cherenkov telescope array

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département d'astronomie

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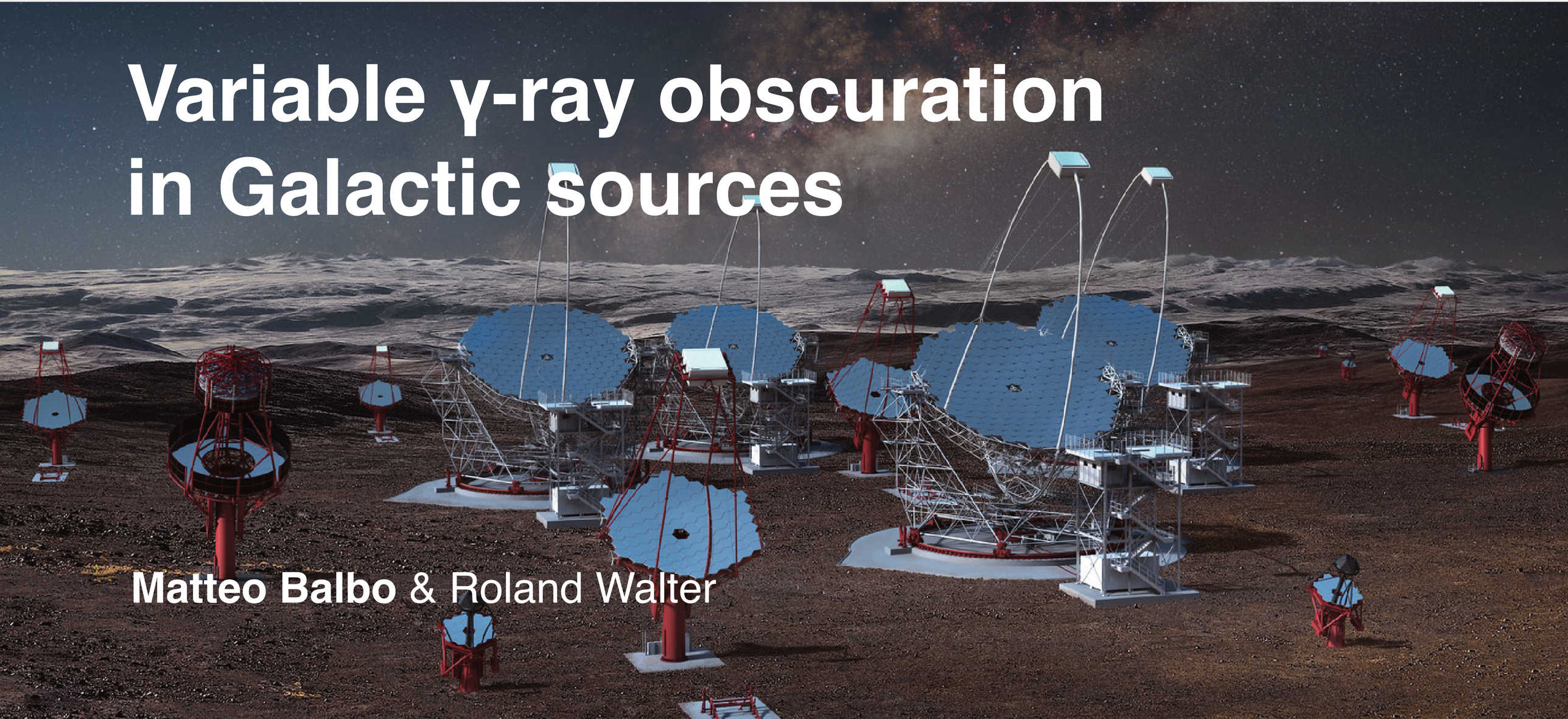
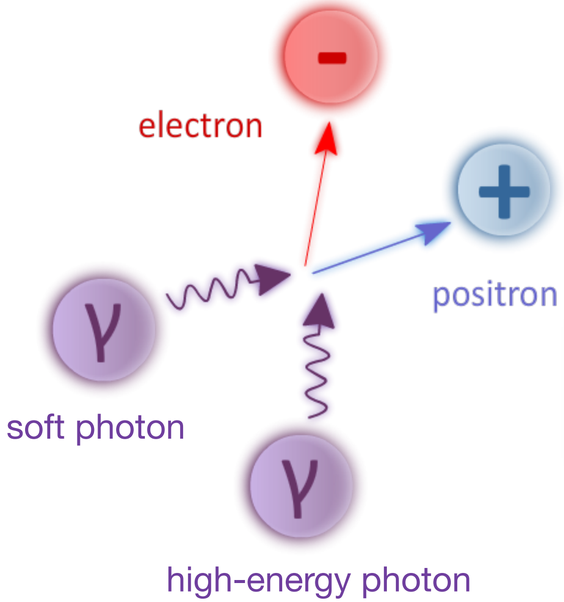
Variable γ-ray obscuration in Galactic sources

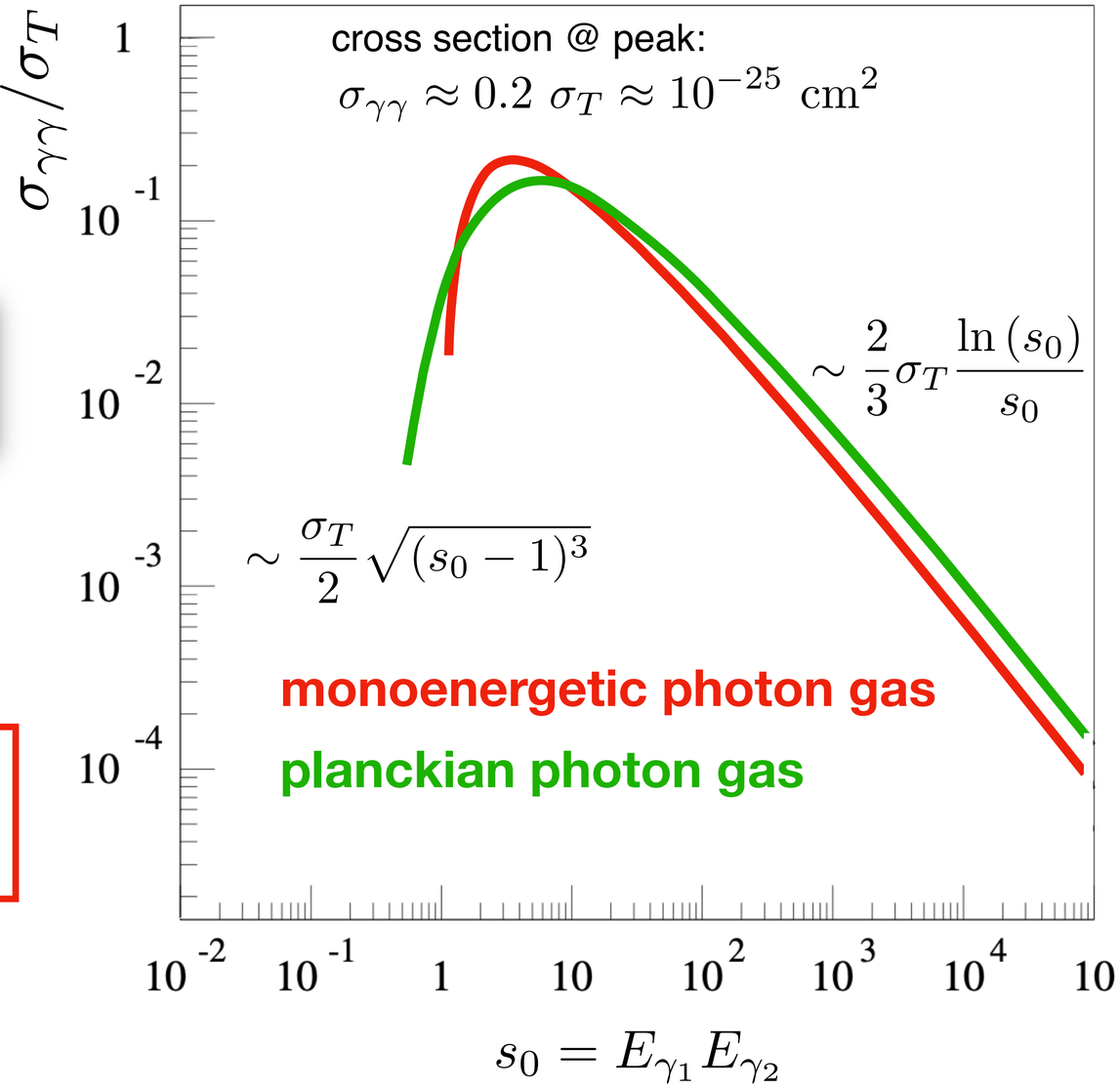


Matteo Balbo & Roland Walter

Photon-photon interaction



$$\gamma_1 + \gamma_2 \rightarrow e^+ + e^-$$



Optical depth:

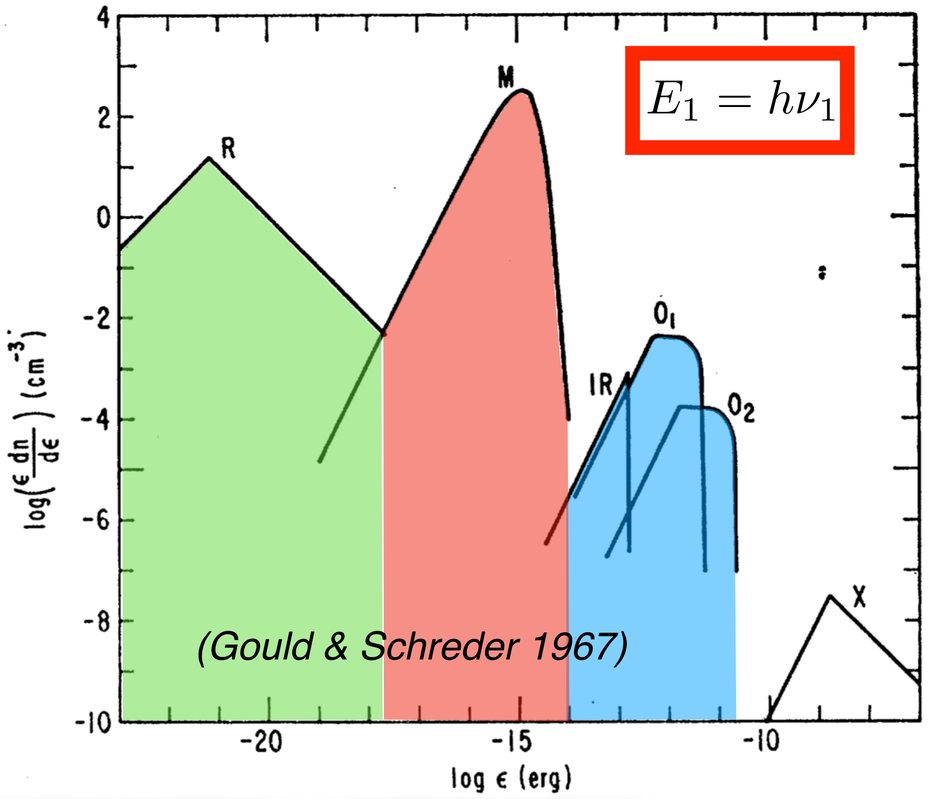
$$\tau\left(E_{\gamma_2}\right) = \int_0^{R_{obs}} \int_{E_{\gamma_1}} \sigma_{\gamma\gamma}\left(E_{\gamma_1}, E_{\gamma_2}, \theta\right)\, n\left(E_{\gamma_1}, T\right)\, \mathrm{d}E_{\gamma_1}\, \mathrm{d}l$$

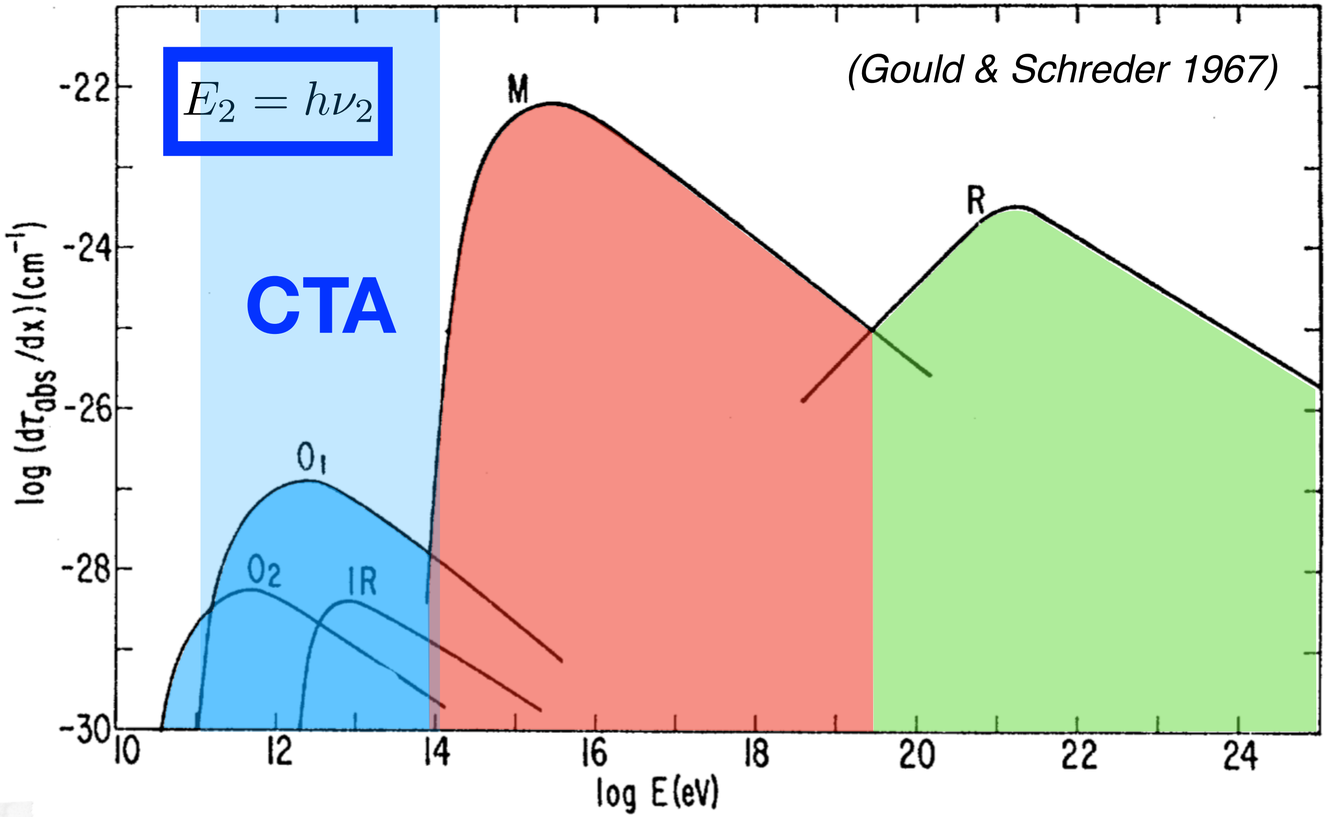
Energy threshold:

$$h\nu_2 \gtrsim \frac{2.6 \times 10^{11}}{h\nu_1} \quad [\mathrm{eV}]$$

Photon-photon interaction

$$\tau\left(E_{\gamma_2}\right) = \int_0^{R_{obs}} \int_{E_{\gamma_1}} \sigma_{\gamma\gamma}\left(E_{\gamma_1}, E_{\gamma_2}, \theta\right)\, n\left(E_{\gamma_1}, T\right)\, \mathrm{d}E_{\gamma_1}\, \mathrm{d}l$$





Sources	Energies	
	$h\nu_1$ [eV]	$h\nu_2$ [GeV]
CMB	7×10^{-4}	4×10^{5}
starlight	2	10^{2}
X-ray	10^{3}	3×10^{-1}

CMB:

$\mathcal{E} \approx 0.3\ \mathrm{eV/cm^3}$

$\langle E \rangle \approx 7 \times 10^{-4}\ \mathrm{eV}$

$n \approx 400\ \mathrm{ph/cm^3}$

cross section @ peak: $\sigma_{\gamma\gamma} \approx 0.2\ \sigma_T \approx 10^{-25}\ \mathrm{cm}^2$

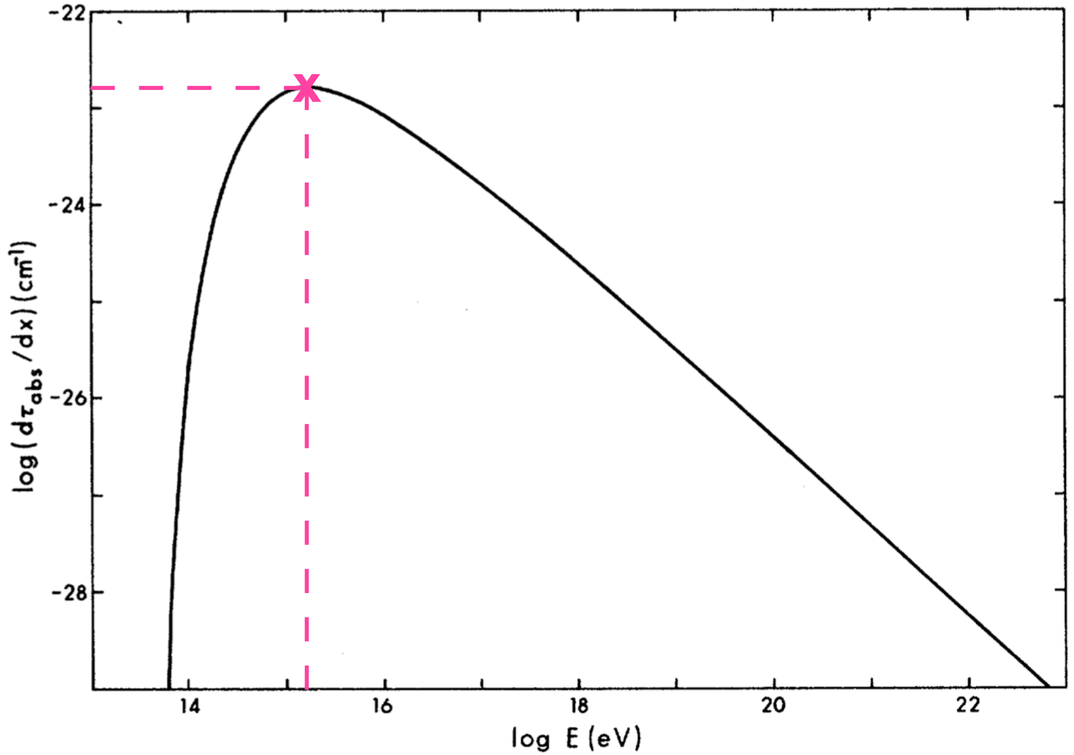
absorption probability: $\frac{\mathrm{d}\tau_{abs}}{\mathrm{d}x} \approx 10^{-22}\ \mathrm{cm}^{-1}$

mean free path: $\lambda \sim \left(n\,\sigma_{\gamma\gamma}\right)^{-1} \sim 0.01\ \mathrm{Mpc}$

Diluited photon field

$$\tau_{\gamma\gamma}\left(E_\gamma\right) = \int_0^\infty \mathrm{d}l \int_0^{\cos^{-1}(c_{min})} \sin\left(\theta\right) \mathrm{d}\theta \int_0^{2\pi} \mathrm{d}\phi \int_{\epsilon_{\star,min}}^\infty g\, n_{\epsilon_\star}\, \sigma_{\gamma\gamma}\, \mathrm{d}\epsilon_\star$$

$$g(\hat{\mathbf{e}}_\gamma, \hat{\mathbf{e}}_\star)\, n_\epsilon(\epsilon_\star, T_\star, \vec{\mathbf{d}})\, \sigma_{\gamma\gamma}(\epsilon_\star, E_\gamma, \hat{\mathbf{e}}_\gamma, \hat{\mathbf{e}}_\star)$$



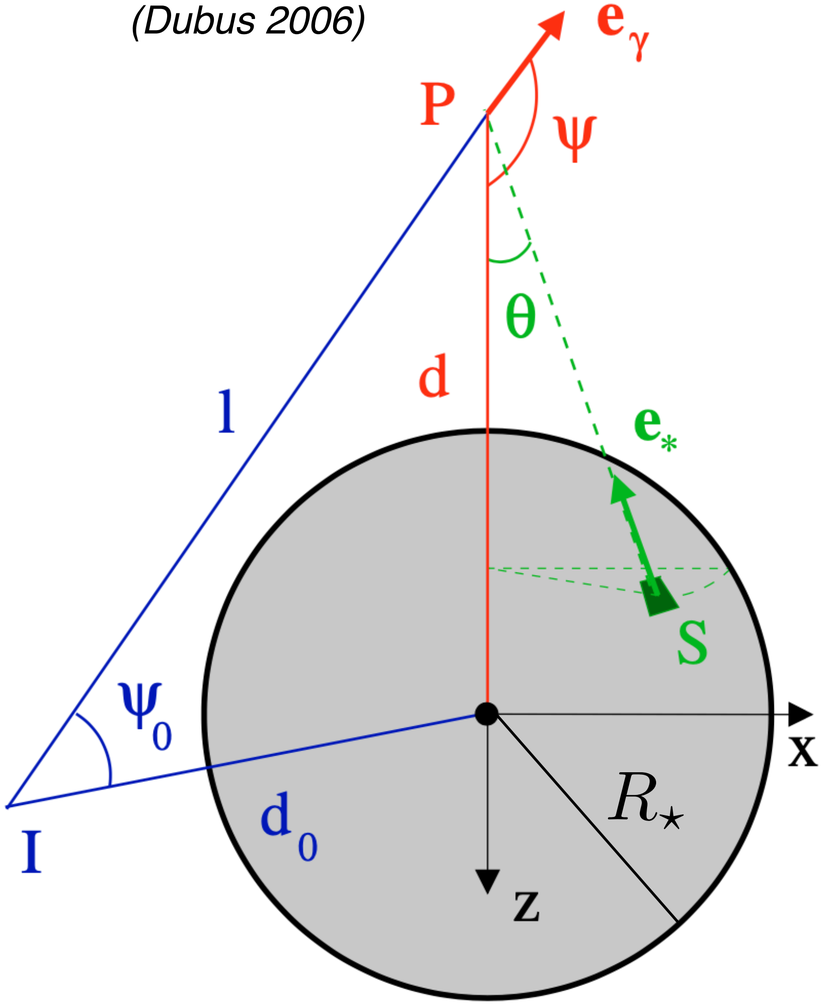
Effects on τ by changing:

- radius
- temperature
- luminosity
- magnetic field
- orbital parameters

Pointlike approximation:

$$\int\int\int\int \xrightarrow{R_\star \ll d} \int\int$$

(Dubus 2006)

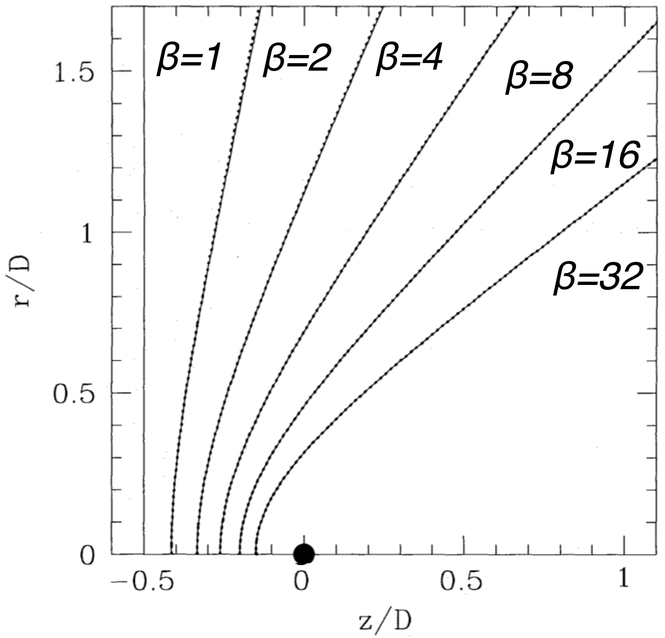


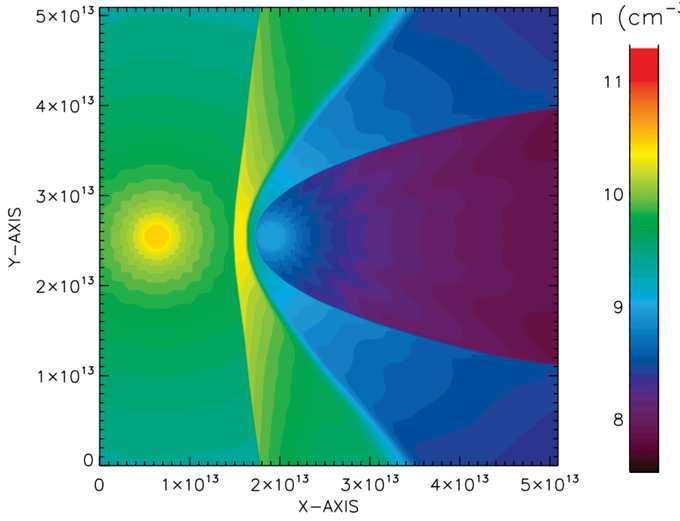
Eta Carinae's orbit

optical Hubble
UV Hubble
X-rays Chandra

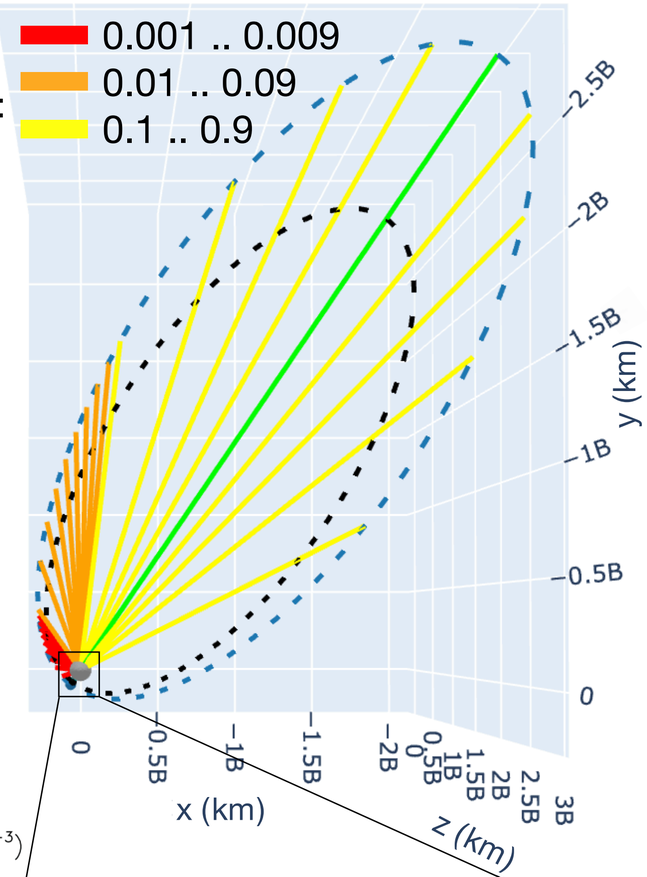
Credit NASA/ESA/N.
Smith, J. Morse and A. Pagan

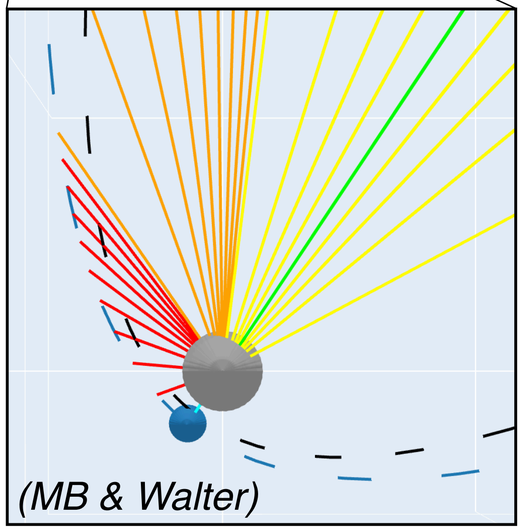
(Canto et al. 1996)





(Falceta-Gonçalves et al. 2012)

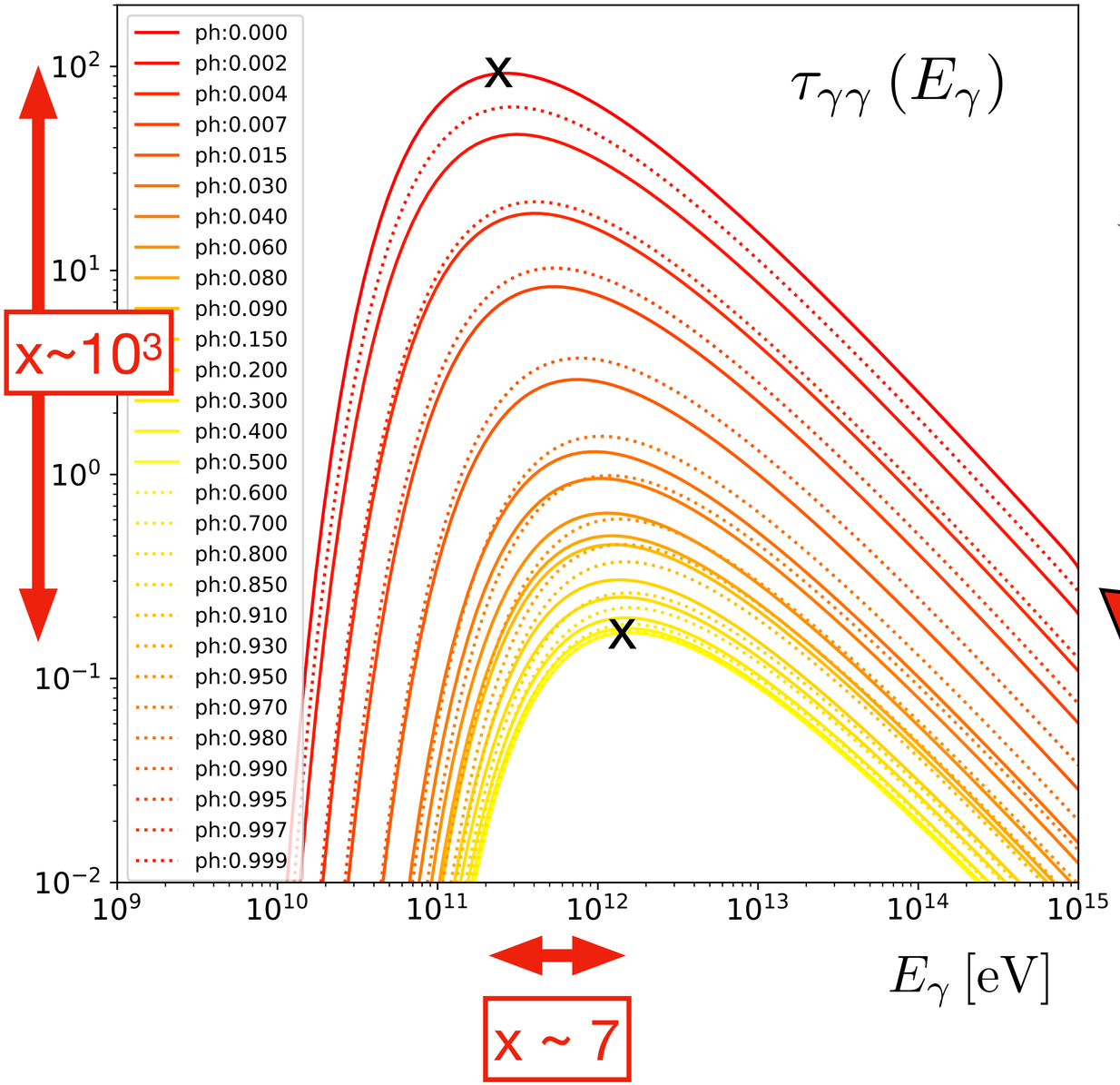


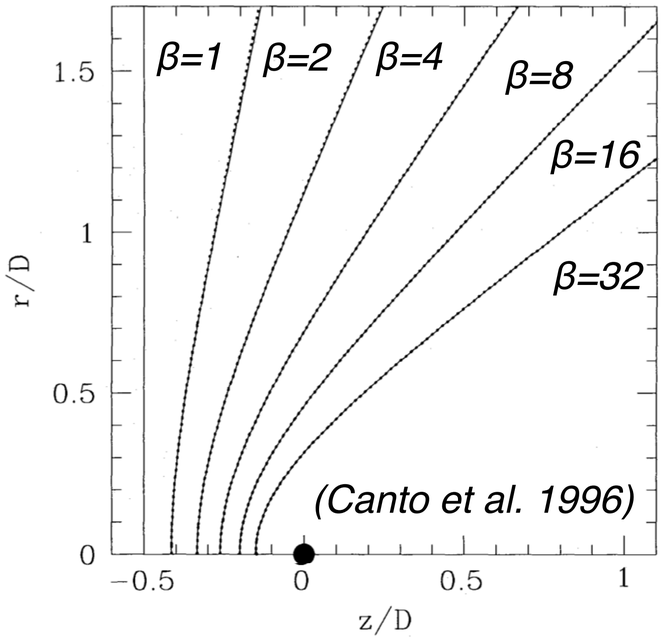


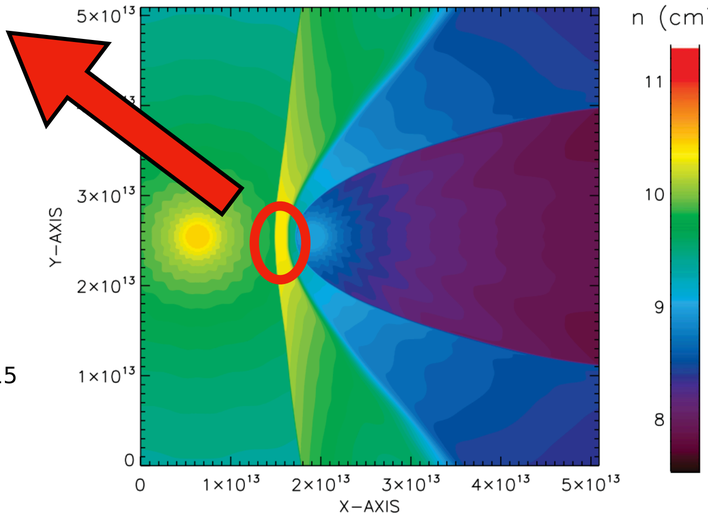
(MB & Walter)

HE γ-rays: “stagnation” approximation

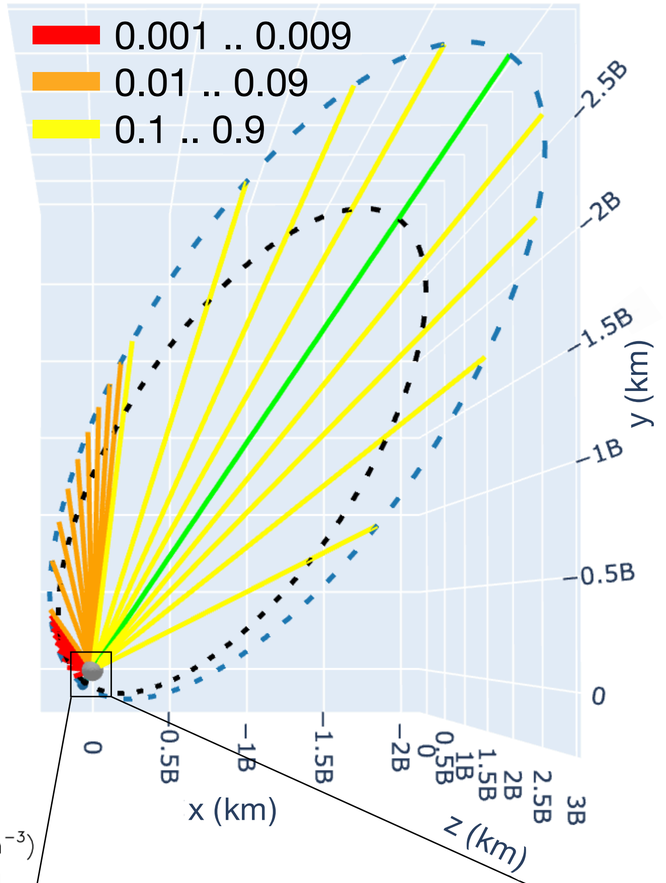
(MB & Walter)

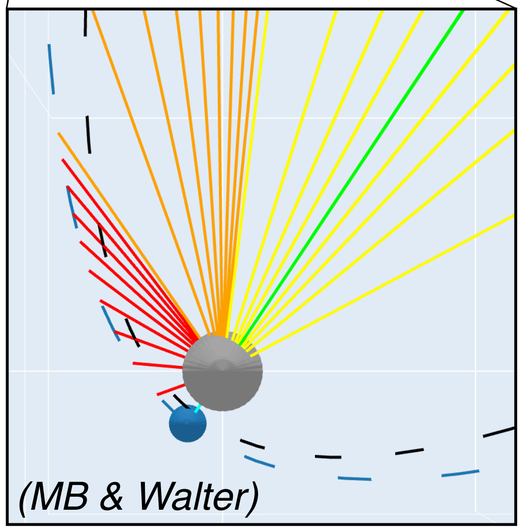






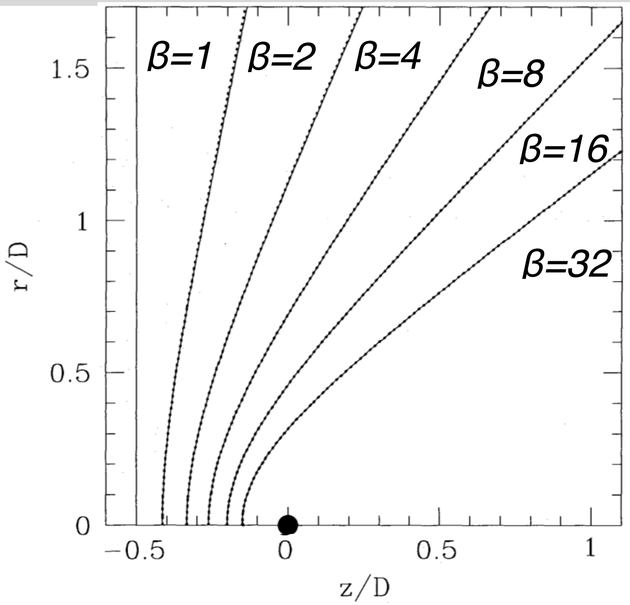
(Falceta-Gonçalves et al. 2012)



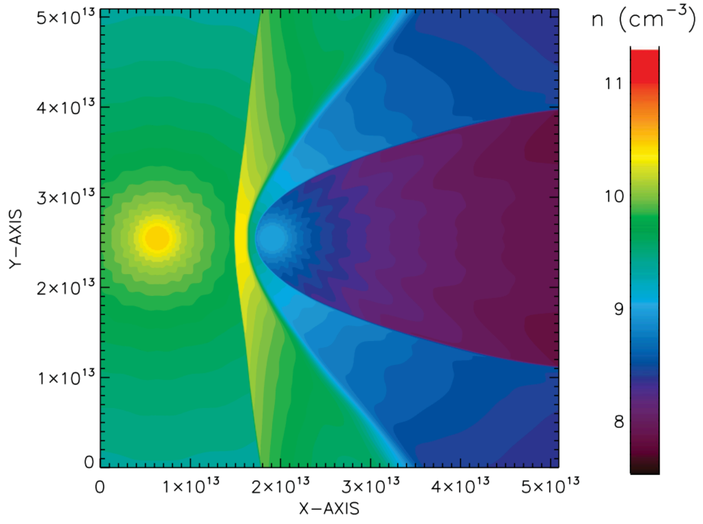


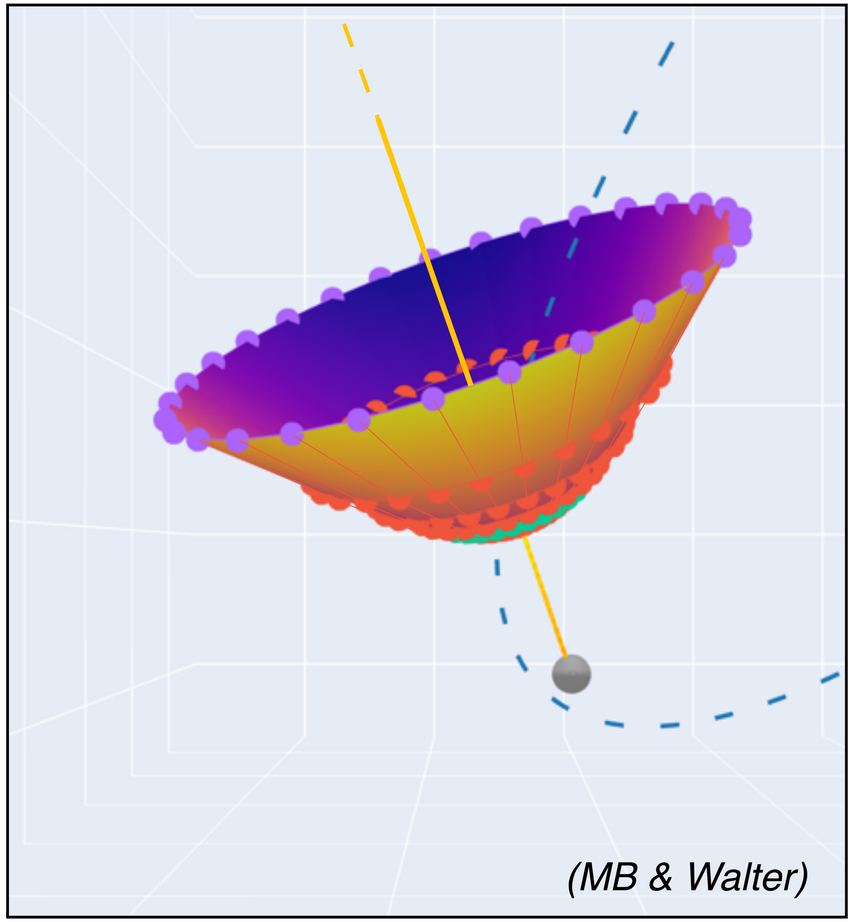
HE γ-rays: “paraboloid” approximation

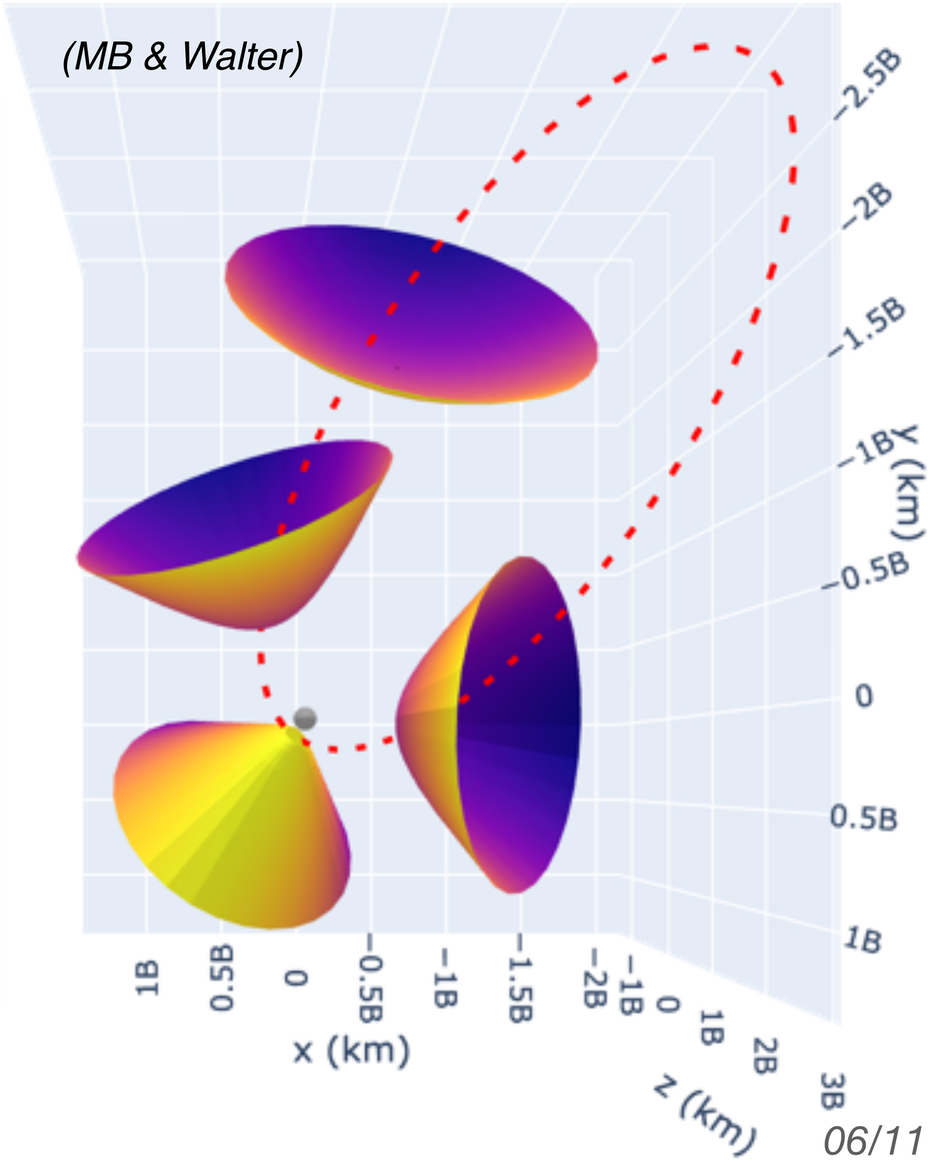
(Canto et al. 1996)



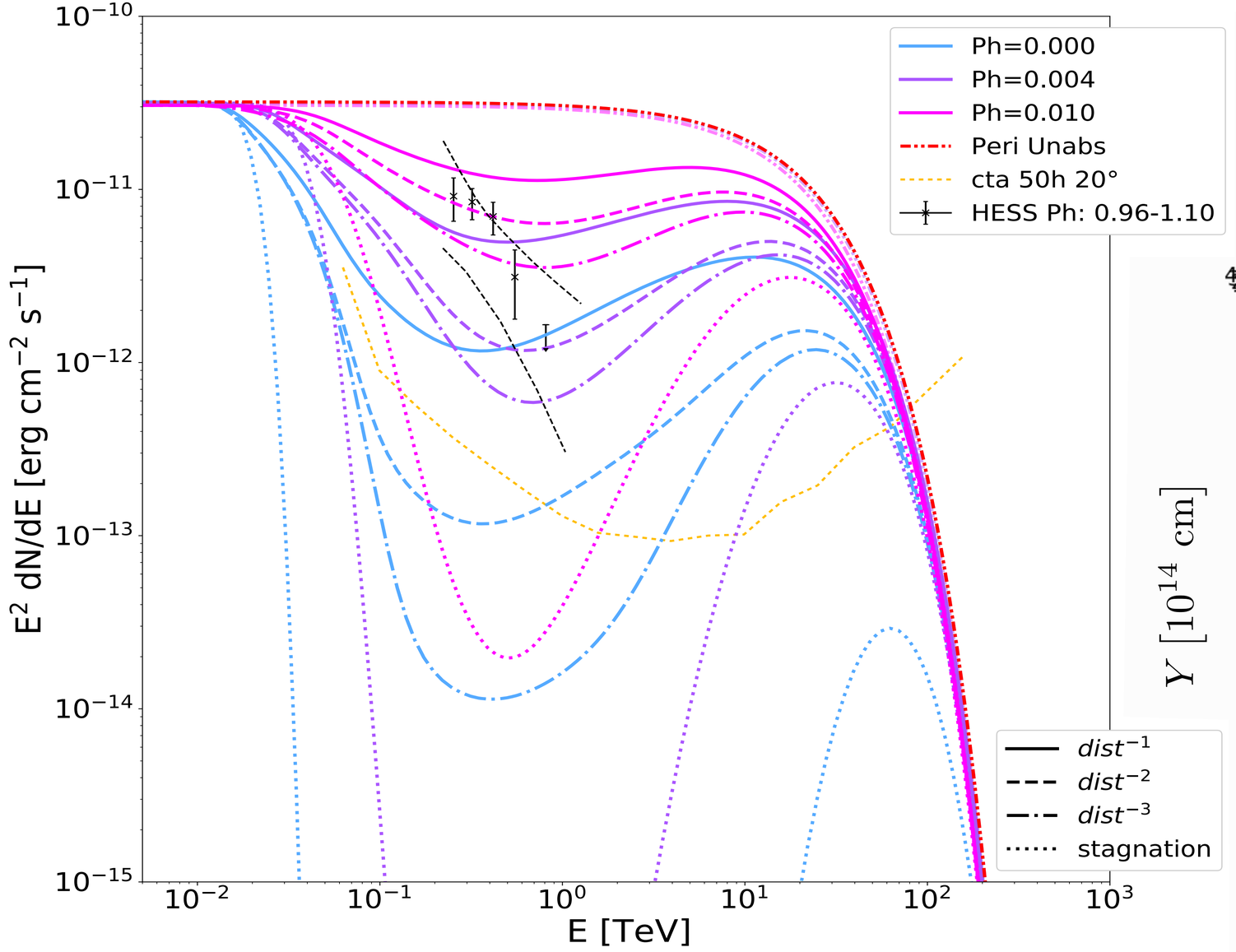
(Falceta-Gonçalves et al. 2012)

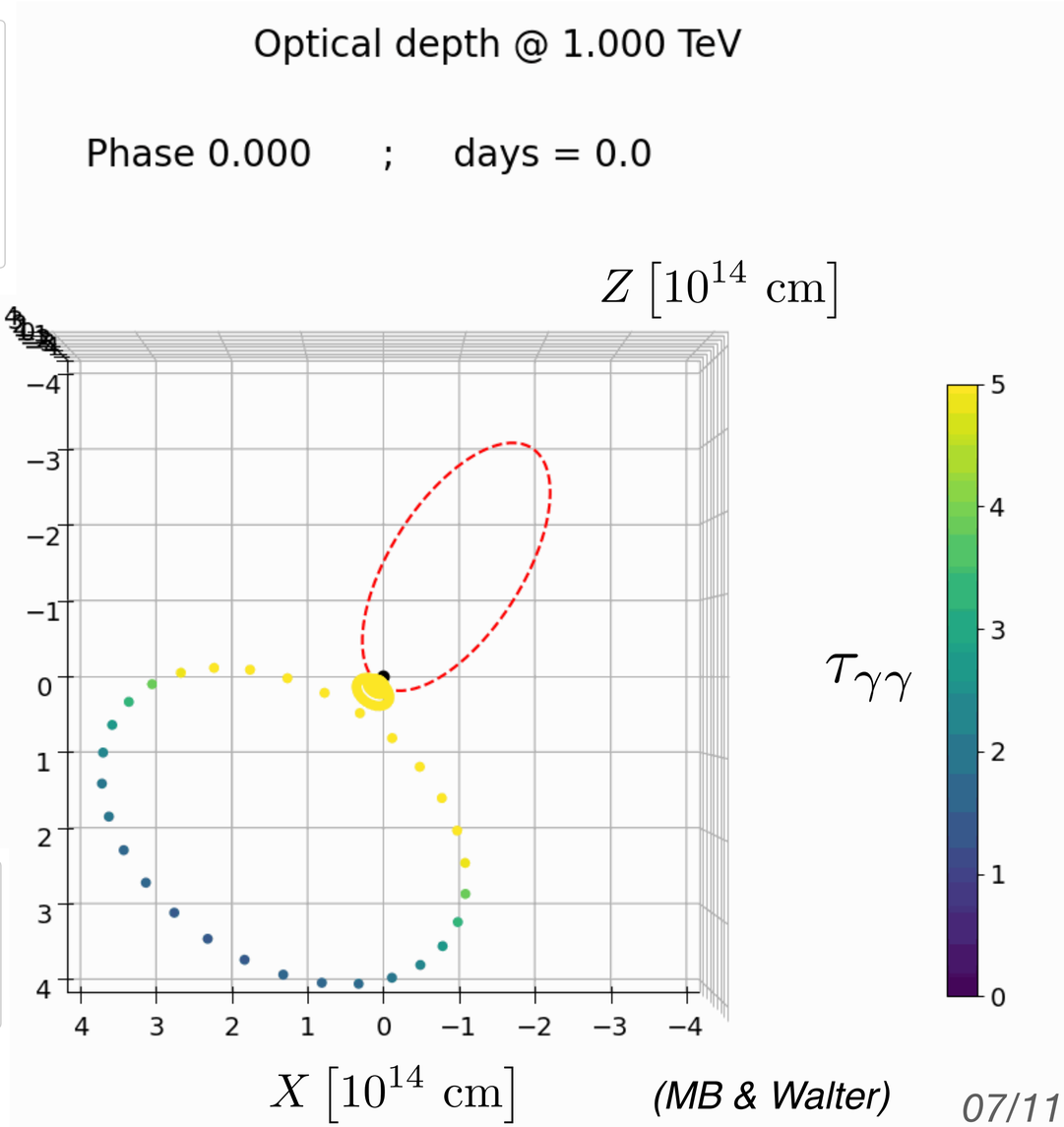






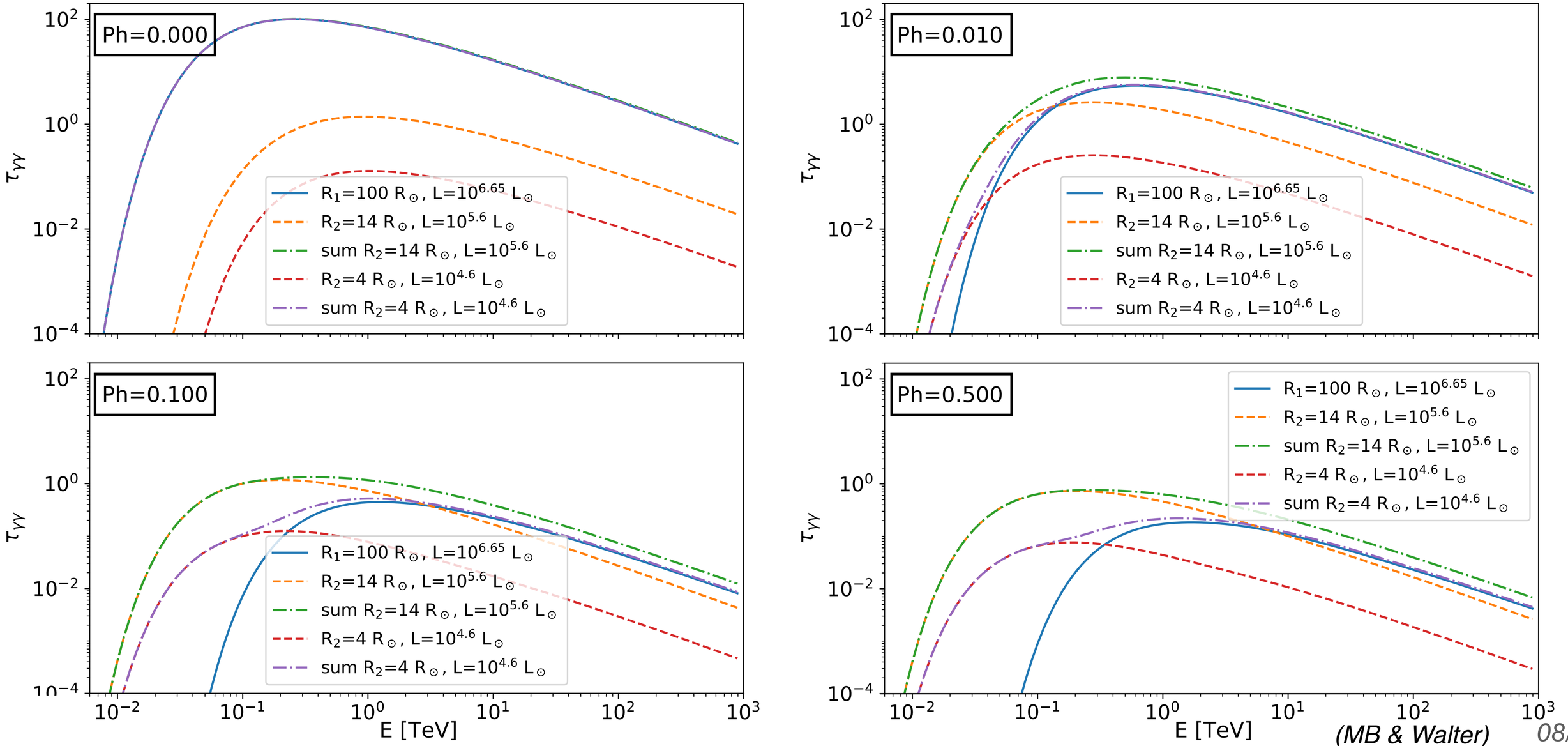
Simulated absorption: variability of the SED





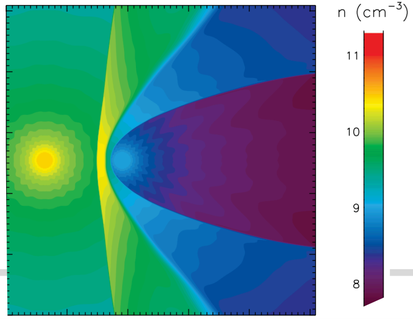
(MB & Walter)

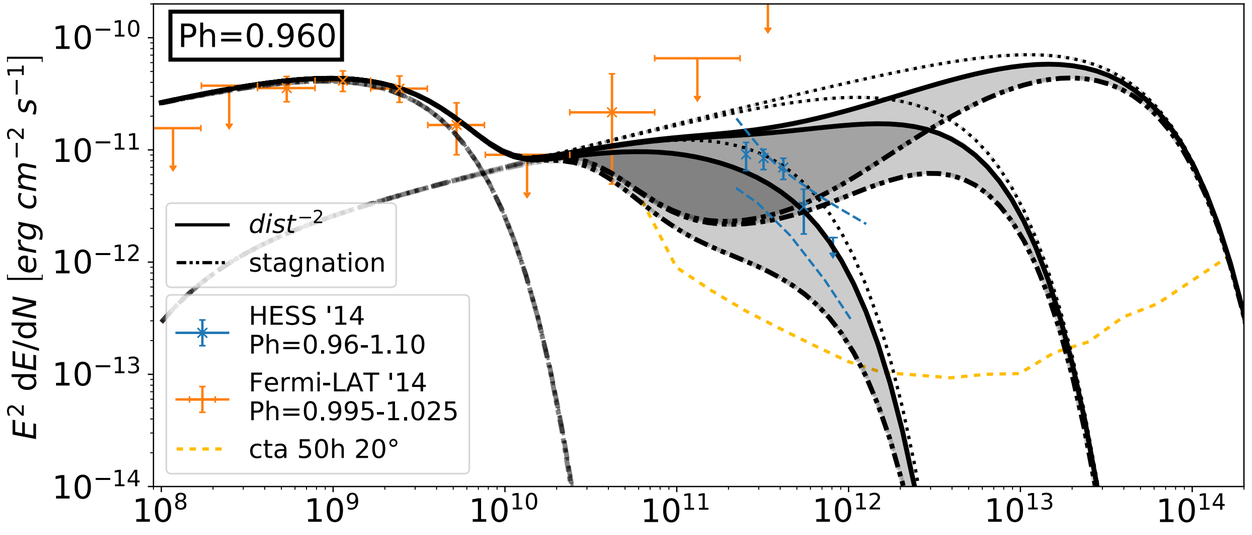
…with secondary star contribution: stagnation

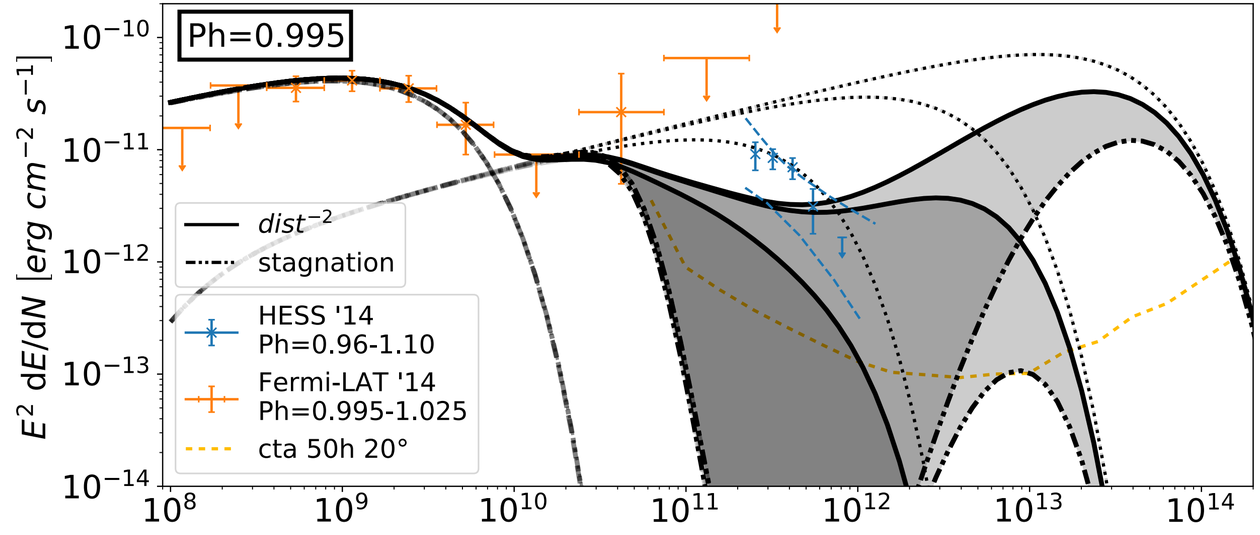


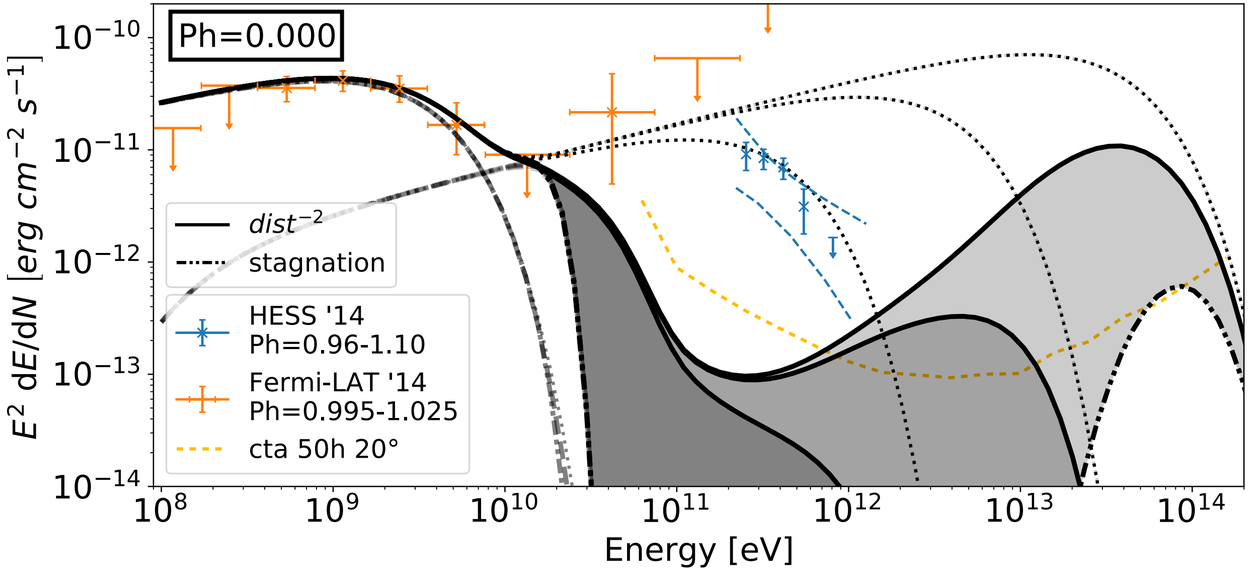
(MB & Walter)

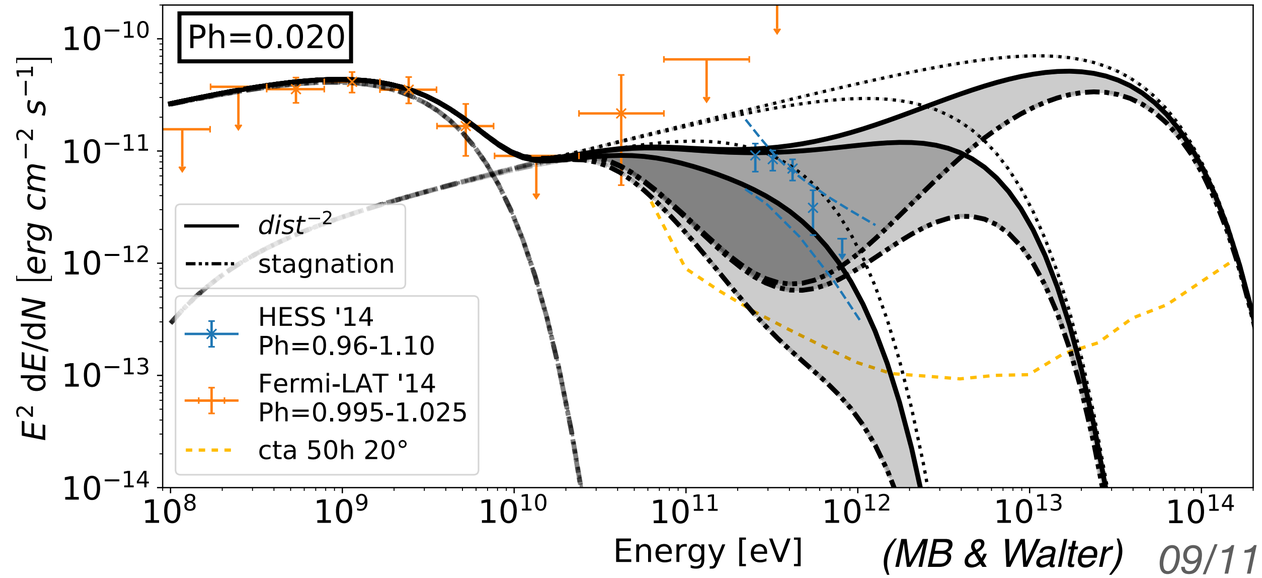
Double shock + both stars





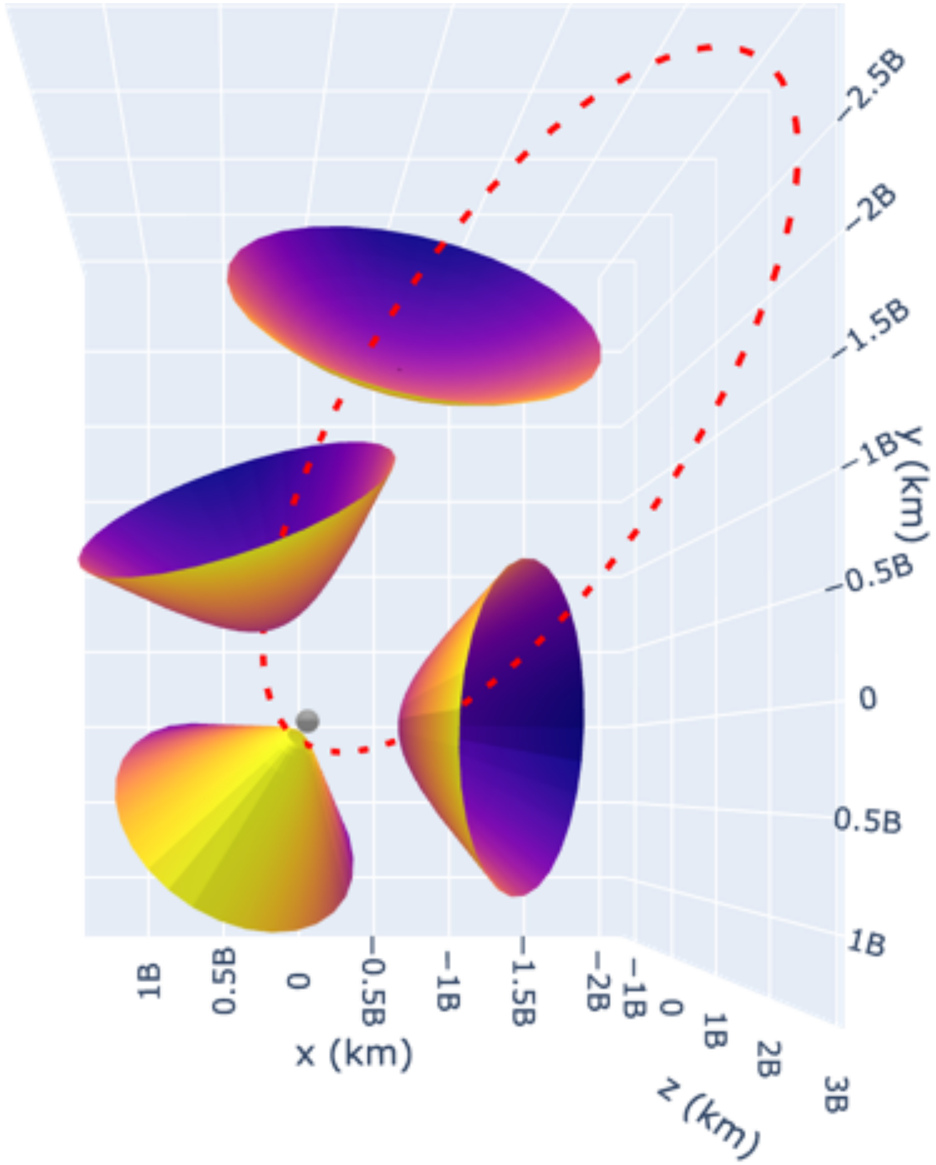


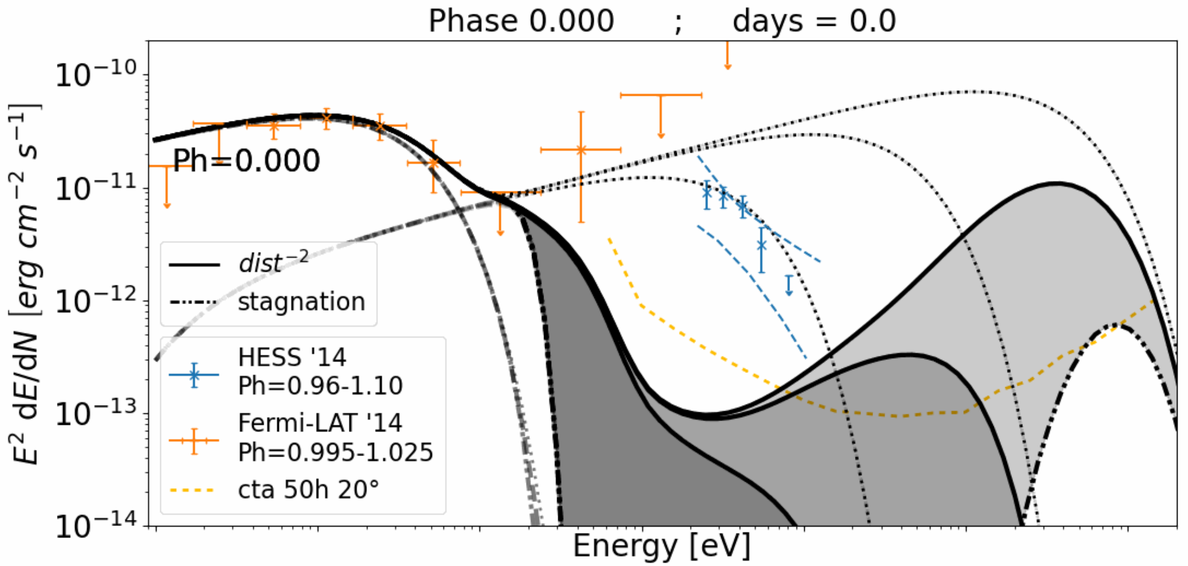


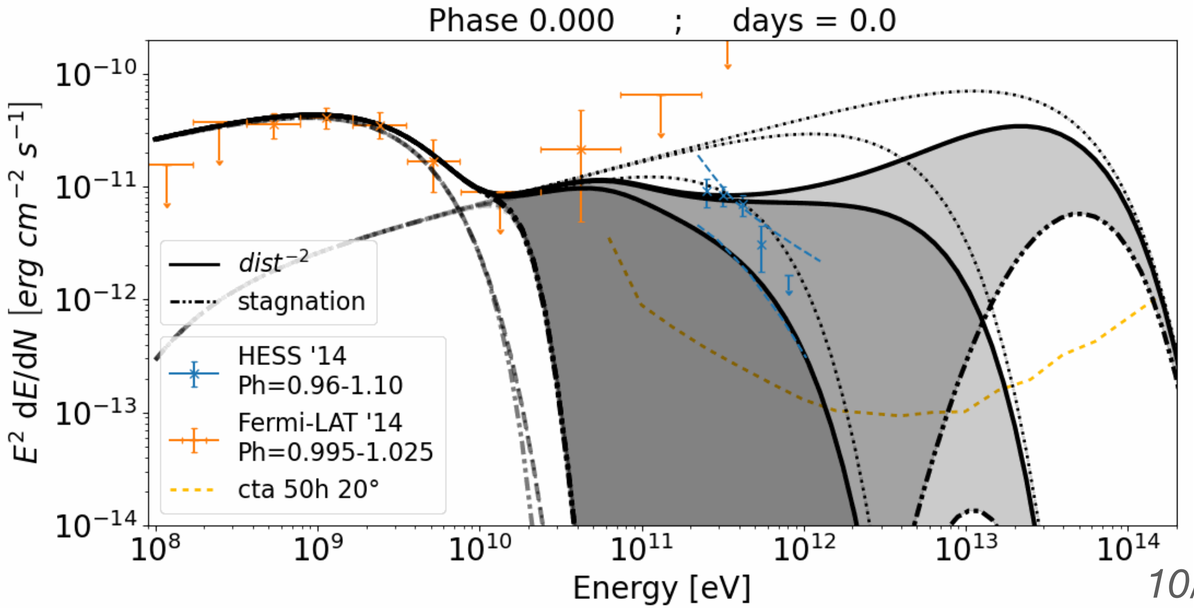


(MB & Walter) 09/11

Different orbital orientations







Conclusions & Take home message

- γ-γ absorption with consequent e^+/e^- production in the Galaxy requires very large amount of seed photons;
- in order to pair-produce, HE γ-ray in the energy range of CTA should interact with optical/UV photons;
- periodically variable γ-ray obscuration occurs if one of the following conditions occur:
  - the density of soft photons varies;
  - the density of HE photons varies;
  - the collision angles (w.r.t. observer) vary;

  } all γ-ray binary systems

- if $E_{cut\text{-}off}$ of intrinsic γ-ray spectrum > $E(\tau_{max})$, CTA observations performed during different orbital phases can provide useful indirect informations on:
  - ☑ location where HE γ-rays are produced
  - ☑ orbital orientation of the binary system
  - ☑ magnetic field
  - ☑ maximum energy at which particles can be accelerated

the **absorption model** we have **developed** is an important tool to interpret **CTA data**