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The 1908 Tunguska Cosmic Body (TCB) Explosion: Role of Hydrogen Thermonuclear Explosion in Support of Cometary Hypothesis

Yeong E. Kim

Purdue Nuclear and Many-Body Theory Group (PNMBTG), Department of Physics Purdue University, West Lafayette, Indiana 47907, USA

The explosion on 30 June 1908 over Tunguska, Central Siberia, released ~ 30 megatons (TNT equivalent) of energy at an altitude of ~ 5 km without creating crater(s) on the Earth's surface. Many hypotheses (antimatter, a small black hole, carbonaceous asteroids, comets, etc.) have been proposed. Recent measurements of anomalous isotope ratios in the 1908 peat layers at and near the epicenter have ruled out most of the proposed hypotheses, and provide many supporting evidences for the cometary hypothesis [1]. The cometary core consists mostly of frozen ice.

Compressional heating explosion of falling cometary bodies in the atmosphere was proposed as early as in 1930, and has been investigated theoretically [1]. A possibility of thermonuclear explosion with the conventional Maxwell-Boltzmann momentum distribution was ruled out for falling cometary bodies[2].

Based on earlier works on quantum field theoretic techniques developed by Galitskii and Migdal [3] and Galitskii [4] in 1958 (see also the book by Abrikosov et al. [5]), Galitskii and Yakimets (GY) [6] in 1966 showed that the quantum energy indeterminacy due to interactions between particles in a plasma leads to a generalized momentum distribution which has a high-energy momentum distribution tail diminishing as an inverse eighth power of the momentum, instead of the conventional Maxwell-Boltzmann (MB) distribution tail decaying exponentially.

GY's generalized distribution function $f(\boldsymbol{p})$ by GY [6],

$$f(\boldsymbol{p}) = N \int_o^\infty dE \; n(E) \delta_\gamma(E, \epsilon_p), \tag{1}$$

with the normalization N given by $\int d^3p f(\boldsymbol{p}) = 1$.

Eq. (1) was also derived by Martin and Schwinger in 1959 who developed non-perturbative theory of many-particle systems based on quantum field-theoretic techniques using thermodynamic Green's function [7].

The distribution probability function n(E) in Eq. (1) is a Maxwell-Boltzmann (MB), Fermi-Dirac (FD), or Bose-Einstein (BE) distribution function, and is modified by the quantum broadening of the momentum-energy dispersion relationship, $\delta_\gamma(E, \epsilon_p)$, due to multi-body particle interactions.

A derivation of a general form of the spectral function $\delta_\gamma(E, \epsilon_p)$ in Eq. (1) is given in the book by Kadanoff and Baym [8].

Recently a theory of quantum plasma nuclear fusion (QPNF)[9, 10] has been developed using the generalized momentum distribution function[6], and obtained the quantum corrections to the conventional plasma fusion rates. Based on our semi-analytical formula, substantially enhanced QPNF rates have been predicted for deuteron-deuteron (d + d) and proton-lithium (p+Li) plasmas [9].

The total nuclear fusion rate, R_{ij}, per unit volume (cm^{-3}) and per unit time (s^{-1}) is given by can be written approximately as [9, 10]

$$R_{ij} \approx R^C_{ij} + R^Q_{ij} \tag{2}$$

where R^C_{ij} is the conventional plasma fusion rate calculated with the MB distribution which is negligible at low temperatures. R^Q_{ij} is given by

$$R^Q_{ij} = \frac{\rho_i \rho_j}{1+\delta_{ij}} < \sigma v_{rel} > \approx \frac{N}{1+\delta_{ij}} (4(5!)) \frac{(\hbar c)^3}{\mu c} \alpha^2 S_{ij}(O) (Z^e_i Z^e_j)^2 \frac{\rho_c \rho_i \rho_j}{E^3_G} \tag{3}$$

where we assume $N \approx 1$, E_G is the Gamow energy, $E_G = (2\pi\alpha Z_i Z_j)^2 \mu c^2/2$, ρ_i is the number density of nuclei, and $S_{ij}(0)$ is the S-factor at zero energy for a fusion reaction between i and j nuclei. ρ_c is the number density of charge particles scattering centers.

The reaction rate for $d(p,\gamma)^3He$ is expected to be comparable to or even larger than the rates for $d(d,n)^3He$ and $d(d,p)^3H$ since the number density of hydrogen is much larger than that of deuterium in water even though the cross section for $d(p,\gamma)^3He$ is much smaller than those for $d(d,^3He)n$ and $d(d,p)^3H$. Because of substantially increased fusion rates for $d(p,\gamma)^3He$, $d(d,n)^3He$, and $d(d,p)^3H$, due to QPNF, thermonuclear nuclear explosion by the above reactions may compete with compressional heating explosion. Therefore, it may be possible that compressional heating explosion induced hydrogen thermonuclear explosion and that both the compressional heating explosion and thermonuclear explosions occurred in the 1908 Tunguska event.

Definitive tests of the above proposed hydrogen thermonuclear explosion mechanism are to measure various isotope ratios $(^2H/^1H,^3He/^4He,^{13}C/^{12}C,^{14}C/^{12}C,^{15}N/^{14}N,^{17}O/^{16}O$, and $^{41}K/^{39}K)$ to look for predicted anomalous changes in the ratios. $^{13}C,^{14}C,^{15}N,^{17}O$, and ^{41}K are produced by 2.45 MeV neutrons from $d(d,n)^3He$ fusion reaction.

If the Tunguska explosion occured at altitudes of $5-10$ km, the explosion debris and dust are expected to move upward into the stratosphere and to be dispersed into the wider area [1], and hence we may not find the explosion debris and dust at the inferred epicenter on the ground.

A recent investigation of Lake Cheko, located ~ 8 km NWW of the inferred Tunguska explosion epicenter suggests that the lake fills an impact crater [11].

It has been suggested that this impact crater was created by one of the broken fragments of the comet [12]. One possible scenario is that the comet was broken up into several fragments in the atmosphere by compressional heating and stress, and that the leading fragment exploded. One of the following smaller fragments decelerated due to the front explosion, picked up the explosion debris, and finally landed into the Lake Cheko location carrying the debris. The above scenario suggests that the explosion traces could be found at and near Lake Cheko.

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