Design of an Innovative Ice Cloud Imager for the Global Measurement of Cirrus Cloud

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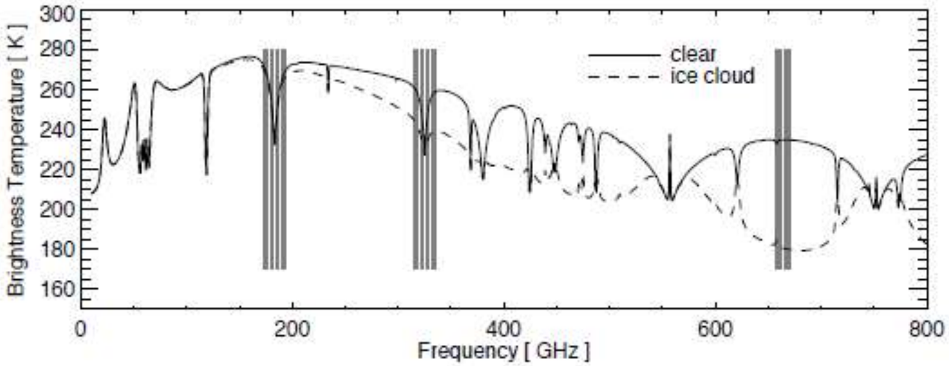
Concept

- Project concept started when still unclear if ICI was selected for MetOp-SG
- Passive radiometers, sensitive to ice content in cirrus clouds – operate in sub-mm wavelength
- This study addressed the scenario where ICI is not selected for MetOp-SG, so asked <u>not</u> "what is the best instrument?" <u>but</u> "what is the cheapest acceptable instrument?"



Activities

- TN1 – Requirements Review
- TN2 – Cost Drivers Review
- TN3 – Technology assessment & Tradeoff
- TN4 – Preferred Solution
- (Project Management)
- [N.B. TN2 and TN3 preformed in parallel]

TN1 – Requirements Review

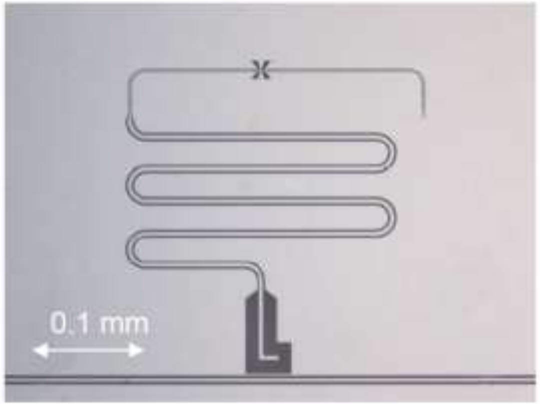
- Based on discussion with expert users:
  - Stefan Buehler (Lulea Univ of Technology, Kiruna)
  - John Eyre, William Bell (UK Met Office)

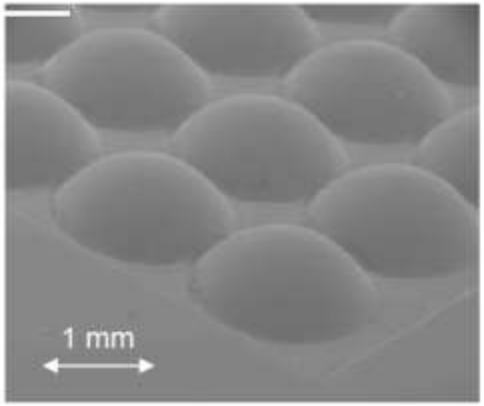
Pr	ICI	CONSERVATIVE
Channel centre	**5 channels at 183, 243, 325, 448, 664 Ghz**	**3 channels, at 183, 325, 664 GHz**
Sub-band selection	**183 : ±2 /3.4 / 7** **243 : ±2.5** **325 : ±1.5 / 3.5 /9.5** **448 : ±1.4 /3.0 / 7.2** **664 : ±4.2**	**183 : ±1/3/7/10** **325 : ±1/3/7/10** **664 : ±4.2**
NEDT	**183 : 0.6-0.7 K** **243 : 0.6K** **325 : 1.1-1.4K** **448 : 1.3-1.9K** **664 : 1.5K**	**All V only** **183 : 5K** **243 : 5K** **325 : 5K** **448 : 5K** **664 : 5K**

Requirements Review continued

Pr	ICI	CONSERVATIVE
MLST	**As above**	**As ICI**
Swath	**2000km (OZA of 53 degrees)**	**As ICI**
Overlap	**50% overlap in along track, 3 x oversampling across track**	**50% overlap in across and along track.**
OZA	**Driven by mission, with OZA as before**	**As before (driven by mission)**
Horizontal resolution	**15km**	**20km**
Convergence	**Standalone instrument**	**Standalone instrument**
Lifetime	**7.5 years**	**3 years (proof of concept)**
Reliability	**Reliability >0.84**	**>0.84, but allowing channels to fail**

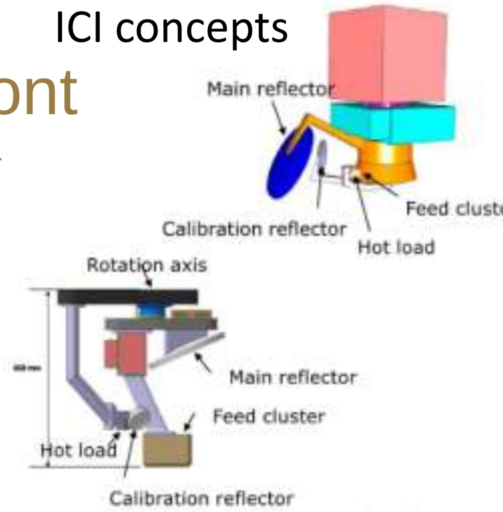
- Detectors
  - RF Heterodyne (baseline for ICI)
    - Significant hardware (LO generation, Horn, SHM, Filter, Amplifier)
  - Cooled Bolometers (e.g. Planck HFI)
    - To meet NEDT requirement need cryogenic temperatures
  - Quantum (KIDs)
    - Low noise, low TRL, cryogenic temperatures



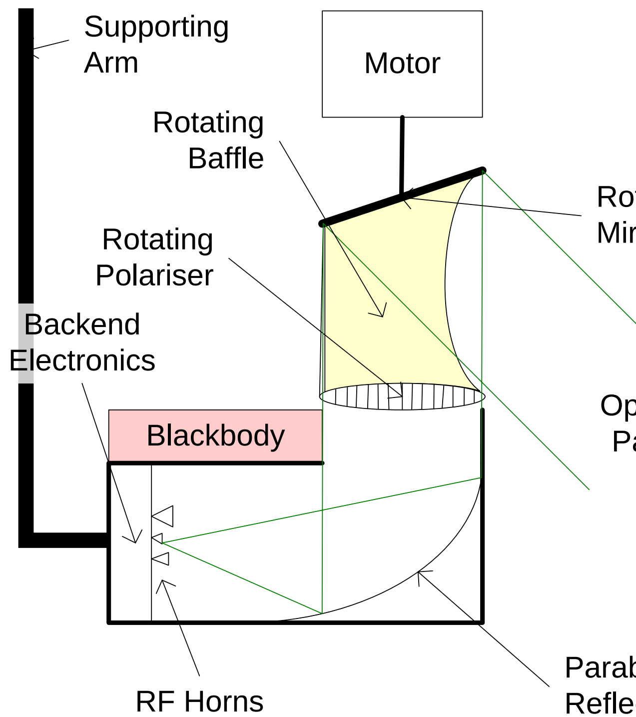


TN3 – Technology assessment & Tradeoff cont

ICI concepts

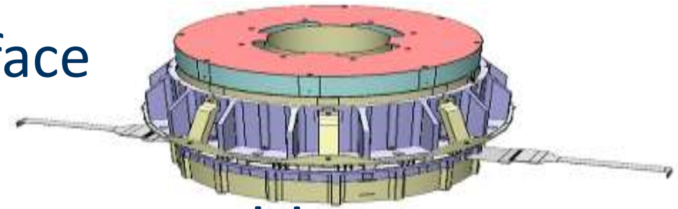


- Mechatronics
  - Conical scan preferred (from requirements)
  - Polarisation defined wrt scene
  - RF polarisation defined in horn + SHM
    - Hence horn needs to rotate with the scan
    - Hence front end electronics needs to rotate with the scan
    - Hence active rotating elements
    - Hence big and bulky rotating elements
  - Alternative approach
    - Define polarisation with passive elements
    - Then can keep all active elements non rotating



TN2 – Cost Drivers Review

- RF heterodyne requires significant RF hardware (LO generation, SHM, Filter, Multiplier, etc) – significant cost drive
- Bolometers require cryogenic system, significant system in itself, significant cost
  - RF Heterodyne vs Bolometers approximately cost neutral
- Active Rotating element strong cost driver
  - Split the electronics
  - Power and Data across rotating interface
  - Heavy complex rotating elements



- Conclusion – passive rotating element would potentially bring major savings

TN4 – Studied Solution

- Focused on passive rotating solution
- Focused on RF heterodyne (Cryogenic Bolometer covered in earlier study)
- Polarisation can be performed passively with polarisation grid, and these can be manufactured
- However RF heterodyne detectors can only detect RF in a single polarisation
- Both H and V must be detected to synthesise unpolarised response
- Δ cost to measure both H&V is small
- [n.b. Option delete polarisation grid]

Conclusions

- Both cryogenic bolometers & RF heterodyne are viable detector technology for sub-mm radiometry
- Bolometers more applicable at higher frequencies (e.g. 875GHz), RF heterdynes are easier at lower frequencies
- Passive scan mechanism is favourable from complexity and cost reasons
- Passive polarisation grids are a good partner for unpolarised detectors (e.g. bolometers), but not compatible with polarised RF heterodyne detector technologies
- Interesting concept, but of course lower TRL than ICI

Benefits

- Study has reviewed technology
- At least as important has been the relationships developed/reinforced:
  - Users
    - Stefan Buehler (Lulea Univ of Technology, Kiruna)
    - John Eyre, William Bell (UK Met Office)
  - Technologies
    - Bolometer radiometers – Cardiff
    - Cryogenic coolers – STFC/RAL
    - RF radiometer components – STFC/RAL sub-mm
    - Radiometry – JCR Systems
- ICI on MetOp-SG now confirmed, so MetOp-SG opportunity has faded
- UK well placed for future sub-mm radiometers
- The single step from simulations direct to 3× operational instruments and a >20year commitment is not ideal. A simple quick demonstrator is still desirable (ICI flight 2023)

Ancillary Info

Presentations given	None as yet
Publications	None as yet
Patents	None as yet
Leverage achieved	ICI instrument was confirmed on MetOp SG. CASA is prime. Future opportunities TBD
Collaborations forged	Consolidated links with RAL, Cardiff University, JCR systems, Met Office, LUT
Training and knowledge exchange	As above.
UK Capability enhancement	Links forged with non-UK scientists. Strengthened SEA system understanding of sub-mm instruments.
Benefits to UK Space	As above. Confirmed desirability of flying a cheap demonstrator for operational instruments.