HIGH COLLIMATION OF ELECTRON-POSITRON PAIR JETS PROCEEDING TO RADIO JETS

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1. Introduction

The one of the possibilities concerning the cause of AGN jets is the super-Eddington luminocity around the Massive Black Hole. If the case of optically thick state is assumed, we can define the super-Eddington temperature in the optically thick case, from the following condition that

$\partial p_{rad}/\partial r > GM/r^2$ which reduces to $T > 3.5\times10^8\left(r_*\partial \ln T/\partial \ln r_*\right)^{1/4}$, where $r_* = 2c^2r/GM$. The creation of electron- positron pairs and the pahse change are expected to occur in the such temperature rage around 10^9K, where the radiation pressure is dominant in the lower temperature and the pair pressure be in the higher one.

2. Genral Relativistic Hydrodynamic Equations

In this concerned situation, the genral relativistic equations must be employed. Otherwise, the flow could not satisfy the equivalence principle, because the gases composed of photons and pairs. Here, the relativistic hydrodynamical equations are considered including pairs and photons in the optically thick state. The particular relativistic effect is the addtion of the compression term to the momentum equations, represented by $\boldsymbol{w}(U^\nu\partial_\nu)\ln n_0$, where n_0 is the nuclei number density, U^ν the four velocity satisfying $U_\nu U^\nu = -1$. And $\boldsymbol{w}$ is the factor of relativistic efficiency, given by

$$\boldsymbol{w} = -1+\{w[(2x+H)^{-1}(2x-x^{-1}H')+\zeta_T]+12p_{rad}\}/[e(H'+\zeta_T)+12p_{rad}],$$

where e and w are the internal and enthalpy of pairs per volume, p_{rad} the radiation pressure, $x = kT/m_ec^2 = T/5.93\times10^9K$. $H = \theta[K_4(\theta) -$

Y. Sofue (ed.), The Central Regions of the Galaxy and Galaxies, 471-472.

$K_0(\theta)]/4K_2(\theta)$ and $H' \equiv \mathrm{d}\ln H/\mathrm{d}\ln x$, where $\theta = x^{-1}$. K_n is the n-th modified Bessel function. ζ_T is the differential coefficient of the positron fraction z to the nucleous number density n_0 , defined by $(\partial \ln z/\partial \ln T)_{n_0} = 1+\theta\{1+\theta[K_3(\theta)+K_1(\theta)]/2K_2(\theta)\}$.

Now, the hydrodynamical feature is represented by the characteristic conoid , given by

$$[\mathrm{d}x_{||}-\boldsymbol{a}(1-\frac{1}{2}\boldsymbol{w})V\mathrm{d}x^0\,]^2+[\boldsymbol{a}^2+\frac{1}{4}\boldsymbol{w}^2V^2\,](\mathrm{d}x_{\perp})^2=(\boldsymbol{a}^2+\frac{1}{4}\boldsymbol{w}^2V^2\,;)(\mathrm{d}x^0)^2$$

where $\mathrm{d}x_{||}$ and $\mathrm{d}x_{\perp}$ are the transformed coordinates parallel to the stream line at the concerned position. $V = (U_1U^1+U_2U^2)^{1/2}$. $\boldsymbol{a}$ is the sound velocity given by $\boldsymbol{a} = \{[2n_0z(1+\zeta_T)+4p_{rad}]/[e(H'+\zeta_T)+12p_{rad}]\}^{1/2}$.

The relativistic facter $\boldsymbol{w}$ deforms the circular cross section of the conoid in the classical case of $\boldsymbol{w} = 0$, to the elliptical one elongated to the direction of the stream line.

Then,the magnitude of $\boldsymbol{w}$ and $\boldsymbol{a}$ are almost similar between in the photon state and in the pair state, that is, $\boldsymbol{w} \sim 0.33$ and $\boldsymbol{a} \sim 0.577$, although these factors decrease 30% in the middle of the phase change.

3. The Characteristics of the Relativistic Gases

The other one of the characteristic features of the relativistic gases is the resistive effect to the enegy-momentum equations through the coupling between the velocity shear and the thermal conductivity. Furthermore, the resistive terms include the time variations of velocity and temperature. Therefore, it is expected that the thermodynamical behavior of the accretion flow of relativistic gases must differ from the nonrelativistic case, although the grand behavior may not differ from the advection model of the similarity teratment by Narayan and Yi (1994).

If the accretion flow with the super-Eddington temperature turns to the outward motion overcoming the swallaw of the black hole, the ejected pair gase will suffer from the annihilation of pairs, which produces the gamma-ray beam. This radiation acts on the genuine normal gase as the Compton rocket, called by O'Dell (1981). However, the annhilation process should be required in elaborate consideration done by Brandford and Levinson (1995). The annihilation of pairs will cool the jet strongly to make it slender (cf. Kondo 1995).

References

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