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The Virgin Islands robotic telescope

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Abstract. The Etelman Observatory of the University of the Virgin Islands is the southernmost and easternmost optical observatory in the United States. The observatory is located at an elevation of 420 meters on the island of St. Thomas, US Virgin Islands. The site has exceptionally good seeing (frequently better than 1 arc-second), dark skies, and the ability to reach deep into the southern hemisphere and to plug the northern-hemisphere longitude gap between the US and Europe. Astronomers at the College of Charleston, South Carolina State University, and the University of the Virgin Islands have formed a consortium to refurbish the facility, conduct detailed site surveys, purchase a 0.5-meter telescope and instrumentation, and operate the facility robotically. The telescope, instrumentation, and dome have all been installed, and we are remotely obtaining commissioning observations. Our operations mode (manual, remote-controlled, or fully robotic) will simultaneously support our research, participation in multi-site campaigns, and the educational and outreach missions of our institutions. Further details are available at http://astro.uvi.edu/.

Key words: telescopes: robotic – instrumentation – observatories

1. Why chose a robotic observatory site in the Virgin Islands?

The US Virgin Islands is the southernmost and easternmost location in the US. At 18° North, it is close enough to the equator to provide coverage of most of the southern sky and all of the northern sky. At 65° West, it fills a longitude gap between observatories in the Canary Islands and those in the western US. Filling this gap makes continuous coverage of a celestial target over a 24-hour cycle far more likely.

The atmospheric conditions in the Virgin Islands are remarkably predictable and stable. We expect routine seeing conditions of about 1 arc-second (the worst we've measured is 1.7 arc-seconds). The diurnal weather cycle is far more prominent than the annual cycle. The sky is free of mid-level and high-level clouds nearly every night from about 2 hours after sunset until about sunrise. Low-level clouds form in the evening from orthographic lifting. These pose a major problem only when there is another mountain upwind. Therefore, time of day and wind direction are the best predictors of local conditions at the observatory.

Our site on Crown Mountain in St. Thomas, US Virgin Islands also offers more practical advantages. There is an existing facility owned by the University of the Virgin Islands (UVI) on the site. It has adequate road, power, water, and other supporting infrastructure. The existing telescope pier is adequate for our robotic telescope. The College of Charleston (CofC) and UVI have a long-standing bilateral agreement governing student and faculty exchanges, and students from CofC have been conducting astronomical and meteorological research at the site for the past 8 years.

There are some distinct challenges to overcome in this tropical paradise. Weather conditions change quickly and locally on tropical islands. Humidity is high year round (80 to 90%), and low-level evening clouds often deposit small amounts of rain or fog with very little warning. Hurricanes pass frequently in the late-summer months. Like other island sites, everything must be flown or shipped in, which adds to the expense and complexity.

2. Description of the facilities

Properties of our telescope (Figure 1) and the rest of our observatory system are summarized in Table 1 and described below. More information about the history and status are given by Neff et al. (these proceedings), and our initial science plans are discussed by Giblin et al. (these proceedings).

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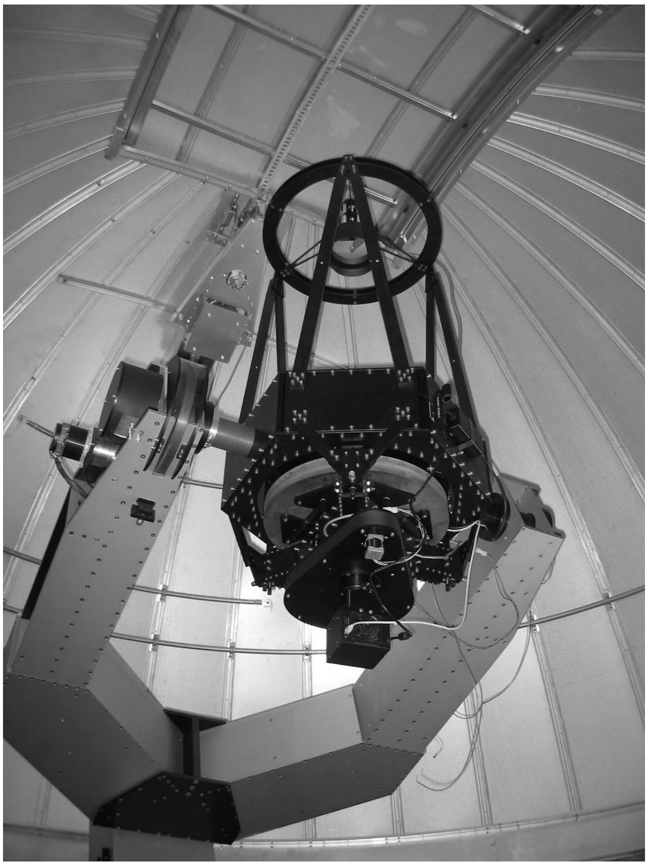

Fig. 1. Torus Precision Optics (now Optical Mechanics, Inc.) CC05 telescope at the University of the Virgin Islands. Note the long equatorial fork allowing observations to the horizon at 18° North latitude. Also visible are the 12-position filter wheel and the Finger Lakes Instruments CCD camera. A single serial cable from the control room controls the entire observatory system. A second USB cable controls the camera. Optical encoders on the RA and Dec axes provide 0.1" precision. Secondary focus, filter position, and dome position are "open-loop" control systems driven by extremely reliable servo motors.

2.1. Telescope

Combining contributions from the College of Charleston, South Carolina State University, and an NSF grant to the University of the Virgin Islands, we purchased a 0.5-meter (CC05) telescope from Torus Precision Optics (now Optical Mechanics Inc.). The equatorial mount has extra long forks that permit observations at low altitudes despite the low latitude of the observatory. All work is done at the f/10 classical cassegrain focus. Torus had already delivered approximately 10 custom-built telescopes and had a plan to mass produce "Rigel" observatory systems, so our telescope was designed with "turn-key" robotics in mind.

2.2. Instrumentation

Our initial instrument is optimized for wide-field imaging through standard photometric filters. The 12-position filter wheel was provided by Torus as part of the telescope design. Currently, we have 50mm Johnson-Bessell UBVRI filters along with clear and neutral density filters. We are purchasing narrow-band filters that will enable other science programs. The CCD camera is an IMG model purchased from Finger Lakes Instruments. It is thermoelectrically cooled to about 50° C below ambient. Maximum read time (full array, 1x1 binning) is about 80 seconds, but the USB-controlled camera can be used with almost any subarray or binning factor.

Table 1. Properties of the Virgin Islands robotic observatory

	Location
latitude	18° 21' 09" North
longitude	64° 57m 24s West
elevation	420 m
	Telescope
manufacturer	Torus Precision Optics
primary aperture	0.5 m
principal focus	f/10 Classical Cassegrain
	Instrumentation
camera	Finger Lakes Instruments; IMG
CCD	back-illuminated Marconi 42-40
coating	broad-band
cooling	thermoelectric
pixels	2048×2048
pixel size	13.5μm × 13.5μm
field of view	18.5' × 18.5'
12-position Filter Wheel	UVBRI, ND, Clear

The camera contains a Marconi 42-40 CCD with 2048x2048 13.5 μm pixels. With a mid-band coating, thinning, and back illumination, it yields a quantum efficiency over 80% from 450 to 750 nm and over 90% from 500 to 650 nm. At the f/10 focus, our field of view with this CCD is 18.5×18.5 arc-minutes.

2.3. Observatory infrastructure

We enclosed the telescope in a 5 meter "Ash" Dome. The enclosure building was reinforced to better withstand severe weather during hurricane season, The observatory sits atop the Etelman house, which has been renovated to provide an air-conditioned control room and dormitory space for visiting astronomers. It also includes a class room and meeting room. The facility has adequate water, electrical power, roads, parking, etc. An auxiliary generator has been ordered. Further renovations are being discussed, but all parties agree that they must not degrade the astronomical value of the facility.

2.4. External inputs to robotic control system

We have high-speed internet access via a microwave link, a local area network connecting 5 computers, and a wireless network throughout the observatory. Only 1 computer is actually used to control the telescope. The others are used for data analysis, data storage and staging, web servers, and as backups for the telescope control computer. With the exception of a PC running windows to communicate with one of the weather stations, all the computers have linux operating systems. A GPS receiver is used to continually update the clock of the telescope control computer.

We currently have two weather stations at the site. We also share data (not real time) with other weather stations on St. Thomas in order to study the "microclimate" of the island. The telescope system purchased from Torus includes a Davis weather station integrated into the telescope control system (with a range of alarms or shutdown flags allowed for any parameter). The Davis measurements are also logged to a file every 2 seconds. We intend to retain these log files for future high-time resolution meteorological studies. We also installed a Campbell weather station on a 10 meter tower upwind of the observatory. Two minute averages are stored in an on-board data logger and transmitted via a microwave link to a pc in the control room. These are not yet directly integrated into the control system, but they are available for real-time analysis via our web server. We are installing a web-cam that will provide a view to the east, giving advance warning (by at least a few minutes) of the local weather conditions.

2.5. Control system

2.5.1. Hardware

The principal distinguishing characteristic of the Torus observatory system is its control system. Each "axis" is equipped with a Clear Sky Institute motor controller integrated circuit card. The 5 CSIMC cards are ethernet coupled, and a single serial cable couples the telescope/dome to the control computer. The RA and Dec axes are closed-loop control systems using optical encoders with 0.1 arc-second resolution. The focus, filter wheel, and dome azimuth are open-loop. Each axis is driven with a dc servo motor and receives input from a magnetic "home" position switch. The RA and DEC axes are also equipped with limit switches on each end of travel. While this arrangement minimizes the wiring and control computer requirements, it is not presently amenable to full manual control with a handpaddle. Instead we use a laptop computer at the telescope with a USB keypad expansion to simulate handpaddle control.

2.5.2. Software

The observatory system is controlled with the Talon (formerly OCAAS) software, originally written by Elwood Downey (Clear Sky Institute). This linux-based software is now open source. Local and remote operations are identical; you simply use an x-windows or vnc connection to the control computer. Robotic operations are conducted from the lower level CSIMC software (Talon simply provides a user-friendly interface). X-windows based packages can be used to control the observing (XEPHEM and XOBS), instrumentation (CAMERA), and robotic scheduling (TELSCHED). The software also includes various command line tools for scheduling, planning, engineering, data analysis, etc.

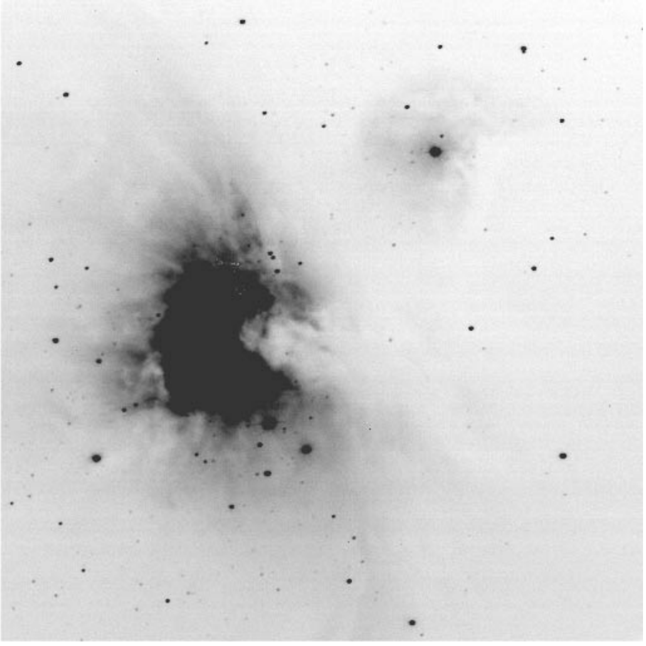

Fig. 2. Our "first-light" image, a 1-second white-light exposure of M42 obtained in January 2004 (no flat fielding or other image processing).

3. Status and plans for initial science operations

The telescope was installed in November 2003. Initial tests were completed in January 2004 (see Figure 2). Further testing had to await the automation of the dome, which was completed in July 2004. We plan a full engineering evaluation (heavily relying on remotely-conducted observations) of the system during the Fall 2004.

We are continuing detailed meteorological and microclimate studies to improve our weather triggering algorithms. We would be happy to share our experiences with others interested in tropical sites, and we would accept any available advice that would contribute to safe and reliable robotic observations.

Initial science operations include a key project to monitor optical counterparts of gamma-ray bursts (see Giblin et al., these proceedings). We plan to have fully robotic capability by the time the Swift spacecraft begins actively providing coordinates of gamma-ray bursts. The telescope will be used both for faculty and student research and for the educational/outreach missions of our institutions. We remain open to new ideas and available for new collaborations, and we plan to make the telescope available for coordinated observing campaigns.

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