Nucleosynthesis in Jets from Rotating Magnetized Stars during Core Collapse

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During collapse of a star more massive than 35-40$M_\odot$, the stellar core is likely to promptly collapse to a black hole. When the star has sufficiently high angular momentum before the collapse, an accretion disk with extremely high accretion rates greater than $0.1 M_\odot\,\mathrm{s}^{-1}$, is formed around the hole and jets are shown to be launched from the inner region of the disk through magnetic processes [1, 2] and neutrino heating. Gamma-ray bursts (GRBs) are expected to be driven by the jets. This scenario of GRBs is referred to as the collapsar model [3] and such the rotating star collapsing to a black hole as a collapsar. Assisted by the accumulating observations that imply an association between GRBs and the deaths of massive stars this model seems to be most promising. An innermost region of the disk related to GRB is dense and hot enough to become neutron-rich through electron capture on protons [4, 5]. Nucleosynthesis inside the jets from the neutron-enriched disk has been investigated with steady, one-dimensional models of the disk and the jets [5, 6]. It has been shown that not only neutron-rich nuclei [5] but also *p*-nuclei [6, 7] are likely to produce inside the jets.

In the present work, we perform more elaborate calculation of the nucleosynthesis [8, 9] in jets from collapsars, based on two-dimensional magnetohydrodynamic simulation of the collapsars [2]. We follow the evolution of the abundances of about 4000 nuclides from the collapse phase to the ejection phase using a large nuclear reaction network. We find that the *r*-process successfully operates only in the energetic jets ($> 10^{51}$ erg), so that U and Th are synthesized abundantly, even when the collapsars have a relatively small magnetic field (10^{10} G) and a moderately rotating core before the collapse. The abundance patterns inside the jets are similar to that of the *r*-elements in the solar system. The higher energy jets have larger amounts of ^{56}Ni. Less energetic jets, which have small amounts of ^{56}Ni, could induce GRB without supernova, such as GRB060505 and GRB060614. Considerable amounts of *r*-elements is likely to be ejected from GRB with hypernova, if both the GRB and hypernova are induced via jets that are driven near the black hole.

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