NIMCAM

Near Infrared Multispectral Camera for Atmospheric Methane

a new instrument concept for observing atmospheric methane from a CubeSat platform

JEROME WOODWARK (UNIVERSITY OF EDINBURGH)

PAUL PALMER (UNIVERSITY OF EDINBURGH)

DAVID LEE (UK ATC, STFC)

DAMIEN WEIDMANN (RAL SPACE, STFC)

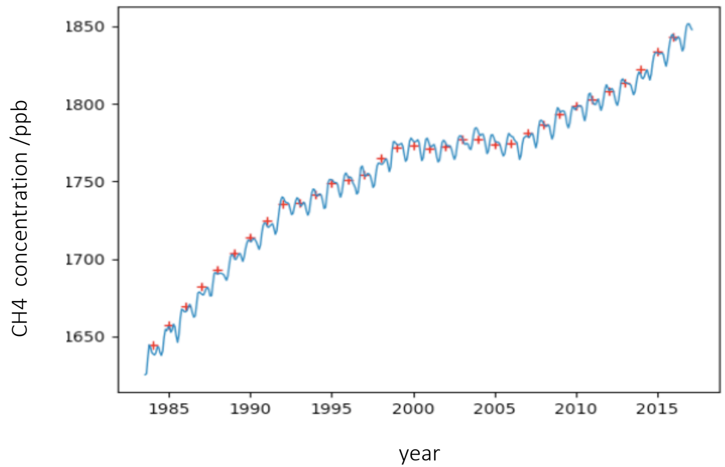
THE UNIVERSITY of EDINBURGH

Science & Technology Facilities Council

Motivation

Methane, a key greenhouse gas:

- GWP of 86 over 20 year period
- 20% of warming due to GHGs since 1700s
- Recent growth trends poorly understood
- Relevance to: natural gas as a transition fuel; fracking; cities; methane calthrates



Existing satellite data could be improved:

- Low spatial resolution, typically order 10s km
- Poor planetary boundary layer sensitivity
- Incomplete coverage, long revisit intervals

Opportunities for climate scientists, policy makers, and industry if data on methane concentrations could be improved

A low-cost, CubeSat deployed instrument with good sensitivity to boundary layer methane at a high spatial resolution would help address these needs

NIMCAM – science drivers

Science driver	Instrument requirements		
	Accuracy	Ground pixel size	Temporal resolution
GCOS 2011 target requirements	~ 100 ppb km (10 ppb accuracy for tropospheric column)	5 – 10 km	hours
NIMCAM target requirement: background level monitoring	10 ppb km	1 – 5 km	weeks
NIMCAM target requirement: identification and localisation of fugitive emissions	1 ppm km	100 metres	days

Technology basis – NIR multispectral imaging

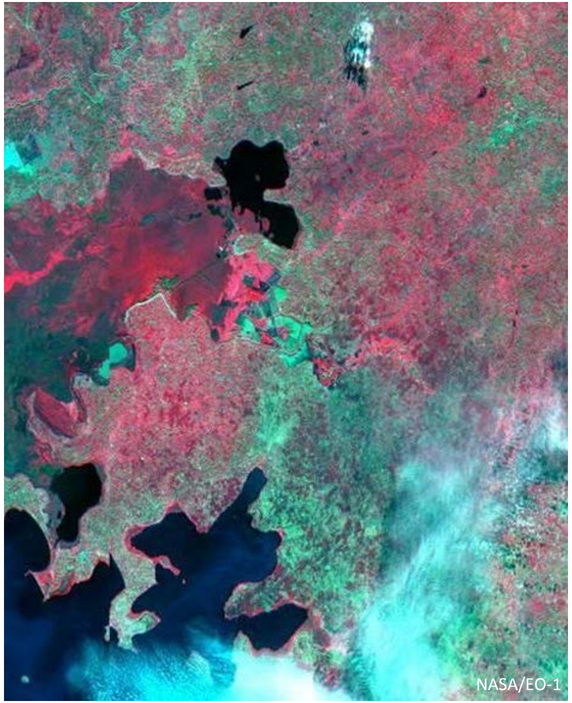
Technology review undertaken– considered diffractive system, Fourier transform, spatial heterodyne, laser heterodyne radiometer, Fabry-Perot, multispectral imaging, active (LIDAR)

Multispectral imaging selected:

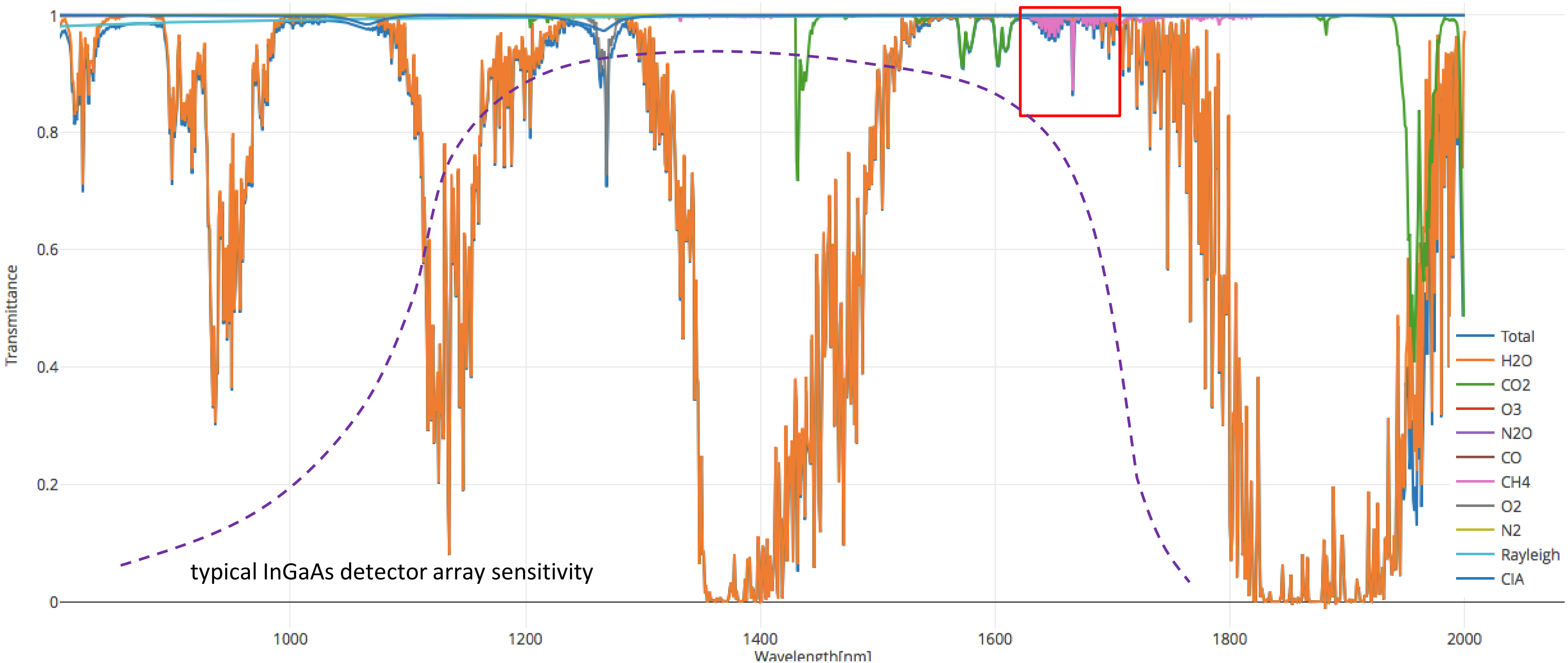
- **Maximised methane sensitivity** for the available (weak) signal
- **High resolution images** (order 100 metre pixels) from a fast moving satellite platform – short integration time, wide FOV, all pixels used for spatial information
- Low cost, robust technology, low power draw, no moving parts – **well suited to CubeSat platform**

SWIR signal more sensitive to boundary layer methane

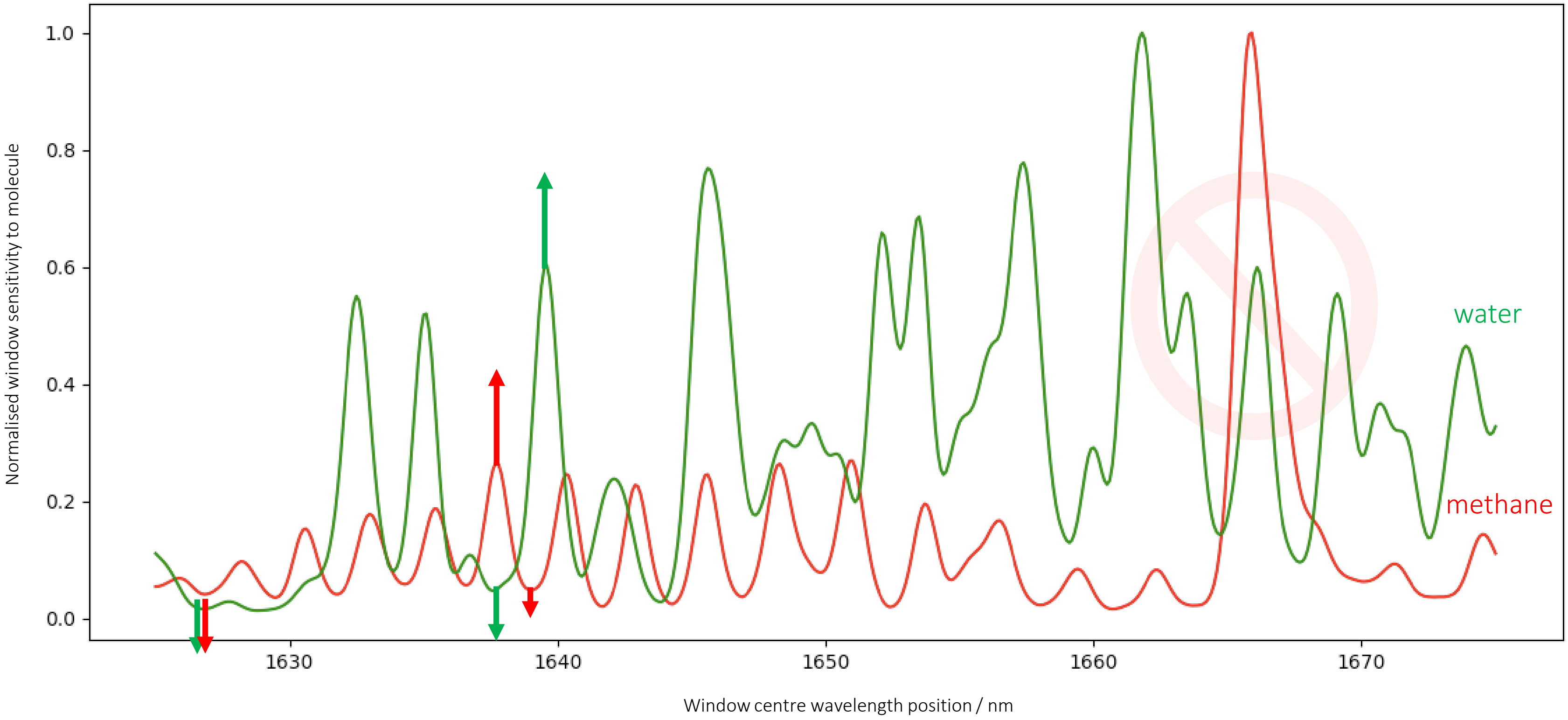
Eventual **constellation deployment** to improve revisit times from days to hours



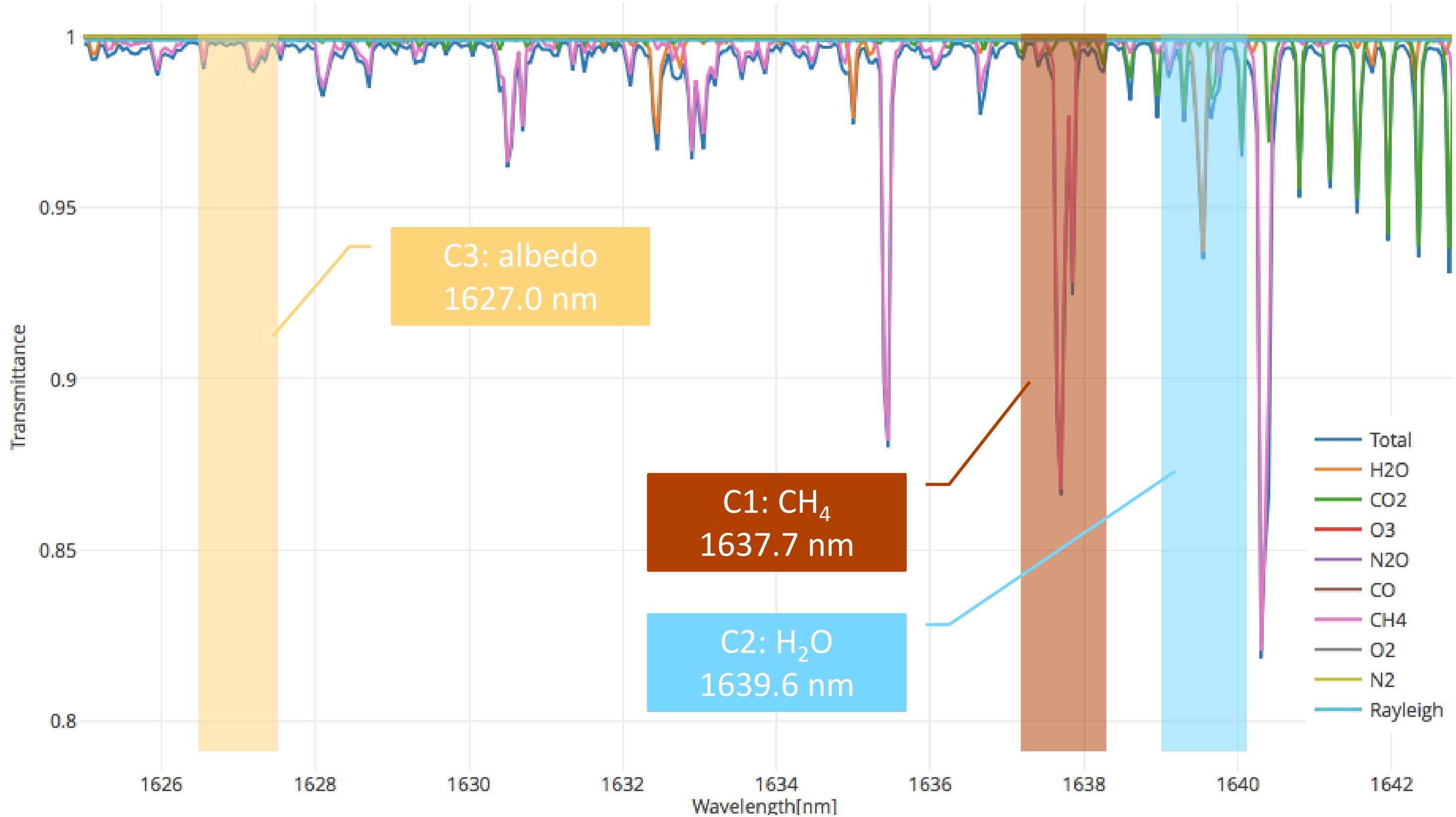
Band selection



Band selection – 1nm bandwidth window search

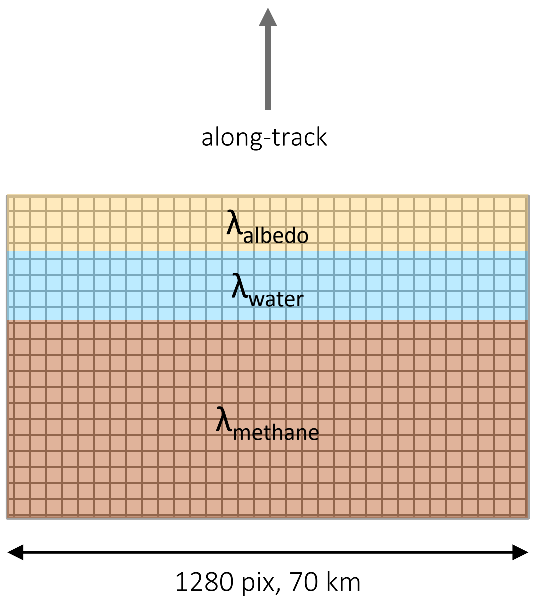


Band selection



NIMCAM – current concept

Filters	Three 1 nm bandwidth bandpass filters
Orbit	480 km Sun-Synchronous LEO
Focal length	90 mm
Ground pixel	70 metre side length
Swath	70 km cross track width
Aperture	90 mm
Detector array	InGaAs 1280 x 1000 pix
Averaging	4 pixel binning, along-track co-addition @ 50 Hz
Platform	12U CubeSat (200 x 200 x 300 mm)



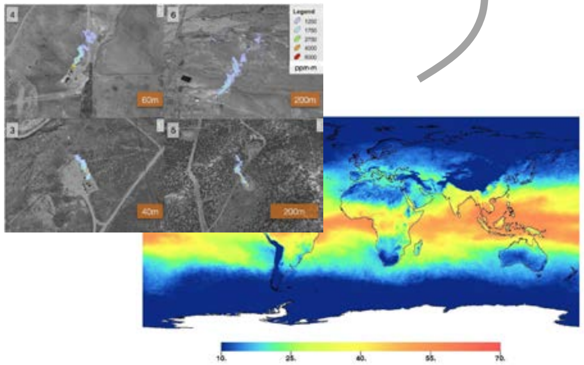
Modelling - ”Observation Simulator”

Radiative Transfer Model

- Varying boundary layer methane concentration
- Varying column water vapour concentration
- Varying surface albedo
- Varying aerosols

Instrument Model

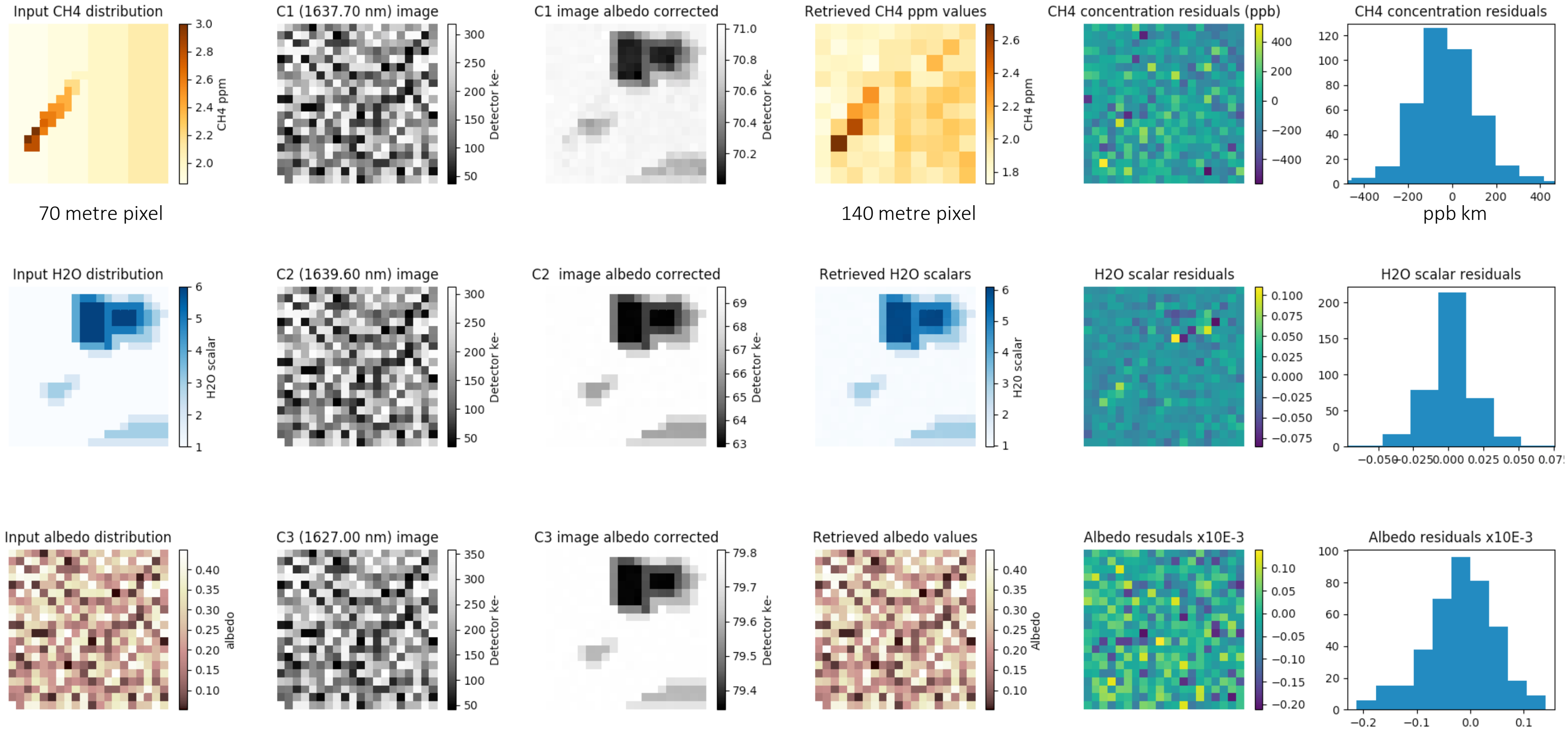
- Optical design (aperture, FOV)
- Filter design (passband size and position, efficiencies, cone angle impact)
- Detector (size, efficiency, noise sources)
- Co-addition/averaging schemes
- Optical efficiencies



Retrieval

- Retrieval assuming all methane enhancement in boundary layer
- Full inverse model – future work

Model output



On-going and future work

Further development of instrument and observation model– moving towards implementation of a full **Observation Simulator**

- Implementation of a full retrieval algorithm next important step to evaluate performance
- Inclusion of aerosol model

Further refine **instrument design** in context of CubeSat platform

- Electrical power and thermal budgets
- Ensure feasibility of field deploying proposed system

Narrowband filters

- Manufacturing quotes now obtained but challenging requirements
- Integration with optical design to ensure performance is maintained

Construction and testing of **laboratory demonstrator** to validate core concept

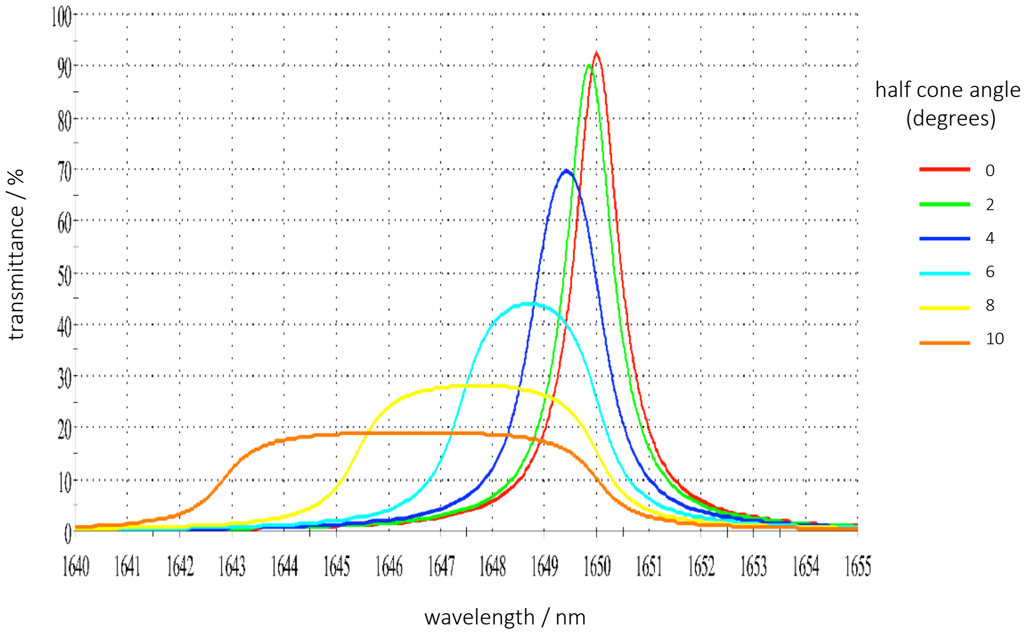
Questions?

JEROME.WOODWARK@ED.AC.UK

Narrowband filters

Several issues:

- Challenging to manufacture filters with required narrow bandpass at these SWIR wavelengths
- Maintaining coating uniformity across filter at larger diameters difficult
- Shift and broadening of bandpass at larger half cone angles in optical system
- Smallest half cone angle at input optics but also largest diameter
- Negligible centre wavelength shift with temperature (0.02 nm/K)



Methane plume modelling

- Rough model based on figures from Frankenberg et al. 2016 paper “Airborne methane remote measurements reveal heavy-tail flux distribution in Four Corners region”
- Show methane enhancements associated with fugitive emissions from well pads, pipeline leaks, storage tank leaks
- Measurements from aircraft based imaging spectrometer AVIRIS-NG