THE SUBARU/XMM-NEWTON DEEP SURVEY (SXDS). II. OPTICAL IMAGING AND PHOTOMETRIC CATALOGS

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ABSTRACT

We present multi–wave band optical imaging data obtained from observations of the Subaru/XMM-Newton Deep Survey (SXDS). The survey field, centered at R.A. = 02h18m00s, decl. = −05◦00′00″, has been the focus of a wide range of multiwavelength observing programs spanning from X-ray to radio wavelengths. A large part of the optical imaging observations are carried out with Suprime-Cam on Subaru Telescope at Mauna Kea in the course of Subaru Telescope “Observatory Projects.” This paper describes our optical observations, data reduction and analysis procedures employed, and the characteristics of the data products. A total area of 1.22 deg² is covered in five contiguous subfields, each of which corresponds to a single Suprime-Cam field of view (∼34′ × 27′), in five broadband filters, B, V, R, i′, and z′, to the depths of B = 28.4, V = 27.8, R = 27.7, i′ = 27.7, and z′ = 26.6, respectively (AB, 3σ, φ = 2′). The data are reduced and compiled into five multi–wave band photometric catalogs, separately for each Suprime-Cam pointing. The i′-band catalogs contain about 900,000 objects, making the SXDS catalogs one of the largest multi–wave band catalogs in corresponding depth and area coverage. The SXDS catalogs can be used for an extensive range of astronomical applications such as the number density of the Galactic halo stars to the large-scale structures at the distant universe. The number counts of galaxies are derived and compared with those of existing deep extragalactic surveys.

The optical data, the source catalogs, and configuration files used to create the catalogs are publicly available via the SXDS Web page (http://www.naoj.org/Science/SubaruProject/SXDS/index.html).

Subject headings: cosmology: observations — galaxies: evolution — galaxies: photometry — large-scale structure of universe

1. INTRODUCTION

Understanding the formation and evolution processes of the individual galaxy and the growth of the large-scale structures (LSSs) in the universe is one of the major goals in extragalactic astronomy today. In the scheme of a typical ΛCDM model, the growth of structures is governed by the gravitational growth of initial fluctuations of dark matter. The baryonic material cools in the process by well-defined statistical galaxy samples.

Optical imaging is arguably the cornerstone of any extragalactic survey, since it provides identifications and positions of celestial objects for follow-up spectroscopy. In recent years, there have been a number of deep imaging survey projects which devote significant amounts of telescope time, such as the Great Observatories Origins Deep Survey (GOODS; Giavalisco et al. 2004) and the Cosmic Evolution Survey (COSMOS, an HST Treasury project; Feldmann et al. 2006; Scoville et al. 2007). These surveys provide multi–wave band galaxy samples at faint magnitudes. Then, the photometric redshift techniques (Furusawa et al. 2000; Bolzonella et al. 2000; Feldmann et al. 2006) are frequently used to preselect candidates for spectroscopy. Although a great deal of information can be obtained from the optical data alone, the value of the data set grows significantly as...
data at other wavelengths from other facilities are added. We therefore elected to use a multiwavelength approach for the Subaru/\textit{XMM-Newton} Deep Survey (SXDS; K. Sekiguchi et al. 2008, in preparation, hereafter Paper I) from the very start, ensuring that our chosen field would be accessible and suitable for observations at all wavelengths. An equatorial field, centered at R.A. \(= 02^h 18^m 00^s\), decl. \(= -05^\circ 00' 00''\) is chosen to tie up with the deep X-ray observations with \textit{XMM-Newton} observatory (Ueda et al. 2007), and also due to the accessibility by all major observatories, both existing and planned. The major multiwavelength observation programs on the SXDS field (SXDF) include deep radio imaging with the VLA (Simpson et al. 2006), submillimeter mapping with SCUBA (Coppin et al. 2006; Mortier et al. 2005), mid-infrared observations with the \textit{Spitzer Space Telescope} (Lonsdale et al. 2003), deep near-infrared imaging with the UKIRT Wide Field Infrared Camera (WFCAM; Foucaud et al. 2007; Dye et al. 2006; Lawrence et al. 2007), and the X-ray observations with \textit{XMM-Newton} observatory. Importantly, the survey field of an infrared ultra deep survey (UDS; Foucaud et al. 2007) covering \(0.77\) deg\(^2\) as part of the UKIDSS project (Lawrence et al. 2007) is centered on the SXDF. It is expected that our extensive multiwavelength data set will provide photometric redshifts accurate to \(\Delta z \leq 0.1\) over a wide range of redshift, as well as detailed spectral energy distributions for the vast majority of the objects in the field.

The SXDS has been undertaken as a part of the Subaru Telescope “Observatory Projects,” in which a large amount of observing times are devoted to carry out intensive survey programs by combining observing times rewarded to builders and observatory staff of the Subaru Telescope. Note that Subaru Deep Field (SDF; Kashikawa et al. 2004) is another observatory project, which targets a field different from the SXDF. The data set of the SDF is slightly deeper than the SXDF, but concentrates on a field one-fifth narrower than the SXDF. Thus, these surveys complement each other, and they can be used for a wide variety of studies.

In this paper, we describe the observation details and data reduction and analysis of our optical imaging survey with the prime-focus camera on Subaru Telescope, as well as the resultant data products. A detailed description of the survey strategies, scientific objectives, and multiwavelength survey plans is given in a companion paper (Paper I). In § 2 we describe optical imaging observations by Subaru Telescope, and in § 3, we explain the data reduction procedure employed. We present creation of multiwave band photometric catalogs including object detection and aperture photometry in § 4, and calibrations of photometry and astrometry in § 5. In § 6 we discuss characteristics of the catalogs such as limiting magnitude, detection completeness, and number counts of galaxies. The summary is given in § 7. Throughout this paper, all the magnitudes are expressed in the AB system unless otherwise mentioned.

2. OBSERVATIONS AND DATA

The optical imaging observations of the SXDF are carried out using the prime-focus camera (Suprime-Cam; Miyazaki et al. 2002) on the Subaru Telescope in the period from 2002 September to 2005 September. Suprime-Cam is a camera that has a \(5 \times 2\) mosaic of 10 MIT/LL butttable \(2048 \times 4096\) CCDs. It has a \(34'' \times 27''\) field of view with a projected pixel scale of \(0.202''\). The layout of the pointings is arranged as a cross shape so that each of the north–south and the east–west directions has an extent of \(\sim 1.3\) deg (Fig. 1). This corresponds to a field span of a transverse dimension of \(\sim 75\) Mpc at \(z \sim 1\) and \(\sim 145\) Mpc at \(z \sim 3\) in the comoving scale for \((h, \Omega_m, \Omega_\Lambda) = (0.7, 0.3, 0.7)\). The coverage of the comoving volume is \(\sim 3.2 \times 10^7\) Mpc\(^3\) for \(z = 0 \sim 3\). Table I lists field center coordinates of the five pointings. Hereafter, the five pointings are referred to as C (Center), N (North), S (South), E (East), and W (West), with respect to their relative positions on the sky.

Observations of the SXDF are performed using five broadband filters, \(B, V, R, i', z'\) to cover the entire wavelength range observable with Suprime-Cam. The transmission curves of the five filters employed in the SXDS, convolved with the CCD sensitivities, reflectivity of the primary mirror, transmissions of corrector lenses, and atmospheric transmission, are given in Figure 2. Also given in Figure 2 are the redshifted spectral energy distributions (SEDs) of an early-type galaxy at \(z = 0.5\) and 1.2 and a late-type galaxy at \(z = 0.5\) and 5.0 for reference. With photometric data sampled in the five bands, we can investigate color properties of red passively evolving galaxies to \(z \sim 1\) (see Kodama et al. 2004; Yamada et al. 2005) and young star-forming galaxies at high redshift such as Lyman break galaxies (LBG; Ouchi et al. 2004, 2005). The observations used in this paper span observing runs over a period of 3 yr. A total of 160 hr are allocated to the SXDF imaging observations as a part of Subaru Telescope “Observatory Projects” (see also Kashikawa et al. 2004) combined with observatory staff times. In addition to these times, we use 14 hr of the observing times offered by the Supernova Cosmology Project (Doi et al. 2003; Lidman et al. 2005), which add the total exposure time of the center and the west pointings in the \(i'\) band (\(i'\)-C and \(i'\)-W). Moreover, in the course of another survey program for Ly\(\alpha\)-emitting galaxies (Ouchi et al. 2005, 2008), 3 hr are devoted to the \(i'\)-band imaging. In total, 133 hr are used for on-source exposures for the final data set described in this paper. The complete log of the observations is given in Table 2.

The coordinates of the five pointings are carefully chosen so that the resultant images uniformly cover the entire SXDF, although we analyze each of the pointings separately in the present study. In addition, to eliminate bad pixels, gaps between individual CCD chips, and cosmic ray events, a circular dithering pattern is used for each pointing. This dithering pattern employs a circular motion with radii of \(60'' - 120''\) around the center position of each pointing, combined with slight offsets to the center positions of the circular motion. As an example, the dithering pattern for the \(R_c\) band is plotted for each pointing in Figure 3.

3. DATA REDUCTION

The SXDS images obtained are processed using an in-house pipeline software package (see Ouchi 2003). We use it in almost the same way that is successfully used for the SDF (Kashikawa et al. 2004). This pipeline is based on a software package developed for Suprime-Cam data reduction (Yagi et al. 2002) and several IRAF tasks (\texttt{geomap}, \texttt{geotran}, etc.) are used in the process of a geometrical transformation and alignment of final stacked images. We use a standard mosaic-CCD data reduction procedure, which is briefly summarized below.

First, we apply a bias correction to the raw data. The median count of the overscan region is computed for each line, which represents a typical bias level at that line, and this median count is subtracted from the counts in all the pixels in that line. The overscan regions are trimmed after the bias subtraction. We assign a flag number (–32768) to the saturated or detected bad pixels, and these pixels are ignored in the following reduction processes. Since pixels in the outside edges of each frame are likely to be affected by noises which cannot be corrected by the following flat-fielding process, they are also masked with the flag number.

Flat frames are constructed from the normalized object frames taken during the same observing run. We use more than 150 object frames to create flat frames. If the number of object frames is less than 150 frames, object frames taken in different observing
runs within 3 months or twilight flat frames taken in the same run are combined to increase the signal-to-noise ratios (S/Ns) of the flat frames for that period. The median value of the each pixel is used to create the flat frames. Pixels which could be affected by bright objects and vignetting by the autoguider probe are flagged out before processing the flat frames. Then, object frames are divided by the flat frames. The peak-to-peak ratios of background levels over the entire flat-fielded frames are less than 2%. We do not expect any significant systematic errors from the flat fielding that affect accuracies of the following analyses.

After the flat-fielding process is done, the distortion correction is applied to each frame using the fifth-order polynomial transformation formula derived from Miyazaki et al. (2002). The changes in shapes and sizes of objects in the frames due to the distortion are negligible compared with the size of PSFs. Each pixel is transformed so that the surface brightness of the pixel is conserved, since the relative flux in each pixel has been already corrected by the flat-fielding process. Positional displacement of objects along the perpendicular orientation due to the atmospheric effect is also corrected at the same time.

The sky background is subtracted from each distortion-free frame. We divide an image into temporary meshes with 64 × 64 pixels, corresponding to 12.9″ in one direction. The mode of counts in each mesh is adopted as the sky background levels after being smoothed by a median filter with a 3 × 3 kernel. This global sky subtraction should not affect photometric accuracies of compact objects such as galactic stars and faint galaxies. However, caution must be taken when we apply these values to extended objects such as nearby galaxies with low surface brightness.

The stacking of the images is performed for each of the pointings separately in the following way. First, we choose 100–200 unsaturated stellar objects with a peak flux of >500 ADU in each frame distributing evenly over the entire frame. Second, we determine a reference frame of all the reduced frames. For the other frames, relative positions and rotation ($\Delta x$, $\Delta y$, $\Delta \theta$) and flux ratios...
to the reference frame are determined based on a least-squares method using these stellar objects commonly detected in the frames. Third, for all the frames, the positional shifts and rotations are corrected. Here, we do not use frames which have flux ratios of less than 30% of that of the reference frame. Finally, all the frames are co-added by calculating flux-weighted average values in each pixel with a 3 σ clipping process. The clipping process effectively removes cosmic rays, bad or saturated pixels, satellite trails, etc., and should not affect the resulting total fluxes of objects, because the difference in counts among frames with various seeing sizes is mostly within the 3 σ threshold.

After the co-adding of each band images, all the five-band \((B, V, R_c, i', z')\) images are registered into identical positional coordinates, as we intend to execute multi-wave band aperture photometry. The positional registration is performed by the geometrical transformation by third order polynomials fitting using the positions of stellar objects common to the co-added stacked images. The rms deviation of residuals of transformed positions with respect to the reference positions in the \(R_c\)-band images is approximately 0.1″–0.15″.

For each pointing, the geometrically matched images are smoothed with Gaussian filters iteratively, so that the PSF sizes of all the images become the same as that in the worst image used in this study. The PSF sizes of the resultant images are 0.80″, 0.84″, 0.82″, 0.82″, and 0.82″ in SXDS-C, SXDS-N, SXDS-S, SXDS-E, and SXDS-W, respectively.

Finally, regions with low S/Ns or those affected by saturation or overflow of electrons are carefully checked and assigned as flagged regions which are indicated in photometric catalogs. The resultant PSF sizes and total usable areas of each pointing is summarized in Table 3.

### TABLE 2

**Summary of Observations and Data of the SXDS**

| Band-Pointing | Exp. Time (min) | PSF Size (arcsec) | Zero Points for Images \((\text{mag}_{AB} \text{ ADU}^{-1})\) | \(m_{\text{lim}}\) (\(\text{mag}_{AB}\)) | \(N_{\text{obj}}\) | Date of Obs. |
|---------------|-----------------|-------------------|---------------------------------|-----------------|----------------|----------------|
| \(B-C\)       | 345             | 0.80              | 34.723                          | 28.09           | 197,317        | 2002 Sep 29, 30, Oct 1; 2003 Nov 17 |
| \(B-N\)       | 330             | 0.84              | 34.701                          | 28.39           | 176,372        | 2002 Nov 2, 5, 27, Dec 1, 7; 2003 Nov 17 |
| \(B-S\)       | 330             | 0.82              | 34.706                          | 28.33           | 189,916        | 2002 Nov 2, 4, 5, 27, Dec 1, 7; 2003 Nov 17 |
| \(B-E\)       | 330             | 0.82              | 34.698                          | 28.06           | 179,478        | 2002 Nov 4, 5, Dec 1, 7; 2003 Nov 17 |
| \(B-W\)       | 330             | 0.78              | 34.716                          | 28.21           | 197,770        | 2002 Nov 4, 5, 27, Dec 1, 7; 2003 Nov 17 |
| \(V-C\)       | 319             | 0.72              | 33.639                          | 27.78           | 213,851        | 2002 Oct 2, 24, 26; 2004 Jan 16, Oct 9, Dec 10, 14, 15; 2005 Jan 5 |
| \(V-N\)       | 313             | 0.80              | 33.648                          | 27.65           | 203,299        | 2003 Oct 2, 26, Nov 17; 2004 Jan 16, Dec 10, 14, 15; 2005 Jan 5, Sep 28 |
| \(V-S\)       | 321             | 0.82              | 33.643                          | 27.75           | 186,545        | 2002 Oct 2, 24, 26; 2004 Jan 16, Dec 10, 14, 15; 2005 Jan 5, Sep 28 |
| \(V-E\)       | 291             | 0.76              | 33.639                          | 27.77           | 192,951        | 2003 Oct 2, 26; 2004 Jan 16, Dec 10, 14, 15; 2005 Jan 5, Sep 28 |
| \(V-W\)       | 293             | 0.72              | 33.649                          | 27.72           | 205,915        | 2003 Oct 2, 26, Nov 17; 2004 Jan 16, Dec 10, 14, 15; 2005 Jan 5, Sep 28 |
| \(R_c-C\)     | 248             | 0.76              | 34.315                          | 27.57           | 188,079        | 2002 Sep 30, Oct 1, 7; 2003 Nov 17 |
| \(R_c-N\)     | 232             | 0.78              | 34.276                          | 27.74           | 174,365        | 2002 Nov 1, 9, 30, Dec 6; 2003 Nov 17 |
| \(R_c-S\)     | 232             | 0.74              | 34.219                          | 27.67           | 178,416        | 2002 Nov 1, 9, 30, Dec 6; 2003 Nov 17 |
| \(R_c-E\)     | 232             | 0.76              | 34.259                          | 27.51           | 173,856        | 2002 Nov 2, 9, 30, Dec 6; 2003 Nov 17 |
| \(R_c-W\)     | 232             | 0.82              | 34.247                          | 27.53           | 186,648        | 2002 Nov 2, 9, 30, Dec 6; 2003 Nov 17 |
| \(i'-C\)      | 647             | 0.78              | 34.055                          | 27.62           | 181,352        | 2002 Sep 29, 30, Nov 1, 2, 5, 9, 27, 29, Dec 6, 7; 2003 Oct 20, 21 |
| \(i'-N\)      | 440             | 0.76              | 34.042                          | 27.66           | 176,394        | 2002 Sep 29, 30, Nov 1, 2, 9, 29, Dec 7; 2003 Sep 22, Oct 2, 21 |
| \(i'-S\)      | 309             | 0.68              | 34.046                          | 27.47           | 187,791        | 2002 Sep 29, 30, Nov 1, 2, 9, 29; 2003 Sep 22, Oct 2 |
| \(i'-W\)      | 368             | 0.74              | 33.986                          | 27.49           | 175,404        | 2002 Sep 29, 30, Nov 1, 2, 9, 29, Dec 7; 2003 Sep 22, Oct 2, 21 |
| \(z'-C\)      | 598             | 0.82              | 34.087                          | 27.58           | 178,543        | 2002 Sep 29, 30, Nov 1, 2, 5, 9, 27, 29, Dec 6, 7; 2003 Oct 20, 21 |
| \(z'-N\)      | 217             | 0.70              | 33.076                          | 26.57           | 183,324        | 2002 Sep 29, 30, Oct 1, Nov 4, 5 |
| \(z'-S\)      | 252             | 0.74              | 32.278                          | 26.64           | 163,324        | 2002 Nov 4, 5, 10; 2003 Sep 21, 22, 10, 2 |
| \(z'-E\)      | 184             | 0.76              | 32.258                          | 26.39           | 167,779        | 2002 Nov 4, 5, 10; 2003 Sep 21, 22, Oct 1 |
| \(z'-W\)      | 267             | 0.74              | 32.743                          | 26.49           | 160,415        | 2002 Nov 4, 5, 10; 2003 Sep 21, 22, Oct 1 |
| \(z'-W\)      | 311             | 0.74              | 32.776                          | 26.60           | 167,748        | 2002 Nov 4, 5, 10; 2003 Sep 21, 22, Oct 1, 2 |

**Notes.**—Col. (1): Filter passband \((B, V, R_c, i', z')\) and the pointed field (center: C; north: N; south: S; east: E; west: W). Col. (2): Total exposure time in minutes. Col. (3): The PSF size (FWHM) of the stacked image. Col. (4): Photometric zero point. Col. (5): 3 σ limiting magnitude in AB magnitude, measured by random sampling with 2′ diameter aperture. Col. (6): Number of objects detected in the image. Col. (7): Date of observations.
4. MULTI-WAVE BAND PHOTOMETRIC CATALOGS

We construct multi-wave band photometric catalogs of the objects identified in the SXDF.

4.1. Object Detection

Object detection and photometry are performed using SExtractor version 2.3.2 (Bertin & Arnouts 1996). Before performing the object detection and photometry, the outskirts of the stacked images are trimmed in order to eliminate any failure such as inappropriate estimation of sky levels and memory overflow during extraction of objects by SExtractor due to a high noise level. After trimming the outskirts, each individual image has a similar size of approximately 10 × 800 × 8100 pixels. We use the detection criteria that at least five pixels which have values of >2σ of sky background rms noise must be connected in order to be included in our object list. Positions of detected objects are translated to sky coordinates based on the astrometric calibration which will be discussed in § 5.2.

4.2. Aperture Photometry

After the object detection is completed in one of the five bands, which we call “detection band,” multi-wave band aperture...
photometry is carried out with SExtractor for the other four bands using the same apertures at the same positions as those in the detection band. We perform aperture photometry with fixed circular apertures (MAG_APER) of 2" and 3" in diameter and variable elliptical apertures (MAG_AUTO and MAG_BEST) using the Kron’s first moment scheme with apertures’ radii of 2.5rKron (Kron 1980). Measured fluxes of objects are converted into magnitude using the photometric zero points, which will be described in §5.1. The extracted magnitude is considered to be the asymptotic total magnitude of galaxies, which should sample at least 94% of the flux of a galaxy (Bertin & Arnouts 1996). Other useful parameters for objects including, for example, the shape, size, and stellarity, are also extracted by SExtractor at the same time. All the object parameters which are listed in the catalogs are summarized in Table 4.

In this procedure, B-, V-, Rc-, i′-, and z′-selected multi-wave band catalogs are created for each pointing separately, which means that each object has measurements in the five bands (B, V, Rc, i′, and z′) in each catalog. Thus, 25 catalogs (five pointings for five detection bands) in total are created.

4.3. Flagged Areas

Although we have flagged out bad pixels from the image frame in the reduction procedure, there still remain (1) areas strongly affected mainly by overflow of electrons or envelopes of extended objects, and (2) areas weakly affected by large halos from very bright stars or noisy regions. In our catalogs, the objects which are located in these areas are flagged 1 and 2, respectively. Otherwise, the objects located in the clean area have a flag value of 0.

The basic parameters used in the object detection and aperture photometry are summarized in Table 5. The complete configuration files for SExtractor can be found online.16 Note that we adopt default parameters of SExtractor for the source extraction unless we do not find any problem with the output values. The parameters adopted are suitable for extraction of moderate to faint compact galaxies and not heavily optimized to extraction of extended objects or very faint objects. Thus, the reliability of the current catalogs for those objects should be regarded with some caution.

5. CALIBRATIONS

5.1. Photometric Calibration

Photometric zero points in all the five bands are determined in the following way. First, we compare our observation with the earlier calibrated observations for the same overlapping field, which were made by the Suprime-Cam instrument development team (Ouchi et al. 2001, 2004). The southern half of our center pointing (SXDS-C) is overlapped with the northern half of the image obtained by Ouchi et al. (2001). They determined the photometric zero points in the Suprime-Cam band system based on observations of photometric standard stars SA 92 and SA 95 for B, V and Rc bands and a spectrophotometric standard star SA 95–42 for i′ and z′ bands.

We estimate the photometric zero points for our center pointing (SXDS-C) by comparing magnitudes (MAG_AUTO) of ~200 objects which are commonly detected in the two images and have FWHMs of smaller than 1.2" with a magnitude range of 20.0–24.0. Then, we extend these zero points to the surrounding four pointings by using objects in the overlapping areas in the same manner as for the determination of the zero point for the SXDS-C.

In our catalogs, we list the instrumental magnitude obtained in the Suprime-Cam band system. Hence, no transformation of magnitude considering color terms of band responses are conducted. The color terms between the Suprime-Cam band system and the standard system are basically small: for the reddest stars, of order 0.1 in the B, V, i′, and z′ bands and slightly larger (~0.3) in the Rc band.

To test internal consistency of our zero-point calibrations, we examine colors of stellar objects in our photometric catalogs and those computed by convolving typical stellar SEDs covering the complete ranges of spectral types (Gunn & Stryker 1983) with Suprime-Cam response curves. We find that it is necessary to apply corrections to the zero points of ΔV = +0.03 and Δz′ = +0.03 for all the five pointings, and Δi′ = +0.05 and +0.02 for the south and east pointings (i′-S and i′-E), respectively. After these corrections are applied, the colors of the stellar objects in our catalogs agree with those computed for the SEDs from Gunn & Stryker (1983) within 0.03 mag in all the five bands (Fig. 4). The systematic errors adjusted here may be due to relatively small number of stellar objects used in the determination of the photometric zero points.

To ensure the accuracy of our zero points, we conduct CCD photometric observations of a part of the SXDF in B, Rc, i′ and z′ bands with the University of Hawaii 88 inch (2.2 m) telescope at Mauna Kea on 2002 October 9 and 10. We compare magnitudes of objects in B, Rc, i′ and z′ bands obtained by the University of Hawaii observations with our catalog values. We find that our catalog values agree within 0.05 mag rms for B and Rc bands and within 0.1 mag rms for i′ and z′ bands. The relatively large difference seen in i′ and z′ bands are probably due to the difference in the band responses between the UH 88 inch system and the Suprime-Cam system and the low S/Ns of shallow SXDS images used for comparison with the UH 88 inch data. To confirm accuracy of the photometric zero points in the i′ and z′ bands in our catalogs, follow-up observations are made for the two bands with the 1.0 m telescope at the United States Naval Observatory (USNO). The observations at the USNO were performed on the photometric night of 2004 December 3 in the course of photometric calibration for a high-z supernovae search (N. Yasuda et al. 2008, in preparation). We find that a systematic difference between zero points in our catalogs and those determined by the USNO observation is as small as 0.03 mag rms.

Thus, we conclude that the uncertainties of calibrated photometric zero points of the SXDS images are 0.03–0.05 mag rms. The adopted photometric zero points are listed in Table 2.

5.2. Astrometric Calibration

Astrometric calibration is performed using ~200 stars with magnitude of J_{Vega} < 16.5 derived from 2MASS point-source catalogs (PSC),17 in each of the five stacked Rc-band images. Since images in the other bands have been geometrically transformed, the positions of objects detected on the images should coincide with those found in the Rc-band images (see §3). The world coordinates for the images are calculated for the Rc-band images and written in the FITS headers of all the stacked images with the IRAF tasks ccmap and ccsetwcs. The rms uncertainties of the determined coordinates across the FOV with respect to the PSC positions are on the order of 0.2″ in both R.A. and decl. in each pointing (Table 6). The positional error of the PSC is reported as ~0.07″.

16 See http://www.naoj.org/Science/SubaruProject/SXDS/index.html.

17 VizieR Online Data Catalog: II/246 (R. M. Cutri et al. 2003), http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=II/246.
| Parameter Name         | Unit       | Description                                                                 |
|------------------------|------------|-----------------------------------------------------------------------------|
| ID                     |            | Sequential unique ID of the object in the catalog                           |
| X                      | pixels     | X-coordinate of detection                                                   |
| Y                      | pixels     | Y-coordinate of detection                                                   |
| R.A                     | H:M:S      | Right ascension of detection                                                |
| Dec1                    | D:M:S      | Declination of detection                                                   |
| Kron_Radius            | pixels     | Kron radius $r_{\text{c}}$ defined in Bertin & Arnouts (1996)               |
| A_IMAGE                |            | Second-order moment along the major axis                                   |
| B_IMAGE                |            | Second-order moment along the minor axis                                   |
| Ellipticity            |            | Isophotal weighted ellipticity of the object (=$A\_\text{IMAGE}/B\_\text{IMAGE}$) |
| Theta_image            | deg        | Position angle of the major axis, counter-clockwised, $0.0 = X$ axis         |
| ISOAREA_IMAGE          | pixels     | Area of the lowest isophote                                                |
| IsophotalMag(B)        | mag        | Isophotal magnitude in $B$                                                 |
| IsophotalMag(V)        | mag        | Isophotal magnitude in $V$                                                 |
| IsophotalMag(R)        | mag        | Isophotal magnitude in $R_c$                                               |
| IsophotalMag(i)        | mag        | Isophotal magnitude in $i'$                                                |
| IsophotalMag(z)        | mag        | Isophotal magnitude in $z'$                                                |
| IsophotCorMag(B)       | mag        | Corrected isophotal magnitude in $B$ defined by Bertin & Arnouts (1996)    |
| IsophotCorMag(V)       | mag        | Corrected isophotal magnitude in $V$ defined by Bertin & Arnouts (1996)    |
| IsophotCorMag(R)       | mag        | Corrected isophotal magnitude in $R_c$ defined by Bertin & Arnouts (1996)  |
| IsophotCorMag(i)       | mag        | Corrected isophotal magnitude in $i'$ defined by Bertin & Arnouts (1996)   |
| IsophotCorMag(z)       | mag        | Corrected isophotal magnitude in $z'$ defined by Bertin & Arnouts (1996)   |
| 2.0ApertureMag(B)      | mag        | $\phi^2$ fixed-aperture magnitude in $B$                                    |
| 2.0ApertureMag(V)      | mag        | $\phi^2$ fixed-aperture magnitude in $V$                                    |
| 2.0ApertureMag(R)      | mag        | $\phi^2$ fixed-aperture magnitude in $R_c$                                  |
| 2.0ApertureMag(i)      | mag        | $\phi^2$ fixed-aperture magnitude in $i'$                                   |
| 2.0ApertureMag(z)      | mag        | $\phi^2$ fixed-aperture magnitude in $z'$                                   |
| 3.0ApertureMag(B)      | mag        | $\phi^3$ fixed-aperture magnitude in $B$                                    |
| 3.0ApertureMag(V)      | mag        | $\phi^3$ fixed-aperture magnitude in $V$                                    |
| 3.0ApertureMag(R)      | mag        | $\phi^3$ fixed-aperture magnitude in $R_c$                                  |
| 3.0ApertureMag(i)      | mag        | $\phi^3$ fixed-aperture magnitude in $i'$                                   |
| 3.0ApertureMag(z)      | mag        | $\phi^3$ fixed-aperture magnitude in $z'$                                   |
| Mag_Auto(B)            | mag        | Automatic-aperture magnitude in $B$                                         |
| Mag_Auto(V)            | mag        | Automatic-aperture magnitude in $V$                                         |
| Mag_Auto(R)            | mag        | Automatic-aperture magnitude in $R_c$                                       |
| Mag_Auto(i)            | mag        | Automatic-aperture magnitude in $i'$                                        |
| Mag_Auto(z)            | mag        | Automatic-aperture magnitude in $z'$                                        |
| Mag_Best(B)            | mag        | MAG\_AUTO(B) if there are no neighbors, or IsophotCorMag(B) otherwise     |
| Mag_Best(V)            | mag        | MAG\_AUTO(V) if there are no neighbors, or IsophotCorMag(V) otherwise      |
| Mag_Best(R)            | mag        | MAG\_AUTO(R) if there are no neighbors, or IsophotCorMag(R) otherwise      |
| Mag_Best(i)            | mag        | MAG\_AUTO(i') if there are no neighbors, or IsophotCorMag(i) otherwise     |
| Mag_Best(z)            | mag        | MAG\_AUTO(z') if there are no neighbors, or IsophotCorMag(z) otherwise     |
| Err(IsophotalMag(B))   | mag        | Isophotal magnitude rms error in $B$                                        |
| Err(IsophotalMag(V))   | mag        | Isophotal magnitude rms error in $V$                                        |
| Err(IsophotalMag(R))   | mag        | Isophotal magnitude rms error in $R_c$                                      |
| Err(IsophotalMag(i))   | mag        | Isophotal magnitude rms error in $i'$                                       |
| Err(IsophotalMag(z))   | mag        | Isophotal magnitude rms error in $z'$                                       |
| Err(IsophotCorMag(B))  | mag        | Corrected isophotal magnitude rms error in $B$                              |
| Err(IsophotCorMag(V))  | mag        | Corrected isophotal magnitude rms error in $V$                              |
| Err(IsophotCorMag(R))  | mag        | Corrected isophotal magnitude rms error in $R_c$                            |
| Err(IsophotCorMag(i))  | mag        | Corrected isophotal magnitude rms error in $i'$                            |
| Err(IsophotCorMag(z))  | mag        | Corrected isophotal magnitude rms error in $z'$                            |
| Err(2.0ApertureMag(B)) | mag        | $\phi^2$ fixed-aperture magnitude rms error in $B$                          |
| Err(2.0ApertureMag(V)) | mag        | $\phi^2$ fixed-aperture magnitude rms error in $V$                          |
| Err(2.0ApertureMag(R)) | mag        | $\phi^2$ fixed-aperture magnitude rms error in $R_c$                        |
| Err(2.0ApertureMag(i)) | mag        | $\phi^2$ fixed-aperture magnitude rms error in $i'$                         |
| Err(2.0ApertureMag(z)) | mag        | $\phi^2$ fixed-aperture magnitude rms error in $z'$                         |
| Err(3.0ApertureMag(B)) | mag        | $\phi^3$ fixed-aperture magnitude rms error in $B$                          |
| Err(3.0ApertureMag(V)) | mag        | $\phi^3$ fixed-aperture magnitude rms error in $V$                          |
| Err(3.0ApertureMag(R)) | mag        | $\phi^3$ fixed-aperture magnitude rms error in $R_c$                        |
| Err(3.0ApertureMag(i)) | mag        | $\phi^3$ fixed-aperture magnitude rms error in $i'$                         |
| Err(3.0ApertureMag(z)) | mag        | $\phi^3$ fixed-aperture magnitude rms error in $z'$                         |
| Err(Mag_Auto(B))       | mag        | Automatic-aperture magnitude rms error in $B$                               |
| Err(Mag_Auto(V))       | mag        | Automatic-aperture magnitude rms error in $V$                               |
| Err(Mag_Auto(R))       | mag        | Automatic-aperture magnitude rms error in $R_c$                             |
| Err(Mag_Auto(i))       | mag        | Automatic-aperture magnitude rms error in $i'$                              |
| Err(Mag_Auto(z))       | mag        | Automatic-aperture magnitude rms error in $z'$                              |
We examine possible systematic differences in the calculated world coordinates between different pointings by using objects in the overlapping areas of two pointings. Figures 5 and 6 show the differences in R.A. and decl. of pointlike objects with FWHMs < 1.2′ in the magnitude range R = 20.5–24.0 detected both in the SXDS-C image and other surrounding images. From the figures, the world coordinates assigned to each of the five pointing images are in good agreement with one another with accuracy of about 1″ at the edges of the images. The differences of the world coordinates between two pointings studied here are thought to be for the worst cases, since they are derived based on only the objects in the overlapping areas which are located at the edge of each image. Slopes and offsets in the residuals are seen in each panel of the figures. These disagreements in the positions of objects between two overlapping images come from possible tilts, offsets, and/or difference in geometrical scale of the world coordinate systems between the two images. Residuals of distortion in the images and the atmospheric effect, which have not been completely removed in the reduction process, may cause the errors in determination of the world coordinate systems. Nevertheless, the SXDS catalogs have a good enough positional accuracy to perform follow-up spectroscopy.

The astrometrically and photometrically calibrated images of the SXDS in five bands (B, V, R, i', z') described in this section are released via the SXDS Web page.18 The data set described in this paper is based on the data release 1 (DR1). A complete history of the data release is summarized in the Web site. The raw image data are also available to the public via Subaru Telescope Archives System (STARS).19

### 6. PROPERTIES OF THE CATALOGS

#### 6.1. Galactic Extinction

All the magnitudes listed in the catalogs are not corrected for the Galactic extinction. The magnitude attenuation in each band estimated for the central position (02h18m00s, −05°00′00″; J2000.0) based on Schlegel et al. (1998), assuming an extinction curve with RV = AV/E(B − V) = 3.1 is as follows: AB = 0.091, AV = 0.070, AR = 0.056, AI = 0.044, and AZ = 0.031. Table 7 summarizes the magnitude attenuation in each band for all the pointings. The Galactic extinction above must be taken into account when studying extragalactic objects.

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### Table 5

| Parameter               | Value  |
|-------------------------|--------|
| DETECT_MINAREA          | 5      |
| DETECT_THRESH           | 2.0    |
| ANALYSIS_THRESH         | 2.0    |
| FILTER                  | N      |
| DEBLEND_JITHRESH        | 32     |
| DEBLEND_MINCONT         | 0.005  |
| BACK_SIZE               | 32     |
| BACK_FILTER_SIZ         | 3      |
| BACKPHOTO_TYPE          | GLOBAL |
| BACKPHOTO_THICK         | 24     |
| SATUR_LEVEL             | 50000.0|
| GAIN                    | 2.6    |

Notes. — Parameters for SExtractor used to create catalogs. The above values are common to all the SExtractor runs regardless of detection bandpasses.

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18 Online at http://www.naoj.org/Science/SubaruProject/SXDS/.
19 Available online at https://stars.naoj.org.
6.2. Limiting Magnitudes

We examine $3\sigma$ limiting magnitudes measured for the $2''$ diameter apertures in all five bands ($m_{\text{lim}}$ column in Table 2) in the following manner. First, counts in units of ADU falling into the $2''$ diameter apertures are measured at approximately 10,000 positions randomly selected and spreading over the entire image. Next, a histogram of the counts is produced and only the faint side of the histogram is fit by the Gaussian function, as the bright-side tail is composed of not only the sky background, but also photons from the objects. The $\sigma$ of the best-fit Gaussian is regarded as the $1\sigma$ sky fluctuation of the image for the $2''$ diameter apertures. We find that limiting magnitude in each band is $B = 28.4$, $V = 27.8$, $R_c = 27.7$, $i' = 27.7$, and $z' = 26.6$ (AB, $3\sigma$, $\phi = 2''$) in the deepest images of the five pointings.

6.3. S/N Distribution Map

To examine the homogeneity of S/Ns of the SXDS data across the entire field, we investigate the S/N distribution map in the $R_c$-band images. First, we calculate the sky fluctuation per $2''$ diameter aperture within a mesh with a size of $350 \times 350$ pixels at each position in the same manner as in estimation of the limiting magnitudes. The mesh is shifted with a step of 175 pixels to cover the entire field of view. Then, the fluctuations for the $2''$ diameter aperture are converted to S/Ns for objects with an $R_c$ magnitude of 27.5 at each position.

Figure 7 shows the S/N distribution maps for 27.5 mag objects thus obtained for each pointing. The contour lines superimposed on the figures represent S/N = 3 positions. First, we see that the

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|}
\hline
Pointing & rms (R.A.) & rms (Decl.) & Number of Stars \\
& (arcsec) & (arcsec) & \\
\hline
Center & 0.160 & 0.151 & 233 \\
North & 0.220 & 0.218 & 208 \\
South & 0.251 & 0.207 & 194 \\
East & 0.261 & 0.225 & 199 \\
West & 0.217 & 0.201 & 218 \\
\hline
\end{tabular}

\caption{Result of Astrometric Calibration}
\end{table}

Notes.—The resultant rms of astrometric calibration. The number of stars used for calculation of the world coordinates is shown in the far right column.
brightest sources on the images significantly affect the S/Ns around the sources. These areas are flagged in the catalogs. Second, each image shows an almost axisymmetric pattern of the S/N distribution when we ignore the low S/N areas due to the brightest sources. This pattern reflects the vignetting of the prime focus. Third, the pattern is slightly distorted for each image, probably due to bright sources, vignetting by the autoguider probe, difference in the quantum efficiency among CCDs, etc. However, the difference in S/Ns between those in such distorted areas and those in clean areas with higher S/Ns is on the order of 20% at the maximum. This difference is negligible in most studies even for faint sources. Thus, we can securely use the data with quite homogeneous S/Ns across the field of view.

6.4. Completeness and False Detection Rate

Completeness of the object detection as a function of magnitude for each band and for each pointing is estimated. The detection completeness is determined based on a Monte Carlo simulation by adding artificial objects which have Gaussian profiles with their Poisson photon noise into a stacked image used to create the catalogs and then detect them again in the same manner as in creating catalogs. The detection rate thus obtained is regarded as the detection completeness. Here the artificial objects are added to random positions in the effective area of the image. The FWHMs of the Gaussian profiles are set to be the same as the PSF sizes representative of the images which are derived from Table 3. The artificial objects contaminated by any neighbor sources listed in the catalogs are removed in calculation of the detection rate. If such blended objects are not removed from the sample, the detection rate should slightly decrease. However, since the contamination by neighbor objects leads to misidentification of the artificial objects in the object detection process, we adopt the approach which excludes the blended artificial objects, which was also employed in Kashikawa et al. (2004).

The completeness determined by this procedure is shown in Figure 8 for all of the five bands. For the five pointings, the curves of the detection completeness drop similarly with increasing magnitude. We can summarize that the detection completeness in each image is at approximately 50% for objects with the $5\sigma$ magnitude and 30% for objects with the $3\sigma$ magnitude, with a slight difference depending on the band.

On the other hand, rates of the false object detection are also estimated as a function of magnitude. We generate negative images of each pointing and in each band by multiplying all the
counts of the stacked images by $-1$, and then perform object detection for the negative images in the same manner as in creating the catalogs.

In this process, detected objects are considered to be spurious objects. Thus we define the false detection rate as the number of the spurious objects divided by the total number of objects in the catalogs in each magnitude bin, i.e., $N_{\text{spurious}}(m)/N_{\text{total}}(m)$ (Fig. 9). It is seen that a contribution of the false detection is negligible, which does not exceed 0.5% if any, in the magnitude range brighter than the $3\sigma$ limiting magnitude.

### 6.5. Magnitude Differences among the Catalogs

In the areas where two images overlap with each other, a large fraction of objects are detected and their magnitudes are measured in both of the pointings. We can check systematic differences in magnitude of those objects between the two catalogs. Since photometric zero points of the catalogs are determined so that $\text{MAG\_AUTO}$ of objects in the overlapping areas should coincide between any two catalogs (see § 5.1), the magnitude difference in $\text{MAG\_AUTO}$ is negligible. $\text{MAG\_BEST}$ should be identical to $\text{MAG\_AUTO}$ for isolated objects. Therefore, magnitude differences for only the $2''$ and $3''$ diameter aperture magnitudes are investigated in the following manner.

First, we choose only compact objects with FWHMs $< 1.2''$ which are listed in the $z'$-selected catalog for both SXDS-C and another pointing which overlap with each other, then we measure the difference in magnitude of the objects by subtracting the magnitude in this second catalog from SXDS-C. Then, we determine the offset in the magnitude difference, i.e., systematic magnitude difference, by fitting the magnitude difference for a range of $21.0$–$23.5$ mag by a least-squares method. Table 8 lists the systematic...
Fig. 7.—Contour maps of the sky S/N distribution in the $R_c$ band. The deviation (in ADU) of sky background fluctuations per $2\degree$ diameter aperture are measured and converted to the S/Ns for objects with a magnitude of 27.5 at each position.

Fig. 8.—Object detection completeness of the five pointings as a function of magnitude in each band.
magnitude difference thus obtained for the 2" and 3" diameter aperture magnitudes in each band for each pair of catalogs. We note that 2" and 3" diameter aperture magnitudes indicate small systematic differences of \( \pm 0.05 \) mag between the catalogs. We think that this difference is probably due to difference in the PSF shape of the stacked images among the pointings.

In order to see the effects of the systematic difference in the aperture magnitudes, we plot differences in colors of objects between the catalogs measured with the 2" diameter aperture magnitude (Fig. 10). In this figure, for each of the four pairs of catalogs, the differences in colors \((B - V, V - R_c, R_c - i', i' - z')\) are plotted. We see the systematic difference in the 2" diameter aperture colors of objects, which is no larger than 0.1 mag, due to the difference in the aperture magnitude between the catalogs. Since the magnitudes in the catalogs are not adjusted for this difference, the magnitude difference between the catalogs should be taken into account in the case in which the 2" or 3" diameter aperture magnitude is used. For MAG_AUTO and MAG_BEST, which are considered as asymptotic total magnitude, the magnitude difference is negligible.

In the same manner as mentioned above, the rms of the magnitude differences for each band are calculated as a function of MAG_AUTO, which shows no systematic difference. Here the detection band for catalogs are chosen to be the same as the band for which the magnitude difference is investigated. For instance, to obtain the magnitude difference in the \( B \) band, the \( B \)-selected

| POINTING | \( B \) | \( V \) | \( R_c \) | \( i' \) | \( z' \) |
|----------|-------|-------|--------|------|------|
| C - N    | -0.04 | -0.04 | -0.03  | 0.03 | 0.03 |
| C - S    | -0.05 | -0.02 | -0.02  | 0.00 | 0.00 |
| C - E    | -0.02 | -0.02 | -0.01  | 0.00 | 0.00 |
| C - W    | +0.01 | +0.03 | +0.01  | +0.00| +0.00|

**Notes.**—The systematic differences in aperture magnitudes of objects between the catalog of SXDS-C and that of another surrounding pointing. For each band, the magnitude differences in 2" and 3" diameter aperture magnitude are listed. The column of pointing denotes the pair of pointings compared. For instance, the line for C - N indicates magnitude differences calculated by magnitudes in SXDS-C minus those in SXDS-N.
catalogs are used. Again, only the objects with FWHMs $< 1.2''$ are used for measurement of the magnitude difference. The rms of magnitude differences measured in the above way are shown in Figure 11 for each band. It is seen that the rms steadily increases with increasing magnitude. The rms of the magnitude difference can be converted into random magnitude error by dividing it by $\sqrt{2}$. We find that the magnitude errors thus estimated are entirely consistent with those expected from our calculation of the limiting magnitude discussed in § 6.2. Note that the magnitude errors listed in our catalogs are computed by SExtractor assuming the simple Poisson statistics for the sky background fluctuations. The sky background noises measured in photometry apertures for the stacked images are likely to be larger than those estimated by SExtractor. Therefore, the magnitude errors in the catalogs are underestimates and are not suitable for immediate analysis such as SED fitting and photo-$z$ estimation.

6.6. Number Counts of Galaxies

To examine the characteristics of the catalogs, we compare the number counts of galaxies with data from previous surveys. We calculate the number counts of galaxies by correcting our raw counts of detected objects against the detection completeness estimated in § 6.4. The detailed studies of density fluctuations of galaxies based on the number counts or luminosity functions of galaxies can be found elsewhere (e.g., Yamada et al. 2005). Study of Star/galaxy separation is conducted based on FWHM and 2'' diameter fixed-aperture magnitude of the objects, for which the effect of the Galactic extinction (Table 7) is corrected. The criteria for the separation is determined so that objects which have PSF sizes equal to both the images and saturated objects are effectively

![Figure 10](image1.png)

**Fig. 10.**—Residuals in colors measured for the 2'' diameter aperture magnitudes of the objects common in two separate pointing catalogs.

![Figure 11](image2.png)

**Fig. 11.**—Random magnitude difference as a function of magnitude in each band. The random magnitude differences are computed by comparing fluxes of compact objects with FWHMs $< 1.2''$ between the central pointing and the four surrounding pointings.
removed. For fainter magnitudes (>22.5 mag), no separation is performed, since a large fraction of galaxies have small sizes similar to those of stars, and the contribution to the number count by stars is small at the faint magnitudes. The criteria for the separation adopted is summarized in Table 9.

The results of the number counts of galaxies are as follows:

First, internal comparison of the number counts among the five pointings of the SXDS are shown for each band in Figures 12–16. In each figure, raw number counts of the galaxy samples extracted by the star/galaxy separation process above are plotted with open symbols. Effective areas used to calculate the number counts per unit area are given in Table 3. The number counts of galaxies which are corrected for the detection completeness are also superimposed with filled symbols. Here, the correction is performed by using the detection completeness as a function of magnitude which has been estimated for the Gaussian profiles, i.e., \( N(m)_{\text{corr}} = N(m)_{\text{obs}} \times \text{completeness}(m) \). Error bars are calculated on the assumption of simple Poisson noise. We can say that no large systematic difference is seen in the superposition of the number counts of galaxies among the five pointings in \( B \), \( V \), and \( R_c \) bands down to the 3 \( \sigma \) magnitudes. Similarly, in the other two bands, the number counts are consistent with one another among the five pointings within the Poisson errors at magnitudes brighter than \(~25\) mag. However, differences in the number counts at fainter magnitudes are found to be a factor of 1.4 in the \( i' \) band and 1.7 in the \( z' \) band. This might be partly due to the field-to-field variation in the number counts of galaxies. However, since we have used only the Gaussian profiles with FWHM \(~0.8''\) in the simulation of the detection completeness, the completeness is likely to be overestimated in the faint magnitude range, where most objects have extended profiles. So, we cannot conclude that the differences in the number counts at the faint end seen in the \( i' \) and \( z' \) bands implicate a field-to-field variation.

Next, the number counts in the SXDF are compared with results by previous surveys (Figs. 17–21). Here, we calculate mean number counts of galaxies corrected for the detection completeness

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### Table 9

| Band | Criteria |
|------|----------|
| \( B \) | \((m = 19.5 - 23.0, \sigma > 4.5, \sigma > -2.5 [m - 20.3] + 4.5) \lor (m > 23.0)\) |
| \( V \) | \((m = 19.5 - 23.0, \sigma > 4.5, \sigma > -2.5 [m - 20.0] + 4.5) \lor (m > 23.0)\) |
| \( R_c \) | \((m = 19.5 - 22.5, \sigma > 4.5, \sigma > -2.5 [m - 20.3] + 4.5) \lor (m > 22.5)\) |
| \( i' \) | \((m = 19.5 - 22.5, \sigma > 4.5, \sigma > -2.5 [m - 20.1] + 4.5) \lor (m > 22.5)\) |
| \( z' \) | \((m = 18.5 - 22.5, \sigma > 4.5, \sigma > -3.0 [m - 19.3] + 4.5) \lor (m > 22.5)\) |

**Notes.**—The criteria used in the star/galaxy separation procedure. Objects satisfying these criteria are recognized as galaxies. In the criteria list, \( m \) denotes a 2'' diameter fixed-aperture magnitude, and \( \sigma \) is the FWHM of objects in the corresponding band.
for the entire SXDF using the above sample for the five pointings and plot them with filled circles with error bars which may be within the filled circle. The error bars are again based on the Poisson noise.

The results in other surveys are derived from Kashikawa et al. (2004) and Capak et al. (2007) and the references cited therein. A complete list of references compared in the figures is SDF: Kashikawa et al. (2004); HDFs/WHDFs: Metcalfe et al. (2001); Arnouts99: Arnouts et al. (1999); SDSS: Yasuda et al. (2001); CADIS: Huang et al. (2001); Kummel&Wagner01: Kümmel & Wagner (2001); Tyson88: Tyson (1988); Arnouts01: Arnouts et al. (2001); Capak04: Capak et al. (2004); Smail95: Smail et al. (1995); SH93: Steidel & Hamilton (1993); Hogg97: Hogg et al. (1997); COSMOS: Capak et al. (2007); Postman98: Postman et al. (1998); Lilly91: Lilly et al. (1991).

From the comparison of the number counts among various surveys, we understand that our sample is consistent with results in other surveys for blank fields for the following reasons. First, the mean number counts of the SXDS show a good agreement with those from previous surveys down to magnitudes where the number counts start to turn off. Second, it reproduces the faint-end

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**Fig. 15.**—Same as Fig. 12, but for $i'$-band data.

**Fig. 16.**—Same as Fig. 12, but for $z'$-band data.

**Fig. 17.**—Comparison of the galaxy number count of the SXDS (blue filled circles) with other major optical imaging surveys. The SXDS values are corrected for the detection completeness and the mean value for the five pointings is plotted.

**Fig. 18.**—Same as Fig. 17, but for $V$-band data.
data points derived from Hubble Deep Field (HDF). Again, the detection completeness simulated with the Gaussian profiles might cause a slightly large uncertainty of the corrected number counts at the faint end in each band. Thus, we conclude that the SXDS catalogs in the present study have characteristics similar to those in previous surveys and can be applied to general statistical studies on faint objects ranging from Galactic objects to high-redshift galaxies.

We would like to mention how the Poisson error on the number counts is decreased by increase of the survey area. Figure 22 shows a comparison of the Poisson error associated with the number counts of galaxies among three surveys which are based on different survey areas, namely the HDF-North (5.3 arcmin^2), GOODS-North (170 arcmin^2), and Suprime-Cam 1 FOV (918 arcmin^2).

The uncertainty in the number counts due to the Poisson error is shown with a pair of lines for each of the surveys. For reference, the number count of SXDS is superimposed with a thick solid line. From the figure, we clearly see that the Poisson error decreases with increasing survey area. In particular, at the bright magnitudes of 21–23 mag, a large uncertainty by a factor of >3 in the number count is found for the HDF-North area (dotted lines). For the same magnitude range, the uncertainty for a field of view of Suprime-Cam (dot-dashed lines) is 8–15 times smaller than...
that for the HDF-North area and 1.5–2.5 times smaller than that for the GOODS-North area. Even at the faintest magnitudes of >27 mag, a significant difference in the uncertainty from one survey area to another is seen. Thus, it is emphasized that the SXDS data, which consists of five pointings of Suprime-Cam field of view, is a useful data set for studies of celestial objects which dominate a large fraction of the number counts without suffering from Poisson error and field-to-field variation, e.g., a study of evolution of the LSSs.

7. SUMMARY

The optical imaging observations of the SXDS project are carried out using the Suprime-Cam on the Subaru Telescope in the $B$, $V$, $R_c$, $i'$, and $z'$ bands. The SXDF has a contiguous area coverage of $\sim 1.2$ deg$^2$, which consists of five Suprime-Cam pointings.

The photometric zero points are determined with an absolute accuracy of no larger than 0.05 mag rms in the photometry. The rms of the astrometric accuracies across the field are of order 0.2$''$ in both R.A. and decl. The systematic differences in the adopted world coordinates between different pointings are within about 1$''$ at the outer edge of the field of view. Thus, our SXDS catalogs have positional accuracies that are good enough to perform follow-up spectroscopy.

Multi–wave band photometric catalogs of detected objects are created for each band and for each pointing. Each of the catalogs contains more than 160,000 objects. The catalogs have quite homogeneous S/Ns across the field. The achieved limiting magnitudes in each band are $B = 28.4$, $V = 27.8$, $R_c = 27.7$, $i' = 27.7$, and $z' = 26.6$ (AB, $3 \sigma$, $\phi = 2''$).

The detection completeness as a function of magnitude is estimated by a Monte Carlo simulation assuming a Gaussian profile. The number counts of galaxies in the SXDF in each band are computed by correcting the detection completeness, which is consistent among the five pointings, with a slight difference at faint magnitudes. The mean number counts of galaxies averaged over the five pointings show a good agreement with results from previous surveys down to the faint-end magnitude.

With the aid of the wide coverage area of SXDS data, the uncertainty of the number counts of galaxies due to the Poisson error is greatly decreased. It is emphasized that the SXDS data is extremely useful for pursuing studies on celestial objects spreading in a wide field without suffering from Poisson error and field-to-field variation. The SXDS catalogs can be applied to studies whose scientific objectives range from the Galactic objects to the large-scale structures of the universe. The optical data, the compiled photometric catalogs, and configuration files used to create the catalogs have been released to the public and can be retrieved from the public data archives server of National Astronomical Observatory of Japan.$^{21}$

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$^{21}$ See also (N. Metcalfe 2007) http://star-www.dur.ac.uk/~nm/pubhtml/counts/counts.html.

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