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 $M_\odot$
- Effective Temperatures < 3800 K
- Luminosity < 0.05 $L_\odot$
- 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

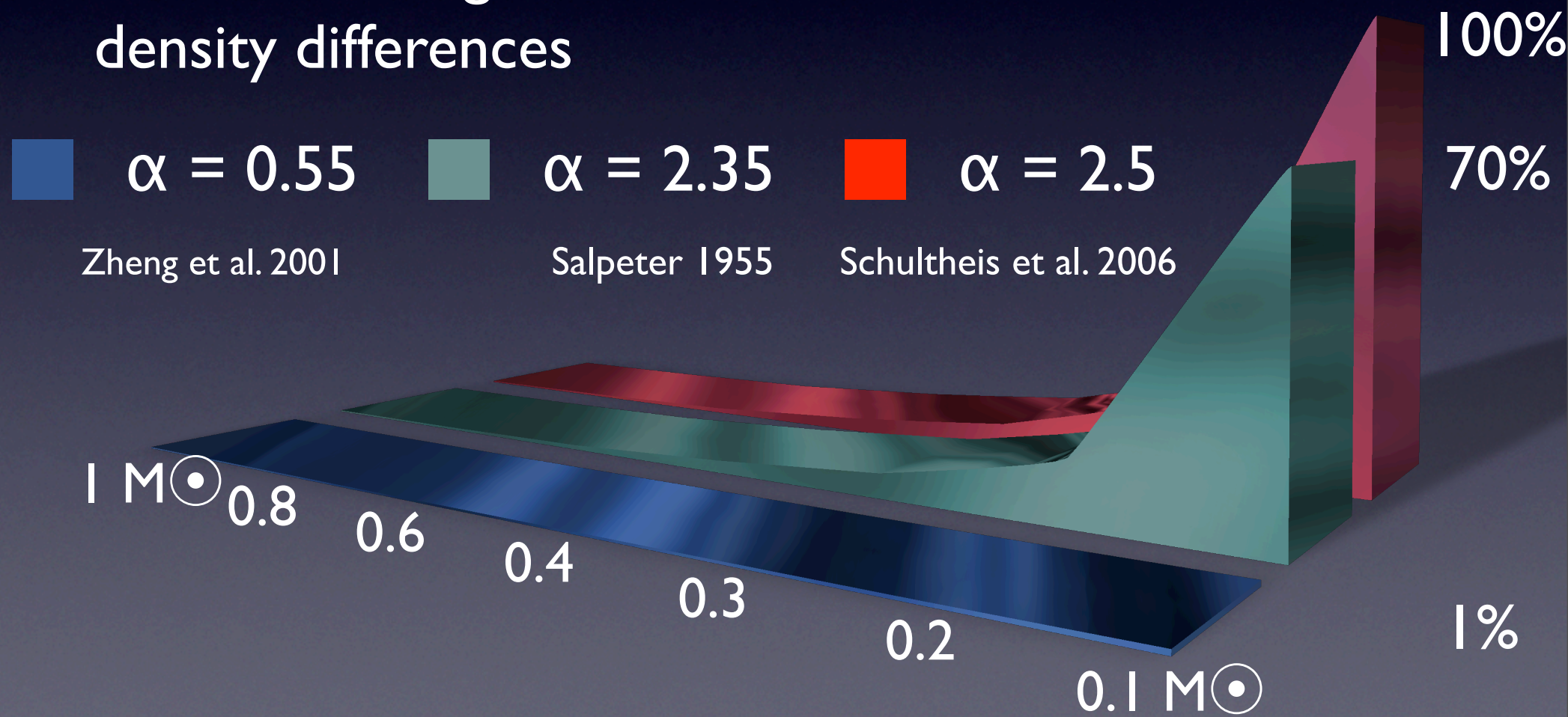
- M Dwarfs 101
- The Luminosity Function
- The Mass Function
- Conclusions

Previous Low-Mass Field LFs and MFs

- Problem: Uncertainty in IMF power law slope (α) of ~2 → leads to large relative density differences

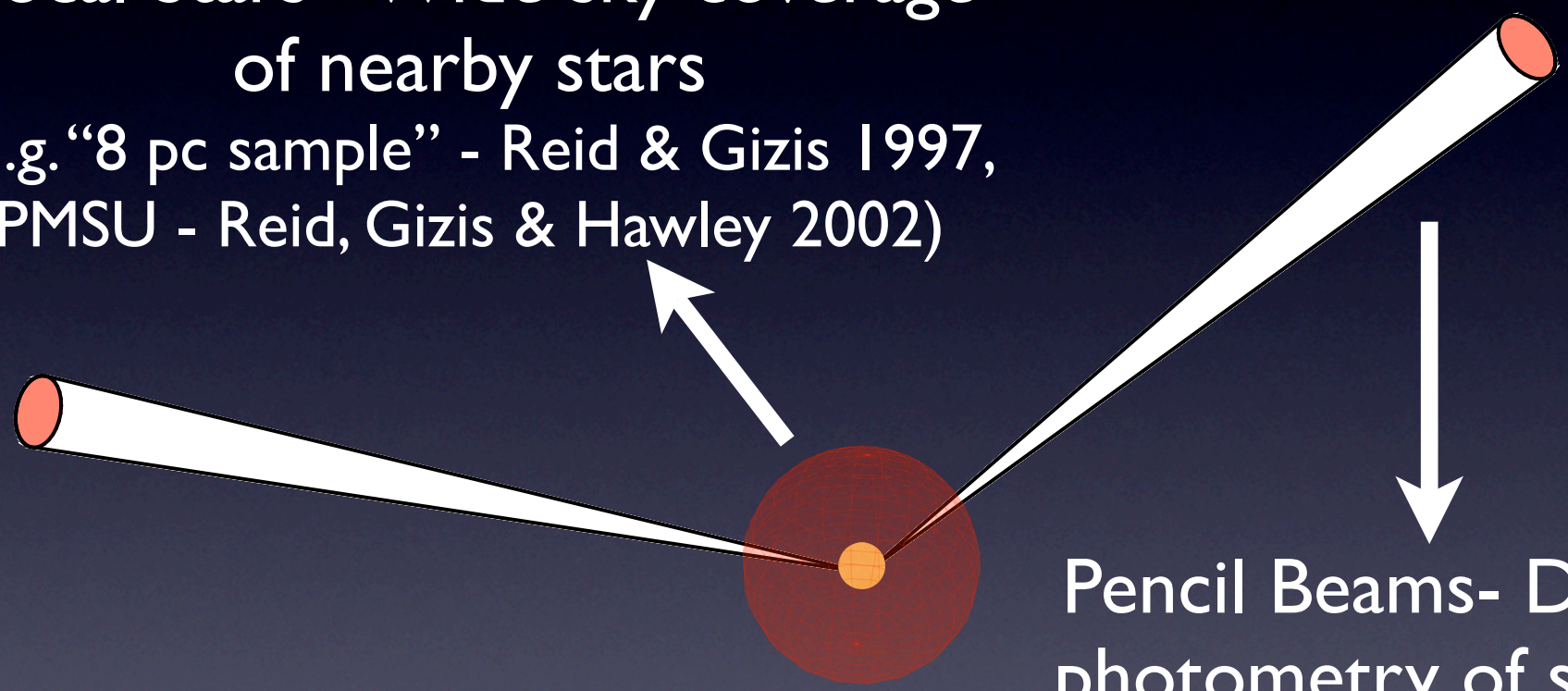
$$LF = dN/dL$$

$$(I)MF = dN/dM \propto M^{-\alpha}$$



Previous Low-Mass Field LFs and MFs

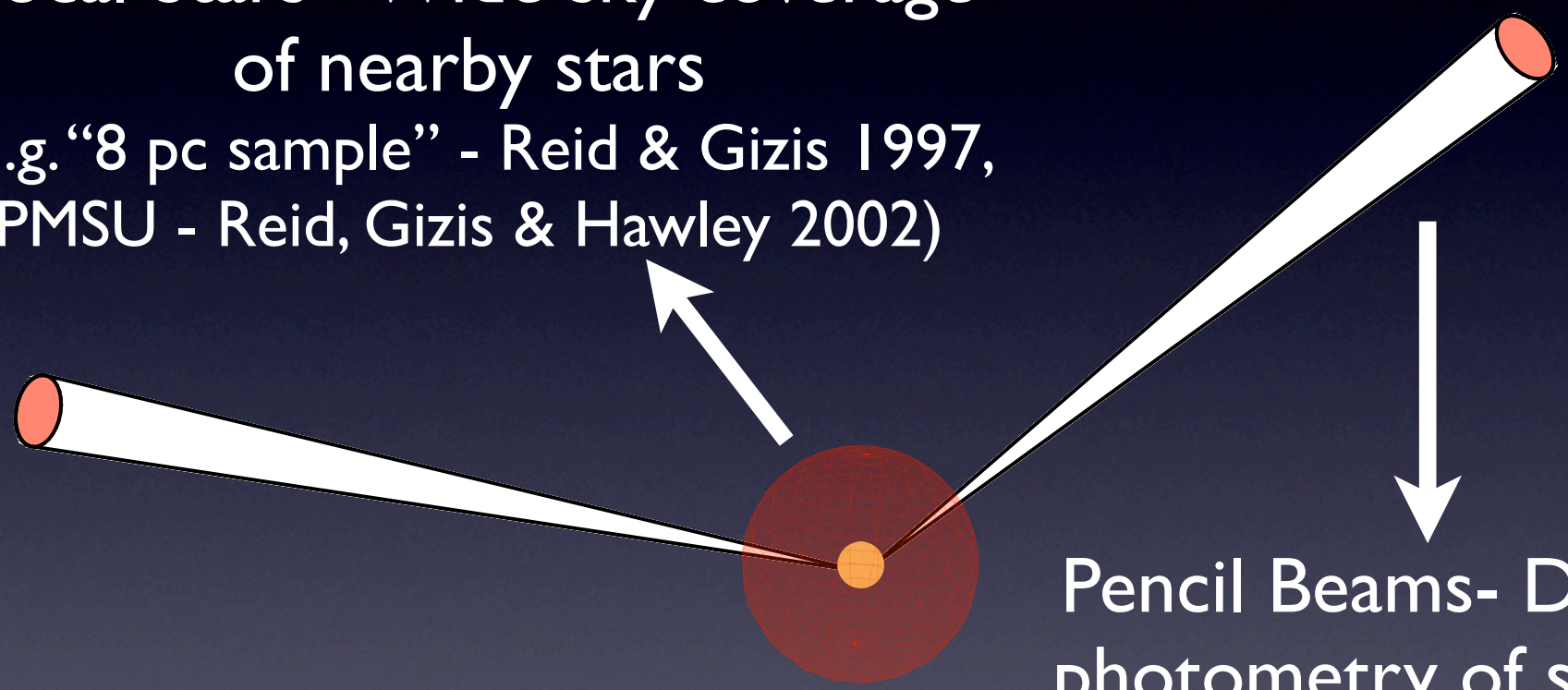
Local Stars - Wide sky coverage of nearby stars
(e.g. "8 pc sample" - Reid & Gizis 1997, PMSU - Reid, Gizis & Hawley 2002)



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)

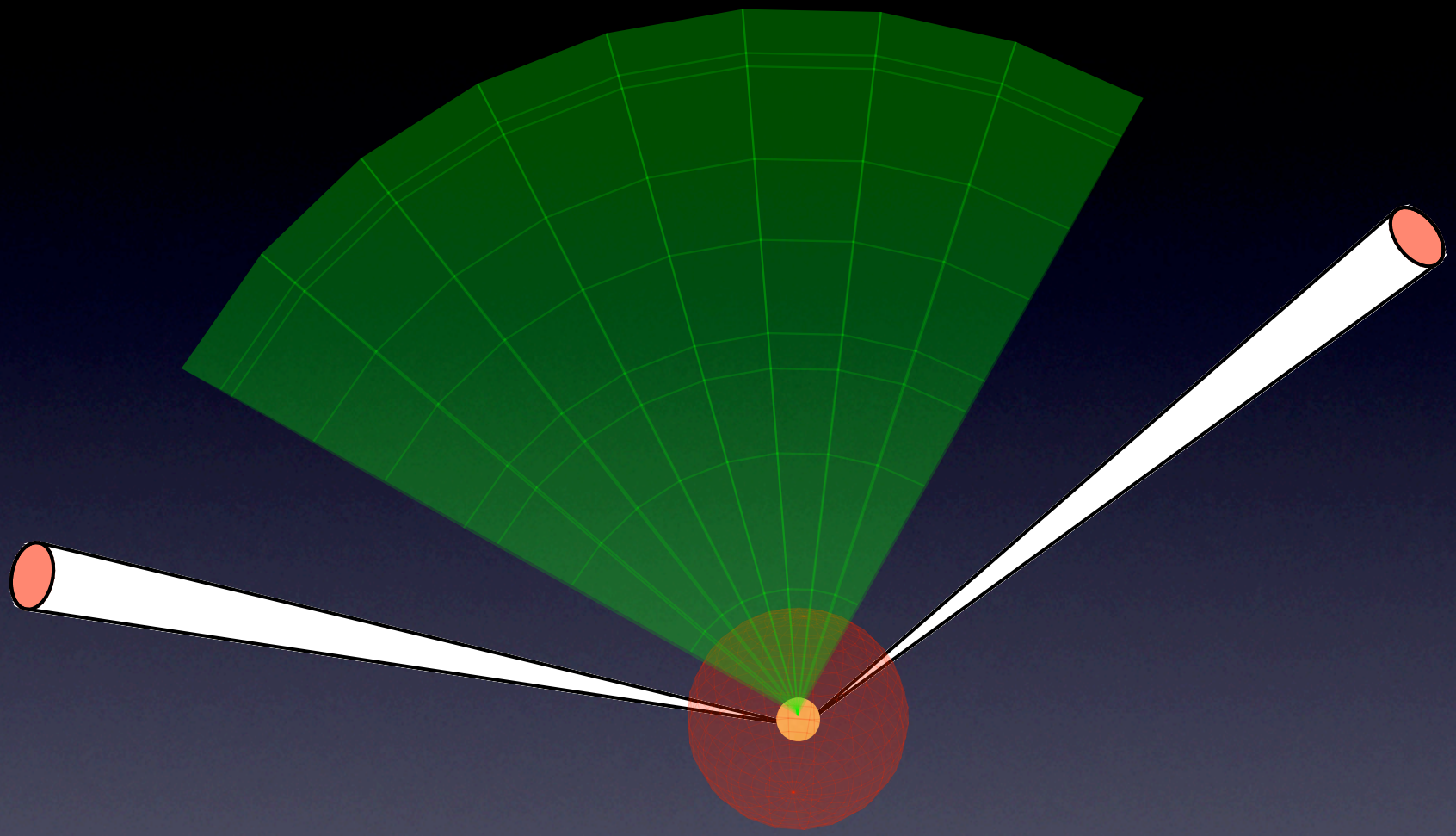


Pencil Beams- Deep photometry of small solid angles
(e.g. Martini & Osmer 1998, Zheng et al. 2001)

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



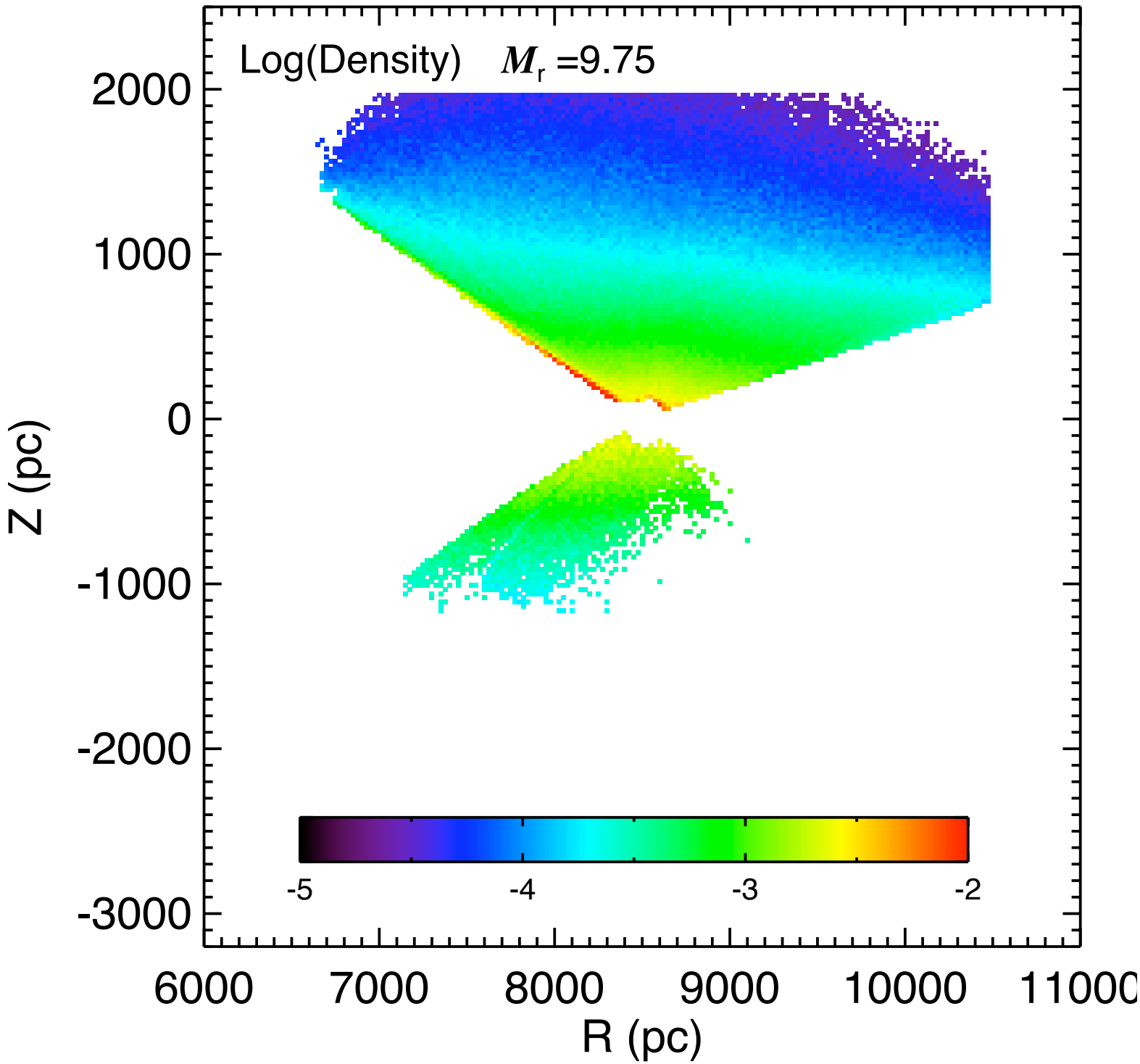
SDSS offers a fundamentally different set of data

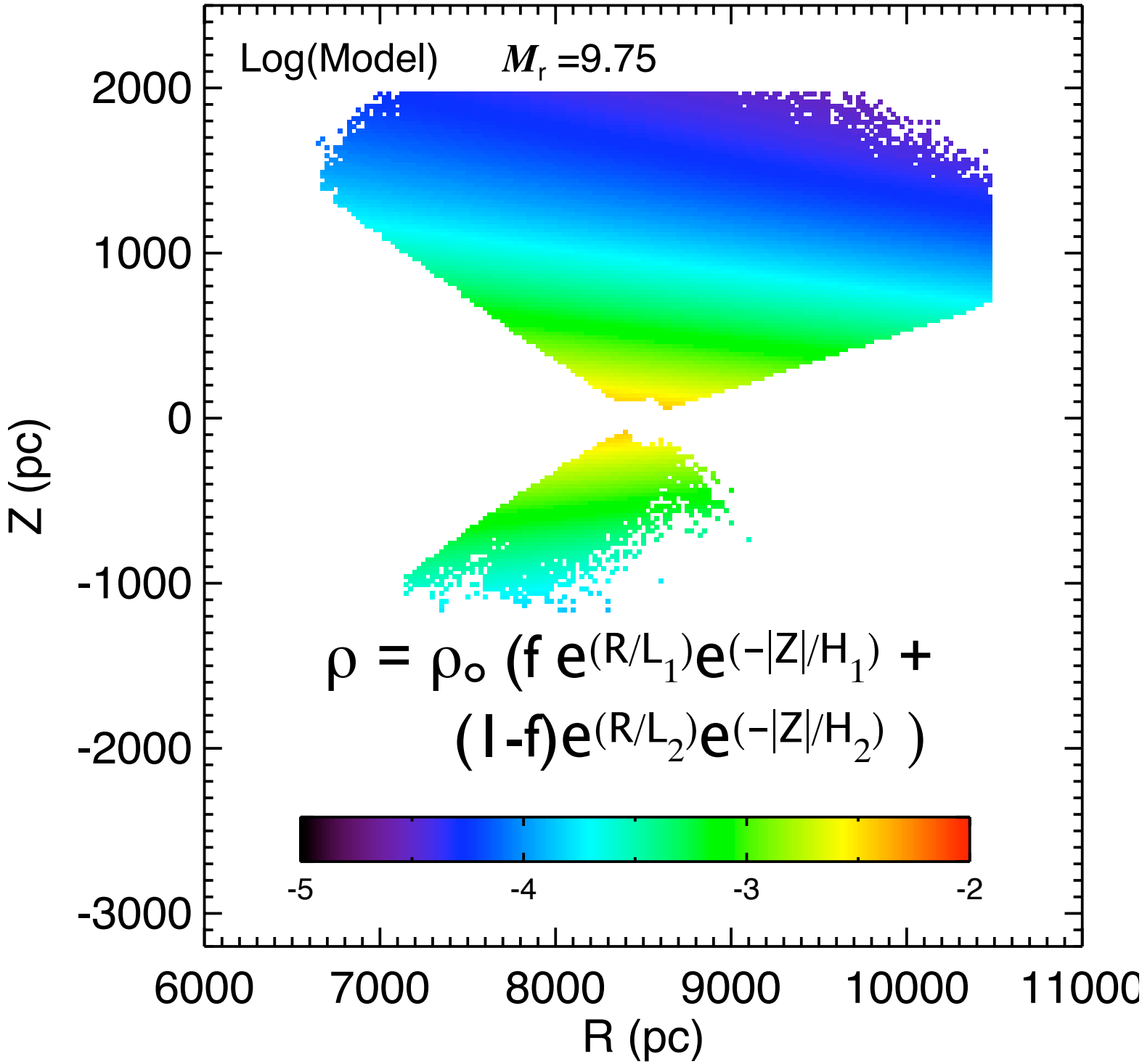
Luminosity Function Issues

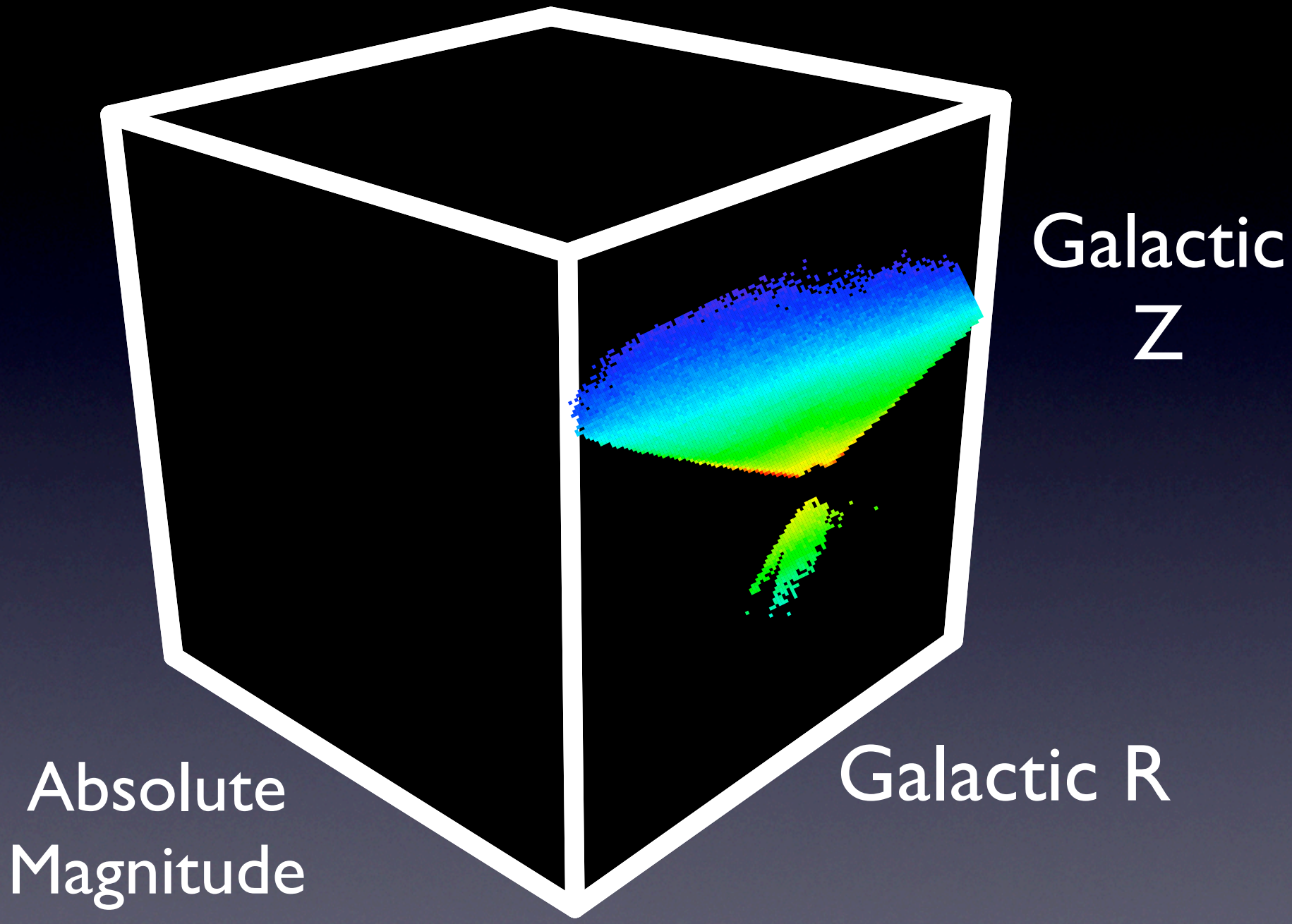
- Contamination -
  Massive Spectroscopic Followup
- Accurate distances are necessary -
  New Photometric Parallaxes
- Galactic structure needs to be taken into account -
  Measured simultaneously

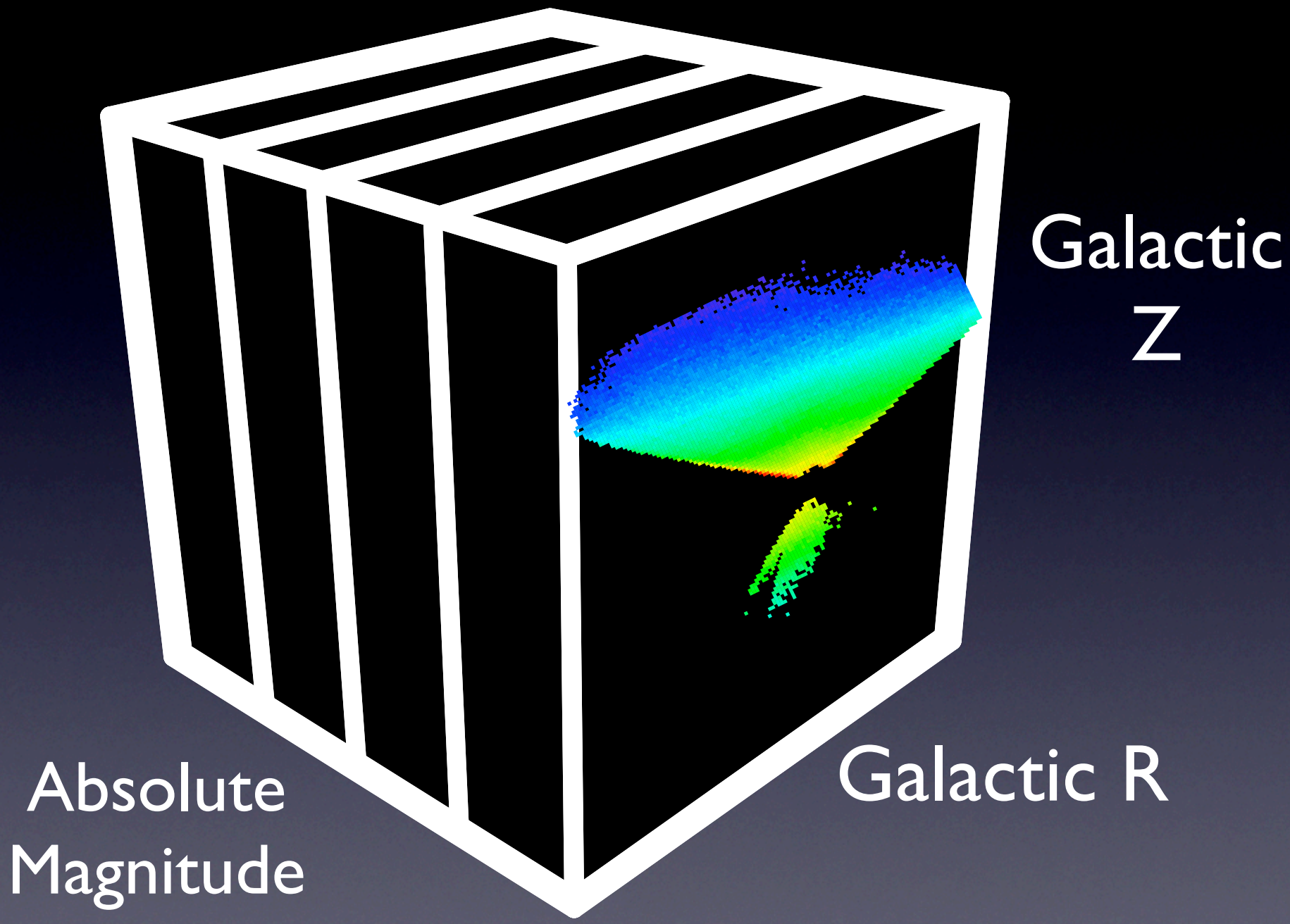
Measuring the LF & Galactic Structure

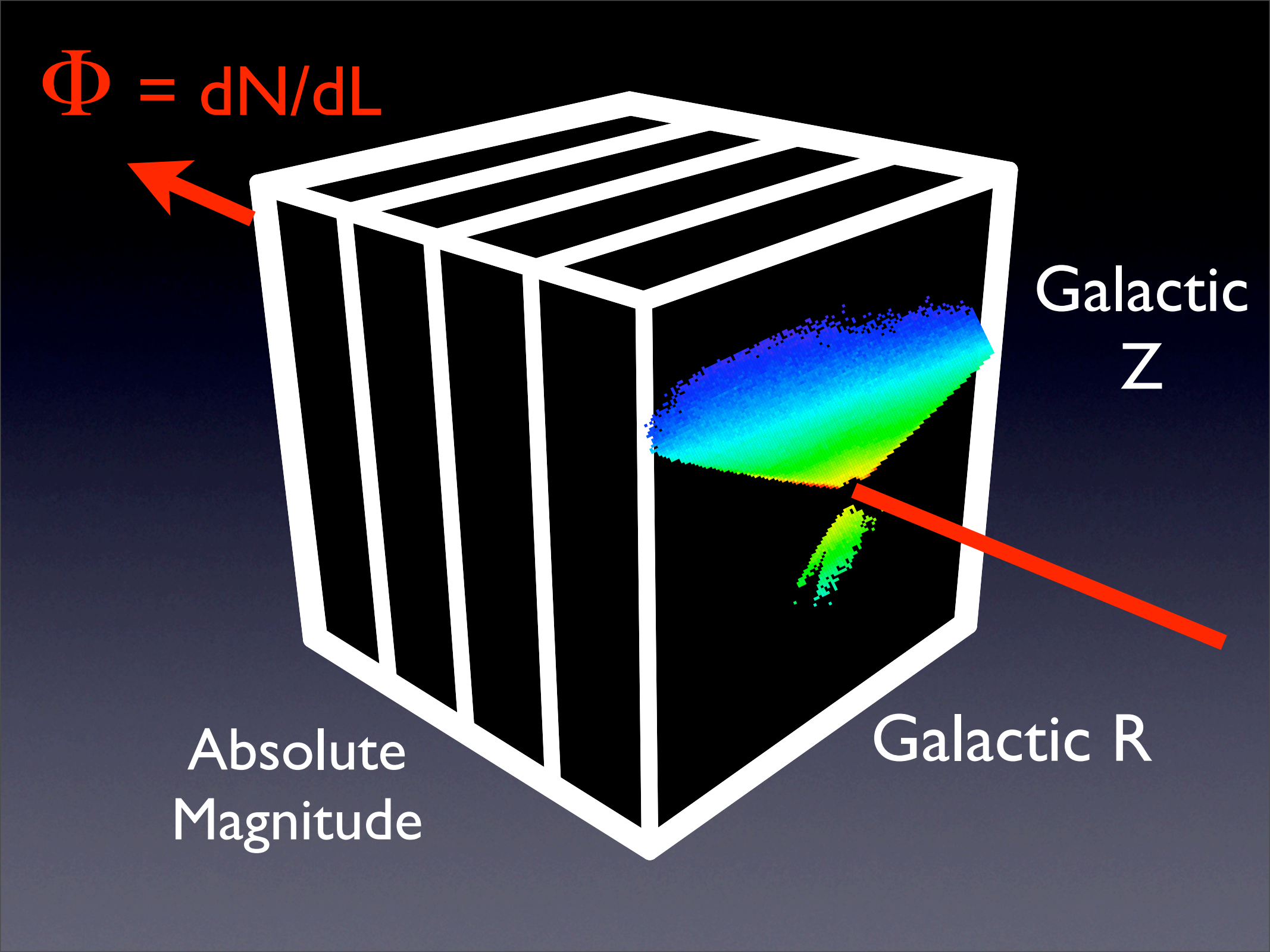
- Assign absolute magnitude and distance to each star
- Select stars in one absolute magnitude slice
- Count stars as a function of R, Z
- Compute volume of each R, Z bin
- Calculate a density at each R, Z
- Fit with model, record local density
- Do this for each absolute magnitude bin

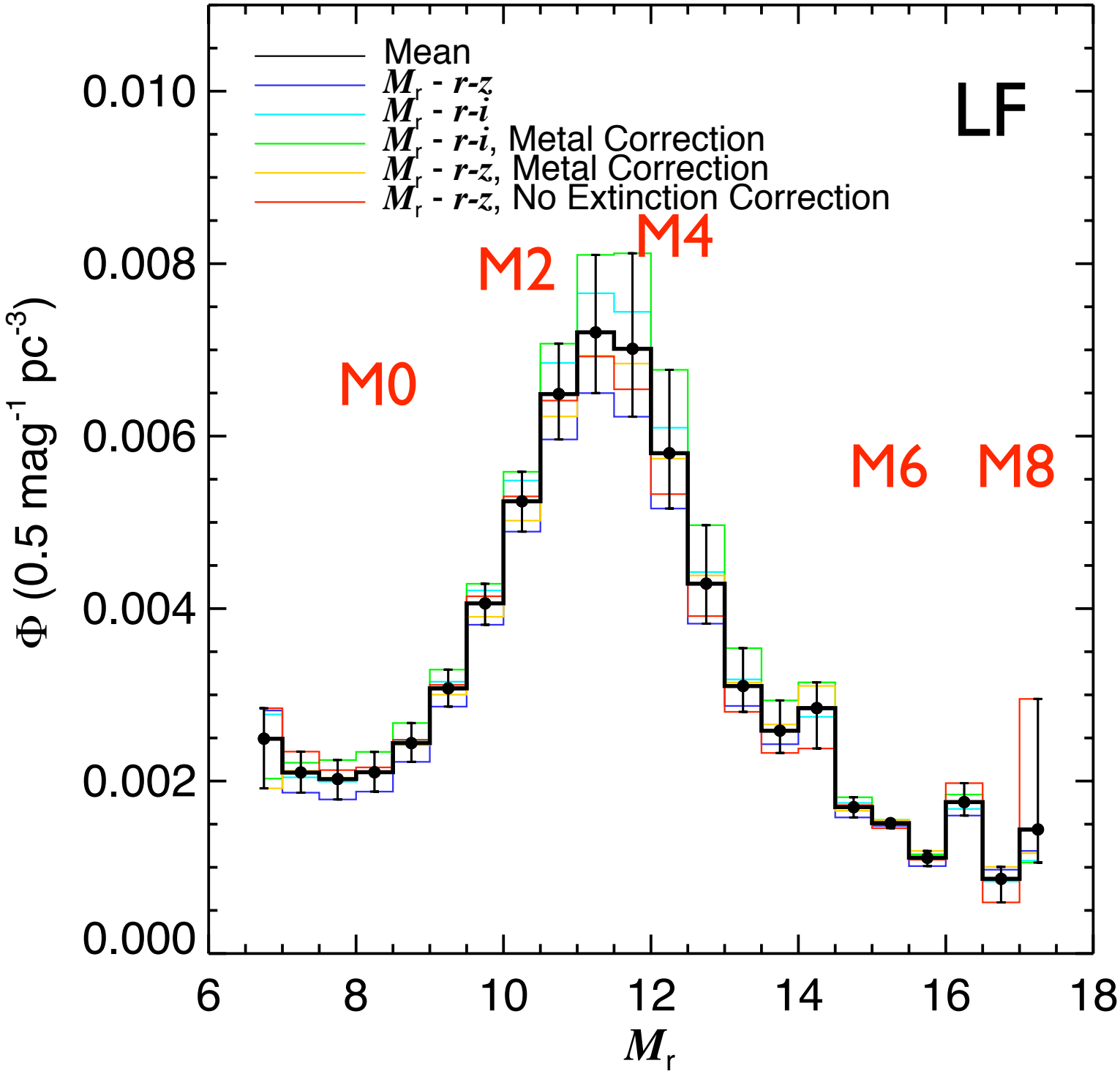

Log(Density) M_r =9.75
2000
1000
0
-1000
-2000
-3000
Z (pc)
6000
7000
8000
9000
10000
11000
R (pc)
-5
-4
-3
-2

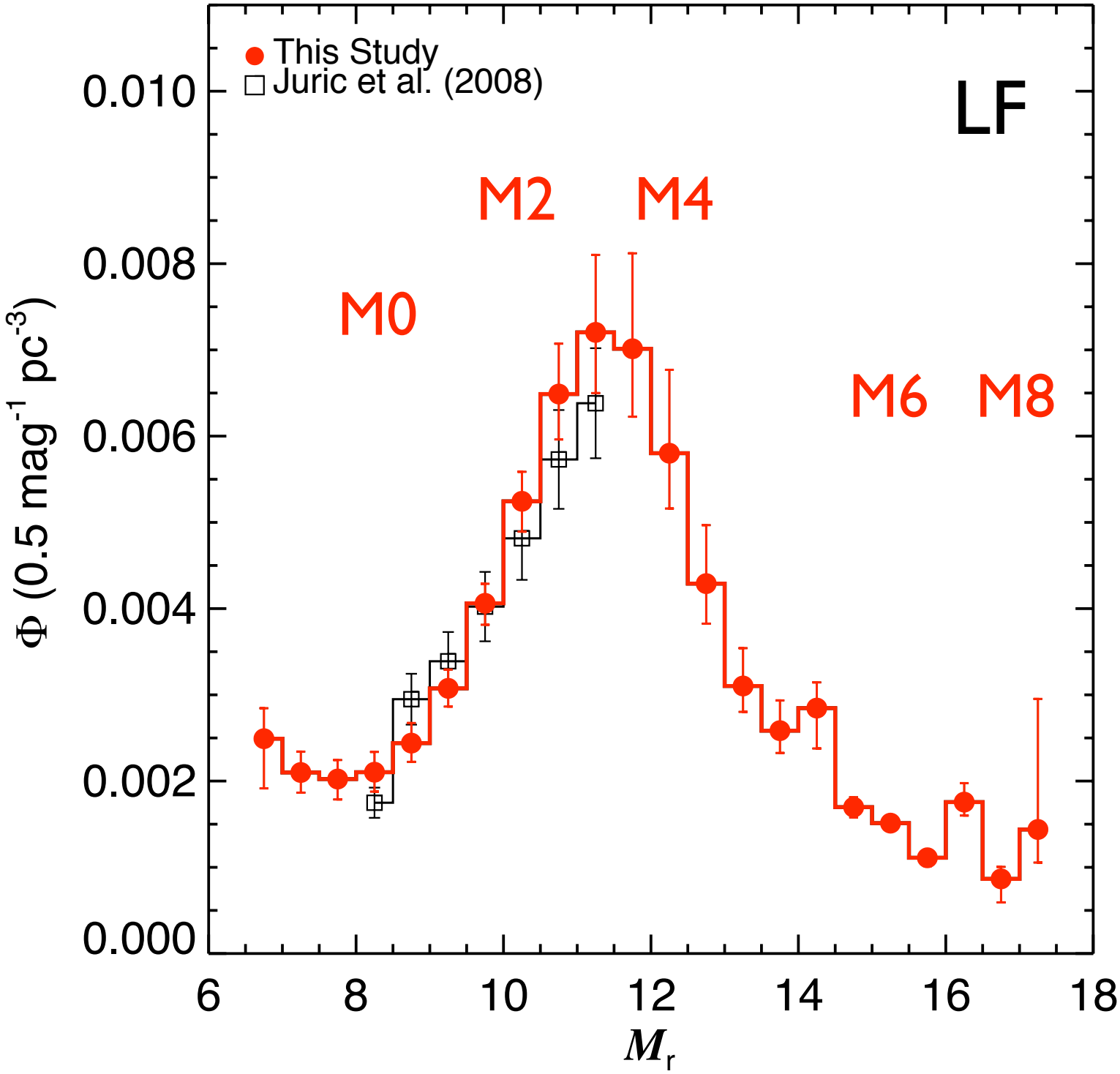

Log(Model)
M_r =9.75
2000
1000
0
-1000
-2000
-3000
Z (pc)
6000
7000
8000
9000
10000
11000
R (pc)
-5
-4
-3
-2
$\rho = \rho_o (f\, e^{(R/L_1)} e^{(-|Z|/H_1)} + (1-f) e^{(R/L_2)} e^{(-|Z|/H_2)})$

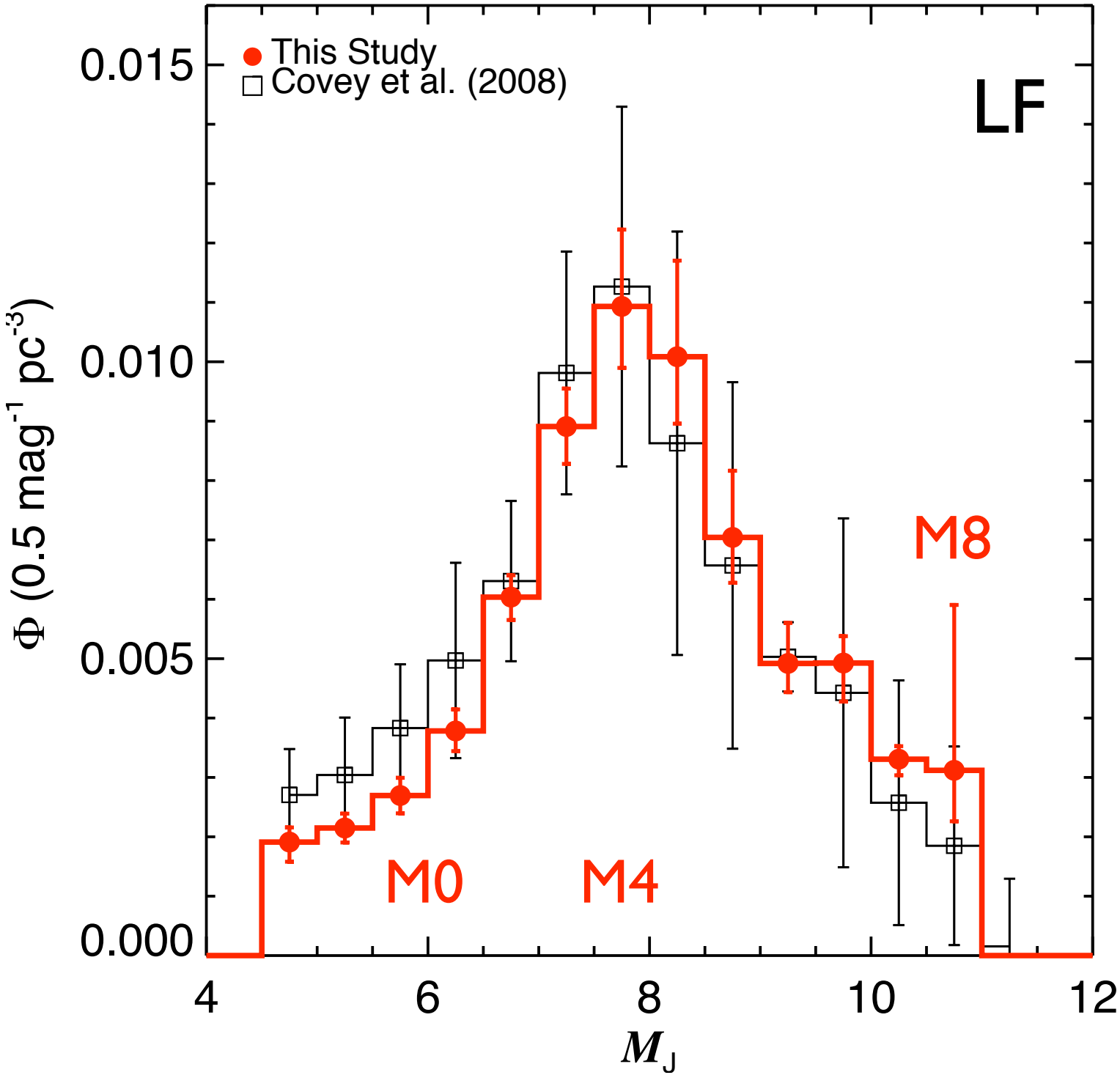

Galactic
Z
Absolute
Magnitude
Galactic R

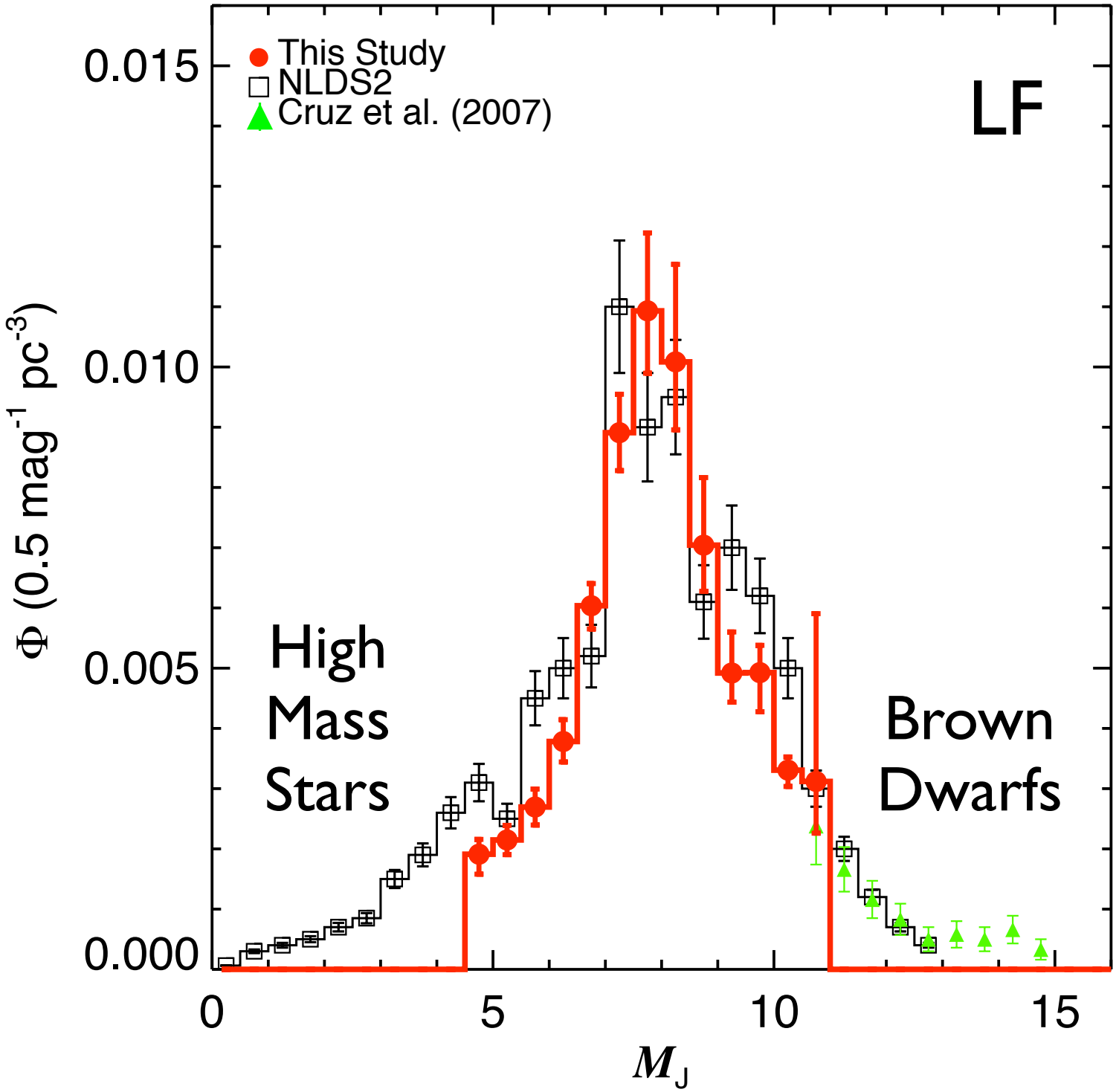

Galactic
Z
Galactic R
Absolute
Magnitude


Φ = dN/dL
Galactic Z
Galactic R
Absolute Magnitude


Mean
M_r - r-z
M_r - r-i
M_r - r-i, Metal Correction
M_r - r-z, Metal Correction
M_r - r-z, No Extinction Correction
LF
M0
M2
M4
M6
M8
0.010
0.008
0.006
0.004
0.002
0.000
6
8
10
12
14
16
18
Φ (0.5 mag^{-1} pc^{-3})
M_r


This Study
Juric et al. (2008)
LF
M0
M2
M4
M6
M8
0.010
0.008
0.006
0.004
0.002
0.000
6
8
10
12
14
16
18
Φ (0.5 mag^{-1} pc^{-3})
M_r


This Study
Covey et al. (2008)
LF
M0
M4
M8
0.015
0.010
0.005
0.000
4
6
8
10
12
Φ (0.5 mag^{-1} pc^{-3})
M_J

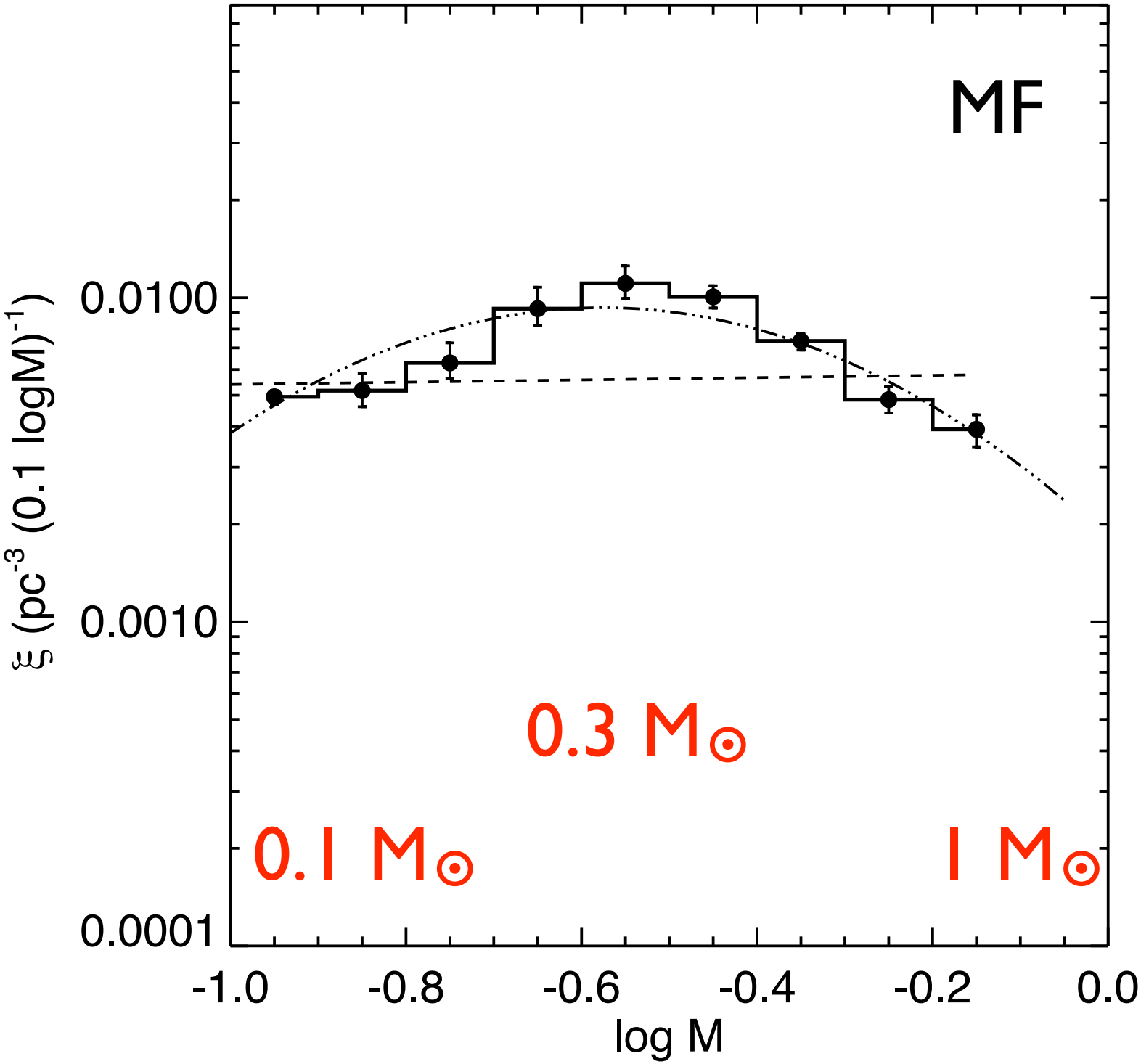

This Study
NLDS2
Cruz et al. (2007)
LF
High Mass Stars
Brown Dwarfs
0.015
0.010
0.005
0.000
0
5
10
15
Φ (0.5 mag^{-1} pc^{-3})
M_J

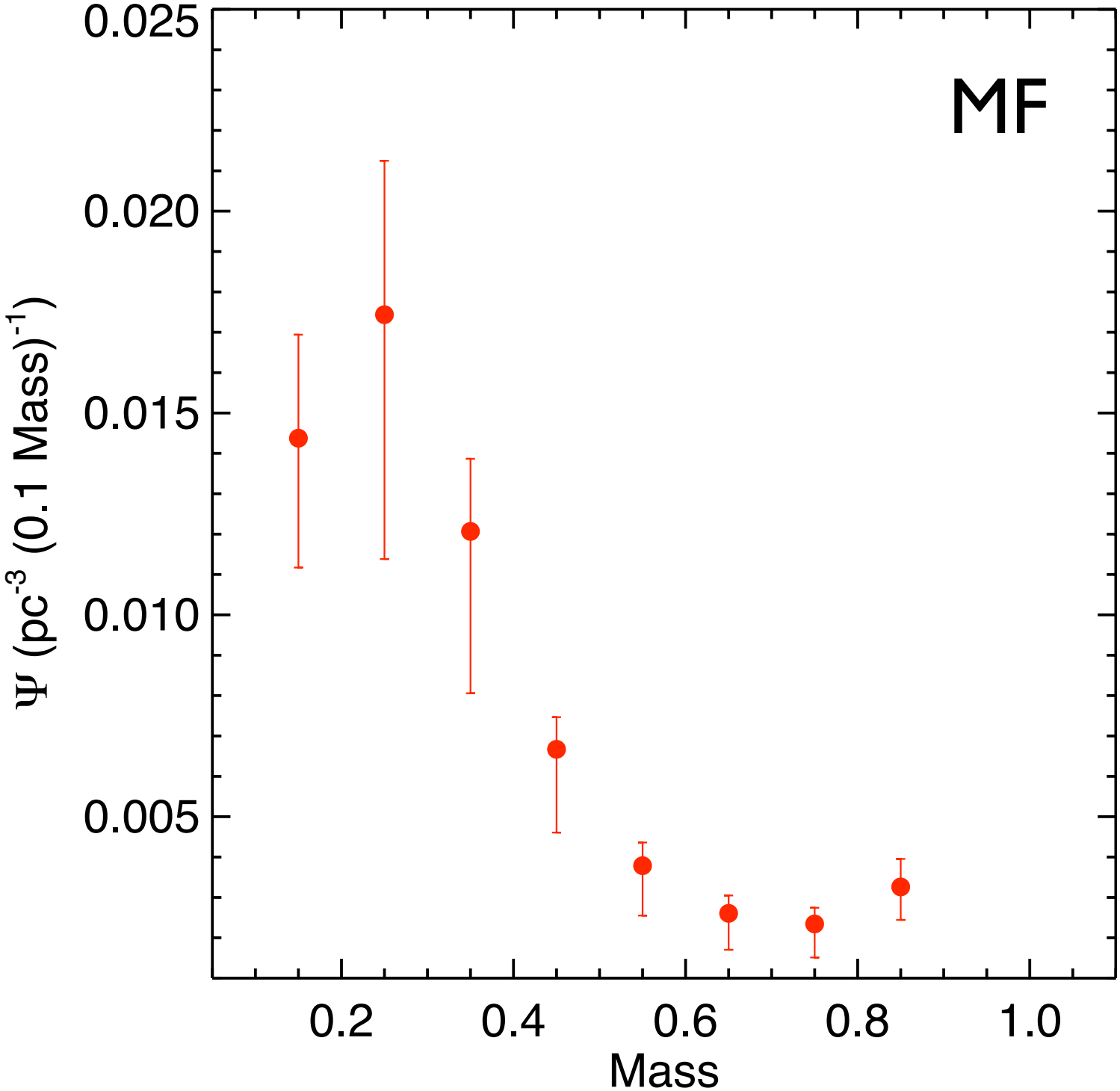
Outline

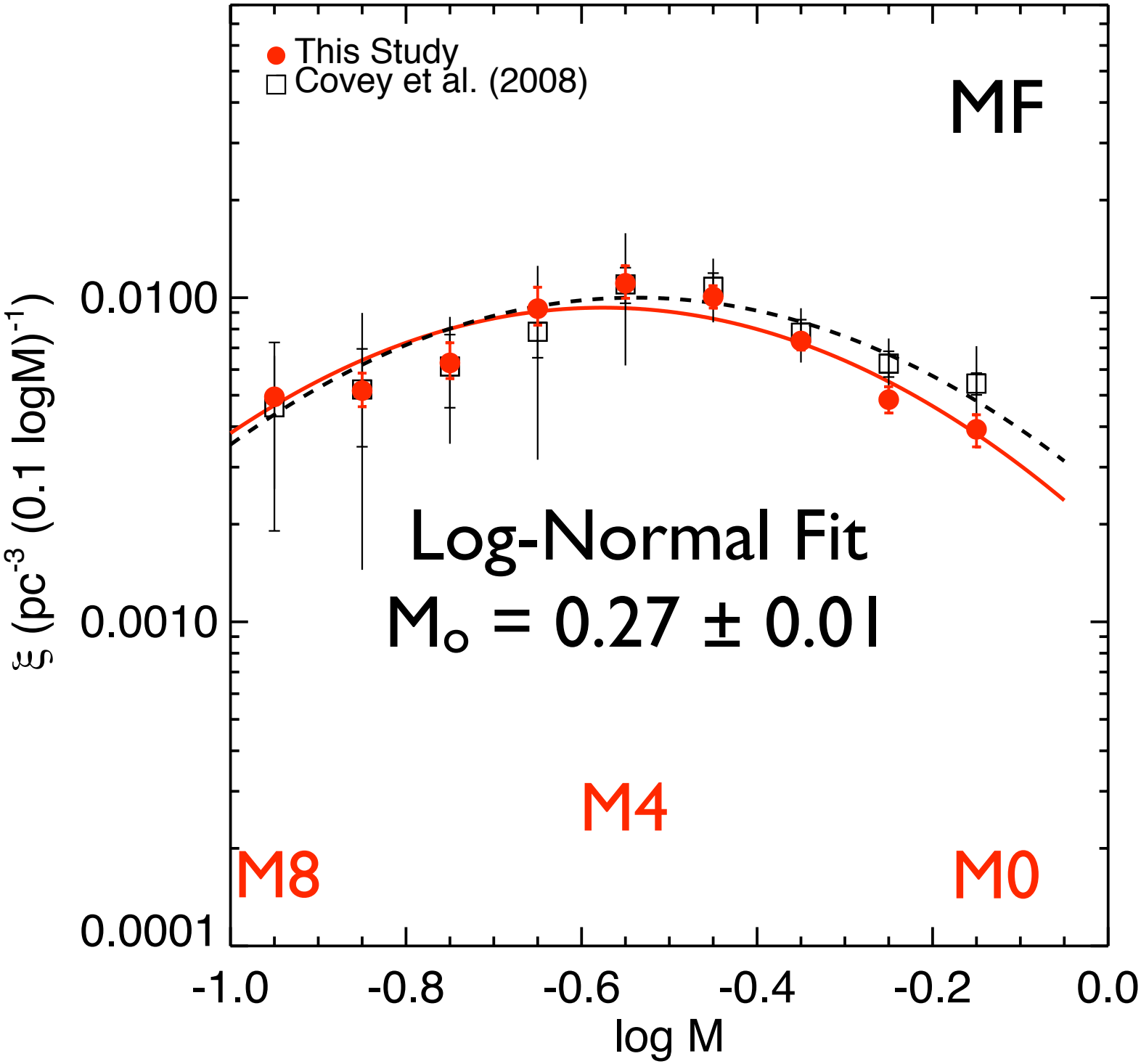
- M Dwarfs 101
- The Luminosity Function
- The Mass Function
- Conclusions

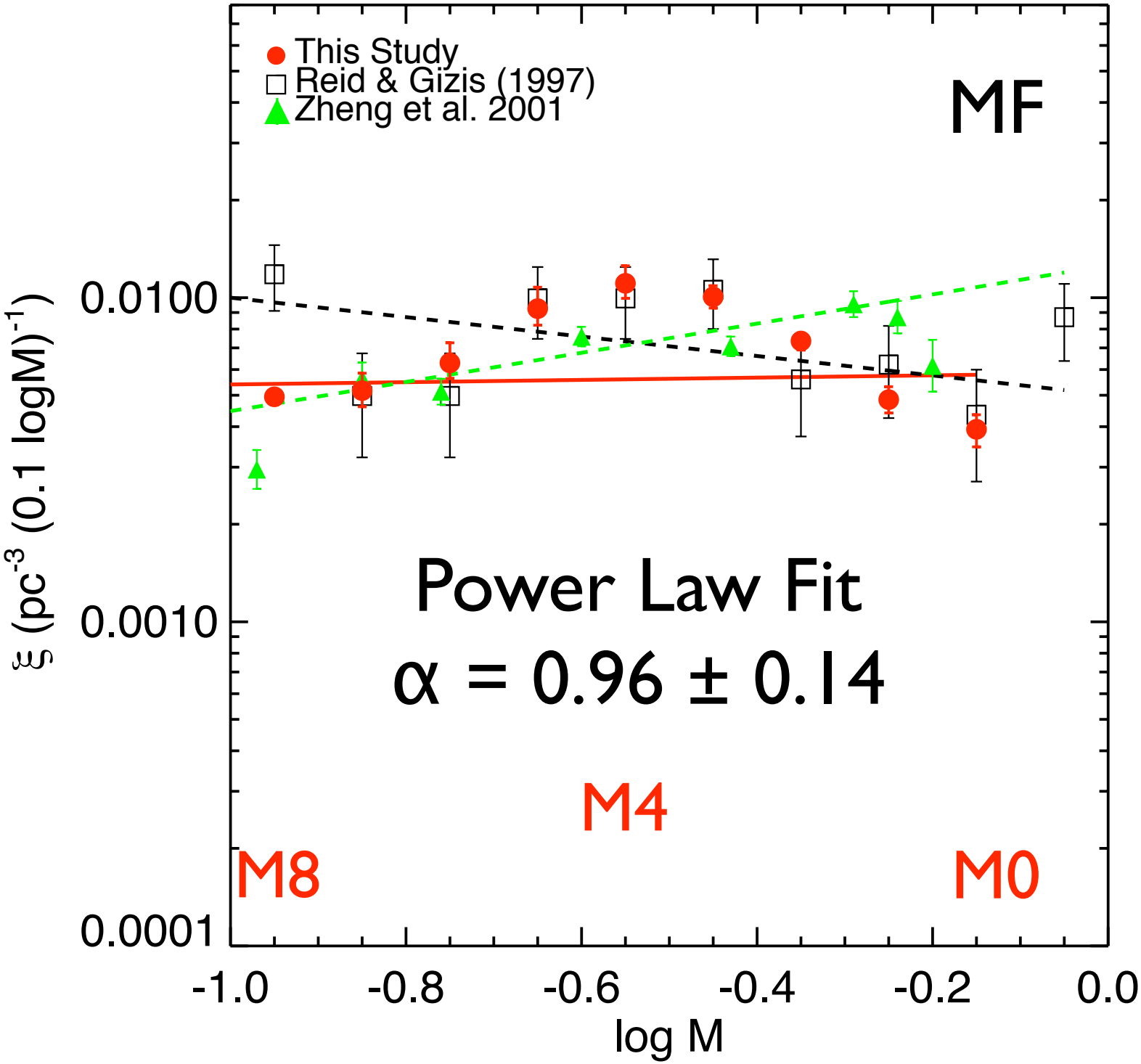
Mass Function

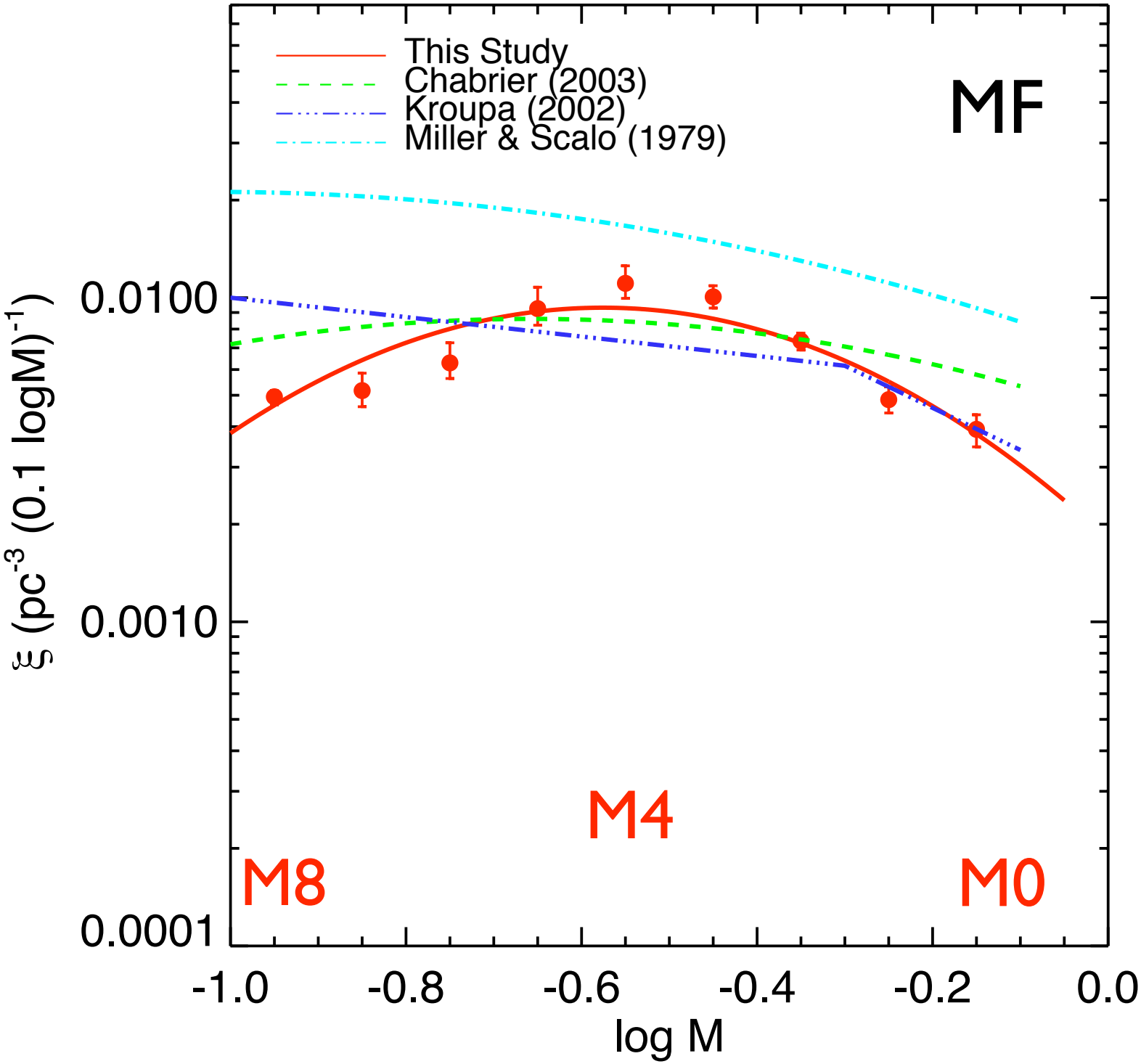
- Use Mass - Luminosity Relations measured from eclipsing binaries (Delfosse et al. 2000)
- Converted from M_J LF


MF
0.0100
0.0010
0.0001
ξ (pc^{-3} (0.1 logM)$^{-1}$)
0.3 M⊙
0.1 M⊙
1 M⊙
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
log M


MF
0.025
0.020
0.015
0.010
0.005
Ψ (pc^{-3} (0.1 Mass)$^{-1}$)
0.2
0.4
0.6
0.8
1.0
Mass


This Study
Covey et al. (2008)
MF
Log-Normal Fit
$M_o = 0.27 \pm 0.01$
M8
M4
M0
0.0100
0.0010
0.0001
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
log M
ξ (pc^{-3} (0.1 logM)$^{-1}$)


This Study
Reid & Gizis (1997)
Zheng et al. 2001
MF
Power Law Fit
α = 0.96 ± 0.14
M4
M8
M0
0.0100
0.0010
0.0001
ξ (pc^-3 (0.1 logM)^-1)
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
log M


This Study
Chabrier (2003)
Kroupa (2002)
Miller & Scalo (1979)
MF
M8
M4
M0
0.0100
0.0010
0.0001
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
log M
ξ (pc^{-3} (0.1 logM)$^{-1}$)

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