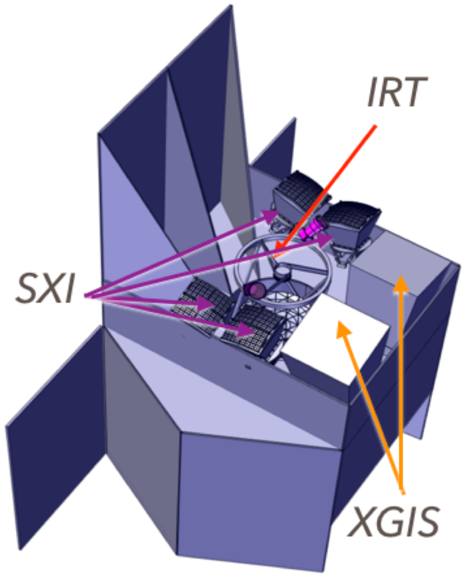
Journée THESEUS France

theseus
TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR



Amphithéâtre Turing
23 septembre 2019
09:30-17:30

theseus
transient high energy sky and early universe surveyor

Programme 1/2

09:30 → 10:00	**Accueil des participants & café**	30m
10:00 → 10:50	**La mission**	
10:00	**La mission THESEUS** **Orateur**: Diego Gotz (CEA Saclay)	30m
10:30	**Le télescope IRT** **Orateur**: Stephane Basa (Laboratoire d'Astrophysique de Marseille)	20m
10:50 → 12:30	**L'Univers Profond**	
10:50	**Les premières galaxies** **Orateur**: Dr Johan Richard (Université de Lyon)	30m
11:20	**Foreground Asborbers** **Orateur**: Pasquier NOTERDAEME (IAP)	30m
11:50	**High z hydro-dynamic simulations** **Orateur**: Dr Jeremy Blaizot (Université de Lyon)	20m
12:10	**High z dust and extinction** **Orateur**: Veronique BUAT (LAM)	20m
12:30 → 14:00	**Pause déjeuner**	1h 30m

Chairwoman S. Vergani

Chairman E. Le Floc'h

Programme 2/2

Chairman S. Basa

14:00 → 15:30 **L'Univers Transitoire**

14:00	**Transitoires galactiques et TDEs** **Orateur**: Natalie Webb (IRAP)	20m
14:20	**Synergie avec ATHENA** **Orateur**: DIDIER BARRET (IRAP)	20m
14:40	**Synergies avec les télescopes radio** **Orateur**: Stephane Corbel (University Paris Diderot & CEA Saclay)	20m
15:00	**Les sursauts gamma cosmiques** **Orateur**: Frédéric Daigne (Institut d'Astrophysique de Paris - Université Pierre et Marie Curie)	30m

15:30 → 16:00 **Pause Café** 30m

Chairman D. Götz

16:00 → 17:10 **L'Univers multi-messagers**

16:00	**Les ondes gravitationnelles en 2030** **Orateur**: Eric Chassande-Mottin (CNRS AstroParticule et Cosmologie)	30m
16:30	**Le neutrinos dans les années 2030s** **Orateur**: Damien Dornic (CPPM)	20m
16:50	**Synergie avec CTA** **Orateur**: Fabian Schussler (CEA/Irfu)	20m

17:10 → 17:30 **Conclusions de la journée** 20m

Orateur: Susanna Vergani (CNRS-Observatoire de Paris)

The ESA Cosmic Vision Programme

❖ Selected missions

- M1: Solar Orbiter (solar astrophysics, 2020)
- M2: Euclid (cosmology, 2021)
- L1: JUICE (exploration of Jupiter system, 2022)
- S1: CHEOPS (exoplanets, 2018)
- M3: PLATO (exoplanets, 2026)
- L2: ATHENA (X-ray observatory, cosmology, 2031)
- L3: gravitational wave observatory (eLISA, 2034)
- M4: Ariel (exoplanets, 2028)
- M5: 2032 launch – phase 0/A selection in 2018: *THESEUS among the three selected missions! (with SPICA and EnVision)*

Theseus killing the Minotaur
Museo archeologico di Napoli

May 2018: THESEUS selected by ESA for M5 Phase 0/A study

Activity	Date
Phase 0 kick-off	June 2018
Phase 0 completed (EnVision, SPICA and THESEUS)	End 2018
ITT for Phase A industrial studies	February 2019
Phase A industrial kick-off	June 2019
Mission Selection Review (technical and programmatic review for the three mission candidates)	Comleted by May 2021
SPC selection of M5 mission	June 2021
Phase B1 kick-off for the selected M5 mission	December 2021
Mission Adoption Review (for the selected M5 mission)	March 2024
SPC adoption of M5 mission	June 2024
Phase B2/C/D kick-off	Q1 2025
Launch	2032

- **Smooth CDF study, successful MDR -> Phase A**
- Efficient and positive interaction between ESA and consortium

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TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR

- ***THESEUS* Core Science is based on two pillars:**
  - probe the **physical properties of the early Universe**, by discovering and exploiting the population of high redshift GRBs.
  - provide an **unprecedented deep monitoring** of the soft X-ray transient Universe, providing a fundamental contribution to multi-messenger and time domain astrophysics in the early 2030s (synergy with aLIGO/aVirgo, eLISA, ET, Km3NET and EM facilities e.g., LSST, E-ELT, SKA, CTA, ATHENA).

- ***THESEUS* Observatory Science includes:**
  - study of thousands of faint to bright X-ray sources by exploiting the **unique simultaneous availability of broad band X-ray and NIR observations**
  - Possibility to provide a **flexible follow-up observatory** for fast transient events with multi-wavelength ToO capabilities and **guest-observer programmes**.

I. THESEUS: Main scientific goals

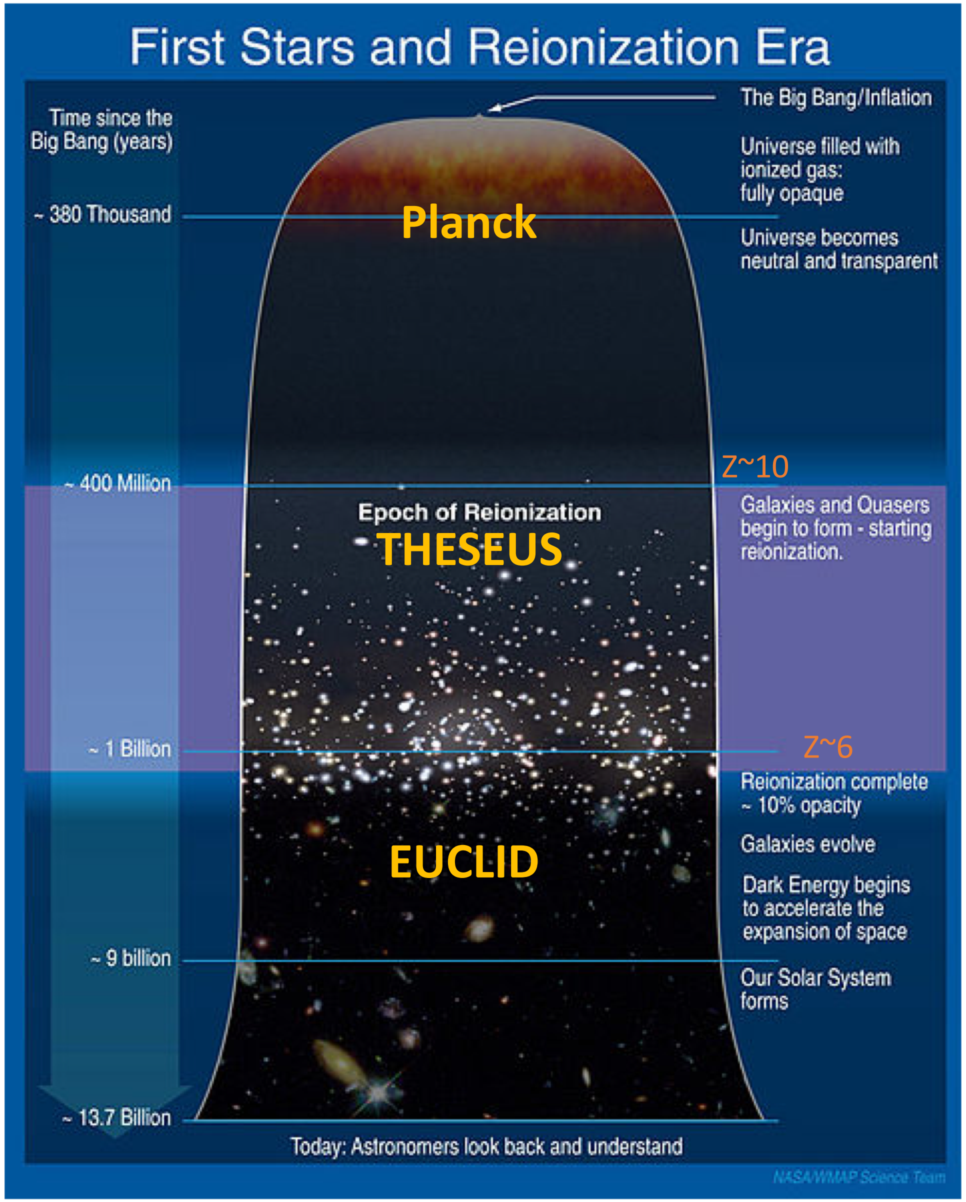
A) Exploring the Early Universe (cosmic dawn and reionization era) by unveiling the Gamma-Ray Burst (GRBs) population in the first billion years

The study of the Universe before and during the epoch of re-ionization represents one of the major themes for the next generation of space and ground–based observational facilities. Many questions about the first phases of structure formation in the early Universe will still be open in the early 2030s:

Q1: *When and how did first stars/galaxies form?*

Q2: What are their properties? When and how fast was the Universe enriched with metals?

Q3: Which objects did contribute to reionization?



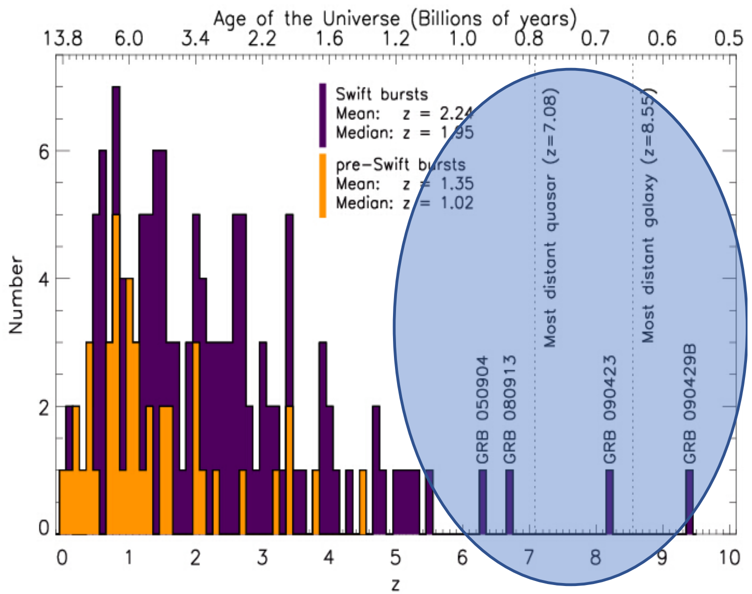
Deep Universe Science in the early ‘30s

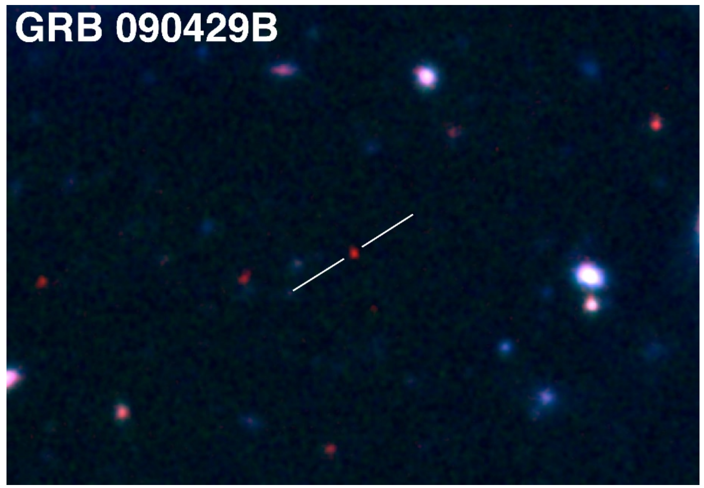
Thanks to their brightness (during prompt and afterglow emission), Gamma Ray Bursts (GRBs) can be detected up to very high redshifts (GRB 090423 at z = 8.2 and GRB 090429 at z = 9.4)

GRBs represent a unique tool to study the early Universe **up to the re-ionization era.** To date there is no consensus on the sources of re-ionization and GRB progenitors and their hosts are very good representative candidates.

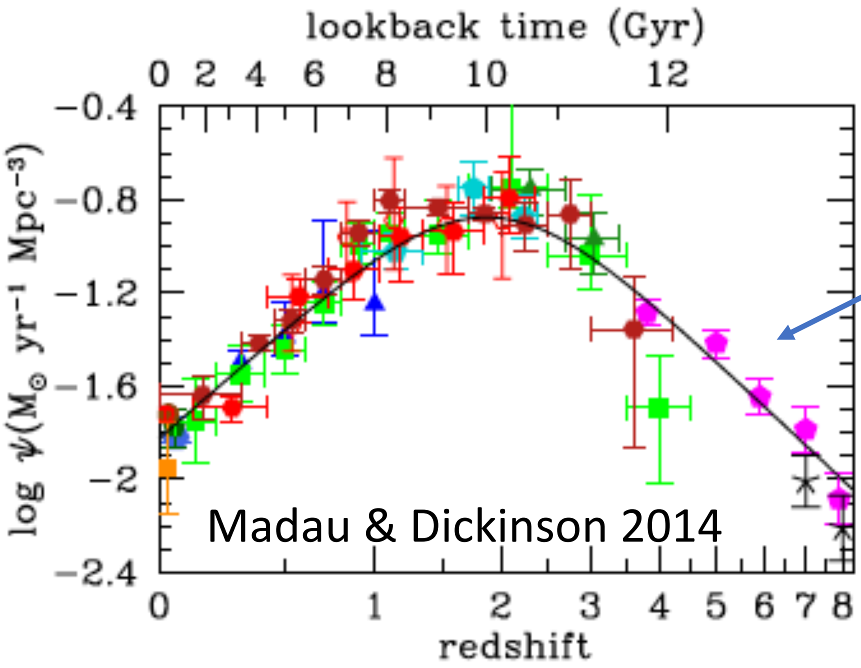
Indeed a statistical sample of high–z GRBs can provide fundamental information about:

- the number density and properties of low-mass galaxies
- the neutral hydrogen fraction
- the escape fraction of UV photons from high-z galaxies





Q1 *The challenge: finding the first galaxies*

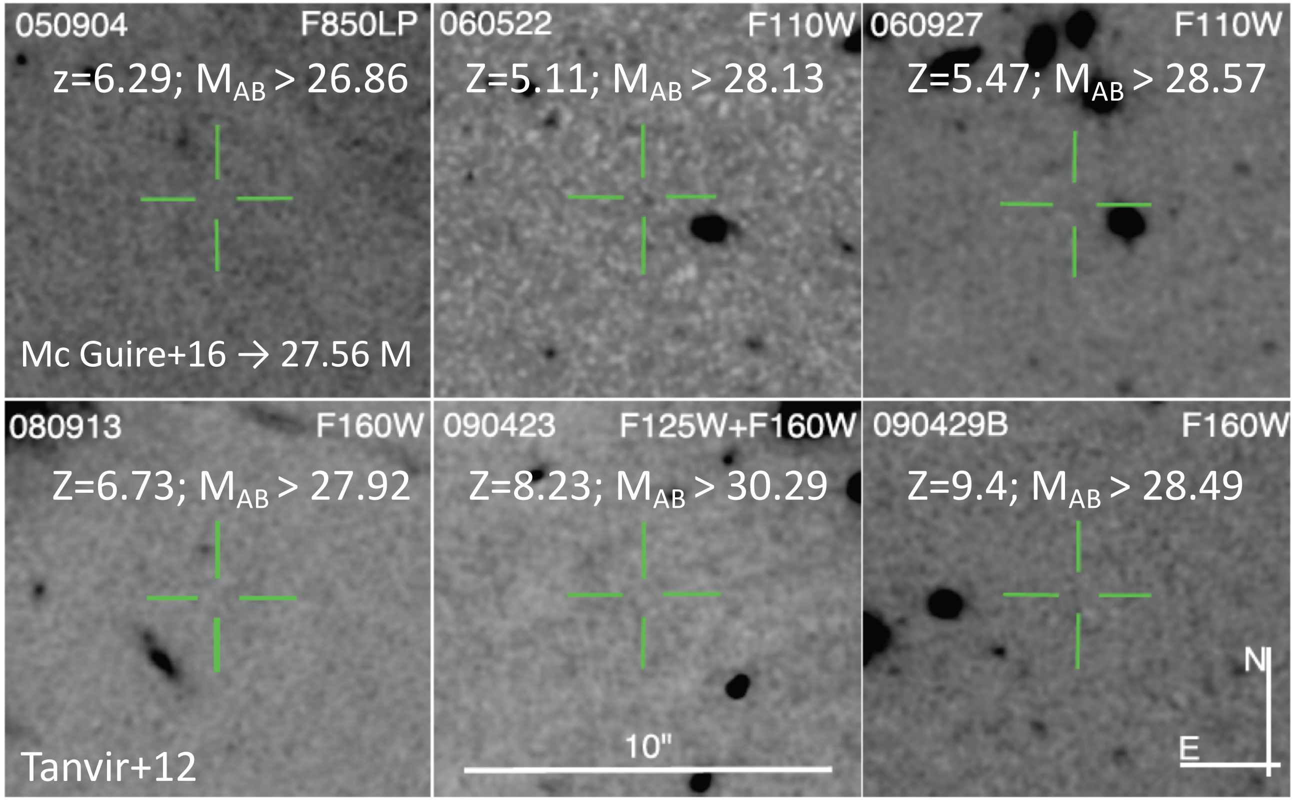


Rapidly declining number density of star forming galaxies in the first Gyr

- The evidence of increase of SFRD from z=8 to z~2 is limited to the rarest and most ultra-luminous galaxies leaving considerable uncertainty about how much SFRD we may have been missing.
- At z>4, current surveys are strongly biased towards UV-bright galaxies.
- At z>8 even UV-bright galaxies can hardly be spectroscopically confirmed (->JWST).

Q1 The challenge: finding the first galaxies

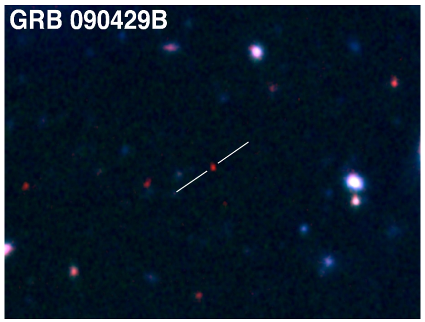
High z GRB hosts can be quite faint!

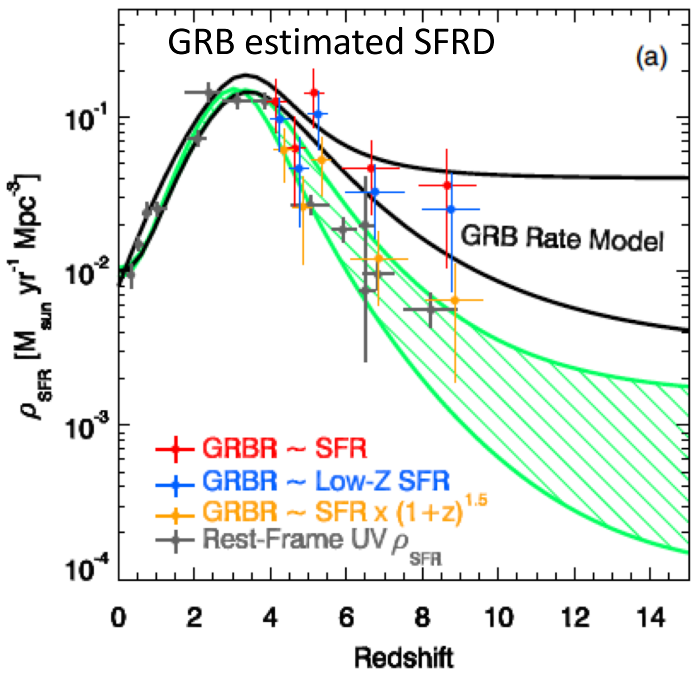


Even JWST and ELTs surveys will be not able to probe the faint end of the galaxy Luminosity Function at high redshifts (z>6-8)

THESEUS Goals:

- Measure independently the **cosmic star–formation rate**, even beyond the limits of current and future galaxy surveys
- Directly (or indirectly) detect the first population of stars (pop III)
- Determine the number density and properties of low-mass galaxies

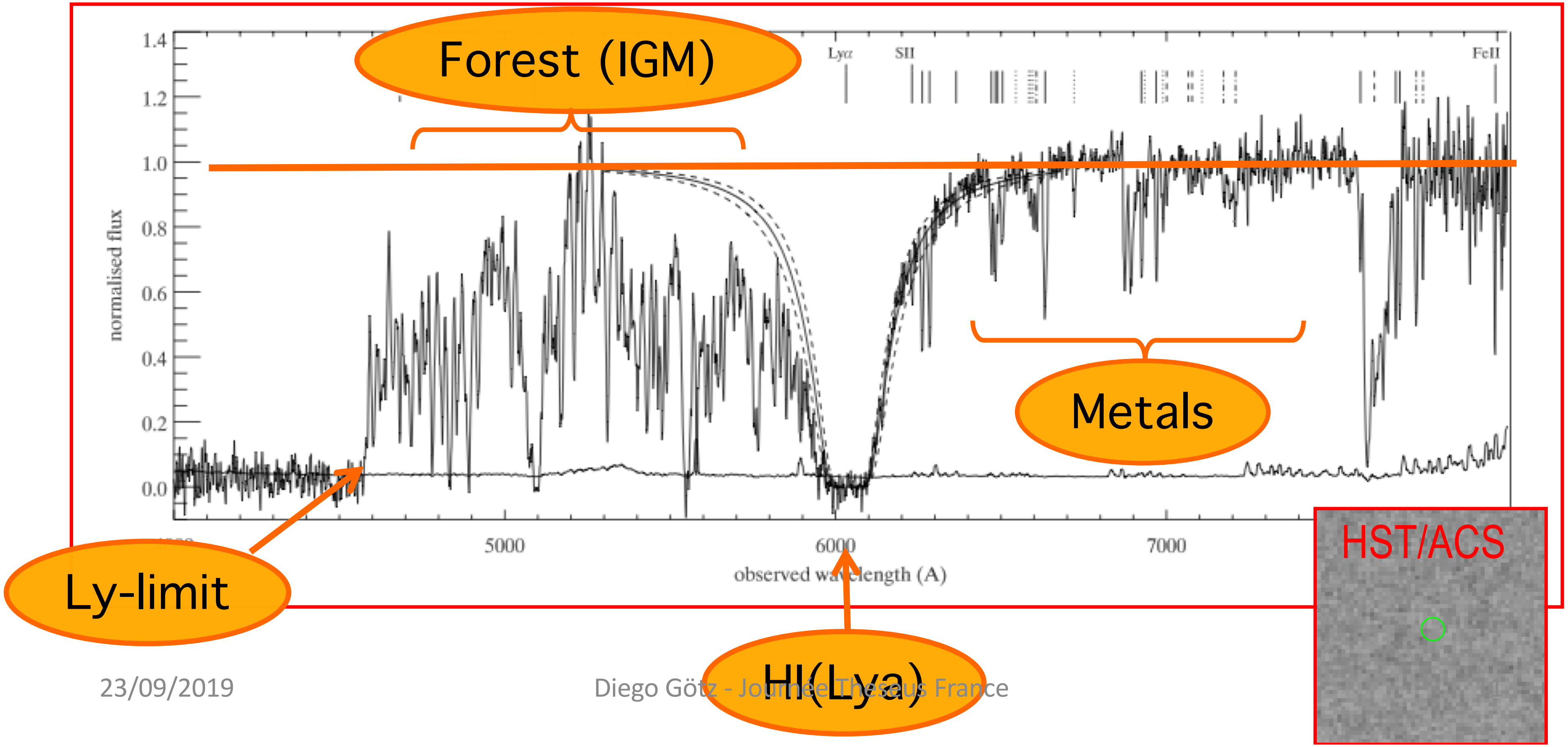




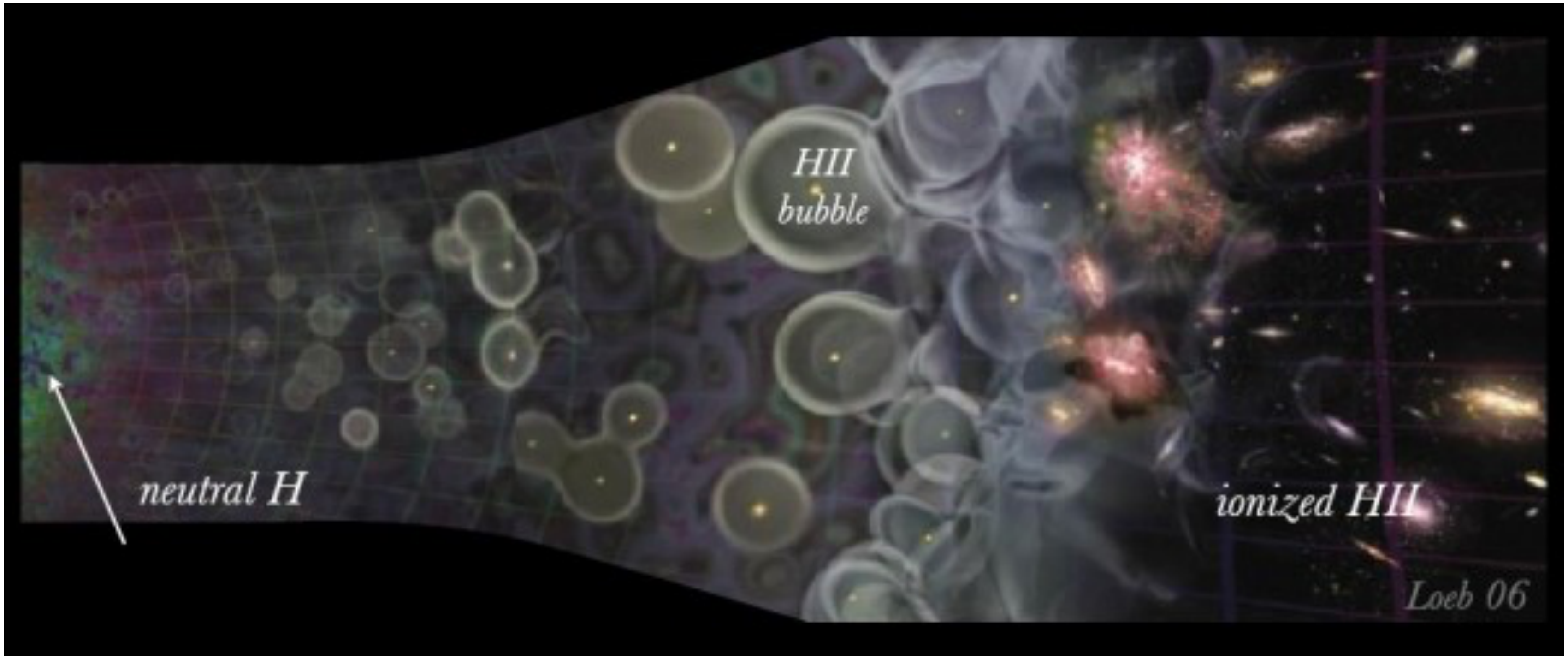
Q2 *GRB afterglow spectroscopy*

- the neutral hydrogen fraction
- the escape fraction of UV photons from high-z galaxies
- the early metallicity of the ISM and IGM and its evolution

Abundances, HI, dust, dynamics etc. even for very faint hosts. E.g. GRB 050730: faint host (R>28.5), but z=3.97, [Fe/H]=-2 and low dust, from afterglow spectrum (Chen et al. 2005; Starling et al. 2005).



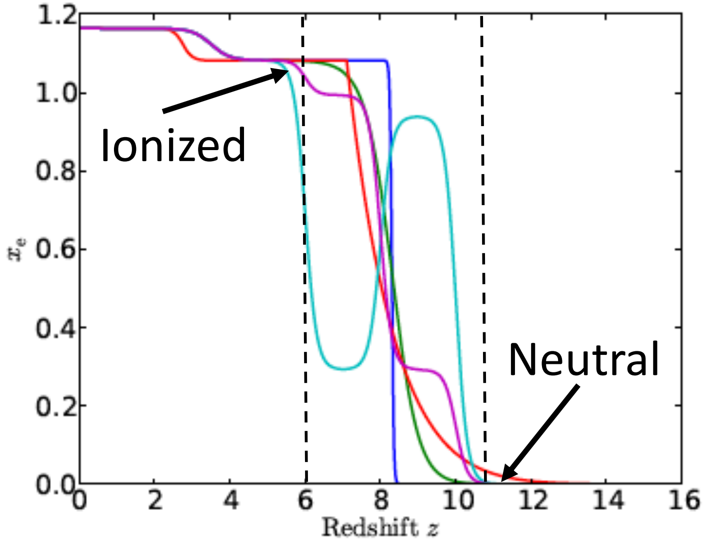
Q3 Reionization



When first galaxies formed, the Universe was bathed in UV radiation from young stars, which produced ionized radiation in the intergalactic medium between the galaxies, turning it from neutral H to ionized HII.

Finding and characterizing the first galaxies will provide us with a statistically robust picture to confirm this scenario.

CMB polarization: reionization epoch constraints



CMB polarisation probes foreground electron scattering from the start of reionization to the present epoch. It is measured via optical depth of scattering Tau, which constrains the mean redshift and duration of reionization.

Reionization started at z~10-12 and ended at z=6

Q3 *Did galaxies reionize the Universe?*

To test this hypothesis we need to know

- ***The integrated abundance of high-z star forming galaxies (<u>including faint ones!</u>)***
- ***The nature of stellar population which determines the ionizing radiation production rate***
- ***The fraction of ionizing photons escaping in the IGM (with GRB afterglows spectroscopy!)***

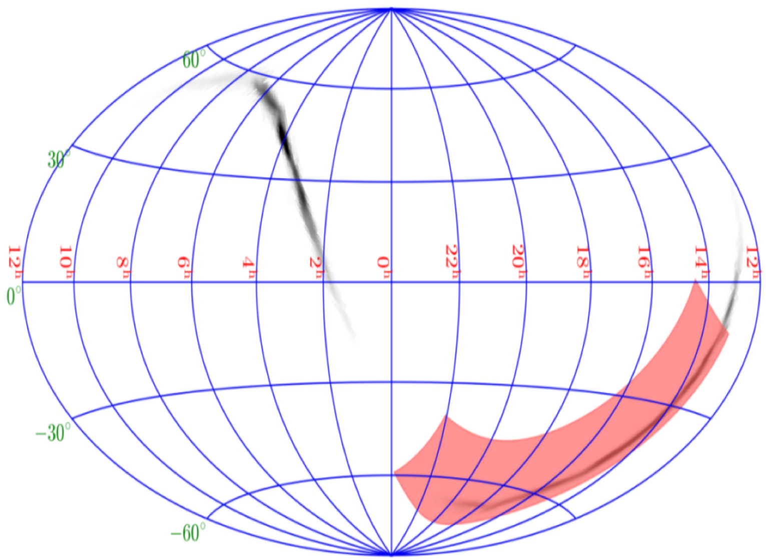
Observed z~7-8 galaxies do not produce enough radiation to re-ionize hydrogen (Robertson+10, Finkelstein+12), but ***fainter currently unseen galaxies may be sufficient.***
GRB selected host galaxies have the unique potential to probe the z=8-12 Universe in terms of stellar population and host galaxies and test this hypothesis

B) Perform an unprecedented deep monitoring of the soft X-ray transient Universe 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;**

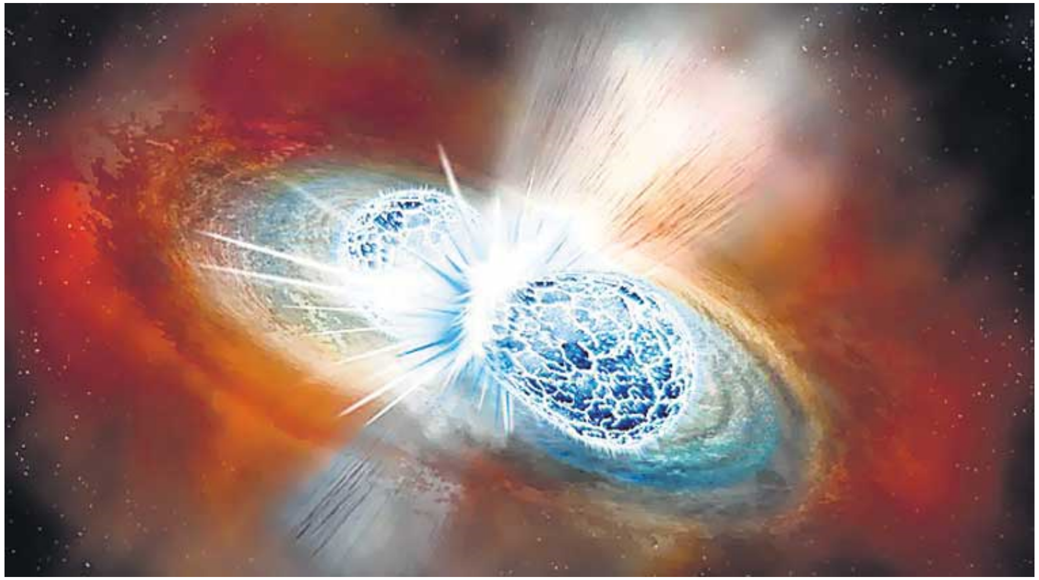
- Provide accurate near real-time triggers (~1 arcmin within a few seconds; ~1'' within a few minutes) for follow-up with next-generation optical-NIR (E-ELT, JWST (if still operating)), radio (SKA), X-rays (ATHENA), TeV (CTA) telescopes; synergy with LSST

- Provide a fundamental step forward in the comprehension of the physics of various classes of transients and discover new classes

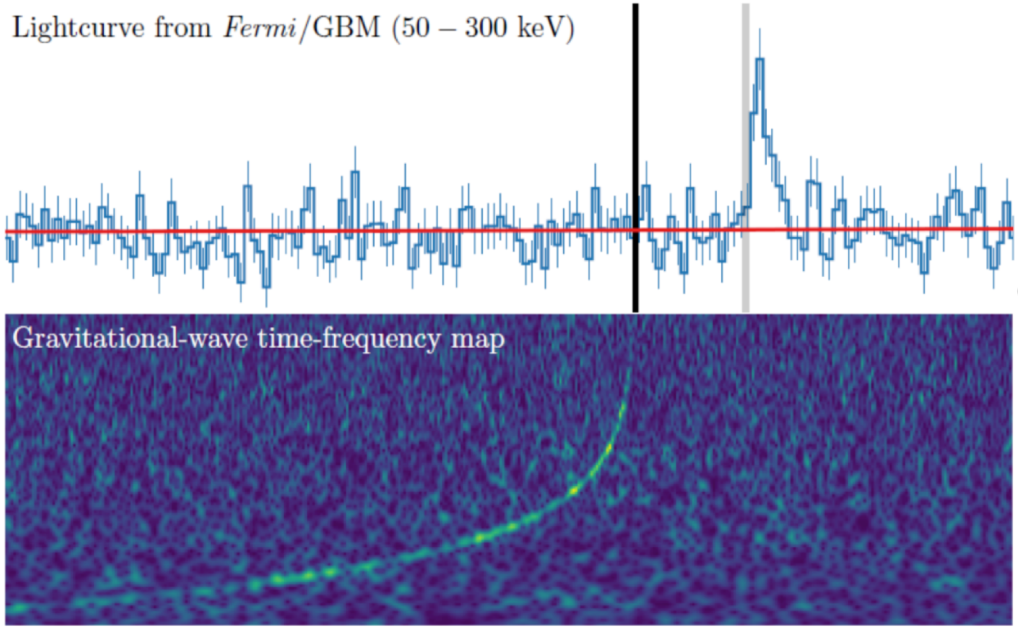


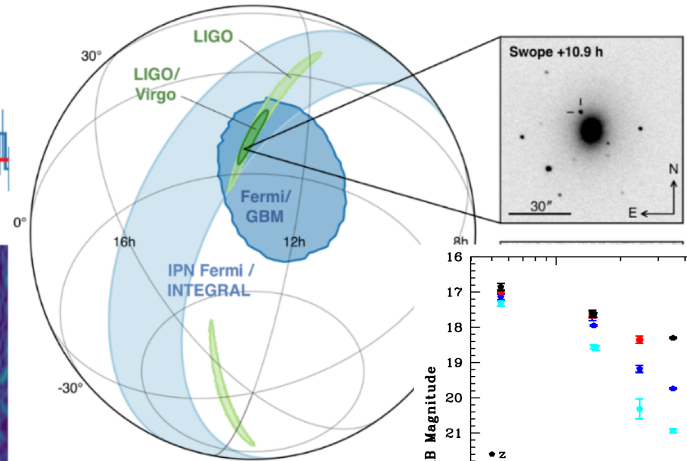
Transient type	SXI Rate
GW sources	0.03-33 yr^{-1}
Magnetars	40 day^{-1}
SN shock breakout	4 yr^{-1}
TDE	50 yr^{-1}
AGN+Blazars	350 day^{-1}
Thermonuclear bursts	35 day^{-1}
Novae	250 yr^{-1}
Dwarf novae	30 day^{-1}
SFXTs	1000 yr^{-1}
Stellar flares	400 yr^{-1}
Stellar super flares	200 yr^{-1}

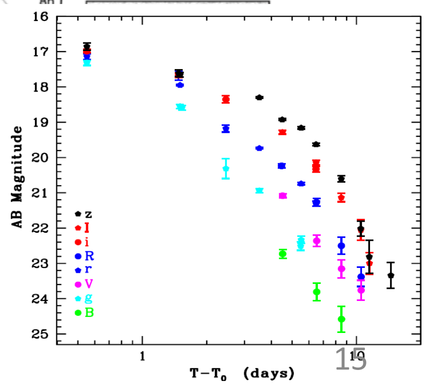
August 2017: short GRBs as e.m. counterparts of gravitational-waves sources!!!



LIGO, Virgo, and partners make first detection of gravitational waves and light from colliding neutron stars







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The THESEUS space mission concept: science case, design and expected performances

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THESEUS: A key space mission concept for Multi-Messenger Astrophysics

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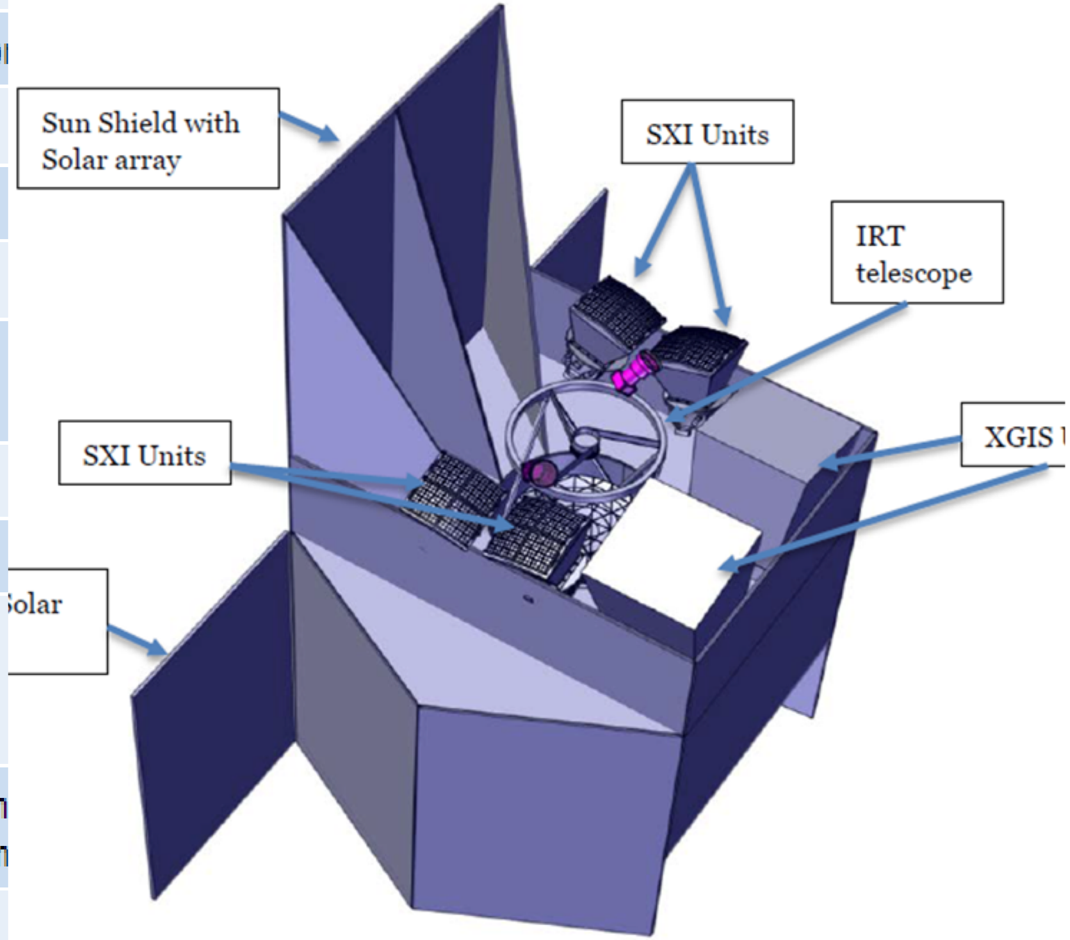
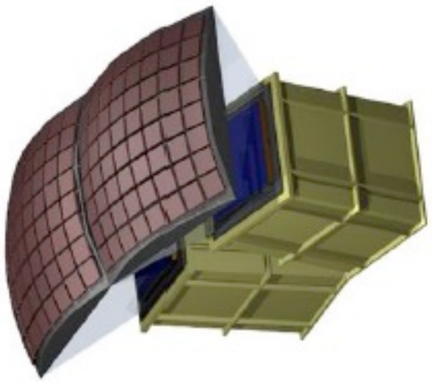
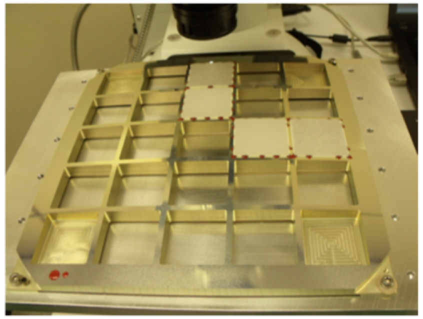
Mission profile and budgets

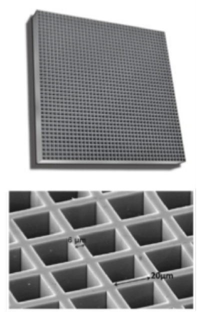
Launch vehicle	VEGA-C (backup Ariane62)
Launch date	2032 (night launch)
Lifetime	Nominal 3 years (consumables fo
Orbit	Circular LEO
Altitude	600 km
Inclination	5.4°
Ground stations	Malindi (backup Kourou) VHF SVOM network
Delta-V	225.8 m/s
Re-entry	Controlled re-entry (4 burns)
Mass	Dry mass w/ margin 1504 kg Wet mass 1702 kg Total (wet + adapter) 1697 kg
Dimensions	Launch conf.: 4.23 m x 3.02 m Deployed conf.: 4.23 m x 4.40 m
Payload	1x InfraRed Telescope (IRT) 2x X-Gamma-rays Imaging Spect 4x Soft X-ray Imager (SXI) 2x Radiation monitors

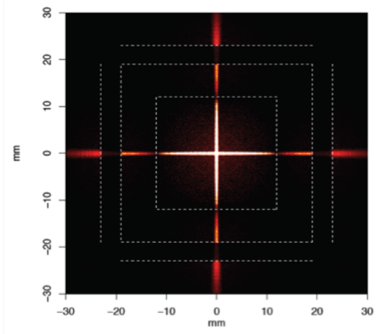


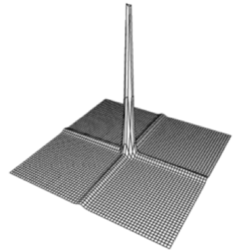
The Soft X-ray Imager (SXI)











4 DUs, each has a ~ 31 x 26 degree FoV

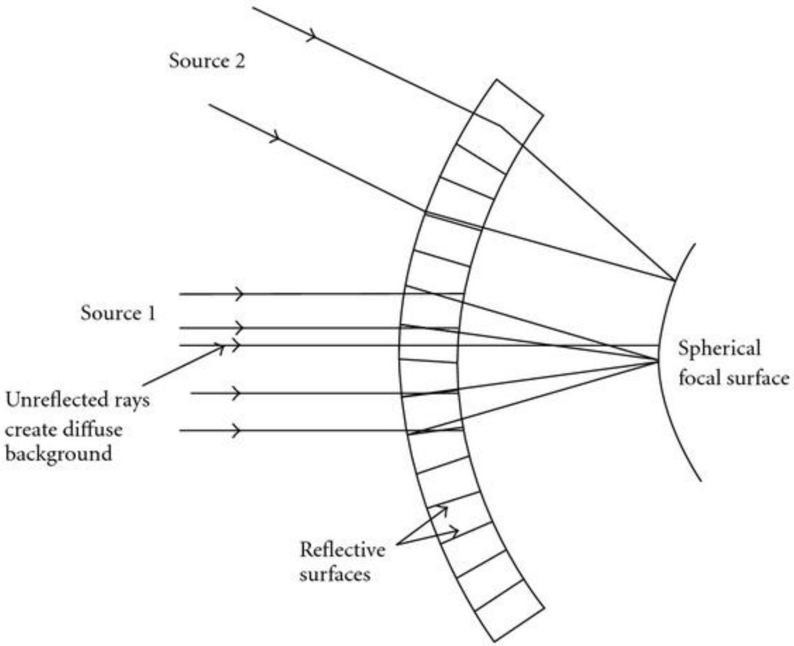
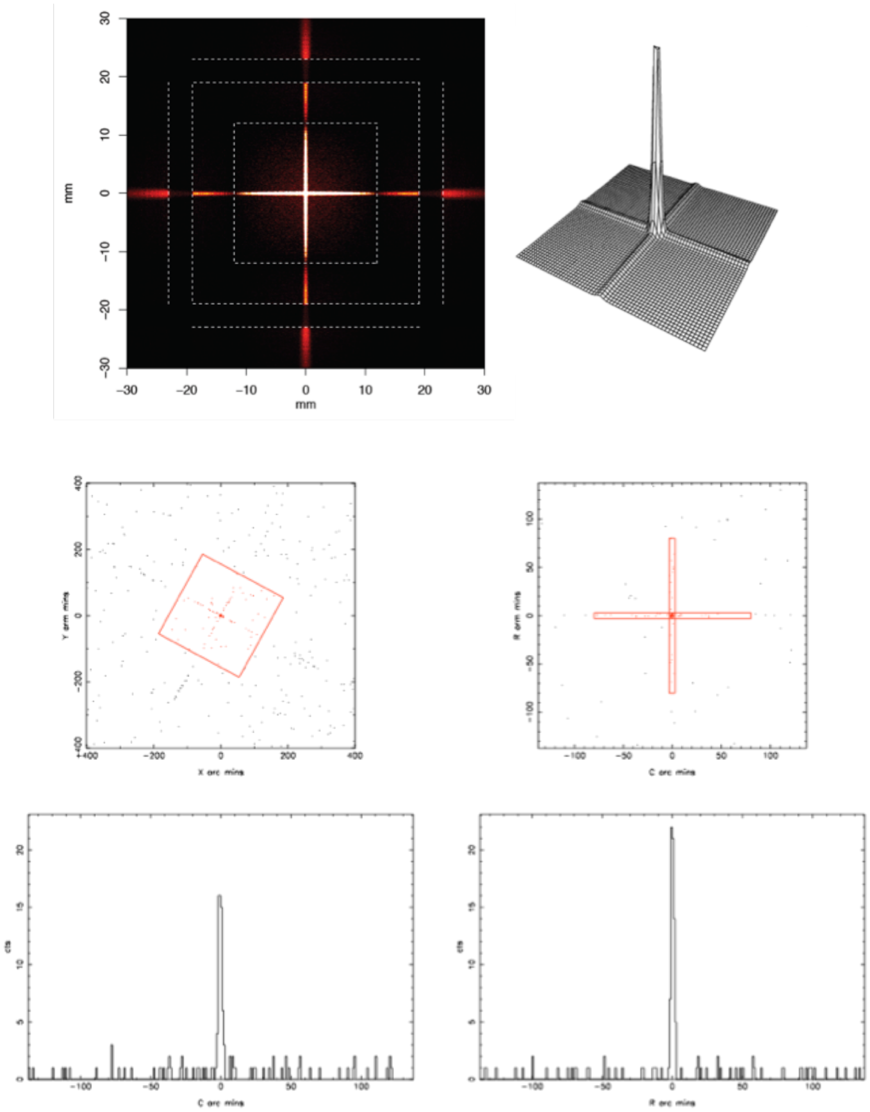


Table 4 : : SXI detector unit main physical characteristics

Energy band (keV)	0.3-5
Telescope type:	Lobster eye
Optics aperture (mm2)	320x320
Optics configuration	8x8 square pore MCPs
MCP size (mm2)	40x40
Focal length (mm)	300
Focal plane shape	spherical
Focal plane detectors	CCD array
Size of each CCD (mm2)	81.2x67.7
Pixel size (µm)	18
Pixel Number	4510 x 3758 per CCD
Number of CCDs	4
Field of View (square deg)	~1sr
Angular accuracy (best, worst) (arcsec)	(<10, 105)
Power [W]	27,8
Mass [kg]	40

The triggering algorithm



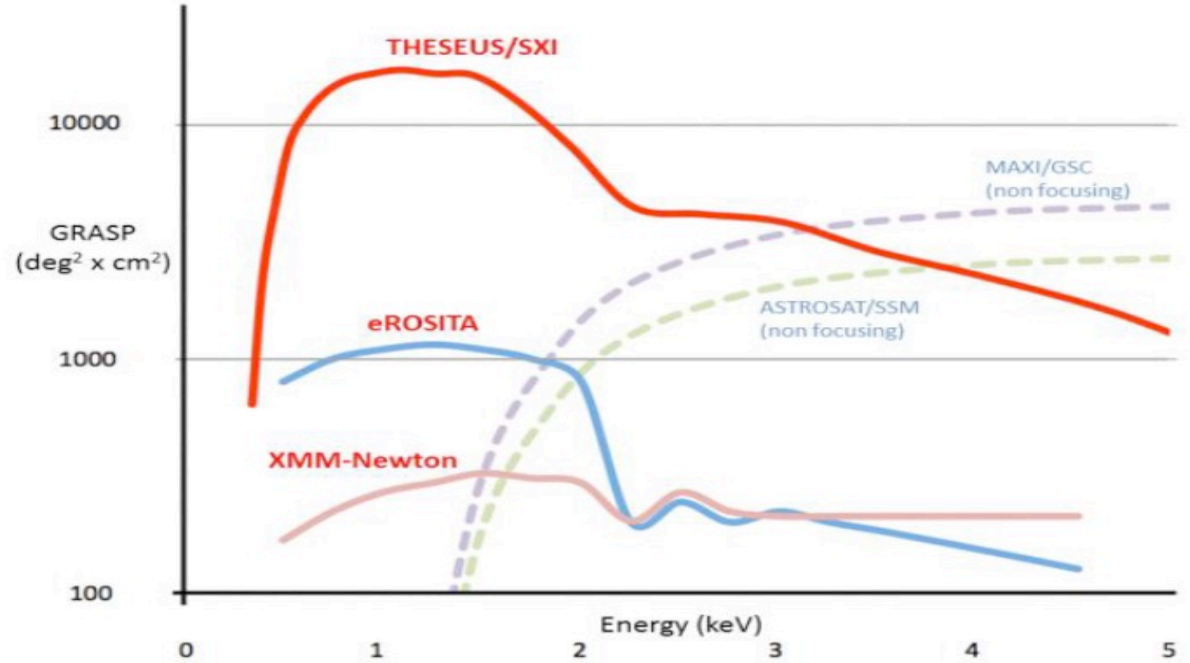
A two stage trigger algorithm:

Top left-hand panel: defining a square around the an initial guess position: the detected event distribution $\Delta T=4$ seconds and a source count rate of 40 cts s^{-1} over the full PSF are shown.

The Top right-hand panel: the detected event distribution in the selected patch of sky aligned to the cross-arm axes of the PSF (shown as the red rectangle in the top left-hand panel).
The red cross-patch indicates the area used for the second stage of the algorithm.

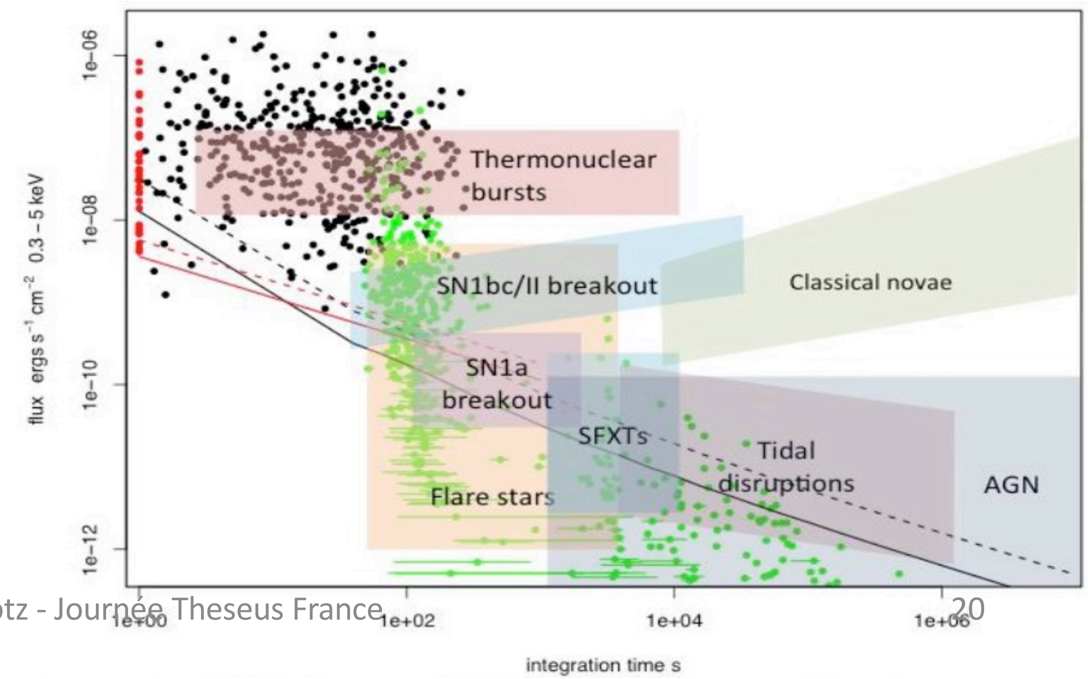
Bottom panels: the histograms along columns and rows in the patch, where the 2x1D maxima are looked for.

GW/multi-messenger and time-domain astrophysics

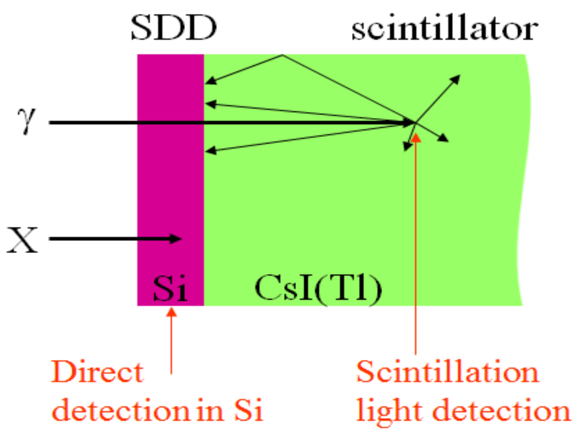


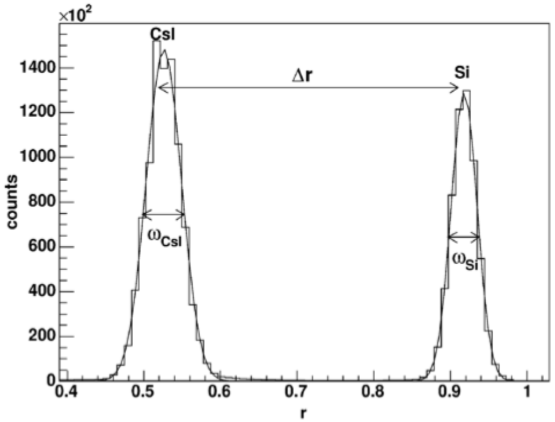
Survey capabilities of transient phenomena complementary to the Large Synoptic Survey Telescope (LSST) in the optical

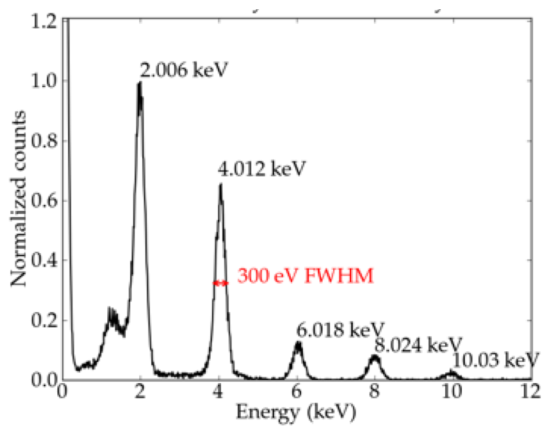
IR survey and guest observer possibilities, allowing a strong community involvement

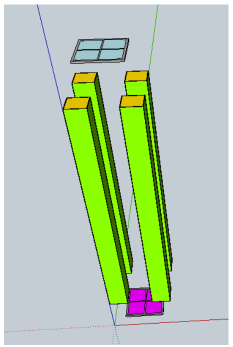


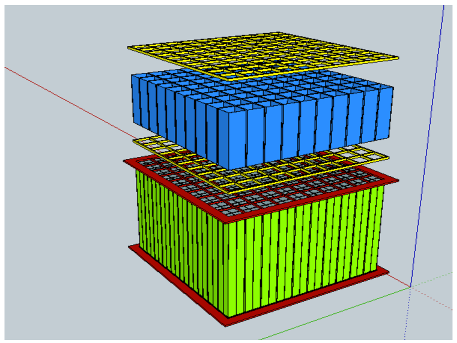
X-Gamma-ray Imaging Spectrometer (XGIS)

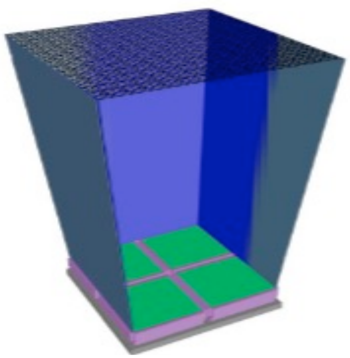










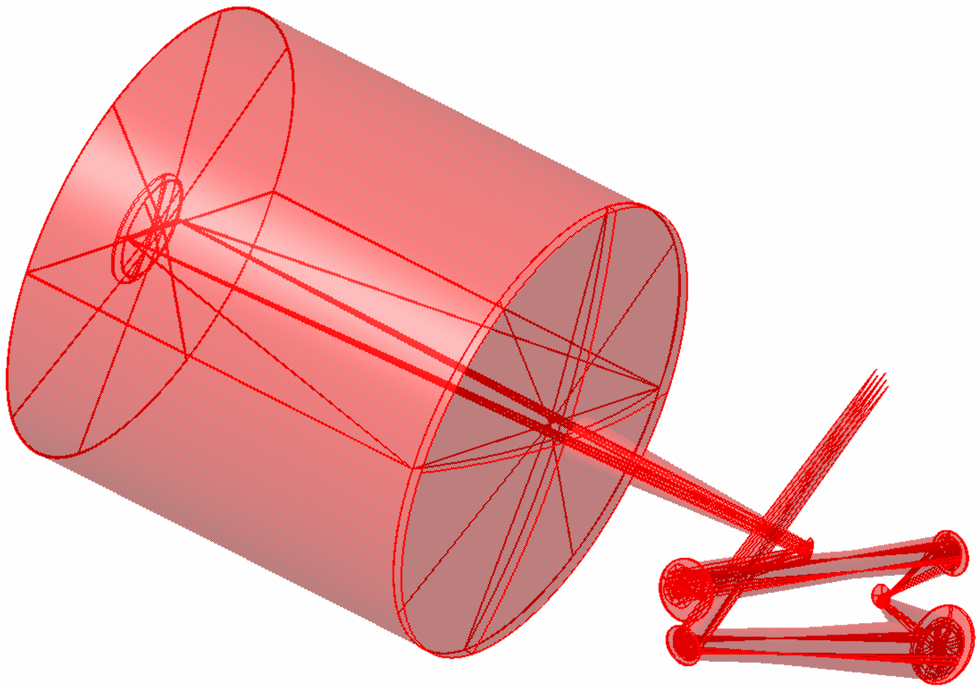


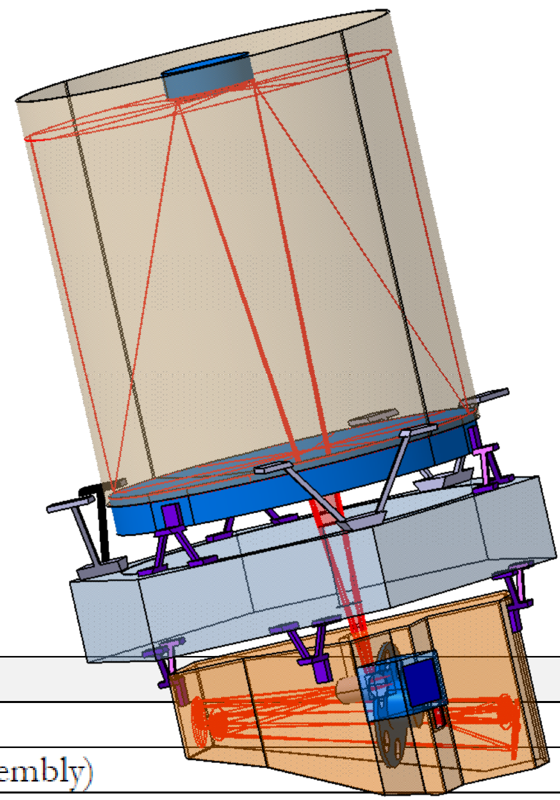
Energy band	*2 keV – 20 MeV*
# detection plane modules	*4*
# of detector pixel / module	*32x32*
pixel size (= mask element size)	*5x5 mm*
Low-energy detector (2-30 keV)	*Silicon Drift Detector 450 μm thick*
High energy detector (> 30 keV)	*CsI(Tl) (3 cm thick)*
Discrimination Si/CsI(Tl) detection	*Pulse shape analysis*
Dimension [cm]	*50x50x85*
Power [W]	*30,0*
Mass [kg]	*37.3*

	2-30 keV	30-150 keV	>150 keV
Fully coded FOV	9 x 9 deg²		
Half sens. FOV	50 x 50 deg²	50 x 50 deg² (FWHM)	
Total FOV	64 x 64 deg²	85 x 85 deg² (FWZR)	2π sr
Ang. res	25 arcmin		
Source location accuracy	~5 arcmin (for >6 σ source)		
Energy res	200 eV FWHM @ 6 keV	18 % FWHM @ 60 keV	6 % FWHM @ 500 keV
Timing res.	1 μsec	1 μsec	1 μsec

Extends the FOV beyond the SXI
Provides better spectral characterization

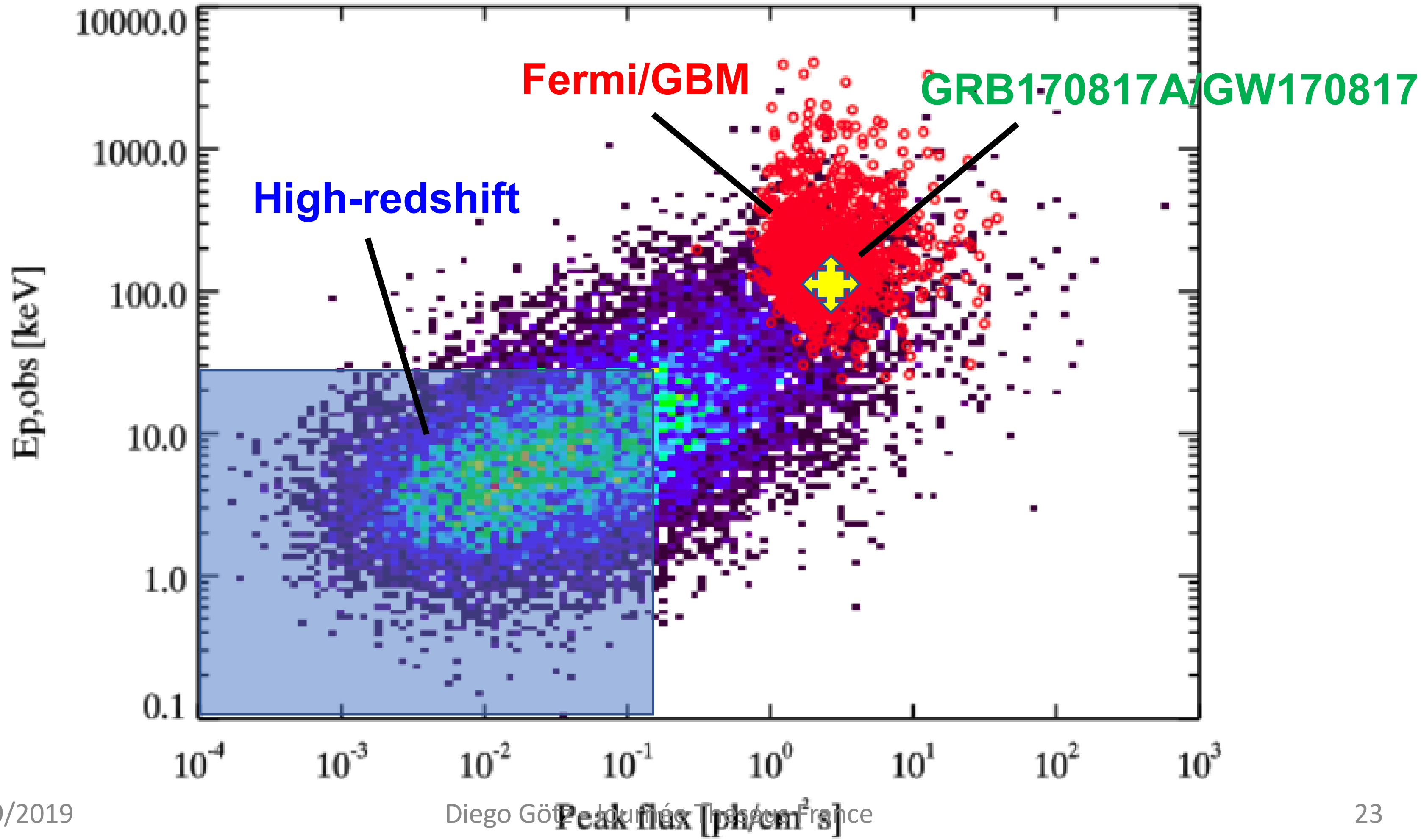
The InfraRed Telescope (IRT)



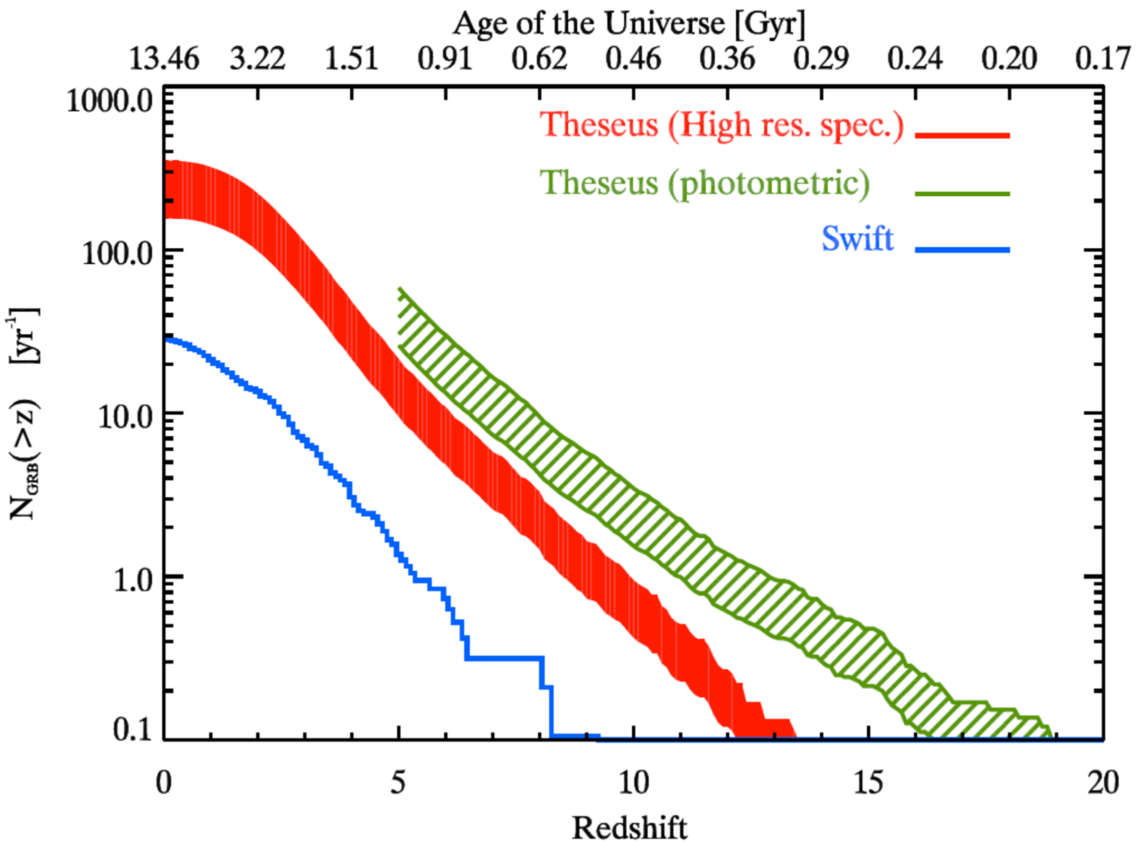


Primary & Secondary size:	700 mm & 230 mm		
Material:	SiC (for both optics and optical tube assembly)		
Detector type:	Teledyne Hawaii-2RG 2048 x 2048 pixels (18 µm each)		
Imaging plate scale	0".3/pixel		
Field of view:	10' x 10'	10' x 10'	5' x 5'
Resolution ($\lambda/\Delta\lambda$):	2-3 (imaging)	20 (low-res)	500 (high-res), goal 1000
Sensitivity (AB mag):	H = 20.6 (300s)	H = 18.5 (300s)	H = 17.5 (1800s)
Filters:	ZYJH	Prism	VPH grating
Wavelength range (µm):	0.7-1.8 (imaging)	0.7-1.8 (low-res)	0.7-1.8 (high-res, TBC)
Total envelope size (mm):	800 Ø x 1800		
Power (W):	115 (50 W for thermal control)		
Mass (kg):	112.6		

❑ **THESEUS will have the ideal combination of instrumentation and mission profile for detecting all types of GRBs (long, short/hard, weak/soft, high-redshift), localizing them from a few arc min down to arc sec and measure the redshift for a large fraction of them**

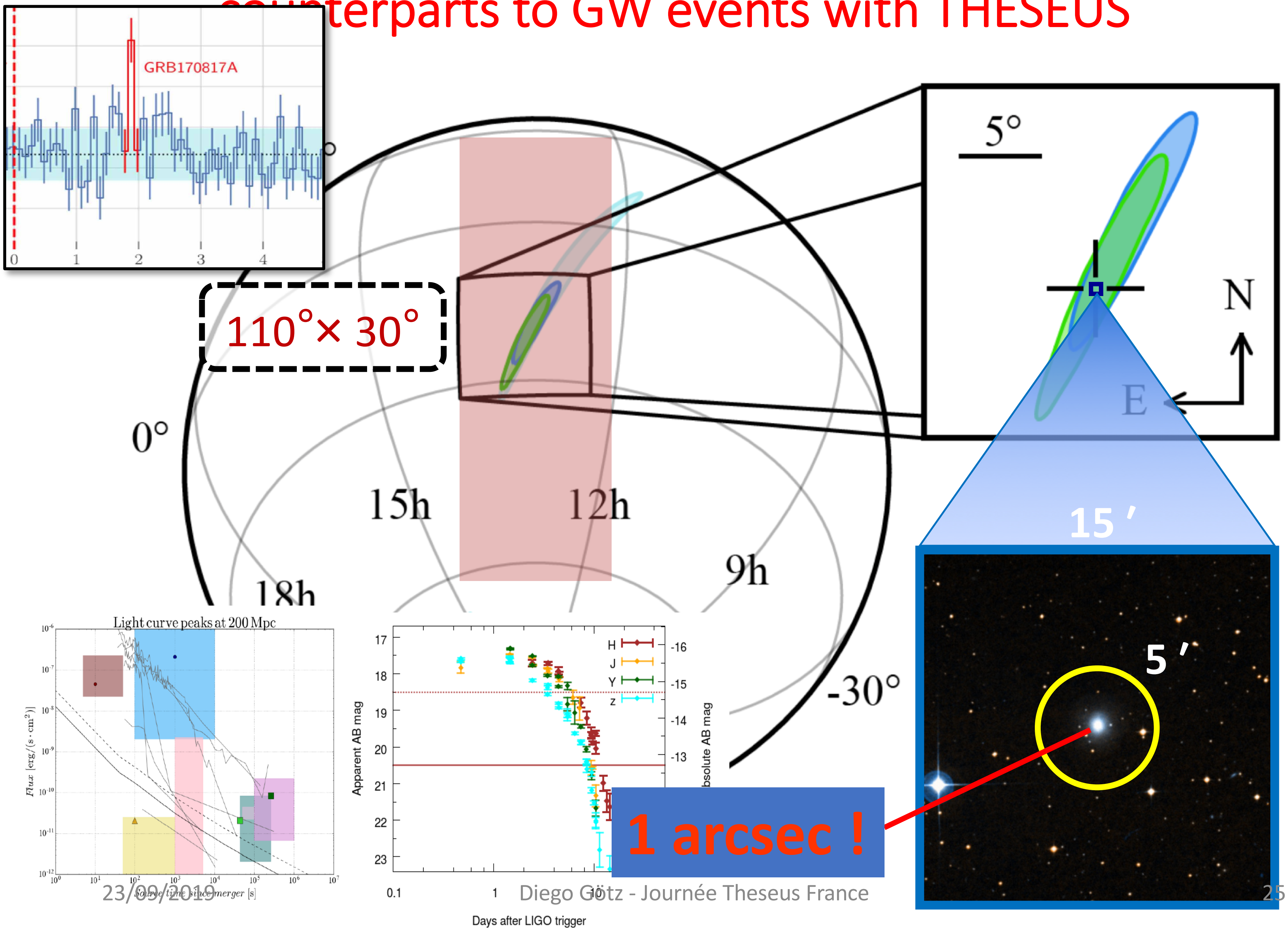


❑ Shedding light on the early Universe with GRBs

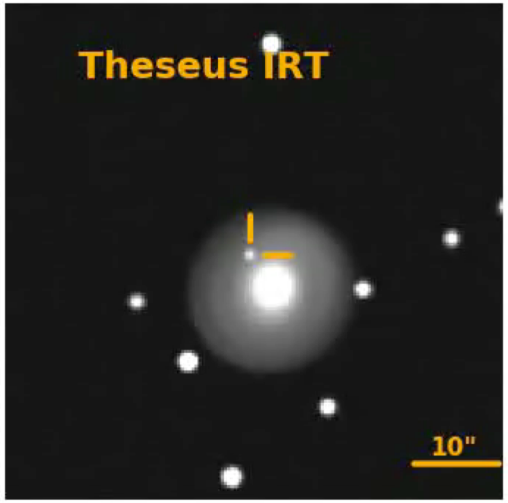


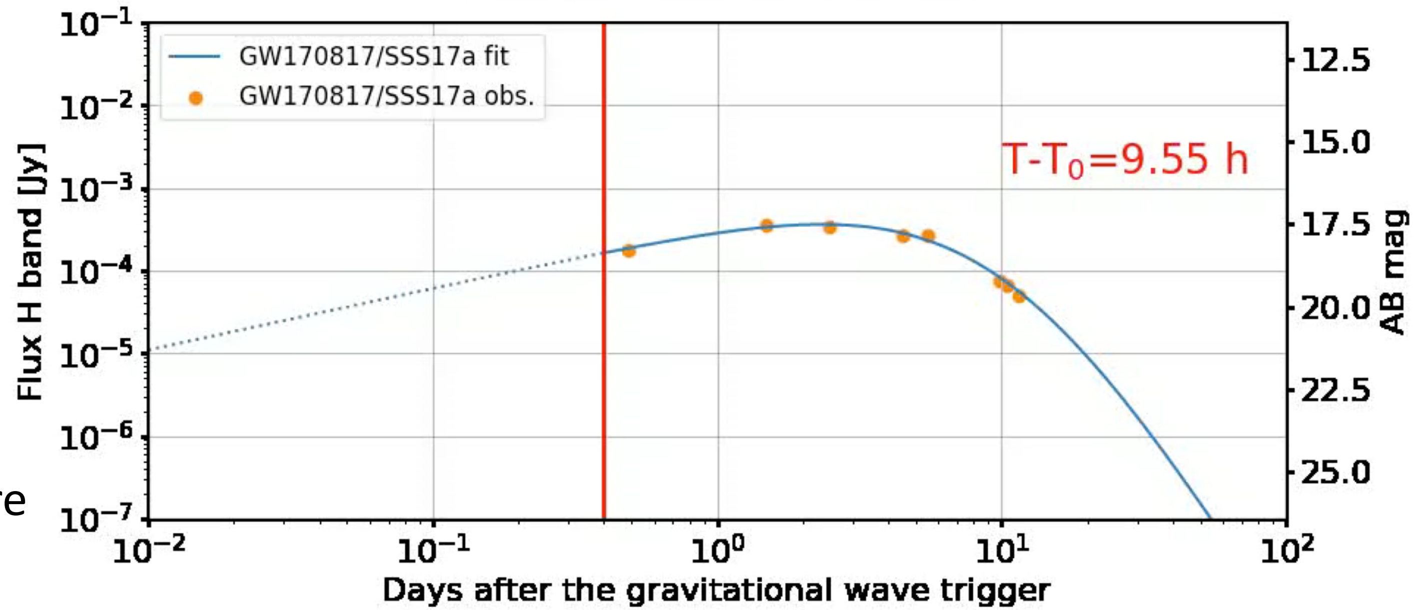
THESEUS GRB#/yr	All	z > 5	z > 8	z > 10
Detections	387 - 870	25 – 60	4 – 10	2 - 4
Photometric z		25 – 60	4 – 10	2 - 4
Spectroscopic z	156 - 350	10 - 20	1 - 3	0.5 - 1

❑ Promptly and accurately localizing e.m. counterparts to GW events with THESEUS



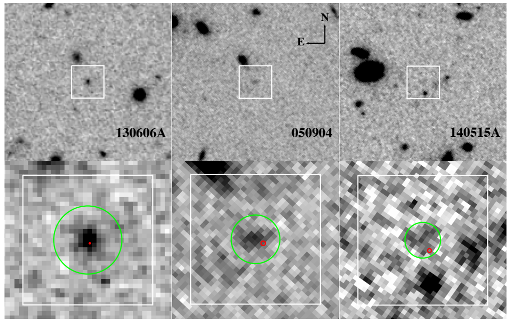
GW170817/SSS17a seen by Theseus IRT in H band

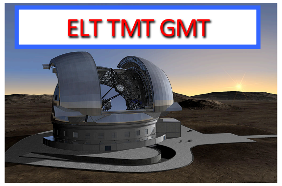




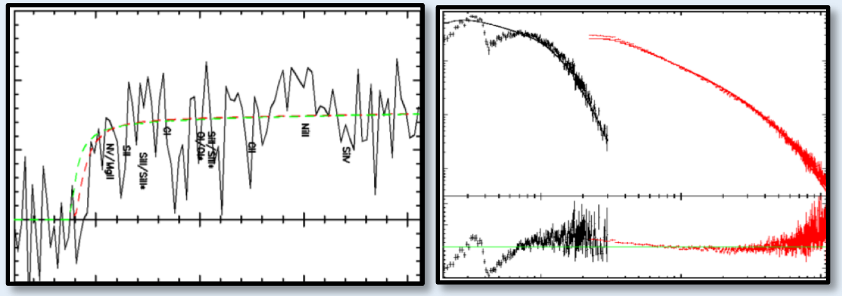
S. Basa/D. Corre

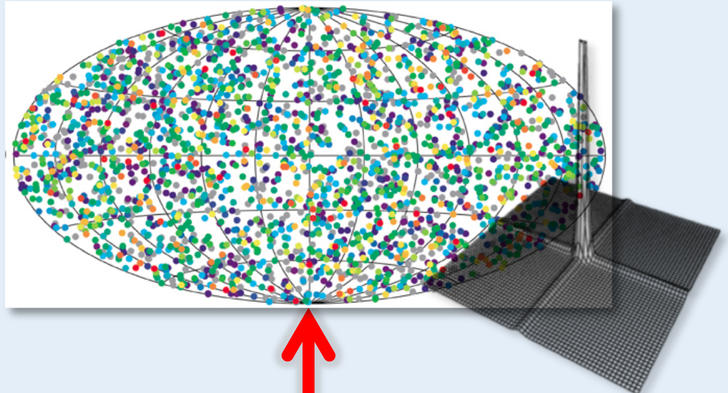
Star formation history, primordial galaxies





GRB accurate localization and NIR, X-ray, Gamma-ray characterization, redshift

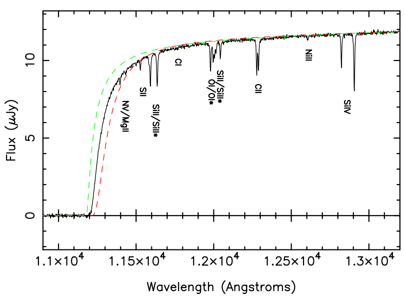


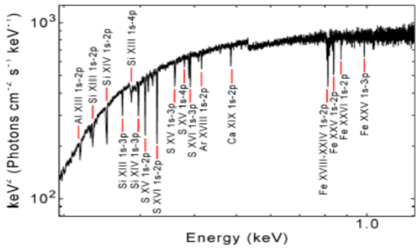


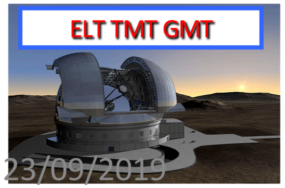
Neutral fraction of IGM, ionizing radiation escape fraction

Cosmic chemical evolution, Pop III

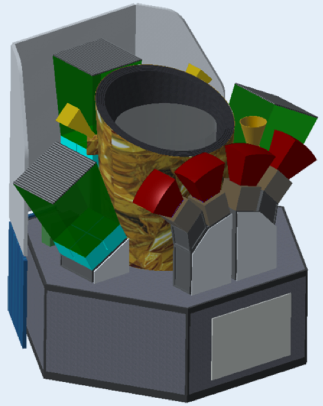
z=8.2 simulated ELT afterglow spectrum







theseus
TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR

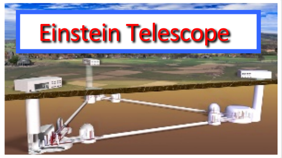


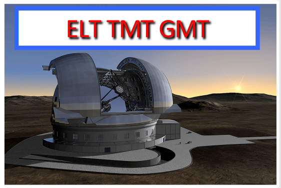
THESEUS SYNERGIES

THESEUS SYNERGIES

Localization of GW/neutrino gamma-ray or X-ray transient sources
NIR, X-ray, Gamma-ray characterization

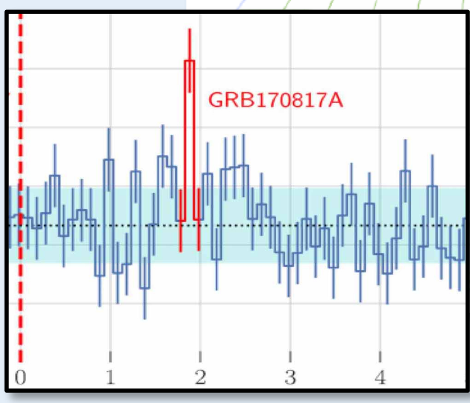
NS-BH/NS-NS merger physics/host galaxy identification/formation history/kilonova identification

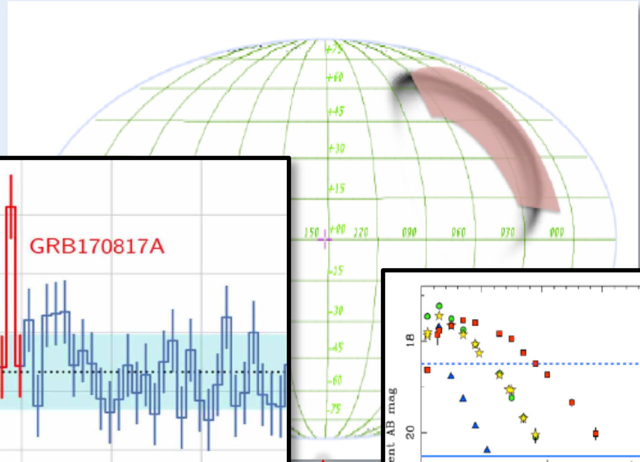


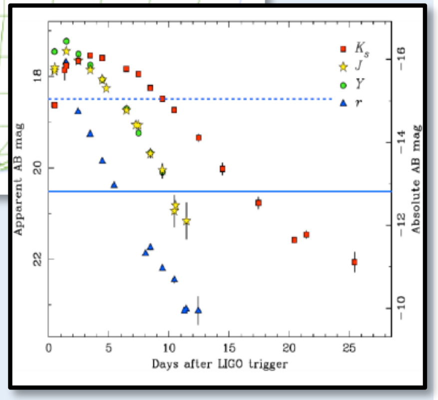


Hubble constant

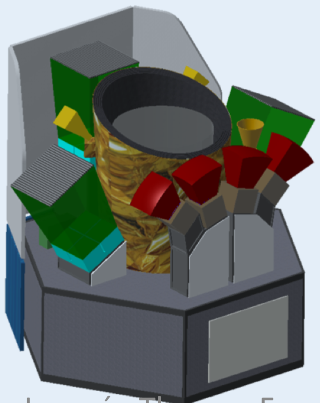
r-process element chemical abundances







TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR

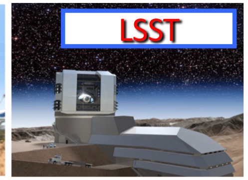


Transient sources multi-wavelength campaigns

Accretion physics

Jet physics

Star formation



The THESEUS Consortium

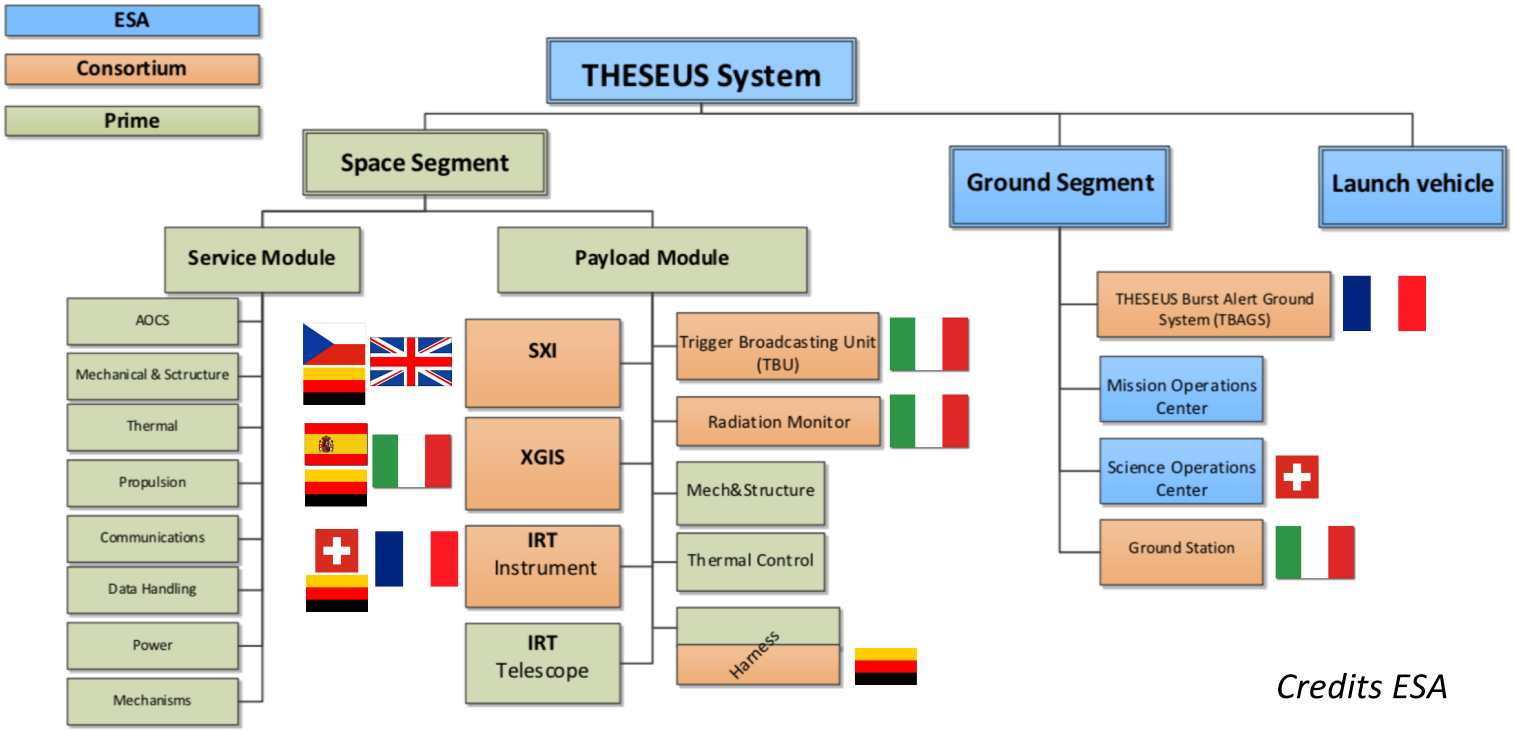
Lead Proposer (ESA/M5): Lorenzo Amati (INAF – OAS Bologna, Italy)

Coordinators (ESA/M5): Lorenzo Amati, Paul O'Brien (Univ. Leicester, UK), Diego Götz (CEA-Saclay, France), C. Tenzer (Univ. Tuebingen, D), E. Bozzo (Univ. Genève, CH)

Payload consortium: Italy, UK, France, Germany, Switzerland, Spain,
Poland, Czech Republic, Ireland, Hungary, Slovenia , ESA

Interested international partners: USA, China, Brazil

THESEUS Organisation (CDF Product Tree)

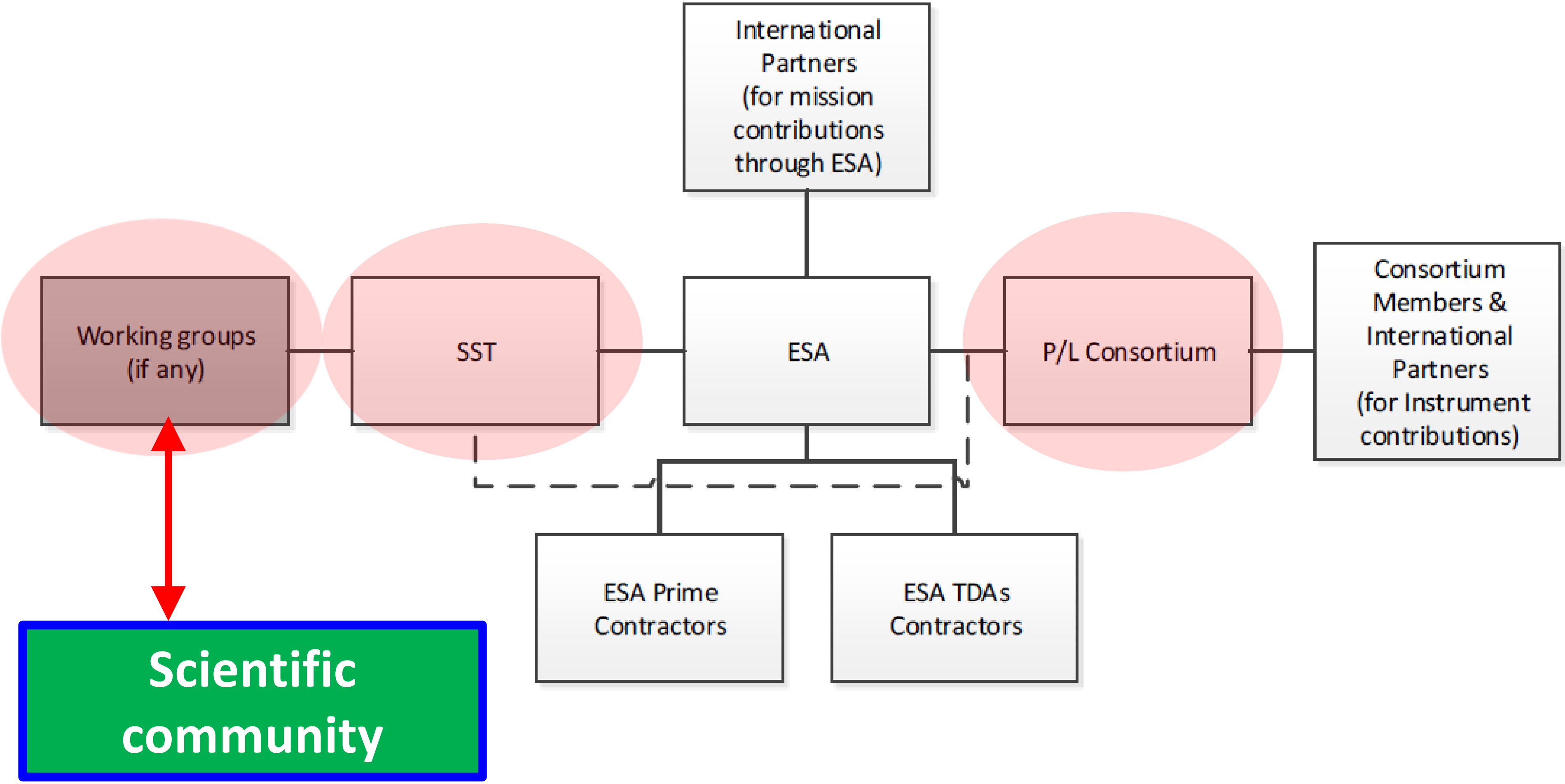


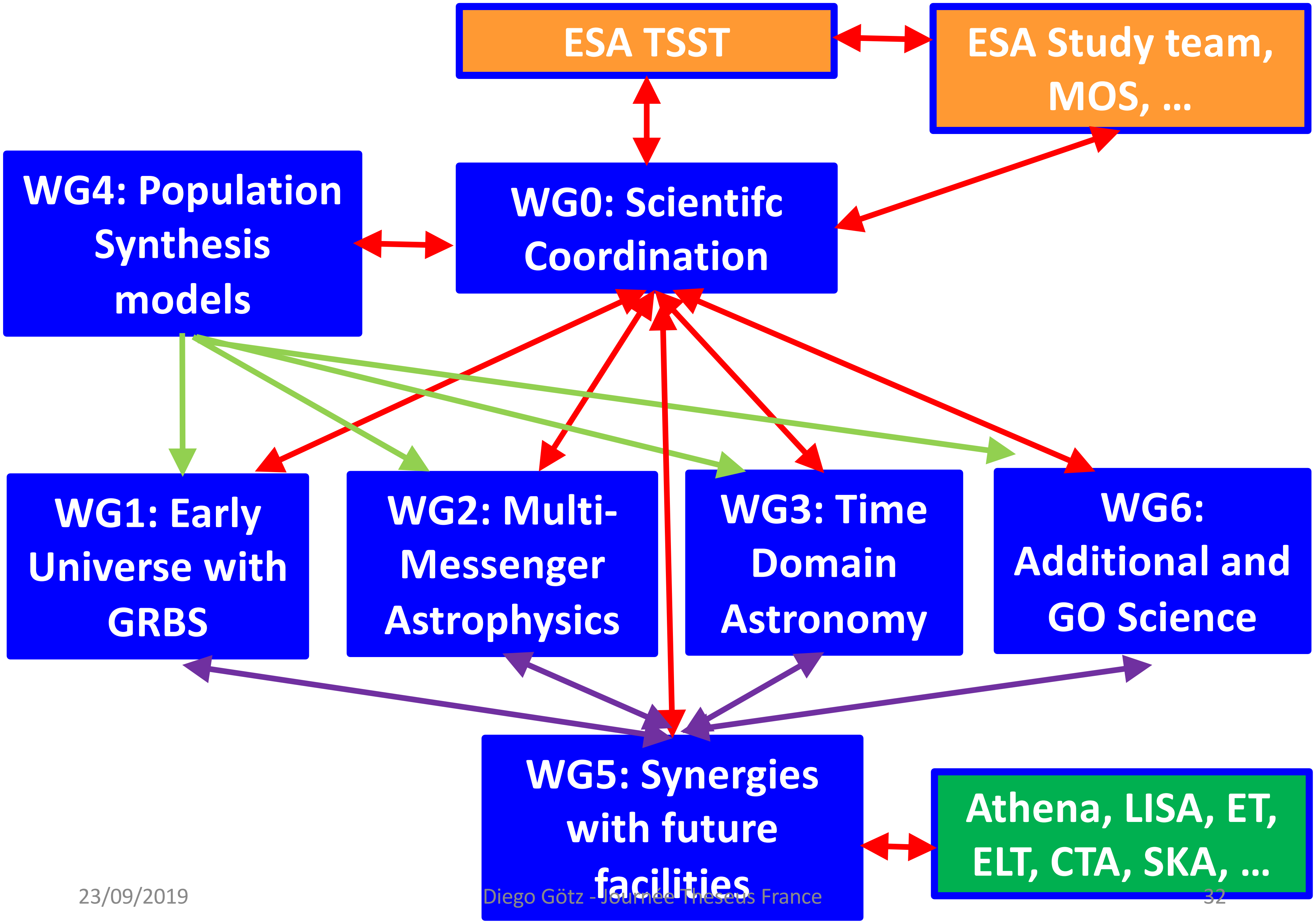
Credits ESA

France is leading the development of the IRT, and is resposible of the VHF alert receiving network (reuse of the SVOM VHF system)

Two French members (out of 11) in the of the THESEUS Science Study Team, responsible of the THESEUS mission Scientific Requirements Document

Science Activities for Phase A




ESA TSST
ESA Study team, MOS, …
WG4: Population Synthesis models
WG0: Scientifc Coordination
WG1: Early Universe with GRBS
WG2: Multi-Messenger Astrophysics
WG3: Time Domain Astronomy
WG6: Additional and GO Science
WG5: Synergies with future facilities
Athena, LISA, ET, ELT, CTA, SKA, …

WG scheme and coordinators

TSST Members

- **SWG0**- Scientific Coordination (L. Amati, P. O'Brien, D. Götz, E. Bozzo)
- **SWG1** - Exploring the early Universe with GRBs (N. Tanvir, L. Christensen, E. Le Floc'h)
- **SWG2** – Multi-Messenger Astrophysics (G. Stratta, R. Ciolfi, S. Paltani)
- **SWG3** – Exploring the time domain Universe (or "Non-GRB transients") (L. Hanlon, M. Caballero-Garcia, S. Mereghetti)
- **SWG4** - Populations synthesis models (G. Ghirlanda, R. Salvaterra, J. Osborne)
- **SWG5** - Synergies with future large observatories (S. Basa, P. Rosati, M. Branchesi)
  - SWG5.1 - Theseus after SVOM, EP, and GRB missions of the 20s: B. Cordier
  - SWG5.2 – Theseus – Athena (P. O'Brien)
  - SWG5.3 - Theseus – LISA (A. Sesana)
  - SWG5.4 - Theseus – 3G GW detectors (ET, CE) (M. Maggiore)
  - SWG5.5 - Theseus- SKA, Alma and large radio facilities (A. Ferrara)
  - SWG5.6 - Theseus- Extremely large tel. (ELT/TMT) synergies: (S. Vergani)
  - SWG5.7 - Theseus- CTA synergies: (F. Schüssler)
- **SWG6** – Observatory science (A. Blain, A. Castro-Tirado, A. De Rosa)

Perspective time line

by end of September 2019

•WG sections on Theseus website
• Call to the consortium members for confirming / asking membership
• Message to the worldwide community for updating on Theseus study and inviting to join WGs

by end of October 2019

- Activation of WGs: interaction of WG coordinators with scientific coordinator to further discuss and better focus the activities
- Interaction of WG coordinators with WG members, so to activate them and provide a first idea of main tasks and timeline
- Addressing specific urgent tasks: supporting the TSST for addressing instrumental trade-offs

from Fall 2019 to Spring 2020

- Start preliminary discussions on structure, content and needed investigations for yellow book structure of science sections (meeting in late 2019)
- THESEUS science meeting (with WGs splinter sessions): March – April 2020 (TBC)
- Presentations of status of work at THESEUS conference in Malaga (12-15 May 2020)