For any complex number $|z| < 1$:

$$(1+z)^{-1} = \sum_{n=0}^{\infty} (-z)^n$$

In particular assuming $|g| < 1$ and $|\epsilon| < 1$, so that $|g^{\star}\epsilon| < 1$:

$$(1+g^{\star}\epsilon)^{-1} = \sum_{n=0}^{\infty} (-g^{\star}\epsilon)^n$$

So,

$$\begin{aligned}
\epsilon' &= \frac{\epsilon+g}{1+g^{\star}\epsilon} \\
&= (\epsilon+g)(1+g^{\star}\epsilon)^{-1} = (\epsilon+g)\sum_{n=0}^{\infty}(-g^{\star}\epsilon)^n \\
&= \epsilon+g+\sum_{n=1}^{\infty}\left[(-g^{\star})^n\epsilon^{n+1} + g(-g^{\star})^n\epsilon^n\right]
\end{aligned}$$

Taking expectation from both sides,

$$\langle\epsilon'\rangle = g + \langle\epsilon\rangle + \sum_{n=1}^{\infty}\left[(-g^{\star})^n\langle\epsilon^{n+1}\rangle + g(-g^{\star})^n\langle\epsilon^n\rangle\right]$$

So, in general, $\langle\epsilon'\rangle = g$ **exactly** if $\langle\epsilon^n\rangle = 0$ for all $n \geq 1$.

But this is, in fact, the case. Note that any particular ellipticity can be written in terms of its magnitude and angle in the complex plane:

$$\epsilon = \epsilon_0 e^{i\theta},\ 0 \leq \theta \leq 2\pi$$

Assume the that distribution of intrinsic ellipticities $f(\epsilon_0, \theta)$ is uniform in the angle, this means that $f(\epsilon_0, \theta) = f(\epsilon_0)$ (only depends on the radius). Then, the expectation $\langle\epsilon^n\rangle$ over this distribution f becomes,

$$
\begin{aligned}
\langle \epsilon^n \rangle &= \frac{1}{2\pi}\int_0^1\int_0^{2\pi}\epsilon^n f(\epsilon_0,\theta)d\theta d\epsilon_0 = \frac{1}{2\pi}\int_0^1 \epsilon_0^n f(\epsilon_0)d\epsilon_0\int_0^{2\pi} e^{in\theta}d\theta \\
&= \frac{1}{2\pi}\int_0^1 \epsilon_0^n f(\epsilon_0)\left(\left.\frac{e^{in\theta}}{in}\right|_0^{2\pi}\right)d\epsilon_0 \\
&= \frac{1}{2\pi in}\int_0^1 \epsilon_0^n f(\epsilon_0)\left(e^{i2\pi n}-1\right)d\epsilon_0 = 0, \quad \text{for } n = 1,2,3...
\end{aligned}
$$