

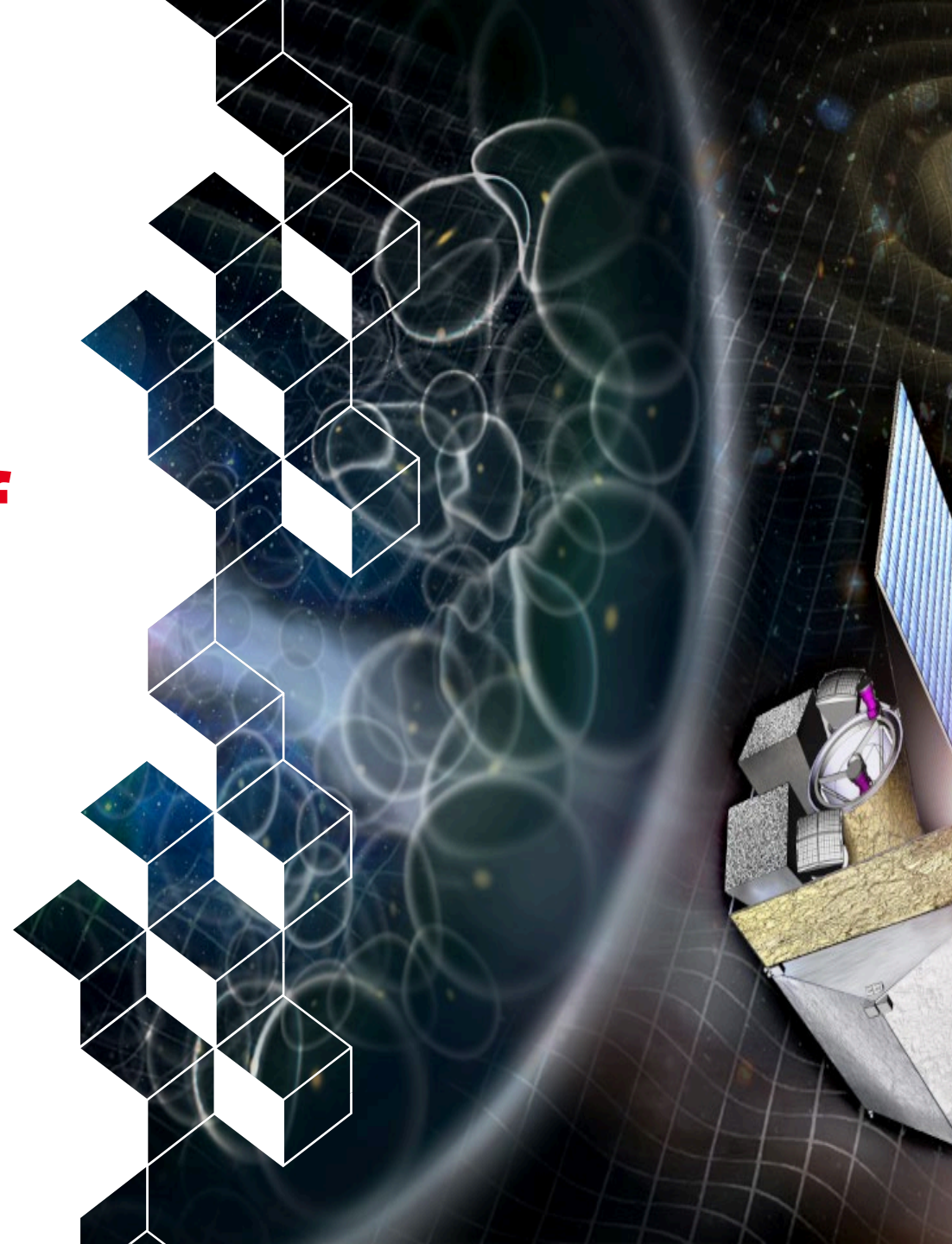
The Camera of the Infra-Red Telescope of the THESEUS mission

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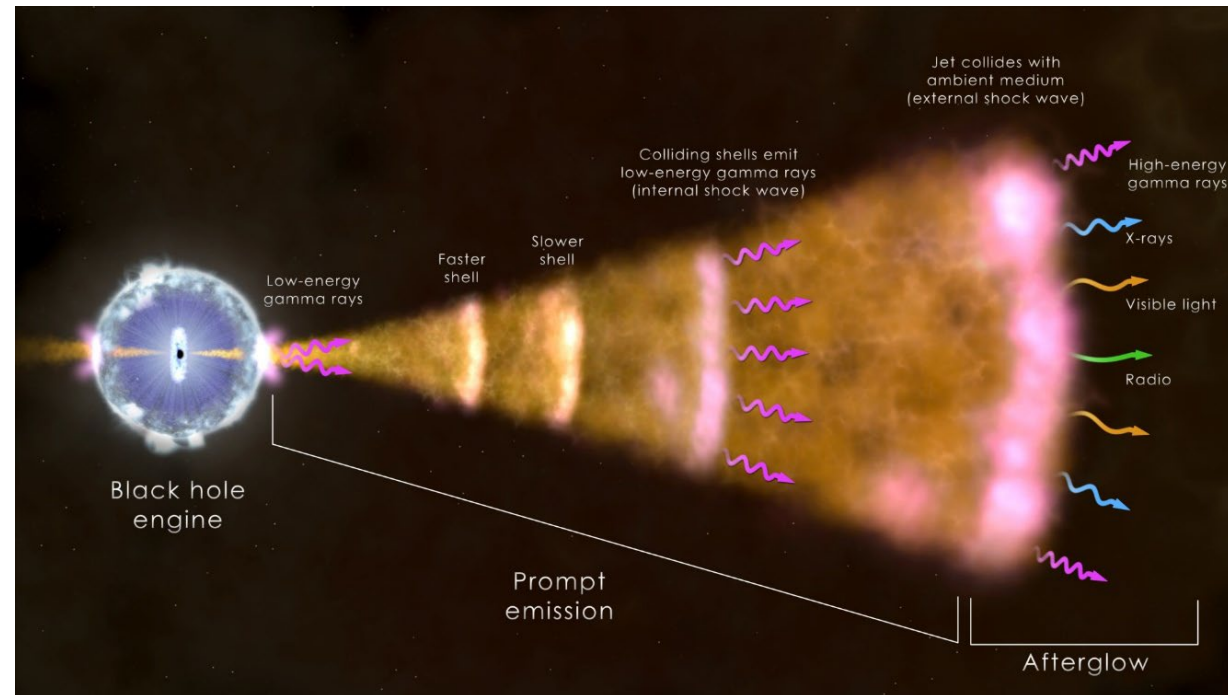
Outline

- 1. The THESEUS mission: The early Universe and the local and variable Universe**
- 2. The IRT design: from the telescope to the detector**
- 3. Operational sequences of the detection chain**
- 4. Conclusion**



Scientific context, the gamma-ray bursts (GRB)

- The **Gamma-ray bursts** are the most energetic events of the Universe. They can appear everywhere in the sky.



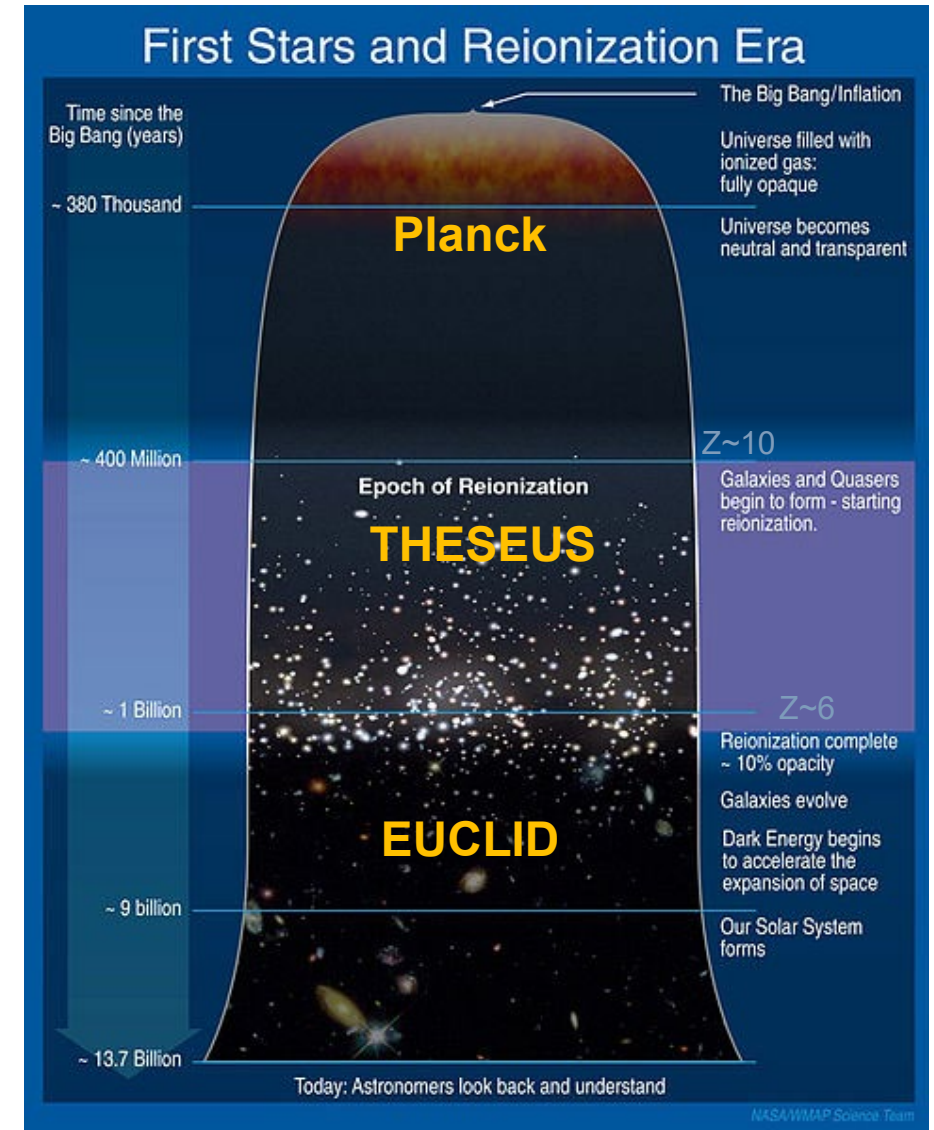
- Short gamma-ray bursts (< 2 s) are produced by colliding neutron stars, associated to the emission gravitational waves (observational evidence in August 2016) → **Era of multi-messenger astrophysics**.
- The physics of GRB requires the information of the **distance which is contained in the infrared afterglow emission**. Dedicated missions: Swift (2004) and SVOM (2024). None of them has a infrared instrument on board.

The early Universe: GRB as probes

GRB were observed from redshifts ~ 0.1 to 9.6. They can be used to light galaxies at the epoch of reionisation (z from 6 to 10), not visible even by JWST.

- When and how did the first stars and galaxies form? What are their properties?
- When and how did the Universe become enriched with metals?
- What sources contributed to reionization?

Infrared emission contains information on matter in the light of sight, so the **host galaxy properties** (mass, metallicity) and their **star formation rate**.



The THESEUS mission

Transient High Energy Sky and Early Universe Surveyor

The candidate for the ESA M7 mission is built around two main pillars:

- The early Universe
- The local and variable Universe

It is composed of **three instruments optimised for GRB observation**:

- **SXI (Soft X-ray Imager)** : 0.3-0.6 keV, 1 sr field of view, 2 arcmin angular resolution
- **XGIS (X-Gamma rays Imaging Spectrometer)** : 1 keV - 10 MeV, 1 sr field of view, 5 arcmin angular resolution
- **IRT (Infra-Red Telescope)** : 0.7-1.8 μm wavelength range, 10 x 10 arcmin² field of view

The mission is planned to be placed in **low-Earth orbit** for fast alert transmission and receiving.

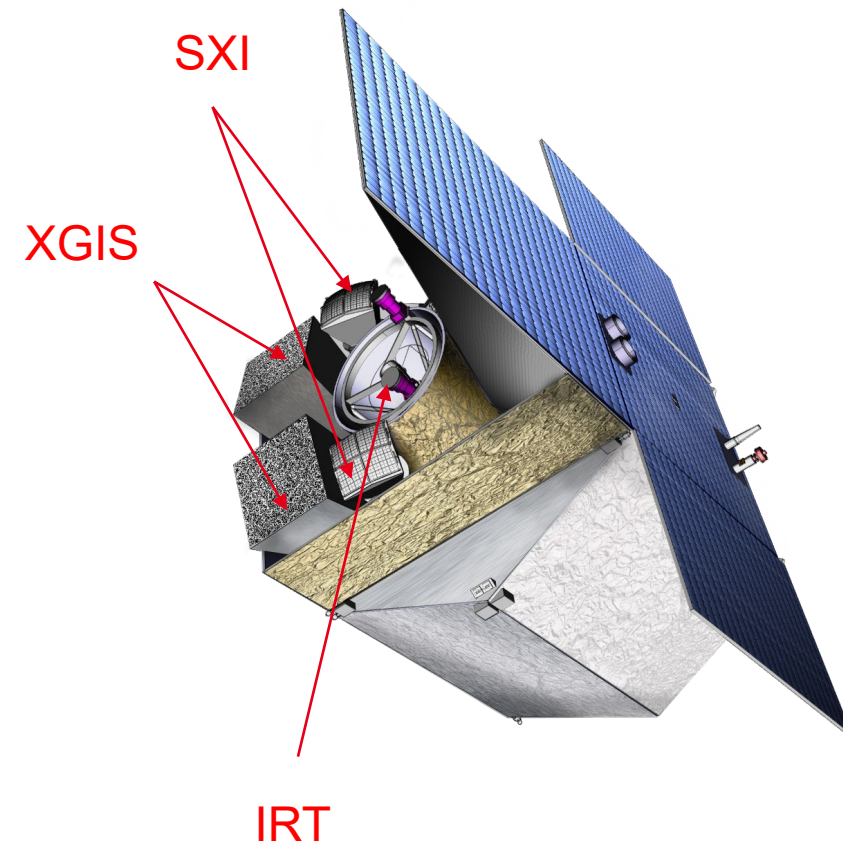
Cosmic Vision M7 context

Phase A: 2024-2026

Mission selection: June 2026

Mission adoption: 2029

Mission launch: 2037

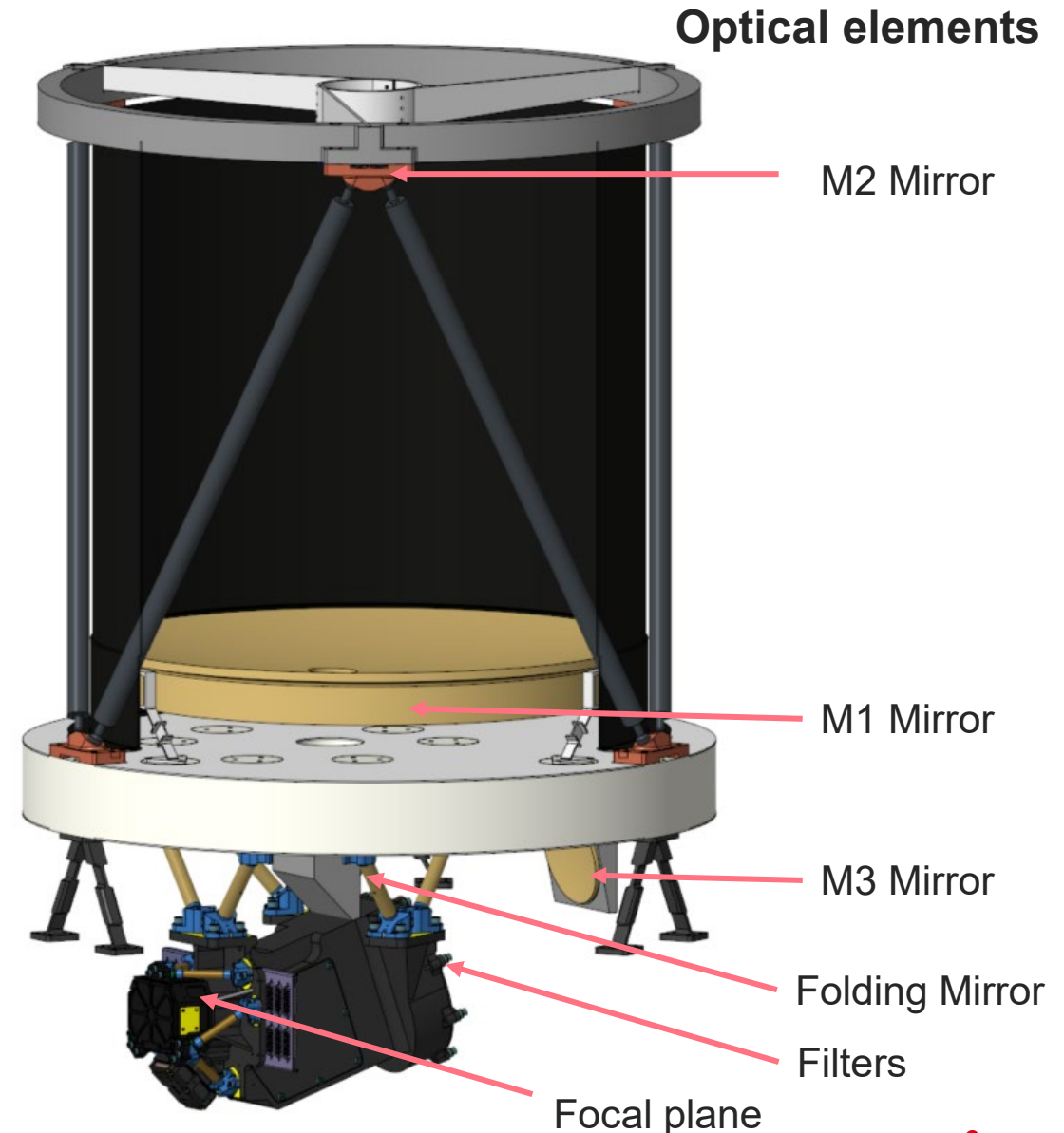


The IRT instrument

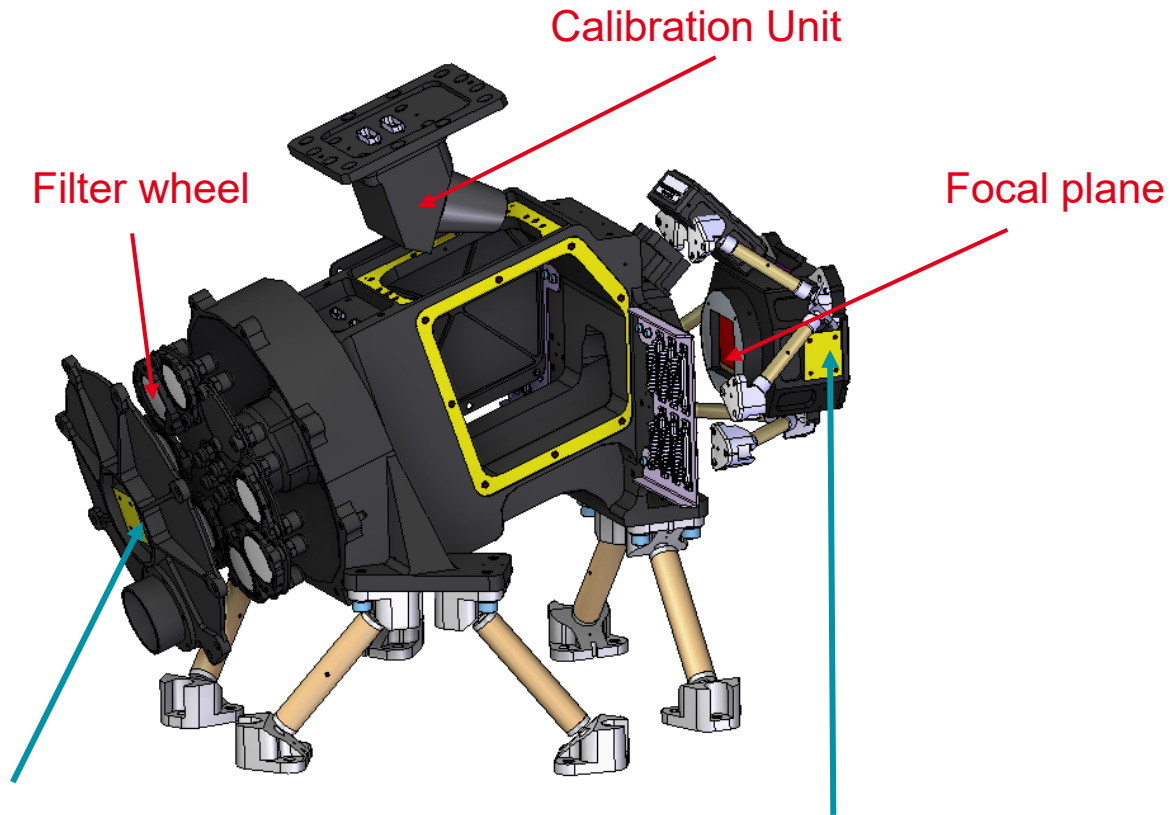
The main goals of the IRT are to

- Detect, localize and determine the GRB distance in near-real time
- Characterize the GRB and its environment (light curves/spectra)

Parameters	Expected Value
Type	Focusing on-axis Korsch observing off-axis Fields of views (FoVs) (Line of sight in photometry: 0.884° from M1-M2 axis of symmetry)
Entrance pupil	700 mm (M1 rim)
Collecting area	$> 0.34 \text{ m}^2$
M1-M2 distance	675 mm
Focal length	6167 mm
Field of view	Photometry: $15' \times 15'$ (goal: $19.8' \times 15.3'$) Spectroscopy: $2' \times 2'$ (Separation: $1'$)
Wavelength range	700-1800 nm for photometry (filters IZYJH) 800-1600 nm for spectroscopy



The IRT Camera

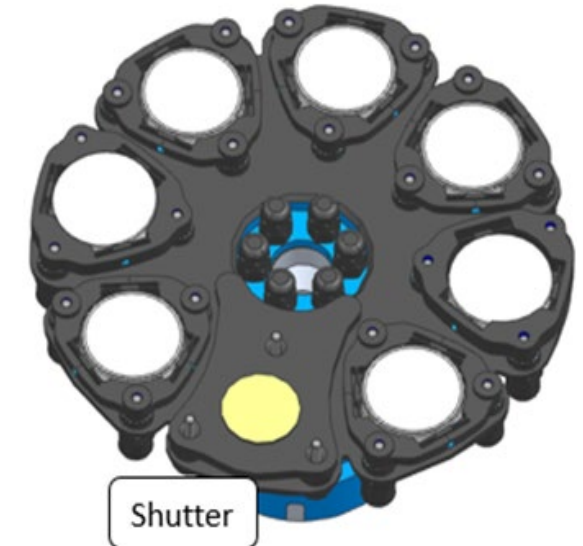


Structure at 160 K
(thermal background)

Focal plane enclosure at 120 K
(detector performance)

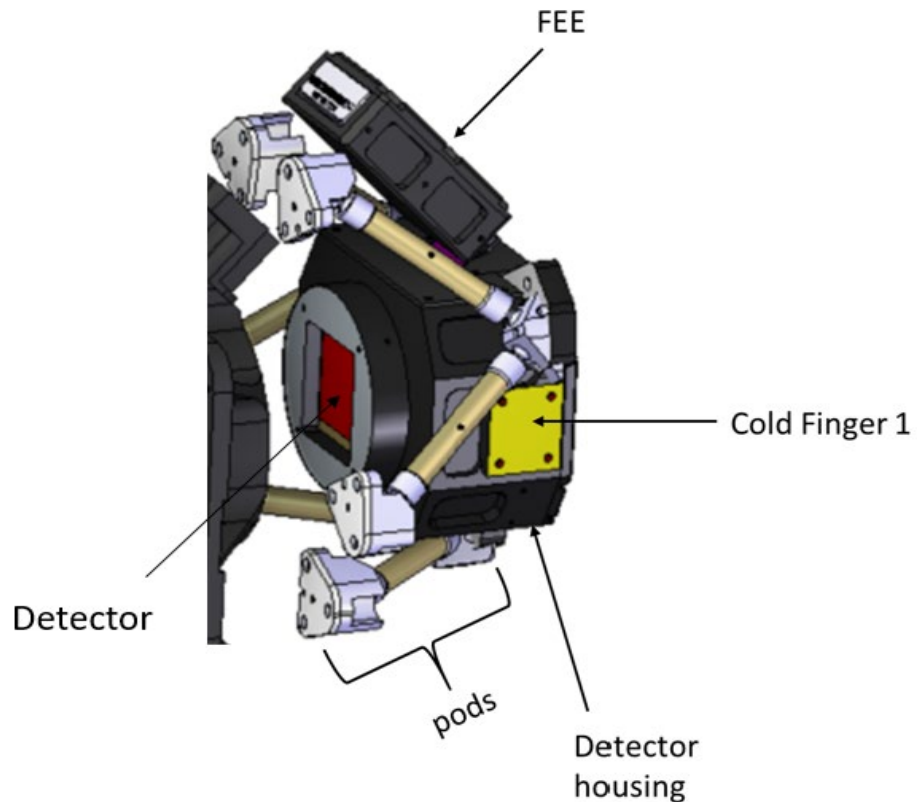
Managed by cryocoolers in the platform

Wheel position



- « Open » 0.7 – 2.3 μm filter to limit thermal background
- Closed (for calibration)
- **5 filters**: I, Z, Y, J, H centered on 0.8, 0.9, 1.0, 1.2 and 1.6 μm for photo-Z imaging
- **Grism** for spectroscopy between 0.7 and 1.8 μm

The Focal plane assembly



Detector: H2RG

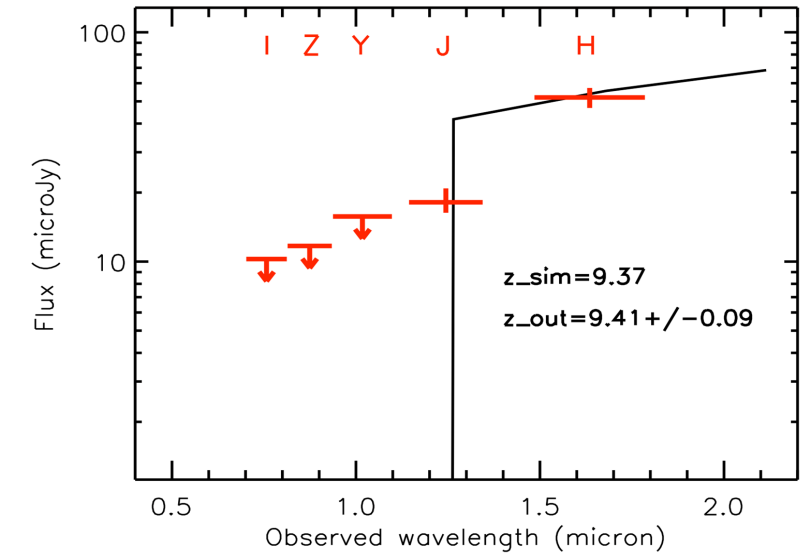
Design / provider	Teledyne (US)
Technology	HgCdTe – substrate CdZnTe
Cut-off wavelength	2.3 μm
Pixel array	2048 x 2048
Pixel size	18 μm
Pixel scale	0.6 arcsec
Dark current at 120 K	1 or 2 e-/s/pix

FEE: SIDECAR ASIC

- 18 electrons rms (13 electrons in CDS mode)
- 0.5 W

Observational sequence: FOLLOW-UP

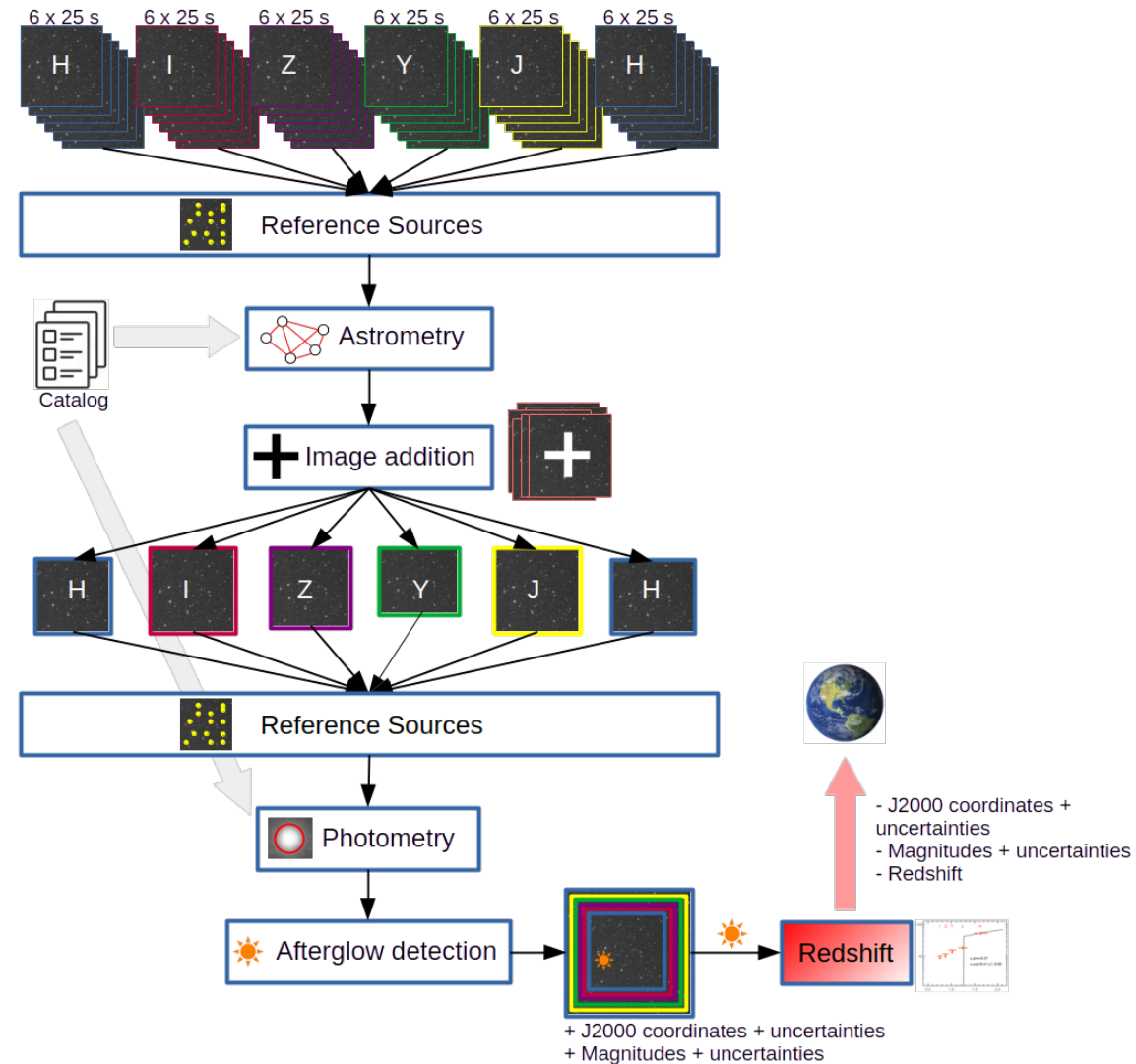
- A. Burst detection by SXI or XGIS (gamma-ray prompt emission)
- B. Satellite slew to put IRT FoV in the localisation error box
- C. **Start of FOLLOW (15 min)**
 1. 6 images of 25 seconds for each filter band (H, I, Z, Y, J, H)
 2. Source localisation: astrometry on-board (comparison of the sky image with a star catalog)
 3. Redshift evaluation by photo-Z imaging technique: detection of the Lyman- α break



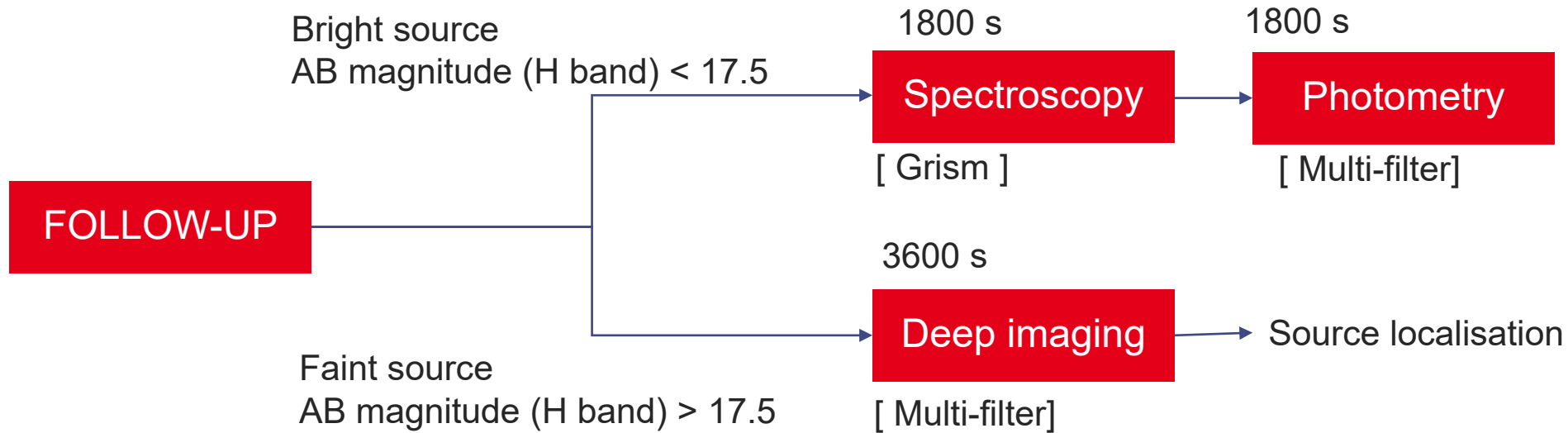
Performance requirements:

- Sensitivity: AB magnitude 20.8 (H band) with SNR = 5 [1.7 photons/s/pixel]
- 1.2 arcsec localisation precision
- 10% accuracy on the redshift
- 5% accuracy on the photometry (maximum flux of 6000 photons/s/pixel)

Data processing

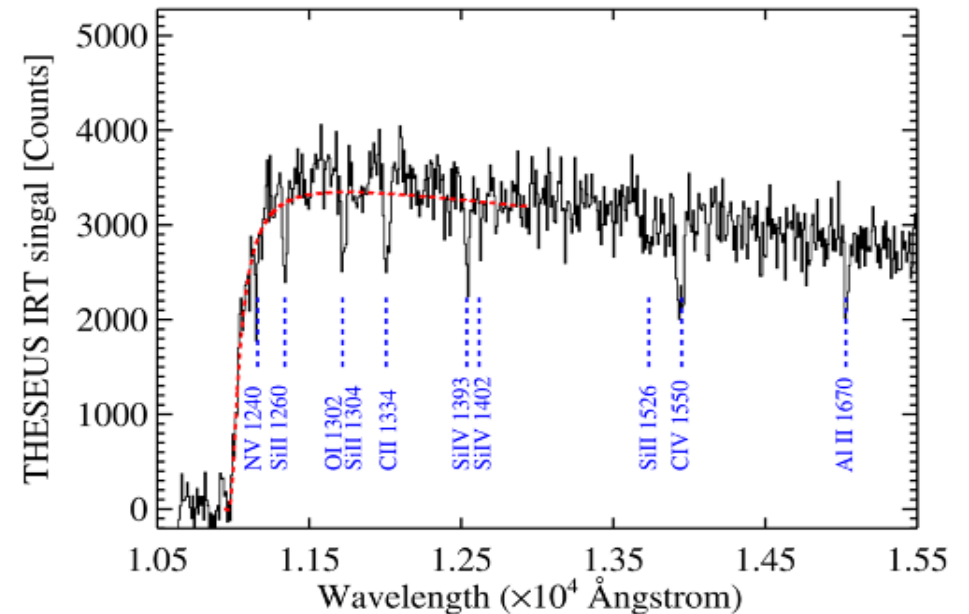


Observational sequence: CHARACTERISATION

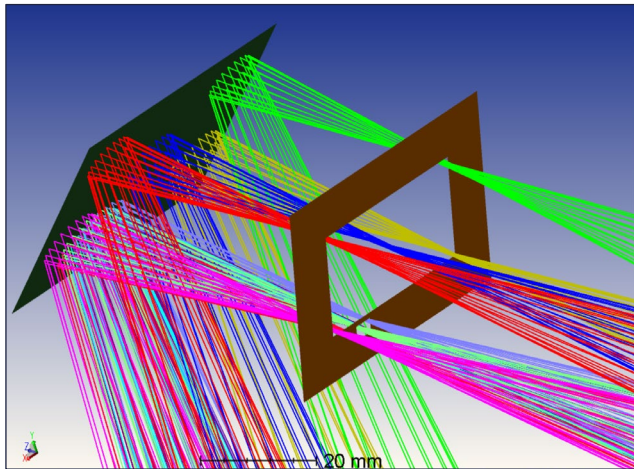
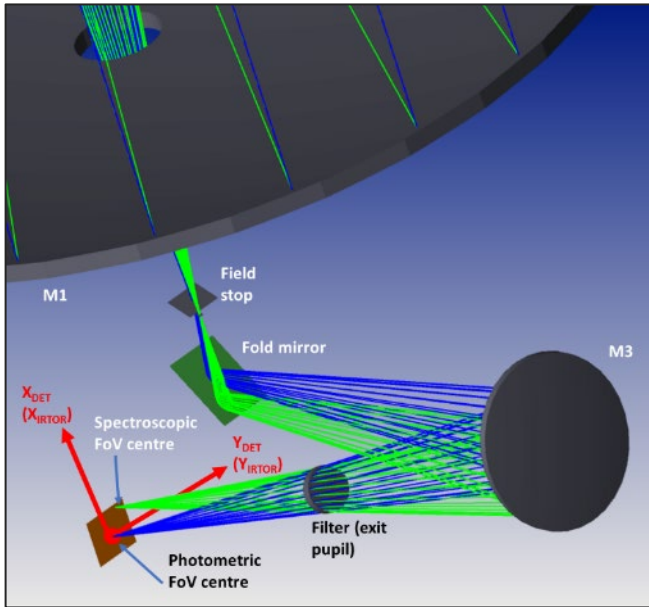


Performance requirements:

- Sensitivity: AB magnitude 16.4 (H band) with SNR = 10 (line doublet Ca II, Fe II, Si IV, Si II separation)
- Resolution power: 400 (at 1.1 μm)
- Pointing stability during the 60 s integration time (for each image or spectrum)



One single detector for 2 modes

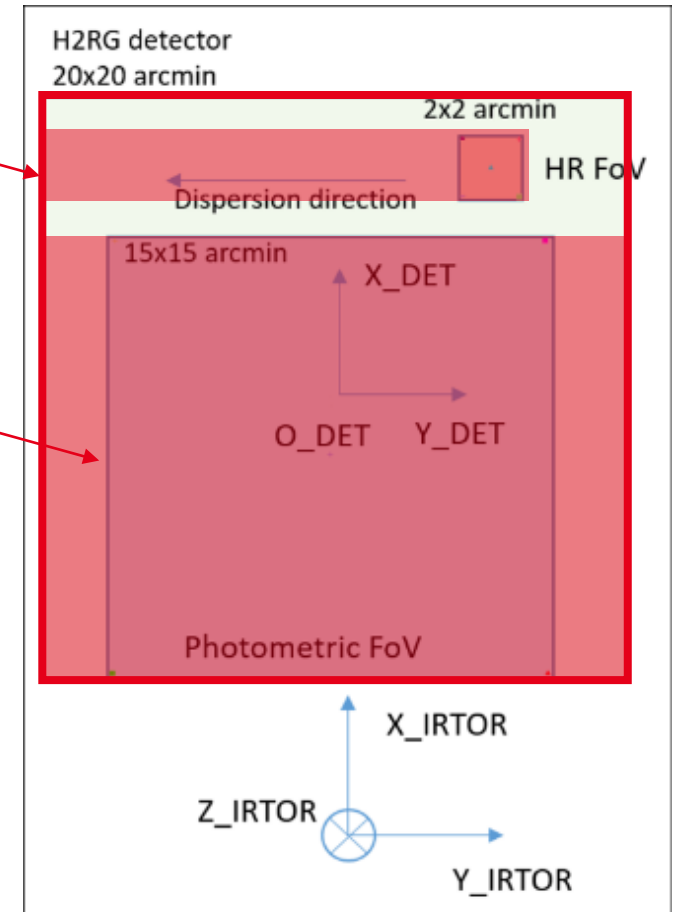
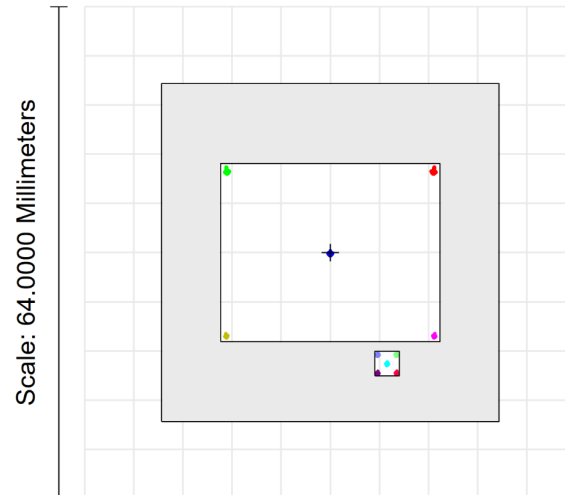


2 field of views by the field stop → 2 active area on the detector

Active area for spectroscopy
240 x 2048 pixels (including telescope stability)

Full frame acquisition and image « cropping »

Active area for photometry
1740 x 2048 pixels (including telescope stability)



Conclusions

- The THESEUS Infrared telescope implements with a single HgCdTe detector:
 - **Photometry** for GRB **localisation and redshift measurement**
 - **Spectroscopy** for **host galaxy characterisation**, in particular in the early Universe (reionisation epoch).
- In phase A, a global performance model was built to compute the **sensitivity of the instrument** and the **resolving power**, and was used to constrain the telescope image quality and the pointing stability by the platform and the instrument.
- (If selected in June 2026), a detailed model of the detection chain will have to be implemented in phase B to consolidate:
 - The readout mode requirements (CDS, MACC?)
 - The detector requirements (**leakage current, QE uniformity, persistence**)