The SuperConducting Ether

A Many Body Interpretation of Dirac's Negative Energy Sea of Electrons

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abstract

The SuperConducting Ether (SCE) reinterprets Dirac's negative energy sea of electrons as a filled Fermi sea (FFS) of both spin-up and spin-down electron neutrinos with collective modes on the Fermi surface (FS), BCS condensation, and particles with mass and charge created when excited across the BCS energy gap. Newtonian gravitation derives from zero sound phonons with propagation velocity, $s = c/\sqrt{3}$, and with a Doppler force effect. Electric and magnetic fields are collective modes of dipolar quasi-particles and holes. The fine structure constant is interpreted to be a Thomas-Fermi many body screening effect. Special relativity is a byproduct of interactions occurring on the Fermi surface (FS) with c = v_F. Quantum single pair decays cause photon propagation losses that result in a distance-dependent red shift superseding the geocentric Doppler red shift. The Fermi surface has a finite temperature that results in Cosmic Microwave Background (CMB) and Gravitational Wave Background (GWB) with black body like spectra. Particles are categorized as composites of their final stable decay products resulting in a self-consistent buildup of particle number consistent with the two-neutrino FFS. Quarks are nonexistent. Neutrino mass is disregarded. Matter and antimatter are balanced. The SCE is therefore a steady state universe. Black holes are problematic. The quantum nature and limitations of classical field theory are made evident. SI units are used for explicit expression of free space constitutive parameters. SCE is a physical realization of the Plank units.

Dirac's negative energy sea of electrons is reinterpreted to be a filled Fermi sea (FFS) of zero mass and zero charge fermions, both spin-up and spin-down. The rational derives first from the similarity of Dirac's electron energy (*1*)

$$E = \sqrt{(p \cdot c)^2 + (m \cdot c^2)^2} \tag{1}$$

and the BCS particle energy (*2, 3, 4*)

$$E = \sqrt{\varepsilon_p^2 + \Delta^2}. \tag{2}$$

In the Dirac energy equation,

$$\varepsilon_p = p \cdot c \tag{3}$$

is the dispersion of a zero mass particle where the transverse mode velocity of light is assumed to be the Fermi velocity. The assumption of zero charge follows along with the identification of the FFS particles being electron neutrinos, ν_e, hereafter called 'neutrinos'. The validity of the neutral FFS is discussed below.

The assumption of the sea being filled with both spin up and spin down neutrinos has the following rationale: If one assumes a filled Fermi sea of traditional neutrinos and removes one, the hole is not a traditional antineutrino therefore the addition of the opposite spin neutrino. This leads to a modified lepton conservation with two pairs in particle creation instead of one, a factor affecting Strangeness.

The ground state of the universe is then a filled Fermi sea of right and left handed neutrinos:

$$|G\rangle = \prod_{k \le k_F} c_{k\uparrow}^{\dagger} c_{k\downarrow}^{\dagger} |0\rangle \tag{4}$$

The distribution of particle states on the Fermi surface is approximately:

$$\delta n_k \approx n_k \cdot (1 - n_k) \quad (5)$$

where

$$n_k = n_0 / \left(1 + e^{\beta \cdot \varepsilon_k}\right) \quad (6)$$

is the Fermi-Dirac statistical distribution function for a sea of fermions,

$$n_0 = k_F^3 / 3 \cdot \pi^2 \quad (7)$$

is the number density of the filled Fermi sea at zero temperature (^{0}K), and

$$\beta \equiv 1/k_B \cdot T \quad (8)$$

is the Boltzmann thermal energy factor where k_B is Boltzmann's constant and T (^{0}K) is the temperature.

Classical fields are collective modes on the Fermi surface. Interactions are strongly dependent upon the density of states and Pauli Exclusion.

Newtonian gravitation is interpreted as an effect of zero sound phonons (*5*) on the Fermi surface (FS). In SCE, gravitation is a negative pressure wave, the gradient drawing everything towards its source.

Define the mass displacement field or flux as

$$\mathcal{H} = \sum g \cdot \delta n \ \ [\mathrm{m/r^2}] \quad (9)$$

where

$$g = m/k_F \quad (10)$$

is the equivalent mass dipole and δn is the distribution of particle states on the Fermi surface.

$$\mathcal{G} = \sum G \cdot g \cdot \delta n \quad (11)$$

is the gravitational field,

$$\mathcal{G} = \nabla \phi. \quad (12)$$

where ϕ is the potential.

The gravitational pressure wave is

$$P = \mathcal{G} \cdot \mathcal{H}. \quad (13)$$

It is this negative pressure wave that creates the attraction between all particles through its gradient as interpreted in the many body SCE.

$$\nabla P = \rho \cdot \ddot{\vec{x}} \quad (14)$$

The phonon velocity is

$$s^2 = \frac{\partial P}{\partial \rho} = \frac{1}{\kappa_T \cdot \rho} = \frac{c^2}{3}, \quad (15)$$

where the isothermal compressibility (*5*) is

$$\kappa_T = 3/n_0 \cdot \varepsilon_F, \quad (16)$$

the mass density is

$$\rho = m \cdot n, \quad (17)$$

and

$$m = h \cdot k/c \quad (18)$$

is the mass equivalent of a zero mass particle.

This implies a zero sound phonon mode of Newtonian gravitation. These results are due to the neutral Fermi sea and Pauli Exclusion. If the FFS was composed one kind of neutrino, the velocity would be $c/\sqrt{6}$.

Classical electric fields are modeled as collective modes of quasi-particle/hole electric dipole moments,

$$p = 2 \cdot e/2 \cdot k_F = e/k_F \tag{19}$$

where e is the electron charge and k_F is the radius of the Fermi sea. In this trial model, we will assume at the start that the virtual particles and holes carry a full electron charge. The electric flux is therefore

$$\vec{P} = \sum \vec{p} \cdot \delta n_k \text{ [Q/m}^2\text{]} \tag{20}$$

on the FS. The magnetic field is likewise a collective mode of microscopic magnetic dipole moments, m,

$$\vec{H} = \sum \vec{m} \cdot \delta n_k. \text{ [A/m]} \tag{21}$$

The free space constitutive parameters depend upon the density-density correlation function, $\chi\,(q,\omega)$. (5) The parameters are dependent upon the FFS of neutrinos and not the BCS condensate of electrons. Treating the medium as bosons, the correlation function is as follows:

$$\chi(q,\omega) \sim \sum \left\{ \frac{\langle b_q^\dagger b_q \rangle}{\omega - \omega_q + i\delta} - \frac{\langle b_q b_q^\dagger \rangle}{\omega + \omega_q + i\delta} \right\},\ \omega_q = \varepsilon_{k+q} - \varepsilon_k, \tag{22}$$

Treating the correlation function as bosonic quasi-particle/hole pairs, the correlation function is as follows where Pauli Exclusion prohibits same quantum states:

$$b_q^\dagger \cong \sum c_{k+q}^\dagger \cdot c_k \approx n_q \tag{23}$$

and

$$b_k \cong \sum c_k^\dagger \cdot c_{k+q} \approx 1 - n_k. \tag{24}$$

In terms of the quasi-particle/hole pairs, the density-density correlation function is (6)

$$\chi(q,\omega) \sim \sum \left\{ \frac{n_{k+q} \cdot (1-n_k)}{\omega - \omega_q + i\delta} - \frac{n_k \cdot (1-n_{k+q})}{\omega + \omega_q + i\delta} + \frac{\delta_{k'+q\uparrow,-k\downarrow} c_{k+q\uparrow}^\dagger c_{-k'\downarrow} - \delta_{-k\downarrow,-k'\downarrow} c_{k+q\uparrow}^\dagger c_{k'+q\downarrow}}{\omega - \omega_q + i\delta} + \right.$$
$$\left. \frac{\delta_{k\uparrow,-k'-q\downarrow} c_{k'\uparrow} c_{-k-q\uparrow}^\dagger - \delta_{-k\downarrow,-k'\downarrow} c_{k+q\uparrow}^\dagger c_{k'+q\uparrow}}{\omega + \omega_q + i\delta} \right\}. \tag{25}$$

The shorthand version is as follows:

$$\chi\,(q,\omega) = \sum \frac{n_{k+q} - n_k}{\varepsilon_{k+q} - \varepsilon_k + i\delta} \tag{26}$$

The function has real and imaginary terms:

$$\chi = \chi' + i\chi'' \tag{27}$$

where the real part at low energy is (5)

$$\lim_{q\to 0} \chi'(q,0) \cong\ 3 \cdot n_0/\varepsilon_F, \tag{28}$$

good until q approaches the Fermi wave number, k_F, and the imaginary part is (5)

$$\chi'' \cong \frac{\pi}{2} \cdot \omega_q \cdot \chi' \cdot \left[\delta(\omega - \omega_q) - \delta(\omega + \omega_q)\right]. \tag{29}$$

The real part of the density-density correlation function represents the disallowed states hence the filled Fermi sea. The imaginary part represents the allowed states hence the Fermi surface. Only quasi-particles and holes near the Fermi surface take part in interactions; the rest of fermions remain inactive beneath the Fermi surface.

The lossy part of the density-density correlation function is interpreted as follows. (*5*) Propagation of radiation modeled as collective modes on the FS is accompanied by small losses to single pair decay as outlined in Pines and Nozierres (*5*). For translationally invariant neutral systems, the f-sum rule is exhausted by the contributions of the collective zero sound mode and single pair excitations. (*5*)

Free space constitutive parameters are modeled after classical analogs (*7*) or Kubo's formula (*8*).

Newton's gravitational constant,

$$G^{-1} \cong g^2 \cdot \chi \tag{30}$$

permittivity,

$$\epsilon_0 \cong p^2 \cdot \chi \tag{31}$$

and permeability,

$$\mu_0^{-1} \cong m^2 \cdot \chi \tag{32}$$

where the microscopic quasi-dipoles are, dimensionally, respectively,

$$g = m/k_F \tag{33}$$

$$p = e/k_F \tag{34}$$

$$m = c \cdot p \tag{35}$$

The repeated appearance of the low frequency density-density correlation function, $\chi' = 3 \cdot n_0/\varepsilon_F$, in the constitutive parameters implies the Fermi sea is at low temperature, isotropic, translationally invariant, neutral, and collissionless. It actually implies the existence of the SCE. The gravitational constant has been used to estimate the fundamental unit of length k_F^{-1}, in this case the inverse Fermi wave number.

Maxwell's equations treat interactions between charges but are incomplete in treating interactions between fields. Traditional electrodynamics has forces within fields only though derivatives. (*9*) In the SCE, there is a negative 'tension' along the field lines and a positive 'pressure' between them both due to the $\vec{p} \cdot \vec{p}'$ and $\vec{m} \cdot \vec{m}'$ dipolar interactions.

The fine structure constant (FSC) (*10*), α, behaves like a Thomas-Fermi screening term (*5*). It can be explained with a many body dipolar model such as with the SCE.

$$\alpha \cdot \epsilon_0 \cong \frac{e^2}{\hbar \cdot c} \cong \frac{p^2 \cdot n_0}{\varepsilon_F} \tag{36}$$

Equation 36 also implies that the SCE FFS is isotropic, at low temperature, and collissionless. (*5*)

The Thomas-Fermi screening distance is dependent upon the FSC:

$$k_s \cong \frac{p^2 \cdot n_0}{\epsilon_0 \cdot \varepsilon_F} \cdot k_F \cong \alpha \cdot k_F \tag{37}$$

The screening implies that potentials have an exponential dependence: (*5, 11*)

$$\varphi \approx \varphi_0 \cdot e^{-k_s \cdot r} \rightarrow \frac{\varphi_0}{k_s \cdot r} \tag{38}$$

as the distance, r, increases.

This gives us the 1/r dependence for the long range classical forces. (*11*) This is one way that the fine structure constant gets into classical and QED.

The Fermi surface has a temperature spectrum similar to a boson BB distribution

$$BB \cong \varepsilon_k / \left(1 - e^{\beta \cdot \varepsilon_k}\right) \tag{39}$$

but is defined by the underlying fermion particle/hole distribution

$$\delta n_k \approx n_k \cdot (1 - n_k) \tag{40}$$

This distribution is similar to the traditional black-body spectrum as follows: (See Figure 2.)

$$SCE\ BB = n_k \cdot (1 - n_k) = e^{\beta \cdot \varepsilon_k} / \left(1 + e^{\beta \cdot \varepsilon_k}\right)^2 \tag{41}$$

This distribution is the source of Cosmic Microwave Background (CMB) (*12*) and Gravitational Wave Background (GWB) (*13*). This implies the possibility of a steady state universe (*14, 15*).

Hubble first used brightness to estimate distance to stars. Then, he observed that there was a redshift proportional to distance. Possessing only classical electromagnetics, he postulated that the redshift was a Doppler effect due to the relative velocity between the stars and earth. (*16*) This became Hubble's law and the strongest evidence of an expanding universe and the Big Bang model.

$$v = H_0 \cdot D, \tag{42}$$

where v is the relative velocity, H_0 is the Hubble constant, and D is the relative distance.

The change in frequency is estimated to be a function of the velocity

$$\frac{\Delta f}{f} = \frac{\sqrt{1+\beta^2}}{\sqrt{1-\beta^2}} - 1 \cong \frac{v}{c} \ll 1, \tag{43}$$

The SCE model has a quantum basis for the redshift based upon photons losing energy through emission of single quasi-particle-hole pairs. This is a distance dependent redshift in agreement with observation. Doppler redshifts and blueshifts cause excursions above and below the Hubble formula. The SCE redshift is the distance-dependent observation with Doppler effects affecting error and uncertainty:

$$\text{SCE Red Shift} = H \cdot D\ (\text{distance}) \pm \Delta f\ (\text{Doppler}) \tag{44}$$

Gravitational redshift (*17, 18*) is the process by which electromagnetic radiation propagating towards a gravitational source is blue shifted and if propagating away from a gravitational source is redshifted.

The gravitational redshift of a photon can be calculated in the framework of general relativity (using the Schwarzschild metric outside of a non-rotating, uncharged mass which is spherically symmetric) (*19*):

$$1 + z = \frac{1}{\sqrt{1 - \frac{2 \cdot G \cdot M}{r \cdot c^2}}}, \tag{45}$$

where $z \equiv \frac{\Delta f}{f} \cong \frac{v}{c} \approx \frac{G \cdot m \cdot c^2}{r} \ll 1$ (46)

The gravitational field in SCE compresses the density of states at the Fermi surface. That effects the permittivity and hence the velocity of light. In terms of Newtonian gravitation in SCE nomenclature, the redshift is approximately

$$z \cong \frac{m \cdot c^2}{\varepsilon_F} \cdot \frac{1}{k_F \cdot r}. \tag{47}$$

where r is sufficiently large compared to the Schwarzschild radius, r_S (see equation 48, below), i.e. when $z \ll 1$.

Therefore, in SCE the gravitational field distorts the density of states on the FS instead of space-time.

Extrapolating the gravitational redshift to heavier objects led to speculation about black holes.

If all the mass of an object were to be compressed within the Schwarzschild radius (*19*), it is postulated that light could not escape, thereby forming a black hole.

The Schwarzschild radius is given as (*19*)

$$r_S = \frac{2 \cdot G \cdot M}{c^2} \quad (48)$$

If the sun were to be compressed into its Schwarzschild radius (*19*)

$$r_s \approx 3km, \quad (49)$$

such an object would have mass density about$\cdot 10^{20}\text{kg/m}^3$, a thousand times more dense than nuclear matter and a million times the density of a neutron star, about 10^{17}kg/m^3. It seems unlikely that Newtonian gravity can bring photons to a halt (at the event horizon or anywhere else) and overpower Pauli Exclusion, with or without general relativity. The gravitational velocity of propagation difference makes it less likely. Such strong compression would result in some form of energy ‘boiling’ out of the hole. Black holes seem problematical unless they are rotating at enormous speeds. The centrifugal force would allow a larger Schwarzschild radius and lower densities.

When in general relativity we say that light follows a constant geodesic, we say in SCE that light follows a constant density of states on the FS.

Traditional thinking about gravitational waves is that gravitational waves cannot exist under Newton's law of universal gravitation because that law is predicated on the assumption that the gravitational fields propagate at infinite speed. Attributing a finite velocity to Newtonian gravitation propagation reopens the question. Also, when Einstein published his theory of general relativity in 1915, (*18*) he was skeptical about radiation since the theory implied there were no gravitational dipoles. However, examination the solution to Helmholtz equation with of the mass density of a binary with equal masses, M, in a circular orbit reveals a sinusoidal term that shows up in the scalar field as a “ripple” or waves:

$$\left(\nabla^2 - \frac{1}{s^2} \cdot \frac{\partial^2}{\partial t^2}\right)\psi = 4 \cdot G \cdot \rho, \quad (50)$$

$$s = c/\sqrt{3}. \quad (51)$$

$$\rho(x, y, z) = M \cdot \{\delta(x - x_1) \cdot \delta(y - y_1) \cdot \delta(z) + \delta(x - x_2) \cdot \delta(y - y_2) \cdot \delta(z)\},$$
(52)

$$x_1 = a \cdot \cos\varphi \quad (53)$$

$$y_1 = a \cdot \sin\varphi \quad (54)$$

$$x_2 = -a \cdot \cos\varphi \quad (55)$$

$$y_2 = -a \cdot \sin\varphi \quad (56)$$

$$\varphi = \omega \cdot t \quad (57)$$

$$\iiint \rho \cdot d^3x \approx M \cdot (e^{i\sqrt{2}\cdot\frac{v}{s}\cdot\sin\left(\omega\cdot t + \frac{\pi}{4}\right)} + e^{-i\sqrt{2}\cdot\frac{v}{s}\cdot\sin\left(\omega\cdot t + \frac{\pi}{4}\right)}), \text{ where } k \cdot a = \frac{v}{s} \ll 1. \quad (58)$$

Therefore, there is longitudinal Newtonian gravitational radiation other views notwithstanding. These waves are very difficult to detect because of their low amplitude and the lack of differential forces across sensors. (*20*)

In SCE, leptons, mesons, and baryons are ‘tabulated’ by their final decay particle (both matter and anti-matter) numbers (N) as follows in Tables 1, 2, 3, and 4, below. Muon neutrinos are modeled as an electron neutrino plus a neutrino/antineutrino pair as in Table 1. Gauge Bosons are assigned the composite number ‘2’, Table 2. Mesons exist in units of four SCE particles and holes consistent with the assumption of four fundamental particles, two neutrinos and their anti-matter holes, Table 3. Baryons decay into two separate decay channels – a proton channel and a neutron channel, pion decay illustrated in Table 4. Therefore, baryons build up in SCE particle units of four. The number four is appropriate by lepton conservation with two types of neutrinos in the FFS, i.e. you don't excite one pair; you excite two pairs. Bound states of matter and anti-matter do not decay within the FFS because of unavailable final states and the composite spin = 1 has the quasi-particle spins oriented the same implying a repulsive force.

The solar neutrino problem and neutrino oscillation have the same basis as the redshift, above; that is, the neutrinos absorb and emit neutrino pairs in transit.

A clue about the constituent electrons/positrons in a proton is the ratio of the proton magnetic moment to the electron magnetic moment normalized for mass. The ratio is 2.8 or about 3 inferring an $e + e/\underline{e}$ proton building block. Using the underlying building block of four (meaning we need two more fundamental particles, $P = \nu_e/\underline{\nu_e}$) infers the proton may be $p = e + B/\underline{P}$ as in Table 4. Likewise for the neutron, the ratio of magnetic moments is 1.98 or about 2 indicating the additional charge in W^- is oriented opposite the other three.

In Table 4, Baryons, below, the change in numbers of pions, $\Delta\pi$, as we ascend the particle number corresponds to the Strangeness quantum numbers – $\Delta n = 0, 1, 2, \& 3$, ignoring signs.

Associated production of 'strange' particles is creation of $W+$ and $W-$ pairs (four composite quasi-particles per SCE schematic, Table 2), one pair for $S = 1$, two pairs for $S = 2$, etc. in the two V-particles, one with strange and the other with antistrange assignments. A second clue to strangeness assignments is the pion decay of the baryons in Table 4; that is, one pion decay denotes $S = 1$, two pion decay denotes $S = 2$, etc.

SCE does not have a reinterpretation of particle and nuclear forces or of Big Bang or stellar nucleosynthesis.

In summary, many old issues have been lying around too long:

1. Dirac's negative energy sea of electrons (Modeling Dirac's sea as a neutral filled Fermi sea and letting charge be created along with mass across the BCS energy gap opens this issue for a many body treatment.)

2. Plank units [21] (The parameters of the filled Fermi sea are a physical realization of the Plank units with numerical factors included for the different definitions.)

3. Classical fields (Modeling classical fields (gravitation, electric, and magnetic fields) as quasi-particle/hole collective modes on the Fermi surface connects the quantum ether with the observed fields.)

4. Velocity of propagation of Newtonian gravity (Modeling gravitation as a phonon-like phenomenon settles this issue although this first trial model concludes $s = c/\sqrt{3}$.)

5. Constitutive parameters (The repeated appearance of the low frequency density-density correlation function, $\chi' = 3n_0/\varepsilon_F$, in the constitutive parameters implies the Fermi sea is at low temperature, isotropic, translationally invariant, neutral, and collissionless. It implies the existence of the SCE.)

6. Pressure between EM field lines and tension along them (The dipolar microscopic model of electric and magnetic fields allows evaluation of field-to-field interactions not possible in the classical model.)

7. Hubble's Doppler shift assumption about distant stars (Hubble relied upon the only available model at hand – classical electromagnetics and the Doppler shift. Modeling the field propagation as a collective mode on the Fermi surface introduces losses due to single pair decay. This is a distance-dependent redshift that counters belief in an expanding universe.)

8. The source of Cosmic Microwave Background (CMB) (The Fermi surface with a non-zero temperature is a source of radiation with a black body kind of a spectrum. This counters belief in the Big Bang.)

9. Source of the fine structure constant (The fine structure constant looks like a Thomas-Fermi screening factor with a very large potential energy, $\approx \alpha \cdot \varepsilon_F$.)

10. Newtonian gravity (The relationship between Newton's gravitational constant and the FFS compressibility is due to the neutrality of the Fermi sea and Pauli Exclusion.)

11. Radiation of Newtonian gravity (Questions about the infinite velocity of propagation and the lack of gravitational dipoles hindered this issue. Putting realistic time dependent moving mass sources in the inhomogeneous Helmholtz equation settles the argument.)

12. Gravitational dipoles (A simple model of binaries as a source for the inhomogeneous scalar Helmholtz wave equation settles this issue. Binaries are not true dipoles however they do create ripples in their gravitational fields)

13. Composite structure of particles and fields (A two neutrino filled Fermi sea results in a buildup of composite particles consistent with observations without a multitude of extra ad hoc particles.)

14. Imbalance of matter and antimatter (The filled Fermi sea and composite particles consisting of particles and holes means that matter and antimatter are balanced.)

15. Steady state versus expanding universe (Without the classical Doppler effect as the primary mechanism for observed redshifts and using instead a distance-dependent shift plus using the Fermi surface as a source of black body like radiation implies a steady state universe.)

16. Black holes (The filled Fermi sea and Pauli exclusion render black holes questionable. Assuming light comes to a screeching halt at the Schwarzschild radius is a problematic.)

17. Einstein's space-time ether versus a material ether (General relativistic effects in the SCE will appear as quadrapolar collective modes on the FS.)

18. Creation of the elements (The SCE does not account for the nucleosynthesis of elements through lithium attributed to the Big Bang. The temperature of the Fermi surface probably can't boil off enough particles heavier than electrons and positrons. Believing that the tail of the thermal distribution can produce enough for stellar nucleosynthesis is unrealistic and requires a naïve trust in analytical statistical distribution 'tails'.)

The SuperConducting Ether with a Fermi sea filled with two neutrinos and with a BCS energy gap lends itself towards resolving old issues. SCE recognizes the quantum nature of everything. SCE recognizes that classical (non-quantum) physics are low frequency long range approximations, not the basic theory. All physics in the universe takes place on the Fermi surface where interactions depend on the density of states and Pauli Exclusion. These concepts have been developed mostly from Pines and Nozierres *Theory of Quantum Liquids: Vol. I, Normal Fermi Liquids* (1966). Problem solving starting at low energies (frequencies) first then working up is inherent to this paper's philosophy and SCE particle-field elementarity. It appears that models depending upon a vacuum ground state will end up with a CP-invariant expanding universe while an ether model will end up with a steady state universe. The death of the ether in the early 20th century was that of a classical medium. It was never resurrected as a quantum medium.

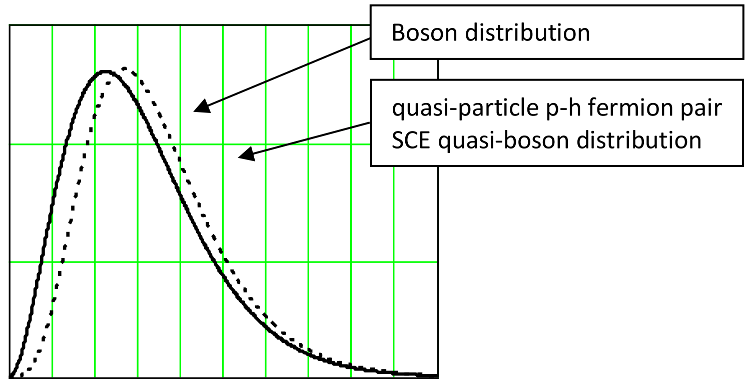

Figure 1. SCE quasi-boson and boson energy distribution at Fermi surface (normalized)

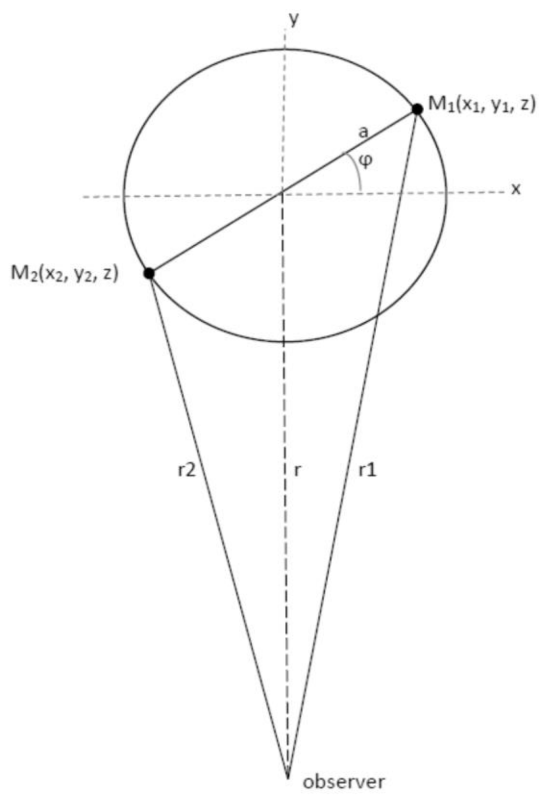

Figure 2. Geometry of Binary Relative to an Observer

Table 1. Leptons		
	N	
ν_e	1	fundamental
e	1	fundamental
ν_μ	3	$\nu_e + \nu_e / \underline{\nu}_e$
μ	5	$e + \nu_e + \underline{\nu}_\mu$
ν_τ	5	$\nu_\mu + \nu_e/\underline{\nu}_e$
τ	7 13	$W_e + \nu_\tau$ $W_\mu + \nu_\tau$

Table 2. Gauge Bosons		
	N	
γ (photon)	2	$\nu_e/\underline{\nu}_e$
$W^\pm$	2	$e/\underline{\nu}_e$ & $\underline{e}/\nu_e$
B (aka Z_0)	2	$e/\underline{e}$

Table 3. Mesons		
	N	
π^0	4	$\gamma + \gamma$
$\pi^\pm$	8	$\mu + \underline{\nu}_\mu$
$K^\pm$	8	$\mu + \underline{\nu}_\mu$
K^0_S	8	$2\ \pi$
K^0_L	12	$3\ \pi$

Table 4. Baryons					
p-channel		**N**	**n-channel**		**Δπ**
e+B+γ	p	5			0
		7	n	$p + W^-$	0
$p + \pi^0$	Σ^+	9			1
		11	Λ^0	$n + \pi^0$	1
$p + \pi^-$	Λ^0	13			1
		13	Σ^0	$n + \pi^0 + \gamma$	1
$p + \pi^- + \gamma$	Σ^0	15			1
		15	Σ^-	$n + \pi^-$	1
		15	Σ^+	$n + \pi^+$	1
		15	Ξ^0	$n + \pi^0 + \pi^0$	2
$p + \pi^- + \pi^0$	Ξ^0	17			2
		19	Ξ^-	$n + \pi^- + \pi^0$	2
$p + \pi^- + \pi^-$	Ξ^-	21			2
		23	Ω^-	$n + \pi^- + 2\cdot\pi^0$	3
$p + \pi^- + \pi^- + \pi^0$	Ω^-	25			3

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