Removing Standing Waves from HIFI Level 2 Spectra
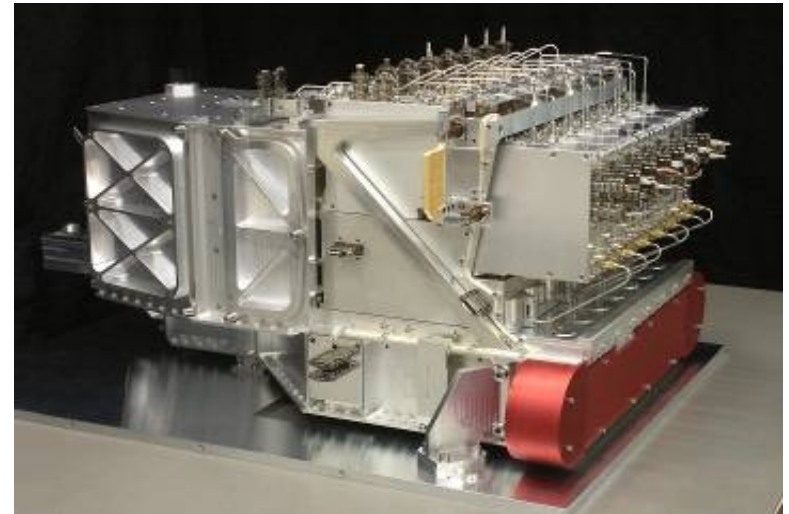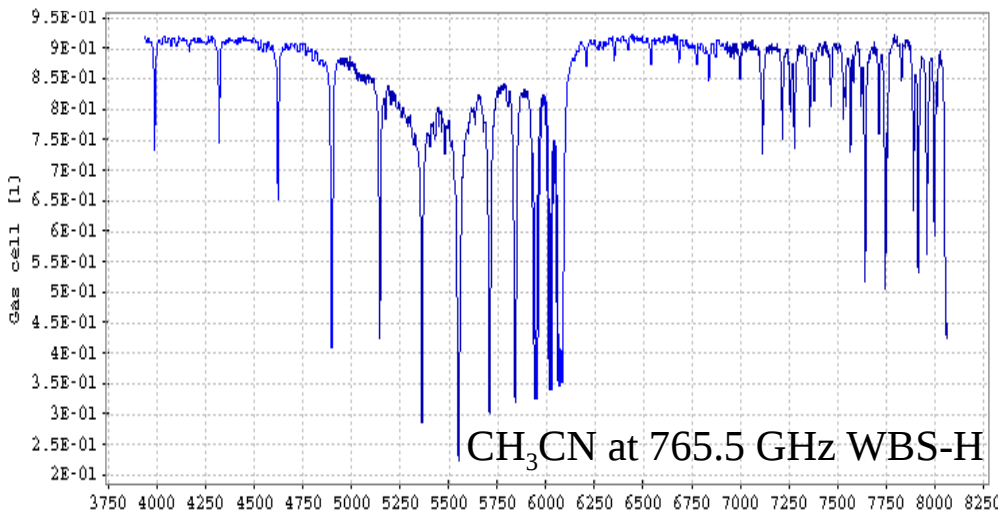
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CH_3CN at 765.5 GHz WBS-H

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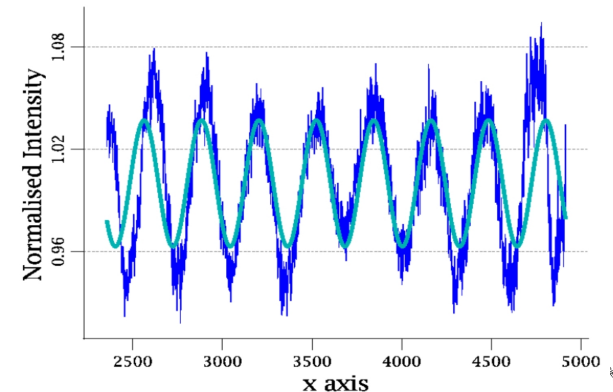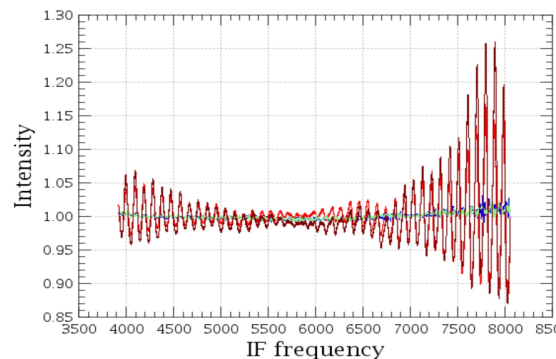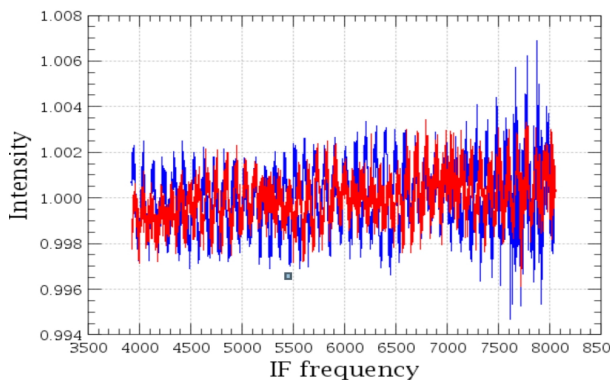
Level 1 → 2 Processing
Standing Wave Removal: the Problem

Standing waves from optical and electronic components seen (as expected) in HIFI spectra. Pipeline removes those by using appropriate chopping against sky or load, nodding, or frequency switch. Standing wave residuals might still be seen in Level 2 data. Wave-type is HIFI-band dependent:

- Beamsplitter bands 1, 2, and 5 show sine waves

- Diplexer bands 3 and 4 show sine waves with amplitude increasing to IF band edges

- HEB bands 6 and 7 waves are not sine waves. Requires special treatment, not discussed here.

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Steps to remove *residual* standing waves (SW), <u>*with as little user-interaction as possible*</u>:

- Separate SW from:
  - other baseline fluctuations
  - emission/absorption lines

HH1 HIFI before and after (red) fringe removal

- Fit N sine waves with different periods, amplitudes, phases to baseline-subtracted, line-masked spectrum.
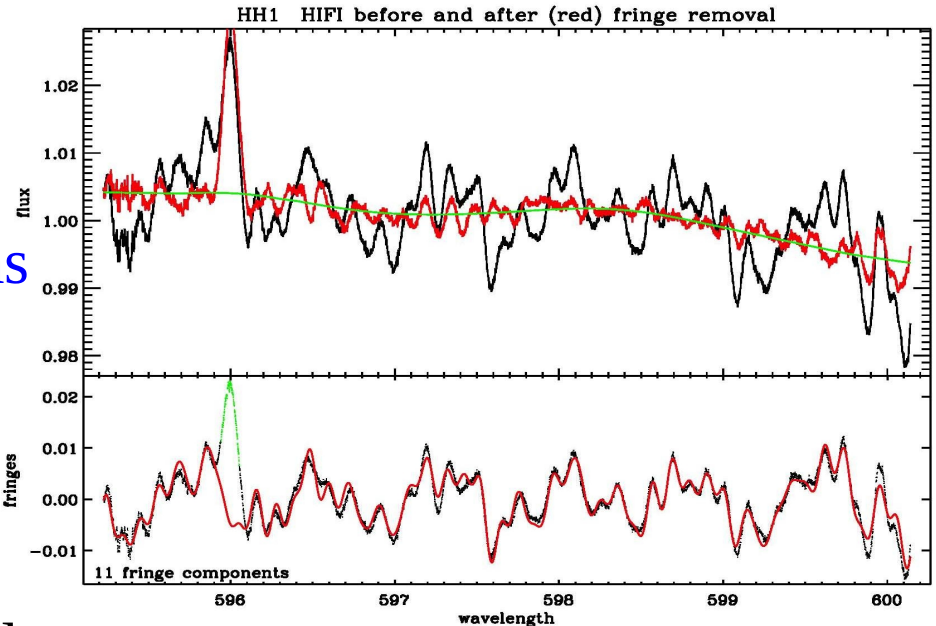
- Subtract SW fit from original input data. Caveat: should be division, but often not possible as 'continuum' level uncertain. Not big effect as SW amplitude <few%

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- Baseline and mask determined using iterative filtering, smoothing, sigma-clipping algorithm. Needs to know 'typical' longest standing wave period, to separate waves from other baseline structure.

- N sine waves A*sin(x)+B*cos(x)=C*sin(x+phase) fitted to baseline-subtracted, line-masked spectra iteratively:

A) Determine period, amplitude, phase of wave 1 at minimum chi^2

B) Determine period wave 2 at minimum chi^2 in sine-wave subtracted data

C) Solve for amplitude and phase **combined waves 1+2** using 'LU' matrix decomposition in original input data

D) Subtract **waves 1+2** from original input data

E) Repeat steps B, C, D for waves 1+2+3, ..., 1+2+3+...+N

Level 1 → 2 Processing
Standing Wave Removal: in HIPE

- FitHifiFringe: HIFI standing wave removal tool. Still being improved based on ongoing PV experience. Makes use of core tasks:

  – FitFringe: fits sine waves to SpectralSegments (basically, any wavelength [in micron!], flux spectrum). Not instrument specific, i.e. could be adapted for use with PACS and SPIRE spectra.

  – SmoothBaseline: used by FitFringe, but can be used in standalone mode (*e.g. getRMS, baseline script*). Returns baseline AND line mask. NOT a polynomial baseline fit, but rather a smoothed, clipped version of the spectrum. Use with care!
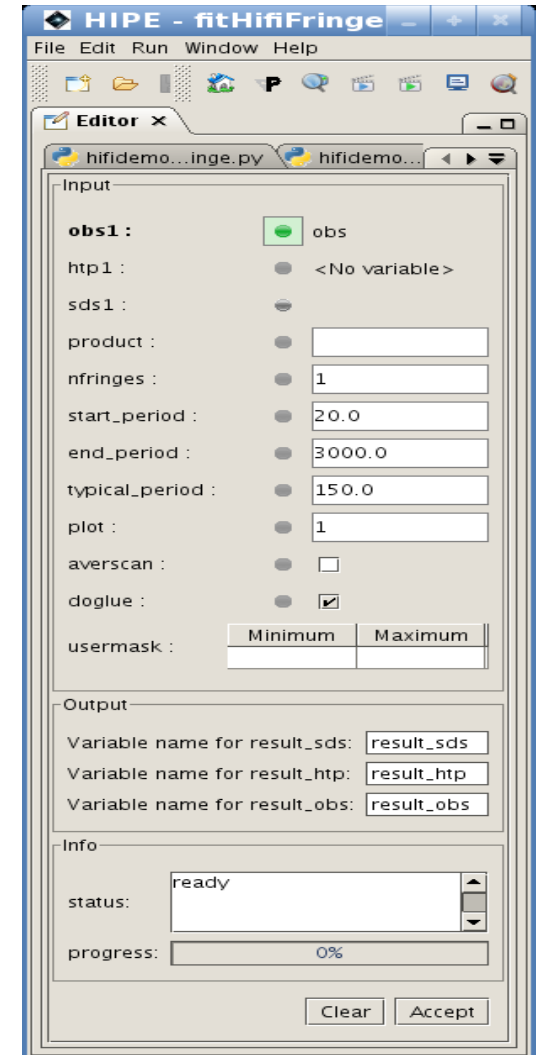
Level 1 → 2 Processing
Standing Wave Removal: in HIPE

FitHifiFringe input:

- **ObservationContext**, **HifiTimelineProduct** or **SpectrumDataset**

- **product** for ObsContext (e.g. WBS-H-USB)

- **nfringes**: number of sine waves to fit

- **start_period**: shortest period SW to search for

- **end_period**: longest period SW to search for

- **typical_period**: typical SW expected in data. Longer period structures are assumed to be baseline or sky features.

- **plot**: 0=not, 1=most important plots

- **averscan**: determine SW from average of all scans, and subtract that from all. Might be useful if waves are weak.

- **doglue**: determine SW on combined sub-bands

- **usermask**: user-defined mask

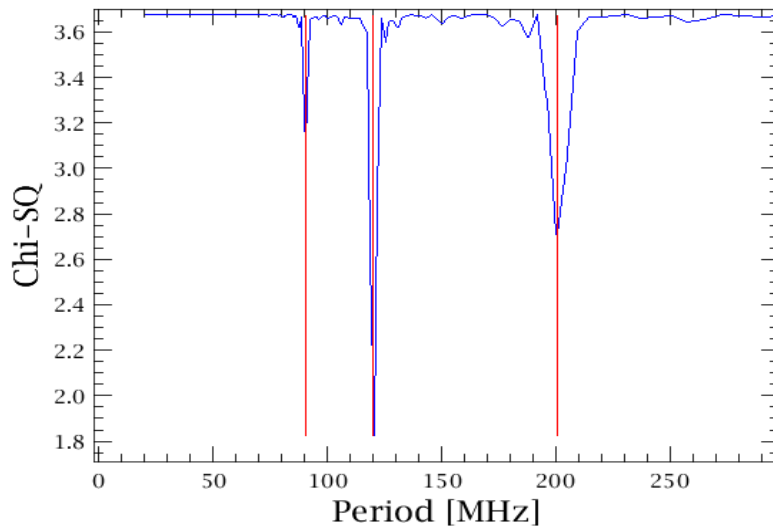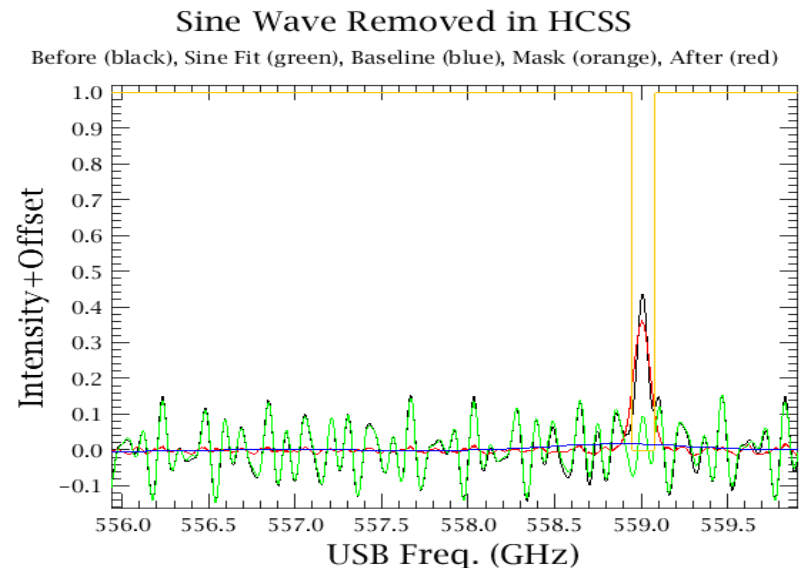Output: sine wave(s)-subtracted data (obs, htp, sds) and list of sine wave parameters fitted

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FitHifiFringe shows fitted periods, amplitudes, phases in HIPE console and by default produces 2 plots:

- Chi^2 as function of period. Minima found are indicated with red vertical lines

- Result plot: input data, sine wave fit, baseline, mask, sine-wave subtracted spectrum

Sine Wave Removed in HCSS

Before (black), Sine Fit (green), Baseline (blue), Mask (orange), After (red)

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Standing waves were successfully removed with FitHifiFringe in all bands, but it cannot be guaranteed for every observation:

- If there are so many lines, that little 'clean' baseline is left

- Bands 3 and 4 'diplexer' waves are not pure sine waves. It helps if lines are near middle of band, where amplitudes are lowest.

- Band 6 and 7 'electronic' waves are not pure sine waves. An alternative 'current-matching' method is being implemented in the pipeline

Known bugs FitHifiFringe in HIPE 2.6, to be solved in HIPE 3:

• Best period at edge search range causes crash. Try changing start_period, end_period, typical_period

• Highest resolution HRS modules cause crash.

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- FitHifiFringe will keep evolving as more PV data becomes available and the 'problem' becomes better constrained

- Suggestions welcome