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"COSMO" What Next: INFN establishes the priorities in astroparticle physics research

interview with Antonio Masiero, deputy head of INFN, professor of theoretical physics at University of Padova.

Professor Masiero, the new frontiers of particle physics today encroach on fields that traditionally belong to cosmology and astrophysics. Already from the imminent start up of the LHC particle physicists are expecting important information about the nature of dark matter. What led to this widening of the horizon?

First of all, I would like to say that this is neither a change of direction nor a sudden widening of our research horizons. It is a process which takes place in the more general context of *What Next*, the path of prioritisation of future research of the institution, in progress since 2014. The commitment in areas in which we still do not have a specific presence is due, on the one hand, to a cultural interest justified by the relationship that these issues have with those of INFN's research, and on the other, the awareness that our specific know-how can provide an important contribution to research in this area.

Strictly speaking, moreover, our particle physics started out as cosmic ray physics and the union between microcosm and macrocosm is part of INFN's research mandate. The first accelerator used by physicists to study particles was precisely the cosmos, but even after the development of accelerators, we continued with an intense program of cosmic ray physics. With ground telescopes for gamma astronomy, for example. In this context, our flagship instrument is the Magic telescope, in the Canary Islands, now officially integrated into the largest CTA project (*Cherenkov Telescope Array*), which represents the future of physics in this field. Cosmic particle research has in the past also seen important collaborations such as the Italian-Chinese Argo project, in Tibet, the highest cosmic ray telescope in the world, and we are currently involved in the Auger project, in the Argentine

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Pampas, for the study of cosmic photons, but also of high-energy neutrinos. In the field of neutrinos, we rely on the synergic efforts of numerous experiments at the Gran Sasso National Laboratories: in the past with Macro and Gallex, today with Borexino, engaged for some time now in research on atmospheric and solar neutrinos and geoneutrinos, produced in the Earth's crust, and LVD (*Large Volume Detector*) for research on neutrinos produced in supernova explosions. Then there is the large international Km3net project, the underwater laboratory for the study of high energy cosmic neutrinos. Significant efforts are also conducted in the field of gravitational waves. With the construction of large interferometers, as the French-Italian Virgo, in the countryside near Pisa, there's now the concrete possibility that their detection will reach the expectations of scientists. We have also since many years been participating in successful space programmes, which have seen INFN taking leadership roles: for example in the case of the Pamela satellite, whose research programme is integrated with that of the NASA, AMS-02 (*Alpha Magnetic Spectrometer*) and Fermi satellites, in which we have a very significant role. The near future will also see our participation in the experiment on the Gamma 400 satellite, which will be launched on a Russian rocket in about two years time. Participation in the Chinese DAMPE (*DArk Matter Particle Explorer*) experiment also opens an important avenue of collaboration with the Chinese space programme. The latter includes, among others, the construction of a space station on which we plan to install an important experiment, HERD (*High Energy cosmic Radiation Detection*), for the indirect search for dark matter in space.

After dark matter, the great frontier of cosmological research is the study of dark energy which constitutes more than 70% of the Universe. How do we address a challenge of this magnitude?

We theoretical physicists have an advantage over experimental physicists in that we have lower limitations on our research possibilities and can go beyond the boundaries of what is accessible to experiments. In this sense we have several interesting collaborations (which we call "specific initiatives"), two of which are focused on cosmology issues, in particular on the study of cosmic background radiation and on the study of dark energy.
On the cosmic background radiation front, the image of the primordial universe that dedicated satellites are able to detect and study, we are engaged in the study of an experiment aimed to the detection of a property of cosmic background radiation, polarisation, which can provide important clues on the inflation, a mechanism which shortly after the Big Bang, 13.5 billion years ago, was instrumental in the formation of our Universe as it is today.
For these studies, we have activated a collaboration with INAF (*National Institute for Astrophysic*) within the context of the LSPE (*Large Scale Polarization Explorer)* experiment. The experiment involves the launch of hot-air balloons from the Svalbard Islands, North of Norway, on which detectors

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are installed which, returning after a few days or a few months, bring information on important properties of cosmic background radiation and, in particular, on its polarisation. Currently international collaboration BICEP (*Background Imaging of Cosmic Extragalactic Polarization*) is engaged in the study of the polarization of the cosmic microwave background. In particular, in 2014 BICEP gave results that were initially interpreted as an imprint of gravitational waves generated during inflation on the cosmic background radiation, in particular on the polarization of the photons that make it up. This result was definitively not confirmed but there are good reasons to believe that it is be possible to obtain more accurate data by extending the field of investigation of the experiments and their range.
For the study of dark energy, we plan to collaborate in a larger ESA (*European Space Agency*) experiment, EUCLID (*European Cooperation for Lighting Detection*), which has as its primary objective the measurement of the acceleration with which our universe is expanding, which is believed to be due to the presence of dark energy. In particular, the variations of this acceleration could result in a corresponding variation of dark energy over time. The subject of the investigation, in this case, are the galaxies, whose distribution is kept under observation by comparing photographs of space made at ever greater distances, corresponding to increasingly remote eras of the life of the Universe.
Last, not in terms of interest but because it comes about in a peculiar manner, is the collaboration with the Planck experiment, in which INAF and ASI (*Italian Space Agency*) are involved for Italy, dedicated to exploration of the deep universe. In this case INFN will participate with a group composed largely of young people, with the primary objective of training them, participating for the first time in the scientific production of the experiment.

How is the collaboration with institutions whose primary mission is cosmological research organised?

The interest in research aspects that lie on the boundary of the primary goals of particle physics is also due to two other important factors, in addition to the cultural interest and the experience that we can put in play. One concerns the state of the art of research with accelerators and in the astroparticle field, which is increasingly shifting the efforts of physicists towards expectations of discovery of new physics, of new particles and extensions of the current framework of elementary particles and their interactions. The other is of a sociological nature: we are increasingly interested in broadening the scope of our collaborations with other institutions, in Italy, in particular with ASI and INAF, and abroad, with a view to synergic collaborations in areas of common interest. It is a process that is also developing in other countries, where institutions similar to ours are increasingly engaged

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in cosmology research. Other important factors are the sharing of technological expertise acquired through experiments in fundamental physics and the possibility of sharing training experiences for young researchers.
We can contribute with a know-how unique in Italy in terms of particle detectors and silicon technologies. Also research with accelerators has allowed us to acquire unique skills in the fields of electronics and computing, the latter essential for handling the huge amount of data deriving from space physics. An example is provided by physicists who are today involved in the AMS-02 and Fermi experiments, largely coming from particle accelerator physics.
Research experience in extreme conditions also makes INFN laboratories a valuable resource for the development of high-level technologies. In particular, a specific infrastructure in the National Laboratories in Frascati is in the design phase, with the prospect of creating a technological hub for space physics, an interesting opportunity also in terms of training young researchers in this field.