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Three Predictions of Gravitational Waves, and Black Holes

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Abstract

Gravitational wave forms a focus of physics, astrophysics and cosmology. First, we propose three predictions of gravitational waves: their observations must be nonlinear waves; velocity of gravitational wave should be slightly higher than the velocity of light; gravitational waves in black holes may emit and be observed. Next, we discuss the analogies of the gravitational and electromagnetic fields, and research some relations between black holes and gravitational waves. Finally, we propose the directed gravitational wave observatories of high-energy astrophysics, as such for the huge black holes in the Galactic center.

Keywords: Gravitational wave; Nonlinearity; Velocity of light; Black hole; Prediction.

1. Introduction

Recently, gravitational wave forms a focus of scientific development, and is a few of the most exciting and important challenges in physics, astrophysics and cosmology [1].

First, LIGO and Virgo observed gravitational waves GW150914 from a binary black hole (BBH) merger, frequency from 30 Hz to 250 Hz, and signal lasted for 0.2 seconds [2, 3]. We forecast that further investigations may discover difference between gravitational wave and electromagnetic wave [4]. In 2017 LIGO and Virgo observed gravitational waves from a binary neutron star (BNS) inspiral, and detectors observed association with the γ-ray burst (GRB) 1.7s after GW170817 [5]. This proved clearly both velocities of gravitational wave and electromagnetic wave are different [6].

Further, GW190412 is originated from the merger of two black holes with unequal masses respectively about 30 and 8 times the mass of the Sun ($M_{\odot}$). GW190425 is originated from the merger of a compact binary with total mass of about 3.4 $M_{\odot}$. In 21 May 2019, LIGO and Virgo observed GW190521, in which a binary black hole merger with a total mass of 150 $M_{\odot}$ [7]. GW190814 is the merger of a binary system, in which a 23 $M_{\odot}$ black-hole and the heaviest neutron star about 2.6 $M_{\odot}$, and merger resulted in a final black hole about 25 $M_{\odot}$ [8]. In this paper, we propose three predictions of gravitational wave, and research some relations between black holes and gravitational waves.

2. Three Predictions of Gravitational Wave

It is known that gravitational waves may be continuous, such as neutron binary stars (PSR J0537-6910) and rotating stars, etc., or be explosive gravitational waves.

2.1. Observable Gravitational Wave Must Be Nonlinear Wave

Einstein gravitational field equations are nonlinear, so long as the equations are not the simplest linear equations at first approximation, their solutions, whether soliton or instanton, or kink, or chaos, *etc.* cannot be a simple linear wave, and should be a type of nonlinear waves and may exhibit some new corresponding characteristics. We obtained quantitatively some simple nonlinear solutions in harmonic coordinates, etc [6].

The nonlinearity of the gravitational wave originates from a nonlinear essence of the gravitational field [6]. In particular, the observed gravitational waves must be the strong gravitational fields. The soliton solution shows that Weber's detection may not be repeatable.

The invariant gravitational field and constant metric cannot emit gravitational waves, which can produce only when changing mass or motion. Weak gravitational fields are very difficult to measure gravitational waves, so they must be strong gravitational fields, which are generally nonlinear equations and fields. And the effect is much smaller than the electromagnetic waves, so it must be a large mass change or big motion.

Kramer, et al., discussed some exact solutions of Einstein field equations [9]. In vacuum T_{ik} =0, so gravitational field with no-source derives gravitational wave. But, $R_{ik} = 0$ are still very complex nonlinear equations of $g_{\mu\nu}$. The difference of both velocities between gravitational waves and electromagnetic wave is related to $g_{\mu\nu}$.

In 2002 Canfora, et al., analyzed vacuum gravitational fields invariant for a non-Abelian Lie algebra, and derived nonlinear gravitational waves and their polarization [10]. In 2003 Servin, et al., discussed nonlinear self-interaction of plane gravitational waves [11]. In 2004 Llberg, et al., considered nonlinear interaction between gravitational and electromagnetic waves in a strongly magnetized plasma, and discussed nonlinear coupled Alfvén and gravitational waves [12]. Aldrovandi, et al., proved the nonlinear essence of gravitational waves and their form and effects [13, 14]. In 2016 Kistovich, et al., proposed the analytical models of stationary nonlinear gravitational waves [15].

New observed gravitational waves are necessarily nonlinear waves, because binary black hole merger [2, 3] and binary neutron star merger [5] must be nonlinear mechanics, and gravitational waves with large energy must be pulse waves (solitons), for example, GW150914, 151216 BBH, and GW170817, 170825 BNS, and GW190412, 190512 BBH, and GW190425, 190814 BNS are all separated merger waves.

In a word, usual gravitational field equations are all nonlinear equations, and corresponding gravitational waves are also nonlinear waves [4, 6].

2.2. Velocity of Gravitational Wave Should Be Slightly Higher Than Speed of Light

The velocities of gravitational and electromagnetic waves are different for bimetric or vector-tensor or stratified theories, but they are the same in general relativity or scalar-tensor theories [16]. We proposed that the two propagation velocities are different *i.e.* the velocity of the gravitational wave should be slightly higher than the velocity of light, because at least since light deflects while the gravitational wave propagates along a straight line in a strong gravitational field, like an electromagnetic wave in an electromagnetic field, in particular when photon-photon interactions are neglected [6].

For GW170817 a new character is to observe association with the γ-ray burst (GRB) 170817A which was observed 1.7s after GW170817. This is very small value, but, it shown clearly that both velocities of gravitational wave and electromagnetic wave are different [6], and is inevitable result of general relativity. We calculated simply its gravitational redshift and the deflection of light, whose delay time is 0.1792s [17]. And the speed of light will become smaller along with the mass increases due to gravitational redshift and the deflection of light.

PSR1913+16 is a well-known binary pulsar, which discovered by R.A. Hulse and J.H. Taylor in 1974, and may test general relativity [18-20]. Its two neutron stars have nearly equal in mass, about 1.4$M_\odot$, radii is about 15km.

According to the same equation (1) of gravitational redshift, the time-difference of both different velocities of gravitational wave and electromagnetic wave are:

$$\Delta t = R / \Delta V = cR^2 / GM \quad (1)$$

Its value is:

$$\Delta t = \frac{3\times10^{10} cms^{-1}(1.5\times10^6 cm)^2}{6.67\times10^{-8} cm^3 g^{-1} s^{-2} \times 1.4 \times 2\times10^{33} g} = 3.60\times10^{-4} s \quad (2)$$

It should be observable. Observed value of change rate for PSR1913+16 is $3.2\times10^{-12} s$.

2.3. Gravitational Wave Emitted in Black Holes

Since light deflects in a strong gravitational field, as such in black holes, but the gravitational wave propagates along a straight line, therefore, the gravitational waves in black holes should be able to emit and be observed. The black holes have only three observables: mass M, angle momentum J and charge Q. Theoretically, three have all gravitational waves.

So far GW190814 has the biggest 9 ratio in the binary system. For the huge black holes in the Galactic center with 4.4 million times the solar mass, the accreting matter increases only by a very small fraction. Such its gravitational wave will probably show some new characters.

In a word, the big progresses in astronomy and universe are all related to important philosophy of science. Based on general relativity, we discussed some progresses: binary stars and their form [21-23], negative matter and inflation [24-31], etc. We proposed three predictions of gravitational waves: their observations must be nonlinear waves; velocity of gravitational wave should be slightly higher than the velocity of light; gravitational waves in black holes may emit and be observed. The directed gravitational wave observatories for high-energy astrophysics are proposed [22].

3. Analogies of the Gravitational and Electromagnetic Fields

From the higher approximation of the motion equation in general relativity Einstein obtained a vector equation, which is completely analogy of Lorentz equation [32]:

$$\frac{d}{dl}[(1+\bar{\sigma})v] = grad\bar{\sigma} + \frac{\partial M}{\partial l} + [rotM, v] \quad (3)$$

Here $\bar{\sigma} = \frac{k}{8\pi}\int\frac{\sigma dV_0}{r} = \frac{\gamma_{44}}{2}$, $M = \frac{k}{2\pi}\int\frac{\sigma\frac{dx_\alpha}{dl}dV_0}{r} = i\gamma_{4\alpha}$.

The equations of motion (3) show that 1. The inert mass is proportional to $1+\bar{\sigma}$, and therefore increases when ponderable masses approach the test body. 2. There is an inductive action of accelerated masses, of the same sign, upon the test body. This is the term (∂M/∂l). 3. A material particle, moving perpendicularly to the axis of rotation inside a rotating hollow body, is deflected in the sense of the rotation (Coriolis field). The centrifugal action, mentioned above, inside a rotating hollow body, also follows from the theory.

Landau, et al., obtained also a similar Lorentz equation [33]:

$$f = -mc^2 grad\ln\sqrt{-g_{00}} + mc\sqrt{-g_{00}}(V\times rotg) \quad (4)$$

Here $g = g_{\alpha 0}/g_{00}$, and corresponds to a vector field **A**. It is completely analogous to the Lorentz equation. Here $\bar{\sigma}\sim g_{00}\sim\gamma_{44}$ is similar to electric field, $g_{0\alpha}\sim\gamma_{4\alpha}$ is similar to magnetic field. Both changes and mutual conversion can get gravitational waves. More generally, $\Gamma^{\mu}_{\nu\alpha}$ are not constant that will derive the gravitational wave.

Based on the complete similar Lorentz equation by Einstein and Landau methods [32, 33], various corresponding gravitational waves can be obtained. The equation of gravitational wave is $R_{ik}=0$. Otherwise, the similar electromagnetic field and Maxwell equations may be obtained.

The rotation and motion of mass may produce a like magnetic field [32, 33]. Both alternately also form gravitational waves, such as the Kerr black holes.

A new vector $\zeta_i = g_{i0}$ is introduced, Weinberg derived the equation [34]:

$$\frac{dV}{dt} = -\nabla(\phi+2\phi^2+\psi) - \frac{\partial\zeta}{\partial t} + V\times(\nabla\times\zeta) + 3V\frac{\partial\phi}{\partial t} + 4V(V\cdot\nabla)\phi - V^2\nabla\phi. \quad (5)$$

Here the first three terms on the right are similar Lorentz equation.

The first system of Maxwell equations is:

$$\frac{\partial F_{lm}}{\partial x_k} + \frac{\partial F_{mk}}{\partial x_l} + \frac{\partial F_{kl}}{\partial x_m} = 0 \quad (6)$$

It is analogous completely to

$$R^i_{klm} + R^i_{mkl} + R^i_{lmk} = 0, \quad (7)$$

and the Bianchi identities.

The second system of Maxwell equations is:

$$\frac{\partial F_{ik}}{\partial x_k} = \frac{4\pi}{c}j_i \quad (8)$$

It is analogous to Einstein gravitational field equations:

$$R_{kl} = \frac{\partial\Gamma^i_{ki}}{\partial x_l} - \frac{\partial\Gamma^i_{kl}}{\partial x_i} + \Gamma^i_{nl}\Gamma^n_{ki} - \Gamma^i_{ni}\Gamma^n_{kl} = \kappa T_{kl}* = \kappa(T_{kl} - \frac{1}{2}g_{kl}T) \quad (9)$$

And $R_{\mu\nu} = R_{\alpha\beta} + R_{\alpha 0} + R_{00}$. (10)

Here $R_{\alpha\beta}\sim rotH$, $R_{\alpha 0}\sim\frac{\partial E}{\partial t}$ and $R_{00} = \frac{1}{c^2}\Delta\varphi = \frac{4\pi k}{c^2}\rho$. (11)

Constant $g_{\alpha 0}$ corresponds to the constant magnetic field H. $g_{\alpha 0}\sim A$, $rot(g_{\alpha 0})\sim H$. It is again related to the angular momentum J and the angular velocity. Mutual transformation g is similar to electromagnetic waves.

Moreover, $(G^{\mu 0})_{;0} = -(G^{\mu i})_{;i}$, etc. [35], are also similar to the electromagnetic theory.

Gravitational waves may be similar to the electrostatic wave, the electromagnetic E-H field conversion wave, and the Lense-Thirring (1918) drag wave, whose precession angular speed is:

$$\Omega_{LT}(R) = \frac{2G}{c^2}\frac{J_{BH}}{R^3}, \quad (12)$$

and precession period $\tau_p = \frac{2\pi}{\Omega_{LT}}$.

A simple estimate $\omega = Mc^2/\hbar = AM$, where the frequency is proportional to the mass M. It is known that gravity $F = -\frac{GmM}{r^2}$, and potential energy $V = -\frac{GmM}{r}$. The Coulomb force $F = \frac{qQ}{r^2}$, and potential energy $V = \frac{qQ}{r}$. Such $Q \sim \sqrt{G}M, Q = 10^{18} M \approx c^2 M$.

Dirac proposed graviton, and E=hv. Such its frequency is very small, $\nu_g = 10^{-36}\nu_c$ or $\nu_g = 10^{-18}\nu_c$.

4. Black Hole and Gravitational Wave

We discuss three observables of black holes, and corresponding gravitational waves.

1. Mass changes, such as from neutron star to black hole, and binary mergers produce gravitational waves. It can be a continuous wave due to continuous inhalation mass, or burst wave due to merger and star vibration, etc.

2. Rotation produces gravitational waves, such as the Kerr black hole. It is known that the gravitational radiation power of a rotating star is [35]:

$$L = \frac{32}{5}\varepsilon^2 J^2 (2\pi\nu)^6 . \qquad (13)$$

Here J is the inertia moment, and v is the rotational frequency, ε is the elliptic rate. The rotational frequency of Pulsar PSR1937+214 is 642Hz [36]. For PSR B1937+21, the rotation period is 6.22 ms, and rotation speed of up to 716 laps per second.

3. It must be accompanied by the electromagnetic waves. The charge rotation produces a magnetic field, and there must be electromagnetic waves. Further, we should study three term superimposed gravitational waves.

Black holes are celestial bodies with no light waves and only gravitational waves. Their potential energy is $V = -\frac{GmM}{r}$, the larger the M, the greater its effect, no matter to gravitational redshift and the deflection of light.

The frequency of gravitational waves produced by the merger of two black holes, etc., should be determined not only by the total mass M, but also by mass difference, such as for GW150914 M=65, △M=3.

Some black hole systems exhibit X-ray has the constant and stable approximate periodicity, called quasi-periodic oscillation (QPO) [37, 38]. There are oscillations that must produce gravitational waves. A low-frequency QPO for a 10 $M_\odot$ black hole with an orbital frequency of 3Hz. High-frequency QPO of black hole binaries have general frequency of 40 to 450 Hz.

Rees-Meszaros proposed the fireball-shock model [38-40]. In 1995 Urry-Padovani contrasts the different types of active galaxy nuclei, and proposed a unified model of active galaxy nuclei [41]. The rotating energy of black hole drives the jet through the Blandford-Znajek (BZ) process, which extracts the rotating energy between the black hole and its surrounding electromagnetic field [42]. The rotational energy of the accretion disk drives the jet through the Blandford-Payne (BP) process, which extract the rotational energy of the accretion disk by large-scale magnetic field [43].

When the star is near a massive black hole, the tidal force is greater than the star self-gravity, which is disintegrated into debris and accreted by the black hole, called the tidal disruption event (TDE), and supermassive black hole binaries [44-46]. They should also be the sources of the gravitational waves.

The current directly observed gravitational waves are all discontinuous nonlinear pulse waves. The two types of the gravitational waves from the accretion disk before the giant matters enter the black hole and from after entering the black hole should be different.

5. High-energy Astrophysics and Directed Gravitational Wave Observatories

GW150914 from 35Hz to 250 Hz, the amplitude reaches the maximum, then the frequency remains essentially constant, the amplitude gradually decreases, and the final signal disappears with duration of 0.2 sec.

Further, we discuss the wavelength and frequency of the gravitational waves.

1. Suppose that the gravitational wave spectrum is proportional to the mass of the transformation $E_g = k\Delta M$. The largest is that with LIGO frequency about 100Hz, and Virgo observed gravitational waves from a binary black hole (BBH) merger [2, 3]. Next, in 2017 LIGO and Virgo observed gravitational waves from a binary neutron star (BNS), i.e., GW170817 [5]. Later, they are supernova and gamma-ray bursts (GRB), the active galactic nuclei, huge massive black hole in the center of the Milky Way with a mass of about 4.4 million solar masses and a radius of about 6.6 million km, etc. The quasar should be a massive black hole surrounded by a rapidly rotating accretion disk, and the optical spectrum has a certain width between $\nu_0(1-v/c)$ and $\nu_0(1+v/c)$. v~5000km/s is speed of motion of the gas atoms in the accretion disk. Further, small are rotating Kerr black holes and neutron stars, etc. The

white dwarf frequency is approximately 10^{-5} ~1Hz. The minimum is solar gravitational waves, which may not be detectable now.

2. On the other hand, the gravitational waves should be divided into nonlinear pulse-soliton waves and continuous waves, such as the cosmic background radiation is 2.7K. The corresponding gravity also has the background radiation $2.7\times10^{-36}K$, or $2.7\times10^{-18}K$, and frequency is very small $10^{-17}\sim10^{-15}$ Hz, which is basically a vacuum.

3. Assume that both energies of gravitational wave and electromagnetic wave are directly proportion, i.e., $E_g = C^{-1}E_{em} = 10^{-36}E_{em}$. Preliminary hypothesis $c_g = c = \nu\lambda$, for speed of light E=hv, E=pc, and E/p=c. If the gravitational wave and the electromagnetic wave have the same energy, frequency of the gravitational wave must be particularly large, and the wavelength is particularly small.

Further, since black holes only radiate gravitational waves without emitting electromagnetic- light waves. Such we can develop some directed gravitational wave observatories, as such for the huge black holes in the Galactic center.

Various high-energy celestial phenomena, such as supernovae, GRB, active galactic nuclei, huge jets, quasars, neutron star mergers, etc., and their changes, should produce gravitational waves. The neutron star can produce gravitational waves, which is best to test the difference of velocities between gravitational and electromagnetic waves. Also are the black holes, especially the gravitational waves of Kerr black holes. On the contrary, gravitational waves can test various different gravitational theories [16].

Some gravitational waves, such as with quasars, etc., should accompany various electromagnetic waves, which may test our prediction 2. Further, we research some aspects of gravitational waves, such as gravitational-wave theory of accretion disks and jets, and stationary or discontinuous mutations inside black holes, etc.

6. Conclusion

Based on the general relativity, we propose three predictions of gravitational waves, and research some relations between black holes and gravitational waves. Further, we propose the directed gravitational wave observatories of high-energy astrophysics, as such for the huge black holes in the Galactic center, which are possible and meaning for astronomy and hamanity.

References

[1] Abbott, B. P., 2017. "Ligo scientific collaboration and virgo collaboration a gravitational-wave standard siren measurement of the hubble constant." *Nature,* vol. 551, pp. 85-88.

[2] Abbott, B. P., 2016. "Ligo scientific collaboration and virgo collaboration, ligo bags another black hole merger." *Phys. Rev. Lett.,* vol. 116, p. 241103.

[3] Abbott, B. P., 2016. "Ligo scientific collaboration and virgo collaboration, Observation of gravitational waves from a binary black hole merger." *Phys.Rev.Lett.,* vol. 116, p. 061102.

[4] Chang, Y. F., 2016. "Calabi-Yau manifolds of nebula-galaxies and their possible dynamics, and gravitational wave." *International Journal of Theoretical Physics,* vol. 5, pp. 22-38.

[5] Abbott, B. P., 2017. "Ligo scientific collaboration and virgo collaboration, GW170817: Observation of gravitational waves from a binary neutron star inspiral." *Phys. Rev. Lett.,* vol. 119, p. 161101.

[6] Chang, Y. F., 1996. "Nonlinear nature of gravitational wave." *Apeiron,* vol. 3, pp. 30-32**.**

[7] Abbott, B. P., 2020. "Ligo scientific collaboration and virgo collaboration, GW190521: A binary black hole merger with a total mass of 150 m⨀." *Phys. Rev. Lett.,* vol. 125, p. 101102.

[8] Barneo, P., Castañeda, J., and Guixé, G., 2020. "GW190814: Gravitational waves from the coalescence of a 23 solar mass black hole with a 2.6 solar mass compact object." *ApJ. Lett.,* vol. 896, p. L44.

[9] Kramer, D., Stephanie, H., Hert, E., and MacCallum, M., 1980. *Exact solutions of einstein's field equations*. Cambridge University Press.

[10] Canfora, F., Vilasi, G., and Vitale, P., 2002. "Nonlinear gravitational waves and their polarization." *Phys. Lett.,* vol. B545, pp. 373-378.

[11] Servin, M., Marklund, M., and Brodin, G., 2003. "Nonlinear self-interaction of plane gravitational waves." *Phys. Rev.,* vol. D67, p. 087501.

[12] Llberg, A. K., Brodin, G., and Bradley, M., 2004. "Nonlinear coupled Alfvén and gravitational waves." *Phys. Rev.,* vol. D70, p. 044014.

[13] Aldrovandi, R., Pereira, J. G., Rocha, R. D., and Vu, K. H., 2010. "Nonlinear gravitational waves: their form and effects." *International Journal of Theoretical Physics,* vol. 49, pp. 549-563.

[14] Aldrovandi, R., Pereira, J. G., and Vu, K. H., 2007. "The nonlinear essence of gravitational waves." *Foundations of Physics,* vol. 37, pp. 1503-1517.

[15] Kistovich, A. V., Chashechkin, and Yu, D., 2016. "Analytical models of stationary nonlinear gravitational waves." *Water Resources,* vol. 43, pp. 86-94.

[16] Hawking, S. W. and Israel, W., 1979. *General relativity*. Cambridge University Press.

[17] Chang, Y. F., 2018. "Basic principles of physics and their applications, and logical structure of quantum mechanics." *International Journal of Modern Theoretical Physics,* vol. 7, pp. 16-39.

[18] Taylor, J. H. and Weisberg, J. M., 1982. "A new test of general relativity—gravitational radiation and the binary pulsar PSR 1913+16." *Astrophysical Journal,* vol. 253, pp. 908-920.

[19] Taylor, J. H. and Weisberg, J. M., 1989. "Further experimental tests of relativistic gravity using the binary pulsar PSR 1913+16." *ApJ.,* vol. 345, pp. 434-450.

[20] Weisberg, J. M., Nice, D. J., and Taylor, J. H., 2010. "Timing measurements of the relativistic binary pulsar PSR B1913+16." *Astrophysical Journal,* vol. 722, pp. 1030-1034.

[21] Chang, Y. F., 2013. "Lorenz model and plane general relativity model on formulation of binary stars." *International Journal of Modern Theoretical Physics,* vol. 2, pp. 1-12.

[22] Zhang, Y. F. and Chang, Y. F., 2000. "A nonlinear dynamical model of formation of binary stars from a nebula." *Chinese Astronomy and Astrophysics (UK),* vol. 24, pp. 269-274.

[23] Chang, Y. F., 2007. "Hydrodynamics and a nonlinear dynamical formation model on binary stars." *Physica Scripta,* vol. 76, pp. 385-387.

[24] Chang, Y. F., 2007. "Negative matter, repulsion force, dark matter and inflation cosmos, Higgs mechanism." *ARXIV,* vol. 0705, p. 2908.

[25] Chang, Y. F., 2011. "Negative matter, dark matter and theoretical test." *International Review of Physics,* vol. 5, pp. 340-345.

[26] Chang, Y. F., 2013. "Field equations of repulsive force between positive-negative matter, inflation cosmos and many worlds " *International Journal of Modern Theoretical Physics,* vol. 2, pp. 100-117.

[27] Chang, Y. F., 2014. "Astronomy, black hole and cosmology on negative matter, and qualitative analysis theory." *International Journal of Modern Applied Physics,* vol. 4, pp. 69-82.

[28] Chang, Y. F., 2017. "Negative matter as unified dark matter and dark energy, and possible tests." *Hadronic Journal,* vol. 4, pp. 291-308.

[29] Chang, Y. F., 2021. "Development of matter and testable negative matter as unified dark matter and dark energy." *Philosophy Study,* vol. 11, pp. 517-526.

[30] Chang, Y. F., 2022. "Some progresses in astronomy, and three predictions of gravitational wave." *Philosophy Study,* vol. 12, pp. 181-184.

[31] F., C. Y., 2020. "Negative matter as unified dark matter and dark energy: simplest model, theory and nine tests." *International Journal of Fundamental Physical Sciences,* vol. 10, pp. 40-54.

[32] Einstein, A., 1955. *The meaning of relativity*. 5th ed. Princeton.

[33] Landau, L. D. and Lifshitz, E. M., 1975. *The classical theory of fields*. Pergamon Press.

[34] Weinberg, S., 1972. *Gravitation and cosmology*. John Wiley.

[35] Weber, J., 1961. *General relativity and gravitational waves*. New York: Interscience.

[36] Backer, D. C., Kulkarni, S. R., Heiles, C., Davis, M. M., and Goss, W. M., 1982. "A millisecond pulsar." *Nature,* vol. 300, pp. 615-618.

[37] McClintock, J. E. and Remillard, R. A., 2006. *Black hole binaries*. Cambridge Univ. Press, pp. 157-213.

[38] Remillard, R. A. and McClintock, J. E., 2006. "X-ray properties of black-hole binaries." *Ann.Rev.Astron.Astrophys,* vol. 44, pp. 49-92.

[39] Piran, T., 2000. "Gamma-ray bursts, a puzzle being resolved." *Physics Reports,* vol. 333, pp. 529-553.

[40] Rees, M. J. and Meszaros, P., 1994. "Unsteady outflow models for cosmological gamma-ray bursts." *Astrophysical Journal,* vol. 430, pp. L93-99.

[41] Urry, C. M. and Padovani, P., 1995. "Unified schemes for radio-loud active galactic nuclei." *Publ.Astron.Soc.Pacific. Japan,* vol. 107, pp. 803-845.

[42] Blandford, R. D. and Znajek, R. L., 1977. "Electromagnetic extraction of energy from Kerr black holes." *Mon.Not.R.Astron.Soc.,* vol. 179, pp. 433-456.

[43] Blandford, R. D. and Payne, D. G., 1982. "Hydromagnetic flows from accretion disks and the production of radio jets." *Mon.Not.R.Astron.Soc.,* vol. 199, pp. 883-903.

[44] Liu, F. K., Li, S., and Chen, X., 2009. "Interruption of tidal-disruption flares by supermassive black hole binaries." *Astrophysical Journal,* vol. 706, pp. L133-L137.

[45] Liu, F. K., Li, S., and Komossa, S., 2014. "A milliparsec supermassive black hole binary candidate in the galaxy SDSS J120136.02+300305.5." *Astrophysical Journal,* vol. 786, pp. 103-116.

[46] Rees, M. J., 1988. "Tidal disruption of stars by black holes of 106-108 solar masses in nearby galaxies." *Nature,* vol. 333, pp. 523-528.