

Istituto Nazionale di Fisica Nucleare

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BIG DATA AND HEALTH: A PROMISING DIALOGUE FOR MEDICINE OF THE FUTURE

Interview with Michele Stasi, President of the Italian Association of Medical Physics (AIFM) and Director of the Health Physics Department of the Ordine Mauriziano Hospital of Turin

On 12 December, AIFM and INFN organised the "Big data and Health in the perspective of the Bologna Technical Hub" conference, with the aim of discussing the issue of the impact that big data will have on the medicine of the future and the challenges related to the analysis and management of this valuable digital mine of information with a multidisciplinary and territorial approach. The conference was a first opportunity for discussion among experts from research communities and institutions working in the field of big data and AI, having the skills and technologies crucial to building a new digital alliance for public health. The choice of organising the conference in Emilia Romagna stems from a uniqueness that characterises this region: the future Bologna Technical Hub, which will be one of the eight centres selected by the European Union, the only one in Italy, to host a pre-exascale class computer, a supercomputer with extremely high computing power. A project with a total investment of approximately 240 million euros for Italy and approximately 900 million at the European level and in which INFN can make a fundamental contribution thanks to decades of experience in the management and analysis of big data accessible through efficient cloud platforms, also using machine learning techniques.

We met Michele Stasi in Reggio Emilia, at the Oncology and Haematology Centre of Reggio Emilia (CORE), venue of the conference.

AIFM and INFN have recently signed a collaboration agreement. What does it concern and what are the objectives?

This is a long-term collaboration agreement that stems precisely from the need to give an initial response to a health system that in the future will be increasingly multidisciplinary and multi-professional, and this Reggio Emilia event is the first implemented within the scope of this agreement. The objective, together with scientific companies in the radiology area, is to address the new challenges of an increasingly personalised medicine, in which technological innovation and artificial intelligence will be the protagonists. Hence an idea



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emerges: combining the expertise of INFN researchers and the computing infrastructure available to them (such as the future Technical Hub in Bologna), with the health and medical physics facilities in which AIFM is present, which are disseminated throughout the country, also exploiting both the technology transfer knowhow of medical physicists, as well as the crucial possibility of using health technologies.

What are the most significant recent advances in medical physics and what are the most interesting prospects that are opening up for the coming years, particularly with regard to the big data issue?

The applications of physics to medicine have been fundamental, starting from the end of 19th century, with the discovery of X-rays and the X-ray tube by Roentgen, of radioactivity by Marie Curie and Bequerel and, subsequently, with the Nobel Prize winners for the invention of CT and MRI. Certainly, in recent years, the most important technological transfer from the world of fundamental research to medicine has been that of accelerators which, from basic research in particle physics, subsequently found applications in radiotherapy and hadrontherapy, where the example of the CNAO in Pavia represents the highest point of integration between research and medicine in recent years. The future is what we mentioned at the beginning of this interview: big data and Artificial Intelligence (AI) are now fundamental tools to study the state of health of individuals and define personalised treatment plans.

Automatic learning (machine and deep learning) techniques, borrowed from the field of artificial intelligence (AI), are, in fact, able to recognise patterns or causal relationships in phenomena or in the health data of individuals, thus providing new knowledge useful to produce forecasting models. These techniques exploit the ability of computers to handle huge amounts of data and to adopt reasoning typical of the human mind, demonstrating to be capable, for example, of extrapolating the guidelines to be adopted to solve new problems from previous knowledge. However, these new processes must be governed, verified, validated and optimised. In this context, the collaboration between INFN and AIFM is a fundamental element.

"BIG data and health" is a topic with promising applications extended to many areas of biomedicine, including molecular biology, genomics, oncology, immunotherapy, radiology and precision radiotherapy. Where are we on this and what are the challenges?

There are countless applications and systems based on Big Data and Artificial Intelligence that are used in many areas of medicine, especially in the field of diagnostics and the process of introducing machine learning or deep learning systems into health is more ongoing than ever before. Suffice it to say that this year, at the Radiology Society of North America (RSNA) Congress, there were more than 160 companies dealing with artificial intelligence. Of course there are still many problems to be solved, including those of an ethical nature, but certainly, as far as the management of Big Data is concerned, the main problem to be addressed



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is that of privacy and of the correct application of the new general Data Protection Regulation (GDPR) in this context.

Going back to medical physics, could you tell us what AIFM does and what are the issues that characterise the work of the association? Why is it important that there is an association for this type of professional?

The Italian Association of Medical Physics (AIFM) represents specialists in medical physics at the scientific and professional level who work in the health field, both as hospital employees as well as freelance professionals, but also physicists who deal with medical physics in research, university teaching and industry. We are speaking of a community of approximately 1200 physicists. AIFM is the only scientific society, recognised by the Ministry of Health, for medical physicists pursuant to Legislative Decree 24/17 (Gelli Law). For this reason it can participate in drafting guidelines that represent good practice also for the purpose of professional liability. AIFM is also a national provider of continuous medical education (ECM), both for residential as well as on-line courses, and with its post-graduate school of medical physics and the radiation protection school, it organises more than 15 training courses per year for medical physicists.

How has the profession changed in recent decades?

It has changed a lot and a lot more will change in the future. The health physics facilities in Italy (and beyond) were created to manage the problems of radiation protection of workers and patients due to the use of ionizing radiation. For many years, the medical physicist was seen as the radiotherapy physicist or qualified expert. Today she/he is a health professional who works with all types of radiation, with technology to support clinicians but above all provides her/his fundamental contribution to prevention, quality and safety in increasingly personalised medicine. In short, we can say that the paradigm has changed: from Physics in Medicine (with technology at the centre) to a Physics for Medicine (with people at the centre).

And how does Italy compare to other European countries?

Italy is at the forefront in Europe for basic and continuous education, application to diagnostics and treatment, for its scientific and research role and also in terms of the size of the community. As a demonstration of this, suffice it to say that next year, from 23 to 26 September 2020, in Turin, Italy will host the third European Congress of Medical Physics (ECMP III) together with the XI National AIFM Congress.

What is the path to be followed for a career in medical physics and what are the most promising career opportunities?



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To become a professional in medical physics, the path is quite long: five years for the Master's degree and then three years of specialisation in medical physics (often unpaid). The main job opportunities are in the National Health System in the public sector and as a physicist manager in the private sector. At the moment there is a lot of demand in the job market and, in some regions, in fact, demand is higher than supply, with positions not being filled, especially for fixed-term contracts. My advice to youngsters is to choose this profession for many reasons: first of all you work as a physicist, or rather a physicist at the service of patients, and then there is demand in the job market and it is also a well-paid profession.



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RESEARCH THE FIRST LST-1 GAMMA SOURCE

On 23 November, LST-1, the first large telescope of the Cherenkov Telescope Array (CTA) - inaugurated in October 2018 in La Palma, in the Canary Islands - detected its first gamma source by targeting

the famous Crab Nebula, considered to be the "standard candle" of high energy astrophysics. This is LST-1's first detection of a real gamma-ray source, after the "first light" detected by the telescope on the evening between 14 and 15 December 2018. Already from the first analyses of the data collected it was possible in this second event to identify a clear high energy photon (between 20 and 200 GeV) signal coming from the Crab Nebula.

After having developed and refined the analysis tools for over a year on Monte Carlo simulations, this result confirms that the tools and the analysis chain, to which INFN contributed significantly, work properly and are able to provide the first scientific results.

LST-1 is the first of four Large Size Telescopes that will be present at the two CTA observation sites located in the two hemispheres, one on the island of La Palma (Canary Islands, Spain) and the other near the ESO site of Paranal in Chile.

The LST telescopes will be essential for detecting high-energy gamma rays and, thanks also to their fast targeting capability, will study the weakest and most distant sources and transient phenomena, in particular gamma-ray bursts.

This first result was also achieved thanks to the significant contribution of INFN and of the various Italian universities involved in the CTA project which, although still in the completion phase, with this success of LST-1, takes an important step forward and opens the way to acquisition of the first scientific data.





RESEARCH FERMI FINDS A HALO AROUND PULSAR GEMINGA

Around the pulsar Geminga, 815 light years far from us, there's a faint but sprawling glow of gamma rays that could provide the solution to a 10 years long mystery. This is what emerges in a recent study based

on the data recorded by the Fermi Gamma-ray space telescope and published on the journal Physical Review D on December 17. The study is the result of a work by researches from the NASA's Goddard Space Flight Center, the INFN and the University of Turin.

The mystery is about some particles, which are surprisingly abundant near the Earth: positrons, the antiparticles of electrons. This excess of positrons was observed in the last 10 years by experiments in space like Pamela, Fermi itself and AMS-02 onboard the International Space Station. And several hypotheses have been made on the origin of this excess: from the pulsars' emissions to the decay or annihilation of particles of galactic dark matter.

In this study, a decade of Geminga gamma-ray data acquired by Fermi's Large Area Telescope (LAT) at energies higher than 8 GeV was analysed. This allowed not only to discover an extended halo of gamma rays around Geminga, but also to determine its physical characteristics. From the results, it emerges that Geminga alone could be responsible for as much as 20% of the observed positrons. If we consider all the pulsars of our galaxy, pulsars seem to be the main responsible for the excess of positrons observed around the Earth at energies higher than the tens of GeV.



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RESEARCH INFRUSTRUCTURES LHC WILL START UP AGAIN IN MAY 2021

During the Council meeting of 12 December, CERN's management presented the new calendar for the next scientific runs of the LHC accelerator, the Large Hadron Collider. According to the updated

programme, the LHC will start up again in May 2021, two months after the initially planned date: the extra time will be needed by the accelerator and the experiments to complete the preparations for run3. The new programme also envisages the extension of run3 by one year, which will therefore last until the end of 2024. At the same time, the machine upgrade projects envisage that all the technological equipment necessary for the future High Luminosity LHC (HiLumi LHC, the high luminosity successor to the current LHC) project and its experiments, will be installed during the Long Shutdown 3 (LS3), between 2025 and mid 2027. HiLumi LHC will come into operation at the end of 2027.

Important works are also under way on all machines and infrastructures: the particle acceleration chain has been entirely renewed within the scope of the LHC Injectors Upgrade (LIU) project, new equipment has been installed in the LHC and numerous experiment components, including entire sub-detectors, are being replaced in order to prepare for high luminosity.

HiLumi LHC will produce many more collisions than the current accelerator, so as to be able to accumulate as much as ten times more data than its predecessor. The new machine will be able to detect extremely rare phenomena and improve the measurement accuracy. In order to fully exploit the increased amount of data, the experiments have initiated ambitious programmes to upgrade the detectors, also thanks to the work of the researchers and technical staff of INFN, who are carrying out fundamental activities in this enterprise where high technology plays a key role.





INTERNATIONAL COLLABORATIONS

THE SESAME GUEST HOUSE IS INAUGURATED WITH THE CONTRIBUTION OF ITALY

It will host researchers of the SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East)

international laboratory, scientists who come from all over the world to work on the synchrotron light source in Allan, Jordan, the first in the Middle East. The SESAME guest house was inaugurated on 4 December, thanks to the fundamental contribution of Italy, with MIUR (the Ministry of Education, University and Research) and INFN. The guest house is intended for scientists, especially young ones, who habitually carry out their research at the SESAME laboratory, with the aim of creating a place for sharing, dialogue and exchange.

Inaugurated in 2017, SESAME is a "special" laboratory, because it represents an opportunity not only for scientific knowledge and technological development, but also for economic growth and especially for intercultural dialogue in a troubled area, bringing together people - Palestinian National Authority, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan and Turkey - which have difficulty in finding other common ground for collaboration and discussion. The Italian Government has been participating in the project since 2013, through MIUR and the technological and scientific expertise of the INFN research community.

The heart of SESAME is an internationally competitive third generation synchrotron light source, which is now a resource for the entire MENA (Middle East and North Africa) region. It is a very powerful microscope, based on an electron accelerator, allowing studies and applications in many fields, including physics, life sciences, materials science and archaeometric studies. SESAME is therefore a centre of excellence for multidisciplinary research, able to attract scientists from various countries and very different sectors.



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MAGIC OPENS A NEW ERA IN GAMMA ASTRONOMY

On 14 January 2019, perfect teamwork, involving space and Earth telescopes as well as hundreds of researchers worldwide, made it possible to record, for the first time, high-energy photons emitted by a Gamma Ray Burst (GRB): short but powerful cosmic explosions that suddenly appear in the sky about once a day, the result of a very powerful cosmic explosion. These photons, which reached energies of the order of the tera electron volt, thousands of times greater than those of visible light, were captured by the twin MAGIC (Major Atmospheric Gamma Imaging Cherenkov Telescope) telescopes on the island of Las Palmas, in the Canary Islands (Spain). The Italian scientific contribution, with the INAF National Institute of Astrophysics, the INFN, the ASI Italian Space Agency and various universities was fundamental to the discovery. The results were published in Nature at the end of November.

The gamma-ray burst as a whole was discovered independently by two satellite instruments, the Neil Gehrels Swift Observatory and the Fermi Gamma-ray Space Telescope. On the ground, the INAF robotic telescope, REM, located in Chile, which captured the optical emission, and the two Cherenkov MAGIC light telescopes, in the Canary Islands, equipped with mirrors with a diameter of 17m and designed to detect very high-energy gamma photons (25 GeV-50 TeV), emitted from galactic and extragalactic sources, were ready to receive the alert. The MAGIC telescopes, in particular, were designed to rapidly respond to GRB alerts and work on a dedicated follow-up strategy. After pointing in the direction of the GRB 190114C, the two telescopes captured the highest energy photons ever measured for this type of celestial event, detecting its presence up to half an hour after the GRB explosion. Thanks to the intensity of the signal received and to the particular real time data analysis procedure, it was possible to communicate the discovery to the international astronomical community within a few hours of its observation: an unprecedented result, which provides new information essential for understanding the physical processes in progress in GRBs.



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Discovered in the late 1960s, the origin of GRBs remained mysterious until the late 1990s when, thanks to the Italian astronomy satellite X BeppoSAX, it was possible to precisely identify and subsequently observe the region of the sky in which they occur with the most powerful telescopes. Today we know that they are the result of the explosion of very massive stars or the fusion of neutron stars in distant galaxies. Nevertheless, although the origin of these phenomena has been identified, more than 50 years after their discovery, many aspects of them still remain mysterious: the observations with very high-energy gamma-ray telescopes are fundamental to give an answer, because they let us directly observe the core of the phenomenon.

MAGIC owes its observational capability to the Cherenkov radiation detection technique, radiation emitted when high-energy gamma rays penetrate the Earth's atmosphere giving rise to showers of secondary particles. Given the very high energy of the photons from which they originate, the particles produced propagate at a speed higher than that of light in the atmosphere, giving rise to clouds of weak bluish light lasting only a few fractions of a second: Cherenkov radiation, an effect comparable to the sonic boom produced by the shock wave of a supersonic jet. Working in a coordinated manner, the two MAGIC telescopes are able to capture this radiation, thanks to the size of their mirrors and their ultra-sensitive detectors.

MAGIC was built by a largely European collaboration that includes approx. 160 researchers from Germany, Spain, Italy, Switzerland, Poland, Finland, Bulgaria, Croatia, India and Japan. Italy participates through INFN, which is one of the founding institutes, together with the Universities of Padua, Udine and Siena, and the INAF, which joined the experiment in 2006.



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COVER

MAGIC (Major Atmospheric Gamma Imaging Cherenkov Telescope) telescopes on the island of Las Palmas, in the Canary Islands (Spain)

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