The great synergy between THESEUS and ELT/SHARP

Transient High-Energy Sky and Early Universe Surveyor

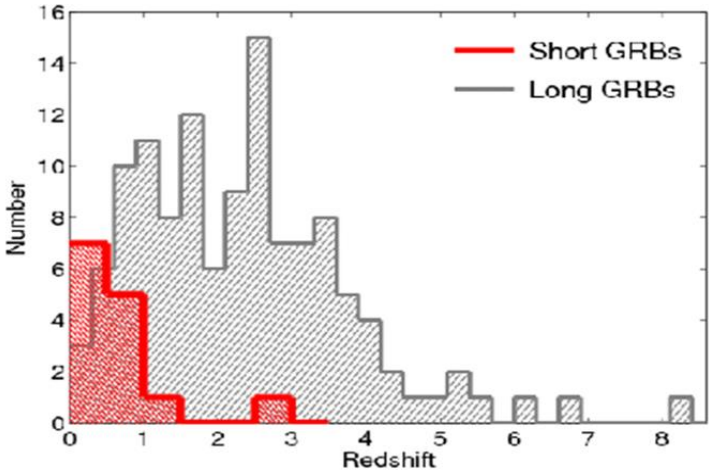
Lorenzo Amati

on behalf of the

THESEUS Consortium

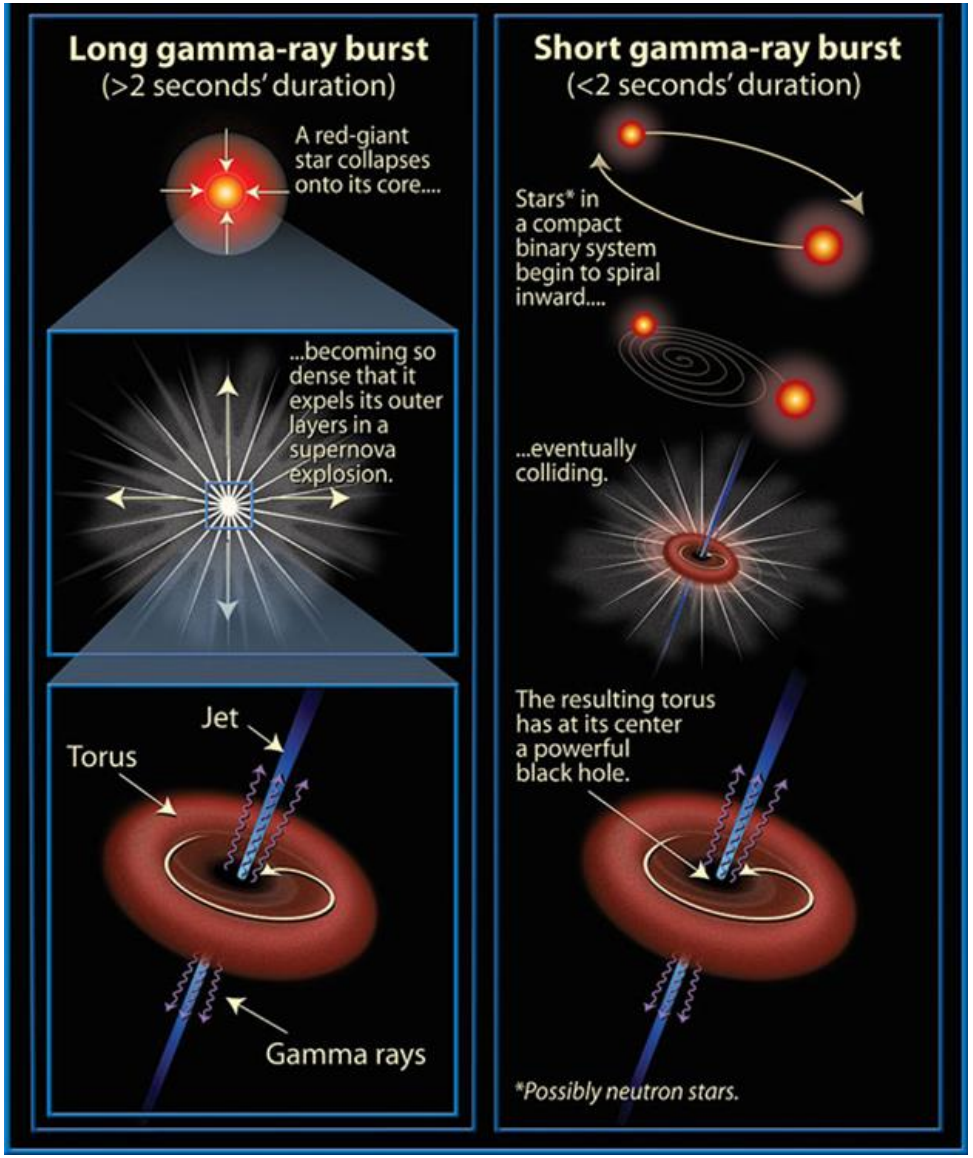
Unveiling the Universe with SHARP

Gamma-Ray Bursts: the most extreme phenomena in the Universe



Long GRBs: core collapse of pecular massive stars, **association with SN**

Short GRBs: NS-NS or NS-BH mergers, **association with GW sources**



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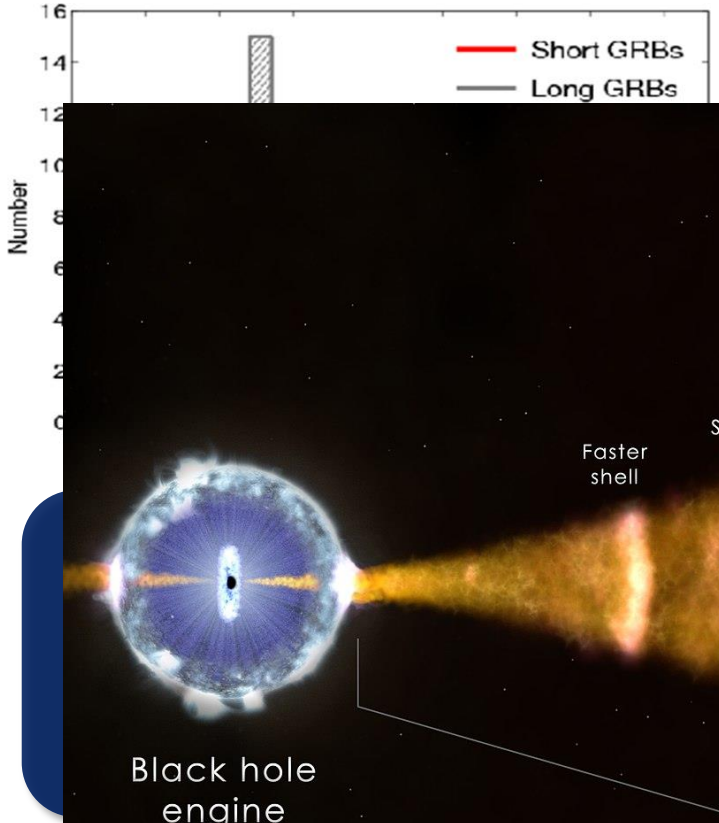
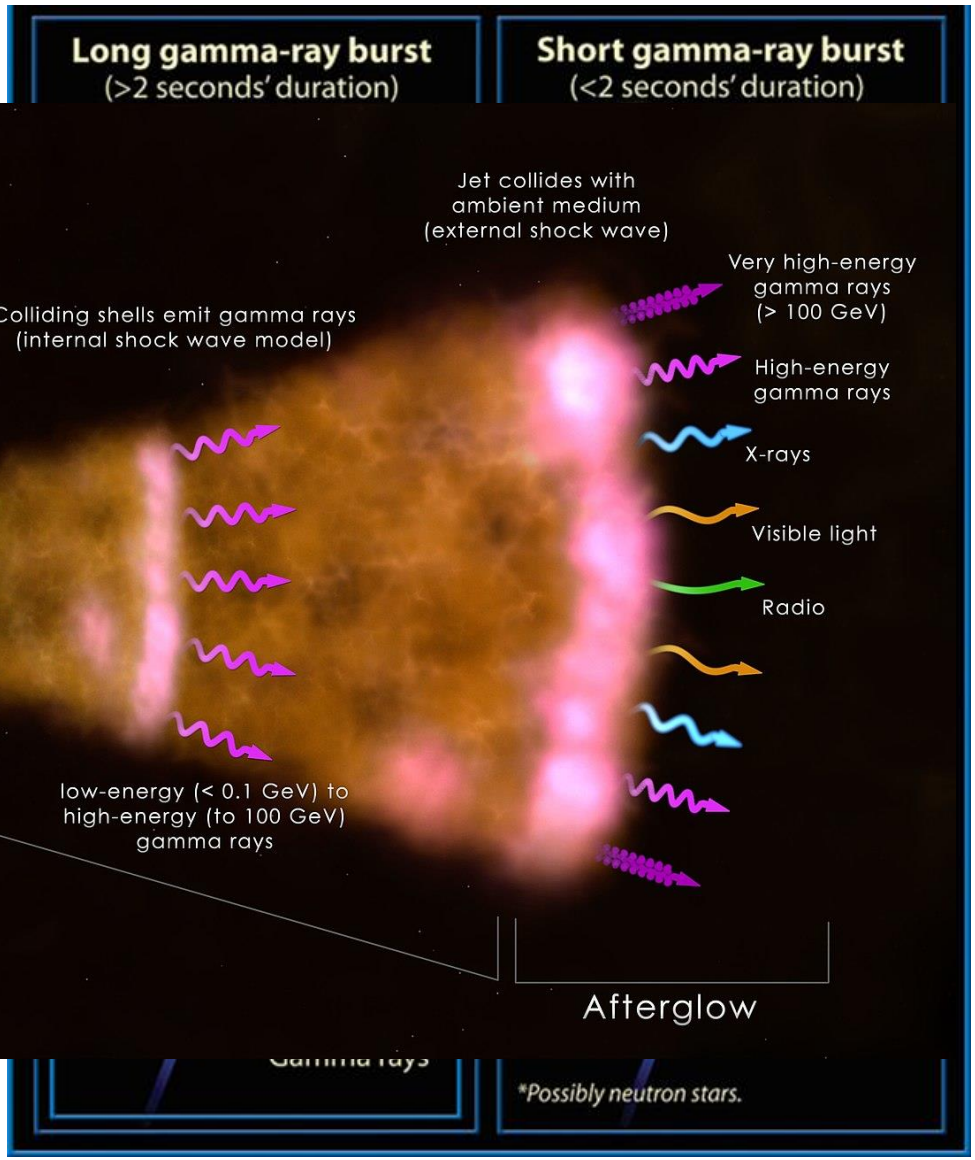
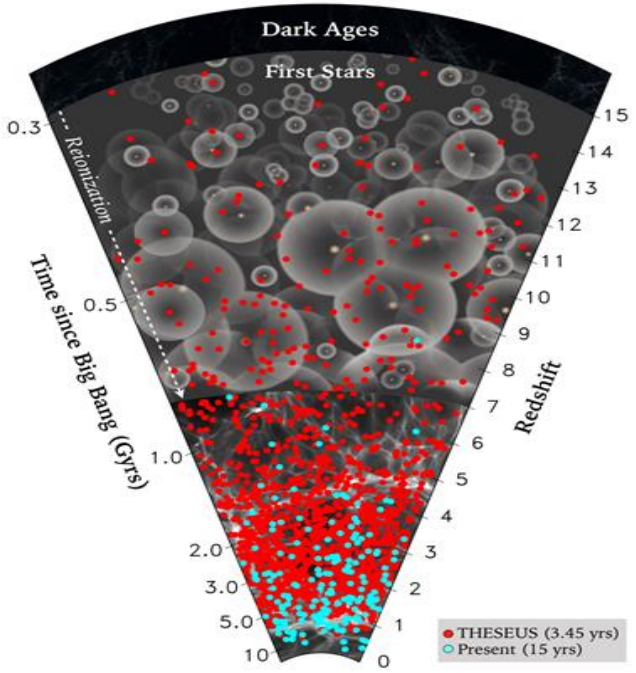




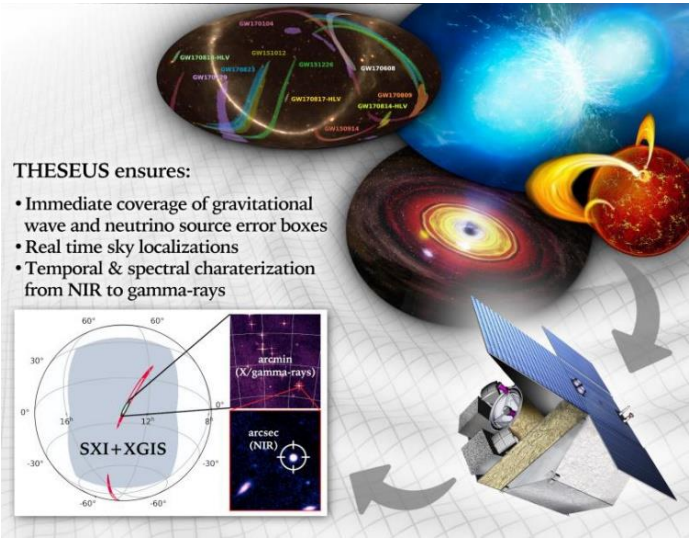
association with GW sources

Next generation GRB missions ('30s)

- Probe the **early Universe (first stars, first galaxies, cosmic reionization)**, by unveiling and exploiting the population of **extremely distant cosmic Gamma - Ray Bursts (GRB)**



- Provide a **fundamental contribution to multi-messenger astrophysics through GRB produced by merging neutron stars** and other X/gamma-ray transient sources



- 2018-2021: ESA PHASE-A STUDY (2018-2021) AS M5 CANDIDATE
- 2022: SELECTED FOR PHASE 0 STUDY (2023) WITHIN M7 PROCESS
- 2023: SELECTED FOR PHASE-A STUDY (2024-2026) AS M7 CANDIDATE
- M7 TIMELINE: PHASE-A (2024-2026), ADOPTION 2028, LAUNCH 2037

Payload consortium: Italy, Germany, UK, France, Switzerland, Spain, Poland, Denmark, Belgium, Czech Republic, The Netherlands, Norway, Slovenia, Ireland, Hungary

Leads: L. Amati (INAF – OAS Bologna, Italy, lead proposer), A. Santangelo (Un. Tuebingen, D), P. O'Brien (Un. Leicester, UK), D. Gotz (CEA-Paris, France), E. Bozzo (Un. Genève, CH)

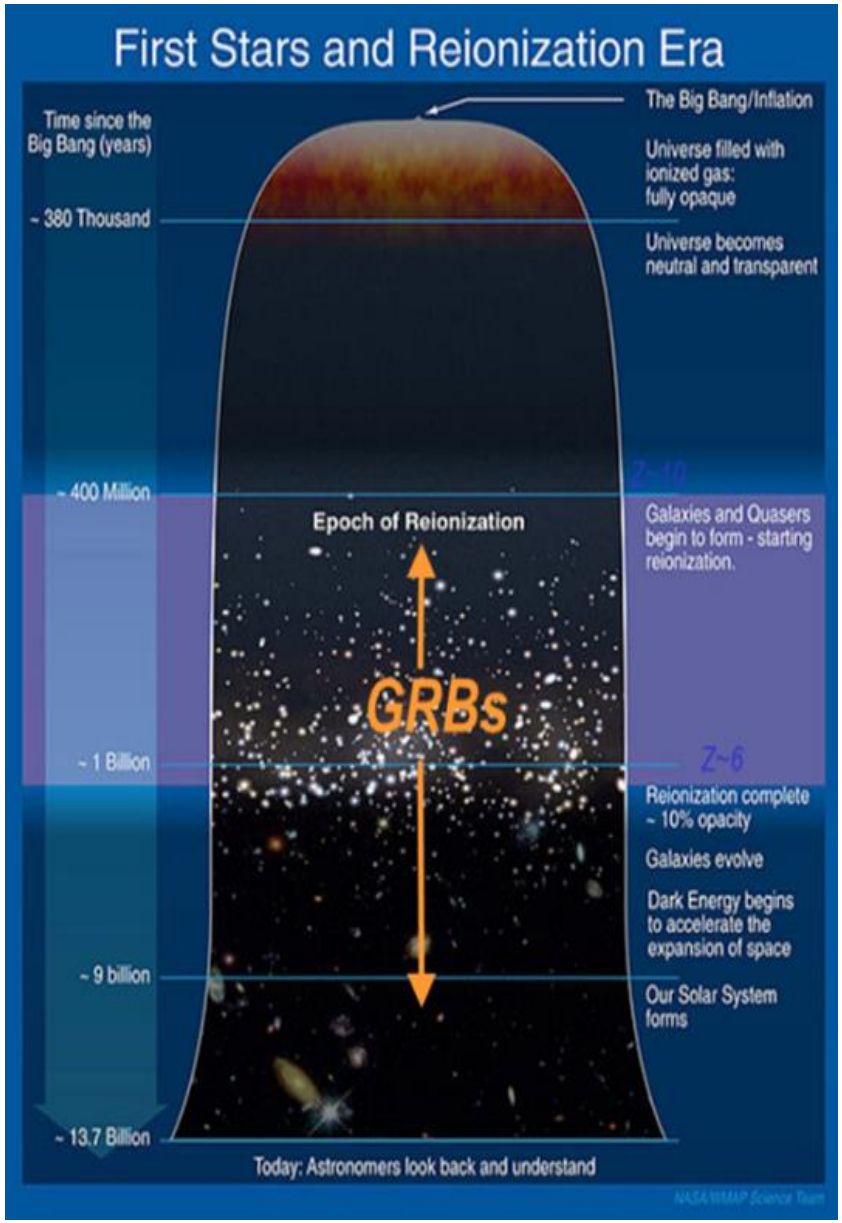
Amati et al. 2018 (Adv.Sp.Res., arXiv:1710.04638)
Stratta et al. 2018 (Adv.Sp.Res., arXiv:1712.08153)
Articles for SPIE 2020 and Exp..Astr. (all on arXiv)
http://www.isdc.unige.ch/theseus

Shedding light on the early Universe with GRBs

- **Long GRBs:** huge luminosities, mostly emitted in the X and gamma-rays

- **Redshift distribution** extending at least to z ~9 and association with exploding massive stars

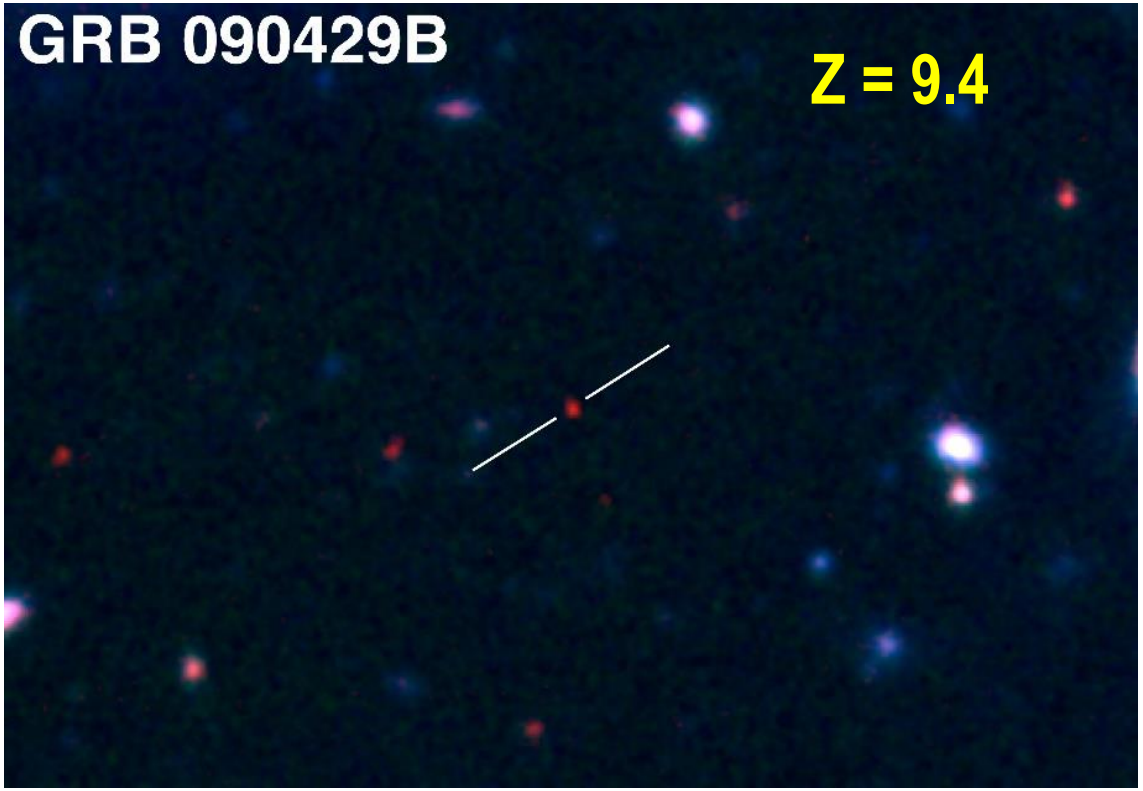
- **Powerful tools for cosmology:** SFR evolution, physics of re-ionization, high-z low luminosity galaxies, pop III stars



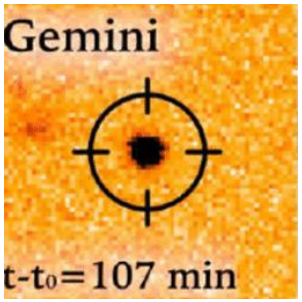
Shedding light on the early Universe with GRBs

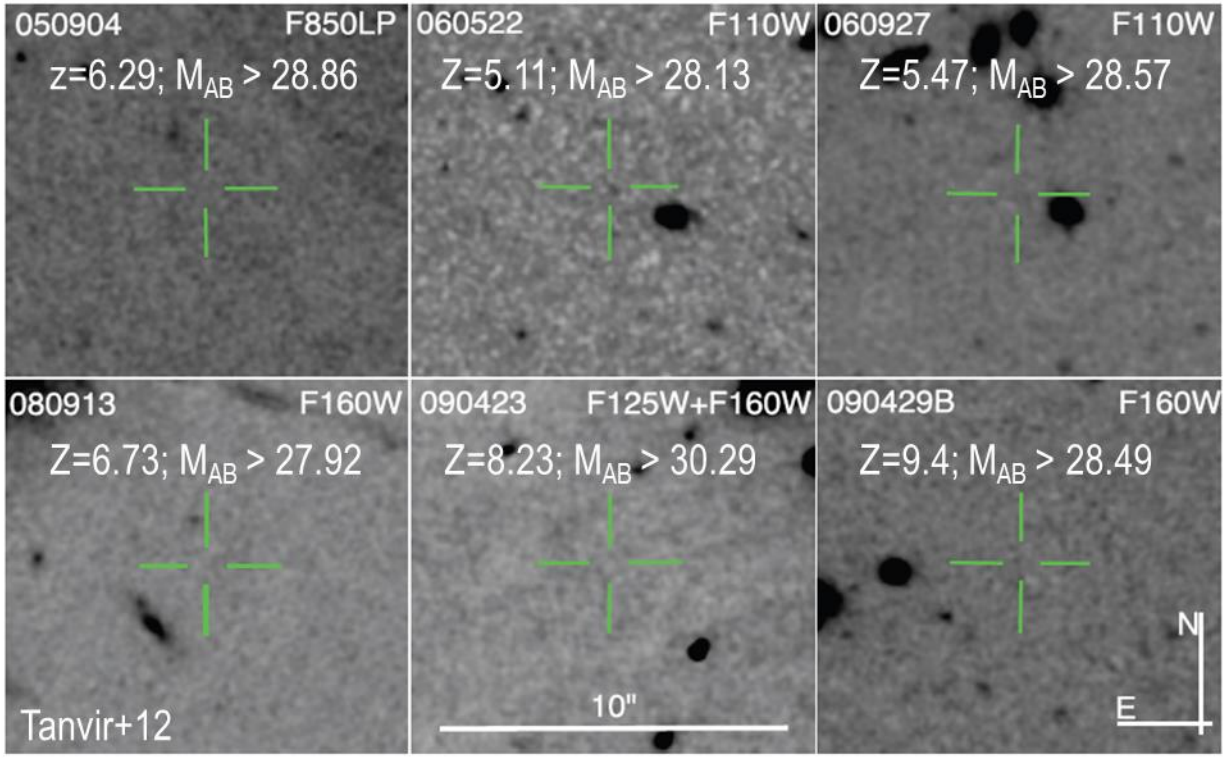
A statistical sample of high–z GRBs can provide fundamental information:

- 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)**



Detecting and studying primordial invisible galaxies

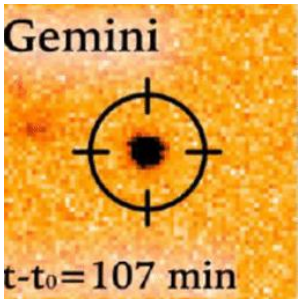


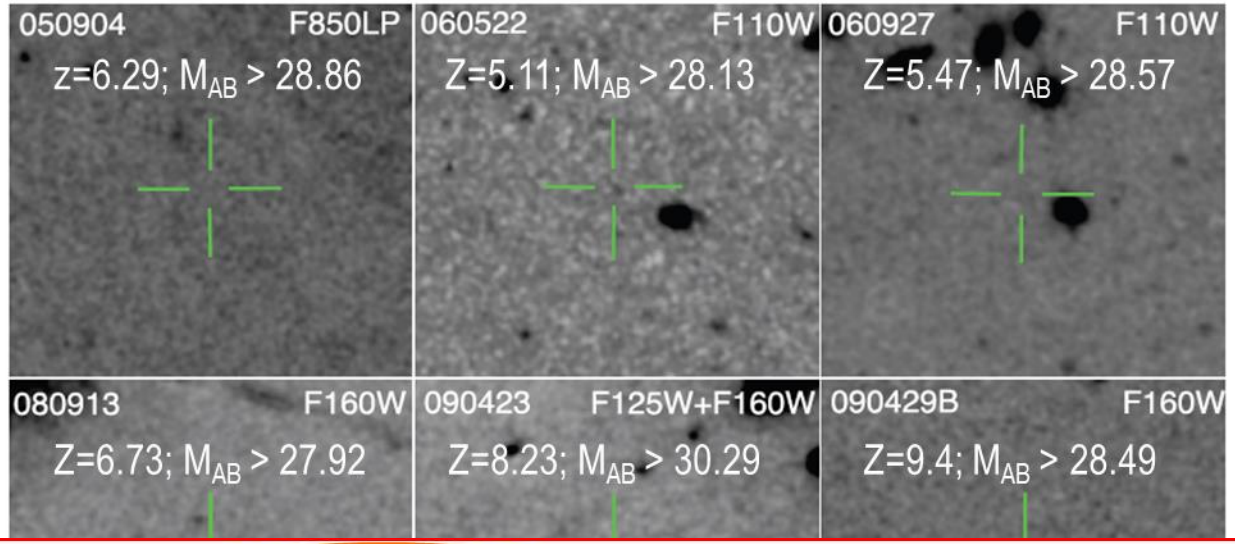


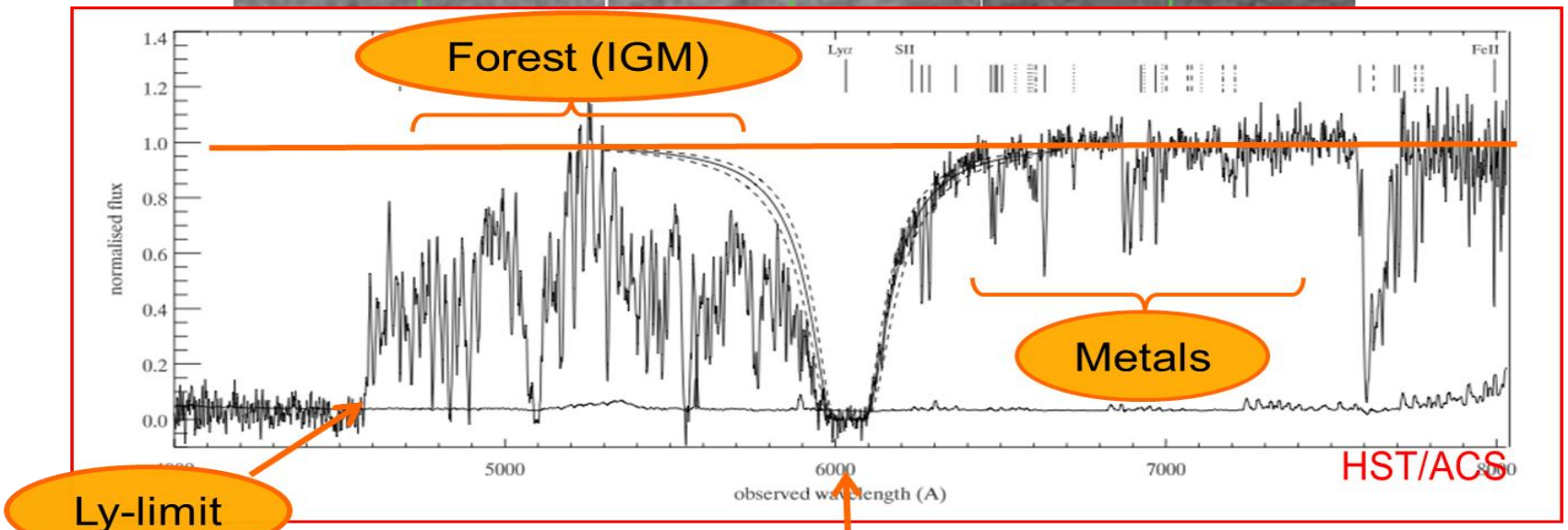
Robertson&Ellis12

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)

Detecting and studying primordial invisible galaxies







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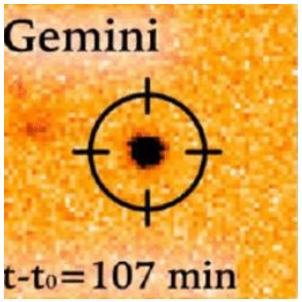
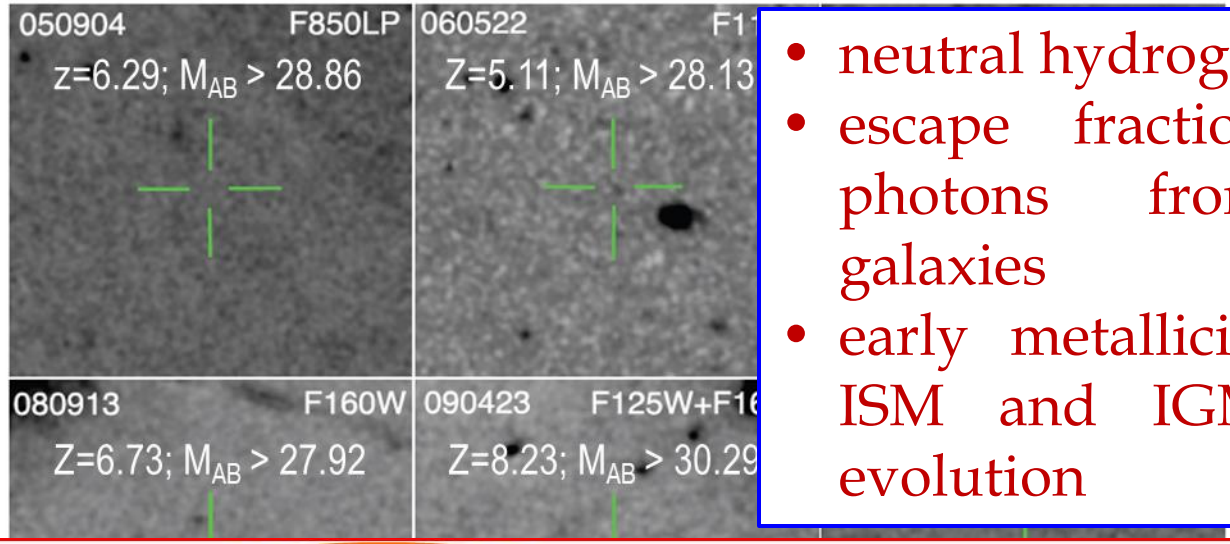
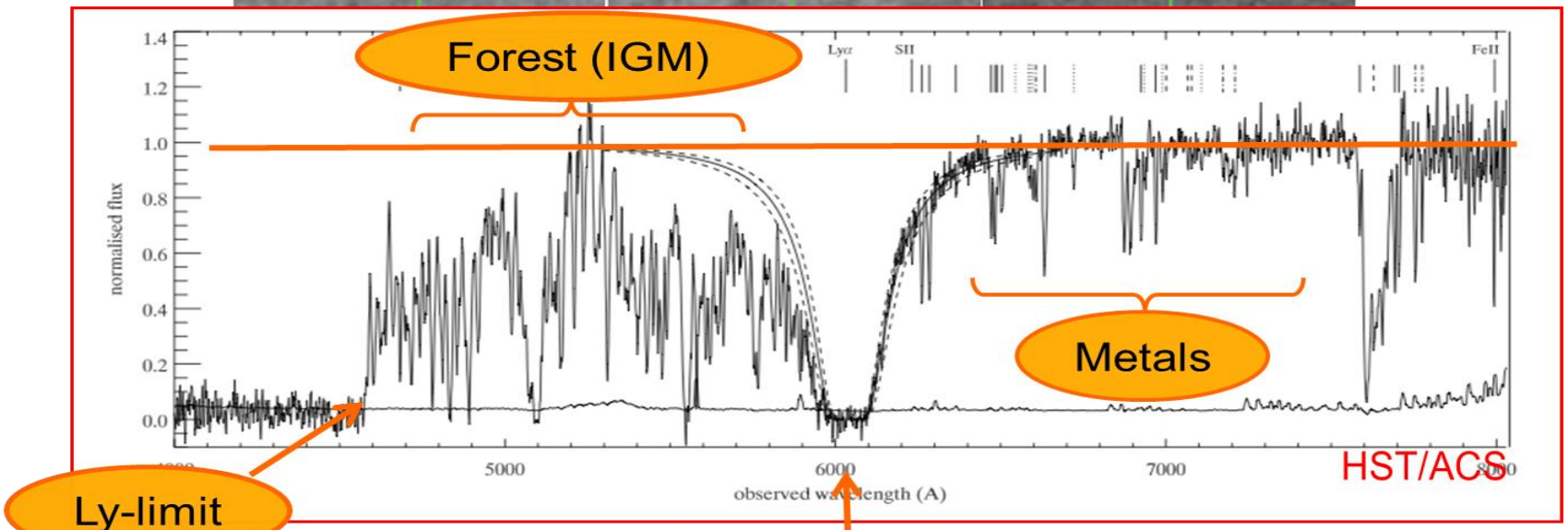




- neutral hydrogen fraction
- escape fraction of UV photons from high-z galaxies
- early metallicity of the ISM and IGM and its evolution



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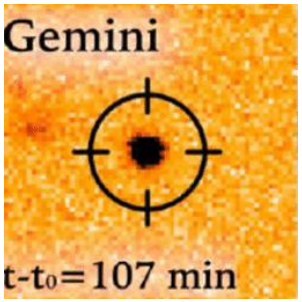

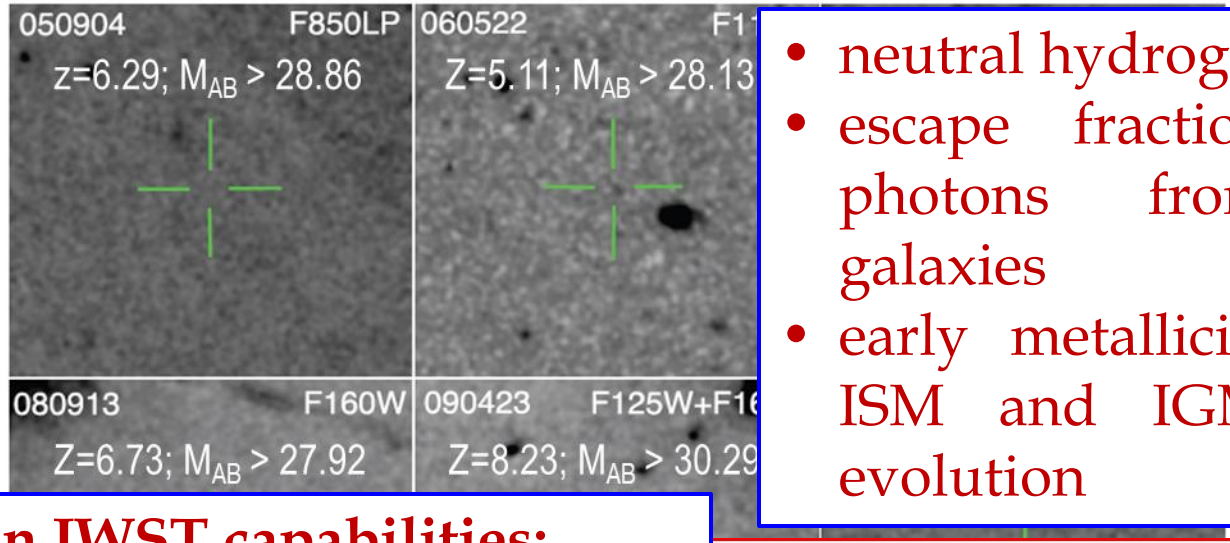

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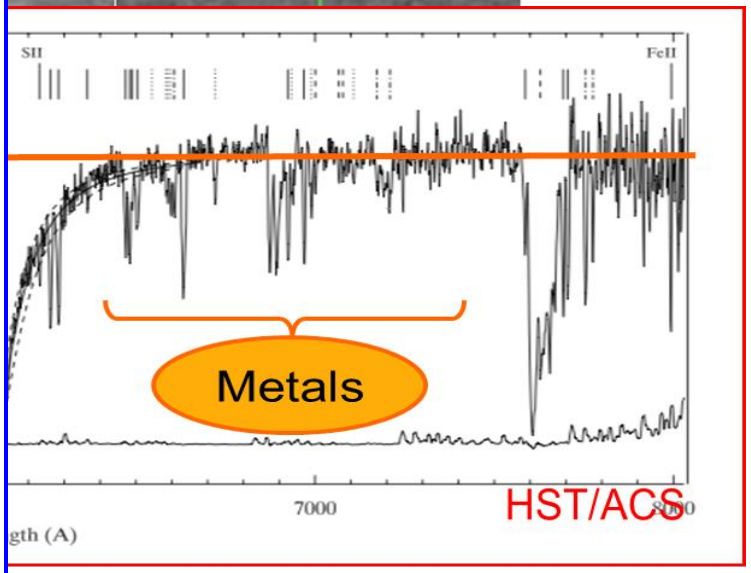
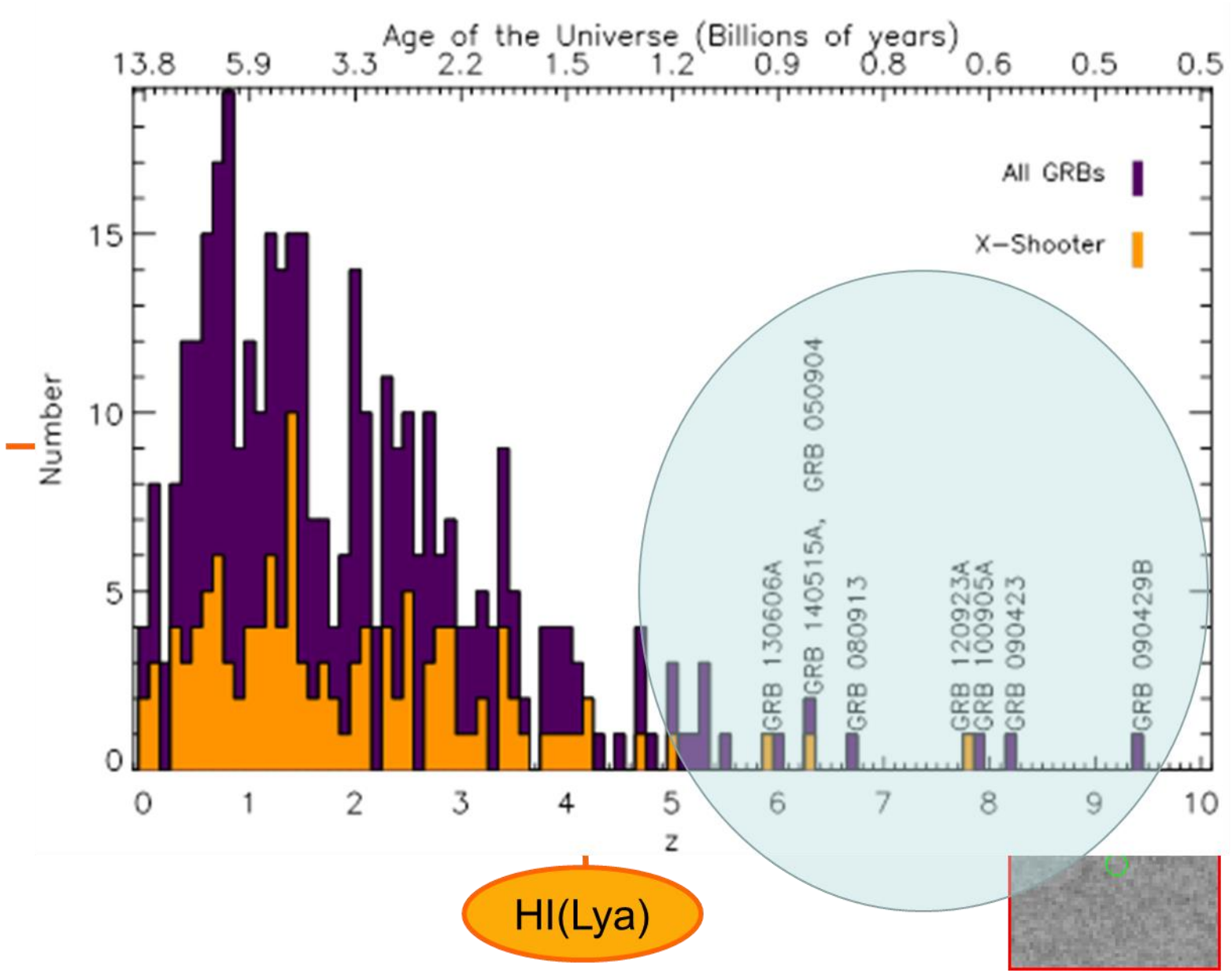
Beyond even JWST capabilities:

- Primordial galaxies detection and characterization Independent on mass and luminosity
- Allow absorption spectroscopy (needed because most metals are in neutral gas and and for dust ratio)
- Properties of primordial IGM
- Targets for JWST

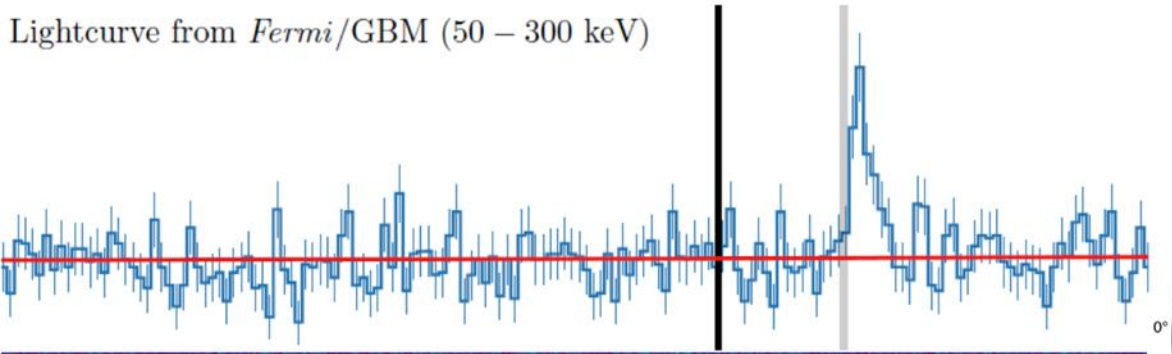


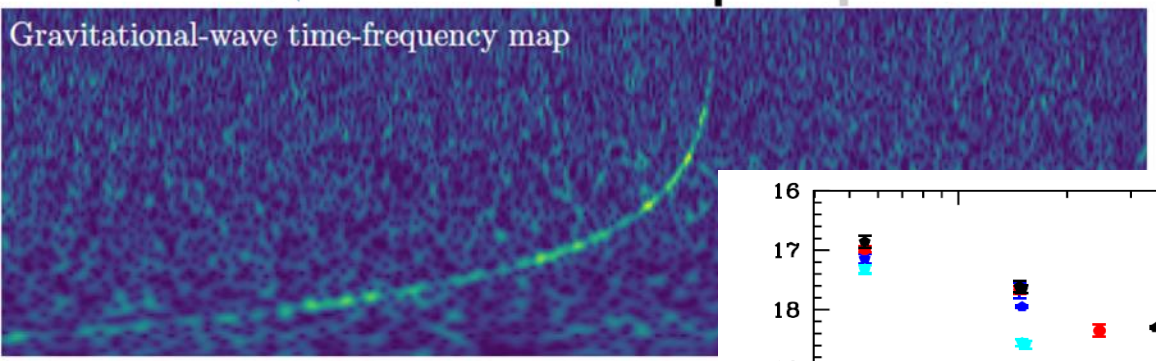
Shedding light on the early Universe with GRBs

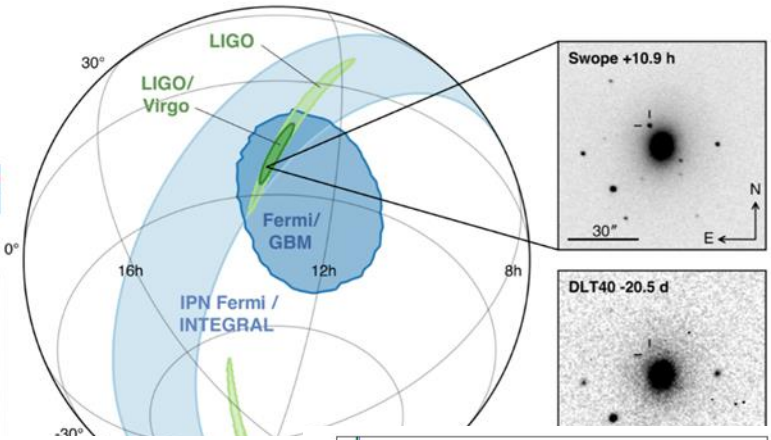


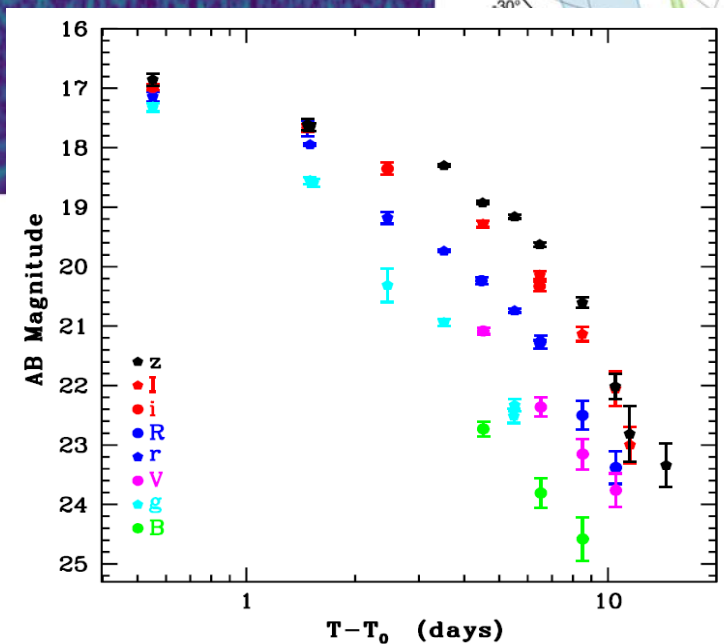
Short GRBs and multi-messenger astrophysics

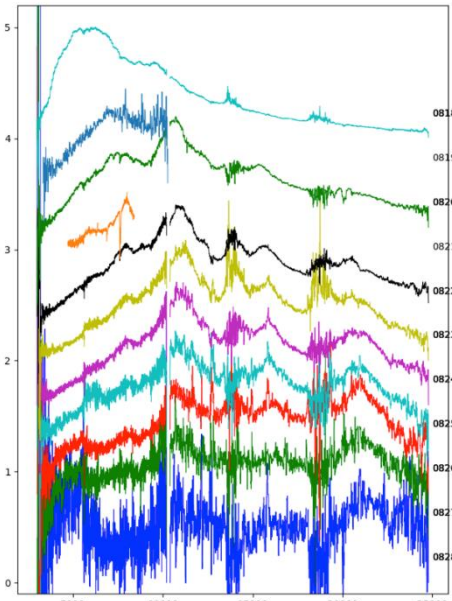
GW170817 + SHORT GRB 170817A + KN AT2017GFO (~40 Mpc):











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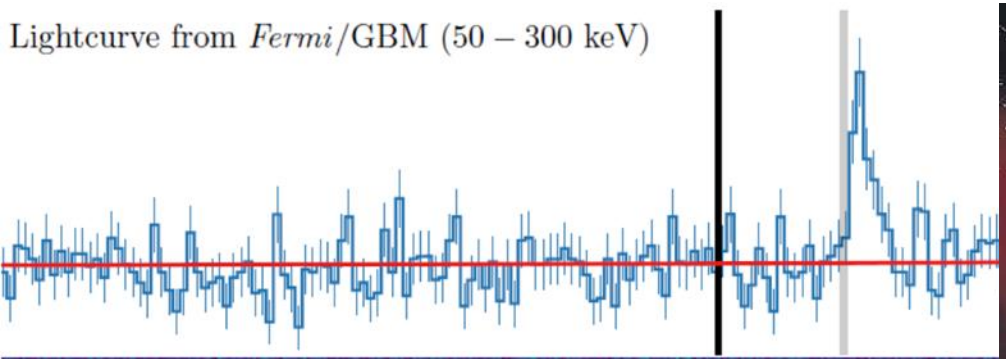
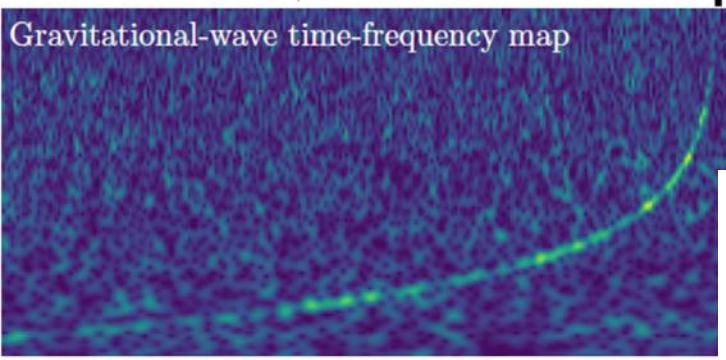
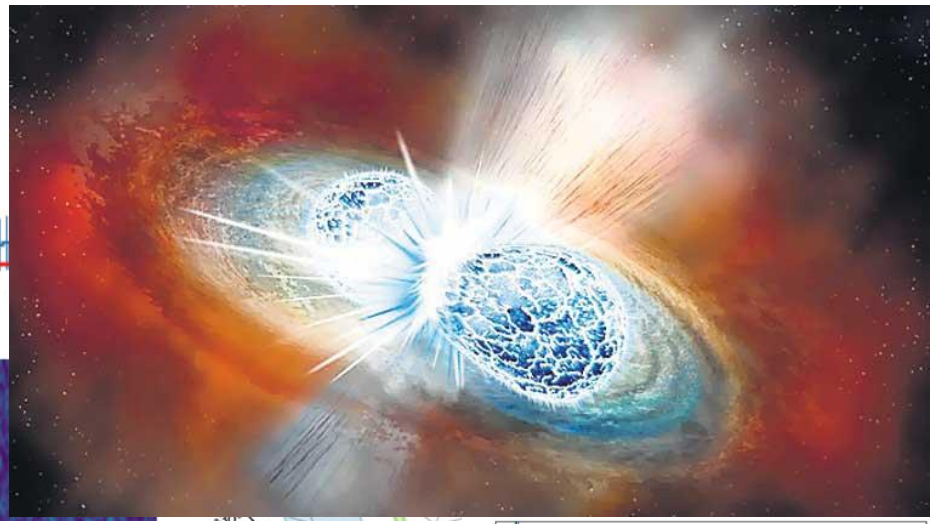
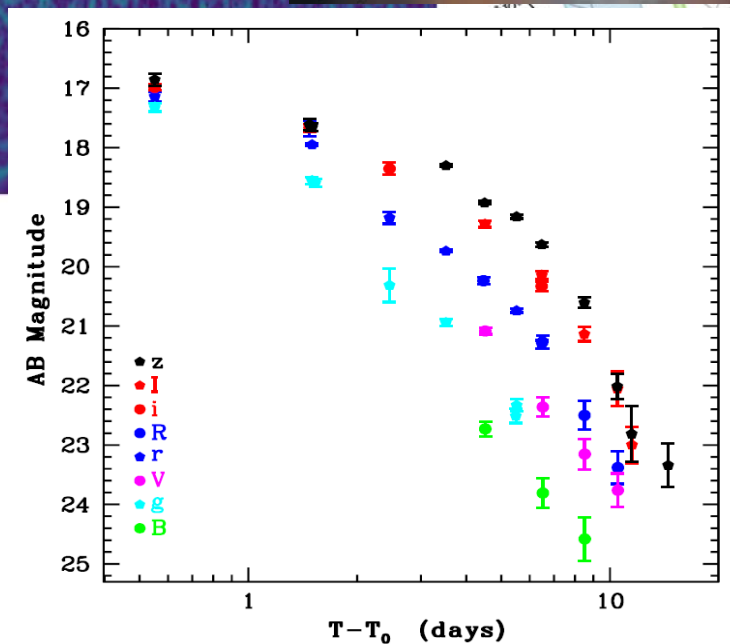
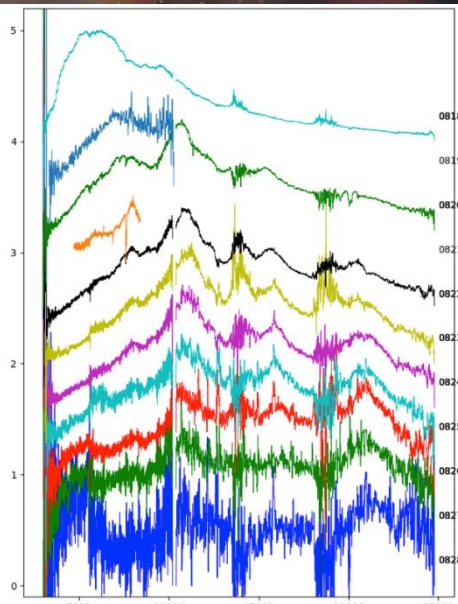






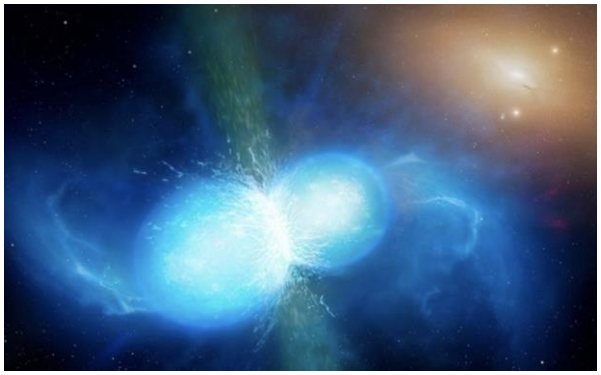




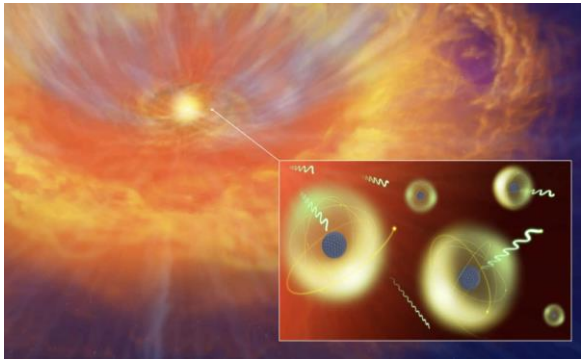
GRB: a key phenomenon for multi-messenger astrophysics (and cosmology)

GW170817 + SHORT GRB 170817A + KN AT2017GFO

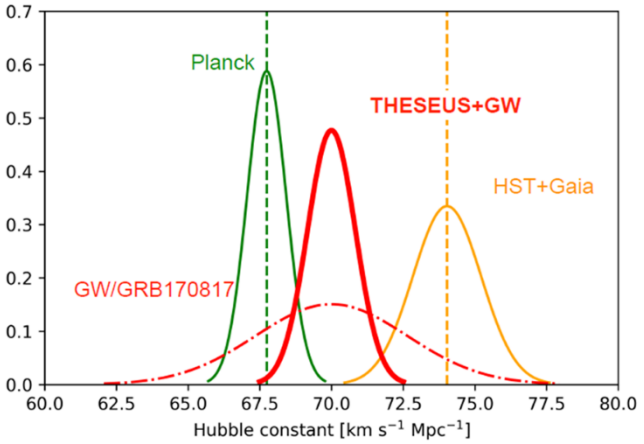
Relativistic jet formation, equation of state, fundamental physics



Cosmic sites of r-process nucleosynthesis



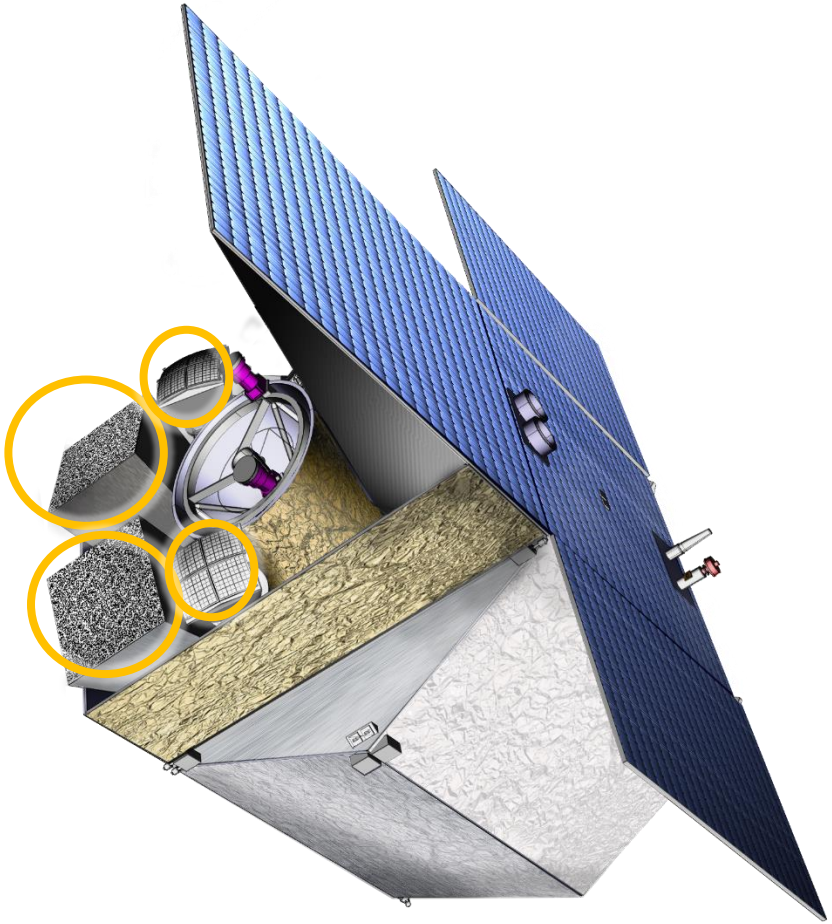
New independent route to measure cosmological parameters



THESEUS Mission Concept

THIS BREAKTHROUGH WILL BE ACHIEVED BY A MISSION CONCEPT OVERCOMING MAIN LIMITATIONS OF CURRENT FACILITIES

Set of innovative wide-field monitors with **unprecedented combination of broad energy range from gamma-rays down to soft X-rays, FOV and localization accuracy**



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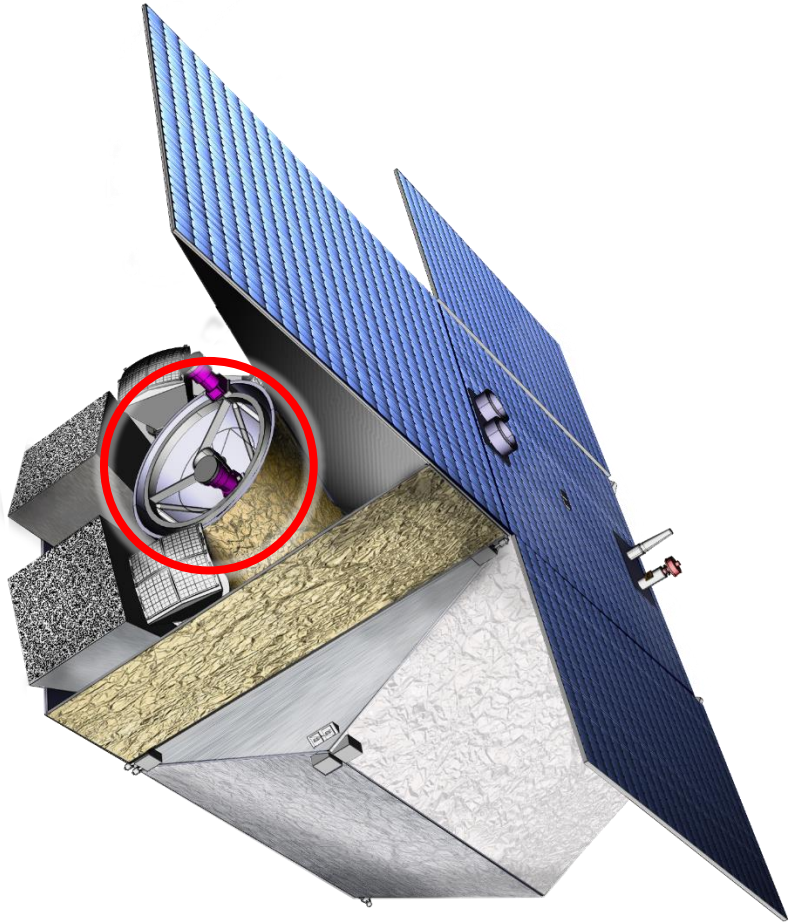
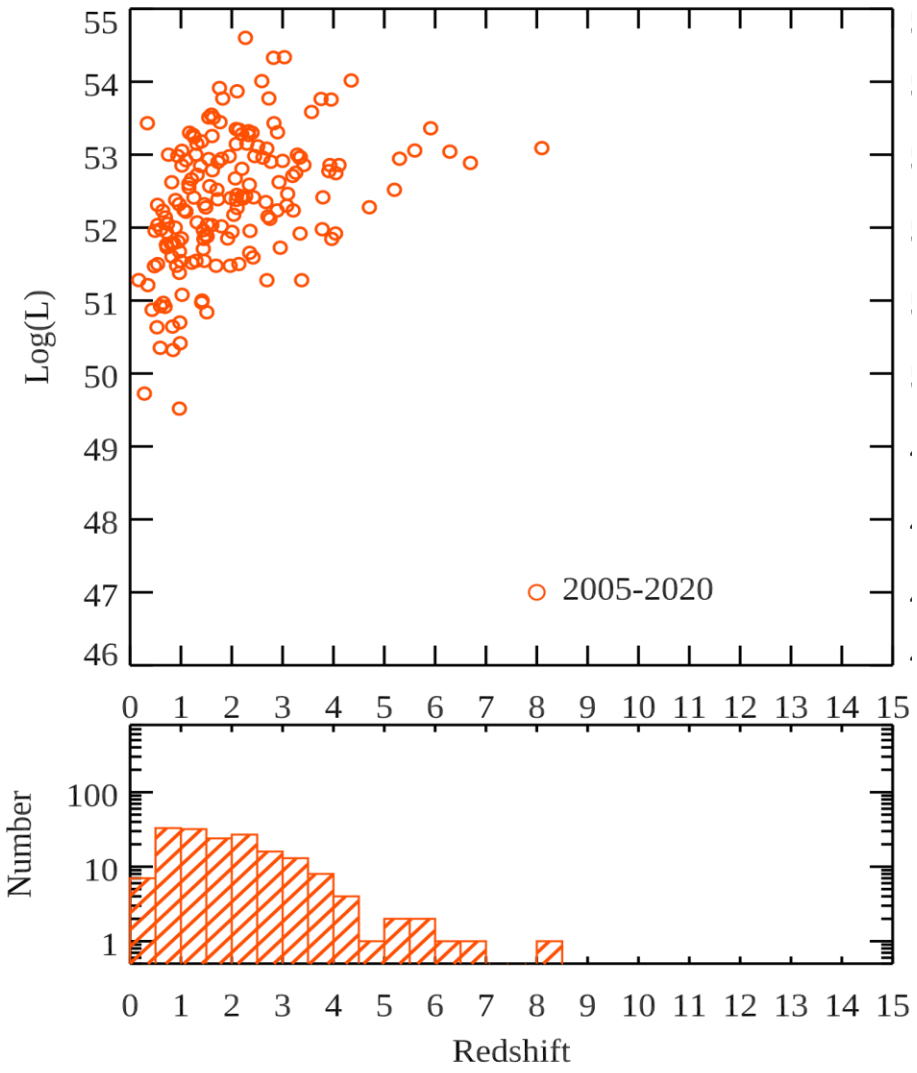
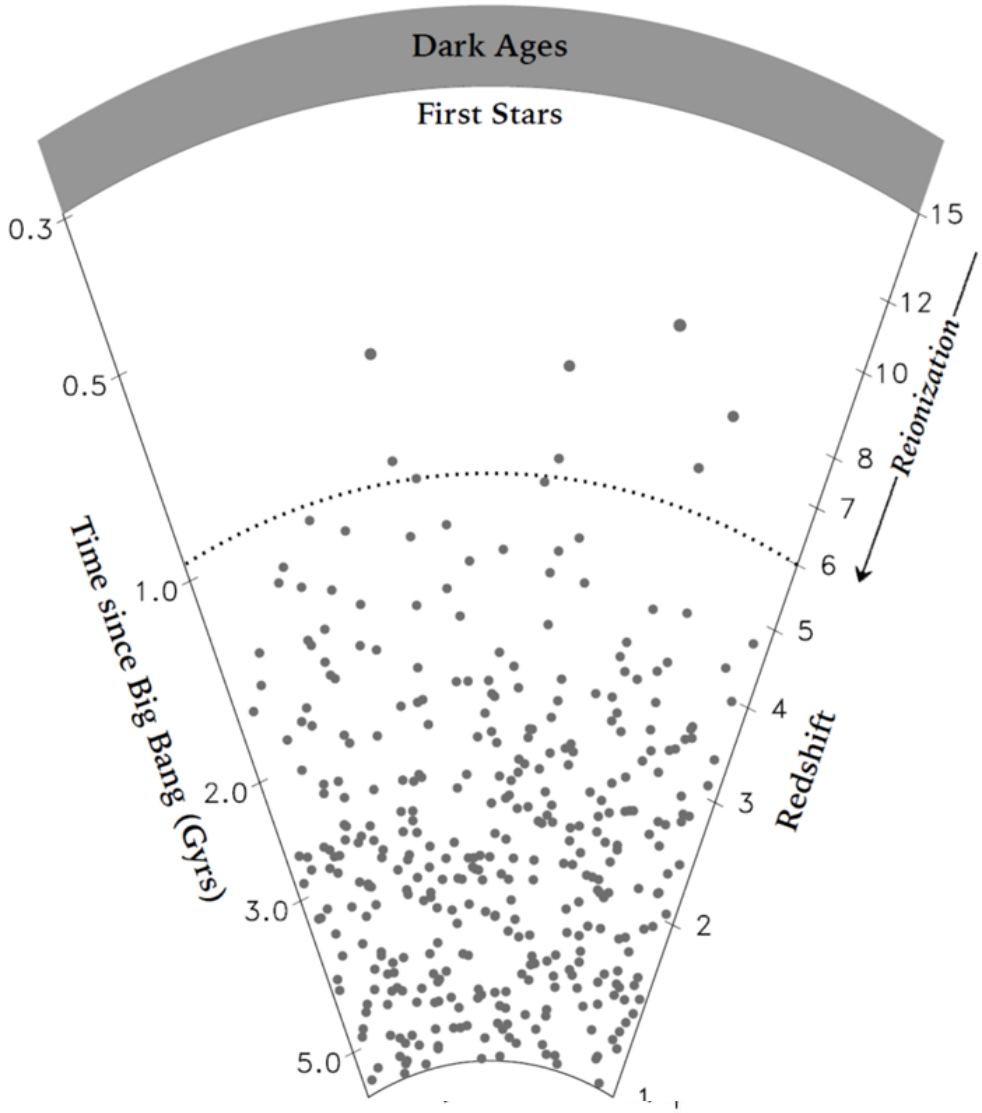
On-board **autonomous fast follow-up in optical/NIR**, arcsec location and **redshift measurement** of detected GRB/transients



Expected performances: early Universe





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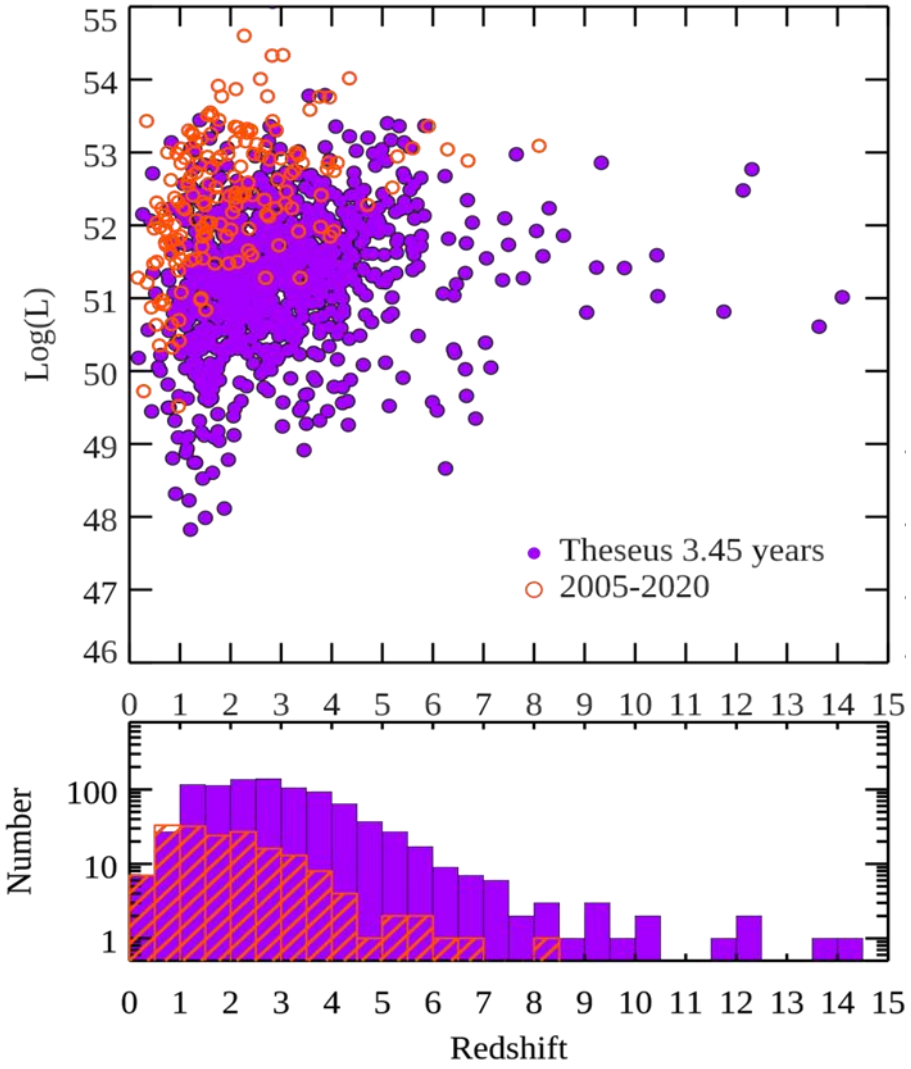
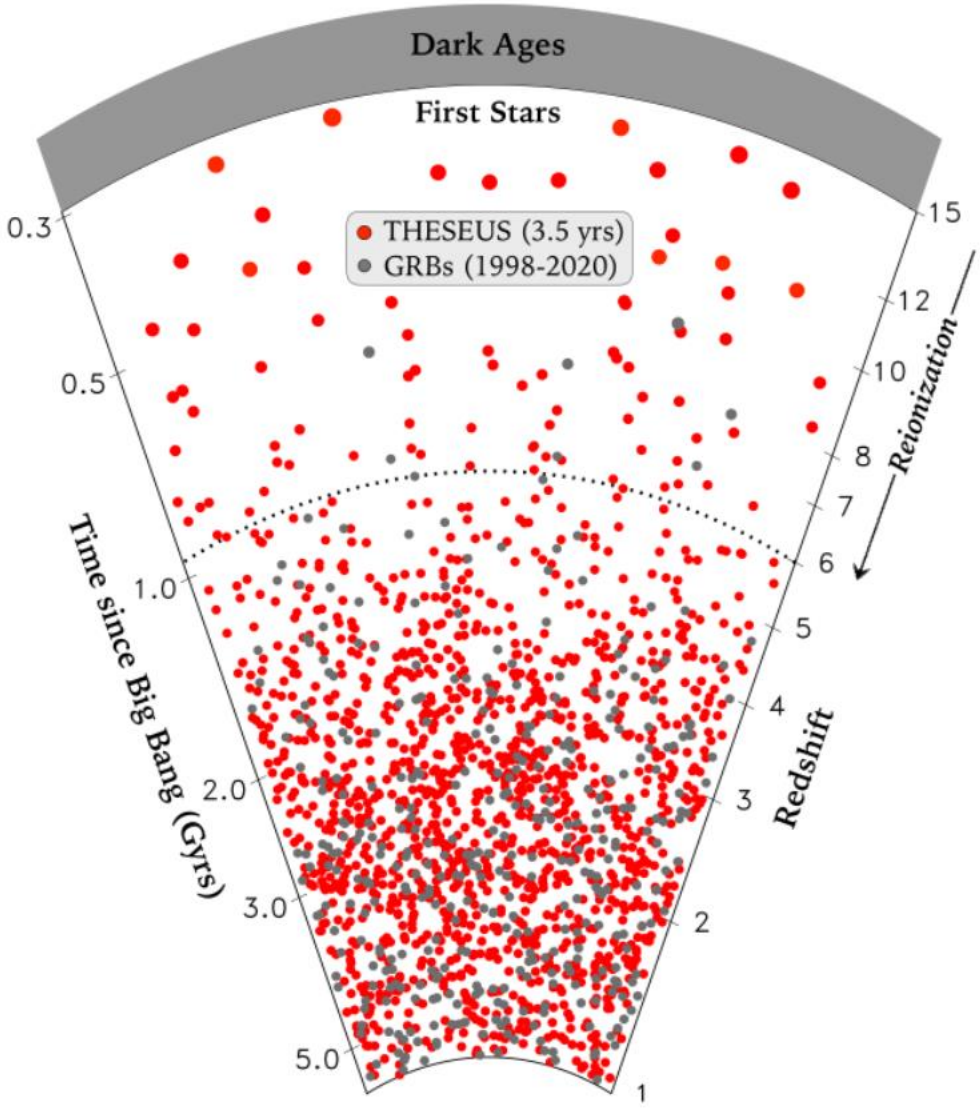
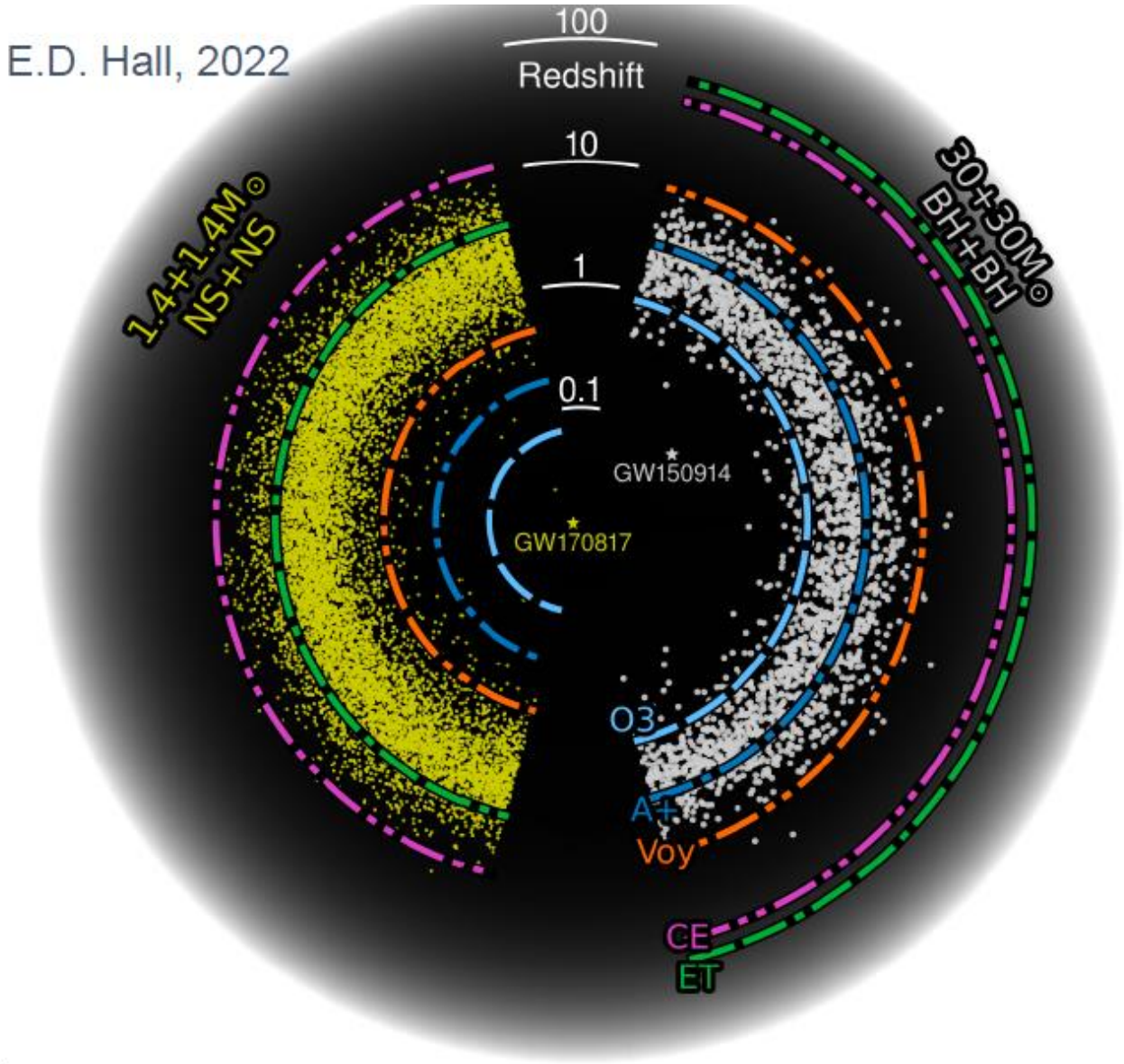




Multi-messenger science with THESEUS

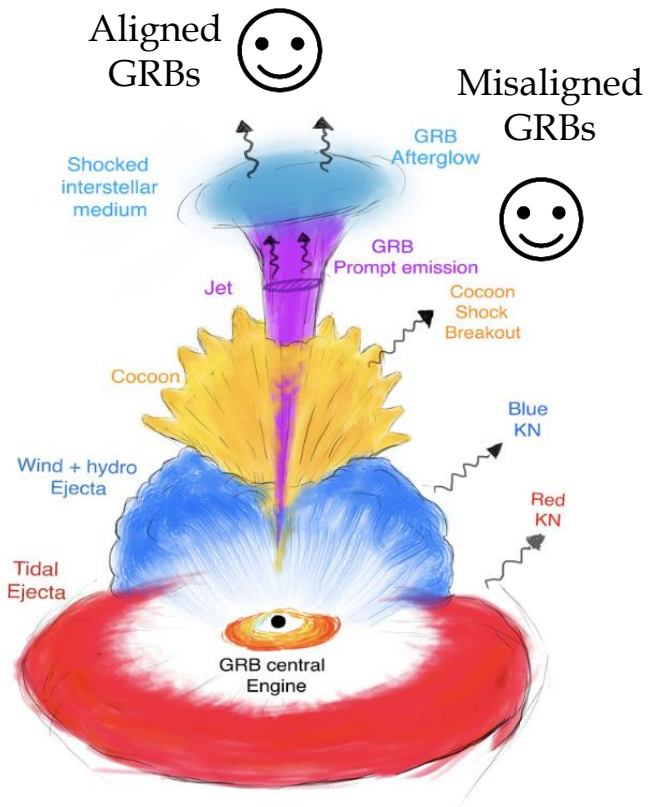
M7 timeline: great synergy with 3G GW detectors (ET, CE)



Multi-messenger science with THESEUS

INDEPENDENT DETECTION & CHARACTERISATION OF THE MULTI-MESSENGER SOURCES

Lessons from GRB170817A



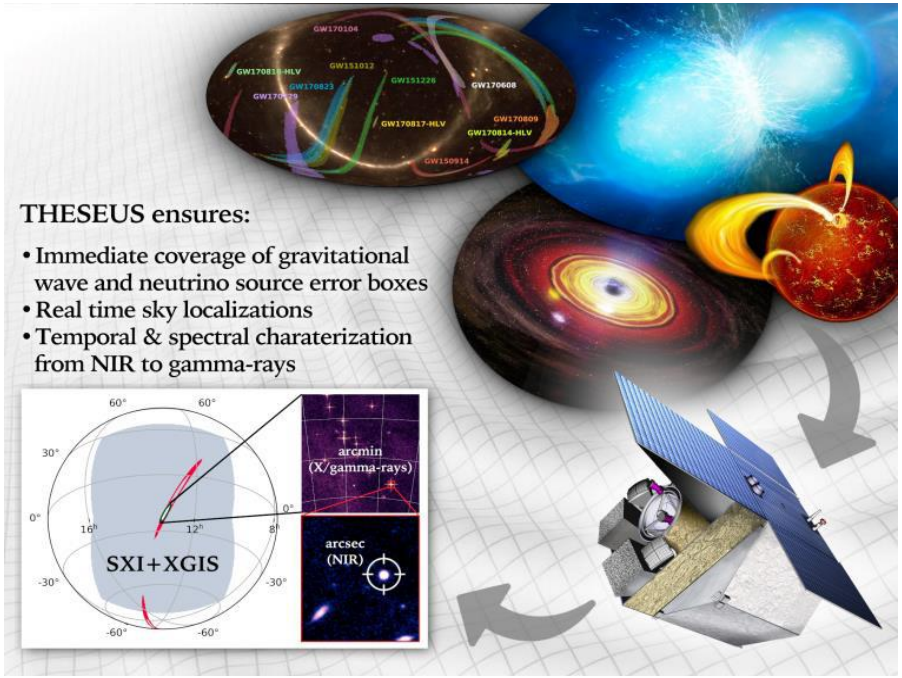
THESEUS + ET in 3 years:

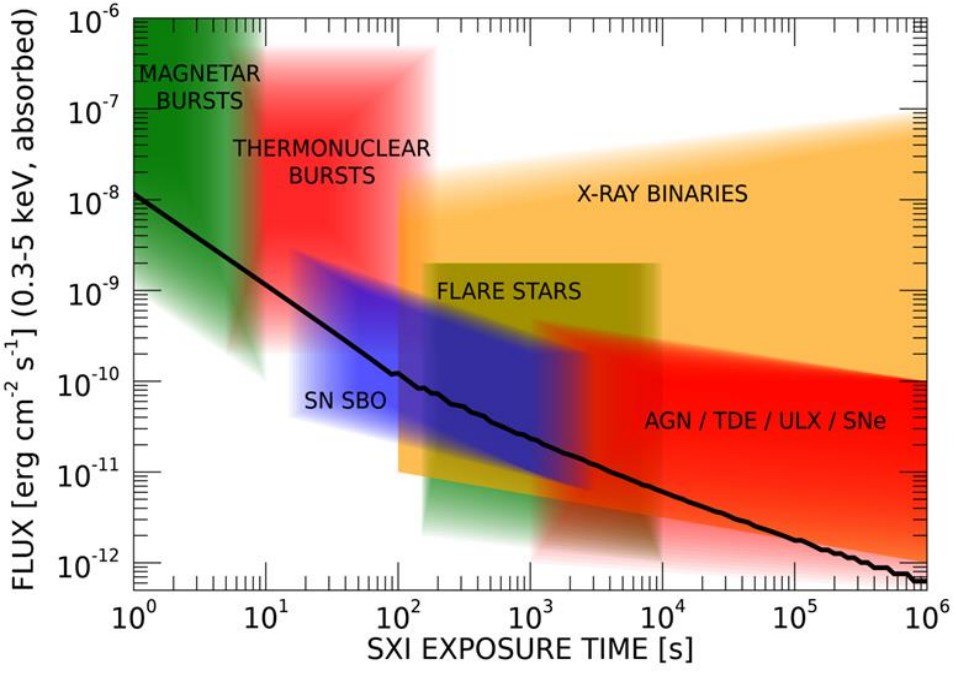
- ~70 aligned+misaligned short GRB
- additional long GRBs from mergers and possible GW-X-ray transients

Higher redshift events – X/γ is likely only route to EM detection: larger statistical studies including source evolution, probe of dark energy and test modified gravity on cosmological scales

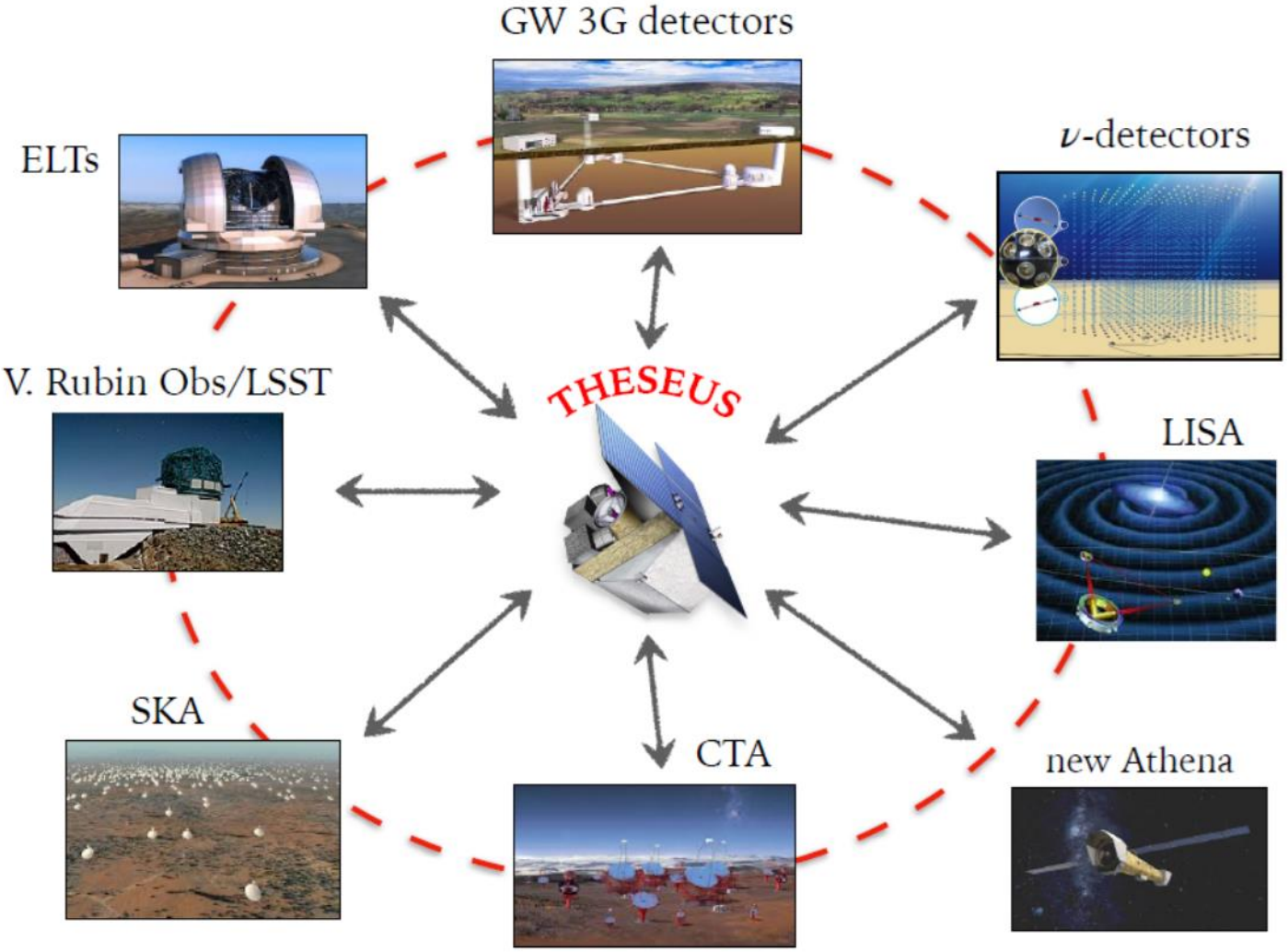
Exploring the transient sky

- **GRBs extreme emission physics**, central engine, sub-classes & progenitors, **cosmological parameters & fundamental physics**
- Study of **many classes of X-ray sources** by exploiting the **simultaneous broad band X-ray and NIR observations**
- Provide a **flexible follow-up observatory** for fast transient events with **multi-wavelength ToO capabilities** and **guest-observer programmes**



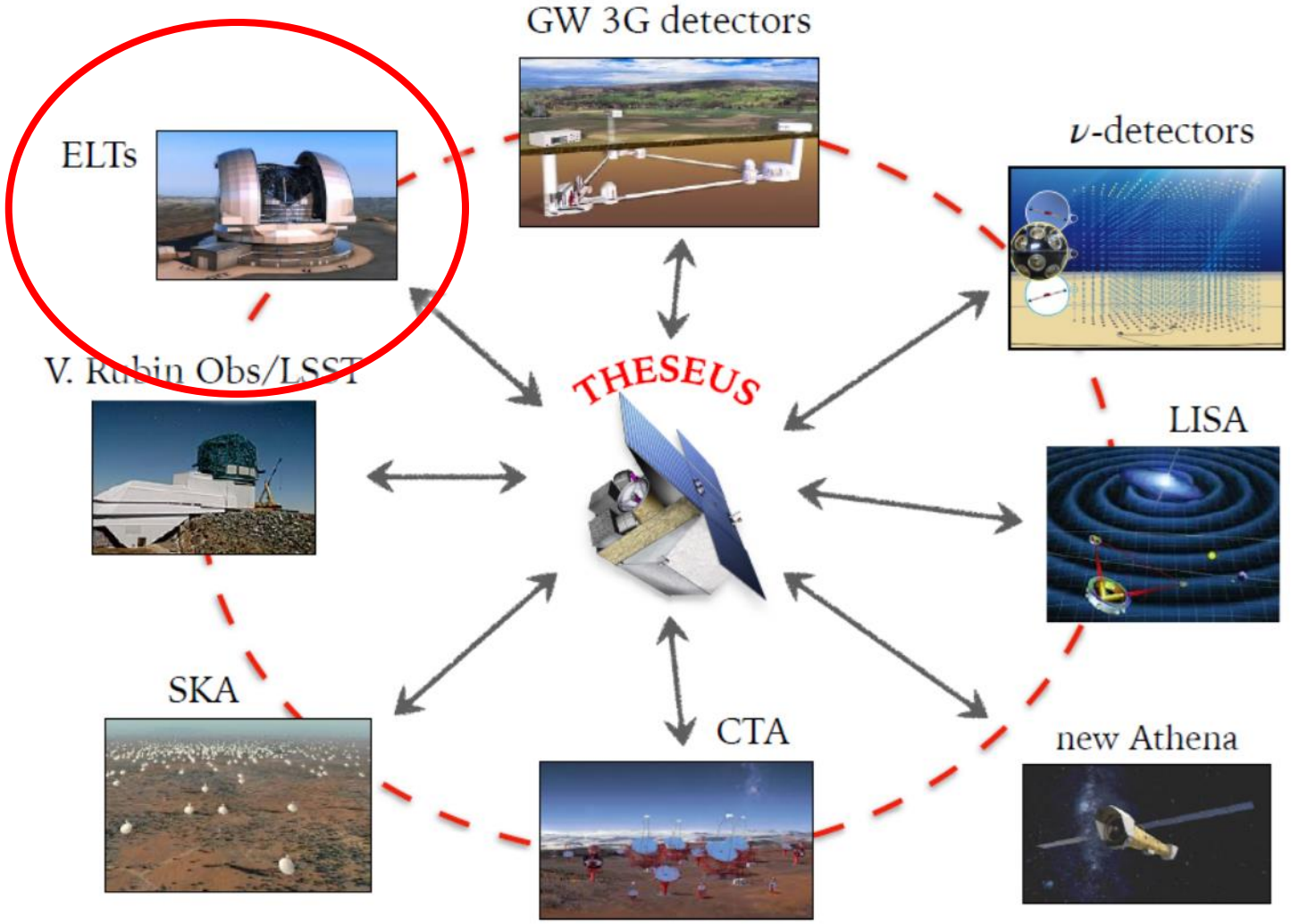


THESEUS: crucial synergies in the late '30s



The «**M7**» **timeline** will allow to **widely broaden the mission scientific impact** by taking advantage of the **perfectly matched synergies** with major facilities coming fully operative in the 2030s **(e.g., 3G GW detectors)**

THESEUS: crucial synergies with ELT



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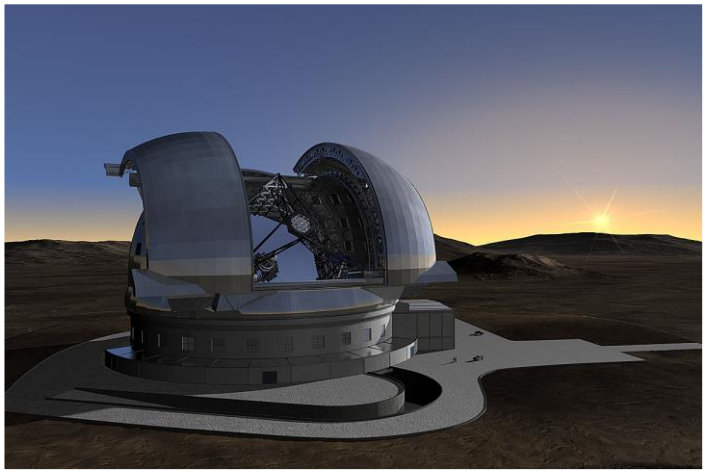
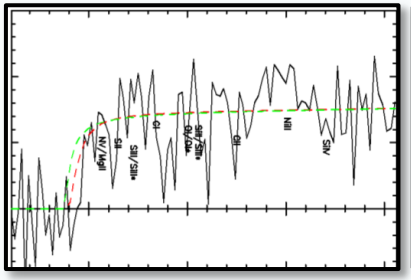
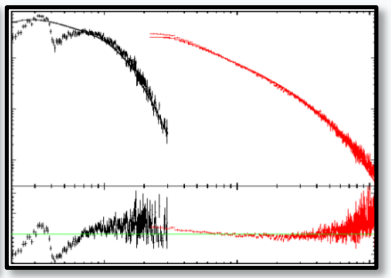
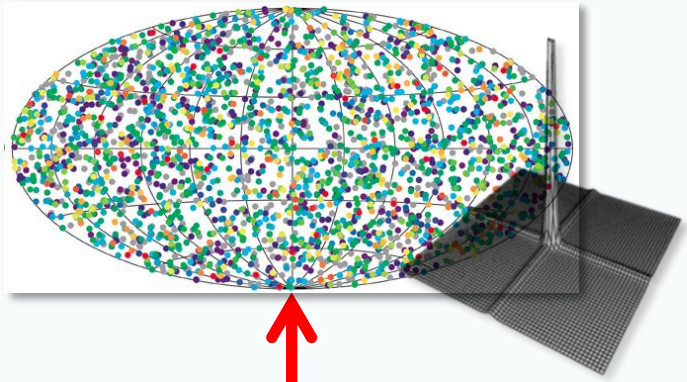
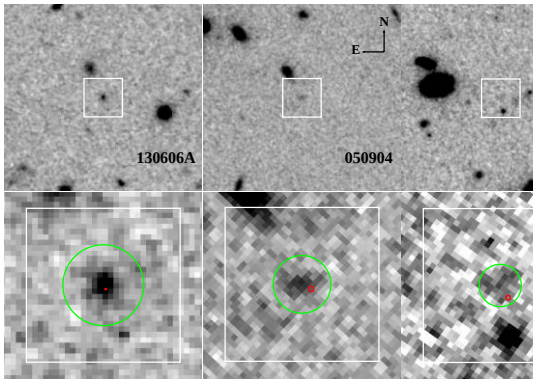


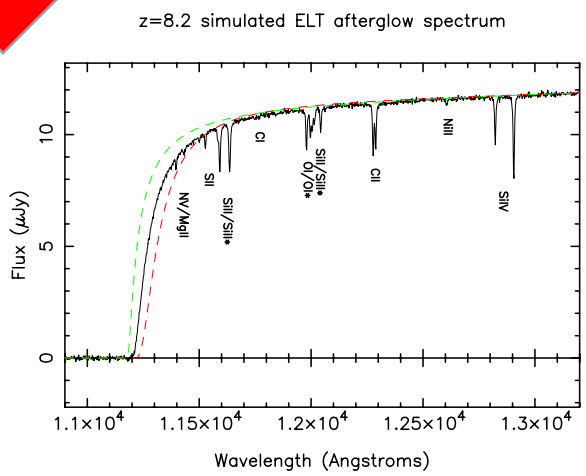
GRB accurate localization and NIR, X-ray, Gamma-ray characterization, redshift



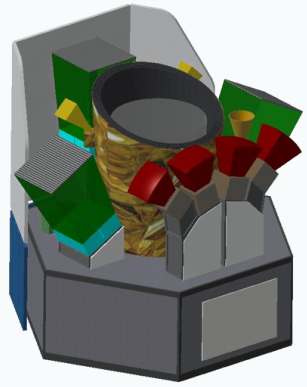








theseus
TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR

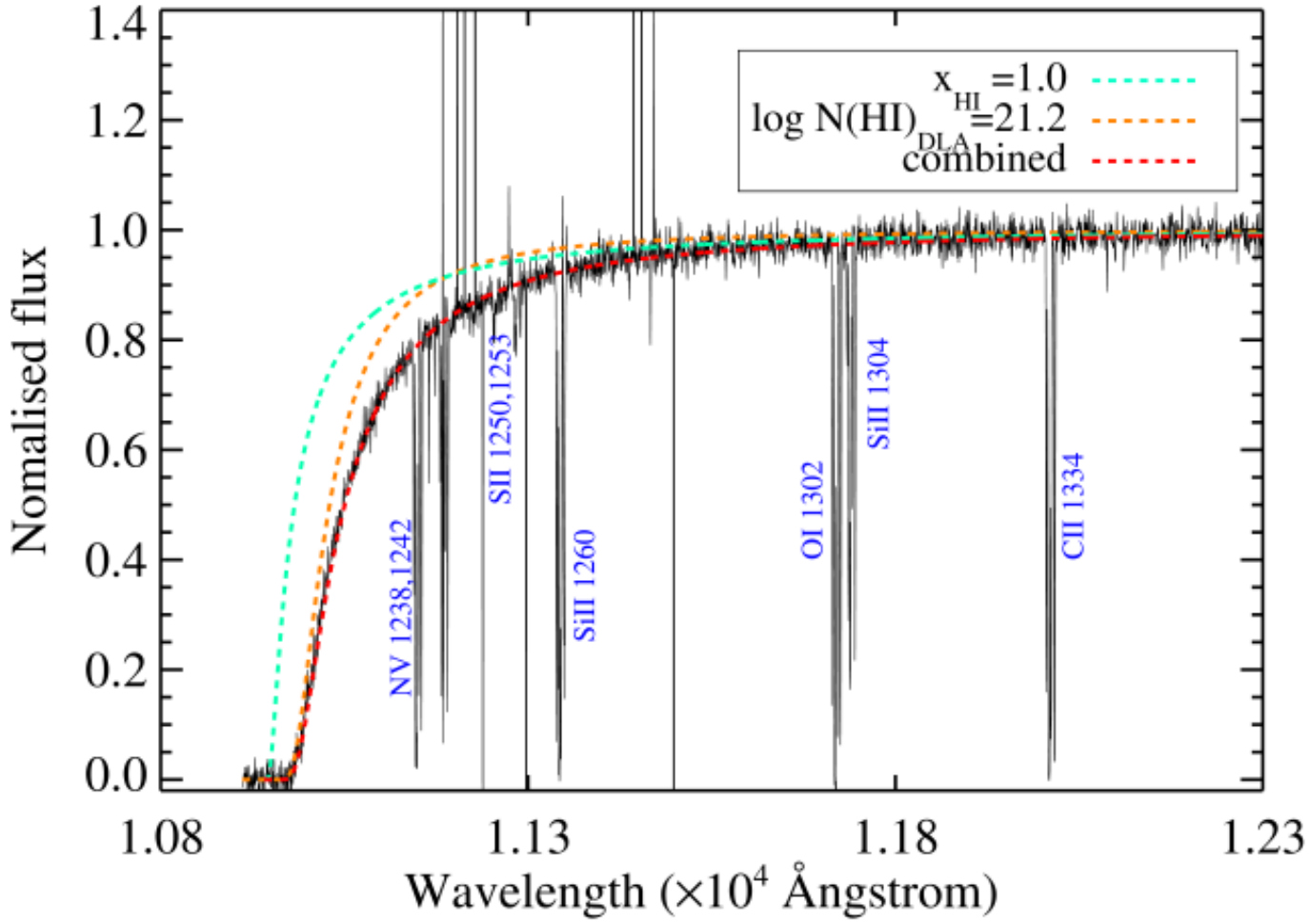


Star formation history, primordial galaxies

Cosmic chemical evolution, Pop III

Neutral fraction of IGM, ionizing radiation escape fraction,

THESEUS SYNERGIES



Simulated ELT 30-minute spectrum of a z=8.0 GRB afterglow with J(AB)=20 (typical after ~0.5 day). The S/N provides exquisite abundance determinations from metal absorption lines (in this example, 1% solar metallicity), while fitting the Ly-alpha damping wing simultaneously fixes the IGM neutral fraction and the host HI column density, as illustrated by the two overlaid models, a pure 100% neutral IGM (green,) and a log(N_{HI}/cm^{-2})=21.2 host absorption with a fully ionized IGM (orange). A well-fitting combined model is shown in red.

THESEUS and ELT/SHARP

Why SHARP - Rationale and Main Requirements

SHARP

THE DISTANT UNIVERSE

Understanding and reconstructing how baryonic matter assembled at early times to form the first stars, galaxies and structures, how these evolved over cosmic time.

- Common core scientific objectives on early Universe and likely same timeline
- Synergy will greatly enhance scientific return of both, with THESEUS identifying and localizing faintest high-z galaxies and SHARP allowing faintest ELT reachable fluxes with wavelength range up to 2.45 μm
- Synergy also on multi-messenger science (e.g., pushing KN study at the limit)

In summary

- GRBs are a key phenomenon for **cosmology**, **multi-messenger astrophysics** and **fundamental physics**
- Next generation GRB missions, like **THESEUS**, developed by a large European collaboration, studied (M5 Phase A) and re-selected (M7 Phase-0) by ESA **will fully exploit these potentialities and also provide unprecedented clues to GRB physics and a substantial contribution to time-domain astronomy**
- The "M7" timeline will allow an **unprecedented great synergy with future very large observing fa**cilities, with ELT being a key one which **would be importantly enhanced by SHARP**
- Because of the wide scope of its science goals, the great synergies and timeline and a **guest-observer programme**, **THESEUS scientific return will involve an unprecedented wide scientific community.**

- **THESEUS: ESA/M5 Phase A study and selected for M7 Phase 0 (->2037)**

SPIE articles on instruments, Adv.Sp.Res. & Exp.Astr. articles on science

http://www.isdc.unige.ch/theseus/