as the contrast-related efficiency gain of that instrument[5]). The evaluation of C is conducted with the help of Berek's theory of vision (section 9.1.2). To evaluate C', the same model is now applied to the virtual image of the object, which yields[6]):

$$\sqrt{\frac{T}{\mu}C'} = \frac{1}{\sigma m'}\sqrt{\frac{\phi(\mu L_{\mathrm{a}})}{\mu L_{\mathrm{a}}}} + \sqrt{\frac{b(\mu L_{\mathrm{a}})}{\mu L_{\mathrm{a}}}} \,. \quad (10.14)$$

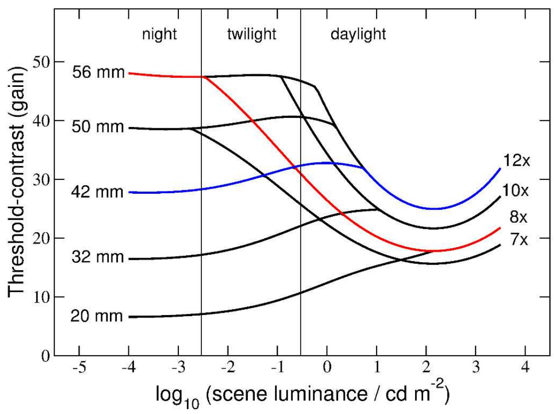
Once again, σ stands for the objective angle of the target (in arcmin), and L_{a} for the adaptive luminance of the unaided eye. We assume that the eye is well adapted to the scene luminance, and that the binocular modifies that luminance by the factor μ, its total light transmission. Berek writes $\mu = T + \nu$, a composition of useful transmission T (the *signal*) and unwanted stray light ν (the *noise*). Instead of the magnification m, the effective magnification $m' = md'/d_{\mathrm{e}}$ is employed, scaled with the ratio of the effective exit pupil diameter d' as introduced in section 10.2, and the eye pupil diameter. Note that $m' = m$ whenever $d' = d_{\mathrm{e}}$, i.e. whenever the eye pupil diameter is smaller than the exit pupil. Berek's empirically derived functions for the characteristic luminous flux $\phi(L)$ and the characteristic luminance $b(L)$ have been discussed in section 9.1.2. Since the object is now observed through the instrument, they are functions of the adaptive luminance L_{a}, multiplied with the light transmission μ of that instrument. The implicit assumption is that the observer's eye is adapting to the modified flux that is entering through the eyepiece.

We assume that the target is sufficiently small so that the adaptive luminance coincides with the background luminance L_{b}, and after combining equations (10.13), (9.5) and (10.14), we obtain the contrast-related efficiency, defined as a gain in threshold-contrast:

$$E_{\mathrm{c}} = T\left(\frac{\frac{1}{\sigma}\sqrt{\phi(L_{\mathrm{b}})} + \sqrt{b(L_{\mathrm{b}})}}{\frac{1}{\sigma m'}\sqrt{\phi(\mu L_{\mathrm{b}})} + \sqrt{b(\mu L_{\mathrm{b}})}}\right)^2 \,. \quad (10.15)$$

To compute the effective magnification m', the eye pupil diameter is required, which we take from equation (8.1), assuming a young observer of age 30. The apparent angle of the (circular) target amounts to $\sigma = 1$ arc minute, just barely resolvable to the unaided eye in bright daylight.

Figure 10.7 displays the results for different binoculars with magnifications between 7x and 12x, and objective diameters from 20mm to 56mm. The vertical lines are separating the scene luminance regimes as defined by Köhler et al. (section 10.2): daylight ($L_{\mathrm{b}} > 0.3\mathrm{cd/m^2}$), night ($L_{\mathrm{b}} < 0.003\mathrm{cd/m^2}$), and



10.7

Threshold-contrast gain for a young observer, when sighting a target of 1arcmin **apparent angle. The scene luminance varies between almost complete darkness (left) and bright daylight (right). The 8x56 binocular (red) is scoring higher than the 12x42 (blue) under twilight conditions.**

[5]) Since with the aid of an instrument, the threshold-contrast for object sighting is dropping, we have defined $E_{\mathrm{c}} = C/C'$ rather than $E_{\mathrm{c}} = C'/C$, so that a high numerical value implies high efficiency.

[6]) M. Berek, *Die Nutzleistung binokularer Erdfernrohre*, Z. Phys. **A 125**, S. 657 (1949)