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POYNTING VECTOR OF ONE-WAY NULL ELECTROMAGNETIC FIELD IN THE KERR SPACE-TIME

Volodymyr Pelykh, Yurii Taistra

Pidstryhach Institute for Applied Problems in Mechanics and Mathematics

vpelykh@gmail.com

We consider a one-way null solution with separated variables of the Maxwell equations in the Kerr space-time [1]

$$\varphi_{2m}(t,r,\theta,\phi,\omega) = \frac{C_m(\omega)}{\sin\theta(r - ia\cos\theta)} e^{i\omega\eta_1 + im\eta_2} e^{-a\omega\cos\theta} \frac{(1-\cos\theta)^m}{\sin^m\theta}. \quad (1)$$

$$\eta_1 = t - r - M\ln\Delta - \frac{M^2}{\sqrt{M^2 - a^2}} \ln\left(\frac{r - r_+}{r - r_-}\right),$$

$$\phi - \frac{a}{2\sqrt{M^2 - a^2}} \ln\left(\frac{r - r_+}{r - r_-}\right),$$

$C_m(\omega)$ is complex constant, $\omega \in \mathbb{R}$ is wave frequency, $m \in \mathbb{Z}$ is azimuthal number, M is a black hole mass ($M > 0$), a its specific angular momentum ($0 < a < M$), $\Sigma = r^2 + a^2\cos^2\theta$, $\Delta = r^2 - 2Mr + a^2$, $r_+ = M + \sqrt{M^2 - a^2}$ and $r_- = M - \sqrt{M^2 - a^2}$ event horizon and Cauchy horizon respectively.

The Poynting vector $\mathbf{S}$ of such electromagnetic field is computed in Kinnersley orthonormal frame

$$\mathbf{S} = -\frac{c}{4\pi} \left(\frac{|C_m(\omega)|^2 e^{-2a\omega\cos\theta}}{\Sigma\sin^2\theta} \left(\frac{1-\cos\theta}{\sin\theta}\right)^{2m} \right) \mathbf{i}. \quad (2)$$

The angular momentum of the black hole affects the energy flow of electromagnetic waves, which can be seen from the factor $e^{-2a\omega\cos\theta}$. In the northern hemisphere ($\cos\theta > 0$) the rotating black hole reduces the energy flow of the right circularly polarized wave ($\omega > 0$) and amplifies the left circularly polarized wave ($\omega < 0$) energy flow. In the southern hemisphere ($\cos\theta < 0$) — on the contrary.

1. *Pelykh V.O., Taistra Y.V.* Solution with separable variables for null one-way Maxwell field in Kerr space-time // Acta Physica Polonica B. – 2017. – **10**, №2. – P. 387–390.

http://iapmm.lviv.ua/mpmm2023/materials/ma09_30.pdf