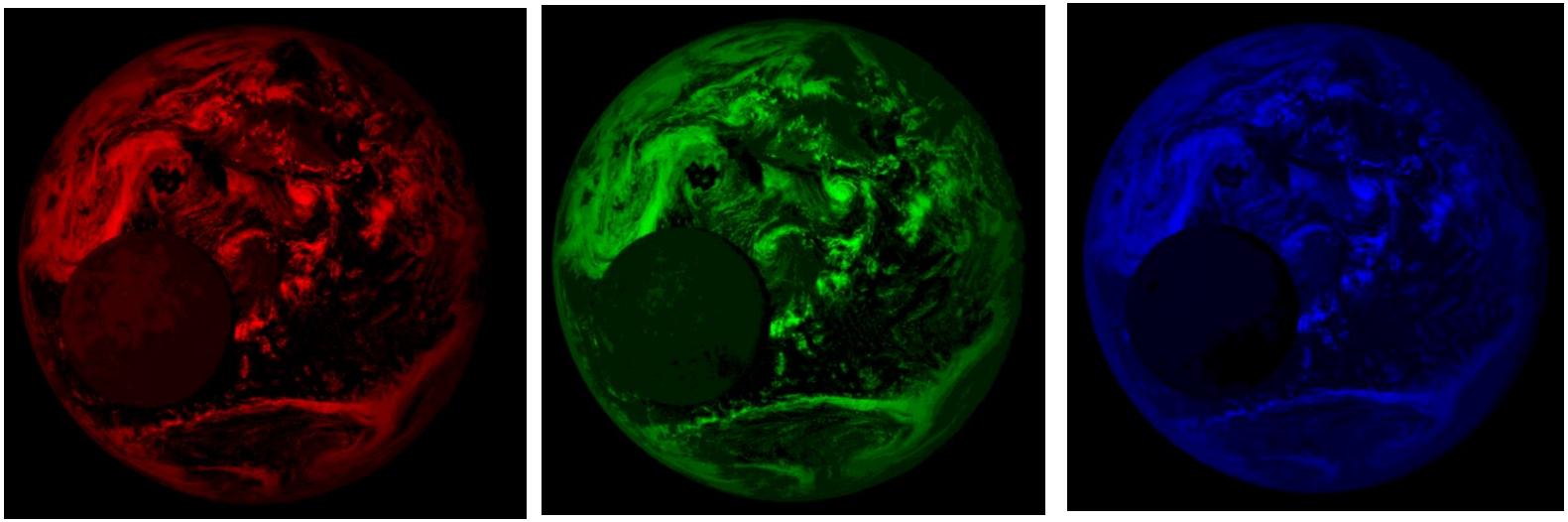
RGB

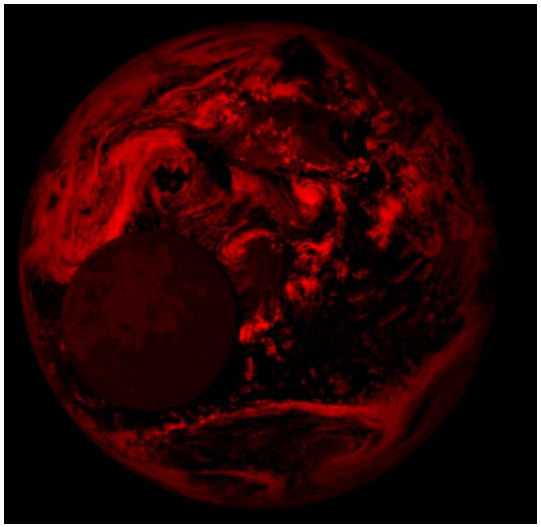
This color code is similar to what we would see through one of the filters.

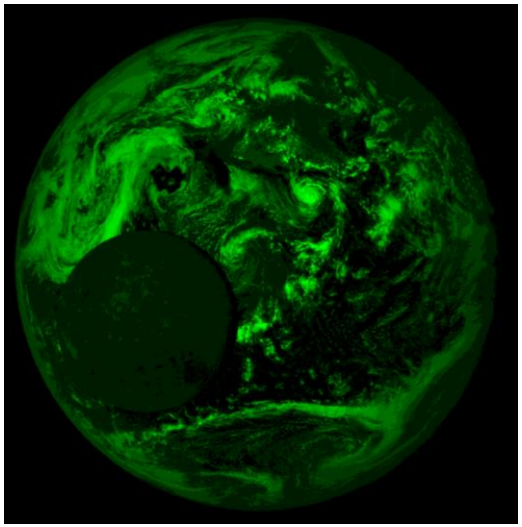


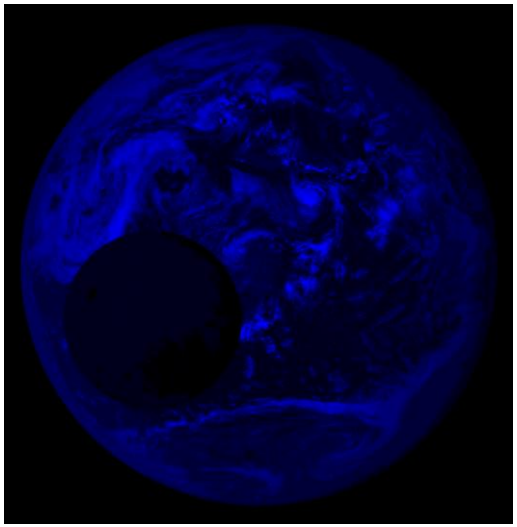


Rotate and shift










North America
Hurricane Dolores
South America

RGB Movie

Images 15min apart