GENERAL RELATIVISTIC COLLAPSE OF AN AXIALLY SYMMETRIC STAR LEADING TO THE FORMATION OF NEUTRON STARS AND BLACK HOLES

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Using the [(2+1)+1]-dimensional representation of the Einstein equations, we have computed the general relativistic collapse of a rotating star. We adopt the cylindrical coordinate. The system is assumed to be axially and plane symmetric. The number of meshes is 28×28 in R and Z direction. The equation of state is $P=1/3\rho\varepsilon$ for $\rho<\rho^*\equiv 3\times 10^{14}$ g/cm^3 and $P=(\rho-\rho^*)\varepsilon+1/3\rho^*\varepsilon$ for $\rho\geqq\rho^*$. We use the following initial conditions; $\rho\propto\exp(-(R^2+Z^2)/\lambda)$, $\Omega\propto\exp(-R^2/\lambda)$ where Ω and λ are angular velocity and a size parameter, respectively. We have calculated three models;
(1) Model 1 $M=10M_\odot$, $\rho_c=3\times10^{13}$g/cm^3, $\alpha=0.20$, $\beta=0.05$.
(2) Model 2 $M=10M_\odot$, $\rho_c=3\times10^{13}$g/cm^3, $\alpha=0.20$, $\beta=0.12$.
(3) Model 3 $M=10M_\odot$, $\rho_c=3\times10^{13}$g/cm^3, $\alpha=0.20$, $\beta=0.22$.
where $\alpha=E_{int}/|E_{grav}|$ and $\beta=E_{rot}/|E_{grav}|$. In all models, an apparent horizon was formed, that is, a black hole was formed. In Model 1, the final density distribution is oblate shape. In Model 2, there is a ringlike peak of the proper mass density distribution at the final stage. In Model 3, the determinant of the metric tensor goes to nearly zero at the ring in the equatorial plane, so that the proper mass density shows strong ringlike peak which is inside the apparent horizon. As the curvature invariant made from the Riemann tensor becomes very large at this ring, this may be a ring singularity of the space-time. These rotating black holes look like the Kerr black hole.

DISCUSSION

Gaffet: In the case of a black hole emerging from a pure gravitational wave, I would like to make the comment that, of course, the total mass has to be introduced as an initial condition, even though in this case there is no matter at all.

Nakamura: Even though there is no matter, the gravitational field does exist and it contains the energy. The total mass is determined by the asymptotic form of the metric tensor at large distance. So we don't have to introduce the total mass as an initial condition.

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