On the role of relativistic electrons in the imploding stage of supernovas

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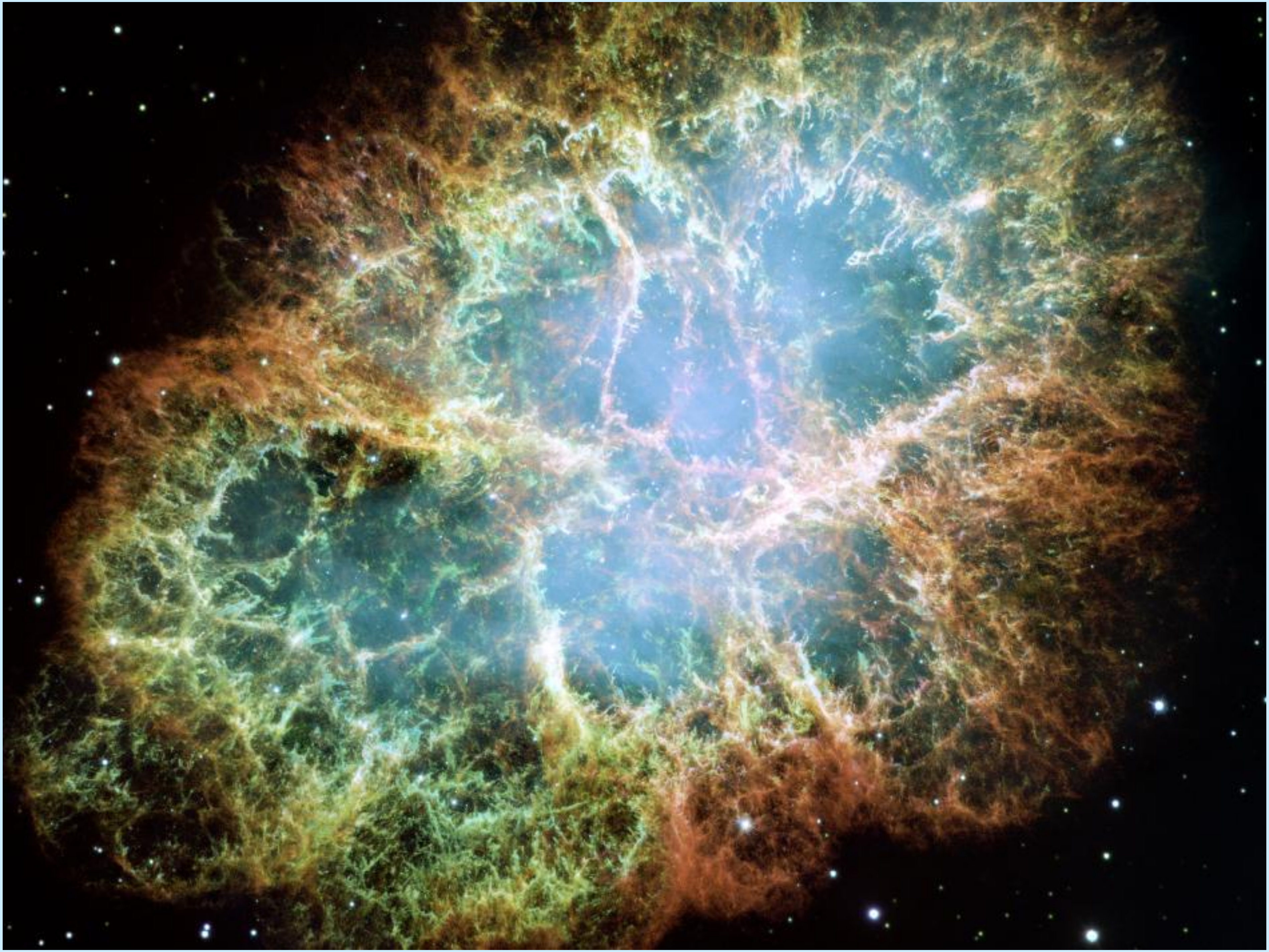
Outline

- **Supernovas**
- **On relativistic electrons**
- **Role of relativistic electrons in supernova**
- **Additional processes**

Supernova is a kind of exploding star, in which the whole star first collapses and then bounces back into an explosion in a short time.

Here is a photograph of Crab Nebula 6500 light years distant, which is the remnants of a star that exploded, seen firstly as a supernova in 1054.



Astronomers have observed thousands such brightly exploding stars, called supernovas by the time of their explosion.

A supernova can outshine its entire galaxy during the first days after the explosion. Matter is ejected at velocities of tens of thousands km/sec

SUMMARY

We are dealing with type II supernovas caused by explosion of stars exceeding 8 M_{SUN}

Supernova processes start with implosion before the explosion.

The processes causing implosion are relatively well understood.

Not so the processes that reverse the implosion into explosion.

We propose and discuss three possible relativistic processes that can reverse implosion of a star into an explosion, causing supernova.

WHAT CAUSES A SUPERNOVA?

In a star the gravitational attraction, which tends to cause the collapse of the star, is balanced by the pressure caused by exothermic nuclear reactions, in this case fusion.

Additional already known relevant processes are

- **Electron-positron pair production,**
- **Electron capture** (in atoms ^{16}O, ^{32}Si, Mg, Fe),

both cause core collapse, that is core implosion.

MAIN HEAT PROCESSES IN STARS

usually considered in simulations of supernovas

- **$4H^1$** join to **He^4** **release** **energy, impedes implosion**
- **$3He^4$** join to **C^{12}** **release** **energy, impedes implosion**
- **Exothermic processes terminate with Fe^{56} creation**

But at $10^{10}K^o \approx 0.85$ Mev:

- **Fe^{56}***disintegrates* to **$13He^4+4N$ - an endothermic process that contributes to collapse and implosion because it demands 2.22 Mev per nucleon**

At $2X10^{10}K^o \approx 1.7$ Mev:

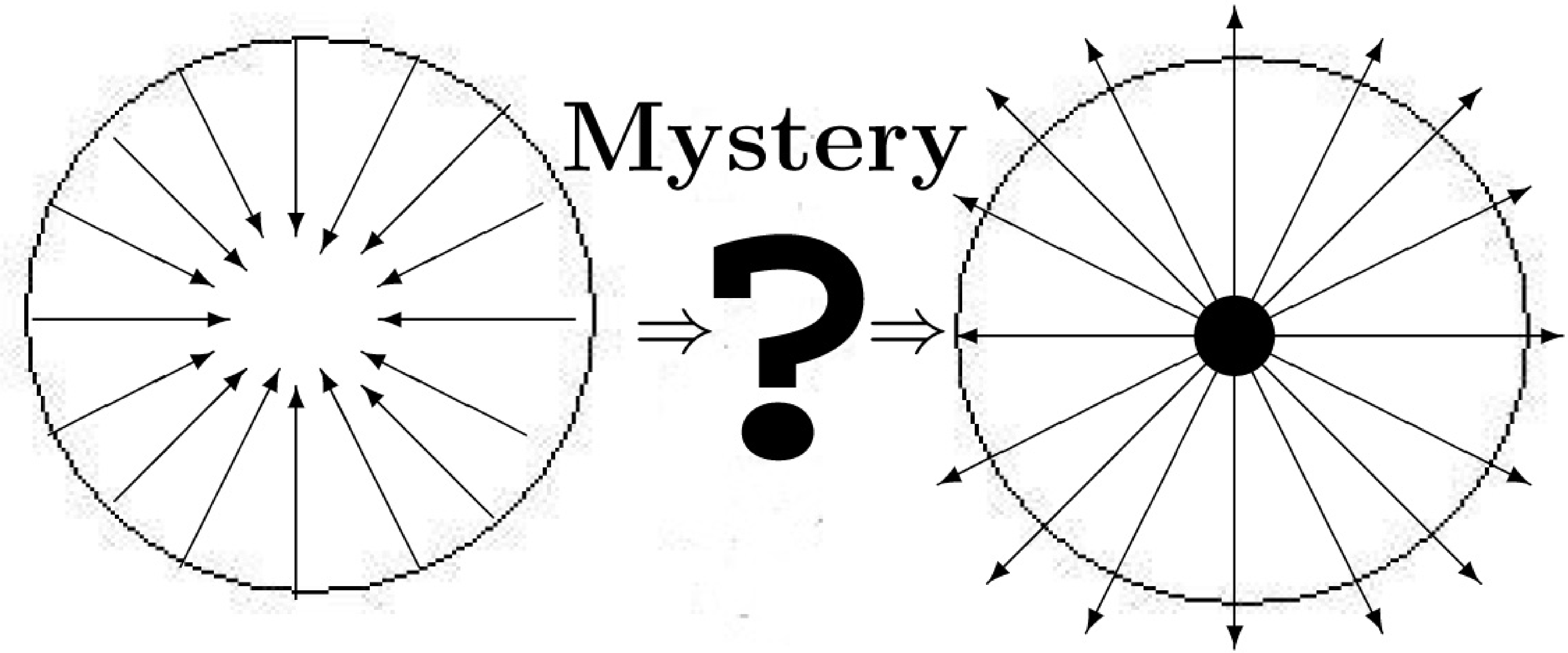
- **He^4** *disintegrates* endothermically to **$4H^1$, enhancing implosion because this demands 8 Mev per nucleon**

MYSTERY

- **Computer simulations show implosion, but not how the implosion *bounces back* to an explosion so violent that it blows up the entire star, exhibiting the *supernova* phenomenon (Liebendörfer et al. (2008), Shaviv (2009), Podsiadlowski (2012))**
- **Wikipedia (2013) in "List of unsolved problems in physics" poses the problem: "What is the exact mechanism by which an implosion of a dying star becomes an explosion?"**

SPECIFICALLY

- Podsiadlowski (2012) puts it this way: "How a fraction of the implosion energy can be deposited just below the accretion shock [=implosion] and be allowed to accumulate till enough energy is available to drive an explosion"
- Simulations actually give a weak bounceback but insufficiently strong to make the whole star explode as SUPERNOVA



Implosion $\longrightarrow$? $\longrightarrow$ Violent explosion

How this energy is stored before explosion?

Without sufficient storage of energy for explosion, the result is implosion to black hole, but

we observe supernova explosions!

Up to here – the knowledge accepted today.

Following are our proposals

1. Our first proposal is based on

variable mass gravitation **and variable electric charge, about which I lectured at IARD2006 meeting but I summarize in short below. First about variable mass gravitation. The force between *m* and *M* interacting gravitationally is**

$$-F = m(r)MG/r^2 \qquad (1)$$

We let *m* to vary with *r* (the distance between point masses *m* and *M*). Also,

$$-F = dE(r)/dr = d(\,m(r)c^2)/dr = c^2 d(m(r))/dr \qquad (2)$$

Equating (1) and (2),

$$m(r)MG/r^2 = c^2 d(m(r))/dr \qquad (3)$$

$$m(r)MG/r^2 = c^2 d(m(r))/dr \qquad (3)$$

Solving, we obtain variable *exponential mass*

$$m(r) = m_\infty \exp(-MG/c^2 r) \qquad (4)$$

for masses with zero velocity. Others have also arrived at the same solution (4)

(Milne 1938, Yilmaz, Kiesslinger, Vankov, Hatch, Turanyanin, Majernik, Marmet, Ben-Amots 2007)

This variable mass theory is beyond Einstein's Equations.

VARIABLE ELECTRIC CHARGE

Because of analogy between inverse of square distance law of gravitational attraction and Coulomb forces, we can consider an analogous variable electric charge

$$q(r)=q_{\infty}\exp(-QY/r) \qquad (5)$$

where Q is the electric charge of the central mass and Y is a constant (we skip here its explanation).

(Usually it is assumed that elementary electric charge is invariable).

Equation (5) when applied to modify the Bohr atom model leads to an additional ***set*** of ***sub-Bohr*** circular orbitals of electron with relativistic velocity around nuclei and with radiuses much smaller than the Bohr radius (Ben-Amots 2007, IARD2006)

- **Milne (1943, 1951), Corben (1963), and Santilli (2003) found *one* additional sub-Bohr circular orbital of an electron. Milne, and also Corben calculated the sub-Bohr orbital energy as 50 Mev. In all these cases variable electric charge was not used.**

For the corresponding sub-Bohr orbitals of hydrogen our theory has the lowest orbital energy of 51Mev implying electron velocity of approximately

$v = c$ -8 km/sec

$v = c * \cos(1/137.036)$

and higher orbitals of

$E_n = 51+(n-1) * 51.5$Mev

with radius ≈ 2.8 × 10 ^{-13}cm

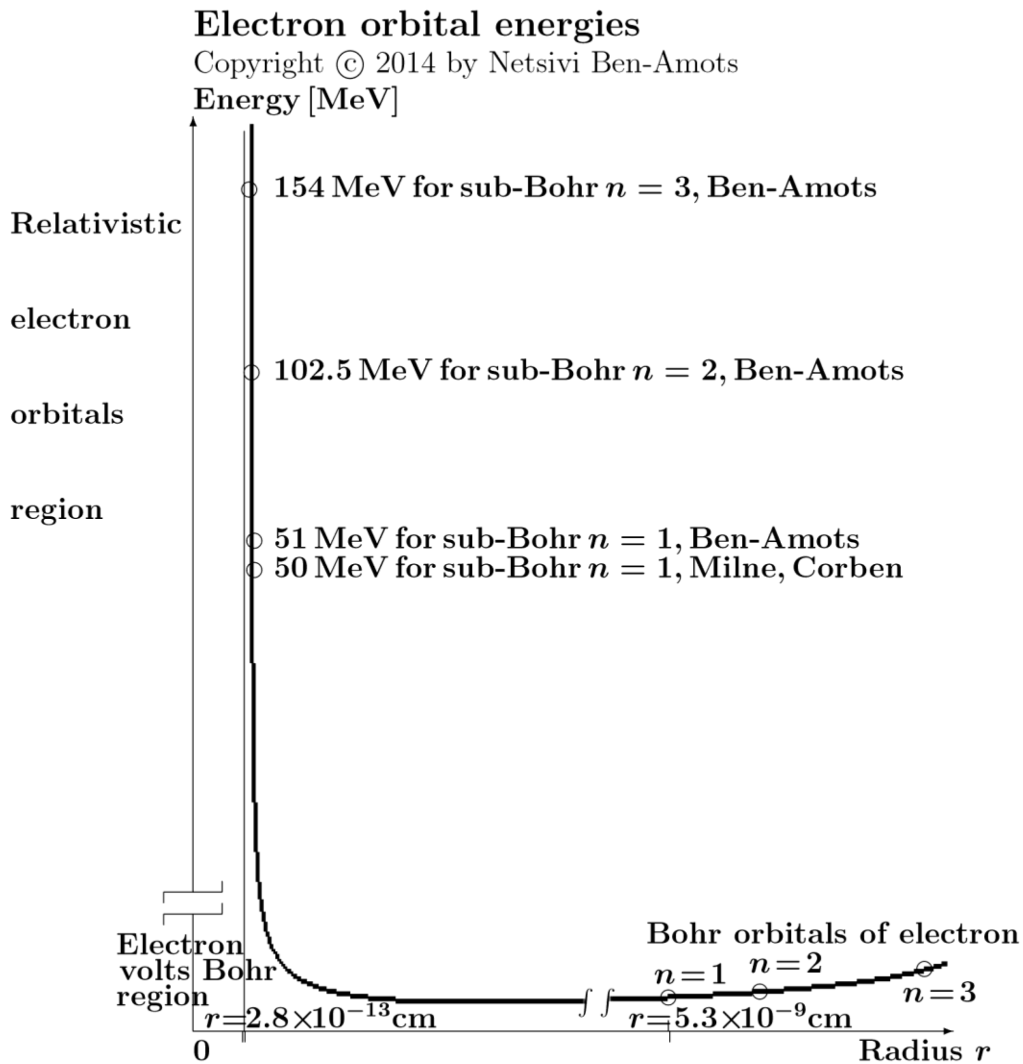


Figure 1: **Energy dependence on the distance r between a proton and an electron orbiting the proton in a circular orbit, presenting sub-Bohr and Bohr levels of energy with n=1, 2, 3 (schematic graph)**

The radiuses of the sub-Bohr set of electron orbitals are much smaller than the radiuses of the Bohr electron orbitals. They are of the order of 10^{-13}cm.

Our derivation (Ben-Amots 2007, IARD2006) leads to a <u>SECOND ORDER ALGEBRAIC EQUATION</u> that gives both solutions:

a) The Bohr set of electron orbitals, and

b) A *set* of sub-Bohr orbitals, which have radius of about 2.8×10^{-13}cm, which is slightly more than twice the proton radius of about 1.2×10^{-13}cm.

$r_{Bohr} = \dfrac{\quad}{\{½ + ½ \sqrt{[1- (4q_{e\infty}{}^2\pi/nch)^2]}\} (nh/2\pi q_{e\infty})^2 \ /m_{e\infty}}$

$\approx (nh/2\pi q_{e\infty})^2 \ /m_{e\infty}$ = Bohr radiuses set (6)

$r_{sub\text{-}Bohr} = \dfrac{\quad}{\{½-½ \sqrt{[1- (4q_{e\infty}{}^2\pi/nch)^2]} \} (nh/2\pi q_{e\infty})^2 \ /m_{e\infty}}$

$\approx q_{e\infty}{}^2 / (m_{e\infty} c^2)$ (7)

where n = 1,2,3….

Notice that the r_{Bohr} and $r_{sub\text{-}Bohr}$ of the same n are two solutions of the same second order algebraic equation, the difference being the + or – sign in the solution.

r_{Bohr} = ____________________

$\{½ + ½ \sqrt{[1- (4q_{e\infty}{}^2\pi/nch)^2]}\}$ $(nh/2\pi q_{e\infty})^2 \ /m_{e\infty}$

$\approx (nh/2\pi q_{e\infty})^2 \ /m_{e\infty}$ = Bohr radiuses set (6)

In Eq. (6), $(4q_{e\infty}{}^2\pi/nch)^2 << 1$ and can be neglected, and ½+½=1

We get $(nh/2\pi q_{e\infty})^2 \ /m_{e\infty}$ = Bohr set of radiuses

$r_{sub\text{-}Bohr} = \frac{}{\{½-½ \sqrt{[1-(4q_{e\infty}^2\pi/nch)^2]}\} (nh/2\pi q_{e\infty})^2 / m_{e\infty}}$

$\approx q_{e\infty}^2 / (m_{e\infty} c^2)$ (7)

In Eq. (7) if we neglect $(4q_{e\infty}^2\pi/nch)^2$ we get $r_{sub\text{-}Bohr} = 0$, so we cannot neglect it here.

In Eq. (7) we get a *first approximation* as sub-Bohr radius $r_{sub\text{-}Bohr} \approx$

$(2q_{e\infty}^2\pi/nch)^2(nh/2\pi q_{e\infty})^2 / m_{e\infty} \approx q_{e\infty}^2 / (m_{e\infty} c^2)$

equal for all *n* (found by Milne and Corben by other means). Yet by second order approximation we get a *set* of very close *sub-Bohr radiuses* for different *n*=1,2,3…

c) The differences between the radiuses in the sub-Bohr set are of order of 10^{-17}cm

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We can see more clearly the formulas for sub- Bohr radiuses in this slide

SECOND ORDER SUB-BOHR RADIUSES SET

$$r_{\text{sub-Bohr}} = \frac{\qquad}{\{\tfrac{1}{2}-\tfrac{1}{2}\sqrt{[1-(4q_{e\infty}{}^2\pi/nch)^2]}\}\,(nh/2\pi q_{e\infty})^2\ /m_{e\infty}} \qquad (7)$$

In Eq. (7) second order approximation gives

$$r_{\text{sub-Bohr}} =$$

$$q_{e\infty}{}^2 / (m_{e\infty}\ c^2) + [2\pi\ q_{e\infty}{}^3 /(n\ c^2\ h)\ ]^2 / m_{e\infty}$$

$$=[(q_{e\infty}/c)^2 /m_{e\infty}\ ] * [1+1/(137.036n)^2]$$

so, for larger n we get smaller $r_{\text{sub-Bohr}}$

The electrons in our sub-Bohr orbitals have a very high ***positive*** energy, which for small quantum number *n* is about $n \times 51.5$Mev

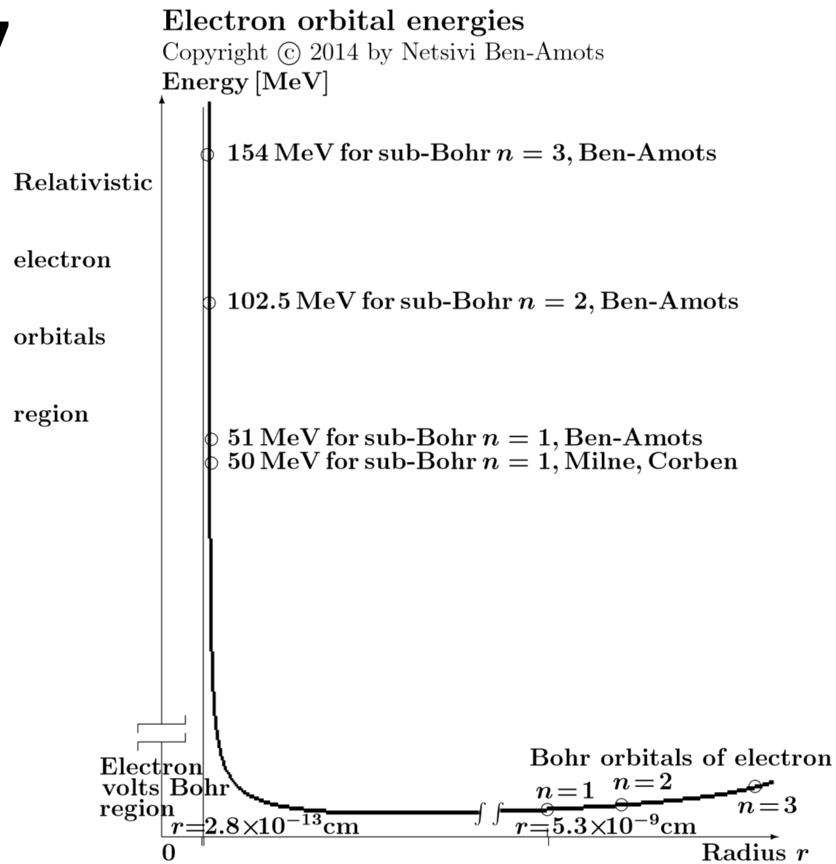


Figure 1: Energy dependence on the distance r between a proton and an electron orbiting the proton in a circular orbit, presenting sub-Bohr and Bohr levels of energy with n=1, 2, 3 (schematic graph)

Because of the high positive energy, a sub-Bohr orbital may be populated by an electron only under enormous pressures, possible in centers of very massive stars during supernovae collapses.

Ben-Amots 2007, IARD2006

We obtained a whole set at energies E_n

$-0.5+n\times 51.5$ Mev, n=1,2,3…n_{max}

En [Mev] =

51 ; 102.5 ; 154 ; … Emax

Milne (1943) obtained only *one* 50 Mev orbital.

Ben-Amots 2007, IARD2006

This positive energy is a consequence of the centrifugal forces that in combination with the exponential forces create a narrow high barrier peaked at about 2.8×10^{-13}cm, which prevents electron capture by the proton.

SUB-BOHR ORBITALS in supernova

When the star collapses the temperature increases. When the temperature reaches 51Mev ($\approx 6 \times 10^{11} K^{O}$) –> electrons start to populate the sub-Bohr orbitals.

An electron in sub-Bohr orbital

1) takes an energy of 51.5 Mev from the available thermal energy, and

2) does not contribute anymore to the total number of free particles in the core of the star.

27 Both 1 and 2 enhance implosion

But they <u>*ACCUMULATE*</u> *significant* energy.

Consequently as pressure increases with collapse, each electrons populate <u>*inner*</u> , <u>*higher*</u> , more energetic orbitals, accumulating additional 51.5 Mev for each new higher populated orbital.

When the relativistic electron reaches the maximal sub-Bohr level of energy

~ n_{MAX} × 51.5 Mev, wherever it goes from here, inside to be captured by the proton to become a neutron, or outside to separate itself from the proton, it *suddenly*

When the relativistic electron reaches the maximal sub-Bohr level of energy ~ $n_{MAX} \times$ 51.5Mev, wherever it goes from here, inside to be captured by the proton to become a neutron, or outside to separate itself from the proton, it *suddenly*

***RELEASES** the accumulated*

$n_{MAX} \times 51.5$ Mev energy!

In the electron capture process a neutrino

To get an idea of the released energy, if

$$n_{MAX} > 20$$

then the maximum accumulated energy

is larger than the rest energy of the

PROTON $E=M_P c^2$!

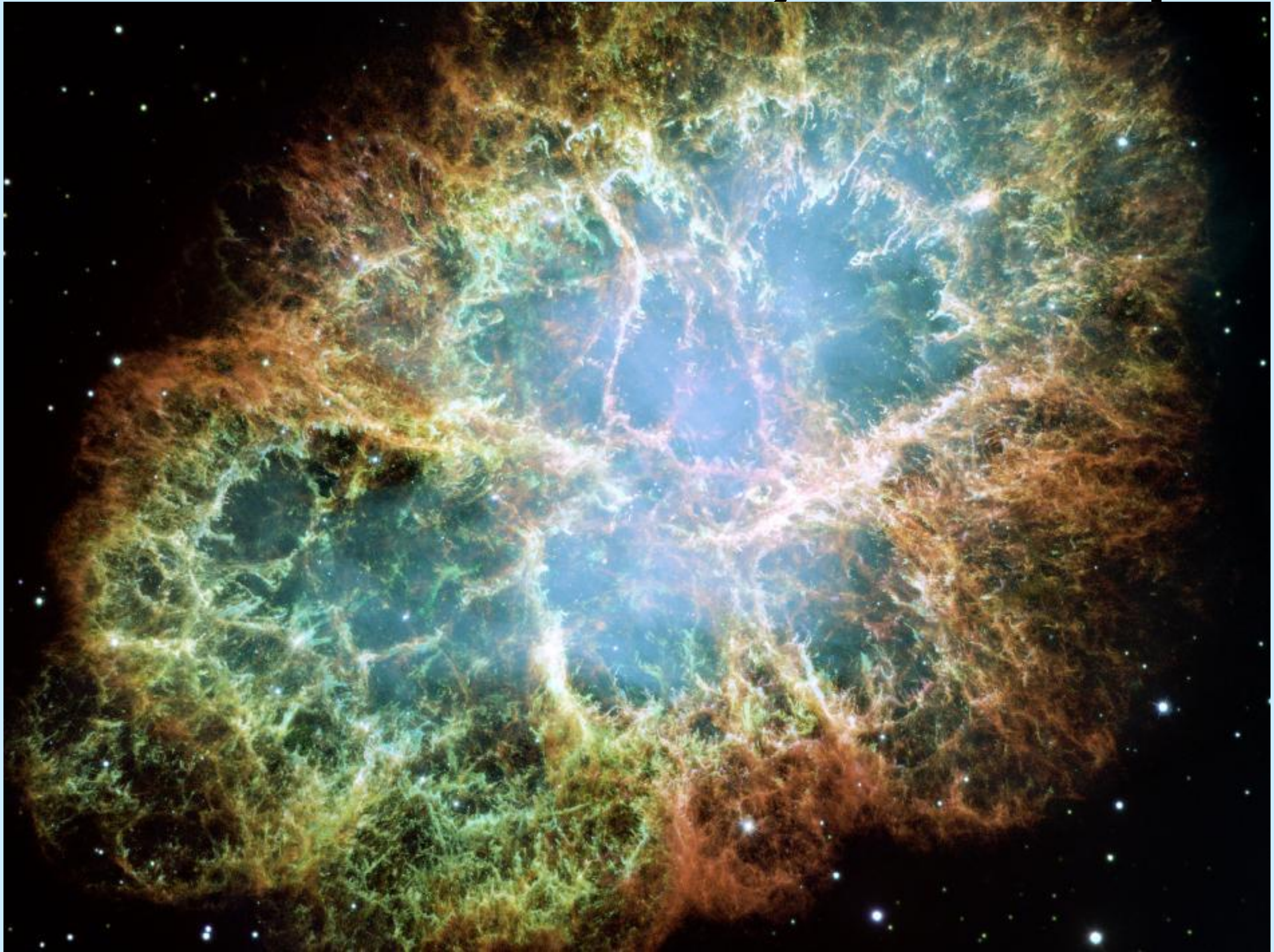
This is part of the bounceback energy we are searching for to solve the enigma of the energy needed for the supernova explosion

As the star collapses the pressure in the core increases, so the energy of the core increases at the expense of gravitational energy originated in the collapse of the upper layers of the star. If so, the energy accumulated in the sub-Bohr orbitals in the collapsed star core can INCREASE to the order of several times of $E = Mc^2$ where M is the mass of the core, at the expense of the gravitational energy of the upper layers of the star.

THEN, THERE IS A SUDDEN RELEASE OF ENERGY WHEN THE SUB-BOHR ELECTRONS ARE CAPTURED BY THE PROTONS, OR SEPARATE FROM THE PROTONS, RELEASING THE SUB-BOHR ORBITAL HUGE ACCUMULATED ENERGY, WHICH STOPS THE IMPLOSION AND

CAUSES EXPLOSION OF THE STAR =SUPERNOVA? Not yet sure.

Explosion seen here after years of expansion



ENIGMA SOLVED?

We showed a first possible way to create a significantly strong bounceback, but perhaps not yet sufficient for supernova explosion.

Note that models based on general relativity alone miss the second set of sub-Bohr electron orbitals since constant electric charge is assumed.

Accumulation of energy in sub-Bohr electron orbitals may occur if electron capture does not happen before the sub-Bohr electron orbitals start to be populated by relativistic electrons. Electron capture is a weak reaction that happens slowly at ordinary pressures in stars, so that the process of populating the sub-Bohr orbitals may or may not occur faster than electron capture, depending on how fast the pressure rises during the implosion of the supernova. The conditions in stars when electron capture occurs are known (Shaviv 2009).

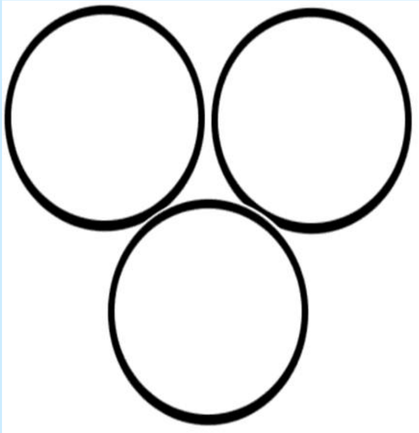
The sub-Bohr electron did not supply more energy than if accumulated. Alone, it enables a significant bounceback, but a limited one.

Ball mini experiment.

What supplies the additional energy that results in so strong explosion that increases the velocity of the ejected matter to tenth of the speed of light?

We briefly mention two other bounceback processes that may be involved too and give answer:

2. Another possible mechanism that can explain the source of energy during collapse of the supernova involves quarks. The high pressure in the core of the star produced by sudden stopping of the fast collapse may cause sudden close contact between quarks, friction between the spinning quarks constituting the nucleon and sudden quenching of the rotation of the three quarks within the nucleons (we presume that then the circumferential layers of the quarks suddenly interpenetrate) (Ben-Amots, 2003, IARD2002)



A quark has a very high but nonhomogeneous density.

Its density at its equator where velocity is at 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 0.99999999999984 *c*

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

The kinetic energy of mass ejected at a tenth of the speed of light is

$$E_K = m_0\, c^2 \left(1/\sqrt{1-0.1^2}-1\right) = 0.005$$

about 0.5% of mc^2 of the star mass. So, for ejecting the whole mass of a star at velocity of tenth of the speed of light c, the necessary mass of quarks whose rotation should be fully quenched is only 0.5% of the mass of the star. Additional energy is necessary for thermal heating, production of heavy elements and in particular for neutrinos. Quenching of the rotation of the quarks of few percents of the mass of the star is necessary for all forms of energy of supernova explosion.

The quenching of the quark rotation with associated photon pressure:

1) Is possibly is the origin of the energy of quasars, AGN, etc. (Ben-Amots, 2003, IARD2002),

2) It may be the much looked after reservoir of energy needed in models of supernovas that together with the huge energy accumulated in the sub-Bohr orbitals may stop the implosion of a star and reverse it to an explosion (as explained in the first part of this lecture).

Supply of such amount of energy is essential to the explosion of supernova. Accumulation of energy (by sub-Bohr electron orbitals or else) may contribute to the explosion of supernova in addition to the supply of energy by quark spin quenching.

In some cases the implosion might be stopped without producing supernova explosion, but instead by forming a massive celestial object stabilized by continuous energy production of quenching the rotation of the quarks, as suggested above in possibility 1) and in (Ben-Amots (2003, IARD2002).

Another possible mechanism of energy accumulation for reversing the implosion of supernova into explosion involves

3. GRAVITATIONAL FIELD ENERGY

Einstein & Infeld in their book "The evolution of physics" (1938, pp. 256-260) argued:

"The mass of the matter, and mass of the gravitational field, can be indistinguishable"

and later EINSTEIN (1939) WROTE:

"Matter cannot be concentrated arbitrarily"

Einstein A., Ann. Math. 40, 922 (1939).

See page 936

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We deduce that together this mean that gravitational field cannot be concentrated infinitely.

Ben-Amots (2011, IARD2008) went into some details.

Summing up, we deduced that the implosion compresses the gravitational field beyond a maximal balanced density.

The overcompressed gravitational field causes outward pressure, which stops the implosion and triggers outward forceful explosion.

CONCLUSIONS

We showed various processes that alone or together may stop implosion of a star and initiate its explosion:

- **First possibility: $n \times 51.5$ Mev set of sub-Bohr relativistic electron orbitals around a proton accumulates and then can release energy. This accumulated energy is significant at temperature greater than 51 Mev ($=6 \times 10^{11} K^{o}$)**
- **Quenching of quark rotation of nucleons as a *source* of energy additional to the *accumulated* energy of the first and third possibilities,**
- **Bounce-back of compressed massive gravitational field during implosion.**

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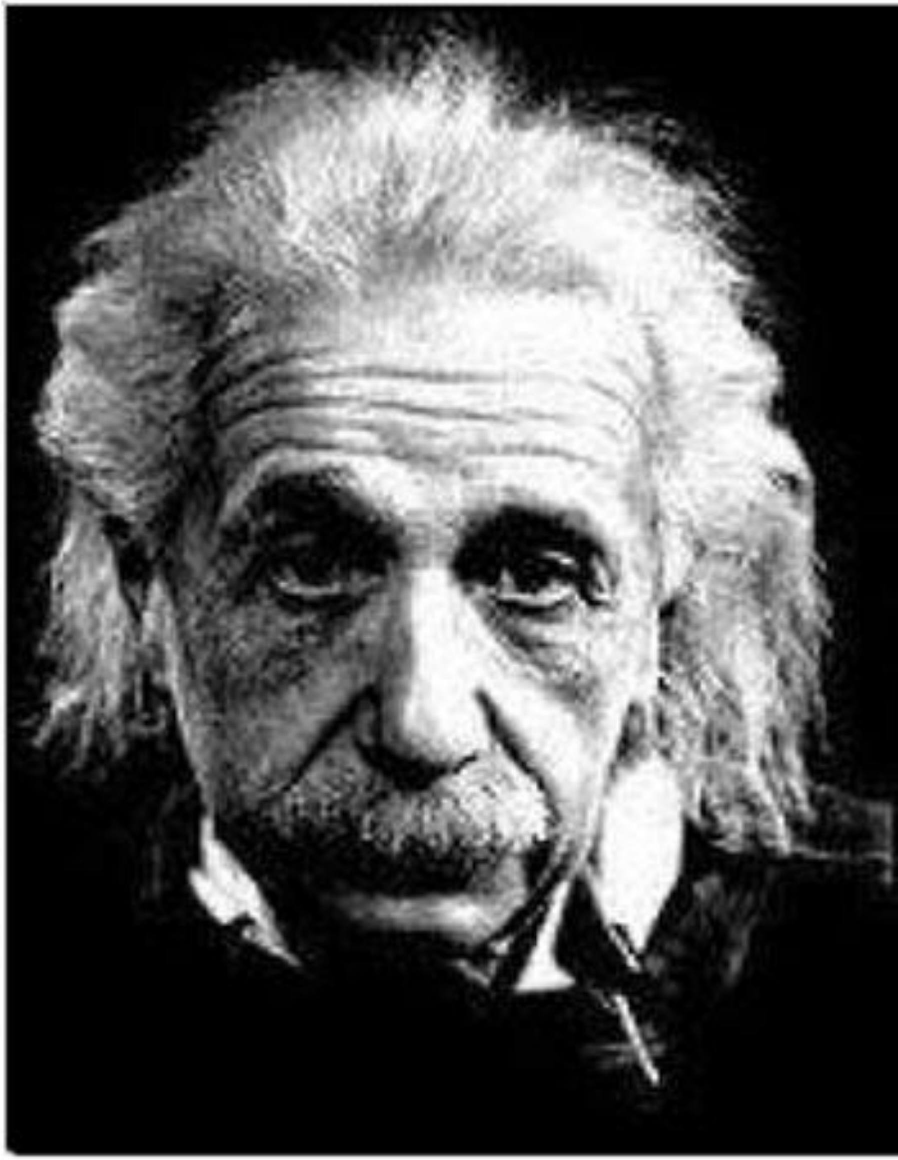
"WE CANNOT SOLVE OUR PROBLEMS WITH THE SAME THINKING WE USED WHEN WE CREATED THEM"




LECTURE END
THANK YOU