Preface of English Edition

Progress in astronomy has been fueled by the construction of many large classical and modern telescopes. Today, astronomical telescopes image celestial sources not only across the wide electromagnetic spectrum from 10 m radio waves to 100 zm (10^{-19} m) gamma rays, but also through other spectra in gravitational waves, cosmic rays, and dark matter. Electromagnetic and other waves or particles cover a very wide energy density range. Very high energy cosmic rays have energy a billion times greater than that accelerated at Fermilab and some light dark matter particles have tiny energies beyond the detection limit of the finest existing quantum devices. Now astronomical telescopes are very large, very expensive, and very sophisticated. They are colossal in size, extremely demanding in technology, and terribly high in cost. Because of the technology, scale of construction, and the desire of scientists to plumb the depths of the Universe, astronomy today epitomizes the oft-used expression "Big Science."

Over the past 400 years, the size, the wave or particle types, and the spectral coverage of astronomical telescopes have increased substantially. Currently, large optical telescopes have apertures as large as 10 m (78 m^2). It is important to note that the total optical collecting area around the world in the past 20 years has more than tripled. At radio wavelengths, the largest collecting area of a single telescope is still dominated by the 300-m Arecibo telescope (roughly 70,000 m^2) although a 500-hundred-meter-diameter Aperture Spherical radio Telescope (FAST) is under construction in China. For interferometers, the Very Large Array (VLA, roughly 13,000 m^2) located in New Mexico (USA) is currently dominant. By comparison, the Atacama Large Millimeter Array (ALMA), presently being constructed in northern Chile, will have a collecting area of roughly 6,000 m^2. In gravitational wave detection, the Laser Interferometer Gravitational wave Observatory (LIGO) has two very long laser interferometer arms, each 4 km long (much longer if multi-reflection is taken into account). The sensitivity acquired by this instrument is as high as 10^{-21}. For cosmic ray detection, one site of the Pierre Auger Observatory has 30 fluorescence detectors and 1,600 water Cherenkov detecting stations over a surface area of 6,000 km^2 on earth. In the search for dark matter particles, thousands of detectors are located inside ice layer between 1,400 and 2,400 m underground at the South Pole. Detectors are also located at other underground or underwater locations all over the world. Some of these detectors are working at extremely low temperatures of 20–40 mK.

At the current time, plans are underway to construct optical telescopes with apertures up to 42 m, radio telescope arrays up to a square kilometer aperture area, and space telescopes of diameters up to 6.5 m. Extremely sensitive gravitational wave detectors, large cosmic ray telescopes, and the most sensitive dark matter telescopes are also under construction. Larger aperture area, lower detector temperature, and sophisticated technology greatly improve the sensitivity of telescopes. This means more detecting power for fainter and far away objects and increasing clarity of star images. However, it is not just the size and accuracy of a telescope that matters; the gain in efficiency that results from performing many functions simultaneously and the ability to measure spectra and to monitor rapid variation are also important figures of merit.

Interferometry was pioneered by radio interferometers. A resolution of 50 milliarcsecs was routinely obtained by the VLA. Long baseline interferometry at millimeter wavelengths, using the Very Long Baseline Array (VLBA), can achieve a thousand times better angular resolution than that of the VLA. In the optical field, an important breakthrough has been achieved in optical interferometers. Another important achievement is the development of active and adaptive optics (AO). Active and adaptive optics holds promise to transform a whole new generation of optical telescopes which have large aperture size as well as diffraction limited image capability, improving the angular resolution of ground-based telescopes. In nonelectromagnetic wave detections, extremely low temperature, vibration isolation, adaptive compensation for interference, superconductor transition edge sensors, and SQUID quantum detectors are widely used for improving instrument sensitivity and accuracy. All of these are pushing technologies in many fields to their limiting boundaries. In general, modern telescope projects are very different from any other comparable commercial projects as they heavily involve extensive scientific research and state of the art innovative technical development.

To write a book on these exciting and multi-field telescope techniques is a real challenge. The author's intention is to introduce the basic principles, essential theories, and fundamental techniques related to different astronomical telescopes in a step-by-step manner. From the book, the reader can immediately get into the frontier of these exciting fields. The book pays particular attention to relevant technologies such as: active and adaptive optics; artificial guide star; speckle, Michelson, Fizeau, intensity, and amplitude interferometers; aperture synthesis; holographic surface measurement; infrared signal modulation; optical truss; broadband planar antenna; stealth surface design; laser interferometer; Cherenkov fluorescence detector; wide field of view retro-reflector; wavefront, curvature, and phasing sensors; X-ray and gamma ray imaging; actuators; metrology systems; and many more. The principles behind these technologies are also presented in a manner tempered by practical applications. Telescope component design is also discussed in relevant chapters. Because many component design principles can be applied to a particular telescope design, readers should reference all relevant chapters and sections when a telescope design project is undertaken.

The early version of this book started as lecture notes for postgraduate students in 1986 in Nanjing, China. The notes had a wide circulation among the postgraduate students. In 2003, the Chinese version of this book was published. The book was well received by the Chinese astronomical community, especially by postgraduate students. With a wide circulation of the Chinese version, requests were received from English speaking students for an English language version. The translation of this book started in 2005. The basic arrangement of the book remains unchanged. The book is intended to target postgraduate students, engineers, and scientists in astronomy, optics, particle physics, instrumentation, space science, and other related fields. The book provides explanations of instruments, how they are designed, and what the restrictions are. This book is intended to form a bridge between the telescope practical engineering and the most advanced physics theories. During the translation of this English version, many experts and friends provided great help both with technical contents and the English language. Among these reviewers, Dr. Albert Greve of IRAM reviewed all chapters of this book. In the language aspect, Ms. Penelope Ward patiently reviewed the entire book. Without this help, the book translation project would not have succeeded.

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