CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

The Black Hole Explorer (BHEX)

Request for Information

4K Spaceflight Cryocooling System

Table of Contents

BHEX 4K Spaceflight Cryocooler

1. Introduction

The Smithsonian Astrophysical Observatory has issued this request for information regarding a spaceflight cryocooler system which will be integrated as a subsystem for the Black Hole Explorer (BHEX) instrument. The primary goal of this request is to receive information that includes a solution and services necessary for the delivery of a space-qualified 4K cryocooler system that can cool the BHEX receiver system at its 100K, 20K, and 4K temperature stages (the telescope will not be cooled). This includes the design, assembly, integration, and test (AIT) of the full cryo-chain for the cooling system, and AIT tasks for the integration of the cooling system with the receiver system and spacecraft. This information will be used in support of the NASA SMEX AO proposal submittal. The following information is competition sensitive.

2. Background

BHEX is a space-based very long baseline interferometry (VLBI) mission that will perform precision black hole measurements, detect the photon ring around a black hole, explore the spacetime, spin, and mass properties of black holes, and attempt to experimentally validate predictions of General Relativity. The BHEX team is led by PI Dr Michael Johnson at SAO and the team is developing a proposal for the NASA Small Explorer (SMEX) AO, with an expected proposal deadline of July 2025. These ambitious goals are achieved using cryogenic receivers offering nearly quantum-limited sensitivities across a wide frequency coverage.

3. Objectives

The BHEX science instrument is a dual-band, dual-polarization radio astronomy receiver system operating from 80-110 and 240-320 GHz. Optimizing the sensitivity of the receiver requires the use of detectors operating at or below 20K and 4.5K. The cryocooling system will reach two cold stages; a 20K stage which must lift a heat load of approximately 120mW and a 4.5K stage lifting approximately 10mW of heat load. Vibrations at the cold stage mounting surfaces need to be maintained below 5μm.

3.1. Cryocooler

The location of the cryocooler within the BHEX instrument is shown in Figure 1. The receiver system is integrated with the cryocooler, and the combined system is integrated into the spacecraft.

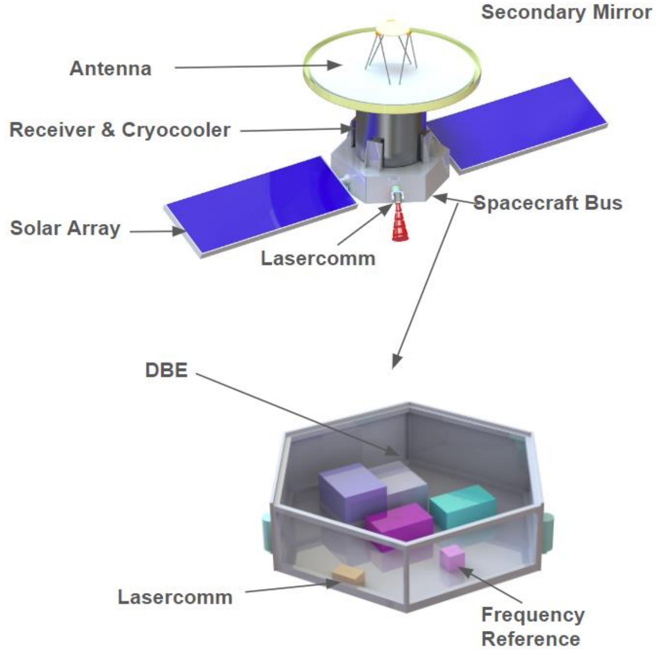

Figure 1: A schematic of the BHEX spacecraft, where the subsystems that comprise the instrument are indicated. The receiver system is integrated into the 4K cryocooler.

3.2. Technical Objectives

The cryocooler must meet the cooling requirements at each of the cold stages, as outlined above. The cryocooler may utilize a combination of different cryocooler technologies (Stirling, pulse tube, Gifford-McMahon, Joule-Thomson, or any other similarly capable technology) in a design that fits within the scope of the SMEX mission constraints: the full instrument mass budget and power budget, consisting of all the subsystems including the cryocooler, is approximately 300kg and 700W respectively. The cryocooling system should be able to adequately reject heat into space from a polar orbit of 20,000km altitude. The cryocooling system will need to undergo typical spaceflight qualification testing, and technologies with a demonstrated successful flight heritage are preferred. The General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Project standard shall be assumed as the environmental testing requirements.

4. Scope

The scope of this work is to provide information regarding the cryocooling capabilities of your technology to meet the afore-detailed requirements to cool the BHEX receiver. The scope of work shall include a detailed breakdown of the thermal-cryo chain, the heat loads and cooling powers at each stage, the input power required, and other key design and operational information. Moreover, results from on-ground environmental performance testing will be fundamental, as well as any information on spaceflight performance.

5. Request for Information

To support SAO proposal efforts, please provide a summary of your 4K spaceflight cryocooling technology and details of its environmentally tested performance as well as spaceflight performance. Please include information on the technology's ability to meet the heat load cooling requirements, vibration constraints, power electronics needs, passive heat rejection considerations, and expected lifetime performance. Please also provide information on the cooling system performance at higher cold end temperatures, particularly within the 4-10K range. This would need to include variation of input power, efficiency and other key performance parameters as a function of cold end temperature. Highlighting facilities for design and testing capabilities and heritage information for the cryocooling system is recommended. The BHEX team would be responsive to meetings and/or conference calls to further discuss requirements and solution approaches.

For planning and budgetary purposes, please also define a rough order of magnitude (ROM) cost for the delivery as well as the lead time for the 4K spaceflight cryocooler.

The responses to this RFI are requested by **14th June 2024**. Please contact the following with responses, questions or for forwarding supporting information:

Rebecca Baturin
BHEX Instrument Project Manager
Center for Astrophysics | Harvard & Smithsonian
Office: (617) 496 7707
Email: rebecca.baturin@cfa.harvard.edu
100 Acorn Park Drive | MS 5 | Cambridge, MA 02140

Janice Houston
BHEX Instrument Systems Engineer
Center for Astrophysics | Harvard & Smithsonian

Office: (617) 495 2818
Email: Janice.houston@cfa.harvard.edu