A STUDY OF CRUISING-PHASE SCIENCES USING THE SOLAR POWER SAIL. T. Iwata[1], S. Matsuura[2], K. Tsumura[3], H. Yano[1], T. Hirai[4], D. Yonetoku[5], A. Matsuoka[1], R. Nomura[1], and O. Mori[1], [1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan; iwata.takahiro@jaxa.jp), [2]Kwansei Gakuin University (Sanda, Japan), [3]Tohoku University (Sendai, Japan), [4]Japan Aerospace Exploration Agency (Mitaka, Japan), [5]Kanazawa University (Kanazawa, Japan).

Introduction: The Solar Power Sail is a Japanese candidate deep-space probe that will be powered by hybrid propulsion of solar photon acceleration and ion engines [1, 2]. The main scientific objectives are studies of Trojan asteroids in the Jovian L4 or L5 regions. The long distance and period from the launch to the swing-by at Jupiter will give us a good opportunity to explore the solar system between the Earth and the Jupiter, and to execute long-period, long-baseline observation for astronomy.

We define the cruising-phase sciences of the Solar Power Sail as the scientific theme that will be explored or observed from the launch to the swing-by at Jupiter. In this paper, we report candidate instruments, as well as individual and integrated sciences of the cruising-phase sciences.

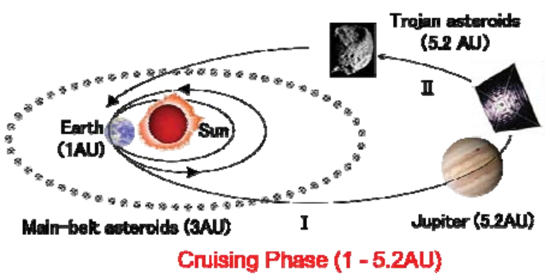

Figure 1. Cruising phase between the Earth and Jupiter in the mission profile of the Solar Power Sail.

Mission Outline: The Solar Power Sail has a large membrane of about 35x35 m that is accelerated by the pressure of sunlight. The sail membrane has thin-film solar cells that supply enough electric power in the outer planet region without nuclear technology. These technologies follow the heritage of IKAROS, which demonstrated the first solar yacht and observed interplanetary dust and gamma-ray bursts [3, 4, 5].

Figure 1 presents an example of the mission profile of the Solar Power Sail. The year in the figure and the following text are the tentative schedule in the Phase-A study. The probe will be launched by H-IIA launch vehicle in 2023, and the cruising-phase science observations will be started after the initial check-out of the spacecraft. The probe will be accelerated by the Earth swing-by in 2025 and accelerated by the Jupiter swing-by in 2029. Ion engines will be in full operation to change orbit after the Jupiter swing-by. Therefore, the cruising-phase science observations will be finished in this phase. The probe will approach and rendezvous with the Trojan asteroids in 2037-2039. It will return to the Earth with samples of Trojans in 2049.

Scientific Objectives: The cruising phase from the launch to the Jupiter swing-by provides about a six-year observation period from the near Earth to the Jovian orbit through the main asteroid belt. The wide range (1AU to 5.2AU) in the heliocentric distance provides a good opportunity to investigate the radical structure of the solar system.

Zodiacal light observed at visible and near-infrared wavelengths is thought to be sunlight scattered by interplanetary dust or micrometeoroids. The two-dimensional distribution of zodiacal light reflects the three-dimensional structure of interplanetary dust [6]. However, it is still controversial whether the dust originates from asteroids or comets. Therefore, the comparison of the radial distribution of zodiacal light and the in-situ dust observation will help clarify the distribution and components of solid particles in our solar system. It will also shed light on template information for exoplanetary discs.

The temperature of the solar wind, which depends on the heliocentric distance, is greater than that predicted by the adiabatic model [7]. Therefore, there seems to be heating processes, such as plasma turbulence or magnetic reconnection. The observation of the magnetic field by the devices separated in the scale of the membrane of the Solar Power Sail provides the resolution of the plasma turbulence on the electron scale. Thus the intermittent observation of the magnetic field between the Earth and Jupiter would determine the heating mechanism of the solar wind.

Additional scientific objectives are astronomy from deep space. Zodiacal light scattering beyond the main asteroid belt is estimated to be 1 to 2 orders of magnitude fainter than that at 1AU on the ecliptic plane. Therefore, the cosmic infrared background can be detected directly. One of the most desired objectives of this dust-free observation is to search for the first stars of the early universe, the sources of cosmic reionization at the redshift of z ~ 10. Simultaneous observation of gamma-ray sources using the high-resolution positioning obtained by the very long base-line (up to about 6AU) between the probe and the Earth is also useful for clarifying the physical status in the early universe.

Candidate Instruments: The Exo-zodiacal Infra-red Telescope (EXZIT) is a visible-light and infrared (tentatively 0.4 to 10 micro-meters) offset Gregorian telescope with a 10cm-diameter aperture [8]. The all-aluminum telescope and the Linear Variable Filter (LVF) are based on the Cosmic Infrared Background Experiment (CIBER)-2 [9]. EXZIT will observe the zodiacal light from the launch to the main asteroid belt, and then search for the first stars until it approaches to Jupiter.

Arrayed Large-area Dust Detectors in Interplane-tary space (ALADDIN) 2 detects interplanetary dust using the Polyvinylidene Fluoride (PVDF) dust sen-sors installed on the membrane. It is an improved model of ALADDIN that was installed on IKAROS and observed interplanetary dust between the Earth and Venus [4]. ALADDIN2 will detect interplanetary dust between the Earth and Jupiter and compare the distribution with the results of EXZIT. It will observe the dust around the Trojan asteroids after it approaches to the Trojan.

The Magnetometer (MAG) is an improved fluxgate magnetometer model of the Magnetic Field Experi-ment (MGF) on the Exploration of Energization and Radiation in Geospace (ERG) that will be injected into the orbit on the Earth. Two or four devices will be installed in the tip of the framework of the membrane to provide the resolution on the electron scale for in-terplanetary plasma turbulence. MAG will measure the interplanetary plasma in the cruising-phase, and it will measure the magnetic fields around the Trojan asteroids after it approaches to the Trojan.

The Gamma-ray Burst Polarimeter (GAP) 2 is an improved model of GAP on IKAROS [5]. GAP2 will monitor gamma-ray burst phenomena to clarify the particle acceleration mechanism and gravitational waves. It will also search for exploding early stars in the early universe, which complements to the infrared first-star search by EXZIT.

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