Techical Report on Progress made during the grant period.

Numbers refer to papers publication list in accompnaying attachment.

It has been shown that the proper oscillation frequencies (termed quasinormal modes), that dominate in the response of the asymptotically Goedel space-time to perturbation, are qualitatively similar to those of anti-de Sitter space- times, where the inverse angular momentum of the Goedel space-time plays the same role as the anti-de Sitter radius. Therefore, Dirichlet boundary conditions should be imposed on perturbations and a rotating black hole in asymptotically Goedel space will suffer from the superradiant instability [7]. We showed this in [7] for the 5-dimensional rotating black hole solution found in [Gimon and Hashimoto Phys. Rev. Lett. 91 (2003) 021601] and for its charged generalization [Wu, Phys. Rev. Lett. 100,121301 (2008)].

In [6] it was also shown that four and higher dimensional asymptotically Goedel space-times allow for the stability of tachyon fields up to some threshold mass, which is similar to the Breitenlohner-Freedman threshold in the anti-de Sitter space-time.

We have studied the quasinormal spectrum of scalar and Dirac tardyon fields in the expanding and rotating cosmological background and showed in [5] that the spectrum of the Dirac field has a discontinuity as a function of the z- component of the wave vector k at k = 0. This property is not observed for non- rotating cosmological backgrounds.

In [4] we tested the stability of various wormholes and black holes supported by a scalar field with a negative kinetic term (1) wormholes with flat asymptotic behavior at one end and AdS on the other (M-AdS wormholes) and 2) regular black holes with asymptotically de Sitter expansion far beyond the horizon (the so-called black universes)). A difficulty in such stability studies was that the effective potential for perturbations forms an infinite wall at throats, if any. Its regularization is in general possible only by numerical methods, and such a method was developed in a general form in [4]. We showed that all configurations under study are unstable except for a special class of black universes where the event horizon coincides with the minimum of the area function. For this stable family, the frequencies of quasinormal modes of axial perturbations were calculated [4].

In [2] and [3] we considered two phenomena (quasinormal radiation and test particle motion) in the vicinity of the deformed Schwarzschild and Kerr black holes. The deformation parameter can be stipulated by the tidal force of the surrounding matter and magnetic field (as in [3]) or by (possibly, yet unknown) alternative theory of gravity (as in [2]).

In [3] we showed that both the tidal gravitational force and the magnetic field strongly enhance the release of the binding energy for the matter spiralling into the black hole. We analyzed stability of Larmor and anti-Larmor orbits of charged particles and showed that the larger the tidal force, the closer the innermost stable orbit to the black hole for both types of rotation. We found that the real oscillation frequencies of the characteristic quasinormal modes are considerably suppressed by the tidal force.

In [2] we calculated some quantitative characteristics of the classical (quasinormal) and quantum (Hawking) radiation for the Johannsen and Psaltis space-time [Phys. Rev. D 83, 124015 (2011)], which describes Schwarzschild and Kerr-like black holes with a deformation parameter which is not constrained by the current observations. This is another type of deformed black holes, aimed at a kind of unified phenomenological description of alternative theories of gravity. For these space-times we found the binding energy of matter spiraling onto the black hole, quasinormal modes and late-time tails of fields of various spin, intensity of Hawking radiation. The binding energy released when a particle goes over from a given stable orbit in the equatorial plane to the innermost stable one was calculated for such Kerr-like black holes. We were unable to separate variable in the wave equations in the most general case, so that the perturbations and stability of scalar, Dirac, and electromagnetic fields were analyzed for vanishing rotation only. We are looking for some numerical approach to the analysis of perturbation equation in the most general Johannsen and Psaltis space-time.

Finally, in [1] we studied charged, massive scalar field perturbation in the Kerr-Newman background. So far analysis of the quasinormal spectrum of a massive charged scalar field in the black hole background has been limited by the regime of small mM and qQ, where m, q (M, Q) are mass and charge of the field (black hole). In [1] we suggested a comprehensive picture of quasinormal modes, late-time tails and stability of a massive charged scalar field around Kerr-Newman black holes for any physically meaningful values of the parameters. We showed that there is no indication of instability of the scalar field under quasinormal modes' boundary conditions. We showed that for some moderate values of qQ dominant quasinormal modes may have arbitrarily small real oscillation frequencies. The larger the field's charge, the sooner asymptotic tails dominate in a signal, making it difficult to extract quasinormal frequencies from a time-domain profile. For the near extremal Kerr-Newman black holes we have obtained a more general picture of the mode branching found recently for massless fields [Yang H. et. al. Phys. Rev. D 87, 041502(R) (2013)] in the Kerr background.