

The HIFI AOTs

Herschel OT-1 Uplink Workshop

ESAC, 3-4 June 2010

Anthony Marston
Herschel Instrument and Calibration Scientist
Team Lead,
Herschel Science Centre, ESAC.

Overview:

- **Full information about pointed modes are contained in the ‘HIFI Observers’ Manual v2.0.’**
- All point observation modes have the following
 - **Full frequency range of all available HIFI mixer bands.**
 - **All available resolutions of the High Resolution Spectrometer (HRS). Note: At high frequencies the highest resolution mode is effectively redundant.**
 - **Wide band (WBS) and high resolution (HRS) spectrometers can be used in parallel (up to 3 resolutions at one time).**
 - **Target, LO frequency and position of subbands of the HRS always selectable for all modes.**
 - **All pointed observations provide dual sideband data only.**

Overview II:

- Timing of sequence of observations/pointings for pointed observing modes based on time or noise and required resolution requested by user.
 - **Timing based on system stability times for the given band.**
 - **Time between needed load calibrations.**

The HIFI pointing modes

- *Single point* observations
- *Mapping* observations (*raster-like*, or *On-the-fly*)
- *Frequency surveys*

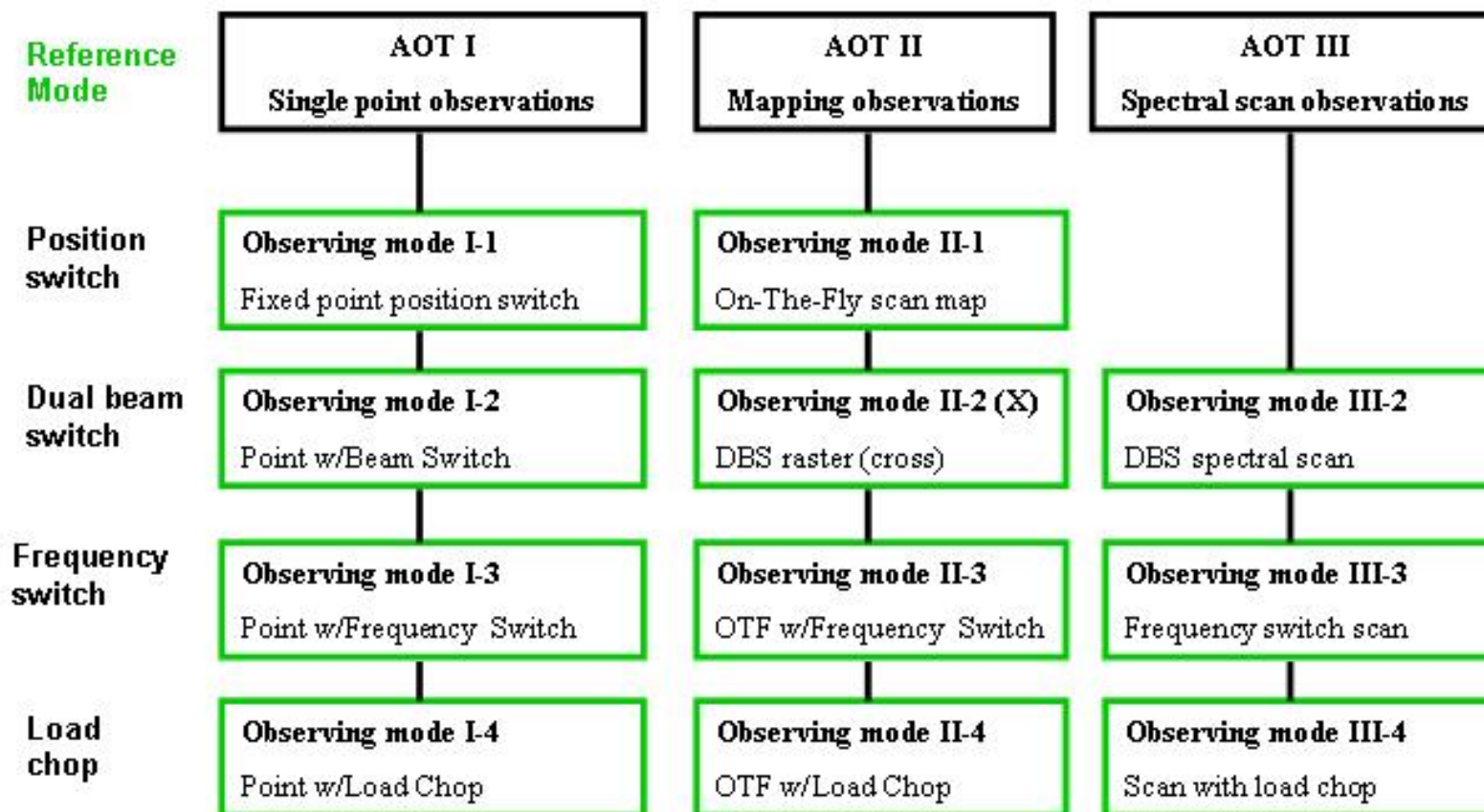
Observations are allowed for only 1 tuned frequency (*LO* frequency)

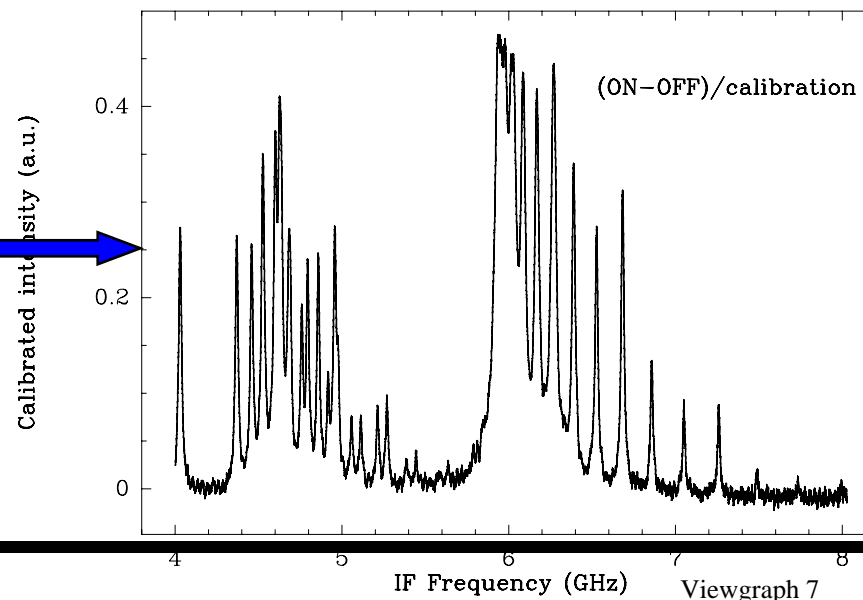
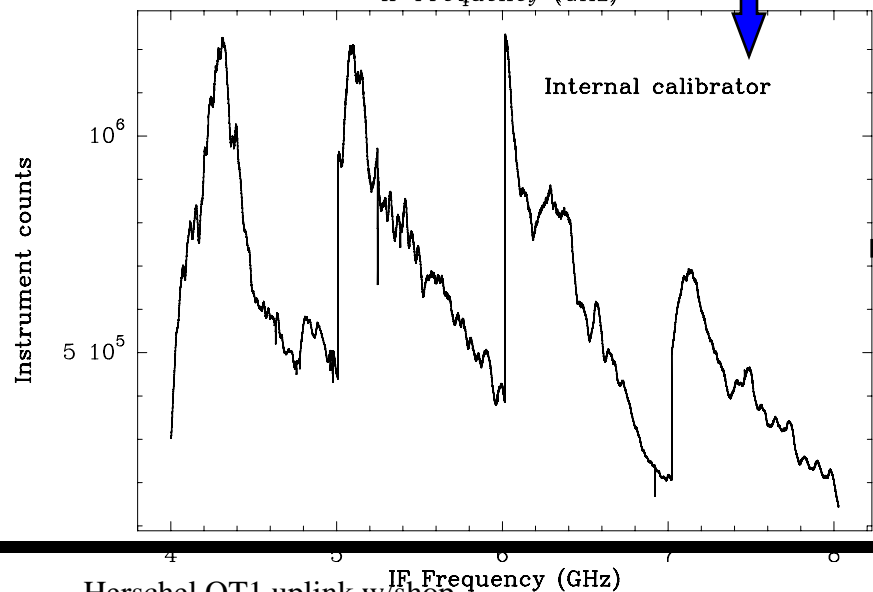
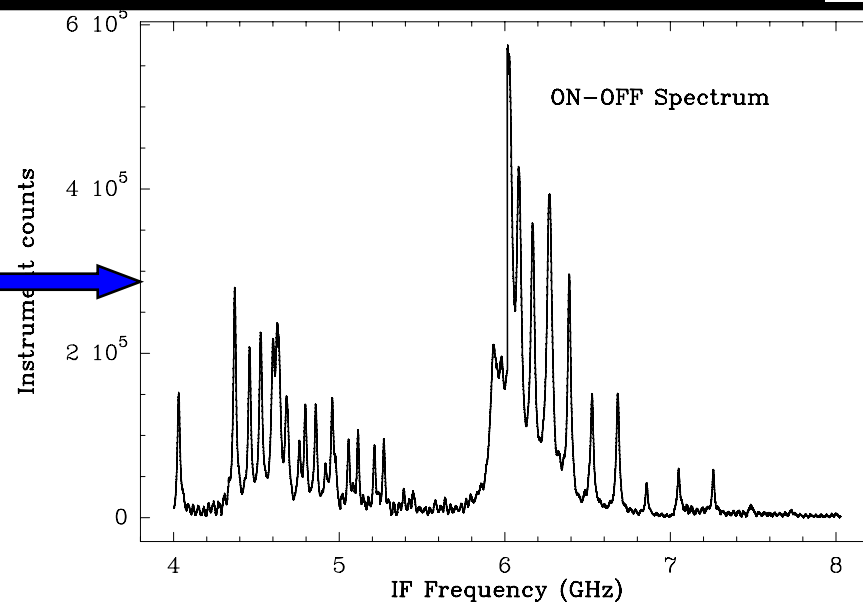
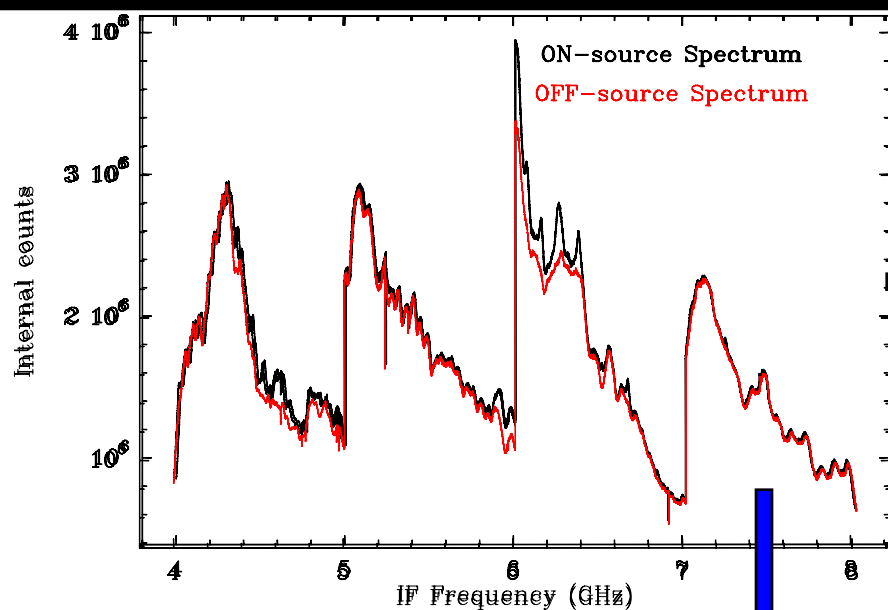
Observations offer several frequencies but are allowed for only 1 line-of-sight

HIFI Observing Modes Available

- Basically a choice of reference (ON – OFF) schemes whether *pointed*, *mapping* or *spectral scan*.
- *Dual Beam Switch (DBS)* – uses chopped positions either side of target for reference.
- *Position switch/OTF map* – uses single position within 2 degrees of the target for reference (no chopper).
- *Frequency switch* – uses neighbouring frequency as a reference (no chopper).
- *Load Chop* – uses internal load for reference.

HIFI Modes





Dual Beam Switch (DBS)

- Purpose:**

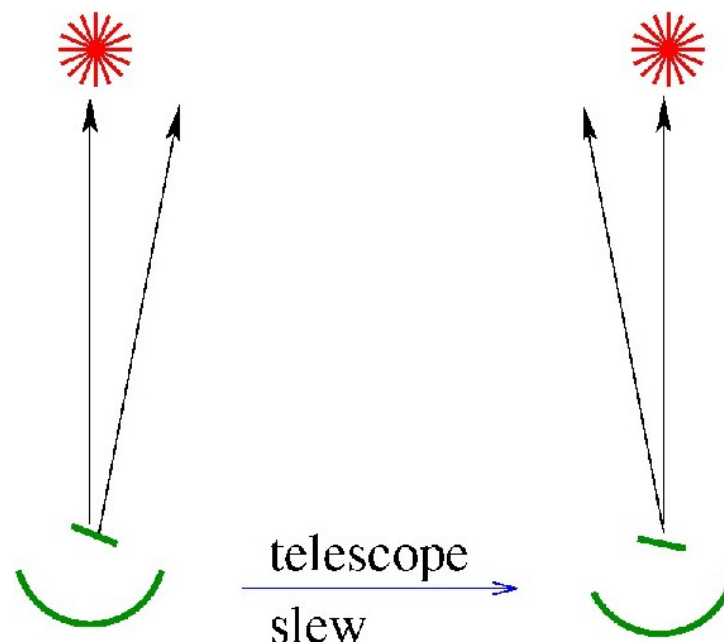
Used for spectral line or continuum measurements of isolated point sources.

- Description:**

Chopper is used in two positions to look at target plus position offset 3', for a number of chopper cycles

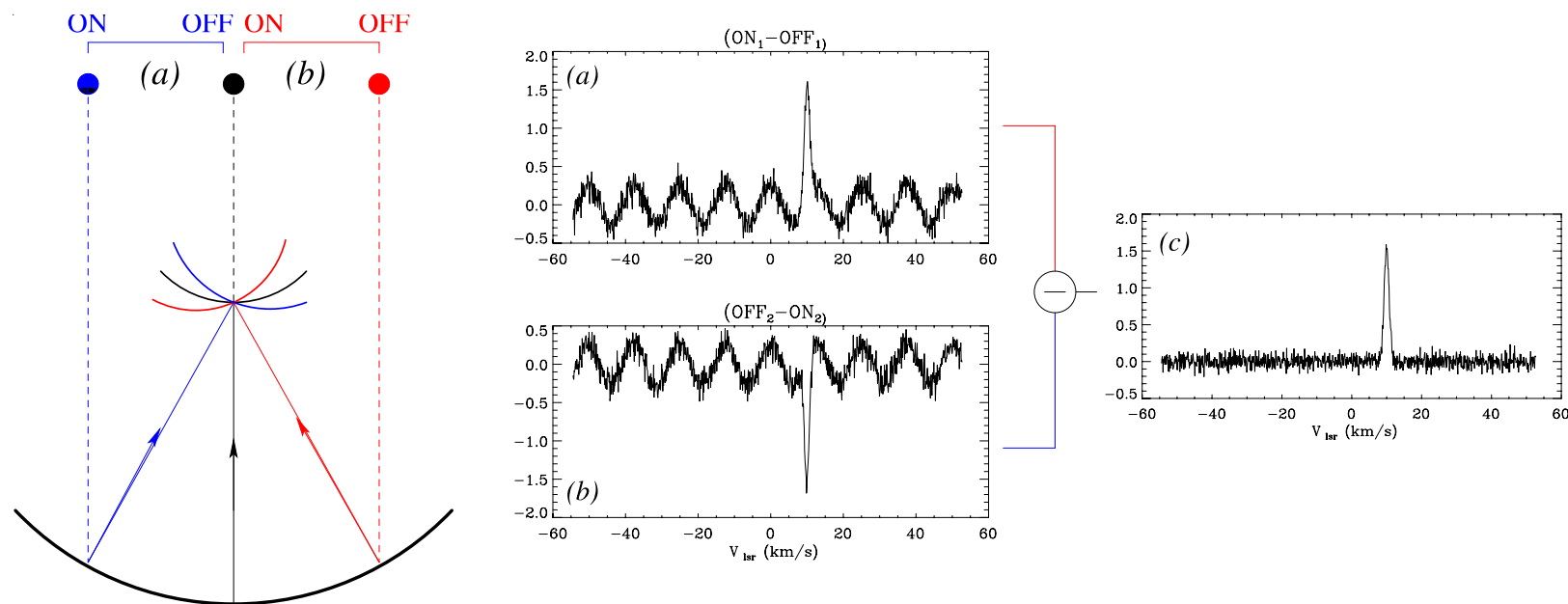
Telescope slew then to place target in second of chopper positions and chopping sequence repeated.

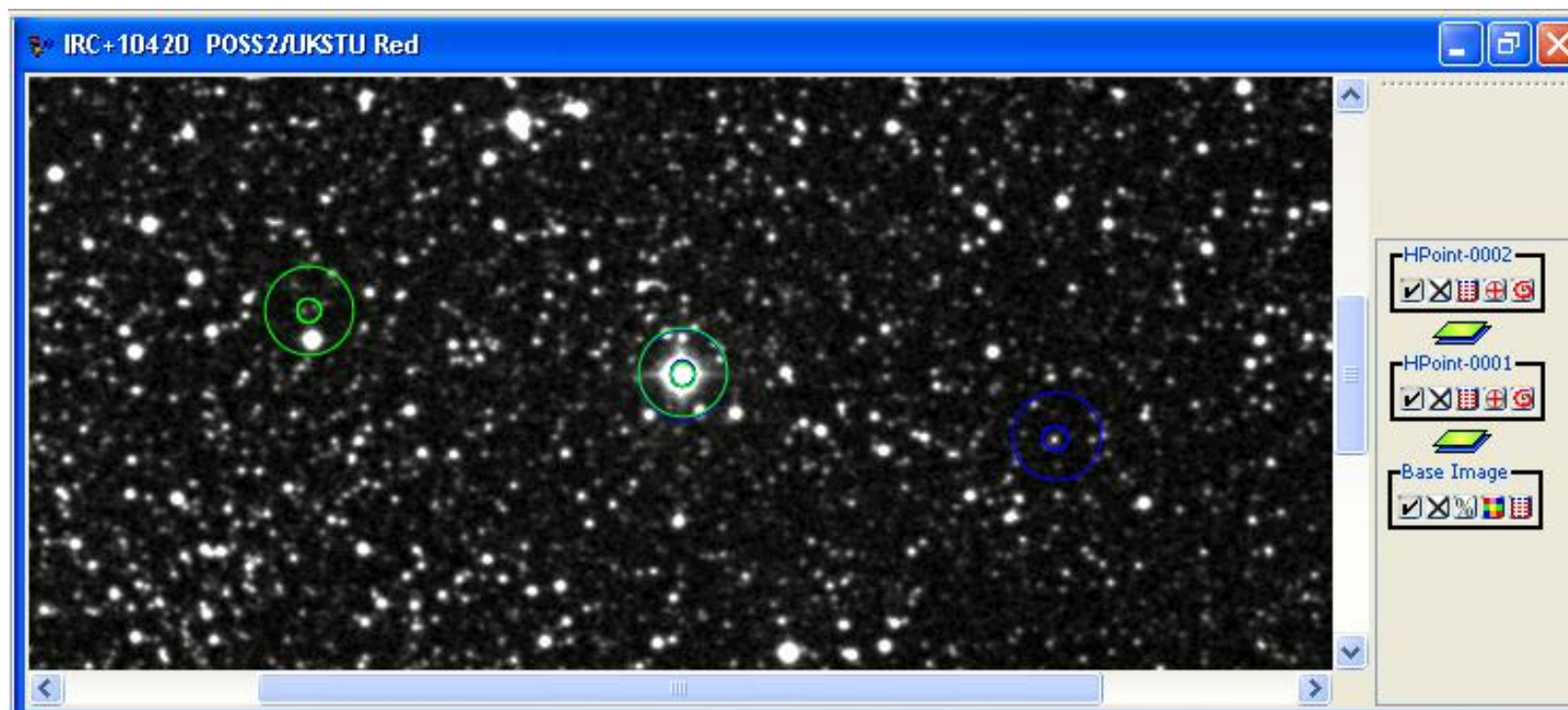
Combination (double difference) allows for removal of standing waves (e.g., due to light path differences) and linear instrumental drifts.



Robust – good for standing wave removal.

Continuum measurements are possible – but more telescope movement necessary.



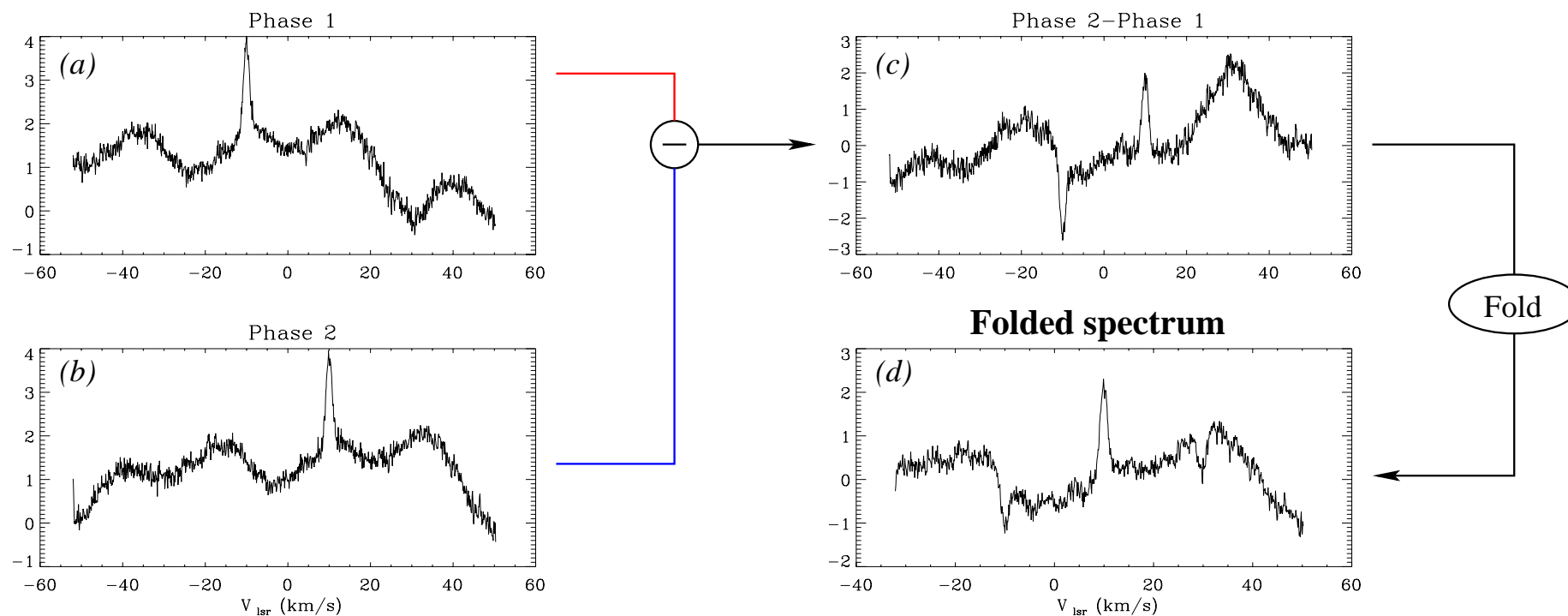


Position Switch Observations

- **Purpose:**
- For spectral line or continuum measurements for objects that are in regions of extended emission ($> 3'$ across).
- **Description:**
- Instrument integrated on the target with continuous data dumps to the satellite.
- After a period of time, based on the instrument stability, an OFF reference is made at a second telescope position.
- [Calibration is done against internal hot/cold load measurements – taken during slews.]








Frequency Switch (w/OFF)

- **Purpose:**
- Efficient mode for emission-line source measurements. **No continuum information.**
- **Description:**
- Reference is made between two observations at slightly different LO frequency settings.
- Accurate baseline measurements need the use of an OFF reference position, that is viewed at both LO frequencies.
- Double differencing gives most accurate baselines but at a cost in terms of time.
- **NOT RECOMMENDED FOR USE WITH BANDS 6 AND 7**



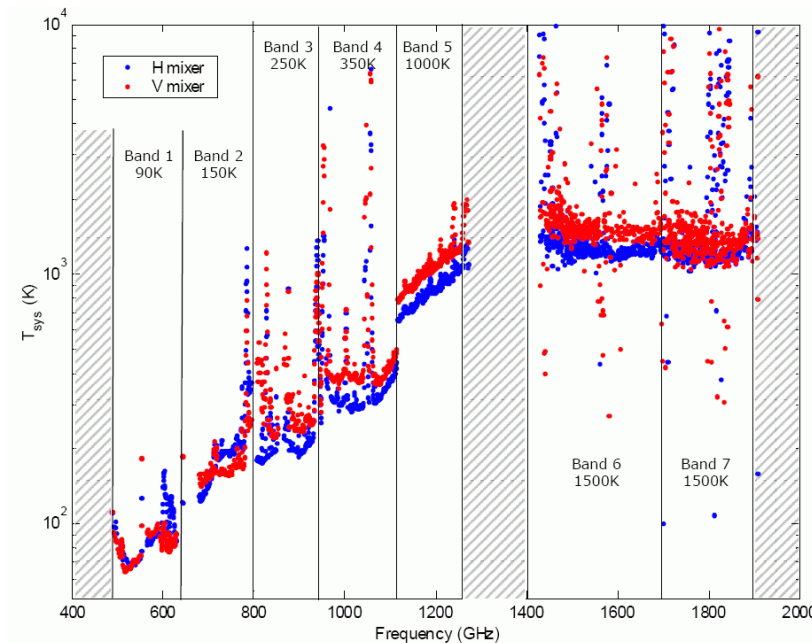
Load Chop (w/OFF)

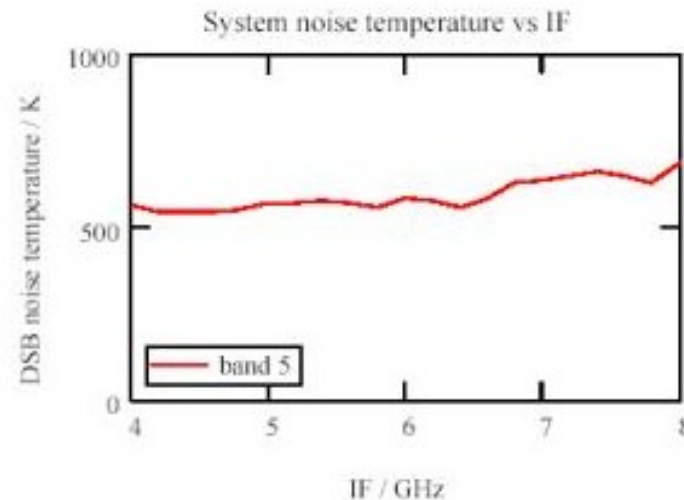
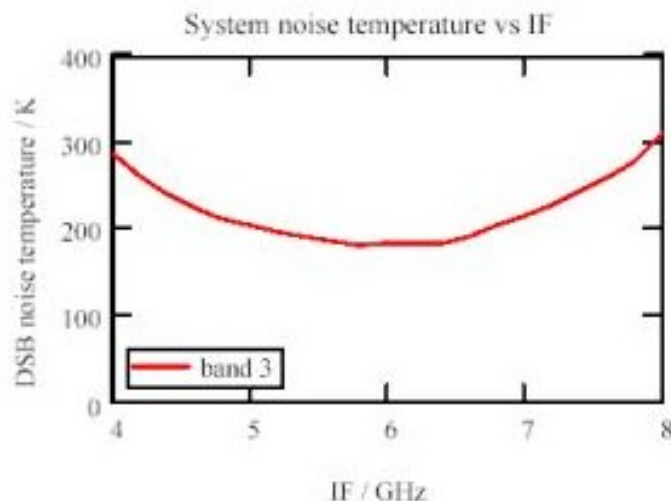
- Purpose:
- Spectra of single sources, particularly where no nearby reference OFF position is readily available and short stability times.
- Description:
- Similar to the frequency switch mode except that the cold internal calibration source is used for the reference.
- Double differencing (by similar data taking on an OFF position) allows for accurate baseline determination at the expense of observing time.

Mode	Best Used For....	Notes	Efficiency
<i>DBS</i> (+ <i>fast chop</i>)	For point sources, small extension	Fast chop for short stability times	
<i>DBS</i> (<i>cont. timing</i>)	Improved continuum accuracy.		
<i>Frequency Switch</i> (w/ <i>OFF</i>)	For sources with low (narrow) line density + no near reference	No continuum measures	 ()
<i>Position switch</i>	Basic mode – no clear nearby reference source		
<i>Load Chop</i> (w/ <i>OFF</i>)	For sources with high line density or broad lines + no near reference	Fall-back wrt position switch	 ()

Sensitivities

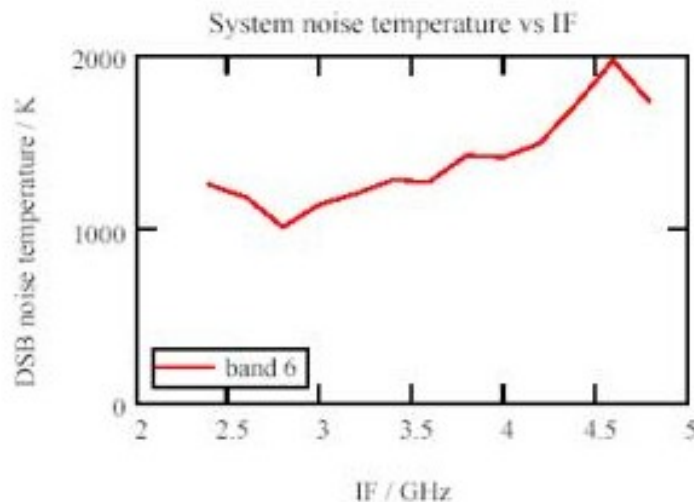
- Given as single polarization, single sideband values in HSpot and based on in-flight measurements.
- Noise levels are for best placement within the visible 2.4 or 4GHz bandwidth of the IF band.





Generic plots of noise across the frequency range seen at one time.

Diplexer SIS (top left), beamsplitter SIS (top left), HEB band.



HiFi Single Point Observation

Unique AOR Label:

Target: Saturn Type: Moving Single
NAIF ID: 699 - pos. ephemeris dependent

Number of visible stars for the target: None Specified

Instrument Settings

Mixer settings

Mixer band:

Low limit (GHz):

High limit (GHz):

Redshift selection

Radial Velocity:

Redshift:

Frame:

Spectrometer choice

Select the spectrometer to use:

WBS Resolution (MHz):

Separate setup for each polarisation of HRS sub-bands?:

The HRS Mode for H or both polarisations:

HRS Resolution (MHz) for H or both polarisations:

The HRS Mode for V polarisations:

HRS Resolution (MHz) for V polarisation:

Frequency Settings

Observing Mode Settings

Time Estimator Settings

Observing Mode Settings

Choose one of the modes below:

☐ No mode selected ☐ Load Chop ☐ Position Switch ☐ Frequency Switch

Selections:

☐ Fast Chop Selected

☐ Stability Optimisation for Continuum

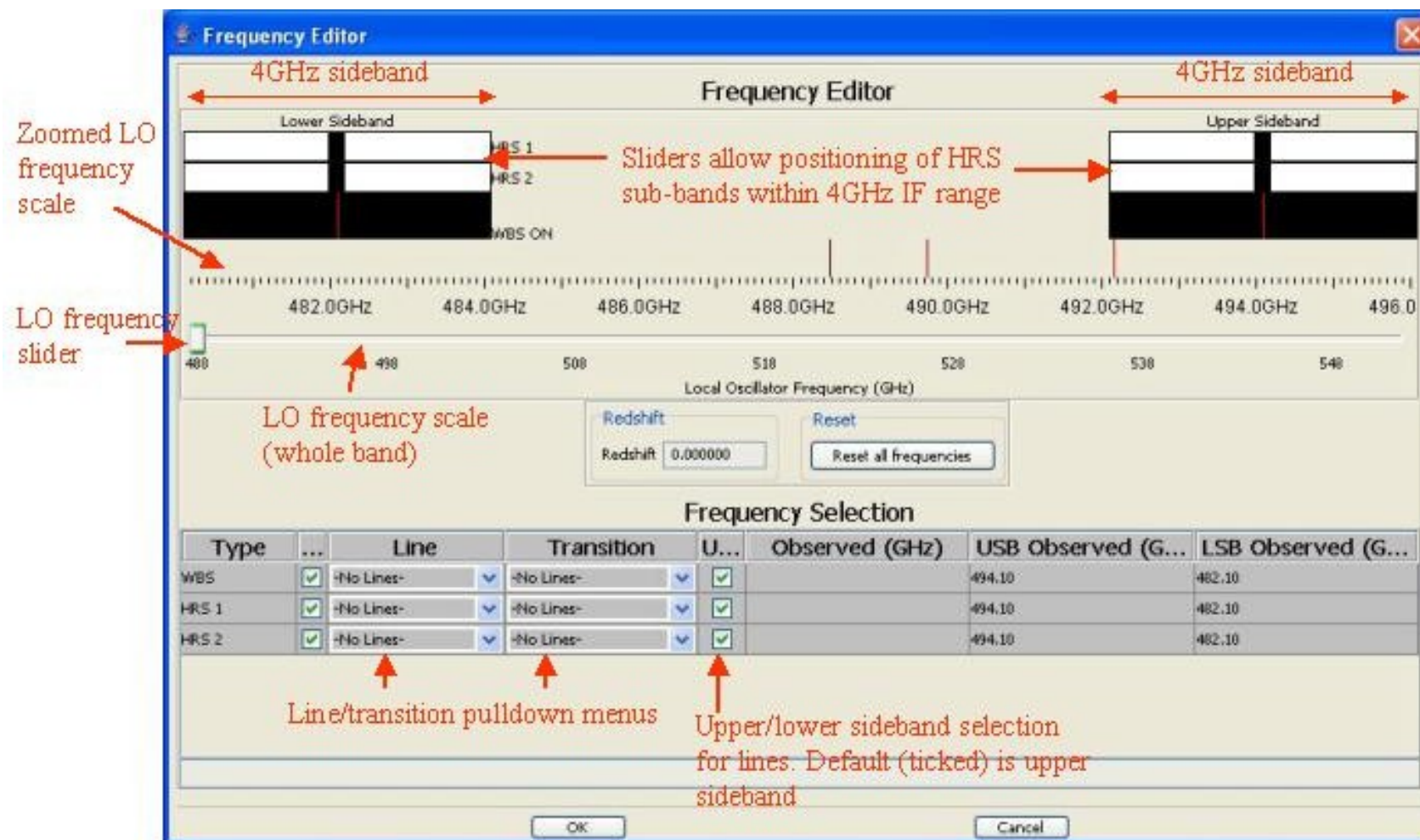
Time Estimator Settings

Estimate Type:

Resolution units:

☒ One GHz Reference

LOF	Goal resolution minimum	Goal resolution maximum	Time (s)	Noise (K)
LOF 1	0.480	10.000	180	0.100



Mapping Modes

- Similar to point modes, except moving/scanning across target – so OTF w/ OFF is similar to position switch.....
- Exception is DBS raster (DBS at given positions).
- No cross mode at present.

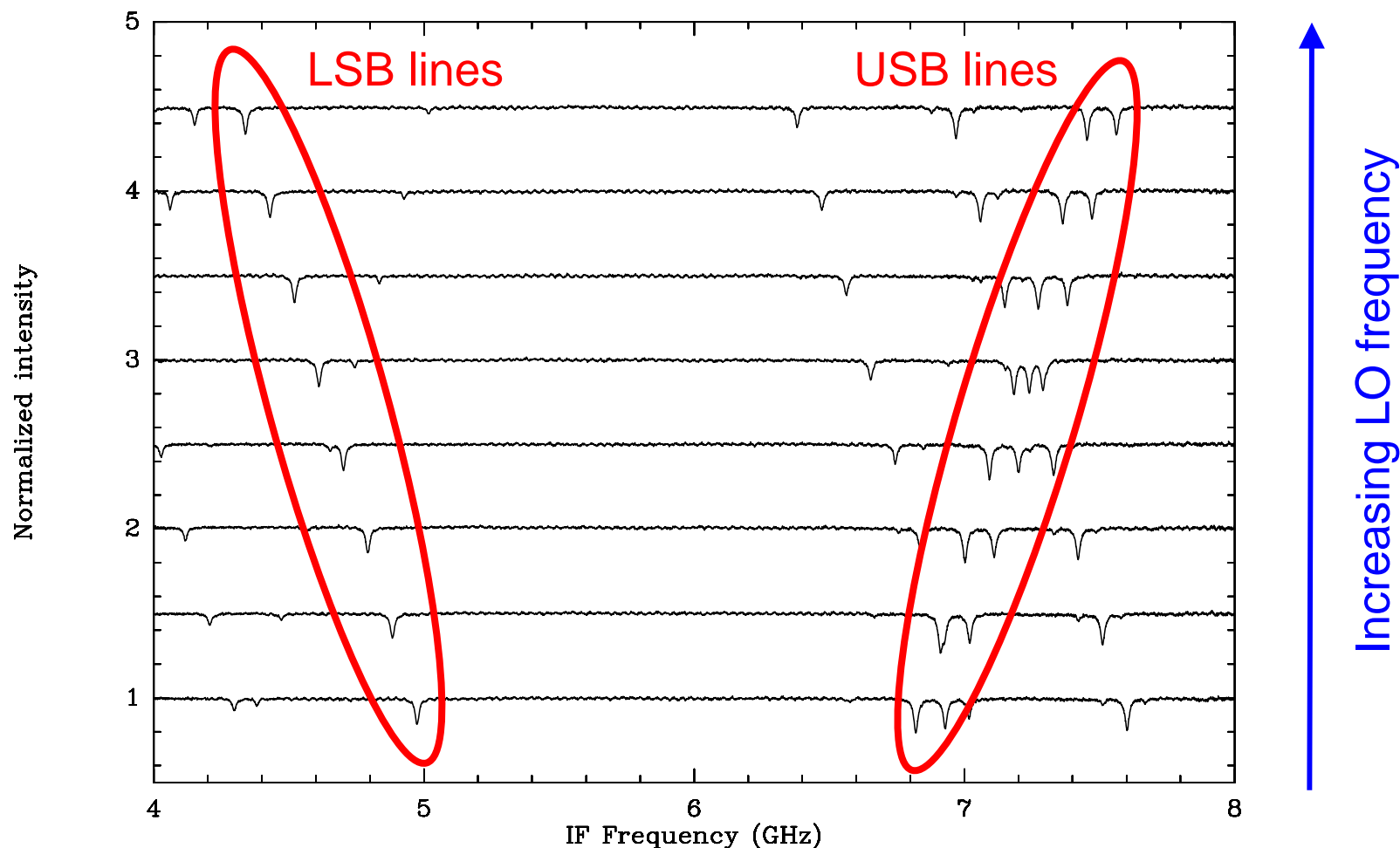
Spectral Scans

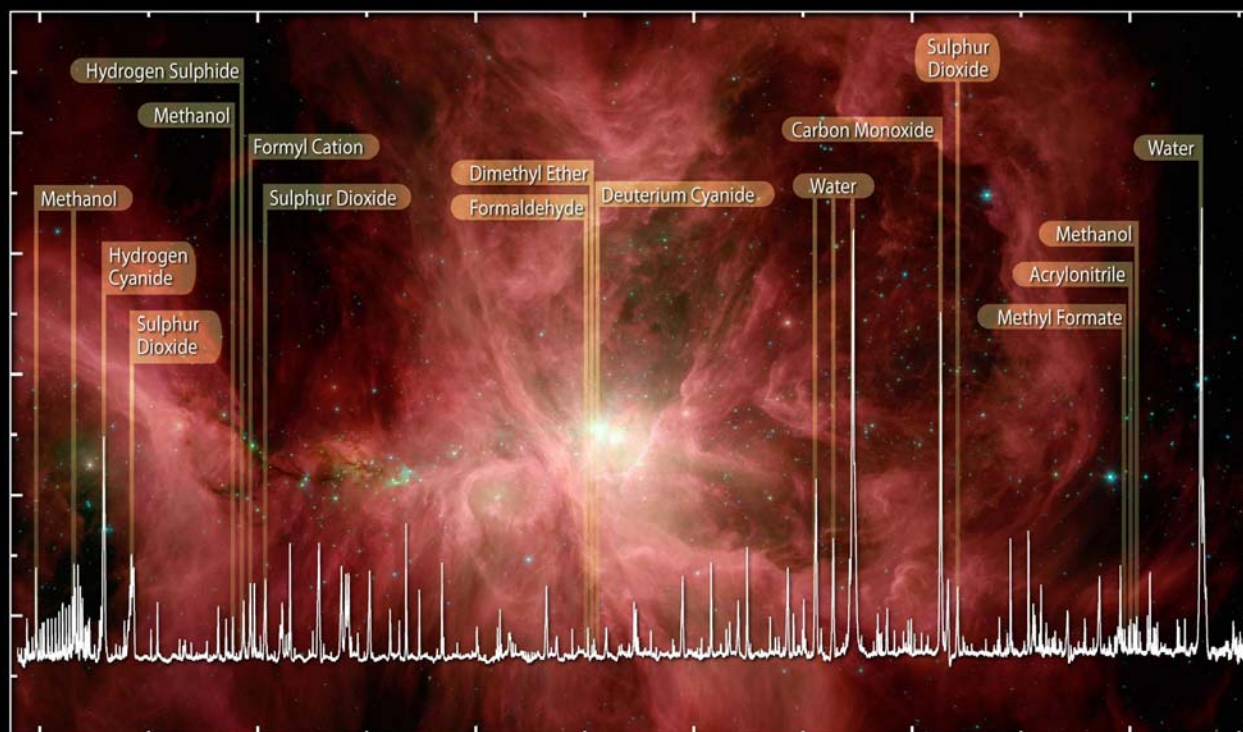
- *Single source* observations
- *Multiple frequency* settings extended over frequency coverages larger than the IF bandwidth
- Largest frequency coverage per AOR is presently limited to that of a complete LO band (H/W stabilization issue)
- Use of the *WBS* spectrometer only (instantaneous coverages of 4 GHz @ 1.1 MHz resolution)
- Use of DBS, Load Chop or Frequency Switch (do not use with bands 6 and 7).

Redundancy in Spectral Scans

- Because HIFI is a *double-side-band (DSB)* instrument, observations need to be *deconvolved* in order to assign sky frequencies to spectral lines
- Lines belonging to different side-bands will move in opposite directions in the IF at various LO frequencies, observations at frequency steps smaller than the IF bandwidth allow us to distinguish which sideband they are in.
- The number of independent LO tunings per IF bandwidth is called *redundancy*.
 - Low redundancy (2-3) are sufficient to deconvolve very simple spectra (assignment can almost be done by eye)
 - High redundancy (6-8) are needed for crowded spectra, esp. since they will mix very strong and very weak lines

Example Ground Test Survey





HIFI Spectrum of Water and
Organics in the Orion Nebula

© ESA, HEXOS and the HIFI consortium
E. Bergin

HiFi Spectral Scan

Unique ADR Label:

*Target: **ngc1333** Type: **Fixed Single***
*Position: **3h29m01.92s,+31d20m52.8s***

Number of visible stars for the target 22
 Star tracker target Ra: 232.258 degrees Dec: -31.348 degrees

Mode Settings

Settings

Mixer band:

Range:

Range From (GHz):

Range To (GHz):

Redundancy:

WBS Selection:

Only the WBS is used in this mode

Observing Mode Settings Time Estimator Settings

Observing mode settings:

Time estimator settings:

Observing Modes

Observing Mode Settings

Choose one of the modes below

Reference Position

Specifications

Type: ☒ By offset ☐ By position

RA offset (arcmins):

Dec offset (arcmins):

RA (degrees):

Dec (degrees):

Time Estimator Settings

Time Estimator Settings

Estimate Type:

Resolution units:

☒ One GHz Reference

LOF	Goal resolution minimum	Goal resolution maximum	Time (s)	Noise (K)
LOF 1	1.100	10.000	1800	0.100

Timing of Observations

Reference loop

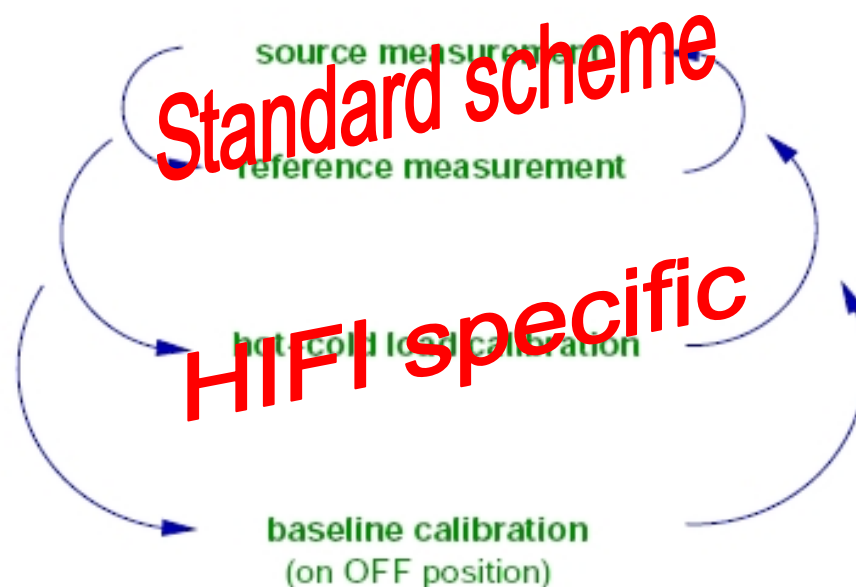
length determined by system
Allan time t_A

Bandpass calibration loop

length determined by band-
pass stability time $t_{A,load}$

Baseline calibration loop

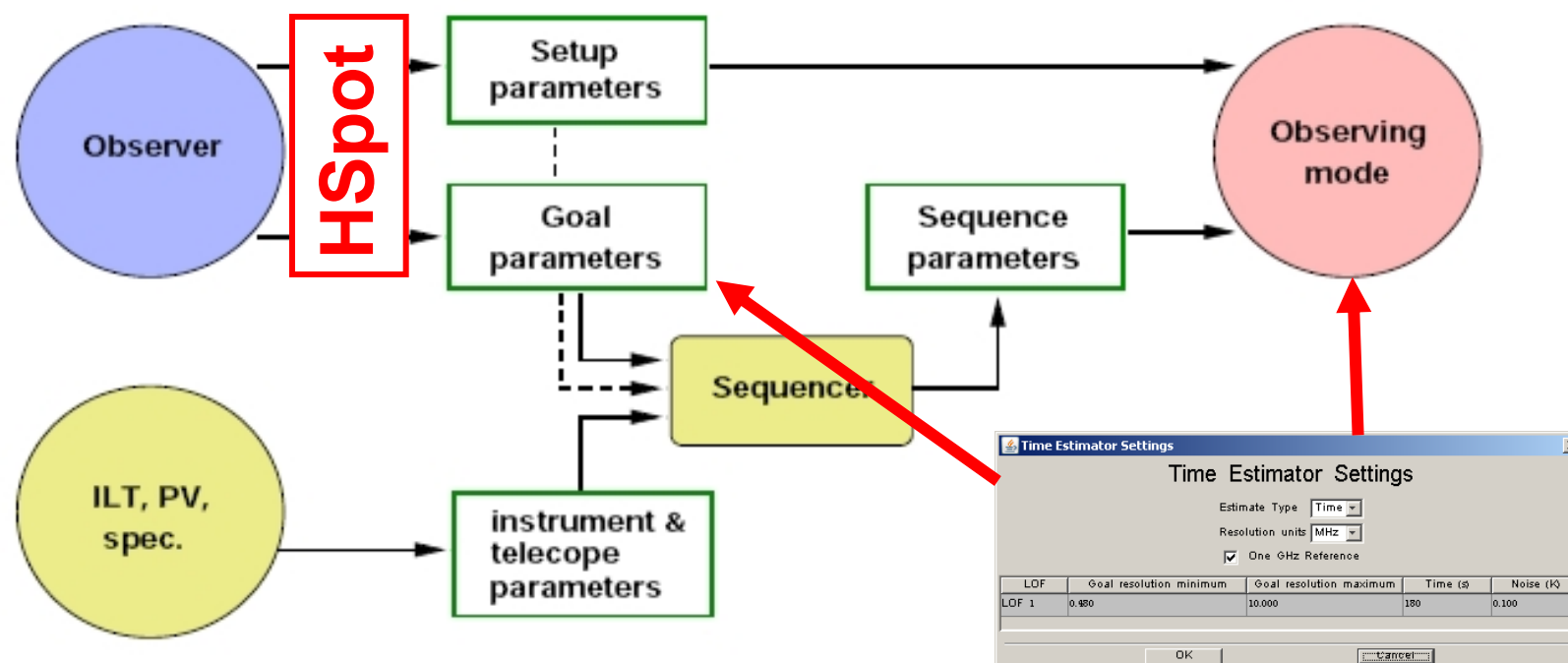
length determined by standing
wave Allan time $t_{A,sw-diff}$



- Observations are organised according to a hierarchical structure of loops reflecting the various timescales of the instrument stability (measured in terms of *Allan times*)

Making Time Estimates

- Observing sequence parameters (number of loops/cycles, elementary readout times, etc) are derived from *goal parameters* via a *sequencer*
- The *sequencer* optimises the timeline to minimise the noise per observing time



Summary

- HIFI is very versatile for use in high-resolution spectroscopy.
- Requires reference spectra – regular chopping or switching of the telescope. Generally, quicker is better, especially at the higher frequencies.
- Some frequency areas not so good and for high frequency bands frequency-switch is highly discouraged.
- Much information available to help in HSpot – see hands-on information later.