NEUTRINOS AND THE ABSORBER THEORY OF RADIATION

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This is a short report of the application of the absorber theory of radiation to the neutrino field. Before considering the neutrinos it is interesting to look at the case of the electromagnetic fields. This has already been described by Hogarth [1]. His analysis will be given here in a somewhat different form.

In the conventional electrodynamics only the retarded potentials are used to describe the fields of charged particles. As Maxwell's equations are time symmetric, this preference for retarded solutions only appears to be arbitrary. In their absorber theory of radiation Wheeler and Feynman start with the assumption that the intrinsic field of a particle is the time symmetric field $\frac{1}{2}(F_{\text{ret}}+F_{\text{adv}})$ instead of the usual retarded field F_{ret}. The observed retarded field is then explained in the following way. The observed field F_{ret} travels into the future light cone of the particle and sets the particles in the universe (known collectively as the "absorber") into motion. The combined advanced field of the particles in the absorber is then shown to be equal to the field $\frac{1}{2}(F_{\text{ret}}-F_{\text{adv}})$ near the source particle. This field supplies the radiative reaction and when added to the intrinsic field of the particle it gives the total field F_{ret}. Thus the solution is self consistent.

However, owing to the time symmetric nature of the equations the above argument when applied to a static universe, also leads to other consistent solutions. For instance, F_{adv} is also a possible solution. Indeed, any linear combination of the form $AF_{\text{ret}}+BF_{\text{adv}}$ is also a solution, where A, B are constants such that $A+B=1$. This was realized by Wheeler & Feynman and a way out of this difficulty was suggested by them in their original paper [2]. This involved the use of unsymmetrical initial conditions that, on statistical grounds, would favour retarded rather than advanced solutions.

Hogarth has shown that this extra postulate is not in general necessary in a non-static universe. He considers conformally flat expanding universes with line element of the form

$$ds^2 = \exp[2\zeta(t)]\cdot\{-dr^2-r^2(d\theta^2+\sin^2\theta d\varphi^2)+dt^2\}. \quad (1)$$

Suppose fields are Fourier analysed and only a single monochromatic component is considered. Taking the total field of a particle to be of the form

$AF_{\text{ret}}+BF_{\text{adv}}$ we see that AF_{ret} interacts with the future absorber and BF_{adv} with the past absorber. The reactions of these absorbers will be of the form $Af\cdot\frac{1}{2}(F_{\text{ret}}-F_{\text{adv}})$ and $Bp\cdot\frac{1}{2}(F_{\text{adv}}-F_{\text{ret}})$ respectively where f, p are complex numbers. For consistency we require

$$AF_{\text{ret}}+BF_{\text{adv}} = \frac{1}{2}(F_{\text{ret}}+F_{\text{adv}})+(Af-Bp)\cdot\frac{1}{2}(F_{\text{ret}}-F_{\text{adv}}).$$

Equating coefficients on both sides gives the relations

$$A=\frac{1}{2}+\frac{1}{2}(Af-Bp), \qquad B=\frac{1}{2}-\frac{1}{2}(Af-Bp). \quad (2)$$

Except when $f=p=1$, the solution is

$$A=\frac{1-p}{2-f-p}, \qquad B=\frac{1-f}{2-f-p}. \quad (3)$$

When $f=p=1$, there is no unique solution; we only have the one equation $A+B=1$. This is the situation encountered by Wheeler & Feynman for the static universe. In an expanding universe f, p are in general different and a unique solution exists for A, B.

It is illuminating to look at the above picture in terms of particles instead of fields. We then have each source emitting photons into past and future. The interaction with the absorber takes the form of scattering—which in the electromagnetic case is the classical Thomson scattering.

When looked at in this way it is possible to describe the analogue in the case of neutrinos, even though not much is known about them as in the case of photons. All we need to know are the following three properties: (i) the mode of transmission of neutrinos in curved space time; (ii) the scattering properties and (iii) the refractive index owing to the presence of the scatterers. All these properties are known in the case of neutrinos.

It is then possible to work out f, p for neutrinos in the various cosmological models. It is seen that the form of energy dependence of the cross section makes the condition $f=1$, $p\neq 1$ (necessary for purely retarded neutrinos) more difficult to satisfy than in the case of photons. For example, the steady state model, which easily satisfied this condition for photons, only "just" manages to do so for neutrinos. The Einstein-de Sitter model satisfies it in neither case. The details of the calculation may be found elsewhere [3].

REFERENCES

[1] J. E. Hogarth, *Proc. Roy. Soc.* A**267**, 365 (1962).
[2] J. A. Wheeler and R. P. Feynman, *Rev. Mod. Phys.* **17**, 157 (1945).
[3] J. V. Narlikar, *Proc. Roy. Soc.* A (to be published).