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Preface

New advances in interdisciplinary observation and understanding of the solar system

1. Background

Nowadays, planetary science has become a significant interdisciplinary field of research with the advances in space exploration and ground based studies (Jin et al., 2011, 2013), which ventures far beyond the solar system to include planets around other stars. Detailed characterization of planetary environments within and beyond our Solar System requires collaborative studies across the fields of geology, atmospheric science, geophysics, geodesy, seismology, aeronomy, planetary origins, chemistry and astrobiology (Jin and Park, 2006; Jin et al., 2013; Jin and Zhang, 2014).

Spacecraft missions on planetary exploration and sciences have been heating up in recent years. For Mars, the NASA Mars Atmosphere and Volatile EvolutioN (MAVEN) and ESA ExoMars and its lander have been on their mission orbit, which were designed to investigate the Martian atmosphere, especially trace volatiles such as H2O and CH4. The evolution and pattern of the Martian climate, astrobiology, and the vanishing of the magnetic field of Mars are expected to be revealed or examined by these observations. Measurements and results from the missions provide initial reference to the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) Mission that was about to study the interior of the red planet. For the Moon, the Chinese Chang'E series, NASA's ongoing LRO mission have achieved multi-objectives across the above field. For Venus, the atmosphere and the surface-atmosphere interaction was studied by ESA's Venus Express and JAXA's Akatsuki mission. For the outer planets, the Juno mission has made comprehensive observations to Jupiter since 2011. Other fly-by missions were also conducted to investigate the gravity field of the planets.

Several main challenges have been identified for these and future missions. For the engineering part, the mass of the probes, the tracking and communication between the ground station and probes, and the mission duration especially to the outer planets pose significant challenges for interplanetary missions. For the scientific part, many fundamental parameters and observations, which are the key to a deeper understanding of these planets, are still unconstraint or poorly known due to couple of reasons. For example, the surface and the interior structure of the far-side of the Moon are not well explored and observed by scientific instruments. The wind field, the direct evidence of liquid water, and the interior of Mars are still poorly constrained. The lower atmosphere and surface of Venus are not well-understood due to limited observations. The research for the outer reach of the solar system beyond Saturn is solely relying on limited observations during the fly-by of spacecrafts.

The 1st IUGG Symposium on Planetary Science (IUGG-PS2017): Interdisciplinary observation and understanding of the Solar System was held on July 3–5, 2017, Berlin, Germany with aver 120 participants (Fig. 1). The IUGG-PS2017 aims to bring together international scientists and engineers focused on an interdisciplinary work on exploration and science of the solar system and seeking life beyond Earth. Topics include planetary geodesy, remote sensing, atmosphere, ionosphere/plasma physics, magnetic and gravity field, geomorphology, geophysics, geodynamics, geology, petrology, volcanology, geochemistry, interior physics, Life & Astrobiology. All objects from the terrestrial and giant planets to exoplanets, including small bodies are welcomed. The IUGG-PS2017 was sponsored by the IUGG Union Commission on Planetary Sciences (UCPS), International Association of Planetary Sciences (IAPS) and German Aerospace Center (DLR). The UCPS was established by the Executive Committee of International Union of Geodesy and Geophysics (IUGG) in June 2015 to advance emerging and existing interdisciplinary research on planetary sciences.

2. New results and advances

2.1. Orbit determination and navigation

This Special Issue contains nine papers, covering lunar gravity-crustal structure, new interplanetary navigation method, precise orbit determination of Mars orbiter, mineral composition and crystalline hydrate analysis of Mars local region, water flow system and transport agents on Mars, impact craters simulation, the solar wind payload on Aditya-L1. These papers were from an open call to the scientific community and a special call for participants at the 1st IUGG Symposium on Planetary Science (IUGG-PS2017): Interdisciplinary observation and understanding of the Solar System.

New results and advances are obtained by these researches. The current Precise Orbit Determination (POD) methods and future techniques for Mars and interplanetary spacecraft are evaluated. Yan et al. (2018) evaluated the performance of using VLBI and Doppler data to determine the Mars orbiter and lander. Three observational models and their geometry are given in terms of same-beam VLBI, four-way/three way Doppler observations. The proposed tracking models are validated by computer simulations by using Mars Gravity Recovery and Analysis Software (MAGREAS) and the supercomputer resources from Wuhan University. The location of ground station, the perturbations of the dynamical core, and the occultation of Earth and Mars are considered to simulation the real situations. The results show that all of the three tracking models can give effective positioning results to the landers with accuracy of 60 m and within 1 m, respectively. The orbit precision of the orbiter cannot be improved by the same-beam VLBI due to lack of ranging constraints. The combination of four-way Doppler with the VLBI equals

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Fig. 1. A group picture of participants to the 1st IUGG Symposium on Planetary Science (IUGG-PS2017).

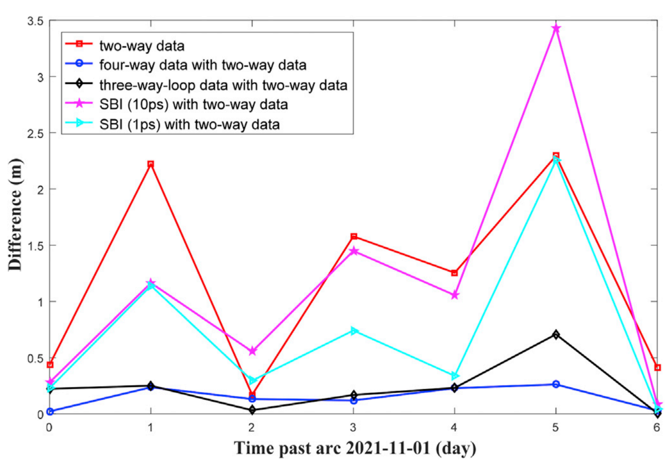

Fig. 2. Initial orbit position difference between solutions and true one (Gravity field model error and measurement bias are not considered). The difference is the total discrepancy from initial orbit position in J2000 frame.

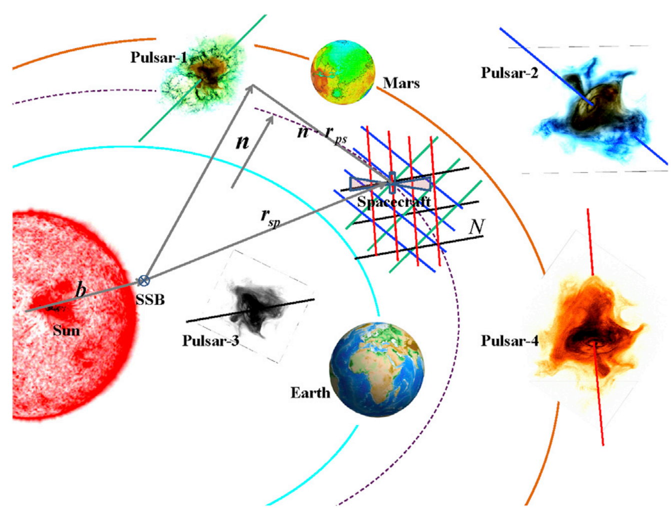

Fig. 3. Absolutely Navigation of XNAV by multiple X-ray Pulsars.

to integrate the angle with the ranging measurements, which the positioning accuracy for both the orbiter and lander could achieve to meter levels. The three-way loop Doppler model, which has the strongest geometric configuration as illustrated by the paper, has similar performance with the combination modes. Thus, the three-way loop is highly recommended for the future Mars Missions.

In order to show the contribution of these methods in orbit determination clearly, the initial orbit position difference between solutions and true one was generated in Fig. 2. The orbit accuracy is improved after adding these data, except for same-beam differential VLBI with 10 ps noise. The highest and most stable orbit determination accuracy can be reached by adding four-way data or three-way loop data. The three-way loop Doppler and two-way Doppler shows high stability in the orbital accuracy as compared with the solution from two-way Doppler data alone. The improvement was similar to that from the fourway data.

The traditional tracking models provide time-delay, ranging/ranging rate, and Doppler by ground VLBI and Radar system, with the tracking-communication system being heavily oversubscribed and the navigational accuracy strongly dependent on the growing ground-probe distance. New techniques are proposed and evaluated in terms of simulation using nonlinear Kalman Filter to complete interplanetary navigation tasks (Wei et al., 2013; Liu et al., 2017). The XNAV, optical method, and gravity-aided odometry are investigated to conduct spacecraft navigation and rover absolute positioning. The impact of the changing of visible X-ray Pulars to the XNAV system have been investigated (Fig. 3) and it is determined that the appropriate number of the Pulsars the detector should scan is 4 (Liu and Jin, 2018). The worst performance for this combination is within 2.5 km. The accuracy varies from 150 km to several tens meters during the scanning target number changing from 3 to 7, which indicates the physical nature of the Pulsars have huge impact on the XNAV performance. For an integrated system, the optical system has no accuracy contribution to the system performance but could provide robust solution during the breaking of XNAV system. The Gravity-aided odometry for rover positioning can be accurate to 300–400 m, which

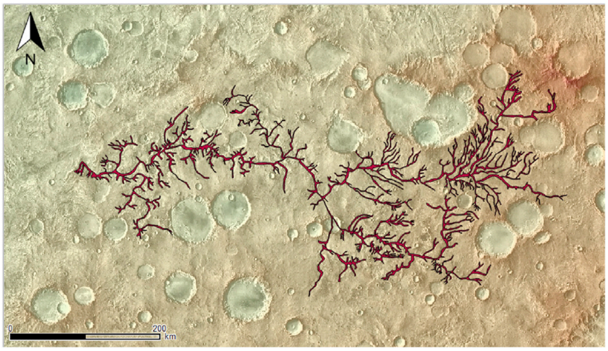

Fig. 4. Map of *Evros Vallis* (Valley ID 46) centred around 12.0°S 13.9°E. In red is shown the area of the large polygon obtained by means of QGIS joining a large number of smaller polygons (see text). Since the sides of these polygons must follow as precisely as possible the valley outer walls, they are not visible at this scale (Orofino et al., 2018).

are tested by different matching algorithms. The XNAV system have vast prospect to promote planetary science.

2.2. Planetary environment and geology

The Mars geology evolutions and its relationship with astrobiology are interesting topics which have vital importance to understand Mars. Several minerals that are vulnerable to weathering and hydrothermal effects are identified in Mars Gale and Nili Fossae regions. The research uses MRO CRISM near-IR image to describe the large-scale distribution of these minerals. The mafic are wide distributed on the surface. Additionally, the hydrated and carbonates minerals are dominated around the riverbed. Six hydrous minerals are found which suggested there a habitable environment might have existed on Mars. The complex composition of the Gale regions indicates the area experienced complex and long-term weathering changing and evolution. Specifically, the gypsum abundances at Columbus crater on Mars are investigated by Liu (2018). The gypsum, bassanite, and anhydrite are analyzed in Raman, mid-infrared (mid-IR), and near infrared (NIR) spectroscope in ground lab. The data are used compare with the CRISM albedo data in Columbus crater to identify these hydrates. The results indicate the abundance of gypsum approximates to 55%, which is very high compare with the poly- and mono-hydrated sulfates (20%–25%). The results also support exist of liquid water during the ancient time.

Kapui et al. (2018) investigated the origin of the Mars sediments grains using Earth analogue observations, which the results are prepared for the ExoMars 2020. The sentiments samples are from desert and river in Hungry and Iceland. The particulate sediments, which analogues to the Mars surface sentiments are investigated in terms of degree of sorting, the grain diameter/perimeter ratio, the circularity and convexity of particles. The results show the aeolian sediments are always having high diameter/perimeter ratio, which means mature state. Grain size and shape parameters are potential indexes to separate fluvial with aeolian grains. The high-resolution ExoMars CLUPI camera could distinguish grain sizes into 100–200 mm, which is suitable to study the Mars sediments origin.

Orofino et al. (2018) estimated the flow duration of the Mars ancient fluvial systems by 63 valleys identified by CTX data. The valleys with interior channel, which include 13 riverbeds, were first evaluated by four-level sediment discharges using transport models. The formation time is evaluated from the geometrical parameters of the interior channels, which can be acquired from these high-resolution CTX data. The erosion rates are estimated based on the formation time. The formation time of the rest 50 valleys are estimated by using the mean erosion rates from the first 13 valleys. Results show that these flows are neither continued water nor water with 0.1% intermittence. Consequently, the flows have formation time from 5×104 to 8×109 yr with 1%–5%

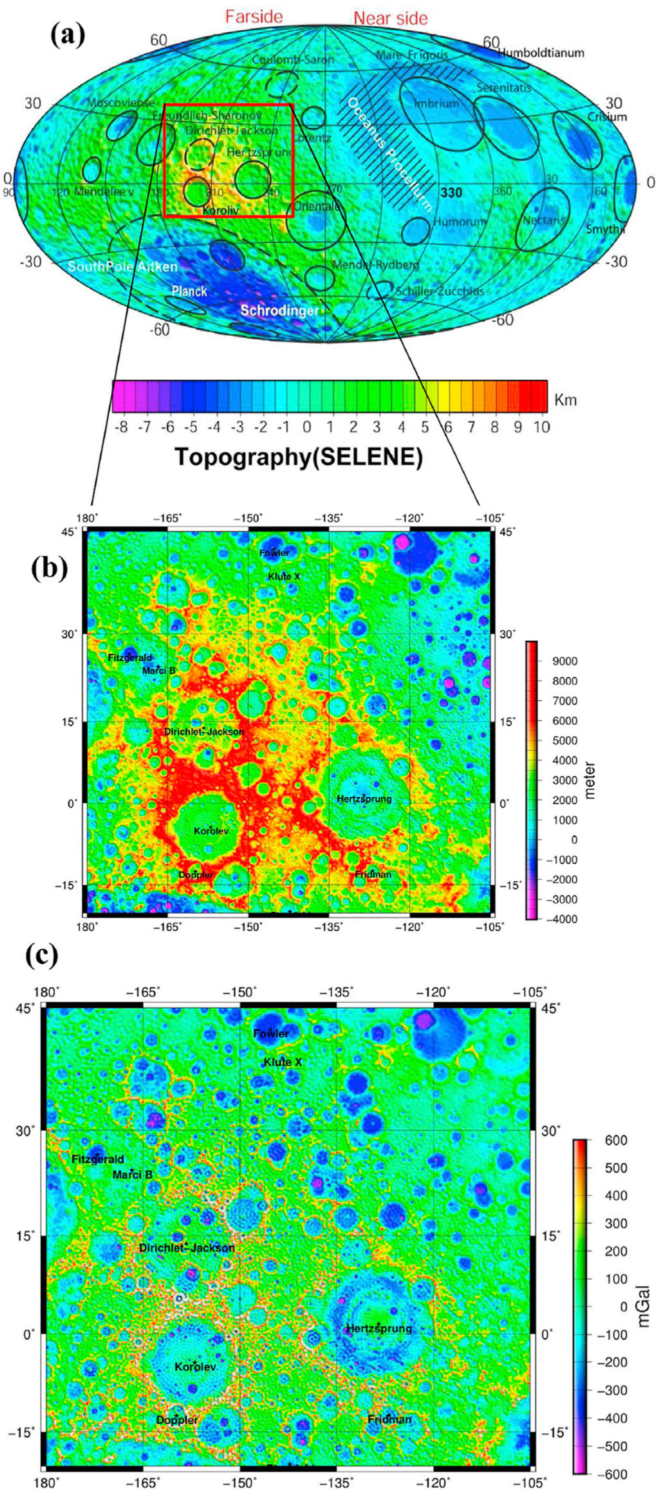

Fig. 5. a) Global topographic map of the Moon, which is plotted in Hammer's projection centred at 270°E longitude, showing the near and far sides of the Moon on either side. b) Topographic map (c) Free-air gravity anomaly maps of the study region covering the Dirichlet-Jackson, Korolev, Hertzsprung Basins of Farside and adjoining regions of highlands (Satya Kumar et al. (2018).

intermittence. The results support warm and water flow climate during the Noachian Mars. For example, The result for a valley of sample group (Evros Vallis, Valley ID 46) is shown in Fig. 4.

Satya Kumar et al. (2018) used gravitational and topographic observations to look into the crustal structure of the lunar far-side highland, where surface data are not observed. Firstly, the Bouguer crustal density is deduced by fractal-based method due to the nature of gravity and topography. The Lunar gravity model GRAIL900C intercept to degree and order 600 and high-resolution lunar topography are used to determine global Bouguer gravity anomalies map. Fig. 5 shows the topography and Free-air gravity anomaly maps of the studied region extracted up to degree and order 660. The Effective Elastic Thickness (EET) of the region is estimated by analysis the correlation between the gravity anomalies and the topography. The regional gravity anomalies are also deduced at same time. The crust thickness is estimated by inversing the gravity anomalies. The gravity anomalies of the region can be caused by inner high-density mass. These results also can be used to detect invisible craters in this region.

An exquisite experiment was conducted by Kadono et al. (2018) to reveal the spallation propagation of the impact on a cylindrical target. The breaking point is deduced from the experiments with the ratio of projectile and the target radii equals to 1/20 the crater size will be enlarged sharply. The simulation also confirms the results. The research has strong applications in planetary sciences such as estimations the projectiles size based on the crater size. The research of crater characteristic of planetary bodies can also benefit from this paper.

2.3. Planetary exploration technology

Goyal et al. (2018) introduced the Solar Wind Particle instruments onboard the Aditya-L1 mission which will be conduct by India. The instrument includes two sub-systems in terms of Solar Wind Ion Spectrometer and the SupraThermal & Energetic Particle Spectrometer. The instruments will be sent to the Sun-Earth L1 point to measure the Solar winds & partials and its coupling effects with the interplanetary medium. The instruments structures are introduced in detail. The ground tests show the instruments could complete its science goals as well as promote the research of understanding solar wind the its impact on near-Earth environments.

3. Summary

The papers in this issue of Planetary and Space Science present the recent progress in interdisciplinary observation and understanding of the Solar System, including navigation, geology, geophysics planetary origins, chemistry and astrobiology of the Moon and Mars, and scientific payload introduction. These results include lunar gravity-crustal structure, new interplanetary navigation method, precise orbit determination of Mars orbiter, mineral composition and crystalline hydrate analysis of Mars local region, water flow system and transport agents on Mars, impact craters simulation, and the solar wind payload on Aditya-L1.

References

Goyal, S.K., Kumar, P., Janardhan, P., et al., 2018. Aditya Solarwind Particle EXperiment (ASPEX) onboard the Aditya-L1 mission. Planet. Space Sci. 163, 42–55. https://doi.org/10.1016/j.pss.2018.04.008.

Jin, S.G., Zhang, T.Y., 2014. Automatic detection of impact craters on Mars using a modified adaboosting method. Planet. Space Sci. 119, 112–117. https://doi.org/10.1016/j.pss.2014.04.021.

Jin, S.G., Arivazhagan, S., Araki, H., 2013. New results and questions of lunar exploration from SELENE, Chang'E-1, Chandrayaan-1 and LRO/LCROSS. Adv. Space Res. 52 (2), 285–305. https://doi.org/10.1016/j.asr.2012.11.022.

Jin, S.G., Park, P.H., 2006. Strain accumulation in South Korea inferred from GPS measurements. Earth Planets Space 58 (5), 529–534. https://doi.org/10.1186/BF03351950.

Jin, S.G., Zhang, L.J., Tapley, B.D., 2011. The understanding of length-of-day variations from satellite gravity and laser ranging measurements. Geophys. J. Int. 184 (2), 651–660. https://doi.org/10.1111/j.1365-246X.2010.04869.x.

Kapui, Z., Kereszturi, A., Kiss, K., Szalai, Z., Újvári, G., Hickman-Lewis, K., Foucher, F., Westall, F., 2018. Fluvial or aeolian grains? Separation of transport agents on mars using earth analogue observations. Planet. Space Sci. 163, 56–76.

Kadono, T., Suzuki, A.I., Araki, S., et al., 2018. Investigation of impact craters on flat surface of cylindrical targets based on experiments and numerical simulations. Planet. Space Sci. 163, 77–82.

Liu, J.D., Wei, E., Jin, S.G., 2017. Cruise orbit determination of Mars from combined optical celestial techniques and X-ray pulsars. J. Navig. 70 (4), 719–734. https://doi.org/10.1017/S0373463316000874.

Liu, J., Jin, S.G., 2018. Evaluation of Mars probe positioning using X-ray pulsars, celestial, gravity-aided and ground-based measurements. Planet. Space Sci. 163, 14–34.

Liu, Y., 2018. Raman, Mid-IR, and NIR spectroscopic study of calcium sulfates and mapping gypsum abundances in Columbus crater, Mars. Planet. Space Sci. 163, 35–41.

Orofino, V., Alemanno, G., Di Achille, G., Mancarella, F., 2018. Estimate of the water flow duration in large Martian fluvial systems. Planet. Space Sci. 163, 83–96.

Satya Kumar, A.V., Raja Sekhar, R.P., Tiwari, V.M., 2018. Gravity anomalies and crustal structure of the Lunar far side highlands. Planet. Space Sci. 163, 106–113.

Wei, E., Jin, S.G., Zhang, Q., Liu, J., Li, X., Yan, W., 2013. Autonomous navigation of Mars probe using X-ray pulsars: modeling and results. Adv. Space Res. 51 (5), 849–857. https://doi.org/10.1016/j.asr.2012.10.009.

Yan, J., Yang, X., Ye, M., Li, F., Jin, S.G., Jin, W., Barriot, J., Li, H., 2018. New tracking modes and performance for Mars spacecraft orbit determination and lander positioning. Planet. Space Sci. 163, 5–13.

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