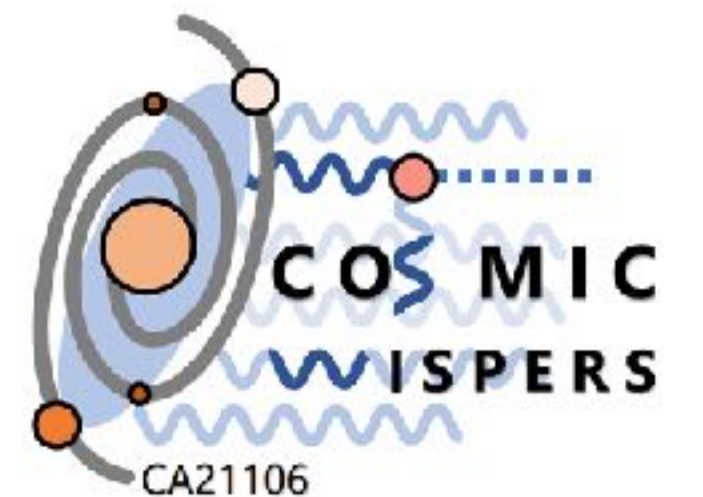


NuSTAR as an Axion Helioscope

Elisa Todarello (University of Turin and INFN Turin)

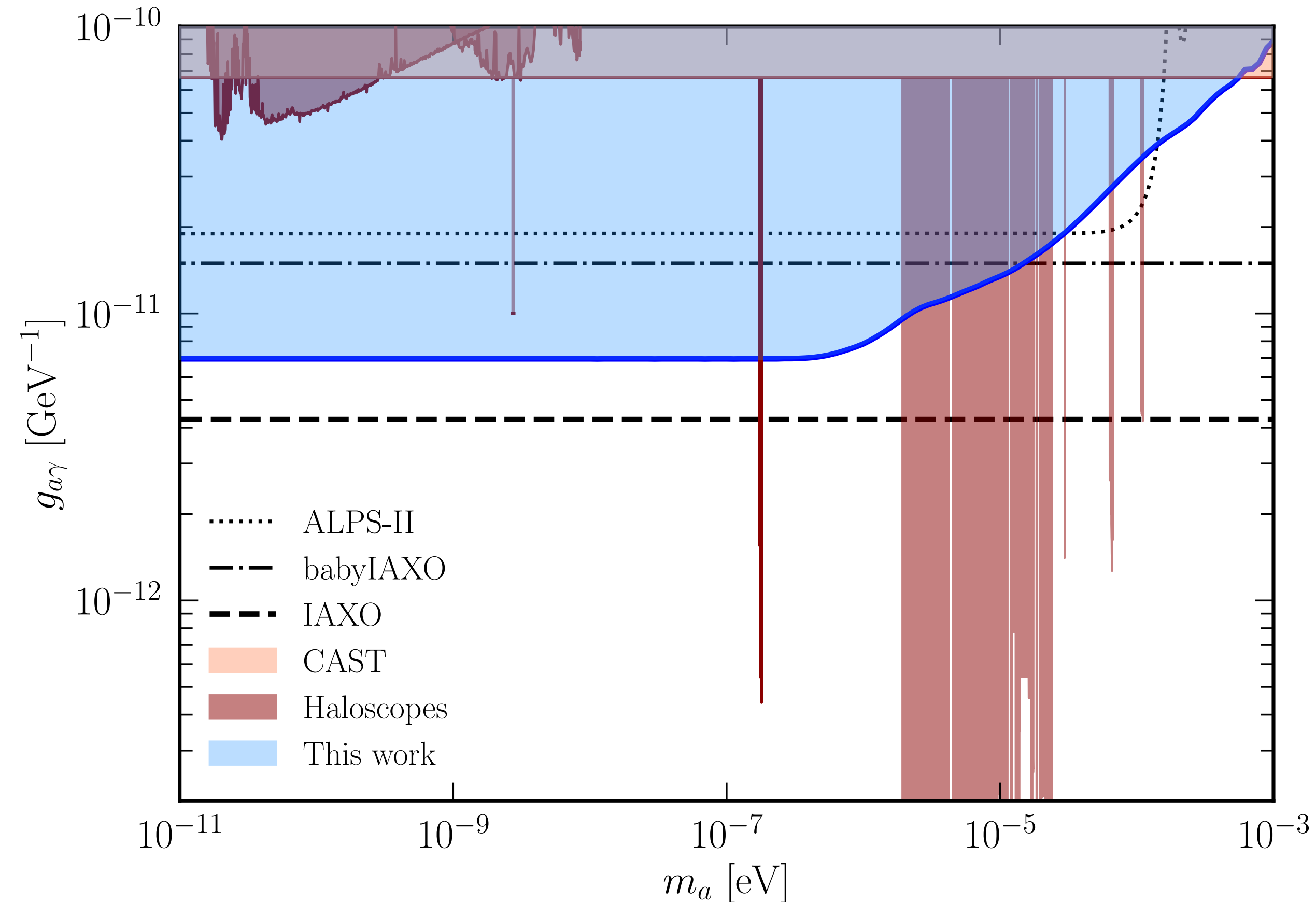
19th Patras Workshop on Axions, WIMPs and WISPs
Sep 18, 2024



NuSTAR as an Axion Helioscope

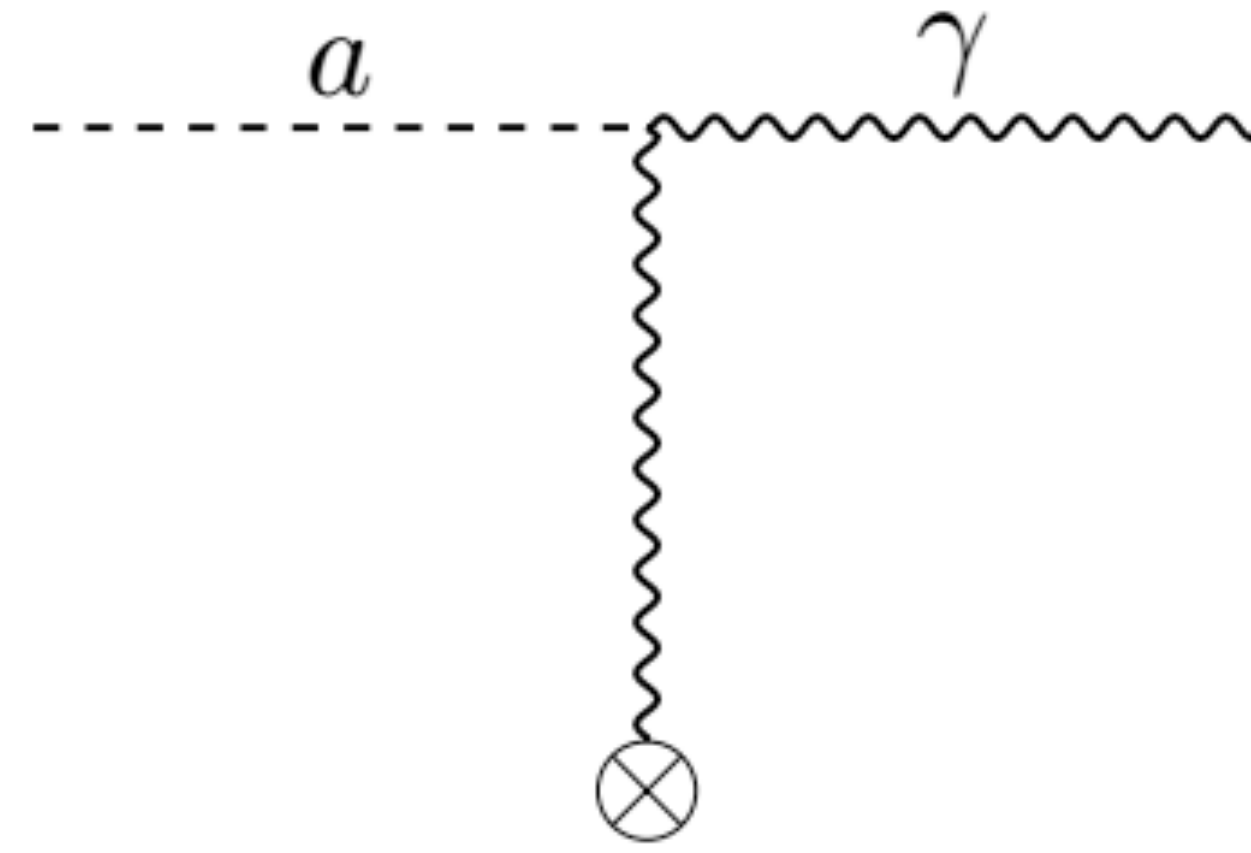
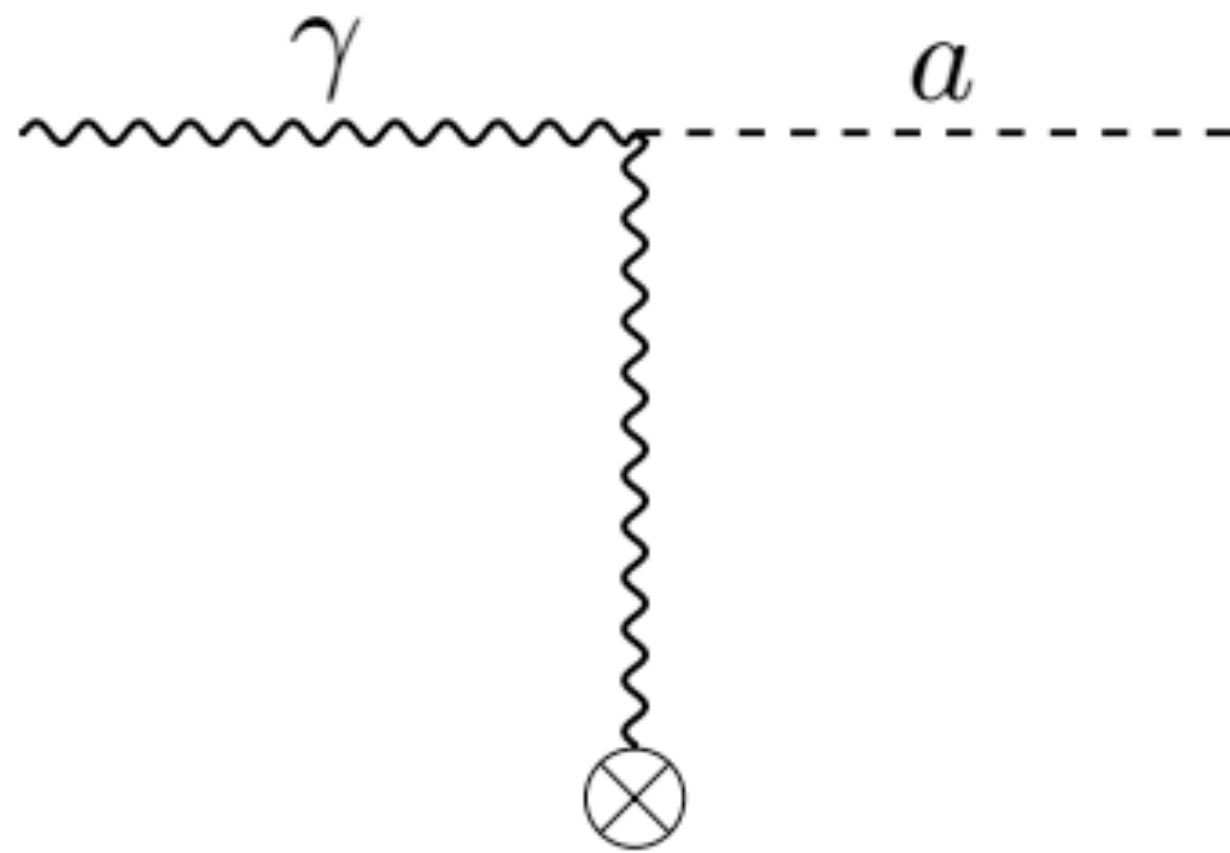
J. Ruz, **ET**, J. K. Vogel, M. Giannotti, B. Grefenstette, H. S. Hudson, I. G. Hannah, I. G. Irastorza, C. S. Kim, T. O'Shea, M. Regis, D. M. Smith, M. Taoso, J. Trujillo Bueno

arXiv:2407.03828

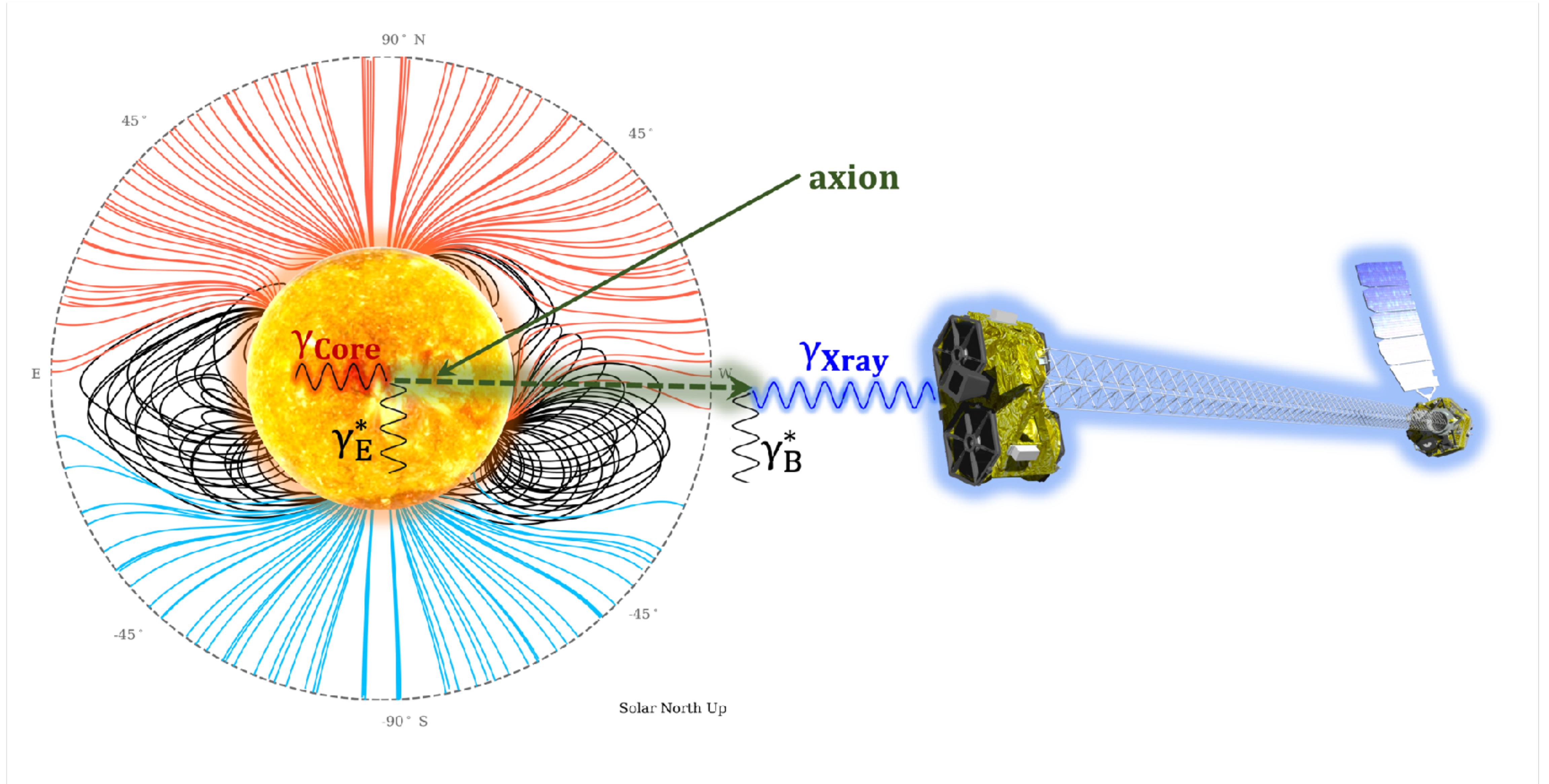


Axion-Photon Conversion

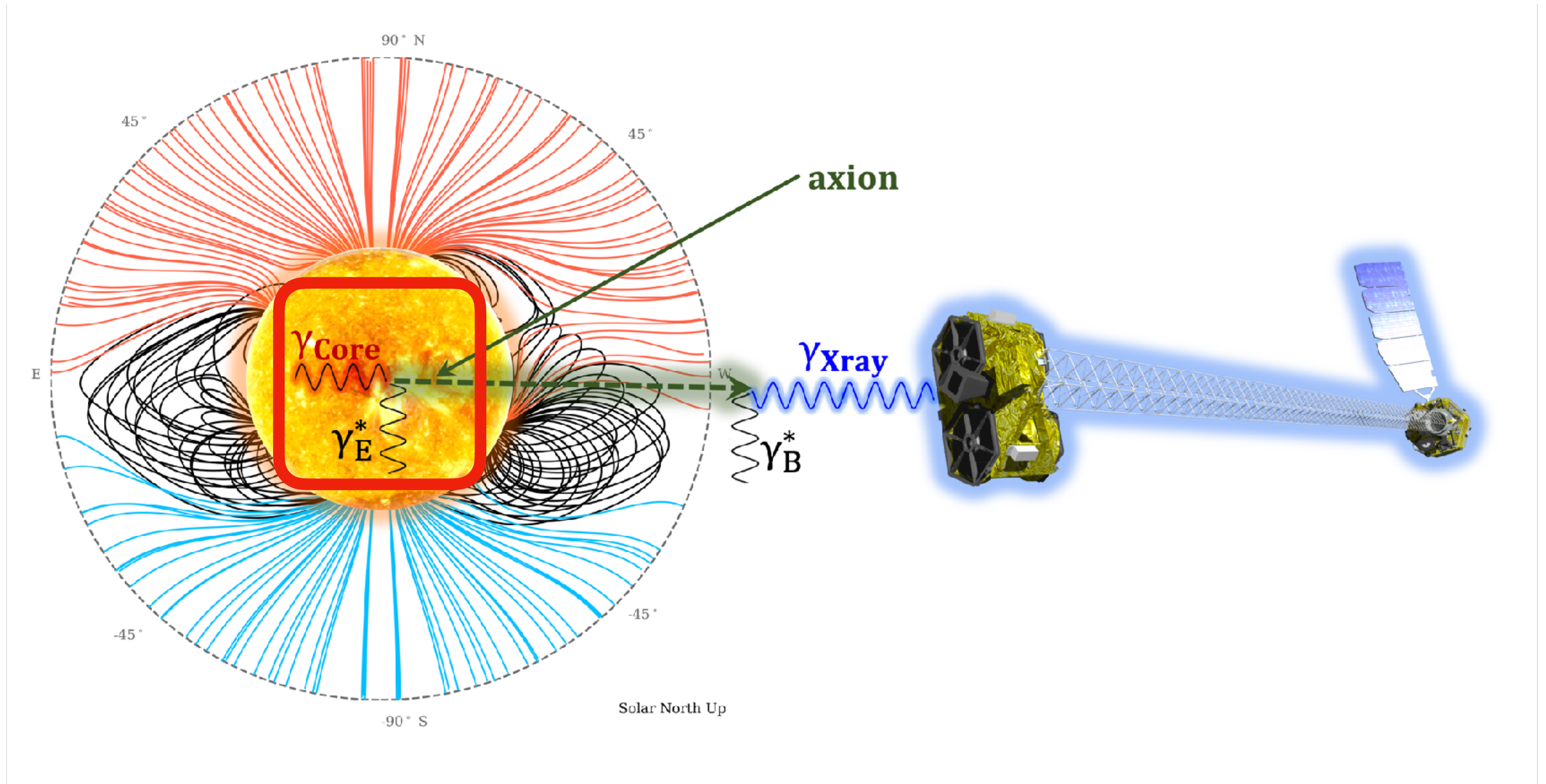
$$\mathcal{L}_{a\gamma\gamma} = \frac{1}{4} g a F_{\mu\nu} \tilde{F}^{\mu\nu}$$



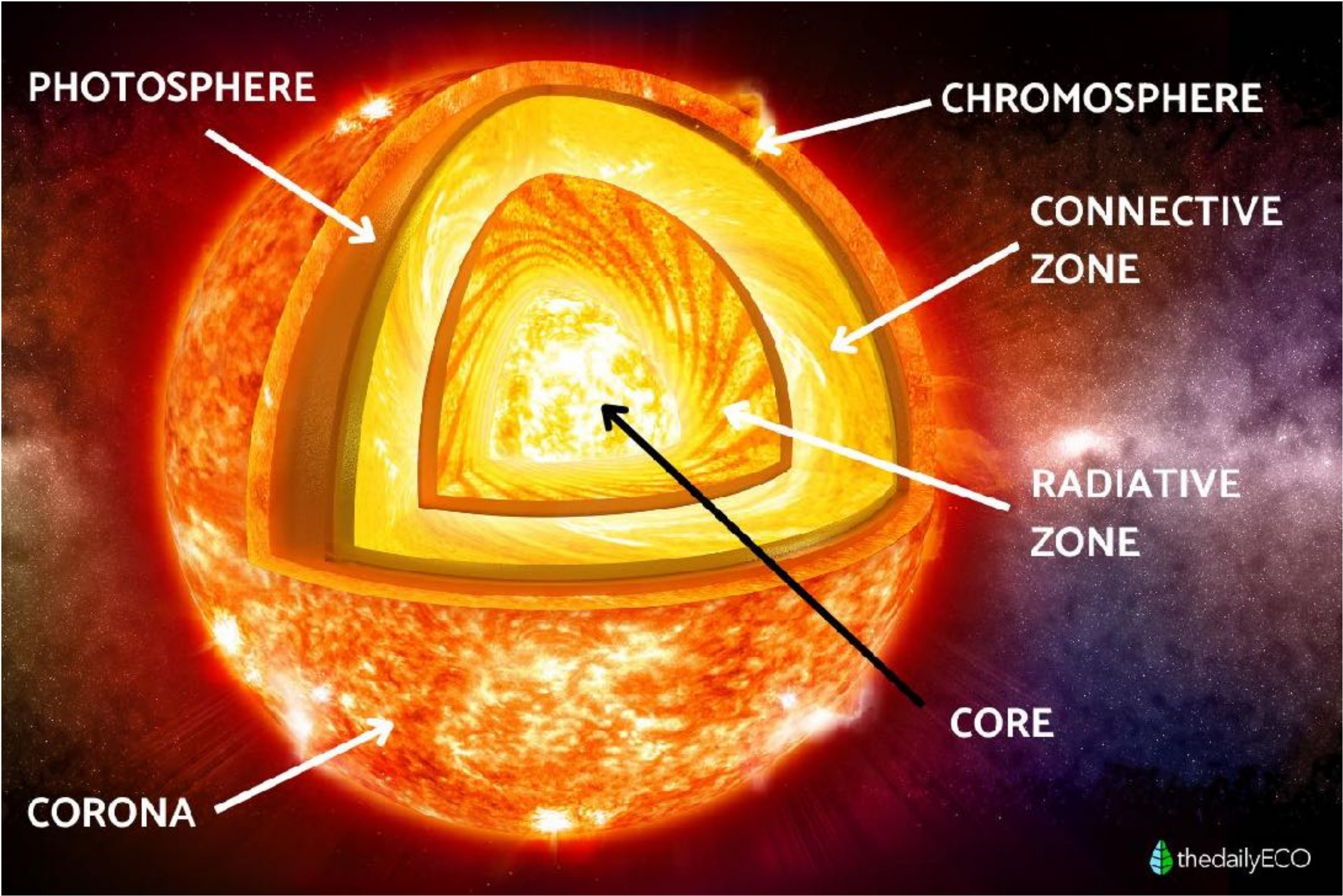
NuSTAR as an Axion Helioscope



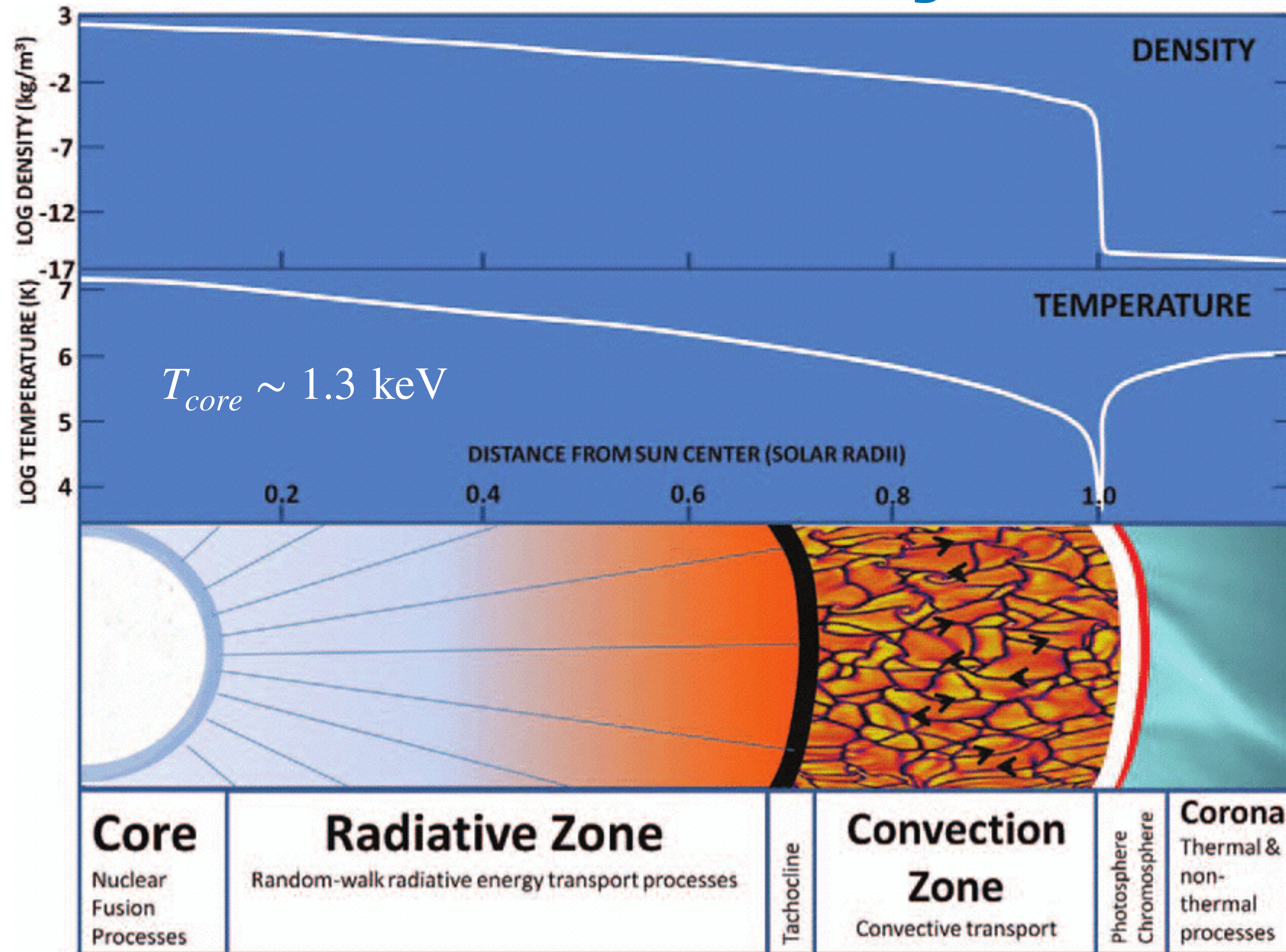
NuSTAR as an Axion Helioscope



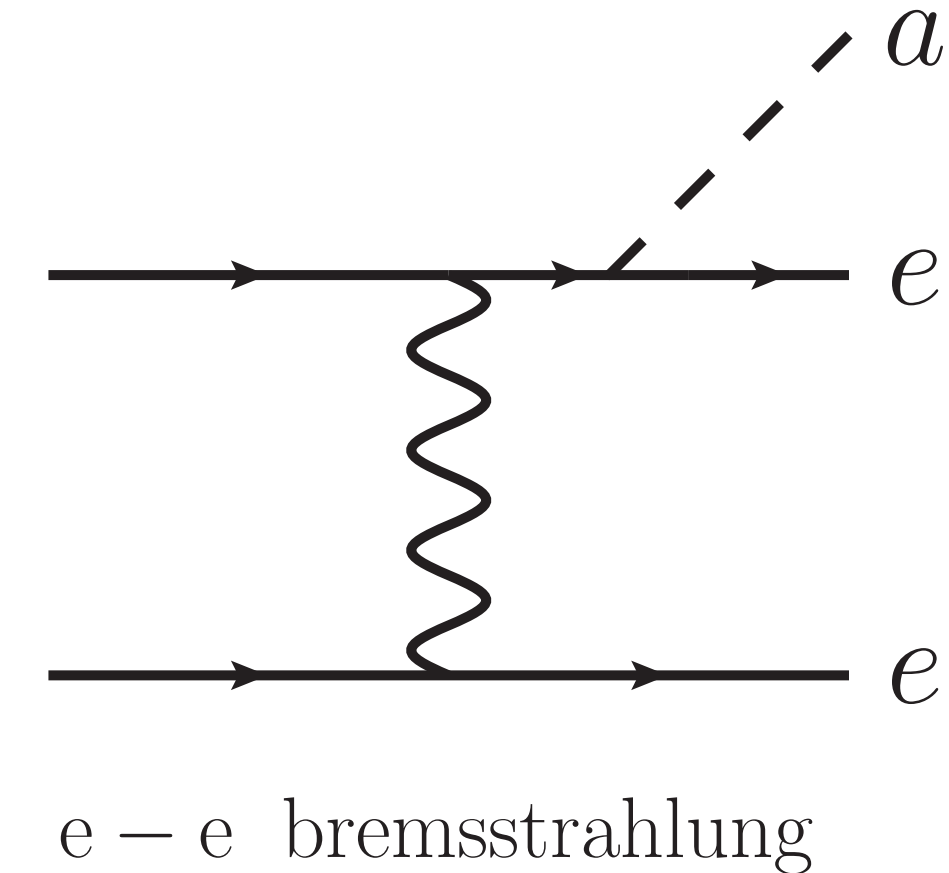
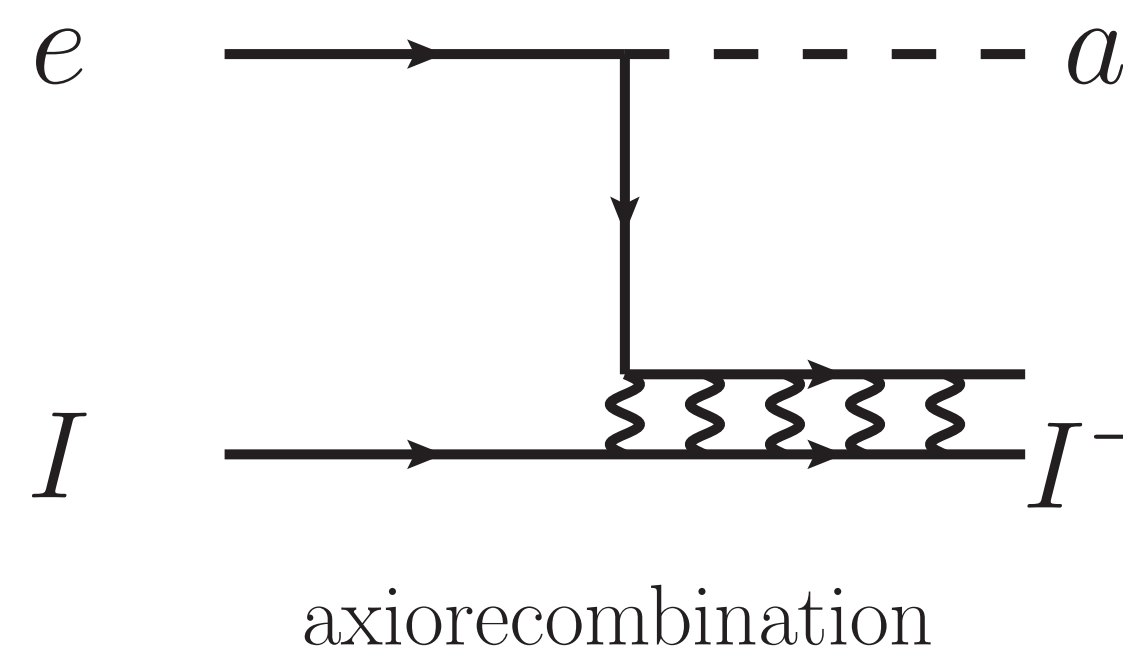
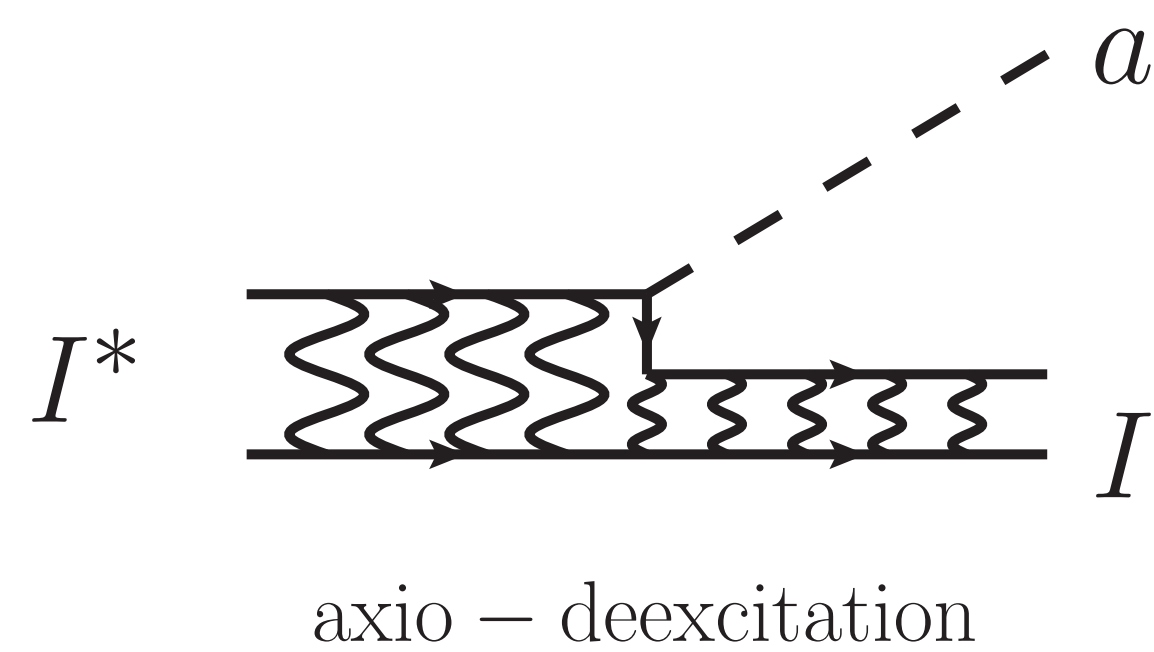
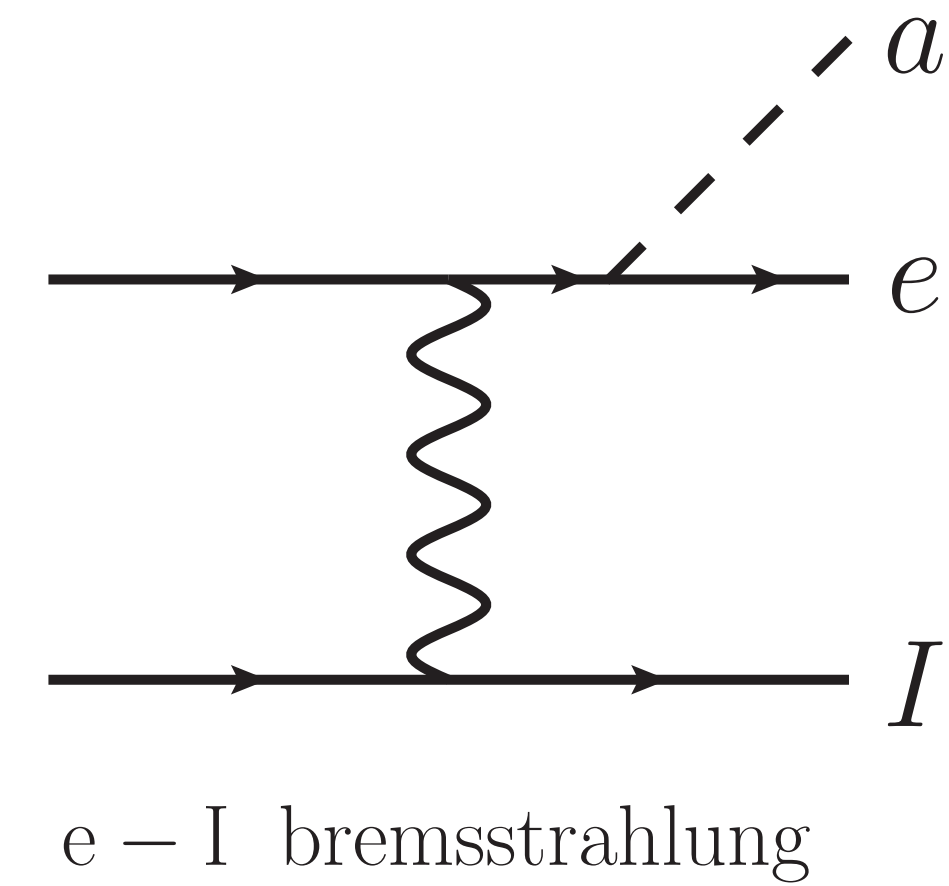
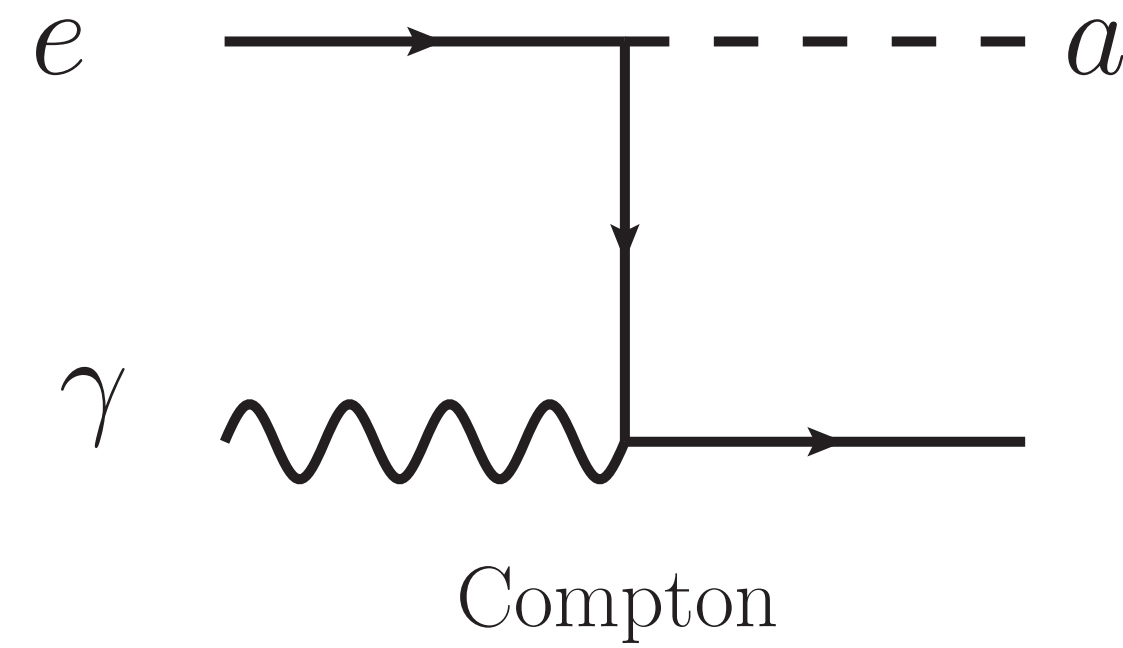
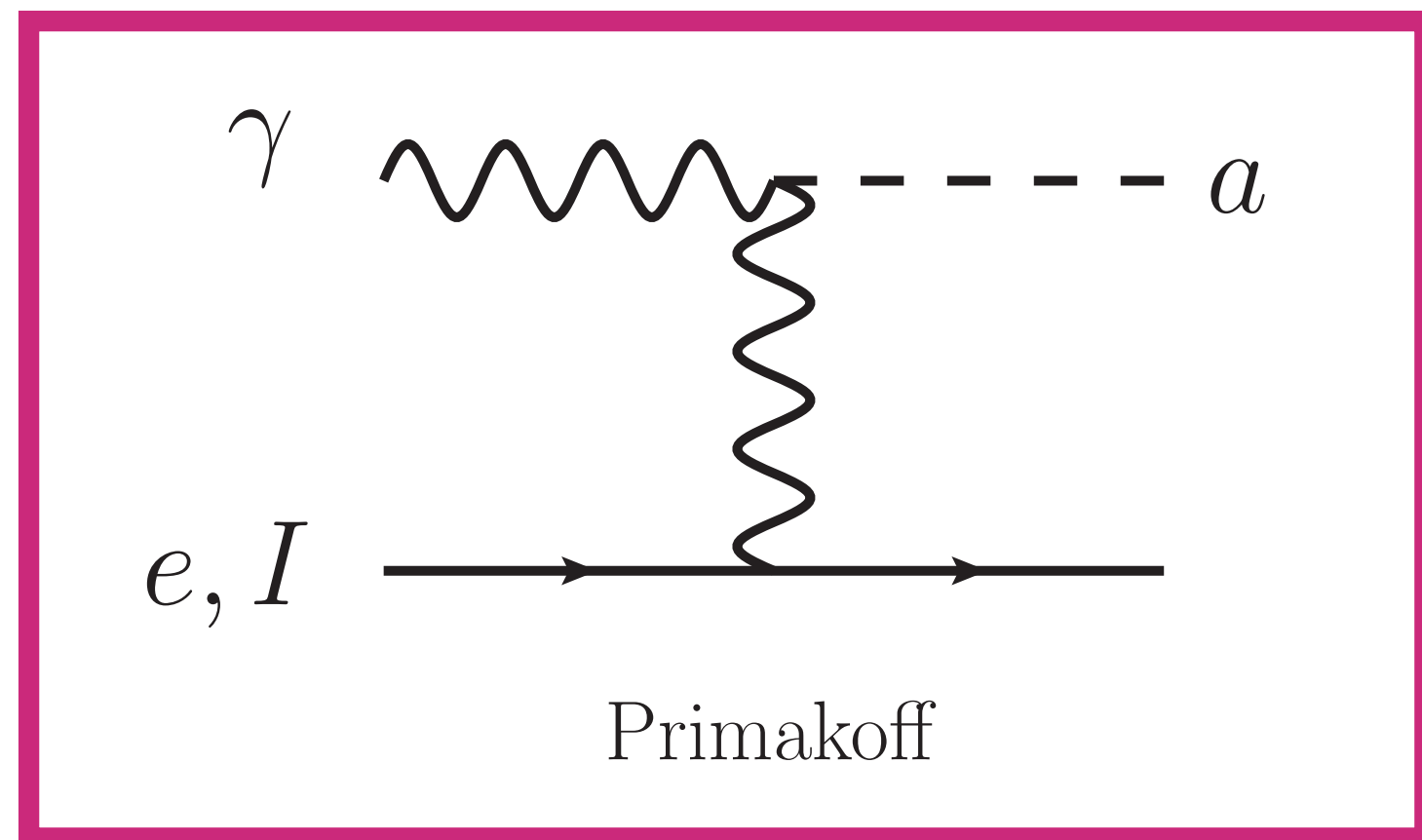
The Sun



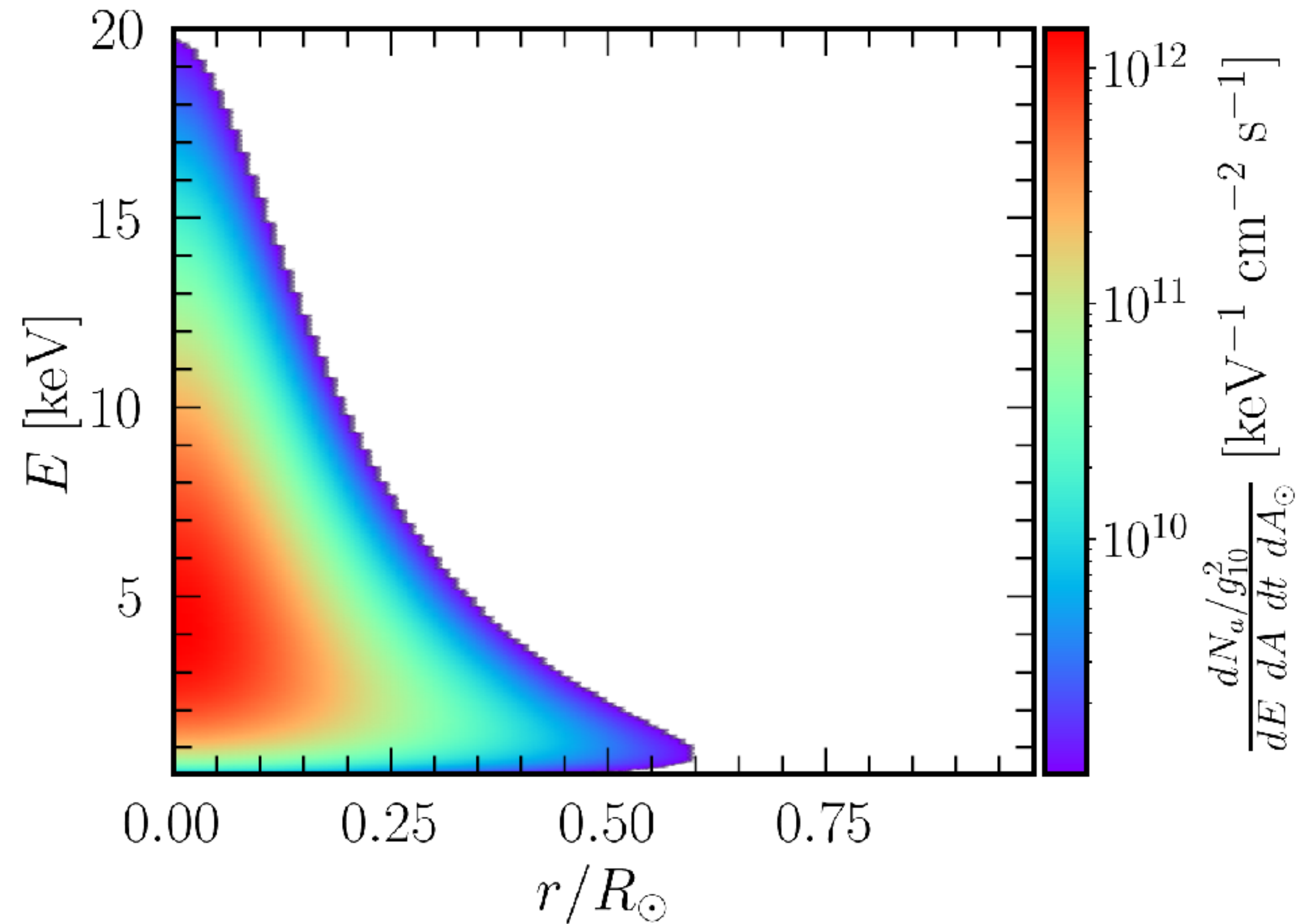
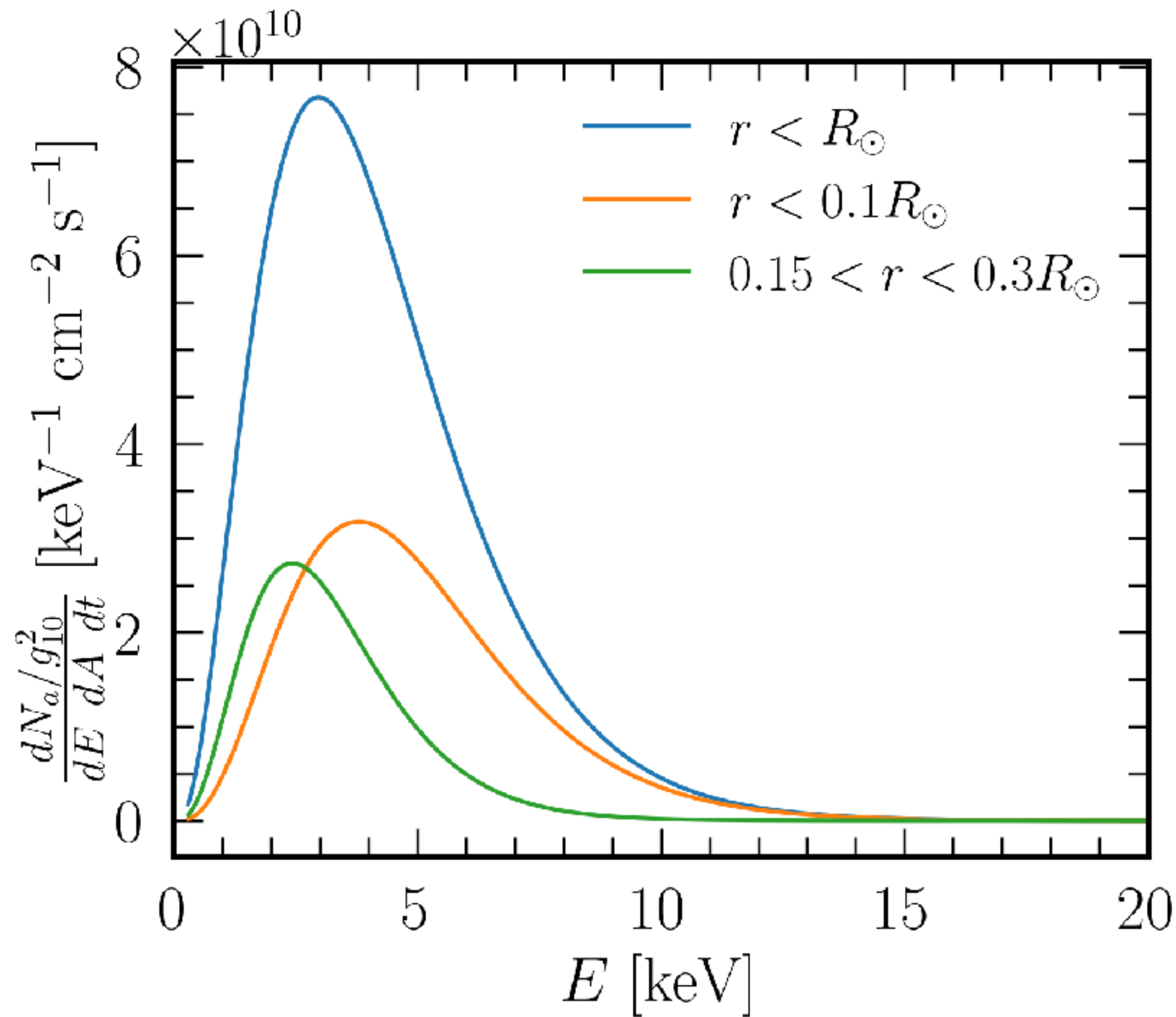
The Sun's Layers



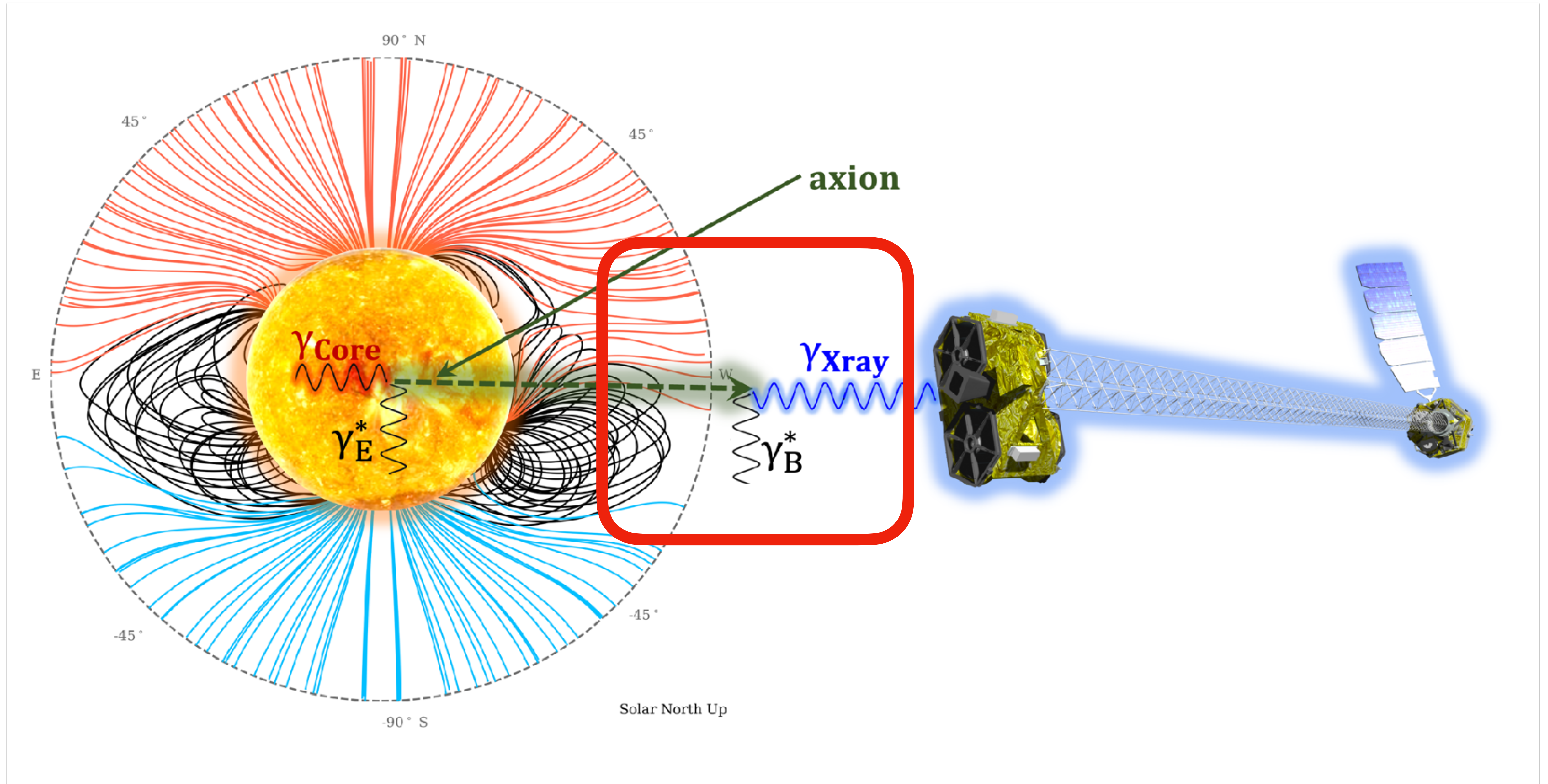
Axions from the Solar Core



Axion Flux at Earth



NuSTAR as an Axion Helioscope



Axion-Photon Conversion

In a static background $\omega = \omega_a$

$$(n^2\omega^2 + \nabla^2)\vec{A} = ig\omega\vec{B}_0a_0 e^{i\vec{k}_a\cdot\vec{x}}$$

Index of refraction in a weakly magnetized plasma

$$n = \frac{k}{\omega} = \frac{\sqrt{\omega^2 - \omega_p^2}}{\omega}$$



The photon gets an effective mass

Conversion of Ultra-relativistic Axions

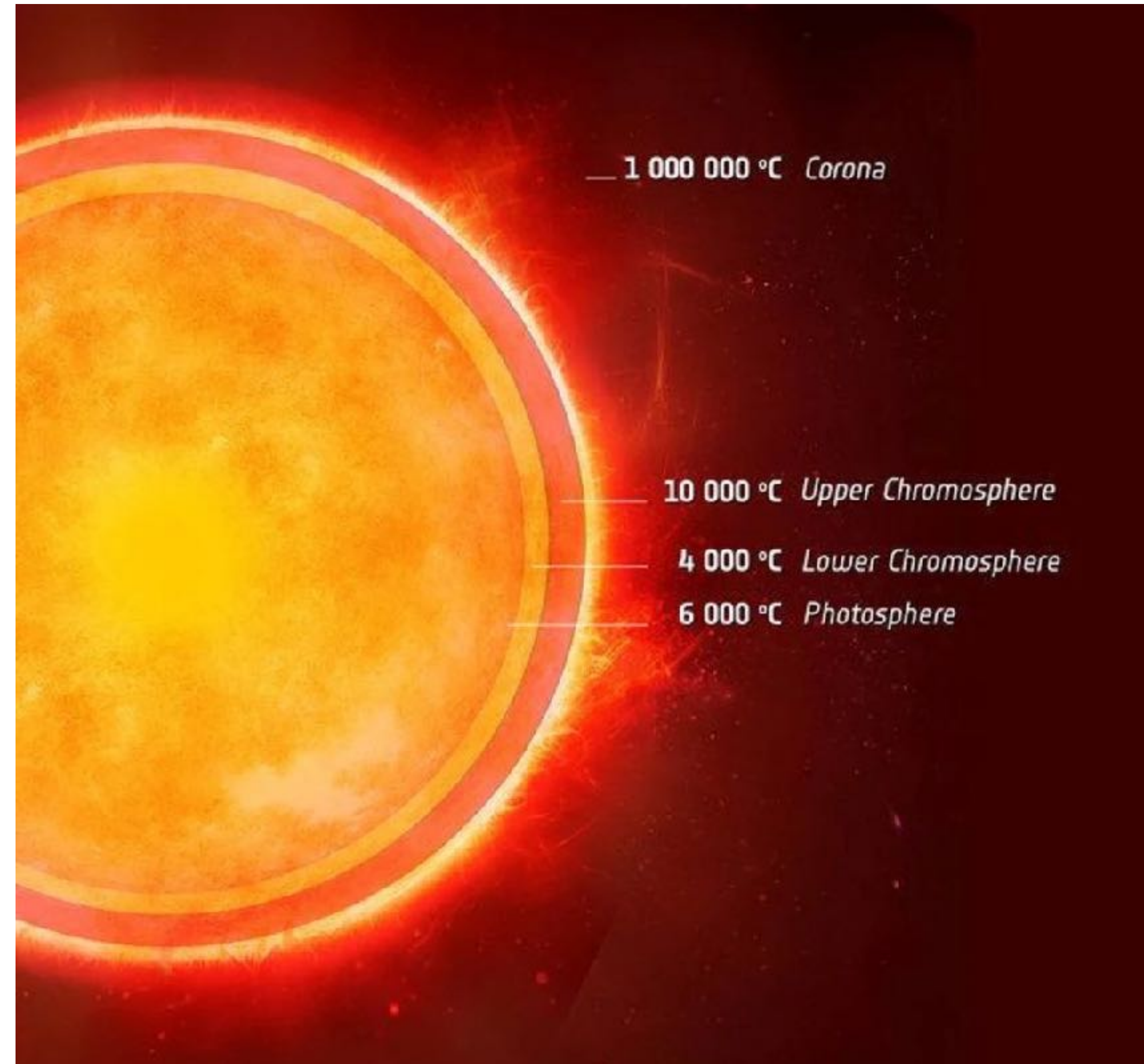
In the limit $E \gg \omega_p$

$$P_{a \rightarrow \gamma}(h) = \frac{1}{4} g^2 \left| \int_0^h dh' B_{\perp}(h') e^{i \int_0^{h'} dh'' q(h'')} e^{-\frac{1}{2} \int_{h'}^h dh'' \Gamma(h'')} \right|^2$$

$$q = k - k_a \approx \frac{\omega_p^2 - m_a^2}{2E}$$

$$\Gamma = \sum_i n_i \sigma_i$$

The Solar Atmosphere



Quiet Sun's Magnetic Field

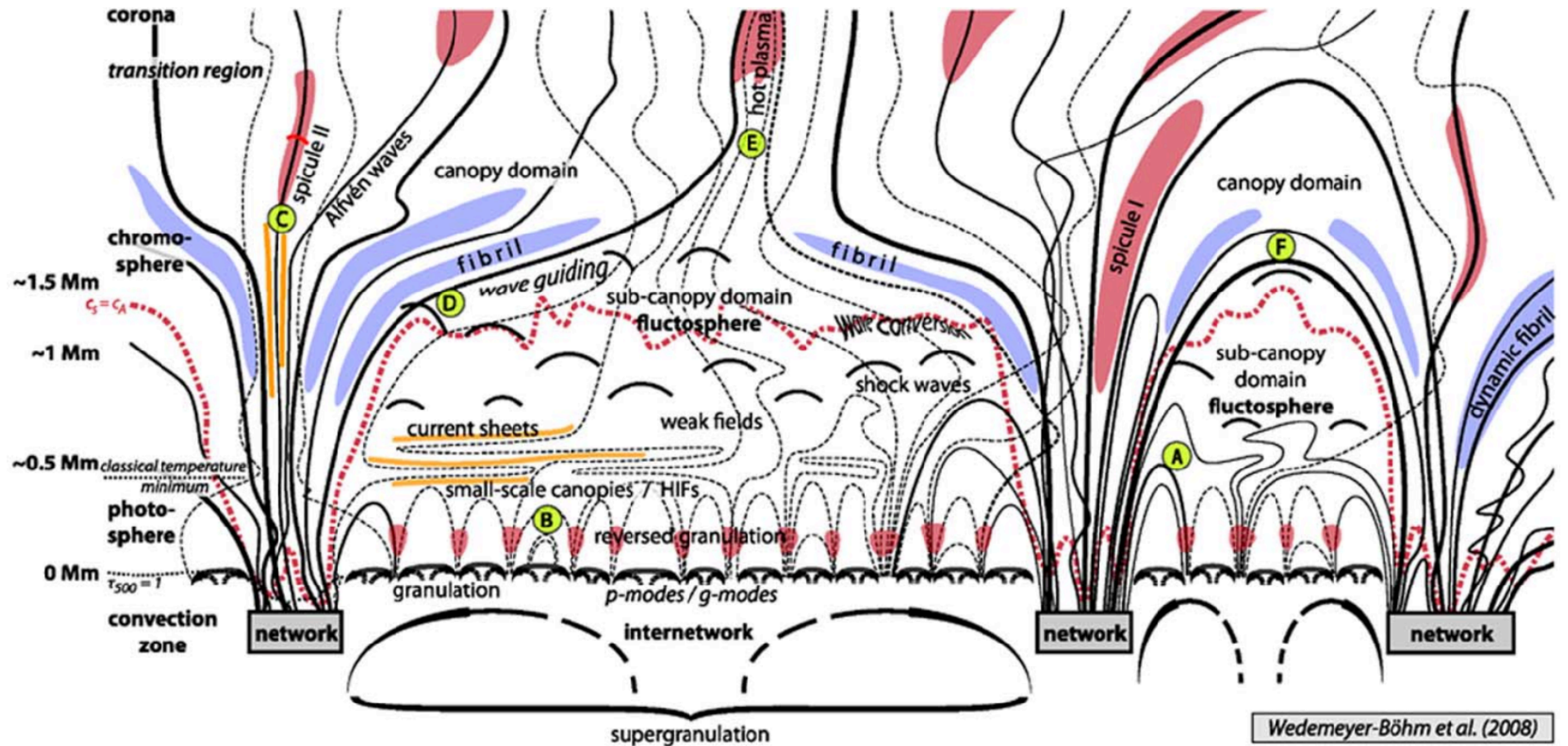
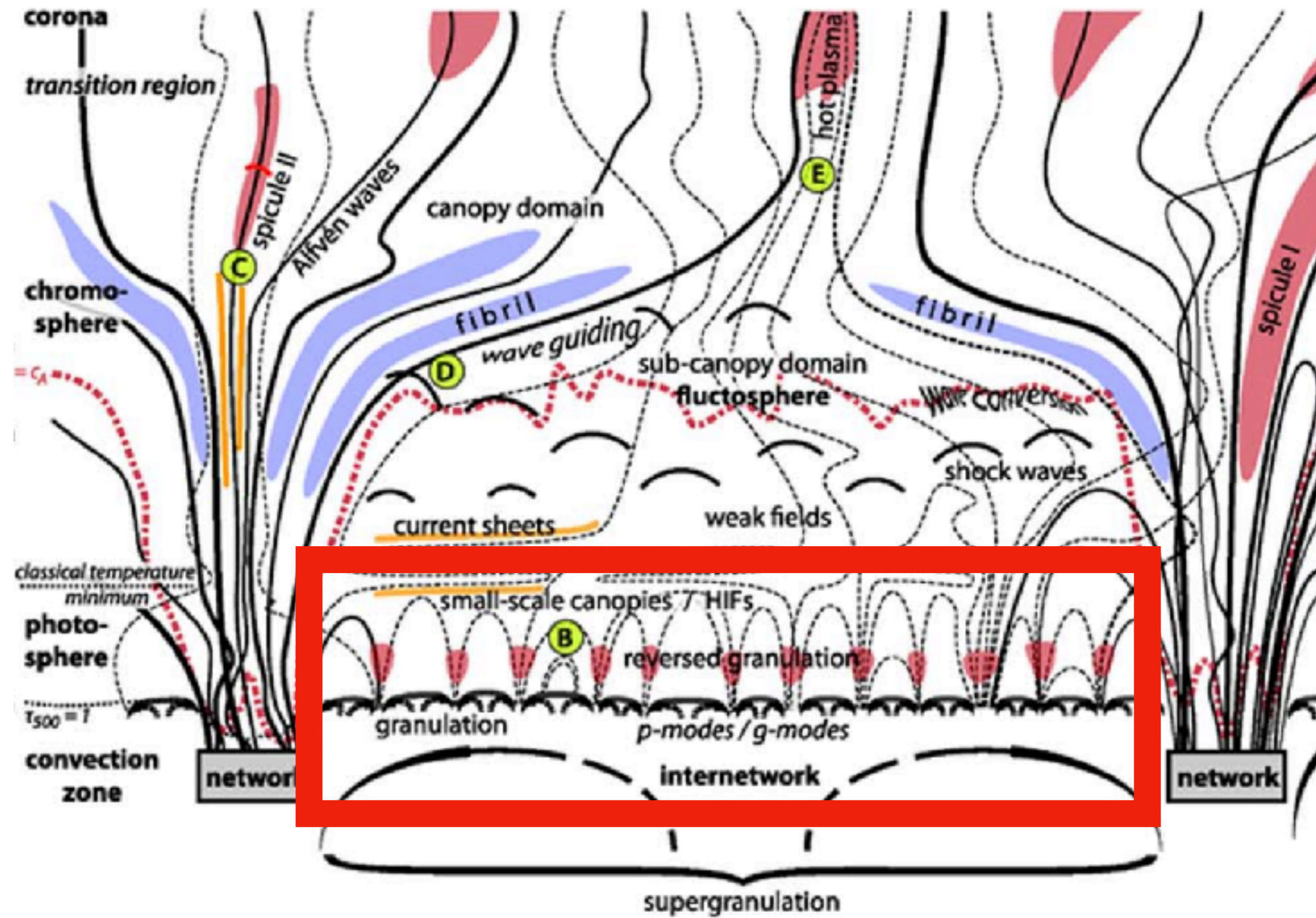


Fig. 16 Schematic, simplified structure of the lower quiet Sun atmosphere (dimensions not to scale): The *solid lines* represent magnetic field lines that form the magnetic

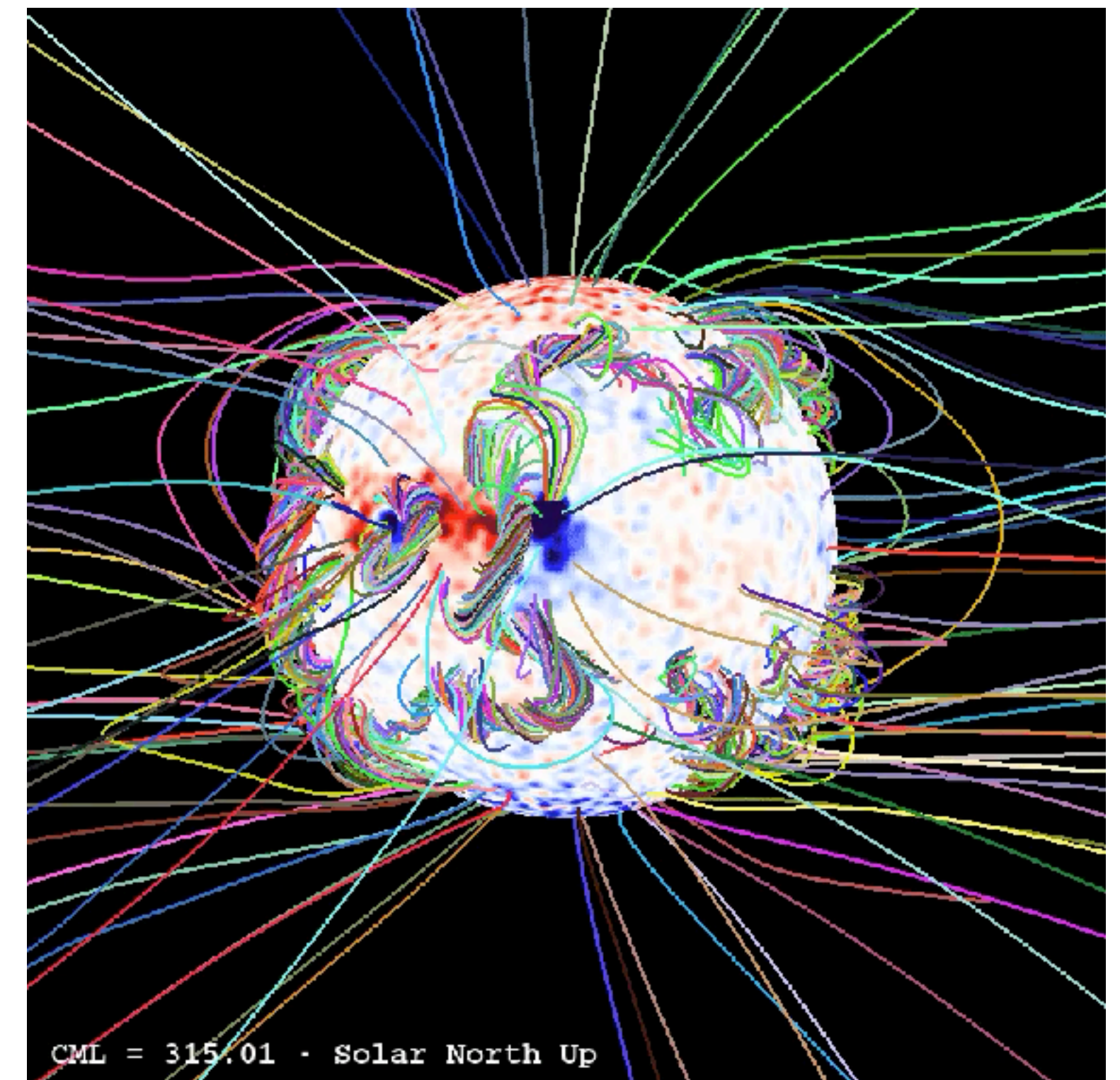
Magnetic Field

Photosphere (Rempel, 2014 ApJ 789 132)



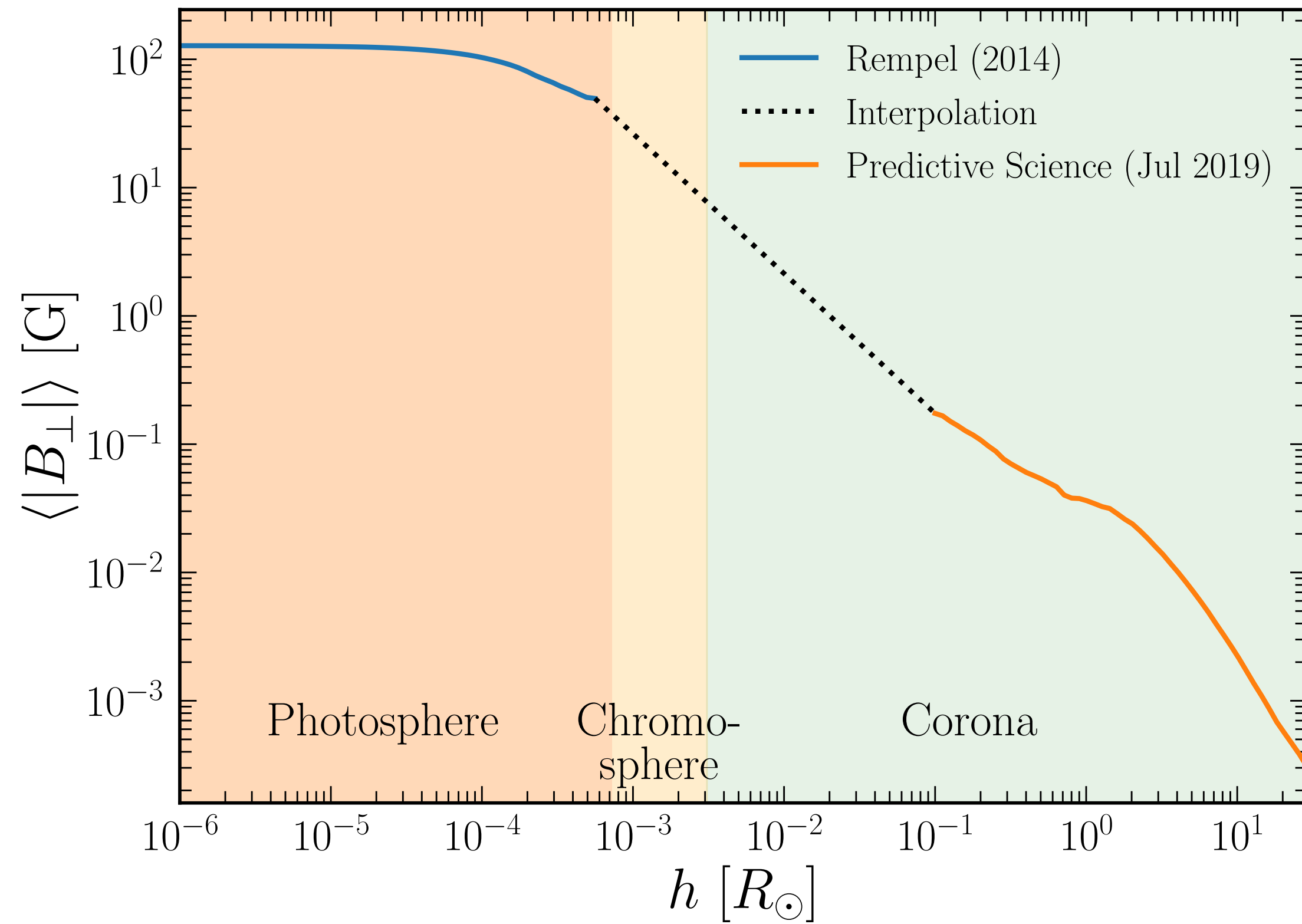
↔ Interpolation ↔

Corona (Predictive Science Inc., 2019 eclipse)

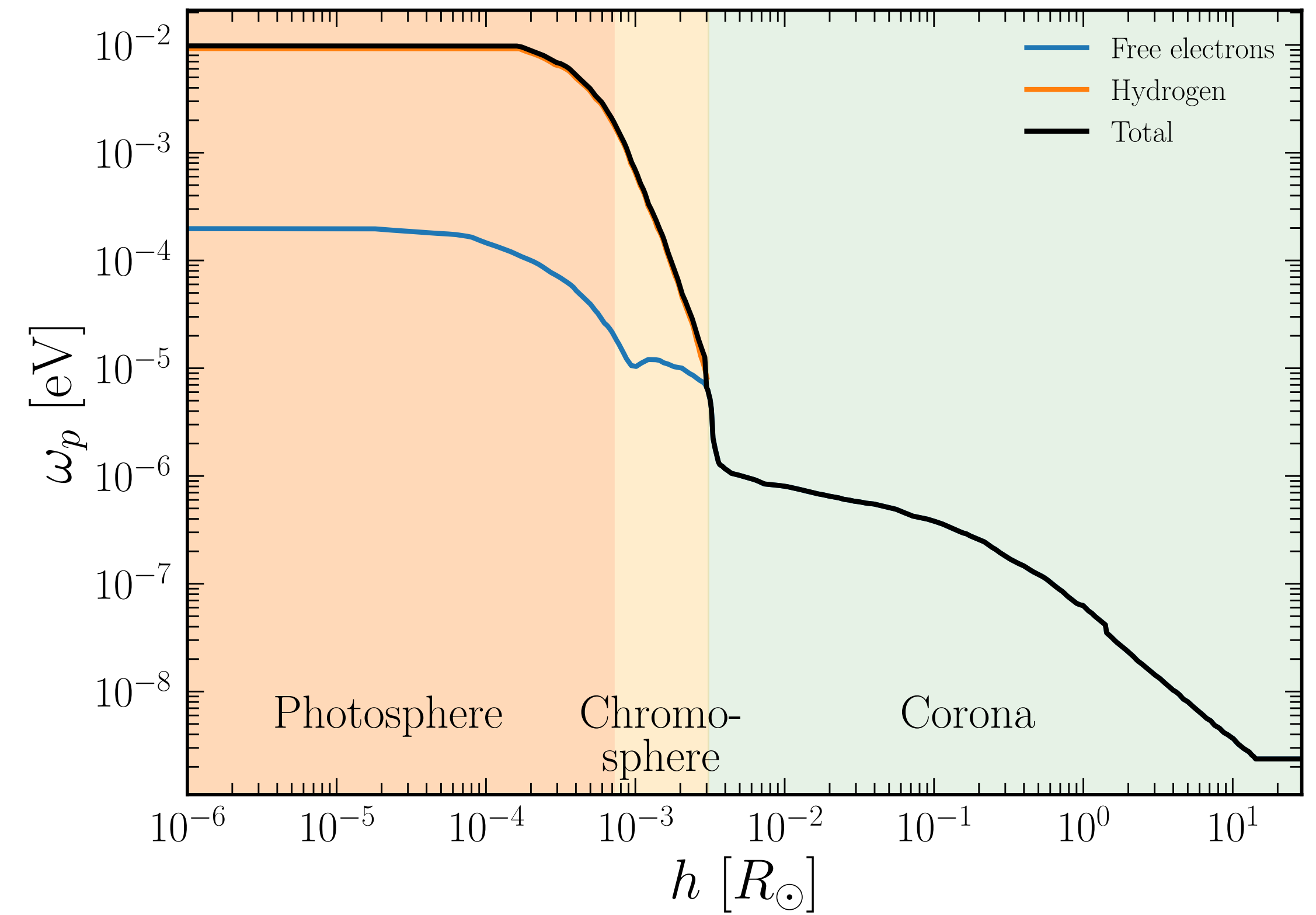


Model of the Quiet Sun's Atmosphere

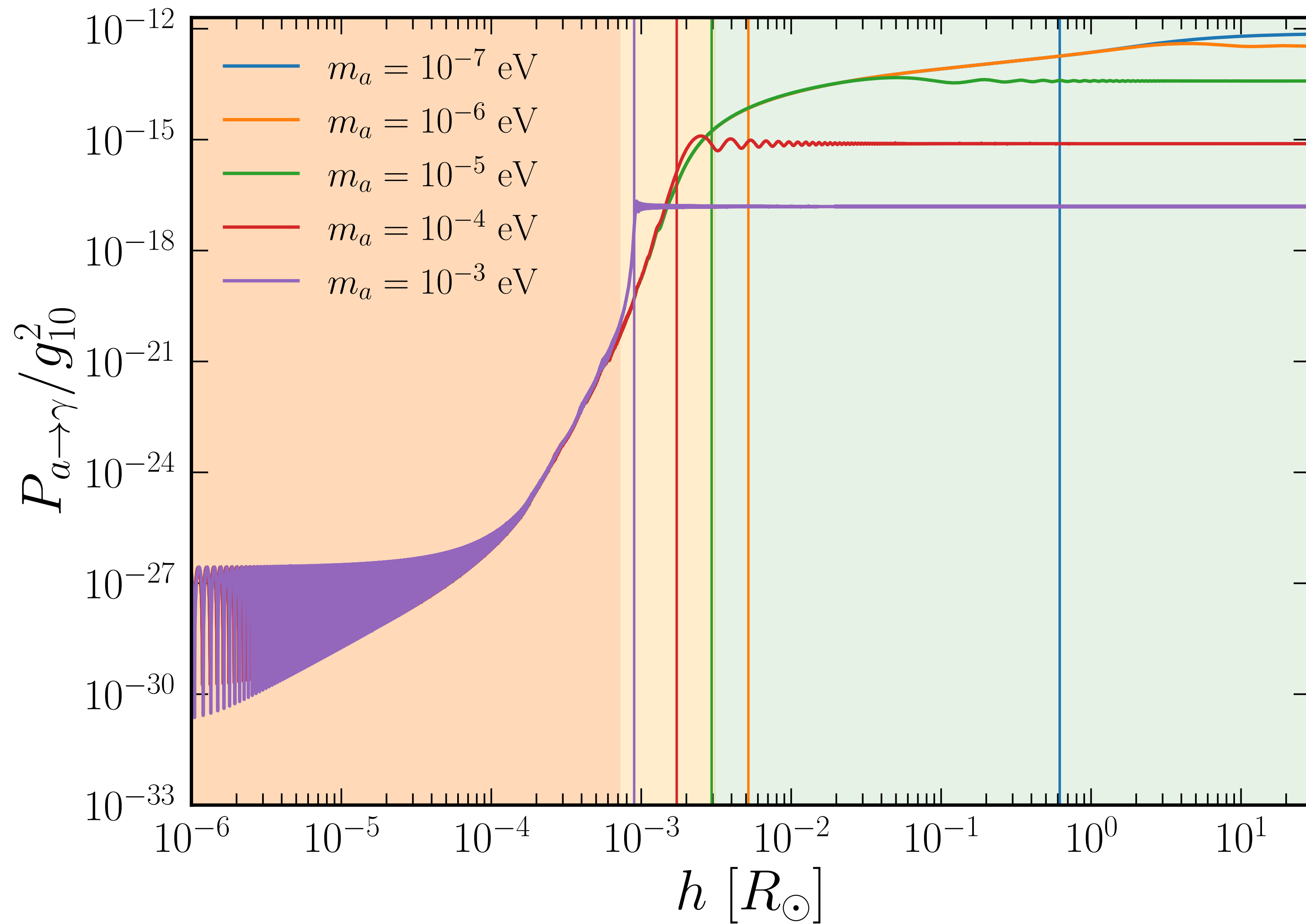
Perpendicular magnetic field



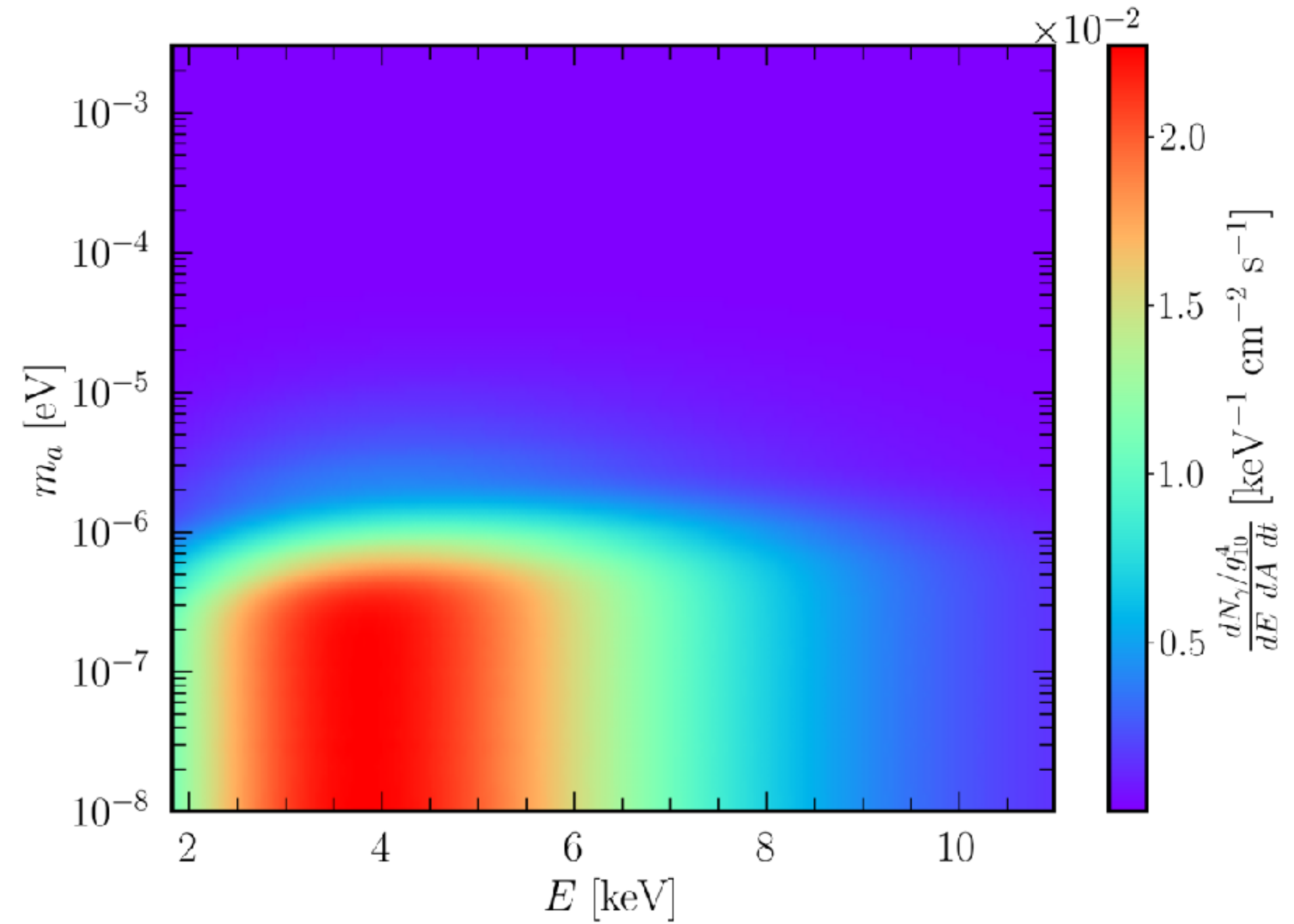
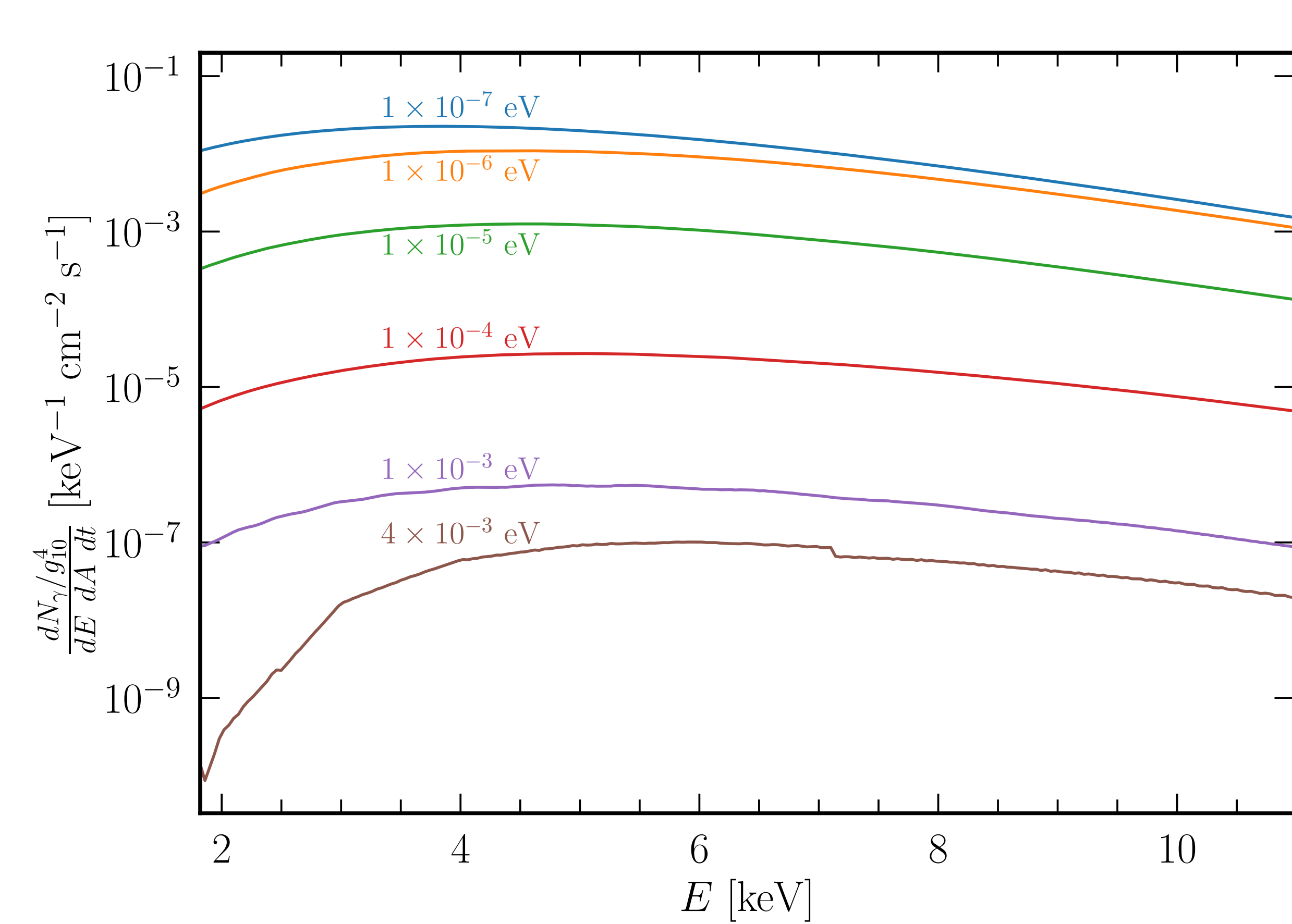
Plasma frequency



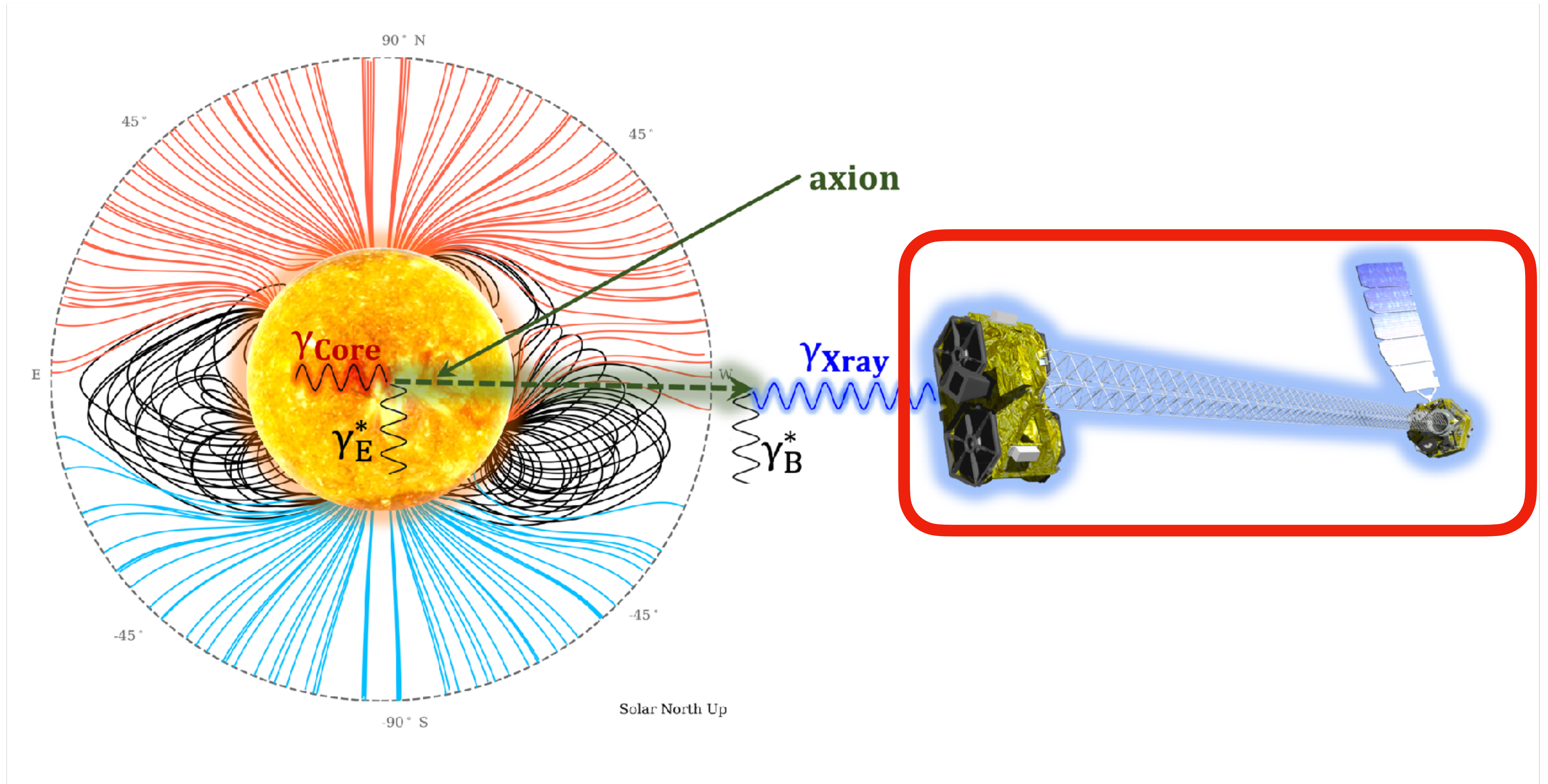
Conversion Probability



X-ray Flux



NuSTAR as an Axion Helioscope



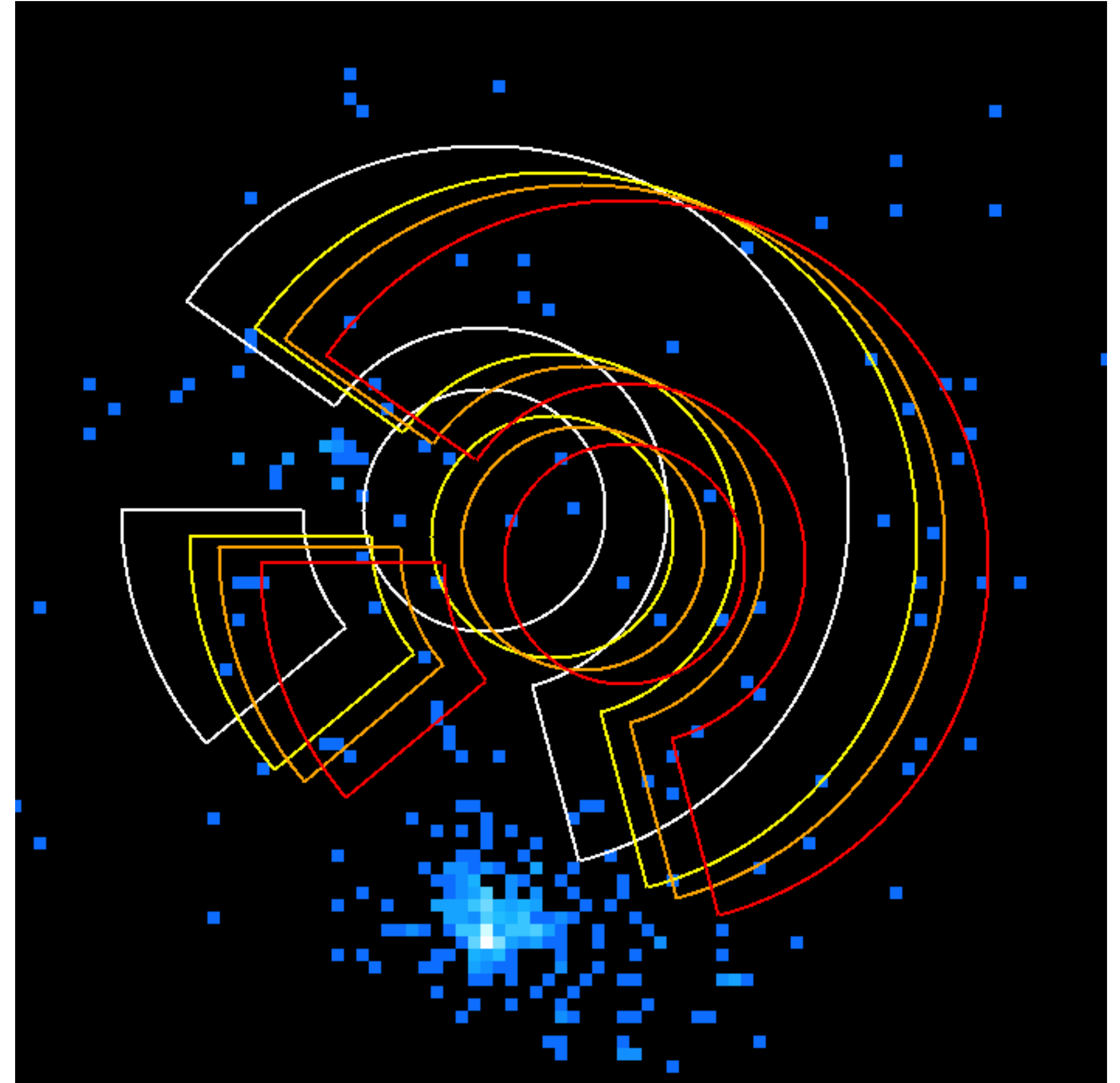
NuSTAR Data

Observed the center of the solar disk for 23,000 seconds during solar minimum in 2020

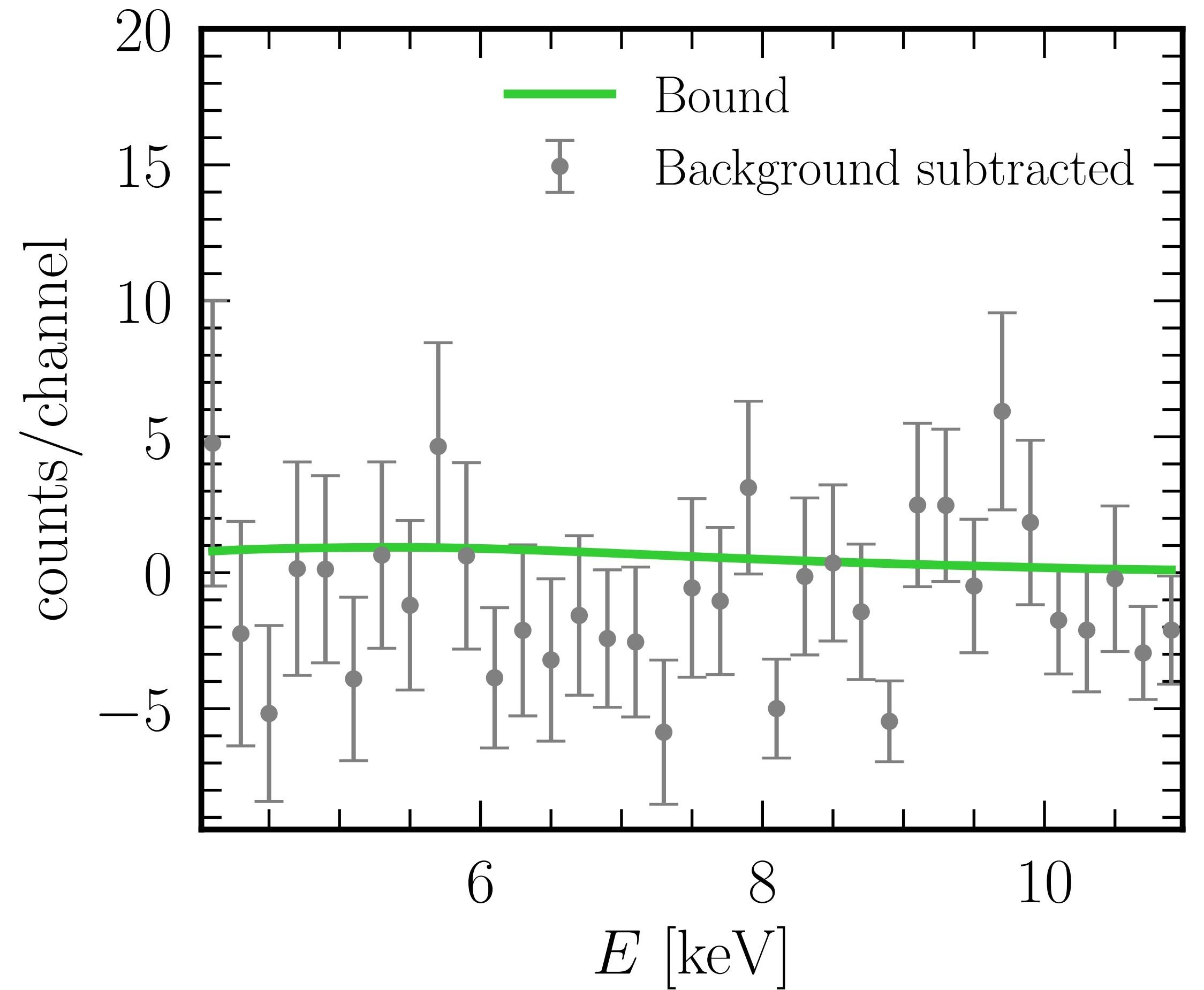
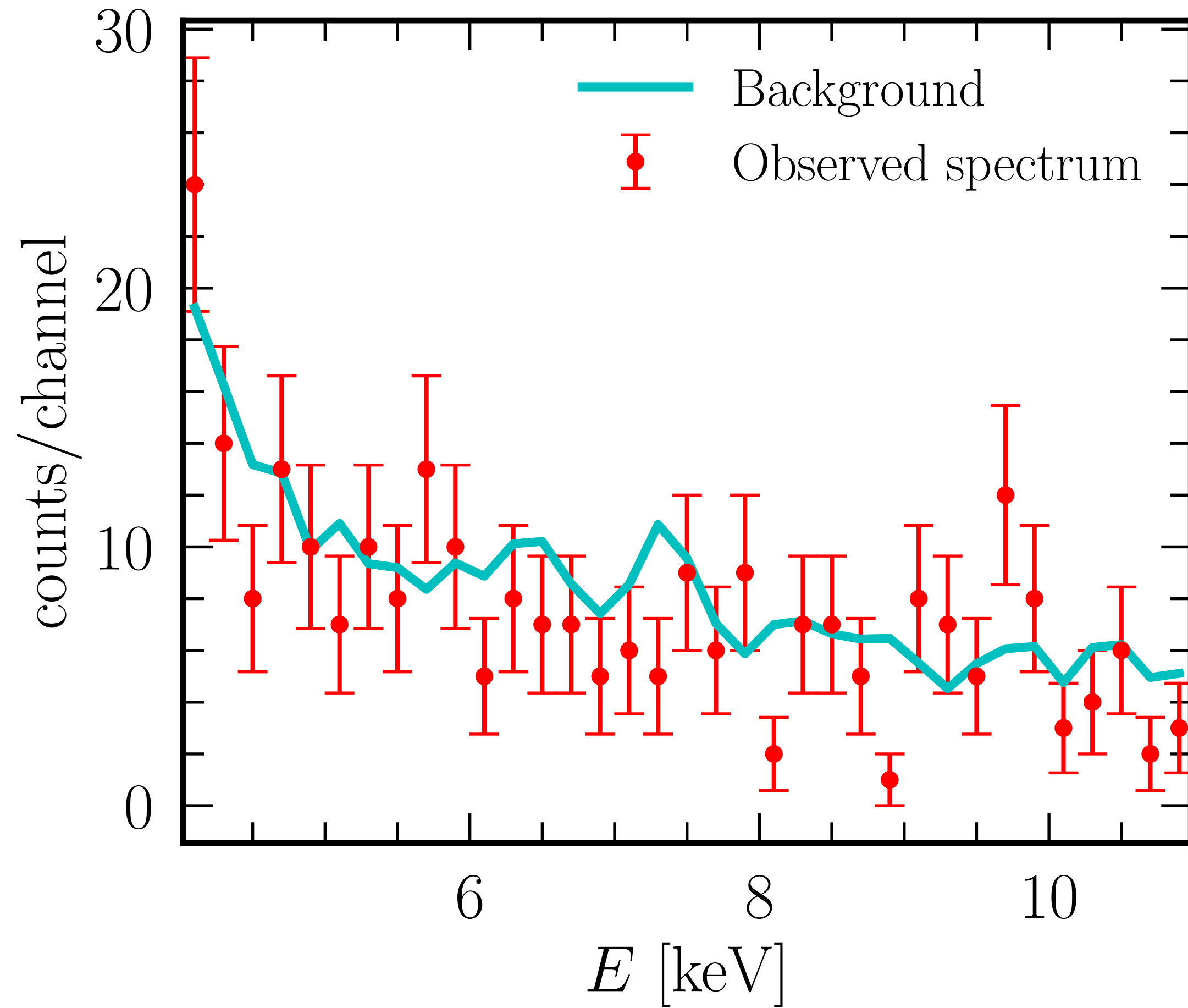
Signal region $r < 0.1R_{\odot}$

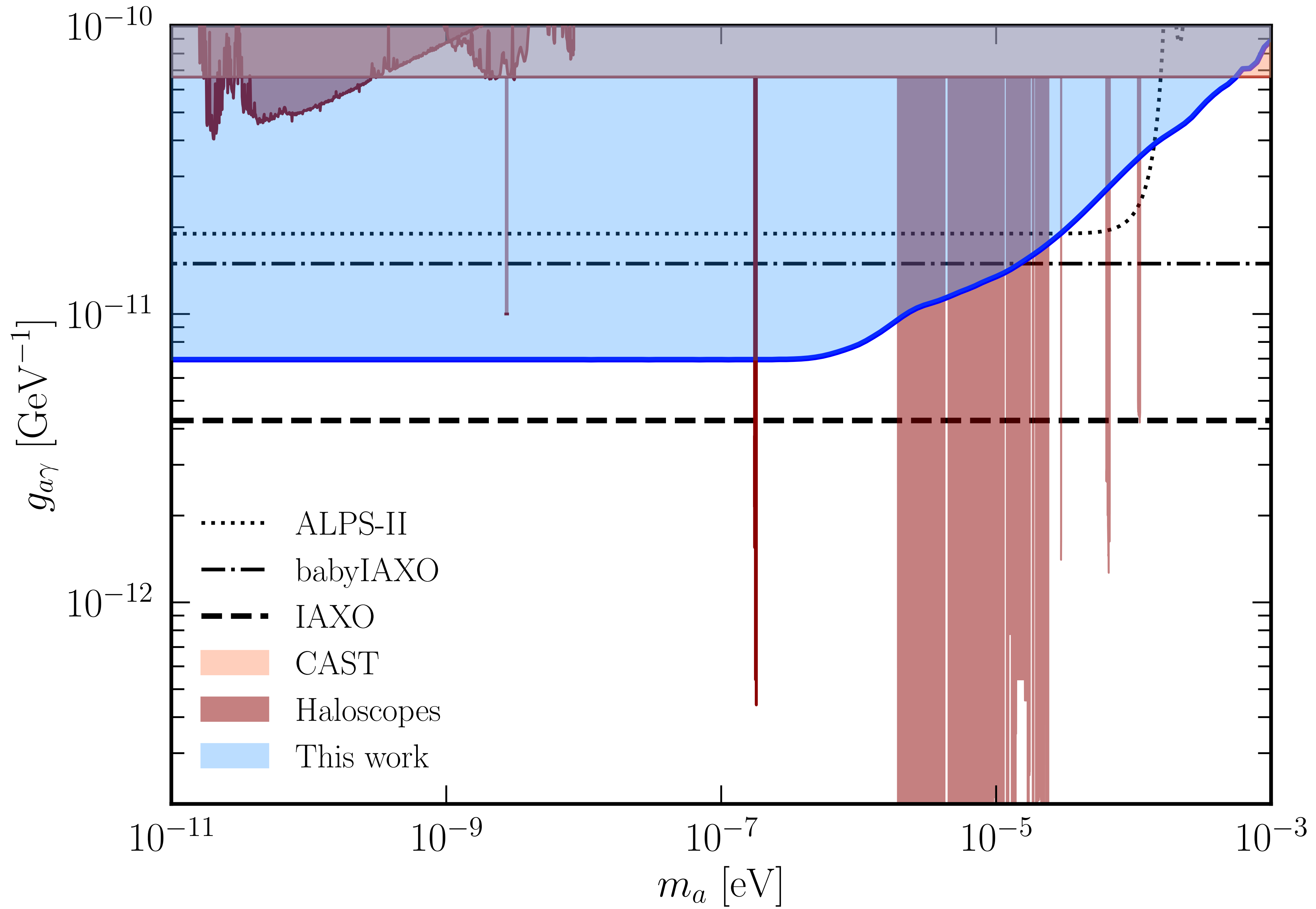
Background region $0.15R_{\odot} < r < 0.3R_{\odot}$

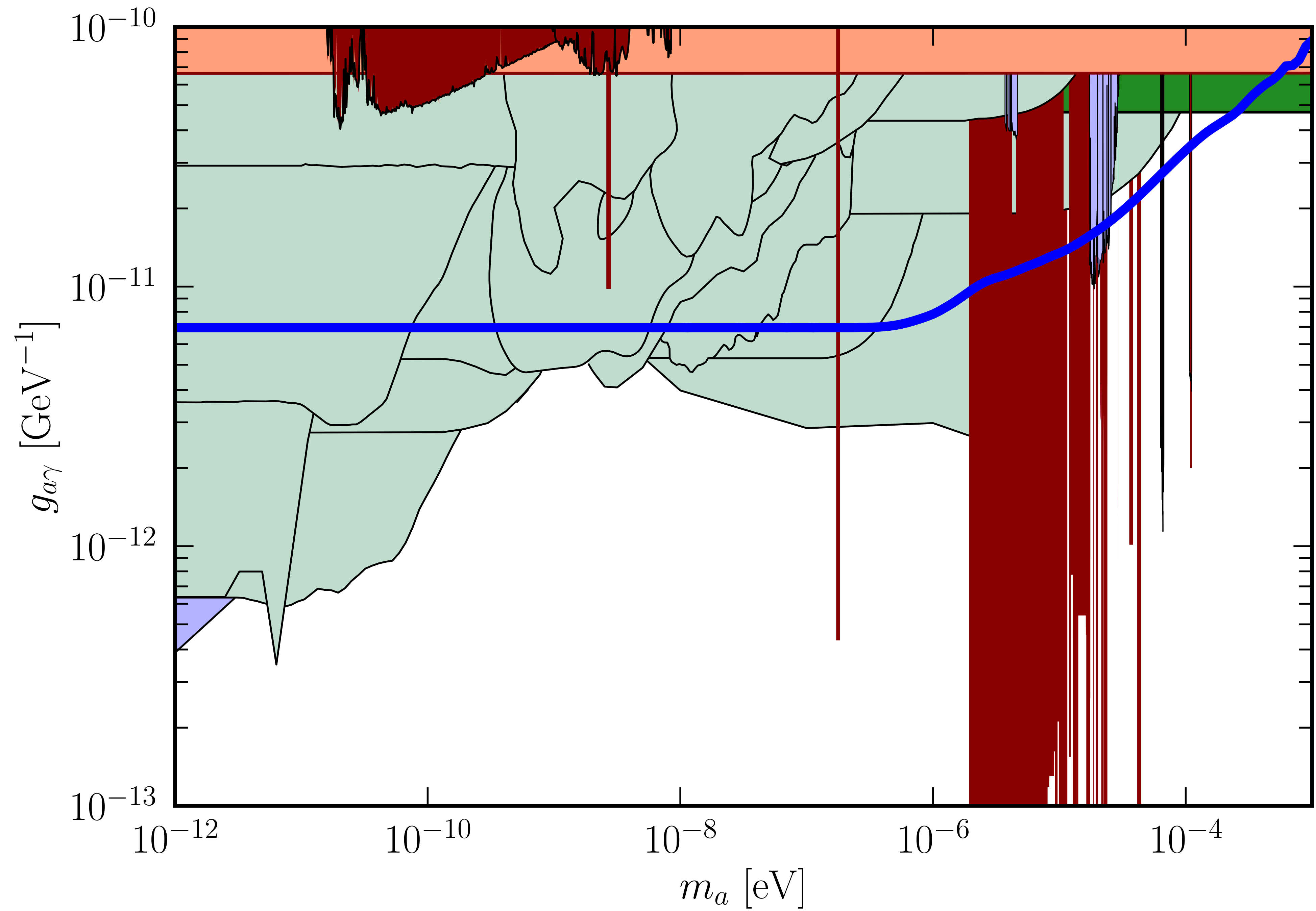
Remove wedges containing X-ray bright points



NuSTAR Data









THANK
YOU