Our 15 Million Nearest Neighbors: The Luminosity and Mass Functions of SDSS M Dwarfs

John Bochanski
SDSS Symposium
August 16th, 2008
Collaborators

- Suzanne Hawley (UW)
- Kevin Covey (CfA)
- Neill Reid (STScI)
- Andrew West (Berkeley / MIT)
- Željko Ivezić (UW)
- Dave Golimowski (STScI)
Outline

• M Dwarfs 101
• The Luminosity Function
• The Mass Function
• Conclusions
M Dwarfs 101

• Mass < 0.7 M☉
• Effective Temperatures < 3800 K
• Luminosity < 0.05 L☉
• Lifetimes > 10^{12} yr
• ~70% of stars

Reid & Hawley, 2005
Why should we care?

- M dwarfs are ~70% of all stars (by number)
- Shape of the IMF places strong constraints on star formation mechanisms (e.g. fragmentation, competitive accretion, ejection)
- The low-mass IMF also contributes to external galaxy stellar mass measurements (extrapolating a Salpeter slope is WRONG!)
- Makes a great thesis project
Outline

• M Dwarfs 101
• The Luminosity Function
• The Mass Function
• Conclusions
Previous Low-Mass Field LFs and MFs

- **Problem**: Uncertainty in IMF power law slope ($\alpha$) of $\sim 2$ → leads to large relative density differences

$$\begin{align*}
\text{LF} &= \frac{dN}{dL} \\
(\text{I})\text{MF} &= \frac{dN}{dM} \propto M^{-\alpha}
\end{align*}$$

- $\alpha = 0.55$ (Zheng et al. 2001)
- $\alpha = 2.35$ (Salpeter 1955)
- $\alpha = 2.5$ (Schultheis et al. 2006)
Previous Low-Mass Field LFs and MFs

Local Stars - Wide sky coverage of nearby stars
(e.g. “8 pc sample” - Reid & Gizis 1997, PMSU - Reid, Gizis & Hawley 2002)

Pencil Beams- Deep photometry of small solid angles
(e.g. Martini & Osmer 1998, Zheng et al. 2001)
Previous Low-Mass Field LFs and MFs

Local Stars - Wide sky coverage of nearby stars
(e.g. “8 pc sample” - Reid & Gizis 1997, PMSU - Reid, Gizis & Hawley 2002)

Pencil Beams - Deep photometry of small solid angles
(e.g. Martini & Osmer 1998, Zheng et al. 2001)

This limited sample sizes to a few thousand stars
SDSS Field LF and MF

- Queried SDSS for ALL point sources with M dwarf colors
- Spread over 8,400 square degrees
- 15 million stars in the sample
- Previous largest sample (Covey et al., 2008)
  - 30 square degrees
  - 29,000 stars
SDSS offers a fundamentally different set of data.
Luminosity Function

Issues

• Contamination - Massive Spectroscopic Followup

• Accurate distances are necessary - New Photometric Parallaxes

• Galactic structure needs to be taken into account - Measured simultaneously
Measuring the LF & Galactic Structure

- Assign absolute magnitude and distance to each star
- Select stars in one absolute magnitude slice
- Count stars as a function of $R$, $Z$
- Compute volume of each $R$, $Z$ bin
- Calculate a density at each $R$, $Z$
- Fit with model, record local density
- Do this for each absolute magnitude bin
Log(Density) $M_r = 9.75$
\[ \rho = \rho_0 \left( f e^{(R/L_1)} e^{-|Z|/H_1} + (1-f) e^{(R/L_2)} e^{-|Z|/H_2} \right) \]
Absolute Magnitude

Log(Density) $M_r = 9.75$

-5 -4 -3 -2

Galactic Z

Galactic R
\[ \Phi = \frac{dN}{dL} \]
Mean $M_r$ - $r-z$
Mean $M_r$ - $r-i$
$M_r$ - $r-i$, Metal Correction
$M_r$ - $r-z$, Metal Correction
$M_r$ - $r-z$, No Extinction Correction

$\phi$ (0.5 mag$^{-1}$ pc$^{-3}$)

$M_r$

6 8 10 12 14 16 18
This Study
Juric et al. (2008)

LF

$\phi (0.5 \text{ mag}^{-1} \text{ pc}^{-3})$

$M_r$

M0  M2  M4  M6  M8
This Study
Covey et al. (2008)
This Study
NLDS2
Cruz et al. (2007)
Reid & Gizis (1997)
Zheng et al. 2001
Outline

• M Dwarfs 101
• The Luminosity Function
• The Mass Function
• Conclusions
Mass Function

• Use Mass - Luminosity Relations measured from eclipsing binaries (Delfosse et al. 2000)

• Converted from M_f LF
$$\xi \text{(pc}^{-3} (0.1 \log M)^{-1})$$

- $0.0001$
- $0.0010$
- $0.0100$

$$(pc^{-3} (0.1 \log M)^{-1})$$

$0.1 M_\odot$

$0.3 M_\odot$

$1 M_\odot$
Log-Normal Fit

$M_0 = 0.27 \pm 0.01$

This Study
Covey et al. (2008)
Power Law Fit

\[ \alpha = 0.96 \pm 0.14 \]

This Study
Reid & Gizis (1997)
Zheng et al. 2001
This Study
Chabrier (2003)
Kroupa (2002)
Miller & Scalo (1979)
Outline

- M Dwarfs 101
- The Luminosity Function
- The Mass Function
- Conclusions
Summary

• SDSS provides a fundamentally different dataset for measuring the LF and MF

• The low-mass MF is well fit by a log-normal distribution

• Uncertainty in the MF may be due to comparing fits, not data