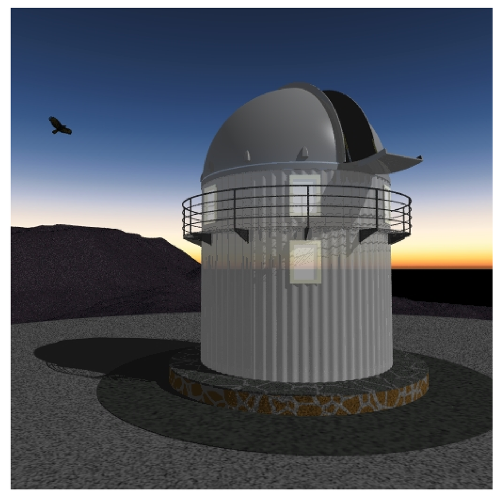

Skinakas Observatory BVR Sky Brightness During Dark time and Sunspot minimum

Photometric Observations

The photometric data set presented here has been obtained with the 2048 × 2048 pixels Andor DZ436 back-illuminated CCD camera, mounted in direct imaging mode on the Skinakas 1.3m telescope. Observations were made on three consecutive dark nights, August 3-5, 2008. The sky areas observed – mostly Landolt's and Stetson's standard star fields – were selected so that sky pointings would cover a more-or-less uniform grid in altitude and azimuth, as shown in Fig. 1. Care has been taken to avoid fields with galactic latitude $|b| < 10°$.

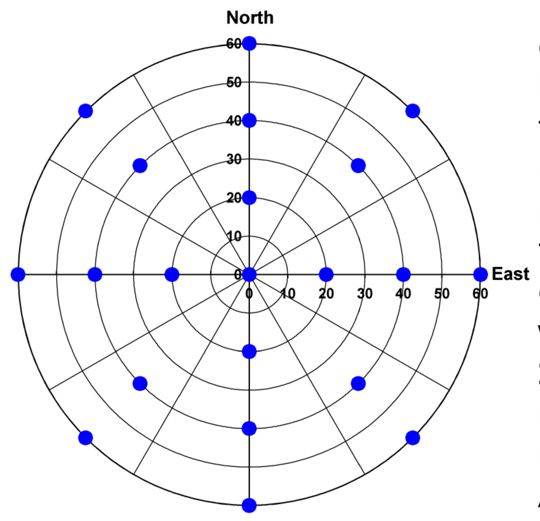

Fig. 1 Intended sky coverge grid in altitude and azimuth.

The observing sequence of the sky fields was kept the same on all three nights. Strong northerly wind during part of the third night forced us to skip some of the Northern targets, which were replaced by Southern ones, resulting in a slight N-S asymmetry in sky coverage. All fields observed at a time distance from the closest twilight < 1 hour were excluded from the photometric data set that estimates the sky brightness; they were only used in the photometric transformation equations. The filters used were standard broadband BVR Johnson-Bessel, and the exposure times were selected to get an SNR of at least 6 (in B filter). The sequence of exposures was either BVRRVB or RVBBVR.

The image reduction consisted of the standard steps of bias subtraction, flat-field correction and was followed by photometric analysis (DAOPHOT and DAOGROW), standard star matching and solution of the photometric transformation equations, separately for each night:

$$
\begin{aligned}
b &= z_B + B + k_B X + l_B(B-V)X + m_B(B-V) + n_B(B-V)^2 \\
v &= z_V + V + k_V X + l_V(B-V)X + m_V(B-V) + n_V(B-V)^2 \\
r &= z_R + R + k_R X + l_R(V-R)X + m_R(V-R) + n_R(V-R)^2
\end{aligned}
$$

where small letters correspond to instrumental magnitudes and capital letters denote the absolute magnitudes in the corresponding filters. These model equations were fitted to the actual data using an iteratively reweighed least squares method.

Sky surface brightness in the standard BVR photometric system was calculated with the aid of the photometric equations given above, with instrumental sky magnitude given by

$$m_{sky} = -2.5\log\left(\frac{I_{sky}}{t_{exp}\,p^2}\right)$$

where I_{sky} is the sky background in counts per pixel, p is the detector's scale (arcsec pix^{-1}) and t_{exp} is the exposure time in seconds. Then m_{sky} is expressed in mag arcsec^{-2}.

These sky values were taken from the sky calculation around each star found by DAOPHOT, as were estimated over an annulus of inner radius 30 pixels and outer radius of 50 pixels. On each frame, an average value of the sky intensity and σ_{sky} was calculated (3-sigma clipping) among the roughly 300 measurements provided by DAOPHOT. **No correction for atmospheric extinction was applied**, since the effect is mainly due to the atmosphere itself. The results appear in Fig. 2, where sky surface brightness (uncorrected for extinction) is plotted versus airmass, for each filter used.

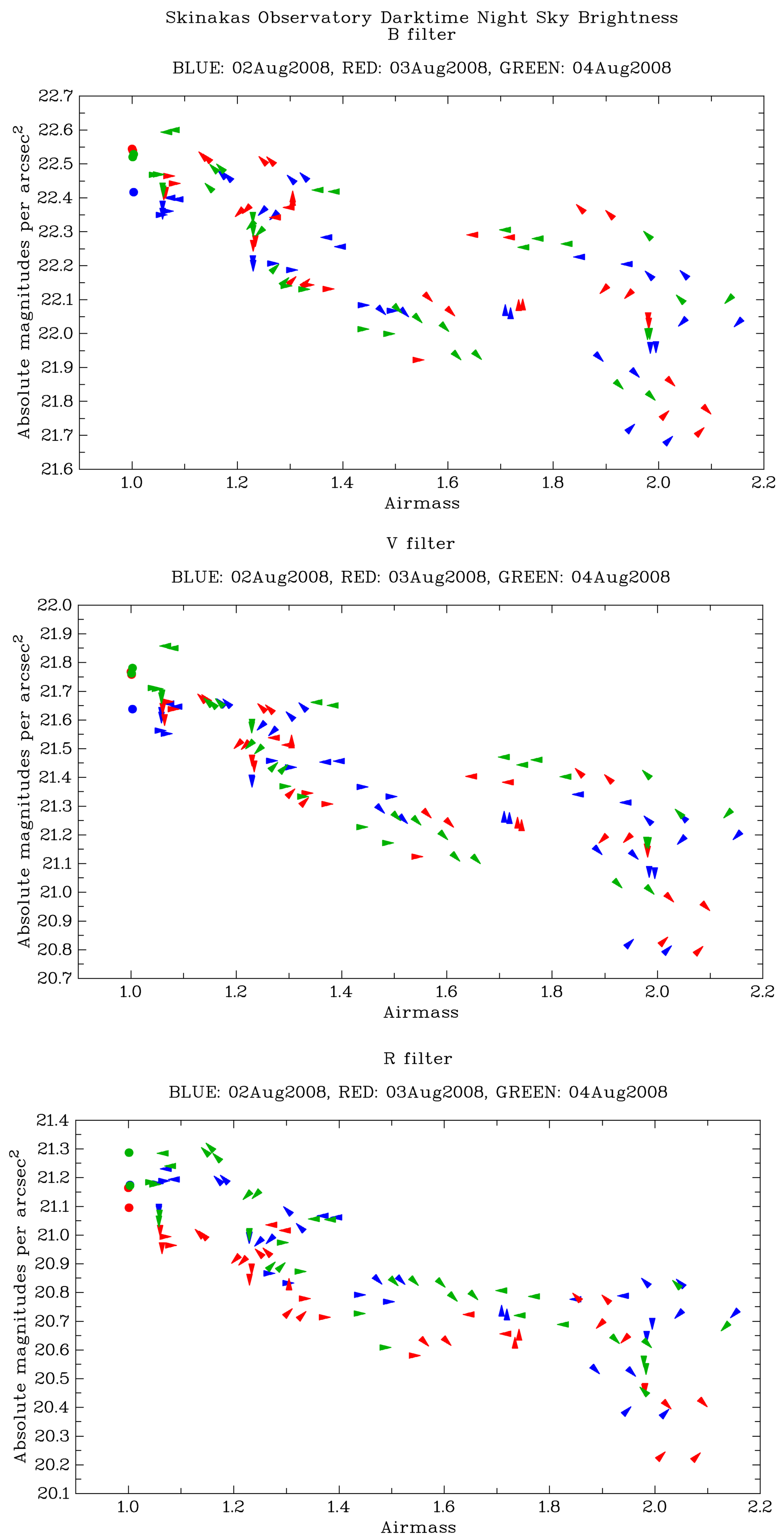

Fig. 2. Absolute magnitude as a function of airmass for B, V and R filter. Each color corresponds to a different day of observation. The direction of each arrowhead symbol suggest the azimuthal direction of the corresponding observation. Filled circles denote observations toward the Zenith direction.

Next, a **zenith correction** was applied to the sky surface magnitudes, as described in F. Patat (2003, A&A 400, 1183, Appendix C). This correction is given by the additive magnitude $\Delta m = -2.5\log[(1-f)+fX] + k(X-1)$, where f is the fraction of the total sky brightness generated by the airglow (value used was $f = 0.6$), X is the optical path length along the line of sight and k is the atmospheric extinction coefficient for the given passband. This correction is actually taking care of the sky brightness dependency on the zenith distance and allows comparison between different sky pointings. The computed zenith corrected magnitudes are shown in Fig.3 as a function of azimuth (measured from North to East in degrees). Fig. 4 depicts the average value calculated in groups of azimuth centered at the 8 basic azimuthal directions (N, NE, E, SE, S, SW, W and NW) and span an angular range of 22.5° on either side of the center. The Zenith average value is also given.

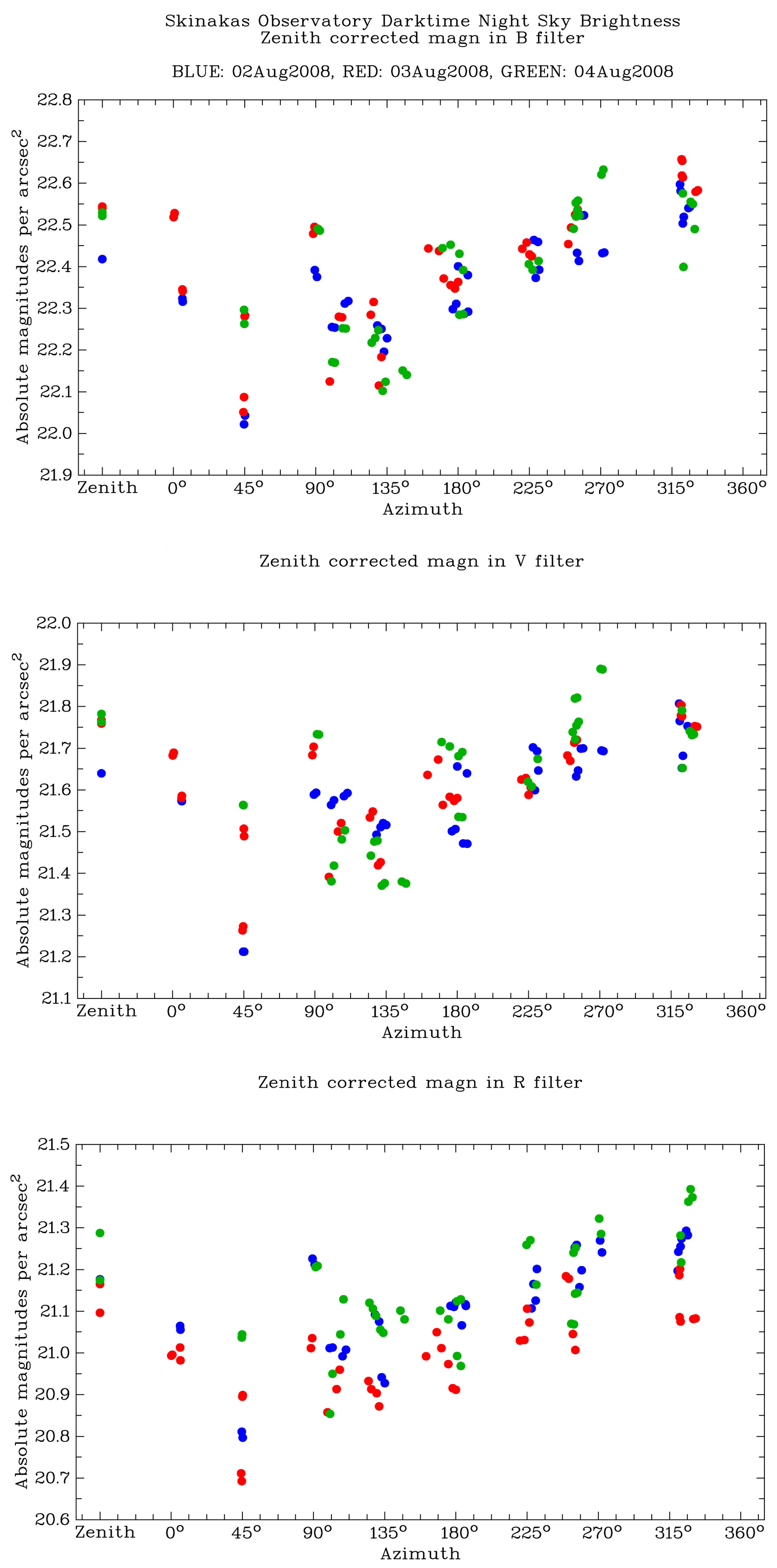

Fig. 3. Zenith corrected absolute magnitude as a function of azimuth for B, V and R filter. Each color corresponds to a different day of observation.

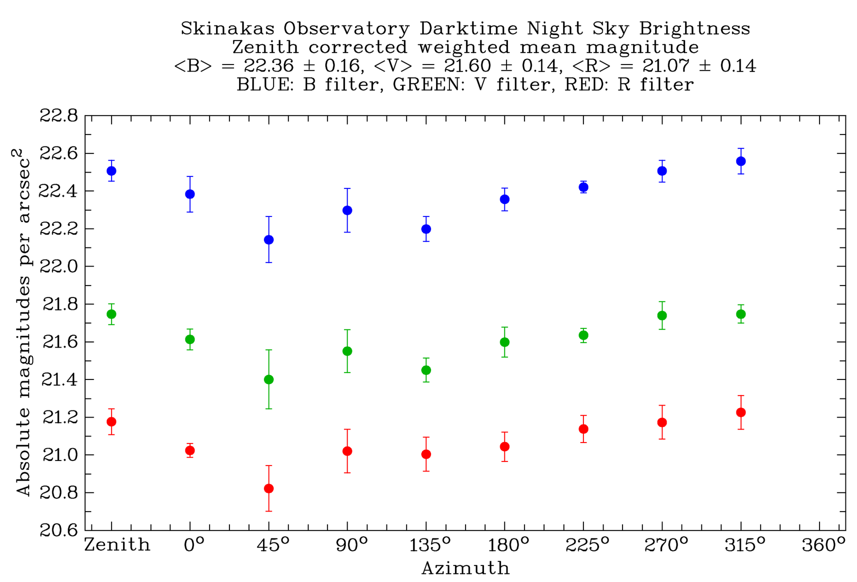

Fig. 4. Zenith corrected mean values of night sky surface brightness in the direction of the eight major azimuthal directions and towards zenith.

In an attempt to give a global picture of the sky brightness at Skinakas Observatory, we present the color-coded magnitude plots in Fig. 5 and 6, along with contours. These were constructed through a 3D surface fit on the deduced magnitudes, both for the uncorrected for atmospheric extinction case and the zenith-corrected. The fitted surface used was a linear combination of the first 15 Zernike functions.

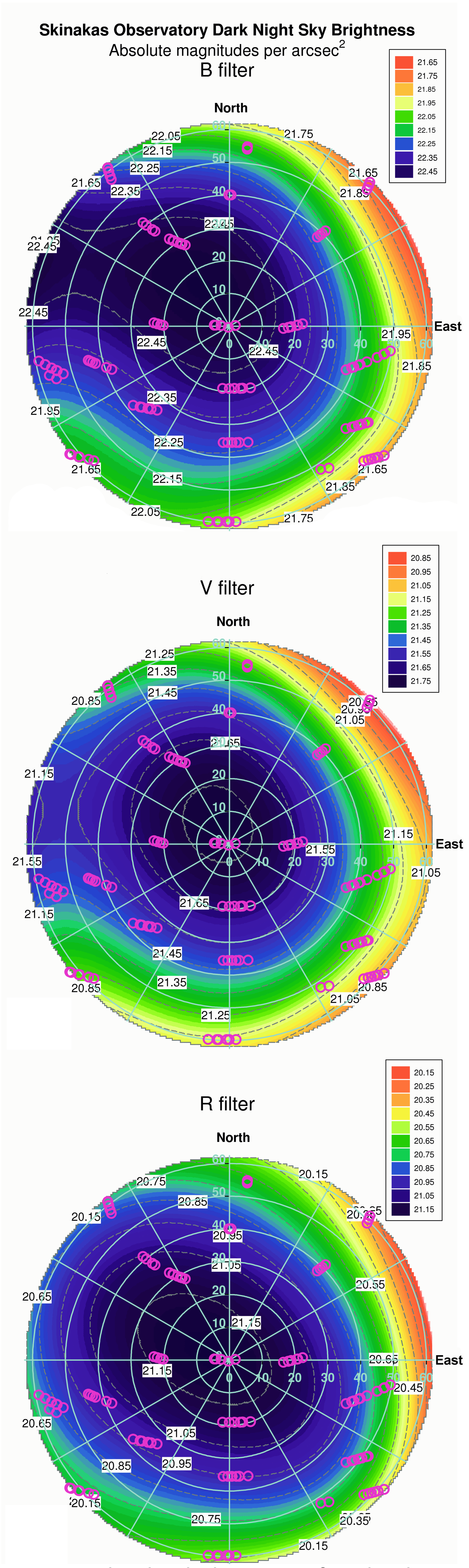

Fig. 5. Night sky dark time surface brightness contour map, uncorrected for atmospheric extinction, in the passband of B, V and R filter. The polar grid indicates the local horizontal coordinate system. The pink open circles correspond to the telescope pointings of the actual observations.

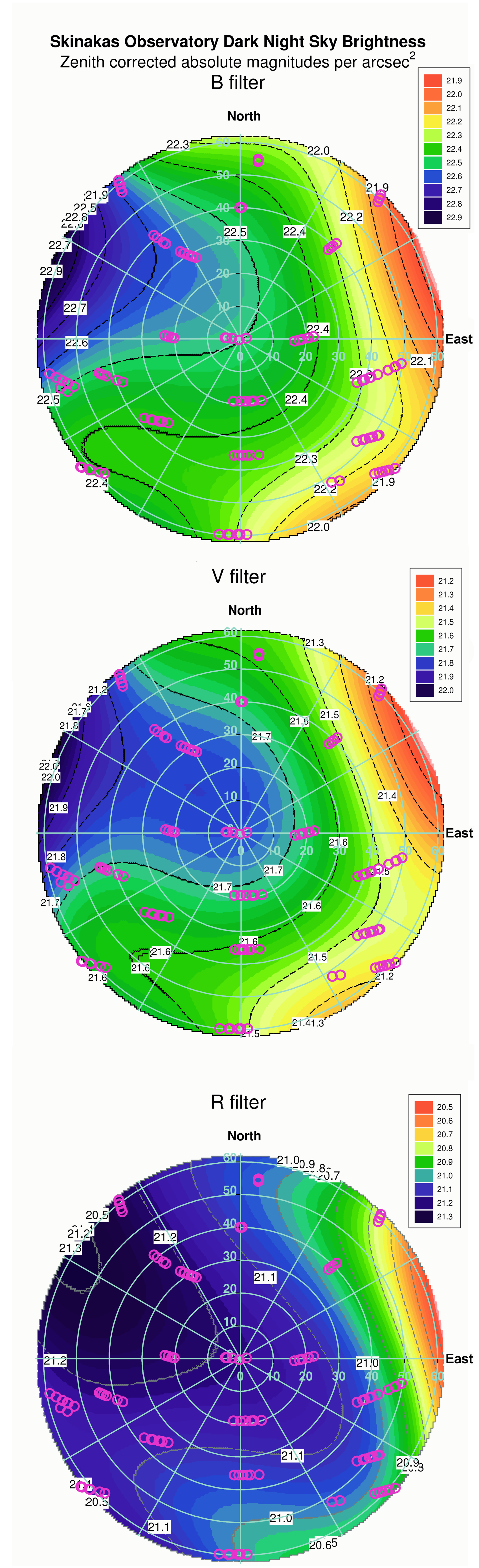

Fig. 6. Night sky zenith-corrected surface brightness, as in Fig. 5.