EXPLORING THE MOON

3rd SPACE SCIENCE SCHOOL

HANDBOOK

October 17-24, 2023

Si Racha, Chon Buri, Thailand

CONTENTS

Editor/Graphic Design: Garfagnoli Francesca, ISSI-BJ

I am very much honored to share my views with you on the 3rd APSCO & ISSI-BJ Space Science School on "Exploring the Moon".

During and after the 1st Space Science School co-organized with ISSI-BJ on "How to design a Space Science Mission" in 2016, and the 2nd Space Science School co-organized with ISSI-BJ on "Study Space Weather Effects, From the Sun to the Ground" in 2018, we received a lot of positive feedback from participating students and young researchers from APSCO Member States. There always was a great demand for the 3rd Space Science School among our Member States, and now after the pandemic period, we are able to attend to this demand with an amazing topic.

Throughout the millennia, the Moon has always attracted the attention of mankind. In the mythology of almost every country, there is a unique place for this bright celestial neighbor. A fairy who lives on the moon is synonymous with mystery, beauty and purity. For thousands of years, to touch upon these mysteries, countless explorations have been made. Since the last century, we could really get close to it and understand it, scientifically. With all these in mind, we would like to organize a science school related to the Moon as an important platform for capacity-building through sharing a wide range of space knowledge and scientific data among young generations.

Thanks in large part to the efforts of the organizers, the participants of this school can look forward to a compelling program taught by leading experts in their field. They will also be presented with significant opportunities for hands-on work with the data and in-depth knowledge of the Lunar studies, observational methods and their relevance to applications.

Last but not the least, I would like to thank the main co-organizer of the school, ISSI-BJ for the outstanding collaboration in all aspects of the school, GISTDA for hosting the event and all the lecturers, tutors/mentors and other support staff in advance, for what I am sure will be a thoroughly engaging educational opportunity for all participants during this science school.

With my best wishes,

Dr. Mohammad Ebrahimi Seyedabadi
Director General of Education and Training
Asia-Pacific Space Cooperation Organization (APSCO)

I am most pleased and honored to write this message for this edition of our ISSI-BJ - APSCO Space Science biennial School on "Exploring the Moon".

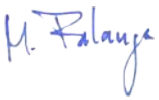
When back in 2013 we discussed for the first time the concept of the space science school, my vision was to organize for young space scientists and engineers a learning by doing school, specially focused on analyzing data from space. However, for the first edition, organized with a perfect and solid partner Asia-Pacific Space Cooperation Organization (APSCO), we decided to have a school on "How to design a Space Science Mission" based on lectures. High-level experts and well-recognized scientists, engineers, and space managers gave the lecturers. This was a highly successful school that left us with unforgettable memories, i.e., a master example of friendships and professional networking coming from a joint effort between d ifferent countries and expertise. At the end of the school everyone, students, lecturers, and organizers took the lessons learned back home.

ISSI-BJ and APSCO understood very fast, that it is time for the second and third editions of the school to involve the students more actively, learning by doing. So, now the school is based on general lectures about Exploring the Moon, but the second and main part is devoted to letting the students work hard on geological survey. Each group will produce a report, and all group reports will be merged and published after the school. The school will finish with the presentations of the groups' results.

I strongly hope that this school will build links between the students, lecturers, and tutors from different countries, where the students may have the potential to become leaders in the future, and collaborate with the sole goal of benefiting the science. Let's work all together to the benefit of the students, science, and to bring this school to a second successful millstone.

I would like to thank all the sponsors and supporters, and send warmly thanks to my very productive and efficient ISSI-BJ staff: Lijuan En and Francesca Garfagnoli, who with dedication, professionalism, and enthusiasm, contributed to organizing this school. I would like to extend my thanks and appreciation to APSCO and especially to Ebrahimi Seyedabadi Mohammad (Director General, Department of Education and Training and Database Management) and Charis Xiong (E&T Manager of Education and Training Department) for hosting this school.

Yours sincerely,



Prof. Maurizio Falanga,
Director
International Space Science Institute (ISSI)

It is my great privilege to address you as you are preparing to immerse yourselves in the third ISSI–Beijing/APSCO Space Science School on "Exploring the Moon". Our biennial joint Space Science Schools are now an established fixture of ISSI–Beijing programming. They have become highly valued by all involved—ISSI–Beijing, APSCO, our expert lecturers and, of course, all participants.

Although we had initially planned to organise a Space Science School on lunar science in 2020, the global COVID-19 pandemic forced us to postpone this in-person event to 2023. However, this unanticipated delay has actually had the unintended effect that the School's subject area is now highly topical.

At the time of this writing, China's presence on the lunar surface is well-established through its ongoing Chang'e programme, but other nations are vying for a seat at the table. Whilst Russia's Luna-25 mission sadly ended in a collision with the lunar surface, India recently became the fourth nation to successfully land a probe on the Moon, whereas our Japanese colleagues are eagerly anticipating the arrival and subsequent soft landing of its SLIM lunar vehicle, which was launched in early September 2023 jointly with the country's latest X-ray telescope, XRISM.

Meanwhile, our U.S. colleagues are eyeing a human return to the Moon later this decade, or perhaps early in the 2030s, whereas other emerging space nations have rekindled an interest in Solar System exploration beyond our home planet—yet those efforts might find it useful to have an established lunar base as an intermediate way-station.

That consideration is now back in the spotlight given the tentative discovery of (frozen) water ice in the densely cratered regions near the lunar south pole.

But don't forget that these meetings are also important stepping stones to establishing lifelong friendships and collaborations. Outside of your dedication to lunar exploration, make sure to get to know the other participants in an informal setting. After all, the young scientists of today will be the scientific leaders of tomorrow, and having extended international networks of colleagues, friends and acquaintances will make those developments (and, likely, your career progression) just that little bit easier.

To conclude, I wish you a great Space Science School! I would be remiss if I didn't acknowledge those colleagues who have made this School a reality, expertly led by Professor Maurizio Falanga, and including the ISSI–Beijing staff (Lijuan En, Yinong Li and Francesca Garfagnoli) and our colleagues at APSCO (particularly its Director General Education and Training, Ebrahimi Seyedabadi Mohammad)—as well as our sponsors who have generously supported the School's organisation. Thank you to all!

With my best wishes,

Prof. Richard de Grijs
Executive Director

International Space Science Institute-Beijing (ISSI-BJ)

ORGANIZERS & SPOSNSORS

International Space Science Institute - Beijing

The International Space Science Institute in Beijing (ISSI-BJ) was jointly established by the National Space Science Center (NSSC) and the International Space Science Institute (ISSI) with the support of the International Cooperation Bureau and the Space Science Strategic Project of the Chinese Academy of Sciences (CAS). ISSI-BJ is a close cooperation partner of ISSI in Bern. The two institutes share the same Scientific Program Committee, the same study tools, and other information of mutual relevance and interest. However, both use independent operational methods and different funding sources.

ISSI-BJ is a non-profit research institute. Our main mission is to contribute to the achievement of a deeper scientific and technological understanding of future space missions as well as of the scientific results from current and past missions through multidisciplinary research, possibly involving, whenever felt appropriate, ground based observations, modelling, numerical simulation and laboratory experiments, using the same tools as ISSI, i.e. Forums, International Teams, Workshops, Working Groups or individual Visiting Scientists.

The Program of ISSI-BJ covers a widespread spectrum of space science disciplines, including astrophysics, solar and space physics, planetary science, astrobiology, microgravity science and Earth observation from space.

Asia-Pacific Space Cooperation Organization

The Asia-Pacific Space Cooperation Organization (APSCO) was formally inaugurated in 2008 with the objective of peaceful uses of space by developing space applications, exploiting space technology and exploring space science for promotion of sustainable social-economic development and benefit of people in the Asia-Pacific region.

APSCO actively and continuously implements the collaborative activities following the organizational objectives and incorporating the interests and demands of all APSCO Member States. APSCO developed its mid-to-long term strategic implementation plan and implemented a number of engineering and joint research projects. APSCO regularly conducted the degree education and training programs, organized international symposiums and space law forums/workshops periodically, which laid the solid technical foundation of the future development of the organization and gathered rich experience of multilateral cooperation for resources sharing upon those efforts.

With accumulated knowledge and experiences, APSCO is now developing smoothly. In order to bring the common prosperity in the Asia-Pacific Region, APSCO will focus on the integration of current resources, infrastructures and program results to establish operational service networks such as education, data sharing, ground-based space observation, space technology application, disaster monitoring, and even satellite constellation and ground stations.

As an inter-governmental space cooperation organization, APSCO has already developed eight full Member States namely Bangladesh, China, Iran, Mongolia, Pakistan, Peru, Thailand, Türkiye, one Signatory State Indonesia, one Associate Member Egypt and one Observer State Mexico. APSCO is open to all the countries in Asia-Pacific region and even countries outside this region could join as associate members. It does believe, by pooling up the resources of space activities, the more Member States join APSCO family, the more efficient use and share of the space resources and greater benefits may be achieved.

SCHOOL OUTLINE & PROGRAM

About the School

This is the third joint space science school organized between the Asia-Pacific Space Cooperation Organization (APSCO) and the International Space Science Institute in Beijing (ISSI-BJ).

It is intended to promote a biennial School on space sciences for Master's and Ph.D. students, as well as post-doctoral and early career scientists or engineers.

This school will provide the participants with the in-depth knowledge of the science of the Moon, observational methods and its relevance to applications. The school will build links between participants and between teachers and participants in order to facilitate future collaboration on moon related researches.

Objectives of the School

The School will be divided in two Working Groups: the first will focus on "Understanding the Gravity Field of the Moon". Students from this Working Group will study the high-resolution data from the Gravity Recovery and Interior Laboratory mission, which have made it possible to investigate spatial variability of crustal porosity. The second Working Group will focus on "Field Geology of the Moon".
Students from this Working Group will study the topography of the moon, which consists of highlands, impact craters, and various volcanic features.

The School will also facilitate and initiate different discussions in an international and multi-disciplinary way; it will encourage creativity and provide the contacts for the participants to develop a professional network. International collaboration will also be an important theme at the school.

Structure

The school starts with one day and a half of invited speakers giving introductory lectures about exploring the Moon. After each lecture, there will be plenty of time for questions and discussion. The speakers are chosen among experts and well-recognized scientists and engineers with an excellent reputation in teaching and supervising participants.

The participants will be divided in two groups **to analyze evolution and geological events of the Moon.** Each group will have its own theme and agenda using actual observations, as well as computer models. Each group will produce a report, and all group reports will be merged and published after the school (see below). The different groups will be supported and guided by expert tutors. At the end of each day, a joint dinner is planned where the students, teachers, tutors, and organizers reflect on the day and interact with each other on a more social level. The school will finish with the presentations of the groups results to which feedback will be given from the other groups, as well as the teachers and tutors.

Equipment

Wi-fi connection will be available on the campus. However, all the participants are required to bring their own laptops in order to have access to all necessary experimental data, models, and literature through the Internet. The tutors will provide/indicate the data and models on-site to the students.

Time & Place

This is a 8-days School (Tuesday, October 17 - Tuesday, October 24, 2023). The school will take place at Sirindhorn Center for Geo-Informatics (SCGI) located in Space Krenovation Park (SKP).

Publications & Website

The presentations given by the different lecturers will be stored electronically on the School webpage and will be accessible to the School participants.

The final report will be published jointly with APSCO in the TAIKONG ISSI-BJ magazine.

After the School, this TAIKONG publication will be provided to all the School participants, sponsors, and will be widely distributed to the media.
Full information about available at: http:/www.issibj.ac.cnprogram/sss/3sss/abo/

Students Working Groups

Working Groups	Research Topics
Understanding the Gravity Field of the Moon	Gravity Analyses (Theory, Simulations, Observations with Data)
Field Geology of the Moon	Geology of the South Side of the Moon (Theory, Simulations, Observations with Data)

School Program

Tuesday, October 17

	Subject	Contributor
09:00 – 10:30	Registration	
10:30 – 11:00	Welcome Speeches and Introduction to the School	Apaphant Pakorn, Ebrahimi Mohammad, Falanga Maurizio
11:00 – 12:30	Introduction to the China's Lunar Exploration Program and New Insights of Water on the Moon from the Chang'E Missions	Zou Yongliao, Liu Yang
12:30 – 14:00	Lunch Break	
14:00 – 15:30	New Geological Insights from Chang'E Lunar Exploration Missions	Xiao Long
15:30 – 16:00	Group Photo & Coffee Break	
16:00 – 17:30	Introduction of Chang'E Data	Huang Jun

Wednesday, October 18

	Subject	Contributor
09:00 – 10:30	Impact Craters and Crater Chronology on the Moon	Xiao Zhiyong
10:30 – 11:00	Coffee Break	
11:00 – 12:30	The Shallow Subsurface of the Moon	Xu Yi
12:30 – 14:00	Lunch Break	
14:00 – 14:45	Understanding the Gravity Field of the Moon	Ding Min
14:45 – 15:30	Geodynamic Simulation of Post-impact Viscoelastic Relaxation on the Moon	Ding Min
15:30 – 16:00	Coffee Break	
16:00 –	Introduction of the Working Groups	Ebrahimi Mohammad, Falanga Maurizio

Thursday, October 19 / Friday, October 20

	Subject
09:00 – 12:30	Working Groups, Coffee Break Available at Any Time
12:30 – 14:00	Lunch Break
14:00 –	Working Groups, Coffee Break Available at Any Time

Saturday October 21

09:00 – 12:30	Working Groups, Coffee Break Available at Any Time
12:30 – 14:00	Lunch Break
14:00 – 15:00	Visiting Space Inspirium Laboratories of GISTDA
15:00 –	Free Time to Visit the Attractions Also: All Facilities are Available for the Group Works

Sunday, October 22

all day	Excursion With a Social Dinner

Monday, October 23

09:00 – 12:30	Working Groups, Coffee Break Available at Any Time
12:30 – 14:00	Lunch Break
14:00 –	Working Groups, Coffee Break Available at Any Time

Tuesday, October 24 (Chaired by Dr. M. E. Seyedabadi, Prof. M. Falanga)

09:00 – 10:00	WG1 Presentation
10:00 – 11:00	WG2 Presentation
11:00 – 11:45	Coffee Break
11:45 – 12:30	Final Remarks
12:30 – 14:00	Lunch

About the Organizers

Xiong Charis

E&T Manager of Education and Training Department
ASIA-PACIFIC SPACE COOPERATION ORGNIZATION (APSCO)

As one of the local staff members working in APSCO Secretariat for many years, it's still my first time organizing a Science School. Most of my previous work experience was in projects related to engineers and/or managers, and I rarely had the opportunity to participate in student-related activities. I am honored to collaborate with ISSI-BJ and grateful to the co-host provided by GISTDA for their help!

Garfagnoli Francesca

PR and Editorial Manager of ISSI-BJ

I'm very new to this reality and this is my first time attending a Space Science School. In these first few months at ISSI-BJ I was able to understand how important this type of events are. I hope that you'll be able to take as much as possible from the lectures, and put that knowledge into practice during the working groups. I also hope that you'll try and make as many connections as you can that could possibly help you in the future.

En Lijuan

Assistant to the Executive Director of ISSI-BJ

I cherish this opportunity to organize a Space Science School in Thailand. We will try our best to provide you with a platform for discussing and learning moon-related knowledge.
I am honored to collaborate with APSCO and grateful to the co-host provided by GISTDA for their help.
May all of us gain what exceeds our expectation!

Students Working Groups Outlines

Working Group 1: Understanding the Gravity Field of the Moon

Tutors: Ding Min, Deng Qingyun

Outline

The gravity field plays a pivotal role in shaping our understanding of the earth and other terrestrial planets, including the Moon. High-resolution gravity data from the Gravity Recovery and Interior Laboratory (GRAIL) mission (Zuber et al., 2013) have made it possible to investigate spatial variability of crustal porosity, depth-dependent megaregolith structure, and internal structures of small-scale geologic features from impact craters to lava tubes and rifts.
On the other hand, the long-wavelength gravity field unravels crustal and lithospheric structures on the Moon, and thus provide constraints to its thermal evolution. Comparison between the Moon and the other terrestrial planets help us obtain deeper insights into their internal structures and evolution histories and identify primary influencing factors. This working group aims to understand the lunar gravity field by focusing on different wavelengths and geologic features.

Main Topics

1. Gravity forward modeling and inversion for crustal thickness (Wieczorek et al., 2013)
2. Inversion for lateral (Wieczorek et al., 2013) and vertical variations (Besserer et al., 2014; Gong et al., 2016) of crustal density/porosity
3. Impact structures: Large impact basins (e.g., Neumann et al., 2015) and small impact craters (e.g., Soderblom et al., 2015)
4. Linear features: Procellarum border rift system (e.g., Andrews-Hanna et al., 2014) and lava tubes (e.g., Chappaz et al., 2017)
5. Comparison with other terrestrial planets (e.g., Wieczorek, 2015)

Main Tasks

LOLA topography: https://pds-geosciences.wustl.edu/missions/lro/lola.htm

GRAIL gravity model: https://pds-geosciences.wustl.edu/missions/grail/default.htm

SHTools (python or fortran): https://shtools.github.io/SHTOOLS/ (see Wieczorek & Meschede, 2018)

Additional references for gravity modeling and analysis: Parker, 1973; Oldenburg, 1974; Forsyth, 1985; Telford et al., 1990 (Chapter 2); Simons & Olhede, 2013; Wieczorek, 2015

Recommended Literature

- Andrews-Hanna, J. C., Besserer, J., Head Iii, J. W., Howett, C. J. A., Kiefer, W. S., Lucey, P. J., et al. (2014). Structure and evolution of the lunar Procellarum region as revealed by GRAIL gravity data. Nature, 514(7520), 68–71. https://doi.org/10.1038/nature13697
- Besserer, J., Nimmo, F., Wieczorek, M. A., Weber, R. C., Kiefer, W. S., McGovern, P. J., et al. (2014). GRAIL gravity constraints on the vertical and lateral density structure of the lunar crust. Geophysical Research Letters, 41, 5771–5777. https://doi.org/10.1002/2014GL060240
- Chappaz, L., Sood, R., Melosh, H. J., Howell, K. C., Blair, D. M., Milbury, C., & Zuber, M. T. (2017). Evidence of large empty lava tubes on the Moon using GRAIL gravity. Geophysical Research Letters, 44, 105–112. https://doi.org/10.1002/2016GL071588
- Forsyth, D. W. (1985). Subsurface loading and estimates of the flexural rigidity of continental lithosphere. Journal of Geophysical Research: Solid Earth, 90(B14), 12623–12632. https://doi.org/10.1029/JB090iB14p12623
- Gong, S., Wieczorek, M. A., Nimmo, F., Kiefer, W. S., Head, J. W., Huang, C., et al. (2016). Thicknesses of mare basalts on the Moon from gravity and topography. Journal of Geophysical Research (Planets), 121, 854–870. https://doi.org/10.1002/2016JE005008
- Neumann, G. A., Zuber, M. T., Wieczorek, M. A., Head, J. W., Baker, D. M. H., Solomon, S. C., et al. (2015). Lunar impact basins revealed by Gravity Recovery and Interior Laboratory measurements. Science Advances, 1(9). https://doi.org/10.1126/sciadv.1500852
- Oldenburg, D. (1974). The inversion and interpretation of gravity anomalies. GEOPHYSICS, 39(4), 526–536. https://doi.org/10.1190/1.1440444
- Parker, R. L. (1973). The rapid calculation of potential anomalies. Geophysical Journal International, 31(4), 447–455. https://doi.org/10.1111/j.1365-246X.1973.tb06513.x

- Parker, R. L. (1973). The rapid calculation of potential anomalies. Geophysical Journal International, 31(4), 447–455. https://doi.org/10.1111/j.1365-246X.1973.tb06513.x
- Simons, F. J., & Olhede, S. C. (2013). Maximum-likelihood estimation of lithospheric flexural rigidity, initial-loading fraction and load correlation, under isotropy. Geophysical Journal International, 1300–1342. https://doi.org/10.1093/gji/ggt056
- Soderblom, J. M., Evans, A. J., Johnson, B. C., Melosh, H. J., Miljković, K., Phillips, R. J., et al. (2015). The fractured Moon: Production and saturation of porosity in the lunar highlands from impact cratering. Geophysical Research Letters, 42(17). https://doi.org/10.1002/2015GL065022
- Telford, W. M., Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). Applied Geophysics. Cambridge University Press.
- Wieczorek, M. A. (2015). Gravity and Topography of the Terrestrial Planets. In Treatise on Geophysics (pp. 153–193). Elsevier. https://doi.org/10.1016/B978-0-444-53802-4.00169-X
- Wieczorek, M. A., & Meschede, M. (2018). SHTools: Tools for working with spherical harmonics. Geochemistry, Geophysics, Geosystems, 19(8), 2574–2592. https://doi.org/10.1029/2018GC007529
- Wieczorek, M. A., Neumann, G. A., Nimmo, F., Kiefer, W. S., Taylor, G. J., Melosh, H. J., et al. (2013). The crust of the Moon as seen by GRAIL. Science, 339(6120), 671–675. https://doi.org/10.1126/science.1231530
- Zuber, M. T., Smith, D. E., Watkins, M. M., Asmar, S. W., Konopliv, A. S., Lemoine, F. G., et al. (2013). Gravity Field of the Moon from the Gravity Recovery and Interior Laboratory (GRAIL) Mission. Science, 339(6120), 668–671. https://doi.org/10.1126/science.1231507

Working Group 2: Field Geology of the Moon

Tutors: Huang Jun, Wang Le

Outline

The Moon is Earth's only satellite. Since the short distance between the Moon and Earth, scientific observation and research on it began earlier than on other extraterrestrial bodies. Topography of the Moon primarily consists of highlands and maria, impact craters, and various volcanic features.

Identifying these geological features and creating related geological maps helps analyze the Moon's geological evolutionary history, providing a geological background reference for in-situ explorations. This working group will focus on identifying lunar surface features and mapping regional geological maps.

Main Topics

a. Introduction of QGIS
b. Mappy for geological mapping
c. Draw profile map

Main Tasks

The main tasks of the group will be to identify the geological features within the Von Kármán crater in the South Pole-Aitken Basin, draw regional geological maps and profile maps, and narrate the regional geological evolutionary history.

Date	Topic ID	Mission
Oct. 18	a	Introduction of the QGIS interface, and installation of related plugins. Basic practices of QGIS, including image loading, properties setting, image clipping, and drawing vector layers.
Oct. 19-21	b	OpenCraterTool + Craterstats for surface dating. Geological mapping by the QGIS plugin, Mappy.
Oct. 23	c	QGIS + Inkscape to draw profile map.

Data

The data for the geological mapping course includes the lunar surface elevation data and orthoimages obtained by China's Chang'e-1, as well as the lunar surface spectral data obtained internationally by Clementine. These data will be provided before the course.

Computer/Software Requirements

It is highly desirable that students bring their laptops with pre-installed QGIS, Inkscape, and IDL. Several plugins of QGIS are required to install, including qProf, OpenCraterTool, and Mappy. Craterstats2 is used to plot isochrons. We recommend installing QGIS 3.28 LTR (stable version), Inkscape 1.3 (stable version), and IDL >=8.7 (required by Craterstats2). But you can select the appropriate version according to your laptop. The system can be used including Windows, Mac, and Linux.

QGIS download link: https://www.qgis.org/en/site/forusers/download.html
Inkscape download link: https://inkscape.org/release/inkscape-1.3/
OpenCraterTool Download link: https://github.com/thomasheyer/OpenCraterTool
Mappy Download link: https://github.com/europlanet-gmap/mappy
Craterstats2.0 Download link: http://hrscview.fu-berlin.de/mex4/software/craterstats2/craterstats2.zip
IDL Download Link:
https://www.nv5geospatialsoftware.com/Product-Downloads/moduleId/19311/viewOrder/previous/controller/Item/action/Index

Recommended Literature

Students are encouraged to read the following literature and internet resources related to our group topics before the School:

Huang, J., Xiao, Z., Flahaut, J., Martinot, M., Head, J., Xiao, X., Xie, M., Xiao, L. (2018). Geological characteristics of Von Kármán crater, northwestern south pole-Aitken Basin: Chang'E-4 landing site region. Journal of Geophysical Research: Planets, 123(7), 1684-1700.

Ling, Z., Qiao, L., Liu, C., Cao, H., Bi, X., Lu, X., Zhang, J., Fu, X., Li, B., Liu, J. (2019). Composition, mineralogy and chronology of mare basalts and non-mare materials in Von Kármán crater: Landing site of the Chang'E– 4 mission. Planetary and Space science, 179, 104741.

Qiao, L., Ling, Z., Fu, X., Li, B. (2019). Geological characterization of the Chang'e-4 landing area on the lunar farside. Icarus, 333, 37-51.

Lu, Y., Wu, Y., Michael, G. G., Ma, J., Cai, W., Qin, N. (2021). Chronological sequence of Chang'E-4 landing zone within Von Kármán crater. Icarus, 354, 114086.

QGIS Documentation: https://docs.qgis.org/3.28/en/docs/user_manual/introduction/getting_started.html

PRACTICAL INFORMATION

Registration

Time: Tuesday, October 17, 09:00 - 10:30

Fee: Applicants under APSCO are fully supported. For all other participants the registration fee is 550 USD or 18.500 THB, which includes:

- 8 days of housing at the school, meals, social dinner, coffee breaks,
- transport from the airport to the school by van.

The payment of the fee will be done at arrival to the school at the registration desk, in cash only.

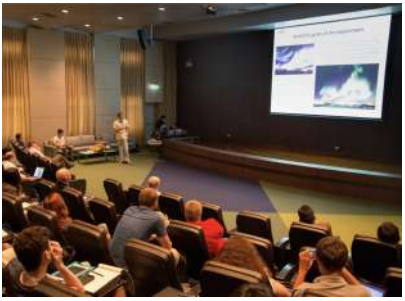
Venue

The school will take place at Sirindhorn Center for Geo-Informatics (SCGI) located in Space Krenovation Park (SKP).

Address:
Space Inspirium, Thung Sukhla, Si Racha District, Chon Buri, 20230, Thailand

Sirindhorn Center for Geo-Informatics (SCGI)

Sirindhorn Center for Geo-Informatics (SCGI) is established under the cooperation between the Ministry of Science and Technology of Thailand by Geo-Informatics and Space Technology Development Agency. It serves as an institute for research and knowledge in space technology and geo-informatics.



THE FOLLOWING COUNTRIES CAN ENTRY THAILAND VISA FREE FOR 30 DAYS UPON ARRIVAL:

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?sqrpg_* @_fp_gl*
@cjegsk* @p_xgj* @pslcg*
A_l_b_* Afgl_* Axcaf
Pcns`jga* Bclk_pi*
Cqrmlg_* Dglj_lb*
Ecpk_lw* Epccac*
Fmle lmle* Fsle_pw*
Gacj_lb* Glbmlcqg_*
Gpcj_lb* Gqp_cj* Gr_jw*
H_n_l* Pcns`jga md
lmpc_* lsu_gr* J_rtg_*
Jgcafrclqrcgl*Jgrfs_lg_*
Jsvck`mspe* K_j_qw_*
K_jbgtcq* K_spgrgsq*
Kml_am* Rfc
Lcrfcpj_lbq* Lcu
Xc_j_lb* Lmpu_w*
Mk_l* Ncps* Rfc
Nfgjgnngl cq* Nmj_lb*
Nmprse_j* O_r_p* Q_l
K_pglm* Q_sbg ?p_`g_*
Qgle_nmpc* Qjmt_i*
Qjmtclg_* Qmsrf ?dpga_*
Qn_gl* Qucbcl*
Qugrxcpj_lb* Rspicw*
Sip_glc* S?C* Sl* SQ?*
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Transportation

Transportation between the Bangkok Suvarnabhumi International Airport and Holiday Inn & Suites Siracha Laemchabang will be provided for all participants on their arrival and departure. A driver will pick up the participants at the Arrival Gate with a plate (below) with our logos.

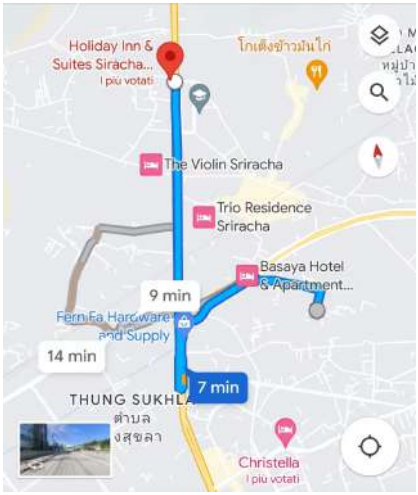
Lunch & Dinner

Lunch will be provided at the Cosmo Cafeto in Space Krenovation Park (SKP). Dinner will be arranged at Holiday Inn & Suites Siracha Laemchabang hotel. Meal coupons will be provided, please keep them carefully.

Useful Information

Credit Cards: Major credit cards such as Visa, Mastercard, JCB and American Express, are readily accepted at most hotels, airlines, restaurants and upscale merchants.

Currency: USD 1.00 = 31.57 THB (approximately)
EUR 1.00 = 39,14 THB (approximately)



Sirindhorn Center for Geo-Informatics

- 1 Auditorium (80 seats)
- 1 Canteen Room for Coffee Break and Lunch (80-85 seats)
- 2 Reception Rooms
- 1 Meeting Room for a Side Meeting (30-40 seats)

Accommodation

Holiday Inn & Suites Siracha Laemchabang, about 7 minutes by car from the venue.

Address:
12 Moo 7, Sukhumvit Road, Siracha, 20230, Thailand

Email:
DMKSR.RSVN@ihg.com

Telephone:
+66 (0) 33 251 699

Mobile:
+66 (0) 83 888 1515

For the taxi driver:

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Emergency Numbers

Tourist police 24-hour national call centre:
Pattaya tourist police: 038-429-371 1155
Call the tourist police to reach an English-speaking operator.

Police (General Emergency Call)	191
Ambulance and Rescue	1554
Medical Emergency Call	1669
Tourist Service Centre :	1672
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LECTURERS & LECTURES

Ding Min

Macau University of Science and Technology, China

Associate Professor at State Key Laboratory of Lunar and Planetary Sciences (SKLplanets), Macau University of Science and Technology, since 2023. Received Bachelor's degree from University of Science and Technology of China in 2009; and graduated from Massachusetts Institute of Technology / Woods Hole Oceanographic Institution Joint Program in 2015. Then worked as Postdoc Associate at MIT and Peking University, and joined SKLplanets in 2019. As a planetary geophysicist, she is intrigued by the interaction between long-term tectonic evolution and short-term catastrophic processes on terrestrial planets (Moon, Mars, and Earth. By combining computational geodynamics with geodetic observations, her research focuses on thermo-mechanical evolution of the lithosphere and its response to various external and internal loading processes (e.g., impacts, volcanoes and earthquakes) on time scales from minutes to millions of years. Personal website: www.dingmin.ink.

Lecture Title: Understanding the Gravity Field of the Moon

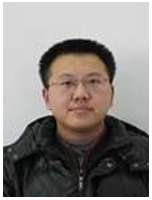
Abstract: The gravity field plays a pivotal role in shaping our understanding of the earth and other terrestrial planets, including the Moon. High-resolution gravity data from the Gravity Recovery and Interior Laboratory (GRAIL) mission have made it possible to investigate spatial variability of crustal porosity, depth-dependent megaregolith structure, and internal structures of small-scale geologic features from impact craters to lava tubes and rifts. On the other hand, long-wavelength gravity field unravels crustal and lithospheric structures on the Moon, and thus provide constraints to its thermal evolution. This lecture will cover the basics of gravity analysis and explain how these analysis techniques have been applied to the GRAIL gravity data to understand the internal structure and evolution of the Moon. Comparison between the Moon and the other terrestrial planets help us obtain deeper insights into their internal structures and evolution histories and identify primary influencing factors.

Lecture Title: Geodynamic Simulation of Post-impact Viscoelastic Relaxation on the Moon

Abstract: The Moon's surface is dominated by impact structures, making them the most prevalent geologic features. Experimental and theoretical attempts have mainly focused on the impact excavation and collapse that form the impact structures within hours. But over geologic timescale of millions of years, the lower crustal materials could continue evolving through viscous flow, especially for those impact basins formed early in the Moon's evolution history with a hot thermal state. Elastic deformation is also important for understanding the compensation states of impact basins. This lecture will show how we may couple thermal and mechanical analyses to simulate the post-impact viscoelastic relaxation for impact basins, which help us explain their crustal structures at present. This simulation could serve as an example to apply computational geodynamics to understand the lunar interior.

Huang Jun

Planetary Science at China University of Geosciences, China



Professor of Planetary Science at China University of Geosciences (CUG), Wuhan. He has worked on numerous Mars missions including China's Tianwen-1, the 2001 Mars Odyssey Thermal Emission Imaging System (THEMIS), Mars Global Surveyor Thermal Emission Spectrometer (TES), and Moon missions including Chang'E-3, Chang'E-4 and Chang'E-5. Jun participated in these science teams since pursuing his Ph.D. at China University of Geosciences (Wuhan), as a Postdoctoral Fellow at Arizona State University and now at CUG. His research focuses on the composition, physical properties and processes, and morphology of planetary surfaces, with an emphasis on Mars and the Moon. His research uses infrared spectroscopy and comparative planetary geology. He is very active in education and public outreach.

Lecture Title: Introduction of Chang'E Data and Geological Mapping of the Moon

Abstract: In the talk we delve into the multifaceted realm of lunar exploration data derived from the Chang'E missions. The presentation will provide an overview of the various types of data collected by the Chang'E missions with a particular focus on imaging and spectral data. Attendees will gain insights into the methodologies and techniques employed to process this invaluable data.

Furthermore, the talk will shed light on the intricate process of geological mapping of the Moon, emphasizing the utilization of multi-source remote sensing data. This session promises to offer a comprehensive understanding of the Chang' E mission's contributions to lunar studies and the advanced techniques in lunar geological mapping. Join us for a journey that bridges data acquisition from space missions to the detailed cartography of our celestial neighbor.

Liu Yang

National Space Science Centers, China

Professor at the National Space Science Center in of the Chinese Academy of Sciences (CAS). Professor Liu got his Ph.D. in Washington University in St. Louis and was a Urey fellow at Lunar and Planetary Institute (LPI) in Houston. Professor Liu serves as team members of a few China's space exploration missions including Chang'e series and Tianwen-1 missions. He was also a co-investigator on NASA's Lunar Reconnaissance Orbiter (LRO) mission, and he also participated NASA's Mars Reconnaissance Orbiter (MRO) mission and ESA's Mars Express mission. Professor Liu's research program is focused on understanding the formation and evolution of planetary surfaces by integrating remote sensing observations, quantitatively theoretical modeling, and laboratory spectroscopy.

Lecture Title: Introduction to the China's Lunar Exploration Program and New Insights of Water on the Moon from the Chang'E Missions

Abstract: Over the last decades the lunar science community has made significant progress in addressing key lunar science and exploration goals, while there are still critical scientific questions to be answered about the formation and evolution of the Moon. The International Lunar Research Station (ILRS) is a planned lunar base which will serve as a comprehensive scientific experiment base built on the lunar surface or in lunar orbit that can carry out multi-disciplinary and multi-objective scientific research activities including exploration and utilization, lunar-based observation, basic scientific experiment and technical verification, and long-term autonomous operation. The first part of this talk will introduce the planning and the scientific objectives of ILRS. The second part of the talk will give an introduction of the water detection on the Moon by Chang'E missions. Lunar volatiles have been one of the hot topics in the lunar study in the recent years. Understanding their origin, the form and their distribution is important for both understanding the evolution of the Moon and in situ resource utilization.

Xiao Long

Planetary Science Institute, China University of Geosciences, Wuhan ,China

He is one of the leading planetary scientists and educators in China. He established the Planetary Science Institute and launched a PhD program for planetary geology in China. He has been extensively involved in Chinese lunar and Mars exploration program, especially for scientific researches of returned data from Chang'e-2, Chang'e-3 and Chang'e-4, landing site selection and sample study for Chang'e-5, and scientific goals setting for China's Tianwen-1 and Tianwen-3 Mars exploration programs.

His research works include most endogenic and exogenic geological processes of terrestrial and celestial bodies, and mainly focus on volcanism and tectonism of the Moon, volcanism and water-related geological processes of Mars, extraterrestrial materials (meteorite, Chang'e-5 lunar soils), and analog study. He has published more than 230 per-reviewed papers and books, and has been awarded many research and teaching excellence awards.

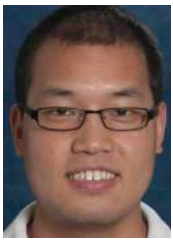
Lecture Title: New Geological Insights from Chang'e Lunar Exploration Missions

Abstract: China has successfully conducted five lunar explorations science 2007, including two orbiters (Chang'e-1 and Chang'e-2), two landers (Chang'e3-Yutu and Chang'e4-Yutu-2) and one sample return (Chang'e-5). Chang 'e-1 and Chang 'e-2 carried out imaging and material composition detection on the whole lunar surface from different orbital altitudes with various equipment, obtained high-precision images and digital elevation models covering the whole moon, obtained the distribution map of various major elements such as Si, Mg, Fe, and the lunar soil thickness on the whole lunar surface, etc. he Chang 'e-3 landed in the basalt area in the northern part of Mare Imbrium. The Yutu rover conducted accurate detection of the lunar soil composition at multiple locations along the way, and discovered new types of lunar soil. Ground penetrating radar data revealed that there were multiple volcanic eruption events in the area. Chang 'e-4 landed in the Von Karman Impact Basin on the far side of the moon.

The Yutu 2 lunar rover defected the composition and source of the lunar soil in the area, and ground-penetrating radar obtained the stratification characteristics of the subsurface structure, which provided new in situ data for understanding the geological evolution of the South Pole-Aitken basin on the far side of the Moon. Chang 'e-5 returned 1,731 grams of lunar soil samples, which recorded a young volcanic events about 2 billion years ago, as well as hydroxyl (water) formed by solar wind injection and complex space weathering processes on the Moon.

Xiao Zhiyong

Planetary Environmental and Astrobiological Research, Sun Yat-sen University, China



After receiving Ph.D training of planetary geology at China University of Geosciences (Wuhan) and the University of Arizona, Dr. Zhiyong XIAO did a postdoc at the University of Oslo and then worked at the Planetary Science Institute, China University of Geosciences (Wuhan) for 6 years as a lecture and then associate professor. During this time, Dr. Zhiyong XIAO was also hired by the Space Science Institute of Macau University of Science and Technology and invited as a visiting scholar to the University of Freiburg. Since 2019, Dr. Xiao worked at Sun Yat-sen University as an associate professor and then professor. He is currently the group leader of planetary geology and deputy director of the Planetary Environmental and Astrobiological Research Laboratory. Dr. Xiao takes an interdisciplinary approach to understand the physics behind planetary surface processes. Besides research duties on lunar and deep space missions (e.g., Chang'E-3, 4, and 5, Tianwen-1, and MESSENGER), the primary research interest of Dr. Xiao is impact cratering, mainly containing three parts: (1) study the impact history of solar system bodies, calibrate the age determination technique using crater statistics; (2) decipher unknown processes during impact cratering; (3) search for potential impact craters in China, especially the source crater of the Australasian Strewn Field of tektites and microtektites.

Lecture Title: Impact Craters and Crater Chronology on the Moon

Abstract: Lunar impact flux, collision rates of different-sized impactors in the Moon history, has long been a core pursuit in planetary sciences. This information connects planetary endogenic evolution with orbital dynamics of Solar System bodies, and the resulting crater chronology enables remote age estimation for geological units on exterrestrial bodies. Lunar features extremely low degradation rate and large expanses of exposure ages, and impact records are well preserved since the formation of the primary crust. Ubiquitous impact structures on the Moon and their widespread impact melt are the major agents used to untangle lunar crater chronology. Anchored by 10 successful sample return missions from the Moon, cumulative crater densities were derived for 15 terranes based on their interpreted exposure ages (~3.92 Ga to 25 Ma) and superposed crater densities.

Afterward, crater production rates in the entire history of the Moon were constructed based on hypothesized change patterns of impact flux. It is a common consensus that lunar impact flux before ~3.8 Ga was orders of magnitude larger than that afterward, and the latter was more-or-less stable but punctuated by discrete spikes.However, different versions of lunar crater chronology exist, due to insufficient constrains by available anchor points and widespread disagreements on both sample ages and crater densities of existing anchor points. Endeavors from various disciplines (e.g., sample analyses, remote observation, and modelling crater formation and accumulation) are making prominent progresses, future sample returns with optimized sampling strategy and analyzing techniques are appealed to fundamentally improve the impact flux.

Xu Yi

Macau University of Science and Technology, Macau, China

Currently an associate professor of the State Key Laboratory of lunar and planetary sciences at Macau University of Science and Technology (MUST). She obtained her PhD from the University of Pittsburgh in the US and then joined MUST in Macau. She was a visiting scholar at the University of California, Los Angeles in 2017. Her current research area is planetary surface processes and mainly focuses on subsurface stratigraphy and property inversion of subsurface materials based on the data of ground penetrating radar equipped on a rover or spaceborne radar of the ongoing Chinese missions. She is also studying the geomorphologic features of landforms on the Mars and Earth. She is a member of the scientific team of the Chang'E series lunar missions and the Tianwen-1 martian mission. She has participated in the pre-study of the future lunar polar exploration mission.

Lecture Title: Shallow Subsurface Structure of the Moon

Abstract: Most surface on the Moon is covered by a weathering layer (regolith or soil). The properties and fine-resolution structure of the regolith layers in this airless planetary body are the results of surface processes that developed over millions/billions of years.

Lunar rovers of Chinese Chang'e-3 and Chang'e-4 missions are equipped with ground-penetrating radar (GPR) that can reveal high-resolution near-surface structural and dielectric characteristics using two different frequency channels. The detection range of the high-frequency channel is ~ 10 m,

while the low-frequency one can probe deeper, down to hundreds of meters, to constrain the local geologic history. In this talk, I will introduce the observations and results of the GPRs from two missions that landed on two sides of the Moon separately.

The permanently shadowed regions at the lunar poles, believed to potentially harbor water ice, have emerged as hotspots for future exploration programs. I will also present findings of various remote sensing instruments, including radar from years of observations in these areas.

Student Groups Tutors

Deng Qingyun

Wuhan University, China

He has a Bachelor's degree in Engineering Surveying, School of Geodesy and Geomatic, Wuhan University, and a Ph.D. in Geodesy and Surveying Engineering, State Key Laboratory of information Engineer in Surveying, Mapping and Remote Sensing, Wuhan University. Since 2021, he has been working as Postdoctoral Fellow (Assistant Researcher) at State Key Laboratory of information Engineer in Surveying, Mapping and Remote Sensing, Wuhan University (Supervisor: Prof. Li Fei and Prof. Yan Jianguo).

His research topics are: The gravity field model of Mercury and its implications; High degree gravity field and shallow sub-surface structures of the Moon; Lithosphere structures and thermal evolution of terrestrial planets; Tidal response and interior structures of terrestrial planets and icy satellites.

Wang Le

China University of Geoscience (CUG), China

A doctoral student of Planetary Geology at the China University of Geoscience (CUG), Wuhan. His research focuses on the morphology of planetary surfaces. His research uses the remote sensing data acquired by China's Tianwen-1 and international Mars exploration missions to carry out the Martian geologic mapping, and measurement of surface morphologies. He has measured the morphology and analyzed origin of pitted cones, mesa, and small mounds in the Zhurong landing region. Relevant research results have been published in internationally renowned SCI journals.

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4	Enkhjargal	Odbaatar	Institute of Geography and Ecology, Mongolian Academy of Sciences, MONGOLIA
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2	Wang	Le	China University of Geosciences, Wuhan, CHINA

Lecturers

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2	Huang	Jun	China University of Geosciences, Wuhan, CHINA
3	Liu	Yang	National Space Science Center, CHINA
4	Xiao	Long	China University of Geosciences, Wuhan, CHINA
5	Xiao	Zhiyong	Sun Yat-sen University , CHINA
6	Xu	Yi	Macau University of Science and Technology, CHINA

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