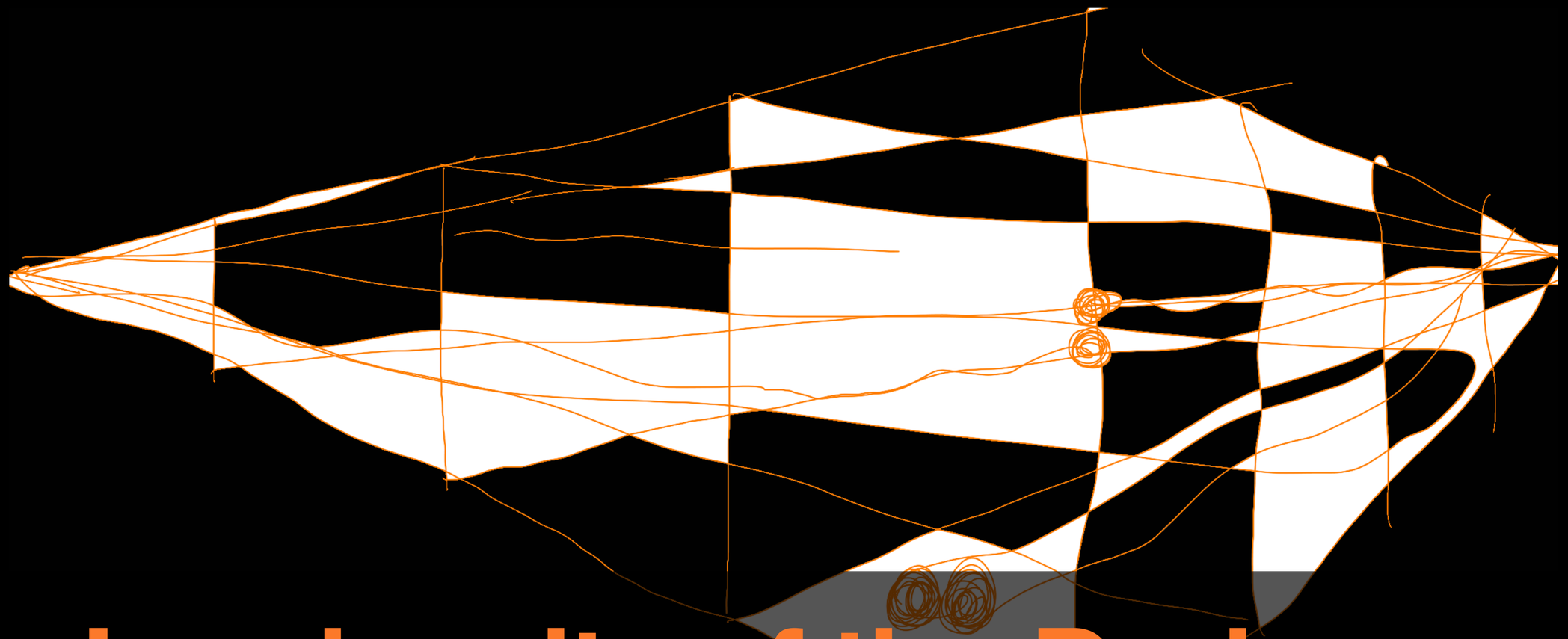


The Luminosity of the Darkness

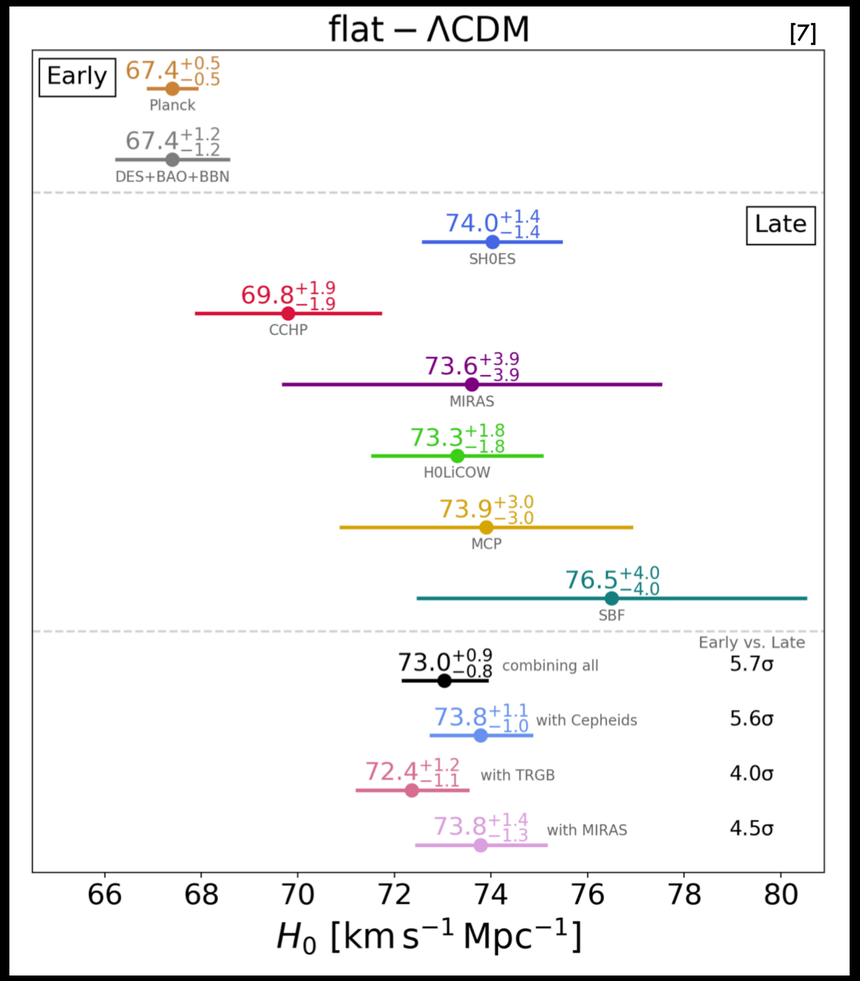
Schechter function in cosmological analyses with dark sirens

Maria Lisa Brozzetti, C. Turski, G. Dálya, A. Ghosh e M. Punturo

Gravi-Gamma-Nu Workshop 2024 — Bari 2024

Cosmology with GW events

A new way to solve the Hubble Tension



Schutz (1986) theorised method that exploits the properties of gravitational waves to be **independent** of the **cosmic distance ladder**:

$$A_{GW}(t) \propto \frac{M_{det}}{d_L}$$

STANDARD SIREN [14]

offering the opportunity to solve the **Hubble tension**, that is a discrepancy of about $\sim 4-5\sigma$ between late and early measurements.

$$d_L(z) \simeq \frac{c}{H_0} z \qquad z \leq 1$$

Cosmology with GW events

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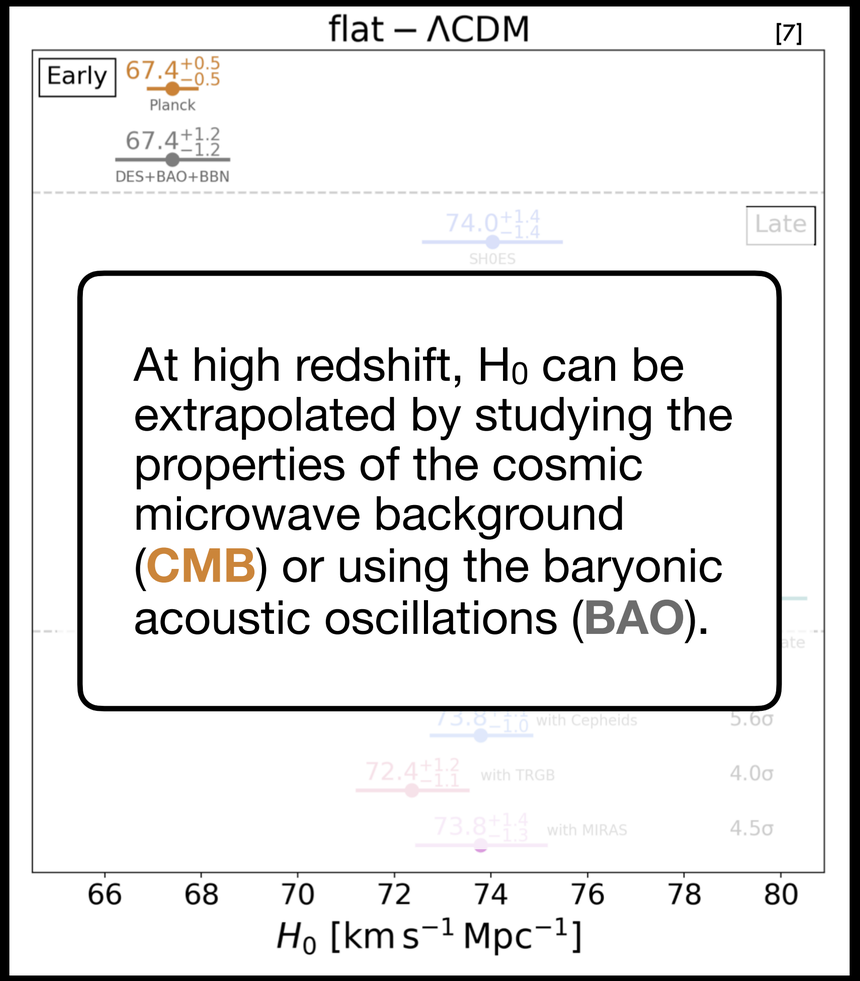

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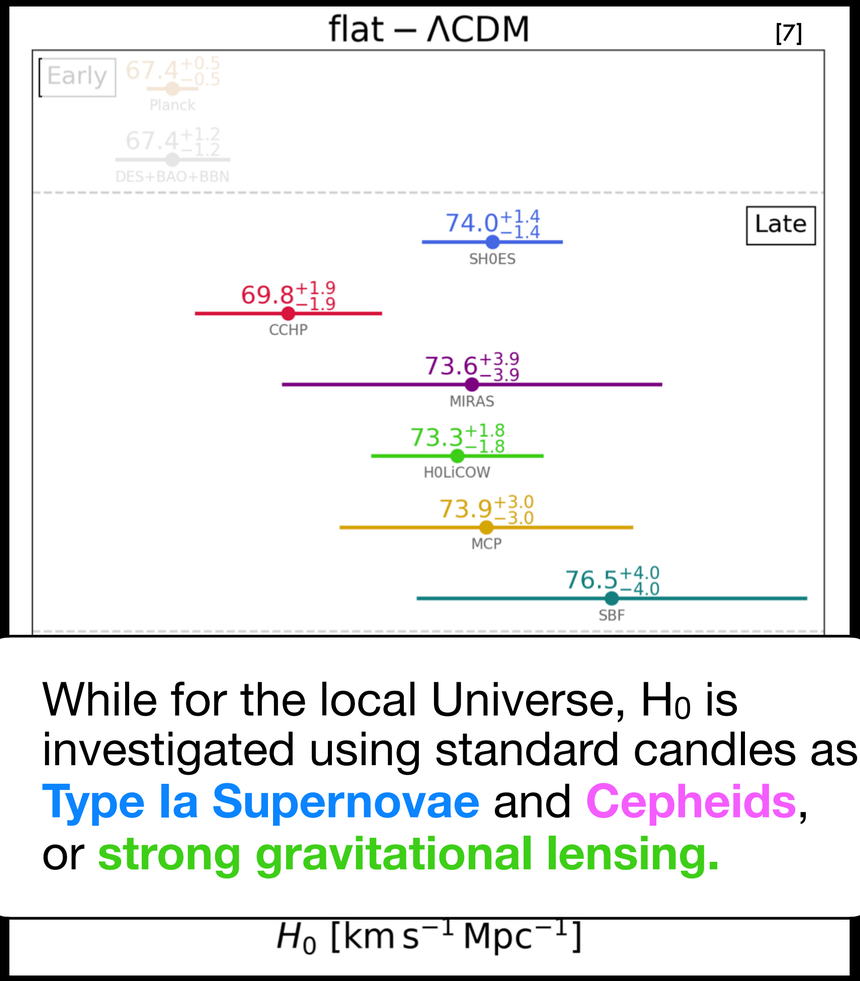

While for the local Universe, H_0 is investigated using standard candles as **Type Ia Supernovae** and **Cepheids**, or **strong gravitational lensing.**

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Cosmology with GW events

How to break the mass-redshift degeneration

$$M_{det} = (1+z)\frac{(m_{1,S}\, m_{2,S})^{3/5}}{(m_{1,S}+m_{2,S})^{1/5}}$$

Mass-Redshift degeneration

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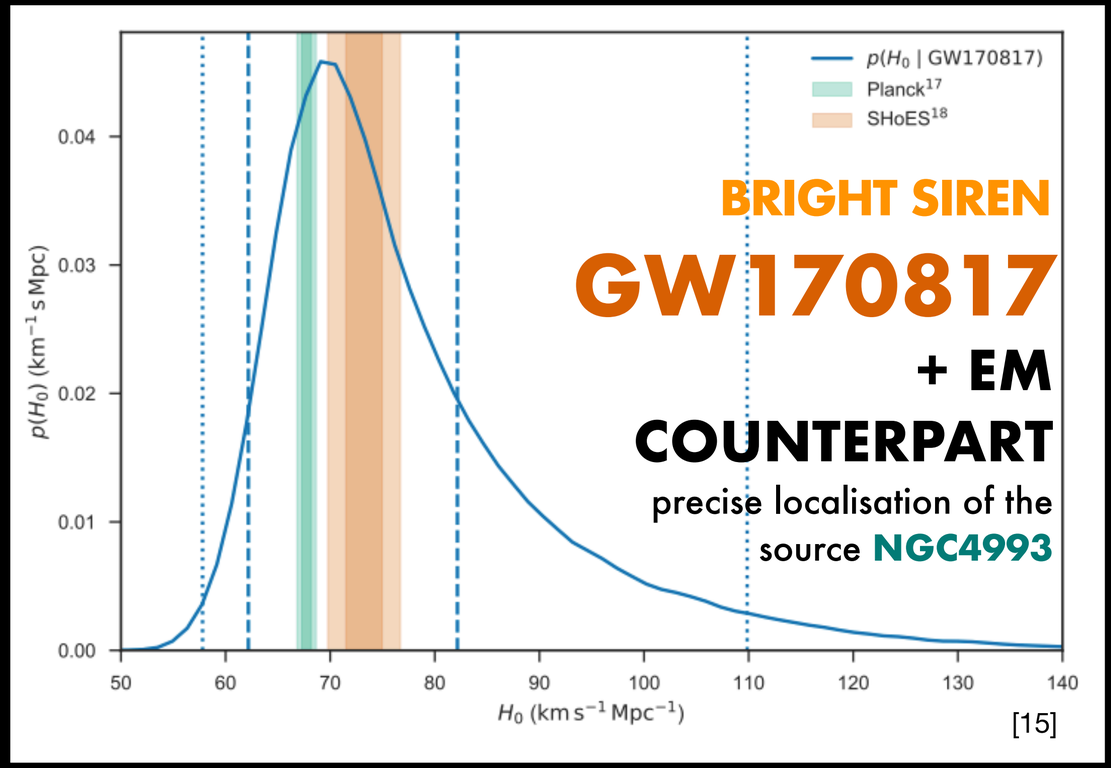

[15]

Cosmology with GW events

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Mass-Redshift degeneration

SPECTRAL SIREN METHOD

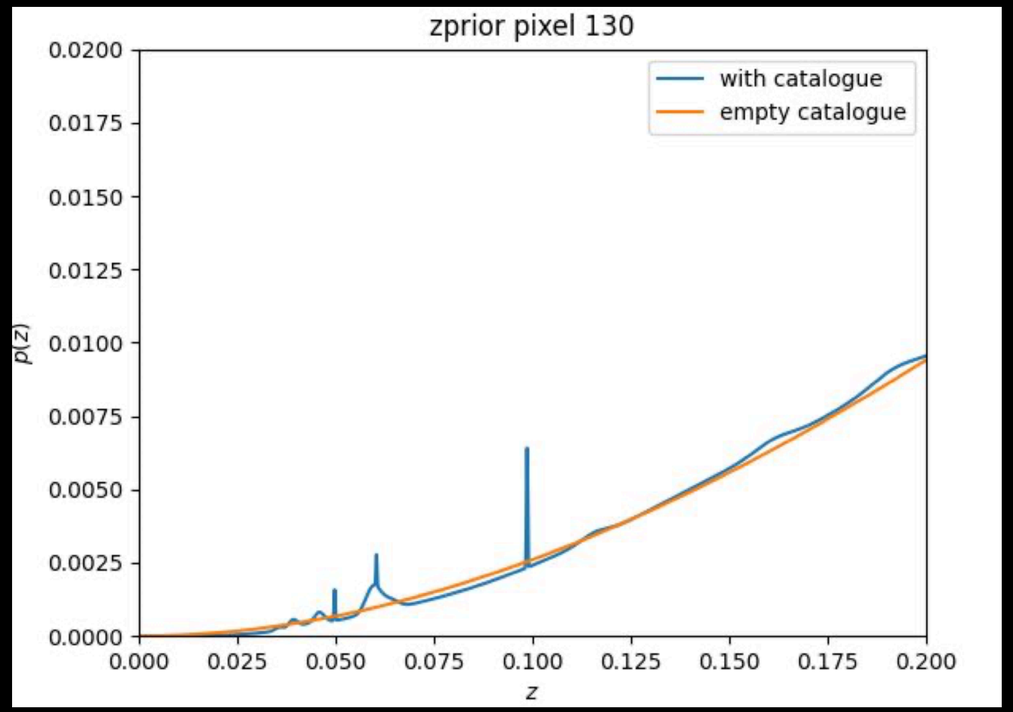
the study of the properties of the mass distribution of GW sources that break the mass-redshift degeneracy

$$\frac{dN_{CBC}}{d\theta d\Omega\, dz\, dt_s} = R_0\, \psi(z;\Lambda)\, p_{pop}(\theta \mid z,\Lambda)\frac{dV_c}{dz d\Omega}$$

[26]

Cosmology with GW events

How to break the mass-redshift degeneration



SPECTRAL SIREN METHOD

GALAXY CATALOG METHOD

The Line Of Sight (LOS) redshift prior, $p(z)$ is built from a galaxy catalog. It's not uniform in co-moving volume, due to the point-like nature of galaxies. [22-24]

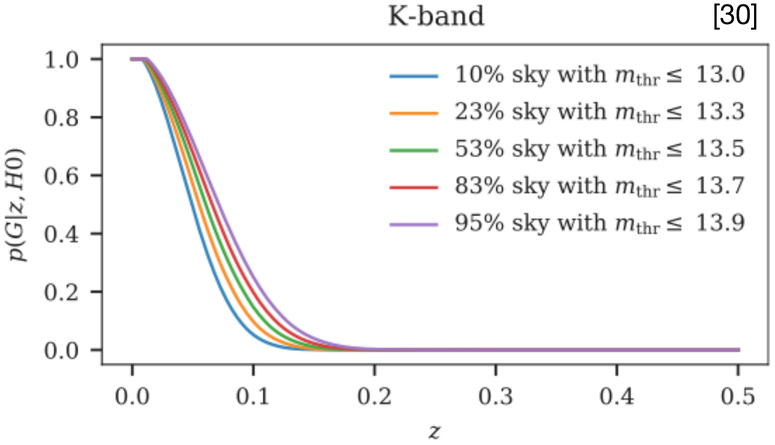
Facing the Incompleteness

$$p(G\,|\,z, H_0, \Lambda) = \frac{\int_{M_{min}(H_0)}^{M_{max}(z_i, m_{th}(\Omega_i), H_0)} \Phi\,(M')dM'}{\int_{M_{min}(H_0)}^{M_{max}(H_0)} \Phi\,(M')dM'}$$

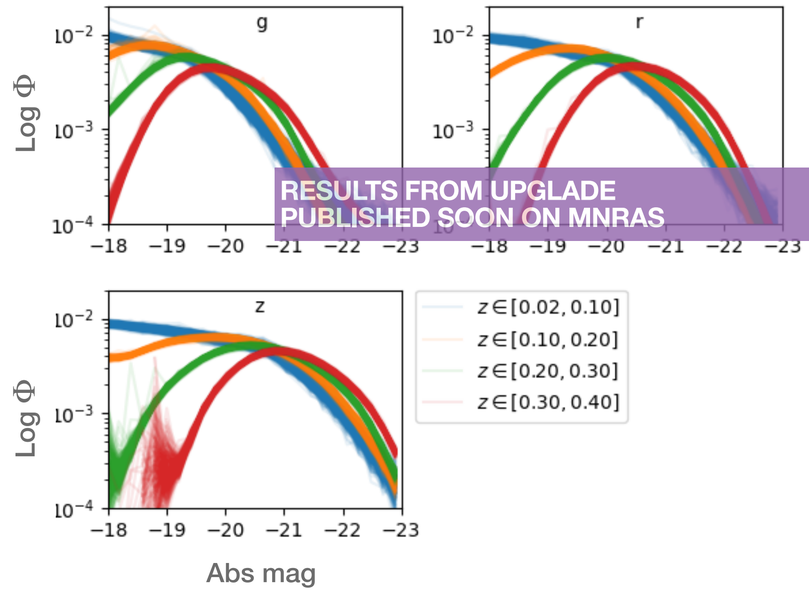
Schechter function is a semi-analytical model describing the basic shape of any luminosity function

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

GLADE+



UpGLADE



RESULTS FROM UPGLADE PUBLISHED SOON ON MNRAS

Facing the Incompleteness

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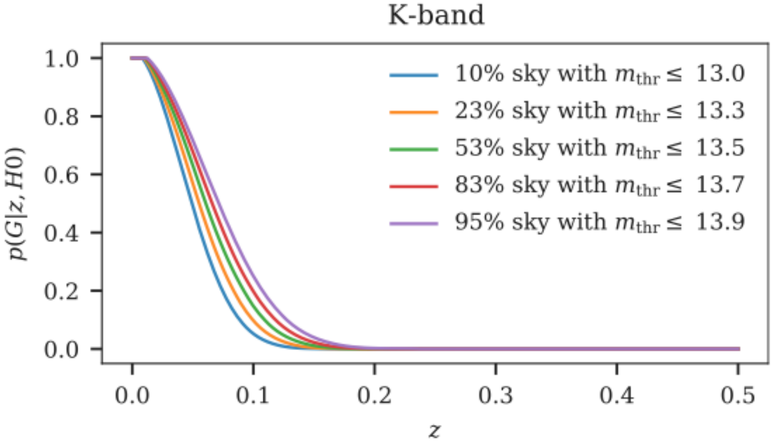
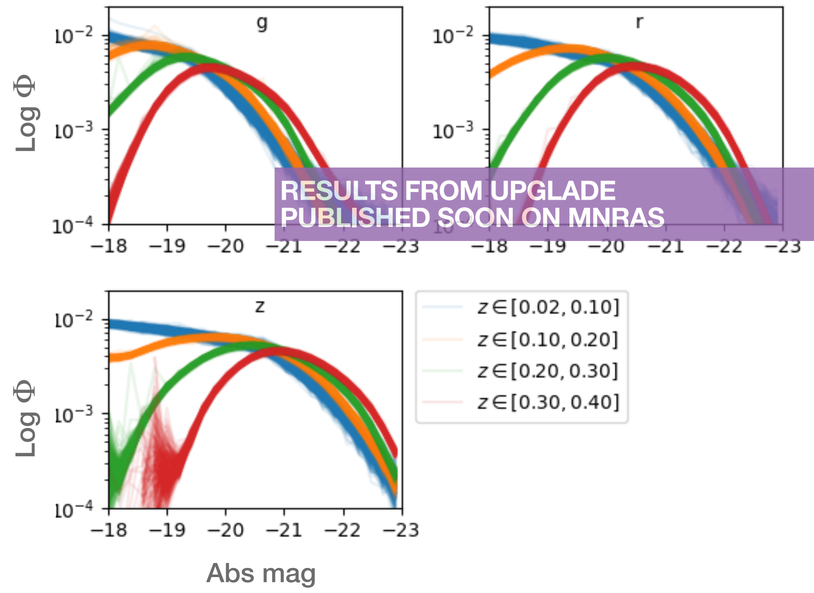
$p(\bar{G}\,|\,z, H_0, \Lambda)$

incompleteness correction: the luminosity of galaxies that are outside of our telescopes' threshold – **the luminosity of darkness**

GLADE+



UpGLADE



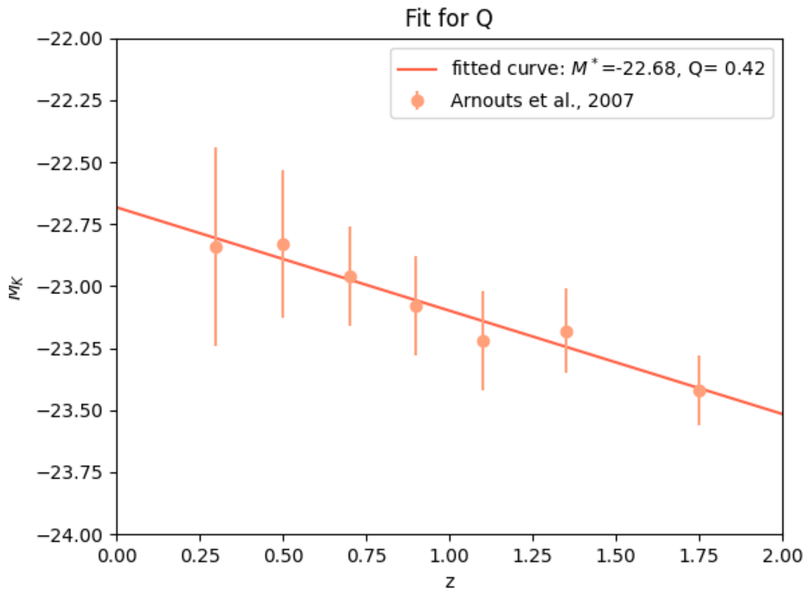
RESULTS FROM UPGLADE PUBLISHED SOON ON MNRAS

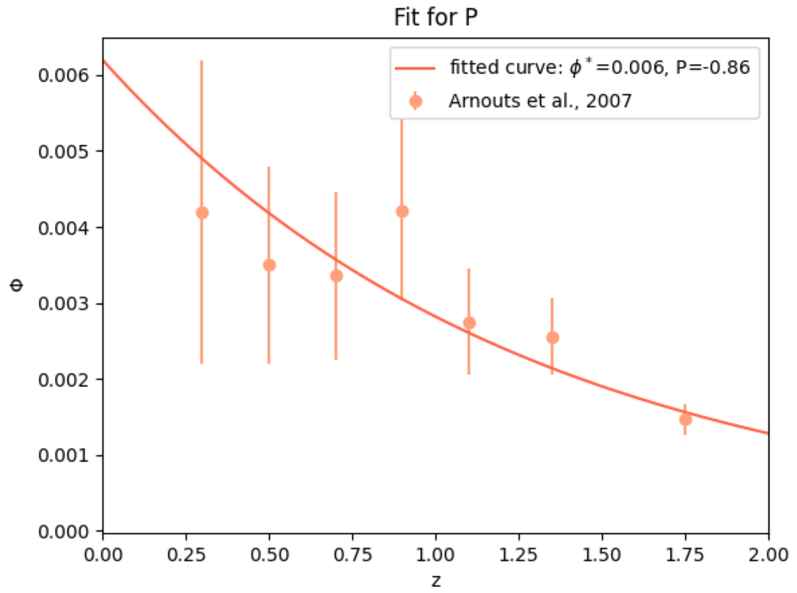
SF evolution with z

Effects on the line-of-sight redshift prior

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

$$M^*(z) = M^*(0) - Qz \qquad \Phi^*(z) = \Phi^*(0) 10^{0.4Pz} \qquad \alpha^*(z) = \alpha^*(0)$$

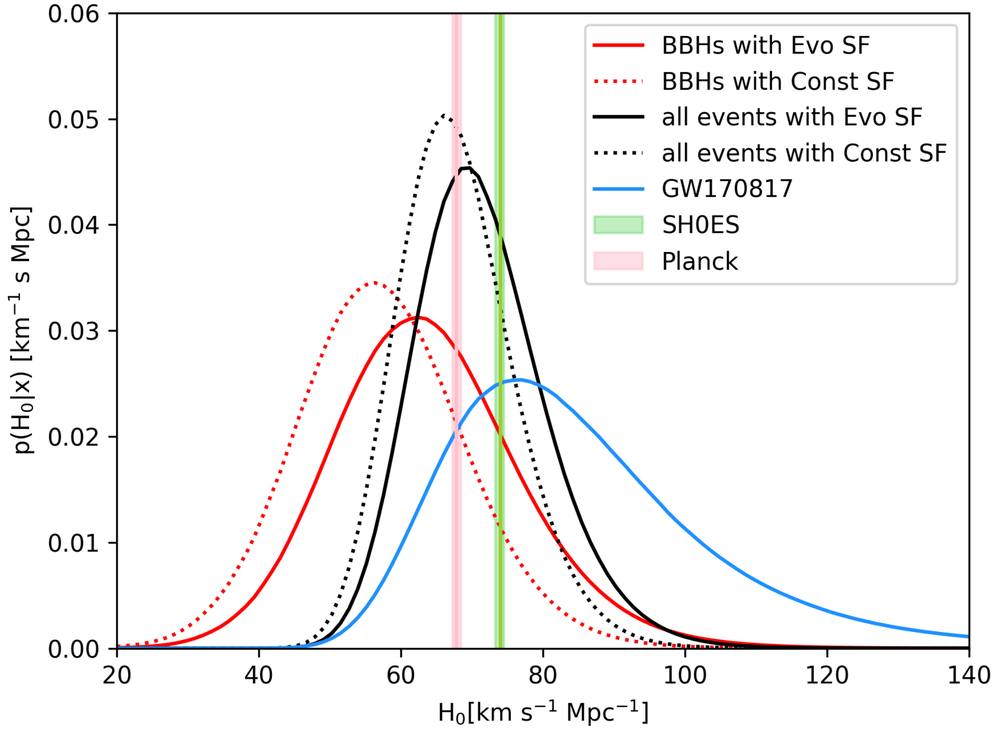


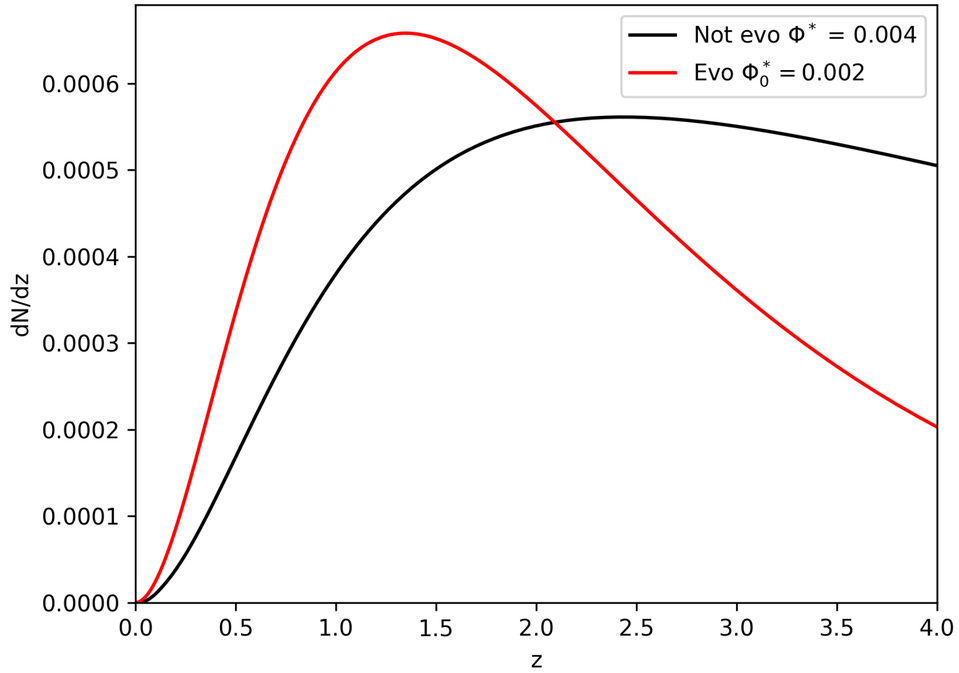


The Luminosity of the Darkness

1. Redshift dependency impacts the LOS prior.

p(H0|xGW) combining the H0 posteriors from 42 BBHs with SNR>11, along with the H0 posterior from GW170817 as bright siren





2. possible biases from systematic effects of the galaxy models

➡ the importance of evaluating the LF z dependency and the catalogue incompleteness at high zs

Thanks for your attention!

State of the Art

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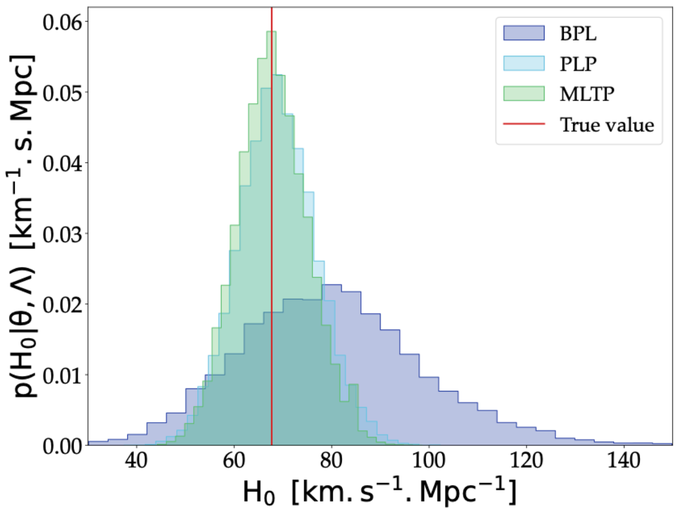
BACKUP SLIDES

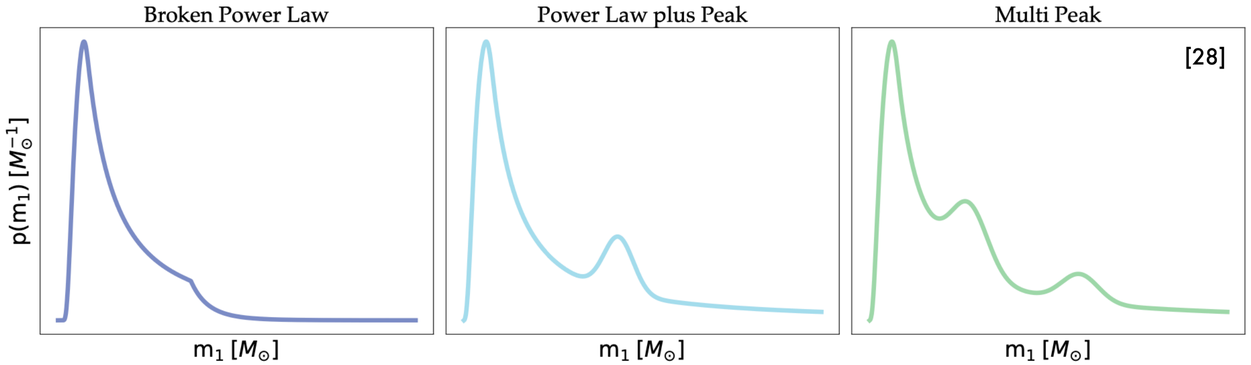
Metodi d'inferenza cosmologica

Spectral sirens

Basato sullo studio delle proprietà della distribuzione delle masse di sorgenti di GW che rompono la degenerazione massa-redshift.



Distribuzione a posterior di H0 marginalizzando su diversi modelli di massa : broken power law (BPL), power law + peak (PLP), e multi peak (MP). In rosso il valore iniettato pari al valore di Planck15 H0= 67.7km s-1 Mpc -1 [28]



L'INFORMAZIONE DEL REDSHIFT DERIVA DAL TASSO DI COALESCENZE FATTORIZZATO NEL VOLUME COMMOVENTE

$$\frac{dN_{CBC}}{d\vec{m}_s d\theta d\Omega dz dt_s} = R_0\,\psi(z;\Lambda)\,p_{pop}(\vec{m}_s\theta\,|\,z,\Lambda)\frac{dV_c}{dz d\Omega}$$

$$p(H_0 \,|\, \{x_{GW}\}, \{D_{GW}\}, I) \propto p(H_0 \,|\, I)\, p(N_{det} \,|\, H_0, I) \prod_i^{N_{det}} p(x_{GW_i} \,|\, D_{GW_i}, H_0, I)$$

1. sky position dependency is not negligible $= \int p(x_{GW}, \Omega \,|\, D_{GW}, H_0, I)\, d\Omega$
2. assuming uniform detection probability and
3. an isotropic Universe

...the likelihood has been pixelated

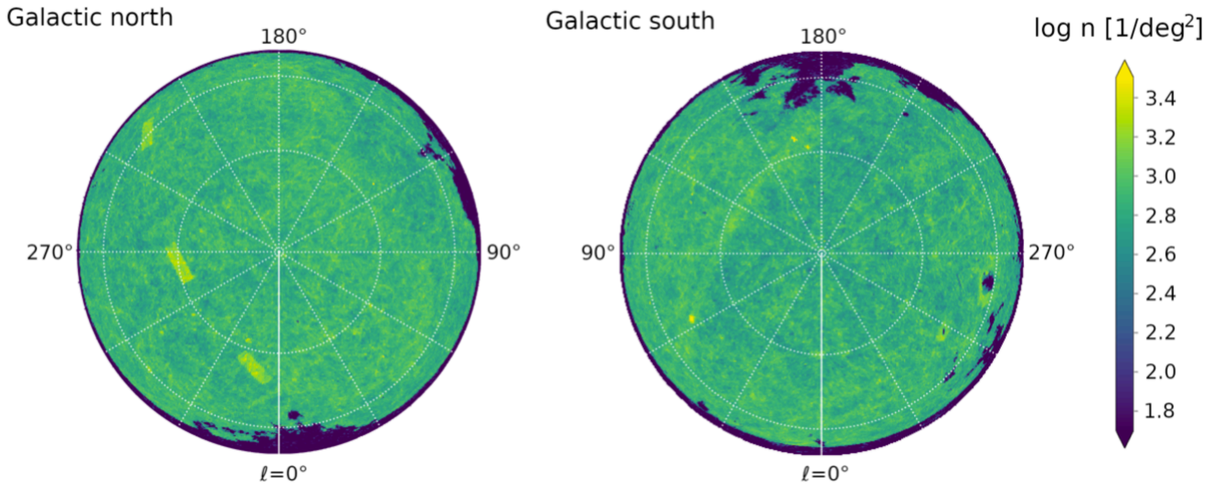
4. the LOS redshift prior, $p(z \,|\, \Omega_j, H_0, I)$, can be marginalised over the possibility of the host being **inside** (G) or **outside** ($\bar{G}$) the galaxy catalog

$$p(x_{GW} \,|\, \Omega_i, D_{GW}, H_0, I) = p(x_{GW} \,|\, \Omega_i, G, D_{GW}, H_0, I) p(G \,|\, \Omega_i, D_{GW}, H_0) + p(x_{GW} \,|\, \Omega_i, \bar{G}, D_{GW}, H_0, I) p(\bar{G} \,|\, \Omega_i, D_{GW}, H_0, I)$$

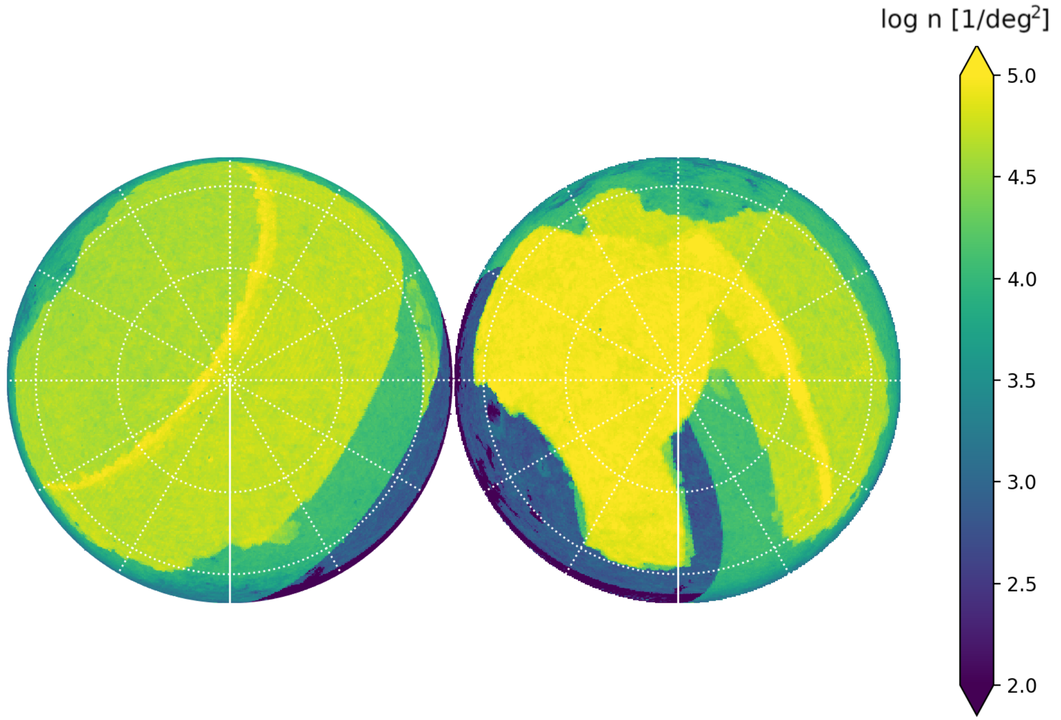
depends on the galaxy ***luminosity function*** in comoving volume

GLADE+ Galaxy List for the Advanced Detector Era

- 22,5 million galaxies up to ~ 90 Mpc in the B-band;
- 6 catalogues crossmatched together : GWGC , 2MASS XSC, 2MPZ, HyperLEDA, SDSS-DR12Q WISExSCOSPZ, SDSS-DR16Q



Number density (n) of objects in GLADE+.



UpGLADE is coming!

- 1,2 billion galaxies
- z_{photo} & z_{spec}

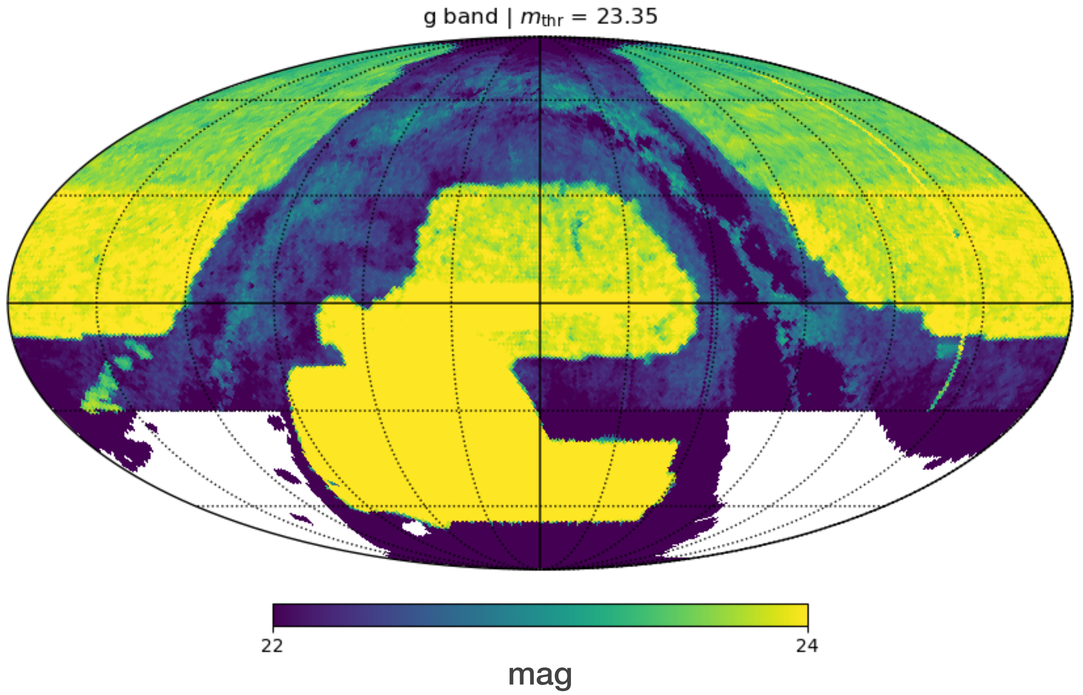
UpGLADE

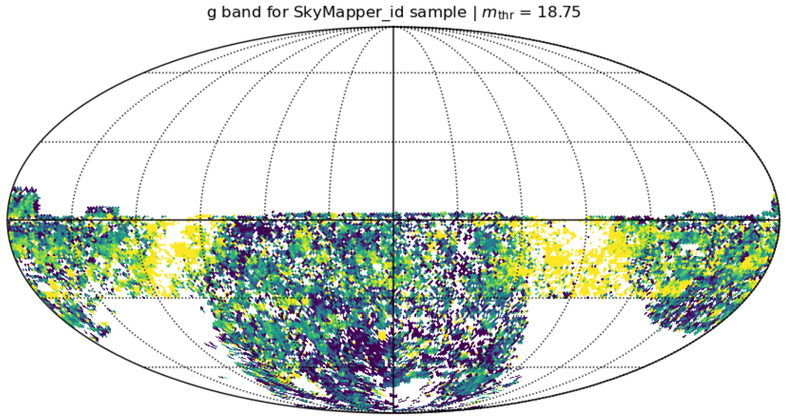
g, r, i, z ,y - W1, W2, W3 and W4.

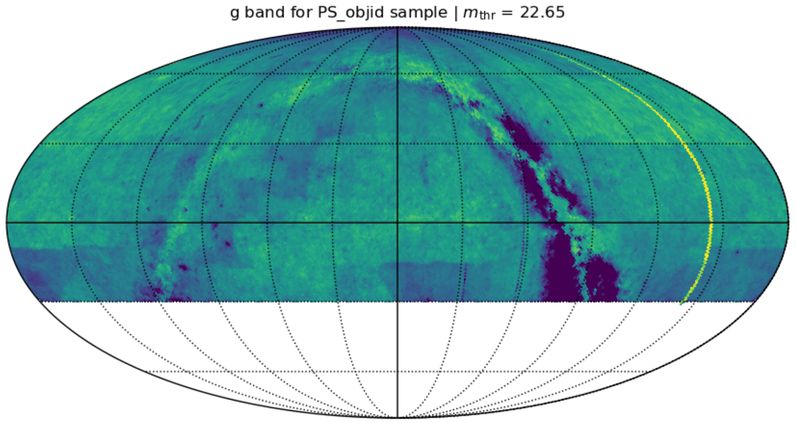
Adding…

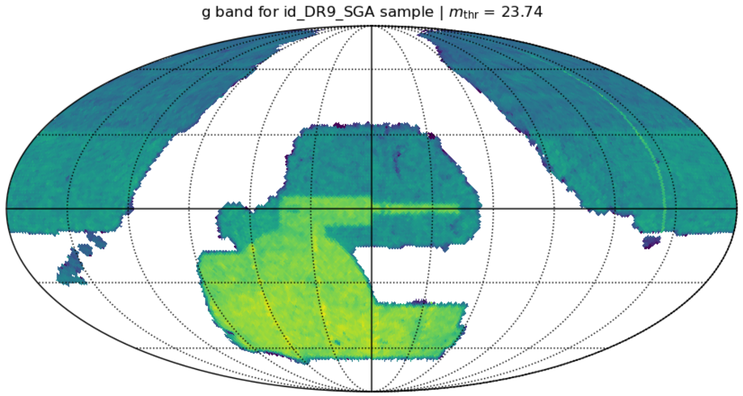
1. Pan-STARRS
2. DESI Legacy Survey
3. CatWISE
4. Siena Galaxy Atlas
5. SkyMapper
6. SDSS

…to GLADE+









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