With cylindrical tube length l and diameter d, if the eye is centered at one end of the tube, the half-angle of the field of view is $\tan(\theta) = d/2l$. The fraction of (sky viewed)/(whole sky) is $\frac{1}{2} - \frac{\cos(\theta)}{2}$. For the toilet paper in our house, $l = 11.5$ cm, and $d = 4.0$ cm, yeilding $\theta = 9.87$ degrees, and a fraction of the sky covered of 0.0074. The *correction factor* to translate your star counts to the whole sky is the inverse of this fraction, or 135. You will want to confirm that the tube you are using is the same size as mine before you just blindly multiply by 135 to get the answer.

That was the result. Here are the intermediate steps. The definition of solid angle is

$$d\Omega = \sin\theta \mathrm{d}\theta \mathrm{d}\phi$$

where ϕ is the azimuthal angle (zero to 2π) and θ is the altitude angle starting at zero at the "north pole" (0 to π). Over the whole sky,

$$\Omega = \int_0^{\pi} \int_0^{2\pi} \sin\theta d\theta d\phi$$

$$\Omega = 2\pi \int_0^{\pi} \sin\theta d\theta$$

$$\Omega = 2\pi[-\cos\theta]_0^{\pi}$$

$$\Omega = 2\pi[- - 1 - -1]$$

$$\Omega = 4\pi$$

For the partial-sky case, we integrate from zero to θ, to get

$$\Omega_\theta = 2\pi \int_0^{\theta} \sin\theta d\theta$$

$$\Omega_\theta = [-\cos\theta]_0^{\theta}$$

$$\Omega_\theta = 2\pi[-\cos\theta - -1]$$

$$\Omega_\theta = 2\pi[1 - \cos\theta]$$

And the ratio, or fraction of sky covered, is

$$\frac{\Omega_\theta}{\Omega} = \frac{1}{2} - \frac{\cos(\theta)}{2}$$