

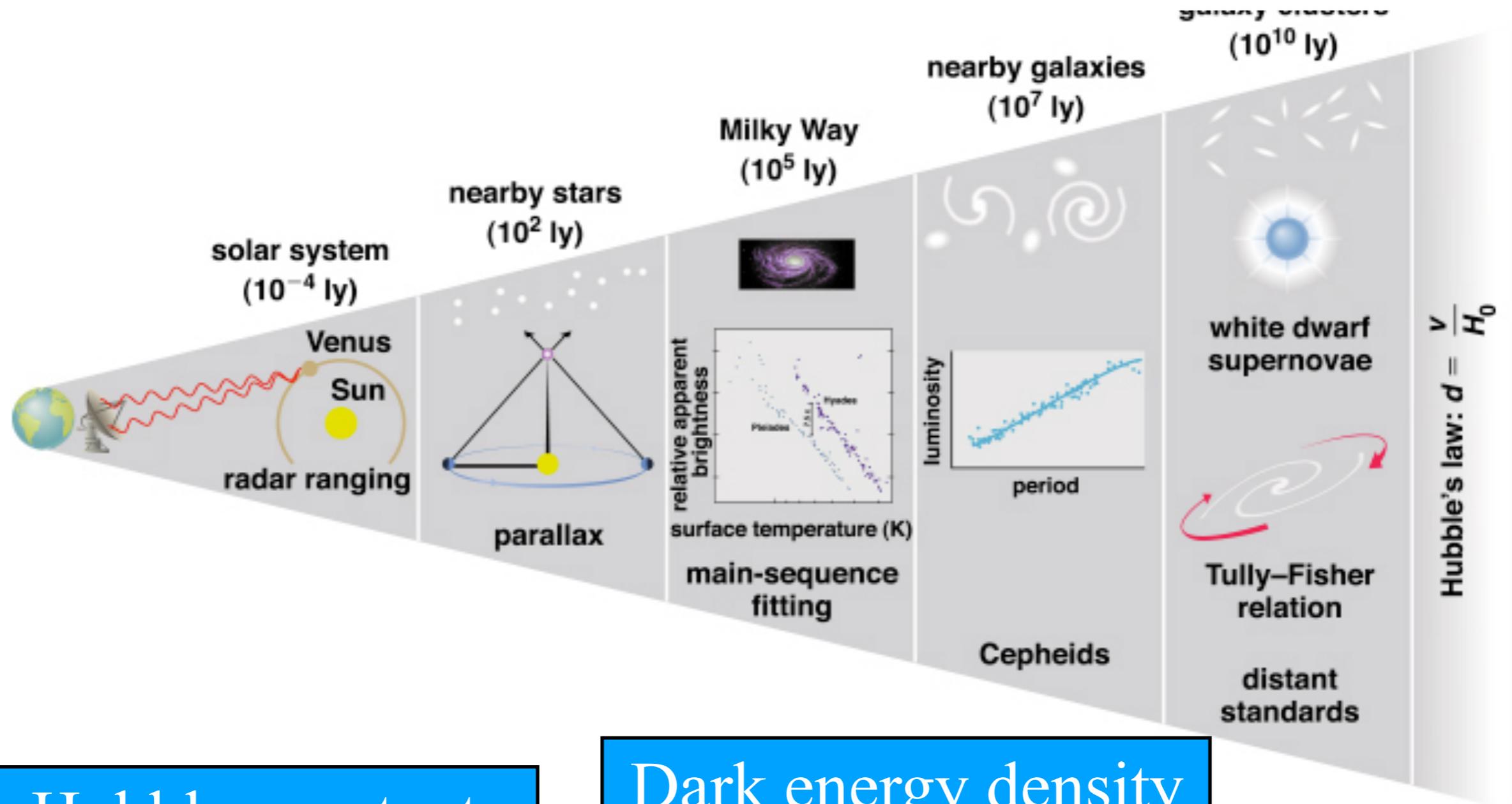


A NEW COSMIC DISTANCE LADDER

ANURADHA GUPTA, DEREK FOX, B.S. SATHYAPRAKASH, B.F. SCHUTZ
Penn State, Max Planck Institute for Gravitational Physics, AEI, Cardiff



COSMIC DISTANCE LADDER



Hubble constant

Dark matter density

Dark energy density

Dark energy equation of state

CALIBRATING SUPERNOVAE IN CLUSTERS WITH STANDARD SIRENS

Q: What are the chances to observe a BNS in the same galaxy as a SNe Ia?

A: Very tiny.

$$\mathcal{R}_{\text{SNeIa}} = [2.38, 3.62] \times 10^4 \text{ Gpc}^{-3} \text{ yr}^{-1} \quad \text{Li+, 2011}$$

$$\mathcal{R}_{\text{BNS}} = [0.01, 0.4] \times 10^4 \text{ Gpc}^{-3} \text{ yr}^{-1}$$

galaxy number density in the local Universe $\sim 10^7 \text{ Gpc}^{-3}$

1 SNe Ia every ~ 300 years per galaxy!

Q: What are the chances to observe a BNS in the same galaxy cluster as a SNe Ia?

A: Non-negligible.

$$\mathcal{R}_{\text{SNeIa}} \sim [0.9, 1.4] \times 10^{-12} L_{\odot}^{-1} \text{ yr}^{-1} \quad \text{Dilday+, 2010}$$

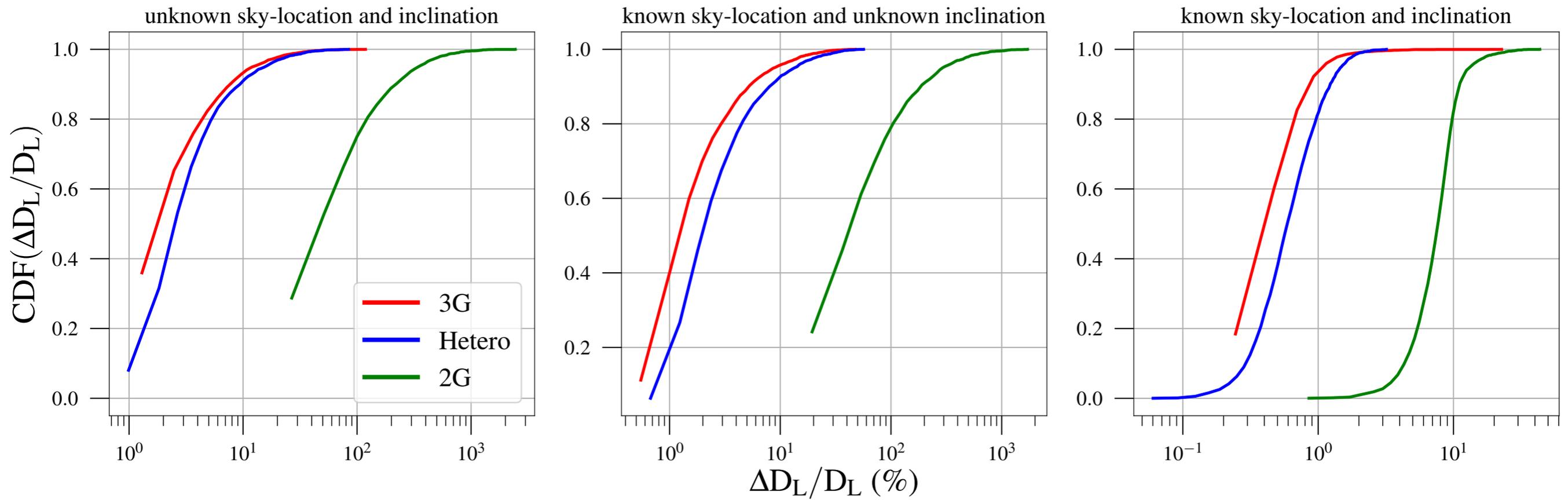
$$\mathcal{R}_{\text{BNS}} \sim [0.0005, 0.0192] \times 10^{-12} L_{\odot}^{-1} \text{ yr}^{-1}$$

~ 6 SNe Ia per year in a Coma-like cluster

~ 0.20 BNSs per year in a Coma-like cluster

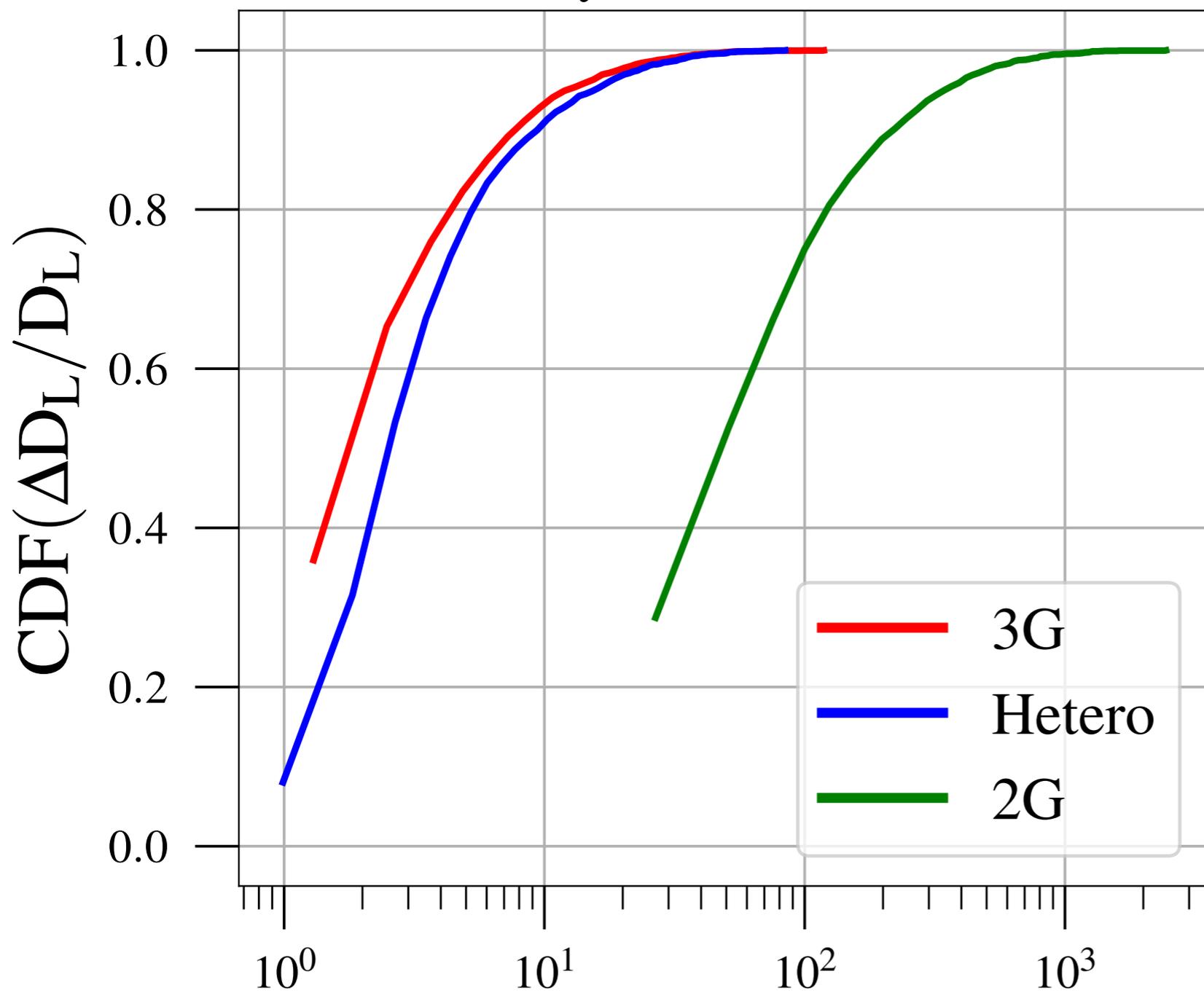
There are ~ 34 clusters within 300 Mpc; each of those clusters will have ~ 1 BNS event in five years

ACCURACY OF DISTANCE MEASUREMENT

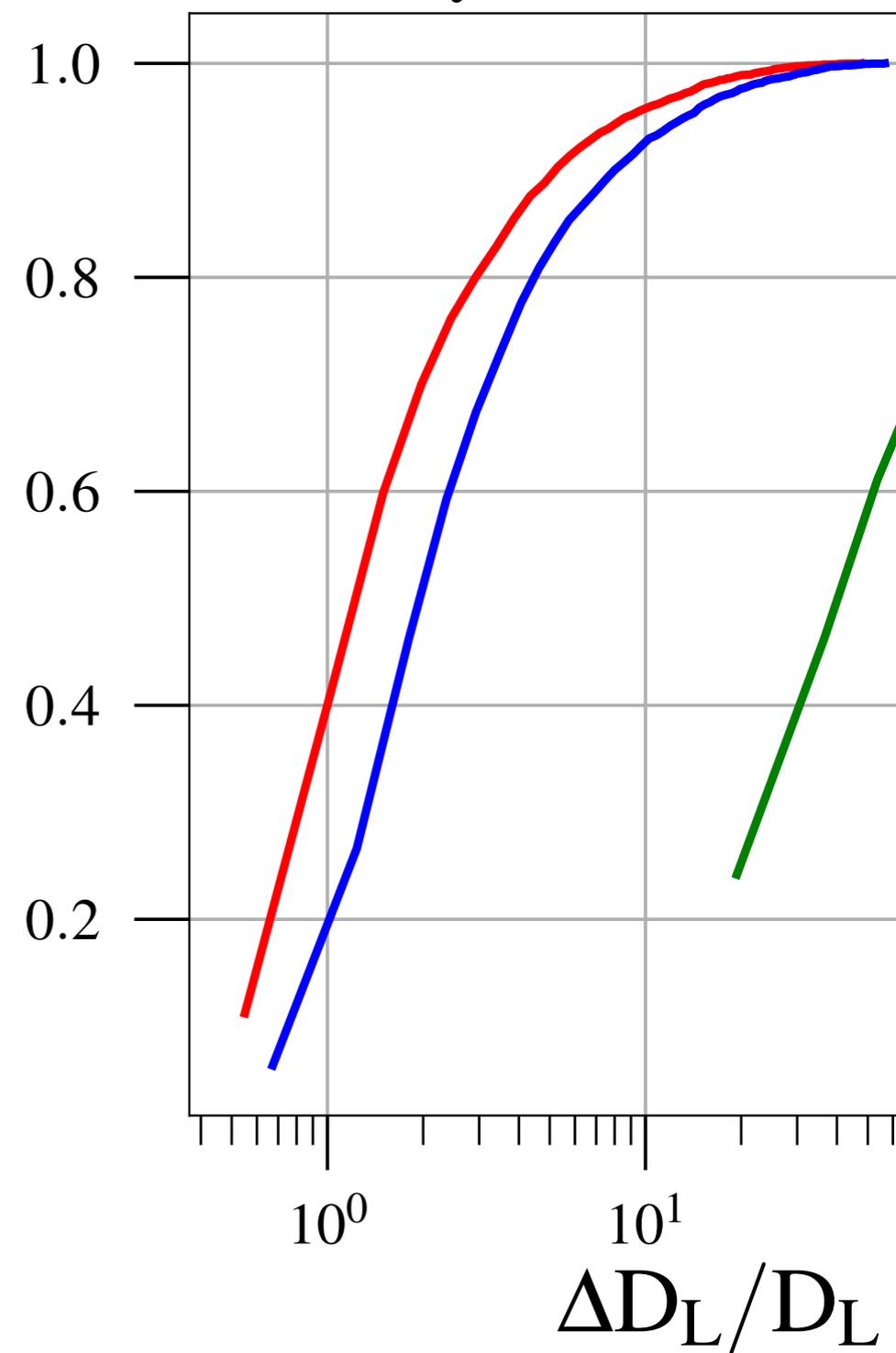


ACCURACY OF DISTANCE MEASUREMENT

unknown sky-location and inclination

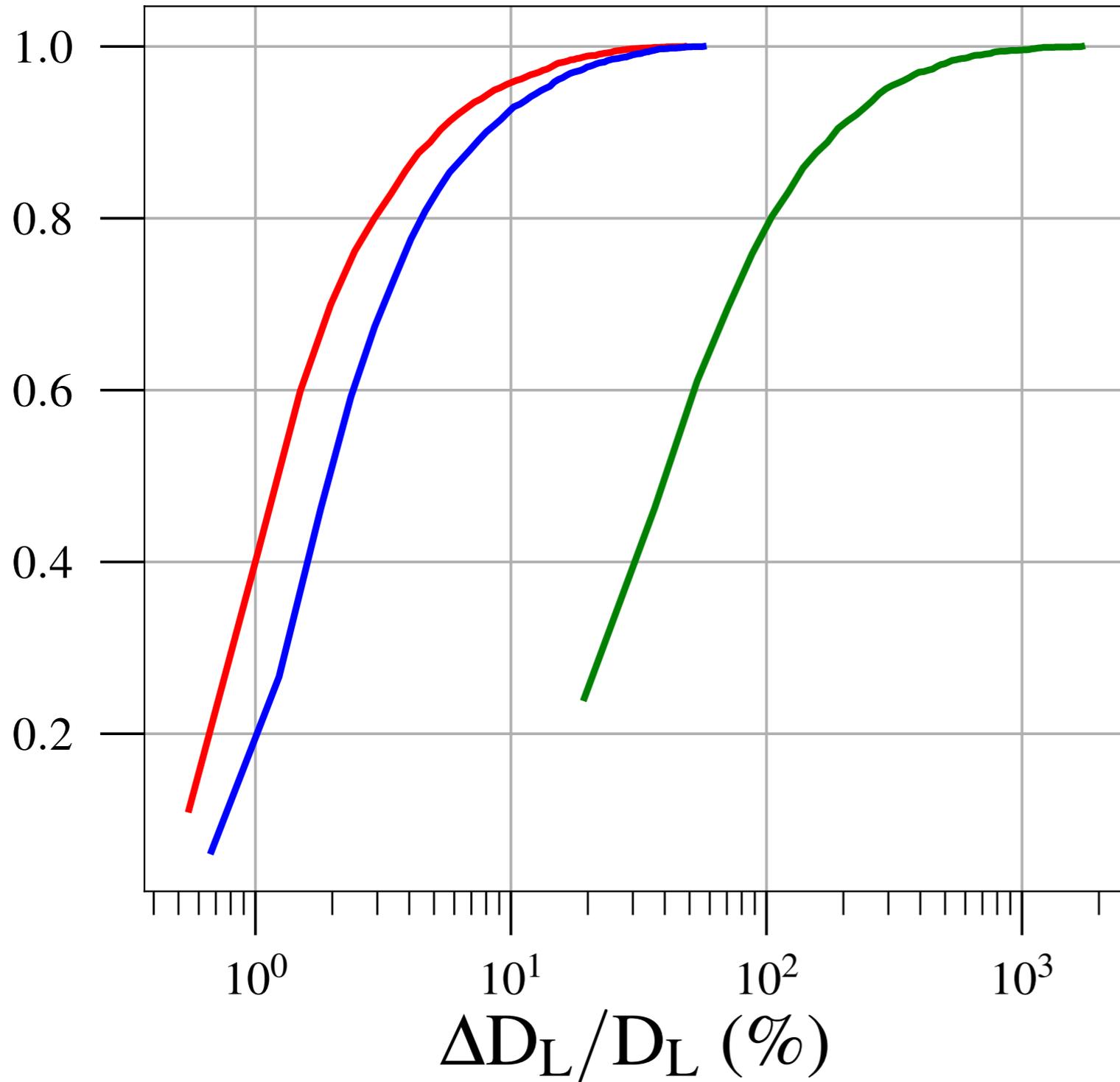


known sky-location and un

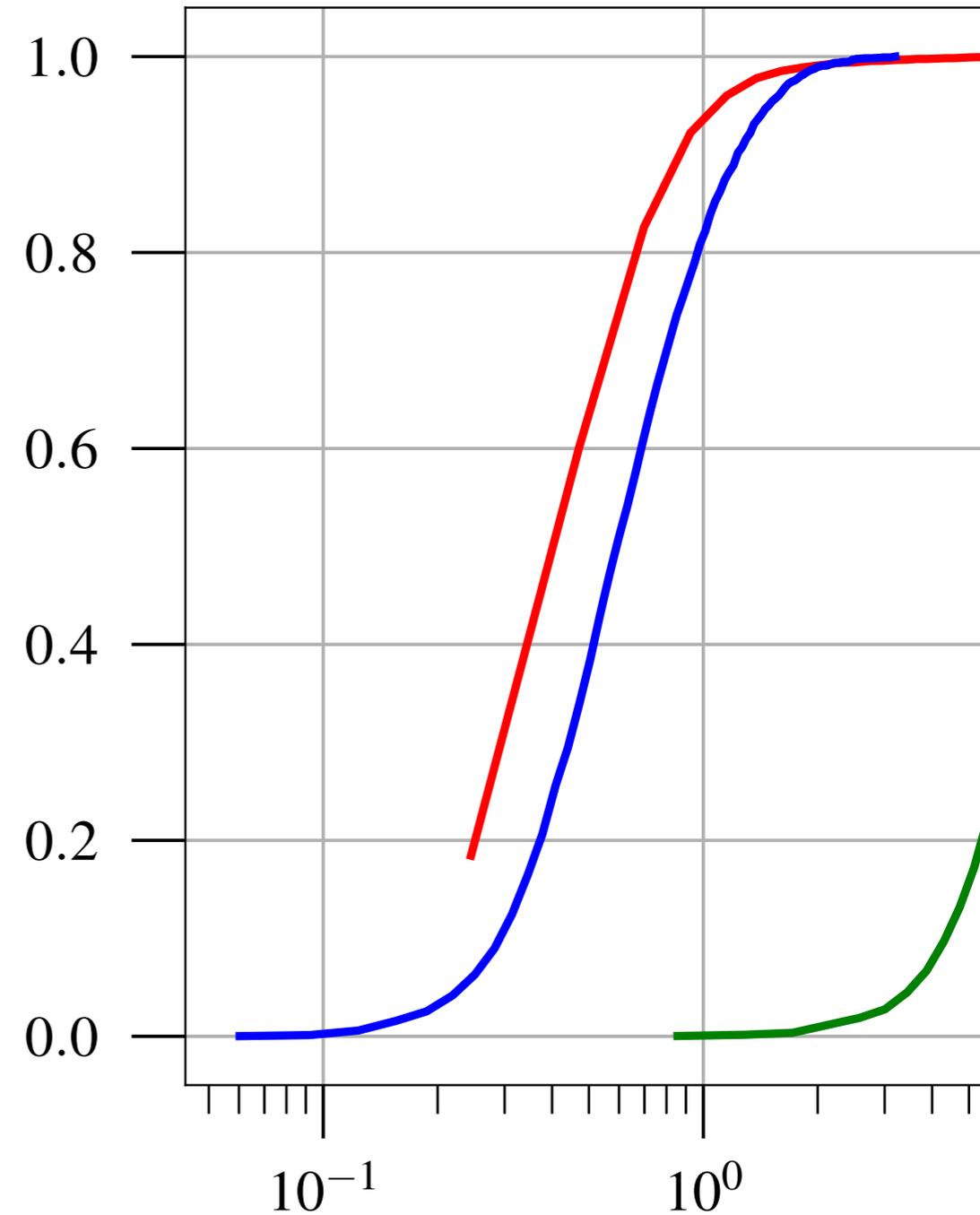


ACCURACY OF DISTANCE MEASUREMENT

known sky-location and unknown inclination

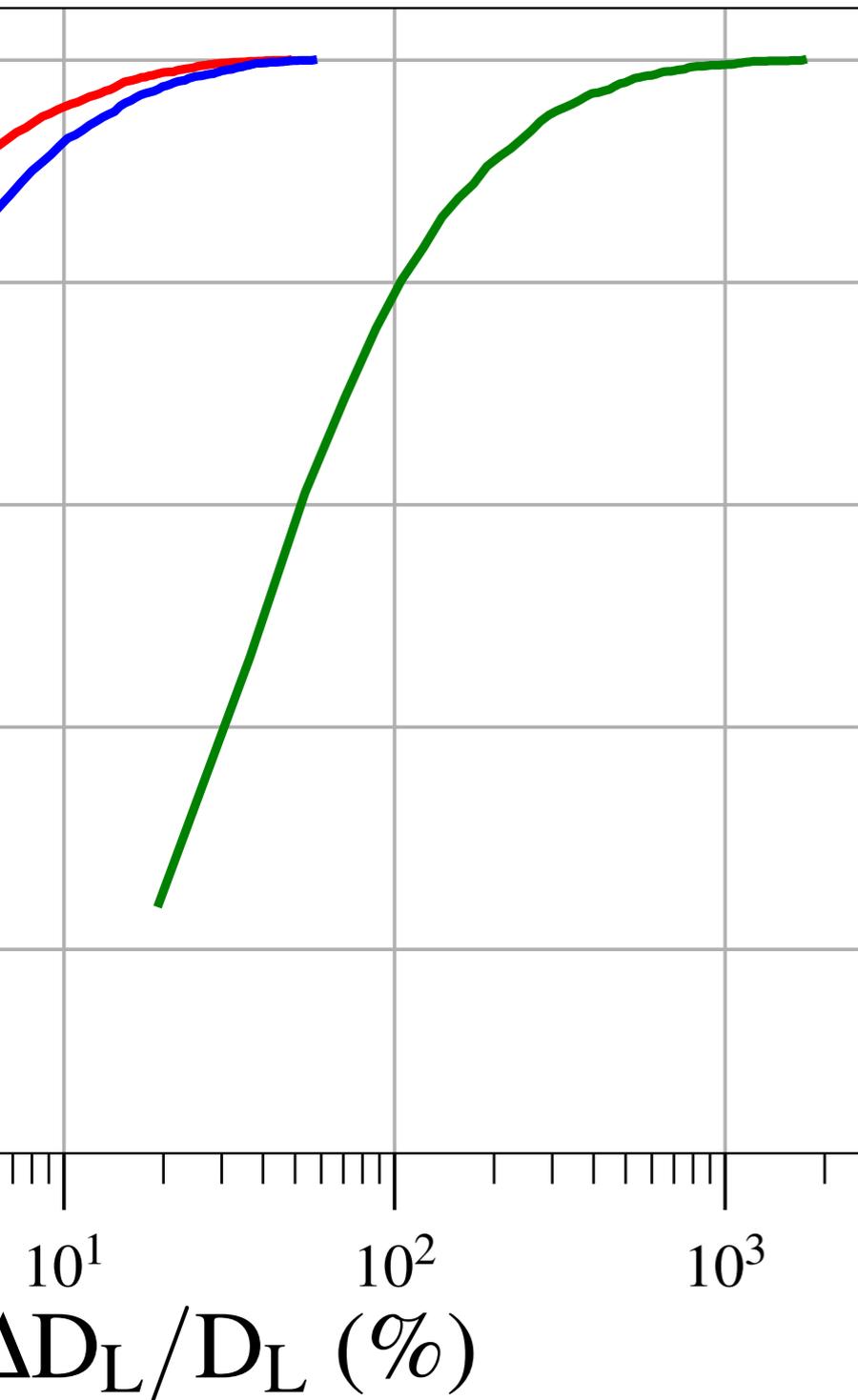


known sky-location and i

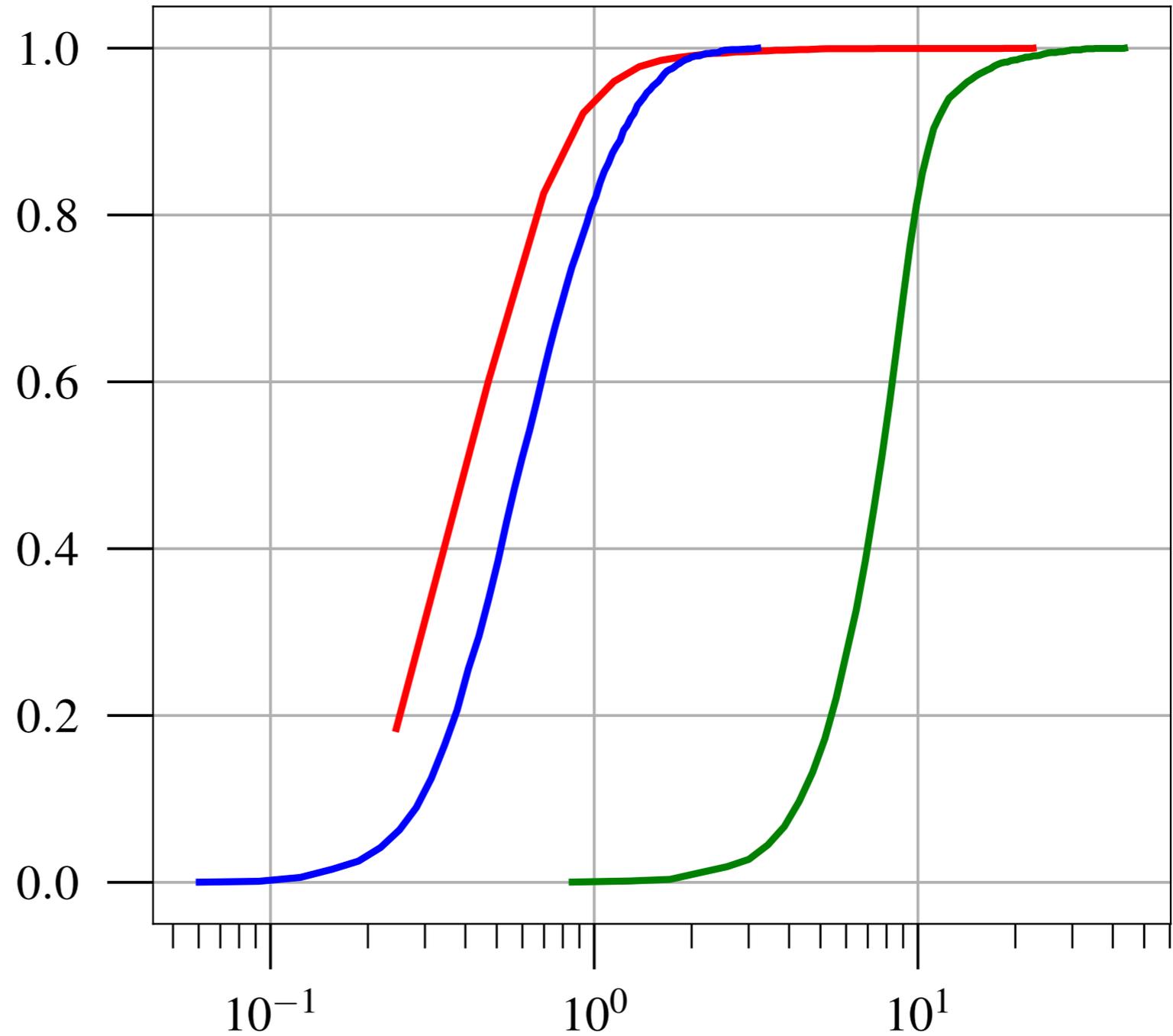


ACCURACY OF DISTANCE MEASUREMENT

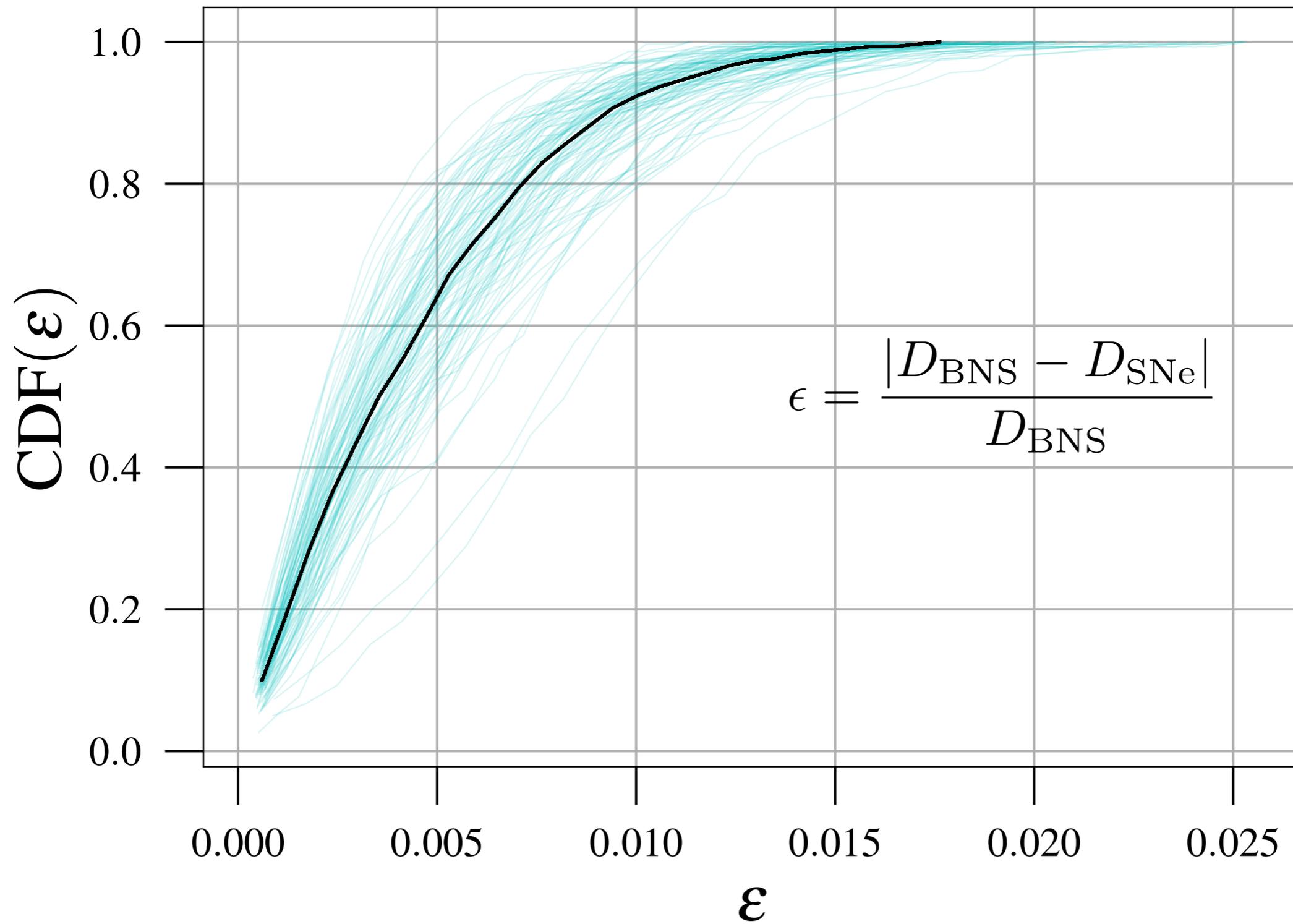
known sky-location and unknown inclination



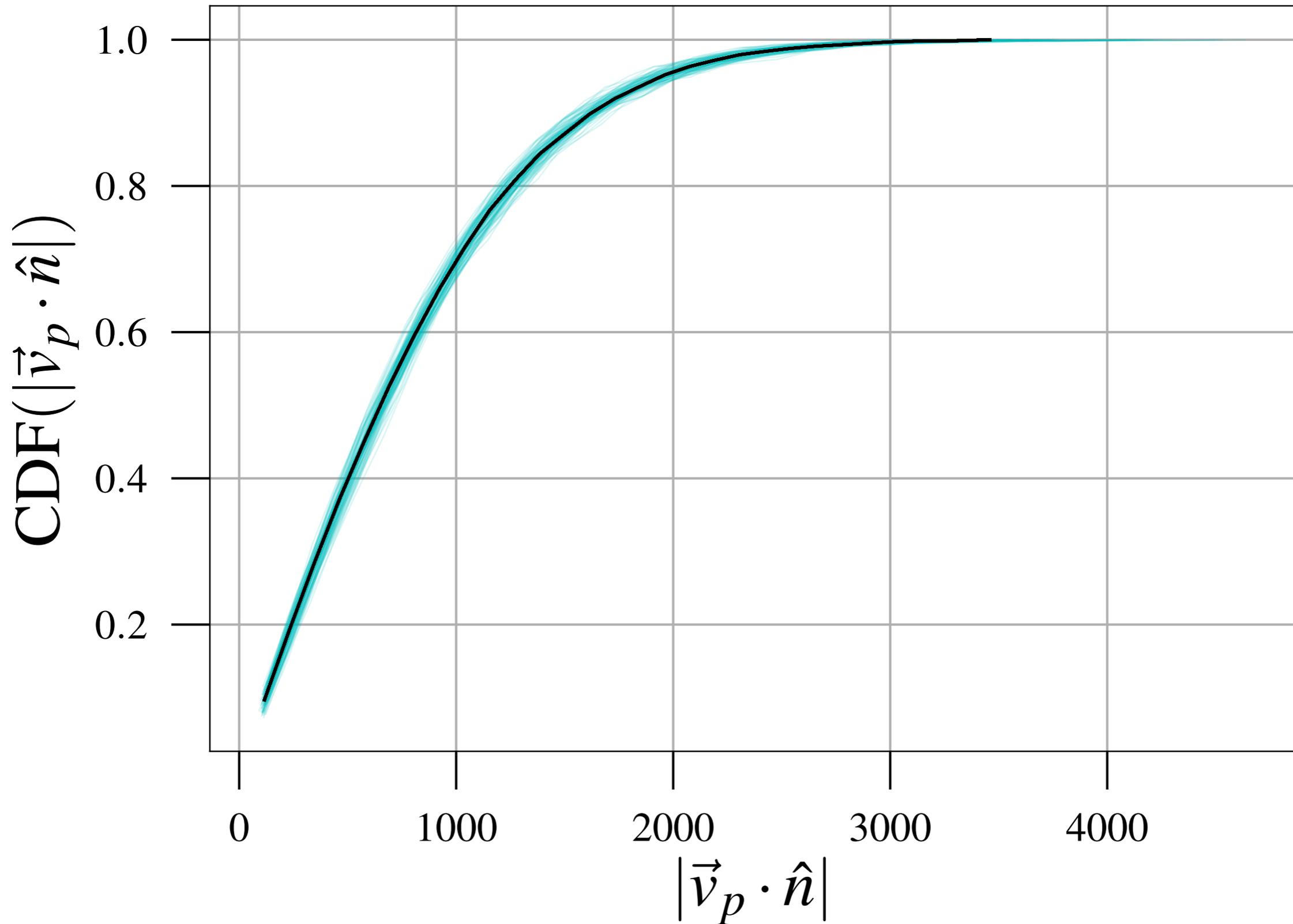
known sky-location and inclination



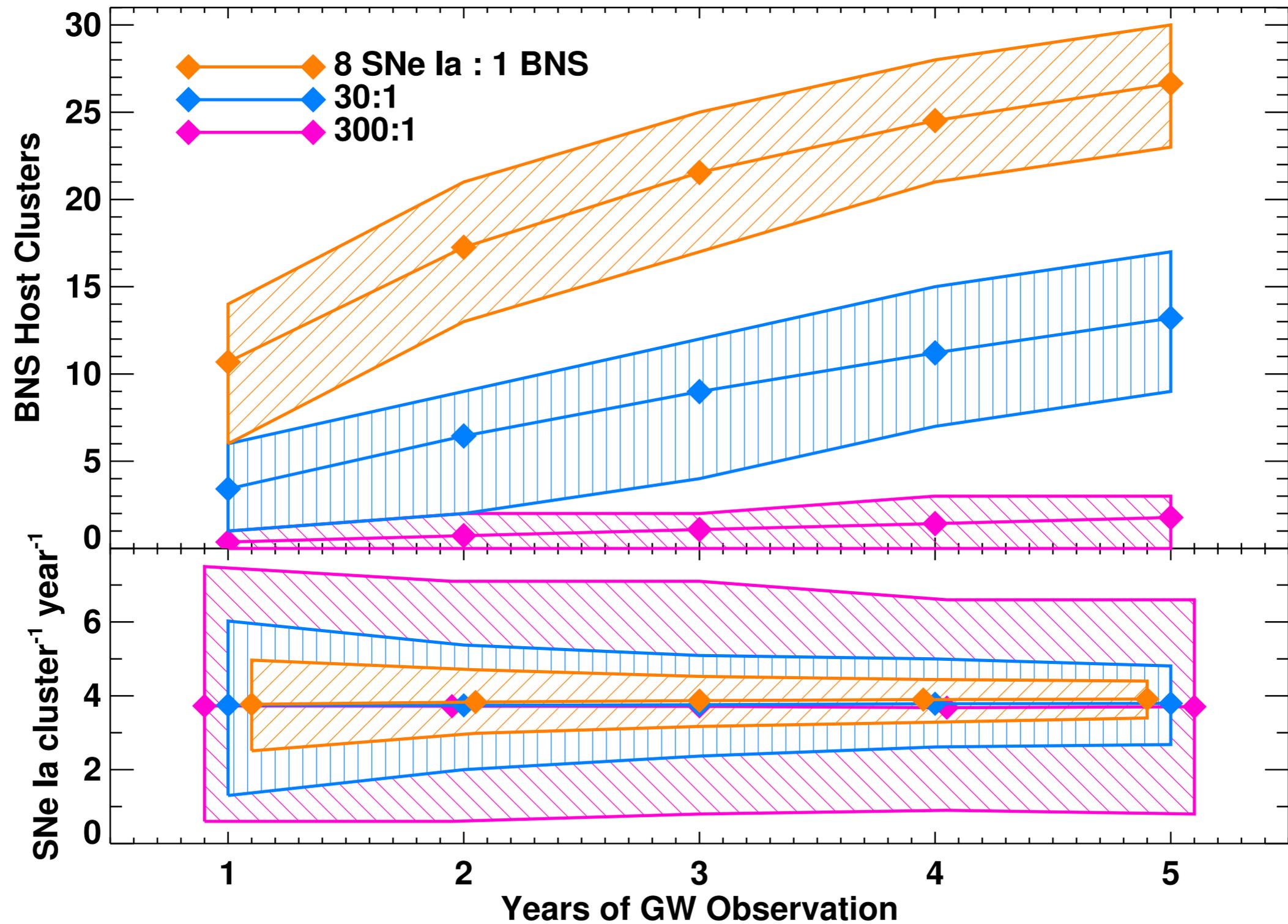
CALIBRATING SUPERNOVA TYPE IA IN CLUSTERS: UNKNOWN HOST GALAXY



CALIBRATING SUPERNOVA TYPE IA IN CLUSTERS: PECULIAR VELOCITIES



COINCIDENT OBSERVATION OF BNS AND SUPERNOVAE



CHALLENGES

- need complete supernovae catalog
 - especially in clusters; LSST may be able to do this, but can we get enough information from LSST that can be used to calibrate supernovae?
 - cluster SNe Ia are not normally used in H_0 measurements because cluster peculiar velocities are very large; this is not a problem for calibrating SNe Ia with BNS in the same cluster
- what are the challenges in following up BNS events within 300 Mpc
 - we need coordinated effort among EM telescopes to meet up to the challenge of observing $\sim 1-2$ events every week
 - shouldn't we start thinking about this now so that we are prepared to do this already in O4 or the A+ era