

Brief information about the project

Name of the project	Exploring the q-metric with high-resolution multi-wavelength observations. AP25795219
Relevance	This research focuses on testing the q-metric against observational data from the EHT and GRAVITY experiments, providing new insights into the gravitational properties of compact objects like black holes and neutron stars. By bridging the gap between theoretical models and real-world observations, the study will enhance our understanding of how quadrupole moments affect gravitational fields, light-bending, and shadows. These findings contribute to advancing theoretical astrophysics and observational methods, while also fostering international collaboration in Kazakhstan's scientific community.
Purpose	The aim of the project is to constrain the q-metric, a theoretical model of deformed compact object spacetime, using high-resolution observational data from the EHT and the GRAVITY instrument. This will provide a more accurate understanding of the gravitational properties of these objects and bridge the gap between theoretical models and real-world observations.
Objectives	Task 1: Constraining the q-metric by analyzing radio-interferometric data from the Event Horizon Telescope, focusing on the photon ring, black hole shadow, and bright spots observed around M87 and SgrA*. Task 2: Comparing theoretical models of orbital motion with observed near-infrared GRAVITY data, specifically examining dynamics of bright near-infrared flares and S-star clusters near SgrA*, to derive constraints on the q-metric. Task 3: Predicting observable phenomena, such as light-bending and gravitational lensing effects, unique to the q-metric, which can serve as direct observational probes of spacetime deformations near compact objects.
Expected and achieved results	1. First-ever constraint on the q-metric derived from the analysis of radio-interferometric data from the Event Horizon Telescope, including the study of the photon ring, black hole shadow, and the interpretation of the bright spots observed around sources M87 and SgrA*. At this stage, an analysis was carried out of high-resolution images of black hole shadows obtained with the Event Horizon Telescope (EHT). The study focused on the objects M87 and Sgr A* in order to assess the influence of the quadrupole moment on the size, shape, and angular structure of the shadow. The theoretical predictions of the q-metric were compared with observational data, which made it possible to estimate possible quadrupolar deformations. The obtained results provided observational constraints on the q-metric and

	demonstrated its differences from the Kerr and Schwarzschild models. 2. First-ever constraint on the q-metric through comparison of orbital motion with observed near-infrared GRAVITY data, specifically from bright flares and S-star clusters near Galactic center supermassive black hole SgrA*. Within the framework of this task, theoretical models of orbital motion based on the q-metric were compared with near-infrared observational data obtained with the GRAVITY instrument. The features of the dynamics of bright infrared flares, as well as the motion of S-class stars in the immediate vicinity of Sgr A*, were considered. The necessary observational and computational data were selected, processed, and systematized for the subsequent imposition of constraints on the parameters of the q-metric. 3. Predictions of observable signatures, such as light-bending and gravitational lensing effects, unique to the q-metric that could serve as direct probes of spacetime deformations near compact objects. The project tasks are being implemented in stages in accordance with the calendar plan: Tasks 1 and 2 have been completed, while the implementation of Task 3 is planned for the next reporting period.
Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles	Muratkhon Aray, PhD in physics and astronomy. ScopusID: 57219511165, (Scopus h-index=3, WoS h-index= 4), WoS/PublonsID: V-1168-2018; ORCID:0000-0001-9920-5193. Tursunov Arman PhD, RNDr., DSc., researcher at the Max Planck Institute for Radio Astronomy (MPIfR) in Germany, assistant professor at the Silesian University in Opava (Czech Republic). ScopusID: 36943530700; (Scopus h-index=19, WoS h-index=18); WoS: JPK-4731-2023.
Usage	The project results can be used to study strong gravitational fields, analyze the properties of compact astrophysical objects, and interpret observational data obtained by EHT and GRAVITY. In addition, the results may be applied in research activities and in the educational process in astrophysics and gravitational theory.
Priority compared to real-world alternatives	The advantage of the project lies in the fact that the q-metric is considered not only as a theoretical model, but also as an object for comparison with real observational data from EHT and GRAVITY. This ensures a more concrete and application-oriented scientific outcome compared with similar studies.
List of publications with links to	On 24 December 2025, an article was submitted to the

them	journal <i>Physical Review D</i>. The current status of the manuscript is: under review. Saken Toktarbay, Aray Muratkhan, Nurgissa Myrzakulov, Hernando Quevedo. <i>Shadows observable correspondence in Kerr and static quadrupolar spacetimes</i> // <i>Physical Review D</i>. Submitted 24 December. Status: under review. On 23 December 2025, one article was submitted to the journal <i>Physical Sciences and Technology</i>. The current status of the manuscript is: under review. Жантай Муратхан, Манас Хасанов, Арай Муратхан, Алия Таукенова. <i>Корреляционный анализ параметра ускорения ветра в высокомассивных рентгеновских двойных</i> // <i>Physical Sciences and Technology</i>. Submitted 23 December. Status: under review.
Patents	No patents are planned under the project, since the research is fundamental and theoretical in nature.