Session 1 Recent Progress in ILRS
Chairs: T Otsubo and Zhao Y

Great introduction for this workshop, nicely covering the hot topics in/around the SLR community.

- **Zhang Z**: wide variety of new development going on at the satellite/lunar laser ranging stations in China.
- **M Blossfeld** and **S Merkowitz**: new satellite missions (GENESIS 2028 and GRITSS 2025) for accurate terrestrial reference frames by strengthening space tie and local tie.
- **J Kodet**: final update on the upcoming ISS-ACES (2025) mission, an accurate time base in space. Opportunity to be a part of clock tie.

Session 2 summary

Claudia C. Carabajal, Liang Zhipeng,
Yang Yongzhang, Mathis Bloßfeld

23rd International Workshop on Laser Ranging (IWLR)

October 20th-26th, 2024

Kunming, China

23rd IWLR – session 2 summary

- Monday, 21.10.2024
- 2 parts
- 4 chairs: Claudia Carabajal, Liang Zhipeng, Yang Yongzhang, Mathis Bloßfeld
- 10 onsite and 2 online talks

© Abdelrahim Ruby

23rd IWLR – session 2 summary

1) **Take advantage of numerous SLR-tracked satellites in orbit**
   - decorrelation of parameters and increased sensitivity (e.g., Westpac, **LARES-2 is of equal importance than both LAGEOS**)
   - challenges: refined/different orbit model required (NP formation, perturbations, observation corrections, relative weighting of observations (static vs. VCE-based), etc.)
   - co-location satellites are already in orbit → possibility to already prepare your s/w for Genesis

2) **SLR is a very valuable tool to support geodetic and geophysical research**
   - Terrestrial Reference Frame and Earth Orientation Parameters
   - spherical harmonics of the Earth gravity field (←→ support/extension of satellite-based TVG models)
   - solar pressure, Earth radiation pressure, and thermospheric drag scaling factors

3) **ILRS network observations are essential for many scientific experiments and products**
   - good global coverage of observations needed → thanks to all contributing SLR/LLR stations!!

Session 3 – Station Operations and Upgrades

Ongoing improvements at stations were presented and included modern networking and monitoring at the Kunming station and refurbished telescope and detector hardware at the Graz station.

Understanding the system delay time series at the Kunming station could help improve stability.

Some major updates at stations will have a significant impact on the productivity, including San Fernando and MLRO.

The new station in Yebes is operational and has met the quarantine requirements to join the network.

Session 4, Part 1 : Lunar Laser Ranging and Future missions

Chairs Dong Xue, Clément Courde

Presentation 1

Title : hHz monostatic LLR at WLRS,

Speaker : Johann Eckl, in-person

Affiliation : Federal Agency for Cartography and Geodesy

Report presentation 1 : a new amplification stage for LLR is implemented at WLRS, allowing an increasement of the laser repetition rate to 250 Hz. The T/R switch is based on polarization. Succesfull tracking with this new setup is presented. The control and the adjustement of the polarization are highlighted by the change of the detection rate on the uncoated reflector which are known to have a diffraction pattern depending on the polarization.

Session 4, Part 1 : Lunar Laser Ranging and Future missions

Chairs Dong Xue, Clément Courde

Presentation 2

Title : the first laser retroreflector deployed on the lunar far side onboard China's Chang'E6 mission

Speaker : Di Kaichang, in-person

Affiliation : Aerospace Information Research Institute, Chinese Academy of Sciences

Report presentation 2 : the presentation reports on the expanding of the global laser retroreflector network on the Moon. The INstrument for Landing-Roving Laser Chang'E6 was mounted on the lander top panel. The successfull landing of ChangE'6 marks the first precise reference point on the farside of the Moon. The localization and the validation have been done thanks to the Lunar Reconnaissance Orbiter around the Moon and its altimeter LOLA. The China's Lunar Exploration Program is presented for the near future.

Session 4, Part 1 : Lunar Laser Ranging and Future missions

Chairs Dong Xue, Clément Courde

Presentation 3

Title : ESA's Nextgen Lunar Laser Retroreflector with Pointing Actuators for NASA's CP11 Mission

Speaker : Simone Dell'Agnello, in-person

Affiliation : National Institute for Nuclear Physics (INFN)

Report presentation 3 : the presentation reports on the future Moonlight next gen single large CCR for LLR. This laser retro reflector developped by INFN-LNF is equiped with a pointing actuator and is unaffected by lunar libration. A variety of laser retro reflectors dedicated for lunar science & exploration are presented: 4 INRRIs, 1 MPAc, 1 NGLR and 2 microreflectors on SLIM & CHA-3 are scheduled for the next years, allowing laser ranging by the altimeters around the Moon and LLR stations on the Earth.

Session 4, Part 1 : Lunar Laser Ranging and Future missions

Chairs : Dong Xue, Clément Courde

Presentation 4

Title : Lunar laser ranging progress at Kunming station

Speaker : Li Zhulian, in-person

Affiliation : Yunnan Observatories, Chinese Academy of Sciences

Report presentation 4 : the presentation reports on the upgrades, the progresses and the plans for the future done at the LLR Kunming station (7820). A 100 Hz laser and a 2x2 SNSPD detector have been implemented on the station and validated by measurements on the satellite Compassg8. Validation on the Moon are scheduled for the end of 2024. New kHz laser, adaptive optics and a new LLR station @ 4600 meters of altitude are planned.

Session4: Lunar Laser Ranging and Future Mission

Summary

Chairperson: Stephen Merkowitz, Zhang Zhongping

The 23rd ILRS Workshop, Kunming, China, Oct.21--26, 2024

Summary of session4: Lunar Laser Ranging and Future Mission

- **This session has 5 oral presentations.**
- **The first one is from Sun Yat-Sen University, its title "Research progress on Lunar ranging at Tianqin station".**
  - **The Tianqin lunar ranging station was built from the project of Tianqin gravitational wave observatory. This station uses 1.2m telescope with the Common optical path and high power 1064nm laser with the 100Hz repetition rate, superconducting single-photon detector.**
  - **The 5 Moon-based LRAs were measured and also laser data was obtained at full moon for A15. they will do daylight and two-color laser ranging for High-precision orbit determination of Tianqin3 satellite.**
- **The second one is from Yunnan Observatory with the title "CPF calculation in circumlunar satellite laser ranging observations".**
  - **This talk is focused on the production of CPF predict file for circumlunar satellite laser ranging. The coordination of ITRS to ICRS, Time conversion(UTC to TDB) are introduced and some corrections are also considered and producing CPF file for Moon-based LRAs and circumlunar satellite at Kunming station.**

Summary of session4: Lunar Laser Ranging and Future Mission

- **The third one is also from Sun Yat-Sen University with the title "Computer Vision Based Lunar Ranging Signal Detection ".**
  - **Due to the weak signal for LLR, the method of signal identification based on the computer vision and machine learning is investigated at Tianqin LLR station.**
  - **The model of YOLO ((You Only Look Once))for target detection was tested and the preliminary results are obtained.**

- **The forth one is from Institute of Applied Astronomy RAS with the title "High precision modern ephemeris of the Moon EPM2023 at the IAA RAS" .**
  - **This presentation focus on clarifying the parameter of the Moon's ephemeris EPM2023 and using the new LLR data to update the parameter of the lunar ephemeris within the modernized ERA-8 system.**
  - **The total number of 32689 LLR NPs data are used and about 100 parameters of new lunar ephemeris have been improved. Currently, all the three ephemeris (other two ones from France and USA)are of the same level of accuracy by comparison**

Summary of session4: Lunar Laser Ranging and Future Mission

- **The fifth one is from Institute fui Erdmessung, Leibniz University Hannover with the title of "Lunar Laser Ranging for testing relativity and studying the Earth-Moon system".**
  - **This talk give an overview of various LLR applications and their recent research results by using LLR data. Different tests of General Relativity is carried out to research EP（equivalent principle）etc.**
  - **Investigating Earth rotation by using LLR data with a min. of 15 NPs per night to estimate the Earth rotation phase UT1, xp and yp.**
  - **The DLLR technique is also addressed to expect to have the higher accuracy for LLR, benefiting for studying the parameters of lunar interior.**

Summary of Session 5 (Space Debris Laser Ranging)

- Number of Presentation : 5 (2 on-line and 3 off-line)
- Experiment in bi-static laser ranging to space debris by Univ. of Latvia
  - 1m telescope, HPD(Hybrid Photo Detector), Event stream timer
  - Active stations : Borowiec and Graz
- Space debris laser ranging with range-gate-free SNSPD by Yunnan observatory
  - The SNSPD array in automatic recoverable range gate-free mode enables DLR under the inaccurate orbital prediction
  - Low false alarm probability and high signal detection probability
- Development of daytime DLR technologies by Changchun station
  - Infra-red(1064nm) SPAD package with low-noise and low-jitter
  - Under the development of new technologies for daytime DLR
- Attitude estimation of defunct satellites using bi-static SLR simulation
  - Austrian Academy of Science, surface vector propagation method
- Attitude estimation of Falcon-9 rocket body based on automatic differentiation
  - Yunnan observatory, photometric measurement of light curves
  - AD allows the fast and accurate attitude estimation by computing efficiently the derivatives of complex photometric functions

Session6: SLR for Gravitation and Relativity

Summary

Chairperson: Simone Dell'Agnello, Zhang Haifeng

The 23rd ILRS Workshop, Kunming, China, Oct.21--26, 2024

Summary of session6: SLR for Gravitation and Relativity

● This session has 4 oral presentations.

1) The first presentation is "Testing Local Lorentz Invariance with SLR", talked by Roberto Peron from National Institute for Astrophysics(INAF)

- **Local Lorentz Invariance (LLI) represents a pillar of General Relativity, this presentation a measurement of the PPN parameter α1 based on the analysis of the orbital residual of the LAGEOS2 over a time interval of 28 years.**
- **Author think the possible existence of Preferred Frame Effect due to the motion of Earth-Sun-satellite system with the respect to the Cosmic Microwave Background radiation.**
- **In high-energy physics LLI is well tested. But in GR, it is more difficult because of weak-field regime and in the strong or quasi-strong field regime. Through LLR, the parameter α1 and α2 were obtained and improved.**

Summary of session6: SLR for Gravitation and Relativity

2) The second one is "The Galileo for Science 2.0 Project: SLR Campaign and Project" , talked by Alessandro Di Marco from INAF.

- **The Galileo for Science 2.0 project was funded by ASI with the aim of conducting Fundamental Physics measurements through Galileo-FOC satellites, with multiple objectives in the field of fundamental physics, dark matter, precession of satellite orbit.**
- **To realize the objective, the POD of satellites, clock-bias with extreme precision are necessary with the campaign of ILRS tracking.**
- **This presentation gives the current the results for Galileo satellites under the current laser tracking and hope continuous laser tracking to support this project.**

Summary of session6: SLR for Gravitation and Relativity

3) The third one is "Testing Gravitational Redshift through Simulation of the China Space Station Laser Timing Experiment", talked by Abdelrahim Ruby from Wuhan university.

- **China Space Station equipped with a set of high precision atomic frequency standards and time transfer experiment instruments, including hydrogen, cooled atom microwave and optical atomic clocks.**
- **Through simulations based on the optical two-way laser timer transfer links, the aim of testing GRS was studied and the accuracy of 10^-6 will expect to be achieved through time transfer experiments.**
- **This work shows that the laser timing experiments is necessary to advance our understanding the fundamental physics and contribute to space-based scientific research.**

Summary of session6: SLR for Gravitation and Relativity

4) The fourth one is "Detecting gravitational waves with SLR", talked by Diego Blas from Institute de Fisica d'Altes Engerine/Catalan Institution for Research and Advanced Studies

- **This presentation show how SLR (and LLR) can be used to detect the gravitational waves coming from super-massive black holes in the centers of galaxies or from the early universe.**
- **A well designed SLR strategy/constellation may be the only way to detect these signals.**
- **Some new results from SLR / LLR were given to detect the gravitational wave and hope using more satellites, such as GNSS constellation and real SLR analysis.**

Summary of Session 7: Development of SLR and Time Transfer (chairs: Luceri, Zhilian)

- **Development of the Omni-SLR system: concepts and project status (**Toshimichi Otsubo)
  - Rationale: not continuous tracking, unreachable zones, satellites number increases,number of stations is not increasing significantly
  - OMNI-SLR very compact, low cost, multi purpose, using COTS
  - First results from Tracking SARAL, Starlette and many other LEO. Test it in Antarctica in 2026-2027
  - Stability to be improved
  - OMNI-SLRx2 for time transfer

- **Overview of Lishan SLR station of National Time Service Center** (Wang Xiao)
  - 1.05 meter aperture reflecting astronomical telescope available in Lishan since 1990
  - Recently upgrade with the support of Chinese Academy of Sciences(CAS)
  - Ranging precision to LAGEOS about 1cm, to navigation satellite about 2.5 cm
  - ILRS form in preparation to join the ILRS network

- **Wuhan SLR station progress and time synchronization for multi-station ranging** (Zhang Jie)
  - Since 1970, 60 cm telescope
  - New 1 meter telescope in 2018, 2kHz repetition rate
  - Improve ranging of Wuhan SLR station using time synchronization technology between two SLR stations

Summary of Session 7: Development of SLR and Time Transfer (cont.)

- **Pulse repetition frequency of 1Hz~1MHz industrial picosecond laser for satellite and space debris laser ranging** (Zhang Haifeng)
  - Customized laser, very expensive and often more than one laser necessary at the stations for different purposes. The idea is that one laser unit can be used for multifunctions
  - Collaboration with the Superwave company, industrial level laser unit installed in Shanghai in nov 2023, pulse repetition frequency (PRF) of 1Hz-1 MHz, 15 ps pulse width
  - Single-shot ranging precision for spherical satellites and calibration reaches the millimeter level

- **Time/Distance Metrology based on Free-Space Optical Communication Links (**Phung Duy-Hà)
  - high-data-rate Free Space Optical communication (or laser communication - lasercom) link for time/distance measurement
  - 10 Gbps telecom signal to achieve high accuracy for ground-space link

- **Advancements in Satellite-Ground Laser Time Transfer at the Shanghai Astronomical Observatory** (Wu Zhibo)
  - SHAO Laser Time Transfer on Beidou satellites since 2007
  - Laser time transfer payload (CLT) onboard China Space Station
  - Experiments conducted by satellite laser ranging systems in Shanghai, Xi'an, and Beijing
  - 2 dedicated SLR stations (Bejing and Xian) for time transfer
  - Plan to extend satellite-ground laser time transfer to Earth-Moon space

Session 8 wrap up

SLR Data Processing

Johann Eckl, Zhang Jie

- 5 talks (4 in person & 1 online)
- covering variety of topics:
- data/noise reduction, intra-technique comparison, inclusion of LARES-2, data screening techniques, rotational behavior of AJISAI

- **Mathew Wilkinson presented the data reduction procedure of Herstmonceux SLR-station**
  - Challenges due to variable noise and echoe, large Time-Biases and different echoe RMS
  - Implemented elevation dependent RMS filter for satellites with flat panels →available in orbitNP.py soon (THANKS!!!)
- **Lalida Tantiparimongkol compared different kinds of data (Radar & Laser)**
  - Each technique has its advantage
  - Even SD-SLR by 1 or 2 orders of magnitude better than Radar in precision as well as accuracy

- David Sarrocco presented initial results to include LARES2 in the ILRS products
  - Less or comparable amount of data compared to LAGEOS
  - Results show improvement of products especially in the important up component
  - Discussion to make stations aware of this probably most important target for ILRS, designed for mm precision ranging???
- Linda Geisser talked about different techniques to determine/stabilize COM correction for LAGEOS
  - Request to submit +-5 sigma reduced full-rate data

- Carlo Calatroni developed a model to predict sunlight flashed from satellite AJISAI
  - Predctions shall be used to conduct time-transfer via laser pulse reflection on the curved mirrors

Summary session 9: New devices for Laser Ranging

5 presentations

Large-area High-speed SNSPDs for Laser Ranging (Wang Hao)

Optical time and frequency transfer over fiber and free-space (Hu Liang)

New RGG development for bistatic LLR system based on cRIO controller (Gao Jian)

Eventech Stream Time-Tagger ESTT (New Updates) (Viktors Kurtenoks)

Hollow Retroreflectors and Applications (Jing Hongwei)

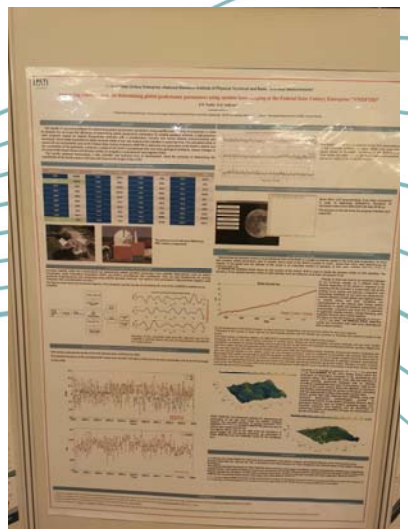
Summary of the Poster Program

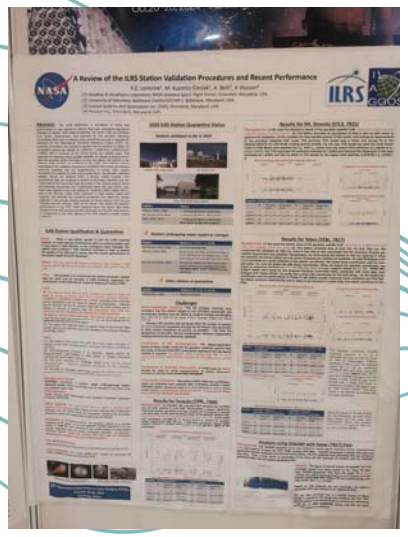
YANG Yongzhang
on behalf of
Kunming LOC

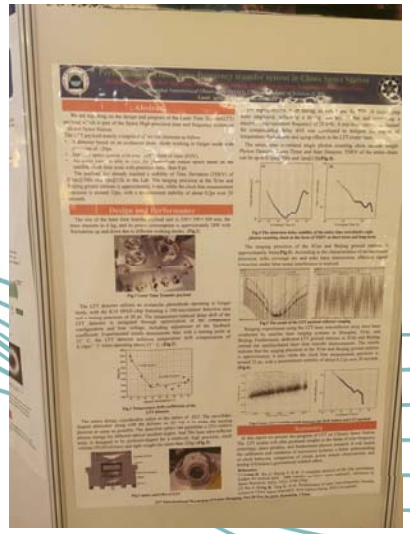
Overview

- ✓There are 21 Posters during the meeting,
- ✓Our discussions span various advanced applications of SLR in both scientific research and technological development.

Session A

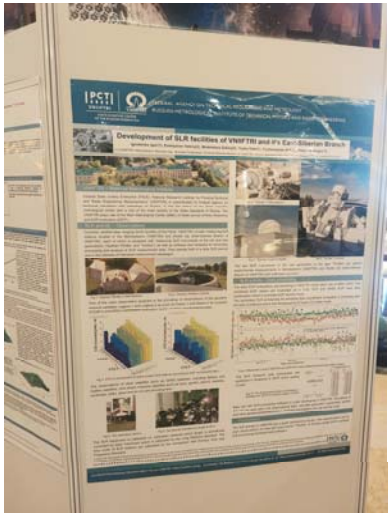


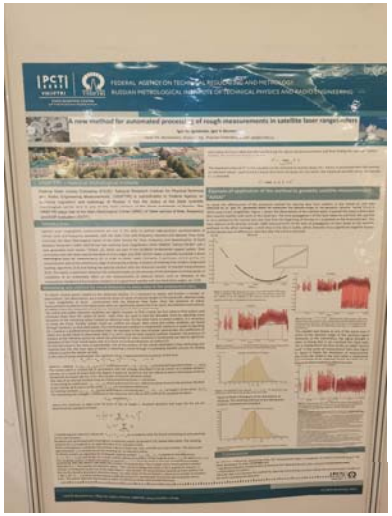

A Review of the ILRS Station Validation Procedures and Recent Performance
ILRS

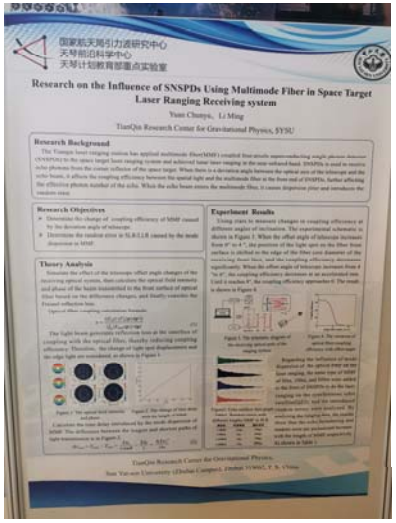


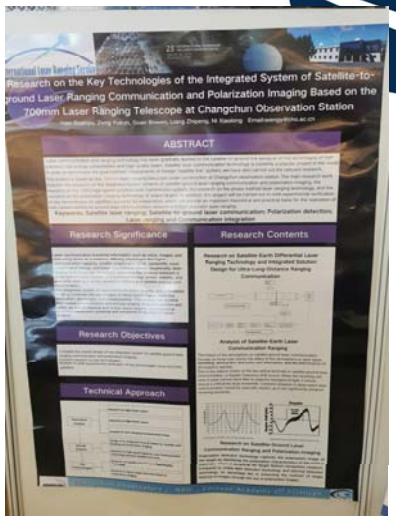

The Crustal Dynamics Data Information System (CDDIS) – SLR Updates
CDDIS

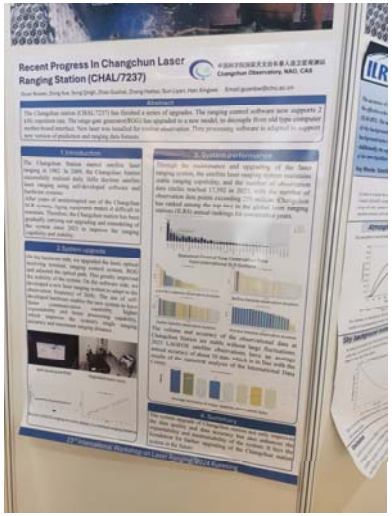
Session B

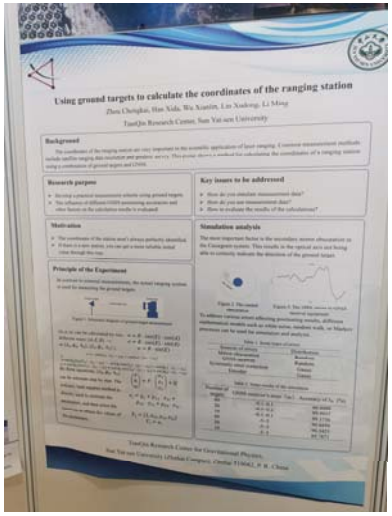

Development of SLR facilities of VNIIFTRI and it's East-Siberian Branch

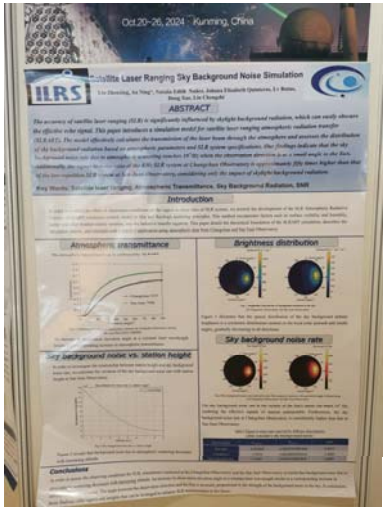

A new method for automated process of rough measurements in satellite laser ranger-rollers

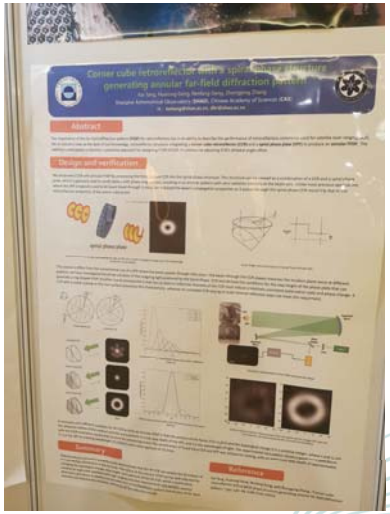

Research on the Influence of SNSPDs Using Multimode Fiber in Space Target Laser Ranging Receiving system
Research Background
Research Objectives
Theory Analysis
Experiment Results


Research on the Key Technologies of the Integrated System of Satellite-to-ground Laser Ranging Communication and Polarization Imaging Based on the 700mm Laser Ranging Telescope at Changchun Observation Station
ABSTRACT
Research Significance
Research Contents
Research Objectives
Technical Approach

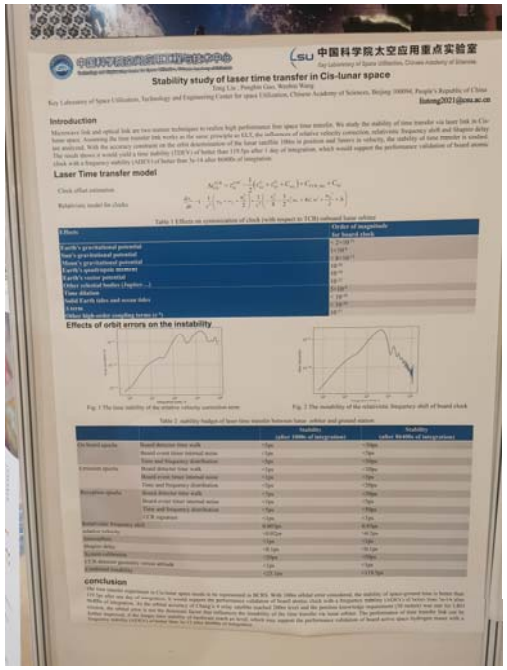

Recent Progress in Changchun Laser Ranging Station (CHAL/7237)

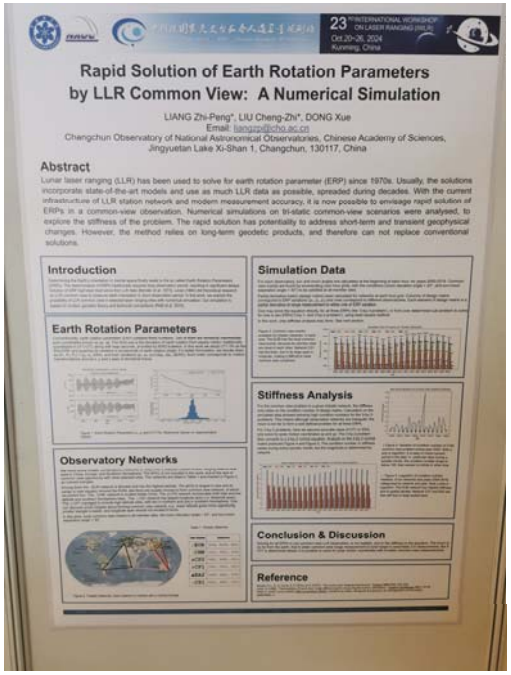

Using ground targets to calculate the coordinates of the ranging station

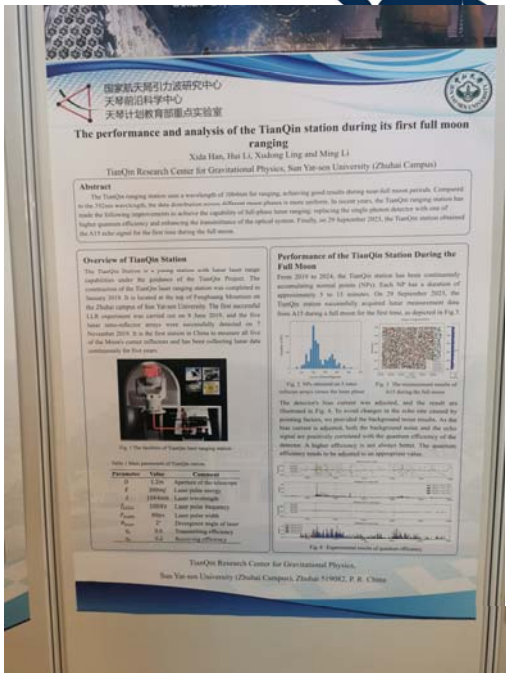

Oct.20~26, 2024 · Kunming, China
Satellite Laser Ranging Sky Background Noise Simulation
ABSTRACT
Introduction
Atmospheric transmittance
Brightness distribution
Sky background noise rate


Abstract
Design and verification
Summary
References

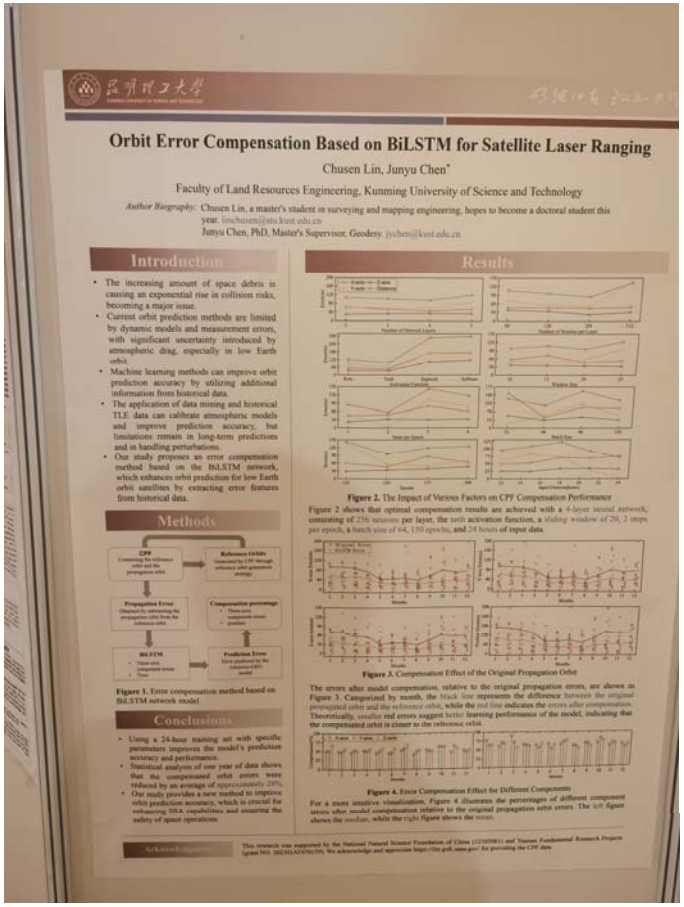
Session C


中国科学院太空应用重点实验室
Stability study of laser time transfer in Cis-lunar space
Introduction
Laser Time transfer model
Effects of orbit errors on the instability
conclusion


23 INTERNATIONAL WORKSHOP ON LASER RANGING (WLR)
Oct 20-26, 2024
Kunming, China
Rapid Solution of Earth Rotation Parameters by LLR Common View: A Numerical Simulation
LIANG Zhi-Peng*, LIU Cheng-Zhi*, DONG Xue
Email: liangzp@cho.ac.cn
Changchun Observatory of National Astronomical Observatories, Chinese Academy of Sciences, Jingyuetan Lake Xi-Shan 1, Changchun, 130117, China
Abstract
Introduction
Simulation Data
Earth Rotation Parameters
Stiffness Analysis
Observatory Networks
Conclusion & Discussion
Reference


国家航天局引力波研究中心
天琴前沿科学中心
天琴计划教育部重点实验室
The performance and analysis of the TianQin station during its first full moon ranging
Xida Hao, Hui Li, Xuduo Ling and Ming Li
TianQin Research Center for Gravitational Physics, Sun Yat-sen University (Zhuhai Campus)
Abstract
Overview of TianQin Station
Performance of the TianQin Station During the Full Moon
TianQin Research Center for Gravitational Physics,
Sun Yat-sen University (Zhuhai Campus), Zhuhai 519082, P. R. China

Session D



昆明理工大学

Orbit Error Compensation Based on BiLSTM for Satellite Laser Ranging

Chusen Lin, Junyu Chen*

Faculty of Land Resources Engineering, Kunming University of Science and Technology

Author Biography: Chusen Lin, a master's student in surveying and mapping engineering, hopes to become a doctoral student this year. linchusen@stu.kust.edu.cn

Junyu Chen, PhD, Master's Supervisor, Geodesy. jychen@kust.edu.cn

Introduction

- The increasing amount of space debris is causing an exponential rise in collision risks, becoming a major issue.
- Current orbit prediction methods are limited by dynamic models and measurement errors, with significant uncertainty introduced by atmospheric drag, especially in low Earth orbit.
- Machine learning methods can improve orbit prediction accuracy by utilizing additional information from historical data.
- The application of data mining and historical TLE data can calibrate atmospheric models and improve prediction accuracy, but limitations remain in long-term predictions and in handling perturbations.
- Our study proposes an error compensation method based on the BiLSTM network, which enhances orbit prediction for low Earth orbit satellites by extracting error features from historical data.

Methods

Figure 1. Error compensation method based on BiLSTM network model

Conclusions

- Using a 24-hour training set with specific parameters improves the model's prediction accuracy and performance.
- Statistical analysis of one year of data shows that the compensated orbit errors were reduced by an average of approximately 28%.
- Our study provides a new method to improve orbit prediction accuracy, which is crucial for enhancing SSA capabilities and ensuring the safety of space operations.

This research was supported by the National Natural Science Foundation of China (12103081) and Yunnan Fundamental Research Projects (grant NO. 202301AT070139). We acknowledge and appreciate https://ilrs.gsfc.nasa.gov/ for providing the CPF data.

Results

Figure 2. The Impact of Various Factors on CPF Compensation Performance

Figure 2 shows that optimal compensation results are achieved with a 4-layer neural network, consisting of 256 neurons per layer, the tanh activation function, a sliding window of 20, 2 steps per epoch, a batch size of 64, 150 epochs, and 24 hours of input data.

Figure 3. Compensation Effect of the Original Propagation Orbit

The errors after model compensation, relative to the original propagation errors, are shown in Figure 3. Categorized by month, the black line represents the difference between the original propagated orbit and the reference orbit, while the red line indicates the errors after compensation. Theoretically, smaller red errors suggest better learning performance of the model, indicating that the compensated orbit is closer to the reference orbit.

Figure 4. Error Compensation Effect for Different Components

For a more intuitive visualization, Figure 4 illustrates the percentages of different component errors after model compensation relative to the original propagation orbit errors. The left figure shows the median, while the right figure shows the mean.


Grazie!
شكرًا! !
Gracias!
Takk!
Thank you!
谢谢!
ありがとう!
Merci!
Dziękuję!
Спасибо!
Danke!
감사합니다!
Paldies!