Plugstars: a Physical Alternative to Supermassive Black Holes

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Observations of hypermassive central objects M87* and SgrA* have led to the classical interpretation of supermassive black holes. However, a critical analysis of the inner Schwarzschild metric reveals the existence of a stable subcritical structure, which could explain these objects without requiring an event horizon. We demonstrate that these objects, called "plugstars", have a finite gravitational redshift compatible with observational data.

Keywords: black hole, quasar, Janus cosmological Model

I. INTRODUCTION : PROBLEM OF SUPERMASSIVE BLACK HOLES.

For several decades, black holes have been considered as the natural outcome of the gravitational collapse of massive objects. However, their description is based on the existence of an event horizon and an infinite gravitational redshift, two concepts that are not directly verifiable. Observations of the central objects of M87 and SgrA* by the Event Horizon Telescope (EHT) collaboration provide finite redshift measurements, challenging the existence of horizons.

II. THE SCHWARZSCHILD MODEL FOR AN INCOMPRESSIBLE FLUID STAR

In his article of February 1916 [1] Karl Schwarzschild gives this construction of the metric describing the geometry inside a sphere filled with an incompressible fluid. We reproduce this expression exactly as it appears in equation (35) of the original German edition

$$ds^2 = \left(\frac{3\,cos\chi_a \,-\, cos\chi}{2} \right)^2 dt^2 - \frac{3}{\kappa\,\rho_0}(d\chi^2 + sin^2\chi\, d\vartheta^2 + sin^2\chi\, sin^2\vartheta\; d\phi^2) \tag{1}$$

Schwarzschild takes the value c of the speed of light in a vacuum to be equal to 1. ρ_0 is the density, which is constant inside the sphere. We have :

$$\kappa = 8\pi G \tag{2}$$

The angles (χ, ϑ, ϕ) are the classical spherical coordinates. A characteristic length appears in the expression:

$$\hat{R}^2 = \frac{3c^2}{8\pi G \rho_0} \tag{3}$$

We can pass from the angular coordinate to the radial coordinate r, the Euclidean norm of space vector (x, y, z) by :

$$r \,=\, \hat{R}\, sin\chi \tag{4}$$

The radius of the star is given by :

$$R^* \,=\, \hat{R}\, sin\chi_a \tag{5}$$

Schwarzschild denotes by f_4 the term g_{tt} of the metric

$$f_4 \,=\, \left(\frac{3\,cos\chi_a \,-\, cos\chi}{2} \right)^2 \tag{6}$$

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The time factor is the expression corresponding to a stationary observer, located inside the sphere :

$$f \;=\; \left(\frac{3\,cos\chi_a \;-\; cos\chi}{2}\right) \tag{7}$$

Then we have

$$ds \;=\; f\,dt \tag{8}$$

Schwarzchild then obtains (his equation (10)), the way in which the pressure inside the sphere varies:

$$(\rho_0 + p)\,\sqrt{f_4} = \;konst.\; = \;\gamma \tag{9}$$

In this parenthesis, Schwarzchild sums the constant energy density $\rho_0 c^2$ (with $c\,=\,1$) and the pressure. We can consider that the matter at the centre of a star, when the energy density becomes very high, is in the form of radiation, with a radiation pressure:

$$p \;=\; \frac{\rho_0\,c^2}{3} \tag{10}$$

The modern form of this internal metric [2] is :

$$ds^2 = \left(\frac{3}{2}\sqrt{1-\frac{R^{*2}}{\hat{R}^2}} \;-\; \frac{1}{2}\sqrt{1-\frac{r^2}{\hat{R}^2}}\right)^2 dt^2 \;-\; \frac{dr^2}{1-\dfrac{r^2}{\hat{R}^2}} \;-\; r^2 d\Omega^2 \tag{11}$$

The term $f_4 \;=\; g_{tt}$ becomes zero when $cos\chi_a \;=\; 1/3$, i.e. when

$$R^* \;=\; R_{crit,phys} \;=\; \sqrt{\frac{8}{9}}\,\hat{R} \;=\; \frac{c}{3\pi G\rho_0} \tag{12}$$

According to relation (9), as Schwarzschild notes, the pressure at the centre of the star becomes infinite. We are therefore faced with a first physical singularity. As the star's mass increases, at constant density (which could describe a neutron star where the centrifugal force linked to rotation could be neglected), this physical singularity occurs before a geometric singularity. This last occurs when the star's radius identifies with its Schwarzschild radius, i.e. when :

$$R^* \;=\; R_{crit,geom} \;=\; \sqrt{\frac{3\,c^2}{8\pi G\rho_0}} \tag{13}$$

The two critical radii are linked by the relation :

$$R_{crit,phys} \;=\; \sqrt{\frac{8}{9}}\;R_{crit,geom} \tag{14}$$

We can consider that this situation does not belong to the physical world [3], which amounts to considering that this exact solution to Einstein's equation, independent of time, does not belong to physics, by invoking a 'speed of sound', varying as the square root of the pressure gradient. But if we consider that the medium can be assimilated to radiation, then this speed of propagation becomes that of light. This leads us to consider, as Schwarzschild was the first to do, that the speed of light varies, and can reach an infinite value at the centre of the star. He gives the law of variation of this speed of light in his equation (44):

Die Lichtgeschwindigeit in unserer Kugel

$$V \;=\; \frac{2}{3\,cos\chi_a \;-\; cos\chi} \tag{15}$$

This fraction must be multiplied by the value c of the speed of light in a vacuum:

$$V \;=\; \frac{2\,c}{3\,cos\chi_a \;-\; cos\chi} \tag{16}$$

If we assume that the speed of light can take on a value, if not infinite, then at least very high, at the centre of the object, we obtain a situation where the force of pressure balances the force of gravity. All that remains is to examine the stability of such an object.

What happens when it benefits from an influx of matter, which would be the case for a subcritical neutron star receiving matter from a nearby standard star?

If we rely on the mathematical solution, the time factor f then becomes negative, but along a geodesic it is impossible to turn back:

$$ds > 0 \Rightarrow f\,dt > 0 \tag{17}$$

In this central part of the object, the time coordinate t reverses. Following the dynamic group theory of mathematician J.M.Souriau ([4],[5]), this inversion of the time coordinate implies the inversion of energy and mass.

General relativity opposes the presence of negative mass in the universe [6], because of the unmanageable runaway effect. To go a step further, we need to place ourselves in the geometric framework of the Janus model [7].

In this new scheme, masses of opposite signs repel each other. We also conjecture that a gravitational and quantum phenomenon occurs under these conditions of criticality, in which the excess masses are reversed.

The object in criticality, having received mass from the outside, contains an equivalent quantity in a small sphere filled with negative mass and initially centered on the origin.

The presence of negative mass at the star's center only makes a very weak contribution to the gravitational field mainly created by the positive mass. Thus negative mass is expelled from the object and then expelled from the galaxy into the negative-mass environment between galaxies.

We thus obtain a mechanism that guarantees the stability of such subcritical objects, which we propose to call "plugstars", like an overflow valve that evacuates excess water.

III. CALCULATION OF THE GRAVITATIONAL REDSHIFT

Such objects will exhibit a gravitational redshift effect with respect to a distant observer. This corresponds to :

$$1 + z = \frac{\lambda(observer)}{\lambda(emitter)} = \frac{\sqrt{g_{tt}(observer)}}{\sqrt{g_{tt}(R^*)}} = \frac{1}{f(R^*)} \tag{18}$$

In a situation close to criticality :

$$f = \frac{3}{2}\sqrt{1 - \frac{8}{9}} - \frac{1}{2}\sqrt{1 - \frac{8}{9}} = \frac{1}{3} \tag{19}$$

An observer will therefore see an object whose central part has an attenuated luminosity, such that the ratio of wavelengths resulting from a gravitational redshift effect is

$$\frac{\lambda(observer)}{\lambda(emitter)} = 3 \tag{20}$$

IV. OBSERVATIONAL DATA

Let us refer to the images of hypermassive objects obtained using the EHT Collaboration ([8][9]). The chromatic bars provide equivalent temperature values, which are in fact indications of luminosity. This light, in any case, is emitted by photons of energy $h\nu$. By forming the ratio of maximum and minimum luminosity, we obtain the wavelength ratio.

In the image of the hypermassive object at the centre of M87, the colour bar shows that :

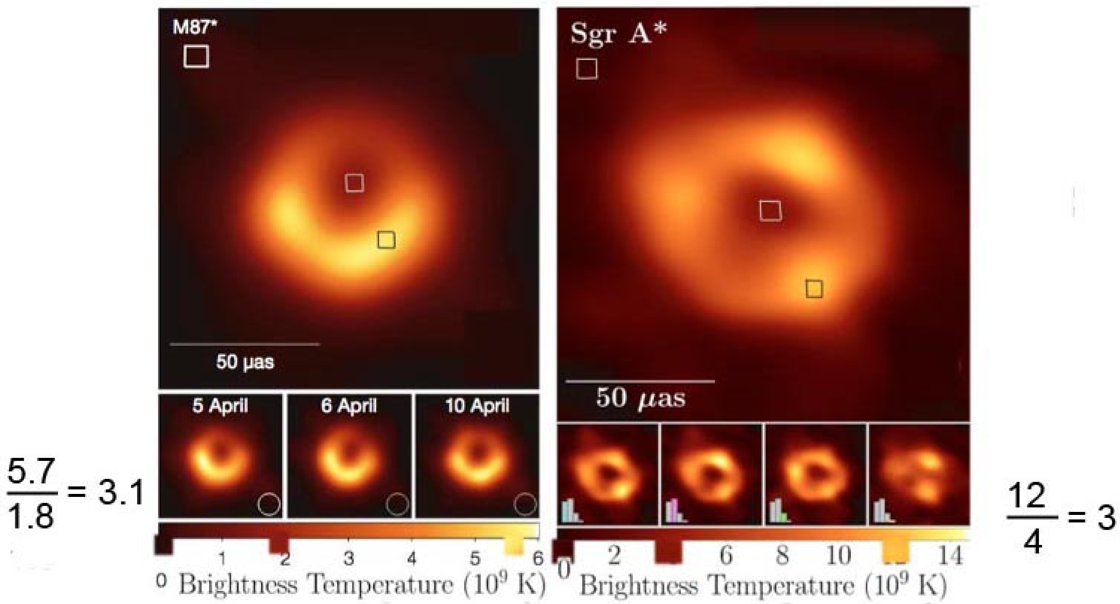

FIG. 1. Images of M87* and SgrA*

- The maximum equivalent temperature is $5.7 \times 10^9 K$.
- The minimum equivalent temperature is $1.8 \times 10^9 K$.

The corresponding wavelength ratio is :

$$\frac{\lambda(observer)}{\lambda(emitter)} \approx 3.2 \tag{21}$$

On the image of the hypermassive object at the centre of SgrA* the colour bar shows that :

- The maximum equivalent temperature, approximately, is $12 \times 10^9 K$.
- The minimum equivalent temperature is $4 \times 10^9 K$.

The corresponding wavelength ratio is :

$$\frac{\lambda(observer)}{\lambda(emitter)} \approx 3.0 \tag{22}$$

This result is in very agreement with observational data.

Of course, these central objects are not giant neutron stars. But the very high pressure inside them, due to the increase in the speed of light, allows the radiation pressure to counterbalance the force of gravity.

V. PHYSICAL IMPLICATIONS OF PLUGSTARS

Unlike black holes, these objects:

- have a finite gravitationnal redshift, explaining the darkening of their central part.
- have no horizon or internal singularity.
- are stabilized by the masse inversion processes, in the case of the Janus model, preventing collapse.

When the axes of symmetry of the objects are accessed through the axes of symmetry of the jets, they often correspond to the axes of symmetry of the galaxies [10]. If this phenomenon is general, then these objects would not be formed by mass accretion.

VI. AN ALTERNATIVE INTERPRETATION OF THE QUASAR PHENOMENON

They could be the result of the convergence of a centripetal density wave, like the one suggested in the Hoag galaxy fig. 2.

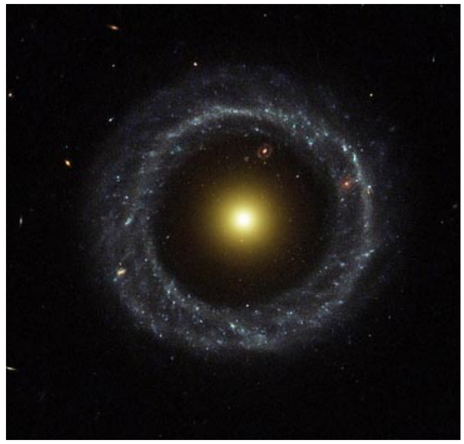

FIG. 2. Hoag galaxy

This galaxy, located in the constellation Serpens Caput, was discovered by Arthur Hoag in 1950. The absence of neighbouring galaxy and debris seems to rule out the possibility that it formed as a result of a collision. Its structure resembles that of a density wave, whose propagation would then be radial.

If a density wave propagates in a galaxy, whether it is a spiral wave or this type of circular, converging wave, its speed of propagation is not that of the matter itself.

This is the classic difference between group velocity and phase velocity. The wave from the Hoag galaxy, if its propagation is centripetal, would then be comparable to a circular tsunami. The rise in density in the wave gives rise to young stars which, emitting in the UV, ionise the medium, making the formation visible, as is the case for spiral waves. In this plasma, if the magnetic Reynolds number is high, this wave will drag along the field lines of the very weak magnetic field (one microgauss) that already exists in the galaxies.

Such a rise in the field in the ring could be demonstrated by polarisation measurements.

When the wave would reaches the centre of the galaxy, there would be a sudden rise in density and temperature [11]. Lawson's conditions would be then realised in a considerable mass, triggering a massive production of energy by fusion. Such model would explain the quasar phenomenon.

The convergence of the magnetic field lines would give to the object a very high dipolar magnetic field. The fusion energy would be then focused on the two jets with which M87* is equipped.

This field has a gradient that accelerates charged particles over very large distances, giving them very high energies. This is how cosmic rays would be formed.

The M87* jet is discontinuous, which seems to indicate that the phenomenon is sporadic. The absence of jets for SgrA* would qualify it as an 'extinct quasar'. This model is based on the hypothesis of the repetitive birth of spiral density waves.

We still need a theory to explain their appearance. This is what we are currently trying to construct, within the framework of the Janus model, in terms of joint fluctuations in the metrics of positive and negative masses.

We conjecture that future images of hypermassive objects located at the center of galaxies will all present the same *wavelength ratio 3.*

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[11] When the wave causes a rise in density, the angular momentum of the mass concerned is conserved, and the speed of rotation increases. But this phenomenon generates a centrifugal force that cannot be compared with the forces of gravity and pressure. This explains the excellent agreement with the data derived from the Schwarzchild solution.