# Vulcano Workshop 2018 - Frontier Objects in Astrophysics and Particle Physics

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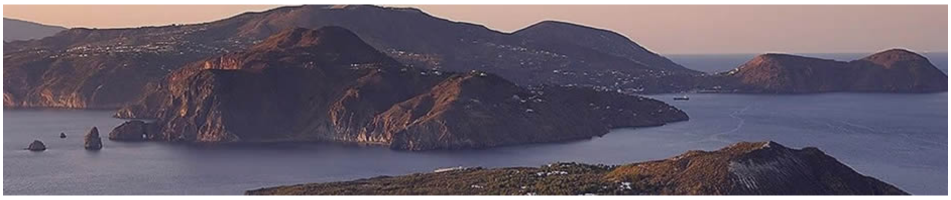

# Book of Abstracts

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# The MIssing Baryon in a Warm-Hot Intergalactic Medium

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It has been known for decades that the observed number of baryons in the local Universe falls about 30-40% short of the total number of baryons predicted by Big-Bang Nucleosynthesis and inferred by density fluctuations of the Cosmic Microwave Background. While theory provides a reasonable solution to this paradox, by locating the missing baryons in hot and tenuous filamentary gas connecting galaxies, it also sanctions the difficulty of detecting them because their by far largest constituent, hydrogen, is mostly ionized and therefore virtually invisible in ordinary signal-to-noise Far-Ultraviolet (FUV) spectra. Indeed, despite the large observational efforts, only a few marginal claims of detection have been made so far. Here we show that the missing baryons are indeed found in a tenuous warm-hot and moderately enriched medium that traces large concentrations of galaxies and permeates the space between and around them. We detect two highly ionized oxygen (OVII) intervening absorbers in the exceptionally high signal to noise X-ray spectrum of a quasar at redshift >0.4. These absorbers lie in regions characterized by large galaxy over-densities. We show that the number of OVII systems detected down to the sensitivity threshold of our data, agrees well with numerical simulation predictions for the long-sought hot intergalactic medium, and its detection adds a fundamental tile to the long-standing missing baryon puzzle.

**1**

# Fast Radio Bursts as cosmological probes

**Author:** Marta Burgay[1]

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In this talk I will review the main observational properties of Fast Radio Bursts, a fast growing family of millisecond-duration extragalactic radio flares, whose origin is still debated. I will report on the latest news, in particular relating on their multiwavelength follow-up and on the possibility to use FRBs as cosmological probes.

**2**

# New physics searches with NA62

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The NA62 experiment at CERN is designed to measure precisely the rare decay $K^+ \to \pi^+ \nu\nu$. The intensity and energy of the primary (proton) and secondary (Kaon) beams, as well as the hermetic detector coverage and overall geometry, give in addition the opportunity to search for hypothesized weakly-coupled particles. I will review these opportunities, present results and sketch the prospects of some pertinent searches.

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## INTEGRAL and GW: the present and future perspectives

**Author:** Pietro Ubertini[1]

**Co-authors:** Angela Bazzano [2]; James Rodi [2]; Lorenzo Natalucci [3]

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The talk will summarize the scientific implication of the INTEGRAL observations of the LVC O2 run and, in particular, of the upper limits for the BH-BH mergers and the detection of the first prompt electromagnetic counterpart coincident with a GW170817.

Authors : UBERTINI, Pietro (IAPS-INAF), BAZZANO, Angela (IAPS-INAF) ; NATALUCCI, Lorenzo (INAF/IAPS) ; RODI, James (IAPS-INAF) et al on behalf of the INTEGRAL GW Team.

**Summary**:

The first detection of the prompt electromagnetic counterpart coincident with a GW170817 has been a forward step in our knowledge of NS-NS merging.
An unexpected result was the extremely low isotropic luminosity of the event relative to other short gamma-ray bursts (SGRBs) with known redshifts, revealing a population of low luminosity SGRBs. The most popular interpretation has been that GRB 170817A was viewed off-axis, rather than that the event had an intrinsically low luminosity. In either case, this
result has spurred off-line searches for SGRBs below instrument trigger thresholds in hopes of finding similar events.
We will present a data set from the INTEGRAL soft gamma-ray detector IBIS/PICsIT (~200 keV - 10 MeV) to corroborate the list of publicly available un-triggered SGRB candidates reported by Fermi/GBM.

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## Spectral features in galactic cosmic rays

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Recent results by space borne experiments took cosmic ray data to a precision level. These new results are now able to challenge the conventional scenarios for cosmic ray production and acceleration in the Milky Way, also leaving the room for new, exotic sources.
In this talk we will give an overview of the latest results of the cosmic ray fluxes, and some possible interpretations will be discussed, for both primary and secondary species. These measurements have a common feature, namely the presence of unexpected and still not yet fully understood spectral features.

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## AGN outflows as accelerator of CRs and neutrinos

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**Co-authors:** Antonio Stamerra [2]; Dafne Guetta [3]; Fabrizio Fiore [4]; Lucio Angelo Antonelli [5]; Nicola Menci [6]

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Various observations are revealing the widespread occurrence of mildly relativistic wide-angle AGN outflows, likely launched from accretion disks around supermassive black holes, and interacting strongly with the gas of their host galaxy.
During the interaction, strong shocks are expected to form that can accelerate relativistic particles. The interactions of shock-accelerated particles with surrounding interstellar medium can generate gamma-rays and neutrinos via the decay of neutral and charged pions generated in inelastic proton-proton collisions.
I will show the predictions for the cumulative gamma-ray and neutrino emission from AGN outflows obtained by a state-of-the-art semi-analytic model of galaxy formation.
This is based on galaxy interactions as triggers of AGN accretion and on expanding blast wave as the mechanism to communicate outwards the energy injected into the interstellar medium by the active nucleus. I will compare the model predictions with the most recent Fermi and IceCube data.

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# The g-2 experiment at Fermilab: Run 1 Status and Perspectives

**Author:** Marco Incagli[1]

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The Muon g-2 experiment at Fermilab will measure the anomalous magnetic moment of the muon to a precision of 140 parts per billion, which is a factor of four improvement over the previous E821 measurement at Brookhaven. The experiment will also extend the search for the muon electric dipole moment (EDM) by approximately two orders of magnitude. Both of these measurements are made by combining a precise measurement of the 1.45T storage ring magnetic field with an analysis of the modulation of the decay rate of the higher-energy positrons from the (anti-)muon decays recorded by 24 calorimeters and 3 straw tracking detectors. The current status of the experiment as well as results from the first months of data taking will be presented.

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# Neutrinos in the Multimessenger Era

**Author:** Claudio Kopper[1]

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With the recent discovery of high-energy neutrinos of extraterrestrial origin by the IceCube neutrino observatory, neutrino astronomy is entering a new era. The highest-energy neutrinos observed to date exceed 1 PeV in energy, a regime of particular interest because the neutrinos should point back to the still elusive accelerators of the highest energy Galactic and extragalactic cosmic rays. This talk will cover currently operating and future high-energy neutrino detectors in water and ice, the latest results from searches for a flux of extraterrestrial neutrinos and current efforts in the search for steady and transient neutrino point sources. Special emphasis will be given to multimessenger aspects connecting neutrino, gamma ray, and cosmic-ray observations.

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## Search for Dark Matter at the LHC

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Investigating the origin of Dark Matter, so far observed only through its gravitational interaction, is one of the most important goals of the LHC. Indeed, the ATLAS, CMS and LHCb experiments have a vast and diverse program of analyses related to Dark Matter.
I will briefly review the latest results in LHC searches for events with missing energy plus a single object (jet, Z, Higgs, top quark) and also in other searches related to DM, such as those for light mediators (dark bosons) and for particles belonging to a dark sector. I will try to give a broad overview of the LHC contributions to this field and put the accent on new experimental signatures.

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## Overview of ASI science missions

**Author:** Elisabetta Cavazzuti[1]

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In this talk I will go through the current operating science missions and experiments to which ASI participates and which are giving relevant contributions to the astrophysics and particle physics. Starting from PAMELA via AMS to CALET in the cosmic rays study and starting from INTEGRAL via Swift, AGILE, Fermi, NuSTAR in the high energy astrophysics branch. I will discuss also the future opportunities in these science fields.

**10**

## K+→π+νν: First Result from the NA62 Experiment at CERN

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The decay K+→π+νν, with a very precisely predicted branching ratio of less than 10^(-10), is one of the best candidates to reveal indirect effects of new physics at the highest mass scales. The NA62 experiment at CERN SPS is designed to measure the branching ratio of the K+→π+νν with a decay-in-flight technique, novel for this channel. NA62 took data in 2016, 2017 and another year run is scheduled in 2018. Statistics collected in 2016 allows NA62 to reach the Standard Model sensitivity for K+→π+νν, entering the domain of 10^(-10) single event sensitivity and showing the proof of principle of the experiment. The preliminary result on K+→π+νν from the analysis of the 2016 data set is presented and prospects for future reviewed.

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## Results from the first experiments of the JEM-EUSO program

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The origin and nature of Ultra-High Energy Cosmic Rays (UHECRs) remain unsolved in contemporary astroparticle physics. To give an answer to these questions is rather challenging because of the extremely low flux of a few per km^2 per century at extreme energies such as E > 5 × 10^19eV.
The objective of the JEM-EUSO program, Extreme Universe Space Observatory, is the realization of a space mission devoted to scientific research of cosmic rays of highest energies. Its super-wide-field telescope will look down from space onto the night sky to detect UV photons emitted from air showers generated by UHECRs in the atmosphere.
The JEM-EUSO program includes different experiments using fluorescence detectors to make a proof-of-principle of the UHECR observation from space and to raise the technological level of the instrumentation to be employed in a space mission.
EUSO-TA, installed at the Telescope Array site in Utah in 2013, is in operation. It has already detected 9 UHECRs in coincidence with Telescope Array fluorescence detector at Black Rock Mesa.
EUSO-Balloon flew on board a stratospheric balloon in August 2014. It measured the UV intensity on forests, lakes and the city of Timmins as well as proved the observation of UHECR-like events by shooting laser tracks.
EUSO-SPB was launched on board a super pressure balloon on April 25th and flew
for 12 days. It proved the functionality of all the subsystems of the telescope
on a long term; observed the UV emission on oceans and has a self-trigger system
to observe UHECRs with energy E > 3x10^18 eV.
TUS, the Russian mission on board the Lomonosov satellite in orbit since April
28th 2016, is now included in the JEM-EUSO program and has detected so far in
the UHECR trigger-mode a few interesting signals.
Mini-EUSO is in its final phase of integration in Italy, where several performance tests are being held. Mini-EUSO will be installed inside the International Space Station (ISS) in late 2018 or early 2019.
During this contribution I will summarize the main results obtained so far by such experiments and put them in prospect of future space detectors such as K-EUSO and POEMMA.

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## Update on the Measurement of the Full-sky Anisotropy of Cosmic Rays with IceCube and HAWC

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We present updated results on the joint analysis of the arrival direction distribution of Galactic cosmic rays by the High-Altitude Water Cherenkov (HAWC) Observatory (located at 19° N) and the IceCube Neutrino Observatory (located at 90° S). We describe the methods used to combine the IceCube and HAWC data, including an improved reconstruction method that can recover the amplitude of large-scale angular features that are attenuated by a limited field of view at mid latitudes. We also address the individual detector systematics and study the region of overlapping FoV between the two observatories. The combined analysis eliminates biases introduced by partial sky coverage that result in strong correlations between different multipole modes $C_\ell$. The updated results include a combined sky map and an all-sky angular power spectrum in the overlapping energy range of the two experiments at around 10 TeV for angular scales down to $\sim 15°$ using data collected by the HAWC Observatory and data from the IceCube Observatory.

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# Low energy solar neutrinos with Borexino

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Low energy solar neutrinos, fundamental for the discovery of the neutrino flavour oscillation, are a unique tool to investigate the nuclear reactions that fuel the Sun. The Borexino experiment, based on a 270 ton ultra-pure liquid scintillator detector at Laboratori Nazionali del Gran Sasso, was conceived to measure solar neutrino fluxes in the MeV and sub-MeV energy range. The data taking started on 2007 and thanks to the unpreceded level of radio-purity achieved in the inner part of the detector, a real time spectroscopy of the main components of the pp chain was possible. After a purification process, in the phase II data, the simultaneous fit of all the pp-chain components was performed and the interaction rates of pp, 7Be and pep were extracted with the highest precision to date. In addition, the 8B neutrinos were measured with the lowest-threshold and a limit on the hep neutrino flux was also set. In the talk, after a description of the main properties of Borexino detector, the analysis of the phase II data will be explained and the new results on the low energy solar fluxes will be shown as well as their implications on the survival probability of solar electron neutrinos at different energies.

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# Highlights from AGILE

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AGILE is an Italian Space Agency (ASI) space mission devoted to gamma-ray observations in the 30 MeV-50 GeV energy range, with simultaneous X-ray imaging in the 18-60 keV band. Launched in April 2007, the AGILE satellite is in its 11th year of operations in orbit, and it is substantially contributing to improve our knowledge of the high-energy gamma-ray sky. I will summarize some

AGILE highlights, focusing in particular on compact objects emitting broad-band non-thermal electromagnetic radiation, also believed to be emitters of
other multi-messenger signals, such as cosmic rays, neutrinos, and gravitational waves.

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## The muon collider, status and prospects

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Muon-based accelerators have the potential to enable facilities at both the Intensity and the Energy Frontiers in Particle Physics. A Muon Collider has the ability to study the direct (s-channel) production of scalar resonances like the Higgs boson while extending operations to a multi-TeV energy region enables a new field of measurements and discoveries. The traditional approach for these machines is based on the production of muons by means of an intense proton source. One of the most critical issues of this design is the cooling of the muons emerging from the hadronic interactions in the target. An alternative approach is based on muon pair production by a positron beam impinging on electrons at rest in a target. The main advantage of the new scheme is that the muons produced in the process at threshold are constrained into a very small longitudinal and transverse phase space region. This approach still needs to be verified with extensive studies and tests. Muon decays in the ring impact both the magnet and shielding design of the collider itself as well as backgrounds in the detector. Progress in muon accelerator designs has advanced steadily in recent years and therefore a muon collider appears more feasible in our future.

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## my title

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my abstract

**17**

## Origin of heavy elements from Neutron Star Mergers, lessons from GW170817

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The first gravitational-wave detection of the merger of a neutron star binary (GW170817) corroborated many theories on the nature of these events while at the same time, displaying a number of surprises. Although long-believed to be an engine for gamma-ray bursts, the off-angle detection of

gamma-rays suggests a wider jet opening angle than previously believed. Similarly, the inferred rate of mergers and the detection of optical and infra-red from the ejecta (so-called kilonova or macronova emission), demonstrated the importance of these mergers in producing r-process elements. But the strong optical emission suggests that the ejecta is not limited to pure r-process elements, and these mergers now suffer from some of the same issues supernovae have in explaining the r-process.

I will review what we know of r-process production from both theory and observations of the GW170817, discussing the differences between neutron star mergers and supernovae in the production of r-process elements. From this work, we can begin to address the successes and challenges of this important site of r-process production.

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# Recent results from the TUS/LOMONOSOV Space Mission

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TUS (Tracking Ultraviolet Set-up) is the first orbital detector of extreme energy cosmic rays (EECR). It was launched into orbit on April 28, 2016, as a part of the scientific payload of the Lomonosov satellite mission. The detector is aimed to test the technique of measuring UV fluorescent and Cherenkov radiation of extensive air showers (EAS) generated by primary cosmic rays with energies above 50 EeV. The TUS detector is a UV telescope looking in the nadir direction from the altitude of ~500 km. It consists of a 2 m2 mirror and a 256-pixel photo detector and has a ±4.5° field of view with 5×5 km2 spatial resolution in the atmosphere. During more than a year of operation, a number of EAS-like events were measured by the detector. Some of them are caused by atmospheric phenomena of anthropogenic sources, some are considered as EAS candidates. We report results of a search for EAS-like events in the TUS data and their analysis with an emphasis on a strong EECR candidate registered on October 3, 2016. Conditions of the measurements were studied to exclude thunderstorm atmospheric events. An arrival direction and energy of a primary particle were estimated basing on results of extensive simulations and new reconstruction algorithms.

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# Highlights from ATLAS and CMS

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After a brief description of the ATLAS and CMS detectors and their performance during the last year data taking, the main focus of the talk will be on

the latest physics results.

In particular, most recent measurements on the Higgs production and its decays, including differential measurements, will be illustrated together with selected topics on searches for new physics.

A very brief discussion of the upgrade programs of the two collaborations for the Hi Luminosity phase of LHC will be presented.

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## Radio counterparts of GW events

**Author:** Alessandra Corsi[1]

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On 2017 August 17, the field of gravitational-wave (GW) astronomy made the big leagues with a dazzling discovery. After several GW detections of black hole (BH)-BH mergers with no convincing electromagnetic counterparts, advanced LIGO and Virgo scored their first direct detection of GWs from a binary neutron star (NS) merger, an event dubbed GW170817. Soon after the GW discovery, GW170817 started gifting the astronomical community with an electromagnetic counterpart spanning all bands of the spectrum. In this talk, I will review what we have learned from GW170817 focusing on the radio band, what questions remain open, and what are the prospects for future EM-GW studies of the transient sky.

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## Addressing the missing matter problem in galaxies through a new fundamental gravitational radius

**Author:** Salvatore Capozziello[1]

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We demonstrate that the existence of a Noether symmetry in extended theories of gravity gives rise to a further gravitational radius, besides the standard Schwarzschild one, determining the dynamics at galactic scales. By this feature, it is possible to explain the baryonic Tully-Fisher relation, the rotation curve of gas-rich galaxies, and the features of fundamental plane of ellipticals without the dark matter hypothesis.

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## Constraining Dark Matter models with extremely distant galaxies

**Author:** Marco Castellano[1]

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The investigation of distant galaxy formation and evolution is a powerful tool to constrain dark matter scenarios, supporting and in some cases surpassing other astrophysical and experimental probes. The recent completion of the Hubble Frontier Field (HFF) programme combining ultra-deep Hubble Space Telescope observations and the magnification power of gravitational lensing produced by foreground galaxy clusters has enabled the detection of the faintest primordial galaxies ever studied. In this talk I will show how the number density of such primordial galaxies enables to constrain a variety of DM models alternative to CDM. In particular, it provides stringent limits on the mass of thermal WDM candidates, and on the parameter space of sterile neutrino production models, and

other DM scenarios featuring particles in the keV mass range which is also supported by recent detections of a 3.5keV X-ray line.

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## Multi-Messenger Astronomy with High-Energy Photons

**Author:** Jordan Goodman[1]

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Understanding the most energetic events in the Universe requires that we study them all the tools available to us. The means using the electromagnetic spectrum from radio to the highest energy gamma-rays, neutrinos, and gravitational waves. Wide-field instruments such as LIGO, IceCube, Fermi, SWIFT, and HAWC can provide prompt detection of events that can be followed up by pointed instruments. In this talk, an overview of the HAWC instrument will be presented including recent results on transient studies and follow-ups of neutrino and gravitational events will be presented.

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## ANTARES and KM3NeT experiments: status and future developments

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The ANTARES detector, located 40 km off the French coast, with an instrumented volume of more than 0.01 cubic kilometres, is the largest neutrino telescope in the Northern Hemisphere and the first one to be operated in the deep sea. It has been taking data continuously since 2007. The primary goal of such a telescope is to search for astrophysical neutrinos in the TeV-PeV range. The latest results from ANTARES will be presented, including a search for the diffuse cosmic neutrino flux as well as more specific searches for astrophysical sources such as Active Galactic Nuclei or Galactic sources.

The next-generation neutrino telescope in the Mediterranean, KM3NeT/ARCA, is currently under construction 80 km offshore Capo Passero, Sicily (Italy). It will consist of an instrumented volume several hundred times larger than ANTARES.

The second branch of KM3NeT, ORCA, to be deployed not far from the ANTARES site, aims instead to address the long-standing unsolved question of whether the neutrino mass ordering is normal or inverted by measuring matter oscillation effects with atmospheric neutrinos.

ARCA and ORCA exploit the same technological solutions, based on a pioneering design of a multi-PMT optical module. The construction of the two detectors has started. First results from both experiments, as well as the potential for their respective scientific goals, will be illustrated.

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## A review on neutrinoless double beta decay

**Author:** Stefano Dell'Oro[1]

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The current status of the neutrinoless double beta decay (0νββ) search is summarized, exploiting the up-to-date knowledge of the oscillation parameters and of the recent theoretical developments in the understanding of the 0νββ process, especially those concerning the nuclear description and its limitations. This also allows to infer expectations and uncertainties for the experimental search for the 0νββ.
The strong relevance of post-Planck cosmological analyses for the study of 0νββ is pointed out. Several combinations of data probing different scales indicate very stringent bounds on the sum of the active neutrino masses, Σ. These developments have just become very relevant for numerous laboratory investigations including the ones for the 0νββ search.
Finally, aiming at the neutrino mass hierarchy discrimination, the requirements in terms of exposure, background index and energy resolution for a next (or next-to-next) generation 0νββ experimentare highlighted.

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## Status of the LHAASO experiment

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The Large High Altitude Air Shower Observatory (LHAASO) is under construction at the Mountain Haizishan (4410m a.s.l.), Sichuan Province, China. LHAASO comprises of 4 major kinds of detector arrays, such as the Electro-magnetic particle Detector (ED) array, the Muon Detector (MD) array, the Water Cherenkov Detector Array (WCDA), and the Wide-Field-of-view air Cherenkov Telescope Array (WFCTA). By the end of 2018, a quarter of the whole detector arrays will be deployed and operated, since then some interesting astronomical objects can be observed and some observation results can be obtained. In this talk, the physics and the design of the LHAASO detectors is briefly introduced, the construction status is demonstrated, and some of the near-term targets of opportunity are anticipated.

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## Fermi-GBM highlights in the Era of Gravitational-Wave Astronomy

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The Fermi Gamma-Ray Burst Monitor (GBM) is the secondary instrument onboard the Fermi mission, which is celebrating its 10-yrs anniversary in Space in 2018. Fermi-GBM has a wide field of view, high uptime, and both in-orbit triggering and high time resolution continuous data acquisition, thus enabling offline searches for weaker transients. Fermi-GBM triggered on more than 2300 Gamma-Ray Bursts (GRBs), but also on many soft gamma-ray repeaters, X-ray bursters, solar flares and terrestrial gamma-ray flashes. At the dawn of Multi-Messenger era, Fermi-GBM started providing context observations and follow-ups of gravitational wave events detected by LIGO/Virgo.
In this talk, I will give a broad overview of the main Fermi-GBM results obtained during its first 10

years of operation, focusing on its key role in the Era of Gravitational-Wave Astronomy, and on its highlights collected during the last 3 years, in particular during the O1 and O2 observation runs of LIGO/Virgo.

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## The PTOLEMY project: from an idea to a real experiment for detecting the Cosmological Relic Neutrinos

**Author:** Marcello Messina[1]

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The first part the seminar will be about a novel idea for the detection Cosmological Relic Neutrinos (CRN) and more in general, for the detection of neutrinos of vanishing energy. This idea is described in detail in the paper [1]. The method is based on the fact that neutrino interactions on beta-instable nuclei have the key feature of requiring no energy threshold for the neutrino interaction. Some phenomenological aspects will be presented.
The second part of the seminar will be dedicated to the PTOLEMY project, in a starting phase at the Laboratori Nazionali del Gran Sasso. In this project we aim at demonstrating the detection principle of the CRN and finalize the design of the future full scale experiment. The technologies on which the detector concept is based will be presented and the key features explained.

[1] A. Cocco, G. Mangano and M. Messina, "Probing Low Energy Neutrino Backgrounds with Neutrino Capture on Beta Decaying Nuclei,"
Journal of Cosmological and Astroparticle Physics 0706 15 (2007).

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## Cosmic Rays in the Multimessenger Era

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The Cosmic Ray (CR) physics has entered a new era driven by high precision measurements coming from direct detection (especially AMS-02 and PAMELA) as well as gamma-ray observations (Fermi-LAT). In this talk I will focus on how such data impact the understanding of the supernova remnant paradigm for the origin of CRs. In particular I will discuss advancements in the field concerning the three main stages of the CR life: the acceleration process, the escape from the sources and the propagation throughout the Galaxy. I will also comment on the impact that CRs can have in the Galactic dynamics.

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## Cosmic Ray Anisotropy with the IceCube Observatory

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The IceCube Observatory is a neutrino telescope deployed at the geographic South Pole, aimed to detect and identify high energy neutrinos of astrophysical origin. IceCube is also able to detect cosmic rays with the 1 km^3 neutrino telescope buried 2500 meters under the Antarctic ice and with a dedicated 1 km^2 surface array. IceCube has analyzed data over the last several years to determine, for the first time, the tiny anisotropy of cosmic ray arrival direction distribution. e anisotropy shows a complex angular structure and a strong energy dependence from 10 TeV to a few PeV per particle. TeV cosmic ray anisotropy is being investigated as a possible new probe into the properties of the local interstellar medium and the heliosphere. Its astrophysical reaches are also being investigated.

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## Observations of HE Neutrino in a multimessenger approach

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The SKK measured fluxes of solar neutrinos are the first example of the possible use of neutrino fluxes to identify, and locate, a neutrino source. The detection of neutrinos originated in the SN_1987-A as a counterpart of its optical observation has been the first example of a multi-messenger event. High Energy neutrino astronomy has been proposed, and after the IceCube discovery of the extragalactic neutrino flux is now a reality, to enlarge the visible horizon searching for the sources of the most energetic Cosmic Rays observed so far. ANTARES, and KM3NeT in the near future, are complementing in the North Hemisphere the IceCube experimental effort. The joint observation of astrophysical sources by four different messengers, electromagnetic radiation, Cosmic Rays, Neutrinos and eventually gravitational waves will not only allow to identify the sources but also to understand their nature, the acceleration mechanisms. Different messengers can be originated by different astrophysical processes, and thus their presence/absence carry important information about the sources. A description of the present and future search for H.E. neutrinos in the contest of the multi-messenger approach, will be presented.

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## Testing gravity with Gaia

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As of April 25th the second release of the Gaia catalogue (DR2) becomes available to the scientific community worldwide. It contains the five-parameter astrometric solution (positions on the sky, parallaxes, and proper motions) for more than 1.3 billion sources, with a limiting magnitude of $G = 21$ and a bright limit of $G \approx 3$, and median radial velocities for more than 7.2 million stars. The uncertainties of the DR2 astrometry is still too low to detect clearly relativistic effects associated to the received null geodesic from within the multi-gravitational fields of the Solar System. However, a method of differential astrometry applied to the data appears capable of spotting the complex light deflection by Jupiter; and this technique could be extended to consider passing gravitational waves which affect photon propagation.

Moreover, the independent astrometric solution underway at the Italian data processing center in

Turin (DPCT), for verification purposes, is based on a precise general relativistic treatment of the data that implements, in a sophisticated computing infrastructure, theoretical models for the observables and the observer.

This implies that the Gaia catalogue delivers a relativistic kinematic as far as the five-parameter astrometric solution is concerned demanding, for the sake of consistency, a relativistic dynamics for the Galaxy whose structure, formation, and evolution is Gaia's main goal.

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# LATTES: a Southern window to the extreme Universe

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LATTES, the Large Array Telescope for Tracking Energetic Sources, is being designed to be a detector sensitive to gamma rays with energies in the range from 100 GeV all the way up to 100 of TeVs, operating day and night, with a large field of view. The detector, to be installed at altitudes of about 5.000 m a.s.l. in the Andes mountains in South America, is based on a novel concept to detect air showers, combining the time resolution and space granularity of Resistive Plane Counters (RPCs), with the calorimetric sensitivity of Water Cherenkov Detectors (WCD). Although it has limited resolution in energy and direction as compared to Imaging Air Cherenkov Telescopes, such as CTA, its UPTIME and wide field of view make it an early-warning system for transients, being able to trigger and observe long-term variable sources, or short such as gamma-ray bursts or gravitational waves. This detector is complementary to the Cherenkov Telescope Array (CTA), to be installed in Chile. In this talk a description of its main components, as well as the strategies to select the site for this detector will be given. The full simulation of the detector show the performance of each of its parts, leading to the expectation that it can detect a source fainter than the Crab Nebula, emitting at 100 GeV, with a 5 σ significance, by running for one year. Above 1 TeV it could detect a source as faint as 10% of that.

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# Recent Results from the High Altitude Water Cherenkov (HAWC) Observatory

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“The HAWC Observatory: Detecting the Highest Energy Gamma-Rays”

The High Altitude Water Cherenkov (HAWC) is a continuously operating (>95% on-time), wide field-of-view (~2 sr) observatory located at 14000’ above sea level near Puebla, Mexico. HAWC observes ~2/3 of the sky each day and had detected nearly 50 sources of which about one quarter were previously unknown. Several of these sources have emission > 50 TeV. Most of the sources are within the Galactic plane. Of particular interest are the nearby pulsar wind nebulae Geminga and PSR B0656+14 which are postulated to produce high energy positrons at Earth. HAWC’s wide field of view allows measurement of the angular extent out to several degrees thereby constraining the diffusion of positrons away from their sources. The resulting diffusion is much slower than previously assumed and thus the contribution to the local positrons is reduced. Also, within the region surveyed by HAWC are many dark matter rich objects, such as dwarf spheroidal galaxies, and these HAWC data place some of the strongest constraints to date on annihilating or decaying dark matter with masses >10 TeV.

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# The Pierre Auger Observatory: an ultra-sensitive facility measuring extremely energetic particles.

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The most energetic particles ever detected can impose several constrains on our understanding of Nature. However, the most fundamental human questions in the context of ultra-high energetic particles have not been satisfactorily answered yet: Where do they come from? What are they? How are they created? In the last decade, the Pierre Auger Observatory has allowed us to progress decisively in the direction of solving these puzzles. The data measured by the Observatory confirmed with unprecedented statistics a suppression of the flux at the highest energies, showed a very strong limit of neutrinos and photons, determined an unexpected and very firm increase of the mean mass of the primary cosmic rays with energy, proved an excess of muons in comparison to hadronic interaction predictions and demonstrated a very isotropic distribution of sources in the Universe however with a small large-scale dipolar anisotropy for energies above 8x10^{18} eV. This last result indicates that these particles are extragalactic, which solves a century-long controversy. In this talk, we will review these results achieved by the Pierre Auger Observatory and we will discuss the new targets its upgrade named AugerPrime aims at.

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# Direct measurements of Cosmic Rays

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With precision instruments like CALET, DAMPE and AMS in space a plethora of new experimental data from direct cosmic ray measurements has become available in recent years.
The precision of the measurements reveals many unexpected features, some of which challenge our current understanding of cosmic ray acceleration and galactic transport.
This talk provides an overview over some of the most exiting and often surprising results from the first 7 years of AMS data dating on ISS as well as the first results from CALET, DAMPE and other

experiments. I will briefly discuss their impact on our understanding of the origin and transport of galactic cosmic rays and give an outlook to future prospects.

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## Gamma ray Physics in the Fermi era

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After almost 10 years of data taking by the Large Area Telescope on board the Fermi Gamma-ray Space Telescope, we present an overview of the current status of high-energy gamma-ray astrophysics. Particular emphasis will be given to the broad range of time-domain astrophysics topics studied by the LAT and to the increasingly important multimessenger connections involving gamma-ray sources.

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## The AHEAD program for Integrating Activities in High Energy Astrophysics

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Since 2015, AHEAD (Integrated Activities in the High Energy Astrophysics Domain) is providing a framework to bring together Europe's science community working in this highly competitive field. AHEAD is an ongoing project funded by the EU Horizon 2020 programme for Research Infrastructures, with the main goal of integrating efforts by the European science community and keeping them at the cutting edge of science and technology.
The landmark for AHEAD is the future Large X-ray Observatory, Athena. Besides its substantial technology development program, AHEAD is offering funding opportunities for transnational visits, workshops and dissemination activities and a strong public outreach program. Much effort is also devoted to the exploitation of current space missions with the organization of meetings, schools and training activities and enhancing gamma-ray science.

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## Dark Matter Direct Detection

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Dark Matter is one of the most challenging puzzles of modern physics. Its undisputable evidence so far comes solely from its gravitational interaction, but it is believed to have particle nature. The Weakly Interacting Massive Particle (WIMP) still remains the best-motivated candidate. After a brief

introduction and motivation to the WIMP paradigm, the WIMP direct detection principles will be explained, and a review of the leading experiments and their recent results will be given.

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## Dark photon searches and the PADME experiment

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While accelerator particle physics has traditionally focused on exploring dark matter through high energy machines, inspired by the WIMP paradigm, testing dark-sectors hypothesis requires innovative low energy and high intensity beams.
This scenario offers attractive opportunities to low energy machine and small size experiments with high sensitivity detectors. In this paper we will focus our attention on the Dark Photon (DP) scenario, reviewing the current status of searches and new opportunities, with particular attention to the PADME experiment at Laboratori Nazionali di Frascati.

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## A review of stellar nucleosynthesis

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Understanding stellar nucleosynthesis requires expertise in stellar modelling and nuclear physics. Hints and constraints to the nucleosynthesis models come from atmospheric abundance analysis of different stars, as obtained by means of high resolution spectroscopy, and measurements of solar (and pre-solar) composition, as obtained by combining, beside solar spectroscopy, the abundance analyses of planets, minor bodies and, in particular, meteorites. Eventually, chemical evolution models coupled to abundance determinations of the interstellar gas may provide additional constraints.
In this review I will introduce the methods currently adopted to calculate stellar chemical yields and I will discuss the present limits and future developments.

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## The initial mass - compact remnant relation as a function of mass, metallicity and initial rotation velocity.

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I will discuss the range of possible masses of the remnants that are left by the explosion of a massive stars as well as current uncertainties in their estimates. I will show that current stellar models easily predict masses in the range of those observed by the LIGO-VIRGO collaboration

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## Future collider projects at CERN

**Author:** Lucie Linssen[1]

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In this talk an overview will be given of the future pp and e+e- collider studies currently hosted by CERN: FCC-hh, FCC-ee, HE-LHC and CLIC. For each of the projects the current status of the accelerator design and the corresponding performance parameters will presented. Similarly, the current baseline designs of the detectors and their performance will be shown. Highlights of the physics potential will be presented for each of the facilities.

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## Hints on the nature of DM from gravitational lensing

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Strong gravitational lensing, in which light is bent and distorted by massive objects, provides a powerful probe into the dark Universe. I will discuss strong gravitational lensing constraints on the abundance and mass of massive compact objects, as well as on the halo mass function and the free-streaming length of particle dark matter. I will conclude by describing how the next generation of telescopes will enable several orders of magnitude improvement in the mass sensitivity of these measurements.

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## The Cherenkov Telescope Array Project: current status and science goals

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The Cherenkov Telescope Array (CTA) will be the next generation gamma-ray observatory, open to the scientific community, to investigate the very-high-energy emission from a large variety of celestial sources in the 20 GeV - 300 TeV energy range. The full array, distributed over two sites, one in the northern and one in the southern hemisphere, will provide whole-sky coverage and will improve the sensitivity with respect to the current major arrays such as H.E.S.S., MAGIC and VERITAS by a factor of five to twenty, depending on the energy. CTA will investigate a much higher number of already known classes of sources, going to much larger distances in the Universe. Along with accurate variability and spatially-resolved studies, these improvements will also enable population studies. Moreover, new light will be shed on new classes of TeV sources, such as GRBs and clusters of galaxies. Furthermore, by pushing the high-energy limit to E > 100 TeV, CTA will allow a thorough exploration of the cut-off regime of the cosmic accelerators. The search for an annihilation signature of dark matter in the Galactic halo and in prominent dwarf spheroidal galaxies is one of the most important goals of CTA. We review the current status of the CTA project, introducing

the highlights from the telescope prototypes and discuss the main CTA Key Science Projects, which will focus on major scientific cases, allowing us to provide legacy data sets of high value to a wider community.

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## Welcome address

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## Introduction to GW and Gravity

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## The dawn of Gravitational Waves Astromomy

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## Formation of stellar BHs and origin of binary sistems

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## Multimessenger Astrophysics: The new era of GWs

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## Neutrinos in the multimessenger era

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## Discovery of the X-ray counterpart and the GW - GRBs connection

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## Origin of heavy elements from GW events

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## Theory of off-axis GRBs and GW events

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## Testing gravity with the BepiColombo mission

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## Stellar Nucleosyntesis

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## BBN, Neutrinos and Nuclear Astrophysics

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## The connection between gamma rays and CRs

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## AGN outflows as accelerator of CRs and neutrinos

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## CALET Experiment

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## Detection and origin of Fast Radio Bursts

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## Recent results from the TUS/LOMONOSOV Space Mission

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## Hints on the nature of DM from gravitational lensing

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## Constraints on the nature of DM from the abundance of extremely distant galaxies

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## Low energy solar neutrinos with Borexino

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## Flaring blazar and high-energy neutrinos

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## Nucleus-Nucleus interactions at LHC and in cosmic rays

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## AHEAD, High Energy Astrophysics H2020 infrastructure

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## Beyond Einstein's Gravity

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## Emission of Gravitational Waves from the BH coalescence

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## Radio counterparts from GW events

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## Search for dark matter at LHC

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## Search for dark matter at fixed target, status and prospects

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## The Muon g-2 experiment at Fermilab

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## Dark sector in accelerators

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## Results and future projects on KL–>pinunu

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## The Research Activities within CERN Neutrino Platform

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