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2.

Proton flux = no. of photons received /m^2/sec^2.

$$(2eV)\ \phi = \frac{L}{4\pi R^2} \quad (L \rightarrow \text{luminosity}) = \frac{(2\times10^{10} L_\odot)}{2eV \times 4\pi (z d_H)^2}$$

(2eV: energy per photon; ϕ: no. of photons)

here $(R \sim z H)$

↳ for $z \ll 1$.

$$\Rightarrow \phi = \frac{(2\times10^{10}) \times (2.4\times10^{45})\ eV/s}{2(eV) \times 4\pi z^2 \times (4300\ Mpc)^2}$$

$d_H = 4300\ Mpc \Rightarrow \phi = \dfrac{2.4\times10^{55}}{4\pi \times z^2 \times (4300\times3.086\times10^{19})^2}$

$d_H^2 = (4300\times3.086\times10^{19})^2\ km^2$

$d_H^2 = (1.765\times10^{46})\ km^2$

$$= \frac{2.4\times10^{55} \times 1000000\ m^{-2}s^{-1}}{4\pi \times 1.765\times10^{46} z^2} \quad (km^2 \text{ to } m^2)$$

$$\phi = \frac{2.4\times10^{55+6-46}}{4\pi\times1.765}$$

$$\phi = \left(\frac{2.4\times10^{55}}{4\pi\times1.765}\right) \times \frac{10^{55}}{\times10^{46}\times10^{6}} \frac{m^{-2}s^{-1}}{z^2} \simeq \frac{108\ m^{-2}s^{-1}}{z^2}$$

↓ for km^2 to m^2

3. flux of nearby galaxy vs. flux of nearby star

$$= \frac{L_{gal} \cdot 4\pi \times (R_{star})^2}{4\pi (R_{gal})^2 \, L_{star}}$$

taking

$L_{star} \approx L_\odot$

$L_{gal} = 2 \times 10^{10} L_\odot$

$R_{gal} \sim 1\,Mpc$

$R_{star} \sim 1\,pc$

$$= \frac{2 \times 10^{10} \, L_\odot \, (1\,pc)^2}{L_\odot \, (10^6\,pc)^2} = 2 \times 10^{-2}$$

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4. no. of CMB photons $= 411/cm^3 = 4.11 \times 10^8/m^3$

no. of stellar photons

$$= \frac{\left(10^8 \frac{L_\odot}{Mpc^3}\right) \times \left(\frac{1}{H_0}\right)}{2\,eV}$$

luminosity (present) × age of universe / energy per photon

$$= \frac{10^8 \times 2.4 \times 10^{45} \times \frac{1}{70\ km/s/Mpc}}{2 \times (3.09 \times 10^{19})^2\ km^2}$$

$$= \frac{10^8 \times 2.4 \times 10^{45}\ J/s}{2 \times (3.09 \times 10^{19})^2 \times 70{,}000\ m/s \times \underbrace{10^6}_{km^2 \text{ to } m^2}} \simeq 1904/m^3 \ll n_\gamma \text{ CMB}$$