Diego Götz
CEA-Irfu (AIM-Département d’Astrophysique)

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

**Sequence after stabilization**

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

- **Bright source**
  - $H < 17.5$ (AB)
  - IRT acquires 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 $z \sim 9.2$

UKIRT & Gemini N
The IRT Telescope is under ESA responsibility

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Focusing off-axis Korsch</td>
</tr>
<tr>
<td>Entrance pupil</td>
<td>700 mm</td>
</tr>
<tr>
<td>M1-M2 distance</td>
<td>675 mm</td>
</tr>
<tr>
<td>Exit pupil</td>
<td>36 mm</td>
</tr>
<tr>
<td>Collecting area</td>
<td>&gt; 0.34 m²</td>
</tr>
<tr>
<td>Wavelength range</td>
<td>700-1800 nm</td>
</tr>
<tr>
<td>Throughput</td>
<td>&gt; 80%</td>
</tr>
<tr>
<td>Pixel scale</td>
<td>0.6 arcsec/pixel for an IRT detector pixel pitch of 15 µm</td>
</tr>
<tr>
<td>Focal length</td>
<td>6188 mm</td>
</tr>
<tr>
<td>Temperature</td>
<td>240 K</td>
</tr>
<tr>
<td>Field of view (photometric)</td>
<td>15 x 15 arcmin²</td>
</tr>
<tr>
<td>Field of view (spectroscopic)</td>
<td>2 x 2 arcmin²</td>
</tr>
<tr>
<td>LoS (photometric)</td>
<td>0.884° from M1-M2 axis of symmetry</td>
</tr>
<tr>
<td>Straylight requirement</td>
<td>70 photon/m²/arcsec²/s</td>
</tr>
<tr>
<td>Image quality requirement (at</td>
<td></td>
</tr>
<tr>
<td>1800 nm wavelength)</td>
<td>50% of the encircled energy diameter &lt; 1.28 arcsec</td>
</tr>
<tr>
<td></td>
<td>80% of the encircled energy diameter &lt; 2.29 arcsec</td>
</tr>
</tbody>
</table>
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 Instrument will be cooled by dedicated cryo-coolers to 160 K for the structure and 120 K for the detector plane.
### The IRT Resources

<table>
<thead>
<tr>
<th>Element</th>
<th>Mass (kg)</th>
<th>Average Power (W)</th>
<th>Maximum/Average Required telemetry (Gb/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRT-CAM</td>
<td>32.5</td>
<td>36.2</td>
<td></td>
</tr>
<tr>
<td>IRT Data Handling Unit</td>
<td>11.0</td>
<td>30.1</td>
<td></td>
</tr>
<tr>
<td>IRT instrument total</td>
<td>43.5</td>
<td>66.3</td>
<td>40/13.5</td>
</tr>
</tbody>
</table>
The IRT Instrument Organization

IRT Instrument Management
- Instrument Scientist: S. Baez
- Principal Investigator: D. Datz

IRT Science Team
- IRT Science Team Lead: E. Le Roc'h

IRT Instrument Product Assurance Team
- Product Assurance Manager: S. Lermer

IRT Instrument System
- System Manager: N. Pilloy
- Mechanical Architect: T. Pampaloni
- Optical Architect: L. Herlet
- Thermal Architect: T. Sourette
- Electrical Architect: C. Cera
- System command control unit S/C TBC

IRT Instrument Products
- IRT Camera: L. Martin
- IRU-CAM harness: CEA
- BCU-CAM harness: CEA
- ECU-FPA harness: CEA
- WECU-MTA harness: Uni. Geneva
- CCU-CSA harness: TBD
- Wheel: Uni. Geneva
- Calibration unit: TBD
- Data Handling Unit C.Tesser
- Data Processing Unit IAAT
- Software IAAT
- Wheel control unit IAAT
- Detector control unit CEA
- Calibration Control unit TBD
- Power supply unit CRM/IAAT

IRT Instrument AIVT
- ANT manager: C. Fabron
- Electrical AIVT manager: CEA
- ANT command control manager: IAAT
- IRT Camera AIVT manager: C. Fabron
- IRT RHEA manager: IAAT
- MUSE LAM
- ODSE LAM
- TIGSE CEA
## Infra-Red Telescope Performance

<table>
<thead>
<tr>
<th>IRT Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photometric wavelength range</td>
<td>0.7-1.8 microns</td>
</tr>
<tr>
<td>Spectroscopic wavelength range</td>
<td>0.8-1.6 microns</td>
</tr>
<tr>
<td>Photometric field of view</td>
<td>15 x 15 arc min (goal: 17’ x 20’)</td>
</tr>
<tr>
<td>Pixel size/scale</td>
<td>18 microns / 0.6 arc sec</td>
</tr>
</tbody>
</table>
| Required Photometric sensitivity (AB, in 150 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)                                |
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 linked 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.