



SPIRE Spectrometer Data Analysis: An Introduction

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(On behalf of the SPIRE ICC, HSC & NHSC)





Outline

- Do you generally need to reprocess FTS data yourself?
- Data analysis examples with scripts and tasks available within HIPE.
 - Quick spectral noise assessment
 - Detector footprint on the sky
 - Faint source observations: further background subtraction and/or comparison with SPIRE photometer data
 - Deriving spectral line fluxes
 - Flux correction for a semi-extended target or a pointing offset
 - Mapping data analysis



Do you need to reprocess your FTS data?

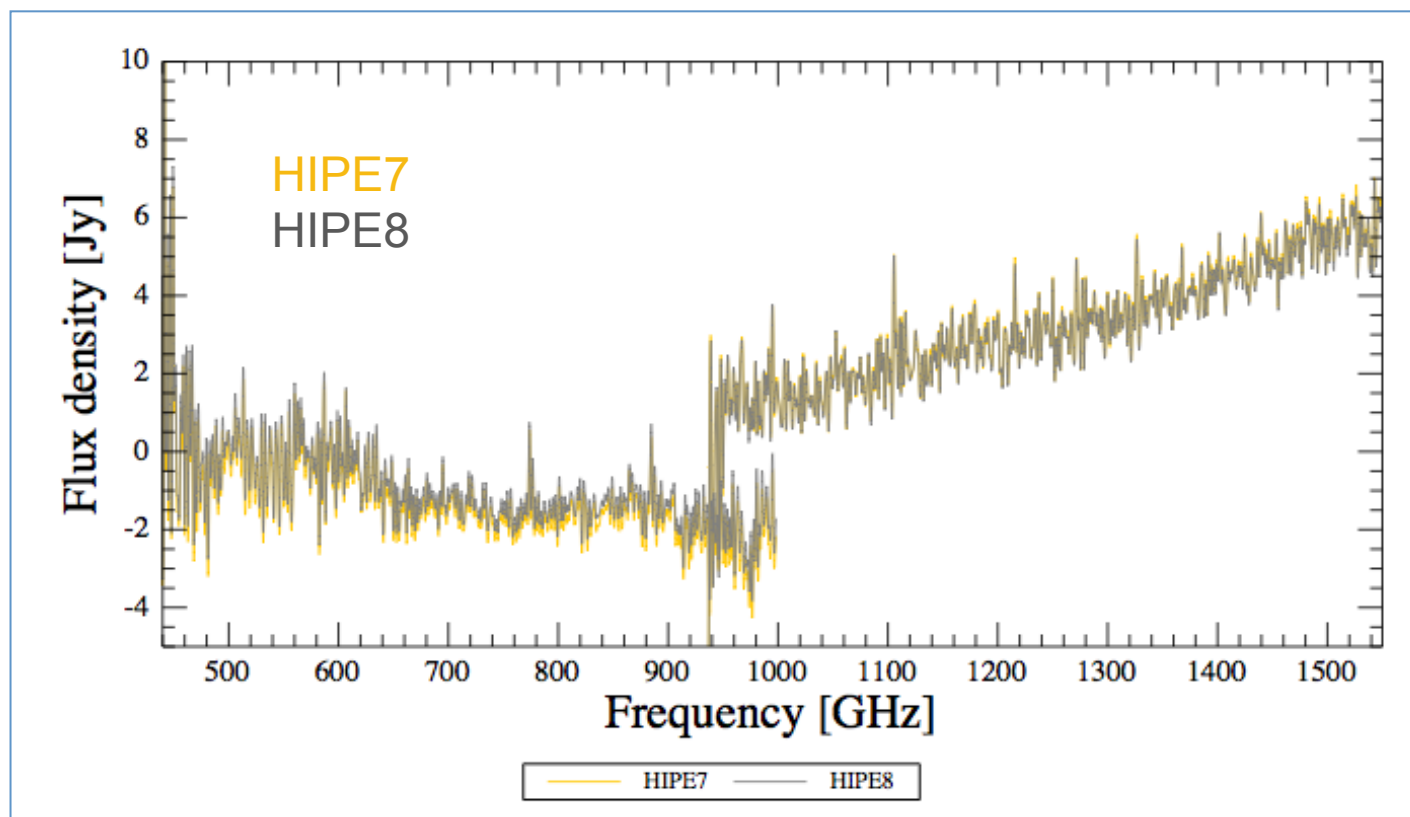
Normally, the answer is NO if you have data from HIPE 11 and onward. But,

- Both calibration and pipeline are still being improved at this point. There are times when you might want to reprocess your data with the latest calibration product.
 - For example, in HIPE 13 (~Jan 2015):
 - The nonlinearity correction will be upgraded to improve telescope background subtraction for those observations taken at the beginning of SPIRE cooler cycles (i.e., at lower detector temperatures than normal).
 - Some low-resolution observations will be better calibrated in HIPE 13 as well.
- At this point, HIPE 11 data are available in the Herschel science archive. To obtain HIPE 12 data, you can either
 - request on-demand data reprocess in the user interface of the Herschel science archive, or
 - reprocess HIPE 11 data to HIPE 12 using the reprocessing script in HIPE



FTS Spectra in Different HIPE Versions

Mrk 231 observed on OD209

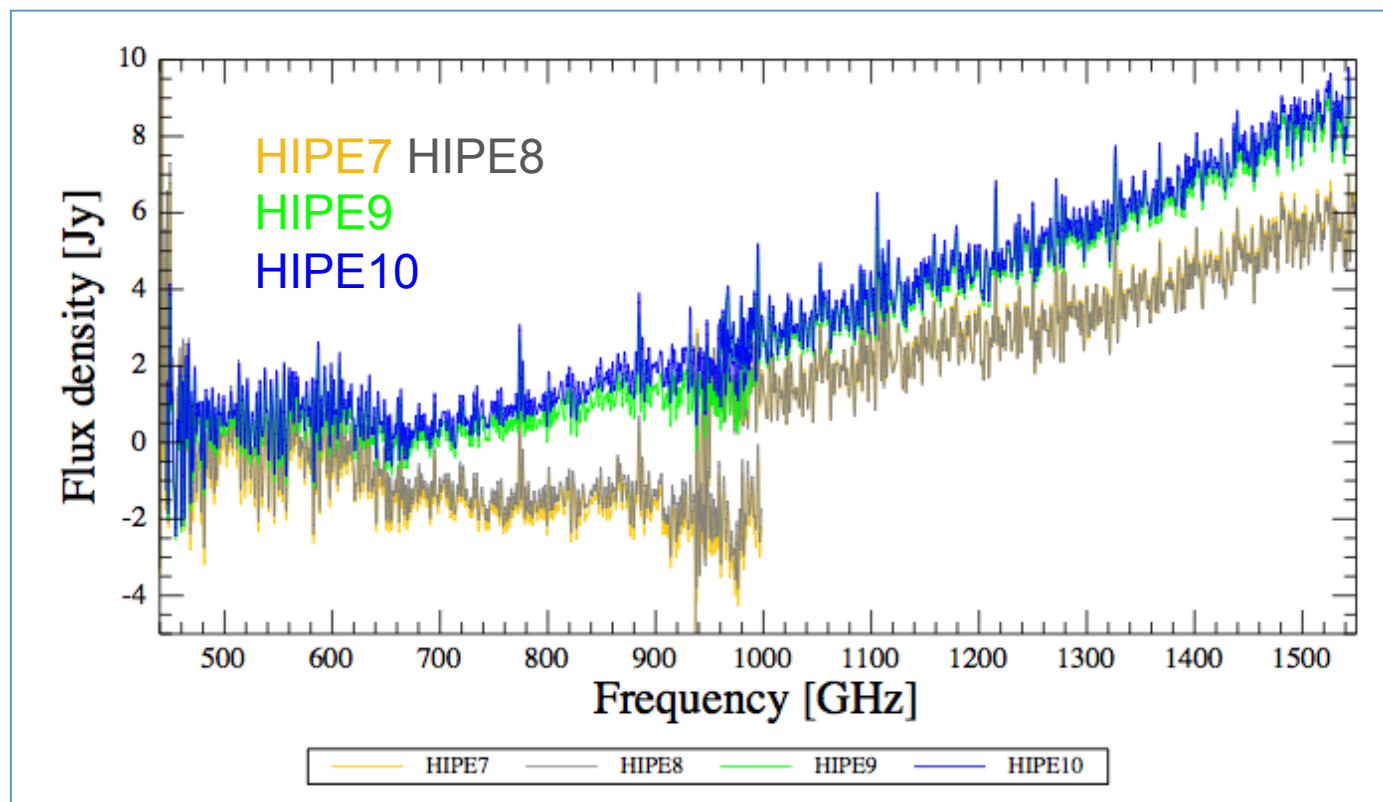


Standard pipeline Level-2 output



FTS Spectra in Different HIPE Versions

Mrk 231 observed on OD209

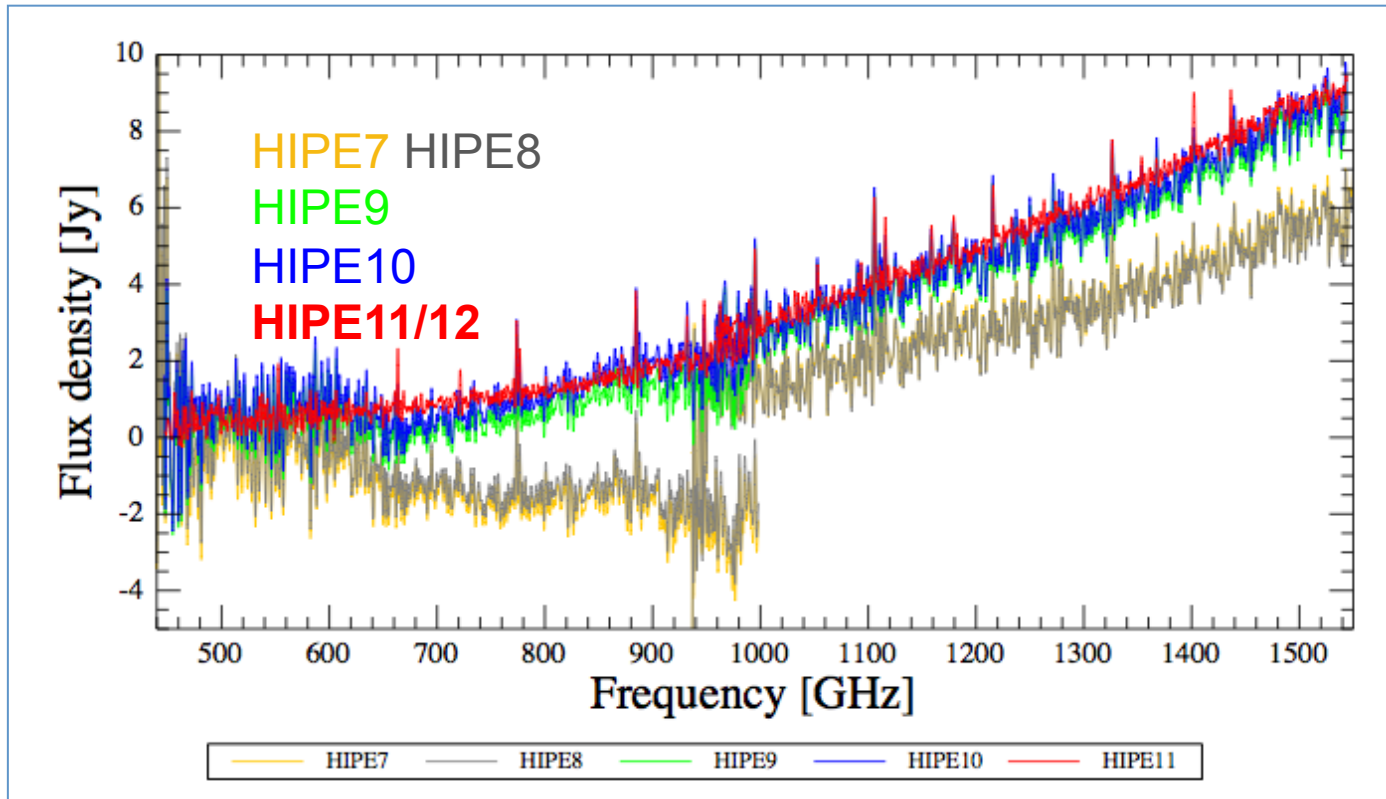


Standard pipeline Level-2 output



FTS Spectra in Different HIPE Versions

Mrk 231 observed on OD209



Standard pipeline Level-2 output



Getting HIPE v12 data

Option I: Elect the on-demand processing option in HSA

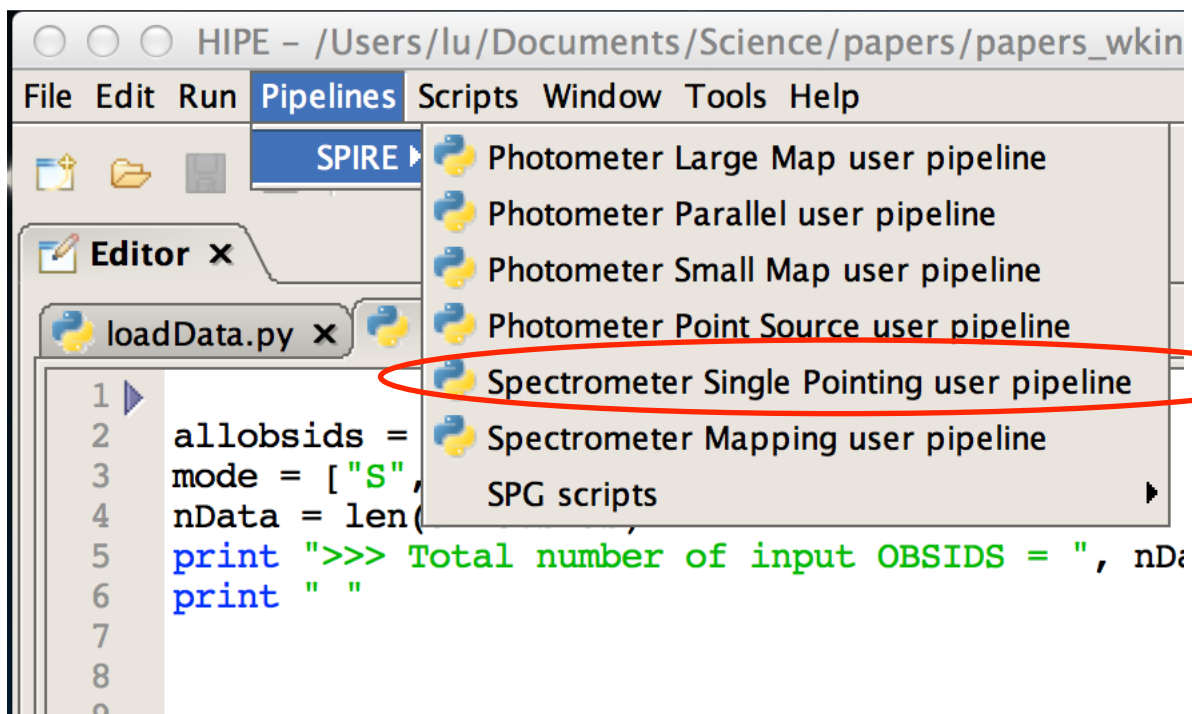
The screenshot shows the HSA Science Archive v5.2.1 interface. A purple arrow points to the 'On Demand Reprocessing' option in the 'Observations' section. The interface includes a menu bar (File, View, Windows, Account, Tools, Help), a toolbar with icons for search, shopping basket, and help, and a main content area with a table of observations. The table has columns for Observation, Target Name, RA, DEC, and OD. A 'Submit Request' button is visible at the bottom right of the table area.

Observation	Target Name	RA	DEC	OD
systematic	Mrk 231	12h 56m 14.24s	+56d 52' 25.34"	209



Getting HIPE 12 data

Option II: Alternatively, one can reprocess an observation of HIPE 11 to HIPE 12 using the reprocessing script that comes within HIPE.





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 - Mapping data analysis



Background Documents

- **The SPIRE Data Reduction Guide** (DRG; data structure, processing, reprocessing, many details and cookbooks)
- **The SPIRE Handbook** (instrument observing modes, calibration...)
- [Swinyard et al. 2014, MNRAS, 440, 3658](#) - **FTS calibration**
- [Makiwa et al. 2013, Applied Optics, 52, 3864](#) - **FTS beams**
- [Wu et al. 2013, A&A, 556, 116](#) - **Semi-extended sources**
- Public wiki on SPIRE
<http://herschel.esac.esa.int/twiki/bin/view/Public/SpireCalibrationWeb>



SPIRE Data Reduction Guide (DRG)

TOC Search Glossary

Introductory

- Welcome
- Quick Start Guide
- HIPE Owner's Guide

Analysis Tools

- Data Analysis Guide
- Scripting Guide

SPIRE

- SPIRE Data Reduction Guide
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 - 3. Overview of Scripts in HIPE
 - 4. SPIRE Observation Context Data Structure
 - 4.1. Accessing SPIRE Data
 - 4.2. SPIRE Observation Context Data Structure
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 - 5. SPIRE Calibration Data
 - 6. SPIRE Photometer Mode Cookbook
 - 7. SPIRE Spectroscopy Mode Cookbook
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 - 7.5. Recipes for semi-extended sources
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SPIRE Data Reduction Guide

For HIPE 12 version 3.0, Document Number: SPIRE-RAL-DOC 003248
28 February 2014

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General SPIRE data info

SPIRE/FTS data structure and processing, and data analysis recipes





Spectrometer Useful Scripts

- Array Footprint Plot
- Background Subtraction
- Line Fitting
- Thumbnail Mosaic Plot
- Convolve Spectrum
- Noise Estimate
- Cube Fitting
- Combining PACS and SPIRE spectra

Available in HIPE!

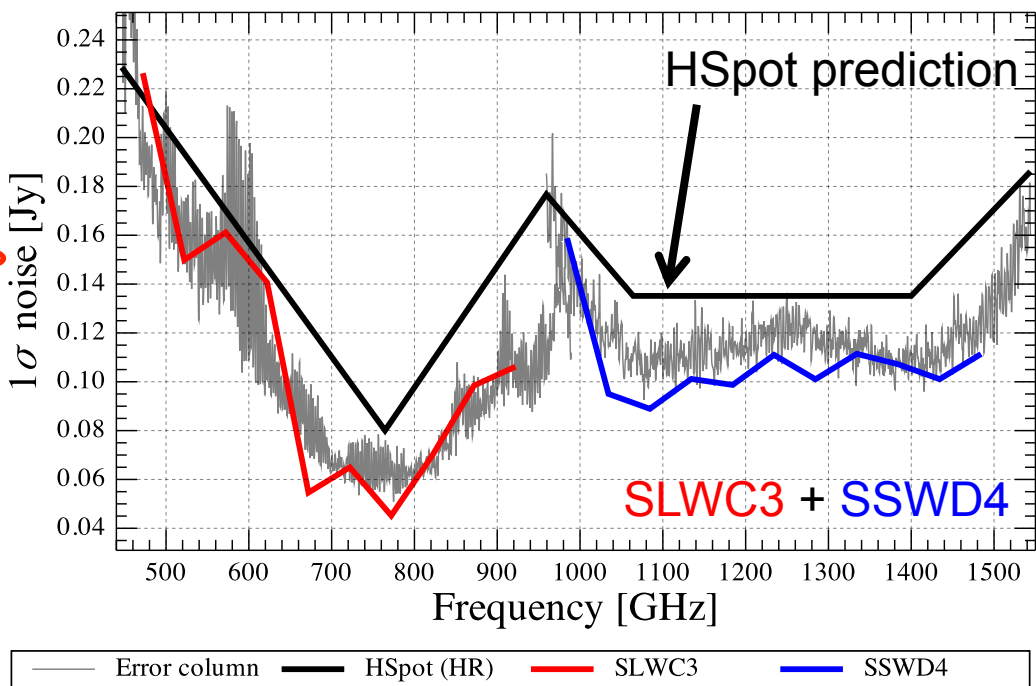


Quick Noise Assessment

- Red and blue: Total rms noise (systematic + random)
- Gray spectrum: random noise only
- Black curve: HSpot predicted total noise

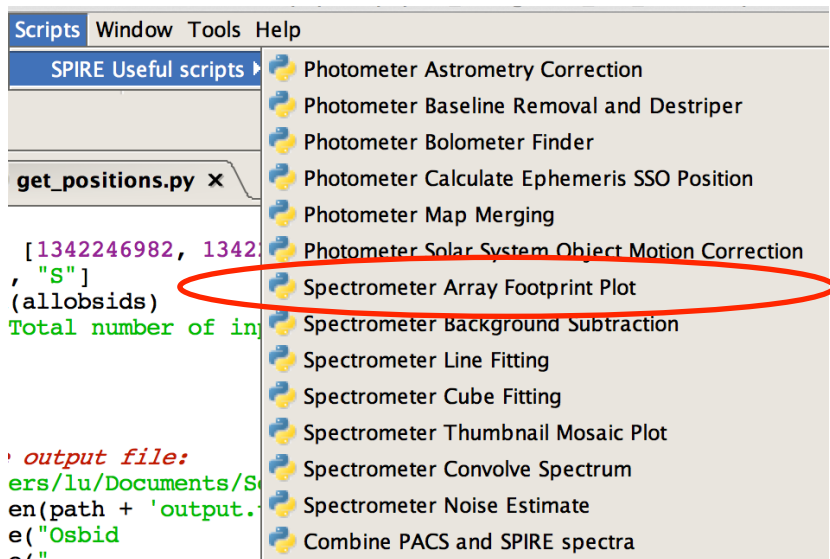
```
Scripts Window Tools Help
SPIRE Useful scripts
  Photometer Astrometry Correction
  Photometer Baseline Removal and Destriper
  Photometer Bolometer Finder
  Photometer Calculate Ephemeris SSO Position
  Photometer Map Merging
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  Spectrometer Line Fitting
  Spectrometer Cube Fitting
  Spectrometer Thumbnail Mosaic Plot
  Spectrometer Convolve Spectrum
  Spectrometer Noise Estimate
  Combine PACS and SPIRE spectra
get_positions.py x
[1342246982, 1342
, "S"]
(allobsids)
Total number of in
' output file:
ers/lu/Documents/s
en(path + 'outout.
e("Osbid
e/'
```

➔ Useful to see if an observation suffers any significant systematics

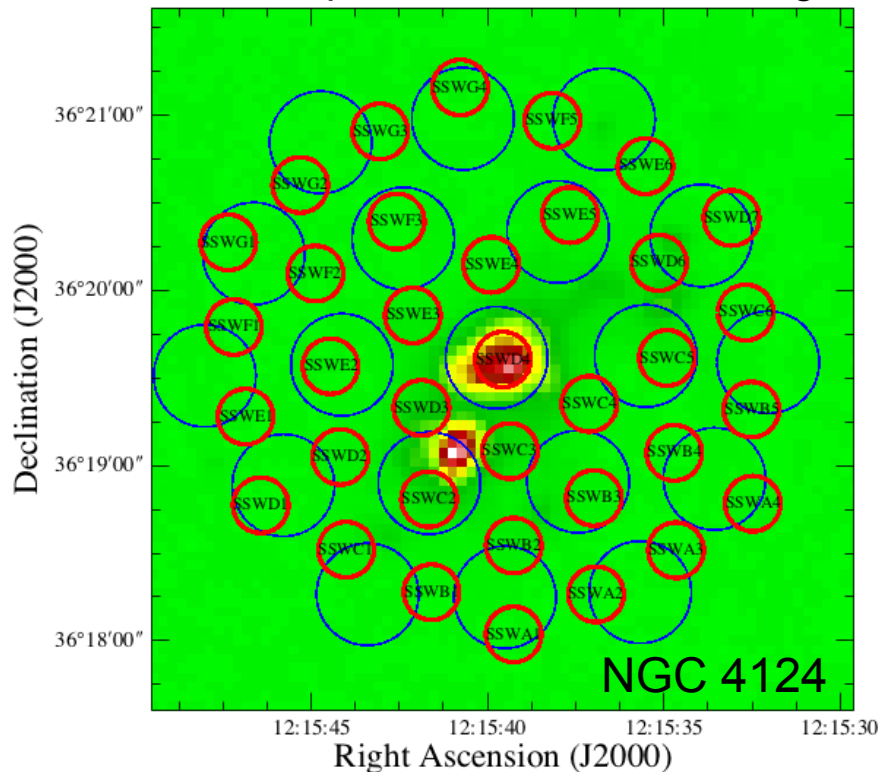




Detector Footprint on Sky



FTS footprint on PACS 70um image

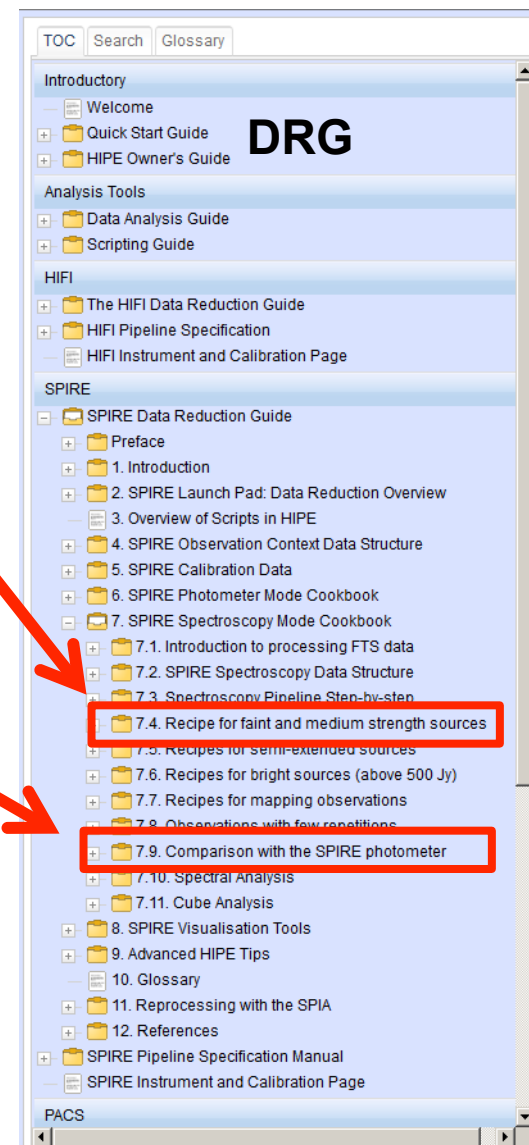


Useful for visualization of the extent and relative location of the target w.r.t. the detector array.



Faint Point-like Targets

- Checking the source extent
 - To make sure it is a point source
- Further background subtraction
- Comparing with the photometer



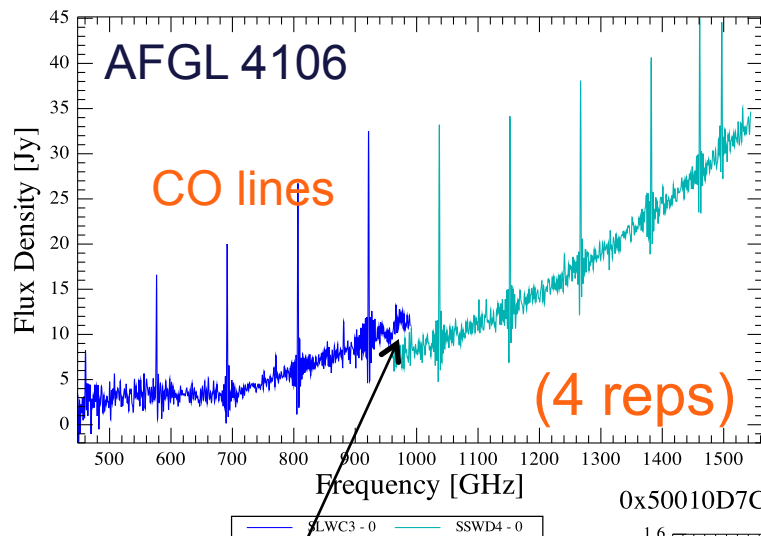
Faint sources: a few to $< \sim 10$ Jy;
Medium sources: ~ 10 to $< \sim 100$ Jy.



Examples of Point-source Spectra

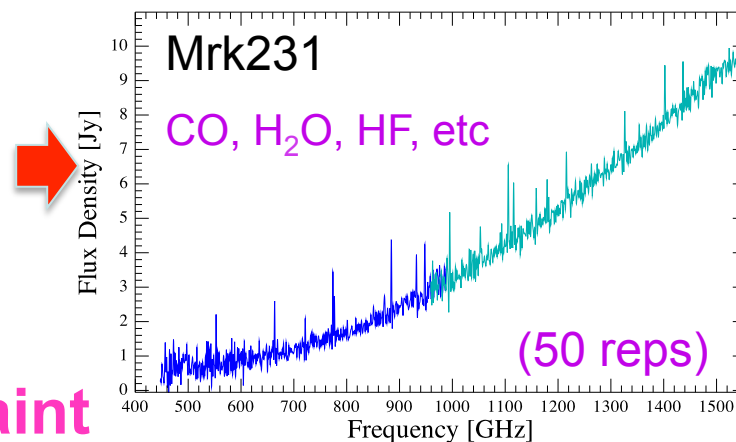
Medium source

0x5001104F - 0xA1060001 - 2012/Jun/12 23:57:21 UTC



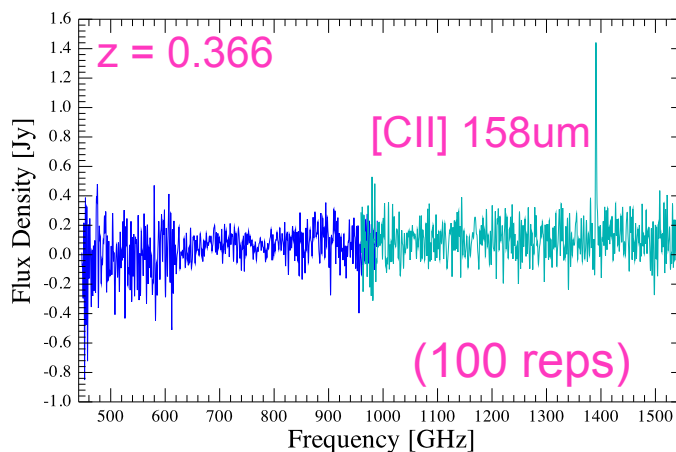
Faint

0x50002975 - 0xA1060001 - 2009/Dec/09 07:19:41 UTC



Super faint

0x50010D7C - 0xA1060001 - 2012/May/29 18:50:21 UTC



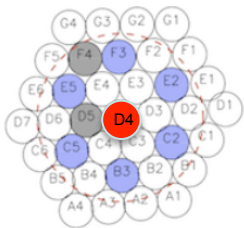
Level 2
pipeline
products

Gap: may indicate
some residual telescope
background, which can
be further removed.

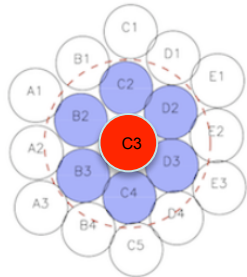


Residual Telescope Emission Removal: Using Surrounding Channels

SSW

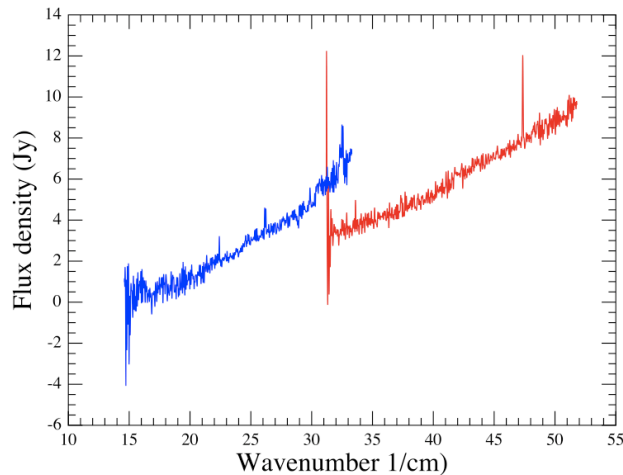


SLW

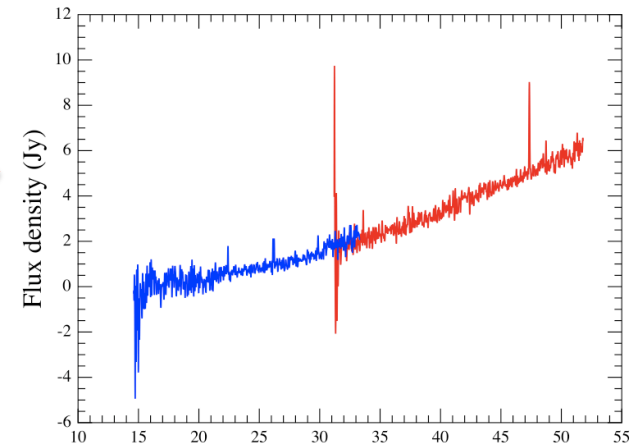


- Using a median spectrum from the **co-aligned detectors** as the residual telescope spectrum.
- This (or a polynomial fit to it) is then subtracted from the spectrum of the **central detectors**.

ESO099-G004: SSWD4 + SLWC3

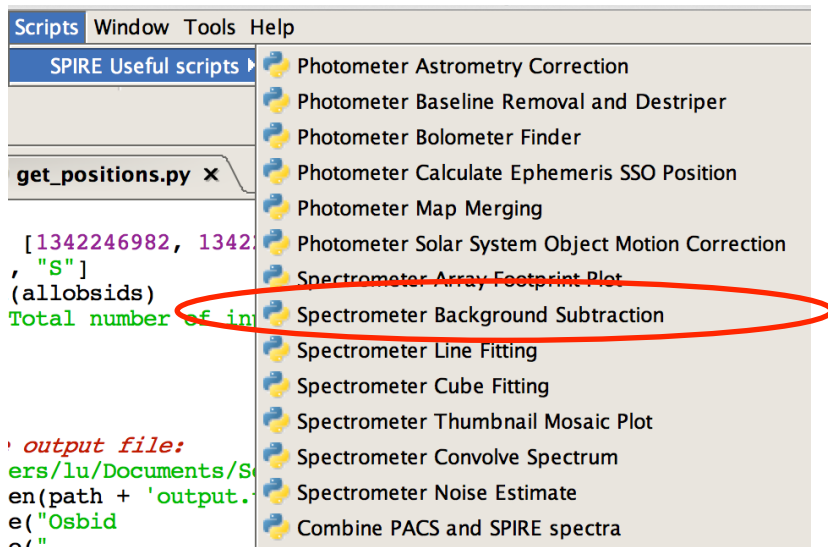


ESO099-G004: SSWD4 + SLWC3



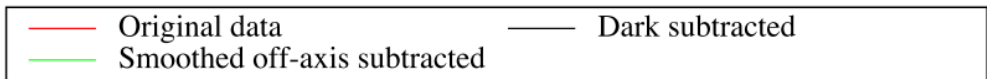
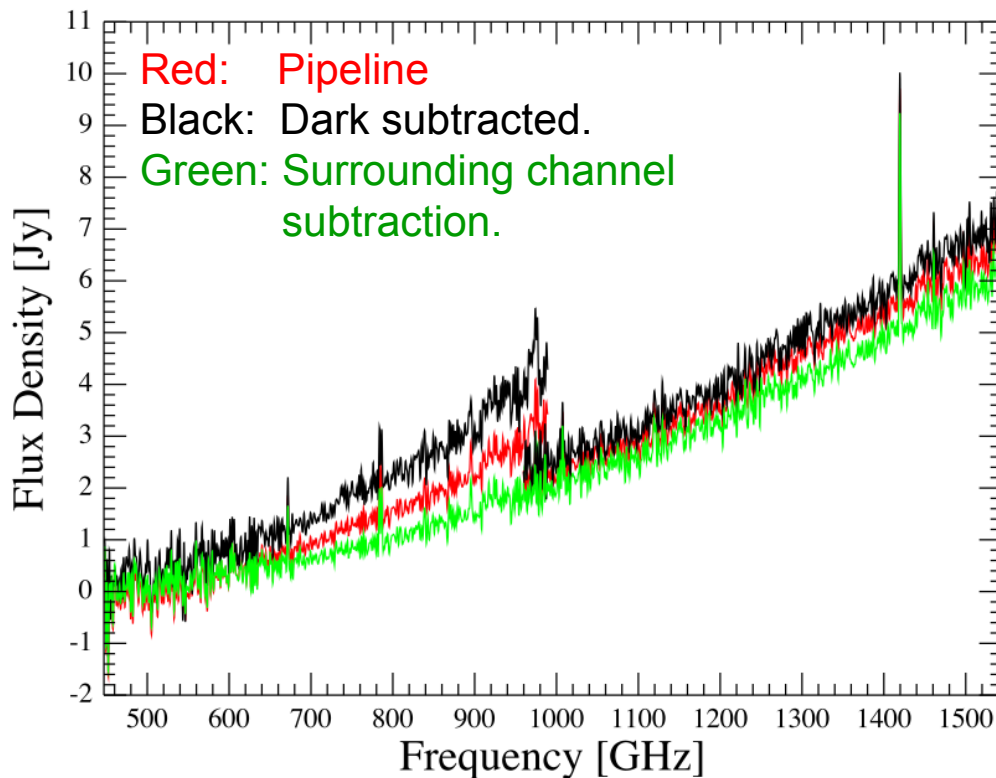


Background Subtraction



0x5000CF93 (OD 879)

ESO099-G004, 40 reps

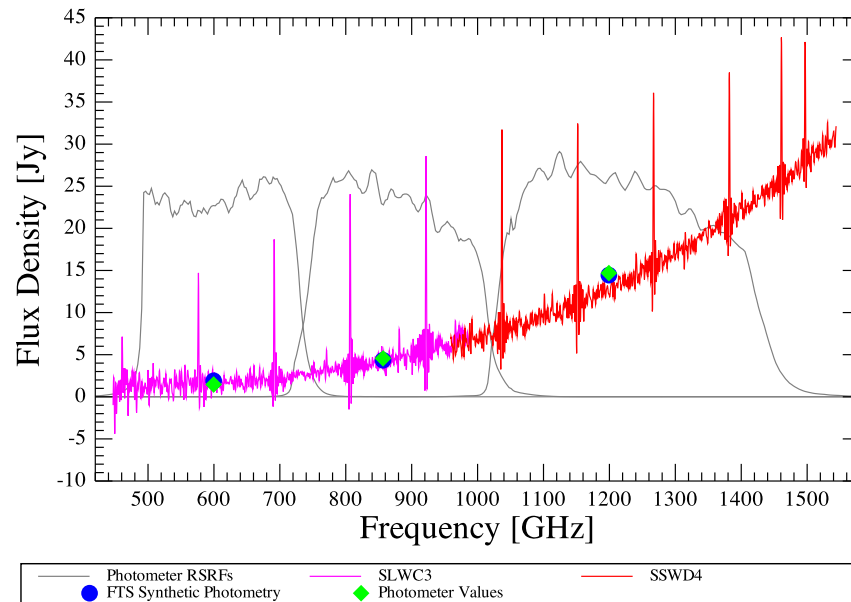
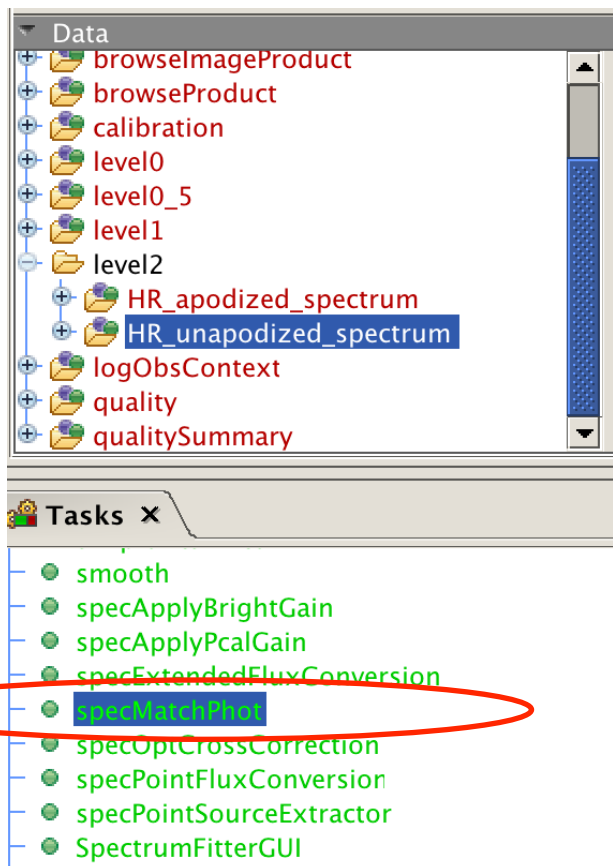


Improves the continuum flux of a faint, point-like target.



Comparing with SPIRE photometer

HIPE task SpecMatchPhot



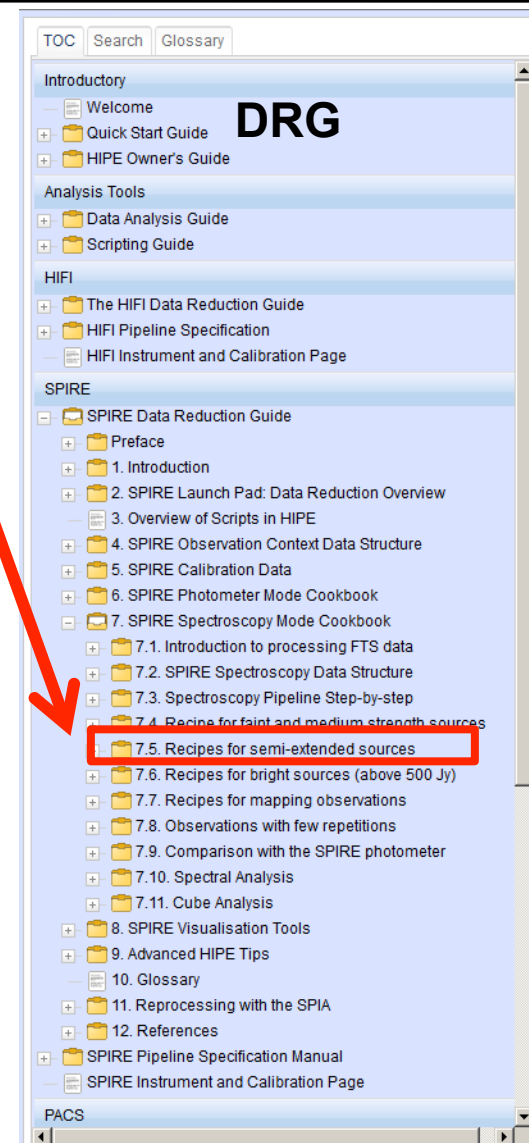
Synthetic photometry also output in a table:

Synthetic photometry results							
Meta Data							
None							
Table Data							
Index	names []	spec250 [Jy]	spec350 [Jy]	spec500 [Jy]	phot250 [Jy/beam]	phot350 [Jy/beam]	phot500 [Jy/beam]
0	SLWB2	0.5524880934532026	2.2750690830393063	NaN	1.4595235477934987	4.5625949527907	14.688015400555697
1	SLWB3	1.7079940700571916	2.900204401489005	NaN	1.4595235477934987	4.5625949527907	14.688015400555697
2	SLWC2	0.7795710130592949	2.4846351262954545	NaN	1.4595235477934987	4.5625949527907	14.688015400555697
3	SLWC3	3.5301211206430834	7.208739635225893	NaN	1.4595235477934987	4.5625949527907	14.688015400555697
4	SLWC4	2.271641002463886	3.1913230785009703	NaN	1.4595235477934987	4.5625949527907	14.688015400555697
5	SLWD2	1.910852171027807	3.147223386802127	NaN	1.4595235477934987	4.5625949527907	14.688015400555697
6	SLWD3	2.4930847414696724	3.41185471573297	NaN	1.4595235477934987	4.5625949527907	14.688015400555697
7	SSWB2	NaN	NaN	1.7915315388884716	1.4595235477934987	4.5625949527907	14.688015400555697
8	SSWB3	NaN	NaN	1.5853857093619672	1.4595235477934987	4.5625949527907	14.688015400555697



Partially Extended Sources

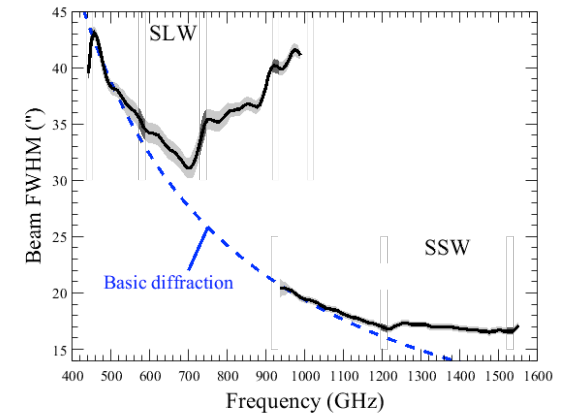
- Effect of a semi-extended source
- What correction is needed?
- Semi-extended (flux) correction tool (SECT) in HIPE





Identifying Possible Partially Extended Sources

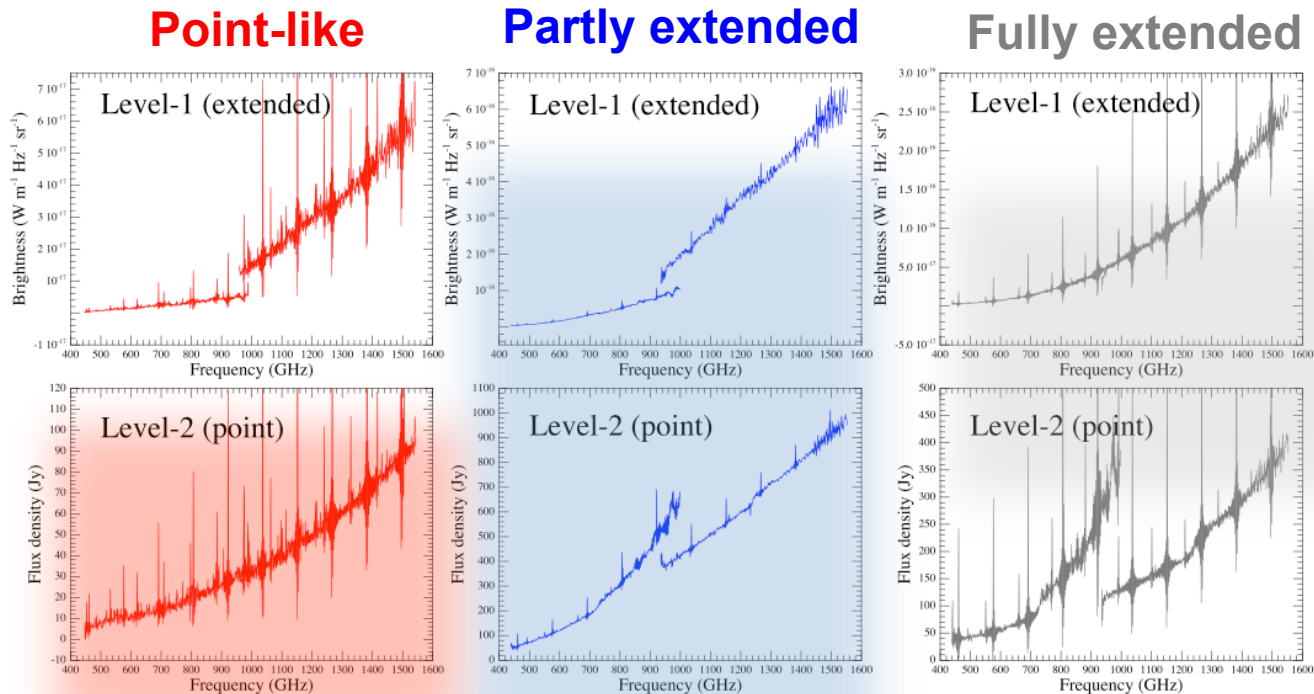
- The spectrum shows kinks and discontinuities where the beam size changes



Extended calibration

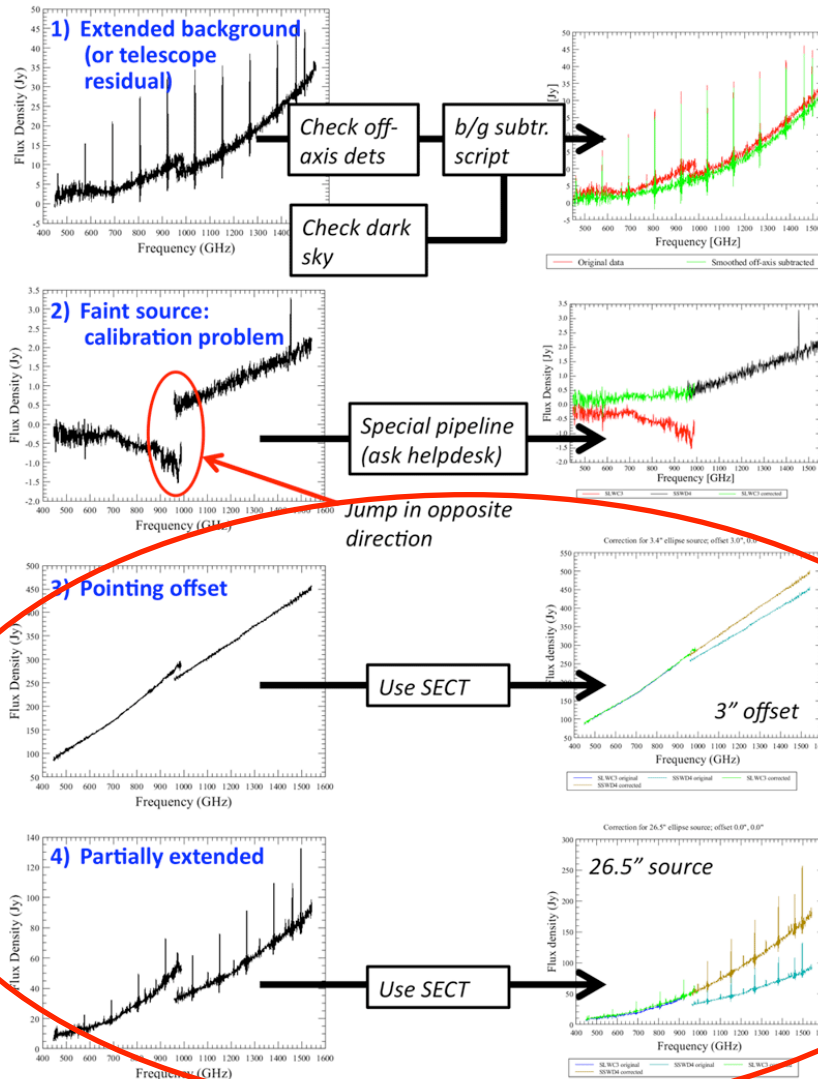


Point-source calibration





Other possible causes for a spectral gap



Cases appropriate for using SECT (the semi-extended source flux correction tool) in HIPE.

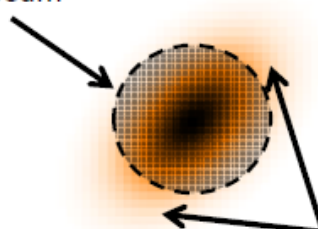
(Caution: the CO lines, from warm/dense molecular gas, may arise from a more compact region than the cold dust continuum.)



Semi-extended Correction Tool (SECT)

(cf. DRG Sect. 7.5)

Reference beam

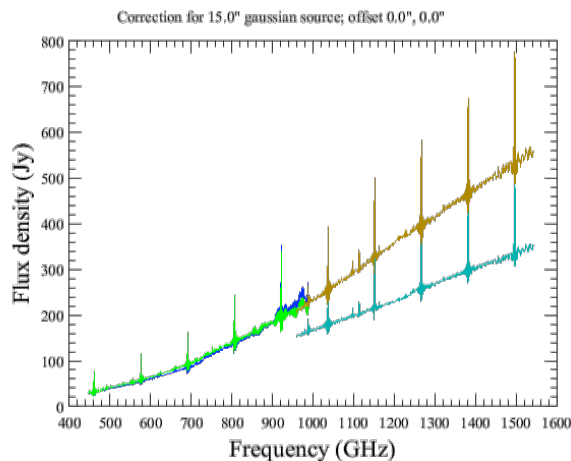


The final spectrum
normalised to include only
emission inside the
reference beam

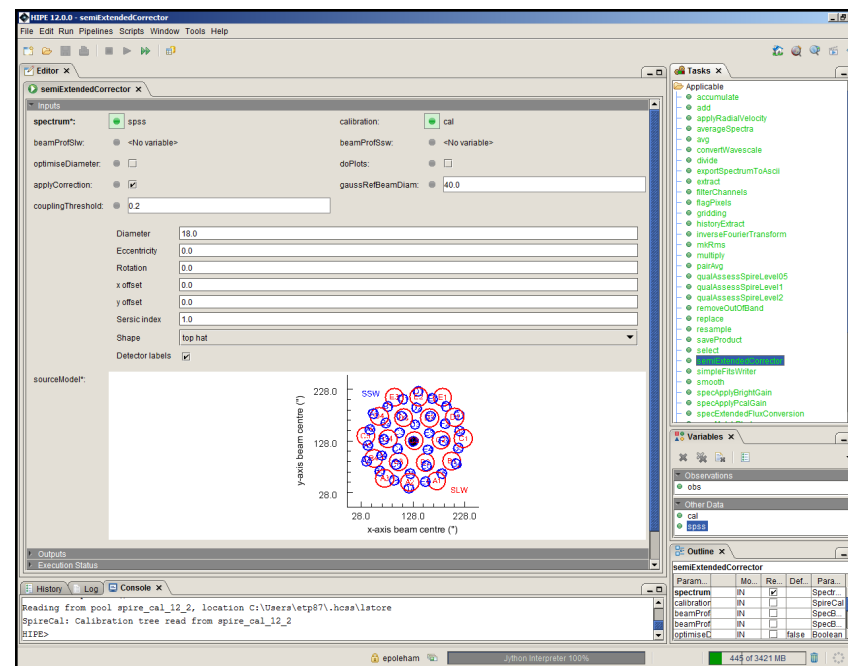
Assumption: source
distribution is independent
of frequency

Emission excluded from
final spectrum

Source model



Units of output
spectrum are Jy
"in the reference
beam"



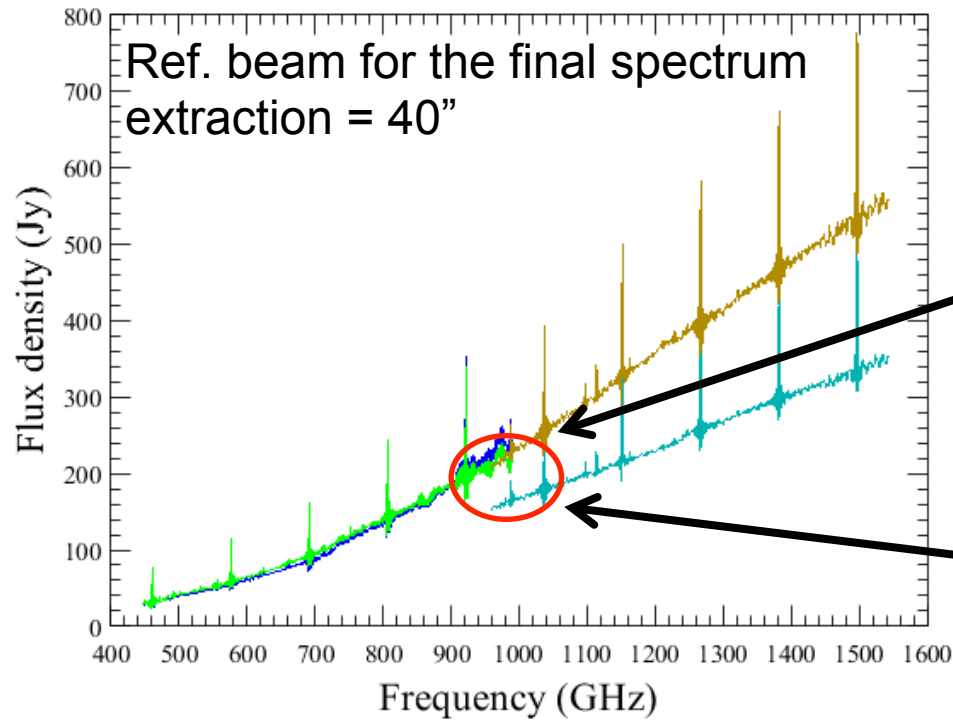
Theory is described in [Wu et al., A&A, 556, 116 \(2013\)](#)



Serpens MM1 (1342216893)

Corrected SERPENS_MM1 spectrum

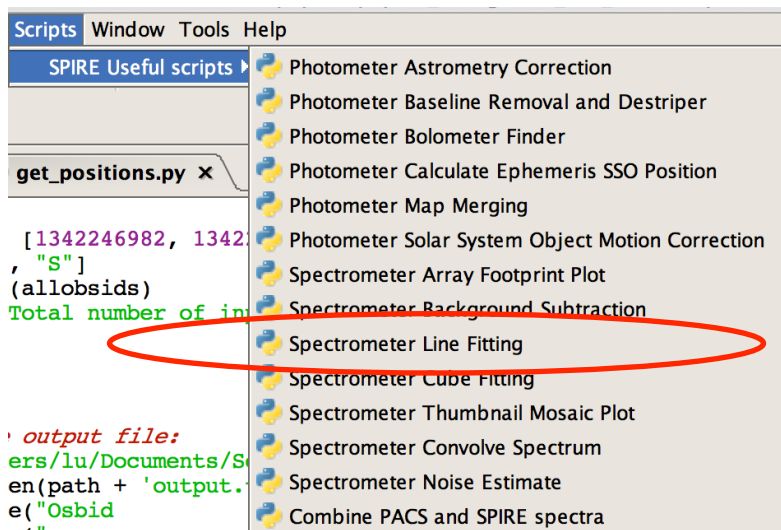
Correction for 15.0" gaussian source; offset 0.0", 0.0"





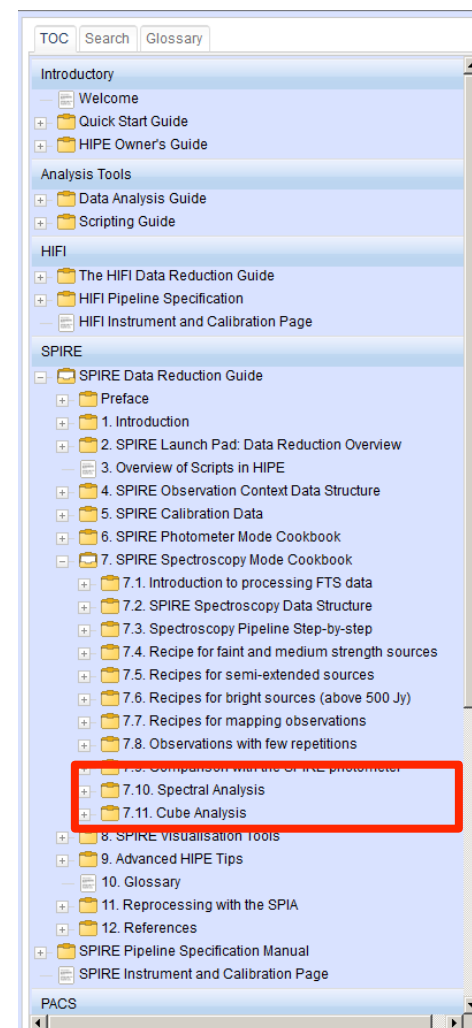
Spectral Line Fluxes

- Line fitting script (for unresolved lines):



- Interactive line fitting (both unresolved & partially resolved lines)
- Cube fitting script (to fit one or more lines in a cube)

DRG



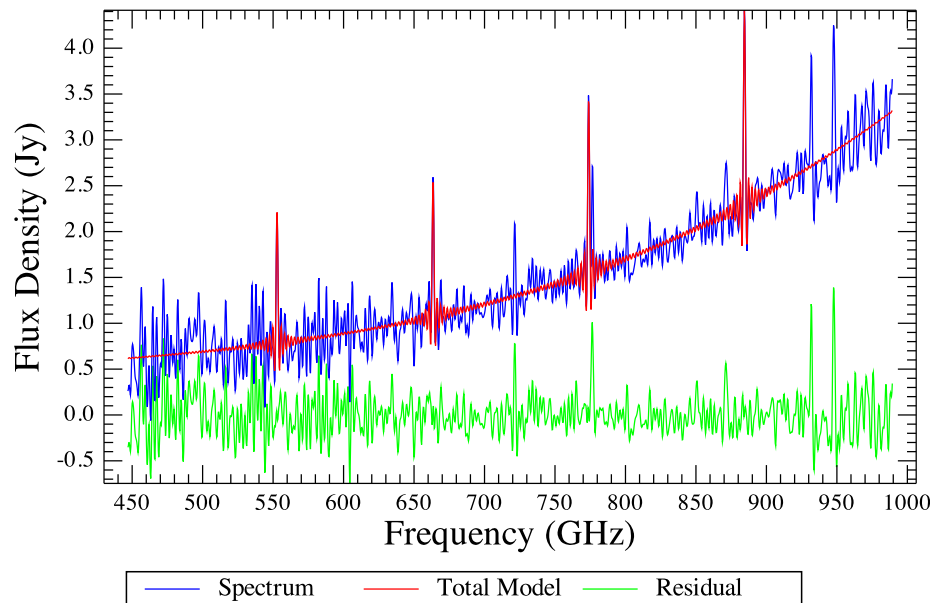


Line Fitting (for Unresolved Lines)

HIPE SPIRE useful script: Spectrometer line fitting

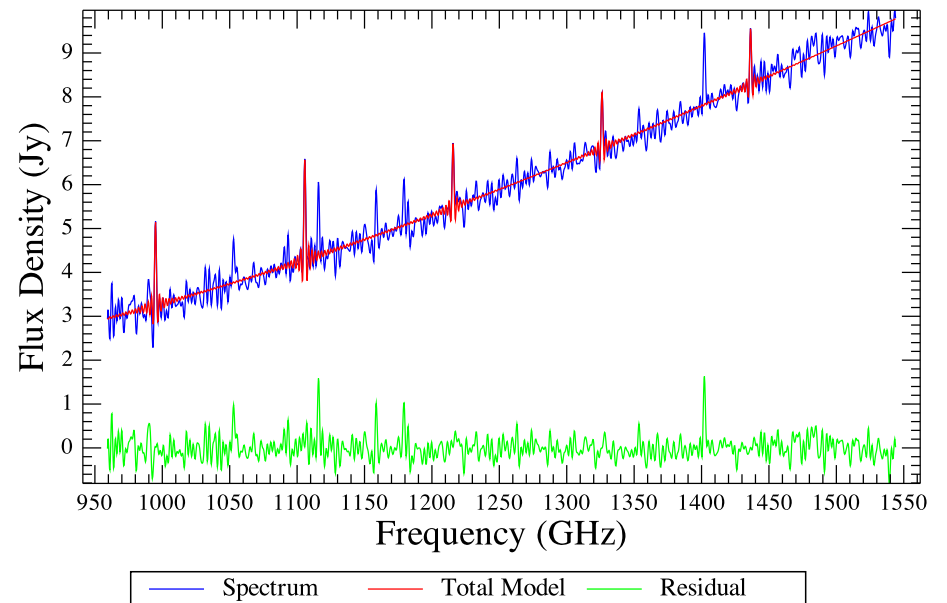
SLWC3: Mrk 231

OBSID: 1342187893 (0x50002975)



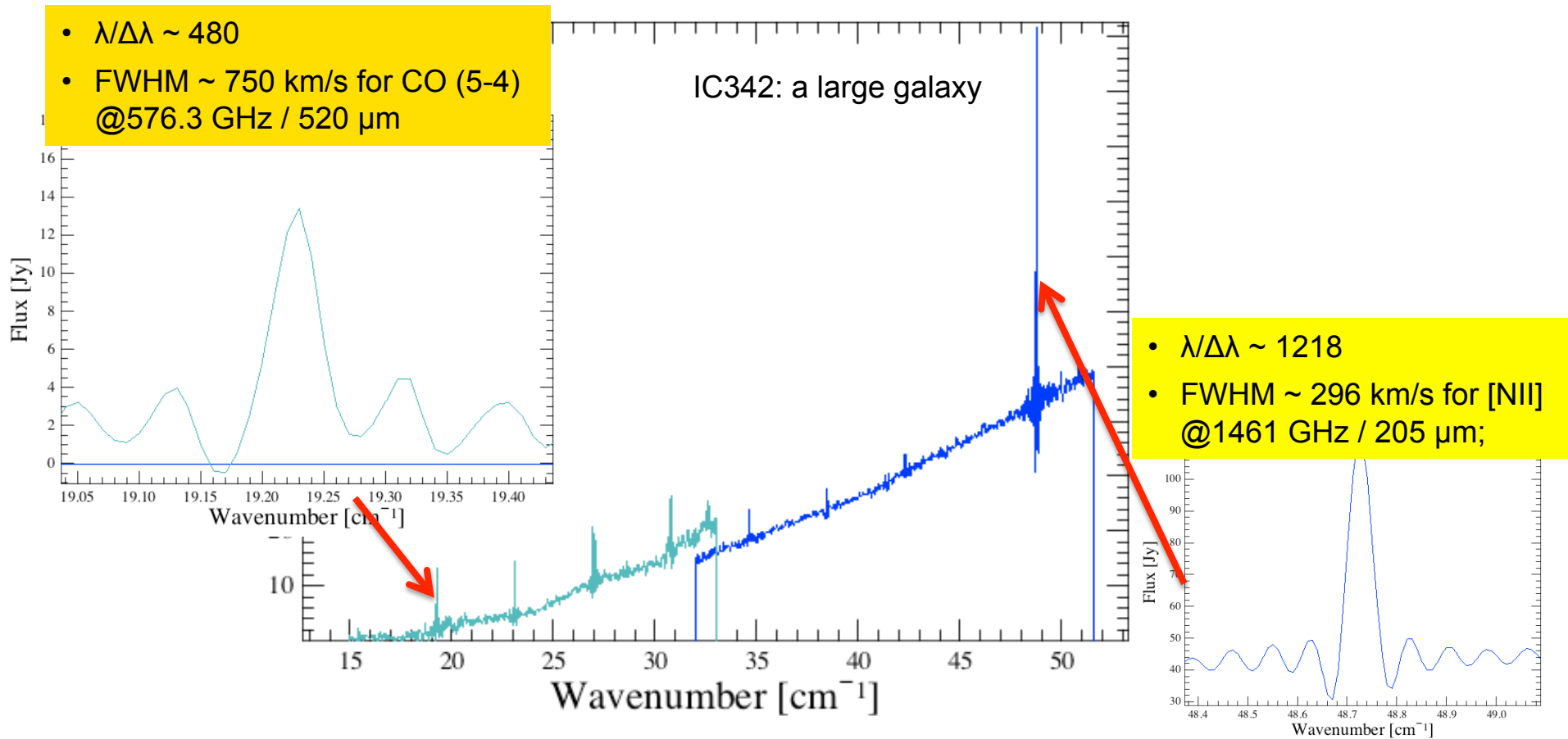
SSWD4: Mrk 231

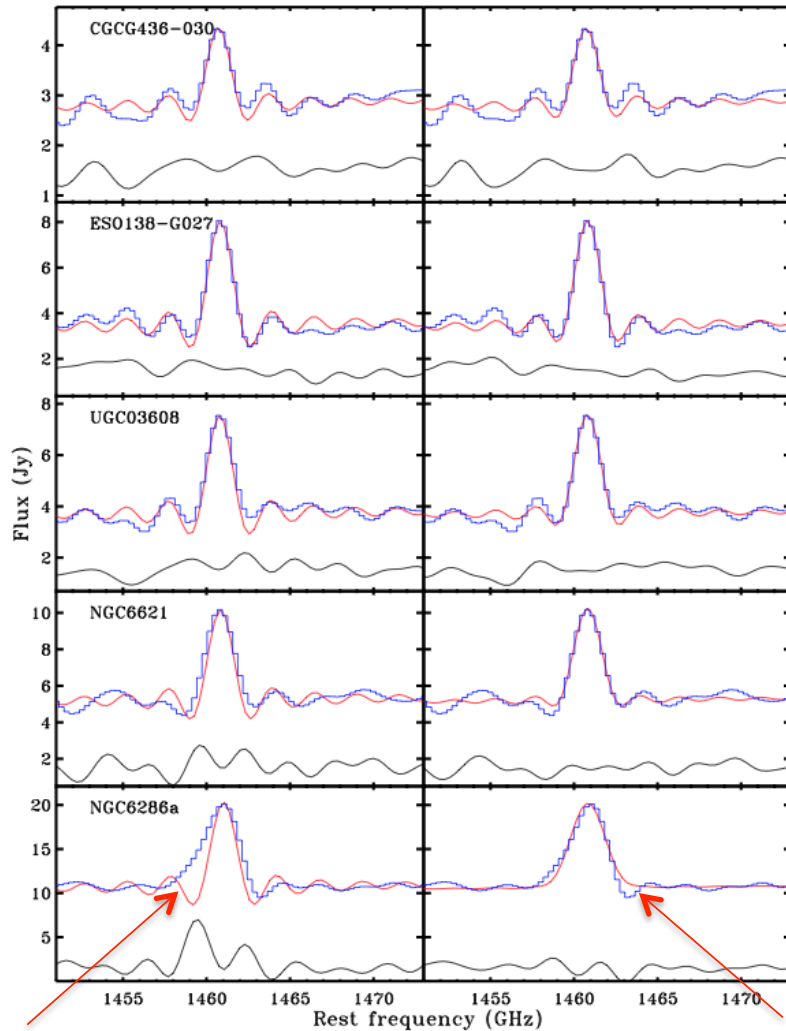
OBSID: 1342187893 (0x50002975)





Spectral Resolving Power Depends on Wavelength





Partially Resolved Lines

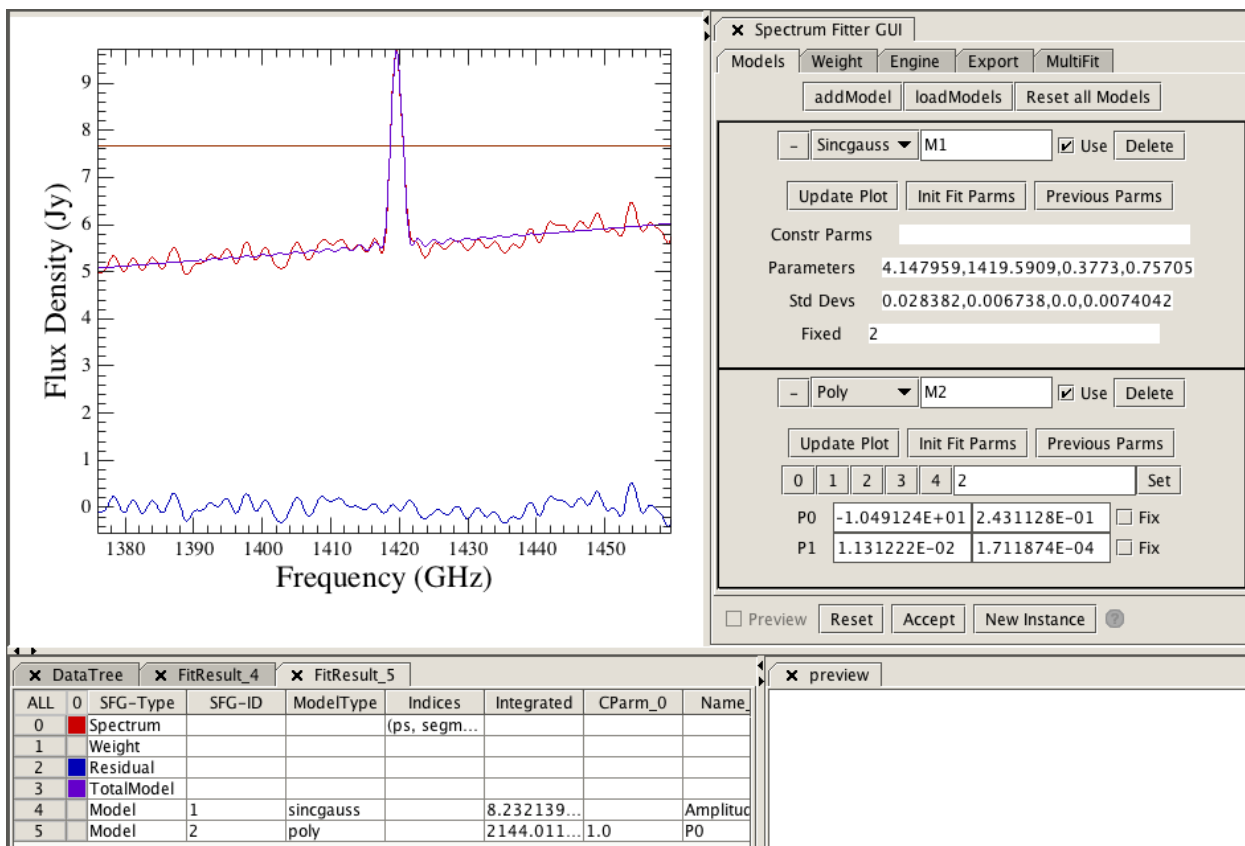
- The [NII] 205 μm line might be partially resolved if its intrinsic velocity is large enough (e.g., > 250 km/s)
- In this case, either use a SincGauss model to fit the line, or apply a correction factor to compensate for the flux underestimate in using a SINC-only line profile (see DRG Sect. 7.10.7)

Fit with SINC only

Fit with SINC convolved with Gaussian (SincGauss model)

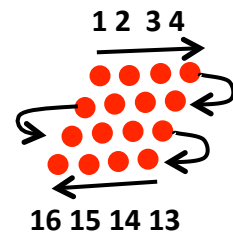
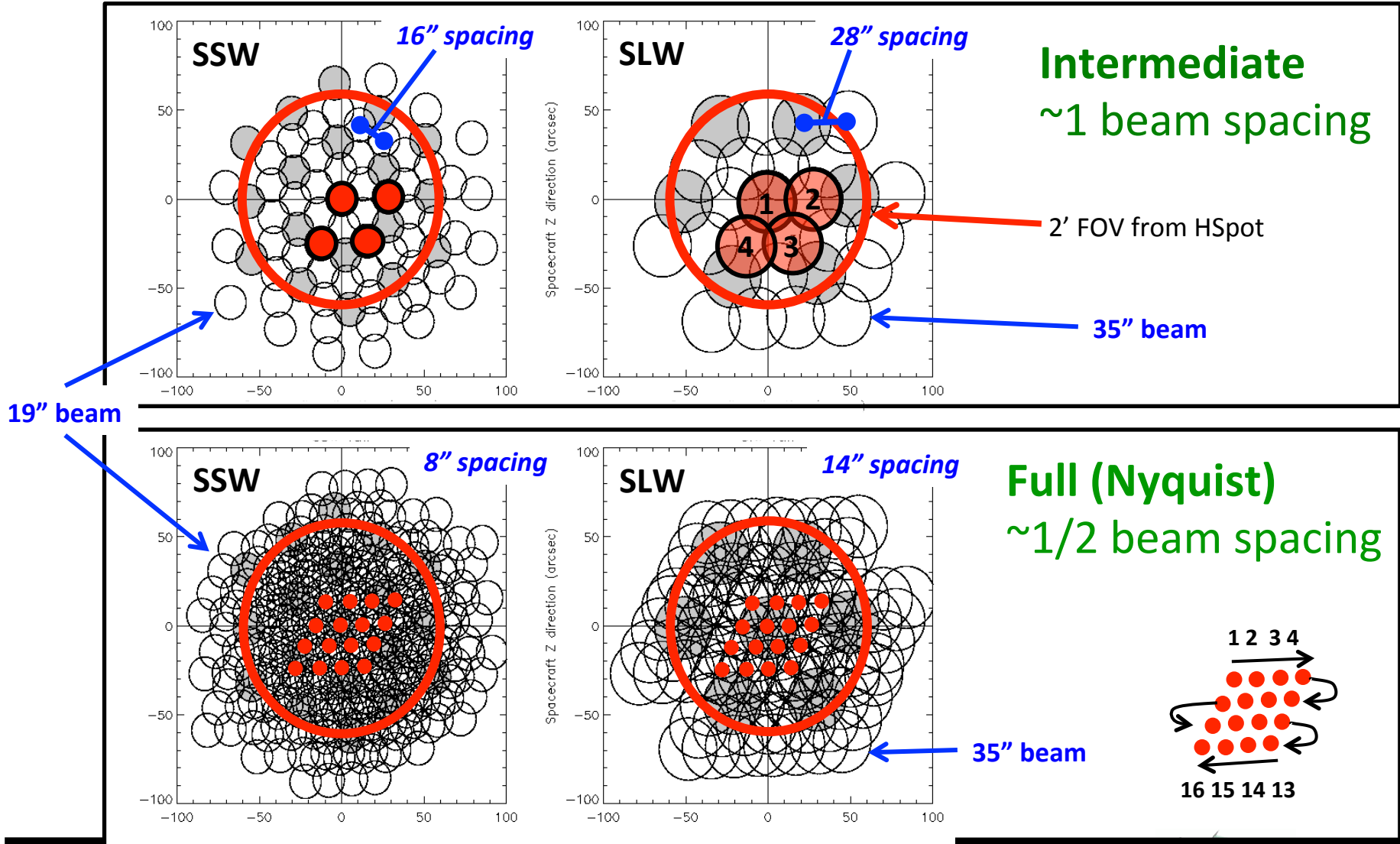


Interactive Line Fitting: SincGauss Profile



- Works best when S/N is high.
- For fainter lines, it might be better to use a SINC profile for fitting, and then correct the resulting flux for an estimated velocity width (see [SPIRE DRG Sect. 7.10.7](#) for more info).

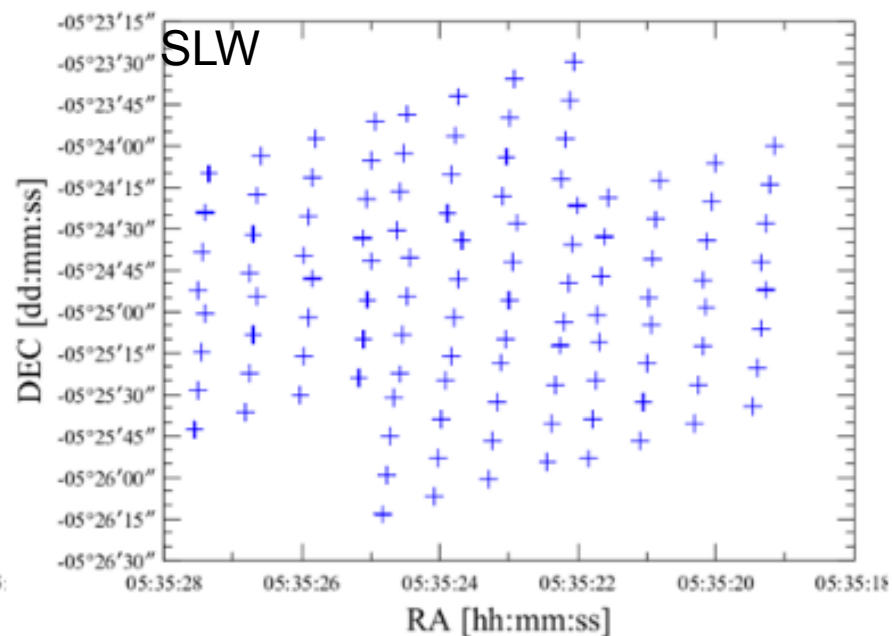
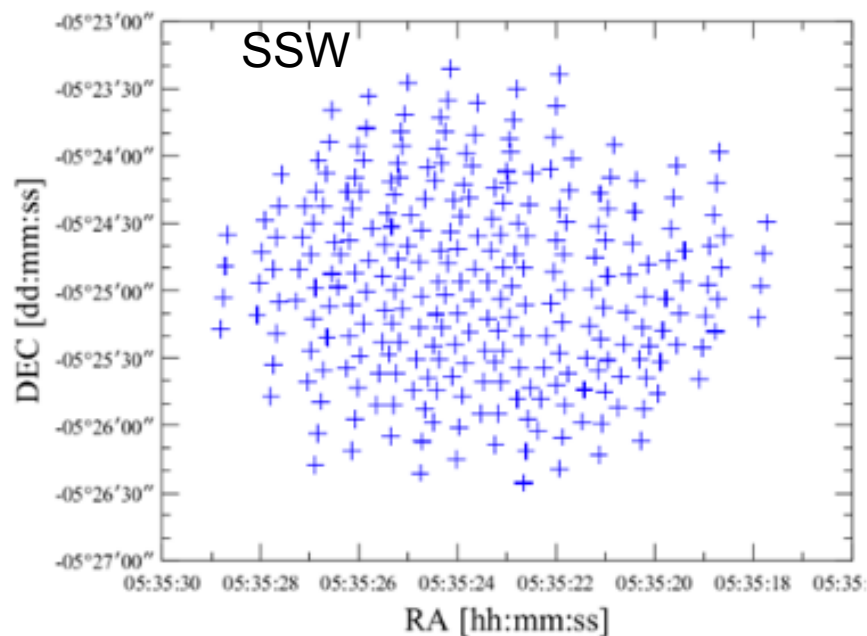
Mapping Observations



Sky Coverage



Actual positions observed on the sky for a fully sampled observation

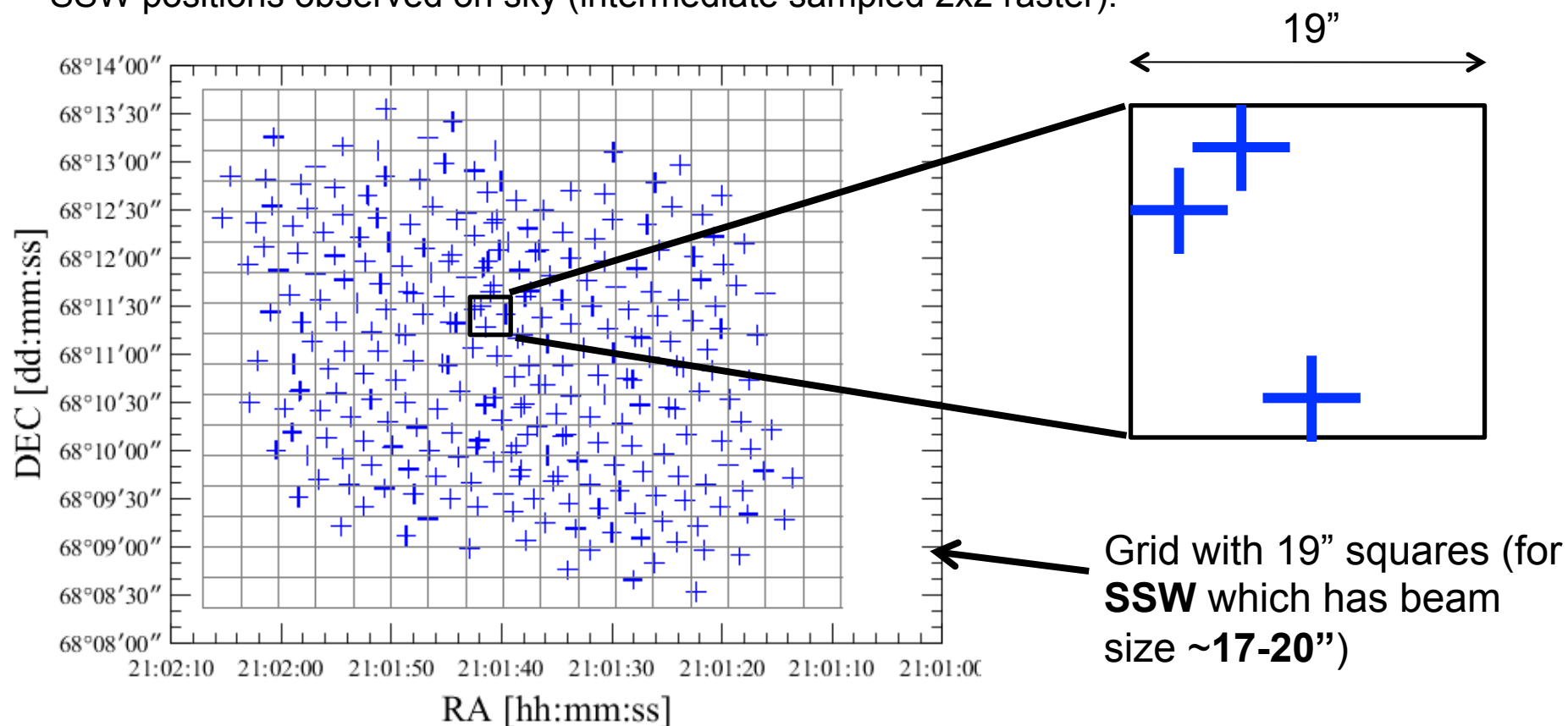


Naïve Projection



Naive Projection is the standard algorithm currently used in the pipeline

SSW positions observed on sky (intermediate sampled 2x2 raster):





Mapping Observations: Investigation & Analysis

DRG

[7.7. Recipes for mapping observations](#)

- [7.7.1. Understanding the SPIRE beam and how it relates to mapping observations](#)
- [7.7.2. Check clipping](#)
- [7.7.3. Restricting the data made into the cube](#)
- [7.7.4. Pointing Information](#)
- [7.7.5. Gridding Algorithm](#)
- [7.7.6. Combining several observations](#)
- [7.7.7. Holes in the map: examining the coverage](#)
- [7.7.8. Maps with faint continuum levels](#)

Investigate the data before mapping:

- Exclude some data?
- Select a map maker (e.g., naïve)
- Grid size considerations
-

[7.11. Cube Analysis](#)

- [7.11.1. SPIRE cubes, general considerations](#)
- [7.11.2. Extracting spectra from a SPIRE spectral cube](#)
- [7.11.3. Extracting a point source from the map](#)
- [7.11.4. Matching cube spectra from SSW and SLW](#)
- [7.11.5. Convolution of a cube to a different beam size](#)
- [7.11.6. Cube fitting with the Spectrum Fitter GUI](#)
- [7.11.7. Cube fitting and line intensity/velocity maps](#)
- [7.11.8. Publication quality plots for mapping data](#)
- [7.11.9. Comparison with photometer maps](#)

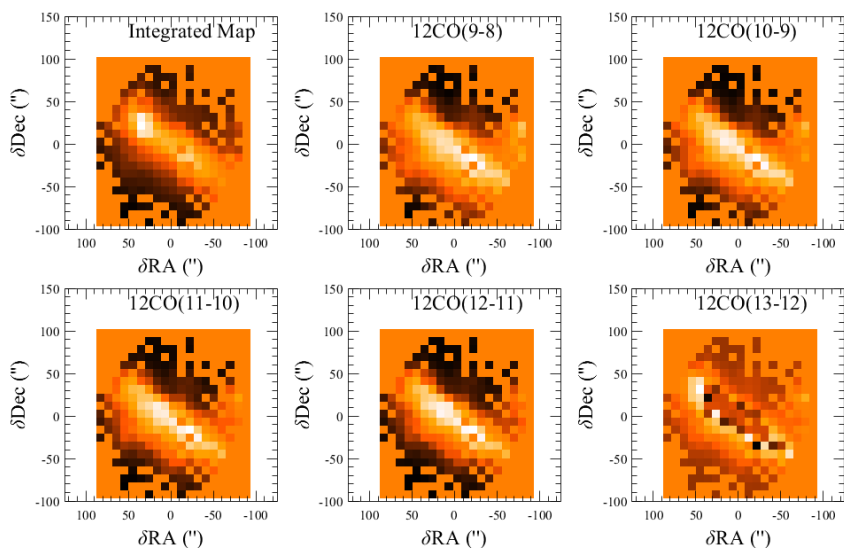
Analyse the data in the final cube:

- Convolve to different beam sizes
- Fit spectral lines to produce line map
-



➤ Line intensity maps:

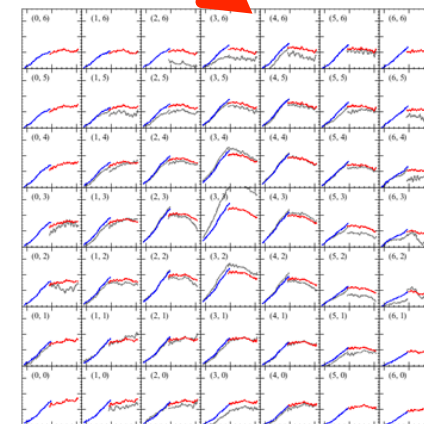
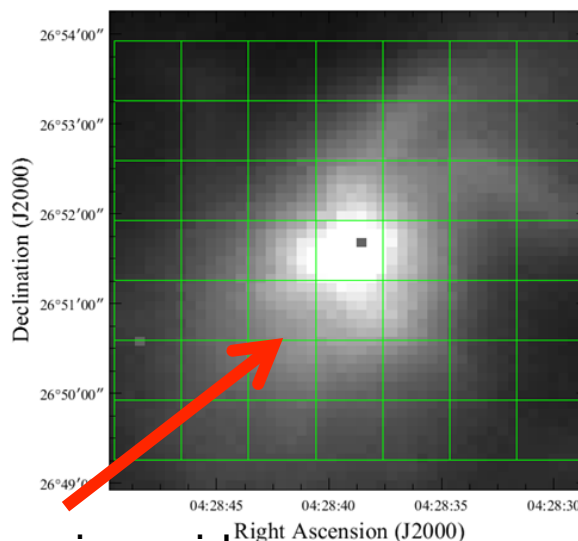
CO line intensity maps



➤ Convolution of a cube to a common beam size (i.e., independent of λ)

Grid of FTS spectra:

- Black curves: original data
- Blue/Red: convolved to a common beam of 80 arcsec



Photometer map of Orion Bar + FTS mapping grid