Astrostatistics

Monday, 04 February 2019

- Statistics Foundations
    - Ivezic Ch 4 “Classical Statistical Inference” & Ch 5 “Bayesian Statistical Inference”
    - F&B Ch 3 “Statistical Inference”
- Review (on your own) properties of multivariate Gaussian random variables and densities
  (see multivariate_gaussian_notes.pdf on website)
- and also other standard distributions (F&B Ch 4 and Ivezic Ch 3)

Determining Astronomical Distances using Standard Candles

1. Estimate or model Luminosity L of a Class of Astronomical Objects

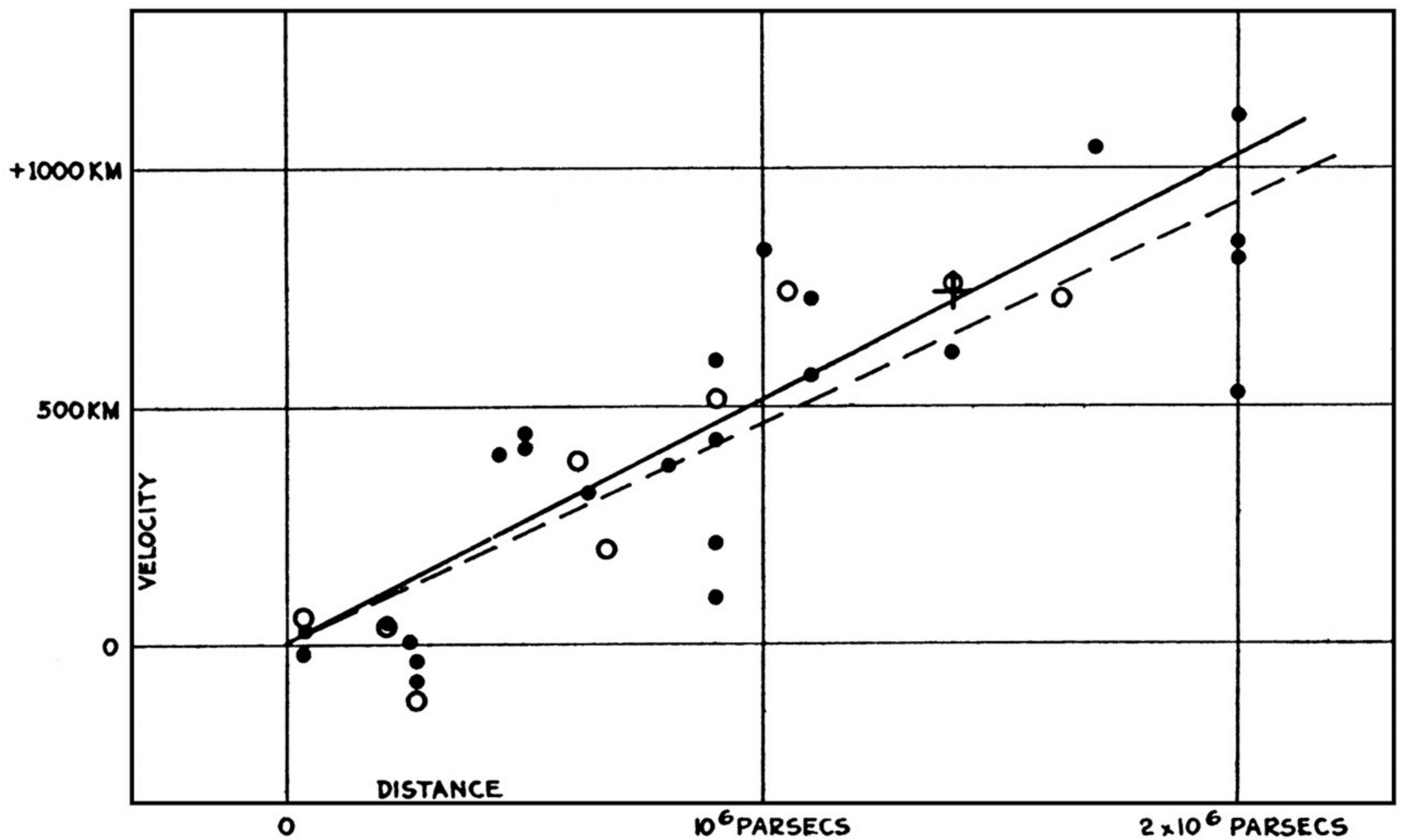
2. Measure the apparent brightness or flux F

3. Derive the distance D to Object using Inverse Square Law: $F = L / (4\pi D^2)$

4. Optical Astronomer's units: $\mu = m - M$

m = apparent magnitude [log apparent brightness flux],
M = absolute magnitude [log Luminosity],
μ = distance modulus [log distance].

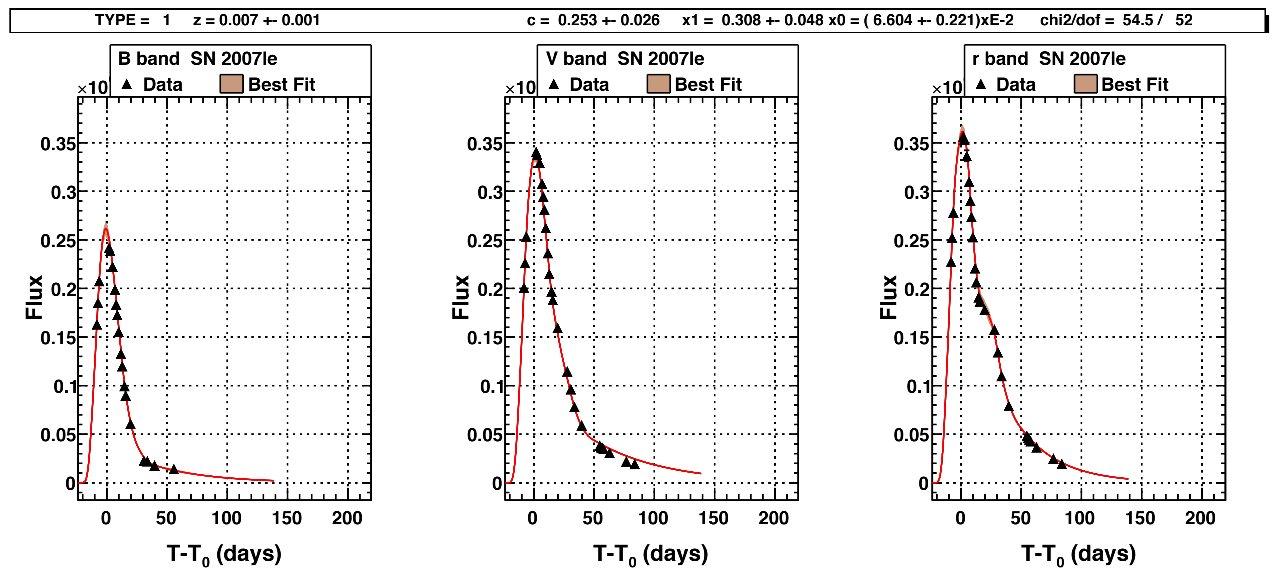
The Expanding Universe:
Galaxies are moving apart! Hubble's Law (1929)



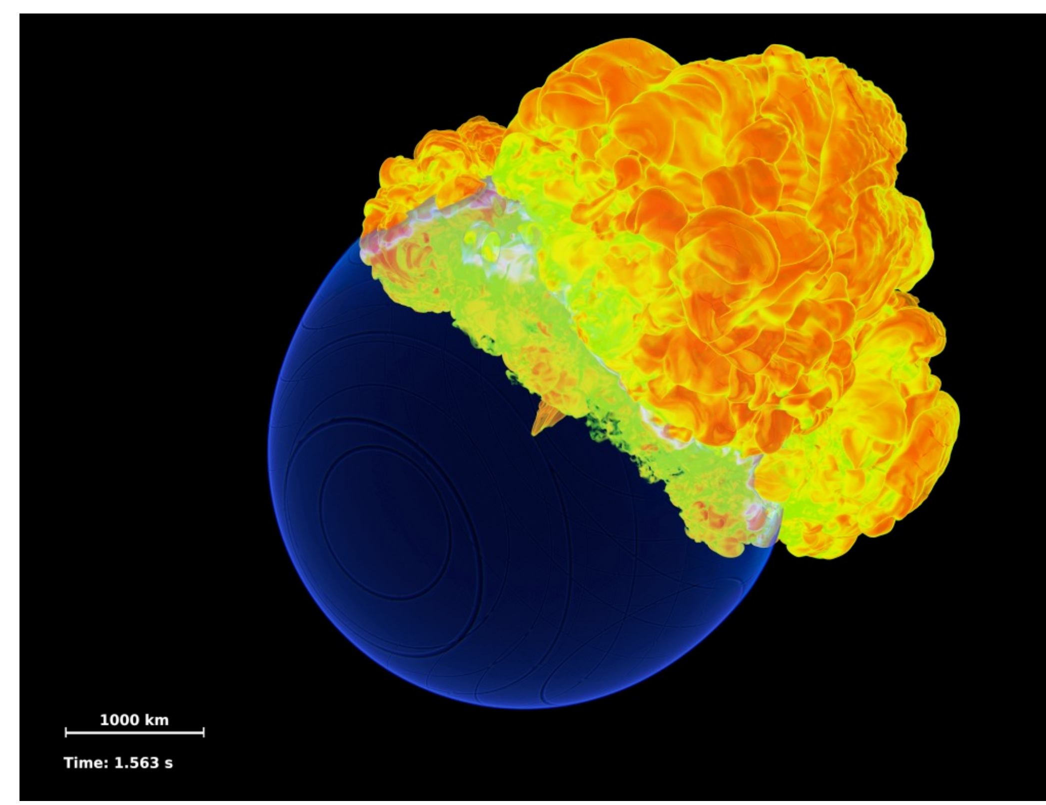
Einstein & Hubble

Distance $\propto$ Velocity (Redshift)

Type Ia Supernovae (SN Ia) are Almost Standard Candles

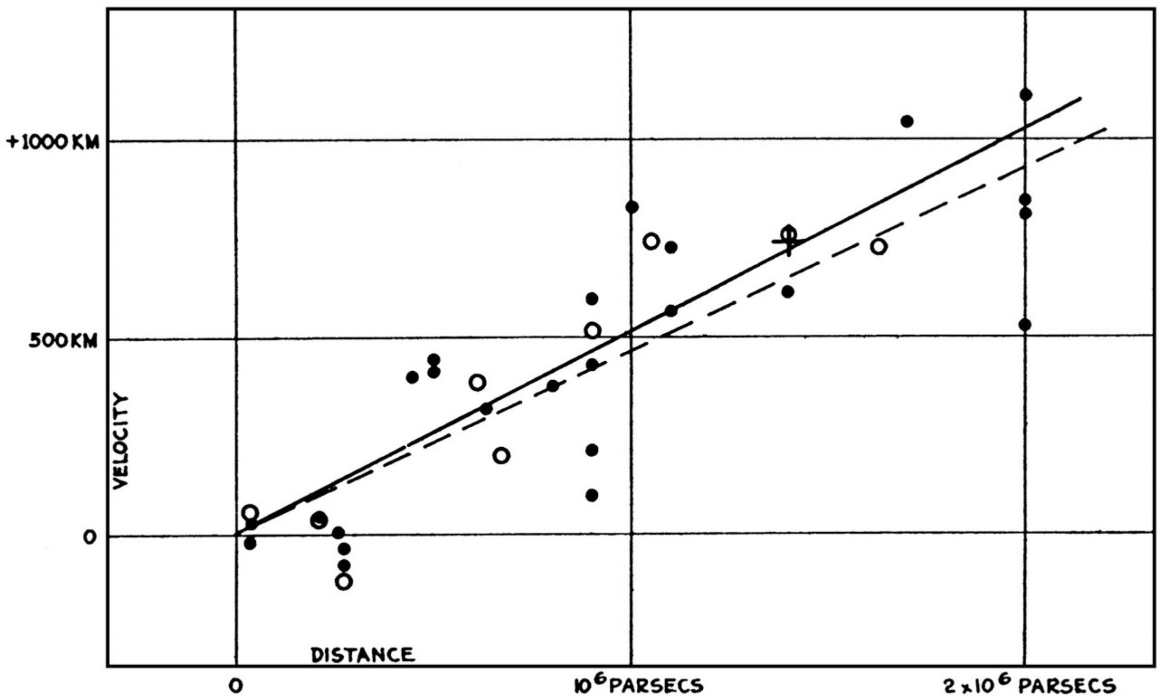


- Progenitor: C/O White Dwarf Star accreting mass leads to instability
- Thermonuclear Explosion: Deflagration/ Detonation
- Nickel to Cobalt to Iron Decay + radiative transfer powers the light curve

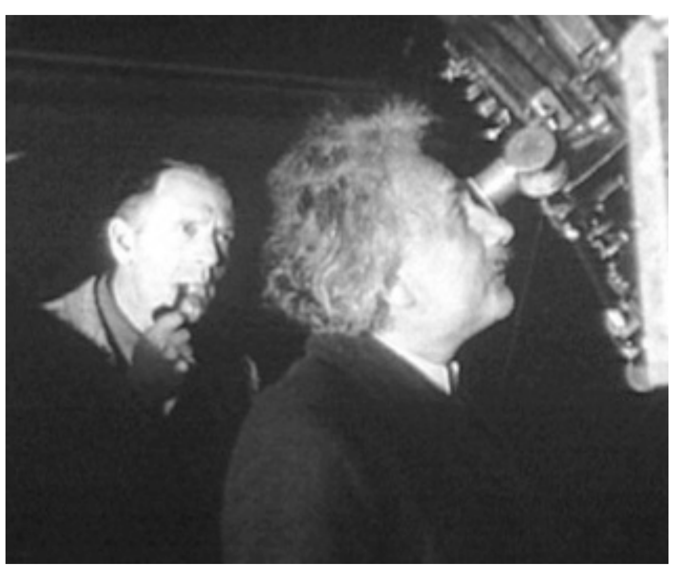


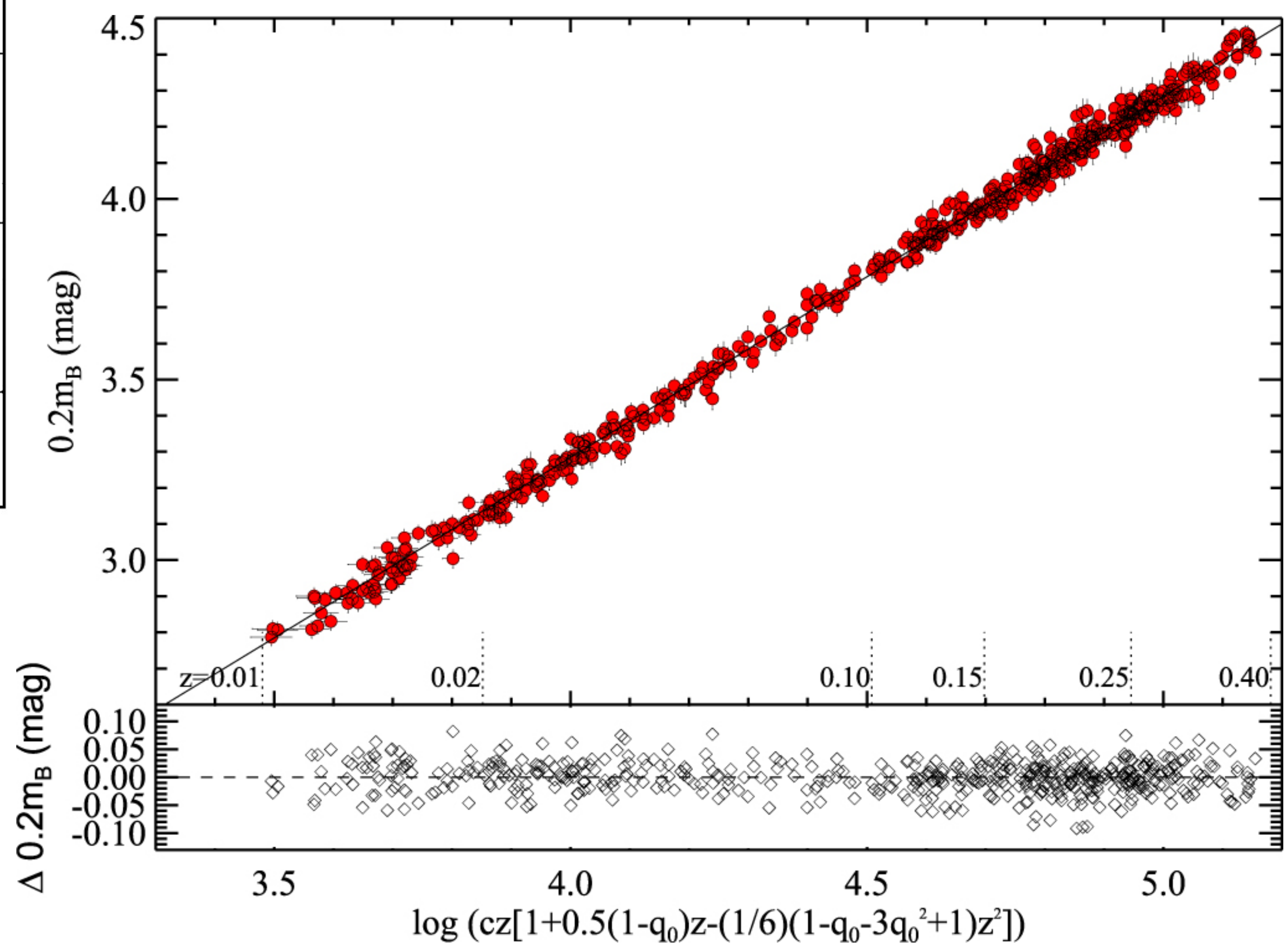
Hubble Constant

Distance = $H_0 \times$ velocity



Hubble (1929)





Riess et al. 2016

Hubble Constant

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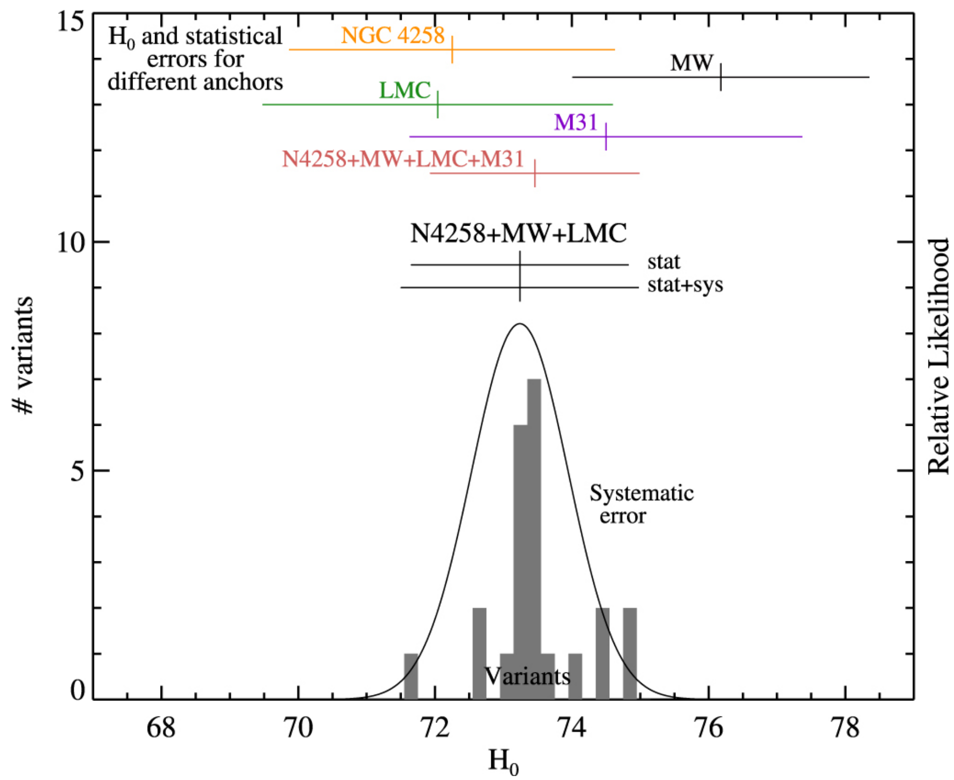
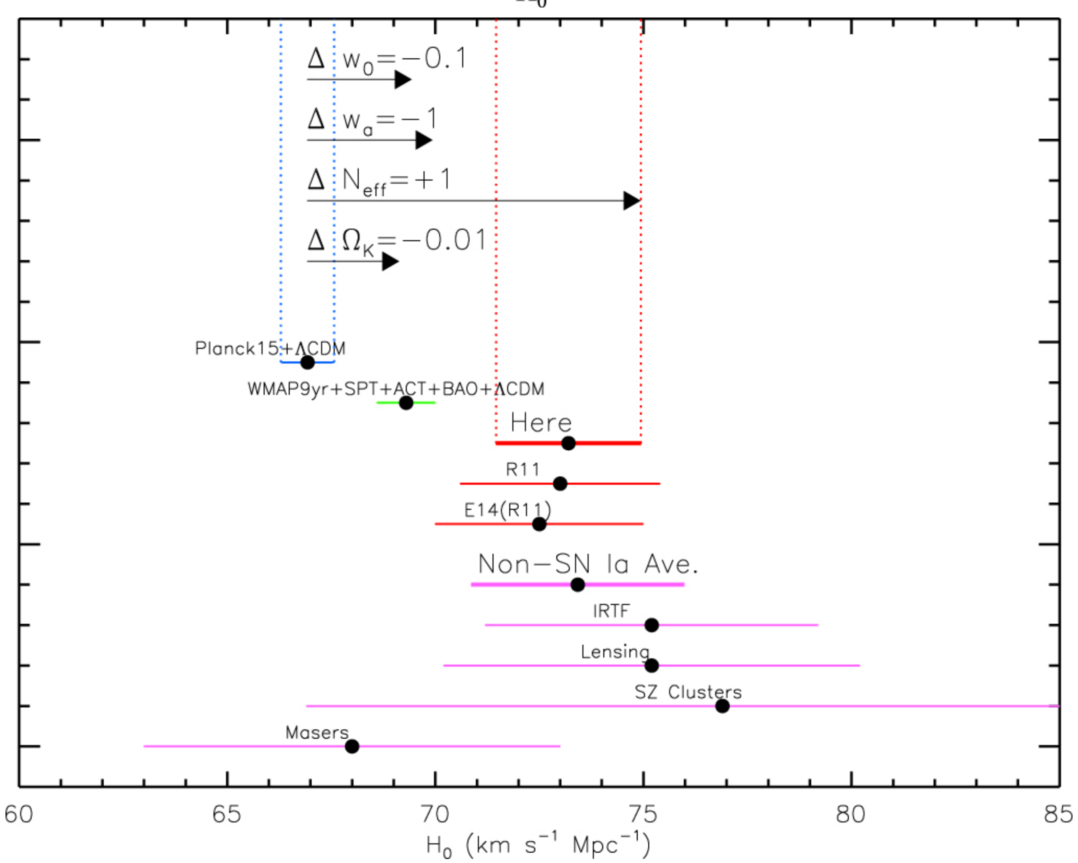
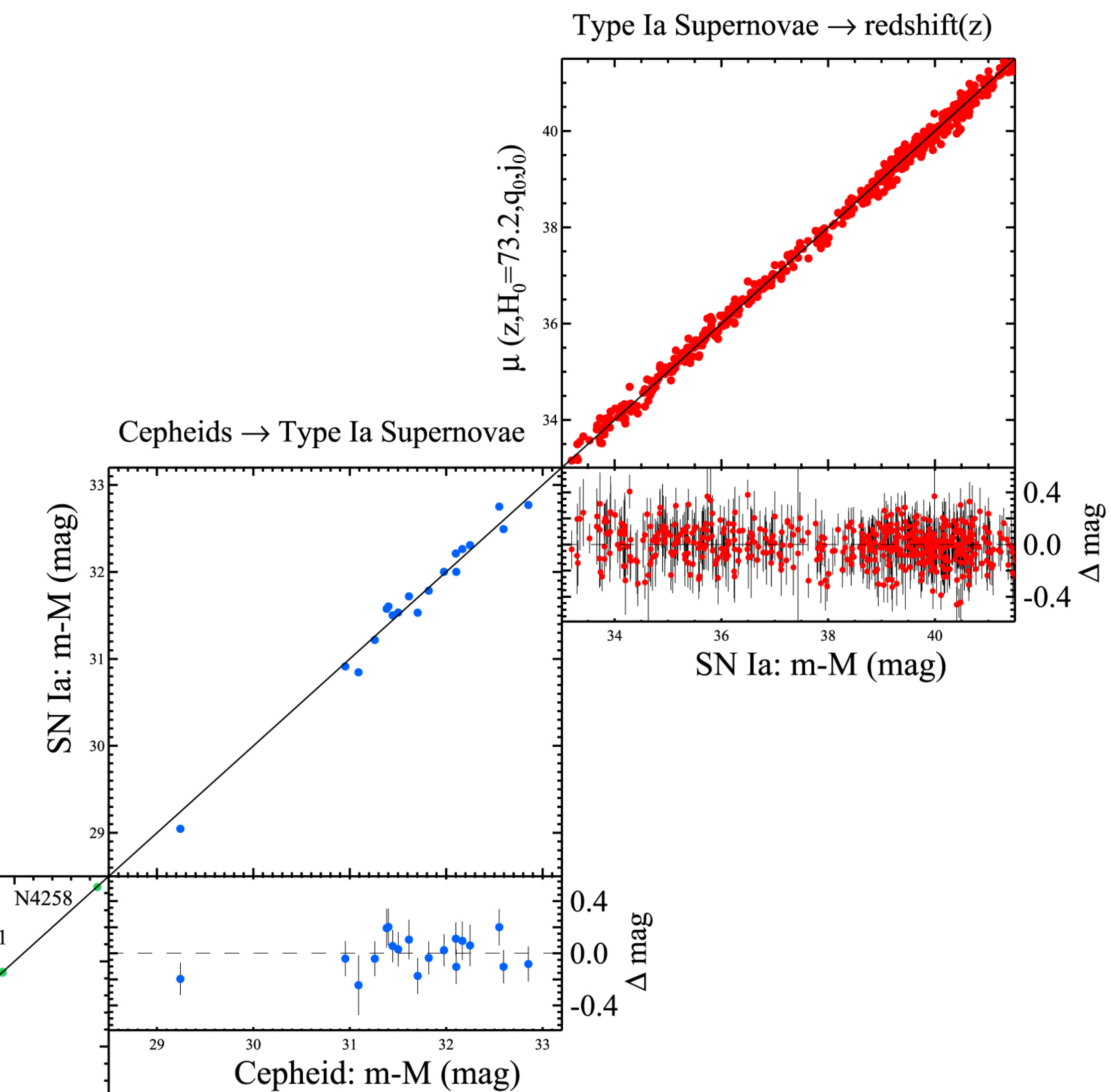
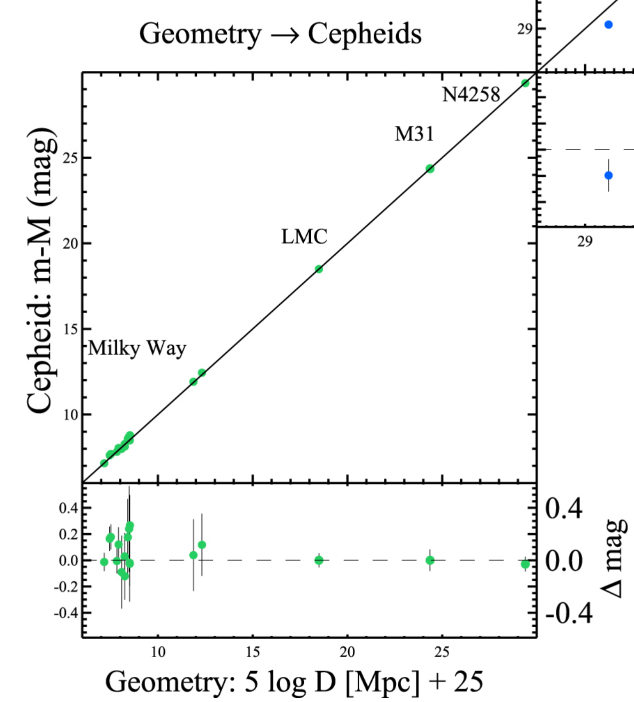


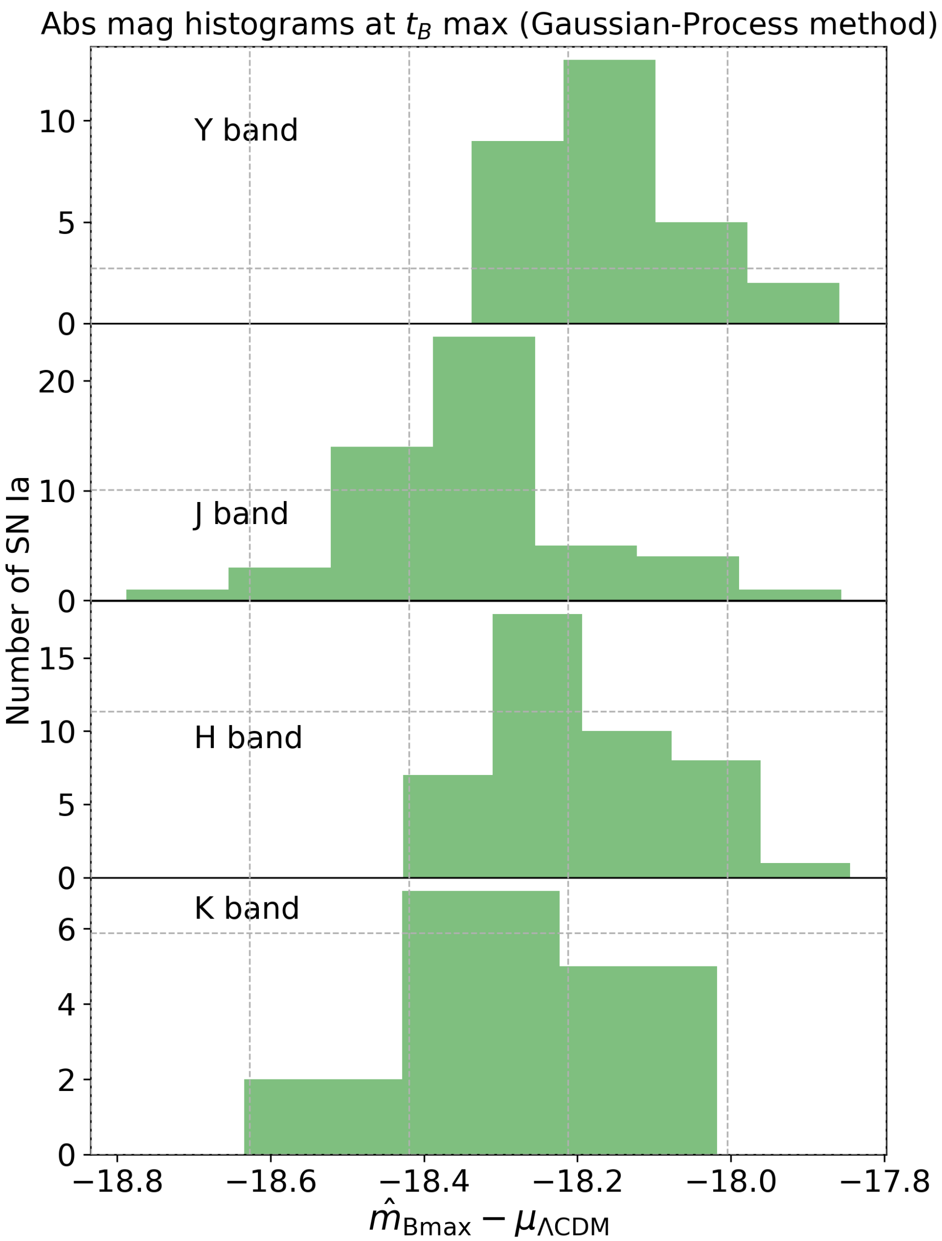






Riess et al. 2016

Calibrating SN Ia Standard Candles
(Avelino, Friedman, Mandel et al. 2019)



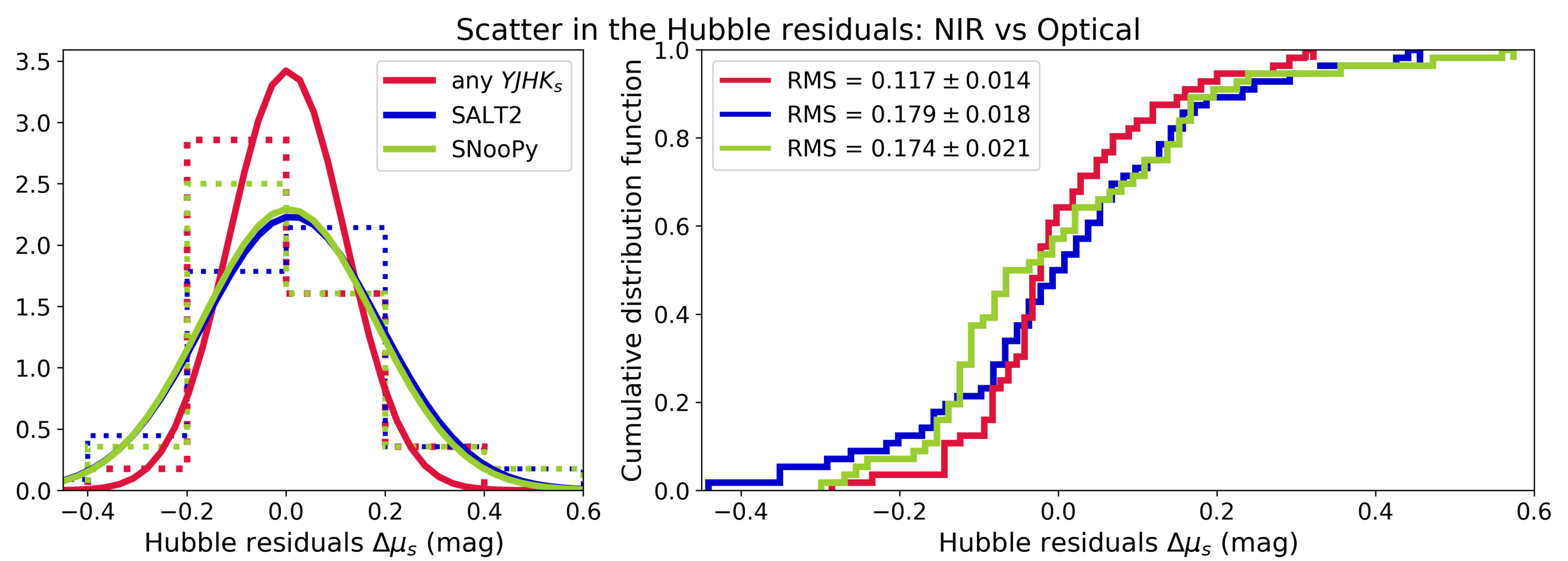
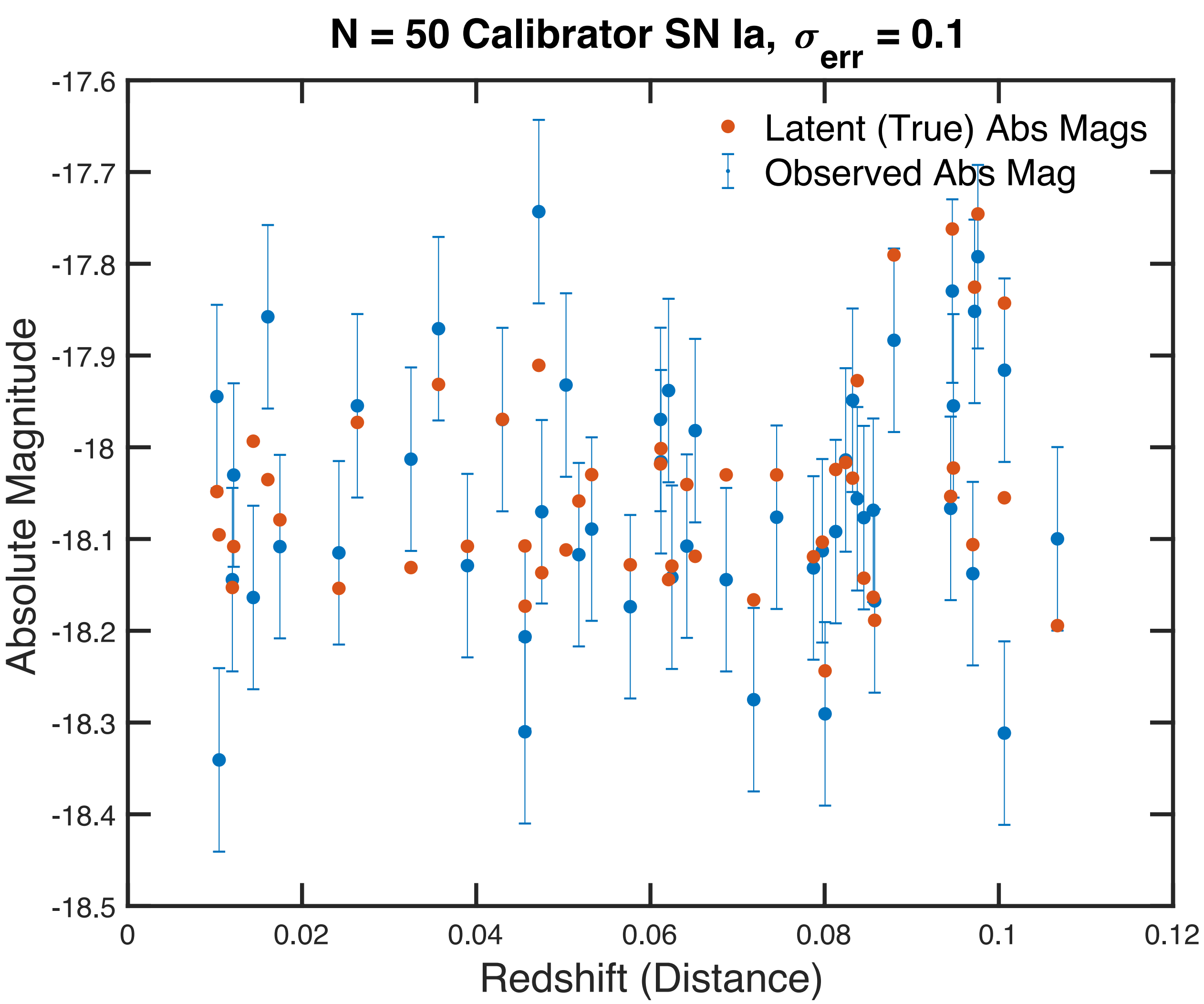
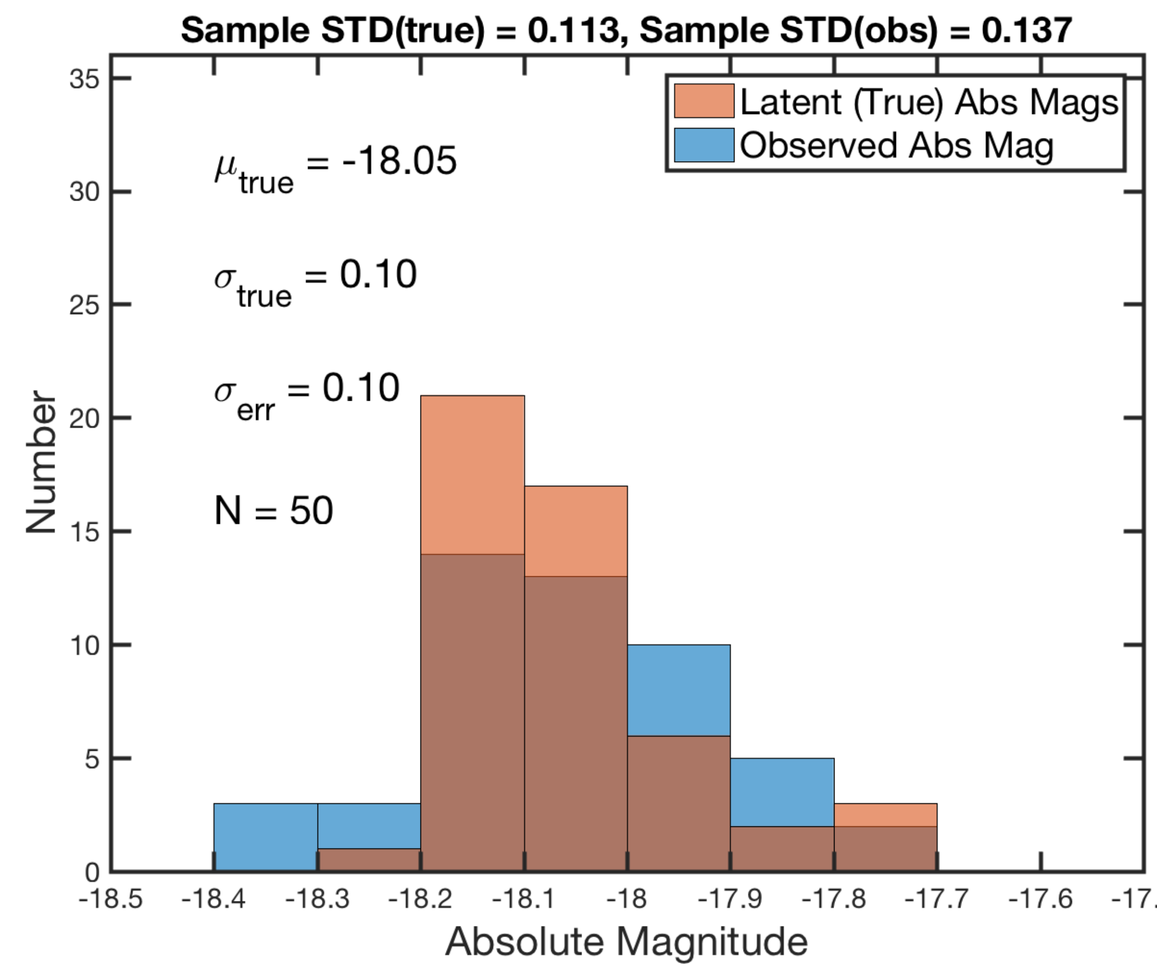


Figure 4: Normalized histograms of the absolute magnitudes at phase = $B_{\max}$, defined as $M_{B_{\max},s} \equiv \hat{m}_{B\max,s} - \mu_{\Lambda\mathrm{CDM}}(z_s)$ for the SN Ia sample in the GP method at B max. The mean, the standard deviation, and the number of supernovae in each histogram are shown in Table 6.

Determining the Distribution of Absolute Magnitudes

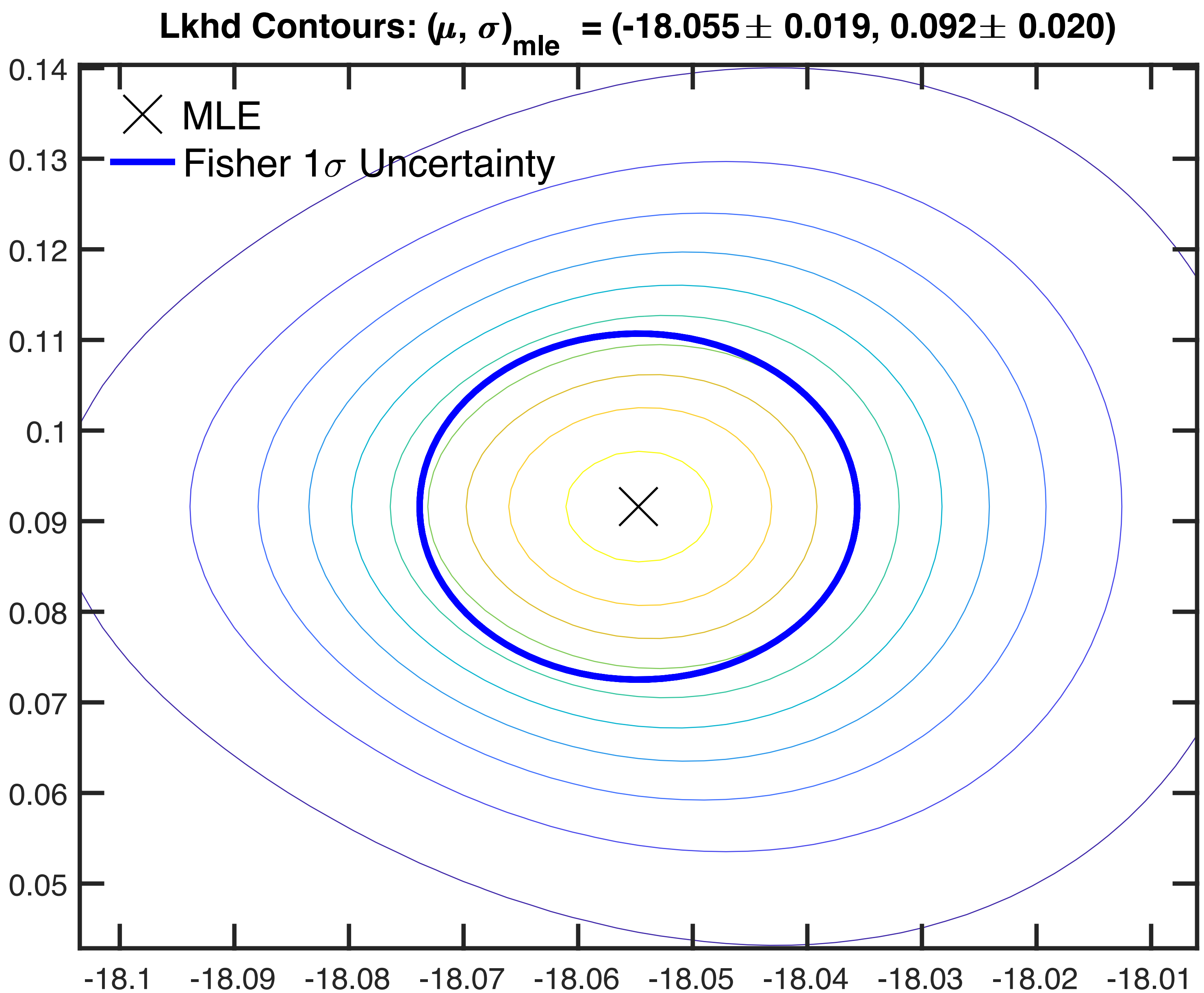
Want to Calibrate SN Ia (N=50) determine M_0, σ_{int} from data with measurement error std dev σ_{err} = 0.1





Maximum Likelihood with measurement error

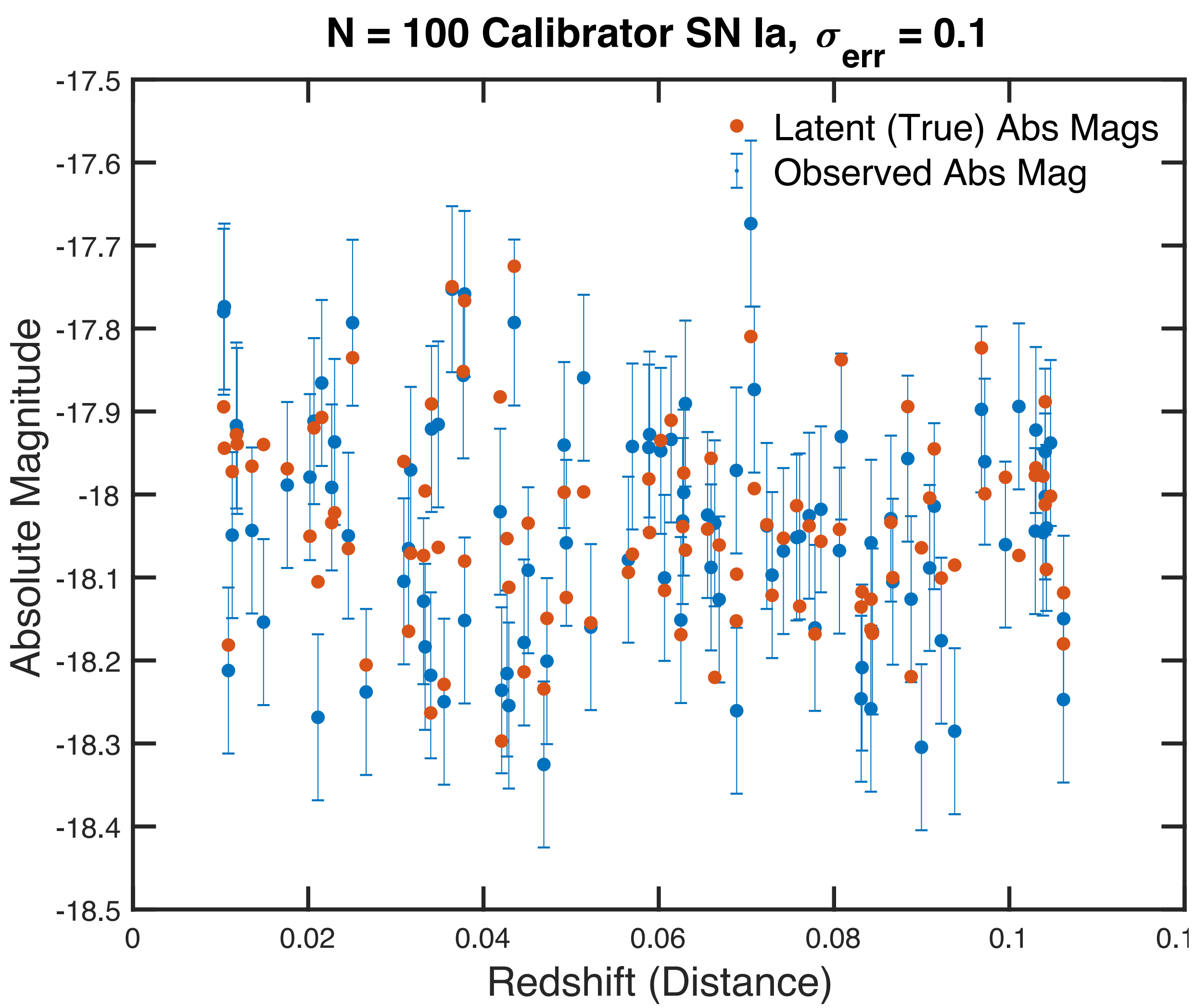
N = 50

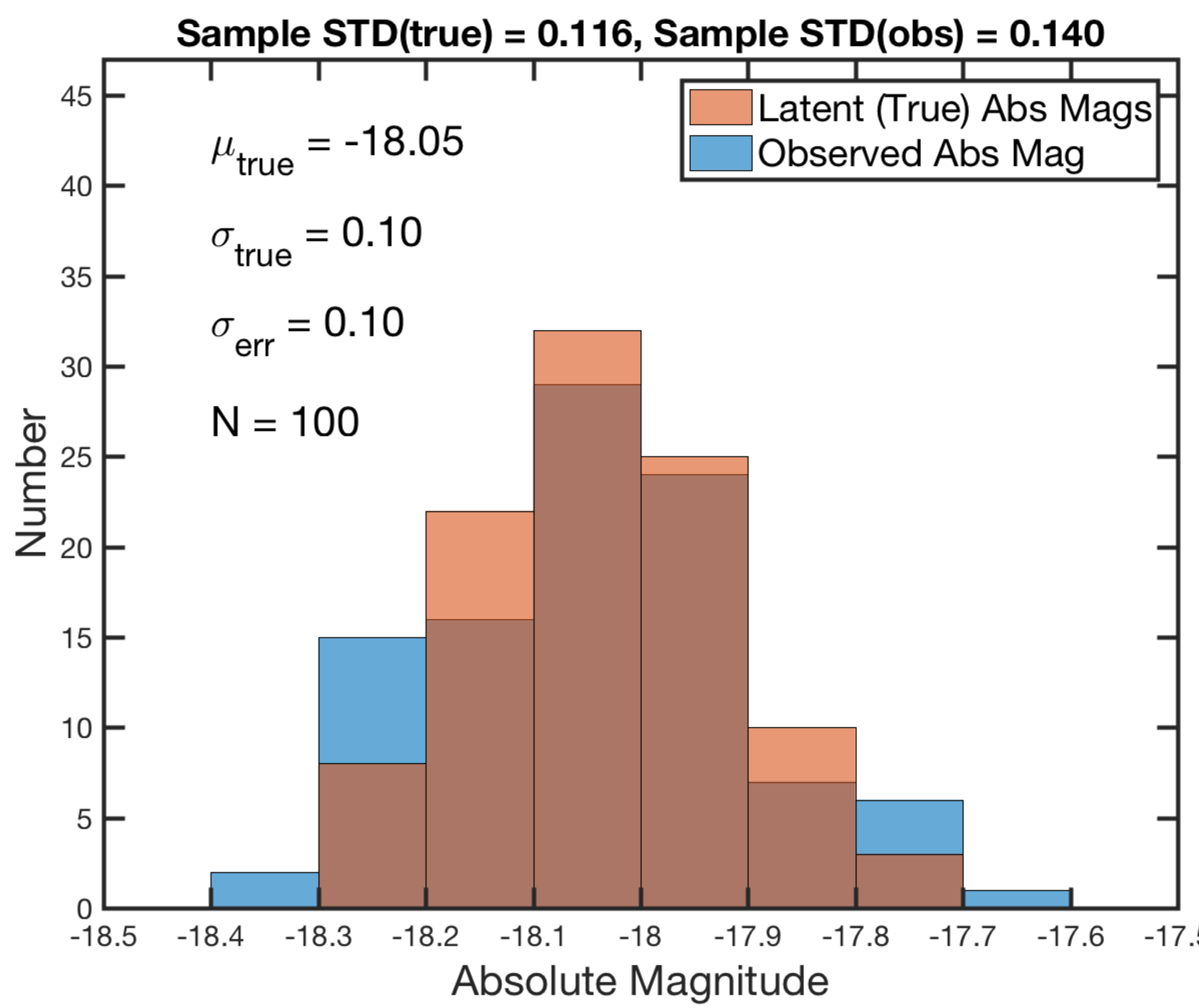


σ_{int}

M_0

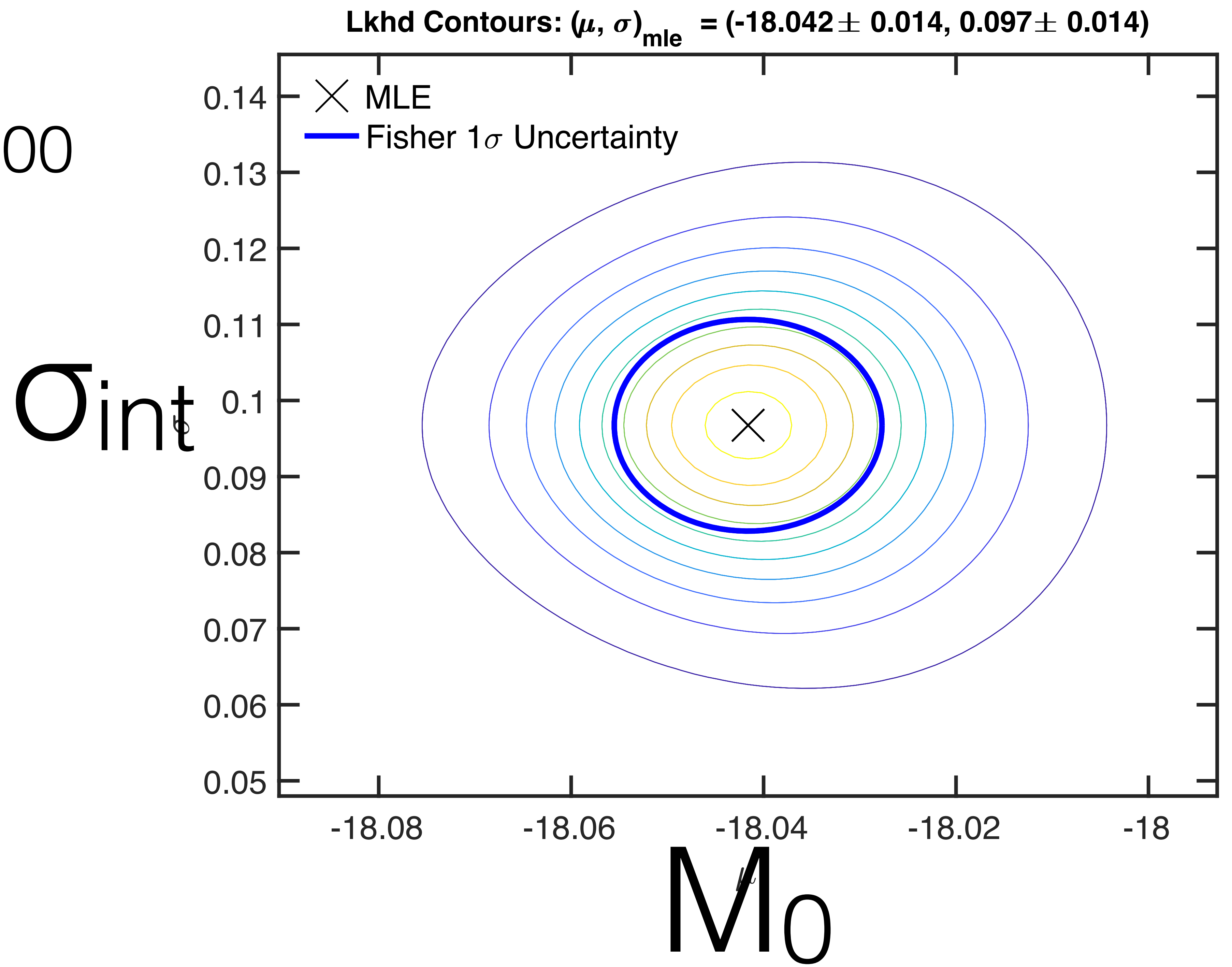
Want to Calibrate SN Ia (N=100) determine M_0, σ_{int}



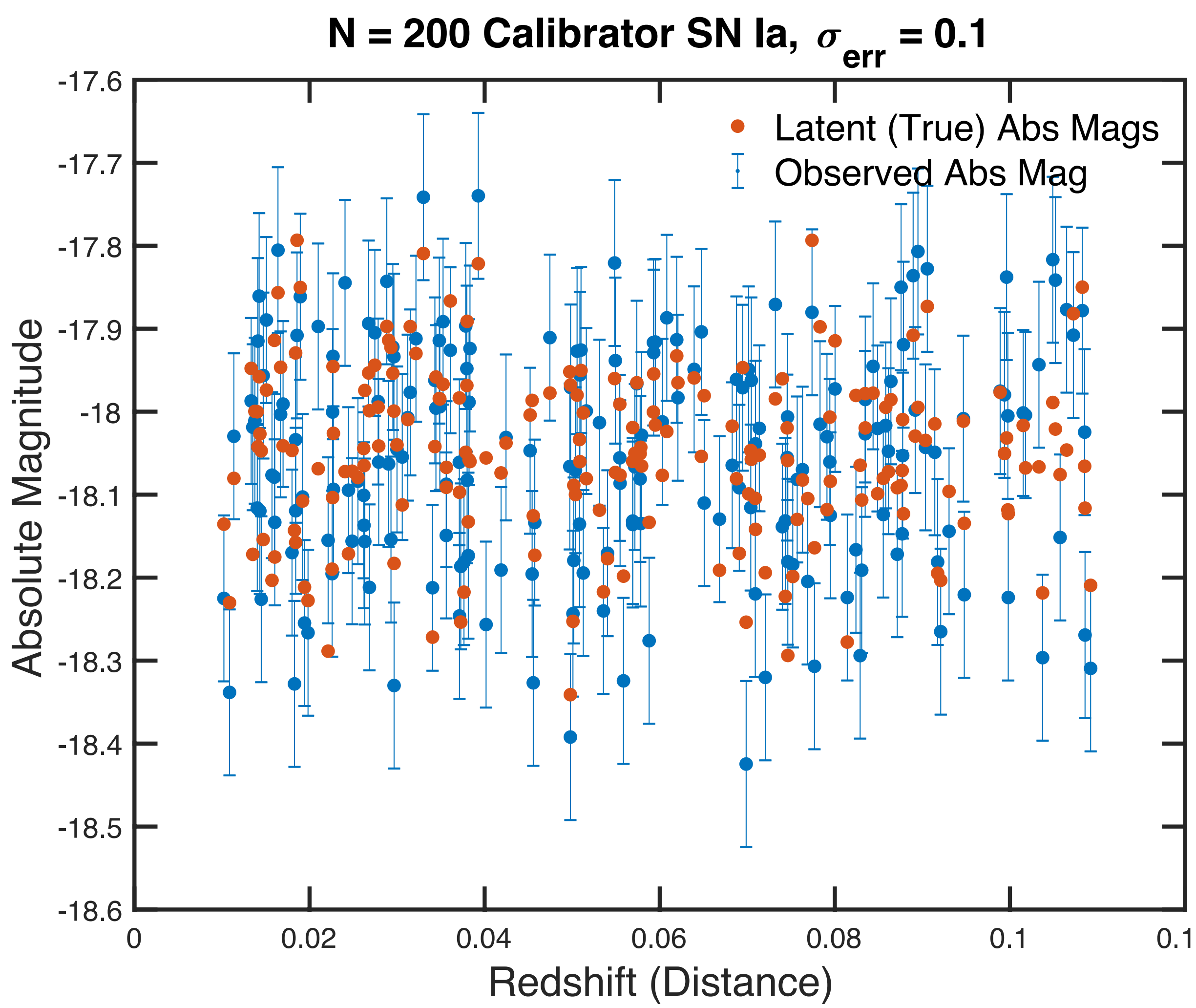


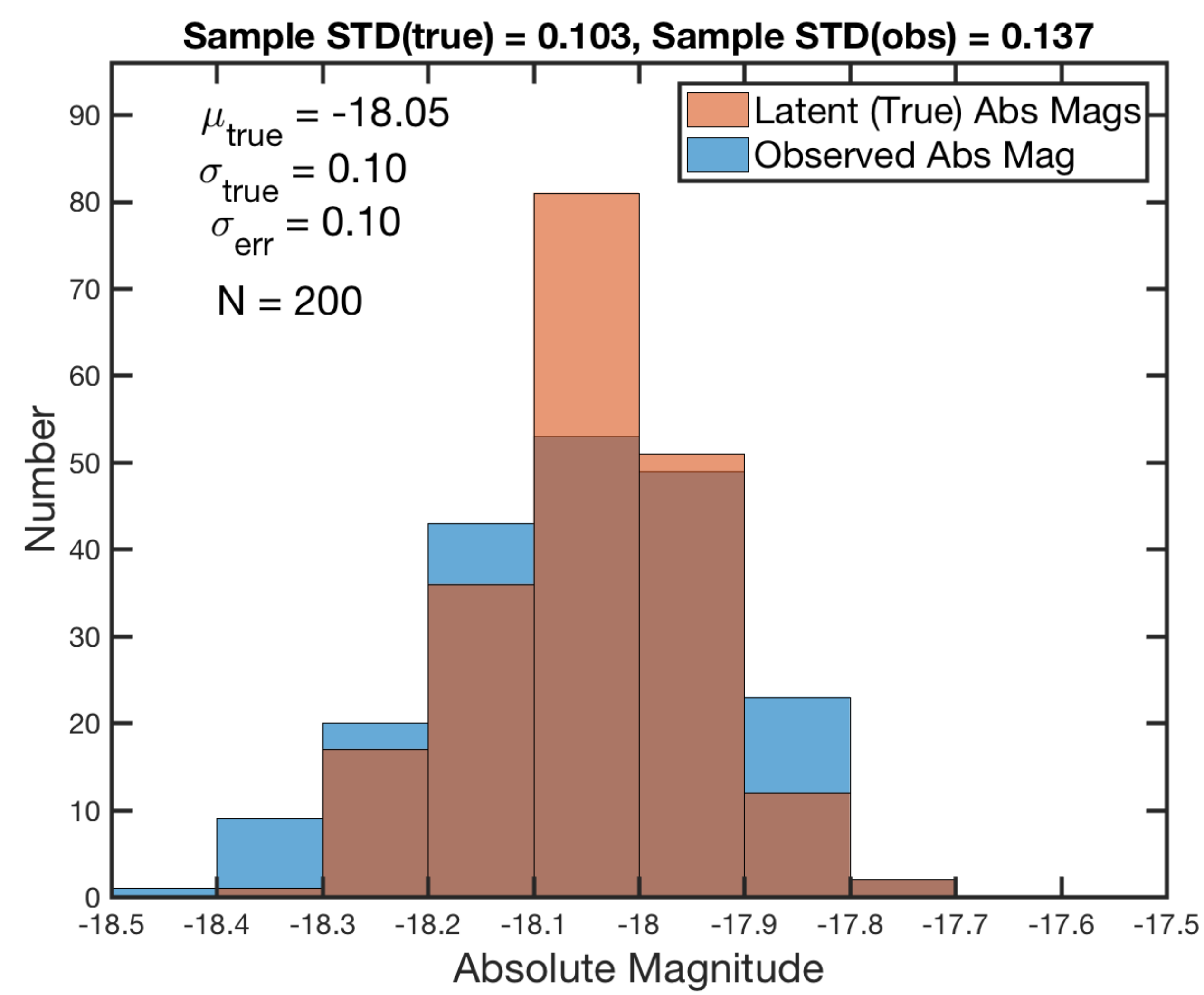
Maximum Likelihood with measurement error

N = 100



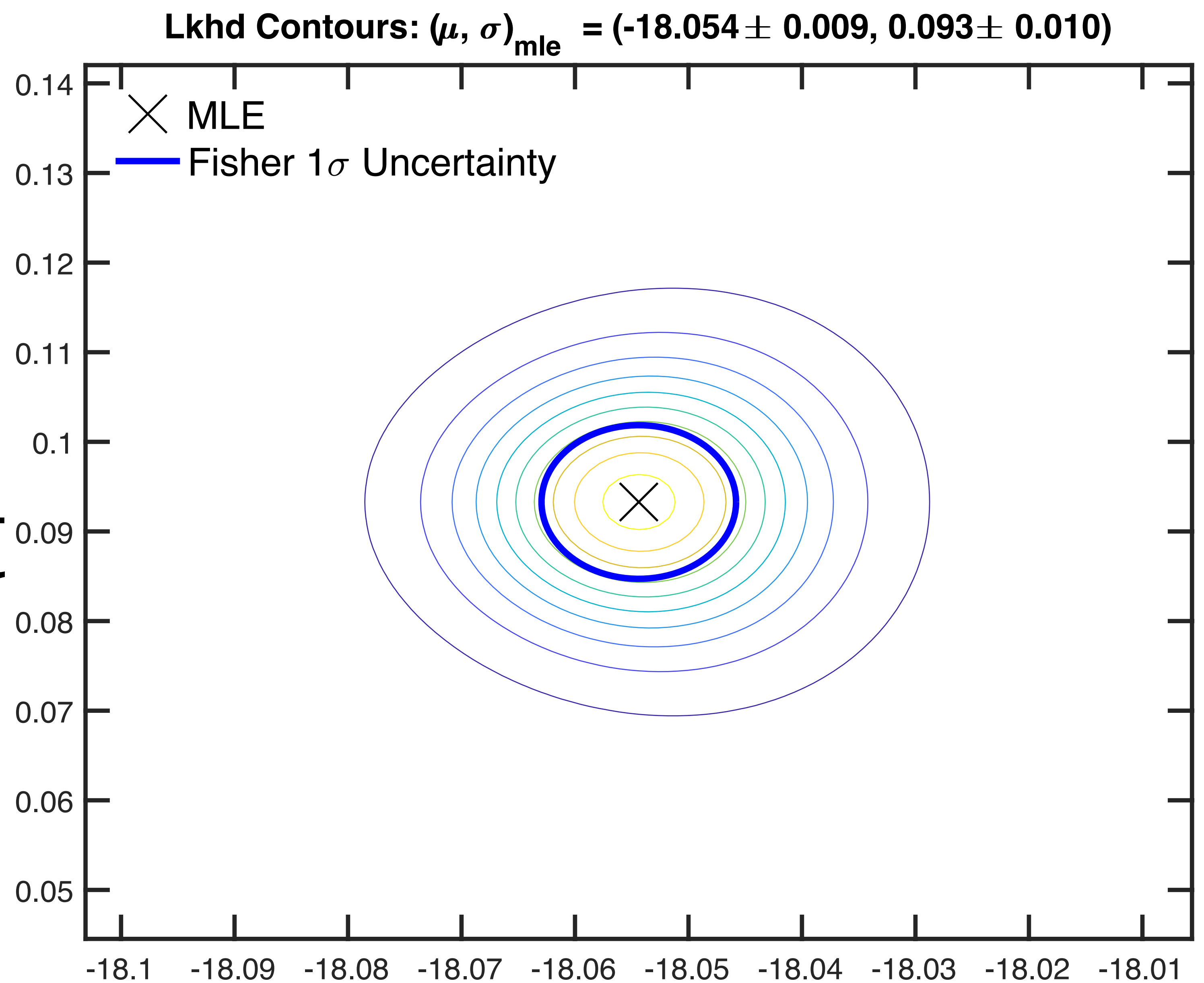
Want to Calibrate SN Ia (N=200) determine M_0, σ_{int}





Maximum Likelihood with measurement error

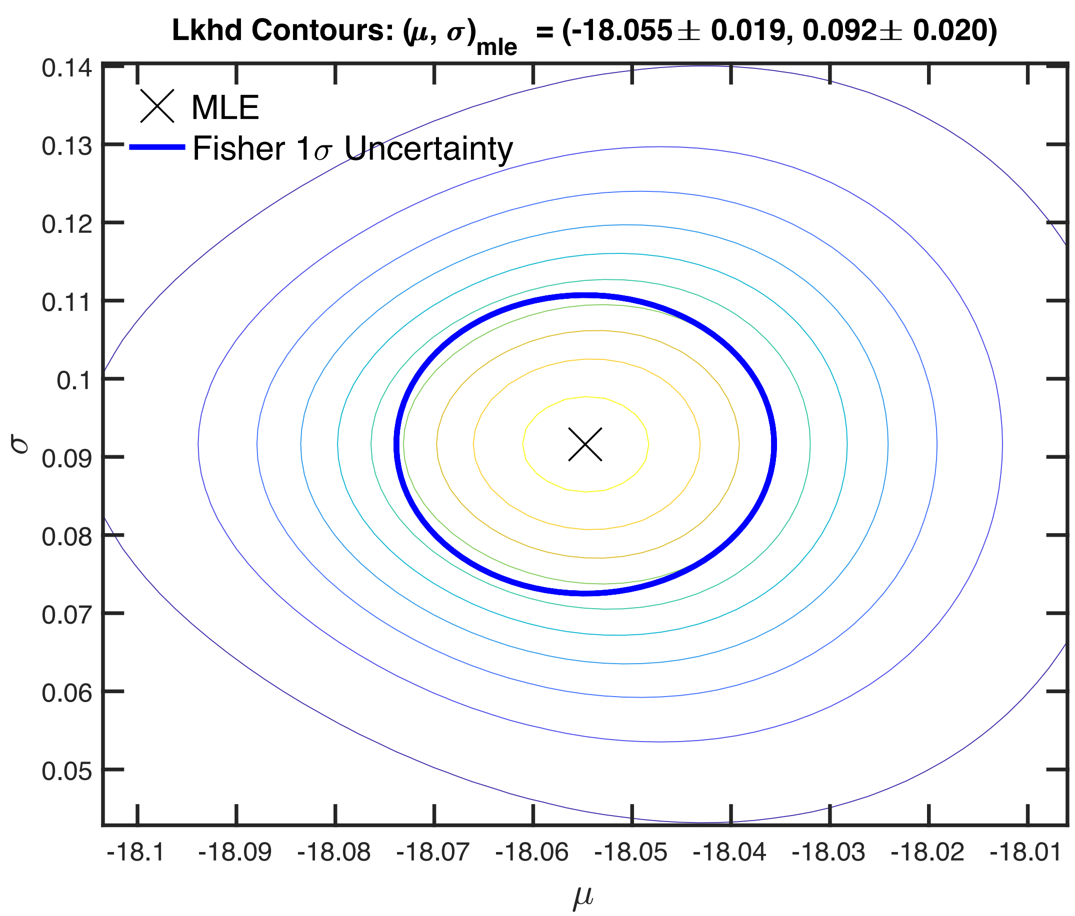
N = 200



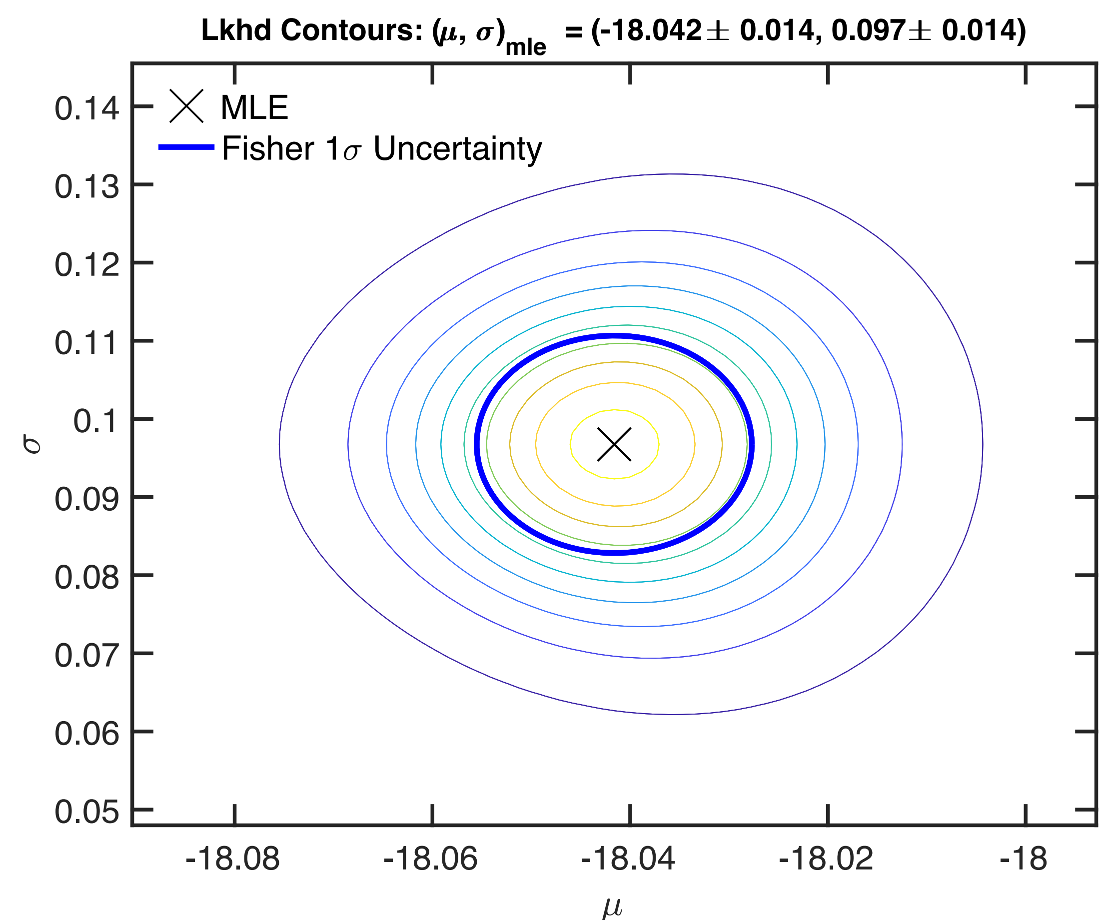
σ_{int}

M_0

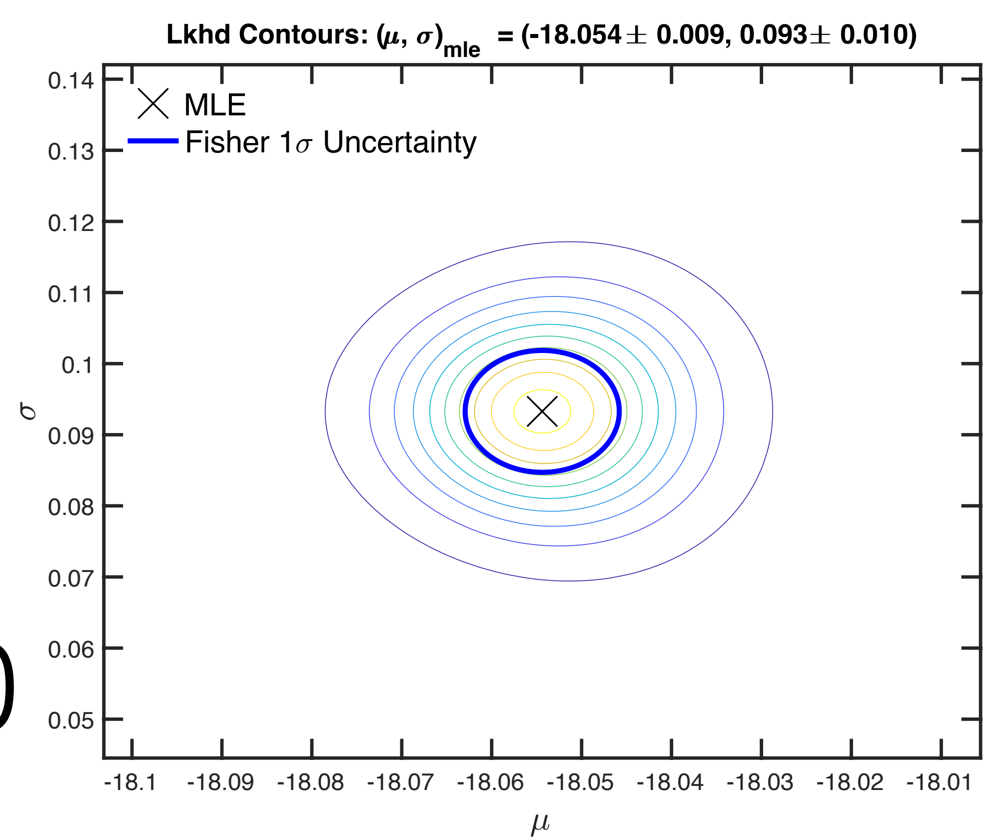
Constraints vs. sample size



N=50

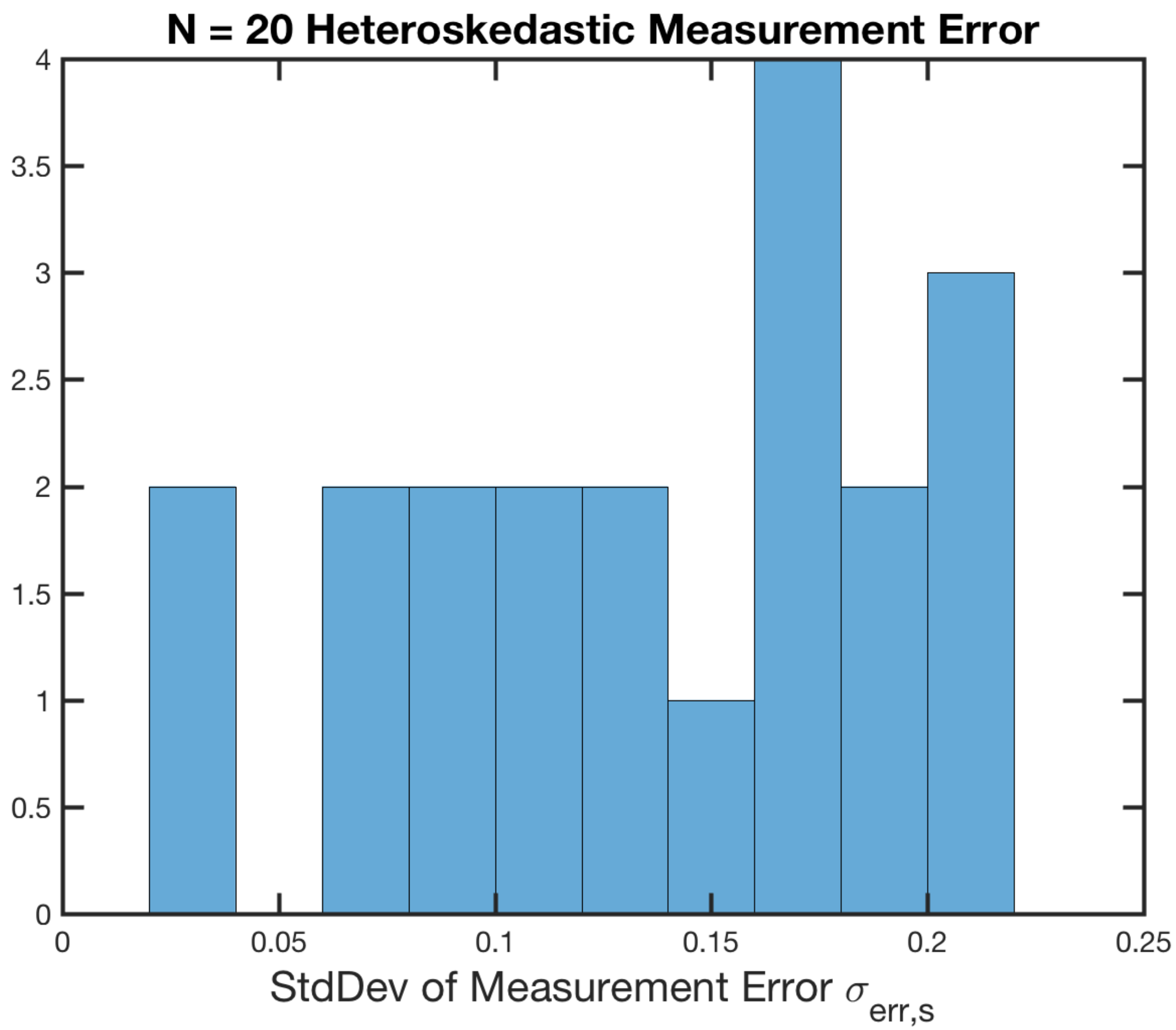


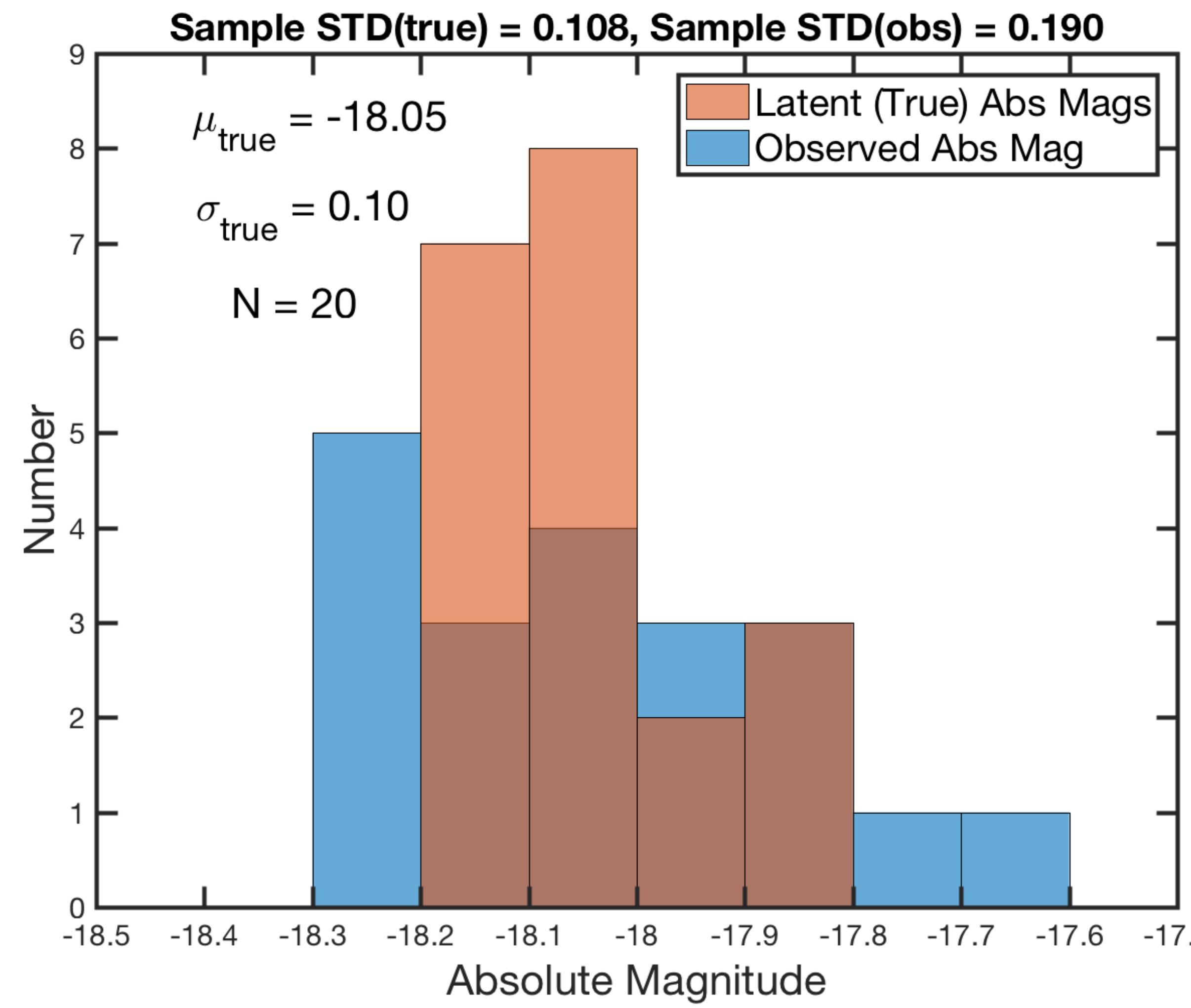
N=100



N=200

Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

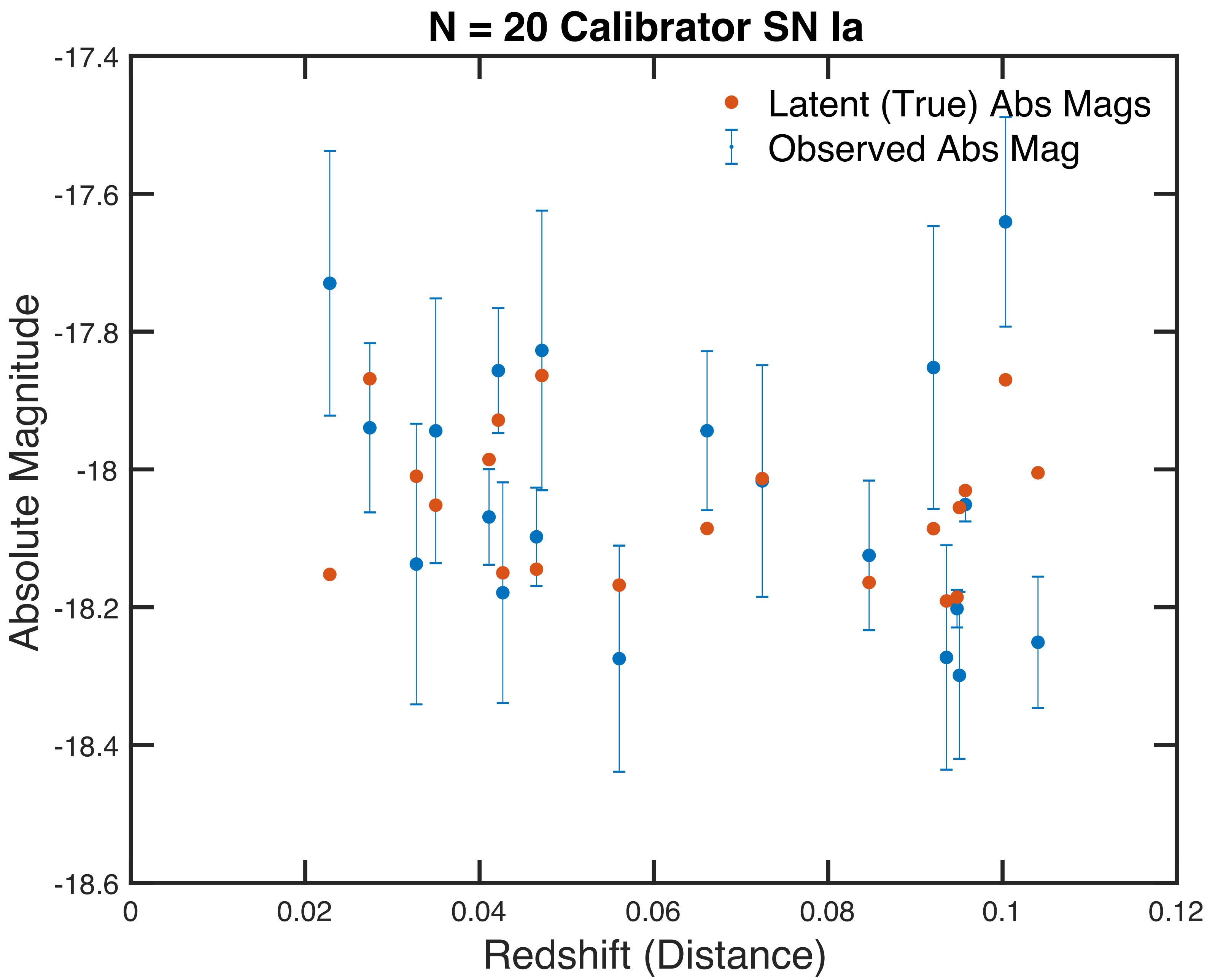




N = 20

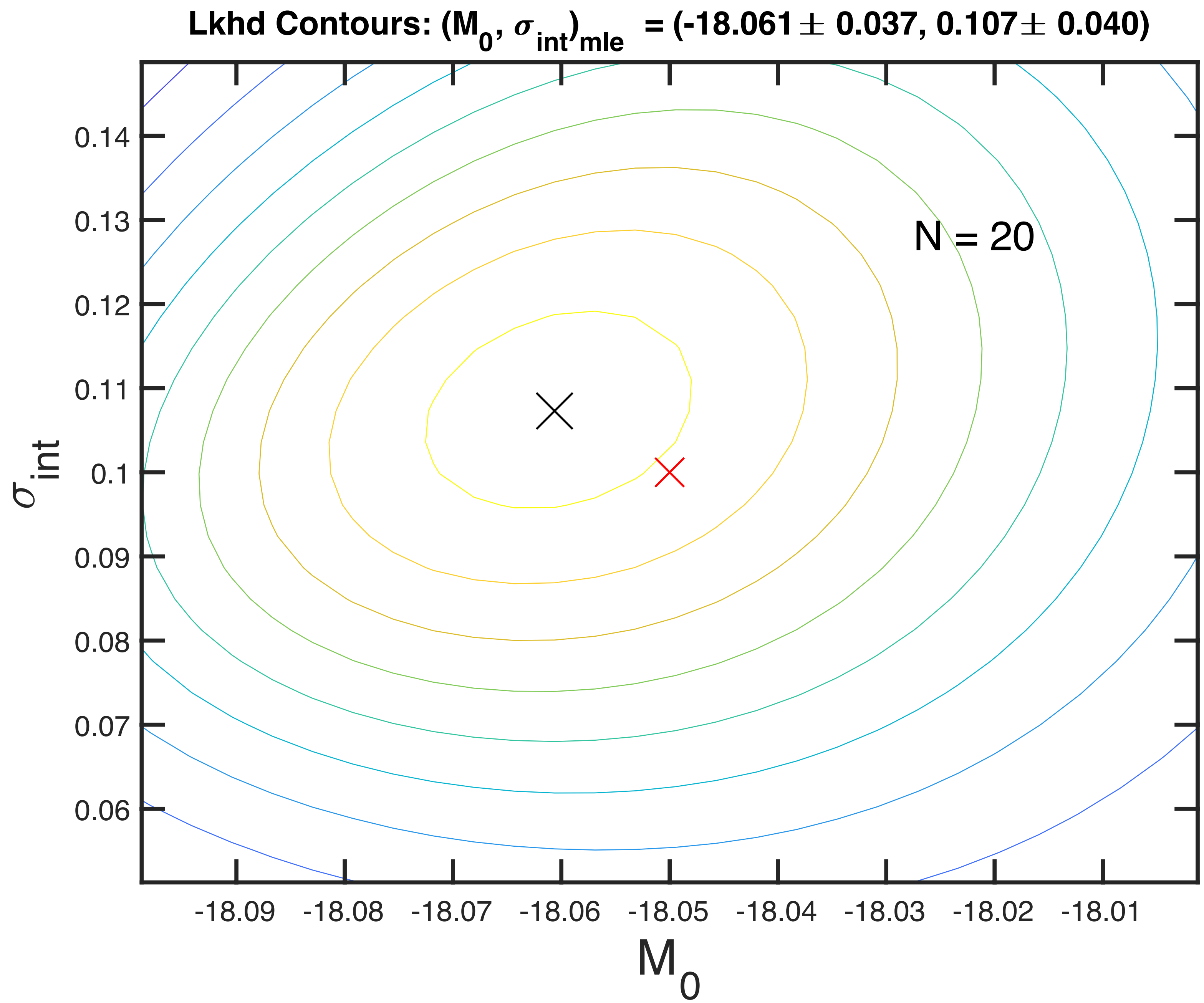
Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

N = 20

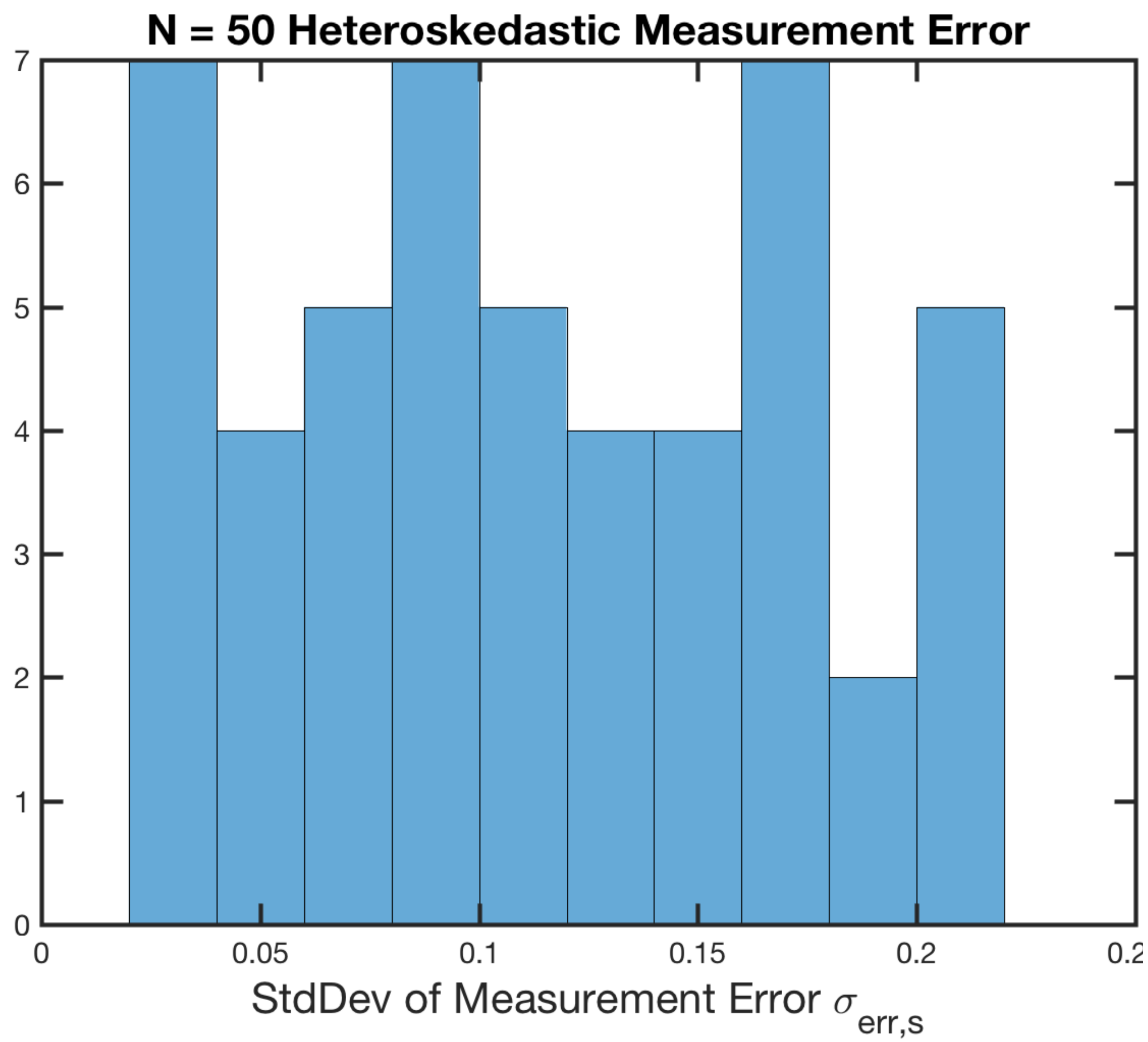


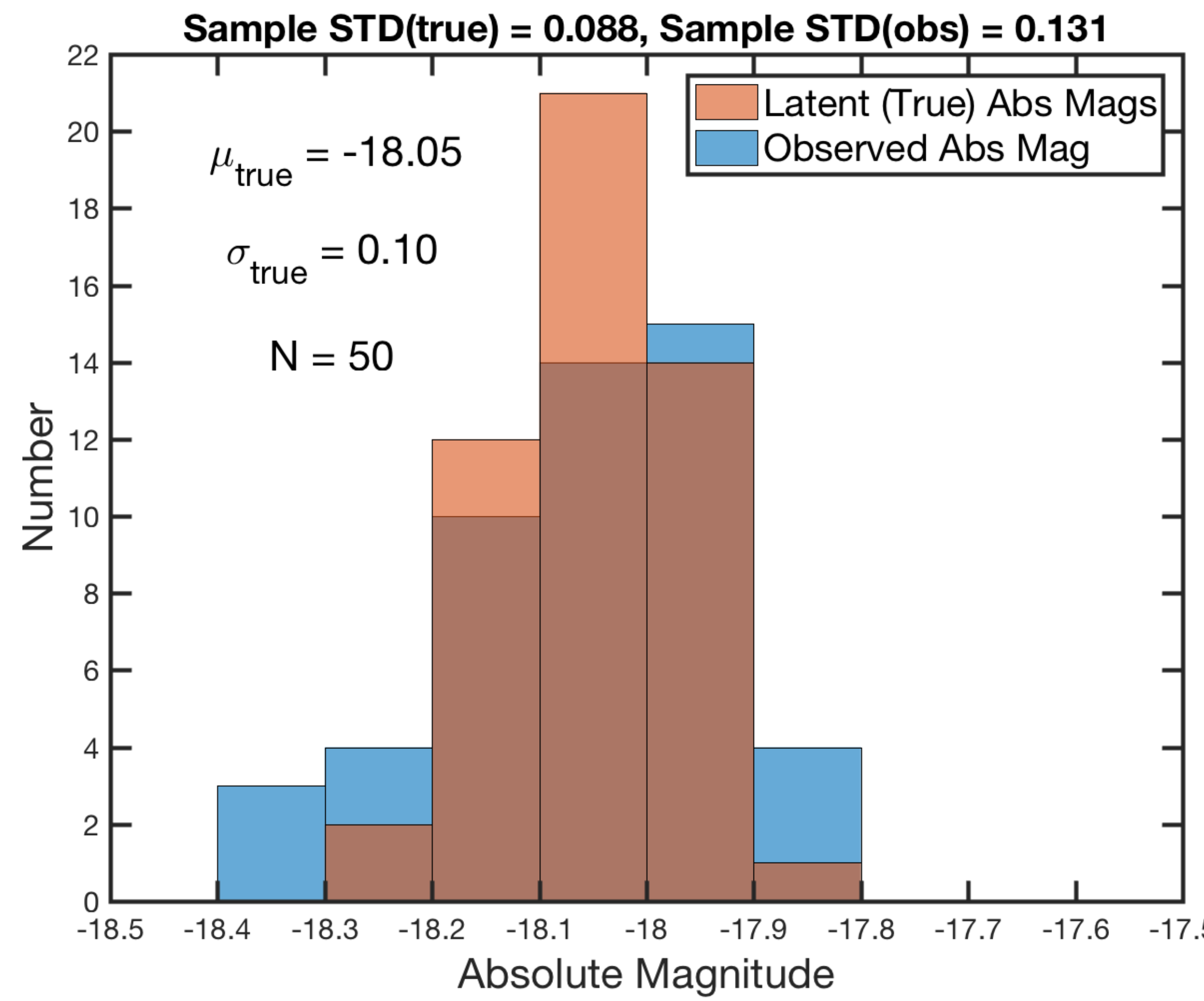
Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

N = 20



Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

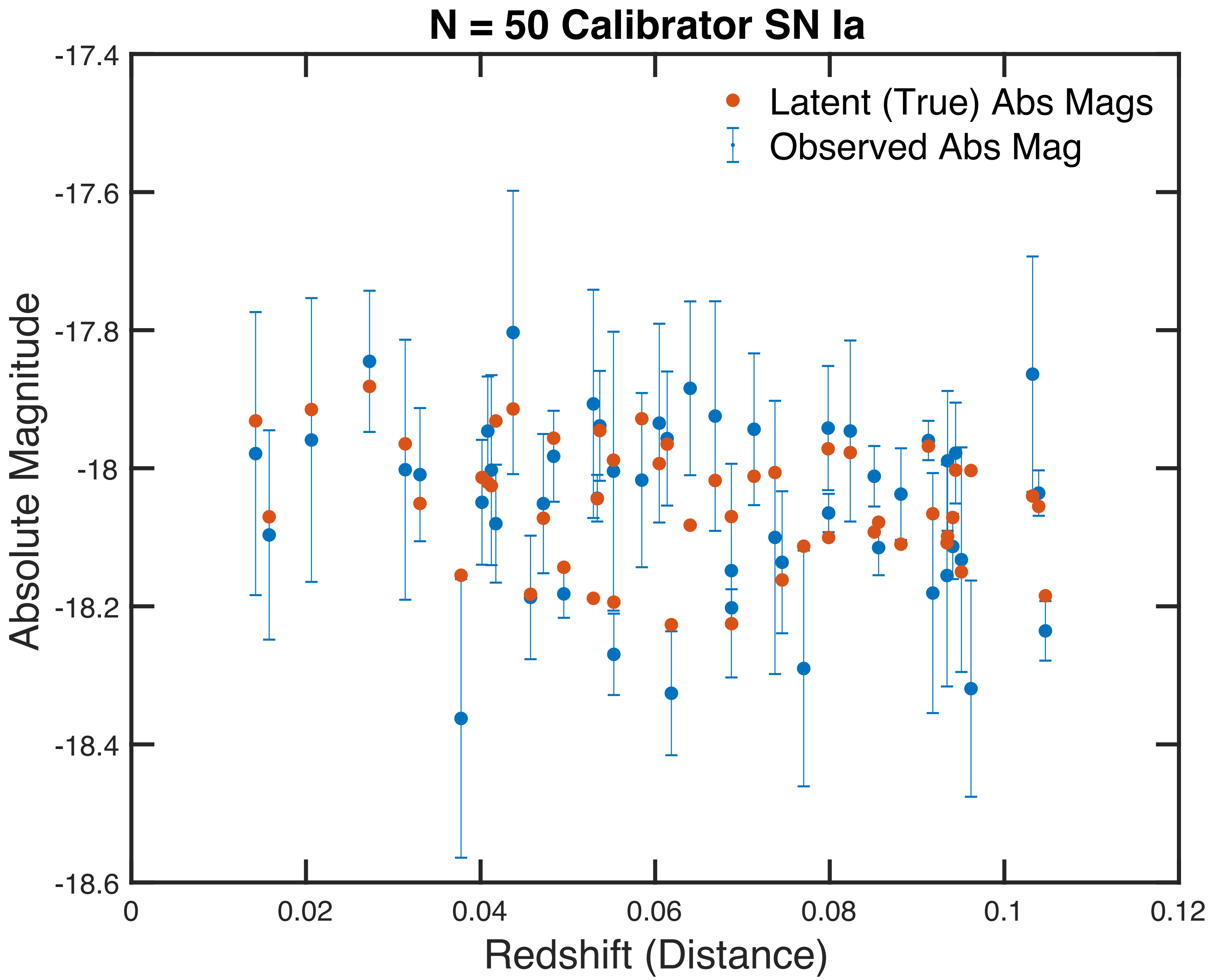




N = 50

Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

N = 50



Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

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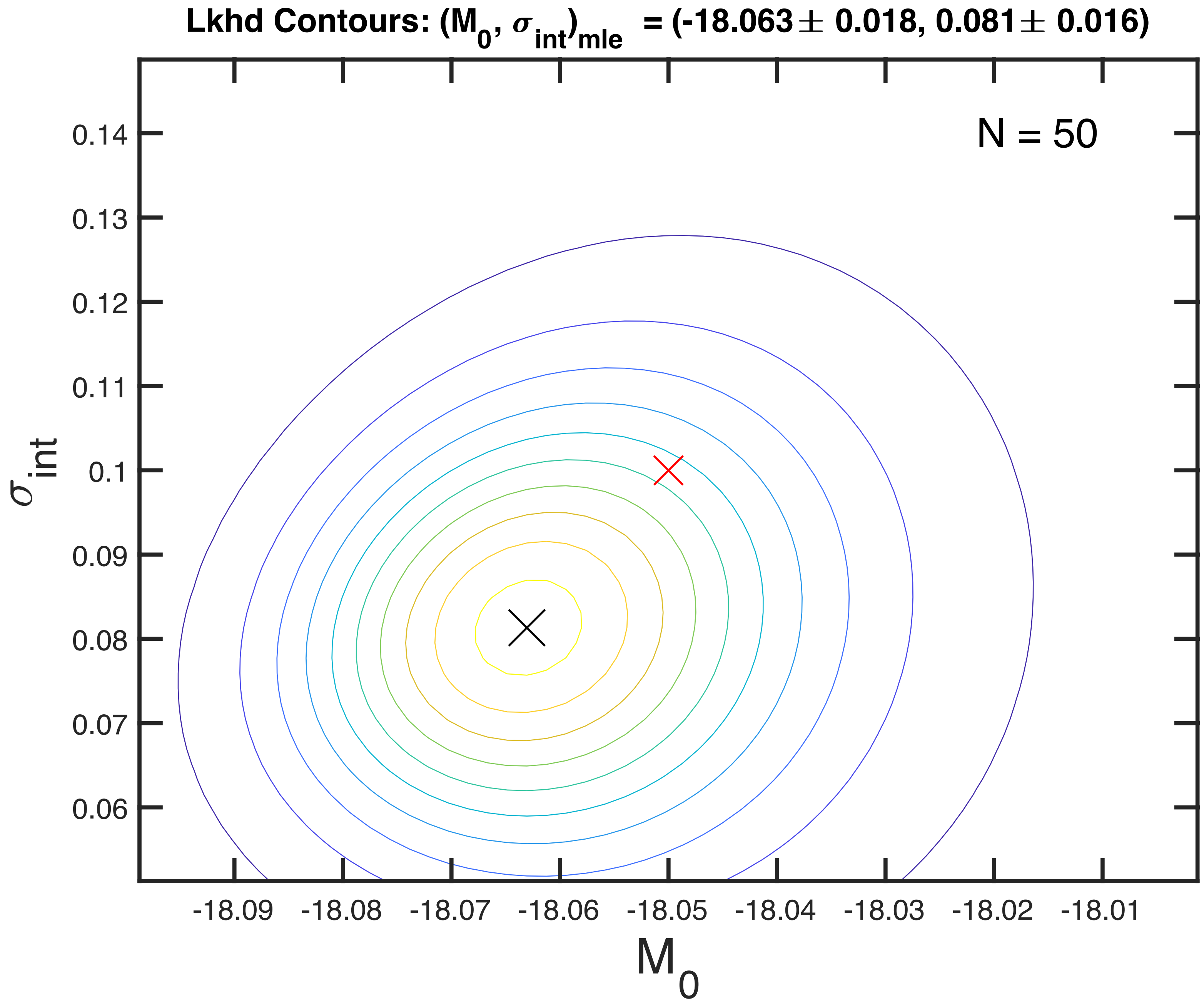
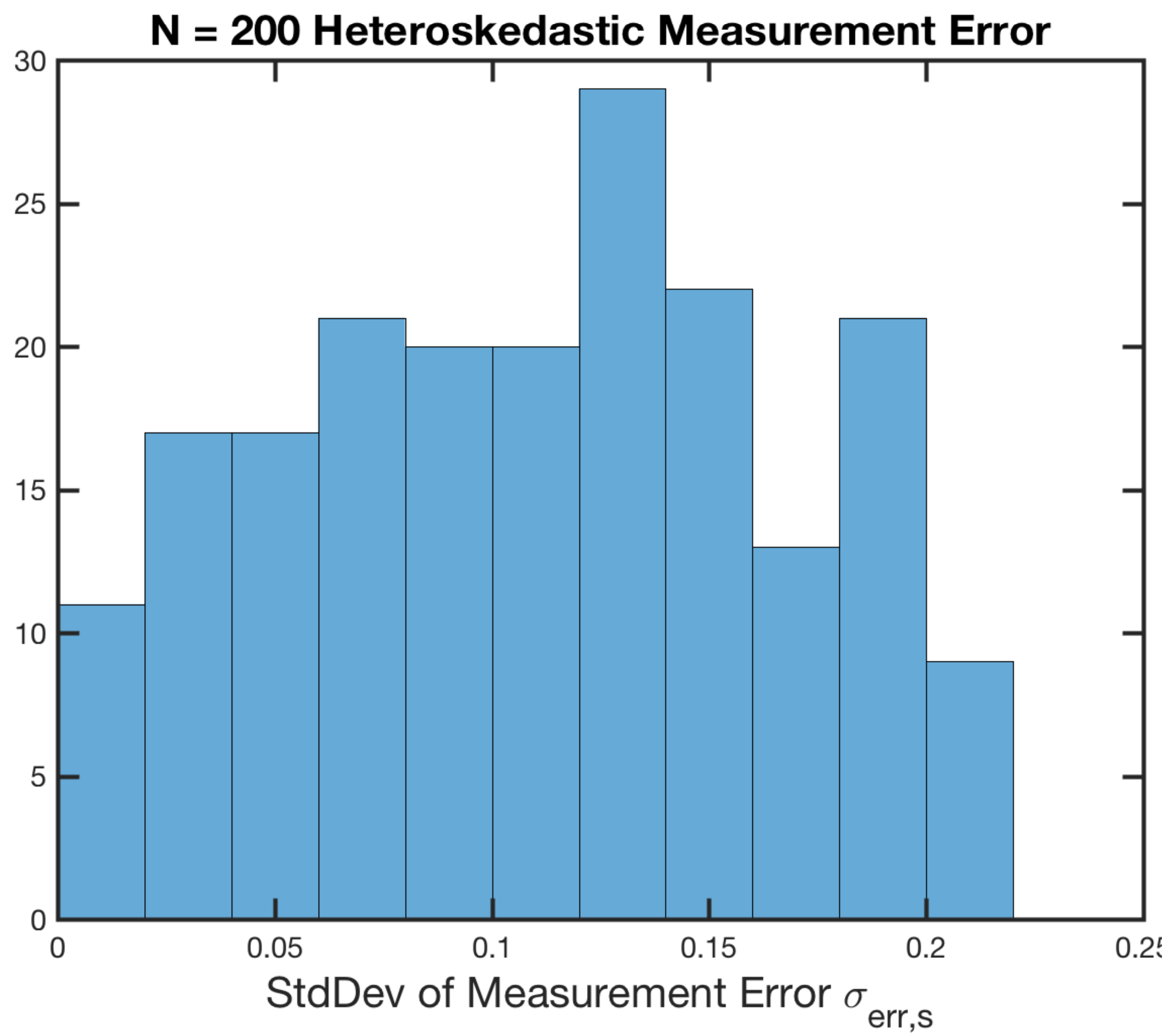
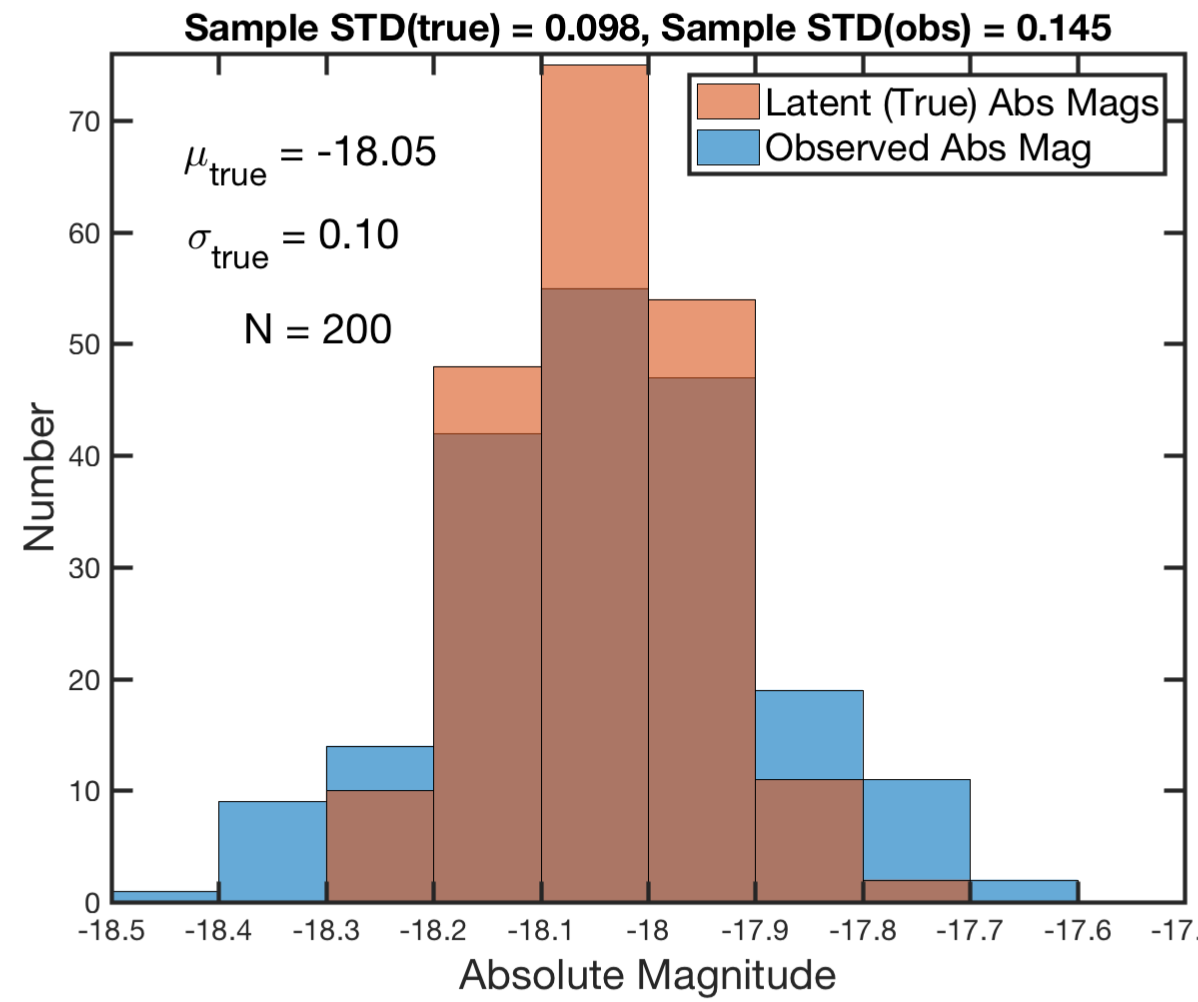


Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

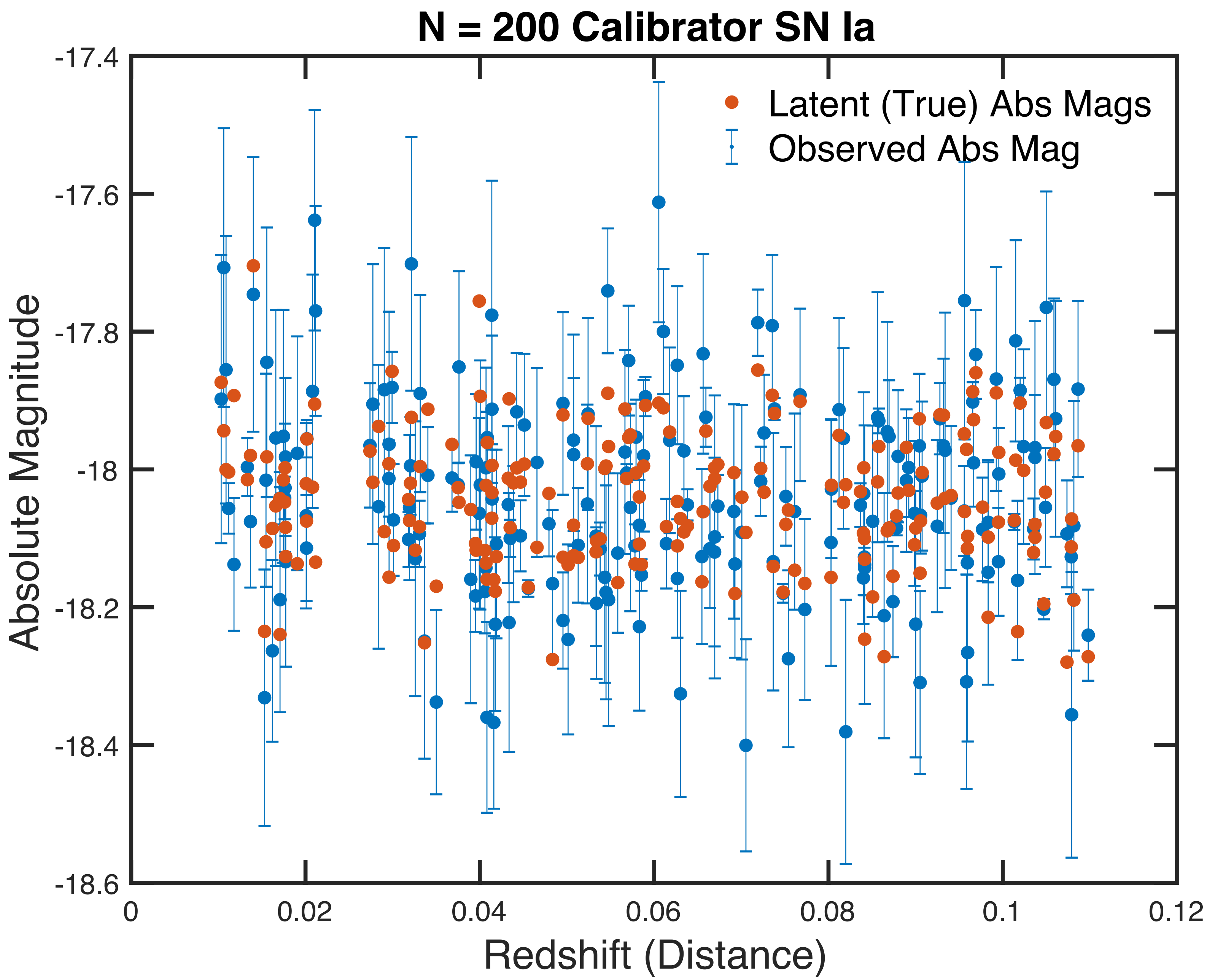




N = 200

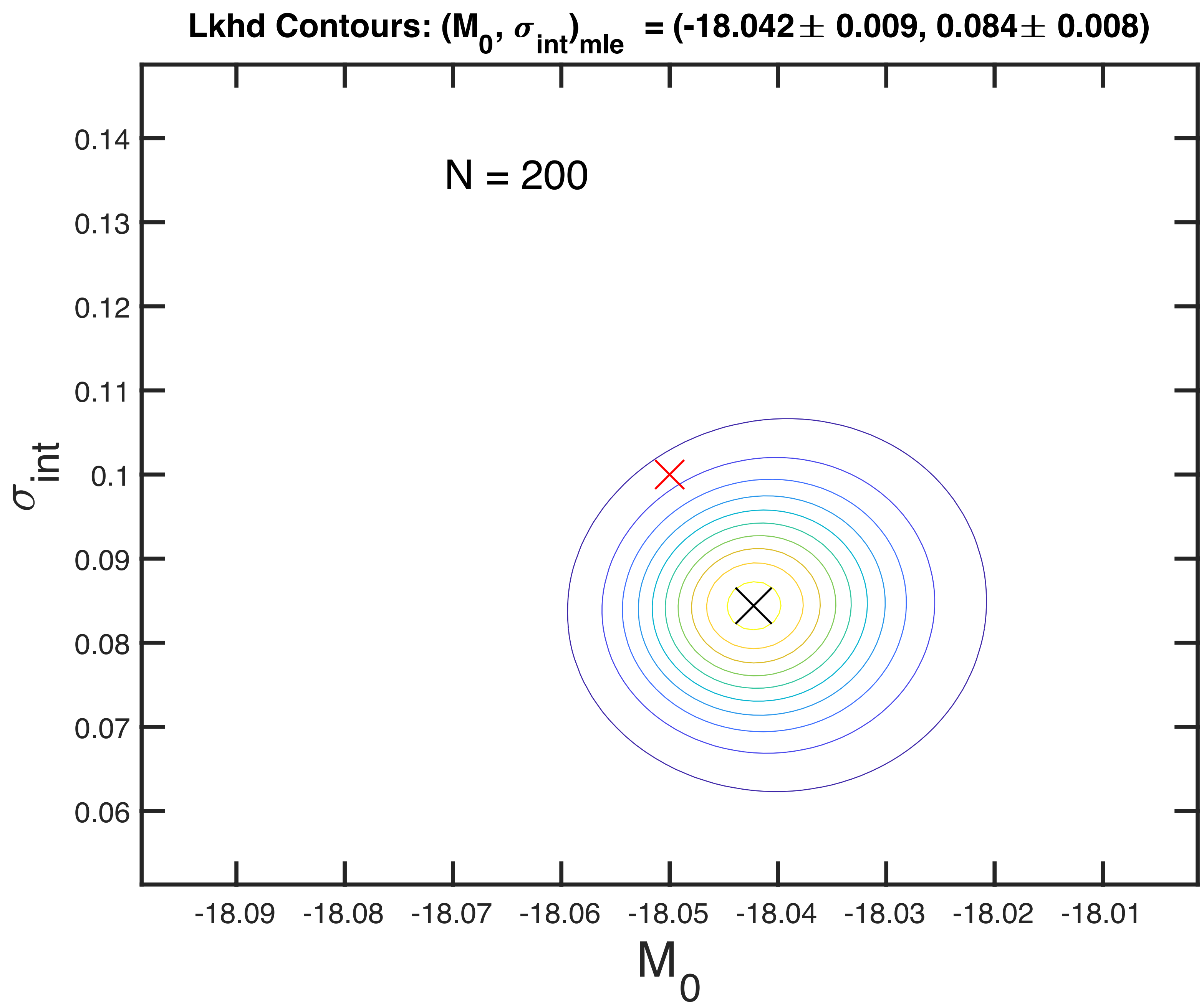
Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

N = 200

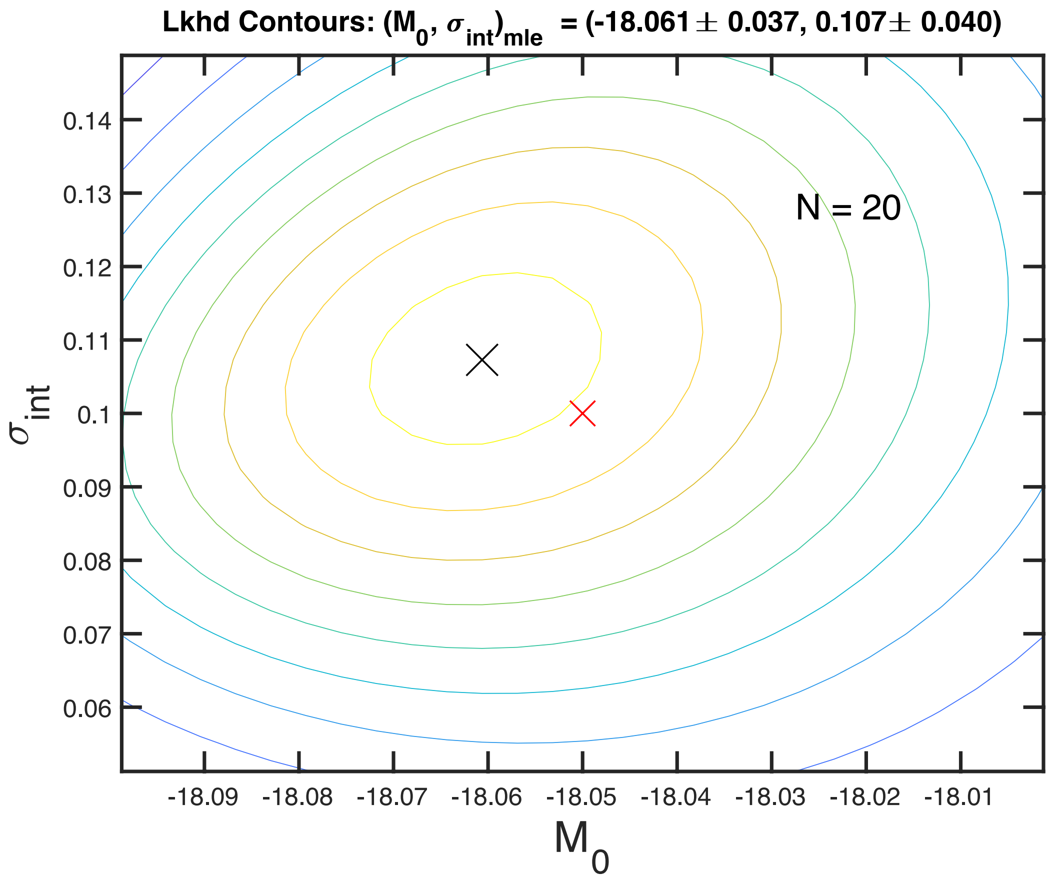


Maximum Likelihood with heteroskedastic measurement error with std devs σ_{err} = 0.01 to 0.21

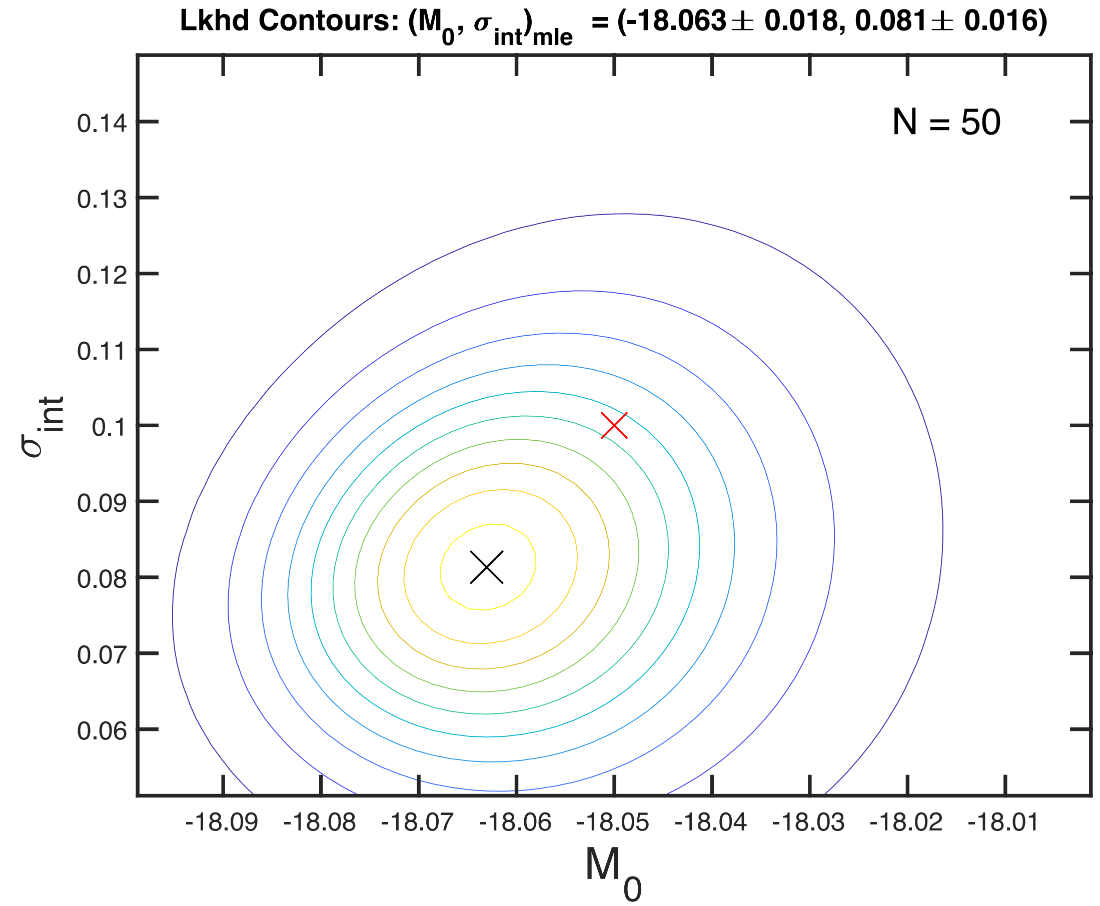
N = 200



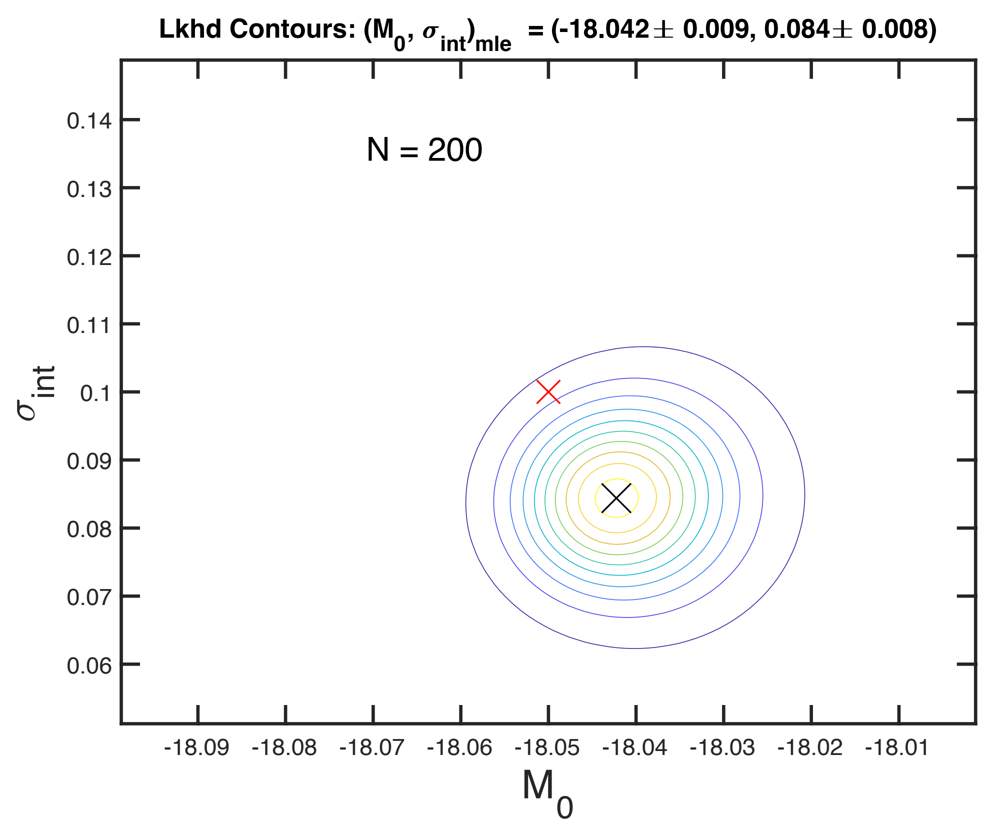
Constraints vs. sample size



N=20

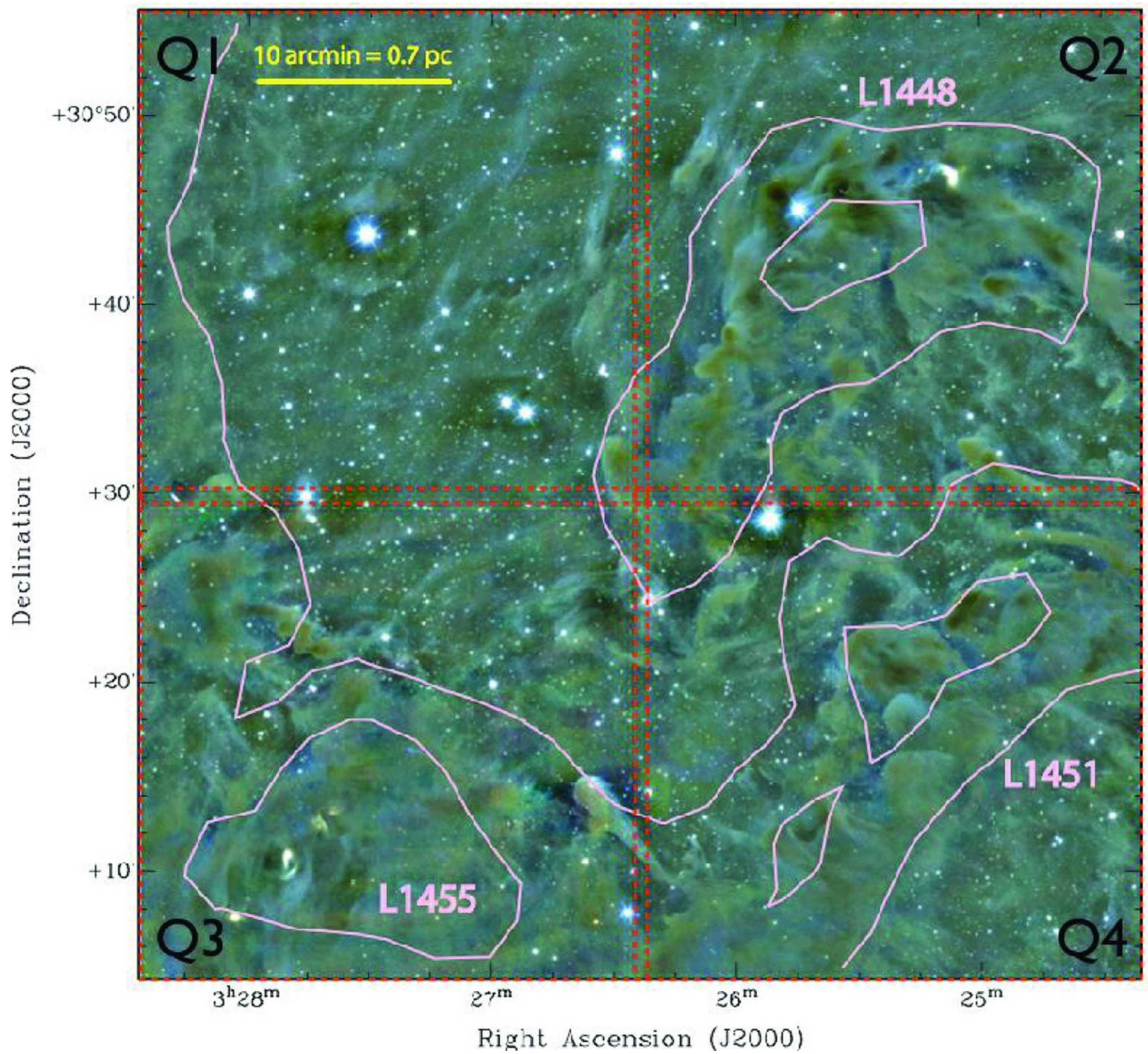


N=50



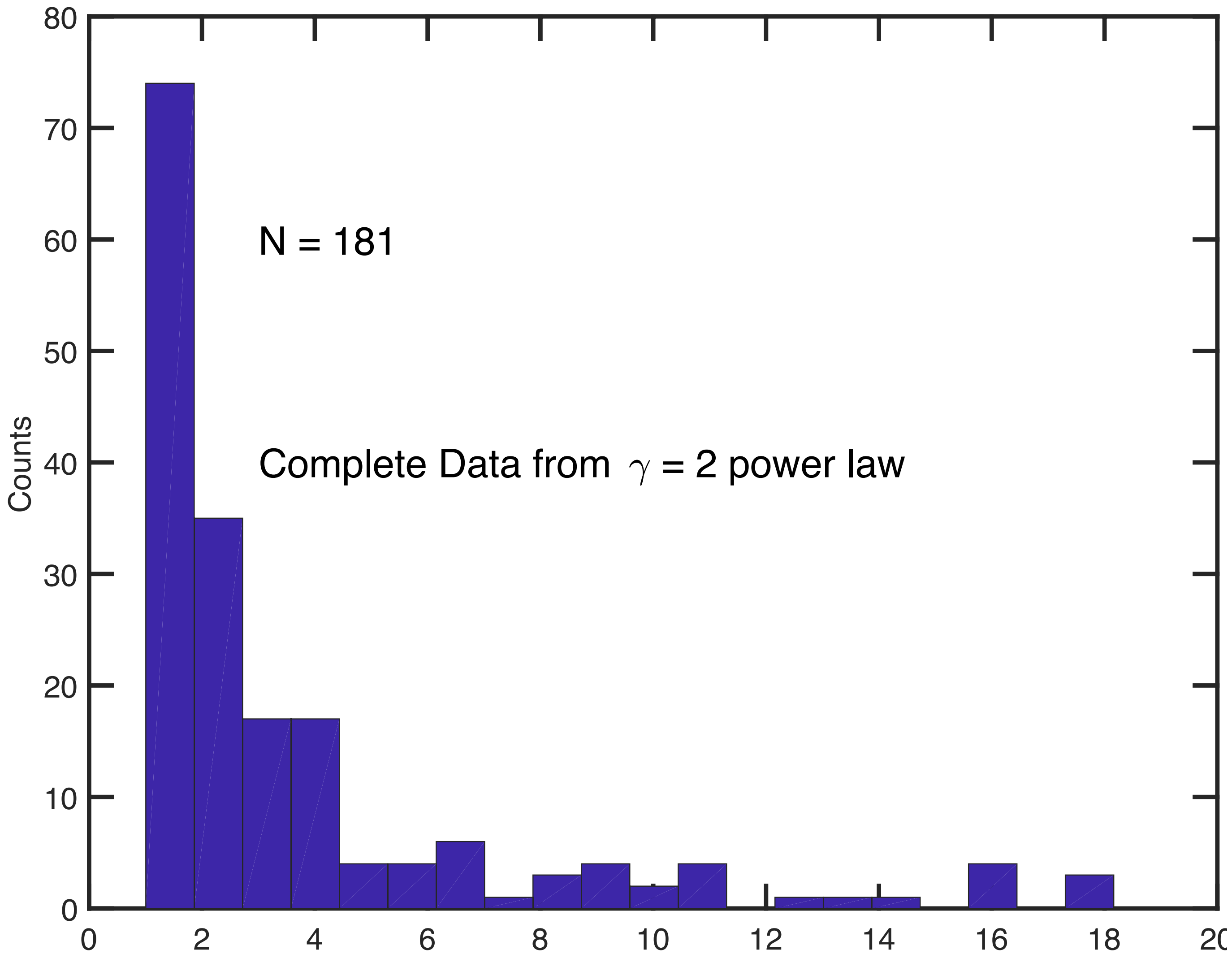
N=200

Star Formation in Perseus

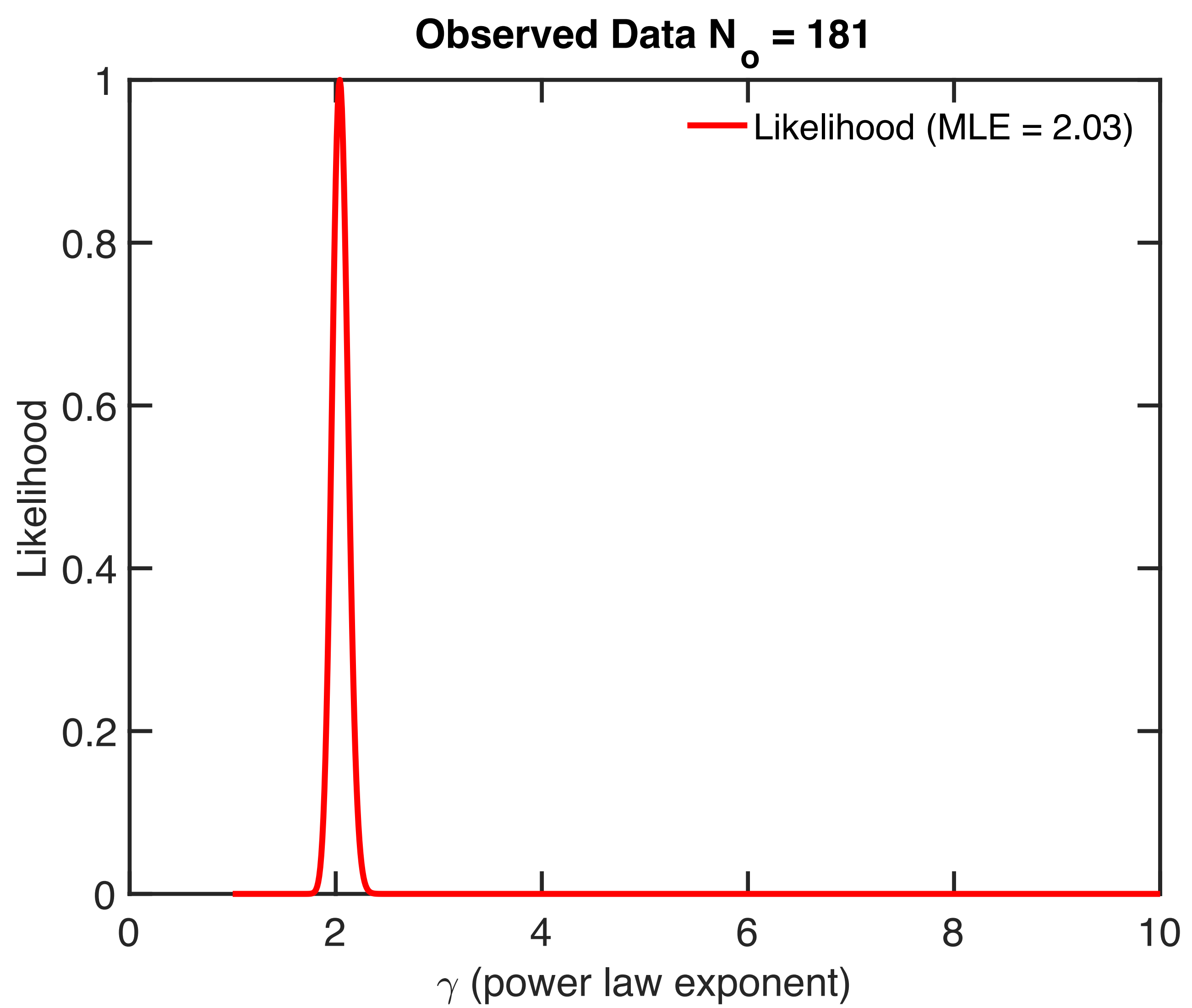


Inference of Stellar Mass Function

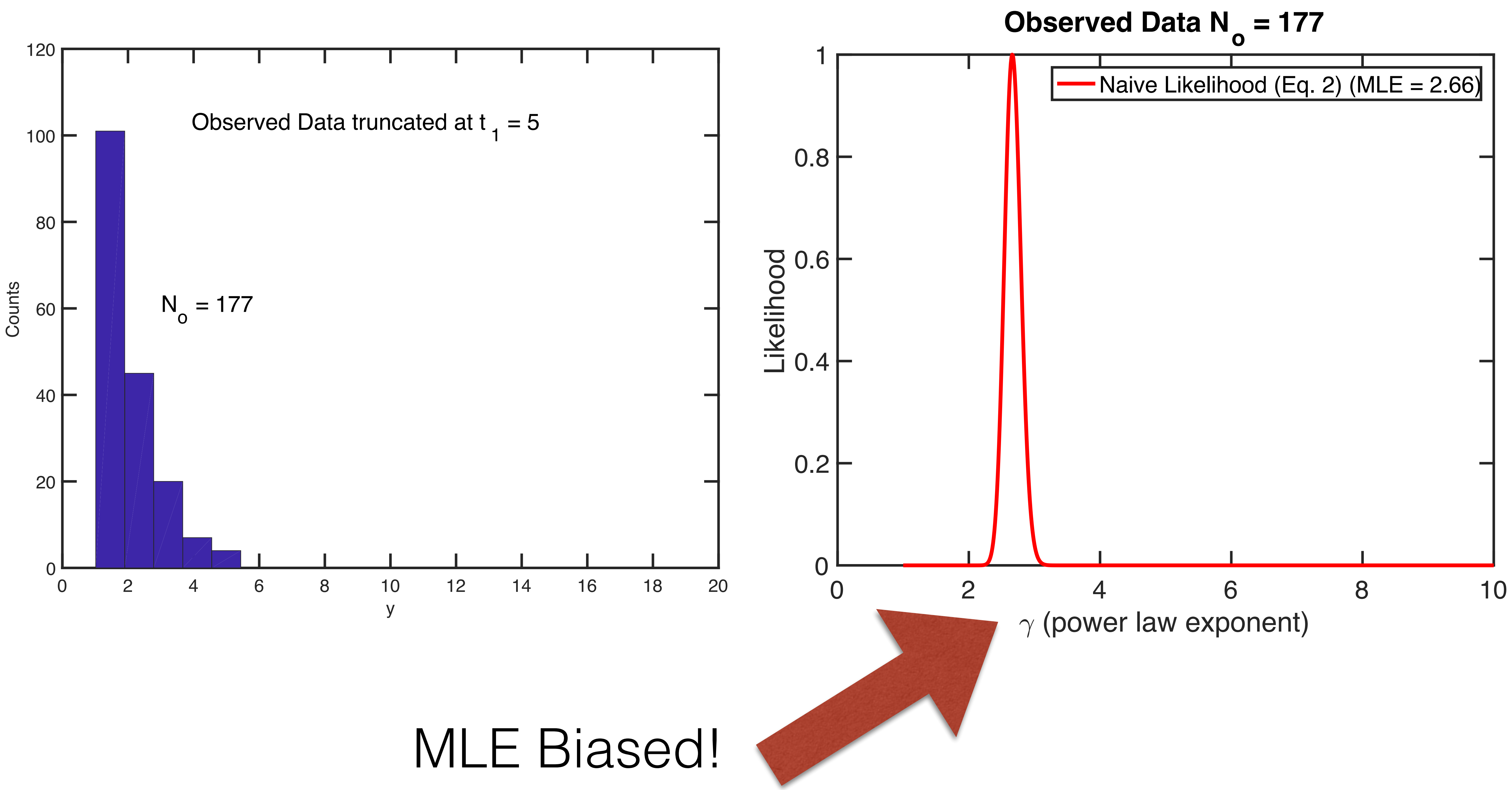
$$P(M) \propto M^{(-\gamma)}$$



Mass

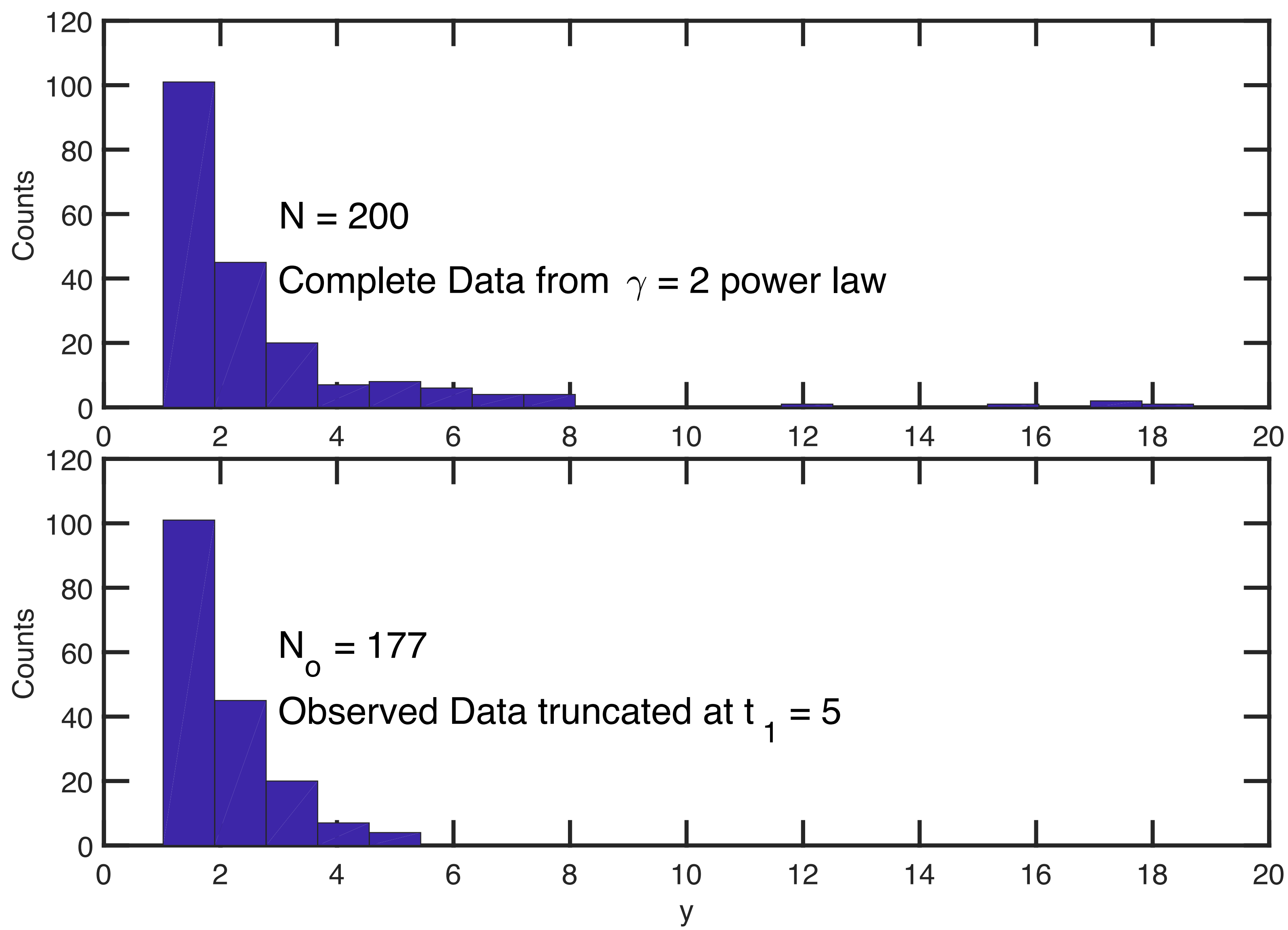


Selection Effect (Truncation)

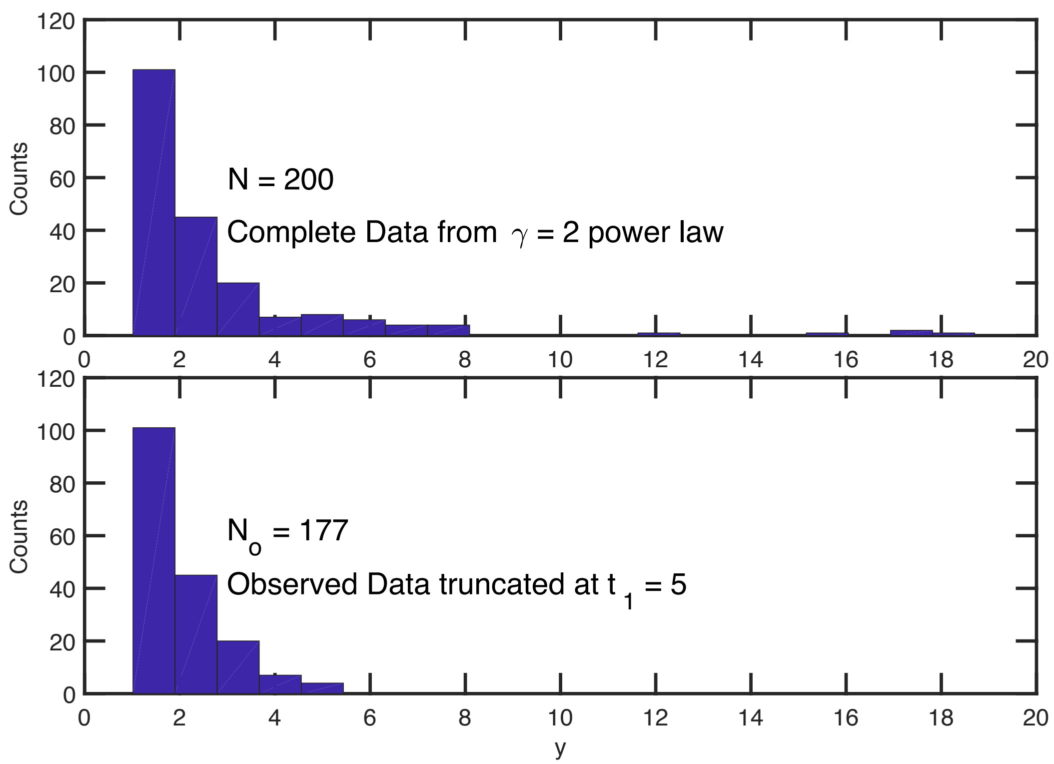


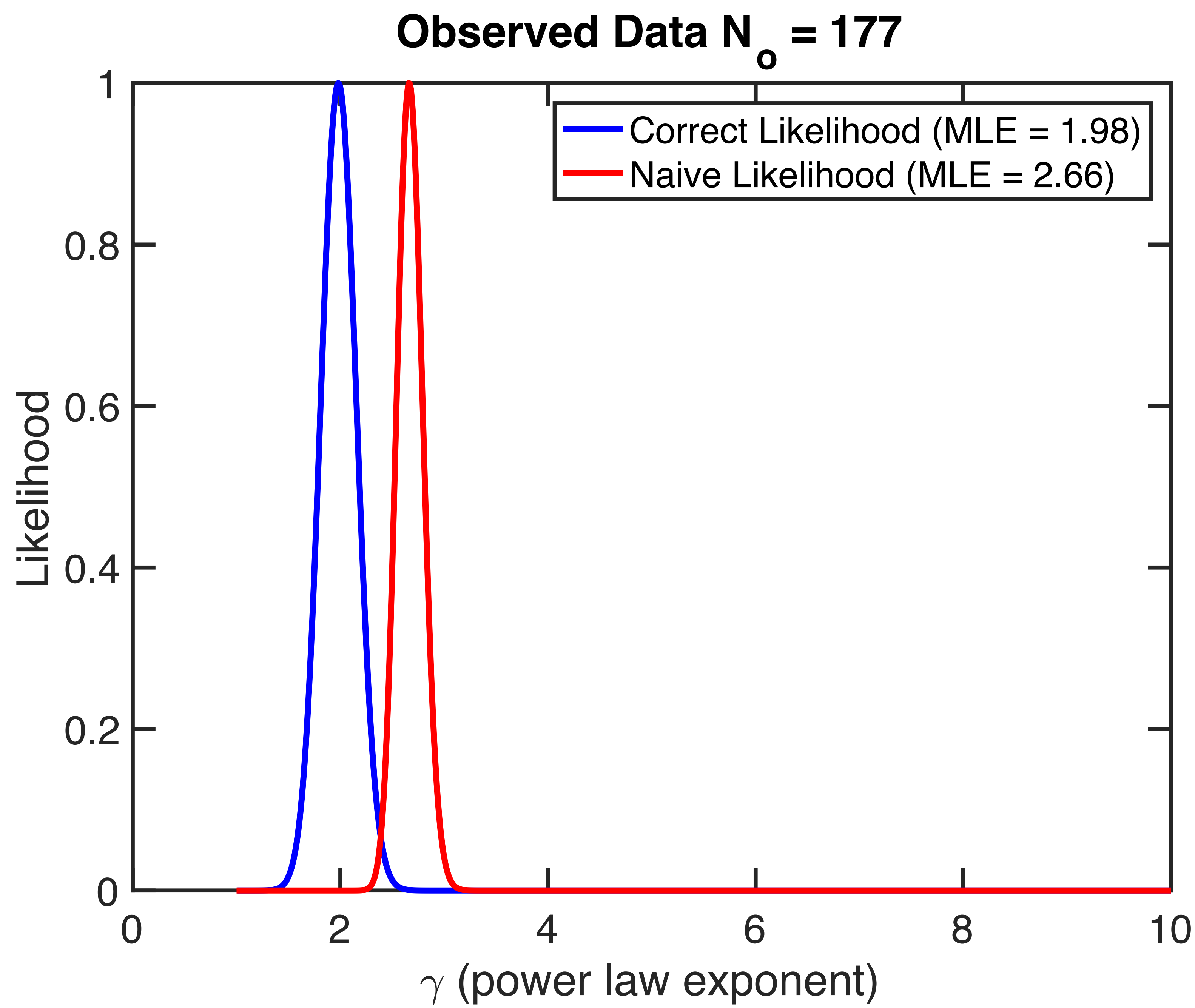
MLE Biased!

Stellar Mass Function Inference with Selection Effect: Complete Data vs. Truncated Data

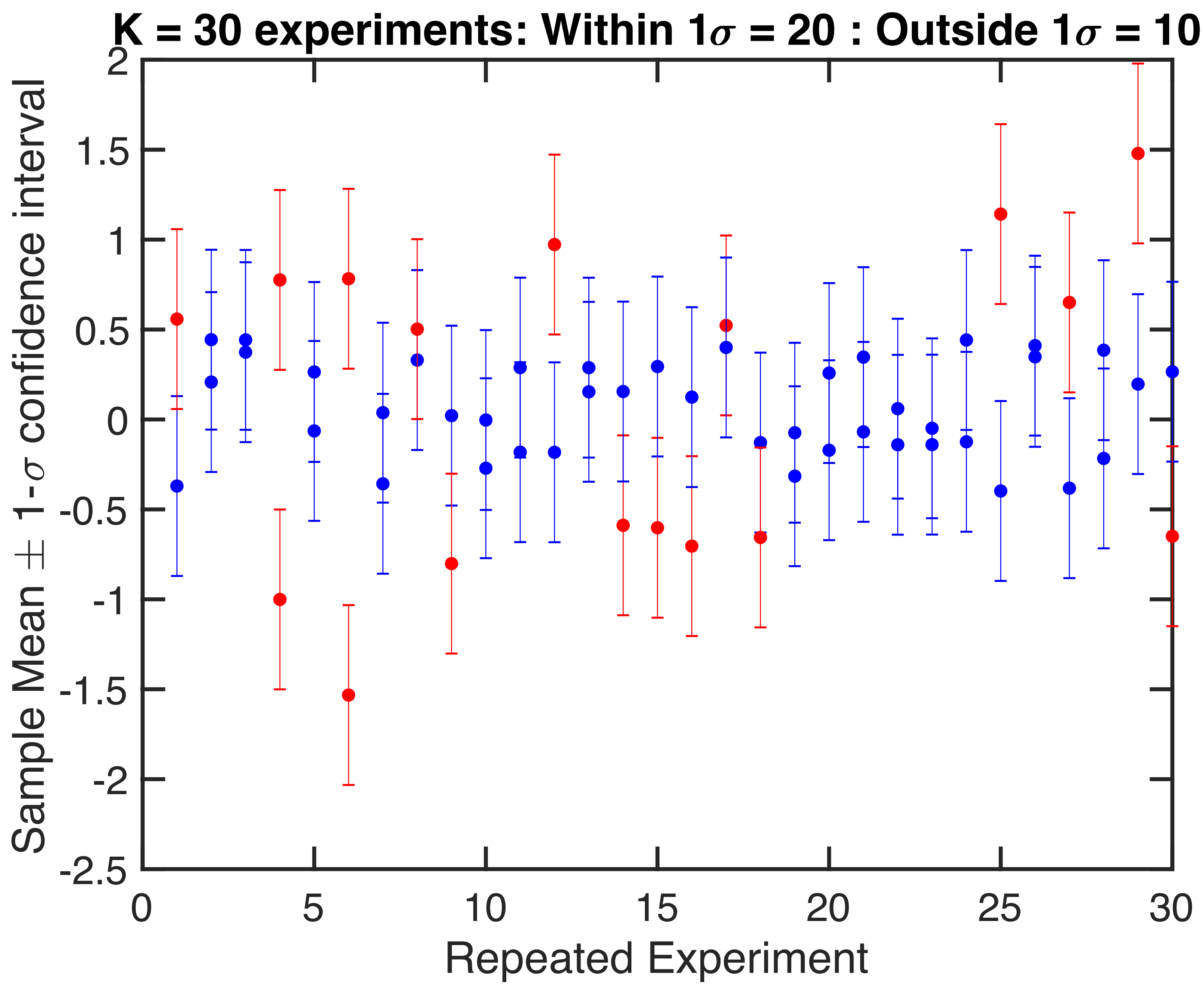


Stellar Mass Function Inference with Selection Effect: Modified Likelihood Function





Frequentist Meaning of Confidence Intervals



Frequentist Meaning of Confidence Intervals