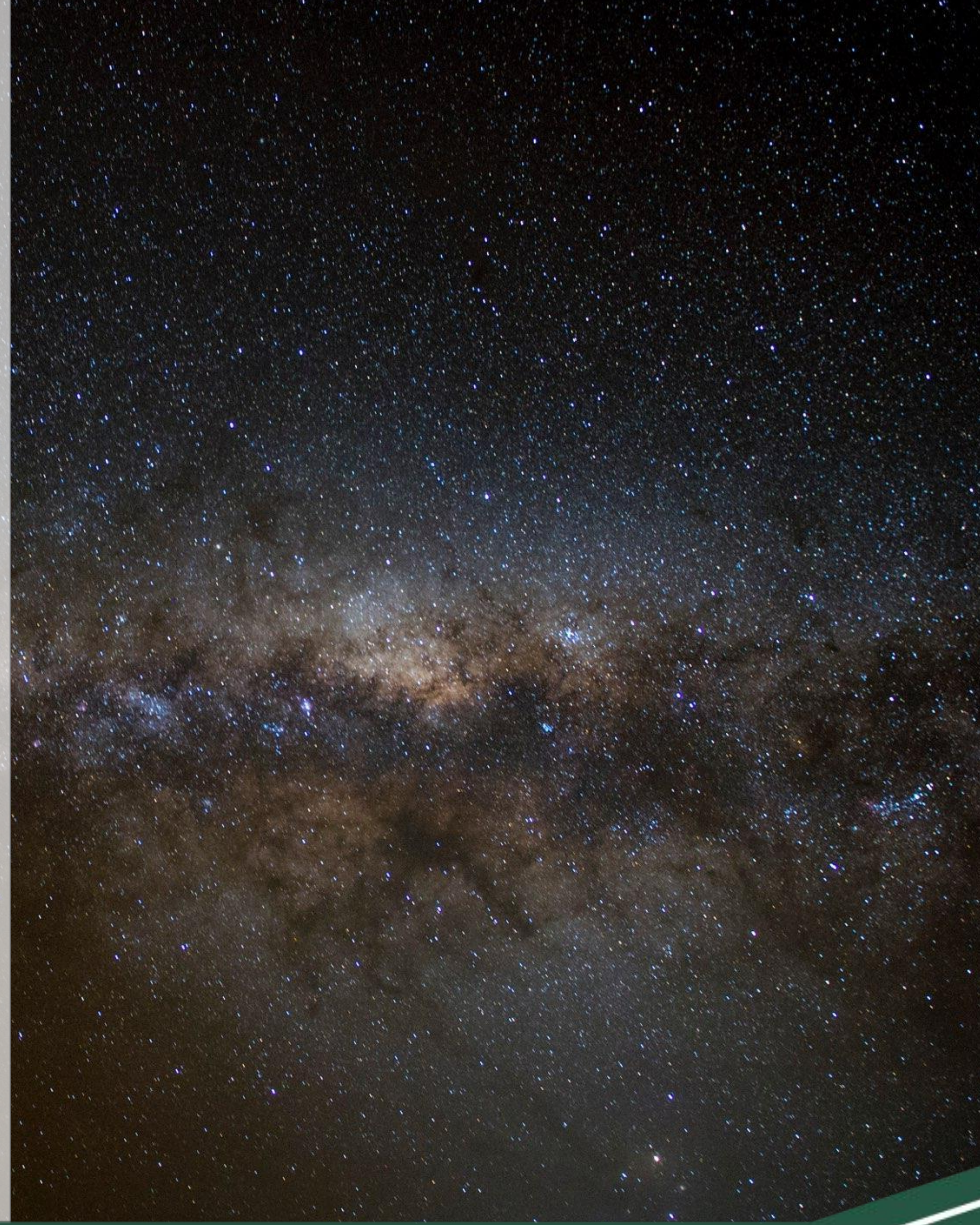
Astronomy
EuRopean
Infrared
Detector
ASTEROID

ASTEROID: “An astronomy infrared detector made in Europe”

Jorge Jiménez

Third Barcelona Techno Week
Meeting Point
July 9th, 2018

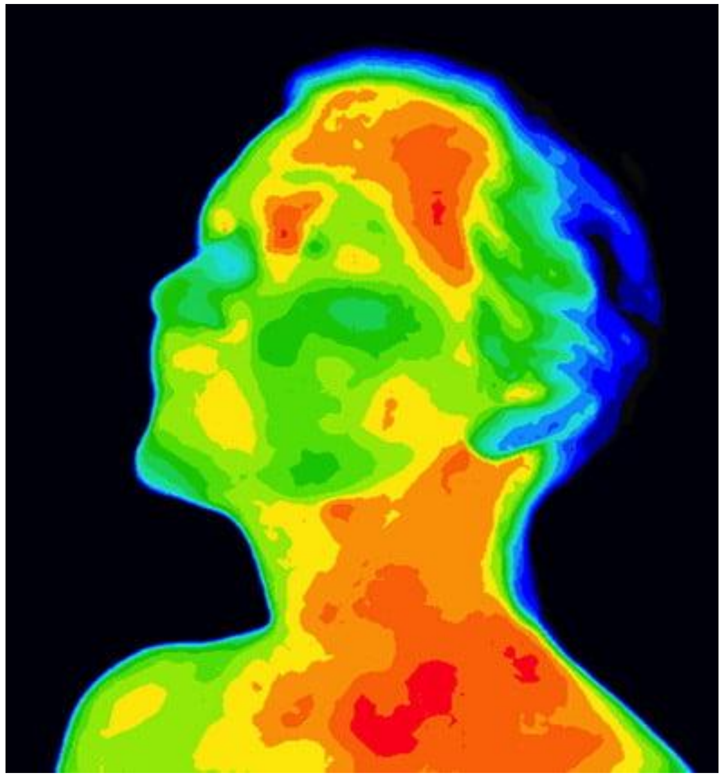


IFAE
25 years 1991-2016
Institut de Física d’Altes Energies
EXCELENCIA SEVERO OCHOA
BIST Barcelona Institute of Science and Technology

Overview

Main questions to be solved:

- **What is ASTEROID project?**
- **Which is the ASTEROID motivation?**
- **What kind of technology ASTEROID plan to use?**
- **Which are the tasks to be performed at IFAE?**



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What is NOT ASTEROID project?

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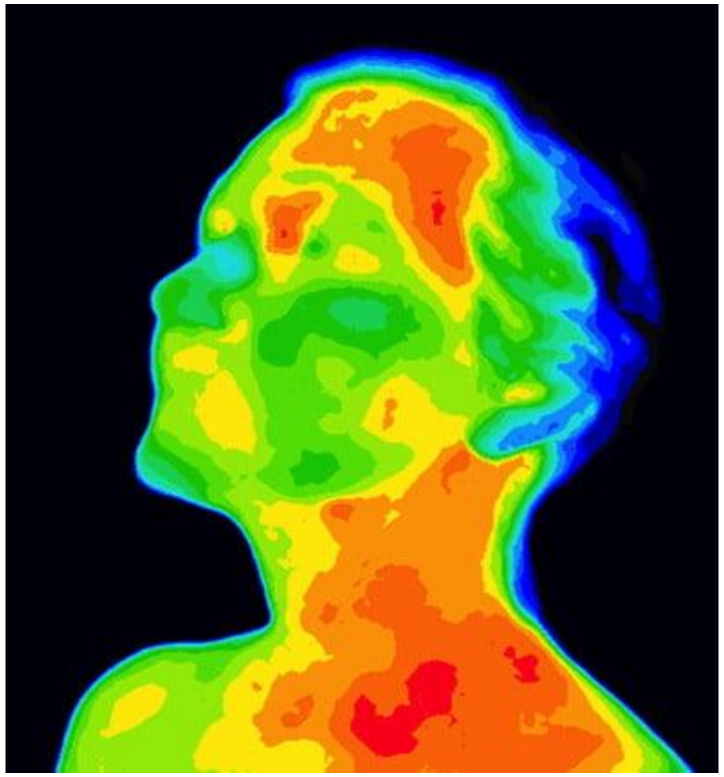


ASTEROID

ASTEROID (ASTronomy EuROpean Infrared Detector) is a H2020 project

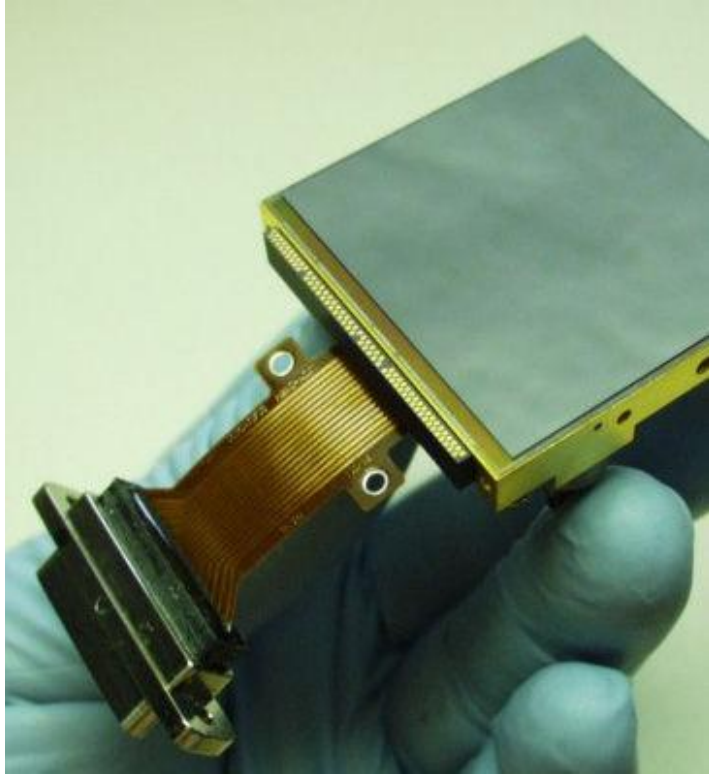
European Commission | Horizon 2020 European Union funding for Research & Innovation

TELEDYNE

- **Develop a NIR and SWIR detector 100% made in Europe**

  Current market is dominated by US and limited by ITAR export regulations

- **The target is to equal or exceed the performance of a Teledyne Hawaii (H***gCdTe* ***A****stronomical* ***W****ide* ***A****rea* ***I****nfrared* ***I****mage***) detector**



Hawaii-2RG detector

Image credits: Teledyne-e2v web page

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ASTEROID

- **Focused on space and ground-based astronomy**

  Main customers: ESA, ESO, CNRS, NASA, etc

- **Consortium of 6 european industrial partners and research institutions**

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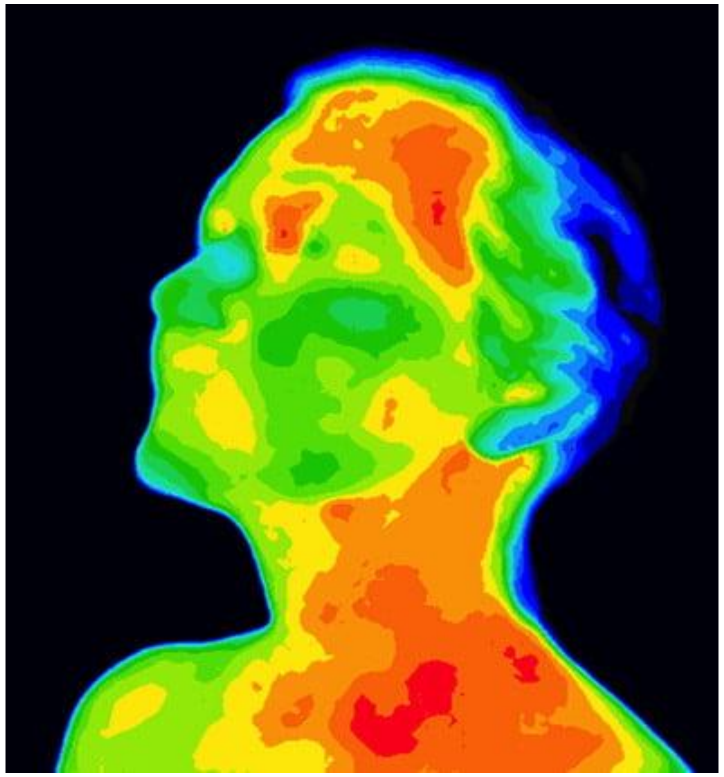
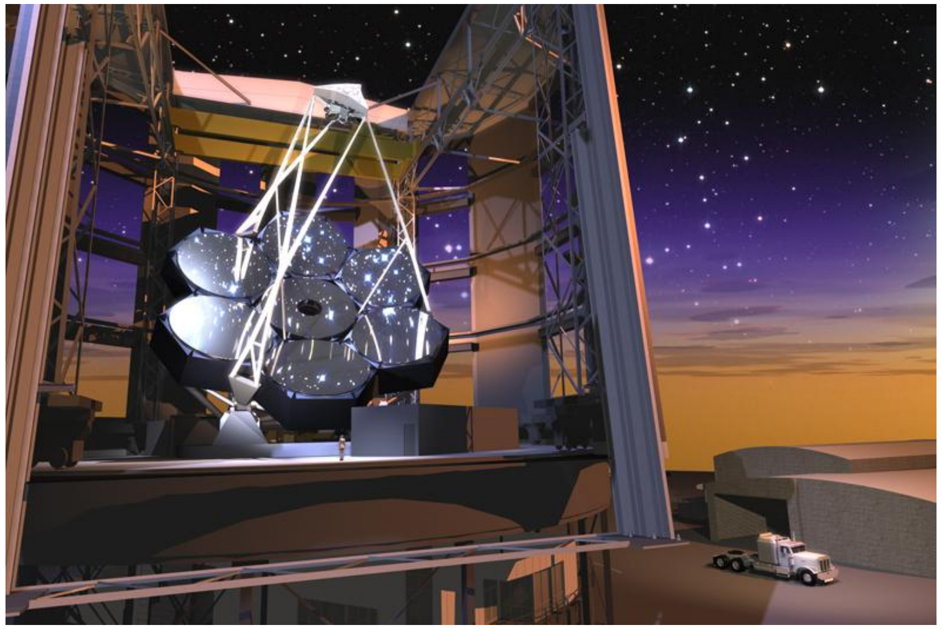


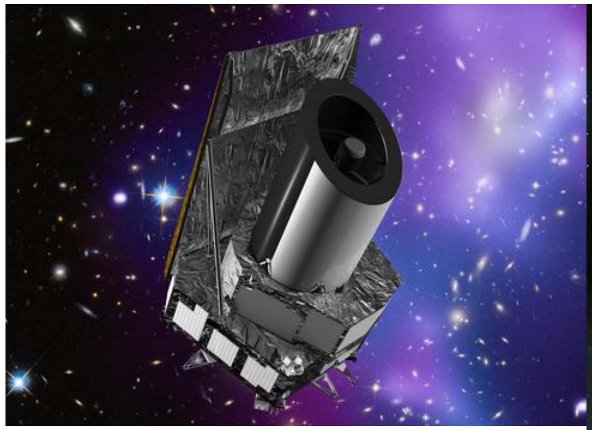
ASTEROID

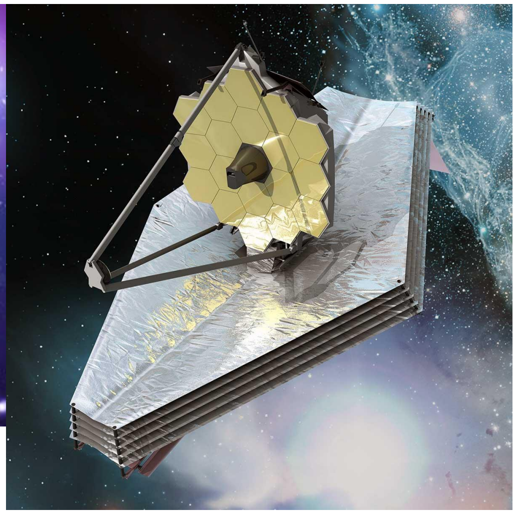
Expected market for the next coming years…



GMT telescope (La Serena, Chile) @ 2018

ESO VLT/VLTI (Atacama desert, Chile)





ESA-NASA Space Missions

TMT telescope @ (Hawaii, USA)

Images credit: ESO, TMT, GMT, EUCLID and JWST web pages

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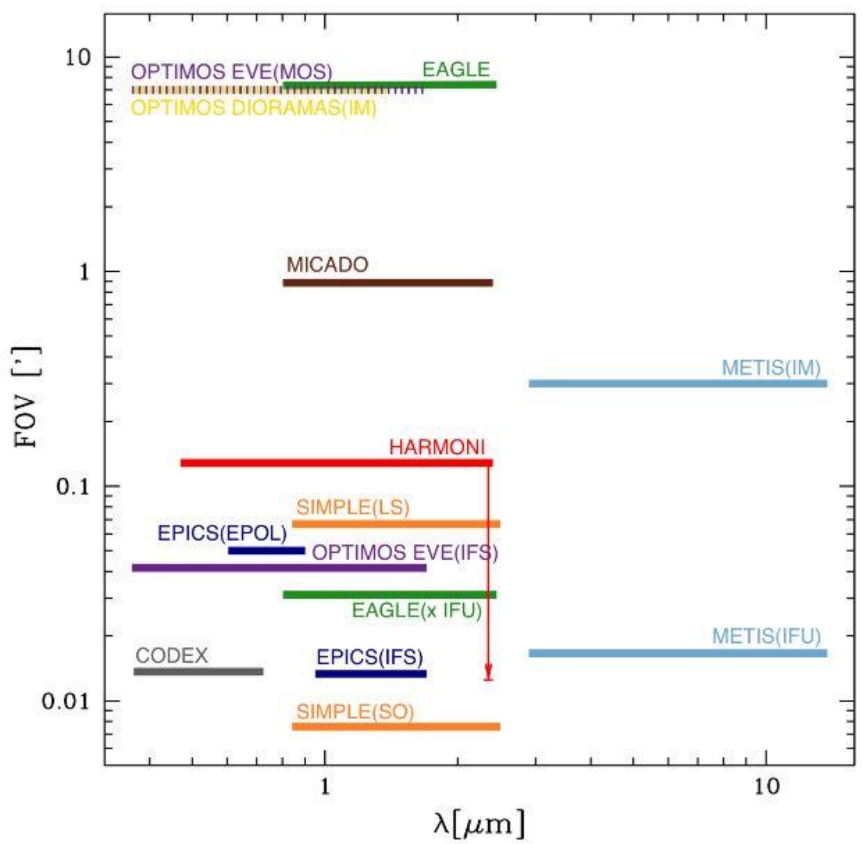
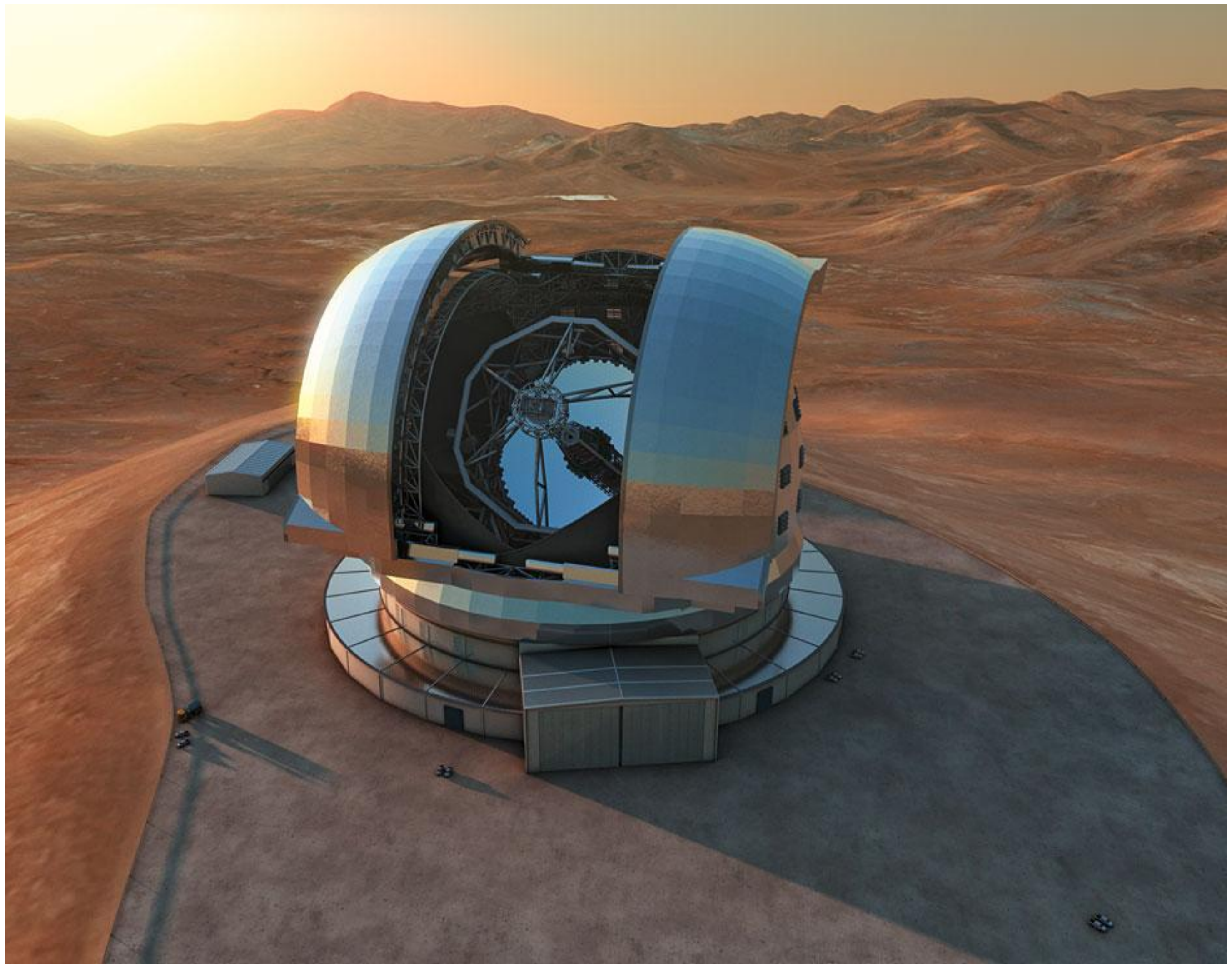
Expected market for the next coming years…(*cont*)

ESO ELT telescope @ 2024 (Atacama desert, Chile)



It will demand more than 220 2k x 2k IR detectors for its first generation instruments!



Source and Image credits: ESO ELT web page

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An analogy example:

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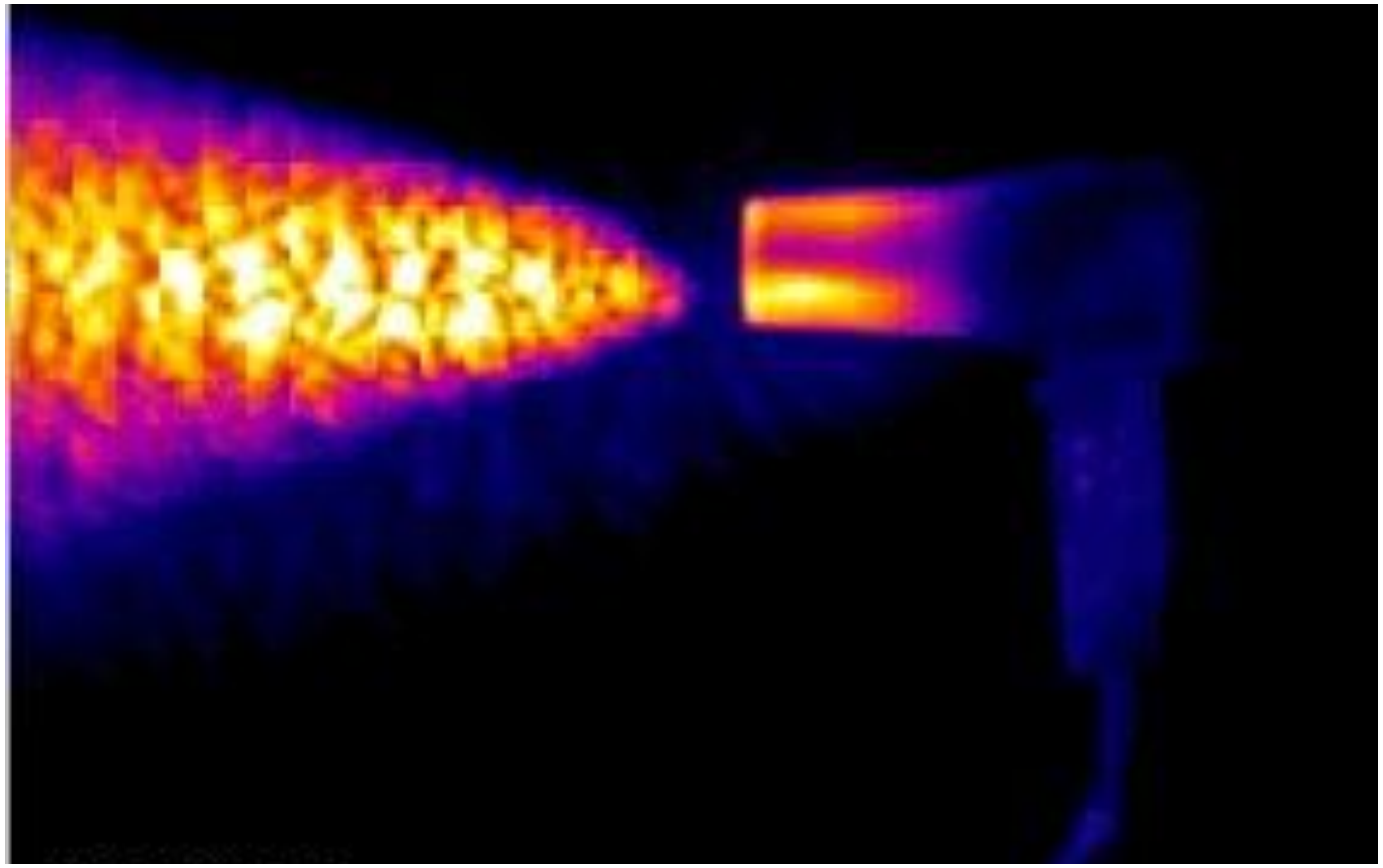

Hair dryer air flow at infrared wavelengths

Image credits: NASA/IPAC

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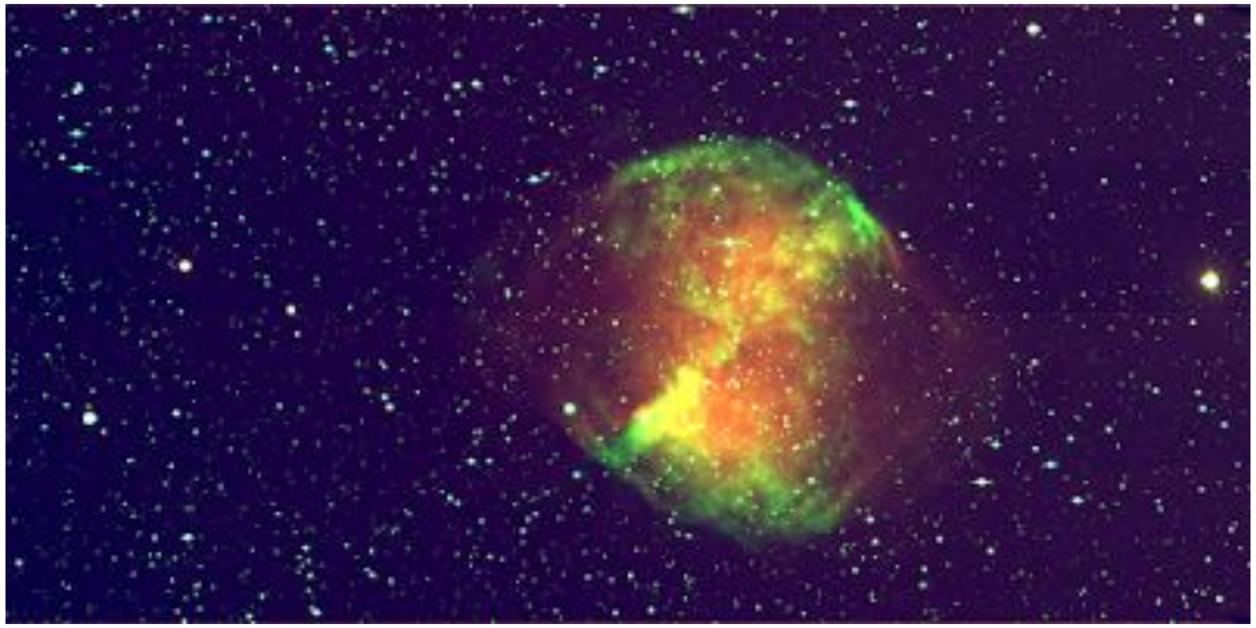
Applications fields:

IR image of the Dumbbell nebula (M27) using the Spitzer Infrared Array Camera (IRAC) at the NASA Spitzer Space Telescope



Visible image of the same nebula nebula (M27) using the the PAUCam at WHT telescope.

Image credits: NASA/SST and PAUCam web pages

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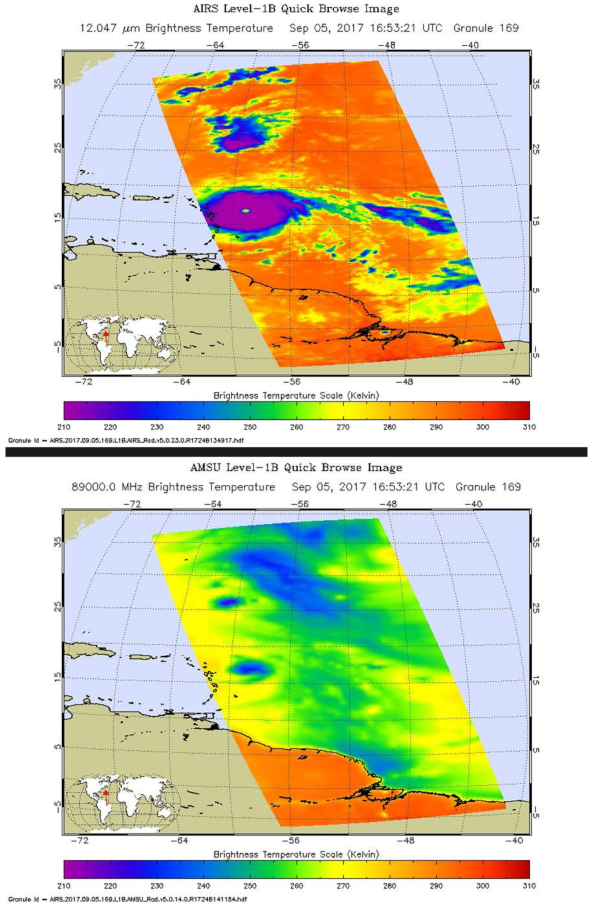
Applications fields:

Ground-based astronomy

"Mystic Mountains" of the Carina Nebula: a lot of more stars are visible that were not before.

Earth observation satellites

NASA NEO infrared image of Irma shows an "angry eye"



Space-based astronomy

Juno JIRAM instrument captures Jupiter's glow in infrared light

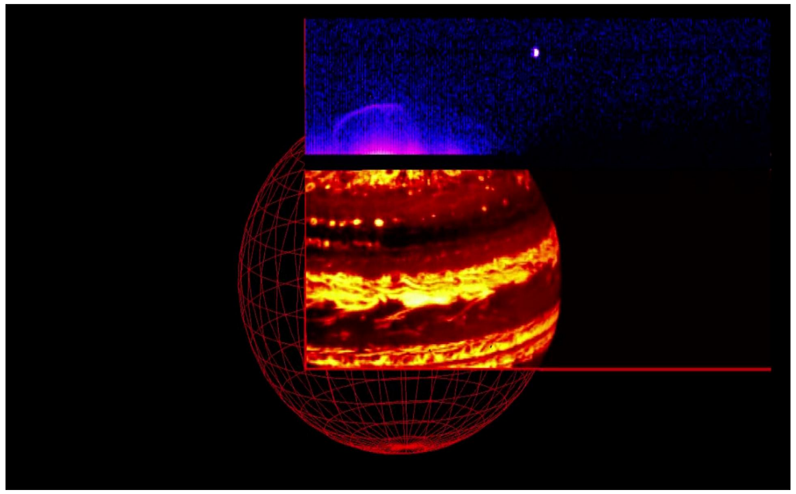


Image credits: NASA/IPAC

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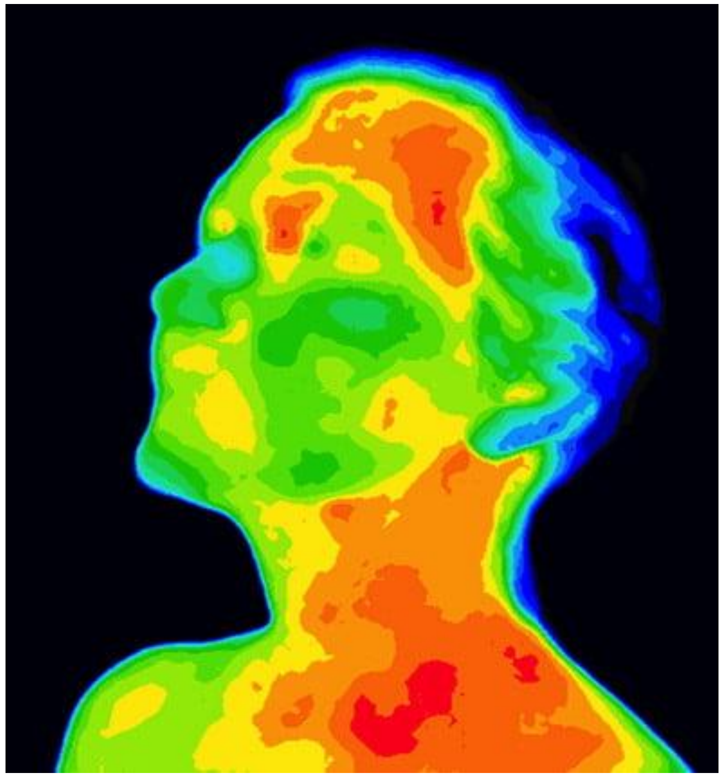

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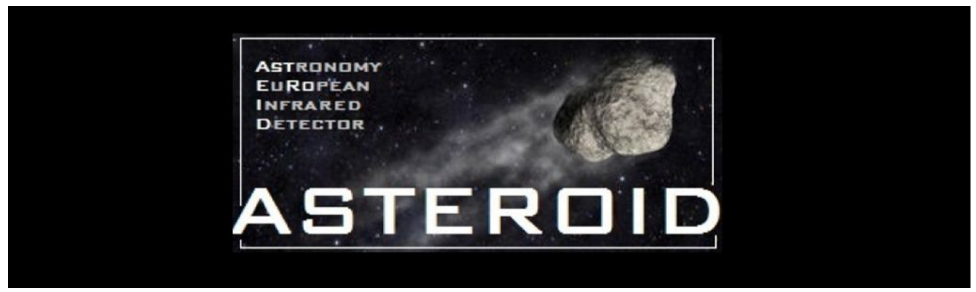

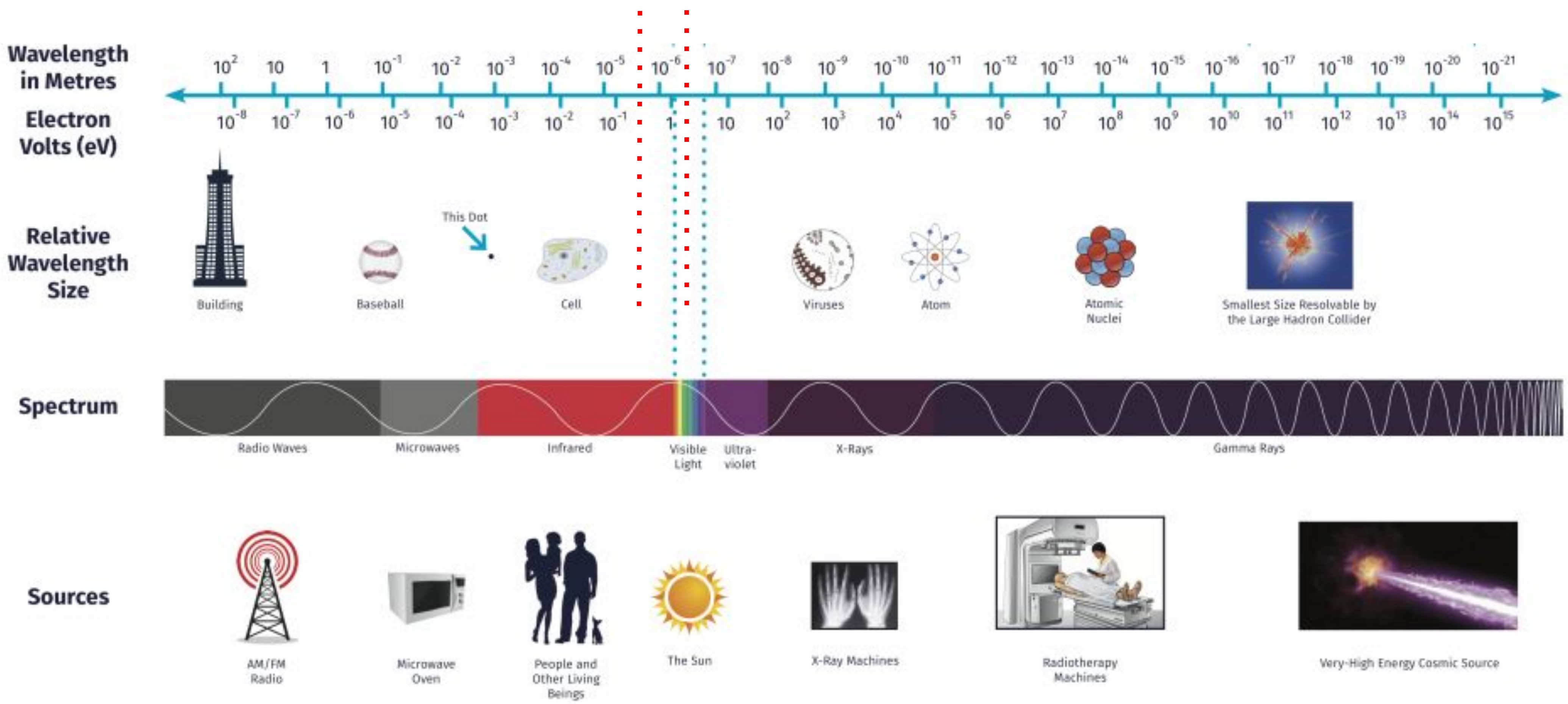

Image credits: Vecteezy.com, Dragonartz.net, NAOJ, NCI, CERN, NASA

ASTEROID

IR detectors

- **Silicon is only sensitive to wavelength below ~1 um**

  This is reason because we don't use CCDs

- **Other (exotics) semiconductors materials must be used for IR**

  Special interest on $Hg_{x-1}Cd_xTe_x$ since it cover a wide wavelength range

Material	Conduction Band [ev]	Cutoff Wavelength [um]
Si	1.11	1.12
InSb	0.18	6.9
Si:As	0.054	23
$Hg_{x-1}Cd_xTe_x$	1.6 … 0.09	0.7…14

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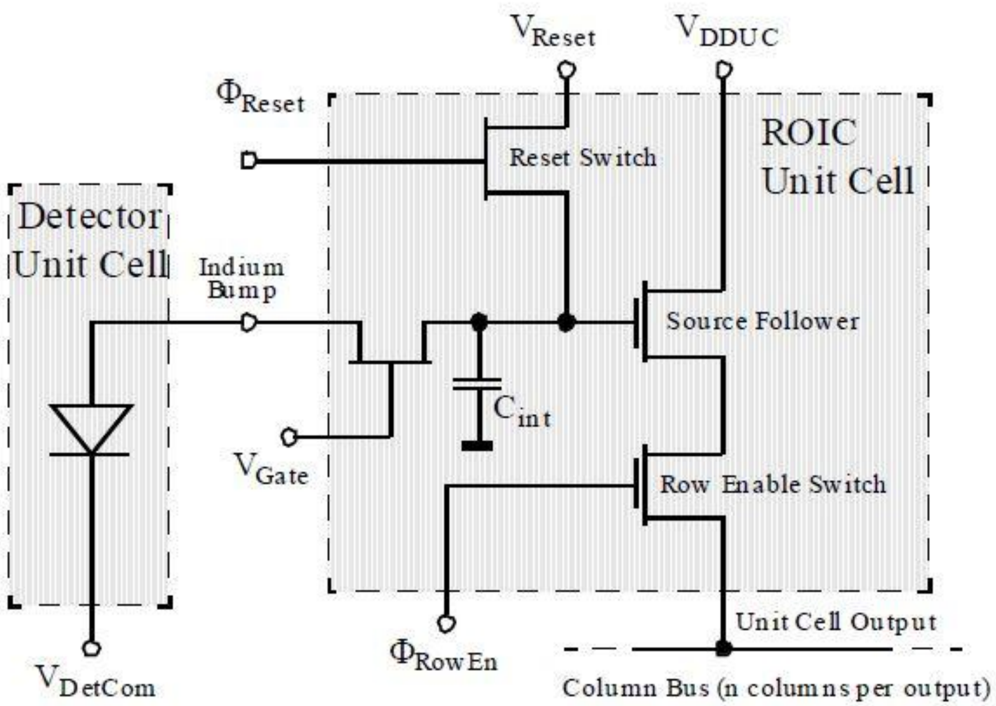
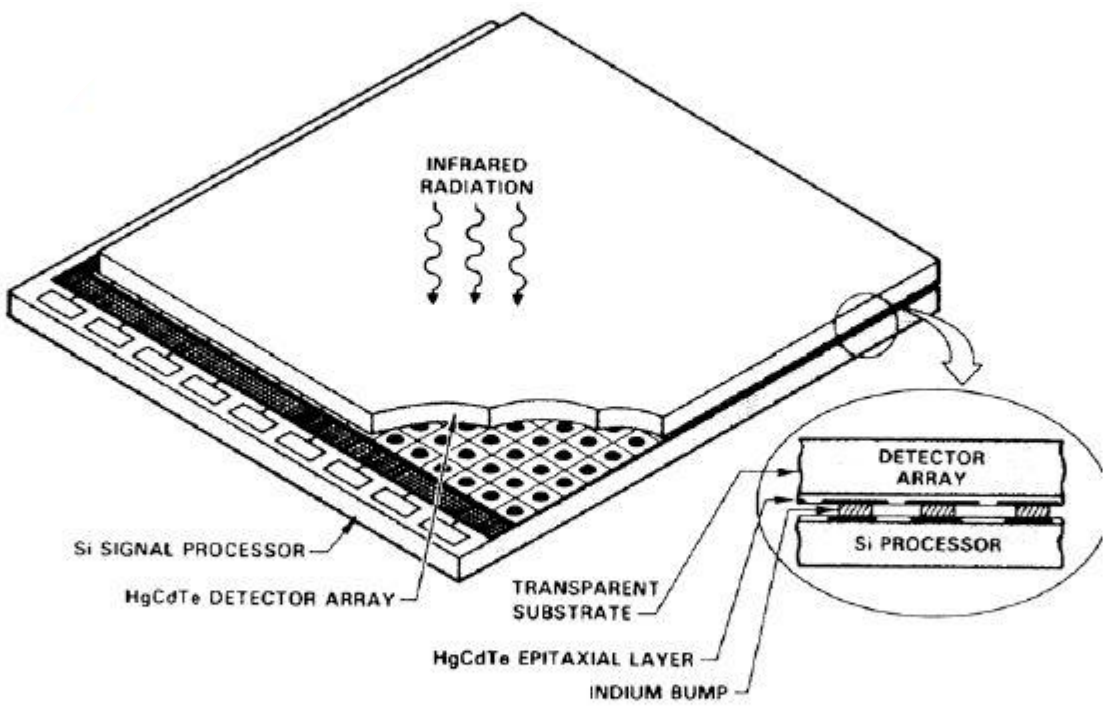
IR detectors (*cont*)

–An hybridized array is the solution!

Use a silicon based readout circuit (ROIC) with an exotic IR detector array





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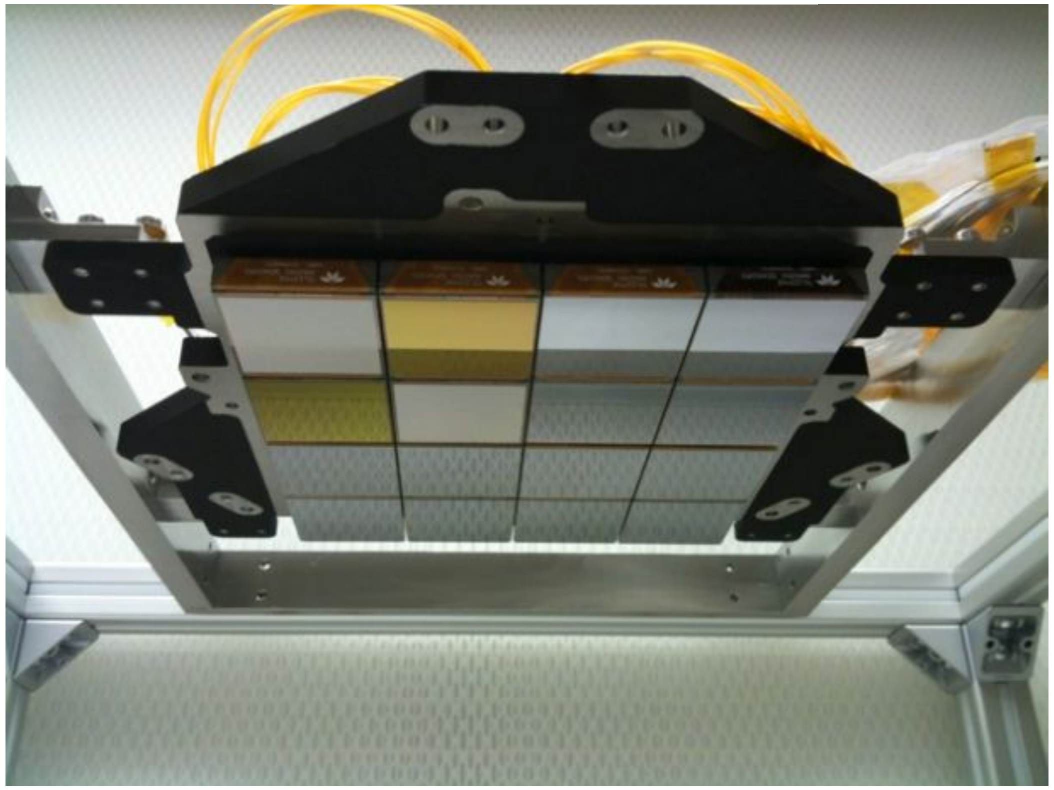
IR detectors (*cont*)

Expected performance for ASTEROID FPA (from a Teledyne Hawaii-2RG)

Parameter	**ASTEROID detector**
Number of Pixels	*2048 x 2048*
Pixel Size	*15 um*
Outputs Channels	*1, 4, 32*
Readout Speed	*500 kHz (slow mode)* *10 MHz (fast mode)*
Readout Noise (CDS)	*< 15 e- (slow mode)* *< 40 e- (fast mode)*
Operation Temperature	*30 K - 300 K*
Full Well	*100 - 150 ke-*
Mean QE (@ 2.5 um)	*> 80%*
Dark Current (@ 77 K)	*< 0.01 e-/sec*

euclid



Euclid NISP instrument focal plane

Image credits: Teledyne-e2v web page

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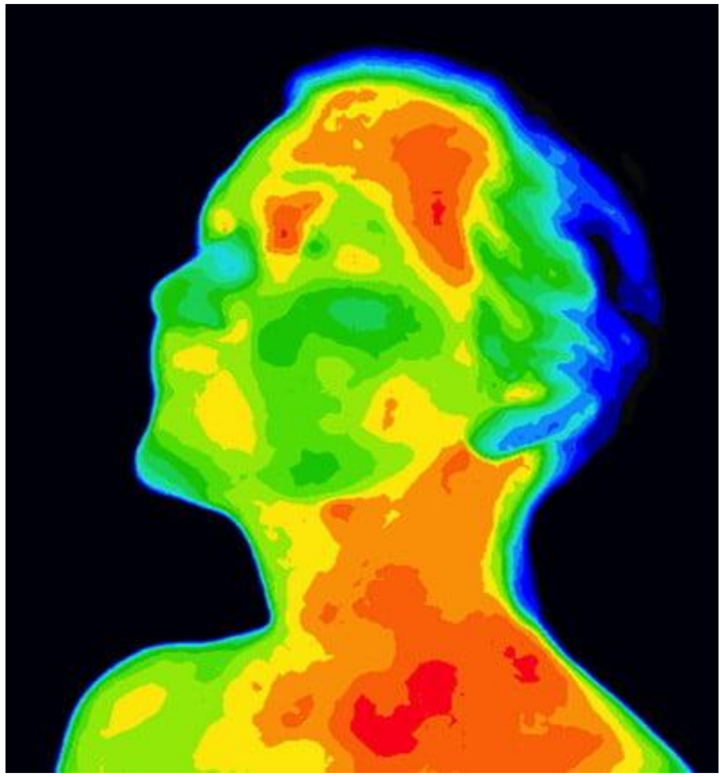
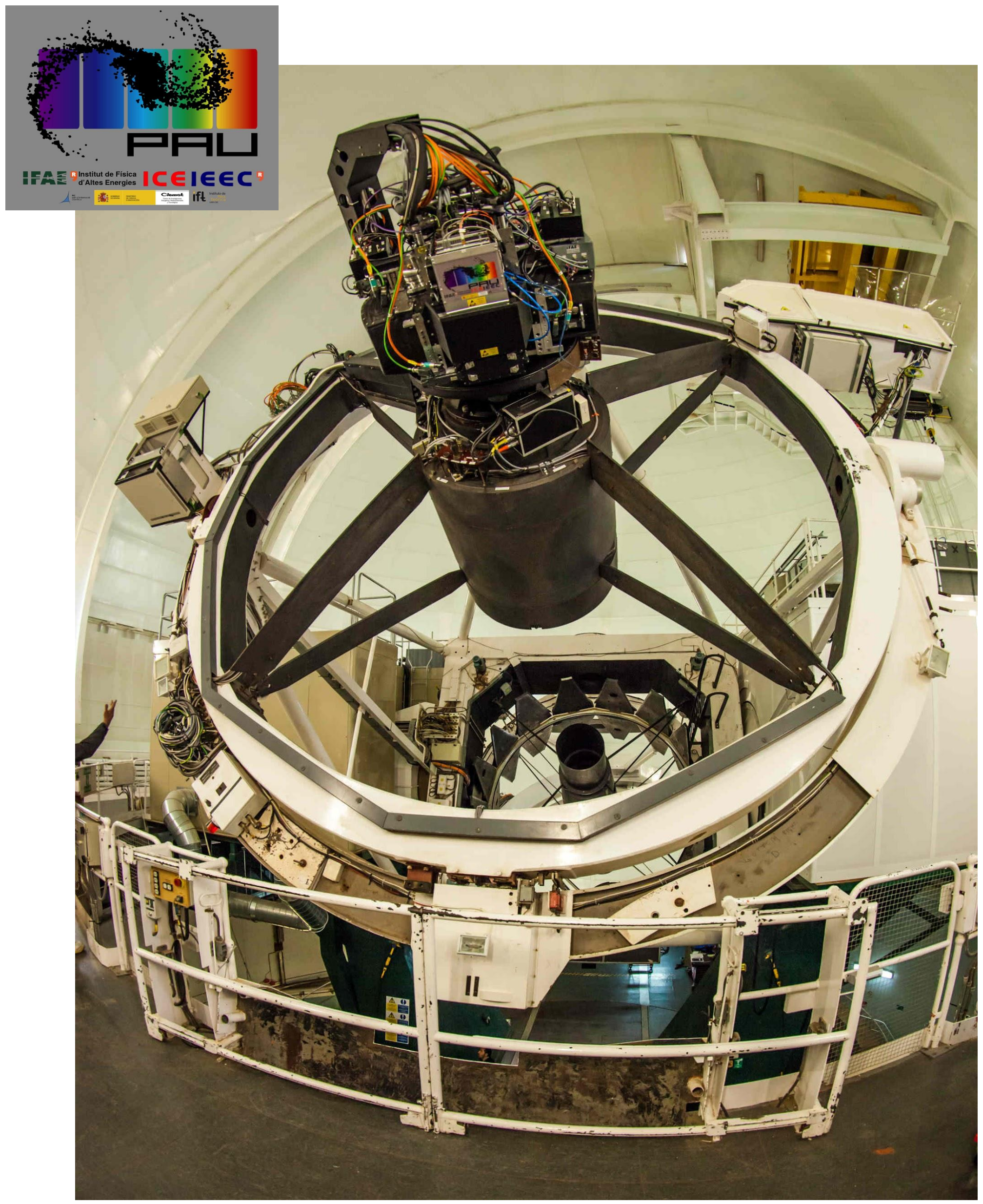
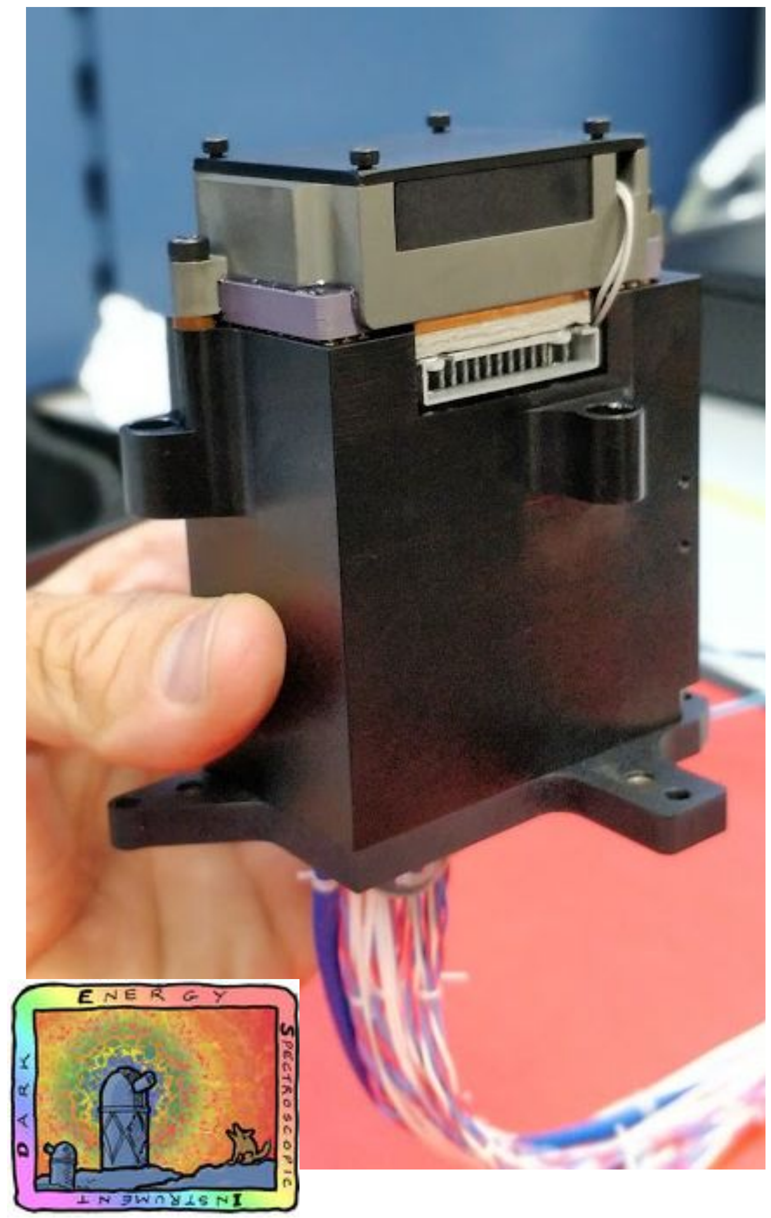
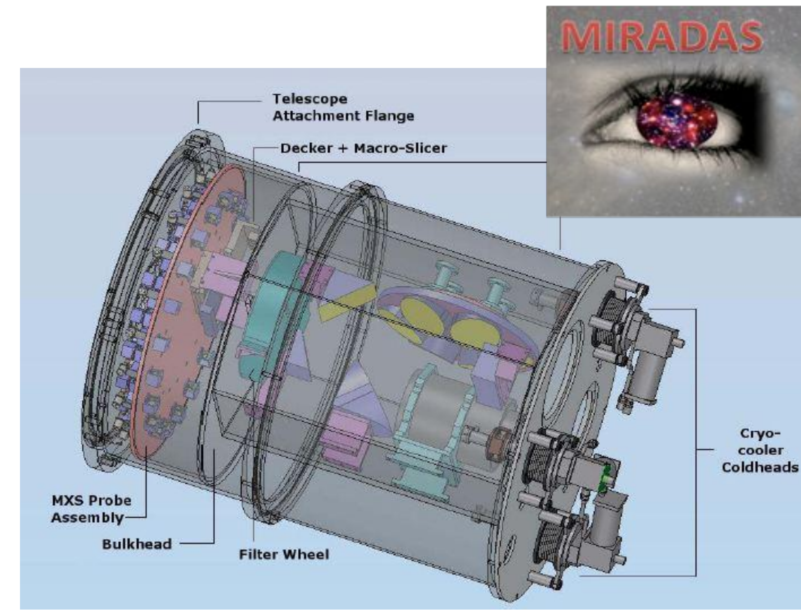


ASTEROID

Optical detectors for astronomy at IFAE







Images credit: PAUCam,Miradas and Decam web pages

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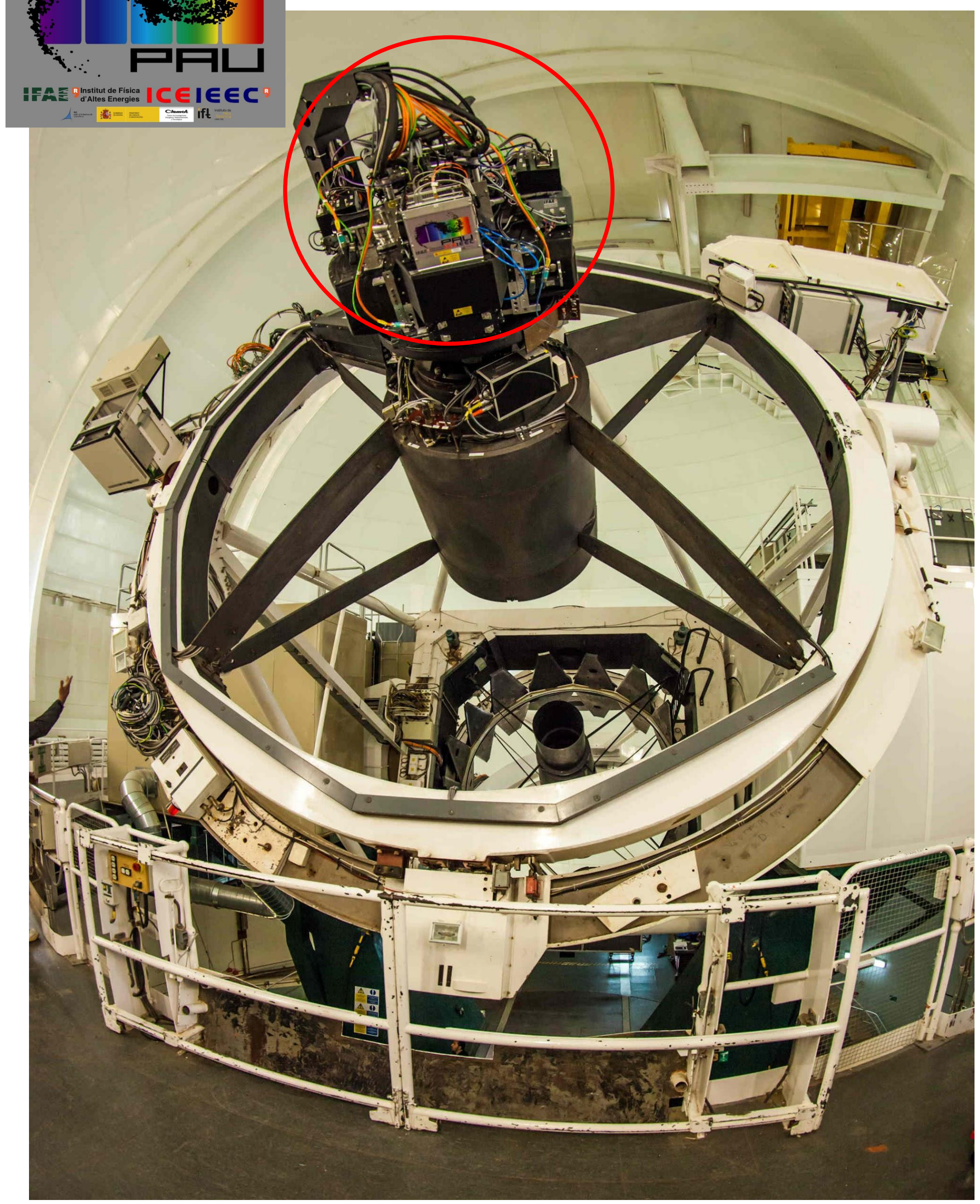

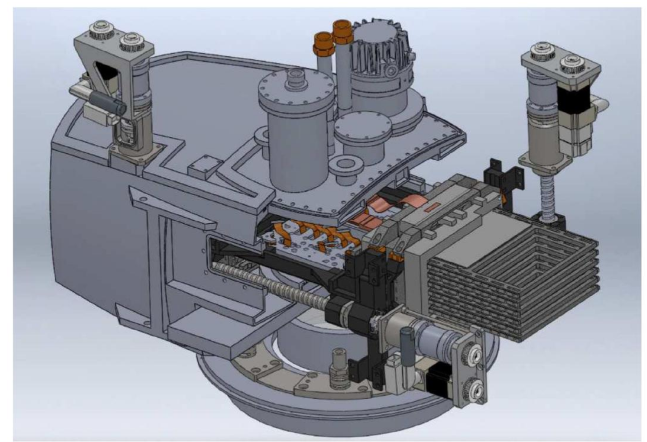

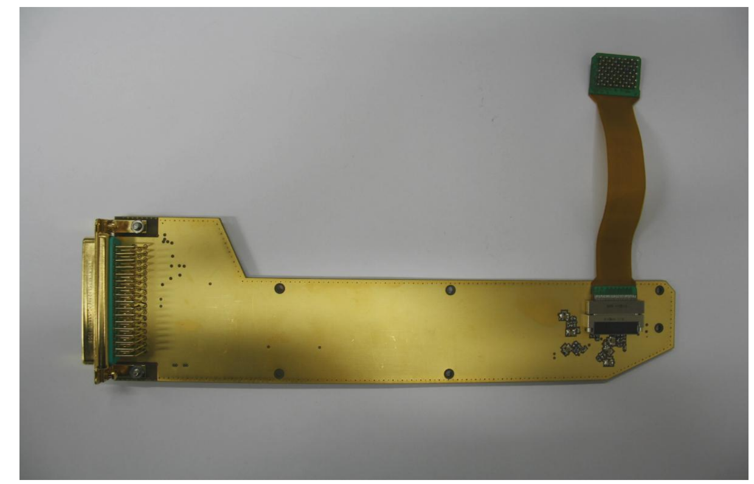

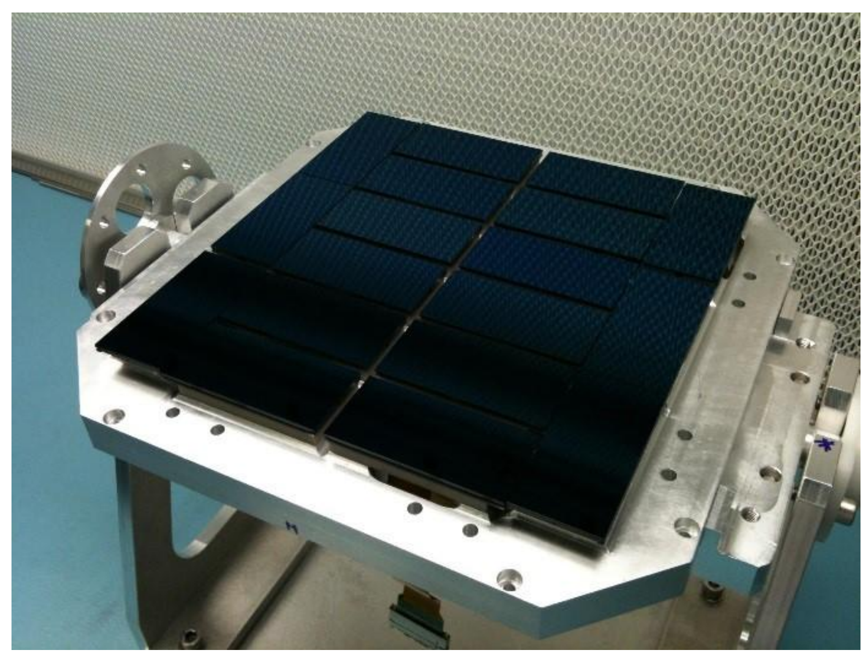

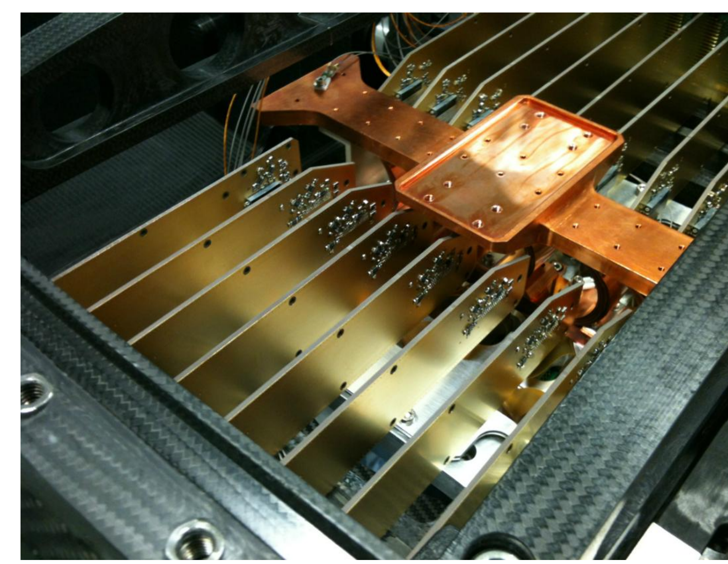

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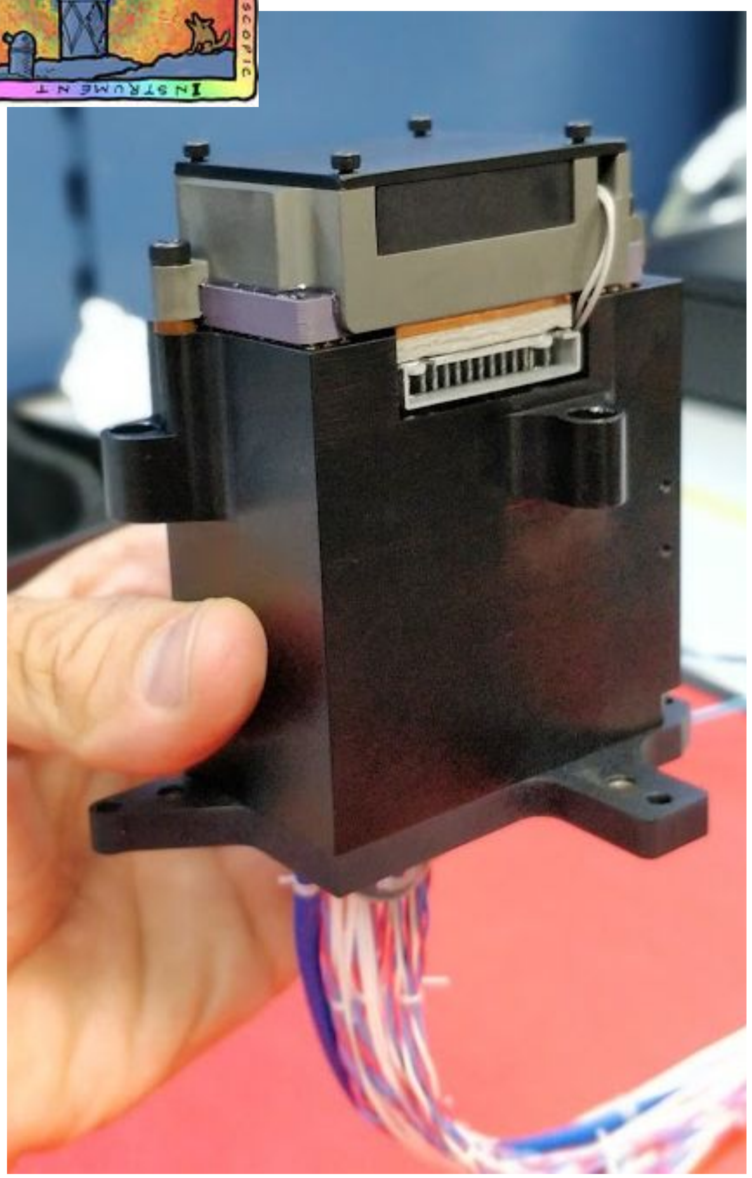

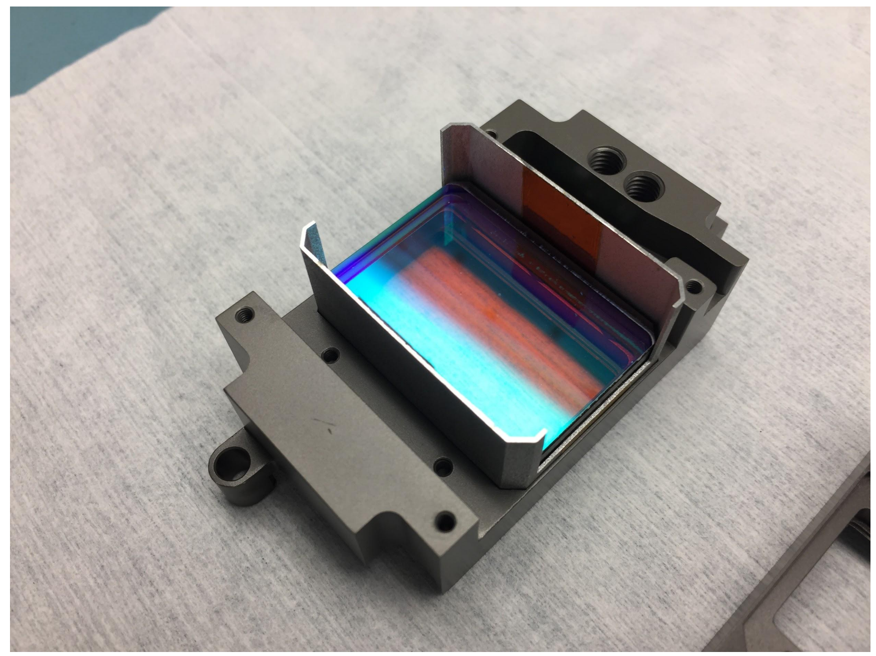

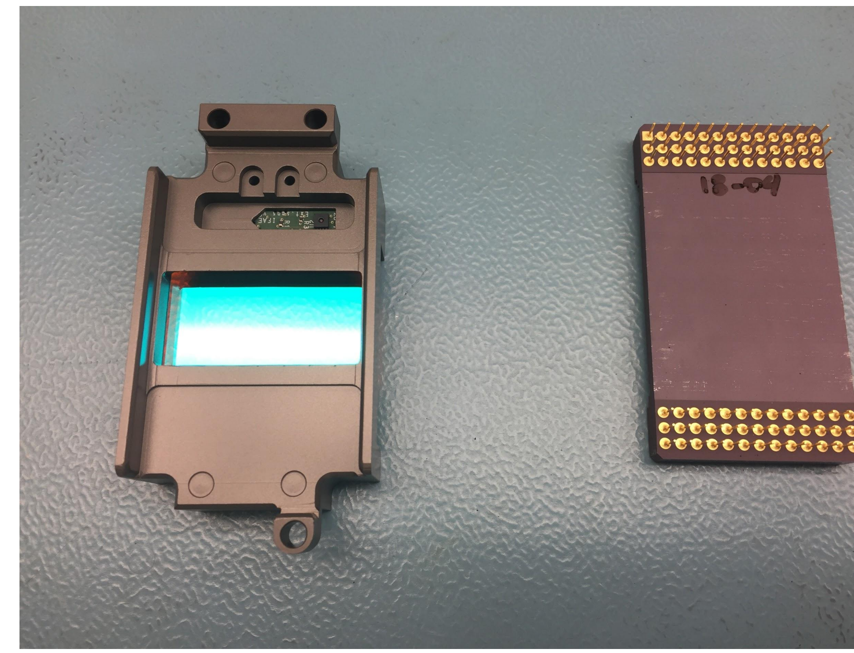

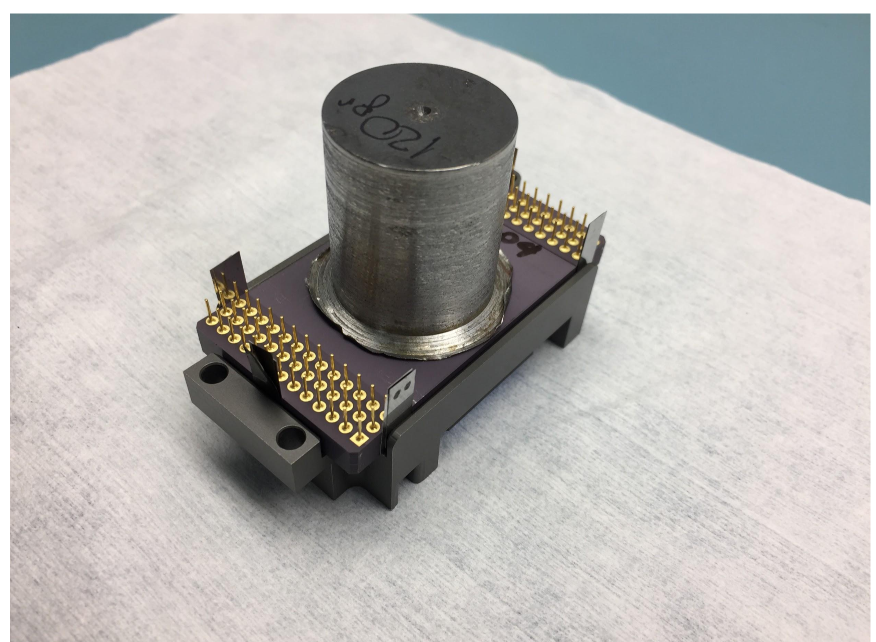

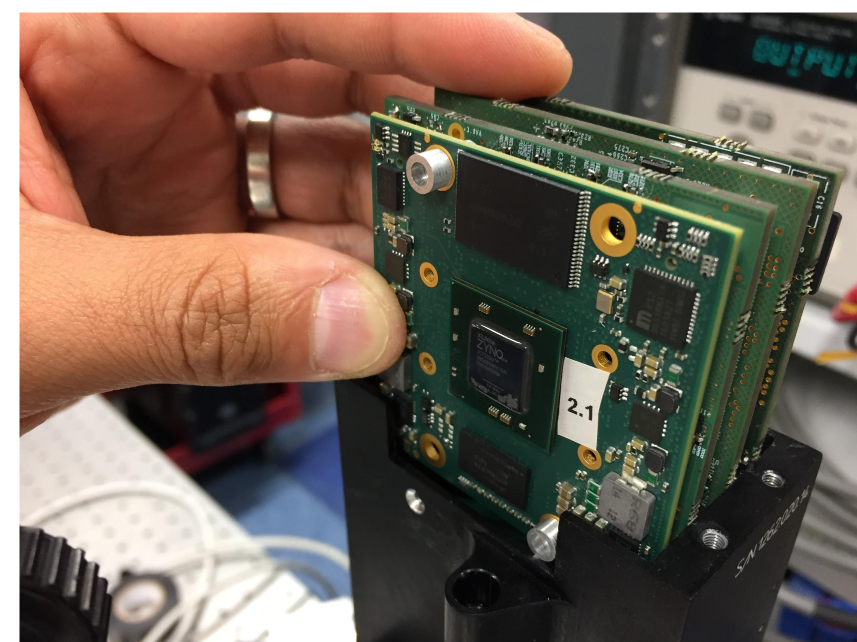

ASTEROID

Main Tasks at IFAE:

1. 2k2 Prototype Validation / Connectivity and Reliability Assessment

After several thermal cycles:

- **Visual Inspection:** Looking for surface crazing, blistering, etc.

  Using microscope up to x50

- **Electrical Test:** Validate connection reliability

  Indium bump is the bottleneck!

- **Electro-optical tests:** Detector characterization

  Get a pixel map (dead pixels, hot pixels, etc)

  Cross-check with CEA-Saclay

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Main Tasks at IFAE:

2. Responsible for the Communications and Outreach:

http://asteroidh2020.eu

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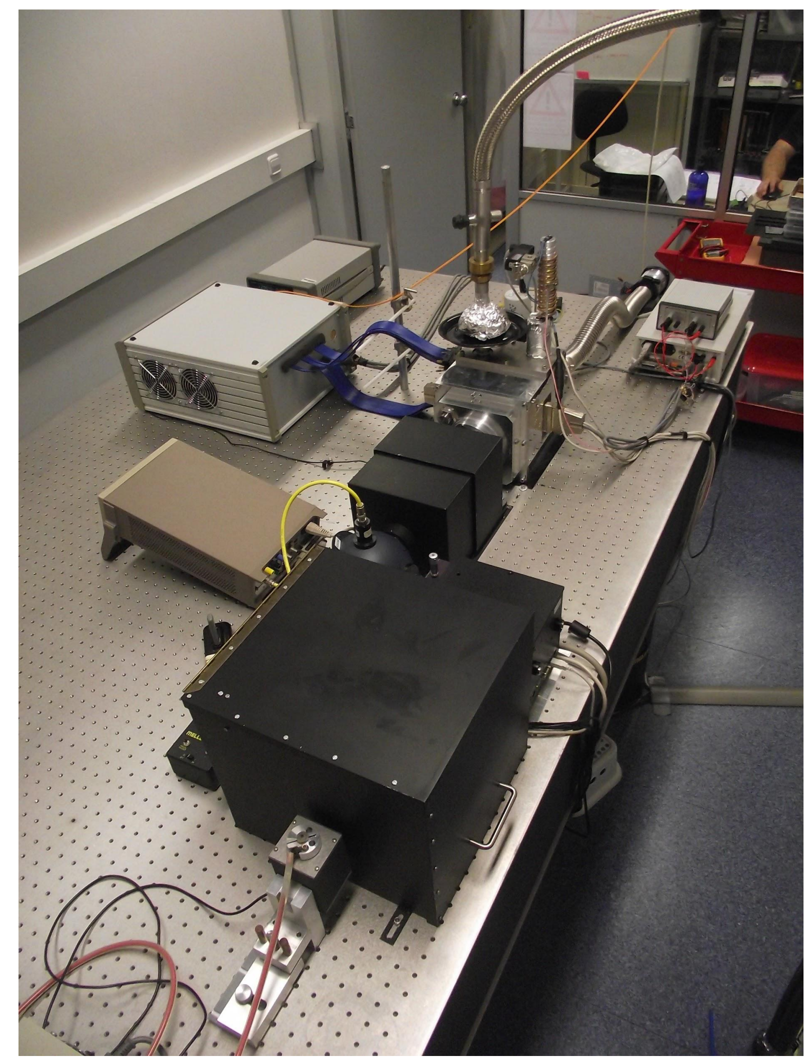
2k2 Prototype Validation / Connectivity and Reliability Assessment

Assembly and Integration Facilities at IFAE:

Optical Laboratory, Mechanical/Electronics Workshop and Clean Room

EPA laminar flow cabinet at IFAE clean room



Optical Setup

ASTEROID

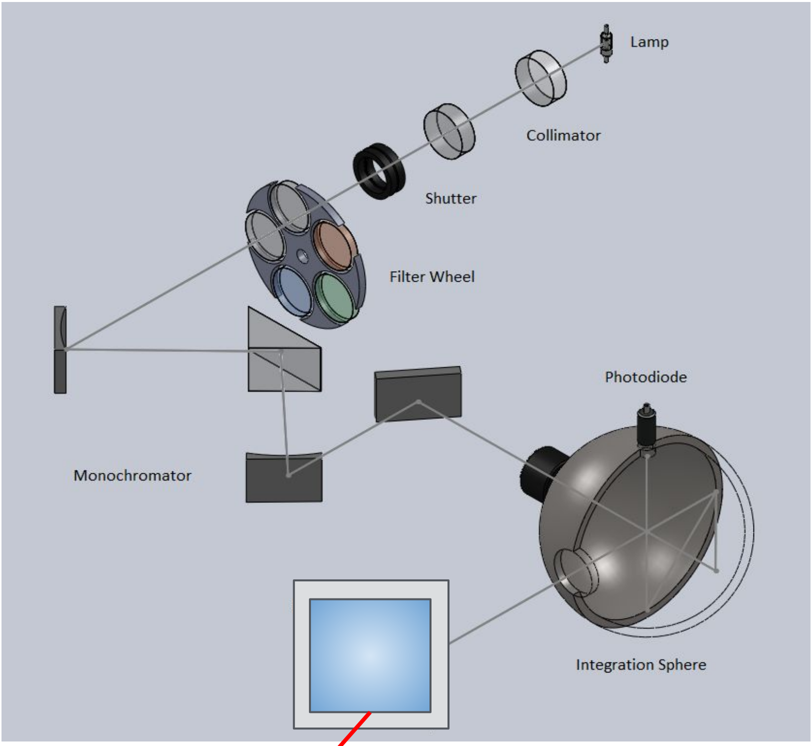
2k2 Prototype Validation / Connectivity and Reliability Assessment

Optical Setup:

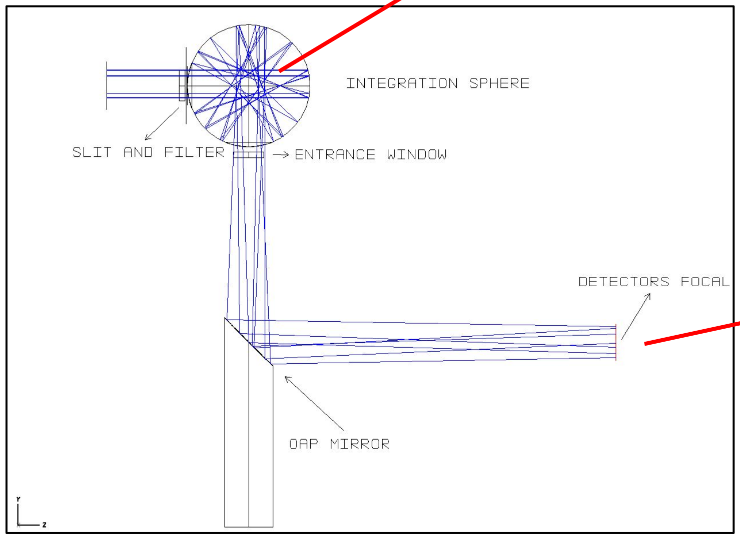
Optical Specifications

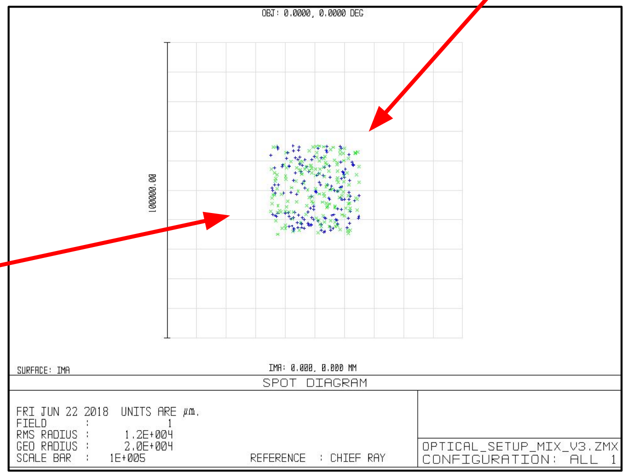
Light Source:	QTH lamp up to 250 W
Wavelength Range:	600 - 2700 nm
Spectral Bandwidth:	1 nm - 10 nm
Wavelength Accuracy:	±0.25 nm
Wavelength Repeatability:	±0.05 nm
Field Uniformity:	≥ 1%
Exit Port Diameter:	1.5 inch
Light Ripple:	< 0.05 % rms
Line Regulation	0.01%

Use gold-coated reflective elements to reduce the thermal radiation



Zemax® simulations of the optical performance





~ 35 x 35 mm Detector Area

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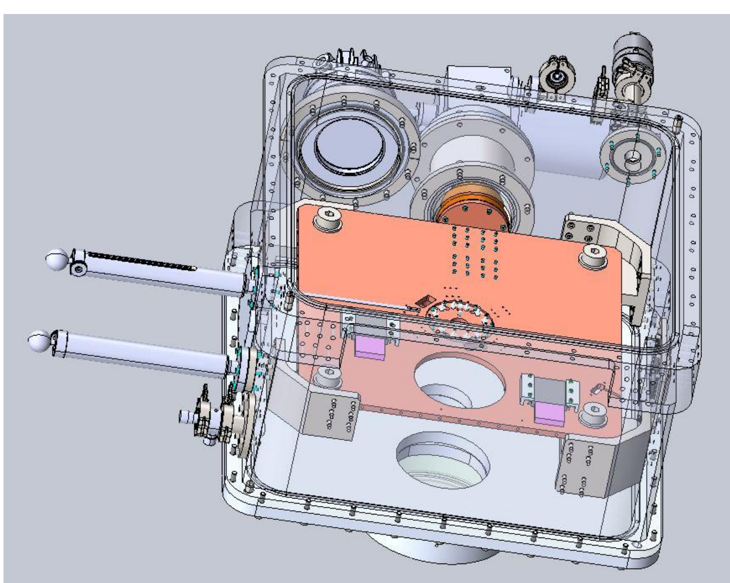
2k2 Prototype Validation / Connectivity and Reliability Assessment

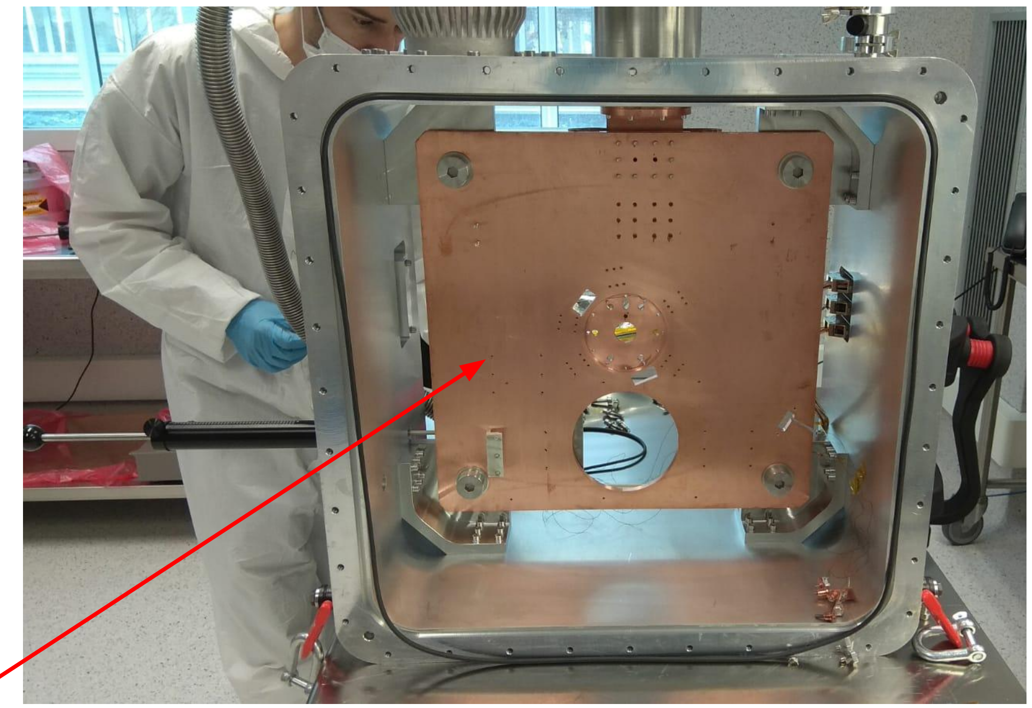
Cryo-Vacuum and Cooling:

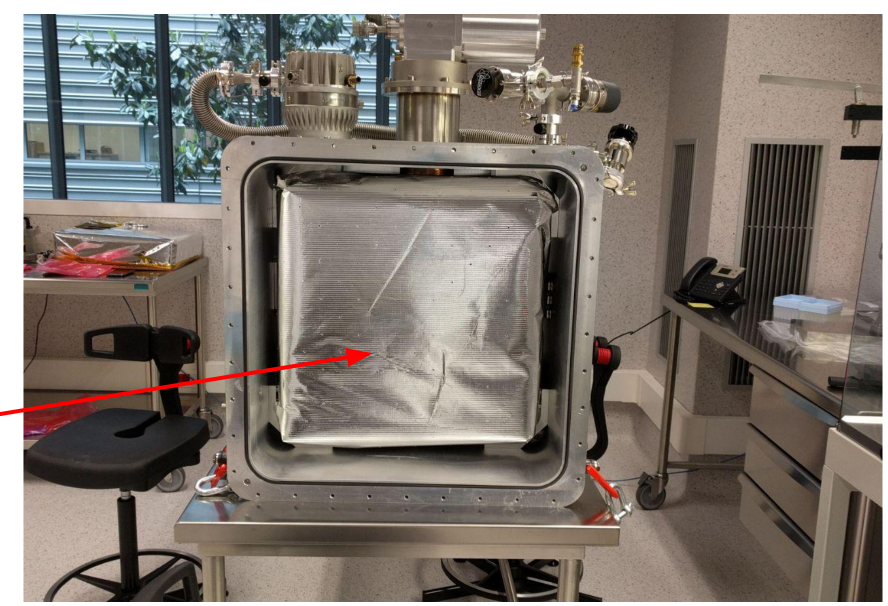
euclid

Cryogenics, Vacuum and Cooling Specifications	
Cooled Breadboard Area	0.2 m² (450 mm x 450 mm)
Cooling Power @ 80K	175 W
Cooldown Time @ 80K	~5 hrs
Pumping Speed @ 1 x 10^{-2} mbar	~10 min
Pumping Speed @ 1 x 10^{-6} mbar	~1 hrs
Temperature Control Accuracy @ 100K	±23 mK
Output Heaters	2
Heaters Power	150 W (100 W + 50 W



Solidworks® cryostat's CAD





Cold Breadboard

Radiation Shield

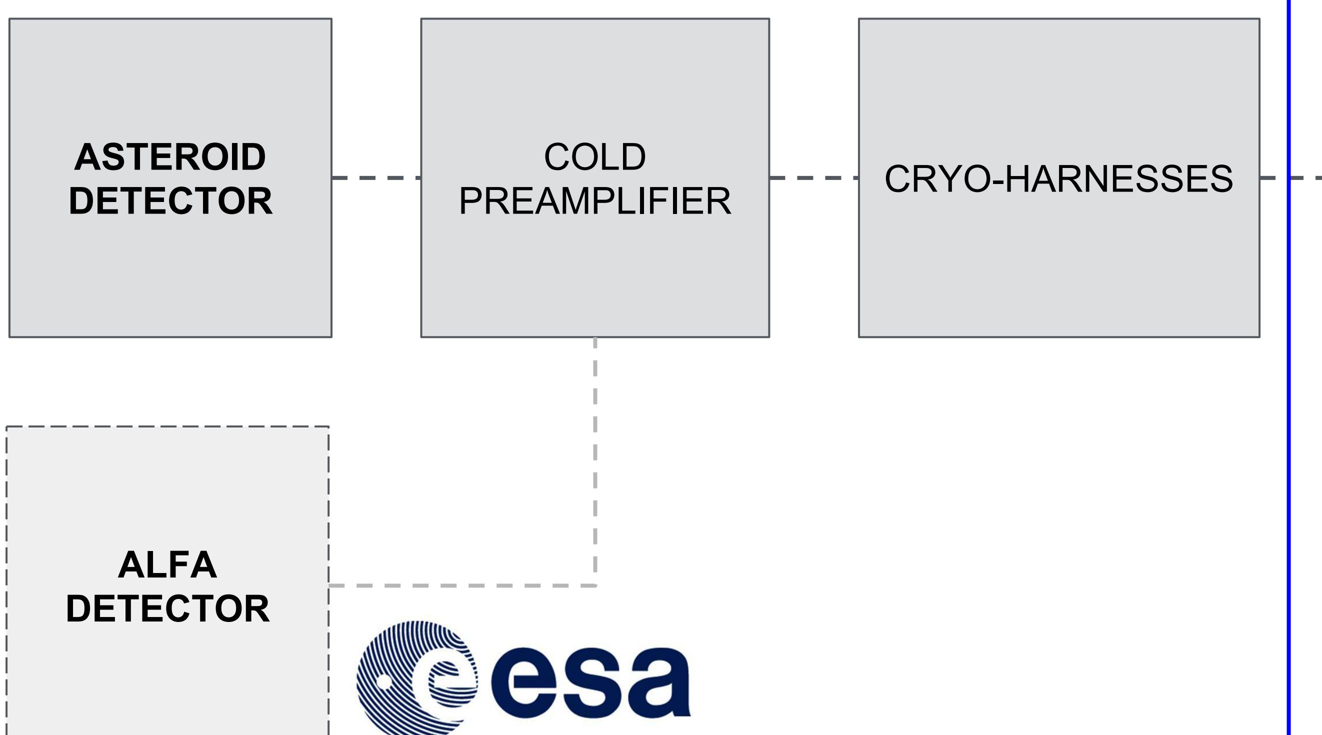
ASTEROID

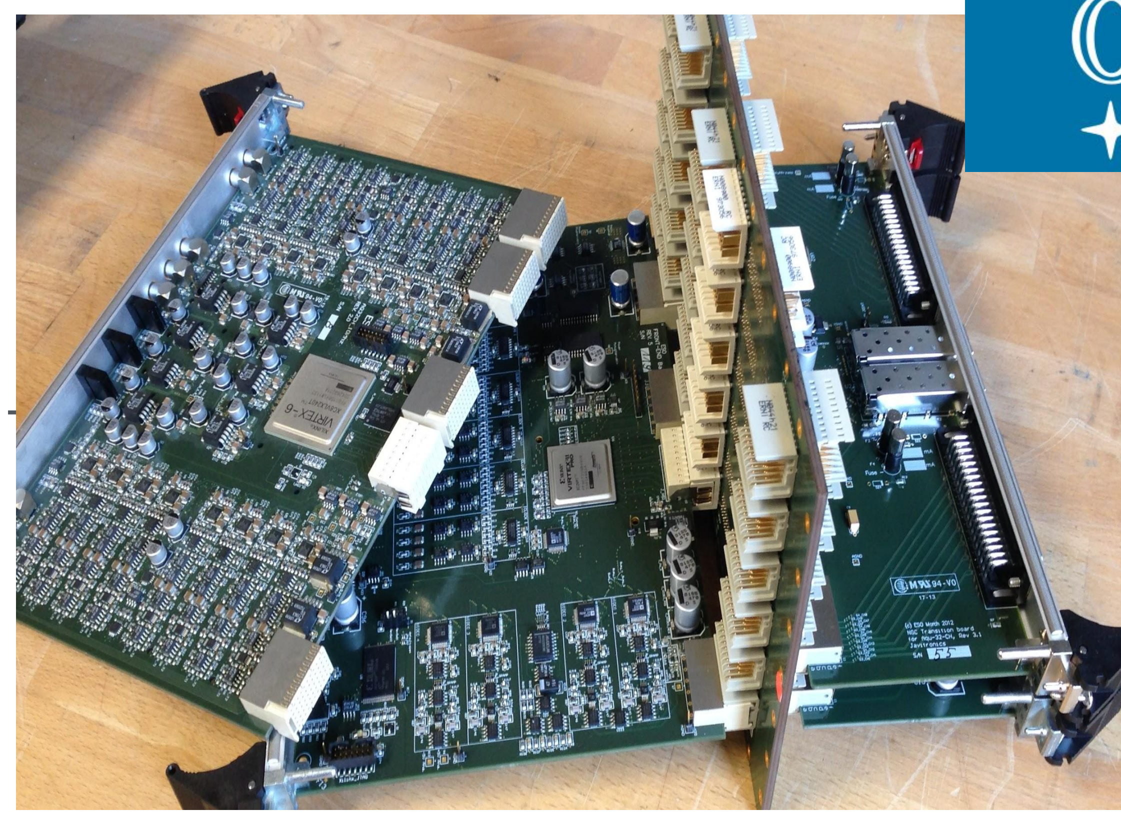
2k2 Prototype Validation / Connectivity and Reliability Assessment

Readout Electronics:

ESO-NGC controller fully compatible with ASTEROID

$T_{DET=}$ **100 K**





T_{ROE}**= ~300 K**

VACUUM SIDE

ATMOSPHERIC SIDE

ASTEROID

Summary:

- The main objective of the ASTEROID project is to extend the dimension of high performance infrared FPA that can be manufactured in Europe.
- This will allow Europe to become independent for the procurement of this type of detectors.
- The targeted format is 2k2 15µm pitch FPA (2048x2048 pixels).
- The project is a collaboration between scientific research institutions and industrial partners.
- IFAE has a new technological knowledge on testing CCDs and large IR detectors and to develop their readout electronics.

Thanks you!