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TECHNICAL REPORT NO. 292

Alignment of Klaus in Mount Wilson

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2007 August 7

This technical report series is published by:

THE UNIVERSITY
OF BIRMINGHAM

High-Resolution Optical-Spectroscopy Group

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Abstract

Contents

1 Introduction

I visited Mount Wilson in 2007 April. I arrived on April 3 and left on April 13. The main tasks that were planned for this trip were:

- Reinstall the aft cell,
- Reinstall the missing detector,
- Clean and align all optics, and
- Check instrument performance.

2 Reinstall the Aft Cell

Unfortunately, due to problems with shipping potassium, the replacement cell did not arrive in time to be installed on this trip. The instrument remains in service with the front-cell only.

3 Reinstall the Missing Detector

On a previous trip, Brek Miller removed one of the detectors and brought it back to Birmingham [1].

Upon arrival on this visit it became evident that there was some confusion as to exactly what had been done. All of the detectors had been removed and the optics cleaned. One of the detectors could not be reassembled properly and had to be taken back to Birmingham for repair. This was apparently one of the aft detectors.

However, it is also documented [1] that the forward port detector was unusually noisy and was also brought home to Birmingham. The aft port detector was moved into the forward port position to replace it. This means that both aft detectors should have been missing. Given that only one detector was missing, clearly something was not right.

There was yet more confusion regarding exactly which detectors were port and which were starboard. On most of our instruments the detectors are on the left and right side of the instrument. When looking from the back out towards the Sun, the detector on the left is labelled as port and the one on the right labelled as starboard. But Klaus doesn't have left and right detectors — it has top and bottom detectors. The confusion is doubled when you realise that the computer classes the forward top detector as port, but the aft top detector as starboard!

So which is which?

It seems that what happened was an aft cell was removed, and the optical mount damaged. Then, when the forward port detector was found to be noisy it was swapped with the aft detector by swapping the face-place and lens-mount assembly in order to pair the good lens-mount with the good detector. The bad detector and broken lens-mount were then taken back to Birmingham.

The broken lens mount was repaired by Barry Jackson. I upgraded the noisy detector with a new photodiode. The combined unit was then carried back out to Mount Wilson on this visit. Attempts to reverse the previous changes and get all four detectors back in their original positions failed. The faceplace on the repaired detector was held on with four screws — one in each corner. The forward top detector had a faceplate held on with three screws in a triangle formation. The two bottom detectors were not checked for faceplate compatability due to difficulties in extracting them from the instrument.

So the repaired detector was simply fitted in the vacant aft-top position. The channel assignment is shown in Table 1. Clearly the port/starboard and fore/aft channel assignments are all wrong.

The detectors in Klaus have two connections. The data go through BNCs while the temperature control and monitoring go through LEMO connectors. For some reason when the detectors

Table 1: Old Klaus Detector Connections

Detector Position	*Signal*	*Cable Label*	*Computer Label*
Forward Top	Data	None	foreport
Forward Top	Temperature	Bottom Front	fstar
Forward Bottom	Data	None	forestar
Forward Bottom	Temperature	Top Rear	aftport
Aft Top	Data	None	aftstar
Aft Top	Temperature	Top Front	fport
Aft Bottom	Data	None	aftport
Aft Bottom	Temperature	Bottom Rear	astar

were first built, three of them were given male LEMO connectors, whilst the fourth was given a female connector. On the previous trip when the detectors were swapped around, this connectivity problem is what caused the signal mismatch. There is no way to correct this problem without working out exactly which detector, and which face-plate, go with which physical detector position. That's a problem for another trip. The BNC connectors on the other hand are all the same, and there is no excuse for this signal mix up.

First we need to work out which side of the instrument is port and which is starboard. The detectors in Klaus have their connectors on the right when looking from the back out towards the Sun. This means that they much have been rotated 90° counter-clockwise from their normal upright position. That makes the top starboard, and the bottom port.

Klaus has four V/F converters — one for each scattering detector — with four BNCs to connect to them. These are labelled 1, 2, 3, and 4. The external cabling for the instrument was adjusted to make the channel numbering inside Klaus match the channel numbers on the scalers. One to One. The internal data coax from each detector was then connected to the V/Fs to make the top starboard for both forward and aft.

There are four BNC connectors on the back of Klaus in a square orientation. The top two are labelled forward and the bottom two are labelled aft. The new cabling has resulted in the left/right top connections being starboard/port, and the left/right for the bottom connections being port/starboard. This is due to a wiring mistake inside Klaus, and is probably where the port/starboard mixup came from originally. This is a small price to pay for the channel numbering and labelling consistency we have now. The new data channel assignments are shown in Table 2.

The repaired aft-top detector with the new photodiode seems to have higher dark-counts than the other three scattering detectors. The fix for this should simply be an adjustment to the offset-control inside the detector. At the moment it doesn't matter. When a new aft-cell is installed in Klaus this problem should be corrected.

4 Clean and Align All Optics

There are five mirrors in the system in front of Klaus. The first two are the cœlostat mirrors. They direct the beam vertically down through the sixty-foot tower. About twenty feet from the

Table 2: New Klaus Detector Connections

Detector Position	*Signal*	*Cable Label*	*Computer Label*
Forward Top	Data	Top Front	forestar
Forward Bottom	Data	Bottom Front	foreport
Aft Top	Data	Top Rear	aftstar
Aft Bottom	Data	Bottom Rear	aftport

bottom, there are two "periscope" mirrors, oriented at 45° to the vertical. They pick off a small part of the beam. The first periscope mirror deflects the beam sideways slightly, and the second deflects it down again.

At the bottom of the tower, the beam hits the fifth mirror and is reflected horizontally into Klaus. The final beam alighment is done with this fifth mirror. It is on an altitude/azimuth mount. Two micrometers allow it to be adjusted in the horizontal (azimuth) and the vertical (altitude) direction.

There is a quadrant photodiode at the back of Klaus, and it was intended that this be used as an alignment monitor. Unfortunately the alignment monitor does not work — it doesn't handle the photodiode signals properly and so it can't actually be used to check the alignment.

The first alignment was done visually by observing the path of the light within the instument. For this to work the interference filter has to be removed in order to be able to see the beam. When comparing the position of the beam with the center of the lenses within the spectrometer, and also checking for vignetting on the quadrant at the back of the instrument, the correct alignment appears to be when the mirror-mount micrometers are set to $x = 9.1\,\mathrm{mm}$ and $y = 2.2\,\mathrm{mm}$.

Whilst the cover was removed from the spectrometer, the opportunity was taken to remove and clean the front red-filter. This was done on 2007 April 6 at 18:30UT and resulted in an increase in intensity of a few thousand counts. At our other sites such cleaning usually results in a jump in intensity of a significant percentage of the total signal. However in Mount Wilson the instrument is safely hidden away and so does not get as dirty — the cœlostat mirrors take the brunt of the weather.

A detailed alignment scan was performed on 2007 April 9. The fifth-mirror was scanned in the horizontal direction with the cell hot, the results are shown in Figures 1 and 2 on page 6. Upon examining the forward ratios it appears that $x = 9.1\,\mathrm{mm}$ is the correct position for the mirror. This is the point at which the ratio, and thus the sensitivity, is maximised. Looking at the sums, a slightly lower value is required in order to work at the point where the port and starboard detectors produce equal intensity signals, but this would be to the detriment of the ratio. The transmission monitor is not quite in the center of the beam.

The fifth-mirror was then scanned in the vertical direction with the cell hot. The results are shown in Figures 3 and 4 on page 7. These plots show clearly that a micrometer setting of $y = 2.1\,\mathrm{mm}$ is the best position. This is the point at which the ratios are maximised, the transmitted sum in maximised, and the port and startboard sums cross over.

As an additional test, the same scans were performed with the cell cold. The horizontal results are shown in Figures 5 and 6 on page 8. The vertical results are shown in Figures 7 and 8 on page 9. Here we want to minimise the cold-scattering sum, and it is clear that the results agree with our previous micrometer settings — the number of counts goes up dramatically as the beam is moved to one side or the other.

The final settings for fifth-mirror position are $x = 9.1\,\mathrm{mm}$, and $y = 2.1\,\mathrm{mm}$.

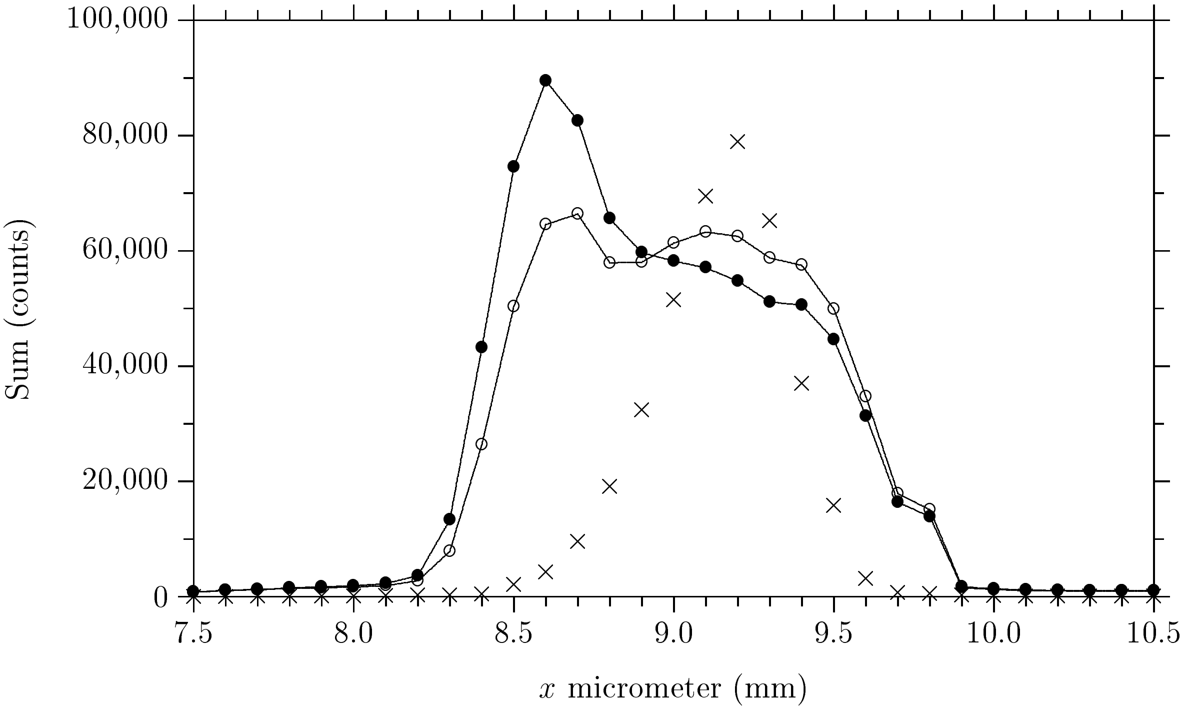

Figure 1: Hot Horizontal Scan — The fifth mirror was scanned in the horizontal (azimuth) direction. The plot shows how the forward starboard sum (•), forward port sum (∘), and the transmission monitor (×) varied. The transmission monitor data has been divided by ten. This scan was done with the altitude micrometer set at 2.1 mm.

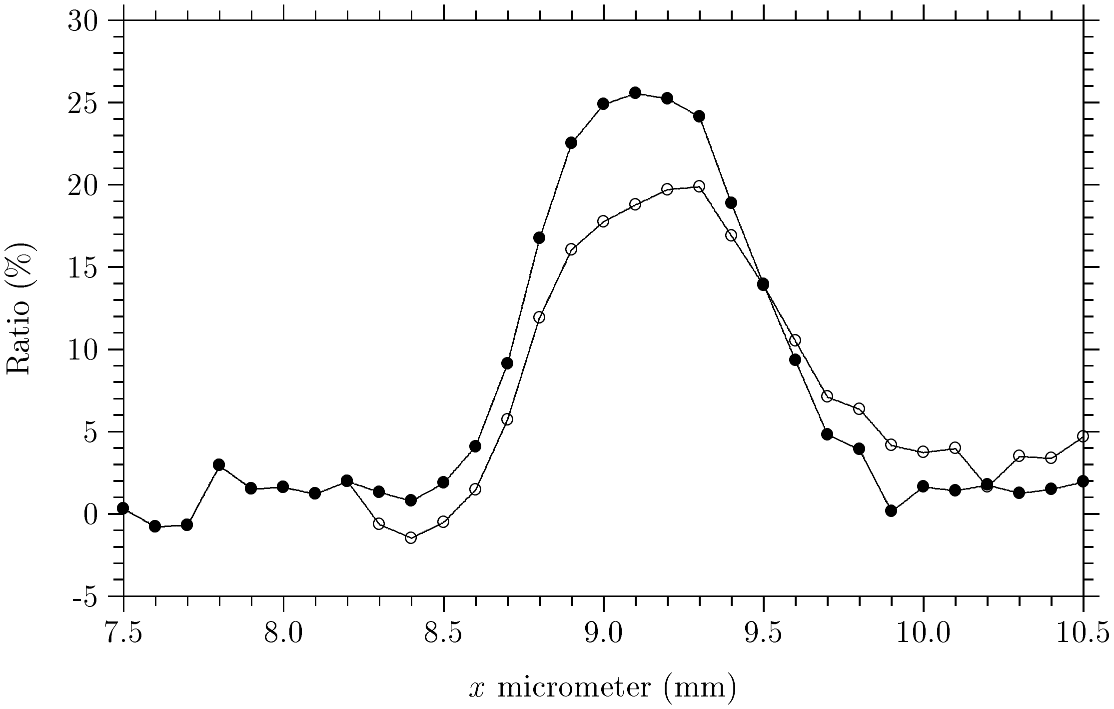

Figure 2: Hot Horizontal Scan — The fifth mirror was scanned in the horizontal (azimuth) direction. The plot shows how the forward starboard ratio (•) and forward port ratio (∘) varied. This scan was done with the altitude micrometer set at 2.1 mm.

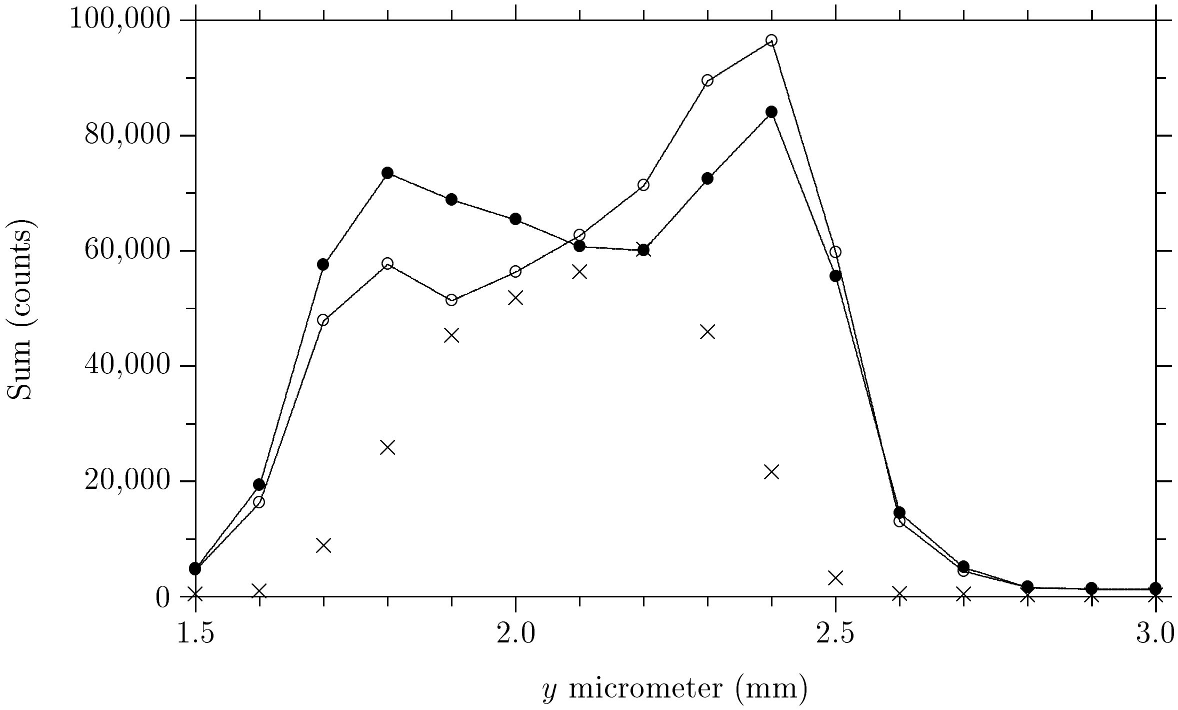

Figure 3: Hot Vertical Scan — The fifth mirror was scanned in the vertical (altitude) direction. The plot shows how the forward starboard sum (•), forward port sum (∘), and the transmission monitor (×) varied. The transmission monitor data has been divided by ten. This scan was done with the azimuth micrometer set at 9.1 mm.

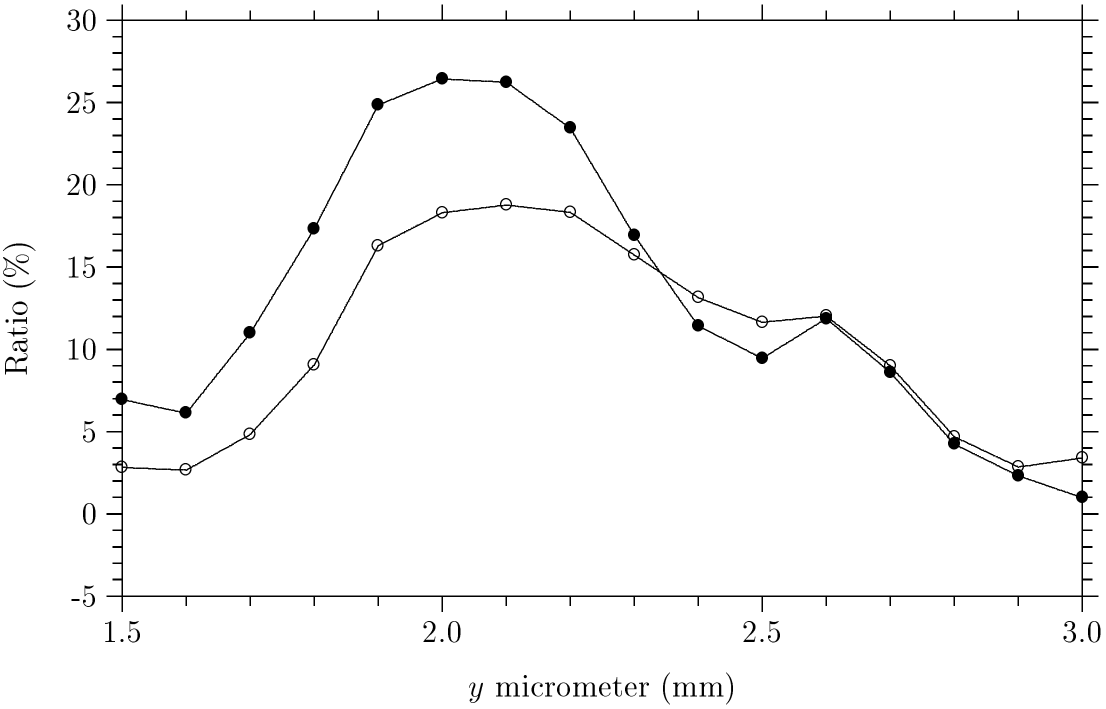

Figure 4: Hot Vertical Scan — The fifth mirror was scanned in the vertical (altitude) direction. The plot shows how the forward starboard ratio (•) and forward port ratio (∘) varied. This scan was done with the azimuth micrometer set at 9.1 mm.

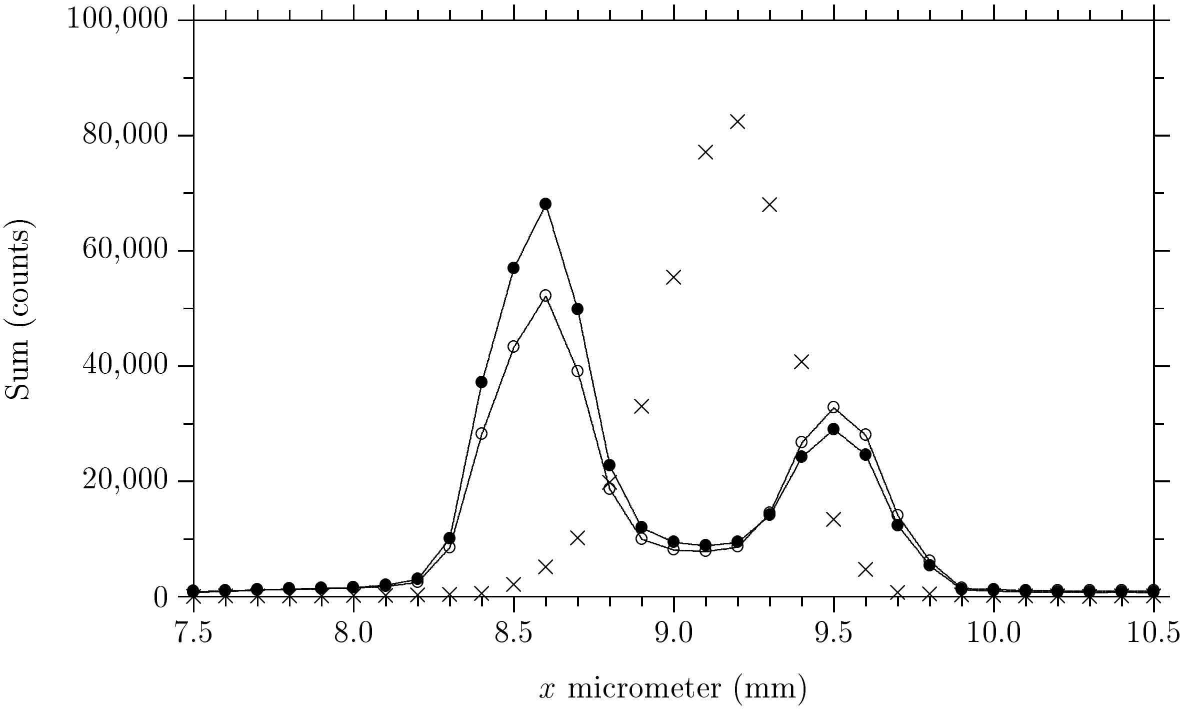

Figure 5: Cold Horizontal Scan — The fifth mirror was scanned in the horizontal (azimuth) direction. The plot shows how the forward starboard sum (•), forward port sum (∘), and the transmission monitor (×) varied. The transmission monitor data has been divided by ten. This scan was done with the altitude micrometer set at 2.1 mm.

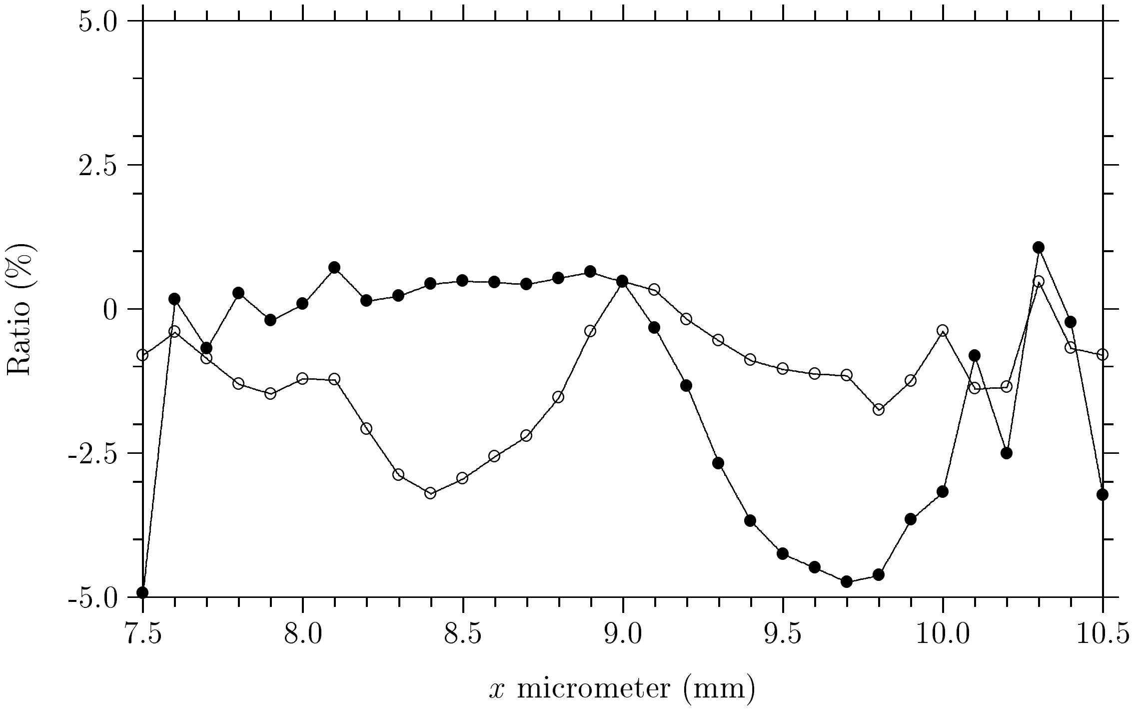

Figure 6: Cold Horizontal Scan — The fifth mirror was scanned in the horizontal (azimuth) direction. The plot shows how the forward starboard ratio (•) and forward port ratio (∘) varied. This scan was done with the altitude micrometer set at 2.1 mm.

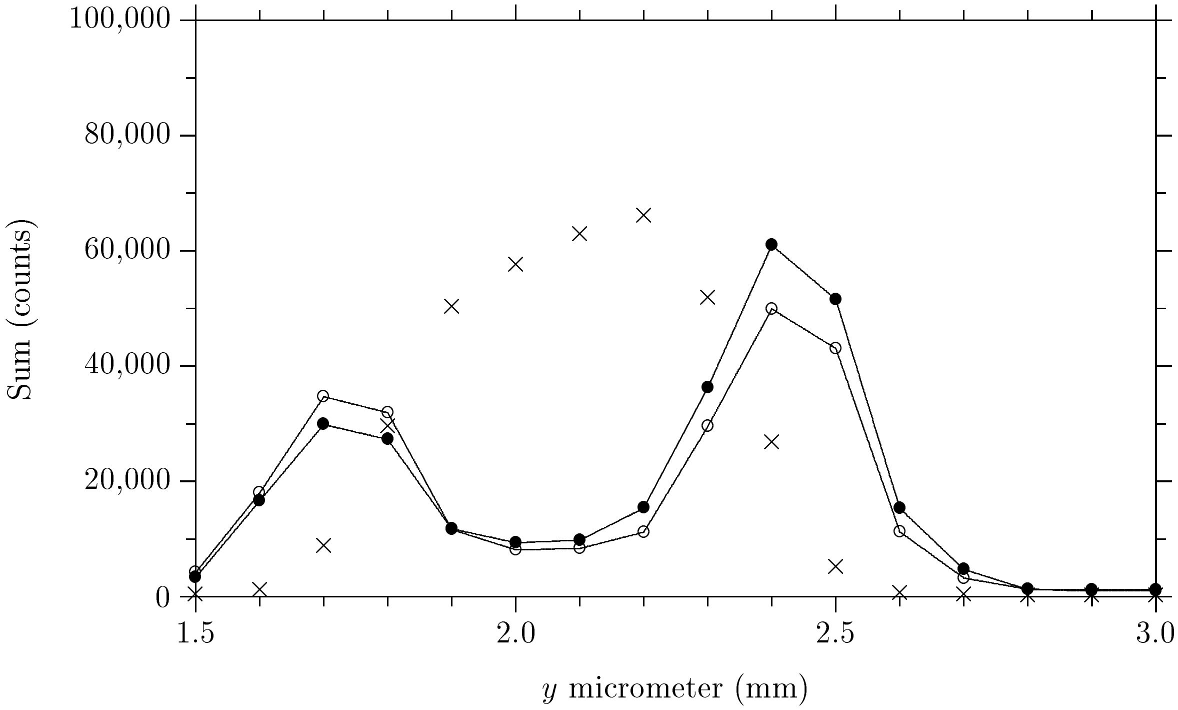

Figure 7: Cold Vertical Scan — The fifth mirror was scanned in the vertical (altitude) direction. The plot shows how the forward starboard sum (•), forward port sum (∘), and the transmission monitor (×) varied. The transmission monitor data has been divided by ten. This scan was done with the azimuth micrometer set at 9.1 mm.

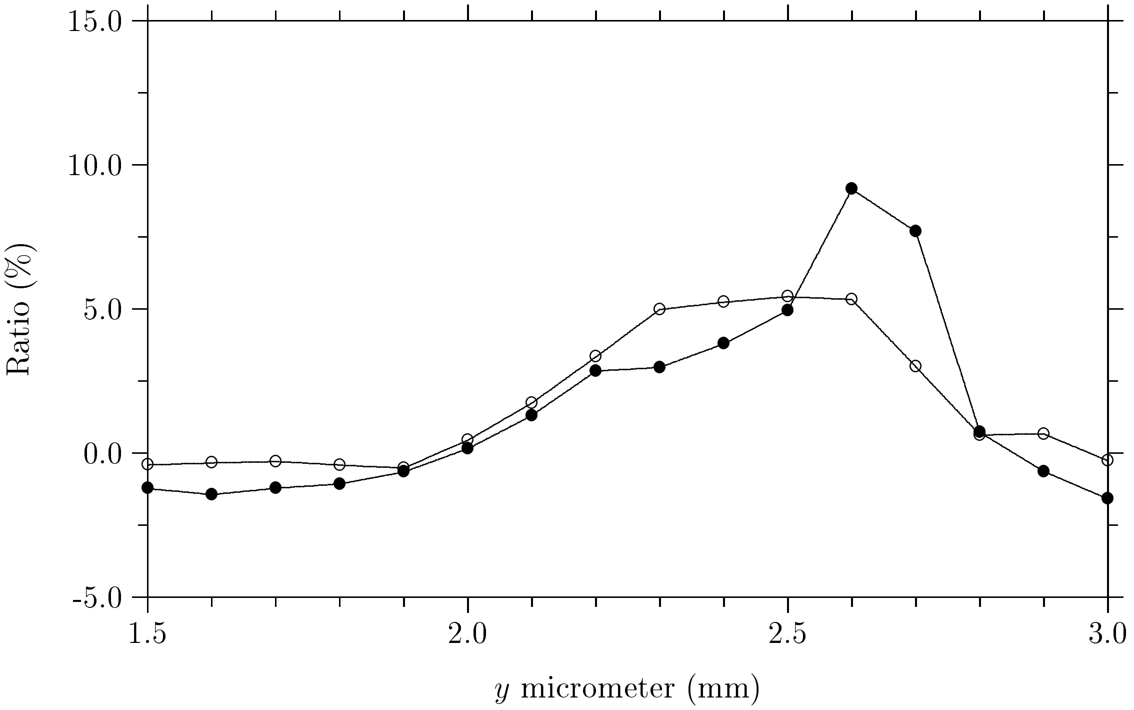

Figure 8: Cold Vertical Scan — The fifth mirror was scanned in the vertical (altitude) direction. The plot shows how the forward starboard ratio (•) and forward port ratio (∘) varied. This scan was done with the azimuth micrometer set at 9.1 mm.

5 Check Instrument Performance

With the instrument correctly aligned, it was time to check the performance of the potassium cells. With the aft cell missing, only the forward cell could be tested on this occasion.

The temperatures of the ovens in Klaus are controlled by Richard Lines temperature controllers. You can set the temperatures of the top and bottom seperately. Nominally, you need to divide the dial number by five in order to get the matching set point temperature. Initially the front oven settings were FTOP = 562.6 (112.5°C) and FOVEN = 462.5 (92.5°C).

Finding the correct temperature setting is a simple task. Firstly the temperature controllers are turned right down and the cell allowed to cool. The temperatures are then gradually increased until the peak level of the scattered sum is found.

The sums and ratios for the heating curve are shown in Figures 9 and 10 on page 9. Looking at the scattered sum the initial setting for the front oven were correct, and so no adjustments were made.

The data show a hot to cold ratio of around 8.4 for the forward cell. This agrees with the heating curve done by Brek Miller in 2005 September [1] and so it appears that no degradation has occured since then.

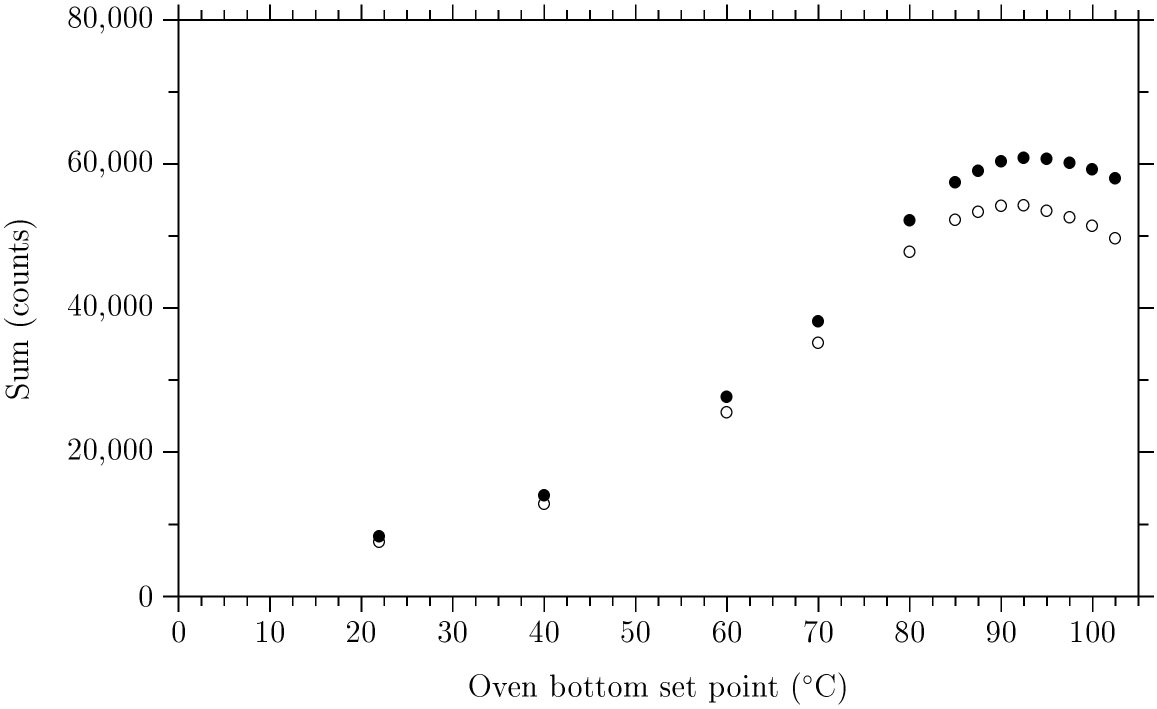

Figure 9: Forward cell heating curve — The plot shows the forward starboard sum (•) and the forward port sum (◦). This run was done on 2007 April 9.

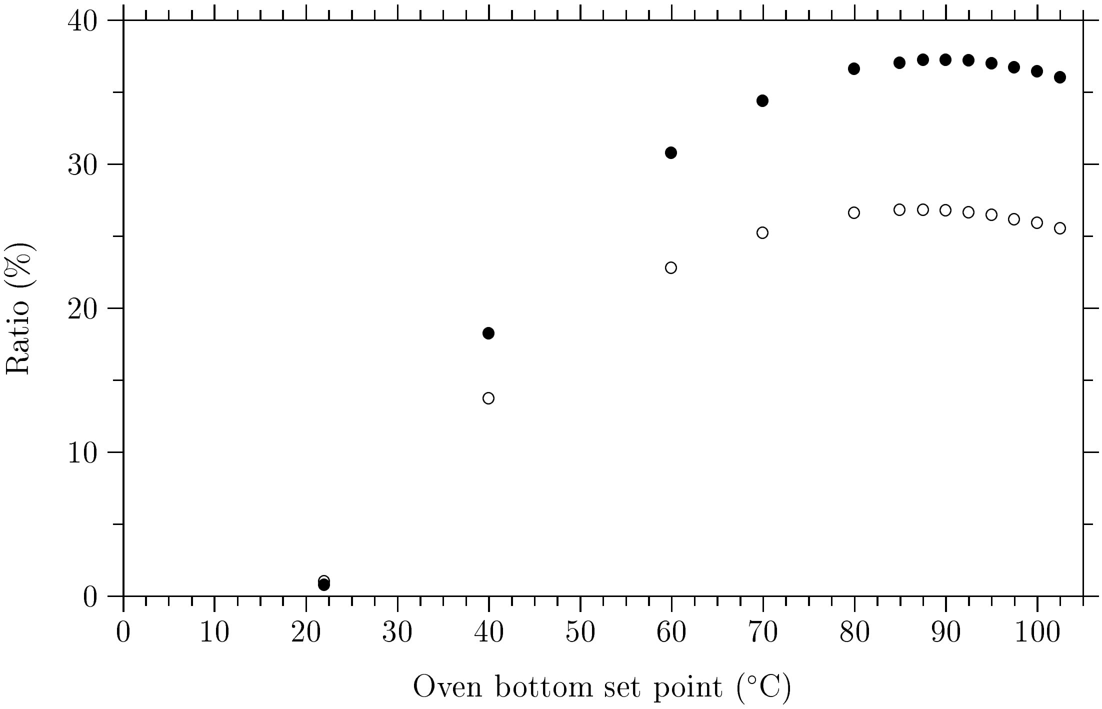

Figure 10: Forward cell heating curve — The plot shows the forward starboard ratio (•) and the forward port ratio (◦). This run was done on 2007 April 9.

6 Solar Image Rotation

6.1 Daily Rotation

Sunlight is collected in Mount Wilson using a cœlostat. A cœlostat is similar to a heliostat, but has a more complex design and, unlike a heliostat, gives an image in a fixed orientation so that the image doesn't appear to move or rotate as the Sun moves across the sky.

Unfortunately, it seems that the Mount Wilson cœlostat does actually show a small rotation through the day. The following is an extract from an email from Thad Szabo.

> I'll attach two plots. The first (Figure 11) shows the daily rotation rate throughout the year including an apparent effect introduced by a non-zero B_0 angle mapping part of the solar rotation into an apparent roll about the center of the image. That B_0 component varies throughout the year with B_0; we assume the central value of the rotation of the image plane to be a constant $0\overset{\circ}{.}018\,\mathrm{hr}^{-1}$ (or $1\overset{\prime}{.}08\,\mathrm{hr}^{-1}$). The second plot (Figure 12) shows the scatter in these values about the $0\overset{\circ}{.}018\,\mathrm{hr}^{-1}$ value. 90% of the values for the tower image plane rotation lie between $-0\overset{\circ}{.}002\,\mathrm{hr}^{-1}$ and $0\overset{\circ}{.}038\,\mathrm{hr}^{-1}$).
>
> The rotation measurements in these graphs came from comparing two integrated images whose centers are set five minutes apart. The comparisons are repeated throughout the day, leading to a determination of the rotation rate for that day. The dP/dt component is removed before plotting the rate. The fit for each daily rate is assumed to be linear.
>
> Measurements I am getting from ring-diagram analysis, however, seem to indicate smaller rotation rates than this. I won't be able to say much more than that until I have enough days processed to show if that is indeed the trend.

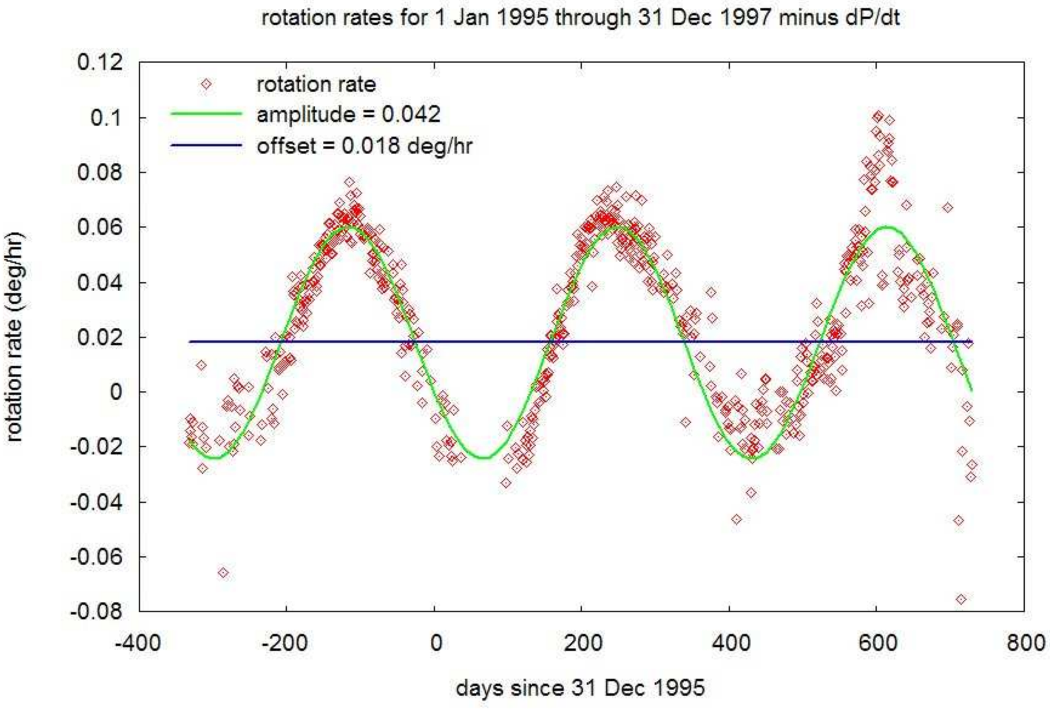

Figure 11: Daily image rotation rate throughout the year.

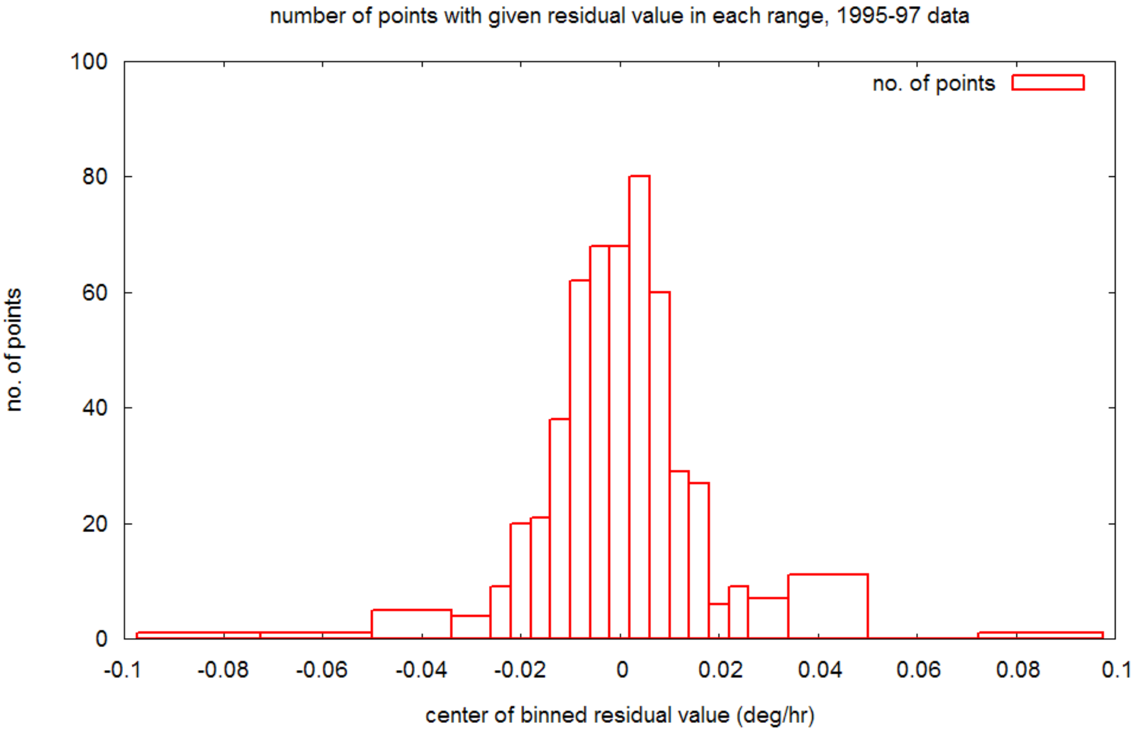

Figure 12: Scatter in image rotation magnitude about the $0.^\circ018\,\mathrm{hr}^{-1}$ value.

6.2 Yearly Rotation

The image also rotates throughout the year, particularly during the times when the primary mirror has to be moved in the middle of the day. This rotation is shown in Figure 13, which was produced by Perry Rose. The SOLAR_P value is the measurement of the solar north-south axis with respect to the top of the CCD chip inside the primary instrument at Mount Wilson.

Figure 14 shows the SOLAR_P angle measured for morning and afternoon on the same plot scale. There are two symbols for morning and afternoon that overlap for the summer months when the Sun is high in the sky, but this still represents an afternoon measurement with the first flat west of the second-flat pier.

7 UPS

Perry Rose has bought a UPS for the main instrument in the sixty-foot tower. Since it has more than enough capacity, it was suggested that we also move our electronics over onto the UPS.

At our other sites we have one large UPS to power the dome in order to allow it to close in the event of a power failure, and also a second smaller UPS just for the PC. In Mount Wilson we do not have to worry about dome power, and all of our other electronics including the PC are connected to one surge-protected power-strip. It was easier to just plug the entire power-strip into the UPS, and so all of our electronics are now protected rather than just the computer.

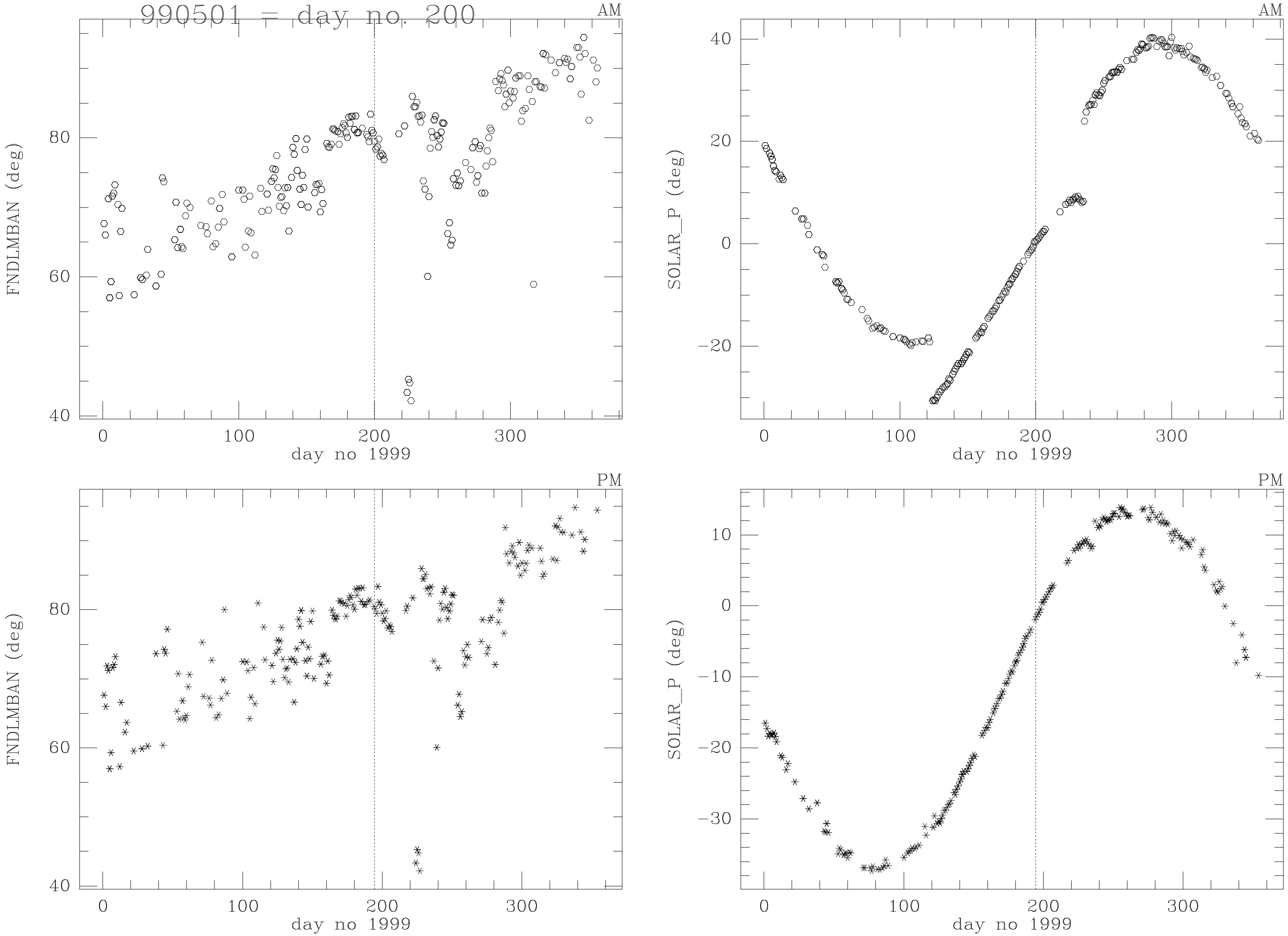

Figure 13: Solar image rotation through out the year.

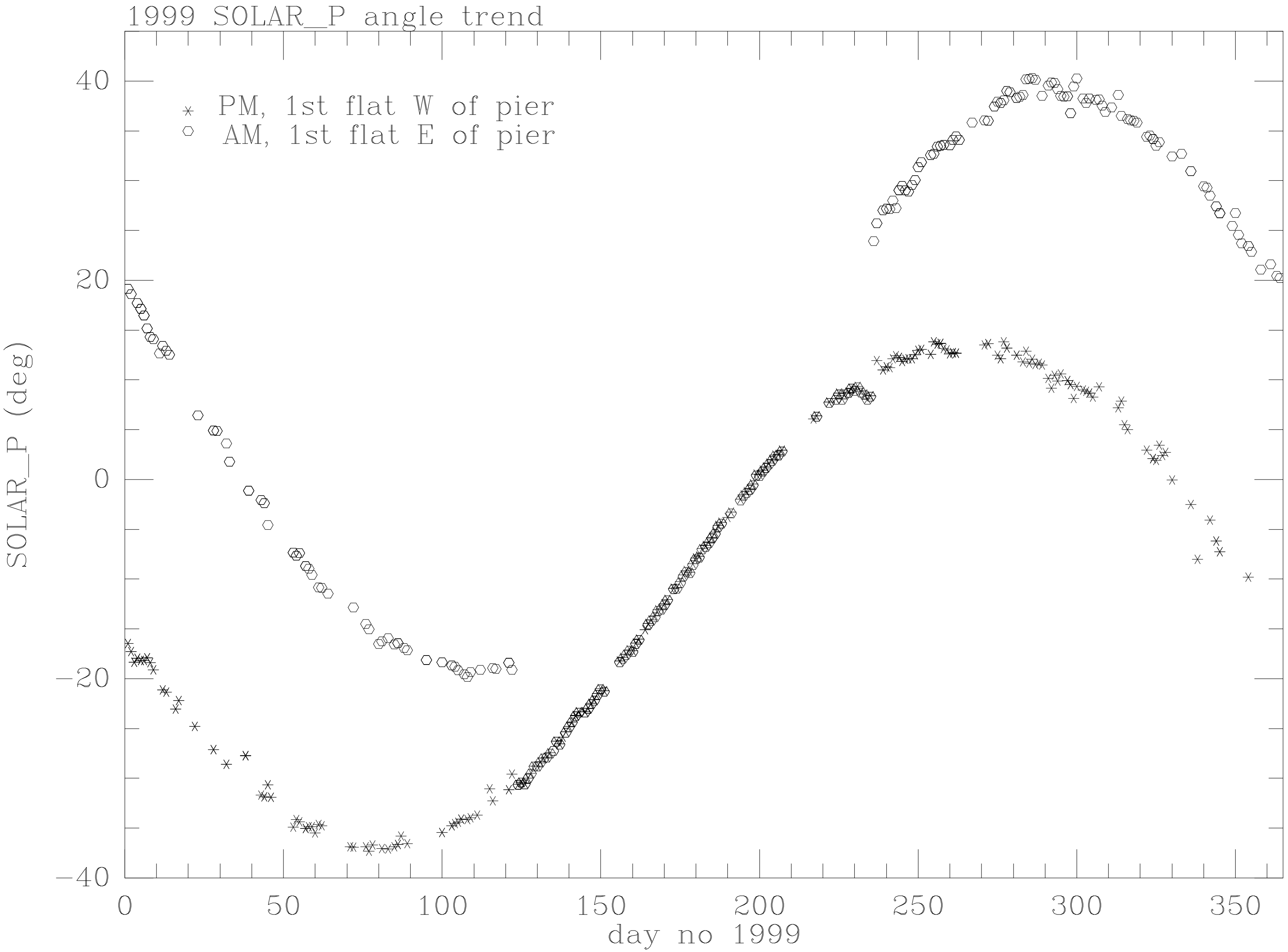

Figure 14: Solar image rotation through out the year plotted on the same scale.

References

[1] Brek A. Miller. The grand opening of the Mount Wilson Zoo. *BISON Technical Report Series,* Number 255, High-Resolution Optical-Spectroscopy Group, Birmingham, United Kingdom, September 2005.