Eletrodinâmica Quântica em Baixas Energias

Felipe Rosa – IF/UFRJ – 2015/??

Mas espera aí um minutinho...
Eletrodinâmica quântica??

https://straightfromtherecliner.wordpress.com/tag/pinky-and-the-brain/

Eletrodinâmica **Clássica**

vs.

Eletrodinâmica **Quântica**

Eletromagnetismo **Clássico**

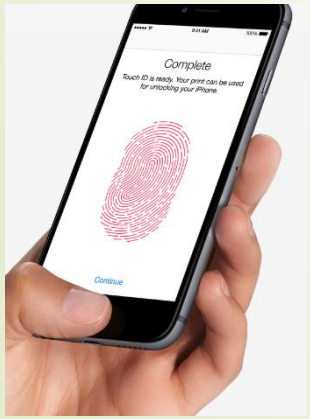
Dispersão

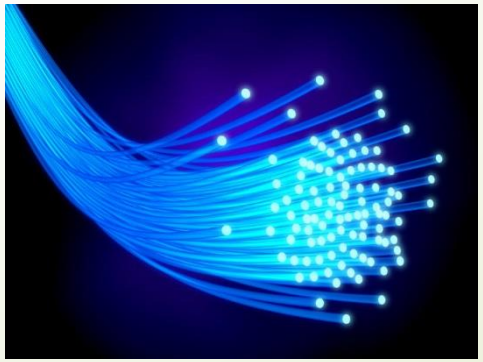
Miragem

Eletromagnetismo **Clássico**

http://kids.britannica.com/elementary/art-90423/The-Very-Large-Array-is-a-group-of-27-bowl

Maravilhas do mundo moderno...

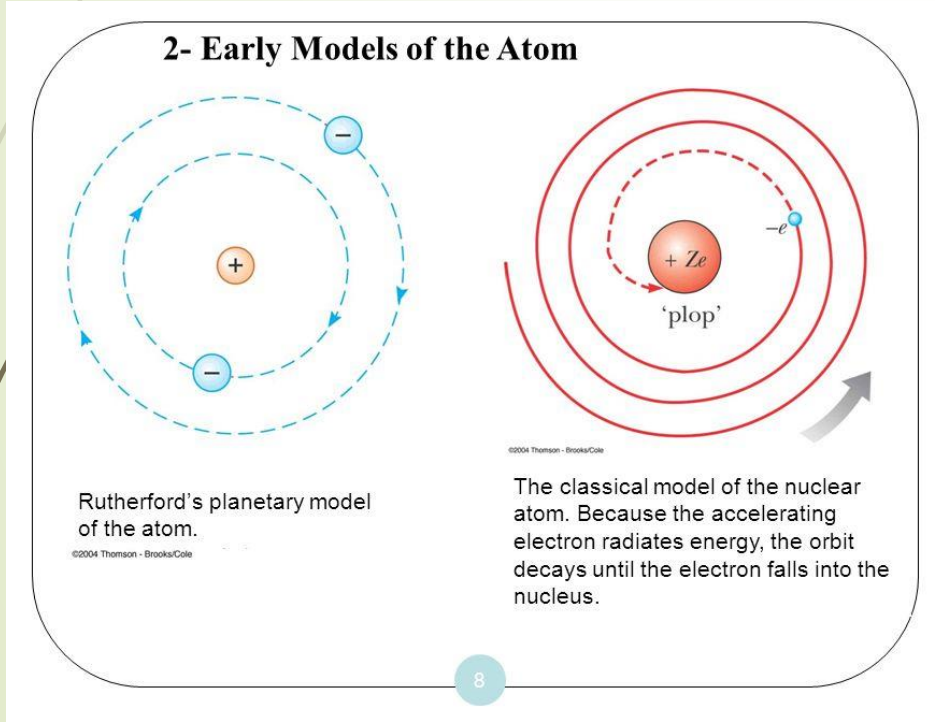




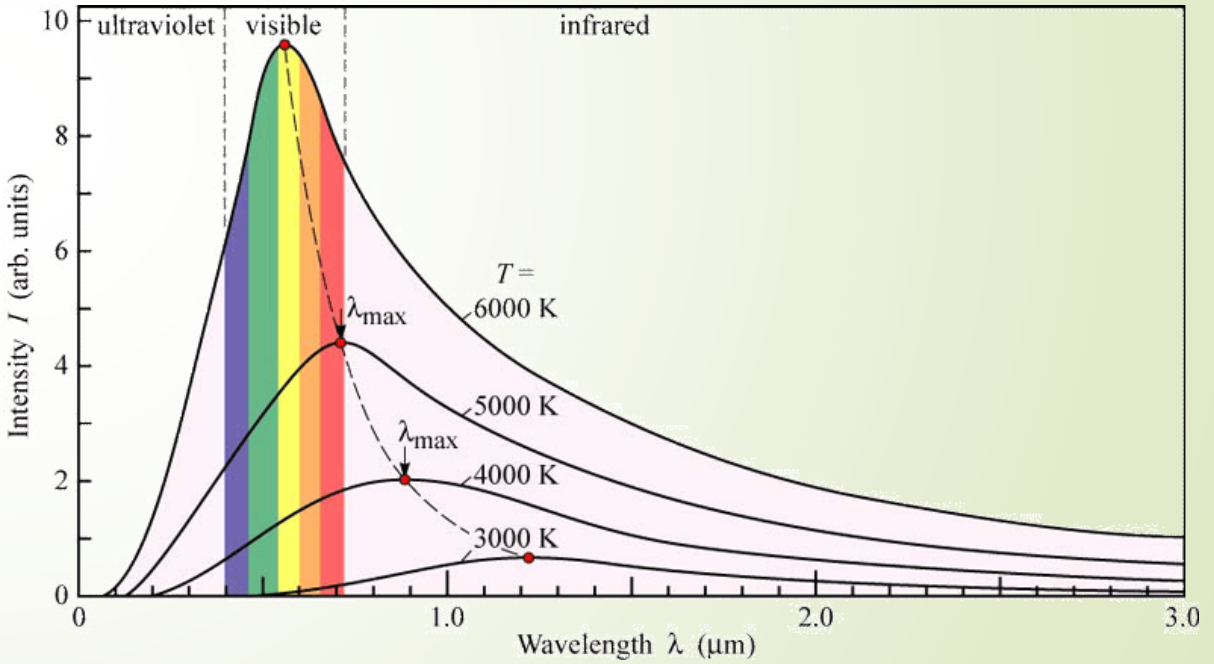
Maravilhas do mundo realmente moderno...

Eletromagnetismo **Quântico**

- Como explicar a estabilidade de certas órbitas atômicas?
- Como explicar o espectro de emissão de certos corpos?

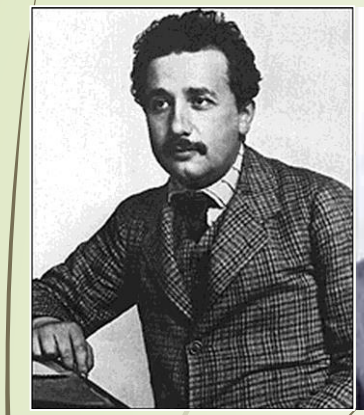


http://slideplayer.com/slide/257194/

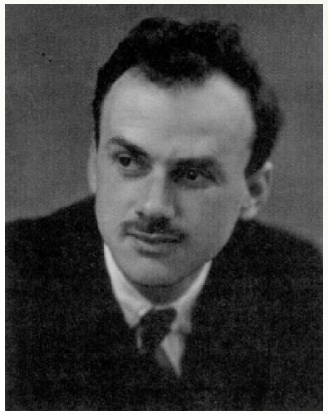


https://www.skepticalscience.com/empirical-evidence-for-co2-enhanced-greenhouse-effect-advanced.htm

Eletromagnetismo Quântico







+


Os campos eletromagnéticos **flutuam!**

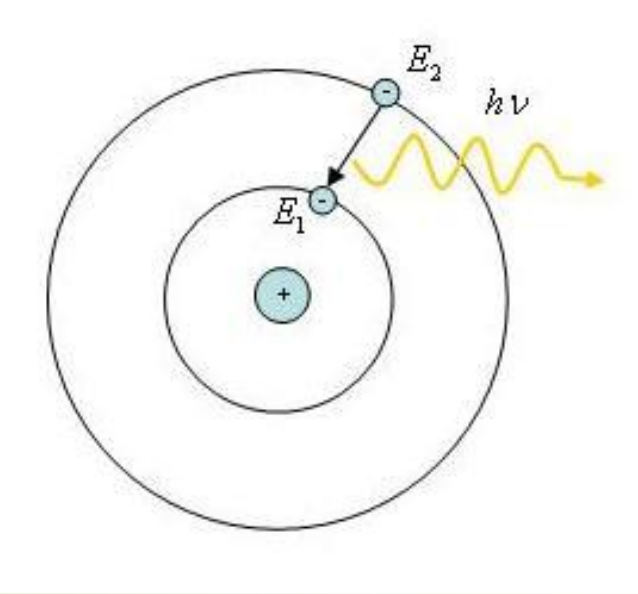
$$\langle E^2 \rangle \neq 0!!$$

A energia associada é **quantizada!**

$$E_\gamma = \hbar\omega_\gamma$$

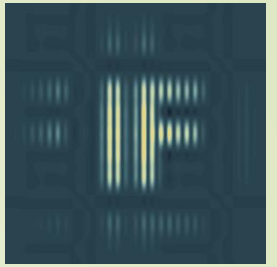
⟶ Fótons!

Eletromagnetismo Quântico



http://www.thespectroscopynet.eu/?Physical_Background:Atomic_Emission:Transition_Moments

A matéria interage com os campos EM **trocando fótons!**



Fim da parte 1...

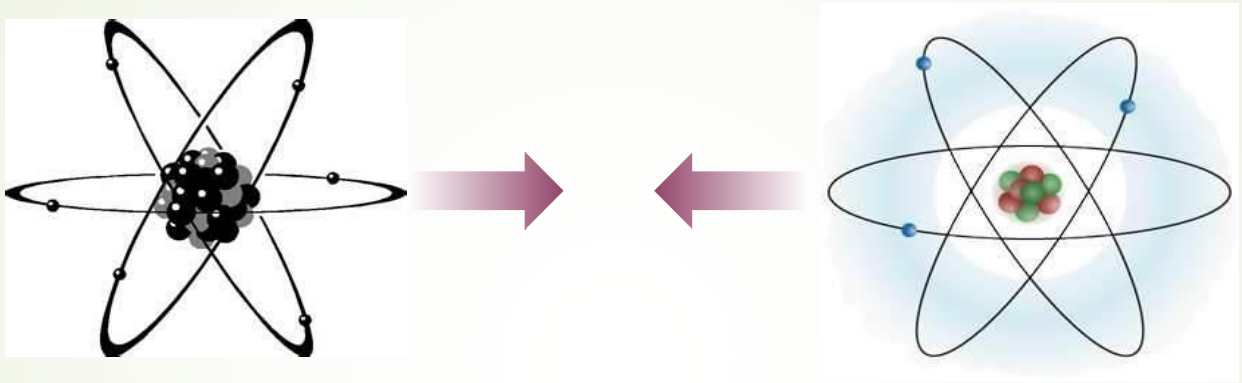
Forças Dispersivas

Forças entre objetos sem densidade de carga permanente.



A **condensação** sugere a existência de tal força.

Forças Dispersivas – van der Waals

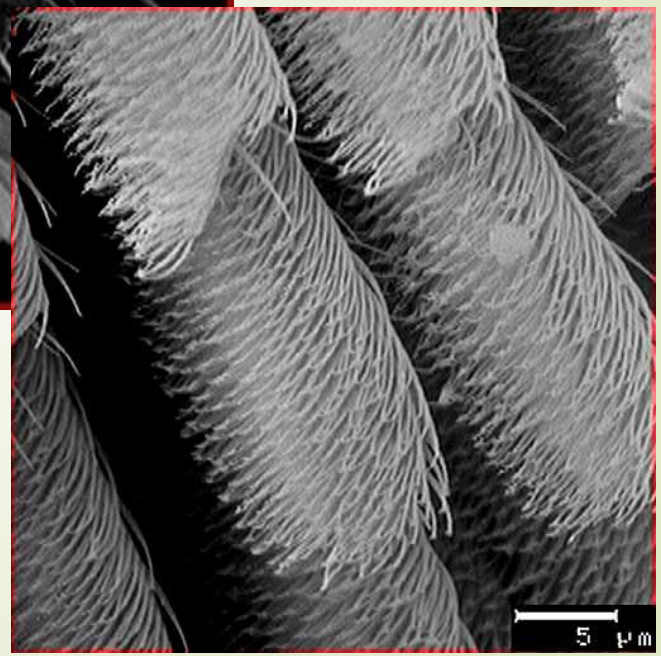


$$U_{vdW} \approx -\frac{C}{r^6}$$

$$K \approx \frac{3}{2} k_B T$$

Forças Dispersivas - Animais

http://www.domyownpestcontrol.com/spiders-c-22.html?page=all



http://whyfiles.org/shorties/152sticky_spider/

Isso significa que...

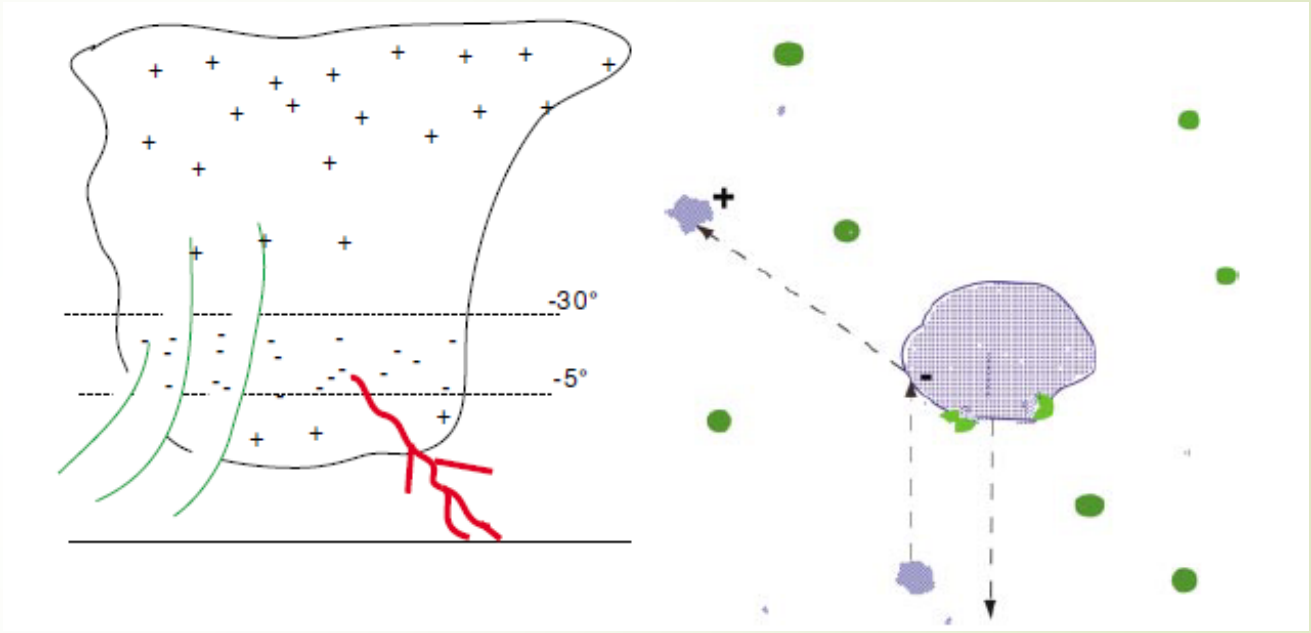
http://www.theamazingspidermangame.com/

Universidade de Kiel, Kiel, Alemanha

Lagartixas também se aproveitam dessas forças!

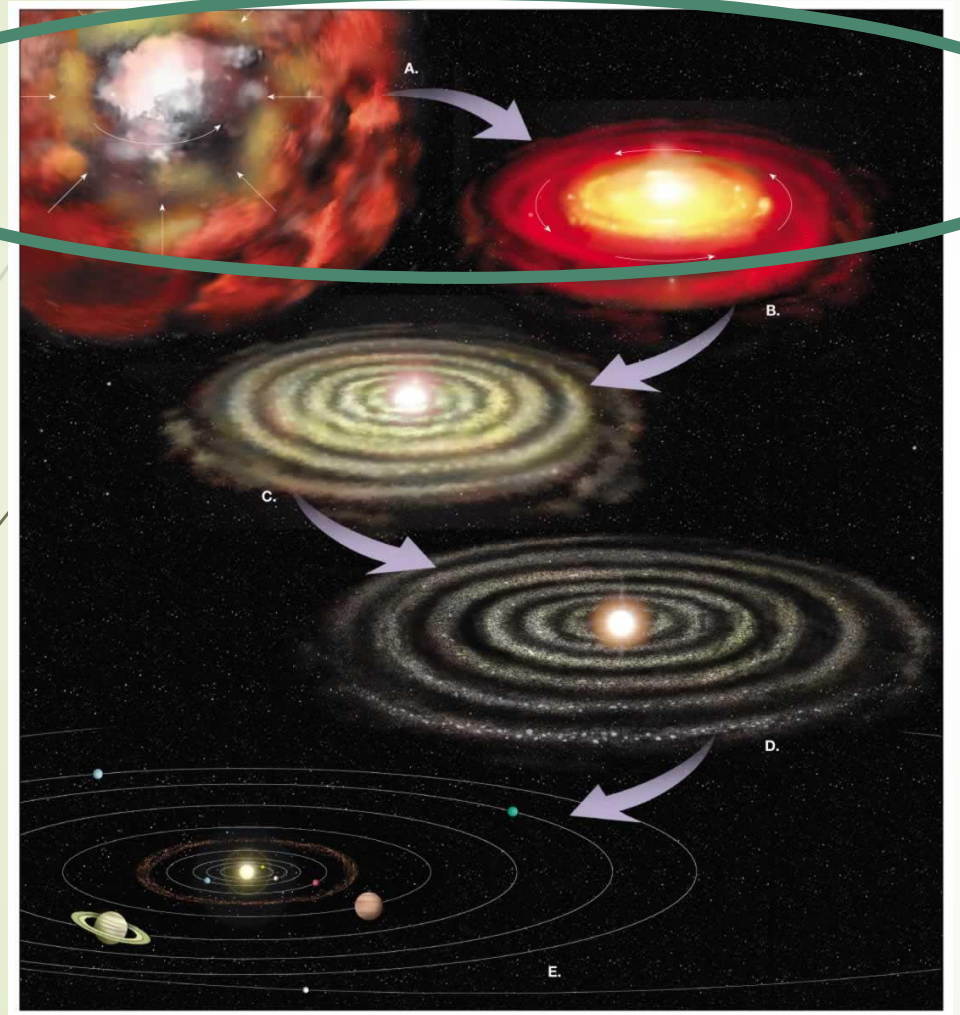
Forças Dispersivas – Tormentas

http://ohsinsider.com/insider-top-stories/lightning-safety-take-shelter-storm



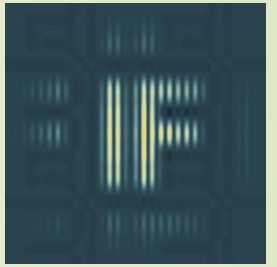
Dash & Wettlaufer, Can J Phys, **81** 201 (2003)

Forças Dispersivas – Acreção de corpos celestes



http://jupiter.plymouth.edu/~sci_ed/Turski/Courses/Earth_Science/Intro.html

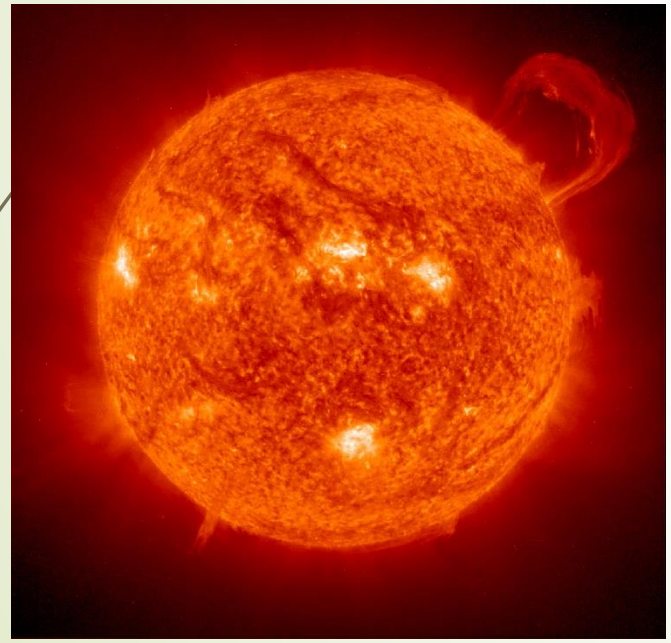
Início da acreção: forças dispersivas



Fim da parte 2...

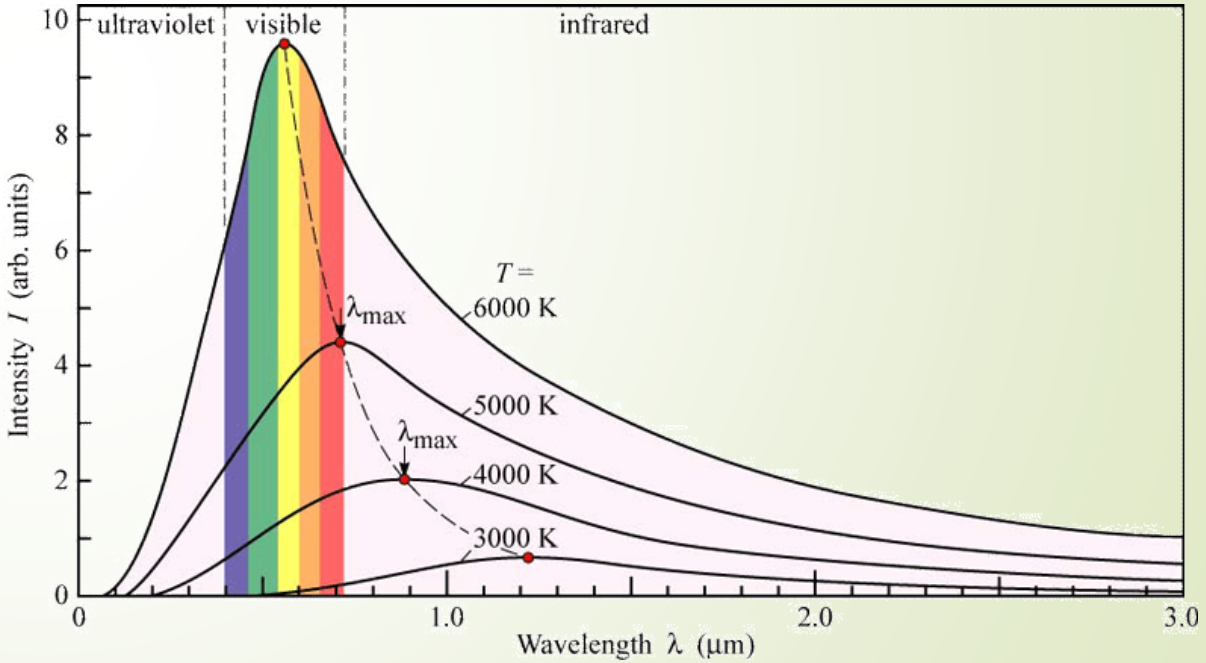
Transferência de calor no campo próximo

Como o calor do Sol chega na Terra?



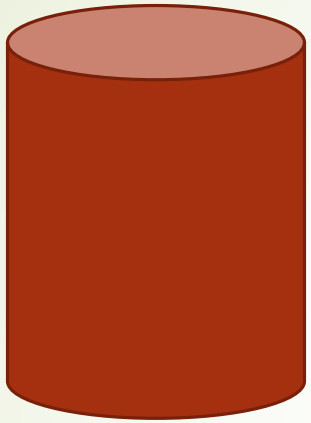
http://www.wikipedia.com

Radiação!

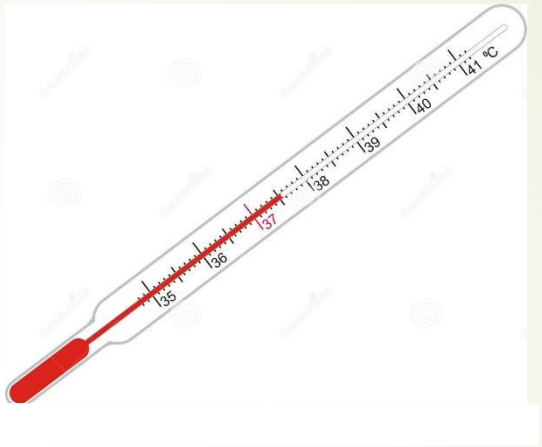


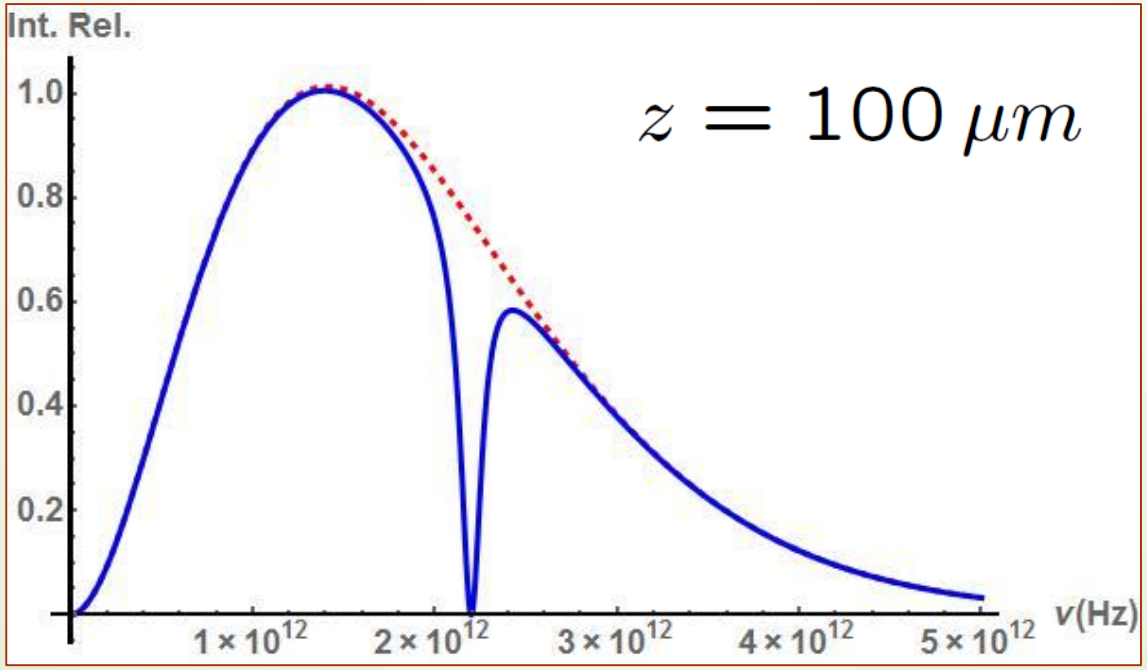
https://www.skepticalscience.com/empirical-evidence-for-co2-enhanced-greenhouse-effect-advanced.htm

E esse padrão se repete em escalas mais “terrenas”...

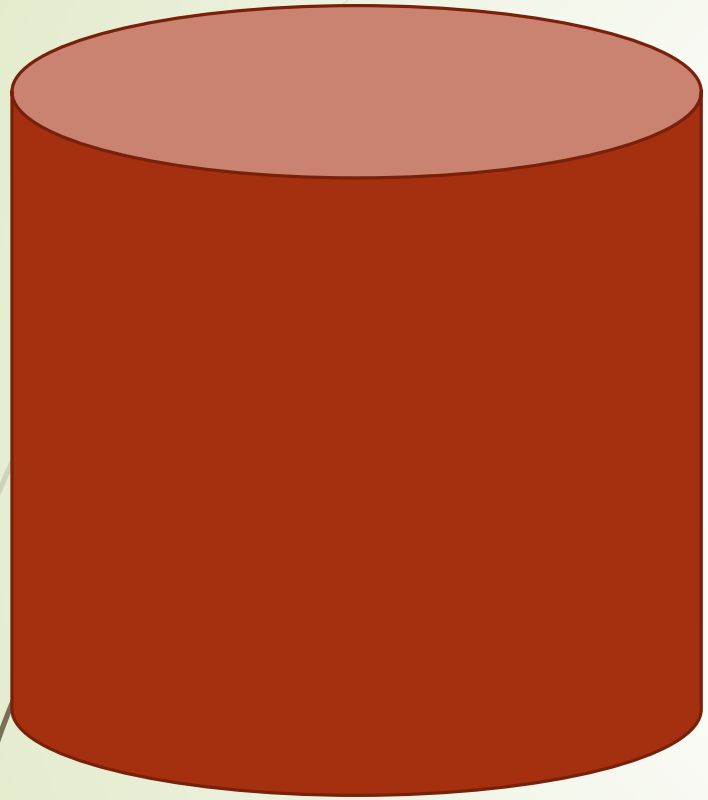


heat

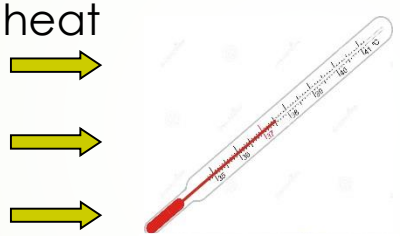




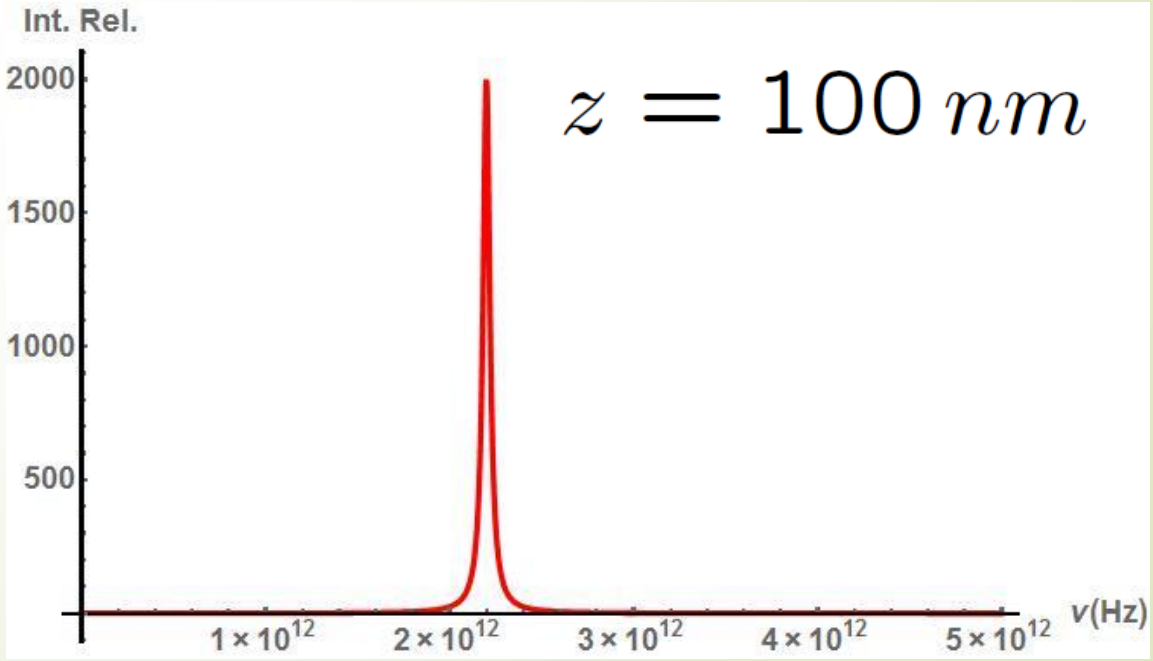
Agora, se colocamos o detector bem pertinho...



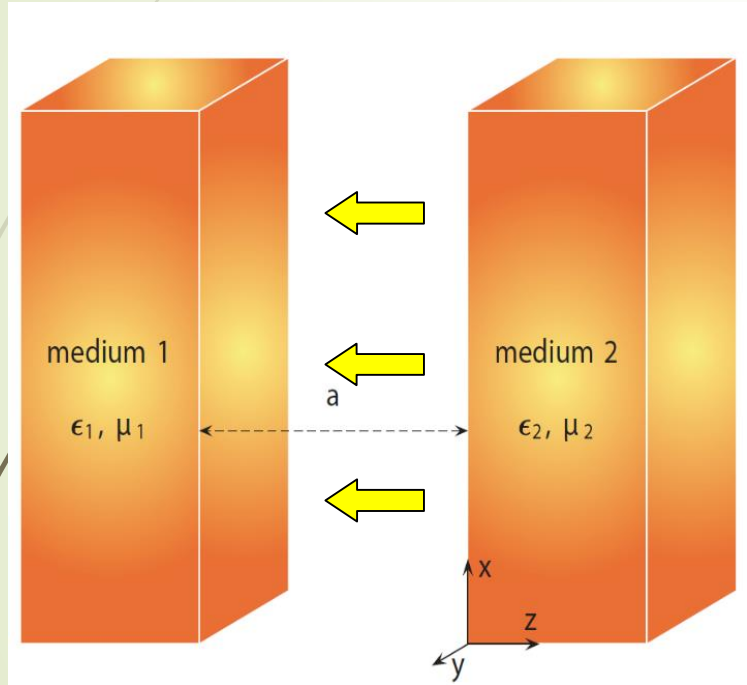
heat

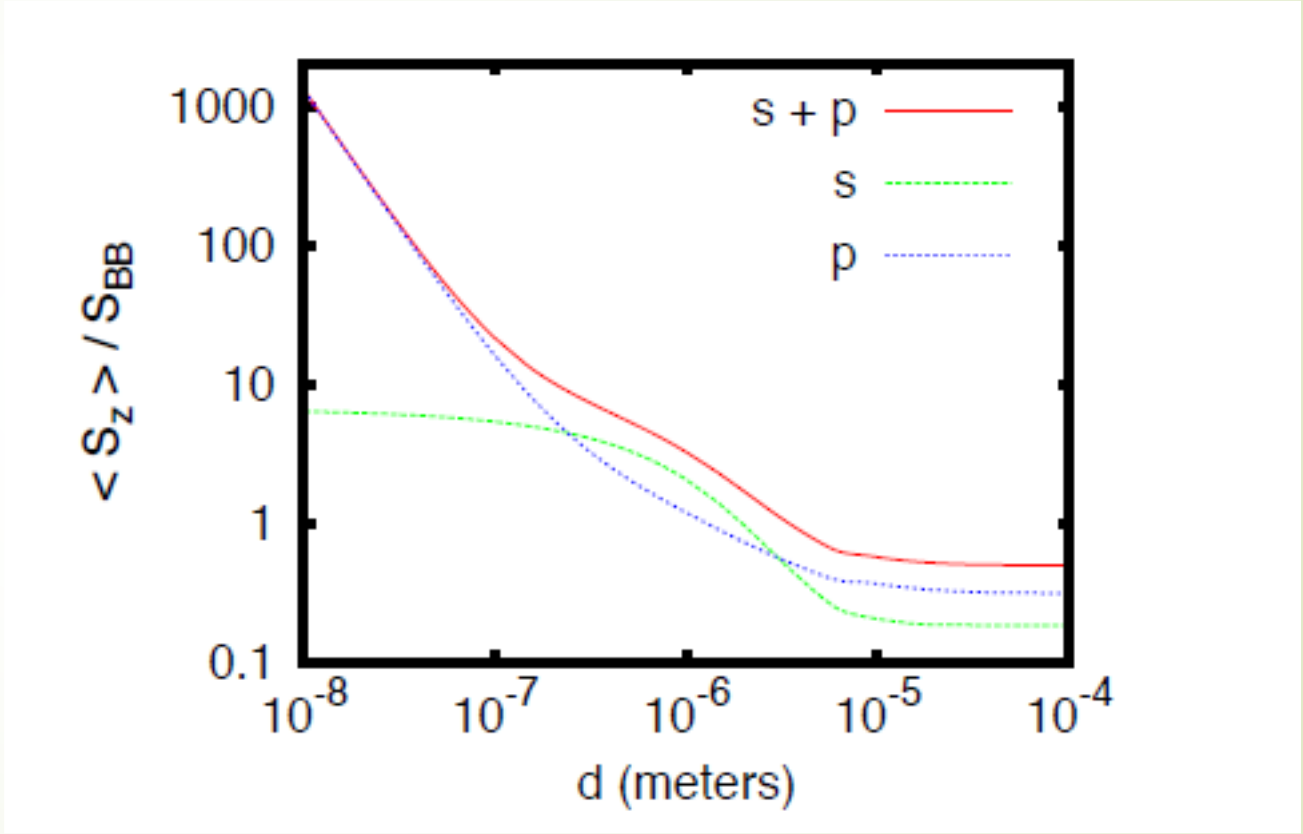


Emissão quase monocromática!
E muito mais intensa!



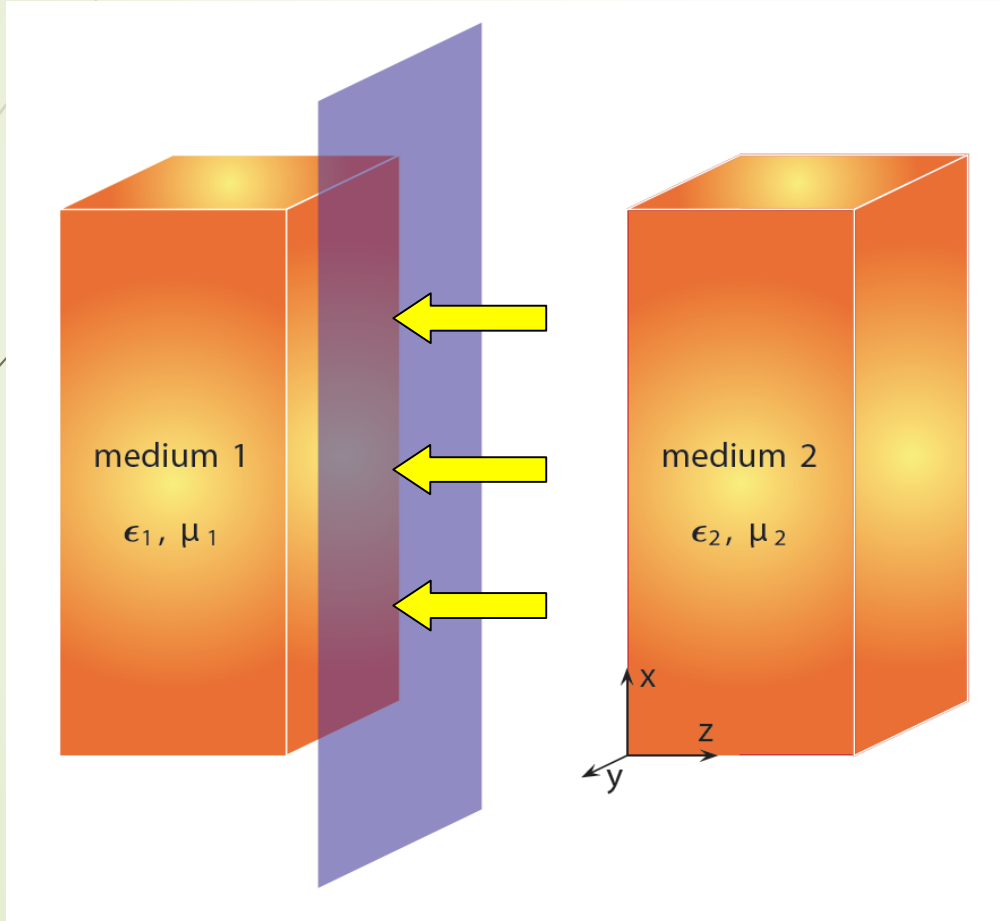
E pode ultrapassar (e muito!) a radiação de corpo negro...





S.-A. Biehs et al, Infrared Radiation, InTech (2012)

The heat flux is given in by the Poynting vector



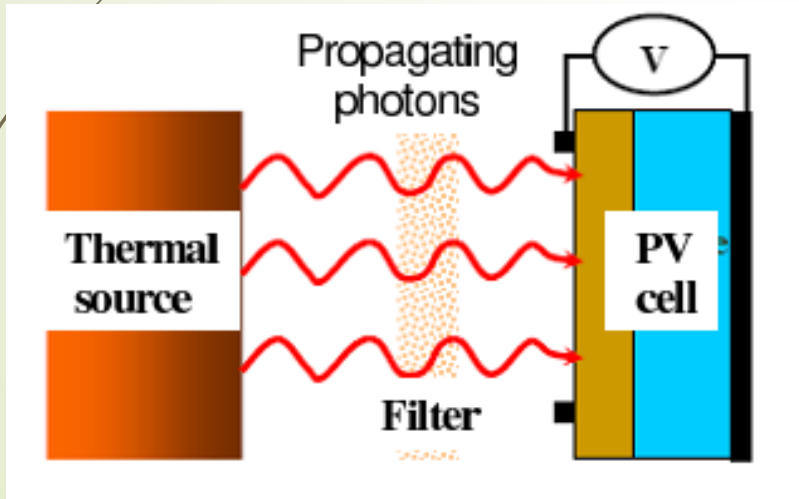
$$\langle P \rangle = \int_A \mathbf{dA} \cdot \langle \mathbf{S} \rangle = A \langle S_z \rangle$$

$$\mathbf{S} = \mathbf{E} \times \mathbf{H}$$

Algumas aplicações

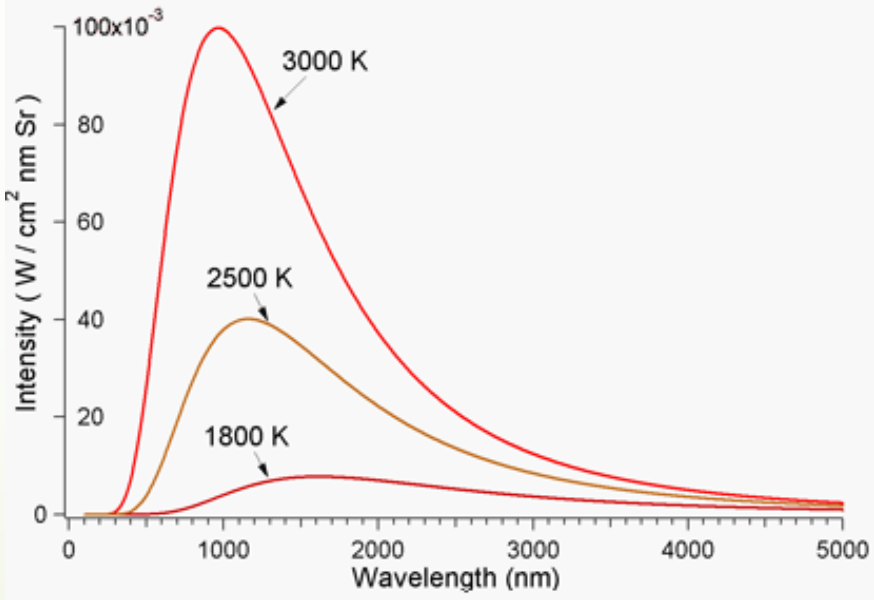
1 – Células termofotovoltaicas

Numa célula TPV típica, os fótons propagantes proveem a energia...



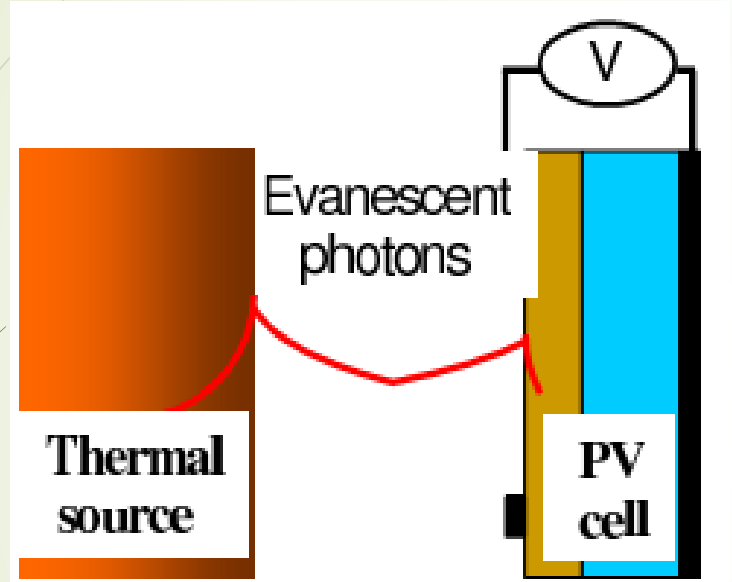
M Canva - http://ed-stits.fr/theses/detail-sujet-de-these/53

Mas o processo não é tão eficiente...

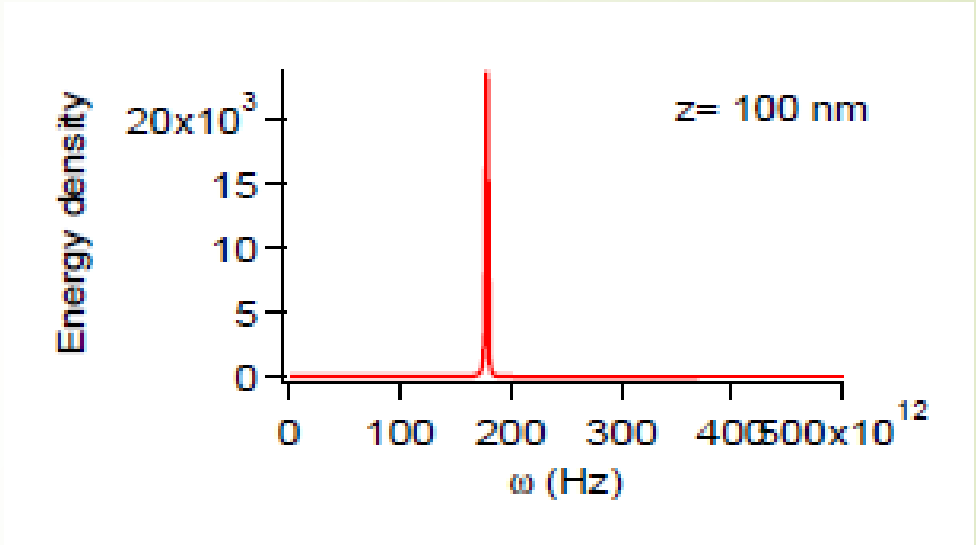


http://www.es.flinders.edu.au/~mattom/science+society/lectures/illustrations/lecture28/blackbody.html

Entra em cena então a TCCP (NHFT)...



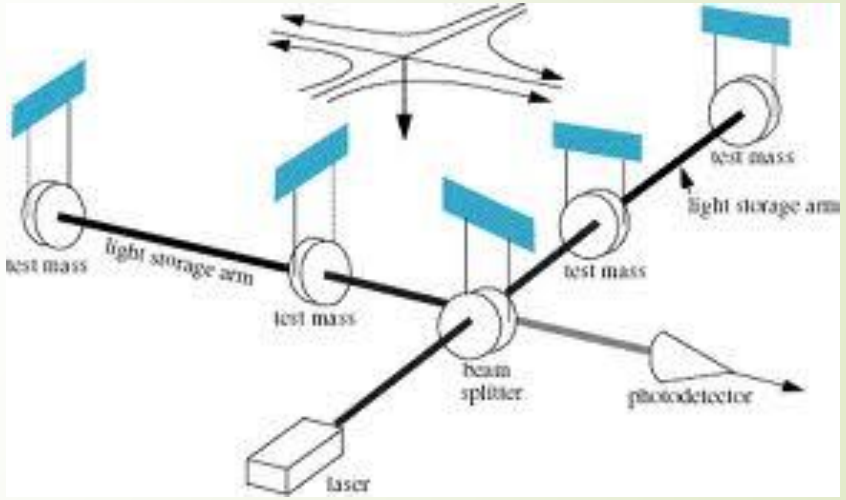
M Canva - http://ed-stits.fr/theses/detail-sujet-de-these/53



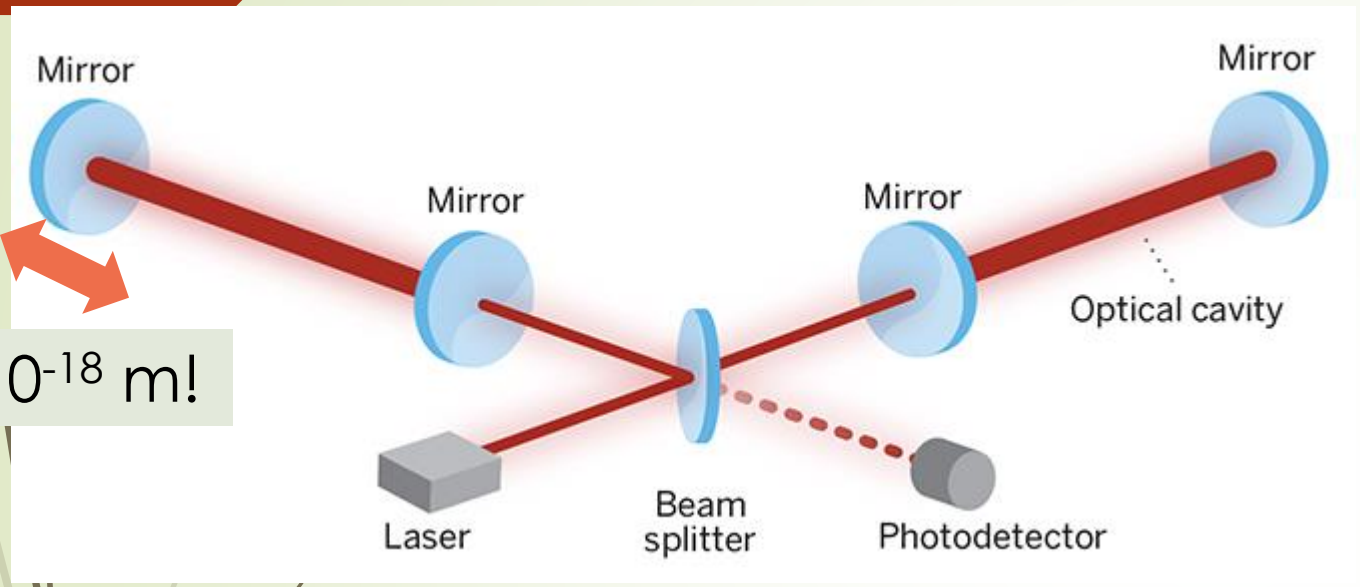
Podemos, em princípio, converter toda a energia térmica!

2 – Detecção de ondas gravitacionais

http://scienceblogs.com/startswithabang/2012/08/21/a-spectacular-chance-for-gravitational-waves/

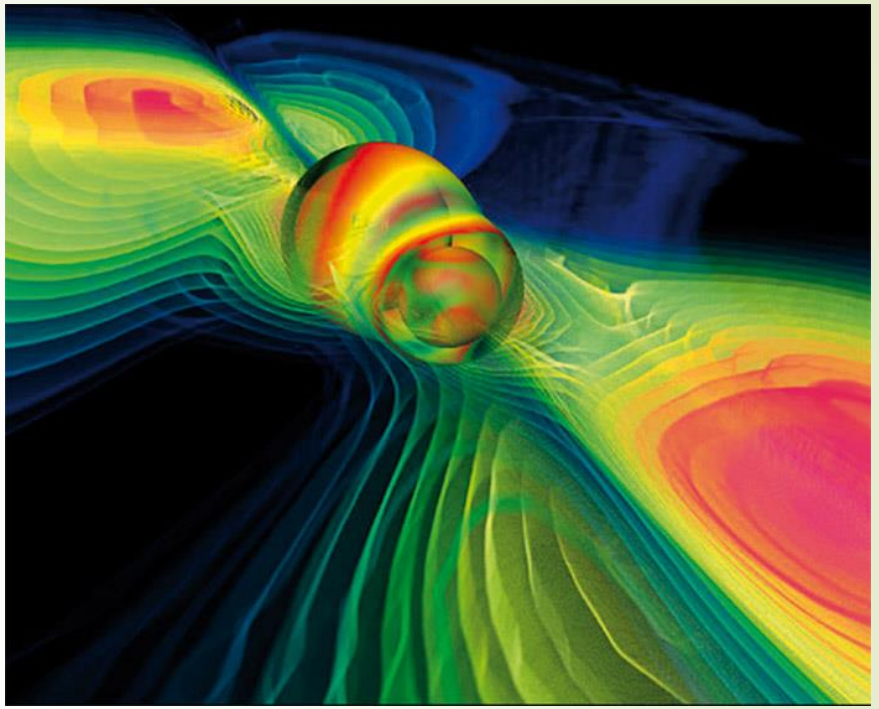


http://www.ligo.org/science/GW-IFO.php



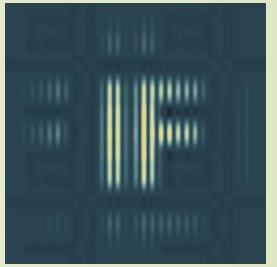
10^{-18} m!

http://legacy.labroots.com/user/news/article/id/271281/title/physicists-gear-up-to-catch-a-gravitational-wave



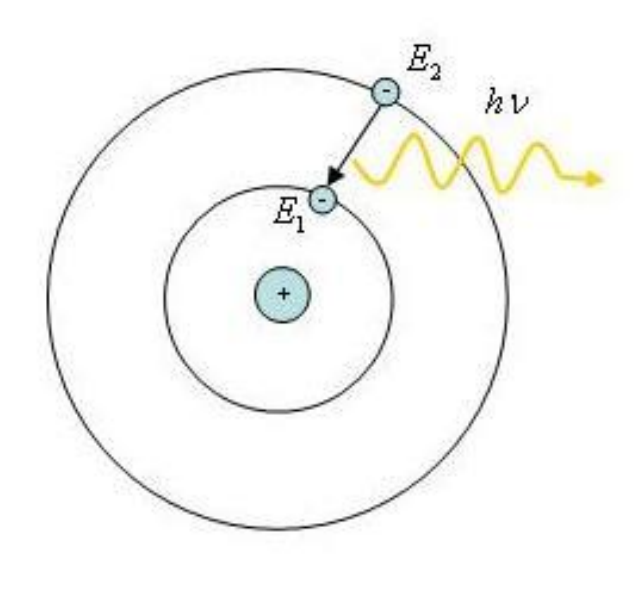
http://news.discovery.com/space/quantum-entanglement-could-aid-ligo-in-hunt-for-gravitational-waves-111106.htm

Controle da espessura dos espelhos é fundamental!



Fim da parte 3...

Emissão Espontânea



http://www.thespectroscopynet.eu/?Physical_Background:Atomic_Emission:Transition_Moments

O campo eletromagnético quantizado, mesmo em seu estado fundamental (vácuo), afeta os entes nele imersos!

(very) Brief history

1916 - Letter from Einstein to Michele Besso:

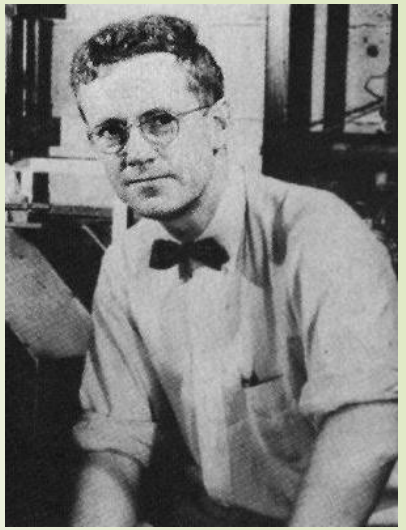
"a **splendid light** has dawned upon me about the absorption and emission of radiation".

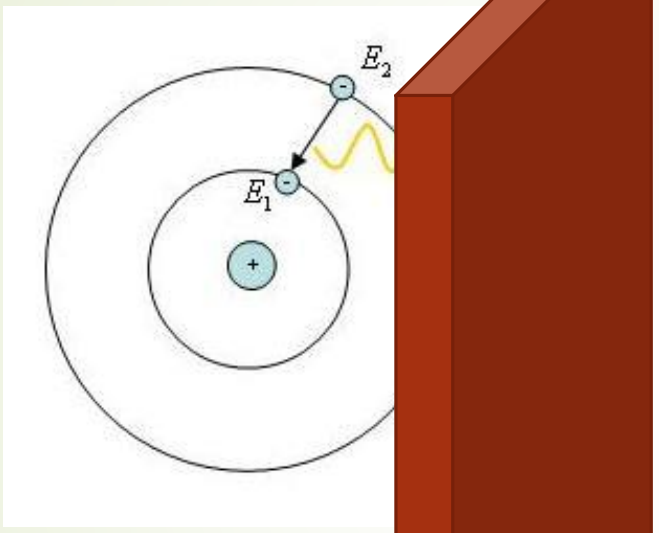
1917 – Einstein gets his A_{21} and B_{21} coefficients – but did not calculate the spontaneous emission rate.

1927 – P. A. M. Dirac successfully calculates the spontaneous emission using the (then) recent developments of QFT.

$$\gamma_0 = \frac{\omega_0^3 |\boldsymbol{\mu}|^2}{3\pi \varepsilon_0 \hbar c^3},$$

The Purcell Effect

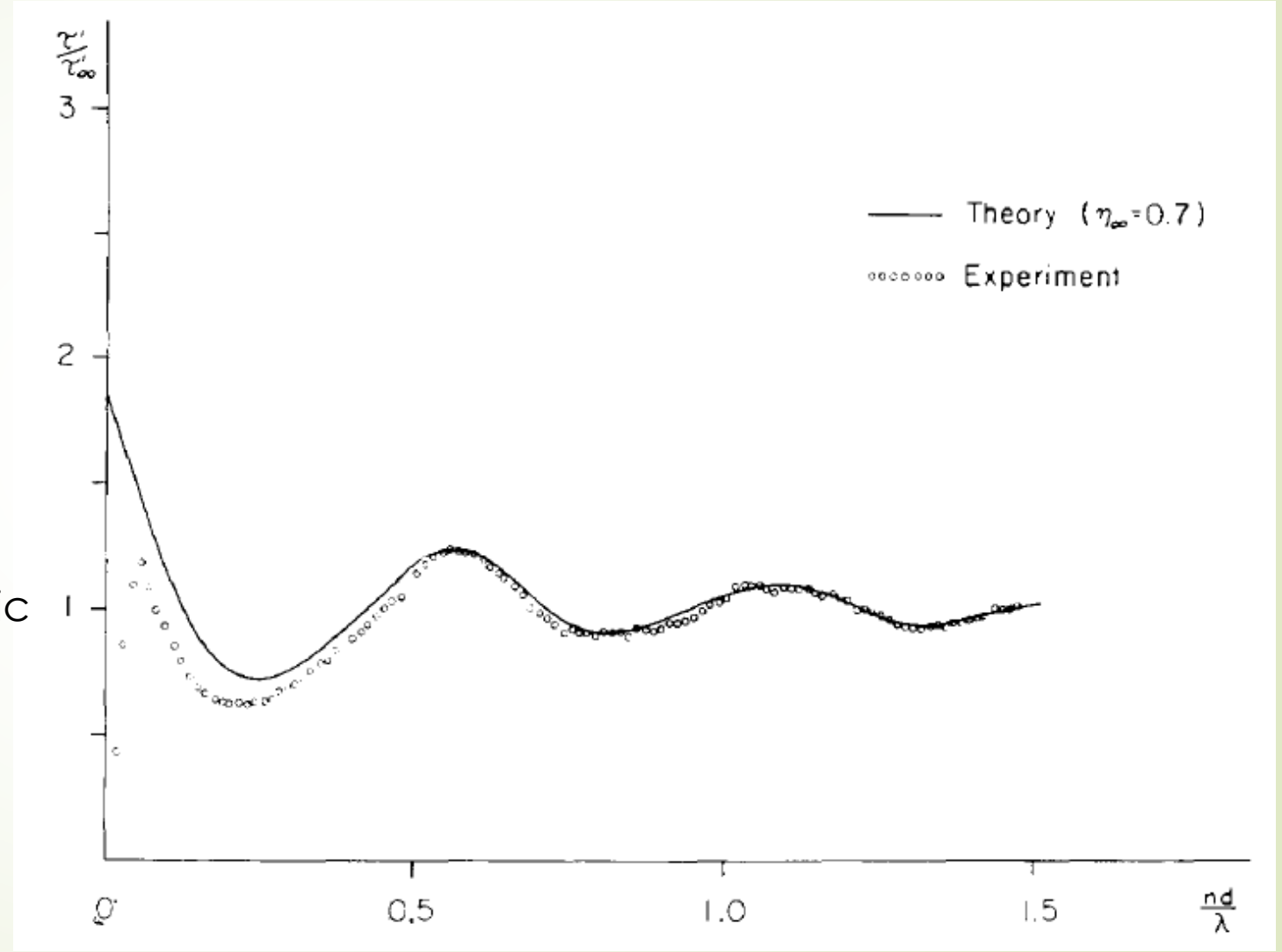




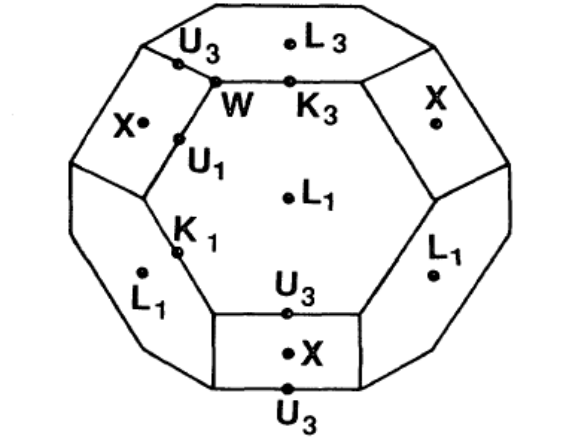
Alteration of SE by placing the emitter near macroscopic bodies!

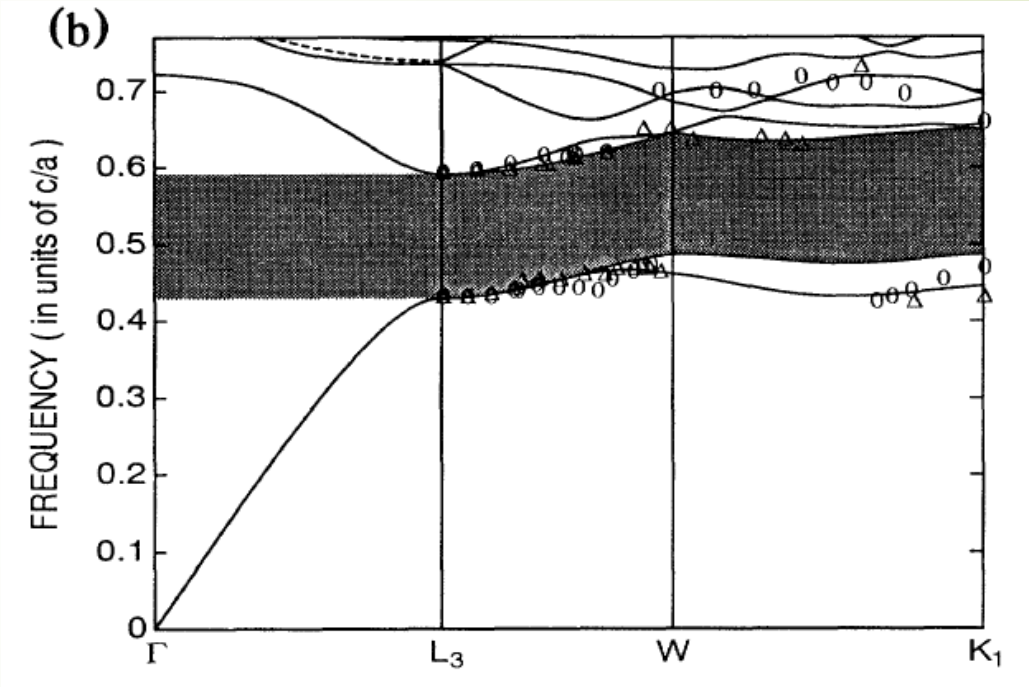
1969 – H. Morawitz calculates the atom-plane SE rate – it oscillates with the distance!

1966, 1970 – K. H. Drexhage et al. verify experimentally the influence of a dielectric plane in the fluorescence of a molecule.



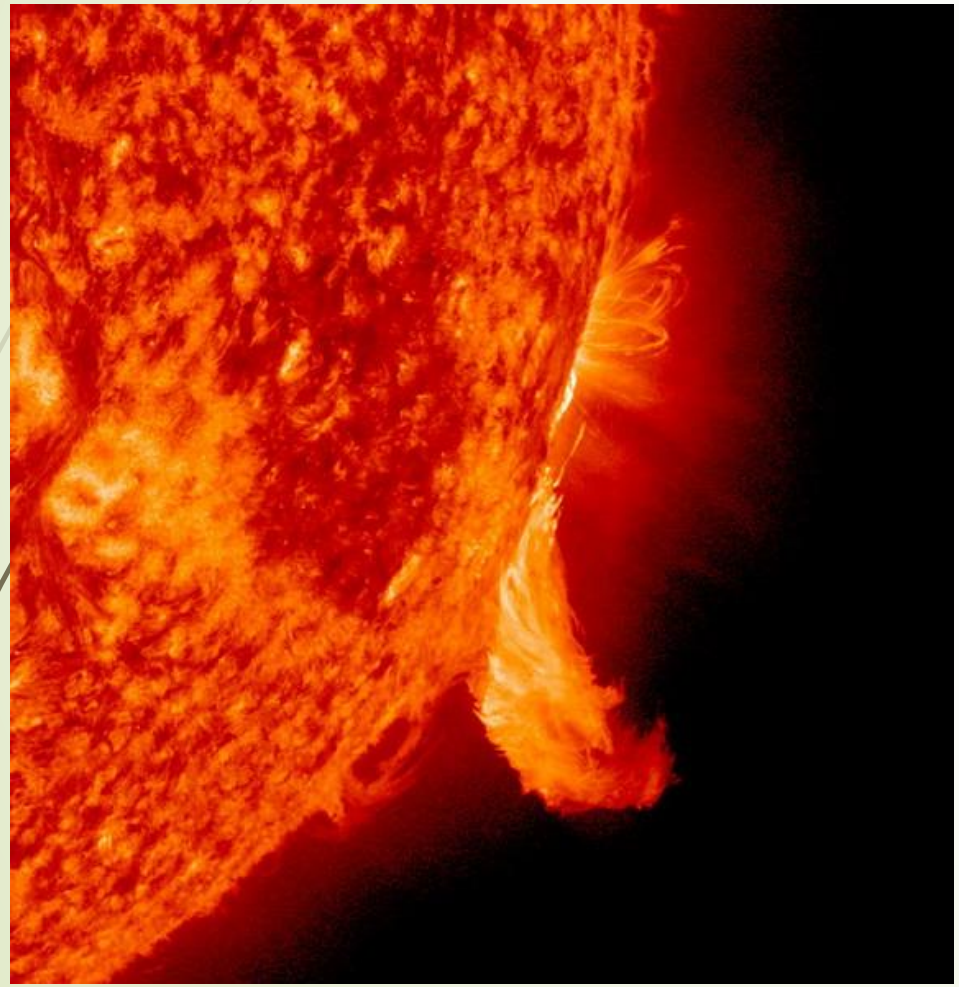
1987 – E. Yablonovich considers the spontaneous recombination rate inside a media (with a gap).





1992 – S. M. Barnett et al. consider the SE rate in absorbing media.

Emissão espontânea – muito comum



Mesmo a **T = 5500 K**, a EE é de longe a maior responsável pela emissão de luz solar!

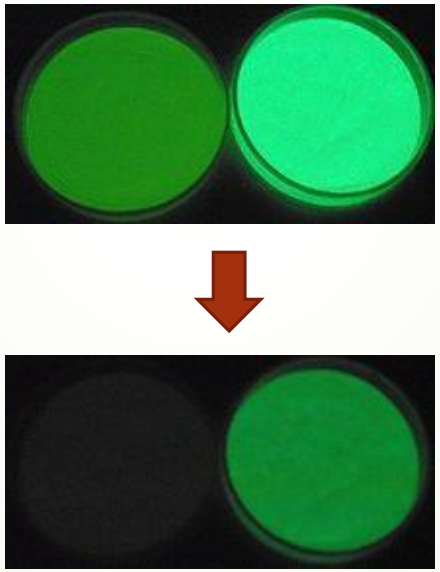
$$\frac{\gamma_{Sp}}{\gamma_{St}} = e^{h\omega/kT} - 1 \approx 690\ (blue)$$

$$\approx 40\ (red)$$

Emissão espontânea – muitos exemplos

Luminescência

Fosforescência



Fluorescência

Fim da parte 4...

O Grupo de Flutuações Quânticas (GFQ)

Prof. Carlos Farina

Prof. Paulo Américo

Prof. Marcus Venícius

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+ Prof. Nathan Viana (LPO)
+ Prof. François Impens
+ Prof. Moysés Nussenzveig (LPO)

+ Reinaldo Souza, Guilherme Bastos, Mateus Lima, Diney Ether (LPO), Luis Pires (LPO), Vinicius Henning, Renan Nunes, Daniela Szilard, Anna Batista, Marcius Vinicius, Patricia Abrantes, Bruno Oliveira, Daniel Martinez...

+ Prof. Felipe Rosa