R-Process in Neutron Star Merger with a New Fission Model

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Magnetorotational Supernova

Underproduction PROBLEM!

Possible Solutions
- Nuclear mass model
- Neutron Star Merger ← NEW!

Nishimura et al. (2006)

Winteler et al. (2012)

Figure 1. 3D entropy contours spanning the coordinates planes with magnetic field lines (white lines) of the MHD-CCSN simulation \( \sim 31 \) ms after bounce. The 3D domain size is \( 700 \times 700 \times 1400 \) km.
r-process Nucleosynthesis

**rapid neutron-capture process**

Condition for the r-process

\[ \tau(n,\gamma) << \tau_\beta \]

- **β⁻ decay**
- **n-capture**

Proton Number $Z$

Neutron Number $N$

- **Fission Region**
- **Magnetorotational Supernova**
- **Neutron Star Merger**

Fission

N=184

N=126

N=82
Important Input Data for Fission and Network Code

Sensitive to Fission!

Nuclear mass model:
Fission Barrier & $Q_\beta$, $(n,\gamma)$
KTUY model
  Koura et al. (2005)

Reaction rates:
$\alpha$ decay, $\beta$ decay, fission
  Koura et al. (2004)
  Chiba et al. (2008)
Fission Fragment Mass Distribution

$^{236}\text{U}$ Theory vs. Exp.

Yield of fission fragment

Fission fragment A

Mass number $A$

Yield of fission fragment

$Z=99, A=279$  
$Z=101, A=288$  
$Z=102, A=291$  
$Z=104, A=303$  
$Z=107, A=312$  
$Z=113, A=325$

Ohta et al. (2007)

Chiba et al. (2008)
Fluid-Dynamical Data in Our Network Code for r-process Nucleosynthesis

Neutron Star Merger
Korobkin et al. (2012), Piran et al. (2013), Rosswog et al. (2013)
• SPH simulation
• Newtonian gravity
• Neutrino Leakage scheme

Ye \sim 0.03
Extremely Neutron-rich!
Abundance Evolution of Neutron Star Merger

Later

Earliest time

Fission Region

2.62E+00

Z

N

Fission>0%

A=290

A parent >290

A parent <290

Yield of Fission Fragment

Mass number

Mass number A

Fission

Parent

Daughter
Elemental Abundances of Neutron Star Merger

Solar r-process element

Neutron Star Merger
Summary

• We calculated r-process nucleosynthesis for the neutron star merger with new theoretical fission data.

• In the neutron star merger, the flat abundance pattern with 100<A<160 are produced by superposition of various fission fragment distributions.

• Contribution from Both neutron star mergers and magnetorotational supernovae can reproduce the abundance pattern of solar r-process elements.