Terahertz Spectroscopic Measurements using the SHIRM-WBS II Breadboard

Instrument development & deployment in support of STEAMR

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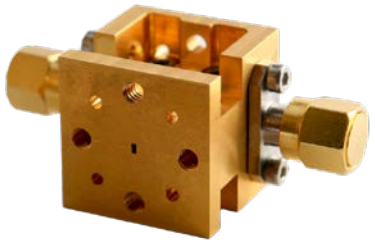
Outline

- SHIRM-WBS II radiometer
  - Instrument
  - Characterisation
- Spectroscopic Measurements
  - Desorption emission spectroscopy
  - Results
- Conclusions

STEAMR Instrument Concept

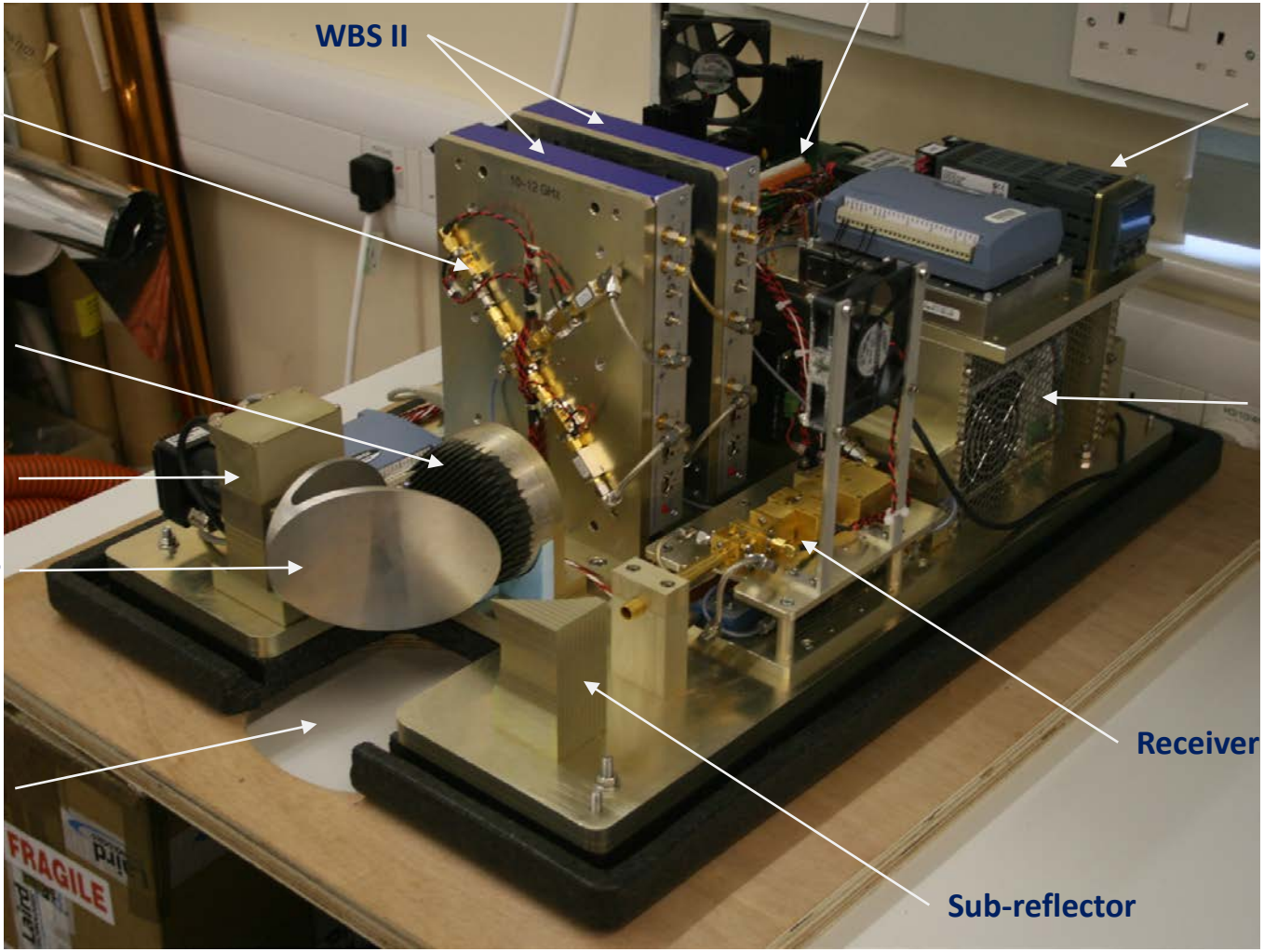
- STEAMR
  - Stratospheric Tropospheric Exchange & Climate Monitor Radiometer
  - Swedish mm-wave limb-sounder instrument concept
- Spectral coverage
  - LSB: 323.5-335.5 GHz (H_2O, O_3, N_2O, HNO_3…)
  - USB: 343.5-355.5 GHz (CO, HCN, ClO, N_2O…)
- Sub-harmonic image-rejection mixer (SHIRM)
  - Key component in sideband separating receiver (2SB)
  - System Noise temperature : ~4000 K
- High-speed digital spectrometers:
  - 2048-point complex FFT
  - Up to 3 GHz Bandwidth/Sideband
  - Spectral resolution : up to 1 MHz



SHIRM component

(WBS II Unit: L=165mm, W=220mm, H=30mm)

SHIRM-WBS II Instrument



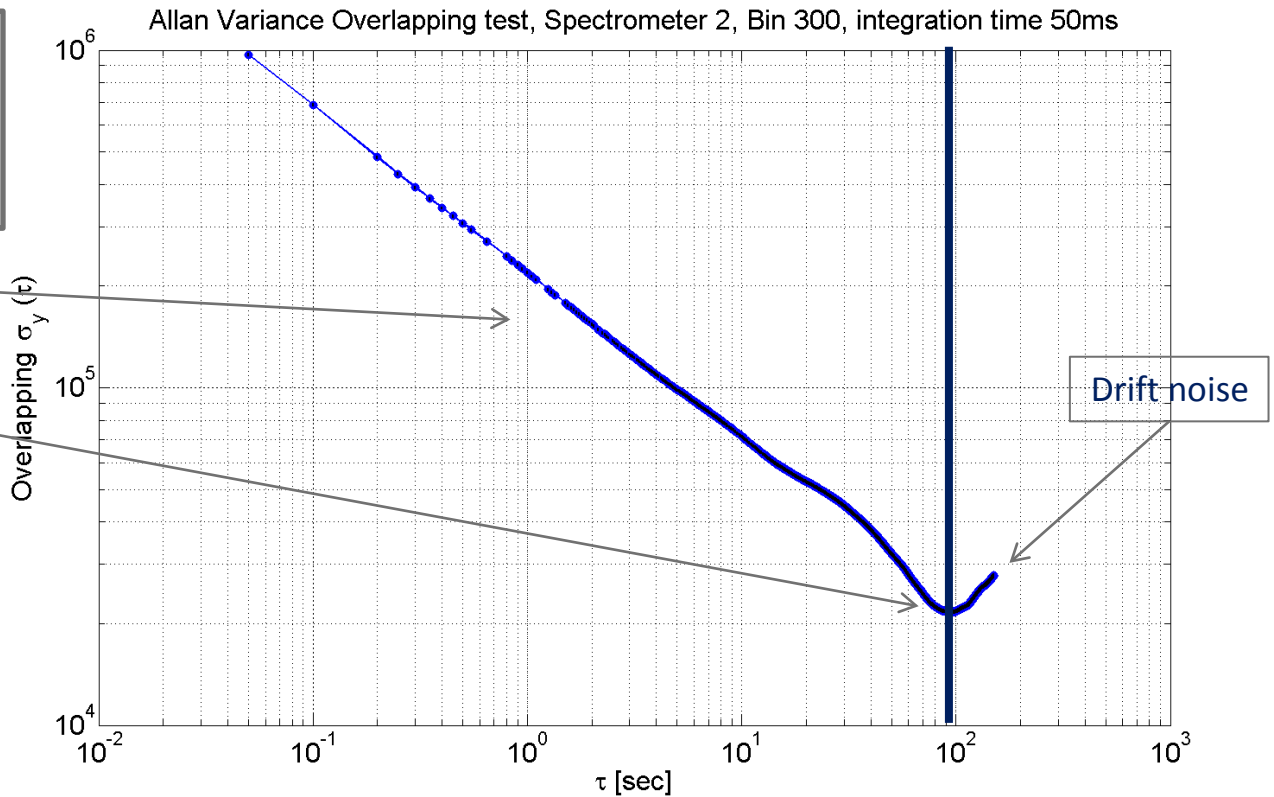
Stability

- Allan Variance test : Standard deviation over time for each spectrometer bin
- Excellent stability (well controlled environment)
- Long integration time achievable ⇒good sensitivity

LO = 334 GHz
Fs = 2,5 GHz
USB
Scene Temperature : 302,05-302,36 K

Thermal - Shot Noise

Flicker noise



⇒ Optimal integration time : above 30s

Sensitivity

- NEδT test: Sensitivity of the instrument :

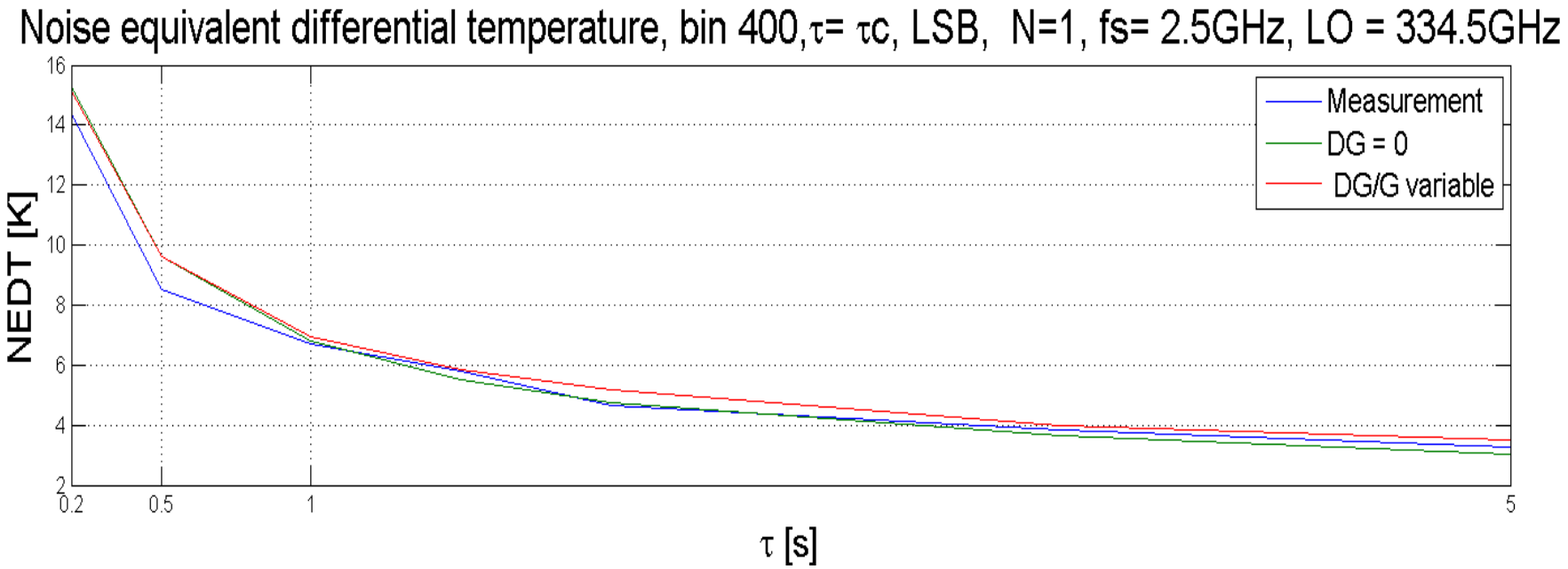
$$NE\delta T = (T_{syst} + T_{scene}) \times \sqrt{\frac{1}{B \times \tau} + \left(\frac{\Delta G}{G}\right)^2 + \frac{1}{B \times N \times \tau_c}}$$

τ : Integration time

T_{syst} : SSB receiver noise temperature

$\frac{\Delta G}{G}$: receiver gain variation

B : Channel bandwidth



- Small integration time = high $NE\delta T$
- Gain variation at high integration time

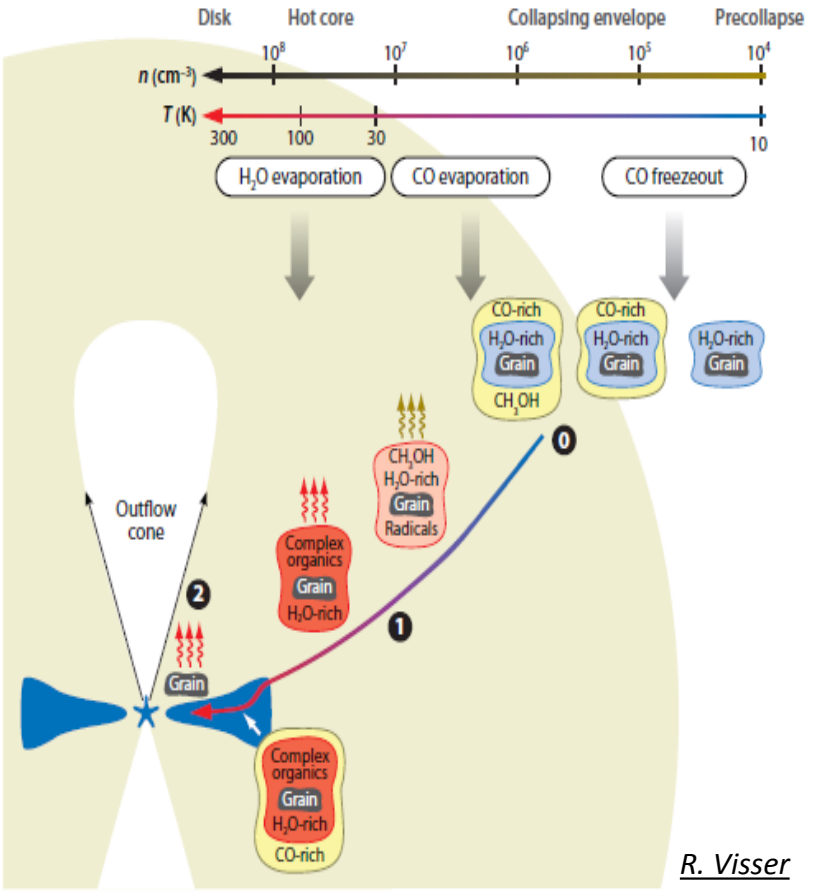
- Small spectral Res = small $NE\delta T$
  - ✓ Bin number
  - ✓ Sampling frequency

Desorption emission spectroscopy

- Desorption processes involve during star formation
  - Ro-vibrational features of molecules sublimating from the ice
  - Chemistry within the ice mantles
  - Two desorption mechanisms

- Key Objectives
  - Laboratory based experiment
  - Comparison between desorption mechanisms
  - Corroborate results with ALMA telescope
  - Star formation models

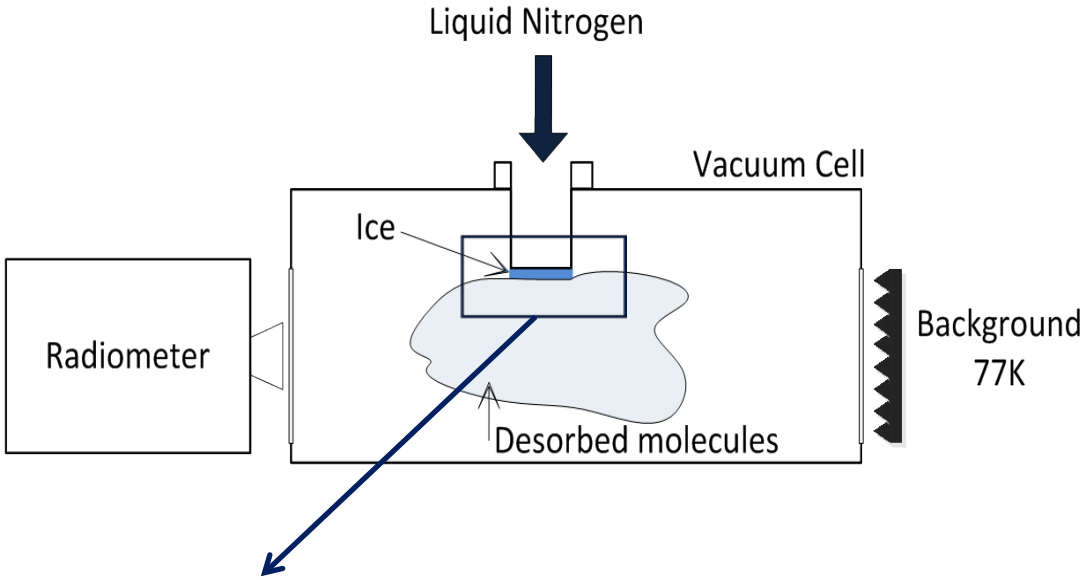
Star forming Region

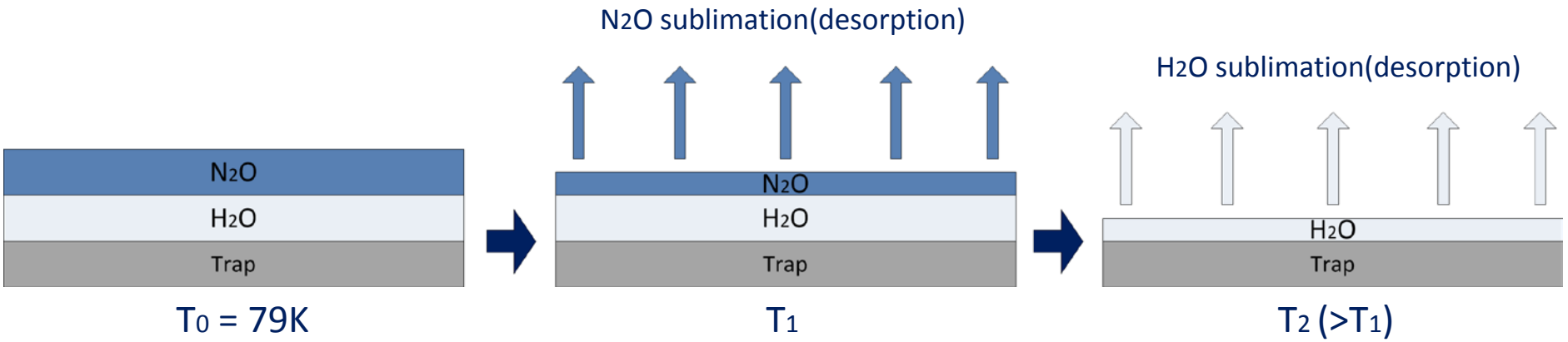


R. Visser

Desorption emission spectroscopy

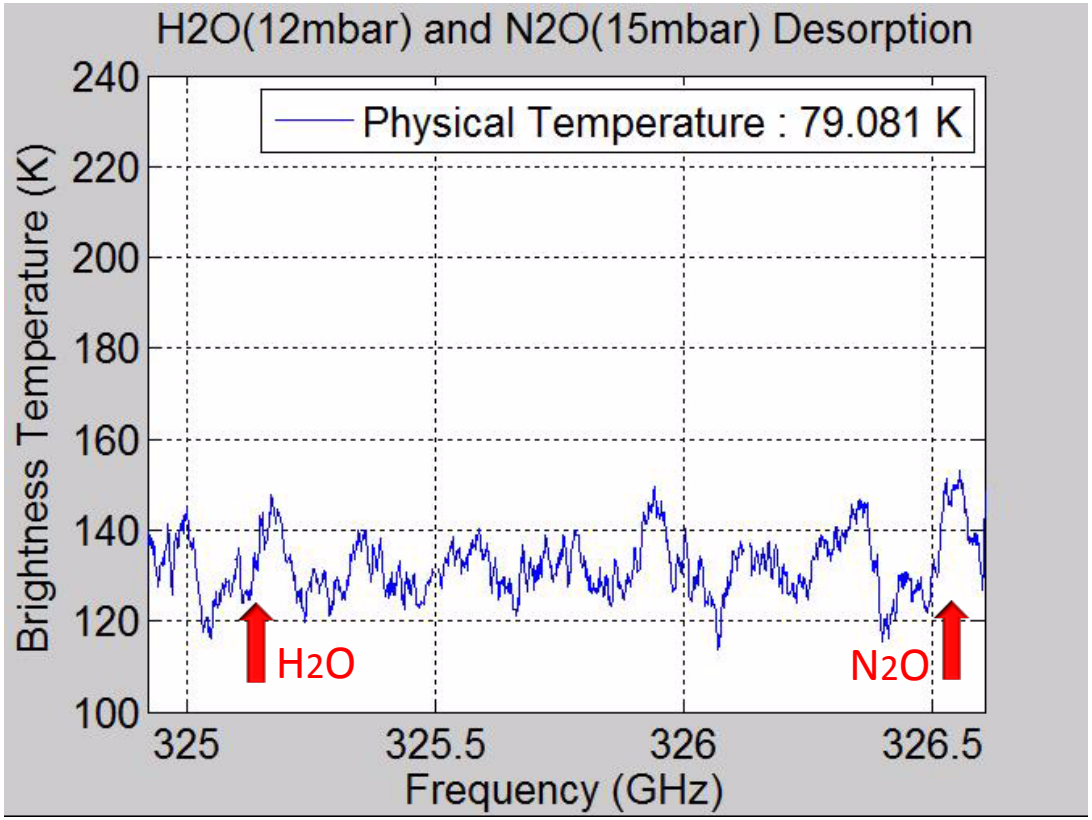
- 1m cell - Mylar windows
- Vacuum pump : 2E-2 mbar
- Cold background target (77K)
- Nitrous Oxide : N_2O
- Water Vapour : H_2O



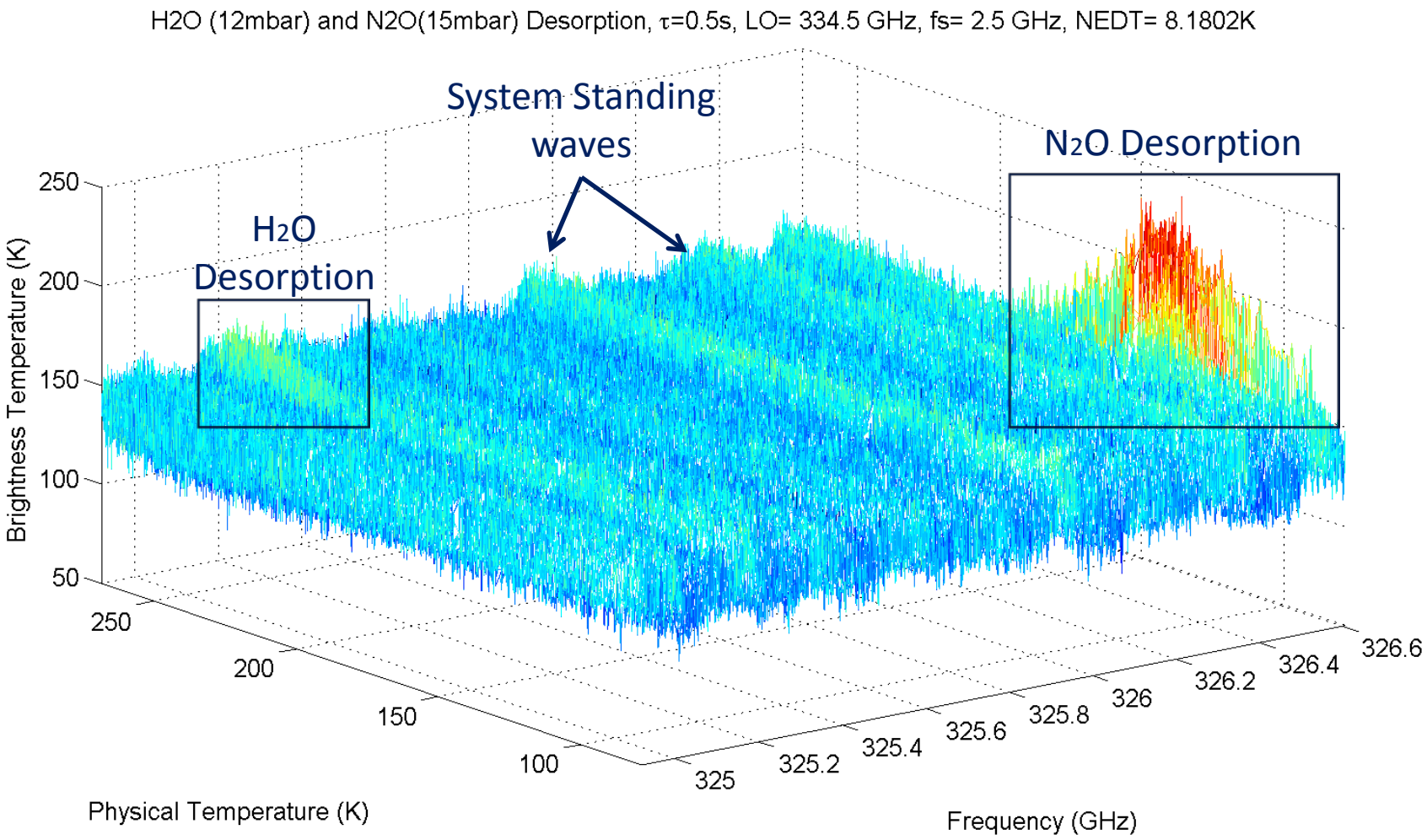


H_2O and N_2O desorption

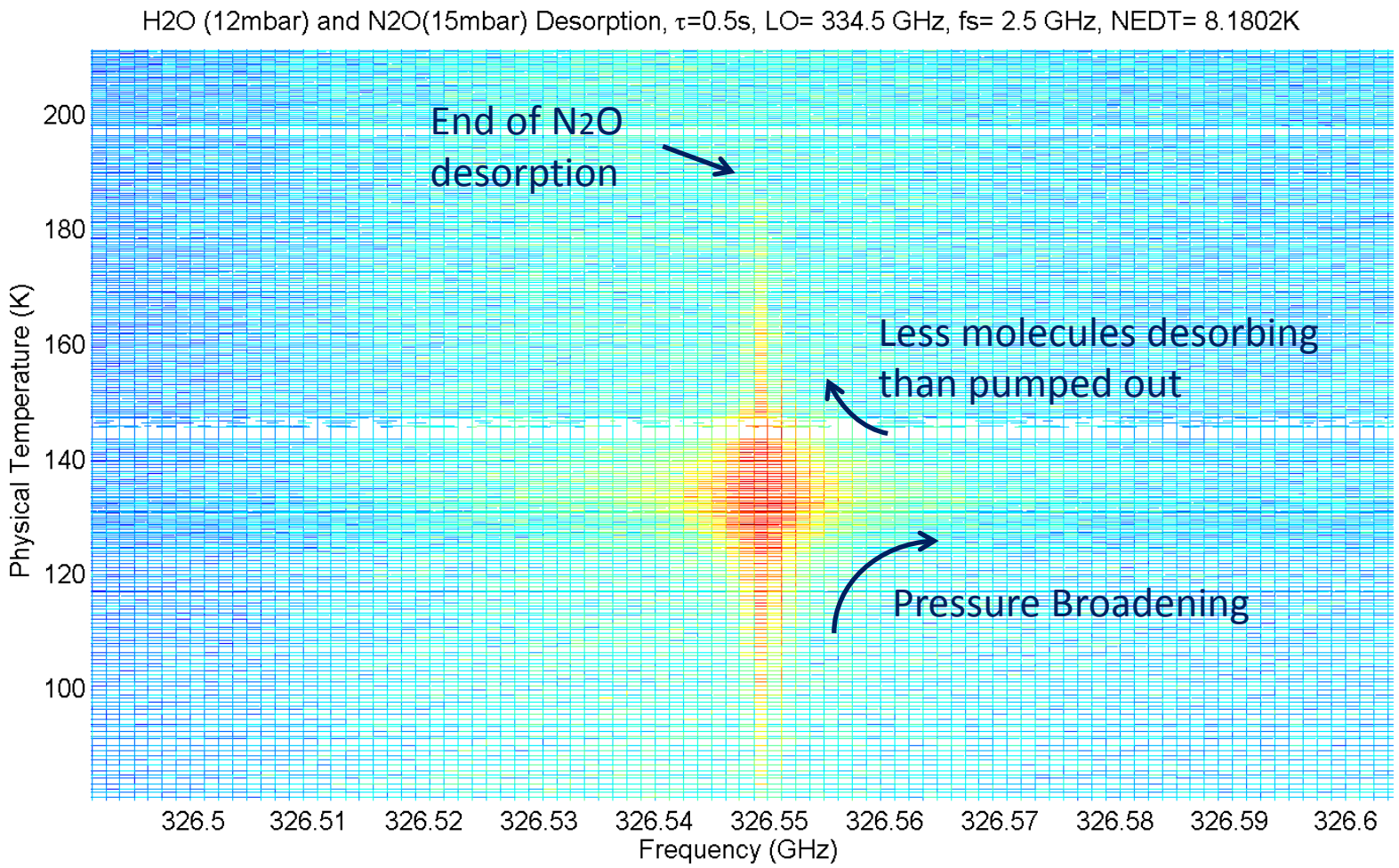
- Growth of the Ice
  - *1st : Water (H_2O) – 12 mbar in cell*
  - *2nd : Nitrous Oxide (N_2O) – 14 mbar in cell*
- Spectral signature
  - *Water (H_2O) :* 325.15 GHz
  - *Nitrous Oxide (N_2O) :* 326.55 GHz



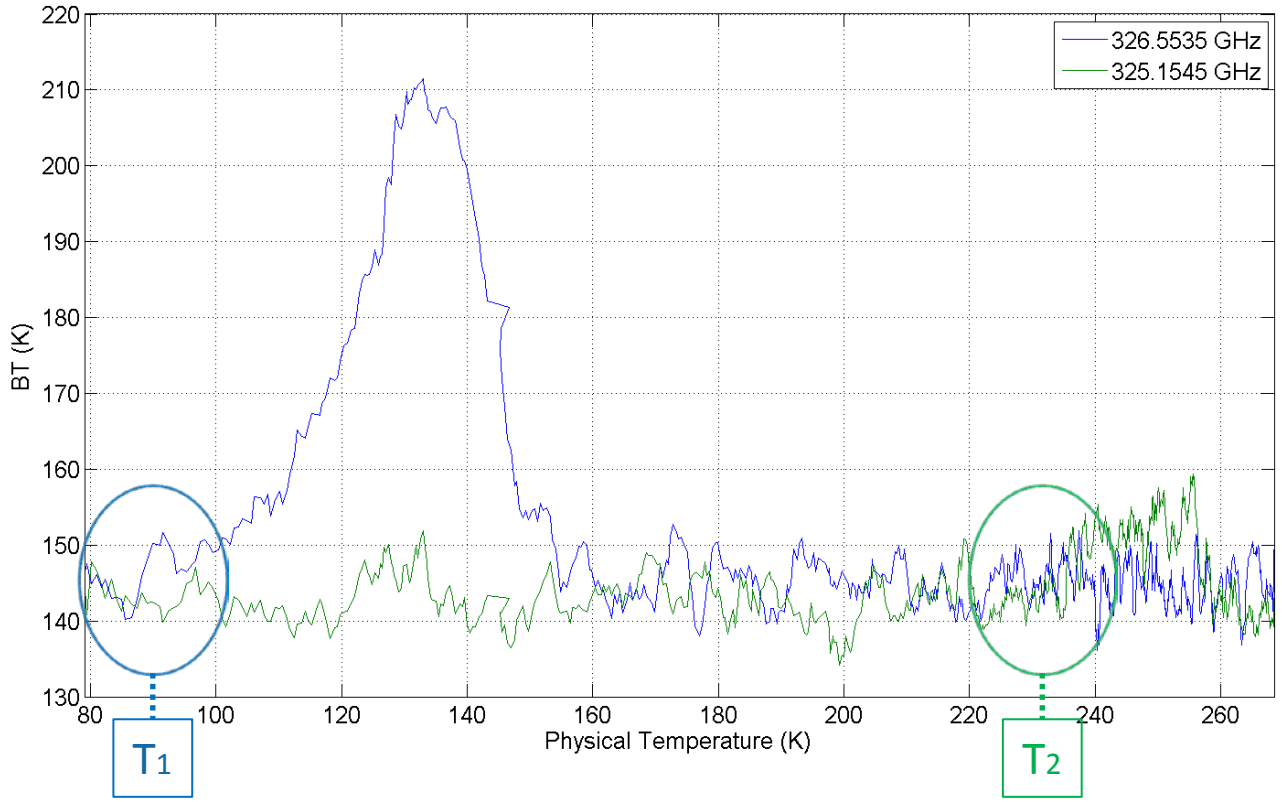
H2O and N2O desorption



H_2O and N_2O desorption



H_2O and N_2O desorption

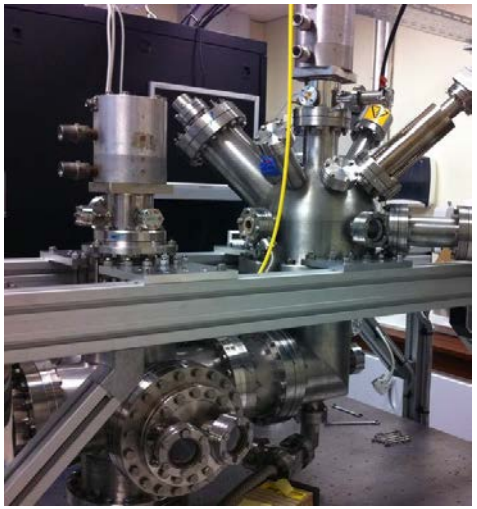


- N_2O Desorption
  - Start : T1 ~ 90 K
  - Peak: ~ 130 K
- H_2O Desorption
  - Start : T2 ~ 230 K
  - Peak: ~ 250 K

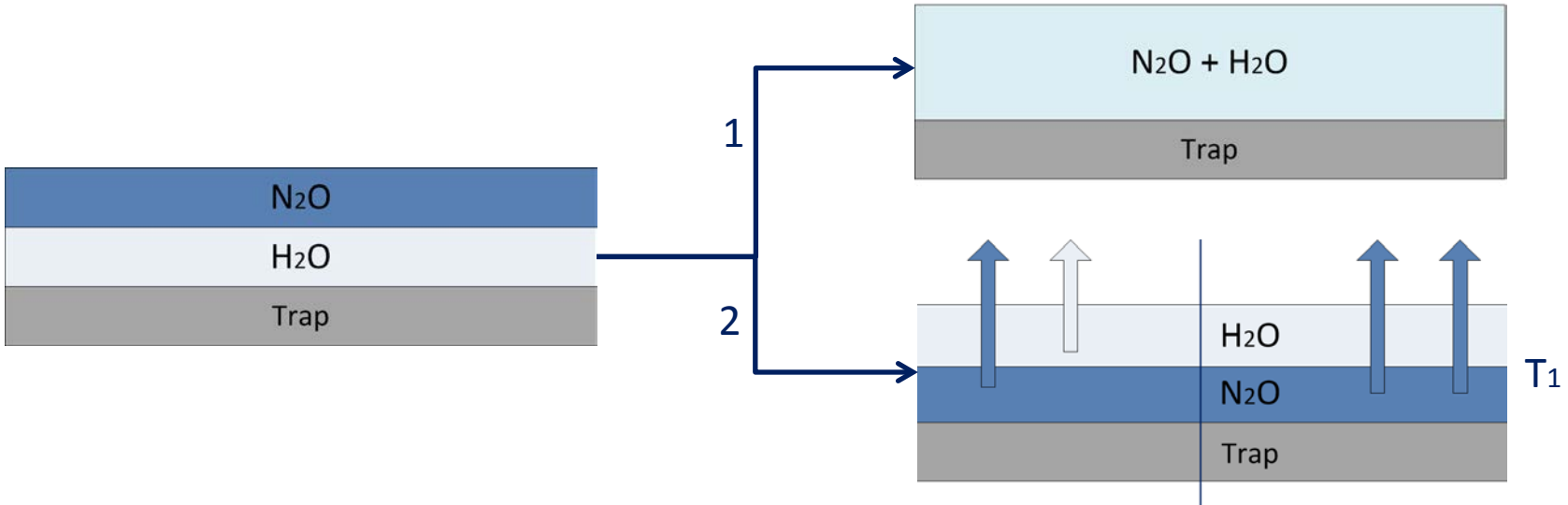
- Molecule Tracer
  - spectral features
  - Line intensity ↔ amount of molecules desorbing
- Ice properties

Next Step

- System improvement
  - *Sensitivity*
  - *Standing waves*
  - *Increase frequency range*
- Desorption
  - *Ultra-high vacuum facility*
  - *Mixtures : Methanol, different growths*

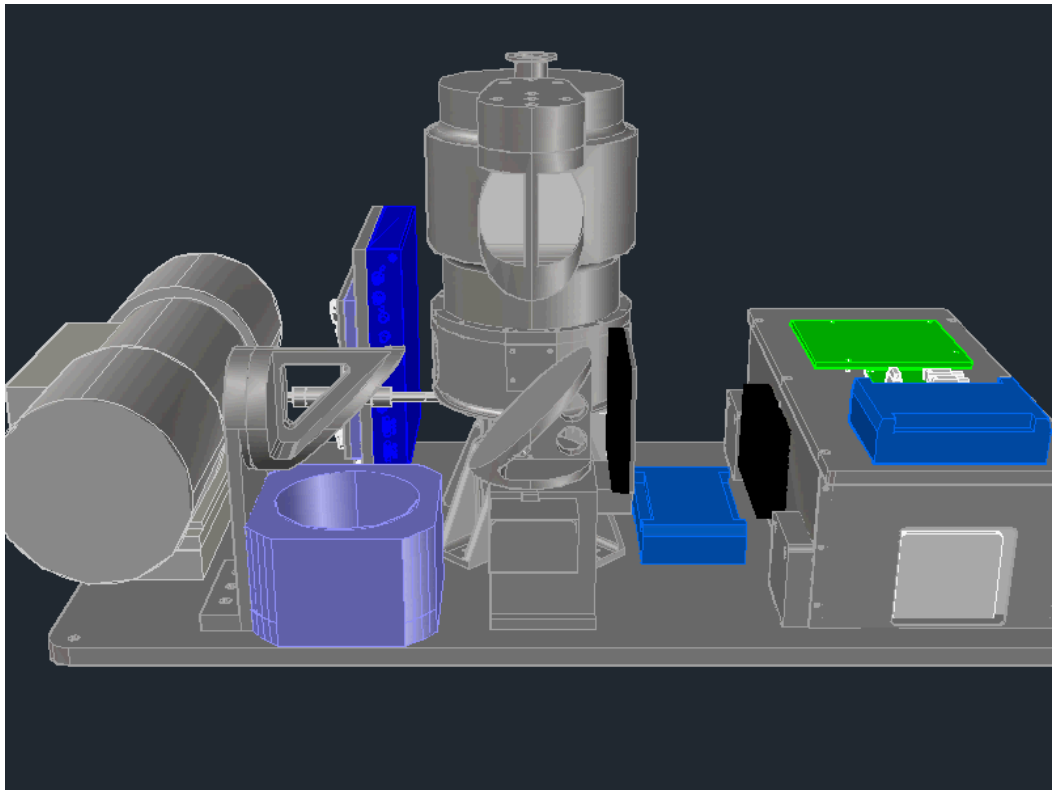


UHV facility at Open University



POSTER: 1.1 THz Receiver for LOCUS

- Total-Power Heterodyne Radiometer
  - *Diode Technology*
  - *Space Cooler Technology*
- Target Molecules : NO, CO, H_2O, O_3
  - *LSB : 1139.6 – 1141.6 GHz*
  - *USB : 1151.6 – 1153.6 GHz*



Conclusions

- High-resolution sideband-separating instrument
  - Frequency range : 320-350 GHz
  - Spectral Resolution : up to 1 MHz
  - Sensitivity : up to 1K

- Desorption Experiment
  - Physical properties of the Ice
  - Molecule tracer (Chemical reaction within the ice)
  - Development of a new facility for space conditions study

RAL Space

Thank you for your attention

Any questions ?

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