AstroTalk: Behind the news headlines of July 2014

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It's getting there: The Thirty Meter Telescope, and China aims at playing a major role in it!

Astronomy is in a golden age. In the past half century, a new generation of telescopes and instruments allowed a golden age of remarkable new discoveries: quasars, black holes, gravitational arcs, planets orbiting other stars, gamma-ray bursts, the cosmic microwave background, dark matter and dark energy have all been discovered through the development of a succession of ever larger and more sophisticated telescopes. In the last two decades, satellite observatories and the new generation of 8 to 10 m (diameter) ground-based telescopes, have created a new view of our Universe, one dominated by poorly understood dark matter and a mysterious vacuum energy density ("dark energy"). This progress poses new, and more fundamental, questions.

As the current generation of telescopes continues to probe the Universe and challenge our understanding, the time has come to take the next step. A small step in telescope size will not progress these fundamental questions. Fortunately, the technology to achieve a quantum leap in telescope size is thought to be feasible. Telescopes of 30 to 50 m in diameter can be built and will provide astronomers with the ability to address the next generation of scientific questions. These telescopes will be so large that they should be able to gather light that will have spent 13 billion years traveling to Earth. This means that astronomers looking into the telescope will be able to see images of the first stars and galaxies forming, some 400 million years after the Big Bang.

In fact, several international projects are addressing the challenges of building such a next-generation "extremely large telescope" head on: the European Southern Observatory (ESO) is spearheading its flagship 39 m diameter European Extremely Large Telescope (E-ELT) in Chile, as is a competing American initiative under the header of the Giant Magellan Telescope (GMT). Third, and of most interest to Chinese astronomers, is the development of the so-called Thirty Meter Telescope (TMT), an initiative in which China is playing a major role. The TMT is scheduled for construction near the summit of Mauna Kea, the highest mountain in the Hawai'ian island chain. Mauna Kea, a dormant volcano, is popular with astronomers because its summit sits well above the clouds at 4205 m, offering a clear view of the sky above for 300 days a year. I have been fortunate enough to have visited and used the Mauna Kea summit observatories a few times over the course of my career; the landscape is Mars-like, and ice and snow may be present, despite the tropical location. It is truly an out-of-this-world experience! Hawai'i's isolated position in the middle of the Pacific Ocean also means that the area is relatively free of air pollution. Few cities mean that there aren't a lot of man-made lights around to disrupt observations.

And this project is now gaining excitement: TMT has recently entered a tangible new phase in its development and construction. The TMT project team has now announced the beginning of the construction phase on Hawai'i Island – colloquially called the "Big Island" by locals and insiders – and around the world throughout the TMT international partnership. China formally joined that partnership in 2009, initially as an observer. Activities near the summit of Mauna Kea are scheduled to start later this year.

> "*It has been an amazing journey for TMT, from idea to shovel-ready project*," said Henry Yang, TMT Board Chair and Chancellor of the University of California Santa Barbara (USA), who upon the joining of China commented that the "*TMT is delighted to take this exciting new step forward in our relationship with the National Astronomical Observatories of China. We appreciate their interest in contributing to this important international endeavor, and we look forward to continuing to work with the Chinese astronomical community in fostering China's collaboration in the TMT project*."

The TMT project was initiated a decade ago by the Association of Canadian Universities for Research in Astronomy, the California Institute of Technology (Caltech, USA), and the University of California as the *TMT Observatory Corporation*. Now, the founding members of the *TMT International Observatory* (TIO) are Caltech, the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC), the National Institutes of Natural Sciences in Japan, and the University of California. India, an associate partner, is expected to become a full member later this year. Canada is also an associate partner and aiming to join as a full member in 2015.

> "*TMT has worked for many years to design an unprecedented telescope, but also to work with the community to incorporate respect for Mauna Kea in our stewardship*," said Gary Sanders, Project Manager for TMT. "*It is an honour and a privilege to now begin building our next-generation observatory in so special a place*."

But the decision to locate TMT near the summit of Mauna Kea also invited protests from some Native Hawai'ian and environmental groups. Native Hawai'ian tradition holds that high altitudes are sacred and are a gateway to heaven. In the past, only high chiefs and priests were allowed at Mauna Kea's summit. The mountain is home to one confirmed burial site and perhaps four more, and environmentalists oppose the telescope on the grounds it would hurt some endangered animal species.

> "*This the kind of legacy they want to leave? They just keep building on our mountain*," said Kealoha Pisciotta in 2009, president of Mauna Kea Anaina Hou, a group with family and religious ties to the mountain.

Work unrelated to the mountain-top construction has already been proceeding off-site and will continue now apace.

> "*Design of the fully articulated main science steering mirror system in the telescope, as well as development of the lasers, laser guide star systems and other high-tech components, is proceeding in China. (…) 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*," said Yan Jun, NAOC Director General.

> "*Japan has seen to the production of over 60 mirror blanks made out 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-metre diameter primary mirror. The final design of the telescope structure itself is nearing completion*," said Masanori Iye, TMT International Observatory Board Vice Chair and TMT Japan Representative for the National Astronomical Observatory of Japan.

The announcement of an imminent start to on-site work, where all initial developments will come together, is welcome news to scientists worldwide. The TMT has begun full-scale polishing of the 1.4 m mirror blanks that will make up the primary mirror. TMT also has developed many of the essential prototype components for the telescope, including key "adaptive optics" technologies (used to correct for the blurring effect of Earth's atmosphere) and the support and control elements for the 492 mirror segments.

> "*The start of construction means that TMT is becoming real, and that's exciting news for astronomers*," said Catherine Pilachowski, an astronomer at Indiana University (USA) and an observer representing the United States astronomical community. "*The science TMT will do is breathtaking, and will engage all astronomers in the adventure of new frontiers*."

When completed, hopefully by the end of this decade, the TMT may be the first of the next-generation of ground-based optical observatories. This revolutionary telescope will integrate the latest innovations in precision control, segmented mirror design, and adaptive optics. Building on the success of the twin Keck telescopes, the core technology of TMT will be a 30 m segmented primary mirror, nearly the length of a Boeing 737's wingspan. This will give TMT nine times the collecting area of today's largest optical telescopes and three times sharper images.

However, the TMT project is facing stiff competition as to which next-generation observatory will be completed first. Indeed, construction on ESO's E-ELT began with a bang on 19th June 2014, as workers demolished a hilltop in Chile's Atacama desert. Thanks to its dry and cold climate, and the lack of light pollution from cities in the remote region, Chile's Atacama desert also provides an ideal location for astronomical research. Just like TMT, the E-ELT aims to give astronomers new insights into the origins of the Universe and help search for potentially habitable planets elsewhere in the Milky Way galaxy.

> Currently, "*we have no proof of the existence of an Earth-like planet at the*

> *same distance from the Sun in our galactic neighbourhood*," said Fernando Comeron, ESO'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 E-ELT, we can*."

Construction of the E-ELT will take an estimated 10 years, and the telescope will be put into service two years later. The first step, estimated at costing US$1.4 billion, involves razing around 5,000 cubic metres of rock off the top of Mount Armazones. The newly flat surface will support the foundation of the telescope.

However, the notion of different country consortia "competing" for the title of "largest" telescope, is not much more than posturing, and what really counts is that the community will soon have access to a number of extremely large telescopes that will indeed cover the entire visible sky. Rolf Kudritzki, the director of Institute for Astronomy at the University of Hawai'i, said Hawai'i's northern hemisphere location will help the TMT complement the science covered by both the GMT and the E-ELT planned for Chile in the southern hemisphere.

With a 30–40 m telescope, astronomers can really go that next step in their pursuit of the origin and evolution of the Universe and its contents. Before my relocation to the Kavli Institute for Astronomy and Astrophysics at Peking University, I was heavily involved in E-ELT preparatory science efforts, as a member of the European "Nearby Galaxies" science development team. Personally, I am therefore now very excited to be part of the TMT project, both as a scientist affiliated with a Chinese institution and as a member of two of TMT's International Science Development Teams that cover science aspects I can contribute to meaningfully – I truly have the opportunity to help shape the future research goals, at an international level!

While the "killer application" of these extremely large telescopes is without a doubt the possibility to directly image planets orbiting stars elsewhere in the Milky Way, let me instead provide you with my personal motivation as to why I think that China's involvement in the TMT project will allow us, as a developing scientific community, and my own research group at Peking University in particular, to make a step change in our development towards greater international competitiveness.

Stars, and in particular the most massive stars, rarely form in isolation. In fact, it is now well established that the vast majority of active star formation occurs in star clusters of some sort. Star clusters are therefore both current and fossil records of episodes of higher-than-average star formation in their host galaxies.

To study the stellar content of clusters of various ages and at increasing distances, one would like to have access to observations that are as little affected by blurring caused by the Earth's atmosphere as possible – this is what we call "diffraction-limited" observations, and this is where the innovative technology of "adaptive optics" comes in very handy indeed. Ground-based observations are crucially dependent on the availability of adaptive optics. This is the area where a 30 m-class telescope has a real niche in studying star-formation processes: the *Hubble Space Telescope* and its successors are and will be less competitive because of their significantly smaller mirror diameters.

This is a fortunate situation in the context of TMT science, since it will allow us to probe right into the core of the most active, dust-enshrouded star-forming regions. This will potentially help solve the key outstanding issue of how star formation occurs, proceeds, and is initiated, as well as what the importance is of the interaction between the newly born stars and their environments. We will be able to study the early evolution and the transformation from the youngest star-forming cluster-like regions to more mature systems in dynamical equilibrium.

Thanks to the significantly larger collecting area of a 30 m-class telescope compared to the current state of the art of 10 m-class telescopes, we will be able to extend studies of resolved stars in dense systems to the Coma Cluster of galaxies (which is at least five times more distant than what we can reach with current, state-of-the-art facilities), and study entire star cluster systems—similar to the systems of old “globular” clusters in the Milky Way or the Andromeda galaxy—out to distances where we will be able to see the effects of the evolution of the Universe as a whole – and this is where the story comes full circle: TMT was partially conceived to probe the earliest stages in the evolution of the Universe as a whole; thanks to its large mirror diameter, this can be done across a large variety of fields in astrophysics. Thus far, I had actually never considered myself a cosmologist, but with TMT this may be changing! This unprecedented access to both “cosmological” distances and significantly earlier epochs in the lifetime of the Universe is an important advantage from a scientific perspective, since star cluster systems of various ages hold a key clue regarding the formation and evolution of galaxies themselves.

In the context of my own group’s research directions at Peking University, I see my personal involvement in TMT-based science as an exciting complement and extension of our current efforts, which would potentially enable us to solve a number of key open questions in the field of star cluster formation and long-term evolution. You can imagine that I am eager to get my hands on the beautiful new data that will no doubt be forthcoming in the next decade!

Figures:

For high-resolution images of the TMT, see http://www.tmt.org/gallery/photo-illustrations and http://www.tmt.org/gallery/renderings; I suggest to include one or more images that show an overview of the site, including the Mars-like landscape and the existing telescopes, e.g., http://www.keckobservatory.org/index.php/gallery

For high-resolution images of the E-ELT, see http://www.eso.org/public/images/archive/category/e-elt/ -- in particular, please include an image from the recent blasting of the mountain top in Chile, e.g., http://www.eso.org/public/images/eso1419a/; it may also be good to include some images of the barren landscape.

For high-resolution images of the GMT, see http://www.gmto.org/gallery/.