CAGIRE

A NIR camera at the focus of the COLIBRÍ Ground Follow up Telescope

to quickly observe SVOM and multi-messengers alerts

J.L. Atteia for the CAGIRE team & S. Basa for the Colibrí team

Context and Partners

- CAGIRE is a NIR camera developed in the context of the *SVOM* mission (https://www.svom.eu/)
  - To quickly observe the afterglows of gamma-ray bursts detected by *SVOM*, *up to the largest distances:* redshift z ≈ 11, when the universe was 3% of its current age (400 10^6 yr).
  - To look for the NIR counterparts of other HE transients and multi-messenger transients: GW or neutrinos.

- CAGIRE is funded by CNES, CNRS (IRAP), and the LabEx FOCUS. CAGIRE involves several partners:
  - Lynred & CEA-LETI
  - LabEx FOCUS
  - CEA-IRFU / CPPM / IRAP / LAM

- Responsibilities:
  - CAGIRE is built under the responsibility of IRAP.
  - Coordination between the different partners is made by CNES.
  - CEA and CPPM will characterize the detector before its integration in CAGIRE.
  - Coordination with Colibrí is made by the project team at LAM.

- CAGIRE will be delivered at OAN SPM in 2024.

FOCUS Decision (back in November 2017…)

Orig. : *Pierre Kern & Pierre-Olivier Lagage*
Dest. : Stéphane Basa
Date : 20 Novembre 2017
Version : v1

Subject : **An infrared camera for the Ground Follow-up Telescope of the SVOM mission**

Cher Collègue

Nous vous remercions d'avoir soumis un projet à l'appel d'offre du labex FOCUS du mois de juin 2017.

Votre proposition de projet au CS FOCUS du 12 juillet 2017 , référencé DIR-EXP-2017-SB et intitulée "An infrared camera for the Ground Follow-up Telescope of the SVOM mission a été retenue. A ce titre le détecteur prototype 2kx2K SOFRADIR qui sera livré à FOCUS à l'issue du développement ALPHA de l'ESA sera attribué à votre projet dans le cadre du programme SVOM. En outre FOCUS financera une électronique de lecture dédiée pour ce projet. Cette électronique de lecture sera approvisionnée par le DAP-CEA à Saclay sur budget FOCUS. Le choix de la solution sera faite avant la fin de l'année 2017 pour un approvisionnement dés que possible en 2018. Il sera nécessaire de rédiger un MOU entre le projet SVOM et FOCUS dans les mois à venir.

Vous trouverez ci après le rapport du conseil scientifique

Cordialement,

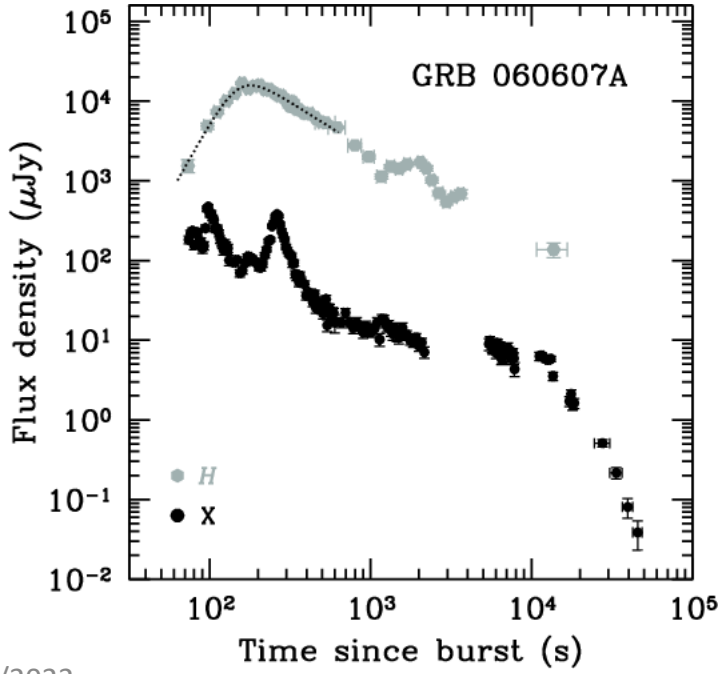
Outline

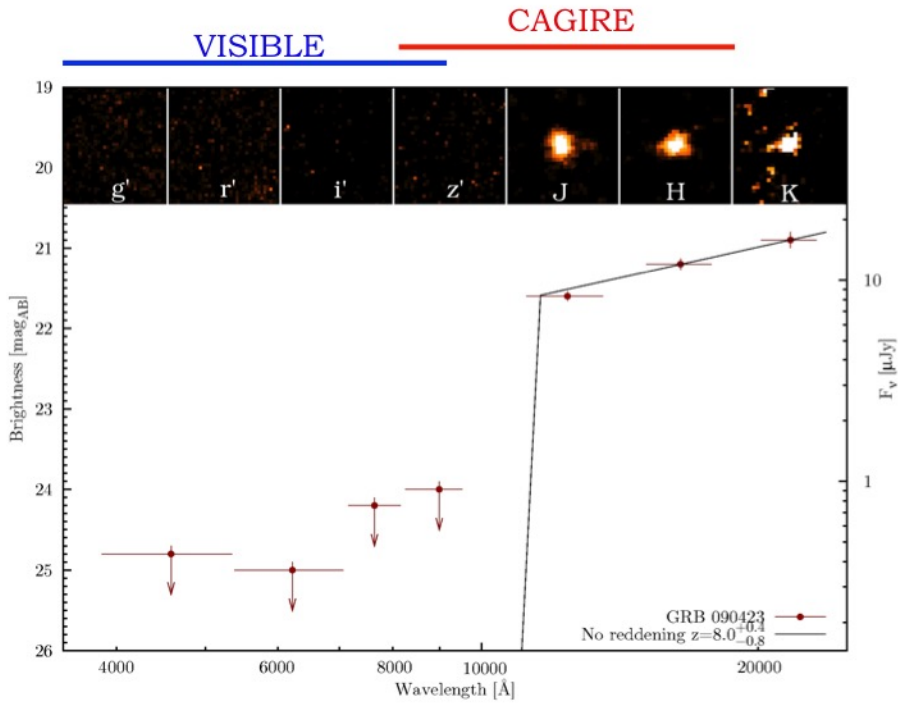
- Science goals
- The instrument
- Instrument status
- The sensor
- Operations

Scientific objectives

- Extend towards the NIR the frequency range of GFT/Colibrí:
  - To detect highly redshifted and extinct sources.
  - To expand the photometry of optical transients and of permanent sources into the NIR: Photo-z, Dust properties, etc.
- The early afterglow (<1000 s) of GRBs is poorly observed in the NIR.
- Soon after the GRB, NIR afterglows can be very bright...

(Molinari et al. 2007 – REM-IR)





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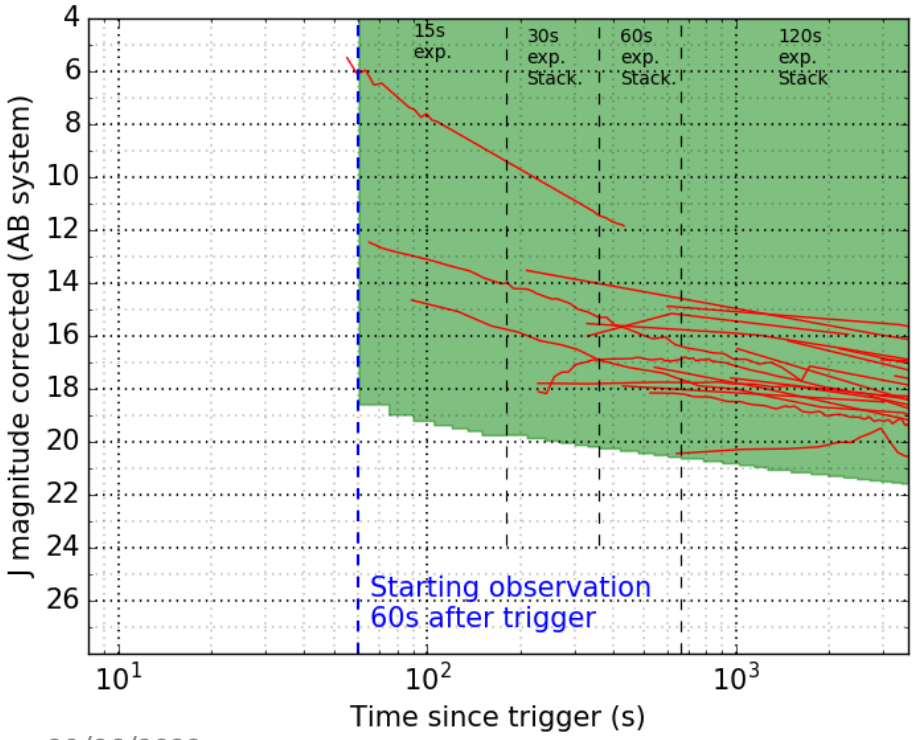
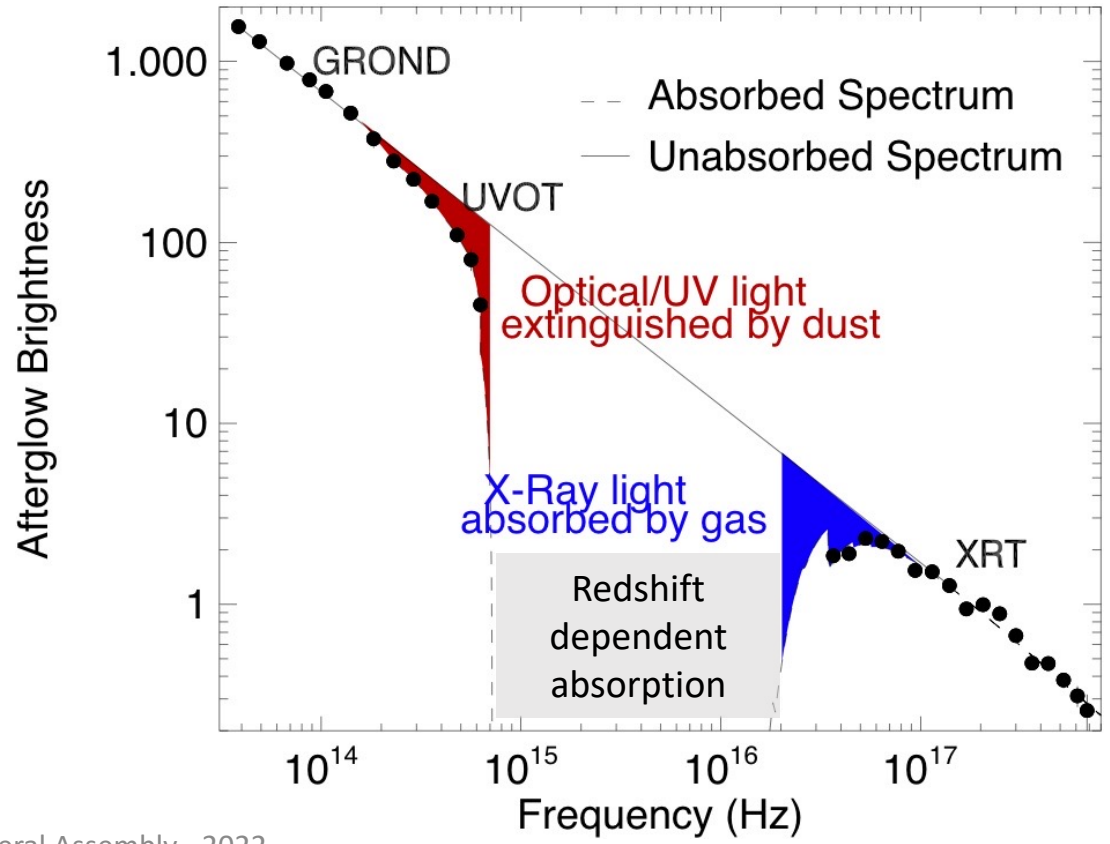
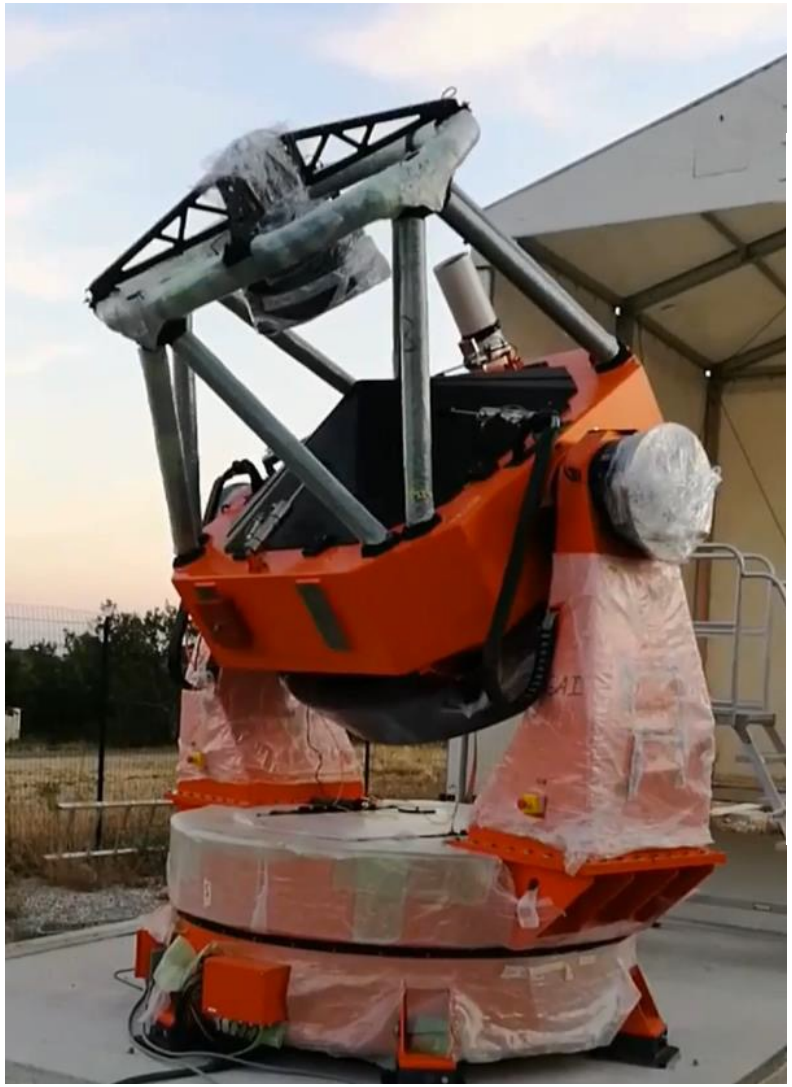
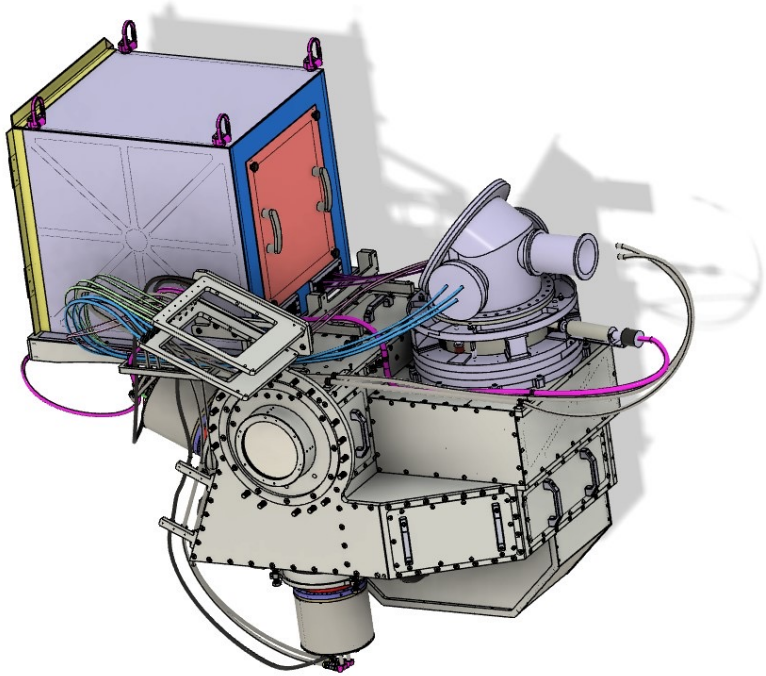


(Credit: P. Schady)



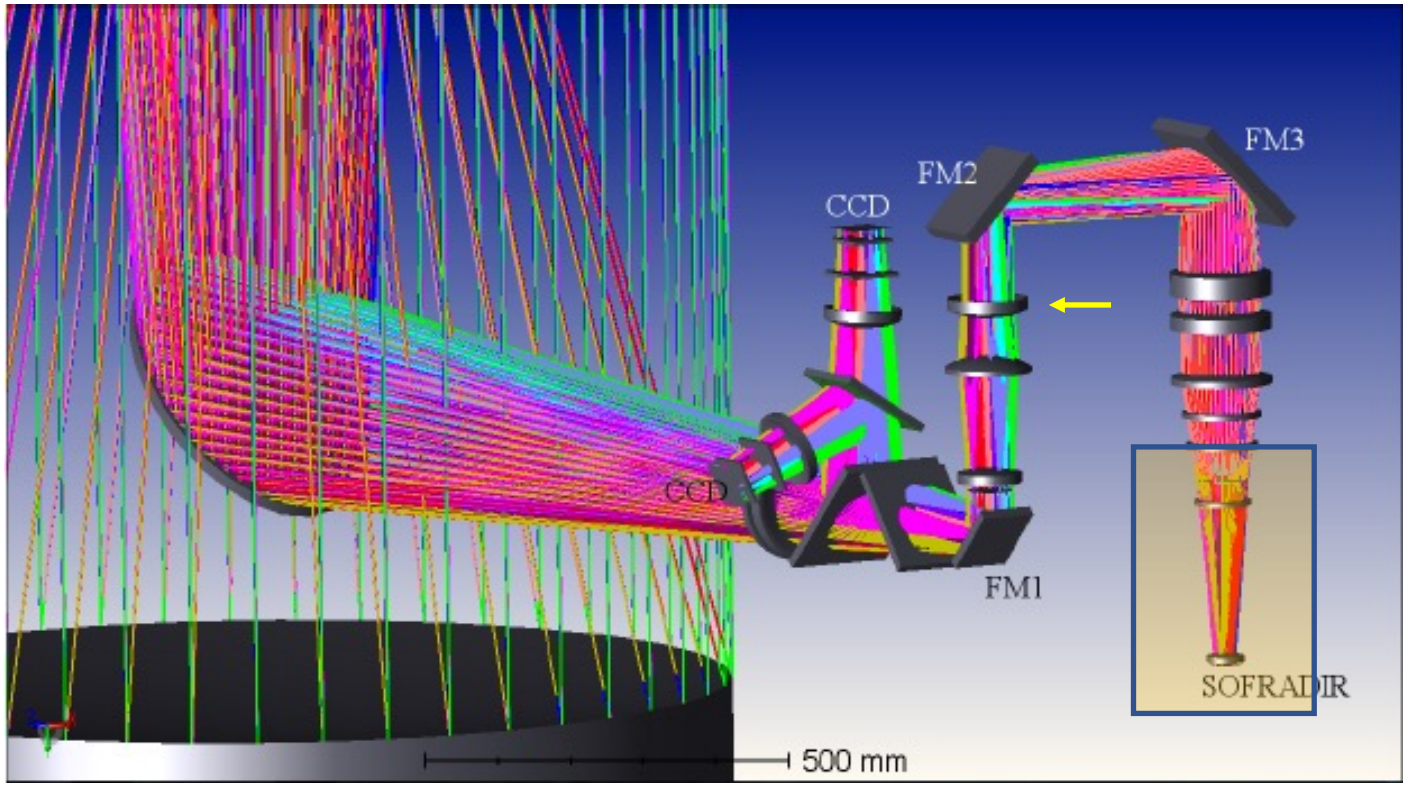
Colibrí and CAGIRE

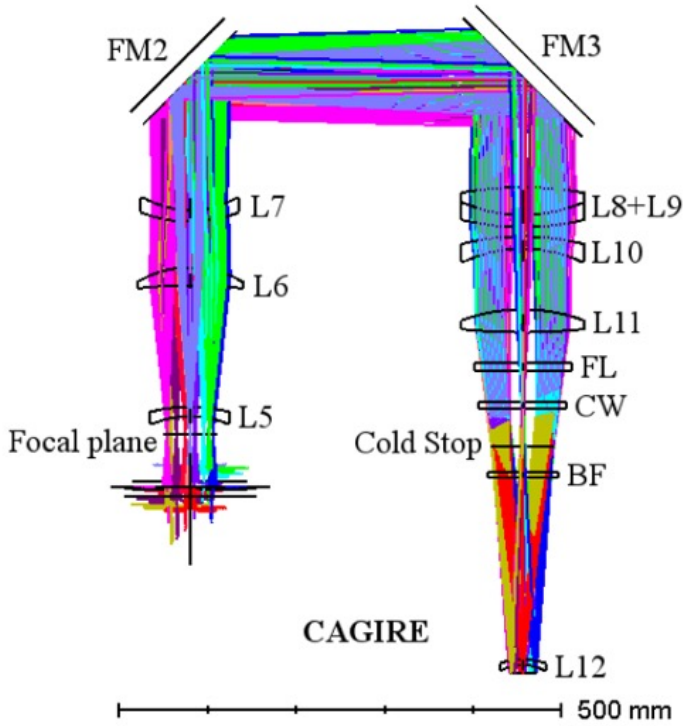




Optical design

- The optical design has been made by UNAM.





CAGIRE science requirements

Criterion	Parameter	Value	Comment
S02[a]	Spectral range	Must cover J & H photometric channels ([1.1 – 1.8] µm)	
S07	Detector readout mode	Up The Ramp	Science mode @ 100 kHz
S08	Time to start a new observation	≤ 5 s	
S09	Time resolution	≤ 2 s	
S10	Timing accuracy	100 ms	
A01	Number of outputs	32	
A02	Readout time	1.33 s	
A03	Linear well CHC	≥ 80 ke-	Linearity better than 5% at 80 ke-
A04	CDS Noise	≤ 55 e- rms	Decrease of mag. limit ≤ 0.15 wrt 20 e- rms
A05	QE @ 100K	≥ 0.7	Measured at 1.3 & 1.7 µm Cf. doc “GFT expected performance”
A06	Dark current	≤ 1 e-/pix/s	Not critical, considering the sky background
A07	Pixel operability	≥ 95% (TBC)	A pixel is operable if the following parameters are in their acceptable range: CDS Noise – Dark current – Linear well – QE – Persistence – Light response
A08	Cross-talk (total)	≤ 5%	Measured at 50% of full well
A09	Persistence	≤ 25 e-/s/pix (TBC)	Measured during 60 s after a 60 s saturated exposure. Cf. doc about persistence

A NIR camera on a fully robotic telescope

Design trade offs

- Outside the cryostat, warm optics:
  - VIS vs NIR separation at 1.1 µm.
  - Focus done by moving L7.
  - Warm shutter
  - J & H filters: [1.17 – 1.33] & [1.49 – 1.78] µm

- Inside the cryostat:
  - Cold pupil.
  - Blocking filter for wavelengths >1.78 µm.
  - 1 ALFA detector from the Lynred company.

  - No cryogenic mechanism in normal operation.
  - Can use a moveable cold shutter to put the detector in darkness, during engineering periods.

- Detector is readout with the New General Controller from ESO.
- All observations made in Up The Ramp mode (UTR).

- No dithering.
- No ADC.
- Fast inline data analysis.

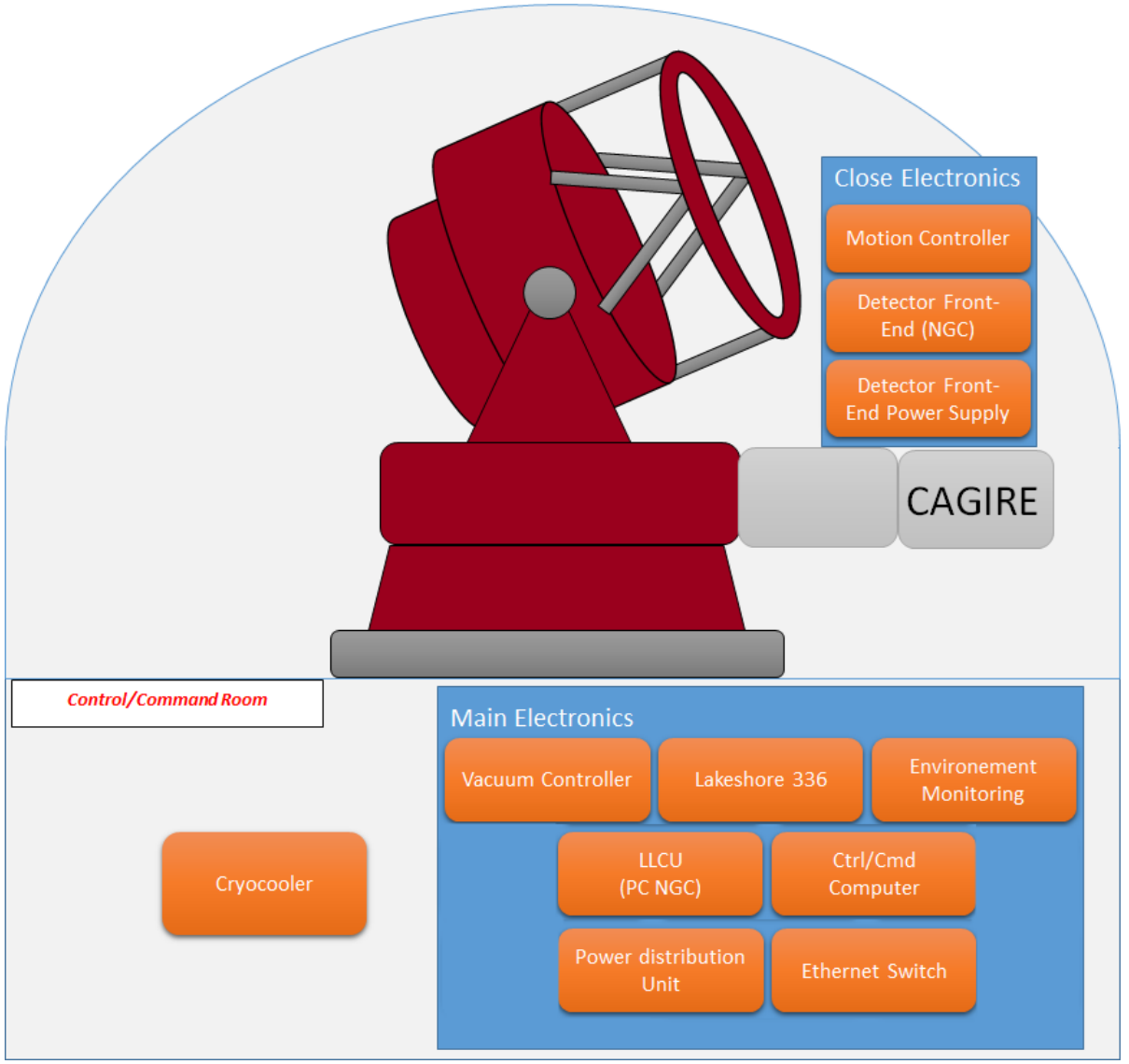
CAGIRE is essentially a passive instrument, which executes ramp observations upon request, and sends back NIR images for the Astronomy pipeline, in typically less than 60 s.

Three subsystems...

- The detector is operated by an ESO NGC controller, the output is amplified by a cold custom preamplifier, built by CEA-IRFU.

- CAGIRE encompasses three sub-systems:
  - Cryostat
  - On-board (close) electronics
  - Remote (main) electronics

- Some consequences:
  - Rotating instrument and controller.
  - Cryogenic vacuum.
  - Cable paths from the control room to the instrument.



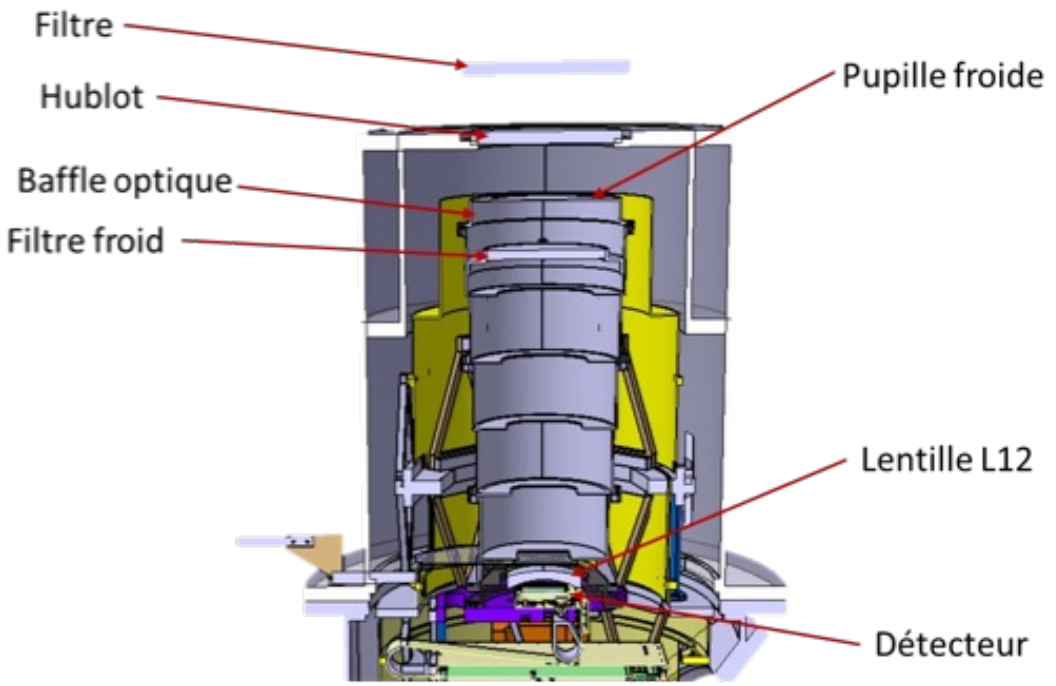
The cryostat

- The cryostat maintains the detector cold, under vacuum.

- Few optical components inside the cryostat:
  - A cold pupil and an optical baffle.
  - A cold filter blocking wavelengths longer than 1.8 µm.
  - A field lens, just in front of the detector.

- In normal operations there is a single mechanism: the warm J/H filter slide.

- A motorized cold shutter permits to have the detector in darkness for calibration purposes. It will be used during special engineering sessions.

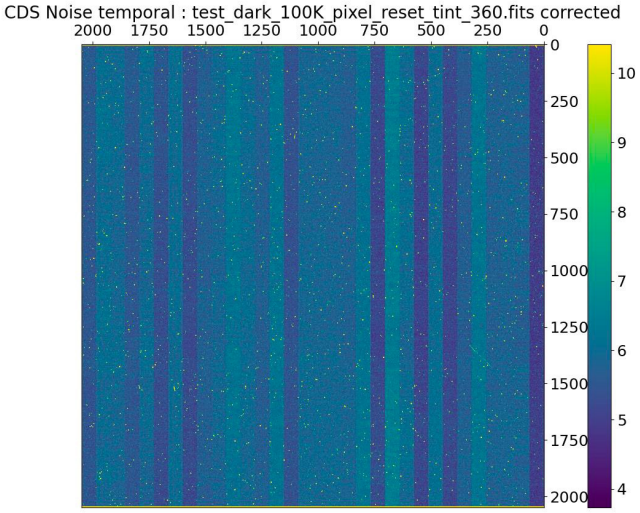


The Sensor

- ALFA (Astronomy Large Focal plane Array) is a 2k x 2k NIR detector jointly developed by CEA-LETI and the Lynred company.
- Two sensors are currently under test at CEA-IRFU. One of them (CH329505) is the future CAGIRE detector.
- Dark current, CDS noise and linearity have been measured, QE and persistence will be measured soon. At this stage, the CAGIRE detector seems to have very good performance, with a uniform response across the entire detector.

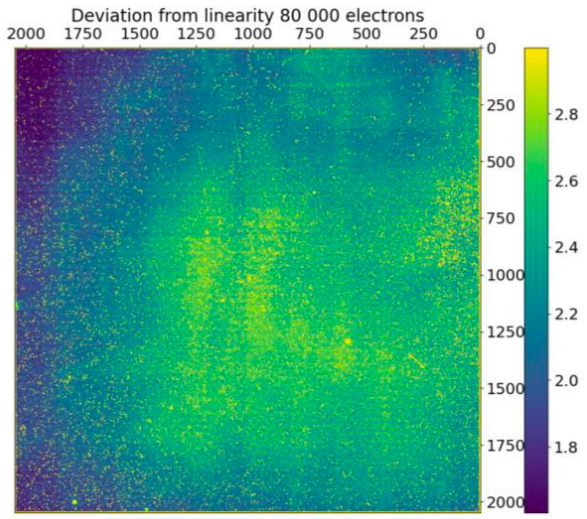
CDS noise

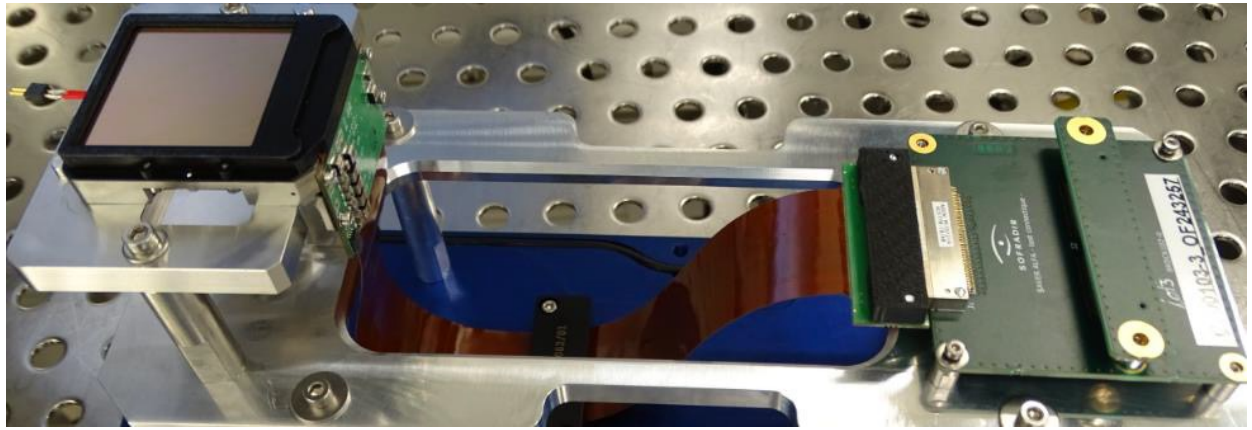
median = 43 e-



Deviation from Linearity at 80 ke-

median = 2.3%





Instrument Status

- PDR passed in June 2020.
- CDR passed in June 2021.
- I/F with Colibrí are fully defined: optical – mechanical – electrical – software
- Call for tender for the cryostat will be issued in the coming days.

- Two warm electronic chains (ROIC + preAmp + NGC) are available at IRAP and CPPM. They are used to prepare all the AIT/AIV activities with the real sensor.

- Two ALFA sensors produced by CEA-LETI and Lynred are being tested at CEA-IRFU, under a contract with ESA.
- ESA agreed to loan a very good sensor to FOCUS, for CAGIRE. The sensor will be made available for CAGIRE this fall. It will undergo a complement of characterization at CPPM, before going to IRAP for integration into the cryostat.

Operations

- CAGIRE is essentially a passive instrument, which executes ramp observations upon request, and sends back NIR images for the Astronomy pipeline, in typically less than 60 s.

- The instrument configuration parameters are minimal:
  - Filter: J or H
  - Ramp duration

- The detector is permanently under reset waiting to start a ramp.
  - When the ramp is finished, it is automatically processed within seconds to produce a flux map and its variance.
  - As soon as it is available, the flux map is made available to the Astronomy pipeline.

Sensitivity

- CAGIRE provides 0.65" pixels on the sky:

- The expected sky signal is 152 e-/s/pix in J and 1250 e-/s/pix in H respectively, or 4.6 ke- (J) and 37.5 ke- (H) in a 30 s exposure. Except for very short exposures, the noise will be dominated by the fluctuations of the sky signal.

- The sensitivity of CAGIRE has been computed in the document “Colibrí expected performance” (GFT-AN-A3135-046-UNAM): for an exposure of 240 s (8 exposures of 30 s), the limiting magnitudes are J_{lim} = 19.7 and H_{lim} = 18.8, complying with the science requirements.

Conclusions

- Studying the first minutes of GRB emission and multi-messenger transients at NIR wavelengths remains a crucial objective.

- CAGIRE has successfully passed the preliminary and critical definition reviews, it is now entering the realization phase.

- CAGIRE relies on the close collaboration of several partners:
  - FOCUS has attributed one ALFA detector → **Many Thanks!**
  - ESA has accepted to loan a very good sensor to FOCUS for CAGIRE → **Many Thanks!**
  - CEA-IRFU and CPPM are full partners of SVOM/CAGIRE, they characterize in details the detector before its integration in the cryostat and share their experience with IRAP.

- The instrument teams are working with enthusiasm to get CAGIRE looking at the NIR sky in spring 2024.