The era of collaborative multi-wavelength and multi-messenger astronomy: science and technology

Tuesday 22 October 2019 - Thursday 24 October 2019

Auditorium della Fondazione Cassa di Risparmio di Firenze (Italy)

THE 2ND PIETRO BARACCHI CONFERENCE

Book of Abstracts

After the success of the first Pietro Baracchi conference held in 2016 in Perth, a second edition is organized in Florence to bring together Italian and Australian astronomy and technology. This series of conferences is named in honour of Pietro Paolo Giovanni Ernesto Baracchi (1851 — 1926), an Italian who played a central role in Australian astronomy in the late 1800s and early 1900s.

Rationale

Italy and Australia are deeply involved in many of the most advanced next-generation astronomical facilities. Australia and Italy contribute to these facilities at fundamental technological and scientific levels and all of these facilities will play a role in the new era of multi-wavelength and multi-messenger astrophysics and cosmology. With the detection of gravitational waves and the identification of their electro-magnetic counterparts, and the rise of synergies between astroparticle physics and electromagnetic astronomy, our communities face exciting advances, but also technological challenges and challenges in coordination and collaboration. This meeting, the second Pietro Baracchi conference, will bring together Italian and Australian astronomers and engineers working across projects and facilities of common interest, with a particular focus on multi-messenger, multi-wavelength astrophysics and cosmology. The goal of the Pietro Baracchi meetings is to encourage closer collaborations between Italy and Australia in astrophysics and technology.

Scientific Organizing Committee

Pietro Bolli (INAF - Arcetri) co-chair
Steven Tingay (Curtin University) co-chair
Marica Branchesi (Gran Sasso Science Institute)
Tamara Davis (University of Queensland)
Adriano Fontana (INAF - Roma)
Elaine Sadler (CSIRO and University of Sydney)

Local Organizing Committee

Pietro Bolli (INAF - Arcetri)
Patrizia Braschi (INAF - Arcetri)
Paola Di Ninni (INAF - Arcetri)
Renzo Nesti (INAF - Arcetri)
Dario Panella (INAF - Arcetri)

Contents

3

Next-generation optical facilities in the multi-messenger era: the SOXS case

Author: Sergio Campana[1]

[1] *INAF - Brera*

SOXS (Son Of X-Shooter) is a spectrograph for the ESO NTT telescope, capable to cover the optical and nIR bands, based on the heritage of the X-Shooter at the ESO-VLT. SOXS will be built and run by an international consortium, carrying out rapid and longer-term Target of Opportunity requests on a variety of astronomical objects. SOXS will observe all kind of transient and variable sources from different surveys and satellites. These will be a mixture of fast alerts (e.g. gamma-ray bursts, gravitational waves, neutrino events), mid-term alerts (e.g. supernovae, X-ray transients), fixed time events (e.g. close-by passage of minor bodies). The design foresees a spectrograph with a Resolution-Slit product ˜4500, capable of simultaneously observing over the entire band the 350-2050 nm spectral range. The limiting magnitude of R_AB˜20.5 (1 hr at S/N˜10) is suited to study transients identified from on-going imaging surveys. Light imaging capabilities in the optical band (grizy) are also envisaged to allow for multi-band photometry of the faintest transients.

11

MAVIS: sharper than JWST, deeper than HST

Author: Giovanni Cresci[1]

[1] *INAF - Arcetri*

MAVIS (MCAO Assisted Visible Imager and Spectrograph) is a proposed instrument for the ESO's VLT Adaptive Optics Facility, currently in Phase A. Australia is leading a consortium that includes the ANU, the AAO, INAF and the Laboratoire d'Astrophysique de Marseille, with associated members ONERA, Swinburne University of Technology and Macquarie University. It is made of two main parts: a Multi-Conjugate Adaptive Optics (MCAO) system, that cancels the image blurring induced by atmospheric turbulence in the visible on a large field, and its post focal instrumentation, for which the baseline is a wide field imager and a IFU spectrograph, both covering the visible part of the light spectrum. MAVIS has the potential to be an extremely novel and powerful facility: with an angular resolution of 15 mas (close to 50 times better than the seeing limited conditions) and a powerful and sensitive post-focal instrumentation, MAVIS will be instrumental to bring answers to a number of astrophysical science questions, from solar system planets and moon, stellar evolution, BH seeds, up to the physical composition of high-z galaxies and early galaxy assembly.

26

Neutral hydrogen in the distant Universe - New HI absorption results from ASKAP

Author: Elaine Sadler [1]

[1] *CSIRO and University of Sydney*

Our knowledge about the amount and distribution of neutral atomic hydrogen (HI) in galaxies in the distant Universe remains patchy and incomplete, yet this component of the interstellar medium is critical to understanding how galaxies evolve over cosmic time. The large (30 square degree) field of view, wide spectral bandpass and radio-quiet site of the Australian SKA Pathfinder (ASKAP)

telescope provide a powerful new capability for large-area HI absorption surveys of galaxies in the redshift range 0 < z < 1. I will show some early science results from observations during ASKAP commissioning, and describe the 'all-sky' 21cm HI absorption survey (ASKAP-FLASH) that our team plans to begin next year.

6

The SkyHopper Space Telescope CubeSat

Authors: Michele Trenti[1]; SkyHopper Team [2]

[1] *University of Melbourne*

[2] _

I will present an overview of the SkyHopper 12U CubeSat, a mission concept for an Australian-Italian space telescope - currently funded in Australia for detailed definition - which will demonstrate feasibility of cryogenic infrared imaging from a nano-satellite platform. SkyHopper will carry a four channel camera covering the spectral range from 0.8 to 1.7 micron simultaneously, and be capable of autonomously pointing to new targets within two minutes. The combination of timeliness on target and low-noise infrared image quality from space will offer a facility unique in the world for multiple areas of astronomy, including rapid follow-up of infrared transients such as Gamma Ray Burst afterglows at the edge of the observable universe, discovery of potentially habitable Earth-size planets around nearby cool stars, and measurement of the Cosmic Infrared Background, which encodes information of galaxy formation processes across time. The talk will focus in particular on the results from the spacecraft's preliminary concept design to illustrate how advances in CubeSat technology are allowing us to meet ambitious mission science requirements and a lean timescale for final design, construction and launch.

16

Optical surveys in the multi-messenger era

Author: Enrico Cappellaro[1]

[1] *INAF - Padova*

In the last decade a new generation of optical surveys have increased the number of transient detections by order of magnitudes. The combination of wider field of view and more frequent temporal sampling, led to the discovery of new class of events which often are labeled unusual, peculiar, extraordinary, etc. We may suspect that the designation reflects our ignorance of the astrophysical mechanism that originates the transients. In many cases, multi-wavelength analysis revealed that the shock of fast expanding ejecta with pre-existing circumstellar medium is shaping the electromagnetic display and hiding the central engine.
In this context, gravitation waves are a new messenger that probes otherwise unaccessible physical quantities. The potential of the new multi-messenger astrophysics has been demonstrated by the first joined observations of August 2017 and motivated a major effort by the astronomical community to guaranty that all new opportunities are exploited.
At the same time, some of the findings of current GW searches are challenging our understanding of the formation of compact remnants and in turn are prompting for a close look to the final fate of massive stars.

20

Fast radio bursts and their multi-wavelength follow-ups

Author: Shivani Bhandari[1]

[1] *CSIRO/ATNF*

Fast Radio Bursts (FRBs), exotic millisecond duration bursts are currently the hottest topic in the field of transient radio astronomy. The discovery of FRBs has stimulated a range of theoretical investigations to understand their origin and physics as well as observational efforts around the world to search for more such bursts. New instrumentation capable of real-time detection has enabled prompt multi-wavelength follow-ups upon detection, which is crucial in determining FRB progenitors. In the recent decade or so, we have learned a lot about them with the discovery of repeating FRBs and localisation of FRBs to their host galaxies, which are providing essential clues to the puzzle of "what produces an FRB". In this talk, I will present the latest FRB discoveries from the Parkes radio telescope and the Australian Square Kilometre Array Pathfinder (ASKAP), along with the results of their multi-wavelength follow-ups. There is no more exciting time to be involved in the field!

25

The host galaxies of Fast Radio Bursts with ASKAP and the VLT

Author: Stuart Ryder[1]

[1] *Macquarie University*

Fast Radio Bursts (FRBs) last only a few milliseconds, but their cause and even their extragalactic origins have remained elusive. The Australian SKA Pathfinder (ASKAP) has the unique capability to not only reveal which galaxy an FRB occurred in, but even where within the host galaxy it occurred. We have used FORS2 and X-Shooter on the VLT to follow-up the first sample of FRB host galaxies from ASKAP. I will present our initial findings on the environments of FRBs, and the intergalactic and circumgalactic media through which they propagate.

7

The role of current and future Italian radio telescopes

Author: Federica Govoni[1]

[1] *INAF - Cagliari*

The attention of the radio astronomical community in the multi-messenger era is distributed across various word-class facilities which includes both single-dish radio telescopes and radio interferometers. I will present the status of the radio astronomical facilities in Italy and the future perspectives for observations at high frequencies.

27

Technologies for Radio Astronomy

Author: Tasso Tzioumis[1]

[1] *CSIRO*

Technologies for radio astronomy is a key component of the CSIRO Astronomy and Space Science (CASS) unit, along with operating Parkes, ATCA, ASKAP and the LBA as a National Facility. CASS capabilities extend along the whole spectrum of the skills required to design, build, install, commission and operate state-of-the-art radio telescope systems. CASS specialises currently in Multi-beam, Ultra-Wide-Band (UWB) and Phased Array Feed (PAF) systems.
An overview of recent and future systems and their engineering challenges will be provided, together with the implications for large telescopes (e.g. SRT) and the SKA.

31

Gas and dust in the host galaxies of Gamma-Ray Bursts

Author: Leslie Hunt[1]

[1] *INAF - Arcetri*

Gamma-ray bursts (GRBs) and their afterglows identify a galaxy population that otherwise is missed by even deep cosmological surveys. This talk describes what can be learned about GRBs from observations of dust and gas in their host galaxies, exploring the new frontiers of multi-wavelength and multi-messenger astronomy.

29

A first glimpse of the Galactic Plane with ASKAP

Author: Umana Grazia[1]

[1] *INAF - Catania*

In the wide context of the ASKAP early-science phase and in preparation for the legacy sur- veys, we report the first observations toward the Galactic plane (The SCORPIO project). The targeted field was chosen to encompass the entire SCORPIO field, a patch of Galactic Plane already observed with ATCA (Umana et al., 2015).
The major scientific goals of SCORPIO are the production of catalogues and the study of different classes of Galactic radio source like radio stars and circumstellar envelopes, related to young or evolved stars (HIIs, Planetary Nebulae, Luminous Blue Variables, Wolf–Rayet stars, Supernova Remnants). SCORPIO will be also used as a technical test-bed for the Evolutionary Map of the Universe survey (EMU; Norris2011), one of the approved ASKAP legacy surveys scheduled to start in late 2019, in particular in helping to shape the strategy for its Galactic Plane sections.
The observations were carried out at a central frequency of 912 MHz and covered a total area of about 40 square degrees. In this talk first results on both point and extended sources will be presented. In particular, the synergy between radio data and data-set obtained at other wavelengths as unique tool for a robust classification of new detections will be discussed.

19

Untangling the Magnetic Field of the Giant Radio Galaxy ESO422-G028 with Australian SKA Precursors

Author: Christopher Riseley[1]

[1] *University of Bologna*

The role played by magnetic fields is one of the key pieces of the puzzle to completing our understanding of the evolutionary picture of radio galaxies. These sources play a crucial role in driving the evolution and chemical enrichment of the Universe, through feedback processes. The largest radio galaxies - known as giant radio galaxies - typically reside in poor groups or clusters, thought to trace the warm-hot intergalactic medium (WHIM), where a significant portion of the missing baryon fraction of the Universe is thought to reside. Thus, by studying the magnetic field structure of these giants, we can probe the magnetic field in the large-scale structure of the Universe.

In this talk, I will present the results of a multi-wavelength campaign to understand the evolutionary picture of one such giant, ESO422−G028. We possess a spectacular radio dataset from a suite of cutting edge radio telescopes spanning the frequency range 88 MHz to 50 GHz. I will discuss what these data tell us about the large-scale magnetic field structure of ESO422, interactions with its surrounding environment, and how the small-scale structure of the radio core relates to the large-scale diffuse radio emission from the lobes.

10

Jets at the extremes: the GLEAM and LAT view of blazars

Authors: Marcello Giroletti[1]; Gabriele Giovannini[1]; Daniele D'Antonio[2]

[1] *INAF - IRA*

[2] *Sydney University of Technology*

We present the results of a cross-correlation between the latest (fourth) catalogue of gamma-ray active galactic nuclei (AGN) detected by the Large Area Telescope on board Fermi (4LAC) and the GLEAM survey carried out with the Murchison Widefield Array at two opposite extremes of the electromagnetic spectrum. The Fermi AGNs are mainly blazars; thanks to the increased sensitivity of GLEAM in comparison to the MWA commissioning survey, the vast majority of Fermi blazars now have a counterpart at low radio frequency, with a detection rate of 70% and a net count of over 1200. Gamma-ray blazars are distinguishable from the rest of GLEAM sources for a flatter spectral index, which indicates that the beamed flat-spectrum inner part of the relativistic jet still contributes also at low frequency. We use the spectral constraints from GLEAM and other radio surveys to discuss the intrinsic value of cores and lobes in radio loud AGNs.

14

Digital beamforming with the cryogenic C-band PHAROS2 PAF

Authors: Alessandro Navarrini[1]; Alessandro Scalambra[2]; Andrea Melis[1]; Simone Rusticelli[2]; Raimondo Concu[1]; Pierluigi Ortu[1]; Giovanni Naldi[2]; Giuseppe Pupillo[2]; Andrea Maccaferri[2]; Alessandro Cattani[2]; Adelaide Ladu[1]; Luca Schirru[1]; Federico Perini[2]; Marco Morsiani[2]; Jader Monari[2]; Juri Roda[2]; Pasqualino Marongiu[1]; Andrea Saba[3]; Marco Poloni[2]; Marco Schiaffino[2]; Simone Mattana[2]; Gianni Comoretto[4]; Renzo Nesti[4]; Enrico Urru[1]; Tonino Pisanu[1]; Francesco Schillirò[5]; Kris Zarb Adami[6]; Alessio Magro[6]; Riccardo Chiello[7]; Keith Grainge[8]; Michael Keith[8]; Simon Melhuish[8]; Michael D'Cruze[8]; Marc McCulloch[8]; Wim van Cappellen[9]

[1] *INAF - Cagliari*

[2] *INAF - IRA*

[3] *ASI*

[4] *INAF - Arcetri*

[5] *INAF - Catania*

[6] *University of Malta*

[7] *University of Oxford*

[8] *University of Manchester*

[9] *ASTRON*

We describe the development of a multi-channel "warm receiver section" (WS) and of a digital beamformer for the PHAROS2 Phased Array Feed (PAF), a PAF demonstrator for radio astronomy application across the 4-8 GHz radio frequency (RF) band. The project is carried out as an international collaboration in the framework of the PAF Advanced Instrumentation Programme for the Square Kilometer Array (SKA).
The PAF is based on an array of 10×11 dual-polarization Vivaldi antennas cryogenically cooled at 20 K along with low noise amplification modules (LNAs). The WS receiver can process the signals from a subset of 24 antenna elements of the array by downconverting them to an intermediate frequency (IF) range, 375-650 MHz, suitable for digitization by the digital beamformer. The latter is based on the iTPM (Italian Tile Processing Module), developed for the SKA Low Frequency Aperture Array (LFAA). We modified the iTPM firmware to synthesize four independent beams across the IF 275 MHz instantaneous bandwidth in the iTPM FPGAs (Field Programmable Gate Arrays). The 24 signals are sent from the WS to the iTPM through analogue IFoF (IF over fiber) optical links.
We will present the design and performance of the WS for PHAROS2 and report on laboratory testbench results of the beampattern characterization and digital beamforming performed with the Vivaldi array at room temperature cascaded with the WS and iTPM.
PHAROS2 is going to be installed on the primary focus of the e-Merlin 25-m diameter Pickmere antenna at the Jodrell Bank Observatory-University of Manchester for few weeks with the goal of calibrating it, verifying the main system functionalities and performing preliminary scientific observations of strong radio astronomy sources.
The beamoformer has been programmed to operate in the two following observing modes: 1) "Imaging and Pulsar search Mode," delivering four integrated beams (spectral channel width 0.81 MHz) across 275 MHz instantaneous bandwidth with integration time from 50 μsec to 1 sec; 2) "Spectroscopic Mode," delivering a single beam with about 25 frequency channels covering approximately 20 MHz instantaneous bandwidth. Fine channelization, achieved through FFT by polyphase filterbank on GPU, provides a frequency resolution down to 100 Hz.

33

Combining large radio continuum surveys with multi-wavelength data to extract the science

Author: Ray Norris[1]

[1] *WSU/CSIRO*

The Australian SKA Pathfinder (ASKAP) is now generating radio images at an unprecedented sensitivity to diffuse emission. In particular, the Pilot Survey of the Evolutionary Map of the Universe (EMU), is starting to produce a stream of exciting new results. Here I will show some of these latest results from ASKAP, and show how we need to combine them with multi-wavelength data in order to understand the science behind them.

5

Multi-frequency polarimetry of complete samples of extragalactic radio sources

Author: Vincenzo Galluzzi[1]

[1] *INAF - Trieste*

The high-frequency (> 20 GHz), bright flux density (> 200 mJy) radio population is dominated by blazars. Their polarization properties are invaluable to study magnetic fields and plasma in the inner and unresolved regions of relativistic jets. For Cosmology, these objects are important contaminant

of CMB at scales smaller than 30' up to 100 GHz, hence they hamper the detection of primordial B-modes associated to inflation. However, their properties are still poorly constrained: results in literature are easily affected by spectral, detection and variability-related biases.
We present an unbiased analysis of high sensitivity (σ_P ˜ 0.6 mJy/beam, ˜90% detection rate at 5σ) multi-frequency (and multi-epoch) polarimetric observations for a complete sample of 104 compact extragalactic radio sources drawn from the faint (> 200 mJy at 20 GHz in total intensity) Planck-ATCA Co-eval Observations (PACO) catalogue, performed with ATCA at 7 frequencies, over the 1.1-39 GHz frequency range. An ALMA project extends the analysis up to 100 GHz for a (complete) sub-sample of 32 objects. We classify our sources in terms of stuctural complexity, finding different behaviours in polarization fractions (linear and circular) and position angles (PPAs). We produced differential source counts in polarization and assess forecasts for CMB studies.

15

Assessing the RQ AGN population: results from observations of the G23 field with ASKAP and ATCA

Author: Isabella Prandoni[1]

[1] *INAF - IRA*

To properly understand the detailed process of galaxy formation and evolution there is an urgent need to identify and quantify the role of AGN feedback, not only through detailed studies in the local Universe, but also at high redshifts, where most of the accretion occurred. Radio surveys have reached a depth where large numbers of star-forming galaxies (SFG) and radio-quiet (RQ) AGNs (i.e. AGN that do not display large scale jets and lobes, and typically associated to Seyfert galaxies and QSO) are detected. This opens new exciting perspectives for deep continuum-radio surveys, providing a unique and powerful dust/gas-obscuration-free tool to get a global census of both star formation and both modes of AGN feedback (radio- and QSO-modes) up to high redshifts; hence tracing the apparently simultaneous development of the stellar populations and the black hole growth in the first massive galaxies. In this talk I will give an overview of our current understanding of radio-selected RQ AGN and of the origin of their radio emission, focusing on the latest results from the GAMA 23 field, observed with ASKAP as part of the EMU early science programme, and with the ATCA (5.5 and 9.5 GHz) in the framework of the GLASS project.

28

UAV-based Antenna Measurements for the Bridging Project of SKA1-LOW

Authors: Giuseppe Virone[1]; Fabio Paonessa[1]; Pietro Bolli[2]; Alessio Magro[3]; Dave Minchin[4]; Andrew McPhail[4]

[1] *CNR - IEIIT*

[2] *INAF - Arcetri*

[3] *University of Malta*

[4] *Curtin University*

The Square Kilometer Array (SKA) is one of the most promising radio telescopes for the next decades. Its low-frequency instrument will consist of a sparse random array of dual-polarized log-periodic antennas operating from 50 to 350 MHz. The LOW Bridging project aims at implementing an SKA1-LOW station architecture called AAVS1.5 at the Murchison Radio Observatory, close to the current AAVS1 installation (previous prototype). Questions and risks associated with station calibration have been addressed from the directions of both electromagnetic simulations, tests and measurements. In order to verify and test the log-periodic based station against a trusted benchmark, and as a risk mitigation strategy, the Murchison Widefield Array (MWA) bowtie dipole antenna has been

deployed and tested in parallel in the so-called EDA2 array. The heritage of CNR and INAF on UAV-based antenna measurements of low-frequency radio telescopes has been exploited to validate the electromagnetic analyses of the three deployed antenna arrays, AAVS1.5 composed of 48 aluminum SKALA4.1 antennas, EDA2 composed of 48 MWA dipoles, and AAVS1 station composed of 256 steel SKALA2 antennas. The collaboration with Curtin Institute of Radio Astronomy (CIRA) has been crucial for the success of the experiments.

21

The Northern Cross Fast Radio Burst project

Author: Gianni Bernardi[1]

[1] *INAF - IRA*

Fast Radio Burst (FRBs) are one of the most enigmatic events in the Universe, whose nature remains still unknown. In this talk I will describe the ongoing work at the Medicina radio station in order to turn the Northern Cross telescope into an FRB survey machine.

4

Looking for Low Frequency GWs with the Pulsar Timing Arrays

Author: Andrea Possenti[1]

[1] *INAF - Cagliari*

The Pulsar Timing Arrays provide the possibility to investigate the gravitational waves in the low-frequency range between few nanoHz and few hundreds of nanoHz, thus being nicely complementary to the current and future gravitational waves detectors operating at higher frequency bands. The status of these experiments will be reported, with particular emphasis on the Italian/European contribution and the Australian contribution.

34

Gravitational wave detectors: prospects for the future

Author: Viviana Fafone[1]

[1] *University of Rome Tor Vergata and INFN Rome Tor Vergata*

In the past three years, the first direct gravitational wave detections by LIGO and Virgo have provided remarkable scientific outcomes. More frequent detections by the ground-based network over the next decade have the potential to shed light on many areas of fundamental physics, astrophysics and cosmology. In this talk, I'll present plans for observations and detector upgrades over the next decade in the context of the global network as well as discuss longer term perspectives toward a new generation of GW detectors for the 2030s and beyond.

23

The population properties of gravitational waves in the transient catalog

Author: Eric Thrane[1]

[1] *Monash University*

At present, LIGO and Virgo have confirmed the detection of gravitational waves from eleven compact binary mergers. New candidate events are announced on a weekly basis. As the catalog of gravitational-wave transients grows, it is increasingly interesting to analyse the population properties of merging compact binaries. In this talk, I highlight how the mass, spin, and eccentricity of compact binaries can be gleaned from gravitational-wave observations in order to understand a variety of phenomena, from the formation mechanism of binary black holes, to the fate of massive stars. I present recent results characterising the eccentricity of binary black holes in the first gravitational-wave transient catalog, and discuss the implications for binary black hole formation.

9

GW signal from transient astronomical events

Author: Martina Toscani[1]

Co-authors: Giuseppe Lodato [1]; Daniel J. Price [2]; Elena Maria Rossi [3]; David Liptai [2]; Rebecca Nealon [4]

[1] *University of Milan*

[2] *Monash University*

[3] *Leiden Observatory*

[4] *University of Leicester*

In this talk I will describe the gravitational wave (GW) signal from tidal disruption events (TDEs). First of all, I will determine the GW emission from a hot rotating accretion torus, formed after a TDE, that is subject to a specific hydrodynamical instability, called the Papaloizou-Pringle instability (Toscani et al, 2019). This study is performed both through an analytical and a numerical study, using the Smoothed Particle Hydrodynamics (SPH) code PHANTOM (Price et al, 2018). Then, I will talk about the new feature for the calculation of GWs that I have implemented in PHANTOM and that is soon to be released. Finally, I will talk about our new investigation of the GW background associated to TDEs.

32

Baracchi and the Great Melbourne Telescope

Author: Phil Edwards [1]

[1] *CSIRO*

At the first Pietro Baracchi conference, we learned that Baracchi was credited with the discovery of two objects in the New General Catalog (NGC), and while reference was found to another “29 new or not identified [nebulae], found by Mr Baracchi” details of these were not known. In this presentation we will continue this story, learning that one of the two nebulae for which Baracchi is credited is in fact an error, but that Baracchi did indeed discover a number of nebulae with the Great Melbourne Telescope. The reason these discoveries are not more widely appreciated will be considered.

8

Neutrino telescopes in the Mediterranean sea for multimessenger astrophysics

Author: Maurizio Spurio[1]

[1] *University of Bologna and INFN*

Neutrino telescopes aim to help in solving long-standing problems in astrophysics, such as the origin of cosmic rays. High-energy neutrinos of cosmic origin have been recently observed by the IceCube detector in the South Pole. However, the sources and production mechanisms of those neutrinos are still largely unknown. In addition to possible Galactic sources, extragalactic plausible candidates are gamma-ray bursts and active galactic nuclei. Combining neutrino data with electromagnetic measurements and, possibly, gravitational waves in a multimessenger approach will increase our ability to identify neutrino sources.
Neutrino telescopes in the Northern Earth hemisphere are possible only undersea and the transparency of the Mediterranean water allows for a very good angular resolution in the reconstruction of interactions from neutrinos of all flavours. This yields an unprecedented sensitivity in the searches for neutrino sources located in the Southern Sky (including most of the Galactic plane) and in the energy range below 100 TeV.
So far, valuable complementary observations have been performed in the Mediterranean Sea by the ANTARES telescope and constraints have been set on the origin of the cosmic neutrino flux. ANTARES has also actively developed a manifold multimessenger program, both in real time and offline. The high quality of the results obtained with a small detector (compared to IceCube) and the competitiveness of the results achieved demonstrate the tremendous potential of the new, much larger array, KM3NeT, now under construction. ANTARES results and the perspectives for the KM3NeT telescope are highlighted in the presentation.

13

Multimessenger astroparticle physics for testing theories of dark matter and new particles

Author: Pat Scott[1]

[1] *ICL*

I will give an update on the GAMBIT programme of multimessenger joint analyses of particle and astroparticle datasets, for evaluating and comparing different theories for dark matter and new particles. I will touch on supersymmetric, Higgs portal and axion theories, and draw together constraints from direct and indirect dark matter searches, neutrino telescopes, cosmology, solar physics, laboratory experiments and high-energy colliders.

18

Cosmic ray physics in the CTA era

Author: Elena Amato[1]

[1] *INAF - Arcetri*

In this talk I will discuss some of the main open questions in cosmic ray physics that the upcoming Cherenkov Telescope Array is likely to help answer. Gamma-ray photons are a privileged channel

to study cosmic ray physics, since gamma-ray emission associated with neutral pion decay offers the most direct probe of relativistic hadrons.

With its unprecedented sensitivity and spatial resolution over a wide spectral range, CTA will discover many new sources both inside and outside the Galaxy and at the same time allow detailed studies of known sources. We expect its results to have a major impact on our understanding of the origin and propagation of high cosmic rays and to help unveil the processes of particle acceleration in a variety of sources. I will discuss what our expectations are for some of these, including star forming regions, Supernova Remnants, the central region of our Galaxy and, on a much larger scale, Clusters of Galaxies.

12

Connecting radio waves and gamma-rays in extreme astronomical settings

Author: Gavin Rowell[1]

[1] *University of Adelaide*

Radio and gamma-ray astronomy are intimately connected via fundamental processes associated with relativistic particles. Such particles are accelerated in extreme astrophysics settings, for example, supernova remnant shocks, pulsar environments, collimated beams and jets generated by accretion, and extreme stellar winds from massive stars. In this talk I will briefly review these connections using observational examples, and take a look at how the Square Kilometre Array and the Cherenkov Telescope Array will take the next steps into this exciting new era of extreme astronomy.

30

The ASTRI mini-array in the context of gamma-ray astronomy

Authors: Giovanni Pareschi[1]; CTA ASTRI Project[2]

[1] *INAF - Brera*

[2] -

The ASTRI Project aims at the design and development of a technologically innovative solution for small (4 m diameter) and large field of view (about 10 degrees) telescopes, of the same class of the small-size telescopes (SSTs) of the Cherenkov Telescope Array (CTA) devoted to cover the energy band up to 100 TeV and beyond. In the first phase of the project, a SST prototype in a dual-mirror Schwarzschild-Couder (SC) configuration has been installed in Mt. Etna (Italy). The prototype, called the ASTRI-Horn telescope (in honor of the Italian-Jewish astronomer Horn d'Arturo, inventor of the segmented mirror solution for astronomical telescopes), has started its scientific operation in fall 2018 and has provided the first detection of very high-energy (VHE) gamma-ray emission from the Crab Nebula by a Cherenkov telescope in dual mirror configuration. A camera based on SiPM sensor and CITIROC read-out electronic has been specifically developed for the scope. As a continuation of the project, a mini-array of 9 (up to 12) ASTRI SST dual-mirror telescopes is currently being implemented. It will be deployed at the Observatorio del Teide, in the Canary Island of Tenerife in collaboration with IAC. Thanks to its expected overall performance, better than current Cherenkov telescopes' arrays for energies above ˜10 TeV and up to 100 TeV, and its wide field of view, the ASTRI mini-array will be an important instruments to perform soon deep observations of the Galactic and extra-Galactic sky at the TeV energy scale and beyond. Important synergy with already existing IACT and Water Cherenkov facilities in the both northern and southern hemisphere are also foreseen. The ASTRI mini-array will also pave the way to the observations to be done with the CTAO SSTs sub-array at the southern site. In this contribution, we introduce the ASTRI concept in the context

of the CTA Observatory and discuss the scientific prospects of the mini-array in the fields of Galactic and extra-Galactic astrophysics, and fundamental physics.

17

Rapid-response radio follow-up of high-energy astrophysical events

Author: Gemma Anderson[1]

[1] *Curtin University*

Only recently have radio telescopes been capable of automatically responding to transient alerts and multi-messenger events through the use of a rapid-response observing system. Such systems enable telescope to automatically repoint and begin observing an event within seconds to minutes of its discovery, responding to transient alerts broadcast by dedicated telescopes or multi-messenger facilities. Many transients and multi-messenger events are known or predicted to produce early-time radio emission. One of the main targets are gamma-ray bursts (GRBs) detected by dedicated telescopes such as Swift and Fermi. Of particular interest are short GRBs, which have been shown to be linked with merging neutron stars detected by gravitational wave detectors. GRBs are predicted to produce prompt, fast-radio burst (FRB) like signals and longer-lived synchrotron afterglow emission. Nearby rapidly rotating magnetised stars, such as M dwarfts, also produce X-ray/gamma-ray superflares that are detected by Swift and MAXI, which simultaneously emit giant, gyrosynchrotron radio flares. The detection of radio emission from such high-energy transients are crucial for localising events, studying the surrounding environment, probing magnetic fields, studying unusual coherent emission mechanisms, and determining the nature of the remnants from merger and cataclysmic events. Using GRBs and flare stars as an example, I will discuss Australia's effects towards the roboticisation and automation of Australian radio telescopes for transient studies through the use of rapid-response observing systems. These telescopes include the Murchison Widefield Array (MWA) and the Australia Telescope Compact Array (ATCA).

24

Nano-satellites for high energy astrophysics and fundamental physics

Author: Fabrizio Fiore[1]

[1] *INAF - Trieste*

A distributed instrument, such that consisting of nano-satellites carrying simple X-ray detectors, can provide accurate (down to a few arcmin) and prompt (within minutes) localisation of high energy transients, such as gamma ray bursts and the electromagnetic counterparts of gravitational wave events. In addition, once the position of the transient is computed, the signals registered by the different detectors can be realigned in time and added together to improve the statistics. This can allow the investigation of the temporal structure of transients down to the microsecond, providing crucial information on one hand on the physics of the transient inner engine, and, on the other hand, on the granular structure of space-time, through the study of light-travel effects.
The advantages of a distributed instrument based on nano-satellites are: a) modularity, which allows redundancies with the associated lower risks; b) the possibility to expand (and/or improve) the experiment with the time; c) low cost and quick development.
I will present the HERMES Pathfinder project, recently funded by the Italian Space Agency and by a H2020-SPACE grant, which foresees the deployment of a first constellation of six nano-satellites the first years of the next decade, and discuss the synergies with the SkyHopper project.

22

The Transient High-Energy Sky and Early Universe Surveyor (THESEUS)

Author: Lorenzo Amati[1]

[1] *INAF - Bologna*

The Transient High-Energy Sky and Early Universe Surveyor (THESEUS) is a space mission concept currently under Phase A study by ESA as candidate M5 mission, aiming at exploiting Gamma-Ray Bursts for investigating the early Universe and at providing a substantial advancement of multi-messenger and time-domain astrophysics. Through an unprecedented combination of X-/gamma-rays monitors, an on-board IR telescope and automated fast slewing capabilities, THESEUS will be a wonderful machine for the detection, characterization and redshift measurement of any kind of GRBs and many classes of X-ray transients. In addition to the full exploitaiton of high-redshift GRBs for cosmology (pop-III stars, cosmic re-ionization, SFR and metallicity evolution up to the "cosmic dawn"), THESEUS will allow the identification and study of the electromagnetic counterparts to sources of gravitational waves which will be routinely detected in the late '20s / early '30s by next generation facilities like aLIGO/aVirgo, LISA, KAGRA, and Einstein Telescope (ET), as well as of most classes of transient sources, thus providing an ideal sinergy with the large e.m. facilities of the near future like LSST, ELT, TMT, SKA, CTA, ATHENA.