Asian scientists prepare to reach for the stars

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The scenery resembles that seen in the often grainy photos of Mars taken by a generation of space probes since the 1960s. However, we're in the heart of the tropics, in the middle of the Pacific Ocean. High above the sun-soaked beaches of the Big Island of Hawaii stands Mauna Kea, or 'White Mountain' in Hawaiian folklore. Getting up to its summit requires careful planning, not least because of the oxygen-starved atmosphere at 4,205 meters above sea level. Rental-car agencies strictly prohibit one from driving up the public dirt road in a regular family car. You will need to book a four-wheel drive vehicle if you really want to admire the amazing views up there, well above the cloud layer.

The summit of Hawaii's highest volcano is considered sacred by the island chain's indigenous population and its vocal supporters. Yet, upon having driven the final few miles to the mountain top on a road that is paved once again, one encounters an army of zealous individuals of a rather different ilk. This is the realm of high-tech science: all around, the landscape is dotted with white and silvery domes that cover some of the world's most advanced astronomical telescopes.

Globally, professional astronomers currently have access to 14 telescopes with mirror diameters in excess of 8 meters. Four of these are located on Mauna Kea alone; five others are found in the northern Chilean desert. This is not surprising. Hawaii and northern Chile offer some of the world's best temperate observing sites. The western trade winds travel unimpeded across the vast expanse of the Pacific Ocean until they hit the high mountains of Hawaii and the Andean range in South America. Most importantly, these smooth air currents prevent formation of the turbulent eddies that are so devastating for world-class astronomical observations: they make stars look blurry!

Such unrivalled conditions are, unfortunately, non-existent on the eastern Pacific Rim and the Asian continent. The scientific communities developing at breakneck speed in some of the region's most advanced economies are therefore looking to join forces with their North and South American counterparts, in pursuit of the rich scientific returns anticipated from exploitation of the next generation of extremely large telescopes. Following decades of meticulous planning, early construction has recently been initiated for not one, not two, but three of the world's newest plus-sized telescopes. As a natural extension of their rapidly increasing global influence, several Asian astronomical communities have now firmly committed to join two of those multilateral projects.

An active cohort of scientists and engineers from China, Japan, and India are taking leadership roles in the scientific and technological preparation for the scientific instrument ('camera') development and construction phases of the 'TMT,' the Thirty Meter Telescope, which will be built alongside the numerous smaller domes near the summit of Mauna Kea. Astrophysicists from the Republic of Korea, on the other hand, have opted to join the Giant Magellan Telescope project, or GMT, an effort spearheaded by the Carnegie Institution for Science in the USA, which operates Las Campanas Observatory in Chile.

> "*Japan has seen to the production of over 60 mirror blanks* [for the TMT] *made of special zero-expansion glass that does not alter its shape with temperature changes. The blanks will be highly polished for use in the telescope's 30-meter diameter primary mirror. The final design of the telescope structure itself is nearing completion*," according to Masanori Iye, TMT Japan Representative.

Whereas the TMT's main mirror will be composed of 492 highly sophisticated, individually tailored mirror segments to construct a vast reflecting surface with a diameter of 30 meters, the GMT's mirror design looks rather odd at first sight. It will be composed of a set of seven of the largest stiff, 8.4-meter diameter mirrors available today, arranged in a rosette pattern. With an effective total mirror diameter equivalent to 24.5 meters, the GMT will be the junior member of this exclusive club of cutting-edge new facilities. The third and largest of the three next-generation, extremely large telescope projects is led by the European Southern Observatory. With a spectacular, televised series of explosions, this latter consortium recently blasted the summit off of Cerro Amazones in northern Chile, the site of its planned 39-meter diameter 'European Extremely Large Telescope.'

New astronomical horizons thus beckon eager scientists in pursuit of new knowledge. Asian astrophysicists fully intend to become major contributors to the cutting-edge science facilitated by the novel observatories under development today. However, a sustained drive to make one's mark in the international arena is, on its own, not enough to succeed in the rat race that is the quest for new scientific discoveries. And this is particularly keenly felt in China. The problem? The type of science one can undertake with a 2.4-meter or even a 4-meter diameter telescope – the largest apertures currently available to Chinese astronomers domestically – is markedly different from that routinely done with 30-meter-class telescopes.

Since TMT's 'first light' – the start of scientific operations – is not expected until early in the next decade, it is thus of paramount importance to train the next generation of Chinese astronomers to make best use of their future observational potential. Time is still on our side. Considerable efforts to facilitate such a step change in scientific performance are, therefore, currently underway, backed financially by the Chinese Academy of Sciences. Its Telescope Access Program was recently awarded a major financial injection to purchase a modest amount of observing time on some of the world's most competitive optical and near-infrared facilities in the 3.6- to 6-meter diameter range.

> "*It is to be emphasized that this is not merely about getting telescope time, but it is more about growing the community and fostering new interactions between astronomers in China, and with different international communities. We encourage development of these collaborations*," says Eric Peng, Telescope Access Program committee chair.

If the Chinese astronomical community can indeed gain an internationally respectable scientific level using these intermediate-aperture facilities, its scientists will be well placed to benefit and, indeed, lead the field in the 2020s and beyond. Chinese expertise is rapidly covering new ground, not least because many of the diaspora's most accomplished young scientists and engineers are enticed to return from abroad to support the nation's high-level scientific development.

> "*We believe that the Thirty Meter Telescope will provide an otherwise unattainable opportunity for the Chinese astronomical community to make significant discoveries, perform cutting-edge science, and advance technological development*," aspires Yan Jun, Director General of the National Astronomical Observatories, Chinese Academy of Sciences.

Irrespective of the actual 30–40-meter telescope available, the new scientific advances foreseen to emerge from these facilities promise to be truly ground-breaking. Beyond the 'killer application' of enabling us to directly image Earth-like planets orbiting other stars for the first time, and perhaps even detect the organic or water molecules in their atmospheres that may signify the presence of life as we know it, we will be able to study the entire local Universe in similar detail as our home, the Milky Way galaxy, today.

> Currently, "*we have no proof of the existence of an Earth-like planet at the same distance from the Sun in our galactic neighborhood*," explains Fernando Comeron, the European Southern Observatory's representative in Chile. "*That's not because they don't exist, but because we didn't yet have the tools to detect them. With the European Extremely Large Telescope, we can*."

During the last two decades, space-based observatories and the current generation of 8–10-meter diameter ground-based telescopes have opened up a new view of our Universe, one dominated by poorly understood dark matter and a mysterious vacuum energy density referred to as 'dark energy,' which is thought to pervade all of space. This progress poses new and more fundamental questions about the nature of the Universe we live in, both near and far. Future generations of astronomers will be well equipped to address these new and exciting fundamental questions across the Universe, because the next-generation telescopes will be so large that they will be able to gather light that has spent more than 13 billion years traveling to Earth. This means that we will be able to see images of the first stars and galaxies forming, nearly 400 million years after the 'Big Bang' jump-started the formation and evolution of the entire Universe.

However, before this next generation of astronomical observatories will be fully operational and provide us with unprecedented physical insights into the most fundamental aspects of the Universe at large, numerous technical problems still require the expert input and formidable brain power of the world's most accomplished scientists and engineers. Simultaneously, fund-raising efforts must continue apace to eventually close the multi-billion-dollar budgets involved. Cutting-edge science – and the enticing promise of international fame – doesn't come cheap!

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