

The background of the slide is a photograph of several astronomical observatories at sunset. The sky is a mix of deep blue, purple, and orange, with wispy clouds. The observatories are dark silhouettes against the bright horizon. The title text is overlaid in a large, yellow, sans-serif font.

Interferência da atmosfera terrestre em observações astronômicas

Bibliography: várias fontes (Observational Astrophysics [Lena];
Meteorology Today [Ahrens])

A grande maioria das observações são sitiadas no solo



Precisamos
conhecer a
atmosfera
terrestre para
saber as
possibilidades
e limitações
da observação
do solo



A atmosfera terrestre é uma fina camada de gases que rodeia a Terra e que é retida pela sua gravidade



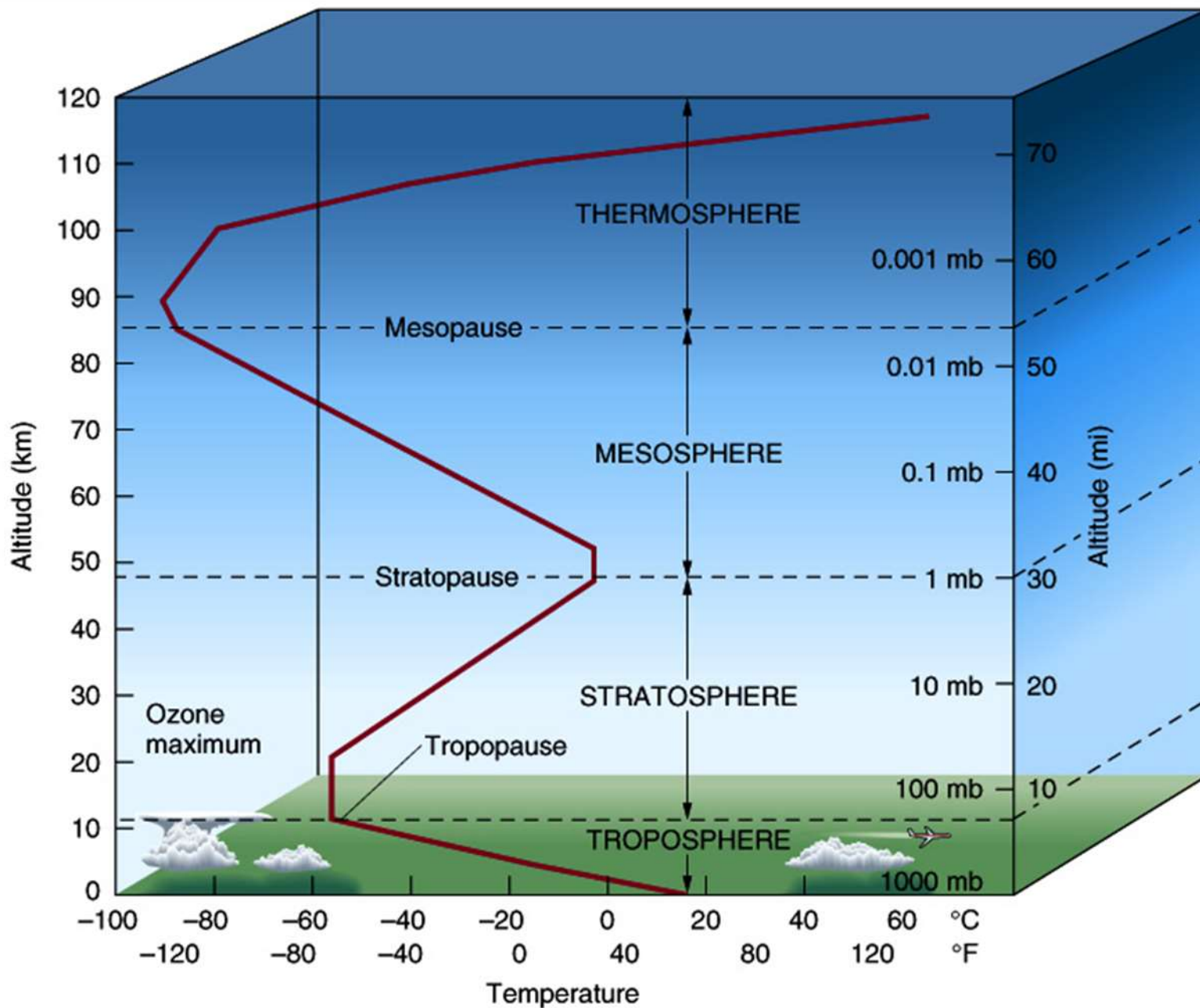
© *Meteorology Today (Ahrens)*

● **FIGURE 1.2** The earth's atmosphere as viewed from space. The atmosphere is the thin blue region along the edge of the earth.



Estrutura da atmosfera terrestre

burro.cwru.edu/Academics/Astr201/Atmosphere/atmosphere1.html



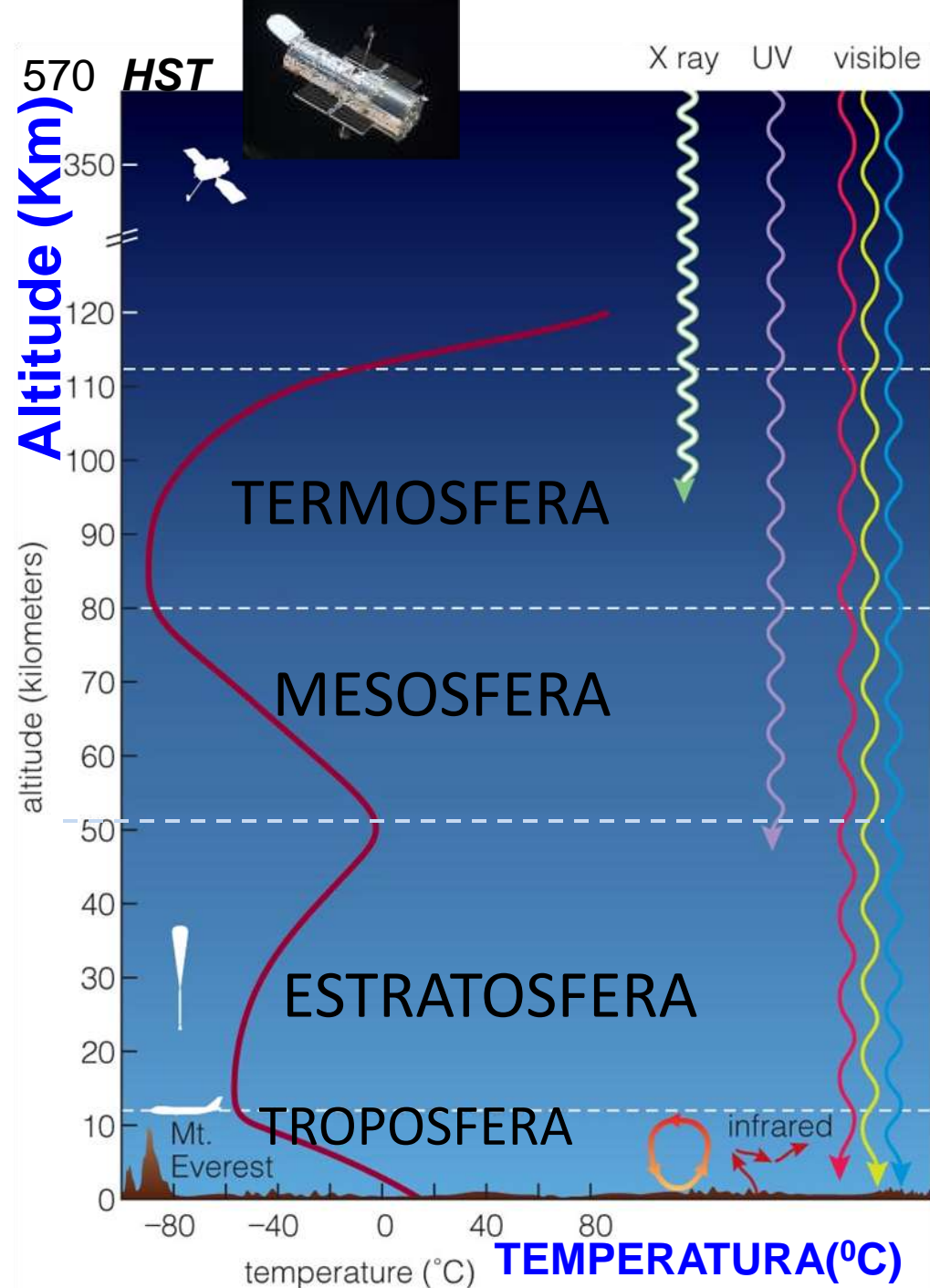
Perfis de temperatura

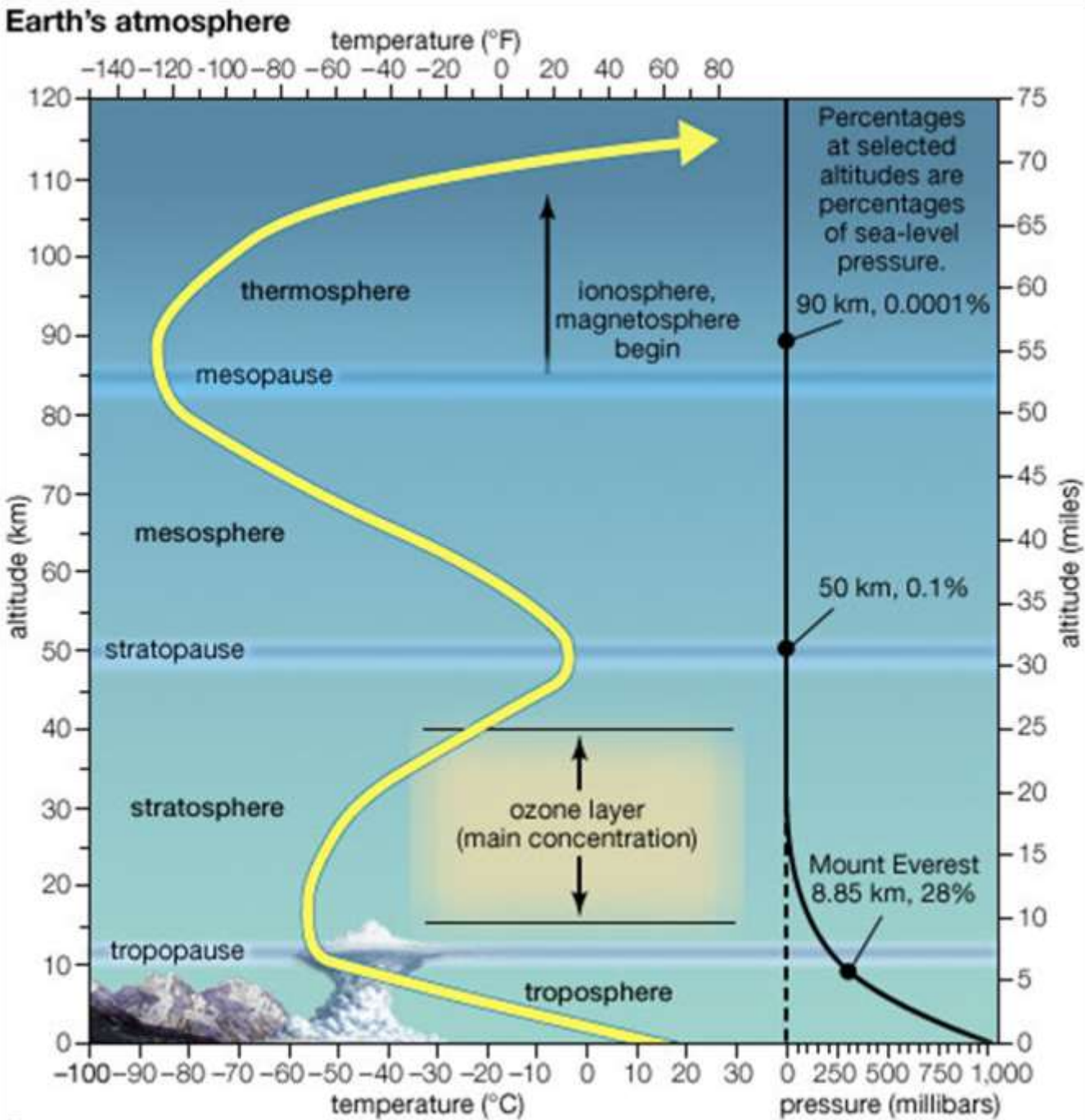
Luz solar UV e raios X aquecem e ionizam gases

Concentração de **ozônio** diminui

Aquecida por absorção de luz UV pelo **ozônio**

Aquecida pela superfície e convecção





Pressão:

decrece exp. com a altura z

$$P(z) = P_0 \exp(-z/H)$$

H: escala de altura
 $(=RT_m/M_0g)$

Composição química cte até 90 km

$$H = RT_m / M_0 g$$

(escala de altura)

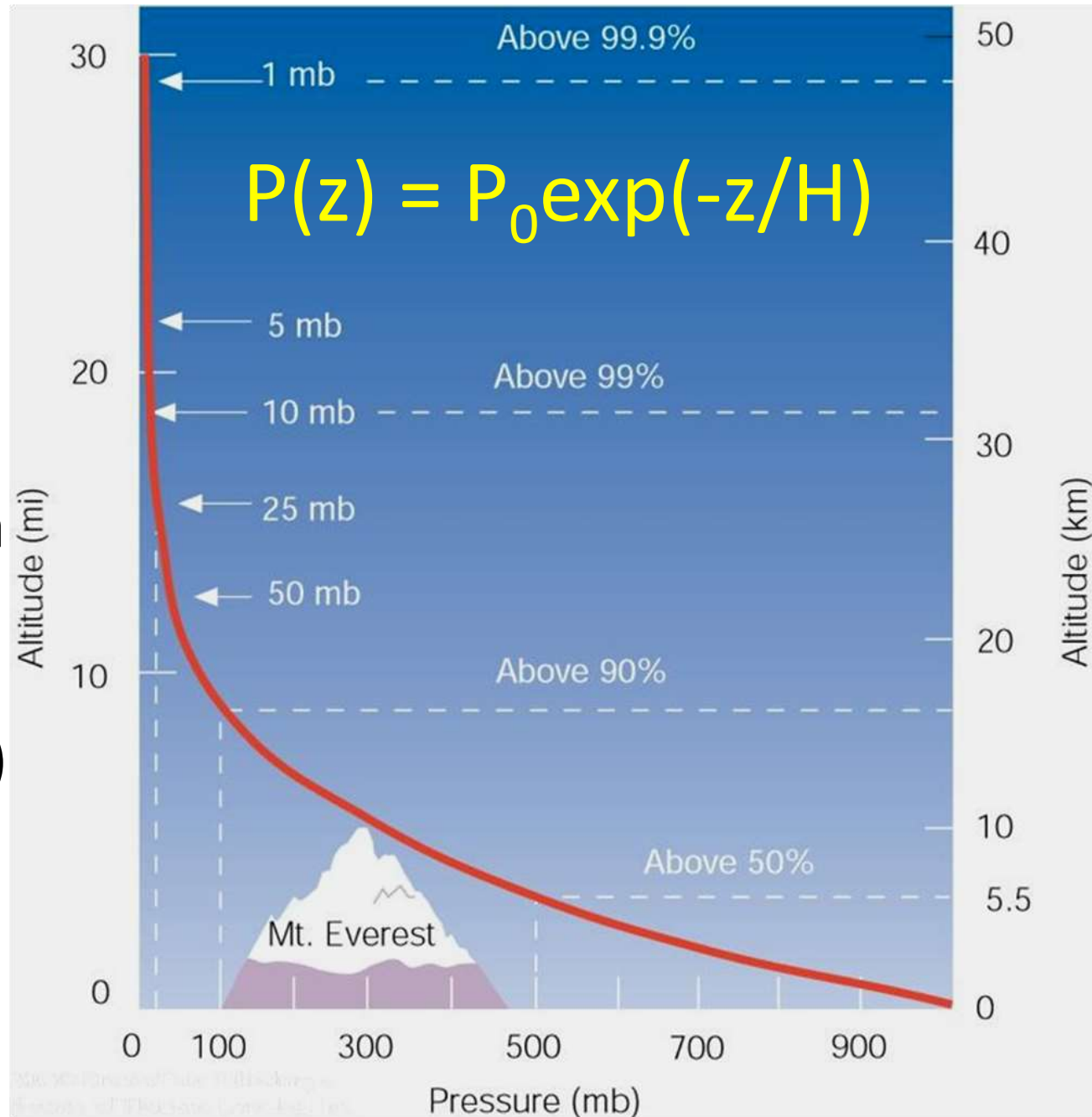
R: cte gases
($8.23 \text{ J K}^{-1} \text{ mol}^{-1}$)

T_m : temp. media
(0° C)

M_0 : massa mol.
Média (0.029 kg)

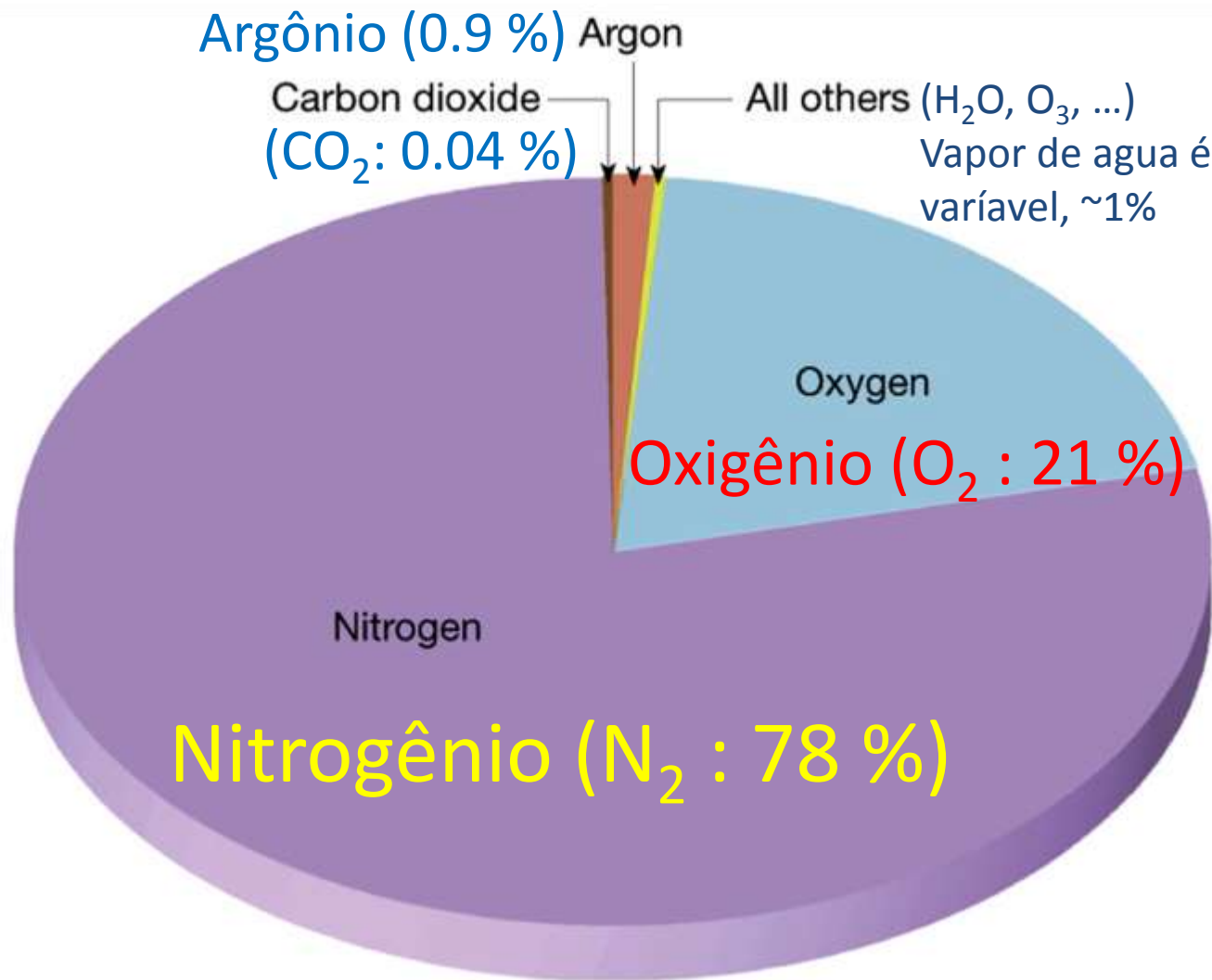
g: acel. grav.

H = 8km



Quais são os maiores
constituintes da atmosfera?

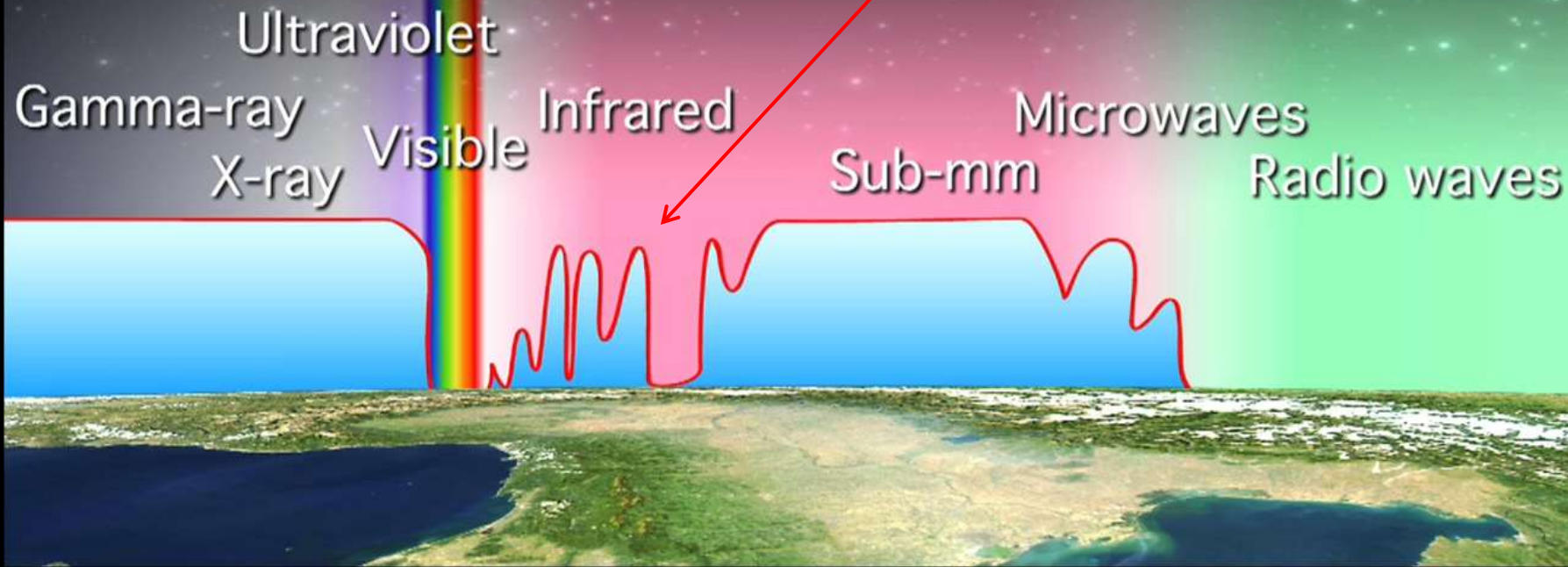
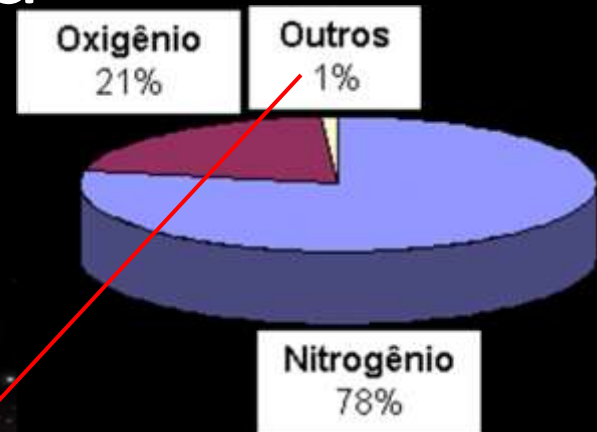
Constituintes da atmosfera



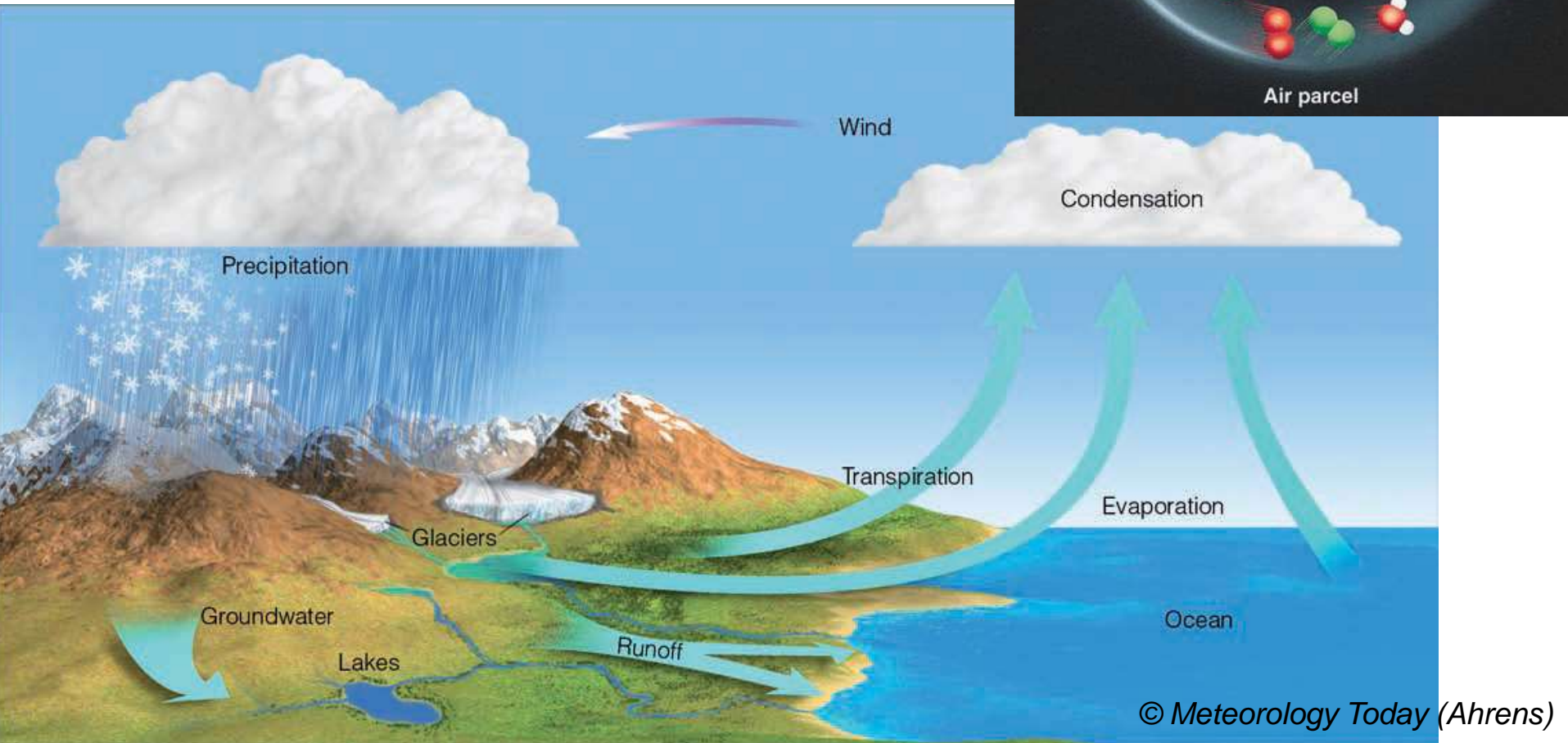
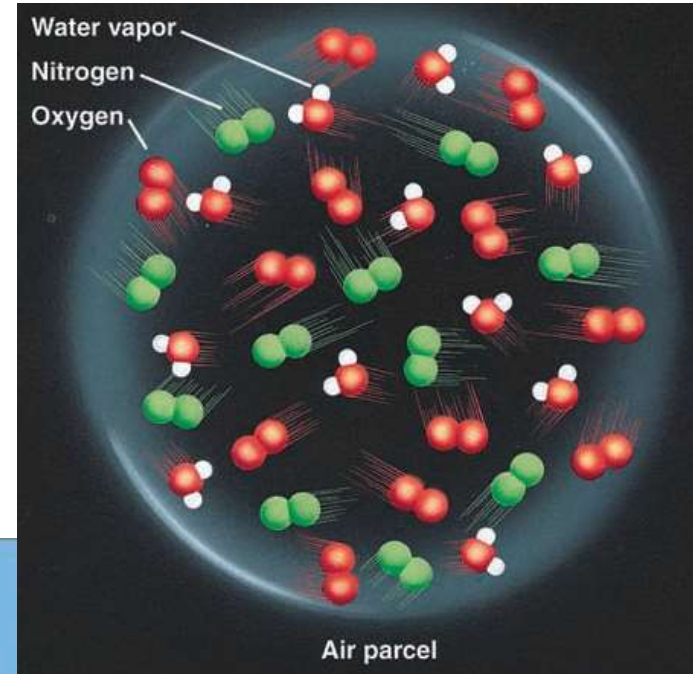
N e O são os principais constituintes e sua proporção relativa é constante entre 0-90 km

Constituintes da atmosfera (CO_2 , H_2O , O_3 ,...)

Os constituintes menores (e variáveis) são importantes fontes de opacidade na atmosfera



Vapor de água: uma das principais fontes de opacidade na atmosfera



Medida do conteúdo de Vapor d'água

O conteúdo fracional (*fractional content*), razão de mistura (*mixing ratio*), ou humidade específica (*specific humidity*) é:

$$r = \frac{\text{mass of H}_2\text{O per m}^3}{\text{mass of air per m}^3}$$

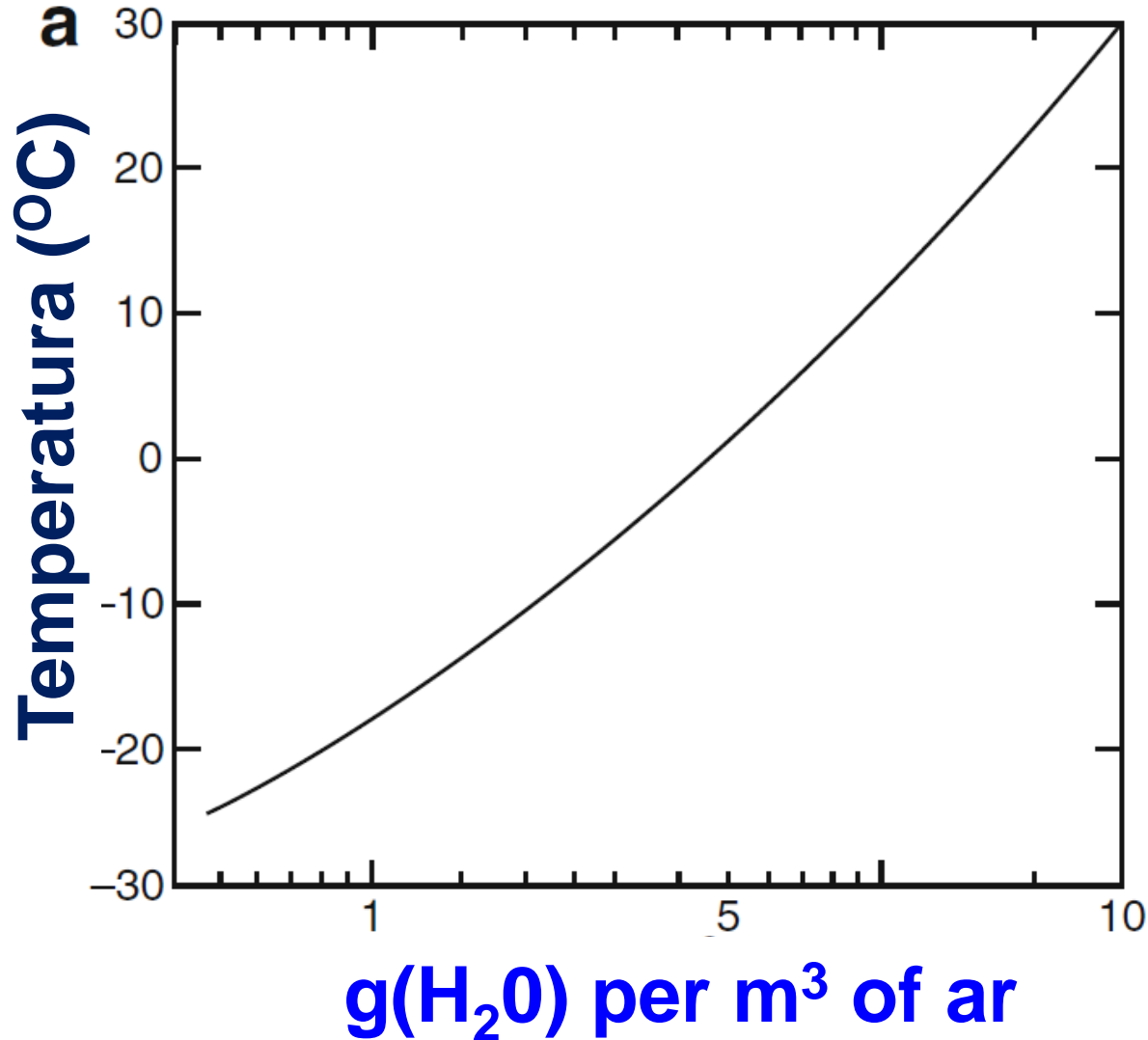
• $0 < r \leq r_s(T)$ (saturação)

$[r] = \text{g/Kg}$

muito sensível à

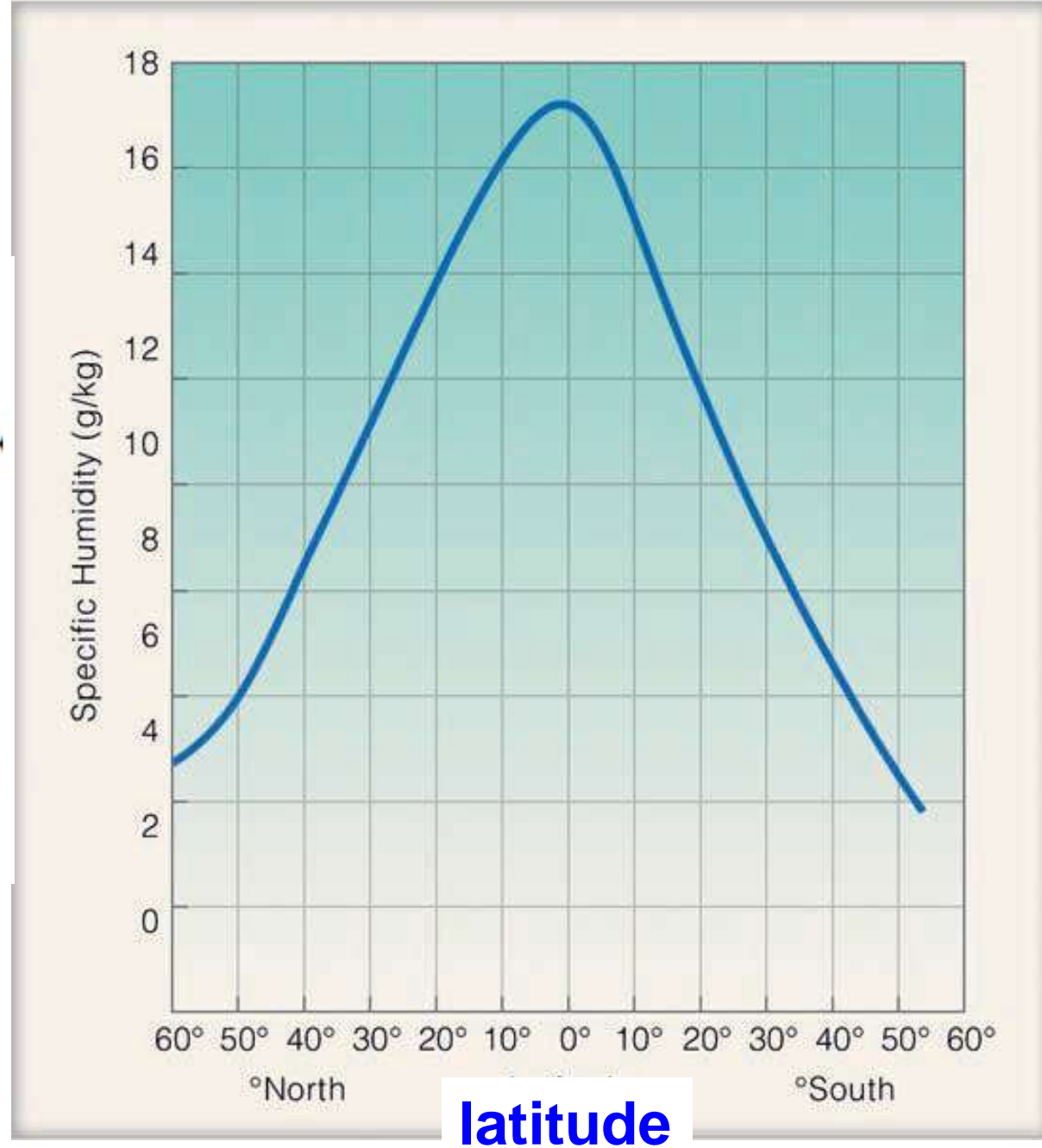
- Temperatura
- z (altitude)
- Latitude
- tempo

Massa de vapor de H₂O por volume de ar saturado a pressão normal em função da temperatura



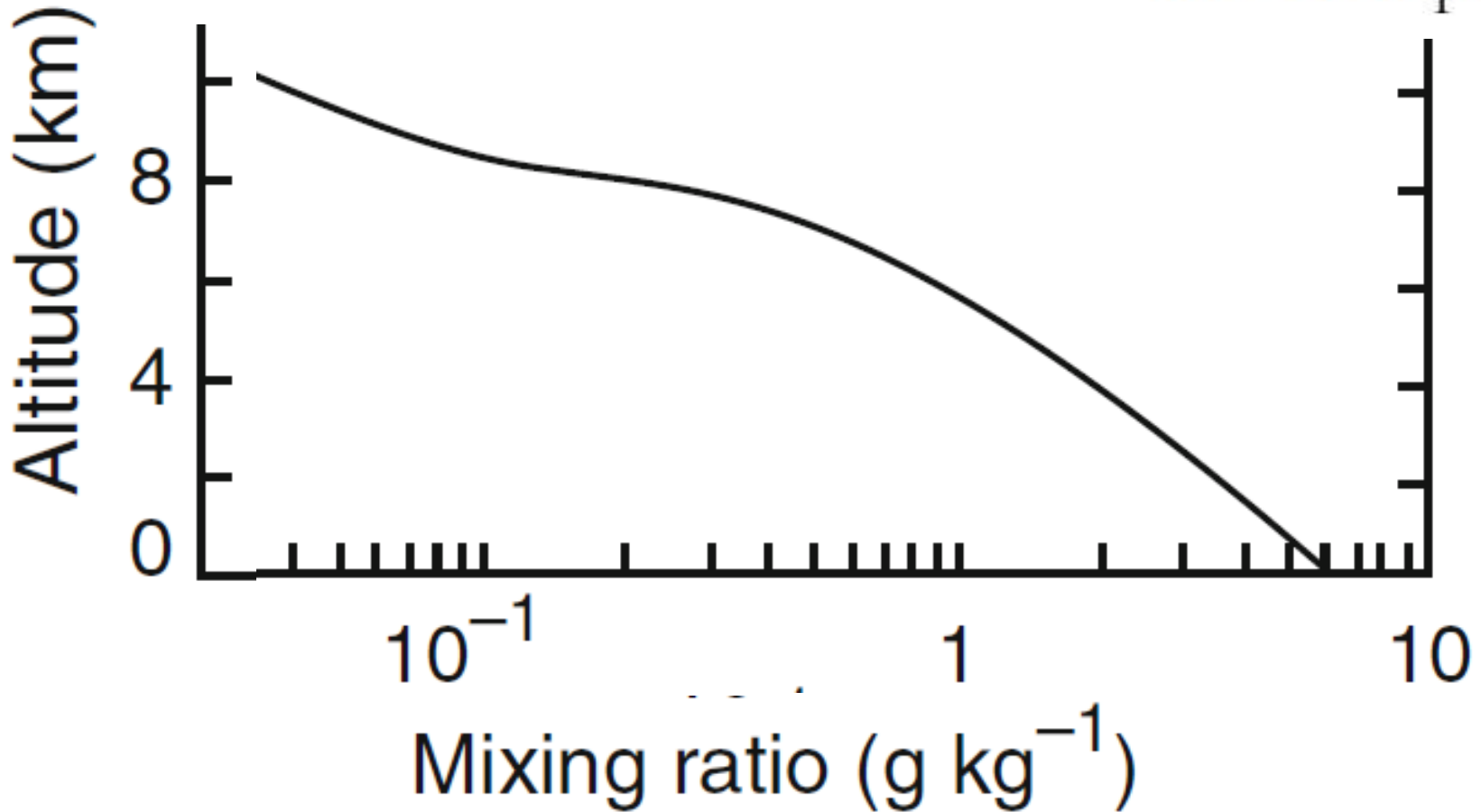
Mixing ratio em função da latitude

$$r = \frac{\text{mass of H}_2\text{O per m}^3}{\text{mass of air per m}^3}$$



Concentração de vapor de H₂O em função da altitude

$$r = \frac{\text{mass of H}_2\text{O per m}^3}{\text{mass of air per m}^3}$$



Quantidade de água precipitável

Água precipitável acima de uma dada altura z_0 é

$$w(z_0) = \int_{z_0}^{\infty} N_{\text{H}_2\text{O}} dz$$

onde $N_{\text{H}_2\text{O}}(z)$ é o número de moléculas / volume

For normal pressure and temperature P_0 and T_0 , respectively,

$$N_{\text{H}_2\text{O}} [\text{m}^{-3}] = 4.3 \times 10^{25} \frac{P}{P_0} \frac{T}{T_0} r(z).$$

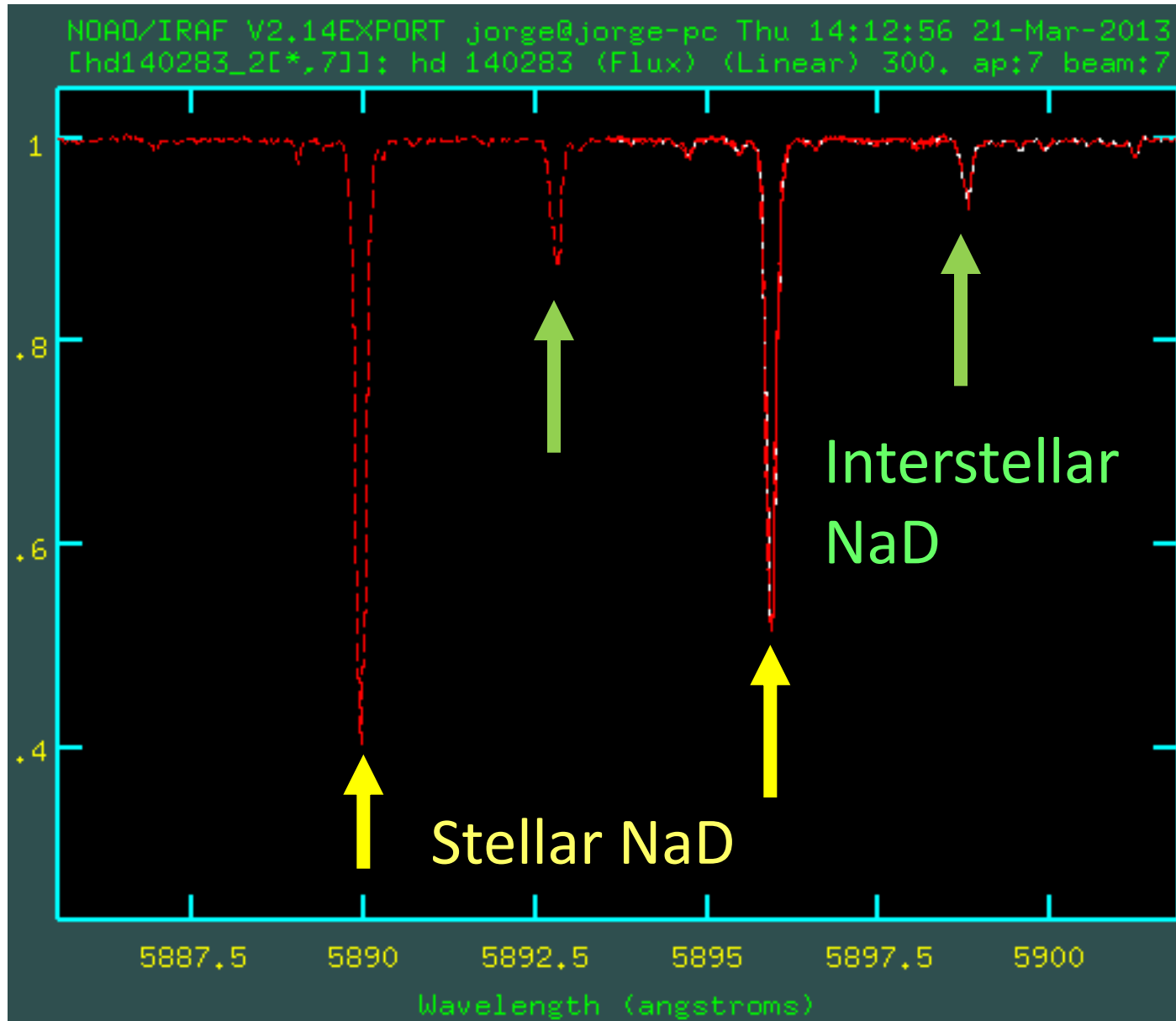
Coluna d'água precipitável

$$h_{\text{H}_2\text{O}} [\text{cm}] = \rho_0 [\text{g cm}^{-3}] \int_{z_0}^{\infty} r(z) e^{-z/H} dz,$$

Onde ρ_0 é a densidade do ar em z_0

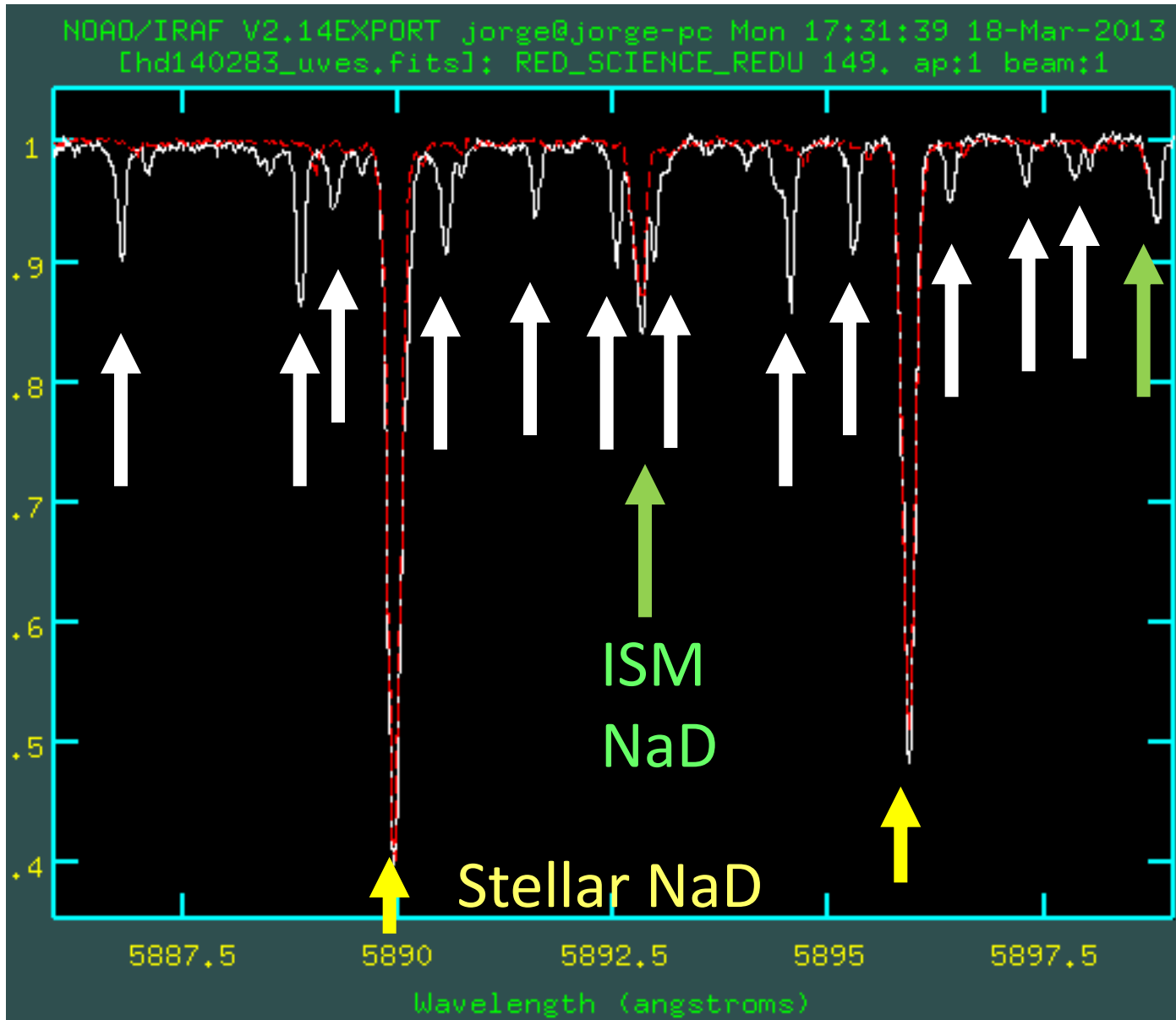
$r(z)$ varia rapidamente: a escala de altura do vapor d'água (3km) é \ll ar seco (8 km)

Keck (4.2km) spectrum of HD140283

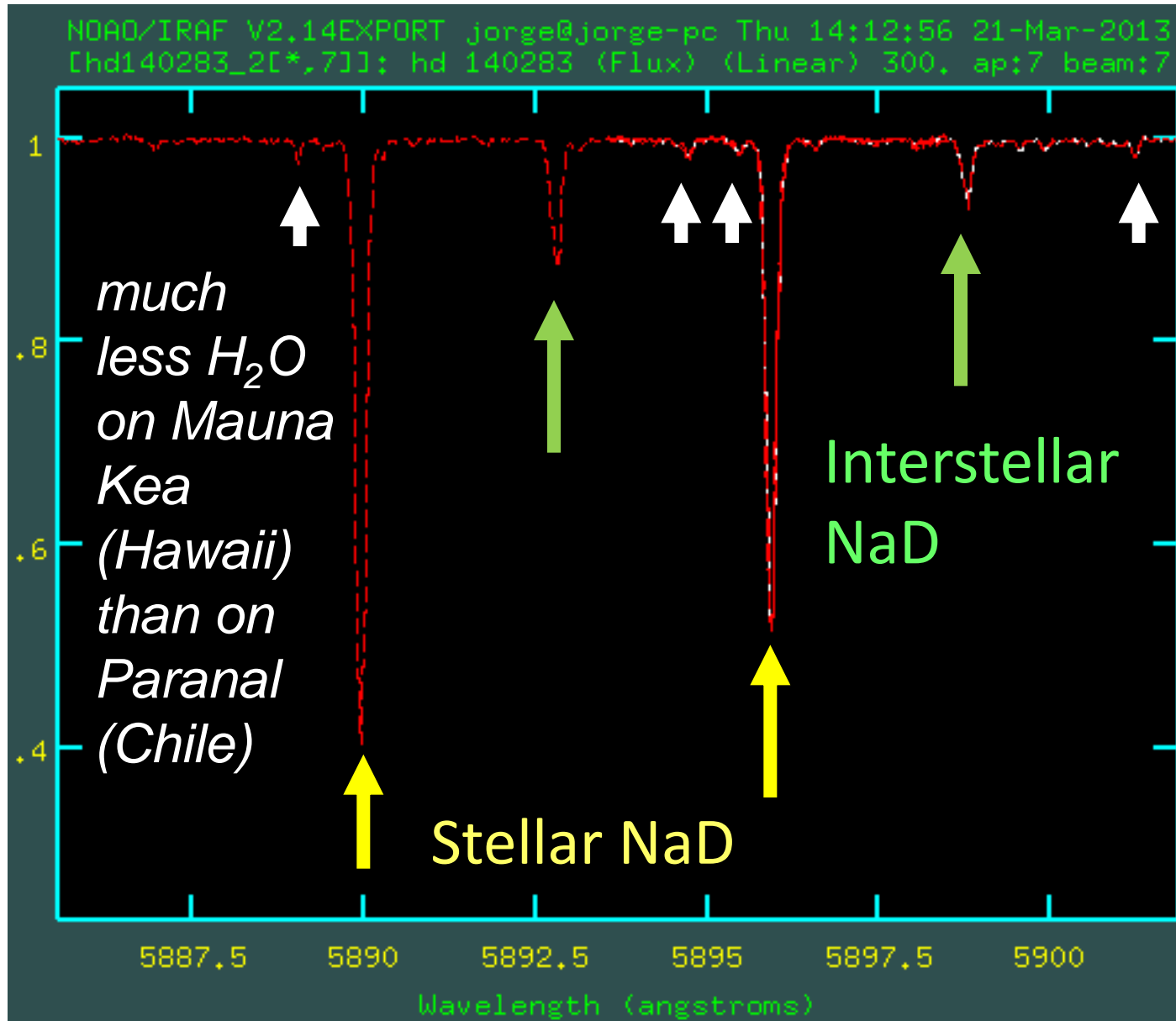


Keck (4.2km) vs. VLT (2.7km)

Water vapor clearly present on Paranal (VLT)

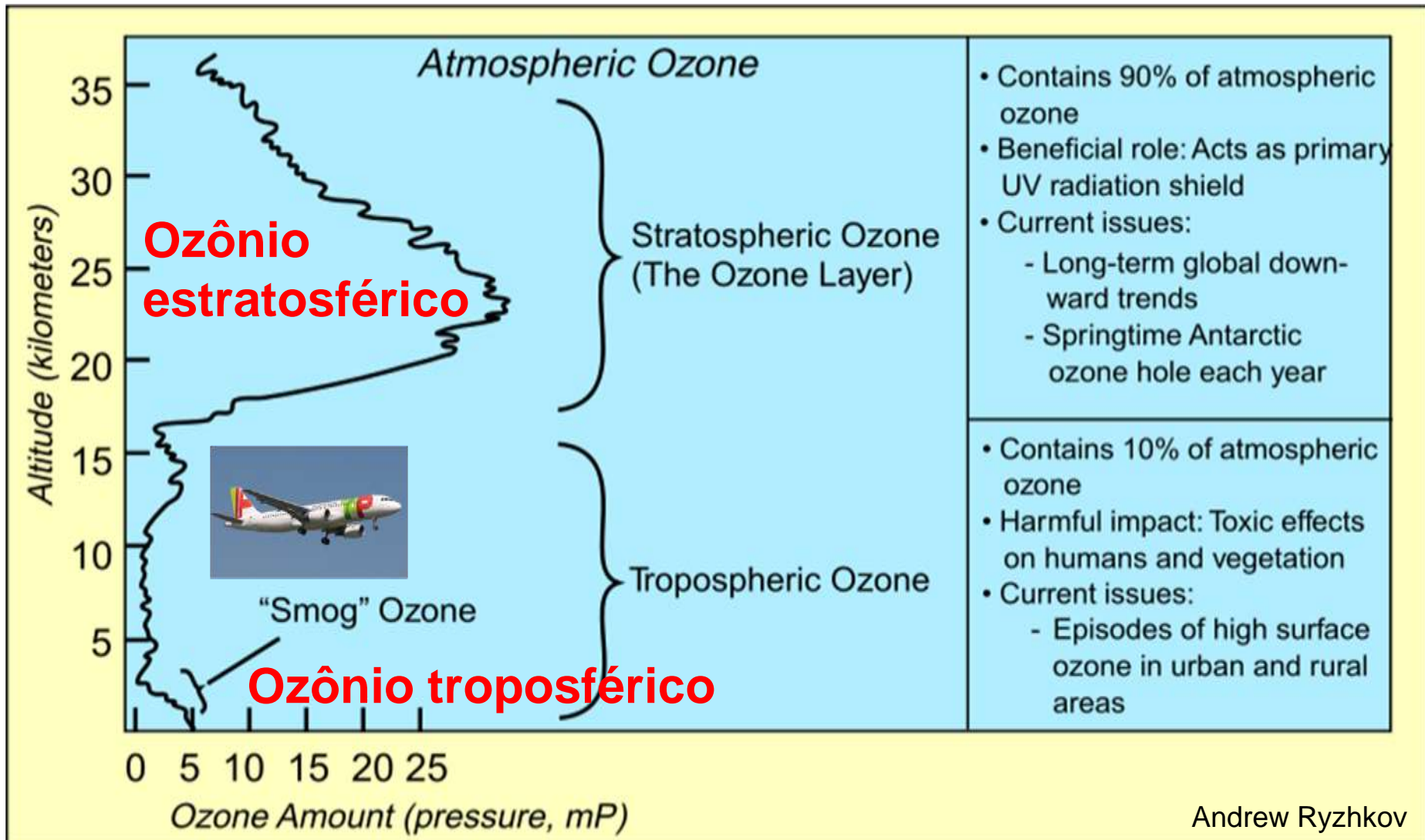


Keck (4.2km) spectrum of HD140283



Ozônio (O₃)

A estrutura vertical do O₃ varia muito (latitude, estação do ano), mas tem um máximo ~20km

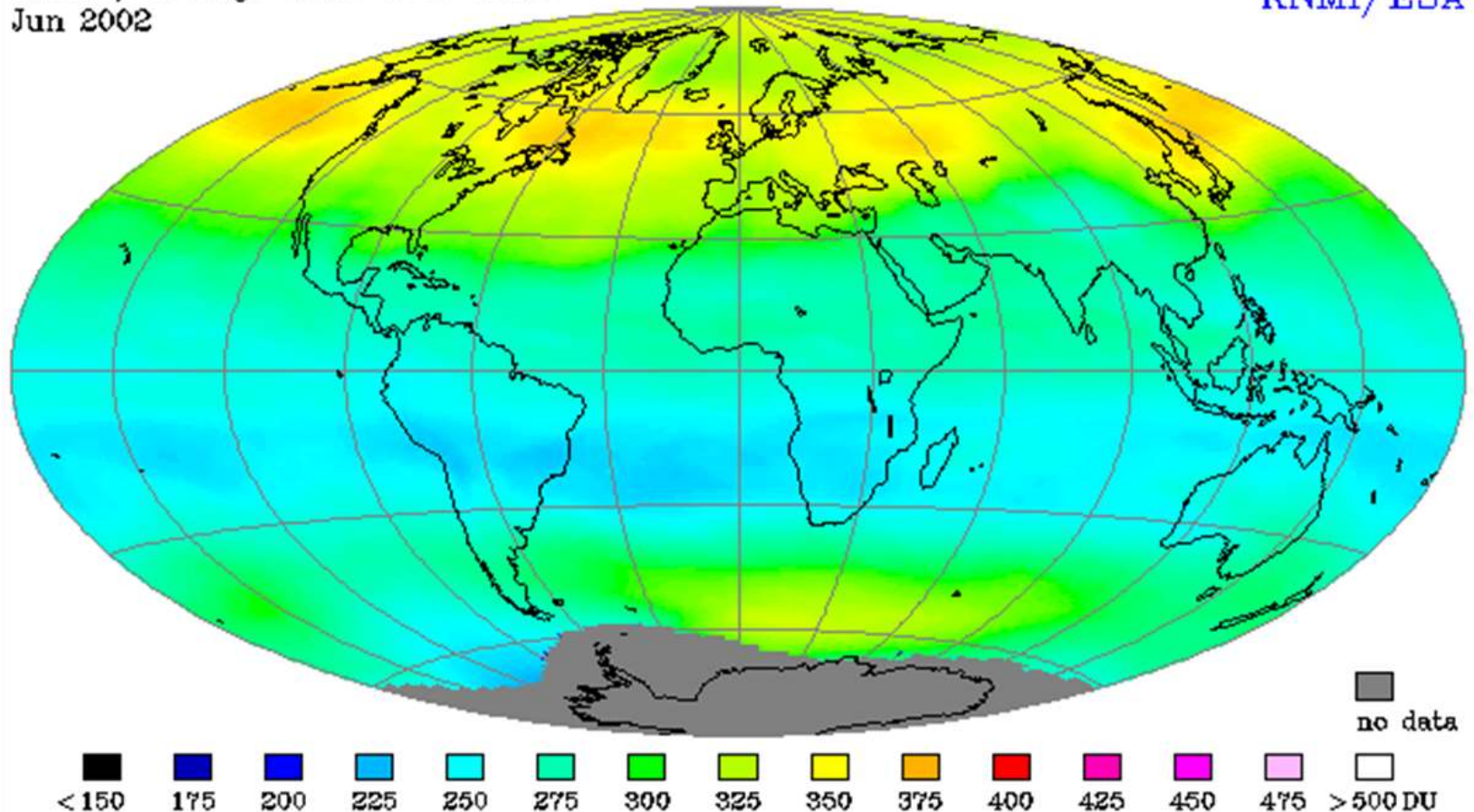


Ozônio (O₃)

O hemisferio norte tem uma maior concentração de ozônio que o hemisferio Sul

Monthly average GOME total ozone
Jun 2002

KNMI/ESA



Ozônio (O₃)

A quantidade total de O₃ tem um ciclo annual

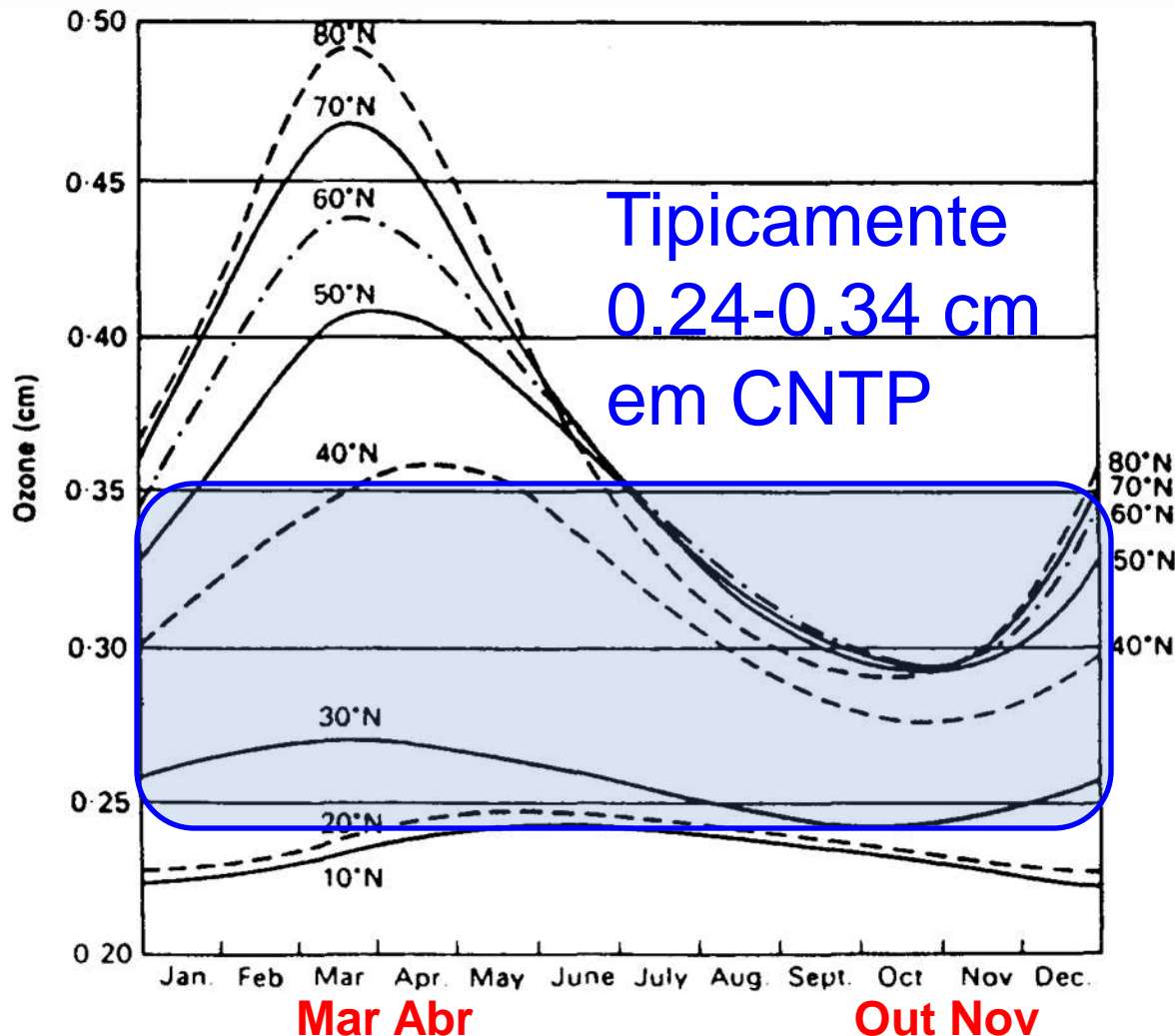
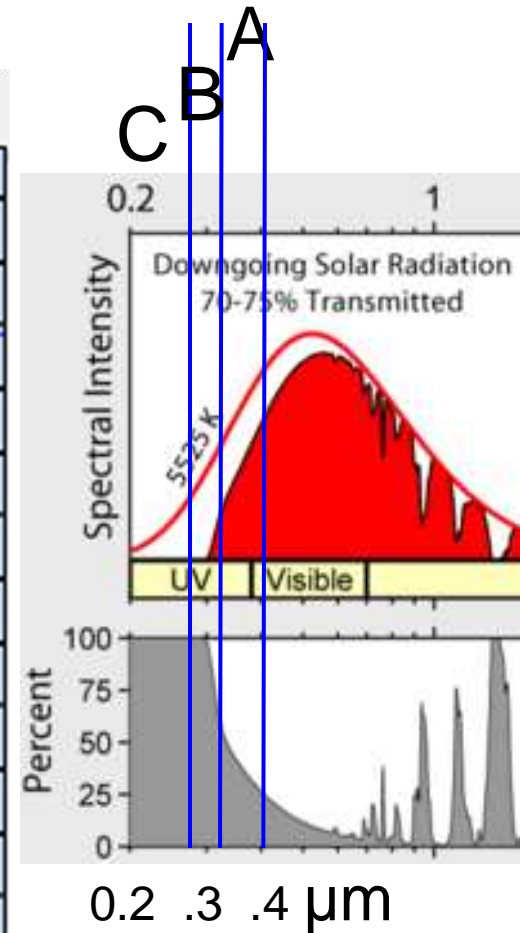
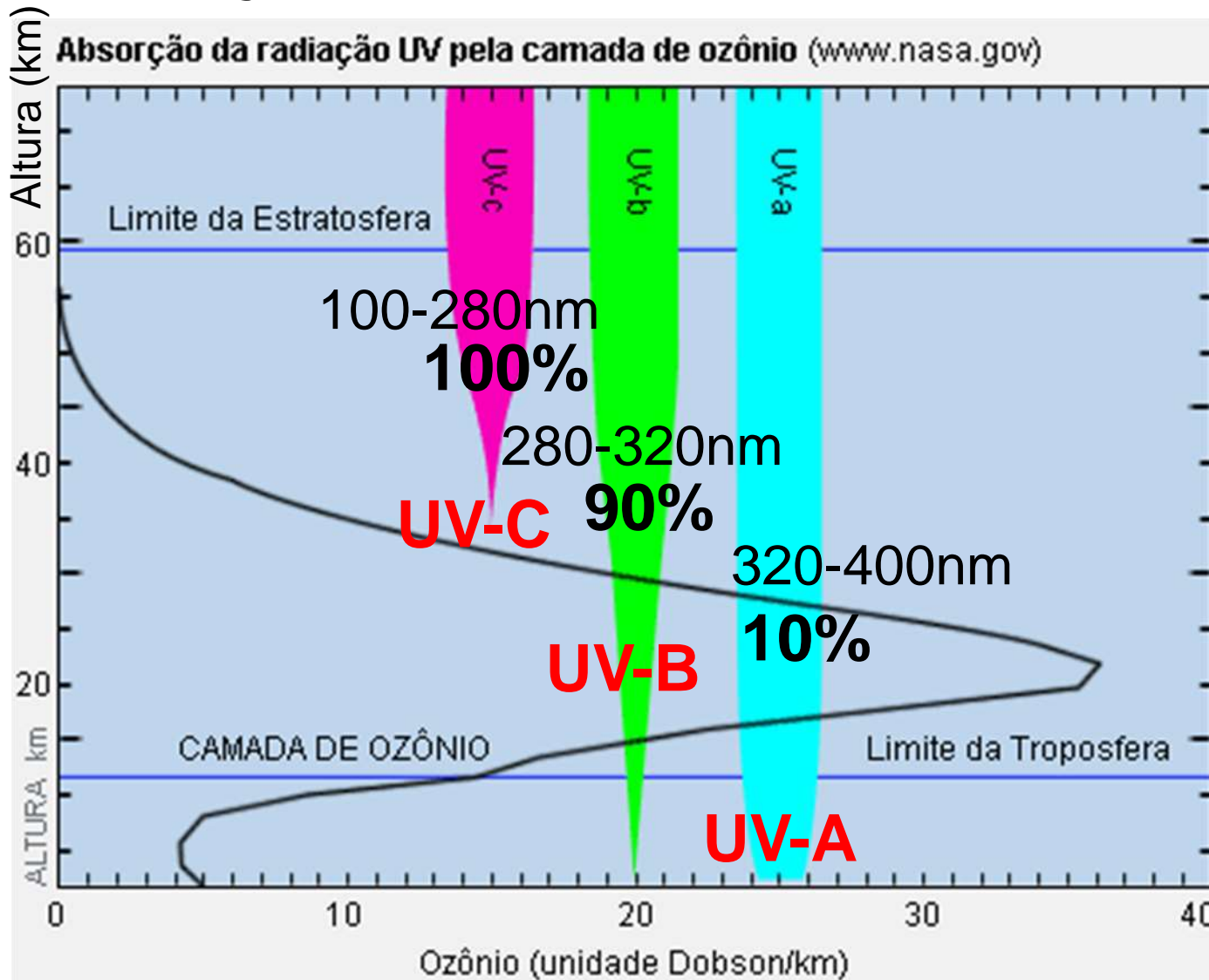
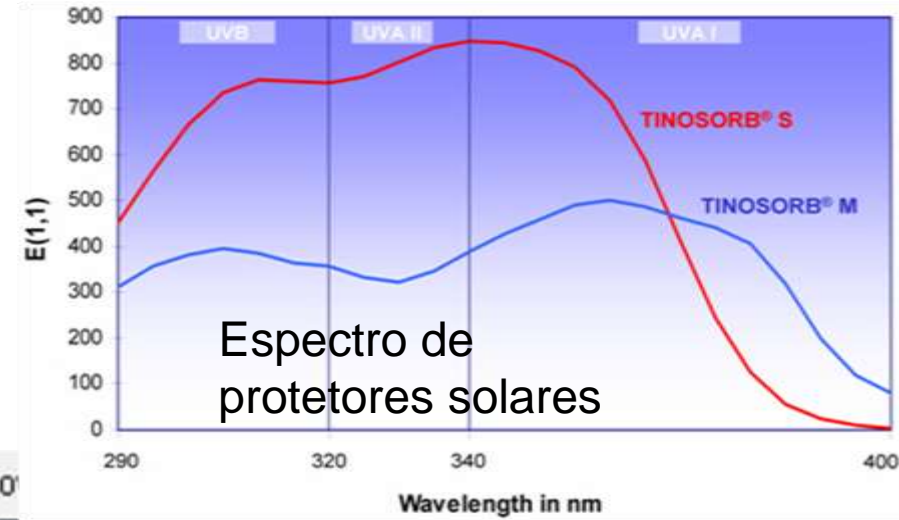


Figure 1. Annual Variation of Total Ozone for Each 10° of N Latitude
Variação annual do ozônio a cada 10 graus de latitude no hem. Norte

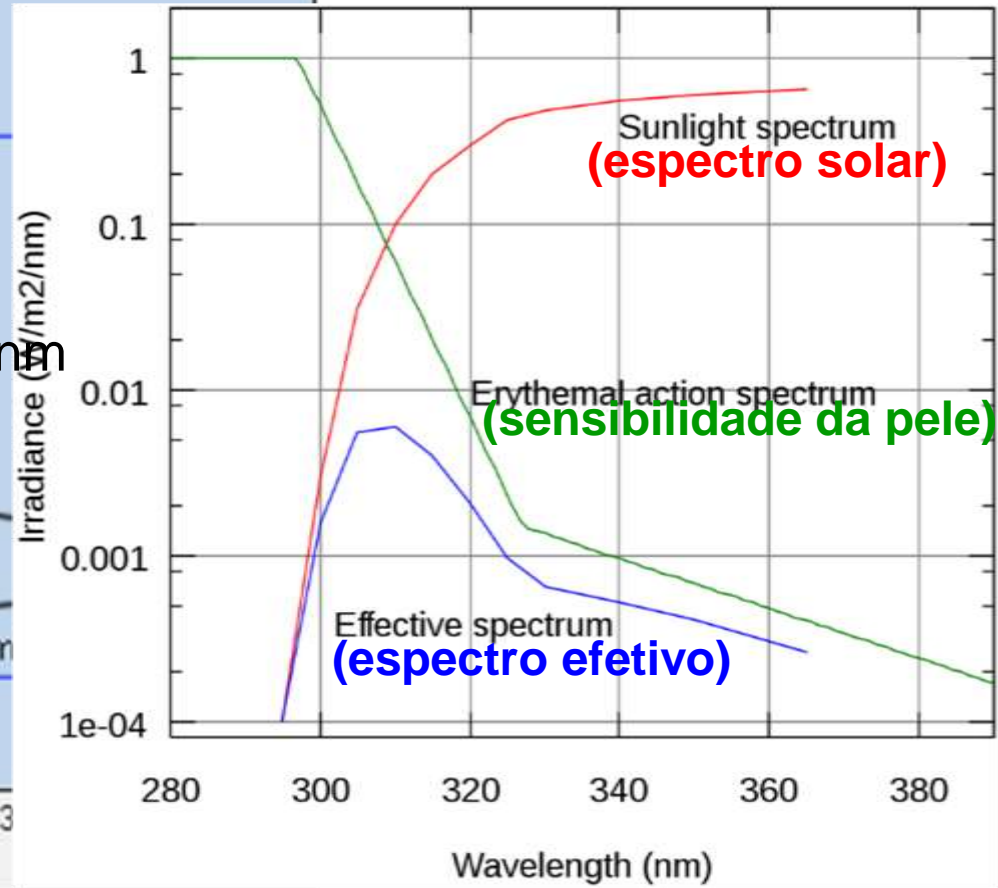
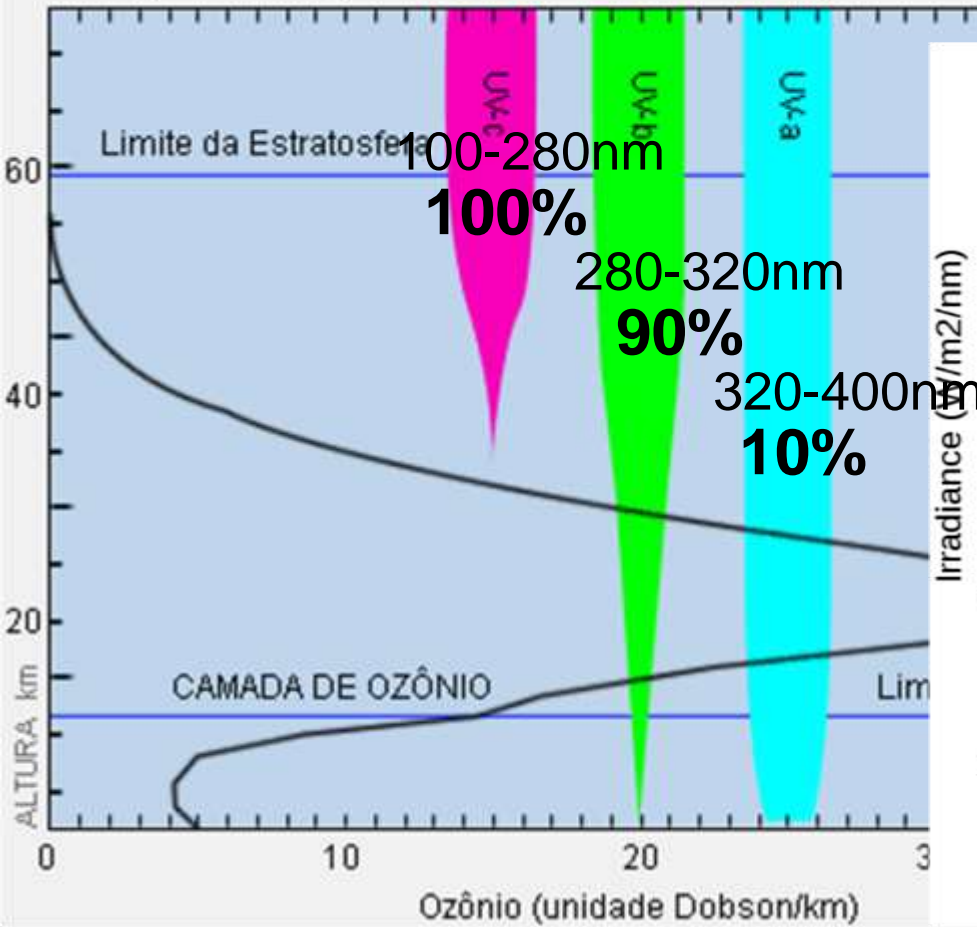
Ozônio: principal proteção contra a radiação UV solar



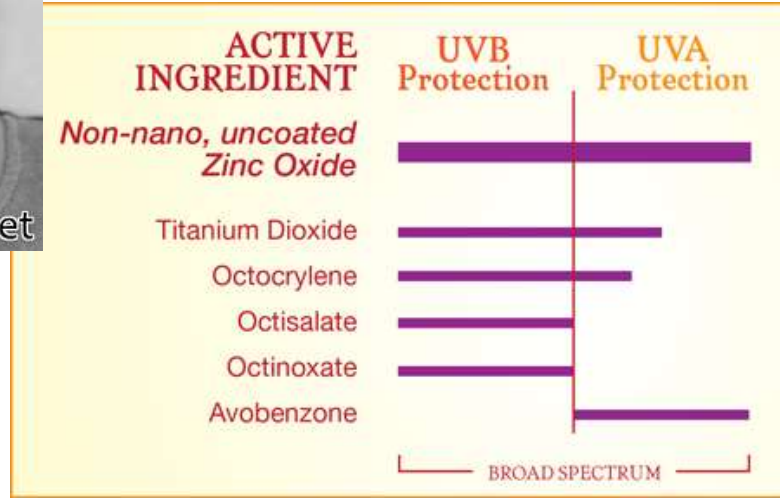
Ozônio: principal proteção à Terra contra a UV do Sol



Absorção da radiação UV pela camada de ozônio (www.nasa.gov)

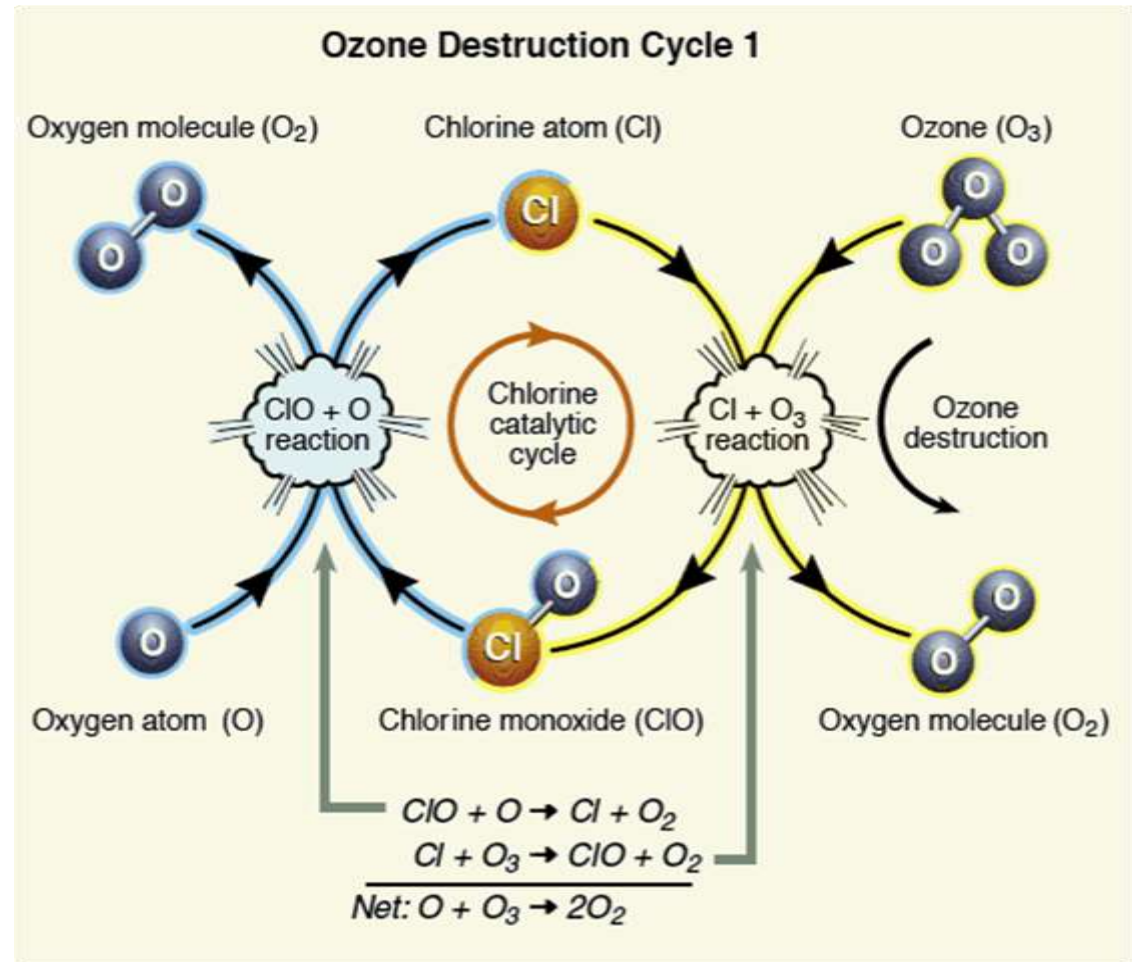


Verificar se seu protetor solar bloqueia UVA!



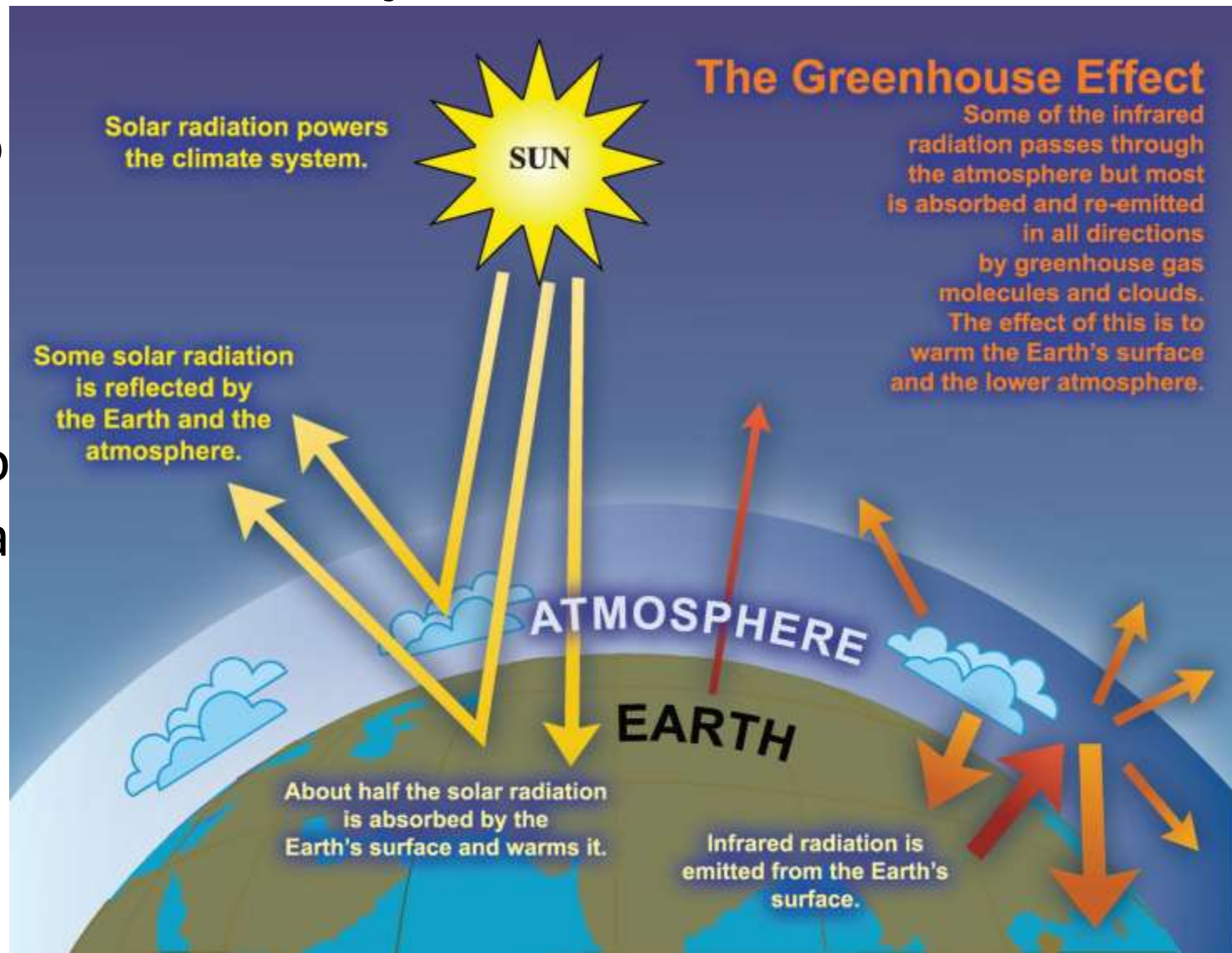
Destruição do Ozônio

- Constituintes menores (Cl, NO) destroem o O_3
- Os cloroflourcarbonetos, CFCs, podem alcançar a estratosfera e destruir ozônio



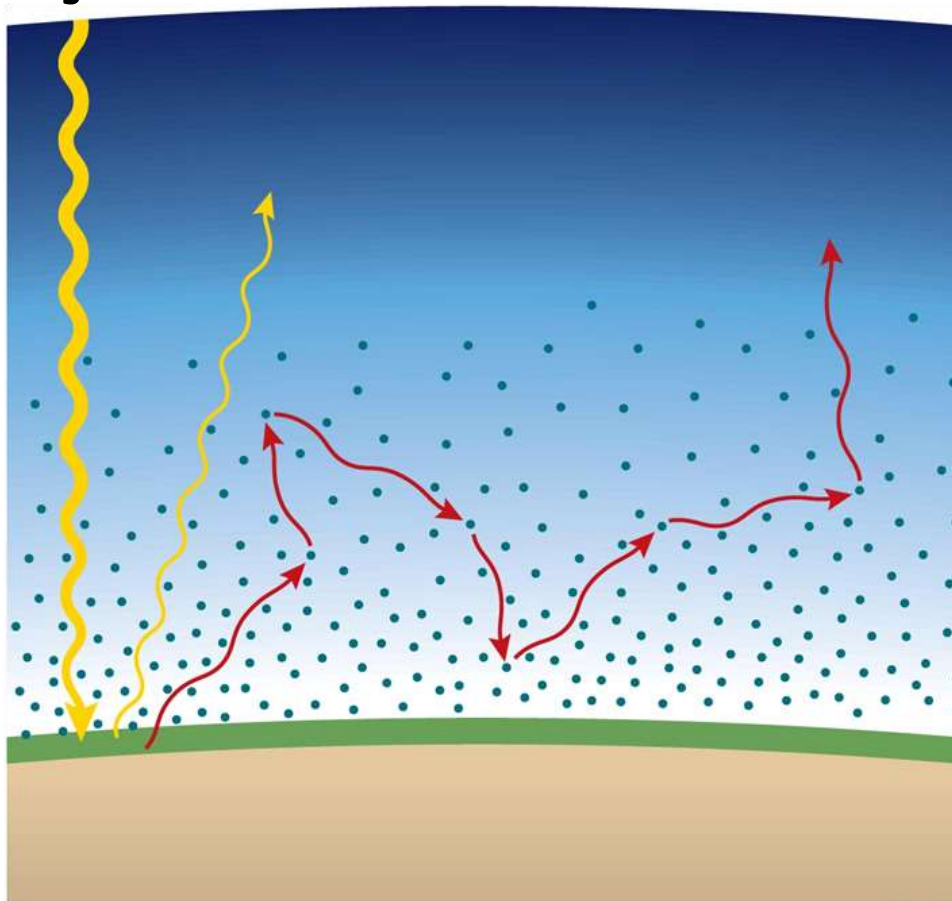
Dióxido de carbono CO_2

- Importante fonte de absorção no infravermelho
- Tem distribuição similar ao O_2 e N_2
- Razão de mistura não depende da altura



CO₂ e aquecimento global

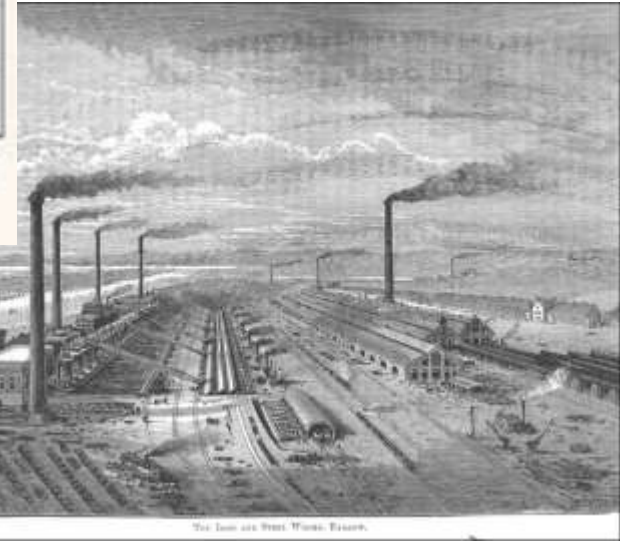
Luz visível atravessa a atmosfera e esquenta a superfície. Os gases (CO₂, H₂O & CH₄) na atmosfera absorvem a luz IR refletida, re-emetindo-a em direções aleatórias.



- CO₂ é a segunda fonte (após H₂O) do aquecimento global

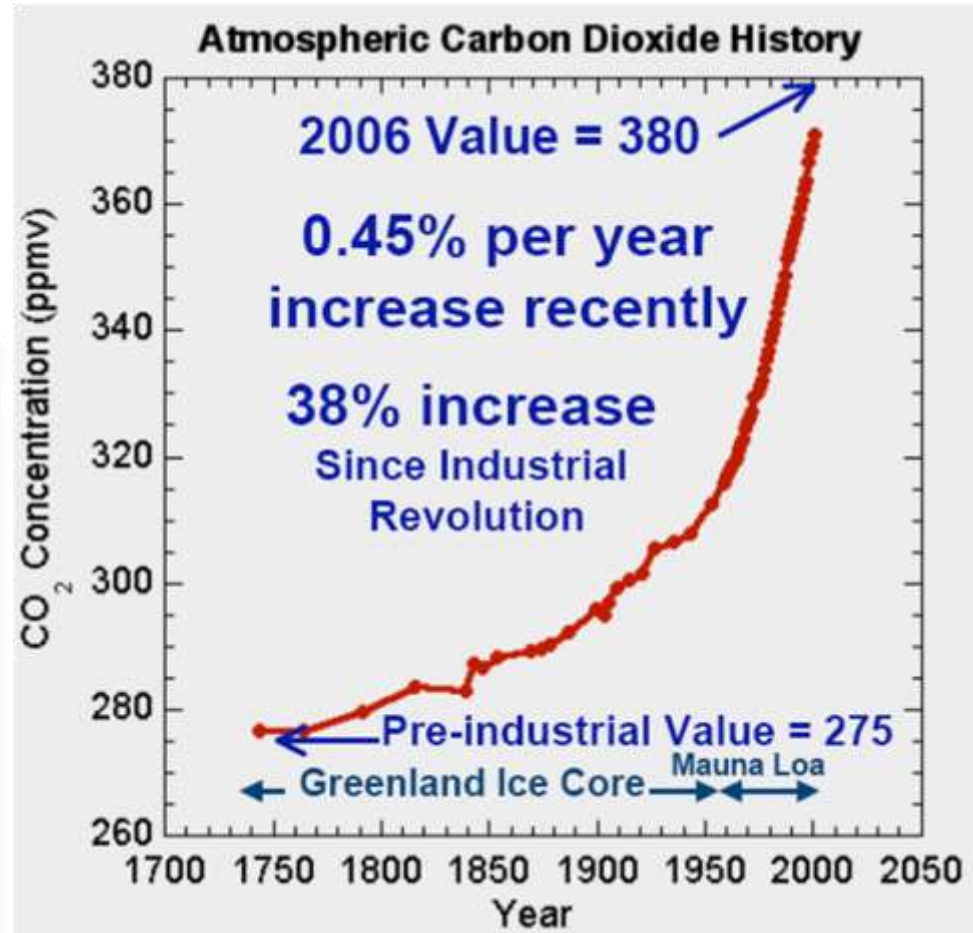
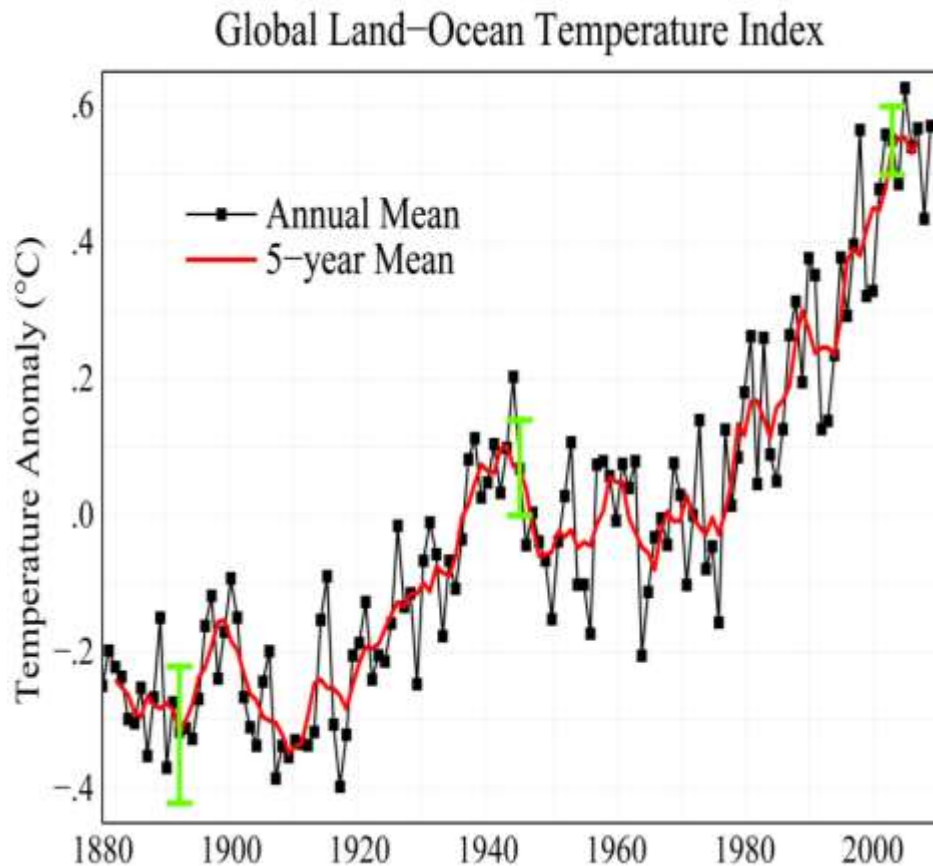
CO₂ e aquecimento global

CO₂ nos últimos 1000 anos

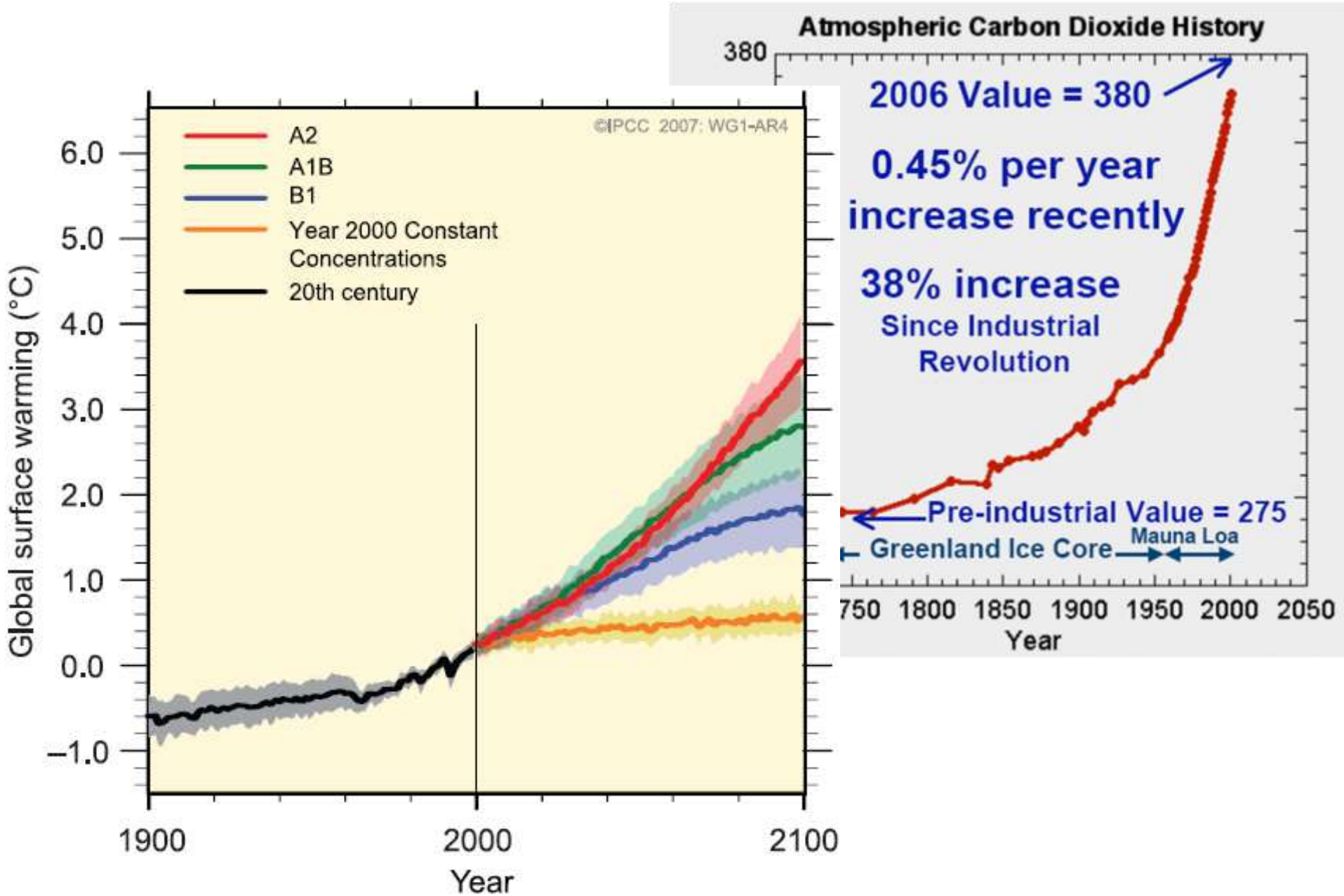


● **FIGURE 1.6** Carbon dioxide values in parts per million during the past 1000 years from ice cores in Antarctica (blue line) and from Mauna Loa Observatory in Hawaii (red line). (Data courtesy of Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory.)

CO₂ e aquecimento global

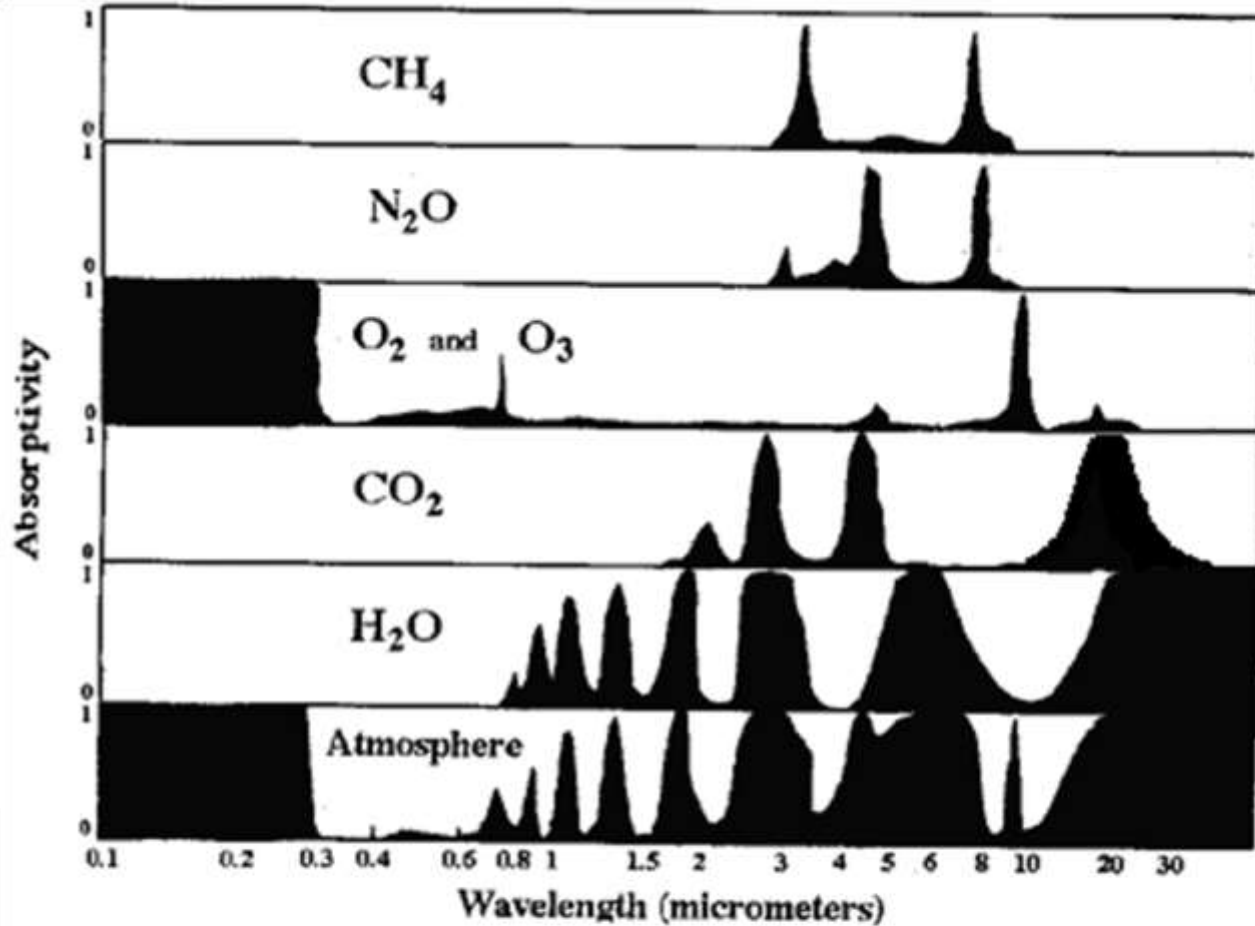
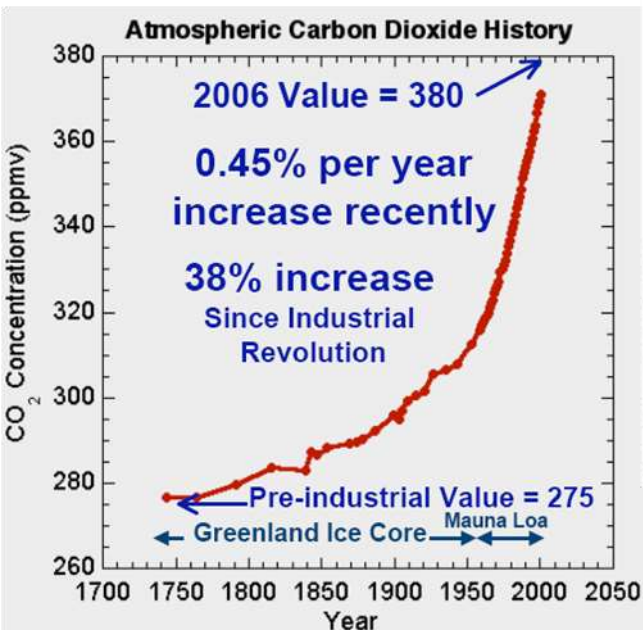


CO₂ e aquecimento global



Impacto na Astronomia

Aumento de CO_2 : maiores bandas de absorção na atmosfera



Absorptivity of various gases of the atmosphere and the atmosphere as a whole as a function of the wavelength of radiation. An absorptivity of zero means no absorption while a value of one means complete absorption. The dominant absorbers of infrared radiation are water vapor (H_2O) and carbon dioxide (CO_2). Oxygen (O_2) and ozone (O_3) absorb much of the sun's ultraviolet radiation.

bandas de absorção atmosférica (bandas telúricas)

Impacto na Astronomia?

PROJECTED PATTERNS OF PRECIPITATION CHANGES

Dec-Feb

multi-model

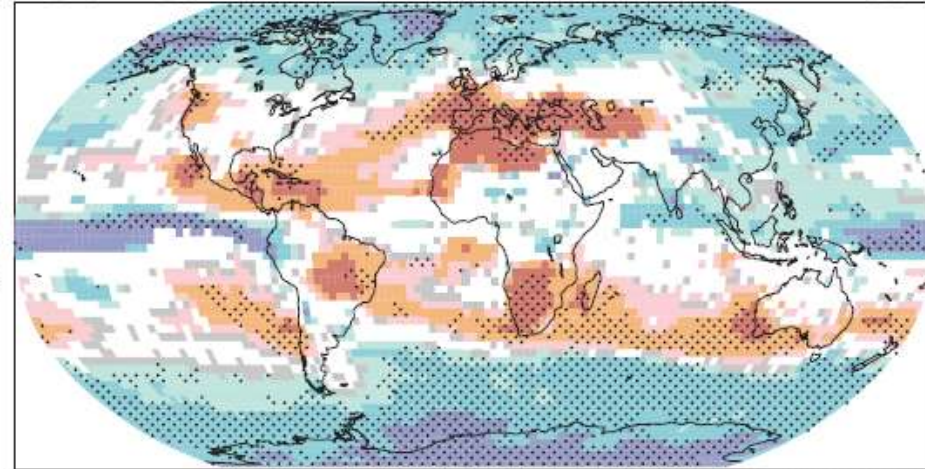
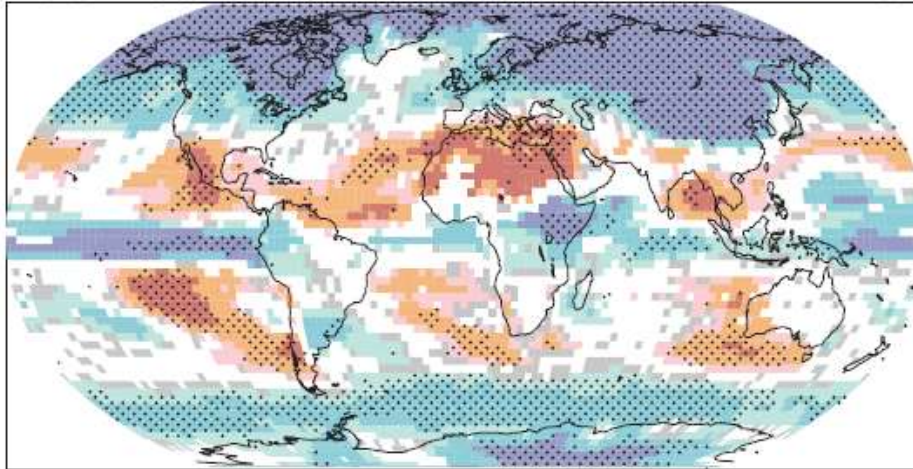
A1B

DJF multi-model

A1B

Jun-Aug

JJA

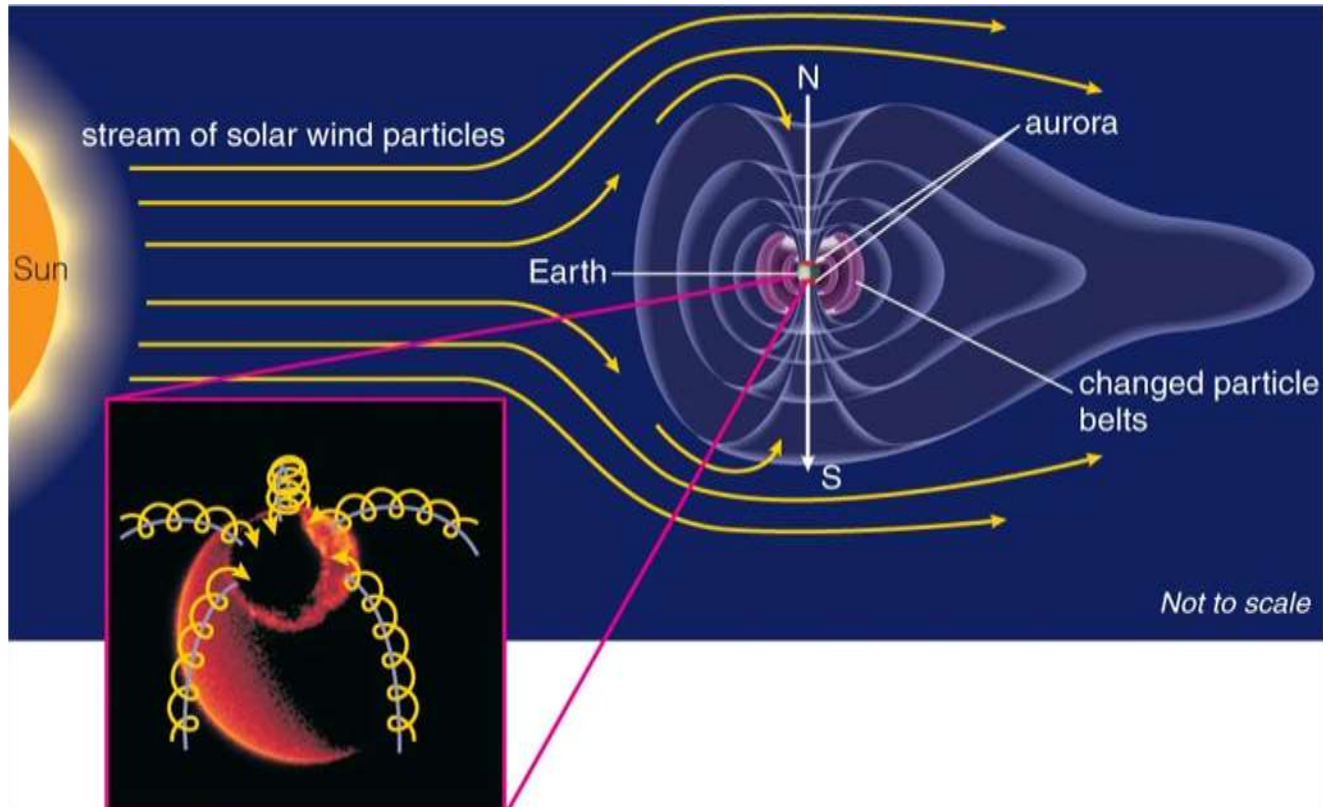


©IPCC 2007: WG1-AR4

Figure SPM.7. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}

Íons

- Acima de 60km, radiação solar UV ioniza a atmosfera
- A Ionização varia com altitude, iluminação solar, ativ. solar
- A altas latitudes, “cascatas” de elétrons entram nos polos magneticos, causam as auroras

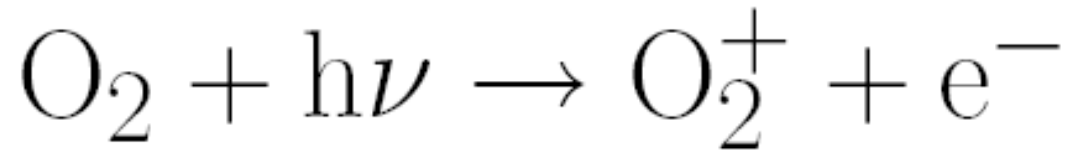


Íons : Auroras



Íons

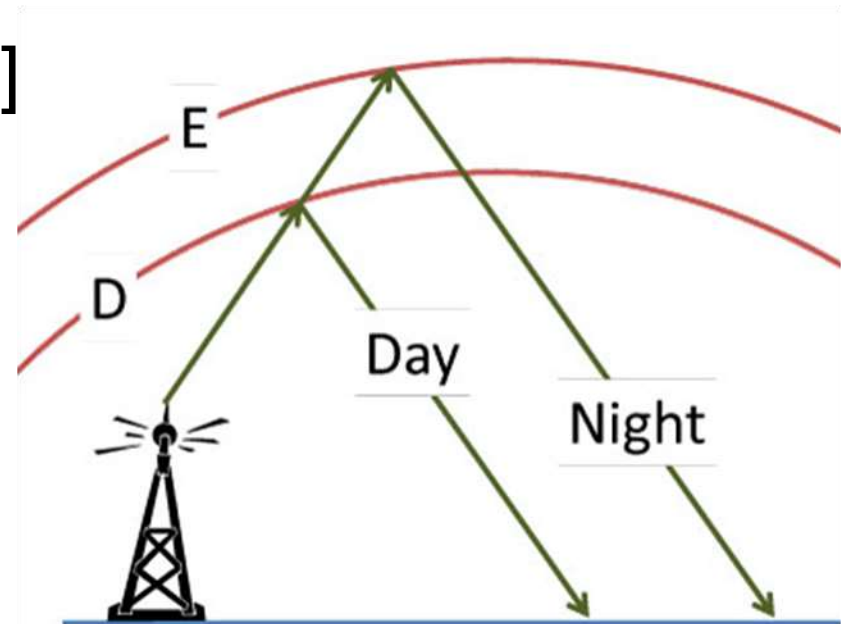
- Reações típicas:



- Variação da dens. eletrônica:

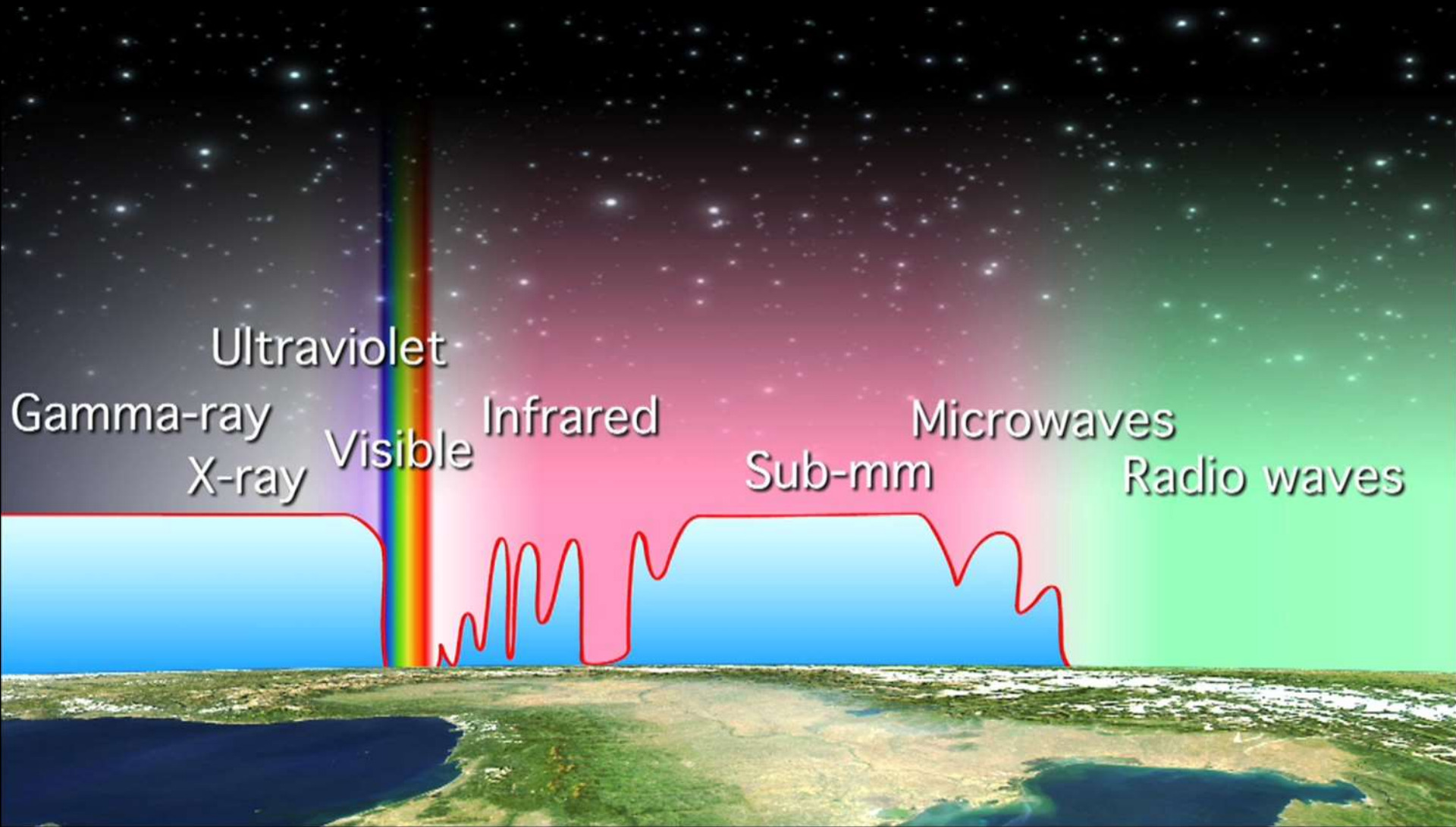
Camada	z(km)	Ne[cm ⁻³]
D	60	10 ³
E	100	10 ⁵
F	150-300	2x10 ⁶
	> 2000	10 ⁴

- D quase desaparece à noite
- Interfere nas ondas de rádio



Absorção da Radiação

A absorção da atmosfera pode ser total ou parcial



Transições Atômicas e Moleculares

ATÔMICAS: O, N

MOLECULARES:

- Eletrônicas

CH₄, CO, H₂O, O₂, O₃, ...

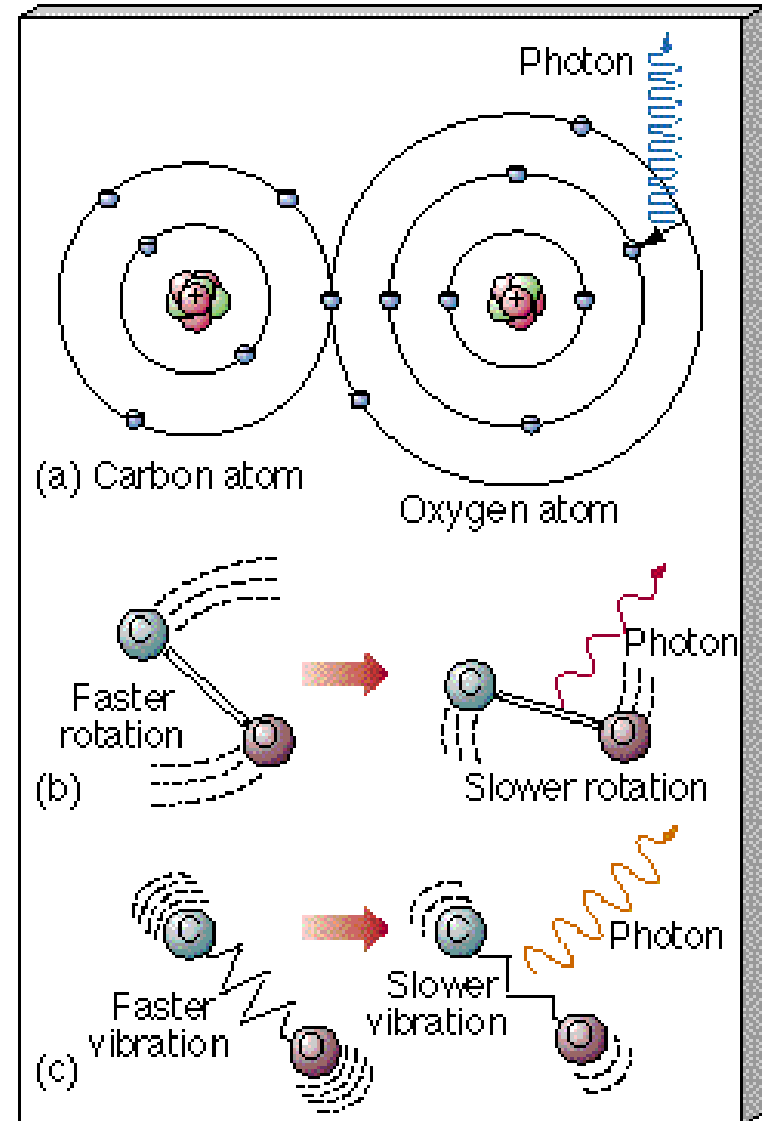
- Rotacionais:

H₂O, CO₂, O₃, ...

- Rotacionais-Vibracionais:

CO₂, NO, CO ...

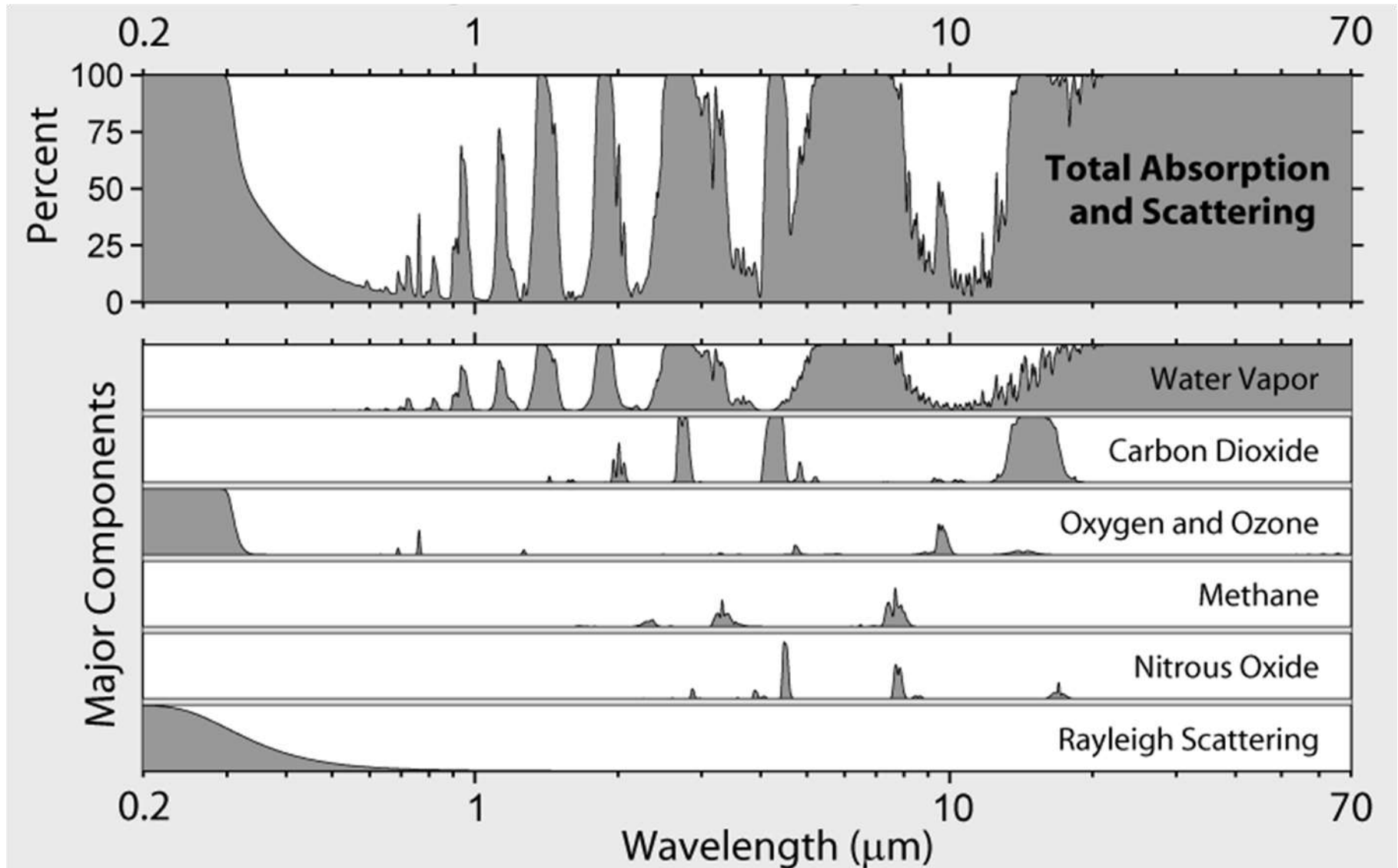
$$E_{el,v'',J''} = [T_e + G_v + F_v(J'')] hc$$



Bandas de absorção atmosféricas

bandas teluricas

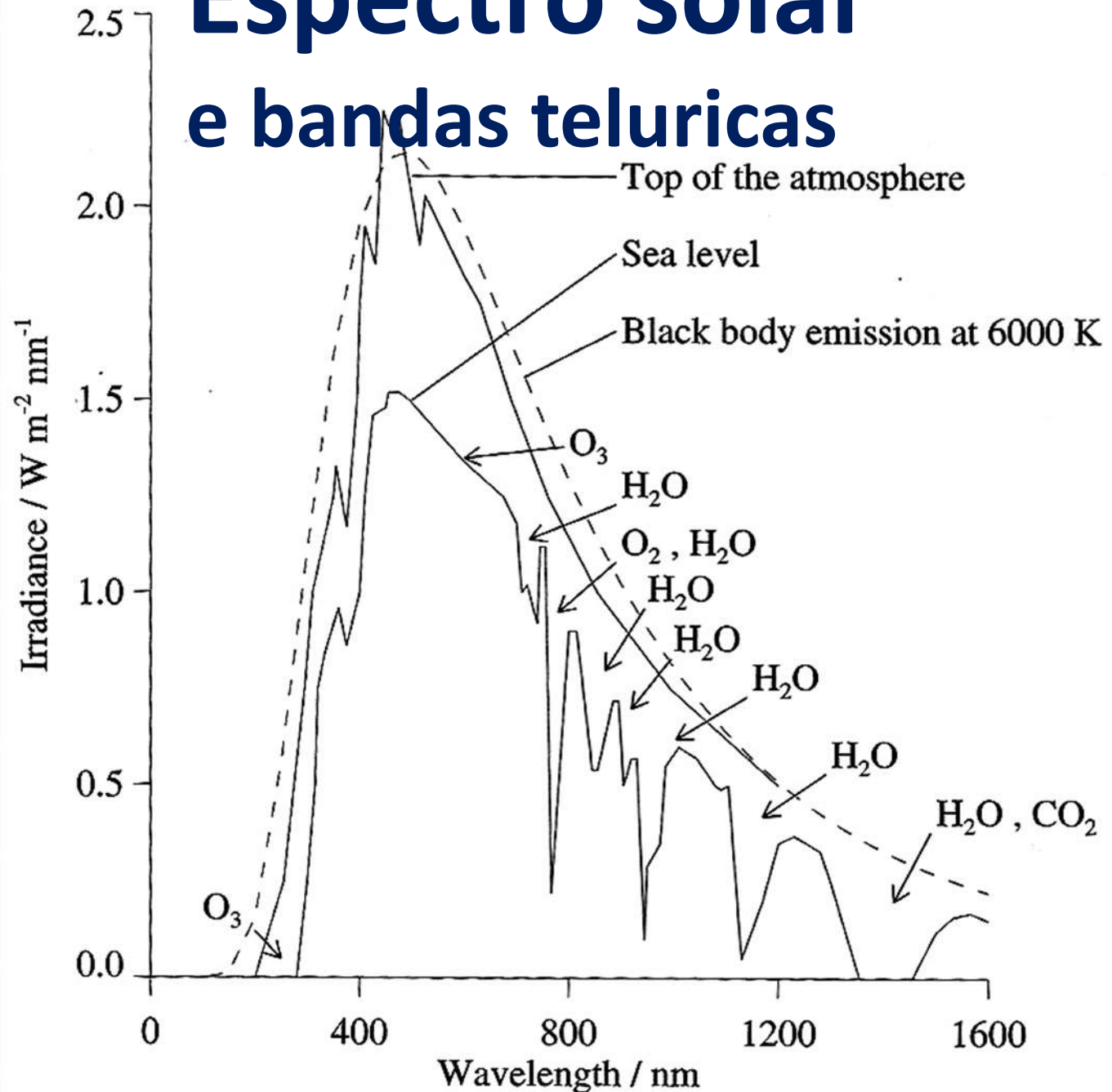
A física atôm. e mol. fornece coef. κ ou σ para c/especie





No otico e infravermelho proximo, O_3 , H_2O e CO_2 causam fortes bandas de absorção na atmosfera terrestre

Espectro solar e bandas teluricas



γ Cas e bandas teluricas

Na região do infravermelho próximo H_2O causa fortes bandas de absorção na atmosfera terrestre

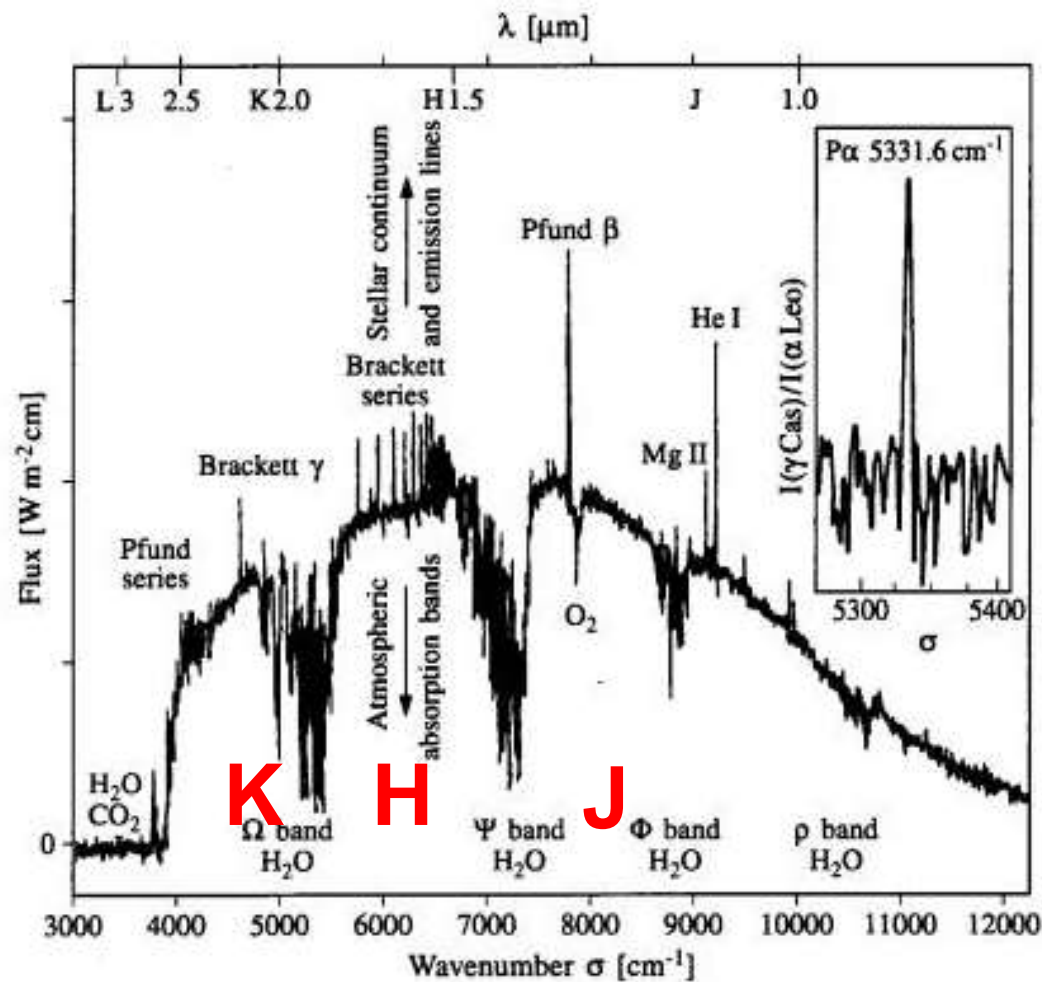
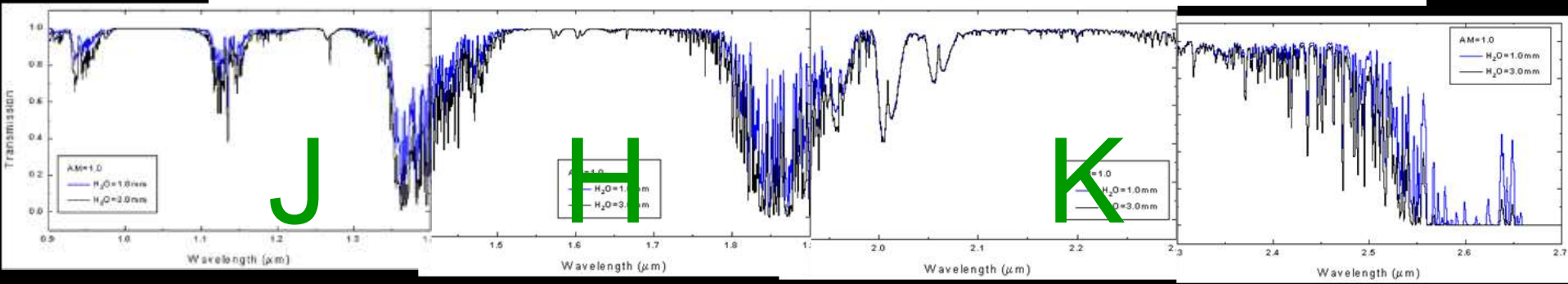


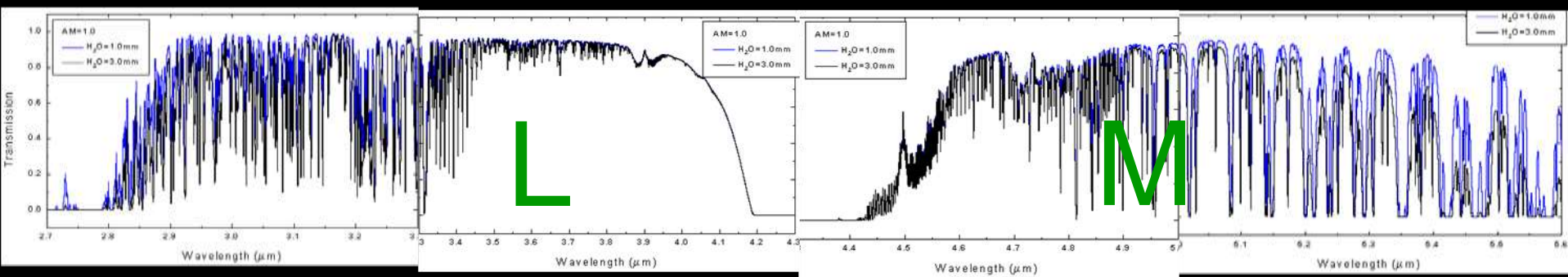
Fig. 2.5. Telluric absorption and spectroscopy: the spectrum of the star γ Cas. The spectrum was obtained using the 3.6 m Canada-France-Hawaii telescope at the summit of Mauna Kea, Hawaii, USA. (4 200 m), with a Fourier transform interferometer (cf. Sect. 5.3.4), in the near infrared atmospheric transmission window, with a resolution of $\Delta\sigma = 0.5 cm^{-1}$. (Chalabaev A., Maillard J.-P., *Ap. J.* **294**, 640, 1984.) Atmospheric absorption bands are indicated, together with photometric windows I, J and K (cf. Sect. 3.3). The star has both a continuum and emission lines (mainly H recombination lines). The inset shows the 3–4 Paschen α line ($5331.6 cm^{-1}$) extracted from a heavily absorbed part of the spectrum: the spectrum of γ Cas was divided by that of a reference star (α Leo) to eliminate atmospheric bands. As α Leo (spectral type B7) also has hydrogen lines, the absolute value of $P\alpha$ is not significant. Observation of $P\alpha$ would be impossible at lower altitude. (With the kind

Transmissão atmosférica

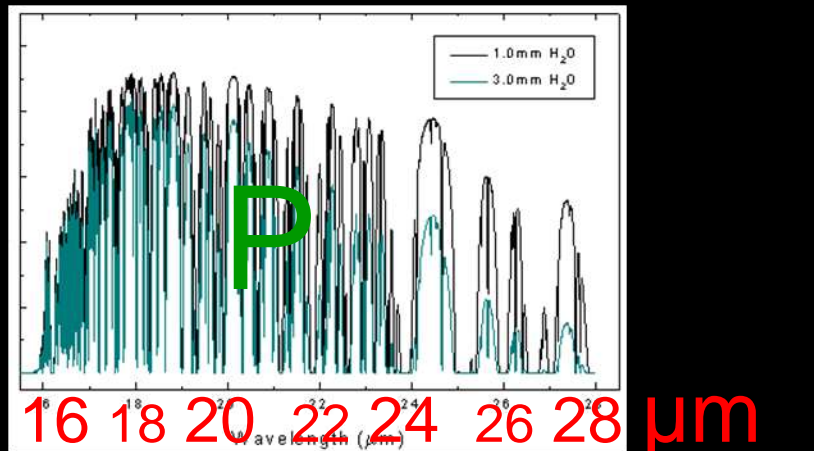
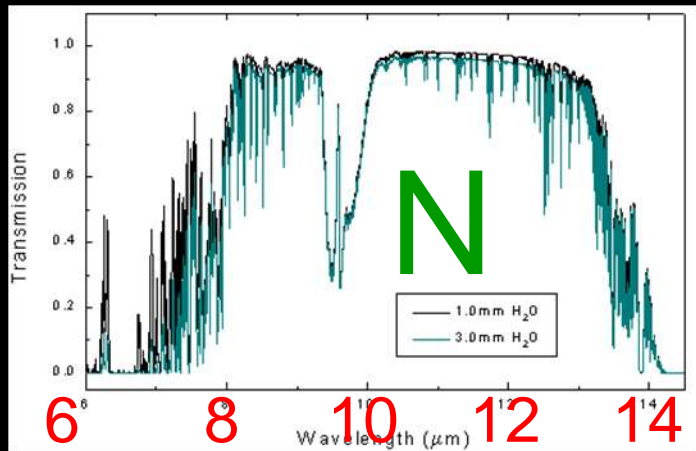
Mauna Kea com H₂O = 1mm(1mm) e 3mm



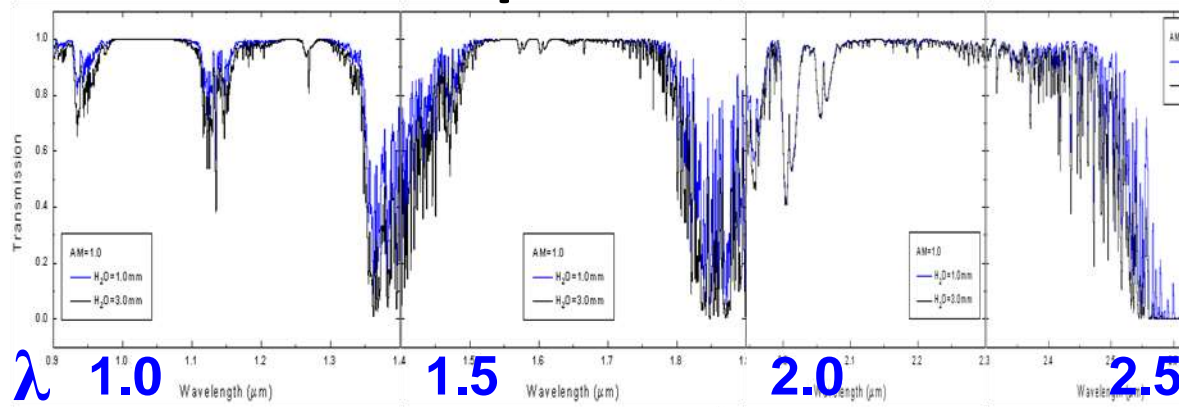
0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.2 2.4 2.5 2.6 2.7



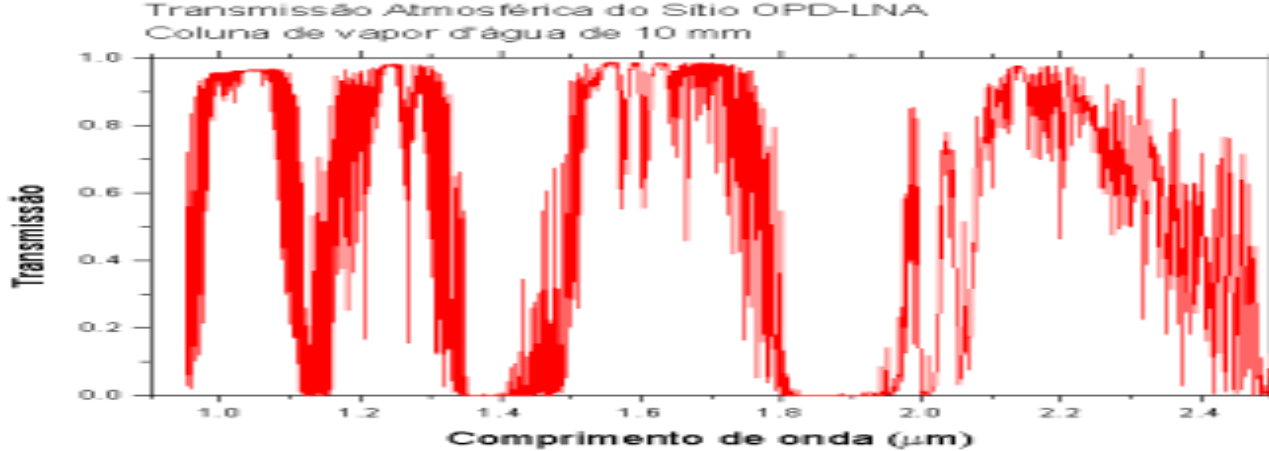
2.8 3.0 3.2 3.4 3.7 4.0 4.2 4.4 4.6 4.8 5.0 5.2 5.4 5.6



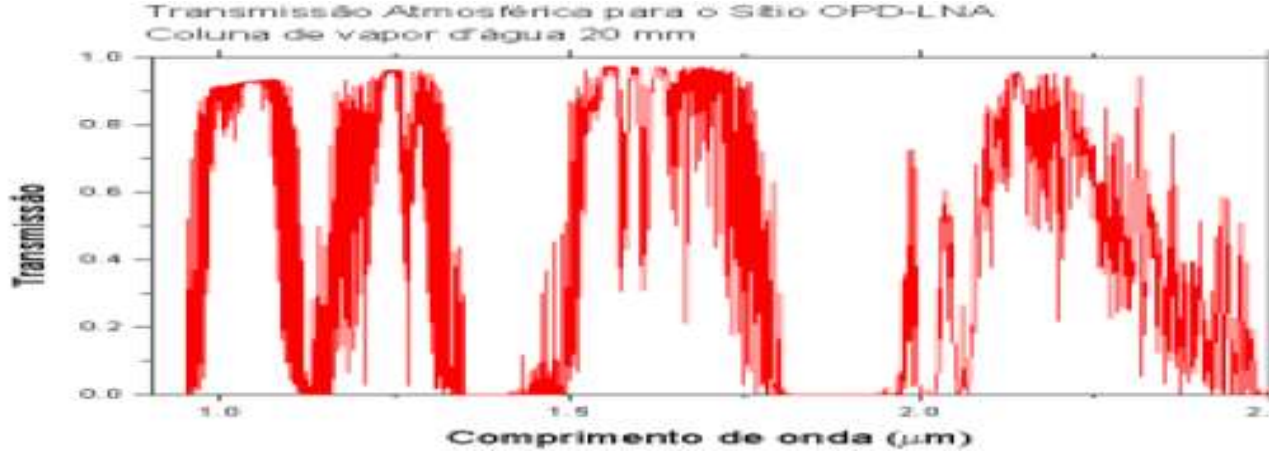
Water Vapor: Mauna Kea vs OPD



Mauna Kea
h(1mm, 3mm)



OPD/LNA
h(10mm)
Barbosa(2000)



OPD/LNA
h(20mm)
Barbosa(2000)

Profundidade óptica

A profundidade óptica ao longo de uma linha vertical, de um constituinte i com taxa de mistura $r_i(z)$ é dada por:

$$\tau(\lambda, z_0) = \int_{z_0}^{\infty} r_i(z) \rho_0(z) k_i(\lambda) dz$$

A atenuação de um raio incidente de intensidade I_0 (topo atmosfera) recebido a uma altitude z_0 e fazendo um ângulo θ com o zênite é:

$$\frac{I(z_0)}{I_0(\infty)} = \exp \left\{ -\frac{1}{\cos\theta} \sum_i \tau_i(\lambda, z_0) \right\}$$

Onde a soma é sobre todas as espécies que absorvem

Atenuação da radiação com a altitude

Atmosphere
totally
opaque for
 $\tau=10$

Ideally
observatories
are feasible
for $\tau < 0.5$
(transmission
> 61%)

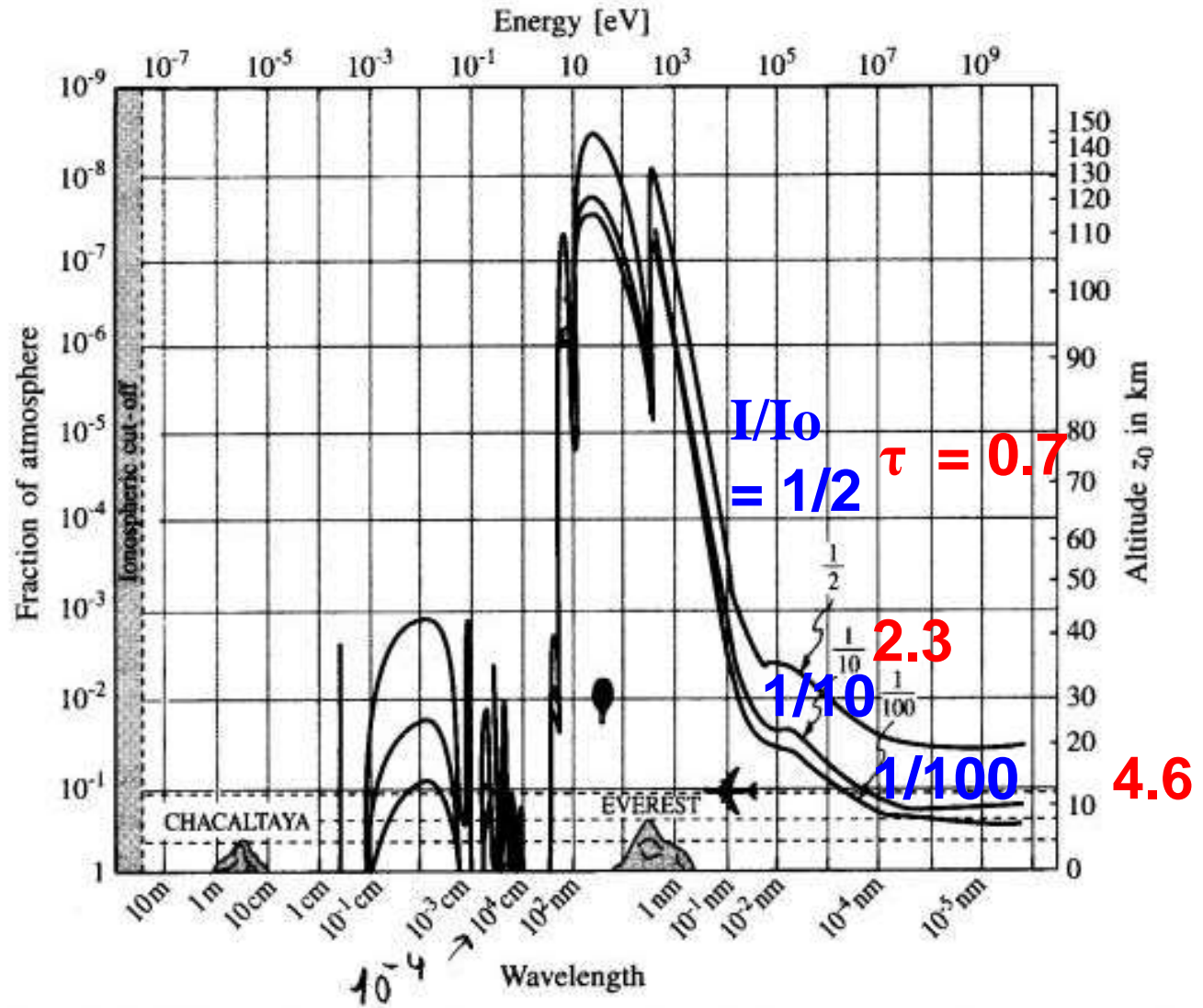


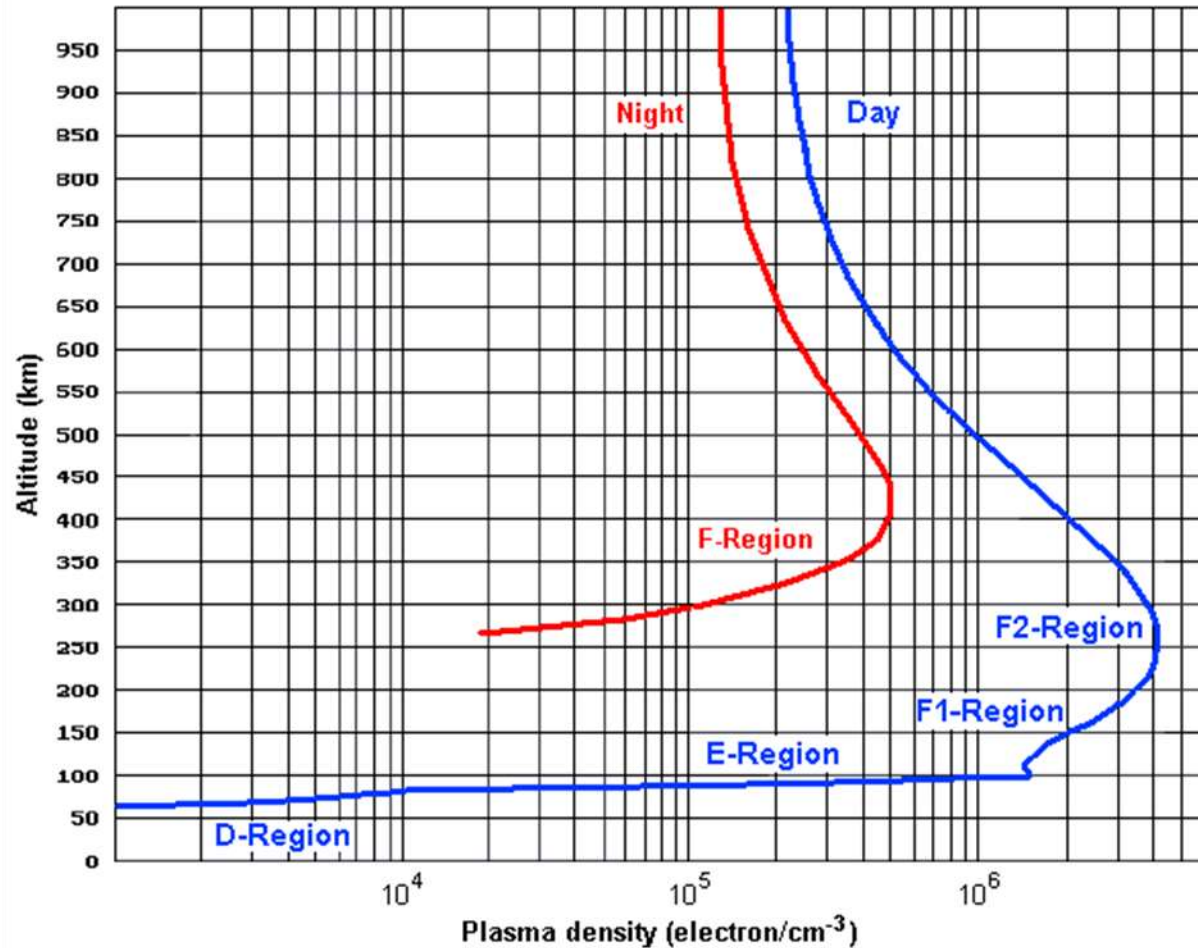
Fig. 2.4. Attenuation of electromagnetic radiation by the atmosphere. Curves give the altitude z_0 (right-hand scale) or the residual fraction of the atmosphere, in mass, above z_0 (left-hand scale), for three values of the ratio $I(z_0, \lambda, \theta = 0^\circ)/I_0(\infty, \lambda)$. Chacaltaya is a site in the Andes (altitude ~ 6000 m)

Plasma Ionosférico

- Camadas ionizadas tem índice de refração n relacionada à dens. eletrônica N_e

- $$n^2 = 1 - \omega_p^2 / \omega$$
$$= 1 - (\lambda / \lambda_p)^2$$

- $$v_p [\text{Hz}] = \omega_p / 2\pi$$
$$= 9 \times 10^3 N_e^{1/2}$$



Total reflection

Para a camada F ($N_e = 2 \times 10^6 \text{ cm}^{-3}$), $\lambda_p = 23.5 \text{ m}$ ($v_p = 12 \text{ MHz}$)

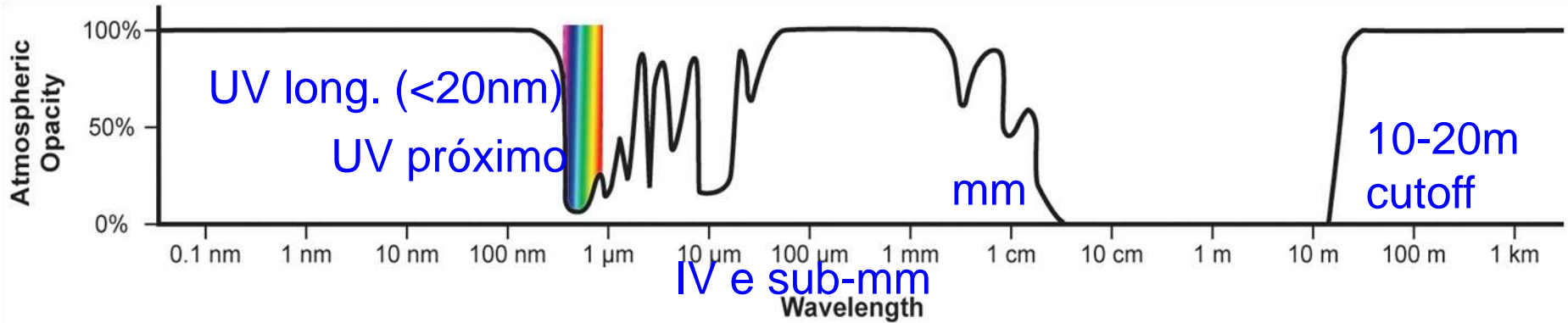
Ground-based observatories

Contínuo N₂

Bandas rot. e v-r

Plasma ionosferico

Bandas elet O₂, O₃, cont O₂ H₂O e CO₂ Bandas rot. H₂O e O₂



JANELA
OPTICA-IV

JANELA
RADIO



Gamma Rays, X-Rays and Ultraviolet
Light blocked by the upper atmosphere
(best observed from space).

Visible Light
observable
from Earth,
with some
atmospheric
distortion.

Most of the
Infrared spectrum
absorbed by
atmospheric
gasses (best
observed
from space).

Radio Waves observable
from Earth.

Long-wavelength
Radio Waves
blocked.



ALMA:

66 antennas working together at mm and submm



Emissão Atmosférica



- A atmosfera emite por fluorescência (*airglow*) e termicamente

FLUORESCÊNCIA: recombinação dos elétrons e íons criados nas reações diurnas de dissociação

- Contínuo: 1-3 Rayleigh Å^{-1}
- Linhas: 500 R

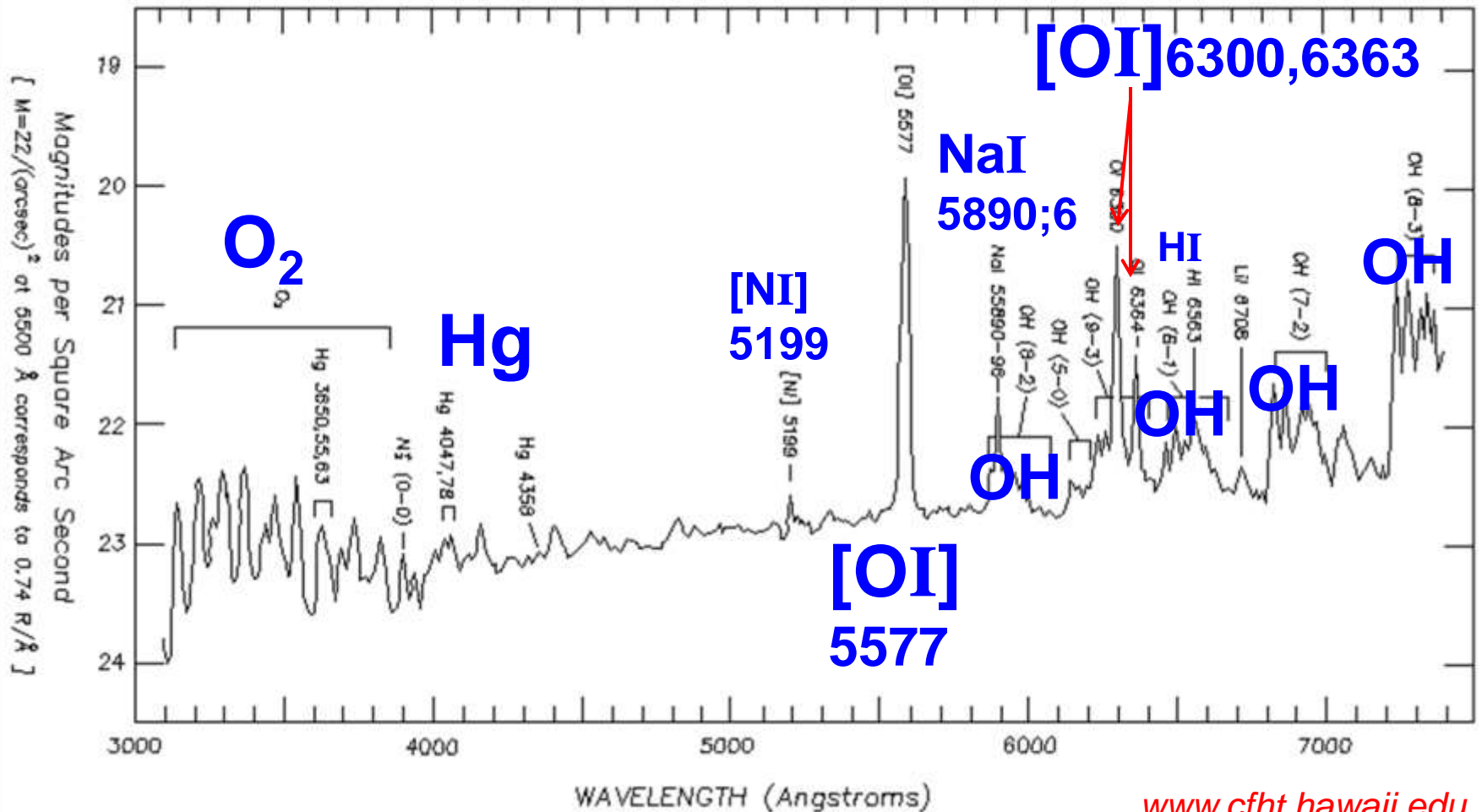
1 Rayleigh (R) = 10^6 fótons $\text{cm}^{-2} \text{s}^{-1} \text{str}^{-1}$

= $6.8 \times 10^{-17} \text{ Wm}^{-2} \text{um}^{-1} \text{arcsec}^{-2}$ (em = 550nm) = 22 mag arcsec^{-2}

- Principais emissores: OI, NaI, O₂, OH, H

Espectro do céu à noite (no ótico)

Mauna Kea (Havaí)



Espectro do céu à noite (no ótico e infravermelho)

Observatório de La Palma (Canary Islands)



Fundo de céu para observações no solo e no espaço próximo à Terra

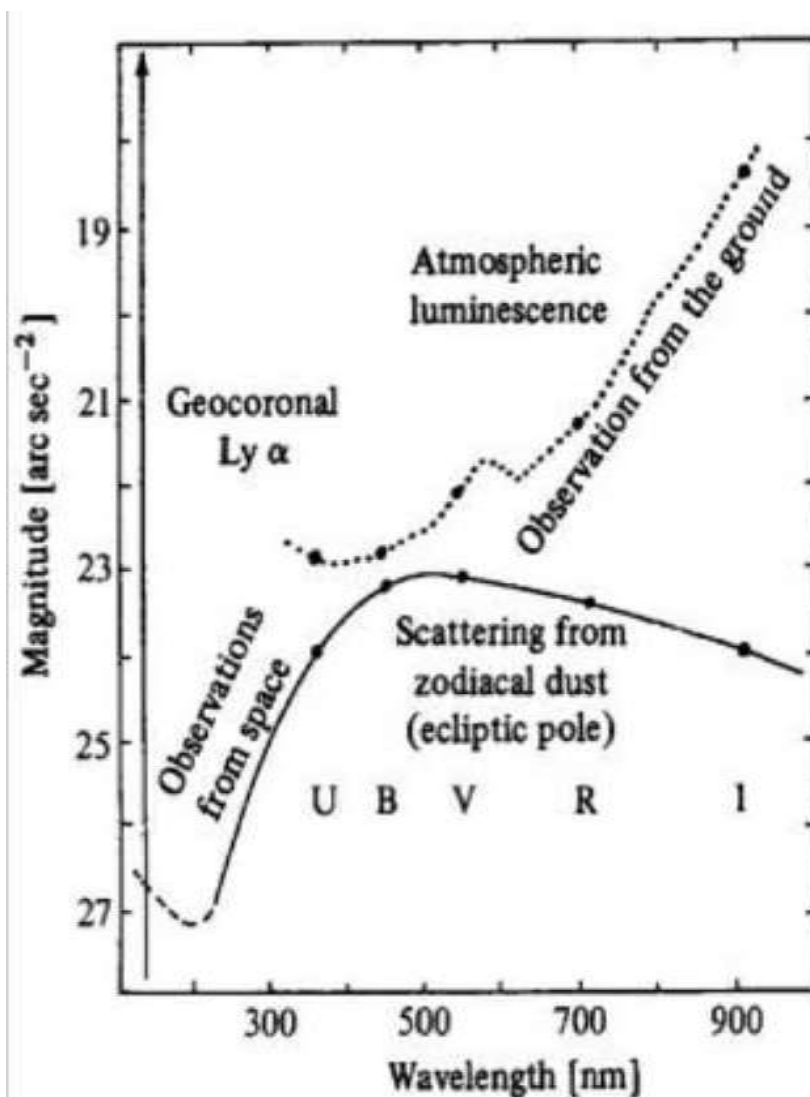
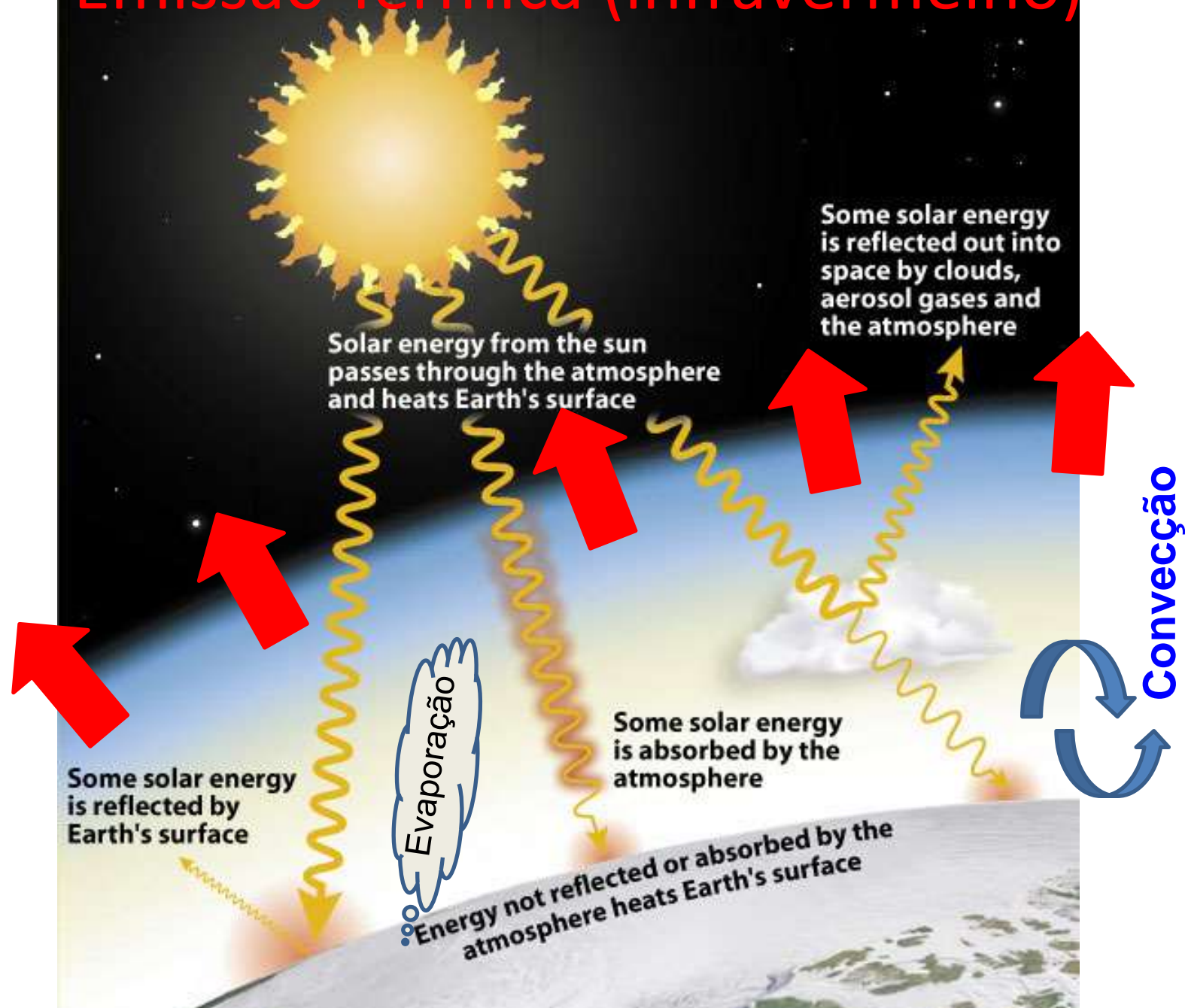


Fig. 2.8. Visible and ultraviolet magnitudes of the sky background per square arc second, for observations from the ground and from space near the Earth. Letters denote the spectral bands of the photometric system (cf. 3.3), corresponding to the points (•). [After Courtès G., personal communication; Smith H.E., Burbidge E.M., *Ap. J.* **210**, 629, 1979; Leinert C., *Sp. Sci. Rev.* **18**, 281, 1975; Machetto F. et al, *ESA-SP 1028*, 1980, European Space Agency]

Emissão Térmica (infravermelho)



Emissão Térmica

- Atmosfera pode ser considerada um gás em ETL até 40-60km
- Para $\tau \ll 1$ (profundidade ótica fina), a intensidade de radiação a altitude z e distância zenital θ é:

$$I_{\lambda}(z) \approx \tau_{\lambda} B_{\lambda}(\bar{T}) \frac{1}{\cos \theta}$$

onde B_{λ} é função de Planck à temperatura média T da atmosfera.

$\tau \ll 1$ e B_{λ} não é desprezível:

- infravermelho próximo: 1 - 20 μm
- milimétrico: 0.5 – 2 mm

Emissão Térmica

$$I_{\lambda}(z) \approx \tau_{\lambda} B_{\lambda}(\bar{T}) \frac{1}{\cos \theta}$$

Usando temperatura média 250K:

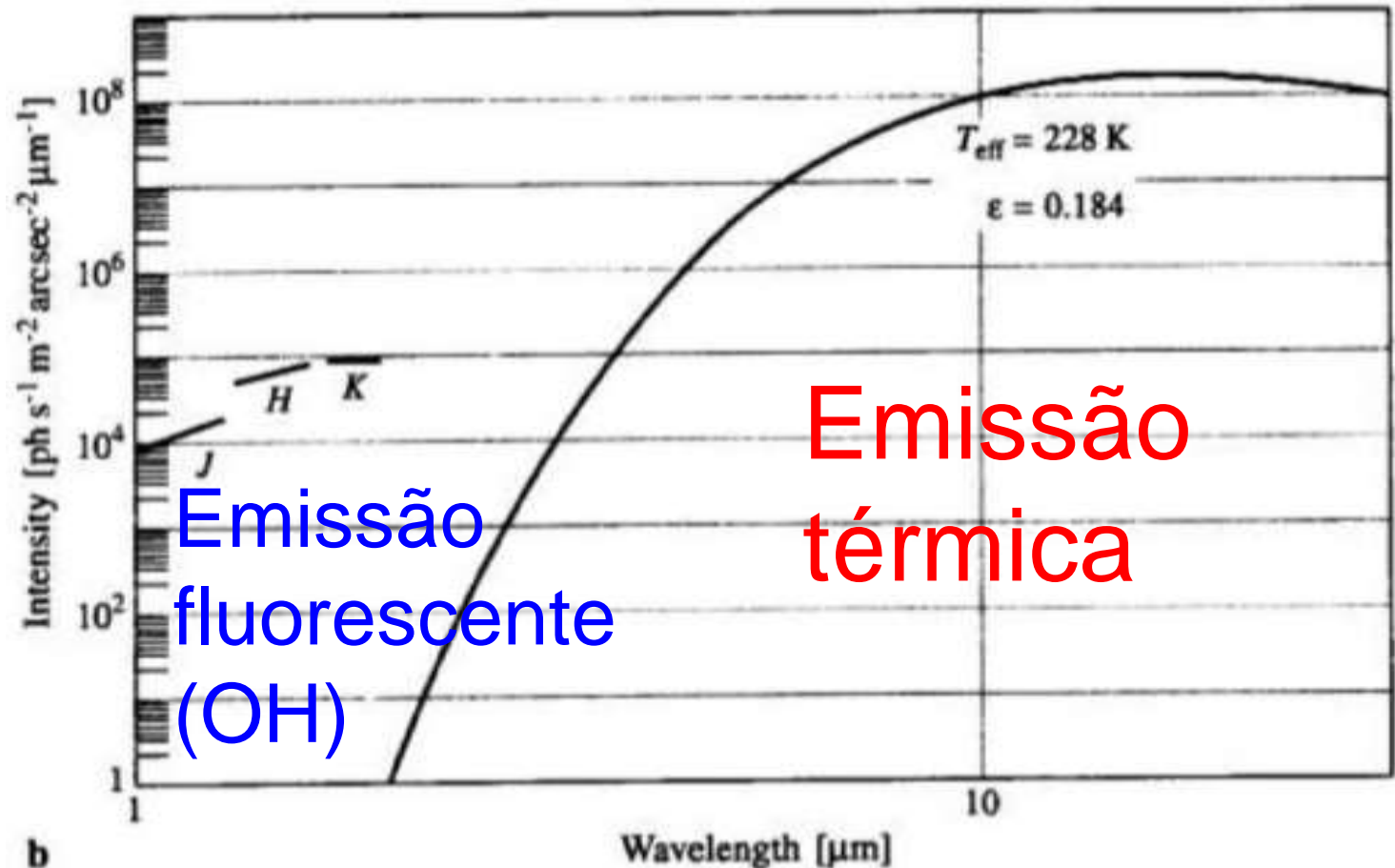
Fontes astronômicas podem ser várias ordens de magnitude mais fracas que a emissão térmica do céu (problema parecido com a emissão fluorescente do céu).

Table 2.3. Mean thermal emission of the atmosphere

Spectral band (cf. Sect. 3.3)	<i>L</i>	<i>M</i>	<i>N</i>	<i>Q</i>
Mean wavelength [μm]	3.4	5.0	10.2	21.0
Mean optical depth τ	0.15	0.3	0.08	0.3
Magnitude [arcsec ⁻²]	8.1	2.0	-2.1	-5.8
Intensity [Jy arcsec ⁻²] ^a	0.16	22.5	250	2 100

^a 1 Jansky = 10^{-26} W m⁻² Hz⁻¹.

Fundo do céu no infravermelho: emissão térmica vs. OH



Brilho de fundo do céu no infravermelho,
em altitude de Mauna Kea (4200m).

Difusão da Radiação: espalhamento Rayleigh e Mie

- Causado por moléculas e aerossóis em suspensão
- A influência das partículas do ar depende da altitude, *mas os aerossóis dependem de ventos, clima, estação, ativ. vulcânica, poluição industrial...*

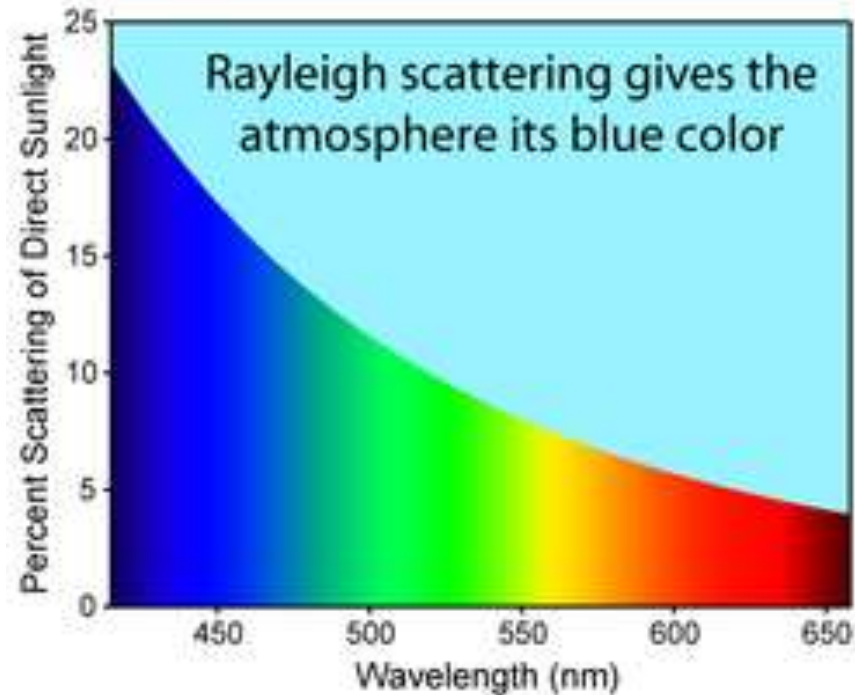


Espalhamento Rayleigh

- Para partículas menores ao comprimento de onda λ da luz

$$\sigma_R(\lambda) = \frac{8\pi^3}{3} \frac{(n^2 - 1)^2}{N^2 \lambda^4}$$

- onde n : índice de refração;
- N : densidade moléculas



Por isso o céu é azul

$$\sigma_R(\lambda) = \frac{8\pi^3}{3} \frac{(n^2 - 1)^2}{N^2 \lambda^4}$$



Hawaii, after observing run ...

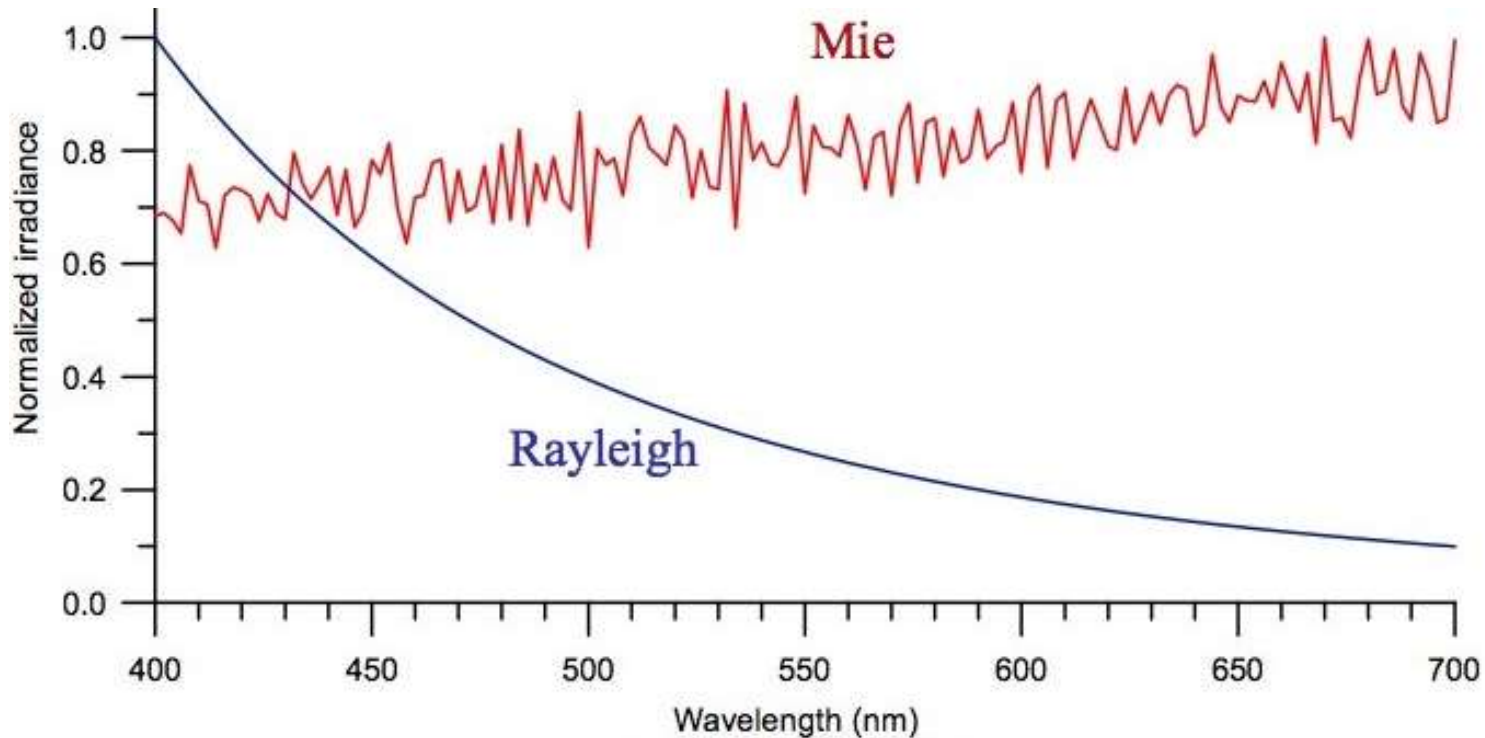
A intensidade do espalhamento Rayleigh depende do ângulo θ de incidência

$$j = \sigma_R \frac{3}{4} (1 + \cos^2 \theta) \frac{d\omega}{4\pi} I$$

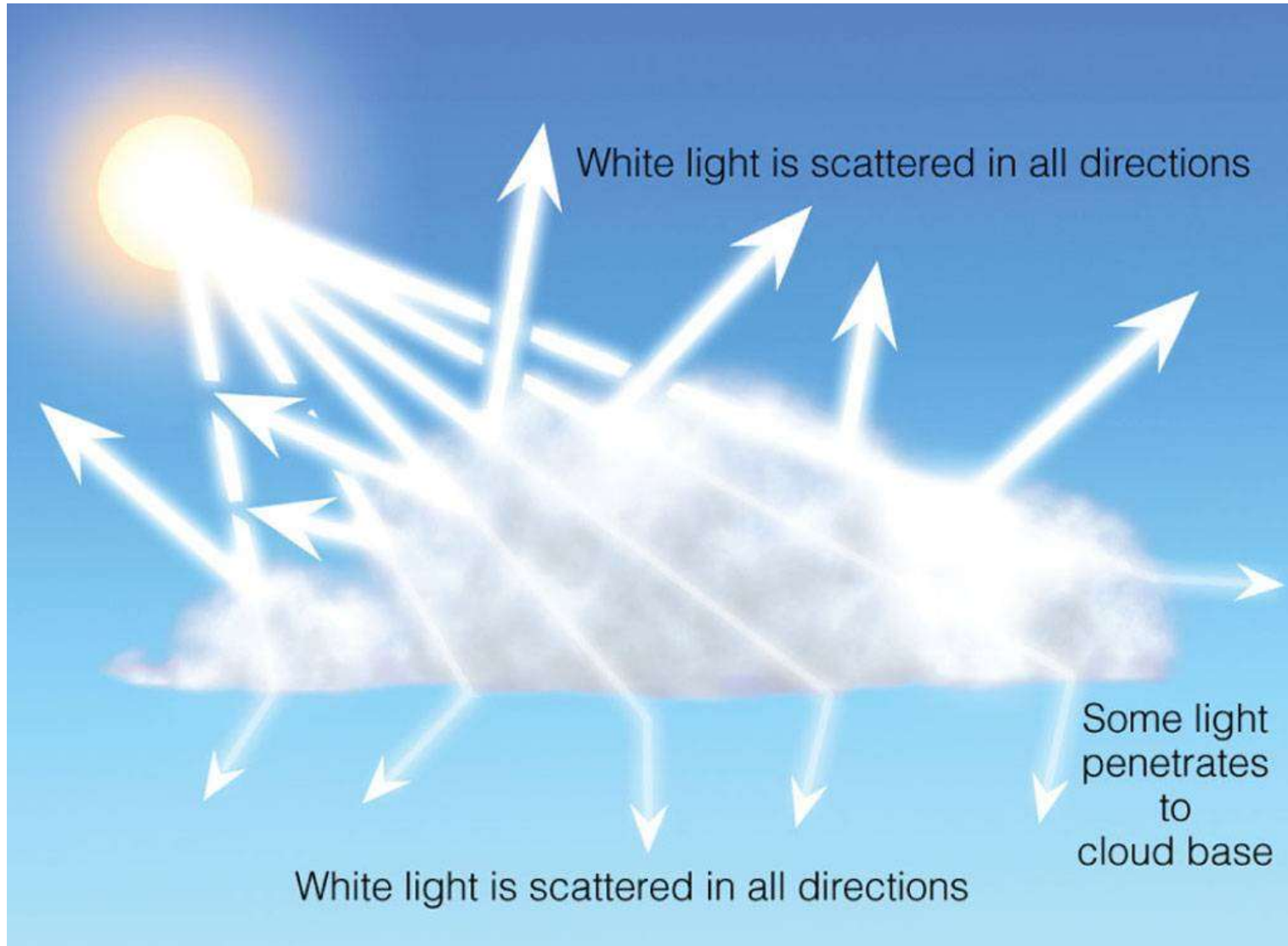
Em $z=2\text{km}$, a 90° do Sol, $\lambda=7000\text{\AA}$, brilho do céu é 10^{-7} daquele do disco solar

Espalhamento Mie

- Espalhamento por partículas maiores ao comprimento de onda λ da luz
- Não depende muito do comprimento de onda



Espalhamento Mie



Contribuição ao brilho do céu (no dia) na região do ótico e infravermelho

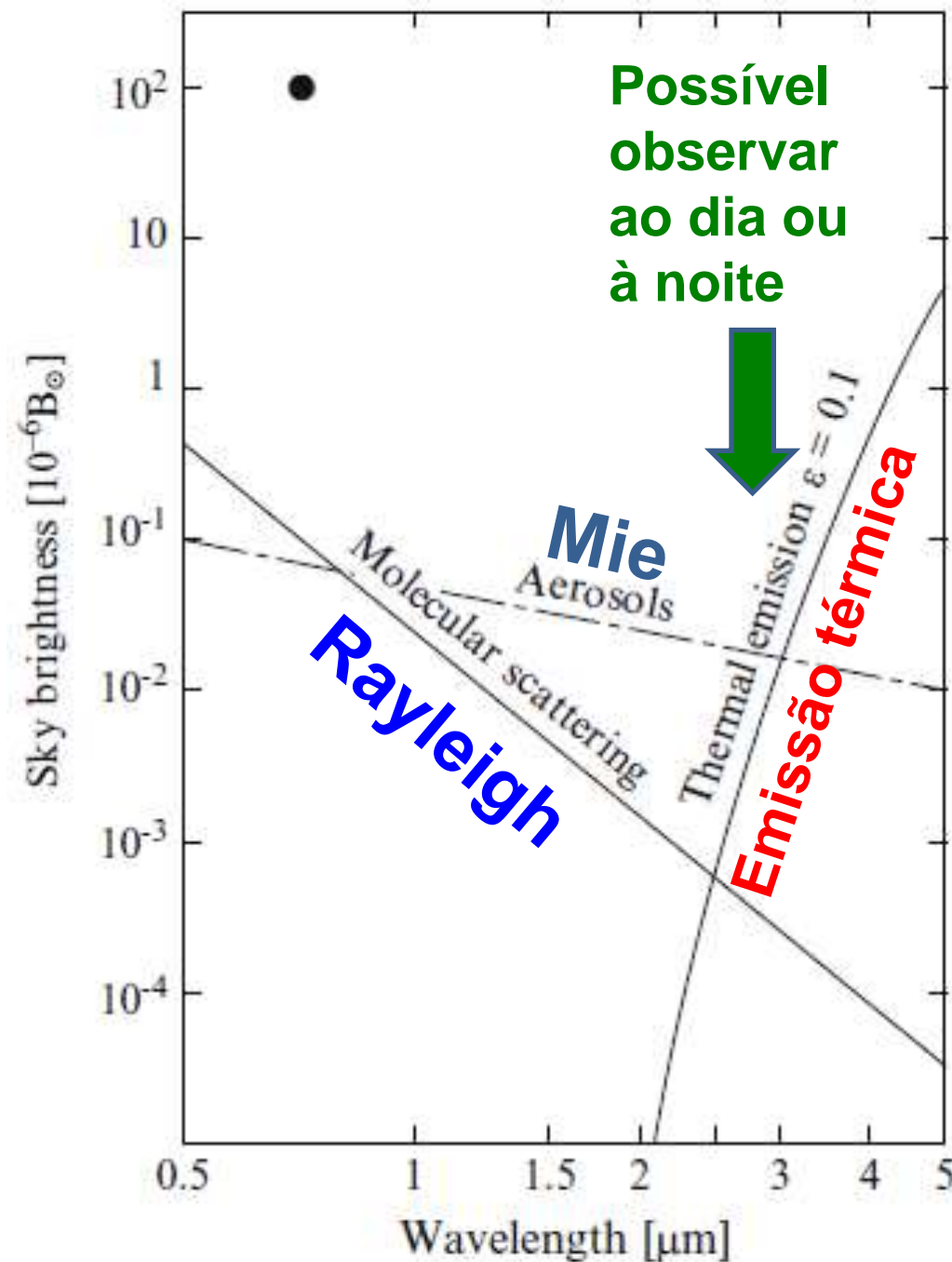


Fig. 2.11 (Lena, *Observational Astrophysics*). Molecular scattering is given for the altitude $z = 2000\text{m}$, at 90° from the Sun. The wavelength dependence is λ^{-4} . Thermal emission is also shown, assuming uniform mean emissivity of 0.1.

The dashed line shows the possible additional contribution due to aerosols, varying as λ^{-1} . For comparison, (•) marks the sky brightness measured at 0.5 arcmin from the Sun's limb at Kitt Peak (Arizona)

Outros fatores atmosféricos: Turbulência atmosférica



Vincent van Gogh

Geração de turbulência na atmosfera terrestre

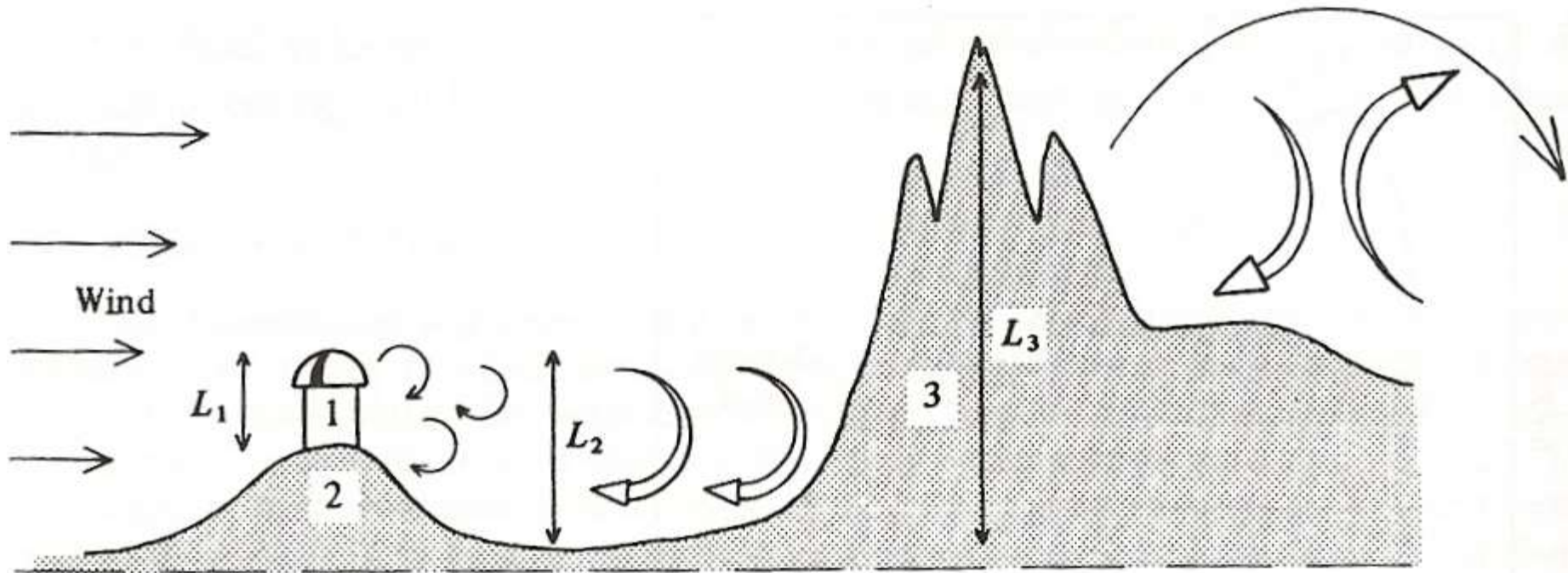


Fig. 2.13. Schematic representation of the generation of turbulence in the atmosphere by different obstacles. The amplitude of the temperature fluctuations depends on the amplitude of the turbulence and on the deviation of the actual temperature gradient from the adiabatic gradient. The scales L_1 , L_2 , L_3 are characteristic of the external scales of turbulence caused by wind around the obstacles 1, 2 and 3

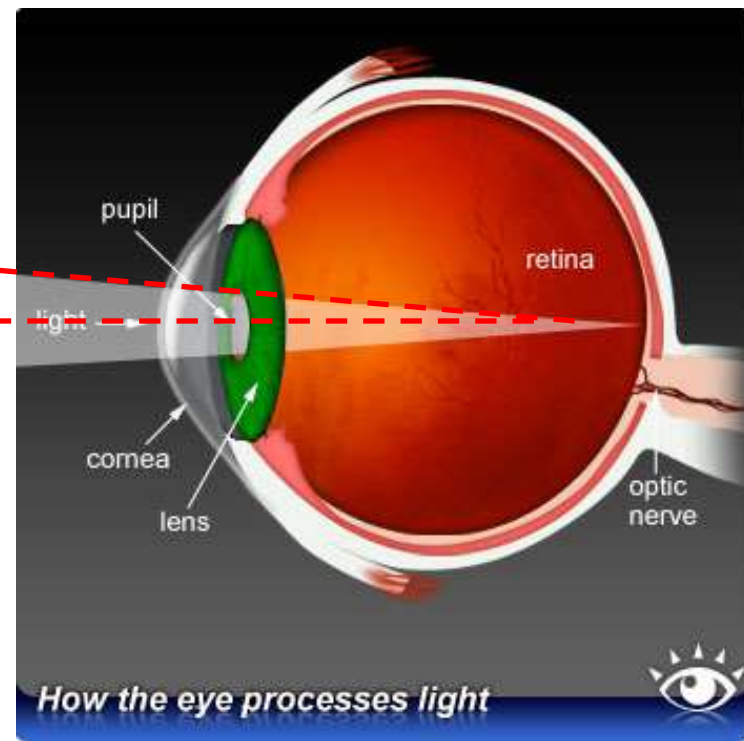
Turbulência atmosférica causada pelo relevo

A turbulência da atmosfera terrestre afeta a qualidade de imagem



Resolução angular

E	1	20/200
F P	2	20/100
T O Z	3	20/70
L P E D	4	20/50
P E C F D	5	20/40
E D F C Z P	6	20/30
F E L O P Z D	7	20/25
D E F P O T E C	8	20/20
L E F O D P C T	9	
F D P L T C E O	10	
F E Z O L C F T D	11	



É o menor ângulo que pode ser discernido

Resolução angular de um telescópio de diâmetro d no comprimento de onda λ



$$\alpha \text{ [rad]} = 1,22 \lambda / d$$

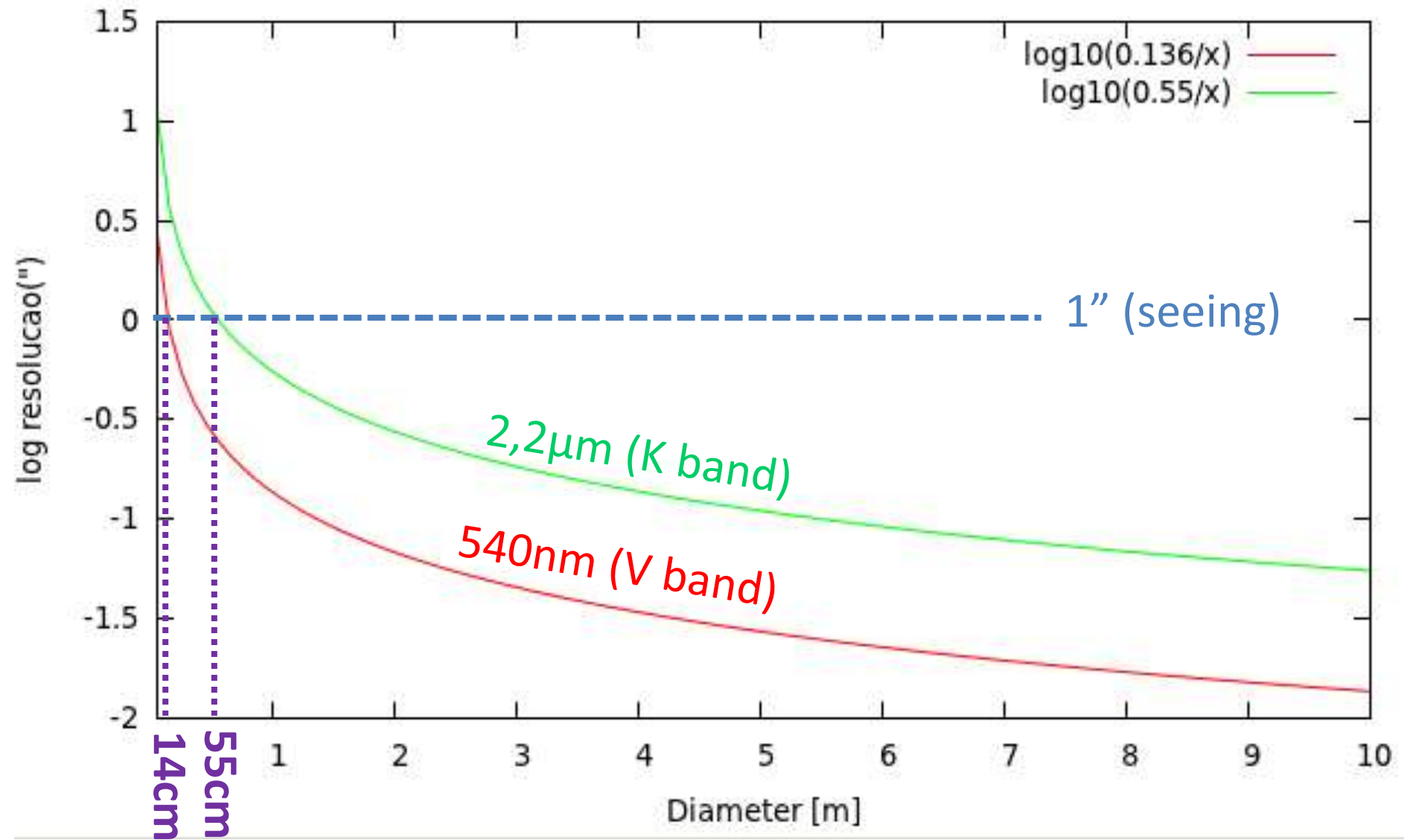
For $V = 540\text{nm}$:

$$\alpha["] = 0,136 / d[\text{m}]$$

For $K = 2,2\mu\text{m}$:

$$\alpha["] = 0,55 / d[\text{m}]$$

Um telescópio com $d = 14 \text{ cm}$ alcança no ótico uma **resolução angular de 1"**, da mesma ordem que o limite imposto pelo **seeing ($\sim 1"$)**



```
gnuplot> set xr [0.05:10]; plot log10(0.136/x), log10(0.55/x); set xlabel 'Diameter [m]'; set ylabel 'log resolucao(")'
```


Effects of atmospheric turbulence

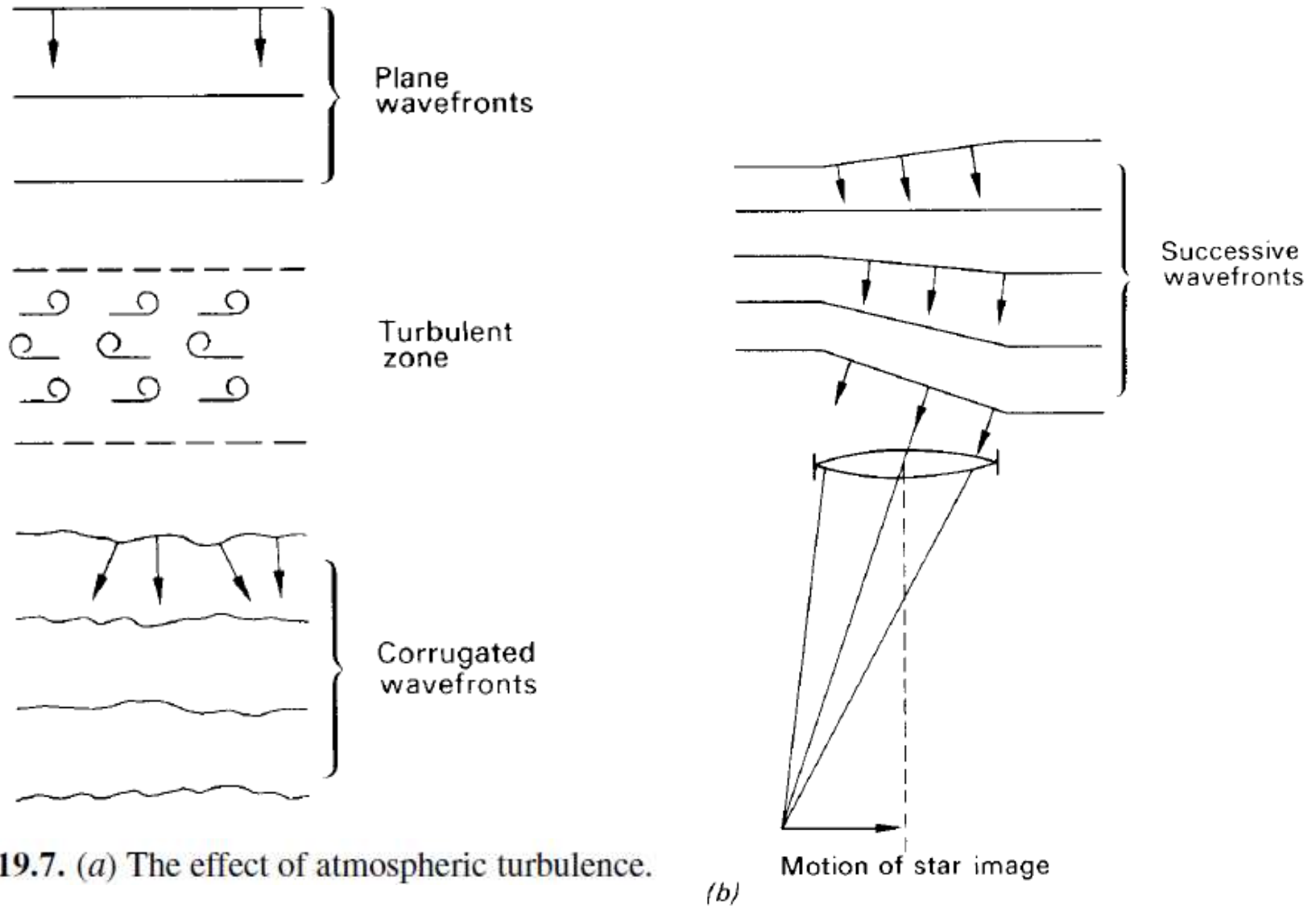


Figure 19.7. (a) The effect of atmospheric turbulence.

(b) The dancing effect of a star image when viewed with a small telescope.

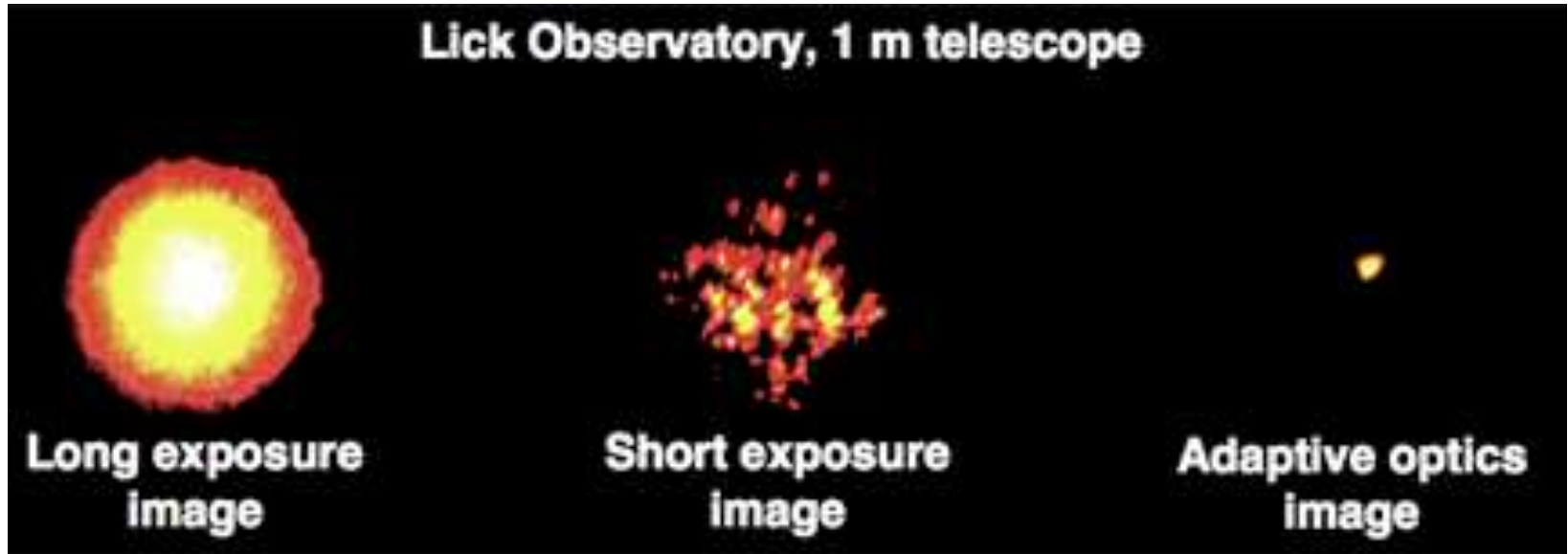
Ótica adaptativa



Without adaptive optics
(Palomar 200 inch telescope)

The binary star IW Tau is revealed through adaptive optics. The stars have a 0.3 arc second separation. The images were taken by Chas Beichman and Angelle Tanner of JPL.

Bright Star (Arcturus)



http://www.ucolick.org/~max/max-web/History_AO_Max.htm

Escala de tempo da turbulência?

Coherence length is $\sim 10\text{cm}$ at $0,5\mu\text{m}$

Turbulent layer wind speed is $\sim 10\text{ m/s}$

Portanto escala de tempo $\sim 0,01\text{ s}$ (= 10ms).

Escala de tempo da turbulência no ótico $\sim 1 - 10\text{ms}$

Seeing vs. Diffraction (angular resolution) limit

Airy disc, I_A . The ratio, $S = I_S/I_A$, is referred to as the **Strehl index** and it is not uncommon for it to be no greater than a few per cent.

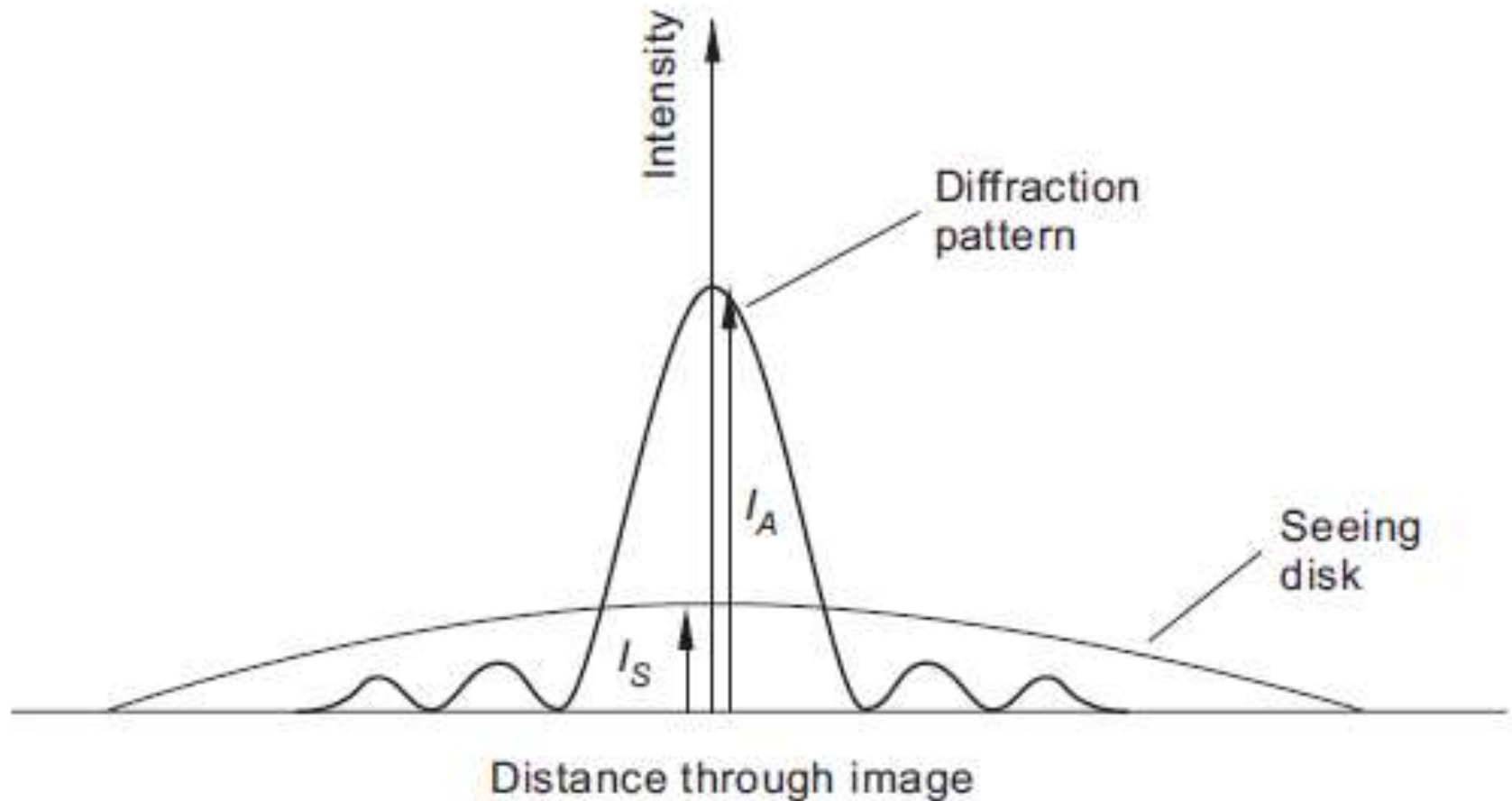
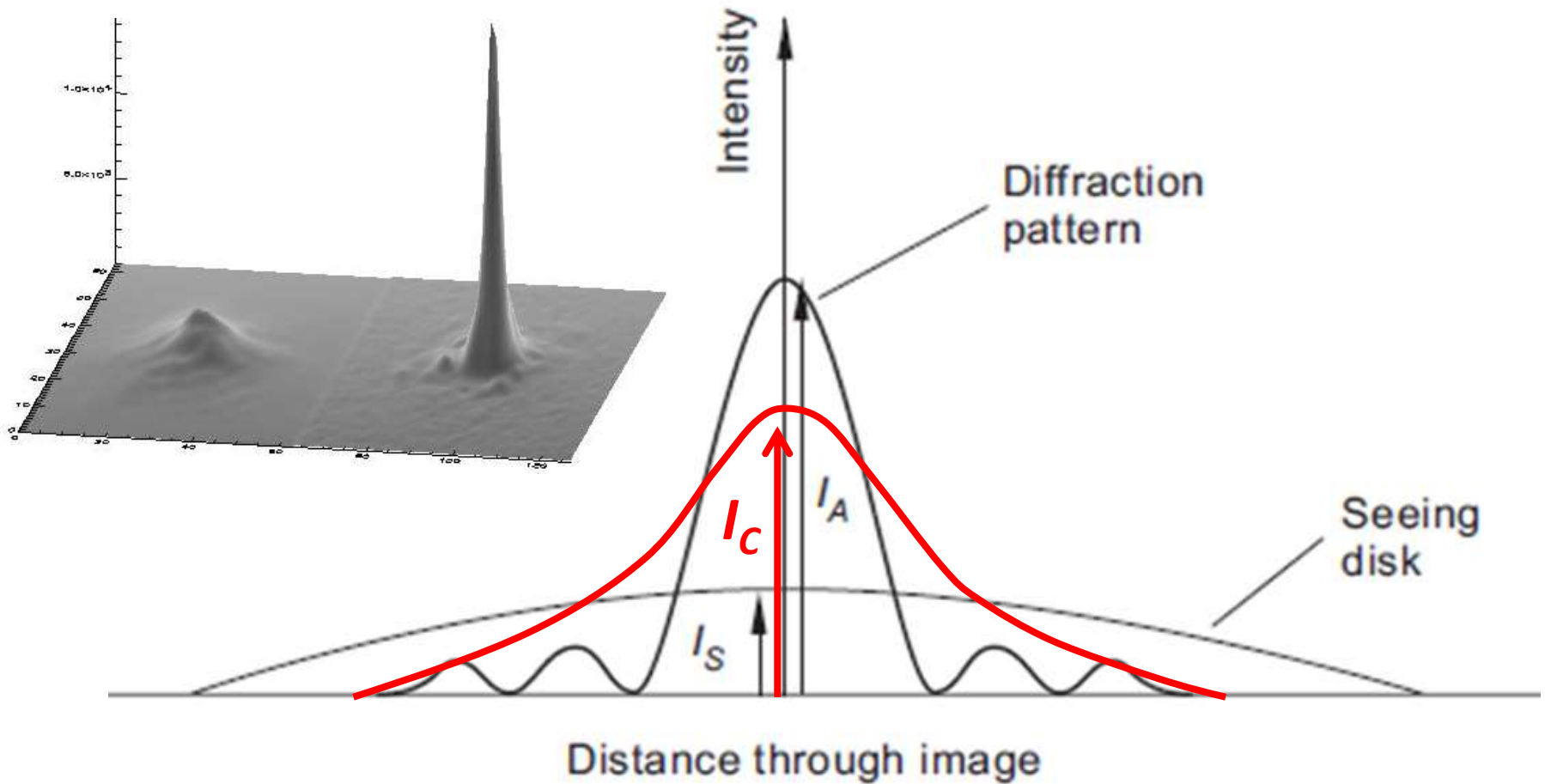


Figure 19.8. The seeing disc of a star is superposed in the theoretical diffraction pattern in the image plane. The ratio of the peak intensities, I_S/I_A is referred to as the Strehl index.

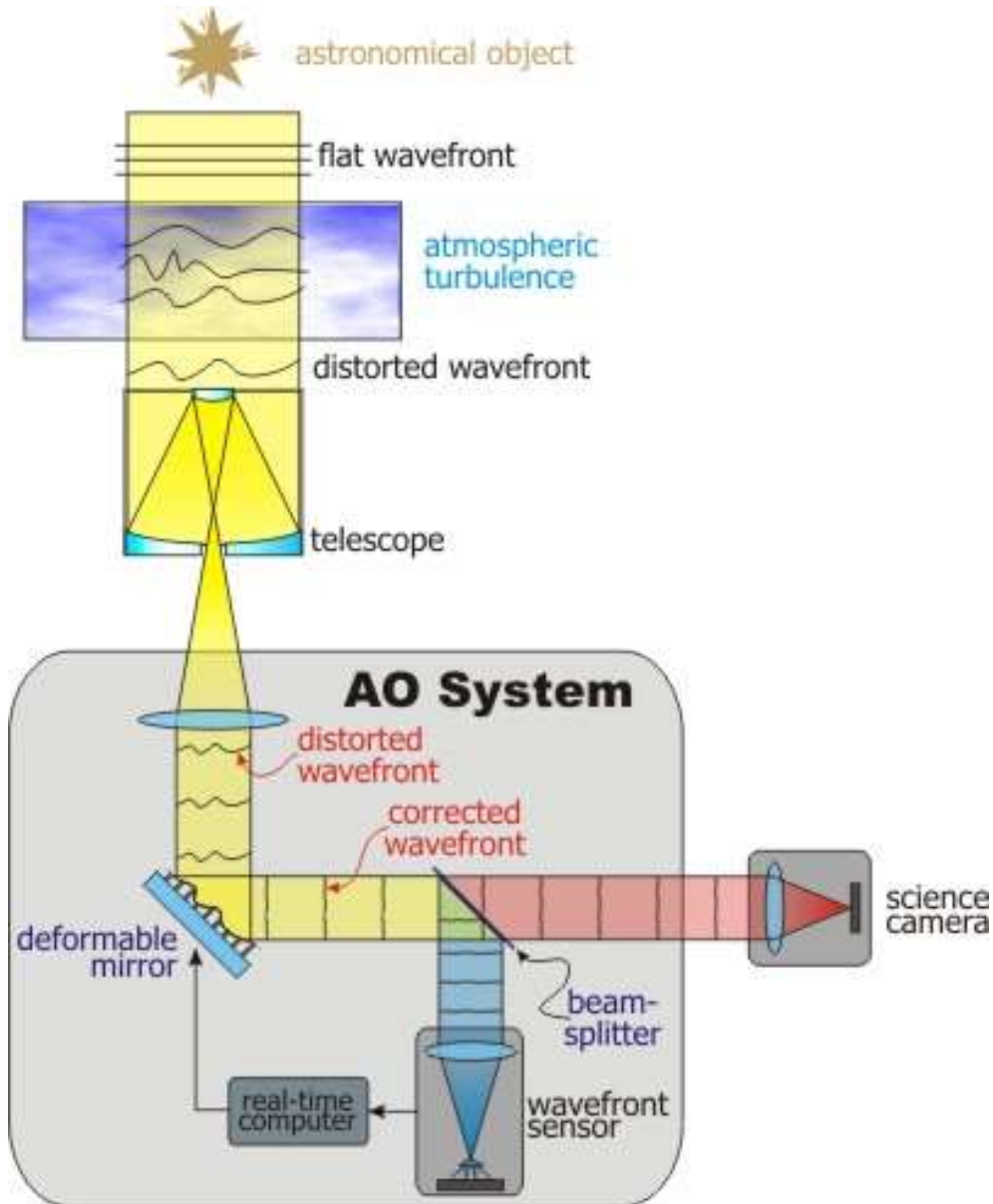
Qualidade da correção: Strehl ratio

$$\text{Strehl ratio} = I_{\text{corrigida}} / I_{\text{difração}}$$



Ótica adaptativa

Centro da nossa Galáxia

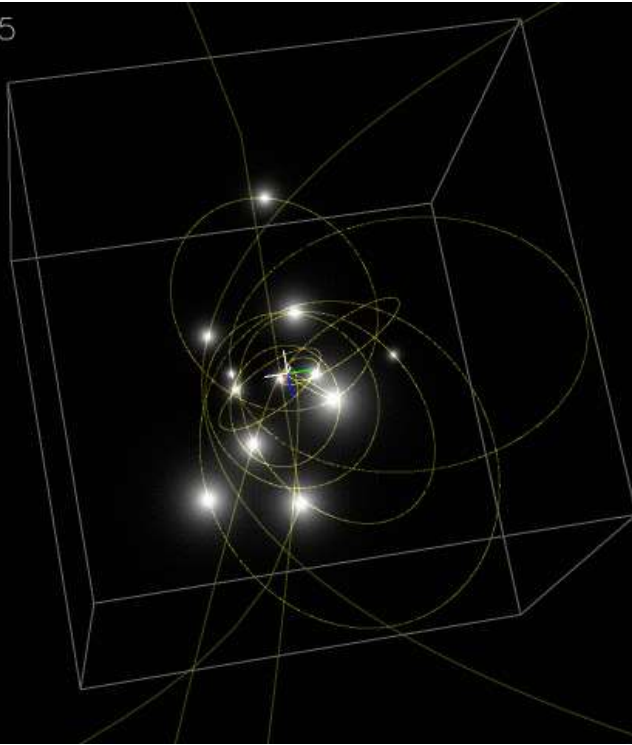


Stars orbiting the Galactic center



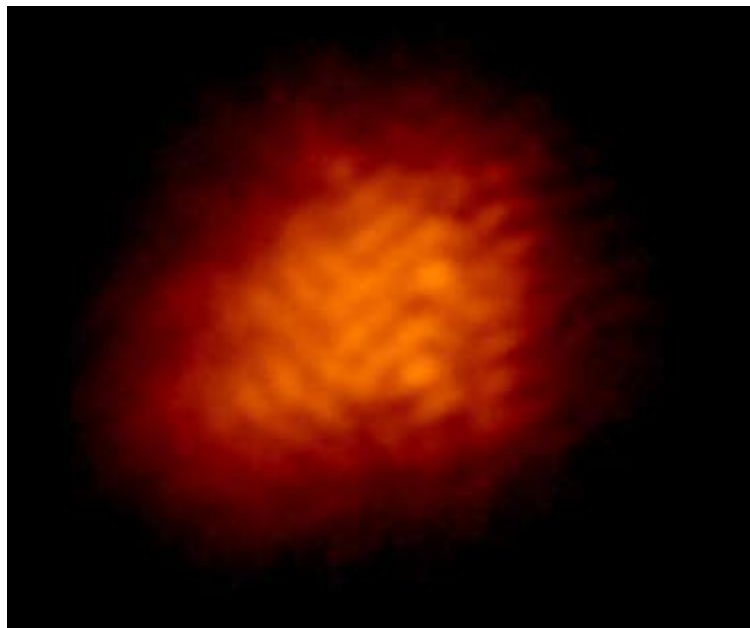
Andrea Ghez
Orbits around the Galactic
center imply **black hole of
4 million solar masses**

Year: 1995.5

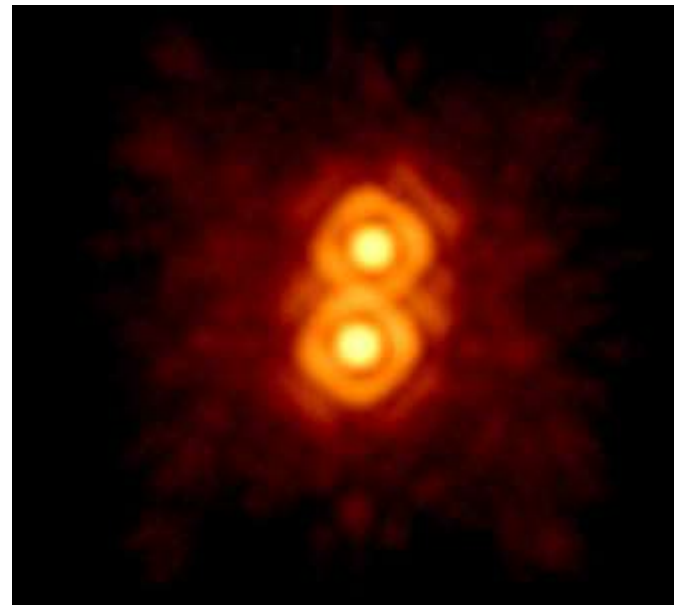


http://astro.uchicago.edu/cosmus/projects/UCLA_Gc

Professor Ghez has actively disseminated her work to a wide variety of audiences through more than 100 refereed papers and 200 invited talks, as well features in textbooks, documentaries, and science exhibits. She has received numerous honors and awards including the Crafoord Prize, a MacArthur Fellowship, election to the National Academy of Sciences and the American Academy of Arts & Sciences, the Aaronson Award from the University of Arizona, the Sackler Prize from Tel Aviv University, the American Physical Society's Maria Goeppert-Mayer Award, the American Astronomical Society's Newton Lacy Pierce Prize, a Sloan Fellowship, a Packard Fellowship, and several teaching awards. Her most recent service work includes membership on the National Research Council's Board on Physics & Astronomy, the Thirty-Meter-Telescope's Science Advisory Committee, the Keck



**Imagem de
sistema binário
(sem correção)**

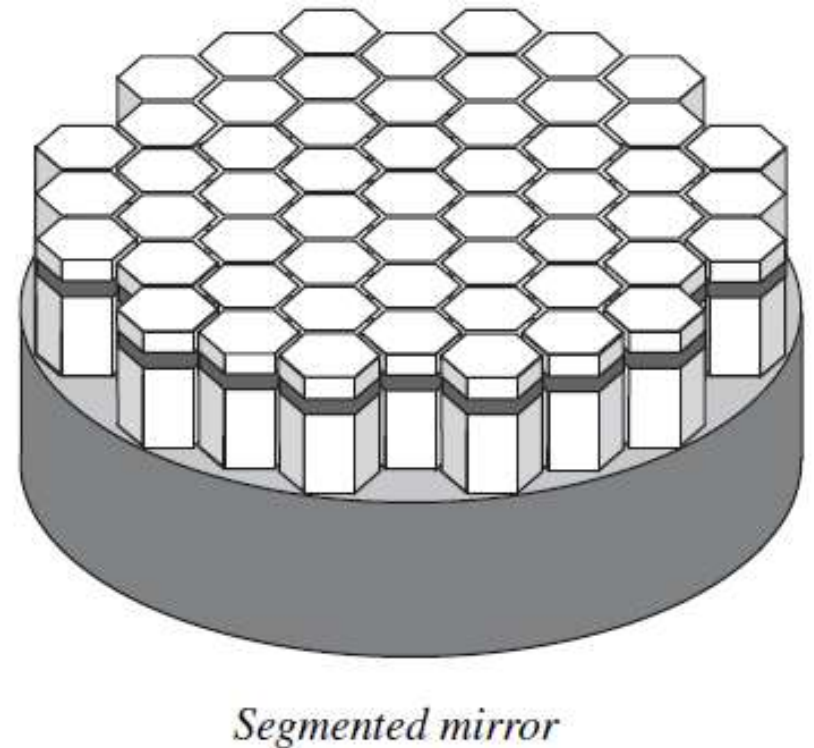
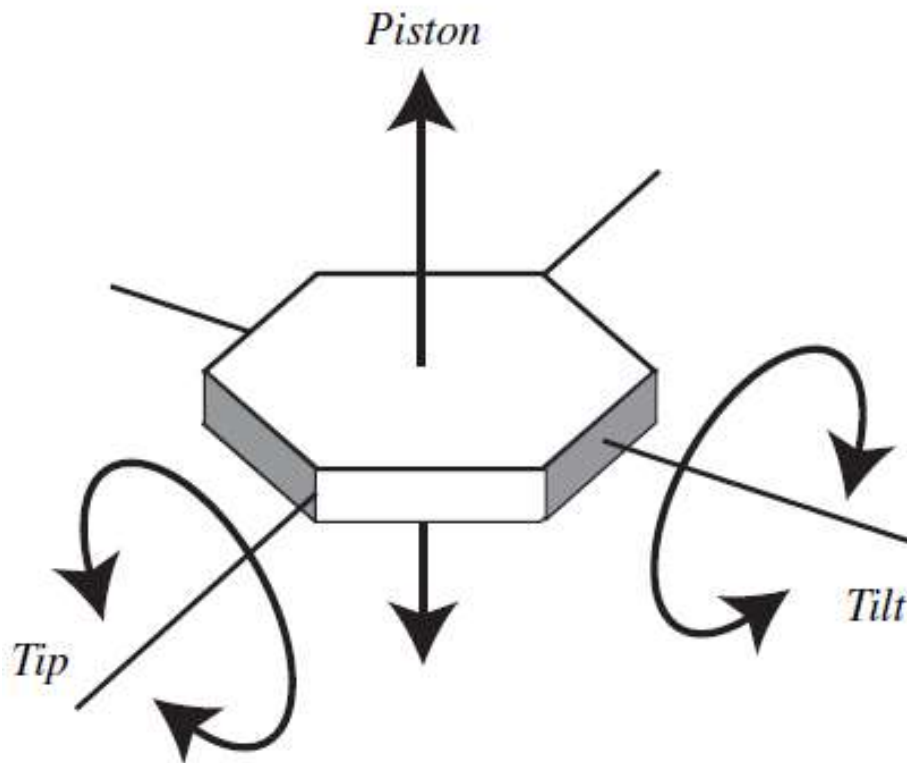


**Com ótica
adaptativa**

The binary star IW Tau is revealed through adaptive optics. The stars have a 0.3 arc second separation. The images were taken by Chas Beichman and Angelle Tanner of IRI

Segmented mirror for Adaptive Optics

Fig. 6.16 A segmented, adjustable mirror for adaptive optics. Individual hexagonal segments (left) are adjustable in piston, tip, and tilt.



Shack-Hartmann sensor for AO

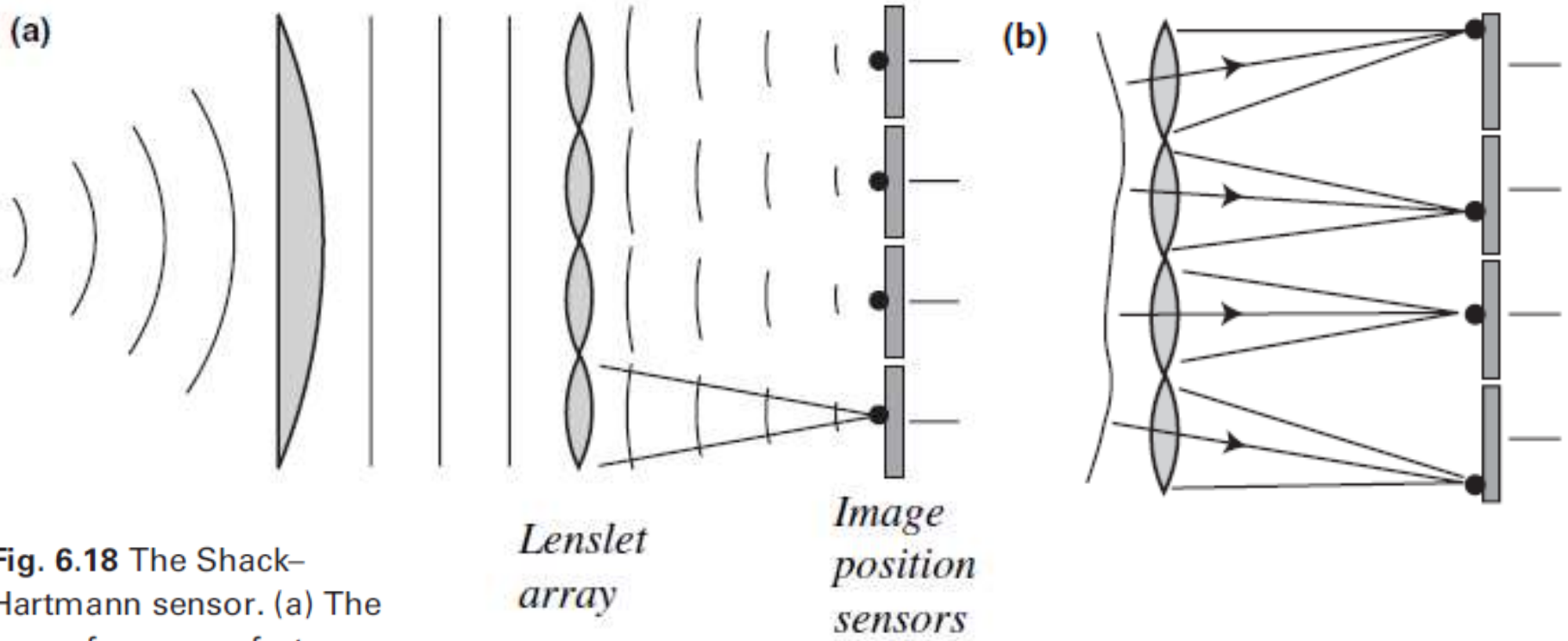


Fig. 6.18 The Shack-Hartmann sensor. (a) The beam from a perfect point source – all images on the sensors are in the null position. (b) A distorted wavefront and the resulting image displacements from tilted segments.

WFS stars must be nearby

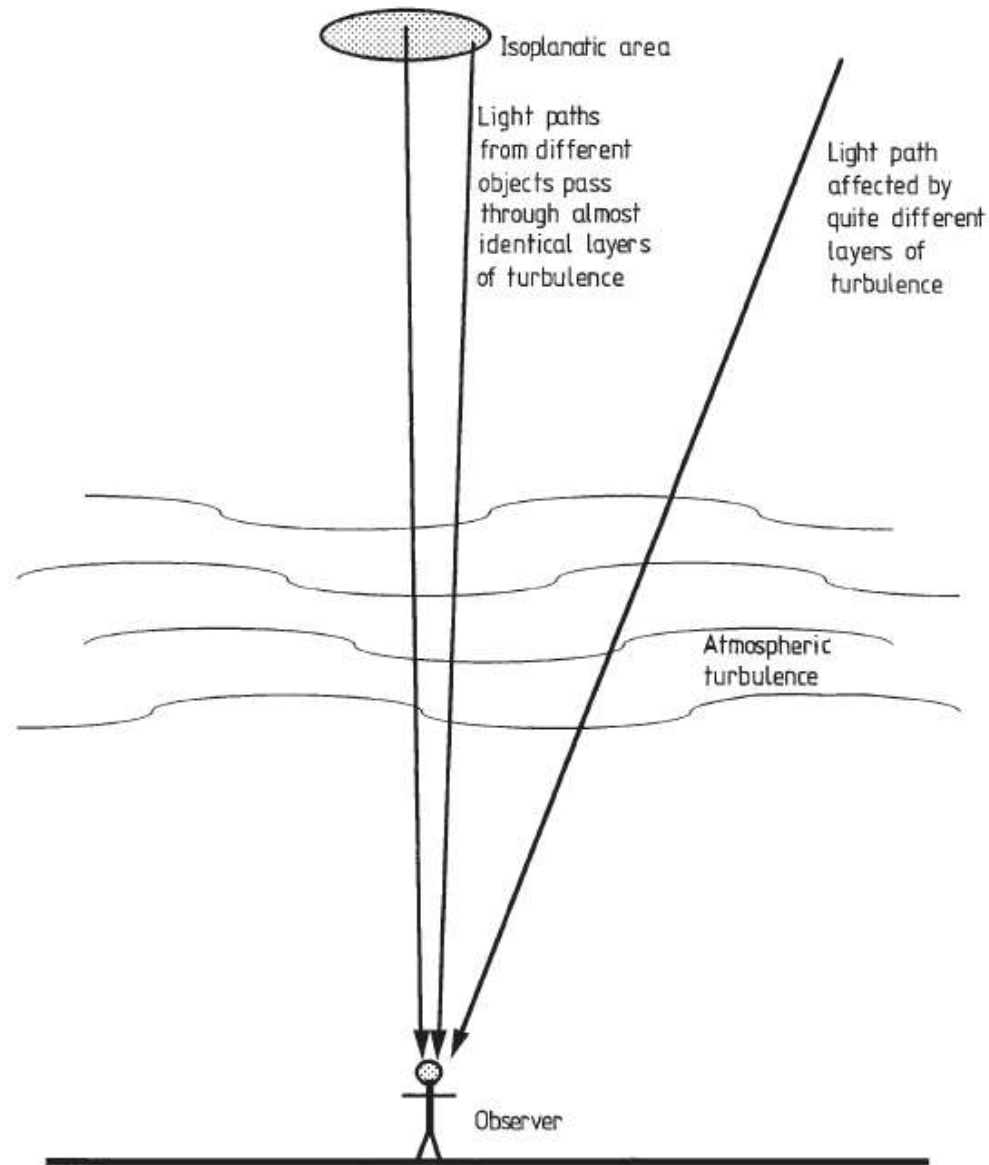


Figure 1.1.53. The isoplanatic area.

WFS stars must be bright

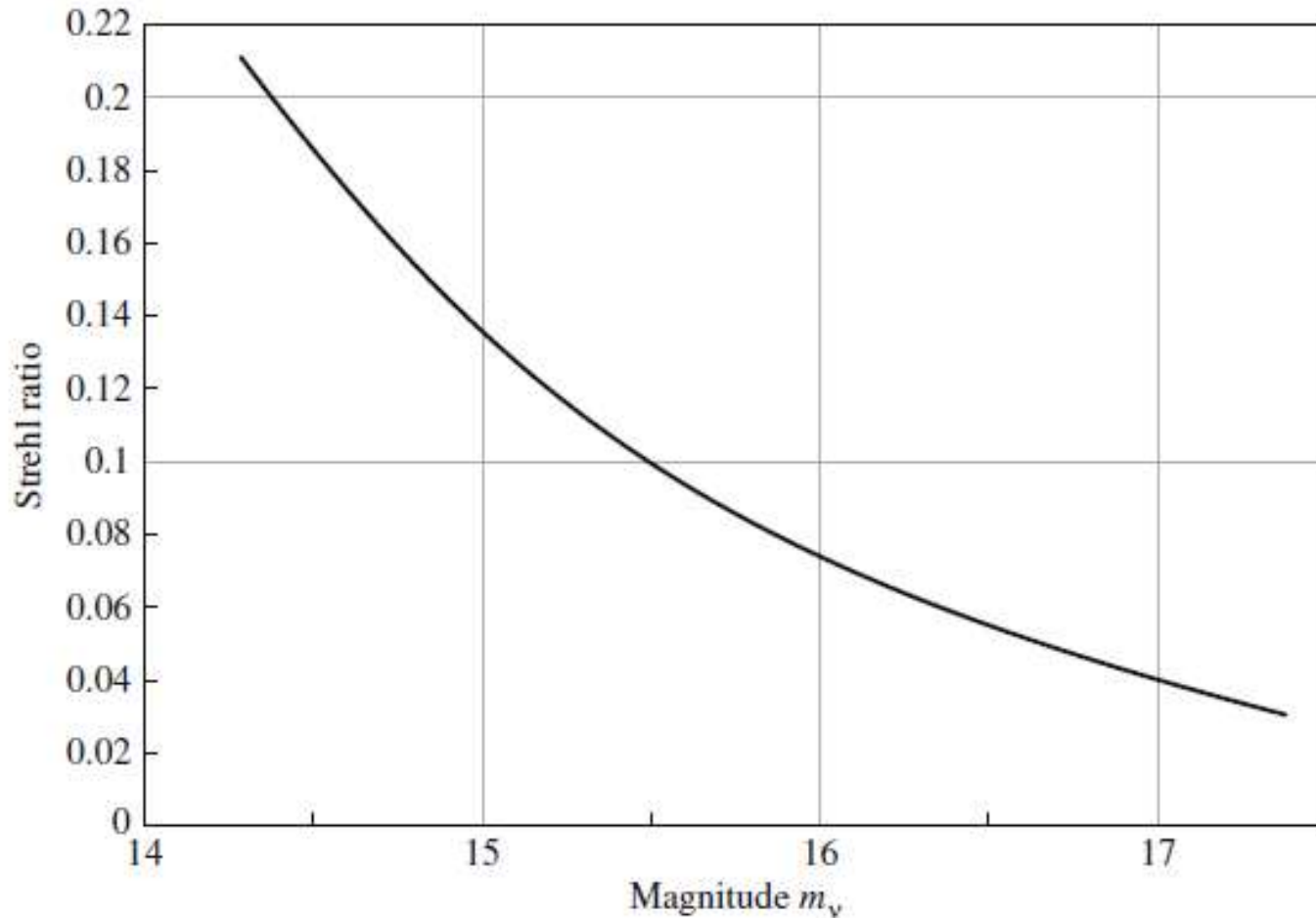
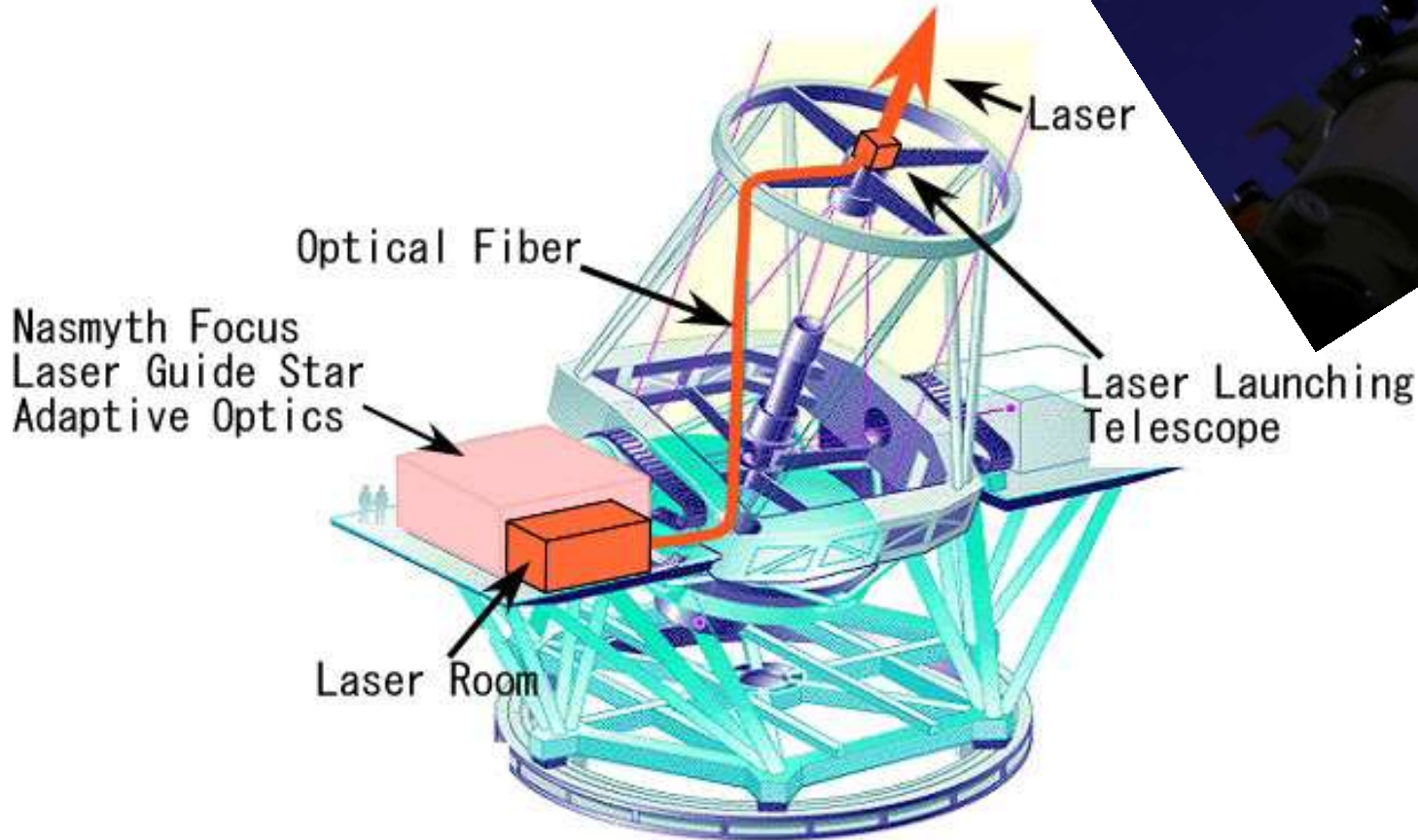


Fig. 6.20 Sensitivity of adaptive optics. *Ordinate*: Strehl ratio \mathcal{S} for an image corrected at $\lambda = 2.2 \mu\text{m}$ (spectral band K), in average turbulence conditions. *Abscissa*: Magnitude m_v of the source used by the wavefront analyser (hence analysis wavelength $\lambda_0 = 0.55 \mu\text{m}$). We assume here that the sensor is equipped with a detector with high quantum efficiency (CCD, $\eta = 0.6$) and a very low readout noise ($2e^-$ rms). From Gendron E., doctoral thesis, 1995

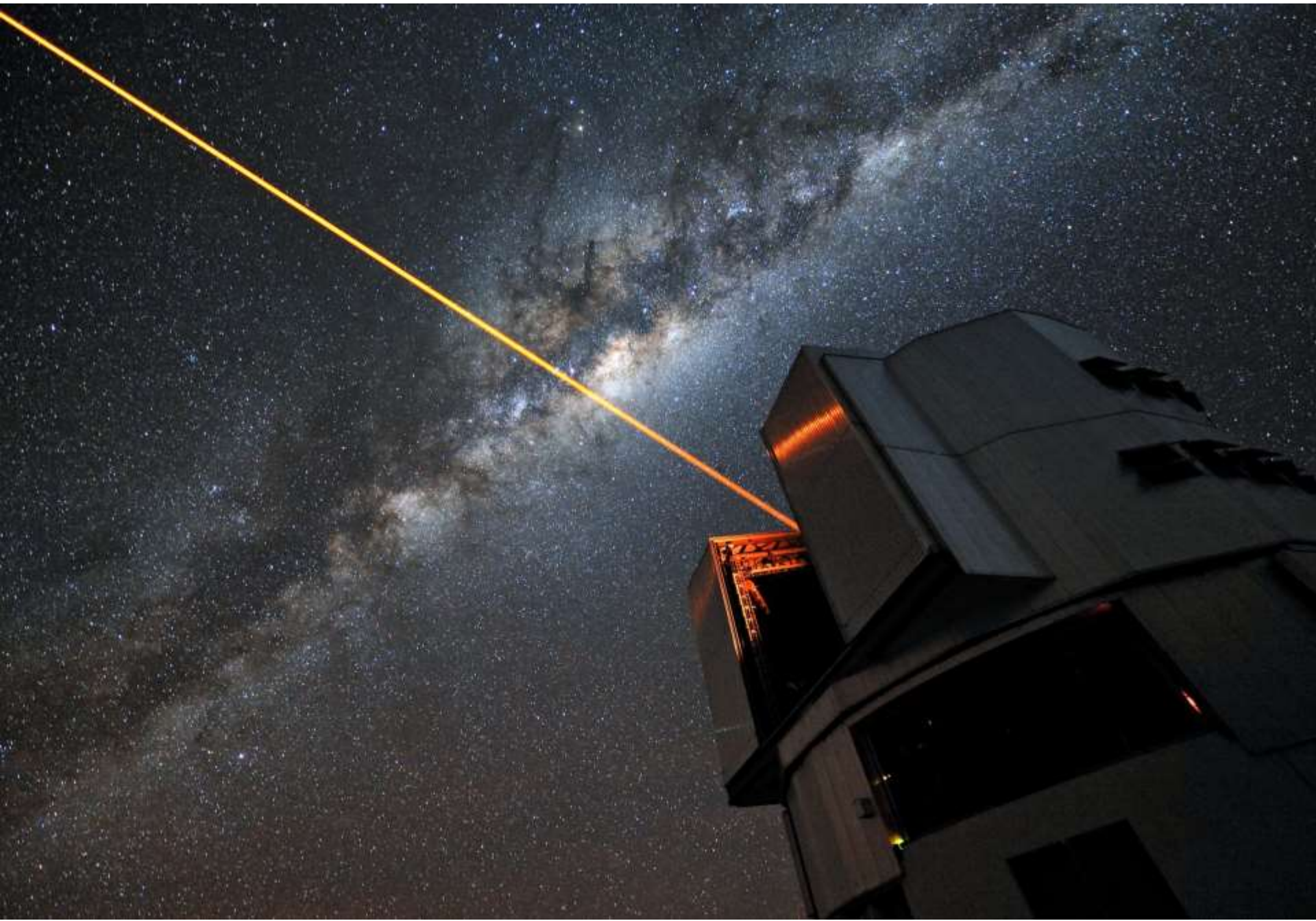
No stars in your field? Create your own star!



(C) Takaetsu Endo

<http://subarutelescope.org/Pressrelease/2005/07/>

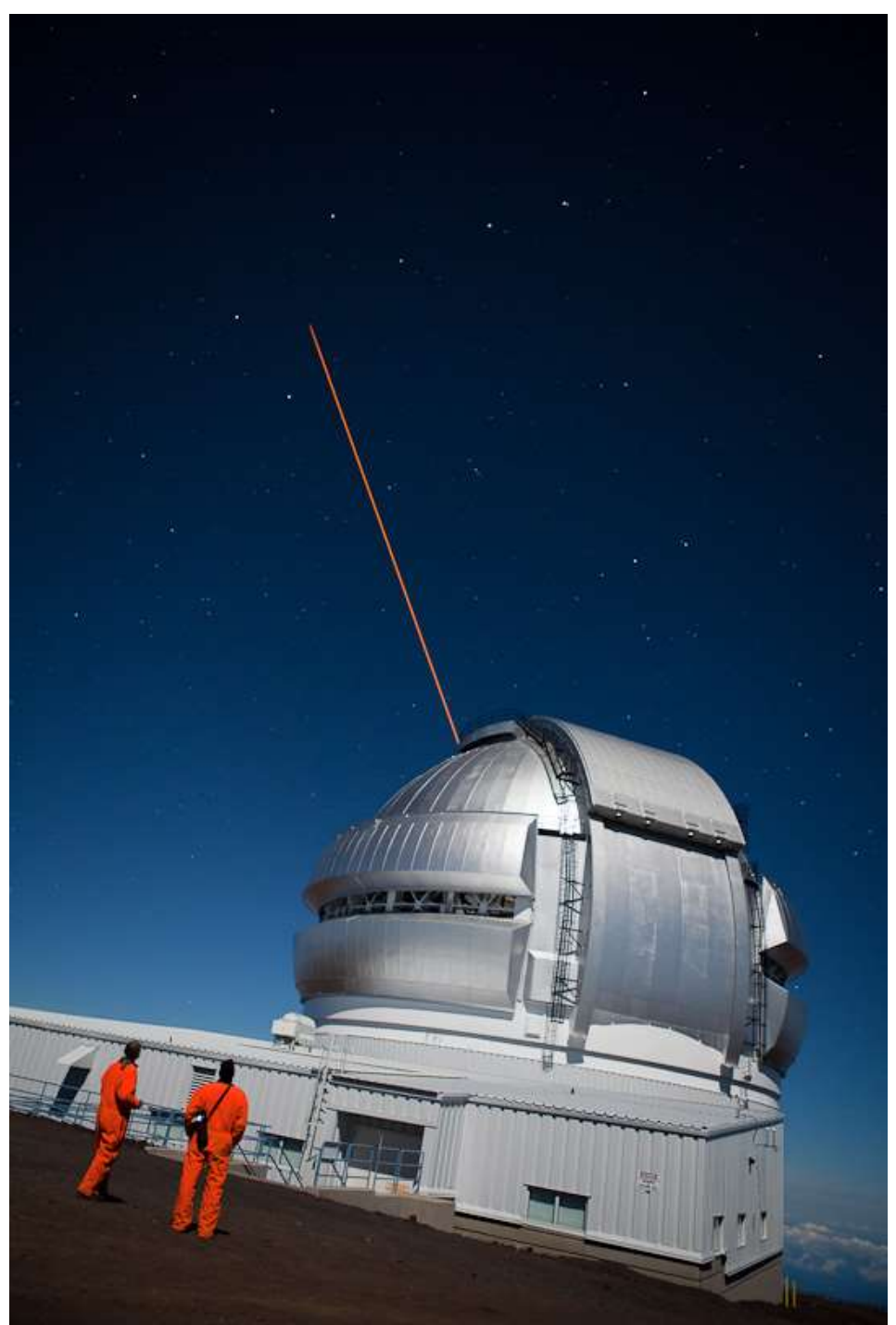
VLT laser



Spotters no observatório Gemini

Two aircraft spotters make sure no aircrafts pass close to the laser beam.

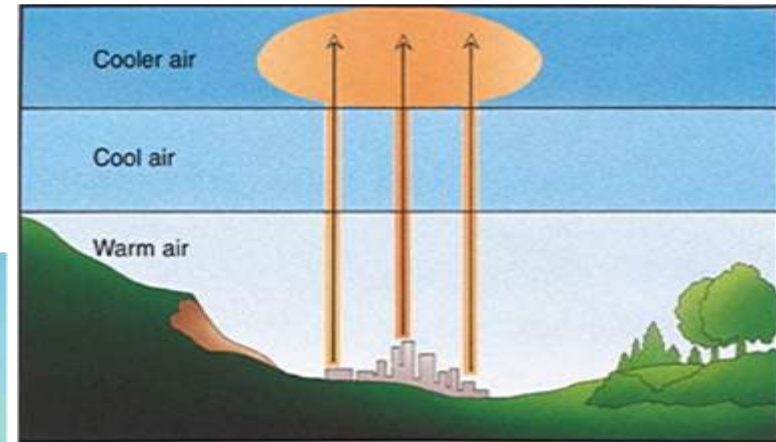
<http://www.paulanthonywilson.com/blog/why-do-some-telescopes-use-laser-beams/>



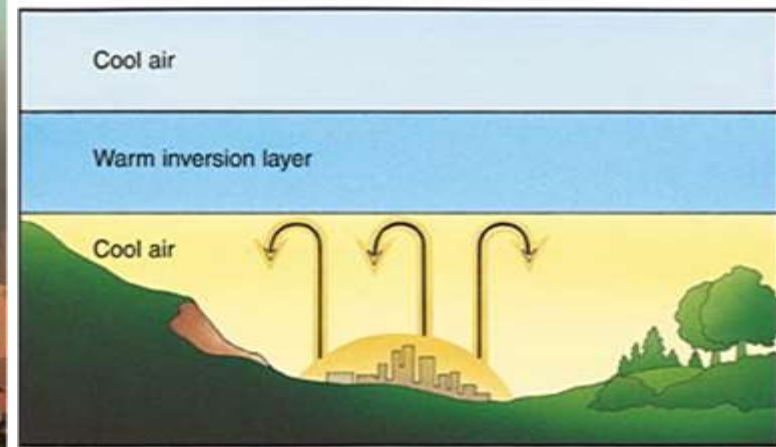
Outros fatores atmosféricos:

Camada de inversão

- Fator na escolha de um sítio astronómico de solo
- Camada de inversão, $\sim 2\text{km}$, mas pode ocorrer a menores z



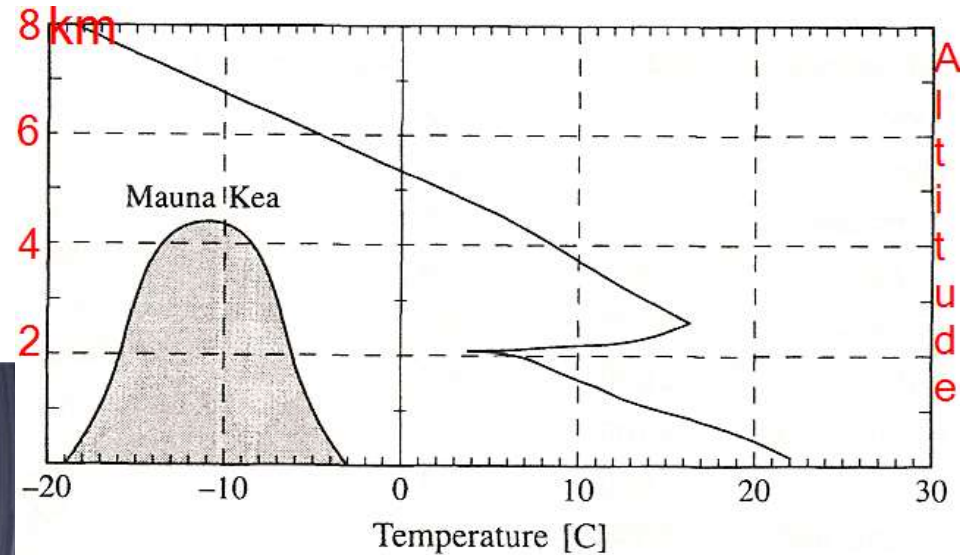
Normal pattern



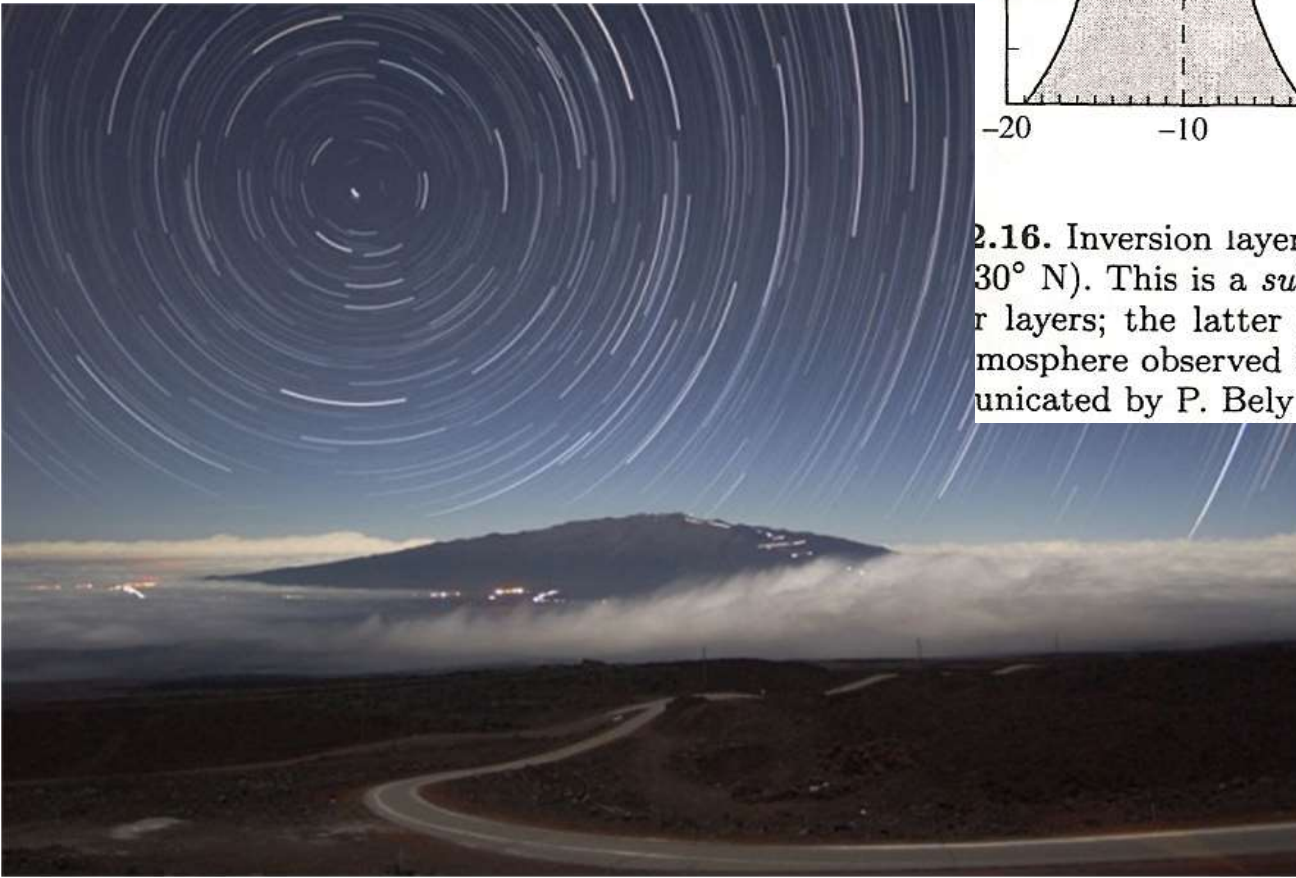
Thermal inversion

Camada de inversão

- Camada de inversão sobre o oceano pacífico em volta da ilha de Havai



2.16. Inversion layer above the Pacific Ocean, near the island of Hawaii (30° N). This is a *subsidence inversion*, caused by reheating of the lower layers; the latter movement itself is caused by the general circulation of the atmosphere observed in *Hadley cells*. (Sounding balloon measurements taken and communicated by P. Bely and the Hilo Weather Bureau, Hawaii.)



Condições meteorológicas em La Silla (Chile)









Estudantes brasileiros @ La Silla, 20/9/2013

1/10/2013

La Silla - MeteoMonitor

Current

Average

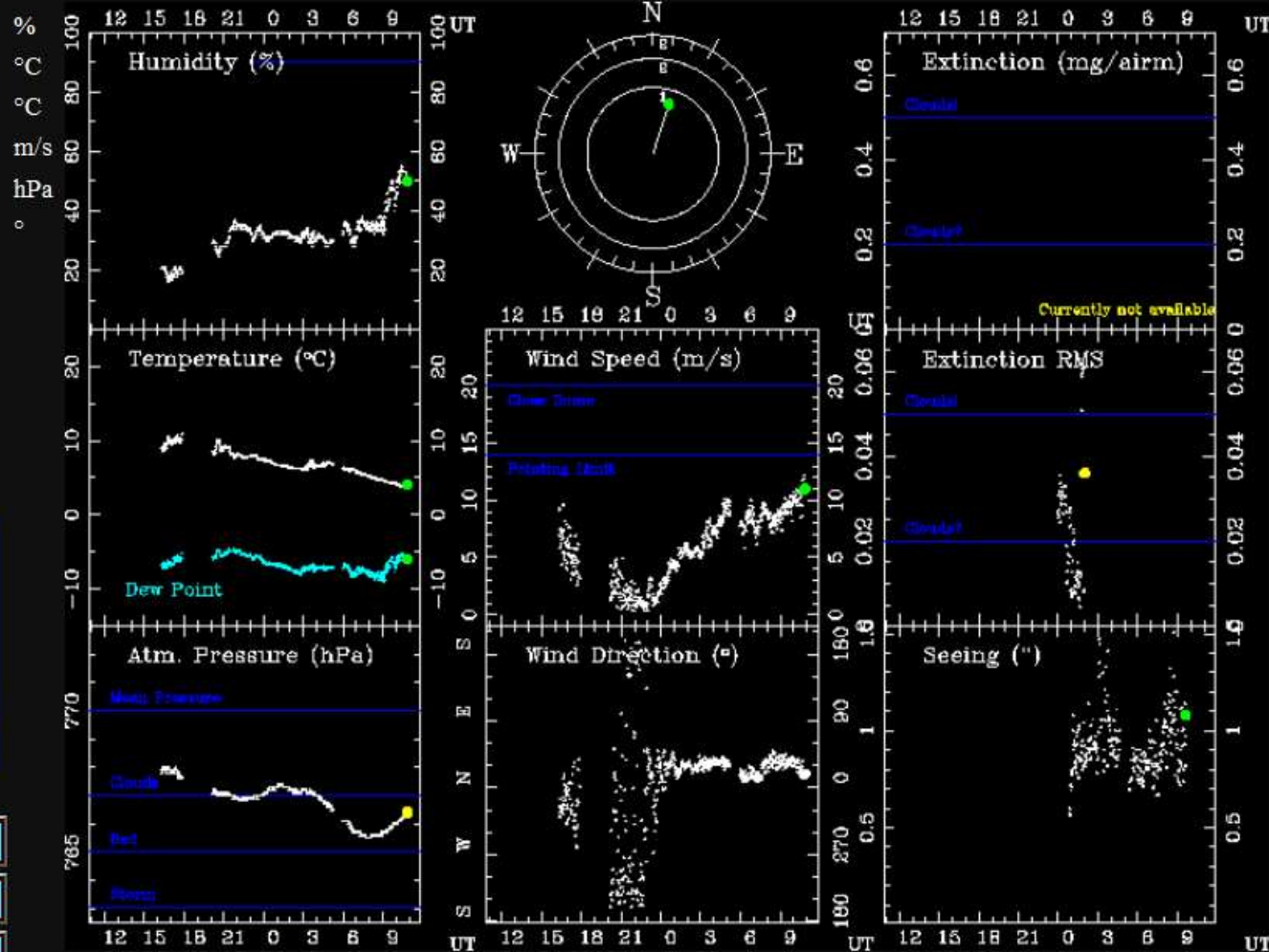
Humidity:	50.0		50.0
Temperature:	4.0		4.0
Dew Point:	-6.0		-6.0
Wind Speed:	11.0		11.0
Atm. Pressure:	766.4		766.4
Sun Altitude:	6.		
DIMM Seeing:	1.08		arcsec

Last Update

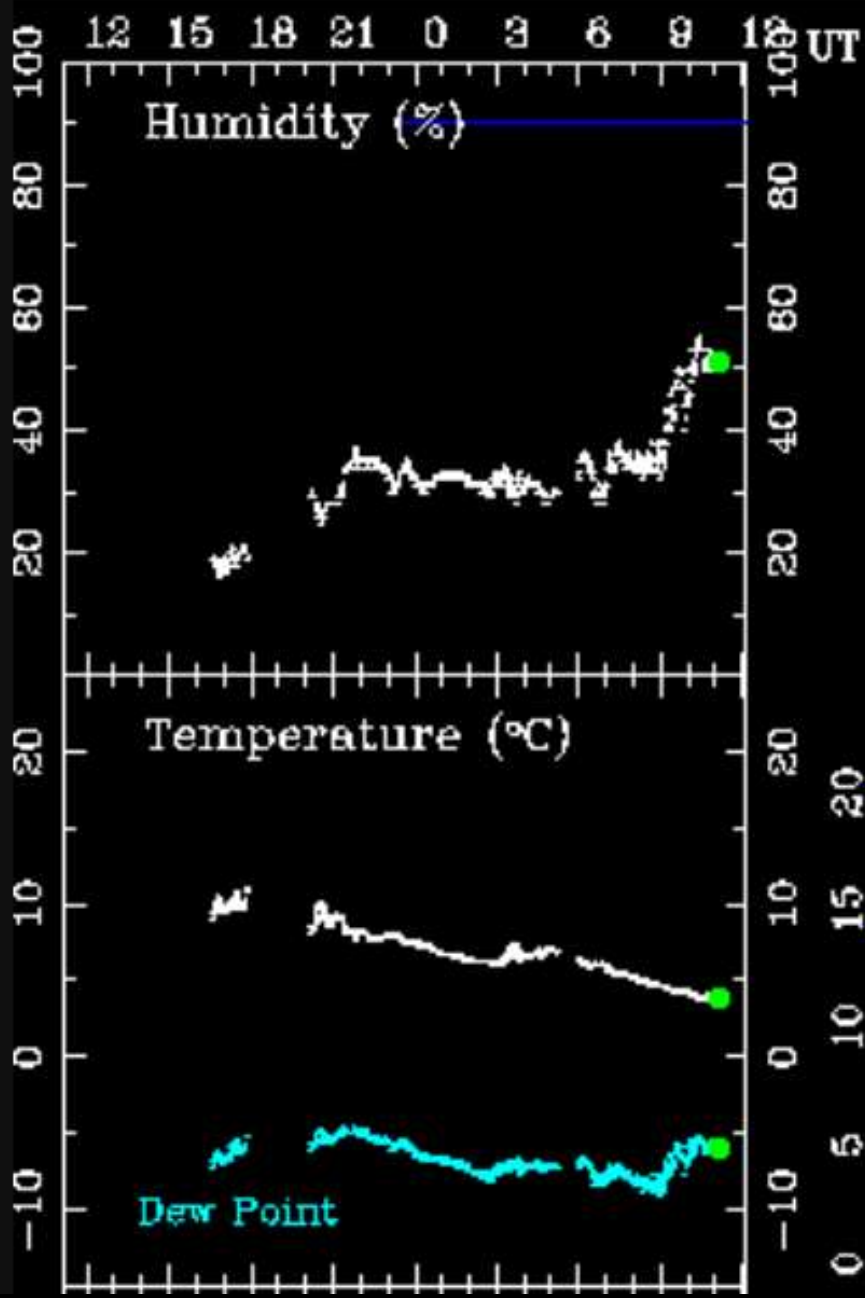
UT: 2013-10-02 10:50

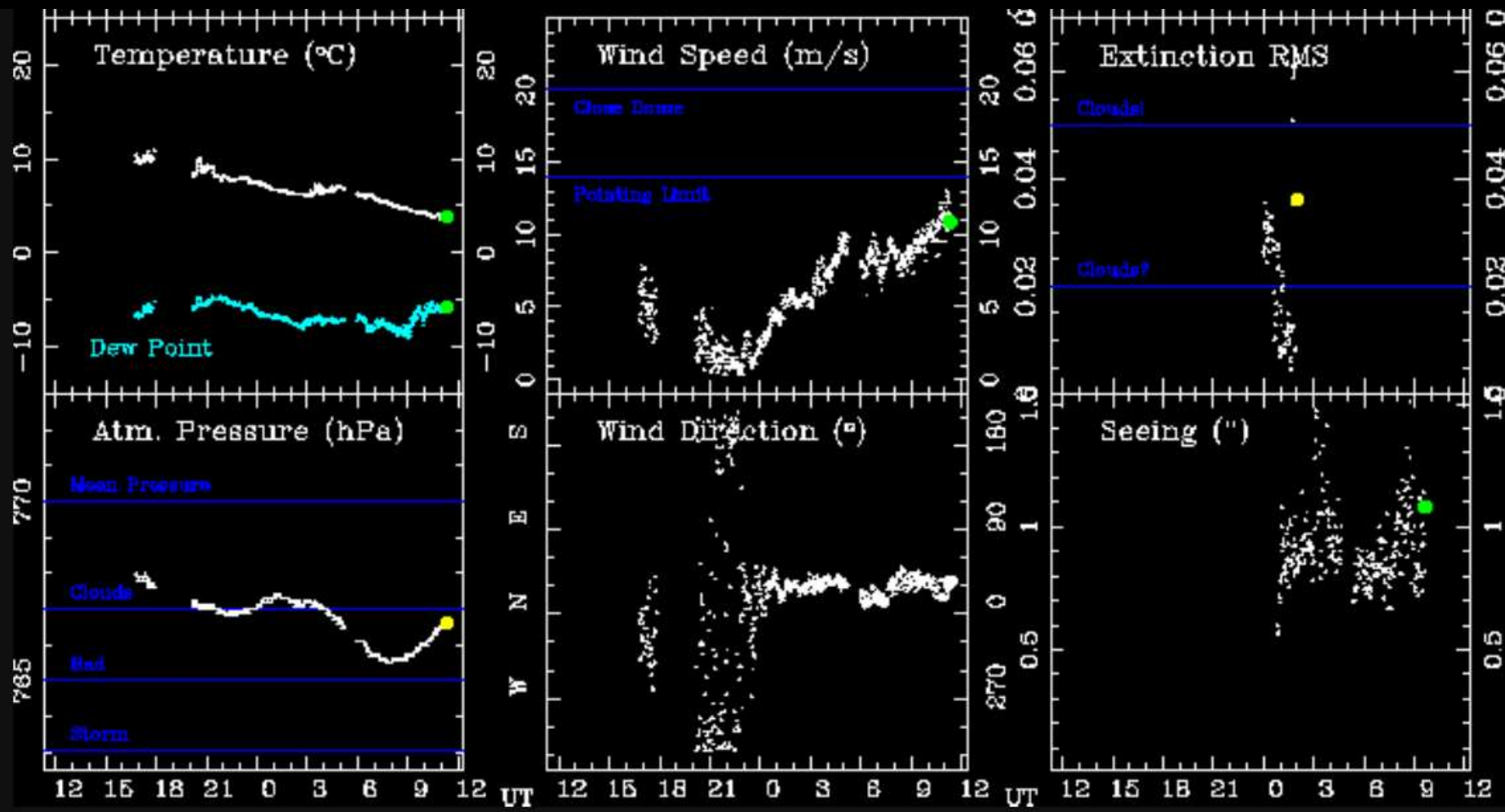
JD: 2456567.951

ST: 06:52

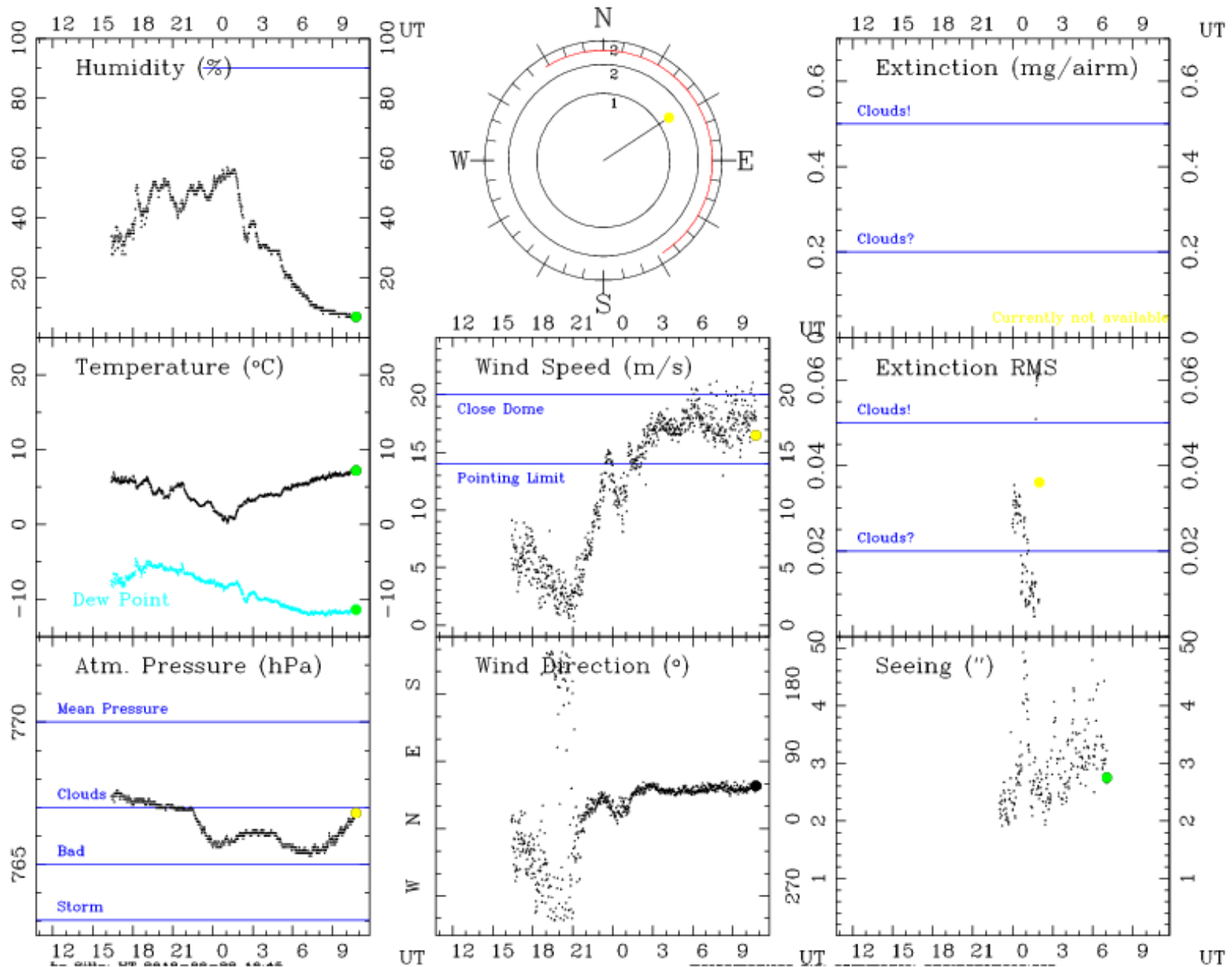


Update	PRINT GRAPH
Help/Info	Zoom graph
Satellite Pics	Plot Archive





La Silla, 22/9/2013



Hawaii



Hawaii, 18/8/2013

Mauna Kea mountain



Mauna Kea Weather conditions



Current Conditions

Temp 1.9 C
 RH 60 %
 Wind W 7 mph
 Road Open

Observations

STN	DATE HST	TIME HST	TEMP °C	DPNT °C	RH %	WSPD mph	PK WSPD mph	WDIR dir	PRES mb	RAIN mm	PW mm	Seeing arcsec	Trends
CFHT/GEM	10/02/13	01:31	1.9	-5.1	60	7	11	W	617	0.00		0.50	Meteogram
UKIRT	10/02/13	01:27	1.9	-5.8	57	5		NW	615				Meteogram
IRTF	10/02/13	01:28	0.0	-5.4	57	6	7	NW					Meteogram
SUBARU	10/02/13	01:28	0.8	-4.9	66	2	4	WNW	621	0			Meteogram
KECK	10/02/13	01:30	2.1	-5.9	56				620				
JCMT	10/02/13	01:26	2.5	-5.5	56	4		N	625		3.16		Meteogram
CSO	10/02/13	01:30	9.3	-3.6	40	0	0	N	626		3.45		Tau
SMA	10/02/13	01:17	3.4	-3.6	60	3		ENE	624	0.0			Trend
VLBA	10/02/13	01:26	5.2	-8.9	36	4	7	NNW	654	0			Meteogram
HP	10/02/13	01:30	9.3	1.3	57	7	8	WNW	727	0			Meteogram
UNITS	UTC HST		°C K F		%	mph Kts mps		dir	mb	mm	Tau mm		arcsec



Escolha de um sítio astronômico

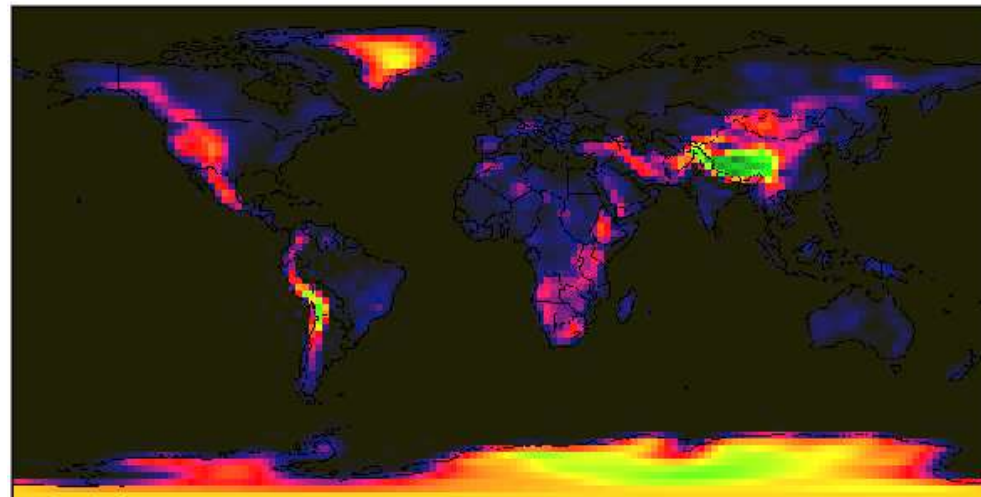
- Ausência de nuvens (ligada à camada de inversão)
- Qualidade fotométrica (estab. transparência atmos.)
- Transparência no IV e mm (vapor H_2O atmosférico)
- Qualidade da imagem (variações na temperatura e índice de refração do ar)

Escolha de um sítio astronômico

FriOWL Version 2.1 (2006)
Southern Observatory & University of Fribourg (Switzerland)



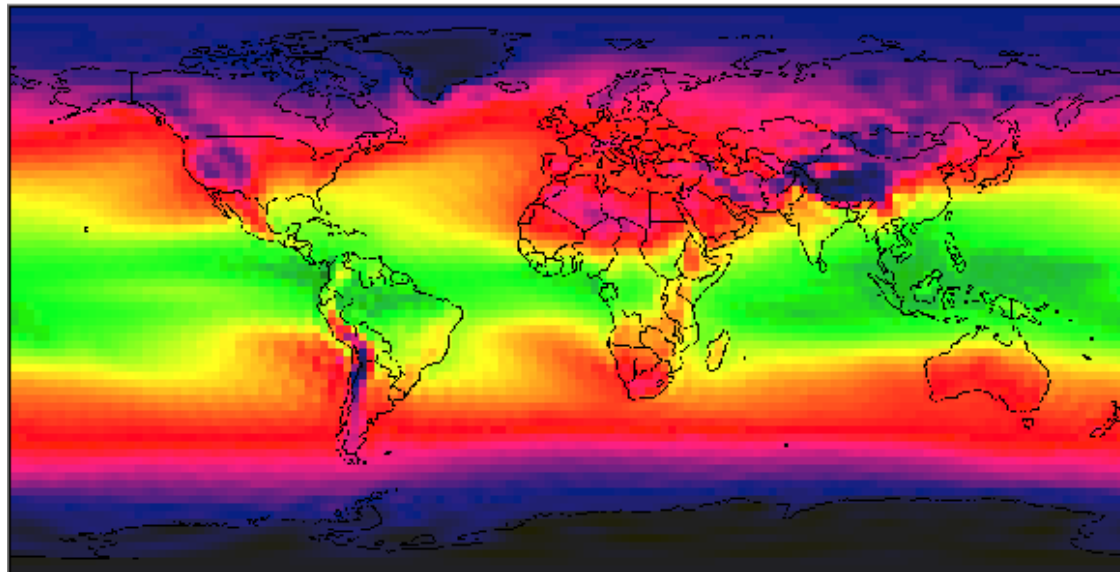
Altitude



Colors



precipitable
 H_2O



-1.719

3.818

9.354

14.89

20.427

25.963

31.5

37.036

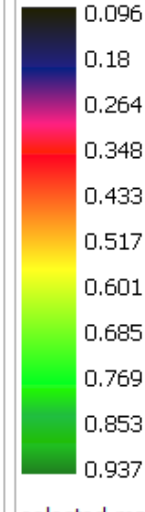
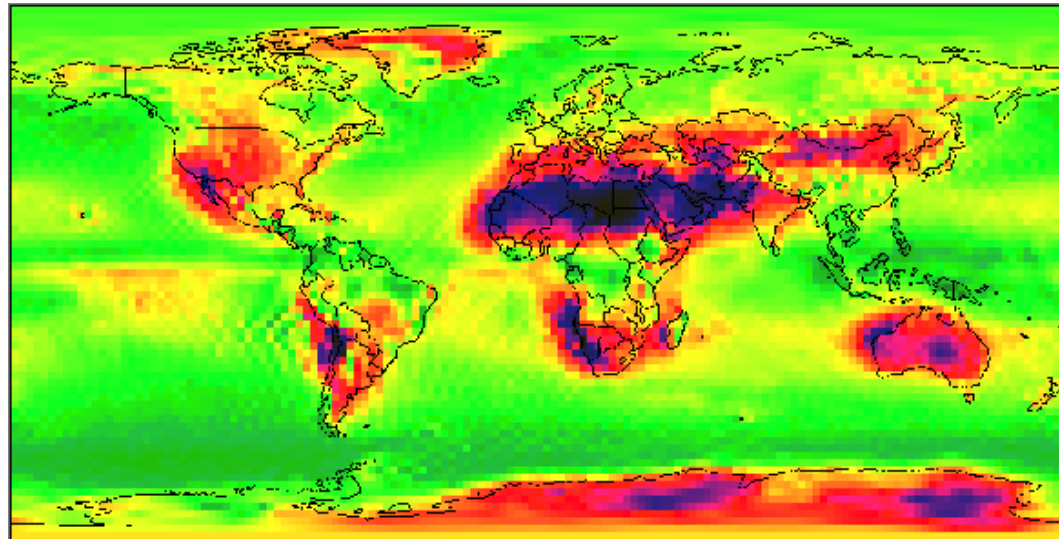
42.572

48.109

53.645

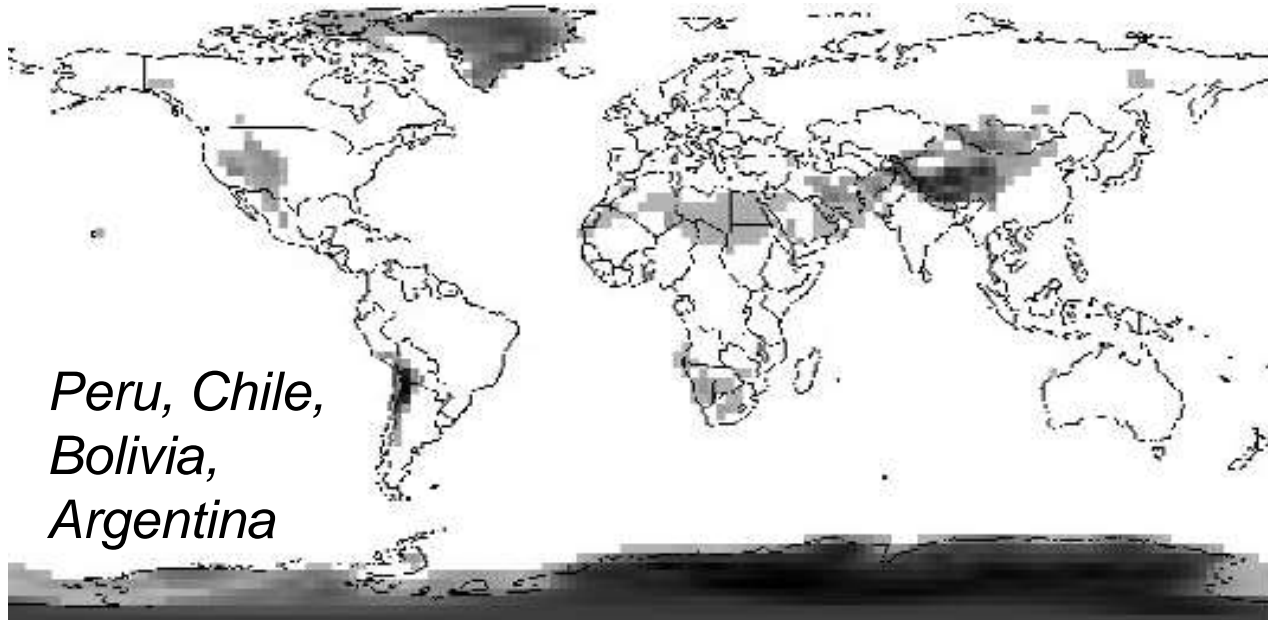
Escolha de um sítio astronômico

Cloud coverage

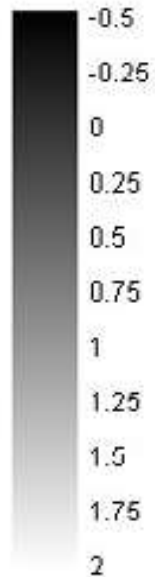


BEST SITES

High
summits
+ low
cloudiness +
low
precipitable
water vapor



*Peru, Chile,
Bolivia,
Argentina*



Se o solo não for bom, podemos ir ao espaço



AKARI
Japanese Infrared
All-Sky Surveyor

GAIA
The Billion Star Surveyor

HUBBLE SPACE TELESCOPE
Expanding the frontiers of the visible Universe

ISO
Infrared Space
Observatory

IUE
Taking the measure of
Massive black holes

HERSCHEL
Unveiling the Universe

IRIST
Striving to observe
the first light

PLANCK
Looking back to the dawn of time

XMM-Newton
A leap forward for
X-ray astronomy

sub-mm

infrared

visible

microwaves

ultraviolet

X-rays

radio waves

gamma-rays

INTEGRAL
Seeking out the extremes
of the universe