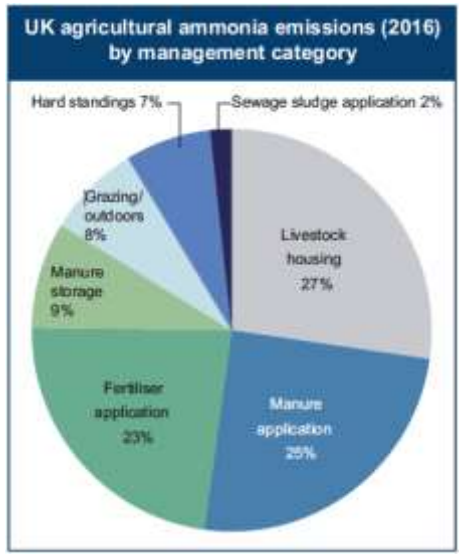
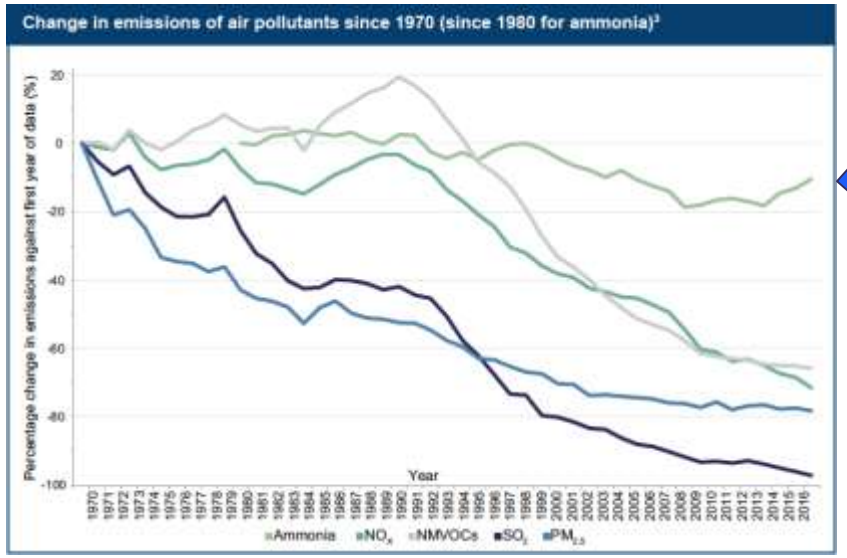
Continuous Ammonia Monitoring for Agriculture (CAMAG)

Case study of a recent STFC Food Network Plus (SFN+) seed-corn project

Ammonia in the Atmosphere

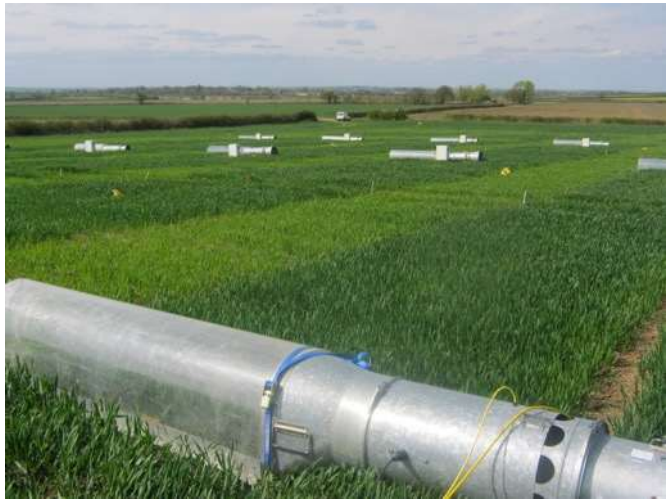
- Ammonia (NH_3) is an air pollutant, mainly from agriculture (88%) and traffic emissions
- It's an irritant, that is detrimental to human health
- It's the only pollutant not to decrease since 1970!





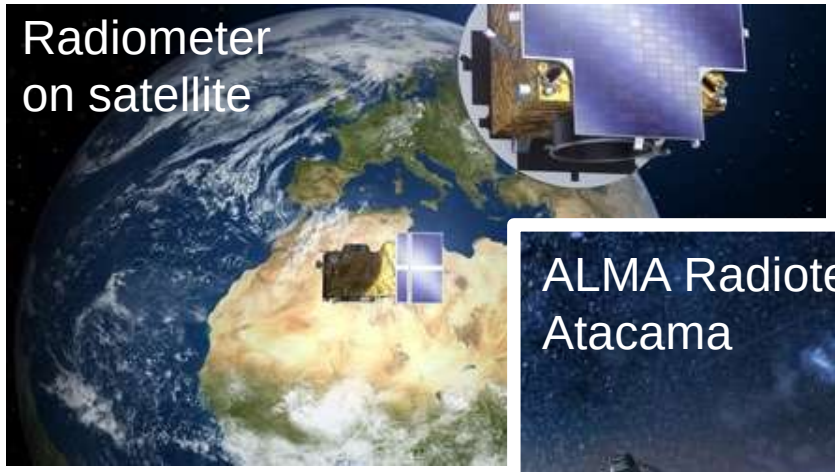
Current Detection Methods

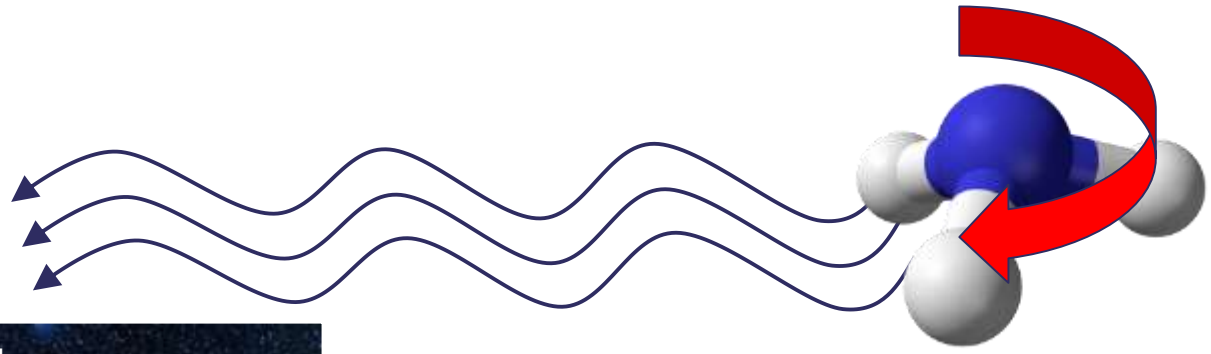
- Wind tunnels and shuttles
- Accurate and reliable, but slow to read out (~ hours)
- A continuous, real-time method would be welcome



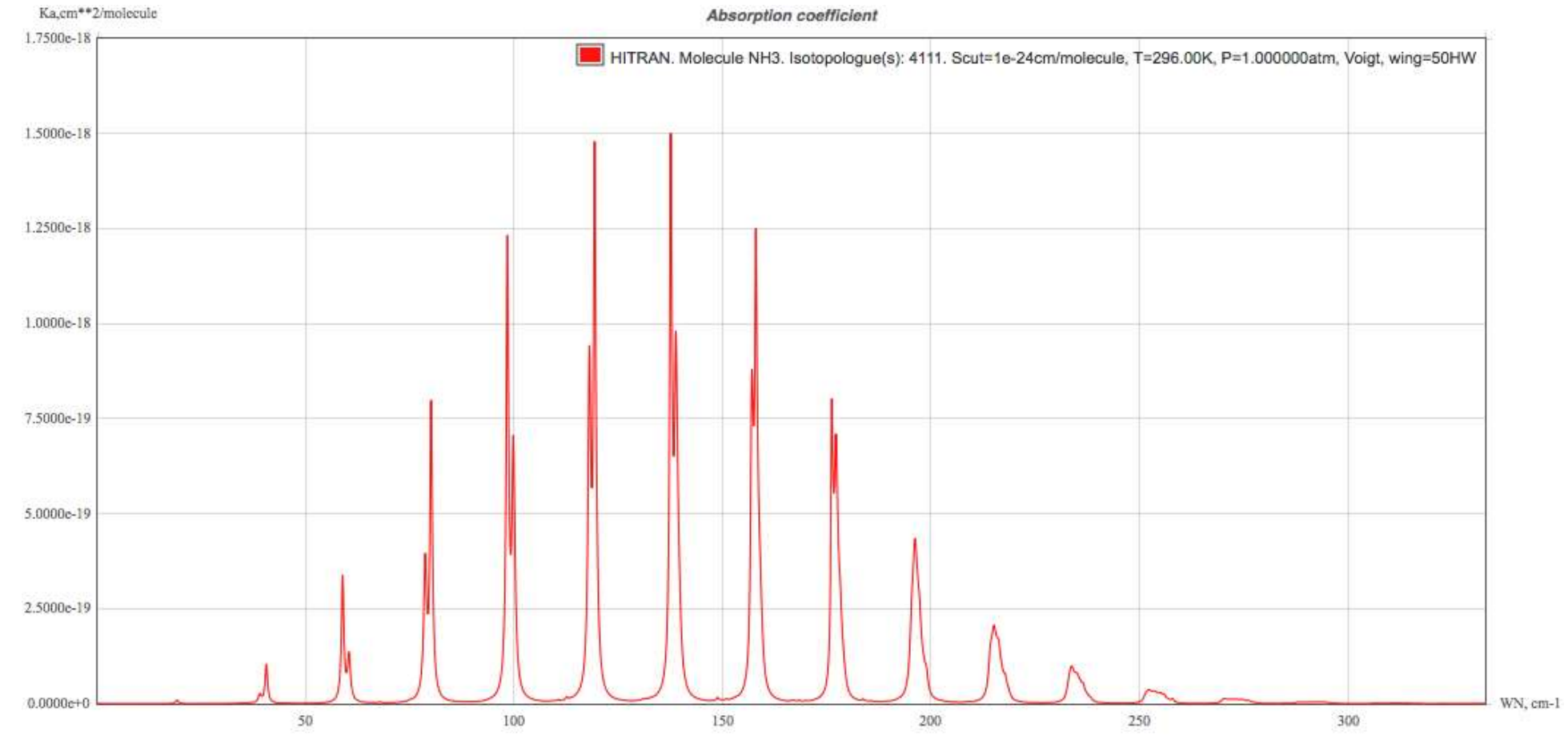
Trace gas remote sensing in astronomy and Earth Observation (EO)

- "*Wiggling*" molecules emit radio signals at characteristic frequencies
- A receiver can pick that signal up, and calculate how much gas there is

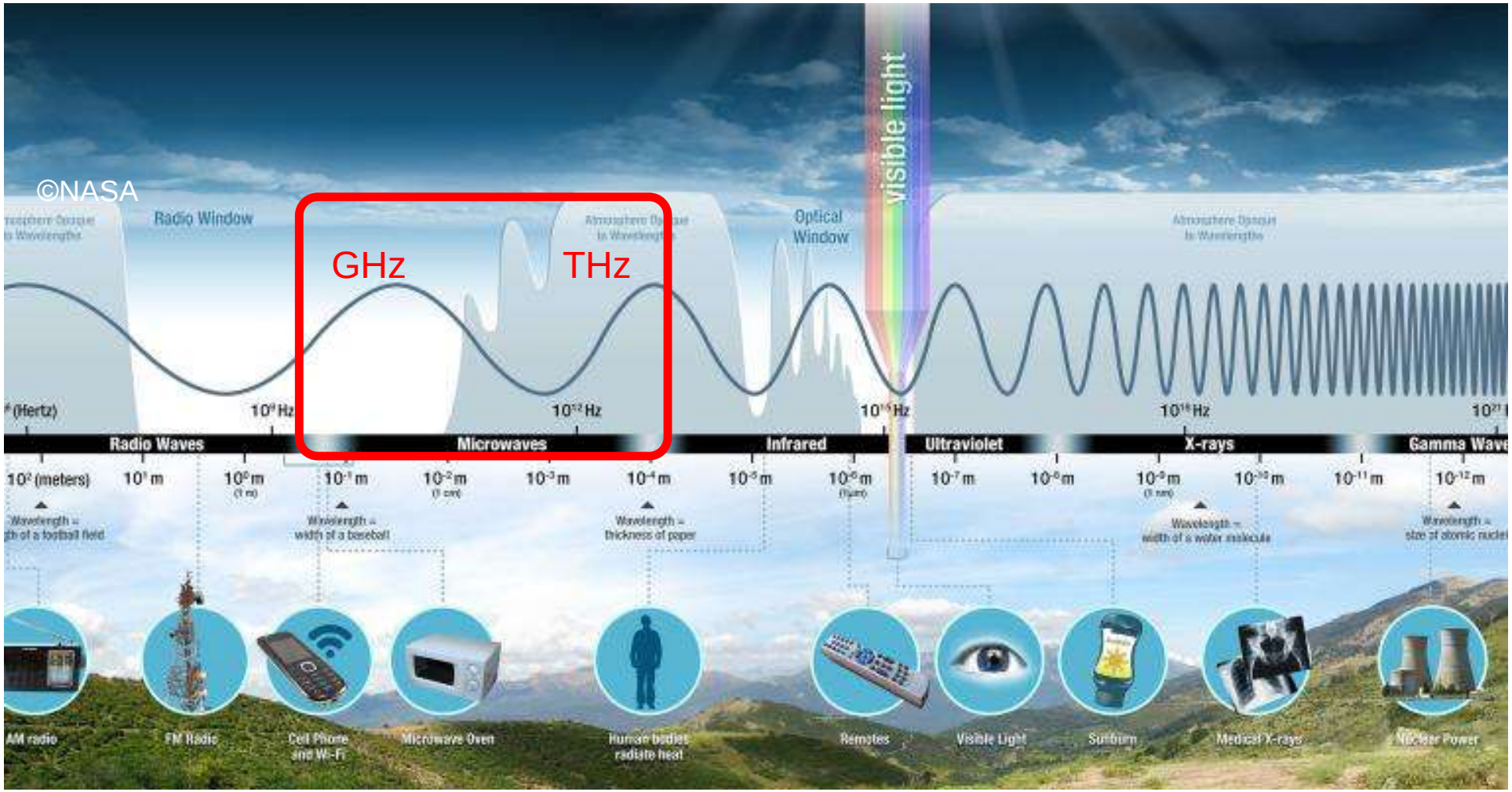




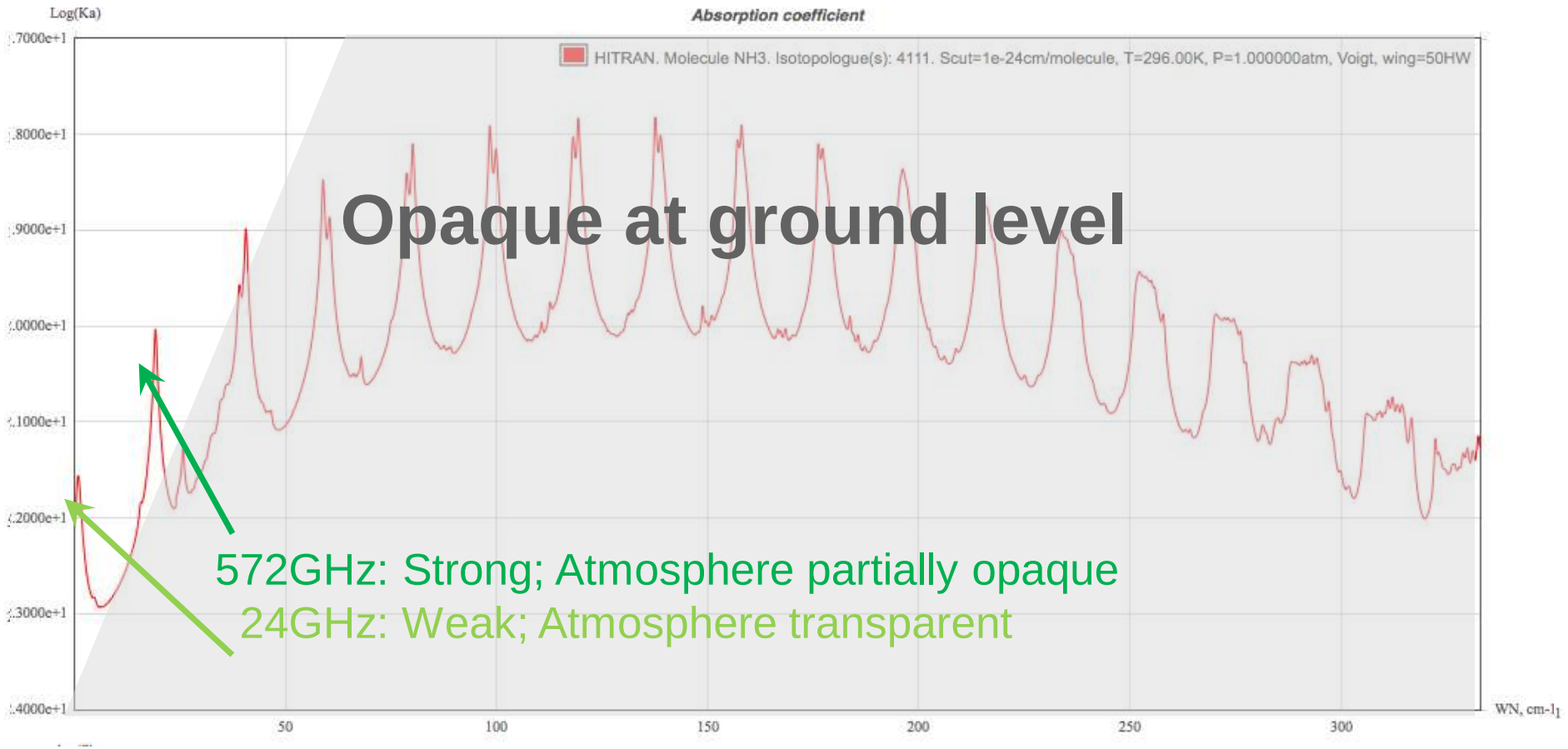
Location of Ammonia Spectral Lines



Atmospheric Transmissivity



Viable Ammonia Spectral Lines



1GHz — Microwaves

5THz — Far-Infrared

10THz — Mid-Infrared

Detectability Analysis for Various Emissions and Atmospheric Scenarios

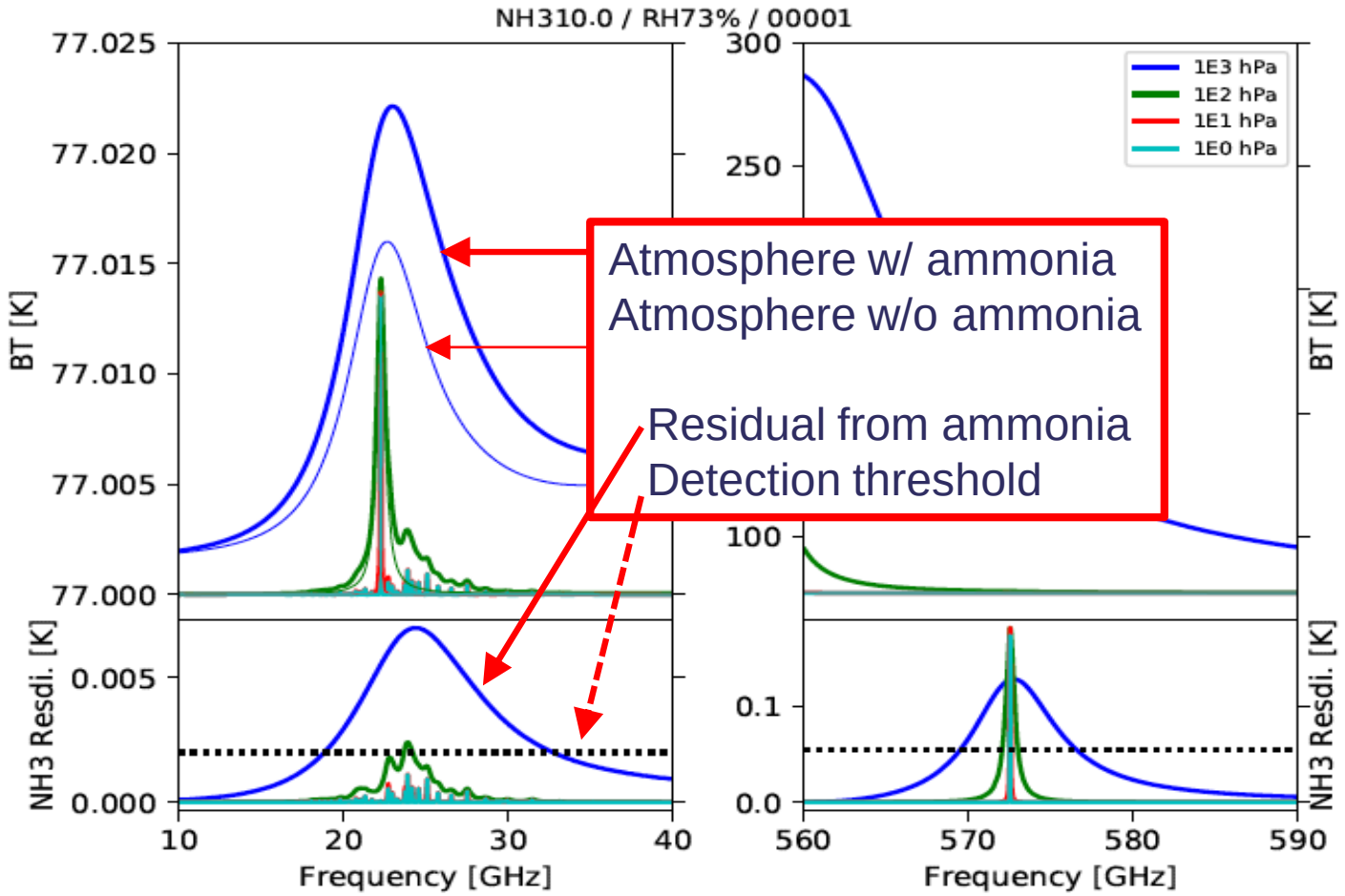
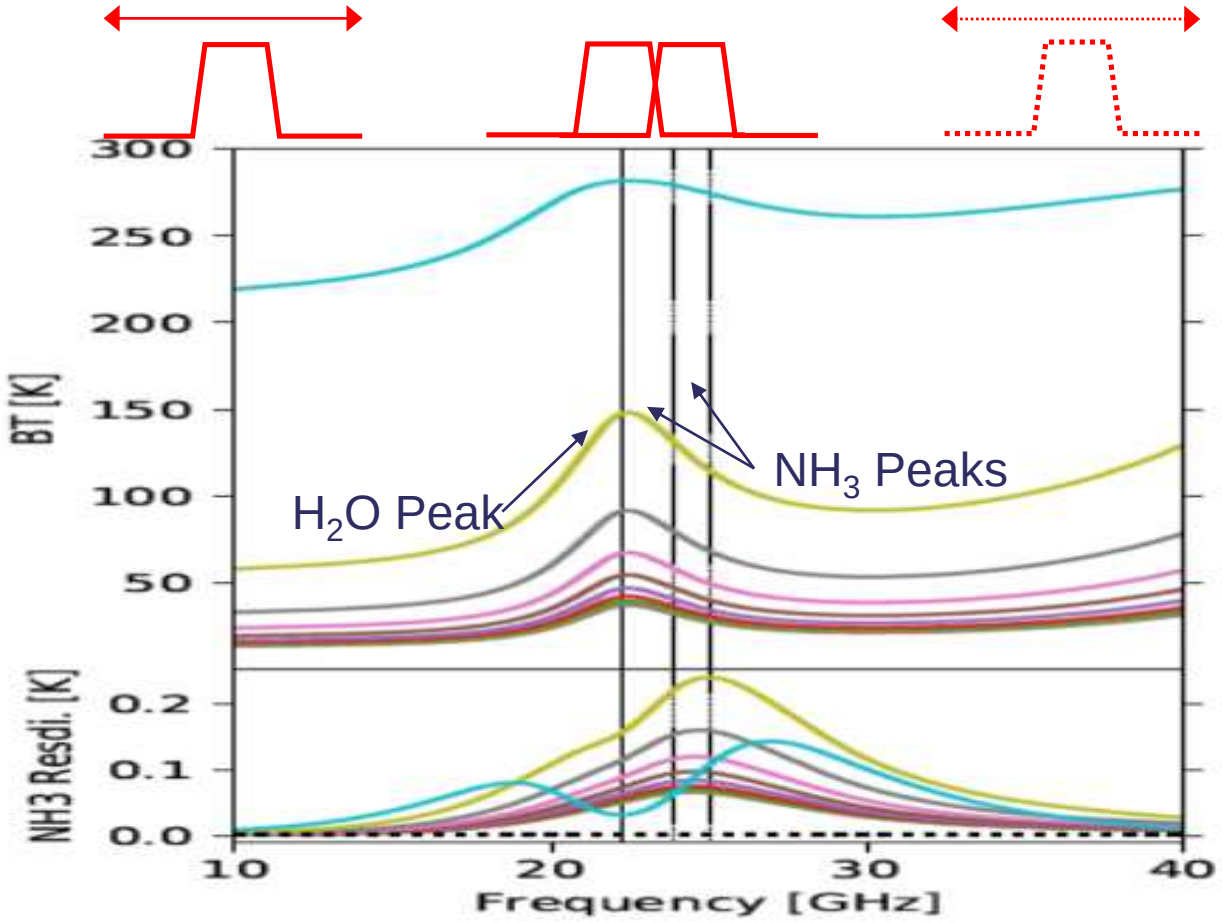


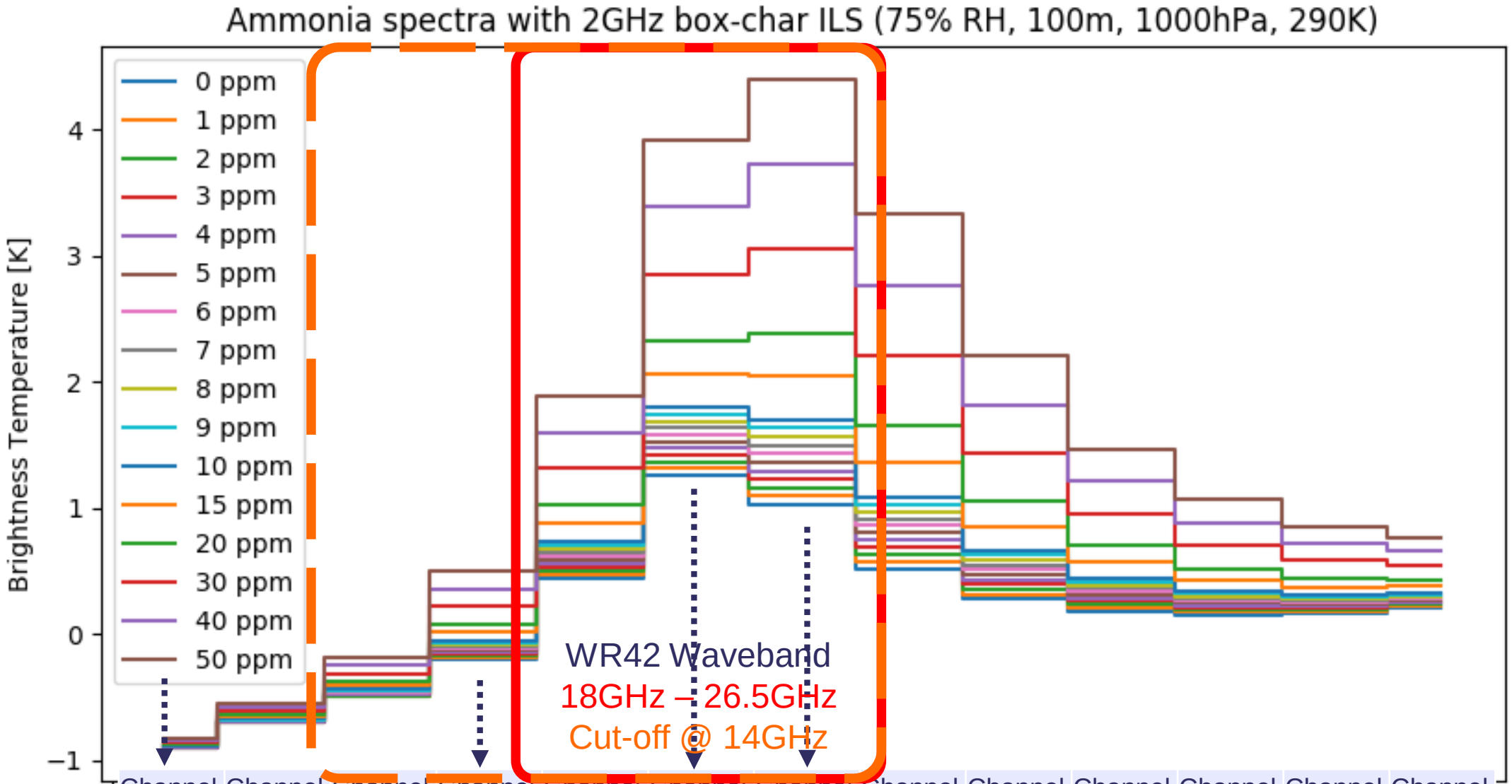
TABLE 2: LIST OF VARIOUS THRESHOLD DETECTION LEVELS [TIMMER,2004] [BECKER,1999]

Detection Limit	Source / Objective
1 ppb	Environmental air monitoring
50 ppb	Breath monitoring
1 ppm	Measuring in stables
10 ppm	Extensive farming / Normal traffic emissions
20 ppm	Chemical alarm: Maximum allowed workspace level
50 ppm	Chemical alarm: Smell detection limit / Severe traffic emissions
500 ppm	Chemical alarm: Immediate and serious irritation of nose and throat
1000 ppm	Chemical alarm: Pulmonary oedema
5,000 ppm - 10,000 ppm	Chemical alarm: Lethal dose (5-10 mins)

Differential Emission Technique

- Three channels should suffice to tell apart NH_3 and H_2O by their differential ratios
  - One 2 GHz channel centered over H_2O
  - One 2 GHz channel centered over NH_3
  - One (or two) channels on the line wing (window channel)
- Cheap and simple!

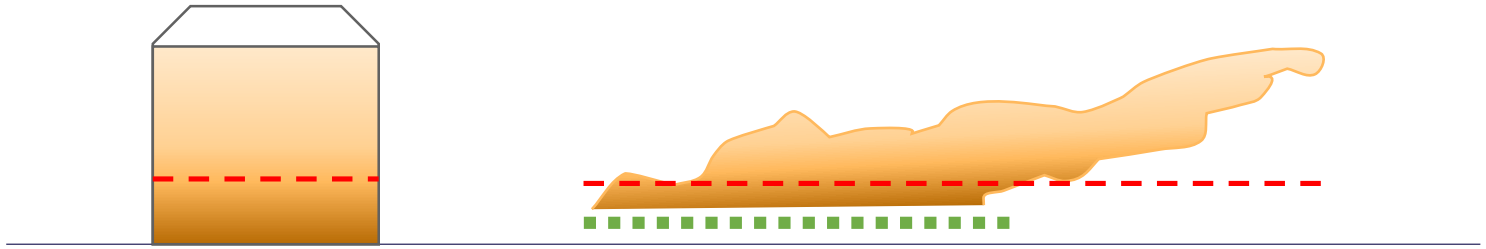


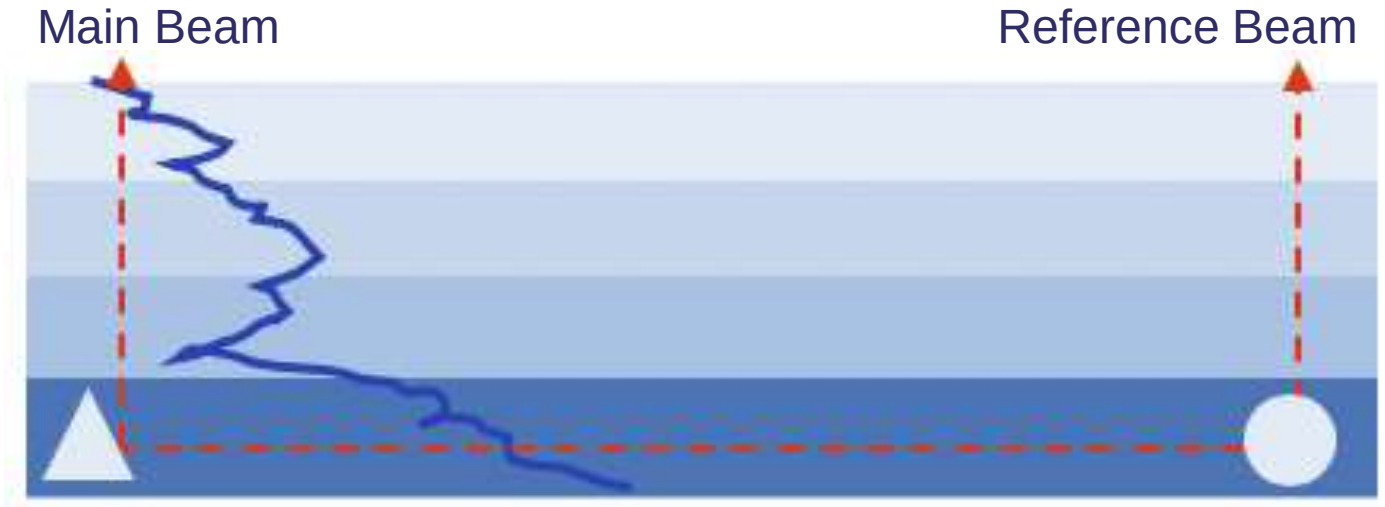


Channel 0	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	Channel 9	Channel 10	Channel 11	Channel 12
			W-Band limit		H2O Peak	NH3 Peak						
11.10	13.32	15.55	17.78	20.01	22.24	24.46	26.69	28.92	31.15	33.37	35.60	37.83

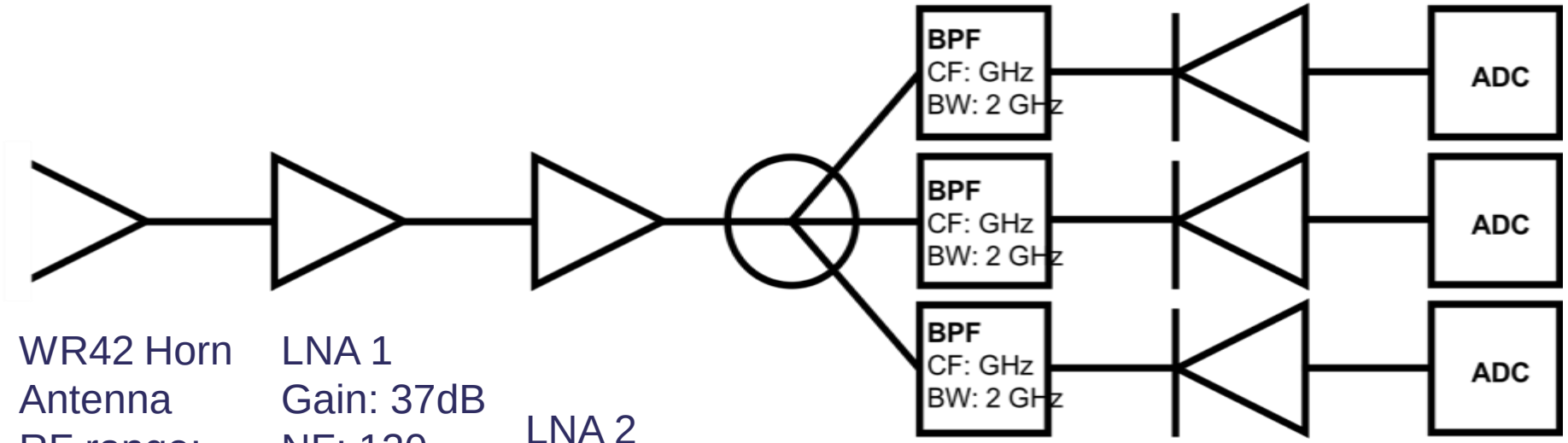
Open Path Observing Systems

- Concentrated NH_3 levels are found in closed spaces (animal houses) and immediate above fertilized fields
- Beam switching to
  - Maximise the NH_3/H_2O ratio (by removing H_2O only layers)
  - Get a cold background
  - Have a known humidity





Instrument Concept



WR42 Horn Antenna
RF range: 15-30GHz

LNA 1
Gain: 37dB
NF: 120

LNA 2
Gain: 37dB
NF: 120

Power Divider
S11: 1dB

Band Pass Filters
BW: 2GHz

Video detectors

ADC
12-bit / Analogue Inputs

Roadmap

- September 2018: Food Network + Seed corn study: £6k
  - Theoretical feasibility study
- March 2019: SFN+ extension: £5k
  - Refinement to feasibility study
- June 2019: STFC Proof-of-Concept study: £40
  - Select an implementation scenario and design the instrument breadboard
- 2020: STFC Challenge Led Applied Systems Programme (CLASP); Security and Environment: Bidding for £250k
  - Proposal to build an instrument prototype and perform laboratory- and field campaigns

Thank you

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