MATTER-ANTIMATTER ANNIHILATION AS AN ENERGY SOURCE IN SEYFERT GALAXIES

G. STEIGMAN and P. A. STRITTMATTER
Institute of Theoretical Astronomy, Cambridge, Great Britain

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Abstract. The extreme infrared luminosities of some Seyfert galaxies place severe requirements on the efficiency of the energy source. It is attractive to suggest that matter-antimatter annihilation supplies the necessary energy source; efficiencies of up to $\sim 50\%$ are, in principle, obtainable. However, there is a price to pay for such an explanation: gamma rays and neutrinos.

In a typical nucleon-antinucleon annihilation roughly $\frac{1}{3}\,Mc^2$ is released in electron-positron pairs, $\sim\frac{2}{3}\,Mc^2$ in ~ 3 gamma rays and $\sim Mc^2$ in ~ 3 electron-neutrinos and ~ 6 muon-neutrinos. As a result, if the observed infra-red power is to be derived from the energy in electron-positron pairs, then the flux of gamma rays would be 10^2–10^3 times the upper limits to the gamma ray flux. It is, of course, possible to account for the absence of the gamma rays by insisting that they be absorbed in the source. The neutrinos, however, will not be stopped and hence provide the possibility of testing the annihilation hypothesis.

We have computed the spectrum of neutrinos produced in annihilation. Assuming the product of the space density and infrared luminosity of Seyfert galaxies varies with redshift (z) as: $L(z)\,n(z) = L_0 n_0 (1+z)^m$ we have computed the flux of μ-neutrinos contributed by all Seyfert galaxies out to a given red-shift for $m=3$ and $m=6.5$ (strong evolution). Further, assuming the "3K" and "0.3 mm" background radiation fields to be caused by a burst of "Seyfert type" objects at appropriate redshifts, we have again computed the expected μ-neutrino flux. When these results are compared with present limits on the flux of μ-neutrinos at the Earth, as determined from experiments performed by several groups deep underground, it emerges that the predicted flux is comparable to or greater than present upper limits. Thus, annihilation probably does not supply the infrared sources in Seyfert galaxies with the energy they require.

Discussion of Papers Read by Elvius and Steigman

Kellermann: I think it is unlikely that the observed radio emission can be explained as being from annihilation electrons. In order for 100 MeV electrons to radiate at millimeter wavelengths, magnetic fields of about 1 G are required, whereas the radio data indicate that the fields are about 10^{-4} G. Also, in a 1 G field, the lifetime for millimeter radiation is only about one month, again contrary to the data for most radio sources.

Longair: Evolution laws of the form $(1+z)^\beta$, where $\beta \simeq 6$, are primarily derived from observations of radio sources and refer only to the most powerful classes of radio source. Seyfert galaxies do not belong to the class and they cannot exhibit such powerful effects. This only refers to the radio proper-

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ties, of course, and it is possible that they behave quite differently in the infra-red. Obviously, counts of Seyfert galaxies in the infra-red is the only way of getting a clue about this.

Steigman: If one wishes to explain the background at about 0.3 mm as a burst of Seyfert-type infrared emitters at a redshift $z \simeq 2.5$ whose energy is derived from annihilation then the flux of muon-neutrinos is about three times the present upper limits.

Allen: I suppose that if the gamma-rays produced in the matter-antimatter model are absorbed in the Seyfert galaxy itself, the result must eventually be ionization of the interstellar gas in the galaxy. Is it possible that this disagrees with the apparently normal neutral hydrogen content of the four Seyfert galaxies which I presented this morning?

Steigman: If the gamma rays are stopped then the ionization produced causes trouble. In particular the free-free emission is probably too large and if the absorbing medium is too dense the electrons and positrons will lose their energy to ionization losses rather than synchrotron losses.

Felten: It did not look as if the non-evolutionary case on your graph violated the Reines condition very strongly. Can you make such a firm conclusion in that case?

Steigman: The case $m = 3$ does not provide a strong test of the annihilation hypothesis since the luminosity and/or space density may be in error.

Ozernoy: Very large γ-fluxes produced by annihilation in a matter-antimatter model for quasi-stellar and other compact objects may turn out to be mortal for these models. Indeed, as was shown recently by V. L. Ginzburg and myself (*Astrophys. Space Sci.*, in press), the photo-disintegration of nuclei due to photo-nuclear reactions must lead to significant differences of chemical abundance from normal in emission-line regions of quasars if the gamma-ray output with energy 20–30 MeV is as large as, say, 10^{46} erg s^{-1}. The absence of appreciable distortions in chemical composition of quasars may give useful restrictions on models of the central part of a quasar and, in particular, indicates the effective mixing of a plasma in its nucleus. But in the matter-antimatter model any mixing may lead only to additional annihilation in which about $\frac{1}{3}$ of the energy is released in the form of gamma-rays. Therefore this model seems to be inconsistent with a normal chemical abundance in quasars.