HOT ACCRETION DISKS AND THE HIGH ENERGY BACKGROUND

M. Kafatos
Department of Physics, George Mason University, Fairfax, VA
and Laboratory for Astronomy and Solar Physics, NASA, Goddard
Space Flight Center, Greenbelt, MD, U.S.A.
Jean A. Eilek
Physics Department, New Mexico Tech, Socorro, NM, U.S.A.

1. INTRODUCTION

The origin of the high energy (X-ray and gamma-ray) background may be attributed to discrete sources, which are usually thought to be active galactic nuclei (AGN) (cf.Rothschild et al. 1982, Bignami et al. 1979). At X-rays a lot of information has been obtained with HEAO-1 in the spectral range 2-165 keV. At gamma-rays the background has been estimated from the Apollo 15 and 16 (Trombka et al. 1977) and SAS-2 (Bignami et al. 1979) observations. A summary of some of the observations (Rothschild et al. 1982) is shown in Figure 1. The contribution of AGN to the diffuse high energy background is uncertain at X-rays although it is generally estimated to be in the 20-30% range (Rothschild et al. 1982). At gamma-rays, in the range 1-150 MeV, AGN (specifically Seyfert galaxies) could account for all the emission.

2. HOT ACCRETION DISKS

Accretion disks around massive black holes can be a copious source of X-rays, gamma-rays and relativistic electron-positron pairs (Eilek and Kafatos 1982). The X-ray emission arises from the Comptonization of seed photons by a hot, thermal gas ($T_e \sim 10^9$ K). The hot electron gas is accreting onto a non-rotating or rotating black hole. The relevant parameter is the so-called Comptonization parameter y defined as equal to the product of fractional energy change of the photons per scattering and the mean number of scatterings or

$$y = 4kT_e/m_ec^2 \cdot \max(\tau_{es}, \tau_{es}^2) \qquad (1)$$

(cf. Shapiro, Lightman and Eardley 1976). A large amplification of the incoming soft flux occurs when $y \simeq 1$ (unsaturated process) and Shapiro, Lightman and Eardley (1976) show that the condition $y \simeq 1$ is a relatively stable condition. The spectral index of the energy flux (keV/cm^2 sec keV) is related to y through the approximate relation $y \sim 4/(3\Gamma+\Gamma^2)$ and, therefore, $\Gamma \sim 1$ when $y \sim 1$.

Rotating (Kerr) black holes are important for the production of gamma-

G. O. Abell and G. Chincarini (eds.), Early Evolution of the Universe and Its Present Structure, 345–346.

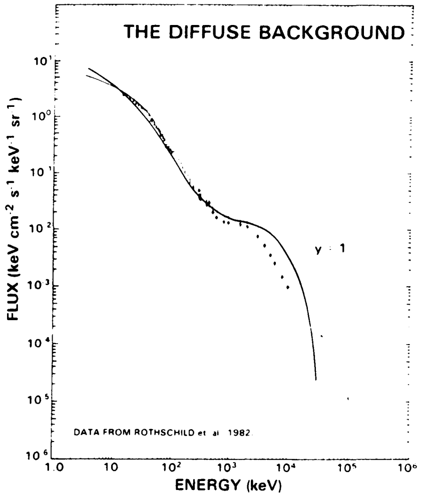

Figure 1. The high energy background and a hot accretion disk fit with y = 1

rays and relativistic electron-positron pairs. The ion temperature T_i is much larger than T_e. We find that in order for the hot, inner region to exist one needs a luminosity of the disk at least a few percent of the Eddington luminosity or $\dot{M}_*/M_8 \gtrsim 0.03\ M_8^{-1/32}\ (\alpha/0.1)^{-17/32}$, where α is the usual viscosity parameter estimated to be in the range 0.01-1 (Shapiro, Lightman and Eardley 1976), $\dot{M}_*$ is the accretion rate in $M_\odot$/yr and M_8 is the mass of the black hole in $10^8\ M_\odot$. We find that for $\alpha \sim 0.1$ the disk is thick. The ion temperature is assured then to be greater than 10^{12} K without any other requirement. Models that are near the Eddington limit produce 10-20% of the bolometric luminosity in gamma-rays of energy greater than 1 MeV, and a similar energy in the form of 50-100 MeV e^+e^- pairs. Figure 1 shows a particular fit for $\dot{M}_*/M_8 = 1$, $\alpha = .1$, y = 1 and a Kerr metric. The general agreement is striking. Other good fits are obtained for y in the approximate range 1-3 as long as the accretion rate remains within a factor of a couple near the Eddington limit. The need to evoke different mechanisms or sources to explain both the X-ray and gamma-ray backgrounds is not present. The gamma-rays and pairs arise from pions produced due to the high ion temperatures. Due to the high $\gamma\gamma \to e^+e^-$ opacity gamma-rays of energy higher than ~ 3-10 MeV do not escape from the disk, in agreement with both the background and gamma-ray spectra of AGN (Bignami et al. 1979). We obtain about 3×10^{-4} sources/Mpc^3 with an average mass of the central object of about $5\times10^4\ M_\odot$, producing on the average 10^{42} erg/sec in the 2-10 keV range. In these models $y \gtrsim 1$.

REFERENCES

Bignami, G.F., Fichtel, C.E., Hartman, R.C., and Thompson, D.J.: 1979, Ap.J. 232, pp. 649-658.
Eilek, J.A., and Kafatos, M.: 1982, Ap.J., submitted.
Rothschild, R.E., Mushotzky, R.F., Baity, W.A., Gruber, D.E., and Matteson, J.L.: 1982, Ap.J., submitted.
Shapiro, S.L., Lightman, A.P., and Eardley, D.M.: 1976, Ap.J. 204, p.187.
Trombka, J.I., et al.: 1977, Ap.J. 212, p.925.

https://doi.org/10.1017/S0074180900039292 Published online by Cambridge University Press