Special Section Guest Editorial: Extremely Large Telescopes

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The construction of the next generation of extremely large telescopes (ELTs) is under way: the Giant Magellan Telescope (GMT), ESO's Extremely Large Telescope (ESO ELT), and the Thirty Meter Telescope (TMT) are becoming reality and involve contributing teams from all over the world. The construction of these telescopes is gathering momentum, thanks to the wide support of the international astronomical community. The decadal survey 2020 indicated the U.S. ELTs are now the highest priority recommendation to the American funding agencies for ground based-astronomy. Likewise, the ESO ELT project has been ranked in the 2010–2025 ASTRONET European strategic planning as one of two clear top priorities for future ground-based astronomical infrastructures. It is therefore timely to have a series of targeted publications, explaining different aspects of these ELTs' design, early construction, and concept of operation.

This common vision for the next generation of telescopes comes from their broad scientific capabilities. Thanks to the addition of first-light adaptive optics systems, the three observatories will be able to combine unprecedented sensitivity with unmatched angular resolution. In fact, these ELTs have been designed from the ground up with their adaptive optics as an integral part of the observatory. Their extremely large primary mirrors will enable observations from ultraviolet to mid-infrared wavelengths with up to 80 times the sensitivity of today's largest telescopes. State-of-the-art adaptive optics systems will compensate for the blurring effects of Earth's atmosphere and deliver images at infrared wavelengths that are more than 12 times sharper than those of the famed Hubble Space Telescope, and 4 times sharper than those of the new James Webb Space Telescope. This combination of sensitivity and image quality will allow these telescopes to peer deeper into the Universe and reveal details of cosmic objects that are invisible with today's observatories. Both observatories incorporate innovations in precision control that make it possible to acquire a new science target anywhere on the sky within a few minutes—a critical capability for rapid follow-up of gravitational wave sources and other cosmic explosions.

Questions involving the formation of the first galaxies and the first stars responsible for seeding the universe we see today will be within the reach of our scientists. The high angular resolution also has everyone excited. The study of exoplanets is still going strong, with a current focus on atmospheres, which tell us a lot more about the planet's characteristics, notably on their potential habitability. Our current capabilities limit us to large and hot planets. The 30-m class observatories will enable similar studies on Earth-like planets and potentially resolve the big question about life outside our own solar system. The huge gain in sensitivity will also allow high-spectral resolution required by the study of distant quasars. It will likely resolve current arguments made about the evolution of fundamental constants, which is one of the many cosmological challenges that require such a powerful "time machine."

These and so many other scientific questions will be at least in part resolved by the ELTs. For now, the three teams of scientists and engineers are focusing and collaborating on solving technical challenges impacting the construction of the observatories. Armed with years of experience in building and operating the 8-10m-class telescopes, the scaling of technologies has been the first solution to some of the many complications facing construction. From complex phasing of the telescope's primary mirrors to demanding wavefront sensing, every aspect of the observatories has required extensive design and prototyping work. With so many of those new technical constraints shared by all three observatories, a high level of collaboration has grown over the last decade. The sharing of expertise and resources has accelerated progress made on many fronts. This particular section of JATIS is intended to provide a centralized reference on the ELTs' development with many papers, including contributions from all three observatories.

The main focus of this special section is to collaboratively present the strategies and missions of the three facilities to allow the community to reach a better understanding of each observatory. The contributions are centered around the main design strategies taken facing the constraints encountered with such large telescopes, such as vibration simulation and potential mitigations, alignment and maintenance strategies for such large and complex facilities. Also, the adaptive optics mentioned above and embedded in the telescopes designs from the beginning come with new problems not seen with the 8–10 m class telescopes. Overcoming the laser guide stars' elongation and fluctuations, compensating for increased island effects, and defining the most performant wavefront sensors are also part of the topics addressed in this section.

Finally, this collection of papers also includes contributions highlighting the philosophies of each observatory regarding instrumentation, operation, and topics of broad appeal to future observatory developers. This section provides a direct view at the sometimes converging, sometimes complementary, approaches undertaken by each team to solve common problems.