FLWO 1.2m telescope:
Image quality, 2012-2015
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The RTS2 system runs the 1.2m telescope and Keplercam. It measures the average of FWHM of stars in each exposure, and records it in nightly logs. I collected FWHM values for filters r and i from these logs for 2012, 2013, 2014, 2015 and the first 3 months of 2016, and made histograms for each period.

Observing Statistics

The table below shows statistics for observations for the 4 years under consideration. In 2015, there were about twice as many nights with no data as in each of the other 3 years. That confirms the perception that the weather was significantly worse that year than in previous years. The perception continues to be that the weather remains worse than expected.

Table 1. STATISTICS 2012-2015

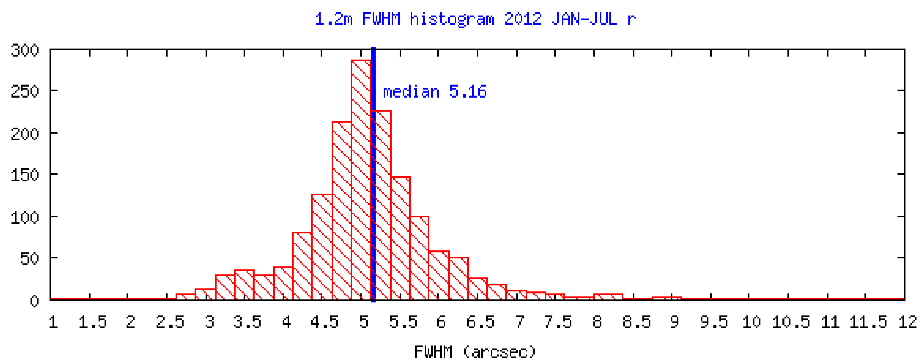
YEAR	Nexp	Ncal	Nsci	Nnights	NoData	Nsci/night
2015	163178	32690	130488	254	80	514
2014	194337	31359	152978	291	43	560
2013	159427	29683	139744	285	49	490
2012	129926	29272	100654	295	39	341

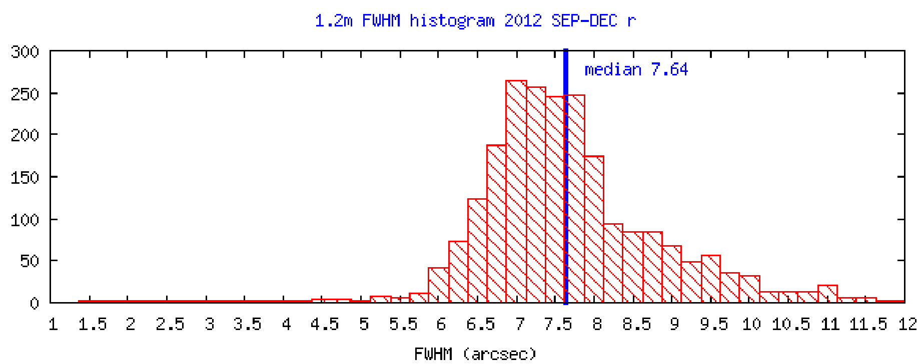
[a]Nnights excludes shutdown and NoData nights, mainly due to weather

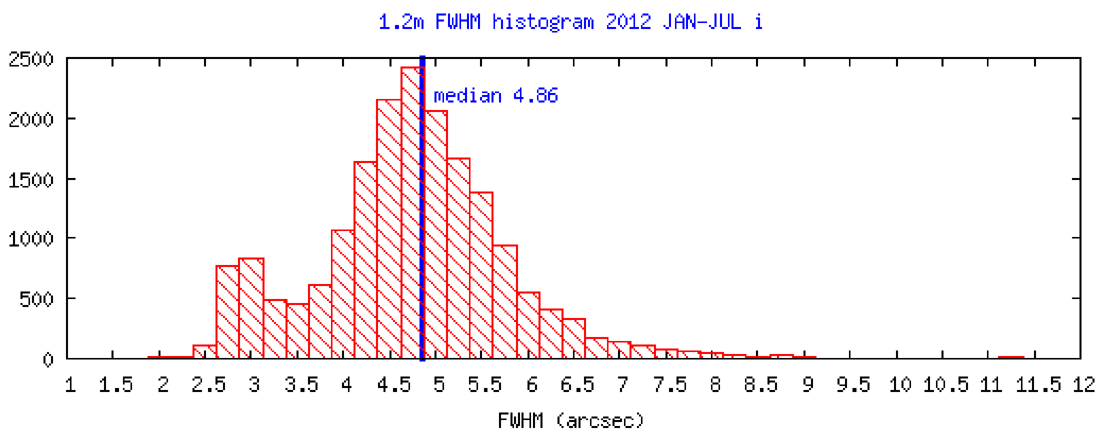
[b]Nsci excludes calibrations (FLAT, BIAS, TEST, FOCUS, defocus for collimation calculations)

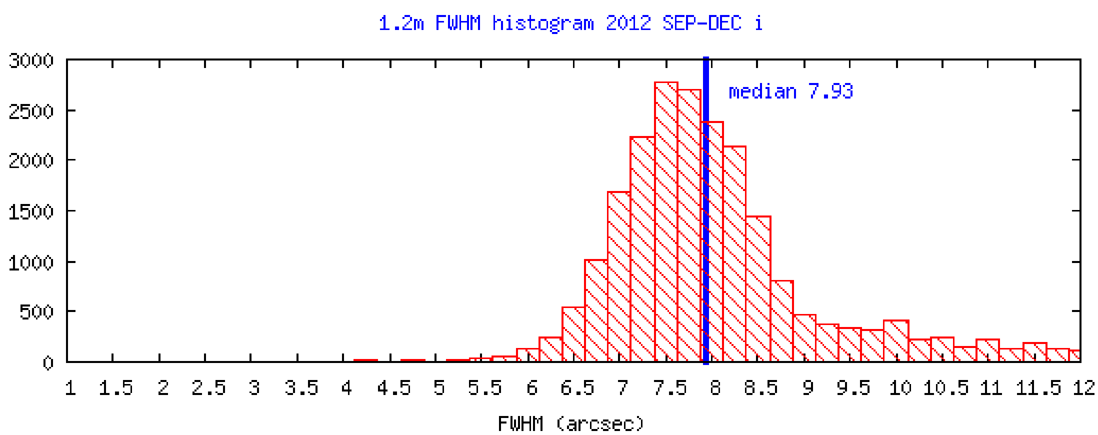
Histograms

- **2012:**
  The histograms show very poor image quality in both r and i.

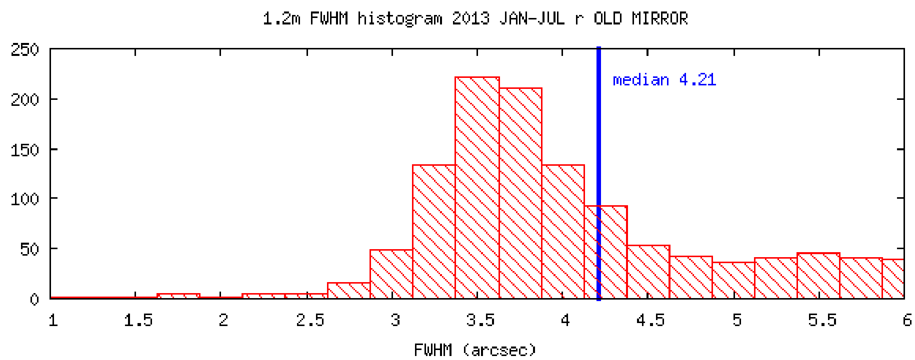


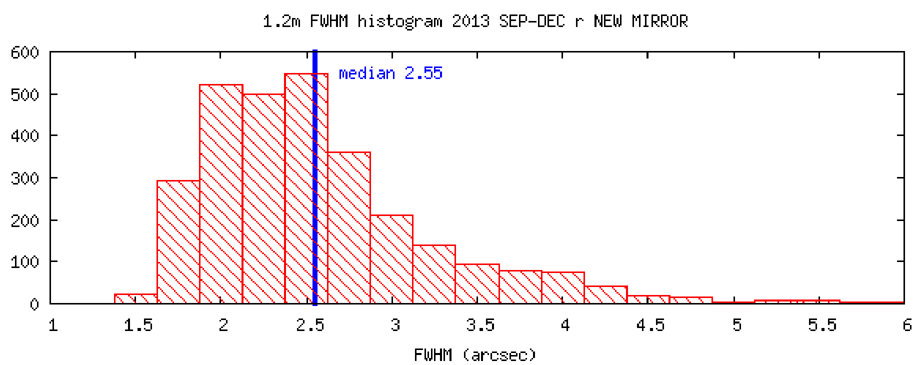


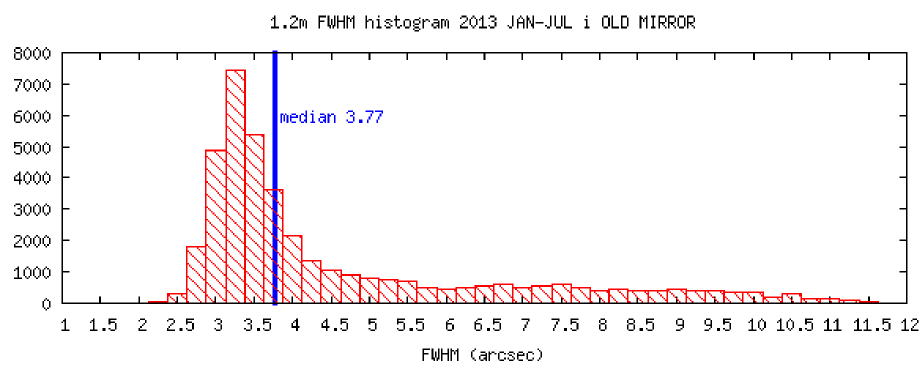

1.2m FWHM histogram 2012 JAN-JUL i
median 4.86
FWHM (arcsec)

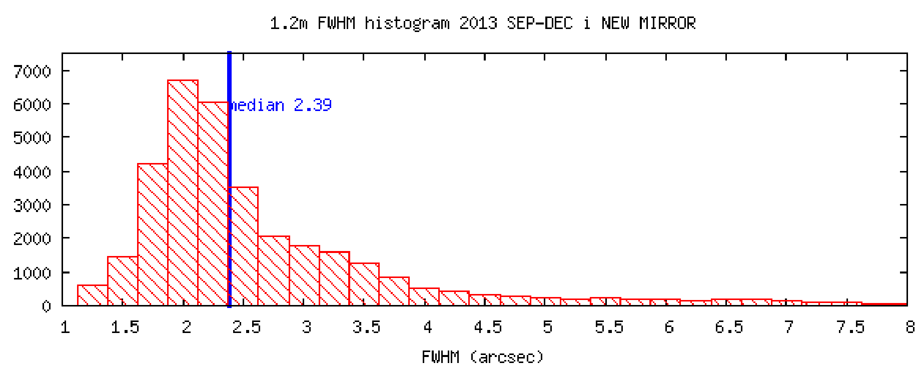

1.2m FWHM histogram 2012 SEP-DEC i
median 7.93
FWHM (arcsec)

- **2013:**
  The histograms show a significant improvement of image quality as we transitioned from the old mirror in the first part of the year, to the new mirror in the second part. From photometric measurements of SNe, Pete Challis provided estimates of the zeropoint improvement with the new mirror: an average of 1.14 mag for V, r and i.

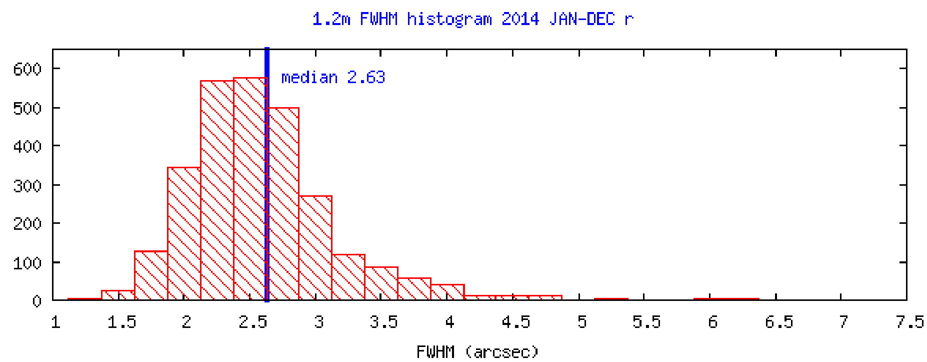


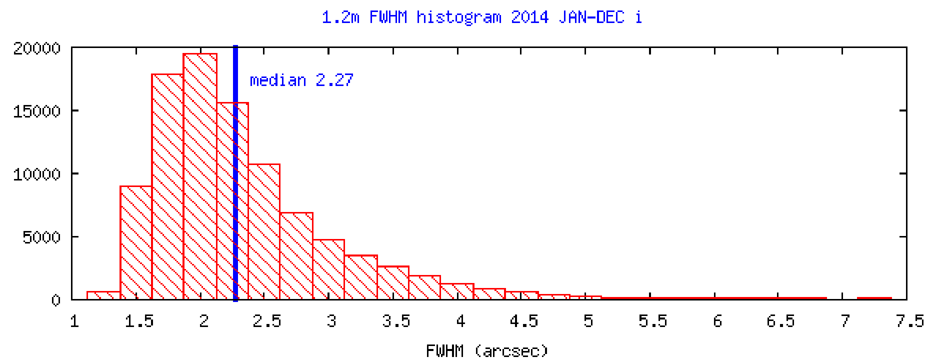



1.2m FWHM histogram 2013 JAN-JUL i OLD MIRROR
median 3.77
FWHM (arcsec)


1.2m FWHM histogram 2013 SEP-DEC i NEW MIRROR
median 2.39
FWHM (arcsec)

- **2014:**
  The histograms show that the image quality in both filters remained similar to that in the second half of 2013.

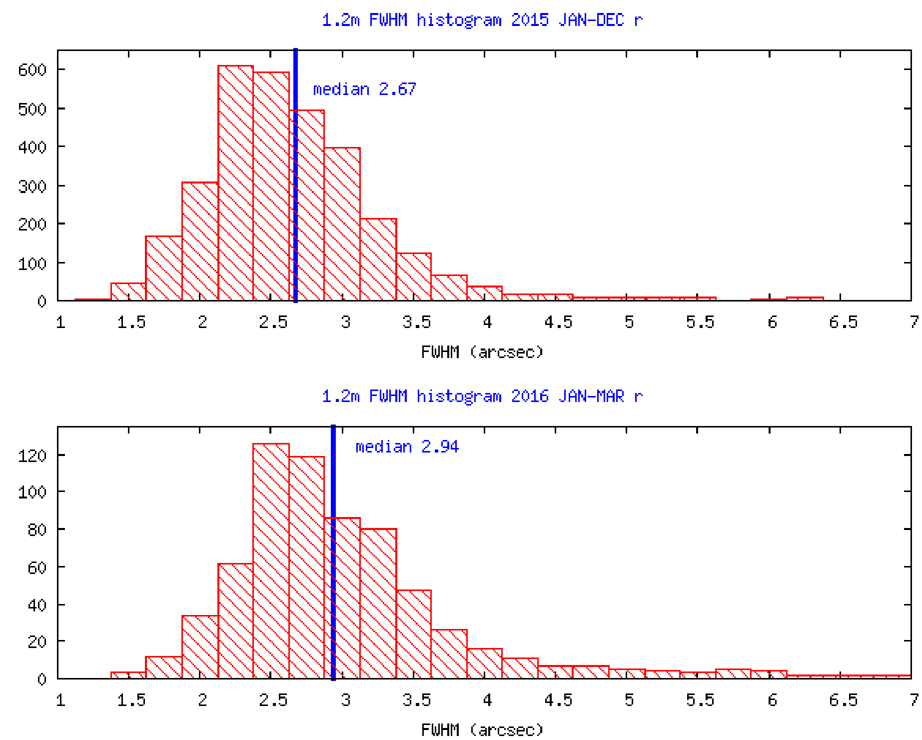


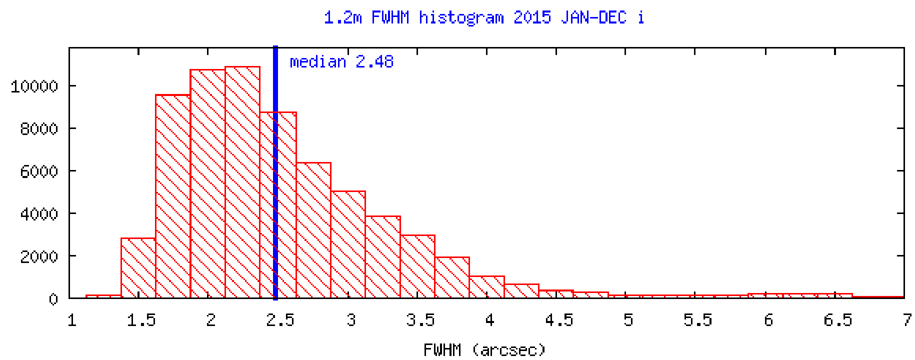


- **2015:**

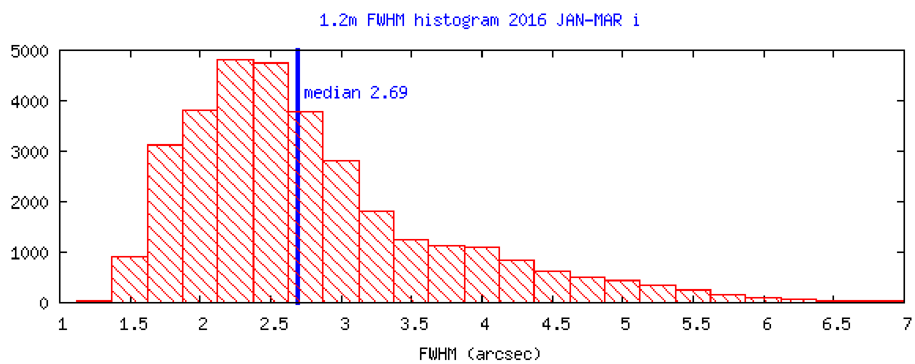
In 2015, the image quality was similar to that of 2014. However, the image quality deteriorated starting in January 2016.

The lower panels for both filters show the histograms for Jan-Mar 2016. During the first 3 weeks of February, we were unable to control the temperature of the primary mirror. We could not run the mirror chiller because the circulation pump for the building chiller had failed and had to be replaced, which took longer than expected. In addition, the mediocre weather conditions that prevailed during these months also contributed to the degradation of our image quality.





1.2m FWHM histogram 2015 JAN-DEC i
median 2.48
10000
8000
6000
4000
2000
0
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
FWHM (arcsec)



1.2m FWHM histogram 2016 JAN-MAR i
median 2.69
5000
4000
3000
2000
1000
0
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
FWHM (arcsec)

Nightly FWHM vs. time plots

In May 2015, we started recording plots of image quality for each night. We generate these plots automatically after each night of observations. The scripts have evolved from generating simple views of FWHM and temperature, to more complex views that include airmass and wind properties. The following are representative examples.

The first example, from May 2015, shows good seeing through most of the night. At the time, we were experimenting with maintaining the mirror at a temperature somewhat lower than ambient. During this period, we set the offset from ambient at -1 C, as is apparent in Fig. 1.

The second example, from February 2016, shows variable seeing trough the night. Starting on 1 February, the chiller pump was not operational. As the chiller was not running, the mirror was colder than ambient for about 2 hours. After that, ambient fell below the mirror temperatures by 1-2 C. That night, the wind remained steady at about 20 mph. The FWHM fell slightly below 2 arcsec early on, following the trend in the airmass, as a transit was observed. Near the minimum in the FWHM trace, the wind was from the West, the most favorable direction for seeing. At about 1am, a new transit was observed. The fwhm remained near 3 arcsec for the rest of the night, as the wind turned to the East, the least favorable direction for seeing. The sharp drop in "T avg" near 20:30 is a glitch in one of the mirror sensors.

The third example, also from February 2016, shows the variation of seeing trough the night, with the chiller pump back in operation. The FWHM clearly tracks the trend in the airmass for the two transits that night.

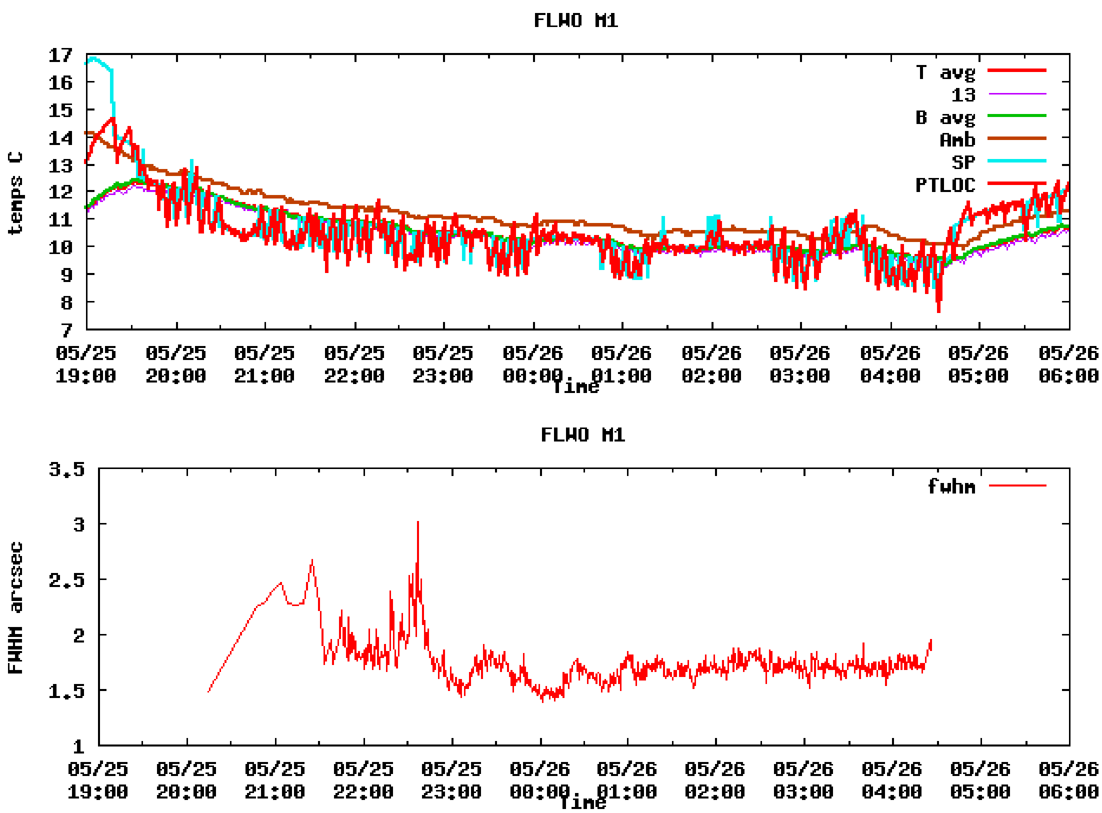


Fig. 1.— Temperature and FWHM for the night of 25 May 2015. Top panel: "T avg" and "B avg" are the averaged top and bottom mirror temperatures. The trace labeled "13" is for sensor No. 13; it is barely distinguishable from the averages in this plot. Sensor 13 has been known to misbehave, so we plot it separately. "Amb" is the ambient chamber temperature. "SP" and "PTLOC" are the chiller set point and coolant temperatures, respectively. Bottom panel: "FWHM" is the value recorded in the logs, measured from the night's exposures with sextractor.

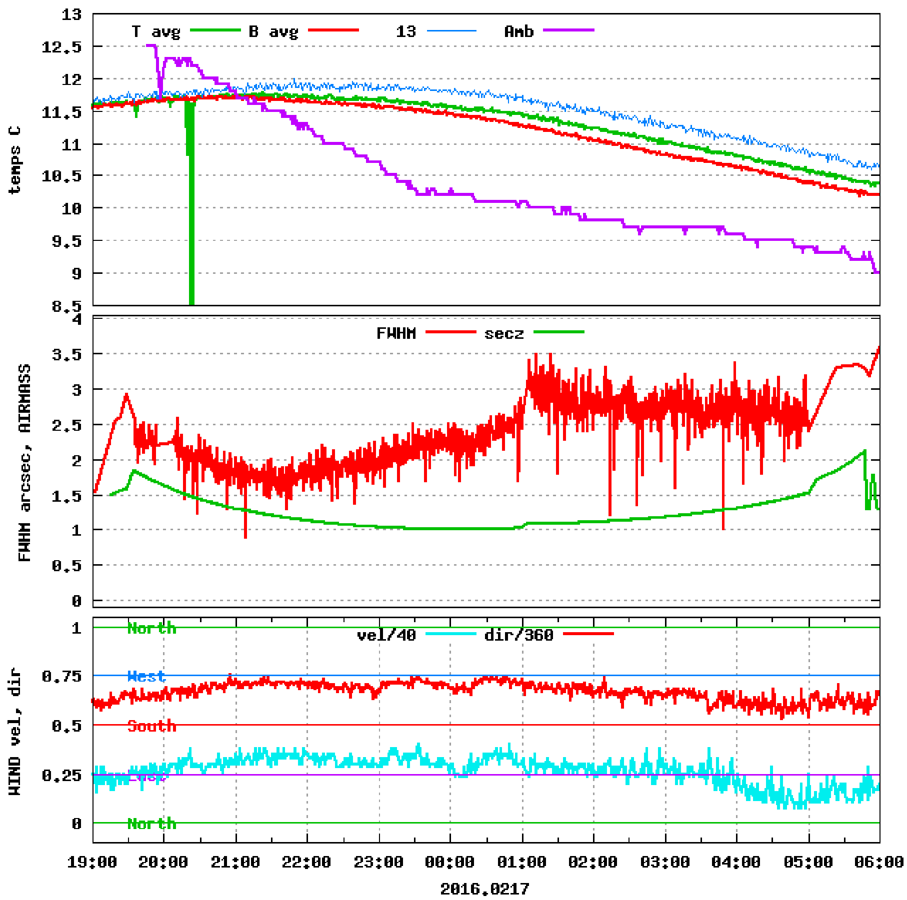


Fig. 2.— Temperature and FWHM for the night of 17 February 2016. Labels for the top and middle panels are described in the caption for Fig. 1. The drop in ambient temperature correlates well with the rise in the FWHM in spite of the drop in secz. When it is within about 1C of the mirror temperatures, the seeing improves, only to rise again as the temperatures diverge. Bottom panel: "wind/40" and "windir/360" are the wind speed and direction scaled by 40 mph and 360 deg, respectively; horizontal lines are labeled with the cardinal directions.

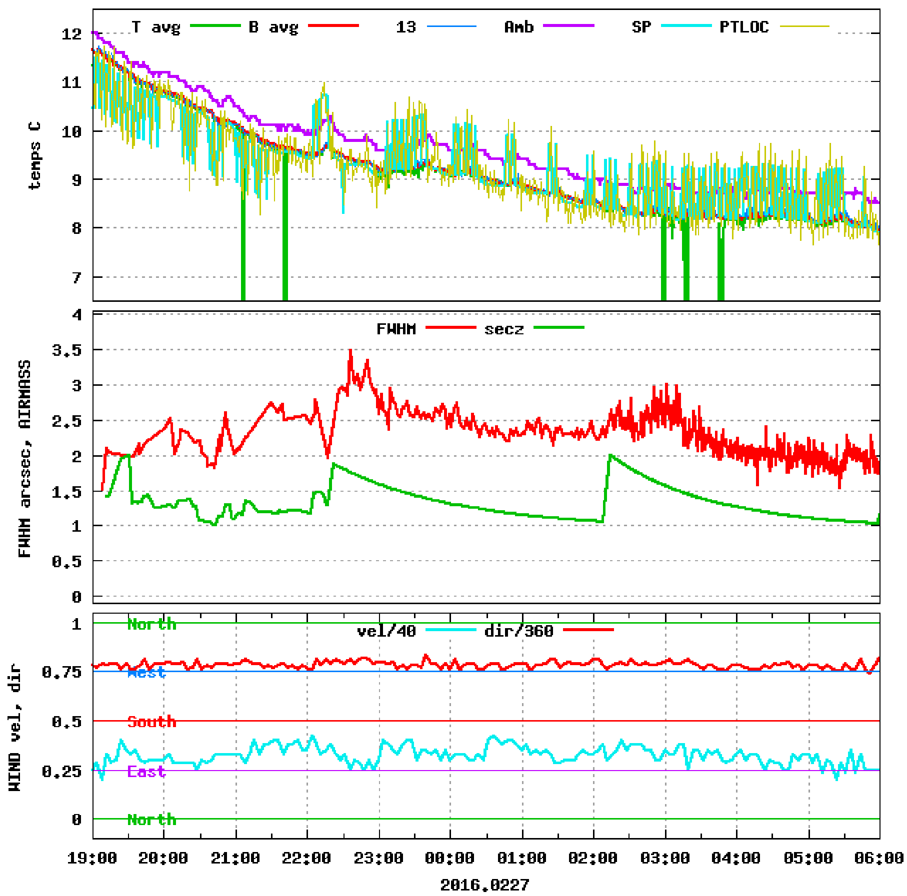


Fig. 3.— Temperatures and FWHM for the night of 27 February 2016, when the wind was fairly steady in speed and direction. Labels for the top and middle panels are described in the caption for Fig. 1. Labels for the bottom panel are described in the caption for Fig. 2. FWHM correlates positively with secz. The first steady drop in secz corresponds to a transit, and the sharp rise and posterior decay in secz at about 02:00 corresponds to a different transit.

Conclusions

The histograms show tails to FWHM values larger than 5 arcsec. Spot checks of images with such high FWHM confirm that the images were not out of focus, and seeing was as reflected by the FWHM.
The image quality remains poorer than we hoped after we replaced the mirror.
We will address this situation by taking the following steps:

- Measure FWHM several times on nights when the schedule allows it, to make sure the focus vs. temperature adjustments that we use are not affecting FWHMs.
- Use the WFS about once a month, to monitor the properties of the optical system.
- Build a DIMM, perhaps using an existing C-14 that sits at the visitor center, to obtain a separate measure of the seeing near the 1.2m.