Extinción **atmosférica**

Flujo total **efectivamente** medido

Transparencia de la atmósfera
Transmisión del instrumento
Sensibilidad del detector

$$\phi_{medido} = \pi A\left(R/r\right)^2 \int_0^\infty I_\lambda T_{A\lambda} T_{i\lambda} S_{i\lambda} d\lambda$$

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UBVRI PHOTOMETRIC STANDARD STARS IN THE MAGNITUDE RANGE $11.5 < V < 16.0$ AROUND THE CELESTIAL EQUATOR[1]

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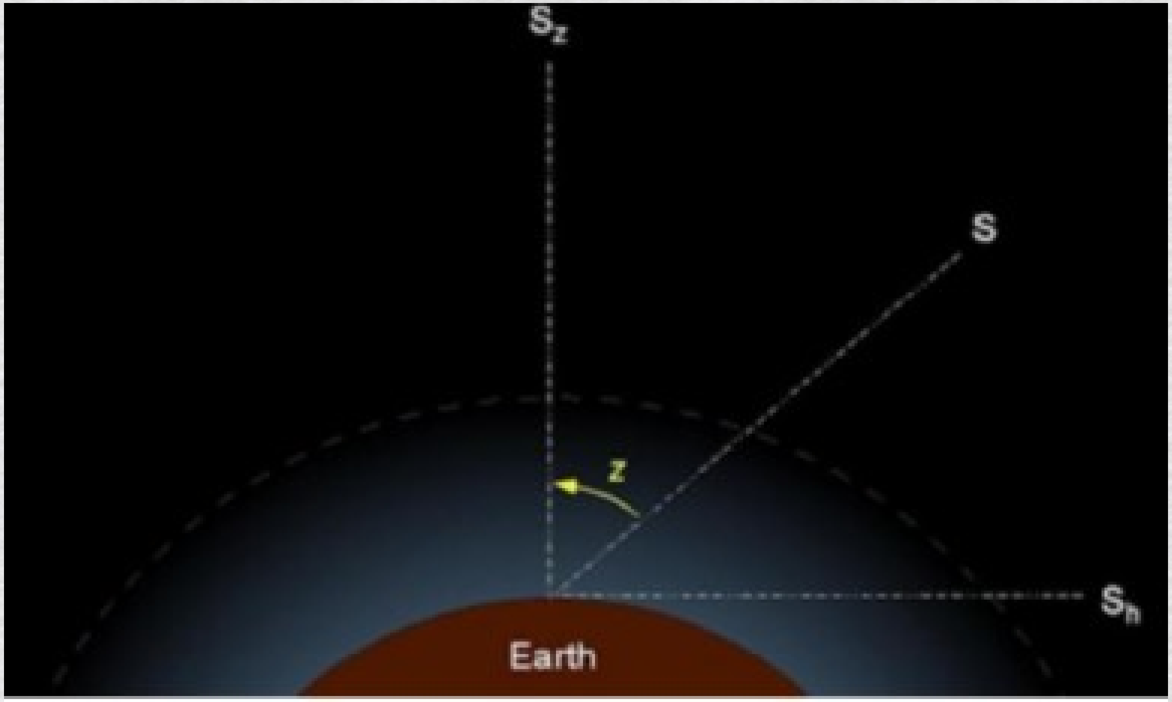
Star	α(2000)	δ(2000)	V	B-V	U-B	V-R	R-I	V-I
95 96	03:52:54	+00 00 19	10.010	0.147	0.072	0.079	0.095	0.174
95 97	03:52:57	-00 00 20	14.818	0.906	0.380	0.522	0.546	1.068
95 98	03:53:00	+00 02 52	14.448	1.181	1.092	0.723	0.620	1.342
95 100	03:53:01	+00 00 13	15.633	0.791	0.051	0.538	0.421	0.961
95 101	03:53:04	+00 02 53	12.677	0.778	0.263	0.436	0.426	0.863
95 102	03:53:07	+00 01 09	15.622	1.001	0.162	0.448	0.618	1.065
95 252	03:53:11	+00 27 19	15.394	1.452	1.178	0.816	0.747	1.566
95 190	03:53:13	+00 16 20	12.627	0.287	0.236	0.195	0.220	0.415
95 193	03:53:20	+00 16 31	14.338	1.211	1.239	0.748	0.616	1.366
95 105	03:53:21	-00 00 20	13.574	0.976	0.627	0.550	0.536	1.088

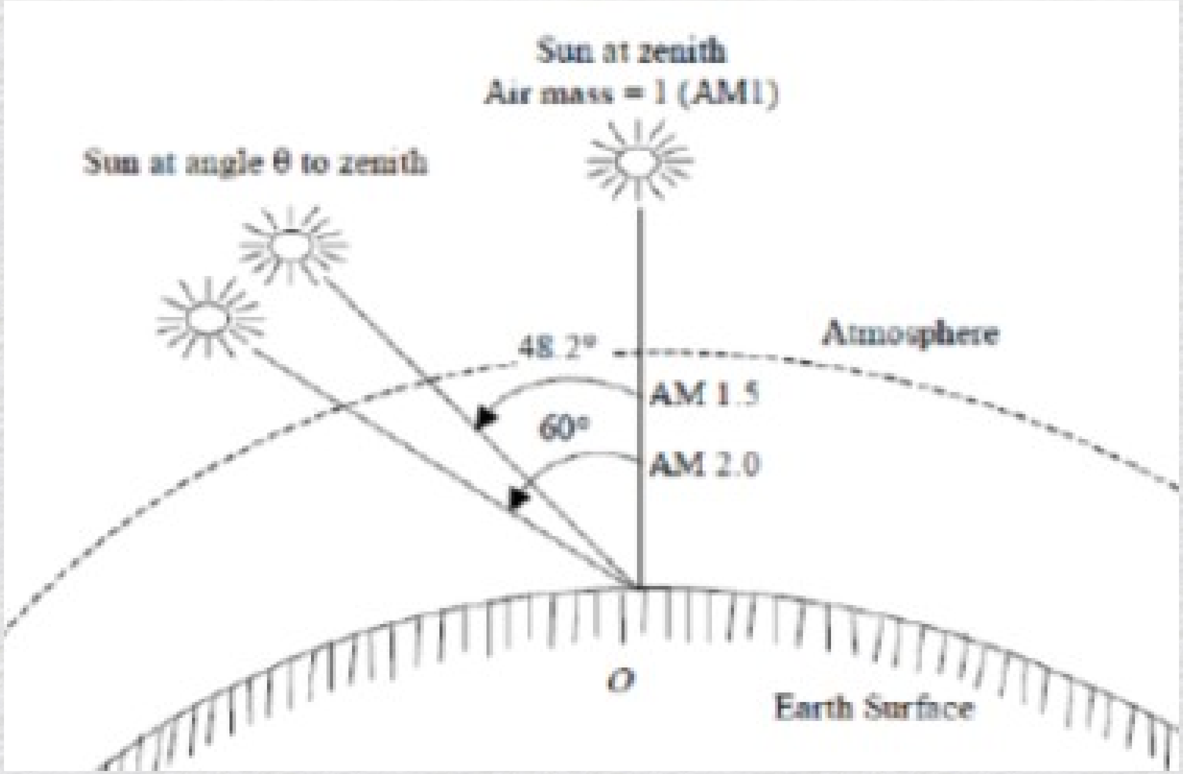
Magnitudes en el sistema standard corregidas por extinción atmosférica

La **extinción** atmosférica →
atenuación de la radiación incidente



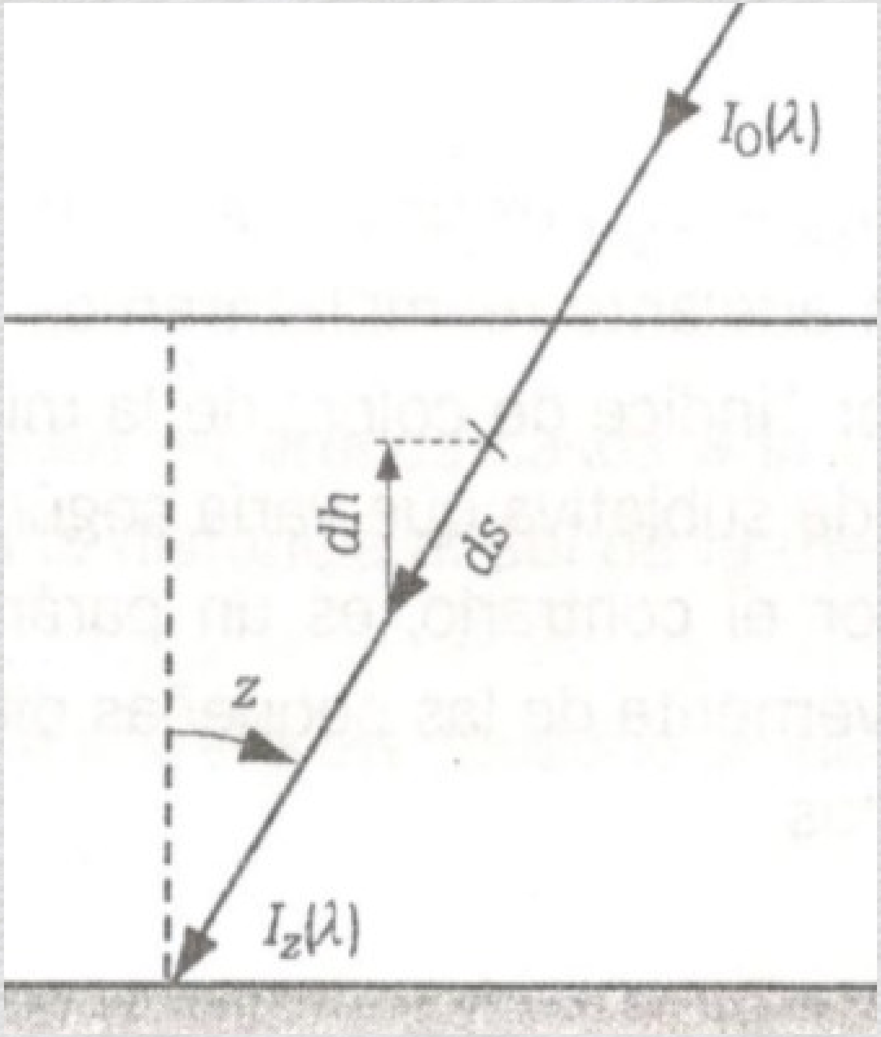
Recordar (una vez más...):
¡no es la absorción interestelar!

La **extinción** atmosférica → **atenuación** de la radiación incidente



Recordar (una vez más...):
¡no es la absorción interestelar!

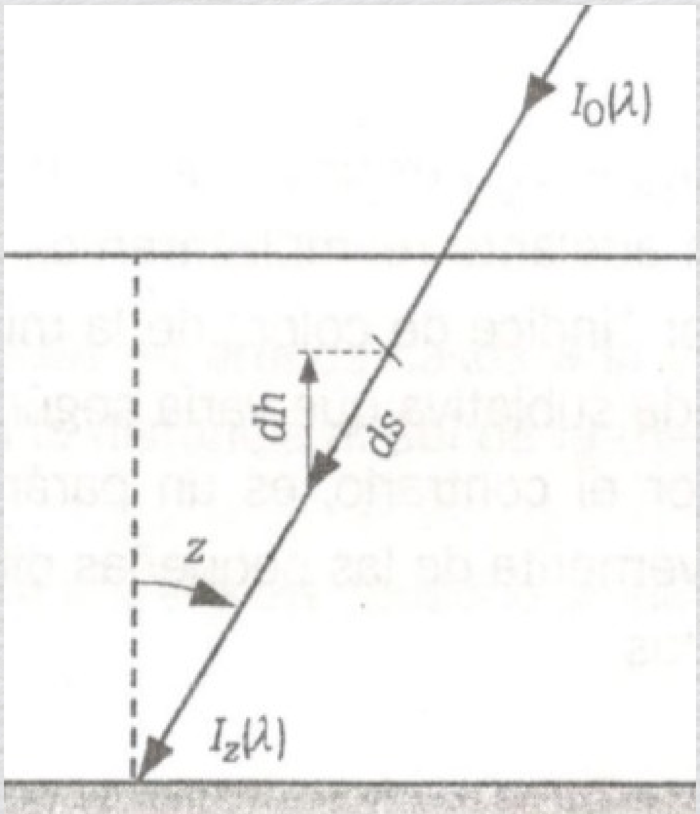
¿Cuánto se extingue la radiación?



$I_o(\lambda)$: Intensidad fuera de la atmósfera

$I_Z(\lambda)$: Intensidad atenuada por la atmósfera observada en z

¿Cuánto se extingue la radiación?



$$m = m_0 + k\ X$$

“masa de aire” (X)

“k”: coeficiente de extinción
Depende de:

- El filtro utilizado
- Del lugar de observación
- Del color del objeto

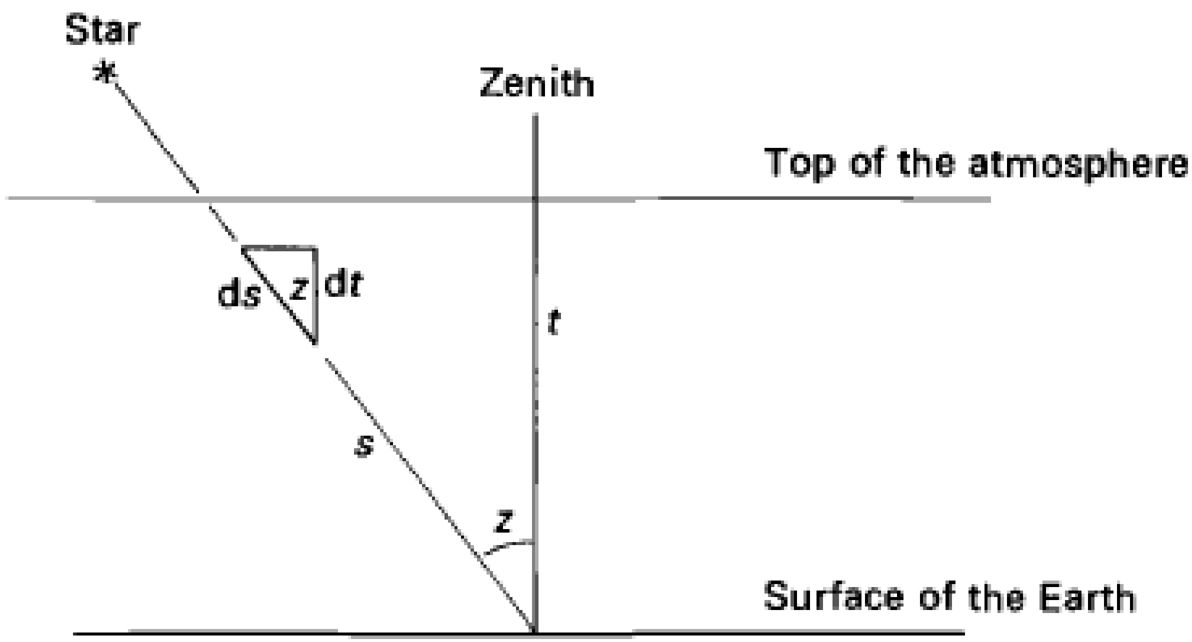


Fig. 4.2. Stellar light is entering the atmosphere at an angle z with respect to the zenith direction (exactly overhead). Light is absorbed along the path s. The longer s the more light is absorbed.

Due to the extinction in the Earth's atmosphere, the light is reduced by a certain amount which is proportional to the intensity I_λ of the beam at wavelength λ. (The more photons there are passing through the atmosphere the larger is the chance that one of them will hit an atom and will be absorbed by the atom.) The chances of absorption are also larger if the path lengths through the atmosphere are larger. It is also large if the atoms are of a kind which want to absorb especially light of the wavelength λ considered. The properties of atoms concerning the absorption of light of a given wavelength λ are described by the absorption coefficient κ_λ per cm, which may be very strongly dependent on the wavelength λ. We then find that the intensity change $\mathrm{d}I_\lambda$ along the path element $\mathrm{d}s$ is

$$\mathrm{d}I_\lambda = -\kappa_\lambda \cdot I_\lambda \, \mathrm{d}s. \tag{4.5}$$

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$$dI_\lambda = -\kappa_\lambda I_\lambda \, ds. \tag{4.5}$$

Dividing by I_λ and remembering that $dI_\lambda/I_\lambda = d(\ln I_\lambda)$ we find

$$d(\ln I_\lambda) = -\kappa_\lambda \, ds = -d\tau_\lambda. \tag{4.6}$$

Here we have defined the so-called optical depth τ_λ by

$$d\tau_\lambda = \kappa_\lambda \, ds \quad \text{and} \quad \tau_\lambda(s_0) = \int_0^{s_0} \kappa_\lambda \, ds. \tag{4.7}$$

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Equation (4.6) can be integrated on both sides between 0 and s and yields

$$\Delta(\ln I_\lambda) = \ln I_\lambda(s) - \ln I_\lambda(0) = -\int_0^s \kappa_\lambda \, ds = -\int_0^{\tau_\lambda(s)} d\tau_\lambda = -\tau_\lambda(s), \tag{4.8}$$

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Taking the exponential on both sides gives

$$I_\lambda(s) = I_\lambda(0) e^{-\tau_\lambda(s)}. \tag{4.9}$$

$$I_\lambda(s) = I_\lambda(0)e^{-\tau_{\lambda s}(s)}. \tag{4.9}$$

The optical depth along the path of the light $\tau_{\lambda s}$ depends on the zenith distance z, as can be seen in Fig. 4.2. We see that $\cos z = t/s = \mathrm{d}t/\mathrm{d}s$, or

$$\mathrm{d}s = \frac{\mathrm{d}t}{\cos z} = \sec z \, \mathrm{d}t. \tag{4.10}$$

It then follows that

$$\tau_{\lambda s} = \int_0^s \kappa_\lambda \, \mathrm{d}s = \sec z \int_0^t \kappa_\lambda \, \mathrm{d}t = \sec z \, \tau_{\lambda t}, \tag{4.11}$$

where $\tau_{\lambda t}$ is the optical depth measured perpendicularly through the atmosphere. We can then write equation (4.9) in the form

$$I_\lambda(s) = I_\lambda(0)\mathrm{e}^{-\tau_{\lambda s}(s)}. \tag{4.9}$$

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It then follows that

$$\tau_{\lambda s} = \int_0^s \kappa_\lambda\,\mathrm{d}s = \sec z \int_0^t \kappa_\lambda\,\mathrm{d}t = \sec z\,\tau_{\lambda t}, \tag{4.11}$$

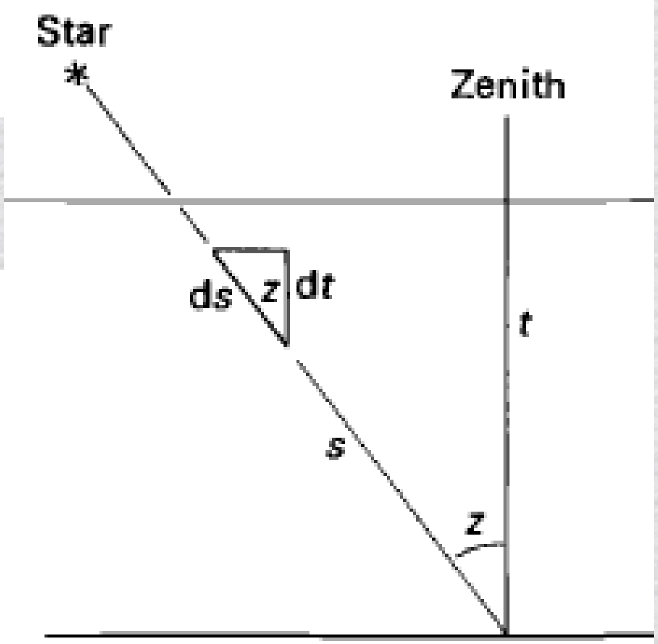
where $\tau_{\lambda t}$ is the optical depth measured perpendicularly through the atmosphere. We can then write equation (4.9) in the form

$$I_\lambda(s, z) = I_\lambda(0)\mathrm{e}^{-\sec z\,\tau_{\lambda t}}, \tag{4.9a}$$

where $\tau_{\lambda t}$ is now independent of z.

$\tau_{\lambda t}$ is called the optical depth of the atmosphere at wavelength λ and is usually written at τ_λ.

$$I_\lambda(s,z) = I_\lambda(0)\mathrm{e}^{-\sec z\,\tau_{\lambda t}},$$



$$\mathrm{d}s = \frac{\mathrm{d}t}{\cos z} = \sec z\,\mathrm{d}t.$$

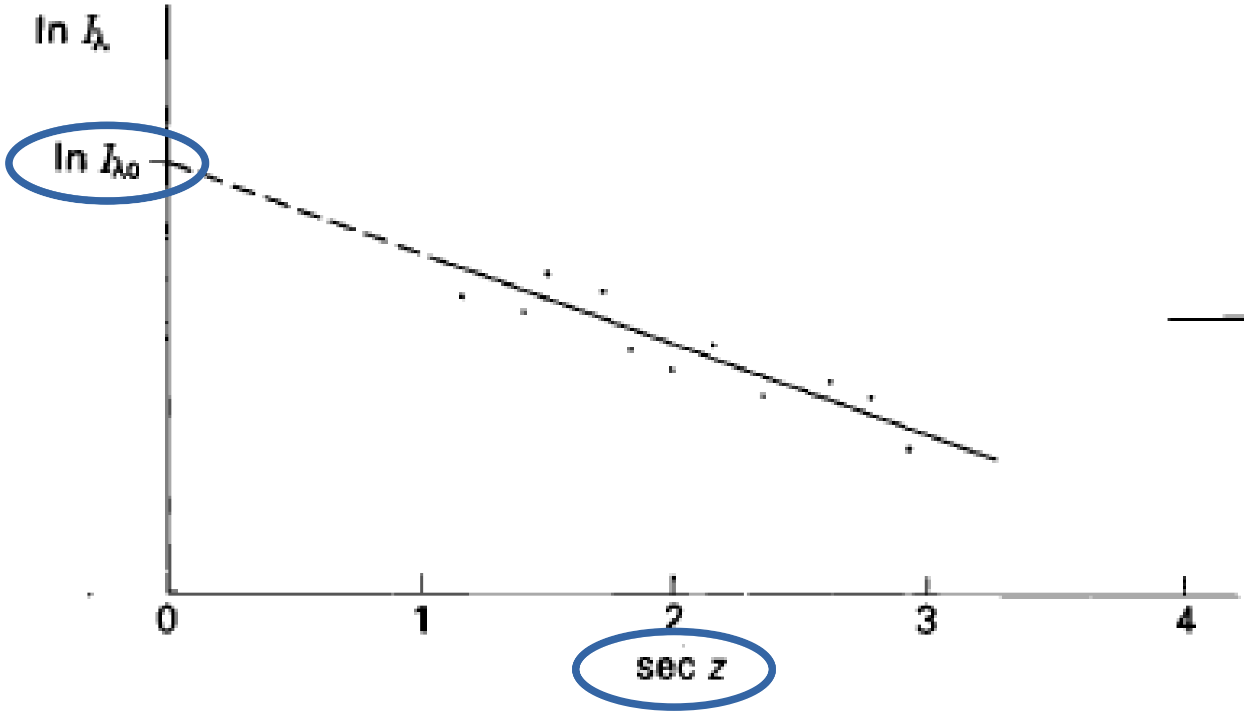


Fig. 4.3. The logarithms of the measured intensities I_λ are plotted as a function of sec z. The best fitting straight line through these points can be determined. The intersection of this line with the ln I_λ axis determines the logarithm of the intensity above the Earth's atmosphere, ln $I_{\lambda 0}$.

Here we have defined the so-called optical depth τ_λ by

$$d\tau_\lambda = \kappa_\lambda\, ds \quad \text{and} \quad \tau_\lambda(s_0) = \int_0^{s_0} \kappa_\lambda\, ds. \tag{4.7}$$

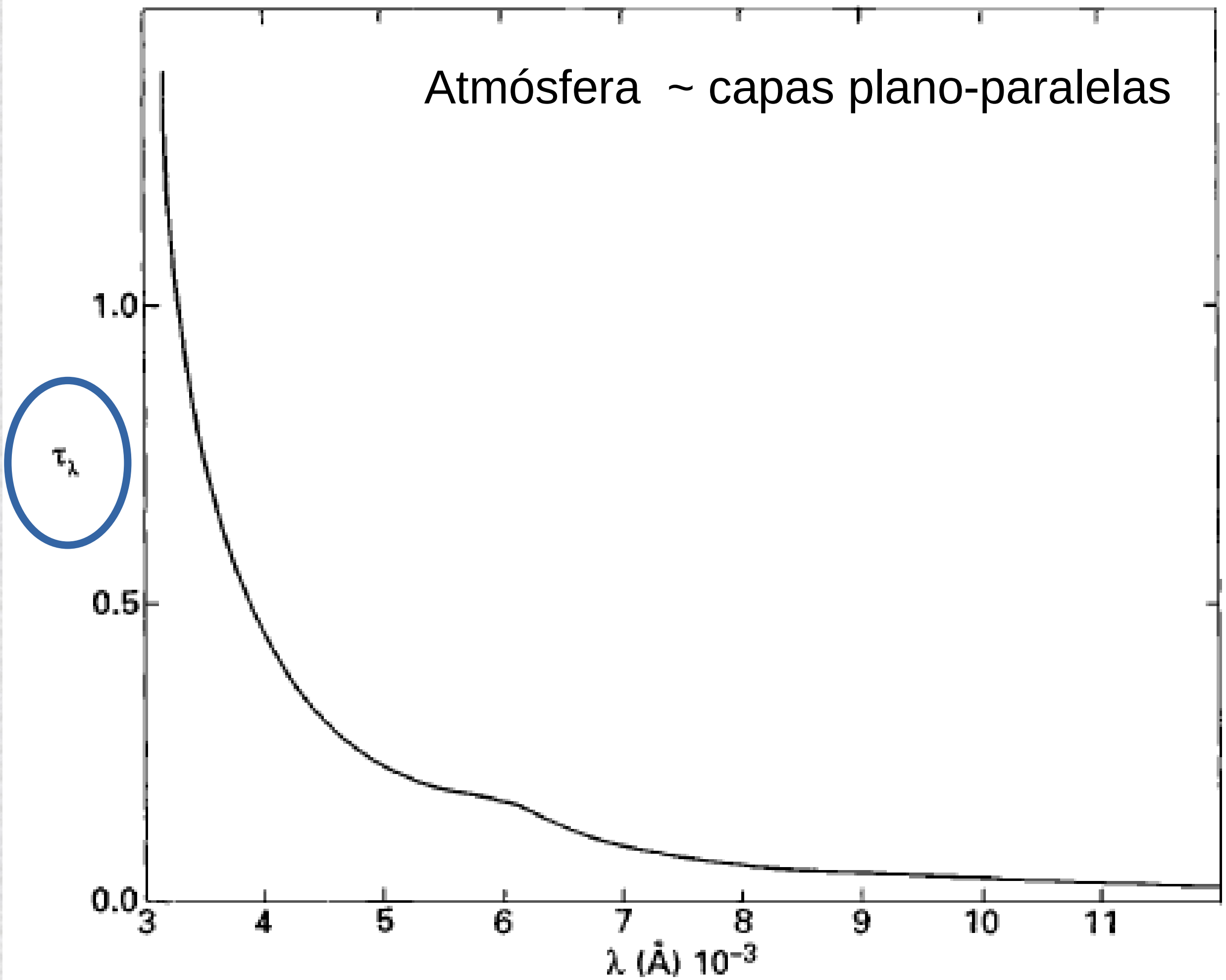


Fig. 4.4. The optical depth τ_λ of the Earth's atmosphere for the continuous absorption is shown as a function of wavelength λ, according to Allen (1968).

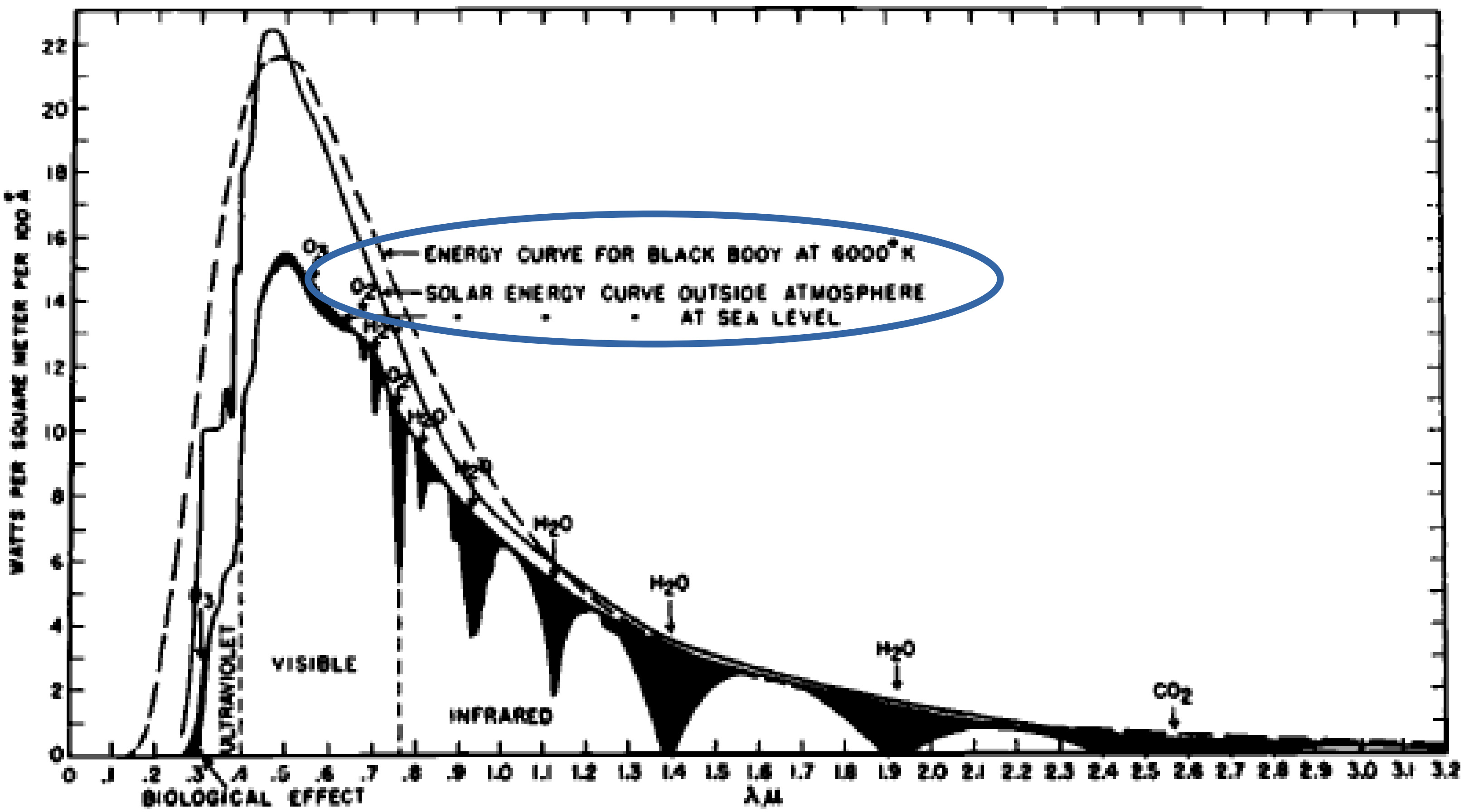
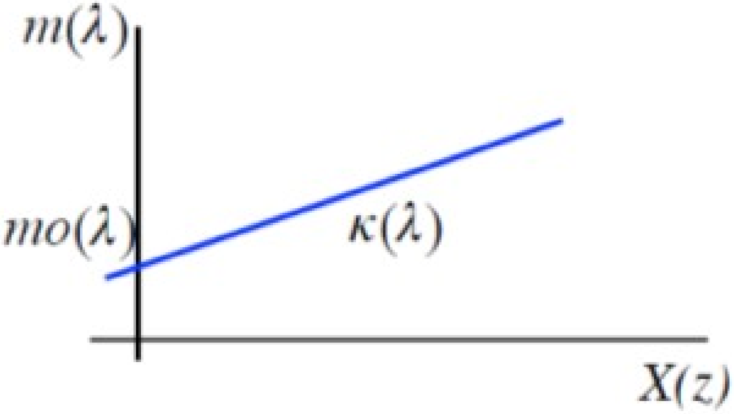


Fig. 4.5. The measured energy distribution of the sun, which means the amount of radiation which we receive from the sun here on the surface of the Earth, is plotted as a function of wavelength of the radiation. The black areas indicate the amount of radiation taken out by the molecular bands of water vapor and of oxygen. Also shown is the energy distribution as measured above the Earth's atmosphere. For comparison we also show the energy distribution of a black body with a temperature of 6000 K, which matches the solar energy distribution rather well. (From Pettit 1951.)

A una longitud de onda en particular, se puede relacionar la magnitud de un objeto por fuera de la atmósfera terrestre $mo(\lambda)$ con la magnitud observada en la superficie $m(\lambda)$.

$$m(\lambda) = m_0(\lambda) + \kappa_\lambda X(z)$$

en donde, $X(z)$ es la masa de aire y $\kappa(\lambda)$ es el coeficiente de extinción y z la distancia cenital.



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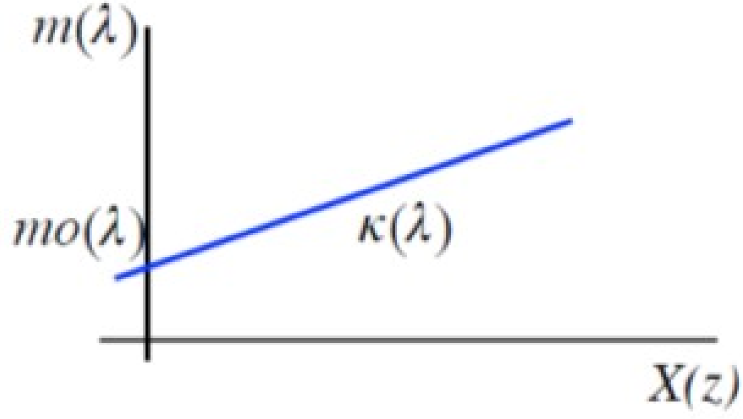


"Método de las tres ternas, de *Bouguer*, ...":

1) Obtener las magnitudes instrumentales de un mismo grupo estrellas a diferentes valores de masa de aire (X)
2) Ajustar una recta para cada estrella en un plano: "m_{inst} vs. X".
3) El coeficiente de extinción (*k*) es la pendiente de la recta

$$m = m_0 + k\ X$$

Ley de Bouguer

$$k = k' + k'' \times IC$$

k' = Coeficiente de extinción de 1er orden
k" = Coeficiente de extinción de 2do orden

- **El término *k'*:** Depende fundamentalmente de la atmósfera y suele cambiar a lo largo del tiempo (p.e. erupciones de volcanes, etc.)
- **El factor *k"*:** Se debe fundamentalmente a la configuración instrumental (detector, filtros, telescopio)
- **El factor IC:** Es un "Indice de Color" de la estrella (usualmente el *B-V*). En principio es el "índice de un catálogo" pero se suele utilizar el "índice observado"

¡Atención a los signos! La extinción **disminuye** la intensidad recibida → **aumenta** la magnitud medida

$$v_0 = v - k_v X,$$

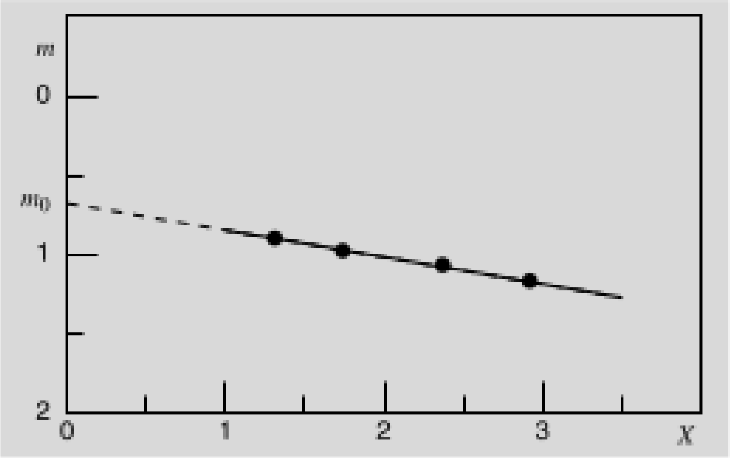
$$(b - v)_0 = (b - v) - k_{bv} X,$$

$$(u - b)_0 = (u - b) - k_{ub} X,$$

Example 4.8 (Reduction of Observations) The altitude and magnitude of a star were measured several times during a night. The results are given in the following table.

Altitude	Zenith distance	Air mass	Magnitude
50°	40°	1.31	0.90
35°	55°	1.74	0.98
25°	65°	2.37	1.07
20°	70°	2.92	1.17

By plotting the observations as in the following figure, we can determine the extinction coefficient k and the magnitude m_0 outside the atmosphere. This can be done graphically (as here) or using a least-squares fit.



Extrapolation to the air mass $X = 0$ gives $m_0 = 0.68$. The slope of the line gives $k = 0.17$.

$$m = m_0 + k\ X$$

Ley de Bouguer

Determinación de la extinción atmosférica

$$v_0 = v - k_v \sec z,$$

$$b_0 = b - k_b \sec z,$$

$$u_0 = u - k_u \sec z,$$

Determinación de la extinción atmosférica

- Elegir 3 grupos de ternas de estrellas (brillantes):

  - en la misma región

  - de colores distintos: roja, blanca y azul

- Las ternas deben diferir en ~ 4 h (R.A.)

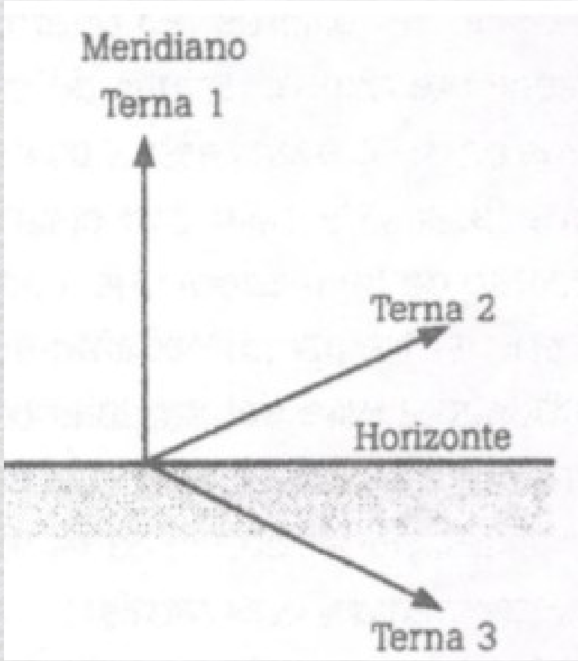
Determinación de la extinción atmosférica

- Elegir 3 grupos de ternas de estrellas (**brillantes**):

  - en la misma región

  - de colores distintos: roja, blanca y azul

- Las ternas deben diferir en ~ 4 h (R.A.)
- Al comenzar: la primera terna ~ en el meridiano, la segunda a 4 h (E) y la tercera, a ~ 8 h de la primera (no apareció sobre el horizonte).



Determinación de la extinción atmosférica

$$v_0 = v - k_v \sec z,$$

$$b_0 = b - k_b \sec z,$$

$$u_0 = u - k_u \sec z,$$

$$v_0 = v - k_v \sec z,$$

$$(b - v) = (b - v) - k_{bv} \sec z,$$

$$(u - b)_0 = (u - b) - k_{ub} \sec z,$$

Determinación de la extinción atmosférica

$$v_0 = v - k_v \sec z,$$

$$b_0 = b - k_b \sec z,$$

$$u_0 = u - k_u \sec z,$$

$$v_0 = v - k_v \sec z,$$

$$(b - v) = (b - v) - k_{bv} \sec z,$$

$$(u - b)_0 = (u - b) - k_{ub} \sec z,$$

$$k_{bv} = k_b - k_v,$$

$$k_{ub} = k_u - k_b,$$

Determinación de la extinción atmosférica

$$v_0 = v - k_v \sec z,$$

$$(b - v) = (b - v) - k_{bv} \sec z,$$

$$(u - b)_0 = (u - b) - k_{ub} \sec z,$$

$$k_{bv} = k_b - k_v,$$

$$k_{ub} = k_u - k_b,$$

$$k_v = k'_v + k''_v(b - v),$$

$$k_{bv} = k'_{bv} + k''_{bv}(b - v),$$

$$k_{ub} = k'_{ub} + k''_{ub}(u - b),$$

Determinación de la extinción atmosférica

$$v_0 = v - k'_v X - k''_v (b - v) X,$$

$$(b - v)_0 = (b - v) - k'_{bv} X - k''_{bv} (b - v) X,$$

$$(u - b)_0 = (u - b) - k'_{ub} X - k''_{ub} (u - b) X.$$

Determinación de la extinción atmosférica

$$v_0 = v - k_v \sec z,$$

$$(b - v) = (b - v) - k_{bv} \sec z,$$

$$(u - b)_0 = (u - b) - k_{ub} \sec z,$$

$$v_0 = v - k'_v X - k''_v (b - v) X,$$

$$(b - v)_0 = (b - v) - k'_{bv} X - k''_{bv} (b - v) X,$$

$$(u - b)_0 = (u - b) - k'_{ub} X - k''_{ub} (u - b) X.$$

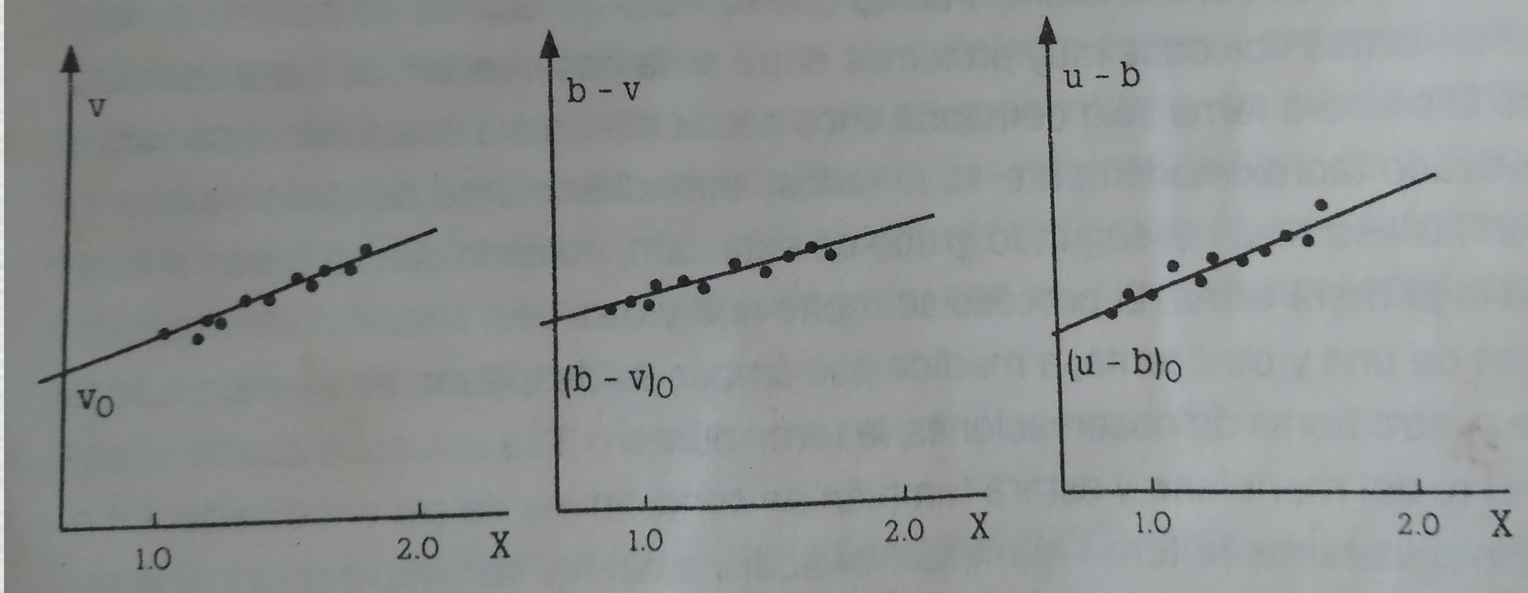


Figura 3-5: Magnitud instrumental v en función de la masa de aire.

Figura 3-6: Color $(b - v)$ instrumental en función de la masa de aire.

Figura 3-7: Color $(u - b)$ instrumental en función de la masa de aire.

Determinación de la extinción atmosférica

$$v_0 = v - k'_v X - k''_v (b - v) X,$$

$$(b - v)_0 = (b - v) - k'_{bv} X - k''_{bv} (b - v) X,$$

$$(u - b)_0 = (u - b) - k'_{ub} X - k''_{ub} (u - b) X.$$

$$k_v = k'_v + k''_v (b - v),$$

$$k_{bv} = k'_{bv} + k''_{bv} (b - v),$$

$$k_{ub} = k'_{ub} + k''_{ub} (u - b),$$

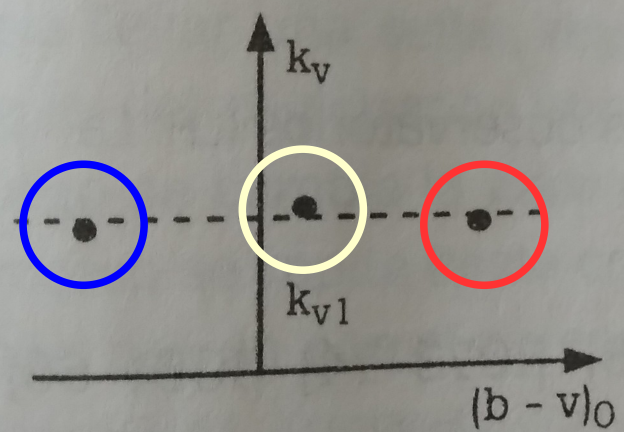


Figura 3-8: Variación del coeficiente k_v en función de $(b - v)_0$.

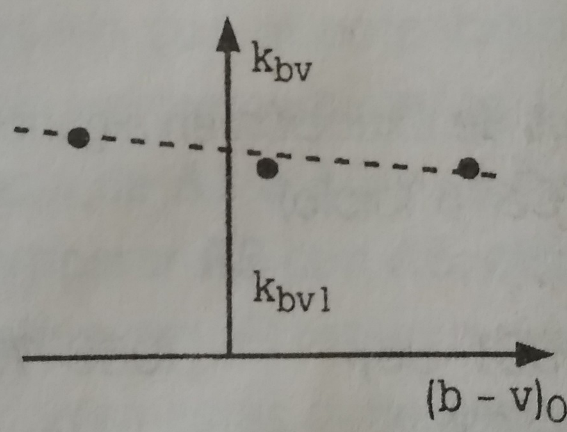


Figura 3-9: Variación del coeficiente k_{bv} en función de $(b - v)_0$.

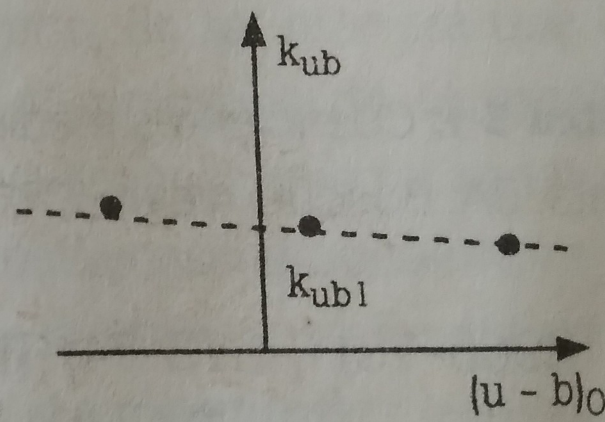


Figura 3-10: Variación del coeficiente k_{ub} en función de $(u - b)_0$.

Determinación de la extinción atmosférica

$$v_0 = v - k_v X,$$

$$(b-v)_0 = \frac{(b-v) - k_{bv} X}{1 + k_{bv2} X},$$

$$(u-b)_0 = \frac{(u-b) - k_{ub1} X}{1 + k_{ub2} X},$$

$$k_v = k_{v1} + k_{v2}(b-v)_0,$$

$$k_{bv} = k_{bv1} + k_{bv2}(b-v)_0,$$

$$k_{ub} = k_{ub1} + k_{ub2}(u-b)_0,$$

Mon. Not. R. Astron. Soc. **323**, 380–384 (2001)

Atmospheric extinction of $U-B$ photometry

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ABSTRACT
Bouguer lines have been used to measure the atmospheric extinction of $U - B$, and two approaches to correcting $U - B$ for the atmosphere are examined. We find that the conventional photometric reductions may be sufficiently accurate when the range of airmass is small enough (in terms of a maximum hazarded error of 0.04 mag per airmass), but we recommend the use of a colour term in the correction for $U - B$ extinction when this condition is not satisfied.

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Atmospheric extinction of $U-B$ photometry

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Extinction corrections are large and essential for ground-based observations, and are modelled to first order simply as a linear function of the airmass. The higher order terms (cf. e.g. Sterken & Manfroid 1992, hereafter SM, and Straižys 1995) are typically smaller, and arise because the extinction coefficients (magnitudes of dimming per airmass) vary as a result of changes in the atmosphere and differences in the spectra or colours of the stars.

The Balmer jump in the spectra of early-type stars is such an instance. There is a steep decline of flux density shortwards from 370 nm wavelength owing to hydrogen absorption where a black-body radiator of the same temperature would show a continuing rise. The Balmer jump in the spectrum produces a 'Balmer dip' in the colour dependence of the atmospheric extinction coefficient, because it reddens the starlight sampled by the U band. Therefore, as the atmosphere is more transparent to red light there is a decrease in the $U-B$ extinction for a restricted range of star types, and hence a dip in the broader correlation. The Balmer dip has a maximum effect of about -0.04 mag per airmass for a star of spectral type A0V, at a temperature near 9500 K and a $B-V$ near 0.05.

However, Johnson (1963) reasoned that a colour term in the $U-B$ extinction '… is not usually important, since the standard stars will be measured at about the same zenith distances as the other stars and the errors will largely cancel out. Small systematic deviations of the U system from that which would have been observed outside the atmosphere will, of course, be present.' Johnson's choice, while understandable at the time, resulted in a $U-B$ standard system that is neither entirely homogeneous nor extra-atmospheric. Thus observers at different altitudes and working airmasses, or reducing with recourse to different subsets of the standards, will be prevented from achieving complete systematic agreement of their $U-B$ data.

Thirty Years of Atmospheric Extinction from Telescopes of the North Atlantic Canary Archipelago

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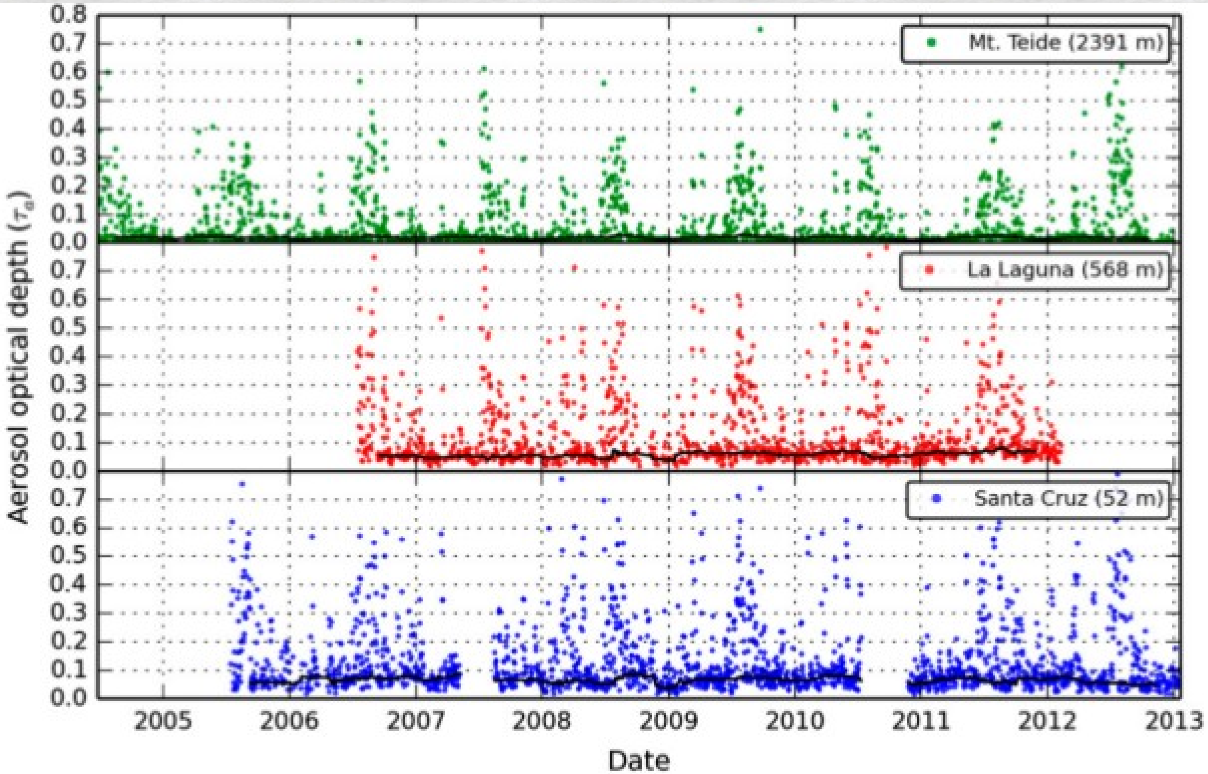

FIG. 10. Level 2.0 quality-assured AERONET daily summary data of a τ_a at 675 nm, from three monitoring sites on the island of Tenerife that are located closely in horizontal space but with large differences in altitudes: (a) Mt. Teide (2391 m), (b) La Laguna (568 m), and (c) Santa Cruz (52 m). Black lines show MCMC-calculated fits to the 50th percentile values, as described in section 3.

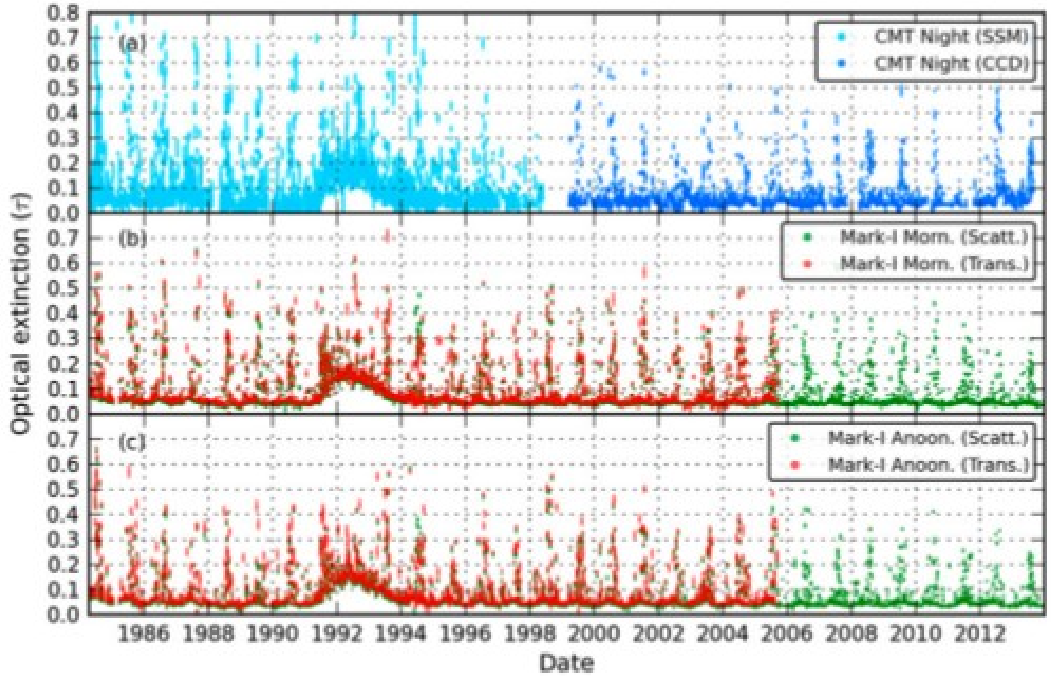

FIG. 5. The time series of τ calculated from individual telescope datasets are presented, distinguished by telescope, times, and method. (top) Nightly averaged data from the CMT recorded using an SSM (light blue) and then the CCD (dark blue) method. The CMT data intensity values have been adjusted to 769.9-nm equivalents. (middle) Mark-1 morning and (bottom) afternoon data from both scattering (green) and transmission (red). All data points are $m \times \mathrm{am}^{-1}$ with the error bars showing the RMSE (m).

https://www.ing.iac.es//astronomy/observing/conditions/#ext