# Astrostatistics

Friday, 01 February 2019

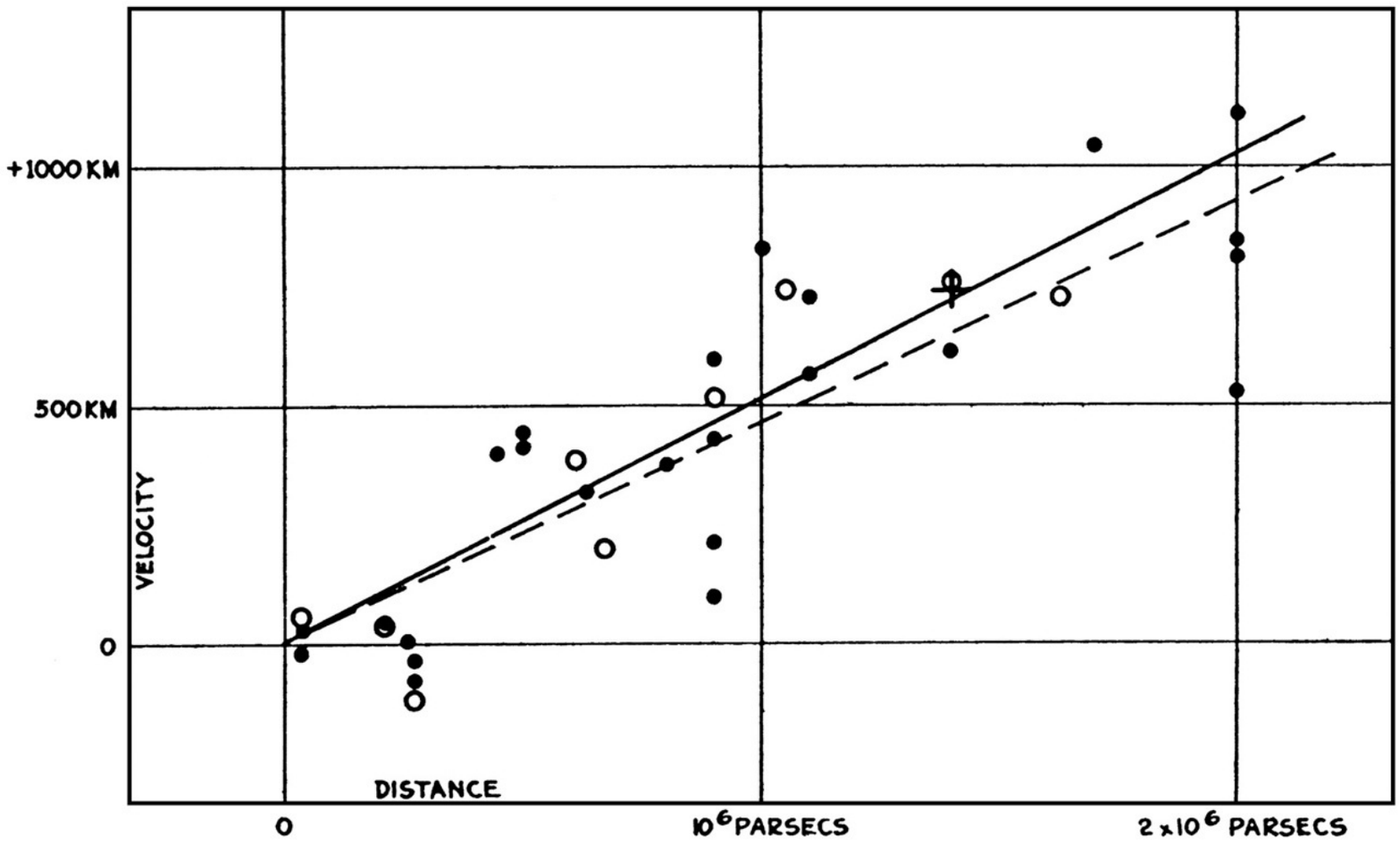
- Statistics Foundations
  - Ivezic Ch 4 “Classical Statistical Inference” & Ch 5 “Bayesian Statistical Inference”
  - F&B Ch 3 “Statistical Inference”
- Review (on your own) properties of multivariate Gaussian random variables and densities (see multivariate_gaussian_notes.pdf on website).

# 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].

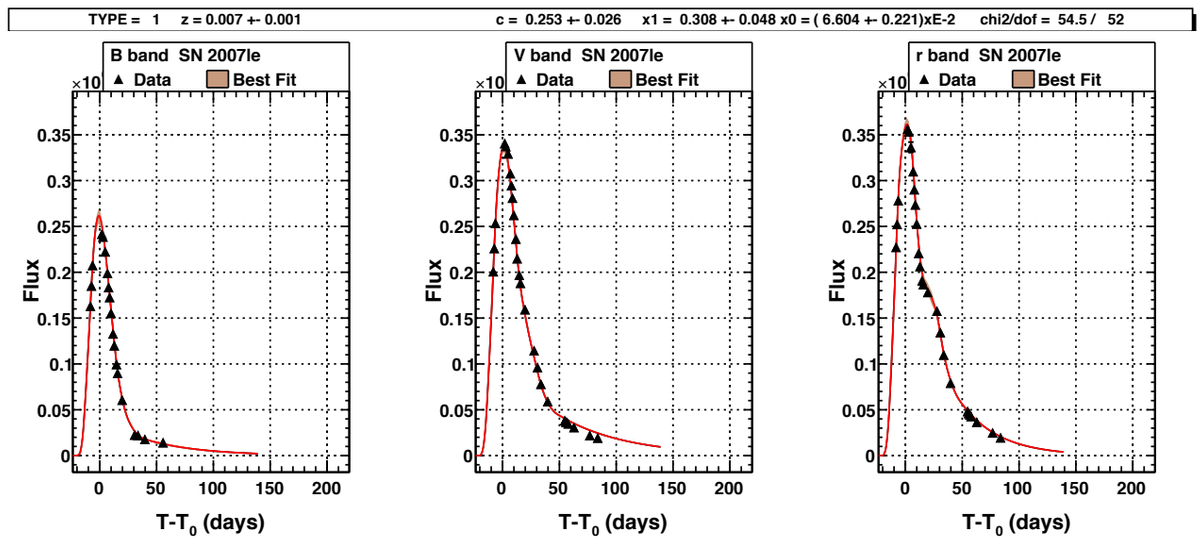
# The Expanding Universe:
# Galaxies are moving apart! Hubble's Law (1929)



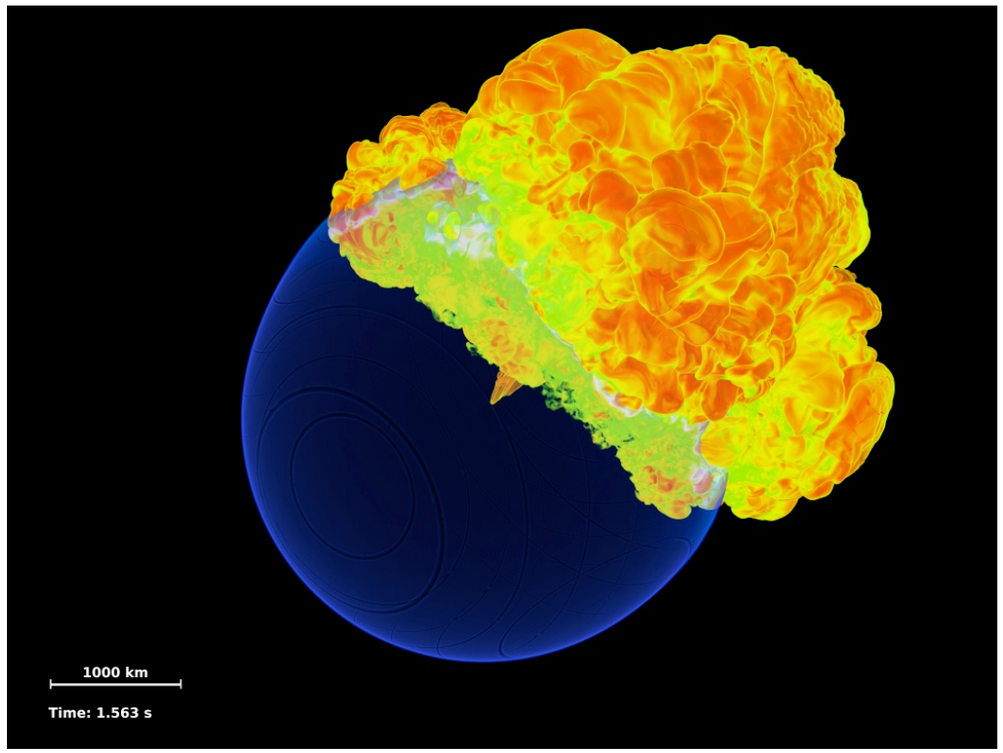

Einstein & Hubble

## Distance ∝ Velocity (Redshift)

# Type Ia Supernovae (SN Ia) are Almost Standard Candles

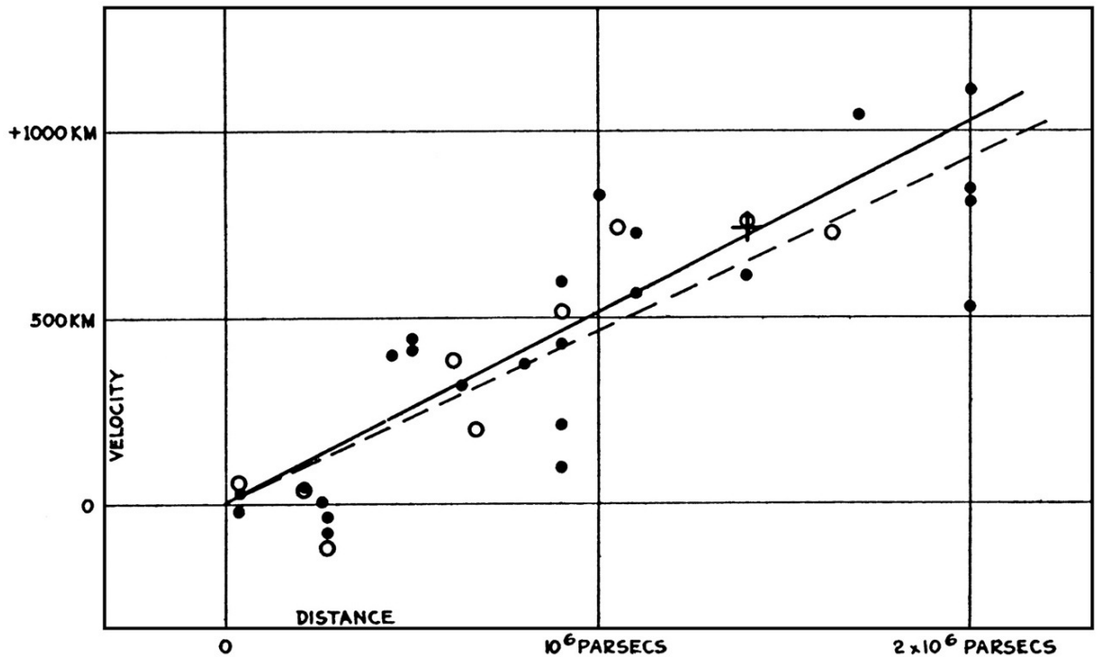




- Progenitor: C/O White Dwarf Star accreting mass leads to instability
- Thermonuclear Explosion: Deflagration/ Detonation
- Nickel to Cobalt to Iron Decay + radiative transfer powers the light curve

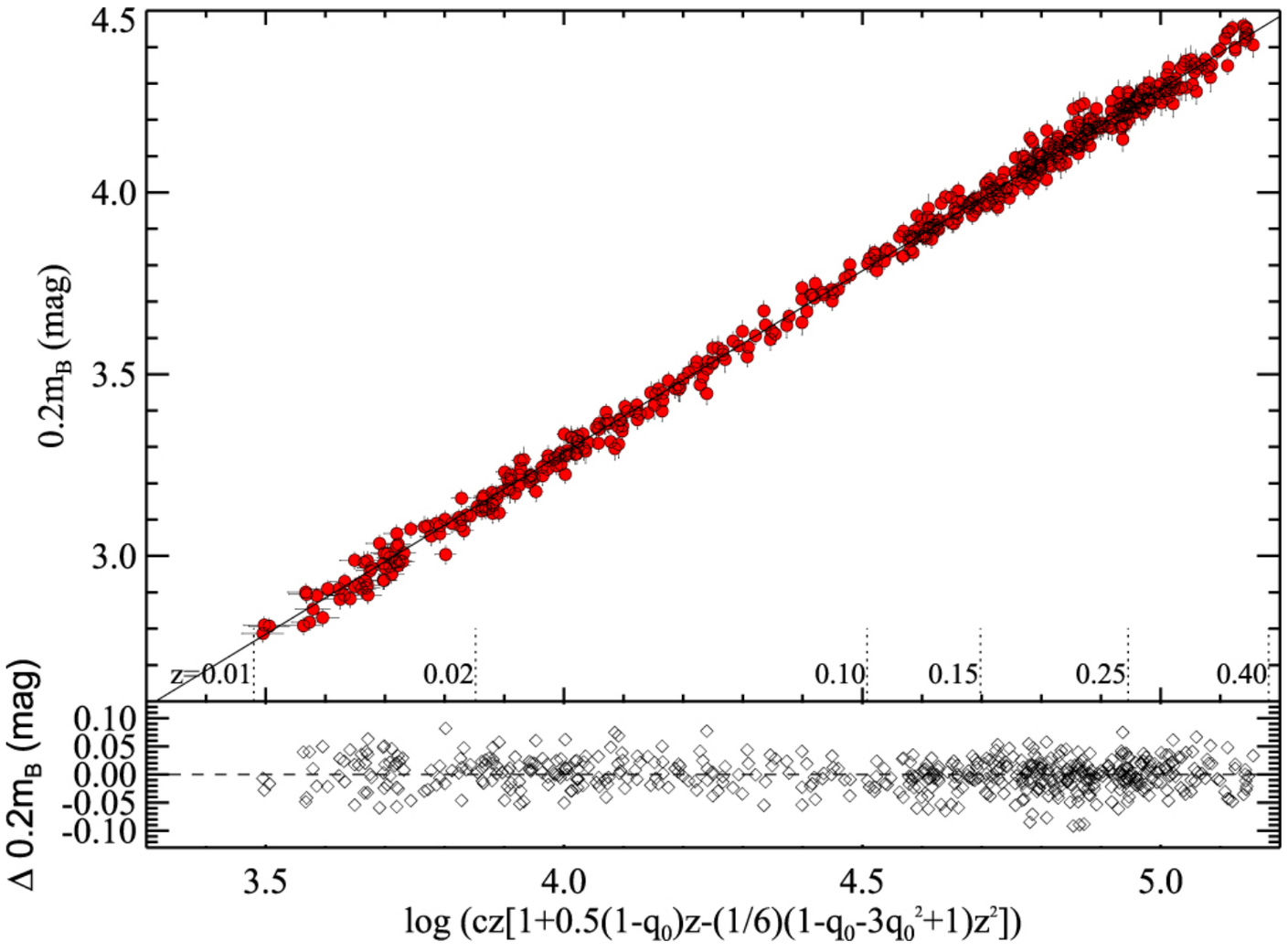


# Hubble Constant

Distance = $H_0$ × velocity



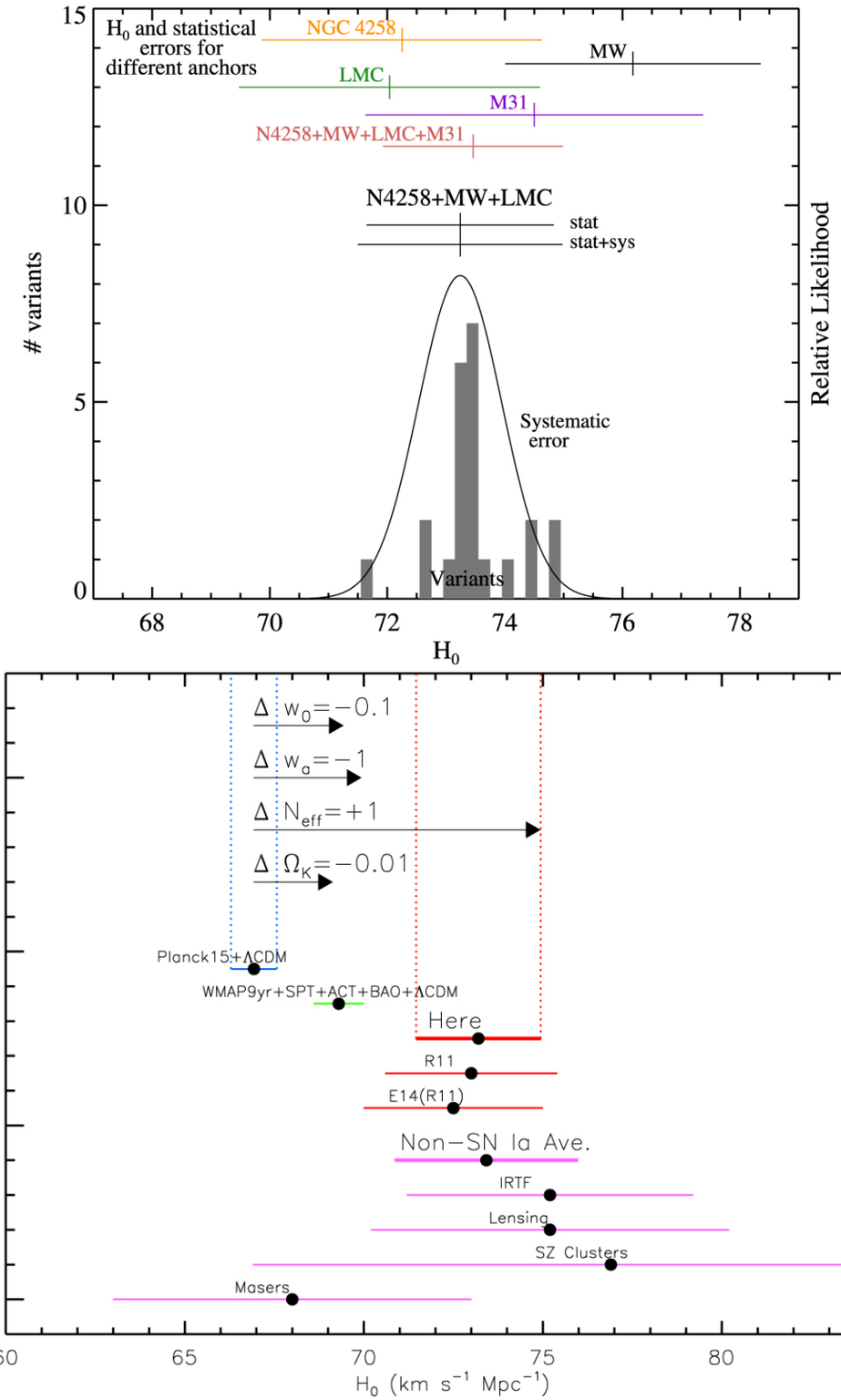

Hubble (1929)

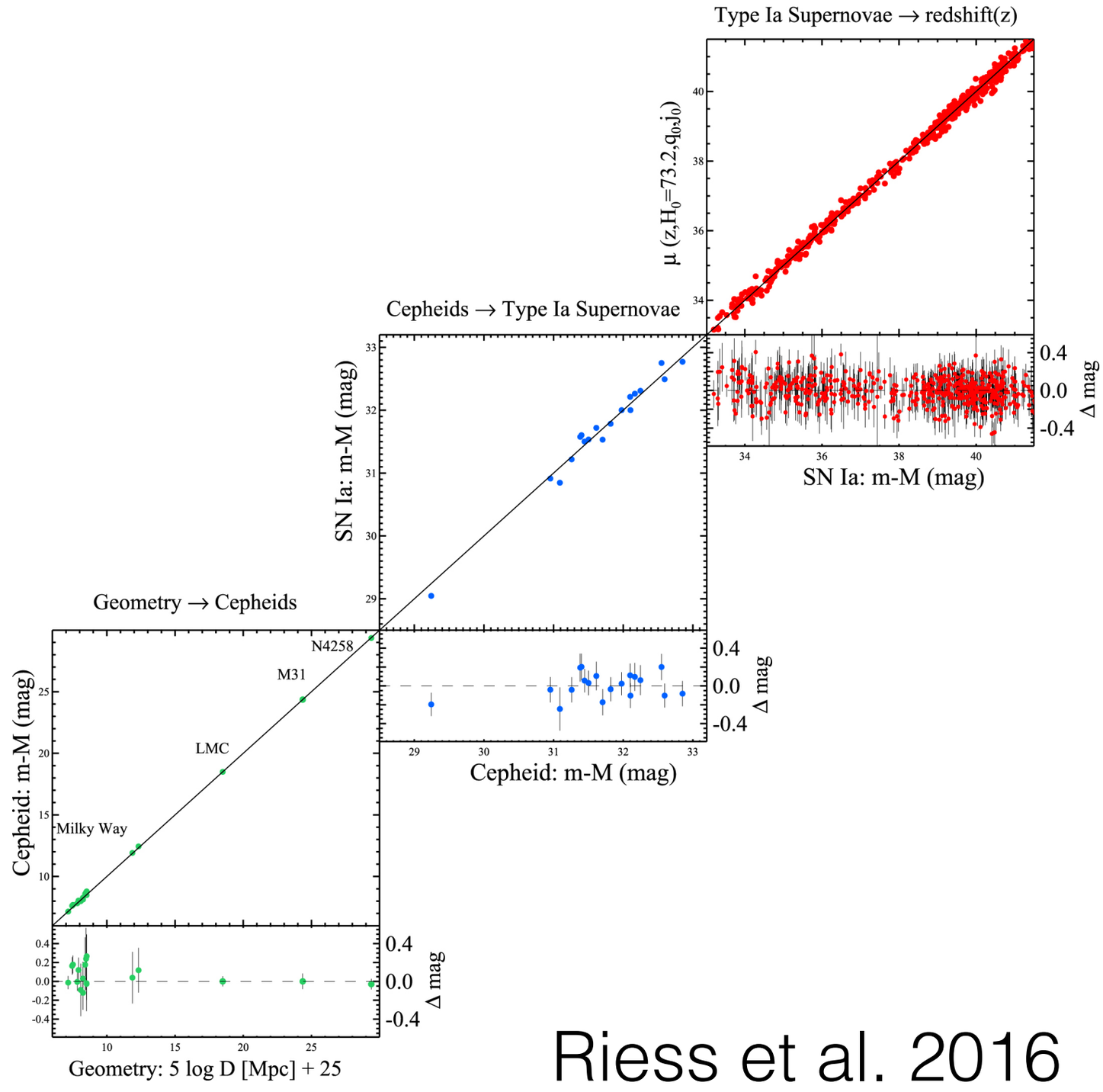



Riess et al. 2016

# Hubble Constant

## Distance = $H_0$ × velocity

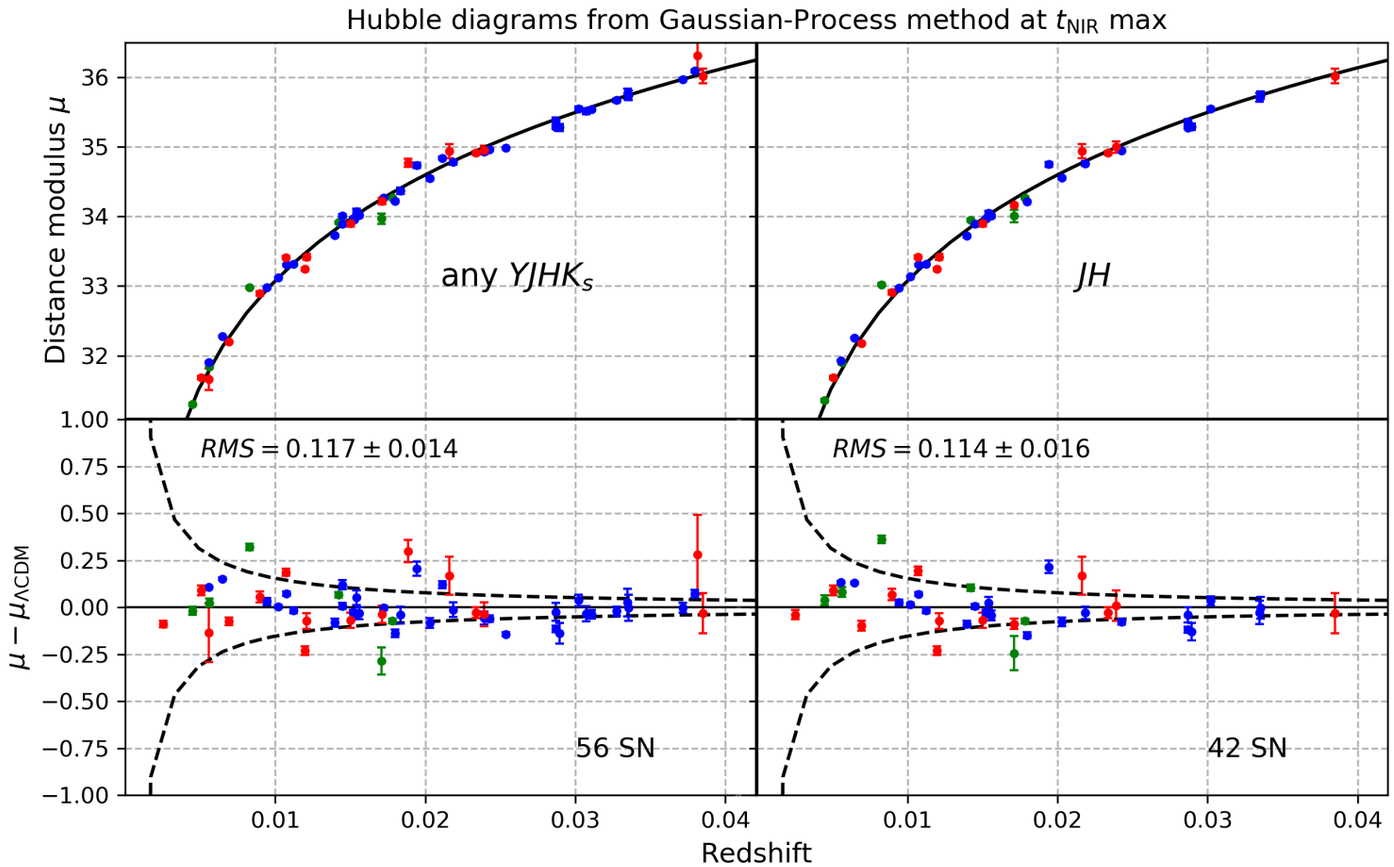


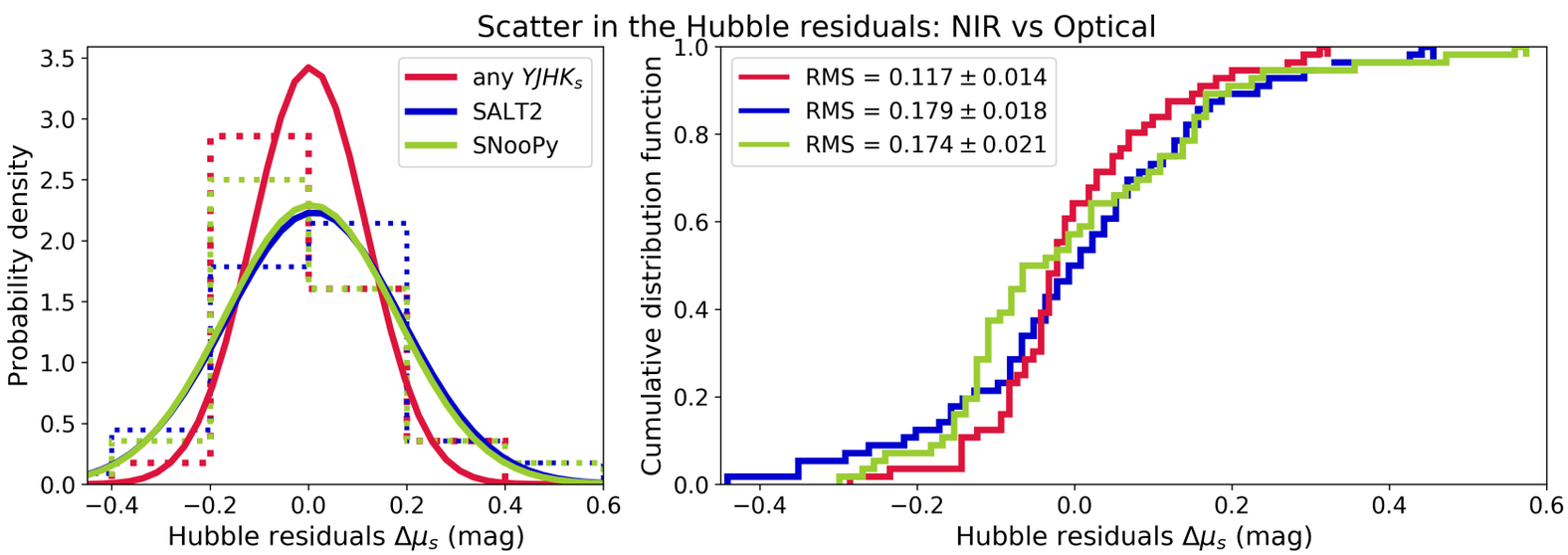




Riess et al. 2016

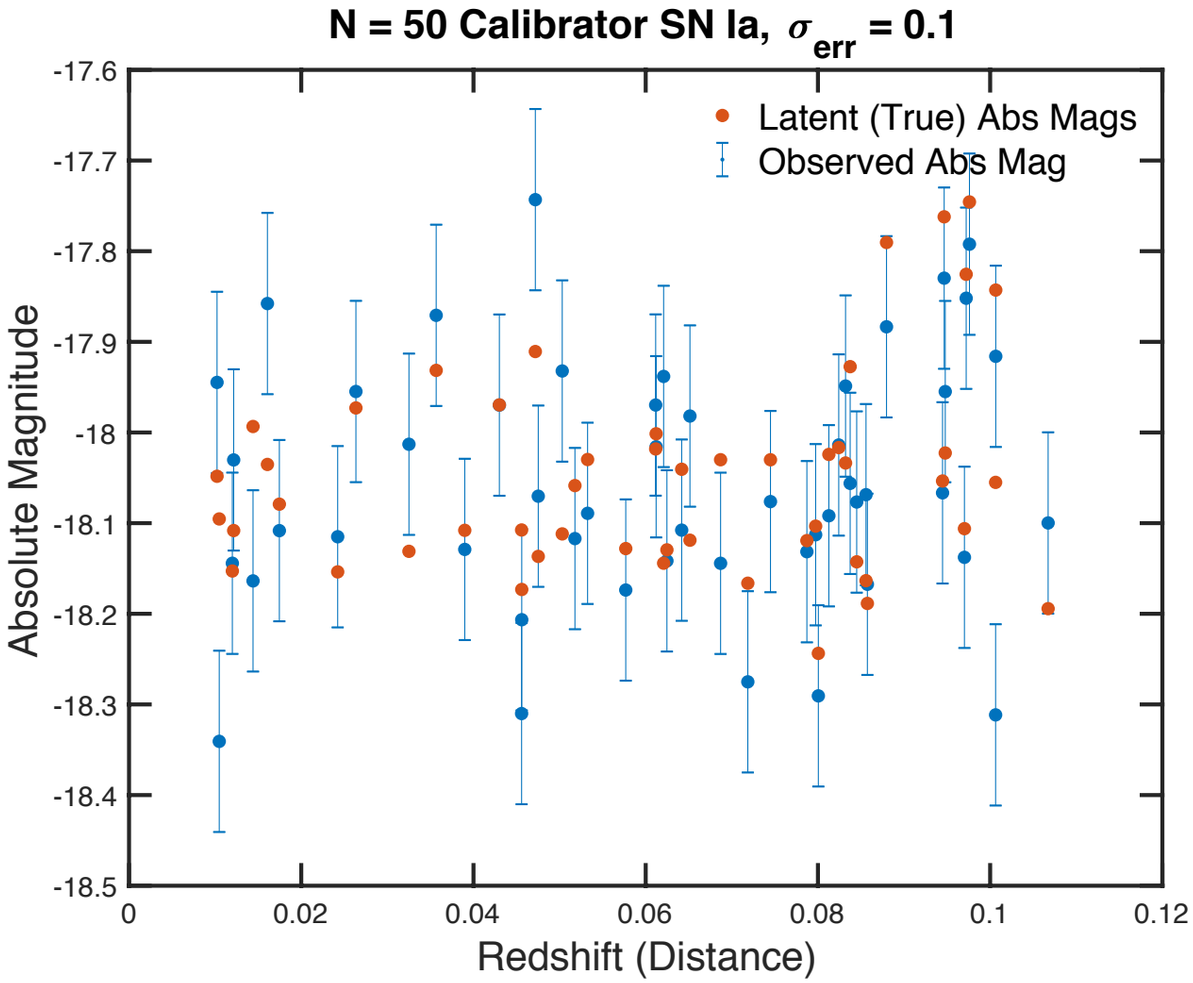
# Calibrating SN Ia Standard Candles

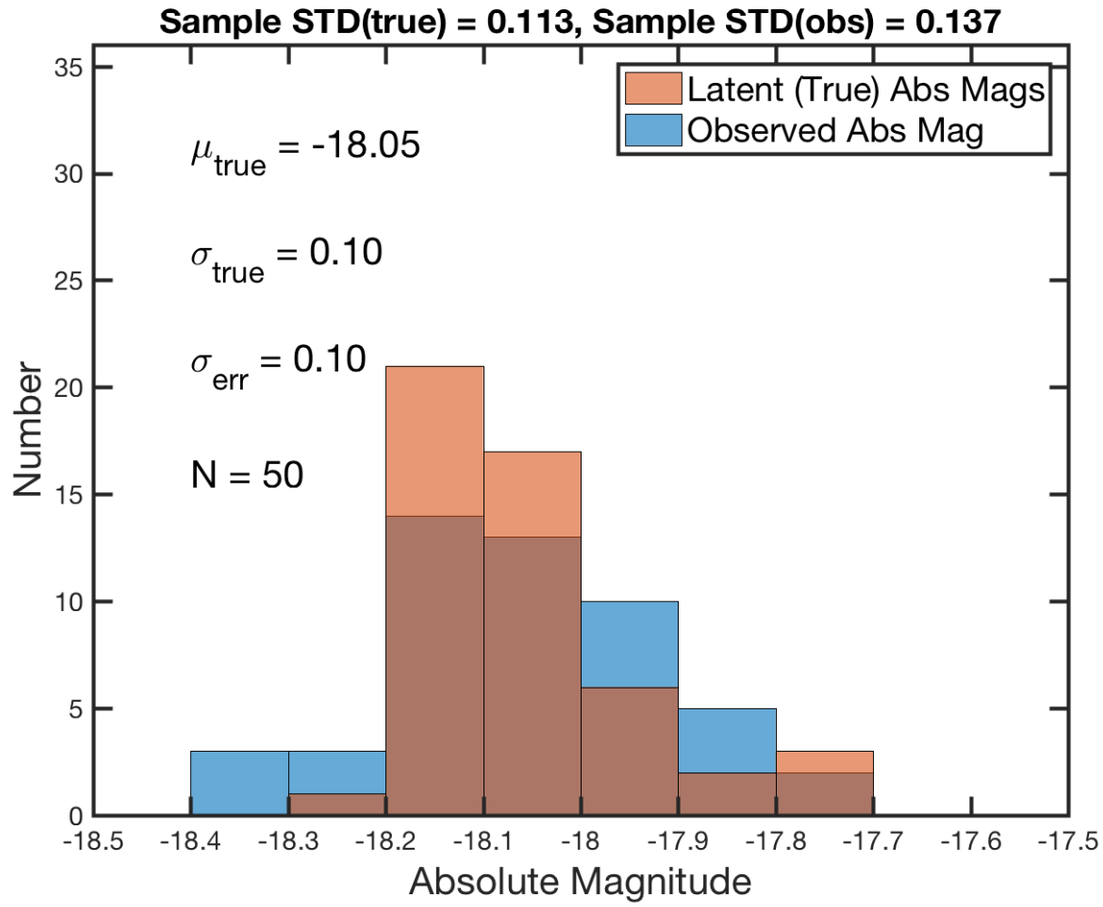
## (Avelino, Friedman, Mandel et al. 2019)



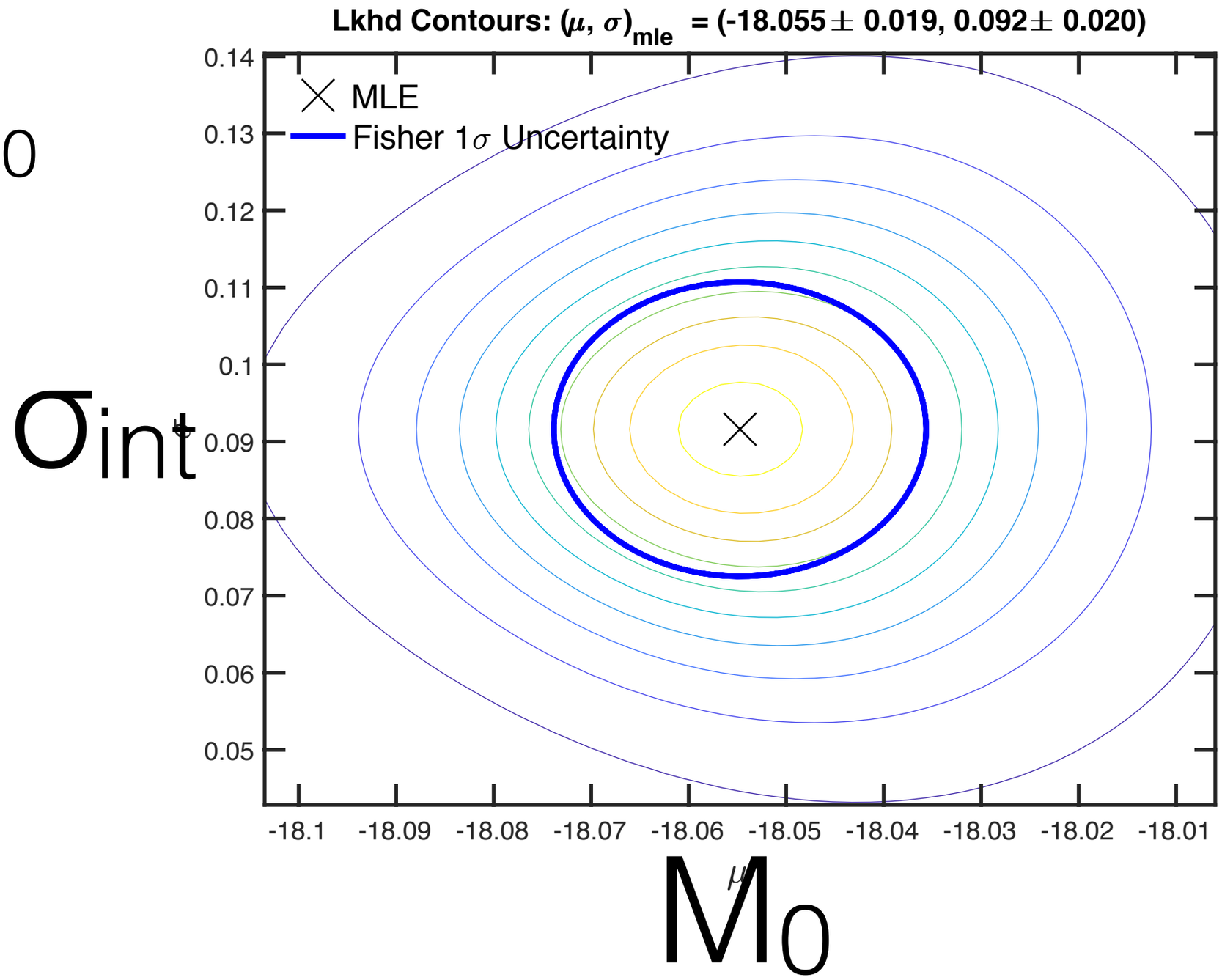
# Want to Calibrate SN Ia (N=50) determine $M_0$, $\sigma_{int}$



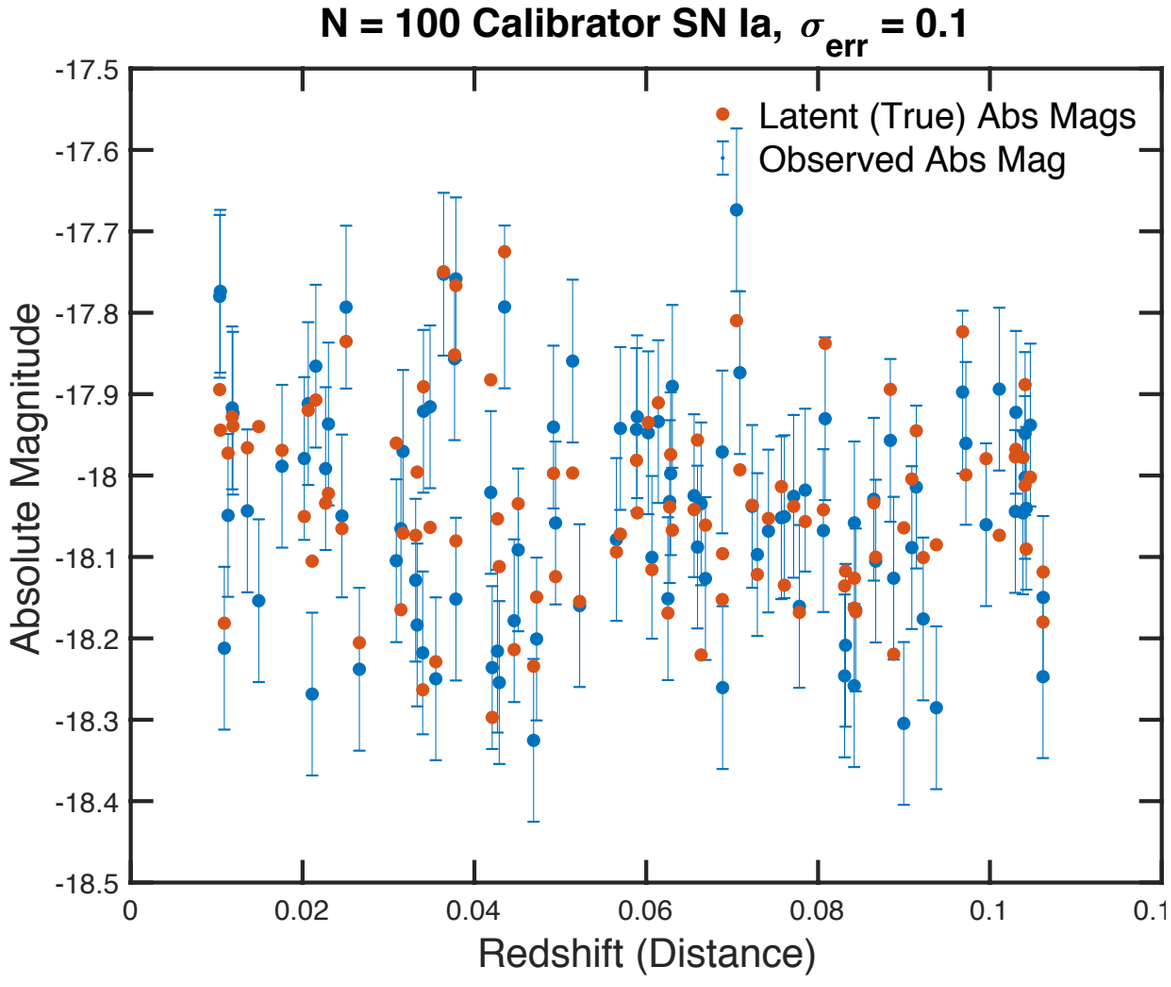



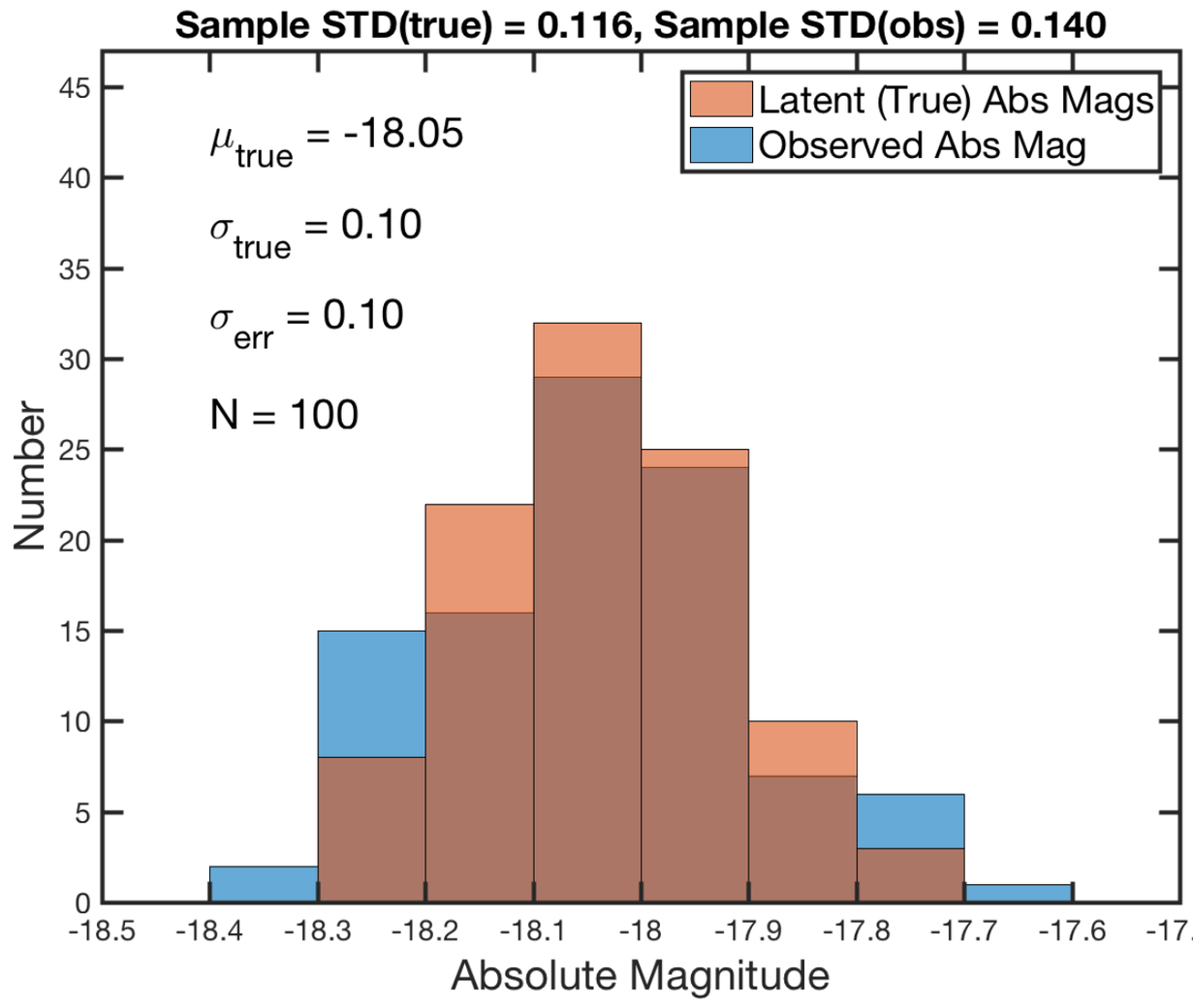
# Maximum Likelihood with heteroskedastic measurement error

N = 50



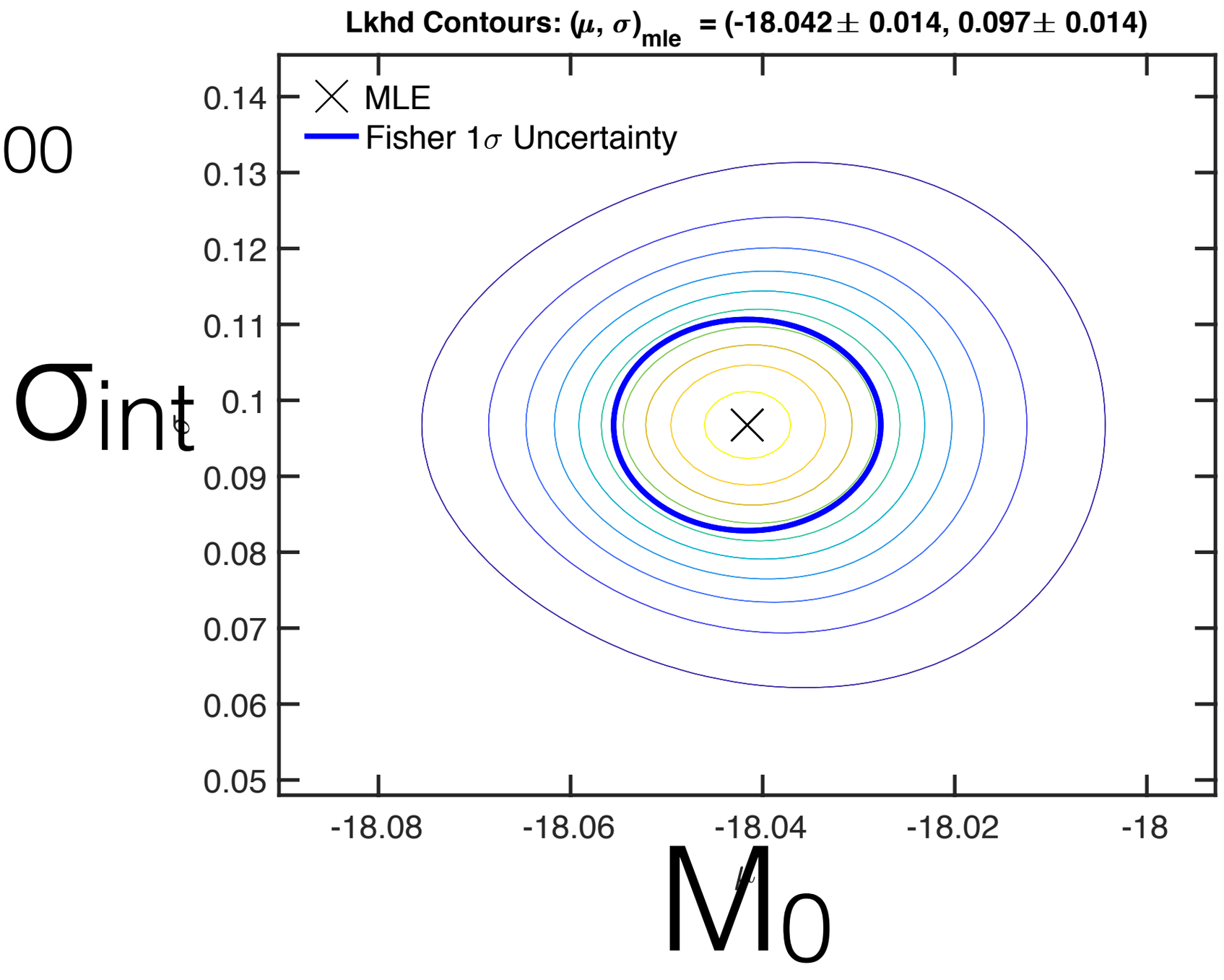
# Want to Calibrate SN Ia (N=100) determine $M_0$, $\sigma_{int}$



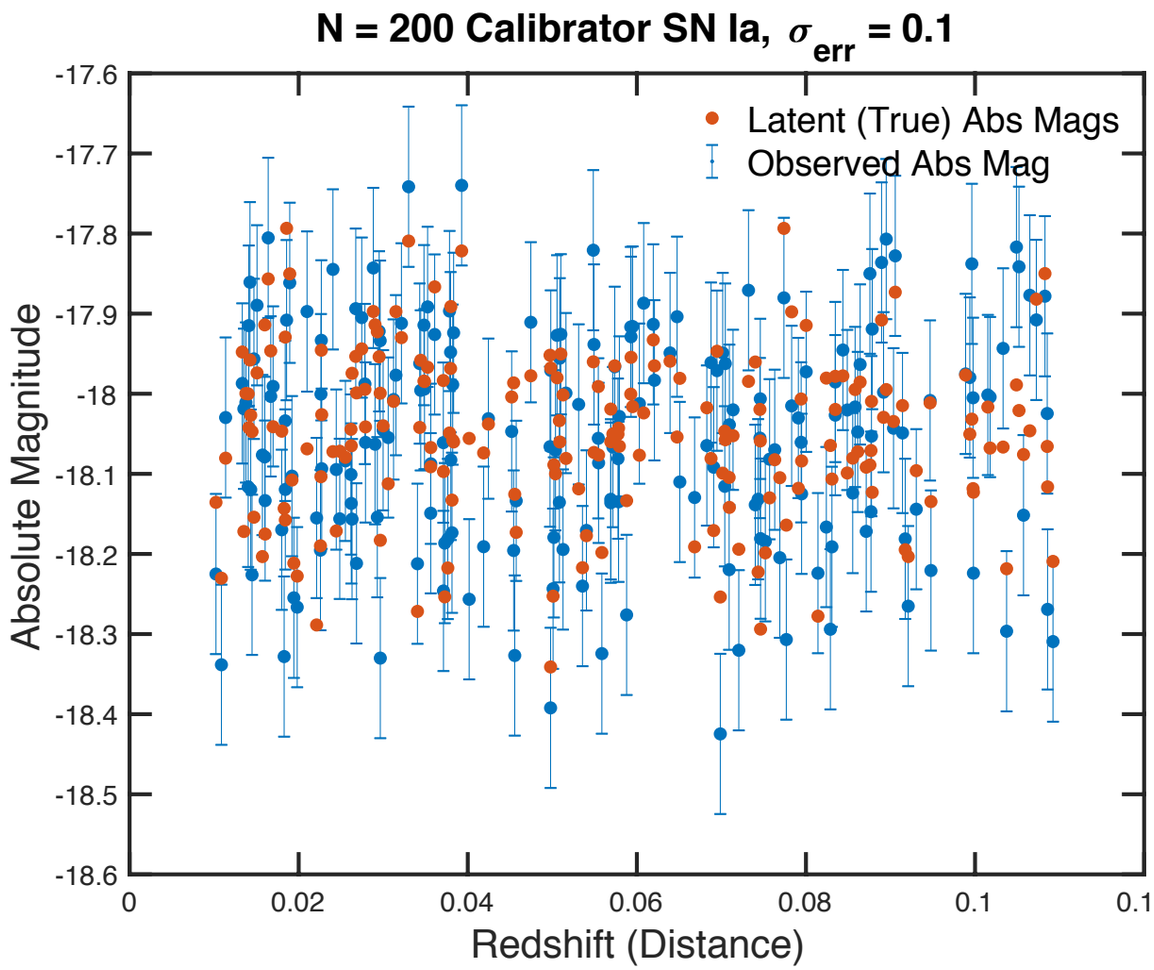



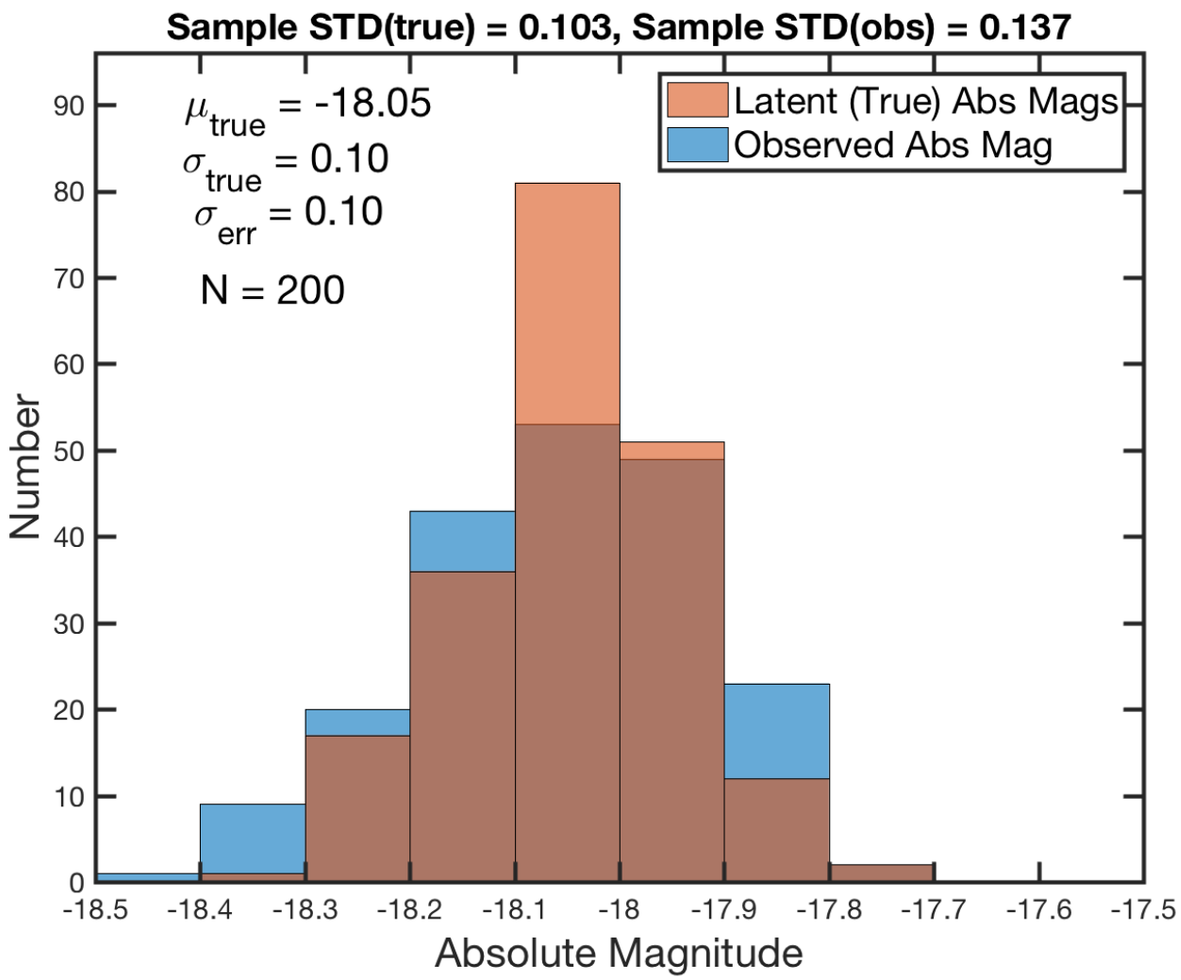
# Maximum Likelihood with heteroskedastic measurement error

N = 100



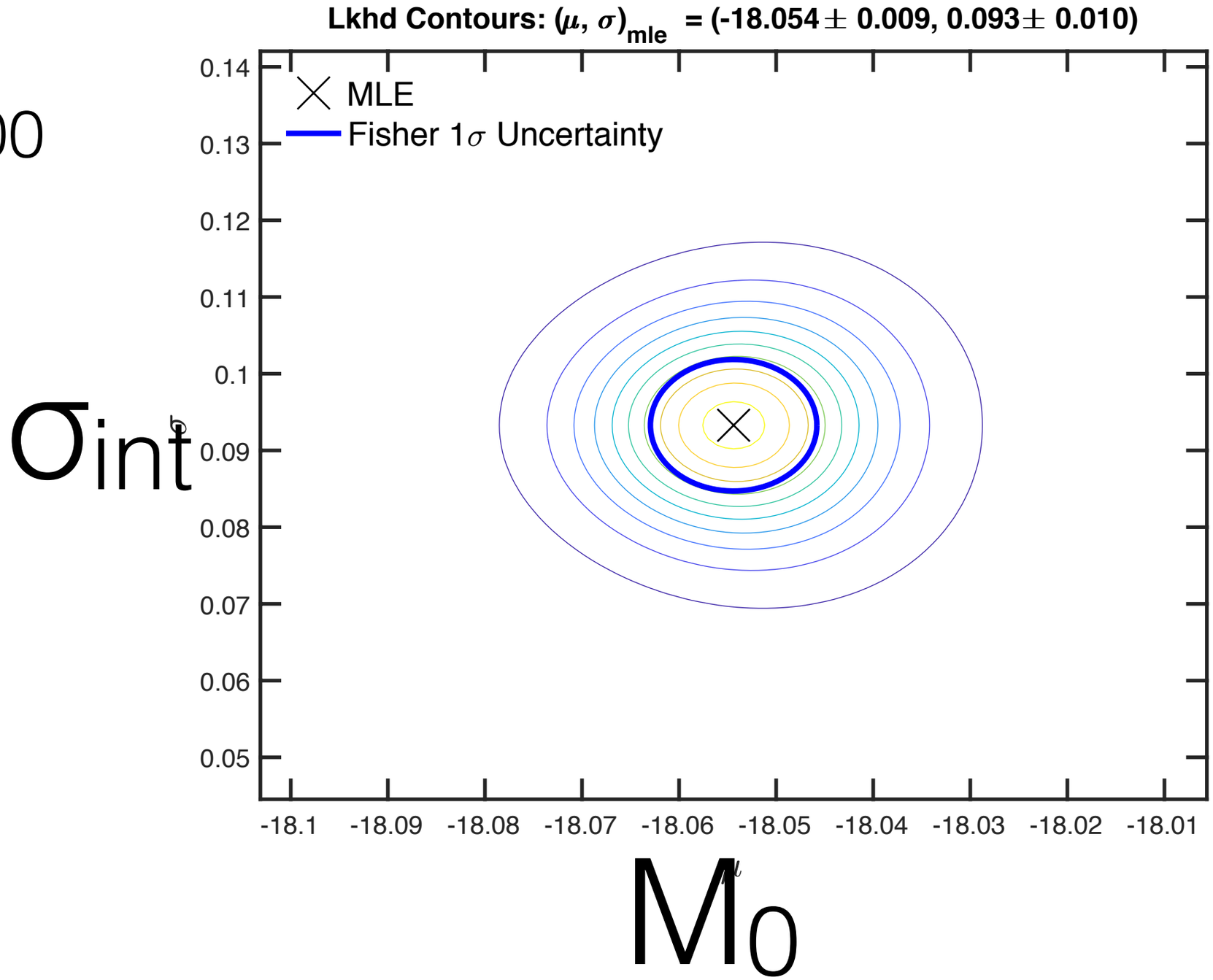
# Want to Calibrate SN Ia (N=200) determine $M_0$, $\sigma_{int}$



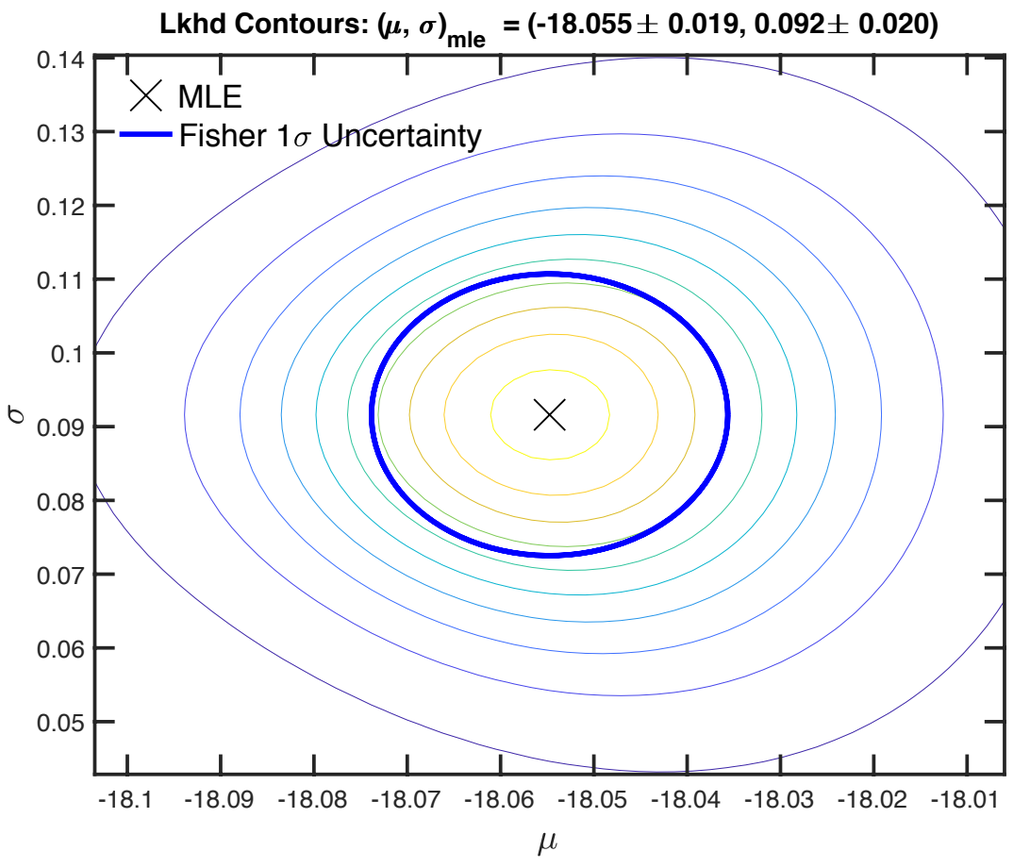



# Maximum Likelihood with heteroskedastic measurement error

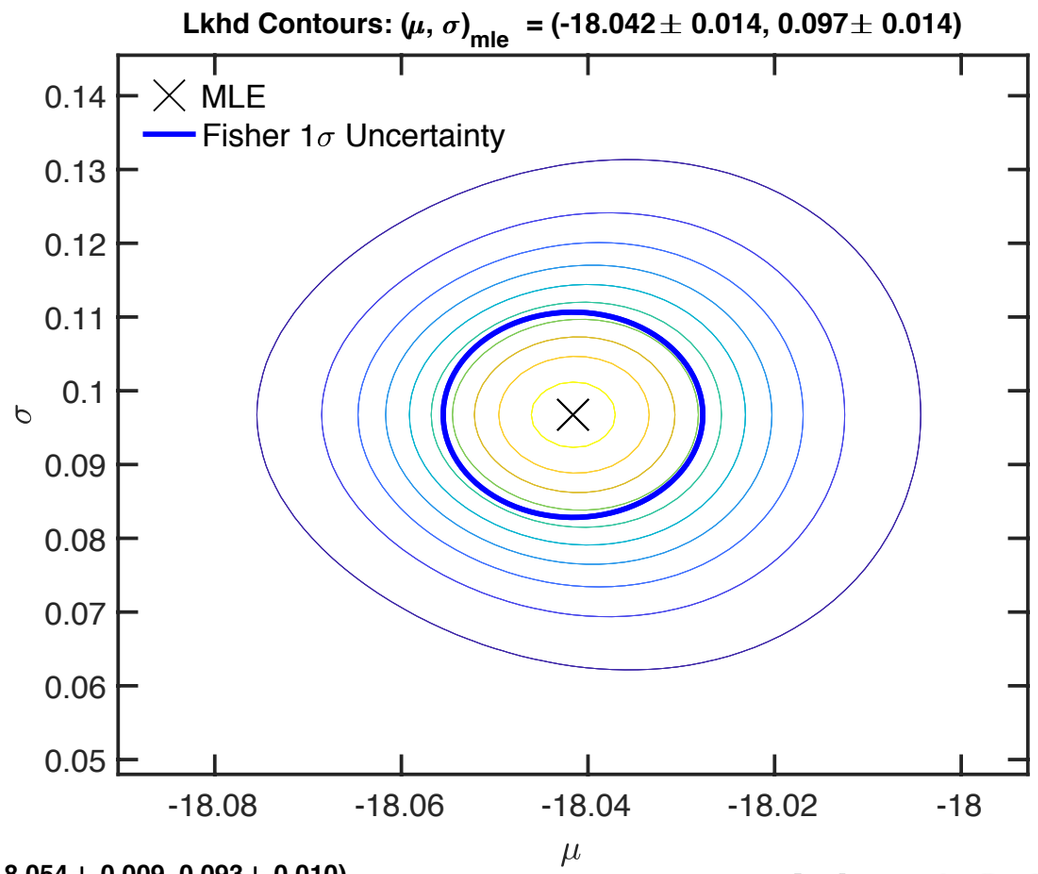
N = 200



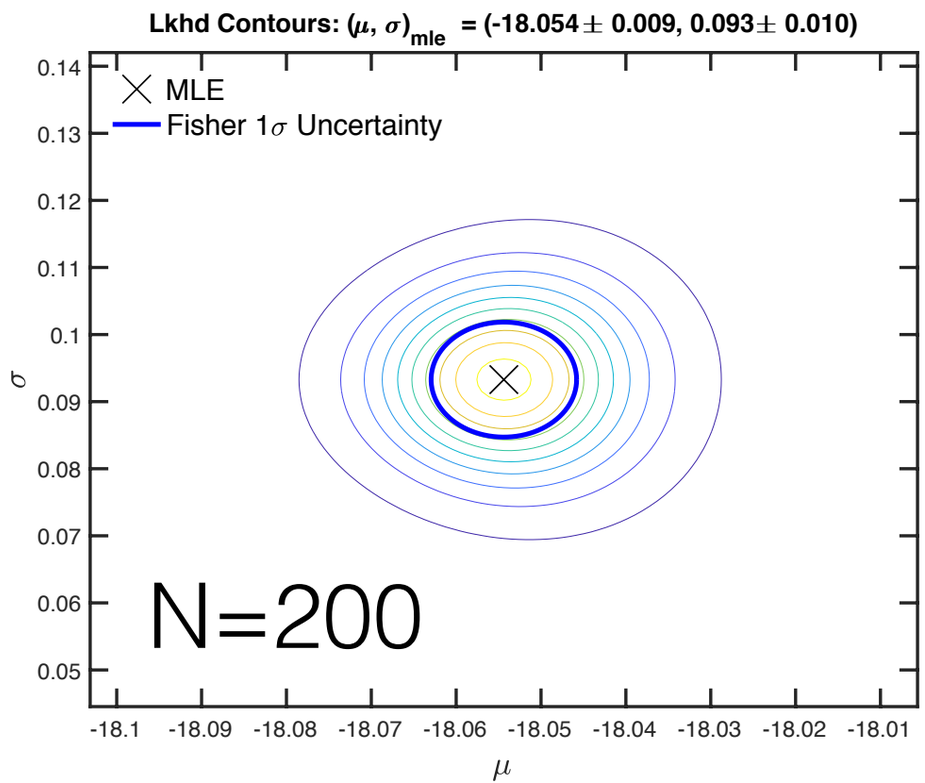
# Constraints vs. sample size




N=50




N=100




N=200