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Abstract

Preliminary results of the McDonald Observatory Skycam Project are presented. The Skycam Project seeks results by implementing an inexpensive sky camera with the freely available *Wolf* image analysis software. The robust software drastically enhances the capabilities of the camera, making the combination a financially viable option for small observatories. The camera's benefit for remote observatories is discussed.

Introduction

Monitoring the dynamic night sky is a challenge to astronomers who depend on clear skies for important scientific observations. The primary difficulty of observational decision making is the lack of quantitative information for parameters like atmospheric transparency, the fraction of visible and invisible clouds, and the background sky level. Additionally, the conditions of the night sky can change on very rapid time scales, increasing the difficulty of decision making. For observatories that host robotic and remote telescopes, monitoring the dynamic night sky is paramount to the safety and success of their observations. Wide angle sky imagers can solve these problems by monitoring the sky continuously throughout the night with a high sensitivity CCD camera and a wide angle lens.

The selection of all sky cameras has historically been limited to custom made full frame fish eye cameras which use expensive optics and CCDs. The benefit of a sky camera exceeded their high cost for only the largest observatories with substantial budgets. Recently the popular Night Sky Live network introduced their “Continuous Camera”, Concam, for sale to large observatories around the world (Nemiroff, 1999). The Concam is a typical full frame fisheye lens and CCD combination sold for approximately $20,000 (Night Sky Live, 2006). Included with the Concam is the pipeline data processing, data storage, and website hosting. The CTIO has developed their own all sky imager *TASCA* which cost more than $15,000 to implement (Smith, 2001). Alternative sky monitoring systems are not cheaper. The Apache Point Observatory's infrared cloud detector is extremely effective in both low and high light levels(Smith, 2001). Unfortunately its $100,000 price tag makes similar systems largely inaccessible to most observatories.

Recently the Santa Barbara instrument group introduced a wide field sky camera, marketed primarily as a meteor camera. This sky camera is not a typical full frame fisheye; rather it has a 90 x 140 degree field of view. The price of the camera reflects its inexpensive optics and CCD. The unit sells for a mere $2,000. The low price of the camera coupled with its ability to meet the goals outlined by the McDonald Observatory made the camera a favorable addition to the Observatory. The hope for the camera was to deliver a maximum amount of information from each image, including photometry information for bright stars throughout the field, transparency maps, and background maps. The existing Wolf software by the Night Sky Live was adopted for image analysis because of its robust feature set.

Observations

Observations were made on 5 clear nights starting 2006, July 27 to 2006, Aug 9 using the SBIG Skycam. Images were taken at 45 second exposure times, spaced by the download time of the images, roughly 1 second. The sidereal times of the images were recorded and added to the fits header for future reference.

The Skycam is equipped with a red filter which completely covers the primary lens. The desire for a clear filter was noted for its higher throughput, and may replace the red filter in the future. The CCD is enclosed inside a rigid metal box, 1 foot in length along its long axis. The box has a hinged lockable door for access to the CCD and cables. The CCD camera is an uncooled, shutterless version of the SBIG ST-402ME.

Analysis

The goal of image analysis and data reduction was to obtain animations of the night sky in GIF format. The steps that transformed a set of raw FITS images to an animated GIF are outlined below. First a set of dark frames of exposure times equal to the sky images were median combined. The median combined dark frame was subtracted from each sky image. The resulting sky images were devoid of bias, dark, and hot pixels. The corrected sky images were then reduced with the *Wolf* software (Shamir, 2005) to yield annotated JPEG sky images and background maps. JPEG sky images are identical to the FITS images, but scaled in dynamic range and compressed in file size. The background maps were created by subtracting stars from sky images, where stars were defined by a certain criteria of standard deviations above background and other thresholds for profile and width. The JPEGs were then converted to single frame GIFs using the program *DJPEG*. Each GIF was then added to the existing animation using the program *Gifsicle*. The animation was uploaded to the web on the nexus server: nexus.as.utexas.edu/mgully, where they were immediately available to the public. The process was repeated until all FITS images for that night had been added to the animation.

Some measured properties of the CCD are listed in Table 1. The CCD properties were measured with a standard procedure- biases were median combined from a set of 33 zero second exposures, darks were median combined from a set of nine 45 second exposures. Flats were not taken due to the difficulty in evenly illuminating the CCD behind a wide angle lens.

Discussion

The CCD parameters were slightly higher than expected. The high bias level reduces the dynamic range of the detector, since more than 9000 analog to digital units (ADU) are thrown out before every image is recorded. The high read noise is significant since it may be the chief noise source when compared to the dark sky background. Also notable is the high dark current. Since the camera is uncooled, the CCD falsely identifies thermal noise as spurious photon detections. The dark current was noted to change slightly during the night. Since the camera has no shutter it is impossible to take dark frames throughout the night. Cosmic rays have not appeared strongly in animations, since a fuzzy logic system used by *Wolf* has been shown to remove >97.5% of cosmic rays (Shamir, 2005b). Once images are dark subtracted, a substantial improvement in animation quality is noted, as seen in animations on the website.

Images have exhibited an assortment of celestial and atmospheric phenomenon. In one example animation from 2006 August 7, a wavelike structure can be seen very clearly, which was not seen with by human eye. Some have attributed such waves to mesospheric gravity waves(Smith(b), 1999), or gravito-acoustic waves (ESO, 2006). Other phenomenon observed included satellites, meteors, iridium flares, and clouds. The Andromeda Galaxy (M31) was clearly visible in those frames in which it was inside the field of view. The Milky was almost always visible, and on dark nights would appear to saturate on poorly stretched JPEG images. Lunar illumination of clouds and lens flare were shown to reduce the visibility of an image, although detection of bright stars was still possible.

The Skycam Project is still in its formative stages and awaits additional computer and mechanical equipment to complete the project. However, the preliminary results have been impressive for the minimal investment cost. When compared to all sky imagers of higher price, the Skycam may rank lower, but not 10 times lower. Using the freely available image analysis software has increased the utility of the Skycam by an order of magnitude over a conventional animation system. Future improvements to the Skycam will utilize all the features available on the *Wolf* software. The Skycam may expand to the educational realm by displaying animations of sky motion and celestial coordinates in annotated sky images.

Summary

In summary The McDonald Observatory Skycam Project was successful in meeting the night sky monitoring goals of the observatory. The Skycam Project was established to monitor the dynamic night sky for changes relevant to astronomers, particularly remote observers. The freely available *Wolf* image analysis software was implemented because of its large feature set. Future developments to the Skycam will include more advanced features of this software.

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Tables

Table 1: ST402ME Sky Camera

Quantity	Advertised	Measured
x Width (pixels)	765	765
y Height (pixels)	510	510
Total Pixels	390,150	390,150
Bias (ADU)	-	9865
Gain (e-/ADU)	1.47	1.47
Read Noise (e- rms)	17	31
Dark current(e-/pix/sec)	1 (0 C)	22.8 (Room temp)
Full Well Capacity(e-)	100,000	> 85,790
Maximum Data Number	65,535	65,535