EPJ Web of Conferences **309**, 03001 (2024) https://doi.org/10.1051/epjconf/202430903001
EOSAM 2024

Inflatable On-Axis and Off-Axis Space Telescope Designs

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Abstract. In the realm of astronomical scientific exploration, deployable and scalable approaches in space telescope systems are reshaping our understanding of the universe. Two revolutionary membrane-based space telescope designs, on-axis OASIS (Orbiting Astronomical Satellite for Investigating Stellar Systems) and off-axis SALTUS (Single Aperture Large Telescope for Universe Studies), have been developed as mid/far-infrared telescope concepts featuring an inflatable primary mirror. Through the scalable primary aperture design, these deployable space telescopes leverage an all-encompassing optical architecture that taps into the uncharted potential of extremely large telescope apertures. These visionary mission and optical designs pave the way for the next generation scalable telescopes of unprecedented dimensions and diffraction-limited imaging resolutions.

1 Introduction

The Orbiting Astronomical Satellite for Investigating Stellar Systems (OASIS) [1] is an on-axis ~20-m scale space telescope as depicted in Fig. 1. It is designed to detect transitions of H_2O (and its isotopologues), deuterated molecular hydrogen (HD), and molecular species in 80 – 660 µm wavelength range that are obscured from the ground by absorption in the Earth's atmosphere.

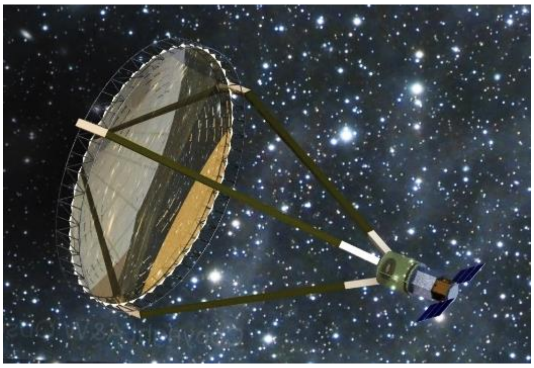

Fig. 1. OASIS space telescope utilizing on-axis ~20-m scale inflatable primary mirror with deployable booms. [1]

The Single Aperture Large Telescope for Universe Studies (SALTUS) [2] is an off-axis 14-m diameter far-infrared (far-IR) space observatory mission concept designed with a short wavelength limit of ~30 µm. A sunshield is used to radiatively cool the aperture to <45K (Fig. 2). This feature is essential for the telescope's ability to capture far-infrared radiation with minimal background noise, further enhancing its wide spectrum observational coverage.

Fig. 2. 14-m diameter aperture space telescope SALTUS using inflatable off-axis primary mirror and sun shield. [2]

2 Membrane-Based Inflatable Mirror

Both OASIS and SALTUS are based on matured membrane-based inflatable mirror technology [3] shown in Figs. 3 and 4. The inflatable membrane is connected to the spacecraft using deployable boom mechanisms.

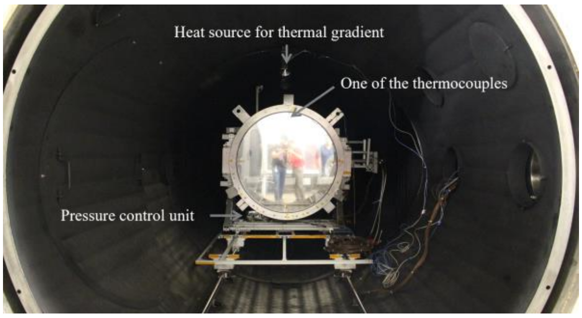

Fig. 3. 1-m class inflatable mirror with thermocouple sensors, pressure control unit, and heat source in a TVAC chamber. [4]

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The shape configurations of the deflated mirror are determined using an inverse problem solver and FAIM, a geometric nonlinear membrane finite element simulation platform [3]. Their optical performance was confirmed through experimental TVAC (thermal vacuum) chamber verifications [4] (Fig. 3) and scalability demonstrations using 3-m scale inflatable mirror (Fig. 4).

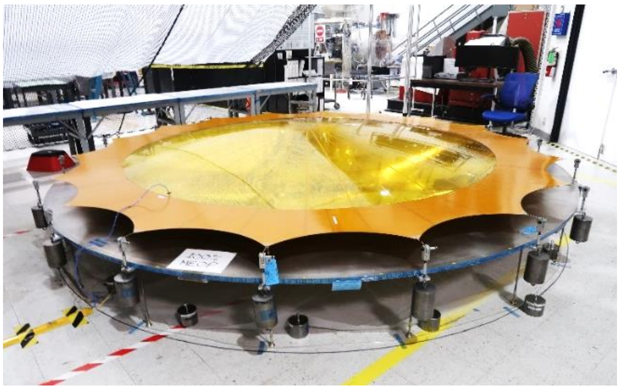

Fig. 4. 3-m scale inflatable mirror designed, modelled, built, inflated, tested, and demonstrated at the L'Garde facility. [2, 3]

3 Inflatable Telescope Designs

3.1. On-Axis OASIS Design

The science objectives of OASIS are met by utilizing 20-meter class inflatable aperture. A 19-m inflatable mirror design [5] utilizing on-axis Hencky primary mirror geometry combined with downstream corrector optics with a ±0.1° Field of View (FoV) is shown in Fig. 5.

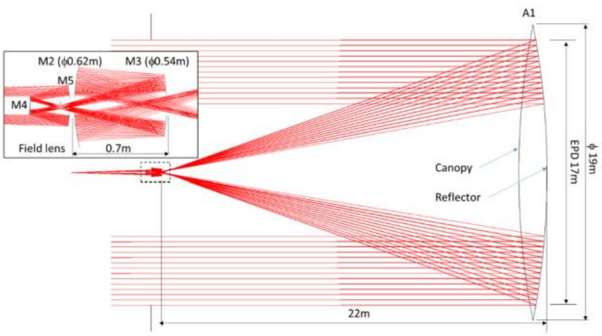

Fig. 5. Optical layout of OASIS telescope with 19-m primary M1 mirror and correction optics (M2, M3 and FoV scanner M4 and M5) enlarged in the inset box. [5]

3.2 Off-Axis SALTUS Design

The deployable SALTUS optical design [2], featuring an off-axis 14-m primary mirror (M1) is illustrated in Fig. 6. The inflatable M1 is connected to the Cold Corrector Module (CCM) via a single boom structure. The CCM corrects the M1 residual aberrations over a ±0.02 × 0.02° FoV, thereby providing diffraction limited performance as demonstrated by the >0.9 Strehl ratio Point Spread Function (PSF) shown in Fig. 7. [2]

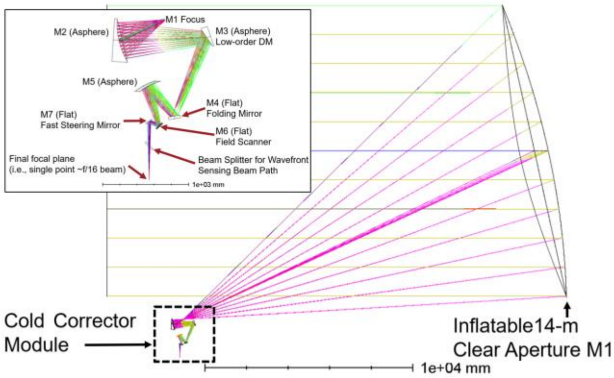

Fig. 6. Optical layout of SALTUS telescope with the off-axis 14-m primary M1 mirror and Cold Corrector Module (CCM) enlarged in the inset box. [2]

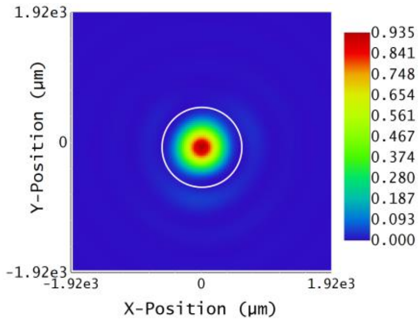

Fig. 7. SALTUS Point Spread Function (PSF) at the ±0.01° field points with the Airy disk (at the shortest science wavelength 30 μm) in white circle.

4 Conclusions

Inflatable mirror-based deployable optical designs offer unprecedentedly large photon collecting capability at a fraction of the cost and mass budget of traditional space telescope missions. Both OASIS and SALTUS telescopes are poised to provide the astrophysics community with an extremely large diffraction-limited space observatory, enabling groundbreaking exploration of our cosmic origins. These designs provide high spectral and spatial resolution with high sensitivity across a wide wavelength range that is largely unexplored by existing ground or space observatories.

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