The Throughput of the APO 3.5m After Realuminization

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Abstract

We have measured the throughputs of the APO 3.5m after the recent realuminization of the primary, secondary, and tertiary mirrors. We used DIS and GRIM II to make measurements from 3500Å to 2.5 micron. The throughout has increased at all wavelengths and the improvement is most spectacular in the blue. At 4000Å the improvement is a factor of 3.7, at 4800Å a factor of 2.7, at 6000Å a factor of 2.1, and between 8000Å and 1.6 micron a factor of 1.4, and at 2 micron a factor of 1.2. Other than the known UV problem with DIS, the throughput of the telescope and instruments appears to be excellent. The telescope mirror reflectivities are estimated to be about 0.93 in the blue, 0.86 in the red, and 0.95 in the near infrared.

1 Throughput Measurements

On the night of 30–31 January 1997 we obtained throughput measurements for the APO 3.5m with DIS and GRIM II. We report these measurements here. Please send comments to `mledlow@nmsu.edu` or `awatson@nmsu.edu`.

1.1 DIS

We obtained a 20 second slitless, low-resolution spectrum of the spectroscopic standard star Feige 34 at an airmass of 1.02. This star has published flux measurements out to 1 micron, so is useful for examining the throughput of the combined telescope+spectrograph over the entire free spectral range. For a description of the data reduction methods, see the document *Results of Engineering Tests on the Dual-Imaging Spectrograph*, written last year by this group, which presents a measurement of the throughput as of April 1996 and documents several concerns with DIS.

As a reminder, the throughput measurements made 9 months ago were anomalously low (peak of about 8–9% for the combined telescope plus spectrograph system). Assuming quoted values for the throughput of the spectrograph components (26%) from Jim Gunn, this low value required that the mirror reflectivities were degraded to below 70% at each reflection. We have all been anxious to discover the level of improvement as a result of the recent mirror realuminization. Bruce Gillespie set aside a half-night of engineering time on 30–31 Jan for this purpose, and miraculously, the sky conditions were photometric all night. Without further ado, here are the results.

The throughput appears to be up by a factor of ~ 2.4 on the blue-chip from measurements made 9 months ago. On the red side (shortward of 8500Å), the efficiency is up by a factor of ~ 2.1. The peak efficiency in the blue is 20.5% at 4850Å (near $H\beta$, which is approximately the blaze-wavelength of the grating), and 16.8% on the red side at $\sim$ 6600Å (near $H\alpha$, also near the grating blaze). In the near-IR (redward of 8500Å), however, the improvement is only on the order of 35%. See Figure 1 for the complete picture. One can see a general trend where the peak efficiency has shifted blueward from the measurements last April. On the red side, the peak efficiency was measured at 7100Å last April, and has now shifted to 6600Å. Similarly, the throughput at 4000Å is actually up by a factor of 3.7!

Using the spectrograph throughput numbers supplied by Jim Gunn (dichroic transmission/reflectivity of 0.9, field optics transmission of 0.97, col-

Table 1: GRIM II Zero Points at 1.5 Airmasses

Date	J	H	K'	K_s	K
1995 Dec 08	22.85	22.66			22.07
1996 Apr 29	22.98		22.20		
1997 Jan 31	23.31	23.05		22.37	22.24

limator transmission of 0.98, gratings efficiency of 0.6, camera transmission of 0.92, CCD QE of 0.5–0.6) with a total near 26%, the approximate mirror reflectivities (assuming all mirrors are equal) are 93% in the blue and 86% in the red. If the spectrograph throughput estimates are overestimated, these values are lower limits.

As expected, the efficiency of DIS still drops precipitously in the UV.

1.2 GRIM II

We measured zero-points at 1.5 airmasses for UKIRT standards 15, 23, and 27 observed between airmasses of 1.1 and 1.9. These measurements are 10 arcsec diameter apertures under photometric conditions with 1.5 arcsec seeing. The 1 sigma uncertainties in our measurements are about 0.01 mag. The zero-points are shown in Table 1.

We chose 1.5 airmasses as our reference to minimize measurement errors and because it is impossible to extrapolate to 0 airmass using measurements between 1 and 2 airmasses; the extinction law in the near infrared is severely non-linear (see Manduca & Bell 1979, PASP, 91, 848 and Young, Milone, & Stagg 1994, A&AS, 105, 259). We elected not to use the K' filter as much of its bandpass lies in the low transmission region between the H and K windows.

Our zero-points can be compared to those measured by Mike Ledlow on 1995 Dec 8 and James Rhoads on 1996 April 29, converted to the same airmass. These zero-points are also shown in Table 1. It can be seen that the thoughput has increased by a factor of 1.4 at 1.2 micron and 1.6 micron and about 1.2 at 2 microns. The improvement at 1.2 micron is roughly consistent with the improvement above 0.8 micron seen with DIS.

We can estimate the integrated QE the telescope plus and GRIM II at 1.5 airmasses assuming:

1. An extinction of about 0.35 mag at 1.5 airmasses (Young, Milone, &

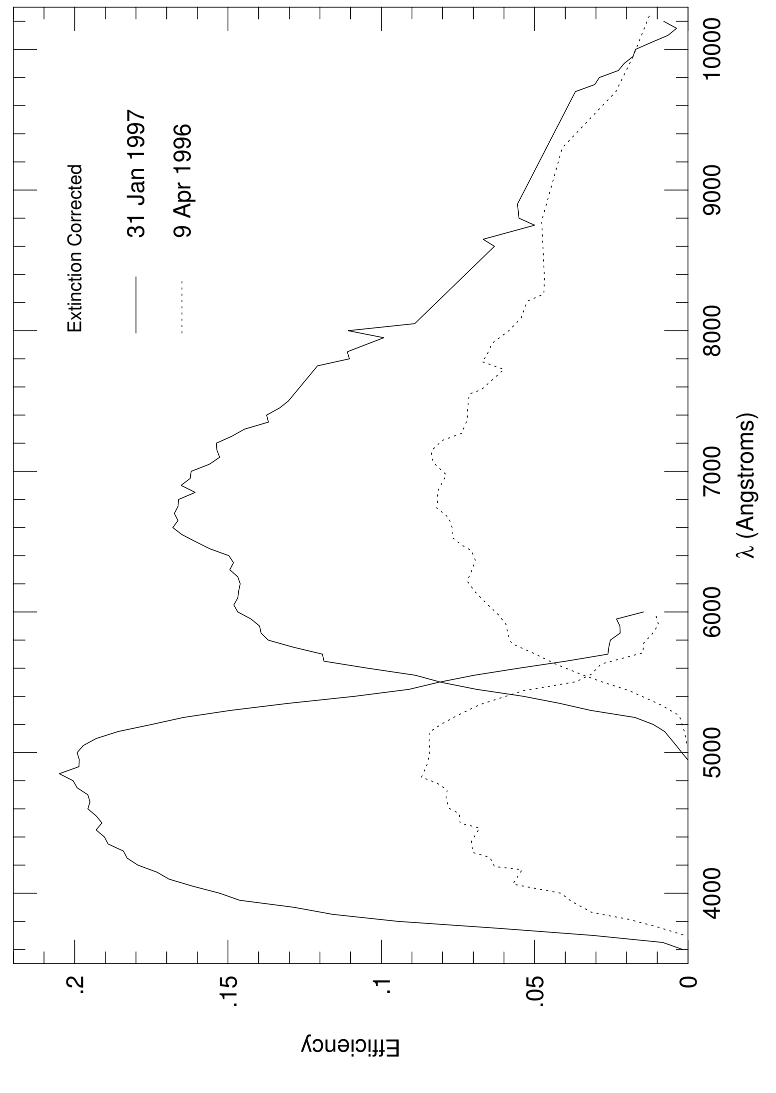

Figure 1: Comparison of throughput efficiency as a function of wavelength before and after mirror realuminization.

Stagg 1994);

2. Flux zero-points from Bessell & Brett (1988, PASP, 100, 1134);

3. A 3.4 m mirror with 10% central obscuration;

4. Integrated transmissions of 0.221, 0.276, 0.300, and 0.305 microns for the J, H, K_s, and K filters from the draft GRIM II handbook (Watson, Hereld, & Rauscher 1997).

This gives 0.37 at J, 0.50 at H, 0.50 at K_s, and 0.46 at K. We can estimate the telescope mirror reflectivity at 2 microns assuming:

1. A peak QE of 0.7 for the detector at K;

2. A combined transmittance of 0.83 for the window and eight lenses of GRIM II (GRIM documentation);

3. A reflectivity of 0.95 for the single fold-mirror in the $f/5$ camera.

This gives mirror reflectances of 0.94 using the K QE and 0.97 using the K_s QE. There is a 3 sigma uncertainty of 0.05 these estimates because of uncertainties in zeropoints (0.03), extinction (0.10) and the filter curves (0.10).

Acknowledgements

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