Expanding Horizons in Italy

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Book of Abstracts

Contents

1

The Atacama Large Aperture Submillimeter Telescope (AtLAST): enabling large-scale sub-mm science beyond 2030

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The Atacama Large Aperture Submillimeter Telescope (AtLAST) is a next-generation, environmentally sustainable (sub-)millimeter astronomical single-dish facility, currently continuing in a second EU-funded development study that will bring the telescope design to PDR level by the end of 2028 (atlast.uio.no). INAF is a Beneficiary Partner of this EU project and the Sardinia Radio Telescope will be used as a pathfinder to test key technologies. With its 50m-diameter primary mirror and the possibility to host multiple instruments accessing a 1 to 2 degree diameter field of view, the strength of AtLAST is in science where a wide field of view, highly multiplexed instrumentation, and sensitivity to faint extended structures is important. As an indication, AtLAST would provide continuum sensitivity comparable to ALMA/WSU but with up to 10^5 faster mapping speed once its focal plane is fully populated.

AtLAST will perform transformational science in most fields of Astrophysics. Among other things, AtLAST will detect the elusive low surface brightness gas that fills and surrounds galaxies in both its cold (T<100K, through molecular/atomic line emission and dust emission) and hot phases (through the Sunyaev-Zeldovich effect), it will resolve 80% of the Cosmic Infrared Background into >50 million galaxies from z=0 to z=8, it will observe the HDO lines in several comets and provide new insights into the origin of water on Earth, and it will be able to map the whole disk of the Sun at very high temporal cadence for the first time in the sub-mm. As a single-dish telescope, AtLAST will also be ideal for time-domain astronomy and sub-mm VLBI observations. As such, AtLAST will be the ultimate complement to ALMA, ELT, Vera Rubin, and SKA in the 2035+, with an expected lifetime of 50+ years.

The requirements of fast scanning speed (3 deg/s), large aperture (50m), large FoV (>1 deg), and high surface accuracy (20µm over the full 50m dish to observe wavelengths from 10mm down to 350µm) make AtLAST's design unique for a radio facility and closer to that of 30m class optical telescopes. The design features a rocking chair mount with an active main reflector surface, a high precision closed-loop metrology system, and the space to house six major instruments. Instruments will be periodically upgraded as spectroscopic focal plane array technologies are expected to significantly advance in the next decades. AtLAST will also feature a cutting-edge energy recovery system that enables the reuse of braking energy. This innovative approach significantly reduces the motion power demand and takes an additional step towards realising a sustainable observatory. From the start of the design phase, AtLAST has placed a renewable and efficient energy generation as a core requirement, by investing resources into the development of a tailored renewable energy system with a hybrid energy storage that can team up with other observatories and/or civil users.

2

Core-Collapse SN detections from Einstein Telescope

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Gravitational waves offer a promising opportunity to investigate the explosion mechanism behind CCSNe, as they are expected to originate from the oscillations of the proto-neutron star formed during collapse. The third-generation gravitational wave detector, the Einstein Telescope, with its sensitivity to low-frequency signals, has the potential to detect GW signatures from such events.
In this talk I will present a recent work carried out for the Stellar Collapse and Rotating Neutron Stars Division of the ET collaboration, focused on the expected rate of CCSNe and the detection capabilities of the ET within the Milky Way and Magellanic Clouds. To assess ET capabilities, we employed simulated waveforms from CCSNe and the GWFISH software to produce SNR-weighted density maps and determine the detection horizon for these signals. This information can be crucial for developing synergies with electromagnetic and neutrino observatories, enabling a multi- messenger search for future Galactic supernovae.

3

The Wide-field Spectroscopic Telescope: pushing the boundaries of spectroscopic surveys

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4

HPC, Big Data and AI for Astrophysics in the Era of Computing

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In the next decade, current and upcoming radio-interferometers, like LOFAR, MeerKAT, MWA ASKAP in the perspective of the SKA, will produce huge volumes of rich and complex data. This will represent not only an invaluable opportunity for scientists, but also an outstanding technological challenge. The expected data volume will be hard to manage with traditional approaches. Data will have to be stored in dedicated facilities, providing the necessary capacity at the highest performance. Corresponding data processing will have to be performed local to the data, leveraging available High Performance Computing (HPC) resources. Data reduction and imaging software tools will have to be adapted, if not completely re-designed, in order to efficiently run at scale. Even more critically, the data analysis pipeline must integrate cutting-edge solutions enabled by Artificial Intelligence. This talk wants to highlight some of the challenges and the solution the are being developed (also besides the radio astronomy domain), with specific focus on those promoted within the new National Centre for HPC, Big Data and Quantum Computing. Since its establishment in 2022, INAF has played a leading role in the National Centre for HPC, Big Data, and Quantum Computing. The Centre now stands as a major national and international infrastructure for advanced computing, data management, and AI-driven research. It offers the astrophysical community a platform of excellence —positioned to support and participate in future major international projects and initiatives, and to foster innovation at the frontier of data-intensive science.

5

Multi-messenger observations in the Einstein Telescope era: binary neutron star and black hole - neutron star mergers

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The Einstein Telescope (ET) will significantly extend the reach of gravitational wave (GW) astronomy for stellar-mass compact binaries, enabling multi-messenger discoveries. Building on the landmark GW170817 observations and recent population modeling (Colombo et al. 2022, 2024, 2025), we explore the prospects of detecting electromagnetic (EM) counterparts to binary neutron star (BNS) and black hole-neutron star (BHNS) mergers with ET. Using a synthetic cosmological population of BNS and BHNS systems, we simulate GW signal-to-noise ratios, sky localization uncertainties, and multi-wavelength EM signatures, including kilonovae and short gamma-ray bursts. We assess ET's multi-messenger yield under different detector configurations and evaluate the impact of key astrophysical uncertainties, such as the neutron star equation of state and compact object mass distributions. Our results, which also contributed to the development of Chapter 4 of the ET Bluebook, will be presented, highlighting the transformative potential and challenges of multi-messenger astronomy in the next decade.

6

Multi-messenger observations in the Einstein Telescope era: a scientific treasure chest to be unlocked

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The next generation of ground-based gravitational wave (GW) detectors is set to dramatically expand the horizon of observable GW sources in the few to 10^4 Hz frequency range. For compact binary mergers — binaries of stellar-mass black holes and neutron stars — this will translate to at least several high-confidence triggers per day. If a network of GW detectors will be operational alongside the Einstein Telescope (ET), the sky localisation of the loudest among these triggers could be exquisitely good (on GW standards), but the sky position of the majority of the sources will not be known to better than several tens of square degrees. Yet, the photometric and spectroscopic observation of these sources, starting as soon as possible after the merger, holds the potential to revolutionise our understanding of many branches of physics, including cosmology, nuclear physics, high-energy astrophysics, and massive stellar binary evolution. In this talk, I will highlight some of these science cases, delineating the requirements that the electromagnetic observations must satisfy in order to answer the underlying questions.

7

Catch me if you can: brief optical flashes as counterparts of gravitational wave signals

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Persistent monitoring of the sky has revealed the presence of transient astronomical phenomena in the scale from milliseconds to days. We learnt to identify newly born and short lasting (< 1 s) signals in the radio frequencies, in the X-rays and gamma-rays. However, it remains extremely challenging to monitor the sky in the visible domain with high temporal resolution. I will present the scientific potential in monitoring gamma-ray bursts (GRBs) and gravitational wave (GW) signals with high time-resolution optical observations. In the context of the GRB prompt emission, the fast optical observations are essential to reveal the origin of the radiative and dissipative processes taking a place in the ultra-relativistic jets of GRBs. In the context of multi-messenger astronomy, prompt optical observations of GWs from binary neutron star mergers provide a unique channel for fast and accurate localisation of GWs. I will then discuss the expected detection rate of these optical flashes with several proposed instruments, including MezzoCielo.

8

The Evolving Role of AI in Astronomical Spectroscopy and Future Telescopes

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Artificial Intelligence is no longer an emerging technology but a standard tool in modern astronomical spectroscopy. Neural network-based software is integral to the analysis pipelines of major spectroscopic surveys, and machine learning algorithms are widely employed to extract knowledge from the datasets generated by current instruments. Next-generation astronomical facilities will arrive alongside rapid progress in AI technologies like large language models and autonomous agents, creating new opportunities to advance research methodologies.
This talk will provide an overview with concrete examples of the current
applications of AI in astronomical spectroscopy, critically assessing both its strengths and limitations. Subsequently, we will discuss the influence of AI on the conception and scientific exploitation of future ground-based telescopes and how investing in the area of AI for Astronomy could help INAF to play a relevant role in the expanding horizon call.

9

Expanding Horizons @ESO

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12

ALMA2040: a high-definition view of the cold universe with a next-generation ALMA

Invited talk.

In the last 15 years, the Atacama Large Millimeter/submillimeter Array (ALMA) has revolutionized astrophysics by providing unprecedented resolution and sensitivity in observing the cold universe, including the formation of stars, planets, and galaxies. With groundbreaking discoveries ranging from the first detailed images of protoplanetary disks all the way to kinematics of galaxies in the epoch of reionization, ALMA has showcased the vast discovery potential of the (sub-)mm wavelength regime. However, in another 15 years from now, the science landscape will have changed dramatically as new major observational facilities will have started their operations or have come towards advanced maturity in their scientific outcome (e.g., JWST, ELT, Euclid, Gaia, Plato, Ariel, Roman Space Telescope, SPHEREx, LiteBIRD, LISA and others). At the same time, ALMA's current Wideband Sensitivity Upgrade will have been in place for ~10 years, and ALMA itself will have been operational for 30 years. This leaves a significant and crucial hole in the scientific discovery space in the 2040's.

In this talk, we discuss how a disruptive leap in (sub-)mm wavelength-range observations at high and intermediate angular resolutions would provide unique and complementary insights into a wide range of key astrophysical questions, with the potential of yielding a transformational view in our understanding of the universe. These constitute the core of the science case for a next-generation, radically upgraded ALMA-like facility ('ALMA2040'). This is based on a European community-wide effort of >300 scientists and nine different scientific working groups, which have already prepared >70 science pitches across a wide range of astrophysical topics. We will outline the key scientific drivers that could be uniquely addressed with this powerful new (sub-)mm interferometer and discuss their synergy with other major astronomical observatories in the 2040's. By providing fundamental insights into the cold universe across time and spatial scales, ALMA2040 represents a broad and ambitious scientific vision for the future of interferometric observations in the (sub-)mm range.

13

Kilometer Baseline Interferometer (KBI) and Time Domain Telescope (TDT), a general overview

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14

Challenges in cosmology in the '40

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Invited talk.

15

Challenges in extragalactic astronomy in the '40

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Invited talk.

16

Challenges in galactic astronomy in the ‘40

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Invited talk.

17

Challenges in star formation in the ‘40

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Invited talk

18

Challenges in exoplanetary research in the ‘40

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Invited talk.

23

Discussion

24

Alta risoluzione spaziale nell’ottico/nearIR all’orizzonte

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Invited talk.

25

Time-Domain & Multi-Messenger

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Invited talk.

26

Advancements in Optics

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Invited talk.

27

Advancement in Detectors

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Invited talk.

28

Superconducting-based technologies for VIS/NIR and sub-mm/mm domain

Invited talk.

29

New Detectors for Radioastronomy

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Invited talk.

31

New materials, Dispersion Elements and Optical Devices

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33

Saluti istituzionali e scopo del Workshop

36

Discussion