NHSC/PACS Web Tutorials

Running PACS photometer pipelines

PACS-201 (for Hipe 12.0)

Level 1 to Level 2 processing:*

The High-Pass Filter pipeline

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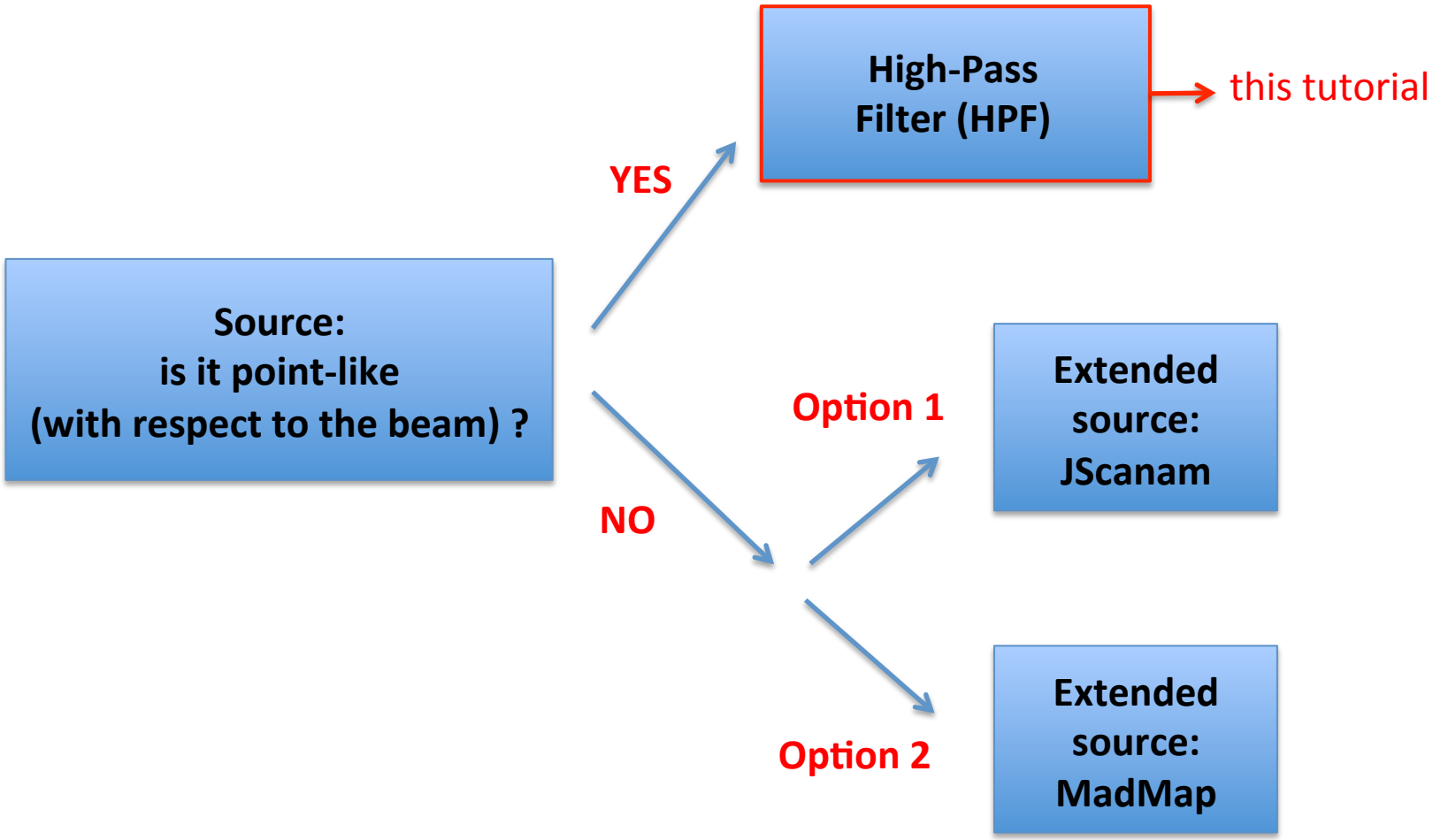
NOTE: the *scanmap_Pointsources_Photproject* ipipe script has been extensively cleaned up in HIPE 12 with respect to the same script in HIPE 11. In addition some bugs have been found and fixed.

Therefore, we highly recommend using version 12.0 rather than previous versions of this script.

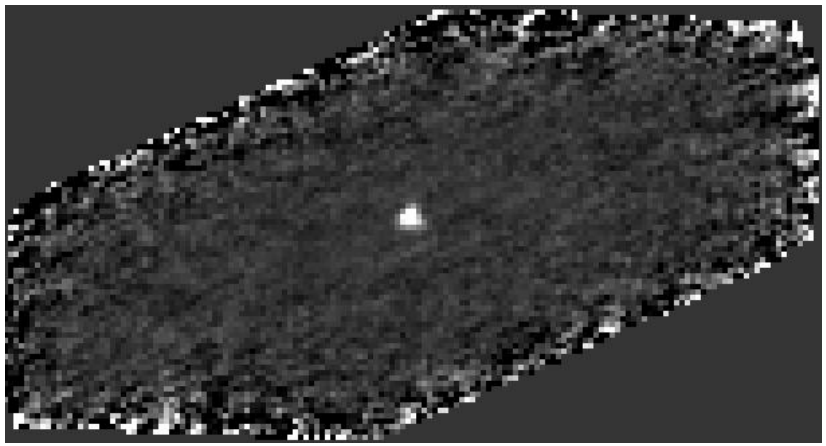
Outline of the tutorial

- Slide 4 to 37: philosophy and walk-through the PACS photometer High-Pass Filter pipeline
- Slide 38 and 39: Deglitching
- Slide 40: High-Pass Filter radius
- Slide 41: outpix & pixfrac
- Slide 42: turnaround removals

PACS Photometer Pipeline: 2 main branches



The HPF branch is optimal for reducing mini scan maps or large scan maps where the focus of the science is on point sources

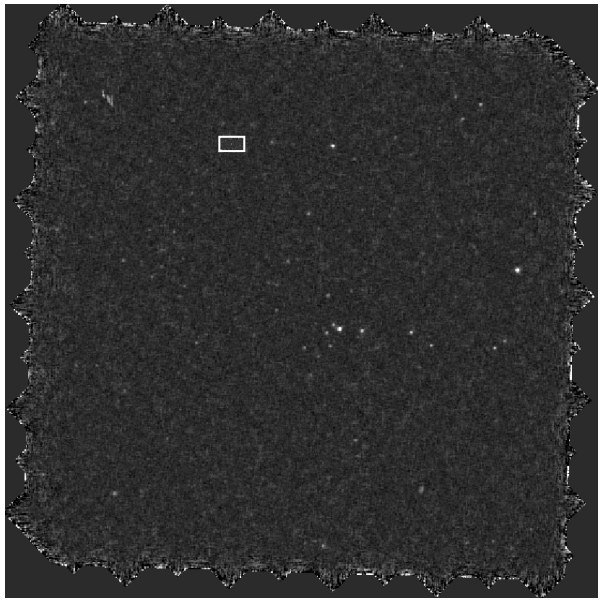


Mini scan map

a single source in the center of the field

Large scan map

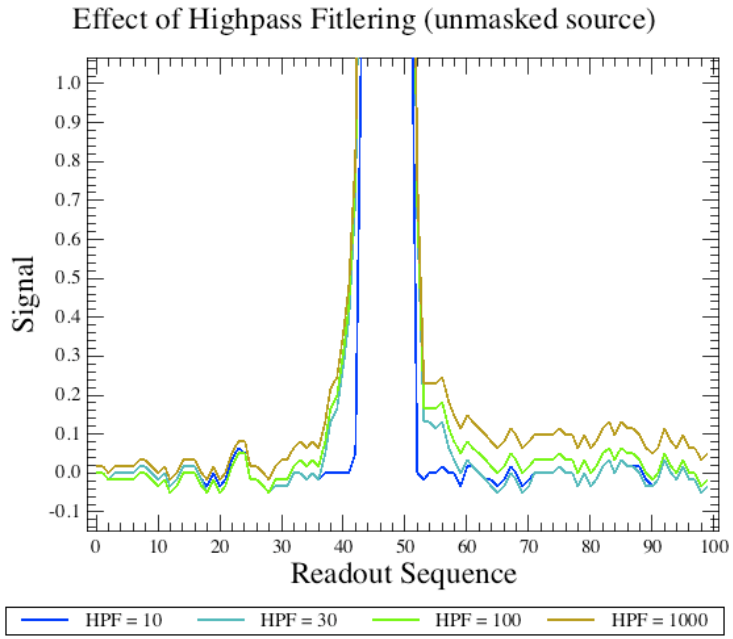
multiple sources distributed in the field

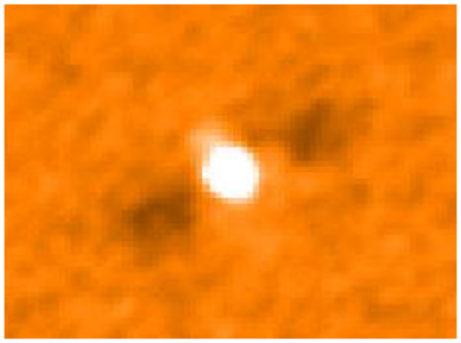


The High-Pass Filter concept

Main Idea:
sliding median-filter on individual pixel timelines to remove large scale drifts

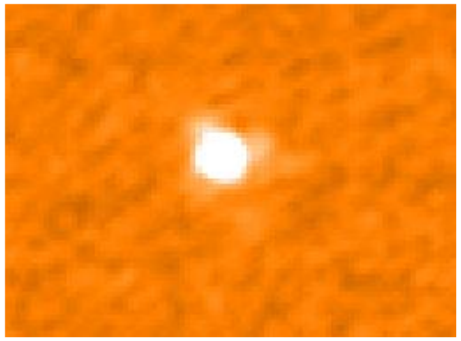
Note: When a bright source enters the filter box, it alters the estimate of the median and thus the drift removal





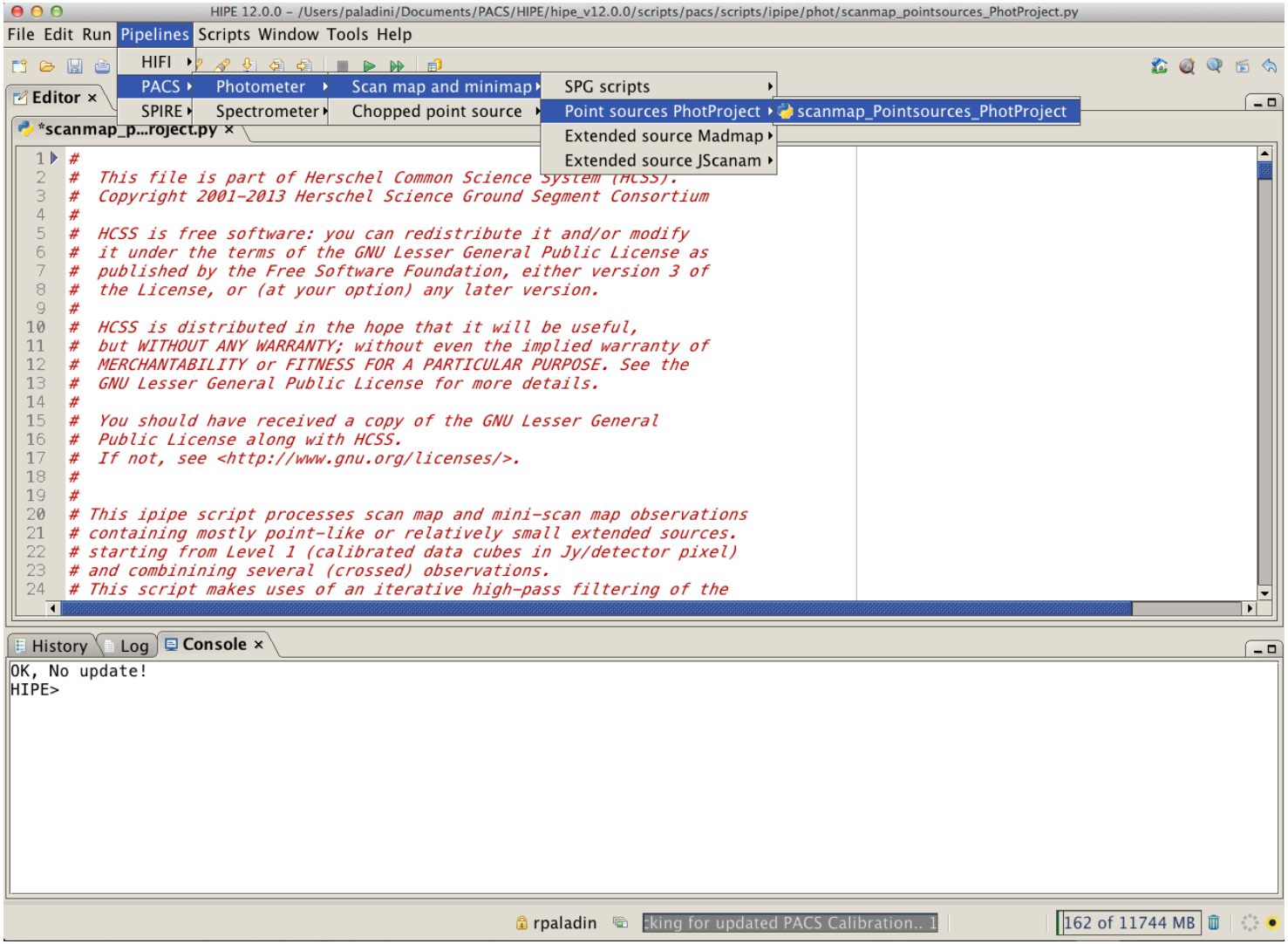
Unmasked Highpass Fitlering

Sources have to be masked !



Masked Highpass Filtering

The ipipe script for HPF processing is: scanmap_Pointsources_PhotProject



Level 1 to Level 2 processing:*

NOTE: Starting with HIPE 11, the PACS photometer *ipipe* script for the High-Pass Filter branch starts from Level 1 (*calibrated cubes)* instead of Level 0 (*raw data*).

This is because the pipeline is now very stable between Level 0 and Level 1 and the user does not need to tweak the processing at the level of raw calibrated data.

HPF Pipeline: Main Concept

The main idea of the HPF pipeline revolves around generating a mask as accurate as possible to "protect" the source/s of interest when the high-pass filtering (which allows the removal of the noise) is applied.

This operation is done in multiple (3) steps.

Structure of the ipipe script:

The script is organized in 3 + 1 major blocks:

- **Part 1**

  → 1st pass: for each OBSID, a mask is generated by statistically identifying sources as "peaks" above the (median) background of the scan. HPF is then applied with this mask

  → 2nd pass: all the individual maps are combined together. A mask is built from these combined maps

- **Part 2**

  HPF is re-applied to each OBSID (e.g. Level 1) with this improved mask. Deglitching is also applied

- **Part 3**

  the mask generated in Part 1 and 2 is updated by using direct information on the coordinates of the source/s of interest. The mask is added to the ones previously generated, and HPF is re-applied (e.g. to Level 1 data) using this final, global mask

- **Photometry:** at the end of the script, aperture photometry is performed on the final map (→ THIS PART OF THE SCRIPT IS NOT TREATED IN THIS TUTORIAL)

Part 1 – 1st pass
(from line 111 to 244)

Generate a mask for each OBSID and use this for 1st pass with HPF

- ✓ the Level 1 data of each OBSID are loaded into HIPE
- ✓ the calTree, which contains all the calibration files, is loaded into HIPE
- ✓ HPF is run on the Level 1 data without masking the sources
- ✓ a map is generated from these 1st pass HPF data
- ✓ the high-coverage pixels of this map are used to identify outliers. These outliers are the "sources" which allow the generation of a mask
- ✓ this mask is applied to the data before re-running HPF
- ✓ a map from the 2nd pass HPF data is created

At the beginning of Part 1, the user has to set:

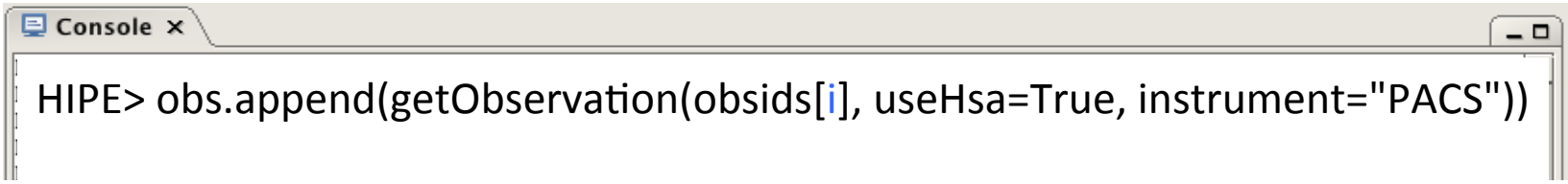
- target name, e.g. M31: object (line # 52)
- OBSID numbers: obsids (line # 54)
- band name, i.e. blue (70 μm), green (100 μm) or red (160 μm): camera (line # 57)
- working directory, i.e. directory where to store generated maps: direc (line # 70)
- prefix (including target name and camera) of files to generate: fileroot (line # 71)
- turnaround removals: lowScanSpeed/highScanSpeed or limits (line # 90, 91 and 92)

… and then decide:

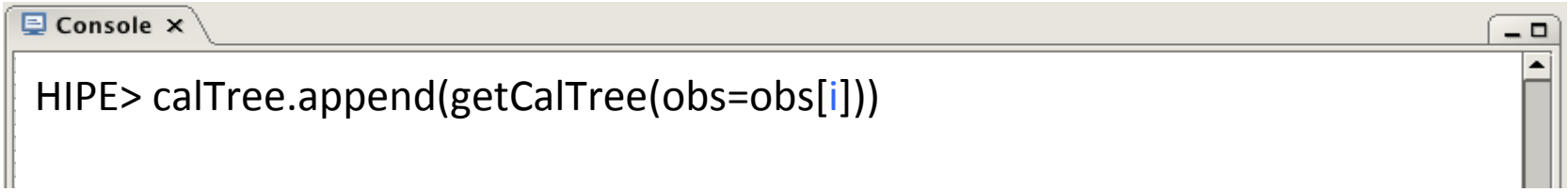
- Improve on 2nd level deglitching: doIIndLevelDeg (line # 78, see slide 38/39)
- whether to do (aperture) photometry as well as processing: doPhotometry (line # 79)
- do 2-d gaussian fit to determine source centroid and improve mask: doSourceFit (line # 80)
- get coordinates of the source/s from external file to improve mask: fromAFile (line # 82)
- If previous line set to 'True', enter filename: tfile (line # 83)

At this stage, the script starts looping over the list of OBSIDs:

1. The Level 1 data of each OBSID, *i*, in the "*obsids* " list, is loaded into HIPE. First load the observation context:



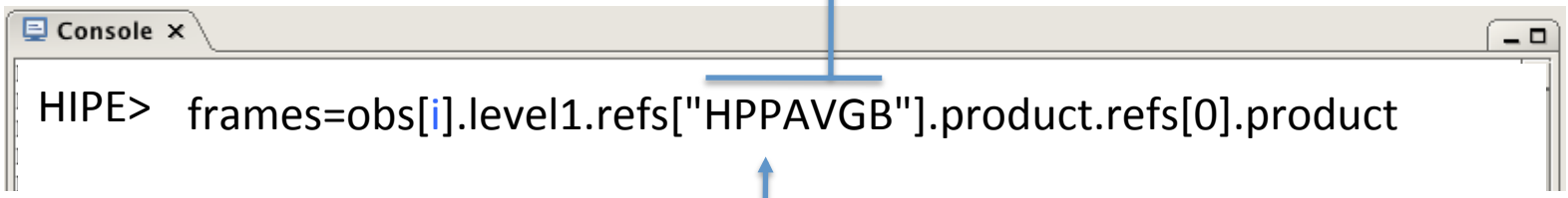
2. Load the Calibration Tree (calTree):



The Calibration Tree (*calTree)* contains all the files necessary to process your data

3. then extract the Level1:

Syntax for Blue/Red array



HPPAVGB/R: **H**erschel **P**ACS **P**hotometer **AVG**erage **B**lue/**R**ed
This is the signal downloaded from the spacecraft after on-board averaging

Now that we have the basic pieces, we can get to the core of Part 1, i.e.:

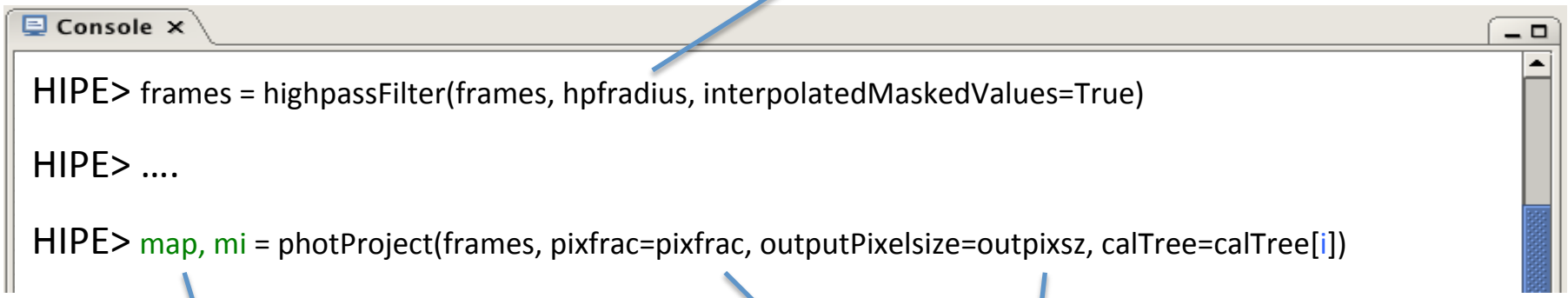
the generation of the mask for <u>each OBSID</u>

At this stage the mask is created **blindly**. This means that the assumption is that one does not know the location (coordinates) of the sources, and these have to be identified as “peaks” above the median background.

Let's see how this works:

4. First apply high-pass filtering without a mask
5. Then create a preliminary map
6. ….next slide

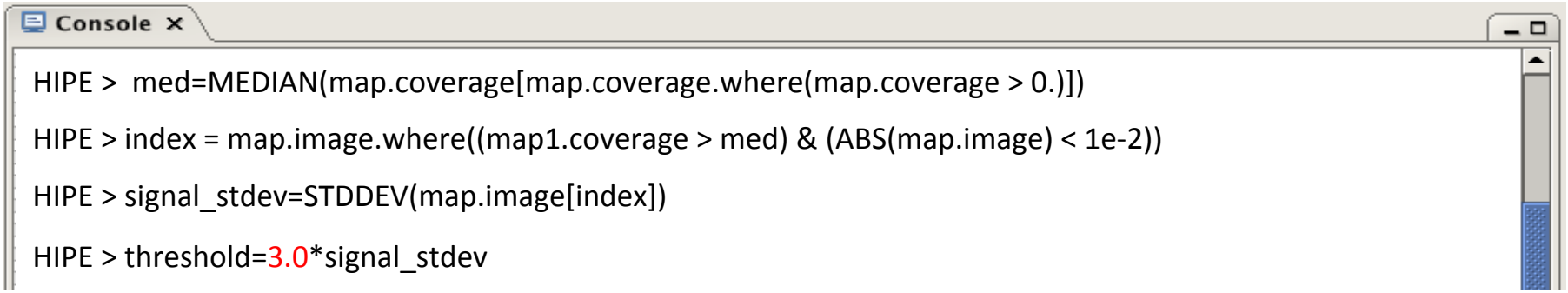
For more information on "hpfradius" see slide # 40



NOTE: This map is NOT good for photometry: It must be used *only* for identifying sources

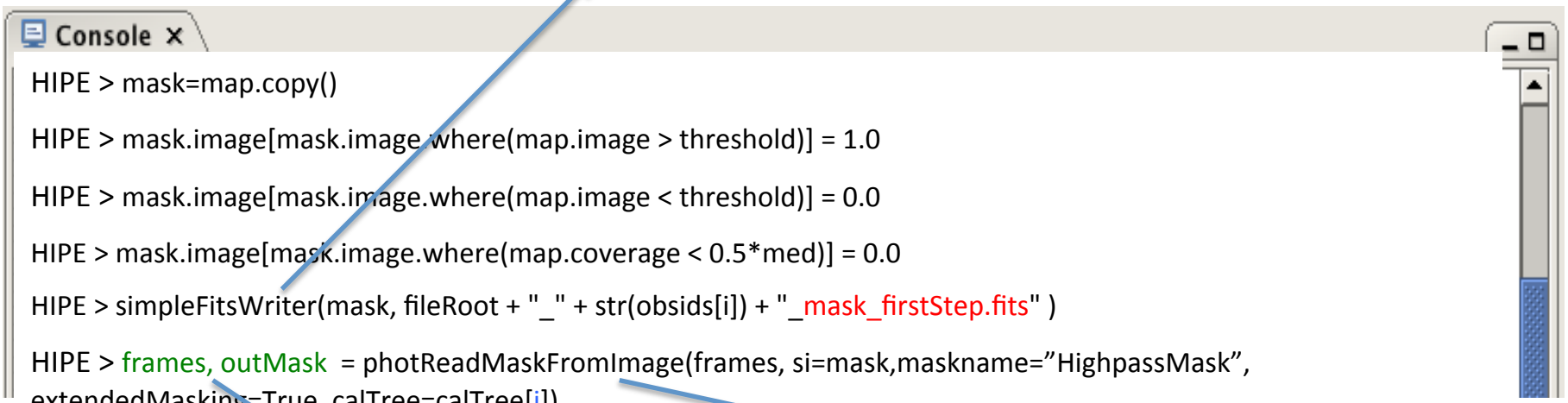
For more information on "pixfrac" and "outputPixelsize" see slide # 41

6. Identify the region of the map with high coverage (i.e. coverage > “med”)
7. Use this region to estimate the signal standard deviation of the map (stdev)
8. Set a threshold (i.e. 3.0) above which map outliers are identified
9. ….next slide



9. Mask everything above the threshold → **these are the "sources"**
10. Save the mask in a .fits file
11. Mask in the timeline all readouts at the same coordinates of the map pixels with signal above the threshold

The *frames* are saved in standard fits format. The saved file can be read back into HIPE:
HIPE> frames = simpleFitsReader(maskfile)



NOTE: since HIPE 12.0, every task having more than one output has this syntax. In this case, the two ouputs of the task are the updated frames and the mask

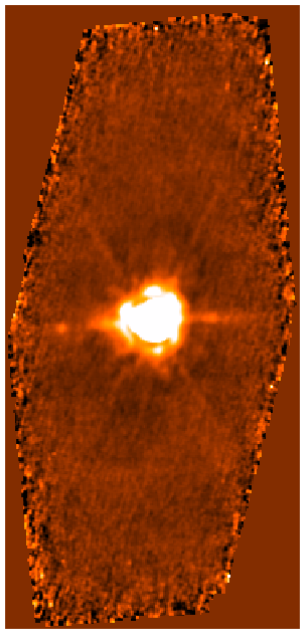
This is how a mask is "attached" to the Level 1 frames !

9. now that you have a mask, re-run high-pass filtering with it
10. create map from high-pass filtered data
11. save map in a .fits file

Console

```
HIPE  > frames  = highpassFilter(frames,hpfradius,maskname="HighpassMask", interpolateMaskedValues=True)
HIPE > .....
HIPE > map, mi   = photProject(frames,pixfrac=pixfrac,outputPixelsize=outpixsz,calTree=calTree[i])
HIPE > simpleFitsWriter(map, fileRoot + "_" + str(obsids[i]) + "_map_firstStep.fits")
```

Map from an individual OBSID – 1st pass



Part 1 – 2nd pass
(from line 213 to 244)

Derive a mask from the combined maps

- ✓ the maps generated in Part 1 are read-in, co-added
- ✓ the new combined map is used to generate an improved mask, following the same procedure as in Part 1 for the individual OBSID maps: the high-coverage pixels of this map are used to identify outliers, an these outliers are the "sources" which allow the generation of a mask

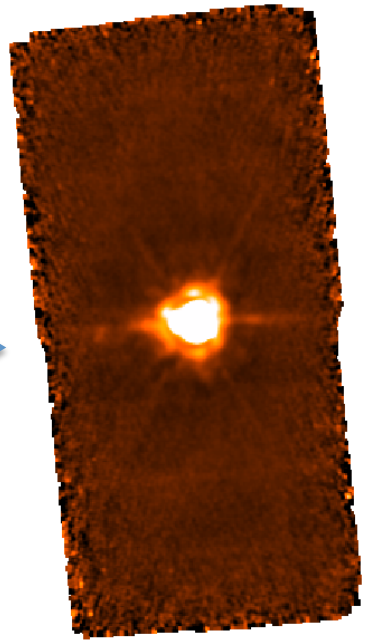
1. First, loop over the OBSIDs and co-add them:

NOTE: in Jython the loop is denoted with an indentation

Console

```
HIPE  > for i in range(len(obsids))
HIPE >     ima=simpleFitsReader(file=fileRoot + "_" + str(obsids[0]) + "_map_firstStep.fits")
HIPE >     images.add(ima)
HIPE >  mosaic=MosaicTask()(images=images, oversample=0)
```

Map from combined OBSIDs



2. Then generate a mask using the combined map.
The procedure is the same as in Part 1 (slide # 17 to 19).

These steps are not repeated in the tutorial, but in summary:

→ Identify the region of the map with high coverage (i.e. coverage > "med")
→ Use this region to estimate the signal standard deviation of the map (stdev)
→ Set a threshold above which map outliers are identified

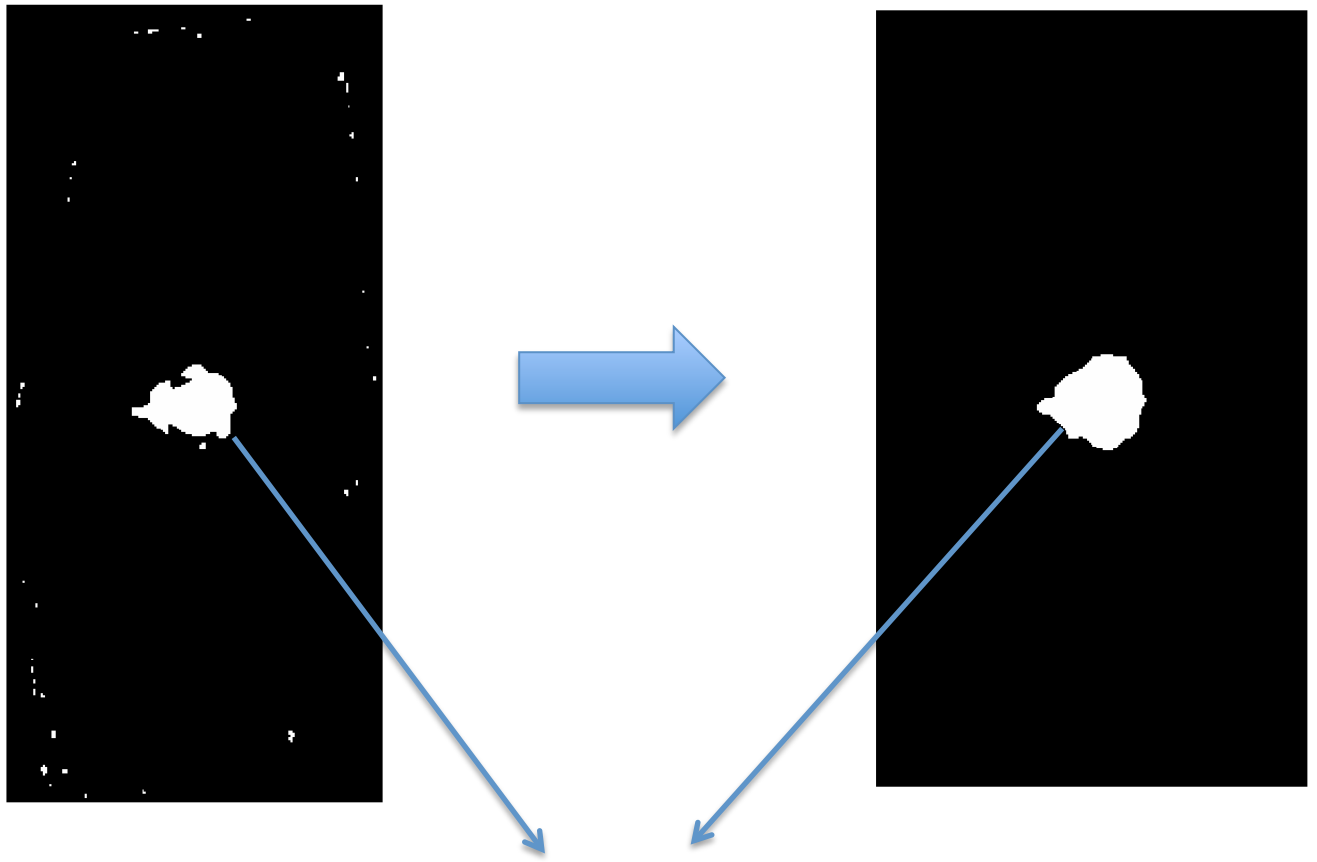
….and then:

→ Mask everything above the threshold → **these are the "sources"**
→ Save the mask in a .fits file
→ Mask in the timeline all readouts at the same coordinates of the map pixels with signal above the threshold

Note: in Part 2, the threshold is set to 2.0 instead of 3.0 as in Part 1

Mask from Part 1:
One for each OBSID

Updated Mask from Part 2:
combined OBSIDs



source

Part 2

(from line 251 to 310)

Now step back, i.e. apply the newly improved mask to do HPF on individual OBSIDs

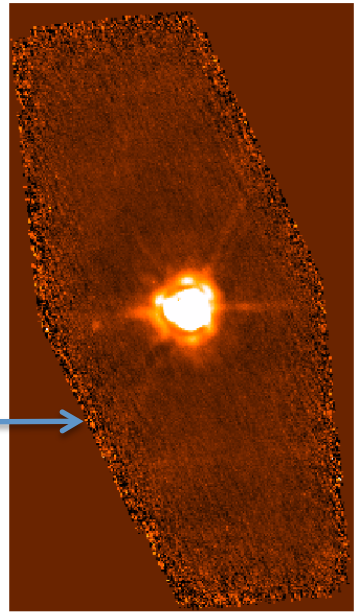
- ✓ With the improved mask derived from the combined maps, step back to Level 1 data of each OBSID: apply HPF using the new mask, and create the map
- ✓ co-add again the individual maps

1. Step back to Level 1 data for each OBSID and apply HPF with improved mask

Console

```
HIPE  > for i in range(len(obsids))
HIPE >     ....
HIPE >     frames, outMask = photReadMaskFromImage(frames, si=mosaicMask, maskname="HighpassMask”,
              extendedMasking=True, calTree =calTree[i])
HIPE >     frames = highpassFilter(frames,hpfradius,maskname="HighpassMask”, interpolateMaskedValues=True)
HIPE >     .....
HIPE >     map, mi   = photProject(frames, pixfrac=pixfrac ,outputPixelsize=outpixsz,
                    calTree=calTree[i])
HIPE >     simpleFitWriter(map, fileRoot + "_" + str(obsids[i]) + "_map_secondStep.fits")
```

Map from
individual OBSID – 2nd pass

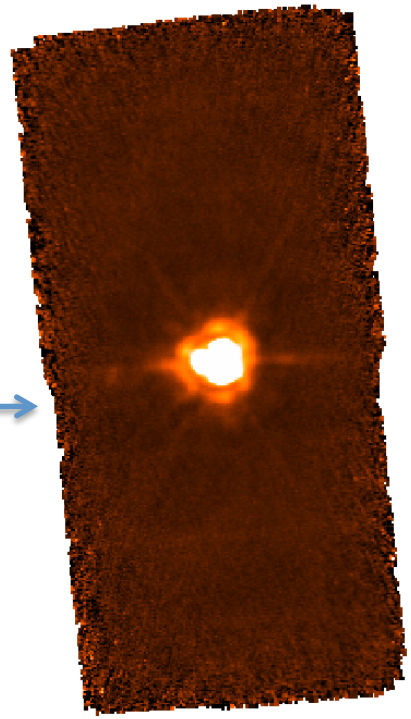


2. Now co-add the 2nd pass HPF maps from individual OBSIDs

Console

```
HIPE > images=ArrayList()
HIPE > for i in range(len(obsids)):
HIPE >     ima = simpleFitsReader(file=fileRoot + "_" + str(obsids[i]) + "_map_secondStep.fits")
HIPE >     images.add(ima)
HIPE >   mosaic=MosaicTask()(images=images, oversample=0)
```

Map from
combined OBSIDs - from 2nd pass



Part 3

(from line 313 to 437)

After generating a "blind" mask in Part 1 and 2, the user can now try to improve on that mask by using the information on the location of the sources (e.g. coordinates), if this information is available.

- ✓ To use the known coordinates of the sources, the script provides two options:

A. The user inputs these coordinates (e.g. from a file) and a 2-d gaussian procedure is used to "refine" the input source/s coordinates. The fitted centroids are then used to generate a mask;

B. The input coordinates (from a file or from the metadata) are used to directly generate a mask at these locations;

Option A:
2-d gaussian fitting

To use this option, doSourceFit (line # 80) has to be set to True

Then:

- ✓ Read-in the file with the input coordinates
- ✓ For each input source, create a postage stamp using a given "cropsize"
- ✓ do a 2-d gaussian fit on each postage stamp
- ✓ use fitted "rasource" and "decsource" to generate a mask

NOTE: option A also includes the alternative case (line # 350 to 353) in which the user, with no a-priori information on the location of the sources (i.e. no input file), performs a "blind" 2-d gaussian image on the map (e.g. mosaic2, see slide #) and uses the fitted centroids to generate a mask.

Option A: in practice..

1. Input source file:

```
HIPE> tlist,ralist,declist=readTargetList(tfile)
```

2. For each source, convert ra/dec into pixel coordinates:

```
HIPE> pixcoor = mosaic.wcs.getPixelCoordinates(ralist[i],declist[i])
```

3. Define boundaries of postage stamp in pixel coordinates: r1, r2, c1, c2. The postage stamp size is defined by "cropsize" (default = 20 pixels), e.g:

```
HIPE> r1 = int(pixcoor[0]-cropsize/2.)
```

4. Create postage stamp:

Console ×

```
HIPE  > cmap    = crop(image=mosaic,row1=int(pixcoor[0]-cropsize/2.), \
row2=int(pixcoor[0]+cropsize/2.),    \
column1=int(pixcoor[1]-cropsize/2.) \
column2=int(pixcoor[1]+cropsize/2.))
```

5. For each postage stamp, do a 2-d gaussian fit:

Console ×

```
HIPE> sfit = mapSourceFitter(cmap)
```

6. Get the coordinates centroid, ra/dec, from the fit:

Console ×

```
HIPE  >  rasource[i] = Double([sfit["Parameters"].data[1]])
HIPE >   decsource[i] = Double([sfit["Parameters"].data[2]])
```

Option B:
Source coordinates from file or metadata

In this case, doSourceFit (line # 80) has to be set to False

Then:

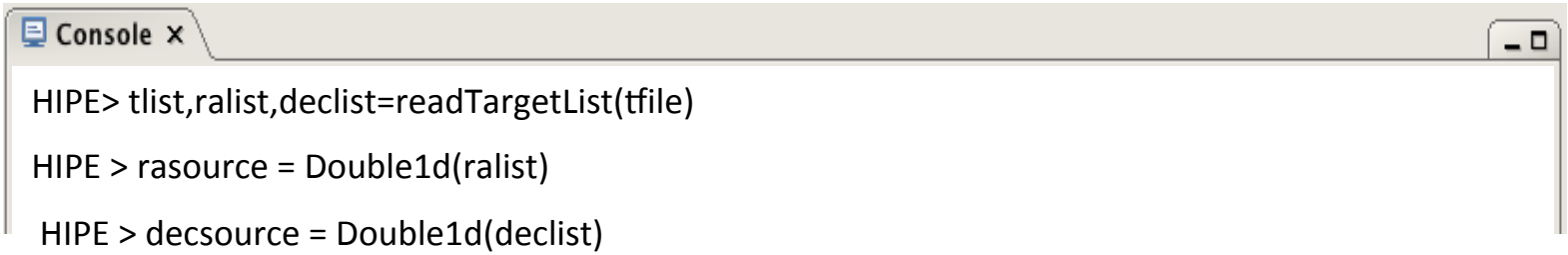
- ✓ If input catalog file is provided, read-in the file with the input coordinates
- ✓ use the input coordinates to generate a mask

Or:

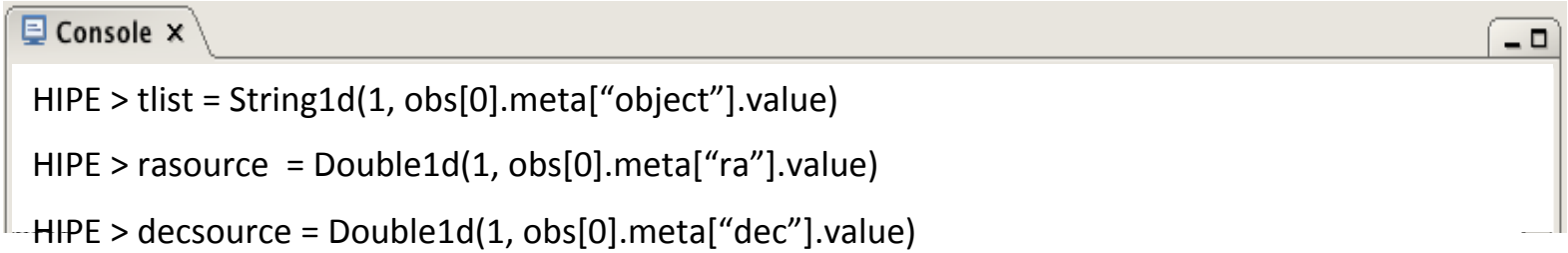
- ✓ get source/s coordinates from metadata
- ✓ use these coordinates to generate a mask

Option B: in practice..

→ **If input catalog file is available:**

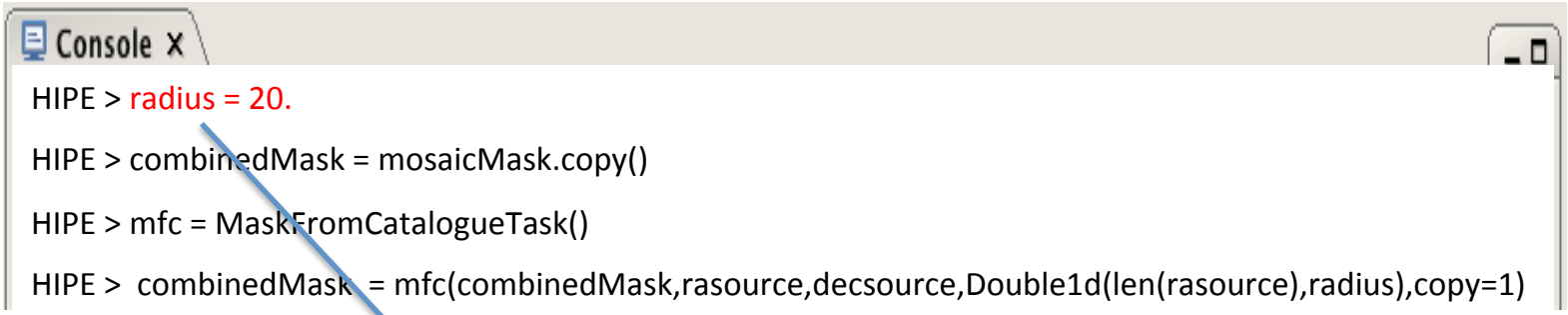


→ **alternatively, if source/s coordinates are read-in from metadata:**



In common to option A and B:

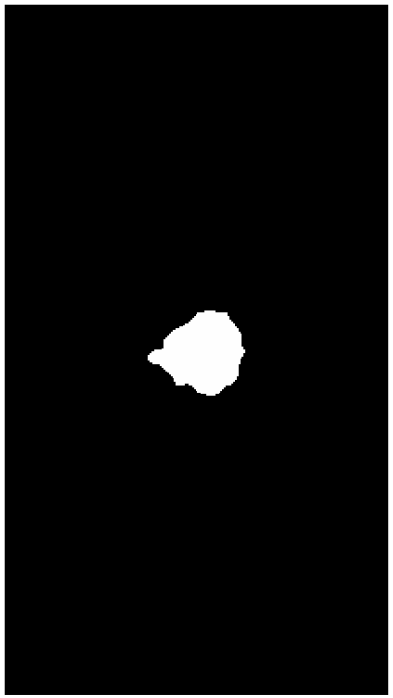
→ With the source/s coordinates ("rasource", "decsource") – either from 2-d gaussian fit/s or direct input/s from catalog/metadata – the new mask can now be generated:



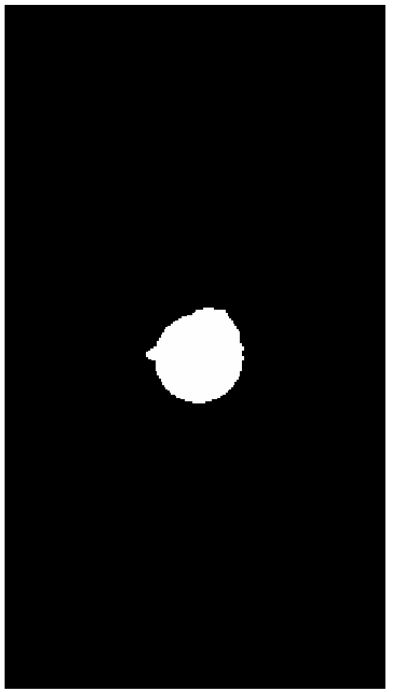
Centered on each source position (ra and dec), create a circular "patch" (i.e. a mask) with a 20" radius. The patch is big enough to fully cover the source in all bands.

Mask from Part 1:
from **each** OBSID

Updated Mask from Part 2:
from **combined** OBSIDs



Updated Mask from Part 3:
From **known** source/s coords.

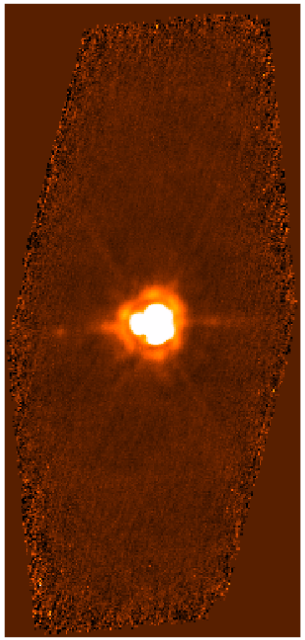


→ **Now step back and apply this new mask (improved version of the mask from Part 1, 2 and 3) to do HPF on the Level 1 data of each OBSID:**

Console X

```
HIPE > for i in range(len(obsids)):
HIPE >     …
HIPE >    frames, outMask = photReadMaskFromImage(frames, si=combinedmask, maskname="HighpassMask",
extendedMasking=True,calTree = calTree[i])
HIPE >    frames = highpassFilter(frames,hpfradius,maskname="HighpassMask",interpolateMaskedValues=True)
HIPE >    ….
HIPE >    map, mi    = photProject(frames, pixfrac=pixfrac,outputPixelsize=outpixsz,
                        calTree=calTree[i])
HIPE > simpleFitsWriter(map, fileRoot + "_" + str(obsids[i]) + ”_finalMap.fits")
```

Map from
individual OBSID – 3rd pass

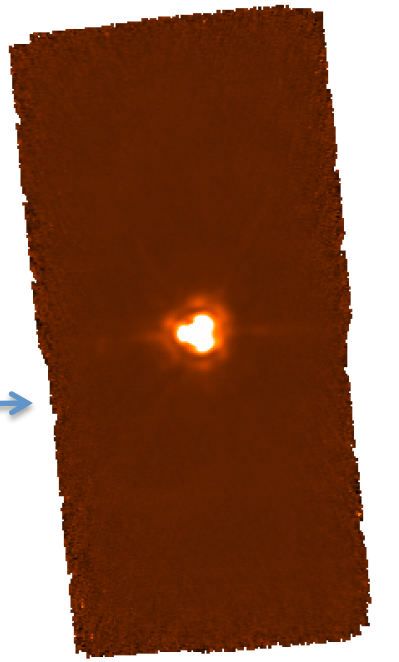


→ now co-add the 3rd pass HPF maps from individual OBSIDs: this is the FINAL map !

Console X

```
HIPE  > images=ArrayList()
HIPE > for i in range(len(obsids)):
HIPE >     ima = simpleFitsReader(file=fileRoot + "_" + str(obsids[i]) + "_finalMap.fits")
HIPE >     images.add(ima)
HIPE >  .....
HIPE > mosaic=MosaicTask()(images=images,oversample=0)
HIPE > simpleFitsWriter(mosaic, fileRoot + "_finalMosaic.fits")
```

Map from combined OBSIDs - 3rd pass (e.g. mosaic)



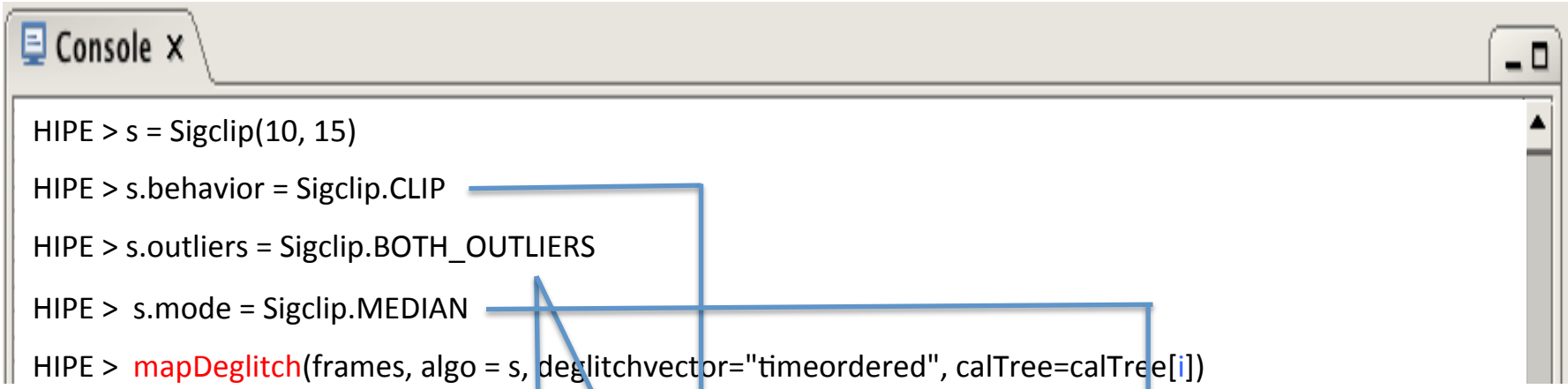
This concludes the walk through for the PACS photometer HPF pipeline !

Deglitching
(more information in tutorial # 402)

- At the beginning of the script (line # 78), the user has to set the switch doIndLevelDeg to either True or False;
- If doIndLevelDeg is set to True, then deglitching is performed again with a threshold for outliers detection more aggressive (15) with respect to threshold (30) applied before Level 1 in the standard SPG pipeline. You may want to follow this approach when the final mosaic still contains many glitches
- Note that, in the script, deglitching is performed in Part 2 (line # 257 to 263)

2nd Level Deglitching

Spatial (2nd Level) Deglitching identifies glitches by exploiting spatial redundancy. This is how it works:



Outliers are detected with a **sigma-clipping** algorithm and flagged as glitches. Both **positive** and **negative** outliers are detected. By default, outliers are detected with respect to the **median**.

High-Pass Filter Radius: hpfradius

Default Values (line # 161 to 164):

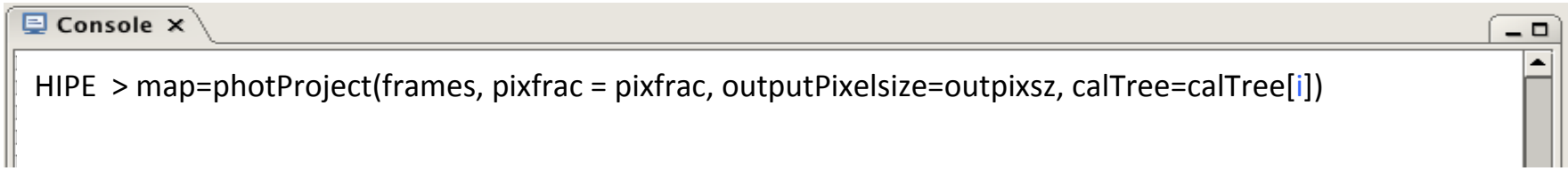
```
HIPE > If camera == 'blue':
HIPE >    hpfradius = 15
HIPE > else:
HIPE >    hpfradius = 25
```

These values (units: readouts) allow removal of 1/f noise while preserving as much as possible the flux in the wings of the PSF (Point Spread Function)

NOTE: the values above are optimized for point-sources. If the source of interest is slightly extended (a few times the fwhm), the use of larger "hpfradius" is recommended.

Making the map: outpixsz & pixfrac

The **photProject** task performs a simple co-addition of the images using the drizzle method (Fruchter and Hook, 2002, PASP, 114, 144). The key parameters are the output pixel size and the drop size (**pixfrac**). **A small pixfrac value can help to reduce the correlated noise due to the projection.**

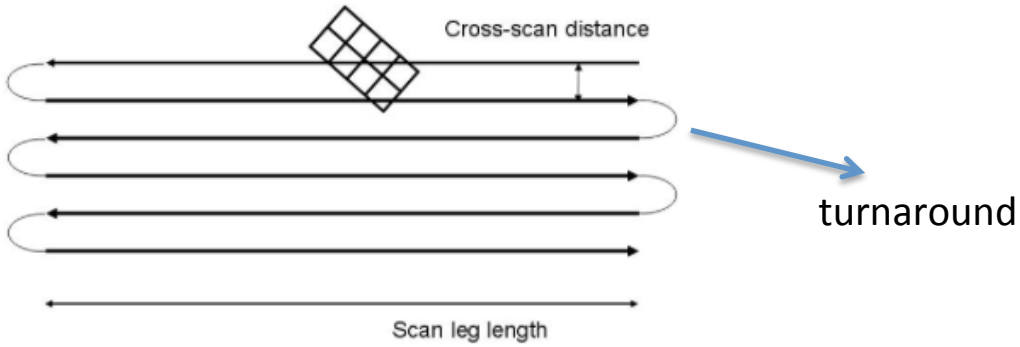


Default Values (line # 104 to 108):

```
HIPE > If camera == 'blue':
HIPE >    outpixsz = 1.0
HIPE >    pixfrac = 0.1
HIPE > else:
HIPE >    outpixsz = 2.0
          pixfrac = 0.1
```

Turnaround removal

NOTE: in the script, the frames corresponding to the telescope turnaround are removed each time before creating the map. Turnaround frames are characterized by much lower coverage (hence sensitivity) then normal science frames.



Console

```
HIPE > frames = filterOnScanSpeed(frames,limit=limits)
```

Turnaround frames are executed at different scan speed than normal science frames

The parameter "limit" is set at the beginning of the script (line # 92).
"Limits = 10" means: remove all the frames with a scan speed 10% higher/lower than science frames scan speed.

Thank you !