Reminiscence of my Sixty-five year Voyage in Astronomy

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Abstract I returned to China from the United Kingdom in 1953, then worked in Purple Mountain Observatory. It was the early days of new China. The elder generation of astronomers was undertaking an effort of “repairing broken and filling defect” during those post-war years, and started planning and laying the foundation of modern astronomy. Under their leadership, I started a journey of astronomy whose main task was construction. The journey has been full of twists and turns. As a result of the “Great Leap Forward” in 1958 and the 1966 launch of the decade-long “Cultural Revolution” period, the situation of construction in astronomy was similar to that in other sciences, suffering bad effects. Not until the “Reform and Opening up” period after those events was construction able to continue, and various disciplines and international connections began to open. A “passage” had gradually developed. In this new circumstance, I kept pursuing the pioneers to explore a forward direction. Looking back today, this journey has been three periods of a four generation relay. This article is divided into three sections that describe my research work in these times that I recall: (1) Looking back at the beginning of the return and tracing the footprints of the founders. (2) Recalling my radio astronomy tour. (3) Retrospection and expectation of LAMOST.

1 LOOKING BACK AT THE BEGINNING OF THE RETURN AND TRACING THE FOOTPRINTS OF THE FOUNDERS

Looking back on these events, the 1950–1952 triennium represents unforgettable days at the University of London Observatory. Before that, I was a ship builder but I strongly desired to do astronomy. This also requires determination and opportunity. In 1950, it was Mr. C.C.L. Gregory, the Director of the Observatory, who offered me a post of an assistant astronomer and gave me many good advice, which enabled me to achieve my desire (see Fig. 1). At that time E.M. Burbidge and G.R. Burbidge were beginning research regarding Gamma Cassiopeiae, which they invited me to join in, and this research lasted approximately half a year (Burbidge et al. 1952). That was my first time doing astrophysics research, and also it was a self-test for me. Soon after Mr. Gregory’s retirement, Prof. C.W. Allen succeeded as the Director of the Observatory. I presented him a research proposal by utilizing the 60 cm telescope at the University of London Observatory for observations, with lots of support and help from him. This was my first time to design my own research topic. Although this program was interrupted due to my return home, all these three years increased my confidence for changing my professional fields.

In autumn of 1952, I received a letter from the Director of Purple Mountain Observatory (PMO), Professor Yuzhe Zhang (Yu-Che Chang), who urged me to return to work in China. When I first arrived at PMO in early 1953, the deputy director, Keding Sun introduced me to the general conditions at the observatory. PMO was built in 1934. The dome and other buildings were designed by the first director, astrophysicist Qingsong Yu (Ch’ing-Sung Yu). There were a 60 cm reflector, which would be have been considered a medium-size instrument at that time, and a few small-size instruments used for different disciplines in astronomy. Soon after, the operation of PMO was interrupted by the Japanese aggression against China. It only restarted after the founding of the People’s Republic of China, and became affiliated with Chinese Academy of Sciences (CAS). Other observatories in China, including the Xujiahui (Zi-Ka-Wei) and Sheshan (Zo-Sé) Observatories in Shanghai, Qingdao Observatory and the Fenghuangshan Observing Station at Kunming also became affiliated with CAS. They were then administrated by PMO.

In the observatory, there were three senior members (colleagues called them “three of the elders”), and their ages were all about fifty. Director Yuzhe Zhang took charge of the general work. Heng Li was assigned to be responsible for astrophysical work, and Zunwei Chen (Tsun-Kuei Ch’en) was responsible for the compilation of an almanac.
Similar to the experiences of Qingsong Yu, they studied astronomy abroad after the New Culture Movement and then returned to China, to contribute to the development of Chinese astronomy.

Among the instruments located at all observatories, the 60 cm reflector at PMO needed to be refurbished. The two observatories in Shanghai were built by French missionaries. There was a record of good quality data taken by the Sheshan 40 cm twin refractor that covered a long time span. After coming to PMO, I joined Prof. Heng Li’s research group, which was working mainly on the establishment of observational astronomical studies. Another team member was Biao Chen. Biao and I were both 30 years old at that time. Biao Chen started to pursue solar physics; whereas I tried to select a few fields of view from the negatives taken by the Sheshan 40 cm double refractor for double-channel photometry and proper motion measurements. The idea of this work was similar to that of my first study at University of London Observatory with observations using a 60 cm refractor. With Prof. Li’s support, I started to prepare the two-color photometry system and the selection of Sheshan negatives.

In 1954 the PMO assigned a team to work with an engineering group from the optical manufacturer Zeiss from “East Germany” to renovate the 60 cm reflector. Director Yuzhe Zhang personally took charge of this project. I was asked to work on the assembly and testing of the optical elements. The renovation of the telescope was successful. I planned to use the newly restored 60 cm reflector to measure two-color photometry instead of the Sheshan 40 cm refractor. With Prof. Zhang’s permission, I began to do some preparatory work but soon I was dispatched to Shanghai for another project.

In 1955, an urgent task related to broadcasting time service was assigned to PMO by CAS. Effective improvement of accuracy of the time signal broadcast was demanded to meet the immediate need of a national geodetic field survey. At that time, Xujiahui Observatory in Shanghai was the only one in China having time service in operation and broadcasting time signals. By the decision of the PMO leaders, I was dispatched to join the time service group there for the effort, and thus began my three year journey in the field of practical astrometry.

The main works I had participated in during this period and several related essential events are briefly noted as follows:

(a) Xujiahui Observatory was built by French Jesuits many decades ago. Its time service facilities were much out of date. The research group had worked out an emergency plan. As a priority measure, we imported a set of quartz-crystal clocks. In addition, several time measurement instruments were ordered for the establishment of time research.

(b) In early 1956, CAS planned to build another time service base in the northwest of China. Sixiang Liu and I went there searching for the site (see Fig. 2). A place in the suburb of Lanzhou was chosen as a potential candidate.

(c) At the end of 1956, PMO sent me and Dingjiang Luo to Pulkovo Observatory in the Soviet Union to learn the technique of photoelectric transit instrument from Professor Pavlov who had invented this technique. In 1957, when I returned to Xujiahui Observatory the next spring, together with several colleagues, we equipped the newly imported transit instruments with photoelectric recorders and employed them in regular time observations.

(d) The accuracy of the Xujiahui time signal had fulfilled the urgent demand and been approved by field workers. In 1957, the Vice President of CAS, Youxun Wu (Y.H. Woo), held a special meeting to summarize and conclude this project.

(e) In 1957, along with the decision to establish Beijing Astronomical Observatory (BAO), CAS decided to set up a Time Service Division attached to the observatory, replacing the base formerly chosen in Lanzhou. I was given the responsibility for setting it up and started to do it by firstly searching and then founding the present Shahe Station as the base of time observation.

Recalling these early days at PMO (and Shanghai) under the direction of Professors Yuzhe Zhang and Heng Li,
I am very much impressed by the devotion and scholarship which were typical for Chinese scientists from that senior generation. For instance, these characteristics were exemplified by the efforts that they devoted to planning and preparing facilities for modern astronomy in this country. They comprehensively surveyed the overall situation of astronomy and held a broad vision on scientific disciplines. Here, I wish to only mention one important thing, which is to lay the foundation of “observational astrophysics” in China.

To lay the foundation means to initiate a scientific discipline from having nothing in a country, i.e., to create adequate conditions and to foster a group of initiators who are able to stand on an international scientific platform. Through continuous scientific progress, this “platform” will ceaselessly grow and rise. For the new China at that time, everything was waiting to be taken up. With the conditions of very limited support, the scientific founders would have to choose an “adequate” (i.e., optimized) road map, based on their academic forecast and strategic consideration, and need to implement concrete approaches and steps. For this purpose, Professors Yuzhe Zhang and Heng Li formulated three schemes: (1) to initiate a site survey in the surrounding areas of Beijing and Tianjin, where there were more clear days in a year, and to select an adequate site with good atmospheric seeing and convenient conditions for reconstruction and operation; (2) to construct a “2 meter” aperture telescope as the key instrument for the new observatory; (3) to urge astrophysicist Maolan Cheng (Mao-lin Tcheng), who worked in France for many years, to return to China for chairing this reconstruction. I saw their frequent communications with Professor Cheng, and guessed that the first two schemes must have been their common consensus. Those bygones seemed to be “just who should be,” as in our mind, from the tradition of “serving the nation by science,” which was held by the elder generation of Chinese scientists. But only after falling down and picking oneself up in our scientific career could we come to realize how farsighted and prudent their consideration was, and their spirit of perseverance and grace of “to achieve success regardless who would own the air of a hero.”

Their suggested road map was written into “The Twelve Year Strategy Plan for Astronomy” published in 1956. The meeting to organize the strategy plan was chaired by Vice President Wu of CAS (see Fig. 3). Attendees at the meeting made a decision to build an “integrated observatory with emphasis on astrophysics” in Beijing. In the next year, the “Preparatory Department of Beijing Astronomical Observatory” was established. Attendees at the meeting also decided to build the Beijing Time Service base by replacing that planned for Lanzhou. In 1957, I was assigned to Beijing for the site survey of the time service base. The site was finally selected in Shahe town, and the reconstruction of the time service base was started then there.

2 RECALLING MY RADIO ASTRONOMY TOUR

Radio astronomy was started based on the development of military radar technology in World War II. Until the middle of the 1950s, there were no activities related to radio astronomy in China. In 1957, CAS decided to adopt, from the Soviet Union, radio astronomical techniques to help with
initiating radio astronomy in China through bilateral cooperation on radio observations of an annular eclipse, which were to be performed in April 1958 in Hainan Island. Members of the eclipse observing team from China not only included scholars from astronomical observatories but also some young teachers majoring at radio science from several colleges. This group was headed by electronics scientist Fangyun Chen and me. Our partners from the Soviet Union had a very strong background, and were led by radio astronomer A.P. Molchanov, who brought us several radio telescopes from observatories in different regions of the Soviet Union, which were able to receive the EM signals at wavelengths from short centimeter to long decimeter. It was a very successful observation carried out at Sanya in Hainan Island. The introduced technologies were learned very well. Molchanov, Fangyun Chen and I have become good friends by then. After this eclipse observation, the Vice President of CAS, Prof. Youxun Wu, asked to borrow two centimeter radio telescopes from our partner in the Soviet Union, and decided to put them at Shahe Station in Beijing. Together with the Institute of Electronics of CAS (IoE), BAO (the preparatory office of BAO at that time) planned to jointly set up radio astronomical research in China (see Fig. 4).

Looking back to that period, it reminds us of the foundation, mentioned earlier, of radio astronomy in China. The strategy was to select the right timing, to race against time, and to set up cross cooperation in the two disciplines overseen by IoE and BAO. It was far-sighted and had been proved by the fact that all “Four Great Discoveries” made in astronomy in the 1960s were the results of successful radio astronomical observations. However, those decisions were soon replaced by concerns related to the so-called “Great Leap Forward” and “Go all out and Go fast” in China. At that time, the cooperative group who participated in the eclipse observation in 1958 was dismissed and the team members including me were separated and sent back to the institutes where they were originally working. The worst thing was that Fangyun Chen was assigned to do research other than radio astronomy, which made the cooperation on establishing radio astronomy disconnected between the two institutes of IoE and BAO. At the same time, the staff members at the preparatory office of BAO increased rapidly, and most of them were new comers to radio astronomy at Shahe Station. Most of these newcomers had newly graduated from high school.

During the climax of the “Great Leap Forward” and the subsequent “Three Years of Natural Disasters” in China, for the newly organized work of radio astronomy at Shahe Station, I initiated three programs: The first was to learn and master the introduced technologies from our team members from the Soviet Union, to dis-assemble and re-assemble the centimeter radio telescope receiver, and then to apply it to the work of regular solar radio observations.

During the early stage of radio astronomy research, it was quite difficult to observe radiations from radio sources in the Universe since they are extremely weak compared to the sensitivity of instruments at that time. However, the Sun radiates a large amount of EM flux and varies much,
therefore it can be easily detected for scientific research even by small radio telescopes. Our plan at that time was to share the observational results with other institutes and universities, who showed interests in radio astronomy, as a starting base, which would help to build up a radio monitoring network for solar activity. The second program was to invite young colleagues focusing on radio astronomy to act as backbones in other institutes, such as astronomical observatories and universities. They would participate in a one-year workshop on radio astronomy at Shahe Station in Beijing. We tried our best to collect all related materials (books, reference papers and telescope components at hand) available at that time, to prepare lecture notes, to enlighten fruitful discussion, and to fill the knowledge gaps of the basic theories and technical methods for those young researchers. Thirdly, driven by the “Go all out and Go fast” effort during the “Great Leap Forward” period, we decided to make a solar radio interferometer at a meter wavelength by adopting the “Christiansen Array” in a big hurry. Among the available radio frequencies used in astronomy, we opted to start at a meter wavelength because only the components required for a meter-wavelength telescope could be provided in China. In addition, manufacturing its aerial required less accuracy compared to those at higher frequencies. It could then be possible to meet the goals of “Go all out” and “Go fast.” Of course, at this frequency the scientific value of a high resolution observation on solar activities was highly recognized. The interferometer array was designed to be built in phases. Its first phase consisted of 16 dish antennas with each of them being 6 m in diameter. The array was aligned along the east-west direction. Each aerial was 72 m apart from its neighbors. The array had a total length of 1080 m, therefore its angular resolution was about 3′ at the wavelength of 1 m.

Once the design was determined, the implementation was executed immediately. We first found a metalworking factory run by a technical school to manufacture the 32 dish aerials and equatorial mount (the extra 16 dishes were prepared for the second phase of the project). In addition, a site survey team was established to search for a suitable place for the array, where there must be very low radio frequency interference and a baseline of at least 2 kilometers long in the east-west direction around Beijing. One difficulty that we met was the manufacture of a transmission line that was several kilometers long. There was no factory that produced such a co-axial cable product in China. Although someone was trying to make this kind of cable in a primitive way, the quality could hardly be guaranteed.

By the end of 1962, the “Three Years of Natural Disasters” period had ended. We had actually done the first two things of all the three mentioned above. Those two had positive effects on our later research activities. For the third thing, 6-meter antennas and matched devices were handed over for manufacturing, and the site for an antenna array was preliminarily selected, which was on the north bank of the Miyun reservoir in Beijing.

In 1963, the China Association for Science and Technology (CAST) hosted an international conference (this might have been the first time for China to host an international science conference). W.N. Christiansen from Australia was on the list of the invited scientists. He invented the “Christiansen Array” that we were emulating in China. Prof. Christiansen was one of the pioneers of radio astronomy after World War II. He was friendly to his Chinese peers. During his first trip to China, he visited Shahe Station, then met and talked to our radio astronomy group there (see Fig. 5). We subsequently enjoyed over 40 years of friendship with him. In the next year, he invited me to visit his lab in Australia, and I had a chance to discuss the details about our current radio research work and future plan. Then he showed interest in visiting the Shahe Station again and helping us on his vacation in 1966.

In May of 1966, he brought us the plan for a “Two-Wire Open Line” (i.e., twin-wire transmission line), which
could be fully self-made and used as a transmission line between an antenna and a receiver (or a transmitter). The transmission line scheme required only copper wires and tubes as components, which were easily available to us in China. The Miyun Station was under construction by that time, while the preliminary study on the transmission line was making progress at Shahe Station. It took about two months for Prof. Christiansen to guide us to learn the whole techniques of assembling, integration and verification. We were still working to assemble the Two-Wire Open Line system when chaos from “the Cultural Revolution” was reaching its climax. The meter wavelength array project was still in preparation.

The overall assembly and verification of the radio interferometer was eventually completed at Miyun Station by the middle of 1967. It produced the first one dimensional map at high resolution on a celestial radio source. After the impact of the first half of events related to “the Cultural Revolution” had passed, many institutes had the chance to do their research work during the quiet interval of the Cultural Revolution. The radio astronomy group at Miyun Station had been trying to improve the functionalities of the instruments, and make the observatory productive (see Fig. 6). The Chinese scientific community at that time was isolated from the rest of the world, except that Prof. Christiansen provided us very valuable information whenever he visited China. In 1973, Prof. Christiansen talked about his antenna array in the University of Sydney, which was to be reconfigured to become an aperture synthesis radio telescope. This idea inspired me very much. The aperture synthesis technique was a revolutionary innovation for radio astronomical technology that was invented in the 1960s. Together with the backup dish antennas, if we utilized the current 16 antennas and implemented the so-called “Earth Rotation-Synthesis” technique, we should be able to build up an international platform for cutting-edge research that could survey the radio Universe at meter wavelength. This was, for sure, a great leap for us. After considering all possibilities, we presented a general layout design shown below (Fig. 7).

In this layout, we needed to increase the diameter of dish antennas to 9 meters. The factory at BAO could easily make it. Concerning the array configuration, a sub-array of 6 dishes each was placed beside the current setup of the interferometer, which could be made up of many interferometer pairs with baselines of 3 d0, 4 d0, ...., 194 d0 (where d0=6m), aligned along the east-west direction, to make use of the Earth’s rotation and the aperture synthesis technique. Concerning the receivers, although we only had some out-of-date electronic components at hand, some early experiments could still be carried out. However, we had to buy a computer for data processing.

In 1974, when Prof. Christiansen visited China again, we discussed the plan with him in detail. He recommended that we send two engineers to his lab in Sydney where they could do the work with some more advanced facilities. Meanwhile, the leader in charge of basic research

Fig. 5 During his first visit to China in 1963, Professor W.N. Christiansen and Mrs E. Christiansen met Moruo Guo (Moruo Go), the first President of the Chinese Academy of Sciences (sixth from left), Youxun Wu (Y.H. Woo), Vice-President of the Chinese Academy of Sciences (fourth from left), Peiyuan Zhou (Peiyuan Chou), President of Peking University (third from left), Maolan Cheng (Mao-lin Tcheng) (second from left) and the author (third from right in the back).
at CAS highly supported us to import a NOVA computer from Japan.

At the end of the “Cultural Revolution,” the Miyun team (radio astronomy group) had mostly completed a pre-study of each part of the project in a tough and backward environment. The overall construction of the project had also sequentially proceeded. However, as China was opening to the world, we soon saw new, high technology that could be integrated into radio astronomy with international cooperation. The Miyun team then started a new round of great efforts (on development of the radio telescope). Eventually in 1984 after the overall test of the radio telescope, the team produced the first map of a radio sky survey (Wang et al. 1986). Observational studies were carried out by Xizhen Zhang, Yijia Zheng and others. They had discovered several supernova remnants, and completed compilation of the Miyun 232 MHz survey (Zhang et al. 1996). In the following years, we continued to conduct the sky survey at meter wavelength. However, initially simple and crude conditions resulted in a high maintenance cost, both in terms of finance and time. Because a large amount of financial and manpower investment would be required for further development, new options were therefore explored. Rendong Nan, Bo Peng and Yuhai Qiu found a Karst area in Guizhou Province that would be an ideal location for the next generation large telescope, named SKA after 1999 (Peng et al. 1995; Nan et al. 1996), and initiated the discussion of a 500 meter spherical telescope (later established as “FAST” in Guizhou Province). At Miyun Station, I proposed to build a radio telescope sensitive to decimeter to meter wavelengths, dedicated to pulsar observation, which would do full time and long-term regular monitoring of a sample of pulsars. Such a monitoring project has at least two advantages in the frontier of astrophysics:

(1) Select a number (such as 20) of pulsars in an appropriate distribution, to form a pulsar clock group (nowadays called a Pulsar Timing Array or PTA), starting as early as possible, in an unremitting search for gravitational waves;

(2) Monitor a number of pulsars with different types and ages, to study the variation of periods in their pulses.

In addition, this also allowed us to do other research on pulsars. The selected decimeter wavelength has been able to meet our scientific requirements, and the manufacturing accuracy was far below that of usual large radio telescopes (normally working at centimeter wavelength), leading to a much shorter preparation and manufacturing time. The main scientific goal, such as exploration of gravitational waves, strongly depends on good fortune, therefore it is important to have the time of monitoring as much as possible. For some reasons, only half of this project was accomplished, and the other half can only hope to be accomplished by the next generation.

3 RETROSPECTION AND EXPECTATION OF LAMOST

The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) was developed by us as a wide-field telescope for a spectroscopic survey. It was designed for a large aperture telescope to possess large field of view as well. When it is equipped with the technology for multi-object fiber spectroscopy to conduct large scale spectroscopic survey observations, LAMOST would be at the forefront of observational research in modern astrophysics. In 1993, we finished the design study and put forward a specific proposal (Wang et al. 1995, 1996). The spectroscopic survey telescope would be set up at Xinglong Station of BAO. It would have a 4 m clear aperture and a
Fig. 7 General layout of the Miyun Meter Wave Aperture Synthesis Radio Telescope (Wang et al. 1986).
field of view of 20 square degrees to accommodate 4000 optical fibers for observing up to 4000 objects simultaneously. The LAMOST project was approved as one of the first national major science projects in China by the Chinese government in 1997. The LAMOST project finished its construction stage in 2009 and started to acquire scientific observations at that time. In Data Release 1 (DR1) from the Xinglong-LAMOST project in 2013, the number of stellar spectra obtained by LAMOST was larger than the sum of all other stellar spectra obtained by other telescopes previously. This showed that our research teams associated with Xinglong–LAMOST had reached the frontier of astronomical spectroscopic surveys in the world.

There were three stages for the LAMOST project: proposal, construction and operation. Those stages have been through several generations of astronomers up to now. I mainly participated in the work during the first stage. In my mind, those processes were just following the foundation started by the older generation of astronomers in China. Recalling sixty years ago, the three measures for the foundation of observational astrophysics (as outlined above) planned by Professors Yuzhe Zhang and Heng Li were ready to be completed when Professor Maolan Cheng returned in 1957. In the movement called the “Great Leap Forward,” the plan was abruptly stopped, as the 2 m telescope was to be made by ourselves with one piece of 2.16 m glass from the Soviet Union instead of being imported as originally planned. When the baton was passed on to us in the era of “Reform and Opening Up” after the “Cultural Revolution,” the situation was: firstly, one of the three measures, namely, establishment of Xinglong Station was completed, and several small telescopes were there in operation; secondly, thanks to the seeds of astronomical studies cultivated by the forerunners, the project of a 2.16 m reflector survived through the period of self-imposed isolation, and the severe hardship encountered had cultivated a strong and capable team able to perform astronomical instrument research; thirdly, Professor Maolan Cheng passed away in 1978, yet the influence due to his direction on the site searching and effort on the promotion of speedy formation of faculty of astrophysics in Peking University will long remain. On the whole, scientific research activities in China returned to normal status after 1978, however, the research levels of international astronomy were at a stage with a larger budget and fast development. In this situation, following the “foundation” (to connect to an international level) that was originally planned by Professors Yuzhe Zhang, Heng Li and Maolan Cheng, we proposed two priority steps: (1) to complete the 2.16 m telescope according to modern standards and discuss the roadmap and plans for “post 2.16 m” with the goal of developing modern astronomy; (2) to send as many key members and graduate students to work and study in advanced countries as possible.

At the end of the 1980s, construction of the 2.16 m telescope had finished and it began to do observations. In that period there were good conditions for Chinese astronomers to make more choices in academic research. The Hubble Space Telescope and “next generation” facilities in optical, radio and space were being constructed and developed around the world. To devise the “post-2.16 m” plans and propose other possible plans, we focused on the goal of wide field spectroscopic observations.

Spectral data from celestial objects are the basis of modern astrophysics. From the beginning, spectroscopic observations faced a bottleneck in technology and hardness in the optics. The bottleneck is that one telescope can only observe the spectrum of one object at a time. The hardness is that it is very difficult to design a telescope to have both “large aperture” and “wide field.” These problems caused spectroscopic observations to have very low efficiency. At the beginning of the 1980s, we noticed that experiments on applying the technology of fiber optics in spectroscopic observation had been carried out successfully at observatories in several western countries. Dr. Shunde Wang of BAO was entrusted to closely follow the development and set up a project that utilized multi-fiber spectroscopy there. In the middle of the 1980s, his results showed that, firstly, multi-fiber spectroscopy in astronomy had good potential, so researchers at BAO were optimistic that they could overcome the bottleneck; secondly, we had the capability of developing multi-fiber spectroscopy for astronomical observations in China by importing necessary parts and techniques. So, the challenge that remained to deal with was to design a telescope with “large aperture” and “wide field.” In an initial sky survey, it would be sufficient that the telescope have an aperture of more than 2 m and a field of view of 5–10 square degrees.

The design of the telescope was a very difficult task. We reviewed the potential risks and benefits, then concluded that without a soaring budget, a spectroscopic survey is the only major project in China that could compete with advanced countries from the same starting point. This represented a rare opportunity in the development of modern astronomy in China. With Professor Dingqiang Su, we decided to face the challenge. At the end of the 1980s we organized a research team working for the project. In addition, we assembled a number of colleagues that specialized in observation or instrumentation to frequently engage in reviews and discussions. The design for LAMOST was finalized in 1993 after many discussions and modifications.

The LAMOST-type design originated from that of a Schmidt telescope whose effective aperture is equal to the corrector aperture. If using a reflecting corrector instead of the correcting lens of a normal Schmidt telescope, the problem of making a Schmidt telescope with large aperture could be solved. As calculated by Professor Dingqiang Su, a “reflecting Schmidt” telescope with a focal ratio of 5 can have a “wide field” as large as 20 square degrees. So, a telescope with a 4 m aperture would be very powerful in conducting a spectroscopic sky survey. However, such a telescope with a 20 m focal length will need a tube that is...
40 m in length to house the optical system, and it would be difficult to point and track an object with such a long tube. The difficulty becomes more serious as the size of the telescope increases.

To solve the problem of having a long tube, we adopted a “Laying-down Meridian Layout,” in which tracking of celestial objects is carried out while they are passing the meridian region. The three main parts of the telescope, the reflecting corrector, the spherical primary mirror and the focal surface, are fixed with respect to the ground and lie in the meridian plane. With such a layout, for the pointing and tracking, it would need to have an additional large plane mirror to reflect light from celestial objects to the corrector. Innovatively, Professor Dingqiang Su proposed an “active corrector” to track the motion of objects and to apply the active optics to get a different aspherical curvature shape of the reflecting corrector during an observation. This configuration is much more concise and effective as it only has two mirrors and requires a shorter light path (Fig. 8).

A LAMOST-type telescope achieves the scientific requirements, although it can only observe celestial objects when they pass the meridian. This constraint is harmless for our purpose since the “meridian observations” are the best choices for conducting a multi-object survey.

Being the first large-scale astronomical facility to be constructed after the 2.16 m telescope, LAMOST was designed as a telescope with a clear aperture of 4 m, a focal

Fig. 8 Configuration and the light path of LAMOST.

Fig. 9 The author and Dingqiang Su in front of the LAMOST Telescope.
The telescope would function more optimally if it were mounted in a site with good observational conditions. In China, however, all first class sites are in the western plateau or in desert regions where surveying, selecting, constructing and maintaining such a facility would be very difficult. One of the major decisions we made in the 1990s was to construct LAMOST at Xinglong Station which had been planned by the older generation of astronomers. The problems arising from that observational site would be discussed as a future plan for “post-Xinglong-LAMOST.”

Here we again emphasize the point of view of enhancing human resource development. We wondered if Xinglong-LAMOST will function as designed? In the following, the development of human resources in two aspects is considered: for managing an astronomical facility and for observational astrophysics.

(a) The development of human resources for managing an astronomical facility:

The LAMOST project has incorporated very high technology components. For example, the “active corrector” represents an innovative and creative use of active optics, and the technology for segmented mirrors has been successfully applied in the 6 m primary mirror and in the 5 m reflecting corrector. Those examples show that astronomical optical technology in China is at a high level for developing huge telescopes. Another good example is the application of fibers in astronomy, which implements the parallel controllable fiber positioning technique developed by a team from the University of Science and Technology of China.

The technical team in China has adopted international methodologies with their creativeness, capabilities at tackling key problems and operating a large facility.

(b) The development of human resources for observational astrophysics:

This should be discussed in an international context. We knew that the SDSS project was starting in the USA when LAMOST was designed in 1993. SDSS has a clear aperture of 2.5 m, a field of view of 7 square degrees and 640 fibers. SDSS is mounted at a good site in the continental USA. Compared to LAMOST, SDSS has good observational conditions and was built earlier. SDSS would go on to produce decisive new results in the influential field of large spectroscopic surveys over a large sky area.

In this situation, we estimated that the Xinglong-LAMOST project has weakness in terms of the observational conditions at the site, such as the number of clear nights and moderate seeing. However, LAMOST has a larger clear aperture to compensate for worse seeing and has 4000 fibers that can obtain many more spectra. Therefore, LAMOST could contribute more in the field of a large spectroscopic survey after the first survey by SDSS. It represented a beginning point for developing a spectroscopic survey which produced Data Release 1 (DR1) from the Xinglong-LAMOST project, which was made available in 2013 as mentioned above.

In the above we described the formation of a LAMOST-type telescope for a spectroscopic survey and the foundation of discipline construction based on the LAMOST facility at Xinglong Station that was planned by the older generation of astronomers.
The goal of the foundation is for further development. This takes the form of an endless process of acquiring more and more spectral information about celestial objects from a spectroscopic survey. Now SDSS has achieved many scientific milestones. Like many important astronomical facilities in the world, “next generation” (meaning “post-SDSS”) facilities have garnered more attention for study and implementation. As a successor to SDSS and LAMOST, we proposed the “LAMOST South” facility as part of an international collaboration. “LAMOST South” would be mounted at the best site in the world with a clear aperture of 4 m (or 6 m if possible in terms of scientific goals and construction period) and have a focal ratio of 5 to maintain the advantage of a wide field. A complete survey of the northern and southern hemispheres would then be conducted by both LAMOSTs.

Both LAMOSTs can produce great scientific benefits and they are very good for the development of human resources related to managing an astronomical facility and for observational astrophysics through this large scale of international collaboration. This process will definitely develop Chinese astronomy to new heights.

We eagerly await these new developments.

I educated more than ten Ph.D. students during my career working for Chinese Astronomy (see Fig. 10). They have played some key roles in the development of astronomy and astrophysics enterprise in China.

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