CHINESE ASTRONOMY AS AN INDICATOR OF TECHNOLOGICAL DEVELOPMENT

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Abstract: This paper illustrated the close relationship between technology development and progress in science. Examples of this connection are discussed using Chinese Astronomy as a study case. Despite remarkable historical contributions to the knowledge of celestial bodies, the role of China in modern Astronomy and Astrophysics did not start until relatively recent times. Only in the last decades has China started to develop impressive astronomical projects (optical telescopes, interferometric radio networks, Cherenkov detector arrays, etc.) in parallel with the country's growth.These facilities provide, or will soon provide, excellent capabilities for observational astronomy in different windows of the electromagnetic spectrum. In addition, Chinese astronomers are currently active members of the major international astronomical collaborations.

Keywords: China, astronomy, technology, telescopes

Introduction.

The history of Chinese science is full of examples that illustrate how this country has contributed to mankind with both scientific and technological innovations. Over the few millennia of recorded human history, findings such as the discovery of press, powder and compass are textbook examples of this statement. The study of heavenly bodies, Astronomy, also flourished since the early times of the Chinese civilisation. Generations of Chinese observers recorded most of the relevant astronomical phenomena visible to the naked eye (eclipses, occultations, comets, novae and supernovae). Perhaps the most famous Chinese record is the observation of the supernova explosion of A.D. 1054 whose remnants are still visible today even with modest amateur telescopes and nicknamed the *Crab Nebula*. This flaring event, actually the death of a massive star, was certainly seen by Europeans but no clear Western record has survived (see for instance Collins et al. 1999). This is in contrast with the Chinese sources that enable a clear identification of a 'new star' located at a position consistent with the Crab Nebula.

Chinese astronomy had its first contact with its western 'sister' back in the 17th century when the Jesuit Mateo Ricci started to spread the European astronomical knowledge among the Asian elites. It has been a long way since then and nowadays China provides a significant fraction of astronomical papers published in the world. Moreover, there are even efforts to make easily accessible astronomical research carried out by modern Chinese scientists to their western colleagues, such as the journal *Chinese Astronomy and Astrophysics*[1]. This is a journal from the well-known Elsevier publisher, that brings English translations of notable articles to astronomers and astrophysicist outside China since 1988.

1. Astronomy and technology: a very close couple.

Astronomy as a modern science is highly demanding discipline in terms of technological resources, and this is true no matter the country where astronomical research is carried out. Astronomers always want to achieve the best sensitivity to see the faintest stars, and the best angular resolution to distinguish the sharpest details in distant astronomical objects. Very often, Astronomy is considered as an important driver of technological advancements that later become of wide use among the general public. Let us consider for instance the early electronic charge-coupled device (CCD) cameras that started to become available in the 80s.

Astronomers were then pushing this technology to its limits for pure scientific purposes. The engineering developments of that time have nowadays resulted in almost everybody abandoning film-based photography and moving to electronic images, thus following the same path that Astronomy already took two decades ago. Nowadays Astronomy is for instance pursuing the exploration of the Universe using radio electromagnetic waves with millimetre wavelengths, that require a new generation of complex and low-noise receivers. This domain of the electromagnetic spectrum is still relatively free from commercial exploitation by cell-phone companies, but it is conceivable that the situation changes when the millimetre-wave technology becomes more mature and widespread.

The two examples quoted above are illustrative of how advances in Astronomy are highly connected with state-of-the-art technology. In this context, significant progress normally takes places in countries able to implement these technological developments. In the next Sections, we will comment about how China has succeeded to provide such implementations in different astronomical facilities that are contributing to front-line advances in modern Astronomy and Astrophysics.

2. The Chinese LAMOST telescope.

The *Large Sky Area Multi-Object Fiber Spectroscopic Telescope* (LAMOST) is one of the most important astronomical projects undertaken by the Chinese Academy of Sciences. It is also known as the Guo Shoujing Telescope as a tribute to this 13th Chinese astronomer who also was a very skilled instrument manufacturer. Located at the Xinglong observing station, LAMOST is essentially a telescope designed to simultaneously disperse the light of several thousands of very faint and distant objects. For each of them, the dispersed light will create what astronomers know as a ‘spectrum’.

This kind of information is very useful to assess the chemical composition, physical conditions and other properties of the celestial object and, when this information is available for a large sample of the same class of objects, statistically robust conclusions can be derived. This is especially relevant for stars, active galaxies, quasars and other cosmological studies. The LAMOST project will enable Chinese astronomers to play a major role in these fields using state-of-the art technology.

Figure 1. The LAMOST telescope at Xinglong station in the Hebei province of China. Image adapted from http://en.wikipedia.org/wiki/LAMOST.

The LAMOST optics features a very innovative design with a quasi-meridian approach and includes active control in real time. Its out of common appearance is clearly displayed in Fig. 1.Details about the performance of this new

telescope can be found at Cui et al. (2010). The scientific perspectives with this instrument are extremely good and even plans have been considered to install a replica of it in Antarctica for accessing the Southern skies.

3. The Chinese VLBI Network (CVN).

Very-Long Baseline Interferometry (VLBI) is a radio astronomical technique that involves observations of the same celestial objects by different antennae (or radiotelescopes) located very distant one from the other. It was developed in the 70s of the last century mainly in the U.S. Nowadays VLBI sessions are carried out in a routine way by different networks that often involve international collaboration. This technique provides the capability to see very sharp details in celestial objects that emit radio waves, of the order of the milli-arcsecond (the apparent size of an Euro coin seen at 2000 km). Moreover, it also enables the distance between telescopes to be measured with centimetre accuracy, which is very important for Geodetic and Earthquake control purposes. The Shanghai Astronomical Observatory (SHAO) is the Chinese institution where VLBI was first introduced in the country back in 1972 (see Zhang et al. 2010 for a review).

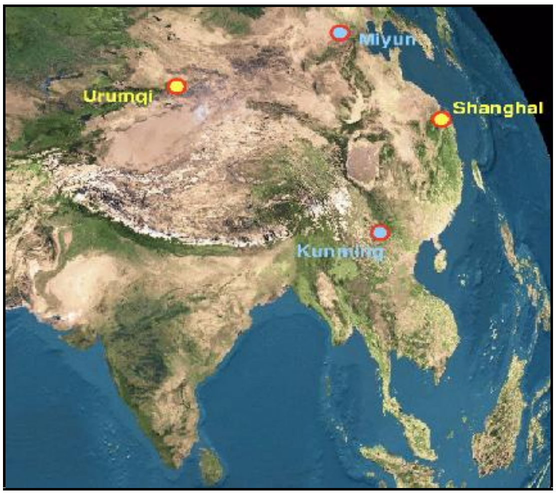

Figure. 2. Satellite Earth image showing the location of Chinese VLBI stations currently participating in the European VLBI network (adapted from http://www.evlbi.org).

At present there are four VLBI stations in Chinese territory (see Fig. 2): the Sheshan (Sh) antenna is located about 40km west of Shanghai; The Nanshan (Ur) antenna about 70 km south of Urumqi, the capital city of the Xinjiang Uygur Autonomous Region of China; the Kunming (Km) antenna is situated on the Phoenix

Mountain, just east of the city of Kunming, Yunnan Province; the Miyun (Bj) antenna is located at Bulaotun, a little town in Miyun County, about 140~km NE of Beijing. Together, they already represent a relevant VLBI network by themselves. The longest baseline (distance between antennae) is 3249 km from Sh to Ur, which is really impressive for a single country alone. However, the true importance of the CVN comes out when working in collaboration with other VLBI antennae across the world. In particular, China is an active member of the European VLBI Network (EVN) that regularly organises VLBI observing sessions with antennae located both in Europe and Asia. The astronomical images generated using VLBI networks are really impressive when compared with traditional ground and even space-based telescopes. In many cases, such goal would not be possible without the extremely long baselines of several thousands of kilometres from European to Chinese telescopes.

In the latest years, operation of VLBI networks in real time has led different countries to set up optical fiber connections with large bandwidth to transmit huge data rates. According to the latest reports, China is ready to joint this way of operation as most of its VLBI stations are already fiber-connected. Another technological progress in the horizon is the so called 'Space VLBI', where one of this antennae is being carried out by an Earth-orbit satellite. The series of Chinese Large March rockets are indeed capable of reaching Earth-orbit with a payload of this kind and are suitable for such a project.

This section devoted to Chinese Radio Astronomy would no be complete without mentioning the future *Five-Hundred-Meter Aperture Spherical Telescope* (FAST). This project was approved in 2008 by Chinese scientific authorities and first construction works have already started (Rendong et al. 2011). The selected construction site is the Dawodang depression in south Guizhou at 1000 m above sea level. When completed by the end of the present decade, it would be the largest single dish radio telescope in the world working at centimetre wavelengths. FAST will follow a design similar to the 305 m Arecibo radio telescope built inside a volcanic crater in the island of Puerto Rico, but with improved pointing capabilities and unprecedented sensitivity. When in operation, FAST will be able to work independently as a single dish antenna or becoming a key station in the Chinese VLBI network.

4. The Tibet Air Shower Array.

This astronomical facility is a Chinese-Japanese collaboration aimed to build a sensitive telescope in the domain of very high-energy gamma-rays (see Amenomori et al. 2008; 2009 for a technical description and results). Its construction started in 1990 at Yangbajing in Tibet, a location at 4300 m above sea level. The array consists of several hundreds of plastic scintillation detectors that allow to reconstruct the direction of arrival of gamma-ray photons produced in the most violent and energetic objects of the Universe (supernova remnants, neutron stars, and active galaxies among them). An example of gamma-ray source detection is displayed in Fig. 3.

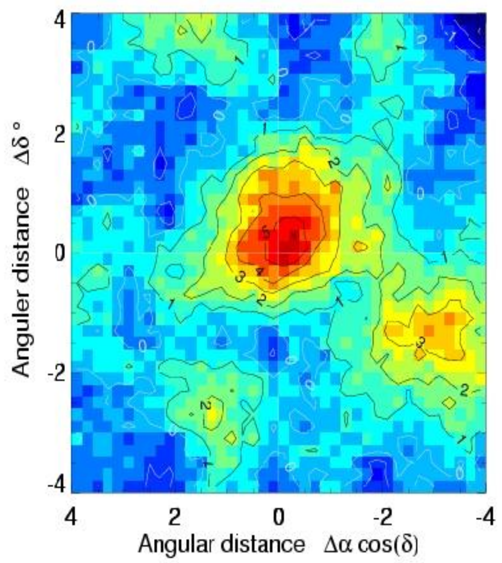

Figure 3. Image of the Active Galactic Nucleus known as Markarian 421 as imaged by the Tibet Air Shower Array during an active phase in 2000-2001. Image adapted from the public gallery in http://www.icrr.u-tokyo.ac.jp/em/.

The domain of very high-energy gamma-ray astronomy is considered is one of the most recently opened windows of observation of the Universe. The technologies involved are still far from being mature and the quality of astronomical images produced is still poor despite the huge technological effort involved. Just to provide an example, the angular resolution in modern gamma-ray images is significantly worse than the degree of detail that

Galileo could see in the 17th century with his primitive telescope at optical wavelengths. In this context, the Tibet Air Shower Array has enabled China to join a world-wide race of gamma-ray telescopes, that include international consortiums such as H.E.S.S., MAGIC, VERITAS, MILAGRO, and CTA among others, to enable astronomers 'see' a previously unsuspected face of the Universe. New phenomena produced by the most energetic particles ever measured begin to emerge, and this information is not only useful to astronomers but to particle physicists as well.

Conclusion and perspectives.

We have reviewed and commented about some of the most technologically advanced facilities build by Chinese scientists for astronomical research. These range from conventional optical telescopes with innovative designs to interferometric networks of radiotelescopes, and high-altitude gamma-ray detector arrays. Scientific and technological development in China is clearly consolidating the position of this country as a leading one in many domains of science. The quality, complexity and high-level of astronomy related projects being carried out in China clearly reflects this situation at present. We are likely to witness even further progress in a near future if China's progress keeps proceeding at this pace as the global socio-economic situation suggests.

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Notas:

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