Type Ia Supernova Models and Galactic Chemical Evolution

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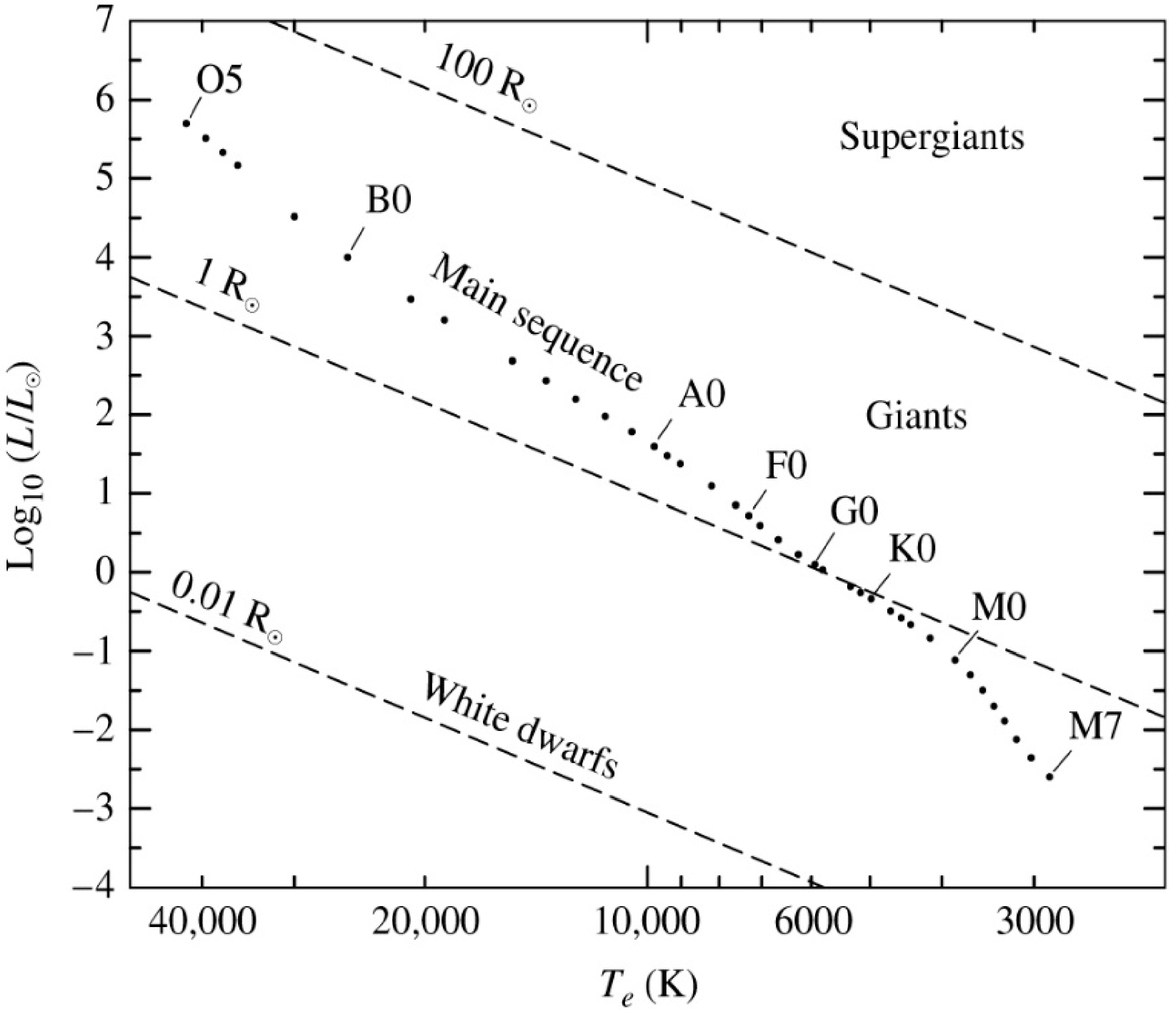
White Dwarf Formation

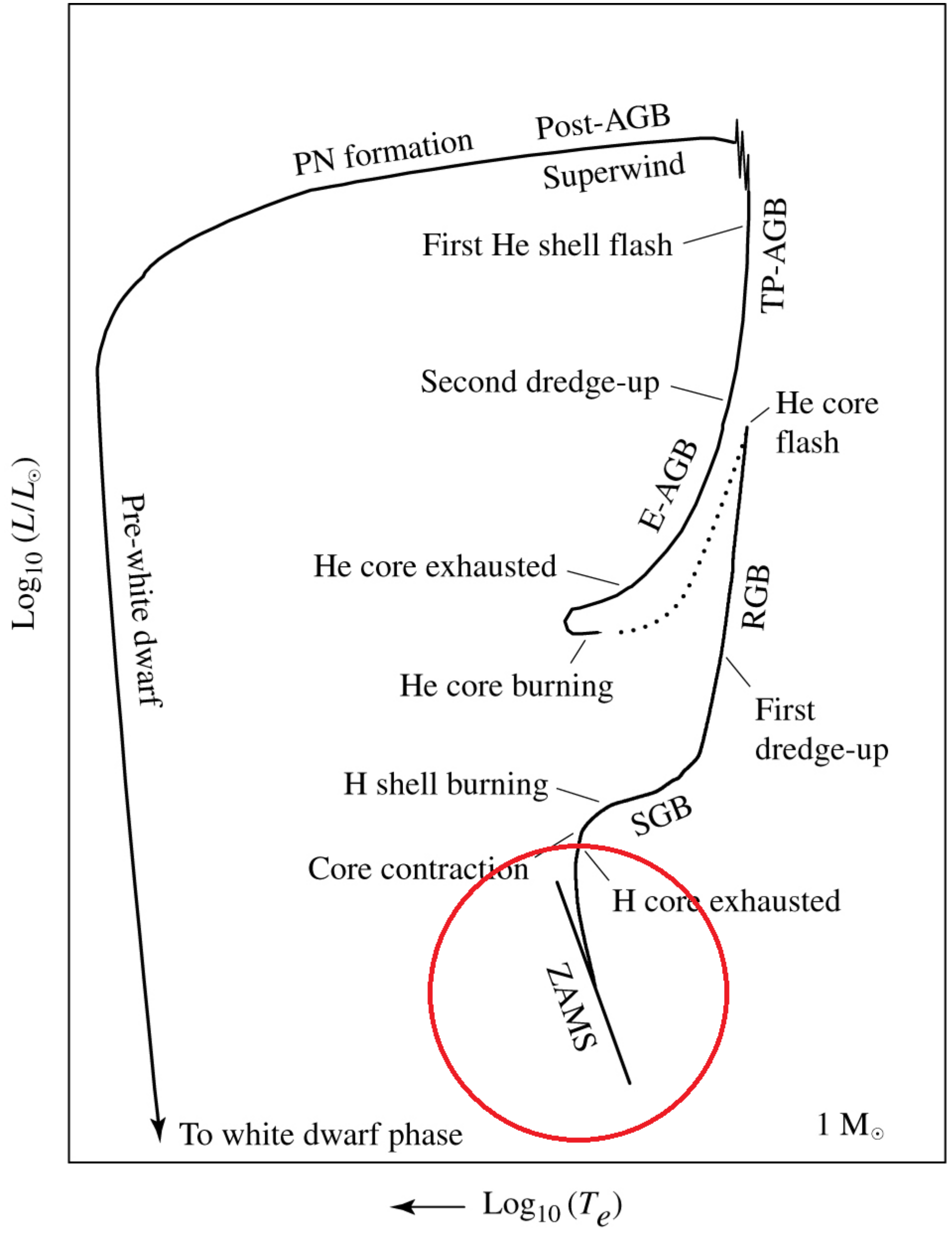


Source: [1]

White Dwarf Formation

<u>Main Sequence</u>

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

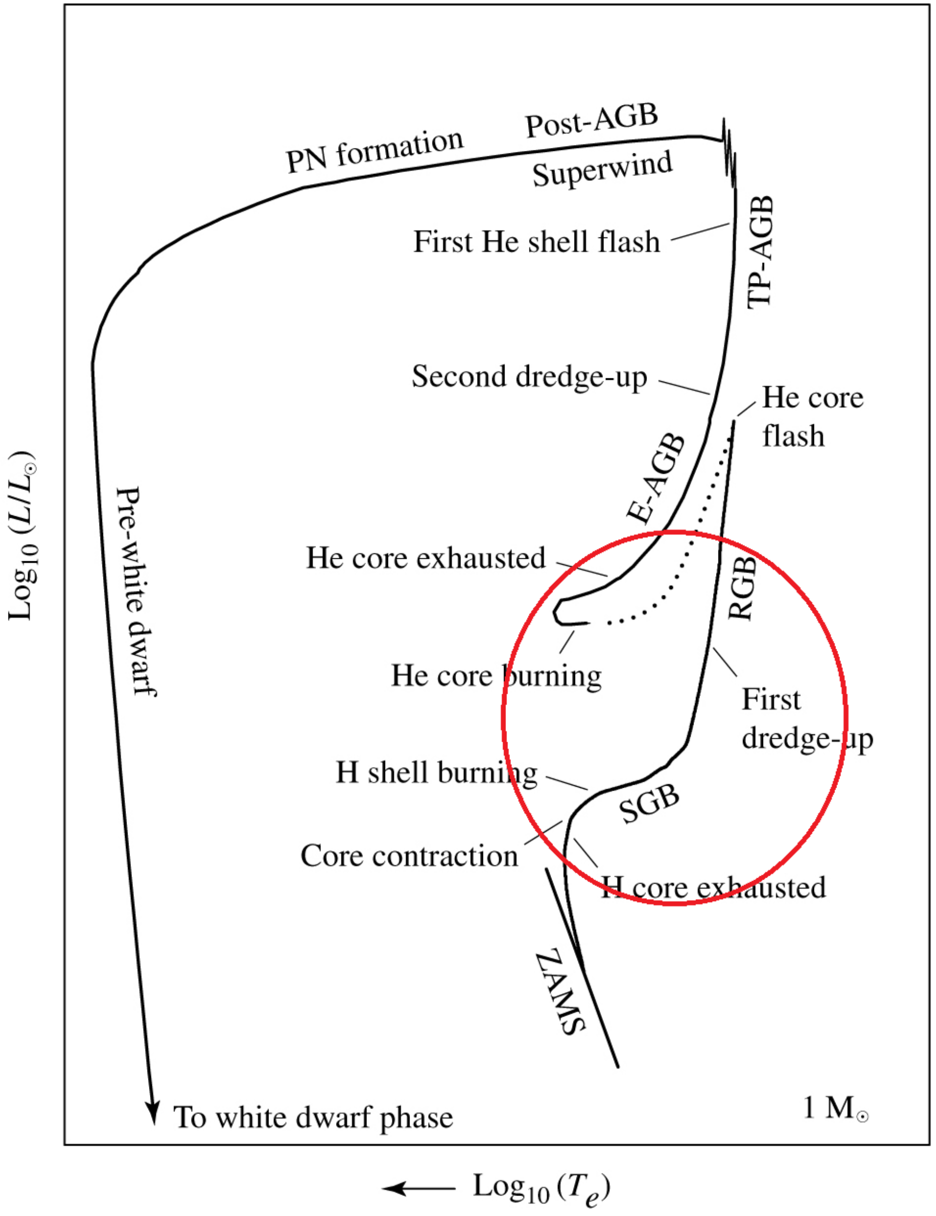


Source: [1]

White Dwarf Formation

<u>Subgiant Branch</u>

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

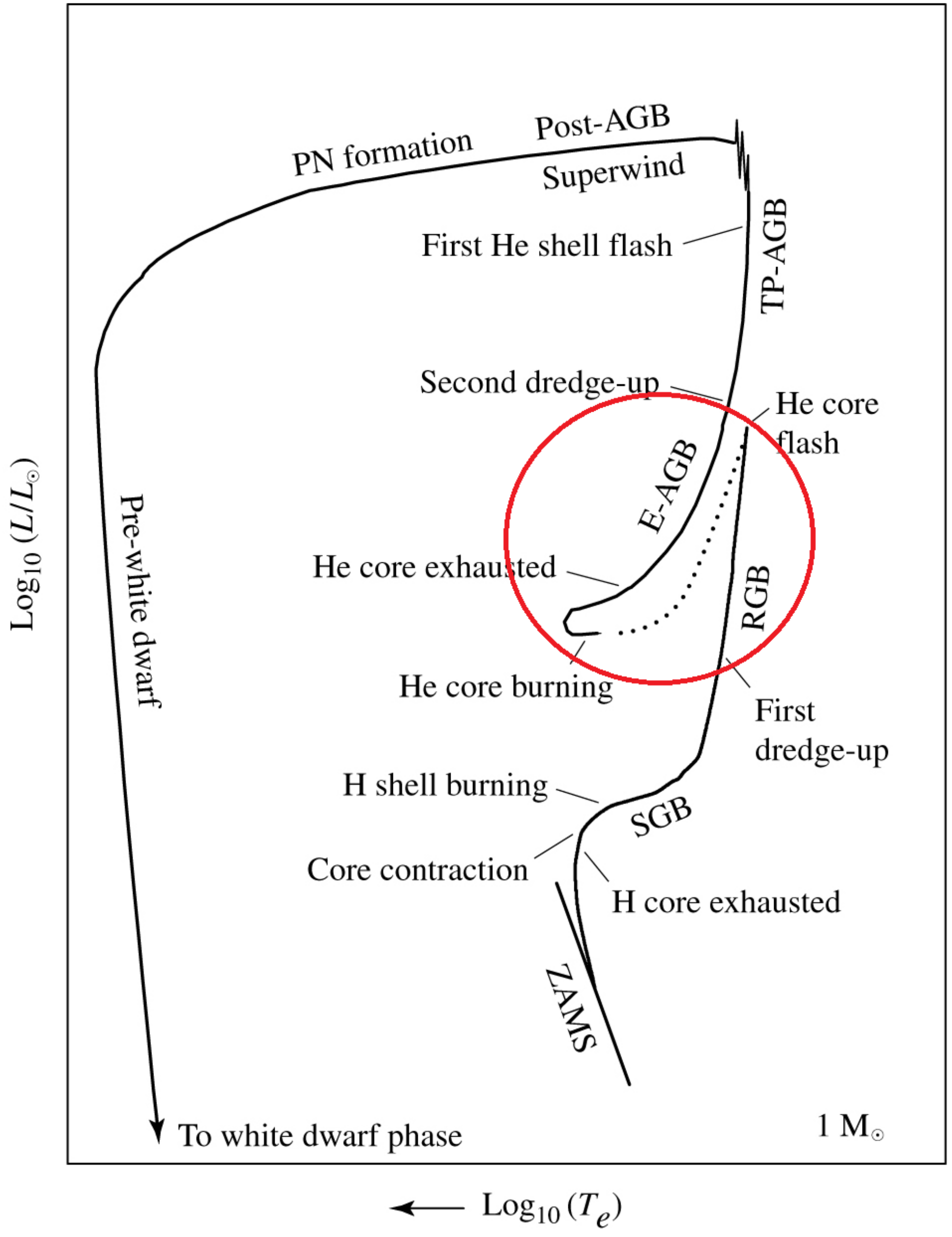


Source: [1]

White Dwarf Formation

<u>Helium Flash</u>

- Burst of He fusion
- Increased core T and Teff
- Horizontal Branch
  - Ends when He fusion ends

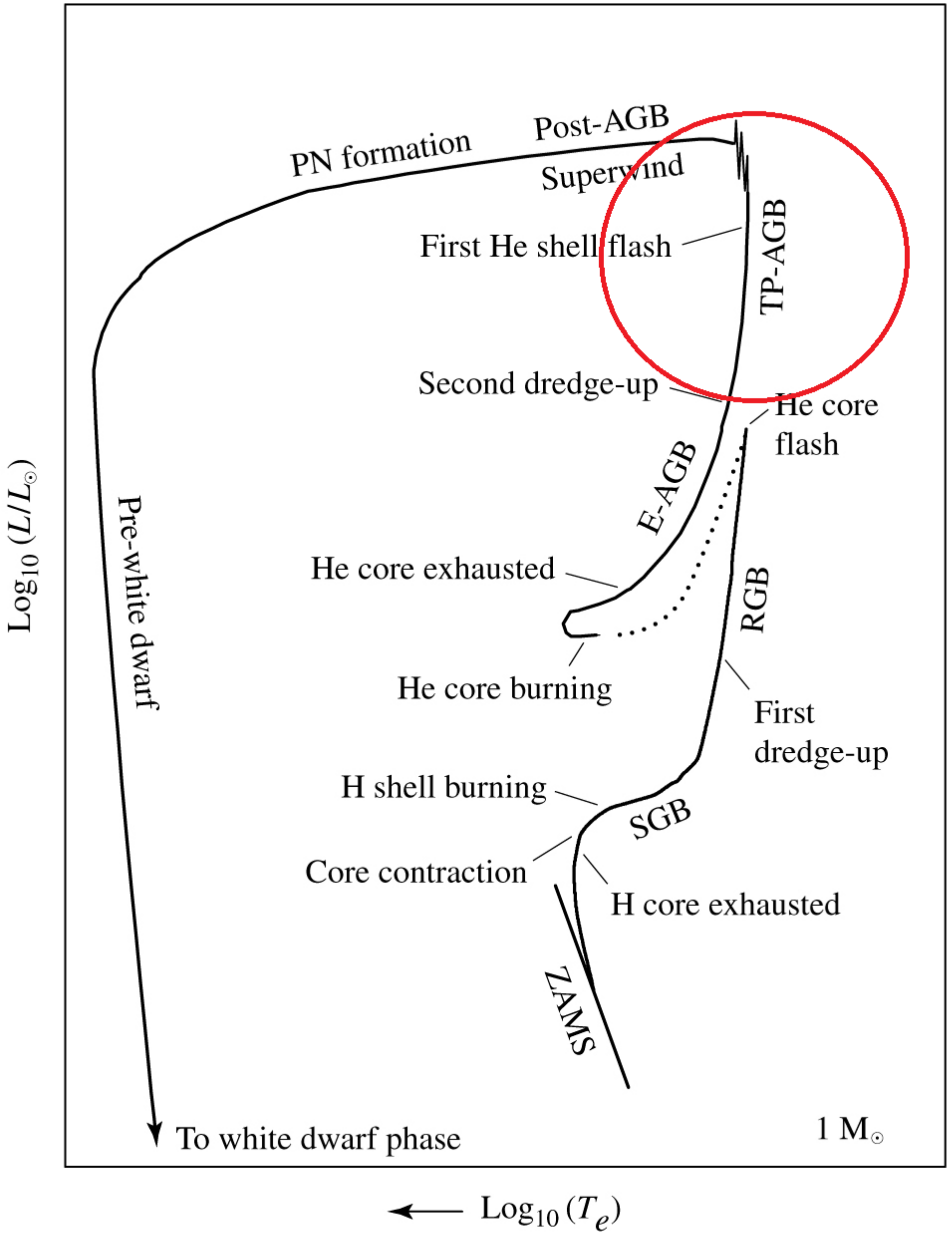


Source: [1]

White Dwarf Formation

Asymptotic Giant Branch

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

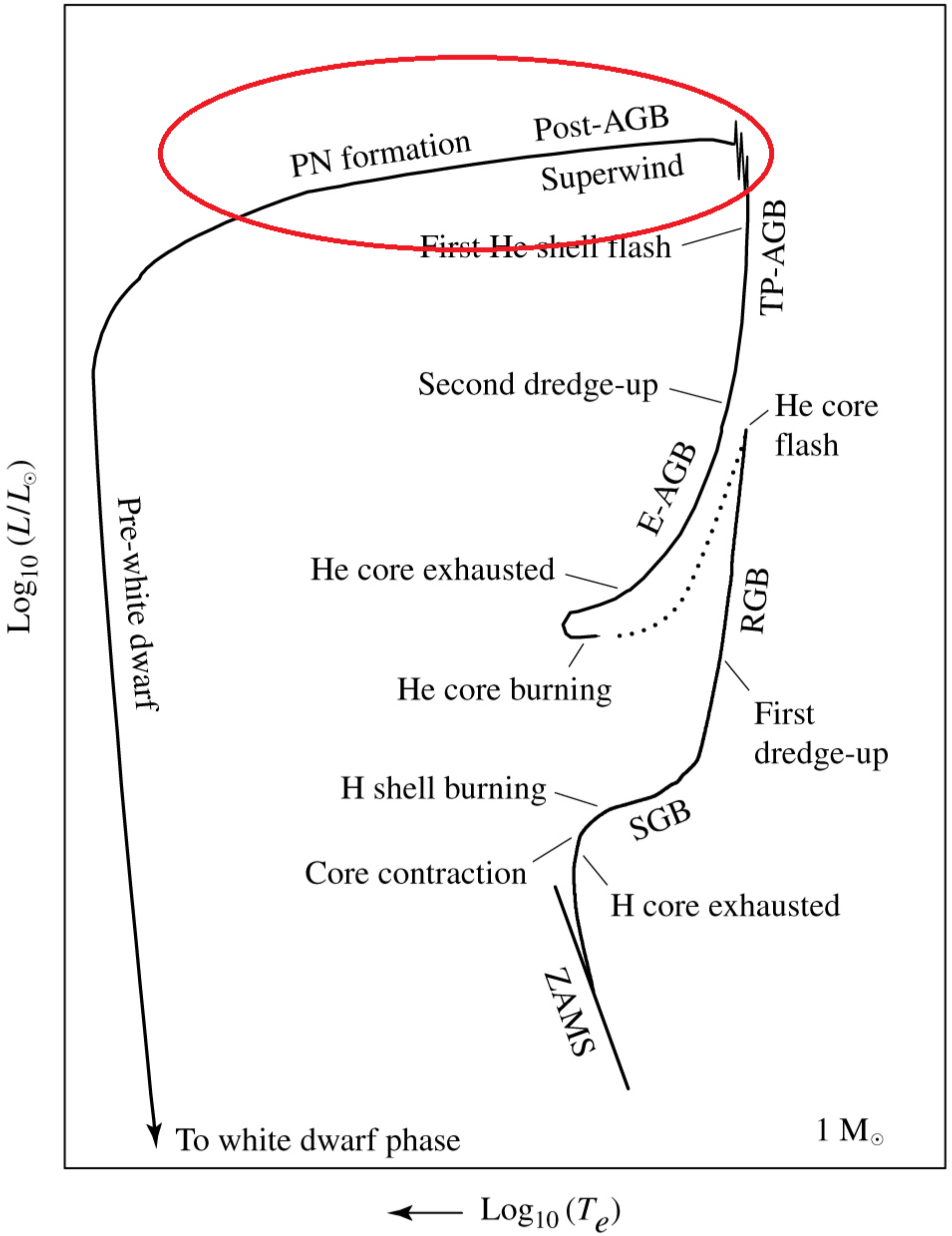


Source: [1]

White Dwarf Formation

<u>Planetary Nebula</u>

- Superwind
- Visible surface moves towards core
- Thin He, H photosphere

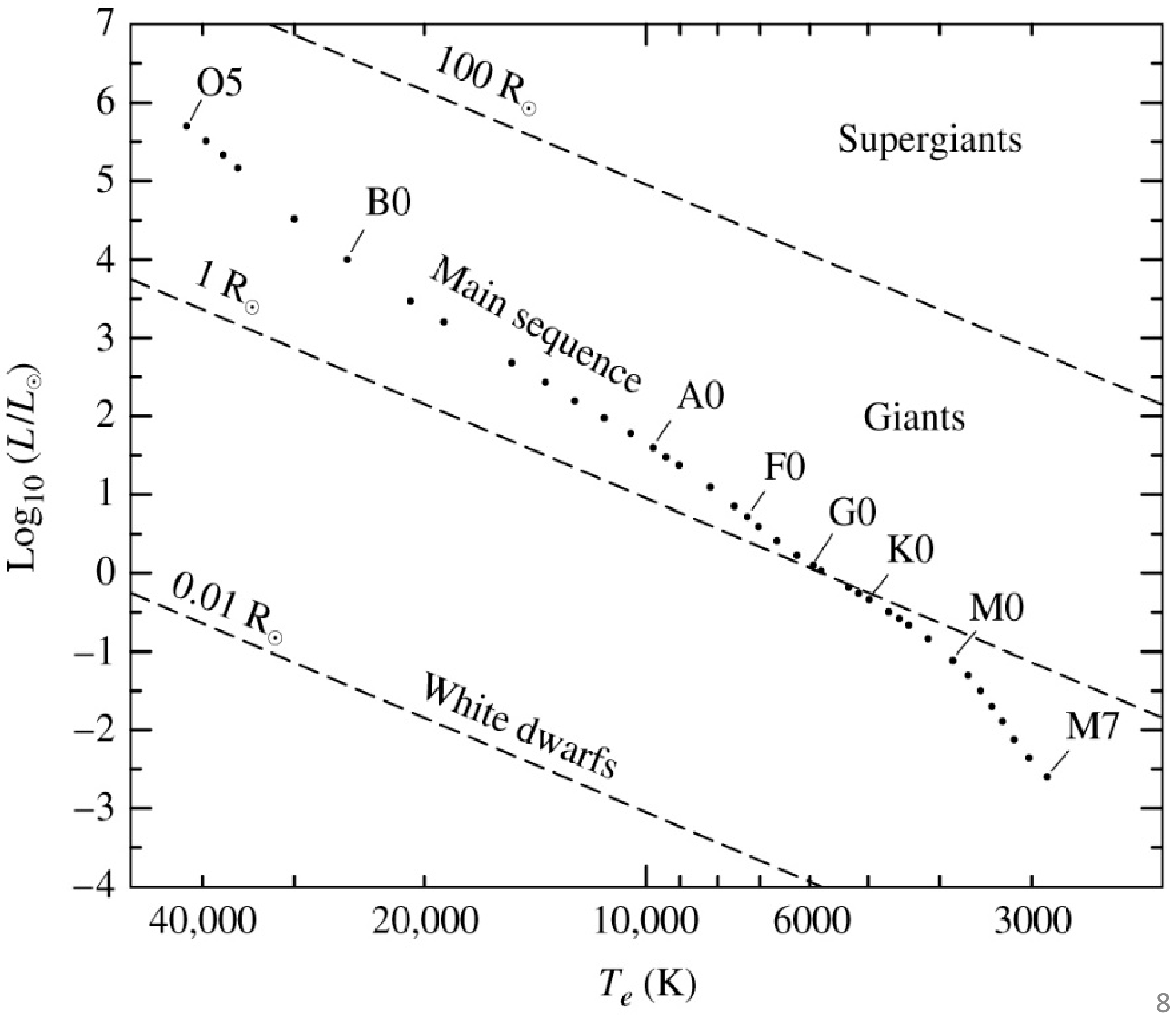


Source: [1]

White Dwarf Formation

White Dwarf

- Cools at constant radius
  - L α T^4
    - Luminosity Decreases

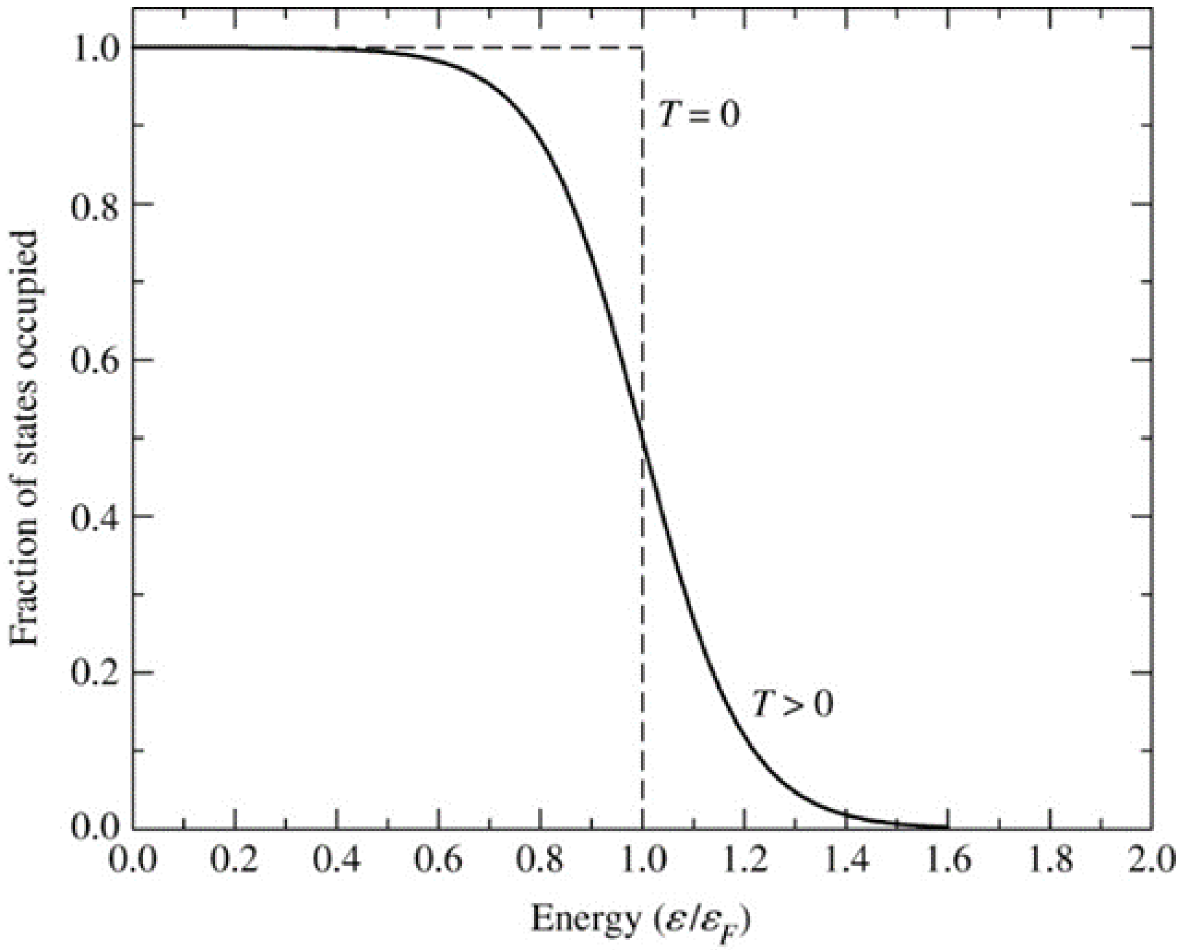


Source: [1]

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_{ch}, triggering fusion (W7)
  - Core densities > 10^9 g/cm^3

- Sub-Chandra: (WDD2)
  - Core densities ≤ 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

$$\frac{d\sigma_i}{dt} = stellar\ death - stellar\ birth + infall + decay$$

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 or page 13

- Trends
  - Agreement towards t_o
  - Spread towards t_f
    - Vanadium

  - At $t_{f\,(WDD2)}$, WDD2 > W7

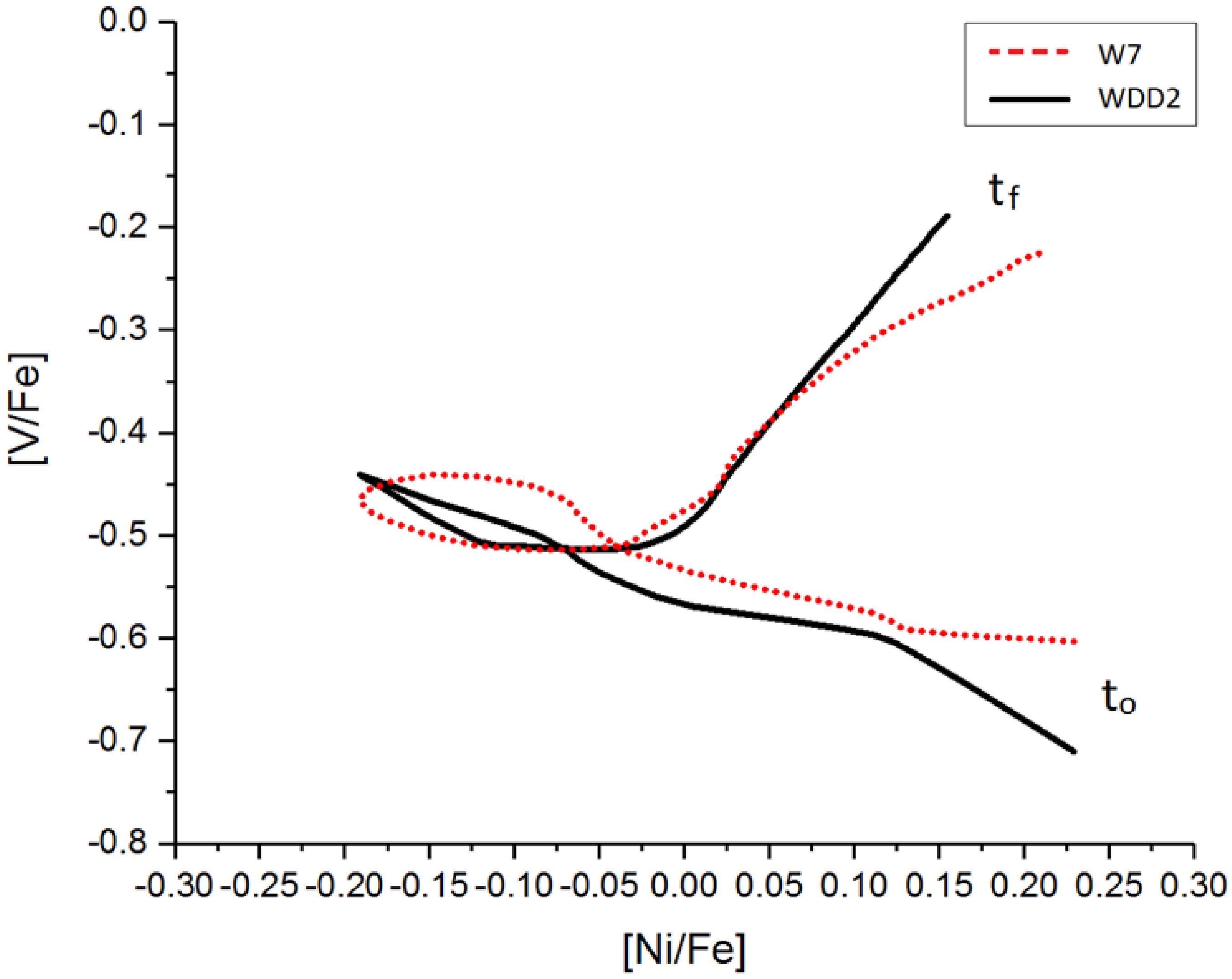


Figure 10: Vanadium

Results

Mapping onto Observed SAGA Data

- Odd numbered figures starting on page 13
- Shows potential agreement, filtered data disputes
- No fitting analysis

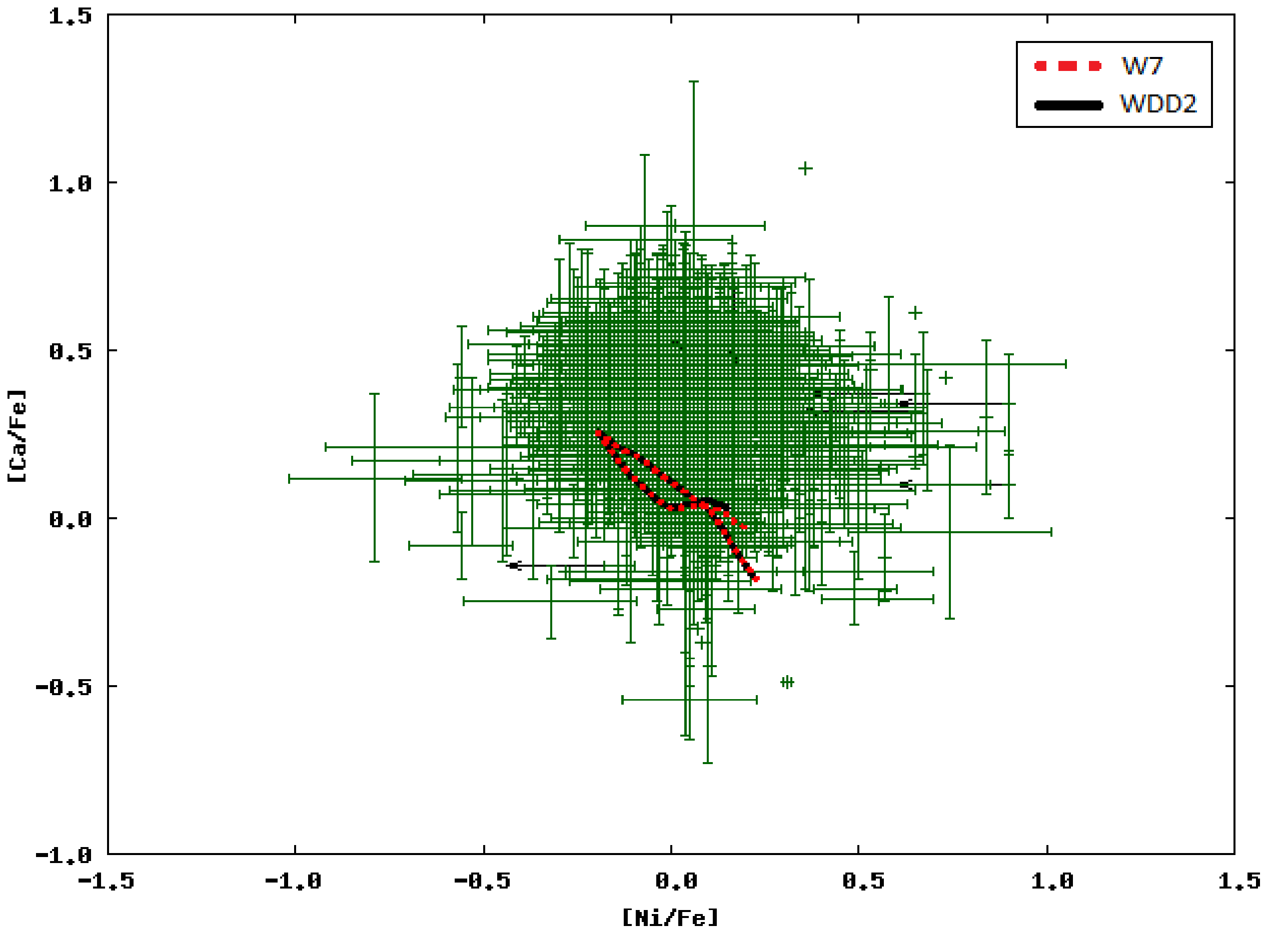


Figure 11: Calcium with Observed Data

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

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