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CDS Export version of APM catalogues

Issue	Author	Date	Comment
1.0	rgm	2000 June 1	Draft Issue
1.1	rgm	2000 June 1	Limitation section added
1.3	rgm	2000 July 11	small edits

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1 Summary

This document contains information describing the APM catalogue that are being delivered to the CDS for the SSC XID program. The conversion from the internal APM format to FITS tables is described.

The data and relevant software is in:

ftp://ftp.ast.cam.ac.uk/pub/ssc/apmcat

2 APM catalogues

There are 3 main APM catalogues

1. APM POSS1 EO catalogue [complete]
2. APM UKST BR [incomplete]
3. APM UKST BRI catalogue [incomplete]

The APM POSS1 EO catalogue is bring exported first to CDS.

The APM UKST BR catalogue has the same data format as the POSS1 catalogue. The APM UKST BRI catalogue has an extra waveband and the resultant data format is slightly different.

Table 1: Description of APM internal data format

Bytes	Format	Description
1-4	R*4	x coordinate in APM pixels
5-8	R*4	y coordinate in APM pixels
9-10	I*2	E plate magnitude*1000
11-12	I*2	E plate image classification
13	I*1	E plate PA
14	I*1	E plate eccentricity
15-16	I*2	E plate isophotal size
17-18	I*2	O plate magnitude*1000
19-20	I*2	O plate image classification
21-22	I*1	O plate PA
23-23	I*1	O plate eccentricity
24-24	I*2	O plate isophotal size

2.1 APM POSS1 catalogue

- The catalogue consists of around 430 field.
- Each field conssists of ~500,000 objects
- Each field file is around 10MB.
- The total volume of the catalogue is around 4GB.

2.2 Internal APM format

The APM internal storage format consists of files with the followiing format:

- 2 Header records of 576 bytes
- Data records are 576 bytes per record with 24 objects per record and 24 bytes per object
- the 24 bytes descriptions of each object are described in the table below

```
Notes on the APM parameters

Notes of magnitudes
Internally the magnitudes are stored at I*2, to convert to original
uncalibrated magnitudes, one must multiple by 1000.

Notes O and E plate magnitudes
set to -1 if the object is absent becuase of a plate edge limit
```

```
Notes on image classification

ICLASS=NINT((7500.0+IC)/15000.0)

CLASS_SIGMA=(I2_3-IC*15000+7500)/75.0


Notes on ellipticity
ELLIPT=(IVAL)+128)/255.0

Notes on PA
TBD

Notes on Major axis size
TBD
```

3 FITs format version of the APMCAT files

To convert the APMCAT files into FITS binary tables. I have written a FORTRAN program CMER2FITS. CMER is the name given to the APM format and standands for Compact Merge format. The FITS format is over 100bytes per object and hence the total APM catalogue expands to around 40GB.

3.1 Datafiles that are needed for the conversion

1. APMCAT cmer files eo'nnnn'.sun
2. APMCAT astrometric calibration files eo'nnnn'.cof
3. POSS1 catalogue table: poss1.cat; this contains information about the exposure times, seeing, date and time of exposures
4. poss1_tycho.table; spatial look up table the corrects for systematic errors in positions

3.2 Converting the data

The software needed to the conversion is in:
ftp://ftp.ast.cam.ac.uk/ssc/apmcat/cmer2fits/

1. Edit the file apmcatrc to define various environment variables
2. source apmcatrc
3. Edit the script cmer2fits_ssc.csh to process all files or just a single field file eg 1393
4. source cmer2fits_ssc.csh

If you want to modify the FITS format output format there are two ways of doing it:

1. edit the subroutine apm_wrfits_record_longform in cmer2fits
2. write a FITs to FITs conversion program and add this to the processing in cmer2fits_batch.csh

3.3 Checking the FITS conversionLimitations of the APMCAT catalogue

4 Limitations of the APMCAT catalogue

Below I list some of the limitations of the APMCAT catalogue focussing on the ones that are in the "lessons learnt" category.

- we should have retained the postitional offsets for all objects between the red and blue plates
- we should have retained the lookup table that is applied when the data is linearized

5 README for the catalogue

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Readme for Public Export version of APM catalogue

Draft 0.1

Richard McMahon 2000, Jan 16

=========================================================================

The APM-POSS1 Sky Catalogue 1.0                    (McMahon+ 2000)

=========================================================================
The APM-POSS1 1.0 Northern Sky Catalogue

(McMahon+ 2000)
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==============================================================================

Keywords: Optical; Positional data; Photometry; Stars; Galaxies

Description:

The  catalogue APMCAT-POSS1-1.0  is  derived from  the first  epoch(1949-1958)
Palomar Observatory-National Geographic Sky Survey(POSS).  The catalog
is based  on digitised scans  with the laser based Cambridge Automated
Plate Measurement(APM) machine of  both the blue  O  plates and  red E
```

plates. The plates are scanned with a pixel sampling 8microns which corresponds 0.49 arcsecs at the nominal plate scale of 61 arc/mm(16.4 micron/arcsec). Further details about the survey material can be found in Minkowski and Abell 1963 and Lund and Dixon 1973.

The main properties of the APM catalogue that differentiate it from other public catalogues of digitisation programs of the POSS1 are:

- o scanned at high spatial resolution 0.49arcsec pixels (cf DSS which used n.n arcsec pixels

- o image are classified into stars and galaxies(unlike USNO)

The APM catalog currently includes all plates with J2000 plate centres between +90 declination and 0 declination inclusive and |b|>25. The catalogued area covers over 10000 square degrees and contains over 100million objects. At the plate limit we have attempted to detect all images that are detectable on the plates with the inevitable price that some spurious image are detected.

The APM POSS1 catalogue contains measurements from both the blue(O) and red(E) plates. The POSS is based on plates taken in two wavebands during the period 1949 to 1955. The blue plates were taken using Eastman 103a-O emulsion, and the red plate were taken with Eastman 103a-E emulsion and hence are commonly known as O and E plates respectively.

Between 1991 and 1995, the SERC Automated Plate Measuring Machine (APM) at the Institute for Astronomy, Cambridge (Kibblewhite et al. 1984) was used to digitize these plates at a resolution of 8.0 microns (0.54 arcsec), the highest spatial resolution yet applied to these images (McMahon and Irwin 1992). An object catalog has been constructed from these data which includes all objects down to the plate limits --- $\sim$20.0 in E and $\sim$21.5 in O --- and contains approximately 2000 stars and 2000 galaxies deg^{-2} at high Galactic latitudes. The catalog contains positions, magnitudes, morphological classification parameters, major and minor axes, and isophotal areas for each source; a merged catalog which matches objects between plates also contains a color (or an upper limit thereto) for each entry. An automated classification algorithm interprets the morphological parameters to classify each object. Here, we present the basic procedures which establish the astrometric and photometric calibration of the APM catalog, and discuss the limits of the image classification system.

The APM machine measures the x and y positions of all objects detected. The conversion relationship between these measured APM positions and celestial coordinates is derived by matching stars in the Tycho catalog (Hog et al. 1997) with stars detected on each plate using a ‘standard’ six plate-constant model that allows for shift, rotation, scale, and shear. The algorithm uses 2-sigma clipping to give a robust fit; the typical rms on the fitted positions of the Tycho stars are 0.4"-0.8"

Irwin (1994) has studied the two-dimensional systematic errors in an earlier version of the APM catalog positions by investigating the intraplate residuals between the measured positions for bright stars in the Positions and Proper Motions Catalog (Roser and Bastian 1991) and the astrometric fit. He found significant, systematic residuals ranging up to 0.5". A residual map generated from this analysis is applied to positions in the standard APM catalog.

APM Photometry

The APM measures photographic density rather than flux; moreover, the central regions of all objects more than a factor of 10 brighter than the sky produce a nonlinear response and/or are saturated. The algorithms used to overcome these inherent difficulties are discussed in detail by Irwin (1985). Briefly, a local background is determined for each of 10^6 locations on each plate by producing a histogram of the pixel values in 64 x 64-pixel regions and finding the mode of each distribution using a maximum likelihood estimator; a two-dimensional smoothing is applied to these million background estimates to derive a background model for the plate. The image detection algorithm then finds connected regions of pixels above a threshold level (typically 2-sigma above the estimated background level for the given plate position). This background-following technique has the advantage that faint objects lying in the halos of bright objects can be detected. However, large objects such as bright stars and galaxies with angular extents >30’ have their raw fluxes underestimated. An additional problem for large images is that the limited memory available to the software means that bright objects sometimes overflow the pixel buffers and are lost. This occurs for images with sizes greater than roughly 1--2mm (i.e. 1-2’), corresponding to stellar magnitudes brighter than around V=9.

Another inherent problem arises in attempting to derive magnitude estimates for extended objects from saturated images. Saturation effects can be corrected for in stars by assuming that stellar images have an intrinsic density profile independent of magnitude, and that this profile can be derived from the unsaturated parts of stellar profiles. A high signal-to-noise intrinsic profile is constructed by taking the core from faint stars and the wings from brighter stars (see Bunclark \& Irwin (1983) for further details). This profile can then be integrated and used to derive a calibration curve to convert saturated stellar magnitudes to a linear system. In the APM catalog, this calibration is applied to all images. This has the unfortunate consequence that galaxies, which have shallower surface brightness profiles and lower central surface brightnesses than stars of the same total magnitude, will have their magnitudes over-corrected. This is a fundamental problem for galaxy photometry determined from photographic sky survey plates (see Metcalfe, Fong, and Shanks (1995) for a discussion).

The basic APM catalog is to have a red-band (E) plate limit of m(r)=20.0. This limit was established during the early stages (1991) of the creation of the APM catalog via comparison with $\sim$10 photometric sequences (Evans 1989; Humphreys et al. 1991). Similarly, a single slope of 1.10, was assumed in converting between the linearized APM magnitudes (Bunclark \& Irwin 1983) and the alpha-Lyrae based Johnston magnitude system. It was noted at the time that there were significant deviations(1mag) from a simple linear relation at magnitudes brighter than V=15. This is not surprising bearing in mind that the POSS-I glass plates measured by the APM are copies that may have different degrees of saturation and have had their contrast stretched to enhance faint features. The assumption of a constant flux limit seemed reasonable, since the plates were all taken in similar dark sky observing conditions with exposure times that were adjusted to ensure uniform sensitivity. A similar assumption is made in all modern photographic cameras where it is assumed that all photographic film has the specified speed. The blue band (O) limit was defined with respect to the red limit; for the 428 fields available in March 1999, this has a range of m(o)=20.6--21.3(+-1sigma range).

Eventually, a full photometric recalibration of the APM using the Guide Star Photometric Catalog (GSPC -- Postman et al. 1998a) CCD sequences is planned. Preliminary comparisons with CCD photometry for 5% of the POSS-I plates show that the APM magnitudes for stellar objects have a global rms uncertainty of 0.5 magnitudes over the range 16 to 20. As discussed above, the uncertainties in the magnitudes of galaxies are more complex, since galaxies have a range of surface brightness distributions, and hence may have complex, partially saturated surface brightness profiles on the POSS-I plates. This is compounded by the range in calibration slopes observed. At faint magnitudes (18--20) where the image profiles are unsaturated, the APM magnitudes may be more reliable, but it is left to the reader to verify this where precise magnitudes are required. For many programs, a uniform set of magnitudes or uniform selection criteria are more critical.

The APM scans result in a parameterization of each detected image which includes an x,y position, a peak intensity, a total isophotal intensity, second moments of the intensity distribution, and areal profiles (defined as the number of pixels above preset levels which increase by powers of two above the threshold level). In addition, a parameter, psf, is calculated which reports by how many sigma the object differs from the stellar point-spread function of its plate. These parameters are then used to classify all images into one of four categories: stellar (consistent with the magnitude- and position-dependent point spread function, cl=-1), non-stellar (a measurably extended source, cl=1), merged objects (sources with two local maxima within a single set of connected above-threshold pixels, cl=2), and noise (objects with nonphysical morphologies, cl=0). For further details of the principles involved, see Maddox et al. (1991a,b). Very bright images can often be misclassified, since the limited set of parameters does not provide an adequate description and the background-following algorithm attempts to track over them in order to detect the faint images in the source halos. The merged/non-stellar boundary is not as reliable as the stellar/non-stellar boundary, so merged stars are often found in the non-stellar list (with a smaller number of galaxies in the merged list). Some objects classified as noise are real; objects found on both plates are the obvious examples.

Bright objects (e.g. O, E < 13) cover a large number of pixels in the APM scans and, as a consequence, magnitude and source-size estimates are very sensitive to small uncertainties in the plate sky level and details of the background-following algorithm; as a result, large uncertainties in the parameter estimations can result, and very bright sources can even be completely missing from the catalog. In addition, bright galaxies with complex surface brightness distributions can be broken up into a swarm of discrete sources. At fainter magnitudes, the limitations of the plate material make reliable separation of stellar and non-stellar sources problematic.

Byte-by-byte Description of FITs long format version of Catalogue

22 fields
76 bytes per object

```
TTYPE1  = 'APMNo   '          / label for field   1
TFORM1  = '1J      '          / data format of field: 4-byte INTEGER
TUNIT1  = 'Integer '          / physical unit of field
TTYPE2  = 'RightAscen'        / label for field   2
TFORM2  = '1E      '          / data format of field: 4-byte REAL
```

```
TUNIT2  = 'Degrees '          / physical unit of field
TTYPE3  = 'Declination'       / label for field   3
TFORM3  = '1E      '          / data format of field: 4-byte REAL
TUNIT3  = 'Degree  '          / physical unit of field
TTYPE4  = 'Xcoord  '          / label for field   4
TFORM4  = '1E      '          / data format of field: 4-byte REAL
TUNIT4  = 'Pixel   '          / physical unit of field
TTYPE5  = 'Ycoord  '          / label for field   5
TFORM5  = '1E      '          / data format of field: 4-byte REAL
TUNIT5  = 'Pixel   '          / physical unit of field
TTYPE6  = 'ImClass_1'         / label for field   6
TFORM6  = '1I      '          / data format of field: 2-byte INTEGER
TUNIT6  = 'Integer '          / physical unit of field
TTYPE7  = 'Stellaric_1'       / label for field   7
TFORM7  = '1E      '          / data format of field: 4-byte REAL
TUNIT7  = 'sigma   '          / physical unit of field
TTYPE8  = 'MajorAxis_1'       / label for field   8
TFORM8  = '1E      '          / data format of field: 4-byte REAL
TUNIT8  = 'Arcsec  '          / physical unit of field
TTYPE9  = 'Ellipt_1'          / label for field   9
TFORM9  = '1E      '          / data format of field: 4-byte REAL
TUNIT9  = '(1-a/b) '          / physical unit of field
TTYPE10 = 'PA_1    '          / label for field  10
TFORM10 = '1E      '          / data format of field: 4-byte REAL
TUNIT10 = 'Degree  '          / physical unit of field
TTYPE11 = 'Magnitude_1'       / label for field  11
TFORM11 = '1E      '          / data format of field: 4-byte REAL
TUNIT11 = 'Mag     '          / physical unit of field
TTYPE12 = 'MagFlag_1'         / label for field  12
TFORM12 = '1I      '          / data format of field: 2-byte INTEGER
TUNIT12 = 'Flag    '          / physical unit of field
TTYPE13 = 'ImClass_2'         / label for field  13
TFORM13 = '1I      '          / data format of field: 2-byte INTEGER
TUNIT13 = 'Integer '          / physical unit of field
TTYPE14 = 'Stellaric_2'       / label for field  14
TFORM14 = '1E      '          / data format of field: 4-byte REAL
TUNIT14 = 'sigma   '          / physical unit of field
TTYPE15 = 'MajorAxis_2'       / label for field  15
TFORM15 = '1E      '          / data format of field: 4-byte REAL
TUNIT15 = 'Arcsec  '          / physical unit of field
TTYPE16 = 'Ellipt_2'          / label for field  16
TFORM16 = '1E      '          / data format of field: 4-byte REAL
TUNIT16 = '(1-a/b) '          / physical unit of field
TTYPE17 = 'PA_2    '          / label for field  17
TFORM17 = '1E      '          / data format of field: 4-byte REAL
TUNIT17 = 'Degree  '          / physical unit of field
TTYPE18 = 'Magnitude_2'       / label for field  18
TFORM18 = '1E      '          / data format of field: 4-byte REAL
```

```
TUNIT18 = 'Mag     '           / physical unit of field
TTYPE19 = 'MagFlag_2'          / label for field  19
TFORM19 = '1I      '           / data format of field: 2-byte INTEGER
TUNIT19 = 'Flag    '           / physical unit of field
TTYPE20 = 'MatchFlag_1'        / label for field  20
TFORM20 = '1I      '           / data format of field: 2-byte INTEGER
TUNIT20 = 'Flag    '           / physical unit of field
TTYPE21 = 'Col_1   '           / label for field  21
TFORM21 = '1E      '           / data format of field: 4-byte REAL
TUNIT21 = 'Colour  '           / physical unit of field
TTYPE22 = 'Colflag_1'          / label for field  22
TFORM22 = '1I      '           / data format of field: 2-byte INTEGER
TUNIT22 = 'Flag    '           / physical unit of field
```

see Notes after the description of the ASCII header

Byte-by-byte Description of long format version of APM POSS1 Catalogue

Bytes	Format	Units	Label	Explanations
1- 4	I4	---	FldNo	POSS1 field number
6- 13	I8	---	APMObjno	Original APM catalogue object number
15- 16	I2	hr	RAh	Right Ascension J2000 (hours)
18- 19	I2	min	RAm	Right Ascension J2000 (minutes)
21- 25	F5.2	sec	RAs	Right Ascension J2000 (seconds)
28	A1	---	DECsign	Declination J2000 (sign)
29- 30	I2	deg	DECd	Declination J2000 (degrees)
32- 33	I2	arcmin	DECm	Declination J2000 (minutes)
35- 48	F4.1	arcsec	DECs	Declination J2000 (seconds)
50	I1	---	ImClasE	Image classification on E plate
51- 57	F7.2	---	StelE	Stellaricity on E plate
58- 65	F7.2	arcsec	RmajE	Major axis diameter of image on E plate
66- 83	F7.3	arcsec	EllipE	Ellipticity of image on E plate
84- 90	I6.1	degree	PAE	Position angle of image on E plate
91- 96	F6.2	mag	MagE	Magnitude of image on E plate
97	I1	flag	MagEFlag	Magnitude flag
98-110	A12	---	EpochE	Epoch of E plate
111-118	A8			POSS1 E Plate
119	I1	---	ImClasO	Image classification on O plate
120-126	F7.2	---	StelO	Stellaricity on O plate
127-133	F7.2	arcsec	RmajO	Major axis diameter of image on O plate
134-140	F7.2	arcsec	EllipO	Ellipticity of image on O plate
141-145	F5.1	degree	PAO	Position angle of image on O plate
146-152	F7.2	mag	MagO	Magnitude of image on O plate
153	B	flag	MagOFlag	Magnitude flag
154-165	A12	---	EpochE	Epoch of O plate
166-171	A6			POSS1 O Plate

172	I1	---	Maflg	BR Match flag
173-179	F7.2	colour	OEcol	B-R colour
180	B	flag	Col1Flag	0:OK; 1:upper limit; 2:lower limit;3:other

Notes:

Notes on APM catalogue name
This is a running number field at the moment but
maybe this should be ASCII name eg EO1393-nnnnnnn ie A14

Notes on Right Ascension and Declination
Maybe the RA, Dec should be HH MM SS.SS SDD MM SS.S

The right ascension and declination are based solely on the red plates for objects that are detected on the red plates. In cases where object is only detected on the blue plate the position on the blue plate is provided.

Notes on Positional errors:
No positional errors are provided in the APM catalogue.
However empirical comparions with external radio catalogue
indicate that the rms positional errors are 0.5".

Notes on the Match Flag and plate matching:
The APM matching is carried out the original pixel reference frame. An initial match is done using a search radius of 5 arcseonds. This match is used to analyze the residual and a distortion map is used. A nearest match search is then redone at a radius of 5 arcseconds. Objects that lie within 2" radius are those within 2 to 5 arcsecs are termed "nearly matched".

In some cases, eg large images, the centroids may be more than 5" apart and hence these objects appear in the catalogue twice as neighbouring E only detections and O only detections.

Notes on the magnitudes

Notes on the colours

Notes on the Image Classification

Image Class Codes

```
 -1: stellar
  0: noise
  1: non-stellar; probably galaxy
  2: merged image
 psf is statistical deviation(sigma) from normalised psf
```

```
Notes on the Position Angle(PA)
The position angle PA is in degrees the standard astronomical
sense ie East of North ie anti-clockwise looking at the original
plates. The APM processing measures the PA in a cartesian frame.
The image PA's have been converted to a celestial
orientation.
```

```
Notes on Magnitude flag
                                    0 if OK
                                    1 if magnitude is a limit
                                   -1 if edge effect
```

```
Response for POSS1 O and E wavebands
```

```
# reference to origin
#
# Tabulated from Fig 1 in
# Minkowski, R.L., \& Abell, G.O., 1963, Stars and Stellar Systems Vol
# III, Basic Astronomical Data, University of Chicago
# Press IX, 481.
#
# see also
# National Geographic Society and Palomar Observatory Sky Survey
# Catalogue of Plates, 1960.
#
#
# The blue plates
# were taken using Eastman 103a-O emulsion, and the red plate
# were taken with Eastman 103a-E emulsion and hence are
# commonly known as O and E plates respectively.
#
# The blue(O)
# band pass is primarily defined on the UV side by the transmission
# characteristics of the glass corrector and the atmosphere,
# and on the red side by the emulsion.
#
```

```
# The red(E) bandpass
# is primarily defined on the blue side by a coloured filter
# (red Plexiglas 2400 which is similar to Wratten 29). The
# red side is determined by the emulsion response.
#
#
# Response of plate-filter-corrector combination:
#
#
# POSS-1 O:
#
#
3200.00  0.
3300.00    2.00000E-02
3400.00   0.340000
3500.00   0.580000
3600.00   0.740000
3700.00   0.850000
3800.00   0.920000
3900.00   0.980000
4000.00    1.00000
4100.00    1.01000
4200.00   0.990000
4300.00   0.950000
4400.00   0.880000
4500.00   0.800000
4600.00   0.700000
4700.00   0.600000
4800.00   0.490000
4900.00   0.380000
5000.00   0.270000
5100.00   0.150000
5200.00    5.00000E-02
5300.00  0.
#POSS-1 E
5800.00  0.
5900.00    2.00000E-02
6000.00    6.00000E-02
6100.00   0.180000
6200.00   0.360000
6300.00   0.680000
6400.00   0.960000
6500.00    1.00000
6600.00   0.600000
6700.00   0.180000
6800.00    2.00000E-02
6900.00  0.
```