The Masses and Origin of the 3 : 2 Twin-Peak QPOs Frequency Ratio in the Microquasars

Sylwester Kornowski

Abstract: High frequency quasi-periodic oscillations (HF QPOs) are characteristic for the X-ray power-density spectra of a few microquasars and low mass X-ray binaries. Sometimes there appear the twin peak QPOs and then the frequency ratio for the peaks is close or equal to 3/2. Mostly the QPOs models assume oscillations of toroidal structures near black holes or neutron stars. At present, there is no consensus on the origin of QPOs. Here we present the model of the twin-peak QPOs as a result of oscillations defined by torus and a ring inside it. We use the Scale-Symmetric Theory (SST), especially the revised theory of black holes and accretion discs. Within presented here model we calculated the masses of the twin peak QPO microquasars. Obtained theoretical results are consistent with observational data. But accuracy of the observational data is very low whereas of the theoretical results is very high so future more precise observational data can be used to verify presented here model. We showed some analogy between the phenomena inside the core of baryons and the phenomena leading to the twin peak QPOs i.e. we showed some analogy between particle physics and cosmology.

1. Introduction

High frequency (hHz – kHz) quasi-periodic oscillations (HF QPOs) are characteristic for the X-ray power-density spectra of a few microquasars and low mass X-ray binaries. Sometimes there appear the twin peak QPOs and then the frequency ratio for the peaks is close or equal to ν_{upper} [Hz] / ν_{lower} [Hz] ≈ = 3 : 2. Mostly the QPOs models assume oscillations of accretion toroidal structures near black holes or neutron stars. At present, there is no consensus on the origin of QPOs. Some recapitulation of the problem we can find here [1].

Here we present the model of the twin-peak QPOs as a result of oscillations defined by accretion torus and a ring inside it.

We use the Scale-Symmetric Theory (SST), [2], especially the revised theory of black holes and accretion discs [3]. Within such revised theory we calculated the external radii of accretion discs, [3], and obtained results are consistent with observational facts [4].

Within the presented model we calculated the masses of the twin peak QPOs. Obtained theoretical results are consistent with observational data [5]. But accuracy of the observational data is very low whereas of the theoretical results is very high so future more precise observational data can be use to verify presented here model.

This study presents the correct model of production of the power-density spectra of the QPO twin peaks. We showed some analogy between the phenomena inside the core of baryons, [2], and the phenomena leading to the twin peak QPOs i.e. we showed some analogy between particle physics and cosmology.

To calculate the masses of two-peak microquasars we will use frequencies presented here [5], [6] (Table 1).

Table 1 *Frequencies of two distinct QPO peaks [5], [6].*

Microquasar	ν_{upper} [Hz]	ν_{lower} [Hz]
GRO 1655-40	450	300
XTE 1550-564	276	174
GRS 1915+105	168	113

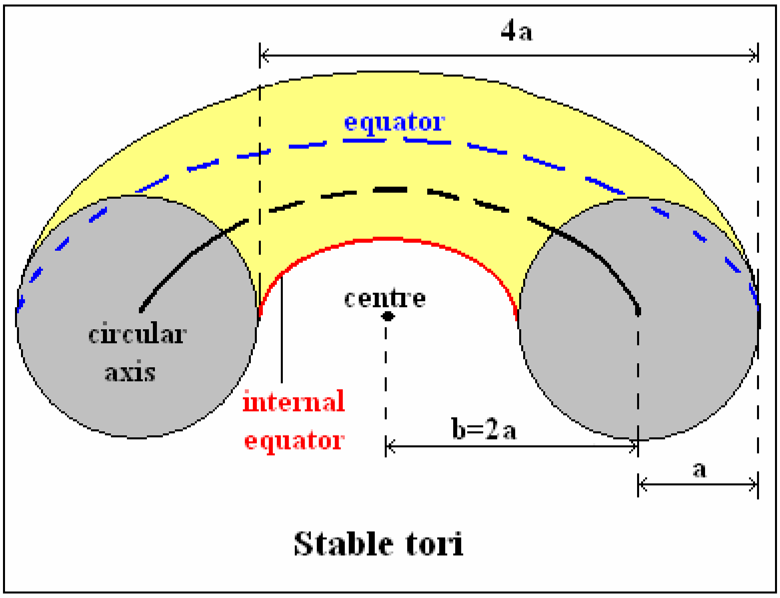
The modified theory of black holes and accretion discs shows that the modified black holes (MBHs) consist of the modified neutron black holes (MNBHs), [3], and that each MNBH carries mass equal to $M_{MNBH} = 24.81$ solar masses [3], [2]. The external radii of the flat accretion discs of MBHs we can calculate using following formula [3]

$$R_{Disc} = R_{MNBH} M_{MBH} / (2\, \alpha_{Weak(proton)} M_{MNBH}) = 1.983 \cdot 10^{-26} M_{MBH},$$

$$R_{Disc} \approx 2 \cdot 10^{-26} M_{MBH}. \qquad (1)$$

where $M_{MNBH} = 4.935 \cdot 10^{31}$ kg i.e. about 24.81 solar masses, $R_{MNBH} = 3.664 \cdot 10^{4}$ m i.e. 36.64 km, whereas $\alpha_{Weak(electron\text{-}muon)} = 9.511082 \cdot 10^{-7}$ is the coupling constant for weak interactions of leptons [2].

Observational data have higher accuracy for more massive modified black holes. From formula (1) follows that for $M_{MBH} = 2 \cdot 10^{38}$ kg is $R_{Disc} = 0.4 \cdot 10^{13}$ m whereas for $M_{MBH} = 6 \cdot 10^{39}$ kg is $R_{Disc} = 1.2 \cdot 10^{14}$ m. These theoretical results are very close to observational facts presented here [4].



Why accretion disc of the modified black holes cannot transform into a torus? It follows from the fact that the ordered virtual radial flows of the Einstein-spacetime components in the accretion discs decrease the dynamic pressure inside them so there appear forces that compress the discs, [3], but the situation is different for modified neutron stars i.e. stars with mass lower than $M < M_{MNBH} = 24.81$ solar masses. Then the negative pressure is too low to protect the flat discs from transformation into torus.

The SST shows that the torus inside the core of baryons is most stable for $b = 2a$ (see Fig. titled *"Stable tori"*) [2]. The same concerns all tori that appear due to the four succeeding phase transitions of the modified superluminal Higgs field [2].

We know that following equation defines a torus:

$$(x^2 + y^2 + z^2 - a^2 - b^2)^2 = 4\, b^2 (a^2 - z^2). \tag{2}$$

For $b = 2a$ we obtain that the ratio of the radius of equator and the circular axis is $3 : 2$.

SST shows that mass of two interacting loops which overlap with the circular axis of the core of baryons (their unitary spins are antiparallel) is equal to the mass of neutral pion (!) [2]. It suggests that around the neutron stars can be produced torus with a ring inside it.

2. Calculations

We assume that the modified theory of black holes and accretion discs is valid for modified neutron stars (MNSs) and that to radii of the tori around the MNSs and to external radii of the flat accretion discs around MBHs we can apply the same formula (i.e. formula (1)). Assume that in tori around the neutron stars are produced standing waves in such a way that distance between next nodes is equal to diameter of the equator of a torus or is equal to diameter of the circular-axis/ring inside it. We can see that length of produced electromagnetic wave is $\lambda = 4R$, where R is the radius of equator of torus or of ring. Then, applying formula (1), frequencies of the emitted waves we can calculate from following formulae

$$\nu_{lower}\,[\mathrm{Hz}] = c / (4\, R_{Torus}) \approx 3.78 \cdot 10^{33} / M_{MNS}. \tag{3a}$$

$$\nu_{upper}\,[\mathrm{Hz}] = 3\, c / (8\, R_{Torus}) \approx 5.67 \cdot 10^{33} / M_{MNS}. \tag{3b}$$

We can see that knowing, for example, ν_{lower} [Hz], we can calculate mass of modified neutron star

$$M_{MNS} \approx 3.78 \cdot 10^{33} / \nu_{lower}. \tag{4}$$

From formula (4) follows that the lower limit for ν_{lower} is for M_{MNS} = 24.81 solar masses and is $\nu_{lower,lower\text{-}limit}$ = 76.6 Hz.

In Table 2 are collected calculated masses of microquasars that we listed in Table 1. Obtained theoretical results are consistent with observational data [5].

Table 2 *Masses of microquasars.*

Microquasar	ν_{lower} [Hz]	Mass [solar masses]
GRO 1655-40	300	6.33
XTE 1550-564	174	10.9
GRS 1915+105	113	16.8
Lower limit for frequency of modified neutron star	76.6	24.81

We used the ground state of the lower frequencies but there can appear the excited states as well so we should observe as well, for example, following ratios:

$3 : (2 + 2) = 3 : 4$

or

$(3 + 3 + 3 + 3 + 3) : (2 + 2 + 2 + 2 + 2 + 2) = 5 : 4$.

It is consistent with observational facts [7], [8].

There can be created torus only or ring only. Then such QPOs are so-called respectively one-peak lower and upper HF QPOs.

3. Summary

Here we proved that the modified theory of black holes and accretion discs can be used successfully to the modified neutron stars. Using the formula for radius of accretion disc of modified black hole to equatorial radius of torus around modified neutron star and on the first assumption that inside the torus is produced ring with radius $3/2$ times smaller and on the second assumption that there are produced the standing waves, we calculated masses of the microquasars which are consistent with observational data. But accuracy of the observational data is very low whereas of the theoretical results is very high so future more precise observational data can be use to verify presented here model. This study presents the correct model of production of the power-density spectra for the QPO twin peaks.

We showed some analogy between the phenomena inside the core of baryons and the phenomena leading to the twin peak QPOs i.e. we showed some analogy between particle physics and cosmology. It means that we described the origin of the $3 : 2$ twin-peak QPOs frequency ratio in the microquasars.

References

[1] P. Bakala, *et al.* (25 May 2015). “Twin peak HF QPOs as a spectral imprint of dual oscillation modes of accretion tori”
arXiv:1505.06673v1 [astro-ph.HE]

[2] Sylwester Kornowski (23 February 2015). “The Scale-Symmetric Physics”
http://vixra.org/abs/1203.0021 .

[3] Sylwester Kornowski (28 August 2015). “The Revised Theory of Black Holes and Accretion Discs”
http://vixra.org/abs/1508.0215 .

[4] Morgan, Christopher W., *et al.* (2010). “The Quasar Accretion Disk Size – Black Hole Mass Relation”
Astrophys. J. 712 (2010) 1129-1136

[5] McClintock J. E., Remillard R. A. (2003).
Astro-ph/0306213

[6] Homan J., *et al.* (2003)
Astron.Tel. 16
http://integral.rssi.ru/atelmirror/

[7] Török, G., *et al.* (2007)
Central European Journal of Physics, 5, 457

[8] Török, G., *et al.* (2008)
Acta Astron., 58, 1
Acta Astron., 58, 15
Acta Astron., 58, 113