In China, even the sky is no longer the limit

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As I walk into Linhua Jiang's office at the Kavli Institute for Astronomy and Astrophysics in Beijing, my colleague is staring intensely at a wall map of western China. "*Are you planning a vacation?*" "*No*," he responds, "*I am trying to figure out how to transport a huge telescope mirror to western Tibet.*"

Our brief chat took place in November 2016. As it turned out, scientific ambitions and real-life logistics were on a collision course. Since then, a logistical nightmare has been averted narrowly and the prospects for major progress in Chinese astrophysics research have improved dramatically.

Like many junior faculty members at universities across China, Linhua recently returned from the United States, attracted by an ambitious scientific agenda and generous funding opportunities. But he now finds himself preoccupied with a project that none of his high-level training abroad really prepared him for. On his return to China, he jumped at the chance to help realize his nation's scientific ambitions. The rapidly growing community of Chinese astrophysics researchers is still small, but their ambitions appear limitless—even the sky is no longer the limit!

With such unbridled aspirations come increasing demands for globally competitive research facilities. Today, the country's largest telescopes for general use have mirrors with diameters of just over 2 meters. Aspiring to take on a future scientific leadership role, the Chinese astronomical community is deeply involved in scientific and technical preparations for construction and operation of the 'Thirty Meter Telescope.' This new observatory is one of three next-generation astronomical facilities—with mirror diameters greater than 25 meters—that are currently under construction around the world. At present, however, the community's homegrown scientists are largely underprepared to take full scientific advantage of such an enormous jump in telescope size.

The ground-breaking questions we will be able to address with the next generation of oversized telescopes are not simply scaled-up versions of the issues we can already explore with our smaller facilities. This predicament is clearly understood by the community's senior scientists. Their concerns about the nation's scientific readiness have resulted in strong support of an interim program which paid for Chinese scientists to access medium-sized telescopes abroad, with mirror diameters in the 4 to 6.5-meter range.

Think of direct observations of planets as small as the Earth orbiting stars other than our Sun, in the hope of detecting so-called 'biomarkers,' which may indicate the presence of life. Or of determining the three-dimensional distribution of galaxies all the way to the edge of the observable Universe. Or even of careful analysis of nearby galaxies at the level of detail we can presently only achieve in our own Milky Way. These are but a few of the exciting, cutting-edge science questions typically addressed using larger telescopes that are all but off-limits to their smaller counterparts. However, pumping money into foreign facilities—no matter how successful this would allow their scientists to become—never sat well with the nation's politicians holding the purse strings: top-level funding commitments have been declining steadily.

Last year, top-down and grassroots ambitions to resolve this reliance on foreign hardware met in an unexpected show of unity. China's 13th Five Year Plan includes

strong central Government backing to develop the country's own next-generation optical telescope, featuring a mirror with a diameter of 12 meters. The initial mandate to achieve this within five years seemed overly optimistic—and, indeed, the directive has now been updated to allow for a more realistic, longer-term design and construction phase.

Almost simultaneously, a coalition of Chinese universities proceeded with plans to build a 6.5-meter-diameter telescope, based on blueprints used previously for the twin Magellan telescopes at Las Campanas Observatory in Chile. Around the same time, Sun Yat-sen University in the southern city of Guangzhou secured a significant cash injection to help its astrophysicists rise to the top of the domestic scientific rankings. As a result, the Guangdong provincial government has now become the project's *de facto* financial backer.

Linhua's growing leadership in preparing a strong scientific justification for development of a Chinese 6.5-meter telescope has not gone unnoticed. His initiative naturally resulted in his current role as the facility's logistics coordinator during the initial planning phase. And this is why I caught him in a pensive mood, staring at his wall chart.

The 6.5- and 12-meter telescope development teams both consider Ali—a site in the western Himalayas, far away from the glare of city lights—their preferred domestic location. Globally, however, Ali cannot compete with the top sites in Hawaii and northern Chile, which offer some of the world's best observing conditions. 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 to world-class astronomical observations: they make stars look blurry.

Such excellent conditions are, unfortunately, non-existent around the eastern Pacific Rim or anywhere in Asia. The high Himalayan mountains, steeply rising from the central Asian plains, seemed a promising alternative: the trade winds are similarly uninterrupted by any geographical features rising up along their eastward path—until they hit Kazakhstan's Tianshan mountains and the high Tibetan plateau.

Ali, at an altitude of more than 5,000 meters, hosts a number of suitable locations for the astronomers' consideration. Yet its high altitude also introduces significant challenges—not least in view of the highly compressed construction season, which is severely limited because of the region's harsh winter conditions that dominate most of the year.

"*The 6.5-meter mirror we plan to install on the telescope will consist of a single piece of glass*," Linhua told me, "*but how can we get it to the site in one piece?*"

The Chilean Magellan telescopes' 6.5-meter mirrors weigh more than 10 tons each, despite their composition of borosilicate glass with a lightweight internal honeycomb structure, so transportation options are limited. An obvious first leg of the mirror's journey from its casting site at the University of Arizona involves sailing up the Yangtze river as far as Chongqing, some 1,700 kilometers from the coast, but still a driving distance more than twice as far from Ali. And it's this road trip that caused Linhua major headaches.

A 6.5-meter-diameter telescope mirror is a phenomenal piece of highly polished glass that must be carefully protected from breakage. It will need to be transported in a protective casing, which adds to the load's overall size. The drive from Chongqing to Ali,

first north through central China's Qinghai province before climbing to the high-altitude Tibetan plateau, would take the shipment through rugged terrain and up high mountain ranges—and, most importantly, also through numerous tunnels.

The team would have to dismantle a few toll stations along the way, but that is not considered a major obstacle—as long as they get the highway administration on their side, of course. The large number of tunnels they will have to pass might pose a more serious problem: the transportation options are limited by the smallest tunnel diameter—if the carefully packaged mirror doesn't fit, there won't be any alternatives to ship it to Ali. This won't be a problem for the 12-meter telescope, given that its mirror will be made up of numerous smaller segments.

With Ali as the possible future center of Chinese ground-based astronomy, there are no alternatives to the more than 4,000-kilometer-long road trip from Chongqing. The observatory's altitude is too high for helicopters to carry heavy loads, and the world's largest cargo planes cannot presently be used for our special consignment either. The next-generation Airbus A300-600ST (Super Transporter) cargo plane, nicknamed Beluga XL because of its whale-like appearance, may be able to do the job—and it will likely be available for charter flights—but the aircraft will be unable to take off from anywhere near the high-altitude telescope site. A lengthy road trip would still be on the cards.

The physical and financial obstacles to reaching a successful conclusion at Ali seemed overwhelming. By all accounts, Ali appears to be the best astronomical observing site in mainland China, but the logistical challenges would add significant expenditure to China's expanding scientific ambitions. Our ambitions may be unbounded, our funding is not.

In encouraging new developments, the Guangdong provincial authorities have recently relaxed their spending criteria. It has just been agreed that construction of China's next-generation large telescope half a world away, in the excellent atmospheric conditions of northern Chile, is now the preferred option. Logistical challenges in Chile seem minor compared with those we would encounter in western Tibet. In addition, the scientists and engineers operating the facility could live at more comfortable altitudes closer to sea level, where oxygen supplies are more abundant.

A major logistical headache has been averted. And Linhua may get to plan a vacation to an exotic destination after all.

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