Focus point on modified gravity theories and cosmology

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1 Introduction

Last decades have been extremely remarkable for cosmology and astrophysics due to several outstanding observational discoveries. The main one has been, without any doubt, the fact that the Universe is dominated by some forms of dark energy and dark matter which, despite showing their effects at large scales, have not been experimentally identified, so far, at fundamental scales. The dark matter hypothetical particles are being actively searched—still without success—at accelerators and underground experimental facilities, while the dark energy, giving rise to repulsive gravity effect, is considered a major problem not only for cosmology but also for fundamental physics being not still framed among fundamental interactions.

In this puzzling situation, theories of gravity are assuming a main role to address astrophysical and cosmological dynamics starting from ultraviolet to infrared scales. In other words, dark energy and dark matter could be nothing else but the signal that Einstein General Relativity, working extremely well at the scales where it has been tested so far, could be modified or extended to address these further phenomena.

A new window for probing gravity and a bunch of fundamental concepts has been opened by the discovery of gravitational waves by LIGO-Virgo collaboration. The study of the details of the wave pulses provided unique information on the black hole and neutron star mergers and enabled to probe gravity theories in strong-field regime.

Another noticeable observational achievement has been the release by *The Event Horizon Telescope Collaboration* of the image of supermassive black hole shadow in the center of giant galaxy M87. Testing black hole physics is a formidable tool for any theory of gravity which, in this perspective, can be probed in its fine features and characteristics.

From a more genuine cosmological point of view, the Hubble tension, i.e., the discrepancy between measurements of the Hubble constant for early and late Universe, is among the recent intriguing observational facts. This is just the most striking case, but other cosmological parameters need to be rethought in view of tensions indicating, in general, some new physics.

These observational facts stimulated the development of modified theories of gravity which can be, essentially, extensions of General Relativity or theories where basic foundations, as

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the Equivalence Principle, are questioned. These new approaches are taken into account both in the strong field as well as in the weak field limits.

The current collection of focus point papers aims to reflect the diversity of modified gravity theories and of their applications to the cosmological problem. The scope of the topics covered here is enough broad, ranging from teleparallel gravity and gravitino problem in extended gravity up to traversable wormholes in $f(R)$ gravity, from a model of lattice universe, up to addressing the Hubble tension within modified gravity. There are also papers dealing with modified gravity tests, namely with Lense–Thirring precession, with observational constraints, including the black hole shadow, with the Solar system constraints to Brans–Dicke and Palatini $f(R)$ theories, as well as with suggestions for high-precision gravitational redshift measurements as probes for gravity theories.

What we want to stress is that modified gravity and cosmology are widely developing areas being in permanent contact with ongoing observational surveys and experimental programs. The appearance of further intriguing theoretical and experimental ideas is certainly expected.