The Dewing or Frosting of Telescope Optics

Clif Ashcraft

Something which I am sure you have encountered using your telescope is just when you are having the most fun or are about to make the most critical observation or photograph, the telescope lens or mirror fogs over from dew or frost. Why is that, and why does it seem to happen at just the worst time?

We can understand this annoying phenomenon with the help of the tutorial on this website by Mike Luciuk, "Temperature and Radiation". In this tutorial, Mike teaches us how radiation is exchanged between objects and how this results in heating or cooling, all as a consequence of the famous Stefan-Boltzmann Law.

For simplicity, let us assume that your telescope is a refractor, and that it is pointed straight up at a cloudless night sky, and that the telescope and the Earth it is standing on is at a pleasant 298K (25°C or 77°F). From the perspective of the objective lens of the telescope, the sky overhead is a complete hemisphere or 2 π steradians of solid angle, and the Earth (including the rest of the telescope) is also 2 π steradians. What is the temperature of the sky? Well, if there are no clouds or not much dirt or smog in the air, the sky is at the temperature of the cosmic microwave background (CMB) relic of the big bang, 2.7K. Cool night, isn't it?

Let's rewrite Mike's equation (3) for the lens, that big black hole up above, and the Earth below:

$$\Omega_{lens} T_{lens}^4 = \Omega_{cmb} T_{cmb}^4 + \Omega_{earth} T_{earth}^4 \tag{1}$$

Plugging in values of 4 π for the angle to which the lens radiates, 2 π for the sky above and the Earth below, and temperatures of 2.7K and 298K for the sky and the Earth, then the equation becomes:

$$4\pi T_{lens}^4 = 2\pi 2.7^4 + 2\pi 298^4 \tag{2}$$

Solving for the lens temperature, we get a value of 251K which is the same as -22°C or -8°F. If the dew point were anything above -22°C, dew or frost would form on the lens. The dew point is often above that temperature, so we often get dew on the lens.

As to why it happens at the worst possible time? It turns out that, when the atmosphere is calm and turbulence is low (great times for observing), there is less air circulation to keep the lens warm by convection. Also, the dew point tends to be higher under those conditions. So, we find yet another corollary of Murphy’s law: “When the conditions are the best for observing, you are most likely to have your objective fog up.” Frustrating, isn’t it?

So, how do we deal with this annoying situation? By putting on a dew cap of course. I am not talking about a fancy thing with resistance heaters built in. Instead, just a short tube on the front of the telescope extending out enough to block off a significant part of the sky from the point of view of the lens will do the job. Let’s say we are using a 4-inch refractor, and we have an 8-inch long dew cap slipped over the cell of the objective and the dew cap has a 5-inch diameter opening in the front. OK, how much sky can the objective see? Well, it varies a bit, depending upon which part of the objective we are talking about, but, from the center of the objective, we see a circle 5 inches in diameter at a distance of 8 inches. From Mike’s equation (2), this works out to be:

$$\Omega = \frac{area}{distance^2} = \frac{\pi 2.5^2}{8^2} = 0.31 \text{steradians} \tag{3}$$

So, instead of being exposed to 2π steradians of CMB, the lens is only exposed to 0.31 steradians (it is actually a bit less because from all points on the lens other than the center, the hole appears to be an ellipse of a slightly smaller area, but let's not worry about that), and, if the dew cap is the same temperature as the rest of the telescope and the Earth, the lens is exposed to a correspondingly greater solid angle of stuff at a temperature of 298K equal to 4π-0.31 steradians.

$$4\pi T_{lens}^4 = (0.31)2.7^4 + (4\pi - 0.31)298^4 \qquad \textbf{(4)}$$

Now, when we solve for the lens temperature, we get a temperature of 296K (23°C or 74°F), and it would take a pretty humid night to get condensation on the lens.

So, the dew cap works. Our little calculation also explains why the guy with the Dobsonian telescope at the star party is having no troubles with dew, while the guy with the Schmidt Cassegrain Telescope (SCT) right next to him is swearing a blue streak. The Dob is probably a Newtonian reflector, most likely with a solid tube made of spiral wound cardboard with the mirror way down at the bottom of the tube looking up at a tiny patch of sky through the end of the tube. Everything else it "sees" is nice and cozy warm. So, the mirror stays above the dew point, and it does not fog. Meanwhile, the guy with the SCT has a thin, low thermal mass, corrector plate just hanging out there "seeing" a whole 2π steradians of black sky. It quickly fogs up as soon as it cools below the dew point. Clearly he needs one of those Velcro wrap-arounds to extend his tube a foot or so beyond the corrector plate.

One complication with dew caps is that they can cool off as well. After all, the dew cap is also exposed to the whole sky at CMB temperatures. Let's say that over the course of the night, the dew cap itself gets down to the temperature we calculated for the lens without the dew cap of 251K. Adding another term ("others" in Mikes equation 3) for the dew cap itself:

$$4\pi T_{lens}^4 = (0.31)2.7^4 + (2\pi)298^4 + (2\pi - 0.31)251^4 \qquad \textbf{(5)}$$

This gives us a lens temperature of 276K (3.3°C or 38°F). This could easily be below the dew point on many nights. So, we find that dew eventually forms on our objective anyway and we feel like buying one of those fancy dew caps with the resistance heaters. But, before spending the money, realize that all you need to do is wrap a warm towel around the poor thing and warm it up a bit and let Stefan-Boltzmann do the rest…

See related tutorial on this website titled, "Temperature and Radiation".