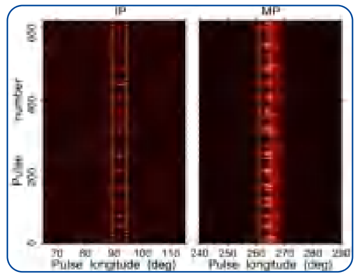
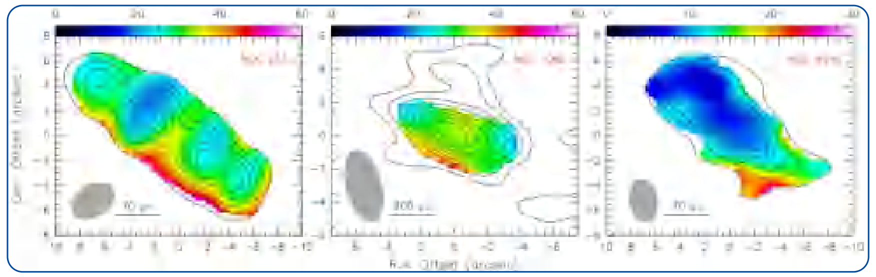
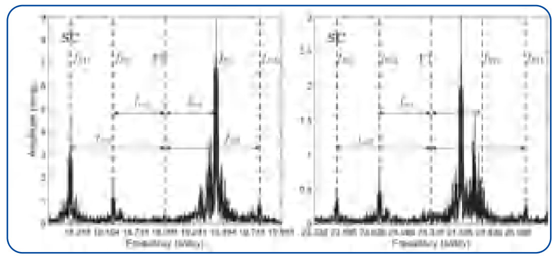
中国科学院新疆天文台

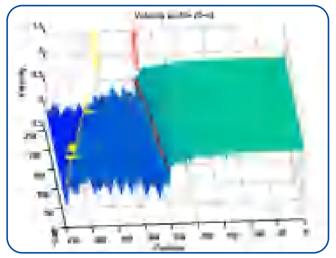
XINJIANG ASTRONOMICAL OBSERVATORY,CAS

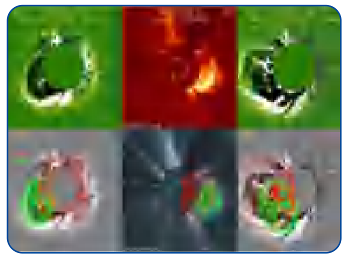
Xinjiang Astronomical Observatory
Chinese Academy of Sciences
Annual Report
2019











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LETTER FROM THE DIRECTOR

It is that time of the year again when we take a moment to evaluate our success over the past year and identify areas that require improvements.

From research perspective, we have gained support on the astrophysics, technological study, equipment development and infrastructure construction from the National Natural Science Foundation of China, the Chinese Academy of Sciences (CAS) and the government of Xinjiang Uygur Autonomous Region. Good progress has been made in a number of study fields. This includes the breakthrough in the research on the acceleration of solar-terrestrial space particles. Analysis via Monte Carlo Method has verified the pile-up effect of the twin shock, which leads to the "ankle-like" shape on the energy spectrum. This effect would be helpful to understand the subtle structure of the energy spectrum and the dispassion processes of the accelerated energetic particles. Research was also performed using the Parkes 64-m radio telescope for study of the radiation characteristics in PSR J1825−0935 to reveal the cyclical switching between the inter pulse and main pulse in association with the weak and strong conditions. Another investigation involves the three nearby starburst galaxies using the ALMA data, which revealed the carbon ratio within hundred parsecs from the center of the Galaxy. Furthermore, the quantity of publications and granted patents has increased under the efforts of our researchers and engineers.

This year we have made significant progress on upgrading the optical equipments and construction. We have completed the structure of the 50-cm diffraction limit telescope, and are actively improving the cooperation between XAO and Beijing Normal University for the construction of the 1.93-m telescope at the Muztagh site of XAO. In addition, we are glad to see the road to the site was constructed. At the Nanshan station, we have started the development of the astronomical spectrometer for the 1.2-m quantum communication telescope. Cooperation have been achieved in projects for filling the gap of satellite laser ranging observation in western part of China. We expect that the construction of the above optical equipments will become one of our powerful science standpoints based on which the window to explore the far-reaching universe will be opened thus expanding our astronomical disciplines with more fruitful results.

The promotion of the QTT program as a big science project leads to the growth of science, engineering technology and management teams. Over the past few years, research has been performed in relation to the program with fruitful results. This includes publications in world-renowned scientific journals with high citation rates, and copyright registration for a number of software and patents granted for innovation, as well as cultivating and training young and middle aged academic team leaders and core technicians. The latter has led to the formation of a radio astronomy innovation team that combines science programs, talents and research. At the same time, we have successfully completed the National Program on Key Basic Research Project (973 Program) for the Key Technologies for 110-m Aperture Fully Steerable Radio Telescope. These raise our confidence for the telescope construction. To maintain such achievements, it is necessary to create an ecological environment that is favorable to scientific and technological innovation, and attractive to distinguished scientific researchers who are willing to devote themselves to the scientific research. We also work on establishments of excellent engineering teams with 'craftsman spirit', and enhancing the management ability of the project managers for building professional teams.

We will further strengthen the building of the education management team, with better optimisation on the relevant systems, and increase the enrollment rate of international students. Our goals are to improve the development of cooperative research and study platform, and enhance student exchange and joint training with universities and institutes at home and abroad.

We encourage the bilateral and multilateral scientific exchange to expand our research areas and to develop our research teams. In conformity with the goal of "Innovation 2020" of CAS: "Transform CAS into an organization defined by democratization, openness and reliance on talent", we will broadly expand the international role of XAO in the development of technological and scientific novelties as well as increasing the original innovation outputs. Focus will be put on enriching communication and collaboration in order to attract researchers and engineers from all over China and across the world to join XAO. Building on our excellent achievements from the past years, we look forward to even greater success in the future and remain enthusiastic upon facing the challenges in 2020 to make a better XAO.

Xinjiang Astronomical Observatory
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MANAGEMENT AND ADMINISTRATION

Management

WANG Na
- Director of XAO, CAS
- Deputy Director of NAOC, CAS
- Research field: Radio astronomy, pulsars, technology of large aperture radio telescope

FENG Tao
- Deputy Director of XAO, CAS

CHEN Maozheng
- Deputy Director of XAO, CAS
- Research field: Radio astronomical methods, microwave cryogenic receiver, digital backend

Jarken ESIMBEK
- Deputy Director of XAO, CAS
- Research field: Radio astronomy, star formation and evolution

MA Lu
- Secretary of Commission for Discipline Inspection of XAO, CAS
- Research field: Space objects and debris

Research

ZHOU Xia
Head of Radio Astronomy Research Division
Research field:Neutron stars and pulsars

LIU Jinzhong
Head of Optical Astronomy Research Division
Research field: Gravitational wave, binary star and population evolution

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Head of Astronomical Application Research Division
Research field: Pulsar timing

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Head of Computer Application Research Division
Research field: Intensive computing and data research

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Head of Solar Physics Research Division
Research field: Multi-wave observation for solar activities

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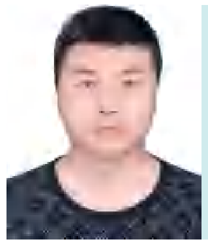
Research field: Time domain optical astronomy,optical technology

LI Rui
Head of Qitai station



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Head of Kashi station
Research field: Pulsar timing

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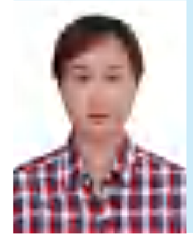
WANG Shi
Chief of General Administration



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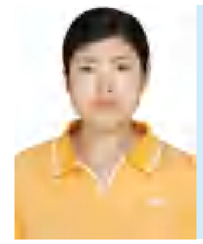
SONG Huagang
Chief of Popular Science Center

LI Gangling
Deputy Chief of Support and Service

WANG Weiping
Deputy Chief of General Administration



ZHU Cui
Deputy Chief of Science and Technology Management

LIU Aixia
Head of Student Office

RESEARCH HIGHLIGHTS

Research Progress in the Energy Dissipation of Solar Wind Burst and Particles Acceleration of the Diffusive Shock

Wang, X.; Giacalone, J.; Yan, Y.; Ding, M.; Li, C.; Lu, H.; Shan, H.

The Astrophysical Journal, 2019, Volume 885, Issue 1, 66.

Solar Eruption is the origin of the Solar Energetic Particles, and it is also the basic impact factor of the solar-terrestrial environment and the space weather. Coronal Mass Ejections (CME) driven-shock is considered to be the important site for particles acceleration in the interplanetary space, making the CME driven-shock the vital technique for researching the solar energetic particles acceleration and energy transportation.

Dr. WANG Xin, who serves as an Associate Researcher in Xinjiang Astronomical Observatory (XAO), and his coauthors proposed twin shock model which based on the observations of the twin CME. By applying the dynamical Monte Carlo method to simulate the processes of the pileup collisions of the twin shock, the researchers found that the proton energy spectrum shows an "ankle-like" property, when the posterior shock catches up to the preceding shock. The "ankle-like" point is located at the energy about 2.0 MeV. At the energy range below 2.0 MeV, the energy spectrum shows a soft slope; but at the energy range above 2.0 MeV,the energy spectrum becomes a hard slope inversely. The researchers consider that the formation of the "ankle-like" structure would have been contributed by such processes. The particles spad by the preceding shock will receive the re-acceleration by the posterior shock, and the subsequent shock should have more effect on the higher energy particles, which have accelerated by the proceeding shock. So the energy spectrum becomes an "ankle-like" shape when the energetic particles undergo the posterior shock re-acceleration.

This research has verified the pileup effect of the twin shock, which lead to the "ankle-like" shape on the energy spectrum, via the Monte Carlo Method. This effect would be helpful to understand the subtle structure of the energy spectrum and the dispassion processes of the accelerated energetic particles. This result would also provide a new understanding for the puzzle of the energy spectral "ankle" on the cosmic ray spectrum.

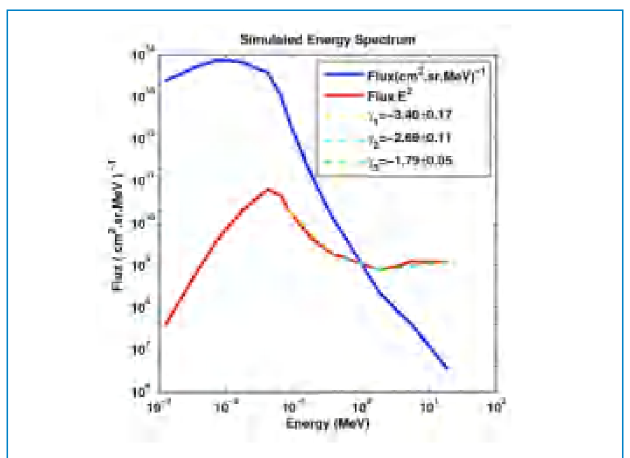


Figure 1. The simulated energy spectrum of the particles. The red curve shows a "ankle-like" point at the energy about 2.0 MeV. At the energy range below the 2.0 MeV, the energy spectral index is $\gamma2$ = -2.69±0.11; at the energy range above the 2.0 MeV, the energy spectral index is $\gamma3$ = -1.79±0.05.

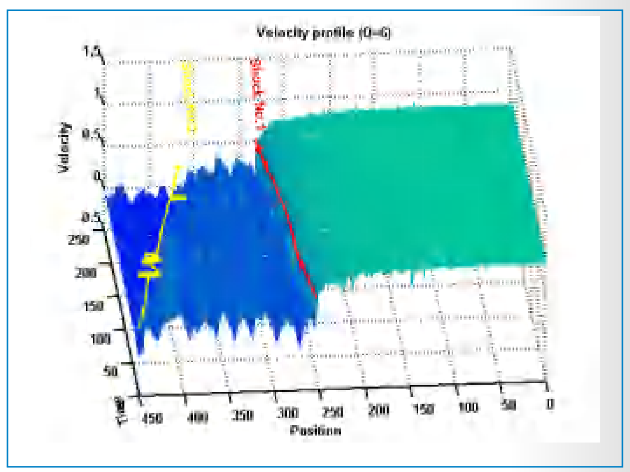


Figure 2. The simulated twin shock pileup collision processes. The red line represents the CME1-driven shock; the yellow line represents the CME2-driven shock.

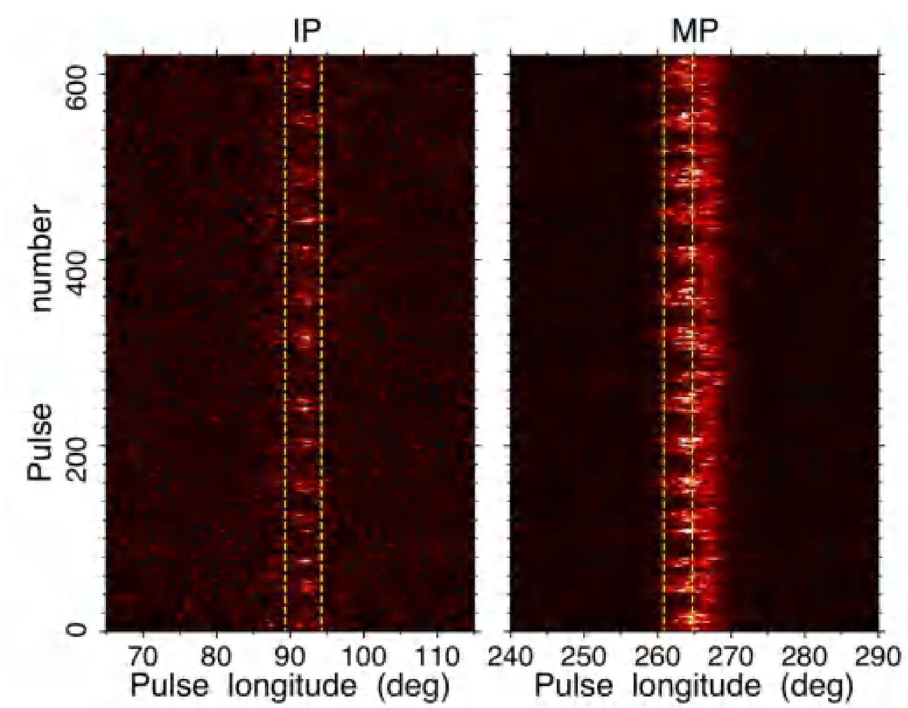
Periodic Q-mode modulation in PSR J1825−0935

Yan, W. M.; Manchester, R. N.; Wang, N.; Yuan, J. P.; Wen, Z. G.; Lee, K. J.

Monthly Notices of the Royal Astronomical Society, 2019, Volume 485, Issue 3, 3241

PSR J1825−0935 (PSR B1822−09) is a well-known young pulsar which shows interpulse (IP) emission. The mean pulse profile of PSR J1825−0935 consists of three main components: a strong and sharp main pulse (MP), a precursor (PC) preceding the MP by about 14.°5 of pulse phase, and a relatively weak IP leading the PC by about 159°. The most remarkable feature of PSR J1825−0935 is the peculiar and significant anticorrelation between the intensity of the IP and the PC. The IP is visible when the PC is weak or absent (i. e. in the Q-mode); on the other hand, the IP becomes very weak or undetectable when the PC is present (i. e. in the B-mode). Another curious property of PSR J1825−0935 is the periodic modulation in the Q-mode. Recently, researchers from the XAO pulsar group reported on high-sensitivity single-pulse observations of PSR J1825−0935 that were made using the Parkes 64-m radio telescope.

The researchers find that the periodic Q-mode modulation is in fact a periodic longitude- stationary intensity modulation occurring in the interpulse and the main pulse. The fluctuation spectral analysis showed that the modulation period is about 43P1, where P1 is the rotation period of the pulsar. Furthermore, they confirm that the modulation patterns in the interpulse and the main pulse are phase-locked. Specifically, the intensities of the interpulse and the immediately following main pulse are more highly correlated than for the main pulse and interpulse at any other lag. Polarization properties of the strong and weak Q-mode states are different, even for the trailing part of the main pulse which does not show the periodic intensity modulation.



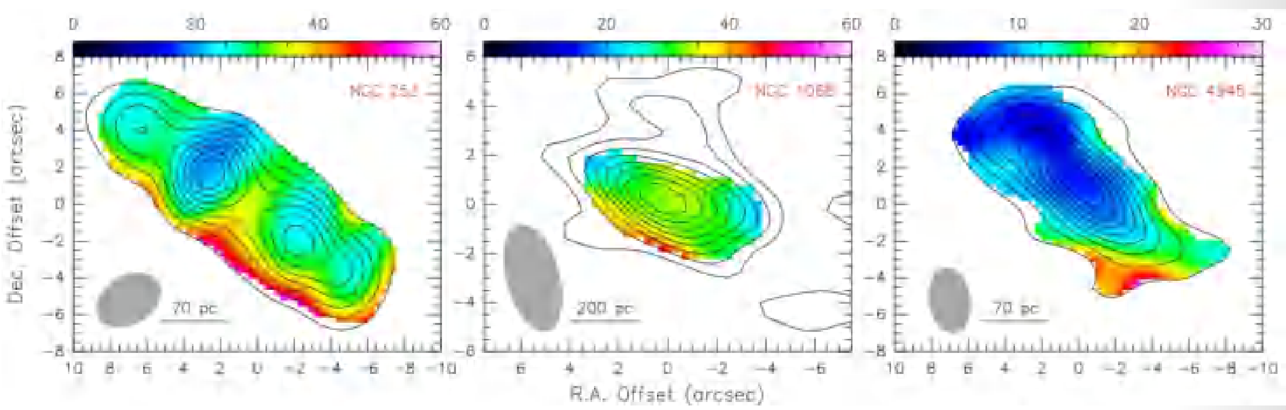
A Q-mode single-pulse stack showing clearly the periodic modulation. The left- and right-hand panels show, respectively, the longitude range around the IP and the MP.

Carbon isotopic ratio 12C/13C in starburst galaxies

Tang, X. D.; Henkel, C.; Menten, K. M.; Gong, Y.; Martin, S. et al.

Astronomy and Astrophysics, 2019, Volume 629, A6.

Even though interstellar carbon isotope ratios are locally understood, in extragalactic space beyond the Magellanic Clouds they are almost unexplored. We lack information on objects outside the Local Group of galaxies t racing environments that drastically differ from those in the Milky Way and the Large Magellanic Cloud. We do not know whether our Galaxy is typical for its class of objects or whether its isotopic properties are exceptional. What would the latter imply? Moreover, will we see strong variations in isotopic ratios when observing nearby galaxies with high angular resolution? Prof. Xindi Tang and his collaborators have used the ALMA telescope to reveal carbon isotope ratio in three nearby starburst galaxies. They derived 12C/13C isotope ratios for the central few hundred parsecs of the three nearby starburst galaxies NGC 253, ± 0.3 in NGC 4945.NGC 1068, and NGC 4945 making use of the 3 mm 12CN and 13CN N=1–0 lines in the ALMA Band 3. The 12C/13C isotopic ratios derived from the ratios of these lines range from 30 to 67 with an average of 41.6 ± 0.2 in NGC 253,from 24 to 62 with an average of 38.3 ± 0.4 in NGC 1068, and from 6 to 44 with an average of 16.9 They found the highest 12C/13C isotopic ratios are determined in some of the outskirts of the nuclear regions of the three starburst galaxies. The lowest ratios are associated with the northeastern and southwestern molecular peaks of NGC 253, the northeastern and southwestern edge of the mapped region in NGC 1068, and the very center of NGC 4945. In the case of NGC 1068, the measured ratios suggest inflow from the outer part of NGC 1068 into the circumnuclear disk through both the halo and the bar. Low 12C/13C isotopic ratios in the central regions of these starburst galaxies indicate the presence of highly processed material. These results agree with the scenario of 12C/13C ratios slowly decreasing in galaxies with time.



Velocity-integrated intensity ratio maps of I(12 CN)/I(13 CN) in NGC 253 (left), NGC 1068 (middle), and NGC 4945 (right). Black contours delineate levels of 13 CN integrated intensity.

Research progress of the light variations in high-amplitude delta Scuti star

Yang, T. Z.; Esamdin, A.

The Astrophysical Journal, 2019, Volume 879, Issue 1, 59

Based on high precision time-series data from Kepler Space Telescope, researchers from Optical Group of Xinjiang Astronomial Observatory reported a double-modulation effect in a double-mode high-amplitude delta Scuti (HADS) star.

HADS stars are typical late-A or early-F pulsators, located in the intersection of the main sequence and the classical instability. Their oscillation periods are between 1 and 6 h, and the peak-to-peak amplitudes are usually larger than 0.3 mag. Their pulsation modes are relatively simple, generally showing mono- or double radial modes.

The researchers presented an in-depth frequency analysis for short cadence data of HADS star KIC 10284901 delivered from Kepler Space Telescope,based on the fact that the first two are the main frequencies: F0 = 18.994054(1) cycle/day，F1 = 24.335804(4) cycle/day, the other two independent frequency fm1 = 0.4407 cycle/day and fm2 = 0.8125 cycle/day are detected for the first time. In addition, a double- modulation of fm1 and fm2 to F0 and F1 modes (quintuplet structures centered on F0 and F1) are detected, as shown in the figure. This is the first detection of a double- modulation effect in a double-mode HADS star. They discussed the origin of this modulation, and pointed out the most possible cause of the modulation effect in the light curve is similar to that in Blazhko RR Lyare stars.

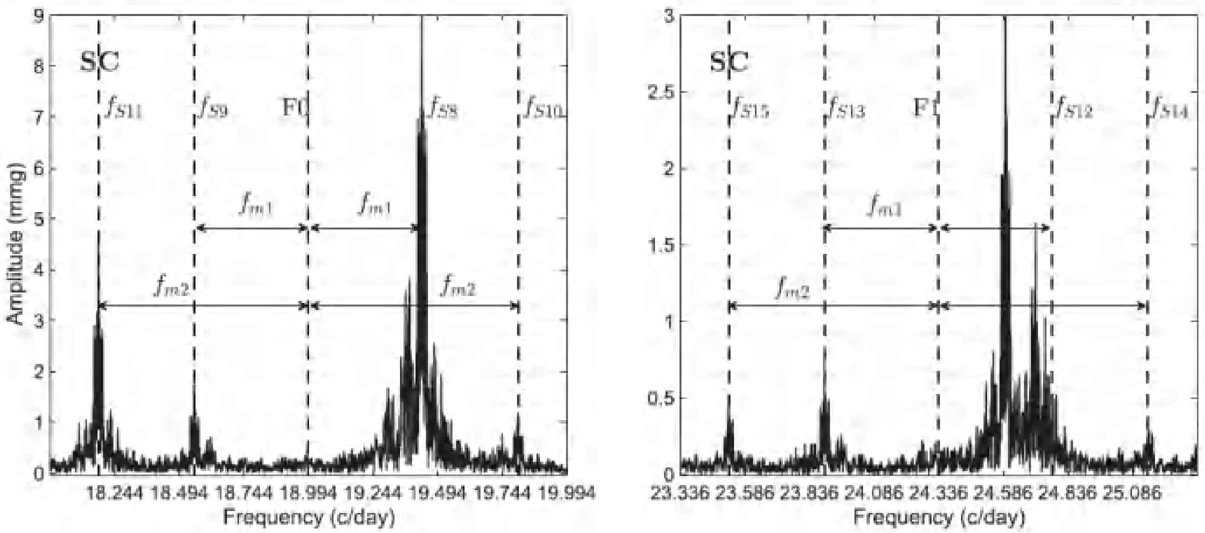


Figure: Amplitude spectra of modulation frequencies fm1 and fm2 to main frequencies F0 and F1. The central dashed lines indicate the locations of the main frequencies of KIC 10284901. The space of the quintuplet structure spectra lines are indicated with fm1 and fm2.

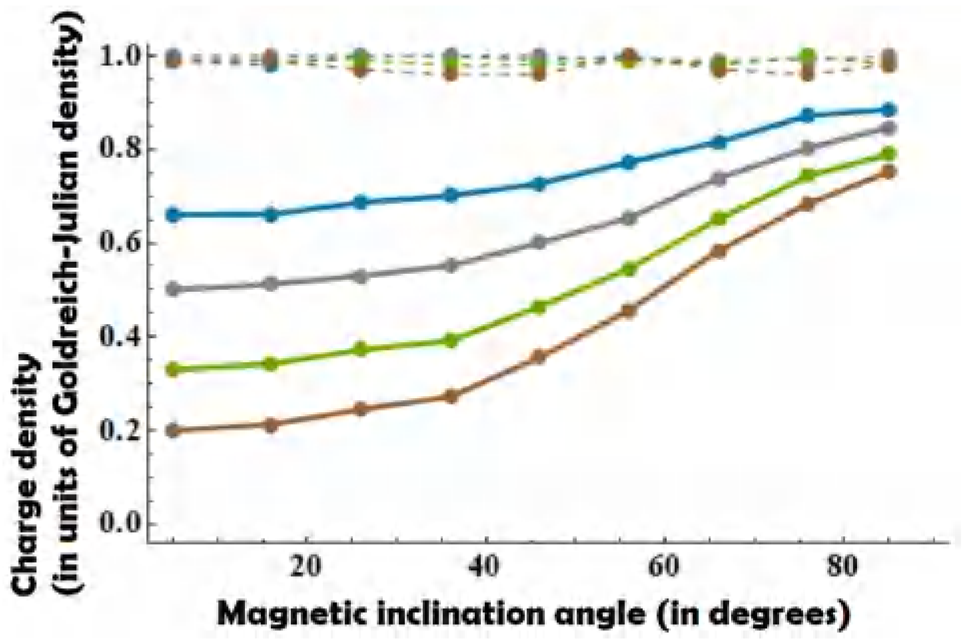
Changes in spin-down rate and intermittent pulsars

Yuen, R.

Monthly Notices of the Royal Astronomical Society, 2019, Volume 484, Issue 1, 1359

The growing number of pulsars with observed switching in emission properties suggests that sudden changes of some kind in pulsar magnetospheres are common. In this project, we investigate properties of the emission on and off states in intermittent pulsars by modeling of the changes in spin-down rate between the two states as due to discrete changes of the spin-down torque in a magnetosphere of multiple states. In this model, each of the different spin-down rates corresponds to a magnetospheric state, designated by the parameter y, and a change in the spin-down rate corresponds to a jump in the y value resulting in an abrupt change in the spin-down ratio. We obtain trends of change in y in the off state as a function of the spin-down ratio with and without presuming y in the on state and find that the magnetosphere is non-vacuum in the emission off state as opposed to traditionally assumed (see figure).

We investigate the charge density, as indicated by y, in each emission state as a function of the magnetic inclination angle for different spin-down ratio. We investigate the charge density, as indicated by y, in each emission state as a function of the magnetic inclination angle for different spin-down ratio. While the charge density is mostly constant in the emission on state, it changes as a function of the magnetic inclination angle in the emission off state suggesting that more distinguishing features for intermittency are likely found in this state of an intermittent pulsar with small magnetic inclination angle. We show that there exists unique y in the off state for spin-down ratio up to six implying that pulsars with large spin-down ratio are possible. Assuming a simple correlation between the magnetic inclination angle and spin-down ratio, we estimate that changes in the latter as a pulsar ages should be detectable.



Variations in the charge density as a function of the magnetic inclination angle between 5 and 85 degrees. Here, the charge density is expressed in units of the Goldreich-Julian density for the emission on (dotted lines) and off (solid lines) states, respectively. Lines of same colour correspond to constant the spin-down ratio at 1.5 (blue), 2 (grey), 3 (green), and 5 (brown).

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Research Bites

Variations in pulsar subpulse drift rate
Yuen, R

A simple model is constructed for variations in subpulse drift rate for obliquely rotating pulsars that exhibits multiple subpulse drift modes. In this model, drift rate for a magnetospheric state is determined by the relative motion between the flow rate of the plasma in that state and corotation along the trajectory of the visible point. Drift mode switching then corresponds to an abrupt change in the magnetospheric state that leads to a change in the plasma flow resulting in a change in the observed drift rate. (Monthly Notices of the Royal Astronomical Society, 2019, Vol. 486, Issue 2, 2011-2019)

Research progress of the formaldehyde absorption line in Molecular Clouds
Komesh, T.; Esimbek, J.; Baan, W. A.; Zhou, J. J.; Li, D. et al.
Since H2CO is only seen in absorption against a background continuum, it only samples the physical conditions in the foreground of the HII region, while other millimeter and submillimeter spectral lines are observed both in front and behind the source. We determined the excitation temperature of the H2CO absorption in the molecular cloud. He proved that the sensitive mapping of H2CO absorption has been able to correctly identify star formation activity in complex molecular clouds such as the Aquila Complex. In addition, the detailed structure of the absorption lines may reveal discrepant velocity components resulting from outflow regions.(The Astrophysical Journal, 2019, Vol. 874, 172)

Molecular environs and triggered star formation around the large Galactic infrared bubble N 24
Li, X.; Esimbek, J.; Zhou, J. J.; Baan, W. A.; Ji, W. et al.

As a result of the feedback from massive stars, the infrared dust bubble is an important stage of star formation and evolution. By using the NH3(1,1) and (2,2) data observed from the NanShan 26-m Radio Telescope (NSRT), and combined with infrared and GRS13CO(1-0) data, various studies on the investigation of dust emission and gas emission properties in this region as well as the surrounding young stars. The studies show that the twenty-three dense clumps are identified in the shell of N24, all of which meet the conditions for the formation of massive stars. The SED fitting results of the 11 identified YSOs indicate that 9 of these have a mass above 8 $M_\odot$. The analysis suggests that the collect-and-collapse mechanism is in play at the boundary of the bubble, but the radiation-driven implosion mechanism may also play a significant role there.(Monthly Notices of the Royal Astronomical Society, 2019, Vol. 487, 1517-1528)

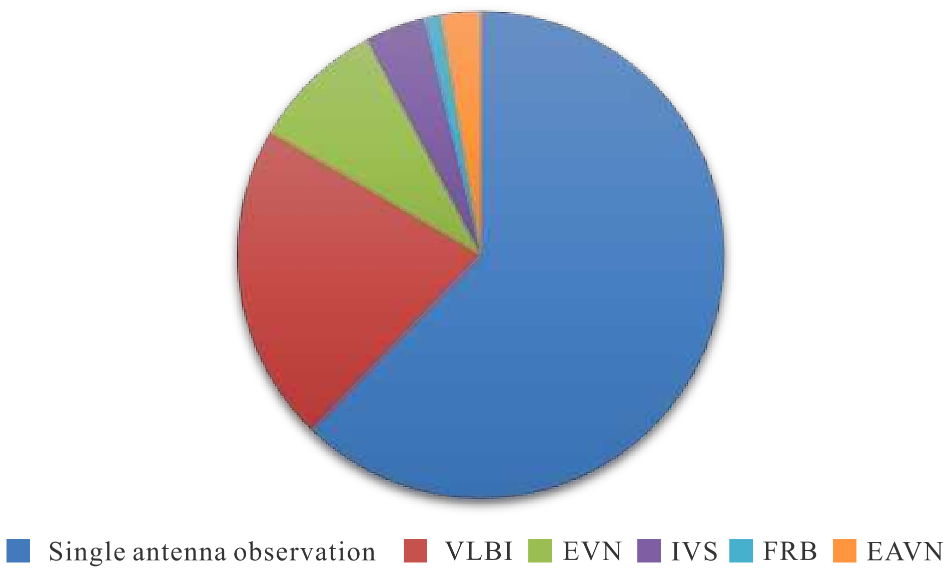
Effects of infall and outflow on massive star-forming regions
Li, Q.; Zhou, J. J.; Esimbek, J.; He, Y.; Baan, W. A.

Infall motions and Outflows are closely associated with the process of star formation. We identified 188 high-mass outflows from 694 massive star forming clumps, with the detection rate of approximately 27%. The detection rate of outflows increases from the proto-stellar stage to the HII stage, but decreases again at the photo dissociation (PDR) stage, they are probably being switched off during the PDR stage. The presence of masers is strongly correlated with outflow, water masers appear together with 6.7 GHz methanol masers. Outflow action has some influence on the local environment and the clump itself, and this influence decreases with increasing evolutionary time as the outflow action ceases. (Monthly Notices of the Royal Astronomical Society, 2019, Vol. 488, 4638-4647)

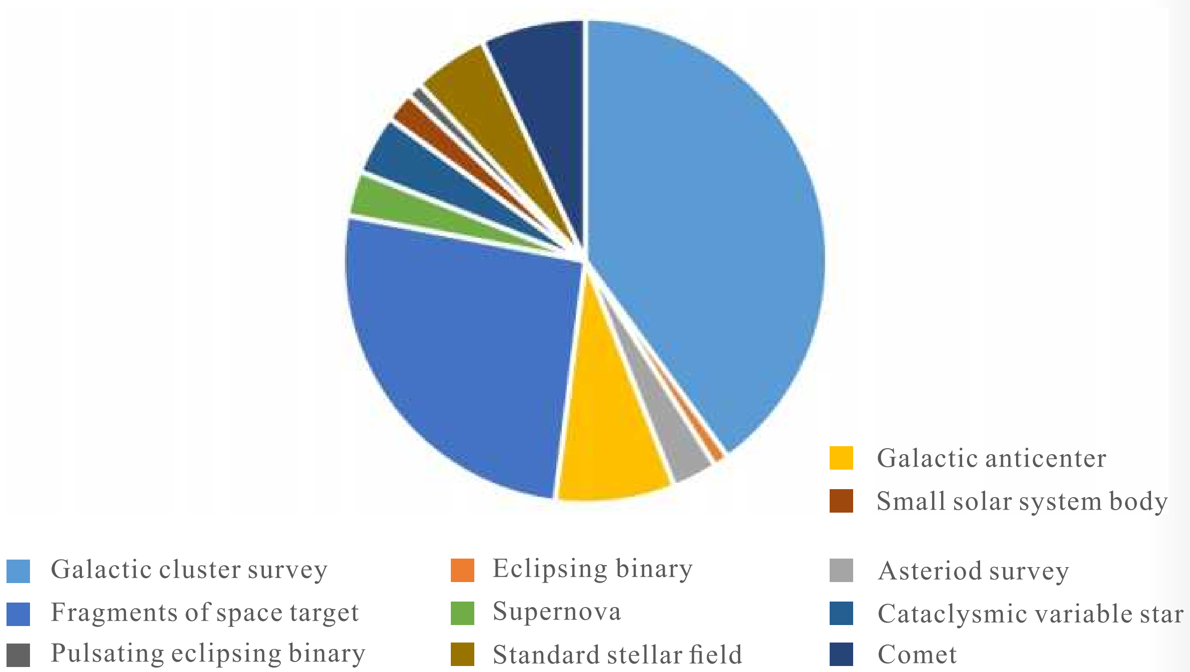
RESEARCH DYNAMICS

Observation Statistics

NanShan 26-m Radio Telescope (NSRT)



Nanshan One-meter Wide field Telescope (NOWT)



The Small Telescope Array

In 2019, the Nanshan station of Xinjiang Astronomical Observatory established a small telescope array for Peking University, Tsinghua University and Beijing Normal University. Including in the array are the All Sky Automated Survey for Supernovae (ASAS-SN) from Peking University, Supernovae observation telescope from Tsinghua University and the 50-cm wide-field survey telescope from the Beijing Normal University.

As a long-range observation platform, the telescope array offers full advantage for observation platform operation, and further strengthens the communication and cooperation between the XAO and universities in China, which will assist the development of astronomy education and scientific research in the universities.

The Small Telescope Array at Xinjiang Astronomical Observatory

The 50-cm high resolution telescope at the Muztagata site

In July 2019, Beijing Normal University cooperated with the National Astronomical Observatory of Chinese Academy of Sciences, Changchun Institute of Optics, Fine Mechanics and Physics, and the Xinjiang Astronomical Observatory for the establishment of the 50-cm high resolution telescope at the Muztagh site of Xinjiang Astronomical Observatory for the astronomical observation and site quality assessment.

After completed the installation and testing, the telescope has been put into operation for research astronomical observation and continuously providing observation data.

The 50-cm high resolution telescope from Beijing Normal University is now located at the Muztagata site

Inception for Building a 1.93-m Optical Telescope at Muztaghata

A construction project for a 1.93-m optical telescope has been initiated under the cooperation of Peking University, Nanjing Institute of Astronomical Optics & Technology, Xinjiang University and Xinjiang Astronomical Observatory (XAO). The telescope will be built at the Muztaghata site, which is located at an altitude of 4526m, with plans to house a photometry backend and a spectrum backend, and it will be used for astronomical observation and education. In July 2019, the "Inception Workshop on the Muztaghata 1.93-m Optical Telescope" was held in Artux city, Kizilsu Kirghiz Autonomous Prefecture in Xinjiang. More than 69 participants from over 22 institutes and governmental units attended the Workshop. An agreement on the cooperation and coordination of the 1.93-m optical telescope construction project at muztaghata site was signed by the leaders from Peking University, Chinese Academy of Sciences, Nanjing Institute of Astronomical Optics &Technology and Xinjiang Astronomical Observatory (XAO).

Group Photo of the Inception Workshop

The NanShan Radio Telescope-2

The NanShan Radio Telescope-2 (NSRT-2) is a 25-m radio telescope, which is located in a town in the southwest suburb of Urumqi called Nanshan. Completed in 2018, NSRT-2 is the second radio telescope in Nanshan situated almost 1500 meters away from the 26-m radio telescope, NSRT-1. The telescope is a single paraboloid reflector antenna with a primary reflector that rotates from 25º to 155º in elevation and fixed azimuth.

The NSRT-2 is equipped with an L-band uncooled receiver (18 cm) as the primary focus and operates at frequencies from 1.1 to 2.9 GHz. The main function of the telescope is to perform single dish observations, such as fast radio burst (FRB) searching and technology experiments.

The NanShan Radio Telescope-2 in Stow

STEERABLE 110-M APERTURE RADIO TELESCOPE

QTT - A Progress Update

Under the support of Chinese Academy of Sciences (CAS) and Xinjiang Uygur Autonomous Region, the preliminary works has promoted orderly and we strive to be prepared for the officially startup of the project.

A. Antenna structure and measurement system

1. The specification of QTT allows the operation of the telescope under main focus mode or Gregory focus mode. This means that a dedicated feed switching mechanism is required. A new type of feed switching mechanism has been designed which uses gravity and motors as driving forces to pull the main focus platform to rotate on hinges. This mechanism can achieve smooth and controllable switching process under short time using two low-power motors. Under the two feeding working modes, it does not cause any additional obstruction to the optical path between the main reflector and the sub-reflector.

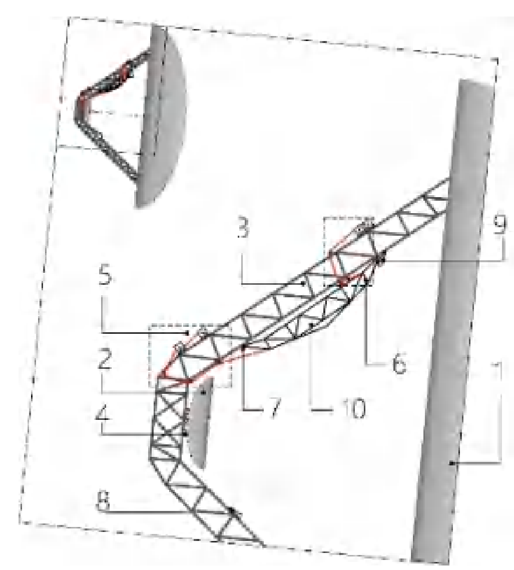


Figure 1. Design of QTT feed switching mechanism

2. With the increase in both the diameter of the dual-reflector antenna and the operating frequency band, the requirements for the antenna have also raised in order to achieve the accuracy of the sub-reflector. Consider the situation in which the antenna is affected by its own weight and other external factors such as wind load and temperature. To better ensure the antenna meets the requirements of high electrical performance, such as high pointing accuracy, based on the strain sensor and modal superposition principle, we use the strain values of the supporting legs and the sub-reflector's own structure separately to quickly reconstruct the posture and topography of the sub-reflector. This process facilitates real-time correction for the sub-reflector adjustment mechanism so that a more accurate position matching of the main and sub-reflector surfaces can be achieved. It also reduces beam pointing errors and gain losses due to deformation of the antenna structure.

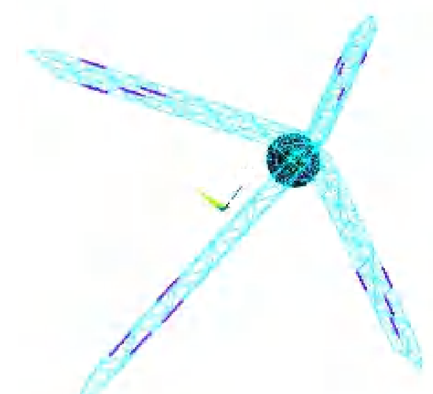


Figure 2. Schematic diagram of strain sensor distribution on supporting legs

3. A critical issue for radio telescope antenna structure design and observation relates to the wind field. As the telescope performance requirements are getting higher and higher, the antenna structure design becomes more

and more complex. The influence of wind load on antenna pointing accuracy in the observation is also significant. Hence, accurate wind field data are needed to ensure that the telecope structure is designed with sufficient stiffness and strength and that the effective observation time is improved during observations. As the traditional setup method for wind tower cannot provide quantitative evaluation on the reliability of the setting point position, we propose another method which based on numerical simulation to optimize the position of the wind tower. The boundary conditions for numerical simulation are determined based on specification parameters, whose overall trend is consistent with the measured data, and therefore the simulation accuracy can meet the requirement.

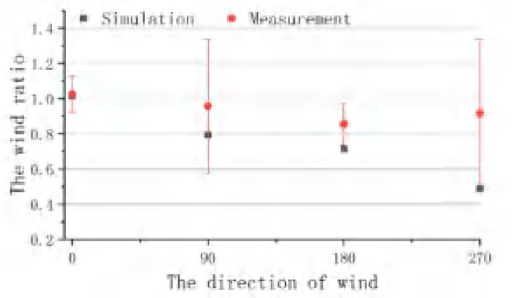


Figure 3. The wind ratio of simulation and measurement

B. Siginal receiving & processing system

1. The completion on the design of 0.27-1.8 GHz ultra wideband feed. The feed is built using carbon fiber material and based on QTT optical path. Other specifications include the voltage standing wave ratio is less than 2, port isolation is greater than 30 dB and aperture efficiency is greater than 65%. Furthermore, the aperture of this feed is 1400 mm and weight at 60 kg. The next step is to carry out performance test on the feed and cryogenic receiver prototype development.

Figure 4. 0.27-1.8 GHz feed design and physical figure

2. The design of the 96 elements for the phased array feed receivers operating at 0.7-1.8 GHz is completed. At present, the front-end design of low-temperature refrigeration system is being carried out.

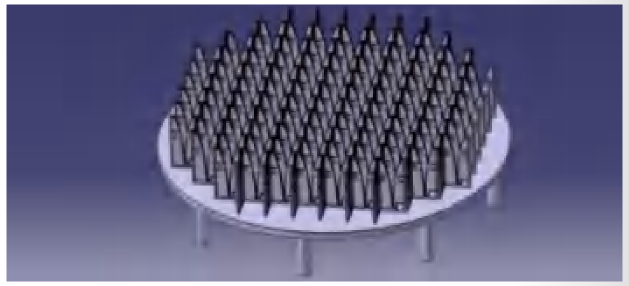


Figure 5. 0.27-1.8 GHz PAF design

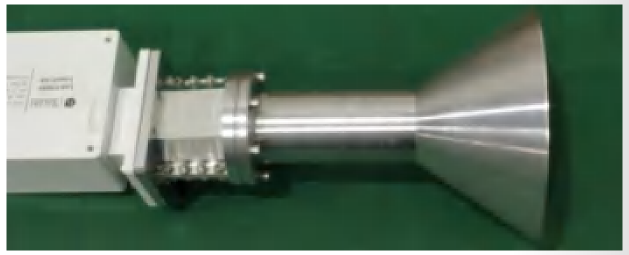


Figure 6. The physical figure of 7-8 GHz horn feed

3. The simulation design and processing of 7 mm ultra wideband OMT and shaped corrugated horn feed are completed, and the later stage is ready for testing. A 7 mm OMT and a shaped corrugated horn feed are designed by simulation. The working frequency is 30-50 GHz. The simulation results of the OMT are as follows: the standing wave is less than -20 dB, and the orthogonal isolation degree is less than -47 dB. The simulation results for shaped corrugated horn feed are (i) main lobe gain 20-23 dB, (ii) main lobe 3 dB bandwidth 11.6-19.7 degrees and (iii) side lobe < -30 dB; cross polarization <-20 dB.

Figure 7. 7 mm OMT model and physical processing diagram

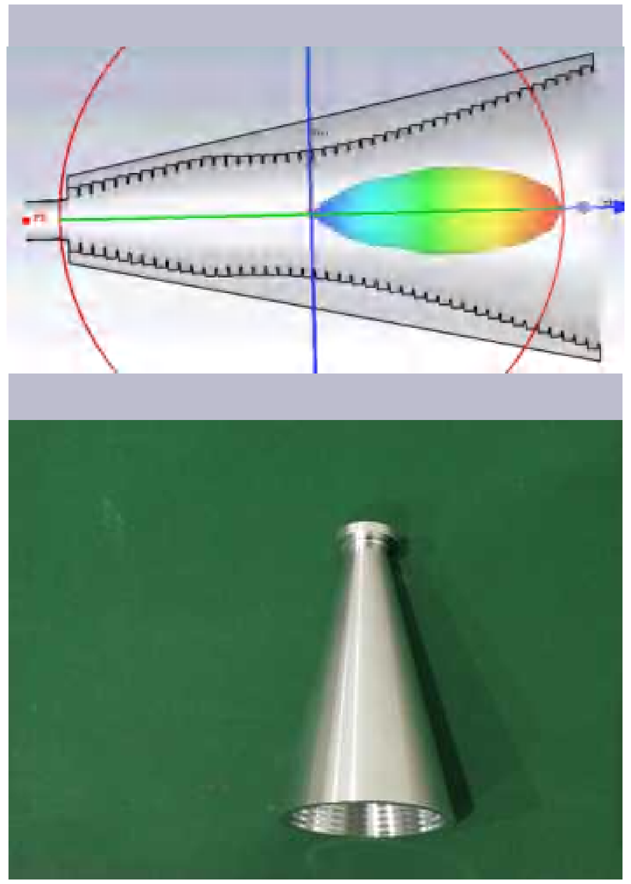


Figure 8. 7 mm shaped corrugated horn feed model and physical processing diagram

4. The simulation design of 0.6-4 GHz UWB MMIC LNA is completed. Two kinds of MMIC low noise amplifiers with circuit structure are designed. The working frequency is 0.6-4 GHz. The simulation results has reached or are close to the low noise amplifier index defined by the low noise factory company.

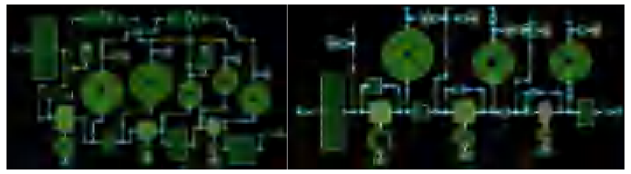


Figure 9. Layout of the minimum and Feedback structure low noise amplifier

5. We have completed the development of the broadband C-band cryogenic receiver, and is now in the stage of laboratory test. The receiver is ready for the installation, commissioning and testing on the Nanshan 25 m antenna next year.

Figure 10 .C-band cryogenic receiver

6. High-performance processing platform has been deployed to investigate the computational requirements for QTT signal processing. The platform carries 2 CPUs (Xeon(R) E5-2678 v3) and 4 GPUs (RTX 2080 Ti, support up to 8 GPUs), with 256GB DDR4 2660M memory and 2x2TB PCIe SDD cards. A variety of astronomical signal processing algorithms have been installed and tested on this platform, including pulsar de-dispersion, pulsar search, FRB search, high-resolution spectra-line and high-speed raw data storage. A photo of this platform shows in Figure 11.

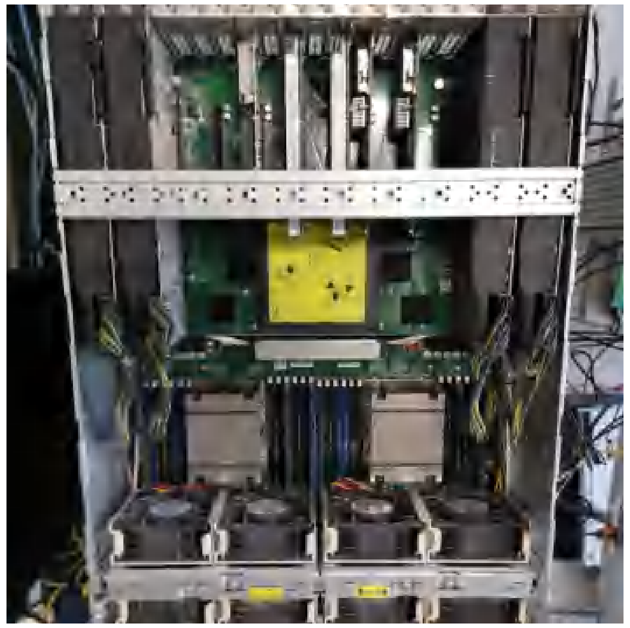


Figure 11. A photo of high-performance processing platform

7. We have completed the development of the broadband C-band cryogenic receiver, and is now in the stage of laboratory test. The receiver is ready for the installation, commissioning and testing on the Nanshan 25 m antenna next year.

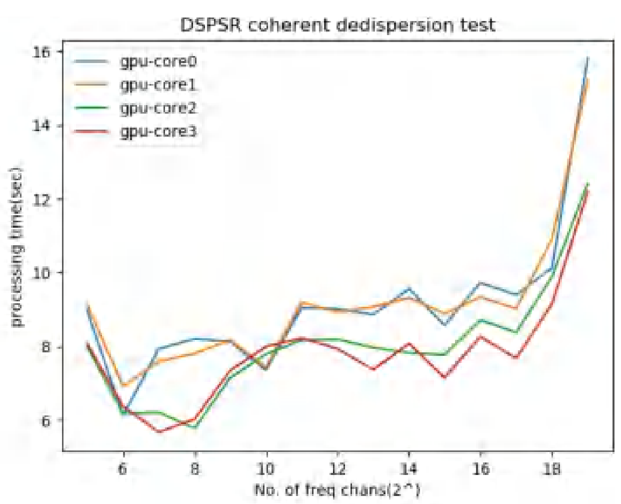


Figure 12. The computational performance on all four GPUs

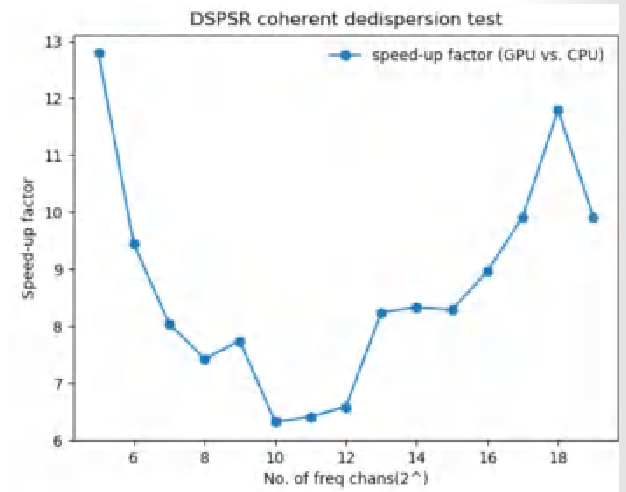


Figure 13. The comparison of computational performance between GPU and CPU

8. After the coherent de-dispersion of different channels, the pulsar waterfall plots are shown in figure14. From left to right, the channel numbers are 32, 128, 4096 and 32768, respectively. The more frequency channels, the better the de-dispersion effect. However, the computation intensive increases with the number of frequency channels.

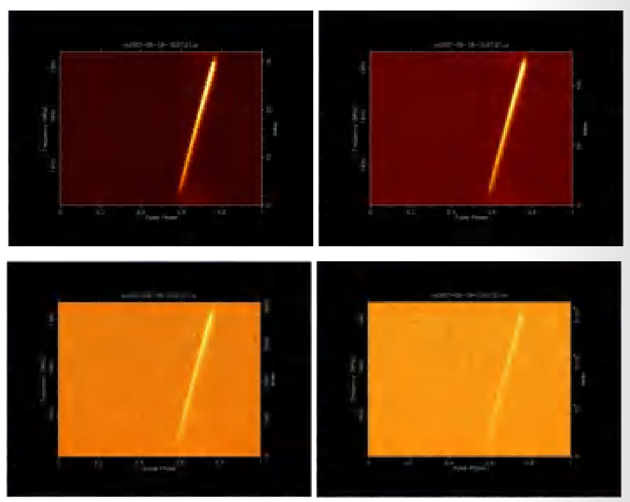


Figure 14. The pulsar waterfall plots for different number of frequency channels. From left to right, the channel numbers are 32, 128, 4096 and 32768, respectively.

9. Analysis of water vapor at QTT site

Based on the global re-analysed data, we studied the atmospheric conditions of QTT site from the aspects of absolute humidity (AH), mixing ratio (MR) and precipitable water vapor (PWV). The left plot in Figure.15 shows that, in the vicinity of altitude of 2000m, the AH of QTT site is less than 3.15g/m3, whereas the value of Effersburg and GBT site is close to 4g/m3 and 5g/m3 respectively. Moreover, with the decrease of altitude, the trend of AH is comparatively stable, and the AH value of QTT site remains lower than that of the other two stations. It further indicates by MR, as shown in right plot in Figure. 1, that the proportion of water vapor in the same air quality unit changed significantly as the altitude increased. Comparing to the dry air quality, the MR value of the QTT site drops rapidly within the maximum range of 0.0036g/g, whereas the value of Effersburg and GBT sites are generally higher than QTT site with a larger maximum range at around 0.0076 g/g.

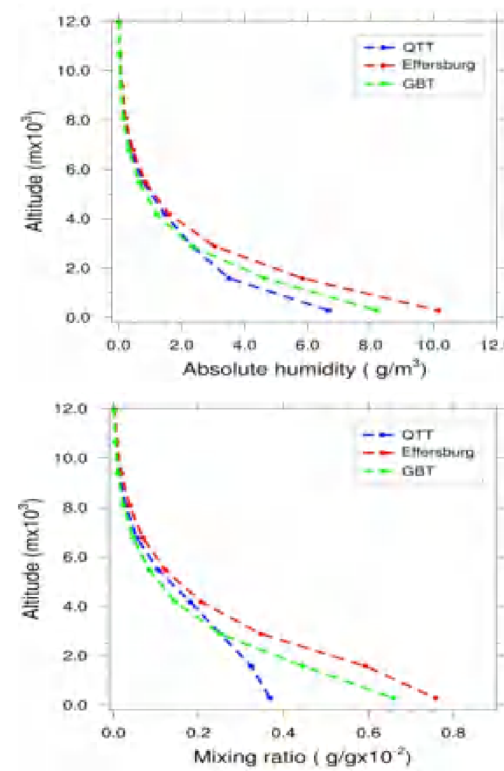


Figure 15. Schematic diagram of AH (left) and MR (right) varying with height from the year 2014 to 2018

The plot on the left in Figure 16 presents the cumulative distribution and histograms of the PWV. It shows that the PWV of QTT site is mostly less than 20mm with more than half of the PWV records are less than 5mm and 80% of the water vapor is concentrated below 10mm. The histograms also suggest that the PWV below 4mm are mostly occur in winter, accounting for more than 40% through the year. We then compared the distribution of PWV with that at GBT and the Effersburg, two well-established sites for astronomical observations, using our five-year period statistics and the results are shown in the right plot in Figure 22. The results from right plot in Figure 21 show that the water vapor distribution curves from Effersburg and GBT sites are very similar, and tend to be consistent from February to April. In general, the PWV at GBT is slightly higher than that at Effersburg in summer but reverse in winter. The annual average is 15.98mm and 16.04mm respectively, which is significantly higher than the average value of 6.64mm at the QTT site. It further shows that the PWV at QTT site is far lower than the previous two records according to the monthly average, especially in January, PWV at Effersburg and GBT sites are 9.95mm and 7.29mm respectively, which is 4-5 times of QTT site. In July, the PWV of Effersburg and GBT sites are 24.95mm and 26.19mm respectively, which is also higher than QTT's value of 14.44mm. Therefore, the water vapor conditions of the QTT site are systematically lower than that at Effersburg and GBT sites as a whole year.

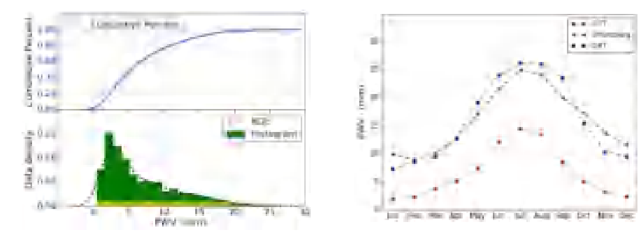


Figure 16. Left: Historical distribution of PWV at QTT site. Right: The statistical distribution of PWV at QTT, GBT and Effersburg sites.

10. Estimation of the effective observation time

Atmospheric water vapor is the main limiting factor for atmospheric transparency in the millimeter and sub-millimeter wavelength spectral windows, and atmospheric transparency is fundamental for site characterization. If cosmic radiation does not penetrate the atmosphere effectively, the astronomical observation will be in vain.

Using our re-analysed data and radiative transfer program, AM, we estimated the effective observation time at K, Q and W bands in both winter and summer for the QTT site. Table 1 shows that the effective observation days on the K band are about 180 days, the effective observation time on Q and W bands are about 157 days and 151 days, respectively, in winter. In summer, the effective observation time decreases to about 150 days, 119 days and 58 days, respectively, due to the increase of water vapor. This work will be valuable for future telescope operation, guiding the strategy of dynamic schedule based on the actual weather conditions and antenna performance.

Table 1. Estimation of effective observation days for 1.3cm, 7mm and 3mm bands

Band	2014(y)[1]		2015(y)		2016(y)		2017(y)		2018(y)	
	W(d)[2]	S(d)	W(d)	S(d)	W(d)	S(d)	W(d)	S(d)	W(d)	S(d)
1.3cm	179	157	182	147	181	135	182	144	181	133
7 mm	158	104	155	101	157	83	164	93	152	93
3 mm	154	55	149	50	150	38	159	40	147	49

1 ”y”is the abbreviation of year.

2 "W" and "S" are abbreviations for winter and summer, respectively, "d" represents the number of days.

C. Antenna control and astronomical observation system

The main contributions from the antenna control and astronomical observation system team in 2019 include software development, telescope pointing and efficiency measurement, and servo control algorithms, which are described below:

1. The architectural design of the QTT astronomical observation system is improved, and the middleware, serialization and data formats of the key technologies for QTT software are studied and analyzed.

2. The development and deployment of the unified user login system, and the commencement of the design and development of telescope operation management system based on Web.

3. Researched on the radio telescope pointing measurement with optical methods, and performed the related experiments.

4. Research on the servo control algorithm, and obtained the frequency domain characteristics of NSRT 25-meter radio telescope, which provides the experimental basis for modeling of the QTT servo system.

D. Civil and supporting engineering construction

1.The construction of canteen, apartments, activity center, janitor’s room and academic exchange center cover a total of 7216 m^2 area of the Qitai site, and the civil engineering facilities have also been completed.

The construction of supporting pipe network facilities has been completed. The switching room of the popular science activity center, 10kV overhead lines, weak current overhead lines, water supply and drainage pipes, and high-level pools have basically been completed. At the same time, a dedicated communication cable at 100Mb has been connected to the park to provide network and telephone services. In addition, the construction of the 35kV transmission and transformation line, invested and constructed by the Autonomous Region, has started, which will be completed by 2020.

Current base construction

STUDENT HIGHLIGHTS

◆ Enrollment and Graduation Data for 2019

As an astronomical observatory, XAO provides excellent research environment and high quality telescopes for students to perform research and conduct experiments as well as guidance from our outstanding postgraduate supervisors.

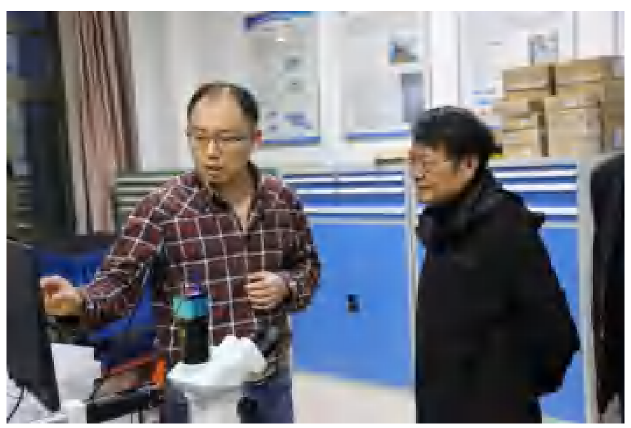
In 2019, a total number of 95 postgraduate students were under research supervision or co-supervision by XAO, of which eight have graduated. In addition, there are 33 undergraduate students enrolled this year. This includes 13 masters and 12 PhD, six postgraduate students and one PhD from joint degree program, and one overseas student.

Student Awards

Name	Major	Graduation theses	Academic degree
YANG Taozhi	Astrophysics	Asteroseismology of the high-amplitude 6 Scuti star	D.Sc
LIU Qi	Astronomical technology and method	Research on EIC Evaluaiton for Large Diameter Radio Telescope	D.Sc
Tohto Nur	Astronomica technology and method	Kev Technologies Research of Pulsar Backend Algorithm Based on GPU	D.Sc
ZHEN Xuli	Astrophysics	The kinetic Monte Carlo model to verify the encounter desorption	Master
LI Xu	Astrophysics	Molecular environs and triggered star formation around the large Galactic infrared bubble N24	Master
LIU Juhui	Astrophysics	An optical and X-ray study of the contact binary, BH Cassiopeiae	Master
ZHU Yan	Astronomical technology and method	Design and implementation of Xiniiang Astronomical Observatory Observation data transmission visualization	Master
LIU Yun	Astronomical technology and method	Research on Measurement Method of Radio Telescope Reference Point	Master
XU Wendi	Astrophysics	WARSHIP: The convolutional neural network algorithms for Astronomical Image Super-Resolution	Master
ZONG Peng	Astrophysics	New Photometric of High Amplitude SX Phe-tpe Star BL Cam	Master

CALENDAR OF EVENTS

20 August 2019
BAI Chunli, President of Chinese Academy of Sciences, during the visit at Qitai station.



13-14 November 2019

GAO Hongjun, Deputy Secretary-General of the Chinese Academy of Sciences (CAS) visited XAO.

17-18 October 2019

ZHANG Tao, Vice President of the Chinese Academy of Sciences (CAS) visit at XAO.

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Visitors and Presentations

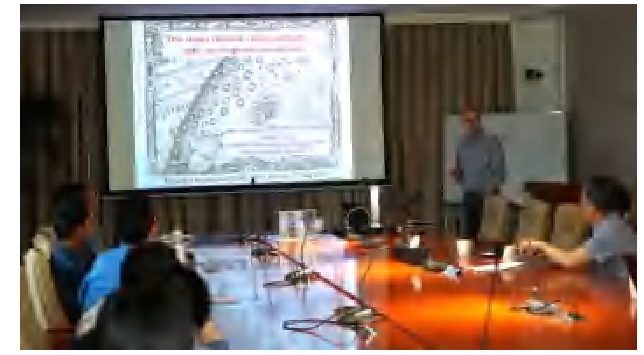
WANG Jinqing
Measurement and calibration for large radio telescope
January 2019
Shanghai Astronomical Observatory

HUANG Jiasheng
Current status and development of Chinese Academy of Sciences South America Center for Astronomy
January 2019
Chinese Academy of Sciences South America Center for Astronomy

WANG Xiaofeng
The mystery of the origin of type Ia supernova
April 2019
Department of Physics, Tsinghua University

WANG Jinxiu
A talk on the research of solar physics – Thoughts on the opportunities, challenges, future development and the possibilities of major breakthroughs
April 2019
National Astronomical Observatory of China

ZHEN Xiaoping
The key scientific issues about neutron stars
May 2019
College of Physical Science and Technology, Central China Normal University



Sándor FREY
The most distant radio quasars - with the highest resolution
May 2019
Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Budapest

LI Chuan
The research on "random process" and "memory process" of solar burst
July 2019
School of Astronomy and Space Science, Nanjing University

Cosimo BAMBI
Testing general relativity using X-ray reflection spectroscopy
July 2019
Fudan University

ZHANG Binbin
Gamma-ray Burst Research in the Gravitational Wave Era
July 2019
Nanjing University

Kazuhiro HADA
First Event Horizon Telescope results on M87 and the East Asian VLBI Network
July 2019
Mizusawa VLBI Observatory, National Astronomical Observatory of Japan

YU Yunwei
An introduction of the Gamma-ray burst neutron star research and its relation to the fast radio burst research
July 2019
Central China Normal University, College of Physical Science and Technology

WANG Ke
High-mass star formation at high-resolution: recent progresses and challenges
July 2019
Kavli Institute for Astronomy and Astrophysics, Peking University

XU Xiaojie
Study of X-ray from accreting white dwarf and the mass of white dwarf
July 2019
NanJing University

ZHANG Jiangshui
Systematic observational studies on Galactic ISM isotope ratios
July 2019
GuangZhou University

FAN Junhui
A brief introduction to center for astrophysics
July 2019
Center for Astrophysics, Guangzhou University

QIU Keping
A comprehensive survey of massive star formation in Cygnus-X
July 2019
School of Astronomy & Space Science, Nanjing University

SHI Wangzhou
Upgrade technology and progress of LCT submillimeter wave telescope
July 2019
Shanghai Normal University

FU Liping
Weak lensing Study in VOICE Survey
July 2019
Shanghai Normal University

JIANG Ning
Infrared echo from a star during black hole tide tearing event
August 2019
University of Science and Technology of China

CHENG Quan
The gravitational wave radiation and interior physics of neutron stars
August 2019
School of Physics and Technology, Wuhan University

DONG Jianmin
Nuclear material superfluid and neutron star cooling
August 2019
Institute of Modern Physics, Chinese Academy of Sciences

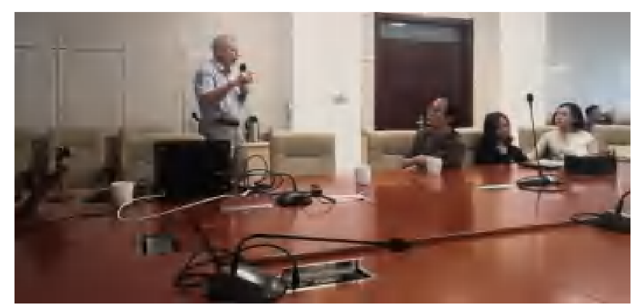
LIU Jingjing
The effect of strong charge shielding on the heating rate of he gamma ray beta decay inside the supernova
August 2019
Hainan Tropical Ocean University

WANG Hongguang
On the emission beam of radio pulsars and mode switching
August 2019
Guangzhou University

Christian HENKEL
Activity in the Central Regions of Highly Obscured Galaxies
August 2019
Max-Planck-Institut für Radio astronomie (MPIfR), Germany

George HOBBS
September 2019
CSIRO Astronomy and Space Science

FANG Hongyuan
Distortion control in welding structures and stress
September 2019
Harbin Institute of Technology

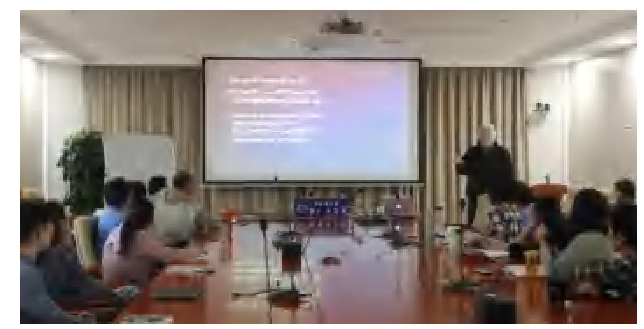


Richard Norman MANCHESTER
September 2019
CSIRO Astronomy and Space Science

LIU Qinghui
Exploration of the Moon and Mars
October 2019
Shanghai Astronomical Observatory, Chinese Academy of Sciences

Ryszard SZCZERBA
Searching for Young Stellar Objects in the Outer Galactic Plane
October 2019
N. Copernicus Astronomical Center (NCAC), Torun, Poland

Willem A. BAAN
Doing good research and What does it take
December 2019
Netherland Institute for Radio Astronomy



LI Di
Detection of interstellar gas
December 2019
National Astronomical Observatory, Chinese Academy of Sciences

Seminars and Colloquia

The 4th International Youth Forum on Antenna Multidisciplinary Design and Measurement (23-26 January, 2019)

The International Workshop on Astrochemistry (17-20 May, 2019)

The Workshop on frontier science and technology of the Steerable 110-m Aperture Radio Telescope (QTT/START)(10-13 June, 2019)

The 12th Zhang Heng Academic Workshop (15-17 July, 2019)

The Inception Workshop on the Muztaghata 1.93-m Optical Telescope (29 July, 2019)

The 2019 Workshop on Molecular Cloud and Star Formation (10-15 July, 2019)

The Across-strait Conference on Astronomy Science (13-16 August, 2019)

Project Acceptance Meeting of 973 Program on the Key Technologies for 110-m Aperture Fully Steerable Radio Telescope (27 September, 2019)

Seminar on Exchange and Cooperation between Beijing Normal University and Xinjiang Astronomical Observatory (9-10 December, 2019)

2019 Seminar on Strategic Planning Committee of XAO (24-26 December)

2019 Symposium for Female Astronomers (26-27 December)

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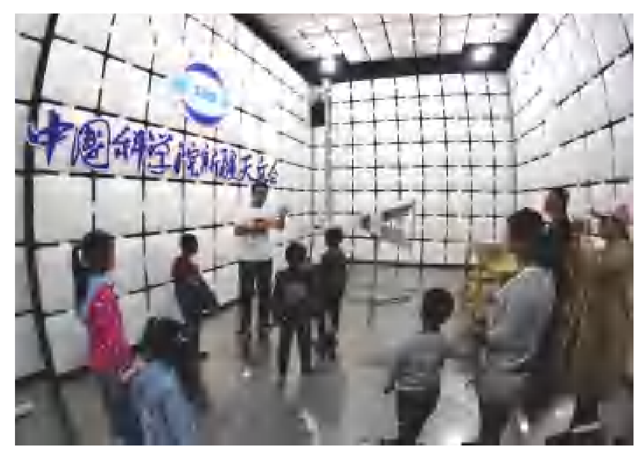
OUTREACH AND EDUCATION

In 2019, we saw the completion of the construction of the " Starry Night" Exhibition Hall and the Meteorite Exhibition Hall Planetarium. Covering 200 square meters in area, the Starry Night Exhibition Hall is made up of three sections, namely the Solar System, Cosmogony and the Galaxies. The Meteorite Exhibition Hall Planetarium covers a total area of 50 square meters, with seven meteorites on display including meteoric stone, iron meteorite and lithosiderite. Also on display are ten boards providing description for the source of each meteorite.

This year, we carried out various popular science activities at Kindergartens, high schools and universities. These include Astronomical Olympic Competition for Primary and Secondary Students, Winter and Summer Camp for youth and college students, observation lessons at high schools and universities and live broadcasting of astronomical events. In addition, annual popular astronomy activities were carried out at XAO several times this year.

"Starry Night" Exhibition Hall

The 20th Xinjiang "Mysterious Firmament" Astronomical Youth Summer Camp



The 15th Public Science Day (visiting the 3-m anechoic chamber at XAO)

"Celestron Cup" Xinjiang Youth Astronomical Olympic Competition

APPENDICES

List of Publications

Refereed Journals

- Bai, C. H.; Zhang, H.; Feng, G. J.; Zhou, J. L.; Zhang, X.; Liu, H. G.; Niu, H. B.; Ma, L.; Aili·Esamdin.; Hu, J. Y.; Jiang, X. J., *"Variable star searching in several areas near the Milky Way disc"*, Astronomical Research & Technology,16(4),488-497
- Bai, J. Y.; Bao, M.; Zhang, T.; Jiang, Y., *"A virtual reality approach identifies flexible inhibition of motion aftereffects induced by head rotation"*, Behav. Res. Methods, 51(1), 96-107
- Cao, H. M.; Frey, S.; Gabányi, K. É.; Yang, J.; Cui, L.; Hong, X. Y.; An, T., *"The loud and the quiet: searching for radio counterparts of two radio-weak BL Lac candidates with VLBI"* MNRAS,482(1),L34-L39
- Chan, M. H.; Cui, L.; Liu, J.; Leung, C. S., *"Ruling Out similar to 100-300GeV Thermal Relic Annihilating Dark Matter by Radio Observation of the Andromeda Galaxy"*, ApJ, 872(2):177
- Chen, J. X.; Fu, J. N.; Niu, H. B.; Li, C., *"G132-12: A one-mode ZZ Ceti star located at the blue edge of instability strip"*, New Astron., 73:Unsp 101276
- Chen, L.; Xie, J. F.; Han, S. T.; Cao, J. F.; Ping, J. S., *"Open Loop Velocity Measurement Scheme Design and Verification of Chang'E-4 Relay Satellite"*, Journal Of Deep Space Exploration, 6(3), 236-240
- Chen, Y.; Sun, Z. W.; Yan, H.; Li, J.; Li, D.; Li, X. F.; Liu, F., *"Conversion of Line Polarization to Circular Polarization in LBand Receiver of 26m Telescope in Xinjiang Astronomical Observatory"* Astronomical Research & Technology, 16(3),262-267
- Gao, Z. F.; Omar, N.; Shi, X. C.; Wang, N., *"The Ohmic decay of dipolar toroidal magnetic fields of magnetars"*, Astro. Nachr.,340, 1030-1034
- Gao, Z. F.; Peng, F. K.; Wang, N., *"The evolution of magnetic field and spin-down of young pulsars"*, Astro. Nachr.,340,1023-1029
- Gao, Z. F.; Song, D. L.; Li, X. D.; Shan, H.; Wang, N., *"The equilibrium equations of Boson-Fermi systems in the Newtonian approximation"*., Astro. Nachr., 340(1-3),241-246
- Gao, Z. F.; Wang, H.; Peng, Q. H.; Shan, H.; Wang, N., *"A hybrid model for pulsar's spin-down evolution"*, Astro. Nachr.,340,1035-1039
- Gong, Y.; Tang, X. D.; Henkel, C.; Menten, K. M.; Mao, R. Q.; Wang, Y.; Lee, M. Y.; Zhu, W. S.; Lin, Y.; Zhang, S. B.; Chen, X. P.; Yang, W. J., *"Searching for further evidence for cloud-cloud collisions in L1188"*, A&A,632:A115

- Han, W.; Wang, N.; Wang, J. B.; Yuan, J. P.; He, D. L., *"Using single millisecond pulsar for terrestrial position determination"*, Ap&SS, 364(3):48
- Jin, H. L.; Huang, J. H.; Ye, Q.; Meng, G. X.; Xiang, B. B.; Wang, N., *"Surface Shape Detection with a Single Far-Field Intensity by Combined Amplitude and Phase Retrieval"*, Int. J. Antennas Propag.,2019:7648604,10
- Komesh, T.; Esimbek, J.; Baan, W.; Zhou, J. J.; Li, D. L.; Wu, G.; He, Y. X.; Sailanbek, S.; Tang, X. D.; Manapbayeva, A., *"H2CO and H110 alpha Observations toward the Aquila Molecular Cloud"* ApJ, 874(2):172
- Kou, F. F.; Tong, H.; Xu, R. X.; Zhou, X., *"Rotational Evolution of the Slowest Radio Pulsar, PSR J0250+5854"*, ApJ, 876(2):131
- Li, K.; Xia, Q. Q.; Michel, R.; Hu, S. M.; Guo, D. F.; Gao, X.; Chen, X.; Gao, D. Y., *"Contact binaries at the short period cut-off - I. Statistics and the first photometric investigations of 10 totally eclipsing systems"* MNRAS, 485(4),4588-4600
- Li, M. Y.; Zhou, J. J.; Esimbek, J.; Quan, D. H.; He, Y. X.; Li, Q.; Zhu, C. H., *"Spatial Variation of the Chemical Properties of Massive Star-forming Clumps"*, ApJS, 243(1):13
- Li, Q.; Zhou, J. J.; Esimbek, J.; He, Y. X.; Baan, W.; Li, D. L.; Wu, G.; Tang, X. D.; Ji, W. G.; Komesh, T.; Sailanbek, S., *"Effects of infall and outflow on massive star-forming regions"*, MNRAS,488(4),4638-4647
- Li, X.; Esimbek, J.; Zhou, J. J.; Baan, W. A.; Ji, W. G.; Tang, X. D.; Wu, G.; Tang, X. K.; Li, Q.; Ma, Y. X.; Sailanbek, S.; Li, D. L.; Alimbetova, D., *"Molecular environs and triggered star formation around the large Galactic infrared bubble N 24"*,MNRAS, 487(2),1517-1528
- Lian, P. Y.; Wang, C. S.; Xiang, B. B.; Shi, Y.; Xue, S. *"Gradient-based optimization method for producing a contoured beam with single-fed reflector antenna"*, Journal of Systems Engineering and Electronics, 30(1), 22-29
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