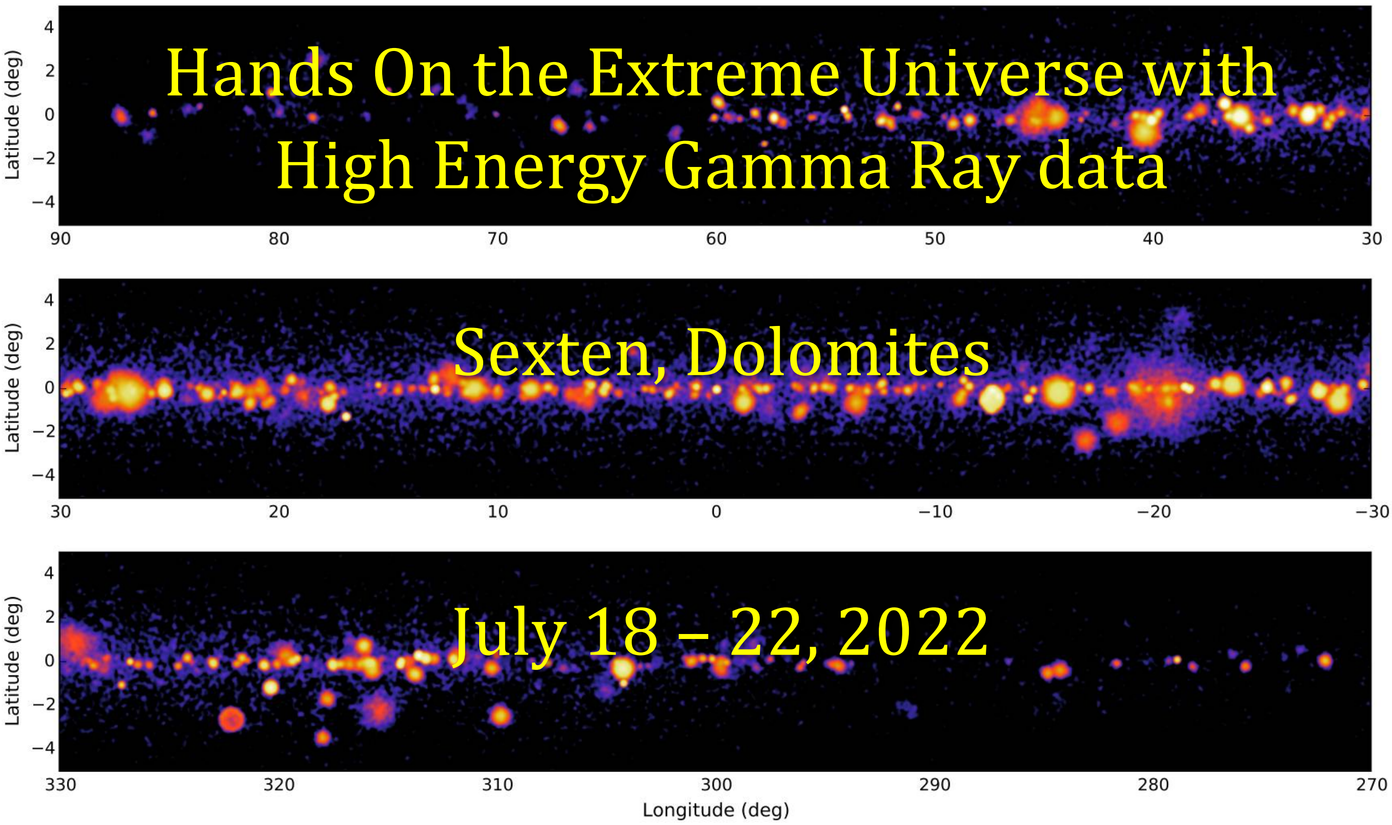
SEXTEN CENTER FOR ASTROPHYSICS

Hands On the Extreme Universe with High Energy Gamma Ray data

Sexten, Dolomites

July 18 – 22, 2022

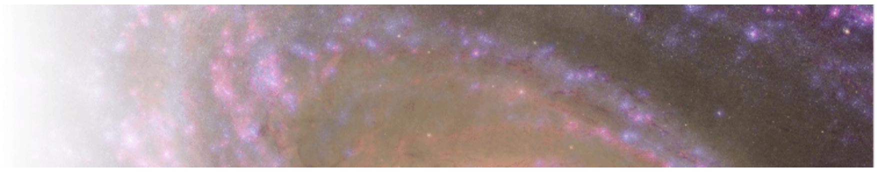


Abstract booklet

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

INFN Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ DEGLI STUDI DI TRIESTE



FINAL SCIENTIFIC PROGRAM

Hands-on the Extreme Universe with High Energy Gamma-ray data

Monday 18.07.2022

The Extreme Universe

- 10:00 – 10:30 The Fermi view of the High Energy sky -- G.Principe
- 10:30 – 11:00 From the current IACT to CTA – W.Hofmann

Coffee Break

- 11:30 – 12:00 Ground-based gamma-ray astronomy with LHAASO – G. Di Sciascio
- 12:00 – 12:30 Science with the Cherenkov Telescope Array Observatory: a general introduction – F. Longo
- 12:30 – 13:00 Introduction to the ASTRI Science goals – A. Giuliani

Next generation IACT telescopes

- 15:00 – 15:30 The CTA LST Project and Science – M.Teshima
- 15:30 – 16:00 Medium Sized Telescopes for the Cherenkov Telescope Array – J.F. Glicenstein

Coffee Break

- 16:30 – 17:00 The prototype Schwarzschild Couder Telescope: a Medium-Sized Telescope for the Cherenkov Telescope Array -- E.Bissaldi
- 17:00 – 17:30 The development of ASTRI telescopes from ASTRI-HORN prototype to ASTRI-Mini Array and CTA-SST-- G.Sironi
- 17:30 – 18:00 Introduction to Gammapy – G.Rodriguez

Tuesday 19.07.2022

Theory of Very High Energy Sources

- 09:00 – 09:45 UHECR propagation in the extragalactic space – D.Boncioli
- 09:45 – 10:30 Emission processes in Blazars – F.Tavecchio
- 10:30 – 11:15 High Energy processes in GRB – D.Miceli

Coffee Break

- 11:45 – 12:30 From Pulsar to PWNe – G.Morlino
- 12:30 – 13:15 ALPs and polarisation – G.Galanti

Tutorials

- 15:00 – 16:00 The Communication as a bridge between Science and Society – R.Spiga

Coffee Break

Gammapy tutorial – I

- 16:30 – 18:30 Tutorial on gammapy for CTAO – F.Pintore, G.Rodriguez, G.Principe

Evening event: Summer night sky observation

Wednesday 20.07.2022

Science with Cherenkov Telescopes

- 09:00 – 09:30 Multimessenger searches of transient sources with Cherenkov telescopes – A. Berti
- 09:30 – 10:00 Dark Matter searches with the Cherenkov Telescope Array Observatory – A.Morselli
- 10:00 – 10:30 The extragalactic TeV sky: past, present, and future – E.Prandini

Coffee break

- 11:00 – 11:30 The fascinating Galactic Science to understand with future Cherenkov Telescopes – M.Cardillo
- 11:30 – 12:00 Pevatron searches – G.Morlino
- 12:00 – 12:30 CTAO Data Challenge – F.Pintore

Participant Contributions – I

- 12:30 – 12:50 Study of periodicity in Blazar light curves observed by Fermi LAT – P.Cristarella Orestano
- 12:50 – 13:10 Simulations of relativistic jets and recollimation in extreme blazars –A. Costa
- 13:10 – 13:30 Extreme TeV Blazars: a phenomenological model – A. Sciaccaluga

Tutorials

- 15:30 – 16:00 From Science to Society: a fruitful path – F. Giordano

Coffee Break

Gammapy tutorial – II

- 16:30 – 18:30 Tutorial on gammapy for CTAO – F.Pintore, G.Rodriguez, G.Principe

Thursday 21.07.2022

Multiwavelength and MultiMessenger connections

- 09:00 – 09:30 eRosita – J.Wilms
- 09:30 – 10:00 The Imaging X-Ray Polarimetry Explorer – E.Costa
- 10:00 – 10:30 Synergies with radio and the Square Kilometre Array Observatory – M.Giroletti

Coffee break

- 11:00 – 11:30 Astrophysical Neutrinos – V.Kulikovskiy
- 11:30 – 12:00 Gravitational waves and their role in multimessenger astrophysics – N.Sorrentino

Participant Contributions – II

- 12:15 – 12:35 Photon-photon interactions, blazar spectral anomalies, and constraints on photon-ALP mixing – A.Franceschini
- 12:35 – 12:55 High-Energy Gamma-ray and Neutrino Production in Clusters of Galaxies – S.Hussain
- 12:55 – 13:15 Using Deep Learning to Search for Fermi-LAT Point Sources – S.Bhattacharyya

Gammapy tutorial – III

- 15:00 – 16:00 Tutorial on gammapy for ASTRI – A.Giuliani/M.Cardillo

Coffee break

- 16:30 – 18:30 Tutorial on gammapy for ASTRI– A.Giuliani/M.Cardillo

Friday 22.07.2022

Participant Contributions – III

- 09:00 –09:20 Cosmic-ray propagation under consideration of a spatially resolved source distribution – J.Thaler
- 09:20 – 09:40 Cygnus OB2 as testing ground for particle acceleration at the wind termination shock of massive star clusters – S.Menchiari
- 09:40 – 10:00 Cosmic Rays origin studies in the W 44 region with Fermi-LAT and MAGIC observations – R. Di Tria

Coffee Break

- 10:30 – 11:30 Partecipants Case studies reports
- 11:30 – 12:00 25 years of GRB afterglows. Lesson learned – E.Costa
- 12:00 – 12:30 Workshop conclusions

The Extreme Universe

The Fermi view of the High Energy sky
Giacomo Principe

The Fermi Gamma-ray Space Telescope was launched more than 14 years ago and since then it has dramatically changed our knowledge of the gamma-ray sky.

With more than three billions photons from the whole sky, collected in the energy range between 20 MeV and more than 300 GeV, and beyond 6,000 detected sources, LAT observations have been crucial to improving our understanding of particle acceleration and gamma-ray production in astrophysical sources.

In this talk, I will review recent science highlights from the LAT and discuss their implications for future observations at gamma-ray energies.

.

From the current IACT to CTA
Werner Hofmann

The talk serves to introduce the CTA instrument, and provides an overview of CTA history and design choices.

Ground-based gamma-ray astronomy with LHAASO
Giuseppe Di Sciascio

During the last two decades Gamma-Ray Astronomy has emerged as a powerful tool to study cosmic ray physics. In fact, photons are not deviated by galactic or extragalactic magnetic fields so their directions bring the information of the production sites and are easier to detect than neutrinos. Thus the search for γ primarily address in the framework of the search of cosmic ray sources and to the investigation of the phenomena in the acceleration sites. The LHAASO experiment in the last two years opened for the first time the PeV sky to observations that demonstrated the existence of many PeVatrons in the Northern hemisphere. We will introduce the experimental techniques used to detect photons with arrays from ground in the overwhelming background of CRs and describe the results obtained by the LHAASO experiment above 100 TeV.

Science with the Cherenkov Telescope Array Observatory: a general introduction

Francesco Longo on behalf of the CTAO and the CTAC

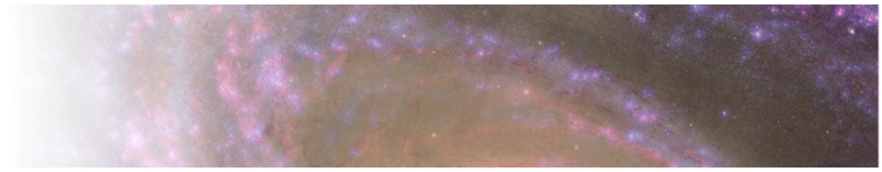
The Cherenkov Telescope Array (CTA) will be five to ten times more sensitive depending on energy with respect to current generation Imaging Cherenkov Telescopes and will have unprecedented accuracy in its detection of very-high-energy gamma rays in the energy range from 20 GeV to 300 TeV. CTA is designed to detect gamma rays over a larger area with dozens of telescopes located on the Canary island of La Palma and in the Paranal desert in Chile, in the northern and southern hemispheres respectively. Together, the northern and southern CTA arrays will constitute the CTA Observatory (CTAO), which will be the first ground-based gamma-ray observatory open to the worldwide astronomical and particle physics communities as a resource for data from unique, high-energy astronomical observations.

The talk will present the perspectives for its scientific observations.

Introduction to the ASTRI Science goals
Andrea Giuliani

The ASTRI Mini-Array is an array of nine Cherenkov telescopes under construction at the Teide Astronomical Observatory in Tenerife, Spain. It will observe the sky in the multi-TeV energy range with a large field of view (FOV, ~ 10 degrees in diameter). In this presentation we will introduce the main ASTRI science goals. The ASTRI Mini-Array observations will address both Galactic and extragalactic science.

On the Galactic plane, the large FOV will allow us to collect data from a few sources simultaneously, with large exposure. Its capability of observing sources in the multi-TeV regime with good angular resolution will allow a spectral and morphological characterization of unidentified sources observed by LHAASO and HAWC. Other science goals of the ASTRI Mini-Array will include studies of PWNe and TeV halos, Blazar monitoring at VHE, fundamental physics and follow-up of transient events.



Next generation IACT telescopes

The CTA LST Project and Science
Masahiro Teshima

The CTA is a new generation International gamma-ray observatory under construction, which will have a wider energy coverage and ten times better sensitivity than the currently running Telescopes, HESS, MAGIC, and VERITAS. The LST collaboration is constructing four Large Size Cherenkov Telescopes (LSTs) with 23m diameter dish in Spain, La Palma, and possibly another four LSTs in Paranal, Chile. The first telescope, LST1, is in the commissioning and engineering phase, and already some exciting results have been delivered. Three more telescopes will be built in 2024. Then the array of four LSTs will provide a significant sensitivity for observing gamma-ray sources with a 20GeV energy threshold, which will expand the visible Universe up to the redshift z = 4 and deliver exciting sciences. We would like to discuss the current status of the LST project and science with CTA-LSTs.

Medium Sized Telescopes for the Cherenkov Telescope Array

Jean-Francois Glicenstein

The Cherenkov Telescope Array is an observatory dedicated to very high energy gamma rays with unprecedented sensitivity between 20 GeV and 300 TeV to be installed on two sites: Canary Island La Palma and Paranal Chile. Three telescope sizes will be used to cover the entire energy range.

The MST telescopes will cover the intermediate energy range from 150 GeV to 5 TeV. The structure is based on the traditional single mirror Davies-Cotton design. Two different camera based on different concepts will be mounted on the telescope structure. In this talk, the different concepts, their scientific performances and the status of the prototypes will be presented.

The prototype Schwarzschild Couder Telescope: a Medium-Sized Telescope for the Cherenkov Telescope Array

Elisabetta Bissaldi on behalf of the SCT Collaboration

The Schwarzschild Couder Telescope (SCT) is a dual mirror Medium-Sized telescope proposed for the Cherenkov Telescope Array (CTA), the next generation of Imaging Air Cherenkov Telescopes.
The SCT design consists of a dual-mirror optics and a high resolution camera with a field of view (FoV) of 8°, which will allow exceptional performance in terms of angular resolution and background rejection. A prototype telescope (pSCT) has been installed at the Fred Lawrence Whipple Observatory in Arizona, USA. Its camera is partially equipped and covers a FoV of 2.7°. The pSCT has recently successfully detected the Crab Nebula with a statistical significance of 8.6 standard deviations. The upgrade of the pSCT focal plane is now ongoing, aimed to equip the full camera with upgraded sensors and electronics, enhancing the telescope field of view from the current 2.7° to the final 8°.
I will provide an overview of the pSCT project and obtained results, together with the camera upgrade status and expected performance.

The development of ASTRI telescopes from ASTRI-HORN prototype to ASTRI-Mini Array and CTA-SST

Giorgia Sironi

ASTRI telescope peculiarity lies in its optical design based on a modified Swarzschild – Couder (SC) configuration perfectly fulfilling the requirement of large collecting area and wide field-of-view necessary for the observation and analysis of Cherenkov events. The SC configuration was originally proposed for optical astronomy at the beginning of 1900 and never realized because of the difficulties in manufacturing the optics. In the last decades the design was recovered for application to imaging atmospheric Cherenkov telescopes (IACTs) taking advantages of the required moderate angular resolution, of the progress in manufacturing and metrology processes and of the new generation of detectors.

The first ASTRI prototype, today entitled ASTRI-Horn, was developed as an end-to-end telescope by INAF installed on Mt. Etna in 2014 and successfully tested. After that INAF supported the realization of the ASTRI Mini-Array strongly believing in the ASTRI-like telescopes potential while CTAO selected the ASTRI mechanical and optical design to be implemented as small size telescope (SST) sub-array at the Southern site telescope in CTAO.

In this talk we review the current open activities on ASTRI telescopes and present the requirements that defined the ASTRI telescope improved design with specific attention to optics manufacturing/metrology.

Introduction to gammapy

Gonzalo Fernandez Rodriguez

Gammapy is a Python package for high-level gamma-ray data analysis built on Numpy, Scipy and Astropy. Gammapy is the CTA science tools. During these Hand-Ons we will learn to analyze gamma-ray data mainly from simulations to create sky images, spectra and lightcurves, to determine the position, morphology and spectra of gamma-ray sources.

Theory of Very-High Energy Sources

UHECR propagation in the extragalactic space
Denise Boncioli

The extragalactic propagation of UHECRs will be described, as well as the connections of UHECRs with other messengers such as high-energy neutrinos and gamma rays.

Emission processes in blazars
Fabrizio Tavecchio

I will discuss current state-of-the-art emission models of blazars. After presenting the general framework, I will focus on the so-called extreme blazars, whose properties challenges our general picture.

Energy processes in Gamma Ray Bursts

Davide Miceli

Very-high energy (VHE, E>100GeV) emission in Gamma-ray bursts (GRBs) has been a topic of great debate for several decades. Despite many discussions from the theoretical side have been conducted, it has eluded observations for a long time. Recent discoveries accomplished by the Cherenkov telescopes MAGIC and H.E.S.S. have unequivocally proven the existence of this VHE emission component in GRBs and have led to unique studies on the physical processes involved at VHE as well as several aspects of GRB physics, including particle acceleration mechanisms, and properties of the GRB environment. In this contribution I will show the impact of these studies on the GRB physics and summarize the current knowledge on the radiation processes involved in the GRB VHE emission component.

From Pulsar to PWNe
Giovanni Morlino

I will discuss the basic physicas of a pulsar magnetosphere and the connection between pulsars and PWNe, highlighting the critical issue that we still do not understand like the particle production and the sigma problem. Than I will focus on radiative processes in PWNe and possible acceleration mechanisms that allow electrons and positrons to gain energies end radiate up to the maximum potential drop.

ALPs and polarization

Giorgio Galanti

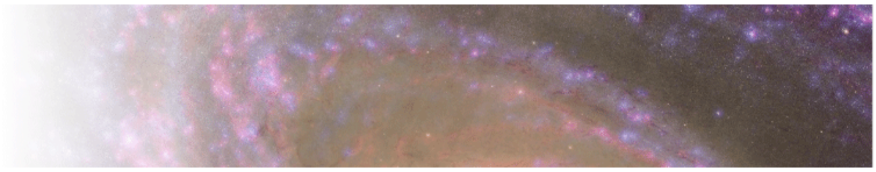
Axion-like particles (ALPs) are very light neutral spin-zero bosons predicted by superstring theory and primarily interacting with two photons. In the presence of an external magnetic field they give rise to two effects: (i) photon-ALP oscillations, (ii) the change of the photon polarization state. The former effect produces a modification of the photon transparency and irregularities in observed spectra. In addition, two hints at ALP existence have been discovered associated with photon-ALP oscillations. The latter effect has attracted less interest but, we show that photon-ALP interaction leads to sizable consequences also on photon polarization in a wide energy band from the X-ray up to the MeV range, when photons are produced in the central region of galaxy clusters or at the jet base of blazars. The ALP induced features on photon polarization can give us additional hints at the ALP existence or further constrain the ALP parameter space. We expect observatories like IXPE and POLSTAR in the X-ray band, and COSI, e-ASTROGAM and AMEGO in the MeV range to possess the capabilities to detect these possible effects. After an introduction about the importance of ALPs in astrophysics, their properties and interactions, we will present their consequences on astrophysical spectra and on photon polarization.

Science with Cherenkov Telescopes

Multimessenger searches of transient sources with Cherenkov telescopes

Alessio Berti

The last five years marked the birth and evolution of multimessenger astrophysics, thanks to the joint detection of signals coming from different cosmic messengers. In most of the cases, these discoveries involved transient sources. These events are usually connected to explosive events, ot to a change in the system producing them (e.g. in binary systems). Acceleration of particles is expected in such conditions, together with emission of gamma-rays up to very high energies (VHE), above hundreds of GeV. In such energy range, imaging atmospheric Cherenkov telescopes (IACTs) are the most sensitive instruments, providing a low energy threshold, large effective area and photon statistics even for short timescales, which are crucial features for the detection of transients. IACTs can provide important information about transients, since VHE gamma-rays can probe acceleration mechanisms at the highest energies, helping in disentangling between models of different origin (e.g. leptonic vs hadronic). Therefore, transient events like gamma-ray bursts, systems generating gravitational waves, neutrino sources, flares or bursts from galactic and extragalactic sources are very well suited for multimmessenger and multiwavelength observations. Given the low duty cycle and generally small field of view of IACTs, such searches are challenging, both from the observational and data analysis side. In this talk I will show the strategies adopted by IACTs for the follow-up of multimessenger events, and the needed synergies with current and future experiments. I will discuss also the importance of suitable data analysis tools and proper data handling (e.g. to avoid false positive detections). Finally, I will give some perspectives on this thrilling branch of astroparticle physics.



Dark Matter searches with the Cherenkov Telescope Array Observatory
Aldo Morselli

In the last decades an incredible amount of evidence for the existence of dark matter has been accumulating. At the same time, many efforts have been undertaken to try to identify what dark matter is. Indirect searches look at places in the Universe where dark matter is known to be abundant and seek for possible annihilation or decay signatures. The Cherenkov Telescope Array (CTA) represents the next generation of imaging Cherenkov telescopes and, with one site in the Southern hemisphere and one in the Northern hemisphere, will be able to observe all the sky with unprecedented sensitivity and angular resolution above a few tens of GeV. The CTA Consortium will undertake an ambitious program of indirect dark matter searches for which we report here the brightest prospects.

The extragalactic TeV sky: past, present, and future
Elisa Prandini

Fifteen years ago, less than 20 TeV emitters were known, up to a maximum redshift of 0.2. The number of discovered TeV sources populating the extragalactic sky in 2022 is nearly 100, mostly blazars located up to a redshift ~1. This is a major achievement of the current generation of Cherenkov telescopes operating in synergy with optical, X-ray, and GeV gamma-ray telescopes. In this lecture, an overview of the extragalactic TeV sky will be presented with a focus on selected highlight results. Future perspectives will be also discussed in detail.

The fascinating Galactic Science to understand with future Cherenkov Telescopes
Martina Cardillo

Gamma-ray astronomy plays a fundamental role in the understansing of our own Galaxy and on its tricky and outstanding sources.

Despite the enormous efforts done in very recent years, both theoretically and experimentally, the Cosmic Ray (CR)origin remain without clear answers. Their commonly accepted galactic sources, Supernova Remnants, were no detected at PeV energies. Instead, the last results published by the LHAASO collaboration revealed the existence of several PeV sources likely related to PWNae, well known leptonic factories (e.g. the Crab Nebula for all). Other candidate sources are star forming regions, like the Cygnus one, and the Galactic Center, both detected at VHEs. Moreover, the recent detection of gamma-ray halo around some PWNae (e.g Geminga) opens a new chance to understand GCR diffusion.

In addition to CR issue, the tricky PeV pulsating emission detected from Crab nebula lacks an explanation yet and the mechanism behind the increasing number of detected Gamma-Ray binaries and micro-quasars is under investigation.

In this context, the future Cherenkov telescopes as ASTRI Mini-Array and CTA, with their unprecedented sensitivity and angular resolution at E>10 TeV, will have a great role.

PeVatron searches
Giovanni Morlino

The flux of cosmic rays detect at the Earth requires the presence of Galactic sources able to accelerate hadronic particles at least up to ~10^15 eV (=1 PeV). These sources, called PeVatrons, have not been identified yet, even if relevant steps forward have been done in the recent years, especially thanks to the VHE gamma-ray detectors like LHAASO, HAWC and Tibet As-gamma. In this talk I will illustrate current evidences for the existence of PeVatrons as well as the requirements those sources need to fulfill in order to explain the observed CR flux. Finally I will outline the expected advancement that we expect in the field thanks to the future Cherenkov Telescope Array Observatory (CTAO).

CTA Science Data Challenge

Fabio Pintore, Giacomo Principe
on behalf of a larger number of authors

We present the science data challenge (SDC) of the Cherenkov Telescope Array Observatory (CTAO). The SDC will simulate seven years of activity of CTAO, in the most realistic way taking into account the latest knowledge on the simulated objects. It is intended to train the very high energy community towards data analysis of high complexity and to serve as a test bed for new algorithms of analysis.
A number of source classes (Galactic and extragalactic) will be included in the simulation, allowing also for time-dependent spectral variability studies. This talk will show an overview of all the scientific and technical aspects related to the SDC creation..

Tutorials

The Communication as a bridge between Science and Society
Rossella Spiga

The communication of Science is a bridge between Science and Society. Science, Society and Democracy are strongly connected. Democracy needs Science since Democracy has the task of administering technology, while Science has the duty to manage the dissemination of knowledge, in an ideally fully integrated system. All of us, as scientists and citizens of a knowledge society, are involved in this unstoppable process in which Science promotes the iconic image of the rational enterprise able to change our daily life, our way to communicate and our vision of the world.

From Science to Society: an interesting path

Francesco Giordano

Never than nowadays the technology transfer from academia fundamental research towards private sectors is becoming extremely important. This can be read by the latest financial plan by the Minister of research in Italy, just to mention one case, where the collaboration within universities as well as public research centers and the private sector is a mandatory conditions to apply to.

This has reduced a lot the distance between the academic research and the innovation pursued by high technological level industries. CTA in Italy may be considered one of the most virtuous example, where the Italian institute for astrophysics and the Italian institute for nuclear physics together with a large number of universities has been approved for a very challenging research program where private industries will be beneficiary as well of the funding obtained.

IoT solutions, Machine learning coding and Artificial Intelligence algorithms are only few examples of activities where industries are developing business, without mentioning hardware products like extremely sensitive Solid state photodetectors are gaining wider and newer markets"

Multiwavelength and MultiMessenger connections

eROSITA

Joern Wilms

I will give an overview of the German eROSITA instrument on the Russian Spectrum-X-Gamma satellite. Launched in 2019, eROSITA has been performing four surveys of the X-ray sky in the band from 0.2keV to 10keV. The survey has revealed the distribution of hot gas in our Milky Way and discovered more than a million new X-ray sources - stars in the Milky Way, accreting neutron stars and black holes, supermassive black holes in the centers of galaxies, and galaxy clusters. The talk will discuss the eROSITA instrument and present an overview of some of the most exciting results obtained so far.

The Imaging X-Ray Polarimetry Explorer
Enrico Costa

The Imaging X-Ray Polarimetry Explorer has been launched on December 9 2021. It is working nominally. First data suggest that IXPE can improve our understanding of some hot topics of High Energy Astrophysics. I give a review of the available data and show the commonalities with VHE astrophysics.

Synergies with radio and the Square Kilometre Array Observatory
Marcello Giroletti

The Square Kilometre Array Observatory (SKAO) will revolutionise the way we observe and know the radio sky. In this lecture, I will describe the two instruments that will make up the SKAO, highlighting the design and location of the low- and mid-frequency components and the respective contributions to the the key science projects and the various science working groups. I will also describe the potential for SKAO as an element of a more extended Very Long Baseline Interferometry network and highlight the possibility of synergy with gamma-ray observations on scales from our Galaxy to the remote Universe.

Astrophysical Neutrinos
Vladimir Kulikovskiy

The neutrinos can be produced at cosmic sources or nearby them as products of the accelerated hadrons interactions. The neutrino detection from a particular source is thus a smoking gun for the hadronic acceleration in such source. Neutrino detectors of cubic kilometer(s) are required to detect the significant amount of neutrinos from the astronomical sources on a time scale of decades. One of such detectors, IceCube is operated in the South Pole and others are in the construction in the Northern Hemisphere (KM3NeT and Baikal). Astrophysical neutrino diffuse flux is measured by IceCube. Recently, time and space correlations are found for the several sources of neutrinos and e/m emission.

Gravitational waves and their role in multimessenger astrophysics

Nunziato Sorrentino

During the last seven years, the increasing number of detected gravitational wave signals (GW) from compact binary coalescences allowed us to investigate the most energetic phenomena of the Universe, e.g. the first discovered event GW150914, which emitted an energy of ~ 3 $M_{\odot}$. These phenomena are often non-visible through electromagnetic waves (EM), because of inclination of collimated radiation or absence of photon emission. GW detections were possible thanks to ground-based interferometers such as Advanced LIGO and Virgo. In 2017 we obtained the first multimessenger observation of a GW event (GW170817), caused by a binary neutron stars merger, and its counterparts in EM radiation as a short gamma-ray burst (GRB170817A). In this talk I will review the recent results in GW astrophysics, including the most relevant signals observed so far. The talk will also cover the development of the current interferometers and their improvements over the past years. I will also mention the prospects for future GW observatories, including the plans for the third-generation ground based detectors such as the Einstein Telescope.

Contributed talks

Study of periodicity in Blazar light curves observed by Fermi LAT
Paolo Cristarella Orestano

Long term periodicity in gamma-ray Blazar light curves could be linked to the innermost zone of the complex structure of AGN, like possible presence of binary system of supermassive black holes, or it could shed light on the origin of gamma-rays emission. The work analyses around 1500 sources, whose 12 years light curves come from the Fermi LAT Repository (https://fermi.gsfc.nasa.gov/ssc/data/access/lat/LightCurveRepository/), making use of Lomb Scargle periodogram and wavelet weighted Z transform.
All the available possibilities for the light curves in the Repository, such as different temporal samplings and the use of photon flux and energy flux, are taken into account in order to ensure more reliable results.
We found out high significance periodicity in less than 1% of the sources considered, and in few other sources hints of possible periodicity.
Our results are compliant with the findings of recent literature focused on searches of periodic modulation in AGNs.

Simulations of relativistic jets and recollimation in extreme blazars
Agnese Costa

AGN jets are the most powerful persistent emitters in the Universe. The understanding of their physical structure, dynamics and impact on the environment plays a fundamental role in our view of black holes, galaxies, clusters, but it involves complex and interlaced processes, ranging from micro to macroscales both in space and time. For describing the plasma dynamics of jets, along with the acceleration of non-thermal particles and their emission, ranging from radio waves to high-energy gamma rays, advanced numerical codes are a necessary tool.
Recent 3D magnetohydrodynamical numerical simulations of relativistic jets surprisingly reveal that the (intensively studied in 2D) recollimation caused by pressure unbalance with the external medium triggers a rapidly growing instability that leads to the deceleration of the jet, eventually disintegrating it, and the development of strong turbulence. By means of these 3D simulations it was found that even if higher magnetic fields would prevent the plasma from becoming turbulent, it is instead possible for low-B jets, as those of the most extreme and enigmatic blazar, the so called EHBL.
These findings are going to have a profound impact on our understanding of relativistic jets and particle acceleration, as they could mean that other mechanisms are at work, possibly consistent with the peculiar high-energy gamma spectrum of EHBL objects.

Extreme TeV Blazars: a phenomenological model

Alberto Sciaccaluga

In recent years extreme TeV blazars are becoming sources of great interest in the gamma ray astronomy community because of their peculiar features: peak of hard gamma spectrum above 1 TeV, hard spectrum at sub-TeV energies and slow variability. This extreme behavior is ideal to test models of particle acceleration and radiative emission. Among the different phenomenological models elaborated for blazars, my approach is based on turbulence. Supposing the existence of a recollimation shock and an inner low magnetic field, the jet plasma becomes turbulent and reaccelerate the non-thermal particles via stochastic interactions. Since the random nature of the turbulent interactions, the time evolution and the equilibrium state of the non-thermal particle and turbulence spectra are studied solving numerically a system of two coupled and non-linear Fokker-Planck equations. Finally the radiative emission is calculated using the Synchrotron Self Compton model. The results will be compared with the existing data of the multiwavelenght spectra and the variability of the extreme TeV blazars.

Photon-photon interactions, blazar spectral anomalies, and constraints on photon-ALP mixing

Alberto Franceschini

We reconsider evidences of spectral anomalies in distant blazars, possibly due to non-standard physics in the propagation of VHE photons, based on a rigorous statistical analysis. While present-day data are unable to offer robust, highly significant constraints, we argue that the forthcoming new-generation IACT arrays will do it, thanks to the wider VHE spectral coverage for blazars on a larger redshift interval, and better statistics."

The analysis was performed between 0.1 and 300 GeV using the Pass-8 event-level selection. In the analysis we considered only photons with |b| > 10° to exclude the galactic plane and therefore to avoid confusion with low latitude diffuse emission. We have analyzed 96 months and also performed a 15-day shift of each month in order to not lose any flare at the edges of each time bin.

Although most of the sources we find are already included in the past Fermi-LAT general catalogs, we do detect new extragalactic gamma-ray sources. Here we report only on those transient sources which are not included in any previous Fermi-LAT catalog and therefore can be considered new gamma-ray emitters.

High-Energy Gamma-ray and Neutrino Production in Clusters of Galaxies

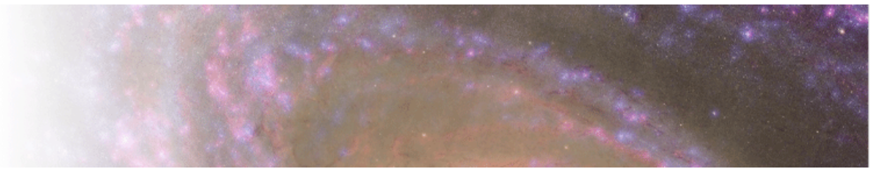
Saqib Hussain

We compute the contribution from clusters of galaxies to the diffuse gamma-ray and neutrino background. Clusters of galaxies can potentially produce cosmic rays (CRs) up to very-high energies via large-scale shocks and turbulent acceleration. Due to their unique magnetic-field configuration, CRs with energy ≤ 10^17 eV can be trapped within these structures over cosmological time scales, and generate secondary particles, including neutrinos and gamma rays, through interactions with the background gas and photons. We employ three-dimensional cosmological magnetohydrodynamical (MHD) simulations of structure formation to model the turbulent intergalactic medium. We use the distribution of clusters within this cosmological volume to extract the properties of this population. We propagate CRs in this environment using multi-dimensional Monte Carlo simulations across different redshifts (from z ~ 5 to z =0), considering all relevant photohadronic, photonuclear, and hadronuclear interactions. We also include the cosmological evolution of the CR sources. We have computed the fluxes of high-energy gamma-rays (E > 10 GeV) and neutrinos and found that the clusters contribute to a sizable fraction to the diffuse gamma-ray flux observed by Fermi-LAT and the flux of neutrinos by the IceCube.

Using Deep Learning to Search for Fermi-LAT Point Sources

Saptashwa Bhattacharyya

Due to the dominating presence of diffuse emission at GeV energies, detecting and localizing gamma-ray point sources in the Fermi-LAT data is a challenging task. Going beyond traditional statistical methods, here we show the application of deep learning and computer vision algorithms to localize and classify gamma-ray point sources starting from the raw Fermi-LAT sky images. We prepare the training data based on 10 years of Fermi-LAT exposure and we use the source properties of active galactic nuclei (AGNs) and pulsars (PSRs) from the incremental version of the fourth Fermi-LAT source catalog (4FGL-DR2). Relative to our previous work, here our training data is more robust, contains yearly flux variation, exploits full detector potential with increasing spatial resolution from lowest to highest energies, covering 300 MeV to 1 TeV. We also discuss the possible way to compare our network generated gamma-ray catalog with the Fermi Catalog. The localization methods developed and applied for the gamma-ray sources, are also tested for astrophysical sources seen in optical wavelengths. Our network performance is agnostic to the different models of diffuse gamma-ray background and the catalog is based only on gamma-ray data. The complete data analysis pipeline for automatic point source search and classification methods using deep learning could soon prove to be a complementary technique to traditional algorithms for catalog preparation.



Cosmic-ray propagation under consideration of a spatially resolved source distribution

Julia Thaler

Numerical simulations for cosmic-ray propagation through the Galaxy are important e.g. for understanding the diffuse gamma-ray emission seen by different experiments. Up to now, the source distributions used as input for such simulations are often relying on analytical functionals rather than individual, observation-based sources.

Here, we investigate the impact of cosmic-ray source distributions produced by combining sources observed with the H.E.S.S. experiment and simulated random sources, which follow the matter density in the Galaxy. We show the impact of different realisations of source distributions on the local gamma-ray emission, simulated using the PICARD code.

Cygnus OB2 as testing ground for particle acceleration at the wind termination shock of massive star clusters

Stefano Menchiari

"In the last decade, the detection by diverse experiments of diffuse gamma-ray emissions toward several galactic massive star clusters has renewed the attention to these objects as potential galactic cosmic ray accelerators. Indeed, the conversion of a few percent of the power supplied by the strong winds from the massive stars into accelerated particles is enough to explain the observed gamma-ray luminosities in a pure hadronic scenario. Cygnus OB2 is one of the massive star clusters found in coincidence with diffuse gamma-ray emission detected in a broad range of energies, from a few GeV up to 1.4 PeV.
In this work, we aim to compare the morphological and spectral features of the observed gamma emission with those predicted from a theoretical model where particles are accelerated at the termination shock of the cluster wind. Both the expected gamma-ray morphology and spectrum depend on the properties of the distribution of accelerated cosmic rays, which are directly affected by the physics of acceleration at the termination shock and by the propagation in the hot expanding bubble created by the cluster wind.
We found our model to be in good agreement with the observed spectral energy distribution. The expected radial gamma-ray profile reproduces fairly well HAWC observations but is not totally in accord with Fermi results. According to the best fit model, Cygnus OB2 should be able to accelerate cosmic rays up to 1 PeV, hence resulting in a likely cosmic ray PeVatron.

Cosmic Rays origin studies in the W 44 region with Fermi-LAT and MAGIC observation

Riccardo Di Tria

W 44 is a well-known Supernova Remnant (SNR) observed in high-energy gamma-rays, widely studied to investigate cosmic ray (CR) acceleration. Several analyses of the W 44 surroundings showed the presence of a gamma-ray emission offset from the radio SNR shell. This emission is thought to originate from escaped high-energy CRs.

We present a detailed analysis of the W 44 region as seen by Fermi-LAT, focusing on the spatial and spectral characteristics of both W 44 SNR and its surroundings. The spatial analysis was limited to energies above 1 GeV in order to exploit the improved angular resolution of the instrument, deriving a detailed description of the region morphology. The spectral analysis was extended down to 100 MeV, favouring the hadronic origin of gamma-rays.

Observations of the North Western region of W 44, also known as SRC-1 from previous works, were conducted with the MAGIC telescopes in the very-high-energy gamma-ray band. We analysed MAGIC data above 130 GeV exploiting the spatial information derived from the Fermi-LAT analysis above 1 GeV.

Here we show the results of both analyses and the combined Fermi-LAT and MAGIC spectra. An interpretation model was developed, assuming that the gamma-ray emission from the surroundings is due to clouds located near W 44 and illuminated by CRs escaping along the SNR’s magnetic field lines, thus obtaining constraining information on the diffusion coefficient of the escaped CRs.