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AHEAD2020

The EU infrastructure for High energy astrophysics

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On behalf of the AHEAD2020 Executive Committee: L. Piro (AHEAD2020 Coordinator), M.Audard, P.Bastia, G.Betancourt, M.Branchesi, V.Burwitz, R.den Hartog, J.W. Den Herder, F. Fiore, M.Giusti, L.Hanlon, G.Hemming, S.Katsanevas, I.Georgantopoulos, D.Martella, L.Natalucci, P. O'Brien, F. Pajot, M.Rossi, S.Sciortino, J.M.Torrejon

EGO MMAW Meeting, 10-12 October 2022

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The AHEAD kickoff meeting in 2015

AHEAD2020 in a nutshell

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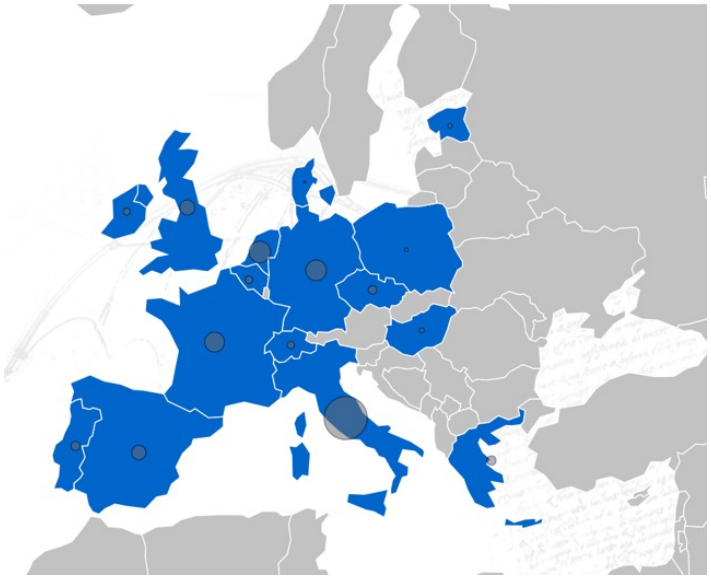
- AHEAD2020 (Integrated Activities for High Energy Astrophysics Domain) is the research infrastructure for High Energy Astrophysics selected as advanced community in the EU Horizon 2020 program.
- AHEAD2020 builds on our previous program, funded in H2020 as starting community, that allowed us to qualify now as advanced community. Its main goal is to improve the level of integration reached by the previous AHEAD program, while broadening its impact to include the new multi-messenger science and the European GW community.
- Started on 2 March 2020; scheduled end was 1 March 2024 (foreseen duration: 4 years); later extended for Covid mitigation to 1 December 2024
- Overall budget: 9.98 M€
- The Consortium is coordinated by INAF (coordinator: L.Piro) and includes 38 European institutions, including 3 SMEs



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The AHEAD2020 goals

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- Integrate and coordinate national activities in high-energy astrophysics
- Push the limits of current technology and strengthen the infrastructure to maximise the scientific return of **new future high energy and multimessenger facilities:** *Athena, satellites for the transient and multimessenger Universe (nanosat, Einstein Probe,Theseus,…), neutrino and GW observatories (KM3NET, LIGO/VIRGO,Einstein Telescope).*
- Give access, free of cost to a network of ground-based test facilities for H/W development, calibration and testing.
- Make accessible and usable multimessenger data, develop advanced data analysis and theory tools
- Promote HE and multimessenger astrophysics at various level
- Prepare the community to the scientific exploitation of the new facilities under development in Europe for HE and multimessenger, by training the next generation of researchers.

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Management scheme

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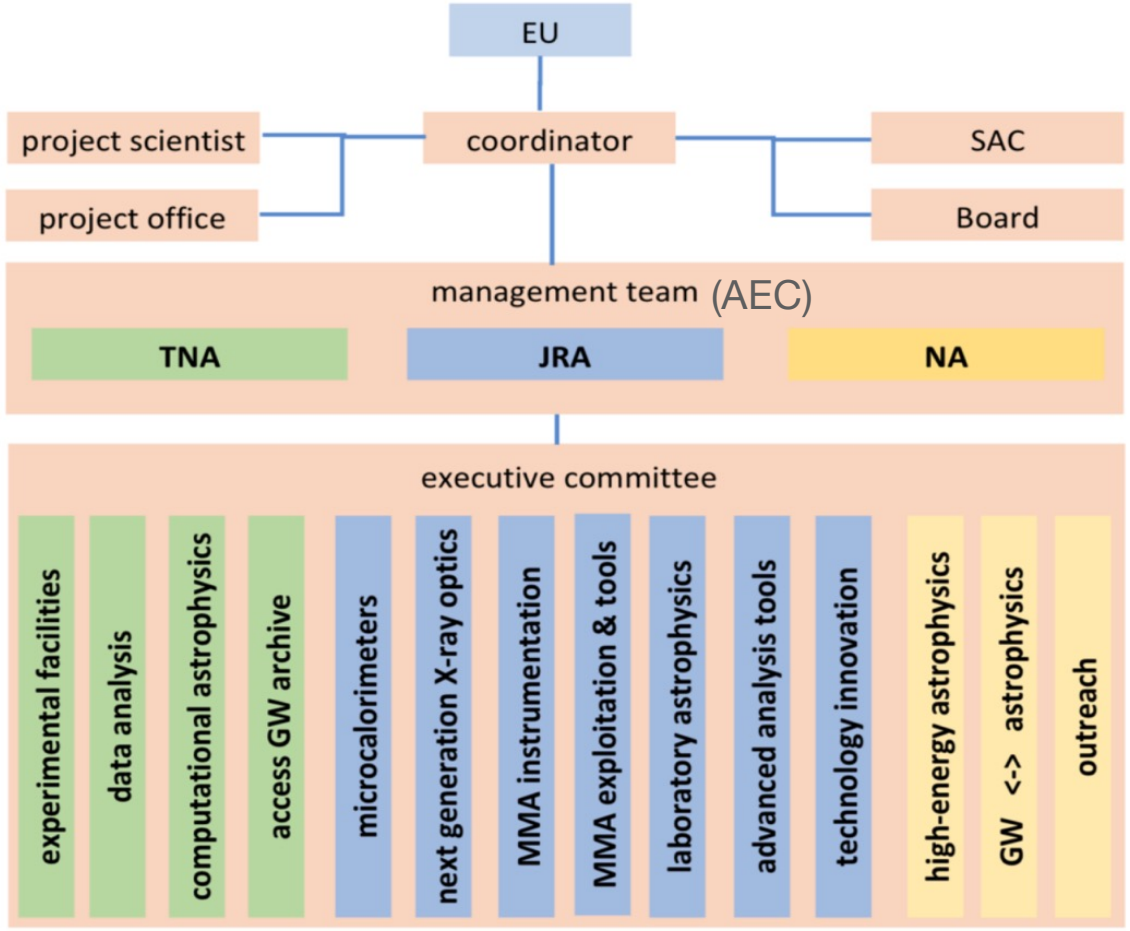

Management meetings

- AEC telecons (monthly)
- JRA: Coordinator, Project Office and leaders of JRA workpackages (bi-monthly)
- NA-TNA-VA: Coordinator, Project Office and leaders of NA,TNA and VA workpackages (bi-monthly)

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Workpackages

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WP number/description	WP leader [Beneficiary]	PM	# Tasks	#Partners
WP1- Management	Luigi Piro (coordinator) [INAF/IAPS]	121	6	1
WP2- General Networking for High Energy Astrophysics	José Miguel Torrejon [Univ.of Alicante]	18.85	4	8
WP3- Networking activities for High Energy Astrophysics	Stavros Katsanevas [EGO]	13.5	6	4
WP4- Public Outreach	Ioannis Georgantopoulos [NOA/Athens]	56.7	7	7
WP5-Access to experimental facilities	Salvatore Sciortino [INAF/OAPA]	32.27	1	5
WP6- Access to data analysis	Paul 'O Brien [ULEIC]	20.6	1	8
WP7- Computational Astrophysics	Marc Audard [UNIGENEVE]	11	1	7
WP8- Access to Gravitational Wave Science Archive and Tools	Gary Hemming [EGO]	12	3	1
WP9- Tecnology and techniques for Microcalorimeters	Roland Den Hartog [NWO-I/SRON]	209.7	4	9
WP10- Optics for next generation X-ray Observatories	Vadim Burwitz [MPE]	76	4	4
WP11- Space Experiments for HE Astrophysics & Multimessenger Astronomy	Lorraine Hanlon [UCD]	109.6	4	14
WP12- Multimessenger Astronomy Exploitation and Tools	Marica Branchesi [GSSI]	244.5	7	11
WP13- Laboratory Astrophysics	Francois Pajot [CNRS/IRAP]	73.2	2	7
WP14- Advanced Tools for Data Analysis	Fabrizio Fiore [INAF/OAT]	168	10	8
WP15- Innovation	Paolo Bastia [TAS-ITALIA]	138	6	9

3 Networking Activities (NA)

3 TransNational Access (TA)

1 Virtual Access (VA)

7 Joint Research Activities (NA)

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Beneficiaries vs WPs

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Institute	WPs	Institute	WPs
INAF	1,2,4,5,6,7,9,10,11,12,13,14,15	CVUT	2, 10
SRON	3,6,9,12,13,14,15	NCAC	6,7
MPG	2,4,10,11,12,13	ULEIDEN	7
NOA	4,6,14	PTB	9
ULEIC	2,4,6,10,11,12,14	UNIGE	9,15
UA	2	EKUT	11,13
EGO	3,4,7,8,12,15	LMU MUENCHEN	7
INFN	3,11,12,15	C2TN	15
CNRS	3,4,11,12,13	UvA	14
GSSI	12,15	SWHARD	9,13
UNIGENEVE	2,6,7,9,11,	UMAINZ	11
CSIC	2,4,9,14	UTARTU	14
CEA	6,9,11,12,14	LIP	11
CNR	5,13	DTU	11
THALES	15	MASARYK U.	2,11
NUID UCD	2,11	UBATH	7,12
ULIEGE	5	DESY	12
UNIFE	2,5,6,7,11	KAON	15
UNIPA	9	COSINE	5

No. Beneficiaries with
1WP: 15
2WP: 10
≥4 WP: 11

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Networking activities (1/2)

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Networking activities in AHEAD2020 deal with the following broad categories:

- **AHEAD2020 Visitor Program (WP2)**
- **Organisation of meetings and schools (WP2,3)**
- **Public Outreach (WP4)**

The AHEAD Geant4 School (2016)

AHEAD workshop "The Power of X-ray Spectroscopy, Warsaw (2017)

A targeted activity is concerning the **Networking activities for the synergies between the Gravitational Wave and High Energy Astrophysics community** (WP3).

Topics addressed are:

- Multimessenger Research
- Synergies with High Energy and Geoscience
- R&D concerning multi-messenger physics with application to next generation GW interferometers
- Low latency Triggers and Access to GW Data
- Definition of the enabling technologies and the key technical design elements of the next generation of large infrastructures (ET)

Projection of the AHEAD Video "The Hot and Energetic Universe" at Researcher's Night 2017 in Frascati

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Networking activities (2/2)

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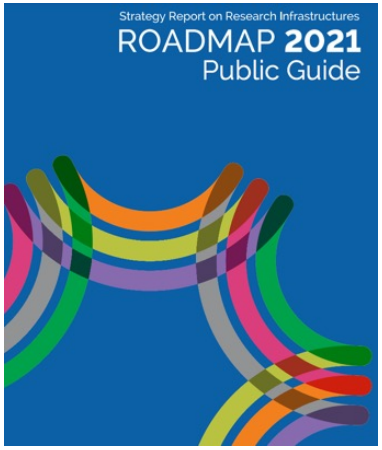
- NA1 is delivering a strong **Visiting programme**. ~40 visitor weeks/year are being granted.
- Organisation of topical meetings and broad community studies. Key results are:
  - support to the **Athena-Multimessenger study** (WP published)
  - support to the **Einstein Telescope studies** (in synergy with JRA4) and other investigations of future GW observatories (e.g. on the Moon)
- Outreach programme has already delivered excellent products that reach millions of people. Worth noting is the **AHEAD2020 video for planetaria**, that won an international prize, currently watched by > 1 million



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9 posters on Multi-messenger Physics (APPEC & AHEAD2020)

https://www.ego-gw.it/posters-multimessenger-astrophysics/

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- **SHARING AHEAD 2022** will see leading scientists and science communicators from the EU and around the world present the latest cutting-edge public outreach activities in astronomy and space science.
- The two days' conference will cover topics and case studies as diverse as the AHEAD 2020 consortium partners are. The Meeting aim is promoting the public engagement, press and social media activities in the field of astrophysics, willing to explore the role of the Research Institutions in the present-day communicating science development.
- At the same time, the Meeting provides an opportunity to strengthen the collaborations and establish new links among the members of AHEAD 2020 Consortium and the members of other EU funded Science Projects, as well as researchers working in the same and in related fields.
- **All participants, including media representatives, can register for the meeting at no cost.**
  The AHEAD communication team is also happy to arrange media interviews with conference delegates.

https://indico.ict.inaf.it/event/2111/

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AHEAD2020 JRAs, X-ray/γ-ray technology studies for future facilities

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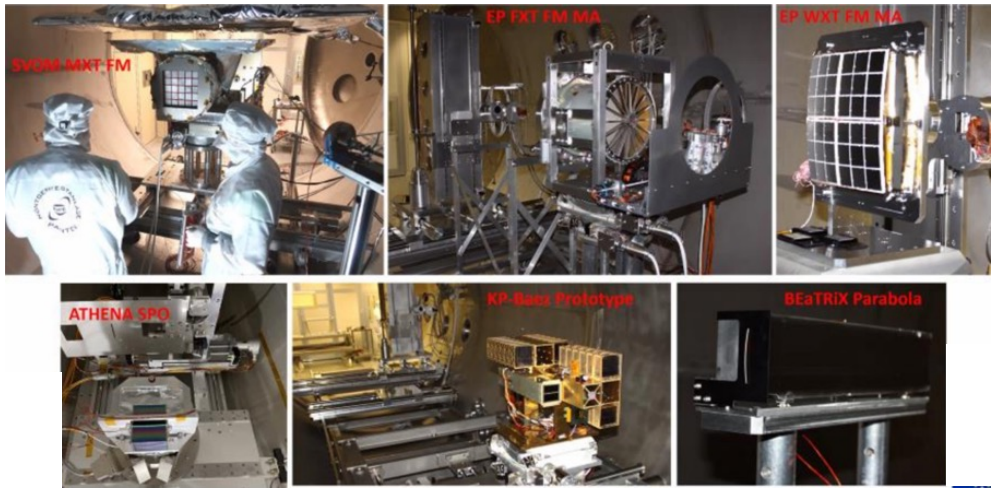
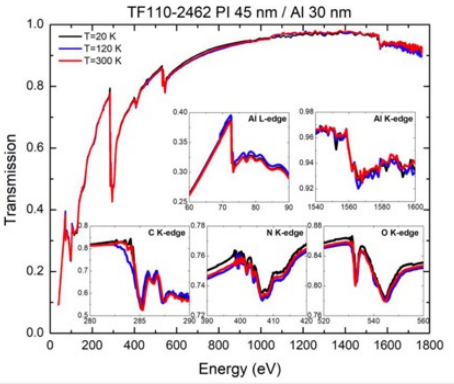
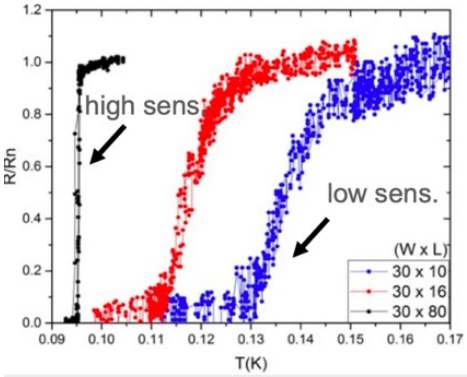
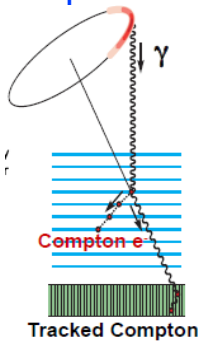


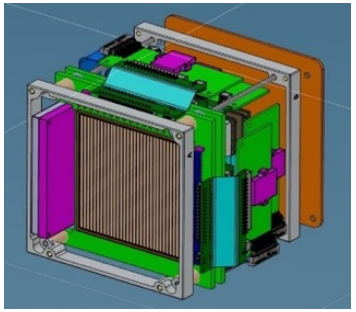
Optics testing/calibration of X-ray optics at Panter (MPE)

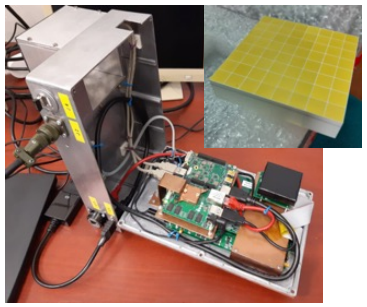


X-ray filters

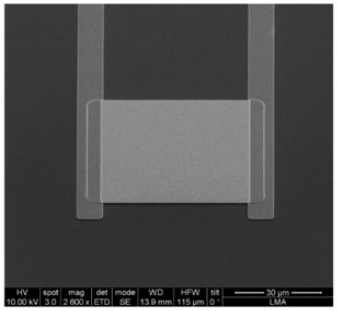


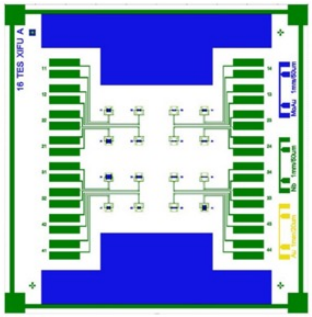






γ-ray instrumentation (Compton telescopes, GRB detectors)





Microcalorimeters/TES technology

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AHEAD2020 JRAs, building tools and new infrastructures

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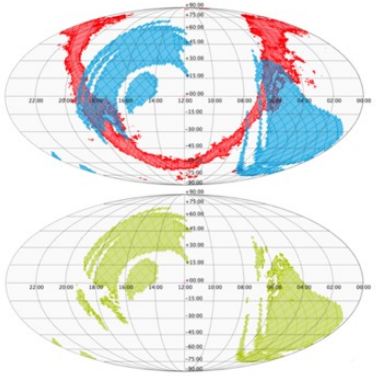
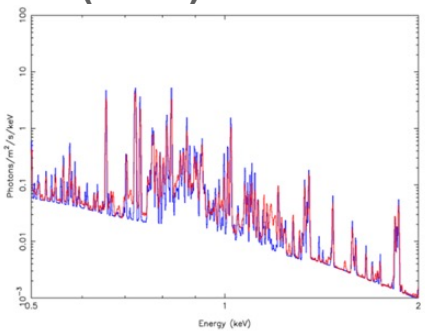
- **Tools development for joint EM/GW exploitation: low latency alerts, prompt localization, data analysis etc. (WP12)**
- **Investigate EM counterparts of neutrinos and HE gamma-rays (WP12)**
- **Ground infrastructures for GS/satellite communication (WP11)**
- **Atomic databases and models to fully exploit high resolution X-ray data from forthcoming missions like XRISM, Athena (WP13)**
- **Advanced tools developments for high resolution spectra fitting, background reduction, cross-calibrations among missions, machine learning & automatic source detection, extended source analysis, etc. (WP9, WP14)**
- **Environmental monitoring and sustainability: applications to seismicity, materials diagnostics, air pollution (WP15)**



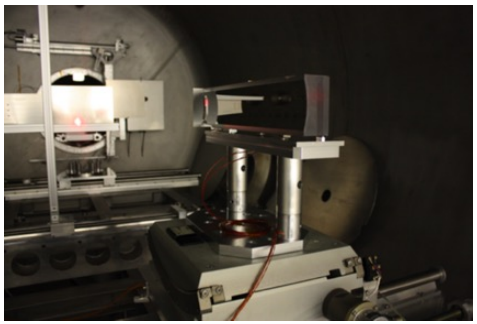
Advanced tools for MMA, alerts, multi-platform analysis

New ground infrastructures for satellite communications



Improved models & Databases for atomic physics

Cultural heritage, diagnostics & environmental monitoring



New mirror calibration facilities

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JRA4- MMA Observational and data analysis tools

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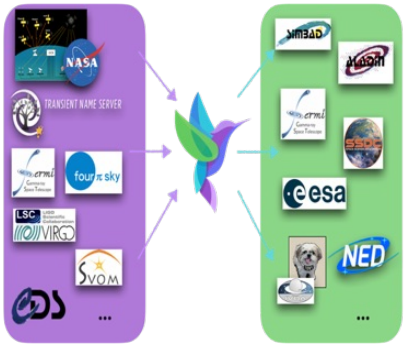
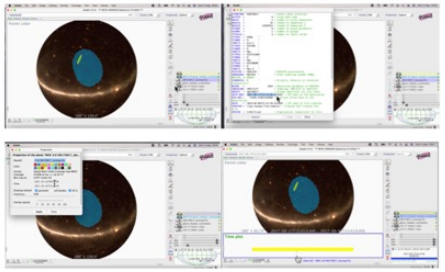
AFIS prototype: platform performing joint analysis of the prompt data detected by AGILE, FERMI, INTEGRAL and SWIFT, including Increasing statistical significance of sub-threshold events. The results of all AFIS facilities are visualised using a web GUI.

Astro-COLIBRI: a novel tool for real-time multi-messenger astrophysics

To evaluates alerts in real time, filter them by user-specified criteria, and provide an assessment of observing conditions of several observatories



Multi Order Coverage (MOC) maps (ESCAPE/AHEAD2020)
to plan multi-messenger observations, managing complex regions of the sky, such as GW sky-maps



- developed within the Virtual Observatory standards
- applied to GW and high-energy data
- under developing for ET

SPACE-TIME MOC (ST-MOC) to encode space and time simultaneously

- for both professional and amateur astronomers
- already regularly employed by burst advocates in several observatories (e.g. H.E.S.S., CTA/LST-1, SVOM, etc.)
- integration into the KM3NeT work in progress

P. Reichherzer et al 2021 ApJS 256 5

SOFTWARE entirely developed to meet the F.A.I.R. principles

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JRA4 - MMA data access, theory modelling and tools

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Gravitational Wave Open Science Center

Provides **open access GW data** from gravitational-wave observatories, along with access to tutorials and software tools

Main work:

- prepare data to be released and tools to access the data, documentation
- organize tutorial
- reviewed the GWOSC data accessibility in Europe

Modeling of relativistic jets and their afterglows

Development of **SCALEFIT**, a routine for fast afterglow modeling based on 2D relativistic hydrodynamic simulations

afterglow library

LSC LIGO Scientific Collaboration
VIRGO
Public Alerts User Guide

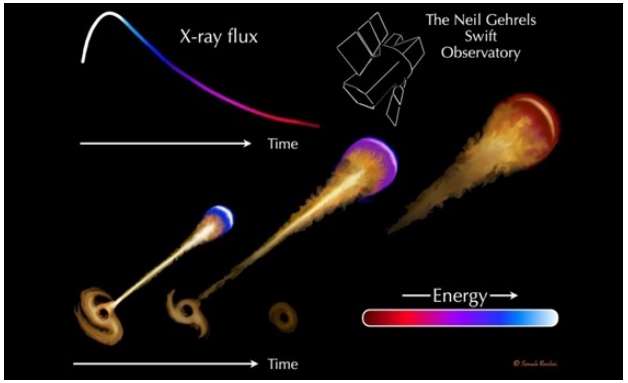
Primer on public alerts for astronomers from the LIGO and Virgo gravitational-wave

Notice Types

For each event, there are up to five kinds of GCN Notices:

An **Early Warning GCN Notice** may be issued for CBC events up to tens of seconds *before* merger. The candidate must have passed some automated data quality checks, but it may later be retracted after human vetting. There is no accompanying GCN Circular at this stage. Early Warning alerts are an experimental feature in O3. Early Warning alerts are only possible for exceptionally loud and nearby CBC events, and are expected to be rare.

GW alerts: *developing data analysis able to produce early-warning triggers for O4*



How GRB jets cool

First evidence of adiabatic cooling of particles in the relativistic outflows of GRBs during the steep decay

Ronchini et al. 2021, Nature Communication

Press-release July 6 2021

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JRA4 - Upcoming/future detector studies

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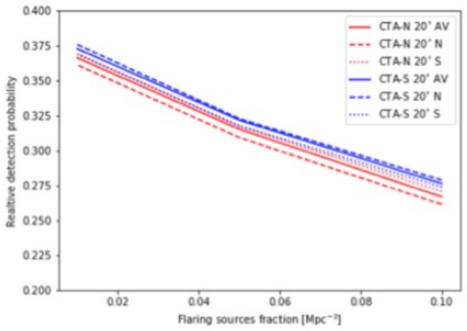
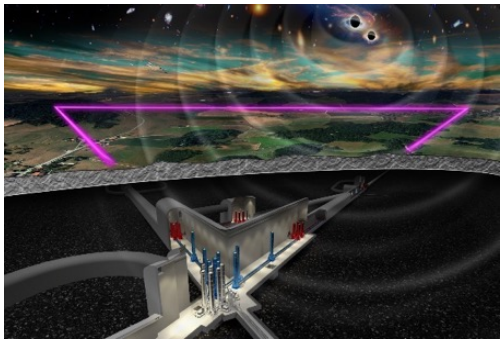
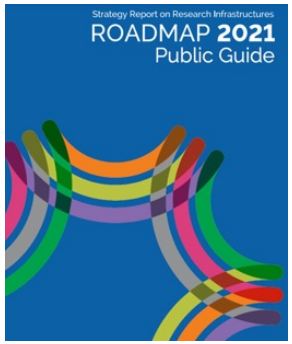
Gamma-ray instruments' strategies to follow-up multi-messenger alerts
Simulation to study **CTA** response to neutrino alerts from generic and steady sources



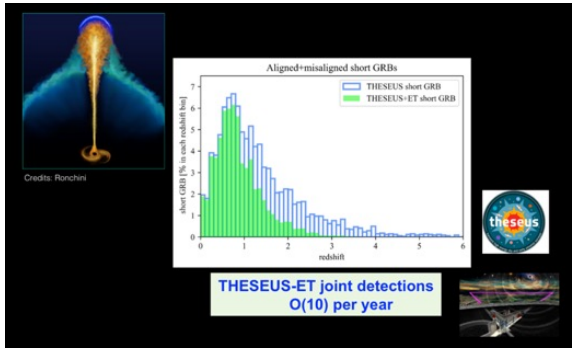
Detection probability for 30 min observation



ET in the ESFRI



Studies of ET/THESEUS



Ciolfi et al. 2021, Experimental Astronomy
Rosati et al. 2021, Experimental Astronomy

Gravitational-wave International Committee roadmap including multi-messenger perspectives

Bailes et al. 2021, Nature Physics Review, 3, 5, 344

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Access opportunities (1 of 2)

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AHEAD2020 will issue 7 AOs during ~5 years to advertise several services mostly (but not solely) based on trasnational visits.

The calls are issued periodically with a bi-annual cadence. Visits of successful applicants are fully funded.

- Trans-national access to ground and test facilities (TA1)

Such facilities are used to test and/or calibrate new technology space hardware as well as hardware developed for specific astronomical space missions, but can be also used in a wider context of space applications.

- Visitor Program (NA1)

Supporting research visits to institutes/laboratories located in European or associated countries, in order to foster new or strengthen existing collaborations. Eligible candidates are scientists or engineers from Astrophysics institutes in both EU and non-EU countries.

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Access opportunities (2 of 2)

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- Trans-national access to X-ray data analysis (TA2)

Providing access to data analysis methods including use of data tools, archives and space instruments via tutorials and mentoring by experienced scientists at the delivery institutes. To exploit both EU-funded and international HE astronomy observing facilities and data archives in order to enhance high-energy astrophysics science across Europe.

- Trans-national access to computational astrophysics (TA3)

This new TNA will provide new opportunities for European researchers to access free of charge complex computational astrophysical simulations, models and tools to simulate, compare, and analyse X-ray and gamma-ray data.

- Virtual access to GW archive services and tools (VA1)

Provision of a website that focuses on facilitating remote access to the existing Gravitational Wave Open Science Center (GWOSC) infrastructure.

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Infrastructures for TNA/VA

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Exp. Facilities

Data Analysis

Access provider short name	Short name of infrastructure	Installation Nr	Installation Short name	Installation Country code	Estimated number of user projects*
ULIEGE	CSL	1	FOCAL 2	BE	2
ULIEGE	CSL	2	Shaker 200	BE	4
ULIEGE	CSL	3	BBOTOC	BE	6
UNIFE	LARIX	1	LARIX-A	IT	3
UNIFE		2	LARIX-T	IT	4
CNR	BABE	1	BABE	IT	8
INAF	XACT	1	XACT	IT	1
INAF	BEaTriX	1	BEaTriX	IT	5
CR	Vibration Facility	1	Shaker	NL	3
ULEIC	DEPT.PHYS.ASTRO	1	DEPT.PHYS. ASTRO	UK	8
UNIGENEVE	DEP.ASTRO	1	DEPT.ASTRO -DA	CH	8
INAF	INAF	1	BOLOGNA	IT	12
INAF	INAF	2	OAR	IT	8
INAF	INAF	3	PALERMO	IT	12
INAF	INAF	4	IAPS	IT	4

Data Analysis

Comp. Astrophysics

VA

Access provider short name	Short name of infrastructure	Installation Nr	Installation Short name	Installation Country code	Estimated number of user projects*
NOA	NOA	1	IAASARS	GR	4
CEA	CEA	1	CEA	FR	8
SRON	SRON		SRON	NL	12
UNIFE	DEP.FST		DEP.FST-DA	IT	4
NCAC	CAMKPAN	1	CAMKPAN-DA	PL	4
UNIGENEVE	DEPT. ASTRO	2	DEPT. ASTRO-CA	CH	7
INAF	OAT	1	OAT	IT	7
INAF	OAPA	1	OAPA	IT	14
ULEIDEN	LEIDEN-OBS	1	LEIDEN-OBS	NL	7
UNIFE	DEP.FST	1	DEP.FST-CA	IT	7
UBATH	DEP.PHYS	1	DEP.PHYS	UK	7
LMU MUENCHEN	USM	1	USM	DE	7
NCAC	CAMKPAN	2	CAMKPAN-CA	PL	7
EGO	EGO	1	EGO	IT	7
EGO	EGO	1	GWOSC	IT	

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Offered experimental facilities

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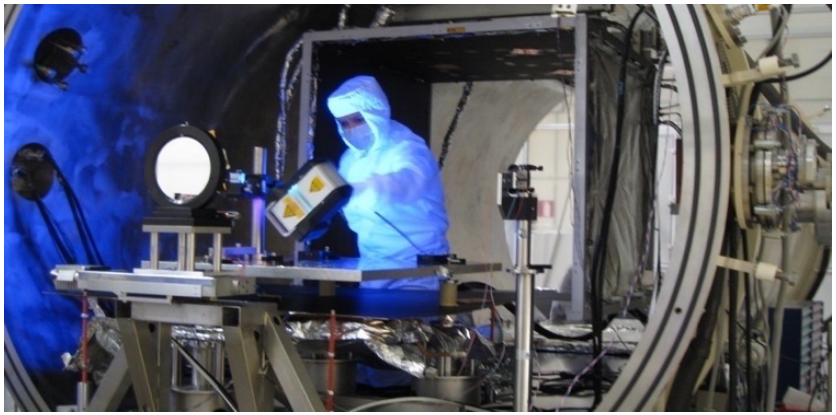
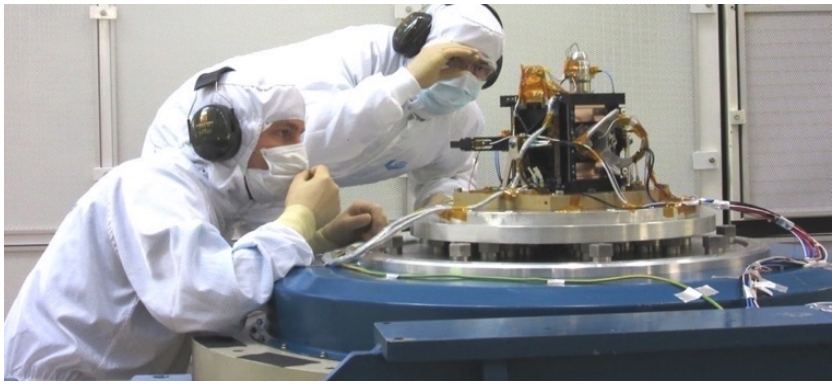
Based on AHEAD experience we have built a TNA offer that covers a range of possible applications and needs and includes:

- one big thermal vacuum chamber (FOCAL2 at CSL),
- two shakers (at CSL and COSINE),
- a facility for testing thin filters (BBOTOC at CSL),
- a system of two beam lines at the Electra Synchrotron covering an ample range of energies (BABE at IOM-CNR),
- general purpose beam-lines for X-rays and gamma-rays (LARIX and XACT, respectively)
- a soft X-ray beam line specialized for testing Silicon Pore X-ray optics (BeaTRiX).





AHEAD 2020

Data Analysis Support Centres

Funded by the Horizon 2020 Framework Program of the European Union Grant Agreement No. 871158

Installation	Involved facilities	Science areas/Topics	Specific Tools and/or Analysis
Department of Physics and Astronomy, University of Leicester	XMM, Swift, SVOM, Einstein probe, SMILE	Gamma-ray bursts, tidal disruption events. active galactic nuclei, galaxy clusters, accretion onto neutron stars and white dwarfs and charge-exchange processes in planetary ionospheres.	Source catalogs for XMM & Swift. Multiwavelenght cross-correlation
NWO-I/SRON Netherlands Institute for Space Research	XMM-Newton, Chandra, and Suzaku, XRISM, Athena	High-resolution X-ray spectroscopy	SPEX spectral analysis package
Department of Astronomy, University of Geneva	INTEGRAL, Chandra, XMM-Newton, Swift, POLAR, Fermi, XRISM, Athena	Galactic nuclei, X-ray binaries, galaxy clusters, and stars	Analyses of INTEGRAL data, including the new On-line Data Analysis. High-resolution spectroscopic data analysis
INAF-Bologna: OAS in collaboration with the Bologna University	Chandra, XMM-Newton, NuSTAR, AGILE, Fermi	extra-galactic X-ray and multi-wavelength surveys, Active Galactic Nuclei, galaxy clusters, physics of accretion and ejection onto super-massive black holes, and X-ray background radiation.	GEant4 Multi-Mission Simulator (BoGEMMS)
INAF-Palermo Observatory	XMM-Newton, Chandra	Galactic X-ray and multi-wavelength surveys, characterization of Star Forming Regions and Young Stellar Objects, stellar coronae, star-planet magnetic interactions, physics of accretion and ejection onto pre-main sequence stars, physics of SNR and cosmic ray acceleration.	Software for re-processing and analysis of high-energy data from XMM-Newton and Chandra
INAF-Rome Observatory	XMM-Newton, Chandra, Swift, NuSTAR, NICER	Timing and spectroscopy of accreting compact objects (e.g. pulsing ULXs, ms pulsars, black-hole transients), Magnetars, GRB afterglows. Emission, absorption and reprocessing mechanisms in nuclear regions of AGNs, AGN-driven winds. Extragalactic surveys, AGN cosmological evolution, high-z quasars and Warm-Hot circum-galactic/Intergalactic Medium	X-ray high-resolution spectroscopy, phase-coherent timing, phase and time-resolved spectroscopy
INAF-Institute of Space Astrophysics & Planetology	INTEGRAL, Swift, XMM, NuSTAR, IXPE	HE surveys and Galactic sources, polarised sources	Analysis of INTEGRAL galactic surveys data. Training on the use of the Geant4 toolkit. Training in calibration methods and laboratory activity for polarimetry instrumentation.
Department of Physics and Earth Science: Università di Ferrara	Swift & other HE missions	GRB physics including studies of prompt and afterglow emission, Tidal Disruption events	Access to HE missions data archives
IAASARS, National Observatory of Athens	XMM, Chandra		Automatic spectral extraction of XMM sources. Automated spectral fitting using standard minimization methods and Bayesian technique. Use of the spectral fit database of the 3XMM sources (an ESA Prodex project). Cross-correlation with optical data
AIM / Service d'Astrophysique, CEA Saclay	Integral, Fermi, Herschel, Planck, SVOM, HESS, CTA	Black-hole X-ray binaries, the Galactic centre, magnetars and gamma-ray bursts, supernova remnants, clusters of galaxies, cosmological surveys.	spectro-imaging of extended sources
NCAC Polish Academy of Sciences, Warsaw	Operational X-ray missions	Physics of accretion.	Accretion disk modelling.

Data Analysis TNA – Visits to SRON-Leiden

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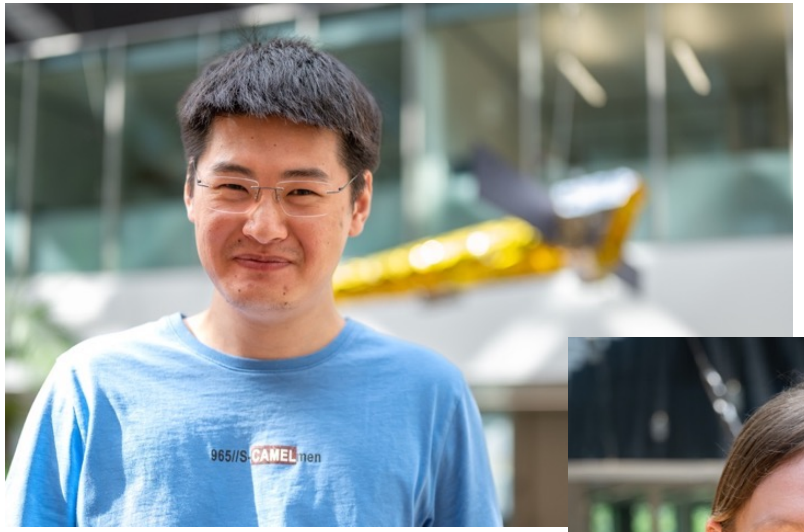
Host: Jelle de Plaa

SRON offers tutorials to analyze high-resolution spectra using the SPEX spectral fitting package together with the analysis tools provided by the relevant missions, like XMM-Newton, Chandra, and Suzaku.

SRON hosted two visits this year:

Menglei Zhou (Tübingen, IAAT):

- Learned to apply Machine Learning techniques on NuSTAR data of High-mass X-ray binaries.



Menglei Zhou

Orsolya Kovács (Brno, Czech):

- Learned to use both Suzaku and Chandra to analyse the outskirts of galaxy clusters.

Orsolya Kovács

We expect three more visits before the end of this year.

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Computational Astrophysics Support Centres

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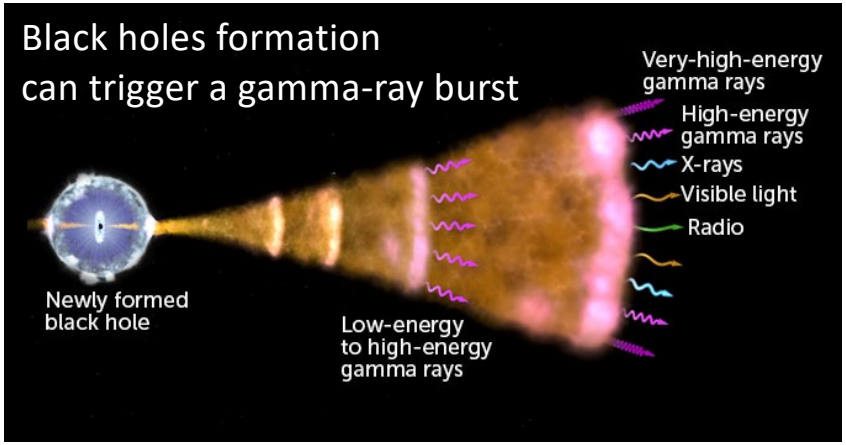
- Department of Astronomy, University of Geneva
- Astronomical Observatory of Trieste, National Institute for Astrophysics, INAF
- Astronomical Observatory of Palermo, National Institute for Astrophysics, INAF
- Leiden Observatory, Leiden University
- University of Ferrara
- Physics Department - University of Bath
- Universitäts-Sternwarte München, Ludwig-Maximilians Universität München
- N. Copernicus Astronomical Centre Polish Academy of Science
- European Gravitational Observatory

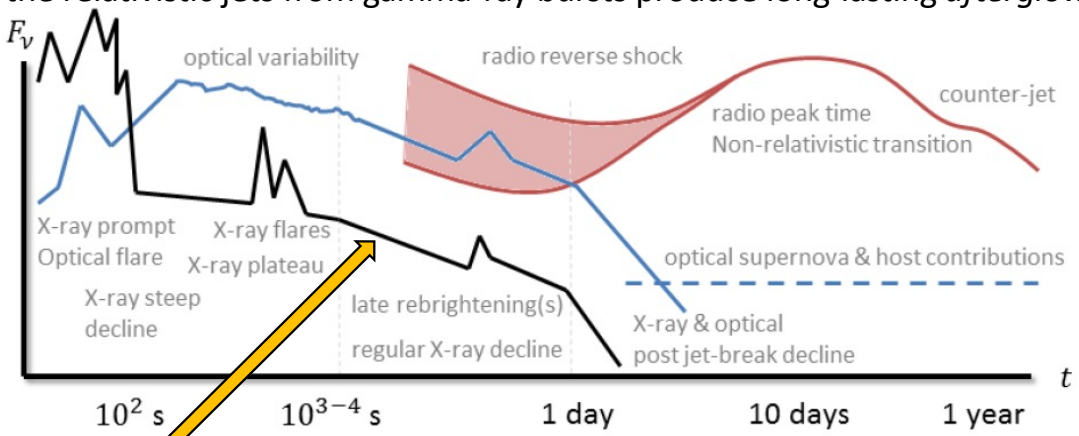
Comp. Astrophysics TNA at the University of Bath,UK

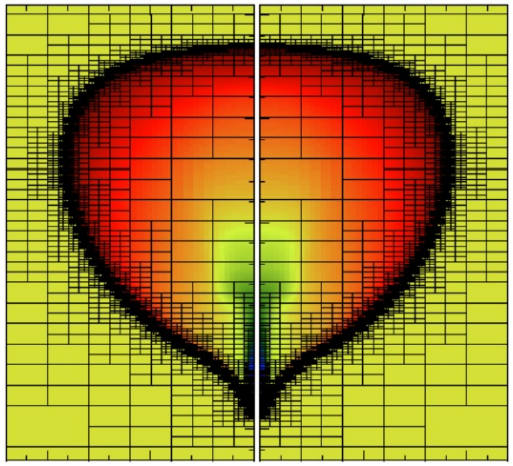
(Host: Hendrik van Eerten)



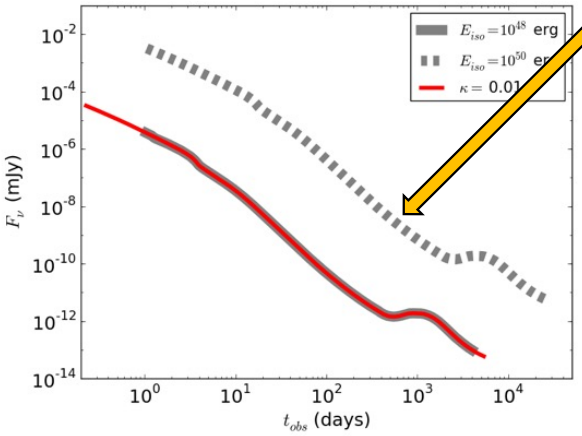
Simulation-based γ-ray burst afterglow modelling

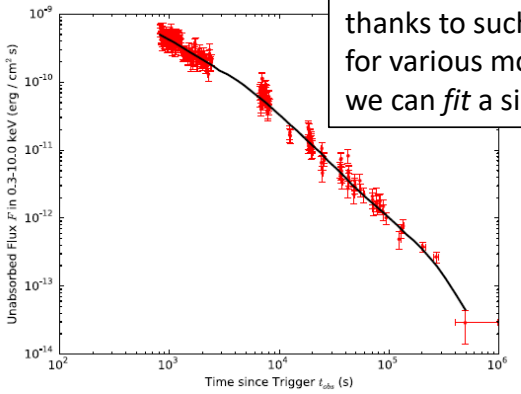
the relativistic jets from gamma-ray bursts produce long-lasting *afterglows*





the evolving, expanding jets can be modelled with high-resolution simulations





we can compute the emission from a jet simulation **and** map the result between e.g. different jet energies to explore parameter space

thanks to such mapping methods for various model parameters, we can *fit* a simulation result to data

At our Bath workshops we share these methods with the HEA community (photo Oct 2022)

AHEAD2020 impact of TNA

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The AHEAD2020 program implemented successfully the EU TNA scheme to:

- give access free of cost to the best test/calibration facilities (synergy research-industry)
- provide expertise and training on data analysis and computational models, mostly for young astronomers paving the way to a new generation of researchers
- enhance the theoretical background of high energy and gravitational wave astrophysics and facilitate application of complex models to users
- improve the data analysis techniques and optimise the exploitation of present observational facilities and data sets in Europe.

In this scheme, TNA centres are providing expertise on a number of topics/tools/datasets, enabling “ expert” access to the average astronomer over the broadest set of facilties in the MM and HE context.

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Conclusive remarks

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The AHEAD2020 TNA success depends on the established strong link with several JRAs that provide improved/new/facilitated services and tools, principally related to:

- data “quality”of observing facilities, e.g. calibration, background and SNR, atomic data base for spectroscopy, ground system for nanosats
- development of several analysis tools, including selected theoretical modelling

… as well as on the related networking activities (visitor program, workshops…)

The TNA scheme implemented in AHEAD2020 easily constitutes a common framework as it can be applied to other wavelengths.

After discussion within the AHEAD2020 Executive Committee we suggest the implementation of a similar scheme for the INFRA-2023-SERV-01-02 proposal.