HJST 2dcoude Spectrograph Advisory

Image quality at the F1 (CS21) foci

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Issue summary

The delivered resolving power at the F1 foci of 2dcoude (CS21) has been varying between R~150,000 and R~210,000 during the past decade. The intent for F1 is to offer a stable resolving power of over 200,000 at all times. Variations in the delivered resolving power at F1 also adversely affects the stability of the resolving power at the F3 foci of 2dcoude (CS23), albeit to a lesser extent.

Issue resolution summary

Tube seeing in the collimator primary mirror tube has been degrading the image quality significantly. The tube seeing occurs when there is a large temperature difference between the slit room and the spectrograph room. To mitigate this, temporary insulation has been installed inside and outside the metal housing of the 2dcoude collimator mirror, and the temperature of the coude slit room has been changed to better match the temperature of the spectrograph room. A robust solution will be engineered when engineering resources become available.

Performance changes

Initial visual and CCD observations at F1 indicate that the implemented changes have restored the resolving power to approximately 200,000. This requires further characterization and analysis to be confident that the F1 image quality has been restored to its nominal value in all conditions.

It is possible that the effective throughput might increase slightly as a result of the improvement in image quality. Light that was being lost from the pupil and was therefore not imaged correctly is now staying in the pupil (explained below). This should increase the amount of light being imaged correctly at any given wavelength.

It should be noted that there are two types of seeing involved with 2dcoude. The first is the telescope seeing involving the full optical path leading to the spectrograph slit. The second is the spectrograph seeing following the slit. While the spectrograph seeing is significantly improved, it is not yet known how the change in slit room temperature has affected the telescope seeing at coude. An investigation of this is required.

Background

During approximately the last 10 years, observers including Ed Barker, Carlos Allende Prieto, Seth Redfield, and Ivan Ramirez have reported and documented the resolving power at F1 changing between limits of approximately 150,000 and 210,000. Ed Barker and David Doss determined that masking off the bottom half of the collimated beam improved the resolving power significantly, whereas masking off the top half degraded the resolving power. This indicated aberrations in the light of the lower half of the optical pupil. Also, the point spread function (effectively, the Th-Ar spectral line profile) appeared asymmetric.

Background (cont.)

Optical testing was undertaken on October 16th and 17th 2007. The first test used a 280 mm diameter telescope to look at the output of the 190 mm diameter collimator (see Figures 1 and 2). The central obstruction of the test telescope fairly much matched the central obstruction of the HJST. The test telescope magnification was 300x, the narrowest slit was used (#1), the light source was the flat field lamp, a 520 nm narrow band filter was used, and the corrector plate for the pupil mirror was removed. When the telescope was in focus the slit could be viewed, and when out of focus, the collimated beam (effectively the pupil) inside or outside of focus could be viewed.

The slit appeared most unsharp and unstable, with its width changing rapidly, its edges being unclear, and multiple images of the slit being visible at times. The secondary slit images tended to be on one side of the primary image, in line with the asymmetric line profiles reported by observers starting with Barker.

The pupil appeared vignetted, with between 25% and 35% of the bottom of the pupil being dark. The time constant for changes was approximately 15 seconds. The illuminated part of the pupil was also turbulent, with a time constant of approximately 3 seconds.

Inspection showed that the long cylindrical aluminum housing of the collimator primary mirror, and the mirror itself were very much colder than the spectrograph room. The temperature difference was 8.5 C° for the housing, and unknown for the mirror although it is most likely the same. The housing and mirror are mounted in the coude slit room and protrude into the spectrograph room through a bellows-sealed hole in the wall. The large surface area, high thermal conductivity, and fairly closed-tube geometry of the housing, along with stagnant spectrograph room air, were allowing cold air to pool in the bottom of the housing. This was causing tube seeing. It is likely that the temperature difference between the collimator primary mirror and the spectrograph room air is causing mirror seeing, albeit of a much lesser amount than the tube seeing.

An initial experiment to mitigate the tube seeing used an approximately 20-inch fan to blow into the collimator primary mirror housing (the cylindrical cavity seen in Figure 4). This quickly made the full pupil visible, and the slit image sharper and more stable. However the pupil showed high frequency turbulence with features changing at a 1-2 Hz rate.

Following the fan experiment, a thick insulated cylinder was fashioned by David Doss and inserted into the collimator housing (see Figures 3 and 4), and the fan was turned off. The appearance of the slit and pupil rapidly improved significantly relative to the fan experiment. Both pupil and slit appeared quite stable and sharp. Insulation was also wrapped around the exterior of the collimator housing in the coude slit room, with no visible effect.

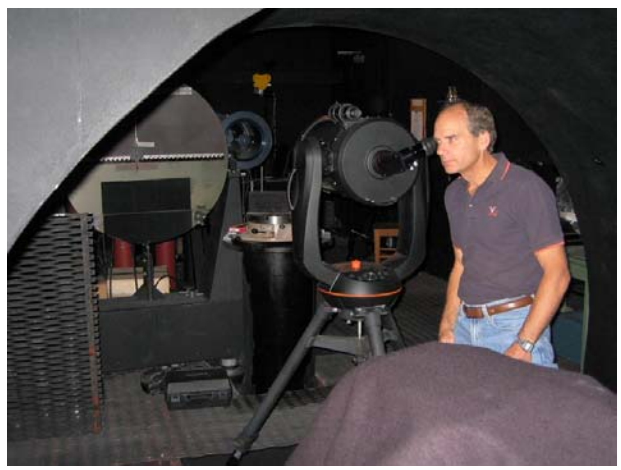
The coude slit room air conditioning was turned off so that the next morning the temperature differential between the slit and spectrograph rooms had decreased to 4.5 C°. The appearances of the slit and pupil images that morning had improved even more, and were extremely stable. Small imperfections in the edge of the slit could be seen, minor aberrations in the pupil were visible, and there was no indication of turbulence or seeing in the pupil.

Background (cont.)

A second test was done as follows. The test telescope was removed, the pupil mirror corrector was re-installed, and an eyepiece holder with 10 mm eyepiece was installed in the CCD mount at F1. A He-Ne laser and a diffuser were installed in the calibration system as a monochromatic light source. The eyepiece simply mimicked using a detector at F1, and allowed the monochromatic image quality and image structure at F1 to be examined. The spectral line was extremely weak, but appeared very sharp and stable. There was no visible motion or change in the speckle pattern. Despite care in this regard, it is possible that the He-Ne line was observed in the wrong diffraction order causing the low throughput. This was not resolved by the time the investigation had to stop, but the result of this test is believed to be robust. Higher light intensity would allow examination of the pupil and therefore wavefront aberrations.

I'd like to express my thanks to David Doss for his considerable assistance, and to Ed, Carlos, Ivan and Seth for their detailed measurements and support.

Figures

Figures 1 & 2: 280 mm telescope on HJST spectrograph optical bench looking into collimator


Figures 3 & 4: temporary insulation on the inside of the 2dcoude collimator mirror housing