Astrophysics from Antarctica
Proceedings IAU Symposium No. 288, 2012
M. G. Burton, X. Cui & N. F. H. Tothill, eds.

doi:10.1017/S174392131201664X

Winter sky brightness and cloud cover at Dome A, Antarctica

Anna M. Moore[1], **Yi Yang**[2,3], **Jianning Fu**[2], **Michael C. B. Ashley**[4], **Xiangqun Cui**[5], **LongLong Feng**[6,7], **Xuefei Gong**[5,7], **Zhongwen Hu**[5,7], **Jon S. Lawrence**[8,9], **Daniel M. Luong-Van**[4], **Reed Riddle**[1], **Zhaohui Shang**[7,10], **Geoff Sims**[4], **John W. V. Storey**[4], **Nicholas F. H. Tothill**[11], **Tony Travouillon**[12], **Lifan Wang**[3,6,7], **Huigen Yang**[7,13], **Ji Yang**[6], **Xu Zhou**[7,14], **Zhenxi Zhu**[6,7]

[1]Caltech Optical Observatories, California Institute of Technology, 1200 E. California Blvd., Pasadena, CA 91107, USA
email: amoore@astro.caltech.edu

[2]Department of Astronomy, Beijing Normal University, Beijing, China

[3]Department of Physics and Astronomy, Texas A&M University, College Station 77843, USA

[4]School of Physics, University of New South Wales, Sydney NSW 2052, Australia

[5]Nanjing Institute of Astronomical Optics & Technology, Nanjing 210042, China

[6]Purple Mountain Observatory, Nanjing 210008, China

[7]Chinese Center for Antarctic Astronomy, China

[8]Department of Physics and Astronomy, Macquarie University, Sydney NSW 2109, Australia

[9]Australian Astronomical Observatory, Sydney NSW 1710, Australia

[10]Tianjin Normal University, Tianjin 300074, China

[11]School of Computing, Engineering & Mathematics, University of Western Sydney, Locked Bag 1797, Penrith South DC, NSW 1797, Australia

[12]California Institute of Technology, 1200 E. California Blvd., Pasadena, CA 91107, USA

[13]Polar Research Institute of China, Shanghai 200136, China

[14]National Astronomical Observatories, Chinese Academy of Science, Beijing 100012, China

Abstract. At the summit of the Antarctic plateau, Dome A offers an intriguing location for future large scale optical astronomical observatories. The Gattini Dome A project was created to measure the optical sky brightness and large area cloud cover of the winter-time sky above this high altitude Antarctic site. The wide field camera and multi-filter system was installed on the PLATO instrument module as part of the Chinese-led traverse to Dome A in January 2008. This automated wide field camera consists of an Apogee U4000 interline CCD coupled to a Nikon fisheye lens enclosed in a heated container with glass window. The system contains a filter mechanism providing a suite of standard astronomical photometric filters (Bessell B, V, R) and a long-pass red filter for the detection and monitoring of airglow emission. The system operated continuously throughout the 2009, and 2011 winter seasons and part-way through the 2010 season, recording long exposure images sequentially for each filter. We have in hand one complete winter-time dataset (2009) returned via a manned traverse. We present here the first measurements of sky brightness in the photometric V band, cloud cover statistics measured so far and an estimate of the extinction.

Keywords. site testing, surveys

1. Introduction

Dome A is the highest point on the Antarctic plateau and a site of recent and extensive astronomical site testing (Yang *et al.* (2009)). The primary goals of the Gattini Dome A project are to (i) obtain the sky brightness in the B, V, and R photometric bands above the Dome A site, (ii) to measure the cloud cover extent during the 2009 and 2010 winter seasons (later extended to 2011 by the National Science Foundation Office of Polar Programs) and (iii) to provide aurora and airglow statistics. Though the experiment was not necessarily designed with high precision photometry in mind an additional goal became (iv) to perform photometry of bright target stars in the field monopolizing on the unprecedented window function available from such a site. The camera hardware, performance and ambitious journey to the highest point on the Antarctic plateau is described in literature (Moore *et al.* (2010)).

1.1. *Data and reduction*

The camera operated throughout the austral winter seasons of 2009 and 2011, and part way through 2010. During operation the filter wheel was cycled continuously with two exposures taken for each filter, of length 30s and 100s. The results presented here concentrate on images taken with the Bessel V band filter of exposure time 100s taken during the 2009 season. The images were bias and dark subtracted and calibrated using 100 or so of the brightest stars across the field. The IRAF 'apphot' routine was used to perform aperture photometry. Approximately 1000 images per day were collected by the system. A limitation on the data reduction was the absence of an adequate flat field image given the difficulty of obtaining such an image on-sky with such a wide field and the stationary nature of the camera. This will be remedied with the acquisition of multi-filter flat field images given the return of the camera to Caltech in mid-2012.

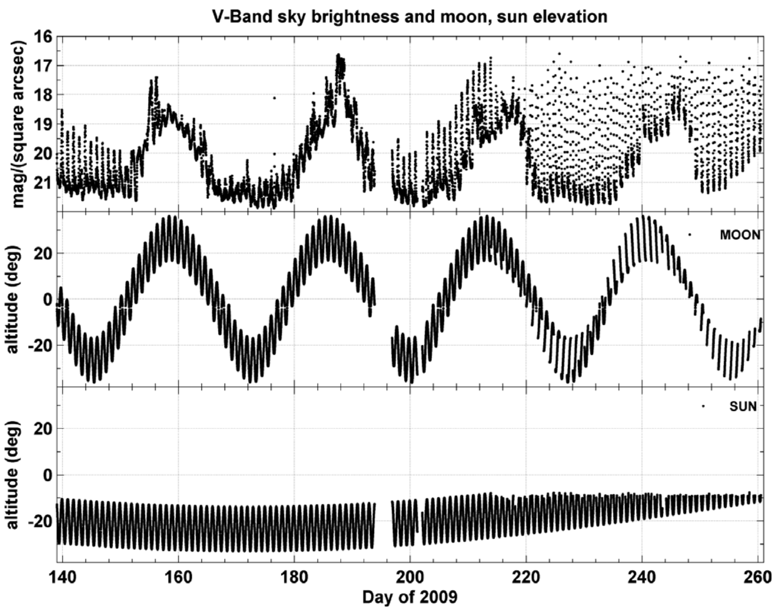

Figure 1. (Upper) Median V band sky brightness in magnitudes/arcsec^2 measured during the 2009 winter season. Recording starts in mid-May 2009. (Lower) Corresponding solar and (middle) lunar elevation are plotted for reference.

1.2. *V-band Sky brightness*

Fig. 1 shows the median sky brightness in V band magnitudes/arcsec^2 for the 2009 austral winter season. The figure shows the corresponding solar and lunar elevation angles for reference. The data has no pre-selection of any form. No attempt as yet has been made to identify areas of low star contamination, and it is acknowledged this could be a contributor, in places, to the median sky brightness displayed in Fig. 1 given the pixel size on the sky is approximately 150 arcsec^2. The general form of the median sky brightness is influenced, as expected, by the lunar monthly cycle and the solar diurnal cycle. However, during periods of low solar elevation and moonless conditions, we see evidence of a minimum of just above 22 magnitude/arcsec^2.

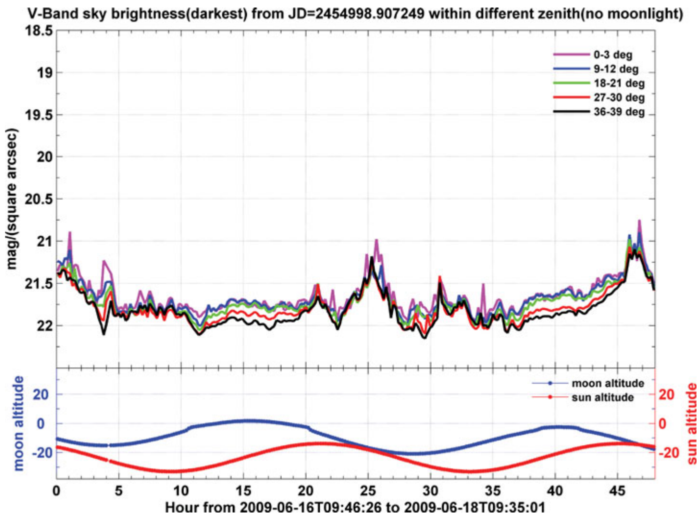

Figure 2. (Top) 48 hour time series of median V band sky brightness under moonless conditions for a range of zenith distances. (Lower) Corresponding lunar and solar elevation. Times shown are UT. For color figures, see on-line version.

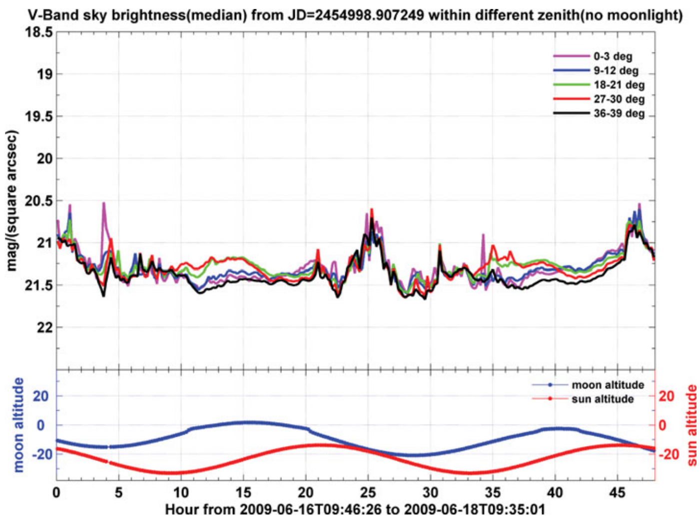

Figure 3. (Top) 48 hour time series of V band sky brightness for darkest 2% under moonless conditions for a range of zenith distances. (Lower) Corresponding lunar and solar elevation. Times shown are UT. For color figures, see on-line version.

For clarity, Fig. 2 shows the equivalent plot for a range of zenith distances over a 48 hour period close to mid-winter. The plot shows a range of values from 21 to 21.5 magnitudes/arcsec^2 with an approximate diurnal peak. The origin of the peak is unknown at this time but it is not caused by direct solar illumination of the upper atmosphere. More likely is an increased aurora activity and/or an airglow related increase. More interestingly, shown in Fig. 3 is the same plot but pre-selected for the darkest 2% of sky brightness values. Here we see a range of sky brightness values between 21.5 and 22.2 magnitudes/arcsec^2. We believe this reflects the sky brightness with the absence of strong aurora lines, given the brightest aurora line corresponding to [OI] emits at 557.7nm that falls within the large passband of the V filter. Work is ongoing in collaboration with the Nigel spectrometer team (Sims *et al.* (2012)) to classify aurora events in the Gattini dataset so that a realistic estimate of sky brightness with and without strong aurora lines can be determined. This is warranted as in practice, strong atmospheric emission lines such as [OI] can be avoided when designing large scale future experiments such as the use of a slightly shortened red cutoff SDSS g' filter in imaging surveys (Zhou *et al.* (2010), Moore *et al.* (2010)).

1.3. *Cloud cover*

A preliminary analysis of cloud cover was performed. Cloud cover was estimated by creating a reference 'pseudo' star from a weighted average of many stars across the field of view. An increase in the pseudo star magnitude it is assumed equates to the presence of some form of extinction whether this is cloud cover or local snow lifted above the height of instrument. Using this method, a total of 75% of the data collected during the 2009 winter season shows a dimming of the pseudo star of less than 0.5 magnitudes only, that corresponds to a cloud cover of less than 37%. This analysis is on-going.

1.4. *Atmospheric extinction*

Atmospheric extinction has been approximated for the 2009 V band data. The lack of adequate flat fields representing the response of uniform illumination across the 90^o field of view of the instrument results in large errors for the approximated extinction values. Extinction values of 0.1 to 0.2 per airmass were calculated. However, accurate extinction will be calculated within the next few months given the arrival of the camera system to Caltech in August 2012 and with this the ability to measure accurate multi-filter flat fields in the laboratory.

1.5. *Acknowledgements*

The research is supported by the Chinese PANDA International Polar Year project and the Polar Research Institute of China. The project was funded by the following awards from the National Science Foundation Office of Polar Programs: ANT 0836571, ANT 0909664 and ANT 1043282. We thank Shri Kulkarni and Caltech Optical Observatories, Gerard Van Belle and Chas Beichman for financial contribution to this project. The operation of PLATO at Dome A is supported by the Australian Research Council, the Australian Antarctic Division, and the University of New South Wales. The authors wish to thank all the members of the 2008/2009/2010 PRIC Dome A heroic expeditions.

References

Yang, H., *et al.* 2009, *Publications of the Astronomical Society of the Pacific*, 121, 876
Moore, A. M., *et al.* 2010, *Proceedings of the SPIE*, 7733
Sims, G., *et al.* 2012, *Publications of the Astronomical Society of the Pacific*, 124, 916
Zhou, X., *et al.* 2010, *Publications of the Astronomical Society of the Pacific*, 122, 889