The Stellar Low-Mass IMF: SDSS Observations of 15 Million M Dwarfs

John Bochanski (Penn State)
Origins of Stellar Masses
October 21st, 2010

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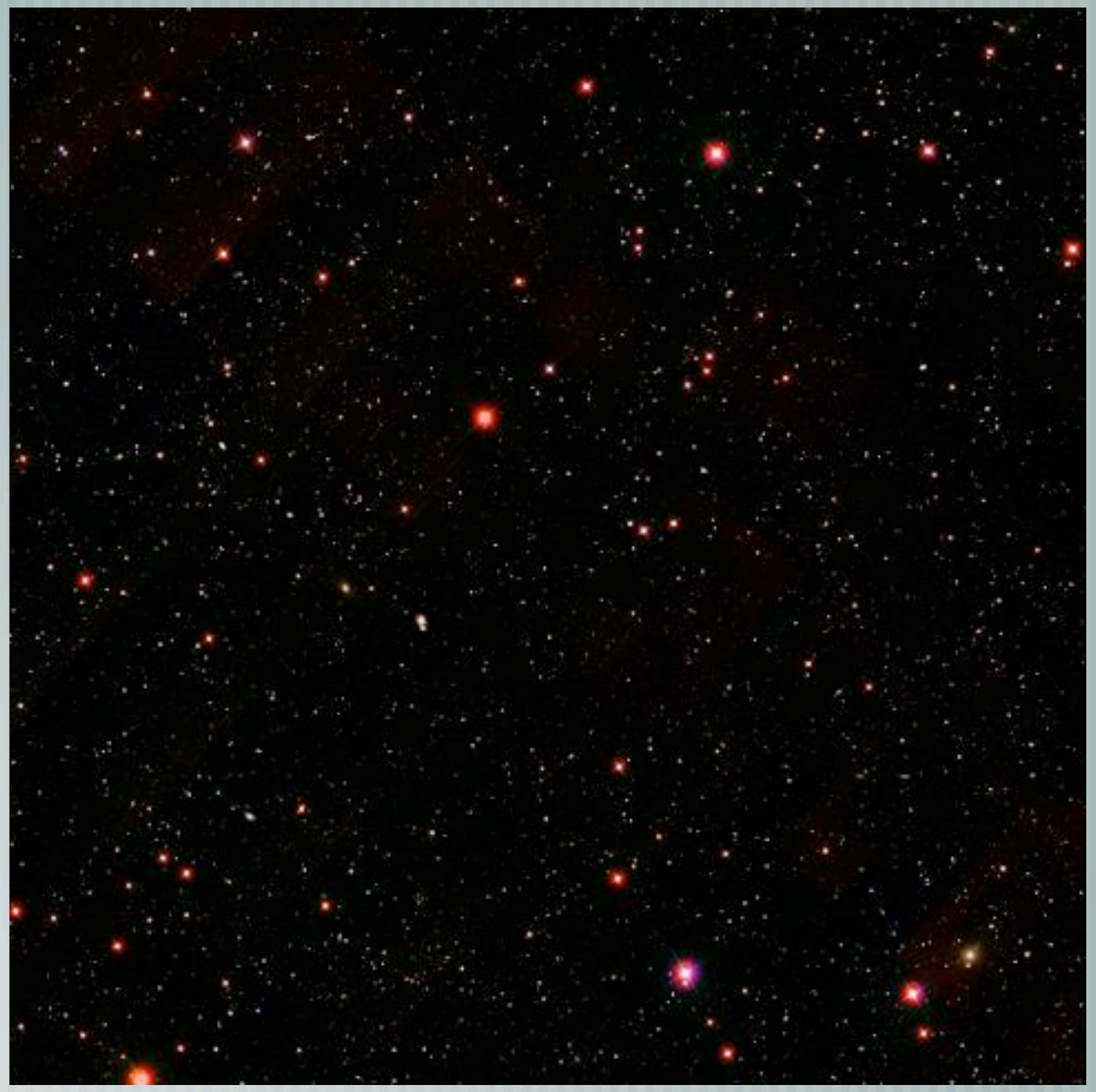
Andrew West (BU), Neill Reid (STScI)

Talking Points

- The field is a good place to measure the IMF
- Small samples are no longer the norm for low-mass stars
- M dwarfs are important tracers of Galactic structure and kinematics

The field is a good place to measure the IMF of M dwarfs.

Clusters vs. The Field



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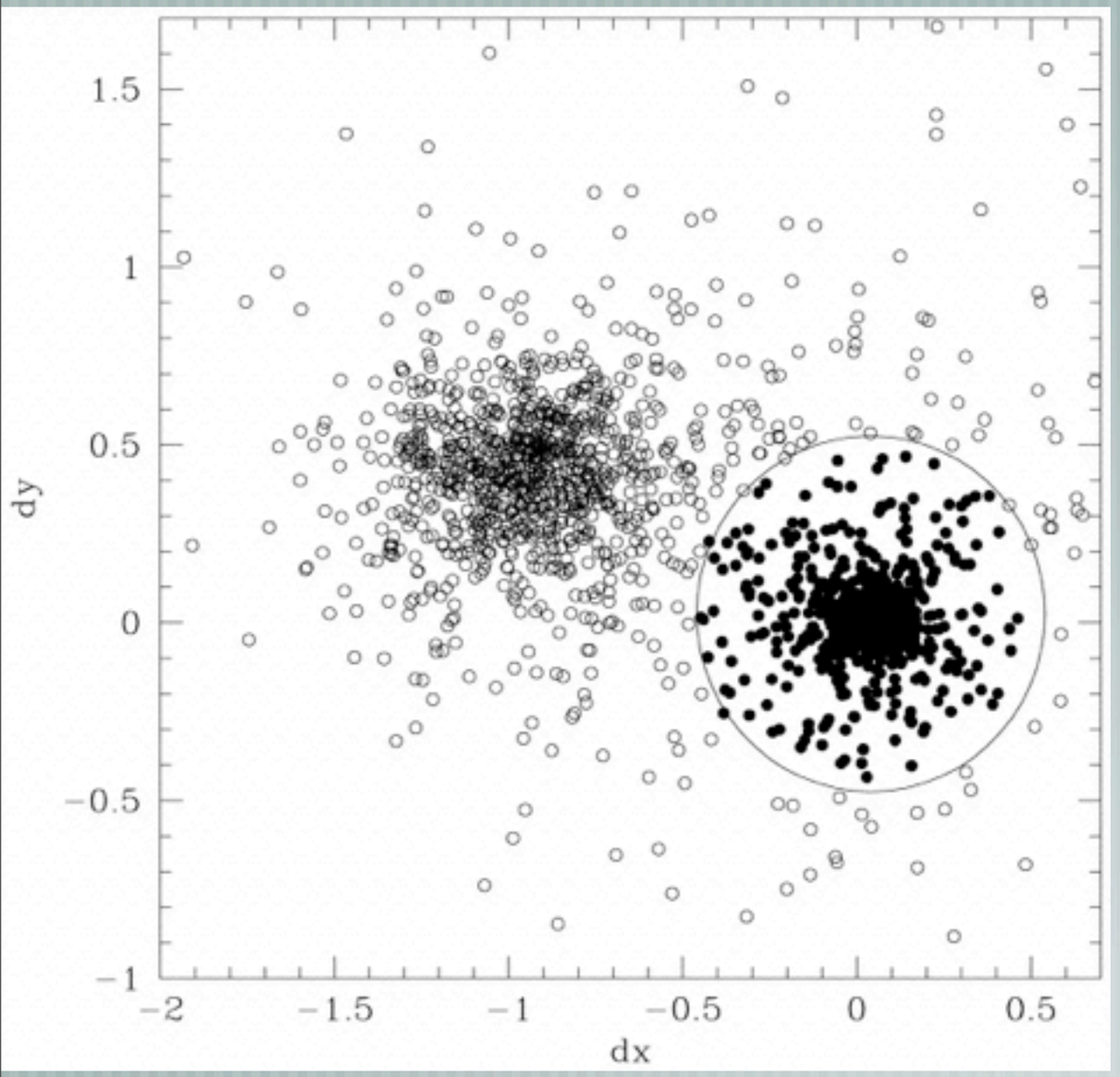

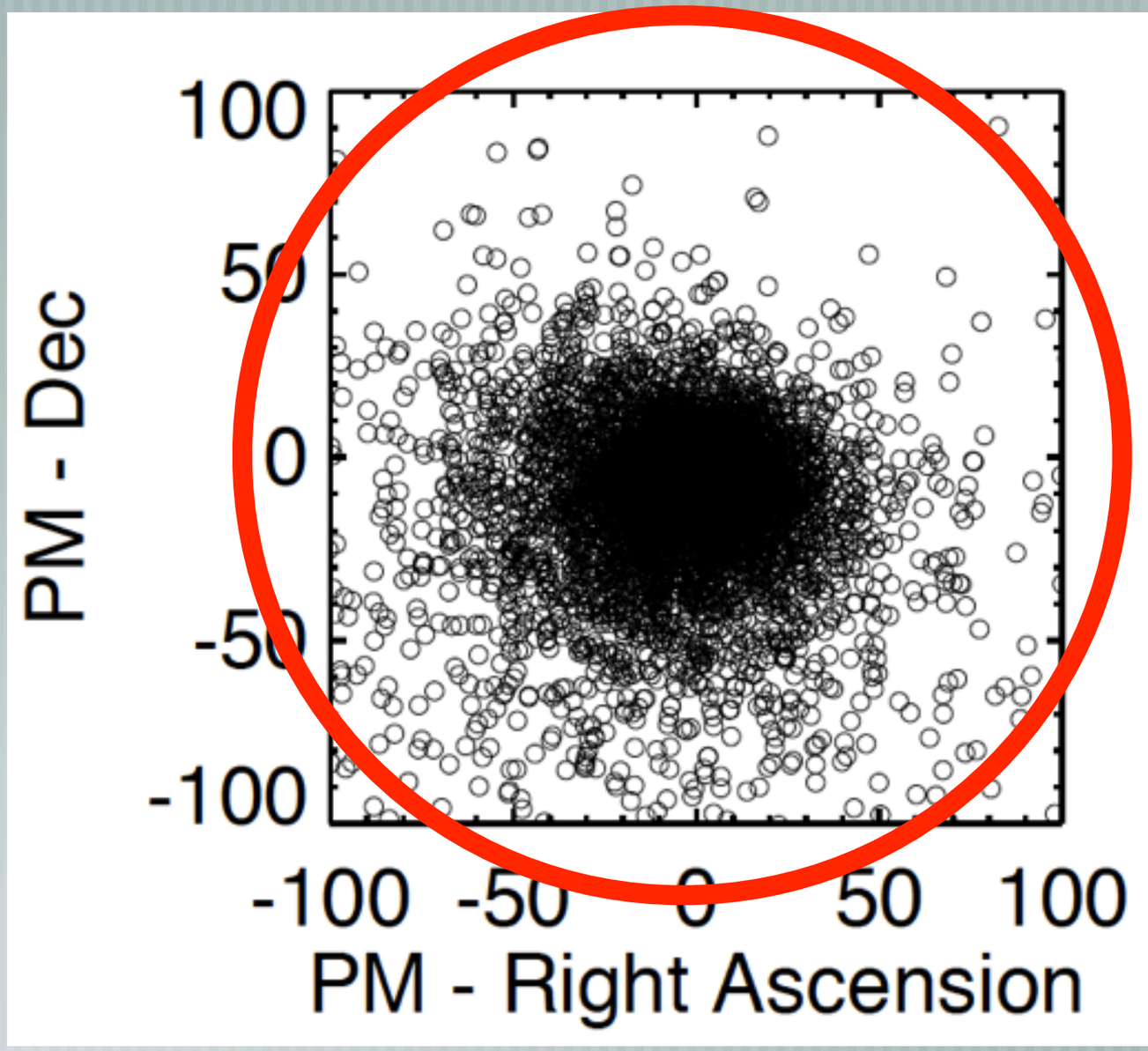

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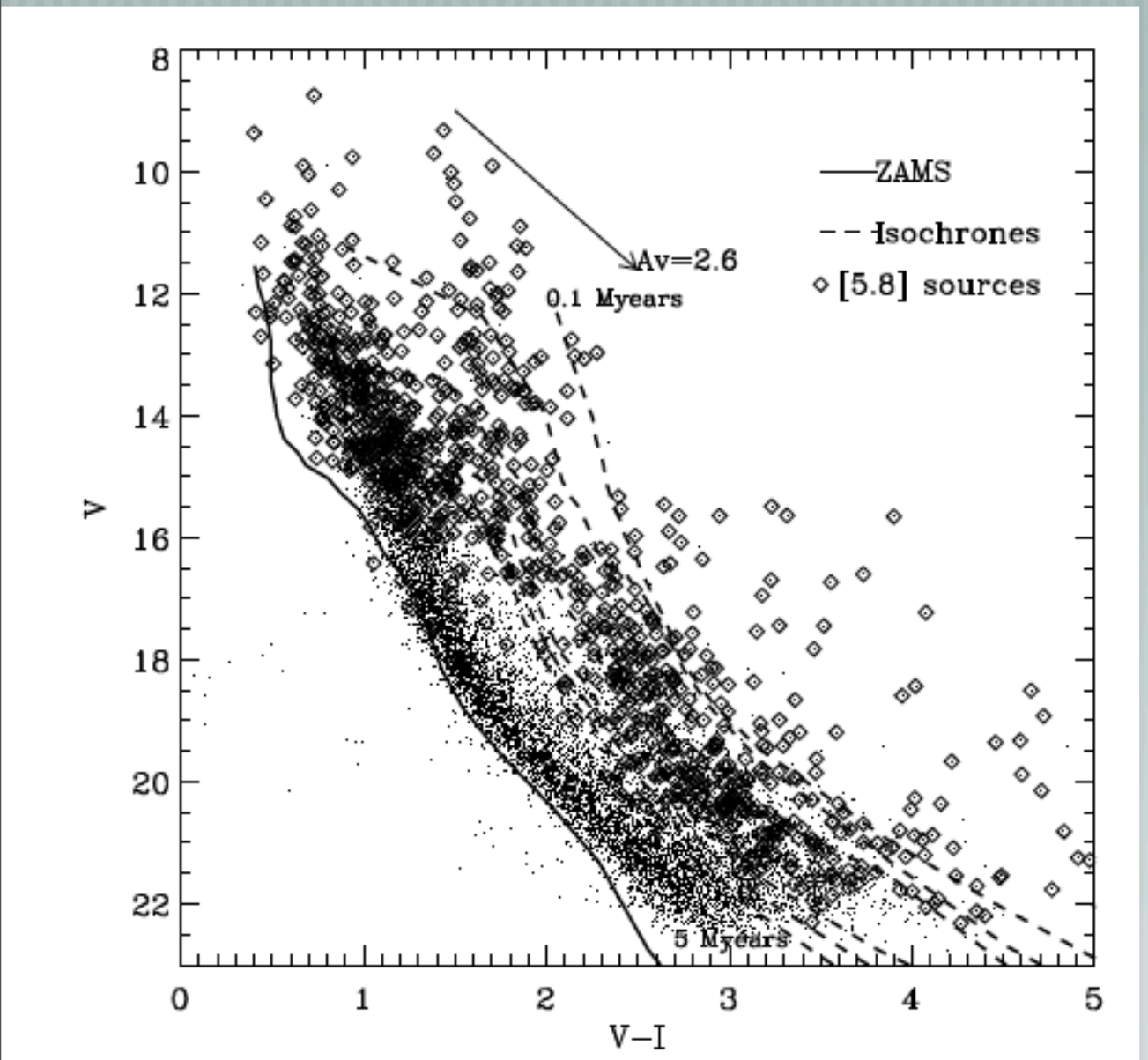
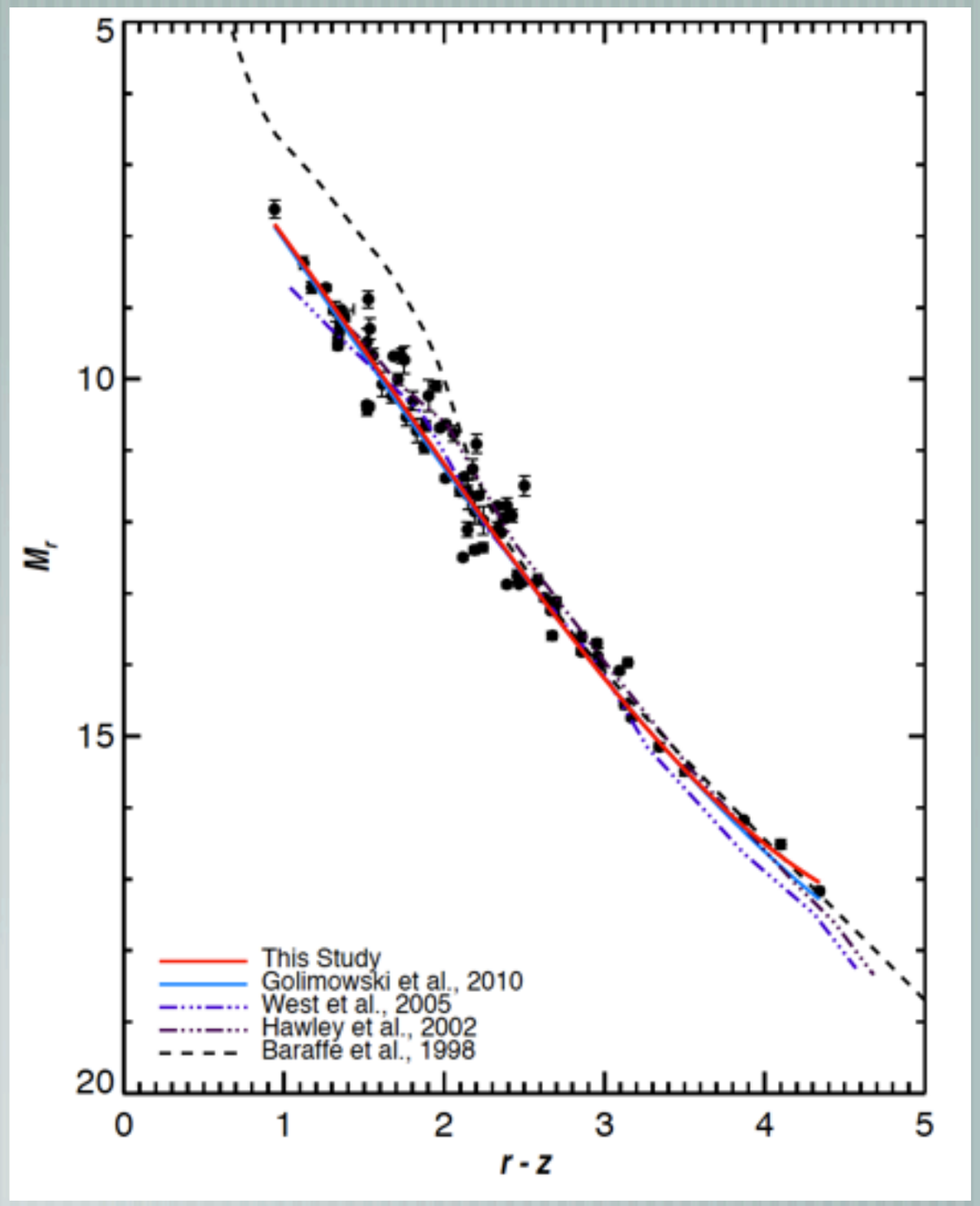
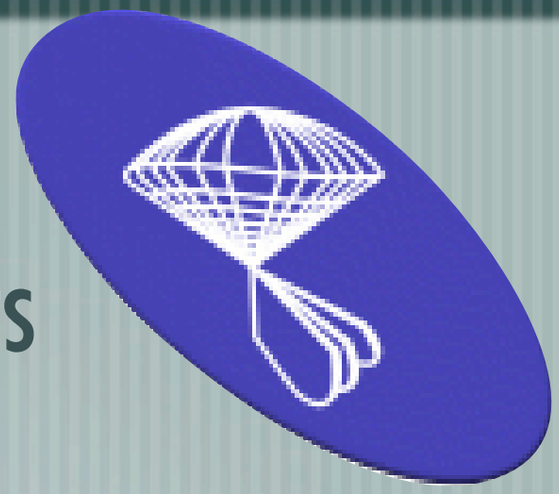


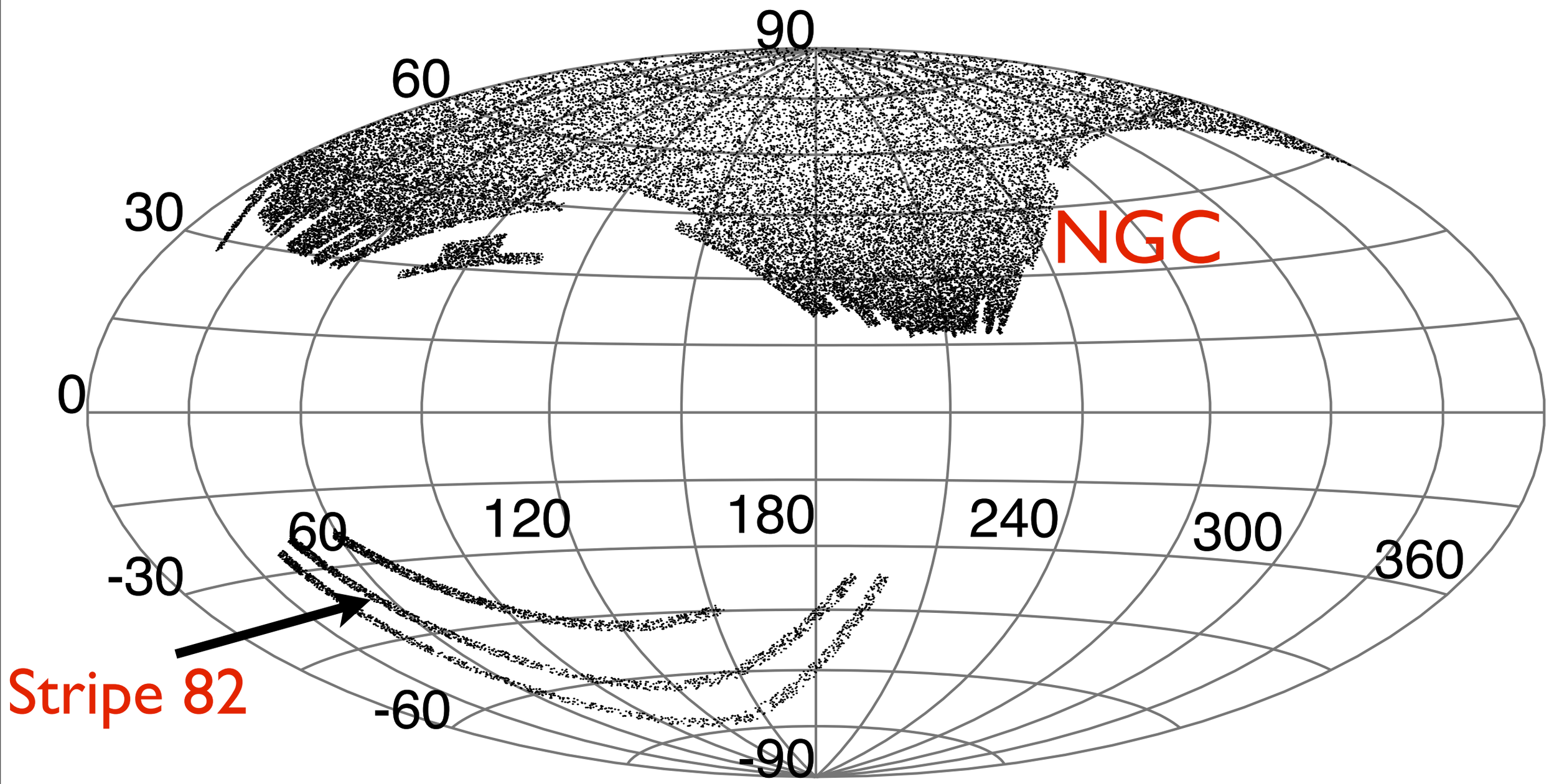


Sloan Digital Sky Survey



- Latest Data Release (DR7)
  - 357 million photometric objects
    - Over 30 million M dwarfs (Bochanski et al. 2010)
  - 1.6 million spectra
    - 70,000 M dwarfs (West et al. 2010)
- SLoWPoKES - 1,300 binaries (Dhital et al. 2010)

SDSS Sky Coverage - Galactic Coordinates

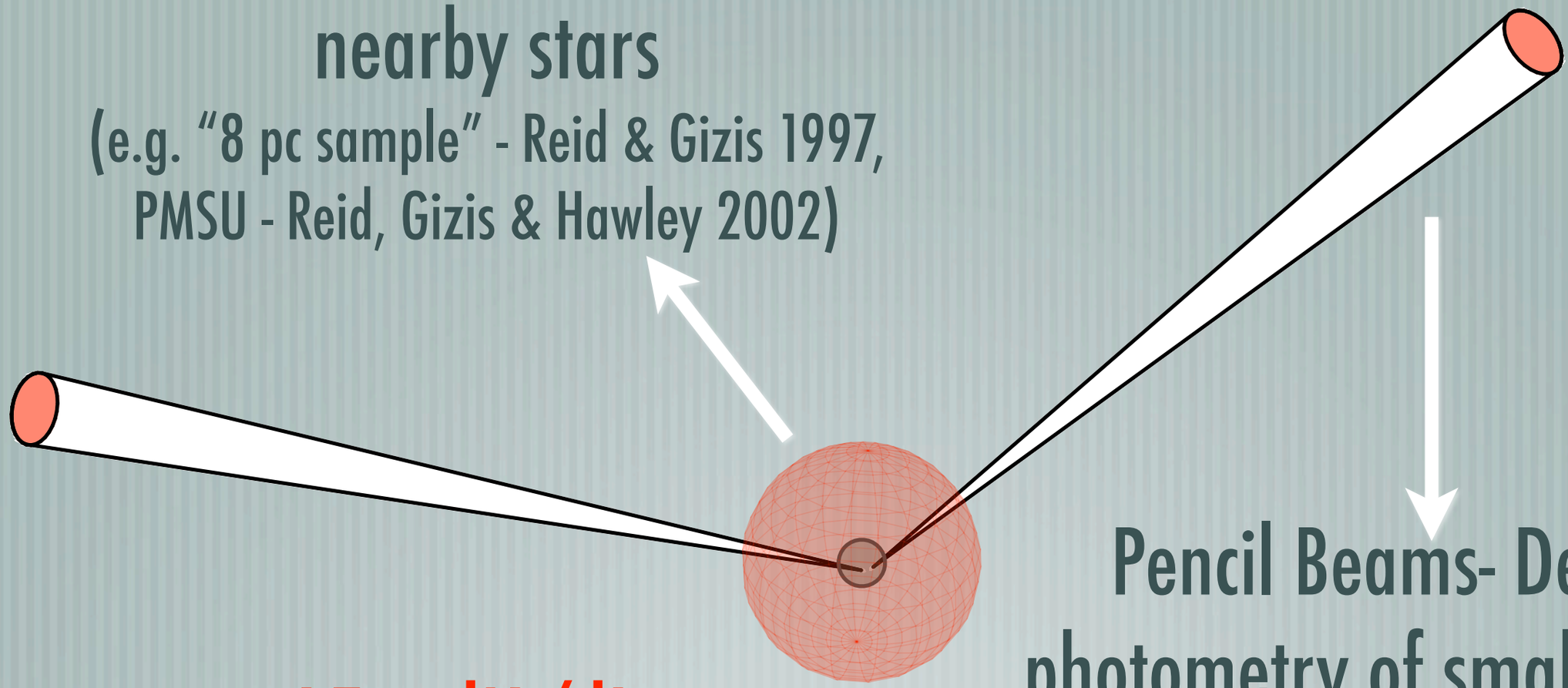


1 x 1 degree - 1 mag fainter per frame

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)



$LF = dN/dL$

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

Pencil Beams- Deep photometry of small solid angles

(e.g. Martini & Osmer 1998, Zheng et al. 2001)

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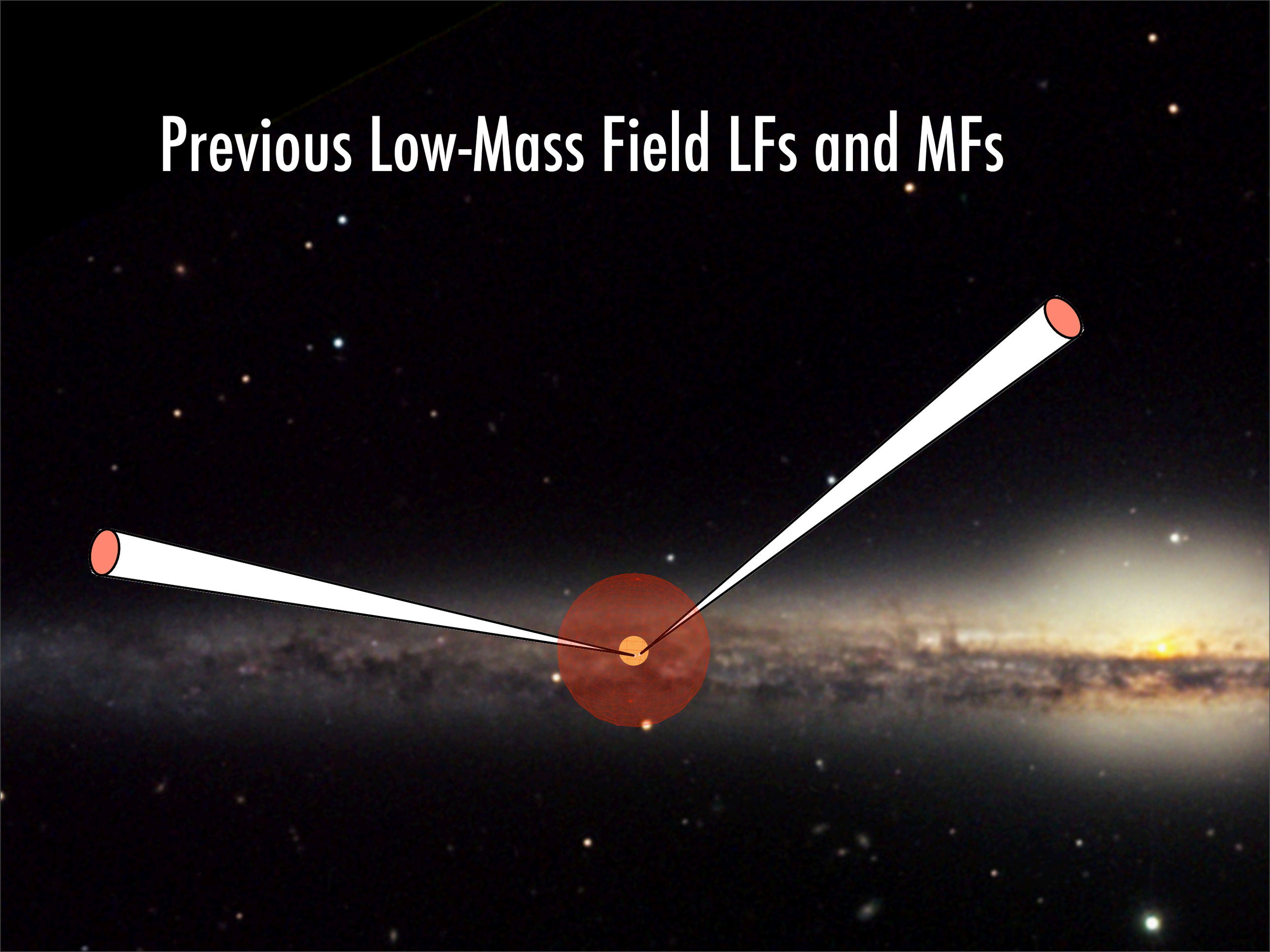
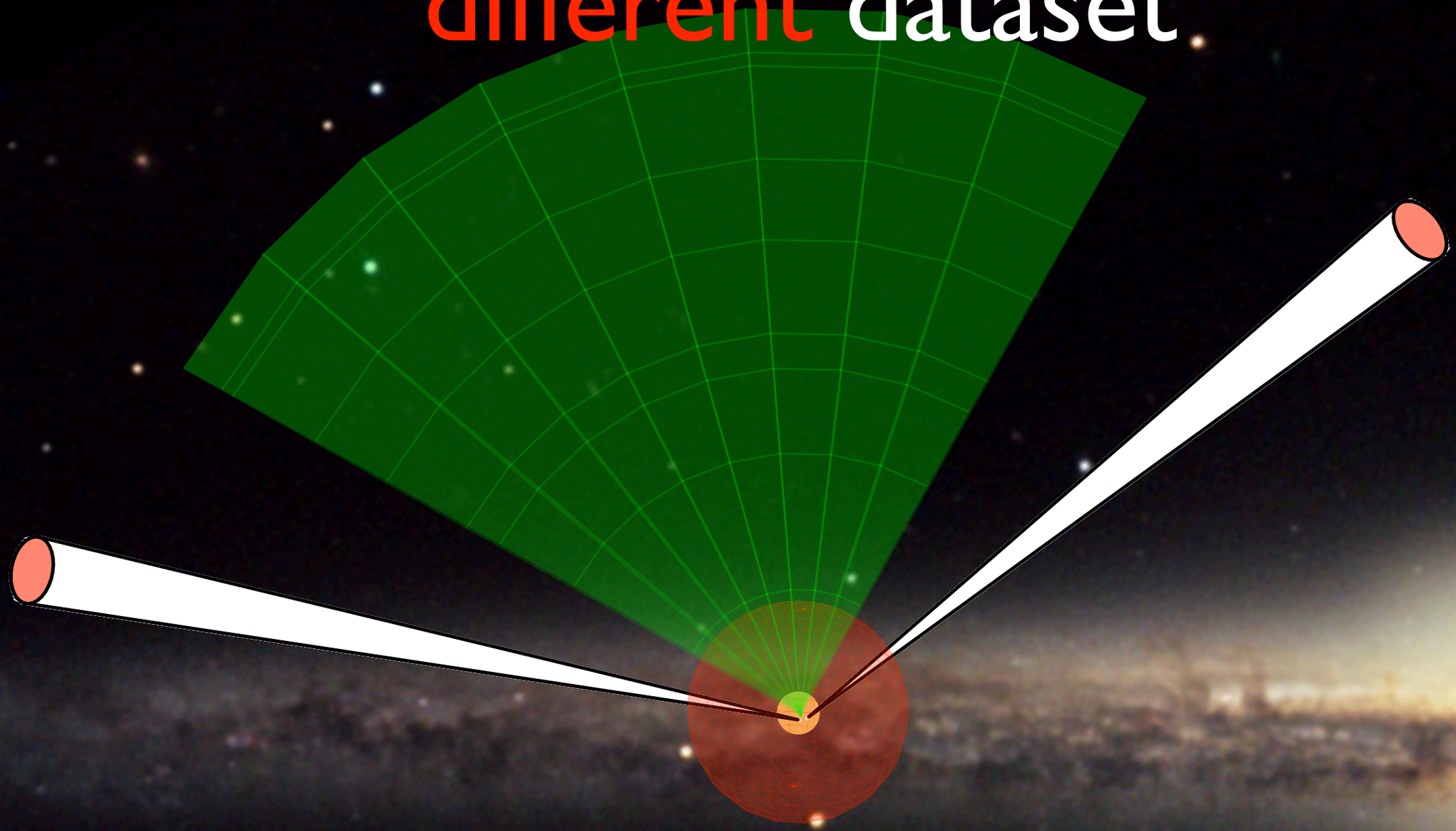


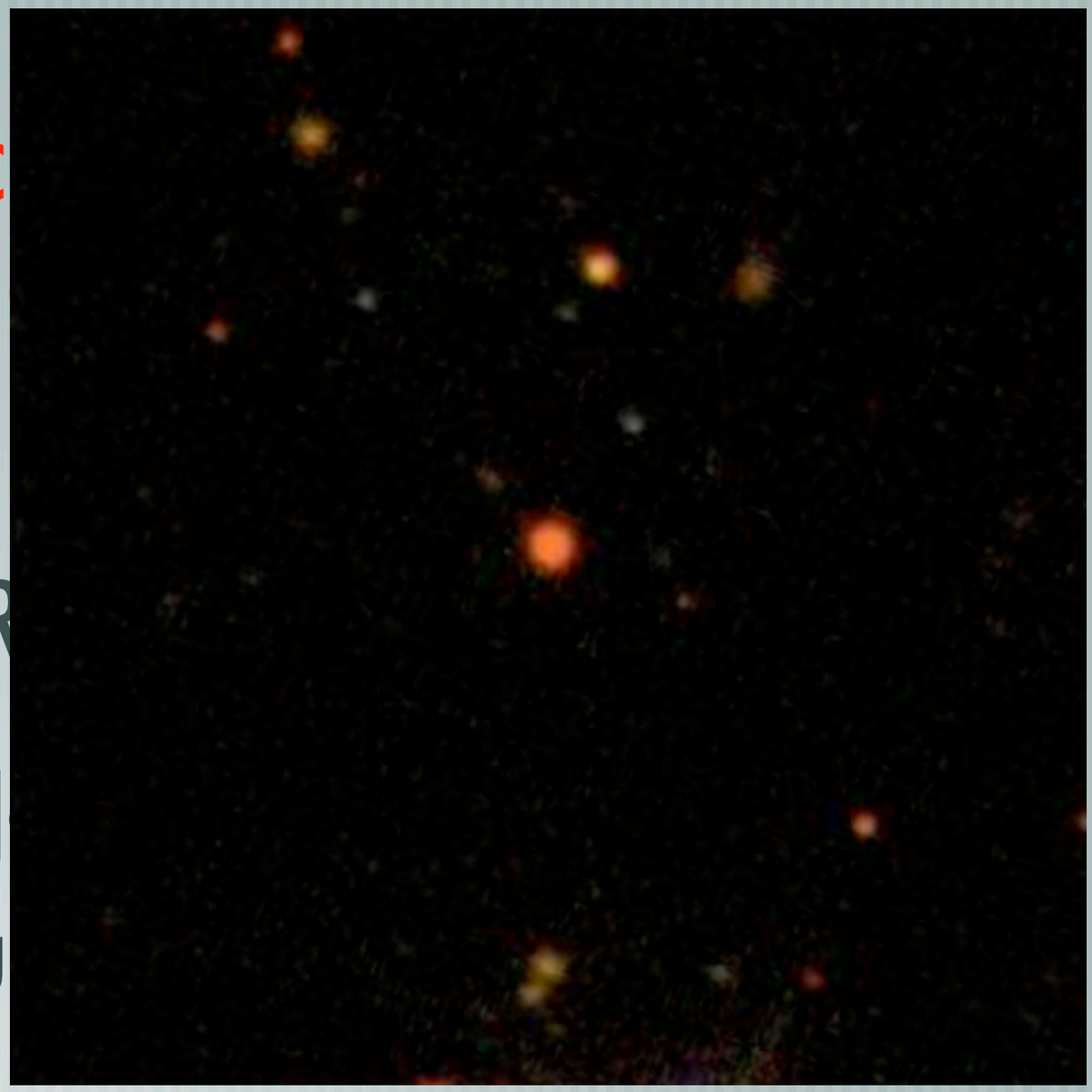
SDSS offers a fundamentally different dataset



Luminosity Function Issues

- Contamination - Only count low-mass stars
  Covey et al. 2008 found < 2-3%
- Accurate distances are necessary -
  New Color-Magnitude Relations (Bochanski et al. 2010)
- Galactic structure needs to be taken into account -
  Measured simultaneously (also see Juric et al. 2008)

Luminosity Function Issues



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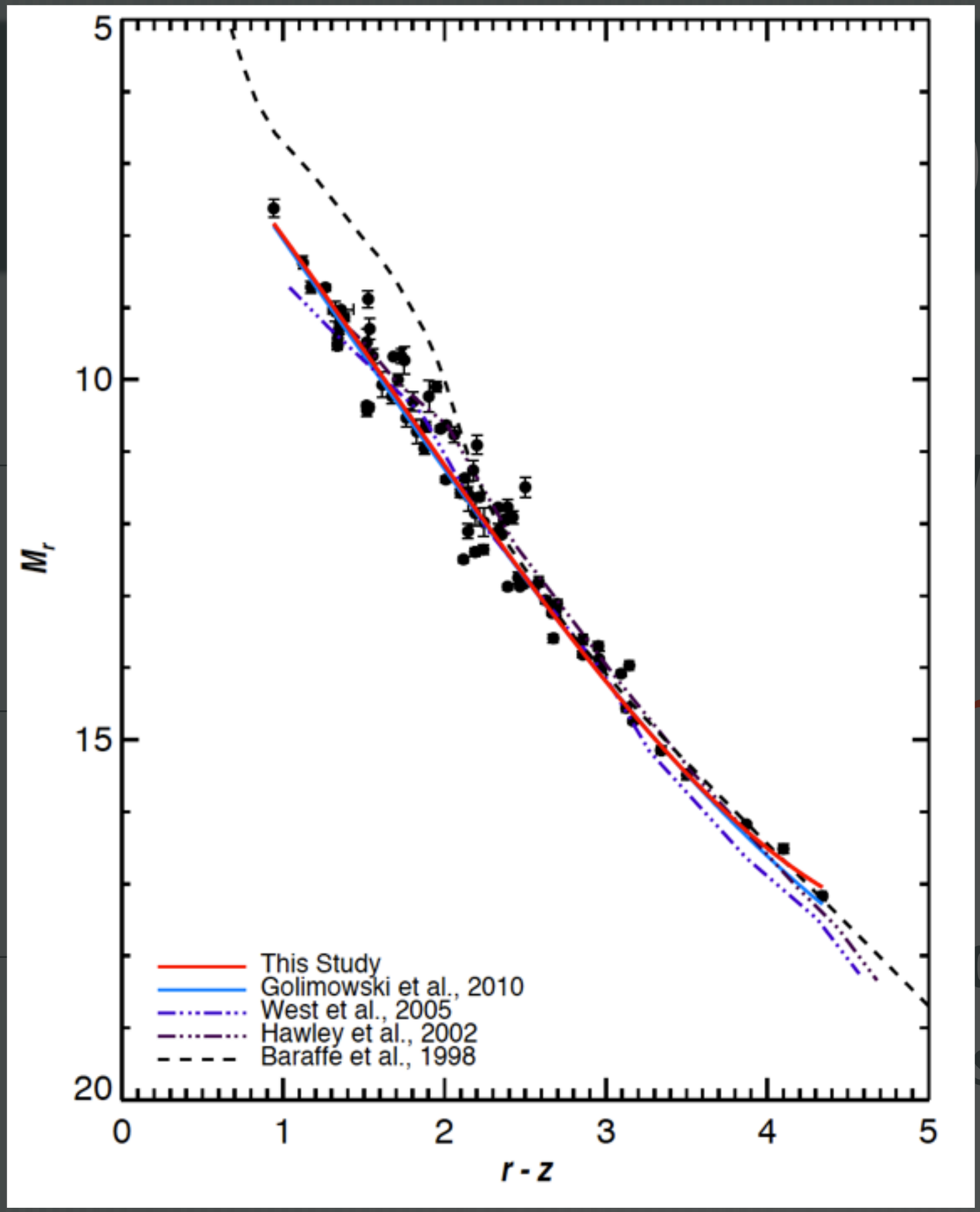
-mass stars

y -

(Bochanski et al. 2010)

aken into account -

see Juric et al. 2008)



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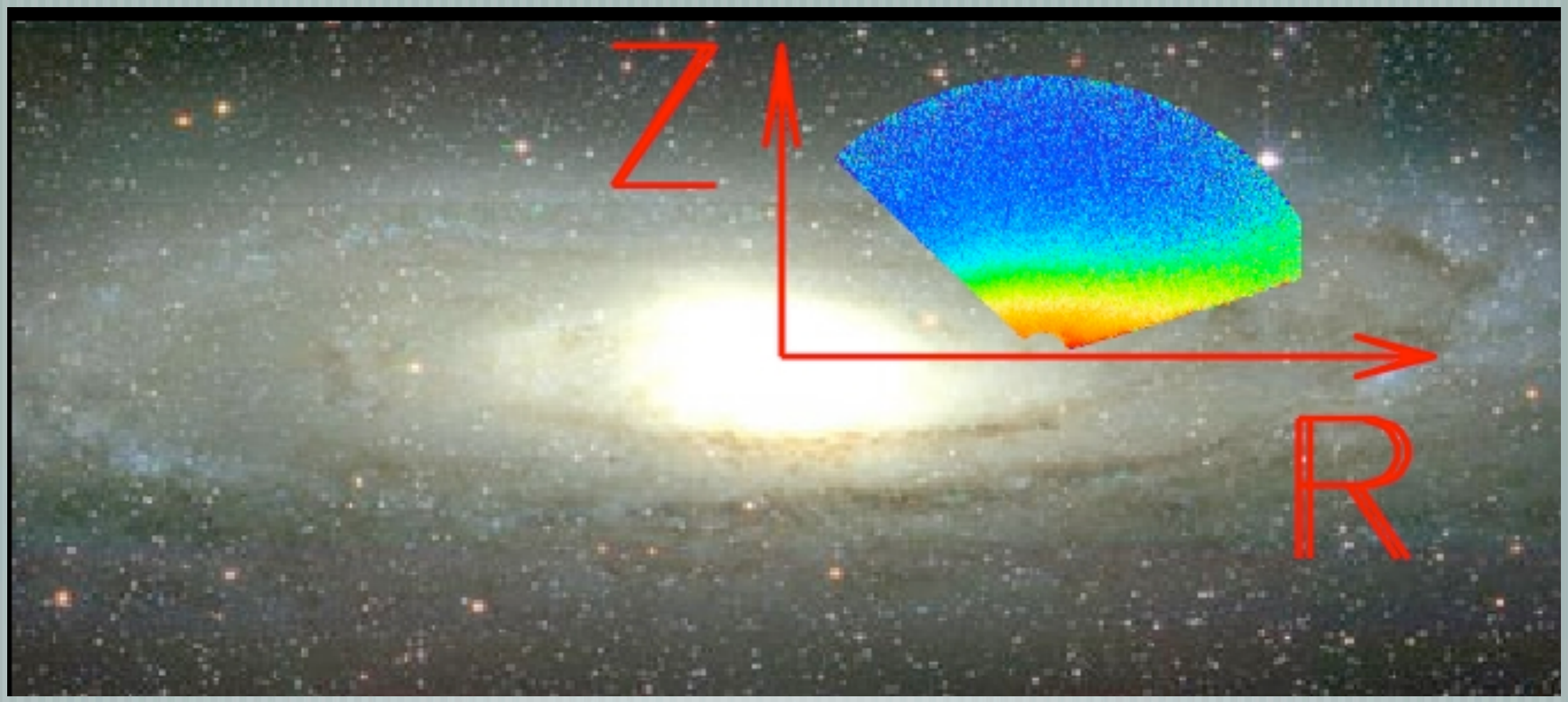
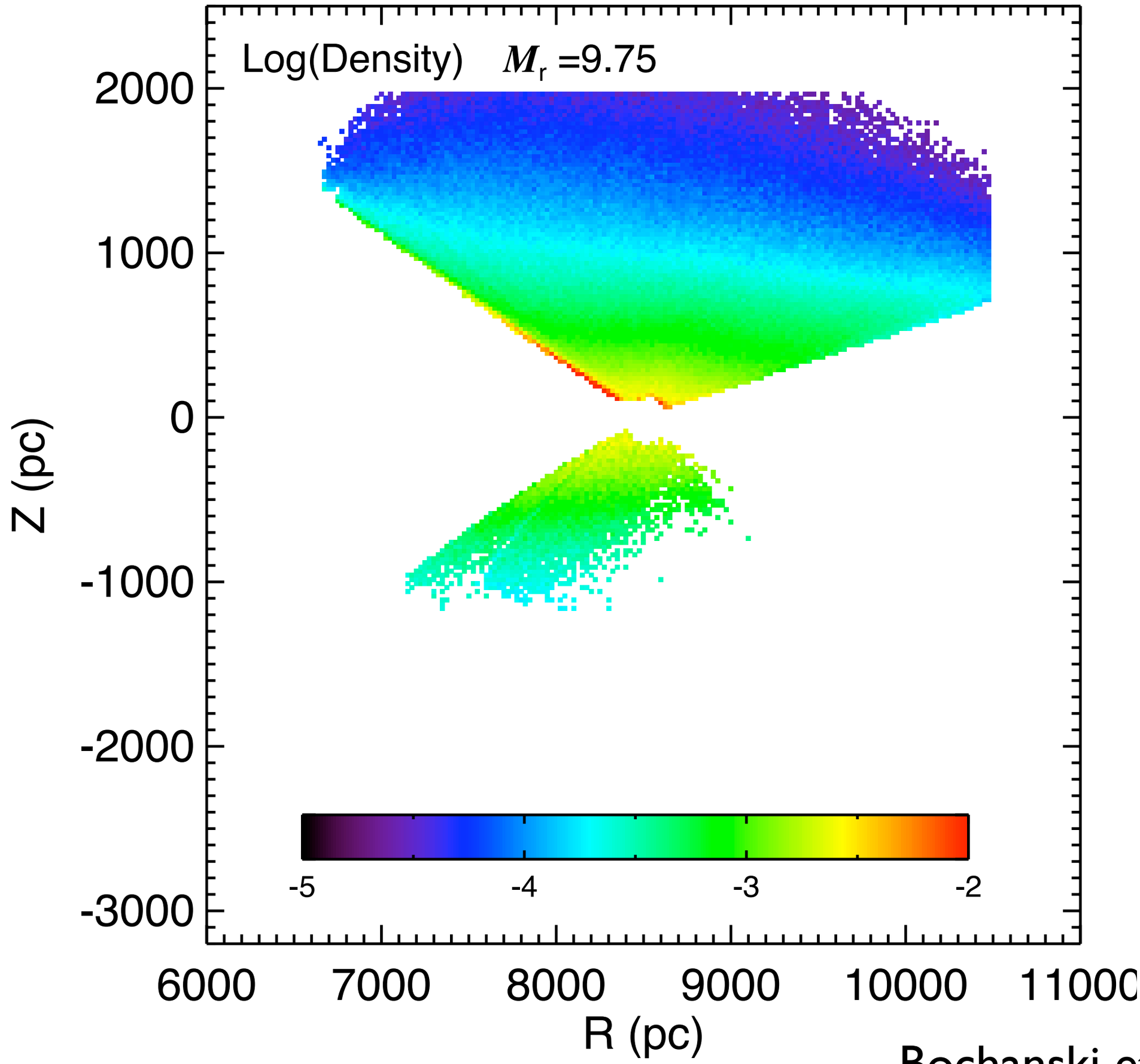
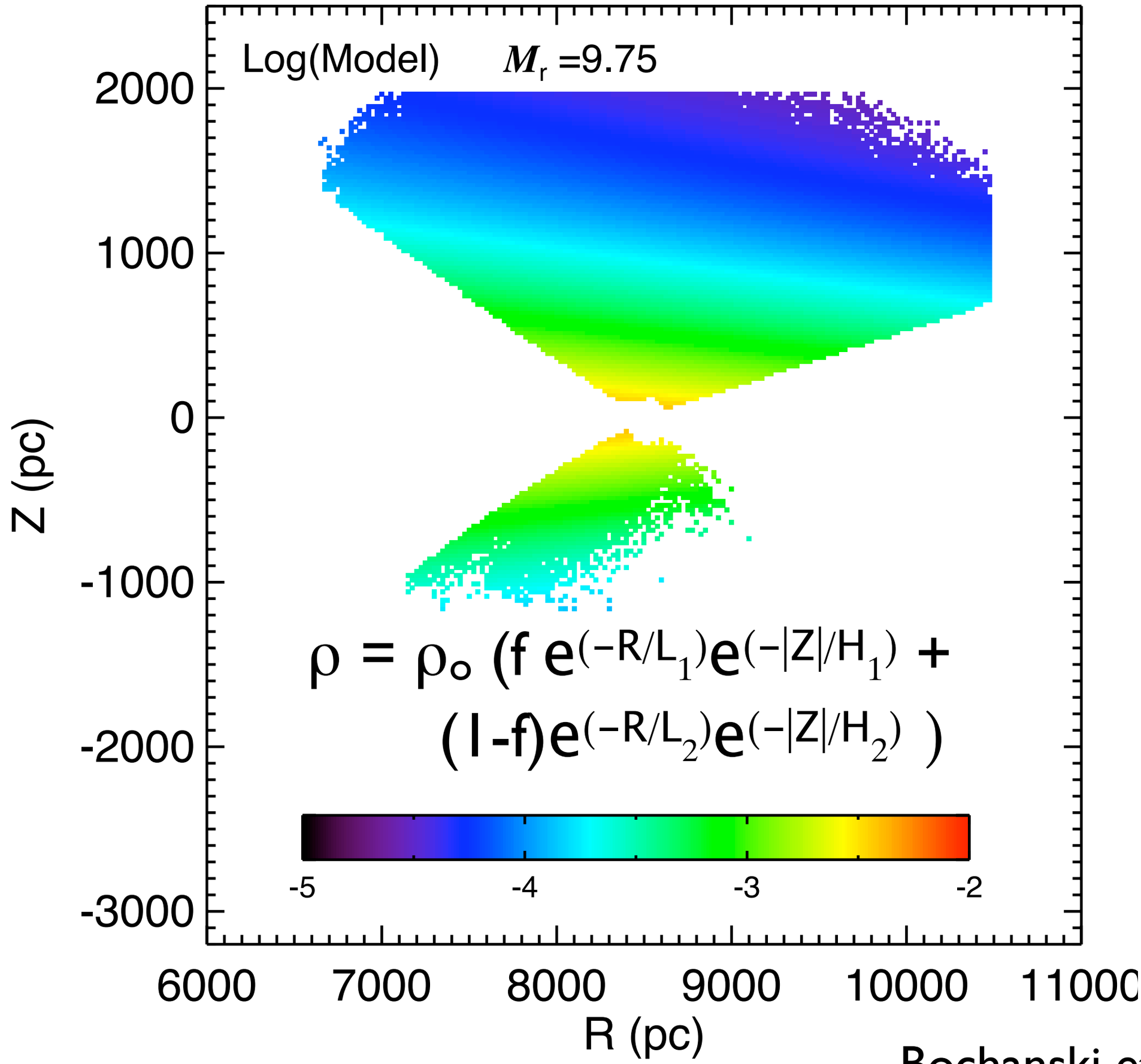

Z
R

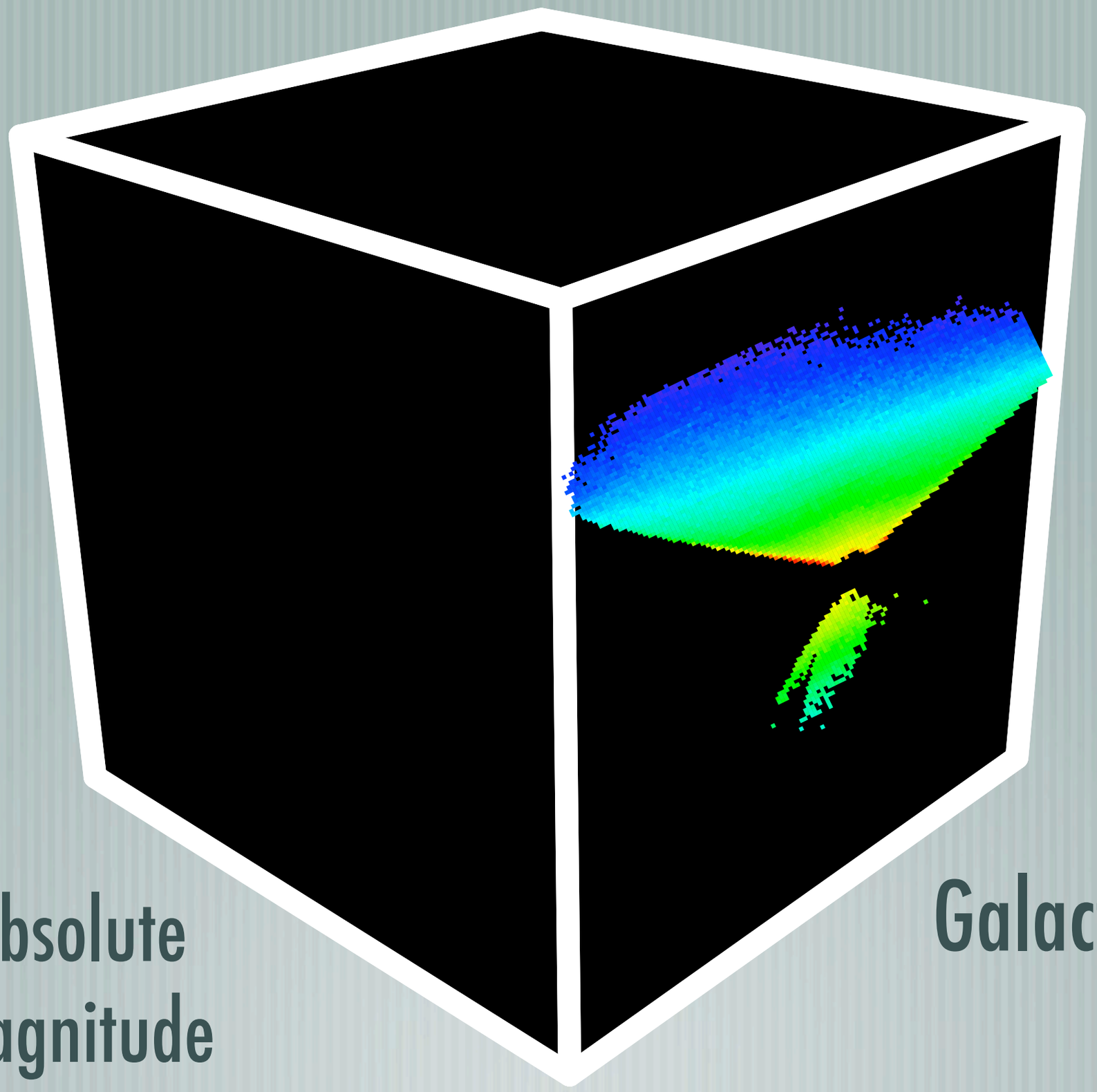


Bochanski et al. 2010



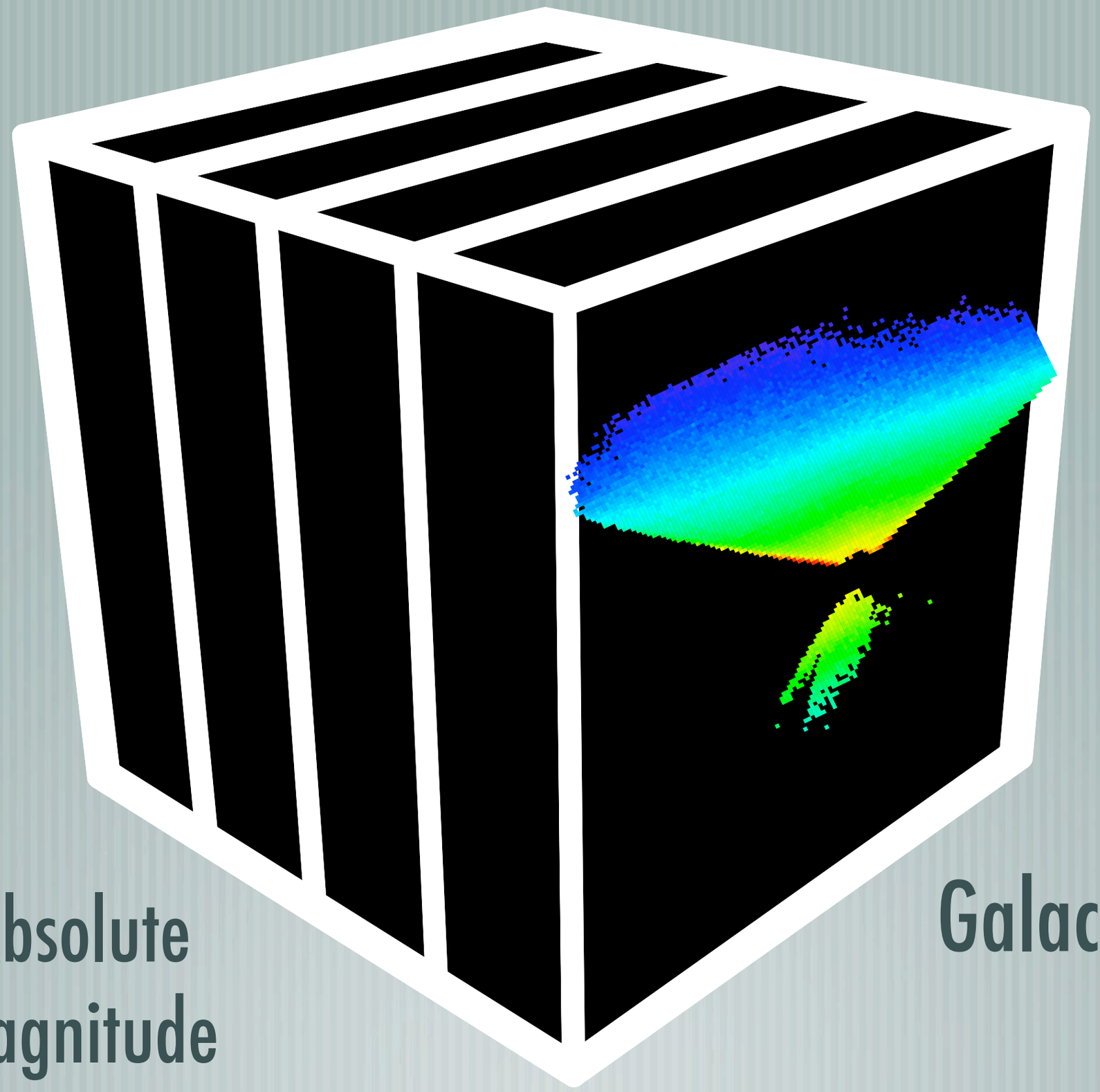
Bochanski et al. 2010

Galactic Z



Absolute Magnitude

Galactic R

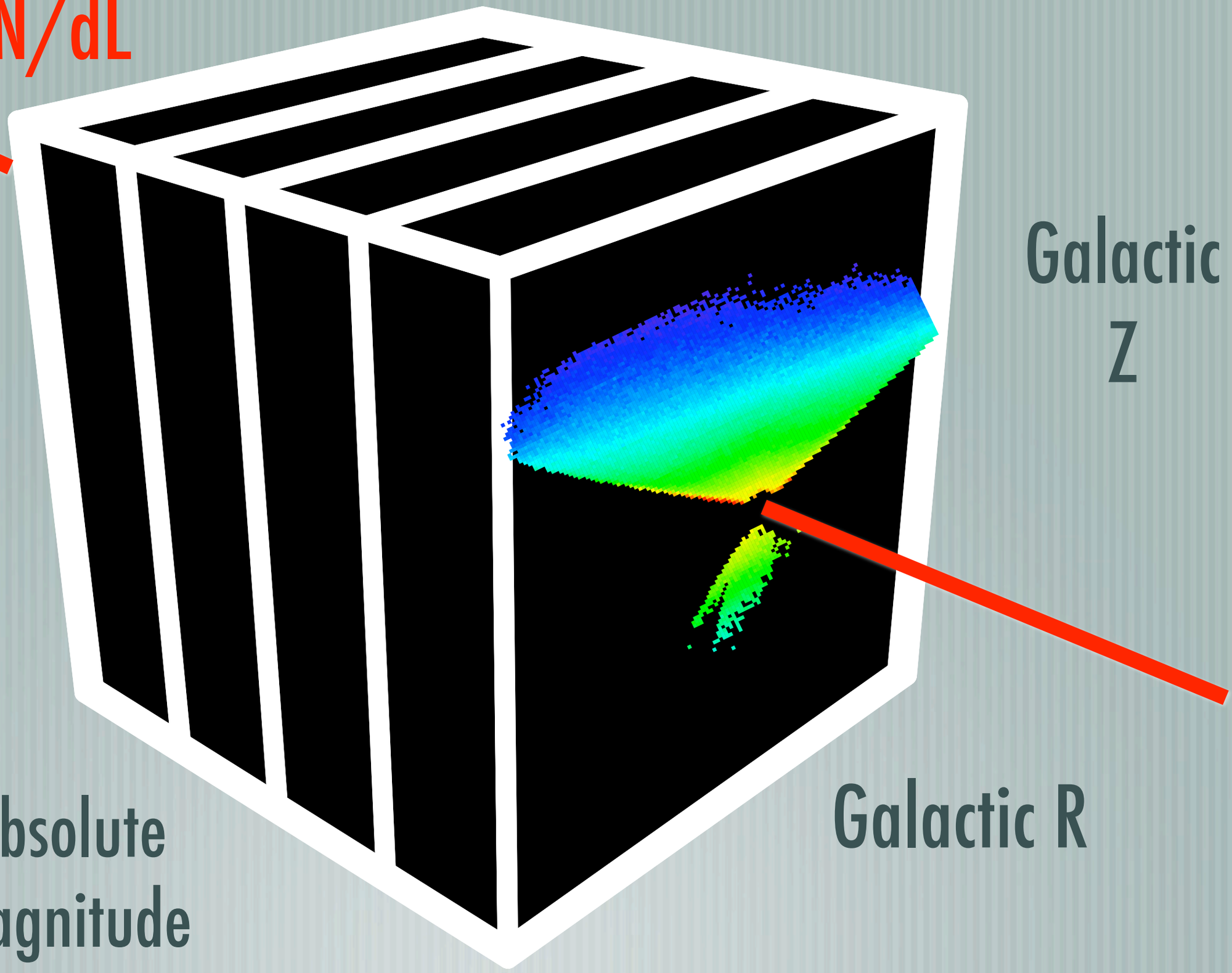


Galactic Z

Absolute Magnitude

Galactic R

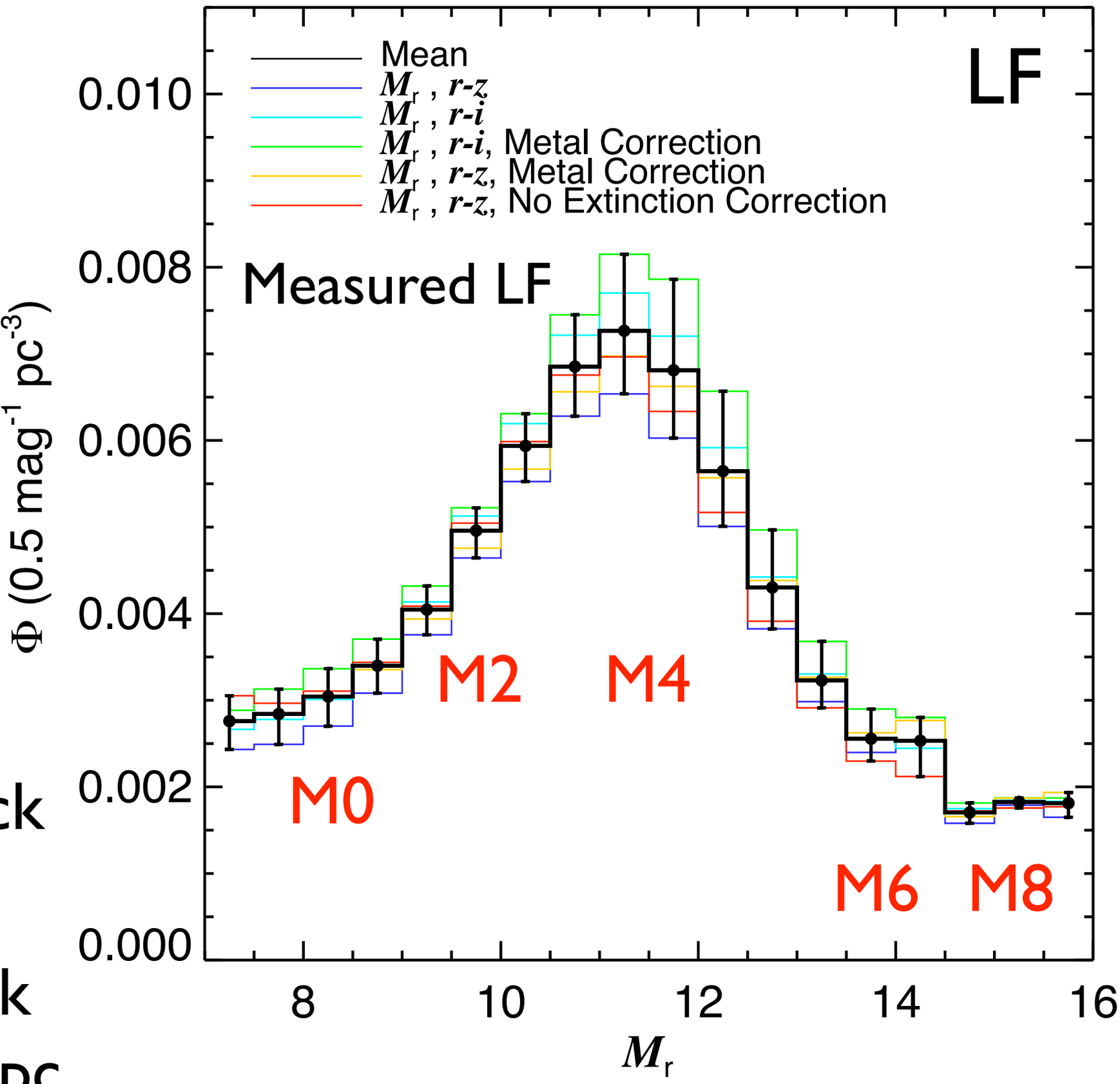
$\Phi = dN/dL$



Galactic Z

Absolute Magnitude

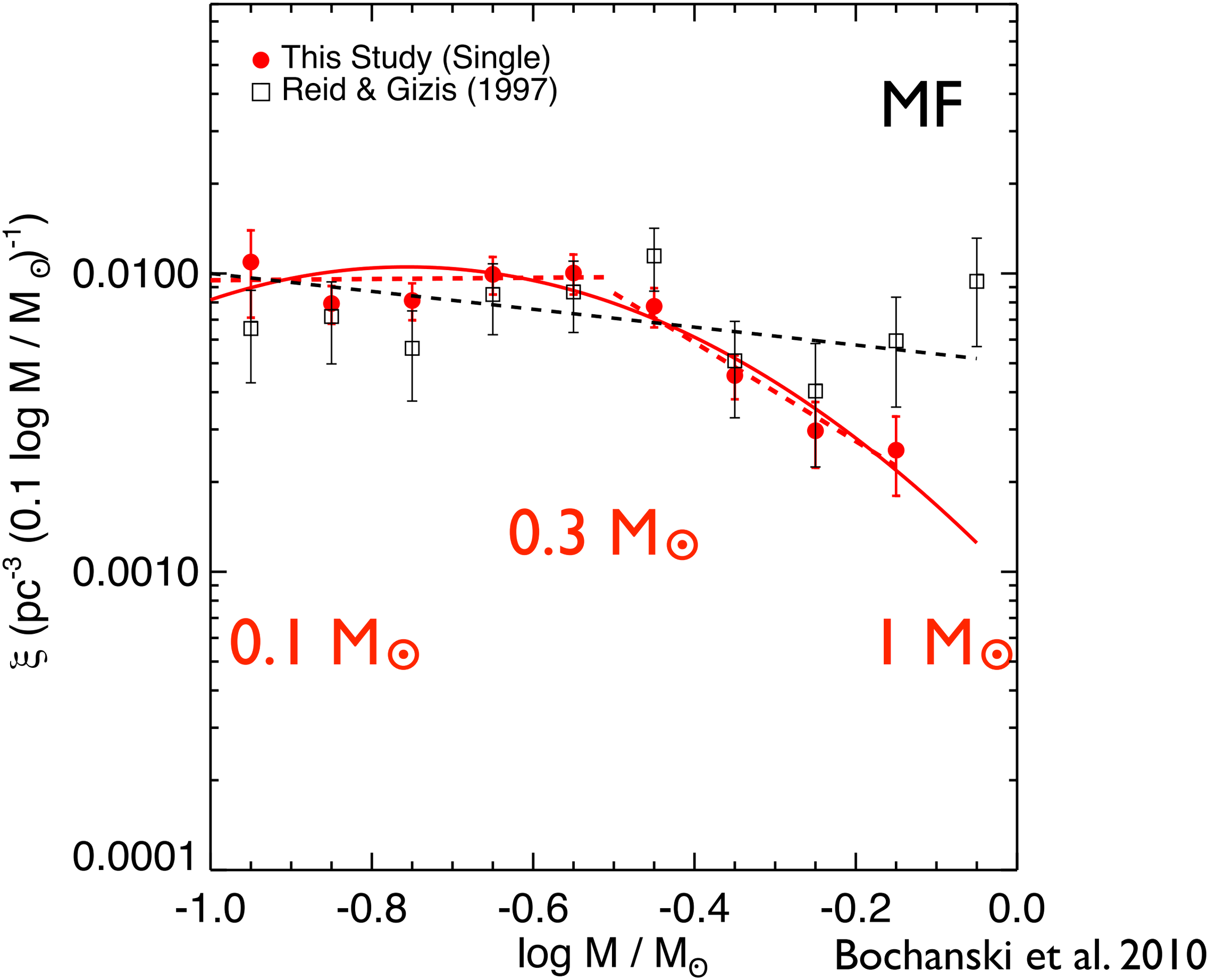
Galactic R

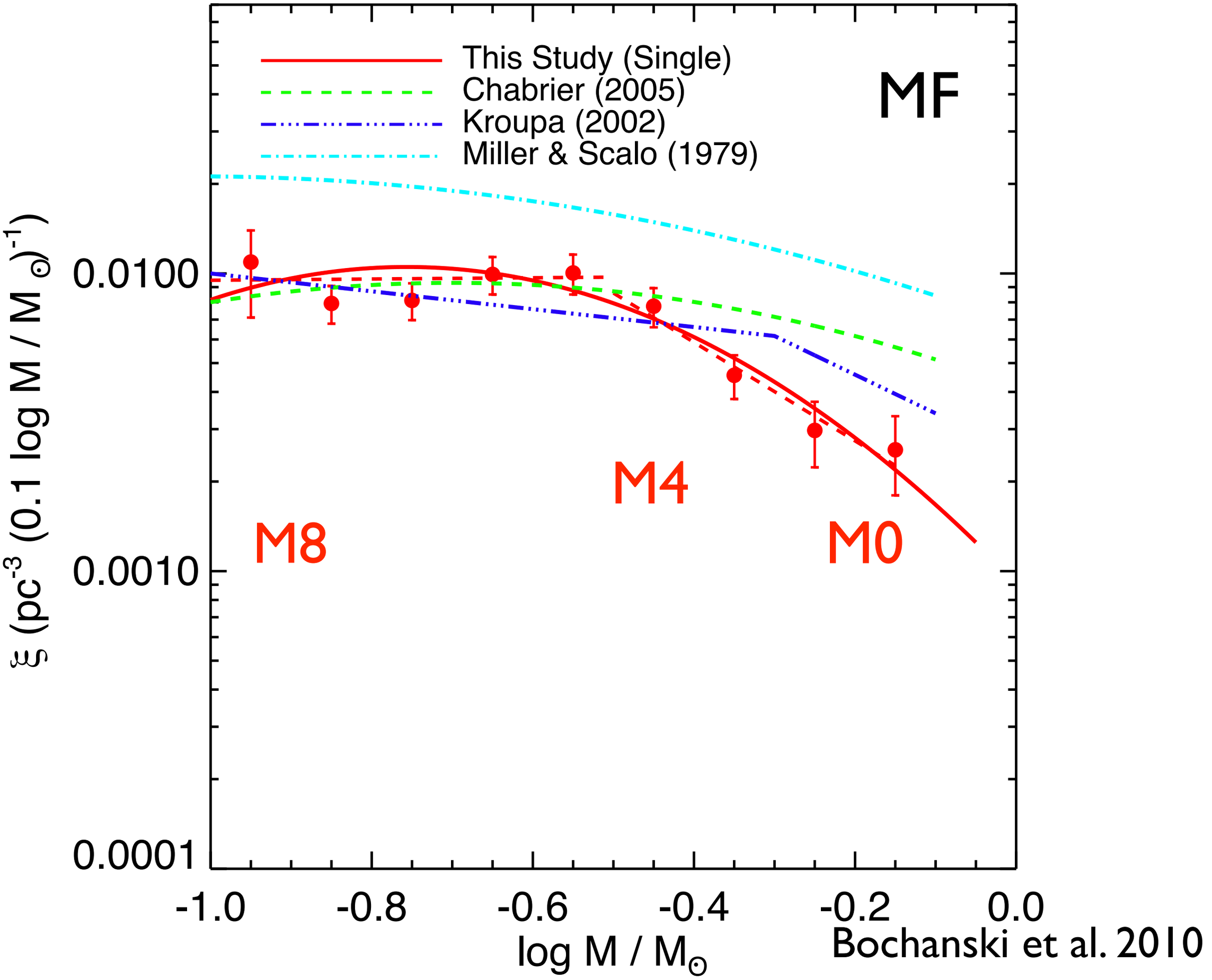


Thin/Thick
f ~ 95%

Thin Disk
H ~ 300 pc

Bochanski et al. 2010


This Study (Single)
Reid & Gizis (1997)
MF
0.3 M⊙
0.1 M⊙
1 M⊙
0.0100
0.0010
0.0001
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
log M / M⊙
ξ (pc-3 (0.1 log M / M⊙)-1)
Bochanski et al. 2010

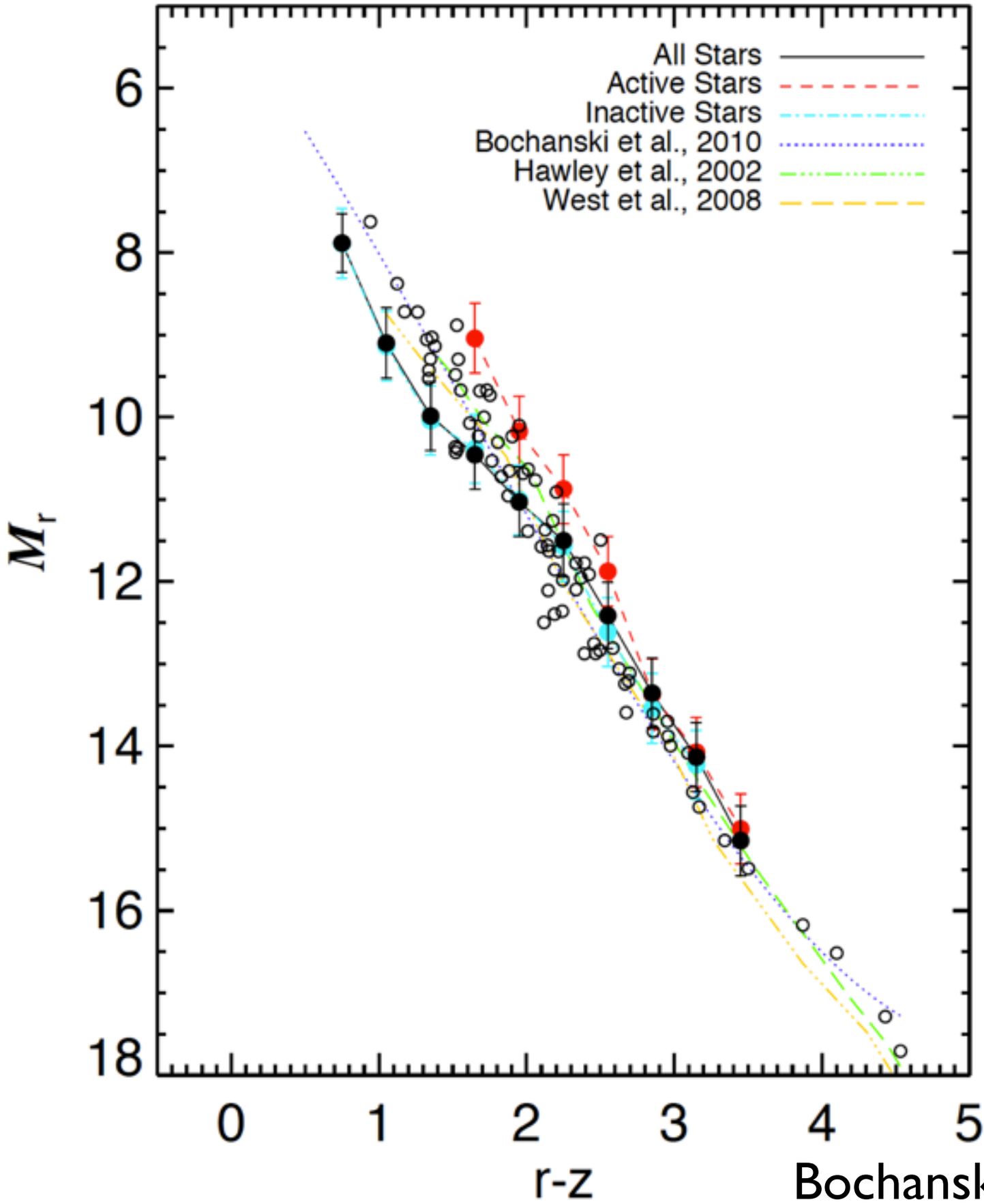

This Study (Single)
Chabrier (2005)
Kroupa (2002)
Miller & Scalo (1979)
MF
M4
M8
M0
0.0100
0.0010
0.0001
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
log M / M⊙
ξ (pc-3 (0.1 log M / M ⊙)-1)
Bochanski et al. 2010

Current & Future Surveys

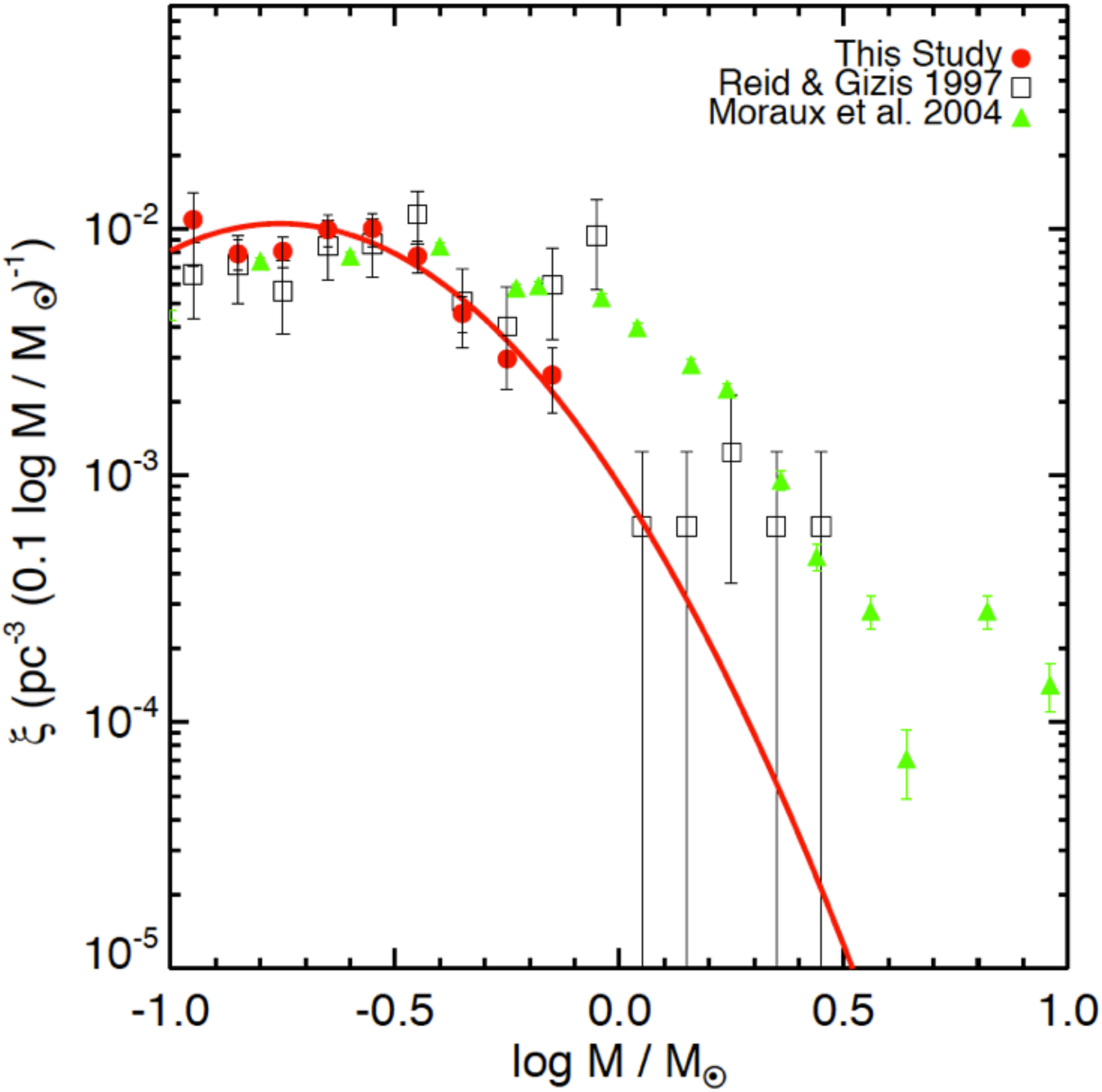
- PanSTARRS (Kaiser et al. 2004)
- UKIDSS (Lawrence et al. 2007)
- VISTA (Emerson et al. 2004)
- Skymapper (Keller et al. 2007)
- GAIA (Perryman et al. 2003)
- JANUS (Burrows et al. 2010)
- LSST (Ivezic et al. 2008)

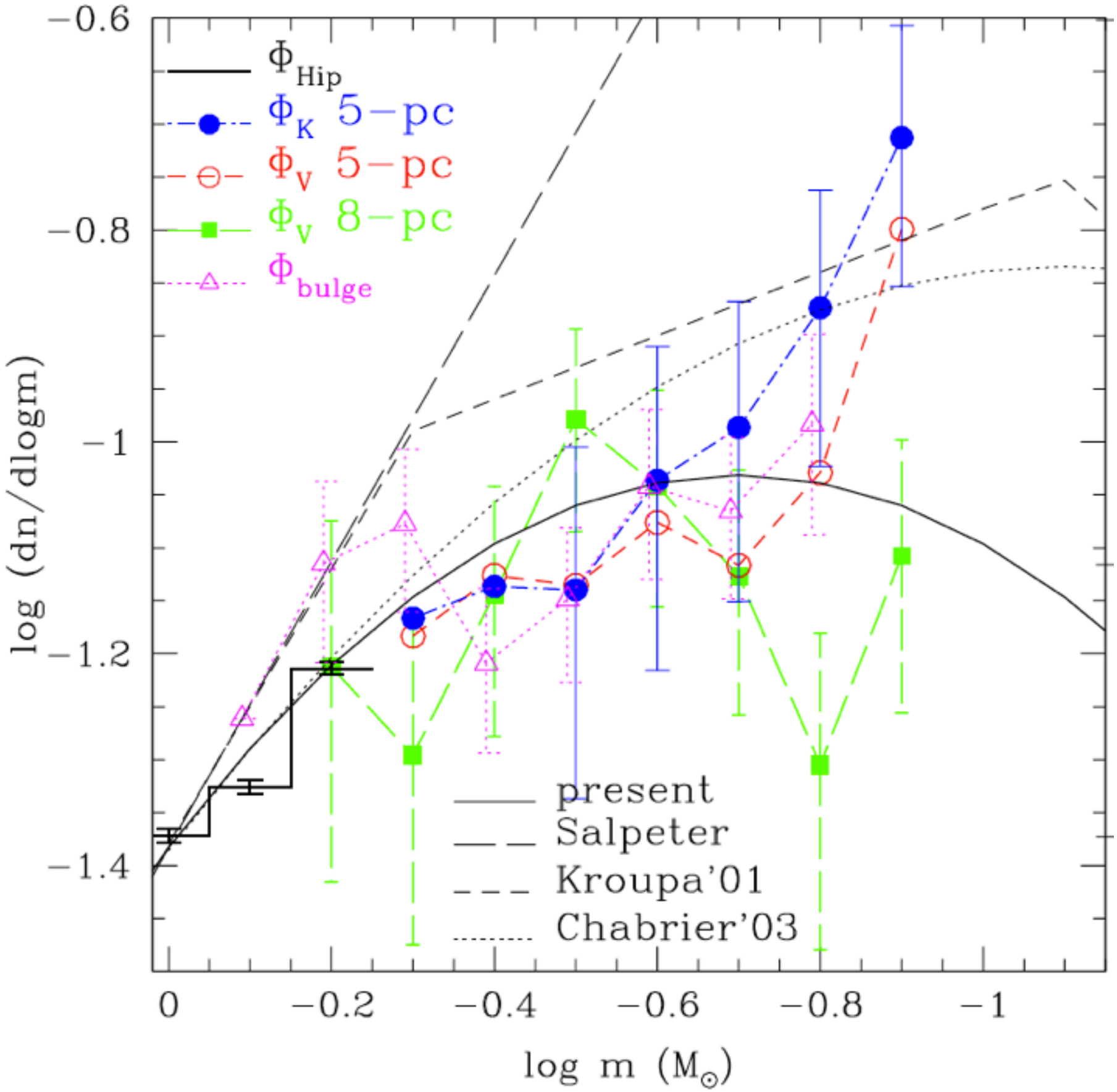
Conclusions

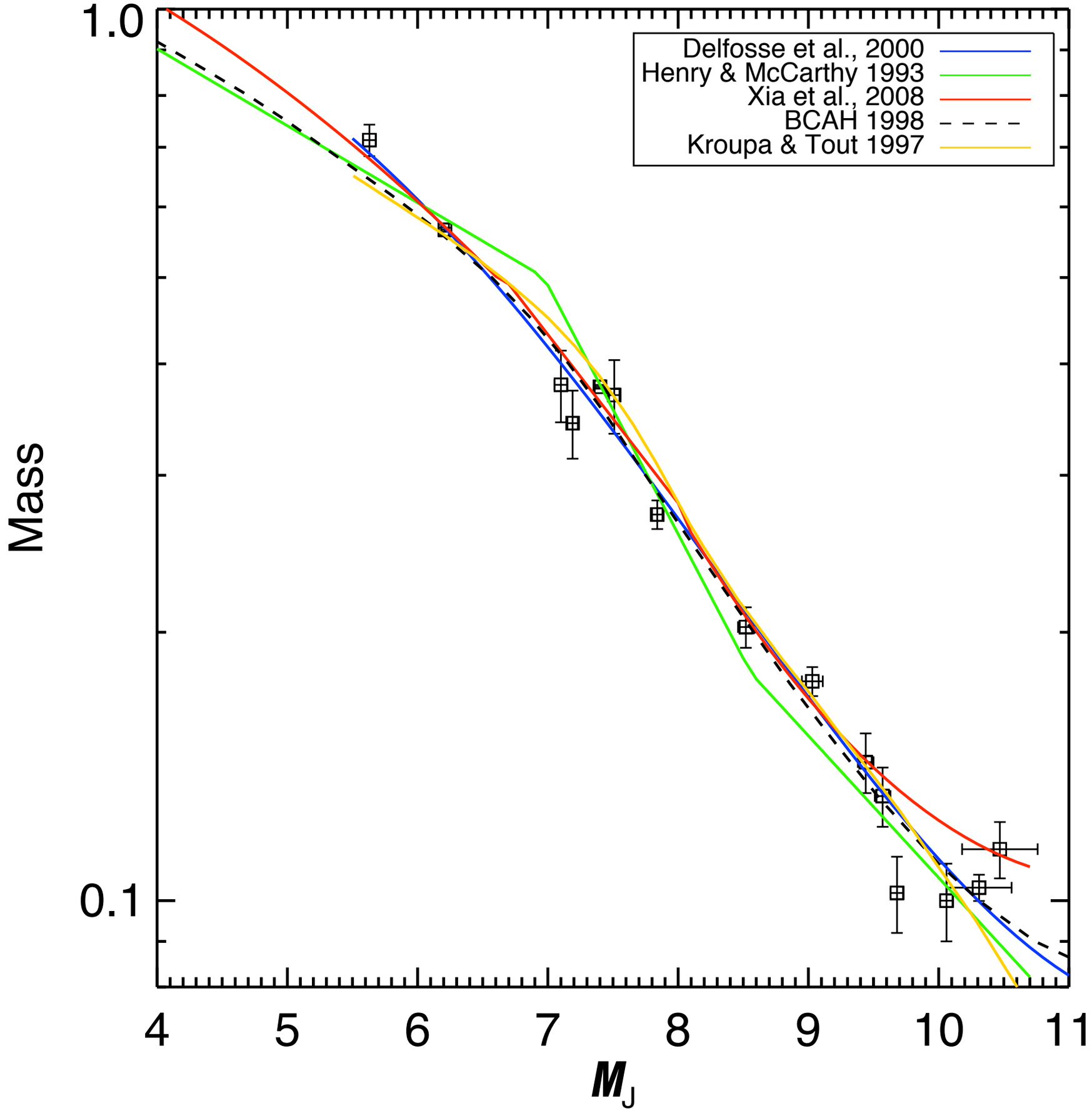
- The field is a good place to measure the IMF
- Small samples are no longer the norm for low-mass stars
- It is important to place large samples of M dwarfs in a Galactic context

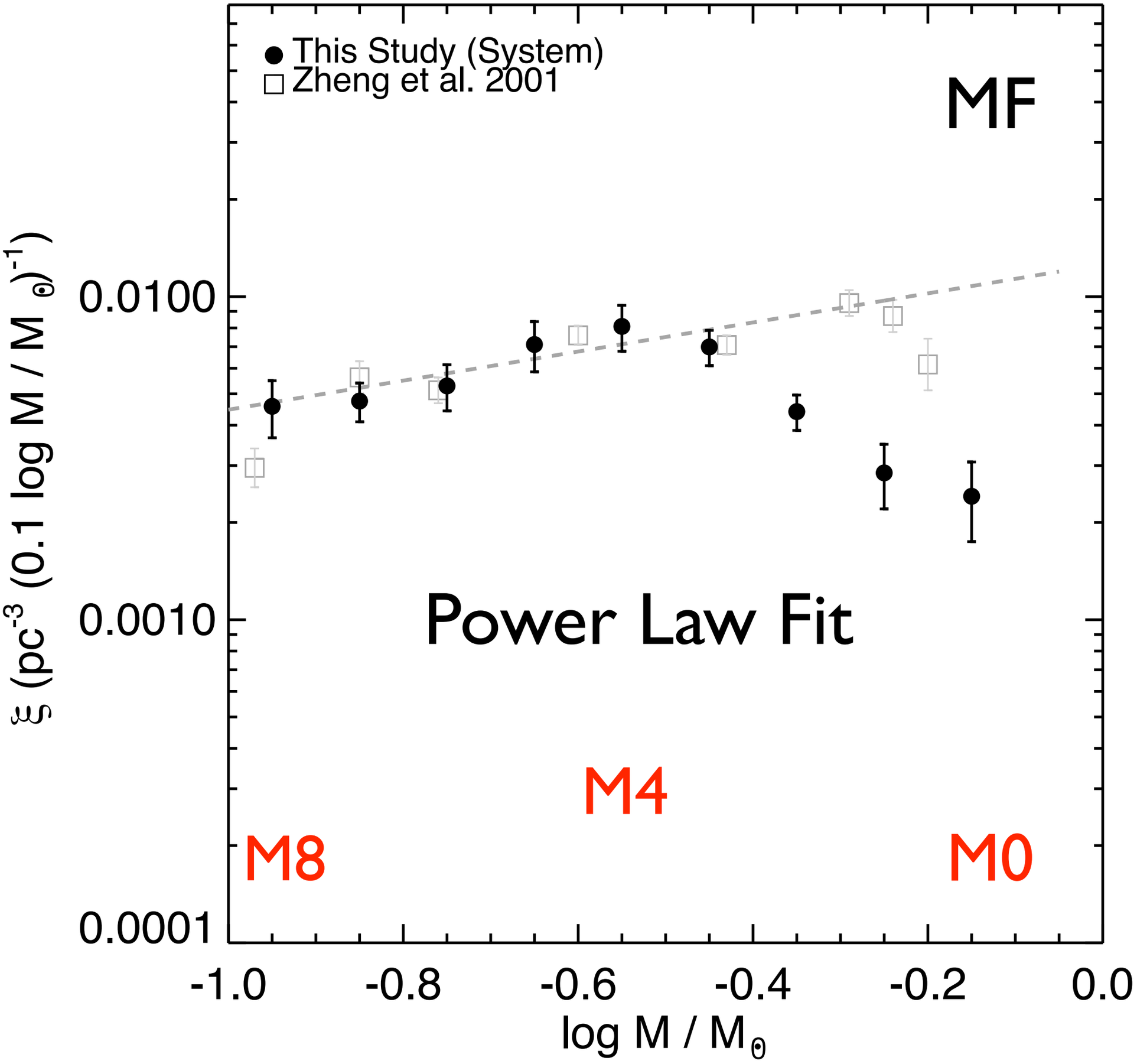


Bochanski et al., submitted


This Study
Reid & Gizis 1997
Moraux et al. 2004
10^{-2}
10^{-3}
10^{-4}
10^{-5}
ξ (pc^{-3} (0.1 log M / M$_\odot$)$^{-1}$)
-1.0
-0.5
0.0
0.5
1.0
log M / M$_\odot$

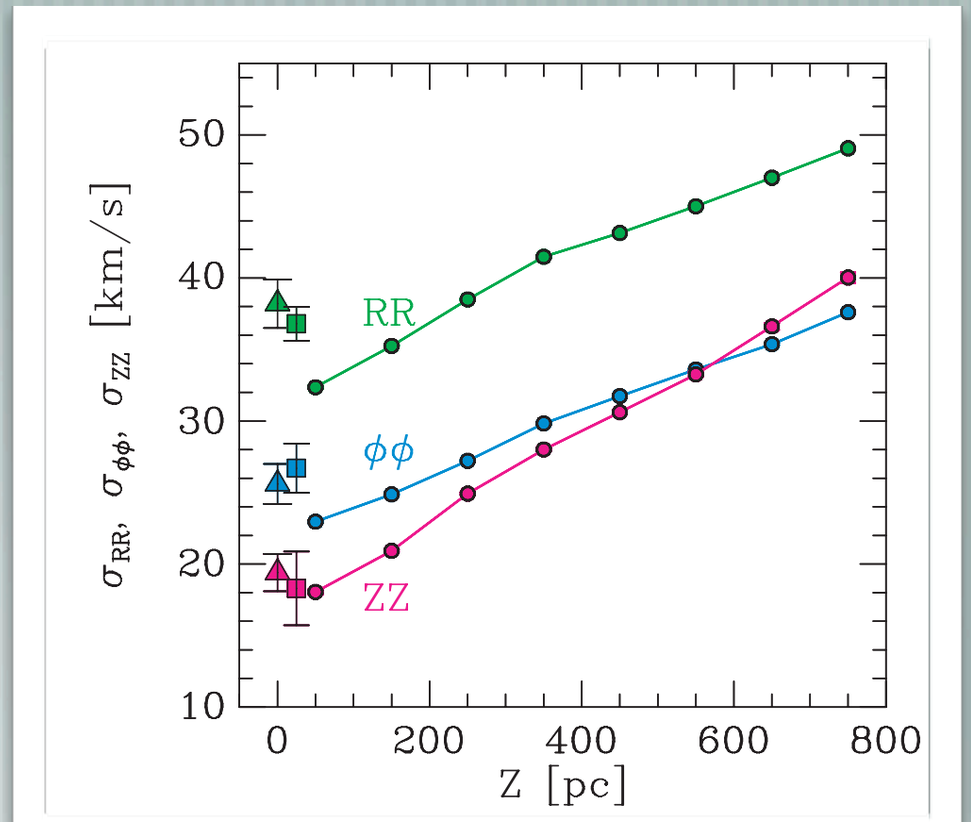

−0.6
−0.8
−1
−1.2
−1.4
log (dn/dlogm)
Φ Hip
Φ K 5−pc
Φ V 5−pc
Φ V 8−pc
Φ bulge
present
Salpeter
Kroupa'01
Chabrier'03
0
−0.2
−0.4
−0.6
−0.8
−1
log m (M⊙)


1.0
0.1
Mass
4
5
6
7
8
9
10
11
M_J
Delfosse et al., 2000
Henry & McCarthy 1993
Xia et al., 2008
BCAH 1998
Kroupa & Tout 1997


This Study (System)
Zheng et al. 2001
MF
Power Law Fit
M4
M8
M0
0.0100
0.0010
0.0001
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
log M / M⊙
ξ (pc-3 (0.1 log M / M ⊙)-1)

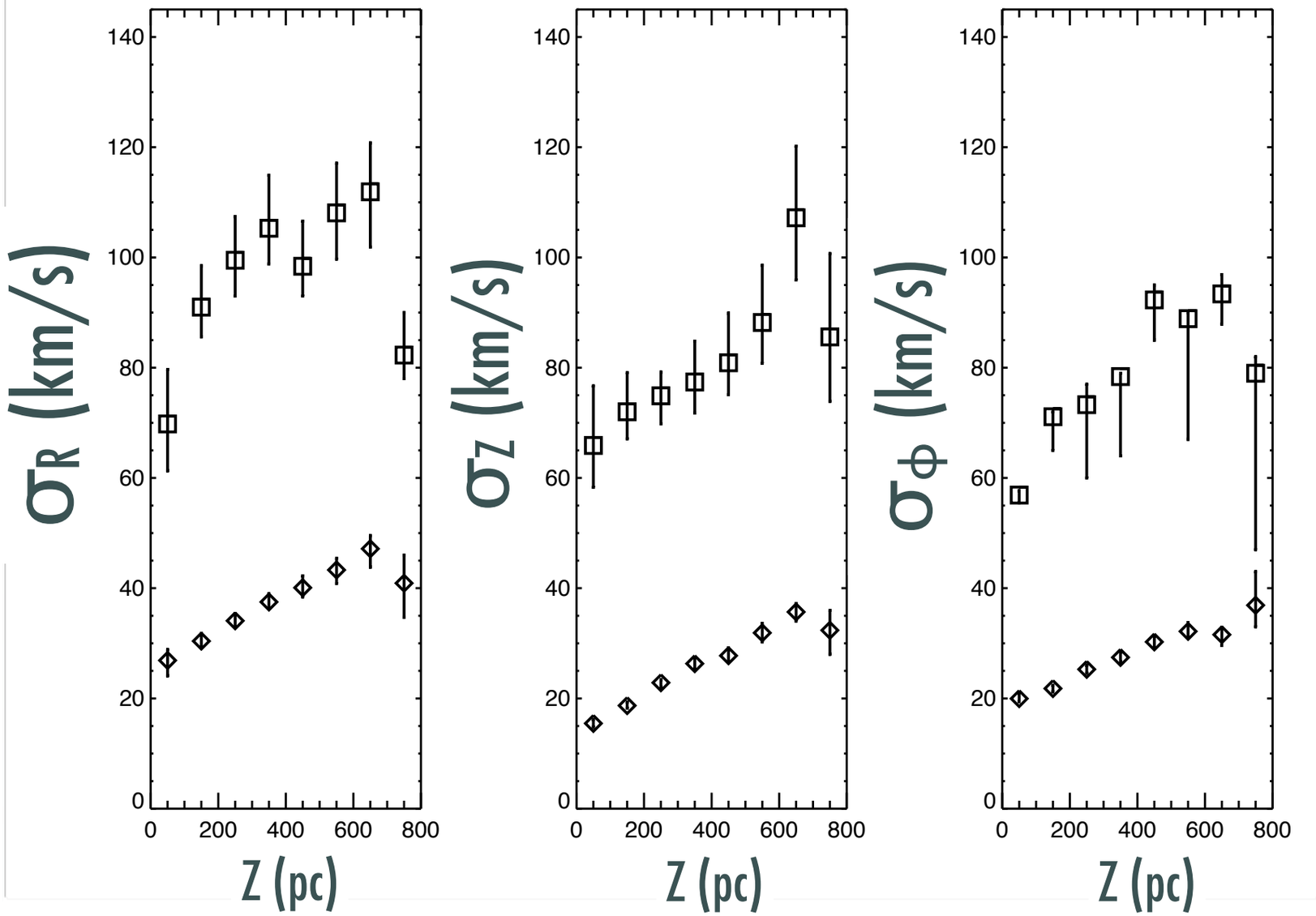
Velocity Dispersions

- Measured by many groups using SDSS data
- Constrains local mass density and Galactic potential
- Influenced by Galactic heating mechanisms



Fuchs et al. 2009

Velocity Dispersions



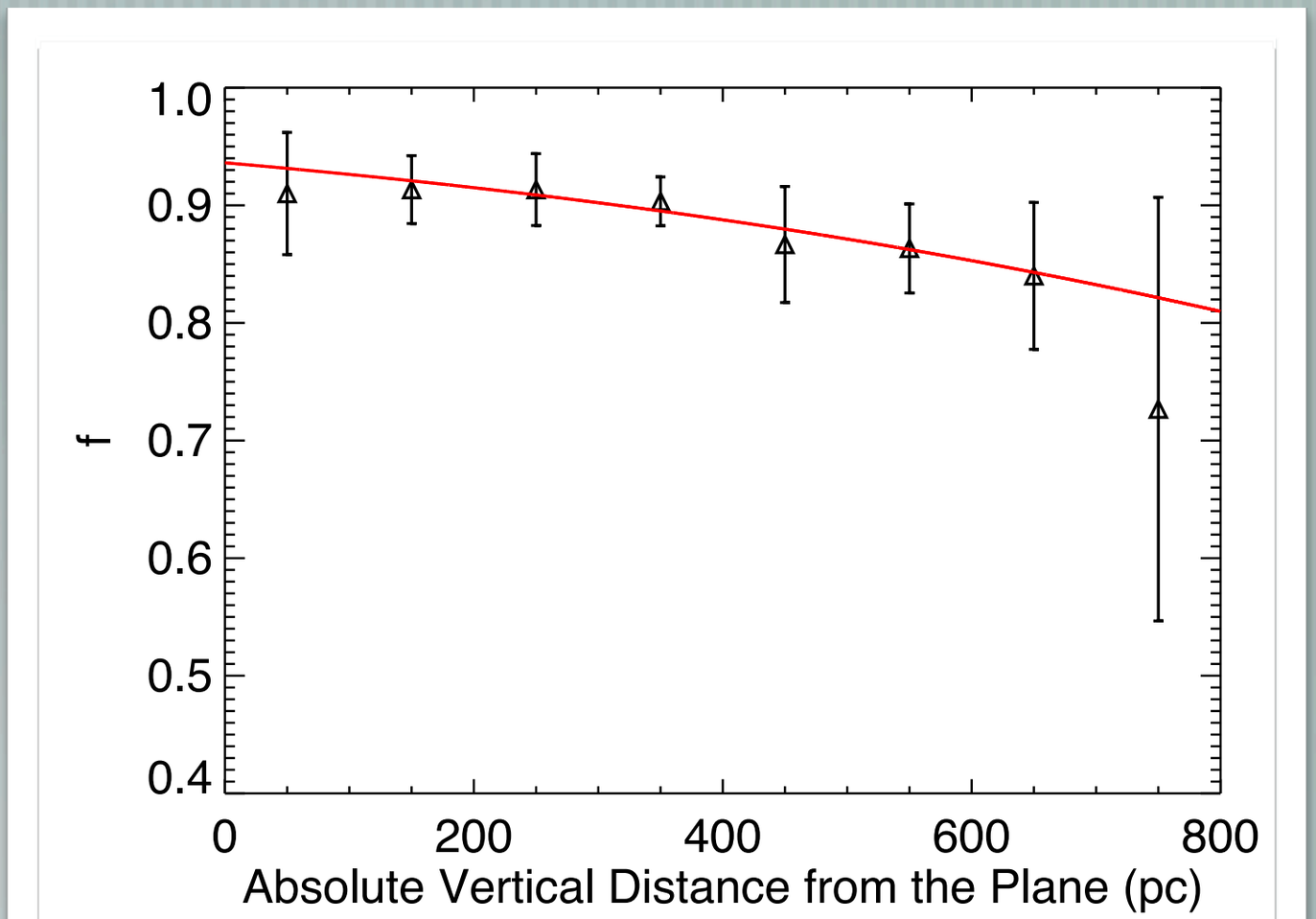
Thick Disk

Thin Disk

Pineda et al. poster. Also see Bochanski et al. 2007

Thick Disk

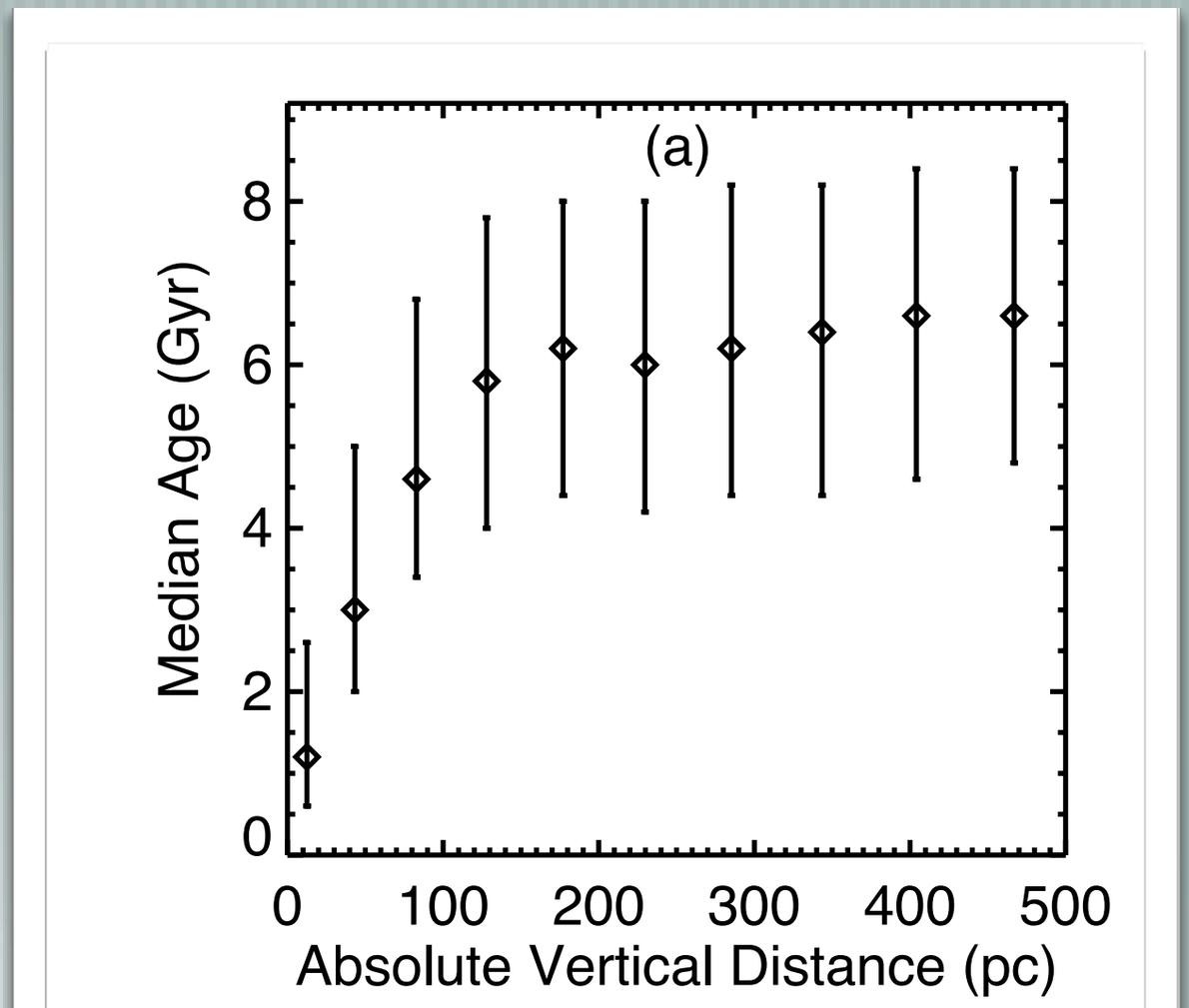
- Can measure local fraction of thin disk stars and scale height



Pineda et al., in prep

Age

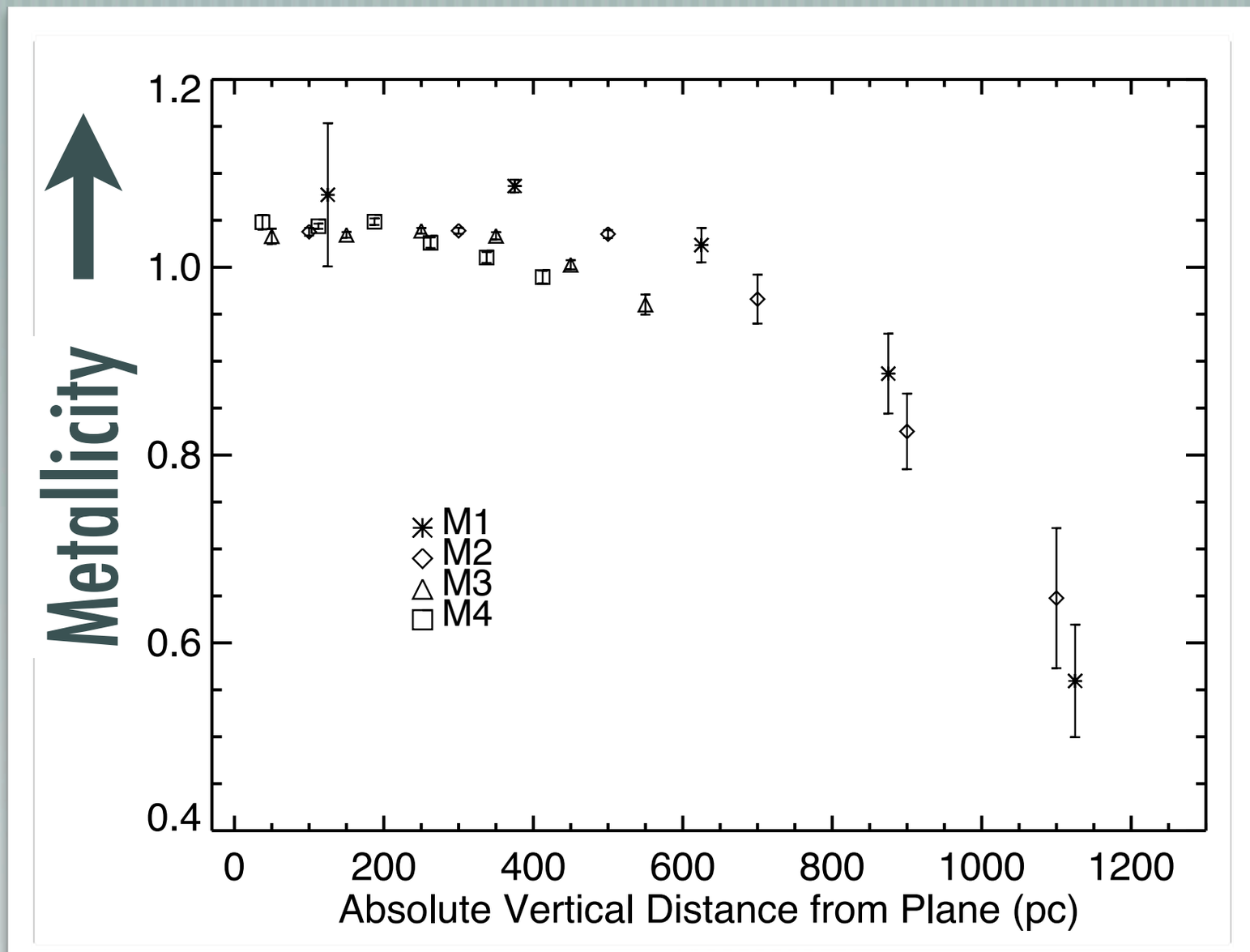
- Difficult to measure
  (MS lifetimes >> Hubble time)
- Statistical calibrations using chromospheric activity and kinematics



West et al. 2008

Metallicity

- NIR and optical metallicity indicators exist (Lepine et al. 2007, Johnson & Apps 2009, Rojas-Ayala et al. 2010)
- Has been studied for massive stars (Bond et al. 2009)
- More work needed before precise metallicities are available for all M dwarfs



West et al. 2010

Recap

Project	Low-Mass Stars	Milky Way
Field LF/MF	log-normal with Mo = 0.18 Msol	thin disk scale height = 300 pc f = 0.96
Kinematics	UVW motions, calibrated age-activity relation	Kinematic scale heights Measured Solar motion f = 0.95
Metallicity	*Fundamental stellar parameter*	*Milky Way chemical evolution,* *Metallicity - velocity correlations*
Age	*Fundamental stellar parameter*	*Dynamic evolution,* *star formation history*