1983ICRC....1...20S

DECAY OF MASSIVE PHOTINOS AND GRAVITINOS AND KeV X-RAY BACKGROUND

C. Sivaram
Indian Institute of Astrophysics
Bangalore 560034
India

Recently many authors (eg.Refs.1) have suggested that decay of massive background neutrinos would result in photons ~10 eV contributing significantly to the ultraviolet background. Again if galactic haloes and clusters are neutrino dominated limits on the ultraviolet luminosity of for instance the coma cluster at 1300 Å enables a limit to be put on the neutrino life-time for decay into photons $t>10^{24}$S., consistent with that calculated from particle physics, for neutrino masses ~20 eV. More recent work on supersymmetry predicts the existence of fermionic counter parts to the photon and gravitinos, the so called photino and gravitino. To remove degeneracy between fermion and boson masses, supersymmetry is expected to be broken giving masses to these particles. Photino and gravitino masses around a few KeV are expected, there being massive spin ½ partners of the gravitino. These particles can decay into photons in the x-ray range of about a KeV with a life-time shorter than the decay of massive neutrinos. It is possible that clusters are bound at least in part by photinos and gravitinos and as all clusters are known x-ray sources estimates are made of the contribution to the background by the decay of these particles. Again there are well known difficulties with the usual diffuse x-ray background models such as requirement of too much hot intergalactic gas conflicting with small Ω from primordial dueterium. These difficulties are partially ameliorated by present hypothesis that a substantial fraction of KeV background is due to decay of these particles.

Introduction

There has been renewed interest of late in the possibility of neutrinos having a non-zero rest mass. The motivation has been both experimental (neutrino oscillations and more meticulous experiments on tritium decay) and theoretical(some models of grand unified theories do give a small neutrino mass). It has been known for some time that massive neutrinos would have interesting astrophysical implications. Thus the cosmological background of neutrinos would add enough matter to close the universe without conflicting nucleosynthetic requirements and can provide the missing matter in galactic clusters and haloes.

Again attempts to incorporate gravity in unified theories have led to supersymmetric versions of these theories. Supersymmetry by putting bosons and fermions in the same multiplet, demands fermionic counterparts to the photon and the graviton, the so called photino and gravitino. Spontaneous supersymmetry breaking can give masses to these particles. Processes in the early universe would have left a background of these particles also and so if they have small rest masses their astrophysical consequences might be significant.

Massive Neutrinos and Ultra-Violet Astronomy

Once we have a cosmological background of massive neutrinos it is well known that they would cluster on mass scales:

$$M_{pl}^3 \Big/ m_\nu{}^2, \quad M_{pl} = \text{Planck mass} = \left(\frac{hc}{G}\right)^{\frac{1}{2}} = 2\text{x}10^{-5}\text{g};$$

which for a neutrino mass $m_\nu = 30$ eV is $\sim 10^{15} M_\odot$, i.e. the scale of large clusters of galaxies. For instance the dynamical mass of the coma cluster is $4\text{x}10^{48}$gm (for Ho = 100 km/s/MPC), so if the neutrinos of average mass ~30 eV, dominate its matter content, then there are ~ 10^{80} neutrinos in the coma cluster. Most unified theories apart from the minimal SU(5) predict a small neutrino mass. Again one can have neutrinos of different masses, and the heavier ones can decay into lighter ones through emission of a photon: $\nu^1 \rightarrow \nu + \gamma$. The reason is that a small rest mass would give rise to a neutrino magnetic moment of order $\sim eG_F h m_\nu/c$, G_F being the universal Fermi constant. The decay rate can then be estimated as $\Gamma = \frac{1}{\tau_\nu}$ = (num. factor) $\propto G_F{}^2 m_\nu{}^5$. This would predict a life time of $\sim 10^{25}$ secs, the photons being in the ultraviolet energy range ~10 eV, i.e. the emitted photon has energy $Eo = M'^2 - M^2/2M'$, in the ν rest frame. $M' >> M, : Eo \simeq M'/2$. Thus if galactic clusters are neutrino dominated, one can use the data on their UV emission in the appropriate wavelengths to put a limit on the neutrino life times. In fact the coma cluster has been observed with the far ultraviolet spectrometer carried on the Apollo 17 mission (Henry, et al, 1978) and the UV luminosity of the cluster at 1300 Å would correspond to the emission of 10^{56} photons/sec. As remarked earlier, since the cluster can be expected to contain 10^{80} neutrinos, this UV luminosity would imply $\tau_\nu > 10^{24}$ secs., quite consistent with the theoretical estimate.

Supersymmetry Breaking Massive Gravitinos and X-rays

The gravitino rest mass is related to the scale F of spontaneous Supersymmetry breaking as: $m_g = (4\pi/3)^{1/2}\ F/m_{pl}$. This would also give mass to the Spin-½ partners of the photon, i.e. photinos and eliminate the goldstino. It has recently been pointed out (Pagels et al, 1982) that the cosmological mass density requires $m_g \sim 1$ KeV. This would give $\sqrt{F} \sim 10^6$GeV. The corresponding Fermi-like coupling constant governing the gravitino decay would be given as $(3\text{x}10^2/10^6)^2 \text{ x } G_F \simeq 10^{-7} G_F$. The mass of the gravitino $\sim 10^3\ m_\nu$. Now the decay rate goes as $G^2 m^5$, so the gravitino life time is $\sim 10^{23}$seconds. The photino mass is also of the same order. These decays will now produce photons in the KeV range, i.e. X-rays. The coma cluster can be estimated to have $\sim 10^{77}$ gravitinos and photinos. When combined with the life time of these particles this would imply a luminosity in KeV X-ray photons $\sim 10^{54}$ photons/sec or an X-ray luminosity of 10^{46} ergs/sec, It is known that most clusters are intense emitters of KeV X-rays. In fact galactic and cluster haloes are more intense emitters of X-ray energy, i.e. larger collimators are observed to give more intensity. There are well known difficulties with the usual models of the X-ray emission.(Field, 1980). The amount of hot intergalactic gas required would be a substantial fraction of the closure density which in turn would conflict with the primordial deuterium abundance consistent with a small fraction 0.1 of the critical density in baryonic form. But as seen above if a significant fraction of the X-rays is from the decay of gravitinos and photinos in the KeV mass range (which as estimated above is $\sim 10^{46}$ergs/sec), one would not require that much of hot intergalactic gas. Alternatively by assuming that most of the X-rays from clusters is from the decay of these particles, one can put an astrophysical constraint on the supersymmetry breaking parameter F.

References

Stecker, F.W., PRL, 45, 1460 (1980)
Henry, R.C. et.al., Ap.J. 223, 437 (1978)
Field, G.B., in Einstein Centennnial Vol., Princeton Univ. (1980)
Pagels, et.al., Phys. Rev. lett. 48, 1303 (1982)