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14 september 2022

PRESS RELEASE

PR064-2022

Final results of MICROSCOPE mission achieve record levels of precision

The MICROSCOPE mission has delivered its latest results and has confirmed the equivalence principle with unprecedented accuracy of 10^{-15}. These results show that bodies fall in a vacuum with the same acceleration regardless of their composition or mass, meaning that the principle of equivalence remains unwavering today, to mark yet another victory for the Theory of General Relativity as proposed by Albert Einstein more than a century ago.

In 2017, the first results of the CNES MICROSCOPE satellite, equipped with ONERA accelerometers, improved the accuracy of the equivalence principle (or universality of free fall) to a level that had placed it as a world reference. Thanks to the first data available at that time, these results were obtained by the Géoazur laboratory (CNRS/OCA/UCA/IRD) and ONERA in cooperation with CNES and in partnership with the scientific working group (CNRS, IHES, Imperial College, University of Bremen, DLR, University of Delft, IGN). They earned four members of the MICROSCOPE team the Prix Servant Award from the French Academy of Sciences in 2019. Since 2017, 15 times more measurements was accumulated until the time of the satellite being deorbited in October 2018. The scientific team analysed all the data and managed to push back the test limits even further by doing 10 times better than in 2017. By comparing the free fall accelerations of two bodies of different compositions, the MICROSCOPE teams were able to demonstrate that their relative free-fall deviation is less than 10^{-15}.

About the principle of equivalence

According to Einstein's theory, the universe is represented by a four-dimensional space-time, and gravitation results from matter bending space-time itself. General Relativity has thus made it possible to explain the hitherto insoluble anomaly of Mercury's orbit, to predict phenomena as surprising as gravitational lenses, black holes or gravitational waves. Nevertheless, a fundamental question remains: why does General Relativity seem incompatible with quantum field theory, which faithfully describes the world of particles and the infinitely small? The search for a universal theory encompassing gravitation and quantum physics is the Holy Grail of physicists. Most candidate theories predict a violation of the founding principle of General Relativity: the equivalence between gravitation and acceleration.

Testing the equivalence principle amounts to testing the foundation of all theories of gravitational and more generally alternative theories to relativity. With its results, MICROSCOPE is pushing the boundaries by bringing new constraints to these new theories at a level of precision such that it will certainly take a very long time to improve on.

About MICROSCOPE

MICROSCOPE (MICROSatellite à trainée Compensée pour l'Observation du Principe d'Équivalence - Compensated Drag MICROSatellite for the Observation of the Principle of Equivalence) is a mission of CNES, carried out in partnership with ONERA, OCA, ESA, DLR, ZARM (microgravity laboratory of the University of Bremen) and PTB (German Physics and Metrology Institute). With its accelerometer-controlled microthrusters, the satellite is able to achieve ultra-fine control of its orbit and compensate for the residual atmospheric drag, at levels never before managed in low Earth orbit. ONERA's T-SAGE instrument is right at the core of this perfect free-fall laboratory, ensconced in a thermal cocoon which stability is better than one

millionth of a degree. The instrument is a differential accelerometer. It measures the position of its test masses, in free-fall around the Earth, with an atomic scale accuracy.

MICROSCOPE was launched on 25 April 2016 and decommissioned on 15 October 2018. Scientific measurements and fine characterisations of the instrument and satellite have made it possible to compare the “free fall” of two different materials, platinum and titanium, over the course of 1642 revolutions around the Earth - i.e.: 73 million km - equivalent to half the Earth-Sun distance.

The culmination of many years of effort, this French experiment represents a shining light in the landscape of fundamental physics and a challenge accomplished for engineers and scientists, who have succeeded in pushing the limits of equivalence principle testing accuracy ever further. These results were obtained by ONERA and OCA’s scientific teams with the contribution of CNES and the collaboration of European laboratories. This analysis has been published in two prestigious physics journals: Classical and Quantum Gravity (IOP Publishing) and Physical Review Letters (American Physical Society).

About CNES
CNES (Centre National d'Etudes Spatiales) is the public body responsible for proposing French space policy to the French Government and implementing it within Europe. It designs satellites and places them in orbit and invents the space systems of tomorrow, encouraging the emergence of new services that will be useful in everyday life. CNES, founded in 1961, is the originator of major space projects, launchers and satellites and is the industry’s natural go-to for driving innovation. CNES has around 2,400 employees with a passion for this domain, one which opens up infinite, innovative fields of application and involves five areas of intervention: Ariane, Science, Observation, Telecommunications, Defence. CNES is a major player in technological innovation, economic development and industrial policy in France. It also forges scientific partnerships and is involved in numerous international cooperative ventures. France, represented by CNES, is one of the main contributors to the European Space Agency (ESA).

About CNRS
The French National Center for Scientific Research is one of the most recognised and renowned public research institutions in the world. For more than 80 years, it has continued to attract talent at the highest level and to nurture multi-disciplinary and interdisciplinary research projects at the national, European and international levels. Geared towards the public interest, it contributes to the scientific, economic, social and cultural progress of France. The CNRS is above all 33,000 women and men, more than 1,000 laboratories in partnership with universities and other higher education institutions bringing together more than 120,000 employees and 200 professions that advance knowledge by exploring the living world, matter, the Universe, and the functioning of human societies. The CNRS ensures that this mission is carried out in compliance with ethical rules and with a commitment to professional equality. The close relationship it establishes between its research missions and the transfer of acquired knowledge to the public makes it today a key player in innovation in France and around the world. Partnerships with companies are at the heart of its technology transfer policy, and the start-ups that have emerged from CNRS laboratories bear witness to the economic potential of its research. The CNRS provides also access to research findings and data, and this sharing of knowledge targets many audiences: scientific communities, the media, decision-makers, economic players and the general public. For more information: www.cnrs.fr

About ONERA, the French aerospace research centre
ONERA is the French national laboratory for aeronautics and space R&T, staffed by 2000 people. Under the supervision of the French Ministry of Armed Forces, ONERA has an annual budget of 266 million euros, of which more than half comes from commercial contracts. As the French expert in aerospace technologies, ONERA prepares tomorrow's defenses, meets the aerospace challenges of the future, and contributes to the competitiveness of the European aerospace industry. ONERA masters all the disciplines and technologies in its aerospace fields.
All major civil and military aerospace programs in France and Europe contain "DNA" from ONERA: Ariane, Airbus, Falcon, Rafale, missiles, helicopters, engines, radars, etc.

About OCA (Observatoire de la Côte d’Azur - Côte d'Azur Observatory):
The Observatoire de la Côte d'Azur (OCA) is part of Côte d'Azur University, and it hosts and runs research activities in Earth and Space sciences within this experimental university by way of three UMRs (mixed research units): Artemis (CNRS-UCA-OCA), Geoazur (CNRS-UCA-OCA-IRD) and Lagrange (CNRS-UCA-OCA). More than 450 people at four sites, including one observation site, work on numerous international projects. Space missions (Gaia, Hera, Euclid, etc.), earthquakes (Teil en Ardèche, Haiti, etc.), general

relativity, gravitational waves, geodesy and asteroids are just some of the topics studied by the teams of the three UMRs. The Côte d'Azur Observatory is home to around one hundred doctoral students in the laboratories.

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