Specifics and post-processing of HIFI Spectral Scan observation data

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Outline

- Reminder of the HIFI spectral scan observing modes characteristics
- What are the HIFI spectral scan data products
- What are their science readiness and what specific caveats still apply to these data
- HIFI spectral scan data taken as calibration measurements
- Correction measures to these artifacts
- Further recipes for deconvolved data: OFF spectra, band merging and bright lines
The HIFI observing modes - reminder

1 – Position Switch
- **AOT I**
  - Mode I – 1: Point-PositionSwitch
- **AOT II**
  - Mode II – 1: OTF

2 – Dual Beam Switch
- **AOT I**
  - Mode I – 2: DBS
  - FastChop-DBS
- **AOT II**
  - Mode II – 2: DBS-Raster
  - FastChop-DBS-Raster
  - DBS-Cross
  - FastChop-DBS-Cross

Optional continuum optimisation

3 – Frequency Switch
- **AOT I**
  - Mode I – 3: FS
  - Switch
  - FS
  - Switch-NoReference
- **AOT II**
  - Mode II – 3: OTF
  - FS
  - Switch
  - OTF
  - FS
  - Switch-NoReference

Optional sky ref measurement

4 – Load Chop
- **AOT I**
  - Mode I – 4: LoadChop
  - LoadChop-NoReference
- **AOT II**
  - Mode II – 4: OTF
  - LoadChop
  - OTF
  - LoadChop-NoReference

Optional sky ref measurement

AOT III
- **AOT III**
  - Mode III – 2: SScan-DBS
  - SScan-FastChop-DBS
  - SScan-DBS
  - SScan-FastChop-DBS
  - SScan-LoadChop
  - SScan-LoadChop-NoReference

Referencing scheme

AOT I
- Single Point Observations

AOT II
- Mapping Observations

AOT III
- Spectral Scan

The HIFI spectral scan data
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The HIFI spectral scan observing mode

WBS (and HRS) stepped in overlapping chunks of 2.4-4 GHz

Full or partial band coverage
Redundancy 2 to 12

In combination with the following referencing schemes:

Frequency Switch

Double Beam Switch

ON1/ON2

OFF1

OFF2

Chopping/nodding

Load Chop

ON

REF (optional)

Internal load

COLD

The HIFI spectral scan data
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By its Double Sidedand nature, HIFI mixes lines from two frequency ranges.

- The doDeconvolution task allows to reconstruct the spectral information from each sideband individually.
- The assignment of signal to one or the other sideband needs that a line is observed several times at different LO settings (redundancy)
Spectral Scan data in the archive

• **Stand-alone browse products:**
  – Level 2.5 products: 1 *deconvolved* spectrum per WBS spectrometer (H/V)

• **Full observation contexts:**
  – Science data are contained in so-called Level0, Level1, Level 2 and Level 2.5
    – *Level0 are un-calibrated data of little interest to the general user*
    – *Level1 data are still in DSB intensity and on an Intermediate frequency scale, but contain all individual science spectra*
    – *Level2 data are averaged spectra of all individual level1 data, per sideband, per polarisation, per spectrometer*
    – *Level2.5 data are deconvolved spectra (SSB scale) for both WBS – note: HRS data are only optionally taken in this mode*
  – Additional calibration data can be useful for further diagnostic, e.g. spectra from the OFF positions (see also later)
The browse product, or postcard, offers a visual summary of the observation content and quality.

- First assessment of possible data characteristics and artifacts – here combination of baseline and standing wave issues
- In spectral scan observation the postcard illustrates the WBS-H and V spectra from the level 2.5
Some particularly nasty SScans

- There exists Spectral Scans in the archive that were taken with non-standard observing parameters or sequences
- While still publicly released, special care need to be taken when exploiting those data
  - Spectral scans taken in Frequency Switching or Load Chop mode without a Reference – those may feature particularly poor baselines
  - Spectral Scans taken in Frequency Switching modes are not always optimally deconvolved
  - Spectral Scans taken with the so-called “Frequency Grouping” scheme, where calibration taken at a given frequency tuning was shared among neighboring tunings – those may also feature particularly poor baselines
  - Any Spectral Scan observation in Frequency Switching in bands 6 or 7
  - Spectral Scans taken in band 1a (535-553 GHz) prior to OD-496, in band 5a prior to OD-595 and band 7b (1866-1888 GHz) prior to OD-305 will suffer from particularly strong spurs issues

SEE ALSO
Top level products from Spectral scan are the outcome of the deconvolution of the level 2 data from the pipeline.

- This means that any artifacts, esp. spurs or standing waves still present there, will be *propagated* in the final products, sometimes in the form of *spectral ghosts*.
- As of HIPE 13, spurious features are cleaned by the pipeline, but other baseline residual will remain and therefore be present in the level 2.5 as well.

Deconvolved output from data with an unflagged spur. The iterative nature of the algorithm propagates the spur over the entire spectral range.

Same spectrum, this time with the spurs masked out. The result reveals some baseline issues that now need to be addressed.

Final result after simple median baseline subtraction of each individual level 2 spectrum.
Data Readiness in Spectral Scan mode

• **How can I further improve my Spectral Scan data**
  
  – **Option 1**: Work from the final deconvolved products
    
    – In principle the standard baseline cleaning tasks (e.g. *FitHifiFringe*) can work on large spectra such as those resulting from the deconvolution
    
    – Those spectra can, however, contain a very large number of channels and the structure of the artifacts present in individual level 2 spectra can be altered in the deconvolved data making its fits more complex
  
  – **Option 2**: Work from the level 2 individual tuning products and perform the deconvolution yourself on the clean spectra
    
    – This is the most commonly used approach, allowing to clean individual level 2 spectra in an optimum fashion and combined the clean data into the deconvolution algorithm
    
    – The approach is the same as for the Single Point mode data (see dedicated talk in this workshop) applied to the collection of level 2 spectra forming the survey
    
    – You need to get those level 2 data in the observation context
    
    – The deconvolution is done through the HIPE *doDeconvolution* task
HIFI data deconvolution

The doDeconvolution task

- Can treat several obsids at a time
- One polarisation at a time
- Ignores spurs marked with flags
- Uses best a priori knowledge of Sideband ratio

The HIFI spectral scan data
Spectral Scan on OFF positions (1)

- **Information from the OFF positions**
  - A synthetic spectrum of the data acquired on the reference positions is also provided within the observation context *(note: it will eventually be served stand-alone as an HPDP but this will not be before HIPE 14)*
  - In the observation context it can be accessed at `obs > calibration > pipeline-out > ReferenceSpectra`
    - It is possible to run the deconvolution task also on those OFF data in order to create a spectrum directly comparable to that of the stand-alone browse products
    - Beware that these synthetic spectra have noticeably poorer baseline quality, esp. strong standing wave residual – in HIPE 13 these will also suffer from spurs but in HIPE 14 the masks applying to ON-target data will be propagated to the OFF spectra
    - See more information in the cookbook:

Spectral Scan on OFF positions (2)

- **Information from the OFF positions**

![Graph showing Orion Bar – band 1a, ON-target deconvolved data, and OFF-target deconvolved data.](image)
Deconvolution of multiple bands

The deconvolution task: multi-obsid processing

- By essence the redundancy of data at band edges of an individual spectral is poorer as only one sideband can be sampled
  - **Sub-optimal SSB line intensity recovery**
  - **Increased noise at band edges**
- However most HIFI bands are overlapping in sky frequency, allowing to fill in this information gap and optimize the SSB solution computation

- doDeconvolution allows to combine several obsids in that respect with optional variable `obs2_array`

- Several items however need to be borne in mind:
  - **Astrometry in combined observations will not be strictly the same**
  - **Sideband ratio may not be the same for a line featured in two different sidebands of two different obsids**
  - **You should not combine data from different mixer bands (e.g. band 4 and 5) when they are still in the $T_A^*$ scale since the telescope coupling was different** – combination shall be done once transformed to a physical scale
The deconvolution task: multi-obsid processing

- Example: a multi-band spectral scan of Mars shown on the $T_A^*$ scale
- Because observations are done at different dates (i.e. different apparent diameter of Mars) the overall coupling to Mars differs from band to band
- The combined spectral scans need to be done in brightness temperature
Deconvolution with bright lines

- Relatively bright lines can lead to negative ghosts in the deconvolution output (generally in the image sideband from where the bright line lies).

- An option exists in `doDeconvolution` that allows to ignore channels flagged as `BRIGHT_LINE` – some tricks are however needed in order to generate a final spectrum both containing strong lines but without ghosts.

See script provided in Scripts > HIFI Useful Scripts > Bright Line Deconvolution
**Possible further steps towards data analysis**

- Polarisation average of the H and V deconvolved spectra
- Unit and scale transformations: Frequency scale conversion, or intensity conversion into main beam antenna temperature or flux density

*Please refer to the workshop talk dedicated to Data analysis and flux extraction for more details*
QUESTIONS