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How Quasars with Thick Accretion Disk Eject Relativistic Jets

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Abstract. One of the unsolved problems in physics is how thick accretion disks produce and eject relativistic jets. "Jet-producing disks are thick" [1]. Another unsolved problem is how quasars and active galactic nuclei persist at least millions of years, while their masses are up to milliards of solar masses. Here we suggest that these problems are connected and solved simultaneously by a series of processes not recognized until now, some of them involving relativistic effects. The thick toroidal accretion disk around a massive central body is derived analytically by Newtonian conservation of angular momentum. Radiation emitted from the accretion disk enhances the particles of the jets to relativistic velocity. The particles are expelled as jets from the poles of the rotating central body, whose mass is millions to trillions of sun masses. The central body possesses radius, as predicted by exponential gravitation [2], [3], [4], [5], [6], [7], [8] and [9] and proved by the discovery of gravitational waves from colliding massive bodies. The source of energy at the center of the massive central body is explained, as well as the formation of the inner jets and how they expel from the poles. Various implications are discussed.

1. Introduction

Djorgovski et al [10] reviewed and summarized the observations and the accepted theories on quasars. See references therein. The question of why do the thick accretion disks surrounding certain astronomical objects, such as quasars and the nuclei of active galaxies, emit relativistic jets along their polar axes remains unsolved [11]. Tchekhovskoy, Narayan et al [1] asked: "Jet-producing disks are thick... Why do only *thick* accretion disks produce jets?" This paper explains both the quasars' structure and their jets and thick accretion disks beyond the currently accepted theories.

There are a few relevant processes that occur simultaneously in a few components: a massive central body, a thick accretion disk and two opposite jets expelled from the central body. They are combined together to produce two other huge very long relativistic jets both associated with the accretion disk.

Each of the relevant processes is not easy to understand and is explained separately. Some of the processes involve rotation in unexpected ways which are not easy to visualize. Nature combined all the simultaneous processes and stages to produce the final products: two opposite up to two millions of light years long relativistic jets.

Section 2 describes the structure of the *thick* accretion disk and explains its focusing effect that enhances the jet at the axis of symmetry of the accretion disk. Section 3 derives analytically the toroidal shape of the thick accretion disk and the inner conical surfaces. Section 4 describes the inner structure of the massive central body, and how the inner jets are formed and expelled from the poles. Section 5 roughly estimates the velocity of the jet when expelled from the poles. Section 6 discusses the implication on the abundance of helium in the universe. Section 7 describes how short-lived jets are formed in the massive central body. Section 8 discusses celestial bodies with a large mass. Section 9 mentions the relativistic effects involved. Section 10 suggests rough estimations of how the collision of photons radiated from the accretion disk with the particles of the jet amplifies the motion of these particles up to relativistic velocity. Section 11 remarks about the advantage of rough estimations in general. Section 12 concludes the paper.

2. Processes in and near a quasar

We claim that the processes that happen inside and near the quasar are (to be explained in detail later in the paper):

(i) A source of energy situated at the center of the quasar that supplies energy which
    a. stabilizes the quasar thermally, and
    b. decomposes the iron nuclei into helium nuclei (alpha particles) and hydrogen nuclei (protons). Massive stars have layers of nuclei of several sorts of elements. The accepted model is Hoyle's "onion" model [12], in which the heaviest is the iron layer in the center of the star. Decomposition of iron to helium at a very large pressure and a very high temperature in the center of massive stars was explained 1955 [12].

(ii) We deduce that the helium and hydrogen nuclei which are produced from the decomposed iron nuclei accumulate and ascend along the axis of rotation of the quasar, and then are expelled from the poles as jets of helium and hydrogen nuclei. In many cases these jets were observed expelled from the poles of quasars or active galactic nuclei.

(iii) Many quasars have a thick toroidal accretion disk around them. A section of this accretion disk is shown in Figure 1, representing our calculation detailed in the next section 3.

(iv) This thick toroidal accretion disk is shaped inside in the form of two conical surfaces symmetric with respect to the torus plane (Figure 1). These conical surfaces emit energetic electromagnetic radiation *perpendicular* to the surface inward towards the torus axis.

(v) This energetic radiation is produced by friction between rotating layers of the accretion disk.

(vi) This radiation is focused and collimated along the axis of symmetry.

(vii) This energetic radiation meets and further collimates the jets of helium and hydrogen nuclei expelled at the poles of the quasar, and accelerates them outwards along the axis of symmetry farther and further, up to relativistic velocity.

(viii) The symmetrically emitted radiation that is coming *perpendicularly* to the conical surface meets the nuclei emitted axially from the poles of the central body as jets, which were observed in many cases. This radiation accelerates and collimates the nuclei on the axis direction to velocities that approach the speed of light c (see Figure 1). These nuclei are accelerated upwards to form two fast opposite relativistic jets in the direction of the rotational axis of the torus.
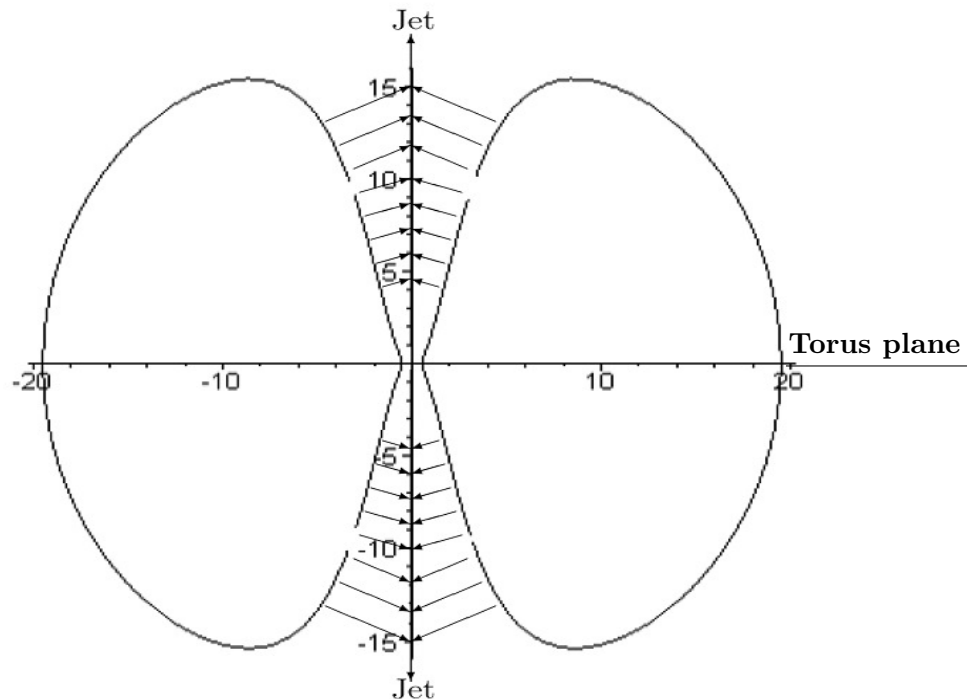
Figure 1. Section of the accretion disk. Radiation from the conical inner surface collimates and accelerates the jets. The axes units depends on the actual size of the thick accretion disk. In large accretion disks each unit represents hundreds of light years! The shape is the grapho-analytical representation of the analytical solution obtained in the next section 3 for the equation derived there

(ix) This process exists in quasars and active galactic nuclei as well as in microquasars. For example, see Harpaz's [13] explanation of how radiation accelerates the hydrogen atom component of the jets of the microquasar SS433. For the original explanation see [14]. These explanations [13] [14] use the lowest excitation level 10.2 eV of a hydrogen atom that enables it to absorb radiation energy in order to increase its velocity without considering the cones. Similarly to these explanations [13] [14], we deduce that every atom or nucleus has excitation level(s) that may enable it to absorb radiation energy in order to increase its velocity.

(x) The decomposition of iron nuclei to helium nuclei [12] and hydrogen (see also items (i)b and (ii) above) also explains why the spectrum of the jets of microquasars shows helium and hydrogen but no other elements (Margon [15]).

(xi) In this way quasars and active galactic nuclei produce and disperse a significant portion of the helium in the universe. This partly explains the abundance of helium in the universe.

(xii) The composition of cosmic rays includes 92% hydrogen nuclei and 6% helium nuclei (MacKeown and Weeks [16]). This similar composition shows that the origin of most cosmic rays may be jets from quasars, galactic nuclei and microquasars.

(xiii) The source of energy at the center of the quasar or the active galactic nucleus involves quarks. The high pressure in the core of the massive body may cause close contact between quarks. This happens because quarks have a radius. (Present accepted theories assume pointlike quarks). MacGregor, using $v = \omega r$, [17] [18] [19] and Ben-Amots, using Franklin's

Table 1. Radii and kinetic energy of rotation of quarks **up** and **down**.

Rotation type	Not relativistic	Rosen [20]	Franklin [21]
Rotation formula	$v = \omega r$	$v = \dfrac{\omega r}{[1+(\omega r/c)^2]^{\frac{1}{2}}}$	$v = c \tanh(\omega r/c)$
Radius of quark calculated by Refs for radius of quark	MacGregor [17] [18] [19]		Ben-Amots [22] [2]
Fraction of mass of quark as kinetic energy of rotation	1/3	96.5%	99.3%
Calculated by	MacGregor [17] [18] [19] Leonard [23]	Ben-Amots [2]	Ben-Amots [22] [2]

rotation [21] $v = c \tanh(\omega r/c)$, [22] [2] calculated the radius of **up** and **down** quarks. See Table 1. Macgregor [24] [25] [26] [19] explained why scattering experiments found a much smaller radius than the correct one.

(xiv) The spinning quarks constituting the nucleon are fermions that cannot pass through each other. They possess radii, and at high pressure and high density the rotation of each of the three quarks within the nucleons is quenched [22], [2], [5]. We presume that then the circumferential layers of the rotating quarks interpenetrate (Ben-Amots [22], [2], [5]).

(xv) The interpenetration occurs between the external surfaces of the quarks. The external surfaces of the spinning quarks have relativistic velocities, as calculated in Chapter 4 of Ben-Amots [2].

(xvi) Burbidge and Hoyle [27] have already suggested that when quarks are converted into neutrinos and photons immense amounts of kinetic energy are released and given to these neutrinos and photons. They did not consider the relativistic rotation of the quarks.

(xvii) The penetration causes intensive Cherenkov radiation [28] in this case, which becomes significant.

(xviii) The energy needed for Cherenkov radiation within the star is taken from the kinetic energy of the rotation of the quarks. This rotation energy of the spinning quark constitutes more than 99% of the quark mass (calculated by Ben-Amots [22], [5], [2]). See Table 1.

(xix) High energy Cherenkov photons are created that supply energy to decompose the iron nuclei into helium and hydrogen nuclei at the center of the quasar.

(xx) The collimation effect of the cone of the inner surface of the toroidal accretion disk is similar to the collimation of the shaped charge or hollow charge explosive that generates a fast plasma jet [29] [30]. The hollow space in the explosive charge is also usually cone-shaped. The missile includes an inner cone surface that collimates the penetrating jet along the axis of symmetry in a forward direction. The shock of the explosion is directed *perpendicular* to the surface of the inner cone, and is focused alomg the axis of symmetry of the cone. The concentrated shock has a component of momentum in a forward direction along the axis of the cone. The resultant momentum and the resultant velocity are in a forward direction along the axis of the cone. All the shock waves concentrate and collimate at the axis of symmetry, with component forward, building plasma "super shock" jet in a forward direction. As the jet moves forward in the direction of the axis of the cone it continues to absorb more and more energy and momentum from other parts of the cone. The plasma jet penetrates the armor of the tank.

The hollow charge explosive was invented in 1883 [31] [29] [30]. In the twentieth century a bazooka hollow charge was widely used as an anti-tank weapon because when hitting a tank it can penetrate the tank's armor. Other hollow charge explosive weapons are widely used at present. Hollow charge explosives also have a few civilian uses, for example [32].

(xxi) We deduce that like in a hollow charge, the cone shape of the inner surface of the torus of the accretion disk produces radiation of photons perpendicular to the cone surface with a resultant in the direction of the axis of symmetry. This accelerates the hydrogen and helium atoms by Compton effect. Therefore, similar to hollow explosive charges but by a continuous process of emission, the two jets emerge in two polar opposite directions from the hollow cones in accretion disks around quasars and active galactic nuclei. The emission is not a single event as in hollow charge weapon, but a continuous phenomenon as long as there is a supply of particles from the quasar or the galactic nucleus and radiation energy from the accretion disk [2].

(xxii) The somewhat "convex cone" of the accretion disk and the continuous emission give a further continuous symmetric boost to the particles in the jet during their path along the jet, up to very far distances, increasing their speed to relativistic velocity and collimating their direction.

(xxiii) The processes as described above are based on a theory that quasars and active galactic nuclei are *not* point-like "black holes," but bodies with some dimensions, in spite of their enormous mass of up to milliards of sun masses. See Ben-Amots [22], [5], [2], [3], [33], [4]. Collisions of "black holes" orbiting each other were already observed by LIGO [34] (Laser Interferometer Gravitational waves Observatory, USA). Such a collision is not possible between two point-like masses orbiting each other without contradicting the law of conservation of angular momentum, thus proving that "black holes" posses radii.

3. A proof of how the cone is created

We consider a cloud of small masses m orbiting around the axis z, and gravitationally attracted to a heavy central point mass M (Figure 2).

We use *spherical* coordinates r, θ, ϕ (Figure 3) where each small mass has constant angular momentum

$$J = mvr\cos\theta \tag{1}$$

From (1):

$$v = \frac{J}{mr\cos\theta} \tag{2}$$

The potential of an orbiting point body in spherical coordinates r θ ϕ is the kinetic energy divided by m

$$\frac{v^2}{2} = \frac{J^2}{2m^2r^2\cos^2\theta} \tag{3}$$

where we ignored the kinetic energy of the smaller motion in the z direction. The gravitational potential (= Energy/Mass) is
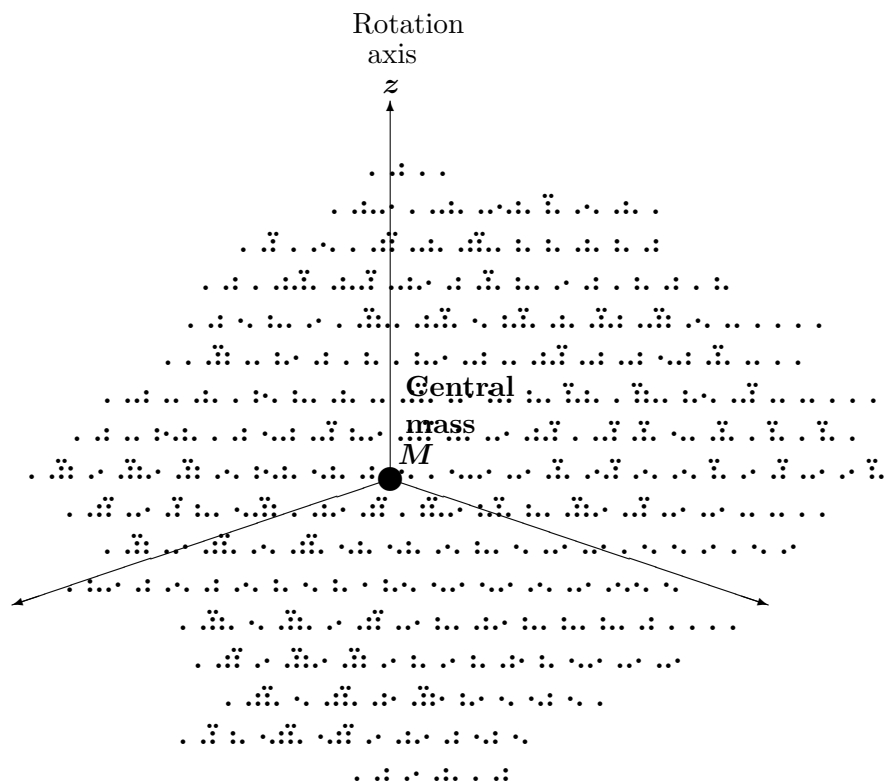
$$-\frac{MG}{r} \tag{4}$$

Together, the potential is

$$-\frac{MG}{r} + \frac{J^2}{2m^2r^2\cos^2\theta} \tag{5}$$

Where this potential is constant, we get a constant potential surface:

$$-\frac{MG}{r} + \frac{J^2}{2m^2r^2cos^2\theta} = k \tag{6}$$

Figure 2. A cloud of homogeneous particles (schematic) rotating around axis $\boldsymbol{z}$. In a *spherical* coordinate system the distance of a small mass $\boldsymbol{m}$ from the central mass $\boldsymbol{M}$ is $\boldsymbol{r}$

where k=constant is associated with energy.

Solving for $r(\theta)$

$$r = \frac{GM \pm \sqrt{G^2M^2 - 2\,kJ^2/(m^2\cos^2\theta)}}{2k} \tag{7}$$

For M=0 there is no stable solution for r, meaning that a torus can exist only around a central mass M.

Normalizing Equation (7) by choosing $GM = 1$ and $J/m = 1$ and K instead $2k$ we obtain:

$$r = \frac{1}{K}\left(1 \pm \sqrt{1 - \frac{K}{cos^2\theta}}\right) \tag{8}$$

Normalization in such cases is a mathematical tool used mainly to obtain values appropriate for numerical calculation. The values obtained by normalization should be convenient to calculate, in the order of 1. The scale in the following figures is normalized. The actual scale depends on the size of the accretion disk. In large accretion disks each unit represents hundreds of light years.

The solution is torus-like. Slow rotation velocity means low K. High K means fast rotation velocity.

Looking at Equation (8) one immediately deduces that K should be limited in order to avoid a square root of a negative value, meaning that the rotation velocity is limited in order to sustain
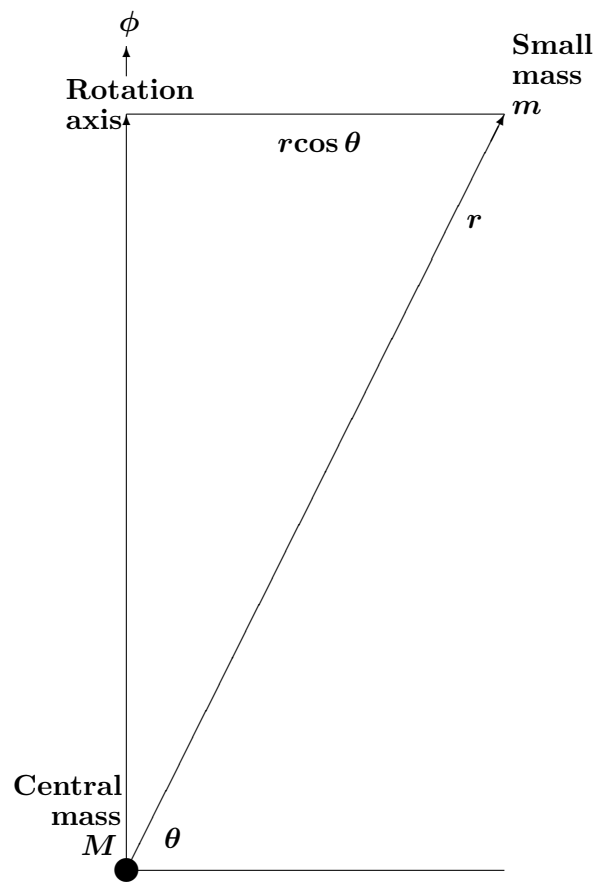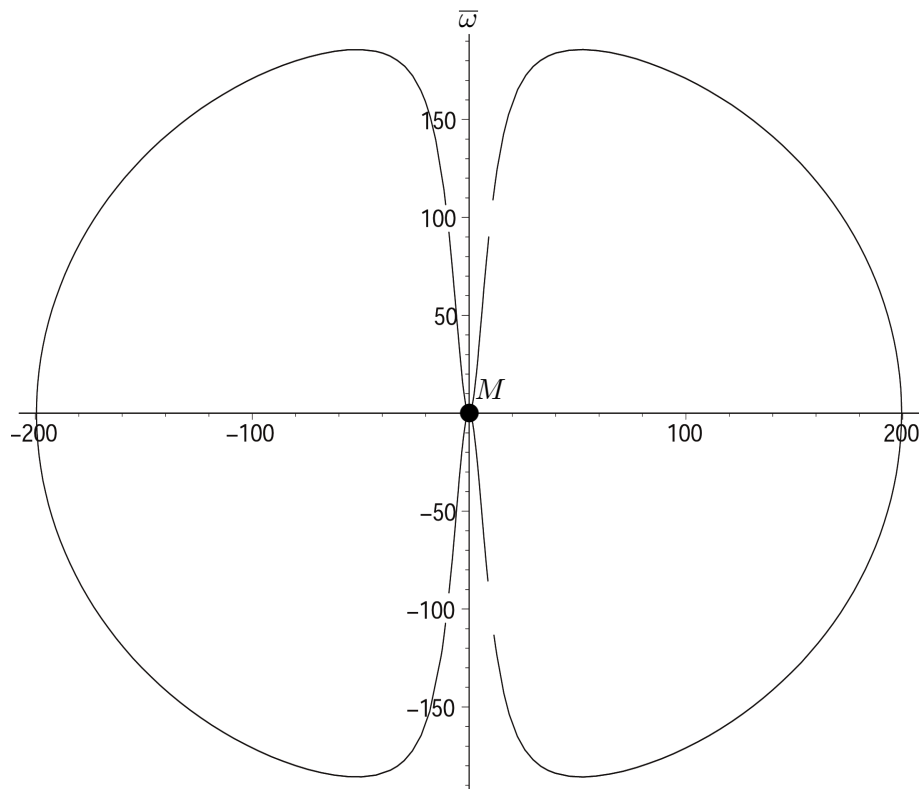
Figure 3. Rotation in *spherical* coordinate system. The distance of an element of mass m from the *central mass M* is r. The distance of an element of mass m from the axis of rotation is $r\cos\theta$

a stable solution. A careful interpretation of the similar (but not normalized) equation (7) leads to the same conclusion.

For K=0.01 (=slow rotation) the shape approaches a spheroid (Figure 4).

Figure 4. Section through a slowly rotating toroidal accretion disk with K=0.01 gravitationally attracted to a central massive body M. This shape is a grapho-analytical representation of the numerical calculation of Equation (8) for k=0.01 (=slow rotation)

Plotting for K =0.1 (Figure 5). The shape in Figure 5 is a grapho-analytical representation of the numerical calculation of Equation (8).
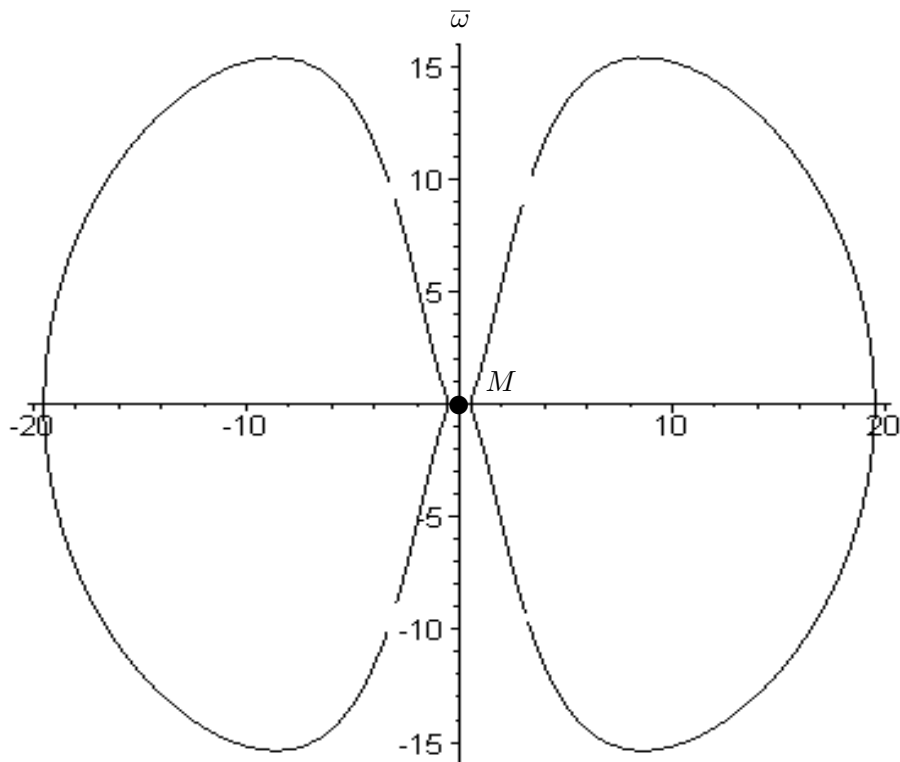
Figure 5. Section through a rotating toroidal accretion disk with K=0.1 gravitationally attracted to a central massive body M. The two inner cone surfaces are the result of the numerical calculation of Equation (8)

See quasi-tori with K=0.3-0.9, 0.99 (Figure 6). These shapes are the grapho-analytical representation of Equation (8) for K=0.3-0.9, 0.99

The torus structure for some astronomical objects was first suggested by Lynden-Bell [35] in 1962. Tori were observed in NGC1068 in 1985 [36], and in NGC4258 in 1995 [37]. Observations of tori were reported later in many papers. In most cases no attention was given to the relevance of the *torus cone* for the collimation of astronomical *jets*.

Other tori were also obtained by other researchers using different methods, but the few who paid attention to the cones explained that each cone is produced because the jet cuts its way through the inner side of the torus.

We claim that on the contrary the two cones *produce* the two jets.

According to our analytical solution (8):

One condition for obtaining torus-like shapes is that the angular momentum per unit of mass (J/m) should be large, but not too large so as to cause the disintegration of the torus. Therefore, the term under the square root sign in the relevant equation above must be positive:

$$G^2 M^2 - 2K(J/m)^2/\cos^2\theta > 0 \qquad (10)$$

This limits the specific angular momentum J/m relative to the mass of the central body represented by GM.

Another major condition is a massive central mass M. No torus is possible without a massive central mass.

Without a massive central mass the solution is a spheroid without the hollow pipe [2].
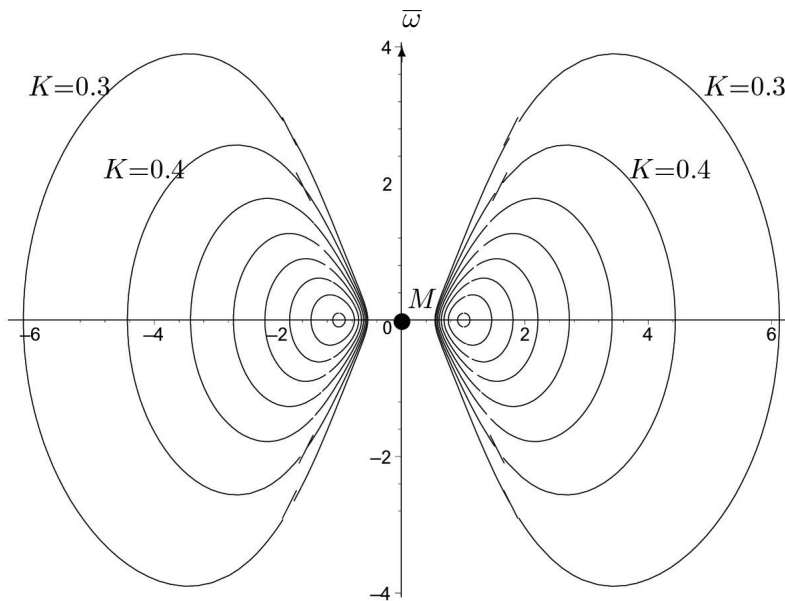
Figure 6. Section through a torus-like rotating accretion disk showing sections of surfaces with K=0.3-0.99. The inner cones with a similar tilt represent the results of the numerical calculations of Equation (8) for various values of K. The thick toroidal accretion disk is also the result of the numerical calculation. The thickness and the cones were obtained for all the values of M, m and J that we tried for $K < 1$ (This is not shown here. See in the text). One conclusion is that when matter in the accretion disk loses energy and angular momentum (by friction between the layers) it "falls" to layers with a smaller K. Only matter in a layer with a very small K may meet the central body M

The central mass may be a quasar or a galactic nucleus, whether active or not.

The collimation is as in Figure 1:

Two cones in a torus collimate radiation to two opposite jets:

The radiation (arrows) is emitted *perpendicular to the conical surfaces* of the torus and is collimated to two opposite jets (K=0.1 in our example).

Usually photons pass easily through other photons, because they may share one place. Particles are necessary for the collimation effect of a cone. Our discussion above does not take into account photon-photon scattering, in which two interacting photons need at least 0.511 MeV for each photon to produce a pair of electron and positron. See Section 10.

Hollow-charge missiles cannot be stabilized in the presence of rotation, because then the collimation of the jet is lost [30]. Therefore apparently the particles necessary for collimating a jet do *not* originate in the rotating torus [2].

We deduce that the rotating torus emits *radiation*, while matter particles have to be already in the axis of rotation, ready to be kicked or boosted by the radiation collimated by the torus.

Thick accretion disks possess cones, but flat accretion disks lack cones. Therefore, flat accretion disks cannot produce or enhance relativistic jets, but "Thick accretion disks produce jets." [1] .

Choosing J/m=1 for normalization fits a certain angular velocity that makes the sections of the tori in figures 1, 4, 5 and 6 look like a circle. For faster angular velocities the sections of the tori would look somewhat different but their inner surfaces would be similar to cones. These cones collimate the radiation that enhances the jets as well. The faster angular velocity is limited in order to avoid a square root of a negative number. A square root of a negative number means in this case disintegration of the torus due to too strong centrifugal forces. For example, for GM=1 and a potential K=0.1 the ratio J/m must not exceed $\sqrt{5}$. For this potential, near J/m=2 the section of the torus is very small, meaning that there is no effective collimation.

Instead of using the Newtonian equation (1), one may use the appropriate relativistic equation, which is not shown here, and obtain another potential equation instead of equation (6). It is solvable, however the solution is too cumbersome but similar.

Fragile [38] [39] and Hawley [40] conducted numerical simulations including magnetic fields and obtained sections through tori similar to our figure 6 (Font [41] for review).

Hawley's 3-D simulations [40] found that "things in the disk seem pretty independent of [magnetic] field topology." This fits our conclusion that gravity alone determines the shape of the thick accretion disk.

In 1982 Paczyński analytically obtained a *similar* torus by similarly using Newtonian potential. See Abramowicz's review [42] and Frank et al's [43] textbook. Paczyński and also Rees et al [44] suggested that the cones they obtained in the inner surfaces of the torus collimate relativistic jets. See Abramowicz [42] for review.

Observations identified the cases in which the directions of rotation were different for the central bodies and their accretion disks (Fragile [38]). The observations revealed that in these cases the jets start in the direction of the axis of rotation of the central body, and farther adjust to the axis of rotation of the accretion disk. Our theory explains that the particles of the two jets are first produced in the non-black-hole supermassive central body and then are expelled in its poles. Later they are accelerated and collimated by the radiation from the inner cones of the torus of the thick accretion disk. Thus there are earlier stages of the jets, before they are further accelerated outside the central mass as described above.

4. Processes inside quasars and galactic nuclei

Formerly we dealt with the amplification and acceleration of the jet *outside* of the central mass (quasar or active galactic nucleus). The outside jet is the *fourth stage*. The *first stage* is production of the jets *inside the central mass near its center*. The *second stage* is the moving of the *inner* jets outward along the axis of rotation. These two early stages are hidden inside the central mass. The *third stage* is expelling the opposite jets at the poles, as already observed in a few cases. These three stages are explained in the following text.

The particles of the jet originate near the center of the central massive body, although and because its mass may be millions or milliards of sun masses. These massive bodies possess radii. The LIGO observation of gravitational waves from *colliding massive bodies* [34] also proved that they possessed radii. We mentioned that if they were pointlike they could not collide without disobeying the law of conservation of angular momentum.

A modification of Hoyle's onion model [12] (1955) takes place. Hoyle [12] showed that the fusion of elements supplies energy and builds "onion" layers of heavier elements within the star. Iron is the inner and the heaviest element close to the center of the star. Hoyle [12] mentioned that at higher temperatures at the center of the massive star iron nuclei decompose to helium nuclei. This decomposition *demands energy*. Hoyle's onion model [12] of the structure of massive stars is accepted, including the decomposition of iron nuclei to helium nuclei in extreme conditions at the center of massive stars.

We claim that in order to sustain stability of a supermassive body an energy source at the center of the massive star supplies energy also to decompose iron nuclei to helium nuclei (alpha

particles) and hydrogen nuclei (protons).

(i) Helium and hydrogen nuclei are produced around the center of the supermassive body.

(ii) By buoyancy, the hot helium and hydrogen nuclei flow outward continuously and/or accumulate in huge bubbles that occasionally burst outward between layers 1-8. These bubbles were observed [45].

(iii) See our modified model of layers (Figure 7) for a celestial body of thousands up to milliards of solar masses (a quasar or an active galactic nucleus).
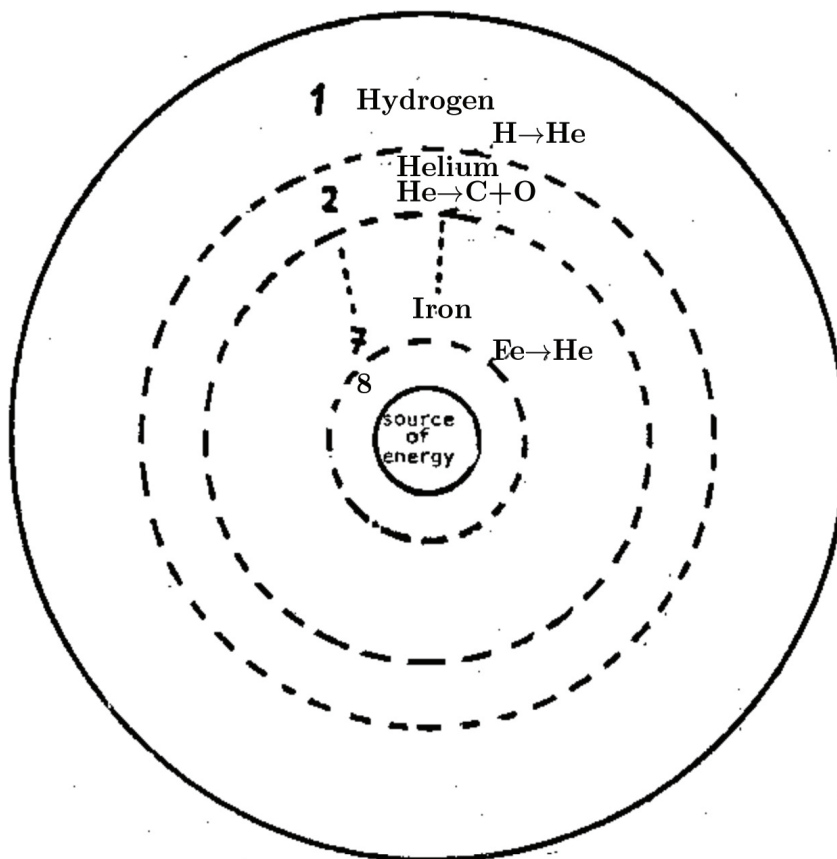
Figure 7. "Onion" layer model of a celestial body of millions to milliards of solar masses (not to scale). Strong convection currents of huge bubble bursts of helium exist between layers 1-8.

The hot helium and hydrogen nuclei are much lighter than the upper layers of the nuclei of metals. The hot helium and hydrogen nuclei ascend to the surface of the massive celestial body as a continuous flow or as accumulated huge bubbles [45].

Huge bubbles may explain the variable luminosity of quasars, because a huge hot bubble that arrives to the surface increases the radiation emitted by the ejected jet.

In which outward direction do they go? We will explain this in the following text.

Centrifugal force would push *heavier* matter to the equatorial bulge, but the super hot helium and hydrogen are *lighter* than the upper layers. The heavier upper layers squeeze the lighter helium and hydrogen nuclei toward to the axis of rotation and upwards *along the axis of rotation*

until they are expelled. There the helium and hydrogen nuclei are ready to be the *particles* in the axis of rotation that are pushed farther and faster by the *collimating radiation* from the cones of the torus.

The gravitational attraction force of the central mass M acts *spherically* inward on a mass m and is equal to mMG/r^2

The centrifugal force acts *cylindrically outward* on the mass m and is equal to $m\omega^2 r \cos\theta$ and is obviously zero at the axis of rotation z where $\cos\theta=0$.

Therefore, at the axis of rotation the gravitational attraction force inward is maximal and is equal to $\Delta m MG/z^2$ for a mass Δm *denser* than the surrounding environment.

In addition, at the axis of rotation the total *buoyancy* force *outward* is *maximal* for a mass *lighter* than the surrounding environment. A *lighter* mass will *ascend* along the axis of rotation outward toward the two poles and be expelled there as *two opposite jets* of hydrogen and helium.

Then the expelled *helium and hydrogen* will be collimated as two opposite jets on the axis directions by a hollow charge mechanism and accelerated to relativistic velocities by the absorption of energy supplied by the *radiation from the cones*.

See more details in Ben-Amots [2].

Porco [46] explained clearly the much weaker Enceladus's polar jet: "a warm region, with lower than average density, will naturally drift toward the axis of rotation. Furthermore, a warmer zone under the south pole would rise in convective motion under the uppermost brittle layer of the ice shell...". The flow of the lighter fraction *inward* to the axis of rotation as in Enceladus and *ascending upwards* along the axis of rotation towards the poles as in Enceladus exists in all rotating stars, quasars and active galactic nuclei. Enceladis is a moon of Saturn. Its diameter is ≈500 km. The much larger dimensions than those of Enceladus mean that there is a similar but much stronger and faster flow *upward* in *inner jets* along the axis of rotation of supermassive bodies, even without any calculation. See rough estimation in the next section 5.

Interpreting the hydrodynamics in a supermassive rotating body one may compare it with the analytical solution of the flow in a star rotating with uniform rotation (Section 9.4 in [13]). Figure 9.2 in [13] presents the characteristic flow. The radius in which the flow changes direction depends on the density. For a supermassive rotating body the radius is relatively close to the surface of the rotating supermassive body. The flow near the axis of rotation ascends along most of the axis of rotation almost up to the external surface.

The buoyancy of the light fraction of hydrogen and helium produces an upward flow along the axis of rotation similarly to Porco's [46] explanation. This upward buoyancy flow is added to the upward flow of the analytical solution in Section 9.4 of [13].

To apply this analysis on a supermasive rotating body one should accept the fact that a supermassive body is *not* a pointlike "black hole." See exponential gravitation in [2], [3], [4]. [5], [6], [7], [8] and [9].

5. Velocity estimation

For a very *rough* estimation we assume a constant acceleration a equal to the acceleration g on Earth 980 [cm/sec], along the radius r of a quasar, presumed to be 5×10^{13} cm (half a milliard km. See [48] p 50). Using the simple Newtonian formula

$$v = \sqrt{2ar} \tag{11}$$

the estimated velocity is approximately 3×10^8 cm/sec or 3000 km/sec or 0.01c, a fast jet but not a relativistic jet. These particles on the rotation axis are further accelerated to relativistic velocities by the radiation collimated by the cone of the torus of the accretion disk as described above in sections 2 and 3.

The acceleration is not constant, yet in small radii the gravitational buoyancy outward is decreased because the active attracting mass is smaller, but increased because of the large difference between the atomic weight of the helium and hydrogen nuclei and between the atomic weight of the iron layer. In large radii the attractive mass is larger and increases the buoyancy, but the environment consists of light atoms with a smaller difference between the atomic weights that decreases the buoyancy.

6. Abundance of helium

Transforming hydrogen to helium is a process that occurs in most of the stars by fusion. It is a slow process. It is accepted [13] that only stars more massive than 8 M_{sun} endure supernova explosions, which disperse the helium produced in the star. These supernovae cannot produce the 25% abundance of helium observed in the universe [47] during the accepted age of the universe, which is 14 milliard years. The accepted theory assumes that most of the helium was produced in a short time during the so-called "Big Bang."

Margon [15] reported that jets ejected from the microquasar SS433 expel only hydrogen and helium. We showed above that quasars and active galaxies nuclei produce and eject huge jets and bubbles of helium nuclei.

Ben-Amots (Section 8.10.7 in [2]) showed that the Cosmic Microwave Background was ended approximately 90 milliard years ago. During 90 milliard years the production and dispersion of helium by the stars and all the quasars, active galactic nuclei, microquasars and other jet emitting celestial bodies could reach the observed 25% of the matter in the universe. Therefore, "big bang" production of helium is redundant.

7. Short lived jets during supernovae

A supernova type II starts with a fast collapse of the core of a large star. Then a bounceback upwards occurs (Ben-Amots [5], [2]) as a shockwave. The fast collapse causes the upper layers of the star to lose their support and collapse as well. We deduce that due to the angular momentum of these layers, a torus with two inner cone surfaces is formed *within the star*, in a similar process as was described in sections 2 and 3. (see Figure 8 and Ben-Amots [2]). The heat of the friction between the layers in the torus is radiated perpendicular to the surfaces of the cones, and *collimates* the matter in the axis of rotation. Thus two opposite ultra relativistic jets *within the star* are formed. These jets break out and are expelled from the poles of the star as two opposite ultra relativistic jets.

A short time later the shock wave outwards reaches the newly born torus *in the star* and disrupts it. This *stops the collimation* and the production of the jets, making them the observed short-lived extreme jets (see more details in Ben-Amots [2]).

8. Celestial bodies with a larger mass

Massive stars of 100-200 sun masses were already observed. For example the estimated mass of Eta Carinae is 100 sun masses [49]. Tracing progenitors of exceptionally luminous supernovae found stars with up to 200 sun masses (Gal-Yam [50]). Larson and Bromm [51] assumed that it is possible that there are ancient stars of 1000 sun masses.

On the other hand, the masses of active galactic nuclei are millions of sun masses and more, up to milliards of sun masses. Quasars possess milliards up to trillions of sun masses. There also exist celestial bodies whose mass is between about 1000 and a million of sun masses. Greene [52] calls celestial bodies in the range of 1000-2000000 M_{sun} "middleweight black holes." Lemonick [53] mentions one million M_{sun}.

Gal-Yam [50] explains that very massive stars endure exceptionally strong supernovae explosions early in their life. This is caused by the electron-positron pair production that occurs and initiates the fusion of oxygen nuclei. The pair production instability as a cause of
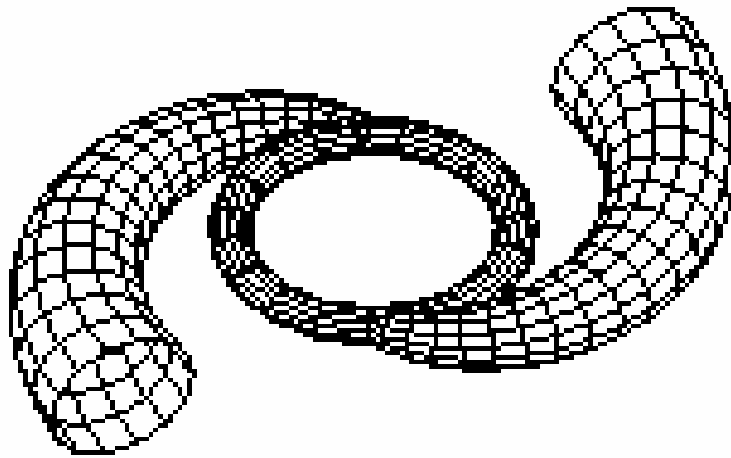
Figure 8. Two stream tubes converge into a torus during collapse of a supernova (schematic). Actually there are many such simultaneous stream tubes converging into the same torus [2]

supernova explosions of very massive stars was predicted and calculated by Barkat et al [54], Rakavy and Shaviv [55], [56] and Shaviv and Kovetz [57] and was confirmed by observations about fifty years later (Gal-Yam [50], [58], Gal-Yam and Leonard [59] and Gal-Yam et al [60]).

This early explosion apparently prevents existence of stars more massive than about a thousand sun masses. That is why there are no stars more massive than a limit of hundreds or a thousand sun masses.

However, the much more massive galactic nuclei and quasars, whose mass is millions of sun masses or much more, avoided and still avoid both the electron-positron pair production instability and the iron decomposing instability. The question of how the pair instability and the iron decomposing instability are bypassed during the formation of active galactic nuclei and quasars exists for any theory of quasar formation, or galactic nucleus formation, regardless of how they are stable later.

9. Relativistic effects

(i) The accepted beliefs that quasars and galactic nuclei are "black holes," and that nothing can be expelled out of a "black hole" led to the belief that the accretion disks supply matter to the jets, bypassing the presumed "black holes."
In this paper it is shown that the accretion disks supply *radiation* to the jets and matter to the quasars and the active galactic nuclei. The matter (hydrogen and helium) is supplied to the jets by expelling from the quasars and the active galactic nuclei. For these explanations the belief in "black holes" should be ruled out. For relativistic rotation and appropriate relativistic theories without "black holes" the interested reader can consult recent papers by Ben-Amots [22], [5], [2], [3], [33], [4], Majerník [6], [7], Walker [8], [9] and earlier references therein.

(ii) Many works were done on various aspects and phenomena involved in the astronomical jets in order to explain the observations of these jets. Among them are various suggestions of processes in order to explain how the velocities of these jets are enhanced even further, how the jets keep moving collimated along thousands to millions of light years and how they disperse at last to giant lobes. Collisions between the nuclei in the jet that increase the

velocity of a small portion of the nuclei in the jet to relativistic velocities were suggested [48]. This work does not deal with these late stages of the astronomical jets (fifth stage according to our counting).

However, a rough calculation in Section 10 below suggests that the above fourth stage of enhancing the velocity of the jet may be sufficient to accelerate it to relativistic velocity, making the fifth stage relevant only during dispersing of the jets to giant lobes.

10. Examples of calculating the velocity of the jet

We mentioned the calculation for the jets of the microquasar SS433 [13] [14]. Radiation of hydrogen atoms from the surface of the microquasar along the axis of rotation at 13.6 eV (912 Å) is redshifted to the lowest excitation level of the hydrogen atom of 10.2 eV (1200 Å), accelerating the jet to 0.26c. Accordingly, the formula for microquasar that takes into account the relativistic redshift is

$$v = c \frac{(13.6/10.2) - 1}{(13.6/10.2) + 1} \tag{12}$$

which gives $v = 0.26c$ [13] [14], as measured in the microquasar SS433 [15]. 13.6 eV is in the ultra-violet radiation range.

If faster jets have a similar process for enhancing their velocity, then by substituting radiation stronger than 13.6 eV from an accretion disk around a quasar or an active galactic nucleus we may use Equation (12) to get approximations for their faster jets.

Looking at figures 1 and 5, for K=0.1 the radiation perpendicular to the surface of the cone has a *component* of approximately 1/4 in the direction of the axis of symmetry of the cone. We assume that this component may accelerate an atom in the jet in the direction of the jet, but in the usual case the components *perpendicular to the jet* do not accelerate the atoms in the jet. We calculate for the hydrogen atom, whose lowest excitation level is 10.2 eV.

Examples of calculating approximations:

(i) Substituting of 850 eV (14.6 Å) in Equation (12) for an example of K=0.1 and radiation perpendicular to the surface of the cone, while considering only 204 eV of it as the resultant contributing to the acceleration of a hydrogen atom in the direction of the jet, a velocity of about 0.995c is obtained. 850 eV is in the X rays radiation range.

(ii) Substituting of 527 KeV (0.0235 Å) in Equation (12) for an example of K=0.1 and radiation perpendicular to the surface of the cone, while considering only 126.5 KeV of it as the resultant contributing to the acceleration of a hydrogen atom in the direction of the jet, a velocity of about 0.99999999c is obtained. 527 KeV is in the γ rays radiation range.

In this case the component perpendicular to the direction of the jet is 511.1 KeV. The head on collision of two opposite photons of 511 KeV or more is capable of producing a pair of electron and positron. A nucleus of hydrogen in the jet may absorb such an electron and may become an atom, that may be accelerated by absorbing 10.2 eV, which is its lowest excitation level.

Another assumption may be avoiding the necessity of mass expelled from the central body, but producing of jets of electrons and positrons from γ rays focused by the cones of the accretion disks.

The scenarios assumed in item (ii) may be realistic only if the accretion disk emits γ rays stronger than 527 KeV.

(iii) The calculation in this section may be valid for *hydrogen atoms*, or for helium *atoms* when the appropriate excitation levels of helium *atoms* are considered instead those of hydrogen. The lowest energy level of He$_4$ nucleus is higher than 20 MeV, but apparently weaker photons in the ultraviolet radiation range or X-ray range are capable of directing jets to

the axis of rotation of the thick accretion disk. Therefore, for hydrogen and helium *nuclei* a different mechanism should be considered:

Each photon possesses momentum in direction perpendicular to the surface of the cone. When many photons collide with a nucleus near the axis of rotation, each photon delivers its momentum to the nucleus. During many collisions the nucleus receives momenta from many photons. The resultant momentum of all the photons that collide with a nucleus is in the direction of the axis of rotation of the thick accretion disk, which is also the axis of symmetry of the cone. This way collisions with many photons increase the velocity of every nucleus in the direction of the jet.

The resultant momentum is small for a too slow rotation of the accretion disk (Figure 4). The section of the torus is small for a too fast rotation of the accretion disk (Figure 6). The conclusion is that the rotation of the thick accretion disk should be effective in producing a fast jet for $0.8 > K > 0.05$.

The photons radiated from the rotating accretion disk are scattered by collisions with the nuclei in arbitrary directions and frequencies. This arbitrary scattering enables us to observe the jets. Therefore, we deduce that apparently these collisions continue to occur along the jets up to the lobes (fourth stage according to our counting).

11. Remark

This paper includes some approximations. In this context we cite
"Thumb's first postulate

It is better to solve a problem with a crude approximation and know the truth, $\pm 10\%$, than to demand an exact solution and not know the truth at all." [61]

12. Conclusions

This paper details the processes in the center of massive celestial bodies like quasars and galactic nuclei. These processes stabilize them and prevent implosions. Production of hydrogen and helium near the center of these bodies is a by-product of these processes. These helium and hydrogen nuclei (or atoms in microquasars) are lighter than their surroundings. A region with lower than the average density will naturally drift toward the axis of rotation. There they rise upward in a very fast convective motion and by buoyancy along the axis of rotation and are expelled at the poles as jets.

This paper also proves that a *thick* accretion disk around such celestial body takes the shape of a torus that includes inner cone surfaces. The torus emits radiation produced by friction between the rotating layers of the accretion disk. The *radiation* that is emitted through the surfaces of the inner cones collimates the helium and hydrogen nuclei (or atoms in microquasars) that are moving along the axis of rotation, and accelerates them by absorption of the radiation to two opposite relativistic jets.

In this way the paper explains the stability of quasars and galactic nuclei as well as the production of relativistic jets, and also adds them as producers of helium that explain a significant part of the abundance of helium in the universe.

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