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Editorial: Recent progress from lunar, mars and asteroid missions

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Editorial on the Research Topic
Recent progress from lunar, mars and asteroid missions

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Space science and engineering is a rapidly developing field that aims to explore the mysteries and potentials of the celestial bodies in our Solar System and beyond. In this Research Topic, we review some of the recent progress from lunar, Mars and asteroid missions, including the orbital design and optimization for the Cis-Lunar space station, the long-term orbital evolution of hierarchical three-body systems, the near-surface temperature reconstruction and simulation at the Zhurong landing site on Mars, the automated detection and analysis of lunar wrinkle ridges, and the gravity calculation and secular motion analysis of an orbit around a cube. The applications of the phasing analysis, the automated LWRs detection process, the observation-based temperature field simulation and the semi-analytical model (based on the averaging technique) can help to explore the dynamics, thermodynamics, and geology of these bodies, and reveal some new features and effects that can help us understand the origin, evolution, and future of these bodies.

One of the challenges in space exploration is the orbital design and optimization for the Cis-Lunar space station, which is a proposed human outpost in the vicinity of the Moon. The phasing orbit on the distant retrograde orbit (DRO) is one of the ideal candidate deployment orbits for the space station and even the deep space exploration transfer station. The DRO is a periodic orbit around the second Lagrange point (L2) of the Earth-Moon system, which has long-term stability and low fuel consumption. Fu et al. proposed (2023) a multi-impulse phasing rolling solving method can reduce the offset of the end position of the DRO phasing orbit and create suitable initial conditions for orbiting, rendezvous, and docking operations. This multi-impulse phasing method can improve the accuracy and feasibility of DRO phasing.

Another challenge is to understand the long-term orbital evolution of hierarchical three-body systems, which are relevant for astrophysical and astrodynamical contexts such as planets in stellar binaries, irregular satellites in planetary systems, and artificial probes about binary asteroid systems. These systems exhibit rich evolutionary behaviors under the effects of various perturbations, such as large-amplitude oscillations of the eccentricity and inclination, orbit flips between prograde and retrograde, chaotic transitions between different regimes, and even collisions or ejections.

Fu et al. found a general dynamical model incorporates the J2 of the central body and the inclined eccentric third-body perturbation to the hexadecapole order with its non-spherical gravity also included. The J2 is a measure of the oblateness or flattening of a body due to its rotation. This model can capture more realistic features than previous models that only consider lower-order terms or neglect some effects. This model can reproduce some observed phenomena such as orbit flips and high eccentricities, as well as reveal some new features and effects that could not be captured by lower-order models.

A third challenge is to model the temperature field near the Martian surface, which is critical for many scientific exploration tasks, such as detecting liquid water and analyzing the existence of saline ice. Meteorological conditions on Mars are highly dramatic, with a daily temperature change of up to 80–100 K. Most previous tasks of surface temperature monitoring on Mars are based on satellite observations, lacking *in-situ* measured data.

Zhang and Zhang reconstructing the near-surface temperature at the Zhurong landing site on Mars using data from the InSight lander is another Martian objective in the northern hemisphere's mid-low latitudes, while referring to the Martian Climate Database. The reconstructed data are then utilized to constrain the numerical simulation of the response of the shallow subsurface beneath the Zhurong landing site. The seasonal temperature change within the top 1 m is significant and is related to the thermal properties of possible subsurface media (e.g., soil, ice, and sandstones). From the perspective of temperature field, there is little possibility of liquid water in the shallow subsurface under the Zhurong landing site. This also provides a new way for the temperature field simulation of the subsurface in areas with insufficient local observations, especially on extraterrestrial objects.

A fourth challenge is to detect and analyze the lunar wrinkle ridges (LWRs), which are important geomorphic features on the lunar surface. They can provide information about the lunar crustal structure, thermal history, and stress state. However, manual mapping of LWRs is time-consuming and subjective, and automatic detection of LWRs is challenging because the ridges are of irregular shapes and many ridges have been eroded and/or degraded over time. Tariq et al. create maps of LWRs using an automated LWRs detection process with Lunar Reconnaissance Orbiter Camera wide range angle camera and Lunar Orbiter Laser Altimeter data and analyze the relations between the morphological parameters and other geomorphic phenomena of LWRs, such as craters, faults, mare basalts, and buried premare structures, which can reveal some new insights into the formation and evolution of LWRs.

A fifth challenge is to calculate the gravity field of irregular-shaped bodies, such as asteroids, and to investigate the orbital dynamics around them. Fu et al. found these bodies have complex shapes and non-uniform mass distributions, which make their gravity fields highly non-spherical and non-central. We can calculate the gravity field on the surface of a homogeneous cube and on spheres inside, outside and intersecting about it by polyhedral or harmonic expansion method and derives analytically and evaluates numerically the spherical harmonics gravity coefficients of a rectangle, which is a special case of a cube. By investigating the secular motion analysis of an orbit around a cube by averaging theory and simulates some special trajectories on a surface plane of a cube, the techniques discussed here can be adopted to analyze the gravity field of other shapes directly.

We have reviewed some of the recent progress from lunar, Mars and asteroid missions. The applications of various methods and models to explore the dynamics, thermodynamics, and geology of these objects, and reveal some new features and effects can help us understand the origin, evolution, and future of these objects. We hope that this Research Topic can provide a useful overview for readers who are interested in space science and engineering.

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Conflict of interest

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