Bright Source Check with OMOC

XMM-PS-TN-39 Issue 1.0

Written by: R. Much

September 13, 2000

Contents

1 Introduction

The operational use of OMOC has two purposes for OM, the verification of the absence of bright sources in the OM FOV and the selection of guide stars needed for the OM field acquisition.
While processing of GT proposals it became obvious that the PHS tool interpretation of OMOC magnitudes overconstrains the brightness limit. OMOC magnitudes must be interpreted with care. The main problems are caused by entries of non stellar types, i.e. extended objects, and by magnitudes of type *photographic*.
Here an overview of the different OMOC types of magnitude is given together with their origin and interpretation. Based on this overview two solutions are discussed to remedy the overconstraint of the magnitude limit applied by PHS tools.

It is proposed that a new catalogue (OMOC2) is compiled solely for the purpose of bright source limit checks and that new selection criteria have to be defined for the PHS tools to filter the entries of the existing OMOC catalogue. Both proposed solutions should be pursued at the same time.

1.1 Documentation

References

[1] C.A. Stephenson. Suspected Problems with Master Catalogue Generation. MAST-PROBS Issue 1.1, SSL, 28 September 1999.

[2] C.A. Stephenson. A short guide to the Optical Monitor Operation Catalogue. XMM-MOC-TN-0041-TOS-GF Issue 1, SSL, 19 August 1999.

[3] A. Batten. without title (OMOC generation algorithm). SSSL/OMOC/DOC/001 Draft A, SSSL, 15 March 1999.

[4] R. Much. Specification for the Optical Monitor Operation Catalogue. XMM-PS-TN-29 Draft, XMM-SOC, May 20 1998.

2 OMOC compilation

2.1 Input Catalogues

OMOC has been created by Flight Dynamics ([1], [2], [3]) using the Star Catalogue Facility (SCF). Various input catalogues were merged into OMOC. In the merging process different priorities were assigned to the various input catalogues. Catalogues entries identified as identical were taken from the catalogue with the highest priority. The input catalogues are listed below according to their priority:

1. SCF master catalogue for stars
   (a) Hipparcos main catalogue (Hip)
   (b) Hipparcos annexes (replaced CCDM)
   (c) Tycho catalogue (Tyc)
   (d) Position and Proper Motion catalogue (PPM)
   (e) Yale bright source catalogue (BSC)
   (f) Hipparcos input catalogue (INCA)
   (g) Guide star catalogue (GSC)
2. USNO-A catalogue (v1.0)

ID	Type Description	Origin
V	visual	Hip, Tyc, INCA, SAO, BSC, PPM
P	photographic	USNO, GSC, SAO, PPM
T	visual	derived from Tycho V_t
H	visual	derived from Hipparcos H_p
X	unkown (visual or photographic)	

Table 1: A description of the OMOC magnitude types, their origin and their identifier

ID	Description
1	Hipparcos
2	Tycho
3	PPM
5	Hipparcos annexes
7	GSC
0	unkown
4	other
6	CCDM (superseded by Hipparcos annexes?)

Table 2: Identifier used for the source catalogue of the magnitude entry

3. SCF master catalogue of extended objects
    (a) Bastos catalogue
    (b) Revised new general catalogue of non-stellar astronomical objects (RNGC)

Entries which were only found in USNO-A and had no corresponding entry in the SCF master catalogue were written into the omoc catalogue extension (omoc_vv_rr.cat.ext, where vv and rr stand for version and revision number).

2.2 Magnitude Types

OMOC has five different magnitude types. Each magnitude type does only occur in certain catalogues. The different magnitude types are indicated in table 1 together with the catalogues of their occurence.
The source of the magnitude of each OMOC entry is encoded as number. The values listed in table 1 are the possible source catalogue identifier.
The listed origin *unkown* (ID 0) is not possible for the SCF master catalogue, because the origin of each entry is known. Therefore "a value of zero was used specifying an origin from OMOC" (this is probably a typo on page 4 of reference document [3] and should read USNO).

Irrespective of the used filter OMOC lists any magnitude derived from a photographic plate as *photographic magnitude*. This leds to misinterpretation of photographic magnitudes by PHS tools. A study of the effective bandpasses of the OMOC2 input catalogues is required to define a crude colour transformation from the catalogue specific magnitude into pseudo V-magnitudes. It would already be useful to know, whether a *photographic* magnitude is closer to V or B.

2.3 Completness of Catalogue

Tycho 1 was checked for completness of stars brighter than 9th magnitude. The check was performed against PPM (cf. Hip/Tyc catalogue vol4 section 17.2). 137 entries were found missing in Tycho 1. Both catalogues list almost the same sources and there is only a tiny fraction of missing entries in the Tycho/Hipparcos catalogue, therefore it can be assumed that the combination of the catalogues Tycho/Hipparcos plus PPM is complete down to m_V=9 mag. Tycho is considered as complete at the 99.9 % level for stars brighter than V=10 mag. Tycho2 can be assumed to be completer, as Tycho2 contains more than double of the entries in Tycho1.
GSC is assumed to be complete down to 13 mag, which is sufficient for the required brightness limit of the the white light filter (11.6 mag).

2.4 Extended Sources

Entries from the Bastos Catalogue, the RNGC and the class of non stellar objects of the GSC act as source catalogues for extended sources in the OMOC generation (cf. section 2.1). These catalogues do in general list total magnitudes integrated over the whole galaxy and only in some cases the aperture size is specified.
As the GSC flag *object class* (stellar/non-stellar) is not transferred into OMOC and as the entries originating from the SCF master catalogue of extended sources cannot uniquely be identified within OMOC it is not possible to identify entries of extended sources (galaxies) with integrated, total magnitudes in OMOC.
Galaxies can be rather extended and their surface brightness is often lower by several magnitudes compared to their integrated total brightness. As an example the total brightness of M31 is 3 mag, while the surface brightness at the center is 12 mag integrated over an area of 20 $arcsec^2$.
The OM bright source limit is specified for a surface brightness, because the infalling photon flux per detector area is causing the performance degradation. However there is no means for the PHS tools to identify extended sources and to estimate the surface brightness for the cases where no source extent is specified in OMOC. In most of the cases observations with extended sources in the FOV are overconstrained by the PHS tool bright source limit check.

3 Discussion

The OM brightness limit is driven by the avoidance of fluoresence of the photocathode. Occurence of fluoresence can be avoided by limiting the photon rat to 19000 cts/sec/(detector

filter	B0 star V-limit	Galaxy (B-V=0.3) V-limit
V	7.7	7.7
UVW2	8.8	3.8
UVM2	8.9	4.5
B	9.4	8.8
UVW1	9.5	6.5
U	9.8	7.8
Magnifier	10.0	9.4
White	11.6	9.7

Table 3: V-brightness equivalent to a B0 star and a blue galaxy (B-V=0.3) with a OM photon flux of 19000 ph/sec. The latter is considered as brightness limit for extended sources in the OM bright source limit check.

area element).
In a conservative approach (B0 star) the photon rate limit of 19000 ph/sec/(detector area element) translates into the magnitude limits listed in table 3. Similarly a limit for galaxies can be calculated. As it is shown in appendix A, the bluest galaxies found had a B-V colour of 0.3 mag, which is equivalent to a spectral type of F0. The last column in table 3 lists the brightness limit for such a blue galaxy. These numbers are used as brightness limit for extended sources.

PPM and Tycho1/Hipparcos are considered as complete down to 9th mag. During generation of the SCF master catalogue these three catalogues had the highest priority and therefore OMOC can be considered as complete up to 9th mag as well.
PPM, Tycho1, Hipparcos and Hipparcos annexes do have a unique value in the *Position data source catalogue field* and *Magnitude data source catalogue field* in OMOC [2]. OMOC entries originating from these catalogues can uniquely be identified using these flags.
Although PPM contains a mixture of visual and photographic magnitudes, the OMOC problem of overconstraining the observations in respect to bright source should not occur with the PPM photographic magnitudes, because PPM only contains stars and does not contain extended sources.

A remedy to the overconstraint of the bright source limit by PHS tools is that **any OMOC entry brighter than 9th magnitude which does not originate from Tycho, Hipparcos catalogue and its annexes or from PPM shall be ignored by the PHS tools.** OMOC entries of sources fainter than 9th magnitude shall be considered from all source catalogues.

A potential caveat of this approach is that extended sources with a total integrated magnitude brighter than 9 mag may have a surface brightness exceeding the limit listed in table 3. However it is shown in Appendix A that in general extended sources are no safety issue. Moreover no galaxy bright enough to cause fluoresence was found in the Hypercat Catalogue.
The proposed approach has the advantage, that the overconstraints imposed by extended

sources with incorrectly interpreted magnitudes is avoided for three filters at least. In addition the filtering of OMOC entries can be implemented into the PHS tools rather quickly and does not require generation of a new catalogue. Existing fields in OMOC can be used to filter the required catalogue entries.

A second, longer term solution is proposed.
The current OMOC catalogue has shown insufficiencies in the proposal enhancement. The orgin of these insufficiencies lays in the fact that OMOC was generated according to specifications, which were written at a time when the bright source limit was thought to be more restrictive. Therefore OMOC aimed to be complete down to the faintest possible magnitude. Special care was taken not to miss out any bright object (i.e. brighter than 14th mag), which led to the requirement also to include non-stellar GSC entries. The bright source limit has been relaxed in the meantime and it is obvious that a less deep catalogue is sufficient for the bright source checks. Completness is only required up to 11.6 mag for point like objects and down to a surface brightness of 9.7 mag for extended object (integrated over the characteristic detector area).

Adding an additional margin the limiting magnitude will be set to 12 mag for point sources and 10 mag for the surface brightness of extended sources. No additional error propagation on the brightness needs to be considered.
A survey of the literture was performed to assess the impact bright galaxies can have on the MIC-detector. It was found that in general surface brightnesses of galaxies integrated over the spatial area of 20 arcsec^2 neither represent a safety issue for OM nor do they violate the galaxy limits listed in table 3. Details of the survey and its interpretation are listed in Appendix A.

Since the compilation of the SCF master catalogue and of OMOC the Tycho2 catalogue has been issued. Tycho2 supersedes Tycho1. Tycho2 is preciser and has more than double of the entries than Tycho1. Detailled information on Tycho2 can be found on http://www.astro.ku.dk/ erik/Tycho-2/. Tycho2 is publicly available. It is an obvious change to the OMOC2 generation process to replace the input catalogue Tycho1 by Tycho2.

OMOC serves two purposes. The validation of the absence of bright sources in observing fields and the selection of guide stars for uplink in the OM Field Acquisition. While originally the brightness range of these two purposes were heavily overlapping, the set of bright sources is now a limited subset of the possible guide stars for uplink because of the relaxed bright source limits.
The USNO catalogue no longer has to be considered for the bright source checks, while it is still required for the GS selection. Only a subset of the current OMOC entries brighter than 9th mag must be considered in the bright source check (namely Hipparcos and annexes, Tycho and PPM), as it was pointed out above.

The changed requirements of the bright source limit check leads to the conclusion:
The OM bright source and guide star PHS tool shall access two catalogues. The guide star positions for uplink shall be extracted from the currently available OMOC. The bright source check is made against a newly defined catalogue. The new catalogue, called OMOC2, shall be generated based on the

specification given below.

Parallel to the short term solution the longterm solution should be pursued at the same time.

4 Specification of OMOC2

The specifications for OMOC2 are listed below. If not other mentioned in this section OMOC2 shall be generated according to the specifications of OMOC [4].

- limiting magnitude is 12 mag for point like objects
- Tycho2 and its supplements shall replace Tycho1 as source catalogue for OMOC2
- USNO catalogue shall not be considered as source catalogue for OMOC2
- OMOC2 entries brighter than m_V= 9 mag shall only be extracted from Hipparcos, Hipparcos annexes, Tycho2 and PPM
- extended objects no longer have to be considered, which means
  - GSC entries of non stellar type (object class 3) shall not be included
  - entries from the SCF master catalogue of extended sources shall not be included

Based on the outcome of the study of the effective bandpasses of the input catalogues, a colour transformation has to be applied to *photographic* magnitudes either during the OMOC2 generation or within the PHS tools.

5 Summary

The composition of OMOC, the magnitude types of OMOC and their origin were discussed. Two solutions were elaborated to reduce the currently existing problem with the interpretation of OMOC magnitudes of extended objects. Both solutions should be pursued at the same time.

As a short term solution a change to PHS tools is proposed. Any OMOC entry brighter than m_V=9 magnitude not originating from Tycho, Hipparcos and its annexes or PPM shall be ignored. Adopting this solution does not fully solve the problem but improves the situation insofar as three filters are no longer overconstraint. The change can easly and quickly be implemented into the PHS tools.
The generation of a new catalogue exclusively used for the bright source handling is the proposed longer term solution. Changes of the requirements of OMOC2 in respect to OMOC are defined in section 4.

Next steps are

- implementation of a filter into the PHS bright source tool
- request of OMOC2 compilation from FD according to requirements outlined in 4

Futher study is needed to define a correct interpretation of the *photographic* magnitudes in OMOC. This requires analysis of the bandpasses used in the different input catalogues and the defintion of a crude colour transformation. Based on the result of the study the colour transformation has to be implemented either in the OMOC2 generation process or in PHS tools.

A Surface Brightness of Galaxies

A survey of the literatue was made to investigate whether surface bright galaxies can violate the OM bright source limit. Based on a discussion with an inhouse galaxy expert (Rolf Jansen) a short list of potentially bright galaxies was established. In a second step a catalogue of galaxies was searched systematically for bright galaxies.

A.1 Filter Criteria

In the galaxy surface brightness search the following filter criteria were applied:

- characteristic area of aperture 20 arcsec^2
- surface brightness limits integrated over 20 arcsec^2 are
  - Vtot=10.0 mag (includes 0.3 mag margin)
  - Btot=11.0 mag
  - Rtot=11.0 mag
  - Itot=11.0 mag

The aperture of 20 arcsec^2 is an empirical estimate based on data from the Report-C on the life time estimation of FM intensifiers (XMM-OM/MSSL/TC/0059.01 02/05/00)
The limiting Vtot limit is based on the fact that the bluest galaxies found had a B-V colour index of 0.3 equivalent to a F0 type spectrum. The photon rate limit of 19000 cts/sec translate for a F0 type spectrum into a brightness of m_V=9.7 mag. Adding an additional safety margin results in the limit of 10.0 mag.
The brightness limit in the B-band is derived from the V filter brightness limit (9.7 mag) and the average B-V colour of galaxies $(B\text{-}V)_{mean}=0.8\pm0.2$ (R. Jansen, private communication). Adding a 2σ margin a Btot limit of 10.9 mag is obtained. The limits of the R- and I-band are derived in a similar manner as 11.0 mag.

Name	Aperture [arcsec^2])	Total brightness [mag]	filter	B-V [mag]
M31	45	11.35	V	1.06
M33	148	13.36	V	0.57
NGC6822	13533	12.67	V	1.00
IC 1613	9804	13.61	V	0.35
NGC 205	37	14.33	V	0.65

Table 4: Brightness of shortlist candidates of representative bright galaxies.

A.2 Shortlist of Bright Galaxies

A shortlist of representative bright galaxies was compiled in consultation with R. Jansen. The brightness of the shortlist candidates are listed in table A.2.

AGNs are too faint to violate the bright source limit. Nevertheless the list of *representative AGNs* in Zombeck was inspected and all entries were found faint. Only NGC1068 is brighter than 12 mag, but a large aperture was applied for the integration (450 $arcsec^2$) and the surface brightness integrated over 20 $arcsec^2$ is only 12.2 mag and not violating the brightness limit.

A.3 Catalogue Search

The Hypercat catalogue of galaxies was selected for the systematic galaxy search. The catalogue is online available (http://www-obs.univ-lyon1.fr/ prugniel/cgi-bin/hypercat/). The aperture photometry entries of the hypercat galaxy database were downlinked and searched for objects with a bright surface.

The Hypercat catalogue continues the compilations published by G. Longo & A. de Vaucouleurs (1983, 1988 Monographs of University of Austin). The catalogue was updated since then by scanning the literature and adding aperture photometry derived from published surface photometry. The Hypercat catalogue and derived magnitudes and colours are presented in Prugniel and Hraudeau (1998, AAS, 128,299).
The catalogue contains 34675 aperture measurements from diaphragm photometry and 72336 derived from surface photometry or image analysis on a total of 7567 galaxies.
It is worth noting, that entries for all members of the short list established in step one were found in the hypercat catalogue.

After the full aperture photometry catalogue of the Hypercat, extragalactic database at CRAL Observatoire de Lyon, was downloaded a search was performed for objects with bright surface. The search logic was as follows:

1. catalogue entries were considered in the priority: V, B, R, I magnitudes
2. if the brightness was found always fainter than the brightness limit the entry was no longer considered: exit

Name	Aperture [arcsec^2])	Total brightness [mag]	filter	B-V [mag]
NGC0221	118	10.50	V	1.01
NGC0676	78	10.50	V	0.84
NGC3031	296	10.58	V	1.00
NGC4736	78	10.68	V	0.90
NGC3034	980	10.70	V	
IC4451	94	10.90	V	1.20
UGC12843	98	10.94	I	
ESO466-021	94	11.07	V	0.48
NGC3115	170	11.18	V	0.96
NGC1023	618	11.20	V	1.01
NGC2841	78	11.20	V	1.05
NGC0224	45	11.34	V	1.06
NGC0224	118	10.58	V	1.08
NGC1068	71	11.49	V	0.73
NGC2775	1027	11.49	V	0.94
NGC5353	2352	11.50	V	1.00
NGC3615	71	12.20	R	
NGC4335	71	12.42	R	
NGC3583	142	12.49	I	
IC2469	71	12.51	I	
NGC3094	296	12.51	I	
NGC3812	71	12.52	R	
NGC5303	428	12.63	I	
IC1392	71	12.83	R	
NGC2800	71	12.83	R	
NGC2537	1126	12.86	V	0.57
NGC3530	205	12.86	I	

Table 5: Entries of the Hypercat Catalogue not passing the initial brightness search criteria. Although these are the entries with the highest surface brightness found in Hypercat, the OM brightness limit is never violated.

3. if the brightness limit is not violate at the aperture closest to 31 $arcsec^2$ the entry was no longer considered: exit

4. information of the entry is printed to the log file

The catalogue contains in all cases larger aperture sizes, so there is no danger that high surface brightness galaxies slip through the filtering process in step 3 because of a too small aperture size.

The intial filter critera were set fainter than the calculated OM brightness limit. The applied limits in the catalogue search were 11.5, 12.5, 13.0 and 13.0 mag for the V, B, R, I filter respectively. Table A.3 lists the entries which were written to the log file, because they did not meet the more restrictive brightness limit.

An inspection of the entries in table A.3 shows that neither of the galaxies does violate the OM bright source limit derived for galaxies (section A.1). The brightest galaxies listed in the V-band have 10.5 magnitudes integrated over a substantially larger area.
UGC12843 violates the limit of 11.0 mag in the R-band by 0.06 mag, but the integration area is 5 times larger than the requested 20 $arcsec^2$ area. This galaxy does not violate the bright source limit.

It can be stated, that in general

- the surface brightness of galaxies is fainter than the soft OM brightness limit, which is set to avoid fluoresence in the detector.
- the surface brightness of galaxies is at least 5 magnitudes fainter than the hard brightness limit, which is set to avoid damage of the detector.

It can be concluded that galaxies do not represent a safety problem for the OM detector. Extended sources can be omitted from OMOC.