
ifpU

The Institute for Fundamental Physics of the Universe

A joint initiative of the International School for Advanced Studies (SISSA), the Abdus Salam International Centre for Theoretical Physics (ICTP), the National Institute for Astrophysics (INAF) and the National Institute for Nuclear Physics (INFN).

IFPU started its activities on November 1st, 2018. IFPU aims to host and promote a vigorous and innovative multi-disciplinary research program focussed on investigating the fundamental laws of Nature under a Cosmological and Astrophysical perspective.

IFPU hosts and promotes a multi-disciplinary research program dedicated to investigating the fundamental laws of Nature as emerging from Cosmological and Astrophysical observations. The focus is on theoretical and phenomenological studies, with connection to the experimental and observational programs in the field and with attention paid to the scientific and technological transfer.

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The ambitious goal is to address a set of basic questions about the Universe, standing as some of the most pressing open issues in Science today…

- Identify the nature of Dark Matter and its footprint on the formation of structures;
- Find out the properties of Dark Energy and their impact on the evolution and fate of the Universe;
- Understand the physics of the primordial Universe and shed light on the relative enigmas, such as the matter-antimatter asymmetry;
- Learn the properties of neutrinos from Cosmology and Astrophysics;
- Understand the nature of gravity both in on the cosmological scale and in the strong-field regime;
- Explore the new frontier opened by gravitational wave detectors.

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The founding Institutions have a consolidated tradition in this field of research, and contributed to creating a rather broad dedicated community of researchers in the area of Trieste, and more at large, in Italy.

IFPU supports their activities, promoting cohesion and new synergies, and coordinating their effort into a single international centre of excellence.

Prominence will be given to theoretical and phenomenological studies; however, these will be in close contact with the large experimental and observational programs which have changed our understanding of the Universe in recent years and which promise to bring a change of paradigm in the near future.

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The main drive of IFPU is to foster international collaborations and exchange of ideas.

The institute promotes an extended visitor plan, including support for:

- long-term visits of internationally renowned scientists with leading expertise in the area within the scientific goals of the institute;
- team research programs, dedicated to small groups getting together at IFPU to develop or finalise a research project;
- focus week programs, in the form of thematic small-scale workshops dedicated to the investigation of a specific research topic.

Research lines

Astroparticle Physics

The aim is to explore particle physics through astrophysical phenomena and cosmology in regimes not accessible to the technology of particle colliders; at the same time, particle messengers can be exploited to study astrophysics and cosmology in regimes not accessible to traditional astronomical probes. Sample topics in this area include, e.g.: the investigation of particle dark matter candidates, the study of neutrino properties and neutrino astrophysics, as well as the open questions regarding cosmic rays.

Title	Principal Investigator
Cosmic rays as a probe of new physics	Riccardo Munini
On the nature of dark matter	

Research lines

Astrophysical Probes of Fundamental Interactions

The Universe is a natural lab for testing environmental conditions and energy regimes that can be well beyond the reach of terrestrial experiments, allowing one to probe or challenge extreme hypotheses. Topics of research in this area are rather diverse, spanning, e.g., from tests of violations of Lorentz invariance, to tests of variation of fundamental constants, up to studies of the equation of state for dense matter in neutron stars.

Title	**Principal Investigator**
Gamma-Ray Bursts as multi-messenger and fundamental physics probes	Annalisa Celotti
The Intergalactic Medium as a Cosmological Probe	Matteo Viel

Research lines

Early Universe

An extremely hot and dense Universe is predicted when extrapolating its current expansion back in time; relics from this early stage, such as the cosmic microwave background radiation and the primordial light elements, provide key evidence for the Standard Model of Cosmology. At the same time, several ingredients to model and understand the early Universe are missing in the Standard Model of Particle Physics. Open questions in this area include, e.g., what has driven inflation and how the Universe reheated after it, what mechanism generated the baryon asymmetry, whether sizeable primordial non-Gaussianity in density perturbations or a stochastic gravitational wave background exist and can shed light on particle physics close to the Planck scale.

Title	Principal Investigator
Cosmic Microwave Background	Nicoletta Krachmalnicoff
From the First Stars to the Epoch of Reionization	Valentina D'Odorico
Phase transitions and early Universe simulations	Toby Opferkuch
Inflation: Theoretical and Phenomenological Aspects	Paolo Creminelli

Research lines

Gravitational Wave Astrophysics

The recent detection of gravitational waves by the LIGO/Virgo collaborations has opened a new frontier for investigating the fundamental laws of Nature. Gravitational wave astronomy will allow for crucial tests of General Relativity, as well as of modified theories of gravity and quantum gravity effects. Compared to electromagnetic probes, it provides a complementary, and in some respect more powerful, diagnostic of compact objects. It may carry an imprint of physics beyond the Standard Model of Particle Physics, e.g., potentially revealing the existence of new ultra-light fields or the occurrence of first-order phase transitions in the early Universe. It is a new window for cosmology and cosmography.

Title	**Principal Investigator**
Gravitational Wave Astronomy: A Paradigm-Shifting Window into the Cosmos	Enrico Barausse

Research lines

Structures in the Universe and Emergent Phenomena

The formation of cosmic structures reflects the fundamental constituents of the Universe and the underlying laws of physics governing its evolution. Key inquiries include discerning the impact of dynamic Dark Energy and modifications of gravity on cosmic structure growth, detecting signs of primordial non-Gaussianity in structure formation seeds, and investigating how structures at various scales unveil properties of dark matter particles. Moreover, we explore the intricate relationship between cosmic structure formation and the potential emergence of life-sustaining environments. The diverse array of physical processes, length scales, and time scales involved adds complexity to this investigation.

Title	**Principal Investigator**
Large-Scale Structure	Emiliano Sefusatti
Galaxies in their cosmic web	Gabriella De Lucia
Numerical Simulations of the Large-Scale Structure	Pierluigi Monaco
The emergence of complexity in the Universe: from galaxies to planets and life.	

Research lines

Theory & Phenomenology of Gravity

General relativity is among the most successful modern physical theories. On the other hand, in the last decades a number of theoretical problems as well as observational facts have led to a renewed interest in the phenomenology of classical extensions of Einstein's theory as well as in quantum gravity models. Topics of research in this area include studying, e.g.: alternative theories of gravity; theoretical approaches to quantum gravity and their phenomenological implications; black holes and compact objects physics within and beyond general relativity; analogue models of gravity.

Title	**Principal Investigator**
Fields on Curved Backgrounds and their Analogue Models	Stefano Ansoldi
Quantum Gravity Phenomenology: Probing the Fundamental Nature of Spacetime	Stefano Liberati
Flat Holography and Gravitational Waves	Daniele Pranzetti

Next …

IFPU special programs

The Institute for Fundamental Physics of the Universe supports and hosts small-scale workshops and meetings dedicated to the investigation of the fundamental laws of Nature as emerging from Cosmological and Astrophysical observations. The focus is on theoretical and phenomenological studies, with connection to the experimental and observational programs in the field.

Priority will be given to selected topics within the IFPU research areas:

- Astroparticle Physics
- Astrophysical Probes of Fundamental Interactions;
- Early Universe;
- Gravitational Wave Astrophysics
- Structures in the Universe;
- Theory and Phenomenology of Gravity.