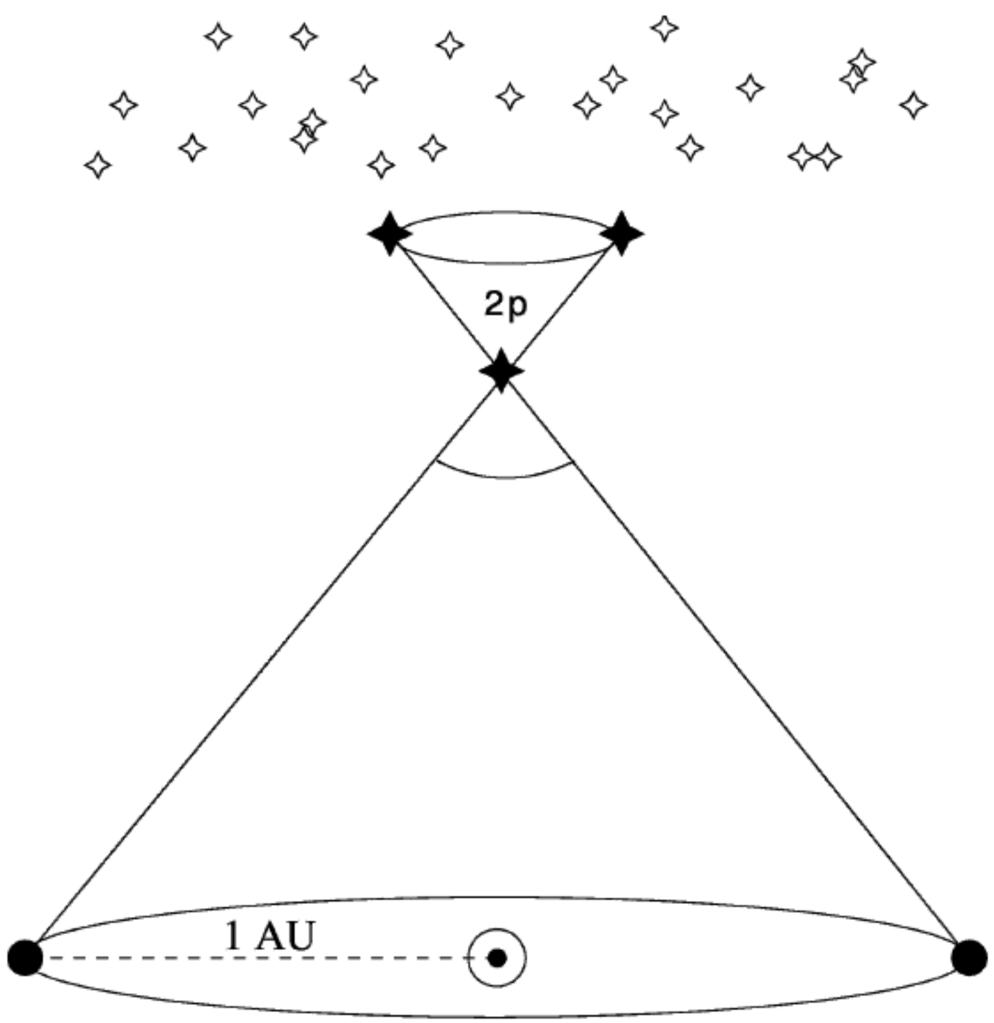
Mediciones astronómicas: distancias determinadas de velocidades

Clase 4

Paralajes trigonométricos



$$\frac{r}{D} = \tan p \approx p\,,$$

$$\boxed{1\ \mathrm{pc} = 206\,265\ \mathrm{AU} = 3.086 \times 10^{18}\ \mathrm{cm}}$$

parsec (pc) $\quad p = 1''.$

$$\boxed{D = \left(\frac{p}{1''}\right)^{-1} \mathrm{pc}}\,.$$

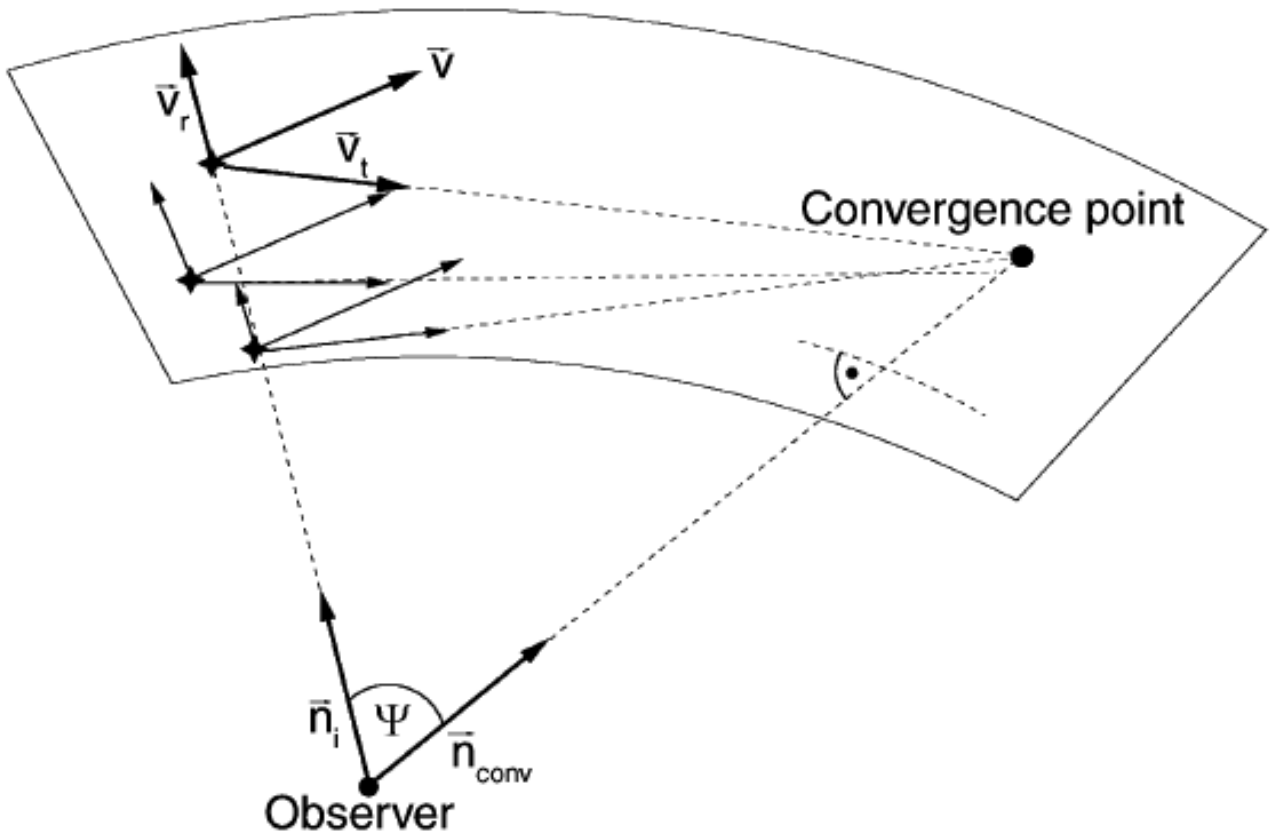
Movimientos propios

$$\boxed{v_{\mathrm{r}} = \frac{\Delta\lambda}{\lambda_0}\,c}\,, \qquad \text{radial component } v_{\mathrm{r}}$$

$$\boxed{v_{\mathrm{t}} = D\mu \quad \text{or} \quad \frac{v_{\mathrm{t}}}{\mathrm{km/s}} = 4.74\left(\frac{D}{1\,\mathrm{pc}}\right)\left(\frac{\mu}{1''/\mathrm{yr}}\right)}\,.$$

$$\frac{v_{\mathrm{t}}}{\mathrm{km/s}} = 4.74\left(\frac{\mu}{1''/\mathrm{yr}}\right)\left(\frac{p}{1''}\right)^{-1}\,.$$

Paralajes de cúmulos estelares en movimiento



Solo para cúmulos cercanos. Consideramos la misma velocidad espacial para todas las estrellas - $\boldsymbol{v}$.

La posición de la estrella *i* con el tiempo esta dada por:

$$\boldsymbol{r}_i(t) = \boldsymbol{r}_i + \boldsymbol{v}t$$

$\boldsymbol{r}_i$ **para** $t = 0$

$$\boldsymbol{n}_i(t) := \frac{\boldsymbol{r}_i(t)}{|\boldsymbol{r}_i(t)|} \ .$$

la dirección de la estrella, vector unitario

$$\boldsymbol{n}_i(t) \to \frac{\boldsymbol{v}}{|\boldsymbol{v}|} =: \boldsymbol{n}_{\rm conv} \ . \qquad t \to \infty$$

$$\cos\psi = \boldsymbol{n} \cdot \boldsymbol{v}/|\boldsymbol{v}| = \boldsymbol{n}_{\rm conv} \cdot \boldsymbol{n}.$$

$$v \equiv |\boldsymbol{v}| \qquad v_{\rm r} = v\cos\psi \ , \qquad v_{\rm t} = v\sin\psi \qquad v_{\rm t} = v_{\rm r}\tan\psi \ .$$

$$\mu = \frac{v_{\rm t}}{D} = \frac{v_{\rm r}\tan\psi}{D} \quad \to \quad D = \frac{v_{\rm r}\tan\psi}{\mu} \ .$$

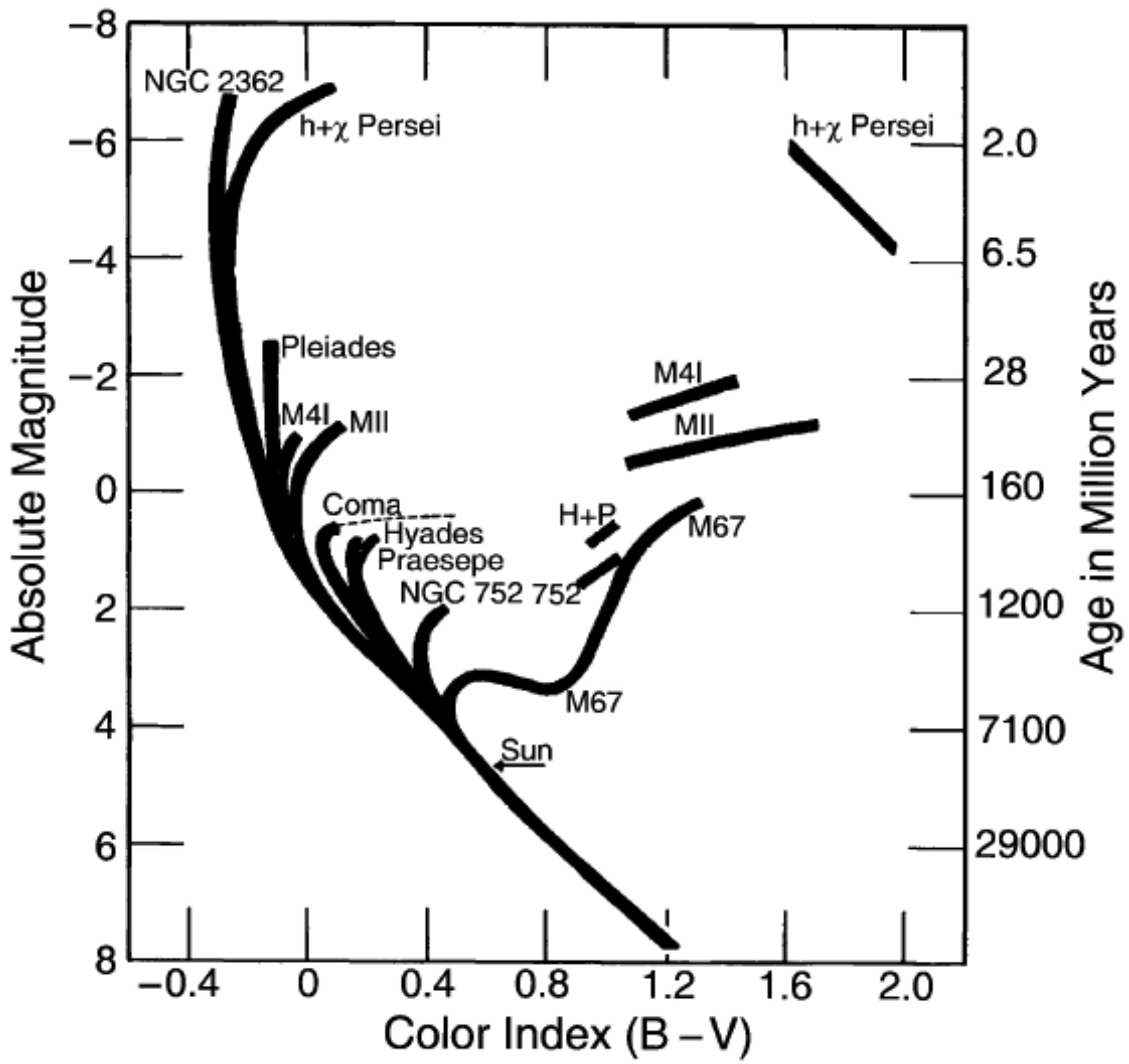
Paralajes de cúmulos estelares en movimiento (ejemplos)

Hyades, a cluster of about 200 stars	$D \approx 45$ pc
Ursa-Major group of about 60 stars	$D \approx 24$ pc
Pleiades with about 600 stars	$D \approx 130$ pc

$$\overline{D}_{\text{Hyades}} = 46.3 \pm 0.3 \text{ pc}$$

Distancia fotométrica; extinción y enrojecimiento

$$m - M = 5\log(D/\mathrm{pc}) - 5$$



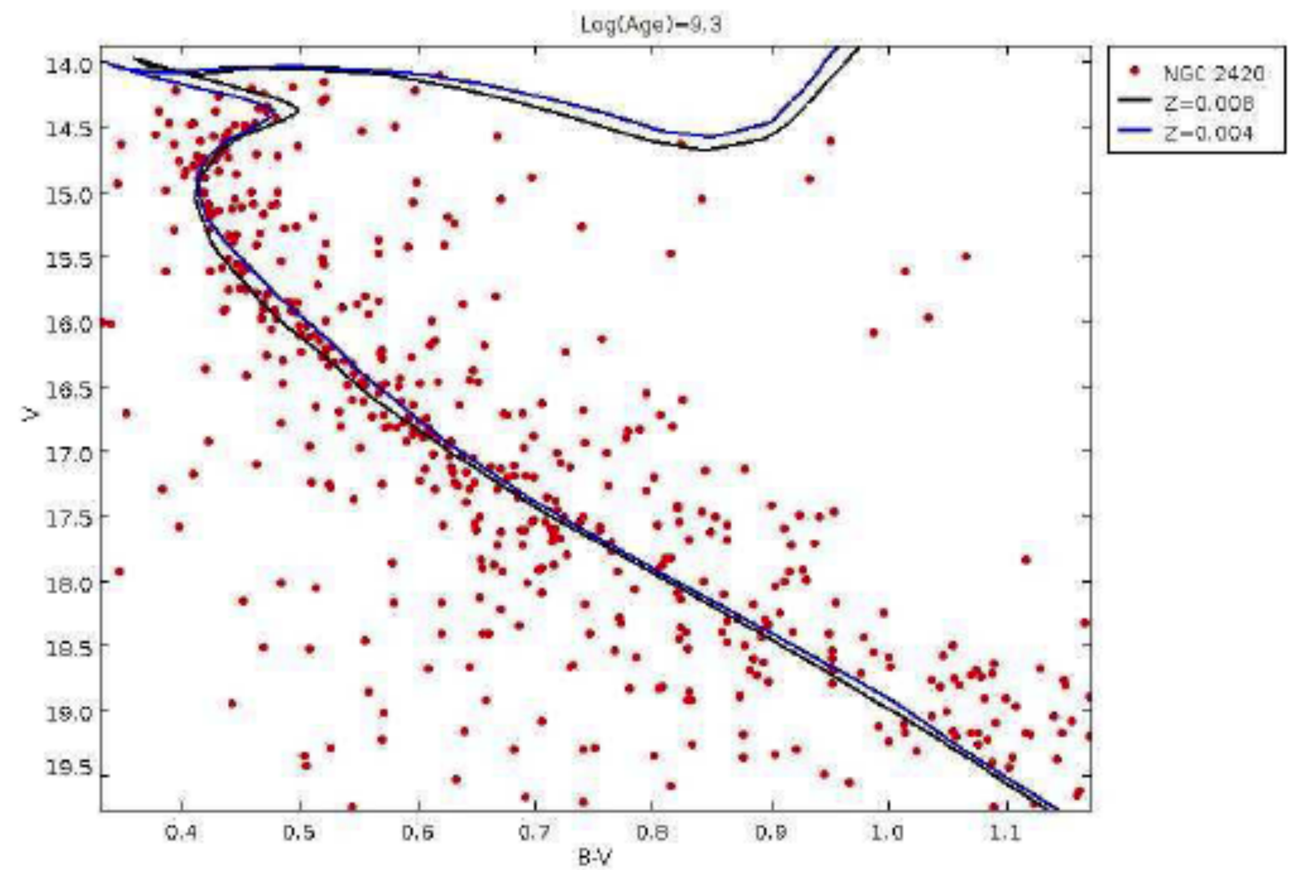


Fig. 9. Fitting of the two best isochrones on the CMD, log(*age*) = 9.3, Z=0.004 (black curve) and Z=0.008 (blue curve).

Distancia fotométrica; extinción y enrojecimiento

$$\boxed{\frac{\mathrm{d}I_\nu}{\mathrm{d}s} = -\kappa_\nu I_\nu}$$

$\mathrm{d}\ln I_\nu = \mathrm{d}I_\nu / I_\nu = -\kappa_\nu\, \mathrm{d}s$ integrating from 0 to s.

$$\ln I_\nu(s) - \ln I_\nu(0) = -\int_0^s \mathrm{d}s'\, \kappa_\nu(s') \equiv -\tau_\nu(s)$$ *optical depth*, τ_ν

$$\boxed{I_\nu(s) = I_\nu(0)\, \mathrm{e}^{-\tau_\nu(s)}}$$

Accordingly, for the flux we obtain

$$\boxed{S_\nu = S_\nu(0)\, \mathrm{e}^{-\tau_\nu(s)}},$$

Distancia fotométrica; extinción y enrojecimiento

$m = -2.5 \log S + \text{const}$

$S \propto 10^{-0.4m}$, one has

$$\frac{S_\nu}{S_{\nu,0}} = 10^{-0.4(m-m_0)} = \mathrm{e}^{-\tau_\nu} = 10^{-\log(\mathrm{e})\tau_\nu}$$

$$\begin{aligned} A_\nu &:= m - m_0 = -2.5 \log(S_\nu / S_{\nu,0}) \\ &= 2.5 \log(\mathrm{e})\, \tau_\nu = 1.086 \tau_\nu\ . \end{aligned}$$

A_ν is the *extinction coefficient*

out absorption, m_0. Since the absorption coefficient κ_ν depends on frequency, absorption is always linked to a change in color. This is described by the *color excess* which is defined as follows:

$$\begin{aligned} E(X-Y) &:= A_X - A_Y = (X - X_0) - (Y - Y_0) \\ &= (X - Y) - (X - Y)_0\ . \end{aligned}$$

curves. The ratio $A_X/A_Y = \tau_{\nu(X)}/\tau_{\nu(Y)}$ depends only on the optical properties of the dust or, more specifically, on the ratio of the absorption coefficients in the two frequency bands X and Y considered here. Thus, the color excess is proportional to the extinction coefficient,

$$\boxed{\begin{aligned} E(X-Y) &= A_X - A_Y = A_X\left(1 - \frac{A_Y}{A_X}\right) \\ &\equiv A_X\, R_X^{-1} \end{aligned}}$$

$$A_V = R_V\, E(B-V)$$

$$\boxed{A_V = (3.1 \pm 0.1)E(B-V)}$$

This relation is not a universal law, but the factor of proportionality depends on the properties of the dust. They

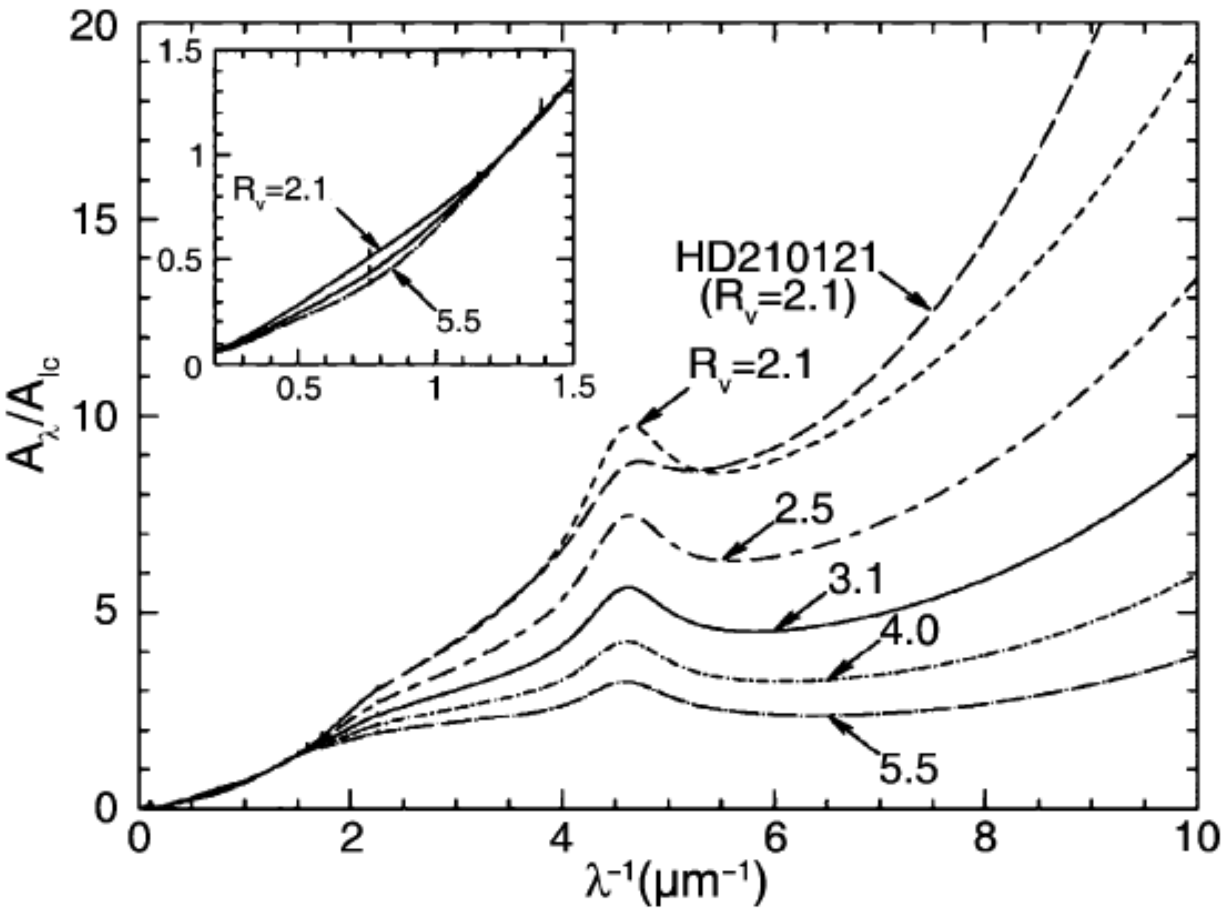


Fig. 2.6. Wavelength dependence of the extinction coefficient A_ν, normalized to the extinction coefficient A_I at $\lambda = 9000$ Å. Different kinds of clouds, characterized by the value of R_V, i.e., by the reddening law, are shown. On the x-axis we have plotted the inverse wavelength, so that the frequency increases to the right. The solid line specifies the mean Galactic extinction curve. The extinction coefficient, as determined from the observation of an individual star, is also shown; clearly the observed law deviates from the model in some details. The figure insert shows a detailed plot at relatively large wavelengths in the NIR range of the spectrum; at these wavelengths the extinction depends only weakly on the value of R_V

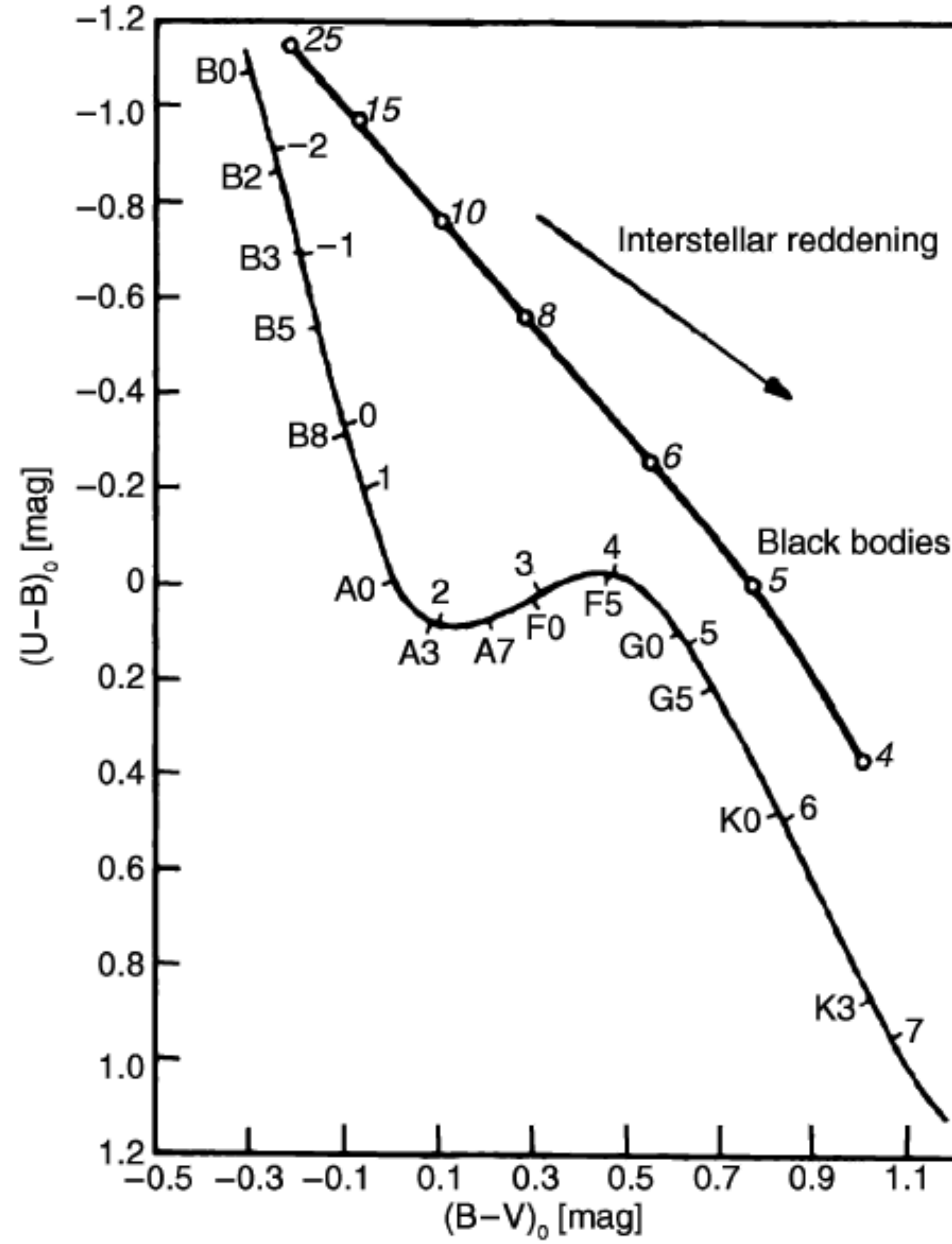
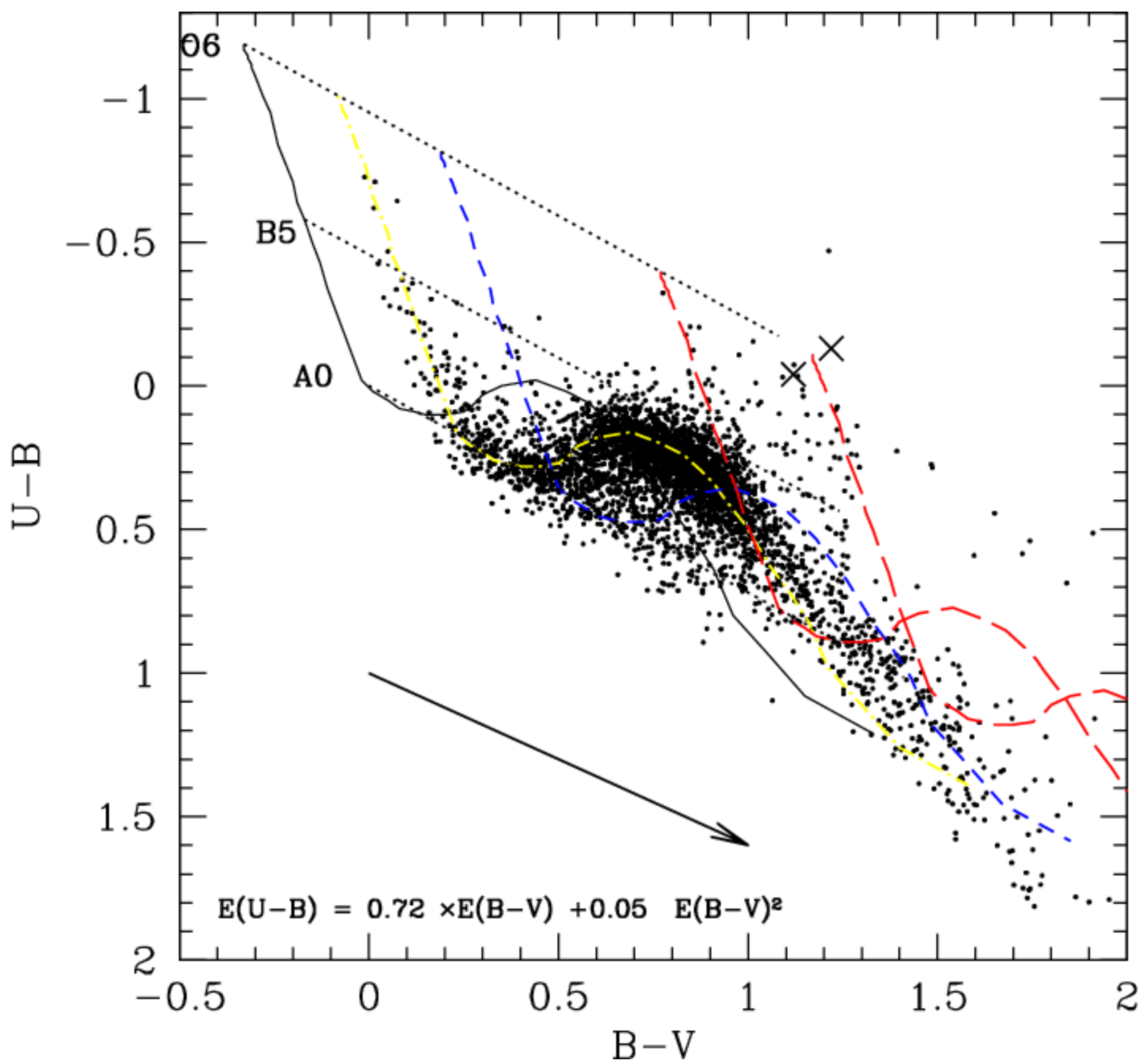


Fig. 2.8. Color–color diagram for main-sequence stars. Spectral types and absolute magnitudes are specified. Black bodies ($T/10^3$ K) would be located along the upper line. Interstellar reddening shifts the measured stellar locations parallel to the reddening vector indicated by the arrow



O6
B5
A0
E(U−B) = 0.72 ×E(B−V) +0.05 E(B−V)²
U−B
B−V

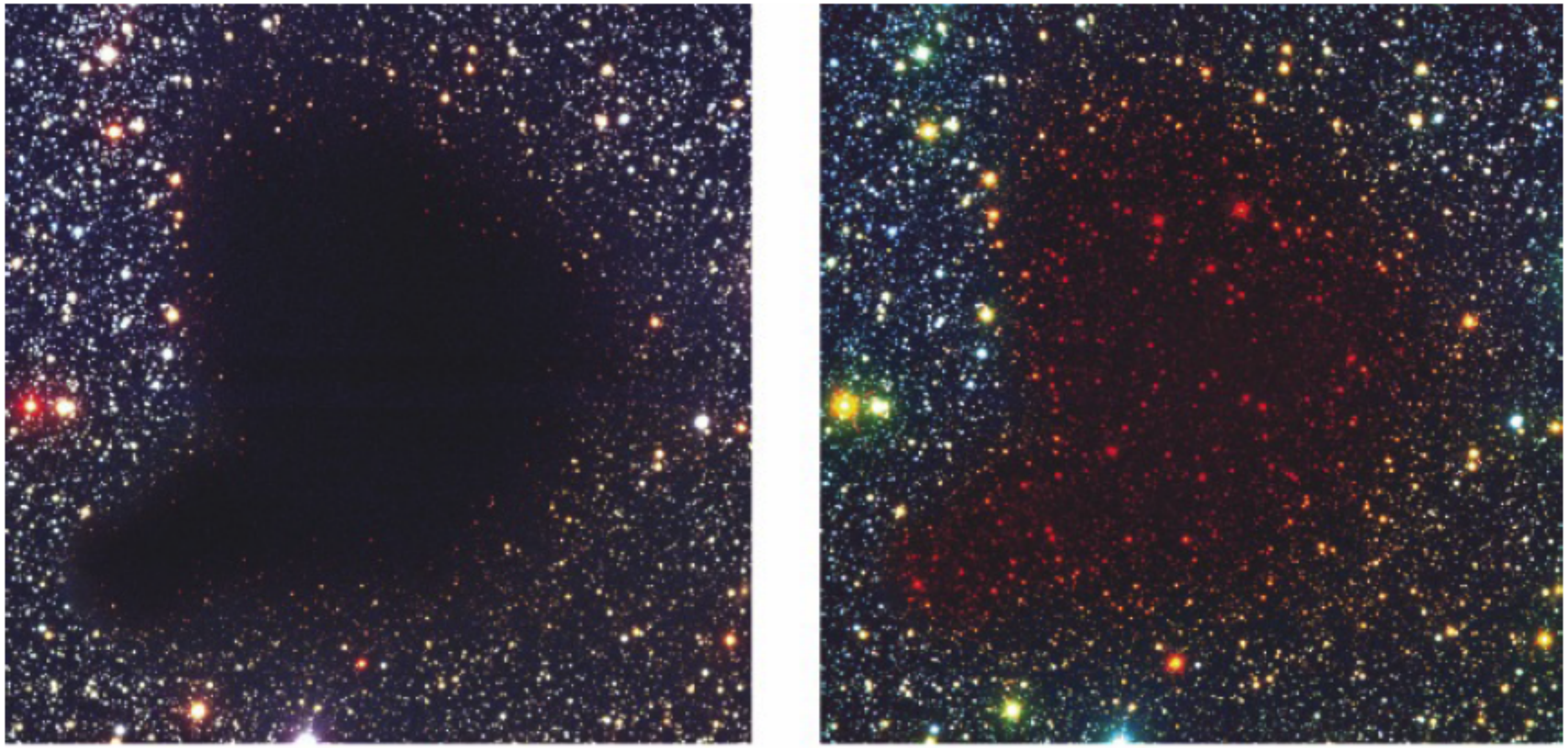


Fig. 2.7. These images of the molecular cloud Barnard 68 show the effects of extinction and reddening: the left image is a composite of exposures in the filters B, V, and I. At the center of the cloud essentially all the light from the background stars is absorbed. Near the edge it is dimmed and visibly shifted to the red. In the right-hand image observations in the filters B, I, and K have been combined (red is assigned here to the near-infrared K-band filter); we can clearly see that the cloud is more transparent at longer wavelengths

In the Solar neighborhood the extinction coefficient for sources in the disk is about

$$A_V \approx 1\mathrm{mag}\,\frac{D}{1\,\mathrm{kpc}}\,, \tag{2.22}$$