



## The Neutrino Pre-Radiation Times of 234 AGN Black Holes

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**Abstract:** In the framework of 'microscopic' theory of black holes [1] and references therein, we address the 'pre-radiation time' (PRT) of neutrinos from black holes, which implies the lapse of time from black hole's birth till radiation of an extremely high energy neutrinos. We estimate the PRTs of AGN black holes, with the well-determined masses and bolometric luminosities, collected from the literature. The simulations for the black holes of masses  $M_{BH} \simeq (1.1 \times 10^6 \div 4.2 \times 10^9) M_{\odot}$  give the values of PRTs varying in the range of about  $T_{BH} \simeq (4.3 \times 10^5 \div 5.6 \times 10^{11}) yr$ . The derived PRTs for the 60 AGN black holes are longer than the age of the universe ( $\sim 13.7 Gyr$ ) favored today. At present, some among remaining 174 BHs, therefore, may radiate neutrinos with energies above  $10^{21} eV$ . These neutrinos can still initiate the cascades of extremely high energy cosmic rays (EHECRs) via very complex chains of Z-burst interactions. However, these results may suffer if no obvious way to feed the BHs recently with substantial accretion. In these the derived PRTs of black holes would be underestimated.

### Introduction

The most important characteristics of the active galactic nucleus (AGN) powerhouse, the central mass and structure, as well as the closely linked process of the black hole (BH) formation in nearby host galaxy, and its growth, are not understood well. A major unsolved problem is how efficiently the required huge energies can be generated to account for the origin of compact objects from the central regions of AGNs. This energy scale severely challenges conventional astrophysical source models. Furthermore, the BH's central singularity does not allow, in principle, an accumulation of matter and, thus, neither a growth of BH mass due to the accretion process nor an increase of energy density should be occurred. To innovate the solution to the vexing problem involved, we develop on the recent view point by [1]-[3] and references therein, of 'microscopic' extension of the phenomenological BH models. The microscopic theory of BH rather completes the phenomenological BH model by exploring the most important processes of rearrangement of vacuum state and a spontaneous breaking of gauge symmetry in gravity at huge energies. Due to it a significant change

of properties of space-time continuum is occurred simultaneously with a strong gravity. This, in turn, causes the matter-to-'proto-matter' phase transition, and hence, the formation of the proto-matter core (SPC) inside the event horizon (EH). The central singularity does not occur in this theory which is now replaced by finite though unbelievably extreme conditions. This accommodates the required huge energy scale ( $> 10^{21} eV$ ) of the resulting radiation of galactic nuclei. The remarkable feature of the microscopic approach is that, in strong contrast to standard BH environment, the metric singularity inevitably should disappear in due course. Afterwards, the neutrinos may escape to outside world. Therefore, in the framework of microscopic theory we address the new concept of "neutrino pre-radiation time"  $T_{BH}$  of the BH. This novel concept has nothing to do with the "evaporation rate" of phenomenological theory. The latter is the rate at which the BH drops back to zero mass because of the escape of mass-energy. But the PRT is the lapse of time from BH's birth till the neutrino radiation. In this, the BH no longer holds as a region of spacetime that cannot communicate with the external universe.

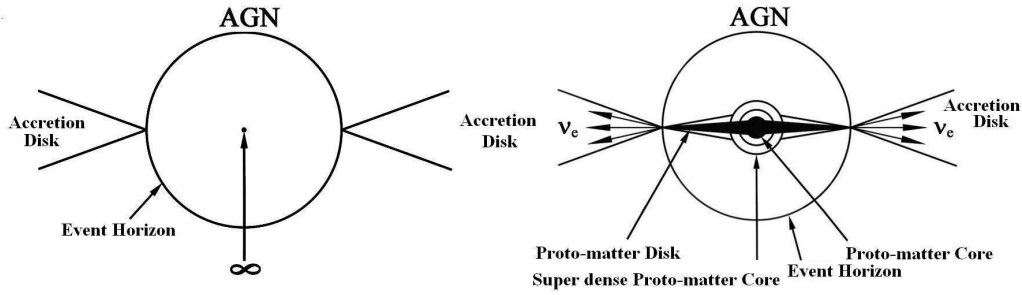


Figure 1: Left panel: The phenomenological model of AGN with the central stationary BH. The meaningless singularity occurs at the center inside of the BH. Either the Kruskal continuation of the metric for a Schwarzschild BH or the Kerr metric show that the static observers do not exist inside the horizon. Any timelike worldline inside the EH must strike the central singularity which wholly absorbs the infalling particles. This disables an accumulation of matter in the central part, and, thus, neither a growth of BH nor an increase of its mass-energy density occur due to accretion of outside matter. Right panel: The microscopic model of AGN with central stable SPC due to which the stable equilibrium holds in outward layers too, and, thus, an accumulation of matter allowed now around the SPC inside the EH.

### Microscopic model of AGN

In analogy with the phenomenological model, the SPC surrounded by the accretion disk is considered as microscopic model of AGN. To highlight a major difference of two models, we schematically plotted both of them in the Fig. 1.

In the microscopic model of AGN an accumulation of matter occurs inside the EH where the central singularity is replaced by the stable SPC, and the static observers can exist. The SPC accommodates the highest energy scale  $> 10^{21} eV$  in protomatter core (PC). Initially the SPC works as the central supermassive BH, namely the engine thought to be responsible for the activity of AGN. But, the most important next stage of EHE neutrino radiation inevitably succeeds too. That is, in due course of time an infalling matter forms the proto-matter disk (PD) around the PC, tapering off faster at reaching out the thin edge of EH. In this the metric singularity disappears provided by the metric singularity cutoff (MSC) effect [1] and the particles may escape, in principle, through this vista to outside world. Only particle which may survive in this extreme conditions is the neutrino. Once created the neutrinos leave the SPC carrying away huge energies ( $> 10^{21} eV$ ) and thus cooling it even after the neutrino 'trapping' in this medium. The 'trapping' is due to the fact that as the neutrinos are

formed in PC at super-high densities they experience greater difficulty escaping from the PC before being dragged along with the matter, namely the neutrinos are 'trapped' comove with matter. The part of neutrinos, further, annihilate to produce the cascades of EHECRs via very complex chains of Z-burst interactions.

### BH Pre-radiation time of neutrinos

The BH's 'pre-radiation time' is the lapse of finite time  $T_{BH}$  when an infalling matter forms the PD around the PC tapering off faster at reaching out the thin edge of EH:

$$T_{BH} = M_d / \dot{M}, \quad (1)$$

where  $M_d$  is the total mass of proto-matter disk,  $\dot{M}$  is the accretion rate. In approximation  $R_d \ll R_g$ , where  $R_g$  is the gravitational radius,  $R_d$  is the radius of PC, the equation (1) reads

$$T_{BH} = \rho_d V_d / \dot{M} \simeq 9.33 \cdot 10^{15} g cm^{-3} R_d R_g^2 / \dot{M}, \quad (2)$$

where  $\rho_d \simeq 6.3 \cdot 10^{15} g cm^{-3}$  is the threshold density of proto-matter corresponding to the distances between particles of  $0.4 fm$ .

## Main Features Of SA Onto SPC

Next step will be a more accurate computation of the mass accretion rate  $\dot{M}$ . It is necessary then to study a main features of spherical accretion (SA) onto SPC. This is summed up in the following three idealized models that illustrate some of the associated physics. Unless otherwise stated then we take geometrized units throughout this paper.

- *Freely moving test particle:* We study the motion of freely moving test particle by exploring the external geometry of the SPC from outside of configuration:  $\tilde{r} > \tilde{r}_b$ :

$$ds^2 = (1 - x_0)^2 dt^2 - (1 + x_0)^2 dr^2 - r^2(\sin^2 \theta d\varphi^2 + d\theta^2). \quad (3)$$

From the view point of post-Newton experiments ( $x_0 \ll 1$ ), a suggested gravitational theory is indiscernible from the general relativity. But, in contrast to Schwarzschild pseudo-singularity, in suggested theory a true physical singularity occurs on the EH sphere of radius  $r = R_g/2$ , at  $x_0 = 1$ . At this the metric component  $g_{00}$  is zero and curvature invariants are singular. But it also should be vanished due to the MSC effect [1]-[3].

- *Mass accretion rate for collisionless SA onto SPC:* The distribution function for a collisionless gas can be determined from the collisionless Boltzmann equation/ or Vlasov equation. For the stationary and spherical flow we obtain

$$\dot{M}(E > 0) = 16\pi(GM)^2 \rho_\infty v_\infty^{-1} c^{-2}, \quad (4)$$

where the particle density  $\rho_\infty$  is assumed to be an uniform at far from the SPC, and the particle speed is  $v_\infty \ll 1$ . During the accretion process the particles approaching to the EH become relativistic.

- *Mass accretion rate for hydrodynamic SA onto SPC:* For real dynamical conditions, it is expected that the accretion of ambient gas onto a stationary, non-rotating compact SPC will be hydrodynamical in nature. Therefore we discuss the relativistic analogue of the Bondi equations for spherical, steady-state, adiabatic accretion onto SPC. The relativistic equations require a transition to supersonic flow in the solution. The boundary conditions at infinity are: the gas is at rest at baryon density  $n_\infty$ , rest-mass density  $mn_\infty$  and total mass-energy density  $\rho_\infty$ . An approximate equality between sound ve-

locity  $a_\infty$  and the mean velocity of the particle provides the hydrodynamical velocity of accretion to be greater than the velocity of non-collisional accretion by the large factor  $\approx 10^9$  for typical ionized interstellar gas.

## PRT Versus Bolometric Luminosity

To estimate more quantitatively the fueling problem for disk accretion onto BH, let us consider the maximum disk efficiencies  $\epsilon \sim R_g/4R \sim 10^{-1}$ , where  $R$  is the radius of an efficient accretion surface. At this the total luminosity is invariably high of about  $L_{bol} = \dot{M}\epsilon c^2$ . This is without corrections on the flow geometry. According to previous Sect., the typical PRT versus bolometric luminosity will be

$$T_{BH} \simeq 0.17 (R_d/R) (M_{BH}/M_\odot)^3 (10^{39} W/L_{bol}) yr. \quad (5)$$

In what follows we use the results of investigation by [4], wherein they collect and compare all AGN/BH mass and luminosity estimates from the literature. These masses are mostly based on the virial assumption for the broad emission lines, with the broad-line region size determined from either reverberation mapping or optical luminosity. Additional BH mass estimates based on properties of the host galaxy bulges, using either the observed stellar velocity dispersion or using the fundamental plane relation.

## Result

The results of computations are summing up in the Fig. 2 as the PRT-to-mass relation given on the logarithmic scales, respectively. Left panel: for SY1=Seyfert 1 and SY2=Seyfert 2, and right panel: for RQQ=radio-quiet and RLQ=radio-loud quasars. The horizontal dashed lines are the fit to log of universe's age = 13.7 Gyr for the set of cosmological parameters favored today. The solid lines are the best fits to data of samples. They read

$$\text{Log}(T_{BH}/yr) = 1.99 \text{Log}(M_{BH}/M_\odot) - 5.71,$$

for the Seyfert galaxies, and

$$\text{Log}(T_{BH}/yr) = 1.61 \text{Log}(M_{BH}/M_\odot) - 4.10,$$

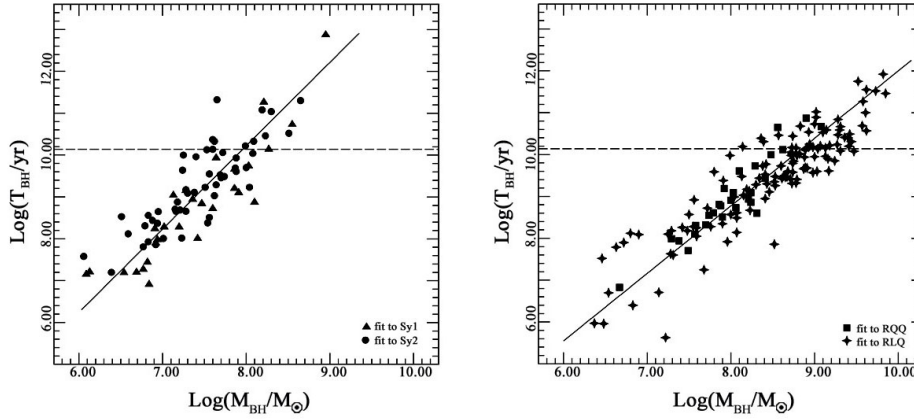


Figure 2: PRT-to-mass relation on logarithmic scales. Left panel: the SY1=Seyfert 1 and SY2=Seyfert 2. Right panel: the RQQ=radio-quiet and RLQ=radio-loud quasars.

for the quasars. The obtained PRT values of about  $T_{BH} \simeq (4.3 \cdot 10^5 \div 5.6 \cdot 10^{11}) \text{ yr}$  correspond to the 234 BHs of masses varying in the range  $M_{BH} \simeq (1.1 \cdot 10^6 \div 4.2 \cdot 10^9) M_{\odot}$ . The derived PRTs for the 60 BH/AGNs are longer than the age of the universe, which indicates that the 174 among these BH/AGNs may no longer remain as a pure black hole, and at present some of them may start to radiate an neutrinos with energies above  $10^{21} \text{ eV}$ .

## Conclusions

We highlight a main difference between the phenomenological and microscopic models of black hole. We estimate the  $T_{BH}$  of AGN black holes with the well-determined masses and bolometric luminosities collected from the literature. For the 234 BHs/AGN of masses varying in the range  $M_{BH} \simeq (1.1 \cdot 10^6 \div 4.2 \cdot 10^9) M_{\odot}$  the values are of about  $T_{BH} \simeq (4.3 \cdot 10^5 \div 5.6 \cdot 10^{11}) \text{ yr}$ . The derived  $T_{BH}$  for the 60 BHs are longer than the age of the universe ( $\sim 13.7 \text{ Gyr}$ ) favored today, which shown that some of them, at present may radiate an extremely high energy neutrinos with energies above  $10^{21} \text{ eV}$ . However, these results may suffer if the reservoir of gas for accretion in the galaxy center must be quite modest, and no obvious way to feed them recently with substantial accretion. In these the derived  $T_{BH}$  would be underestimated.

## Acknowledgements

(G.T.) gratefully thanks the Physics Dept. of SQU (Oman) for their hospitality, and for very friendly and scientifically exciting ambiance.

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