THESEUS

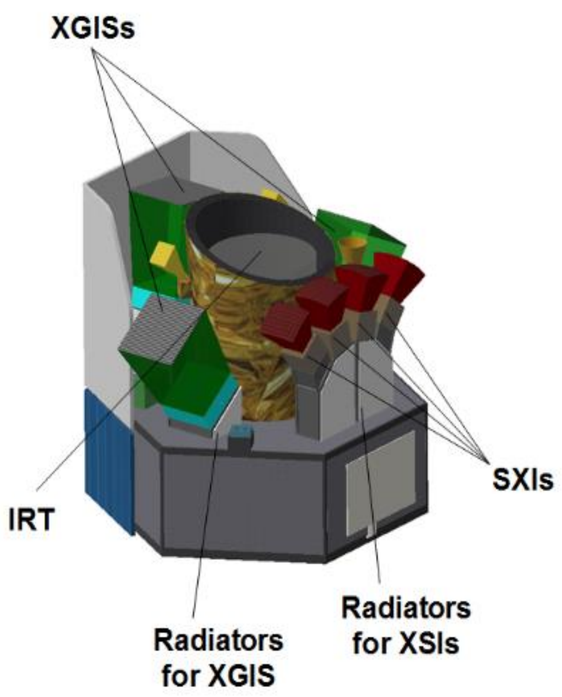
TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR

L. Amati (INAF), P. O'Brien (Univ. Leicester), D. Götz (CEA), C. Tenzer (Univ. Tübingen), E. Bozzo (Univ.of Geneva) and the THESEUS international collaboration (http://www.isdc.unige.ch/theseus)

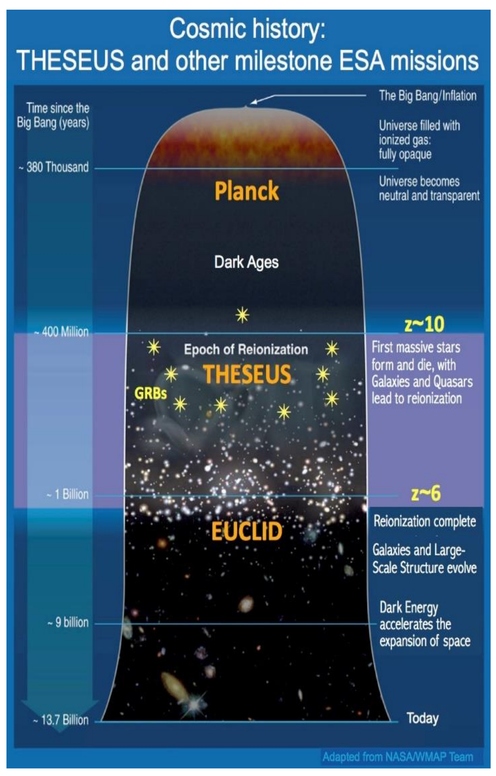
The **THESEUS** mission, proposed to the **ESA M5 call**, is designed to vastly increase the discovery space of the high energy transient phenomena over the entirety of cosmic history. Its primary scientific goals will address the Early Universe ESA Cosmic Vision themes "How did the Universe originate and what is made of?" and will also impact on "The gravitational wave Universe" and "The hot and energetic Universe" themes. This is achieved via a unique payload providing an unprecedented combination of: 1) wide and deep sky monitoring in a broad energy band (0.3keV - 20 MeV); 2) focusing capabilities in the soft X-ray band providing large grasp and high angular resolution; and 3) on board near-IR capabilities for immediate transient identification and redshift determination. The THESEUS consortium is led by Italy, UK, France, Germany, Switzerland, and includes several other ESA countries. Potential international partners include USA, China and Brazil.

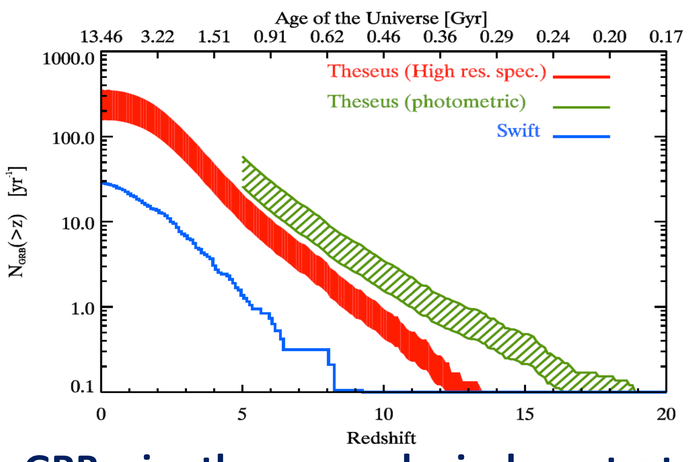
Summary of the THESEUS payload:

- **Soft X-ray Imager (SXI):** a set of four sensitive lobster-eye telescopes observing in the 0.3-0.6 keV band, providing a total FOV of ~1sr with source location accuracy < 1-2';
- **InfraRed Telescope (IRT)**: a 0.7m class IR telescope observing in the 0.7 – 1.8 μm band, providing a 10'x10' FOV, with both imaging and moderate resolution spectroscopy capabilities;
- **X-Gamma rays Imaging Spectrometer (XGIS,)**: 3 coded mask X-gamma rays cameras based on bars of Silicon diodes coupled with CsI crystal scintillators providing 1 keV – 10 MeV band and a FOV of ~1sr overlapping that of the SXI with ~5' source loc. accuracy.

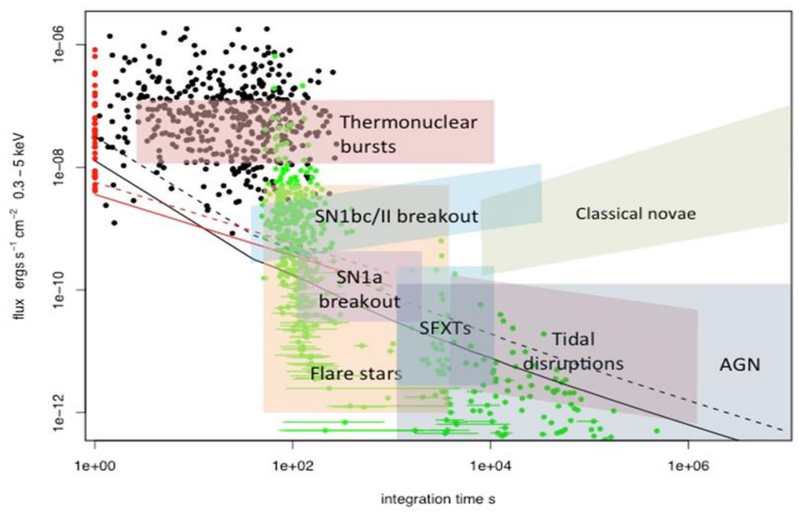


Schematic configuration (left) of the THESEUS spacecraft. The SXI (red) and XGIS (blue) modules monitor the anti-Sun sky each orbit, carrying out a deep transient survey. The IRT (white) will be repointed within a few minutes to a transient source to enable a rapid on-board redshift determination. Information from the trigger will made be rapidly available for follow-up.





GRBs in the cosmological context (left) and Yearly cumulative distribution of GRBs with redshifts as a function of redshift for Swift and THESEUS (top). The THESEUS predictions of >10 times more high redshift GRBs than Swift



Sensitivity of the SXI (black curves) and XGIS (red) vs. integration time. The solid (dotted) curves assume a source column density of $5x10^{20}$ (10^{22}) cm^{-2} . Black dots: peak fluxes for Swift BAT GRBs plotted against T90/2. Red dots: GRBs for which T90/2 <1 second. Green dots: initial fluxes and times since trigger for Swift XRT GRB light-curves. The various shaded regions illustrate variability and flux regions for different types of transients and variable sources to be observed by THESEUS.

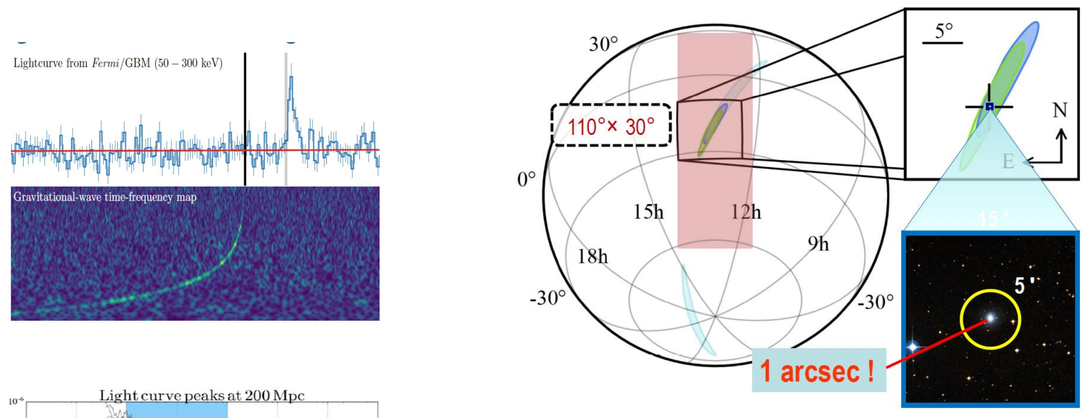
Main scientific goals of the THESEUS mission:

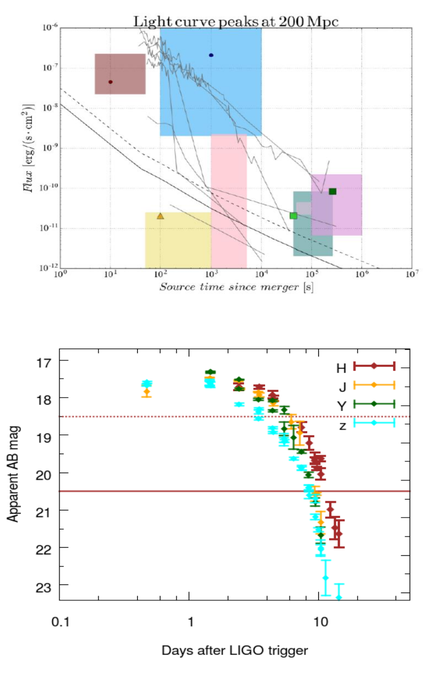
(a) Explore the Early Universe by unveiling a complete census of Gamma-Ray Burst (GRBs). Specifically THESEUS will:

- Perform unprecedented studies of the star formation history of the Universe up to z ~ 10 and beyond;
- Detect and study the primordial (pop III) star population; how did the earliest pop III and pop II stars influence their environments?
- Investigate the re-ionization epoch, the interstellar medium (ISM) and the intergalactic medium (IGM) up to z ~ 8 - 10: how did re-ionization proceed as a function of environment and was it due to star formation? How did cosmic chemical evolution proceed as a function of time and environment?
- Investigate the properties of the early galaxies and determine the galaxies global star formation rate in the re-ionization era.

(b) Perform a deep X-ray transient Universe monitoring in order to:

- Locate and identify the electromagnetic counterparts to sources of gravitational radiation and neutrinos, which may be routinely detected in the late '20s / early '30s by next generation facilities like aLIGO/aVirgo, eLISA, ET, or Km3NET;
- Provide real-time triggers and accurate (~1 arcmin within a few seconds; ~1'' within a few minutes) locations of (long/short) GRBs and high-energy transients for follow-up with next-generation optical-NIR (E-ELT, JWST if still operating), radio (SKA), X-rays (ATHENA), TeV (CTA) telescopes





The superb capabilities of THESEUS for multi-messenger astrophysics. As an example, for GW events produced by NS-NS mergers (as GW170817), THESEUS will be capable to detect, localize (from a few arcmin to arcsec) the associated short GRB (left-top, from LVC), the possible soft X-ray emission (left-middle: colored regions indicate ranges of fluxes and time scales from different model) and the kilonova emission (left-bottom: real data from KN170817, lines show THESEUS imaging and spectroscopy sensitivities)