Processing and analyzing HIFI spectral maps in HIPE

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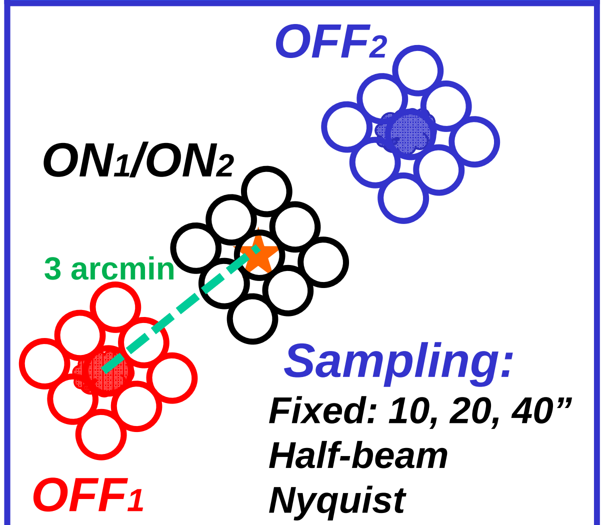
Goals

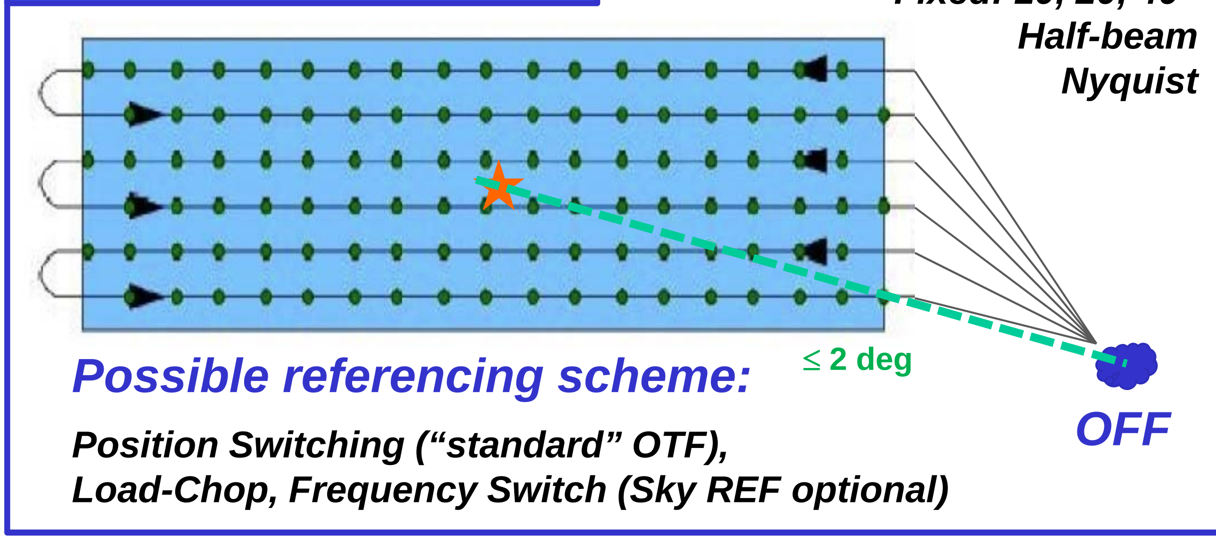
- Familiarity with HIFI's mapping modes
- Inspection
- Cleaning the input spectra (baselines)
- Regridding
- Cube toolbox
- Image analysis
- Saving the output
- [Bonus if time+interest: line fitting with the spectrum fitter tool (unscripted)]

The Mapping AOTs schematically

DBS raster map



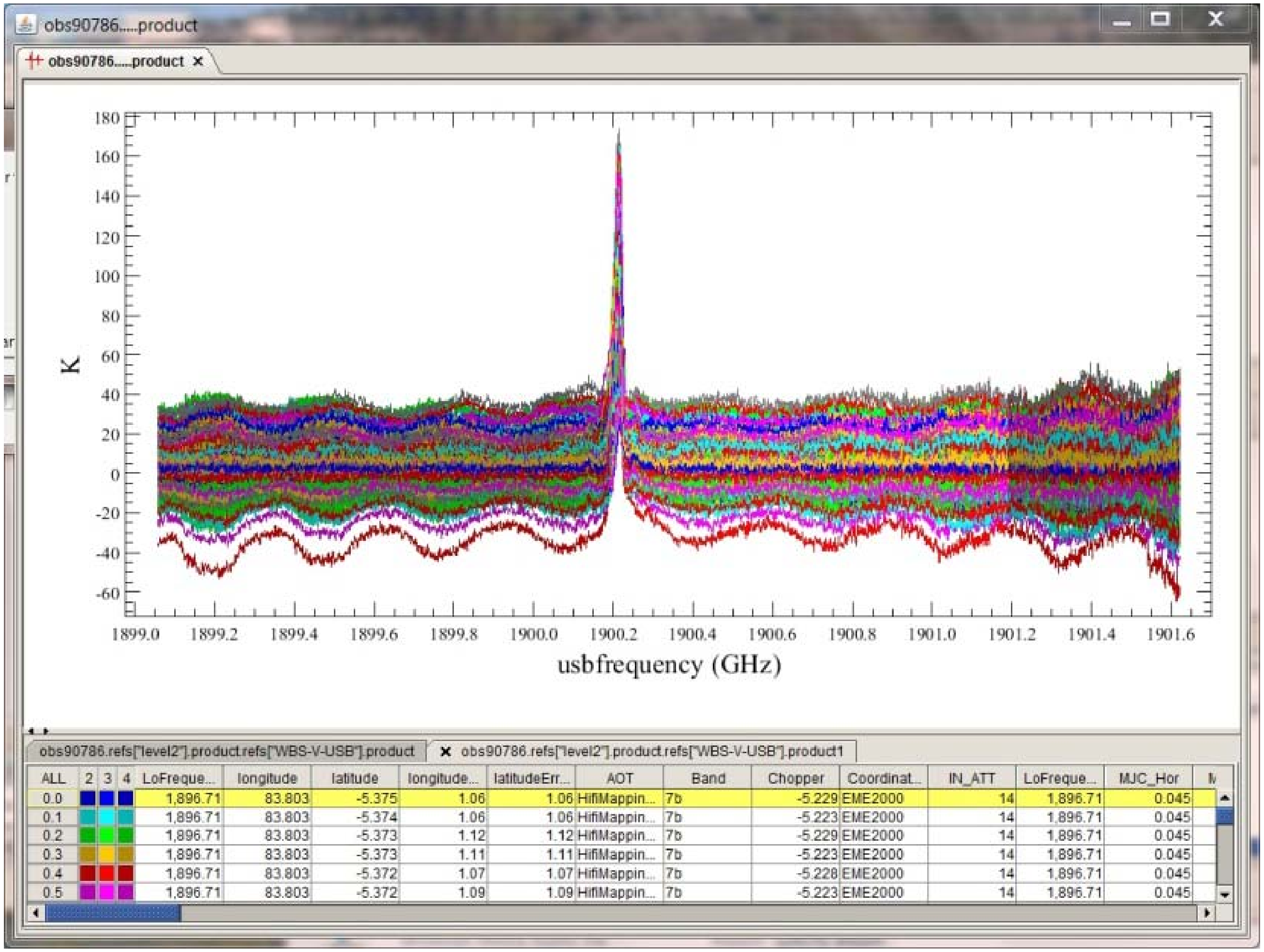
On-the-fly Mapping



The main purpose of the OFF positions is to provide baseline removal of drift + standing waves.

1. The OFFs may sometimes be contaminated with line emission (most often CO and [CII], sometimes others because of the fixed DBS throw). *You should check for this in the data (Sylvie’s demo).*

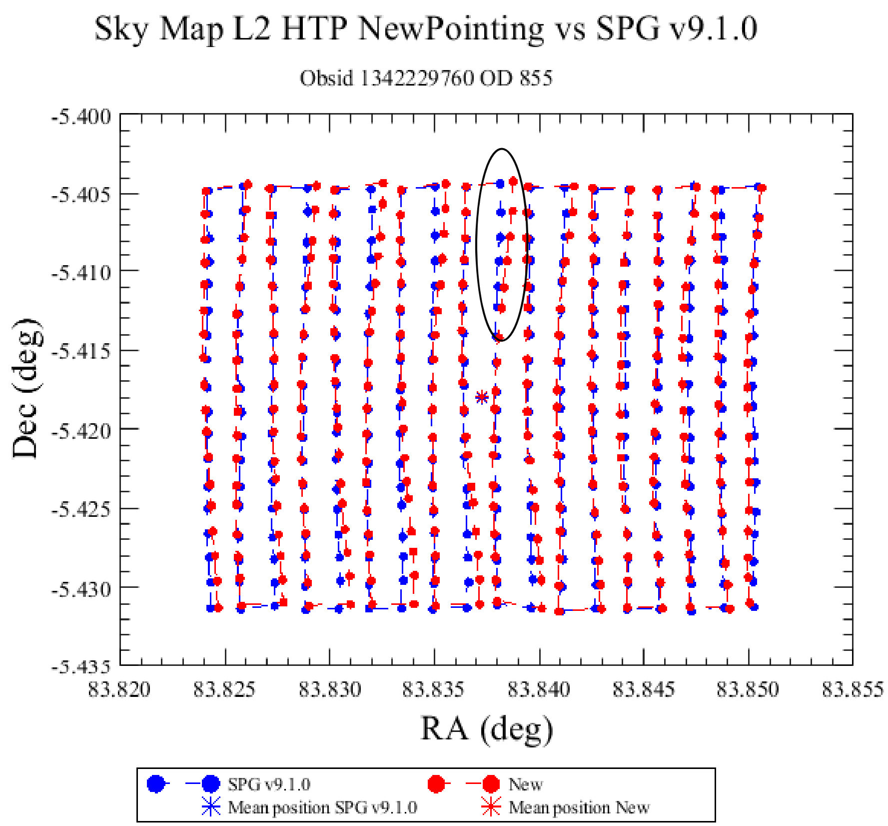
2. The OFFs may sometimes not fully correct the ripples, due to short Allan times (rapid drift cross-over from radiometric noise).



C^+ + 1900 GHz + continuum + drift

OTF maps used a flawed telescope line scan pointing mode

- This mode has been flawed on the telescope, producing departures along the intended scan path.



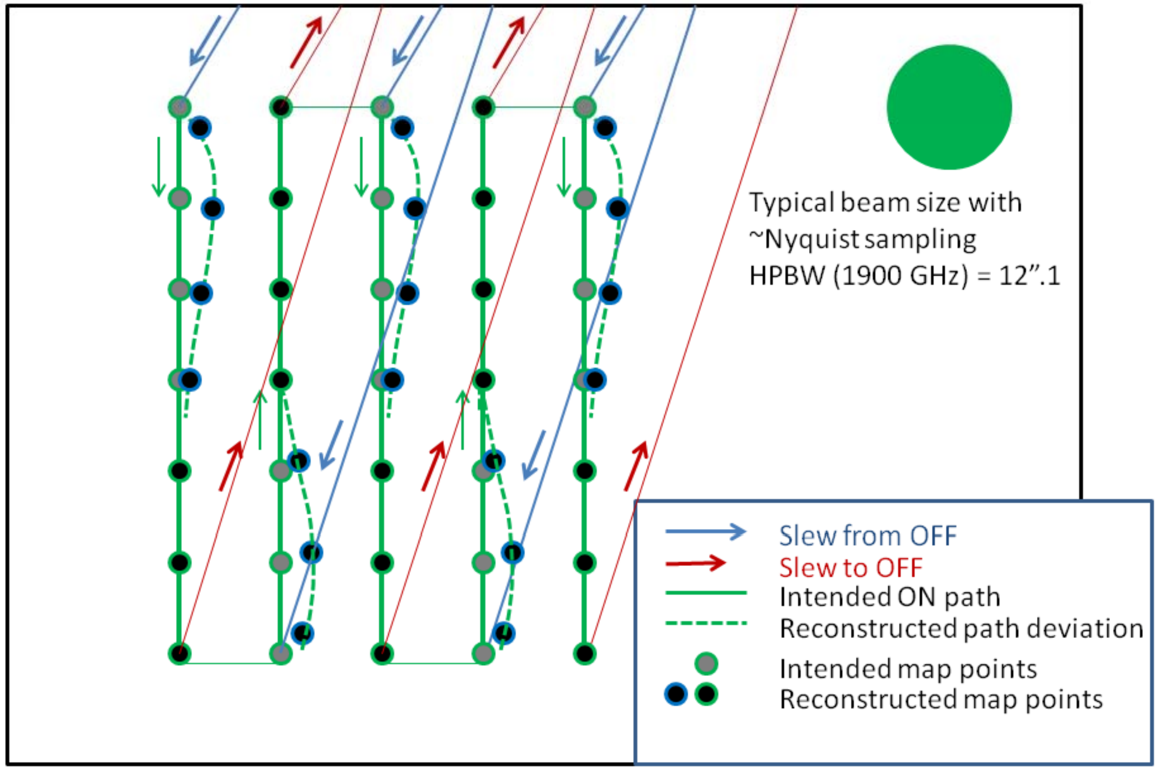
- This behavior is revealed with improved pointing reconstruction currently in development for wider application.

Our current picture

The "zig-zag" has components of slewing errors unrelated to timing errors in HIFI.

Errors are projected in both RA and Dec (not just along the scan line).

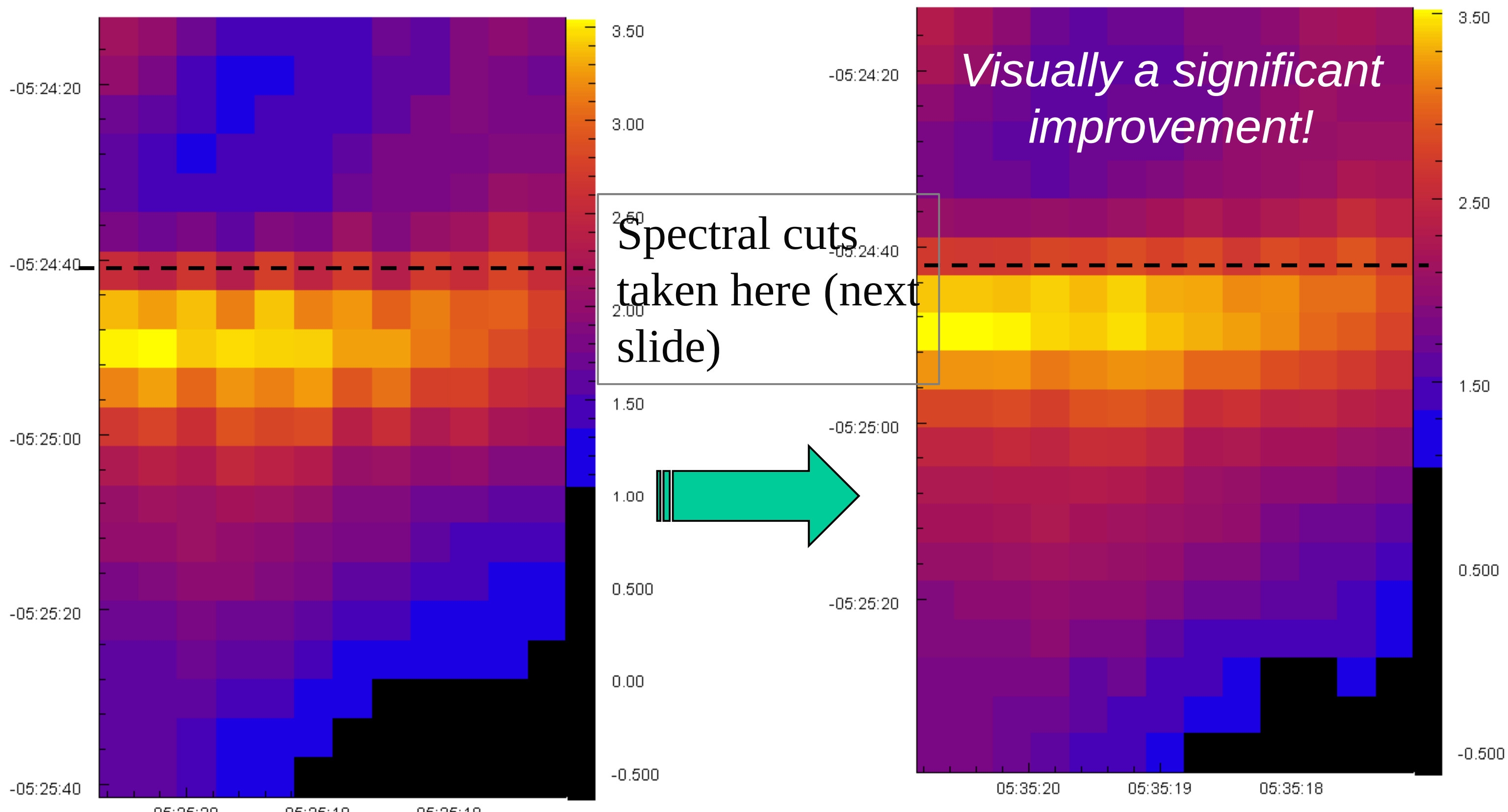
The telescope appears not to be matching the expected speed once scanning, causing map points to bunch up at the beginning.



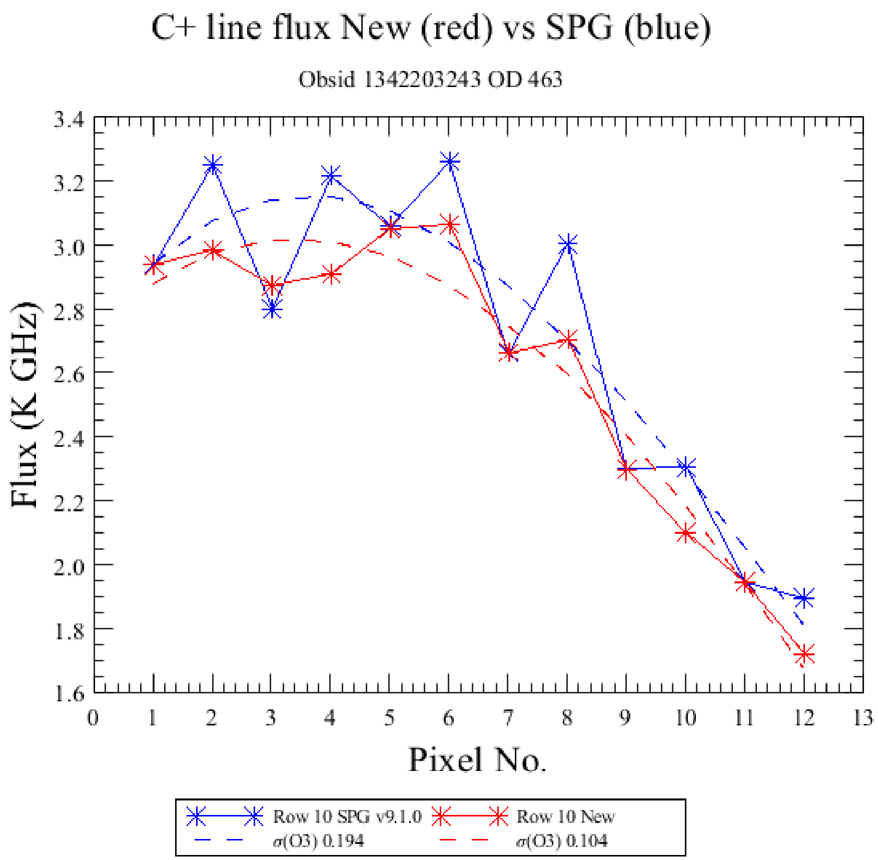
The deviations are clearly correlated with the slews from OFF,
Looks like slew → deceleration → scan transition bugs.

Impact of the anomalous line scanning

- The consequence is that sampling requested in HSpot is not perfect, and until the new pointing reconstruction is available for re-assignment of attitudes, some observations will exhibit a form of “zig-zag”



The new pointing history reduces the zig-zag



C+ line fluxes in spectra extracted from the cube in a slice across the Orion Bar.

Red is based on New pointing and shows ~2x lower noise around an approximating (3rd order) fit to the flux gradient across the PDR.

On to the demo…

- What we will do:
  1. Load a H_2O and ^{13}CO OTF map of massive SFR W51.
  2. Inspect metadata for the map layout on the sky, noise performance parameters.
  3. Remove “artifacts” from the Level 2 spectra.
  4. More discussion of artifacts (ripples).
  5. Regrid into spectral cubes.
  6. Try some tools from the cube analysis toolbox (CSAT)
  7. Highlight some image analysis tools.
  8. Save the output.

1. Loading the data

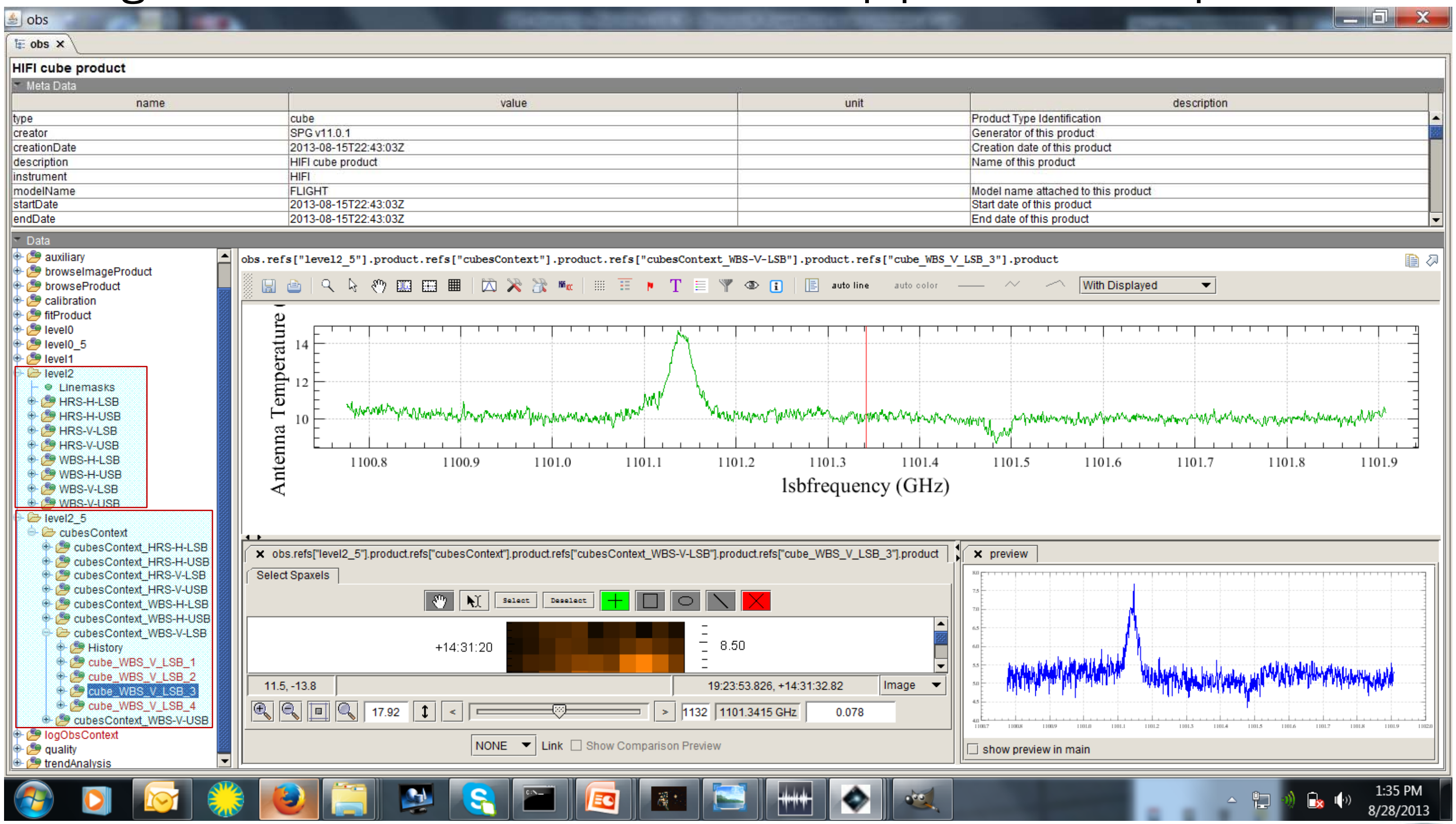
Loading obsid 1342207383 should follow the script

installation_demo_hifidpws_aug2013_v1.py

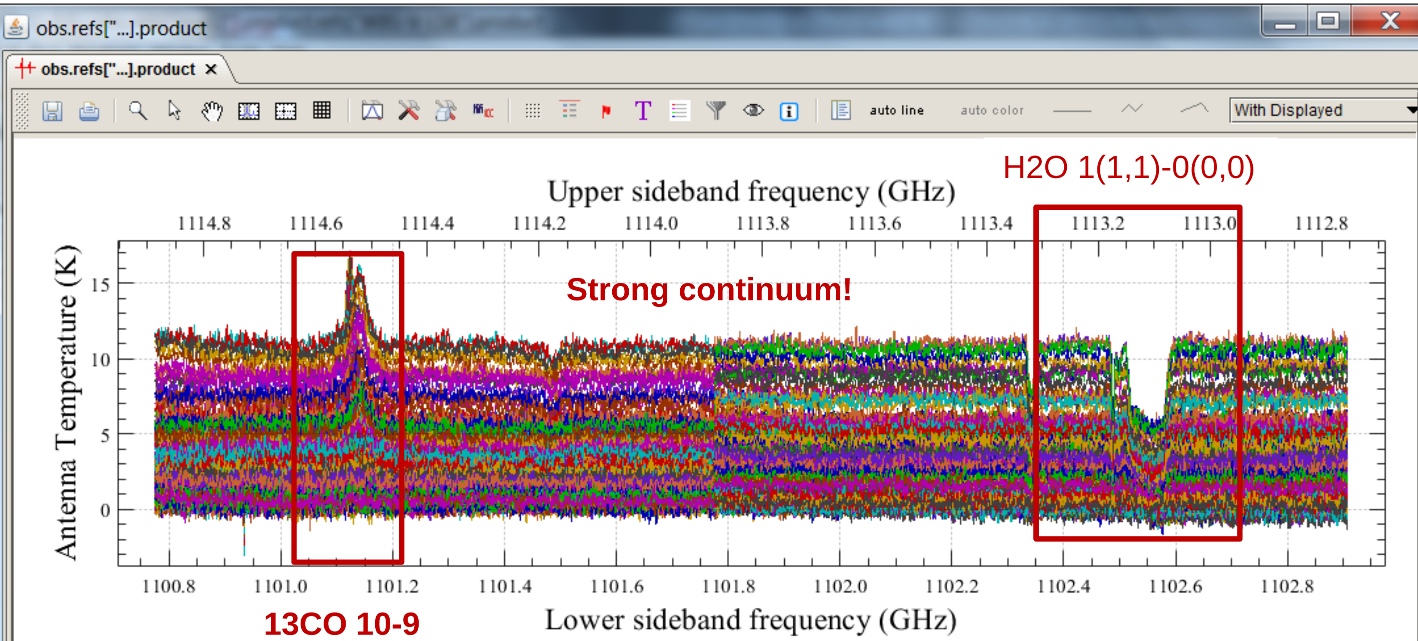
It is a fairly large observation, the pool is ~2 GB.

2. Inspection of the data

- This is a familiarization of the data tree for a spectral map, inspection of the Level 2 HTPs in Spectrum Explorer (for data quality / artifacts), and locating the metadata that describe the map pattern and expected noise.



2. HTP inspection



DataTree | obs.refs["level2"].product.refs["WBS-V-LSB"].product

ALL	1	2	3	4	LoFreque...	longitude	latitude	longitude...	latitudeErr...	Band_ATT	Chopper	IN_ATT	LOF_code	LoFreque...	MJC_Hor	MJC_Ver	bac
0					1,107.831	290.90947	14.49601	1.54	1.54	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
1					1,107.831	290.90963	14.49676	1.79	1.79	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
2					1,107.831	290.90980	14.49750	1.81	1.81	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
3					1,107.831	290.90990	14.49815	1.81	1.81	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
4					1,107.831	290.90995	14.49880	1.52	1.52	[6,4,6,0]	-5.462	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
5					1,107.831	290.90997	14.49945	1.55	1.55	[6,4,6,0]	-5.462	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
6					1,107.831	290.90994	14.50013	1.57	1.57	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
7					1,107.831	290.90989	14.50082	1.53	1.53	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
8					1,107.831	290.90985	14.50151	1.51	1.51	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
9					1,107.831	290.90982	14.50211	1.56	1.56	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
10					1,107.831	290.90980	14.50274	1.56	1.56	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
11					1,107.831	290.90982	14.50342	1.54	1.54	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
12					1,107.831	290.90981	14.50412	1.54	1.54	[6,4,6,0]	-5.462	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
13					1,107.831	290.90979	14.50474	1.47	1.47	[6,4,6,0]	-5.463	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,
14					1,107.831	290.90976	14.50538	1.33	1.33	[6,4,6,0]	-5.462	12	[30688,92...	1,107.81	0.032	0.03	[5,0,0,

2. Key metadata

obs.refs["auxiliary"].product.refs["HifiUplinkProduct"].product["HifiUplinkParameters"]

obs.refs["...ameters"]

HifiUplinkParameters

Meta Data

None

Table Data

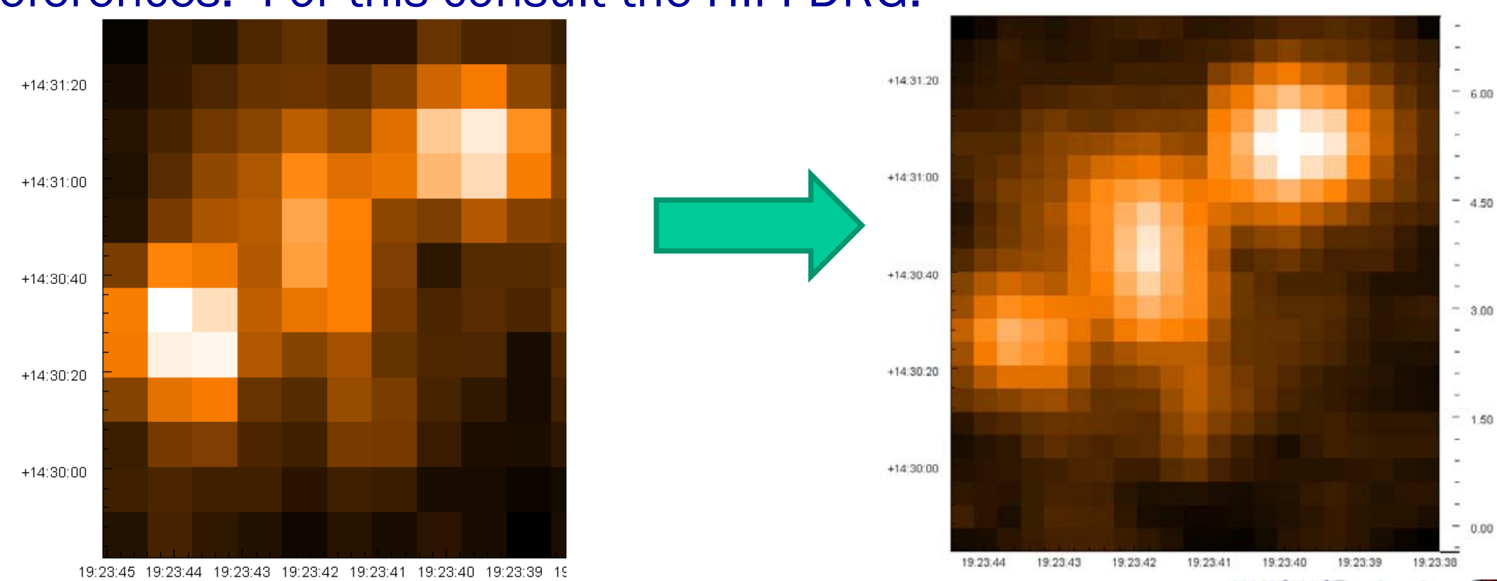
Index	name	value	unit	type	description
0	mapLines	11		java.lang.Long	Number of map lines
1	mapLineStep	9.0	arcsec	java.lang.Double	Map line spacing
2	mapReadouts	11		java.lang.Long	Number of readouts per line
3	mapReadoutSep	9.6	arcsec	java.lang.Double	Line readout spacing
4	noiseMinUsb	UNKNOWN	K	UNKNOWN	Predicted SSB Noise USB at minimum bandwidth
5	noiseMaxUsb	UNKNOWN	K	UNKNOWN	Predicted SSB Noise USB at maximum bandwidth
6	noiseMinLsb	UNKNOWN	K	UNKNOWN	Predicted SSB Noise LSB at minimum bandwidth
7	noiseMaxLsb	UNKNOWN	K	UNKNOWN	Predicted SSB Noise LSB at maximum bandwidth
8	noiseMinWidth	UNKNOWN	MHz	UNKNOWN	Minimum bandwidth for noise predictions
9	noiseMaxWidth	UNKNOWN	MHz	UNKNOWN	Maximum bandwidth for noise predictions
10	tmbReference	789.0	K	java.lang.Double	Temperature (main beam) at noise reference frequency
11	noiseRefFrequency	1108.0	GHz	java.lang.Double	Noise reference frequency
12	observingTime	3091	s	java.lang.Long	Observing time
13	offTime	471.6	s	java.lang.Double	Off source time
14	overheadTime	702.8	s	java.lang.Double	Overhead
15	totTimeEfficiency	77.3	%	java.lang.Double	Total time efficiency
16	totNoiseEfficiency	44.2	%	java.lang.Double	Total noise efficiency
17	driftNoiseContrib	9.0	%	java.lang.Double	Drift noise contribution
18	refSelected	true		java.lang.Boolean	Sky reference selected
19	fe_lof_0	1107.898	GHz	java.lang.Double	LO frequency selected
20	oneGHzReference	true		java.lang.Boolean	One GHz noise estimation bandwidth
21	hrsModeH	Nominal		java.lang.String	HRS resolution mode H
22	flyRefOffsetDec	0.0	arcmin	java.lang.Double	Sky reference offset declination
23	frame	heliocentric		java.lang.String	Redshift velocity frame
24	spectrometer	both		java.lang.String	Spectrometers used
25	dec	14.510694444444445	degrees	java.lang.Double	Target declination J2000.0
26	fe_eff_res_max_0	0.3	GHz or km/s	java.lang.Double	Maximum width spectral resolution at noise goal
27	redshiftType	radio		java.lang.String	Redshift type
28	flyRefOffset	true		java.lang.Boolean	Sky reference offset is relative
29	resolutionMhz	false		java.lang.Boolean	Resolution width units (true = MHz, false = km/s)
30	ra	290.922875	degrees	java.lang.Double	Target right ascension J2000.0
31	decoff	14.5106782913208	degrees	java.lang.Double	Sky reference OFF declination J2000.0
32	fe_eff_res_min_0	0.3	GHz or km/s	java.lang.Double	Minumum width spectral resolution at noise goal
33	goalTime	2800	s	java.lang.Long	Goal observing time
34	flyNyquistSel	true		java.lang.Boolean	Spectral Map Nyquist sampling requested
35	raoff	291.0089416503906	degrees	java.lang.Double	Sky reference OFF right ascension J2000.0
36	redshift	59.5	redshift or km/s	java.lang.Double	Redshift value (km/s if redshiftType is optical or radio)
37	doingTime	true		java.lang.Boolean	Time estimation is based on observing time or rms noise goal
38	flyY	1.5	arcmin	java.lang.Double	Spectral map scan length requested
39	band	4b		java.lang.String	HIFI band
40	goalNoise	0.1	K	java.lang.Double	Goal rms basline noise

3. Removing artifacts

- This observation is well-behaved, following L2 HTP inspection.
- We will remove the baseline under the 13CO line (with no distinction between continuum and baseline offsets).
- We will not go through removal of fringes (since there is no strong residual), but the procedure is basically the same.
  - You may combine both fringe fitting with baseline fitting and removal with fitHifiFringe (sine waves).
  - In the future more advanced ripple correction will be available for observations using Bands 6 or 7 with e-ripples.

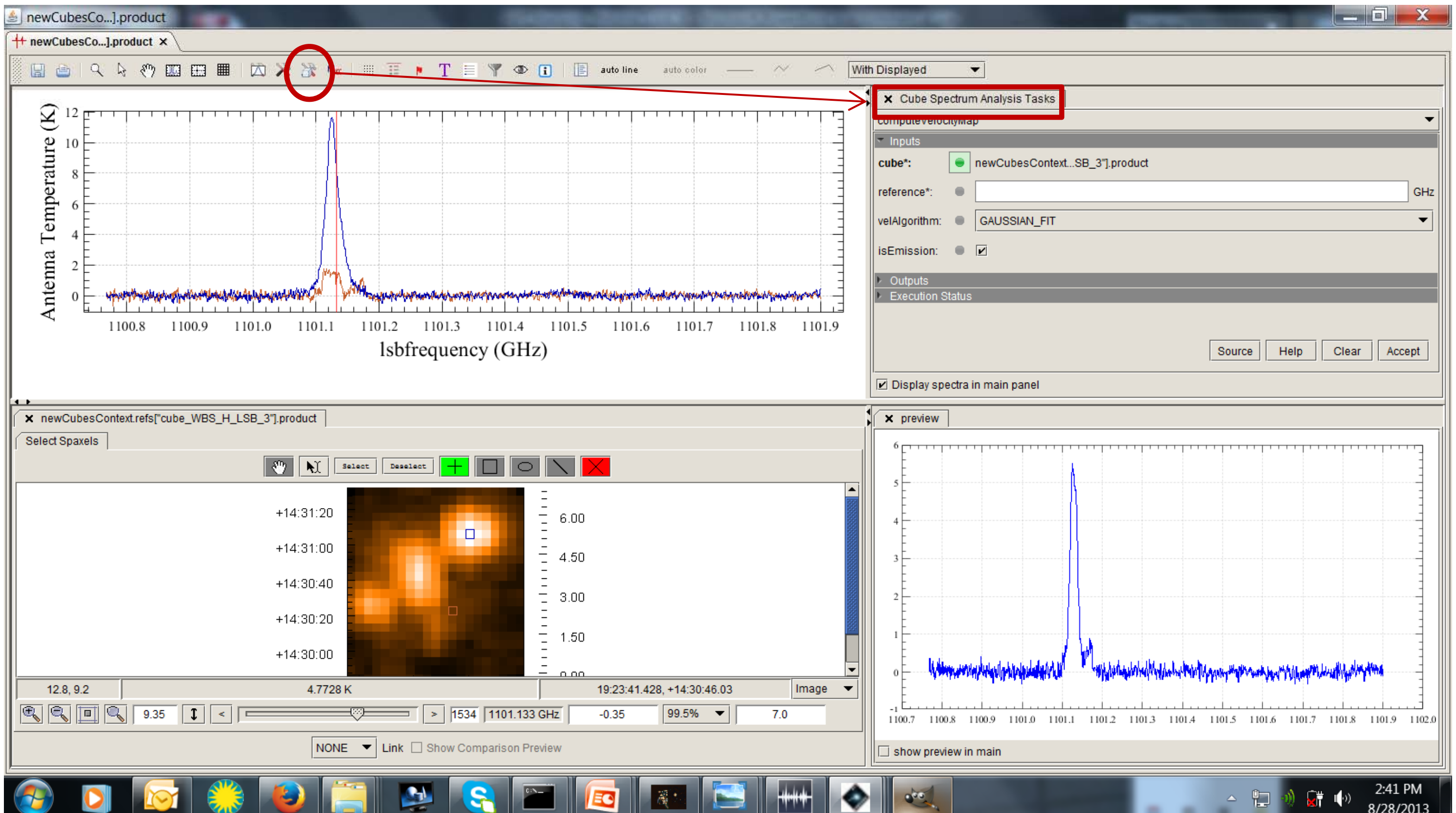
4. Resample with doGridding

- S/N is good experiment with oversampling to ~2 x Nyquist.
  - Remember that structures are resolvable to at least ~1/10 the beam size when S/N is very high.
  - Noise is computed on a map point basis; does not take the convolution into account (thus generally better than predicted).
  - Changing the pixel scale is the most common application, and we do not do a complete experiment with all possible parameters, e.g. altering WCS references. For this consult the HIFI DRG.



6. Cube Spectrum Analysis Toolbox (CSAT)

- We will **crop** in frequency, create a **PV map**, convert the cube units GHz to **velocity**, make a **velocity map**, and an **integrated intensity map.** We can also subtract baselines in the CSAT (not as sophisticated as fitBaseline, but a good means to create a continuum map).

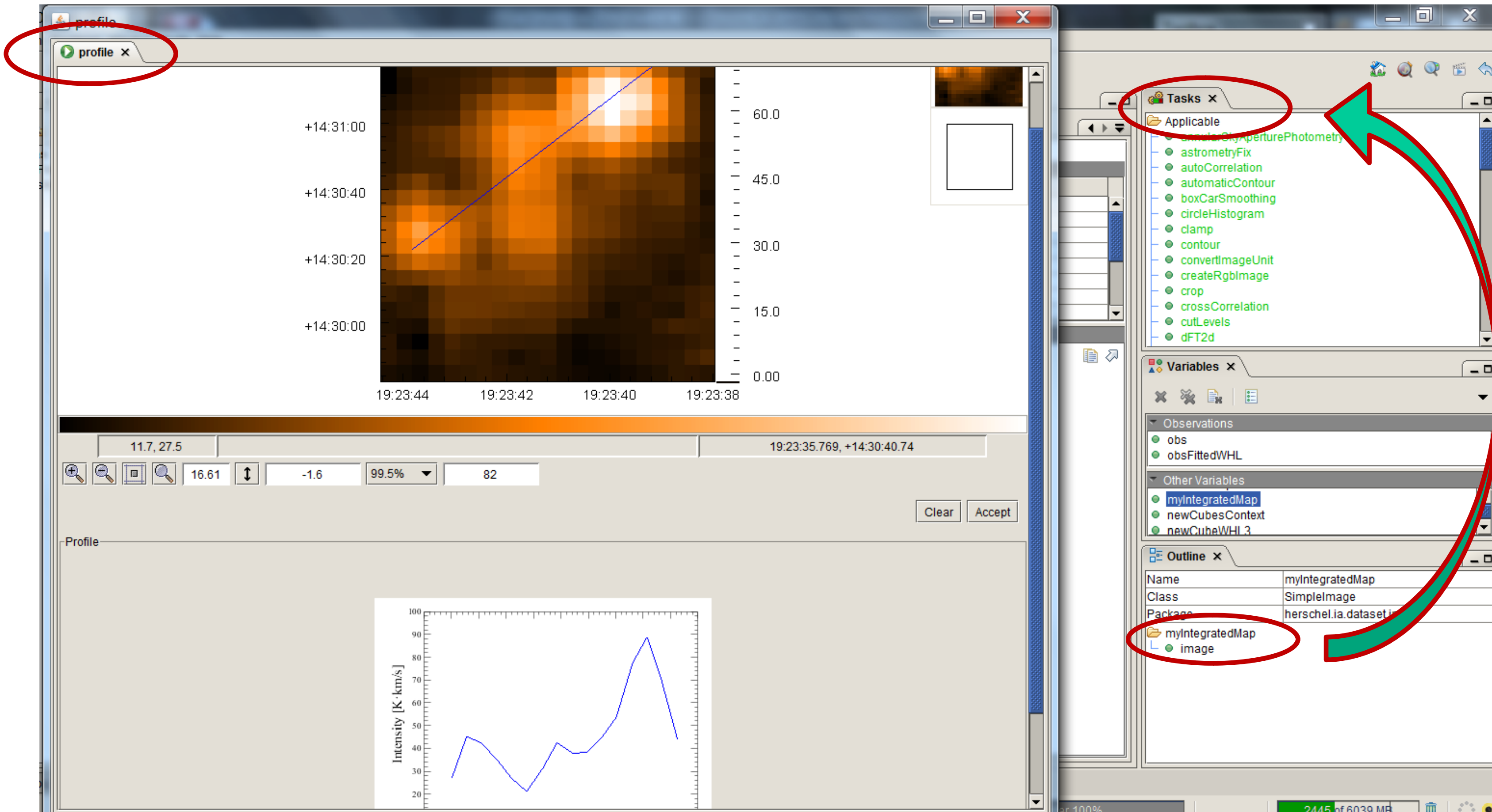


About baseline fitting

- As noted, the CSAT has a subtractBaselineFromCube task, but be careful with this.
- If the data have artifacts, they should be removed before convolving them into the “good” spectra at each map position. Once convolved, the subtraction of the baseline is not accurate.
- Baseline subtraction in the CSAT is valid for continuum emission.

7. Image analysis

- Image analysis tools have been developed by PACS/SPIRE, usable on any HIFI 2D map image.
- Smoothing, contour overlays, source fitting, etc etc.



8. Saving/exporting

- We shall look only at means of FITS export.
- Reinserting our tuned cubes into the obs context is possible, but a big hassle that's worth it only if managing a lot of data (and we can show you how offline or via helpdesk).

Bonus if time: Line fitting (unscripted)