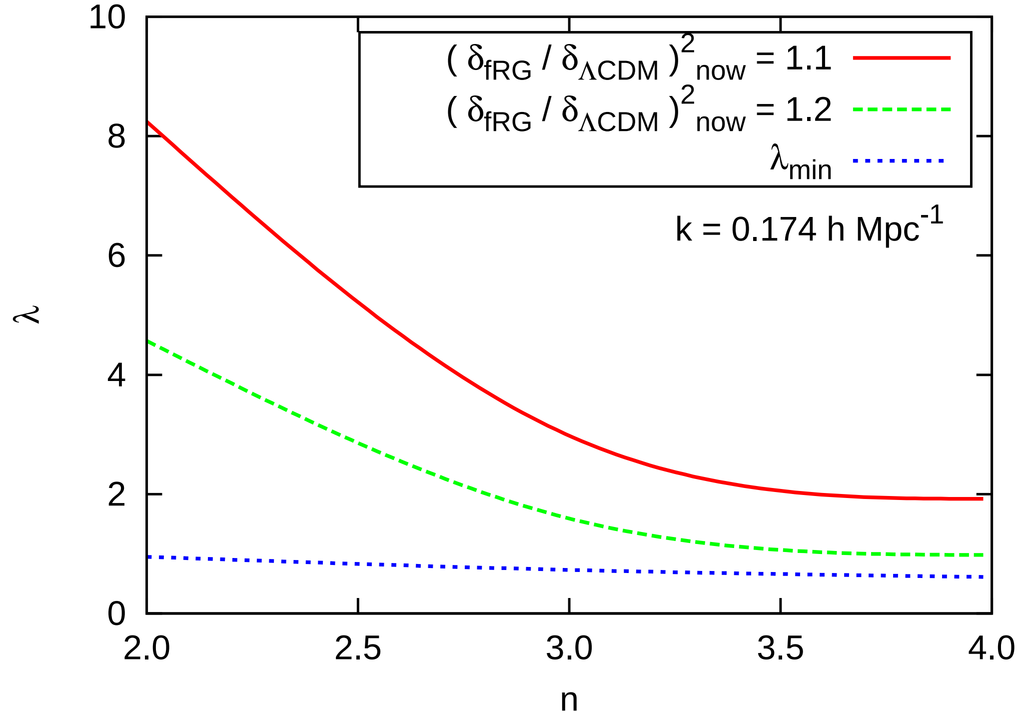

FIG. 5: Constraints for parameter space.

the ΛCDM model in the Einstein gravity.

Figures 6 show evolution of $\gamma(z)$ together with that of $G_{\rm eff}/G$ for different values of k. In the early high-redshift regime, $\gamma(z)$ takes a constant value identical to the ΛCDM model because $f(R)$ gravity is indistinguishable from the Einstein gravity plus a positive cosmological constant then. It gradually decreases in time, reaches a minimum, and then increase again towards the present epoch. We can understand this tendency from the evolution equation for $\gamma(z)$[36],

$$\begin{aligned} &-(1+z)\ln(1-\Omega_{\rm DE})\frac{d\gamma}{dz} \\ &\quad = -(1-\Omega_{\rm DE})^{\gamma} - \frac{1}{2}\left[1+3(2\gamma-1)w_{\rm DE}\Omega_{\rm DE}\right] + \frac{3}{2}\frac{G_{\rm eff}}{G}(1-\Omega_{\rm DE})^{1-\gamma}, \end{aligned} \tag{31}$$

where $\Omega_{\rm DE} = 1 - \Omega_m$ is the density parameter of dark energy based on (8). In the high-redshift era when $\Omega_{\rm DE}$ is small, the above equation may be approximated as

$$\begin{aligned} &(1+z)\Omega_{\rm DE}\frac{d\gamma}{dz} \\ &= \frac{3}{2}\left(\frac{G_{\rm eff}}{G}-1\right) + \Omega_{\rm DE}\left[\frac{11}{2}\left(\gamma-\frac{6}{11}\right) - \frac{3}{2}(1-\gamma)\left(\frac{G_{\rm eff}}{G}-1\right) - \frac{3}{2}(2\gamma-1)(w_{\rm DE}+1)\right]. \end{aligned} \tag{32}$$