Replacement of the FLWO 1.2m telescope primary mirror

1. Introduction

The FLWO 1.2m telescope is currently an essential tool for CfA scientists studying time variable phenomena including transiting exoplanets and supernovae despite the fact that its primary mirror has deteriorated significantly. About 30% of the primary's surface is visibly damaged to the naked eye, and much of the surface is revealed to be defective in optical tests. If we do nothing, the telescope will be unusable in a few years. We therefore propose to replace the primary with a newly cast and polished mirror made by the highly capable Steward Observatory Mirror Laboratory (SOML) from the same Ohara E6 borosilicate glass used for the MMT, Magellan, LBT, and GMT primary mirrors.

Even with the deteriorated optics, the 1.2m has been oversubscribed by 25 to 50%. A properly functioning telescope will have considerably higher sensitivity due to better image quality, higher reflectivity, and considerably lower scattering. This increased sensitivity and support for automated scheduling and observing will open exciting new opportunities with the 1.2m. Hardware upgrades required for automated operation will also be completed by the end of calendar 2009 and software for automated scheduling and processing will be completed by mid-2011.

2. Scientific Justification

2.1. Current Science

A search of the ADS reveals the number of publications that used FLWO 1.2m data between the start of 2006 and August 2009 is 118, which compares very well with other meter-class telescopes such as the SMARTS 1.3m telescope in Chile (33 publications) or the Hall telescope at Lowell Observatory in Flagstaff (20 publications). The following are highlights of current projects.

- Transiting Exoplanets

  Lately, the telescope has had its highest production in high-accuracy photometry of exoplanet transits at optical wavelengths, to confirm detections by HATnet and MEarth at FLWO, or by projects at other observatories. The majority of the publications based on 1.2m data are related to exoplanets.

- Supernovae

  The CFA Supernova Group has obtained multiband photometry of several hundred supernovae with the 1.2m. They acquired the CfA3 SN Ia sample in the period 2001-2008 (Hicken et al. 2009, ApJS in press; H09). CfA3 comprises over 11,500 observations. Most recently, this sample has yielded improved constraints on the dark energy equation of state parameter, w (Hicken et al. 2009, ApJ 700, 1097).

- Other Projects

  In addition to transient observations, the telescope is used for a wide variety of studies, as illustrated by the titles of proposals with time awarded in the September-December 2009 trimester: "Revealing dust formation in naked supernovae with FLWO 1.2m," "Exotic explosions and eruptions: new transient phase-space with Pan-STARRS," "Identifying and monitoring GRB afterglows with the FLWO 1.2m," "Monitoring lensed quasars: microlensing and time delays," "Periodic photometric variability in rapidly rotating ultra cool dwarfs," "Supernova light curves," "Optical photometry of the Orion cloud complex," and "Young AB star disks in Cygnus X."

2.2. Future Science

Time-domain studies have played a major role throughout the history of the CfA, including in the discovery and classification of various types of variable stars, gravitational lensing and microlensing, exoplanet transits, and SNe. However, it is only recently that *all-sky* time-domain surveys at optical and radio wavelengths are coming online, with the goal of characterizing variable and transient objects over a new range of timescales and luminosities. The Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) and the Murchison Widefield Array (MWA) – both of which include the CfA as a major partner – will usher in a new phase of time-domain astronomy. The scientific body at the CfA is well positioned for this opportunity, hosting astronomers with a wide range of interests in transient and variable objects.

Pan-STARRS, MWA and similar facilities are capable of finding an unprecedented number of diverse transient or variable sources. However, a physical understanding of these objects requires detailed follow-up studies. The FLWO 1.2m has a crucial role with its ability to respond promptly to alerts of new transients discovered by Pan-STARRS, MWA, and other facilities including X-ray and gamma-ray satellites. Once its automation is completed, the 1.2m will respond to transient alerts with minimal human intervention.

We envision the 1.2m as the cornerstone in the network of follow-up facilities that will be used to chase newly discovered transient and variable sources. Through prompt multi-band optical imaging, the most intriguing transients can be identified based on their spectral and/or temporal evolution and passed on to larger CfA facilities for detailed follow-up. For example, subsequent observations will include those from (i) the FLWO 1.3m automated PAIRITEL facility to constrain the near-IR emission component, (ii) the FLWO 1.5m and MMT to provide spectroscopic diagnostics and redshifts for the new transients, and (iii) Magellan observations to trace the evolution into the late phase once the transients have become too faint for the smaller CfA facilities. This approach is essential given the expected large numbers and diverse types of new transients that Pan-STARRS and MWA will find.

3. The FLWO 1.2m telescope

The 1.2m is an f/8 Ritchey-Chrétien reflector, with a honeycomb borosilicate f/1.9 primary mirror. DFM Engineering designed and built it for SAO in 1990.

The primary mirror cell is equipped with a temperature-control system that maintains the temperature of the primary within 0.3°C of the ambient temperature in the chamber. The support system for the secondary mirror is a Physik Instrumente hexapod that allows full remote control of the position of the secondary mirror for collimation. The camera available at the telescope since 2005 is Keplercam, with a high-quality, single-chip 4Kx4K CCD.

4. The FLWO 1.2m primary mirror

The mirrors require re-aluminization every 2 years. The surface of the front plate appears susceptible to acid etching during aluminum stripping. Zones of high scattering and "orange peel" are visible on this surface after aluminization (see Fig. 1), covering about 30% of the surface. Corresponding losses due to scattered light are at least 30%. The damage penetrates the glass as is readily visible when the aluminum is stripped. Thus, no amount of polishing will solve this problem.

Deborah Woods designed and built a Shack-Hartmann wavefront sensor (WFS) for the 1.2m telescope as part of her PhD thesis. We obtained images with the WFS on 16 June 2006. Fig. 2 (left panel) shows one of the images. For comparison, the right panel shows a comparable image for the 1.5m telescope (DW modified the WFS for the 1.5m). Both panels should be similar to each other. The differences are striking: several sub-images are missing in the regions of highest surface degradation and many are distorted and dispersed, to the point of preventing an accurate measurement of the wavefronts. A limited analysis showed that the primary has severe aberrations that cause the poor imaging.

The current primary mirror provides an image of about 2.5 arcsec FWHM. A properly functioning mirror will provide seeing-limited images of about 1 arcsec FWHM. Such images will yield much greater sensitivity for faint object photometry, and allow much improved star/galaxy or star/star separations for SNe, GRBs, and gravitational lenses.

5. Replacement Plans

The replacement primary mirror will have an optical design identical to that of the current mirror with tight optical performance specifications to ensure image quality limited only by site seeing. Construction of an identical mirror will allow us to continue operations until the replacement is ready.

The timescale for the replacement project is 2 years. In Phase 1, SOML will first produce detailed drawings of the mirror and then cast the blank after our review and acceptance of the drawings. In Phase 2, SOML will polish the mirror to our specifications. Jeff Kingsley (SOML) has proposed a budgetary estimate for the project (attached), for a total of $715,000.

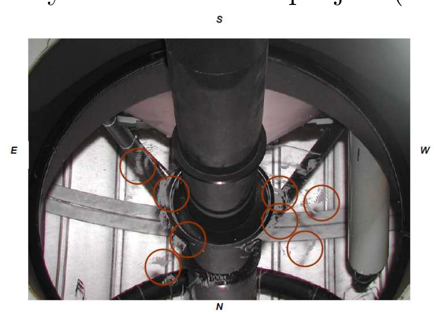

Fig. 1.—: FLWO 1.2m primary on the telescope. Circles indicate the worst areas of degradation.

Fig. 2.—: WFS images for the 1.2m (left) and the 1.5m (right).