Amateur Astronomy in China: Current Status and Future Postprint

Authors: Ye Quanzhi

Date: 2018-05-28T00:00:00+00:00

Abstract

Citizen science refers to scientific research activities organized or participated in by non-professional scientists (such as science enthusiasts), and citizen astronomy is a classic branch of citizen science. Benefiting from advancements in technology, contemporary citizen astronomers effectively supplement areas that professional astronomers are unable or lack the time to address, such as time-domain astronomical observations, manual analysis of big data, and data mining. In recent years, citizen astronomy in China has developed rapidly, with Chinese enthusiasts achieving remarkable results in the search and discovery of new celestial objects. However, compared with citizen astronomy in Europe and America, the interests of Chinese enthusiasts are relatively singular, and their participation in projects such as long-term monitoring and data mining is low. Surveys have found that young people in China constitute a large proportion of the citizen astronomer community. "Interest in astronomy," "learning astronomical knowledge," "gaining enjoyment," and "making friends" are the main motivations for Chinese enthusiasts to participate in citizen astronomy research. These two aspects differ significantly from those of citizen astronomers in Europe and America. As a series of large scientific facilities in China have been constructed and put into operation, the potential of citizen science and citizen astronomy needs to be recognized. The public and enthusiasts should be actively guided so that while acquiring knowledge and gaining enjoyment, they can make greater contributions to scientific research.

Full Text

Citizen Astronomy in China: Present and Future

Quan-Zhi Ye[1,2]

[1] Division of Physics, Mathematics and Astronomy, California Institute of Technology, Pasadena, CA 91125, U.S.A.

[2] Infrared Processing and Analysis Center, California Institute of Technology, Pasadena, CA 91125, U.S.A.

Abstract: Citizen science refers to scientific research conducted or participated in by non-professional scientists (such as hobbyists or members of the general public). Citizen astronomy is a classic branch of citizen science that has benefited from technological advancements, artificial analysis of big data, and data mining. In recent years, citizen astronomy has developed rapidly in China, with Chinese hobbyists making notable achievements in the search for and discovery of new celestial objects. However, compared with their counterparts in Europe and America, Chinese hobbyists tend to have more singular interests, with a strong focus on discovery-oriented activities. Young people constitute a large proportion of the Chinese citizen astronomer community. "Interest in astronomy," "learning astronomical knowledge," "having fun," and "making friends" are the main motivations for Chinese hobbyists to participate in citizen astronomy research—two points that differ significantly from European and American citizen astronomers. As a series of major scientific facilities are completed and become operational in China, the potential of citizen science and citizen astronomy needs to be recognized. The public and hobbyists should be actively guided so that while they acquire knowledge and enjoyment, they can also make greater contributions to scientific research.

Keywords: sociology of astronomy

1. Amateur Observations

Astronomy originated from observations of the night sky, and observation remains the primary activity for amateur astronomers. While the hardware gap between professional and amateur astronomers was once modest, this disparity became increasingly pronounced during the 20th century as technology advanced and nations prioritized basic scientific research. Professional astronomy has long since expanded beyond visible-light studies, yet most amateurs remain focused on visible-light astronomy. Nevertheless, despite the near-saturation of visible-light astronomy, the rise of time-domain astronomy and the rapid development of information technology continue to provide substantial opportunities for hobbyists. Today, images obtained with amateur-level telescopes and CCD cameras can rival those captured by large telescopes with expensive photographic plates 30–40 years ago. Portable spectrographs and other instruments have also entered the commercial market, broadening the research scope for amateurs. Currently, amateur astronomers still play a significant role in the discovery and observation of transient events and small Solar System bodies. Although Chinese hobbyists started relatively late, they achieved notable results even in the 1970s–80s, such as Duan Yuanxing' s independent discovery of the 1975 Cygnus nova (V1500 Cyg), Zhou Xingming' s independent discovery of 12 comets including C/1983 H1, and Ouyang Tianjing' s radio observations of meteor activity. Entering the 21st century, China' s rapid economic development and the advent of the internet era have quickly narrowed the gap between

Chinese and foreign hobbyists in terms of hardware, software, and observational strategies.

1.1 The Rise of Robotic Amateur Observatories Modern civilization has brought light and air pollution that forces observatories to relocate to increasingly remote areas. Meanwhile, the miniaturization of computers and rapid development of network technology have made remote observing possible. As early as 1975, Colgate et al. achieved remote control of a 75-cm telescope via microwave network [7]. The "Robotic Autonomous Observatory" (RAO), capable of executing observations autonomously and adapting to environmental changes (such as cloud cover or rain) without human intervention, emerged in 1984. RAO technology has been widely applied to target-specific observation programs, such as supernova patrols and gamma-ray burst afterglow observations. Castro-Tirado et al. [8] and Cui Chenzhou et al. [9] provide detailed reviews of the history and current status of RAOs.

Remote observing and RAO technology began to be used by amateur astronomers in the late 1990s. The Astronomy Common Object Model (ASCOM) protocol and related software solutions developed by Bob Denny[1] are widely used in amateur observatories and even in some professional facilities. Compared with professional astronomers, hobbyists' work patterns are more flexible; manual intervention is not a technical barrier but rather an integral component of the observing activity. Therefore, although many amateur observatories have achieved high degrees of automation, few have reached the "robotic autonomous" stage, with most being network telescopes for educational or commercial purposes, such as the Bradford Telescope[2] and iTelescope network[3].

Established in 2007 at the Nanshan station of the Xinjiang Astronomical Observatory, Chinese Academy of Sciences, the Xingming Observatory is China' s first stably operating robotic amateur observatory. Built and operated by Gao Xing from Urumqi, it primarily hosts hobbyist-led supernova and comet patrol projects. Its data are publicly available online for analysis and research by hundreds of hobbyists nationwide. Xingming Observatory also collaborates with the Chinese Virtual Observatory on the Public Supernova Search Project . Additionally, it leverages its geographic advantages to join professional-led time-domain astronomy research [10][11]. According to the International Astronomical Union (IAU) Minor Planet Center observatory database, currently active amateur observing stations in mainland China include Suzhou Lüye Observatory and three others (Figure 1 [Figure 1: see original paper]). There are also at least a dozen remote observatories primarily for astrophotography, such as the Tibet Yangbajing Star River Research Society Observatory and Xinjiang Nanshan Ruoyan Observatory. An incomplete list of these facilities is provided in Table 1 .

The buildings of these robotic amateur observatories are mostly designed and constructed by hobbyists themselves. Most are located on privately owned land in suburban or wilderness areas, though a few collaborate with research institutions and are built on institution-owned land (such as Beimian Observatory, Xingming Observatory, and Star River Research Society Observatory). The equipment and supporting software/hardware (telescopes, cameras, observatory control systems, etc.) are almost entirely commercial products. Nearly two-thirds of these observatories were built within the past three years, indicating a rapid increase in the number of robotic amateur observatories in China. However, fewer than one-third have obtained IAU observatory codes. In fact, most robotic observatories are primarily used for astrophotography, with owners publishing their work mainly as photographs on online platforms (astronomy forums, Weibo, WeChat public accounts, etc.) and rarely engaging in scientific research. Hobbyist-organized research efforts like those at Xingming Observatory are quite rare.

Notably, professional astronomers in China have begun to recognize hobbyists' work and collaborate with them, indicating that Pro-Am collaboration has started in the Chinese astronomy community. Typical examples include Xingming Observatory' s assistance to the Purple Mountain Observatory in confirming near-Earth asteroid 2017 BM3 [12] and Wang Xiaofeng' s research group at Tsinghua University helping to certify supernovae discovered by Xingming Observatory [13].

1.2 Observations of Transient Sources and Small Solar System Bodies Transient sources refer to astronomical events with brief visibility, such as supernova explosions, nova outbursts, and returns of Solar System small bodies (asteroids, comets, etc.). Since most transients cannot be predicted in advance, it is difficult for large professional facilities to fully leverage their capabilities, leaving room for hobbyists. Amateurs have contributed particularly to new object discoveries: until recently, supernovae discovered by amateurs accounted for more than 10% of annual discoveries [6]. Chinese hobbyists have also been active in new object searches since the 1970s–80s, including Duan Yuanxing and Zhou Xingming. However, due to technological and communication limitations, most of their discoveries were made later than those by foreign astronomers and hobbyists. Nevertheless, Zhou Xingming' s independent discoveries of C/1990 N1 (Tsuchiya-Kiuchi) and 122P/de Vico were recognized by the IAU despite not receiving naming rights.

China' s first truly leading discovery was Comet 153P/Ikeya-Zhang, discovered by Zhang Daqing from Henan in 2002. Since then, Chinese hobbyists have discovered three comets [C/2008 C1 (Chen-Gao), 325P/Yang-Gao, C/2015 F5 (SWAN-Xingming)], at least 32 supernovae, six novae, and nearly 100 asteroids —almost all discovered by Xingming Observatory. Beyond new object searches, tracking observations of known objects are also common, such as Xingming Observatory's participation in the global comet observation network [18] and Liu Junda from Lüye Observatory' s measurements of rotation periods for multiple asteroids including (2729) Urumqi [19][21]. Additionally, asteroid occultations have attracted hobbyist interest. As a special transient phenomenon observable only within the occultation path, asteroid occultations benefit from hobbyists' wide geographic distribution and high mobility. Contributors in this area include Zhang Xuejun and Chen Donghua .

1.3 Meteor Observations Meteors are essentially atmospheric phenomena, but their origin is directly related to astronomical objects and thus are generally included in astronomy research. Since meteors can appear anytime and anywhere, and a single meteor is visible only from a small area beneath its appearance point, conventional astronomical research methods cannot easily acquire large amounts of data, making hobbyists crucial for meteor research.

Visual meteor observation is a long-standing and simple activity. Historically, it was one of the most common and effective meteor observation methods, only recently being replaced by video meteor networks. The International Meteor Organization (IMO) is the professional body for international meteor research, collecting and analyzing visual meteor observation reports worldwide since 1982. According to published literature, modern visual meteor observations in China began in the 1980s with monitoring of the Aquarid meteor shower [22]. The earliest Chinese participant in IMO coordinated observations was Ouyang Tianjing from Wuhan (1989). As China' s amateur astronomy community has grown, the number of Chinese participants in IMO observations has increased rapidly. In recent years, 10–20% of Perseid meteor shower reports have come from mainland China (Figure 2 [Figure 2: see original paper]). Interestingly, the only recent Perseid campaign without Chinese participation was in 2008, possibly because the shower occurred during the Beijing Olympics. However, despite the rising number of participants, the total observation time contributed by Chinese observers remains very short, accounting for less than 1% of the global total. Even the most active observers contribute only about 10 hours of data annually, below the IMO average (30 hours/person), indicating that hobbyists who persist in visual meteor observations are still rare in China.

Video meteor networks use cameras instead of human eyes to record meteors, greatly reducing labor requirements and minimizing observer subjectivity. In recent years, with the miniaturization and networking of camera equipment, video meteor networks have developed considerably, with a large proportion still built and operated by amateur astronomers. Data processing mostly relies on commercial solutions such as SonotaCo' s UFO series software [23]. China' s first continuously operating meteor monitoring network was the Fireball Monitoring Network built by the Beijing Planetarium, operational since 2010. The first hobbyist-built network was the Guangdong Meteor Monitoring Network , operational since 2012. To date, hobbyists have also established networks in Qingdao (Shandong), Urumqi (Xinjiang), and Ali (Tibet). A brief summary is provided in Table 2 . Some hobbyists have also attempted meteor spectral observations, such as the work by Cheng Sihao and Cheng Simiao [24].

Meteor trails can reflect electromagnetic waves, enabling radio observations of meteors. Radio meteor observations are divided into active and passive modes.

Active observation involves transmitting radio pulses and using reflected signals, while passive observation involves receiving signals from distant transmitters (such as FM radio stations). Passive observation is more commonly used due to simpler instrumentation. Ouyang Tianjing from Wuhan has persisted in radio meteor observations since the 1990s and participated in international radio meteor coordinated observation projects [25]. The Guangdong Meteor Monitoring Network mentioned above also conducts passive radio observations. Active radio observations generally use radar, which is costly and involves policy control issues, making it rare among hobbyists. However, amateur radio bands commonly used by radio hobbyists can also be used for active observations. Zhang Xuejun from Daqing conducted such experiments during the 1998 Leonid meteor shower[1] .

2. Data Mining

Astronomy has entered the era of big data. Various time-domain survey projects such as the Catalina Sky Survey, Pan-STARRS, and the Large Synoptic Survey Telescope (LSST) have produced or will produce petabyte-scale data [26]. These massive datasets not only help professional astronomers study their targets with higher temporal resolution but also provide vast exploration space for hobbyists. Amateurs participate in big data mining in two main ways: first, through spontaneous exploration, such as searching for new objects in survey images; and second, through projects designed by professional astronomers that request public assistance in data analysis, such as Galaxy Zoo and Planet Hunters.

2.1 Spontaneous Research by Hobbyists Spontaneous exploration of data by hobbyists almost exclusively targets new object discovery. When the internet became widespread in China in the late 1990s, it greatly lowered the technical barrier for hobbyists to access data. The first person to successfully discover a new object using public data was Zhou Xingming from Xinjiang, who discovered comet C/2000 X4 (SOHO) in 2000. The SOHO (Solar and Heliospheric Observatory) satellite, a joint mission of NASA and ESA, was designed to study the Sun but serendipitously found that its coronagraph could observe sungrazing comets. Since the first SOHO comet was discovered by mission scientist S. Stezelberger in 1996, more than 100 researchers worldwide (mostly amateurs) have successfully discovered comets in SOHO data. After Zhou Xingming’ s first discovery, China’ s SOHO comet hunter community grew rapidly. As of August 2013, 25 Chinese hobbyists had successfully discovered SOHO comets[11], accounting for one-quarter of all SOHO comet discoverers, with Zhou Bo from Shaanxi ranking first globally with 287 total discoveries.

In addition to the SOHO database, the NEAT database is also commonly used by hobbyists to discover new objects. NEAT (Near-Earth Asteroid Tracking) used the Palomar 1.2-m Schmidt telescope and the Hawaii Haleakala 1.2-m reflector to search for near-Earth asteroids, capturing 690,000 images by 2010, all available on the SkyMorph website[12]. Since 2001, hobbyists have used this database to search for missed asteroids. Chinese hobbyists have discovered 655 asteroids by July 2014, with seven individuals making discoveries since 2005[13]. Except for very early amateur discoveries, asteroids found in the NEAT database have their discovery and naming rights assigned to the NEAT team.

2.2 Professional-Led Research Professional-led citizen astronomy research can be divided into two categories: visual analysis, where the public assists professionals in manually analyzing large datasets according to specified methods; and volunteer computing, where the public uses idle computing resources to help professionals process big data.

Public science visual analysis projects emerged directly from the massive data produced by modern astronomical surveys: complex targets are difficult to study completely with computers, while researcher manpower is limited. The first public science visual analysis project, Stardust@home[1] , required volunteers to manually examine nearly 30 million images from the Stardust spacecraft to find traces of interstellar dust [27]. Galaxy Zoo[1] , which inherited from Stardust@home, required volunteers to manually classify hundreds of thousands of galaxies. The project was highly successful and spawned the Zooniverse platform spanning astronomy, ecology, biomedicine, and other fields, where citizen scientists can find projects of interest. These projects and platforms primarily use English for communication. Although volunteers provided Chinese translations of introductions and analysis guidelines, Chinese hobbyist participation remains low. For example, a 2013 survey by Raddick et al. showed that participants from China accounted for only 0.8% of surveyed users, while users from English-speaking countries (USA, UK, Canada, Australia, etc.) accounted for about 70% [28]. In contrast, Chinese hobbyists participate more in visual analysis projects focused on new object discovery, such as the Fast Moving Object search project initiated by the University of Arizona' s Spacewatch team [29]. By the project' s end in 2005, Chinese hobbyists comprised about 20% of volunteers and discovered six near-Earth asteroids. The Hands-On Universe (HOU) program at the National Astronomical Observatories also organized students from Beijing and other cities in international asteroid search activities from around 2008–2010, discovering seven asteroids[1] . This suggests that language barriers are not the main factor hindering Chinese hobbyists' participation in international projects.

Volunteer computing only requires idle computing resources, making participation costs lower for volunteers. The first volunteer computing project in amateur astronomy was SETI@home for searching for extraterrestrial signals, which evolved into the Berkeley Open Infrastructure for Network Computing (BOINC) platform hosting many volunteer computing projects across different fields. In astronomy, SETI@home remains the most popular project, along with Einstein@home for searching for pulsar gravitational waves, MilkyWay@home for modeling the Milky Way, and Asteroid@home for analyzing asteroid shapes from light curves. Despite dedicated Chinese sites promoting BOINC (China Distributed Computing General Station[1]) and the Institute of High Energy Physics' CAS@home project specifically for Chinese scientist-led projects, BOINC statistics show that China' s contributions still lag significantly behind Europe, America, and even Japan (mainland China ranks 17th among 252 countries/regions in monthly average score, Taiwan ranks 16th), with lower average user contributions (ranking 187th). This again suggests that language barriers and policy orientation are not the main reasons for low participation.

Beyond the directions described above, some hobbyists have made contributions in other fields, such as Liang Zhuxing' s research on pulsar magnetic field oscillation models [30], Lin Jingming' s investigations into asteroid naming history[1] , and Pan Nai's research and writing on astronomical history[1] . However, amateur observations and data mining remain the main areas for citizen astronomers.

3. Motivations of Citizen Astronomers

What drives citizen astronomers to conduct their research? Price and Paxson and Raddick et al. analyzed the main motivations of European and American hobbyists participating in data mining projects [28][31][32], noting that interest in astronomy (or the research field), passion for scientific research, and appreciation of the universe' s grandeur are primary factors, while making friends, learning new knowledge, and having fun are relatively less important. However, surveys targeting Chinese citizen astronomers are still lacking. Therefore, we designed a questionnaire distributed to participants in the "Xingming Observatory Survey Group" on the social media platform QQ. The survey included participants' province/city, age group, gender, highest education level, occupation, whether they are professional astronomers, and primary motivations for participation. Motivation options included eight items selected based on Raddick et al.' s survey [28].

We collected 105 valid questionnaires. After excluding professional astronomers (including astronomy students), 97 valid questionnaires remained. Is this representative of China' s citizen astronomer community? Based on social media topic popularity and astronomy forum user numbers (e.g., Zhihu users following "astronomy" topics, Baidu "astronomy bar" users), users interested in astronomy topics number in the hundreds of thousands; daily active users (e.g., "Mufu" Astronomy Forum, "Tianzhiwen" Forum) and users in more targeted discussion areas number between 1,000-100,000. We estimate the domestic astronomy hobbyist population to be on the order of 10,000-100,000. Based on the ratio of astronomy hobbyists to citizen astronomers in North America [5], China' s citizen astronomer community should be about 10-100 people. Meanwhile, the ratio of professional to citizen astronomers in North America is about 10:1 [5]. Considering the Chinese Astronomical Society currently has about 2,000 members[2] , the number of citizen astronomers in China should be around 200. These numbers are consistent in order of magnitude, suggesting our survey effectively covers China' s citizen astronomer community.

Participant statistics and comparison with Galaxy Zoo results are shown in Figure 3 [Figure 3: see original paper] and Figure 4 [Figure 4: see original paper]. From the basic composition of participants, we observe:

1. **Occupational composition**: Students (including middle school, high school, and possibly some elementary school students, though the questionnaire did not differentiate) and young professionals in computer science, engineering, and education fields dominate. Students and professionals account for 90% of participants, far exceeding their proportions among Chinese internet users (25% and 5%, respectively)[21].

2. **Age composition**: 69% of participants are under 25, confirming the high proportion of students. This differs completely from Galaxy Zoo participants (concentrated in the 25-55 age range). The 15-24 age group also significantly exceeds the proportion of corresponding age groups among Chinese internet users, showing that China' s youth generation has high participation enthusiasm.

3. **Educational background**: Among student participants, high school students dominate. Among working participants, those with bachelor' s or associate degrees form the majority, though some have only high school education. Interestingly, no participants with graduate degrees were found, though there are graduate students (3% of the surveyed group). This may relate to the rapid improvement in education levels among China' s younger generation. This resembles Galaxy Zoo results in that graduated participants are predominantly highly educated, though Galaxy Zoo participants commonly have graduate degrees (54%).

Motivation composition shows that interest in astronomy (considered the most important motivation by 41% of respondents) is the primary driver, while teaching knowledge and helping others (12% of respondents) are the least important. Interest in astronomy is the main motivation for Chinese hobbyists participating in Xingming Observatory' s survey projects, with teaching knowledge and helping others being secondary motivations—similar to Galaxy Zoo results. However, our survey participants also considered learning knowledge, having fun, and making friends as key factors, differing from Galaxy Zoo participants.

Notably, although Chinese hobbyists are enthusiastic about discovering new objects with notable achievements, the survey shows that discovery is not the primary motivation for participating in Xingming Observatory surveys. Are these results contradictory? We believe this indicates that Chinese hobbyists' research interests are malleable and not limited to new object discovery. Recent Chinese discoveries have generated significant interest within the domestic astronomy community. New object searches are simple to start, have short cycles, and yield quick results, bringing enjoyment to hobbyists. The large number of participants has formed small communities that satisfy hobbyists' needs for "learning astronomical knowledge,""having fun,"and "making friends."Long-term monitoring and data analysis projects have longer cycles, higher participation thresholds, and are less able to meet hobbyists' needs, resulting in low participation. However, with appropriate guidance, hobbyists' participation in these projects could be improved.

Although language barriers are not the main factor hindering Chinese hobbyists' participation in international projects, they objectively increase the difficulty of communication with foreign hobbyists. Foreign hobbyists run peer-reviewed journals for citizen scientists to publish results and exchange ideas, but articles from China are rare (Table 3). These phenomena are related to hobbyists' personal interests but also reflect the lack of effective guidance and incentives in China, resulting in concentrated output in short, fast projects.

3.2 The Future of Chinese Citizen Astronomy

For observation-oriented citizen astronomers, the development of big data astronomy and time-domain astronomy is rapidly encroaching on their space. Discoveries of new objects like supernovae and comets have been largely monopolized by professional astronomers, with newly discovered objects becoming increasingly faint and difficult for amateurs to confirm. Next-generation rapid survey projects such as the Zwicky Transient Facility and LSST will further compress hobbyists' space. Additionally, as hobbyists collect increasing amounts of data, they themselves face big data processing challenges; for example, hobbyists searching for new objects often need to write or purchase commercial programs to process larger datasets. However, it should be noted that next-generation rapid survey projects are mostly located in the western hemisphere, while observing facilities in the eastern hemisphere remain relatively scarce. Chinese hobbyists' geographic advantages allow them to still complement professional astronomers to some extent. Therefore, for rapidly changing transient events (such as bright supernova events and comet outbursts), Chinese hobbyists still have great potential. Moreover, hobbyists have considerable development space in "niche" areas that professional astronomers rarely or difficultly cover, such as meteor observations, meteorite eyewitness and recovery, and planetary monitoring.

In big data processing and distributed computing, China has the world' s largest internet user population and high smartphone penetration, giving great potential for public participation in big data science. The Public Supernova Search Project jointly operated by the Chinese Virtual Observatory and Xingming Observatory, as well as the CAS@home project, are excellent attempts. China has built the Five-hundred-meter Aperture Spherical Telescope (FAST), joined the Square Kilometre Array, and is preparing to construct the 12-meter Large Field-of-View Optical-Infrared Telescope and other new optical survey facilities. These major scientific facilities will generate massive amounts of data. Big data processing and distributed computing can further mine these data and enhance their scientific output. Therefore, the completion of these major facilities should be seen as an opportunity for the development of citizen science in China.

Our survey found that young people occupy an enormous proportion of China' s astronomy hobbyist community, and Chinese hobbyists show great interest in "edutainment" -style learning. Although Chinese citizen astronomers' previous contributions have focused mainly on new object discovery, making new discoveries is not their primary motivation for participating in astronomy research. Therefore, their research interests are highly malleable. In this regard, experiences from Europe, America, and Japan are worth referencing:

- Provide journals dedicated to hobbyist publication of academic papers (or provide space or special issues in existing journals), introduce peer review, English abstracts, and other academic community conventions to guide hobbyists to systematize their work and encourage exchange between hobbyists in different regions and internationally.
- Encourage advanced hobbyists to establish regular communication mechanisms for serious discussion of common interests, and encourage interested and capable hobbyists to participate in professional academic conferences.
- Create opportunities for hobbyists to learn about new developments and technologies in research fields, such as automated data processing, machine learning, and big data management.

In summary, how to help China' s public and hobbyists recognize research directions beyond new discoveries and enhance their overall enthusiasm for scientific research is a question worth considering.

4. Conclusion

Chinese citizen astronomy has made great progress in the past one or two decades, with Chinese astronomy hobbyists achieving particularly notable results in searching for and discovering new objects. However, compared with Europe and America, Chinese citizen astronomy still has considerable gaps in breadth and depth, with singular public and hobbyist interests and relatively little interaction between professional scientists, hobbyists, and the public. As economic levels and education continue to improve, the Chinese public's interest in natural science is also increasing, and the astronomy hobbyist community is rapidly growing. Chinese citizen astronomy has vast potential. Realizing this potential will help promote the enhancement of China' s scientific research and education capabilities.

Acknowledgments: We thank Chen Donghua, Cui Chenzhou, Liang Zhuxing, Lin Jingming, and Zhang Xuejun for carefully reviewing this paper and providing valuable comments, and we thank members of the "Xingming Observatory Survey Group" for actively participating in our survey. This work is supported by the GROWTH project (National Science Foundation Grant No. 1545949).

References:

[1] Stebbins R A. Avocational science: the amateur routine in archaeology and

astronomy [J]. International Journal of Comparative Sociology, 1980, 21(1): 34-48.

[2] Cunningham C J, Orchiston W. The clash between William Herschel and the great German 'amateur' astronomer Johann Schroeter [M]// New Insights From Recent Studies in Historical Astronomy. 2005: 205-222.

[3] Orchiston W. Amateur-professional collaboration in Australian science: the earliest astronomical groups and societies [J]. Historical Records of Australian Science, 1998, 12 (2): 163-182.

[4] Williams T R. Getting organized: A history of amateur astronomy in the United States [C]// ASP Conference Proceedings. 2000.

[5] Gada A, Stern AH, Williams TR: What Motivates Amateur Astronomers? [C]//ASP Conference Proceedings. 2000.

[6] Marshall P J, Lintott C J, Fletcher L N. Ideas for Citizen Science in Astronomy [J]. Annual Review of Astronomy and Astrophysics, 2015, 53: 247-278.

[7] Colgate S A, Moore E P, Carlson R. A fully automated digitally controlled 30-inch telescope [J]. Publications of the Astronomical Society of the Pacific, 1975, 87: 565-575.

[8] Castro-Tirado A J. Robotic Autonomous Observatories: A Historical Perspective [J]. Advances in Astronomy, 2010, 2010: 1-8.

[9] 崔辰州，李建，蔡栩，等．程控自主天文台网络的发展【J】．天文学进展，2013，31（2）：141-159.

[10] Henze M, Pietsch W, Haberl F, et al. Supersoft X-rays reveal a classical nova in the M 31 globular cluster Bol 126 [J]. Astronomy & Astrophysics, 2013, 549, A120-A134.

[11] Ye Q Z, Hui M T, Brown P G, et al. When comets get old: a synthesis of comet and meteor observations of the low activity comet 209P/LINEAR [J]. Icarus, 2016, 264: 48-61.

[12] Tan H, Gao X. 2017 BM3 [J]. Minor Planet Electronic Circulars, 2017, 2017 (B51): 1.

[13] Pastorello A, Wang X F, Ciabattari F. Massive stars exploding in a He-rich circumstellar medium - IX. SN 2014av, and characterization of Type Ibn SNe [J]. Monthly Notices of the Royal Astronomical Society, 2016, 456(1): 853-869.

[14] Amorim A. Comet C/2011 W3 (Lovejoy) [C]// International Astronomical Union Circulars, 2011.

[15] Kleyna J T, Ye Q Z, Hui M T, et al. The progressive fragmentation of 332P/Ikeya-Murakami [J]. The Astrophysical Journal Letters, 2016, 827, L26-L32.

[16] Tichy M and others: 2008 TC3 [J]. Minor Planet Electronic Circulars, 2008, 2008 (T54): 1.

[17] Ye Q Z, Brown P G, Bell C, et al. Bangs and Meteors from the quiet comet 15P/Finlay [J]. The Astrophysical Journal, 2015, 814(1): 79-87.

[18] Samarasinha N H, Mueller B E A, Knight M M, et al. Results from the worldwide coma morphology campaign for comet ISON (C/2012 S1) [J]. Planetary and Space Science, 2015, 118: 127-138.

[19] Liu J D. Rotation period of 2019 van Albada [J]. The Minor Planet Bulletin, 2015, 42(4): 247.

[20] Liu J D. Rotation period analysis for 1967 Menzel [J]. The Minor Planet Bulletin, 2016, 43(1): 98-99.

[21] Liu J D. Rotation period analysis for 2729 Urumqi [J]. Minor Planet Bulletin, 2016, 43(3): 204.

[22] 冯占良，徐品新．宝瓶　流星雨目视观测结果的归算和分析 [J]. 天文学报，1990，31 (3)：245-251.

[23] SonotaCo. Meteor shower catalog based on video observations in 2007-2008 [J]. Journal of the International Meteor Organization, 2009, 37 (2): 55-62.

[24] Cheng S H, Cheng S M. Meteor spectral observation with DSLR, normal lens and prism [J]. Journal of the International Meteor Organization, 2011, 39(2): 39-46.

[25] Ogawa H, Toyomasu S, Ohnishi K, et al. The 2002 Leonids as monitored by the International Project for Radio Meteor Observations [J]. Journal of the International Meteor Organization, 2002, 30(6): 225-231.

[26] Zhang Yanxia, Zhao Yongheng. Astronomy in the big data era [J]. Data Science Journal, 2015, 14: 1-9.

[27] Westphal A J, Butterworth A L, Snead C J, et al. Stardust@home: a massively distributed public search for interstellar dust in the stardust interstellar dust collector [C]// 36th Annual Lunar and Planetary Science Conference. 2005.

[28] Raddick M J, Bracey G, Gay P L, et al. Galaxy Zoo: motivations of citizen scientists [J]. Astronomy Education Review, 2013, 12 (1): 1-27.

[29] McMillan R S, Block M, Descour A S, et al. The Spacewatch volunteer search for fast moving objects [J]. Minor Planet Bulletin, 2005, 32: 53.

[30] Liang Z X, Liang Y, Weisberg J M. Testing the rotating lighthouse model with the double pulsar system PSR J0737-3039A/B [J]. Monthly Notices of the Royal Astronomical Society, 2014, 439 (4): 3712-3718.

[31] Raddick M J, Bracey G, Gay P L, et al. Galaxy Zoo: exploring the motivations of citizen science volunteers [J]. Astronomy Education Review, 2013, 9 (1): 10103-10118.

[32] Price C A, Paxson K B. The AAVSO 2011 demographic and background survey [J]. Journal of the American Association of Variable Star Observers, 2012, 40: 1-22.

Footnotes:

[1] http://acpx.dc3.com/

[2] http://www.telescope.org/

[3] http://www.itelescope.net/

http://psp.china-vo.org/

For some stations, names could not be identified and are thus indicated by location in parentheses.

See Chen Donghua, "Guide to Asteroid Occultation Observations," *Astronomy Enthusiast* 2005 No. 4; Zhang Xuejun, "Coordinated Observation of Asteroid Occultation No. 10199," *Astronomy Enthusiast* 2015 No. 6.

http://www.theskylab.org/

http://www.theskylab.org/

http://tqw.lamost.org/zidong.htm

[1] Zhang Xuejun conducted such experiments during the 1998 Leonid meteor shower.

[11] See Sun Peiyuan, http://cometobserver.lamost.org/search/comet/sohorank.pdf

[12] https://skyview.gsfc.nasa.gov/skymorph/skymorph.html

[13] http://www.skaw.sk/discoverers-list-skymorph-archive.htm

[1] http://stardustathome.ssl.berkeley.edu/

[1] https://www.galaxyzoo.org/

[1] See Guo Hongfeng, "Frequent Good News from the Fourth International Asteroid Search Campaign," *China Science and Technology Education* 2010 No. 1.

[1] http://www.equn.com/

[1] Lin Jingming' s work on asteroid naming history.

[1] Pan Nai' s research and books on astronomical history, such as *History of Stellar Observations in China* (Xuelin Press).

[2] See *Science and Technology Review* 2011 No. 21.

[21] See China Internet Network Information Center, "39th Statistical Report on Internet Development in China,"http://www.cnnic.cn/hlwfzyj/hlwxzbg/hlwtjbg/201701/P020170123364672657

[22] In 2016, the ratio of articles published by Chinese hobbyists as first authors to total articles.

Biography: Quan-Zhi Ye (1988-), male, from Guangzhou, Guangdong, Ph.D. Main research directions include optical survey data processing, observations and dynamical studies of small Solar System bodies, and astronomical site selection.

Note: Figure translations are in progress. See original paper for figures.