Advancements in the Hubble Constant Estimation via Gamma-Ray Attenuation

Alberto Domínguez

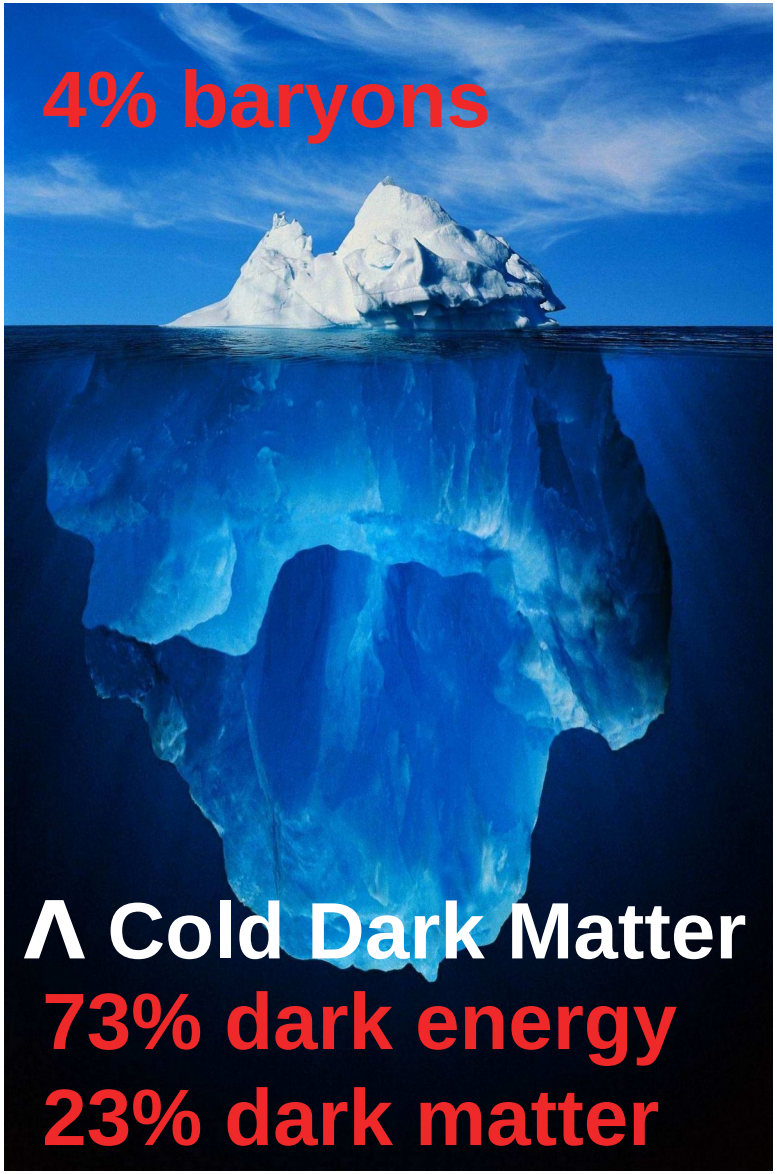
IPARCOS / Universidad Complutense de Madrid

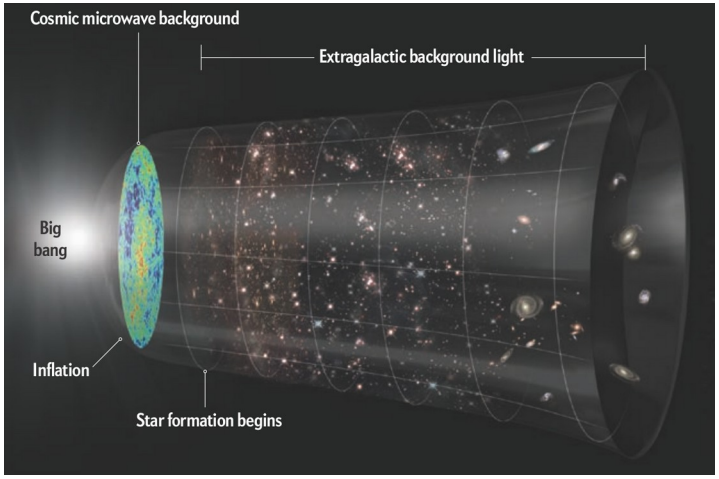
See “Why is the sky dark at night? The 200-year history of a question that transformed our understanding of the Universe”, The Conversation, June 2023

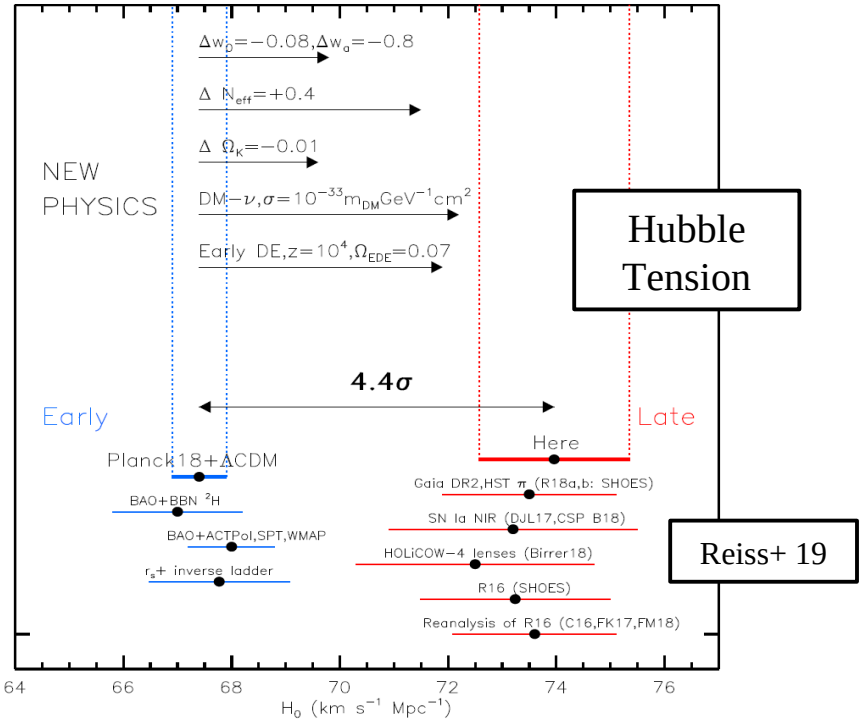
11th International Fermi Symposium

University of Maryland, September 2024

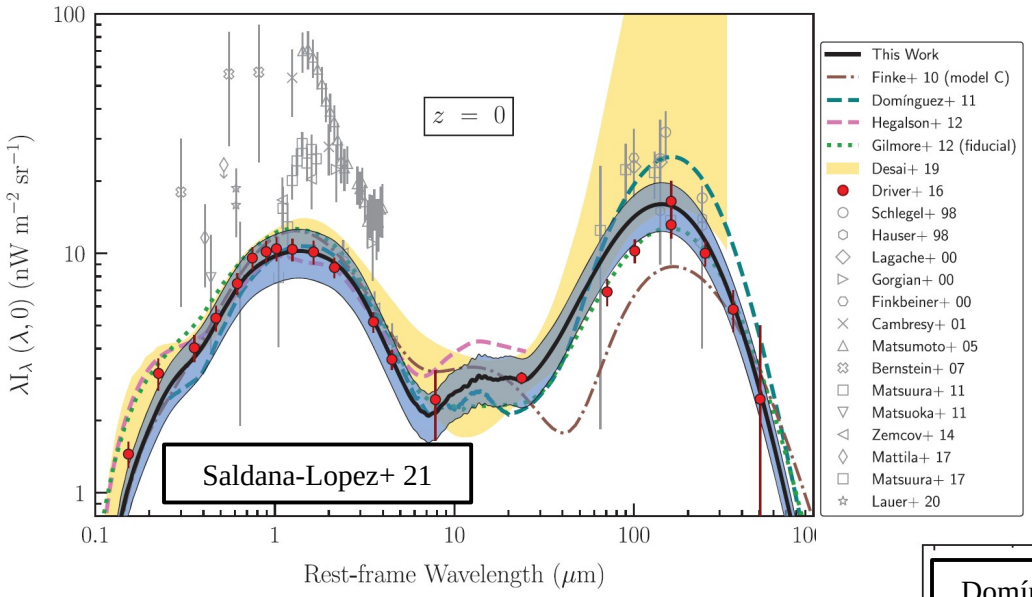
Galaxy Evolution and Cosmology





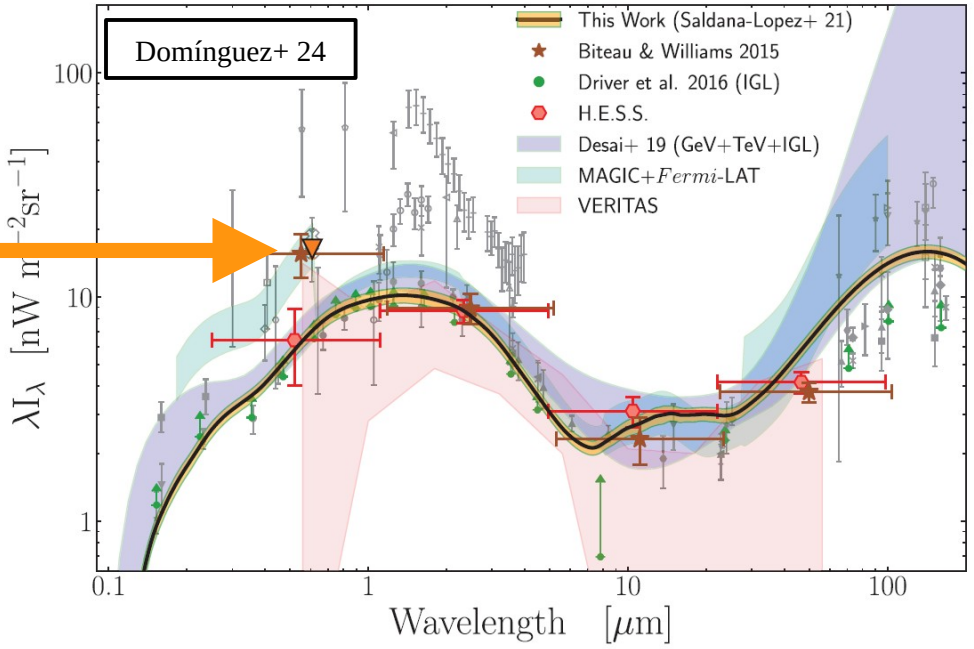


Extragalactic Background Light (Local)

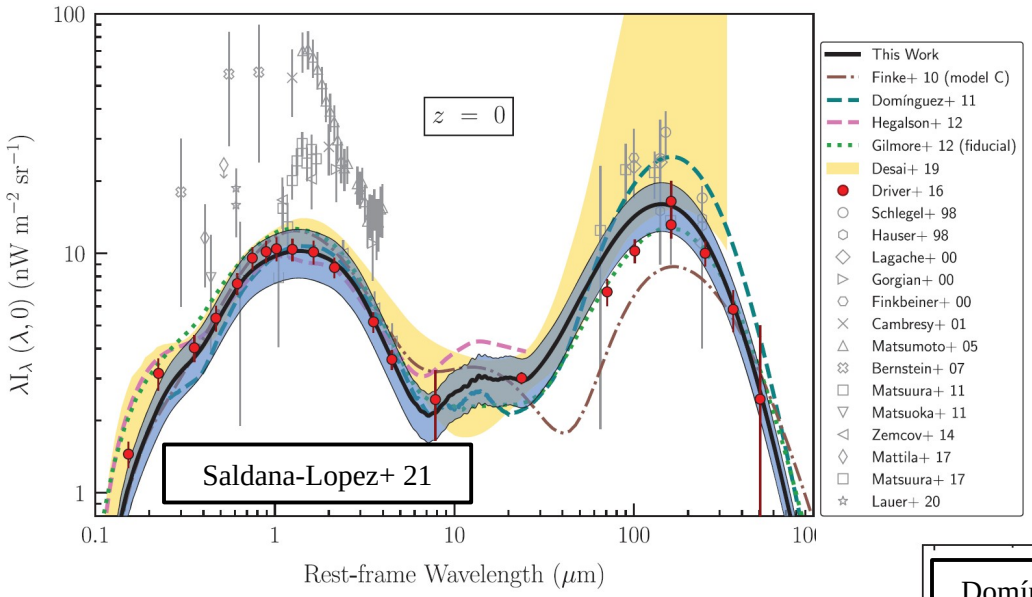


Galaxy counts, EBL models, and gamma-ray attenuation data agree but direct detection tends to be at larger intensities,
zodiacal light contamination?

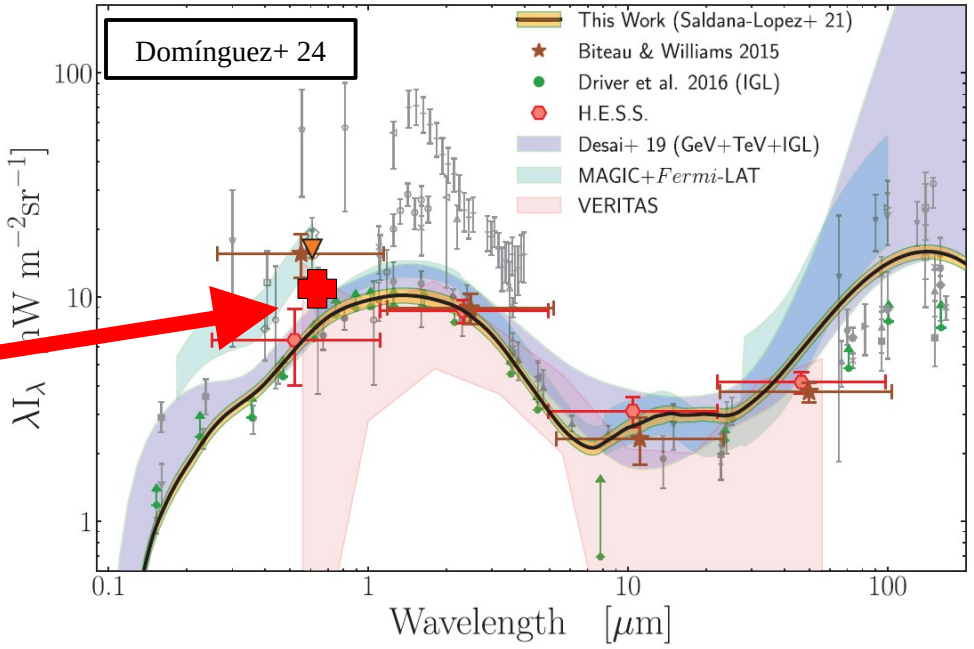
Lauer+ 22 from New Horizons



Extragalactic Background Light (Local)

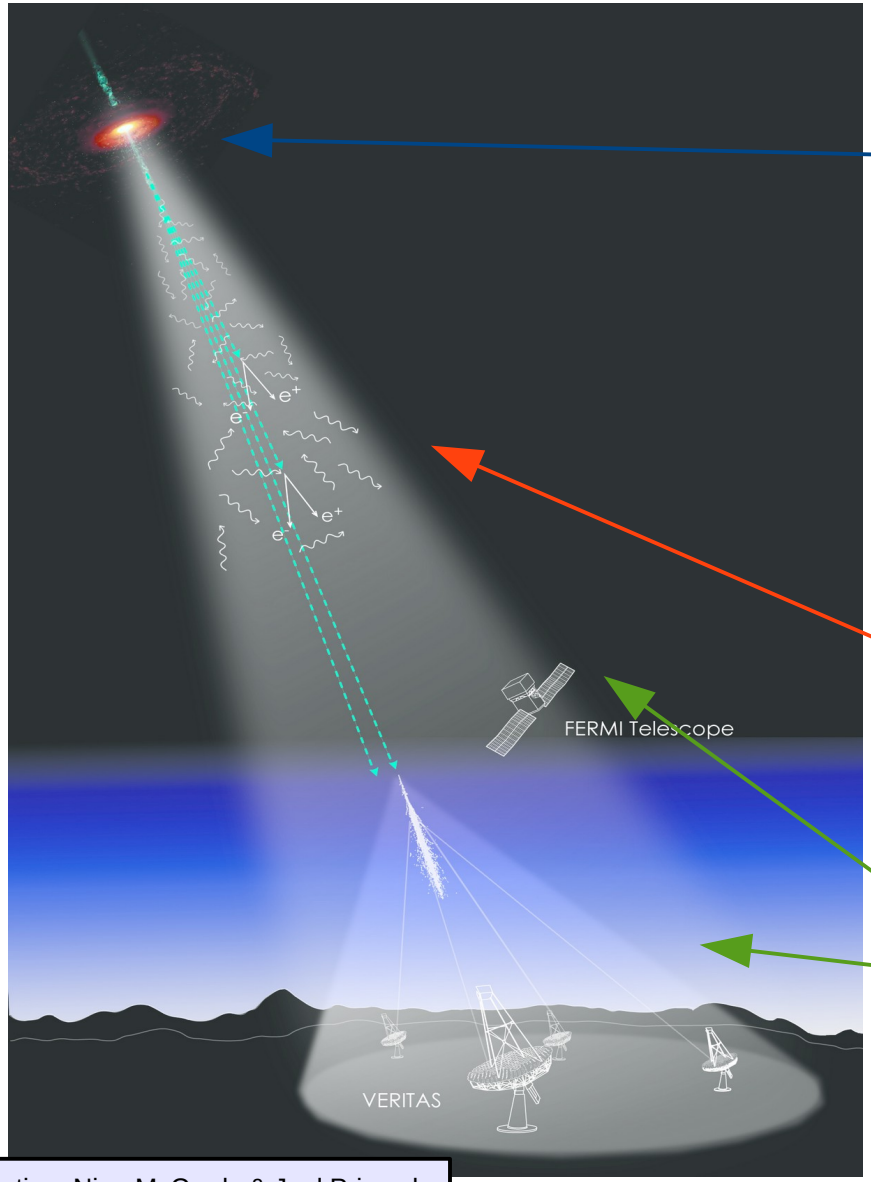


Postman+ 24 from New Horizons



Galaxy counts, EBL models, gamma-ray attenuation data, and now direct detection, all converge!

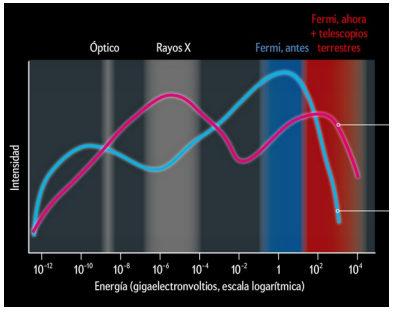
EBL Measurements: Gamma-ray Attenuation



Ilustration: Nina McCurdy & Joel Primack

Extragalactic source:
e.g. Blazar

Blazars: AGNs emitting at all wavelength with energetic jets pointing towards us.



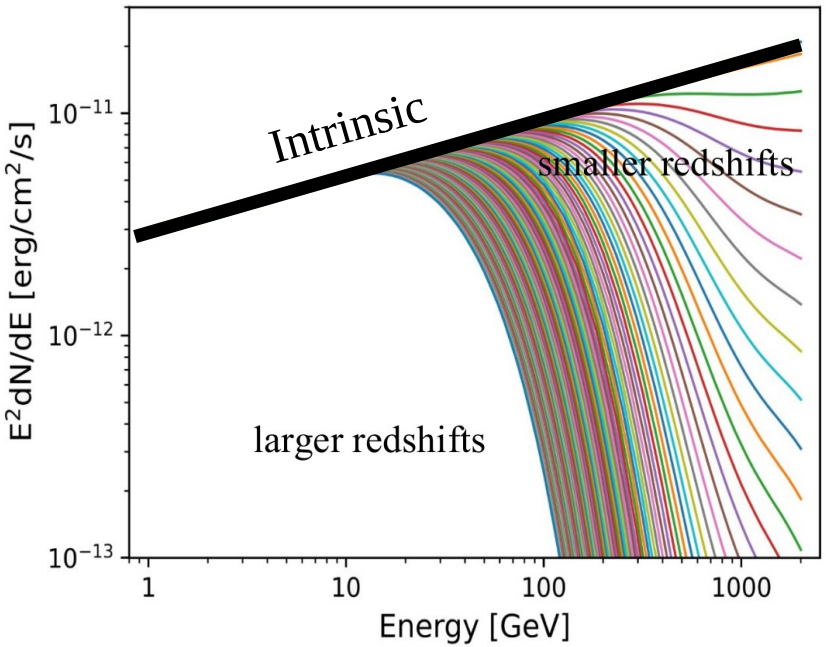
Pair-production interaction

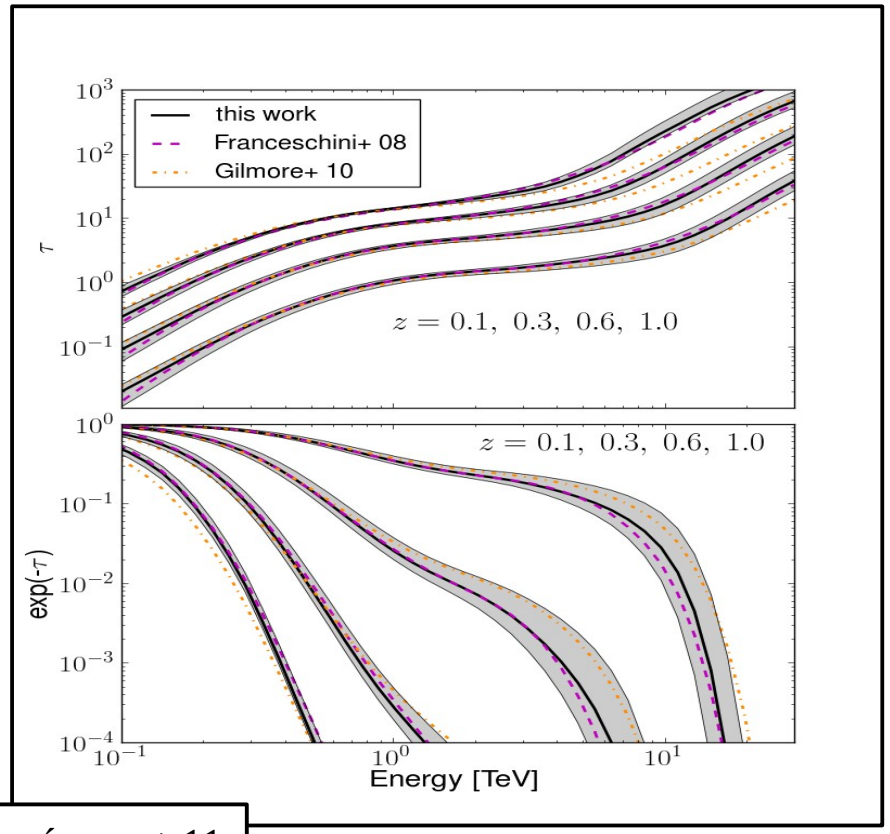
Reverse of most known electron-positron annhilation process

Telescopes: Fermi-LAT and Imaging Atmospheric Cherenkov Telescopes (IACTs)

EBL Measurements: Gamma-ray Attenuation

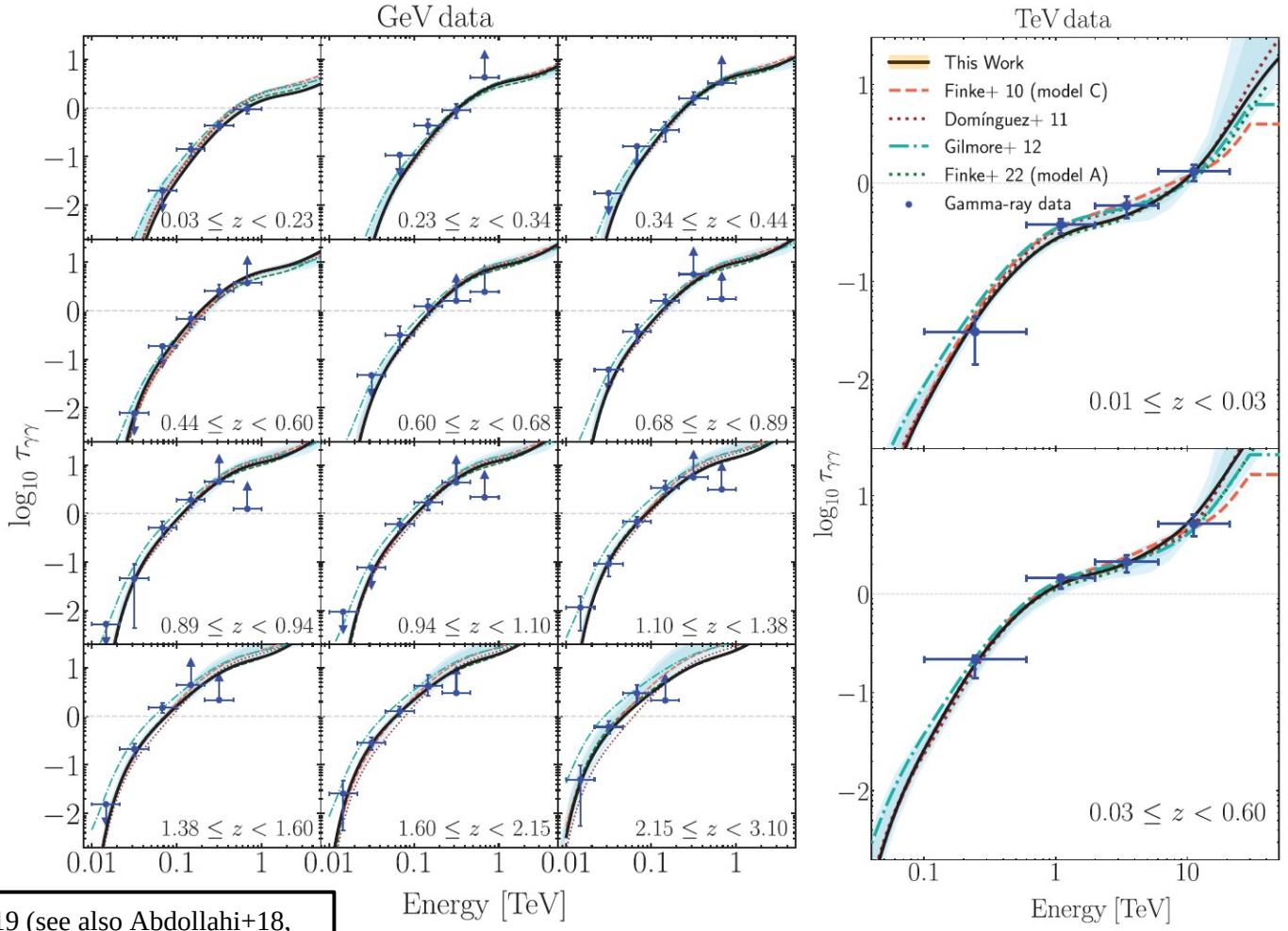
$$\left.\frac{dN}{dE}\right|_{obs} = \left.\frac{dN}{dE}\right|_{int} \exp\left[-\tau(E,z)\right]$$





Domínguez+ 11

EBL Measurements: Gamma-ray Attenuation



Desai+ 19 (see also Abdollahi+18, Domínguez+ 24)

Optical Depths from Fermi-LAT and IACTs

Optical Depths

$$\tau_{\gamma\gamma}(E_\gamma, z_s) = c \int_0^{z_s} \left|\frac{dt}{dz}\right| dz \int_{-1}^{1} (1-\mu)\frac{d\mu}{2} \int_{2m_e^2c^4/\epsilon_\gamma(1-\mu)}^{\infty} \sigma(\epsilon_{\rm EBL}, \epsilon_\gamma, \mu) n_{\rm EBL}(\epsilon, z) d\epsilon_{\rm EBL}$$

distance

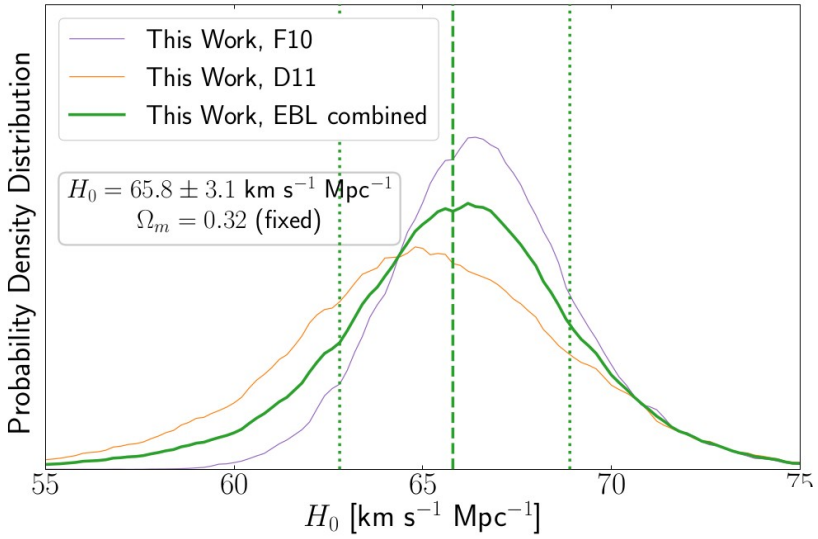
cross section

EBL photon density evolution

The cosmology dependence is on the distance and EBL photon density evolution factors

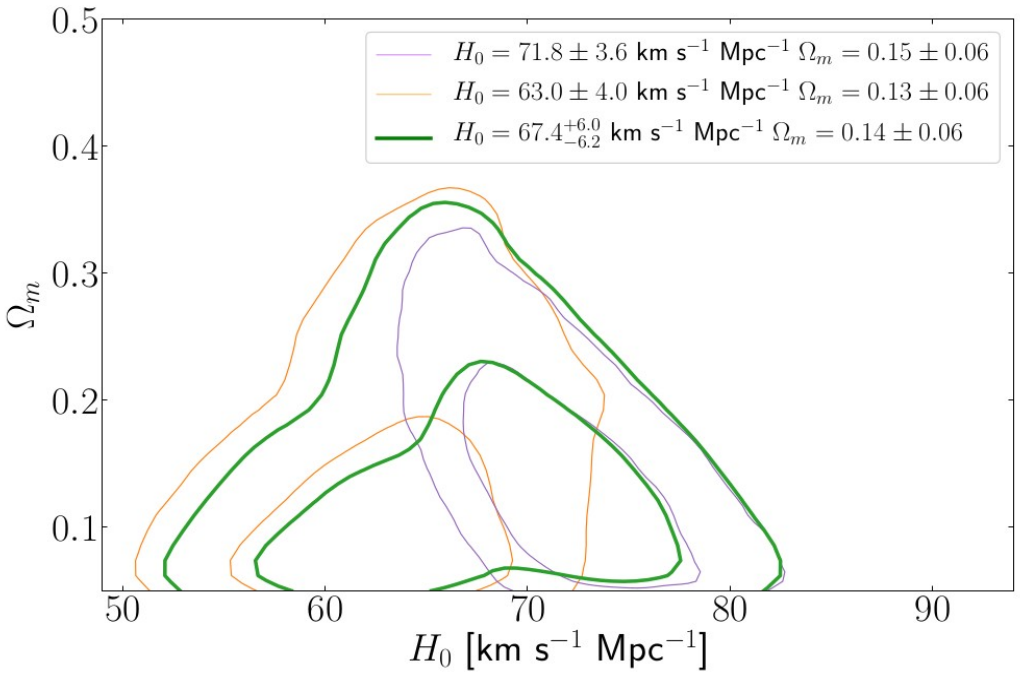
See Domínguez & Prada 13, Biteau & Williams 15

Previous Results: Domínguez+ 19



H0 derivation
fixing Om

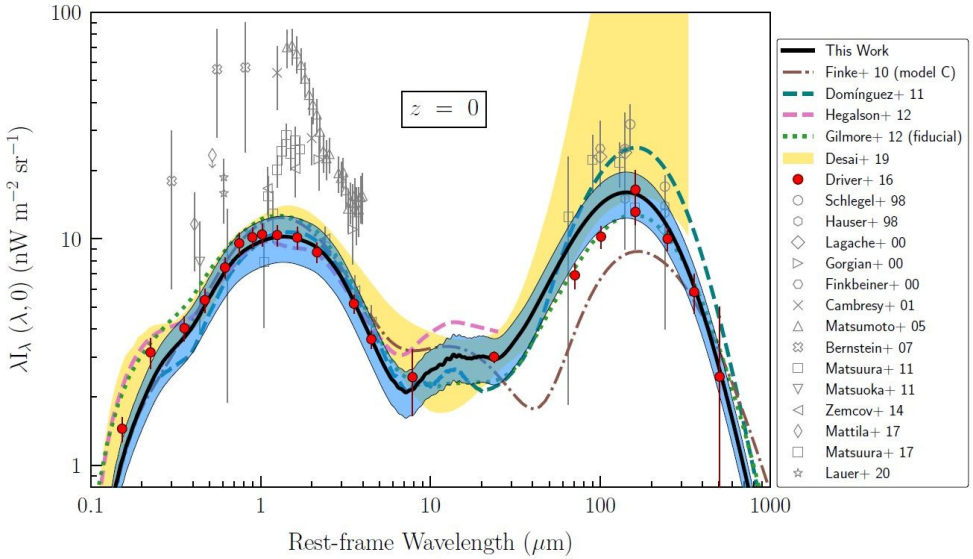
H0 & Om free

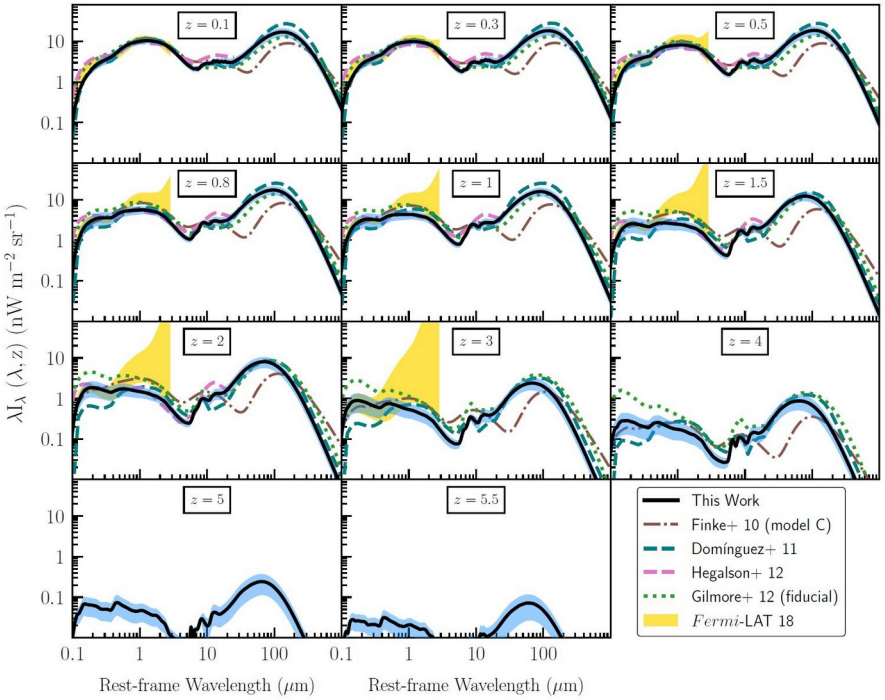


EBL Model Saldana-Lopez+ 21

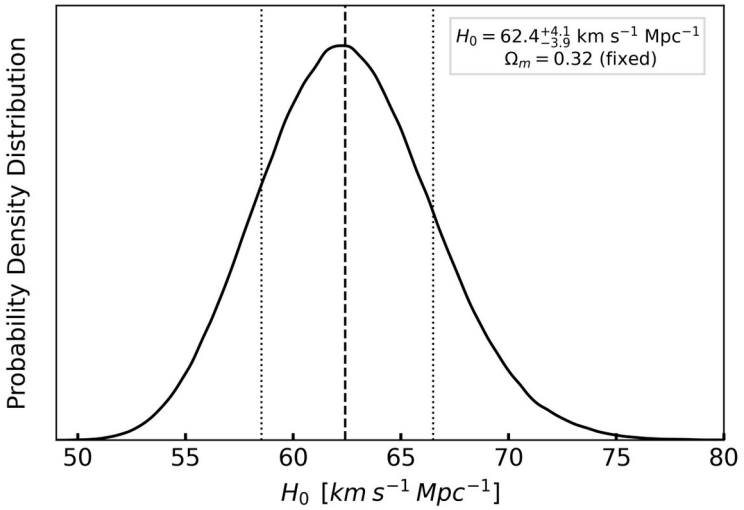
- 150,000 galaxies
- 0 < z < 6
- 5 CANDELS fields, reducing cosmic variance

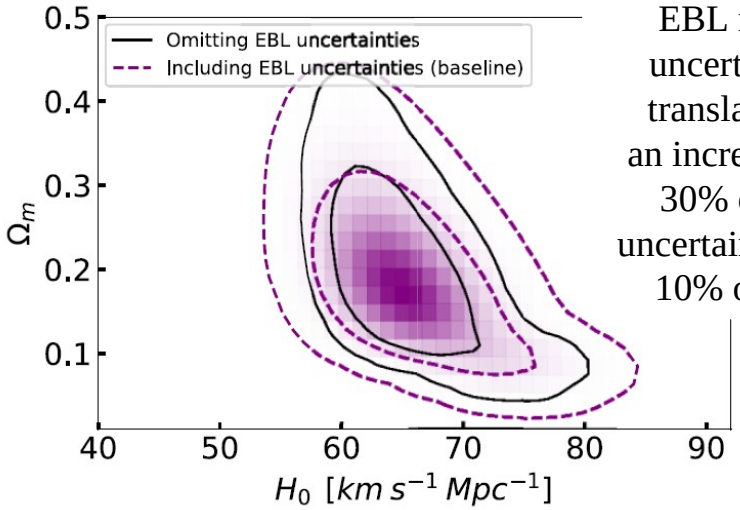
Herschel observations (not necessarily detection) for all galaxies in the far-IR





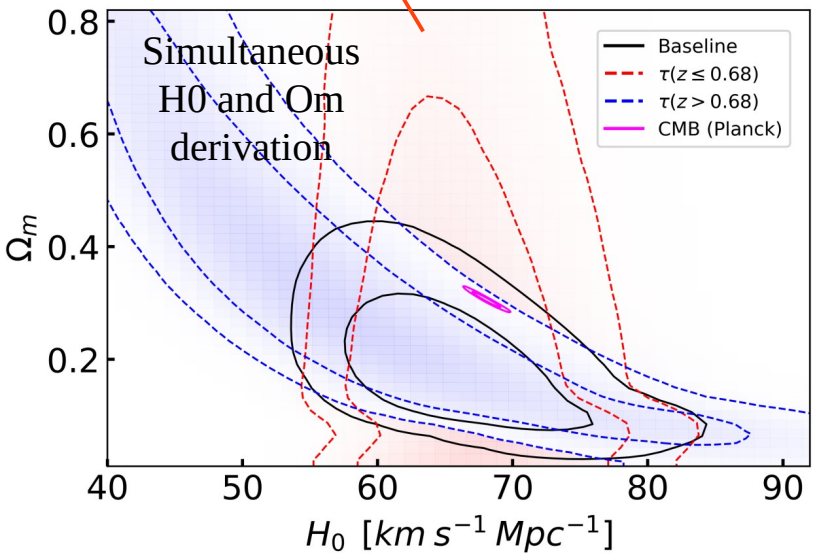
Latest Results: Domínguez+ 24



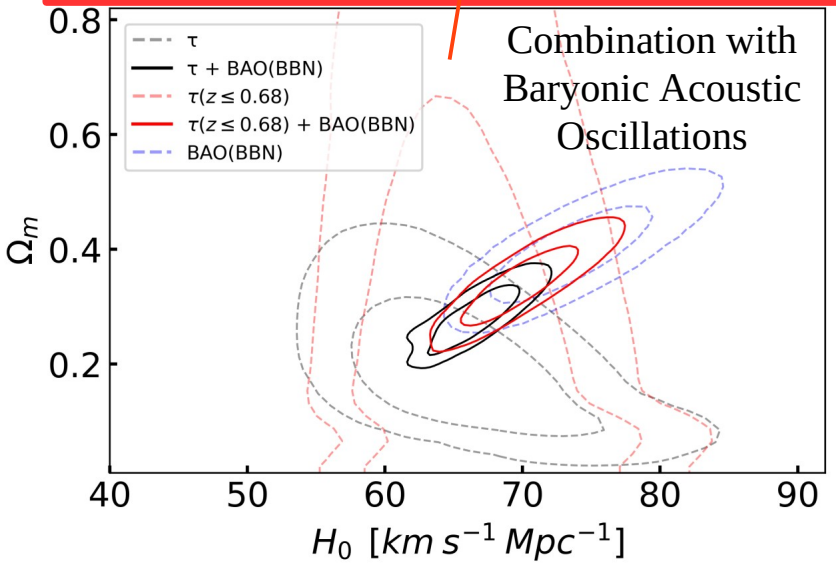


EBL model uncertainties translate into an increment of 30% on H0 uncertainties and 10% on Om

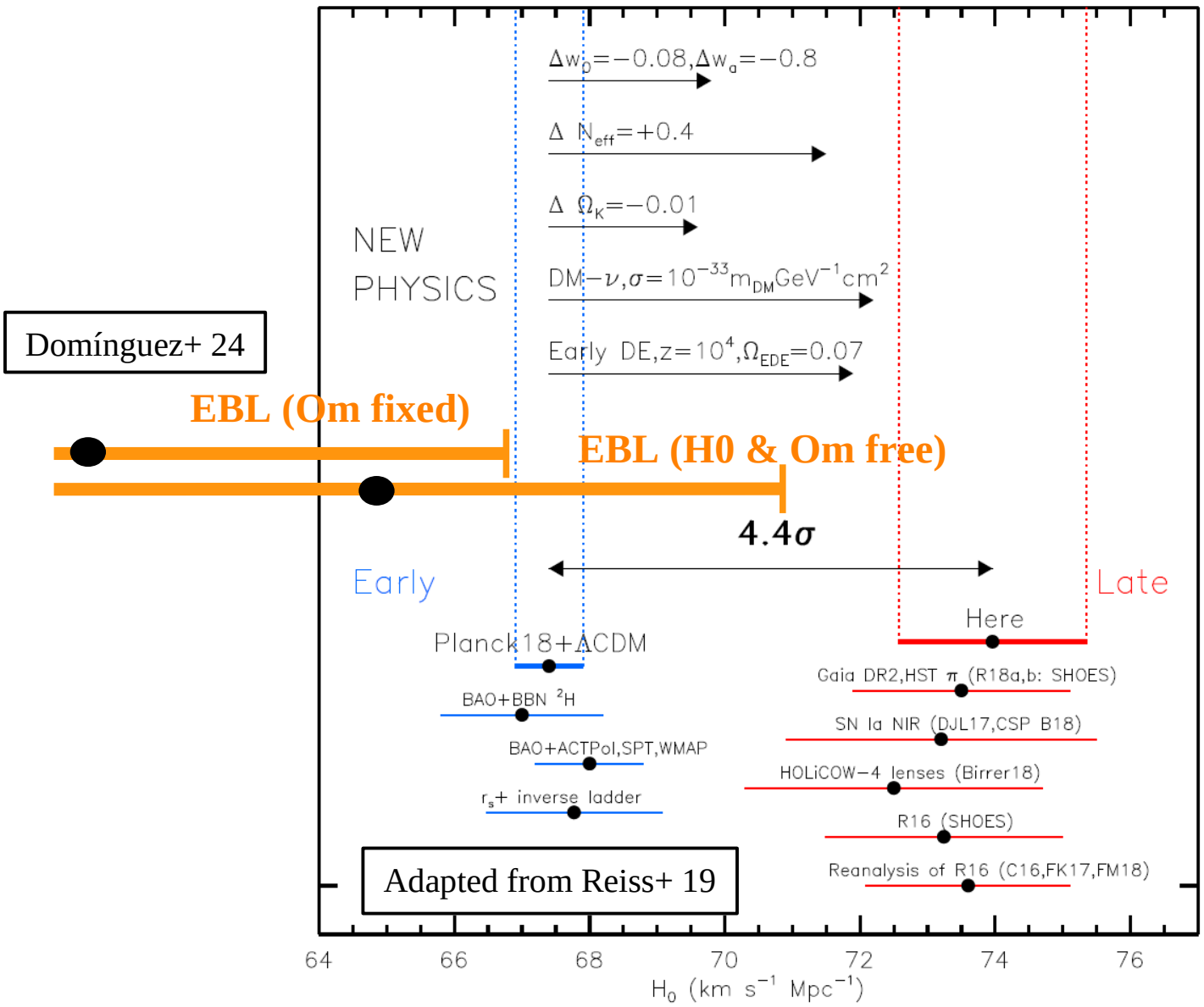
H_0(km s^{-1} Mpc^{-1})	Ω_m
$65.1^{+6.0}_{-4.9}$	0.19 ± 0.08 or (< 0.35 (95 %))



H_0(km s^{-1} Mpc^{-1})	Ω_m
$66.5^{+2.2}_{-2.1}$	0.28 ± 0.04



Comparison on H_0 Measurements



Take Home Messages

1) After decades of research, different methodologies such us galaxy counts, EBL models, gamma-ray attenuation data and direct detection techniques are finally converging, at least in the optical, in the estimate of how much light there is in the Universe.

2) H0 from gamma-ray attenuation seems to be aligned (although still at low significance) with the methodologies that results in lower values, aka cosmological methodologies.

3) Really compelling synergies between high-energy astrophysics and traditional astronomy.

Backup

Cosmology Dependence on the Optical Depth