Brief information about the project

Title	AP22686542 «Numerical study of ray deflection on magnetars, taking into account dark matter».
Relevance	The essence of the Project lies in the expected experimental verification of the effects of nonlinear electrodynamics in vacuum, which necessitates theoretical calculations. The project examines the impact of these nonlinear effects on electromagnetic rays propagating through the ultra-strong magnetic fields of magnetars. Additionally, considering the various distributions of dark matter in the Galaxy, the project investigates how nonlinear electrodynamics in vacuum affects a beam that reaches Earth with a delay. This is achieved by determining the trajectory and deflection angles of electromagnetic radiation as it passes through the intense magnetic and gravitational fields of a magnetar.
Goal	The goal of the Project is the numerical study of the nonlinear electromagnetic and gravitational deflection of electromagnetic radiation passing through the super-strong magnetic field of magnetars. This study is conducted within the framework of a combination of nonlinear electrodynamics of vacuum and the general theory of relativity, taking into account the distribution of dark matter in the Galaxy.
Tasks	To achieve the project's goal, the following tasks have been established: **Task 1:** Obtain and numerically solve the effective geodesic equations of electromagnetic radiation passing through the ultra-strong dipole magnetic field of a magnetar, taking into account the dark matter and the galactic field around the magnetar. The objective of this task is to determine the dependency of the electromagnetic radiation's deflection angle on the distance along the beam's trajectory, considering the distribution of dark matter. **Task 2:** Derive the effective geodesic equations of electromagnetic radiation for the case where fields of baryonic and dark matter are located at the center of the galaxy, and solve them numerically. This task involves studying the dependency of the electromagnetic radiation's deflection angle on distance, taking into account the distribution of dark matter. **Task 3:** The project involves determining the accurately measured trajectory of the beam by utilizing the obtained Geodesic equations and the data from magnetars and gamma rays, which are anticipated to be easily measurable in the near future. This will facilitate further development of the work. The objective here is to ascertain the dependency of the deflection angle of electromagnetic radiation based on actual astrophysical data, while considering the distribution of baryonic and dark matter in the galaxy.
Expected and Achieved Results	During the implementation of the idea and plans of the project, the following results are expected to be achieved: 1. Taking into account the dark matter and the Galactic field, the center of which coincides with the center of the magnetar, the effective Geodesic equations of the electromagnetic beam passing through the ultra-strong dipole magnetic field of the magnetar are obtained, and by solving it numerically, the dependence of the trajectory of the beam and the distance of its deflection angle 2. Taking into account the dark matter and the Galactic field, the center of which coincides with the center of the

	galaxy, the effective Geodesic equations of the electromagnetic beam passing through the ultra-strong dipole magnetic field of the magnetar are obtained, and by solving it numerically, the dependence of the trajectory of the beam and the distance of its deflection angle 3. By determining the Magnetar and gamma glow, which is convenient to measure in the near future, and taking the effective Geodesic equations of the electromagnetic beam passing through the ultra-strong dipole magnetic field of the magnetar from the obtained numerical data and solving it quantitatively, the dependence of the angle of its deflection on the trajectory of the beam and the different circulation of dark matter on the distance is determined.
Names and Surnames of Research Group Members with Their Identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and Links to Corresponding Profiles	**Yernazarov Tursynbek**, ResearcherID: JOZ-1785-2023, Scopus Author ID: 58508797700, ORCID ID: 0000-0001-5916-3662 **Abishev Medeu,** Scopus Author ID:26530759900, Web of Science) Researcher ID Web of Science L-4467-2018, ORCID ID: 0000-0003-3602-6934
Publications list with links to them	1. Beissen, N., Abishev, M., Toktarbay, S., **Yernazarov, T**., Utepova, D., & Zhakipova, M. (2023). The Exploring nonlinear vacuum electrodynamics beyond Maxwell's Equations. International Journal of Mathematics and Physics, 14(1), 61-70. 2. **Yernazarov, T**., Abishev, M., & Aimuratov, Y. (2023). Correspondence of gamma radiation coming from GRBs and magnetars based on the effects of nonlinear vacuum electrodynamics. In The Sixteenth Marcel Grossmann Meeting on Recent Developments in Theoretical and Experimental General Relativity, Astrophysics and Relativistic Field Theories: Proceedings of the MG16 Meeting on General Relativity Online; 5–10 July 2021 (pp. 4401-4409). **The main publications of the project's scientific advisor related to the project topic:** 1. Beissen, N., **Abishev, M.**, Toktarbay, S., Yernazarov, T., Utepova, D., & Zhakipova, M. (2023). The Exploring nonlinear vacuum electrodynamics beyond Maxwell's Equations. International Journal of Mathematics and Physics, 14(1), 61-70.(2ndpercentile, DOI: 10.26577/ijmph.2023.v14.i1.07) 2. Beissen, N ; Utepova, D; **Abishev, M**; Quevedo, H; Khassanov, M; Toktarbay, S, Gravitational Refraction of Compact Objects with Quadrupoles, SYMMETRY-BASEL, -2023. -Vol.15, Issue: 3. (**Q2**, 78thpercentile, DOI10.3390/sym15030614) 3. **Abishev M.E.**, Toktarbay S., Beissen N.A., Belissarova F.B., Khassanov M.K., Kudussov A.S., Abylayeva A.Zh. Monthly Notices of the Royal Astronomical Society.– 2018.–Vol.481, Issue 1. – P. 36-43. (**Q1,** 85thpercentile, DOI:10.1093/MNRAS/STY2272). 4. Toktarbay S., Quevedo H., **Abishev M.,** Muratkhan A. Gravitational field of slightly deformed naked singularities // European Physical Journal C, 2022, https://doi.org/10.1140/epjc/s10052-022-10230-2. SCOPUS: CiteScore= 8.3 (2020); 92nd percentile (2020)

	https://www.scopus.com/sourceid/27545?origin=resultslist SCIMAGO: SJR=1.94 (2020); Q1 (2020) https://www.scimagojr.com/journalsearch.php?q=27545&tip=sid&clean=0 WoS: CI(2019)=1.20; CI(2020)=1.15 https://mjl.clarivate.com/journal-profile 5. **Abishev, M.,** Beissen, N., Belissarova, F., Boshkayev, K., Mansurova, A., Muratkhan, A., Quevedo, H., Toktarbay, S. Approximate perfect fluid solutions with quadrupole moment. // International Journal of Modern Physics D, 30(13), 2150096, 2021. https://doi.org/10.1142/S0218271821500966 SCOPUS: CiteScore=4.4 (2020); 68th percentile (2020) https://www.scopus.com/sourceid/28074 SCIMAGO: SJR=0.82 (2020); Q2 (2020) https://www.scimagojr.com/journalsearch.php?q=28074&tip=sid&clean=0WoS: IF(2019)=0.46; IF(2020)=0.50 https://mjl.clarivate.com/journal-profile 6. **Abishev, M.,**Toktarbay, S.,Abylayeva,A., Talkhat, A.The orbital stability of a test body motion in the field of two massive bodies. // EPJ WebofConferences 168, 04001 (2018). https://doi.org/10.1051/epjconf/201816804001 SCOPUS: CiteScore= 0.9 (2019); 23rd percentile (2019) https://www.scopus.com/sourceid/21100227410 https://www.scopus.com/sourceid/28218 SCIMAGO: SJR=0 (2020) https://www.scimagojr.com/journalsearch.php?q=21100227410&tip=sid&clean=0 7. **M. E. Abishev,** S. Toktarbay, N. A. Beissen, F. B. Belissarova, M. K. Khassanov, A. S.Kudussov and A. Z. Abylayeva, Monthly Notices of the Royal Astronomical Society 481 (November 2018), (**Q1,** 85thpercentile, DOI: 10.1093/mnras/sty2272) 8. **Abishev, M. E.,** Denisov, V. I., Denisova, I. P., & Kechkin, O. V. (2018). The evaluation of electromagnetic forward radiations during the propagation of gravitational waves through the dipole field of the magnetar. Astroparticle Physics, 103, 94-97. (**Q1,** 79thpercentile, DOI: 10.1016/j.astropartphys.2018.07.006) 9. Boshkayev, K., Quevedo, H.,Toktarbay, S.,Zhami, B., **Abishev, M.** On the equivalence of approximate stationary axiallysymmetric solutions of the Einstein field equations. // Gravitation and Cosmology, 22(4), 2016 https://doi.org/10.1134/S0202289316040046 SCOPUS: CiteScore=2.0 (2019); SCIMAGO: SJR=0.39 (2020); Q3 (2020) https://www.scimagojr.com/journalsearch.php?q=17600155002&tip=sid&clean=0 WoS: CI(2019)=0.19; CI(2020)=0.22 https://mjl.clarivate.com/journal-profile

Patent information	Not available