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Dark siren H_0 measurement using bright subsets of galaxy catalog

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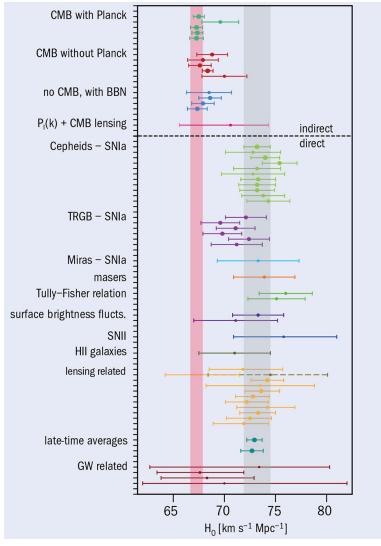
THE HUBBLE TENSION

- two ways of measuring Hubble constant $\Rightarrow$ two different results
  - directly from distance and redshift (SNIa):
    $73.30 \pm 1.04\ km\ s^{-1} Mpc^{-1}$ [Riess et al., 2022]
  - indirectly from CMB:
    $67.4 \pm 0.5\ km\ s^{-1} Mpc^{-1}$ [Aghanim et al., 2020]
- possible reasons:
  - problem with ΛCDM
  - problem in cosmic distance ladder
- GW-based H_0 measurements
  - independent of traditional methods
    $68^{+12}_{-8}\ km\ s^{-1} Mpc^{-1}$ [Abbott et al., 2023]



Source: [Cern, 2021]

Cosmology with GWs

- Low redshift:

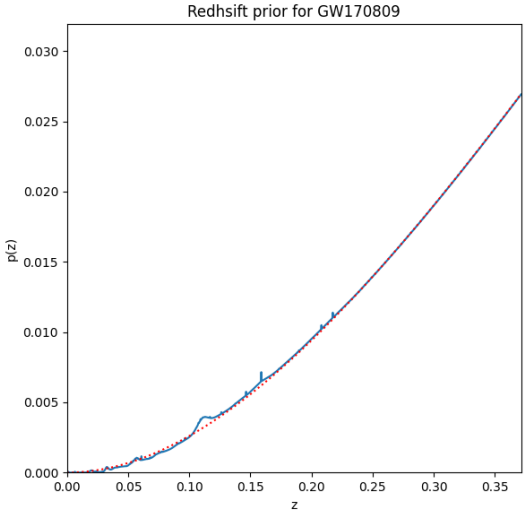
$$d_L \approx \frac{cz}{H_0}$$

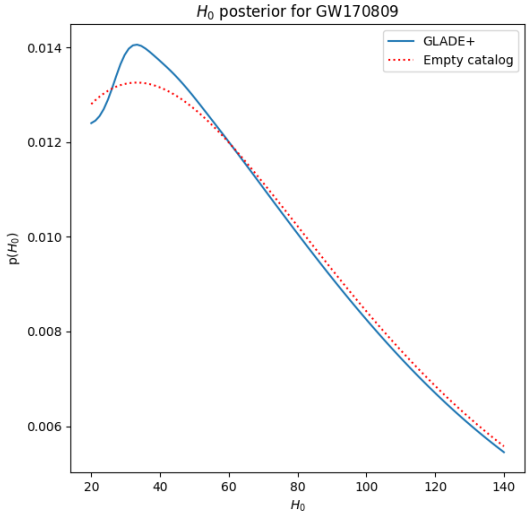
- H_0 measurement techniques:
  - d_L from GW, z from EM observations
  - Bright siren: EM counterparts for GW signals (only 1 till date)
  - Dark siren: no EM counterparts $\Rightarrow$ galaxy catalogs

DARK SIREN ANALYSIS

- gwcosmso: Bayesian statistics
- a number of potential host galaxies $\Rightarrow$ Line-of-sight (LOS) redshift prior
  - combine to get a redshift prior for an event
- catalog incompleteness: host galaxy present in the galaxy catalog or not
  - in-catalog part: weighted sum of Gaussians
  - out-of-catalog part: fill using Schechter function

DARK SIREN ANALYSIS

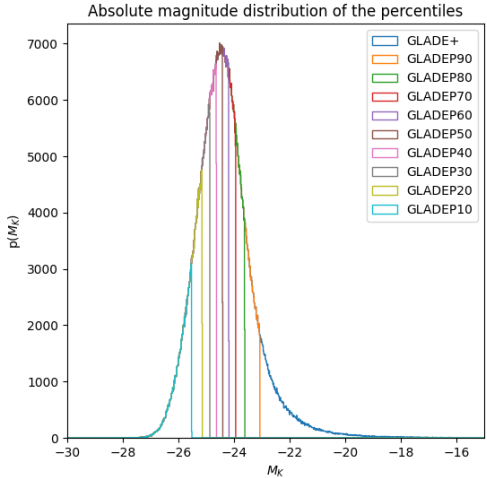


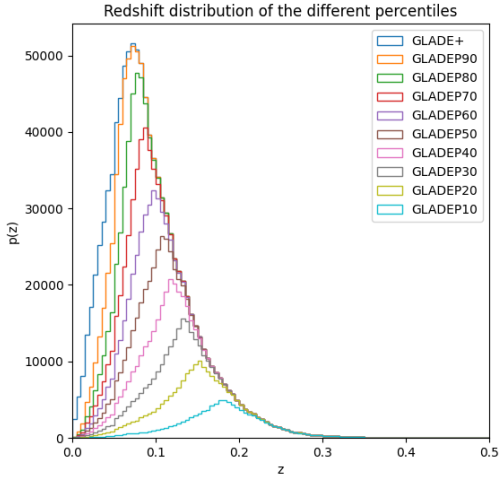


DARK SIREN ANALYSIS

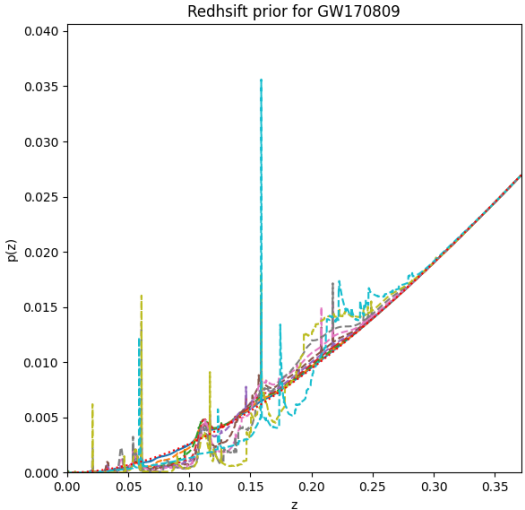
- this project: use bright galaxies, in K-band, to trace the matter distribution (high z)
  - in-catalog part: make subsets of the galaxy catalog
  - out-of-catalog part: maximum magnitude limit for the Schechter function
- GW data:
  - GWTC-3: LVK O1-O3 data
  - high SNR(>11) events
- Galaxy catalog: GLADE+
  - all sky composite catalog
- Simulations:
  - BUZZARD mock catalog: sky area of 1120 deg^2, DES survey
  - GWSim for simulated GW events

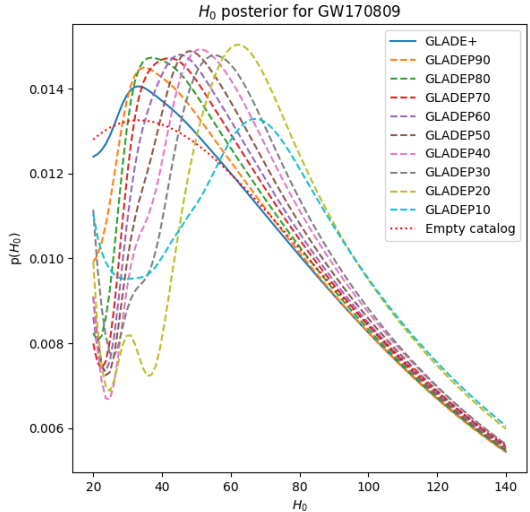
Analysis Using brightest percentiles



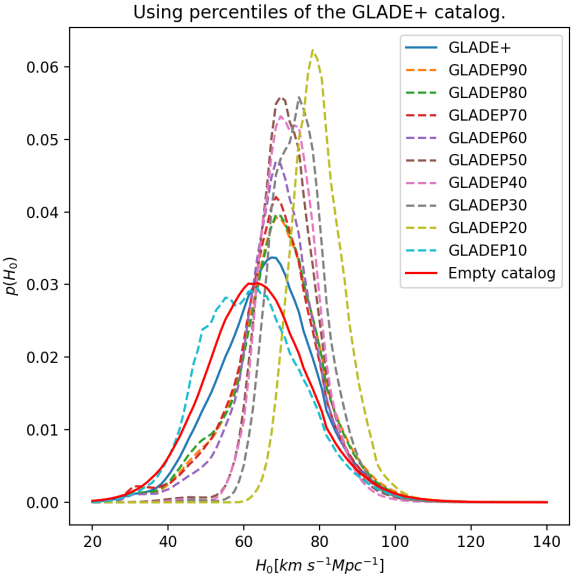


Analysis Using brightest percentiles



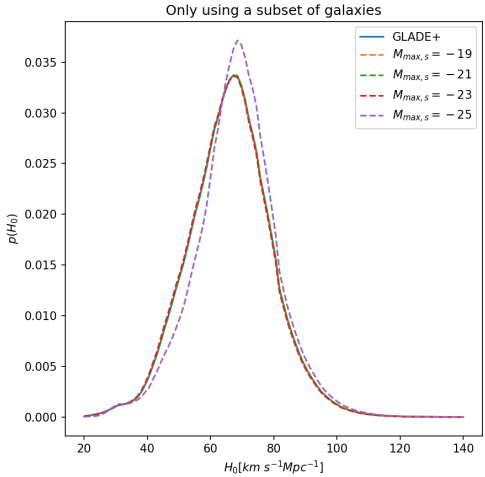


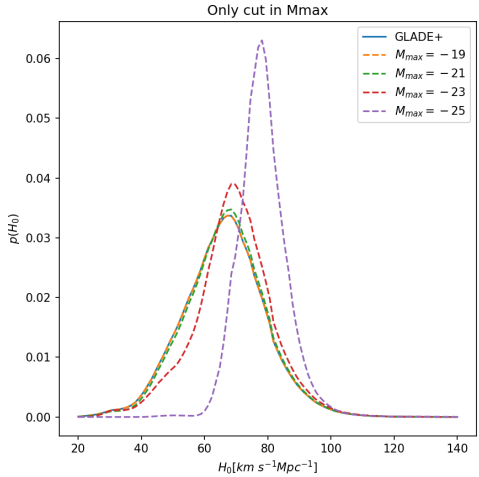
Analysis Using brightest percentiles



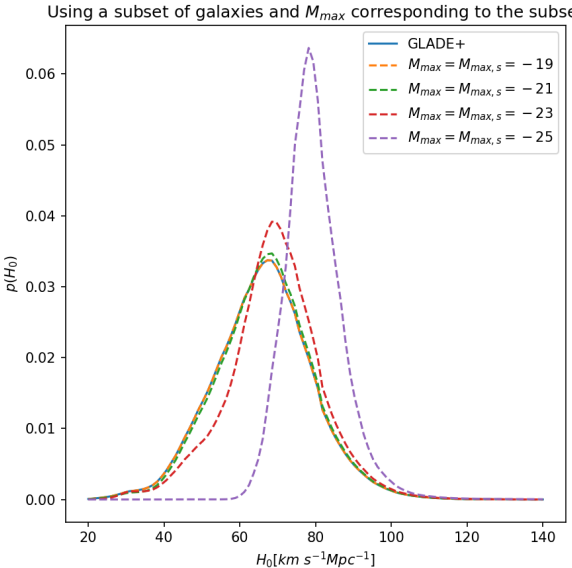
- high-z tail remains unchanged
- redshift prior: galaxies get more weight
- using all events: higher median value with tighter constraints
- GLADEP10: catalog becomes increasingly empty

EFFECTS OF IN- AND OUT-OF-CATALOG PART





EFFECTS OF IN- AND OUT-OF-CATALOG PART

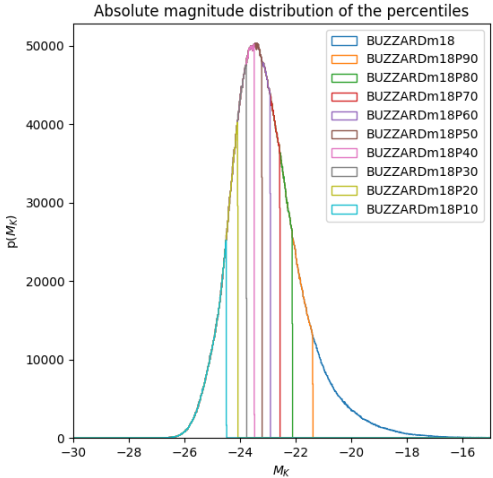


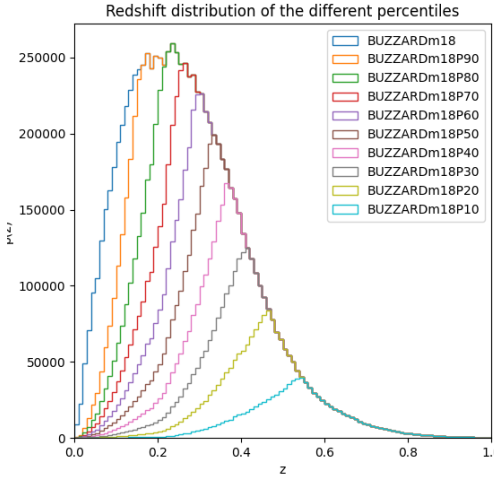
- only using a subset: change only noticeable for extreme cut
- major contribution from out-of-catalog term

Some observations and future direction

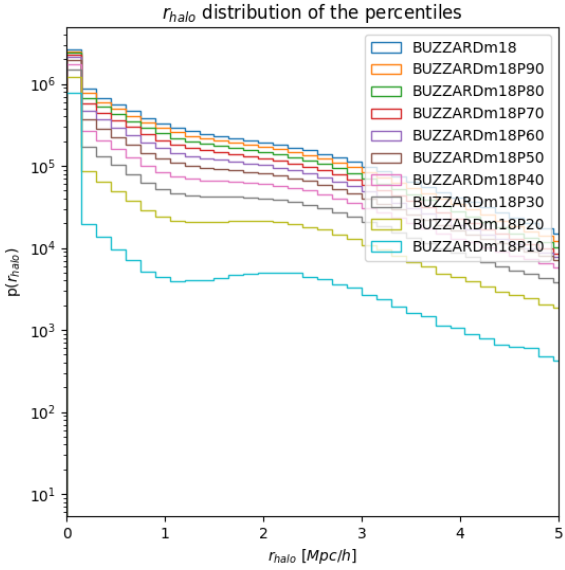
- noticeable improvement: shift to a higher median value with tighter constraints
- Limit: brightest 20-30%
  - catalog becomes increasingly empty
- Next step (in progress): test and verify the results with simulations
  - BUZZARD mock catalog + simulated events (GWSim)

BUZZARD


Absolute magnitude distribution of the percentiles
BUZZARDm18
BUZZARDm18P90
BUZZARDm18P80
BUZZARDm18P70
BUZZARDm18P60
BUZZARDm18P50
BUZZARDm18P40
BUZZARDm18P30
BUZZARDm18P20
BUZZARDm18P10
50000
40000
30000
20000
10000
0
−30
−28
−26
−24
−22
−20
−18
−16
M_K


Redshift distribution of the different percentiles
BUZZARDm18
BUZZARDm18P90
BUZZARDm18P80
BUZZARDm18P70
BUZZARDm18P60
BUZZARDm18P50
BUZZARDm18P40
BUZZARDm18P30
BUZZARDm18P20
BUZZARDm18P10
250000
200000
150000
100000
50000
0
0.0
0.2
0.4
0.6
0.8
1.0
z

BUZZARD



- apparent magnitude threshold (m_{th}) of 18 $\Leftrightarrow$ 13.5 for GLADE+
- high-z tail remains unchanged
- need to fit Schechter parameters
- we trace central galaxies using brightest percentiles

Conclusion

- GLADE+
  - noticeable improvement to existing results
  - out-of-catalog term dominating
    - only 1 million (out of 22.5 million) galaxies present in K-band
  - why K-band?
    - magnitude in K-band correlates with the total luminous mass
    - Schechter function for other bands (e.g. B-band) not well studied
- BUZZARD
  - we trace central galaxies using brightest percentiles in the K-band
  - what next
    - fit Schechter parameters to generate LOS redshift prior
    - run dark siren analysis
    - repeat for deeper cut ($m_{th} > 18$)

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