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IXPE SPACE MISSION KICKS OFF, THE FIRST ONE ENTIRELY DEDICATED TO THE STUDY OF POLARIZED X RADIATION

Interview with Luca Baldini, INFN national spokesperson for IXPE (X-ray Polarimetry Explorer) and co-Principal Investigator of the mission, and Luca Latronico, INFN researcher and local spokesperson for IXPE for the Turin division.

In the early morning of Thursday 9 December when it was 7 a.m. in Italy, the spectacle provided by the trail of the boosters of the Falcon 9 launcher, which illuminated the night sky above NASA Kennedy Space Center in Cape Canaveral, Florida, greeted the launch of the mission X-ray Polarimetry Explorer (IXPE), which only forty minutes later reached its operational orbit at an altitude of 600 kilometres and inclined just 0.2 degrees compared to the equator.
A first milestone – which will hopefully be followed by many more – for which Italy, and the INFN, has much to celebrate. The result of a partnership between NASA and the Italian Space Agency, the IXPE mission is the first entirely dedicated to the study of the polarisation of X-rays emitted by extreme astrophysical sources, such as neutron stars, black holes and supernova remnants. It will be able to rely on new scientific instrumentation designed and built in collaboration between INFN and the Italian National Institute for Astrophysics (INAF). INFN, specifically, was responsible for the development, construction and qualification of the three detectors that represent the core of IXPE. The Gas Pixel Detectors (GPD) – this is the name of the detectors – exploit a technology developed over the past 15 years that uses the expertise acquired by INFN in the particle physics field. By accurately measuring the ionization produced by the electrons emitted as a result of the absorption of photons by the gas they are filled with, the three IXPE detectors will be able to provide accurate indications on the geometry and characteristics of the magnetic field of the source, from which polarization depends.
Luca Baldini, INFN spokesperson for IXPE and co-principal investigator of the mission, and Luca Latronico, local spokesperson for IXPE for the INFN Turin division, coordinated the construction of the three Gas Pixel Detectors of IXPE, which took place in the INFN laboratories of Pisa and Turin.

Dr Latronico, on 9 December, the IXPE mission got underway. Can you describe to us what are the main instruments on the IXPE satellite and what is the main purpose of the mission?
IXPE has only one instrument on board, entirely dedicated to the measurement of the polarisation of X-ray radiation of astrophysical origin. This instrument consists of three identical telescopes, each of which includes an X-ray lens and a Detector Unit (DU), which houses the polarisation-sensitive Gas Pixel Detector, the reading electronics, the thermal control system, and the calibration sources.

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What is meant by X-ray polarisation and why is it important to study this property in astrophysics?
Polarisation is a property of electromagnetic waves, hence of light, that has to do with the direction of oscillation of the electric field and has no strict equivalent with other types of waves (such as, for example, sound waves). At any energy level, and therefore also at kilo-electronvolts (the energy level typical of X-ray radiation), light is said to be polarised if it consists of electromagnetic fields with specific and non-random spatial orientations. Measuring the polarisation of light therefore provides us with information on the mechanism by which the source emits electromagnetic radiation.
In the case of X-rays of astrophysical origin, whose production sites are often characterised by extremely intense magnetic and/or gravitational fields, measuring polarization leads to indirect information on the geometry of the sources that is not accessible by other means. Moreover, measuring polarisation can provide additional information about the interactions that X-ray radiation has in the path from the source to us, potentially indicating the presence of particles never directly observed, such as axions, particles that are thought to constitute the mysterious dark matter.

How did INFN contribute to the implementation of IXPE and what role will the Institute have in the scientific collaboration responsible for the satellite?
INFN conceived the Gas Pixel Detector and qualified it in all its parts for use in space. Specifically for IXPE, INFN designed the architecture of the in-flight GPD acquisition system, designed the detector housing mechanics, integrated the Detector Units into the cleanroom in Pisa and performed the qualification campaign for the flight. The Detector Units were delivered to the Italian Space Agency to be then calibrated in the INAF laboratories, integrated on the satellite by Ball Aerospace in Colorado and finally integrated on the Falcon 9 by Space-X for the launch on 9 December.
The INFN group also developed the software for simulation and reconstruction of the detectors and provided the collaboration with the tools to simulate the observations that will be made with IXPE.
Finally, INFN coordinates the international group that elaborates the IXPE data analysis techniques and participates in the analysis activities for the different classes of sources that we will observe.

Dr Baldini, how did the idea of the Detector Units provided by INFN come about? How do these detectors differ from similar instruments used in the past? And how long did their development take?
The innovation that allows us to measure the polarisation with high efficiency lies in the Gas Pixel Detectors, which were created by integrating, at an unprecedented level, the standard techniques of micro-pattern gas detectors with modern microelectronics for signal acquisition and processing in this single device. Developed starting from an idea of Ronaldo Bellazzini, the creation of dedicated GPDs and data acquisition systems, was conceived and built up by the same research group in Pisa formed around Bellazzini and it took approximately 15 years. The IXPE Detector Units, which INFN designed and implemented, integrate the GPDs, electronics and services in compact units that reflect the size, mass and power requirements imposed by the mission.

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What are the characteristics of Gas Pixel Detectors and what kind of technology do they exploit?
GPDs detect polarisation by reconstructing the path that the single electron resulting from the photon conversion takes in the gas for each photon they capture. They use a charge amplifier, the Gas Electron Multiplier, to generate a detectable amount of charge of a few thousand electrons, and an integrated circuit organised in a matrix of very small pixels with a 50μm (micron) pace, which detects the track of the electron by collecting the amplified charge cloud along its path.
Unlike previous polarisation measurement techniques that worked by selecting particular directions in the plane, in search of the right polarisation angle of the incident radiation, GPDs measure the directions of all incident photons, drastically reducing the exposure time to make each measurement.

What kind of performance will IXPE's Detector Units provide and what information will they make it possible to obtain concerning the astrophysical sources being investigated by IXPE?
IXPE's DUs are designed to be able to measure the polarisation of dozens of different astrophysical sources, with high sensitivity, over a mission pattern of a few years. Since the techniques previously used were highly inefficient (they measured the polarisation only for the two brightest sources in the sky), for the first time IXPE will be able to make a true census of many different sources that are thought to emit polarised radiation, thus providing crucial information to develop emission models of these cosmic accelerators.

In what way did INFN's experience within the Fermi mission contribute to the development of IXPE's detectors?
For the Fermi Gamma-ray Observatory, INFN implemented the largest silicon micro-strip tracer used in space, acquiring enormous expertise in the design, integration and qualification of complex particle detector devices for space. The INFN community then exploited the deep knowledge of this device to extend its observational capabilities to other areas, such as electrons of galactic origin, and investigate particularly complex phenomena such as the nature of dark matter. The value of these contributions and the ability to make them available to the international collaboration resulted in many INFN researchers playing important roles in coordinating the scientific analysis activities.
The same expertise, dedication and spirit of collaboration was transferred to the contribution that INFN brought to the IXPE mission, ensuring, to date, the production of telescopes capable of opening a new observational window on polarisation, and laying the foundations for an exciting scientific adventure with the data that IXPE will collect in the coming years. ■