Clustering effects on GWs Dark Sirens determination of Ho

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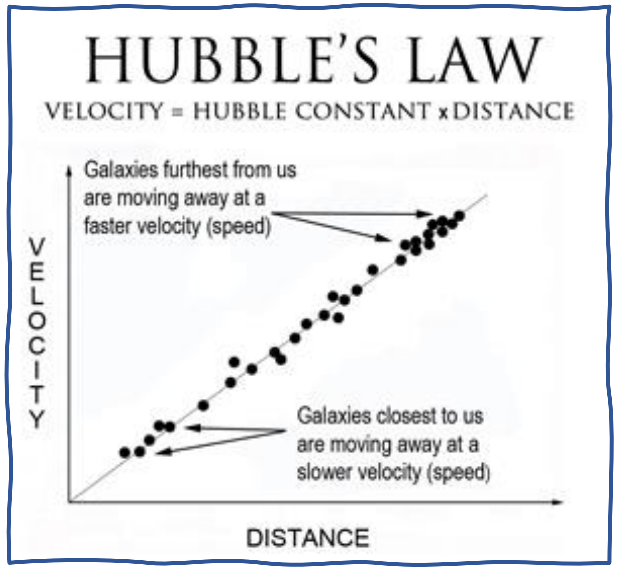
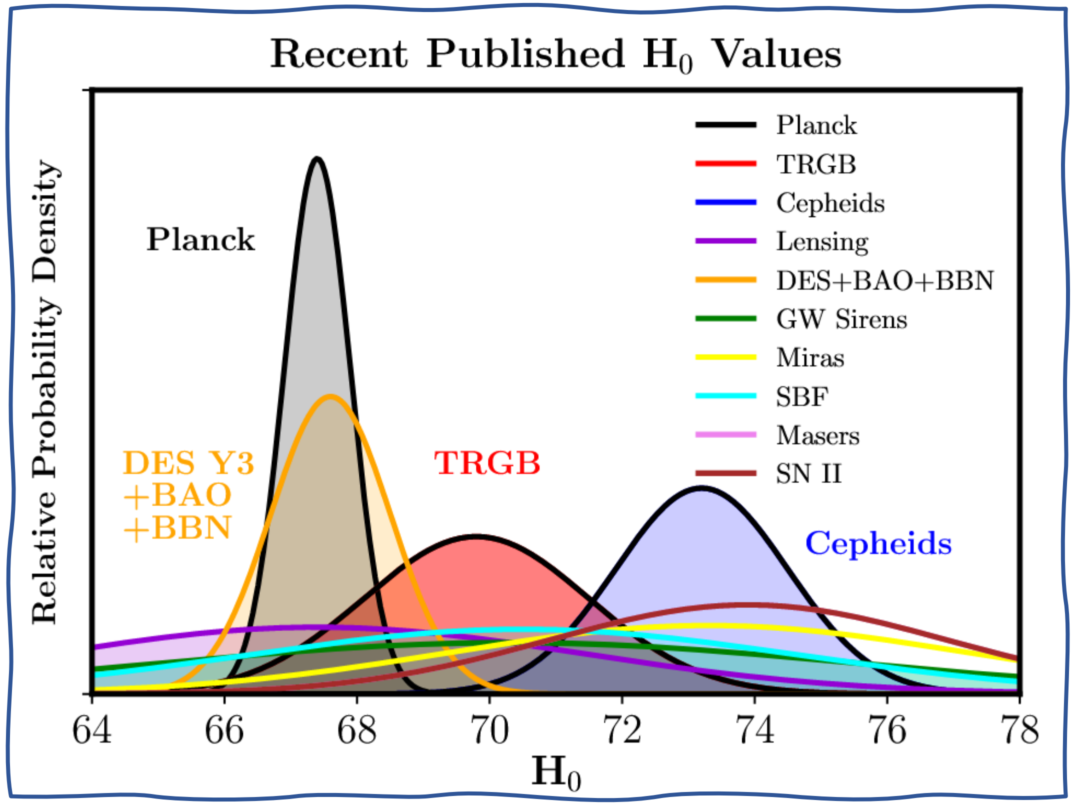
Hubble Trouble?





Wendy L. Freedman 2021

The Hubble constant parameterises the expansion of the Universe:

$V_{total} = H_0 \times D + V_{pec}$

- Most measurements of the Hubble constant (Ho) require a precise determination of the velocity of expansion (through redshift z) and distance to the source (D).

- There seems to be a discrepancy between different methods of determining Ho. Systematics? Or New physics?

Gravitational Waves to the rescue

B. P. Abbott et al. 2017b

GWs can provide an independent probe to the Hubble constant and help resolve the current tension.

Contrary to many other methods, GWs observations allow an “easy” determination of the distance, while it is difficult to get redshift information.

- **Distance** → from GW signal

$$h \propto 1/D$$

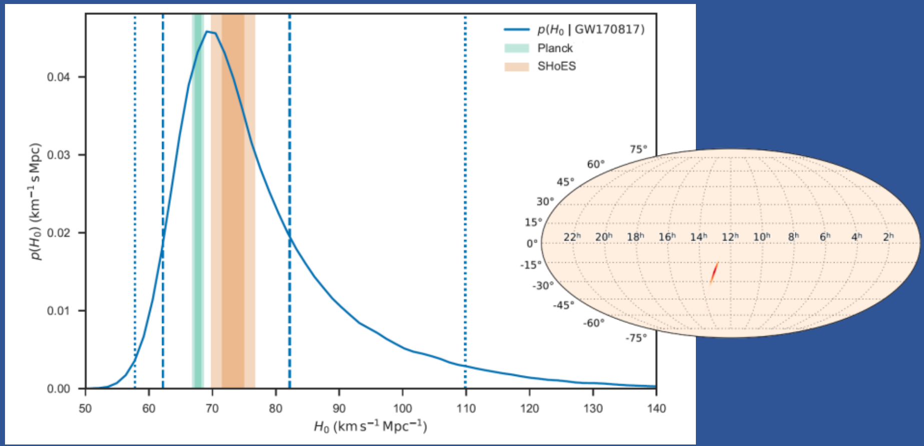
- **Redshift***

1) A direct EM counterpart

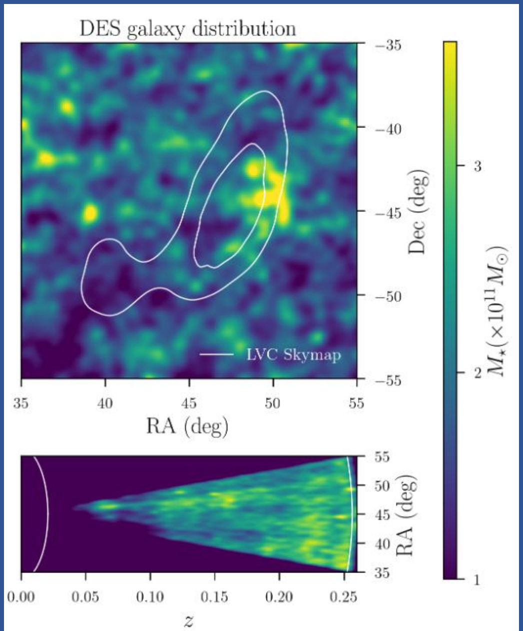
2) A collection of galaxies in GW localisation volume

3) Knowledge of source-frame mass distribution

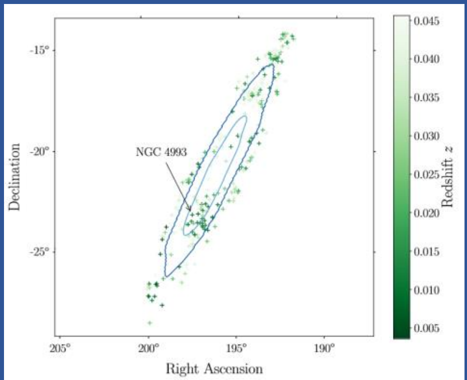
4) For NS: measure of tidal deformability & EoS



Only for specific sources & precise localisation



M. Soares-Santos et al. 2019



Fisbach et al. 2019

Since we do not observe the EM counterpart (Dark Sirens), we need to take into account every galaxy in the region as a possible host (with different weights).

*Based on D. Steer, 2021

Dark Sirens in Simulations*

In **5** + 1 steps:

1) We observe a GW, with no counterpart. In the simulations, we model the GW 3D sky region as a cone.

2) For the cone we assume 2 main errors, following observations (**LOS distance, sky localisation area**). These give different weights to the potential sources.

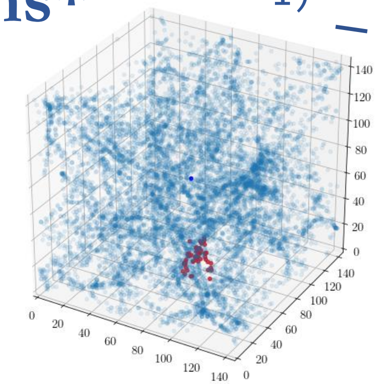
3) We find all haloes in the cone and calculate their distances to the observer. Observer at the centre of the box. Centres of cones at random halo positions in the box.

4) **Randomly choose one distance as the “true” GW distance** (GW source).

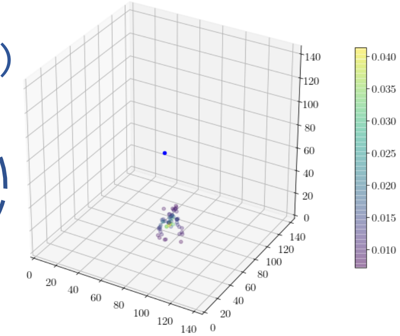
5) Expect, that **due to clustering, there is higher probability the “true” distance to be shared among many haloes.**

6) Power of the method lies in the statistics: Repeat for many cones and “add” together!

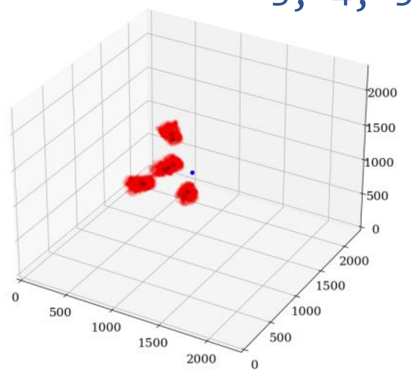
1)



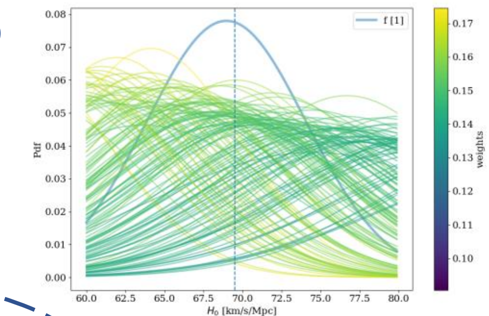
2)



3, 4, 5)

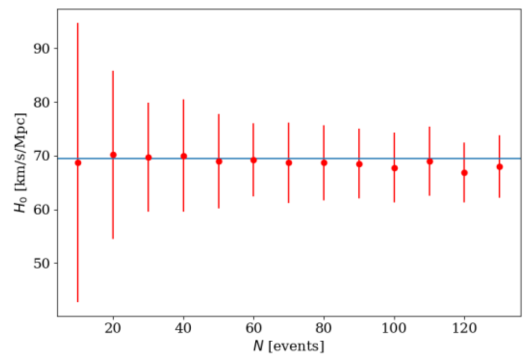


6a)



Results from single observations (colour-coded based on size of error), combine to give a single posterior (blue, solid line)

6b)



Results converging with number of observations (cones) as $1/\sqrt{N}$

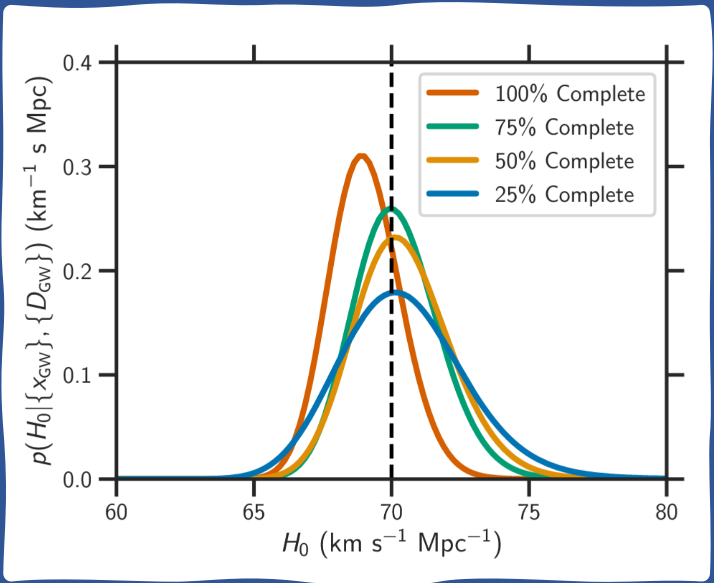
*Most of the boxes here are for visualisation purposes only. For the analysis we use the haloes from a (1.6 Gpc/h)^3 box, with 2048^3 particles resolution from the LEGACY suite.

Results & Conclusions*

BUT: Surveys can't resolve all galaxies. Hence we need to investigate what happens, when we have an incomplete catalogue.

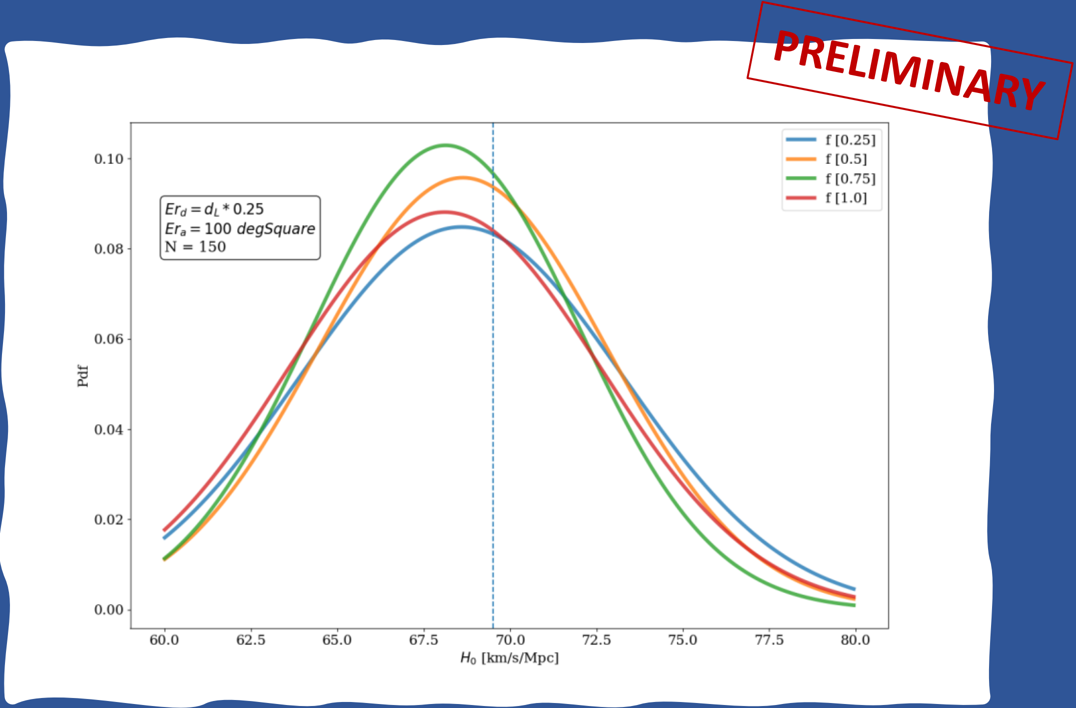
Cuts based on luminosities. Then "complete" the catalogues, by randomly putting galaxies in (following observational practice).

A less complete catalogue will give less precise results (results below do not take into account a galaxy clustering).



Gray et al. 2020

A more realistic approach, will take into account clustering. This increases the possibility of identifying the true host, hence we expect to improve convergence.



Incompleteness cuts by randomly throwing away haloes from our cones (f[0.75] corresponds to 25% of the haloes thrown away), then completing following observations.

Preliminary results indicate that clustering effects can be important when dealing with incomplete catalogues, resulting into similar posteriors for Ho.

Conclusions

- Dark Sirens can provide a robust method for calculating Ho.
- Clustering is improving convergence, even when we have incomplete catalogues.

***Soon on the ArXiv!**