Editorial on special issue on gravitational lensing

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Published online: 14 July 2010
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Although gravitational lensing came into existence almost 100 years ago with General Relativity, and was immediately applied for computing the gravitational deflection of light from background stars by the Sun, it is still a young method for exploring the Universe. From an observational point of view it increasingly captivated astronomers after the discovery of the first multiply lensed quasar in 1979. Since then, in only about 30 years the method developed in an almost exponential way. Gravitational lensing is now a very important tool for astrophysical and cosmological investigation. Both theory and observation made huge progress and the method can now be applied to a large variety of astrophysical and cosmological topics. Note that gravity works at all scales and gravitational lensing manifests itself by a broad diversity of spectacular effects that are routinely observed with astronomical telescopes – like multiple imaging, Einstein rings, luminous arcs, time delays, and microlensing magnifications. For these reasons, it can be used in almost all fields of astronomy and cosmology. In some cases it also opened new territories, like cosmic shear.

Today, gravitational optics is applied to a broad range of problems, and to all astronomical bodies, spanning several orders of magnitudes in terms of size, mass and

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density. Within 30 years, gravitational lensing grew into a mature science. As gravitational deflection depends on the mass of gravitational bodies, gravitational lensing primarily is a probe for the discovery of exo-planets, the exploration of the dark-matter content in the haloes of the Galaxy and of M31, as well as of dark haloes in other galaxies, in clusters of galaxies and in large-scale structures. Furthermore, as gravitational lensing also depends on angular distances and on the nature of the gravitational field, it is also a unique tool for the exploration of the geometry of the Universe, of the properties of dark energy, and for testing alternative gravitational theories. Its outstanding scientific potential and its past accomplishments are testified by the flourishing major ground-based and space surveys planned for the next decades.

Given these very rapid and important developments, the editors of GRG thought that it would be useful and timely to dedicate a special issue to gravitational lensing. We thus set up a list of topics we believe it is worth presenting in GRG and asked known scientists working in the field to provide an updated review on them. We are well aware of the fact that not all topics could be fully covered and that our selection is somewhat biased. Furthermore, because of page limit constraints, not all our favourite subjects could be reviewed in full depths. Nonetheless, keeping in mind these limitations, we believe that the present special volume provides a good summary of results achieved so far by gravitational lensing and that it might constitute a useful reference both for scientists working in the field and for others who just wish to get a brief overview of the recent progress and of the future perspectives of gravitational lensing science. We think that one sees nicely that the field grew in a few years in an impressive way and has now become an established tool for the investigation of the Universe.

This special issue is organised in 12 reviews; one focused on gravitational optics, namely “Mathematics of gravitational lensing: Multiple imaging and magnification”; four on applications of microlensing, “Microlensing as a probe of the Galactic structure; 20 years of microlensing optical depth studies”, “Studying planet populations by gravitational microlensing”, “Pixel lensing. Microlensing towards M31”, “Quasar microlensing”, three on theory and applications of strong and weak gravitational distortion of distant galaxies and on the CMB anisotropies, “On modeling galaxy-scale strong lens systems”, “Weak lensing, dark matter and dark energy” and “Weak lensing of the CMB”; two on gravitational lensing and fundamental physics, “Tests of general relativity on astrophysical scales”, “The relevance of the cosmological constant for lensing”; and finally one review on gravitational lensing theory in the strong field regime, “Gravitational lensing by black holes” and one on exotic gravitational lenses, “Lensing by exotic objects”. Theoretical, phenomenological, numerical and observational aspects of gravitational lensing are presented through one or several of these reviews, with special emphasis on the present and future key scientific questions where gravitational optics is perfectly suited to tackle them. We hope that the reviews will show how fascinating gravitational optics is and how promising its applications to astrophysics and fundamental physics are for the next decades.