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The research and development program for the SNAP dark energy experiment

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Abstract

The SNAP mission includes two surveys to study dark energy. In the deep survey, we detect more than 2000 matched Type Ia supernovae within a 7.5 deg^2 field, with redshifts covering the range $z = 0.1-1.7$. This uniform and high-quality set of "standard candles" will provide the most precise mapping of the expansion of the universe through the magnitude-redshift relation (Hubble diagram) ever constructed. The SNAP wide survey maps 1000 deg^2/year in nine passbands to 28th magnitude. A weak-lensing study of the wide survey data traces the growth of structure and provides completely independent constraints on dark energy parameters. SNAP utilizes a 2 m class rigid light-weight telescope with a three-mirror anastigmatic design for a large, diffraction-limited field of view. The telescope feeds an instrumented ~0.7 deg^2 focal plane with ~600 million pixels sensitive to wavelengths from 400 to 1700 nm. Full-depletion, high-purity silicon CCDs detect visible wavelengths, and 1700 nm cutoff HgCdTe detector arrays detect the near-IR. Passive cooling of the focal plane, fixed solar panels, fixed filters, and fixed antenna for telemetry simplify the mission. Room temperature operation of the telescope facilitates preflight testing. The satellite is placed in orbit about the second Earth–Sun Lagrange point (L2).

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1. The SNAP project

1.1. Introduction

The SuperNova/Acceleration Probe (SNAP) is a proposed space-based experiment designed to measure the expansion history of the Universe, motivated by the discovery that the expansion is accelerating [1]. It will measure dark energy and its time variation by mapping the distance-redshift relation of Type Ia supernovae, and by mapping the distribution of matter and energy using gravitational weak lensing. A 2-m three-mirror anastigmat wide-field telescope feeds a focal plane consisting of a 0.7 deg^2 imager tiled with equal areas of visible and near-infrared sensors, and a high-efficiency, low-dispersion integral field spectrograph. The instrumentation suite provides simultaneous discovery, classification, and light-curve measurements for many supernovae and targets individual objects for detailed spectral characterization. The SNAP mission will obtain high signal-to-noise calibrated light curves and spectra for over 2000 Type Ia supernovae at redshifts between $z = 0.1$ and 1.7 from a deep survey of 7.5 deg^2. The wide-area weak gravitational lensing survey will survey 1000 deg^2/year in nine filters. The weak lensing survey benefits from a stable, high-resolution point spread function, and absence of atmospheric distortions. To facilitate thermal management of the observatory and instruments, and reduce stray light from the Earth's limb, the satellite is placed in orbit about the second Earth–Sun Lagrange point (L2) using a Delta IV or equivalent launch vehicle.

1.2. Description

The overall SNAP observatory is illustrated in Fig. 1. The system is comprised of two main subassemblies, the instrument section (the telescope and focal plane assembly,

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with light baffle and deployable front cover), and a short spacecraft section. The spacecraft includes a command and data handling system with S-band transponder and Ka-band downlink, a power system, an attitude control system, and a monopropellant hydrazine system for orbit trimming, momentum dump, and spacecraft disposal. All spacecraft components are mounted in the spacecraft section except for the solar panel that is mounted on the side of the instrument. Because the survey zones are near the north ecliptic pole, fixed solar panels mounted on the instrument body opposite to the radiator are oriented sunward. To maintain this configuration the satellite performs a 90° roll maneuver every 3 months, which requires that the focal plane sensor configuration also exhibit 90° symmetry.

The telescope is operated near 293 K to simplify fabrication and test, while the instrument suite is cooled to 140 K by the passive radiator. The benign thermal environment and the body mounted solar panels permit highly stable pointing using a straight-forward attitude control system. High-volume image data are downlinked daily using a high-bandwidth Ka-band transmitter. Command uplink and engineering downlink use an S-band link. Most aspects of the SNAP satellite are well within the envelope of proven space technology.

1.3. Telescope

The telescope, shown in Fig. 2, is a Korsch-type annular field three-mirror anastigmat design for a large, diffraction-limited field of view [2]. This ~2 m, f/12 telescope has a flat focal plane. Its 22 m focal length delivers a plate scale of 0.1 arcsec per 10.5 μm pixel. The wide field of view telescope (1.5 deg^2 optical, 0.7 deg^2 instrumented) provides an enormous multiplex advantage, yielding a sufficient time-on-target to deliver the requisite sensitivity and supernova discovery rate. This same wide-field advantage benefits the weak lensing survey.

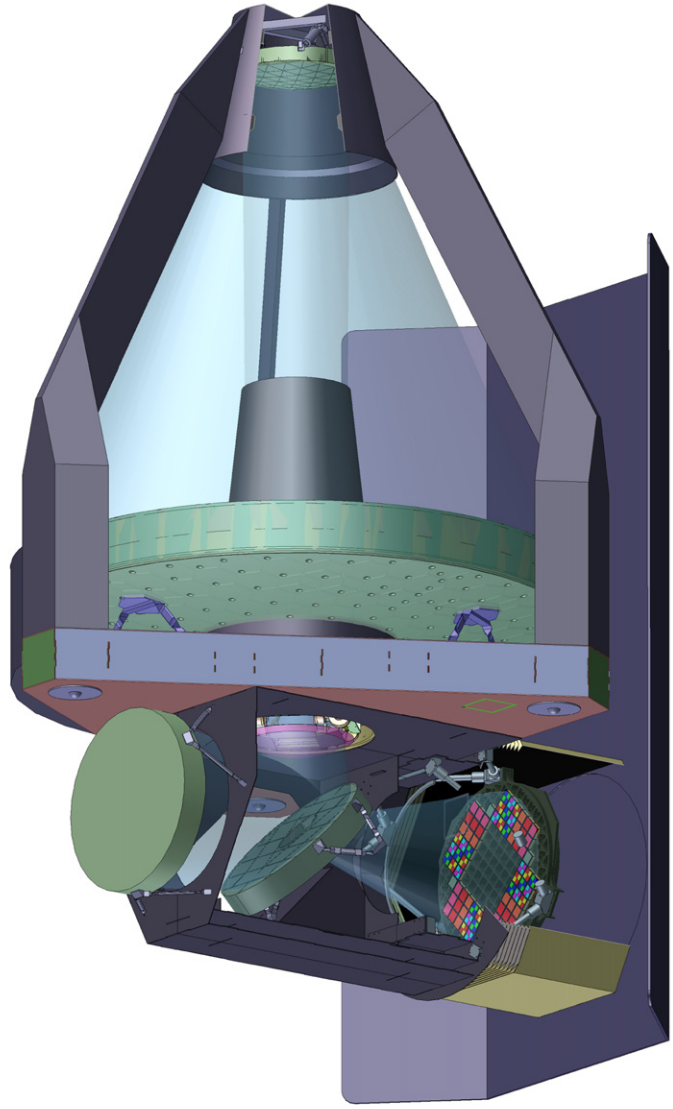

Fig. 2. The SNAP telescope including the metering structure, primary, secondary, and tertiary mirrors are seen in the figure above. Also visible is the 72 detector wide-field camera with its large attached radiator. The light path is shown in light-shading.

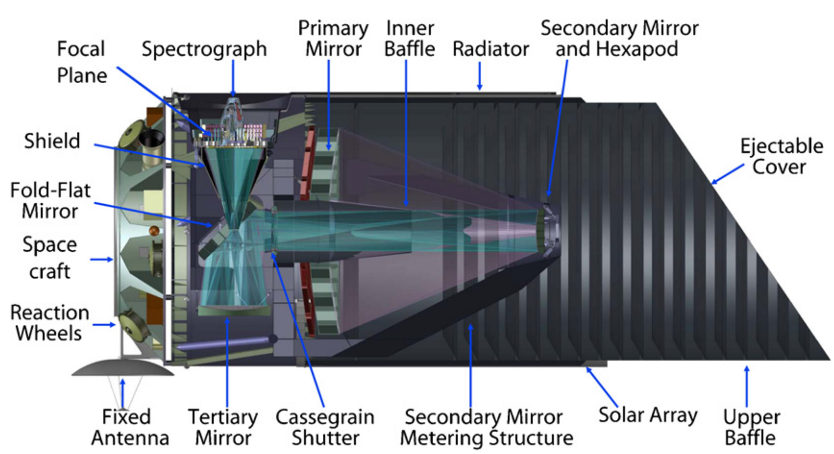

Fig. 1. The SNAP satellite in cross-section showing component details including spacecraft, instrument, telescope, and baffle system.