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Author: Mr. Ben Hudson
KISPE Space Systems Limited, United Kingdom

Prof. Leonid Gurvits
Joint Institute for VLBI in Europe, The Netherlands
Dr. Zsolt Paragi
Joint Institute for VLBI in Europe, The Netherlands
Dr. Maciek Wielgus
Max-Planck-Institut für Radioastronomie, Germany
Dr. Lei Liu
Shanghai Astronomical Observatory, Chinese Academy of Sciences, China
Prof. Weimin Zheng
Shanghai Astronomical Observatory, Chinese Academy of Sciences, China

ZOOMING IN ON PHOTON RINGS OF SUPERMASSIVE BLACK HOLES WITH SPACEBORNE SUB-MILLIMETRE INTERFEROMETERS

Abstract

Recent advances in technology coupled with the progress of observational radio astronomy methods resulted in achieving a major milestone of astrophysics - a direct image of the shadow of a supermassive black hole (SMBH), taken by the Earth-based Event Horizon Telescope. The EHT was able to achieve a resolution of approximately 20 microarcseconds, enabling it to resolve the shadow of a SMBH in two celestial objects, the active nucleus of the galaxy M87 and the central object of the Milky Way, the radio source SgrA*. This pioneering result paves the way for a multitude of astrophysical research of galactic and extragalactic objects with unprecedented sharpness.

The EHT results also mark the start of a new round of development of next generation Very Long Baseline Interferometers (VLBI) which will be able to operate at millimetre and submillimetre wavelengths. The inclusion of baselines exceeding the diameter of the Earth and observation at as short a wavelength as possible is imperative for further development of ultra-sharp astronomical observations. This can be achieved by a spaceborne VLBI system. TeraHertz Exploration and Zooming-in for Astrophysics (THEZA) is a concept of such a system, prepared in response to ESA's call for its next science program Voyage 2050. THEZA's goal is to achieve an angular resolution of around 1 microarcsecond, an order of magnitude improvement over the next generation of the Earth-based EHT.

We consider the preliminary mission design of the THEZA spaceborne interferometer, specifically focused on the detection and analysis of the pattern of photon rings, forming in a black hole observable image as a consequence of extreme gravitational deflection of light. This phenomenon is highly informative for deciphering the properties of space-time in strong gravitational fields and determining key characteristics of a black hole. In our presentation we discuss possible orbit configurations of the interferometer constellation, optimised for the study of photon rings around SMBHs. Optimisation has been conducted using simulated VLBI observations of radio sources with the objective of designing an orbit configuration capable of resolving black hole targets at a range of right ascensions and declinations. Potential Sun-Earth L2 and Earth orbit configurations are presented for this highly versatile system. The key engineering challenges of the practical implementation of this mission concept are also discussed. Such a space-borne

interferometer formation will open up a new area of astrophysical observation, until now unreachable with Earth-based systems and past space interferometers operating at longer wavelengths.