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Strong Gravitational Lensing – Editorial

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The first gravitationally lensed quasar — the double Q0957+571A,B — was discovered more than 45 years ago, by now about 400 multiply imaged quasars are known. Gravitationally lensed quasars have been explored for more than four decades with respect to a variety of cosmological questions: measurement of time delays, determination of the Hubble constant, derivation of the cosmological constant, detection of microlensing, setting limits on compact and smooth dark matter, exploration of quasar size and luminosity profile, modelling of the mass distribution of the lensing galaxy or galaxy cluster, to name just a few.

About 40 years ago, "giant luminous arcs" were discovered, high redshift galaxies gravitationally lensed, magnified and heavily distorted by foreground galaxy clusters. They made Fritz Zwicky's vision from the 1930s come true and opened up a new direction of exploration: Confirming the large masses of clusters of galaxies, and — by their magnification — effectively increasing the diameter of our telescopes.

A few exciting new developments in recent years make the topic of "strong gravitational lensing" very timely and open up new routes for exploration, e.g. the discovery of gravitationally lensed supernovae (as originally suggested by Sjur Refsdal in the early 1960s — before quasars were known!), the new controversy about the Hubble constant, and in particular the data releases of the ESA Gaia mission which allowed to discover many new strongly lensed objects due to the all-sky coverage — opening up a multitude of new roads for exploration.

In the next few years, very wide-ranging cosmological investigations of gravitationally lensed quasars/supernovae/background galaxies will become possible with the NSF-DOE Vera C. Rubin Observatory and in particular the envisioned *Legacy Survey of Space and Time* (LSST): The LSST will open up the time domain for quasar lensing in an unprecedented way which has the potential to revolutionize this field! And in the deep stacked images very many giant luminous arc systems will be discovered in so far unexplored regions of the sky. These very promising developments provide the perfect frame for reviewing the current state of strong gravitational lensing, and allow to discuss new ideas of how to explore the current and near future data treasure with very interesting — even though partly controversial — discussions.

Originally planned for summer 2020, the ISSI Workshop on Strong Gravitational Lensing could not take place due to the corona pandemic. According to the then suggested ISSI "reverse" schedule, about 55 scientists started with an online-kickoff on 18 January 2021 with some review talks and introductory discussions on the important topics to be covered.

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In the following 14 months, twelve more online meetings were held in which the different groups assigned to the relevant scientific topics discussed and presented their progress on the articles to be written. Finally, the "real" ISSI Workshop took place on 18 – 22 July 2022 in beautiful Bern/Switzerland. Although it was meant to just "wrap up" the papers to be submitted soon thereafter, very lively discussions and new developments lead to further time delays until the last manuscripts became available in a quality which satisfied all parties involved — authors, referees and editors.

Our "product" now is a collection of eleven review articles on various aspects of strong gravitational lensing, covering themes like the search for strong lenses, lensing as a probe for dark matter, lensing and microlensing of supernovae, to name just a few. The topical reviews are framed by two introductory articles on "*Essentials*" and "*Basic Elements*", resp., of strong gravitational lensing — complementary ways to enter the field.

It is a great pleasure to thank the International Space Science Institute (ISSI) for its very generous support of this workshop, and the wonderful ISSI staff for hosting and perfectly organizing this workshop, as well as patiently accompanying the production of this collection. We would also like to thank all authors for their long-lasting support and meticulous work, the referees for very carefully reading, reviewing, commenting and improving all the manuscripts, and the staff of Springer Nature for publishing this Special Issue efficiently. May this collection serve as a good overview for experienced researchers and as an excellent introduction for newcomers to the field of strong gravitational lensing for a few years to come.

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Declarations

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