SCT Ventillation and Cooling Study

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ABSTRACT

This is a study of cooling in an 11” carbon fiber Celestron SCT (Schmidt Cassegrain Telescope) after installing ventilation fans and five thermocouples to monitor three surface and two local air temperatures. I describe how I performed the modifications with simple hand power tools and provide detailed plots showing the cooling behavior of the internal OTA (Optical Tube Assembly) components through the night, including the effect of passing clouds and haze.

MOTIVATION

I live in the Hudson Valley region of southern NY and although the seeing is adequate for deep sky imaging with stars in the low 2” fwhm or better, I rarely have seeing that allows good planetary imaging. There are many opinions on the importance of cooling in telescope optics and the role of “tube seeing” in limiting resolution, but much of the discussion is hand wavy and lacks in-situ measurements under real conditions.

I decided to cut ventilation holes and install thermocouples within my C11 OTA mostly to make my own measurements of internal temperatures, with only a small hope that the changes would actually improve my planetary imaging. I was fairly convinced that the planetary video I captured was consistent with fast upper level atmospheric effects rather than tube currents or a hot mirror, but I went ahead with the modifications.

C11 MODIFICATIONS

There are many web sites describing modifications of SCT's to include ventilation fans, flocking, etc. My approach is slightly different because I have minimal power tools and only used hand power tools rather than a drill press for cutting the holes in the mirror cell of the C11. All of these modifications could easily destroy the OTA or cause injury so anyone considering something like this should be prepared for an optical or medical disaster – or both. Use this info at your own risk. In my case everything went fine.

Here are the changes I made:

1. Install two 2” fans blowing inward and mounted inside the OTA so they don't stick out
2. Drill a single 2” exhaust hole
3. Install a dew strap inside the OTA just underneath the corrector
4. Install a total of five ds1820 one-wire thermocouples within the OTA
5. Setup an IR thermometer to read the sky and ambient temperatures to keep track of passing clouds and haze, to see their impact on cooling dynamics
6. Program a PIC microcontroller to read the ds1820's and IR thermometer

Four of the thermocouples are permanent inside the OTA, but the one on the corrector was simply taped temporarily onto the front glass of the corrector. Many people would never consider doing such a thing, but I view it as no big deal and the tiny spot on the corrector cleaned up fine with no obvious damage to the coatings.

Figure 1 is a schematic of the final layout, including the placement of the thermocouples.

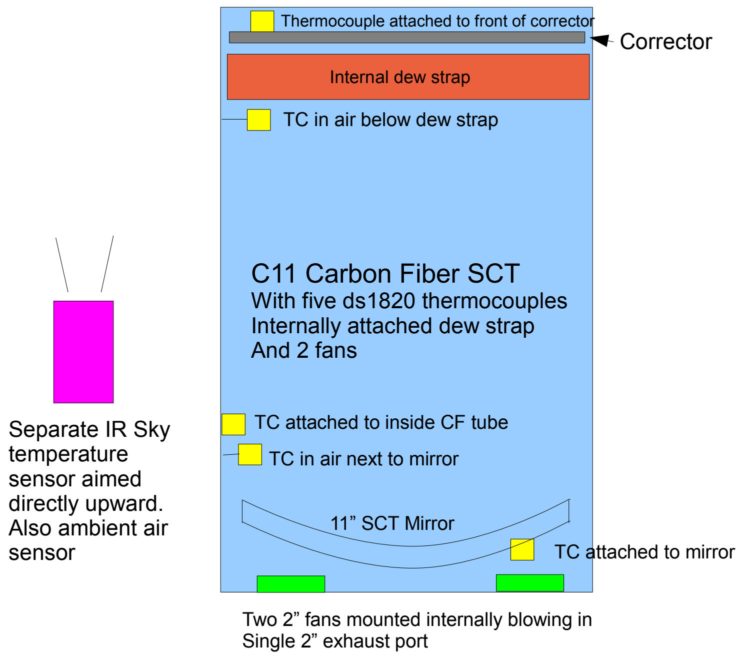

Figure 1. Schematic of the modified C11 OTA aimed upwards at the sky.

The thermocouples (TC's) attached to the mirror and OTA wall were thermally connected with conductive grease and a layer of tape to hold them in place. The TC's for measuring local air temperature were held away from the OTA wall and suspended using the signal wires themselves. The TC near the dew strap was thermally connected to a small heat sink intended to keep it coupled to the local air temperature.

Many people have commented on the importance of filtering air flowing into the OTA, but they also note that even a thin filter greatly restricts air flow. For this study I wanted maximum air flow and I am not concerned about having to open the OTA and clean it occasionally. My main concern is bugs, particularly spiders, getting inside – but since this is currently winter I don't yet have filters of any kind installed and all ports are fully open. At some point I intend to cover it with very thin screen mainly intended to keep bugs out.

DISMANTLING AND CUTTING THE HOLES

It was straightforward to dismantle the OTA and remove the mirror cell. The main challenge is the gentle removal of the corrector. There are many web pages describing ways to do this, but one thing that made it easier for me was that I did not need to remove the front assembly holding the corrector in order to remove the mirror. For my carbon fiber C11, and perhaps all Celestron OTA's, there is a cut-out in the corrector holding ring that is just large enough for the mirror to pass through it when properly oriented sideways with the baffle tube attached. This means you don't need to undo all the screws holding the corrector ring in place. You do need to undo the screws on the mirror cell, however, to separate the cell from the tube.

I placed the three holes in the mirror cell to avoid the structural ribbing, and to avoid the focuser and attached robofocus unit. I drilled the holes with a hand-held drill and 2” hole cutting bit. This took care and was a burden on the drill, but it cut the holes fairly cleanly. Figure 2 shows the result after drilling the holes and attaching the fans. The fan assemblies are not very rigid, so it's important to attach them without warping them, which would prevent their smooth rotation.

Figure 2. View of the mirror cell with two fans installed and single 2” exhaust port.

I then attached the dew strap internally, along with the thermocouples. I just used electrical tape for most of this attachment since it is black and seems to hold pretty well. It may need maintenance over time but I will see how it goes. Many people would flock the inside of the tube at this point, but I'm not optimistic this helps much – and I wanted to get clean temperature measurements for this study.

I also attached the RoboFocus LM335 temperature sensor to the inside of the OTA at this point, so that RoboFocus had a more meaningful measure of OTA temperature.

Figure 3 shows the inside of the OTA with the installed dew strap and thermocouples. Figure 4 shows the rear of the OTA, along with the attached RoboFocus, and Figure 5 is a view of the final configuration at the start of temperature logging when the sun was setting.

Note that attaching the TC to the back of the mirror itself was made easier by direct access through the exhaust port. Prior to installing the mirror I left the TC free near the exhaust port so that once the OTA was assembled I could reach in and attach the TC with thermal grease and a small piece of tape – which I expect will have no impact on the surface figure of the mirror.

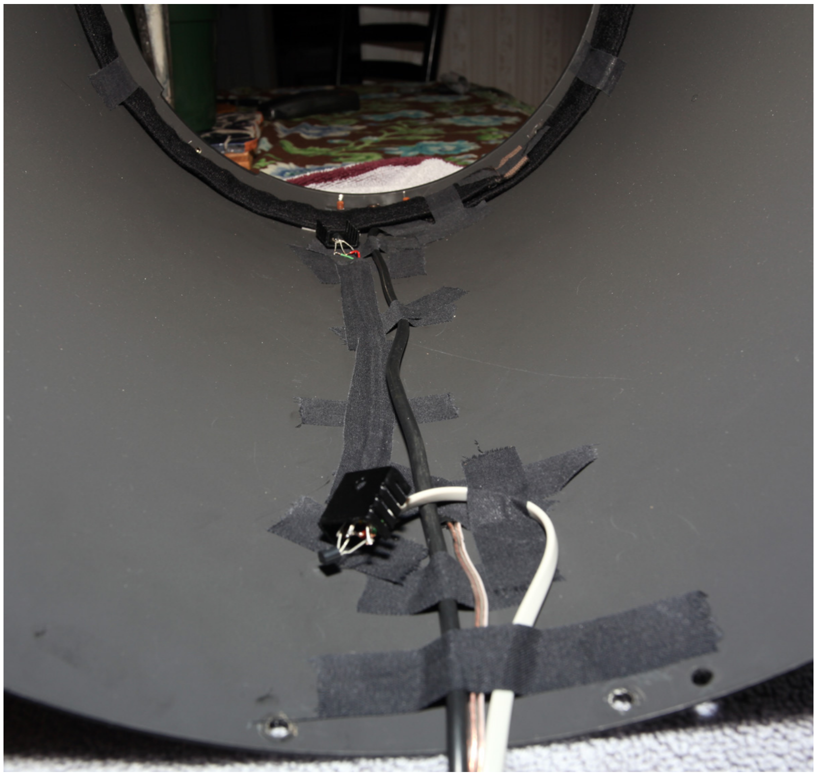

Figure 3. Internal view of carbon fiber tube showing the internal dew strap in the front and multiple temperature sensors with attached heat sinks for better thermal connection to the local air. Unfortunately the one near the mirror, closest to the camera, had to have the heat sink removed to allow insertion of the mirror. There is very little gap between the mirror edge and the tube.

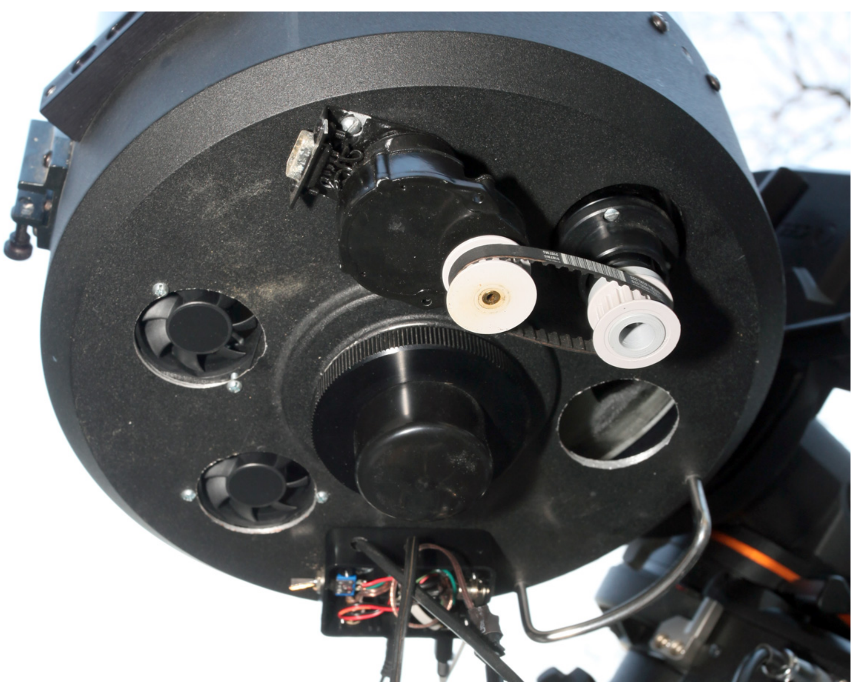

Figure 4. Rear view of the assembled OTA, with exposed fans and exhaust port. Note that the mirror can be seen through the exhaust port.

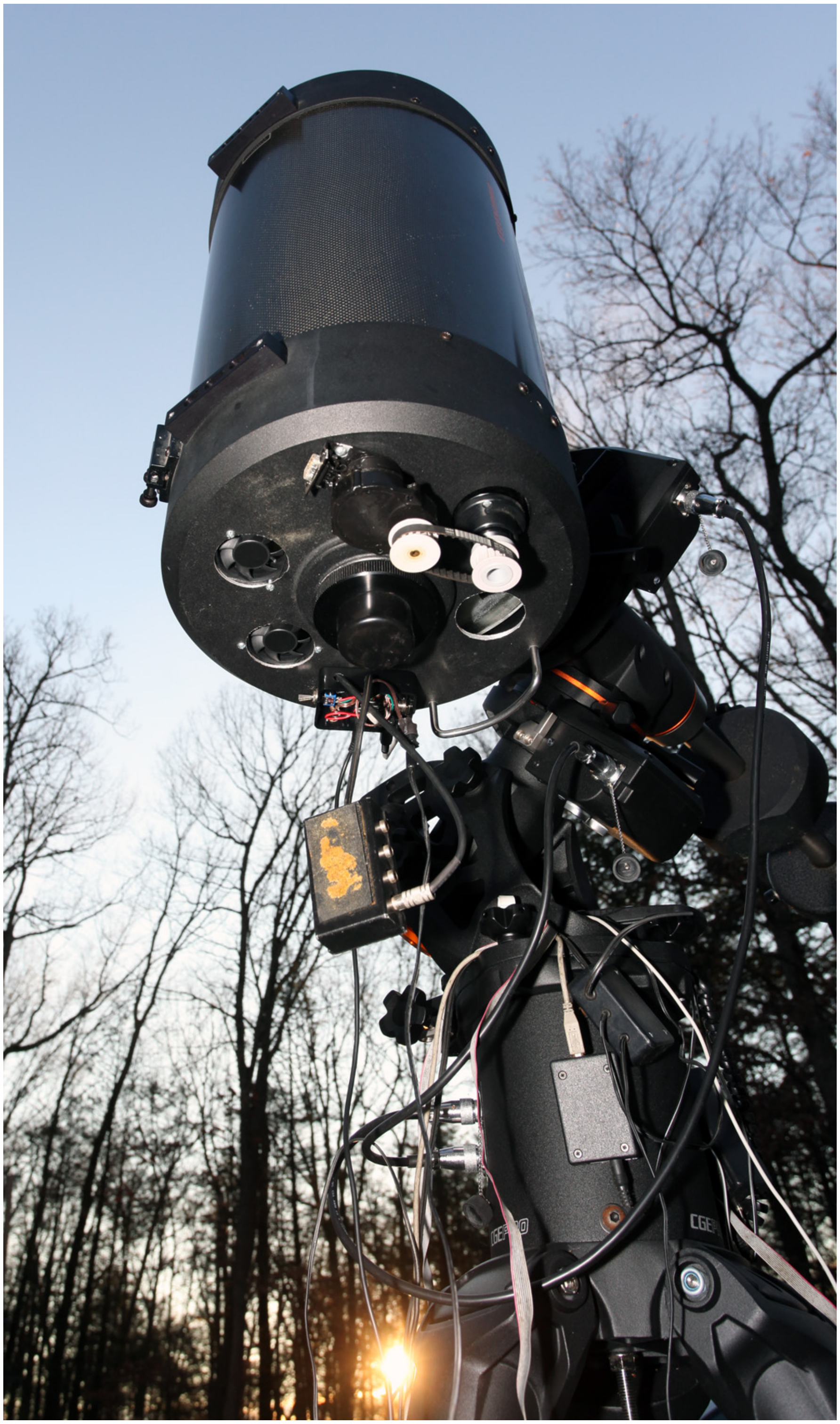

Figure 5. View of the zenith-pointed telescope at the start of temperature logging at sunset. The OTA had been fully equilibrated indoors at about 65 F before being brought outside.

TEMPERATURE MEASUREMENTS

I left the newly assembled OTA indoors so that it was thermally equilibrated at about 65F, and then quickly took it outside near sunset and placed it oriented vertically toward the zenith on a CGE-Pro equatorial mount that was left powered off so there was no tracking. The air temperature outdoors was approximately 37F at the time and the sky was perfectly clear with a temperature of -30F even with the sun up. I began logging all temperatures with the fans and heaters off for 3.6 hours to track the passive cooling of the components. During this period the sky became overcast for a time, as shown in Figure 6. Figure 7 shows the full 20 hour logging run, which goes long after sunrise the next day.

In all the plots the corrector (blue line) reads the lowest temperature except when the dew strap is turned on. When the dew strap is turned on, the air under the corrector becomes roughly five degrees warmer, while the corrector itself only goes up a few degrees to match ambient – as needed to keep it above dew point. This indicates a gentle warming of the corrector using a layer of warmer air just underneath it. The dew strap is a simple non-thermostated Kendrick unit operating at low power.

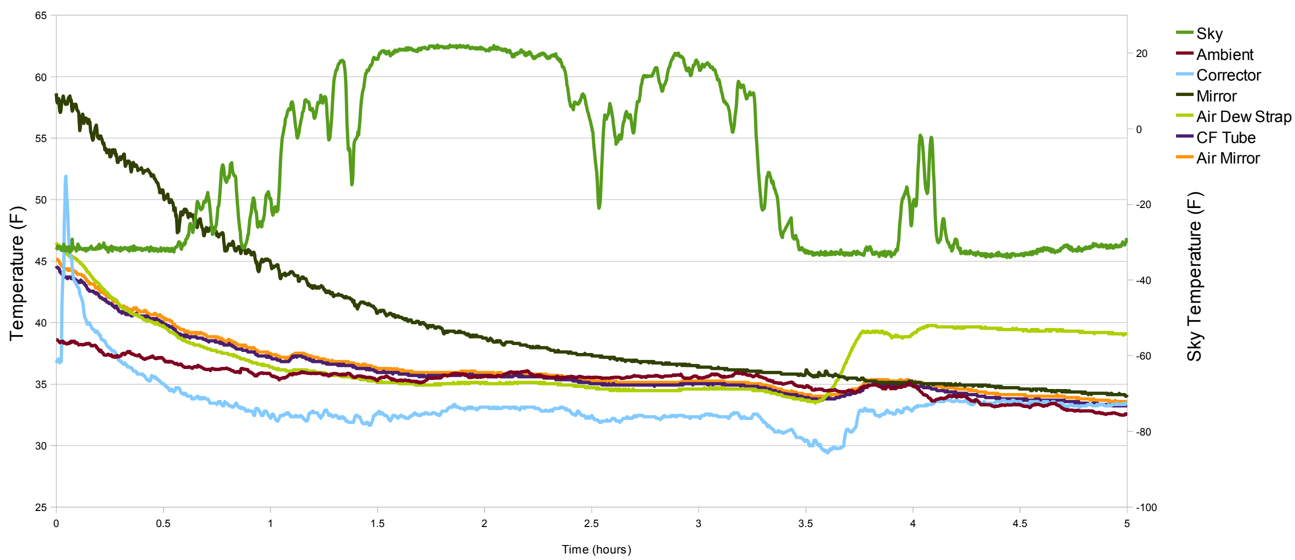

Figure 6. Plot of temperatures during the first five hours of equilibration. The green sky temperature plot refers to the axis scale on the right, and the high areas at 20F correspond to overcast sky, while the regions closer to -30F are when the sky is clear – including at the start when the sun was still up. I turned the dew strap on after about 3.6 hours, where the dew strap air temperature rises abruptly. The sudden drop of corrector temperature (blue line) at 3.2 hours is due to the clearing of the sky at that moment. The sub-ambient temperature of the corrector, and its tracking of the cloudiness above, is consistent with the radiative cooling model of dew formation. The orange and brown lines that are consistently close to each other are the MirrorAir and CFTube temperatures, respectively. Deep in the tube near the mirror, the air does not seem much different from the temperature of the CF tube itself.

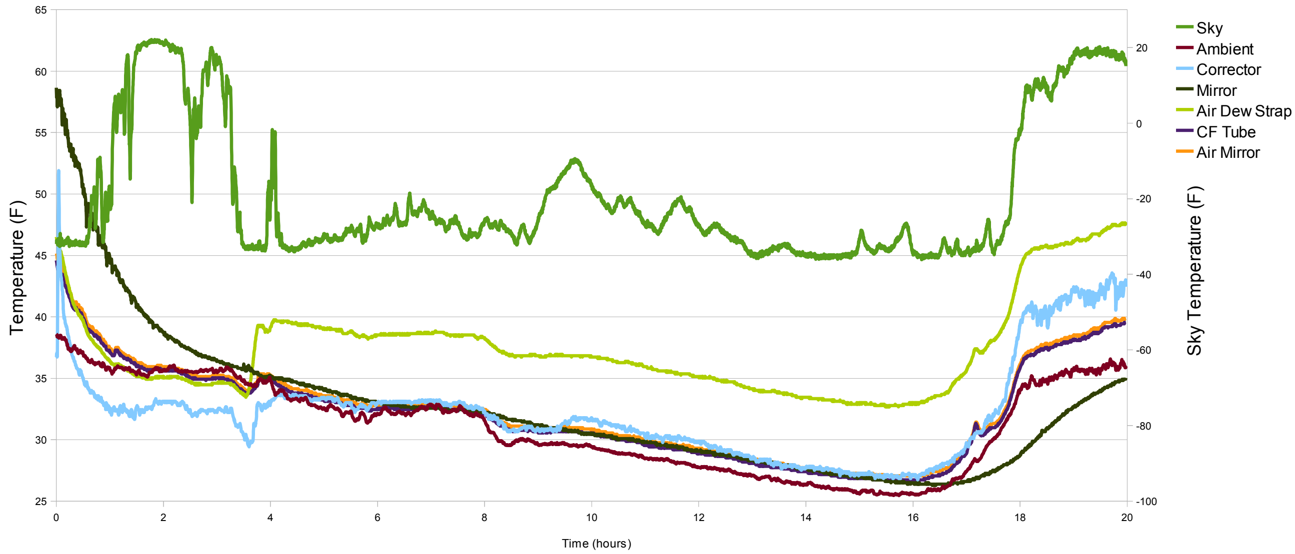

Figure 7. Full plot of the temperature log for 20 hours, going into the afternoon of the next day. Note that the skies became overcast during the first few hours, but during the night there was only passing haze until dawn when the sky clouded over again. The sky temperature is very sensitive to even thin haze. The fan was not left on during the night so that the temperatures would represent a situation where the fans were used only for an initial equilibration. You can see how all temperatures rise dramatically as the sky clouds over at dawn and the mirror temperature slowly lags the change since the fans are not on during this period.

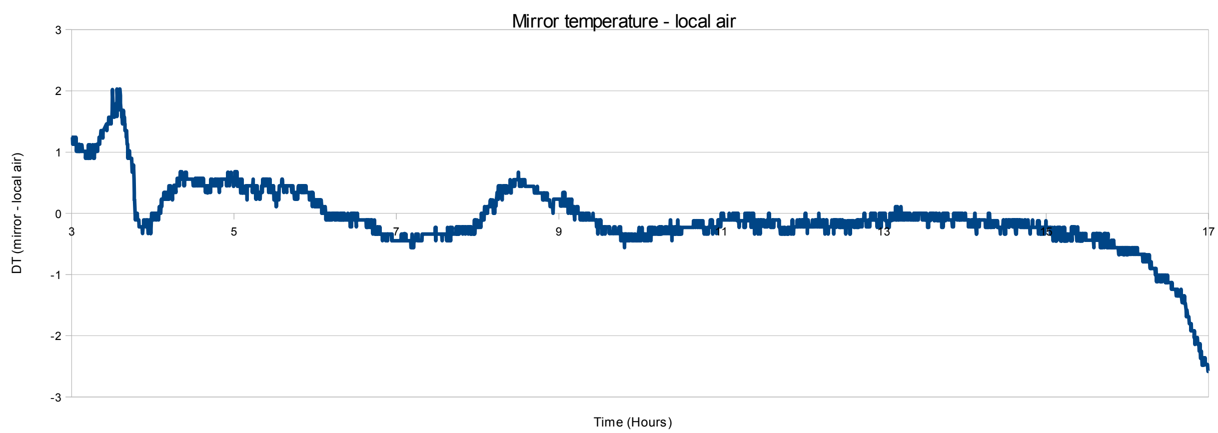

Figure 8. High resolution view of the difference between the mirror temperature and the air near the mirror. This is considered a critical measure of "mirror turbulence" that can greatly impact seeing. Since the temperatures are within a fraction of 1F for many hours, mirror turbulence is not a likely factor in planetary imaging.

DISCUSSION

Although this is only one temperature log, it shows that simple measures can guarantee minimal mirror turbulence caused by a warm mirror in the presence of air a few degrees cooler. It also shows the strong role of passing clouds and haze in the thermal behavior of the OTA and its components.

This log captured a challenging situation where the OTA was brought from indoors to out and passively cooled for several hours. Although the mirror was still warm by 1F or so after 3 hours, passive cooling was adequate to equilibrate the mirror almost fully to the tube air. In fact, I leave my telescope outside under a cover, so there will never be such a large shock to the mirror temperature that would cause a long time to equilibrate.

I recently had an opportunity to do planetary imaging when the Clear Sky Chart predicted transparent conditions with good seeing for my area, so I left the fans on for many hours as I waited for Jupiter to come into view near the meridian. Even though I now had evidence the OTA would be fully equilibrated, the video view of jupiter was only mediocre, with high frequency seeing effects very much unlike tube currents or mirror turbulence – basically the same as before my modifications. Meanwhile, someone under similar skies, according to the CSC, about 100 miles away, obtained excellent images of Jupiter – though he noted changing conditions during the evening. For me this is strong evidence that my planetary imaging is limited by local conditions possibly associated with the Hudson river valley and not the jet stream itself, and certainly not lack of temperature equilibration in my OTA.

OTHER COMMENTS

These logs clearly show the role of radiative loss to the sky in the temperature equilibration of the OTA. As a consequence, the dynamics of equilibration will depend on how much of the sky is exposed to the OTA itself – and even the mount to which it is attached – and not just what the corrector sees. I have a driveway setup surrounded by trees, which greatly reduces the solid angle of exposed sky compared to a fully open-air setup. There would be a similar difference between a dome with a slit vs. an observatory with a roll-off roof. The roll-off roof will cool not only the corrector faster, but all exposed surfaces in the vicinity of the OTA. If the tube ends up cooling much faster and the mirror can't keep up, then the the mirror will be slightly warmer relative to the air around it.

There is also concern that carbon fiber tubes are much worse than aluminum tubes due to the ability of aluminum to retain heat. I don't see anything in my logs to suggest a detrimental impact of my CF tube, while it does appear to reduce the need to refocus during deep sky imaging.

FUTURE

In the future I will take more logs occasionally and try to get more data. Now that the TC's are in the tube, it's just a matter of doing.