From Van der Waals gas to CMBR spectrum, elementary particles, and LENR: A hypothesis

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Introduction

In recent years there are some authors suggesting that the origin of dark energy, quintessence etc. can be related to Van der Waals force-type interaction at cosmic scale. [1][2][3] Interestingly, in this regards, this proposition also reminds us to Prof. Castro-Granik's idea sometime ago that if we indeed live in the Cantorian spacetime Universe [5], then the effect would be as if the Universe resembles a large Bose-Einstein condensate.

Therefore, one interesting question is: Could it be that the Cosmos exhibits CMBR from Cantorian spacetime background which resembles Van der Waals gas (which connects to micro-particle phenomena too). The connection to micro-particle phenomena can be expected not only because of Cantorian spacetime features, but also from experiments suggesting that Van der Waals type-interaction can happen both at micro-scale phenomena and also at macrophenomena [4]

In the present article we will argue in favor of this proposition, by using simple derivation of CMBR temperature from dynamics of critical phenomena (Zurek, Santa Fe Institute, 1990).

Plausible link between Van der Waals gas and Cosmology phenomena

In a rather old paper [1], Kiehn argues that there is plausible 'universality' link between Gibbs energy surface, Gibbs free energy and Van der Waals gas. Gibbs free energy can be written as follows [1]:

$$G= -TS + PV + U \qquad (1)$$

The Gibbs surface for Van der Waals gas is constructed from Legendre transform of the primitive (Internal) energy function, U, subject to the condition that the internal energy function is single-valued. However, the Gibbs (free) energy function, G, is not single-valued. Kiehn argues further that the observations related to this proposition is universal, and were mostly observed in chemistry (Guggenheim 1945), and elsewhere.

It is more interesting to remark here that Hooydonk [4], Gareev & Zhidkova [6] also argue that Van der Waals type-interaction also play significant roles in particle and hadronic interaction.

In this regards, it seems worth to summarize derivation of Van der Waals equation of state from first principles. The free energy of an ideal gas which includes simplest interaction -a(N/V)^2 : [2]

$$F = -TN.(\log (V/N) + \log (T)^{d/2} + \log ((2.pi.m)^{d/2})/(h^d) +1) - a (N/V)^2 \qquad (2)$$

and pressure will be:

$$p = NT/V - a(N/V)^2 \qquad (3)$$

The attraction reduces pressure relative to an interacting gas.

Once atoms in a gas come very close together, they start repelling. We can capture this by assuming that atoms see a 'hard wall' once they heat other atoms. This is as though an atom has instead of V volume to roam in, V -(N-1)b.

This modifies the entropy of the gas, but not the interaction energy. These two modifications of the ideal gas law yield the van der Waals (VdW) equation:

$$(p + a/V^2)(V - b) = T \qquad (4)$$

The VdW equation of state is a good phenomenologicla equation for an interacting gas. The microscopic form of the interaction is well described by the Lenard-Jones potential [2]:

$$u(r) = 4e[(\tau/r)^{12} - (\tau/r)^6] \qquad (5)$$

At low r, short distances, the $1/r^{12}$ gives essentially a hardwall repulsion.But at longer distance, the $1/r^6$ dominates, and we get weak attraction.

An alternative derivation of CMBR temperature from critical Entropy dynamics

In this section we will describe a simplified derivation of CMBR temperature from critical entropy dynamics [7], from which one has the critical entropy Hc and complexity C' and defined by condition:

$$\partial H/\partial c = 0 \qquad (6)$$

From this we find:

$$c' = \log_2 n - \log_2 \log_2 y$$
$$nHc = C' = \log_2 (by - 2^{(-1)}) \qquad (7)$$

where $y=2^n 2^{(-C')}$ is the solution of

$$y \log_e y - y + 1/2 = 0 \qquad (8)$$

that is: $y \sim 2.155535035$. (Note that this is very near to CMBR temperature ~ 2.73 degree Kelvin).

Below Hc the behavior is periodic, above it's chaotic. The latent complexity is given by the difference of the complexities C'' and C' at the transition on the periodic and chaotic branches, respectively:

$$\Delta C = C'' - C' \qquad (9)$$

Along the periodic branch the entropy and complexity are equal, and therefore:

$$nHc = C'' = C' + \log_2 (by - 1/2) \qquad (10)$$

or

$$\Delta C = \log_2 (by - 1/2)$$
(11)

For b=1 this gives numerical solution:

$$\Delta C \sim 0.7272976887 \text{ bit} \qquad (12)$$

Interestingly, this reminds us to the definition of 1 bit of Shannon entropy (=2). Therefore from the

viewpoint
of critical phenomena of Entropy dynamics, the CMBR temperature can be written: [7]

$$T = To + \text{delta } C = 2 + 0.727297 \sim 2.73 \text{ degree Kelvin}$$

Which suggests that CMBR temperature is nothing but the 'minimum' reachable temperature from the viewpoint of critical entropy dynamics. In other words, it is also the temperature of Bose-Einstein condensate at its lowest dynamics permissible by its critical phenomena.

This result (To) also corresponds to Landauer's principle [8][11] that entropy of environment is increased by at least an equal amount, i.e. kT.(ln 2).

Some implications to elementary particles, LENR etc.

With regards to the 'ubiquitousness' proposition, one can refer to arguments by Gareev & Zhidkova [6], that particle modeld based on either Newton/Kepler model, Maxwell equations, Schrodinger and Dirac equation are in reasonable agreement with experimental data, but they are likely to be grounded on some unknown fundamental principle. It seems that this hypothesis is quite similar to Van Hooydonk's argument that Van der Waals type interaction may explain both elementary particles and also Antihydrogen experiments. [4]

From this viewpoint, Gareev & Zhidkova argued that LENR can be explained as 'cooperative processes' in the whole system.
This seems to support the idea of 'cluster' reaction in CMNS/TSC model by Takahashi [9] .

Of course this proposition seems quite counter-intuitive from the viewpoint of High-Energy Physics (hep-th, hep-ph physicists), as Gareev & Zhidkova point out [6]:

> "Almost all nuclear experiments were carried out in conditions when colliding particles interacted with the nuclear targets
> which represented a gas or a solid body. The nuclei of the target are in the neutral atoms surrounded
> by orbital electrons. All existing experimental data under such conditions teach us
> that nuclear low energy transmutations are not observed due to the Coulomb barrier."

Nonetheless, it is possible according to G&Z [6] to argue that the rest mass differences of atoms in beta-decay and electron capture processes are quantized by the formula:

$$M = (n1/n2) * 0.0076294 \quad (MeV/c^2) \qquad (13)$$

where n1 are integer numbers, and n2 =1,2,4,8. This proposed quantization hypothesis holds for atoms and nuclei with different A, N, Z, and the nuclei and atoms represent a coherent synchronized systems -- a series of coupled resonators (oscillators).

Therefore, it seems that the clue from G&Z to understand LENR is that the phenomena shall be understood as interaction inside a cluster of atoms, inside using 'traditional' Coulomb interaction.

Interestingly, Van Hooydonk seems to consider similar method, albeit from pure Van der Waals type interaction. He argues that the classical VdW equation [4]:

$$(p + a/V^2) (V - b) = RT = NkT \qquad (14)$$

can be rewritten in PV-form and scaling by N, which yields:

$$Pv (1 + a/V^2) (1- b/V) = kT \qquad (15)$$

which will lead to similar analytical deviations, including equivalent phase transitions for micro-systems, governed by a 1/r law. For small b, an equivalent form for macro behavior can be rewritten instead of (14):

$$P = (RT/V)(1 + b/V + \ldots) - a/V^2 \quad (16)$$

where the linear term in 1/V represents ideal behavior. From (16), deviations D from ideal behavior for small b are given by

$$D = P - RT/V = bRT/V^2 - a/V^2 \quad (17)$$

Only if a and b are very small, then D tends to zero and both the macro- as well as micro-systems will behave almost ideally.

Interestingly, Van der Waals type-interaction cannot be neglected and it's related to phase transitions observed in the micro-world, obeying a Mexican-hat potential or double-well curved of Hund type.

Therefore, one can conclude that it seems that non-traditional potentials other than Coulomb shall be used to analyse LENR phenomena.

Concluding remarks

In the present summary paper, we review how plausible is a hypothesis that CMBR corresponds to the Van der Waals type-interaction, and how macro-phenomena may have link with micro-particle phenomena as both van Hooydonk and RM Kiehn suggest.

As to implications to LENR, an alternative to Van der Waals equations is in the form of non-Yukawa potential, for instance using solution of biquaternion Klein-Gordon equation that we discussed elsewhere sometime ago [8].

Acknowledgment
Previous discussions with Profs. E. Goldfain, and C. Castro are appreciated.

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