The First Supernovae and the Origins of Metal-poor Stars

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ASIAA Folks at this meeting. (contributing 2 talks+ 2 posters)
Time Machine
Cosmic Dawn

Talks by Takashi, Shingo, Anna
Where were the metals from?
Core-collapse Supernovae Explosions

Courtesy of Jason Nordhaus
Low-energy CCSNe (explosion energy = 0.2 - 0.5 \times 10^{51})

Chen + MNRAS (2017)
The First Mixing of Metals

The diagram shows the log of element abundance versus atomic number. Different markers and lines represent various models and observations, including J031300, Z12 (2D), Z12 (1D), Z60 (2D), and Z60 (1D). The graph highlights the mixing of metals in different stellar environments.
Stellar Feedback of Pop III Stars
Inputs to Cosmological Simulations

Radiation

Supernovae

Table 10.1 Stellar lifetimes and fates

<table>
<thead>
<tr>
<th>Mass (M_☉)</th>
<th>MS (Myr)</th>
<th>post-MS (Myr)</th>
<th>total (Myr)</th>
<th>fates</th>
<th>metals (SN/HN) (M_☉)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>9.478</td>
<td>1.031</td>
<td>10.51</td>
<td>SN</td>
<td>1.388</td>
</tr>
<tr>
<td>30</td>
<td>5.208</td>
<td>0.509</td>
<td>5.77</td>
<td>BH, HN</td>
<td>6.876</td>
</tr>
<tr>
<td>45</td>
<td>3.995</td>
<td>0.394</td>
<td>4.39</td>
<td>BH, HN</td>
<td>13.26</td>
</tr>
<tr>
<td>60</td>
<td>3.426</td>
<td>0.345</td>
<td>3.77</td>
<td>BH, HN</td>
<td>20.66</td>
</tr>
</tbody>
</table>

Table 10.2 Summary of assumed stellar fate characteristics: 

<table>
<thead>
<tr>
<th>X^a</th>
<th>Type</th>
<th>Masses (M_☉)</th>
<th>E^a (B)</th>
<th>mass ejection</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>SN</td>
<td>≤ 25</td>
<td>1.2</td>
<td>all but ∼ 1.5 M_☉</td>
<td>leaves neutron star</td>
</tr>
<tr>
<td>B</td>
<td>BH</td>
<td>≥ 25</td>
<td>0</td>
<td>None</td>
<td>complete collapse to BH</td>
</tr>
<tr>
<td>H</td>
<td>HN</td>
<td>≤ 25</td>
<td>10</td>
<td>∼ 90%</td>
<td>big explosion, leaves black hole</td>
</tr>
</tbody>
</table>

Paving the highway for chemical enrichment

Stellar Feedback of Pop III Binaries
Inputs to Cosmological Simulations

<table>
<thead>
<tr>
<th>Binary</th>
<th>HI  $10^{63}$</th>
<th>HeI $10^{63}$</th>
<th>HeII $10^{61}$</th>
<th>$t^\alpha$ (Myr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S30+S30</td>
<td>3.64</td>
<td>1.44</td>
<td>2.74</td>
<td>5.77</td>
</tr>
<tr>
<td>S45+S15</td>
<td>3.62</td>
<td>1.61</td>
<td>4.43</td>
<td>10.51</td>
</tr>
<tr>
<td>S60</td>
<td>4.18</td>
<td>2.21</td>
<td>8.31</td>
<td>3.77</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case</th>
<th>Masses</th>
<th>Separation</th>
<th>Fate</th>
<th>Fate</th>
<th>Metals (SN/HN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>30+30</td>
<td>wide</td>
<td>HN</td>
<td>HN</td>
<td>13.74</td>
</tr>
<tr>
<td>II</td>
<td>30+30</td>
<td>wide</td>
<td>BH</td>
<td>BH</td>
<td>0.00</td>
</tr>
<tr>
<td>III</td>
<td>45+15</td>
<td>close</td>
<td>BH</td>
<td>..</td>
<td>0.00</td>
</tr>
<tr>
<td>III</td>
<td>45+15</td>
<td>close</td>
<td>HN</td>
<td>..</td>
<td>13.26</td>
</tr>
<tr>
<td>IV</td>
<td>60</td>
<td>..</td>
<td>HN</td>
<td>..</td>
<td>20.66</td>
</tr>
</tbody>
</table>

Poster by Sung-Han Tsai
Radiative+Supernova Feedback

Chemical Enrichment in Cosmological Simulations

Chen+ 2015
External Enrichment Channel

Talks by Britton, Gen, & Mattis
Chemical Enrichment in the Universe?

Cosmologist’s Midas Touch
Resolving the small scales to understand mixing
Multi-code Simulation Approaches

1D Kepler/ZEUS+ 2D ZEUS+ 2D/3D CASTRO

UV Radiation

Supernovae Ejecta
SN enrichment in the realistic setup

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Ken Chen@ITA
How deep can the metal go??


It requires very massive stars to do external enrichment
Self-enrichment Channel

minihalo

forming star

photo evaporating

SN explosion

fallback and mixing

Chia-Jung Hsu

Chalmers University of Technology
Mixing of the First Supernovae Metal

- ZEUS-MP and FLASH
- Supernova in a photo-evaporated halo
- 15 solar-mass star with $10^{51}$ erg energy
- $10^6$ solar-mass halo

See Chia-Jung’s Poster
JWST may have a chance to check these scenarios
First light is expected in 2021?
Many thanks for your attention

My work has been kindly supported by: