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THE DOME C GATTINI SKY BRIGHTNESS CAMERAS: RESULTS FROM THE FIRST YEAR OF OPERATION

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Abstract. The Gattini-DomeC project, part of the IRAIT site testing campaign and ongoing since January 2006, consists of two cameras for the measurement of optical sky brightness, large area cloud cover, and auroral detection above the DomeC site, home of the French-Italian Concordia station. The cameras are transit in nature and are virtually identical except for the nature of the lenses. The cameras have operated throughout the past two Antarctic winter seasons and here we present the results obtained from the 2006 winter-time dataset of the wide field "All-sky camera".

1 Introduction

We present a brief summary of the Gattini cameras, given a full description of the Gattini-DomeC project is found elsewhere (Moore 2006). Shown in Figure 1 are summaries of the transit cameras starting with the wide field All-sky version that contains a fish-eye lens to obtain roughly 100^o of sky coverage per image. On the right in the same figure is a description of the SBC camera that is identical except for a longer focal length lens that enables deeper exposures over a narrower field, centered on the celestial South Pole.

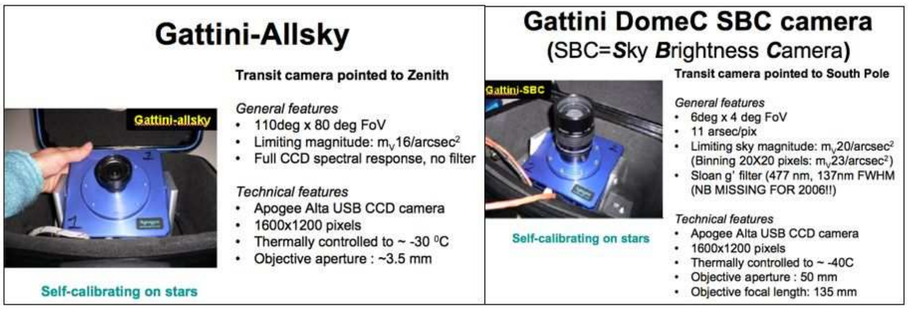

Fig. 1. The specifications for the Gattini cameras are shown for the wide field all-sky camera (left); and for the larger aperture narrow field camera (right).

1.1 Location

For 2006, the cameras were located on the roof of a scientific laboratory near the 30m tower, roughly 1km from the Concordia station in the dark sector. Before the 2007 season, the cameras were moved to the roof of the Concordia station where they reside currently. We have no evidence to show there is a location-dependent effect on the sky brightness magnitudes using cameras of this nature.

2 The 2006 dataset

The cameras have been operational since their installation in January 2006. Each camera takes an image every 5 minutes when the sun is below the horizon that spans the period roughly March to September. The images are saved to local hard disk drives as only a small amount can be transferred off-site via the Iridium satellite network that is largely for status checks. At the end of the season the full dataset is copied at the site and then hand-delivered to the mainland by the winter-over astronomer.

2.1 Data volume

The 2006 dataset is more than 600 Gigabyte in size and has the following statistics:

- 85740 images (total)
- 42431 SBC images
- 43309 all-sky images

2.2 SBC missing filter

After analysis of the returned 2006 dataset and after subsequent discussion with the 2007 winter-over astronomer at the time, it was found that the sloan g' filter was missing from the front of the lens of the SBC camera. The lens had been removed and not been replaced during the previous season. The filter was replaced immediately but only in time for the 2007 winter season. For this reason the results presented here are based on non-photometrically calibrated data, and we await the return of the 2007 data onwards for calibrated photometry.

2.3 SBC window icing

A further complication to this first season was the internal window icing experienced by the SBC camera, not the All-sky camera that has a different window, during the cold winter months. This problem was solved mid-way through the 2007 season by installing a small fan close to the inside of the flat glass window. Unfortunately it meant that much of the SBC data for the 2006 season was too contaminated with icing issues to be useful, a real annoyance as the camera itself performed extremely well, and we rely almost universally on the performance of the All-sky camera for the results presented here.

2.4 Data reduction

We present a summary of the data reduction procedure employed for reduction of data from both cameras. The data reduction was performed at the University of New South Wales.

2.5 Steps

The data reduction, performed using IRAF and a range of bash scripts, can be briefly summarized as follows (1) flat fields were composed for each camera using the variation of stellar magnitude across the field versus catalogue values; (2) A rudimentary coordinate system is added to each image such that they are correctly orientated as shown in Figure 2; (3) stars across the correctly flat-fielded images were identified using *AptAstrom*; and (4) using *AptPhot* aperture photometry is performed on the stars identified in the previous step.

For step (3) above, stars were correctly identified to within 0.13 pixel (1.5 arcsec) rms for the SBC and 0.7 pixel (180 arcsec) rms for the All-sky camera.

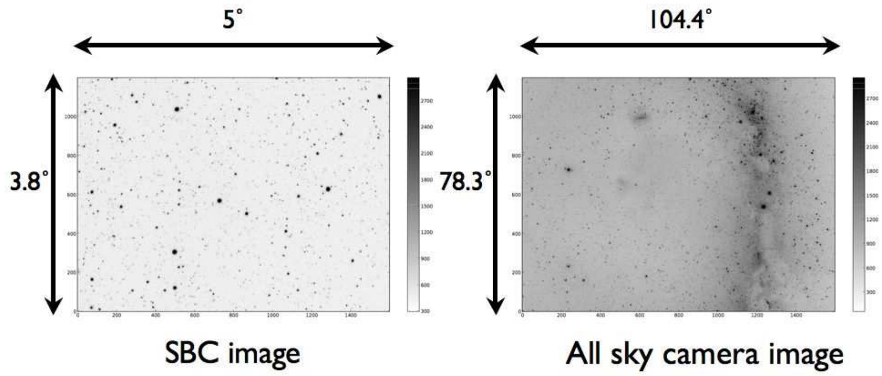

Fig. 2. Correctly orientated and flat-flat fielded images from the SBC camera (left); and the wide field All-sky camera (right).

2.6 Processing time

Roughly 10 to 30sec of processing time is required per image that translates to weeks of CPU time to reduce the entire dataset. In total 22 million star measurements were made (4500 individual stars) to produce a final database a little over 1GB in size.

3 Results

3.1 Optical sky brightness

We present optical sky brightness results for the 2006 All-sky dataset based on roughly 6.5 months of continuous sky monitoring. The magnitude values presented are uncalibrated as the All-sky camera contains no astronomical filter. In addition it employs a (necessary) highly curved dome as the window that is unfortunately a perfect scatterer of stray light into the camera. As discussed in several places the SBC camera incorporates a sloan g' filter and is designed to produce accurate optical sky brightness statistics, but this can only commence with the arrival of the 2007 dataset.

Though many factors affect the visual sky brightness (Kenyon 2007), by far the two largest are the sun and moon. We separate the two effects in the following discussion.

3.1.1 The Sun during a Dome C winter

Figure 3 presents the calculated sky brightness values as a function of solar zenith angle. The data points are color coded using the right-hand scale for moon elevation, the lowest corresponding to an elevation angle of -13^o. The traditional definition of Astronomical twilight at -18^o is marked with a solid line; the true limit of Astronomical twilight at the Dome C high altitude site is more representative at -13^o.

The origin of the scatter in the magnitude values at a solar elevation angle of less than approximately 11^o, around 1 magnitude rms, is not clear at this stage and requires further analysis of the data from both this camera and the SBC. It does not equate to the error in fitting stellar magnitudes across the field that is around 0.1 magnitude, after assuming an offset corresponding to the unfiltered All-sky passband compared to the V band catalogue values. It is possibly a problem with the low-photon count per pixel (the All-sky camera was not designed to measure sky brightness to this level) or a stray light issue due to the highly curved dome window and no camera baffling.

We think it unlikely to be a feature of the site and almost certainly an instrument-introduced effect. We expect that analysis of the 2007 dataset will answer this.

3.1.2 The effect of the moon during a Dome C winter

Shown in Figure 4 are data for sky brightness versus lunar elevation and phase at epochs when the sun is below the astronomical twilight value. It can be seen that the moon starts to increase the sky brightness measurements of the All-sky camera only when close to the horizon, marked with a solid black line in the Figure. There is roughly 3-4 orders of magnitude difference between the brightness values with the moon below the horizon and a dark sky compared to the moon at full phase and maximum altitude.

The large scattering in the data, especially for data corresponding to the lunar elevations above the horizon, in part is due to the scattering from the window of the moon into the unbaffled fish-eye lens. A baffle was added to the All-sky camera in 2007 to reduce the amount of scattering of moonlight and subsequent contamination, in particular for low lunar elevation angles, and again we await the arrival of the 2007 season data to confirm the performance.

3.2 Cloud cover

Cloud cover statistics were derived from analysis of the All-sky camera dataset. It is not always possible to visually resolve the clouds and two methods were employed

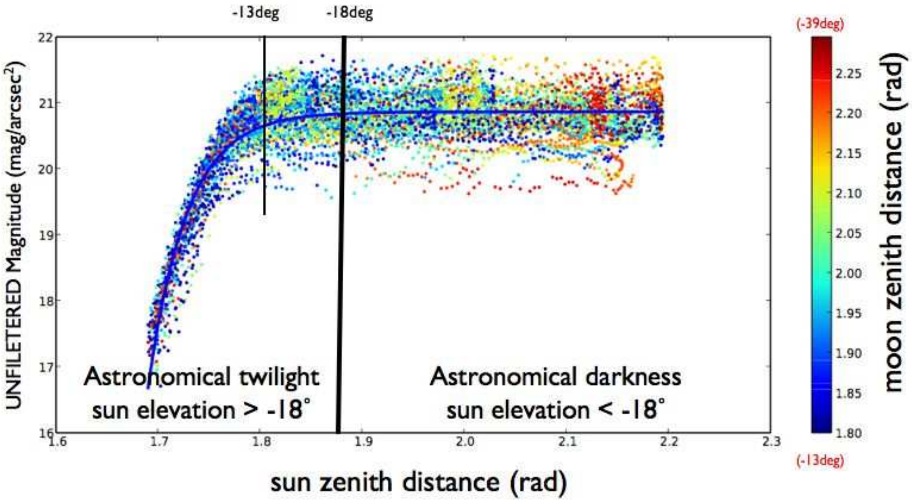

Fig. 3. Optical sky brightness of the winter-time sky above the Dome C site as a function of solar zenith distance. The traditional astronomical twilight condition of -18^o is shown as a solid line and a more representative value of -13^o is shown for the Dome C site. The camera is unfiltered, therefore the sky brightness values are not photometrically calibrated.

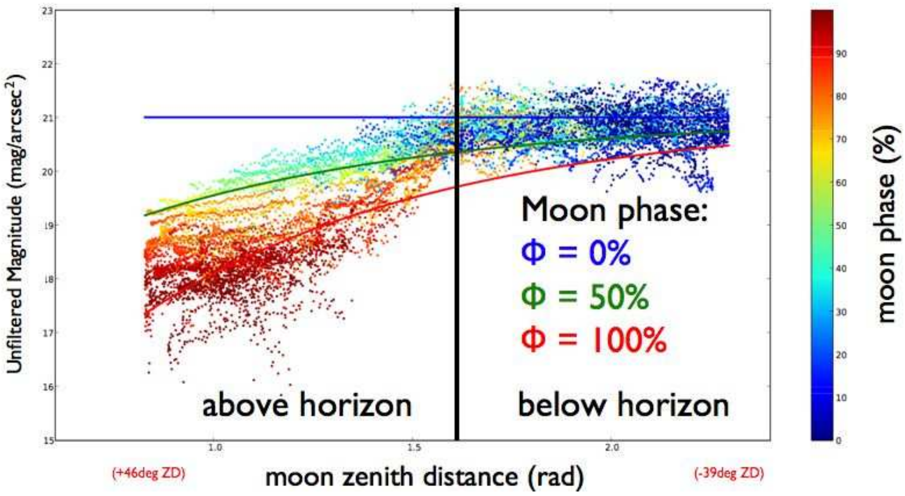

Fig. 4. The effect of the moon on optical sky brightness at the Dome C site as a function of lunar zenith distance and phase. There is no contribution from the sun in this data. The solid black line represents a zenith distance of 90^o.

to automatically calculate the percentage of photometric conditions available from the 40,000 or so stack of images. The images were first analyzed for number of stars per image. An image was classed as photometric if all stars could be identified. The second method employed is to calculate the extinction across the image. If it is low, the image was classed as a low extinction image, again a sign for little cloud cover.

The results for the entire 2006 winter-time dataset are as follows:

- Photometric images: 83%
- Low extinction images: 85%
- Photometric, low extinction images: 79%

These numbers provide a lower bound on the number of cloud free images for the period April 1 to Oct 12, 2006 based on a dataset of over 40,000 images. These values are reasonably consistent with the results presented in Mosser 2007 where a comprehensive duty cycle analysis (based on the visual estimates of cloud cover that were taken during the same season) from an asteroseismology perspective (where bright targets are of interest) was performed. The next stage of analysis for the Gattini data is to combine the 2006 and 2007 All-sky datasets and produce a 2-season duty cycle analysis for a range of target faintness.

3.3 Auroral detection

Neither of the Gattini cameras were designed to detect directly auroral events and cannot produce accurate statistics that any increase in sky brightness is due to aurora. To do this with sufficient sensitivity one can either design a camera adopting a large fish eye lens (eg. ASI, Eriji et al. 1997) with a collimated space for narrow band filters, or use a spectrograph (eg. NIGEL, Kenyon et al. 2006). However, if sufficiently bright aurorae occur within the field of view of the Gattini-All-Sky camera it is possible to identify using structure detection. Only one such event was detected during the 2006 season.

4 The future

The team is extremely excited that the 2007 dataset will shortly arrive containing the ice-free SBC data taken with the sloan g' filter in place. The cameras are soon to be turned on once again for their third season of operation at the Dome C site.

5 Acknowledgements

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