RSS Multi-object Spectroscopy Mask Design

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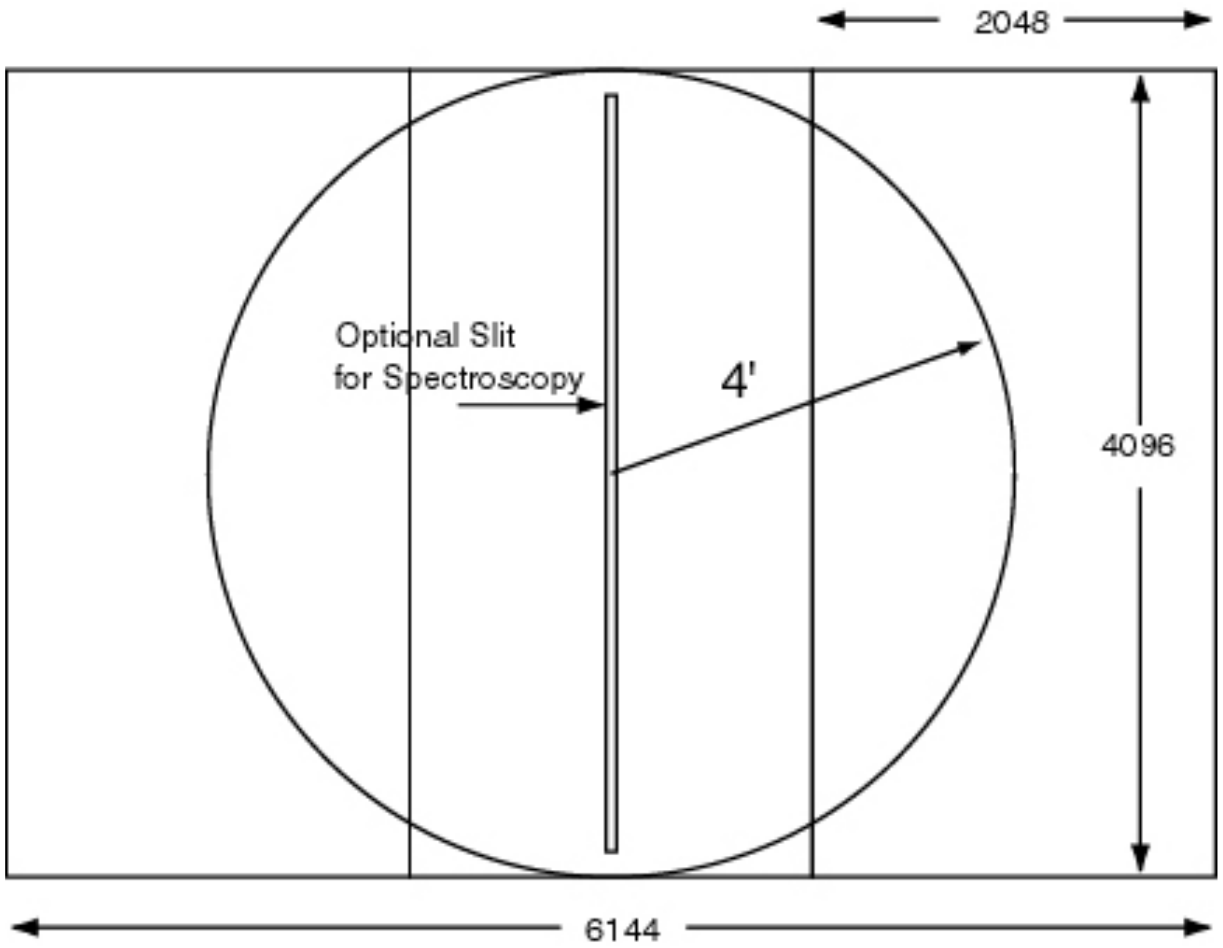
SALT Workshop 15 November 2022

RSS basics - layout

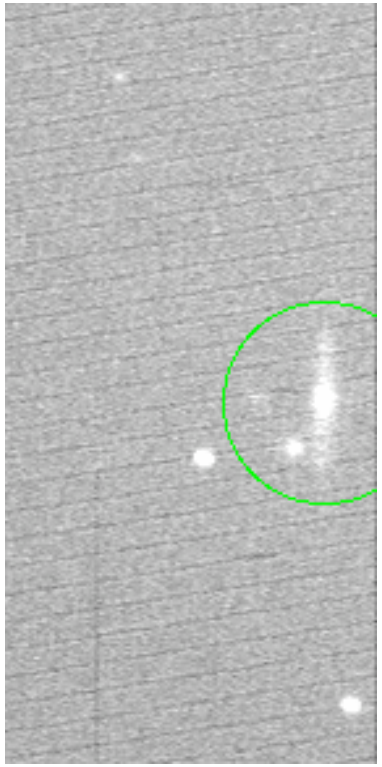
- The RSS detector is made up of 3 CCDs mosaicked with small gaps between them
- The pixel scale is 0.127 arcseconds per pixel
- The height corresponds to the field of view of 8 arcminutes (4096 pixels)
- We are currently working on an upgrade to a single chip



RSS basics

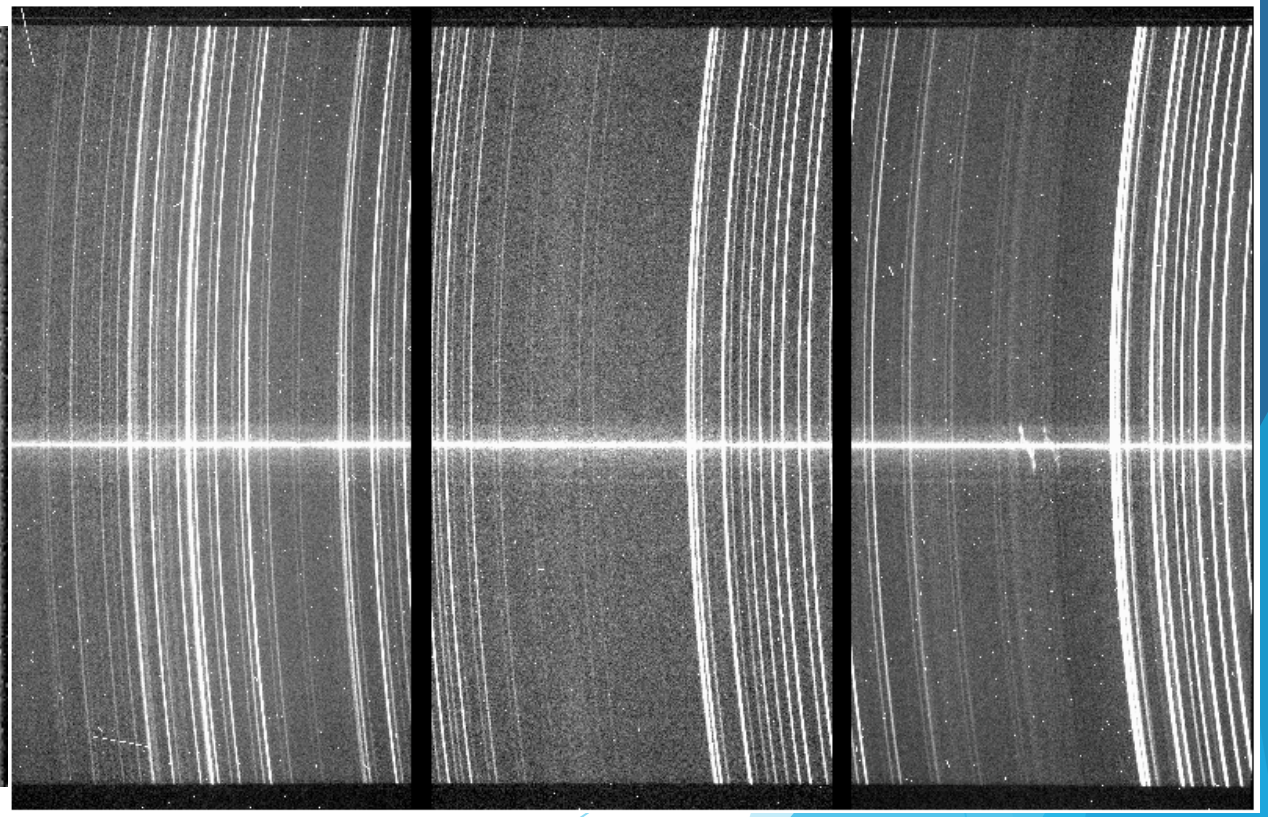
- RSS can be operated as an imaging camera (with no grating), or as a spectrograph, using a single long slit or multiple slits anywhere in the 8 arcminute field of view

- The standard long slits range from 0.6 to 4” in width, and are 8 arcmin in length



SALTICAM image

SALTICAM image of the galaxy on the slit (mirrored)



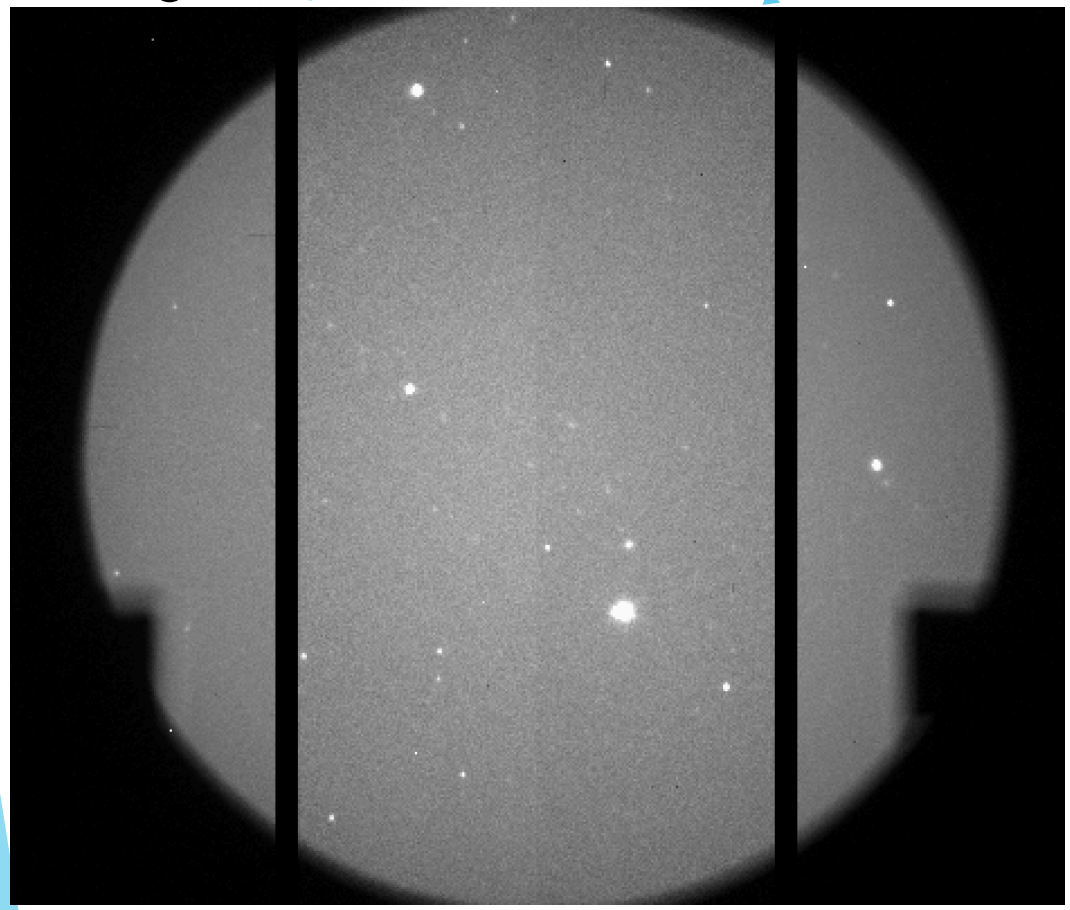
RSS spectrum showing continuum all the way along and emission lines

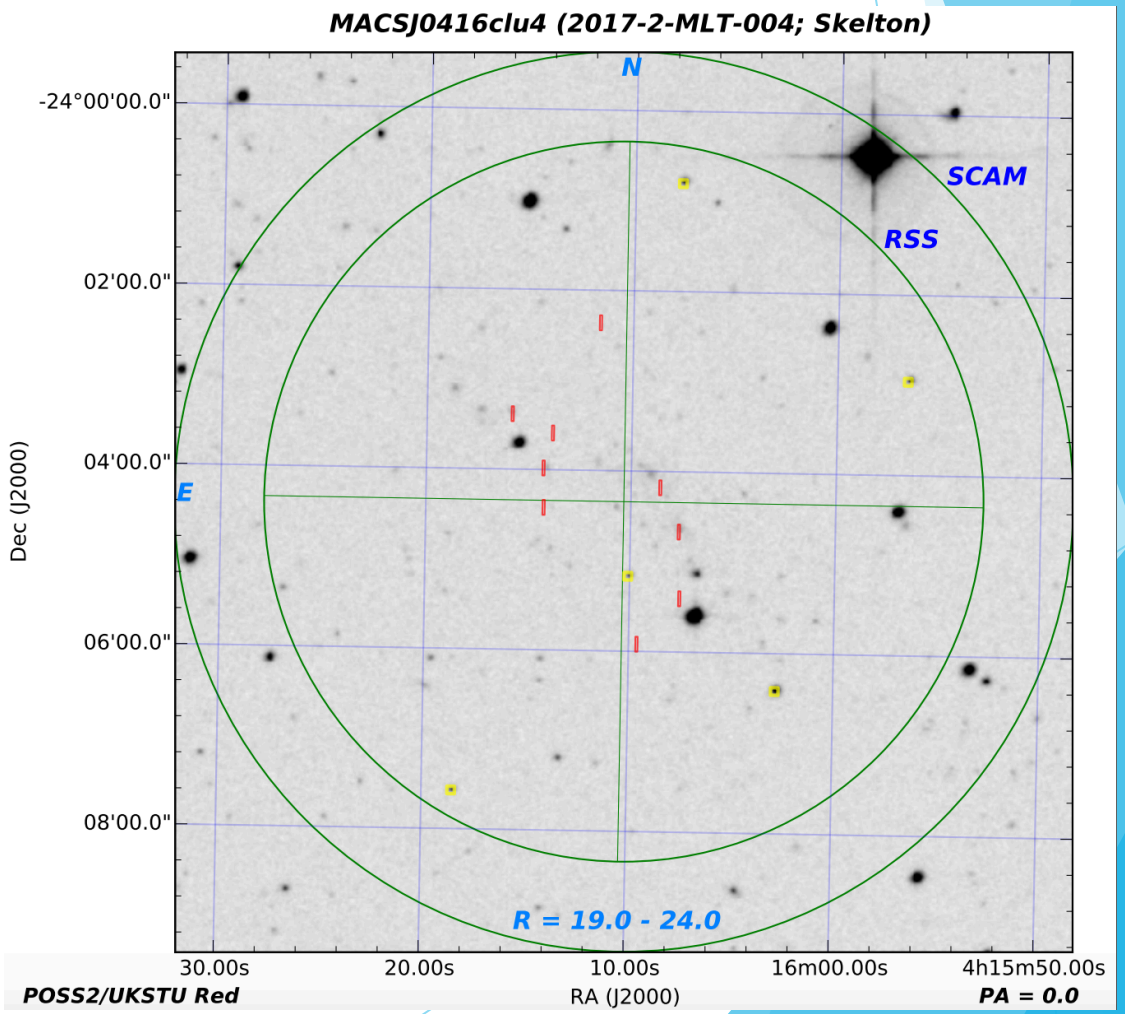
Multi-object spectroscopy

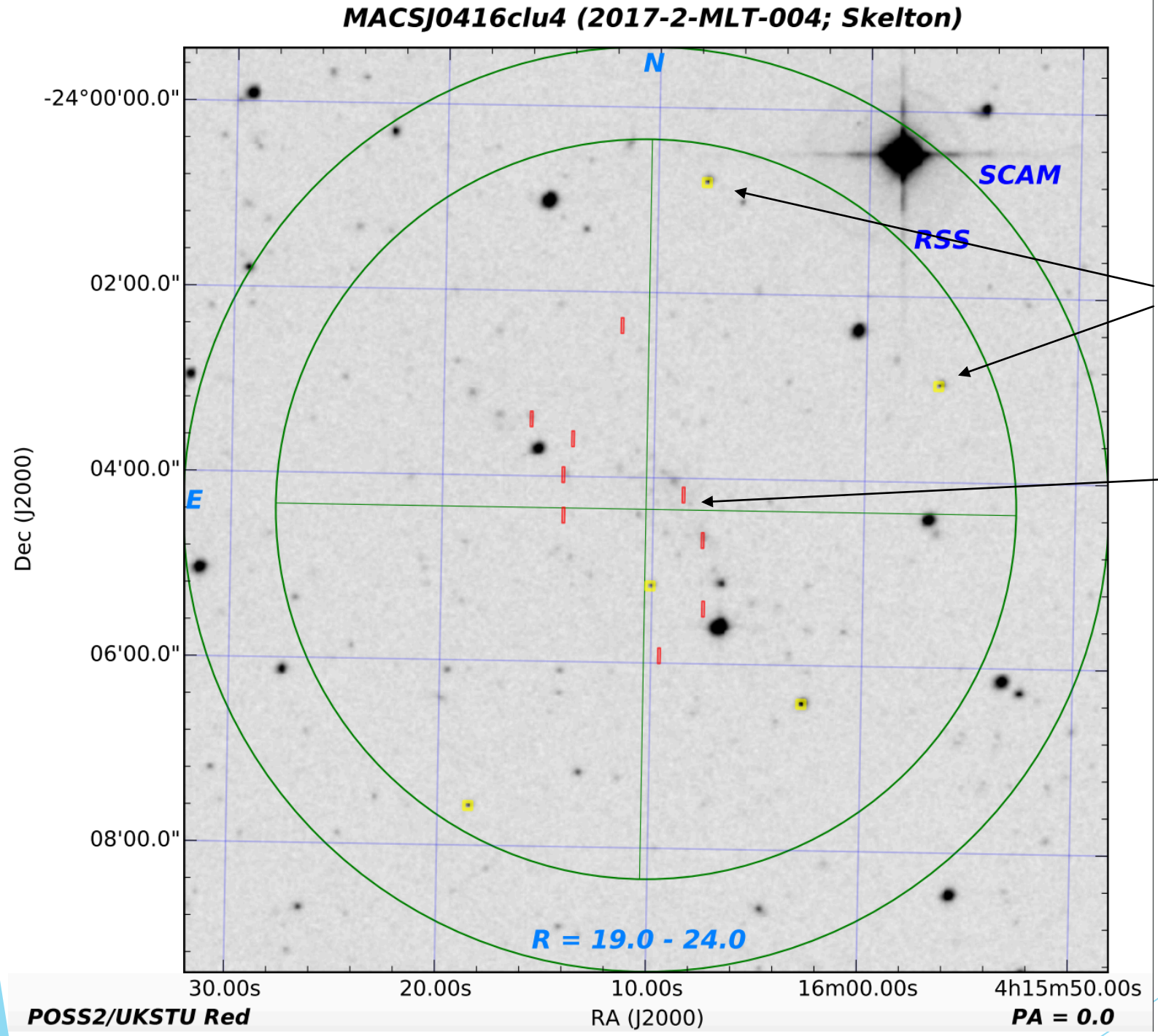
- Targeting 9 galaxies in a galaxy cluster simultaneously.
- Finder chart shows slits in red, reference stars for aligning the mask are the yellow squares

RSS image

CCD gaps



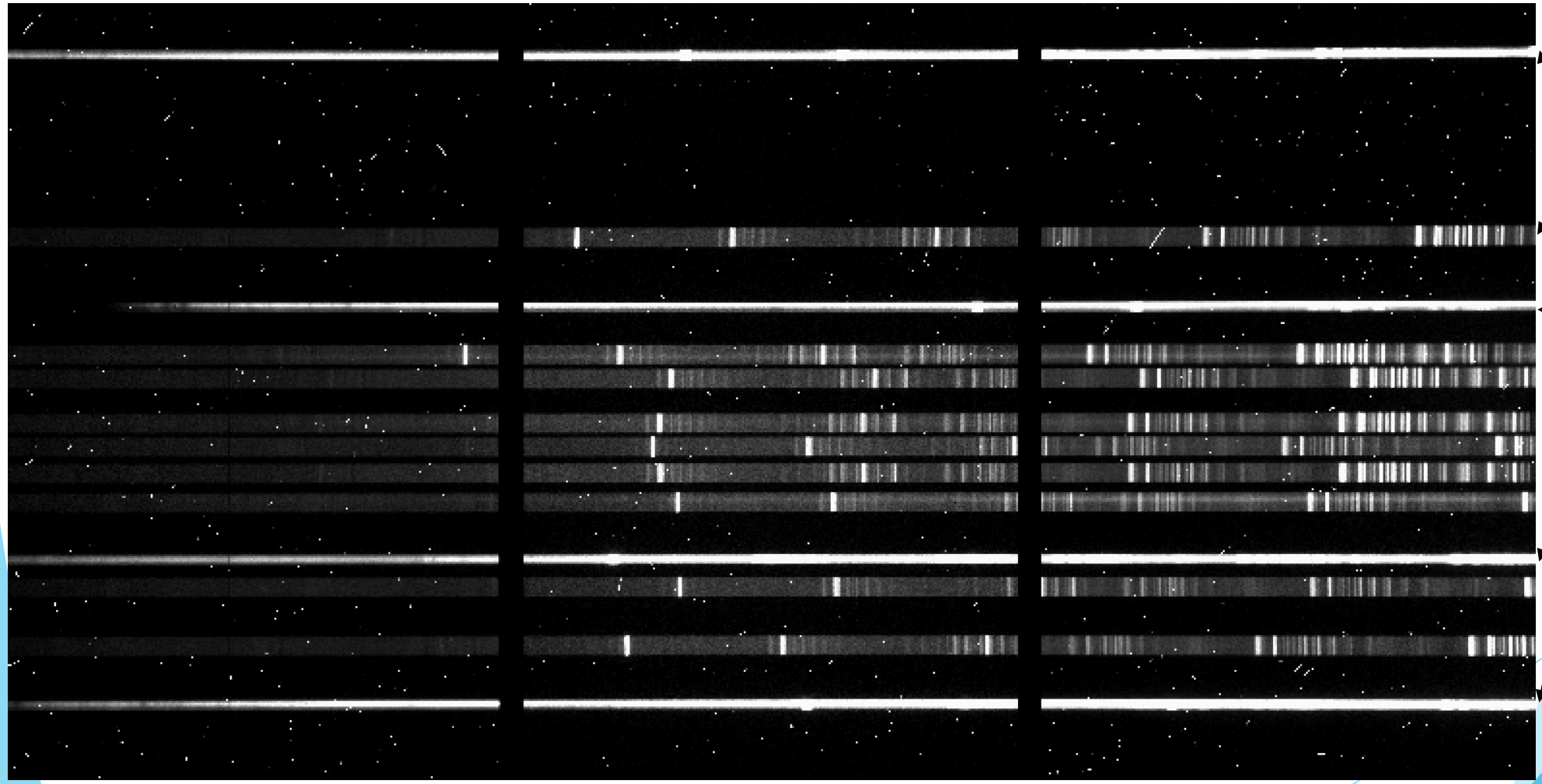




Reference star boxes

Slits

Example MOS data



Now we have 9 galaxy spectra like this

and 4 from bright stars that were used for alignment

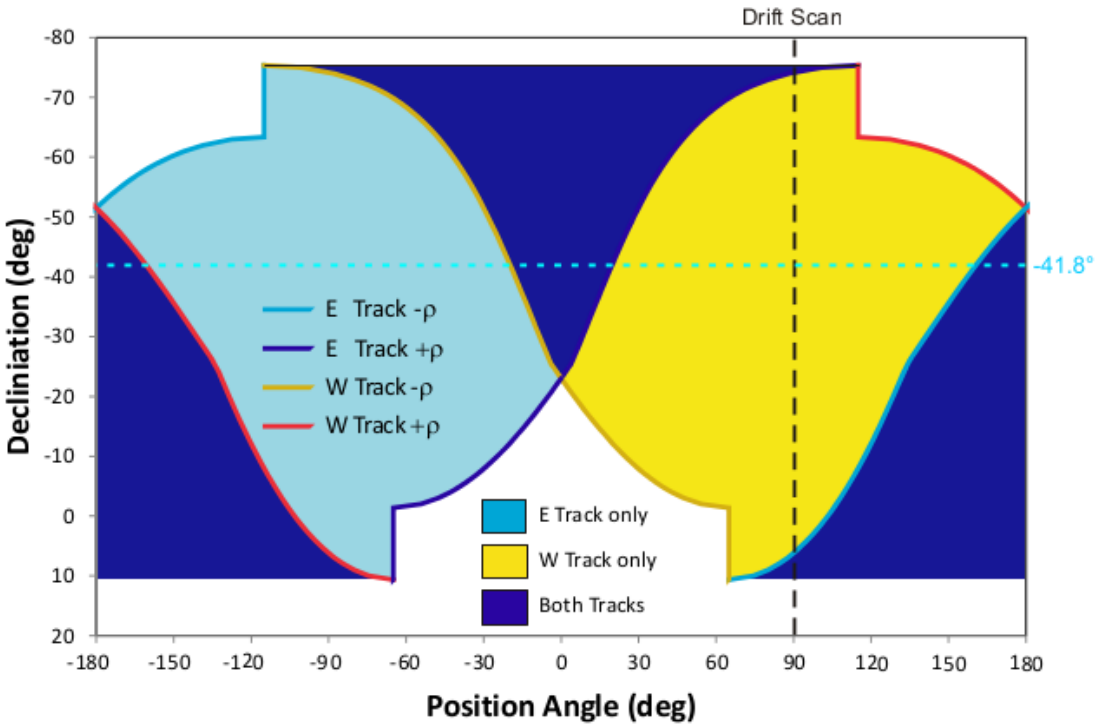
Mask Design Tools

- pySlitmask.py within pySALT (old & buggy…)
  - Updated & much improved as part of polSALT by Ken Nordsieck, but not yet a stable version release
- RSMT java application (even older…)
- Various codes created by SALT PIs
  - E.g. Matt Hilton (see Matt's slides at this workshop), David Gilbank

Mask Design – Input needed

```
1   ##id RA DEC epoch magnitude band priority width length1 tilt
2   1070    64.014699   -24.091486  2000.0  22.634797   r   1.00    2 10 0
3   1115    64.016801   -24.090795  2000.0  23.140064   r   1.00    2 10 0
4   1373    64.011645   -24.093757  2000.0  19.988691   r   1.00    2 10 0
5   1751    64.047042   -24.088629  2000.0  22.775136   r   1.00    2 10 0
6   8   63.985739   -24.049364  2000.0  16.900000   r   -1.00       5 5 0
7   9   64.011862   -24.106984  2000.0  16.500000   r   -1.00       5 5 0
8   13  64.032125   -24.013375  2000.0  17.200000   r   -1.00       5 5 0
9   14  64.04204    -24.0861392 2000.0  17.500000   r   -1.00       5 5 0
10  21  64.077289   -24.126209  2000.0  17.600000   r   -1.00       5 5 0
```

- Catalogue of targets
  - RA, Dec, magnitude, priority 0 - 1
- List of potential reference stars (priority=-1)
  - same source of astrometry as target objects
  - Ideally 15-17th mag
  - Best to have 4 or 5 relatively well-isolated stars well spread over the field
- An image of the field
- Position Angle of the mask – see http://astronomers.salt.ac.za/proposals/mos/
- Desired slitwidths, lengths, tilt (optional – advanced users)



Mask Design – Output

- A mask file that can be loaded into the PIPT in Phase 2, with the ".rsmt" extension
- Actually just a zip file containing an xml file with the slit information & a finder chart

```
(pysalt) ros$ unzip macs0416clu_mask1.rsmt
Archive:  macs0416clu_mask1.rsmt
 extracting: Slitmask.xml
 extracting: Slitmask.png
```

```
rosmac2:testcode ros$ more demo-mask1.xml
<?xml version="1.0" ?>
<slitmask>
  <header>
    <parameter name="VERSION" value="1.1"/>
    <parameter name="PROPOSALCODE" value="2022-2-SCI-001"/>
    <parameter name="MASKNUM" value="test-mask1"/>
    <parameter name="TARGET" value="MACS0416"/>
    <parameter name="PI" value="Skelton"/>
    <parameter name="CREATOR" value="Skelton"/>
    <parameter name="ROTANGLE" value="0.0"/>
    <parameter name="CENTERRA" value="64.030400"/>
    <parameter name="CENTERDEC" value="-24.085442"/>
    <parameter name="NSMODE" value="0"/>
    <parameter name="VALIDATED" value="True"/>
    <parameter name="SPECLENGTH" value="12400"/>
    <parameter name="SPECOFFSET" value="0"/>
    <parameter name="SPECPOLSPLIT" value="0"/>
    <parameter name="SPECHEIGHT" value="0"/>
  </header>
  <slit id="1751" length="10.000000" mag="22.775137" priority="1.000000" width="2.000000" xce="64.047043" yce="-24.088629"/>
  <refstar id="8" length="5.000000" mag="16.900000" priority="-1.000000" width="5.000000" xce="63.985741" yce="-24.049364"/>
  <refstar id="14" length="5.000000" mag="17.500000" priority="-1.000000" width="5.000000" xce="64.042038" yce="-24.086140"/>
  <refstar id="21" length="5.000000" mag="17.600000" priority="-1.000000" width="5.000000" xce="64.077286" yce="-24.126209"/>
  <slit id="1373" length="10.000000" mag="19.988691" priority="1.000000" width="2.000000" xce="64.011642" yce="-24.093758"/>
  <slit id="3152" length="10.000000" mag="22.895987" priority="1.000000" width="1.500000" xce="64.032501" yce="-24.078491"/>
  <slit id="4400" length="10.000000" mag="21.357363" priority="1.000000" width="1.500000" xce="64.057739" yce="-24.073879"/>
  <slit id="20016" length="10.000000" mag="20.914883" priority="0.700000" width="1.500000" xce="64.032677" yce="-24.070150"/>
  <slit id="20021" length="10.000000" mag="21.117691" priority="0.700000" width="1.500000" xce="64.042526" yce="-24.063244"/>
  <slit id="500" length="10.000000" mag="22.385813" priority="0.300000" width="1.500000" xce="64.040039" yce="-24.098679"/>
  <slit id="5059" length="10.000000" mag="23.218807" priority="0.900000" width="1.500000" xce="64.059532" yce="-24.066380"/>
  <refstar id="8" length="5.000000" mag="16.900000" priority="-1.000000" width="5.000000" xce="63.985741" yce="-24.049364"/>
  <refstar id="9" length="5.000000" mag="16.500000" priority="-1.000000" width="5.000000" xce="64.011864" yce="-24.106983"/>
  <refstar id="21" length="5.000000" mag="17.600000" priority="-1.000000" width="5.000000" xce="64.077286" yce="-24.126209"/>
</slitmask>
```

Running pySlitmask.py

- I have an Anaconda environment set up with IRAF/pyRAF, python2.7 and pySALT
- pySlitmask is found within the pySALT proposal tools
- Within a terminal run:

(pysalt) $ python ~/iraf/pysalt/proptools/pySlitMask.py

- Or from within pyRAF: load ‘pySALT’, ‘proptools’, then execute ‘masktool’

```
--> pysalt

      +-----------------------------------------------------+
      |                      _ _                            |
      |   __ _ _  __ __ | | |_    http://www.salt.ac.za     |
      |  | _\ | || _| _`| |  _|   Southern African Large    |
      |  |  /__ |__|\_,_|_|\__|   Telescope PyRAF Package   |
      |  |_| \__'                                           |
      |               Development PRERELEASE                |
      |               Version 0.50  1 Oct 2014              |
      |               Recommend IRAF 2.14/PyRAF 1.8.1       |
      |               Bug reports: salthelp@salt.ac.za      |
      +-----------------------------------------------------+

     Setting imtype=fits

pysalt/:
 proptools/     salthrs/        saltspec/
 saltfp/        saltred/        slottools/
--> proptools
proptools/:
 masktool
--> masktool
Input Catalog of objects (''):
Input image for mask (''):
MASKTOOL catalog= image= logfile=salt.log verbose=yes


2022-11-14 22:00:25 MESSAGE ----------------------------------------
Starting masktool
```

pySlitMask

Target Name:

Mask Name:

Mode:

Manual Centroiding: OFF

Coordinates of Mask Centre:

Centre RA: Centre DEC: Equinox: Positional Angle:

RSS Setup:

Filter: Grating: Camera Ang.: Grating Ang.:

Instructions | Info | Catalogue | Slits | Optimize | Refstars | Finalize

pySlitMask:

This is a quick start guide to design a MOS mask for the RSS on SALT. This tool was designed to be used with object catalogues. A full manual mode is not supported yet. It is therefore strongly recommended that a be created before using this tool. The tool makes use of a priority based optimization, this should be kept in mind when creating the input catalogue.

Preparation:

1. Check the allowed position angle for the field:
   http://www.salt.ac.za/fileadmin/files/observing/documents/SALT_PA_Visibility.pdf
2. Prepare an image of the field with accurate astrometry.
3. Prepare an input catalogue of target objects
   The input catalogue should be an ascii file with the following formatting:

id RA DEC epoch magnitude band priority [width]* [length]* [tilt]*

* these are optional and can be updated in the tool. We currently suggest a minimum width of 1.5" and a minimum length of 8".

The priority should have the following values:
- 1 Object that is pre-selected to be in the mask
- 0-1 Objects with increasing priority for the mask
- -1 Alignment star

Step 1: Fill in Mask Details

. Fill in the Target and Mask name on the main window as well as the proposal information in the Info tab.

Step 2: Load Image and Catalogue

. Load the image of the field. *File -> Load Image*
. Load the input catalogue of target objects. *File -> Load Catalogue*
. Update the Coordinates of the Mask Centre.
. Ensure the Position Angle is correct.

Upon loading the catalogue into the tool, the Coordinates of the Mask Centre are populated with the mean RA and DEC values from the catalogue and a FoV check is run on all the objects in the catalogue. Objects automatically be added to the Slit tab and will be checked for slit collisions. If any collisions were detected, they will be given in the Flags column in the table. Any obvious collisions can be resolved by deleting objec Updating the Mask Centre Coordinates will automatically rerun the FoV checker.

Step 3: Optimize the Mask

. Go to the Optimize tab
. Set the Y spacing in arseconds if needed, the default is 1".
. Run the optimizer

The optimizer runs on all the target objects that lie within the RSS FoV. The optimizer will try and place as many slits on objects as possible while taking the priority into account. Currently, the too a priority of 1 when a slit collision is detected. Objects to be in the mask can be inspected in the Slit table. Reference/alignment stars can be inspected in the Refstars tab. If there are undesired o recommended that their priority be updated (lowered) and the optimizer be run again. This procedure can be repeated until a suitable mask is obtained. The same applies to removing colliding/ur

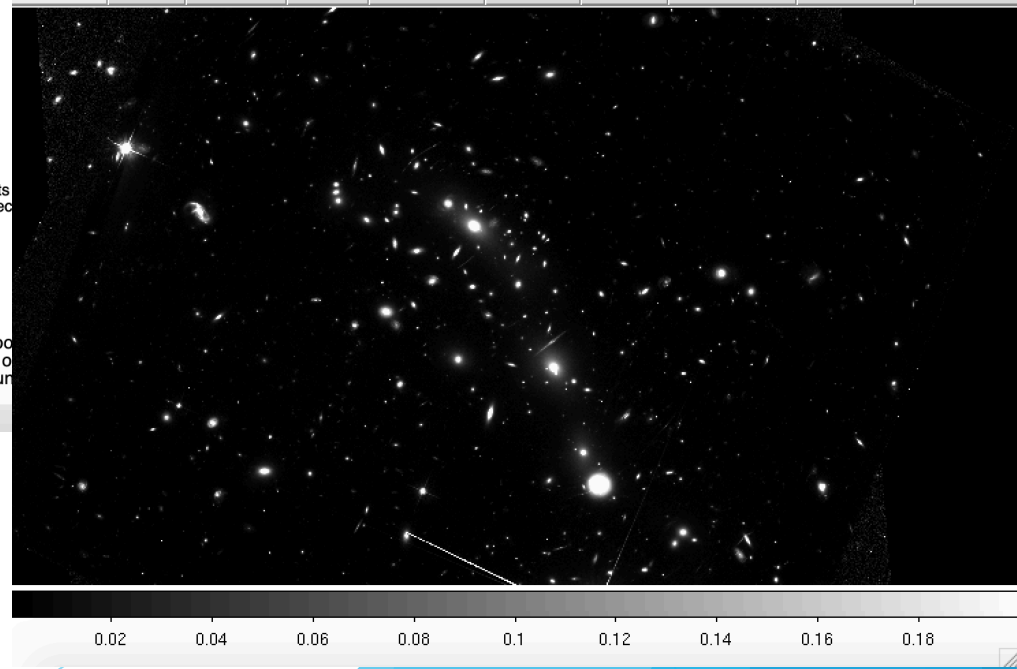
SAOImage var/folders/cp/0g276mys5_v748v51144ghtw0000gp/T//DS9_ds9.29452

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

File macs0416_v0.1_f814w_drz.fits
Object
Value
WCS
Physical X Y
Image X Y
Frame 1 x 0.173611 0 °

file edit view frame bin zoom scale color region wcs analysis help

linear log power sqrt squared asinh sinh histogram min max zscale



pySlitmask tool GUI & DS9 open

File -> Load Image

File -> Load catalogue

Example

Target Name: MACS0416

Mask Name: test-mask1

Mode:

Manual Centroiding: **OFF**

Coordinates of Mask Centre:

Centre RA:	Centre DEC:	Equinox:	Positional Angle:
64.0304	-24.0854	2000	0.0

RSS Setup:

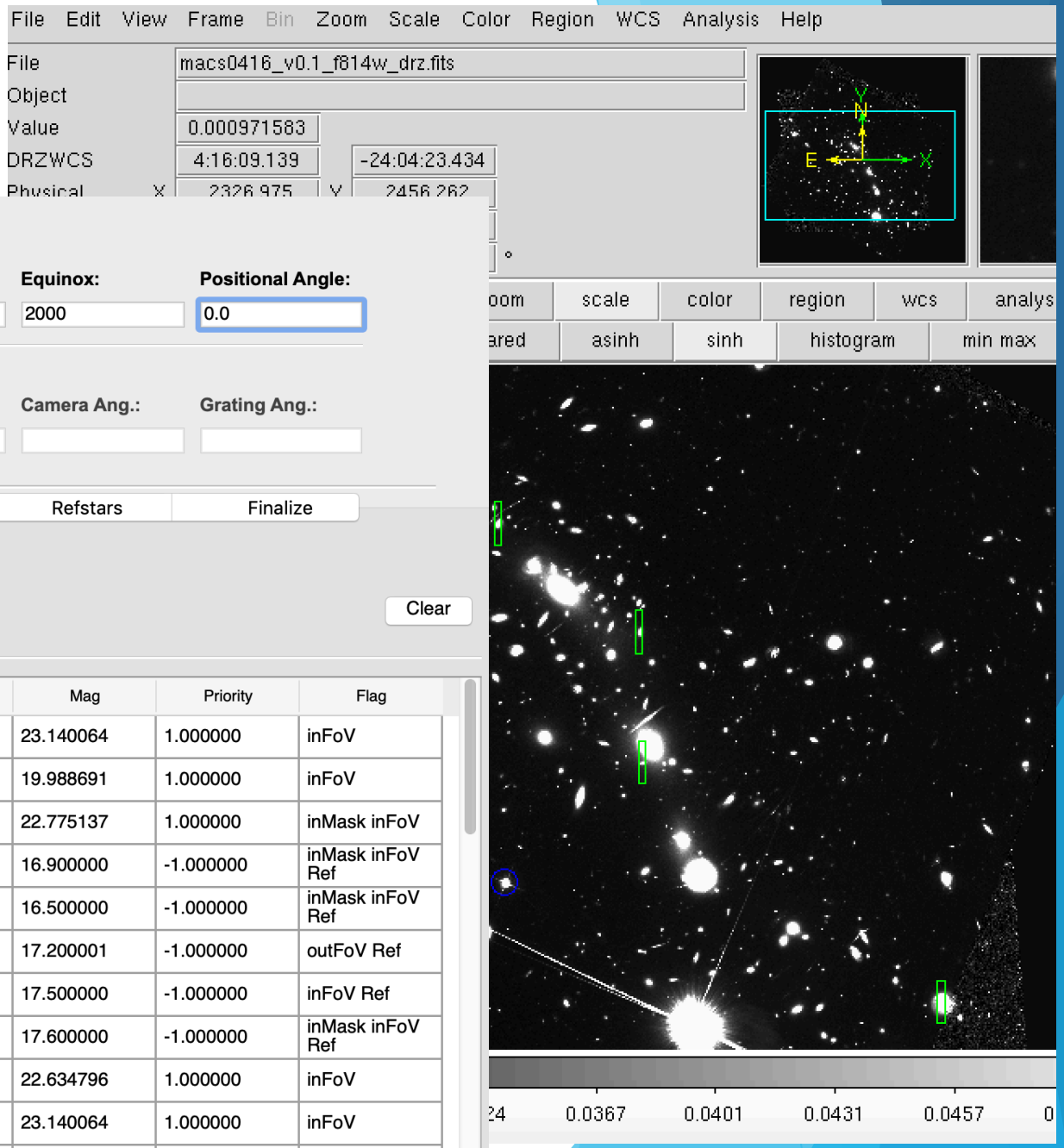
Filter:	Grating:	Camera Ang.:	Grating Ang.:

Instructions | Info | Catalogue | Slits | Optimize | Refstars | Finalize

Input object catalogue. Only needed if Mode is set to Catalogue

Load Catalogue Add Selected Slits Clear

	Object name	RA	DEC	Width	Length1	Length2	Tilt	Mag	Priority	Flag
1	1115	64.016800	-24.090796	2.000000	5.000000	5.000000	0.000000	23.140064	1.000000	inFoV
2	1373	64.011642	-24.093758	2.000000	5.000000	5.000000	0.000000	19.988691	1.000000	inFoV
3	1751	64.047043	-24.088629	2.000000	5.000000	5.000000	0.000000	22.775137	1.000000	inMask inFoV
4	8	63.985741	-24.049364	5.000000	2.500000	2.500000	0.000000	16.900000	-1.000000	inMask inFoV Ref
5	9	64.011864	-24.106983	5.000000	2.500000	2.500000	0.000000	16.500000	-1.000000	inMask inFoV Ref
6	13	64.032127	-24.013374	5.000000	2.500000	2.500000	0.000000	17.200001	-1.000000	outFoV Ref
7	14	64.042038	-24.086140	5.000000	2.500000	2.500000	0.000000	17.500000	-1.000000	inFoV Ref
8	21	64.077286	-24.126209	5.000000	2.500000	2.500000	0.000000	17.600000	-1.000000	inMask inFoV Ref
9	1070	64.014702	-24.091486	2.000000	5.000000	5.000000	0.000000	22.634796	1.000000	inFoV
10	1115	64.016800	-24.090796	2.000000	5.000000	5.000000	0.000000	23.140064	1.000000	inFoV
11	1373	64.011642	-24.093758	2.000000	5.000000	5.000000	0.000000	19.988691	1.000000	inMask inFoV



Instructions | Info | Catalogue | Slits | Optimize | Refstars | Finalize

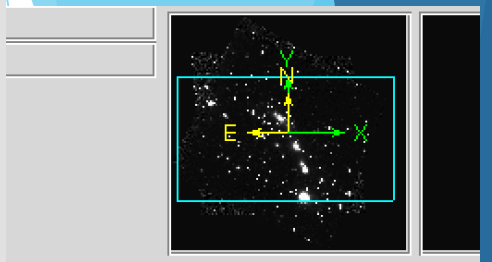
Slit collisionons may be resolved manually by editing the table below or automatically in the Optimize tab

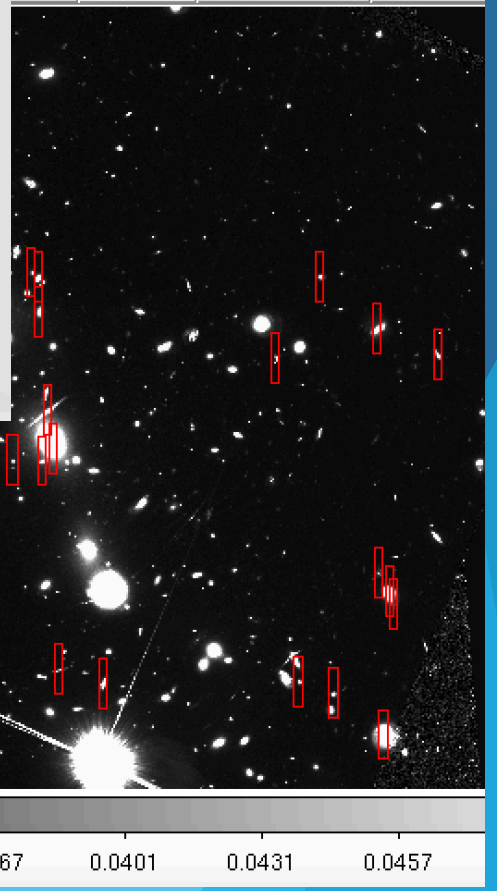
Import from Catalogue: Add slits to all catalogue objects

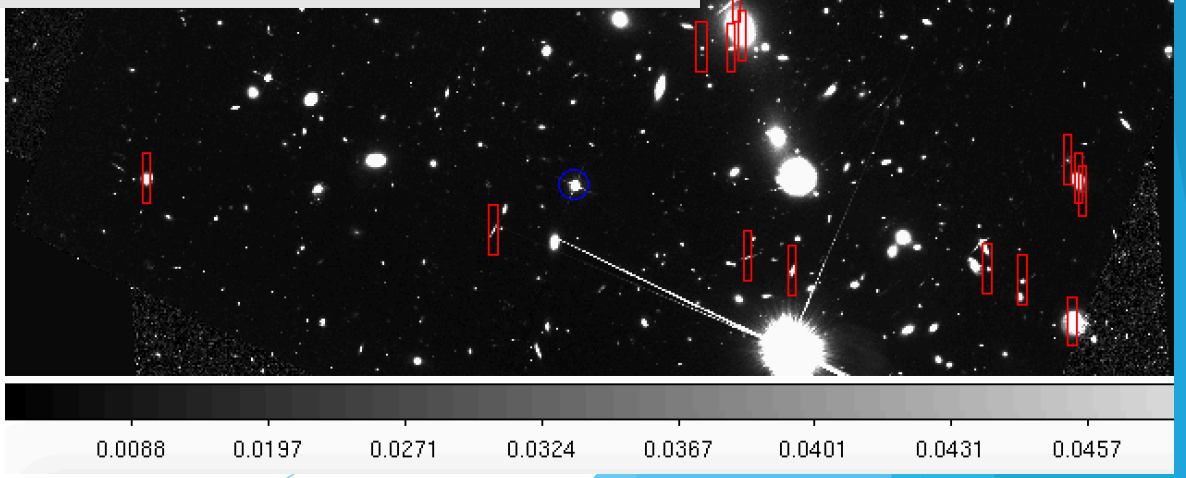
Manually edit slits: Add slit | Delete slit

Import from image Add slit | Delete slit | Clear

	Object name	RA	DEC	Width	Length1	Length2	Tilt	Mag	Priority	Flag
1	1070	64.014702	-24.091486	2.000000	5.000000	5.000000	0.000000	22.634796	1.000000	inMask inFoV Col 1115 137…
2	1115	64.016800	-24.090796	2.000000	5.000000	5.000000	0.000000	23.140064	1.000000	inMask inFoV Col 1070 13…
3	1373	64.011642	-24.093758	2.000000	5.000000	5.000000	0.000000	19.988691	1.000000	inMask inFoV Col 1070 111…
4	1751	64.047043	-24.088629	2.000000	5.000000	5.000000	0.000000	22.775137	1.000000	inMask inFoV Col 1070 111…
5	1070	64.014702	-24.091486	2.000000	5.000000	5.000000	0.000000	22.634796	1.000000	inMask inFoV Col 1115 137…
6	1115	64.016800	-24.090796	2.000000	5.000000	5.000000	0.000000	23.140064	1.000000	inMask inFoV Col 1070 13…
7	1373	64.011642	-24.093758	2.000000	5.000000	5.000000	0.000000	19.988691	1.000000	inMask inFoV Col 1070 111…
8	1751	64.047043	-24.088629	2.000000	5.000000	5.000000	0.000000	22.775137	1.000000	inMask inFoV Col 1070 111…
9	3104	64.034309	-24.078470	2.000000	5.000000	5.000000	0.000000	23.481861	1.000000	inMask inFoV Col 3152 31…







- Trying to add slits to all catalogue objects – slit collisions!

Instructions | Info | Catalogue | **Slits** | Optimize | Refstars | Finalize

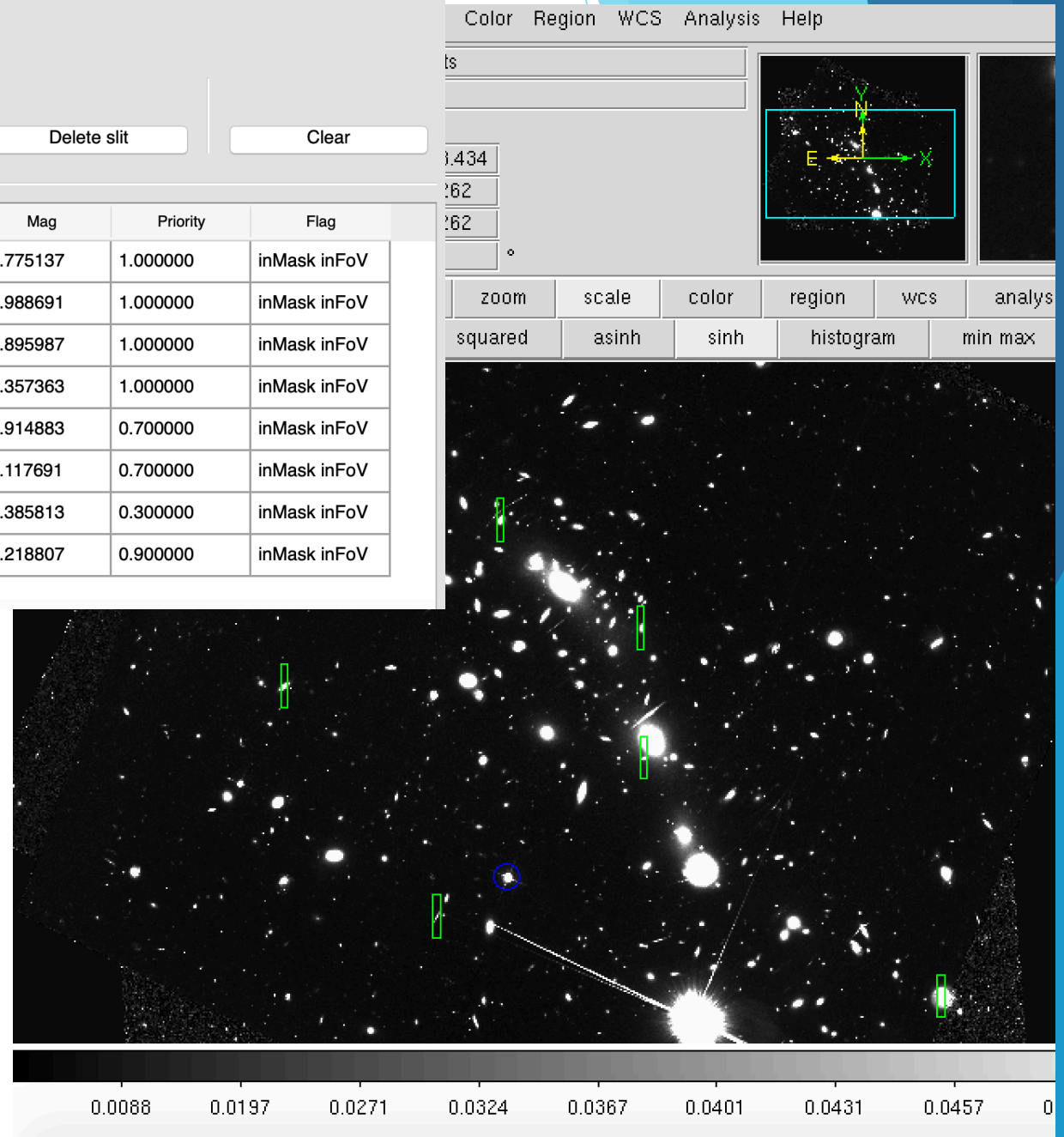
Slit collisionons may be resolved manually by editing the table below or automatically in the Optimize tab

Import from Catalogue: Add slits to all catalogue objects

Manually edit slits: Add slit | Delete slit

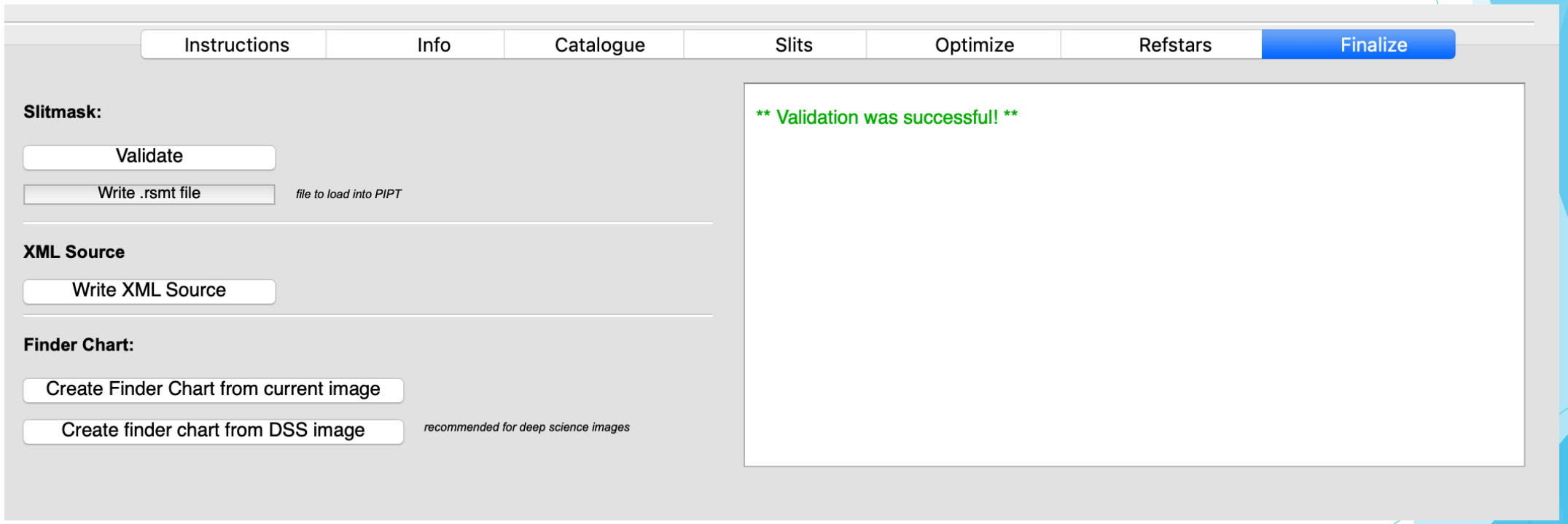
Import from image Add slit | Delete slit | Clear

	Object name	RA	DEC	Width	Length1	Length2	Tilt	Mag	Priority	Flag
1	1751	64.047043	-24.088629	2.000000	5.000000	5.000000	0.000000	22.775137	1.000000	inMask inFoV
2	1373	64.011642	-24.093758	2.000000	5.000000	5.000000	0.000000	19.988691	1.000000	inMask inFoV
3	3152	64.032501	-24.078491	1.500000	5.000000	5.000000	0.000000	22.895987	1.000000	inMask inFoV
4	4400	64.057739	-24.073879	1.500000	5.000000	5.000000	0.000000	21.357363	1.000000	inMask inFoV
5	20016	64.032677	-24.070150	1.500000	5.000000	5.000000	0.000000	20.914883	0.700000	inMask inFoV
6	20021	64.042526	-24.063244	1.500000	5.000000	5.000000	0.000000	21.117691	0.700000	inMask inFoV
7	500	64.040039	-24.098679	1.500000	5.000000	5.000000	0.000000	22.385813	0.300000	inMask inFoV
8	5059	64.059532	-24.066380	1.500000	5.000000	5.000000	0.000000	23.218807	0.900000	inMask inFoV



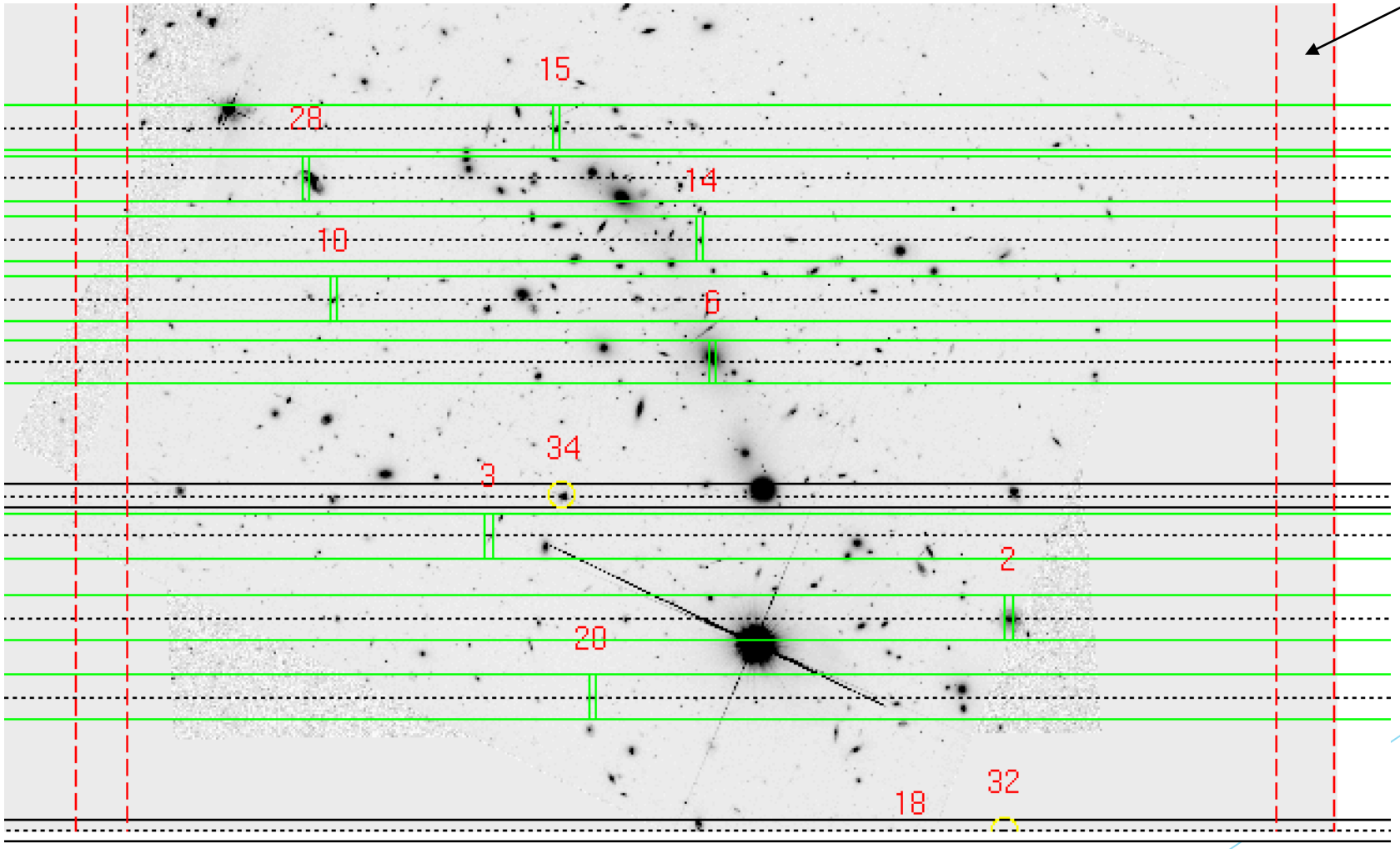
Manually add slits or optimize to remove collisions

Validate and save mask files



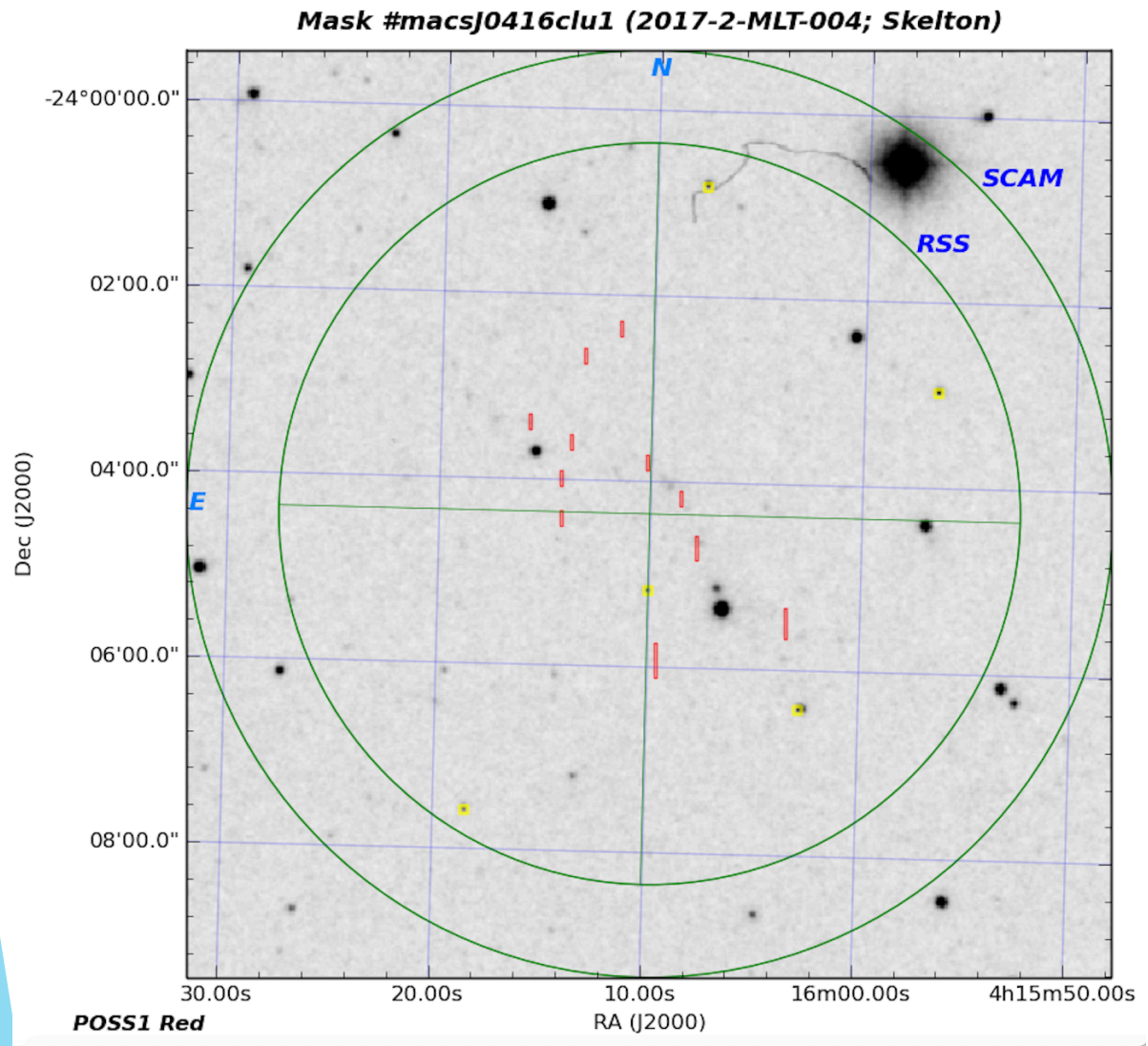
Updated pySlitmask

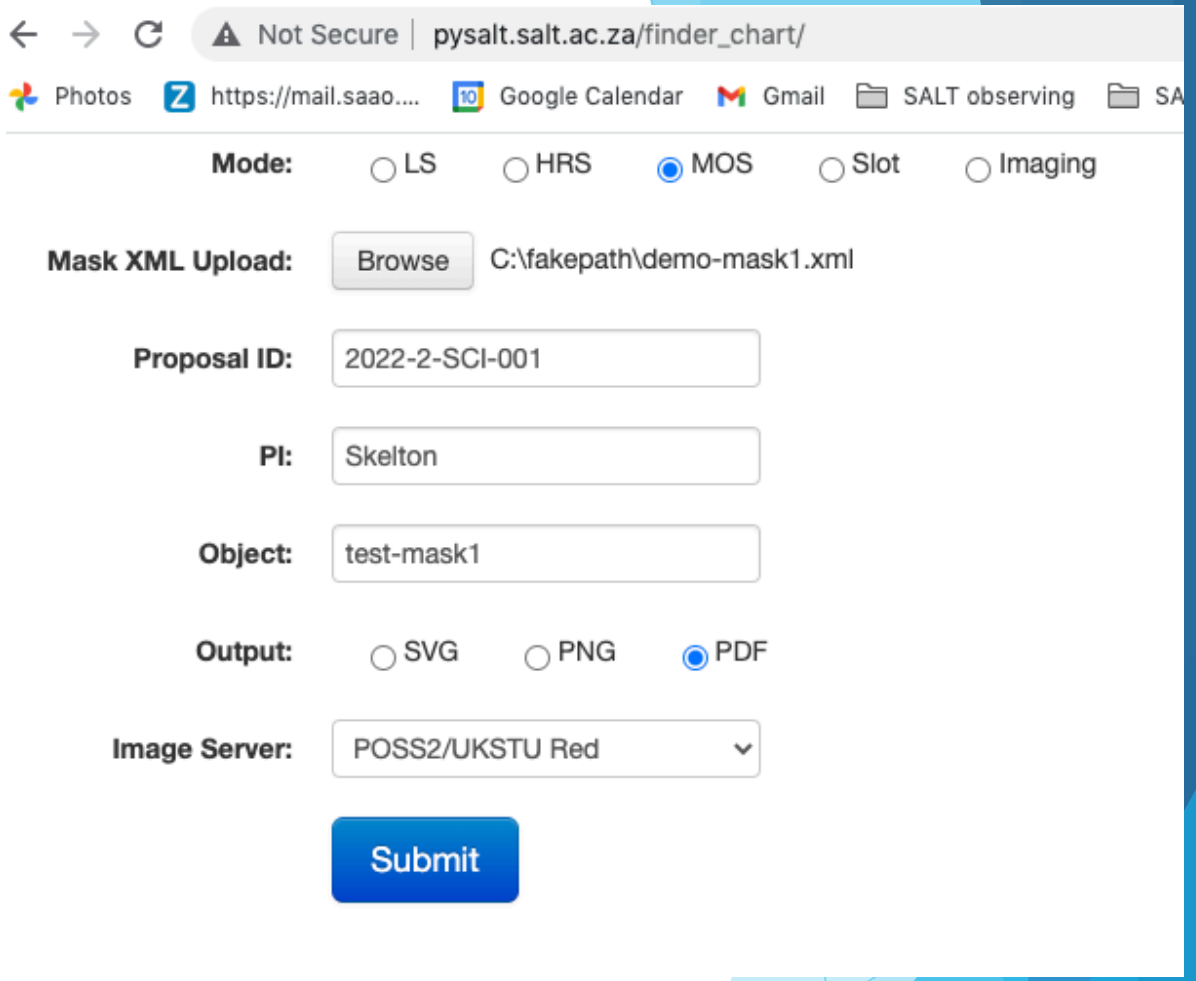
- Adjusted by Ken Nordsieck for polarimetry, various bug fixes & improvements



Still needs testing & to be made available more widely

Finder chart





Another way to create finder charts:
SALT online finder chart tool

- select MOS
- load mask xml

Mask Design – Output

- A mask file that can be loaded into the PIPT in Phase 2, with the ".rsmt" extension
- Actually just a zip file containing an xml file with the slit information & a finder chart

```
(pysalt) ros$ unzip macs0416clu_mask1.rsmt
Archive:  macs0416clu_mask1.rsmt
 extracting: Slitmask.xml
 extracting: Slitmask.png
```

```
rosmac2:testcode ros$ more demo-mask1.xml
<?xml version="1.0" ?>
<slitmask>
  <header>
    <parameter name="VERSION" value="1.1"/>
    <parameter name="PROPOSALCODE" value="2022-2-SCI-001"/>
    <parameter name="MASKNUM" value="test-mask1"/>
    <parameter name="TARGET" value="MACS0416"/>
    <parameter name="PI" value="Skelton"/>
    <parameter name="CREATOR" value="Skelton"/>
    <parameter name="ROTANGLE" value="0.0"/>
    <parameter name="CENTERRA" value="64.030400"/>
    <parameter name="CENTERDEC" value="-24.085442"/>
    <parameter name="NSMODE" value="0"/>
    <parameter name="VALIDATED" value="True"/>
    <parameter name="SPECLENGTH" value="12400"/>
    <parameter name="SPECOFFSET" value="0"/>
    <parameter name="SPECPOLSPLIT" value="0"/>
    <parameter name="SPECHEIGHT" value="0"/>
  </header>
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  <refstar id="8" length="5.000000" mag="16.900000" priority="-1.000000" width="5.000000" xce="63.985741" yce="-24.049364"/>
  <refstar id="14" length="5.000000" mag="17.500000" priority="-1.000000" width="5.000000" xce="64.042038" yce="-24.086140"/>
  <refstar id="21" length="5.000000" mag="17.600000" priority="-1.000000" width="5.000000" xce="64.077286" yce="-24.126209"/>
  <slit id="1373" length="10.000000" mag="19.988691" priority="1.000000" width="2.000000" xce="64.011642" yce="-24.093758"/>
  <slit id="3152" length="10.000000" mag="22.895987" priority="1.000000" width="1.500000" xce="64.032501" yce="-24.078491"/>
  <slit id="4400" length="10.000000" mag="21.357363" priority="1.000000" width="1.500000" xce="64.057739" yce="-24.073879"/>
  <slit id="20016" length="10.000000" mag="20.914883" priority="0.700000" width="1.500000" xce="64.032677" yce="-24.070150"/>
  <slit id="20021" length="10.000000" mag="21.117691" priority="0.700000" width="1.500000" xce="64.042526" yce="-24.063244"/>
  <slit id="500" length="10.000000" mag="22.385813" priority="0.300000" width="1.500000" xce="64.040039" yce="-24.098679"/>
  <slit id="5059" length="10.000000" mag="23.218807" priority="0.900000" width="1.500000" xce="64.059532" yce="-24.066380"/>
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  <refstar id="9" length="5.000000" mag="16.500000" priority="-1.000000" width="5.000000" xce="64.011864" yce="-24.106983"/>
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</slitmask>
```

Potential issues that can be seen from finder charts:

- slits/boxes that clearly overlap in the vertical direction (slit collisions)
- not enough alignment stars
- alignment stars are too faint/too bright
- alignment stars not in their boxes (e.g. large translations/rotations)
- alignment stars behind the gaps (To do: mark on the MOS FCs where the gaps are to make things simpler).
- alignment stars have another star very nearby (double stars) - won't be able to measure the location of the star accurately
- no suitable guide star without blocking some slits
- slits that do not look completely vertical. Some PIs want them diagonal but *never* horizontal!