The IRT Telescope on board the THESEUS mission

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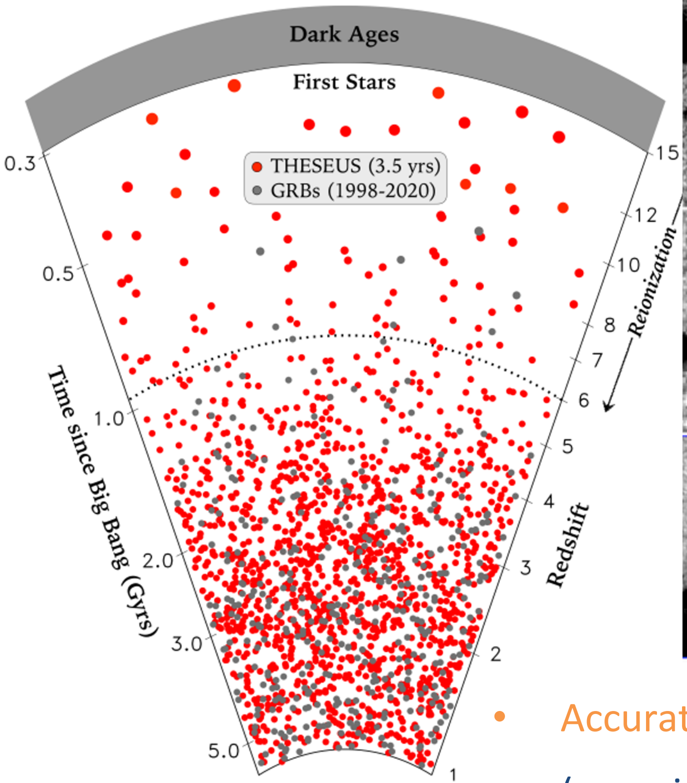
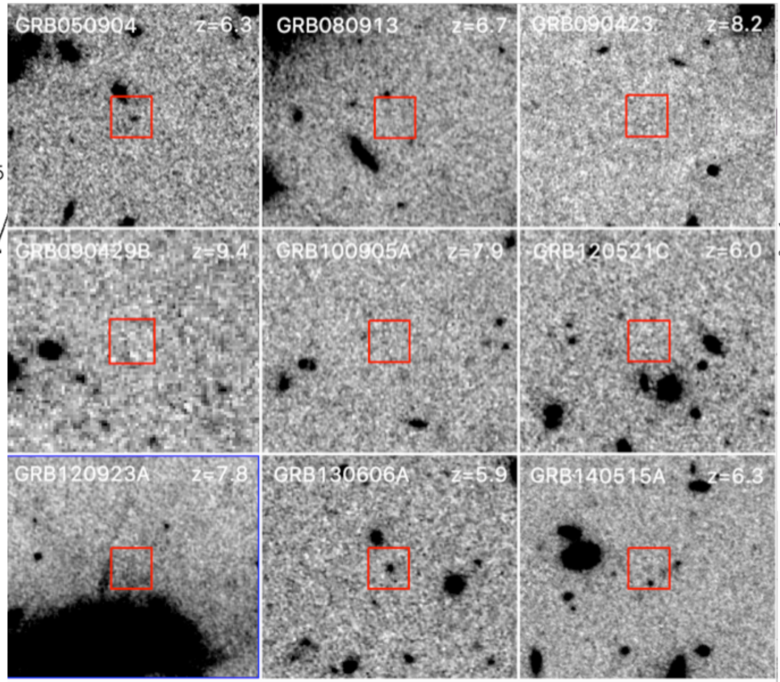
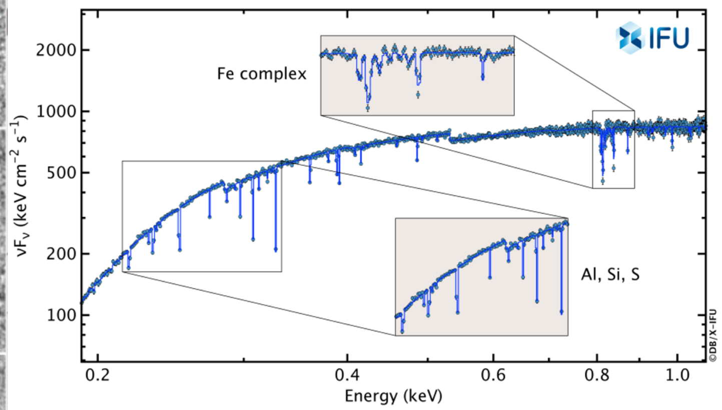
On behalf of the IRT consortium

Scientific Requirements



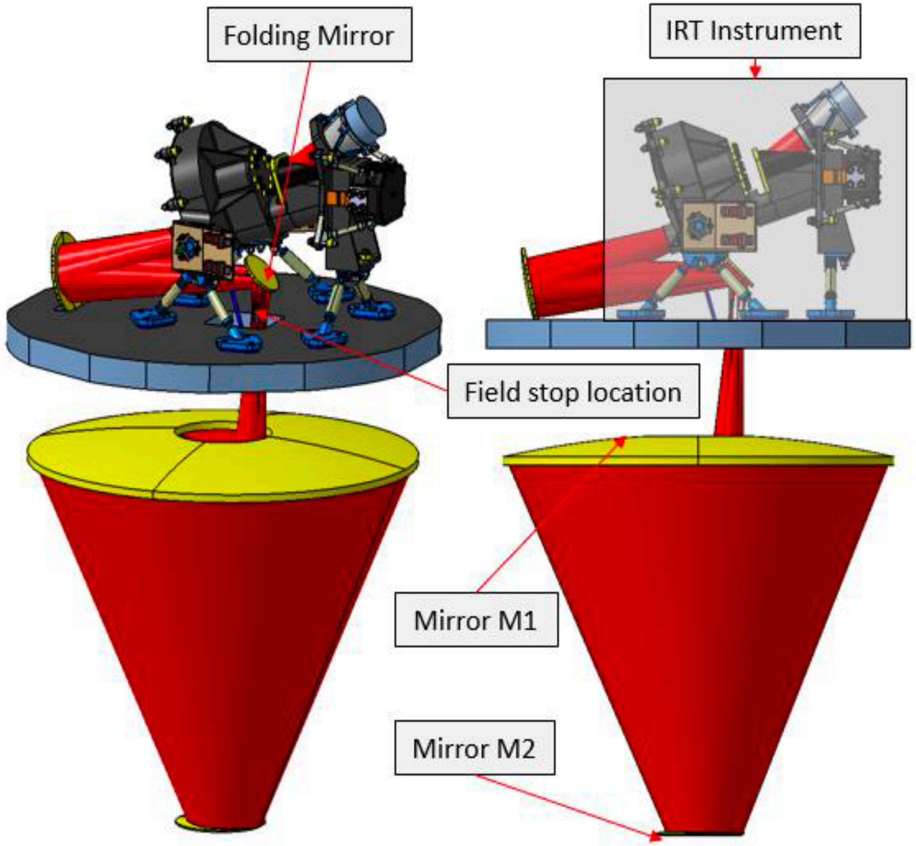




- Accurately localizing and promptly measuring the distance of THESEUS afterglows (especially at high redshift) is a key feature for the success of the mission.
- It enables the main science goals as well as a number of expected synergies
- Having a (near-) infrared autonomous and agile telescope in space has been quickly identified as a key requirement to the mission

The Infra-Red Telescope (IRT)

- *The main goal of the IRT is then to*
  - *Detect, localize and determine the GRB distance in near-real time*
  - *Characterize the GRB and its environment*



Observing strategy

Once a transient source is detected an localized by the SXI and/or the XGIS, a slew is requested to the satellite to point the error region.

Sequence after stabilization

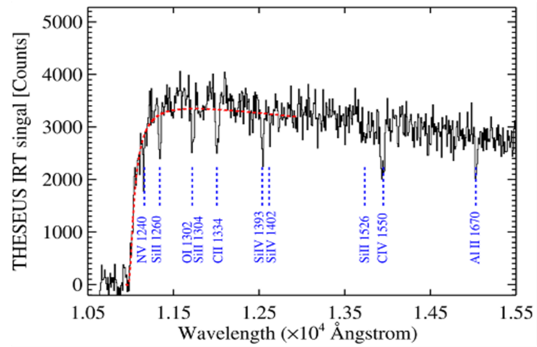
GRB trigger → Satellite slew → IRT acquiers 5 x 150 s images

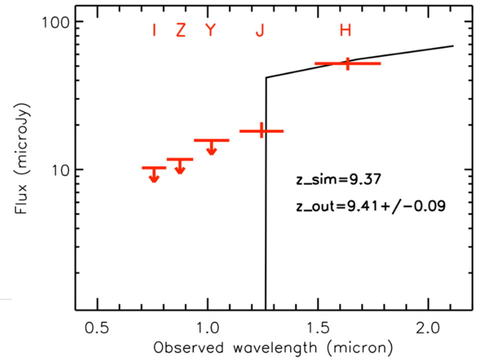
Follow-up mode: IRT acquiers 5 x 150 s images → GRB position and photo-z calculated on board and sent to ground in near real time

Satellite slew:

- *Bright source H < 17.5 (AB)* → *Characterisation mode*: IRT acquiers 1800 s spectrum → IRT performs multi-filter deep imaging for 1800 s
- *Faint source H > 17.5 (AB)* → IRT performs multi-filter deep imaging for 3600 s

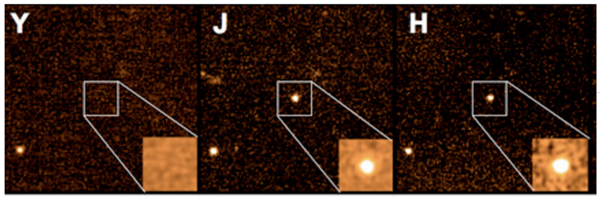
Spectra and images are sent to ground for analysis



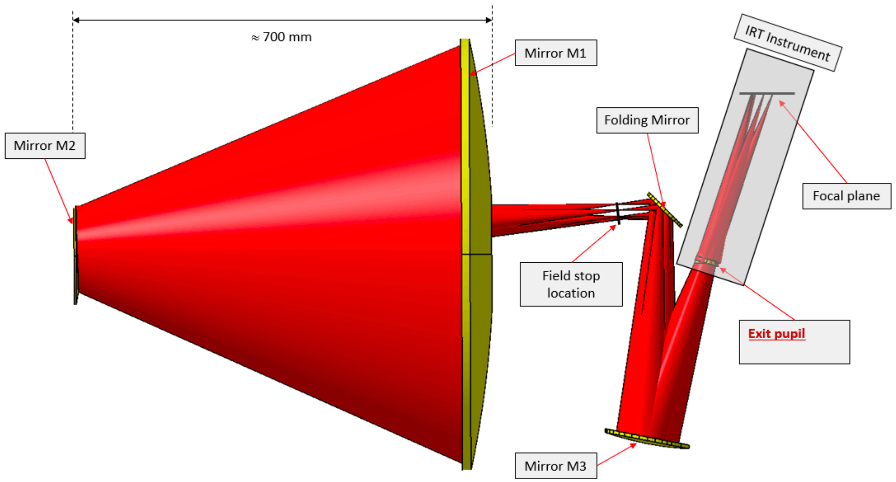


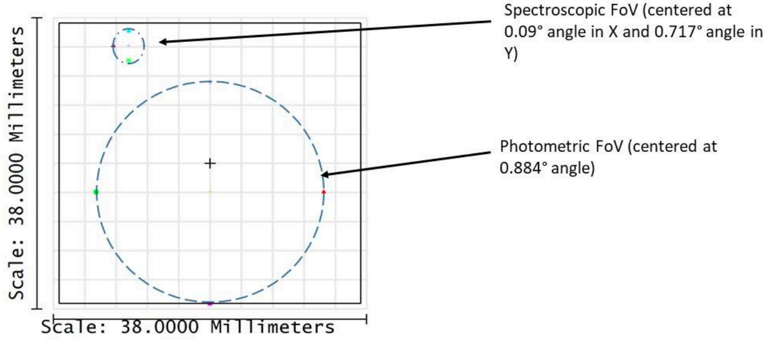
GRB 040923 at z~9.2

UKIRT & Gemini N



The IRT optical design





IRT telescope	
Type	Focusing off-axis Korsch
Entrance pupil	700 mm
M1-M2 distance	675 mm
Exit pupil	36 mm
Collecting area	> 0.34 m^2
Wavelength range	700-1800 nm
Throughput	> 80%
Pixel scale	0.6 arcsec/pixel for an IRT detector pixel pitch of 15 µm
Focal length	6188 mm
Temperature	240 K
Field of view	15 x 15 $arcmin^2$ (photometric) 2 x 2 $arcmin^2$ (spectroscopic)
LoS (photometric)	0.884° from M1-M2 axis of symmetry
Straylight requirement	70 photon/m^2/$arcsec^2$/s
Image quality requirement (at 1800 nm wavelength)	50% of the encircled energy diameter < 1.28 arcsec 80% of the encircled energy diameter < 2.29 arcsec

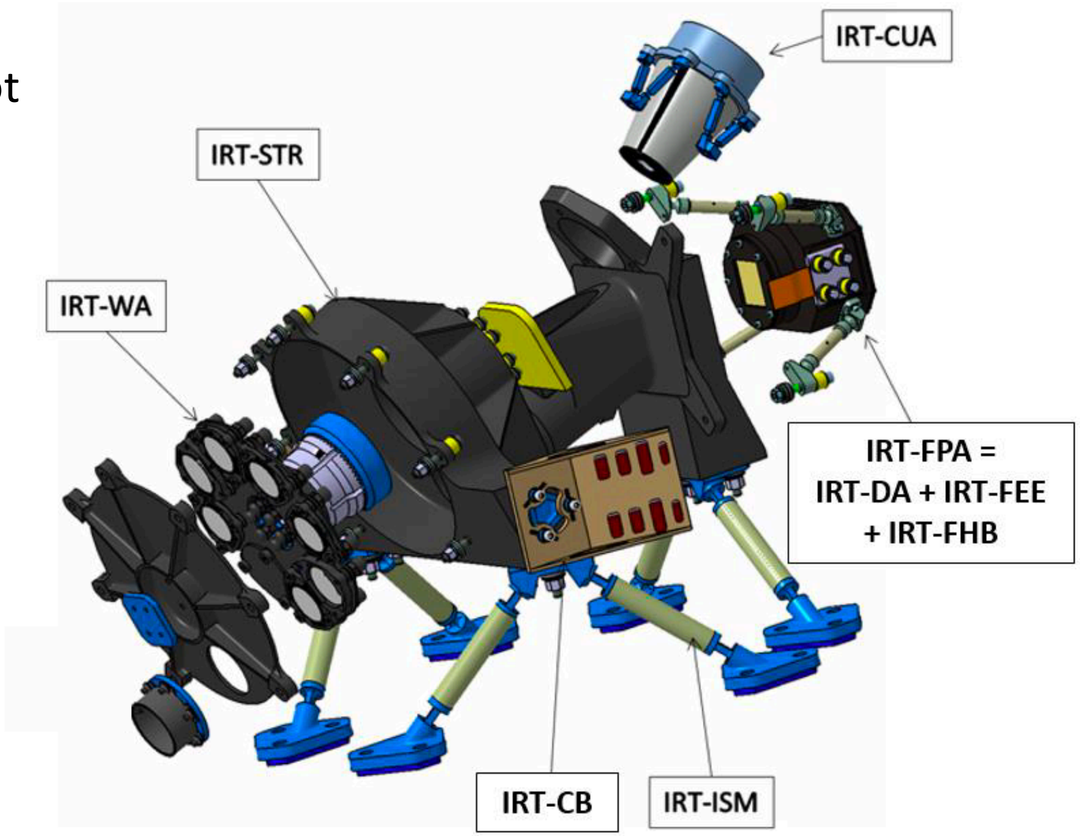
The IRT Telescope is under ESA responsibility

The IRT Instrument

The IRT Instrument is composed by the IRT Camera (IRT-CAM) and the IRT Data Handling Unit (DHU, not shown)

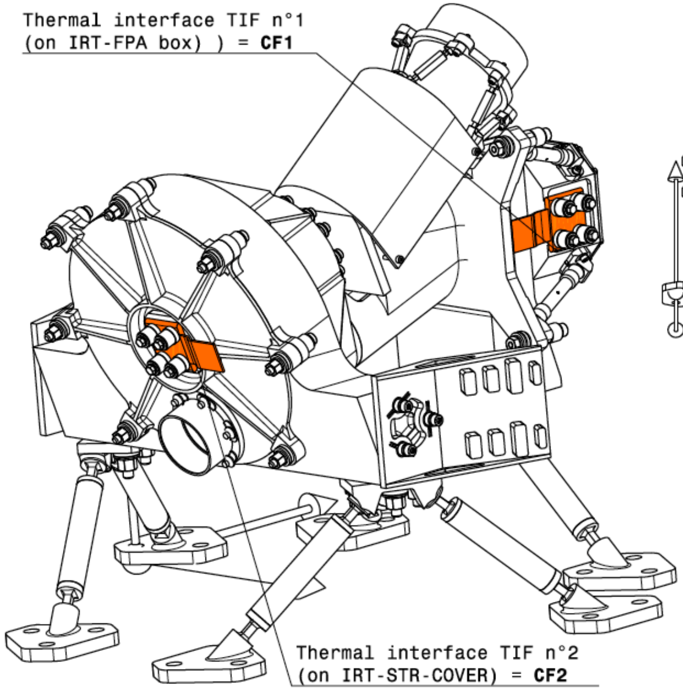
The IRT CAM is mainly composed by

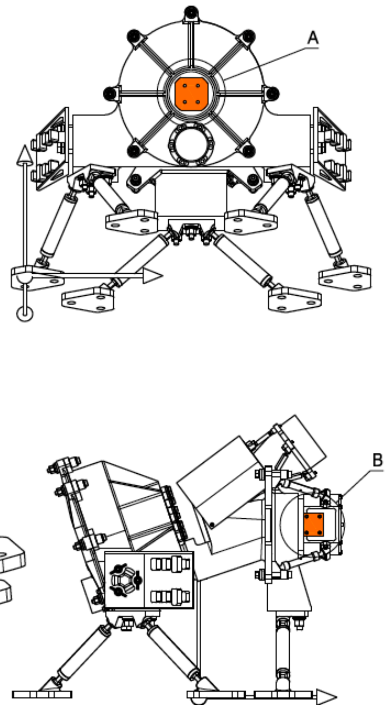
- A wheel assembly (WA) carrying the filters and the grism
- A mechanical structure (STR)
- A focal plane assembly (FPA) carrying the IRT detector (Teledyne H2RG) and its cold electronics
- A calibration unit (CUA)

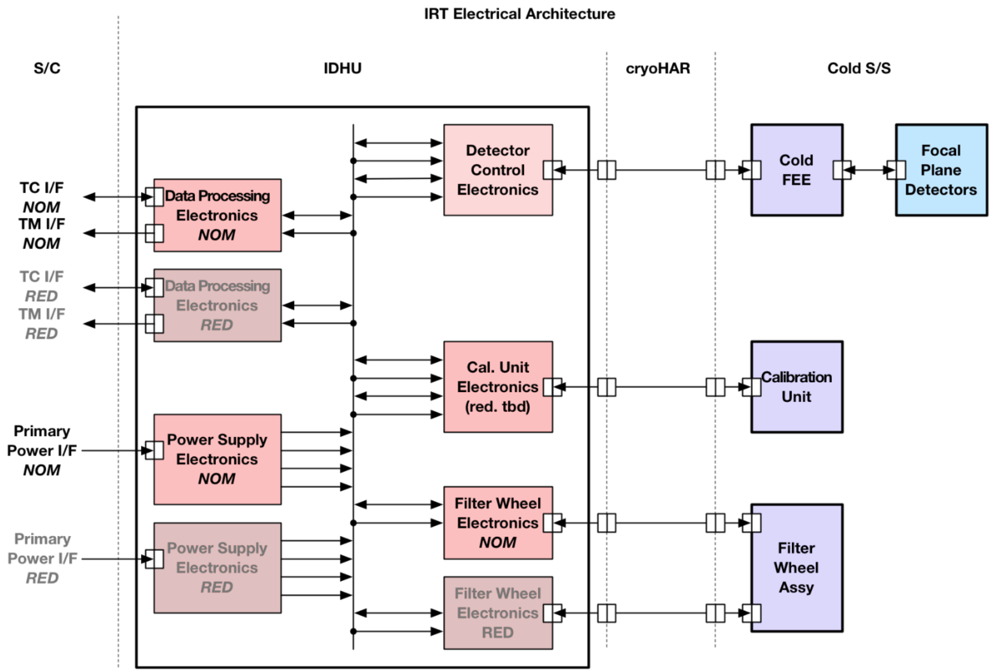


Design heritage from ECULID/NISP

The IRT thermal and electrical interfaces

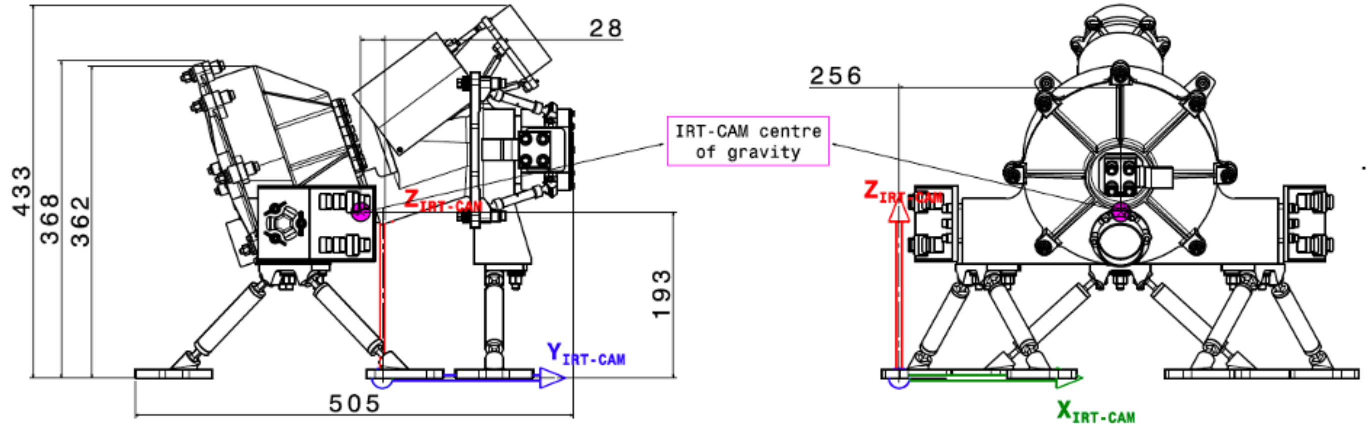






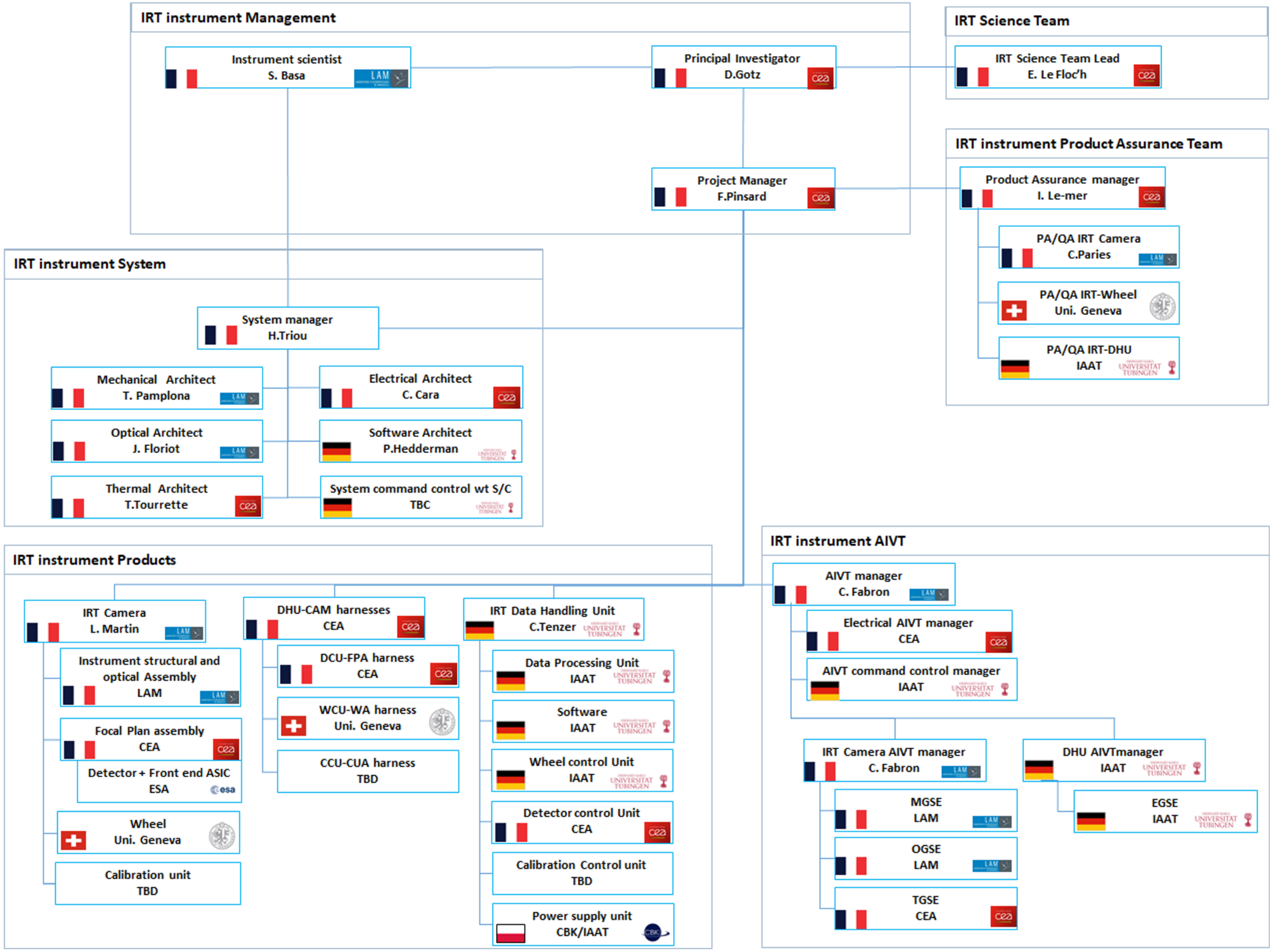
The IRT Instrument will be cooled by dedicated cryo-coolers to 160 K for the structure and 120 K for the detector plane

The IRT Resources



Element	Mass (kg)	Average Power (W)	Maximum/Average Required telemetry (Gb/day)
IRT-CAM	32.5	36.2	
IRT Data Handling Unit	11.0	30.1	
IRT instrument total	43.5	66.3	40/13.5

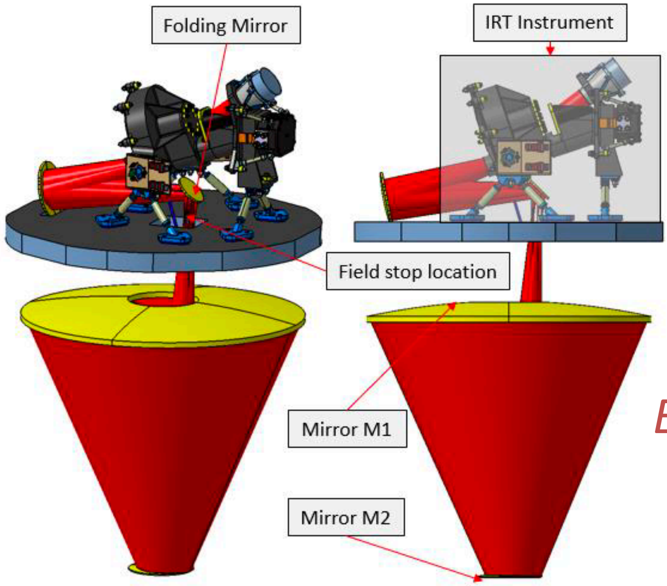
The IRT Instrument Organization



Infra-Red Telescope Performance

IRT Characteristic	Value
Photometric wavelength range	0.7-1.8 microns
Spectroscopic wavelength range	0.8-1.6 microns
Photometric field of view	15 x 15 arc min (goal: 17’ x 20’)
Pixel size/scale	18 microns / 0.6 arc sec
Required Photometric sensitivity (AB, in150 s, SNR=5) for each implemented filter	I: 20.9 (goal: 21.3) Z: 20.7 (goal 21.2) Y: 20.4 (goal: 20.8) J: 20.7 (goal: 21.1) H: 20.8 (goal: 21.1)
Expected photo-z accuracy	< 10%
Astrometric accuracy	< 5 arc sec in near-real time < 1 arc sec after ground processing
Spectroscopic field of view	2 x 2 arc min
Resolving Power at 1.1 microns	> 400
Required Spectroscopic sensitivity (AB, H filter, 1800 s, SNR=3 for each spectral bin)	17.5 (goal: 19)

IRT-Constortium



ESA

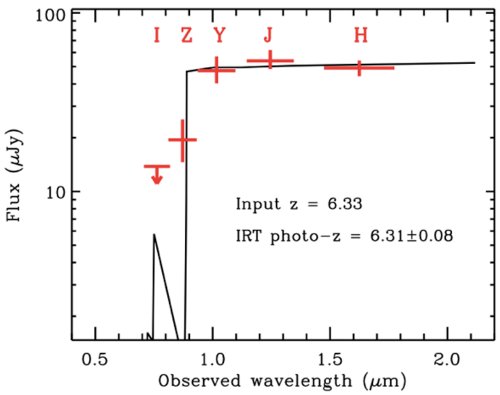
Infra-Red Telescope Performance: photo-z

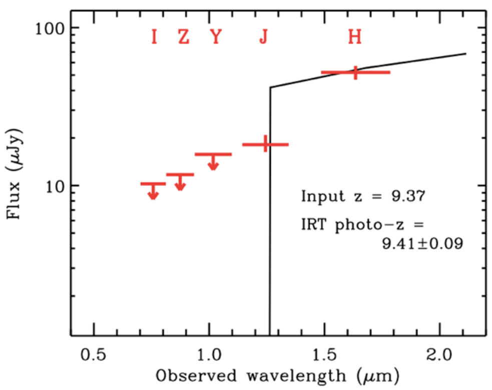
- After a satellite slew, IRT will autonomously detect and identify GRB afterglow candidates.

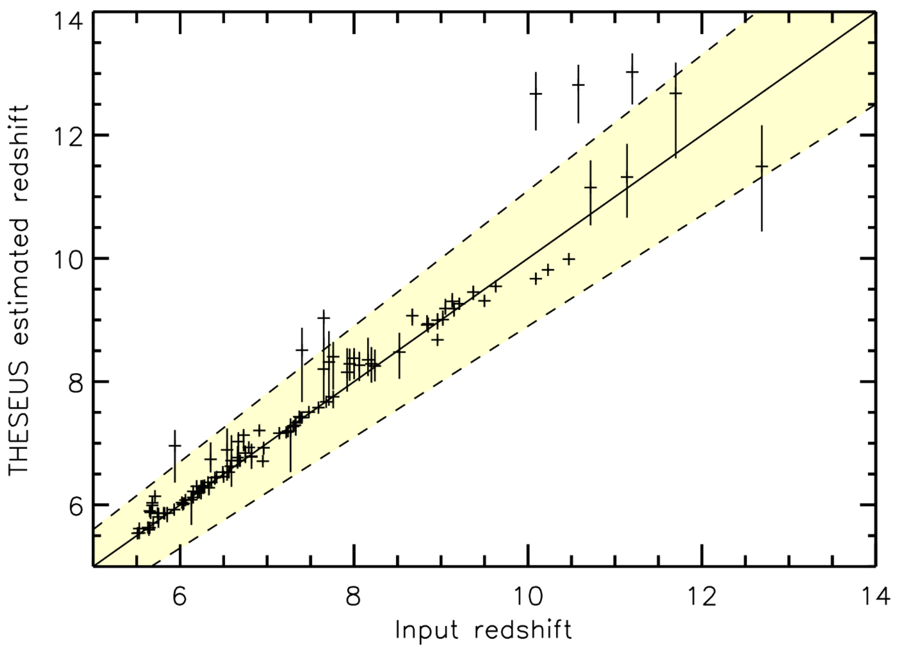
- One 150 s image will be acquired in five different bands (I, Z, Y, J, H) with the goal of detecting the Lyman-alpha break and finally measuring the GRB distance (photometric redshift technique):

- We used the light curves of a synthetic population of high redshift GRBs to validate the IRT performance making use of a MC simulation.

- **A photometric redshift with an accuracy better than 10% is achieved.**







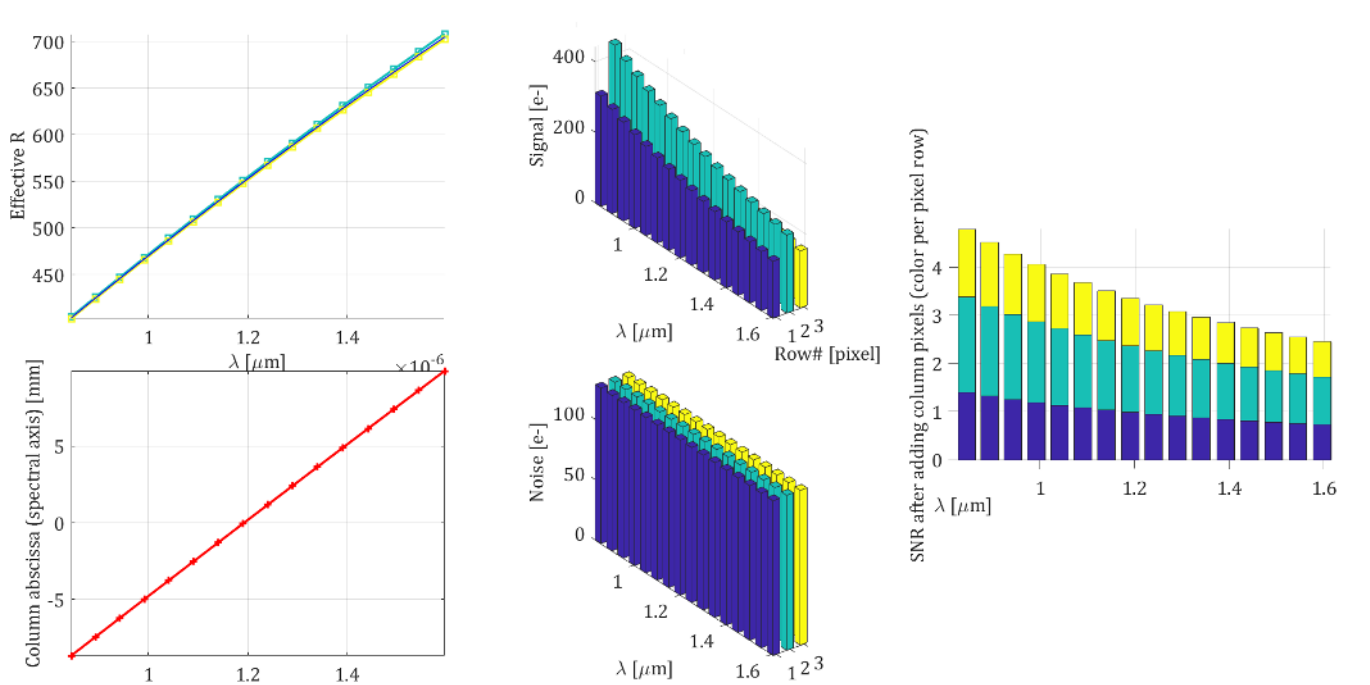
Infra-Red Telescope Performance: spectroscopy

- We required the IRT spectral resolution (R) to be > 400:

- This is liked to the goal of resolving Mg-II doublets in GRB afterglow spectra -> it will allow to measure the redshift also for GRBs with z < 5.5
- It will allow to provide indications about the presence of metals in the GRB environment
- It will allow to measure the neutral column density (N_H) in some GRBs

In order to verify this performance we performed detailed simulations providing R and the SNR for each detector pixel and wavelength.

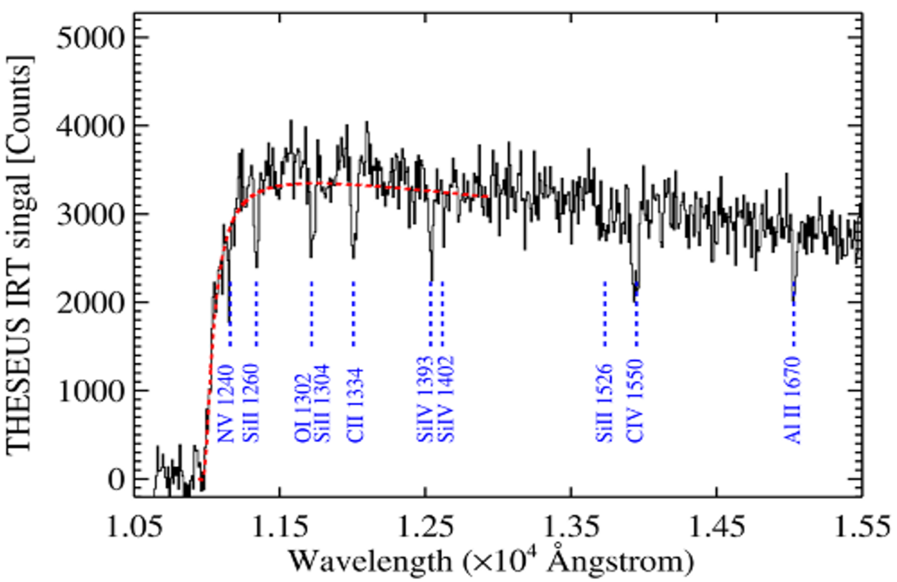
Our simulation include also the spacecraft effects such as the satellite drift and jitter, which play a crucial role.



Spectroscopy: two examples

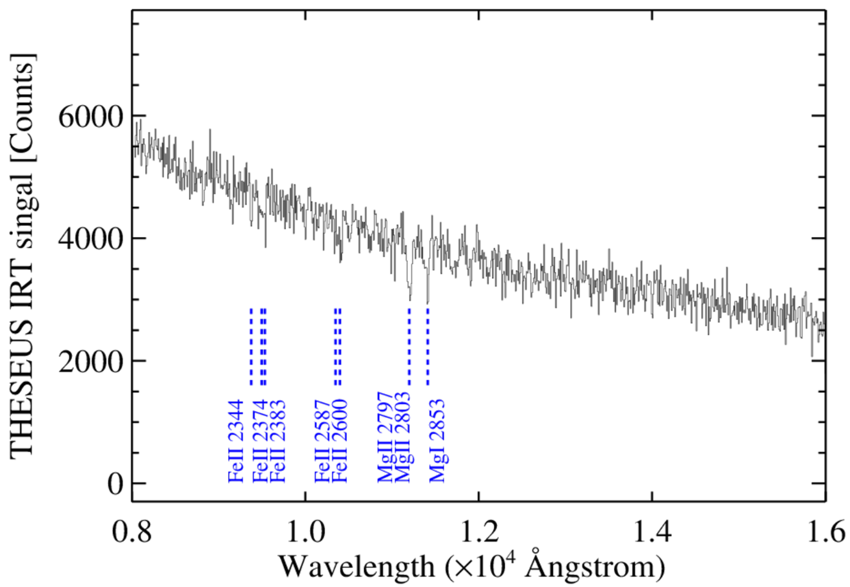
GRB at z = 8

- N_H measurement
- Metal lines identification



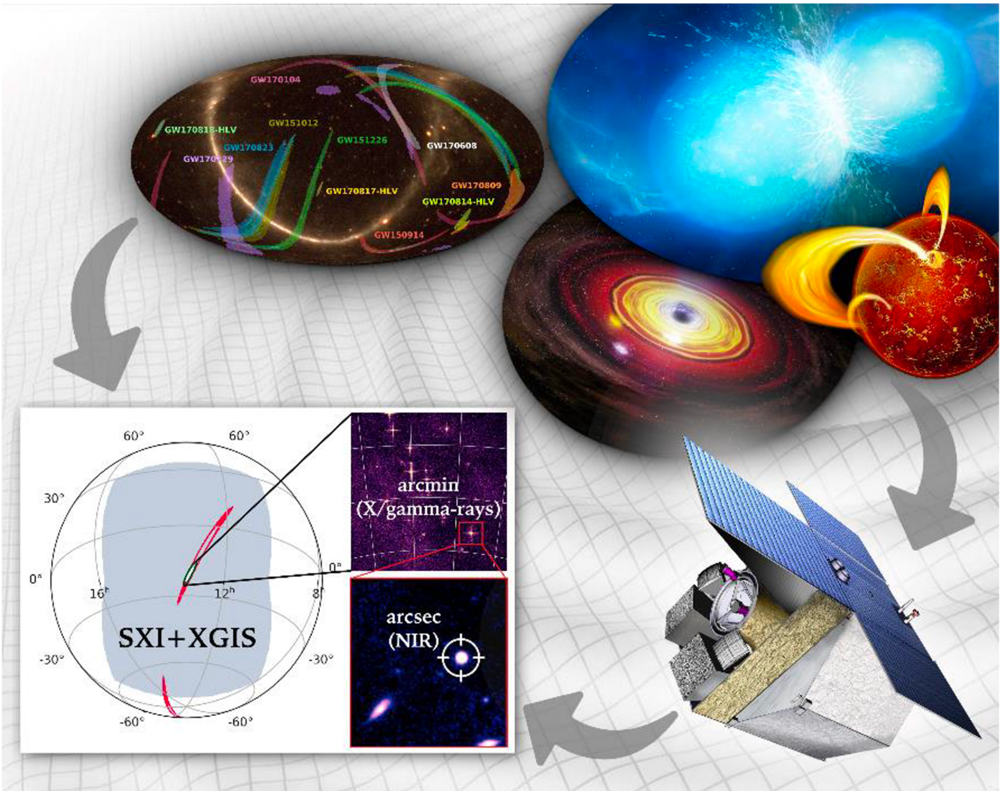
GRB at z = 3

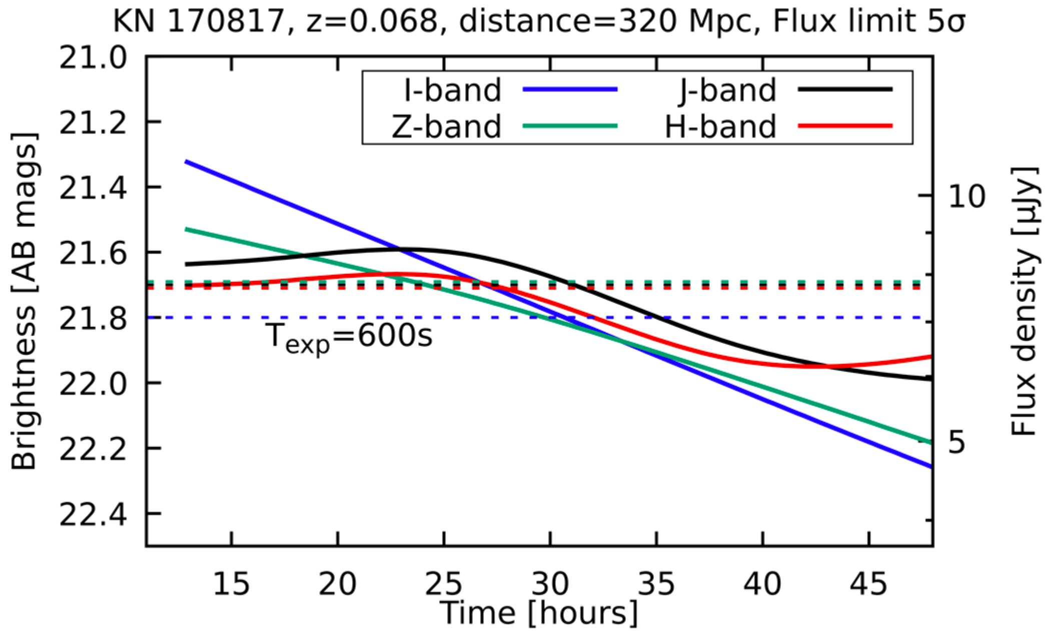
- Redshift measurement



More details in the talk by L. Christensen

Multi-messenger studies





GW 170817/AT2017gfo light curves (shifted to 320 Mpc) compared to IRT sensitivity

See presentation by G. Stratta

Conclusions

We presented the phase A design of the IRT Telescope, which is part of the payload of the THESEUS M5 project.

We have shown that we the current design we are able to meet the required scientific performance

If THESEUS is selected, IRT will play a key role in detecting, localizing and measuring the distance of cosmological Gamma-Ray Bursts

IRT will thus prove essential information to all those facilities interested in the deep Universe science the '30s.