Journal of Physics Astronomy

Research Article | Vol 14 Iss 1

Decoding the Mysterious Disappearance of a Star in Andromeda Galaxy

Prosad Bhattacharya*

Department of Mechanical Engineering, Jadavpur University, Kolkata, India

***Corresponding author:** Prosad Bhattacharya, Department of Mechanical Engineering, Jadavpur University, Kolkata, India; E-mail: prosad_b@yahoo.co.in

Received: February 01, 2025, Manuscript No. TSPA-25-160719; **Editor assigned:** February 04, 2025, PreQC No. TSPA-25-160719 (PQ); **Reviewed:** February 18, 2025, QC No. TSPA-25-160719; **Revised:** March 18, 2026, Manuscript No. TSPA-25-160719 (R); **Published:** March 25, 2026, DOI. 10.37532/2320-6756.2026.14(1).456

Abstract

Recently it has been reported by a researching team from the MIT that a supergiant star M31-2014-DS1 having mass of 20 times the sun has disappeared in the Andromeda galaxy. The star had failed to explode as a supernova and had become directly a black hole. Normally, as per the present theory, when core of a massive (more than 8 times solar mass) star of this type collapses, the final event is accompanied by bursts of light brought on by stellar explosion known as supernova. In this particular instance, the researchers could not get any trace of optical outburst during the last phase of the dying supergiant star and reported direct formation of a black hole. This phenomenon is being hyped as a mystery by the astronomers.

However, it has also been observed by the researchers that though the star was born with an initial mass of about 20 solar mass, it had reached its terminal nuclear burning stage at about 6.7 solar mass. In this article it has been mathematically established that a giant star of mass less than 7.15 times the solar mass cannot explode as a supernova; rather it will become a black hole. Therefore, a star of 6.7 solar mass will logically end up in a black hole and finally will be settled as a black hole-cum-neutron star, without exploding as supernova. It has also been proved that if the star would have a mass of 20 solar mass, it would have exploded as supernova. Therefore, the calculations confirm that there is no mystery behind the disappearance of the said star and formation of a black hole in the Andromeda galaxy.

Keywords: Core collapse supernova; Neutron degeneracy pressure; Gravitational binding energy; Quantum chromo-dynamic binding energy

Introduction

Supernova is the most powerful and luminous celestial explosion. This enigmatic comic phenomenon occurs very rarely in any galaxy. However, the present concept on this event, particularly for the Type-II *i.e.*, the core-collapse supernova, appears to be bit ambiguous. Present theory on core-collapse supernova, in a nutshell, is that it occurs at the last evolutionary stage of a star having mass more than 8 times the solar mass. It is not clear what will happen to those stars having mass in between the TOV limit (around 2.93 times the solar mass) and the 8 times the solar mass. When the nuclear fuels (hydrogen, helium, etc.) in the core of a star get exhausted, its nuclear fusion stops. Consequently, its thermonuclear pressure which was countering the gravity at its main sequence stage of the star) drops and the core of the red supergiant star suddenly collapses. This creates an enormous shock wave that causes the outer part (the shell) of the star to explode as a supernova. A dense core, usually a neutron star or a black hole, is left behind along with an expanding cloud of hot gas and dust called nebula.

Citation: Bhattacharya P. Decoding the Mysterious Disappearance of a Star in Andromeda Galaxy. J Phys Astron. 2026;14(1).456.
© 2026 Trade Science Inc.

This concept does not consider the effect of the degeneracy pressure that is generated inside the red supergiant star at its sub-atomic level while getting squeezed by its gravity [1]. In this paper an attempt has been made to throw light on the role of the degeneracy pressure, a sort of quantum pressure generated inside the star in accordance with the Pauli's exclusion principle. This new approach is significantly different from the existing theory as it also considers the role of Quantum Chomo-dynamic (QCD) binding energy of the neutron which is the main constituent of the core of the star at the time of supernova explosion. This new approach is backed up not only by the mathematical calculations but by a recent observation of the astronomers of a star M31-2014-DS1 of Andromeda galaxy also.

Detailed calculations based on neutron degeneracy pressures and the QCD binding energies show that at the end of their lives, stellar mass stars embrace different fates while core collapsing which are presented below.

- Stars having mass up to Chandrasekhar limit *i.e.,* 1.44 MΘ will become White Dwarfs; those stars cannot become neutron stars or black holes. However, after accumulating the critical mass in accretion process from a companion star white dwarfs may explode as Type-I supernovae.
- Stars in the mass range from the Chandrasekhar limit to the Tolman, Oppenheimer and Volkoff (TOV) limit, *i.e.,* around 2.93 MΘ will become only Neutron Stars. However, at the TOV limit, it is concurrently a neutron star as well as a black hole.
- Massive stars beyond the TOV limit and up to 7.14 MΘ will become black hole first and then those black holes will become neutron stars as well. Stars in this mass range cannot explode as supernovae.
- Beyond 7.14 MΘ all the stellar mass stars will explode as core collapse (Type-II) supernovae.

Materials and Methods

As per the report published in inspire HEP in its website, a group of astronomers led by the lead author Dr. Kishalay De et al., of the Kavli Institute for Astrophysics and Space Research at MIT reported that the supergiant star M31-2014-DS1, which has a mass 20 times greater than the sun and is located 2.5 million light-years away in the neighboring Andromeda galaxy, brightened in 2014 before dimming from 2016 until 2023, when it finally became undetectable to telescopes. As no evidence of supernova explosion could be observed by the researchers, it was reported by many websites globally as a rare mysterious phenomenon of formation of a direct black hole by a dying giant star without being exploded as supernova. However, it was also reported by the researchers that though initially the mass of the M31 supergiant star was 20 times the solar mass, the star attained a terminal mass of 6.7 times the solar mass after exhausting all its nuclear fuels

It has been mathematically established here that a star having mass in the range of the TOV limit (around 2.93 MΘ) and 7.14 MΘ, upon core collapse at the last stage of its life, will become a black hole and can never explode as a supernova. Stars having mass of 7.15 MΘ and above will finally explode as supernovae [2]. Therefore, after core collapse a supergiant / giant star having mass of 6.7 MΘ will form a black hole and it can never explode as supernova. This is totally consistent with the mathematical calculations based on the neutron degeneracy pressure and also the QCD binding energy. It is a necessary condition for a supernova explosion that the Gravitational energy of a star must be equal to or more than its inherent QCD binding energy.

Effect of neutron degeneracy pressure on core collapse (Type-II) supernova

At the end of the main sequence phase of a stellar mass star, its nuclear fuel, mainly hydrogen, gets exhausted in its core and in the absence of the thermonuclear pressure the star starts shrinking. Due to the compression in its volume thermal pressure is created and that pressure causes the remaining hydrogen (and also helium) entrapped inside the shell to fuse. Thermonuclear fusion inside the shell is started. It generates more heat and the shell of the star expands at a huge proportion and a red giant/supergiant is formed. When those nuclear fuels of the shell get totally exhausted, the supergiant starts collapsing. Its volume reduces abruptly as at initial stage only gravity is acting and there is no counteracting pressure. As the rate of collapse is considerably fast, generation of shock wave is expected [3].

But this shock wave may not be able to overcome the binding energy of the nucleons of the star. So, it is unlikely that there will be a supernova explosion at this stage. While collapsing, initially at reduced radii the Electron Degeneracy Pressure (EDP), a type of quantum pressure, will be created at the sub-atomic level of the star. Due to the tremendous pressure exerted by the gravity, more electrons are forced to be accommodated in the same energy states in the orbital of the nucleus than the specified limit, violating the Pauli's Exclusion Principle. Such violation creates a quantum pressure that is called Degeneracy Pressure. Initially the EDP is

formed but this pressure cannot counter the gravitational pressure and the collapse of a supergiant continues. As the star collapses further, the Neutron Degeneracy Pressure (NDP), another type of quantum pressure analogous to the EDP, is created. The NDP is exorbitantly high pressure but even such huge pressure cannot stop the collapsing of the massive star. Its collapse continues. As its radius reduces its escape velocity increases. When the star attains an its Schwarzschild radius, the escape velocity of the star becomes equal to the velocity of light. The erstwhile supergiant becomes a black hole.

Mathematical calculations show that even when it becomes a black hole, its gravitational pressure is more than its neutron degeneracy pressure and so the black hole will continue to collapse further. However, with the reduction of radius, the gravitational binding energy of the black hole goes on increasing. At a certain radius its gravitational energy will become equal to its quantum chromo-dynamic binding energy. The black hole will start disintegrating and the shell or the outer portion, being comparatively less compact than the denser core, will explode as supernova. It is the most violent and bright phenomenon that will light up the sky for a considerable period. As a result, huge energy will be liberated from the exploding black hole, also gases and cosmic dusts will be spread over the galactic space. And the dense core will remain either as a neutron star or a black hole, depending upon the mass of the progenitor star.

Results and Discussion

Supernova as delineated above will occur only if the mass of the black hole is 7.15 times the solar mass and more. The M31 star having initial mass of 20 MʘO would have exploded following the calculations shown in Table 1 below.

TABLE 1. **Core collapse of a red supergiant star of mass 20 MʘO.**

f	M	R	Gr. Pr.	NDP	E V	Gr.E	QCD E	Remarks
	kg	m	$kg.m^{-2}$	$Kg.m^{-2}$	$m.s^{-1}$	Joules	Joules	
20	4.00E+31	6.96E+11	21467.68	0.00014	87318.4	9.10E+40	3.53E+48	$R=10^3 \times RʘO$
20	4.00E+31	6.96E+08	2.15E+16	1.40E+11	2761250	9.10E+43	3.53E+48	R=RʘO
20	4.00E+31	696000	2.15E+28	1.40E+26	87318383	9.10E+46	3.53E+48	
20	4.00E+31	100000	5.04E+31	2.29E+30	2.30E+08	6.33E+47	3.53E+48	
20	4.00E+31	58962.8	4.17E+32	3.22E+31	3.00E+08	1.07E+48	3.53E+48	Black hole
20	4.00E+31	17942	4.86E+34	1.23E+34	5.40E+08	3.53E+48	3.53E+48	Supernova

Table 1 show various parameters of a supergiant star having mass of 20 times the solar mass and the initial radius of one thousand times of the solar radius (though arbitrarily taken for the calculation purpose, the initial radius of a supergiant star may be even bigger than 1000 times RʘO) like gravitational pressure, Neutron Degeneracy Pressure (NDP), Escape Velocity (EV), gravitational binding energy, Quantum Chromo-Dynamic (QCD) binding binding energy, etc. as it collapses after exhausting its nuclear fuels. Initially when its core collapse starts, its gravitational pressure is less and it has not developed NDP. As per presently established theory, at higher radii only the gravitational pressures will be predominant and a shock wave will be generated at that stage that will set off the detonation and the supergiant star will be exploded as supernova. But as shown in the Table 1, at initial radii, the gravitational pressures are comparatively smaller and there are little chances of formation of shock wave.

Even if a shock wave generates it would not be powerful enough to cause supernova explosion of the star [4]. Further, when the radius of the collapsing supergiant star will become around the solar radius, the degeneracy pressures (initially electron degeneracy pressure, EDP and then neutron degeneracy pressure, NDP) will start acting to counter its gravitational pressure and thus reduces the possibility of initiation of a shock wave to cause an explosion. As the calculations suggest the supergiant while collapsing its core will become a black hole first at a radius 58962.8 meters and then upon further collapsing to a radius of 17942 meters will explode as supernova as at that stage the gravitational energy of the star will become equal to its Quantum Chromo-dynamic binding energy (1.18E+48 Joules). But there was no supernova of the star M31 because, as confirmed by the astronomers, though its mass was initially 20 times the solar mass, after nuclear fusion its mass attained a final value of 6.7 times the solar mass. So, instead of Tables 1 and 2 has to be referred.

TABLE 2. **Core collapse of a stellar mass red giant star.**

f	M	R	Gr. Pr.	NDP	E V	Gr.E	QCD E	Remarks
	kg	m	$kg.m^{-2}$	$Kg.m^{-2}$	$m.s^{-1}$	Joules	Joules	
6.7	1.30E+31	6.96E+11	2409.21	2.27E-05	50539.17	1.02E+40	1.18E+48	$R=10^{3}$ RΘ
6.7	1.30E+31	6.96E+08	2.41E+15	2.27E+10	1598189	1.02E+43	1.18E+48	R=RΘ
6.7	1.30E+31	6.96E+05	2.41E+27	2.27E+25	50539168	1.02E+46	1.18E+48	$R=10^{-3}$ × RΘ
6.7	1.30E+31	100000	5.65E+30	3.71E+29	1.33E+08	7.11E+46	1.18E+48	
6.7	1.30E+31	25000	1.45E+33	3.79E+32	2.66E+08	2.84E+47	1.18E+48	
6.7	1.30E+31	19752.54	3.71E+33	1.23E+33	3.00E+08	3.60E+47	1.18E+48	Black hole
6.7	1.30E+31	6554.8	3.06E+35	3.06E+35	5.21E+08	1.08E+48	1.18E+48	Black hole – cum-Neutron Star

As presented in Table 2, upon core collapsing a red giant star of mass 6.7 times the solar mass will become a black hole first when its radius will be 19752.538 meters as it is its Schwarzschild radius. At that condition, as it can be seen from the table, the gravitational pressure of the black hole is more than the neutron degeneracy pressure and the black hole will continue to collapse further. Ultimately, at a radius of 6554.8 meters its gravitational pressure and NDP will be equal and its further collapse will be stopped [5,6]. Theoretically, the black hole will become a neutron star also. Therefore, since at that radius the gravitational energy (1.08E+48 Joules) of the star is less still than its QCD binding energy (1.18E+48 Joules), there will be no supernova explosion of the star.

Table 3 shows the limiting value of 7.15 MΘ below which a dying star will become black hole cum neutron star and beyond this value the star will explode as supernova.

TABLE 3. **Limiting value 7.15 MΘ.**

f	M	R	Gr. Pr.	NDP	E V	Gr.E	QCD E	Remarks
	kg	m	$kg.m^{-2}$	$kg.m^{-2}$	$m.s^{-1}$	Joules	Joules	
6	1.19E+31	17688.84	4.63E+33	1.78E+33	3E+08	3.22E+47	1.06E+48	Black hole
6	1.19E+31	6799	2.12E+35	2.12E+35	4.84E+08	8.38E+47	1.06E+48	BH and NS
7	1.39E+31	20636.98	3.40E+33	1.07E+33	3E+08	3.76E+47	1.24E+48	Black hole
7	1.39E+31	6457.99	3.55E+35	3.55E+35	5.36E+08	1.20E+48	1.24E+48	BH and NS
7.12	1.42E+31	20990.76	3.29E+33	1.00E+33	3E+08	3.82E+47	1.26E+48	Black hole
7.12	1.42E+31	6419.78	3.76E+35	3.76E+35	5.42E+08	1.25E+48	1.26E+48	BH and NS
7.13	1.42E+31	21000	3.28E+33	1.00E+33	3E+08	3.83E+48	1.26E+48	Black hole
7.13	1.42E+31	6418.3	3.77E+35	3.77E+35	5.43E+08	1.25E+48	1.26E+48	BH and NS
7.14	1.42E+31	21049.72	3.27E+33	9.97E+32	3E+08	3.83E+47	1.26E+48	Black hole
7.14	1.42E+31	6417	3.79E+35	3.79E+35	5.43E+08	1.26E+48	1.26E+48	BH and NS
7.15	1.42E+31	21079.2	3.26E+33	9.92E+32	3E+08	3.84E+47	2.26E+48	BH
7.15	1.42E+31	6414.2	3.81E+35	3.80E+35	5.44E+08	1.23E+48	1.262E+48	Supernova
7.15	1.42E+31	6411.6	3.81E+35	3.81E+35	5.44E+08	1.26E+48	1.26E+48	Already exploded
7.16	1.42E+31	21108.68	3.25E+33	9.88E+32	3E+08	3.85E+47	1.26E+48	BH
7.16	1.42E+31	6422.8	3.79E+35	3.78E+35	5.44E+08	1.26E+48	1.26E+48	Supernova
8	1.59E+31	23585.12	2.60E+33	6.82E+32	3E+08	4.30E+47	1.41E+48	BH
8	1.59E+31	7176.5	3.04E+35	2.62E+35	5.44E+08	1.41E+48	1.41E+48	Supernova

In the above calculations, following constants and equations have been used.
Velocity of light, $c=3E+08\ m.s^{-1}$
Universal gravitational constant, $G=6.67E-11\ m^3.kg^{-1}.s^{-2}$
Solar mass, $M\Theta=1.989E+30\ kg$
Mass of the star, $M=M\Theta \times f$
Gravitational pressure $= (1/5) \times (G \times M^2) \times \{(3/4) \times \pi\}^{(1/3)} \times V^{-(4/3)}\ kg.m^{-2}$ (2)
Neutron degeneracy pressure $= \{(\pi^3 \times \hbar^2)/(15 \times Mn)\} \times \{(3 \times Nn)/(\pi \times V)\}^{(5/3)}\ kg.m^{-2}$ (2)
Gravitational energy $= (3/5) \times (G \times M^2/R)$ Joules (2)
QCD energy $= 927.7 \times 1.602 \times 10^{-13} \times Nn$ Joules (3)
Escape velocity $= (2 \times G \times M/R)^5\ m.s^{-1}$
Reduced Planck constant, $\hbar=1.055E-34\ J.s$
Mass of neutron, $Mn=1.675E-27\ kg$
Number of neutrons, Nn = Mass of the star/Mn

Observations of the star M31-2014-DS1 by the astronomers

Tables 1-3, as presented above adequately explain that a star of mass below 7.15 MΘ cannot explode as supernova, instead it will become a black hole and ultimately will arrive at an equilibrium stage by becoming a neutron star. Observations of the researching astronomers have perfectly matched with above calculations as the star M31 which was originally a supergiant star of mass 20 MΘ was reduced to a star of mass 6.7 MΘ at its terminal burning stage. Its mass being less than 7.15 MΘ, the star has become a black hole as predicted in the calculations and there was no supernova explosion. It corroborates the calculations shown in the tables presented above. Therefore, it can be said that there is no mystery behind the disappearance of the supergiant star M31-2014-DS1 of the Andromeda galaxy and it is a common natural phenomenon that no optical outburst could be observed. The black hole so produced is not in pressure equilibrium and its core will further collapse till the pressures (Gravitational pressure and the NDP) are balanced. The astronomers have detected that black hole cum neutron star

Conclusion

The mathematical framework presented in this article has established the following facts beyond any doubt.

- A star having mass in between TOV limit (2.93 MΘ) and 7.14 MΘ will end up as a black hole cum neutron star. In this mass range a dying star cannot explode as a supernova.
- If the mass of a star is 7.15 MΘ and more than the at its last phase the star will explode as a core collapse supernova (Type-II).
- Observations of the researchers on the disappearance of the M31-2014-DS1 star and birth of a black hole is totally congruent with the mathematical model presented in this paper. There is no mystery involved; rather it is a common natural phenomenon.
- However, a supernova explosion or formation of black hole at the terminal stage of a star without explosion is a very rare occurrence, twice or thrice in a century in any galaxy; it is difficult to generate a database to corroborate the theoretical finding based on calculations.
- In this particular case the star M31-2014-DS1 of the Andromeda galaxy has proved that the results of the calculations presented here are matching with the observations of the astronomers.

References

1. Overbye D. Lonely hearts of the cosmos: the story of the scientific quest for the secret of the universe. Hachette UK; 2021.
2. Majkowski TZ, Kozyra M. Lost Worlds of Andromeda. Mass Effect: Andromeda and the Victorian adventure novel for boys. Studia Humanistyczne AGH. 2021;20(2):23-40. [Google Scholar]
3. McKee M. Supernovae and the accelerating universe. Proc Natl Acad Sci USA. 2015;112(5):1243-1244.
4. Schultz D. The Andromeda galaxy and the rise of modern astronomy. Springer Science and Business Media; 2012.
5. James CR. Things that go bump in the universe: how astronomers decode cosmic chaos?. JHU Press; 2023.
6. Hodge P. The Andromeda Galaxy. Springer Science and Business Media; 2013.