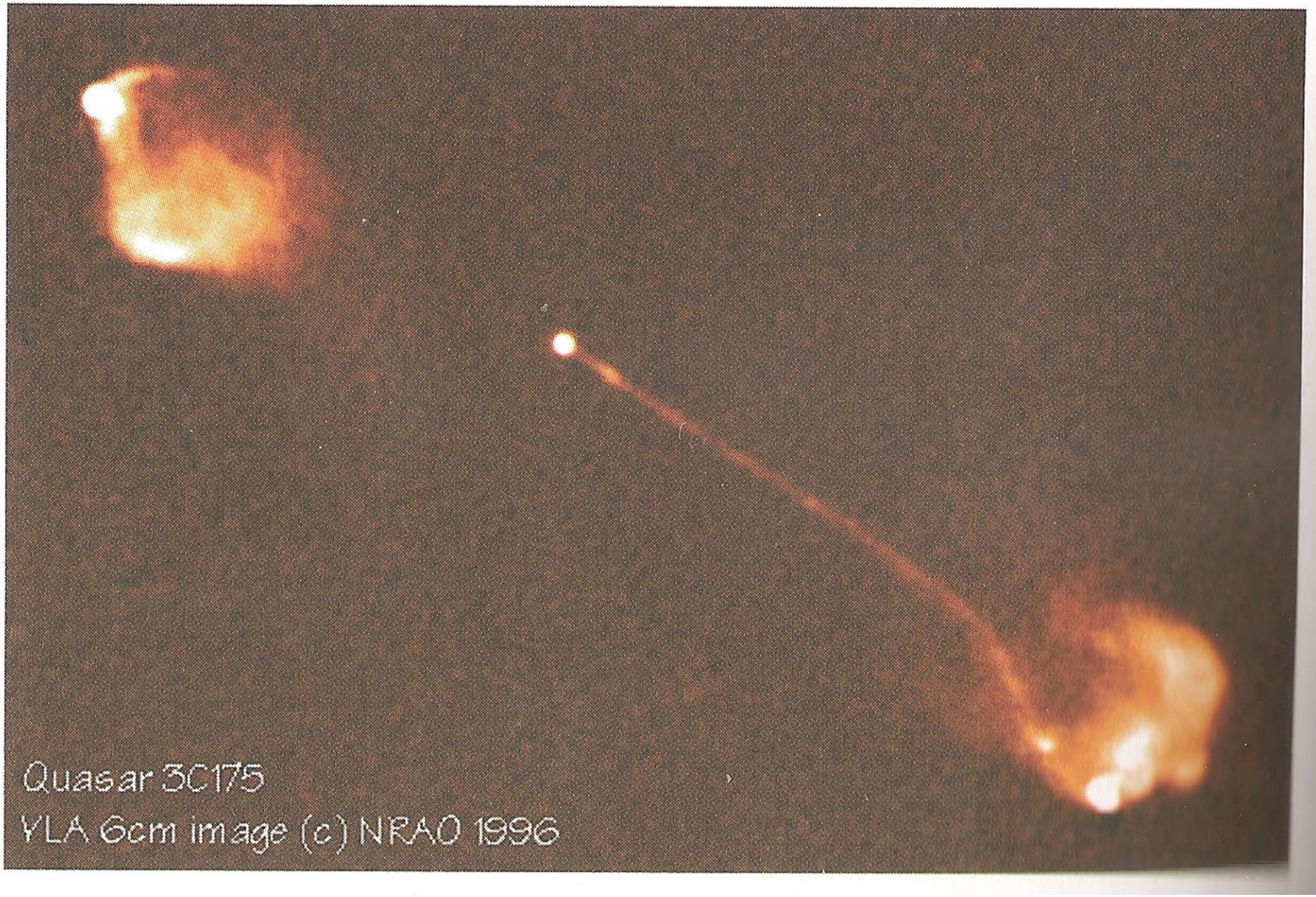
TORUS COLLIMATED RELATIVISTIC ASTRONOMICAL JETS and STRUCTURE OF QUASARES

NETSIVI BEN-AMOTS

Outline


Quasar 3C175
VLA 6cm image (c) NRAO 1996

This is one of two *relativistic* jets going out of the quasar 3c175 with velocities approaching the speed of light *c*.

This one jet is a relatively small one – 150,000 light years, yet longer than the diameter of our galaxy.

Many *relativistic* jets were observed going out of quasars and galaxies' nuclei and even from supernovae, with jet velocities approaching the speed of light *c*.

Some observed jets were found to be shorter, only a few thousand light years long – but a jet whose length is 2,000,000 light years was also observed – about the distance to Andromeda galaxy.

Wikipedia in "List of unsolved problems in physics" includes:

"Why do the accretion disks surrounding certain astronomical objects, such as the nuclei of active galaxies, emit relativistic jets along their polar axes?"

Tchekhovskoy, Narayan and Mckinney (JETS2013 Conf) defined the enigma precisely

"Why only thick disks produce jets"

(but not the flat accretion disks)

HUMANS PRODUCED JETS

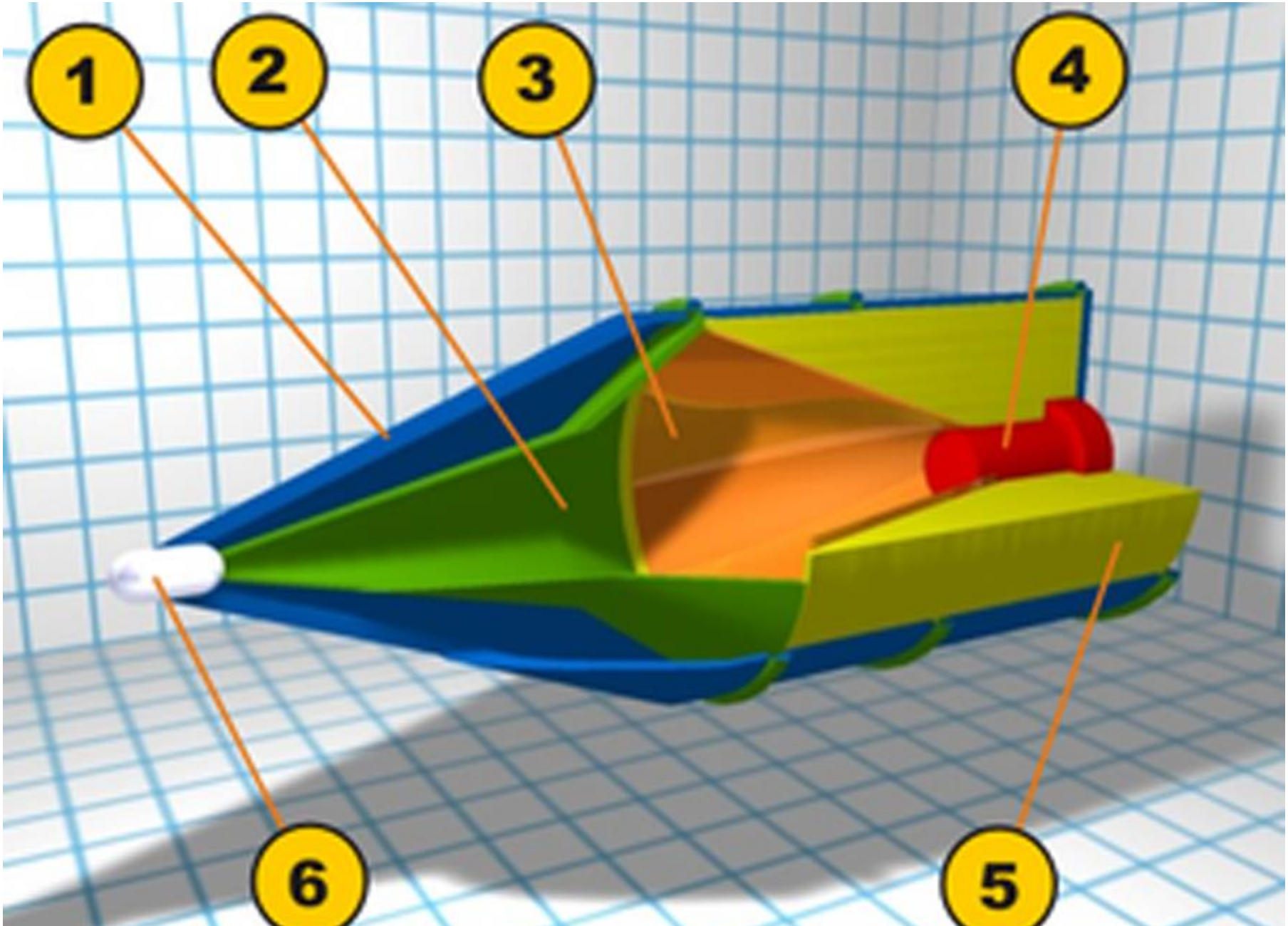
The *shaped/hollow charge* was invented in 1883.

In the twentieth century bazooka *hollow charge* was widely used as an anti-tank weapon, because when hitting a tank, the produced plasma jet can penetrate tank armor. (Recall basic training).

Here is a section about *hollow charge*,

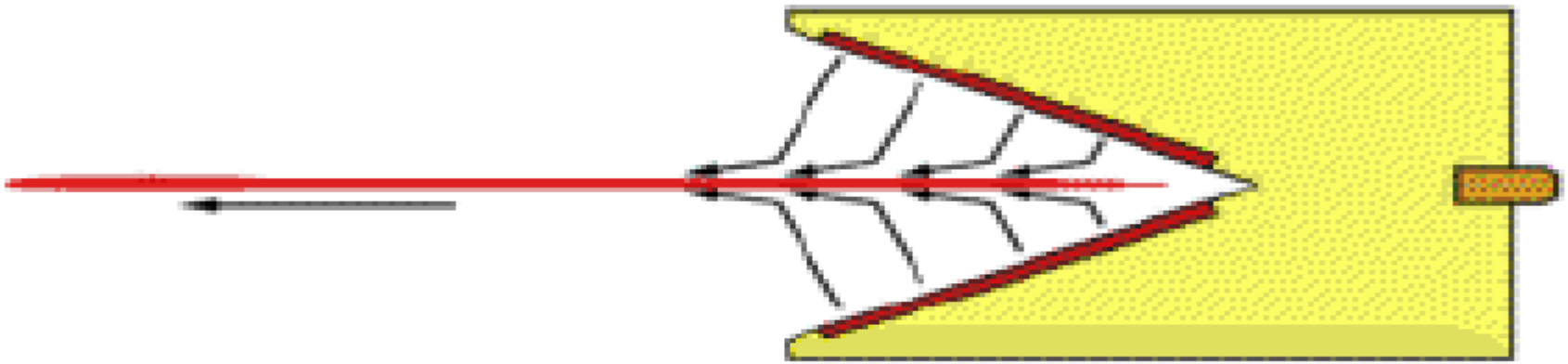
taken from Wikipedia

CONE ↓



Section: The explosion front moves inward, *perpendicular to the surface* of the CONE. SO, THE CONE COLLIMATES THE EXPLOSION FRONT INTO A JET.

…….CONE ↓ ↓perpendicular

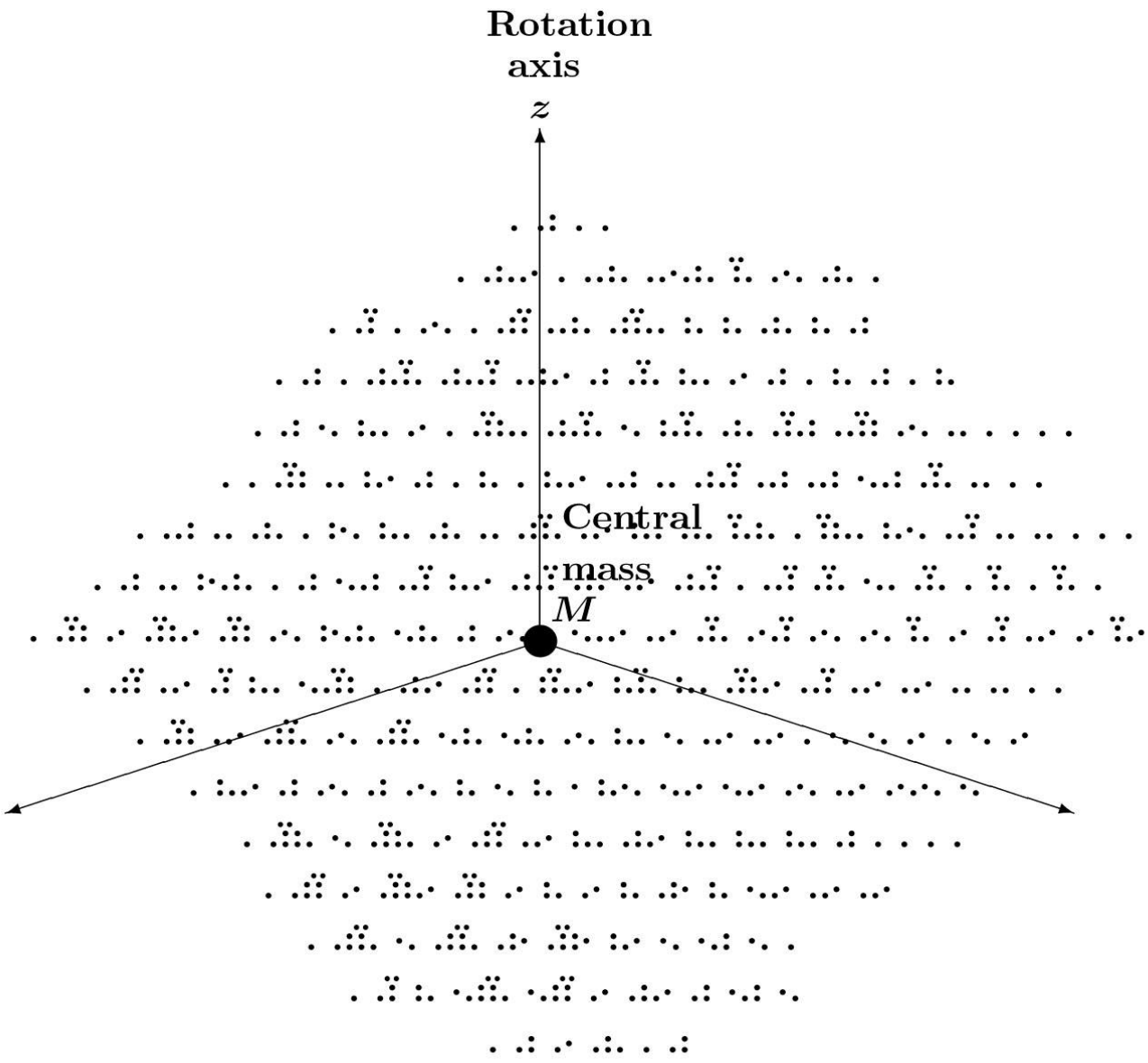


A cone directs the explosion inwards, where it accumulates on the symmetry axis of the cone, to build a jet.

Does a cone exist somewhere in or near the celestial bodies that expel the astronomical jets?

Radio waves observations of the centers of the nuclei of active galaxies NGC1068 and NGC4258 revealed *torus* shapes, which we analyze here.

LET US CONSIDER A CLOUD OF SMALL MASSES *m* ORBITING AROUND AN AXIS, AND GRAVITATIONALLY ATTRACTED TO A HEAVY CENTRAL POINT MASS *M*


Rotation
axis
z
Central
mass
M

We use *SPHERICAL COORDINATES*

r*, *θ*, *Ø

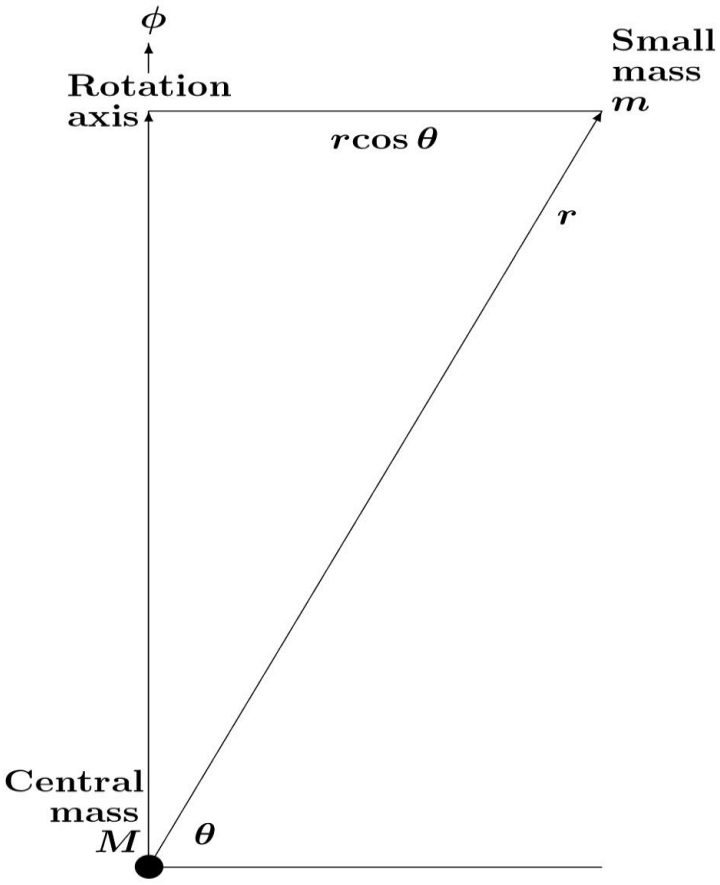
where each small mass has

CONSTANT ANGULAR MOMENTUM

$J = mr\,v\cos\theta$

$v = J/(mr\cos\theta)$

Spherical coordinate system



POTENTIAL OF ROTATING BODY

THE POTENTIAL OF AN ORBITING POINT BODY IN *SPHERICAL COORDINATES r θ Ø* IS THE KINETIC ENERGY DIVIDED BY *m*

$$\frac{1}{2}v^2 = \frac{J^2}{2m^2r^2\cos^2\theta}$$

ITS GRAVITATIONAL POTENTIAL (= ENERGY / MASS) IS

$$-\frac{MG}{r}$$

TOGETHER, THE POTENTIAL IS

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

Where this potential is a constant K_a , we get a constant potential surface $r(\theta)$:

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

Solving for $r(\theta)$

$$r(\theta) = \{GM \pm \sqrt{[G^2M^2 - 2k_aJ^2/(m^2\cos^2\theta)]}\}/2k_a$$

Normalizing by choosing GM=1 and J/m=1

$$r(\theta) = [1 \pm \sqrt{(1 - k/\cos^2\theta)}\,]/k$$

This is valid for *non-viscous* conditions.

The solution is *torus-like*

A similar concept is called elsewhere

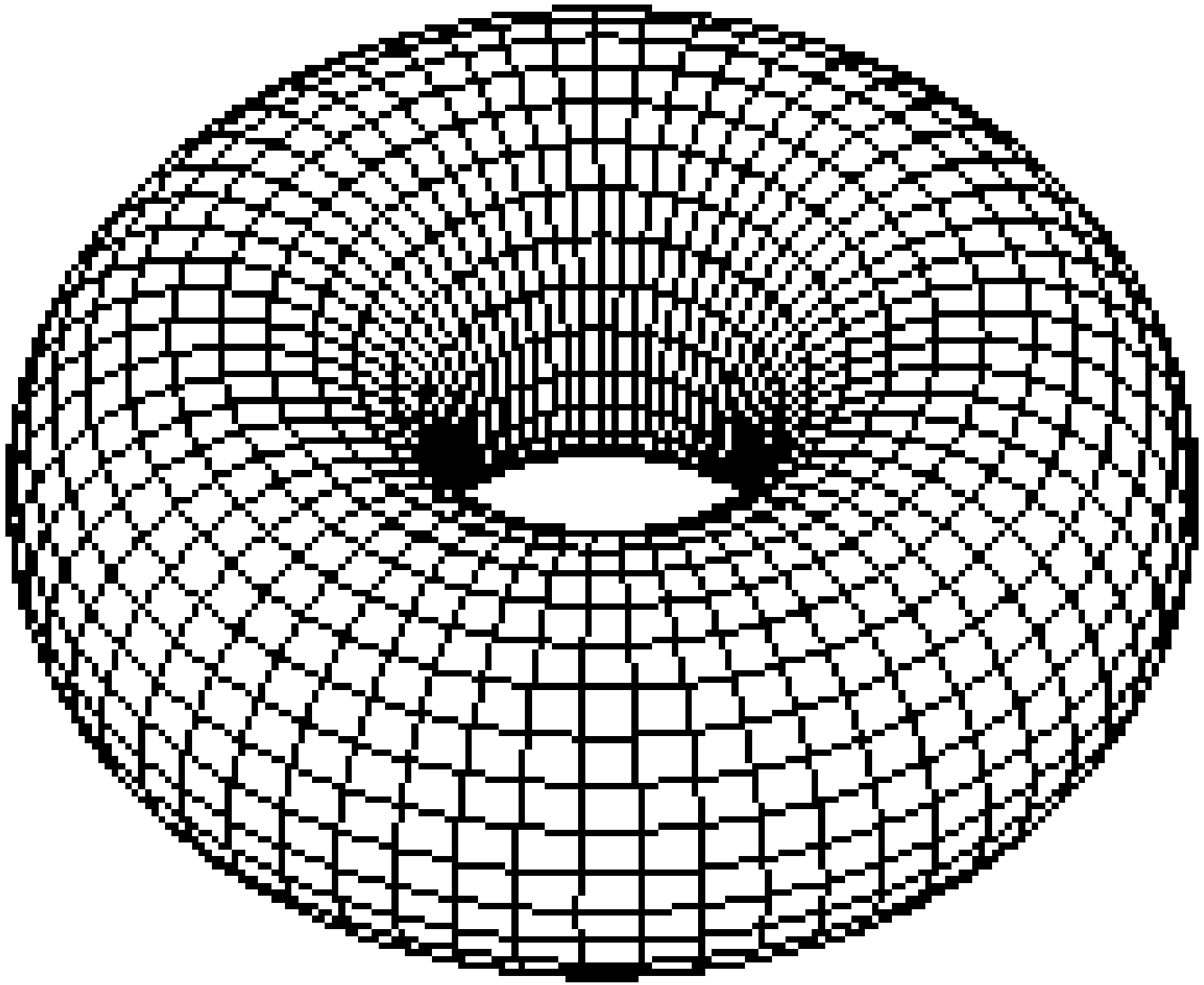
EFFECTIVE POTENTIAL APPROACH

Paczyinski analytically obtained a *similar* torus using the Newtonian potential

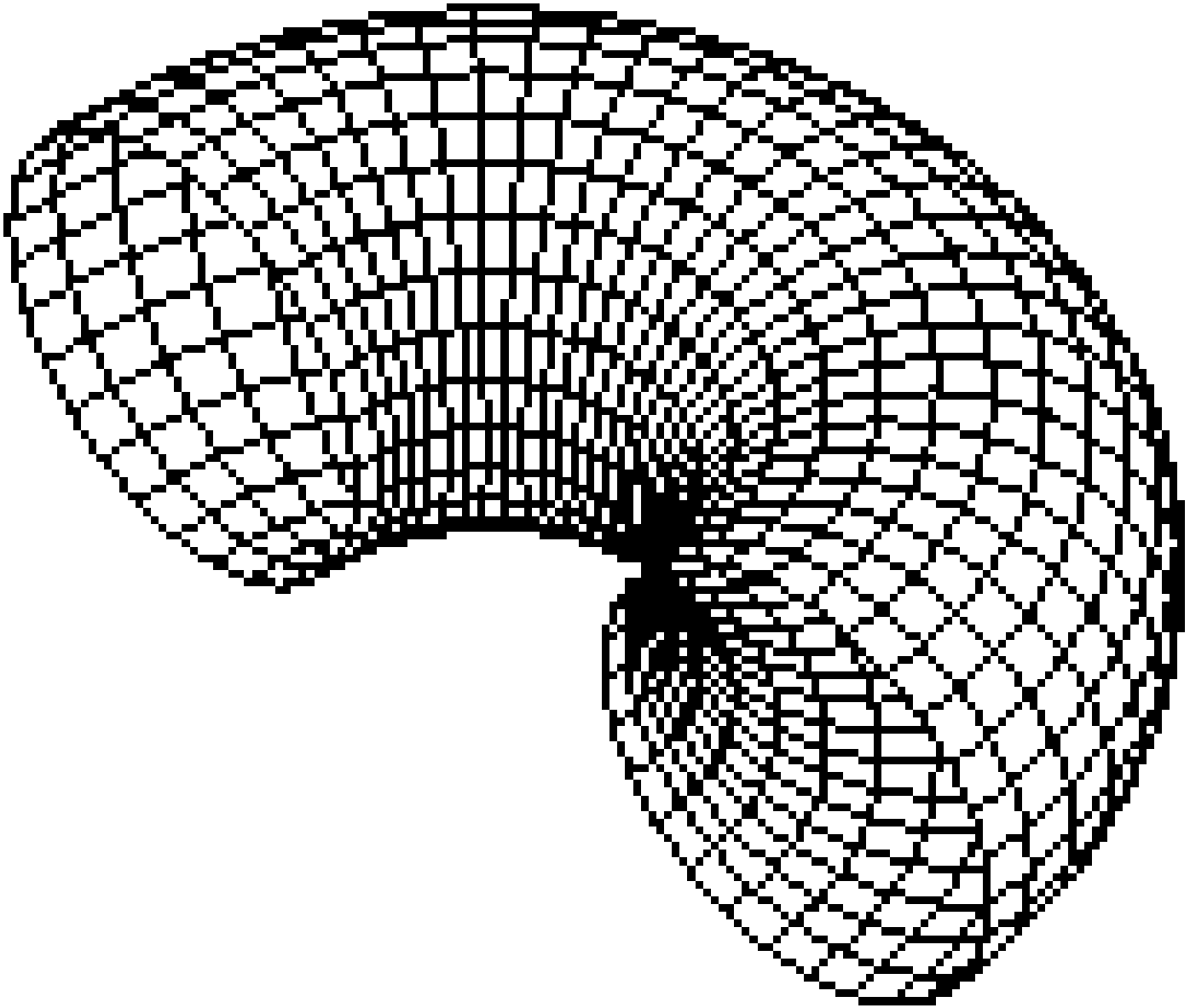
Other tori were also received by others using different methods.

To get into the mood of *torus*

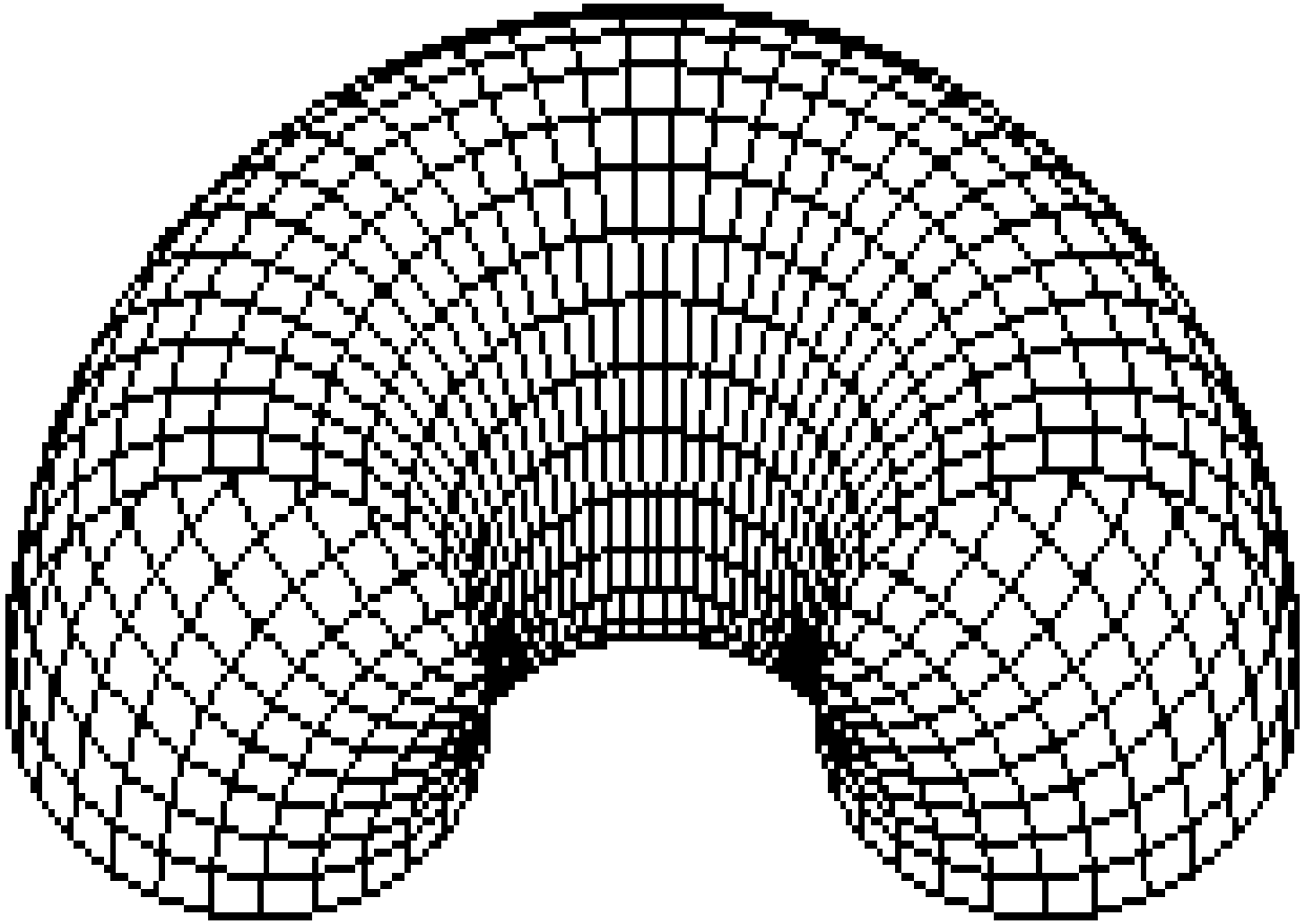
A torus



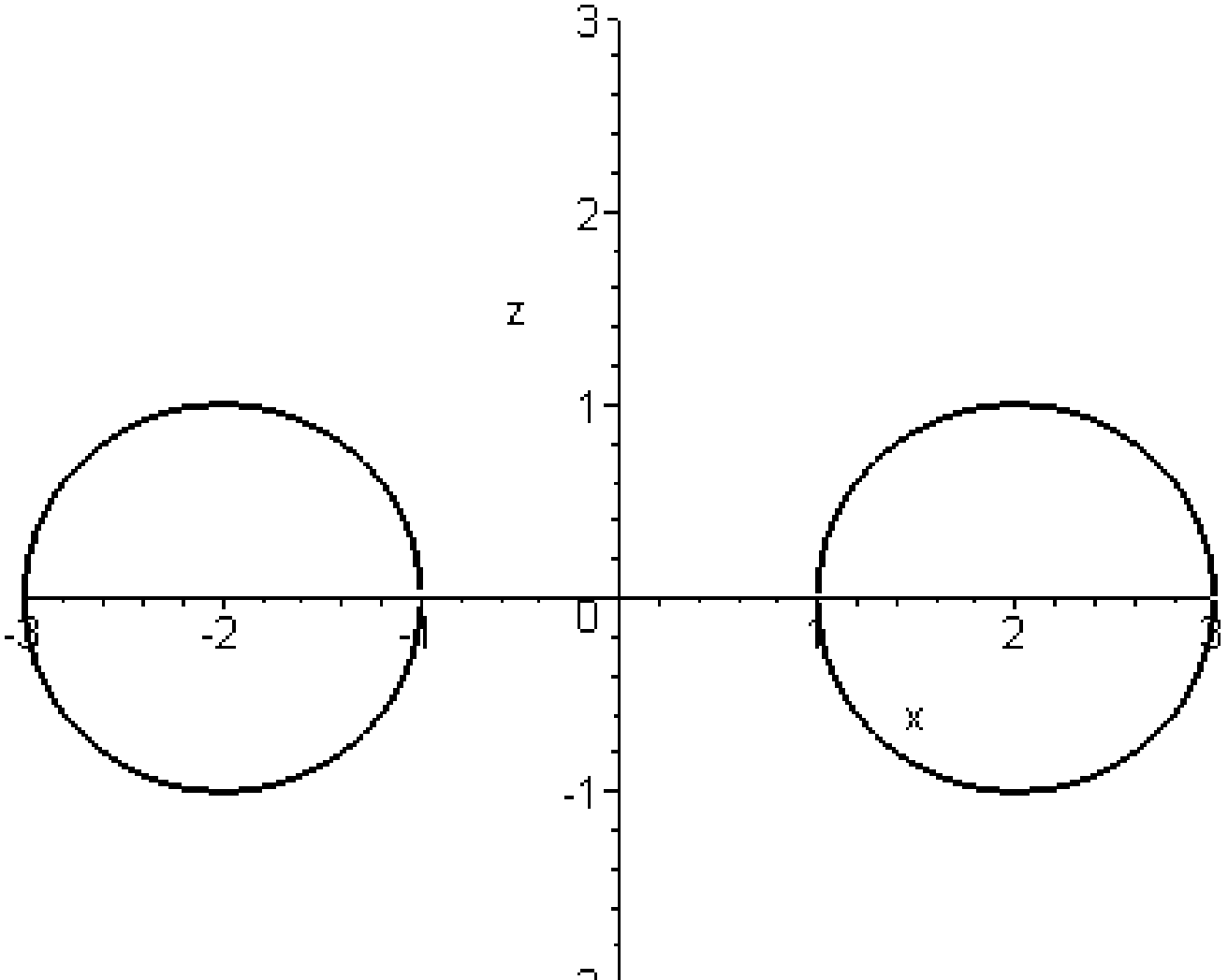
A section through a torus



Section through torus



The same section through torus. We use this to represent a torus



We treat one torus at a time, yet there are many *tori*

Slow rotation velocity means low *k*.

For *k*=0.01 → the shape approaches a spheroid.

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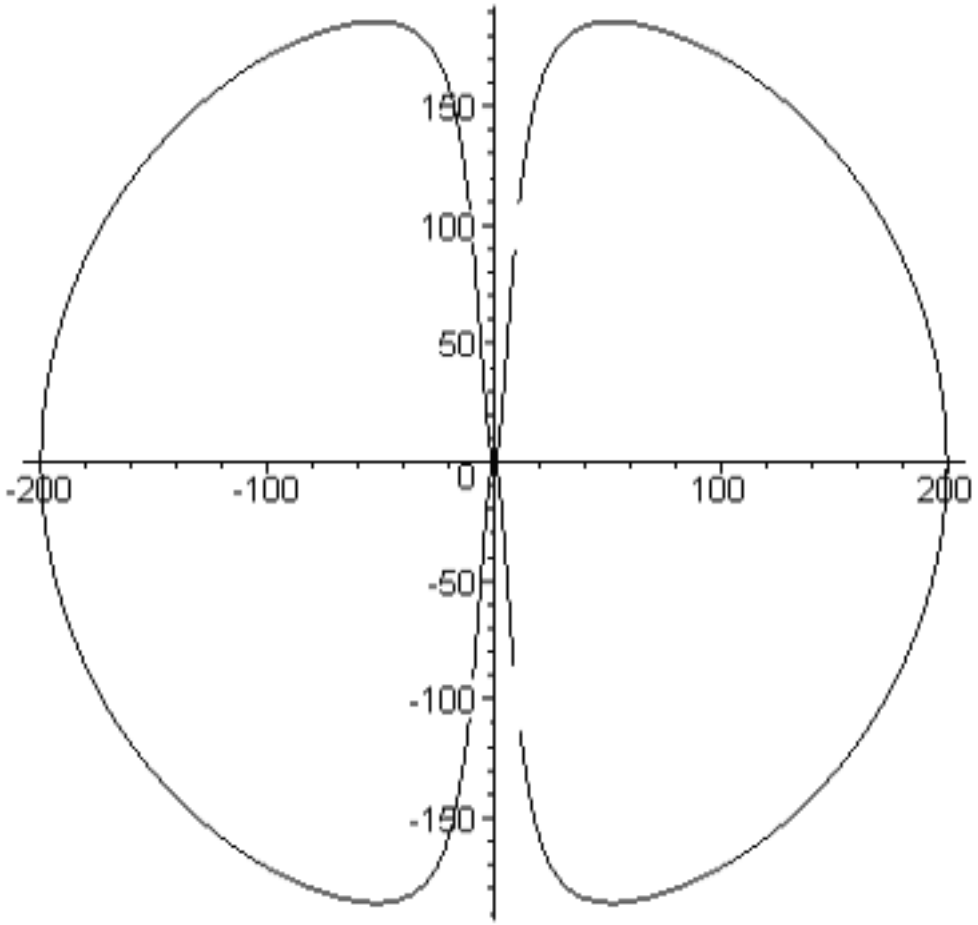
Ø ↑ Axis of rotation



k_a must be smaller than

$k_a < ½ (GMml/J)^2$

otherwise there is no solution (=runaway), because the rotation is too fast.

This condition in the normalized equation is

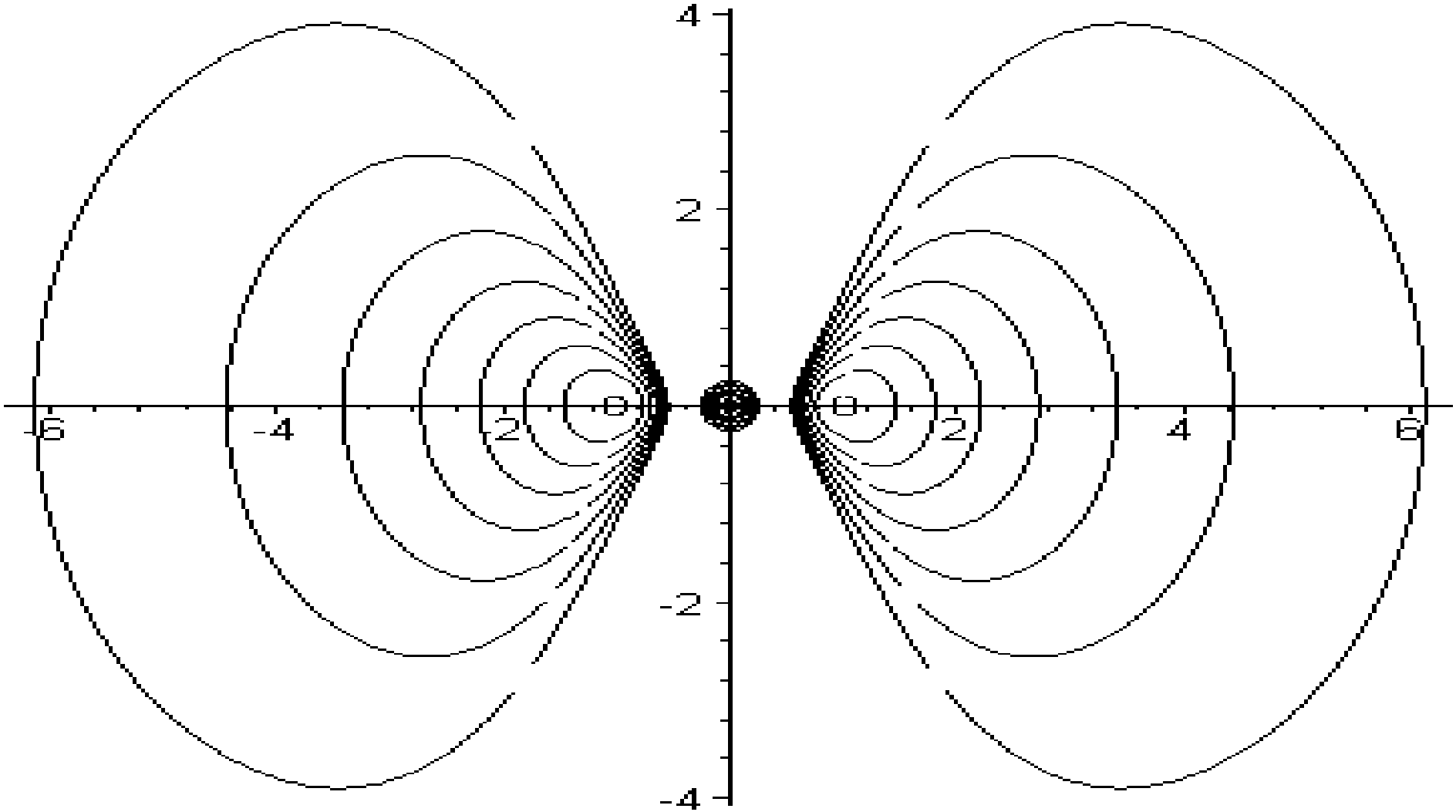
$k < 1$

In addition, the velocity must not exceed the speed of light c, giving an additional condition

$J < mcr \cos(\theta) \equiv k_a < \{ ½c^2 - MGl/[r \cos(\theta)]\}$

Plotting with constants k in the range 0.3 – 0.9 we obtain plots of the sections of ***torus-like*** shapes:

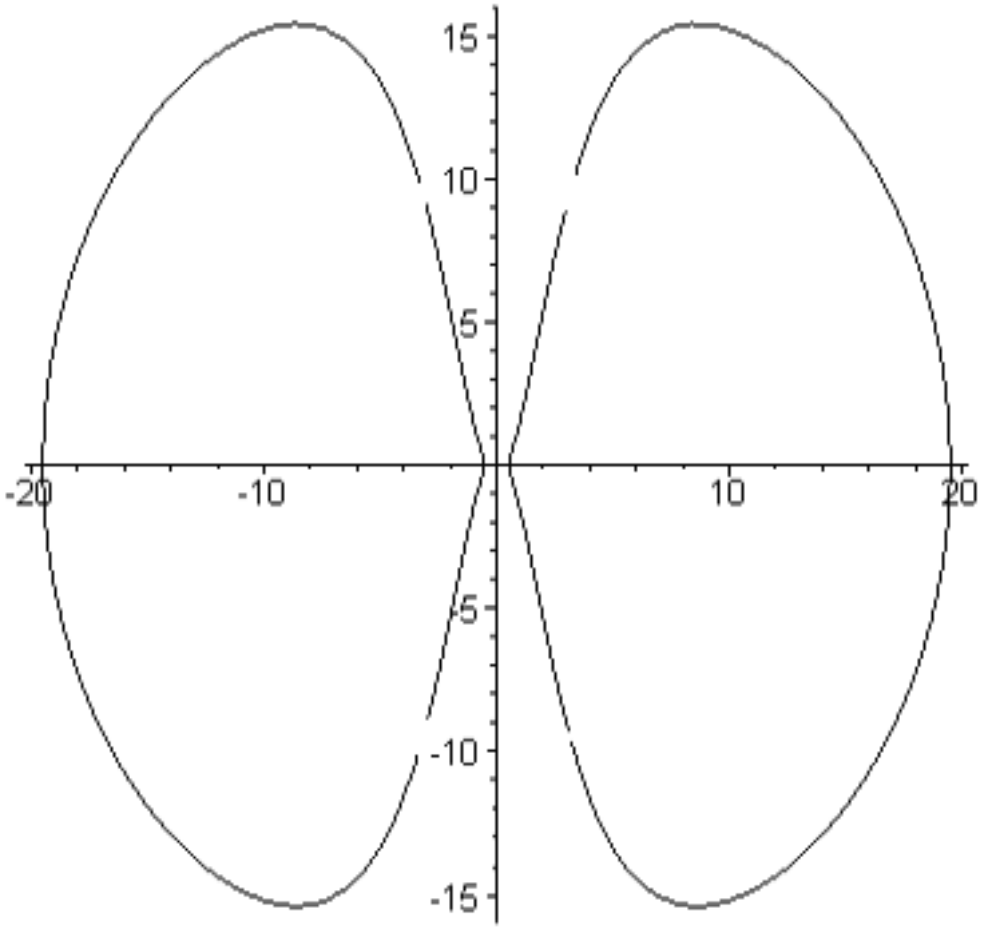
Quasi-tori k=0.3-0.9, 0.99



Plotting for $k = 0.1$

Where is the empty cone?

↑ Rotation



The torus structure for astronomical objects was suggested in 1962.

Torus was observed in NGC1068 in 1985. Many tori were observed later.

The calculations of these tori were done with other kind of methods than ours and no cone shaped inner surfaces were obtained.

In most cases no attention was given to the relevance of the *torus cone* for the collimation of astronomical *jets*.

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.

We take advantage of our analytical solution.

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.

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.

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

Energy sources for astronomical jets

Few energy sources were/are suggested:

a. Penrose process (1969 – ergosphere of a central black hole)

b. Blandford-Znajek process (1976/7 – MHD)

c. Slip between layers in accretion disk, which we consider below in detail

For all three an accretion disk around the central body is requested.

Paczinski and other researchers obtained inner surfaces similar to *cones*, slightly different from ours, and suggested that they collimate relativistic jets.

RIGID ROTATION VERSUS KEPLERIAN ROTATION: SLIP BETWEEN LAYERS

RIGID ROTATION HAS THE EQUATION $v=\omega r$ IN A RIGIDLY ROTATING BODY, THAT IS v IS PROPORTIONAL TO r^1

THEREFORE, THERE IS NO RELATIVE MOTION BETWEEN ITS PARTS, THUS NO FRICTION EXISTS BETWEEN THEM.

IN ACCRETION DISKS *KEPLERIAN/NEWTONIAN* DYNAMICAL MOTION WAS OBSERVED, FOR WHICH

$mv^2/r = mMG/r^2 \rightarrow$

$v = \mathrm{SQRT}(MG/r) \rightarrow$

v IS PROPORTIONAL TO $r^{(-1/2)}$

RIGID ROTATION VERSUS KEPLERIAN ROTATION: SLIP BETWEEN LAYERS

v **IS PROPORTIONAL TO *r*^(-1/2)**

THUS AN ADJACENT

LAYER WITH LARGER *r* MOVES SLOWER

NOT FASTER AS IN RIGID BODIES WHERE $v=\omega r$

THUS LAYERS IN THE ACCRETION DISK CIRCLING AROUND A MASSIVE CENTRAL BODY DO HAVE *RELATIVE MOTION* AND *SLIP* WITH NEIGHBORING LAYERS, CAUSING SHEAR, *FRICTION* AND HEAT BY COLLISIONS BETWEEN MOLECULES OR LARGER AGGREGATES. THIS PRODUCES *ENERGY* THAT IS TRANSFORMED TO *RADIATION.*

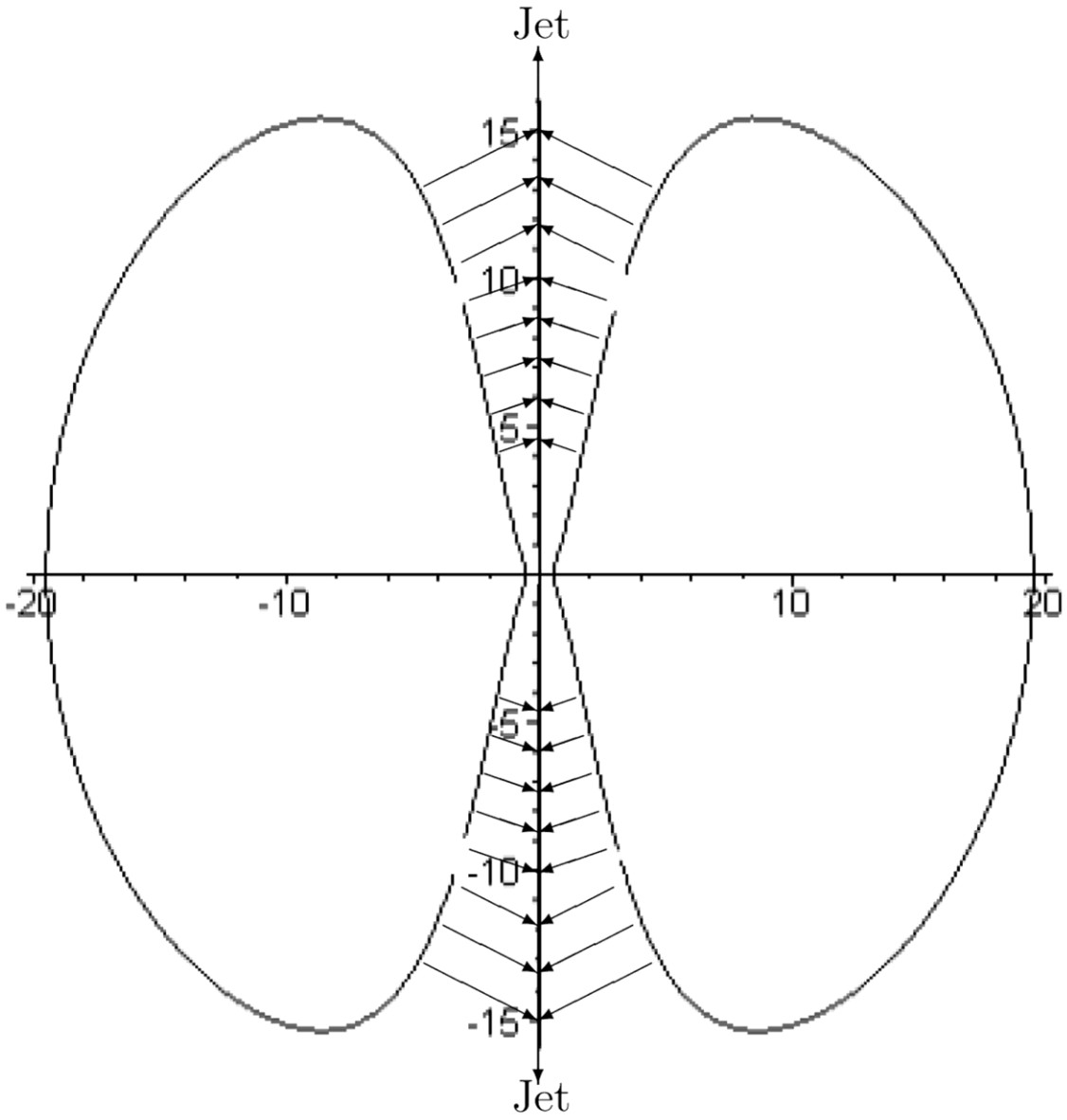
CYLINDRICAL MOTION VERSUS KEPLERIAN MOTION

IN KEPLERIAN MOTION, EACH PARTICLE MOVES SO THAT THE PLANE OF MOTION INCLUDES THE CENTRAL MASS *M*, BUT ITS PLANE OF MOTION IS NOT NECESSARILY PERPENDICULAR TO A GENERAL AXIS OF ROTATION. THEREFORE, THE PLANES OF MOTION OF MANY PARTICLES ARE *NOT* PARALLEL TO EACH OTHER, AND THERE IS A COMPONENT OF MOTION IN THE *Z* DIRECTION. THIS MOTION HAS COLLISIONS BETWEEN PARTICLES, THAT PRODUCE SHEAR, SLIP AND HEAT. THIS IS AN ADDITIONAL SOURCE OF HEAT ENERGY, BUT SMALLER.

CYLINDRICAL MOTION VERSUS KEPLERIAN MOTION

- **WE DISREGARDED THESE MOTIONS BY ASSUMING THAT ALL THE PLANES OF MOTION OF ALL THE PARTICLES ARE PARALLEL TO EACH OTHER, AND PERPENDICULAR TO ONE AXIS OF ROTATION.**
- **THE ACCRETION DISK THAT WE CALCULATED LOOKS LIKE A TORUS WITH INNER CONES SURFACES, WHICH COLLIMATE THE RADIATION AND PLASMA TO RELATIVISTIC *JETS*.**

TWO CONES IN A TORUS COLLIMATE RADIATION TO TWO OPPOSITE JETS



RADIATION VERSUS PARTICLES

PHOTONS PASS EASILY THROUGH OTHER PHOTONS, BECAUSE SEVERAL BOSONS MAY SHARE ONE PLACE.

THEREFORE, MATTER PARTICLES ARE NECESSARY FOR THE COLLIMATION EFFECT OF A CONE.

RADIATION VERSUS PARTICLES

We know that hollow-charge missiles cannot be stabilized in the presence of rotation, because then the collimation of the jet is lost. Therefore apparently the matter particles necessary for collimating a jet do not originate in the rotating torus.

The rotating torus emits just 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.

From our point of view, matter jets are on the axis ready to be collimated and kicked or boosted to relativistic velocity by the radiation emitted from the torus and collimated by the inner cone surfaces.

What may happen that may produce matter particles in the axis of rotation?

A possible source of matter particles

Particles may 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 also proved that they possessed radii. If they were pointlike they could not collide without disobeying the conservation of angular momentum.

A possible source of matter particles

Particles may originate near the center of the central body:

Considering an energy source at the center, a modification of Hoyle's onion model (1955) takes place:

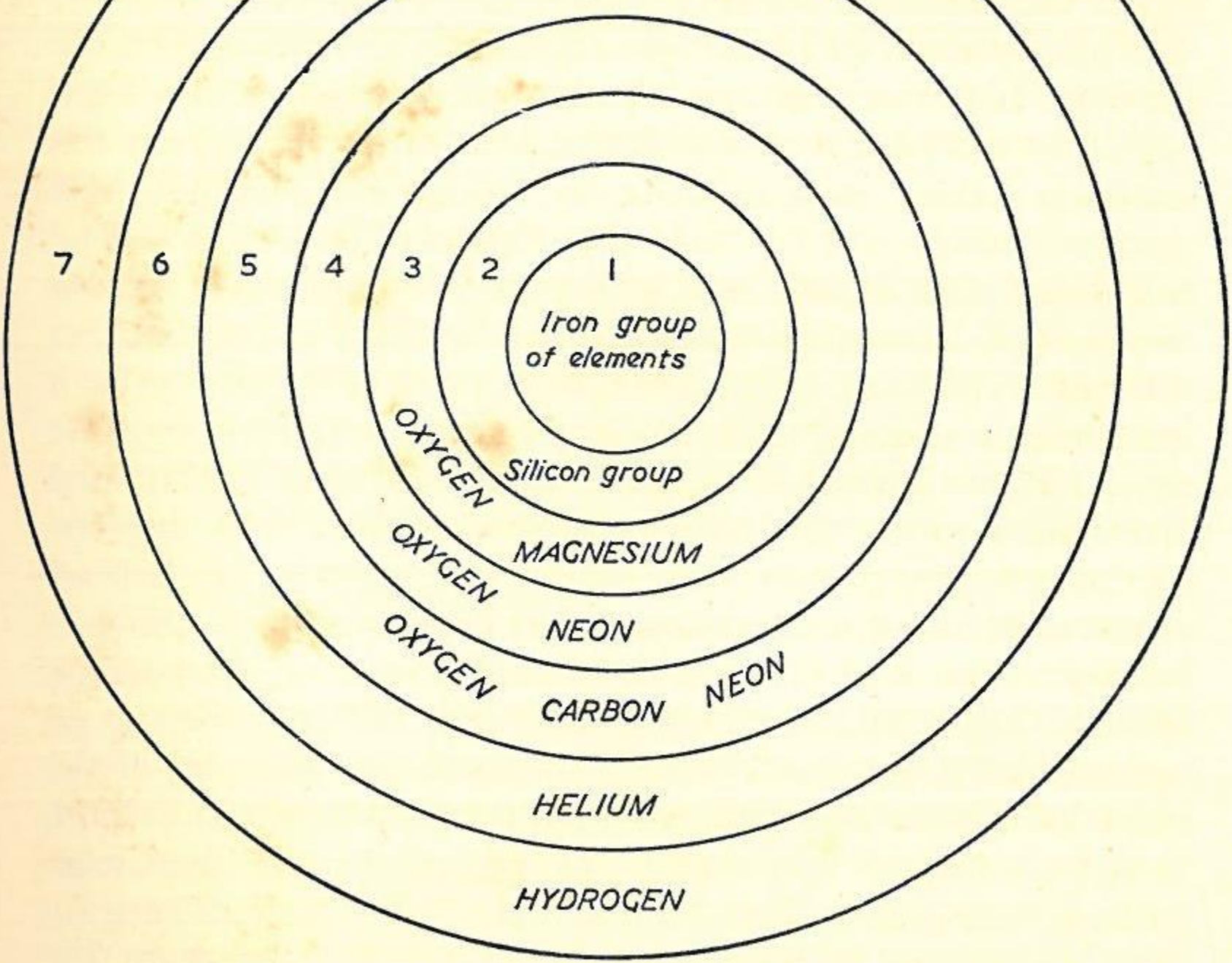
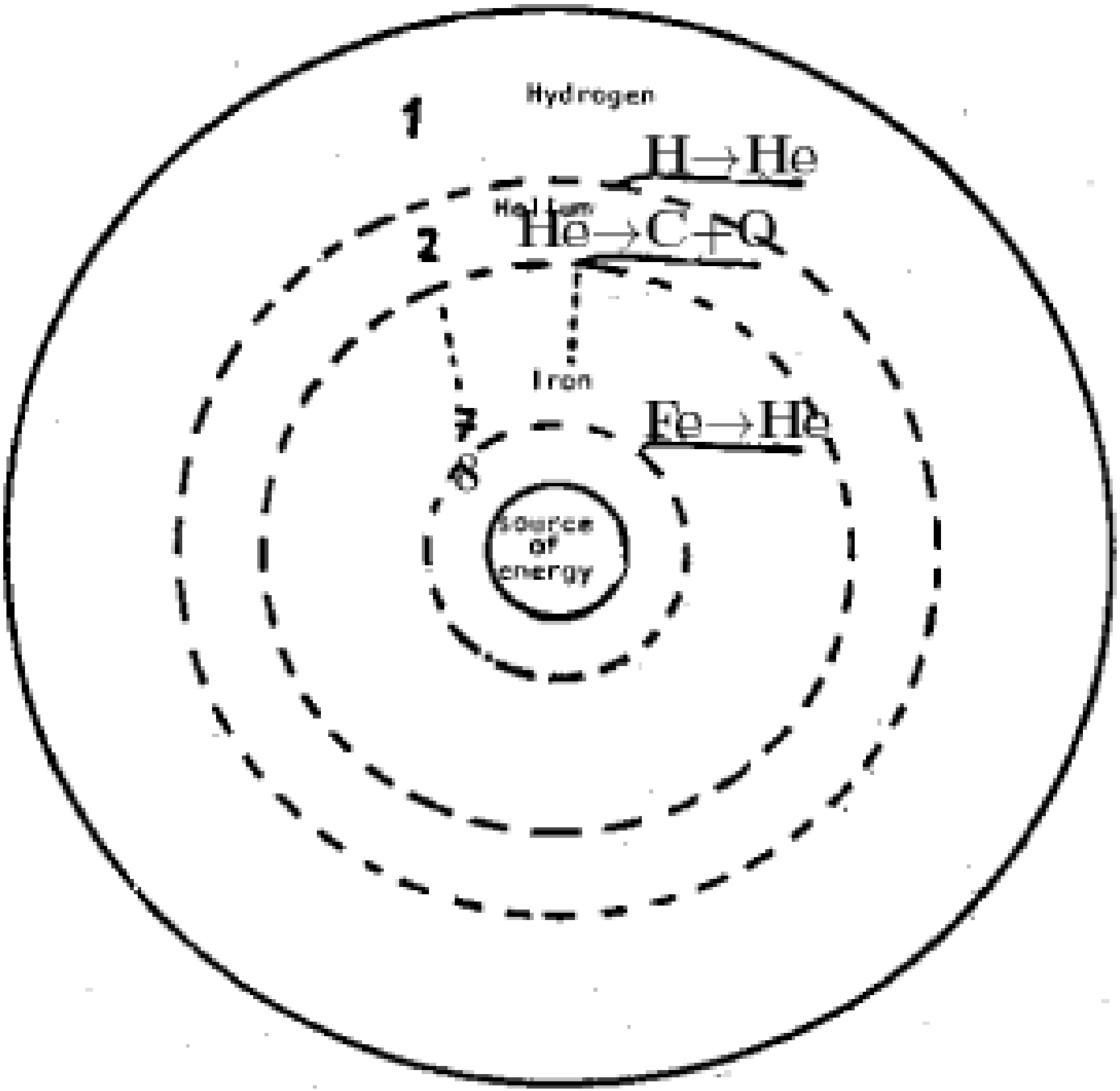


FIG. 47. Schematic drawing of a seven-zoned star.

A possible source of matter particles

The energy source at the center supplies energy to decompose iron to helium and hydrogen.

- Helium and hydrogen nuclei are produced around the center.
- By buoyancy, the hot helium and hydrogen flow upward continuously and/or accumulates in huge bubbles that occasionally burst upward between layers 1-8
- See the model of layers of a celestial body of thousands up to milliards of solar masses (a quasar or an active galactic nucleus). The figure is not to scale.


1
Hydrogen
$H \rightarrow He$
2
Helium
$He \rightarrow C + Q$
7
Iron
$Fe \rightarrow He$
8
Source of energy

Where do the bubbles go?

The hot helium and hydrogen are much lighter than the upper layer. These hot helium and hydrogen go upwards to the surface of the massive celestial body, as a continuous flow or as accumulated huge bubbles.

Where do the bubbles go?

In which upward direction?

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 helium and hydrogen upwards along the axis of rotation, where they are expelled. There the helium and hydrogen are ready to be the matter particles in the axis of rotation that are pushed further and farther by the collimating radiation from the cones of the torus!

Attraction and buoyancy forces

The gravitational attraction force 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 smaller and equal to $mr\,\omega^2$

and is equal to zero at the axis of rotation *z* where $r = 0$.

Therefore, at the axis of rotation the *total attraction* force *inward* is maximal and is equal to mMG/z^2

for a mass *denser* than the surrounding environment.

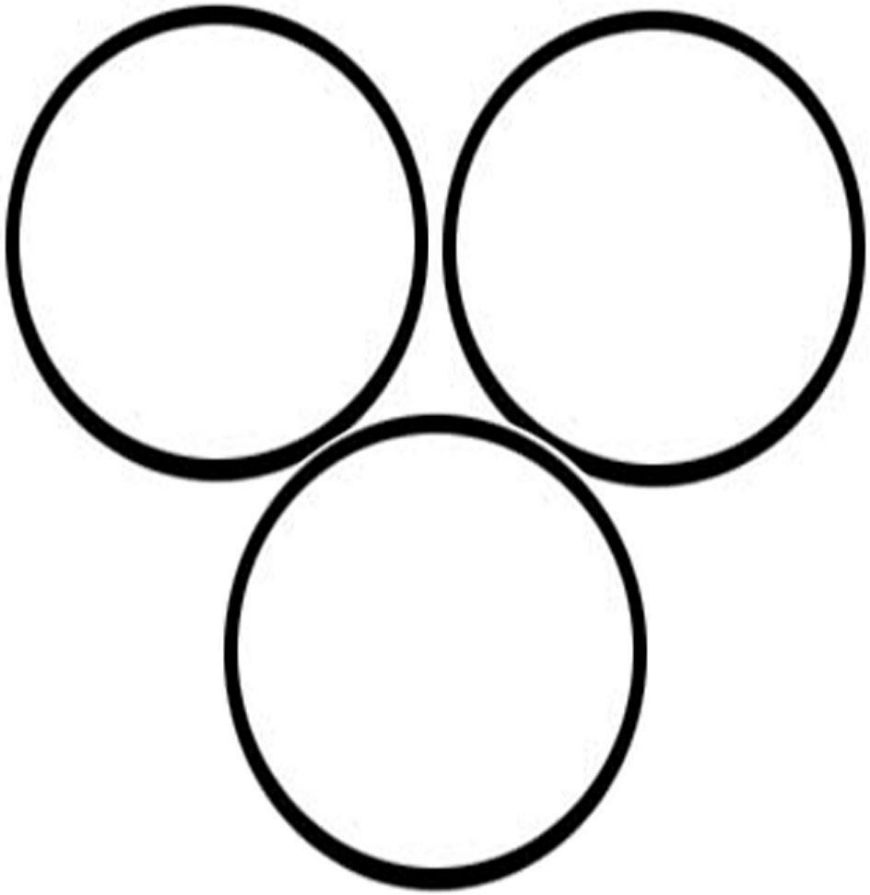
In addition, at the axis of rotation the total *buoyancy* force *outward* is maximal for a mass *lighter* than the surrounding environment. A lighter mass will *ascend* along the axis of rotation upward toward the two poles and be expelled there as *two opposite jets*.

Energy supply at the center

A possible mechanism that can explain this source of energy involves *quarks*. The high pressure in the core of the massive body may cause close contact between quarks, friction between the spinning quarks constituting the nucleon and quenching of the rotation of each of the three quarks within the nucleons. We presume that then the circumferential layers of the quarks *interpenetrate* (Ben-Amots, 2003).

Conversion of the mass of quarks to energy of photons and neutrinos as one of possible sources of energy for quasars was one of a few suggestions by Burbidge and Hoyle, 1966.

We calculate quenching quarks: Quarks possess radii



A quark has a very high but nonhomogeneous density.

Its density at its equator where the circumferential rotation velocity is at a maximum is about 4.3×10^{15} gram/cm^3

As with known dense matter the velocity of light in it should be significantly smaller than *c*

Yet the relative velocity between two quarks in the interpenetrating layers is about 0.999999999984 *c*

51

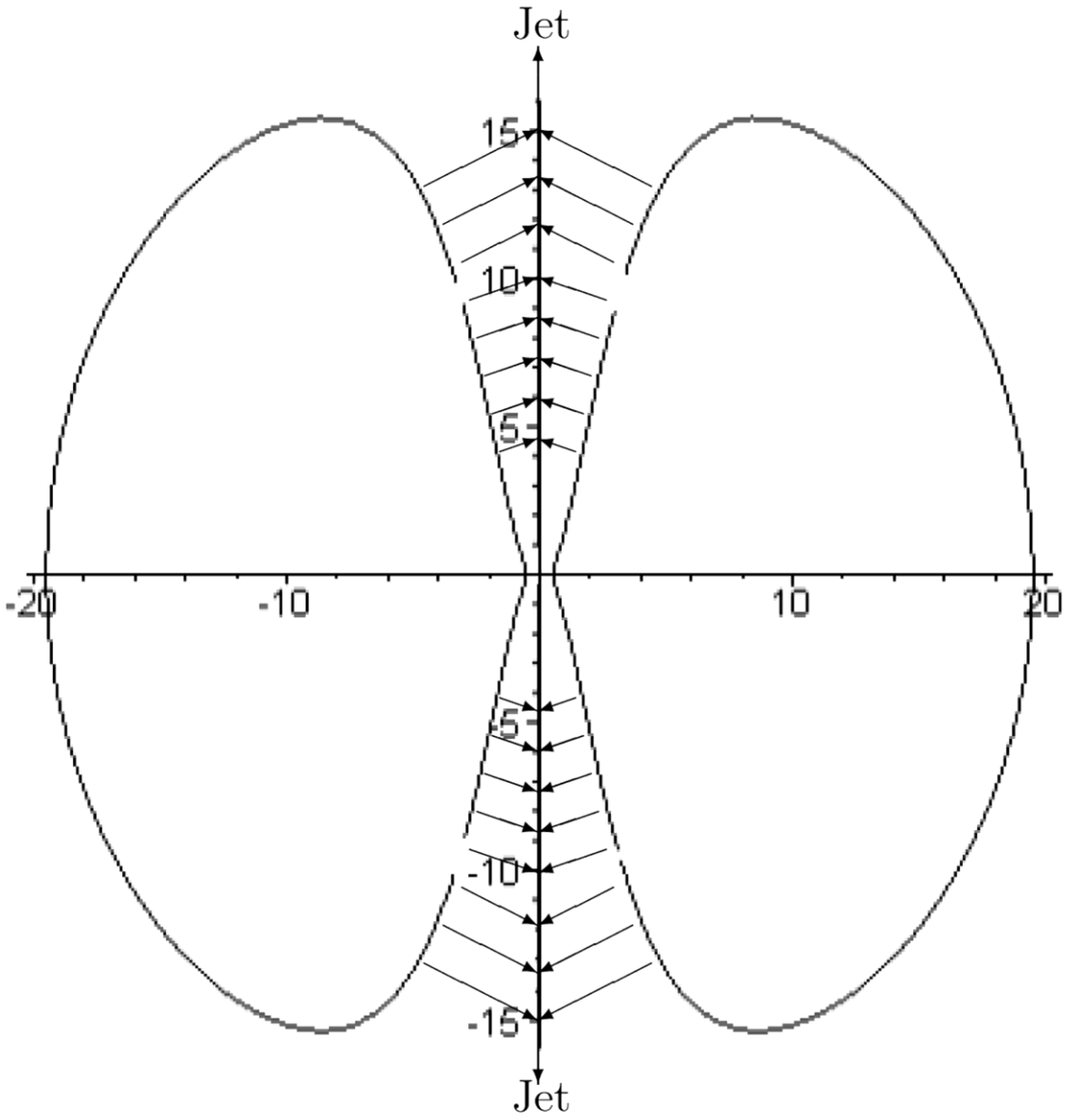
The penetration causes intense CHERENKOV RADIATION in this case, which becomes important.

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 (Ben-Amots, 2003, IARD2002). High energy Cherenkov photons are created that supply energy to decompose the iron into helium and hydrogen

The *inner* part of the torus' surface, which has a *cone-like* shape, collimates the radiation produced in the torus to the helium and hydrogen atoms at the axis. These atoms are expelled, to two fast opposite jets in the direction of the rotational axis of the torus.

The symmetrically emitted radiation that is coming perpendicularly to the conical surface meets the ions emitted axially. This radiation accelerates and collimates the ions by the Compton Effect on the axis direction to velocities that approach the speed of light *c* (see figure).

TWO CONES IN A TORUS COLLIMATE RADIATION TO TWO OPPOSITE JETS

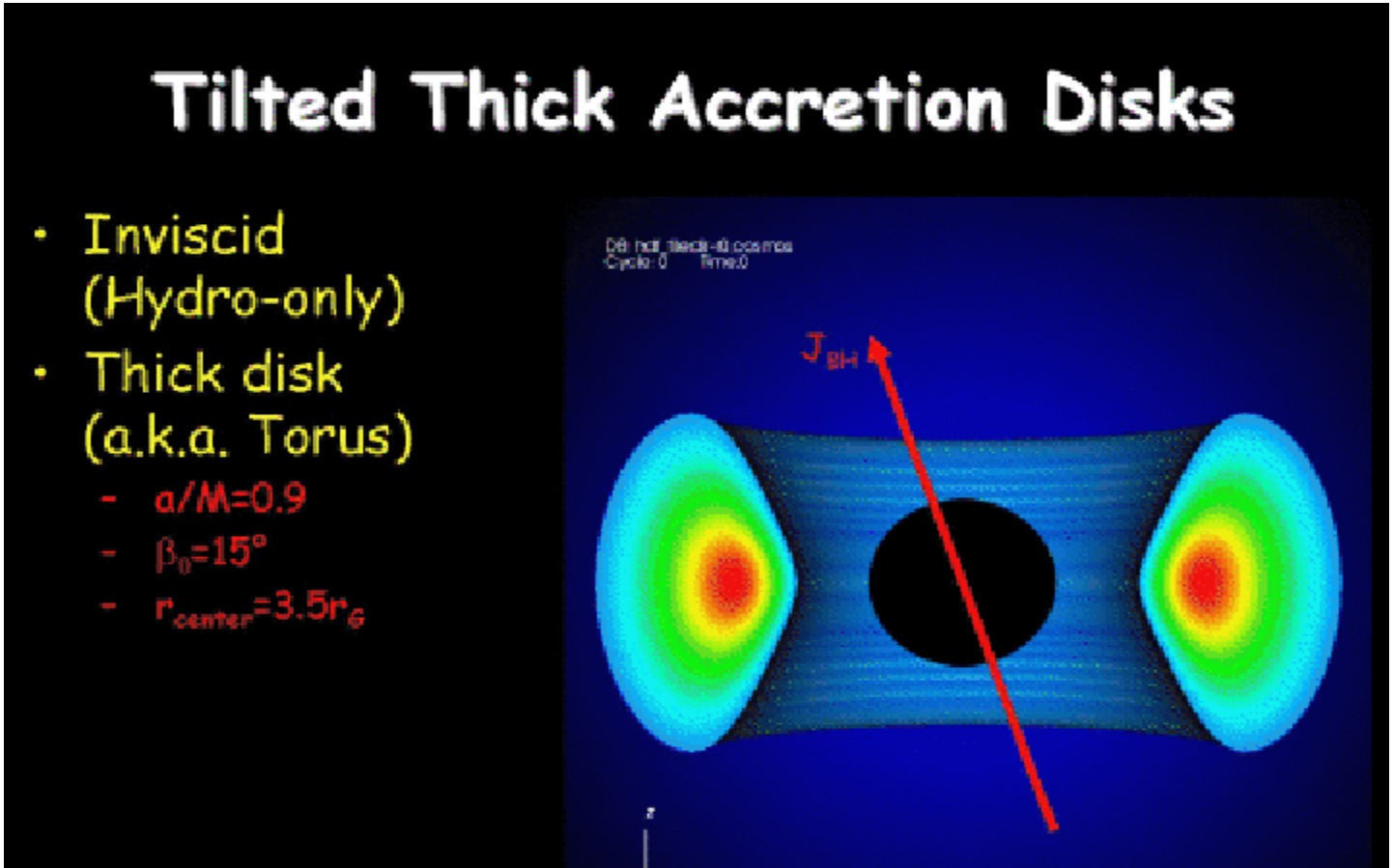


The collimation effect of the cone is similar to the *shaped charge* or *hollow charge* explosive that generates a fast plasma jet. The hollow space in the explosive charge is also usually cone-shaped.

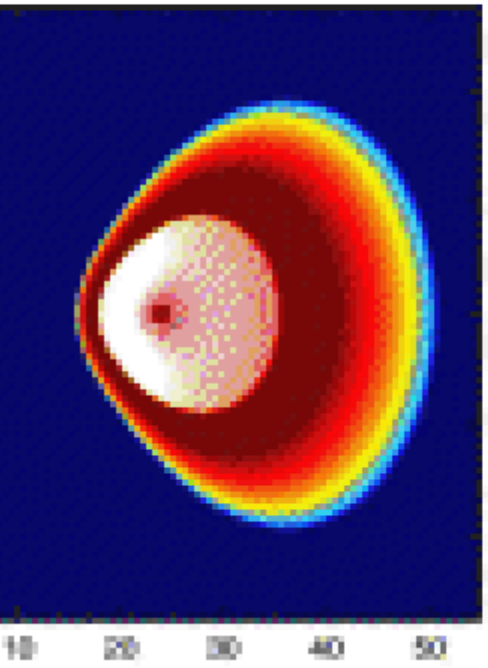
Therefore, similar to explosive charges but by a *continuous* process of emission, the two jets emerge in two polar opposite directions from quasars and active galactic nuclei. The emission is not a single event as in hollow charge weapon, but a continuous phenomenon as long as there is a supply of particles and radiation energy.

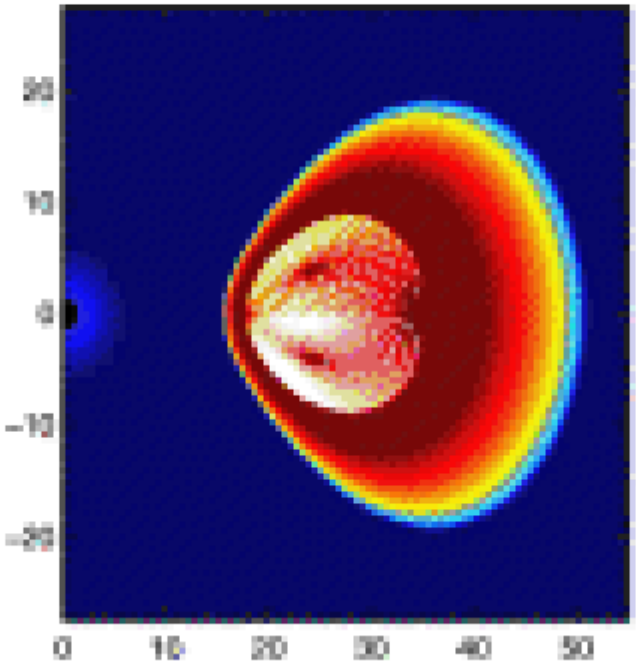
The somewhat curved cone and the continuous emission give a further continuous symmetric boost to the charged particles (plasma) in the jet during their path along the jet, up to very far distances increasing their linear speed to *relativistic* velocity and collimating their direction over up to hundreds of thousands of light years.

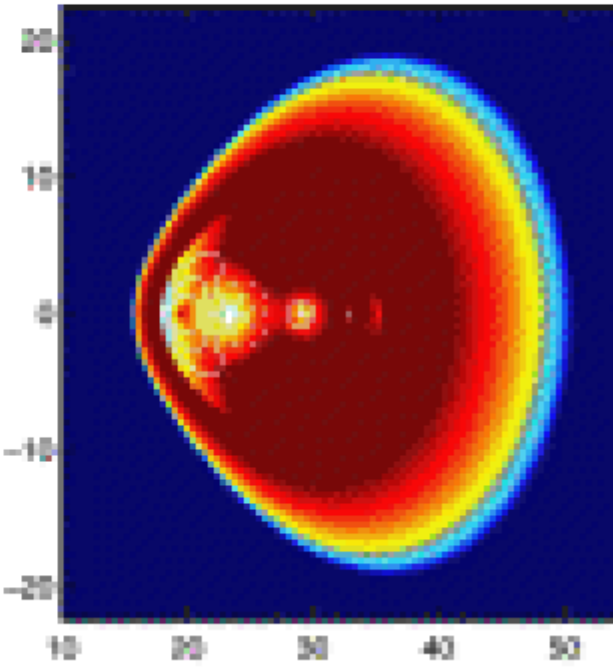
The shape of our analytical torus is similar to that of the torus that Chris Fragile got in simulations using ***other*** equations (KITP Conf. 2005).
He did not mention the hollow charge effect of the cone-like shape on jets.



Other simulations by Chris Fragile (arXiv 2008)







Comments and implications

The jets are perpendicular to the toroidal accretion disk. If the rotation axis of the massive central body is tilted, the initial jet is in the direction of the tilted axis, but soon the collimating radiation from the torus directs the jet perpendicularly to the plane of the torus.

AGNs (Active Galactic Nuclei) and quasars produce and disperse helium. This explains part of the abundance of helium in the Universe.

SS433 and MICROQUASERS

SS433 is a peculiar STAR in the milky way. It has two narrow jets ejected from its poles with jet velocity of 78000 km/sec, and an accretion disk around it, fed from a nearby star. Therefore, a similar to quasars but a weaker jet mechanism acts in some stars called microquasars.

The spectrum of the jets revealed lines of just hydrogen and helium, without any other element, that was an unexplained surprising phenomenon.

The composition of the jets is ONLY hydrogen and helium, (Margon 1980) in full agreement with our super-onion model for AGNs and quasars.

YOUNG STARS

Young stars were also observed

ejecting opposite jets from the poles

These jets are also perpendicular to the accretion disk.

We suggest that the opposite helium + hydrogen jets from quasars, AGNs, microquasars and very young stars are created by our process as described above.

All of them produce and disperse helium, thus explaining a portion of the abundance of helium

DANGEROUS JETS

The astronomical jets are considered dangerous to life on Earth if they hit Earth, even if originated at distances of a few thousands of light years. Even the weaker jets from microquasars are dangerous if they are directed toward Earth.

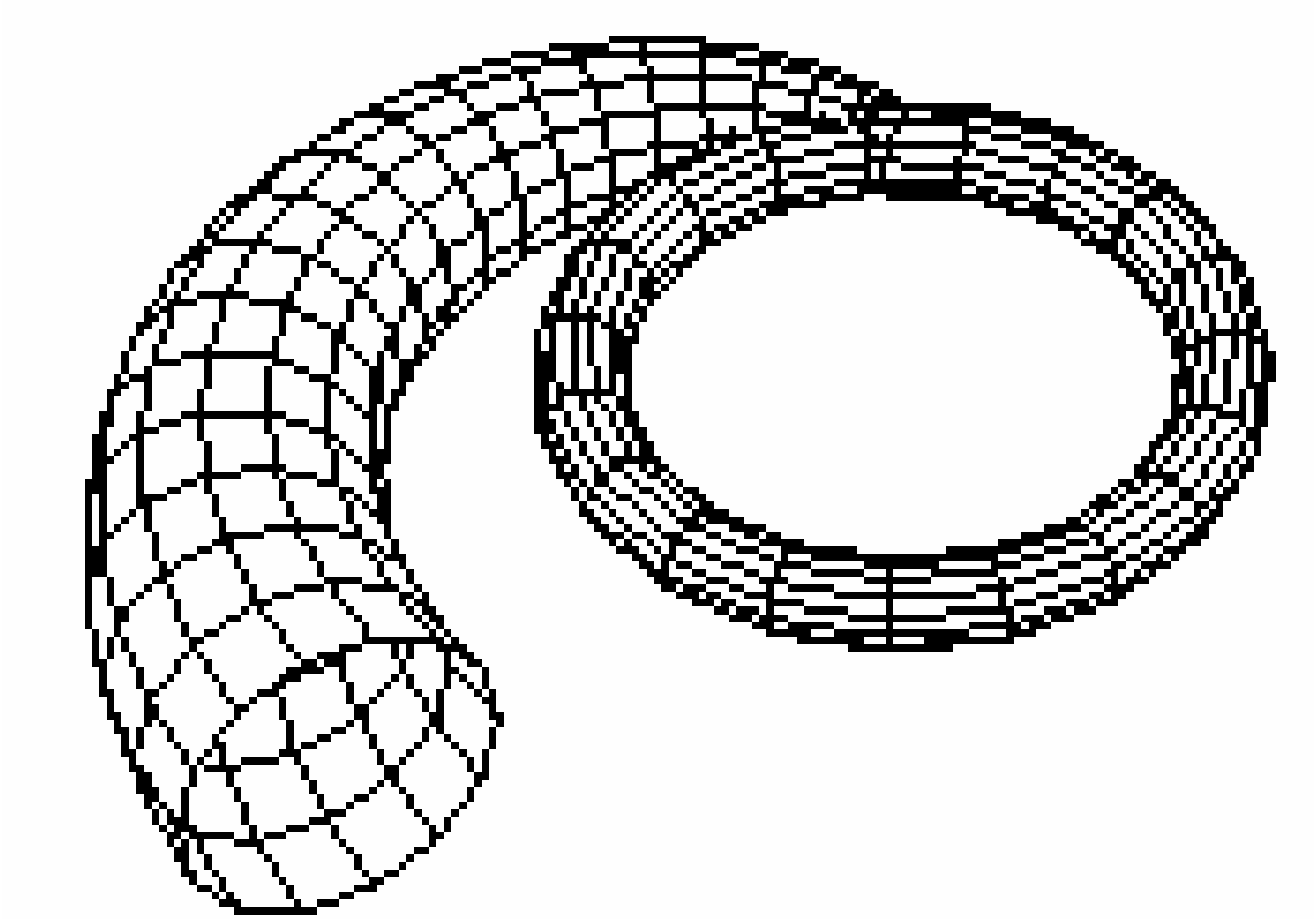
Fortunately no such jet is originated from a dangerous distance.

JETS CREATED BY SUPERNOVAE

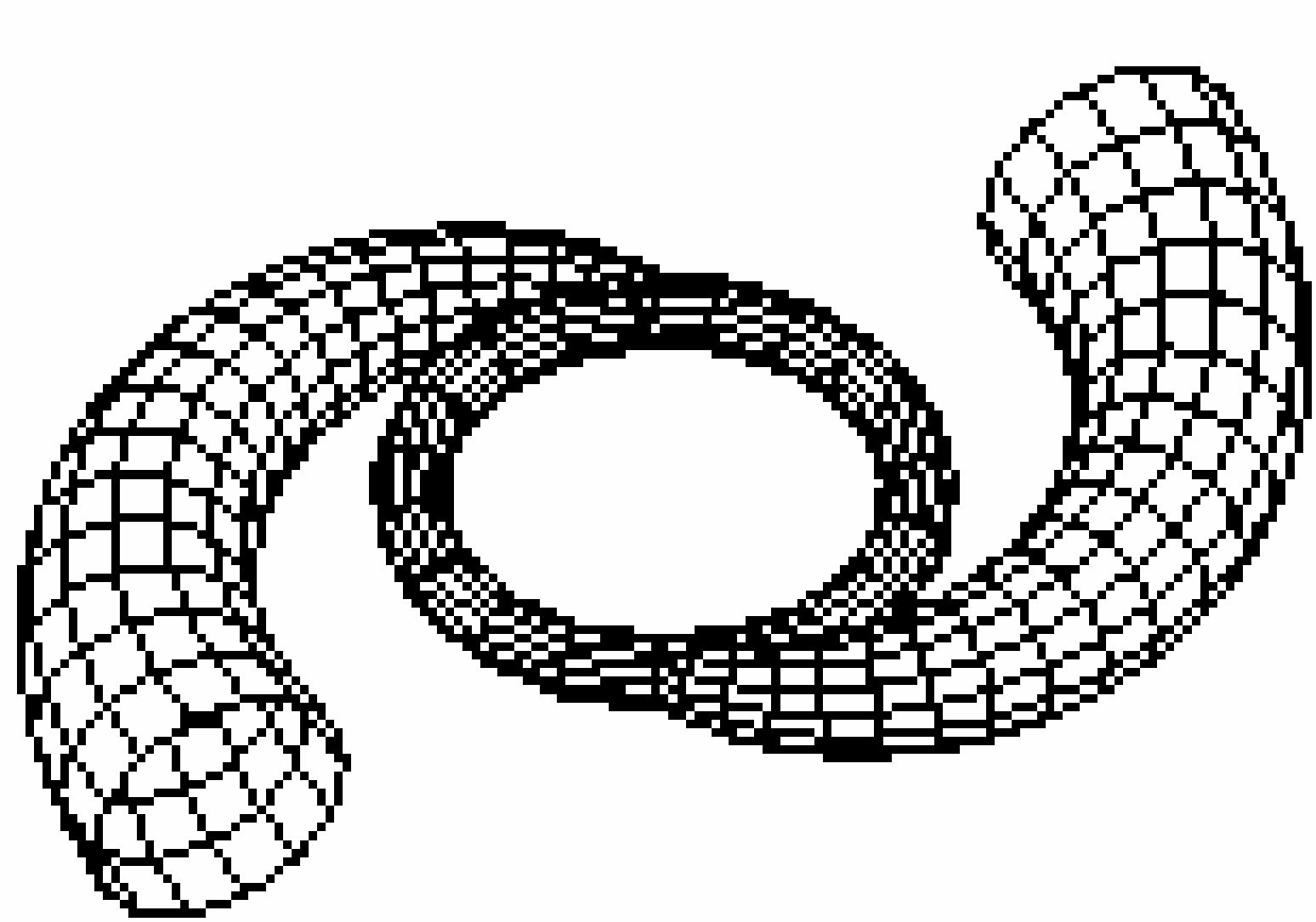
STAGES IN A COLLAPSING FAST-ROTATING STAR:

THE INNER CORE OF THE STAR, WHICH HAS A RELATIVELY SMALL *J* /*m*, COLLAPSES TO A DENSE CENTRAL SPHEROID *M*. THEN THE MEDIUM LAYER OF THE STAR, WHICH HAS HIGHER *J* /*m*, YET LOSES ITS PREVIOUS SUPPORT, COLLAPSES INTO THE INNER *TORUS*.

Collapse into inner torus: a single stream tube converges into the torus



Collapse into inner torus: two stream tubes converge into the torus



The friction between the layers of the inner torus produce intense hard radiation. This radiation is emitted through the cones from the inner surface of this torus.

This radiation is collimated in the axis and accelerates the matter on the axis upwards and outwards of the massive body as TWO OPPOSITE jets.

JETS CREATED BY SUPERNOVAE

- THE INNER TORUS COLLIMATES THE PRODUCED GAMMA RADIATION TO A BEAM.
- WHEN THE CENTRAL MASS *M* EXPLODES, A SHORT TIME LATER THE SHOCK FRONT OF THE EXPLOSION REACHES THE TORUS AND COLLIDES WITH IT.
- THE ENERGY FROM THE COLLISION OF THE EXPLOSION WITH THE FAST-ROTATING TORUS IS TRANSFORMED TO PHOTONS AND NEUTRINOS. THESE PHOTONS AND NEUTRINOES INTENSIFY THE EXPLOSION AND DESTROY AND DISPERSE THE TORUS.

JETS CREATED BY SUPERNOVAE

IF THIS INNER TORUS DISINTEGRATES, ITS COLLIMATING ACTION ON THE RADIATION STOPS AND THE TWO JETS CEASE.

THE HARD GAMMA RADIATION, WHICH WAS PREVIOUSLY COLLIMATED IN THE DIRECTION OF THE AXIS OF ROTATION, IS NOT DIRECTIONAL ANYMORE

THEREFORE, JETS OF SUPERNOVAE MAY BE A SHORT SINGLE EVENT. IF THIS JET IS DIRECTED TO US, WE MEASURE IT AS GRB.

Occam's Razor

We added few phenomena that together explain few unsolved observations.

Occam's Razor says that when you have two explanations for one observation, accept the simpler one. Usually correct but *not always*.

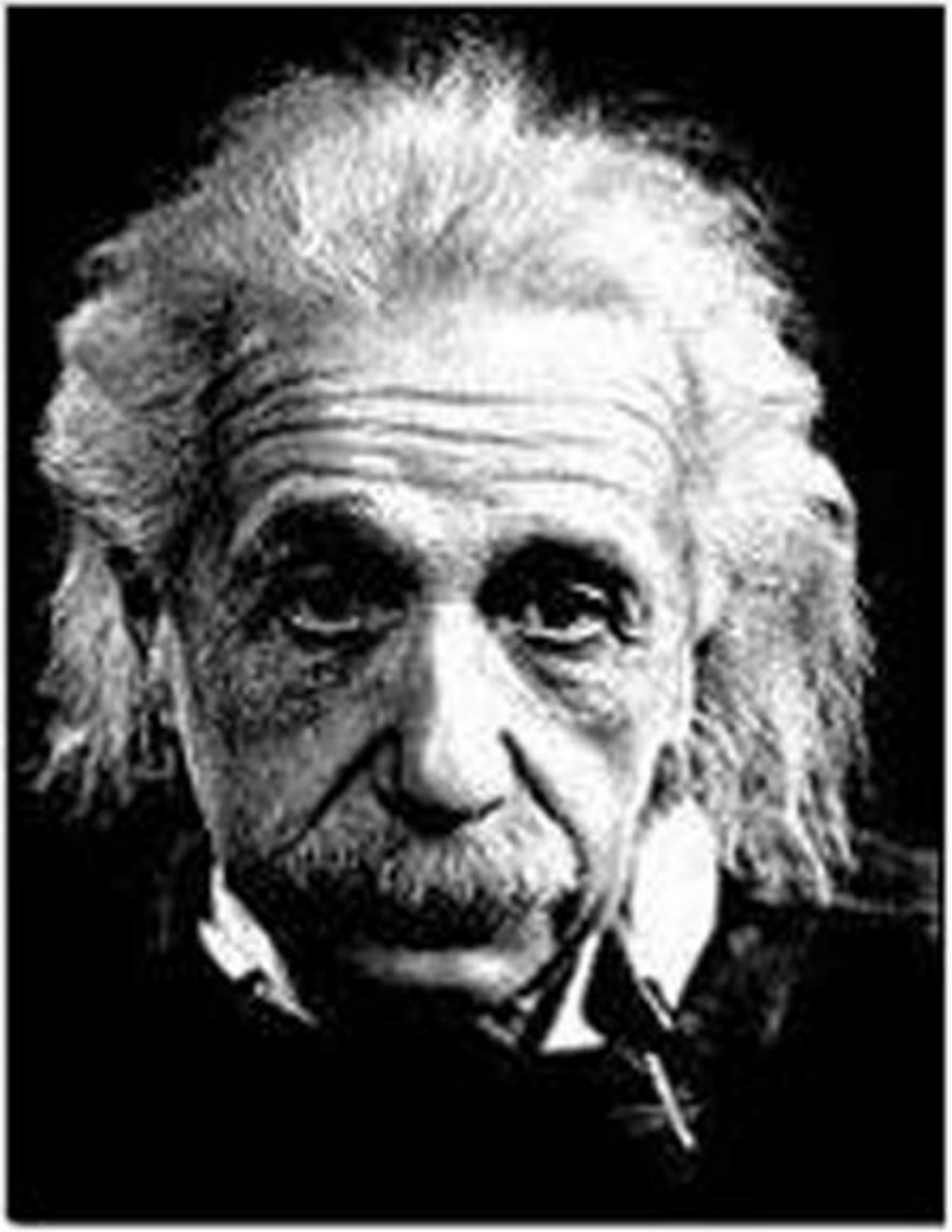
Some scientists add to Occam's razor that when you lack explanation, you should search for only one new thing that will explain it.

In my opinion, it is arrogance to think that for each yet unexplained phenomenon scientists do not know only one thing.

Or: Nature does not care what some scientists add to Occam's Razor.

Decades ago Einstein put it better:

“NATURE DID NOT THINK IT WAS HER BUSINESS TO MAKE THE DISCOVERY OF HER LAWS EASY FOR US”



The relativistic hollow charge was invented by nature milliards of years ago