Overview of the Joint-CART Project Between China and Argentina (Postprint)

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Abstract

The China-Argentina Radio Telescope (CART) has a diameter of 40 m and is equipped with eight frequency bands, including L, S/X, C, Ku, K, Ka, and Q. The S/X dual-band cryogenic receivers and the dual-beam Q-band cryogenic receivers are among the first instruments to be installed on CART from the testing phase onward. CART is a milestone joint project between China and Argentina. Located at the CESCO Observatory of the National University of San Juan in Argentina, it will be the largest single-dish radio telescope and Very Long Baseline Interferometry (VLBI) station in Latin America. It is expected to have strong synergies with LLAMA and the Argentine-German Geodetic Observatory, and to participate in and contribute to major international VLBI campaigns such as IVS, the Square Kilometre Array VLBI, and potentially also the Atacama Large Millimeter/submillimeter Array in the future.

Full Text

Preamble

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Overview of the Joint-CART Project Between China and Argentina

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Abstract

The China-Argentina Radio Telescope (CART) features a 40-meter diameter and eight working bands including L, S/X, C, Ku, K, Ka, and Q. The S/X dual-band cryogenic receivers and dual-beam Q-band cryogenic receivers are among the first systems to be installed during the testing phase. CART represents a milestone joint project between China and Argentina, located at the CESCO Observatory of the National University of San Juan, Argentina. It will become the largest single-dish and Very Long Baseline Interferometry (VLBI) unit in Latin America, with expected synergies with LLAMA and the Argentine-German Geodetic Observatory. CART will participate in and contribute to major international VLBI campaigns such as IVS, Square Kilometre Array Very Long Baseline Interferometry, and potentially the Atacama Large Millimeter/submillimeter Array in the future.

Key words: Astronomical Instrumentation, Methods and Techniques –telescopes –instrumentation: interferometers

1. Historical Review of China-Argentina Astronomical Cooperation

China-Argentina astronomical cooperation began in 1989 when the Beijing Astronomical Observatory of the Chinese Academy of Sciences reached an agreement with the National University of San Juan (UNSJ) to establish an automated Photoastrolabe (PA II) at the OAFA (Observatorio Astronómico FÉLIX AGUILAR) Observatory. This marked the beginning of a new era of continuous scientific output in astrometry until the Hipparcos satellite launch, which further stimulated expectations for deeper collaboration. In 2006, a Satellite Laser Ranging (SLR) system was installed at OAFA Observatory, contributing to the International Laser Ranging Service (ILRS) and achieving major successes in 2009 with observations of the M1 satellite of the BD II navigation system.

In late 2010, the Ministry of Science and Technology of China funded the CART project to address the critical shortage of large-aperture VLBI telescopes in the southern hemisphere. A Global Positioning Service (GPS) station was established at OAFA in 2011. The OAFA Observatory of UNSJ is located in the suburbs of San Juan. While excellent observational stations exist in the southern hemisphere in Chile, Australia, and South Africa, there remains a conspicuous lack of large-scale single-dish and VLBI facilities for observing the southern sky, which contains the Galactic Center, Magellanic Clouds, and numerous prominent star-forming regions.

The primary objective of CART is to establish a VLBI facility that creates a co-location station comprising VLBI, SLR, and GPS in the southern hemisphere. This is critically important for observing and continuously monitoring Earth Orientation Parameters (EOP) and for establishing and maintaining the International Terrestrial Reference Frame (ITRF) and International

Celestial Reference Frame (ICRF), in cooperation with other global VLBI antennas operating in the same frequency bands. Furthermore, potential synergies are planned or expected with the Large Latin American Millimeter Array (LLAMA), Argentine-German Geodetic Observatory (AGGO), Square Kilometre Array (SKA) VLBI, and potentially even the Atacama Large Millimeter/submillimeter Array (ALMA). Meanwhile, CART will be equipped with up to eight working bands and can function as a single-dish radio telescope [Figure 1: see original paper], making major contributions to investigations in astronomy, geodesy, and deep space exploration.

3. Hosting Site

Observational sites suitable for astronomical research are rare and precious resources, with the majority located in the northern hemisphere. The initial plan was to build the VLBI antenna at OAFA Observatory to realize the co-location of VLBI, SLR, and GPS. However, OAFA is situated in the immediate suburbs of San Juan, Argentina, adjacent to residential areas where radio interference across various frequencies is extremely strong. Since CART plans to operate up to eight working bands including L, S/X, C, Ku, K, Ka, and Q, its functionality would be severely compromised at this location.

During the early implementation phase, the joint CART team encountered clear objections from the Argentine astronomical community regarding the OAFA site, with strong requests for a comprehensive site survey and radio frequency interference (RFI) testing to identify a location suitable for hosting an advanced multi-frequency radio telescope. Consequently, an extensive site search campaign was conducted across the remote deserts of San Juan Province. Up to 16 candidate sites were investigated, with detailed RFI testing performed at three optimal locations: Talacasto, near San Juan; the former candidate SKA site in Argentina; and the final selected site at CESCO Observatory. The RFI testing revealed that both Talacasto and the former SKA site represent excellent candidates for hosting CART. As examples, Figure 2 [Figure 2: see original paper] shows RFI monitoring results between 960 and 1440 MHz at Talacasto and the former SKA site. Similar results were achieved at frequencies below 3 GHz, with some enhanced interference from cellular signals. At frequencies above 3 GHz, interference is dominated primarily by satellites [CITE: Zhao et al. 2014].

Significant efforts were initially devoted to building CART at Talacasto, which offered excellent isolation and accessibility. However, this candidate site was a completely undeveloped wilderness deep in a valley, lacking power, roads, or internet connectivity. Due to limited infrastructure construction budgets, the project ultimately relocated to the current CESCO Observatory site, an operational facility with mature logistics, despite requiring extensive earthwork to flatten hills and terrain for CART installation [FIGURE:3, FIGURE:4]. The decisive advantage of the final site is that the concrete foundation can be constructed directly on bedrock. The CESCO Observatory is located within El Leoncito National Park, where radio interference is minimal and establishing a radio-quiet zone centered on CART is significantly more feasible.

4. Key Progress and Implementation Timeline

A memorandum of understanding for the joint CART project was signed in August 2011 among the Chinese Academy of Sciences, CONICET, UNSJ, and the San Juan Government. Argentina' s Ministry of Science, Technology and Innovation approved the CART project in July 2014, conditionally granting $1.5 million USD for infrastructure construction. A four-party agreement was signed in June 2015 among NAOC, CONICET, UNSJ, and the San Juan Government, by which time the disassembled telescope components had been manufactured in China and were ready for on-site assembly. The joint project implementation experienced some turbulence but was ultimately included in the China-Argentina joint declaration in May 2017.

The San Juan provincial government provided crucial financial support for site flattening and preparation of roads, power, water supply, and fiber internet connectivity to the CART site, enabling the project to move forward. Detailed geophysical investigations were conducted in December 2017, followed by site flattening in September 2018. A kick-off ceremony for concrete foundation construction was held in October 2019. Soon after, the COVID-19 pandemic emerged, but foundation work proceeded such that the first concrete pouring was completed in November 2020 after delivery of manufactured templates for precise positioning of embedded components [Figure 5: see original paper], albeit without the originally planned on-site supervision from manufacturer technicians. Seamless welding of the steel tracks was completed in November 2023 after pandemic restrictions eased and technicians could return on-site.

In April 2023, the first batch of CART components began delivery to the construction site in Argentina. Seamless rail track welding was completed in November 2023, after which on-site assembly commenced. Assembly of the steel primary reflector, supporting structure, and pitch axis required approximately ten months [Figure 6: see original paper].

5. Scientific Objectives

As the largest single-dish telescope in Latin America, CART can contribute to pulsar timing, regional line surveys of major star-forming regions, the Magellanic Clouds, the Galactic Center, and supernova remnants in the southern sky, as well as investigations of planets and comets, and follow-up observations of gamma-ray bursts, gravitational waves, and other transient phenomena such as fast radio bursts.

As a VLBI unit antenna—rare in the southern hemisphere—CART can significantly contribute to global VLBI investigations in astrophysics, astrometry, geodesy, and potentially future deep space exploration. CART is expected to have important synergies with LLAMA and AGGO in Argentina and may make major contributions to IVS, SKA VLBI, and potentially ALMA. Notably, dual-beam Q-band cryogenic receivers will be among the first systems equipped on CART during the testing phase, enabling extensive searches and investigations of complex organic molecules that may shed light on the origins of life in the Universe.

6. Working Bands and Receiver Equipment Plan

Eight working bands are planned for CART: L, S/X, C, Ku, K, Ka, and Q . The dual-band S/X and dual-beam Q-band cryogenic receivers are under development and will be installed starting from the test phase observations expected in late 2026. The remaining receivers will be developed and equipped subsequently based on funding availability and scientific objectives.

7. Operation Control Platform

CART's operation control system employs a hierarchical distributed architecture comprising four major components: presentation, application, device management, and infrastructure. This design offers excellent modularity and scalability, ensuring adaptability for future functional expansions and upgrades.

The system is primarily developed in Python, utilizing PyQt5 technology to implement a cross-platform graphical user interface (GUI) that supports real-time multilingual switching. This effectively addresses the operational requirements of the China-Argentina international cooperation and facilitates seamless collaboration among users from diverse linguistic backgrounds.

For backend communication, the software leverages ZeroC-ICE and ZMQ technologies to enable efficient cross-process and cross-node data transmission, ensuring low-latency and reliable interaction between system components. For data management, InfluxDB is utilized for time-series data storage, optimizing handling of continuous high-volume observational data, while Redis is employed for high-frequency data access caching. This combination significantly enhances the system' s real-time performance and throughput capacity for large datasets.

The software encompasses three core modules: real-time monitoring information display, device control, and backend service interfaces. It enables real-time monitoring of critical equipment status, including the antenna, receiver, UDC, and MARK6 recorder. Additionally, the system supports two observation modes: manual command input and program tracking file execution, providing flexibility for various observational scenarios and user preferences. To ensure precise and timely control, the system implements high-frequency data exchange with the Antenna Control Unit (ACU) via the User Datagram Protocol (UDP), guaranteeing prompt response of control commands and accurate status feedback during telescope operations.

This system has undergone field testing at the 13-meter telescope of Sheshan Station, Shanghai Astronomical Observatory. The testing validated its key characteristics, including reliable communication, comprehensive functionality, and strong scalability, confirming its readiness for deployment with the CART 40-meter telescope.

8. Future Perspectives

The implementation of the joint CART project has been a long journey that will soon reach successful completion. As the largest single-dish and VLBI unit antenna in the southern hemisphere, CART is expected to make significant contributions to the astronomical and geodetic communities of both China and Argentina, and will likely play a major role in global cooperative investigations in related fields.

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Reference: Zhao, W. P., Li, J. B., Li, J. Z., et al. 2014, *Progress in Astronomy* (in Chinese), 32, 395

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