Initial Mass Function

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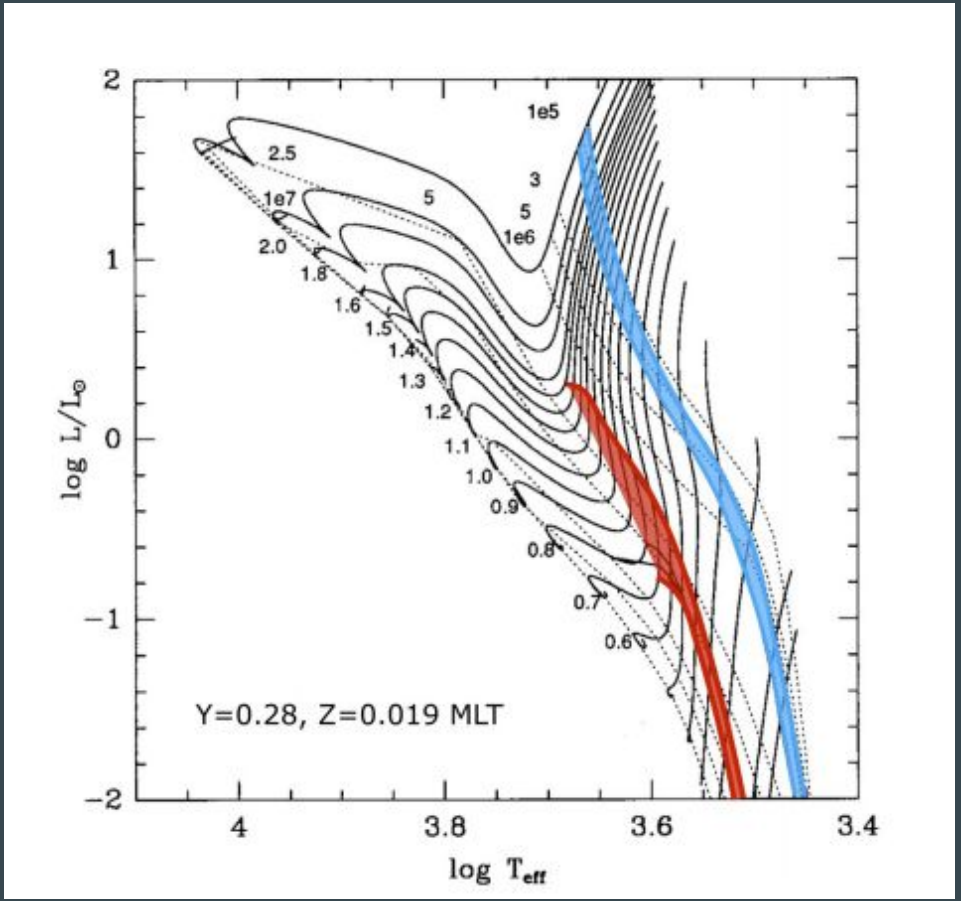


Ch. 12.12 of L&L

The Hayashi Track

- Pre-Main Sequence stars' evolution tracks (0.3 < M < 2.5MΘ)
- Dotted: isochrones with indicative ages
  - Right: 10^5 yr
  - Left: 10^7 yr
- Blue: Locations of destruction of D
- Red: Locations of destruction of Li

Introduction to the Initial Mass Function (IMF) - Overview

- Initial Distribution of Star Masses (from ~0.1 to ~120 solar mass) when formed
  - Probability distribution function
- A derivative of number based on mass of stars
  - General Equation —>

$$\xi(m) = \frac{dN}{dm},$$

- Determining the initial mass function of stars
  - Critical for star formation and star evolution(can constrain star formation process)
  - Not completely understood to this day
  - Most data comes from the stars in the Milky Way Galaxy especially based on solar neighborhood(<30 pc), and nearest young clusters and associations(50 to 300 pc)
- 3 Categories
  - Massive Stars (few; M>M_sun)
  - “Sun-sized” (abundant)
  - Less massive (numbers decrease as mass decreases)

IMF Dependencies

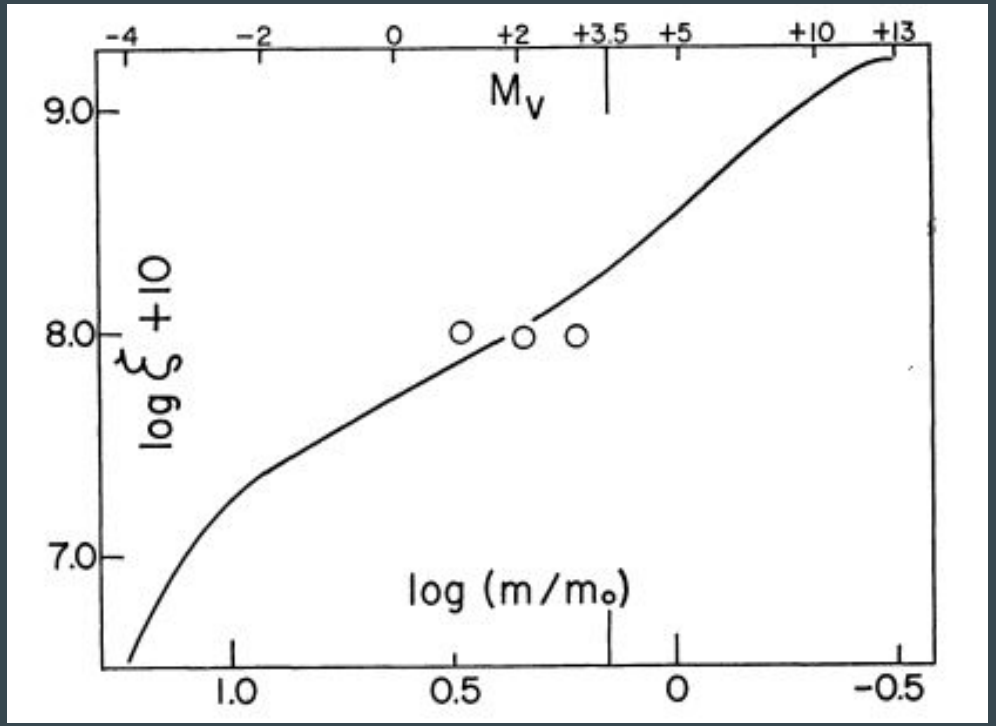
- Uses star clusters - age
  - Possible drifting of low-mass stars
- Uses Field Stars
  - Distances to stars - magnitudes and magnitude limit of the sample
  - Use of magnitudes to get stellar mass
  - Backtrack evolutionary stages that caused mass-loss to find initial masses
- When all apparent magnitude, spectral type, and evolutionary phases are taken into account...
  - Creates an accurate data for the initial mass function

History

- First Model by Edwin Salpeter in 1955
  - Measured nearby stars
  - Simple power law extrapolated data
    - $\xi(m) = \xi_o(m/M)^{-2,35}$
    - $-2.35 = \alpha$
  - Good for 0.4 to 10 solar masses
    - Shown later to work up to 120 solar masses but with high uncertainty
    - Doesn't work well at low mass
- Newer Models flatten out at lower mass

Salpeter Model

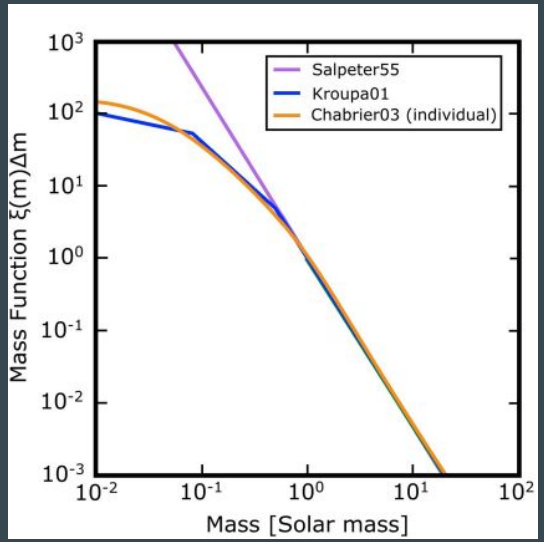
- $\xi(m) = \xi_o(m/M)^{-2,35}$
- Reversed X axis



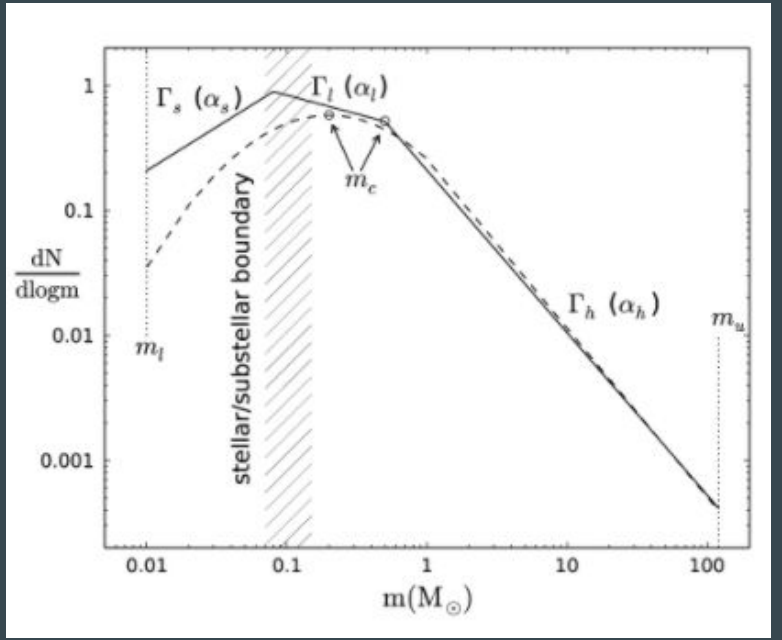
Salpeter, E. E. (1955). The Luminosity Function and Stellar Evolution. ApJ, 121, 161. doi:10.1086/145971

Newer Models

- Steep negative region from around 0.5 solar mass and above
- Flattened region below 0.5 solar mass
- $\Gamma = \alpha + 1$

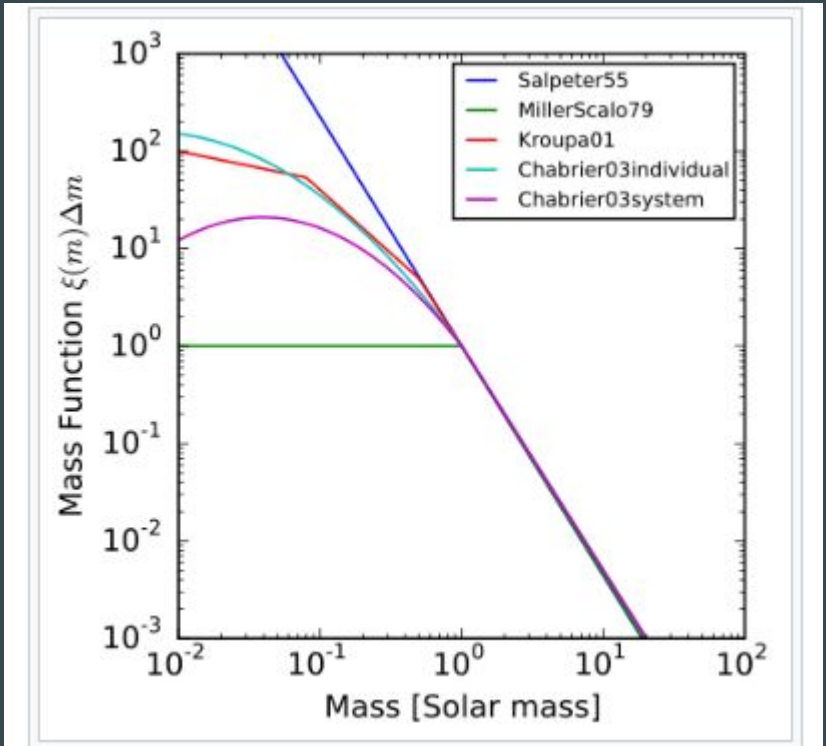


L&L Figure 12.8



Hopkins, A. (2018). The Dawes Review 8: Measuring the Stellar Initial Mass Function. Publications of the Astronomical Society of Australia, 35, E039. doi:10.1017/pasa.2018.29

Up-to-Date from Wikipedia (Eq. 12.21 & 12.22 in L&L)



Kroupa IMF

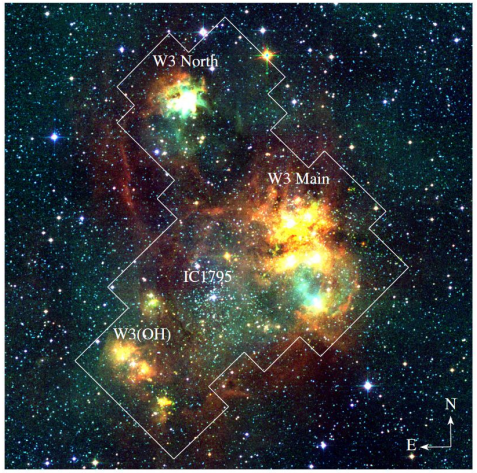
$$N(m)dm = C_1\, m^{-2.3} \quad \text{for} \quad m > 0.5M_\odot,$$
$$N(m)dm = C_2\, m^{-1.3} \quad \text{for } 0.08 < m < 0.5M_\odot,$$
$$N(m)dm = C_3\, m^{-0.3} \quad \text{for } m < 0.08M_\odot,$$

Chabrier IMF

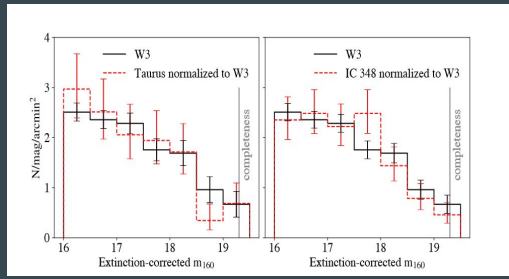
$$N(m)dm = D_1 \frac{1}{m} \exp\left[-\left\{\log\left(\frac{m}{0.08}\right)\right\}^2 / 0.952\right] \quad \text{for } m < 1M_\odot$$
$$N(m)dm = D_2\, m^{-2.3} \quad \text{for } m > 1M_\odot,$$

Brown dwarfs and initial mass function

- Brown dwarfs are celestial objects which have 13 to 80 times of jupiter mass
- Samples of brown dwarfs are from W3 region, Taurus and IC348.
- Luminosity function is the product of Initial mass function and age.
- Age of stars in three regions are uniform
- M160 is from 16 to 20 correspondent to 0.03 to 0.4 solar mass
- luminosity functions correspond to three regions are roughly same.
- But W3 region has much larger number of stars which means that the IMF does not dependent significantly on star forming condition



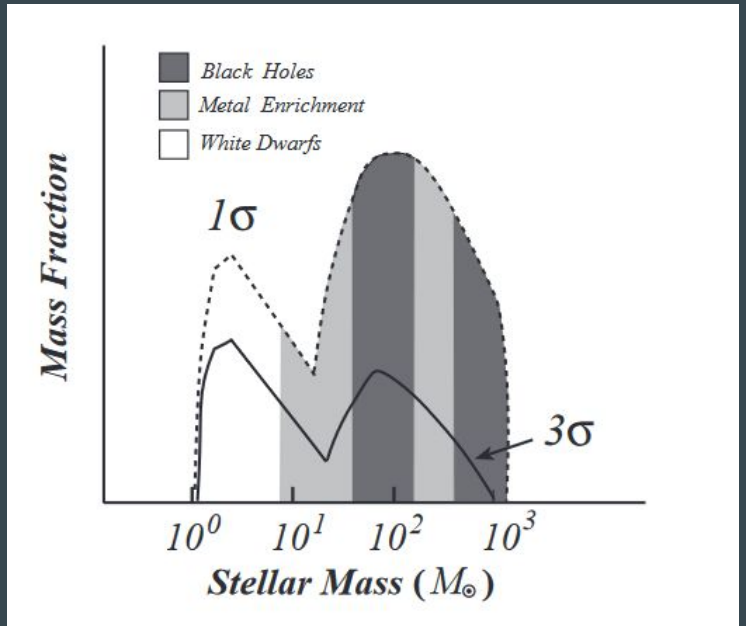
Picture of W3 region
M J Huston. (2021). The Initial Mass Function of Low-mass Stars and Brown Dwarfs in the W3 Complex



Luminosity function vs m160 for W3, IC 348, and taurus
M J Huston. (2021). The Initial Mass Function of Low-mass Stars and Brown Dwarfs in the W3 Complex

Population 3 stars and initial mass function

- Population iii stars are very first generation of objects
- Initial mass function of population iii stars likely to be bimodal with 100 to 1 time of solar mass.
- Sigma is density fluctuation
- Higher density fluctuation means lower over all mass fraction



Broad Observations

- Most mass is generally in lower mass stars
  - Luminosity mostly in high mass stars
- General shape of curve seems to hold for most places
  - Few observations beyond Milky Way

NASA, ESA, and M. Livio and the Hubble 20th Anniversary Team (STScI)
https://www.nasa.gov/content/discoveries-highlights-exploring-the-birth-of-stars

Challenges

- Can only observe current stars
  - Observations skewed towards smaller, longer-lived stars
- Accuracy at high mass: low
  - Large stars uncommon + short-lived —> few stars to observe
- Accuracy at low mass: low
  - Luminosity for low mass stars not as well understood
  - Uncertainty with Brown Dwarf Stars
- Mass estimation has high uncertainty
  - Observed luminosity → back propagate to initial mass with stellar evolution assumptions
- Multiple-star systems
  - Large portion of star systems
  - Pairs affect evolution, luminosity, etc. making mass calculations hard/inaccurate

References

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