Advancements in the Hubble Constant Estimation via Gamma-Ray Attenuation

Alberto Domínguez

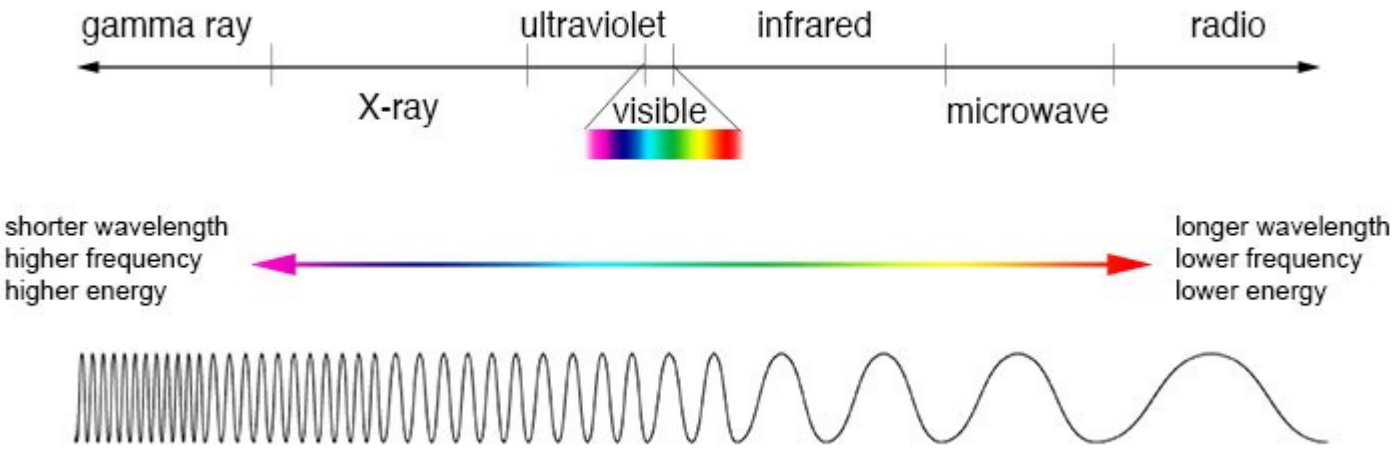
IPARCOS / Universidad Complutense de Madrid

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

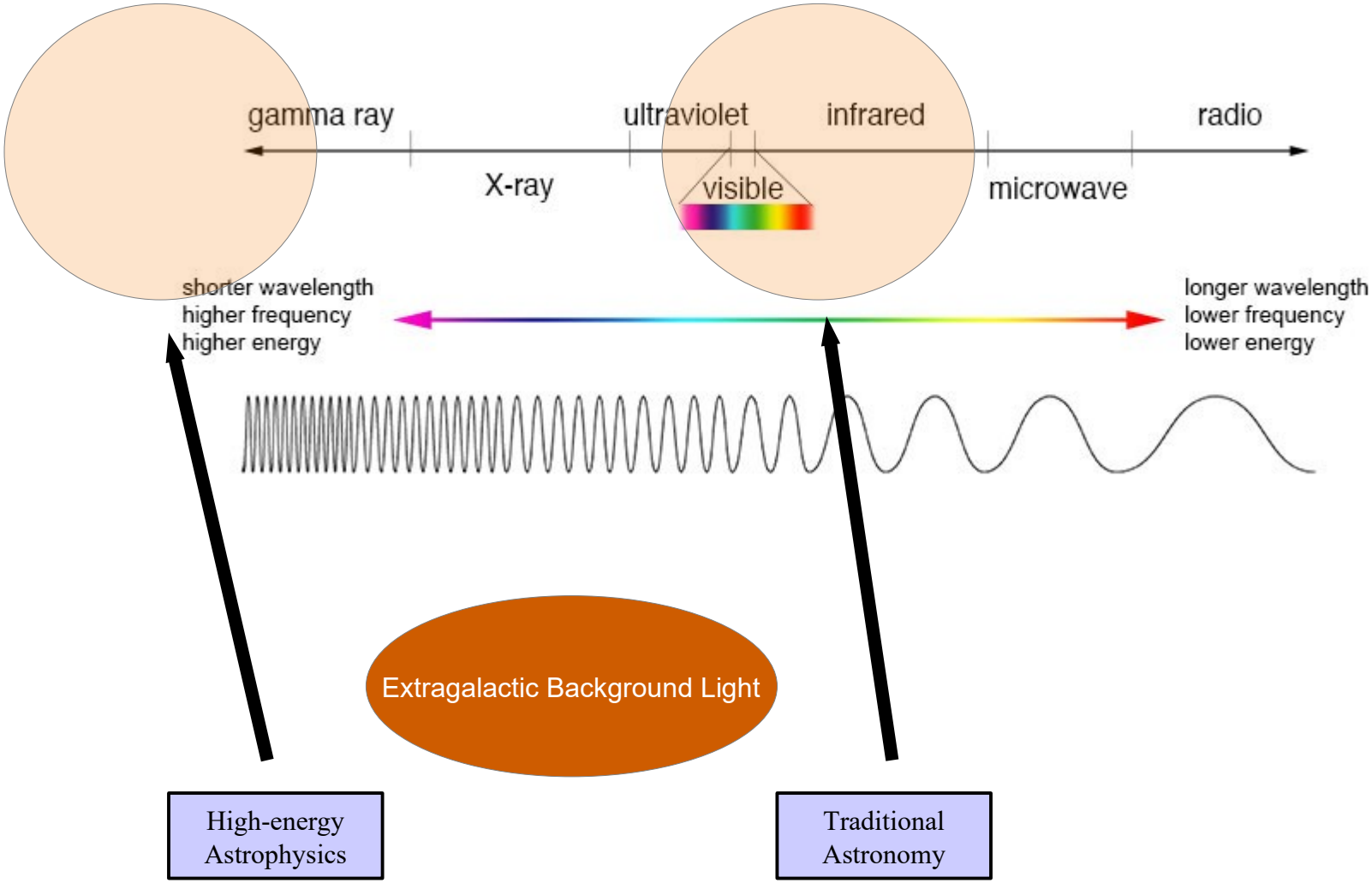
CPAN / RENATA @ Universidad Complutense de Madrid

Madrid, November 2024

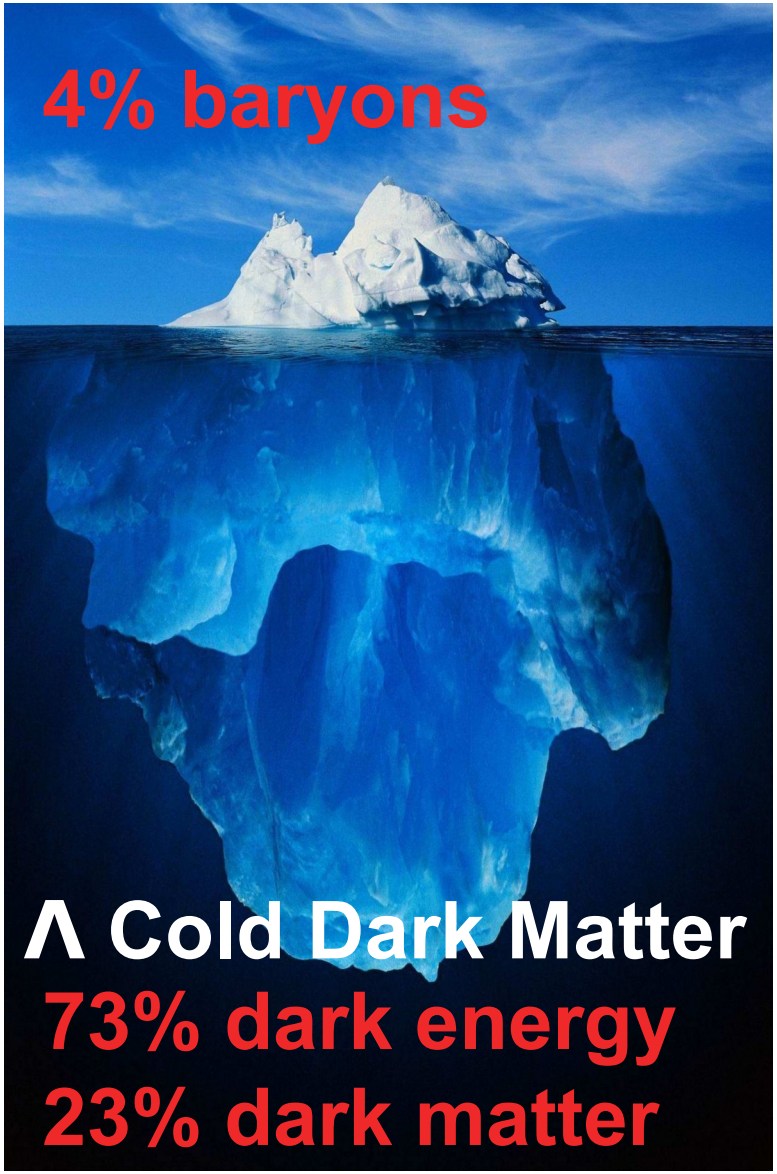
Electromagnetic Spectrum

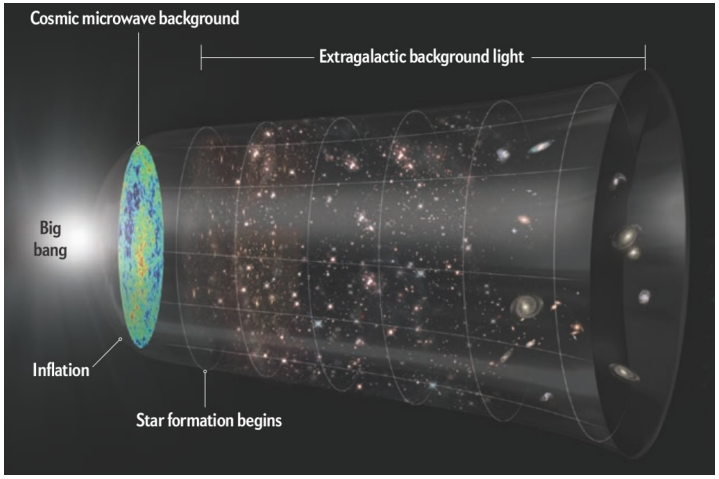


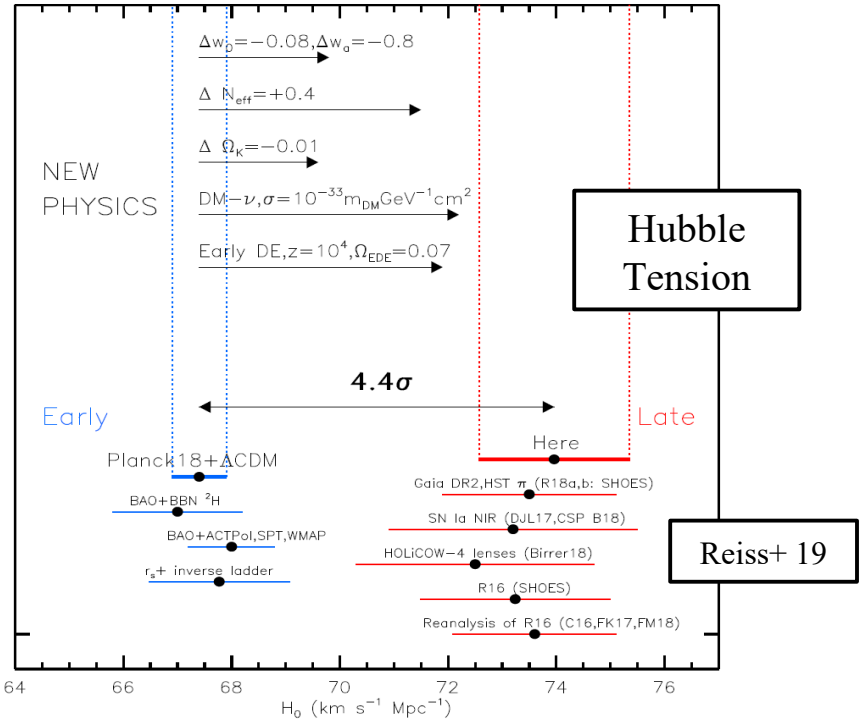
Electromagnetic Spectrum



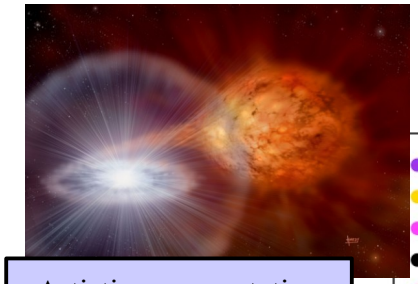
Galaxy Evolution and Cosmology



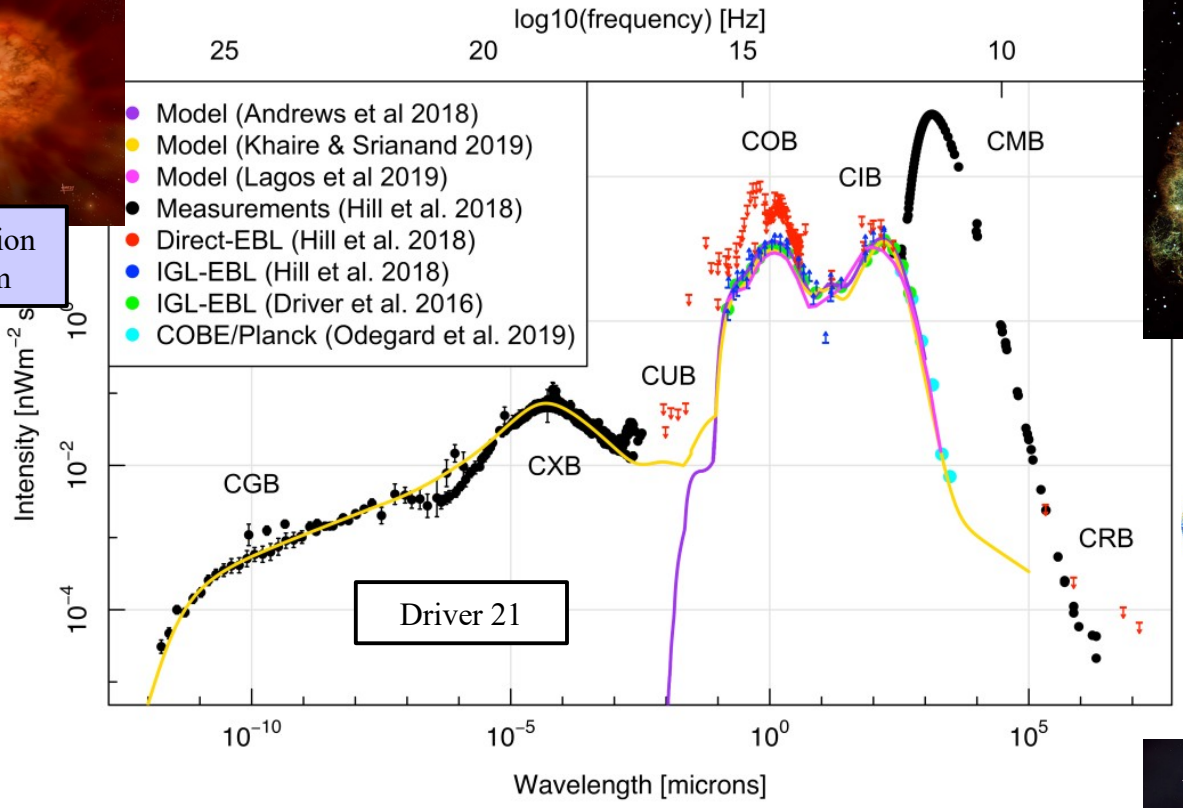




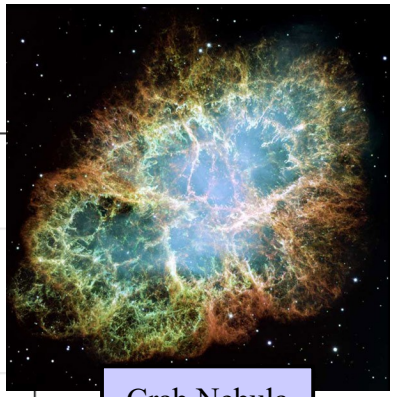
Cosmic Diffuse Extragalactic Backgrounds



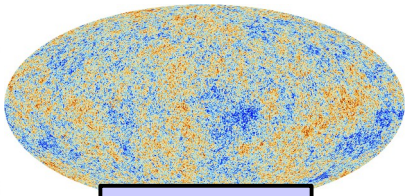
Artistic representation of a binary system



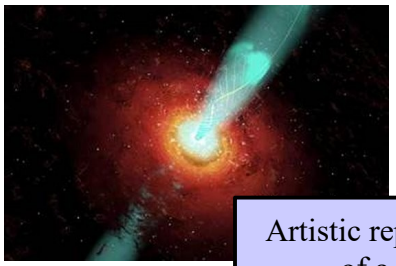
Driver 21



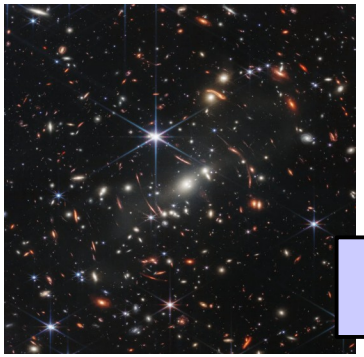
Crab Nebula



Planck CMB



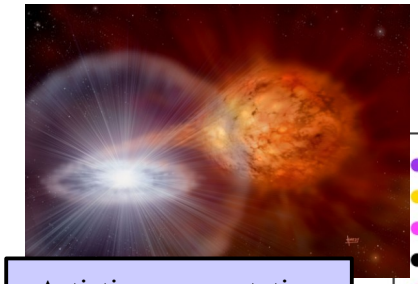
Artistic representation of a blazar



James Webb Space Telescope

Orion Nebula (birth place of stars)

Cosmic Diffuse Extragalactic Backgrounds



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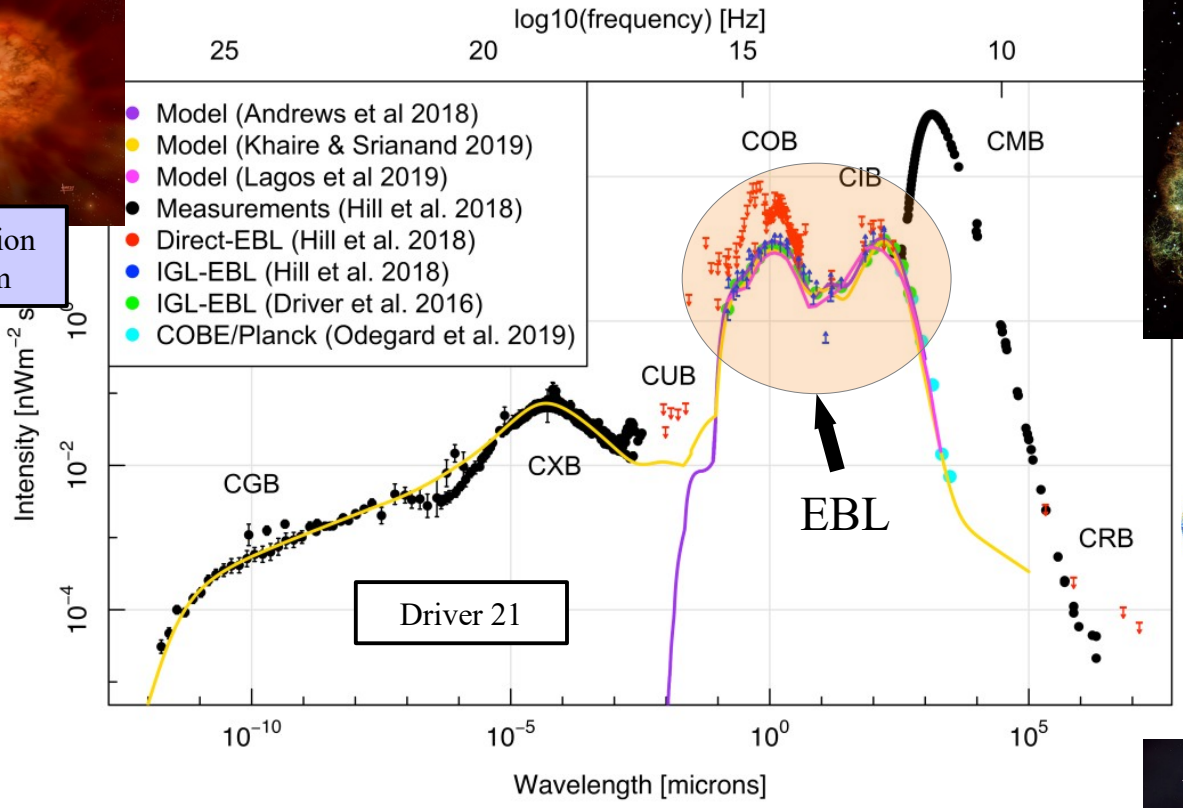
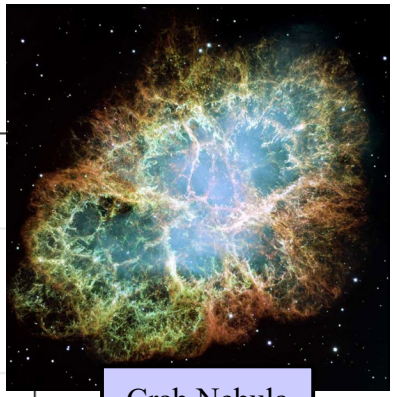
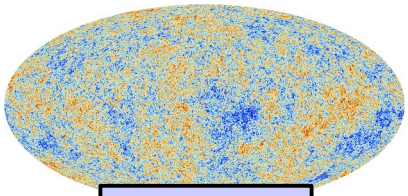


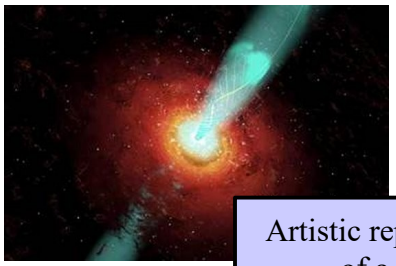
Driver 21



Crab Nebula



Planck CMB



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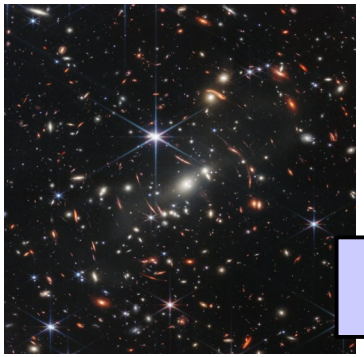
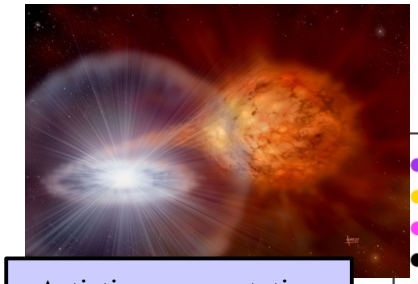


James Webb Space Telescope

Orion Nebula (birth place of stars)

Cosmic Diffuse Extragalactic Backgrounds



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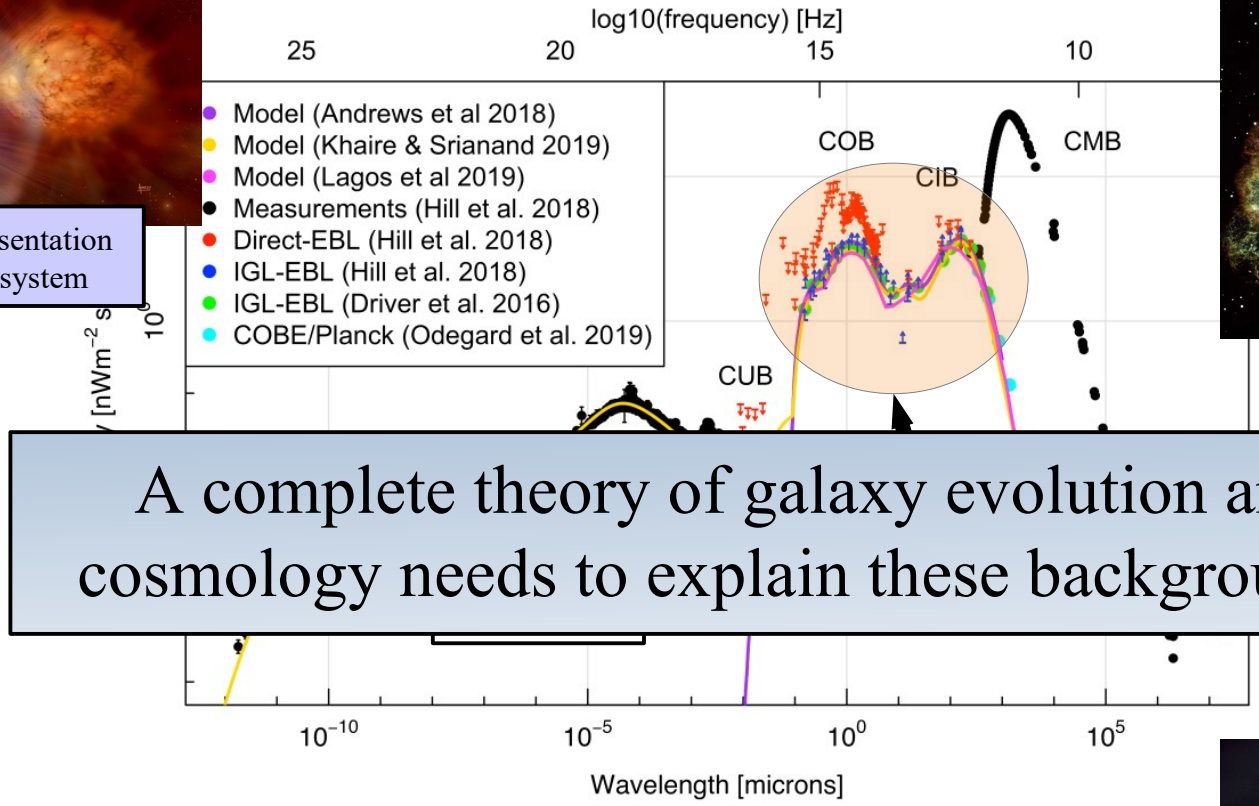
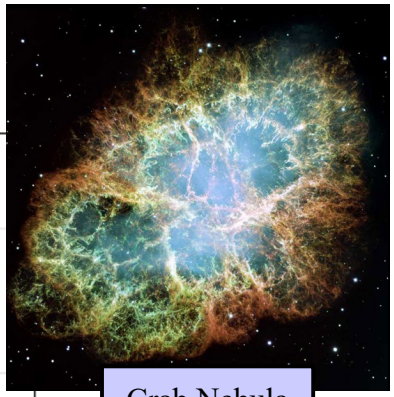
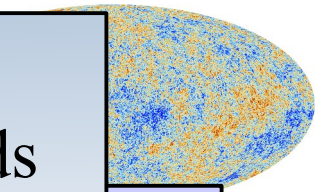




Crab Nebula

A complete theory of galaxy evolution and cosmology needs to explain these backgrounds



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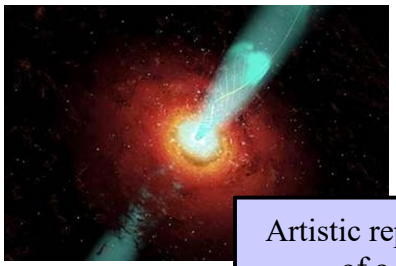

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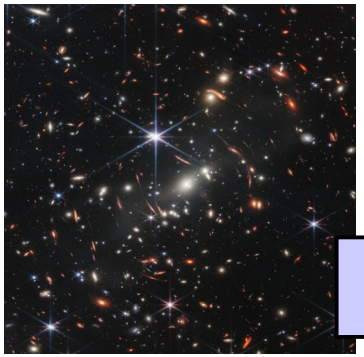
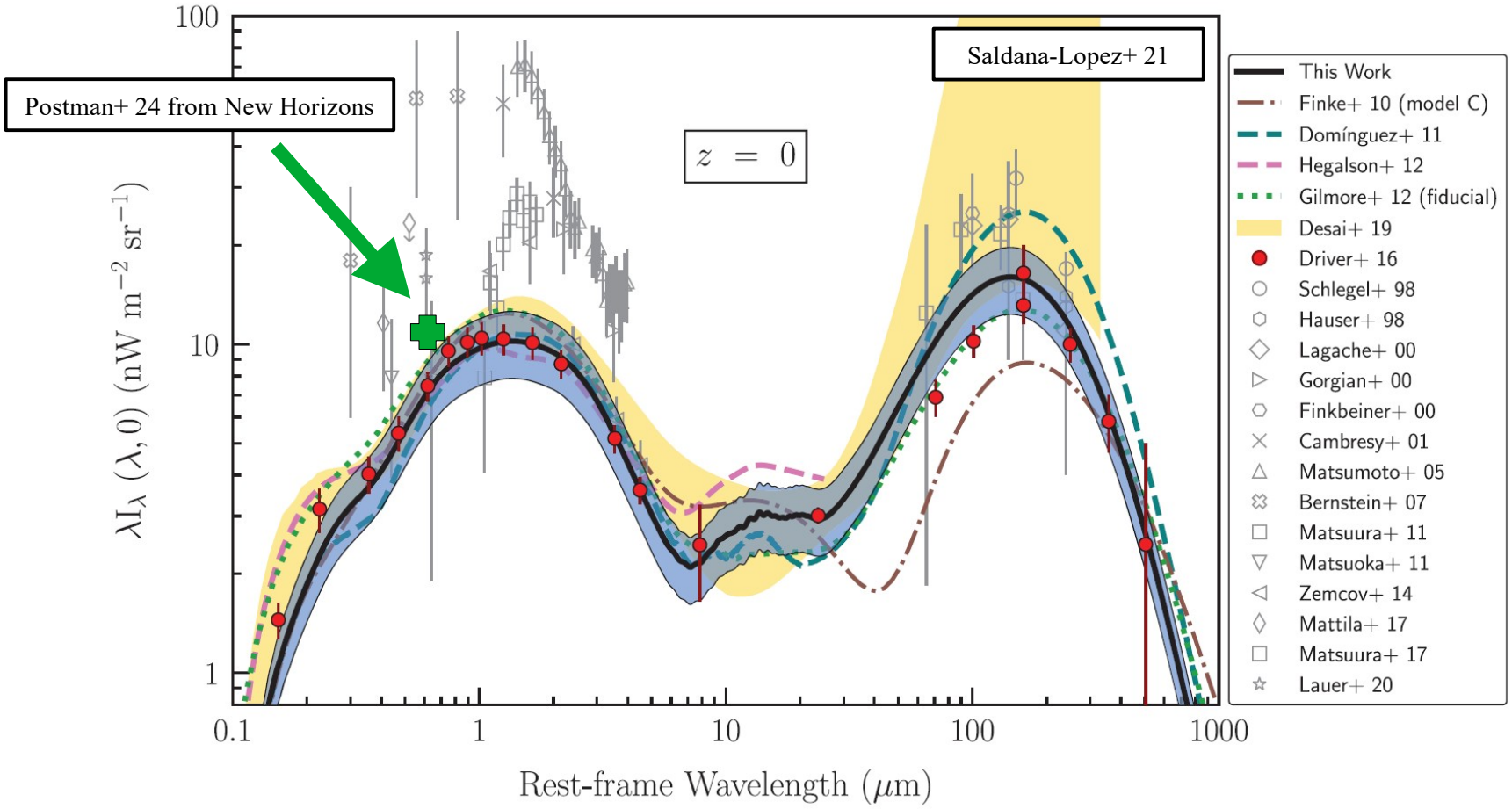


James Webb Space Telescope

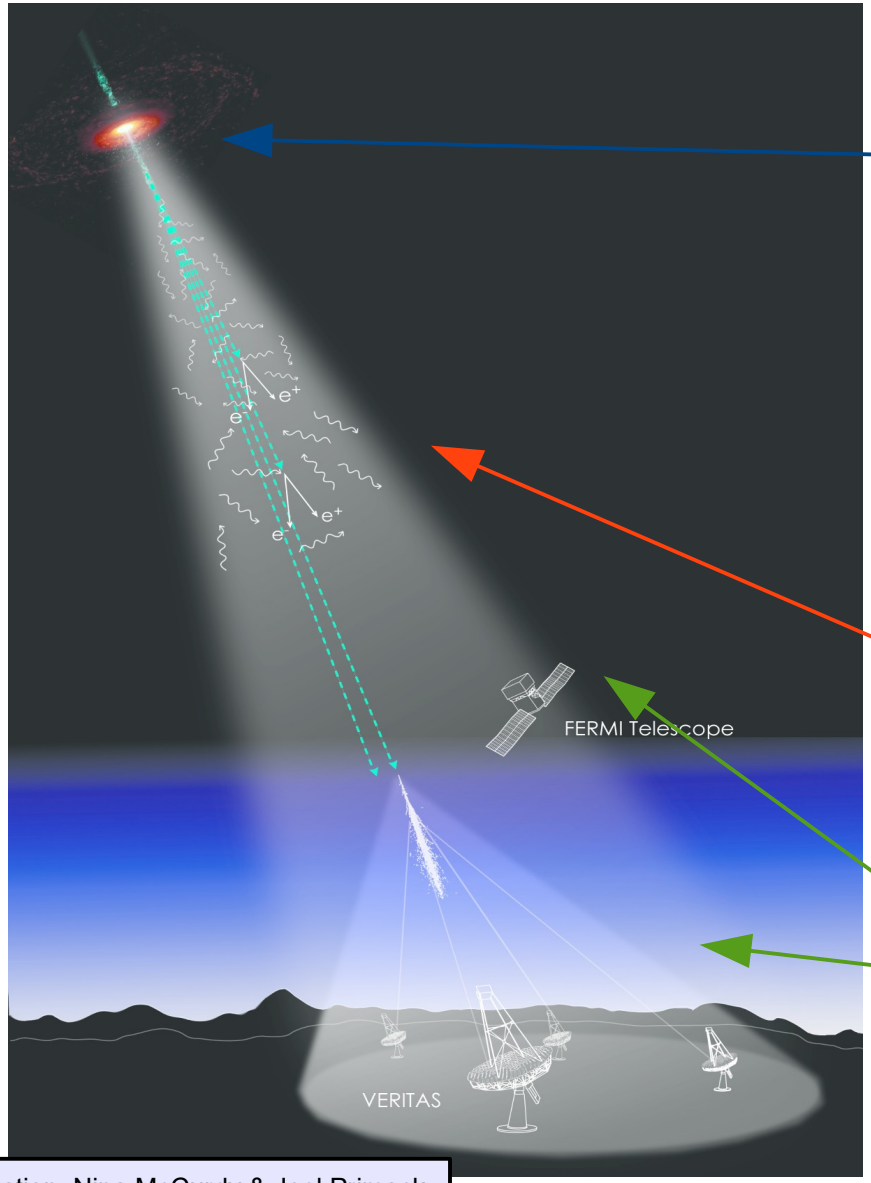
Orion Nebula (birth place of stars)

Extragalactic Background Light (Local)



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

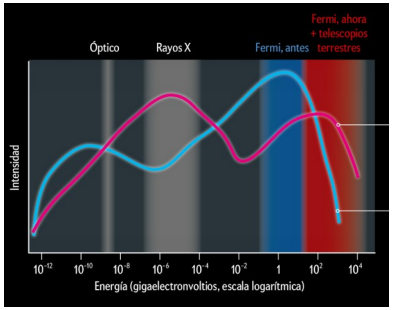
Gamma-ray Attenuation



Ilustration: Nina McCurdy & Joel Primack

Extragalactic source:
e.g. Blazar

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



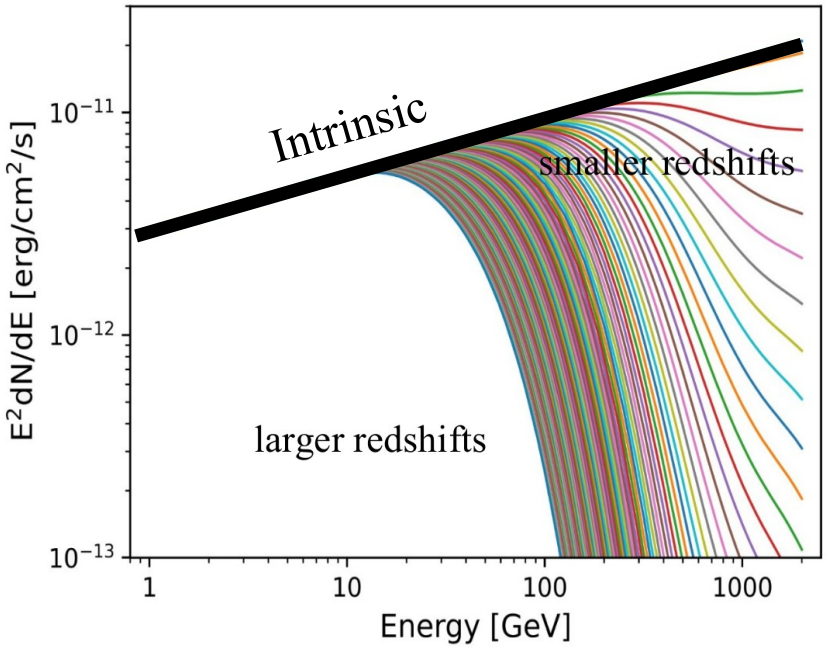
Pair-production interaction

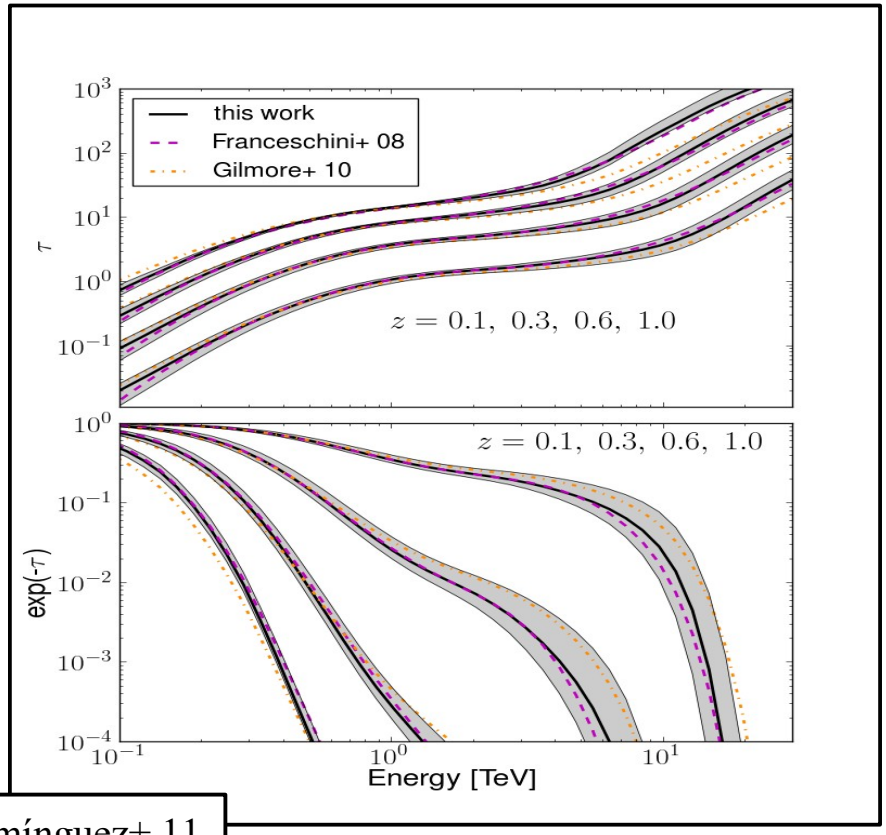
Reverse of most known electron-positron annhilation process

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

Gamma-ray Attenuation

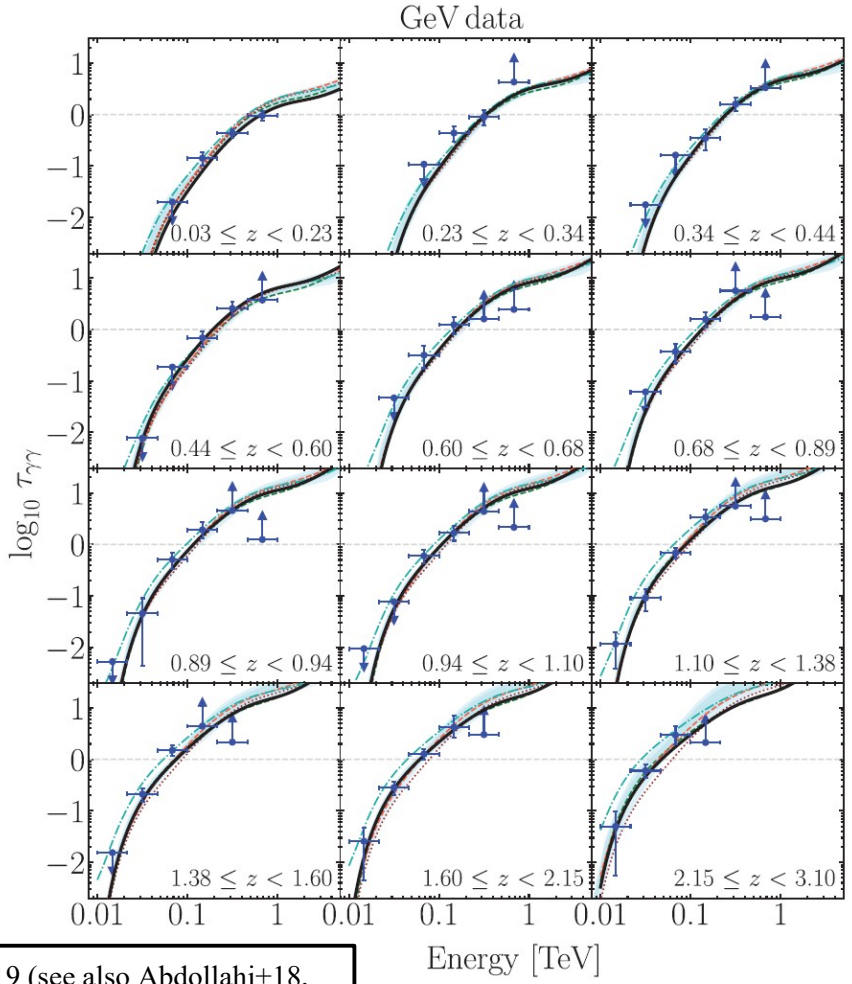
$$\left.\frac{dN}{dE}\right|_{obs} = \left.\frac{dN}{dE}\right|_{int} \exp\left[-\tau(E,z)\right]$$

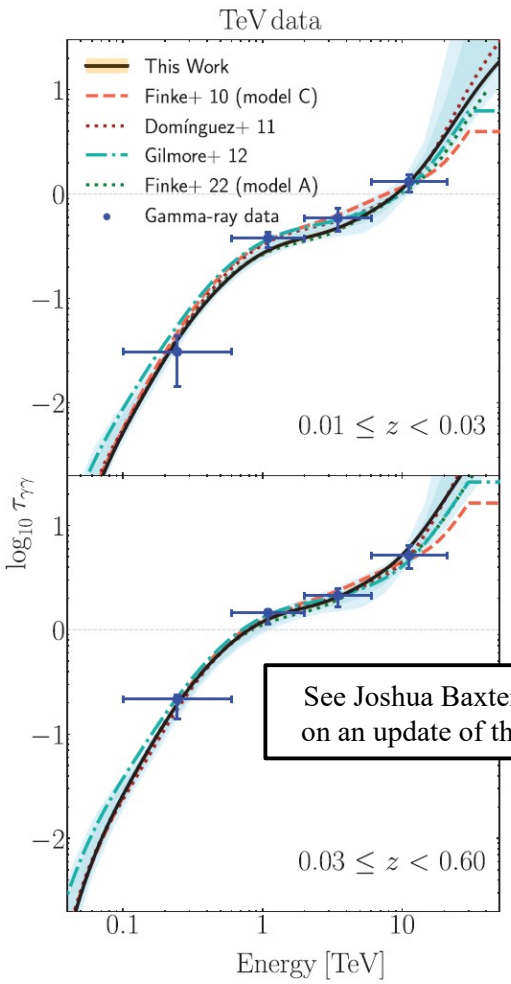




Domínguez+ 11

Gamma-ray Attenuation



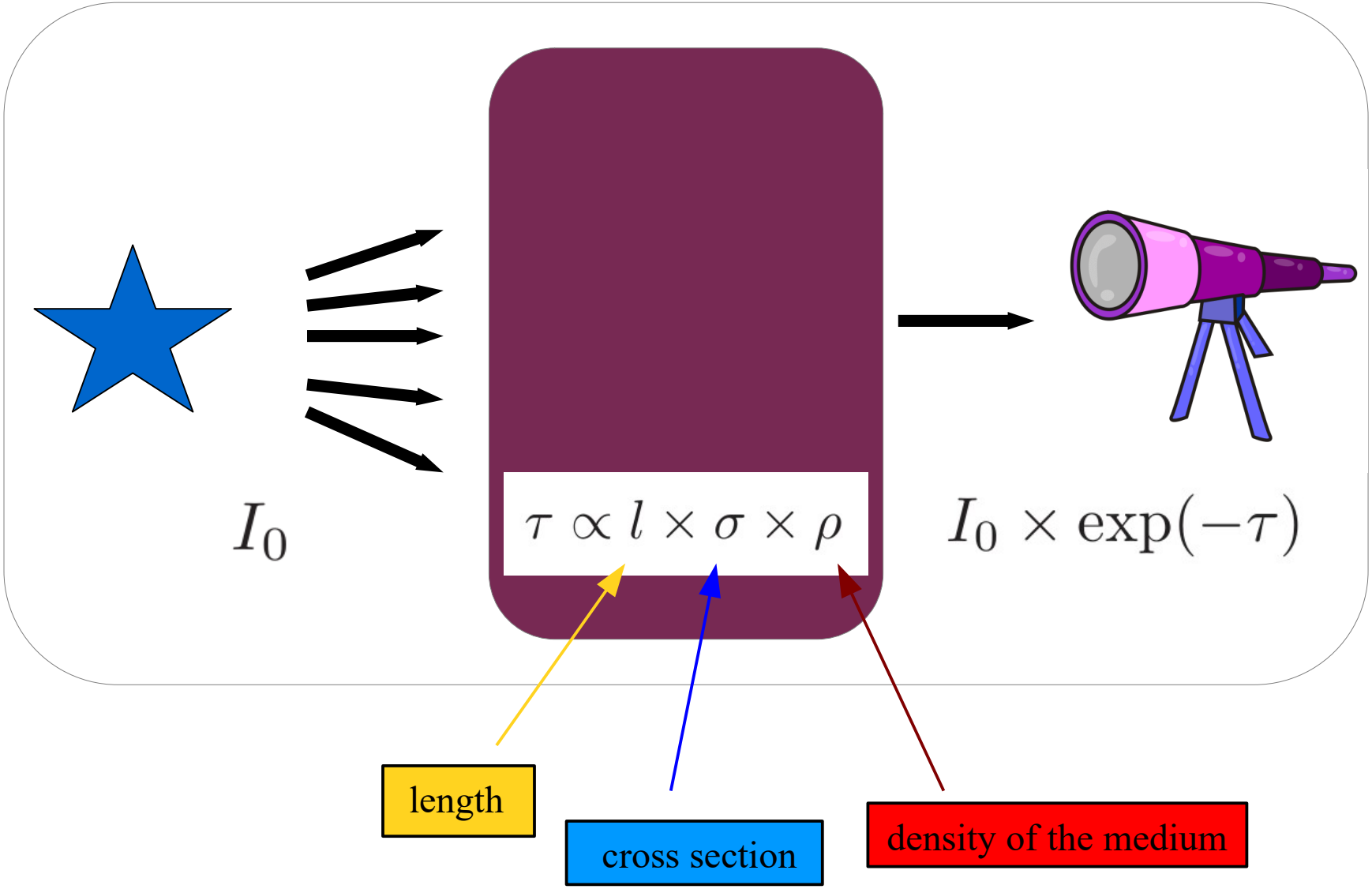


Desai+ 19 (see also Abdollahi+18, Domínguez+ 24)

See Joshua Baxter's talk later today on an update of these measurements

Optical Depths from Fermi-LAT and IACTs

Gamma-ray Attenuation



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

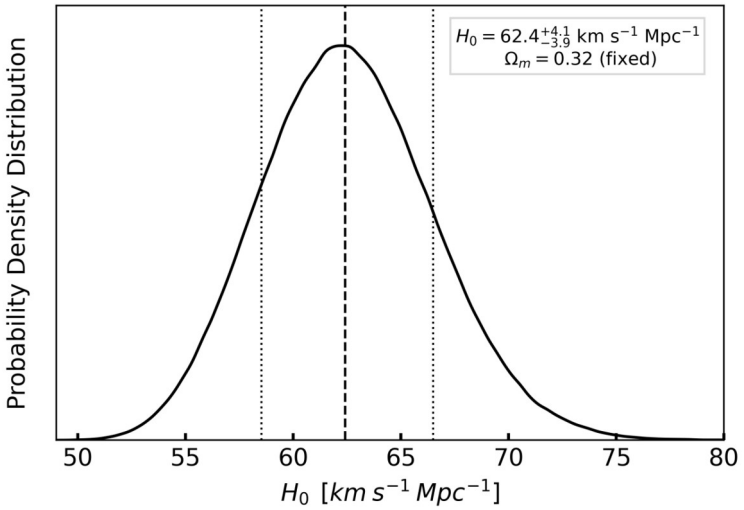
cross section

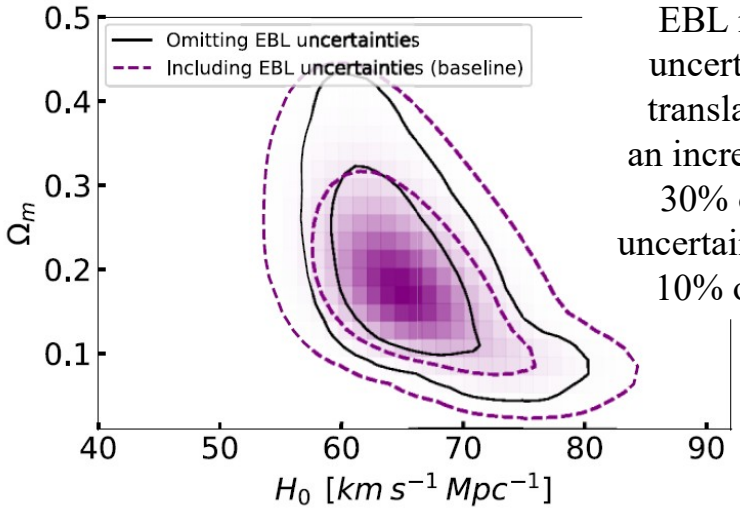
EBL photon density evolution

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

See Domínguez & Prada 13, Biteau & Williams 15, Gréaux+ 24

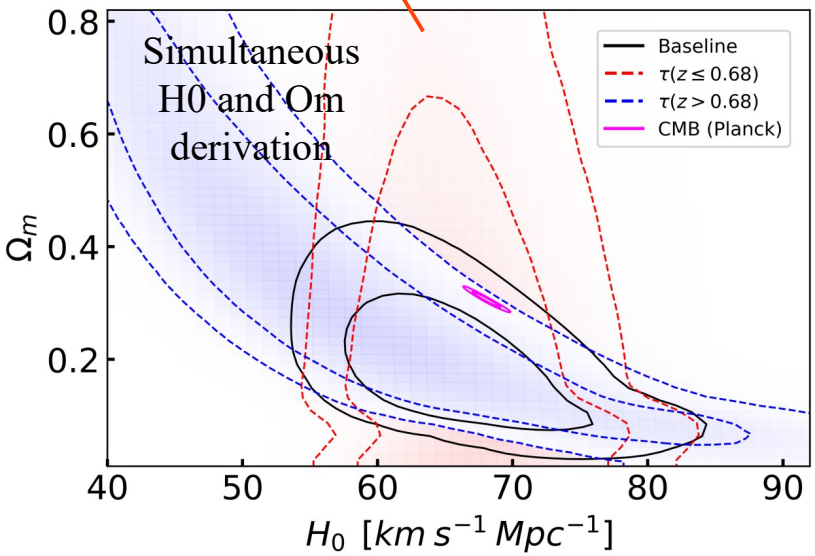
Results on measuring Cosmology with Gamma rays



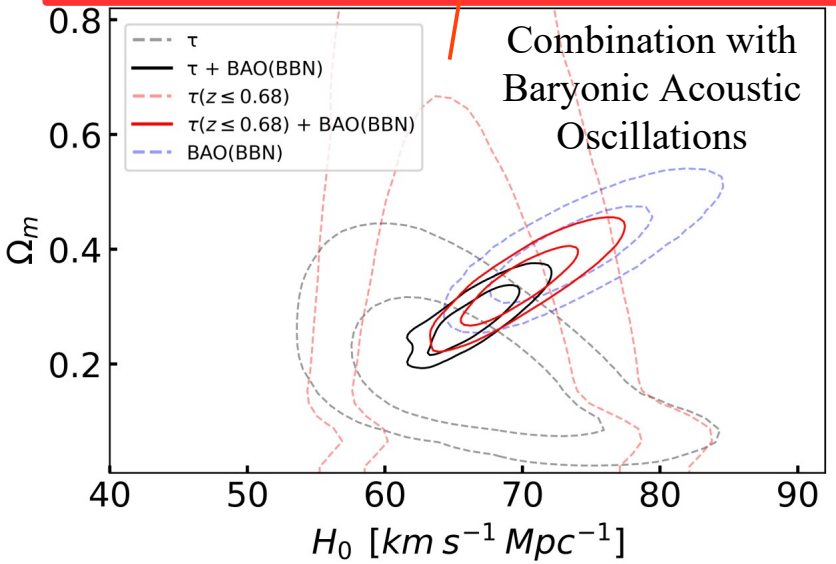


EBL model uncertainties translate into an increment of 30% on H0 uncertainties and 10% on Om

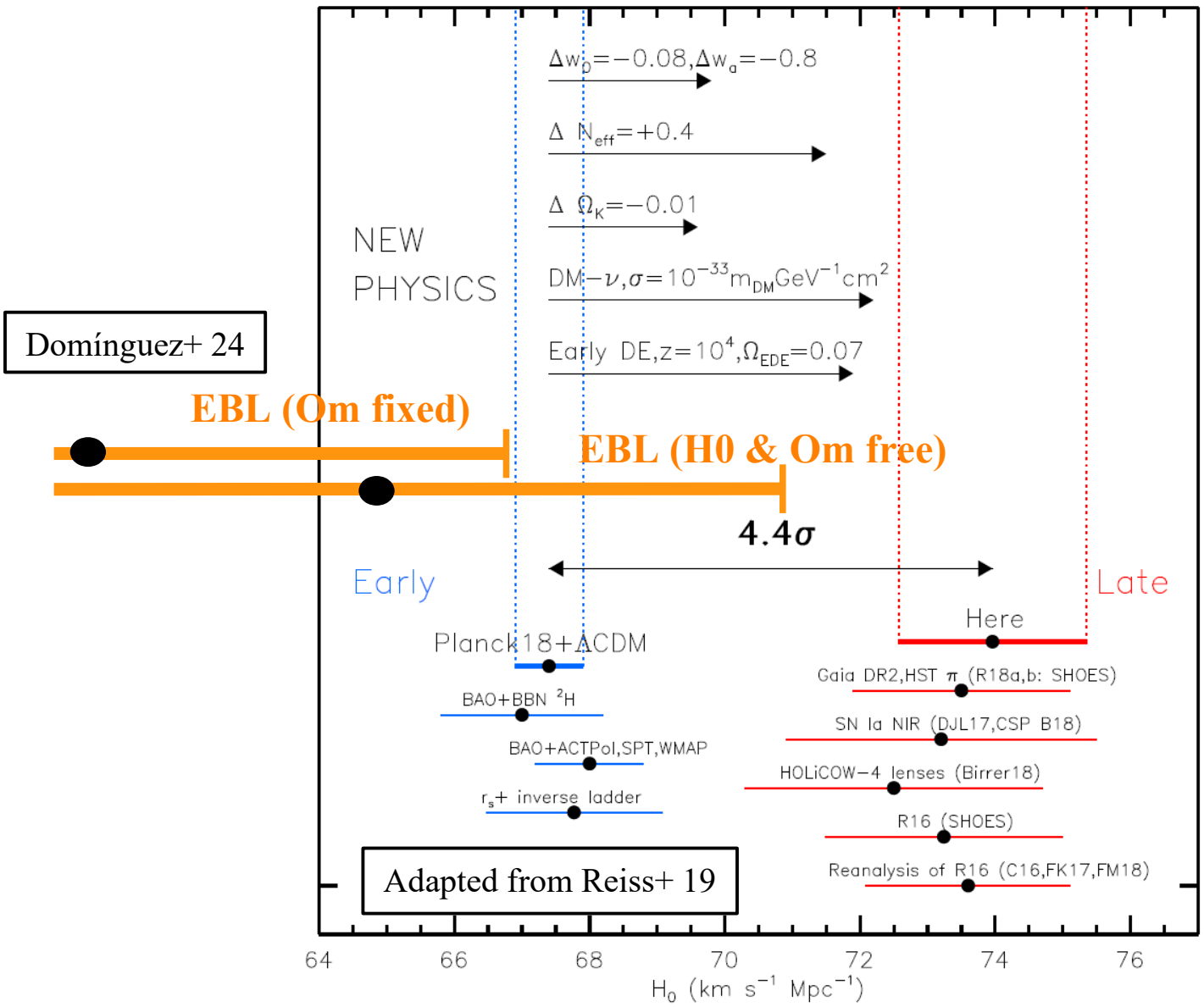
H_0(km s^{-1} Mpc^{-1})	Ω_m
$65.1^{+6.0}_{-4.9}$	0.19 ± 0.08 or (< 0.35 (95 %))



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



Comparison on H_0 Measurements



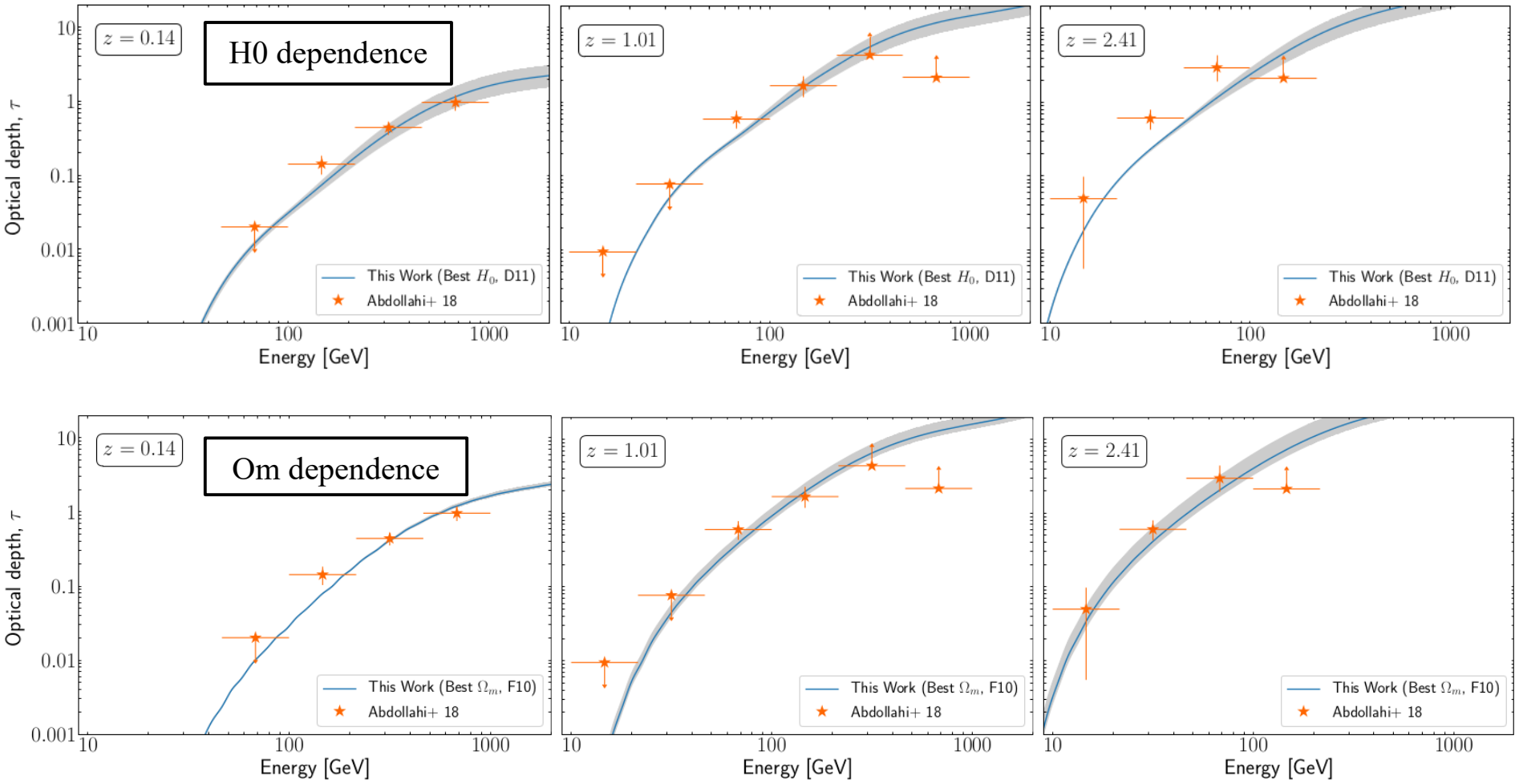
Take Home Messages

1) 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.

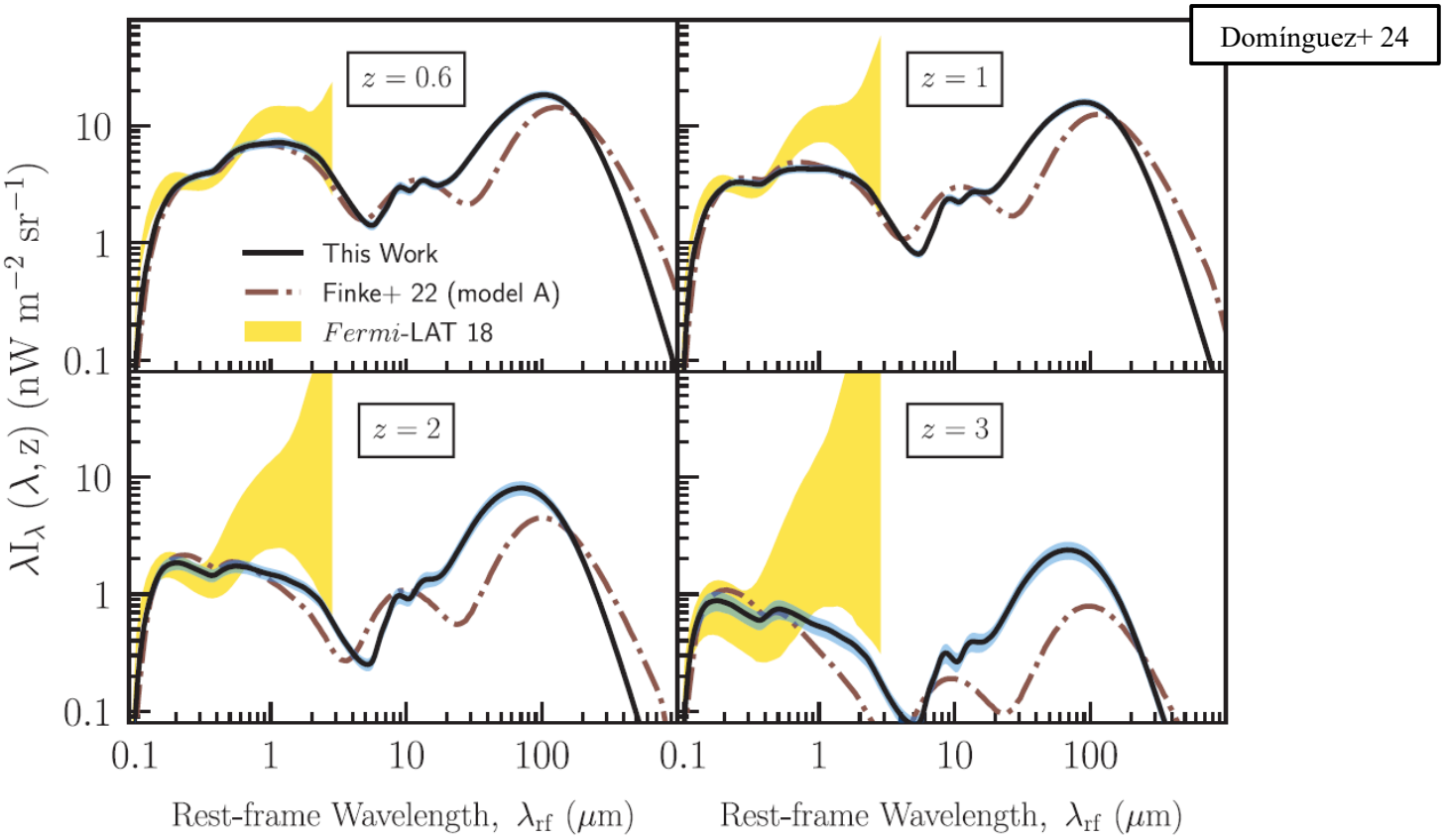
2) Really compelling synergies between high-energy astrophysics and traditional astronomy.

Backup

Cosmology Dependence on the Optical Depth



Extragalactic Background Light (Evolution)



EBL models and gamma-ray attenuation data agree within 1σ in the UV/optical and within 2σ in the near IR