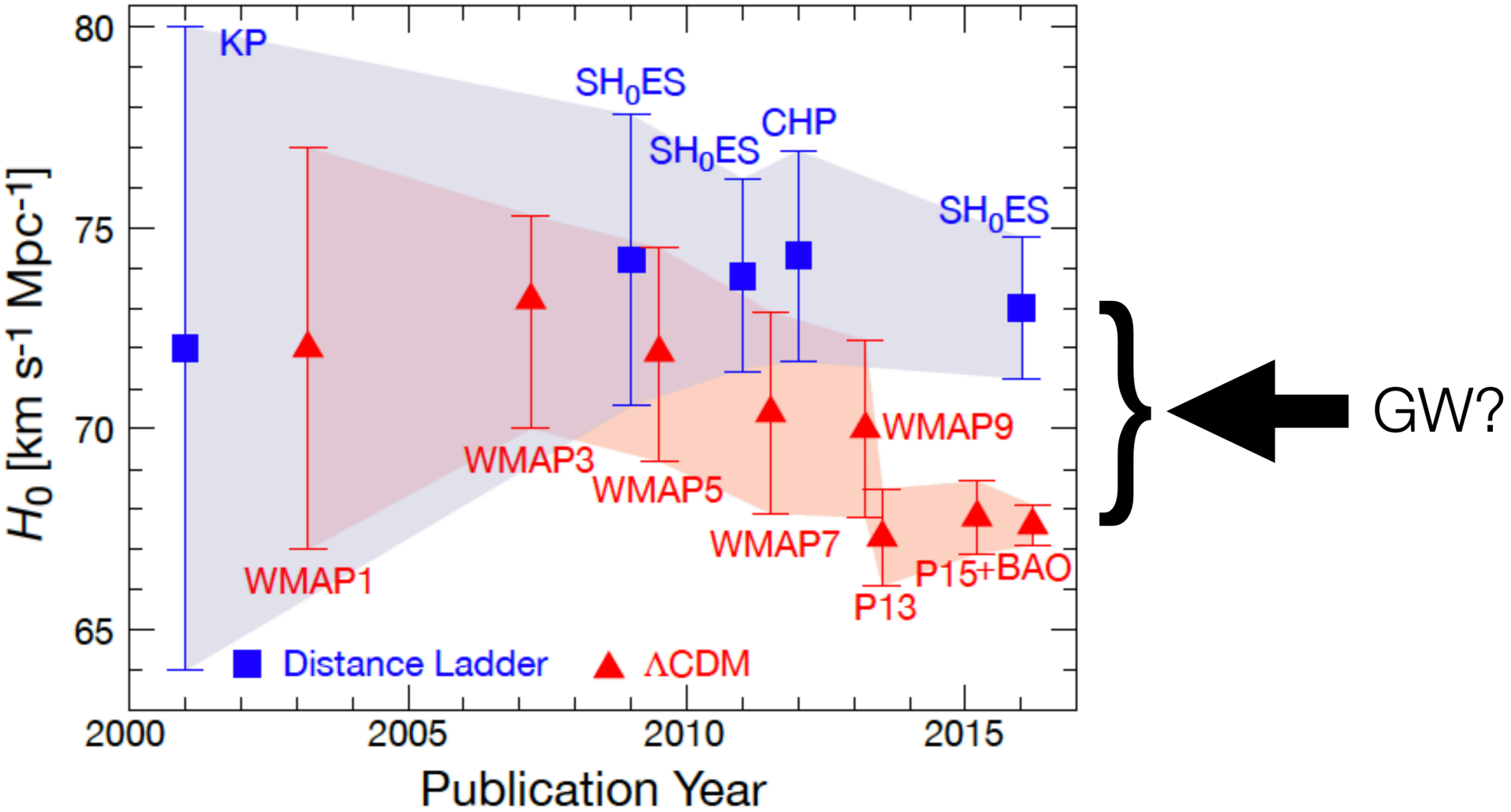
A standard siren measurement of the Hubble constant from GW170817 without the electromagnetic counterpart

Ignacio Magaña Hernandez

YITP, Kyoto University
February 12th, 2019

The Leonard E. Parker
Center for Gravitation, Cosmology & Astrophysics
at the University of Wisconsin–Milwaukee

Motivation: Hubble constant tension



Distance, but not redshift

- Gravitational waves provide a direct measurement of luminosity distance, but they give no independent information about redshift, so called **“standard sirens”**.

$$h(t) = \frac{M_z^{5/3} f(t)^{2/3}}{D_L} F(\text{angles}) \cos(\Phi(t))$$

- Gravitation is scale free: $M_z = (1+z)(m_1 m_2)^{3/5}/(m_1+m_2)^{1/5}$

- GWs from a local binary with masses are indistinguishable from masses at redshift z.

$$(m_1, m_2) \longleftrightarrow \left(\frac{m_1}{1+z}, \frac{m_2}{1+z}\right)$$

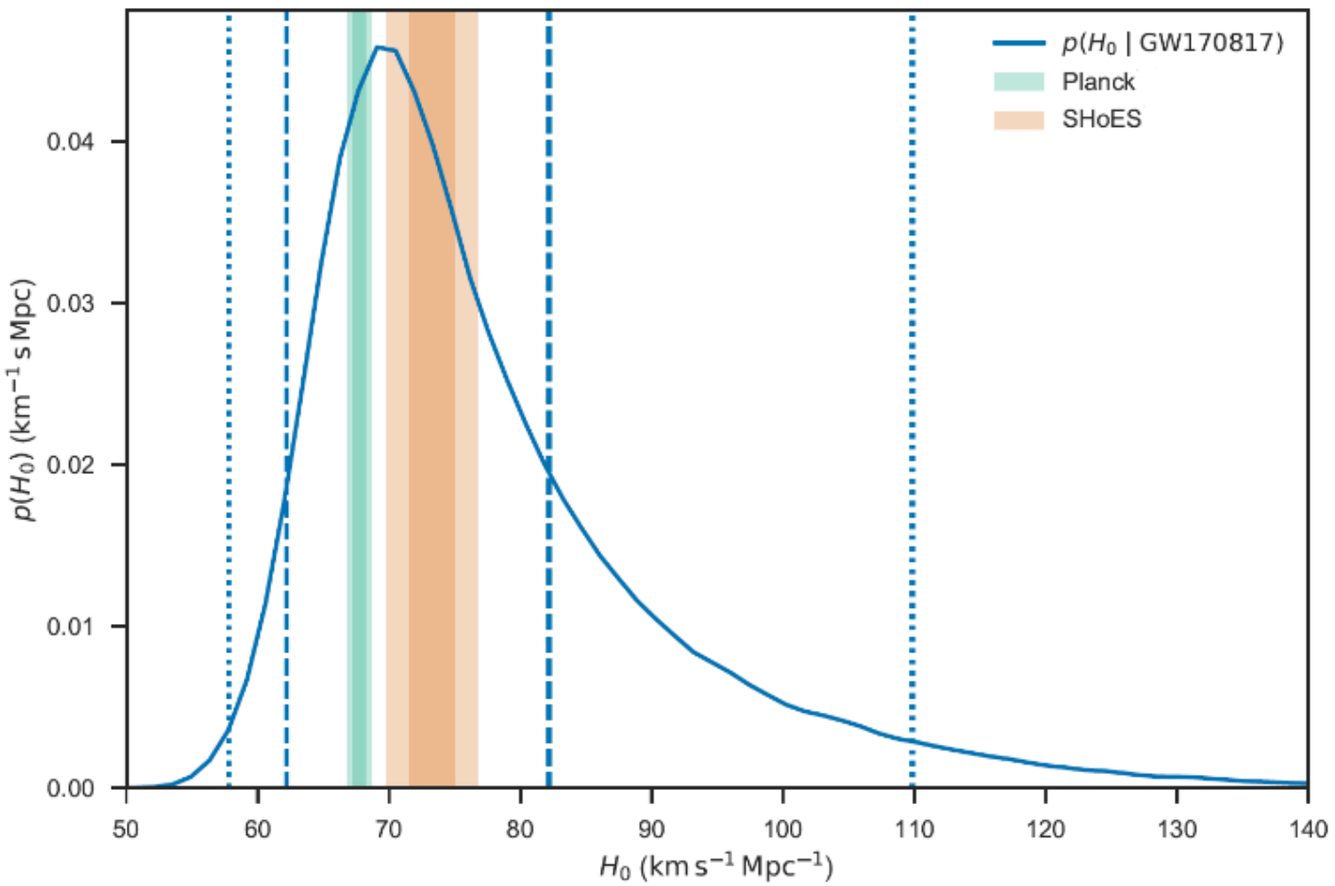
- To measure cosmology, need an **independent** measure of redshift.

Credit: Daniel Holz

How to measure the redshift?

- If the merger produces an EM counterpart (e.g. GRB).
- If one knows the neutron star (NS) equation of state.
- If the shape of the NS mass distribution is known.
- If the post-merger signal is observed.
- Even if no EM counterpart found, one can use a reliable galaxy catalog to cross correlate.

GW170817: First standard siren measurement of H0

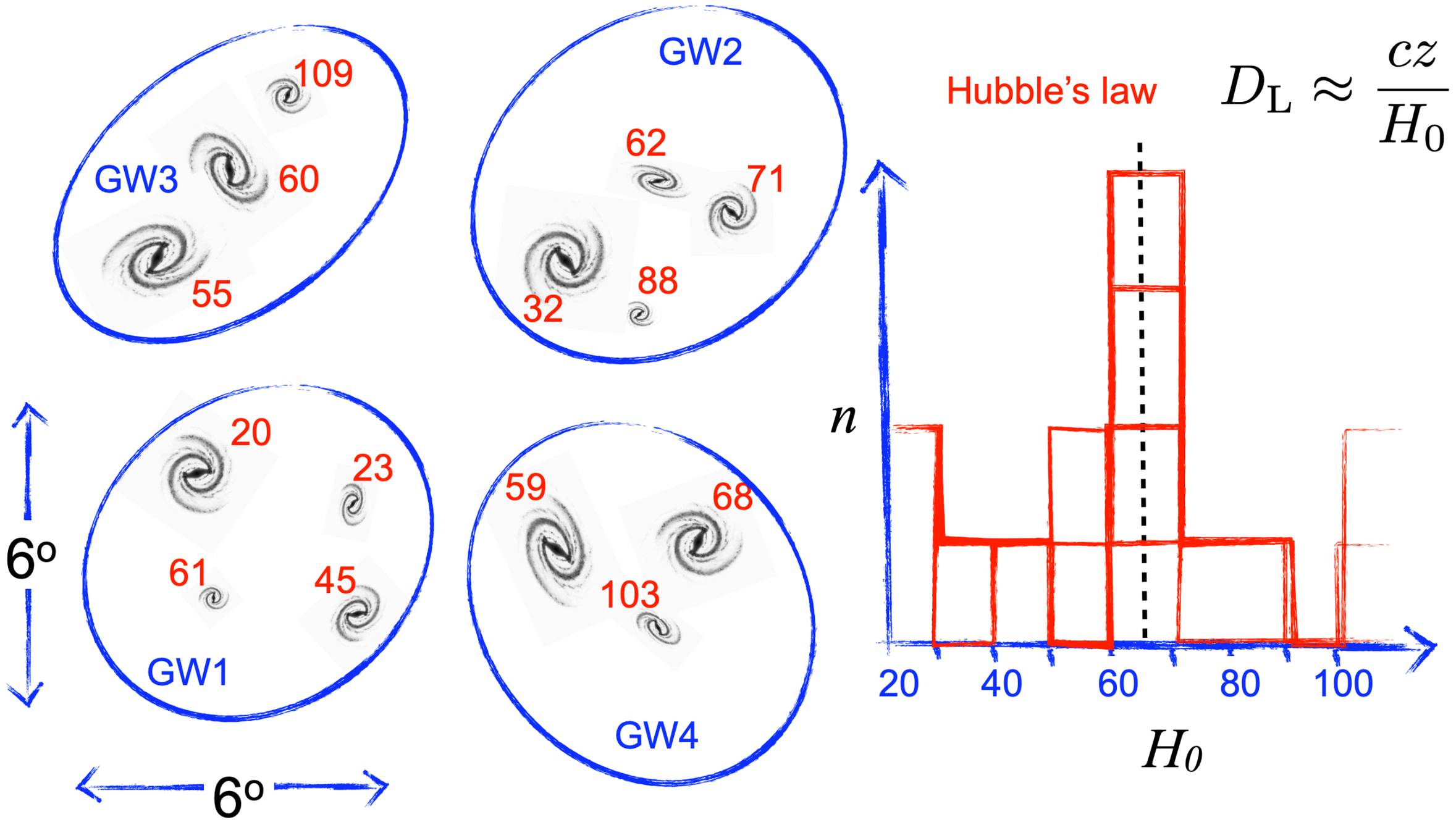


$$H_0 = 70^{+12}_{-8}\ \text{km/s/Mpc}$$

- LVC reported a 1-sigma uncertainty of ~14%
- Of this uncertainty:
  - ~11% came from uncertainty in measuring GW luminosity distance.
  - The rest came from uncertainty in the peculiar velocity of the galaxy w.r.t the Hubble flow.

Credit: Salvatore Vitale

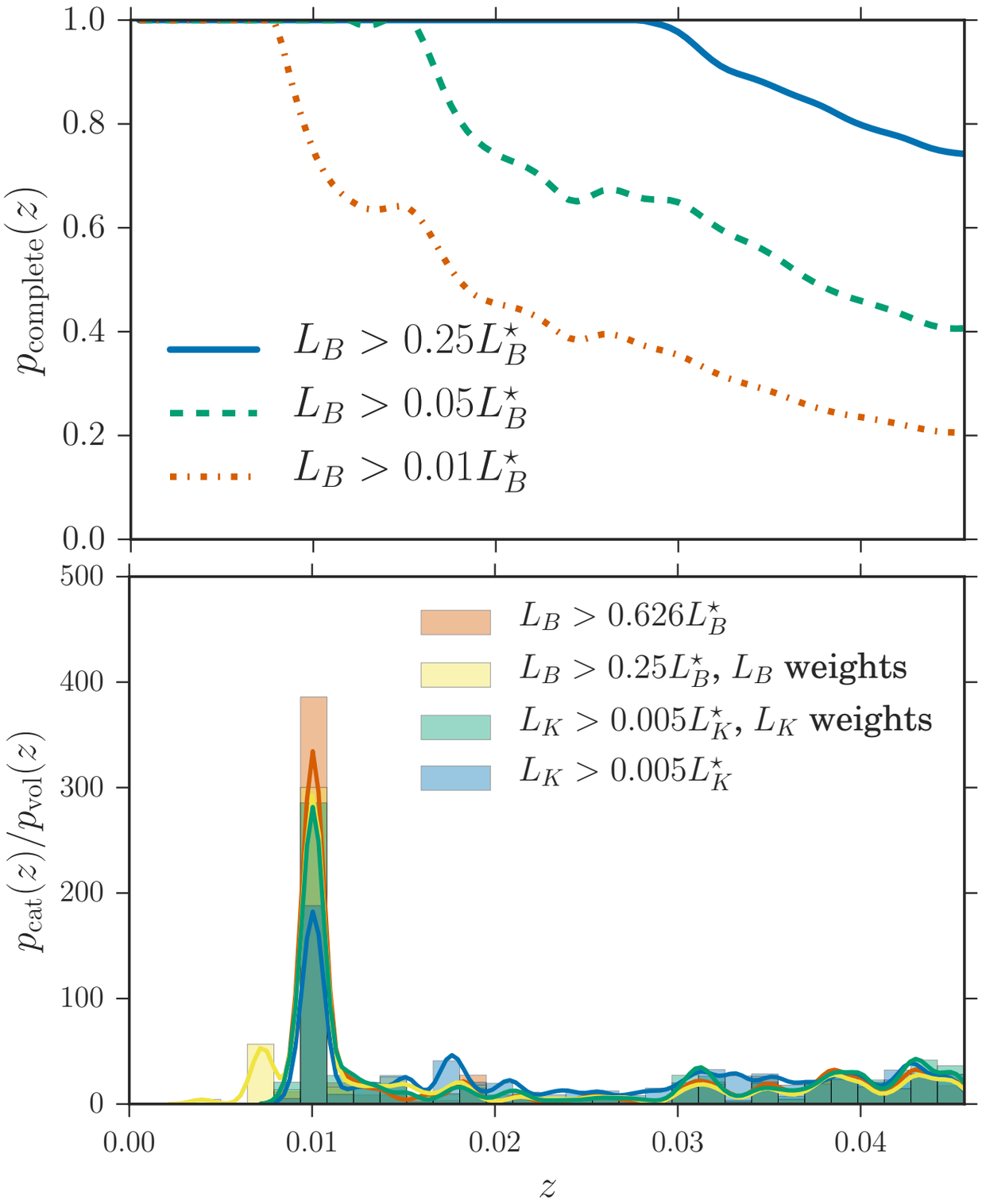
Cross correlating with galaxy catalogs



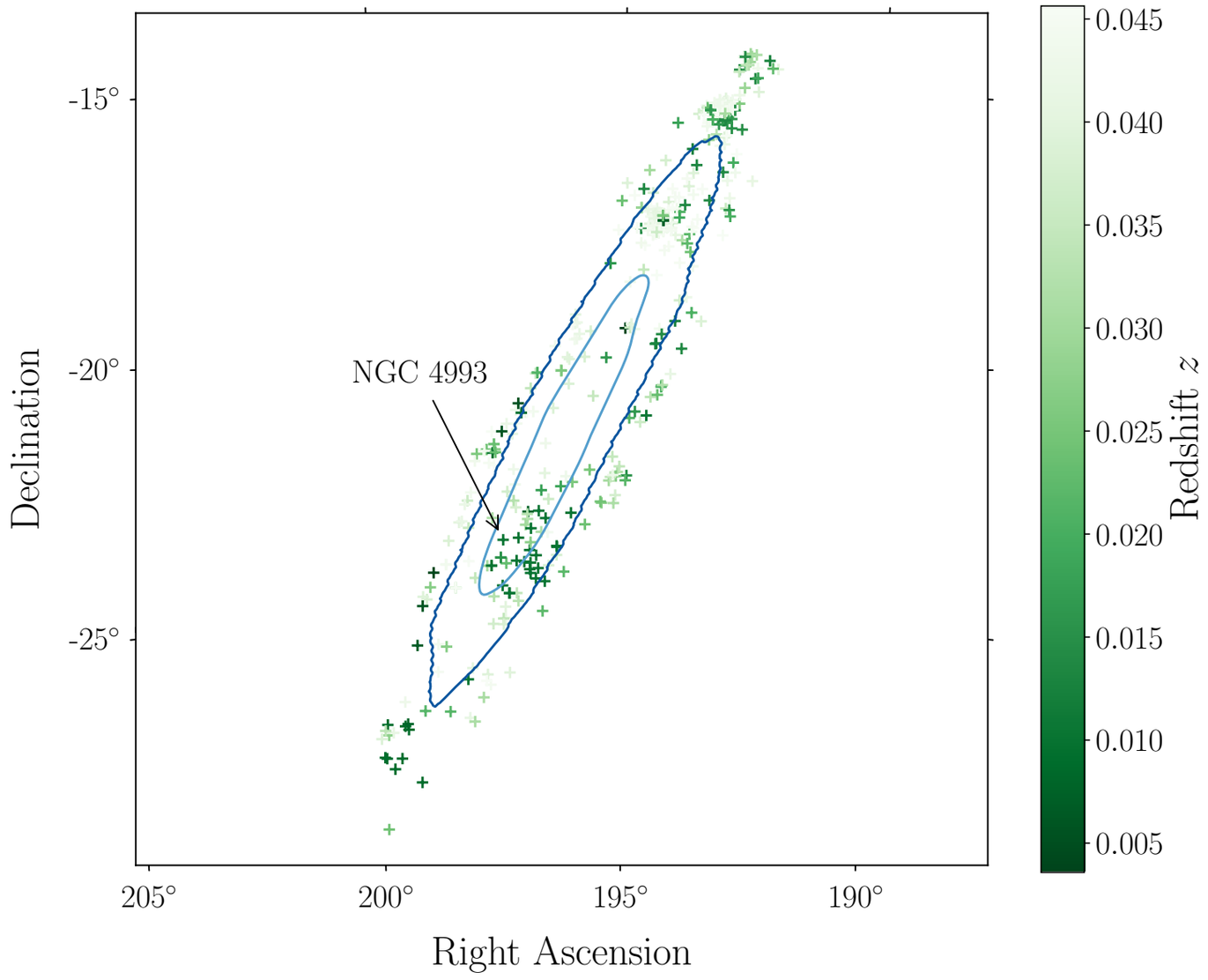
Credit: Chris Messenger

GW170817 statistical H0: Galaxy catalog

- First application of the statistical method to a real GW event.
- In here we pretend we don't know the location of the GW event (at z~0.01).
- We use the GLADE galaxy catalog for cross correlation, around 50% complete out to 120 Mpc.

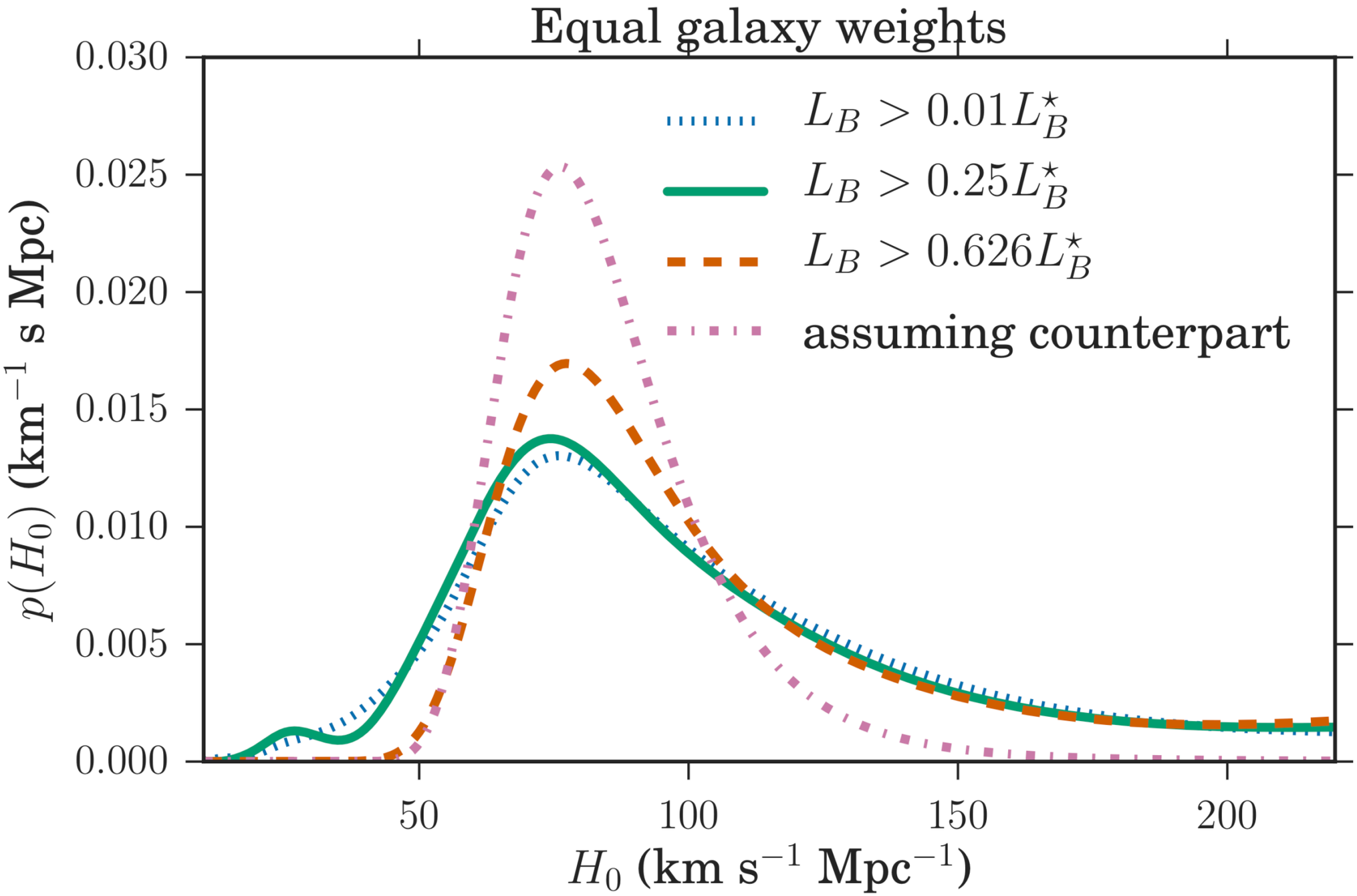


GW170817 statistical H0: Localization

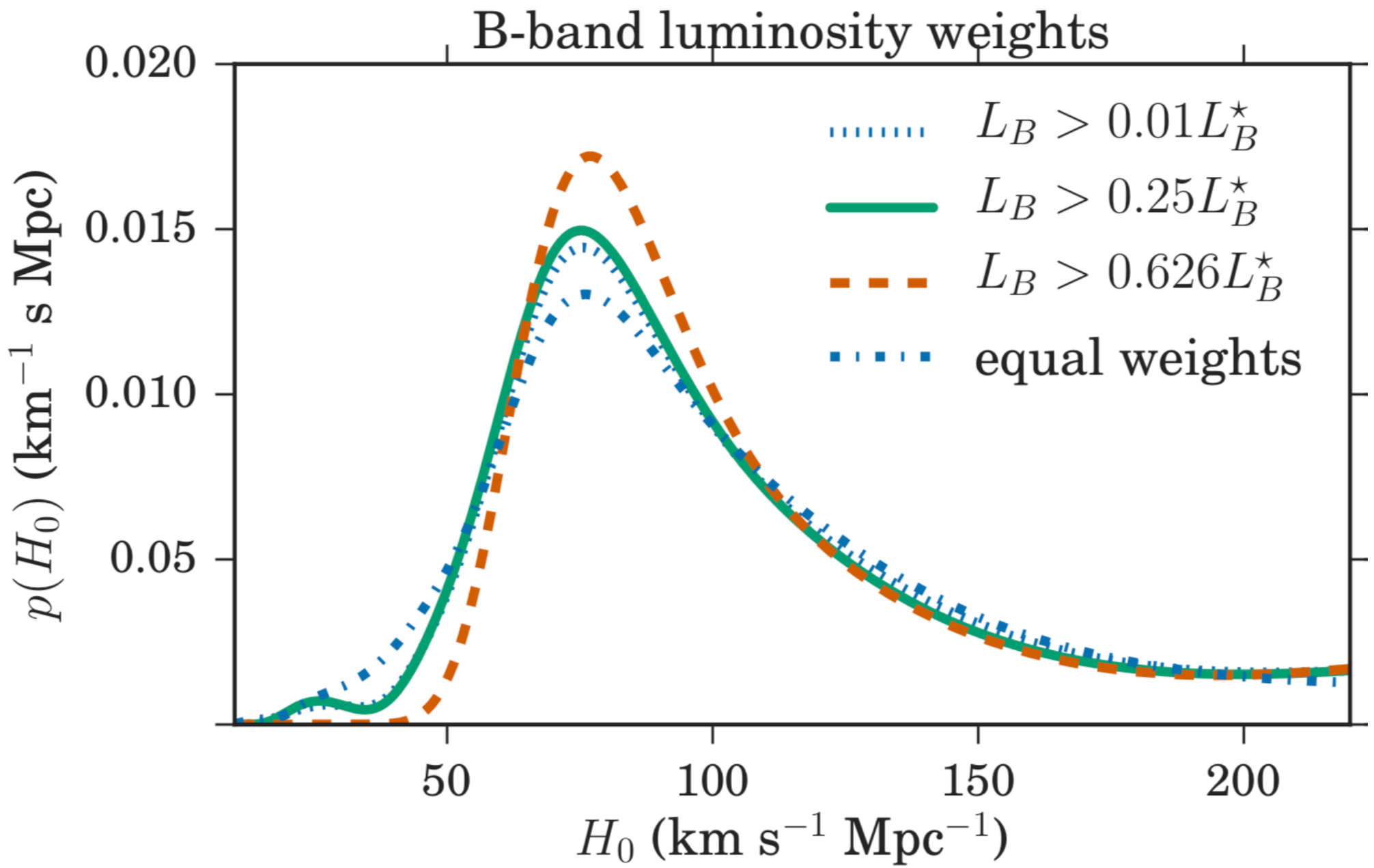


- Galaxies that contribute to the statistical cross correlation with GLADE using the 99% GW170817 localization region within the redshift range $0 < z < 0.046$.

GW170817 statistical H0: Results

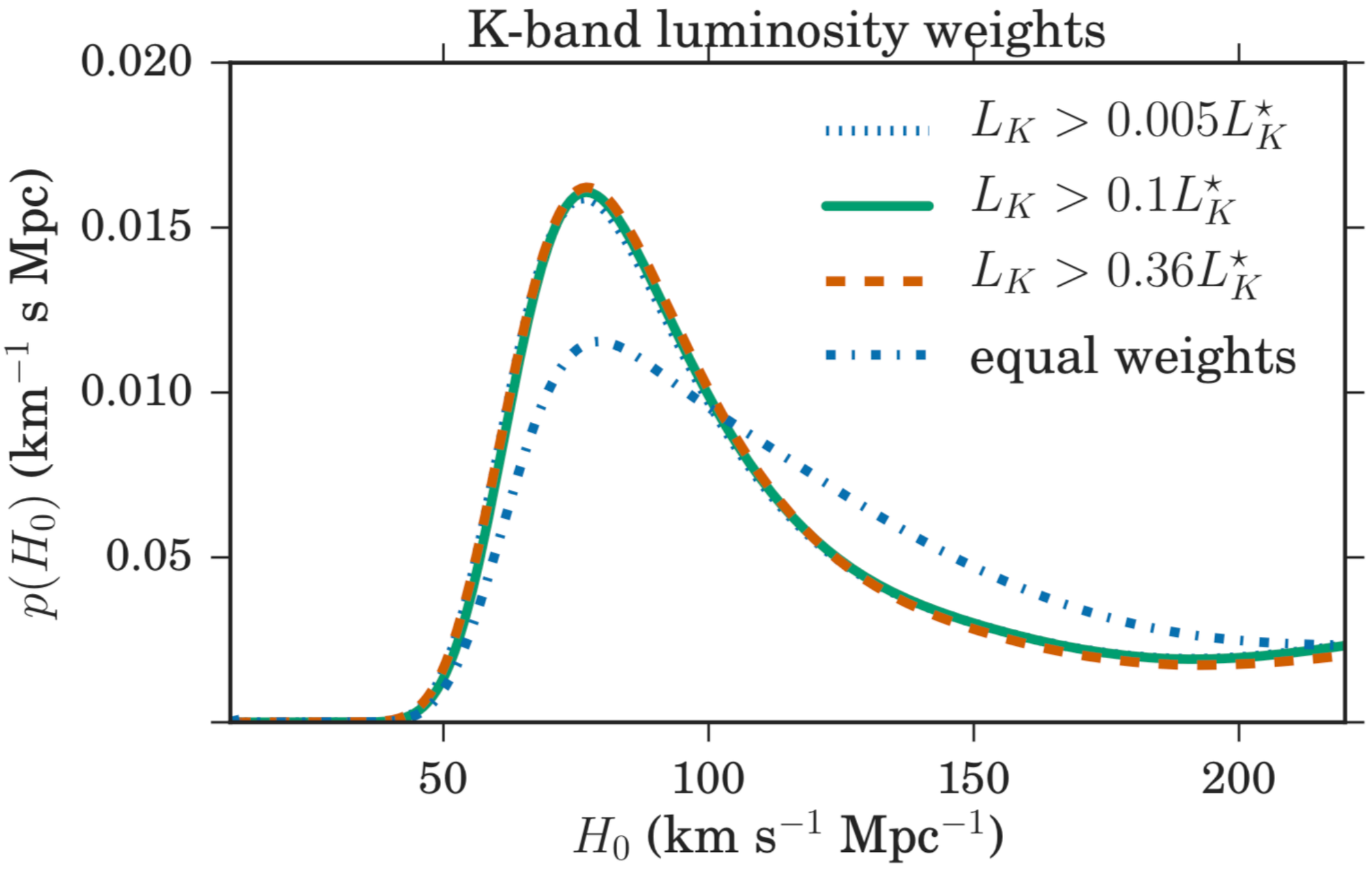


GW170817 statistical H0: Results



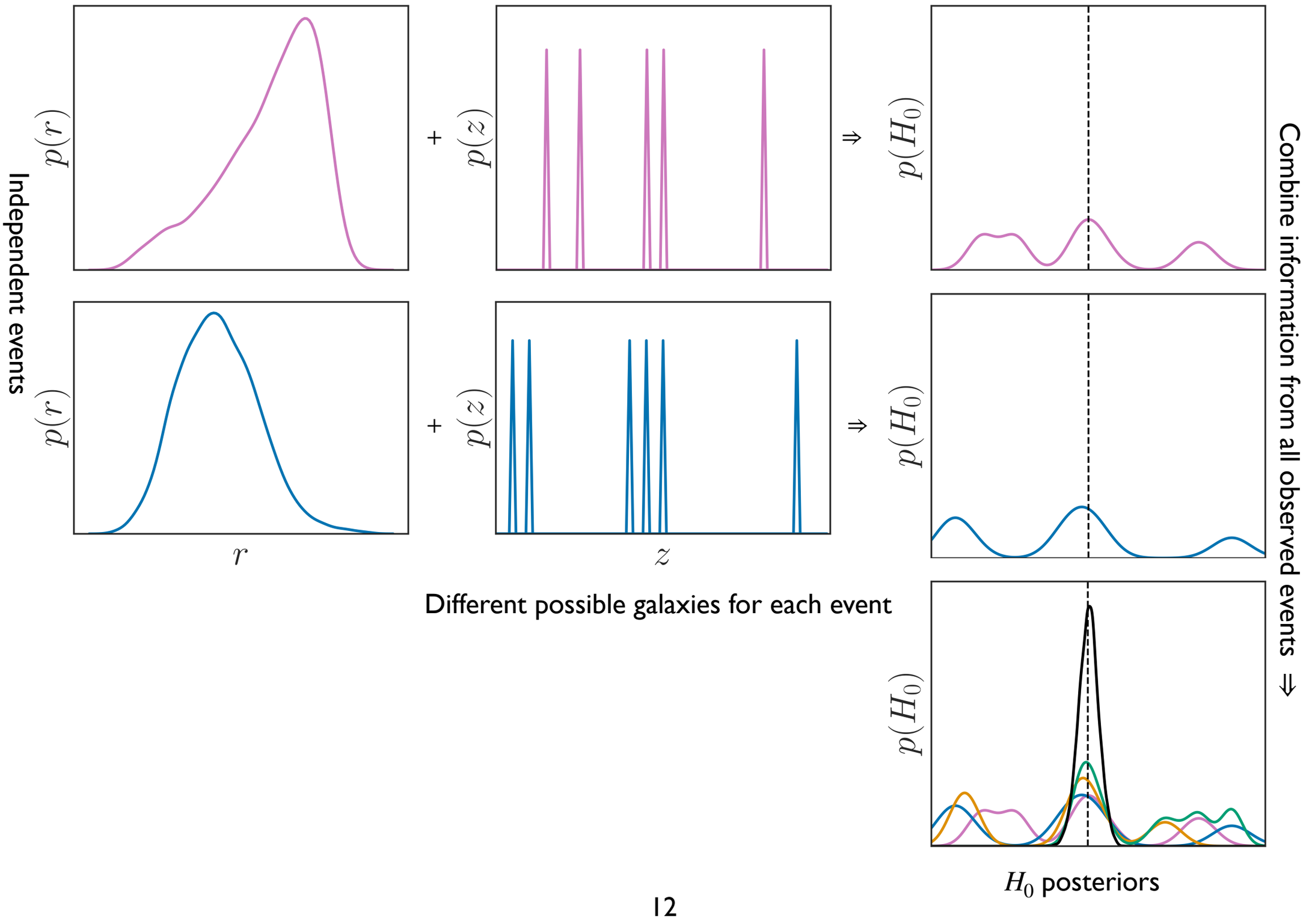
Star formation weights

GW170817 statistical H0: Results



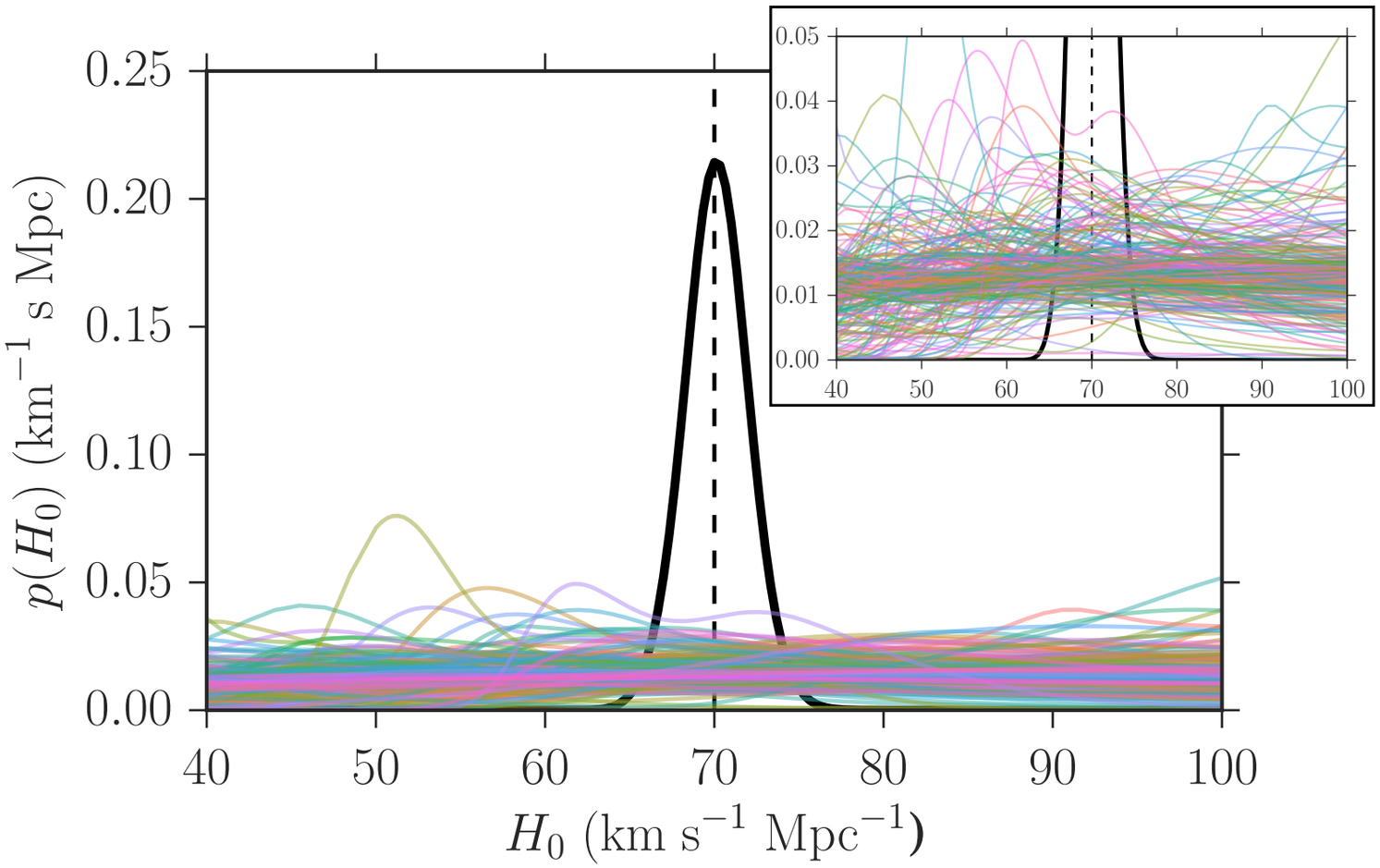
Stellar mass weights

Mock data studies



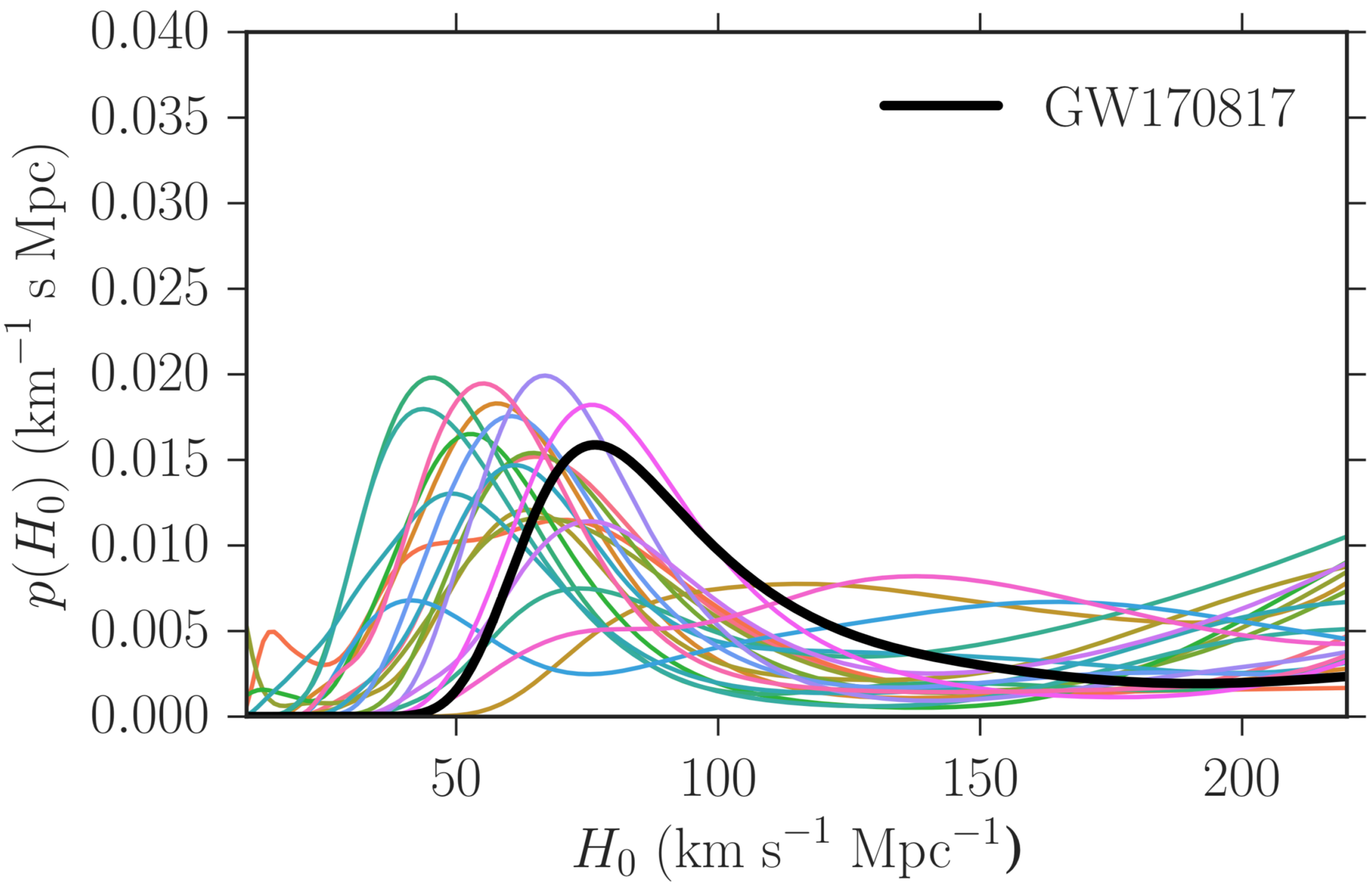
Mock data studies

- Use LIGO's First Two Years dataset:
  - End-to-end simulation of 250 BNS events at O2 like sensitivities.
  - Full parameter estimation for each event available.



- Use the MICE catalog (end-to-end mock galaxy catalog simulation from an N-body light cone simulation).
  - Realistic DES-like galaxy catalog with large scale structure, incompleteness, EM selection effects and more.

How good was GW170817?



Conclusion

- GW standard sirens provide an independent measurement of cosmological parameters

- Statistical method uncertainty due to galaxy catalog incompleteness, photometric redshift uncertainties and large number of galaxies.

- GW+EM counterparts provide the tightest constrains.

- Statistical method might be the only way to constrain cosmology using **binary black holes.**

Thank you for listening