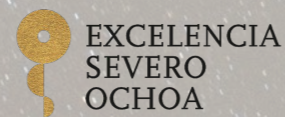




ASTEROID: “An astronomy infrared detector made in Europe”

Jorge Jiménez

Third Barcelona Techno Week
Meeting Point
July 9th, 2018



25
years
1991-2016

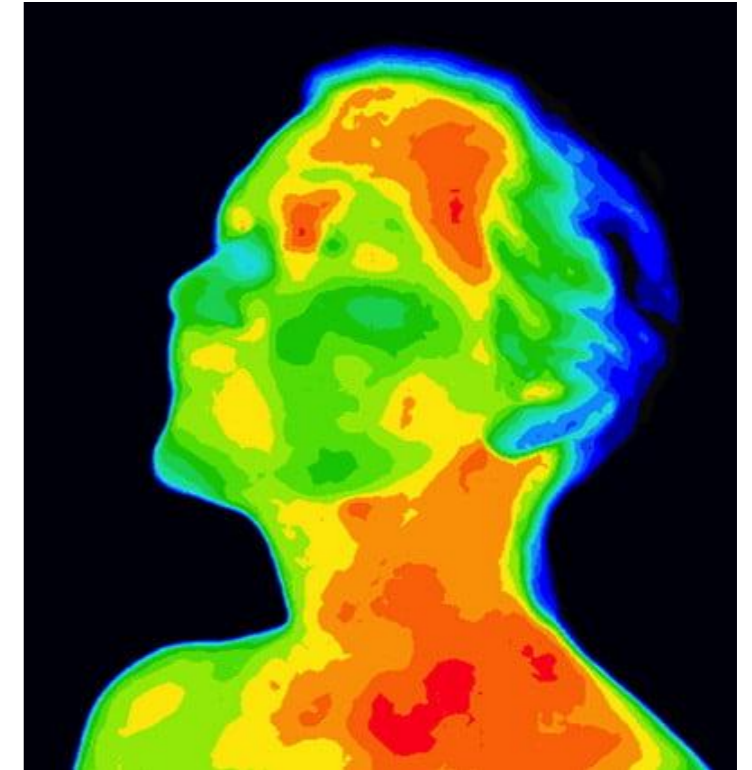
Institut de Física
d'Altes Energies



Barcelona Institute of
Science and Technology

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?**



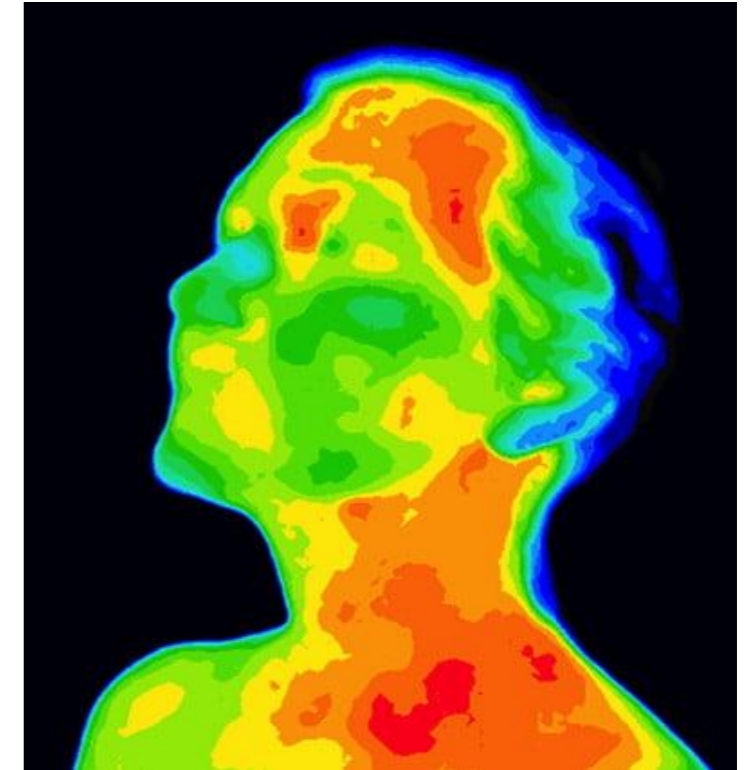
What is NOT ASTEROID project?



What is NOT ASTEROID project?



- **What is ASTEROID project?**
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ASTEROID (ASTronomy EuROpean Infrared Detector) is a H2020 project



European
Commission

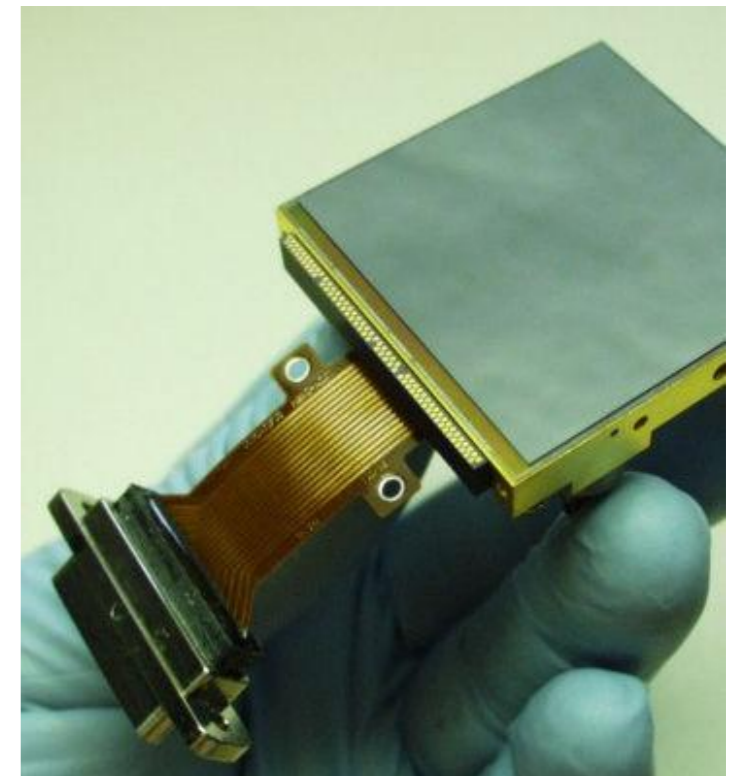
Horizon 2020
European Union funding
for Research & Innovation

- **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 (HgCdTe Astronomical Wide Area
Infrared Image) detector**

Hawaii-2RG detector

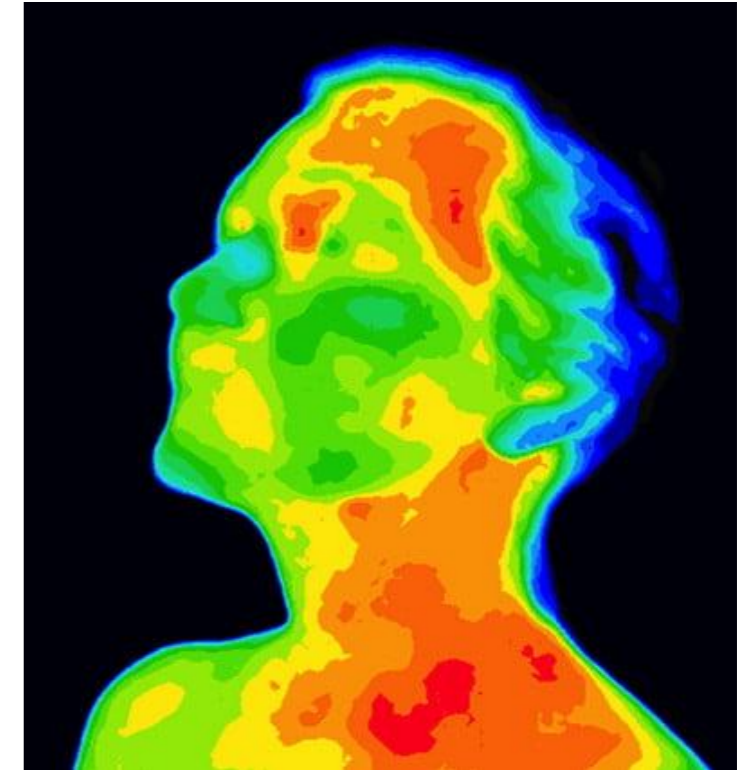


ASTEROID

- **Focused on space and ground-based astronomy**
Main customers: ESA, ESO, CNRS, NASA, etc
- **Consortium of 6 european industrial partners and research institutions**

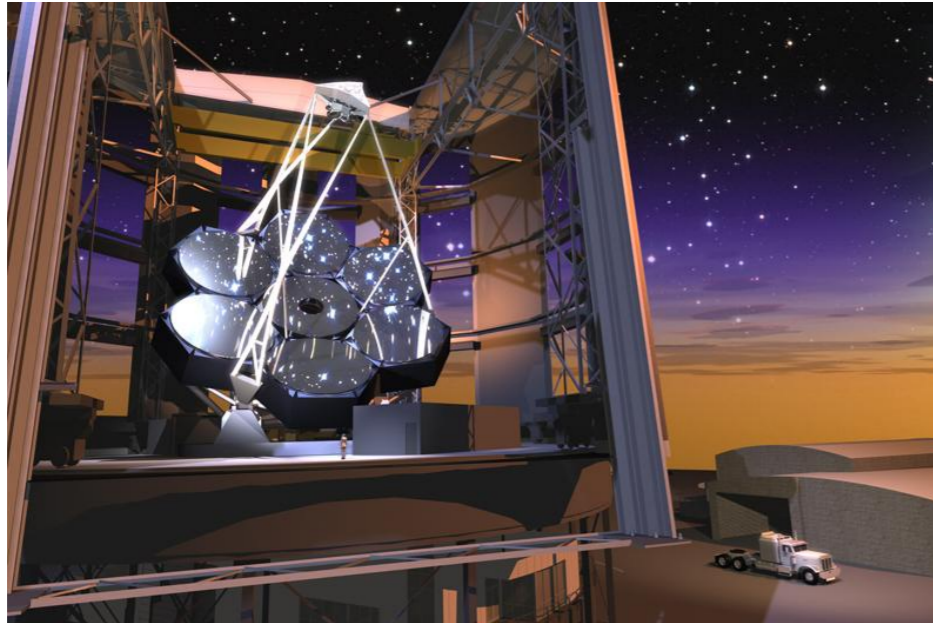


- What is ASTEROID project?
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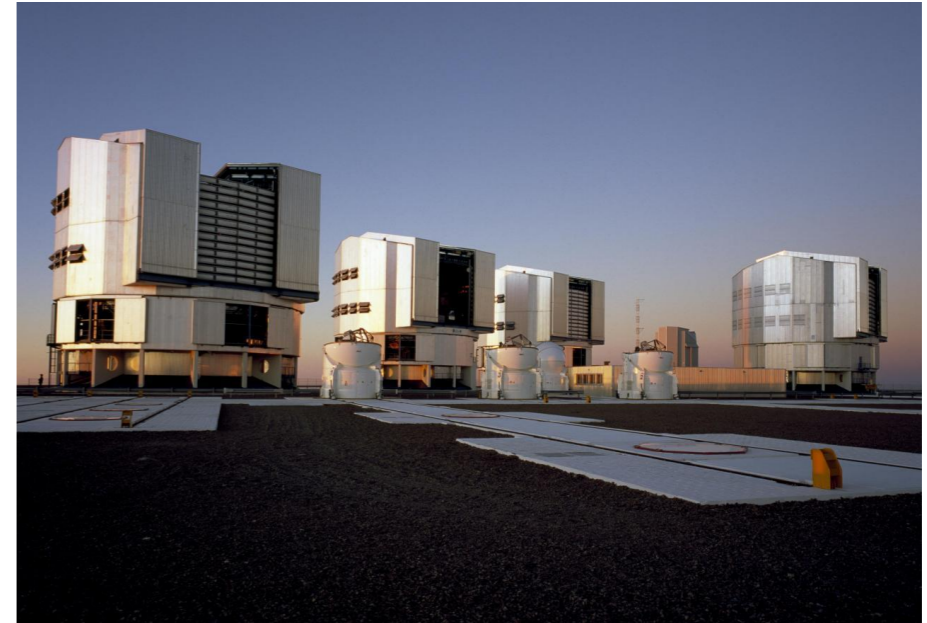


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Expected market for the next coming years...



GMT telescope (La Serena, Chile) @ 2018



ESO VLT/VLTI (Atacama desert, Chile)



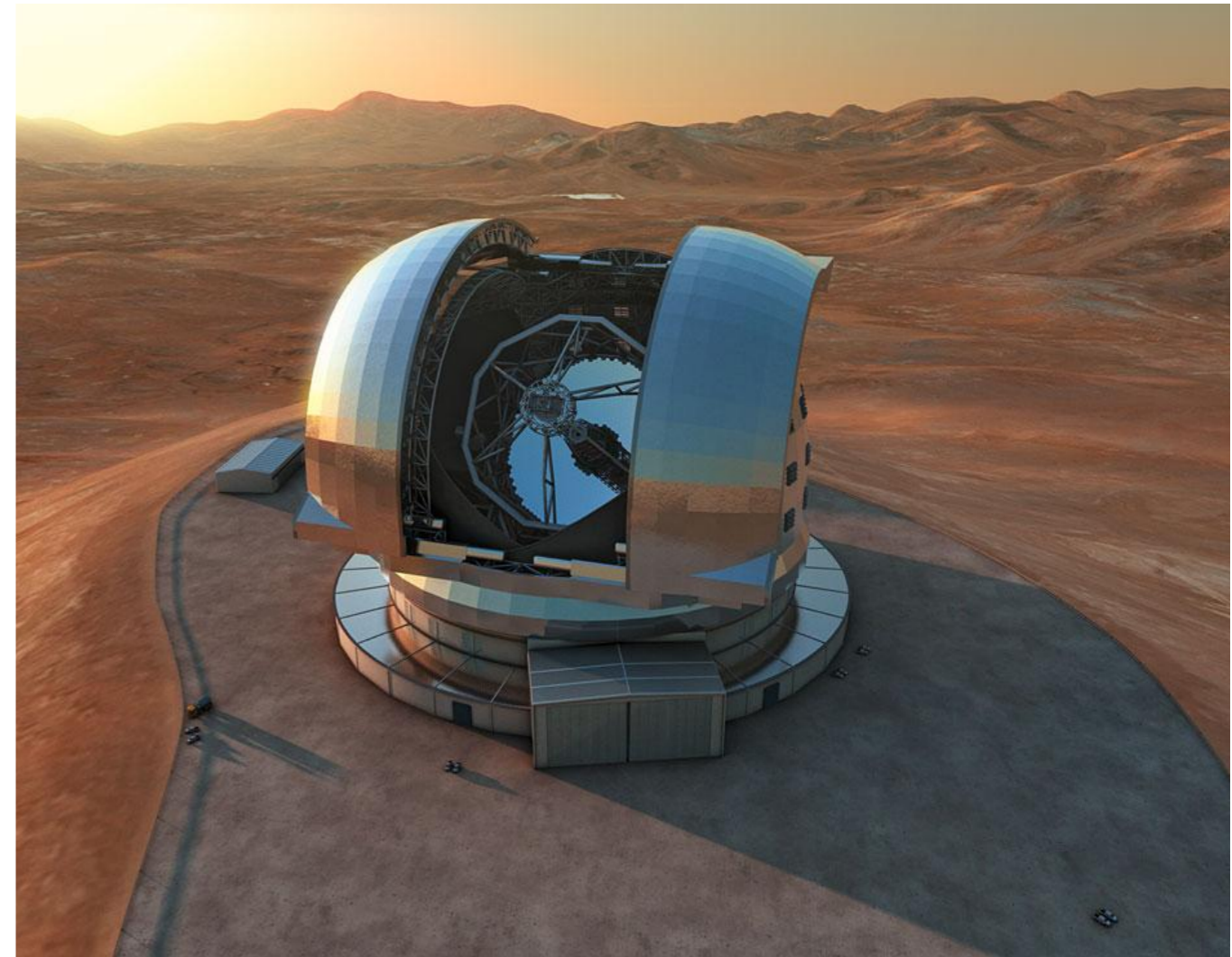
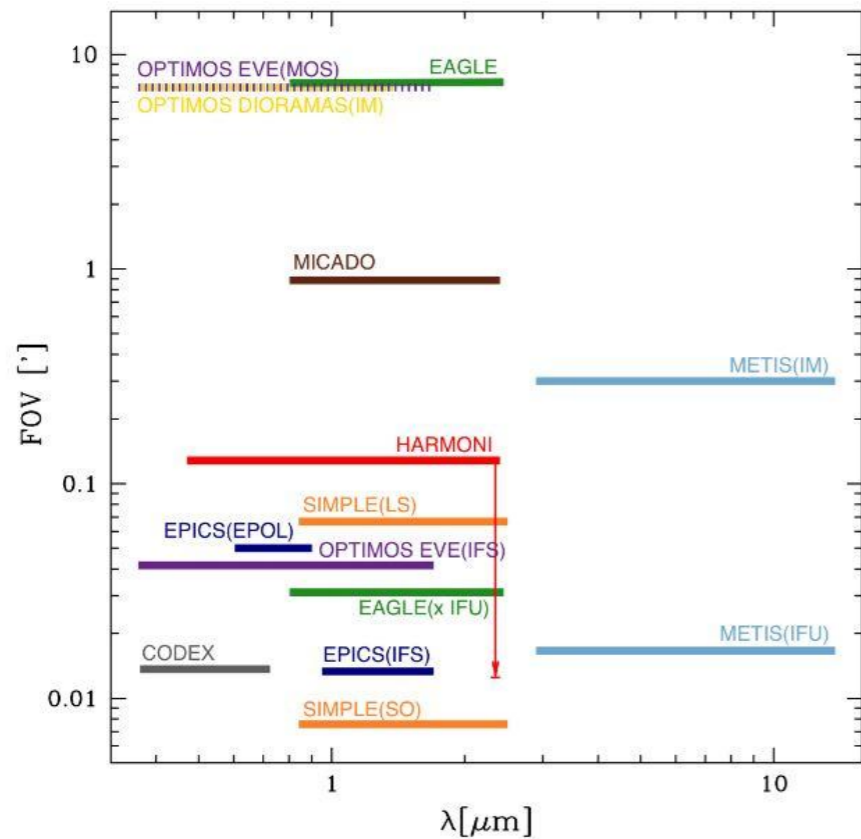
ESA-NASA Space Missions



TMT telescope @ (Hawaii, USA)

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

ESO ELT telescope @ 2024 (Atacama desert, Chile)



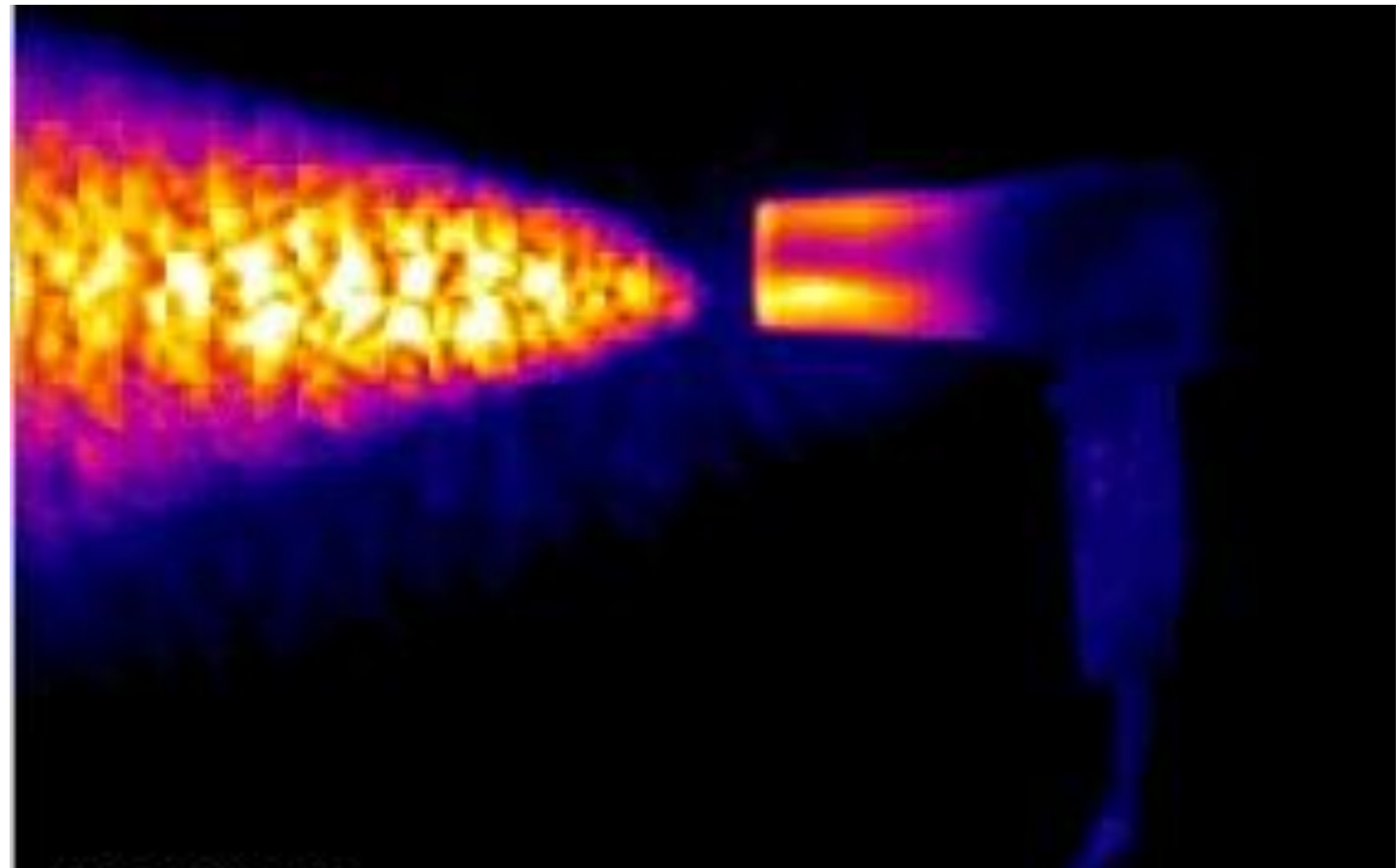
It will demand more than 220 2k x 2k IR detectors for its first generation instruments!

ASTEROID

An analogy example:



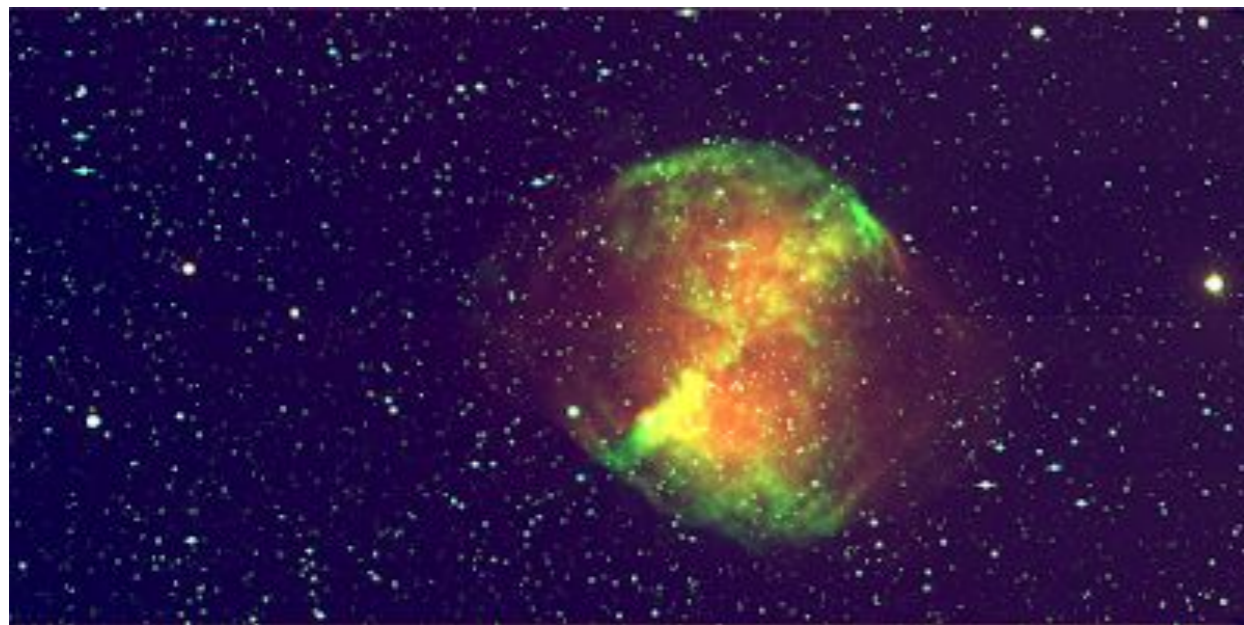
An analogy example:



Hair dryer air flow at infrared wavelengths

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 (M27) using the the PAUCam at WHT telescope.

Applications fields:

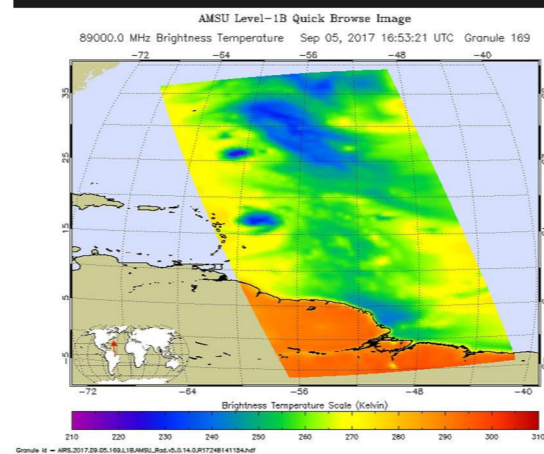
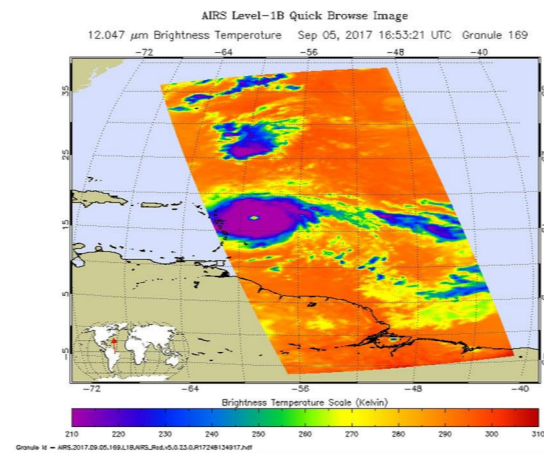
Ground-based astronomy



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

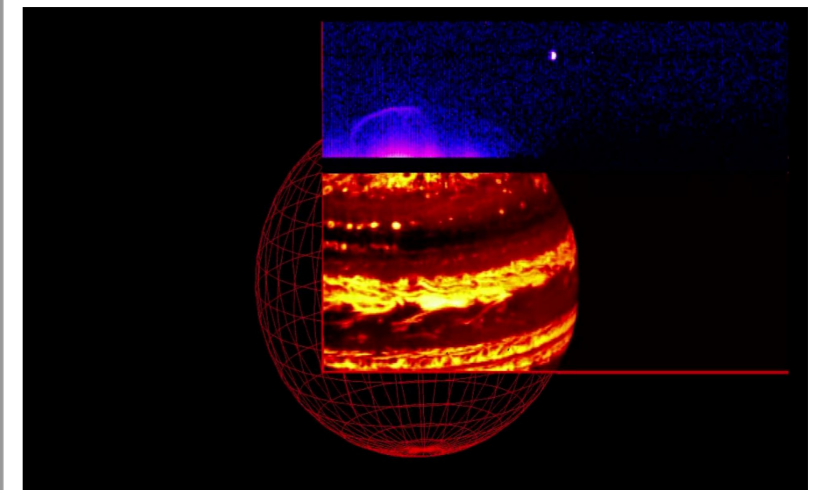
Earth observation satellites

NASA NEO infrared image of Irma shows an “angry eye”

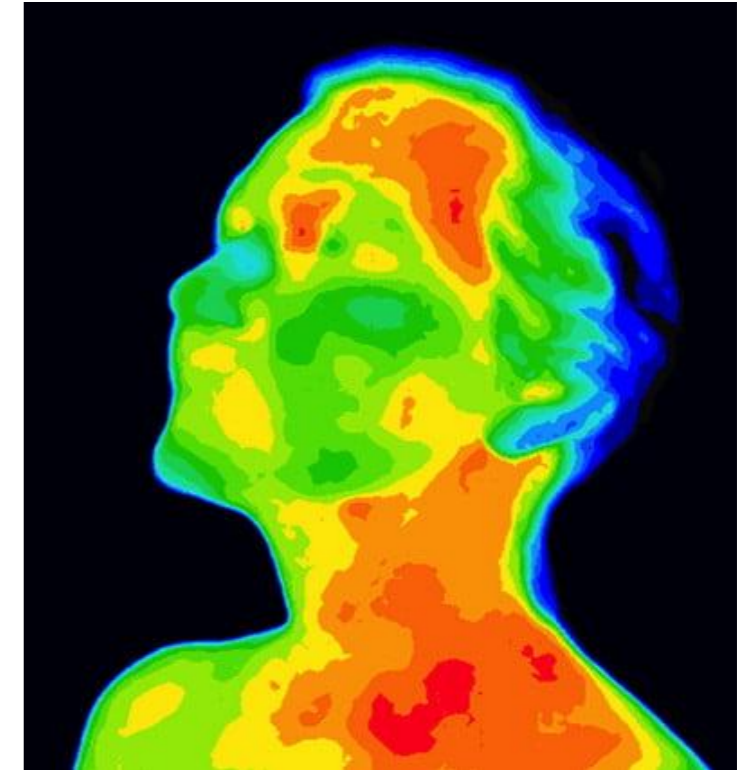


Space-based astronomy

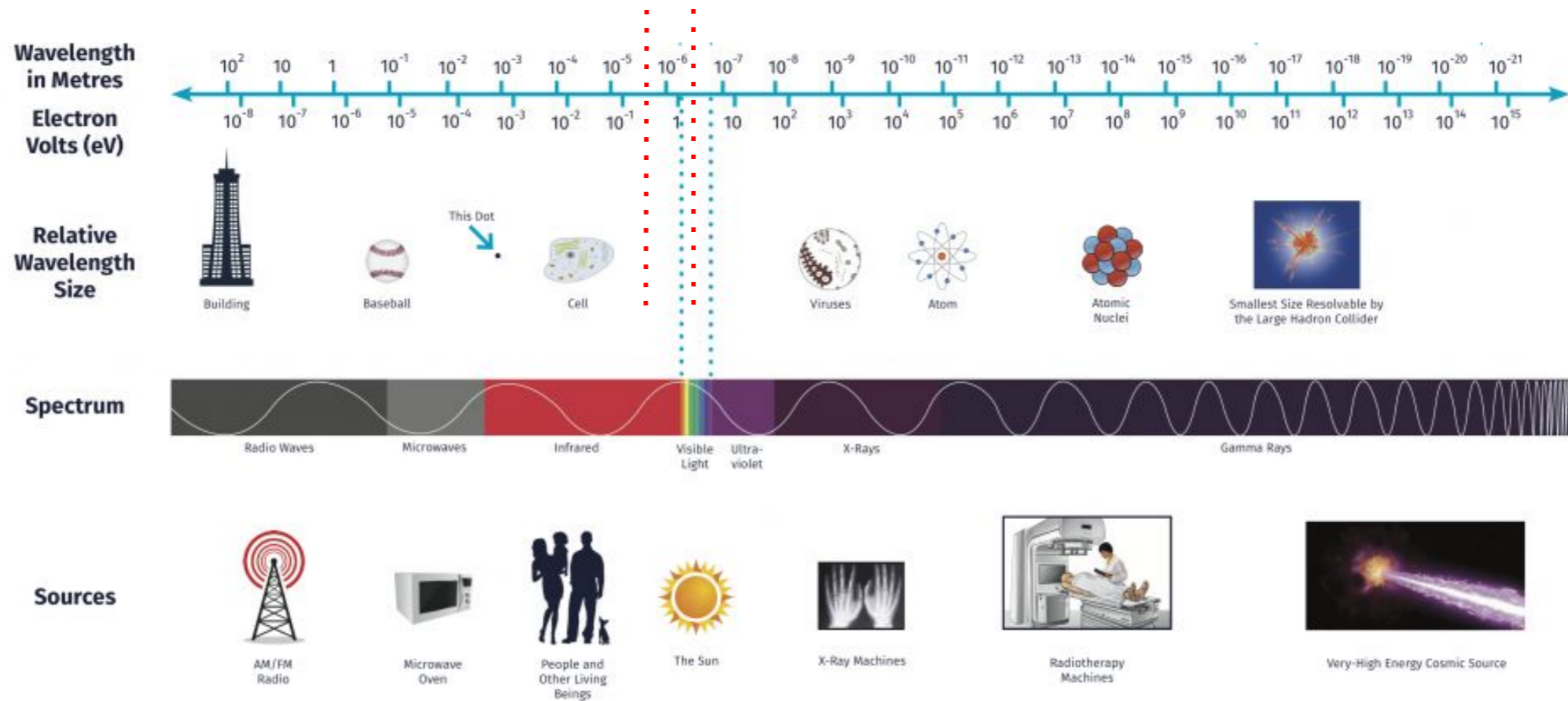
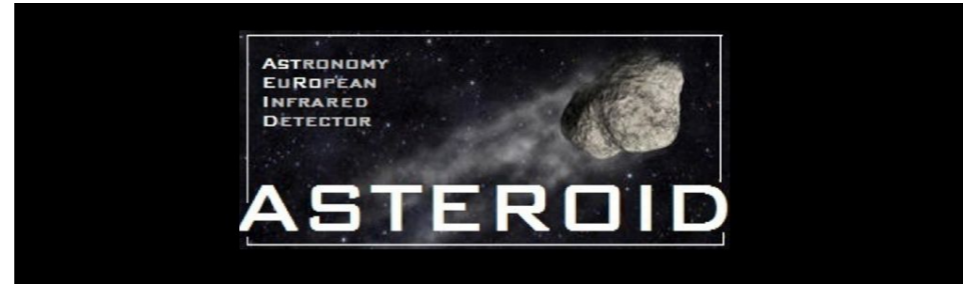
Juno JIRAM instrument captures Jupiter's glow in infrared light



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IR detectors

–Silicon is only sensitive to wavelength below ~1 μm

This is reason because we don't use CCDs

–Other (exotics) semiconductors materials must be used for IR

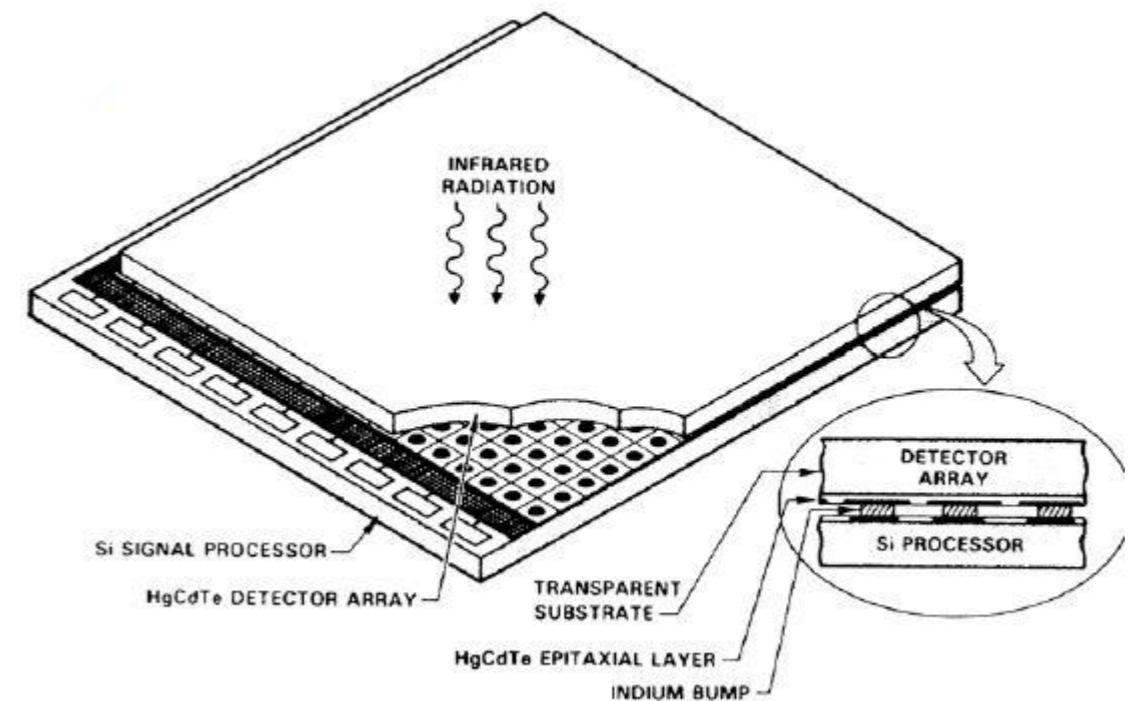
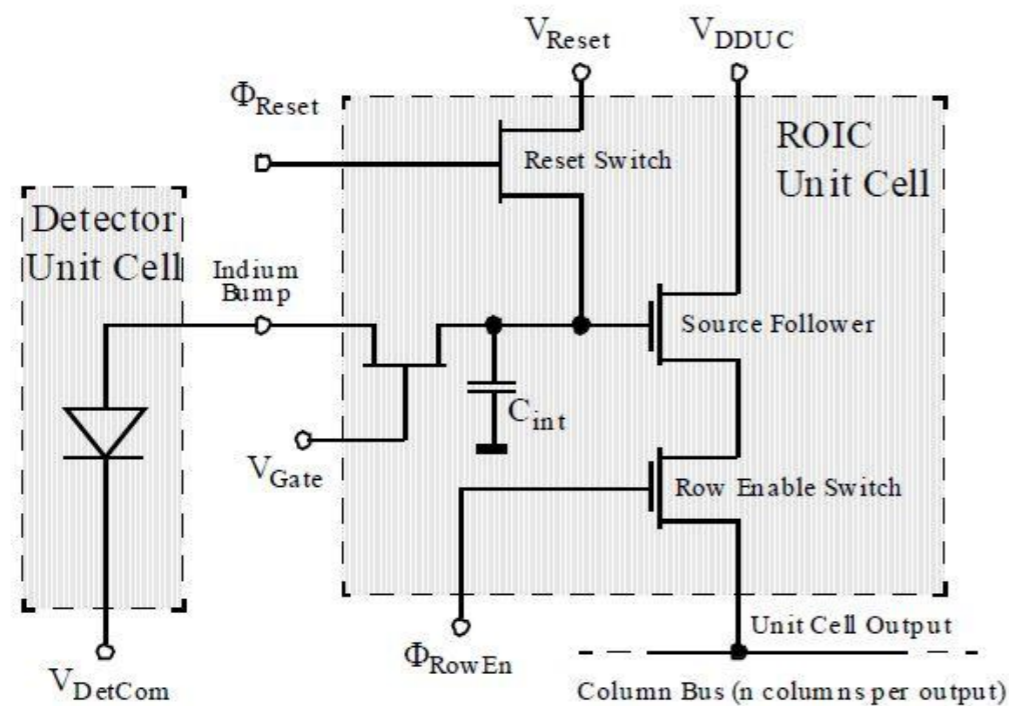
Special interest on $\text{Hg}_{x-1}\text{Cd}_x\text{Te}_x$ since it cover a wide wavelength range

<i>Material</i>	<i>Conduction Band [ev]</i>	<i>Cutoff Wavelength [μm]</i>
<i>Si</i>	<i>1.11</i>	<i>1.12</i>
<i>InSb</i>	<i>0.18</i>	<i>6.9</i>
<i>Si:As</i>	<i>0.054</i>	<i>23</i>
<i>$\text{Hg}_{x-1}\text{Cd}_x\text{Te}_x$</i>	<i>1.6 ... 0.09</i>	<i>0.7...14</i>

IR detectors (*cont*)

–An hybridized array is the solution!

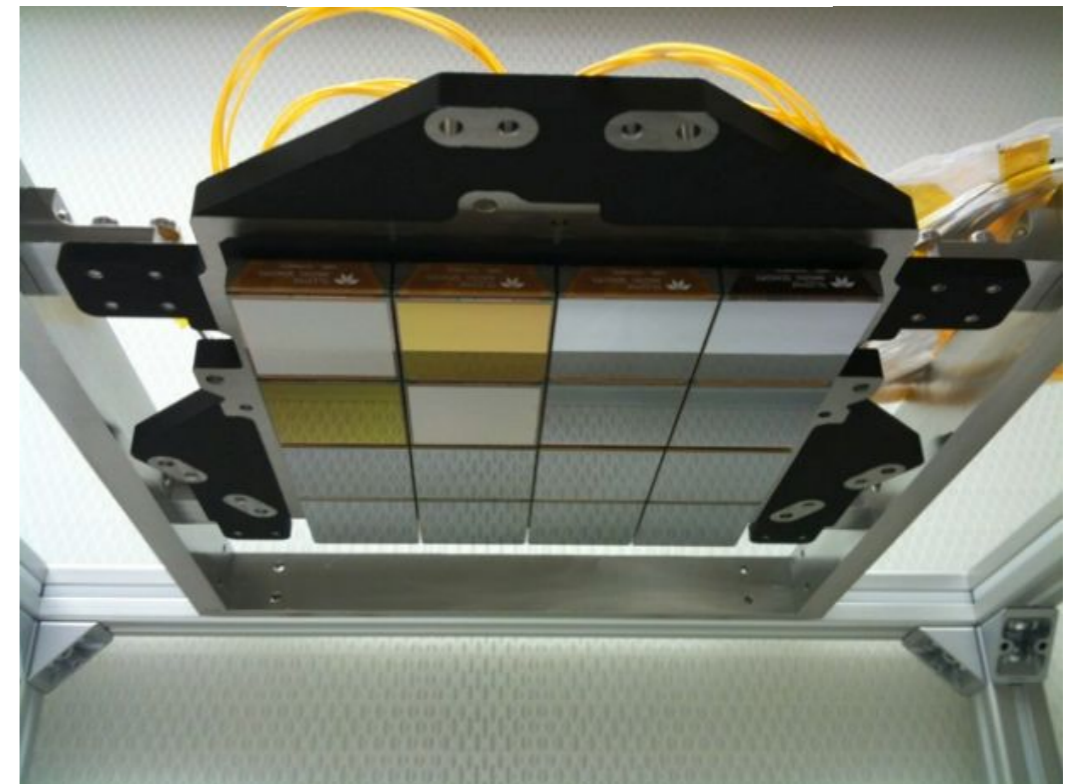
Use a silicon based readout circuit (ROIC) with an exotic IR detector array



IR detectors (*cont*)

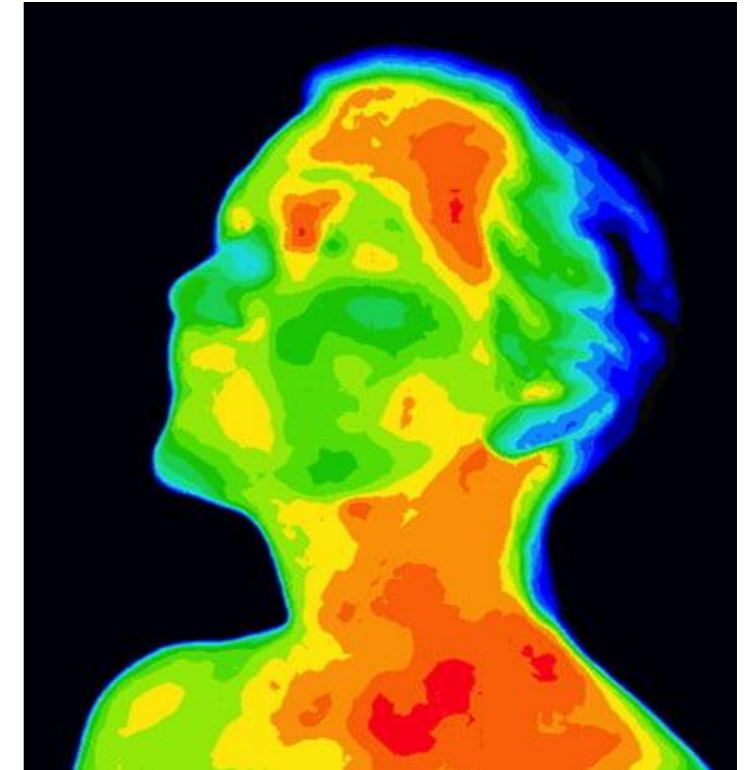
Expected performance for ASTEROID FPA (from a Teledyne Hawaii-2RG)

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

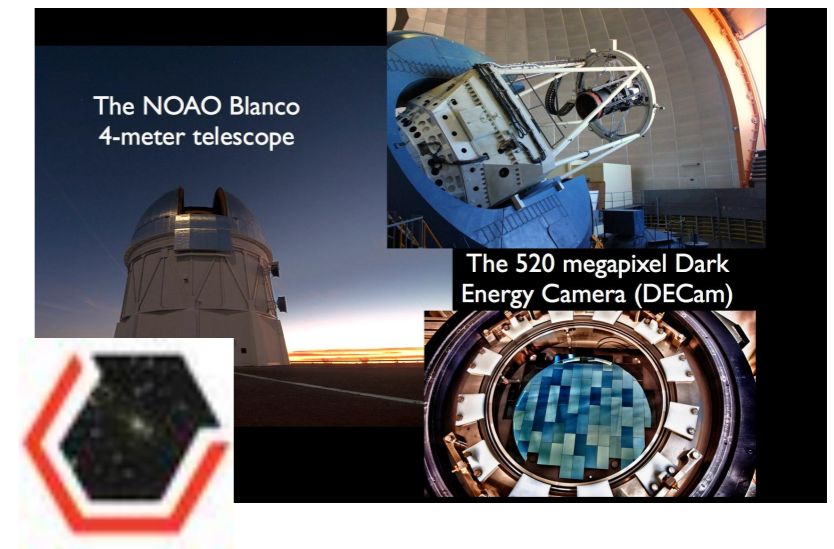
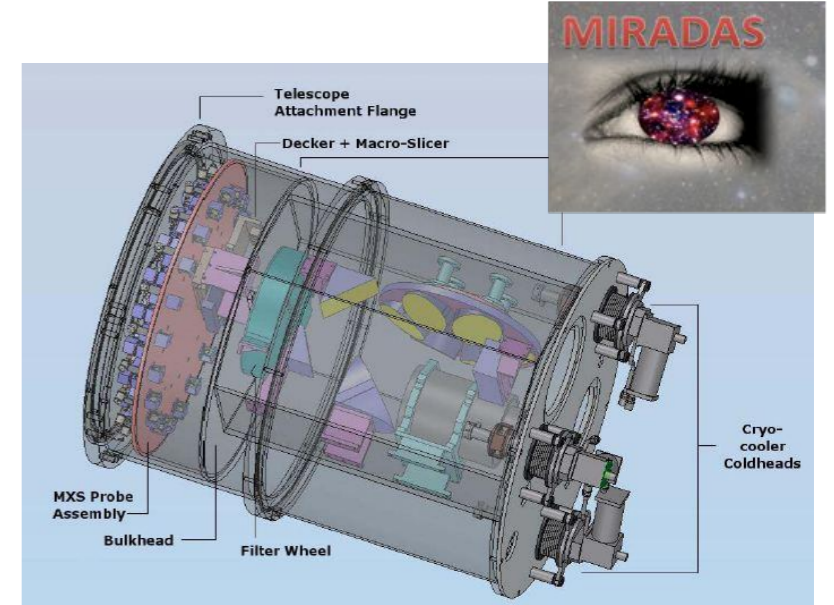
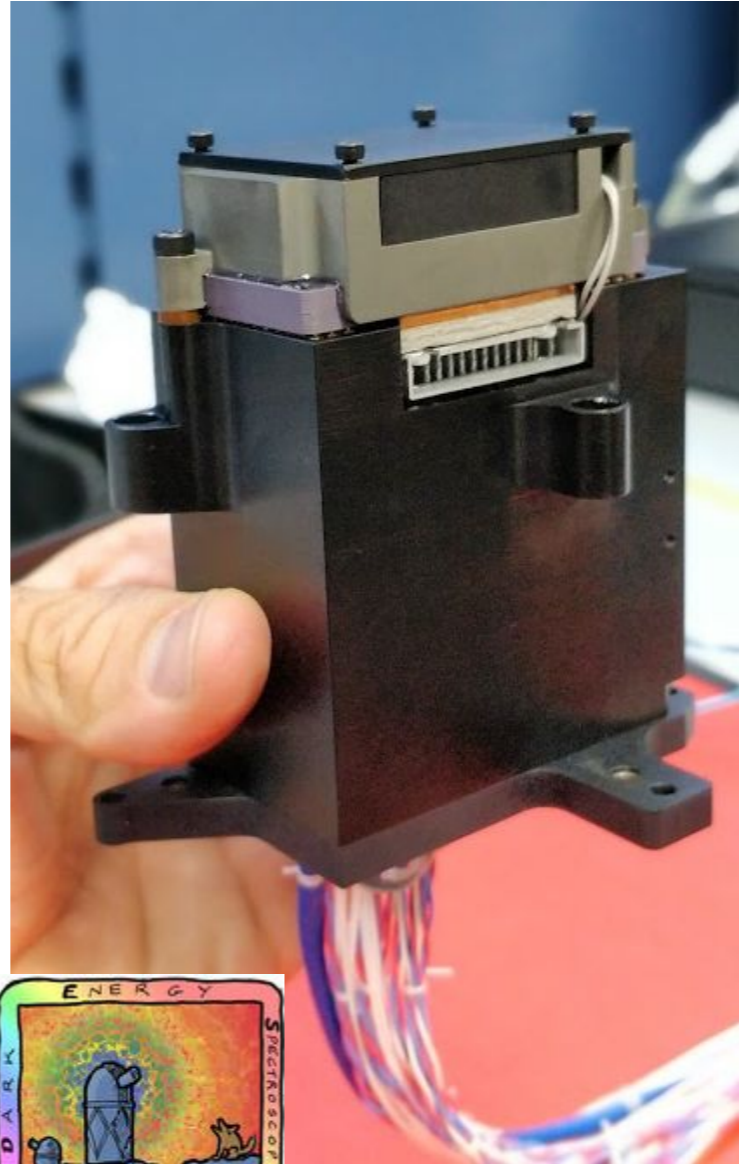
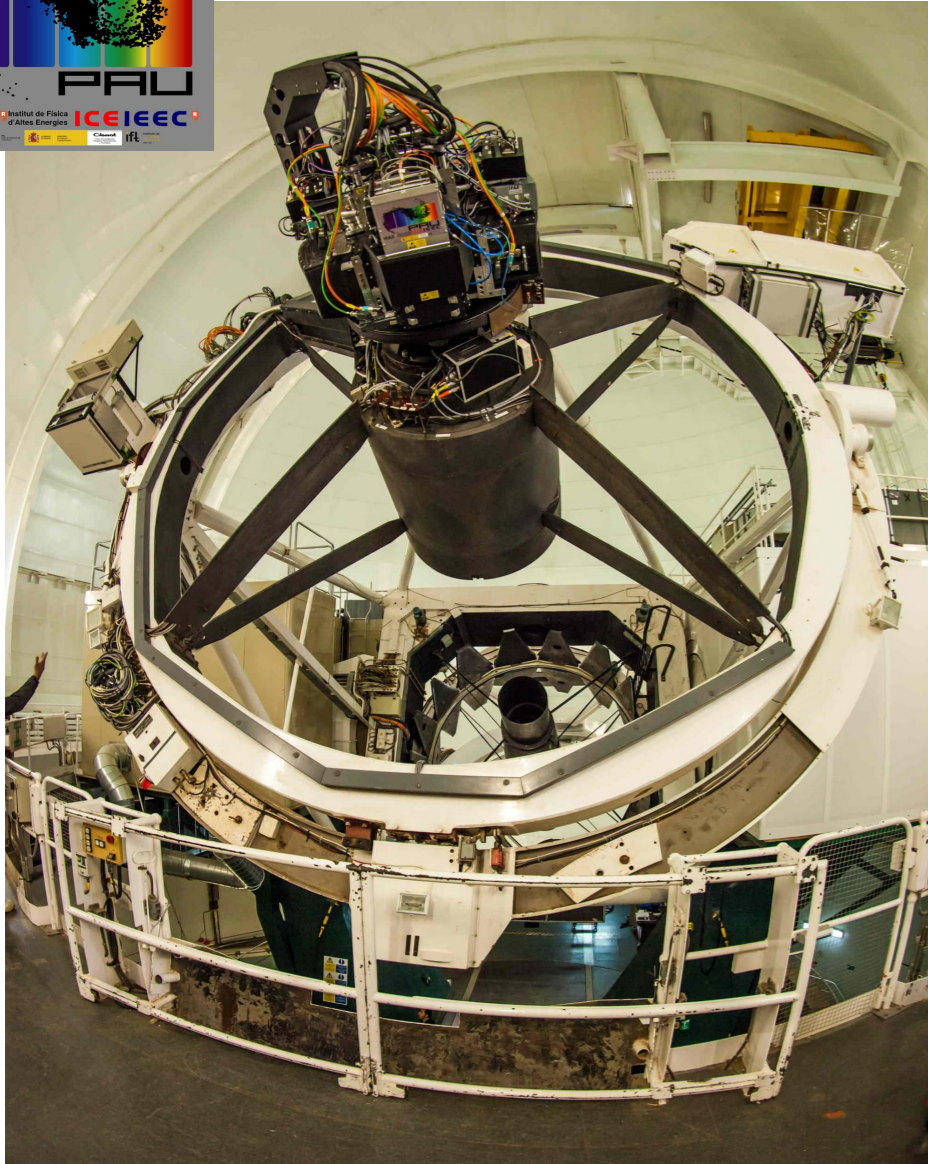


Euclid NISP instrument focal plane

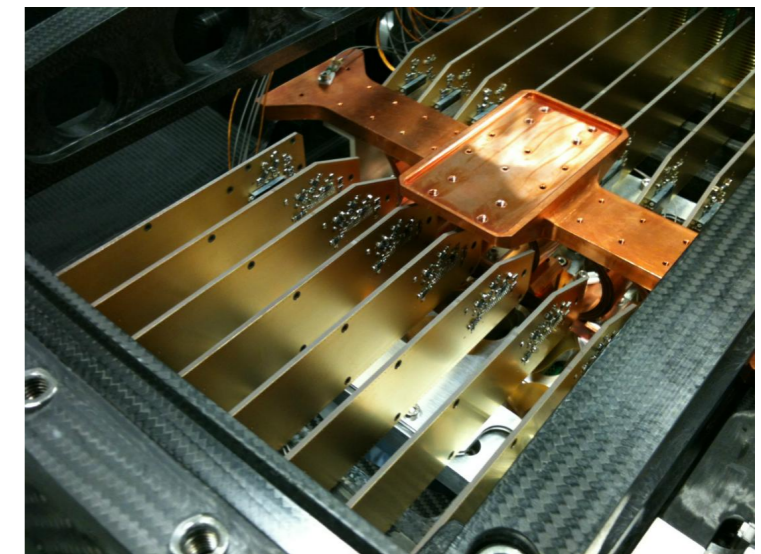
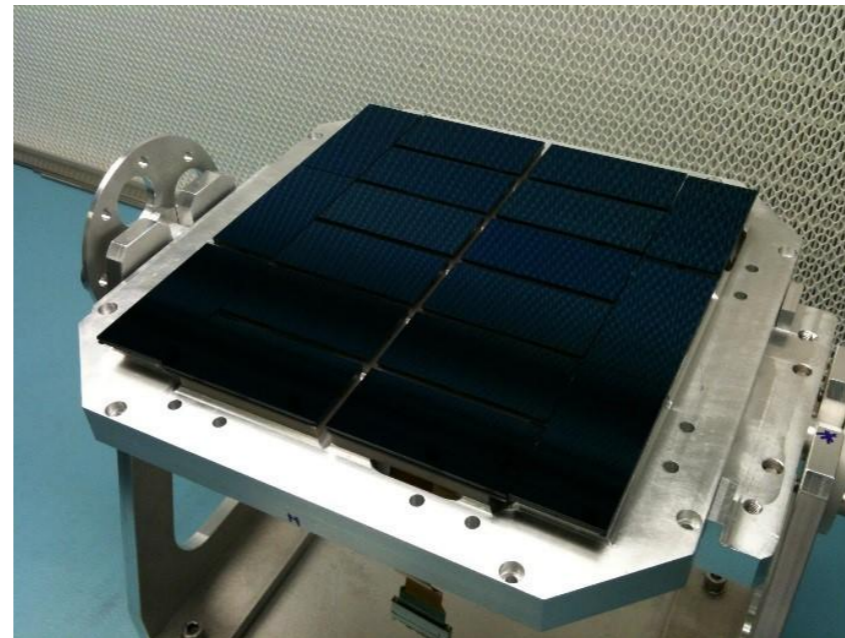
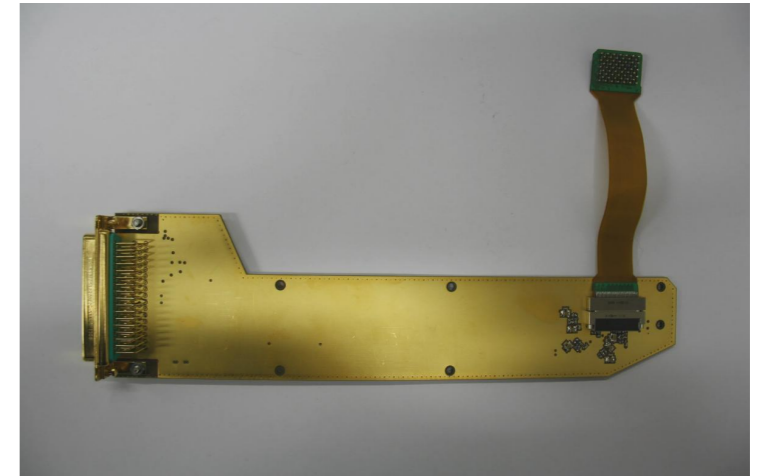
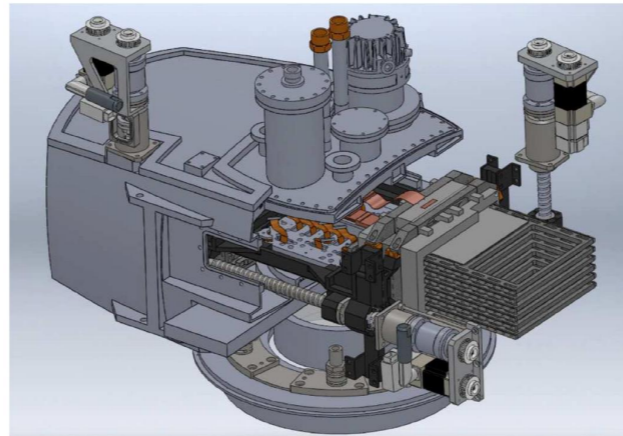
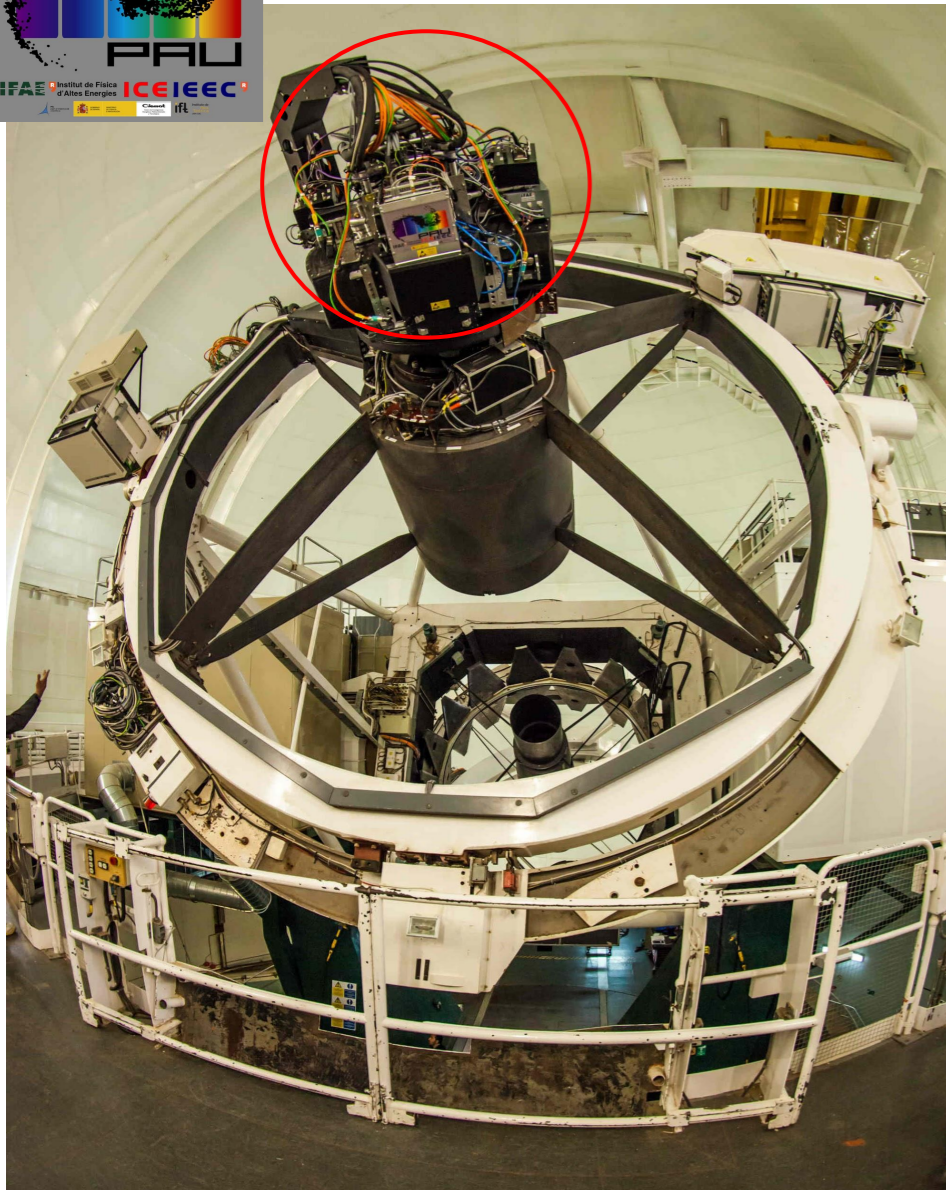
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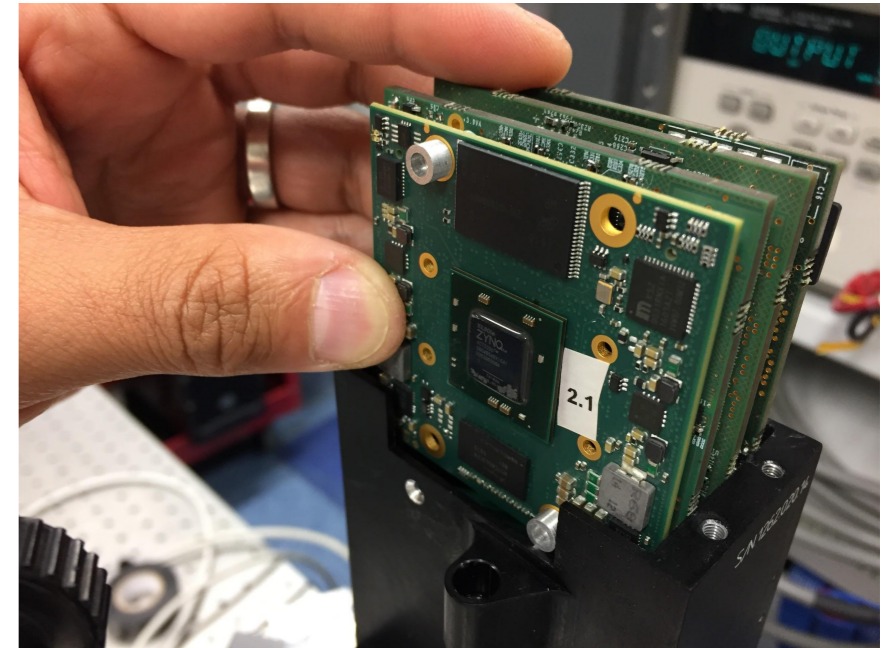
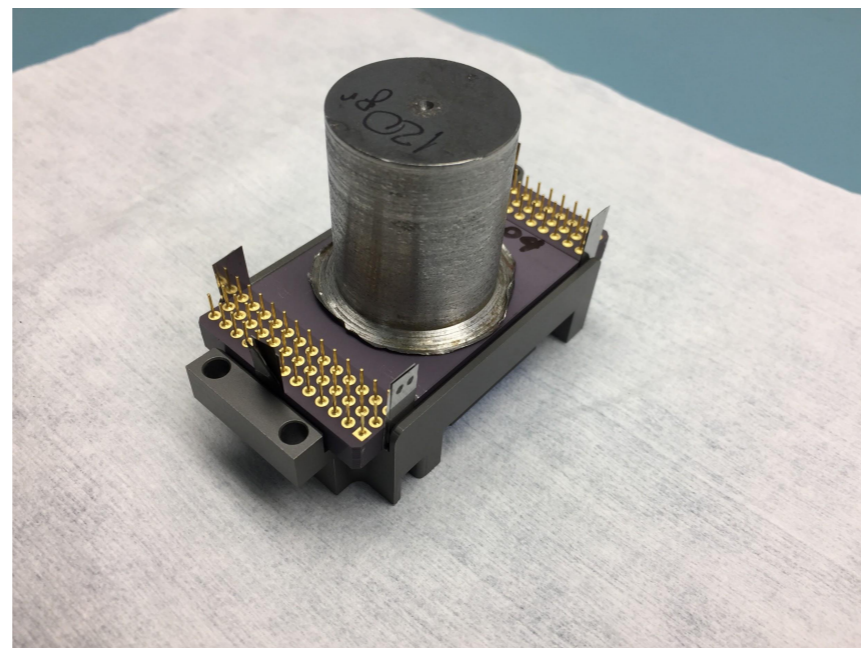
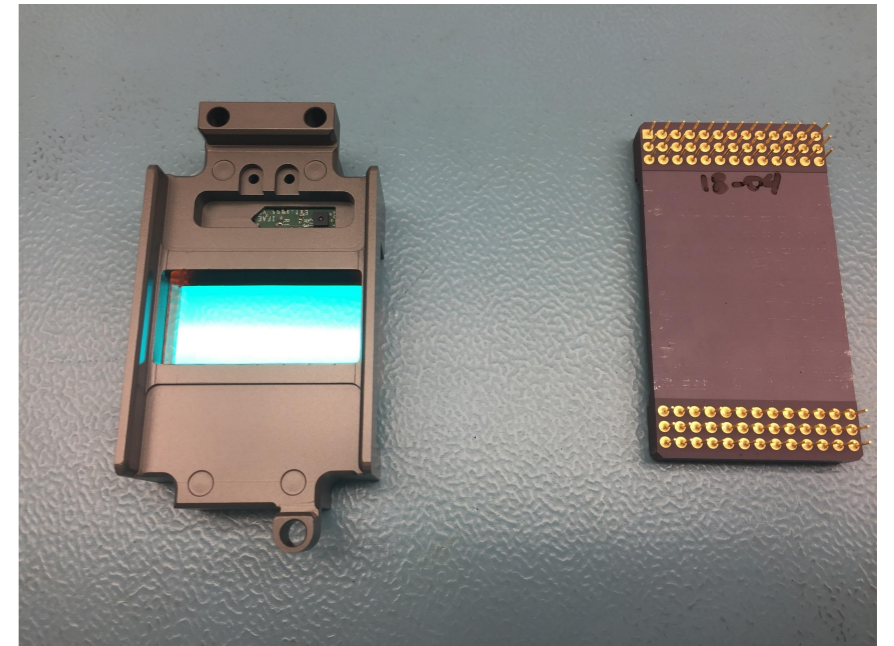
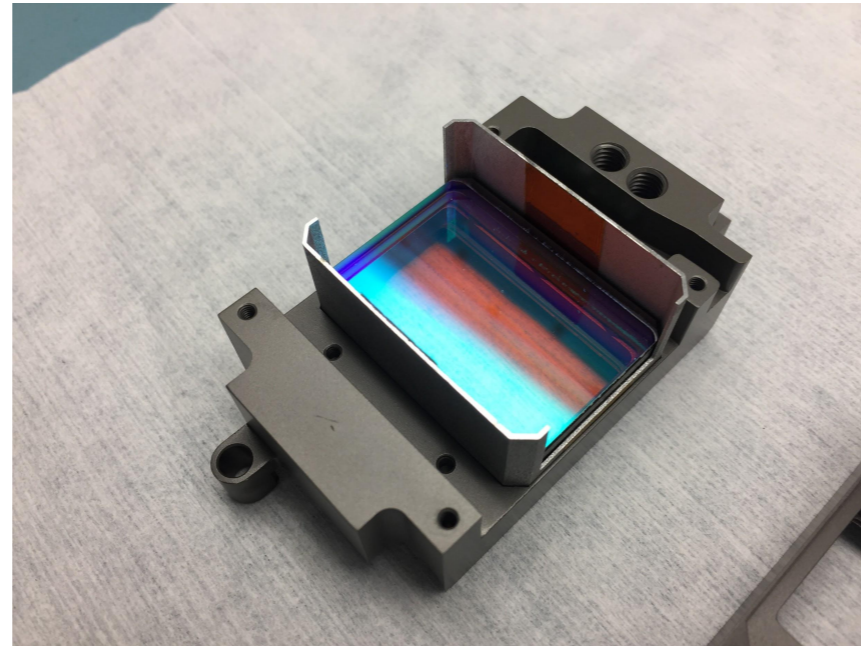
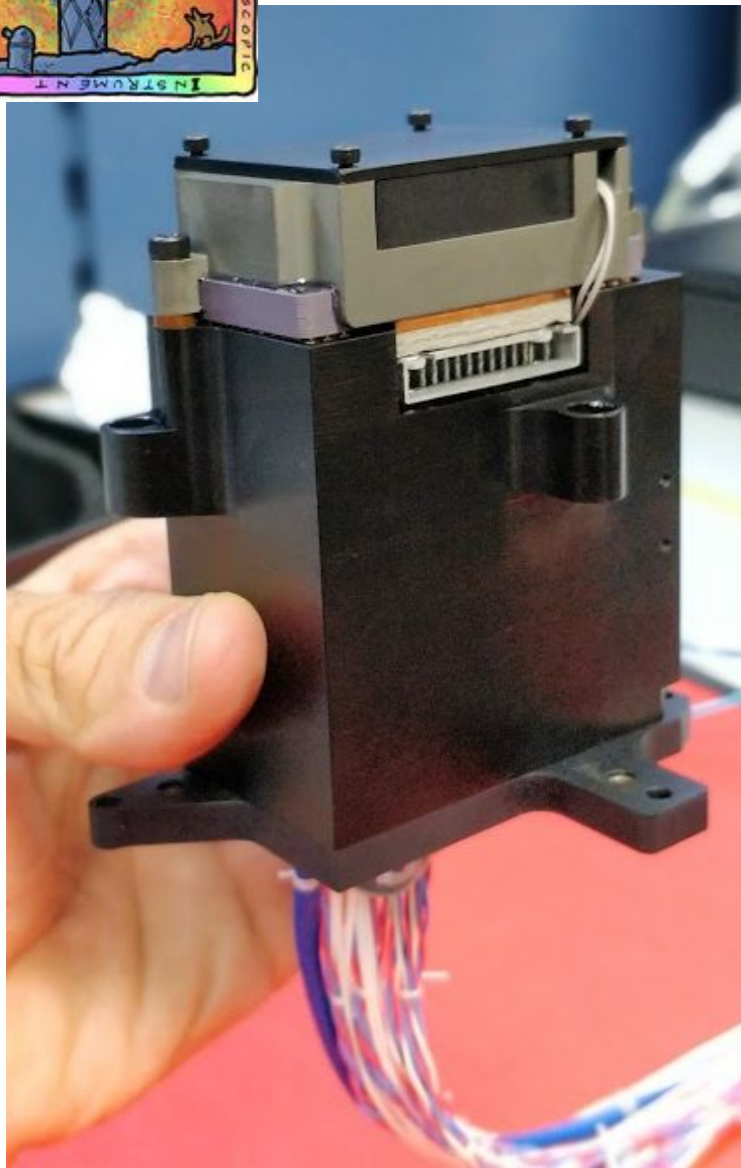
Optical detectors for astronomy at IFAE



Optical detectors for astronomy at IFAE



Optical detectors for astronomy at IFAE



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

Main Tasks at IFAE:

2. Responsible for the Communications and Outreach:

<http://asteroidh2020.eu>



ASTEROID Home News Partners Publications Contact

ASTRONOMY
EUROPEAN
INFRARED
DETECTOR

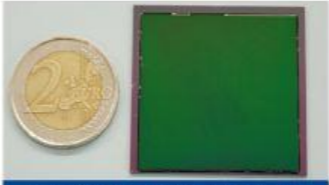
ASTEROID

Home

ASTEROID is an EU funded H2020-COMPET project whose main objective is to provide Europe with the capability to manufacture high performance infrared 2k2 Focal Plane Arrays of 15 μm pitch pixels that can be used in scientific and astronomical space and ground telescope missions.

Classical IR detectors used for tactical or space missions are mainly linear arrays or two dimensions Focal Plane Arrays (FPA) which designs are compatible with the scene to observe. For defense applications, the typical scenes to observe include vehicles, humans and buildings. For Earth observation missions from satellites, the scenes to observe are landscapes, ground, sea and atmosphere.

These applications require detectors compatible with IR flux from Near IR (NIR), ShortWave IR (SWIR), MidWave IR (MWIR) and LongWave IR (LWIR). The fluxes coming from these scenes are in the range of 1000 to 1e6 photons/seconds/pixel. Moreover, the sizes of the classical detector used for these applications are XGA format at maximum (range 1000x1000 pixels).




First mock-up for feasibility evaluation at Sofradir

However, for science and astronomy, specific infrared (IR) detectors are required. These types of detectors have their own specificities. These focal plane arrays (FPA) need to be very large (> four million pixels) and compatible with very high performances, especially very low dark current and very low electrical noise. These requirements are mandatory for observation where the objects (exo-planets, stars, galaxies and other space objects) to observe are very far from Earth and deliver a very small signal to detect. In this case, the infrared flux is of the order of 1 to a few hundreds of photons per second per pixel. The resolution of this type of detector is also an important specification. This constrains the format and pixel size of the detectors. Indeed it is worth noting that the resolution improvement can't be achieved by reducing the pixel size too much which would reduce even further the photon flux per pixel and put too many constraint on the dark current and noise requirements. Therefore with keeping the pixel pitch about constant high resolution IR detectors for science and astronomy can only be achieved with very large surface FPA. Today large dimension infrared focal plane arrays (IR FPA) are only available from US Company Teledyne.

ASTEROID will enable Europe to acquire the technology and knowledge necessary to manufacture 2k² IR FPA, define the types of products to design and define the strategy to create an industrial manufacturing line of these detectors.

ASTEROID teams five European partners working in leading edge technologies to enable Europe to be independent in the procurement of high quality IR detectors allowing prime scientific projects in years to come.

ASTEROID
ASTRONOMY EUROPEAN INFRARED DETECTOR
EU funded H2020-COMPET project

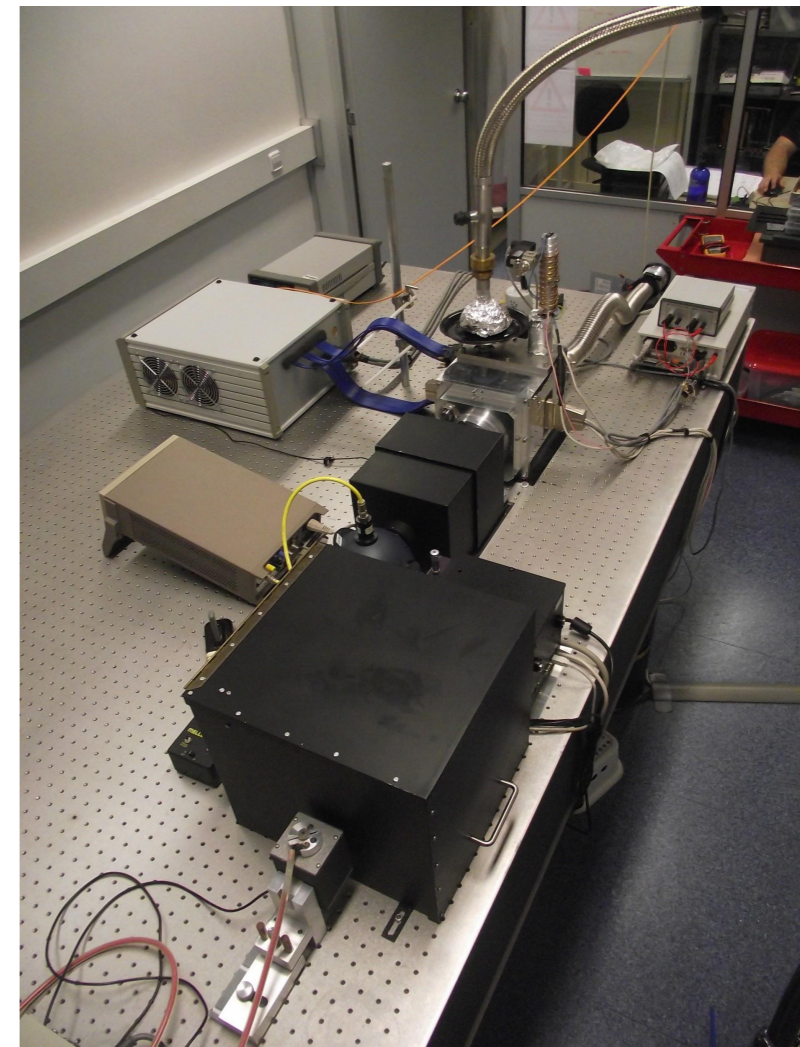
2k2 Prototype Validation / Connectivity and Reliability Assessment

Assembly and Integration Facilities at IFAE:

Optical Laboratory, Mechanical/Electronics Workshop and Clean Room



EPA laminar flow cabinet at IFAE clean room



Optical Setup

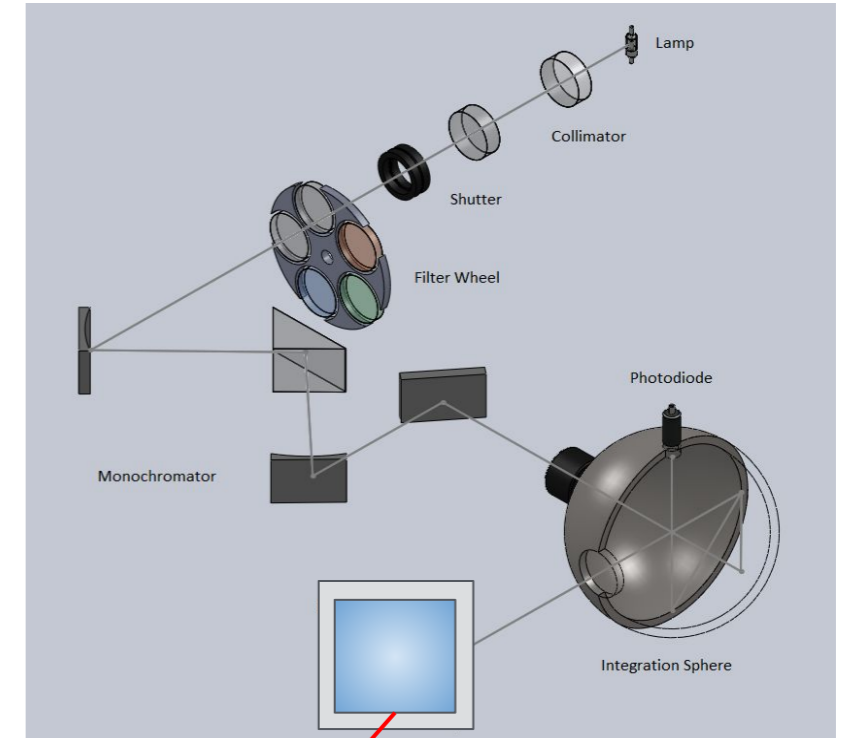
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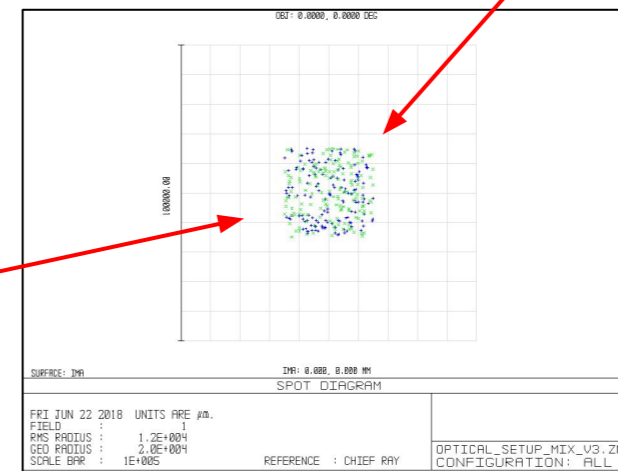
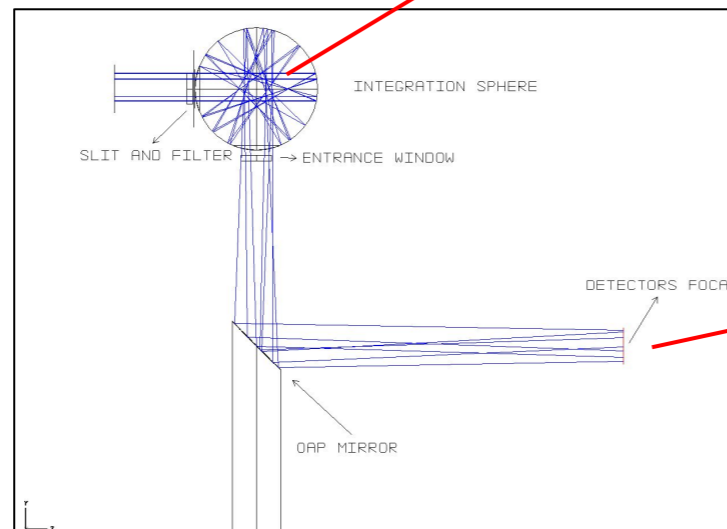
Optical Specifications

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:	$\geq 1\%$
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**

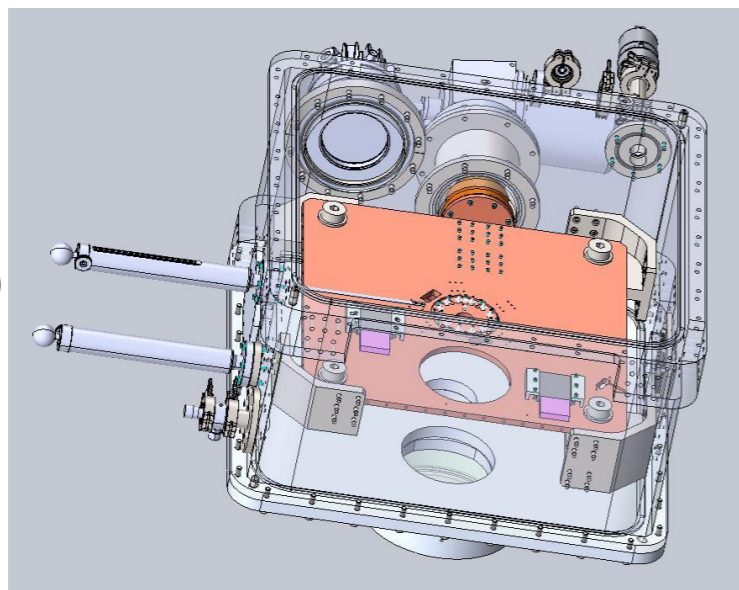
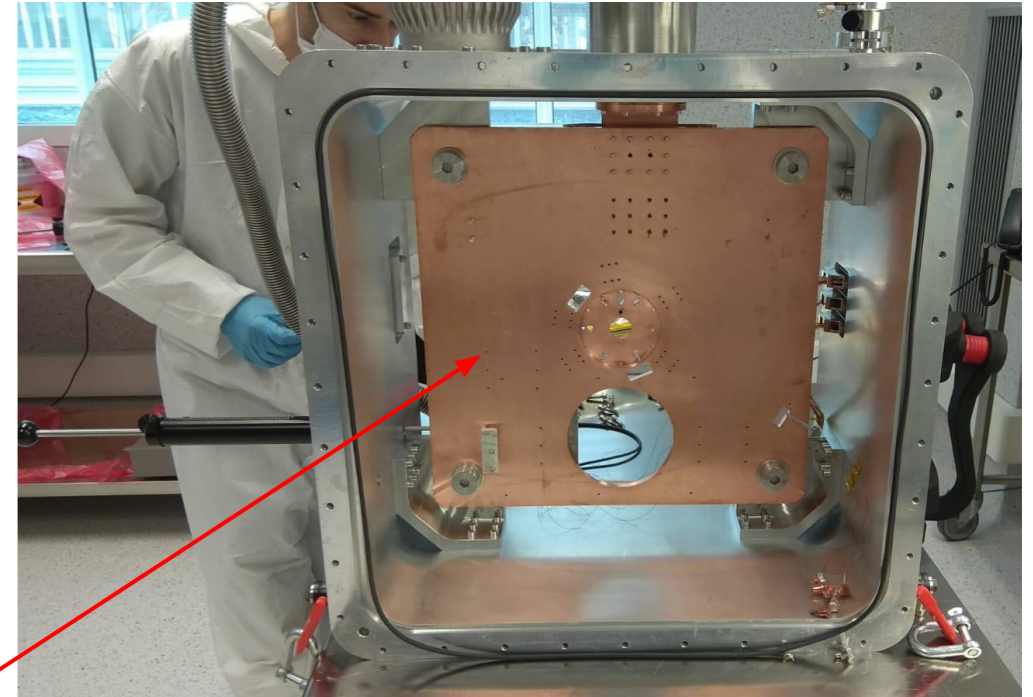
2k2 Prototype Validation / Connectivity and Reliability Assessment

Cryo-Vacuum and Cooling:

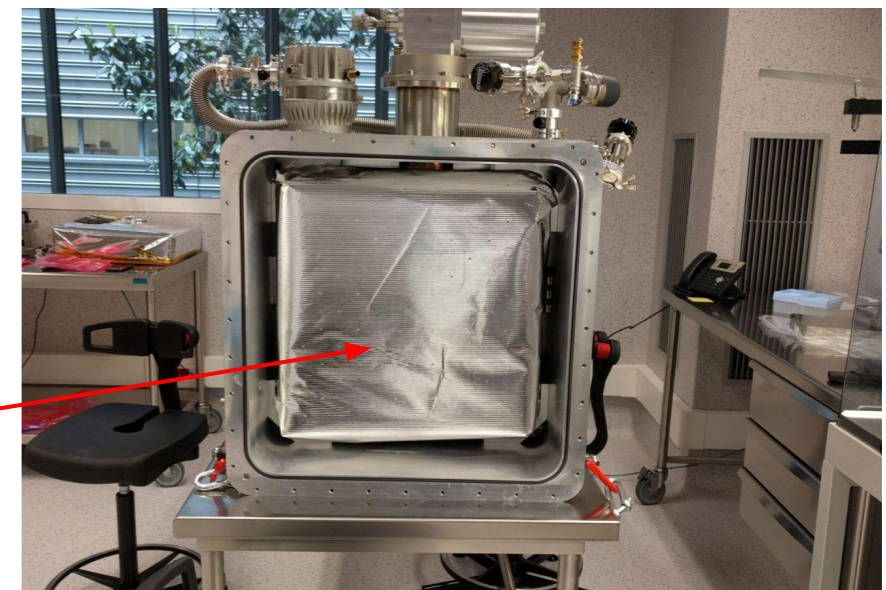


Cryogenics, Vacuum and Cooling Specifications

Cooled Breadboard Area	0.2 m ² (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)



Cold Breadboard



Radiation Shield

**Solidworks®
 cryostat's CAD**

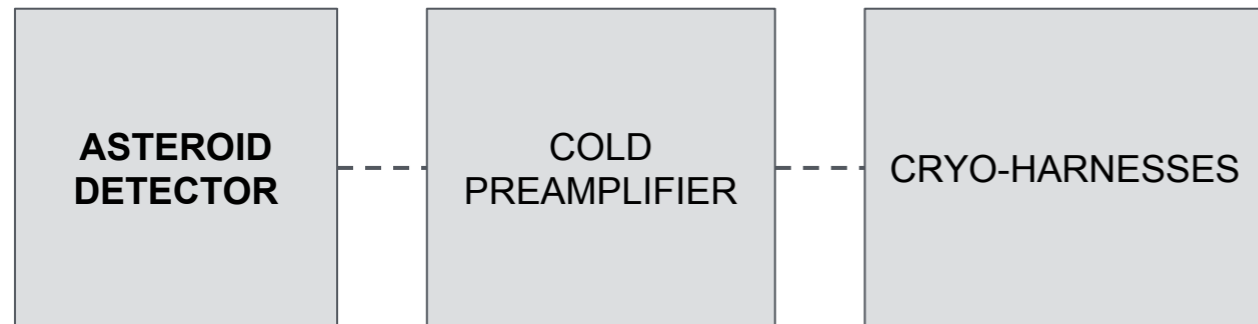
2k2 Prototype Validation / Connectivity and Reliability Assessment

Readout Electronics:

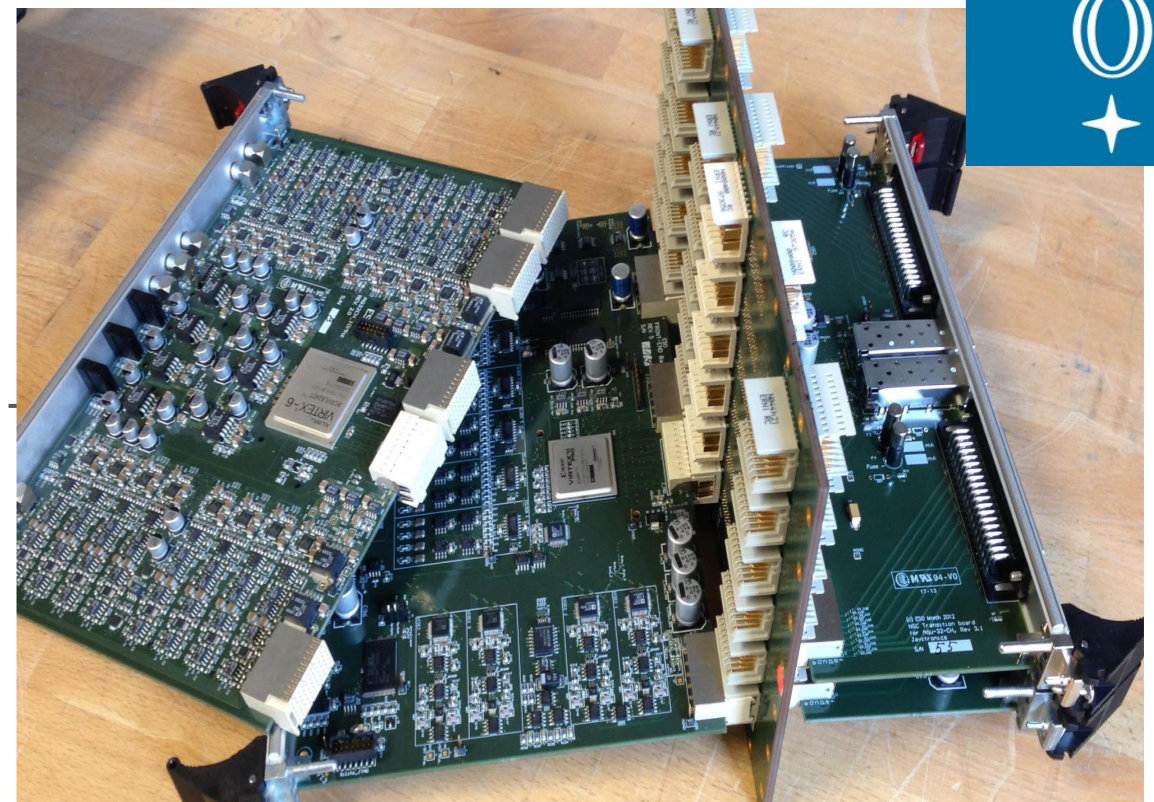
ESO-NGC controller fully compatible with ASTEROID



$T_{DET} = 100\text{ K}$



VACUUM SIDE



$T_{ROE} = \sim 300\text{ K}$

ATMOSPHERIC SIDE

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 15 μ m 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.

ASTEROID

Thanks you!