omscattered

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Abstract

Removes the persistent central scattered light feature from the OM images.

1   Instruments/Modes

Instrument	Mode
OM	IMAGING

2   Use

pipeline processing	yes
interactive analysis	yes

3   Description

XMM Newton Optical Monitor images are contaminated by a persistent scattered light feature (Fig.1). This feature is a consequence of a uniform background outside of the telescope field of view scattered off of shiny telescope structure. It therefore scales with the background and can be removed in principle. The task *omscattered* performs this function.

In order to remove the central scattered light feature a calibrated image containing exclusively this feature is required (the name of the file with this feature can be indicated by the parameter scatset). An example of the image with the calibrated scattered light (for the OM V-filter) is given in Fig.2.

Calibrated images, one for each filter, containing the scattered structure are planned for inclusion in the SAS CAL system. However, for SAS v9.0 these calibration images can be obtained by direct download from the following URL:

`http://www.mssl.ucl.ac.uk/~vny/omscattered/omscatteredfiles.tar.gz`

The task *omscattered* can be called with the following parameters:
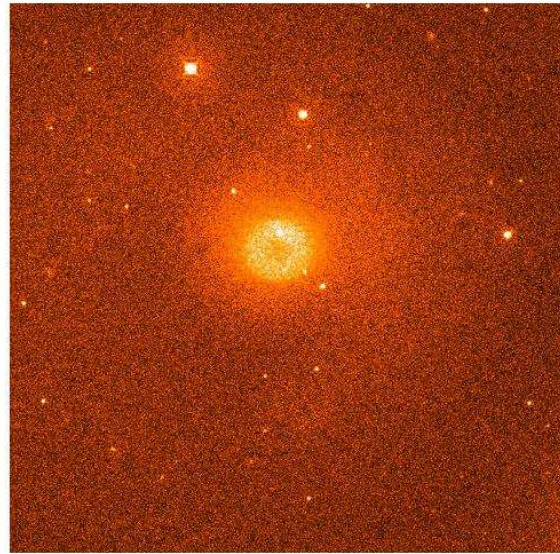
Figure 1: An example of the XMM OM image containing the central scattered light feature (Obs. ID 0112250301, exposure 006, filter V).

```
omscattered
      set=            input data set file name
      scatset=        file with the calibrated scattered light feature;
      outset=         output image file name;
      scalingfactor=  to force the scaling of the calibrated data
                       with a given factor; default value scalingfactor=-1;
      innerradius=    inner radius for scaling the scattered light
                       feature, expressed in unbinned pixels;
                       default value innerradius=-1;
      outerradius=    outer radius for scaling the scattered light
                        feature; default value outerradius=-1;
      mode=           optional parameter for switching between 3
            available modes of calculating the scaling factor;
            default value mode=1
```

(the first two parameters are mandatory).

If the second parameter (*scatset*) is omitted (the file containing the calibrated scattered light feature is not specified) then *omscattered* will first try to find the appropriate calibration file among the files of the SAS system itself, and only in the case of not finding the required file the task will issue an error message and finish without producing any output file.

If the name of the output file (third parameter) is not specified, the task will use the name of the input file but with an extra letter "S" at the beginning of the name.

4 Parameters

This section documents the parameters recognized by this task (if any).

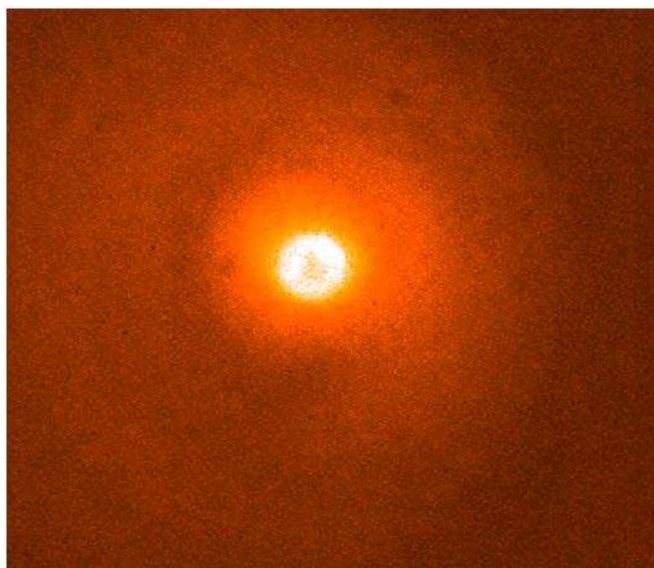| Parameter | Mand | Type | Default | Constraints |

Figure 2: Central part of the image containing the calibrated scattered light feature for the OM V-filter.

set	yes	string	none	

Input OM image file with the central region contaminated by the scattered light feature

scatset	yes	string	none	

Name of the input file containing the calibrated scattered light feature

outset	no	string	none	

The name for the output file whose image would be cleaned from the central scattered light feature.

scalingfactor	no	real	-1	-1 : 10

The scaling factor for the calibrated image containing the central scattered light feature. If set to a positive value, this scaling factor is used for scaling the calibrated image before subtracting it from the input image. Otherwise, the task will compute the scaling factor automatically.

innerradius	no	real	-1	-1 : ∞

The inner radius (in unbinned pixels of the OM-detector) defining the ring-shaped region for measuring the background level of both input and calibrated images. This level is used for automatic calculation of the scaling factor for the calibrated scattered light image. If this parameter is set to a positive value, the task uses the user-defined ring-shaped region for the background evaluation. Otherwise, a default value (currently set to 280 unbinned pixels) is used for the inner radius of this ring-shaped region.

outerradius	no	real	-1	-1 : ∞

The outer radius (in unbinned pixels of the OM-detector) defining the ring-shaped region for measuring the background level of both input and calibrated images. This level is used for automatic calculation of

the scaling factor for the calibrated scattered light image. If this parameter is set to a positive value, the task uses the user-defined ring-shaped region for the background evaluation. Otherwise, a default value (currently set to 350 unbinned pixels) is used for the outer radius of this ring-shaped region.

mode	no	integer	1	1:3

This parameter switches the task between 3 available modes of calculating the scaling factor (see text).

5   Errors

This section documents warnings and errors generated by this task (if any). Note that warnings and errors can also be generated in the SAS infrastructure libraries, in which case they would not be documented here. Refer to the index of all errors and warnings available in the HTML version of the SAS documentation.

NoFile *(fatal)*
> No calibration image file was specified. Could not find any appropriate calibration file within the SAS package.

badType *(fatal)*
> Image is of unsupported data type

The second file name is not specified *(warning)*

> *corrective action:* None

The output file name is not specified *(warning)*

> *corrective action:* None

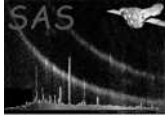**The width of the background region is too small (increasing by 5 pixels)** *(warning)*

> *corrective action:* None

The radius of the inner background region is too small (increasing) *(warning)*

> *corrective action:* None

The radius of the outer background region is too small (increasing) *(warning)*

> *corrective action:* None

6 Input Files

1. OM image file

2. A file containing the calibrated central scattered light feature for the OM filter corresponding to the first input file.

7 Output Files

1. The OM image with the central scattered light feature removed. If the name of the output file is not specified (the parameter *outset* omitted) then the output file will be given the same name as that of the input file with an extra symbol "S" at the beginning of the name.

8 Algorithm

The intensity of the scattered light feature scales linearly with sky background which varies from image to image, so that the calibrated image has to be scaled and adjusted with respect to the background level of the input image in order to properly remove the central scattered light feature.

The background on the OM images depends on many factors, such as exposures time, spacecraft pointing direction, positions of the sun and the moon, etc. Therefore, one cannot simply use the exposure time of a given OM image for scaling the calibrated image.

The scaling factor can either be determined automatically by comparing the background levels of the same regions of the input and calibrated images or, alternatively, by setting the parameter *scalingfactor* to the desired value in order to force the task using a specific scaling factor.

Currently there are three available algorithms within the task for calculating the scaling factor (the algorithm is chosen by specifying the parameter mode=1,2 or 3, with the default value mode=1).

8.1 Using the peripheral background for computing the scaling factor (mode=1)

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The first method of scaling the calibrated scattered light feature is based upon the assumption that the number of counts corresponding to this feature scales linearly with the background level of the OM image.

The background is calculated for the same ring-shaped region of both the input (B_1) and calibration (B_2) images (Fig.3). The scaling factor applied to the calibrated image in this case will be

$$S = \frac{B_1}{B_2}$$

and the output image is obtained by subtracting the scaled calibrated image from the input image and restoring the constant background level of the input image:

$$I_{\text{output}} = I_{\text{input}} - I_{\text{calibrated}} * S + B_1.$$
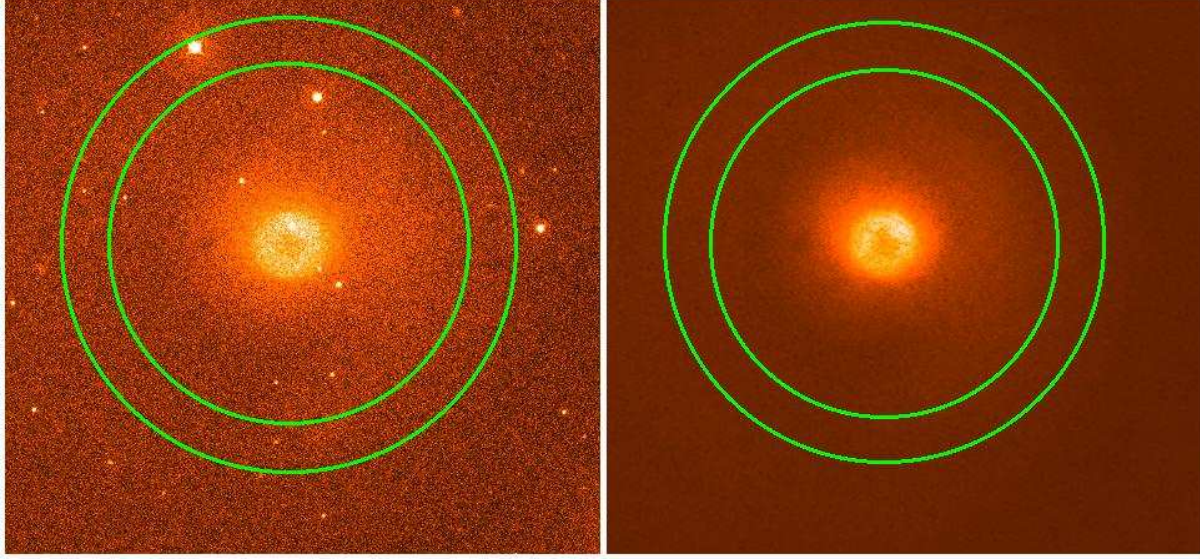
Figure 3: The ring-shaped region used for finding the background levels of the input image (left) and the calibration image (right) in the case of the default algorithm (mode=1) for calculation of the scaling factor of the calibrated image.

Systematic error is reduced in the background calculation by masking sources in the data image. These are identified by an "Emboss-filtering" technique which compares modified versions of the image, shifted by a few pixels in the horizontal and vertical directions.

A histogram of the remaining pixels is computed. The background value is measured from only the most-populated 10% of pixel values. This reduces bias in the measurement from residual structure such as irregular scattered light.

Thus, B_1 is then obtained as the weighted average of the values of these most populated pixels:

$$B_1 = \frac{\sum_{p_c > 0.9 p_c\text{max}} p_c \cdot c}{\sum_{p_c > 0.9 p_c\text{max}} p_c},$$

where c is the number of counts (histogram slot); p_c is the number of pixels having this number of counts; and $p_{c\text{max}}$ is the maximal histogram value corresponding to the most populated count number c^{max}. The value of B_1 is usually close to c^{max}.

8.2 Computing the scaling factor with mode=2 and mode=3

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The second and third methods of calculating the scaling factor (mode=2 and mode=3) are auxiliary and might be used in some difficult cases when the input image is contaminated by a multitude of other scattered light features (like, "huge deformed donuts", smoke rings, modulo-8 pattern around bright sources, etc.).

These algorithms use two annular regions (instead of a single region, as in the case of the mode 1): the larger one is the same as in the case of the mode-1 algorithm and is used for finding the background levels of the input (B_1) and the calibrated (B_2) images.

The smaller region (see Fig.4) corresponds to the known sizes of the "donut" of the central scattered light
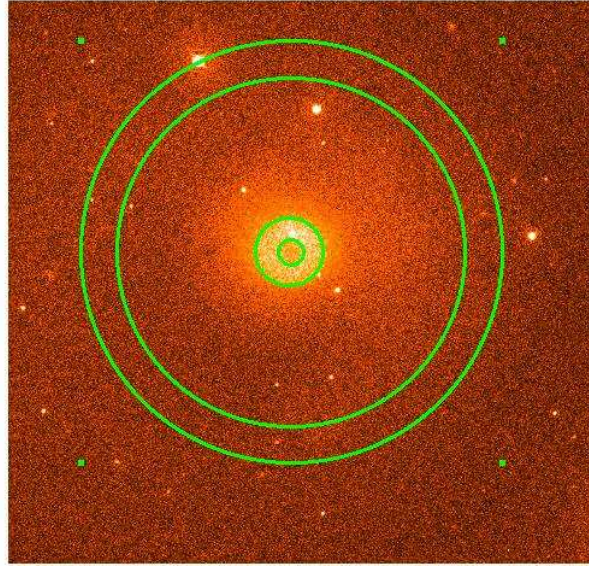
Figure 4: Two ring-shaped regions for finding the background of the input image (the larger ring covering the peripheral parts of the image) and for computing the counts of the central scattered light feature (the smaller ring in the centre enclosing the scattered light feature). These are used for two auxiliary algorithms (mode=2 and mode=3) of calculating the calibration scaling factor.

feature. The count numbers within this region (C_1 for the input image and C_2 for the calibrated image) are found by building histograms of the pixel values, as described in Sec.8.1.

Then, in the case of the mode-2 algorithm, the calibration scaling factor is computed as

$$S = \frac{C_1 - B_1}{C_2 - B_2},$$

and the output image is obtained by subtraction of the scaled and background-free calibration image:

$$I_{\text{output}} = I_{\text{input}} - S \cdot (I_{\text{calibrated}} - B_2).$$

In the case of mode=3 the latter subtraction is made for the scaling factor varied (in a loop) with small steps (of 0.02) from the values 0.2 to 2.8. The optimal scaling factor (S_{opt}) is then assumed to correspond to the minimum of the absolute value of the difference between the background B_1 and the number of counts within the smaller annulus. The final output image will then be:

$$I_{\text{output}} = I_{\text{input}} - S_{\text{opt}} \cdot (I_{\text{calibrated}} - B_2).$$

8.3 The sequence of operations of the task *omscattered*

```
Read parameters

Read the input image

Read the calibration image

If the input image is binned than apply the same binning factor
to the calibrated image (the calibrated image is supposed to
```

be a full-frame high-resolution image)

Check that the filters for each file are identical- if not issue a warning.

Prepare the output image by crating an empty array having
the same sizes as the input image and copy the header parameters
from the input image to the output image

Remove point sources from the input image (by masking them)

If mode=1 (the main algorithm) then

    Compute the background B1 inside of the ring-shaped region of the input image

    Compute the background B2 inside of the same region of the calibrated image

    Compute the scaling factor S as S=B1/B2

    Subtract the scaled calibrated image from the input image:

$$OutputImage = InputImage - S * CalibratedImage + B1$$

If mode=2 then

    Compute the background B1 inside of the peripheral ring-shaped region
    of the input image

    Compute the count level C1 inside of the ring-shaped region corresponding to
    the central scattered light feature of the input image

    Compute the background B2 of the peripheral region of the
    calibrated image

    Compute the count level C2 inside of the ring-shaped region corresponding to
    the central scattered light feature of the calibrated image

    Compute the scaling factor S as S=(C1-B1)/(C2-B2)

    Subtract the scaled calibrated image from the input image:

$$OutputImage = InputImage - S * (CalibratedImage - B2)$$

If mode=3 then

    Compute the background B2 of the peripheral region of the
    calibrated image

    In a loop changing the scaling factor from S=0.2 to 2.8 with spep 0.02:

        Subtract the scaled calibrated image from the input image:

$$OutputImage = InputImage - S * (CalibratedImage - B2)$$

        Compute the background B1 inside of the peripheral ring-shaped region
        of the output image

```
    Compute the count level C1 inside of the ring-shaped region corresponding to
    the central scattered light feature of the output image

    Compute the difference between the count levels of these two values:

        D = abs(C1 - B1)

Chose the optimal value of the scaling factor S_opt correponding
to the minimum of D from the above loop

Subtract the scaled calibrated image from the input image using the
scaling factor S_opt:

    OutputImage = InputImage - S_opt*(CalibratedImage - B2)

Write output image
```

The main algorithm (mode=1) is used as the default option for the task. An example of the output image obtained by applying the algorithm with mode=1 to the input image from Fig.1 is shown in Fig.5.
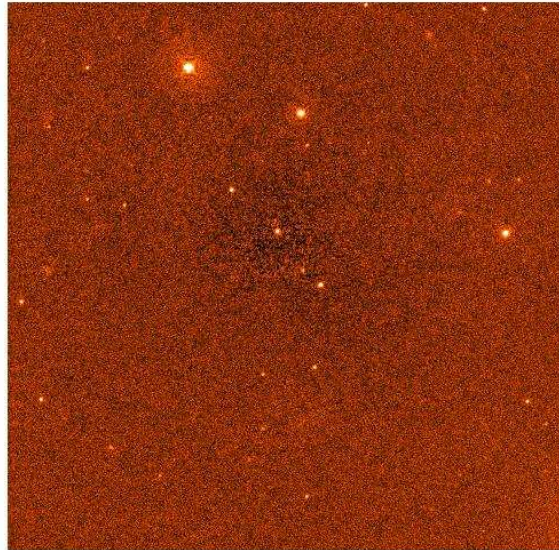

Figure 5: The same example of the XMM OM image as in Fig.1 after applying the scattered light removal algorithm (Mode=1, Obs. ID 0112250301, exposure 006, filter V).

9 Comments

- A new attribute SCFACTOR is introduced into the attribute table of the output file. The value of this attribute corresponds to the automatically computed scaling factor for scaling the calibrated image before its subtraction from the input image. This value can be used for adjusting the scaling factor and obtaining better results by setting the parameter *scalingfactor* to a value defined by the discretion of the user.

9.1 Future developments

- It is likely that the calculation of the scaling factor for adjusting the image with the calibrated scatted light feature to the input image would need further improvements. In some cases the scaling factor might be slightly overestimated (as it is seen, e.g., in Fig.5).

- Currently the calibration files with the central scattered light feature are not included into the calibration (CAL) system of SAS, but the proper way of using these files would be through the standard CAL routines.

References