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China's Future Missions for Deep Space Exploration and Exoplanet Space Survey by 2030*

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Abstract Four future missions for deep space exploration and future space-based exoplanet surveys on habitable planets by 2030 are scheduled to be launched. Two Mars exploration missions are designed to investigate geological structure, the material on Martian surface, and retrieve returned samples. The asteroids and main belt comet exploration is expected to explore two objects within 10 years. The small-body mission will aim to land on the asteroid and get samples return to Earth. The basic physical characteristics of the two objects will be obtained through the mission. The exploration of Jupiter system will characterize the environment of Jupiter and the four largest Moons and understand the atmosphere of Jupiter. In addition, we further introduce two space-based exoplanet survey by 2030, Miyin Program and Closeby Habitable Exoplanet Survey (CHES Mission). Miyin program aims to detect habitable exoplanets using interferometry, while CHES mission expects to discover habitable exoplanets orbiting FGK stars within 10 pc through astrometry. The above-mentioned missions are positively to achieve breakthroughs in the field of planetary science.

Key words Deep space exploration, Exoplanet surveys, Mars, Jupiter, Habitable planets

Classified index P 4

1 Deep Space Exploration Program of China by 2030

Four missions for deep space exploration in China are scheduled to be launched by 2030, which includes two Mars exploration missions, Near-Earth asteroid sample return and main belt comet rendezvous mission, and the exploration on the Jupiter and its moons. Here we summarize the major subjects on these missions as follows in a chronological order.

1.1 First Mars Exploration Mission in 2020

The first China's Mars exploration mission was approved in 2016, and it has been launched on 23 July 2020 by CZ-5 carrier rocket. The Mars mission includes an orbiter, a lander, and a rover. Through the Martian orbiting phase, the global mapping of the surface of Mars will be carried out. The partial extensive investigations will survey surface material composition, landform, and geological structure, while Martian atmosphere and climate environment will be investigated in detail in the patrol phases. Now, the spacecraft is launched from Wenchang, Hainan Province to the Earth-Mars transfer orbit. After seven-month travel in the space, the spacecraft will be captured by the gravity of Mars about February 2021.

Main Scientific Goals[1, 2]

(1) To characterize the global landform and

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geological structure, surface material composition, and internal structure, *etc.*

(2) To characterize the soil and water-ice distribution on Mars.

(3) To assess the characteristics of atmosphere and climate environment surrounding Mars.

1.2 Asteroid and Main Belt Comet Exploration Mission

The Near-Earth asteroid and main belt comet exploration mission is expected to be carried out in 2024. The primary targets are the near Earth object 469219 Kamo'oalewa (also known as 2016 HO_3) which is the fifth quasi-satellite of Earth[3] and the main belt comet 133P/Elst-Pizarro. The mission will fly around the asteroid, then land on it, carry out in-situ measurement, obtain some samples, and return Earth. For the comet phase, the spacecraft will orbit 133P to explore its physical property. The entire mission for two objects will almost last for 10 years.

Main Scientific Goals

For the stage of the asteroid exploration: (i) measure the parameters of its orbit, rotation, shape, and thermo-physical characteristics, *etc.*; (ii) characterize the global landform and geological structures, surface composition, internal structure; (iii) analyze the returned sample and retrieval its physical and chemical parameters, chemical composition, age, and establish the relationship between the samples and in situ measurement.

For the stage of main belt comet exploration: (i) measure the parameters of comet's orbit, rotation, shape, and thermal feature, *etc.*; (ii) characterize the global landform and geological structures, surface material composition, internal structure, the space environment, the existence of water, and the activity of the comet.

1.3 Second Mars Exploration Mission around 2028

The second exploration on Mars is scheduled in 2028 and will take some Martian samples back to Earth.

Main Scientific Goals[2]

(1) To characterize the terrain and chemical composition through in situ measurement.

(2) To analyze the returned samples and get its physical and chemical properties, which can help us to reveal the origin and evolution of Mars.

1.4 Exploration of Jupiter System

The exploration of Jupiter system is scheduled to be launched about 2030. The main targets are Jupiter and its four largest Moons, and perform large-scale remote-sensing observations[2].

Main Scientific Goals

(1) To investigate the environment around Jupiter system, including the magnetic fields and plasmas interaction.

(2) To characterize the structure and composition of Jupiter's atmosphere.

(3) To establish the atmosphere model, the ice surface terrain and internal structures of the Galilian satellites.

(4) To study the structures of solar wind from the Earth to Venus and Jupiter.

2 Exoplanet Space Surveys on Habitable Planets by 2030

China is actively involved in its own space exploration programs of exoplanets, to characterize habitable planets around the neighborhood of the solar system using astrometry measurements and direct imaging observations in the next decades. There are mainly several future exoplanet space surveys on habitable planets by 2030, Miyin, and CHES mission. Miyin program aims to detect habitable exoplanets using interferometry, while CHES expects to discover habitable exoplanets through astrometry.

2.1 Miyin Program

Miyin program expects to find habitable planets around the stars in our neighborhood. The mission will launch spacecraft with groups of telescopes to search for exoplanets with interferometry in the intermediate infrared band. The spatial resolution of the mission will reach 0.01 arcseconds.

Main Scientific Goals

(1) To detect and locate exoplanets in our neighborhood by retrieving their direct images and assess their habitability.

(2) To investigate the objects in our Solar sys-

tem and study the water distribution on the objects.

2.2 Closeby Habitable Exoplanet Survey (CHES Mission)

CHES mission will discover the nearby Earth-like planets around FGK stars within 10 pc from our solar system *via* astrometry. Astrometry can minimize the detection bias of other techniques, like RV or transit, thereby being one of the most important methods of detecting exoplanets. The FOV of CHES is 0.44°× 0.44°, based on 1.2 m primary. CHES will utilize the Space Astrometry technique in the optical band. In order to keep the high stability of the pointing accuracy, minimizing the temperature effect *etc.*, the mission will occupy the L2 orbit. The micro arcsecond astrometry in space will deserve to be the highest precision mission, which may produce fruitful achievements in planetary science, cosmology science, and many other astrophysical research fields. CHES is expected to discover at least 50 Earth-like planets or super Earths during its five-year mission.

Main Scientific Goals

(1) To search for the nearby terrestrial exoplanets in habitable zones, especially Earth-like planet around FGK stars within 10 pc.

(2) To comprehensively survey and detect the nearby planetary systems within 10 pc, to discover the planets with orbital periods ranging from 30 days to 10 years, and further to determine its orbital parameters and the masses.

On the other hand, the high-contrast exoplanet imager mounted on the Chinese Space Station Optical Survey Telescope (CSST), scheduled for launching in 2022, will observe the mature Jupiter-like planets, cold Neptunes and super Earths in the neighborhood of solar-type stars, which expects to detect tens of exoplanetary candidates and brown dwarfs[8]. In addition, there are also other missions proposed to detect Earth twins, such as Super-Kepler Mission, *etc.*

In summary, the above-mentioned missions are positively expected to achieve breakthroughs in the field of planetary sciences.

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