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Wide Field Camera data products for the SSC XID program

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1 Summary

This document contains information describing the data produced from the Wide Field Camera for the SSC XID program. These are divided into three main types or products:

- Reduced images
- Catalogues
- Merged catalogues

Each product is briefly described and example of the quality control measures taken are shown.

Most WFC data used in the XID program was obtained from ITP runs but data for some fields (Lockman Hole, SDS-1) comes from survey runs.

Information on the state of processing of WFC data for all observing runs used in XID work can be found in [1]. Also shown are the locations of the original data files. Information on the availability of data for each field due to be included in the XID program can be found in [2].

Contents

2 Reduced Images

Copies of all reduced images currently being used for XID work for a given field can be found in:

*/data/cass010a/xmmssc/public_html/***field***/wfc/*

where **field** is the subdirectory corresponding to that field. Other images already processed but where XID work has not yet been carried out can be found at the locations specified in [1].

There is one image per field per band (the bands currently in used for XID work are i, z, g, r, U).

The images are reduced by Jim Lewis.

2.1 Description

Each image has 2048 by 2048 pixels, contained in a FITS image extension. The 4 chips of the WFC as disposed as shown on Fig. 1, covering an overall area of roughly 0.2 square degrees. A typical header can be found in Appendix 1.

2.2 Quality condrol

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//// decription of the sybase db with names of columns

//// some seing histograms, etc...

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3 Catalogues

3.1 Description of FITS catalogues

FITS tables containing source lists are produced for each image by Mike Irwin. There is one source list for each CCD in a given image. They can be found at the same location as the images.

A typical header indicating the nature of fields in the FITS table can be found in Appendix 2. Source positions are given as RA and DEC and as X- and Y- coordinates relative to a reference point; the projection used is Zenithal Polynomial (ZPN). Further information on the contents of the headers anf the definition of each column is available in [4]. The highest magnitude detected varies according to the exposure time but never exceeds 29 and the g–band isusually the deepest, although the i–band will be used for XID purposes because it is consistently available for every field with WFC data. The shallowest band is usually the U–band. Number densities vary between 20000 and 75000 per square degree depending on the depth and on each field's galactic latitude, as can be seen on Fig. 2(d).

3.2 Description of IDL DBase catalogues

The IDL package 'dbase' is used to convert the FITS source lists to IDL databases. ASTROLIB routines are used to read the binary table columns into structure fields, which are then built into the database. This process is automatically repeated for each source list, concatenating the 4 CCDs into one database and then sorting it by Right Ascension.

The databse contains only selected fields from the initial FITS source list, as can be seen in Appendix 3, which contains a typical *.dbd* file (*i.e.* the file describing the database format) for a single band source list. RA and DEC are stored in decimal hours and degrees respectively.

Magnitudes are computed from the fluxes given in the FITS files by reading the exposure time t and band name from the FITS header and using the following zero–points (obtained from [3]):

- i–band:$M_0 = 23.7$
- z–band $M_0 = 22.2$
- r–band:$M_0 = 24.3$
- g–band:$M_0 = 24.9$
- U–band:$M_0 = 22.3$

The magnitude M for a given object is then:

$$M = 2.5 * [\log_{10}(t) - \log_{10}(S)] + M_0 \tag{1}$$

where S is the Core flux for that object (hence the magnitude is sometimes referred to as Core magnitude.

For a given field, these database files can be found in:

*/data/cass010a/xmmssc/public_html/***field***/dbase/*

and are called *wfci*, *wfcz*, *wfcr*, *wfcg*, *wfcu* depending on the band.

The 'dbase' package then provides powerful and fast routines for extracting information and comparing entries between databases.

3.3 Quality Control

There are links to all the available qualtiy control plots in [2].

3.3.1 Spatial distribution of objects on image

The RA and DEC information was converted back to X- and Y- coordinates using the same ZPN projection and a scatter plot was produced for each WFC pointing with the CCD outlines overlaid (CCD bounadaries were deduced from the FITS headers). This allowed us both to detect cases where, for instance, a very bright object had been removed from an image leaving a blank area (see Fig. 2(b)), but also to check the conversion from RA and DEC to ZPN coordinates we were performing, as it would be of importance later on.

While the Fig. 1 is a fairly typical example of the distribution of objects over the image and across different object classes examples of some of the defects detected are shown on Fig. 2. Fig. 2(a) shows very strong fringe patterns, which are seen on an important fraction of the images (30%), and usually classified as galaxies. Note that the defringing is still under way (see [3]). Fig. 2(b) shows a case where a bright object was removed. Fig. 2(c) shows a low galactic field which is very crowded. Fig. 2(c) shows a small defect on one of the CCDs.

3.3.2 Differential magnitude histograms

Differential histograms were plotted class by class and CCD by CCD for each band. A typical example of the results is shown on Fig. 3. As expected, stars cover a wide range of magnitudes while galaxies are generally fainter. However the degree of flatness of the distribution for stars varies: see Fig. 4. There is little variation with band except for the fact that some bands go deeper as previously mentioned. No discrepancies were detected for different CCDs.

The faintest part of the distribution is generally constituted of objects classified as noise. Is it worth noticing? Is the excess of bright stars worrying?

For each band, an additional database is generated (named, for example, *wfci_diffmag*) containing the values of differential and cumulative histograms of magnitude for than band. These are used later in the evaluation of the quality of the XID results to calculate a magnitude–dependent bagkround density of WFC objects.

3.3.3 Differential ellipticity histograms

Similar histograms were produced for the ellipticity of the WFC objects. A typical example is shown in Fig. 5(a). As would be expected, galaxies generally have a higher ellipticity than stars,

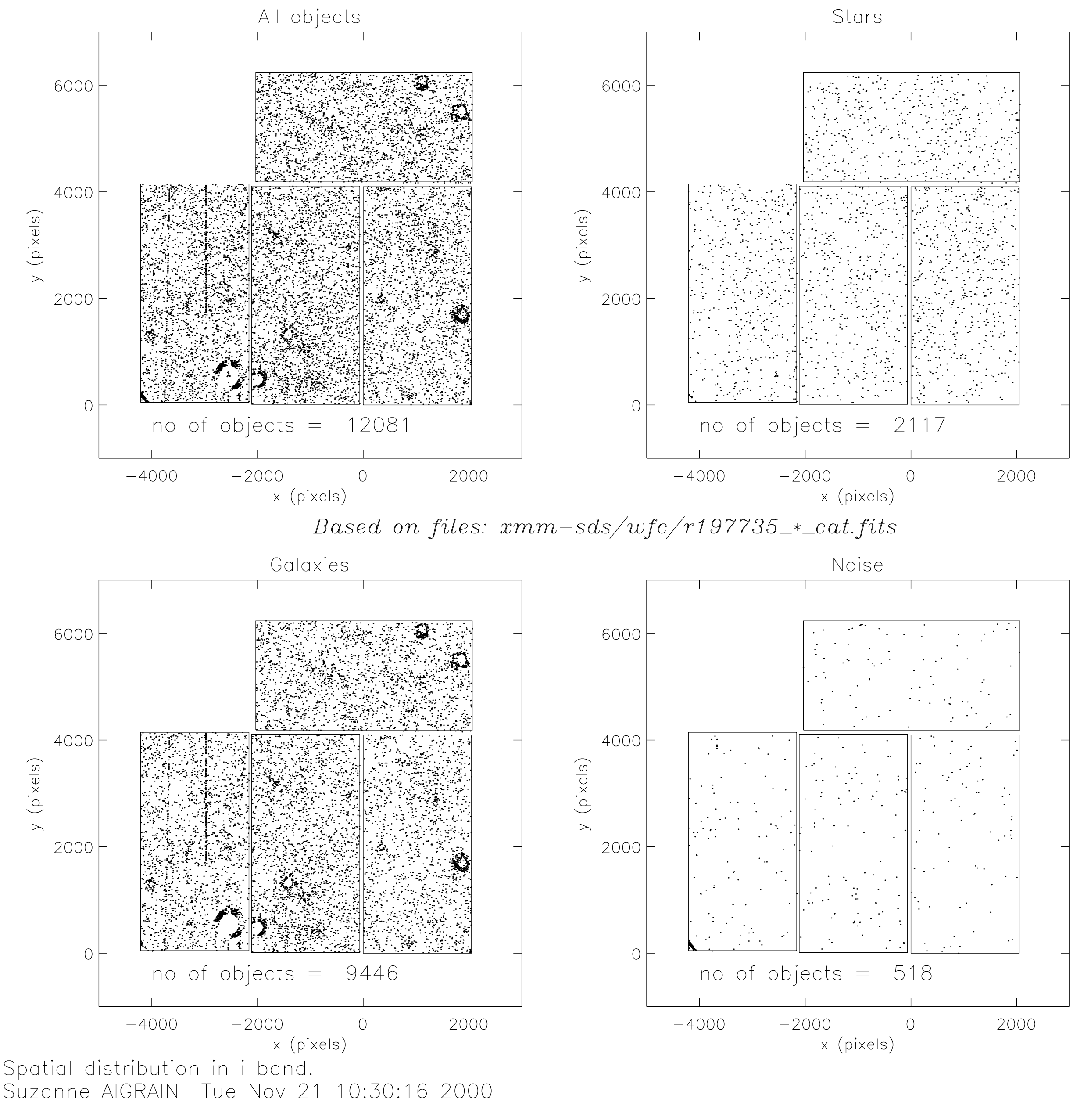

Figure 1: i–band spatial distribution plots for the SDS-1 field, showing (a) all objects, (b) stars only, (c) galaxies only and (d) objects classified as noise only.

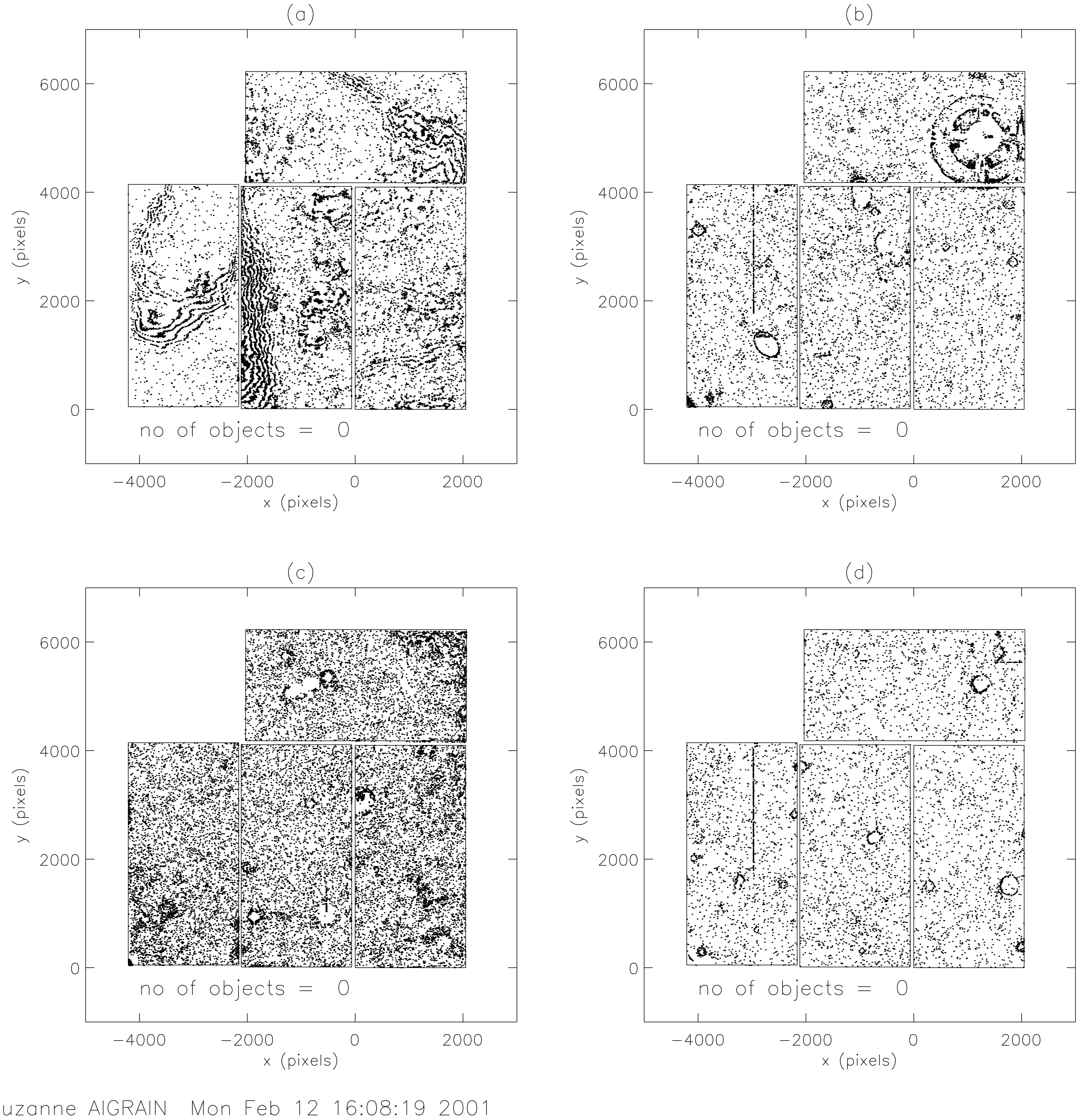

Figure 2: Example of imperfections shown by the spatial distribution plots: (a)z–band G 133 field (galaxies only) showing fringes, (b)z-band, MKN 205 field (all objects) showing the effect of removing a bright object, (c)i–band, GRB 001025 field (all objects) showing a very crowded low galactic latitude field, (d)g–band, EQ PEG field (galaxies only) showing a small defect in the CCD on the left (also seen in (b)).

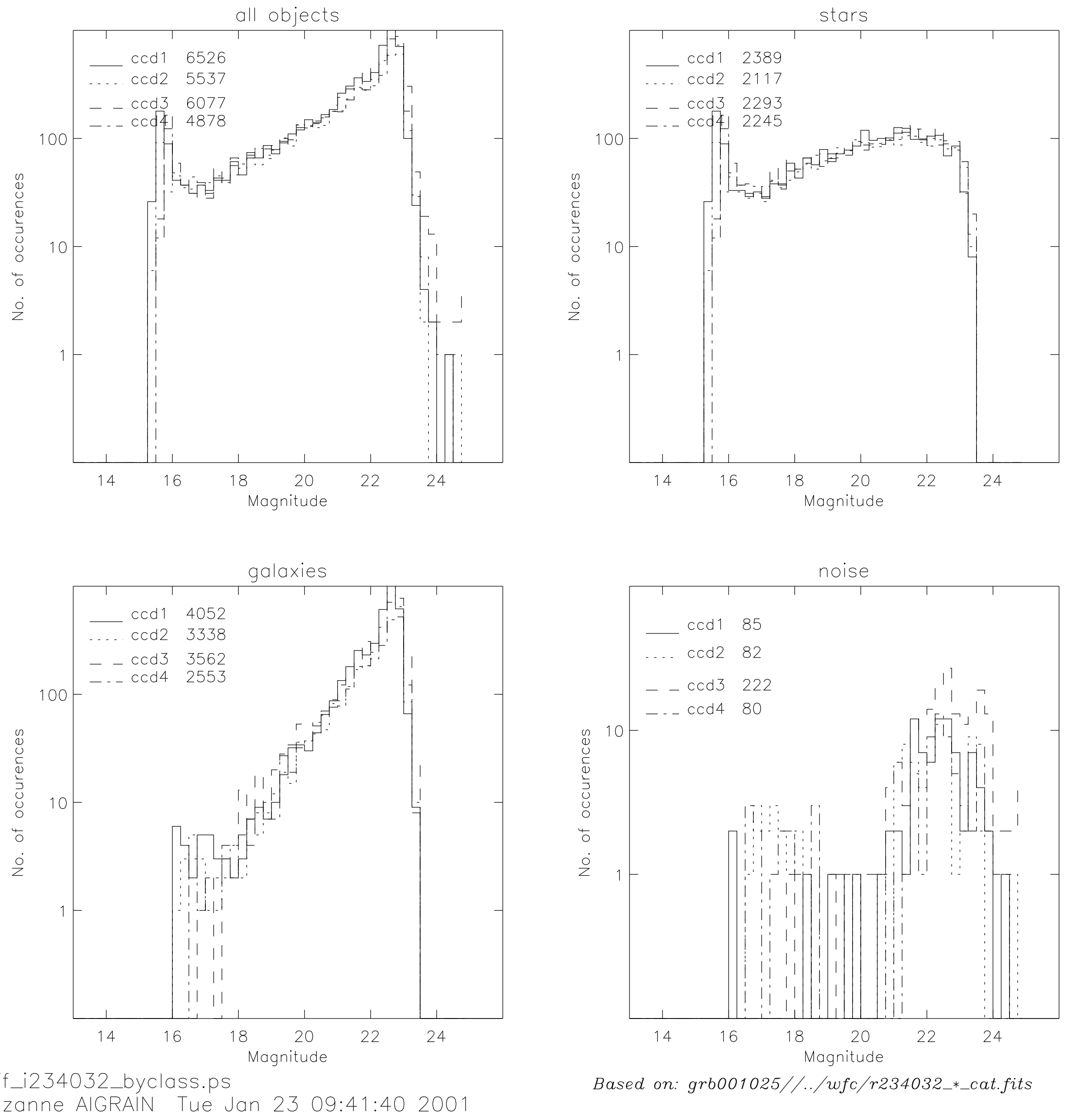

Figure 3: i–band differential magnitude histograms for the GRB 001025 field, showing (a) all objects, (b) stars only, (c) galaxies only and (d) objects classified as noise only. Different line styles correspond to different CCDs.

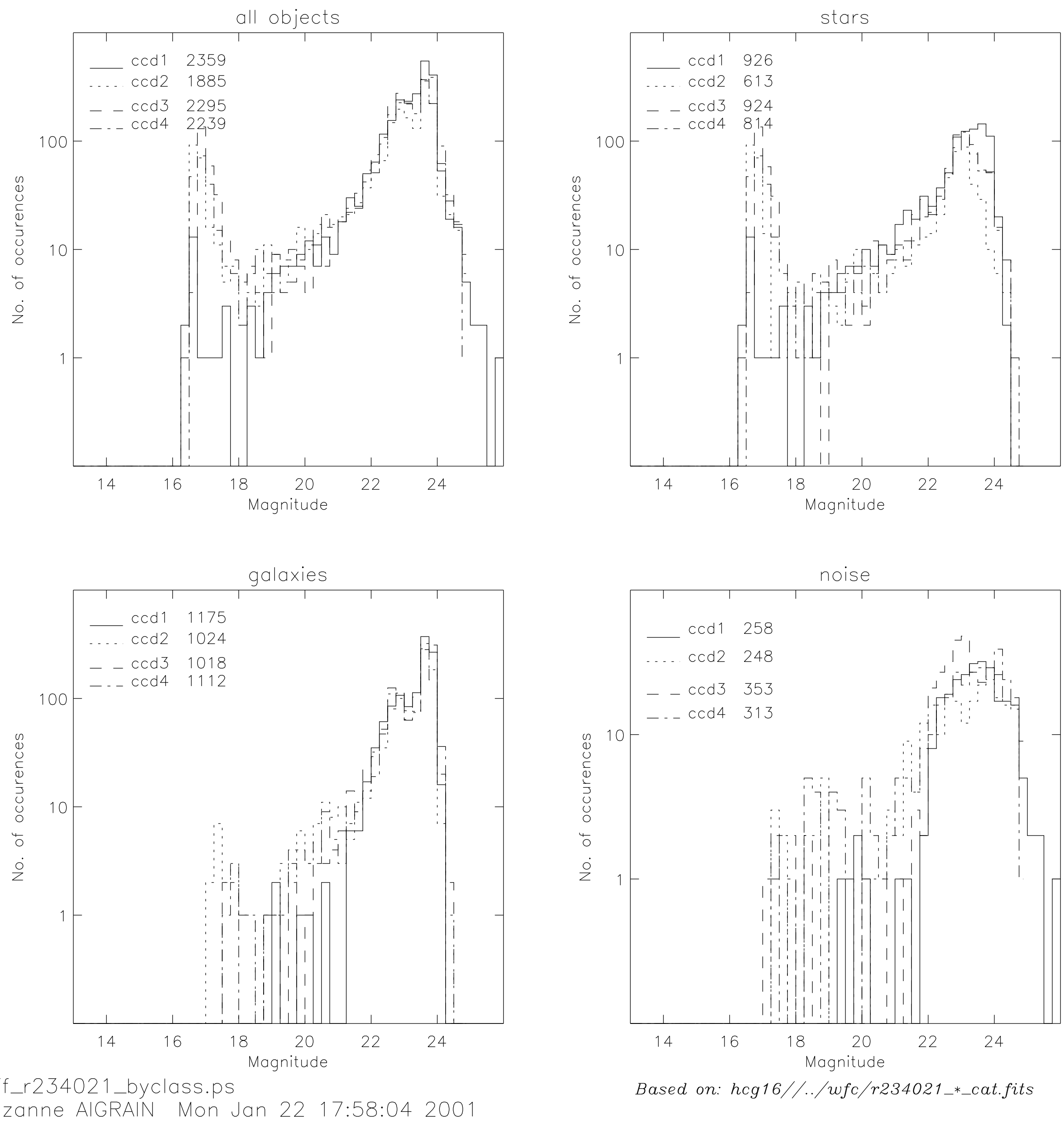

Figure 4: r–band differential magnitude histograms for the HCG 16 field, showing (a) all objects, (b) stars only, (c) galaxies only and (d) objects classified as noise only. Different line styles correspond to different CCDs.

and the high ellipticity tail is classified as noise. The histograms are constistent across different fields, bands and CCDs.

3.3.4 Differential position angle histograms

Position angle histograms show, on the whole, a flat distribution as expected, but there is often a small peak at 80 degrees and the distribution for starsis more irregular than that for noise (see Fig. 5(b)). There is more variability than for the ellipticity histograms, with some fields having a slightly sloped ditribution (Fig. 5(c)) and a consistent discrepancy between CCD 2 and the other CCDs (an example of which is shown in Fig. 5(c) & (d)).

3.3.5 Plots of statisitic versus core magnitude

The parameter referred to as statistic, described in [4], is used to in combination with core magnitude to determine the class of the object. This can be seen in the plots of statistic versus Core magnitude produced for each source list, of which a typical example is shown in Fig. reffig:statgood.

4 Merged catalogues

The merged catalogues are obtained by merging available source lists for a given field, for different bands. Not that the lists are only merged within a given observing run, such that when data was taken for a given field on more than one run there are several sets of merged source lists. When that is the case the merged lists containing i–band information are used for XID work.

4.1 Description of FITS merged catalogues

The unmerged WFC FITS files are merged by Mike Irwin to produce 4 merged files per field (one per CCD) per observing run. On occasions where the same band was observed more than once during the same observing run, both resulting source lists are included. The resultant FITS files contain roughly the same information as the unmerged ones (except that the positions are provided only in terms of X– and Y–coordinates, not in terms of RA and DEC). These X– and Y– coordinates are given relative to a reference point in arcsecs. There is one row per object per band, i.e. if merging files for the i–, z– and g– band there would be three rows per object. Object detected only in some of the bands have zeros in the rows corresponding to bands they were not detected in. For more information see the section on merged files in [4]. A typical merged FITS header is shown in Appendix 4.

The original location of the merged files, as well as that of the copies use for XID work, is the same as for the unmerged files. The merged files are usually named **field**_$*$.*mer*, or sometimes **field**_*x*_$*$.*mer* when there is a slight offset from the target position.

4.2 Description of IDL DBase merged catalogues

IDL database are made from the merged files in the same way as for the unmerged files, by concatenating the 4 CCDs together, then sorting by RA. However there are a few additional considerations to take into account:

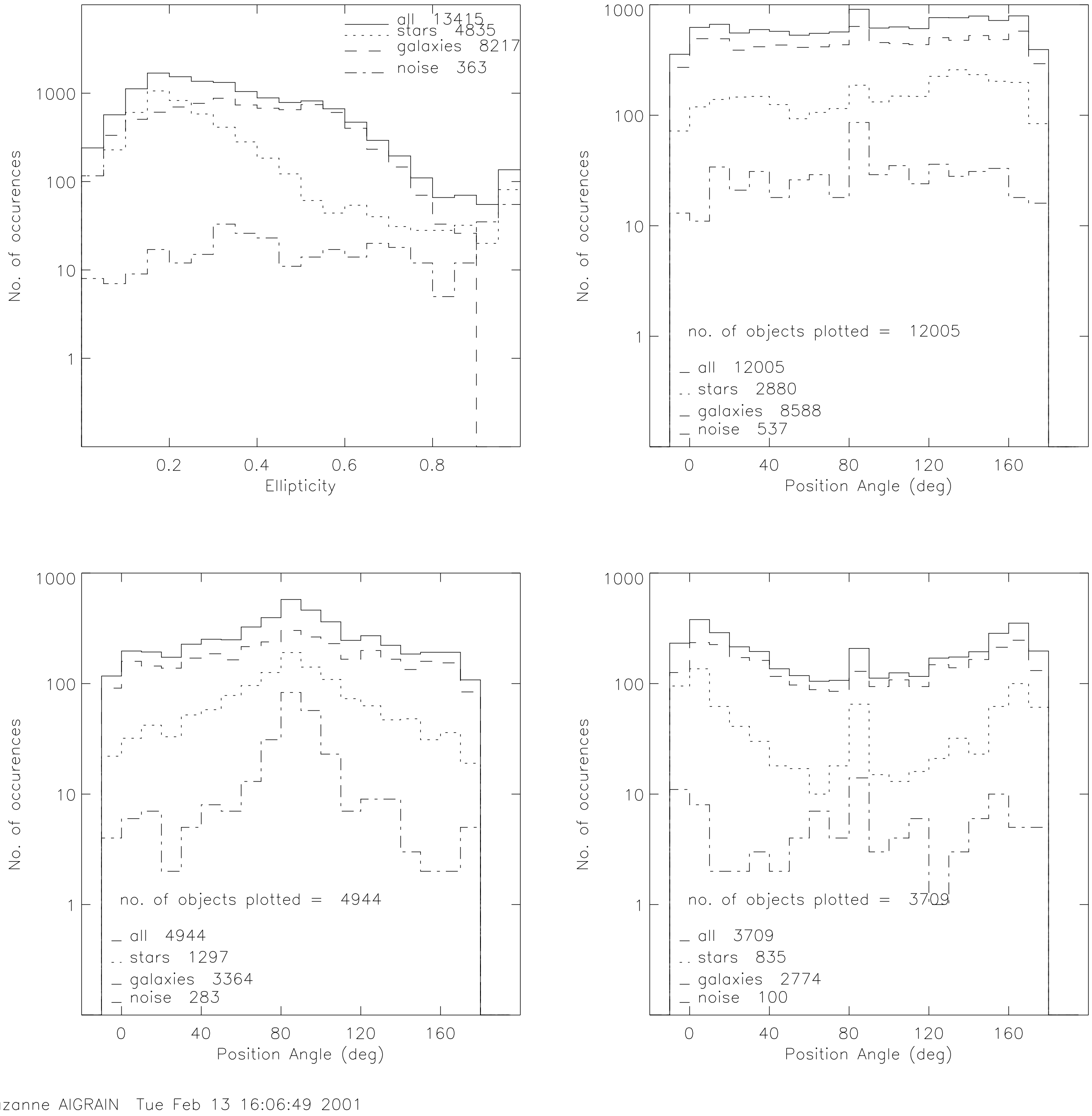

Figure 5: Ellipticity and Position Angle histograms: (a)i–band EQ PEG field (all CCDs) ellipticity histograms, (b)i–band G 133 field (all CCDs) position angle histograms, (c)i–band, HCG 16 field (all objects, CCD 1) showing a slopped distribution, (d)i–band, HCG 16 field (all objects, CCD 2). Clear difference with (c).

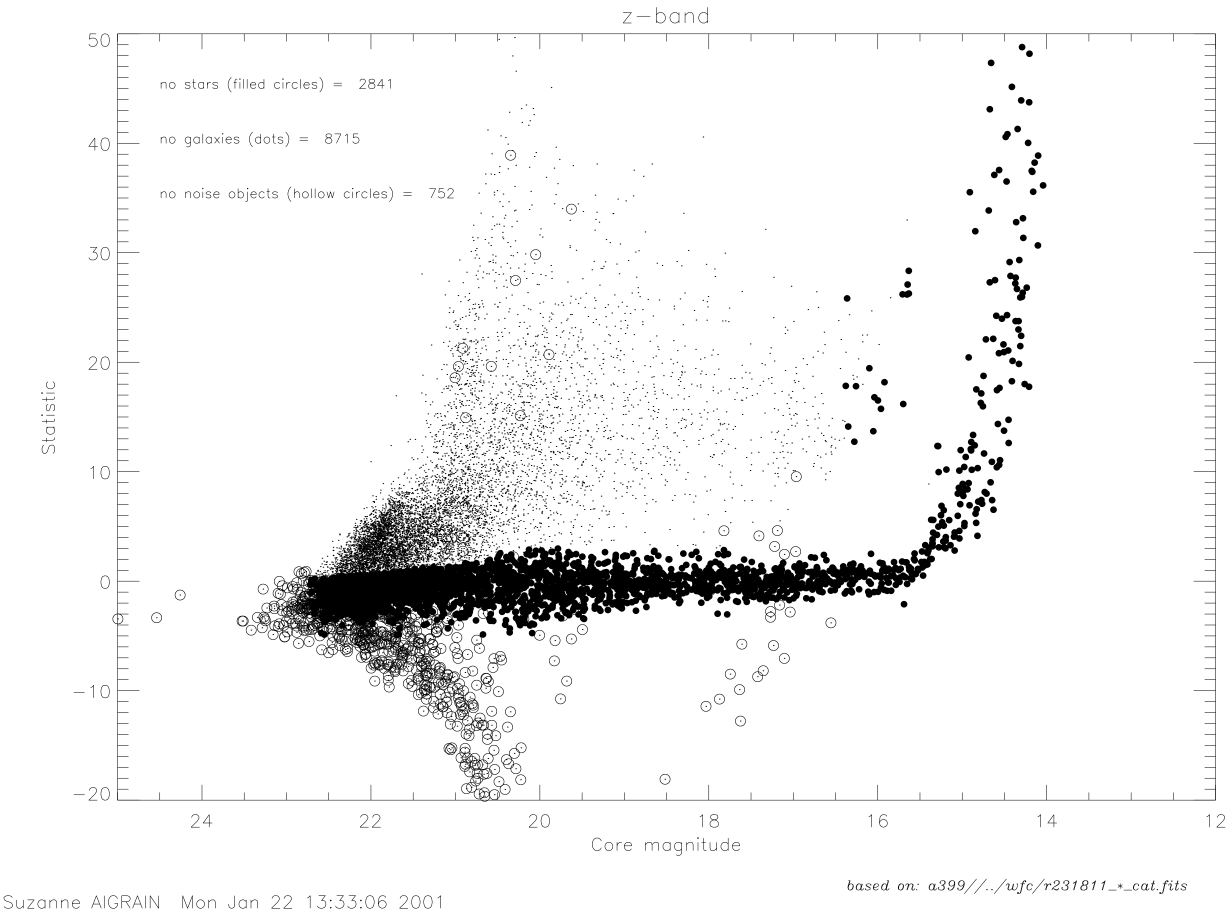

Figure 6: Statistic versus core magntiude for the z–band EA 399 field

- The user is prompted to enter the order in which he or she wants bands to be entered into the database. In the case where there are several occurences of the same band only one occurence should be selected.
- Information for one object occupies only one row, and there are 5 sets of columns per object (columns corresponding to absent bands are filled with zeros).
- The X– and Y–coordinates have to be converted to RA and DEC using a tangent plane calculation.
- The databases are named after the bands they contain in the order chosen by the user *e.g. izrgu* if all bands are present. They are found at the same location as the unmerged databases.

A typical database description file is shown in Appendix 5.

4.3 Quality Control

4.3.1 Colour-Colour plots with synthetic data over laid

There are links to all the available colour–colour plots in [2].

Merged databases allow us to create colour–colour plots for WFC data. It is also possible to overlay synthetic stellar and QSO catalogues available as IDL databases. (Note only colour–colour plots and not colour–magnitude plots are included here because the synthetic values are only meaningful relative to each other).

The two cases for which plots of $g-r$ versus $r-i$, $u-g$ versus $g-r$ and $u-g$ versus $g-i$ are available are shown in Figs. 7 and 8.

Little variability is seen across diferent fields (over a relatively small number of fields which have both merged data and the necessary bands) for the $g-r$ vs $r-i$ plots. (The other colour–colour plots are currently only available in the fields shown here). Noise objects are usually outlying compared to galaxies.

Although the synthetic stellar data is in good agreement with the WFC data in the $g-r$ vs $r-i$ plots, the agreement is less pronouced for the other two plots, with the break in the synthetic curve absent from the WFc data. Note the strange distribution of noise objects in Fig. 8(d). Another interesting point is that certain bands seem to select out the noise objects (i for the MKN 205 field, U for the Lockman Hole field). For MKN 205, i is the band with the longest exposure time, while on the other hand, for the Lockman Hole, U is the shallowest band (remembering noise objects are found at the faint end of the magnitude distribution).

References

[1] Summary of location and state of processing of WFC data: *http://www.ast.cam.ac.uk/x̃mmssc/xid/nights_status.php*

[2] Availability of APM, WFC and CIRSI data for each XID field: *http://www.ast.cam.ac.uk/x̃mmssc/xid/data_status.php?no_update*

[3] Wide Field Survey - Pipeline Processing: *http://www.ast.cam.ac.uk/w̃fcsur/pipeline.html*

[4] README for WFC FITS source lists: *http://www.ast.cam.ac.uk/w̃fcsur/release.summary.readme*

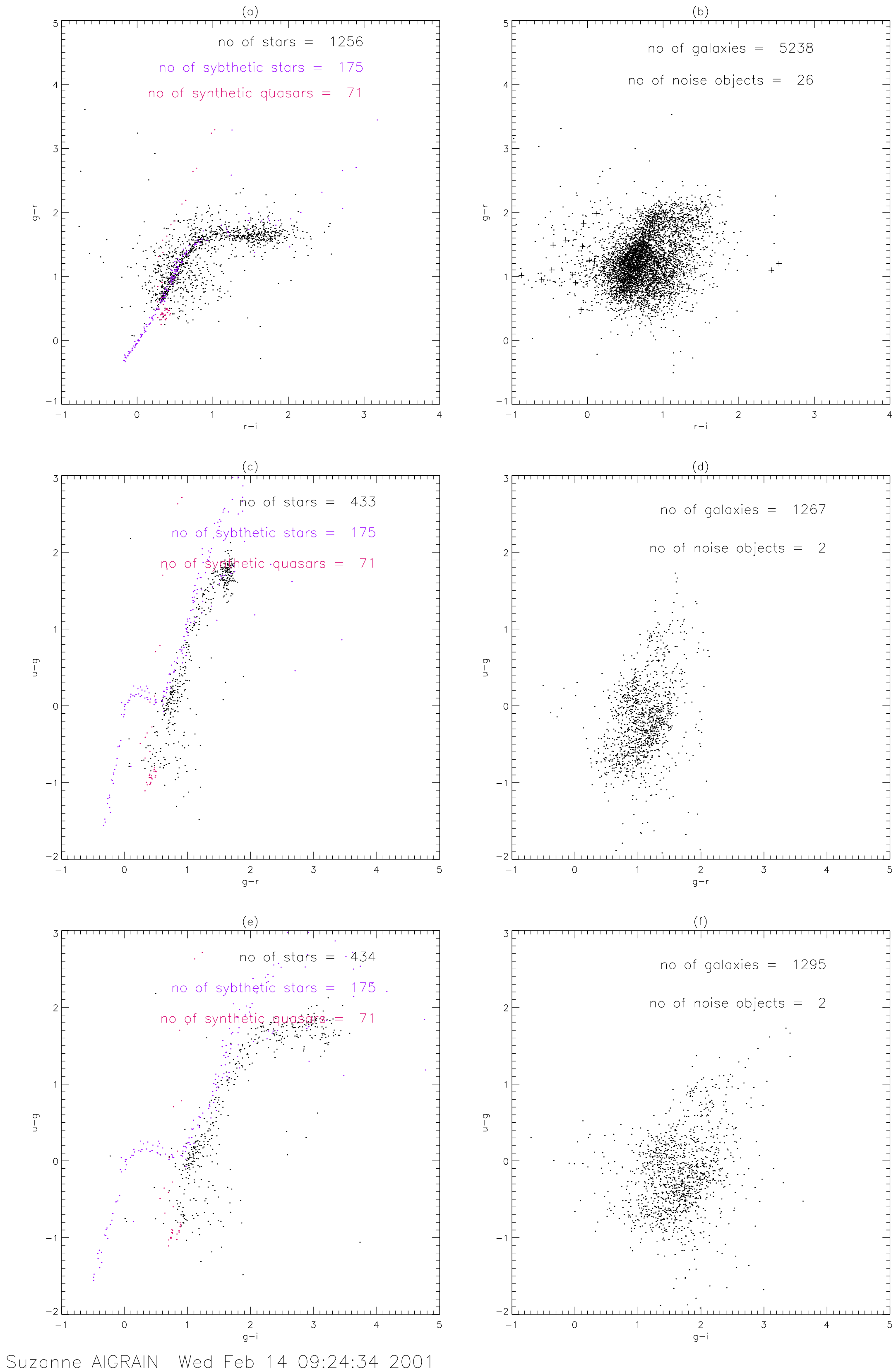

Figure 7: Colour–Colour plots for the Lockman Hole field with synthetic data overlaid: (a) $g-r$ vs $r-i$, stars only with synthetic stars and QSOs, (b) $g-r$ vs $r-i$, galaxies and noise only, (c) $u-g$ vs $g-r$, stars only with synthetic data, (d) $u-g$ vs $g-r$, galaxies and noise only, (e) $u-g$ vs $g-i$, stars only with synthetic data, (f) $u-g$ vs $g-i$, galaxies and noise only.

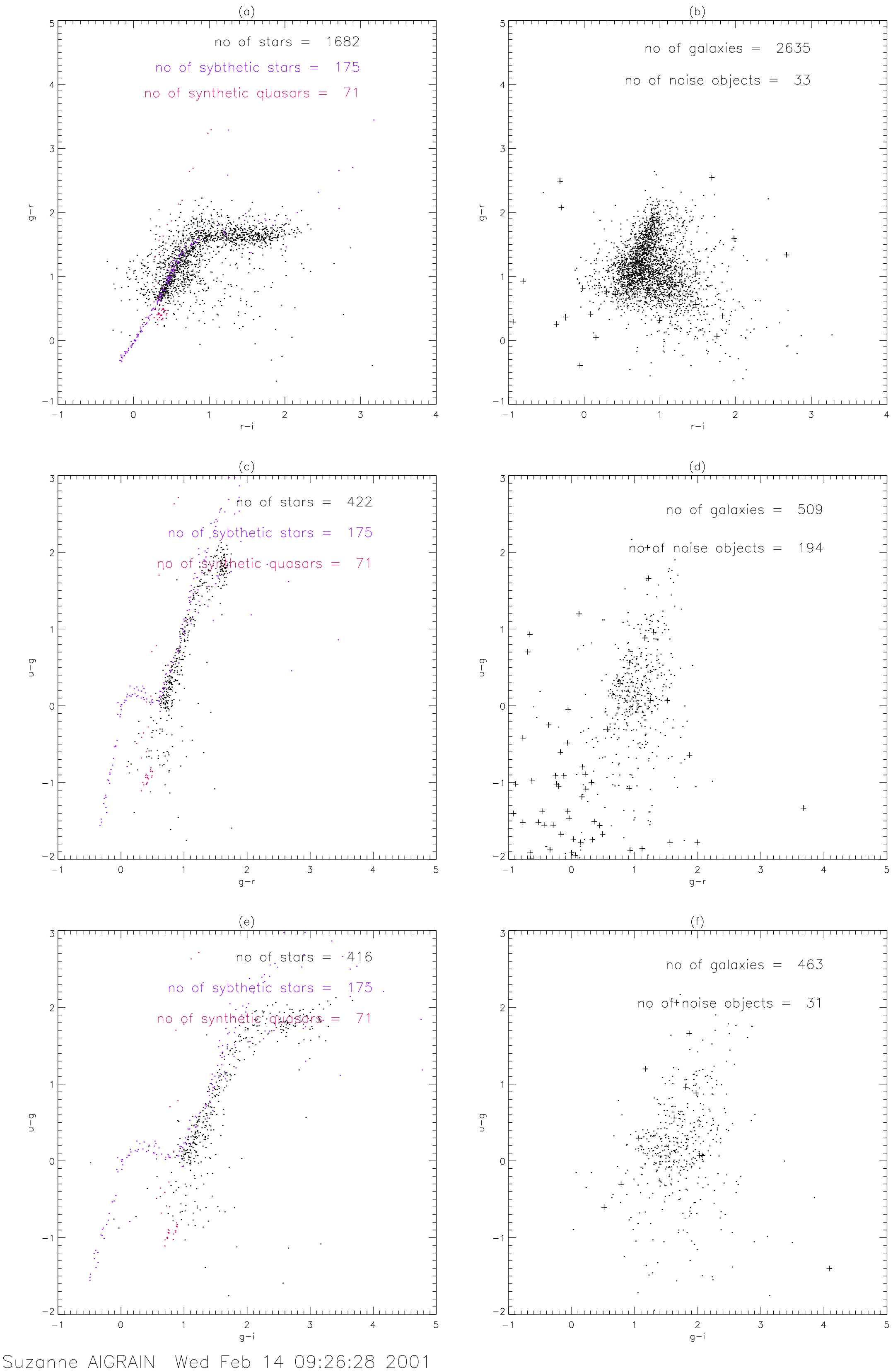

Figure 8: Colour–Colour plots for the MKN 205 field with synthetic data overlaid: (a) $g-r$ vs $r-i$, stars only with synthetic stars and QSOs, (b) $g-r$ vs $r-i$, galaxies and noise only, (c) $u-g$ vs $g-r$, stars only with synthetic data, (d) $u-g$ vs $g-r$, galaxies and noise only, (e) $u-g$ vs $g-i$, stars only with synthetic data, (f) $u-g$ vs $g-i$, galaxies and noise only.

Appendix 1: Typical header for a reduced WFC image

This is the header for the image extension for the file r219698.fit (Lockman Hole i-band).

```
XTENSION= 'IMAGE   '           / Image extension
BITPIX  =                   16 / Bits per pixel
NAXIS   =                    2 / Number of axes
NAXIS1  =                 2048 / Axis length
NAXIS2  =                 4096 / Axis length
PCOUNT  =                    0 / No 'random' parameters
GCOUNT  =                    1 / Only one group
BSCALE  =           1.236264E0 / REAL = TAPE*BSCALE + BZERO
BZERO   =           3.950000E4 /
ORIGIN  = 'NOAO-IRAF FITS Image Kernel July 1999' / FITS file originator
INHERIT =                    F / Inherits global header
DATE    = '2000-07-06T14:17:44' / Date FITS file was generated
IRAF-TLM= '13:28:45 (06/07/2000)' / Time of last modification
OBJECT  = 'Lockman '           / Name of the object observed
RUN     =               219698 / Run number
SYSVER  = '/int/s8-2         ' / Version of observing system
OBSERVAT= 'LAPALMA           ' / Name of observatory (IRAF style)
OBSERVER= 'McMahon           ' / Name of principal investigator
PROPOSAL= 'WFS09             ' / Code for grant of observing time
IMAGETYP= 'run               ' / Type of observation, eg. ARC
LATITUDE=            28.762000 / Telescope latitude  (degrees), +28:45:43.2
LONGITUD=            17.877639 / Telescope longitude (degrees), +17:52:39.5
HEIGHT  =                 2348 / [m] Height above sea level.
SLATEL  = 'LPO2.5  '           / Telescope name known to SLALIB
TELESCOP= 'INT     '           / 2.5m Isaac Newton Telescope
TELSTAT = 'GUIDING '           / Telescope status: TRACKING or GUIDING normally.
RA      = ' 10:53:23.102'      / RA  (163.3462572604746600 degrees)
DEC     = '+57:32:57.00'       / DEC ( 57.5491659455115180 degrees)
EQUINOX = '2000.   '           / Equinox of coordinates
RADECSYS= 'FK5     '           / mean place new (after the 1976 IAU) system
XAPNOM  =        -0.0697222242 / nominal aperture in x (-251.00 arcsec)
YAPNOM  =         0.0905555552 / nominal aperture in y (326.00 arcsec)
XAPOFF  =        -0.0697222242 / total aperture offset in x (-251.00 arcsec)
YAPOFF  =         0.0905555552 / total aperture offset in y (326.00 arcsec)
MJD-OBS =        51719.9012552 / Modified Julian Date of midtime of observation
JD      =      2451720.4012552 / Julian Date of midtime of observation
STSTART = ' 14:34:37.4'        / Local sidereal time at start of observation
ST      = ' 14:34:37.4'        / Local sidereal time at start of observation
AZIMUTH =           323.086813 / Mean azimuth of observation (degrees)
ZD      =            48.384902 / Mean zenith-distance of observation (degrees)
FSTATION= 'PRIME   '           / Focal station of observation
PLATESCA=             6.856013 / [d/m] Platescale ( 24.68arcsec/mm)
TELFOCUS=             0.045998 / Telescope focus (metres)
ROTTRACK=                    T / Rotator always tracks sky on equatorial mount
ROTSKYPA=           179.999978 / Turntable position angle (degrees)
```

```
PARANGLE=           101.546444 / Parallactic angle at observation midpoint
VIGNETTE=                    F / Can we see out?
DOMEAZ  =           328.322631 / Mean dome azimuth during observation
AIRMASS =             1.501661 / Effective mean airmass
TEMPTUBE=            10.892057 / Truss Temperature (degrees Celsius)
CAT-NAME= 'LOCKMAN '           / Target input-catalogue name
CAT-RA  = ' 10:53:23.100'      / Target Right Ascension
CAT-DEC = '+57:32:57.00'       / Target Declination
CAT-EQUI= 'J2000.00'           / Equinox of target coordinates
CAT-EPOC=              2000.00 / Target epoch of proper motions
PM-RA   =             0.000000 / Target proper-motion RA (sec time/year)
PM-DEC  =             0.000000 / Target proper-motion (sec arc/year)
PARALLAX=             0.000000 / Target Parallax (arcsec)
RADVEL  =             0.000000 / Target radial velocity (km/s)
RATRACK =             0.000000 / Differential-tracking rate RA (arcsec/sec)
DECTRACK=             0.000000 / Differential-tracking rate Dec (arcsec/sec)
INSTRUME= 'WFC                ' / INT wide-field camera is in use.
WFFPOS  =                    4 / Position-number of deployed filter
WFFBAND = 'i                  ' / Waveband of filter
WFFPSYS = 'Sloan              ' / Photometric system of filter
WFFID   = '215                ' / Unique identifier of filter
SECPPIX =                0.333 / Arcseconds per pixel
UTSTART = '21:32:49.3         ' / UTC of start of observation
ELAPSED =              599.510 / Length of observation including pauses
DARKTIME=              599.510 / Length of observation including pauses
EXPOSED =              599.510 / Length of observation excluding pauses
EXPTIME =              599.510 / Length of observation excluding pauses
DATE-OBS= '2000-06-24         ' / UTC date start of observation
DETECTOR= 'WFC                ' / Formal name of camera
CCDSPEED= 'FAST               ' / Readout speed
CCDXBIN =                    1 / Binning factor in x axis
CCDYBIN =                    1 / Binning factor in y axis
CCDSUM  = '1 1                ' / Binning factors (IRAF style)
OBSTYPE = 'run                ' / Type of observation, eg. ARC
IMAGEID =                    1 / Number of readout channel.
CCDNAME = 'A5506-4            ' / Name of detector chip (IRAF style)
CHIPNAME= 'A5506-4 '            / Name of detector chip
AMPNAME = 'LH                 ' / Name of detector readout-point
GAIN    =             2.800000 / Gain in electrons/ADU
RDNOISE =             3.900000 / Readout noise in ADU
READNOIS=             3.900000 / Readout noise in ADU
BPM     = '/home/jrl/wfcred/stds/A5506-4MEF.bad' / Bad pixel mask
CTYPE1  = 'RA---ZPX'
CTYPE2  = 'DEC--ZPX'
CRVAL1  =             163.1793
CRVAL2  =             57.48072
CD1_1   =  -9.9686077280003E-7
CD2_2   =  1.30346154372013E-6
CRPIX1  =      -348.0667658355
```

```
CRPIX2  =     3005.44022351332
CD1_2   =  -9.2668163374894E-5
CD2_1   =  -9.2641518413719E-5
WAT0_001= 'system=image'
WAT1_001= 'wtype=zpx axtype=ra projp1=1.0 projp3=259.8'
WAT2_001= 'wtype=zpx axtype=dec projp1=1.0 projp3=259.8'
WFCWCS  = 'Done    '
IMDTOI  = 'Done    '
WCSDIM  =                    2
LTM1_1  =                   1.
LTM2_2  =                   1.
CCDSEC  = '[54:2101,1:4096]'
DETSEC  = '[54:2101,1:4096]'
LTV1    =                 -53.
TRIM    = 'Jul  6 12:22 Trim is [54:2101,1:4096]'
FIXPIX  = 'Jul  6 12:22 Pixel mask is /home/jrl/wfcred/stds/A5506-4MEF.bad'
OVERSCAN= 'Jul  6 12:22 Overscan is [14:53,1:4096], mean 1519.66'
ZEROCOR = 'Jul  6 12:22 Zero is /data/cass36a/wasMEF/mframes/BIAS_962793070.fit'
FLATCOR = 'Jul  6 12:22 Flat is /data/cass36a/wasMEF/mframes/i_962801783.fit[1]'
CCDMEAN =            4451.3645
CCDMEANT=            647353379
CCDPROC = 'Jul  6 12:22 CCD processing done'
XIRMS   =            0.3404403
ETARMS  =            0.5535792
DEFRING0= 'Defringe image i_jun2000_fringe_1.fits scale =    1.2437'
END
```

Appendix 2: Typical header for an unmerged WFC FITS catalogue

This is the header for the FITS table extension for the file r219698_1_cat.fits (Lockman Hole i-band, ccd 1). Only the relevant part has been included (the rest is a repeat of Appendix 1).

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                  128 / width of table in bytes
NAXIS2  =                 2429 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                   32 / number of fields in each row
TTYPE1  = 'No.     '           / label for field   1
TFORM1  = '1E      '           / data format of field: 4-byte REAL
TTYPE2  = 'Isophotal_flux'     / label for field   2
TFORM2  = '1E      '           / data format of field: 4-byte REAL
TUNIT2  = 'Counts  '           / physical unit of field
TTYPE3  = 'Total_flux'         / label for field   3
TFORM3  = '1E      '           / data format of field: 4-byte REAL
TUNIT3  = 'Counts  '           / physical unit of field
TTYPE4  = 'Core_flux'          / Fitted flux within 1x core radius
TFORM4  = '1E      '           / data format of field: 4-byte REAL
TUNIT4  = 'Counts  '           / physical unit of field
TTYPE5  = 'X_coordinate'       / label for field   5
TFORM5  = '1E      '           / data format of field: 4-byte REAL
TUNIT5  = 'Pixels  '           / physical unit of field
TTYPE6  = 'Y_coordinate'       / label for field   6
TFORM6  = '1E      '           / data format of field: 4-byte REAL
TUNIT6  = 'Pixels  '           / physical unit of field
TTYPE7  = 'Gaussian_sigma'     / label for field   7
TFORM7  = '1E      '           / data format of field: 4-byte REAL
TUNIT7  = 'Pixels  '           / physical unit of field
TTYPE8  = 'Ellipticity'        / label for field   8
TFORM8  = '1E      '           / data format of field: 4-byte REAL
TTYPE9  = 'Position_angle'     / label for field   9
TFORM9  = '1E      '           / data format of field: 4-byte REAL
TUNIT9  = 'Degrees '           / physical unit of field
TTYPE10 = 'Peak_height'        / label for field  10
TFORM10 = '1E      '           / data format of field: 4-byte REAL
TUNIT10 = 'Counts  '           / physical unit of field
TTYPE11 = 'Areal_1_profile'    / label for field  11
TFORM11 = '1E      '           / data format of field: 4-byte REAL
TUNIT11 = 'Pixels  '           / physical unit of field
TTYPE12 = 'Areal_2_profile'    / label for field  12
TFORM12 = '1E      '           / data format of field: 4-byte REAL
TUNIT12 = 'Pixels  '           / physical unit of field
TTYPE13 = 'Areal_3_profile'    / label for field  13
TFORM13 = '1E      '           / data format of field: 4-byte REAL
```

```
TUNIT13 = 'Pixels  '           / physical unit of field
TTYPE14 = 'Areal_4_profile'    / label for field  14
TFORM14 = '1E      '           / data format of field: 4-byte REAL
TUNIT14 = 'Pixels  '           / physical unit of field
TTYPE15 = 'Areal_5_profile'    / label for field  15
TFORM15 = '1E      '           / data format of field: 4-byte REAL
TUNIT15 = 'Pixels  '           / physical unit of field
TTYPE16 = 'Areal_6_profile'    / label for field  16
TFORM16 = '1E      '           / data format of field: 4-byte REAL
TUNIT16 = 'Pixels  '           / physical unit of field
TTYPE17 = 'Areal_7_profile'    / label for field  17
TFORM17 = '1E      '           / data format of field: 4-byte REAL
TUNIT17 = 'Pixels  '           / physical unit of field
TTYPE18 = 'Areal_8_profile'    / label for field  18
TFORM18 = '1E      '           / data format of field: 4-byte REAL
TUNIT18 = 'Pixels  '           / physical unit of field
TTYPE19 = 'Core1_flux'         / Fitted flux within 1/2x core radius
TFORM19 = '1E      '           / data format of field: 4-byte REAL
TUNIT19 = 'Counts  '           / physical unit of field
TTYPE20 = 'Core2_flux'         / Fitted flux within sqrt(2)x core radius
TFORM20 = '1E      '           / data format of field: 4-byte REAL
TUNIT20 = 'Counts  '           / physical unit of field
TTYPE21 = 'Core3_flux'         / Fitted flux within 2x core radius
TFORM21 = '1E      '           / data format of field: 4-byte REAL
TUNIT21 = 'Counts  '           / physical unit of field
TTYPE22 = 'Core4_flux'         / Fitted flux within 2sqrt(2)x core radius
TFORM22 = '1E      '           / data format of field: 4-byte REAL
TUNIT22 = 'Counts  '           / physical unit of field
TTYPE23 = 'RA      '           / label for field  23
TFORM23 = '1E      '           / data format of field: 4-byte REAL
TUNIT23 = 'RADIANS '           / physical unit of field
TTYPE24 = 'DEC     '           / label for field  24
TFORM24 = '1E      '           / data format of field: 4-byte REAL
TUNIT24 = 'RADIANS '           / physical unit of field
TTYPE25 = 'Classification'     / label for field  25
TFORM25 = '1E      '           / data format of field: 4-byte REAL
TUNIT25 = 'Flag    '           / physical unit of field
TTYPE26 = 'Statistic'          / label for field  26
TFORM26 = '1E      '           / data format of field: 4-byte REAL
TUNIT26 = 'N-sigma '           / physical unit of field
TTYPE27 = 'Blank   '           / label for field  27
TFORM27 = '1E      '           / data format of field: 4-byte REAL
TUNIT27 = 'Blank   '           / physical unit of field
TTYPE28 = 'Blank   '           / label for field  28
TFORM28 = '1E      '           / data format of field: 4-byte REAL
TUNIT28 = 'Blank   '           / physical unit of field
TTYPE29 = 'Blank   '           / label for field  29
TFORM29 = '1E      '           / data format of field: 4-byte REAL
TUNIT29 = 'Blank   '           / physical unit of field
```

```
TTYPE30 = 'Blank   '           / label for field  30
TFORM30 = '1E      '           / data format of field: 4-byte REAL
TUNIT30 = 'Blank   '           / physical unit of field
TTYPE31 = 'Blank   '           / label for field  31
TFORM31 = '1E      '           / data format of field: 4-byte REAL
TUNIT31 = 'Blank   '           / physical unit of field
TTYPE32 = 'Blank   '           / label for field  32
TFORM32 = '1E      '           / data format of field: 4-byte REAL
TUNIT32 = 'Blank   '           / physical unit of field
EXTNAME = 'APM-BINARYTABLE'    / name of this binary table extension
SKYLEVEL= '        4308.2'     / Median sky brightness (counts/pixel)
SKYNOISE= '          39.1'     / Pixel noise at sky level (counts)
THRESHOL= '          58.7'     / Isophotal analysis threshold (counts)
MINPIX  = '             5'     / Minimum size for images (pixels)
CROWDED = '             1'     / Crowded field analysis flag (0 none, 1 active)
RCORE   = '          3.50'     / Core radius for default profile fit (pixels)
SEEING  = '          3.59'     / Average FWHM (pixels)
ELLIPTIC= '          0.06'     / Average stellar ellipticity (1-b/a)
CLASSIFD=                    T / Class flag: -1 stellar, 1 non-stellar, 0 noise
SATURATE= '       71865.2'     / Average saturation level in frame
APCORPK = '         3.224'     / Stellar aperture correction - peak height
APCOR1  = '         1.092'     / Stellar aperture correction - core1 flux
APCOR   = '         0.324'     / Stellar aperture correction - core flux
APCOR2  = '         0.150'     / Stellar aperture correction - core2 flux
APCOR3  = '         0.062'     / Stellar aperture correction - core3 flux
APCOR4  = '         0.013'     / Stellar aperture correction - core4 flux
```

Appendix 3: Typical .dbd file for an unmerged WFC DBase catalogue

This is the file determining the format of the database entitles=d wfci (Lockman Hole i-band). This file is automatically written according to a pre-set template when the database is created. '#maxentries' represents the maximum number of entries the database can have and is calculated from the size of the FITS table. Formats are standard IDL formats.

```
#title
IDL database corresponding to an unmerged WFC source list

#maxentries
        9841

#items
ra          R*8    Right Ascension (hrs)
dec         R*8    Declination (deg)
mag         R*4    Core magnitude
mag_t       R*4    Total magnitude
mag_i       R*4    Isotophal magnitude
class       I*2    Classification
ccdno       I*2    CCD number
ellip       R*4    Ellipticity
posangle    R*4    Position Angle
stat        R*4    statistic (n-sigma)
g_sig       R*4    Gaussian-sigma (pixels)
ph          I*2    Peak height (counts)

#formats
entry       I6     Entry
ra          F9.6   Right,Ascension,(hrs)
dec         F9.6   Decli-,nation,(deg)
mag         F7.4   Core,mag
mag_t       F7.4   Total,mag
mag_i       F7.4   Iso.,mag
class       I2
ccdno       I1
ellip       F8.6   Ellipti-,city
posangle    F7.3   Position,angle,(deg)
stat        F7.4   Statistic,(n-sigma)
g_sig       F10.6  Gaussian,sigma,(pixels)
ph          I5     Peak,height,(counts)

#index
ra          sorted
dec         sort
ccdno       index
mag         index
class       index
```

```
posangle   index
ellip      index
stat       index
```

Appendix 4: Typical header for a merged WFC FITS catalogue

This is the header for the FITS table extension for the file izrgulockman_1_.mer (Lockman Hole, ccd 1).

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                  100 / width of table in bytes
NAXIS2  =                 5163 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                   25 / number of fields in each row
TTYPE1  = 'Std_coord_Xi'       / label for field   1
TFORM1  = '1E      '           / data format of field: 4-byte REAL
TUNIT1  = 'Arcsec  '           / physical unit of field
TTYPE2  = 'Std_coord_Xn'       / label for field   2
TFORM2  = '1E      '           / data format of field: 4-byte REAL
TUNIT2  = 'Arcsec  '           / physical unit of field
TTYPE3  = 'Ref_core_fluxap'    / label for field   3
TFORM3  = '1E      '           / data format of field: 4-byte REAL
TUNIT3  = 'Counts  '           / physical unit of field
TTYPE4  = 'Ref_class'          / label for field   4
TFORM4  = '1E      '           / data format of field: 4-byte REAL
TUNIT4  = 'Number  '           / physical unit of field
TTYPE5  = 'Ref_pointer'        / label for field   5
TFORM5  = '1E      '           / data format of field: 4-byte REAL
TUNIT5  = 'Number  '           / physical unit of field
TTYPE6  = 'Del_Xi_1'           / label for field   6
TFORM6  = '1E      '           / data format of field: 4-byte REAL
TUNIT6  = 'Arcsec  '           / physical unit of field
TTYPE7  = 'Del_Xn_1'           / label for field   7
TFORM7  = '1E      '           / data format of field: 4-byte REAL
TUNIT7  = 'Arcsec  '           / physical unit of field
TTYPE8  = 'Com1_core_fluxap'   / label for field   8
TFORM8  = '1E      '           / data format of field: 4-byte REAL
TUNIT8  = 'Counts  '           / physical unit of field
TTYPE9  = 'Com1_class'         / label for field   9
TFORM9  = '1E      '           / data format of field: 4-byte REAL
TUNIT9  = 'Number  '           / physical unit of field
TTYPE10 = 'Com1_pointer'       / label for field  10
TFORM10 = '1E      '           / data format of field: 4-byte REAL
TUNIT10 = 'Number  '           / physical unit of field
TTYPE11 = 'Del_Xi_2'           / label for field  11
TFORM11 = '1E      '           / data format of field: 4-byte REAL
TUNIT11 = 'Arcsec  '           / physical unit of field
TTYPE12 = 'Del_Xn_2'           / label for field  12
TFORM12 = '1E      '           / data format of field: 4-byte REAL
TUNIT12 = 'Arcsec  '           / physical unit of field
```

```
TTYPE13 = 'Com2_core_fluxap'   / label for field  13
TFORM13 = '1E      '           / data format of field: 4-byte REAL
TUNIT13 = 'Counts  '           / physical unit of field
TTYPE14 = 'Com2_class'         / label for field  14
TFORM14 = '1E      '           / data format of field: 4-byte REAL
TUNIT14 = 'Number  '           / physical unit of field
TTYPE15 = 'Com2_pointer'       / label for field  15
TFORM15 = '1E      '           / data format of field: 4-byte REAL
TUNIT15 = 'Number  '           / physical unit of field
TTYPE16 = 'Del_Xi_3'           / label for field  16
TFORM16 = '1E      '           / data format of field: 4-byte REAL
TUNIT16 = 'Arcsec  '           / physical unit of field
TTYPE17 = 'Del_Xn_3'           / label for field  17
TFORM17 = '1E      '           / data format of field: 4-byte REAL
TUNIT17 = 'Arcsec  '           / physical unit of field
TTYPE18 = 'Com3_core_fluxap'   / label for field  18
TFORM18 = '1E      '           / data format of field: 4-byte REAL
TUNIT18 = 'Counts  '           / physical unit of field
TTYPE19 = 'Com3_class'         / label for field  19
TFORM19 = '1E      '           / data format of field: 4-byte REAL
TUNIT19 = 'Number  '           / physical unit of field
TTYPE20 = 'Com3_pointer'       / label for field  20
TFORM20 = '1E      '           / data format of field: 4-byte REAL
TUNIT20 = 'Number  '           / physical unit of field
TTYPE21 = 'Del_Xi_4'           / label for field  21
TFORM21 = '1E      '           / data format of field: 4-byte REAL
TUNIT21 = 'Arcsec  '           / physical unit of field
TTYPE22 = 'Del_Xn_4'           / label for field  22
TFORM22 = '1E      '           / data format of field: 4-byte REAL
TUNIT22 = 'Arcsec  '           / physical unit of field
TTYPE23 = 'Com4_core_fluxap'   / label for field  23
TFORM23 = '1E      '           / data format of field: 4-byte REAL
TUNIT23 = 'Counts  '           / physical unit of field
TTYPE24 = 'Com4_class'         / label for field  24
TFORM24 = '1E      '           / data format of field: 4-byte REAL
TUNIT24 = 'Number  '           / physical unit of field
TTYPE25 = 'Com4_pointer'       / label for field  25
TFORM25 = '1E      '           / data format of field: 4-byte REAL
TUNIT25 = 'Number  '           / physical unit of field
EXTNAME = 'APM-BINARYTABLE'    / name of this binary table extension
TPA     =       1.63173294E+02 / Tangent point RA
TPD     =       5.74790192E+01 / Tangent point DEC
DASCHAN =                    1 / WFC CCD no.
REFFILE = 'r219698_1_cat.fits' / Reference_file
FLIMREF =          1.63452E+03 / 5-sigma flux limit
FILTREF = 'i       '           / WFC filter
EXPREF  =          5.99510E+02 / Exposure time
DATEREF = '2000-06-24        ' / UTC date start of observation
UTSTREF = '21:32:49.3        ' / UTC of start of observation
```

```
CTYPE1R = 'RA---ZPN'
CTYPE2R = 'DEC--ZPN'
PROJP1R =          1.00000E+00
PROJP3R =          2.20000E+02
CRPIX1R =          -3.3416E+02
CRPIX2R =           3.0420E+03
CRVAL1R =        1.6317329E+02
CRVAL2R =        5.7479019E+01
CD1_1R  =       -1.1187616E-06
CD1_2R  =       -9.2499402E-05
CD2_1R  =       -9.2470931E-05
CD2_2R  =        1.1867775E-06
COMFILE1= 'r219780_1_cat.fits' / Comparison_file1
FLIMCOM1=          1.56738E+03 / 5-sigma flux limit
FILTCOM1= 'z       '           / WFC filter
EXPCOM1 =          5.99400E+02 / Exposure time
DATECOM1= '2000-06-25        ' / UTC date start of observation
UTSTCOM1= '22:05:35.1        ' / UTC of start of observation
CRPIX1C1=          -3.3414E+02
CRPIX2C1=           3.0420E+03
CRVAL1C1=        1.6317593E+02
CRVAL2C1=        5.7478748E+01
CD1_1C1 =       -1.1310341E-06
CD1_2C1 =       -9.2518960E-05
CD2_1C1 =       -9.2476141E-05
CD2_2C1 =        1.1860529E-06
COMFILE2= 'r219699_1_cat.fits' / Comparison_file2
FLIMCOM2=          1.39013E+03 / 5-sigma flux limit
FILTCOM2= 'r       '           / WFC filter
EXPCOM2 =          5.99430E+02 / Exposure time
DATECOM2= '2000-06-24        ' / UTC date start of observation
UTSTCOM2= '21:44:08.6        ' / UTC of start of observation
CRPIX1C2=          -3.3406E+02
CRPIX2C2=           3.0418E+03
CRVAL1C2=        1.6317288E+02
CRVAL2C2=        5.7479023E+01
CD1_1C2 =       -1.1280347E-06
CD1_2C2 =       -9.2501054E-05
CD2_1C2 =       -9.2476257E-05
CD2_2C2 =        1.1835782E-06
COMFILE3= 'r219779_1_cat.fits' / Comparison_file3
FLIMCOM3=          7.30937E+02 / 5-sigma flux limit
FILTCOM3= 'g       '           / WFC filter
EXPCOM3 =          5.98880E+02 / Exposure time
DATECOM3= '2000-06-25        ' / UTC date start of observation
UTSTCOM3= '21:53:51.6        ' / UTC of start of observation
CRPIX1C3=          -3.3413E+02
CRPIX2C3=           3.0418E+03
CRVAL1C3=        1.6317375E+02
```

```
CRVAL2C3=        5.7478767E+01
CD1_1C3 =       -1.1316866E-06
CD1_2C3 =       -9.2490380E-05
CD2_1C3 =       -9.2453018E-05
CD2_2C3 =        1.1850046E-06
COMFILE4= 'r219778_1_cat.fits' / Comparison_file4
FLIMCOM4=          3.23468E+02 / 5-sigma flux limit
FILTCOM4= 'U       '           / WFC filter
EXPCOM4 =          5.99510E+02 / Exposure time
DATECOM4= '2000-06-25        ' / UTC date start of observation
UTSTCOM4= '21:42:36.0        ' / UTC of start of observation
CRPIX1C4=          -3.3418E+02
CRPIX2C4=           3.0420E+03
CRVAL1C4=        1.6317346E+02
CRVAL2C4=        5.7479004E+01
CD1_1C4 =       -1.1115849E-06
CD1_2C4 =       -9.2484675E-05
CD2_1C4 =       -9.2412432E-05
CD2_2C4 =        1.2235960E-06
END
```

Appendix 5: Typical .dbd file for a merged WFC DBase catalogue

This is the file determining the format of the database entitled izrgu (Lockman Hole).

```
#title
IDL database corresponding to a merged WFC source list (FITS)

#maxentries
       27132

#items
ra         R*8     Right Ascension (hrs) (i-band)
dec        R*8     Declination (deg) (i-band)
i          R*4     i-Magnitude
ic         R*4     i-Class
id         R*4     i-pointer
zraoff     R*8     ra offset between z and i (hrs)
zdecoff    R*8     dec offset between z and i (deg)
z          R*4     z-Magnitude
zc         R*4     z-Class
zd         R*4     z-pointer
rraoff     R*8     ra offset between r and i (hrs)
rdecoff    R*8     dec offset between r and i (hrs)
r          R*4     r-Magnitude
rc         R*4     r-Class
rd         R*4     r-pointer
graoff     R*8     ra offset between g and i (hrs)
gdecoff    R*8     dec offset between g and i (hrs)
g          R*4     g-Magnitude
gc         R*4     g-Class
gd         R*4     g-pointer
uraoff     R*8     ra offset between U and i (hrs)
udecoff    R*8     dec offset between U and i (hrs)
u          R*4     U-Magnitude
uc         R*4     U-Class
ud         R*4     U-pointer
ccdno      I*2     CCD number

#formats
entry      I6      Entry
ra         F9.6    i-band,RA,(hrs)
dec        F9.6    i-band,Dec,(deg)
i          f6.2    i-band,Mag
ic         I2      i,cl
id         I2      i,@p
zraoff     E12.5e2 z-band RA,Offset,(hrs)
zdecoff    E12.5e2 z-band Dec,Offset,(deg)
z          F6.2    z-band,Mag
zc         I2      z,cl
```

```
zd        I2      z,@p
rraoff    E12.5e2 r-band RA,Offset,(hrs)
rdecoff   E12.5e2 r-band Dec,Offset,(deg)
r         F6.2    r-band,Mag
rc        I2      r,cl
rd        I2      r,@p
graoff    E12.5e2 g-band RA,Offset,(hrs)
gdecoff   E12.5e2 g-band Dec,Offset,(deg)
g         F6.2    g-band,Mag
gc        I2      g,cl
gd        I2      g,@p
uraoff    E12.5e2 U-band RA,Offset,(hrs)
udecoff   E12.5e2 U-band Dec,Offset,(deg)
u         F6.2    U-band,Mag
uc        I2      U,cl
ud        I2      U,@p
ccdno     I1

#index
ra        sorted
dec       sort
ccdno     index
i         index
z         index
r         index
g         index
u         index
```