Type Ia Supernova Models and Galactic Chemical Evolution

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White Dwarf Formation

Source: [1]
White Dwarf Formation

Main Sequence
• 90% of lifetime
• H fusion
  • PP-chain, CNO Cycle
• WD Progenitors: M < 8Msun

Source: [1]
White Dwarf Formation

Subgiant Branch

• Gravitational potential energy released – core contraction
  • Outer envelope expands
• Cooler temperatures
  • Redshift on Blackbody spectrum
• Expands to Red Giant

Source: [1]
White Dwarf Formation

Helium Flash
• Burst of He fusion
• Increased core T and Teff
• Horizontal Branch
  • Ends when He fusion ends

Source: [1]
White Dwarf Formation

Asymptotic Giant Branch

- H, He fusion shells
  - Continue to supply CO core
- Increased core T

Source: [1]
White Dwarf Formation

Planetary Nebula
• Superwind
• Visible surface moves towards core
• Thin He, H photosphere

Source: [1]
White Dwarf Formation

White Dwarf

• Cools at constant radius
  • $L \propto T^4$
    • Luminosity Decreases

Source: [1]
Electron Degeneracy Pressure

Degeneracy

• Free electron arrangement
• Limited by Pauli Exclusion Principle
• WD: $kT \ll \varepsilon_f$ approximation

Source: [1]
Type Ia Supernovae

General Features

• Carbon Fusion
  • Triggered by high density, not temperature
  • Fusion not controlled by pressure
    • Thermonuclear runaway

• Distinct Spectra
  • No H
  • Strong Si, Intermediate element absorption
  • Fe-peak elements
Type Ia Supernovae – Two Models

Single Degenerate
• Binary system
  • Accretes matter from companion
  • Erupts in a deflagration (flame) front

Double Degenerate
• White dwarf merger
  • Erupts as detonation
Type Ia Supernovae – Two Models

• Chandra: Mass exceeds $M_{\text{ch}}$, triggering fusion (W7)
  • Core densities $> 10^9$ g/cm$^3$

• Sub-Chandra: (WDD2)
  • Core densities $\leq 10^8$ g/cm$^3$
Supernovae Nucleosynthesis

• Produces elements heavier than iron-56

• Combination of nuclei
  • Creating unstable large nucleus – decay
Galactic Chemical Evolution (GCE)

- Goal: accurately predict chemical abundances for given time, location
  - Calculates elemental abundances

- Limited accuracy, models always improve as field grows
Procedure

• Use of GCE code by Woosley, Weaver (1995)
  • Choice of supernova type
    • Chandra (W7), sub-Chandra (WDD2) models studied

• Nuclear abundances calculated for “radial zones” of galactic disk
  • Added together for total abundance for a given isotope at time t

\[
\frac{d\sigma_i}{dt} = \text{stellar death} - \text{stellar birth} + \text{infall} + \text{decay}
\]

where i = surf. Mass density of isotope i in radial zone
Procedure

• Data collected for Ca, Sc, Ti, V, Cr, and Mn

\[
\left[ \frac{x}{Fe} \right] = \log \left( \frac{x/Fe}{x_{sol}/Fe_{sol}} \right) = \log \left( \frac{x}{Fe} \right) - \log \left( \frac{x_{sol}}{Fe_{sol}} \right)
\]
Results

Experimental Nuclear Abundance Line Comparison

• With filtered data - even numbered figures starting on page 13

• Trends
  • Agreement towards $t_o$
  • Spread towards $t_f$
    • Vanadium

• At $t_f$ (WDD2), WDD2 > W7

Figure 10: Vanadium
Results

Mapping onto Observed SAGA Data

• Odd numbered figures starting on page 13

• Shows potential agreement, filtered data disputes

• No fitting analysis

Figure 11: Calcium with Observed Data
Conclusion

• Trends in Lines from GCE Code
  • Agreement towards $t_o$
  • Spread towards $t_f$
  • At $t_{f(WDD2)}$, WDD2 > W7

• Further data analysis (future studies) needed to determine best fit model
References


