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Editorial: Topical Collection on Astronomical Distance Determination in the Space Age

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Knowing the distance of an astrophysical object is key to understanding its formation and evolution: without an accurate distance, we do not know how bright it is, how large it is, or even when it existed. Astronomical distance measurements are challenging tasks, and indeed the typical information we have about Galactic and extragalactic sources are their

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positions (perhaps as a function of time) and their brightnesses (as a function of wavelength and time).

The first modern milestone in the estimate of nearby distances dates back to the *Hipparcos* space mission (in the 1990s), which provided absolute trigonometric parallaxes at milliarcsecond-level precision across the whole sky for more than 100,000 sources. Around the same time, and to the surprise of many scientists, the Fine Guidance Sensor onboard the *Hubble Space Telescope* (which was designed to guide the telescope) was used as a scientific instrument and provided exquisite trigonometric parallaxes for a handful of primary distance indicators (including Cepheids, RR Lyrae, and δ Scuti variables). In addition, during the past 10–15 years, the use of ground-based 8–10 m-class optical and near-infrared telescopes and space observatories have provided an unprecedented wealth of accurate photometric and spectroscopic data for stars and galaxies in the Local Group (at distances $D < 1$ Mpc) and in the Local Volume ($D < 25$ Mpc). Moreover, interferometric radio observations have also achieved 10 micro-arcsecond astrometric accuracy.

This Topical Collection highlights the tremendous amount of recent and continuing research into a myriad of exciting and promising aspects of accurately pinning down the cosmic distance scale. Putting the many recent results and new developments into the broader context of the physics driving cosmic distance determination is the next logical step, which will benefit from the combined efforts of theorists, observers and modellers working on a large variety of spatial scales, and spanning a wide range of expertise. In our journey from the solar neighbourhood to the edge of the Universe, we shall encounter stars of all types, alone, in pairs and in clusters, their life cycles, and their explosive ends: binary stars, in particular, play an important role in this context; the stellar content, dynamics, and evolution of galaxies and groups of galaxies; the gravitational bending of starlight; and the expansion, geometry, and history of the Universe. As a result, this Topical Collection offers not only a multi-disciplinary, comprehensive study of distance measurements, but a tour of many recent and exciting advances on all (distance) scales in astrophysics.

The eight reviews included in this Topical Collection specifically address future efforts in this field, both theoretically and observationally. This is a critical time in the context of firming up the astronomical distance scale: Very Long Baseline Interferometry sensitivity is being expanded allowing, for example, direct measurement of distances throughout the Milky Way and to Local Group galaxies. The field will benefit tremendously in the *Gaia* era, which is now truly upon us. In addition, the next-generation 'extremely large telescopes' (ELTs) will play a crucial role in cosmic distance determination, since they will allow us to determine the Hubble constant only using primary distance indicators. Significant modelling efforts are currently underway to prepare the community for use of the Thirty Meter Telescope (USA, Japan, China, India), the European ELT, and the Giant Magellan Telescope (California, South Korea, Taiwan).

Space-based observatories, in particular, are allowing major advances to be made, and this will only increase in the next decade. In addition to the European *Hipparcos* and *Gaia* missions, Asian scientists, in particular our Japanese colleagues, are leading the field in relevant space missions. Nano-, micro- and (full) *JASMINE*, as well as the Japanese space interferometry missions *VSOP/VSOP-2* complement Russian efforts related to *eRosita*, in addition to US and European space missions like the *Hubble* and *Spitzer Space Telescopes*, *WFIRST*, *Herschel*, the Wilkinson Microwave Anisotropy Probe, and *Planck*. These space-

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and ground-based facilities will have an immediate bearing on the astronomical distance scale. Nevertheless, many uncertainties remain at the level of at least 5–10%, particularly in terms of our understanding of the physics underlying many of the methods commonly used for distance determination.

Overall, this Topical Collection provides a timely and comprehensive review of the status of ground- and space-based distance determination and the associated uncertainties. It will be particularly useful as an up-to-date reference work for postgraduate students and researchers in any area touching upon the Galactic and extragalactic distance scales. This Topical Collection is the result of an international workshop which took place at the International Space Science Institute—Beijing from 23 to 27 May 2016, where some forty leading scientists came together to discuss the current state of the art and future opportunities to make major progress.