THE INITIAL MASS FUNCTION (IMF)

MACY HUSTON, ASTRO 534, 4/17/19
INTRODUCTION

- Gives number of stars expected to form within given mass bin
  - Written as $\xi(\log m) = \frac{dN}{d\log m}$ or $\xi(m) = \frac{dN}{dm}$
  - For power laws, we get either $\frac{dN}{d\log m} \propto m^{-\Gamma}$ or $\frac{dN}{dm} \propto m^{-\alpha}$, related by $\alpha = \Gamma + 1$
- Can help constrain star formation theory
- Seems fairly universal but perhaps not entirely
PRIMARY METHOD

Used first by Salpeter in 1955 and described in more detail by Scalo in 1986

1. Observationally determine the luminosity function of the solar neighborhood (or other region in question).

2. Convert to a mass function using a mass-luminosity relationship.

3. Correct for stars which have died.

Note: there are many complications and assumptions involved.
FUNCTIONAL FORMS
POWER LAWS AND LOGNORMAL
“Original” mass function first proposed by Edwin Salpeter in 1955

Parametrizes the relative numbers of stars as a function of mass

$$\frac{dN_*}{d\log m_*} \propto m_*^{-\Gamma}$$

$$\Gamma = 1.35$$

$$0.4M_{\text{sun}} < m_* < 10M_{\text{sun}}$$
Central Limit Theorem: the sum of many independent variables approaches normal distribution

If star formation is very complex, IMF could be normal distribution
- logm distribution would be lognormal

Observationally constrained by Chabrier in 2003

Bastian, Covey, & Meyer 2010
**BROKEN POWER LAW**

- Kroupa (2001)
- Very similar to Chabrier

\[
\frac{dN_*}{dm_*} \propto m_*^{-\alpha}
\]

\(\alpha = 2.3;\) \(m_* < 0.5M_{\text{sun}}\)

\(\alpha = 1.3;\) \(0.08M_{\text{sun}} < m_* < 10M_{\text{sun}}\)

\(\alpha = 0.3;\) \(m_* > 0.08M_{\text{sun}}\)

\(\alpha = \Gamma + 1\)

[Graph of mass function vs. mass [Solar mass]]

Johannes Buchner
COMPLICATIONS
MULTIPLICITY AND STAR FORMATION HISTORY
Most IMFs start with monochromatic observed luminosity functions

Unresolved binaries could majorly impact these

Correcting for this requires knowledge of multiplicity fraction and of the mass ratio distribution
STAR FORMATION HISTORY COMPLICATIONS

- Given a region of age $T_0$, stars with $\tau(m) > T_0$ will all be on the main sequence
  $\rightarrow$ PDMF = IMF
- For stars with $\tau(m) < T_0$, some will be evolved
  $\rightarrow$ Assumptions must be made about star formation history
- For $\tau(m) \ll T_0$, an approximation that eliminates SFR history is possible, and the IMF can be estimated with current star formation rate only
IMF COMPLICATIONS BY MASS

Low mass
- Dim
  + On main sequence (PDMF = IMF)

High mass
- Uncommon
  + Approximation can eliminate SFR history from IMF equation

Soar-ish mass
- IMF requires assumptions about SFR history

* Of extra importance because of proximity to break from Salpeter power law
UNIVERSALITY
\[ \frac{dN}{d\log m} \propto m^{-\Gamma} \]
IMF is shown to be similar in many different types of star-forming regions, despite varying:

- Mean density
- Turbulence level
- Magnetic field strength
- Metallicity

A few regions have been reported to show non-standard IMF, but Bastian, Covey, and Meyer (2010) review why many of these can be explained away or require additional follow up.
TAURUS STAR FORMING REGION

Luhman et. al. 2003
IMPLICATIONS FOR STAR FORMATION
No lower cutoff has been found for the IMF yet
- Brown dwarfs have been detected down to $5 - 10M_{jup}$

Upper limit seems to be around $100 - 150M_{\text{sun}}$
- Primarily due to Eddington limit, may not have to do with formation mechanisms
Near-uniformity points to a dominant self-similar, scale-free process at large scales.

Finding non-uniformity could be extremely important for our understanding of star formation.
Core Mass Function (CMF) of prestellar clumps appears to have a similar shape to the IMF.

Evidence that the IMF is determined in the initial gaseous phase rather than collapse process.

Suggests that accretion cannot be the dominant mechanism of star formation.

Onishi et. al. 2002
CONCLUSION

- IMF appears to follow a Salpeter power law at high mass
- It appears to have a break below $M_{\text{sun}}$ and flatten out toward a Kroupa or Chabrier slope
- A lot of uncertainties arise in converting an LF to IMF
- The IMF is uniform over most observed regions, but possibly not all