XUV anomalies

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Agenda

• (Brief) xUV detectors overview
• FUV anomaly
• EUV anomaly
The EUV and FUV detectors share a same architecture:

- Photocathode → Photo-electrons generation
- Micro Channel Plate (5 stages V+Z stack) → Electrons multiplication
- Resistive Anode Encoder → Electron cloud collection (charge, position)

- HV power supply needed to accelerate the electrons
- 2D localization of the electron cloud thanks to a barycenter calculation (4 outputs, one at each corner of the RAE)
- Charge filtering of the events (discriminators)
# xUV detectors overview

## Main differences FUV/EUV

<table>
<thead>
<tr>
<th></th>
<th>FUV</th>
<th>EUV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photocathode</td>
<td>CsTe (145 – 315 nm)</td>
<td>CsI (55 – 155 nm)</td>
</tr>
<tr>
<td>Position of the photocathode</td>
<td>Internal face of the MgF2 window</td>
<td>MCP input surface</td>
</tr>
<tr>
<td>Packaging</td>
<td>Sealed</td>
<td>Vacuum chamber, with openable window (mechanism)</td>
</tr>
<tr>
<td>Nominal HV (as defined on ground)</td>
<td>~4800V</td>
<td>~3600V-3700V</td>
</tr>
</tbody>
</table>

![Image of xUV detectors]
• **Electronics and operating modes**

  • Each detector has its own electronics (HV, 4x Analog chain, Controller/FPGA)
  • Two operating modes:
    • IMG (left): The detector provides a 2D matrix showing the localization of the counts on the RAE
      • Localization of the events is known, but the charge level is lost → Used for science
    • PHA (right): The detector provides a Pulse Height Distribution curve for each of the four channels + sum
      • The charge level of the event is known, but the localization is lost → Used for test/diagnosis
    • + « Test » mode (simulated pulse injection) → Electronics chain testing
• During the commissioning of the detectors with HV ON (May 2019) the FUV have shown a high level of noise.
  • Dark count : 100 to 1000 times higher than on ground
  • Spatial distribution of the counts is not homogeneous
  • Noise increase → resolution degraded (barycentre calculation)
  • High count rate → limited lifetime
  • Behaviour of the detector is stable since 2019
    • Something happened between Oct18 and May19
  • Root cause not understood (radiations, electrostatic effect, internal outgassing, ...)

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Counts revealed out of the nominal area: indicates a high count rate (position calculated while mixing several events) → Upstream the Electronics

-4800V Discri 8
305s exposure

-4500V Discri 8
55s exposure

High density of counts in this corner
FUV Anomaly

• Resolution:

Argon spectrum (2015, ground calibration) Res: 1.6-1.7 nm (FWHM)

Venus (28/08/2020), Res: ~30 nm @ 4550V
FUV Anomaly

• PHA (ground):

![Graph of PHD of PHEBUS/FUV FM]

- 04 Nov 2014
- DISCR SUM LOW: 0x0400
- DISCR SUM HIGH: 0x4800
- Dark

- FUV PHA On ground

Count [count/300sec]

Gain [pC]

- -4.7 kV (0xC0)
- -4.8 kV (0xC4)
- -4.9 kV (0xC8)
- -5.0 kV (0xCC)
• PHA (June 2021):

- Charge increases with HV (OK).
- Nb counts decreases with discri value (OK)
  → Amplification function + discri function seems to be OK.

« PHA vs. HV vs. Discri » test. Need to increase the « discri value » while increasing the HV setpoint to avoid getting too many counts on the RAE/Electronics.
### Possible causes

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Comment/status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation, scintillation of the MgF2 window</td>
<td>Radiation test done, does not explain the current situation</td>
</tr>
<tr>
<td>Electrostatic charging</td>
<td>A test has been done on the FS up to -2kV dc. The detector is not sensitive to this.</td>
</tr>
<tr>
<td>Internal contamination</td>
<td>Could explain the high count rate. Difficult to investigate, low probability: Contamination from where?</td>
</tr>
<tr>
<td>HV converter malfunction</td>
<td>Not compatible with observations (gain changes with HV, relevant charge levels)</td>
</tr>
<tr>
<td>Voltage divider malfunction</td>
<td>Not compatible with observations (gain changes with HV, relevant charge levels)</td>
</tr>
<tr>
<td>Analog chain malfunction</td>
<td>Internal tests shown normal behaviour of the electronics and analog chain</td>
</tr>
<tr>
<td>Discriminators malfunction</td>
<td>Not really compatible with observation. First attempt of in-flight extensive testing failed (commanding issues). Dedicated test will be part of the next checkout.</td>
</tr>
</tbody>
</table>
**FUV Anomaly**

- **What has been tried to improve performances:**
  - « Play » with the Discri values
    - The idea: If the noise corresponds to counts having a low charge (which is usually the case), increasing the discriminators thresholds would remove it partially.
    - Increasing the Discri value has a positive effect on the detector’s performance, but does not allow recovering the expected performances.
    - « Optimum setpoint »: ~4.8kV/Discri14
  - « Play » with the discri mode (« or »/« and »)
    - The idea: The « AND » mode selects only the events that are « seen » by all four channels of the RAE, while the « OR » mode (usually used) selects the events if at least one channel sees it.
    - On the paper, using the « AND » mode can improve the SNR at the center of the detector. But after having tested it, this option is not considered anymore (useful area significantly reduced).
• **Conclusion/Plan**
  
  • Not so many hypotheses or things to investigate...

  • It would worse it processing/analysing again the PHA vs HV data acquired in flight (sum and channel data) + comparison with FS.
  
  • Discri test in flight should be part of the next checkout
• During the commissioning of the detectors with HV ON (in May 2019) an « event » occured during a HV ramp on the EUV detector, showing simultaneously:
  • Count rate increase
  • PHEBUS primary current increase (monitored by the S/C)
  • HV drop
  • + image acquired showing a specific pattern (« trail »)

Discharge/avalanche?
Some general comments:

- 11 occurrences since May 2019 (barely 50% of the observations)
- The symptoms are ~stable (CR, primary current, HV monitoring, images)
  - No clue in the others HKs (voltages, temperatures)
- The conditions under which the event occurs are not yet fully understood
  - -2.5 kV to -3.4 kV
  - With or without outgassing prior observation (usually few days before)
  - Within a quite large range of temperature (MCP: -6°C to +22°C / Elec: -6°C to +36°C)
  - In counting regime (> | -2.8 kV |) or not
  - In observation mode or during the HV ramp
- Typical duration of an event: few tenths of seconds (10 – 70 s)
- The occurrence of the event does not damage the detector (except possible stress)
- After an occurrence, the detector recovers and science continues as if nothing had happened (no idea about a possible repetition rate)
- No degradation seen on the sensitivity of the detector (i.e. no hot spot nor cold spot)
## EUV Anomaly

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>HV ramp</th>
<th>Duration after Switch ON</th>
<th>HV</th>
<th>MCP Temp.</th>
<th>Electronics Temp.</th>
<th>Counting regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 23/05/2019</td>
<td>NECP3</td>
<td>Fast (1 min)</td>
<td>5 min</td>
<td>3.4 kV</td>
<td>~-0.5 °C</td>
<td>~+2°C</td>
<td>Yes</td>
</tr>
<tr>
<td>#2 29/08/2019</td>
<td>NECP4</td>
<td>Fast (1 min)</td>
<td>0 min</td>
<td>Pendant la rampe</td>
<td>~-6°C</td>
<td>~-6°C</td>
<td>Yes</td>
</tr>
<tr>
<td>#3 16/03/2020</td>
<td>Rallumage EUV</td>
<td>Very slow (5h)</td>
<td>5 h</td>
<td>3,15 kV</td>
<td>~+14°C</td>
<td>~+29°C</td>
<td>Yes</td>
</tr>
<tr>
<td>#4 17/03/2020</td>
<td>Observation MuSco</td>
<td>Slow (1 h)</td>
<td>50 min</td>
<td>2,5 kV</td>
<td>~+2°C</td>
<td>~+13°C</td>
<td>Non</td>
</tr>
<tr>
<td>#5 17/03/2020</td>
<td>Observation fond IP</td>
<td>15 min</td>
<td>10-15 min</td>
<td>2,9 kV</td>
<td>~+4°C</td>
<td>~+13°C</td>
<td>Yes (on the edge)</td>
</tr>
<tr>
<td>#6 17/02/2021</td>
<td>Observation Venus</td>
<td>Slow (2h40)</td>
<td>3 h</td>
<td>3.4 kV</td>
<td>~+19°C</td>
<td>~+33°C</td>
<td>Yes</td>
</tr>
<tr>
<td>#7 30/03/2021</td>
<td>Observation cône He</td>
<td>Very slow (5h40)</td>
<td>4.5 h</td>
<td>3.4 kV</td>
<td>~+22°C</td>
<td>~+36°C</td>
<td>Yes</td>
</tr>
<tr>
<td>#8 25/06/2021</td>
<td>Observation BetaCanis Major / IPB</td>
<td>~30-40 min</td>
<td>~1h</td>
<td>3.4 kV</td>
<td>~+7°C</td>
<td>~+21°C</td>
<td>Yes</td>
</tr>
<tr>
<td>#9 10/08/2021</td>
<td>Observation Venus</td>
<td>~30-40 min</td>
<td>~1h</td>
<td>3.4 kV</td>
<td>~+8°C</td>
<td>~+22C</td>
<td>Yes</td>
</tr>
<tr>
<td>#10 01/10/2021</td>
<td>Mercury Fly By</td>
<td>~30-40 min</td>
<td>~30 min</td>
<td>3.3 kV</td>
<td>~+9°C</td>
<td>~+21C</td>
<td>Yes</td>
</tr>
<tr>
<td>#11 09/10/2021</td>
<td>Mercury/Venus</td>
<td>~30-40 min</td>
<td>~25 min</td>
<td>2.7 kV</td>
<td>~+13°C</td>
<td>~+23C</td>
<td>Yes (on the edge)</td>
</tr>
</tbody>
</table>
EUV Anomaly

**XUV Count rate, High Voltage Monitor and PHEBUS current consumption overplot**

- Event setpoint
- HV drop @1500V
- Primary current + 100mA
- CR reaches 700-1200 cps typ.
- Trail on the images (if any)
• **How to explain the « trail » ?**

  • Parasitic capacitor between the RAE and MCP generates « ghost counts » when the HV fluctuates.
  
  • We know that the HV varies during the event (previous slides)
  
  • Currently investigating whether we can verify this by test with the EUV FS :
    
    • Test #1 : Direct measurement of the capacitor
    
    • Test #2 : Pulse injection on « Bias » while operating the detector
• Does it take place in the MCP or Electronics ?
  • MCP exposed to the internal environment of the instrument (« optical cavity »)
  • Electronics in a separate box, vented directly into the S/C
  • No clear evidence yet, but it is more probable that the event takes place in the HV circuit (no hot/cold spot identified yet).

• Root cause ?
  • The main assumption since 2019 and until recently was that a HV discharge could be generated due to outgassing... But :
    • The instrument is in space for more than 3.5 years...
    • We have done several « forced outgassing » (detector ON, HV ON 1 kV for several days) without having noticed any improvement
    • Some analyses have been done showing that the sizing of the vents is OK

➢ Now investigating around the HV electronics itself
EUV Anomaly

• Recent work & work in progress/plan…
  • Electrical/thermal stress analysis for the PHEBUS main electronics (+12 V line)
    • Done, no stress identified
    • +~3 W during the event
    • It is not yet demonstrated that the increase of the primary current seen during the event is the consequence of having the HV converter in current limitation mode. → Test needed
  • Behaviour/stability of the HV converter
    • Working on a test plan to better understand the electrical (dynamic) behaviour of the PICO converter
    • Hardware available:
      • Representative HV board for any kind of test
      • EUV FS @ LATMOS for low risk test
  • Build an electrical model of the detector, including parasitic components (R, L, C)
  • Test on EUV FS
    • Inject transient voltage on last stage of the MCP, other HV terminals shorten (i.e. no electric field in the MCP)
    • → Should produce a trail on the images
  • Extended analysis of the EUV data (images, ...) on going. This will provide clues on:
    • The cause of the trail (parasitic capacitor)
    • The charge drawn during the event

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Thank you!
Questions?