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The luminosity of the darkness

Schechter function in dark siren H_0 measurement

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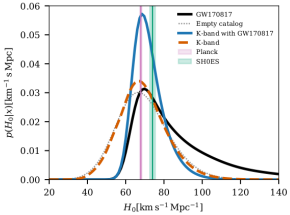
Belgian-Dutch Gravitational Wave Meeting

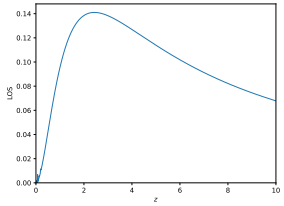
24.10.2023

Introduction

- Dark siren H_0 measurement
- Line of sight redshift prior (LOS)
- Schechter function

Abbott et al. 2021





LOS redshift prior

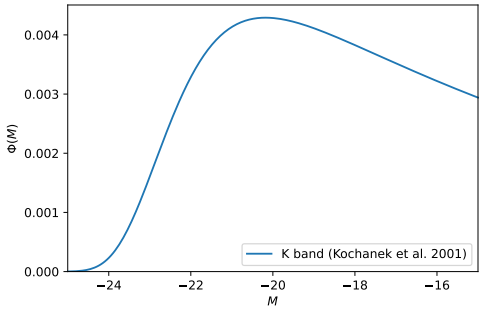
$$\text{LOS out of catalog} = p(z|I) \int_{M(z,m_{\text{th}}(\Omega_i),H_0)}^{M_{\text{max}}} p(M|H_0, I)p(s|M, I)dM$$

- Schechter function $p(M|H_0, I)$
- Only in the out of catalog part
- Change $p(M|H_0, I)$ to $p(M, z|H_0, I)$

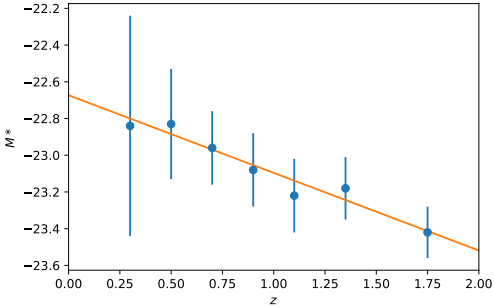
Evolving Schechter function

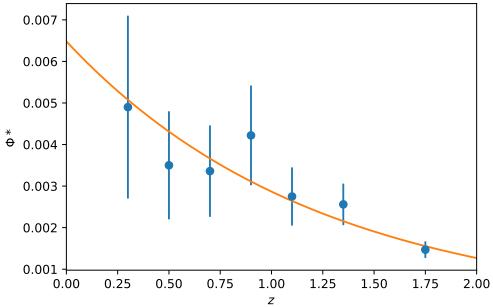
$$\Phi(M,z) = 0.4 \ln 10 \Phi^*(M) \left(10^{0.4(M^*(z)-M)}\right)^{1+\alpha} \exp\left(-10^{0.4(M^*(z)-M)}\right)$$

- Slope: $\alpha(z) = \alpha(z_0)$
- Characteristic magnitude (luminosity): $M^*(z) = M^*(z_0) - Q(z - z_0)$
- Galaxy number density: $\Phi^*(z) = \Phi^*(0)10^{0.4Pz}$



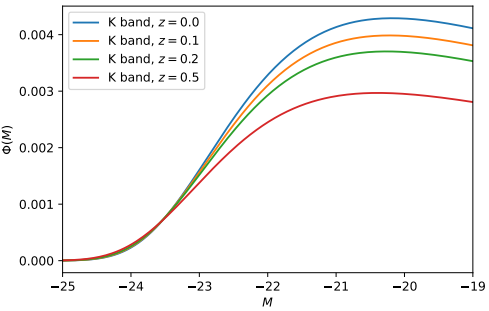
M^* and Φ^* evolution





Arnouts et al.(2007)

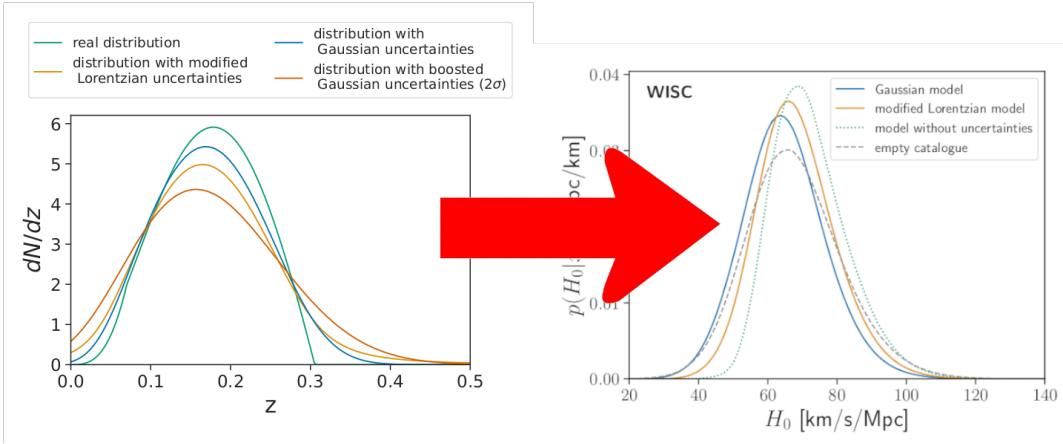
Schechter function evolution



It gets more complicated:

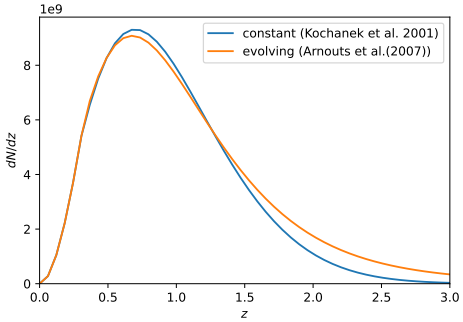
- Positive luminosity evolution in all bands, luminosity evolution is stronger for red than for blue galaxies.
- Number density evolution for blue galaxies is positive in the redder bands, while red galaxies exhibit negative density evolution.

Change in catalog distribution z example



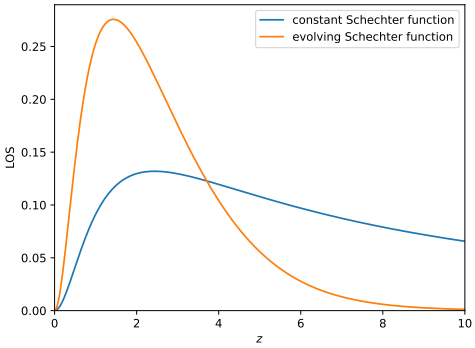
Turski et al. 2023

Change in catalog distribution



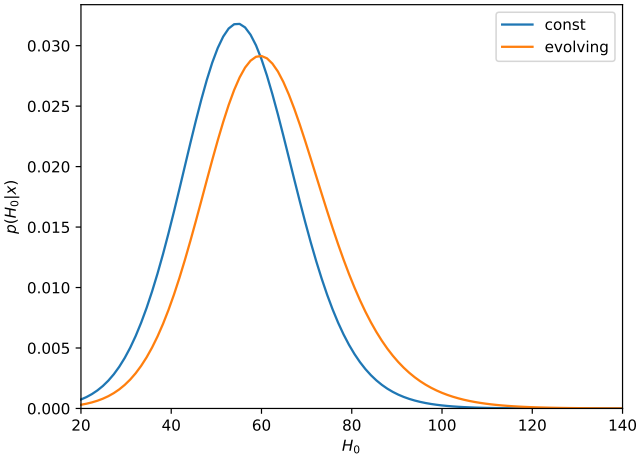
- Change in catalog distribution can influence the H_0 posterior.

Change in redshift prior

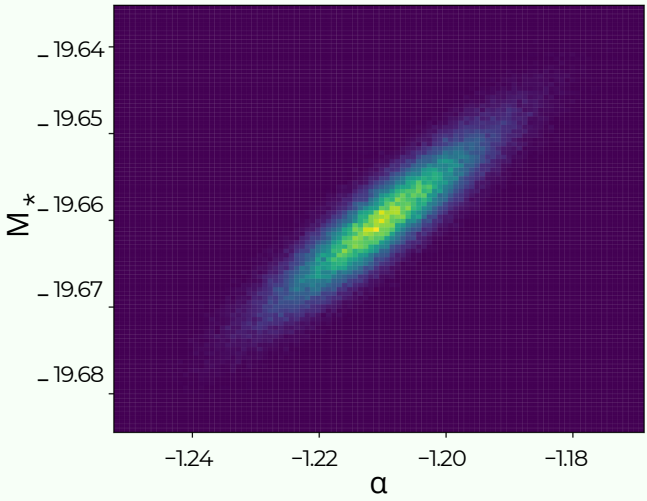


- Both normalized to 1.
- Constant Schechter function predicts galaxies at redshift $z > 10$.
- Evolving Schechter function predicts less galaxies at the earlier Universe.

Hubble constant



Correlation



Correlation

$^{0.1}g$-Band Uncertainty Correlation Matrix

Parameter	σ	δj_M	δQ	δP	$\delta\phi*$	$\delta M*$	$\delta\alpha$
δj_M	0.039	1.000	0.930	−0.885	−0.701	−0.093	0.493
δQ	0.512	0.930	1.000	−0.949	−0.494	0.130	0.584
δP	1.705	−0.885	−0.949	1.000	0.447	−0.144	−0.656
$\delta\phi*$	0.001	−0.701	−0.494	0.447	1.000	0.766	0.219
$\delta M*$	0.018	−0.093	0.130	−0.144	0.766	1.000	0.760
$\delta\alpha$	0.026	0.493	0.584	−0.656	0.219	0.760	1.000

Blanton et al. 2003

What comes next?

- Perform a mock data study (O4 scenario).
- Include Schechter function evolution and uncertainties in *gwcosmo*.
- Include luminosity uncertainties in *gwcosmo*.
- Compare:
  - current Schechter function computation,
  - accounting for uncertainties,
  - adding redshift evolution,
  - different models,
  - luminosity uncertainty analysis.

Conclusion

- Schechter function evolves with redshift.
- Faint end of Schechter function is poorly constrained.
- Different kinds of galaxies evolve differently.
- Schechter function parameters are strongly correlated.
- We are in the process of implementing the above effects into the cosmology inference pipeline *gwcosmo*.